THE PLATE OF BRASS REEXAMINED

A Supplement
1979

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A Supplementary Report

Issued by The Bancroft Library

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The Plate of Brass Reexamined 1977 was a pamphlet issued by The Bancroft Library to report an impartial investigation of the intriguing artifact ostensibly left by Francis Drake on June 17, 1579 at a site in California when he claimed the land for Queen Elizabeth. The authenticity of the Plate had been championed by some scholars but it had also been questioned over some forty years since the skepticism first expressed by Henry R. Wagner, R. B. Haselden and others shortly after its discovery in 1936.

The introduction to *The Plate of Brass Reexamined 1977* concluded "doubtless at later dates other inquiries and further commentary will be forthcoming." In keeping with that statement and in part as a result of expected questioning of views expressed in the Report, further scientific investigations have been conducted under the auspices of The Bancroft Library and are here briefly reported.

They are of two kinds. First come the additional tests of the Plate itself and of the way it was presumably made, followed by further considerations of 16th-century brass.

In the first category is an X-ray diffraction investigation made to determine whether the Plate was hammered or rolled. Knowledge is limited about what might have been achieved by rolling brass in the 16th century, but according to Professor Cyril Stanley Smith of M.I.T., rolling machinery could create only very narrow strips, about two inches in width, such as were employed for making coins, and not a width so great as that of the Plate, which is over five inches. Moreover, Professor Derek de Sola Price of Yale, stated that if a brass sheet of the Plate's size— eight inches long— were rolled in the 16th century, it would have a variation in thickness of about 10% after hammering, rather than the variation of 1.5% in the Plate, whose thickness is almost exactly one-eighth of an inch, a common modern standard gauge. To test the possibility that the Plate of Brass was rolled, Professors Earl R. Parker and Robert H. Bragg of the Department of Materials Science and Mineral Engineering, University of California, Berkeley, examined the Plate's surface by X-ray diffraction to establish whether the pattern of its elemental structure is randomly oriented, as would be true of a hammered plate, or whether it has the clear orientation which is produced by cold rolling. The test (reported upon in Appendix 1) was carried out both upon the Plate of Brass itself and upon a new rolled brass plate similar in size and shape. The densitometer measurement made by Professor Roger Hahn of X-ray diffraction pictures of the Drake Plate led him and Professor Parker to decide "the results provide convincing evidence that the Drake Plate was produced by a modern rolling process rather than having been made by hammer shaping." For, as Professor Cyril Stanley Smith observed in a tape-recorded discussion on February 9, 1979: "It is strongly directional in a way which is unlikely for a hammered strip, except under very special or unusual or unlikely conditions."

Another kind of investigation of the Plate was made by Professor Smith who had it photographed on February 9, 1979 at the Lawrence Berkeley Laboratory so that its edges might be seen at different angles and with reflected light. Comparable photographs were made of a plate of brass of somewhat similar size and shape created by Professor Smith for comparison. The purpose of the photographs was to allow him further study of his previously published view that "the edge [of the Plate] has none of the qualities of the chisel-cut-and-filed edge that one would expect on XVI-century plate." His conclusion about the photographs made in February 1979 is:

"The general rectangularity and the squareness of the cut edges argue strongly against the plate having been cut by any method that would have been used in the 16th century. It could, I suppose, have been laboriously filed to a straight edge, using a template, after it had been cut. Cutting with a chisel (by far the most likely method in the 16th century) would leave a rough jagged edge at an angle to the main surface - as in fact can be seen on the plate itself in the notches that have been cut for the spikes and the hole for the sixpence. (Photos XBC788-8772 and -9670; XBB792-1781 and -1785). One cannot entirely rule out the possibility that the edge had been finished by a filing operation, but it is highly unlikely that anyone doing it would have achieved the close approximation to true rectangularity that is observed. Moreover, had the edges been filed, there would have been little reason for the final treatment of them by hammering." (Letter from Cyril Stanley Smith to James D. Hart, April 1, 1979)

