ARTICLE

Dating the Sir Francis Drake *Silver Maps*

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RÉSUMÉ

Les Drake << Silver Maps >> sont des disques d'argent de 68 mm (2.7 po) de diamètre avec des cartes du monde connu du XVIe siècle sur la route de Drake. Ils ont probablement été estampillés avec des matrices. Les neuf médailles existantes ont des poids de 260 à 424 grains (environ une once pour le plus lourd). Chacune de ces médailles a un diamètre qui est à peu près le même que celui d'un base-ball. Le plus léger est aussi mince qu'un ongle du pouce et le plus lourd est aussi épais qu'une carte de crédit. Cet article montre qu'ils ont été le plus probable statement créés en 1588–89: la preuve la plus forte pour cela est qu'ils ont utilisé la projection de carte stéréographique équatoriale double hémisphère de Mercator qui a été inventé par Rumold Mercator en 1587.

Mots clés : Mercator, Van Sype, carte argentée, route de circumnavigation, projections cartographiques, médailles, cartes nautiques, circumnavigation

ABSTRACT

The Drake *Silver Maps* are 68-mm-diameter silver disks with maps of the sixteenth-century known world featuring Drake's route of circumnavigation. They were probably stamped with dies. The nine existing medallions have weights from 260 to 424 grains (the heaviest one weighs about 28 g). Each of these medallions has a diameter that is about the same as that of a tennis ball. The lightest one is as thin as a thumbnail, and the heaviest one is as thick as a credit card. This article shows that they were most likely created in 1588–89: the strongest evidence for this is that they used the double-hemisphere equatorial stereographic map projection that was first used by Rumold Mercator in 1587.

Keywords: Mercator, Van Sype, *Silver Map*, route of circumnavigation, map projections, medallion, medal, nautical maps, circumnavigation

Introduction

The Drake *Silver Maps* are 68-mm-diameter silver disks with maps of the known world featuring Drake's route of circumnavigation. They were probably stamped with dies.[1] The existing medallions have weights of 260, 275, 284, 300, 312, 326, 383, 410, and 424 grains (Kraus 2022; Christy 1900; Hague 1908). Each of these medallions has a diameter that is about the same as that of a tennis ball. The lightest one is as thin as a thumbnail (0.46 mm), and the heaviest one is as thick as a credit card (0.76 mm).[2] The heaviest medallion weighs about 28 g. In March 2022, this would have been worth about $27 US, $37 Can, £20, or €26.

There are nine known existing copies of the Drake *Silver Map*. The Library of Congress has two of them. One of these has a cartouche on the African side that reads "Micha Merca: fecit extat Londi: prope templũ Gallo: Ano 1589." We translate this as "Made by Michael Mercator in London near the French Church, 1589." The French Church would be the Huguenot church then on Threadneedle Street. Therefore, there is little controversy about the maker[3] (the stamper) and the date of creation of this particular medallion.

However, the other copies do not have this cartouche, and therefore, there is controversy about their authorship and date. The creation dates of these other medallions are the subject of this article. The British Museum (2022) has two silver medallions: one dates from 1585 to 1595 and the other from 1589.[4]

We have provided a list of internet sources for most of the maps mentioned in this article. This list/database is located at http://sysengr.engr.arizona.edu/URLsForSixteenthCenturyMaps.xlsx. This list has URLs for original high-resolution sixteenth-century maps in stable internet locations. Just click on a URL in this file and you will be connected to an original map.

STATEMENTS ABOUT DATING THE *SILVER MAPS*

- The Silver Maps represent the Amazon River as a giant snake. Therefore, they must have been made between 1545 and 1600 (Bahill 2021).

Figure 1. Drake *Silver Maps*. The western (left) and eastern hemisphere (right) (shown actual size). Unless noted otherwise, all maps in this paper have parallels of latitude and meridians of longitude that are spaced ten degrees apart.
Source: Photo credits Michael North and Eric Frazier, Rare Book and Special Collections Division, The Library of Congress. Similar photos, at lower resolution, are available at http://hdl.loc.gov/loc.rbc/rbdk.d058a and http://hdl.loc.gov/loc.rbc/rbdk.d058

- The *Silver Maps* show Drake's route of circumnavigation of the world. Therefore, they must have been made after Drake returned to England in September 1580. It would take some time to engrave dies for such a complicated map. Therefore, they must have been made in or after 1581.
- These maps label the Pacific Northwest of America as "Nova Albion," a phrase invented by Francis Drake. Therefore, these medallions had to be made in or after 1581 after he returned to England.
- Queen Elizabeth knighted Sir Francis Drake on April 4, 1581. The *Silver Maps* refer to him as "Sir." Therefore, these medallions must have been made after April 1581 (Christy 1900).
- Michael Mercator was likely born between 1565 and 1570. Therefore, if he created all the *Silver Maps*, then 1581 is probably too early of a date. At the age of 11 to 16 years, he would have been too young to have accepted a commission for making so many prestigious silver medallions.
- The maps have the name of the newly established colony of "Virginea." This name was invented in 1584. However, its earliest use on a map was likely in Hakluyt's publication of Peter Martyr's *De Novo Orbe* on a map dated 1587 (Hakluyt 1587; Verner 1950).[5]
- Between 1586 and 1588, Thomas Cavendish replicated Drake's circumnavigation of the world. The *Silver Maps* do not show Cavendish's route. Therefore, these maps might have been made before Cavendish completed his trip, or else the cartographer just saw no reason to include it and lessen Drake's glory.
- These medallions used the double-hemisphere stereographic map projection that was first seen on a map made by Rumold Mercator in 1587. Therefore, they must have been made in or after 1587. *This is our strongest point*.
- The medallions do not have the bulge on the western coast of Chile; therefore, they were probably made after Ortelius omitted the bulge in 1588 (Bahill 2022). This is our second strongest point.
- Figure 1 (right) has a cartouche with "Made in London by Michael Mercator . . . 1589 AD" stamped on it. Therefore, we should assume that Michael Mercator stamped this particular medallion in 1589.

Analysing these statements suggests that the Drake *Silver Maps* were created in 1588–89.

Other methods for dating sixteenth-century maps were given in Bahill (2021). The earlier statements determined the *earliest* possible creation dates for these *Silver Maps*. Now, if these *Silver Maps* were meant to celebrate Drake's circumnavigation of the world, why did they wait eight years after he returned to England to make them? Probably because Queen Elizabeth wanted to keep all of Drake's discoveries secret from the detested Spanish. This included the fact that he had circumnavigated the world and his route of circumnavigation. The queen told her subjects that they were forbidden to disclose any of these state secrets *under pain of death* (de Mendoza 1580).

ASSUMPTIONS

- Sir Francis Drake commissioned the creation and production of the *Silver Maps*.

