

Supplementary Materials

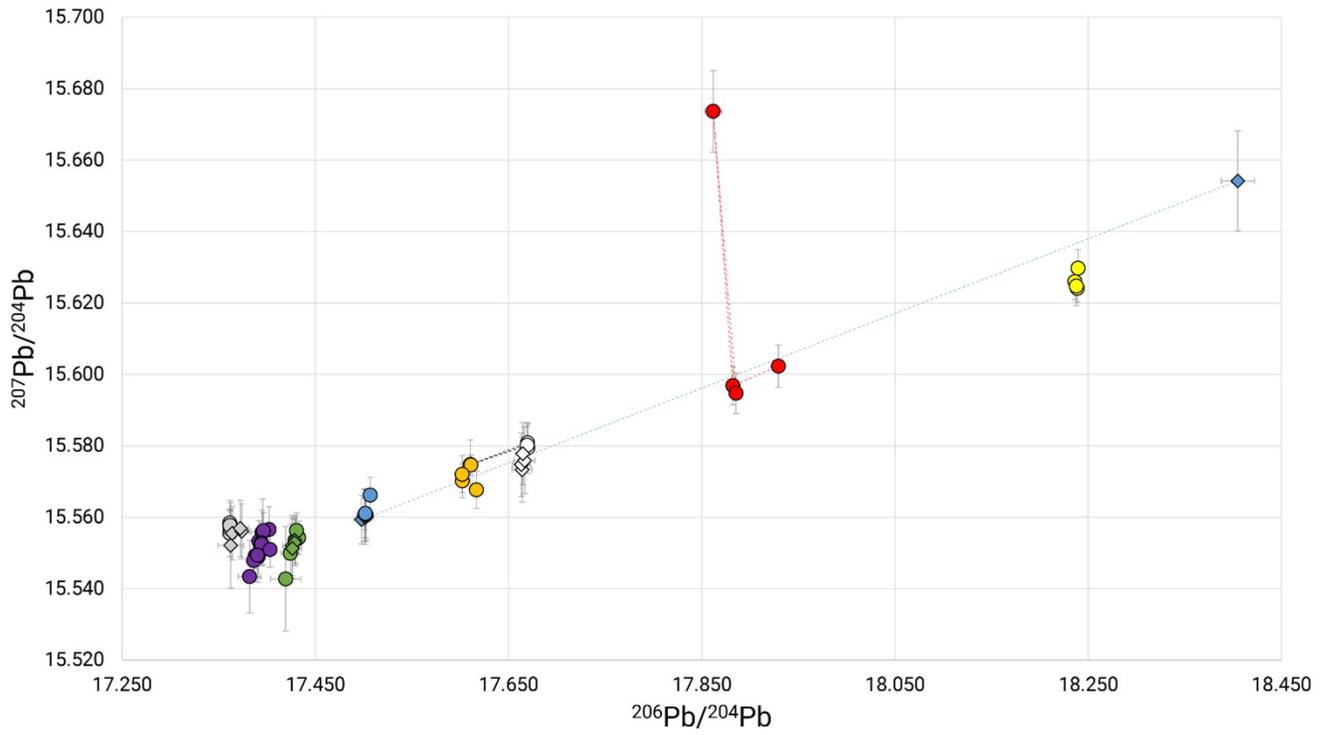
“Observations on sample size for lead isotopic analysis of ancient copper alloys”