The additional inquiries into the subject of known 16th-century brass were of several kinds. They included a quest for Asian brass samples to be chemically analyzed, on the assumption that since they were said to have a very high zinc content unlike 16th-century European brass but comparable to the Plate of Brass, that Plate might have had its origin in the Orient and could have been obtained by Drake as a result of his capturing booty from a Manila galleon. However, Dr. Arthur Norberg, Coordinator, History of Science and Technology Program at The Bancroft Library, discovered by inquiry of the Metropolitan Museum of Art, the Freer Gallery of Art and the Asian Art Museum of San Francisco that none of their representatives was aware of sheet brass created at that period in the Orient. Although bronze and brass objects were made at the time, these were cast. Not only were they small but they would have had to be refashioned to create sheet brass. Therefore to assume that the Plate of Brass was oriental in origin required the assumption that Drake had captured some oriental brass objects, that he had them fashioned into a plate, seemingly by rolling, and that such ostensible rolling resulted in a plate wider than European rolling mills were then able to create. Commenting upon these issues, Professor Smith declared: "There are so many stages. In no case can you say it's impossible; in every case you could say it's unlikely, and if you compound a whole series of unlikelihoods, it gets awful close to negative certainty." (Tape recording, February 9, 1979)

The Bancroft Library's previous Report pointed out that the tests made by the Lawrence Berkeley Laboratory and the Research Laboratory for Archaeology and the History of Art at Oxford University revealed a substantial difference between the chemical constituents of the Plate of Brass and those of 16th-century European brass. The account of this disparity emphasized the greater zinc in modern brass since that had been a subject of discussion from the time of the original inquiries of 1936 into the Plate by Professor Colin Fink and Dr. E. P. Polushkin and the critique by Professor Caley of Princeton. Despite the validity of that contrast, little emphasis was placed on the difference between the relatively high amounts of trace elements found in 16th-century brass, when there was little ability to create pure copper content, and the low level of such trace elements both in known present-day brass and in the Plate of Brass itself. This contrast was observed in the chemical study of the Plate made by Helen V. Michel and Frank Asaro for they stated in the Lawrence Berkeley Laboratory Report of July 27, 1977 (page 7) that Elizabethan brass should be expected to "contain lower levels of zinc than modern brass, contain lead in the percent region, tin in the percent or fraction of a percent region, and may contain cadmium, iron, arsenic, antimony, nickel, magnesium, sulfur, calcium, silver, gold, and indium in measurable amounts." However, their investigation of the Plate on this score in comparison with known 16th-century brass samples led them to find that elemental abundances of these trace elements in the Plate were comparable to modern yellow brass but very different from 16th-century brass. After their Report was issued, Dr. Michel and Dr. Asaro made a supplemental study of a brass astrolabe known to have been created in Louvain about 1570. This inquiry of 1979 (printed as Appendix 2) found that the impurity, that is the levels of trace elements, "in the Astrolabe are about 30 times higher than [in] in the Plate of Brass," quite in keeping with differences between 16th-century and 20th-century brass, as they even label the date of the disputed Plate.

A test of the manner in which the Plate of Brass might have been created was made completely independently by Dr. Edwin M. McMillan, former Director of the Lawrence Berkeley Laboratory. He assumed the Plate to be a modern product and so, for purposes different than Professor Smith's, he also created a counterpart of it in order to learn something about how the original might have been fabricated. He cut his piece of brass into two parts, annealed one "by heating it to a dull red, then cleaned [it] in acid. I stamped into it, with a cold chisel and hammer, some letters, including a 'J' which I then 'erased' at the top & bottom with the ball peen end of the hammer.

"The larger piece was not annealed. The bottom line is the result of stamping letters in this piece. Note how, in the unannealed metal, the act of stamping caused the metal to be raised above the original surface along the stamped lines. The top line on this piece has been hammered over with the flat face of the hammer. I believe that this is the way the Plate was made, first stamping the letters & then hammering over it to reduce the raised edges around the letters.