- The 1589 *Silver Map* with the cartouche was the last medallion made because it would have been easier and more likely to engrave a cartouche onto the original die than it would be to erase a cartouche from it. This article also assumes that the cartouche is original with the medallion and not a later modification made to deceive.
- The cartouche was not engraved on the final medallion. If it were, it would have been obvious. No one has ever noticed this (Christy 1900). It must have been engraved on the dies or moulds.
- This paragraph is pure speculation. Some unknown person engraved the dies for the *Silver Maps*. Then the same or another unknown person struck many medallions using these dies. Then Michael Mercator, a young man, found the dies, engraved a cartouche with his name on it, and stamped a silver medallion. Alternatively, if we assume that the medallions were cast, then someone engraved an original medallion. Then the same or another person used this original to make moulds. They then cast many medallions. Then Michael Mercator found a cast medallion, erased some meridians and parallels, engraved a cartouche with his name on it, made a mould, and cast a silver medallion.
- The *Silver Maps* were made to highlight Sir Francis Drake's circumnavigation of the world. We assume that they were not intended to highlight any other British nautical triumphs, such as Cavendish's circumnavigation of the world or England's defeat of the Spanish Armada in 1588. However, they did present discoveries by Frobisher (1576) on the north-east coast of America.
- All nine of the existing medallions were stamped at about the same time using the same dies. Therefore, they are identical except for their thickness and the cartouche on the last one.
- The American sides are identical on all *Silver Map* medallions. The African sides are identical except for the one with the cartouche bearing Michael Mercator's name and the year 1589 (British Museum 2022).[6]
- The routes on the *Silver Maps* are correct representations of Drake's voyage, including Mucho Island.
- The *Silver Maps* are made of sterling silver, which comprises at least 92.5% silver and about 7.5% copper.

We will now look at our two strongest statements in detail, starting with our strongest statement, map projections.

Types of Map Projections

Definition: A map projection is an algorithm or, since the seventeenth century, a set of equations that allow the transformation of the three-dimensional spherical surface of the Earth onto a two-dimensional flat map.

We have found sixteenth-century maps that used the following map projections: equirectangular, Portolan charts (Van Duzer, 2020), Portolan charts with a latitude scale (McIntosh and Gaspar, 2021), cordiform, Ortelius oval, Bacon globular double-hemisphere, G. Mercator, double-hemisphere equatorial stereographic, and trapezoidal.

For maps we used that were published between 1587 and 1607, 19 used the Ortelius oval map projection, 17 used the Mercator double-hemisphere equatorial stereographic map projection, 3 used the Mercator map projection, 3 used the equirectangular map projection, 2 used the trapezoidal map projection, 1 used the Bacon globular double-hemisphere map projection, none used the cordiform map projection, and, of course, none used the Nicolosi globular map projection (Shirley 1983).

In the late sixteenth century, the most common map projections were the (1) Ortelius oval map projection used in the *Typus Orbis Terrarum* 1570 map (Figure 2) and the (2) double-hemisphere equatorial stereographic map projection used by Rumold Mercator in his *Orbis Terrae Compendiosa Descriptio* 1587 map (Figure 3; Shirley 1983).

MAP PROJECTIONS

We have provided a list of internet sources for the maps mentioned in this article. This list/database is located at http://sysengr.engr.arizona.edu/URLsForSixteenthCenturyMaps.xlsx. It has URLs for high-resolution original maps that are mostly in the public domain.

Ortelius Oval Projection

Example: *Typus Orbis Terrarum* by Abraham Ortelius 1570, Figure 2.

On an Ortelius oval projection map (Snyder and Voxland 1989, 178–79),

- the map of the Earth is contained in an oval shape with a flattened top and bottom.
- the central meridian (usually the zero-longitude meridian for whole Earth maps) and the equator are straight lines bisecting the oval. For *Typus Orbis Terrarum*, the zero-longitude meridian passes through Boa Vista and Sal in the Cape Verde islands.
- parallels of latitude are horizontal straight parallel lines unequally spaced along the central meridian.
- meridians of longitude are circular arcs (not ovals), unequally spaced (except along the equator), and connected at the poles, at the top and bottom of the oval. Along the equator, the meridians are equally spaced and perpendicular to it.

Figure 2. *Typus Orbis Terrarum* by Abraham Ortelius 1570, an Ortelius oval projection.

The Ortelius oval projection was popular for world maps in the sixteenth and early seventeenth centuries. The first oval projection map that we know of was drawn by Francesco Rosselli in 1508. Curiously, many authors call this the *Ortelius* Oval projection, although it was used sparingly 60 years before Ortelius. But *c'est la vie*.

Double-Hemisphere Stereographic Projection

Example: *Orbis Terrae Compendiosa Descriptio* by Rumold Mercator 1587, Figure 3.

On a double-hemisphere equatorial stereographic projection map (Snyder and Voxland, 1989, p. 122),

- the map of the Earth is contained in two circles.
- the central meridian of each circle and the equator are straight lines bisecting the circles. But this time, the central meridian is not the zero-longitude meridian.
- the zero-longitude meridian is the right side of the left circle and the left side of the right circle.
- parallels of latitude are circular arcs unequally spaced along the meridians.
- meridians of longitude are circular arcs unequally spaced along the equator. They come to a point at the poles at the top and bottom of the circles.

This map projection was also used for the *Silver Maps* 1588–89 and by C. de Jode, 1589; Plancius, 1590 and 1594; Hondius, 1590, 1595, and 1597; De Bry, 1596 and 1599; Vrients, 1596; Van Langren, 1596; M. Mercator, 1596; and Wytfliet, 1597. It was also used for 70 percent of the seventeenth-century maps in Shirley (1983). We have found no maps made before 1587 that used this projection.

Which Map Projection Did the Drake *Silver Maps* Use?

After comparing these sixteenth-century map projections, there is no doubt that the Drake *Silver Maps* used the double-hemisphere stereographic map projection.

Just like the double-hemisphere stereographic map projection, the *Silver Maps* are described by

- the map of the Earth being contained in two circles.
- the central meridian of each circle and the equator being straight lines bisecting the circles.
- parallels of latitude are *circular arcs being unequally spaced* along the meridians.
- meridians of longitude are also *circular arcs being unequally spaced* along the equator.
- the zero-longitude meridian being the right side of the left circle and the left side of the right circle because they represent the same meridian.

Figure 3. *Orbis Terrae Compendiosa Descriptio* by Rumold Mercator 1587, the published first double-hemisphere stereographic projection map.

The Drake *Silver Maps* look like maps created with a Nicolosi globular projection, which was invented only in 1660 except that the *Silver Maps* have meridians of longitude that are ***un****equally* spaced along the equator, while the Nicolosi globular projection maps have meridians of longitude that are *equally* spaced along the equator (Snyder and Voxland 1989, 176). This is easy to see visually and easy to measure on the maps.