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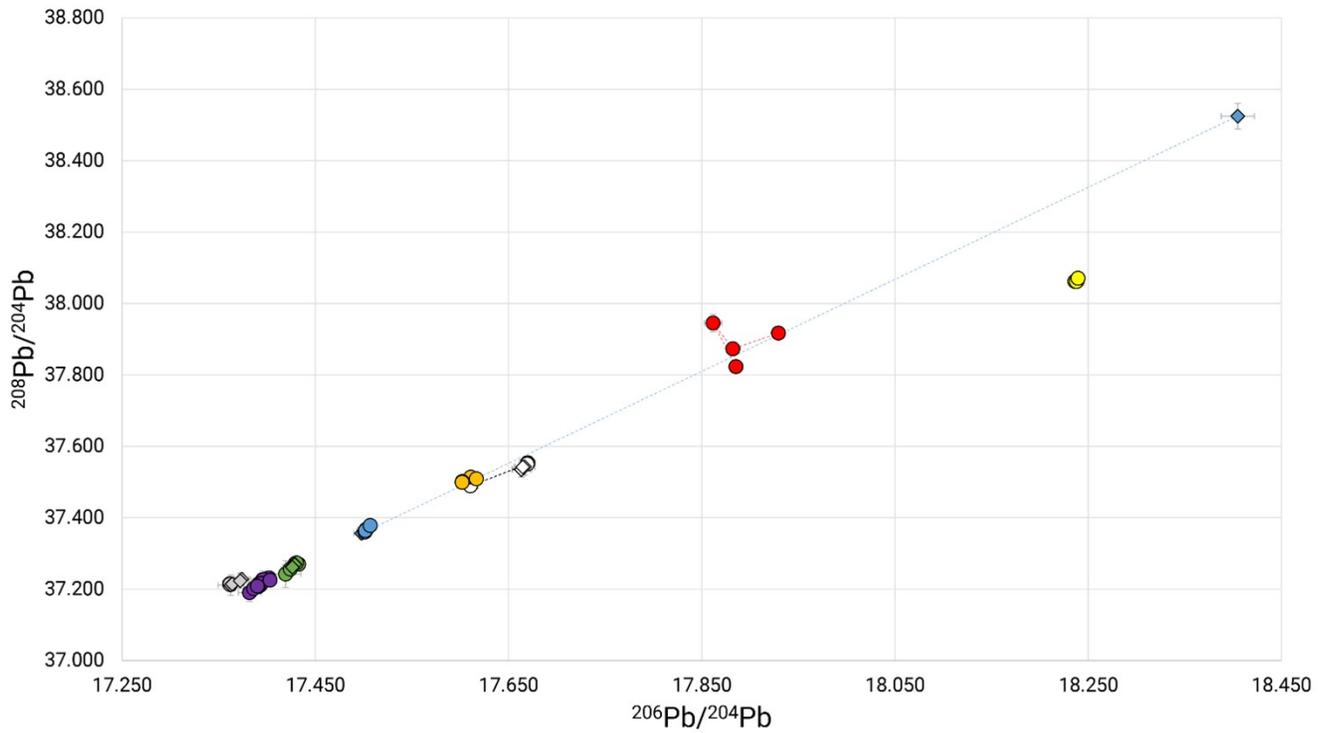
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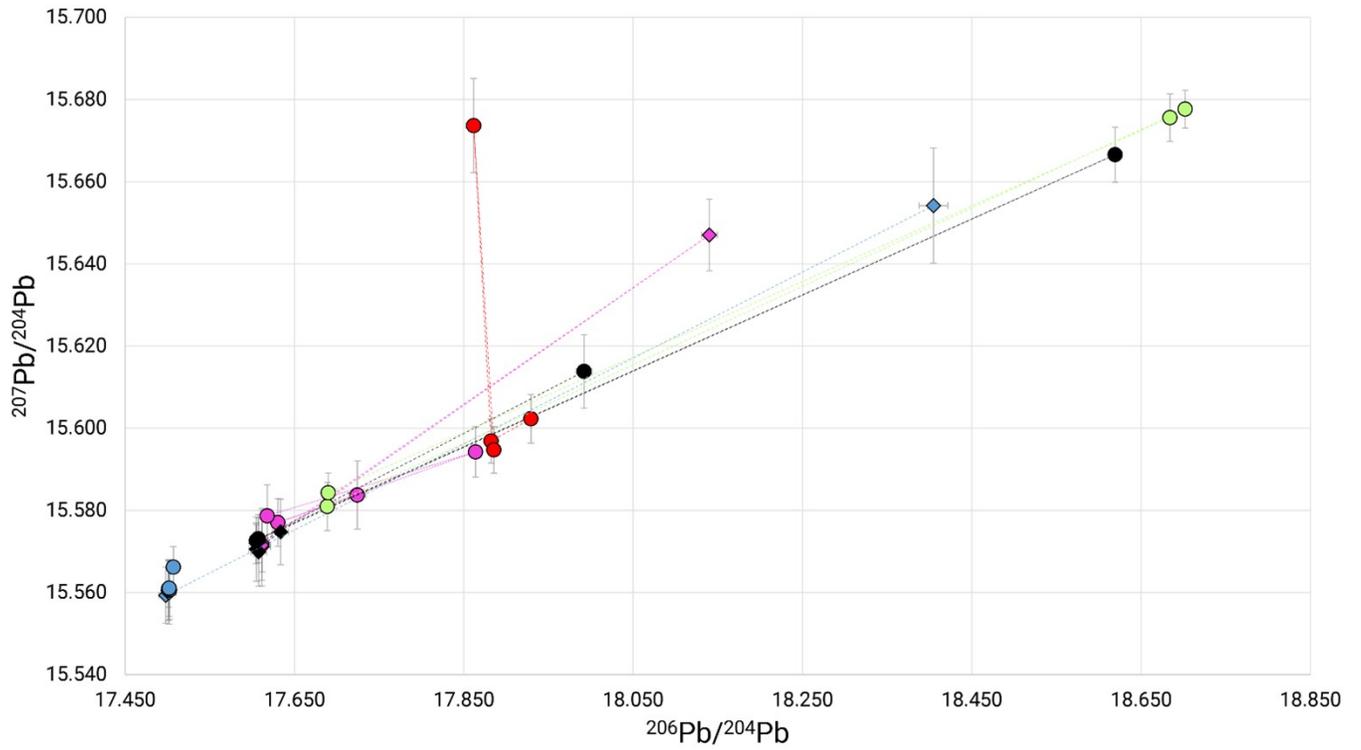
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Additional LI ratio plots

