The Sampling of Gold-Bullion.*

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At the Seventh International Congress of Applied Chemistry I presented a paper,[1] The Assay and Valuation of Gold-Bullion, in which are briefly mentioned a few illustrations of different methods of sampling gold-bullion, particularly cyanide-bars. Since then I have carried on an extensive investigation upon the sampling of gold-bullion in relation to its effects upon the assay-results, in connection with the statement of accounts between the smaller assay-offices of the United States which purchase gold-bullion and the mints where the purchases are re-deposited.

Under the name of gold-bullion are included metals of widely different composition. We may have practically pure metal, 999.75 fine or even more in gold; alloys of gold and silver with only trifling amounts of base metal; alloys of gold and copper with trifling amounts of other metals; ternary alloys of gold, silver, and copper, or gold, silver, and lead; and most complex alloys of from five to eight or more constituents of ordinary occurrence, besides some of the rarer metals occasionally. In any one or all of these classes we may have one or more of the metalloids, which may add to our difficulties.

Of course, with metal 999.75 fine in gold there is only slight opportunity for different samples to differ in fineness, but on such fine metal we expect the assays to agree very closely, and the sampling must be done with the utmost care. When possible, dip- or granulation-samples of the molten metal should be taken; but when it is necessary to sample bars, the chief point to guard against is surface-dirt.

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[1] *Trans.*, xl., 780 to 797 (1909), and in *Annual Report of the Director of the Mint for the Year* 1908–09, p. 25.

In the case of four melts of fine gold, which had been carefully sampled by both dips and chips, one of the chip-bars and an independent bar were chipped, and the chips assayed. Table I. summarizes the results.

TABLE I.—*Fine Gold Sampling.*

Original Report. Fineness.	Sample-Bar. 2d Sample. Fineness.	2d Bar. Fineness.
997.9	997.7	997.9
	998.	
997.5	997.4	997.4
	997.3	
997.4	997.4	997.3
	997.4	
997.2	996.9	996.9

In the case of four melts of metal of much higher grade, independent samples were taken, and assayed after the melts had been reported by the assayer. Table II. summarizes the results.

TABLE II.—*Fine Gold Sampling.*

Original Report. Fineness.	Resamples. Fineness.
999.8*	999.7
	999.7
999.7	999.7
	999.7
999.7	999.7
	999.6
999.6	999.5
	999.5

Our standard gold (coin-gold) contains 900 parts of gold and 100 of copper. When made from pure metals it does not segregate. Four melts of standard gold were carefully sampled by both dips and chips and reported by the assayer. Subsequently one of the sample-bars and a second bar were chipped, and the chips were assayed. Table III. summarizes the results.

TABLE III.—*Standard Gold Sampling.*

Original Report. Fineness.	Sample-Bar. 2d Sample. Fineness.	2d Bar. Fineness.
900	899.8	899.8
	899.9	
899.9	899.8	899.8
899.8	899.7	899.6
899.7	899.7	899.5
	899.8	

In the cases already cited the sampling is a very simple matter, and the variations in the results shown may as well be due to the assaying itself as to the sampling. When, however, we come to consider miscellaneous bullion of more complex composition, the sampling assumes greater importance.

From a bar of strictly homogeneous metal, manifestly it would make no difference how the sample was taken, since any part of the metal would represent the whole. Bars that are practically homogeneous are not uncommon; and such bars would not have to be melted for the purpose of sampling, if we could be certain that they were homogeneous. Only two classes of alloys can form homogeneous bars—those that are solid solutions, and the eutectics; and unfortunately there are no characteristics by which the homogeneity of a bar of gold-bullion may be readily established. As a general proposition it is safe to assume that a brittle bar of gold-bullion will not be homogeneous. We may, of course, happen to get a bullion of eutectic composition, which would be both brittle and homogeneous, but eutectics undoubtedly form a very small proportion of the ordinary run of gold-bullion. On the other hand, it is far from safe to assume that a ductile bar is homogeneous.

The alloys of gold and silver, and gold and copper form continuous series of solid solutions, and they may carry small amounts of other metals without showing marked segregation. In several of the examples cited below, remarkable agreement in the assays of different samples of gold and silver alloys containing small amounts of impurities shows the practical absence of segregation. Alloys of gold and copper are quite similar in their heat-behavior to the gold-silver alloys, but I do not happen to have any satisfactory series of samples of these carrying small amounts of other metals.

When we come to the ternary alloys our knowledge of their behavior on heating and cooling is too scanty to permit valid generalizations, and this is even more emphatically true of the alloys of increasing complexity.

Of general miscellaneous gold-bullion, there is only one universally satisfactory method of taking a sample that shall truly represent the metal sampled. This consists in pouring a small portion of the well-mixed molten metal into water, so as to produce small globules or granulations of the metal. As this is generally done by dipping out a portion of the molten metal in a small cup, such a sample is frequently called a "dip," and this name is generally used throughout the present paper. These samples are, however, often called "granulations;" and they are sometimes made by pouring directly out of the crucible into the water, the operation of casting being interrupted for the purpose.

As already indicated, there are indeed various cases where other styles of sampling may be sufficiently satisfactory, and there are, moreover, many cases where it is desirable or even necessary to sample a bar of solid bullion without melting it. In such cases a chip may be cut off from the bar with an ordinary cold-chisel, or a chisel specially designed for the purpose. Power-driven punches with special tools may be used. Machines are also built which bite out a triangular piece of metal by means of a projection on a lever operated by a cam. Where much chip-sampling is done, especially on small bars, these machines save much time and labor. A third method of sampling consists in boring into the bar, generally with a power-drill, and using the drillings for the assay-sample.

There is but little choice in the location of a chip-sample. It must necessarily be taken from a corner or along an edge of the bar. In the systematic sampling of large bars, generally two chips are cut—one from the top and one from the bottom of the bar—and properly identified.

In taking drill-samples there is a wide choice in the location of the drill-holes and in the sampling of large bars more or less of a plan in placing the holes is often followed. It is a common practice in the Mint Service to drill half-way through a bar at diagonally opposite corners of the top, and unite the drillings for the top-sample. The remaining corners are drilled half-way through from the bottom, and the drillings are mixed for the bottom-sample. Occasionally, especially when sampling very base bars, the four drillings are kept separate; and sometimes holes are drilled near the center of the bar also.

Drill-samples are often more satisfactory than chip-samples, especially where large numbers of bars of fairly uniform size and composition are sampled in accordance with a well-designed plan. Drill-samples of brittle bars are, however, liable to be unsatisfactory, because the fine and coarse portions may differ considerably in composition.

In the purchase of gold-bullion by the Mint Service of the United States, the size of the deposit has an important bearing upon the question of sampling. A very large proportion of the deposits will weigh less than 100 oz. each. Manifestly, slight differences in the samples on such bars will be immaterial. When, however, the weight of a deposit reaches 300 oz. the samples become important, and with bars weighing from 700 to 1,200 oz. correct sampling is essential.

Limiting myself for the most part to these large bars of miscellaneous bullion, I propose to illustrate by specific cases, drawn from actual practice, some of the general principles underlying the sampling of gold-bullion. In considering these illustrations, the assay-results must not be too rigidly interpreted. Besides the variations in the results due to variations in the samples, there are three other variants that must be kept in mind constantly: the chapter of accidents; the personal equation of the assayer; and the effect of the composition of the metal upon the assaying as distinct from its effect upon the sampling. This last point will be specially dealt with by various illustrations. Making reasonable allowances for these variants, it is thought that the illustrations are sufficiently conclusive upon the main points involved.

To begin with alloys of gold and silver containing only small amounts of base metal, four bars, each one carrying less than 4 base, were chipped top and bottom, and each one of the eight samples was assayed in three laboratories. A fifth bar, carrying 10 base, was treated in the same way. Table IV. summarizes the results reported.