The first publication of the projection used on the *Silver Maps* was by Rumold Mercator in 1587. Therefore, it seems certain that the *Silver Maps* were made in or after 1587.

Bulge on the Coast of Chile

In the mid-sixteenth century, printed world maps began to appear that had the Pacific Ocean coasts of the South and North American continents. Most later maps were similar. Over the years, each cartographer just added details. Then in 1561, Girolamo Ruscelli made a unique addition. He added a big bulge to the coast of Chile. In 1569–70, Abraham Ortelius and Gerard Mercator added a bulge on *their* western coasts of Chile. In the next score of years, dozens of cartographers followed their lead and produced maps with a bulge on their coasts of Chile (Bahill 2022).

Figure 4. The left-hemisphere of *Orbis Descripto* by Girolamo Ruscelli 1561, a Bacon Globular Double-hemisphere map projection. Land to the west of the green line and below the Tropic of Capricorn is defined as the bulge on the coast of Chile (Bahill 2022).

ADD THE BULGE TO THE COAST OF CHILE

In 1561 Girolamo Ruscelli in his *Orbis Descriptio* map in his *La Geografia di Claidio Tolomeo Alessandrino . . .* atlas (which was just one more translation of Ptolemy's *Geographia*) put a bulge on the coast of Chile below the Tropic of Capricorn as shown in figure 4. He was followed by Pablo Forlani 1562, Giacomo Gastaldi 1561 (very fuzzy date) and 1565, and Diogo Homen 1565.

This map by Ruscelli was the first double-hemispheric map to appear in an atlas. It resembles the map projection suggested by Roger Bacon in 1265 in that (1) its parallels are straight lines equally spaced on the meridians and (2) its central meridian is straight; however, other meridians are circular arcs equally spaced along the equator but not along other parallels. Of course, Ruscelli probably did not know about Bacon's work.

In 1570, Ortelius published the first modern atlas, *Theatrum Orbis Terrarum*. Then he updated and reissued it just about every year. The *Typus Orbis Terrarum* maps in his atlases from 1570 to 1587 had the bulge on the coast of Chile. Mercator and Ortelius were early adopters of this big bulge in 1569–70. Others followed suit by adding bulges to their coasts of Chile, for example, André Thevet, 1575; Francisco de Belleforest, 1575; Gerald de Jode, 1578; Nicola van Sype, 1589; Joan Martines, 1587; Rumold Mercator, 1587; Urbano Monte, 1587; Sebastian Munster, 1580 and 1588; Cornelius De Jode, 1589; and Theodor de Bry, 1592.

REMOVE THE BULGE FROM THE COAST OF CHILE

In 1588, Ortelius made a dramatic change: he *omitted* the bulge on the coast of Chile. Specifically, he omitted the bulge on the *Typus Orbis Terrarum* map printed in 1588 (Figure 5 right). He did the same on his *Typus Orbis Terrarum*, 1589, and others; his *Americae Sive*, 1587; and his *Maris Pacifici*, 1589. These maps were all contained in his atlases: they were not published individually. This, therefore, makes dating a little more certain.

The following maps omitted the bulge on the coast of Chile: Ortelius *Typus Orbis Terrarum*, 1588 and later; *American Sive . . .* 1587 and later; and *Maris Pacifici*, 1589. In this article, the right side of Figures 1 and 5 do not have this bulge on the coast of Chile.

After 1588 cartographers either followed Ortelius's lead and omitted the bulge on the coast of Chile, or they had never put it there in the first place, for example, the *Silver Maps*, 1588–89; Richard Hakluyt, 1589; C. de Jode, 1593 (*Brazil and Peru*); Petrus Plancius, 1594; Jodocus Hondius, 1597; Theodor de Bry, 1596; Jan Baptists Vrient, 1596; João Lavanha and Luis Teixeira, 1597; Edward Wright and Emery Molyneux, 1598;

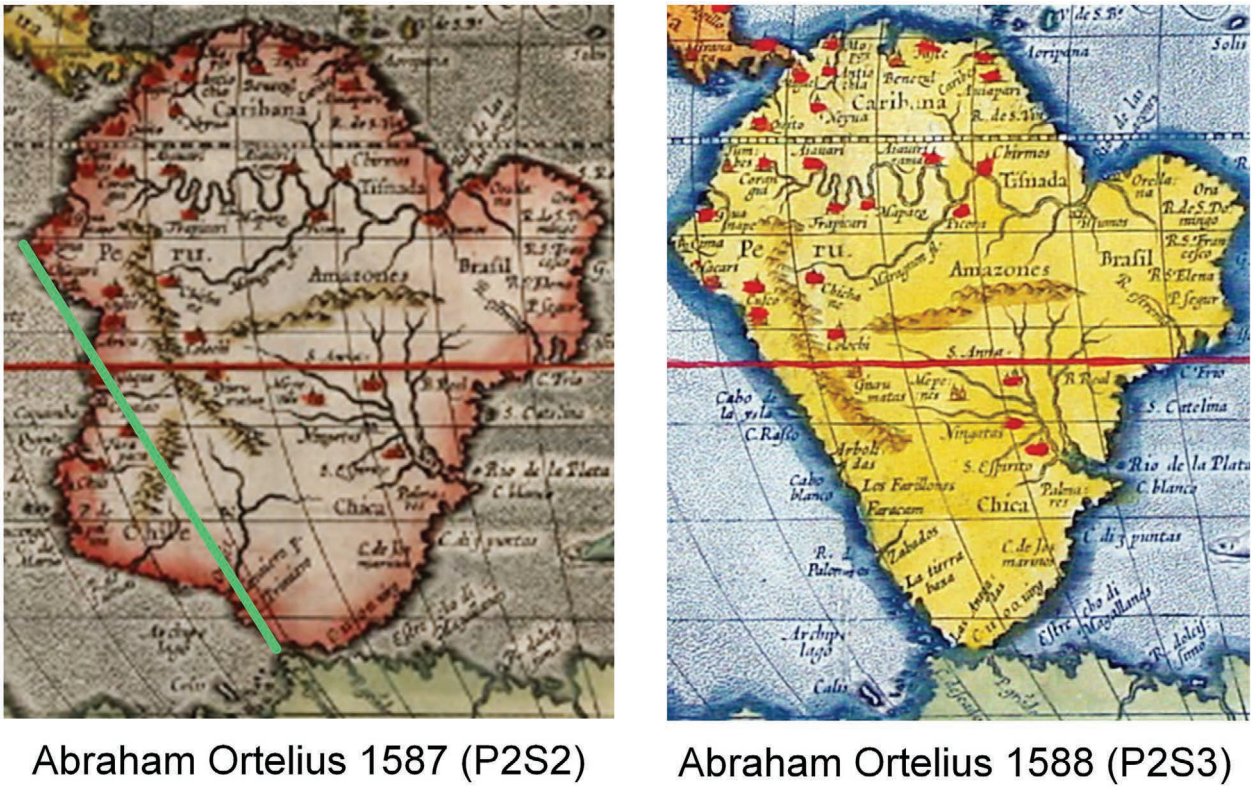

Figure 5. Parts of *Typus Orbis Terrarum* by Ortelius 1587 (P2S2) (left) and 1588 (P2S3) (right). These are Ortelius Oval map projections. Land to the west of the green line is the bulge. The abbreviations P2S2 and P2S3 stand for plate-2 state-2 and plate-2 state-3, respectively. It is a modern shorthand to distinguish maps with small variations (Shirley 1983). The only differences between the two maps are to the left of the green line.

and Matteo Ricci, 1602. A few cartographers, for example, Michael Mercator, 1595, continued using this bulge.