"Then (as suggested by one of the authors of the report) the Plate was heated to give a patina. After this (I postulate) someone pointed out that the formal "Be it knowne" had been omitted, so the top line was added. This time, because of the heating, there were no raised edges and no hammering over was done." (Letter dated Aug. 5, 1977 from Dr. MacMillan to Professor Hart) Professor Cyril Stanley Smith declared after examining the Plate of Brass that this supposition appears to be confirmed by its lettering.

* * *

The Plate of Brass Reexamined 1977 elicited a large response. Some of it was a dramatic and exaggerated contention that the *Report* had definitively proved the Plate to be "a fake" or "a fraud." Some of the response, on the other hand, represented not only the expected skepticism but also concentration on other aspects of the Plate, such as the wording and lettering of its text, on the assumption that since the inquiry into the chemical constituency was not definitively negative, an investigation of the inscription might serve as proof of authenticity. The newspaper and magazine commentary was useful in drawing further notice to the Plate and the scholarly investigation provided further serious study of a significant object. However, emphasis was placed not on the validity of the Plate itself but on the appearance of that which is inscribed upon it.

Dr. R. E. M. Hedges, of the Research Laboratory for Archaeology and the History of Art, Oxford University, one of the original investigators of the Plate for the *Report* of 1977, has since declared: "I am afraid I know of no way to eliminate entirely the 'uncertainty left by the *Plate of Brass Reexamined 1977*'. There is, alas, no known method for dating the manufacture or working of metal with sufficient reliability. I think it a good thing that there should be strong advocacy for the case that the Plate is authentic; I shouldn't like to think that scientific scrutiny is incapable of ever making a mistake; but I am impressed by the large number of points thrown up which require individual ad hoc assumptions of low probability if the plate *is* authentic, but which together easily make a coherent pattern of a rather simple forgery as an alternative explanation. I don't expect there ever to be *proof* of this, hence the uncertainty of which you speak, but I believe the balance of probabilities is so overwhelming that I would regard it as quite unreasonable to continue to believe in the authenticity of the plate." (Letter from Dr. Hedges to Mr. Robert H. Power, October 12, 1977)

Without having known Dr. Hedges' comment, Professor Smith similarly concluded: "Thus, it cannot be said that it would have been absolutely impossible to hammer and planish a piece of brass so carefully as to give it the uniformity of a rolled plate. It is not absolutely impossible that some unusually pure copper and unusually pure zinc ore could have been brought together in the 16th century to make brass of a composition like that of the Bancroft plate. It is not absolutely impossible that a jagged chisel cut could have been subsequently filed and minutely roughened to give it the finely-torn granular appearance of a sheared edge. It is not absolutely impossible that the surface of a piece of brass would be so little worn or corroded after four centuries of exposure to environmental hazards.

Yet every one of these occurrences is *highly* improbable, and that all of them should have happened together has a level of probability so low as to make it virtually certain that the plate is not a piece of sixteenth century brass and, therefore, that it could not have been fashioned by any member of Sir Francis Drake's expedition." (Letter from Professor Smith to James D. Hart, April 1, 1979)

These statements by two leading students of the Plate of Brass resulted from considerations undertaken subsequent to the examinations treated in the first report of The Bancroft Library. However, the investigations reported in this supplement were also undertaken, like those in the initial document of 1977, "without prejudice toward or against authenticity" and their negative findings, like those of the earlier date, are "not issued in a partisan spirit."

James D. Hart
Director
The Bancroft Library
April 1979

Appendix 1

REPORT OF X-RAY DIFFRACTION INVESTIGATION OF DRAKE PLATE

Professors Earl R. Parker, Robert H. Bragg and Paul H. Adler (a research assistant) devised a program involving the use of X-ray diffraction to determine whether or not evidence of cold-rolling exists in the Drake Plate. The examination consisted of two parts: (1) obtaining a new rolled brass plate of the size and shape of the Drake Plate from a commercial source, examining this plate by X-ray diffraction to establish the type of diffraction pattern that exists in a rolled plate, annealing part of the commercial plate to remove the rolling pattern, hammering the annealed plate to establish the diffraction produced by hammering; part (2) of the investigation was to use the same X-ray method to obtain a diffraction pattern from the Drake Plate.