TABLE IV.—*Sampling Gold-Silver Alloys Low in Base by Chips.*

Fineness.	Assays.	Fineness.	Assays.	Fineness.	Assays.	Fineness.	Assays.	Fineness.	Assays.
872.3	1 ...	875.7	... 1	883.3	1 1	884.2	2 ...	873.8	... 1
872.4	2 ...	875.8	1 2	883.4	... 6	884.3	... 1	874.0	1 ...
872.5	5 4	875.9	2 3	883.5	4 2	884.4	1 4	874.2	2 1
872.6	... 2	876.0	4 2	883.6	2 1	884.5	1 2	874.3	1 ...
872.7	... 3	876.1	1 1	883.7	3	884.6	1 ...	874.4	2 1
873.0	1 1	876.2	2 1	....	....	884.7	... 1	874.5	2 4
....	....	....	....	....	....	....	....	874.6	... 1
....	....	....	....	....	....	....	....	874.7	1 ...
Total...	9 10		10 10		10 10		5 8		9 8
Silver...	124		121		114		111		116

Each one of the above bars may be taken as a single product, but a bar obtained by melting 39 small bars of miscellaneous origin into a mass-melt exhibits a remarkable agreement of chip-samples. This mass weighed a little more than 1,300 oz. and was 143 fine in silver. It was chipped, top and bottom, at the assay-office, and twice at the mint of re-deposit. The assay-office samples were assayed in duplicate there, and the four mint samples were assayed in four laboratories; 44 assays were made on the six chip-samples. Table V. summarizes the results reported:

TABLE V.—*Sampling a Mass-Melt by Chips.*

1 assay showed	679.7 fine in gold.
4 assays showed	679.8 fine in gold.
2 assays showed	679.9 fine in gold.
2 assays showed	680.1 fine in gold.
5 assays showed	680.2 fine in gold.
8 assays showed	680.3 fine in gold.
3 assays showed	680.4 fine in gold.
4 assays showed	680.5 fine in gold.
7 assays showed	680.6 fine in gold.
5 assays showed	680.7 fine in gold.
2 assays showed	680.8 fine in gold.
1 assay showed	680.9 fine in gold.
44	

A bar carrying more than 90 base and weighing 606 oz. was chipped, top and bottom, and the samples were assayed at the purchasing office. At the receiving-mint it was drilled, top and bottom, and the drillings were assayed in four service laboratories. Table VI. summarizes these assays.

TABLE VI.—*Chip- and Drill-Samples Agreeing.*

Fineness.	Chip.	Drill.
741.6	...	1
741.7	...	1
741.8	...	
741.9	...	2
742.0	...	2
742.1	2	3
742.2	2	1
742.3	...	4
742.4	...	5
Total	4	20
Silver	165	

A bar weighing more than 800 oz. presents another remarkable case of the presence of considerable base metal without marked segregation. This bar was drilled, top and bottom, and the drillings were united to form one sample. Two other sets of drillings, top and bottom, were taken from the same bar, and each sample kept separate. These five samples were assayed 69 times in five laboratories. Table VII. summarizes the results reported.

TABLE VII.—*Sampling Gold-Silver Alloy, Containing Considerable Base, by Drilling.*

6 assays showed	351.0 fine in gold.
10 assays showed	351.1 fine in gold.
13 assays showed	351.2 fine in gold.
14 assays showed	351.3 fine in gold.
15 assays showed	351.4 fine in gold.
6 assays showed	351.5 fine in gold.
2 assays showed	351.6 fine in gold.
3 assays showed	351.7 fine in gold.
69	

This bar was 604 fine in silver and 44.5 fine in base metals.

Two other bars containing less base metal, but also considerably less gold, yielded much less satisfactory results. These bars weighed nearly 1,200 oz. each. They were drilled, top and bottom, and the drillings united to form one sample. One bar was drilled twice again, top and bottom, and the other three times, top and bottom, each drilling being kept separate. These 12 samples were assayed in five laboratories and Table VIII. summarizes the results.

On the other hand, a ductile bar 778 fine in gold with only 9 base yielded unsatisfactory results for this grade of metal. This bar weighed more than 1,500 oz. and was drilled, top and bottom, the drillings being mixed for one sample. Being ductile, it was chipped twice, top and bottom, at the mint of re-deposit. These six samples were kept separate. The bar was remelted with a loss of 0.38 oz. and two dip-samples were taken. The cold bar was again drilled, top and bottom. These 11 samples were assayed in four service laboratories, and Table IX. summarizes the results reported.

Table VIII.—*Drill-Sampling Gold-Silver Alloy Low in Gold and Base.*

	1st Bar.						2d Bar.						
Fineness.	1st Drill.	2d Drill. T.	2d Drill. B.	3d Drill. T.	3d Drill. B.	Fineness.	1st Drill.	2d Drill. T.	2d Drill. B.	3d Drill. T.	3d Drill. B.	4th Drill. T.	4th Drill. B.
290.2	....	....		2	...	290.6	1	....		....		....	
290.6	1	1	...	2	...	290.9	1	....		....		....	
290.7	....	1	...	2	...	291.1	1	1	...	....		....	
290.8	....	1	...	2	...	291.5	1	....		....		....	
290.9	....	2	...	2	...	291.9	1	2	...	....		....	
291.0	....	....		3	...	292.0	1	2	...	....		1	...
291.1	1	1	...	1	...	292.1	2	....		....		....	
291.2	....	2	...	....		292.2	....	2	...	...	2	2	...
291.3	....	2	...	1	...	292.3	1	1	...	...	1	3	1
291.4	2	2	1	...	2	292.4	....	2	1	...	4	2	3
291.5	4	...	1	....		292.5	3	2	2	...	2	3	3
291.6	2	1	...	...	2	292.6	4	...	4	...	1	1	2
291.7	2	....		....		292.7	....	1	4	...	1	1	3
291.8	....	....		...	1	292.8	....	1	1	...	1	1	...
291.9	1	...	1	...	1	292.9	....	....		....		...	2
292.0	....	....		...	1	293.0	....	...	2	1	1	....	
292.1	....	...	1	....		293.1	....	....		4	1	1	...
292.2	2	...	2	....		293.2	....	1	...	4	...	....	
292.3	....	..	2	...	1	293.3	....	....		2	...	....	
292.4	....	1	3	....		293.6	....	....		1	...	....	
292.5	....	...	1	....		293.9	....	....		1	...	....	
292.7	....	...	1	...	1	....	....	....		....		....	
292.8	....	...	1	...	2	....	....	....		....		....	
292.9	....	....		...	1	....	....	....		....		....	
293.0	....	...	1	...	1	....	....	....		....		....	
293.1	....	...	...	...	1	....	....	....		....		....	
Total...	15	14	15	15	14		16	15	14	13	14	15	14
Silver...		670								671			

Table IX.—*Sampling Ductile Gold-Silver Alloy, Low in Base.*

								Remelt.			
Fineness.	1st Drill.	2d Drill. T.	2d Drill. B.	1st Chip. T.	1st Chip. B.	2d Chip. T.	2d Chip. B.	Drill. T.	Drill. B.	Dip. T.	Dip. B.
777.2	......	....		....		1	...	....		....	
777.3	......	....		....		2	...	....		....	
777.5	......	....		....		....		....		....	
777.6	......	....		....		....		....		....	
777.7	......	....		....		3	...	1	...	....	
777.8	1	....		....		....		....		....	
777.9	......	....		...	1	....		....		....	
778.0	......	....		...	1			1	...	....	
778.1	1	....		....		...	2	2	...	....	
778.2	1	....		2	2	...	1	2	...	....	
778.3	1	3	2	2	3	...	3	2	2	...	1
778.4	1	1	4	...	1	...	3	2	...	...	3
778.5	3	4	3	...	1	....		2	3	2	5
778.6	3	1	2	...	2	...	1	...	5	6	1
778.7	1	....		1	...	....		...	2	1	2
778.8	......	....		....		....		....		1	...
778.9	......	1	...	....		....		....		1	...
779.0	......	....		1	...	....		....		....	
Total......	12	10	11	6	11	6	10	12	12	11	12
Silver......	212.5										

The following case exhibits what is probably the very best agreement between various samples, and between an assay-office and a mint, that can be attained under every-day working-conditions:

A deposit of approximately 3,000 oz. was melted in the assay-office, and two dip-samples were taken. It was cast into three bars, and two chip-samples were taken from each bar. At the mint of re-deposit, two chip-samples were cut from each bar. The mint samples were forwarded to the Bureau, and thence sent to the assay-office and afterwards returned to the mint to be assayed, neither institution being informed what the samples were.

In all, ten samples were taken from this deposit, and 47 assays were made at the two institutions. Table X. summarizes the assays reported.