We have found no explanation for *why* Ortelius omitted the bulge on the coast of Chile. However, this mistake in the maps seems to have vexed Sir Francis Drake (1628), who wrote,

> [W]e continued our course, *Nouember* 1, [1578] still North-west, as wee had formerly done, but in going on we soone espied, that we miglit easily haue beene deceiued; and therefore casting about and steering vpon another point, wee found, that the generall mappes did erre from the truth in setting downe the coast of *Peru*, [Drake refers to the whole coast as Peru, not differentiating between Chile and Peru. Drake continues describing the section of the coast between 52° S and 40° S latitude.] . . . perceiuing hereby that no man had euer by trauell discouered any part of these 12. deg., and therefore the setters forth of such descriptions are not to be trusted, much less honored, in their false and fraudulent coniectures which they vse, not in this alone, but in diuers other points of no small importance.

At the end of his circumnavigation of the world, Drake returned to England in 1580. We conjecture that Drake expressed his displeasure to some cartographers and probably corrected the coast of Chile on his Whitehall map because most cartographers later changed the coast of Chile on their maps. This conjecture is supported by earlier Drake's written words and the *Silver Maps* of 1588–89. A photograph of one is shown in Figure 1. Notice that the bulge on the coast of Chile has been omitted. Ortelius probably never saw the Whitehall map. Rather than feed his information to the cartographers of the time, he probably got information from them.

Ortelius omitted the bulge in 1588. The *Silver Maps* do *not* have the bulge on the coast of Chile; therefore, they were most likely made after the bulge was omitted in 1588.

In the sixteenth century, revising maps was time-consuming and expensive. Therefore, if a map has the bulge on the coast of Chile, this does not prove that the map was made before 1588. It may just be that the cartographer did not have the time, money, or motivation to revise his map, for example, Michael Mercator, 1595. On the other hand, if a mainstream map does not have the bulge on the coast of Chile, then it is most likely that it was made after 1588.

Most world maps published between 1561 and 1588 have a smooth bulge on the western coast of Chile. This bulge lies between the Tropic of Capricorn (23.4° S) and 45° S latitude (Bahill 2022). See the left side of figures 4 and 5. In 1588, Abraham Ortelius omitted this bulge: everyone followed suit except for the Drake-Mellon 1588 map, French-Drake 1589 map, Dutch-Drake 1595 map, Emery Molyneux 1592 globe, Hondius1595 Broadside map, Theodor de Bry 1599 map, and Wright and Molyneaux 1599 map. On these maps, the cartographers did not omit the bulge entirely. Instead, they shrank it horizontally and vertically and made it a smaller ragged protrusion between 46° S latitude and 53° S latitude.

Figure 6. A part of a *Silver Map* from the Kraus Collection of Sir Francis Drake, Library of Congress exhibit no. 58. Photo credit Michael North and Eric Frazier, Rare Book and Special Collections Division, The Library of Congress.

The absence of the bulge on the coast of Chile presents compelling evidence that the *Silver Maps* were made in or after 1588.

Who Made the *Silver Maps*?

This article is about dating the *Silver Maps*. Its purpose is not to determine who created the medallions. But we make a few points in passing.

Of the nine existing silver medallions, the 1589 *Silver Map* with the cartouche was probably the last medallion stamped because it would be easier and more likely to engrave a cartouche onto an original die than it would be to erase a cartouche from one. Furthermore, there are traces of the original parallels and meridians on the cartouche (see Figure 6).

The yellow arrows in Figure 6 show places where the erasure of parallels and meridians was not complete, and they overlap the rim of the cartouche. The pale green lines show where too much of one parallel was erased.

The handwriting in the cartouche is different from that on the rest of the medallion. Compare the writing of Tristan d' Acunna island in the upper-left corner of Figure 6 (present-day Tristan da Cunha Island, 37.1° S, 12.3° W) with the writing inside the cartouche. They are quite different. The lettering outside the cartouche is elegant. In comparison, the lettering inside the cartouche is amateurish.

The following is a possible, but purely speculative, didactic scenario. Some unknown person engraved the dies for the *Silver Maps* in 1588–89. Later, the same or another unknown person struck many medallions using those dies. Of those, eight medallions presently exist. Then Michael Mercator, a young man, found the dies in his Uncle Rumold's workshop. He engraved his name in a cartouche on the back and stamped the medallion shown in the right side of Figure 1.

In 1588 Michael Mercator would have been between 18 and 23 years old. Would Sir Francis Drake have given a monumental commission like this to such a young man, who had not yet published a map on his own, to make Drake's present for the Queen of England? We think not. Therefore, we believe that Michael Mercator did not engrave the *dies* for the *Silver Maps*.

The existing silver medallions use the double-hemisphere stereographic map projection that was first used by his uncle Rumold Mercator and first published in 1587. The cartographer of these medallions must have been familiar with this map projection. This rules out, as cartographers of the *Silver Maps*, G. Mercator, Ortelius, and dozens of other cartographers mentioned in this article who did their work before 1587.

Maps made by the following cartographers did use this map projection: R. Mercator, 1587; C. de Jode, 1589; Plancius, 1590 and 1594; Hondius, 1590, 1595, and 1597; M. Mercator, 1595; De Bry, 1596 and 1599; Vrients, 1596; Van Langren, 1596; and Wytfliet, 1597. Now we must rule out all of these cartographers who apparently gained their knowledge after 1588. This leaves Rumold and Michael Mercator. That is a small field.

Christy (1900) wrote emphatically that the *Silver Maps* were created in 1581 by the same person who created the *Novus Orbis* map in Hakluyt (1587). His initials were F. G. However, this is not likely because the *Silver Maps* used the double-hemisphere stereographic map projection and "F. G." used an Ortelius oval map projection.