The patterns produced by rolling and hammering are distinctly different. If the Drake Plate showed conclusive evidence of a rolling pattern, this would provide strong supporting evidence that the Drake Plate had been produced by rolling. However, absence of evidence indicating rolling would not preclude the possibility that the plate had been rolled, because annealing after rolling (i.e. heating to temperatures above about 800° F) would eliminate all traces of the rolling pattern.

To obtain the X-ray diffraction patterns, the long dimension of each plate was inclined to the X-ray beam by an angle θ, which was chosen so that the X-ray beam would be diffracted from the slip planes in the brass crystals. These are the crystal planes that would have been involved in the shape change that occurred during rolling. A film was exposed by the X-rays that were diffracted by the slip planes of the crystals in the plates. The patterns produced on the film is a thin line in the form of an arc of a circle. In a hammered plate, the intensity of exposure is uniform throughout the length of the arc (because the metal during hammering flows in all directions). A rolled plate produces two regions of high exposure intensity on the arc, with maximum intensities occurring at angles of about $\pm 25°$ away from the line of the X-ray beam. These bright regions are a consequence of the undirectional flow of metal that occurs during rolling.

The Drake Plate was exposed to the X-ray beam in exactly the same way that the commercial brass plate was exposed. The resulting pattern on the X-ray picture was an arc that, when examined by eye, appeared to have faint but clearly evident indications of brighter regions in exactly the same locations as those obtained with the commercial rolled plate. Densitometer measurements of the intensity of light along the arc made by Professor Roger Hahn show that the Drake Plate has variable intensity with peaks at about ±25° from the line of the X-ray beam.

The conclusion that may be drawn from this work is that the results provide convincing evidence that the Drake Plate was produced by a modern rolling process rather than having been made by hammer shaping.