TABLE X.—*Agreement of Assays on Various Samples at Two Institutions.*

1 assay showed	875.5 fine in gold.
1 assay showed	875.6 fine in gold.
4 assays showed	875.7 fine in gold.
4 assays showed	875.8 fine in gold.
14 assays showed	875.9 fine in gold.
12 assays showed	876.0 fine in gold.
6 assays showed	876.1 fine in gold.
4 assays showed	876.2 fine in gold.
1 assay showed	876.3 fine in gold.
47	

If we eliminate the results that were reported only once each, we have 44 assays, ranging from 875.7 to 876.2. This deposit might, therefore, be properly reported by either institution at either 875.75 or 876. It did not contain over 4 base.

On three bars the purchasing office took chip- and dip-samples, and on a fourth bar took dip- and drill-samples. The mint of re-deposit cut two chip-samples from each bar. These samples were assayed in various service laboratories, and Table XI. summarizes the results on the various styles of samples.

TABLE XI.—*Sampling in Various Ways with Satisfactory Agreement.*

Fineness.	Dip.	Chip.	Chip.	Fineness.	Dip.	Drill.	Chip.	Fineness.	Dip.	Chip.	Chip.	Fineness.	Dip.	Chip.	Chip.
861.4	...	1	2	895.1	1	...	2	858.5	1	...	1	883.2	...	...	1
861.5	...	...	1	895.2	...	...	3	858.7	...	1	...	883.3	...	2	...
861.7	1	1	...	895.3	...	1	4	858.9	...	...	1	883.4	1	1	1
861.8	...	4	1	895.4	1	...	2	859.0	1	3	1	883.5	2	1	6
861.9	3	1	4	895.5	1	2	1	859.1	1	1	2	883.6	...	...	1
862.0	3	3	6	895.6	1	1	2	859.2	3	3	7	883.7	...	1	4
862.1	3	1	3	895.7	2	2	1	859.3	1	1	2	883.8	5	4	...
862.2	1	1	...	895.8	3	3	...	859.4	3	...	1	883.9	3	3	3
862.3	2	1	...	895.9	3	4	...	859.5	5	1	...	884.0	3	2	1
862.4	1	...	...	896.0	1	...	1	859.6	...	3	3	884.1	...	...	1
......	...	...	...	896.1	1	...	...	859.7	1	...	...	884.2	...	...	1
......	...	...	...	896.2	...	1	...	......	...	...	...	......	...	...	...
Totals...	14	13	17		14	14	16		16	13	18		14	14	19
Silver...	134					98			137					113	

On three bars the purchasing office took dip- and drill-samples, and the mint of re-deposit took top and bottom drill-samples. These samples were assayed in various service laboratories, and the results are summarized in Table XII., showing a considerable agreement between the dip-samples and the drills taken at the separate offices. But a better agreement is desirable.

TABLE XII.—*Dip- and Drill-Samples Partly Satisfactory.*

Fineness.	Dip.	Drill.	Drill.	Fineness.	Dip.	Drill.	Drill.	Fineness.	Dip.	Drill.	Drill.
822.4	1	......	......	973.4	......	1	......	972.1	......	1	......
822.7	1	......	......	973.5	......	1	......	972.2	1	1	......
822.8	......	......	2	973.6	......	......	1	972.3	3	......	3
822.9	1	1	1	973.8	......	1	1	972.4	4	1	......
823.0	3	1	2	974.0	......	......	2	972.5	......	......	1
823.1	3	2	1	974.1	......	1	......	972.6	3	1	1
823.2	2	4	......	974.2	2	......	2	972.7	1	......	2
823.3	......	3	1	974.3	2	......	......	972.8	......	......	2
823.4	1	2	4	974.4	1	......	1	972.9	......	1	......
823.5	1	......	......	974.5	2	1	2	973.0	......	2	2
823.6	......	......	2	974.6	1	......	......	973.1	......	3	......
823.7	......	1	1	974.7	......	1	2	973.2	1	......	......
823.8	......	......	4	974.8	3	2	4	973.3	1	1	1
823.9	......	......	1	974.9	1	......	2	973.4	......	1	1
824.1	......	......	1	975.0	......	4	1	973.5	......	......	2
......	......	......	......	975.1	1	1	......	973.6	......	......	1
......	......	......	......	975.2	......	1	2	973.8	......	1	1
......	......	......	......	975.3	1	......	1	974.3	......	1	......
......	......	......	......	......	......	......	......	975.7	......	......	2
Totals...	13	14	20		14	14	21		14	14	19
Silver...		162				4			Practically none.		

On four bars the purchasing office took dip- and drill-samples and the mint of re-deposit cut two chips from each bar. These samples were assayed in various laboratories in the service, and Table XIII. summarizes the results reported, showing the chip-samples to be unsatisfactory.

TABLE XIII.—*Chip-Samples Unsatisfactory.*

Fineness.	Dip.	Drill.	Chip.	Fineness.	Dip.	Drill.	Chip.	Fineness.	Dip	Drill.	Chip.	Fineness.	Dip.	Drill.	Chip.
821.8	...	...	1	892.3	...	...	1	898.0	...	...	1	820.7	1	...	
822.3	...	...	3	892.6	...	...	2	898.1	...	...	4	820.8	...	...	2
822.5	...	...	1	892.7	...	...	5	898.2	...	...	2	820.9	...	...	2
822.6	...	...	1	892.8	...	...	2	898.3	...	1	3	821.0	4	...	1
822.7	2	1	1	892.9	1	...	4	898.4	1	2	2	821.1	1	...	...
822.9	...	...	1	893.1	...	2	...	898.6	1	2	1	821.2	2	...	...
823.0	1	1	2	893.2	1	1	1	898.7	3	...	1	821.3	1	...	...
823.1	4	3	3	893.3	4	2	1	898.8	2	2	1	821.4	3	2	...
823.2	3	...	...	893.4	...	1	...	898.9	3	3	...	821.5	1	1	...
823.3	1	2	...	893.5	5	4	...	899.0	3	2	...	821.6	...	1	...
823.4	...	1	1	893.6	3	...	...	899.1	1	...	1	821.7	1	3	1
823.5	4	2	1	893.7	...	1	1	899.4	...	...	1	821.8	1	3	1
823.6	1	3	2	893.8	...	1	...	899.8	...	1	...	821.9	...	...	2
......	...	...	...	893.9	...	1	...	899.9	...	1	...	822.0	...	1	2
......	...	...	...	......	...	...	...	......	...	...	...	822.1	...	2	...
......	...	...	...	......	...	...	...	......	...	...	...	822.5	...	...	1
Totals..	16	13	17		14	13	17		14	14	17		15	13	12
Silver...		160				97				88				172	

On three bars the purchasing office took dip- and chip-samples and the receiving mint cut two chips. These samples were assayed in various laboratories in the service, and Table XIV. summarizes the results reported, showing that the mint chip-samples were entirely unsatisfactory.

A very complete set of samples from five bars, contained in one shipment made by a purchasing office to a mint for re-deposit, shows what may happen under every-day working-conditions in handling bullion of moderate grade. Everything considered, the first set of samples may be taken as fairly satisfactory, but the last set is totally unsatisfactory. At the office of purchase two dips and two drills were taken from each bar. At the mint of re-deposit two drills and two chips were taken. Each one of these eight samples on each bar was assayed in various service laboratories, and Table XV. summarizes the results reported; the assays on each set of two samples being grouped.