Next, we compared the handwriting on the *Silver Maps* to that on the Rumold Mercator 1587 map and the Michael Mercator 1595 map. There is a substantial difference in the slant of the letters. In the toponym Lima, for example, the average slant of the letters on the *Silver Maps* is 20 degrees to the right; for the Rumold Mercator 1587 map, it is 25 degrees to the right; and for the Michael Mercator 1595 map, it is 4 degrees to the right: the letters are almost vertical. This suggests that Rumold, but not Michael, might have engraved the dies for the *Silver Maps*.

These incipient findings suggest that Rumold Mercator engraved the dies for the *Silver Maps*. But this article is not about who created the *Silver Maps*. It is about dating the *Silver Maps*. The issue of who engraved the dies is the subject of another article that we have under preparation.[7]

UNUSUAL REPRESENTATIONS FOR THE NUMBERS 1 AND 2

The font that Michael Mercator used for his map *America sive India Nova* in the 1595 atlas *sive Cosmographicae Meditationes*

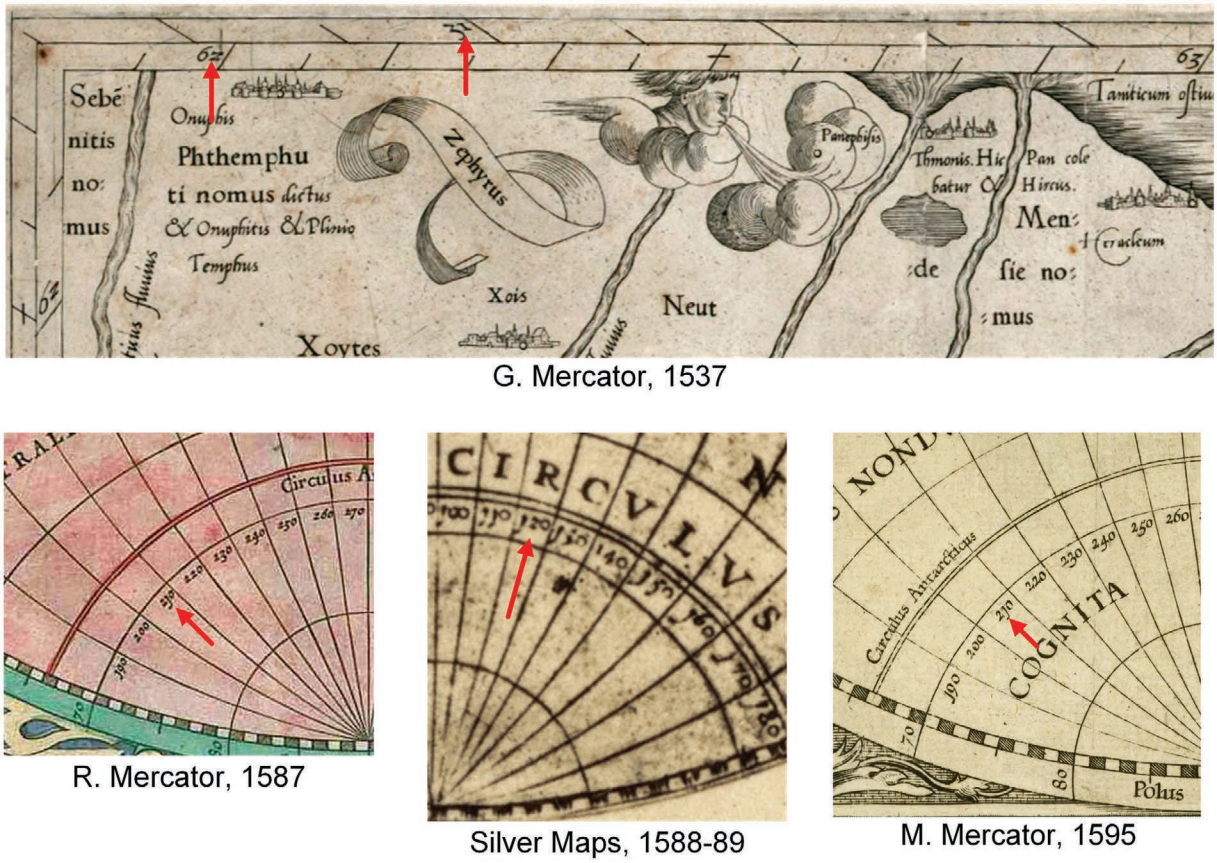

Figure 7. G. Mercator 1537 used a normal '1' and a 'z' for a '2'. The *Silver Maps* 1588–89, R. Mercator 1587, and M. Mercator 1595 used a "j" for a '1' and a normal '2'.

used a symbol for "1" that has a hook on the bottom and a serif on the top that makes it look like a "j" as shown in Figure 7. The R. Mercator 1587 *Orbis Terrae Compendiosa Descriptio* does too, as shown in figure 3, and so, too, do the *Silver Maps*. This certainly implicates the Mercators in the creation and production of the *Silver Maps*.

G. Mercator's 1537 map *Candido lectori S. Palestinam . . .* and his 1538 *World Map on Double Cordiform Projection* (title derived by Library of Congress staff) used the letter *z* to stand for the numeral 2. Neither the *Silver Maps* nor the R. Mercator 1587 map nor the M. Mercator 1595 map used $z = 2$. Therefore, this does not help identify the engraver of the *Silver Maps*.

WHICH MAPS HAD DRAKE'S ROUTE?

The *Silver Maps* show Drake's route of circumnavigation of the world. The following texts and maps describe Drake's route of circumnavigation:

- The Whitehall Map 1581, the original and all copies vanished in the seventeenth century
- Drake-Mellon map, 1587, *Vera descriptio expeditionis nauticae . . .*
- Drake *Silver Maps* 1588–89,
- Richard Hakluyt, 1589, *The Principall navigations . . .*, text no map
- French-Drake Van Sype map, 1589, *La Herdike Enterprinse . . .*
- Dutch-Drake map, 1595, *La Heroike Interprinse . . .*
- Emory Molyneux 1592, *Petworth Globe*
- Jodocius Hondius, 1595, *Vera Totius Exbitionis Nautica*, aka *Broadside*
- Theodor de Bry 1599, *America Pars VIII*

Therefore, all these cartographers could be candidates.

URLs for these sixteenth-century maps in high-resolution in stable Internet locations are located at http://sysengr.engr.arizona.edu/URLsForSixteenthCenturyMaps.xlsx.

UNDER PAIN OF DEATH

Queen Elizabeth wanted to keep all of Drake's discoveries secret from the hated Spanish. The Spanish ambassador to England, in an encrypted letter to his king, wrote, "They are not to disclose the route they took *under pain of death*" (de Mendoza, 1580, emphasis added).