Earl Parker, Professor Emeritus
Material Science and
Mineral Engineering

Roger Hahn
Professor of History

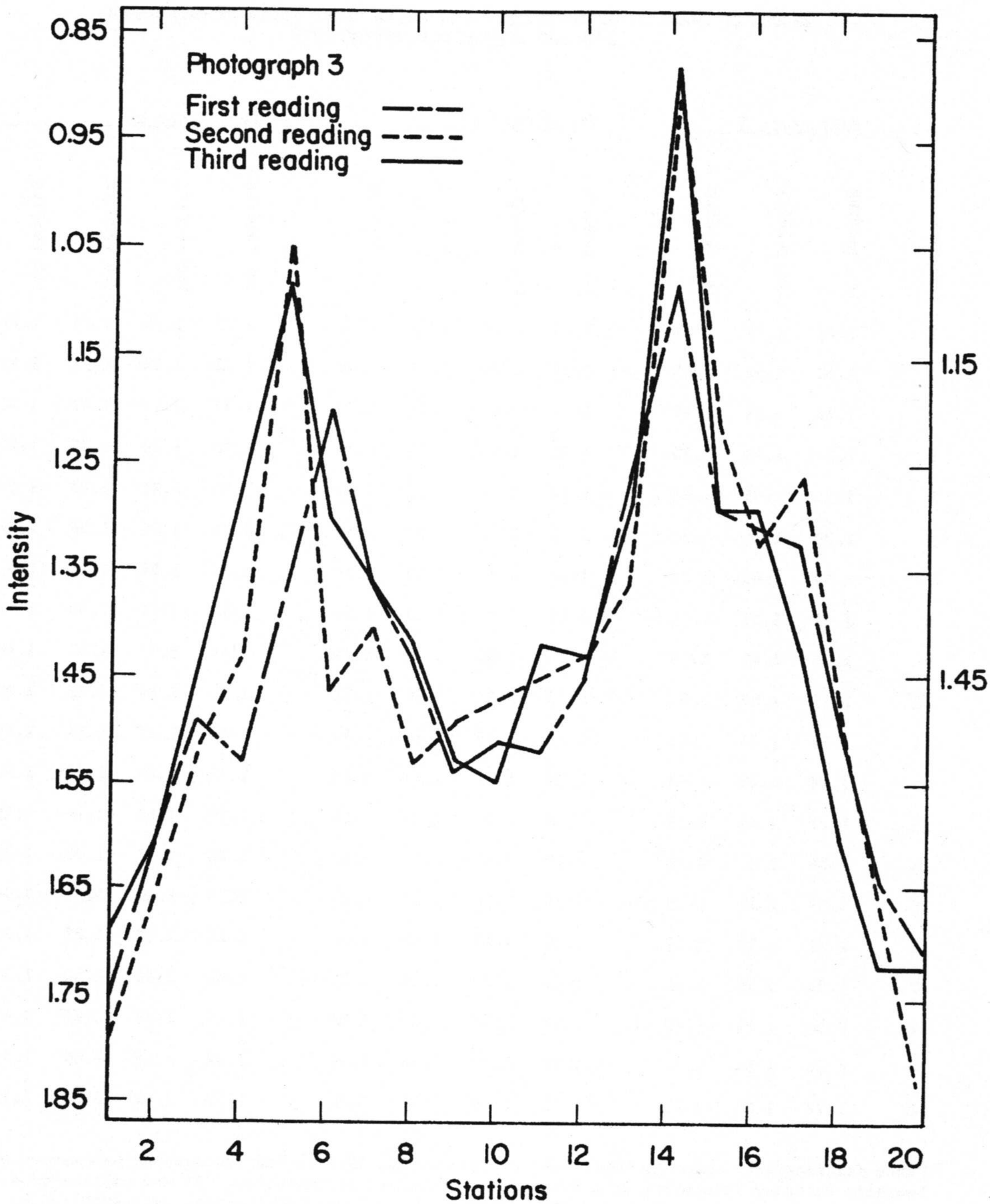
Attachments: (Intensity Readings)
(Graph of photograph 3)
(Graph of photograph b)