TABLE XIV.—*Second Chip-Samples Unsatisfactory.*

Fineness.	Dip.	Chip.	Chip.	Fineness.	Dip.	Chip.	Chip.	Fineness.	Dip.	Chip.	Chip.
879.8	...	...	1	890.3	...	...	1	867.6	...	...	1
880.0	...	...	1	890.5	...	...	2	867.8	...	...	1
880.1	...	...	2	890.6	...	...	2	868.1	...	...	2
880.6	...	...	1	890.8	...	...	1	868.2	...	...	1
881.3	...	...	1	890.9	...	...	4	868.3	...	...	1
881.4	...	...	1	891.0	...	...	1	868.5	...	...	4
881.5	...	...	2	891.1	...	...	1	868.6	...	...	4
881.6	...	...	1	891.2	...	...	1	868.7	...	...	1
881.7	...	...	2	891.3	...	2	1	868.8	...	1	...
881.9	...	1	...	891.4	2	...	...	869.0	...	1	1
882.0	...	1	1	891.5	...	2	...	869.3	1	...	...
882.1	...	...	1	891.6	4	1	...	869.5	...	1	...
882.2	...	2	...	891.7	5	1	...	869.6	1	5	...
882.3	2	3	...	891.8	2	4	...	869.7	1	1	...
882.4	3	1	...	891.9	...	5	...	869.8	2	1	...
882.5	2	4	...	892.0	4	1	...	869.9	1	1	...
882.6	2	...	1	892.2	1	3	...	870.0	1	2	...
882.7	4	...	...	892.3	...	1	...	870.1	3	1	...
882.8	...	3	...	......	...	...	...	870.2	1	2	...
882.9	2	...	...	......	...	...	...	870.3	4	2	...
883.0	3	1	...	......	...	...	...	870.4	1	...	...
883.1	1	1	...	......	...	...	...	870.5	2	1	...
883.2	...	1	...	......	...	...	...	870.6	1	...	...
......	...	...	...	......	...	...	...	870.7	1	...	...
......	...	...	...	......	...	...	...	870.9	1	...	...
......	...	...	...	......	...	...	...	871.0	1	...	...
......	...	...	...	......	...	...	...	871.1	...	2	...
Totals...	19	18	15		18	20	14		22	21	16
Silver...		90				98				95	

TABLE XV.—*Sampling Five Bars of Miscellaneous Bullion.*

Fineness.	Dip.	Drill.	Drill.	Chip.	Fineness.	Dip.	Drill.	Drill.	Chip.	Fineness.	Dip.	Drill.	Drill.	Chip.
630.3	...	1	1	...	755.0	...	...	1	1	544.2	...	...	...	1
630.4	...	1	...	1	755.1	...	...	1	...	544.3	...	...	...	1
630.5	...	...	...	2	755.2	...	...	...	2	544.6	...	...	...	1
630.6	3	...	..	...	755.3	...	...	1	2	544.7	...	...	...	1
630.7	1	1	2	3	755.4	...	...	3	2	544.9	...	...	...	1
630.8	...	...	2	1	755.5	...	1	1	...	545.0	...	...	...	2
630.9	2	1	2	1	755.6	...	...	1	4	545.1	...	...	1	1
631.0	2	2	2	2	755.7	...	...	...	1	545.2	...	...	...	1
631.1	3	...	...	...	755.9	...	1	1	...	545.3	...	...	...	2
631.2	2	2	...	1	756.0	...	...	1	...	545.4	1	...	...	1
631.3	1	2	1	...	756.1	...	1	1	1	545.5	..	...	1	...
631.4	1	2	...	...	756.2	...	2	3	1	545.6	...	...	1	1
631.5	1	2	1	1	756.3	...	1	...	...	545.7	...	...	1	...
631.6	...	...	2	...	756.4	...	1	...	...	545.8	...	1	1	1
631.7	...	1	1	...	756.5	1	...	1	...	545.9	2	...	1	...
......	...	...	...	...	756.6	2	...	1	...	546.0	2	...	...	...
......	...	...	...	...	756.7	2	2	...	...	546.1	3	...	1	...
......	...	...	...	...	756.8	1	1	...	...	546.2	1	...	1	...
......	...	...	...	...	756.9	1	1	...	...	546.3	1	2	...	...
......	...	...	...	...	757.2	3	...	...	...	546.4	3	1	1	...
......	...	...	...	...	757.3	1	1	...	...	546.5	2	2	...	...
......	...	...	...	...	757.4	2	...	...	...	546.6	1	2	1	...
......	..	...	...	...	757.5	1	...	...	...	546.7	...	1	...	...
......	...	...	...	...	......	...	...	...	...	546.8	...	1	1	...
......	...	...	...	...	......	...	...	...	...	546.9	2	1	...	...
......	...	...	...	...	......	...	...	...	...	547.0	...	...	1	...
......	...	...	...	...	......	...	...	...	...	547.2	...	2	1	...
......	...	...	...	...	......	...	...	...	...	547.3	...	...	1	...
Totals...	16	15	14	12		14	12	16	14		18	13	14	14
Silver...			330					203					444	

Fineness.	Dip.	Drill.	Drill.	Chip.	Fineness.	Dip.	Drill.	Drill.	Chip.
549.4	...	...	...	1	568.5	...	...	...	1
549.7	...	...	...	1	569.6	...	...	...	1
550.5	...	...	...	1	573.9	...	...	...	1
551.0	...	...	...	1	574.6	...	...	...	1
551.4	...	...	...	1	575.4	...	...	...	1
551.7	...	...	...	2	575.7	...	...	...	1
551.8	...	...	...	1	576.4	...	...	...	1
551.9	1	...	1	...	576.5	...	...	...	1
552.1	1	...	...	2	577.0	...	...	...	2
552.2	...	...	1	...	577.2	...	...	...	1
552.3	...	...	...	1	577.3	...	...	1	...
552.5	...	...	1	1	577.4	...	...	...	1
552.6	1	...	3	...	577.6	...	...	1	...
552.7	3	...	2	1	577.8	...	...	1	...
552.8	2	1	1	...	577.9	...	...	1	...
552.9	4	4	3	...	578.0	...	...	2	...
553.0	2	...	...	...	578.1	...	...	1	...
553.1	4	5	1	...	578.3	1	...	...	...
553.2	3	3	...	...	578.4	...	1	...	...
553.3	...	3	...	...	578.5	...	1	1	...
553.4	...	1	1	...	578.6	...	3	2	...
553.5	1	...	...	...	578.7	3	2	2	1
553.6	...	...	2	...	578.8	3	1	...	...
......	...	...	...	...	578.9	4	2	1	...
......	...	...	...	...	579.0	4	1	1	...
......	...	...	...	...	579.1	...	3	...	...
......	...	...	...	...	579.2	1	1	...	1
......	...	...	...	...	579.3	2	..	...	...
......	...	...	...	...	579.4	1	1	...	...
......	...	...	...	...	579.5	1	...	...	...
......	...	...	...	...	579.6	...	1	...	...
......	...	...	...	....	579.7	...	1	...	...
Totals...	22	17	16	13		20	18	14	14
Silver....		410					335		

A small bar made by melting up scrap-material has a most interesting and instructive sample-history. The bar weighed a trifle more than 31 oz. and was shipped from the assay-office as 826 fine in gold. At the receiving mint it was drilled, top and bottom, and while the assays on these samples agreed fairly well, yet they averaged considerably less than 826. The bar was again drilled, top and bottom, and these samples yielded very erratic assays. The bar was then melted and two dip-samples were taken. The solid bar was again drilled, top and bottom. These eight samples were assayed in four service laboratories, and Table XVI. summarizes the results reported.

TABLE XVI.—*Sampling a Small Unsatisfactory Bar.*

	Drill.		Drill.		Drill.		Remelt. Dip.	
Fineness.	T.	B.	T.	B.	T.	B.	1st.	2d.
823.0	......	......	......	1	......	......	......	......
823.5	......	......	......	1	......	......	......	......
823.7	......	......	......	1	......	......	......	......
823.9	......	......	......	1	......	......	......	.....
824.3	......	......	......	1	......	......	......	......
824.4	......	......	......	2	......	......	......	......
824.7	......	1	......	......	......	......	......	......
825.1	......	......	......	......	......	......	1	2
825.2	......	2	1	......	......	......	......	......
825.3	......	1	1	......	......	......	1	......
825.4	2	2	......	......	......	......	1	......
825.5	4	2	......	......	......	......	......	......
825.6	2	2	......	......	1	......	3	1
825.7	1	......	......	......	......	1	......	1
825.8	1	......	1	......	......	3	3	......
825.9	......	......	1	......	......	1	1	1
826.0	1	1	1	......	2	......	3	......
826.1	......	......	......	......	1	1	......	......
826.2	......	......	......	......	2	2	......	2
826.3	......	......	2	......	......	1	......	2
826.4	......	......	......	......	1	......	......	1
826.5	......	......	1	......	1	......	......	2
826.6	......	......	2	......	2	......	......	......
827.0	......	......	1	.....	......	......	......	......
Totals......	11	11	11	7	10	9	13	12
Silver......			143					

On three bars drills were taken from diagonally opposite corners on top of the bar and also near the center of the bar. The other two corners were drilled from the bottom of the bar and a drilling was made near the center of the bottom. All the top-drillings were mixed to make one sample, and all the bottom-drillings to make another. These samples were assayed in two laboratories, and Table XVII. summarizes the results reported, to which are added for comparison duplicate assays of two dip-samples of each bar made in one of the laboratories.