There was considerable controversy about this censoring. Evidently, this ban was upheld for eight years. After Cavendish's circumnavigation (1586–88) and the defeat of the Spanish Armada (1588), this restriction must have faded (Toppin 2013), for around 1588, four important descriptions of Drake's route of circumnavigation were published, namely, (1) *Vera descriptio expeditionis nauticae Francisci Draci Angli*, colloquially called the *Drake-Mellon map*, England, 1587; (2) Richard Hakluyt, *The Principall navigations, voiages and discoveries of the English nation*, London, 1589 (text only, no map); (3) the *Silver Maps*, 1588–89; and (4) Nicola van Sype (1589), *La Herdike Enterprinse Faict Par Le Signeur Draeck D'Avoir Cirquit Toute La Terre*.

This discussion helps solidify the date of creation of the *Silver Maps* to the period of 1588–89. But it does not help to identify the cartographer of these medallions. In contrast to our usual technique, this section is based on historical documents, not on the maps alone.

How Were the *Silver Maps* Made?

The *Silver Maps* are very unusual. We know of no other medallions or coins like them. They are not like coins that have the portrait and the letters raised above the surface of the coin. By contrast, for the *Silver Maps*, the lines and letters are pushed into the surface. It looks like they were engraved. However, this is not possible because the nine existing medallions are identical (except for the cartouche). And no engraver could have engraved that many identical medallions (Christy 1900) Therefore, they must have been cast with moulds or stamped with dies.

This paragraph presents two of many purely speculative techniques that could have been used for making the *Silver Maps*. For the stamping technique, the engraver would have engraved a positive image of the map on a medium-hard metal. Then, they would have pressed (hammered) a heated medium-soft metal onto this positive image to make a negative-image die. Finally, they would have used the dies to stamp positive-image silver medallions. The dies would not have to have been made from a hard metal like iron or bronze because they would not have been used to make hundreds of medallions. It would have been all right if they wore out after making only a few dozen silver medallions. For the casting technique, the engraver would have engraved a positive image of the map on any suitable surface, even wax. They would have then poured mould material all over the map to make a negative-image mould. Finally, he would have used the moulds to cast positive-image silver medallions.

But this article is about dating the *Silver Maps*, not about making them. So that is all we will say about manufacturing.

Conclusion

The Drake *Silver Maps* are silver medallions approximately 68 mm in diameter with maps of the late sixteenth-century known world featuring Drake's route of circumnavigation. Their weights depend on their thicknesses. The lightest one is as thin as a thumbnail, and the heaviest one is as thick as a credit card. There are nine known existing copies of these medallions. One of these has a cartouche on the eastern-hemisphere side that states, "Made in London

by Michael Mercator . . . 1589." Because we assumed that the medallion with this cartouche was the last medallion made, then all the *Silver Maps* must have been made in or before 1589. The creation dates of all these *Silver Maps* were the subject of this article.[8]

The following three reasons suggest that all nine of these medallions were made in or after 1581. They had to have been made after Drake completed his circumnavigation and returned to England in September 1580. These maps label the Pacific Northwest of America as "Nova Albion," a phrase invented by Francis Drake during his voyage. Queen Elizabeth knighted Sir Francis Drake on April 4, 1581. These three reasons suggest that these medallions were made after April 1581.

The maps have the name of the newly established colony of Virginia, which was first named in 1584 (Verner 1950). The earliest use of this name is on a map dated 1587.

The medallions do not have the bulge on the coast of Chile; therefore, they were most likely made after the bulge was omitted in 1588.

These medallions used the double-hemisphere stereographic map projection that was first used by Rumold Mercator in 1587. Therefore, they were probably made in or after 1587. This is our strongest point.

The date engraved on the last-made medallion, the one with the cartouche, ensures that all the *Silver Maps* were made in or before 1589. The lack of a bulge on the coast of Chile ensures that they were made after the bulge was omitted in 1588. The use of the double-hemisphere stereographic map projection guarantees they were made in or after 1587. Therefore, we conclude that the Drake *Silver Maps* were created in 1588–89.

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Notes

1 These medallions were not individually engraved. They might have been cast in moulds, stamped between dies, or screw-pressed between dies. Stamping was common at this time. It does not make a difference for this article. Consequently, we just assume that they were stamped. The appendix discusses differentiating between cast and stamped medallions.

2 For comparison, an American Morgan or Peace silver dollar weighs 413 grains, has a diameter of 38.1 mm, and a thickness of 2.58 mm. The Canadian Maple Leaf silver coin weighs 480 grains, has a diameter of 38 mm, and a thickness of 3.3 mm. If one were to flatten such a coin to the thickness of a credit card, then the result would be a good model for a *Silver Map*. The same would be true for an Australian Wedge-Tailed Eagle, a South African Krugerrand, and a Chinese Silver Panda.

3 We use the following definitions: the cartographer draws the original map on paper, the engraver engraves the map on metal dies or metal disks, and the maker (the stamper or caster) is a craftsperson who stamps silver blanks with dies or casts molten metal into moulds. These three roles can be filled by one, two, or three people.

4 The British Museum actually has three *Silver Maps*. It says that the third M.9478 was electroformed. Because electroformation was invented in 1838, the museum is saying that this third medallion is a later replica See relevant page in Appendix.

5 The *Silver Maps* and the Dutch-Drake map also label California. But this is of no help because previous maps by Castillo, 1541; Pereira, 1545; and Gutiérrez and Cock, 1562, had already labelled it.

6 While describing its medallion in the Department of Prehistory and Europe, the British Museum stated, "This medallion has recently been analysed using optical microscopy and micro-X-ray fluorescence to compare its features against a seemingly identical copy in the Department of Coins and Medallions (object no.1882,0507.1). The results indicate that both medallions were cast from the same model but from different batches of metal" (British Museum 2022). This, of course, adds no evidence about casting versus stamping. See https://www.britishmuseum.org/collection/object/H_1891-0905-12.

7 A remaining problem to be addressed is that Michael Mercator's the *America sive India Nova . . .* map in the Mercator 1595 atlas uses the bi-hemispheric stereographic projection; however, it still has the bulge on the southern coast of Chile. If Michael Mercator were the engraver of the dies for the *Silver Maps* and his map in the 1595 atlas, then why did he omit the bulge on the southern coast of Chile on the silver map dies but then put it back on his map in his 1595 atlas? Also, could knowledge of the double-hemispheric stereographic projection have been in the Mercator family, and could Michael Mercator have learned of it from his uncle before its publication in 1587?

8 A secondary purpose of this article is to show that research studies like this could be done based solely on the maps' visual appearance compared to standard works such as Snyder and Voxland (1989). We did not use (1) historical texts or (2) accounts of family, friendship and religious relationships, social status, culture, language, geographical location, or of professional feuds.

References

We have provided a list of internet sources for the maps mentioned in this article. This list/database is located at http://sys-engr.engr.arizona.edu/URLsForSixteenthCenturyMaps.xlsx.