February 5, 1979

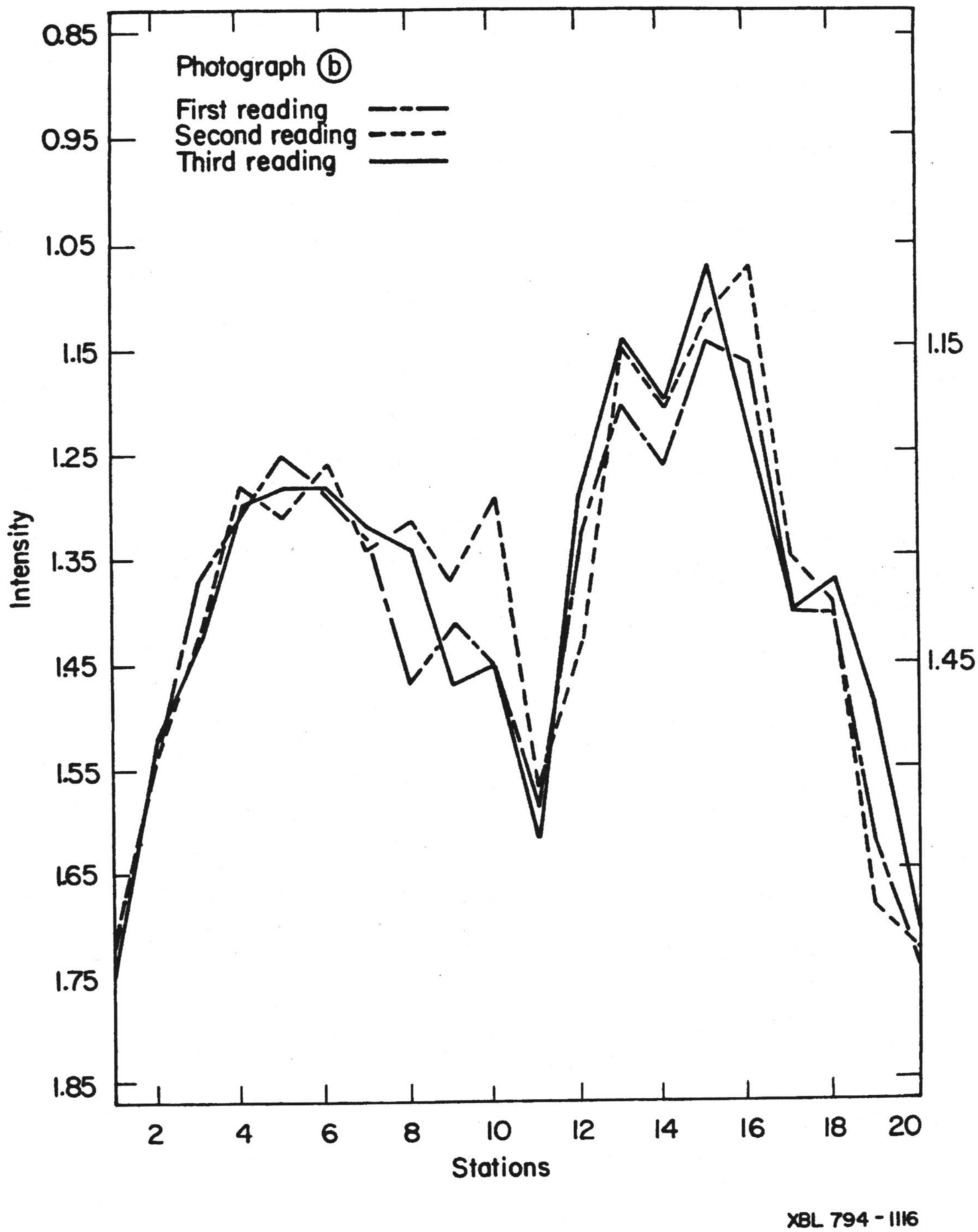
RECORD OF READINGS OF INTENSITY OF LIGHT ON THREE POLAROID PHOTOGRAPHS
OF X-RAY DIFFRACTION EXPERIMENTS

	Photograph 3			Photograph a				Photograph b			
Stations	1st reading	2nd reading	3rd reading	1st reading	2nd reading	3rd reading	4th reading	1st reading	2nd reading	3rd reading	4th reading
1	1.75	1.79	1.69	1.75	1.70	1.79	1.78	1.71	1.70	1.74	1.77
2	1.60	1.66	1.61	1.53	1.70	1.62	1.68	1.52	1.54	1.52	1.53
3	1.49	1.52	1.45	1.27	1.49	1.34	1.37	1.37	1.42	1.47	1.42
4	1.53	1.43	1.28	1.25	1.20	1.30	1.24	1.30	1.28	1.30	1.27
5	1.35	1.05	1.08	1.34	1.30	1.31	1.22	1.25	1.31	1.28	1.29
6	1.20	1.46	1.30	1.42	1.29	1.37	1.33	1.28	1.26	1.28	1.27
7	1.36	1.40	1.36	1.37	1.35	1.37	1.37	1.33	1.34	1.32	1.31
8	1.43	1.53	1.42	1.29	1.25	1.25	1.26	1.47	1.31	1.34	1.33
9	1.54	1.49	1.53	1.29	1.32	1.34	1.33	1.41	1.37	1.47	1.40
10	1.51	1.47	1.55	1.37	1.31	1.36	1.31	1.45	1.29	1.45	1.30
11	1.52	1.44	1.42	1.23	1.29	1.24	1.44	1.59	1.57	1.62	1.59
12	1.45	1.43	1.43	1.29	1.22	1.27	1.28	1.33	1.43	1.29	1.32
13	1.27	1.36	1.29	1.28	1.31	1.23	1.19	1.20	1.15	1.14	1.15
14	1.08	0.91	0.88	1.09	1.12	1.12	1.25	1.26	1.21	1.20	1.15
15	1.29	1.21	1.29	1.14	1.18	1.10	1.17	1.14	1.12	1.07	1.04
16	1.31	1.32	1.29	1.20	1.18	1.24	1.10	1.16	1.07	1.23	1.35
17	1.32	1.26	1.42	1.45	1.32	1.46	1.25	1.40	1.35	1.40	1.39
18	1.50	1.49	1.60	1.57	1.48	1.59	1.50	1.40	1.39	1.37	1.46
19	1.64	1.67	1.72	1.64	1.59	1.64	1.59	1.62	1.58	1.49	1.67
20	1.72	1.83	1.72	1.70	1.70	1.71	1.66	1.73	1.62	1.68	1.76