TABLE XVII.—*Sampling by Top and Bottom Drills.*

	1st Bar.			2d Bar.			3d Bar.	
Fineness.	Bottom.	Top.	Fineness.	Bottom.	Top.	Fineness.	Bottom.	Top.
883.7	2	......	884.8	3	......	888.7	1	......
883.9	4	......	884.9	3	......	888.8	1	......
884.0	1	......	885.0	4	......	888.9	1	......
884.1	6	......	885.1	3	......	889.0	2	......
884.2	3	......	885.2	3	......	889.1	3	......
884.3	1	......	885.3	1	......	889.2	2	......
884.4	1	......	885.4	5	......	889.3	1	......
884.5	1	......	885.5	2	......	889.4	2	......
884.7	......	1	885.6	1	......	889.5	2	1
885.1	......	5	885.7	1	......	889.6	1	......
885.2	......	2	886.2	......	4	889.7	1	......
885.3	......	1	886.3	......	3	889.8	3	......
885.4	......	3	886.5	......	6	890.0	......	2
885.5	......	2	886.6	......	4	890.1	......	3
885.6	......	4	886.7	......	1	890.2	......	2
885.7	......	2	886.8	......	1	890.3	......	1
......	......	......	887.0	......	1	890.6	......	2
......	......	......	......	......	......	891.1	......	1
......	......	......	......	......	......	891.3	......	1
......	......	......	......	......	......	891.4	......	1
......	......	......	......	......	......	891.6	......	1
......	......	......	......	......	......	891.7	......	1
......	......	......	......	......	......	891.8	......	1
......	......	......	......	......	......	891.9	......	1
......	......	......	......	......	......	892.2	......	2
	19	20		26	20		20	20

Dip-Samples.		Dip-Samples.		Dip-Samples.	
884.0	3	885.3	1	889.1	2
884.1	1	885.4	1	889.2	2
		885.5	1		
		885.7	1		

With the exception of the single assay at 889.5 on the third bar, all the top-assays are above the highest bottom-assay on each bar. All the top-assays are above the dip-assays in each one of these cases. Each one of the bars was less than 5 fine in silver.

As a general proposition, a drill-sample will often be better and more satisfactory than a chip-sample, simply because it represents a larger volume of the metal; but a drill-sample of a brittle bullion may be open to a serious objection, because the fine particles of the sample are generally liable to be quite different in composition from the coarse portions, so that, even if the drill-sample as a whole should be fairly representative of the bar, yet it would be necessary to have the 0.5 g. weighed out for the assay composed of fine and coarse material in just the same proportions as the whole sample. Manifestly this will seldom be the case.

Drill-samples of two closely-related bars were sifted on an 80-mesh screen, and yielded the following results:

	1st Bullion.	2d Bullion.
Coarse portion	290.3 fine.	291.4 fine.
	290.4 fine.	291.5 fine.
Fine portion	287.8 fine.	290.1 fine.

Two other drills of these same bars were sifted. The portion between 20- and 40-mesh and that finer than 60-mesh were assayed, with the following results:

	1st Bullion.	2d Bullion.
20–40-mesh	290.4 fine.	291.9 fine.
	291.9 fine.	292.3 fine.
60-mesh	289.6 fine.	290.3 fine.
	290.3 fine.	290.8 fine.

Two other bullions treated like the last illustration showed:

	1st Bullion.	2d Bullion.
20–40-mesh	351.7 fine.	573.2 fine.
	351.9 fine.	573.4 fine.
60-mesh	350.2 fine.	566.6 fine.
	350.5 fine.	567.3 fine.

An entirely different bullion sifted differently showed:

40–60-mesh	585.3 fine.	100-mesh	584.6 fine.
	585.4 fine.		584.7 fine.

A very rich bullion sifted like the last showed:

40–60-mesh	889.2 fine.	100-mesh	887.8 fine.
	889.2 fine.		

Five samples of a bullion which had given discordant assays were subjected to sifting-tests, and the resulting samples were assayed. Four drill-samples were sifted on 100-mesh, and the coarse and fine portions yielded the following results:

A.		B.		C.		D.	
Coarse.	Fine.	Coarse.	Fine.	Coarse.	Fine.	Coarse.	Fine.
615	612.7	615.3	612.2	613.9	612.9	612.8	608.
617	614.4	615.9	612.3	615.1	613.1	616.6	609.4
		617.9	613.7		614.1		610.5

Slightly more than a gram of the small pieces of a dip-sample was crushed and assayed in duplicate. Coarser pieces were crushed and sifted on 80-mesh. The three samples yielded the following results:

Whole Dip-Sample.	Crushed Dip-Sample.	
	Coarse.	Fine.
614.8	614.8	614.8
615.	615.2	614.9

This bullion carried bismuth.

No class of bullion has given assayers the world over so much trouble as the so-called cyanide-bullion. Not all bullion produced by cyanide-mills is troublesome. Hundreds of bars produced by such mills have passed through our Mint Service without the slightest trouble. It is easy enough to produce a high-grade refined bar from the zinc-box precipitate; but when this precipitate is melted direct and put into bars without proper refining, there is liable to be no end of trouble with the assays. Unfortunately, too, in some instances the precipitate is not as thoroughly cleaned from zinc before drying as it might be. These dirty unrefined bars are the ones that are usually spoken of as "cyanide-bars" with so much disparagement.

More than 15 years ago Roberts-Austen[2] gave a startling illustration of the difficulties and uncertainties of assaying this class of bullion. A bar weighing 393 oz. was sampled and assayed in the usual manner, and paid for at £965. The gold from this bar was separated and refined by itself, and was found to be worth £1,028. This meant a loss of £63, or more than $300, to the former owner of the bar.

It is generally assumed that the zinc remaining in the bullion is the cause of the trouble, but no clear and systematic explanation of its action has yet been given. It is quite probable that its action is complex, and differs in different bullions according to the presence or absence of other metals. I have, for instance, published[3] 50 assays made in eight laboratories on a synthetic bullion approximately 590 fine in gold, 245 in silver, 130 in zinc, with a little copper and a very little lead, which

[2] *Annual Report Deputy Master and Comptroller of the Mint*, No. 27, p. 38 (1896).

[3] *Trans.*, xl., 794 (1909). *Annual Report of the Director of the Mint for the Year* 1908–09, p. 34.

ranged from 588.9 to 589.9 fine in gold. Clearly the zinc did not seriously interfere with the actual assaying in this case.

I have also published[4] 207 assays made on three bars of bullion produced in the celebrated Mercur mill, showing widely-varying assays. By a qualitative analysis, this bullion was found to carry both cadmium and nickel, and four other bullions from cyanide-mills in Montana showed these metals. At present I am carrying on, as occasion permits, a series of test-assays on synthetic alloys of gold, zinc, and cadmium.

From our tests in sampling cyanide-bullion I am satisfied that much of the variation ordinarily shown by the assays of this class of bullion is due to differences in the samples, arising from the effect of the zinc upon the physical structure of the metal; but, aside from this, there are many cases where the composition of the metal directly affects the assay-work itself.

TABLE XVIII.—*Effects of Composition Upon the Assay-Work.*

Fineness.	1st Dip.	2d Dip.	Fineness.	1st Dip.	2d Dip.	Fineness.	1st Dip.	2d Dip.
784.9	......	1	816.6	......	1	821.9	1	.....
785.2	......	3	816.8	......	2	822.0	2	......
785.3	1	......	817.0	......	1	822.2	3	......
785.4	3	1	817.2	......	1	822.3	2	2
785.5	2	1	817.3	1	......	822.4	1	3
785.6	1	2	817.4	2	1	822.5	1	2
785.7	3	......	817.5	1	......	822.6	2	......
785.8	1	......	817.6	3	2	822.7	2	......
785.9	2	3	817.7	2	......	822.8	4	1
786.0	1	1	817.8	1	1	822.9	1	......
786.2	1	......	817.9	2	3	823.0	......	2
786.3	......	1	818.0	1	1	823.1	......	3
786.5	1	......	818.1	3	......	823.2	1	2
786.6	1	2	818.2	......	2	823.5	......	1
786.8	.....	1	818.3	1	1	823.6	......	2
787.0	1	3	818.4	1	......	823.7	......	1
......	......	......	818.5	......	2	......	......	......
......	......	......	818.6	......	2	......	......	......
......	......	......	818.7	......	1	......	......	......
......	......	......	818.8	1	1	......	......	......
......	......	......	819.0	1	1	......	......	......
......	......	......	819.1	......	1	......	......	......
......	......	......	819.2	2	......	......	......	......
......	......	......	819.3	......	1	......	......	......
Totals.........	18	19		22	25		20	19

These bars ranged from 5 to 10 fine in silver.