Bahill, A.T. 2021. "The Second Engraver of the Library of Congress Mystery Map." *International Journal of Cartography*. Published ahead of print, December 20, 2021. https://doi.org/10.1080/23729333.2021.1988042

Bahill, A.T. 2022. "Sixteenth Century Bulge on the Coast of Chile." *Journal of Geographical Research* 5(2): 11–27. https://doi.org/10.30564/jgr.v5i2.4357

Bahill, A.T., and G.D. Gitzen. 2021. "The Amazon River Modeled as a Giant Snake." *KN—Journal of Cartography and Geographic Information* 71(3): 173–94. https://doi.org/10.1007/s42489-021-00082-3

Bahill, A.T., and A.M. Madni. 2017. *Tradeoff Decisions in System Design*. Springer Publishing Company.

British Museum. 2022. Department of Coins and Medallions. Museum number 1882,0807.1. https://www.britishmuseum.org/collection/object/C_1882-0507-1. Accessed November 2022.

British Museum. 2022. Department of Prehistory and Europe. Museum number 1891,0905.12. https://www.britishmuseum.org/collection/object/H_1891-0905-12. Accessed November 2022.

Christy, M. 1900. *The Silver Map of the World; a Contemporary Medallion Commemorative of Drake's Great Voyage (1577–80) a Geographical Essay* . . . H. Stevens, SON, & Stiles, London. Available at https://www.unz.com/print/ChristyMiller-1900.

de Mendoza, B., 1896. 'Letter to Philip II, 16 October 1580.' 'Simancas: October 1580,' in *Calendar of State Papers, Spain (Simancas), Volume 3, 1580–1586*, ed. Martin A S Hume, 52–63. London. Available at http://www.british-history.ac.uk/c-al-state-papers/simancas/vol3/pp52-63.

Drake, F. 1628. *The World Encompassed by Sir Francis Drake*. Available at https://archive.org/details/worldencompassed16drak/page/n14.

Hague, J.D. 1908. "The Drake Medallion." *Bulletin of the American Geographical Society* 40(8): 449–69. https://doi.org/10.2307/197325

Hakluyt, R. 1587. "Peter Martyr's *De Novo Orbe*." *Imago*. https://www.imago-images.com/st/0060096813.

Hondius, J. 1595. *Vera Totius Expeditionis Navticae*. London 1590, Amsterdam 1593 and 1595. Available at https://www.loc.gov/resource/g3201s.ct000130/?r=-0.098,0.299,0.835,0.318,0#

Kraus Collection of Sir Francis Drake, Library of Congress. Accessed May 2022. http://hdl.loc.gov/loc.rbc/rbdk.d058a.

Kraus, K.P. 2022. "Silver Maps, Known Specimens of the Silver Map." The Catalogue of the Collection, Sir Francis Drake: A Pictorial Biography by Hans P. Kraus, Rare Book & Special Collections Reading Room, Library of Congress. Last accessed May 2022. https://www.loc.gov/rr/rarebook/catalog/drake/drake-catalogue.html

McIntosh, G. C. and J. A. Gaspar. 2021. "Kunstmann III: The Oldest Known Nautical Chart Incorporating Latitudes," *Imago Mundi*, 73(2): 162-178, DOI: "https://doi.org/10.1080/03085694.2021.1960021".

Shirley, R.W. 1983. *The Mapping of the World: Early Printed World Maps, 1472–1700*. London: Holland Press.

Snyder, J.P., and P.M. Voxland. 1989. "Professional Paper 1453, An Album of Map Projections." *USGS Publications Warehouse*. http://pubs.er.usgs.gov/publication/pp1453.

Toppin, M.D. 2013. *Nova Albion Revealed: Drake's Claim of California Celebrated by Hakluyt and Hondius, 2013*, Oxford University. Available at https://open.conted.ox.ac.uk/resources/documents/nova-albion-revealed-drake%E2%80%99s-claim-california-celebrated-hakluyt-and-hondius.

Van Duzer, C. 2020. *Martin Waldseemüller's 'Carta marina' of 1516—Study and Transcription*. Cham, Switzerland: Springer Open. https://doi.org/10.1007/978-3-030-22703-6

van Sype, N. 1589. *La Herdike Enterprinse Faict Par Le Signeur Draeck D'Avoir Cirquit Toute La Terre*. Library of Congress Rare Book and Special Collections Division, 2004629174. http://hdl.loc.gov/loc.gmd/g3201s.rb000011.

Verner, C. 1950. "The First Maps of Virginia, 1590–1673." *The Virginia Magazine of History and Biography* 58(1): 3–15. https://www.jstor.org/stable/4245671.

Appendix

DIFFERENTIATING CAST AND STAMPED MEDALLIONS

Unlike the rest of our papers, this appendix is not based on the maps themselves. It is speculation based on scientific and historical documents and logical arguments.

For the last three millennia, two primary methods have been used to make coins and medallions: casting molten metal into moulds and stamping metal blanks between dies. Once a coin or medallion has been made, it is hard to tell the difference. The British Museum states that its two *Silver Map* medallions were cast. The Library of Congress states that its two medallions were either cast or stamped. This article has leaned toward the stamping of the *Silver Maps*. This appendix explains why.

If a cast coin (or a medallion) is to be made without destroying the mould, then the mould must have a top and a bottom so that the coin can be removed. Therefore, a cast coin will have a top mould and a bottom mould. When these two halves are joined together, it might leave a joint trace around the edge. When the coin is handled, this joint trace might be visible on a cast coin. The British Museum has two silver medallions: one is dated (1891,0905.12) from 1585 to 1595 and the other (1882,0507.1) to 1589. The museum states that both of these were cast. None of the edges of the nine existing silver medallions are visible on the internet photographs. Therefore, we do not know if they have joint traces.

The British Museum actually has three *Silver Maps*. It says that the third (M.9478) was electroformed. Because electroformation was invented in 1838, it is saying that this third medallion is a later replica.

Some stamped coins of the sixteenth century (and all present-day coins) had reeds or vertical ribs on their edges. But cast coins did not have such edges. Unfortunately, the silver medallions did not have reeding on the edges, so this fact was of no use in differentiation.

With a stereomicroscope, a cast medallion might show more surface bubbles than a stamped medallion. A cast medallion will not have sharp corners, for example, at the base of raised letters. When gently hit on the edge, the cast coin will have a lower frequency and a broader bandwidth (see https://medalblog.wordpress.com/2012/03/26/how-to-tell-struck-medals-from-cast/). Furthermore, the surface of a stamped medallion has residual elastic compression while the surface of a cast medallion has no stress. Non-destructive X-ray diffraction can reveal these differences. Therefore, these properties could be used to differentiate medallions produced by casting or stamping. Unfortunately, these medallions are not available for handling and experimentation.