These readings were taken by Roger Hahn on January 22, 1979 at the Photography Laboratory of Lawrence Berkeley Laboratory on a Speedmaster Universal Densitometer. It was calibrated so that darkness registered +1.84 and light +0.10. The polaroid photographs were supplied by Professor Earl Parker.


Photograph 3
First reading
Second reading
Third reading
0.85
0.95
1.05
1.15
1.25
1.35
1.45
1.55
1.65
1.75
1.85
Intensity
1.15
1.45
2
4
6
8
10
12
14
16
18
20
Stations

XBL 794-1117


Photograph (b)
First reading
Second reading
Third reading
Intensity
0.85
0.95
1.05
1.15
1.25
1.35
1.45
1.55
1.65
1.75
1.85
1.15
1.45
2
4
6
8
10
12
14
16
18
20
Stations
XBL 794 - 1116

Appendix 2

CHEMICAL CHARACTERISTICS OF MEDIEVAL BRASSES

As part of the continuing study of the Plate of Brass[1] two medieval brasses of known origin and age were analyzed by neutron activation analysis (NAA), x-ray fluorescence (XRF) and emission spectroscopy (ES).

It was anticipated that the abundance of elements other than Cu and Zn would reflect the method of refining and impurities in the ores. A brass Astrolabe, whose style indicated it was made by Arsenius in Louvain about 1570 A.D., was generously supplied by Rod and Marjorie Webster from the Adler Planaterium in Chicago, Illinois. The plates were 11 inches in diameter and ~.06 inches thick. The Horizon Plate and Tympan 51 of the Astrolabe were each carefully drilled in three areas and the resulting samples were analyzed by NAA, XRF and ES. The methods of measurement have been previously described.[2]

The composition of the two Astrolabe pieces is shown in Table 1. In order to place these elemental abundances in perspective as to time and/or origin of manufacture, the composition of several medieval brasses has been treated in the following manner. The average ratio of the abundance in medieval brass to the Plate of Brass was summed for eight elements, As, Ni, Sb, Au, Pb, Sn, and Fe. These elements can be much more abundant in old brass than in modern brass. Lead and tin can also be additives to brass besides being impurities. Table 2 shows the abundances of these elements in eight medieval brasses, four from Italy (16th-17th C.), one from the Rhineland (18th C.), one possibly from France or Spain (14th C.), and the two Astrolabe samples (16th C.). The last column is the average ratio of the abundances with respect to the Plate of Brass (19th or 20th C.). In Table 2 and Table 3 it can be seen that the impurity or additive levels in the Astrolabe are about 30 times higher than the Plate of Brass and are similar to those of the 18th C. Rhineland brass.

It was previously shown that the impurities in the Plate of Brass were only consistent with Cu available in the 19th or 20th Centuries. A factor of 30 increase in these levels, which is large indeed, indicates sources of Cu or refining techniques of earlier periods.