[4] *Engineering and Mining Journal*, vol. xciii., No. 15, p. 733 (Apr. 13, 1912).

The illustrations of top- and bottom-drilling given in Table XVII. are from cyanide-bars. Five of these samples show that individual samples of cyanide-bullion may give fairly satisfactory results, but that two such samples from the same bar may leave the question of the actual content of gold in the bar in doubt.

Table XIX.—*Sampling Cyanide-Bullion.*

	1st Bar.			2d Bar.			3d Bar.	
Fineness.	Drills.	Dips.	Fineness.	Drills.	Dips.	Fineness.	Drills.	Dips.
826.9	1	......	816.9	1	......	831.5	1	......
827.2	2	......	817.2	1	......	832.1	......	1
827.3	1	......	817.3	3	......	832.3	......	3
827.4	1	......	817.5	1	......	832.4	......	1
827.6	1	......	818.3	......	1	832.6	......	1
827.7	3	......	818.4	1	......	832.8	1	2
827.8	1	......	818.5	......	1	832.9	1	1
828.3	......	1	818.6	1	1	833.0	......	4
828.4	2	......	818.7	......	1	833.1	1	3
828.5	4	......	818.8	......	1	833.3	1	2
828.6	1	1	818.9	1	2	833.4	1	3
828.7	1	4	819.0	1	1	833.5	3	6
828.8	2	1	819.1	2	1	833.6	1	1
829.0	1	3	819.2	......	1	833.7	1	1
829.1	2	2	819.3	......	1	833.8	2	1
829.2	3	3	819.4	......	1	833.9	......	1
829.3	1	5	819.5	1	3	834.0	1	2
829.4	1	2	819.6	2	3	834.1	1	2
829.5	1	5	819.7	......	2	834.4	1	1
829.6	1	3	819.8	......	2	834.7	1	......
829.7	......	1	819.9	......	4	835.0	1	......
829.8	......	3	820.0	4	4	835.4	2	......
829.9	2	1	820.1	......	1	835.5	1	......
830.0	......	4	820.2	2	2	835.6	1	......
830.1	......	1	820.3	......	2	835.9	1	......
830.3	......	1	820.5	......	1	......	......	......
830.4	1	......	820.6	1	2	......	......	......
830.5	......	1	820.7	2	1	......	......	......
830.8	1	......	820.8	2	......	......	......	......
......	......	......	820.9	2	......	......	......	......
......	......	......	821.0	1	1	......	......	......
......	......	......	821.2	1	......	......	......	......
......	......	......	821.4	1	......	......	......	......
......	......	......	821.5	1	......	......	......	......
......	......	......	821.8	1	......	......	......	......
......	......	......	822.1	1	......	......	......	......
Totals......	34	42		34	40		23	36

All of these bars carried less than 5 of silver.

Again, three bars from the same mill were sampled by dips, twice each, and the six samples were assayed in various laboratories in the service, giving widely varying results, and showing the effect of the composition of the metal upon the actual assaying. Table XVIII. summarizes the results reported.

Three bars deposited at one time by a cyanide-mill furnish an excellent illustration of the general conditions in handling this class of bullion. Two drills and two dips were taken from each bar, and the 12 samples were sent to various laboratories in the service for assay. Table XIX. summarizes the results reported, together with the original assays at the office of deposit, the assays on each kind of sample being grouped.

In one office receiving a great deal of high-grade bullion it is the general experience that the chip-samples will run somewhat below the dip-samples on this rich material. Illustrations already given show that no fixed relation is generally exhibited between the dip- and drill-samples as to the tenor of gold. Where many bars of practically uniform composition are drilled in accordance with a well-designed plan, a more or less fixed relationship between the drill- and dip-assays might appear. Such a plan was developed at one time for certain deposits at one of our mints.

Table XX. shows that with cyanide-bars a drill-sample may give much higher assays than a dip-sample. On the first bar, 13 assays of the drill-samples are above the highest assay on the dip-samples; and on the second bar, 22 drill-assays exceeded the highest dip-assays. Two cyanide-bars, each weighing about 850 oz. and practically free from silver, were drilled, top and bottom, and these four samples, together with four corresponding dips, were sent to various service laboratories for assay. Table XX. summarizes the results reported, together with the original mint-assays, the assays on each kind of sample being grouped.

TABLE XX.—*Sampling Cyanide-Bullion by Drills and Dips.*

1st Bar. Fineness.	Drills.	Dips.	2d Bar. Fineness.	Drills.	Dips.
894.7	1	......	905.6	1	......
894.8	2	......	906.1	2	......
895.0	1	......	906.2	2	......
895.2	1	......	906.6	......	1
895.3	......	1	906.8	1	1
895.5	1	......	906.9	1	......
895.7	......	1	907.0	1	......
895.8	2	2	907.1	1	1
895.9	1	......	907.2	......	2
896.0	1	......	907.3	......	2
896.1	1	1	907.4	......	2
896.2	2	1	907.5	1	2
896.3	3	3	907.6	......	2
896.4	2	1	907.7	2	4
896.5	2	3	907.8	1	2
896.6	3	1	907.9	2	5
896.7	2	3	908.0	2	......
896.8	1	2	908.1	1	......
896.9	1	2	908.3	1	1
897.0	1	......	908.4	2	......
897.1	......	1	908.5	2	......
897.2	......	1	908.7	1	1
897.5	1	......	908.9	1	......
898.0	1	......	909.0	1	......
898.1	2	......	909.4	1	......
898.6	1	......	909.5	3	......
898.7	1	......	909.6	2	......
899.2	1	......	909.7	1	......
899.4	1	......	909.8	1	......
899.6	2	......	909.9	1	......
899.8	3	......	910.3	2	......
......	......	......	910.4	1	......
......	......	......	910.5	1	......
......	......	......	910.7	1	......
......	......	......	910.8	1	......
......	......	......	911.0	1	......
......	......	......	911.4	1	......
......	......	......	911.8	1	......
......	......	......	911.9	1	......
......	......	......	912.0	1	......
	41	23		46	26

Undoubtedly much of the trouble with these cyanide-bars would be avoided by a better cleaning of the zinc-box precipitate. It is, however, easy enough to refine the impure bullion by strongly-oxidizing fusion in the crucible; but this is expensive in labor and reagents, and there is some loss of gold. I have previously published[5] an illustration of this.

A cyanide-bar weighing 643.30 oz. was melted, with a loss of 6.07 oz., and 10 assays on various kinds of samples were made, with the following results :

1	assay showed 844.6 fine in gold.
1	assay showed 846.3 fine in gold.
1	assay showed 846.6 fine in gold.
2	assays showed 847.0 fine in gold.
1	assay showed 847.2 fine in gold.
2	assays showed 847.6 fine in gold.
1	assay showed 847.8 fine in gold.
1	assay showed 848.0 fine in gold.
10	

The bar was melted seven times, when it weighed 502.01 ounces, showing a total loss of 141.29 and an estimated loss of 3.75 oz. of gold. Eight assays were made on various samples of the final metal, with the following results:

1	assay showed 933.2 fine in gold.
2	assays showed 933.3 fine in gold.
2	assays showed 933.4 fine in gold.
1	assay showed 933.5 fine in gold.
2	assays showed 933.7 fine in gold.
8	

The final bar was 21 fine in silver.