The existing Drake *Silver Maps* have weights of 260, 275, 284, 300, 312, 326, 383, 410, and 424 grains. This big variation would not be expected if they were cast from the same moulds. (However, if the moulds were sacrificed instead of being reused, then this might be reasonable.) If they were stamped, such a large variation would seem natural. This variation in weights would simply depend on the thickness of the blank.

Coins and medallions are not perfectly circular. We thought that this lack of circularity could be used to distinguish between cast and stamped medallions. We expected stamped coins to be more circular.

The second column of Table A1 has data for the internet photograph of Exhibit No. 58 (rbdk d058) of the Library of Congress. The third column has data for this same medallion that was photographed especially for us in higher resolution. The fourth column has data for the photograph of Exhibit No. 58A of the Library of Congress that is on the internet. The fifth column has data for the photograph of the British Museum's 1891,0905.12 that is on the internet. The sixth column has data for a photograph of a US 2018 Silver Eagle. To be valid, the photos had to be taken from directly above. Photos that were taken at an angle (probably to show the reeds or groves on the edge) were not used. If a coin or a medallion were perfectly round, then the standard deviation of the average of many measured diameters would be zero. This is not the case for the coins and medallions in Table A1. There, the standard deviations for the sixteenth-century medallions are nearly as small as for the twenty-first-century Silver Eagle. Therefore, this technique was not useful for distinguishing between cast and stamped medallions.

There are many types of mistakes that indicate coins made with a stamping process, for example, those with the image not centred on the base or double-struck coins.

We are now going to examine three processes that present-day craftspeople could use to create a medallion like Michael

Table A1. The results of measuring eight diameters on photographs of different medallions and coins

	Library of Congress No 58	Personal photo of LoC 58	Library of Congress No 58A	British Museum 1891	2018 USA Silver Eagle
Average diameter	67.38	67.82	68.06	68.13	40.54
Standard deviation	0.45	0.26	0.10	0.39	0.17
Stated diameter	68	68	68	68	40.60

Note: Diameters are in mm.

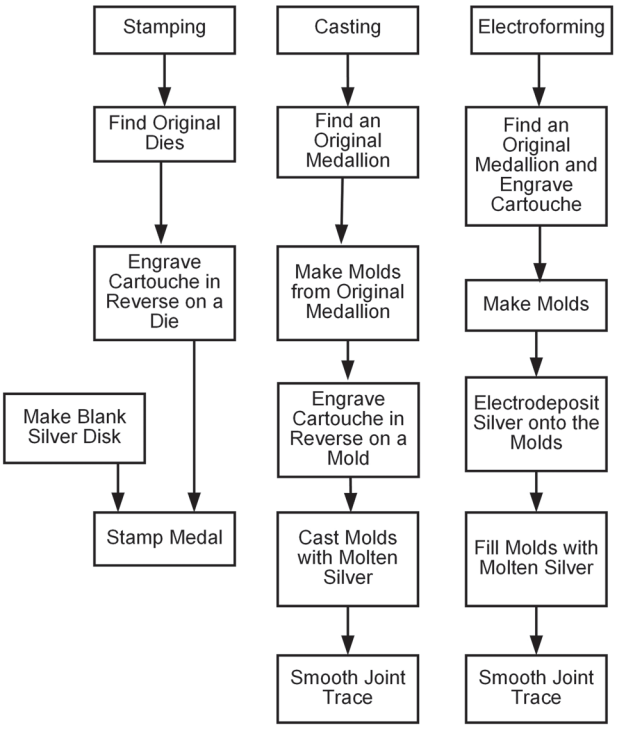

Figure A1. Plausible alternative processes that Michael Mercator might have used to make his 1589 medallion.

Mercator's 1589 medallion: stamping, casting, and electroforming. Figure A1 shows (very simplistically) the steps that would be involved. However, the processes shown in Figure A1 are heuristic. They do not represent any particular minting process. Actual minting processes have many variations. For example, the process of going from a positive image to a negative image to a positive image may occur several times. Furthermore, at any particular mint, many dies may be used either simultaneously or sequentially for the production of each type of coin.

Process 1, stamping

Inputs: original dies and blank silver disks
Outputs: a new medallion and modified dies
States: the dies are altered, we cannot go back

Process 2, casting

Inputs: original medallion and a pile of silver
Outputs: the original medallion and a replica
States: the original medallion could be either modified or unaltered

Process 3, electroforming

Inputs: original medallion and a pile of silver
Outputs: an altered original medallion and a perfect replica
States: the original medallion is altered

Detailed Steps for Process 3, electroforming

- Find an original medallion and engrave the cartouche.
- Pour silicon rubber on the heads (obverse) side to make a mould.
- Separate the obverse side mould from the medallion.
- Then, pour silicon rubber on the tails (reverse) side to make a second mould.
- Separate the reverse side mould from the medallion.
- Carefully coat the insides of both moulds with graphite or another conductor.
- The moulds become the cathode in an electrolyte acid solution (e. g., silver nitrate). Create a silver anode and pass direct current through the cell for a day.
- There will now be a thin silver shell for each side of the medallion.
- Separate the shells from the moulds.
- Assemble the two shells back to back. (The shells will be too thin to engrave the cartouche on one of them.)
- Pour molten silver into this sandwich.
- (Alternatively, the two sides could be filled separately and then joined together.)
- When everything cools, remove the new replica, and smooth off the joint trace between the two halves.

With additional steps, all three techniques could be used to make replicas without altering the originals.

Electroforming was not invented until the nineteenth century. Therefore, Michael Mercator could not have used this process. That leaves stamping and casting. Without examining the original medallions and doing experiments on them we have not been able to determine if the original *Silver Maps* were stamped or cast.

When designing a system, there are four top-level types of requirements: performance, cost, schedule, and risk (Bahill and Madni 2017).

When selecting between stamping and casting for making the original silver medallions, we can first consider performance. Both processes are capable of producing medallions of equal high quality. Therefore, neither process has an advantage here.

When considering cost, casting is less expensive. Dies for stamping must be made of a hard metal and producing and engraving such hard metals is difficult, whereas moulds for casting can be made from anything that can withstand high temperatures, even sand. But we do not think that Sir Francis Drake cared about cost in 1588. After all, he brought back 30 tons of silver, and these medallions only used, at most, an ounce of silver each.

The schedule would be longer for stamping because of the time required to make the dies. But if Drake waited eight years (from 1580 to 1588) before requesting the medallions, then he must not have worried about the schedule.

The risks would be about the same because both require dealing with high-temperature molten metals. We also considered the risks of theft, embezzlement, and damage to the cartographer's reputation. None of these made a difference.

The difference would occur when the required number of medallions is considered. If only a few medallions were required, then casting would be less expensive and faster. However, if hundreds of medallions were required then stamping would be less expensive because dies last longer than moulds.