Iron is not an additive used to improve the quality of brass, and the level in the Rhineland piece is much higher than the Astrolabe pieces. This may be associated with the casting process of the Rhineland piece. This work suggests further studies are desirable to determine if the general level of impurities observed may be characteristic or be a lower limit for German-Belgium brass of the 16th-18th centuries. The impurity of additive levels for the 14th century French/Spanish and the 16th/17th century Italian brasses are on the average about 200 times higher than the Plate of Brass. (See Table 2 and 3). Further work may indicate if this may be characteristic or a lower limit for Italian brasses of that period.

This work was funded by The Bancroft Library of the University of California at Berkeley.

H. V. Michel
F. Asaro
A. L. Norberg

FOOTNOTES AND REFERENCES:

1. *The Plate of Brass Reexamined 1977.* Report issued by The Bancroft Library, University of California, Berkeley.

2. Helen V. Michel and Frank Asaro, *Chemical Study of the Plate of Brass.* LBL-6338. Archaeometry 21:3-19 (1979).

Table 1. Composition of Astrolabe

	ASTR-1 (Horizon Plate)		ASTR-2 (Tympan 51)	
Cu [1]	68.5	± 1.5	68.4	± 1.5
Zn	30.6	± 1.2	30.9	± 1.1
[3] Ag ppm	278.	± 12.	260.	± 11.
As ppm	470.	± 43.	392.	± 36.
Sb ppm	304.	± 5.	67.	± 1.
[3] In ppm	<0.5		1.3	± .3
Au ppm	1.5	± .3	1.3	± .3
Sn	.53	± .10	1.00	± .10
Ni ppm	2598.	± 33.	2413.	± 22.
[4] Fe	.080	± .005	0.140	± .005
[2] Cd	<171.		<179.	
Pb	1.2	± .1	1.4	± 0.1
[4] Mg ppm	7.	± 2.	5.	± 2.

1. Composition in % unless indicated in ppm.
2. XRF measurements done by Lily Goda and Robert Giauque.
3. 20% uncertainty due to flux monitor calibration.
4. Emission spectroscopy done by George V. Shalimoff.

Table 3. Summary of Average Ratios of Old Brasses

Geographic area	Date (century A.D.)	No. of artifacts	Mean	RMSD [1]
Belgium-Rhineland	16-18	3	36	11
Italy	16-17	4	198	13
France, Spain?	14	1	167	
Plate of Brass	(19-20)	1	1	

1. Root-mean square deviation.

Table 2. Trace Element Composition(1) of Brasses

Sample	Date	As	Ni	Sb	Ag	Au (ppm)	Sn	Pb	Fe	Average ratio(3) (to Plate of Brass)
Astrolabe:										
Horizon Plate	1570	.047	.26	.0304	.028	1.5	.53	1.2	.08	27
Tympan 51	1570	.039	.24	.0068	.026	1.3	1.00	1.4	.14	33
Rhineland	18th C.	.036	.09	.033	.020	2.0	1.40	2.8	1.0	48
France/Spain	14th C.	.22	.19	.76	.11	5.6	1.07	6	<1.2(2)	167
Italy	16th C.	.33	.63	.71	.23	67	1.45	2.7	.5	217
Italy	17th C.	.41	.33	.83	.06	18	1.41	3.1	.3	198
Italy	17th C.	.41	.42	.55	.12	35	2.5	3.5	.5	193
Italy	17th C.	.24	.34	.43	.21	72	2.25	4.3	.5	186
Plate of Brass	19-20th C.	<.0055(2)	<.012	.00083	.0048	.21	.006	.10	.027	1

(1) Abundances are in percent except for those of gold which are in parts-per-million (ppm).
(2) One half of upper limit was used in calculation.
(3) Average ratio $= \sum_{i=1}^{I} \frac{(\text{Abund. Brass})_i}{(\text{Abund. Plate of Brass})_i} \Big/ I$ where i = elements 1 thru I.