A great deal of old scrap material of the most heterogeneous character is purchased at some of our offices, and many of these deposits are small. On these small bars the question of sampling and assaying is not so important; but before the purchasing offices ship these small deposits to a mint they are united into mass-melts, when difficulties may appear in the sampling, and become important. Nine small bars were united to make a mass-melt of 338 oz. Dip- and drill-samples were taken at the purchasing office, and the bar was drilled, top and bottom, at the receiving mint. These samples were assayed in various service laboratories, and Table XXI. summarizes the results reported.

[5] *Trans.*, xl., 789 (1909). *Annual Report of the Director of the Mint for the Year* 1908–09, p, 31.

TABLE XXI.—*Sampling Mass-Melt.*

Fineness.	Dip.	Drill.	Drill.
500.7	......	......	1
500.8	......	......	1
501.1	......	......	1
501.7	......	......	1
501.8	......	......	2
501.9	1	......	......
502.0	......		......
502.1	......	1	......
502.4	4	......	2
502.5	......	......	2
502.6	......	......	2
502.8	1	......	1
502.9	1	1	1
503.0	1	1	1
503.1	......	2	1
503.2	......	1	......
503.4	......	2	1
503.5	1	......	......
503.6	......	2	......
503.7	1	......	......
503.8	......	......	1
503.9	2	1	......
504.0	......	......	1
504.2	......	......	2
504.7	1	1	......
Totals........................	13	14	21
Silver........................		225	

What is probably the very worst case of disagreeing samples and assays ever investigated by the Mint Bureau was a bar weighing 774.39 oz., carrying nearly 400 base, largely copper, which was shipped to a mint as being 568 fine in gold. Three sets of drills, top and bottom, were taken, and, these proving very unsatisfactory, the bar was remelted, with a loss of 4.6 oz. Two dip-samples were taken, and the bar was again drilled, top and bottom. These ten samples were assayed in four laboratories in the service and 113 assays were made. Table XXII. summarizes these assays.

TABLE XXII.—*Sampling Bar 400 Base, Largely Copper.*

	Original Bar.							Remelt.			
	1st Drill.		2d Drill.		3d Drill.			Drill.		Dip.	
Fineness.	T.	B.	T.	B.	T.	B.	Fineness.	T.	B.	A.	B.
564.7	......	......	......	......	......	1	571.2	......	2	......	......
565.3	......	......	......	......	......	1	571.3	......	1	......	......
565.6	......	......	......	......	1	......	571.7	......	1	......	......
566.2	......	......	......	......	2	......	571.8	1	......	......	......
566.4	......	......	......	......	1	......	571.9	......	......	......	1
567.0	......	......	......	......	1	......	572.0	1	1	1	......
567.1	......	1	......	......	1	......	572.6	......	2	1	1
567.4	......	......	......	......	......	2	572.8	1	......	1	......
567.5	......	1	......	......	......	......	573.0	......	1	......	......
567.6	......	......	......	......	1	1	573.2	1	2	......	......
567.8	1	......	......	......	......	......	573.5	1	......	......	1
568.0	......	......	......	......	......	1	573.6	......	......	1	......
568.3	......	1	......	......	......	......	573.7	......	1	......	......
568.4	......	1	......	......	......	......	573.8	......	1	1	......
568.5	......	1	......	......	......	......	573.9	1	......	2	1
568.6	......	1	......	......	......	......	574.0	2	......	2	1
568.7	1	......	......	1	......	......	574.1	1	......	1	1
568.8	1	......	......	1	......	......	574.2	1	......	......	......
569.1	......	1	......	......	......	......	574.3	1	......	1	1
569.2	......	2	......	......	......	......	574.4	1	......	......	1
569.4	3	1	......	......	......	......	574.6	......	......	1	1
569.5	......	1	1	......	......	......	574.8	......	......	1	
569.6	......	......	......	1	......	......	575.0	......	......	1	2
569.7	1	1	......	1	......	......	575.5	......	......	......	1
569.8	......	......	1	......	......	......	575.7	......	......	......	1
569.9	......	......	1	......	......	......	576.0	......	......	......	1
570.0	......	......	......	2	......	......	......	......	......	......	......
570.1	1		......	......	......	......	......	......	......	......	......
570.2	1	......	2	......	......	......	......	......	......	......	......
570.3	......	......	......	1	......	......	......	......	......	......	......
570.4	......	......	1	......	......	......	......	......	......	......	......
570.5	1	......	......	1	......	......	......	......	......	......	......
570.6	2	......	2	......	......	......	......	......	......	......	......
570.7	......	......	2	1	......	......	......	......	......	......	......
570.8	......	......	......	1	......	......	......	......	......	......	......
570.9	......	......	1	......	......	......	......	......	......	......	......
571.0	......	......	......	1	......	......	......	......	......	......	......
571.3	......	......	......	1	......	......	......	......	......	......	......
Totals...	12	12	11	12	7	6		12	12	14	14

The presence of so much copper in this metal undoubtedly affected the actual assaying as well as the sampling of the bar.

In describing the taking of dip-samples I have spoken of the molten metal being "well mixed." This condition is absolutely essential to proper sampling. It is quite possible that in some of the cases already mentioned the molten metal had not been thoroughly mixed when the samples were taken. In the following case the molten metal certainly was not well mixed.

Two dip-samples were assayed in duplicate by me, showing a decided difference between the two samples. On a re-assay in duplicate, the same difference appeared. Each sample was also assayed once in two other laboratories. Table XXIII. summarizes the results:

TABLE XXIII.—*Differing Dip-Samples.*

	1st Sample.	2d Sample.
Bureau	615.6	612.8
	616.0	612.8
Re-assay	615.5	611.5
	616.3	611.1
2d laboratory	615.3	612.2
3d laboratory	615.5	611.9

Many melters, samplers, and assayers have an idea that unsatisfactory chip- and drill-samples can be corrected by simply melting the bar and taking fresh samples. There are, of course, cases where there was carelessness in the original melting and sampling, which can be cured by careful remelting and resampling, but in a vast majority of cases simple melting does little or no good. If there is a real difference of importance between two chips or two drillings or between chips and drillings of the same bar, it is due to the fact that the metal segregates on solidifying. This is a function of the chemical composition of the metal; and, under practical conditions, a remelting which does not materially change the composition can accomplish very little in reducing the segregation. If the chemical composition of the metal is such that it interferes with the actual assay-work, manifestly a remelting which does not change the composition of the bar will accomplish no good.

It therefore follows that when the assay-reports on an ordinary bar of miscellaneous bullion differ so widely as to be unsatisfactory, it should be melted and refined by strong oxidation. This will, of course, reduce the weight of the bar, but the loss in weight is nearly all base metal in most cases. The actual loss of gold will generally be small, except where a large amount, 50 oz. or more, of base must be removed, as in the case of many cyanide-bars, when the loss may become considerable. In the case already cited, the removal of 141.29 oz. from a bar weighing originally 643.30 oz. caused a loss of about 3.75 oz. of gold.

A bar carrying about 35 silver and weighing 494.26 oz. yielded varying assays on the gold, and was remelted with a loss of 0.63 oz. Again the assays were unsatisfactory, and it was remelted with a further loss of 1.09 oz. but without improvement in the assays. It was finally melted with a further loss of 5.20 oz. and still gave unsatisfactory assays. Two dip-samples were taken at each melting, and the eight samples were assayed in various service laboratories. Table XXIV. summarizes the results reported.

TABLE XXIV.—*Dip-Samples on Four Meltings.*

1st Melt.		2d Melt.		3d Melt.		4th Melt.	
Fineness.	Assays.	Fineness.	Assays.	Fineness.	Assays.	Fineness.	Assays.
806.0	1	809.9	1	812.8	1	818.3	1
806.1	1	810.1	2	813.0	1	818.4	1
806.3	2	810.6	3	813.2	2	818.8	1
806.4	2	810.7	1	813.3	1	819.1	1
806.5	1	810.8	2	813.6	2	819.2	1
806.7	1	810.9	1	813.7	1	819.3	1
806.8	2	811.0	2	813.8	1	819.5	1
806.9	3	811.1	1	813.9	1	819.9	1
807.0	2	811.3	1	814.2	1	820.2	2
807.1	1	811.6	2	814.6	2	820.5	3
807.2	3	811.8	2	814.8	2	820.6	1
807.4	2	812.2	1	814.9	1	820.8	1
807.5	2	812.3	1	815.0	3	821.0	1
807.6	3	......	......	815.3	1	821.3	1
807.7	2	......	......	......	......	821.4	2
807.8	3	......	......	......	......	......	......
807.9	1	......	......	......	......	......	......
808.0	1	......	......	......	......	......	......
808.1	2	......	......	......	......	......	......
808.2	3	......	......	......	......	......	......
808.3	1	......	......	......	......	......	......
808.5	2	......	......	......	......	......	......
Totals..	41		20		20		19

Another bar carrying about 35 silver and weighing 666.91 oz. was drilled at the ends and in the center, and the drills yielded the following results:

End Drills.		Center Drills.	
Fineness.	Assays.	Fineness.	Assays.
664.1	1	695.4	1
664.5	1	697.4	1
665.5	2	703.0	2

This bar was remelted and two dip-samples were taken, while the cold bar was again drilled at the ends and in the center. After melting, however, even with the loss of 33.29 oz., the metal remained unsatisfactory, as shown by the following assays:

Dips.		Drills.			
		Ends.		Center.	
Fineness.	Assays.	Fineness.	Assays.	Fineness.	Assays.
705.5	1	699.5	2	706.7	1
706.6	1	699.9	1	707.9	1
706.8	1	701.3	1	708.9	1
707.8	1	701.6	1	725.0	1
707.9	1	701.8	1	726.3	1
708.3	1			727.0	1
708.5	1				
708.7	1				

From these gold-assays the silver cannot be given with any exactness, but it was probably about 40.

Conclusions.

The foregoing data are summarized in the following conclusions:

In sampling deposits of miscellaneous gold-bullion weighing more than 300 oz.:

There are various cases where either a chip- or a drill-sample may be satisfactory.

There are various cases where a drill-sample is better than a chip-sample.

Where the assayer is acquainted with the metal, he may accept a chip- or a drill-sample.

On an unknown bullion it is unsafe to accept any sample except a properly prepared dip-sample.

In many cases, particularly of cyanide-bullion, the composition of the metal interferes with the actual assaying and the bullion must be refined before one can expect to determine the gold accurately.

Discussion.

Edward Keller, Perth Amboy, N. J. (communication to the Secretary *):—Mr. Dewey, in his paper, offers a liberal addition of new data to those already to be found in the technical literature on this subject. However, now as before, the work issuing from the U. S. mints and assay-offices conveys the

* Received Jan. 23, 1913.

impression that systematic sampling in those institutions is more or less a secondary consideration, the chief attention being given to the principle of producing approximately homogeneous bars; recourse being taken to remelting or refining the bullion. This practice has been definitely rejected in the realm of copper-bullion sampling, for the reason that in such operations there are always unaccounted losses. Does not the same objection hold true for gold-bullions; although, perhaps, in a lesser degree?

Differences of opinion would seem justified on the following statements made by Mr. Dewey:

1. "Only two classes of alloys can form homogeneous bars—those that are solid solutions, and the eutectics."

There is no doubt as to this characteristic of the eutectics. As to the solid solutions, the late eminent French metallurgist, Floris Osmond,[6] demonstrated conclusively that silver remains in solid solution with copper up to the amount of 1 per cent.; yet silver-bullions, as well as pure copper-silver alloys, within the mentioned range of composition show a very marked degree of diffusion and the bars a consequent heterogeneity, in this case improperly called segregation. Solid solutions are homogeneous only in their microstructure, showing on etched surfaces under the microscope but a single structural element. From the freezing-point curves, theoretically established by Bakhuis Roozeboom,[7] we may deduce the fact that even such binary alloys, the whole series of which form solid solutions, and to which the gold-silver series belong, are bound to have diffusion during freezing or solidification and, therefore, to show heterogeneity in chemical composition in their solid state, although the degree of the latter may be much less than in some alloys of another class. Fig. 1 shows the general diagram of freezing-points of the class of alloys to which the gold-silver series belong. The length of the ordinates at *C* and at *D* represents the temperature of the freezing-points of the two metals *A* and *B*. Of the two curves connecting *C* and *D*, the upper represents the initial and the lower the final freezing-points of the alloy-series. Between the two curves lies the range of the freezing-temperature. The

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[6] Sur les alliages du groupe argent-cuivre, *Comptes rendus de l'Académie des Sciences*, vol. cxxiv., p. 1234 (1897).

[7] Erstarrungs punkte der Mischkrystalle zweier Stoffe, *Zeitschrift für physikalische Chemie*, vol. xxx., p. 385 (1899).

greater the distance between the two curves, the greater the difference between the composition of the initially-freezing and the finally-freezing alloy, or the greater the diffusion and the heterogeneity of the solid alloy. There seems to exist no satisfactory freezing-point curve of the gold-silver series of alloys; one by Roberts-Austen and Kirke Rose consists of few determined points, but it ignores the final freezing.

Mr. Dewey omits to mention that a chemical compound would also be a possibility for a homogeneous alloy. A. Levol[8] first drew attention to this, although he mistook a eutectic for a chemical compound; in his time the character of the eutectic had not yet been demonstrated. Numerous instances of chem-

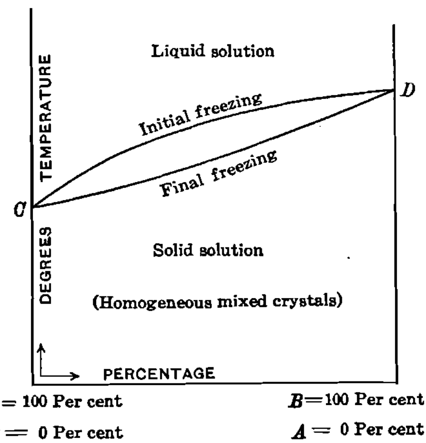

FIG. 1.—FREEZING-POINT DIAGRAM AFTER BAKHUIS ROOZEBOOM.

ical compounds are now known among strictly metallic alloys. I would only refer to the important series of copper-tin and copper-aluminium. The possibility of a gold-bullion being a chemical compound is very remote; unless that some day aluminium be employed as a collecting medium.

2. "It is a common practice in the Mint Service to drill half-way through a bar at diagonally opposite corners of the top, and unite the drillings for a top-sample. The remaining corners are drilled half-way through from the bottom, and the drillings are mixed for the bottom-sample. Occasionally, especially when sampling very base bars, the four drillings are kept separate; and sometimes holes are drilled near the center of the bar also."

[8] Mémoire sur les alliages, considérés sous le rapport de leur composition chimique, *Annales de Chimie et de Physique*, Third Series, vol. xxxvi., p. 194 (1852).

Naturally, if the bars be homogeneous, it is of little importance where and how deep the holes are drilled; but, if there has been diffusion or the bars show "segregation," the corners of the bar would appear the worst possible positions to drill for a correct sample; for these positions are the well-demonstrated centers of concentration—or, as many insist, segregation. From Mr. Dewey's description it does not appear clearly whether these samples are taken as the real sample of the bars, or, perhaps, to show their heterogeneity, and when the latter is established refining is resorted to.

The shape of a bar is always an important factor in the development of heterogeneity, and for that reason the lack of any information on that point may be considered a deplorable omission on the part of Mr. Dewey.

I have but recently endeavored, by graphical demonstration, to show the irrationality of drilling in any one place a bar of bullion with an approximately square cross-section, and I have shown why a saw-section of such a bar would yield a correct sample.[9] Why could not the same scientific principles be applied to the sampling of heterogeneous gold-bullion bars?

Most of the objectionable features of sampling a bar by drilling are eliminated in the comparatively thin plate; this I recommended about 17 years ago in place of the time-honored copper-pig (bar), and the plate, or slab, is now almost universally adopted by the copper-smelteries. While it is not a cure for all evils in sampling, it gives commercially very satisfactory results, and it has finally eliminated the formerly often-recurring sampling-controversies.

3. "Drill-samples of brittle bars are, however, liable to be unsatisfactory, because the fine and coarse portions may differ considerably in composition."

In copper-bullion samples, the fine portion is generally higher in content of precious metals and lower in copper than the coarse; but this is not deemed a difficulty, since the sample is separated by means of a sieve into coarse and fine parts, and the two are weighed in their proper ratio for the assay-charge. Grading into three or more sizes and weighing in proportioned quantities would add but little difficulty.

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[9] The Mathematics of Copper Sampling, *Engineering and Mining Journal*, vol. xciii., p. 703 (Apr. 6, 1912).