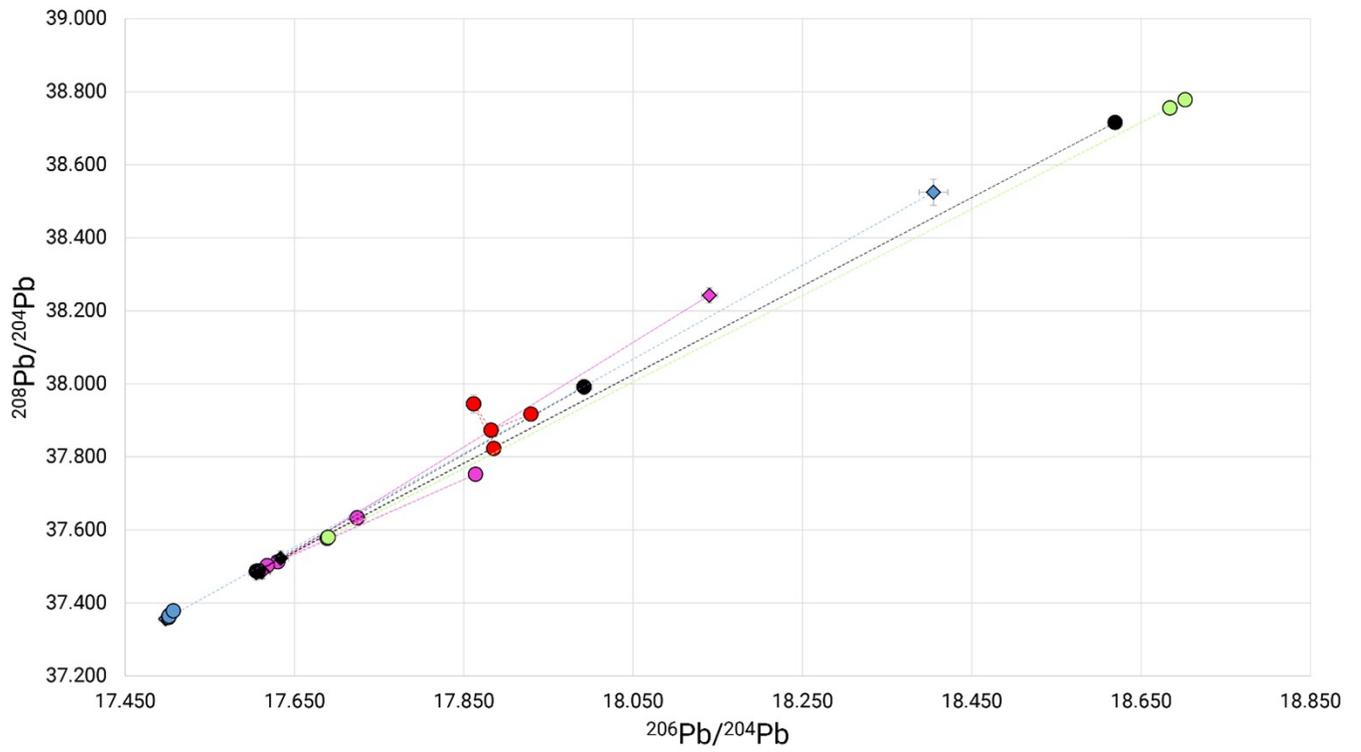


- 32X SN6
- ◇ 32X SN6
- 32X LB15
- ◇ 32X LB15
- 83X PR8
- ◇ 83X PR8
- 85X ANTH
- ◇ 85X ANTH
- 36X CUAS3 A
- 33X GM20 A
- 32X LB17 A
- PB110





● 31X 7835-8 ◆ 31X 7835-8 ● 31X B26 ◆ 31X B26 ● 83X PR8 ◆ 83X PR8 ● 36X CUAS3 A ● 32X SN5 A



Elemental analysis of MBH-CRM-CR32-PB110

Table S.1: Elemental composition of MBH-CRM-CR32-PB110 as determined by ICP-OES analysis (in µg/g, except Cu and Totals in wt%). Au concentrations (in italics) are overestimated due to manganese interference. Included ICP-MS data was obtained following the methodology described by Rademakers et al. (2024; DOI: 10.1016/j.jas.2024.106043).

Sample name	Sample mass (g)	Cu	Ag	As	Au	Bi	Co	Cr	Fe	Mg	Mn	Ni	P	Pb	S	Sb	Sn	Zn	Totals
CRV		90.44		1980		310	900		3390	90	1320	8980	9460	9950	150	5840	33060	17100	
ICP-MS measured, Oct-23		88.87	130	1900	2.3	290	840	50				8240		10250		6040	35600	14529	
Mar-25		91.75	115	2000	1.3	340	890	50				9210				6730	35400		
Jan-16 (PB110)	0.1079	82.2	30	1700	30	300	750	45	3300	70	1100	7800	8700	8100	140	5200	29500	14700	90.4
Feb-16 (PB110)	0.1079	92.7	35	2000	3	340	810	5	3700	80	1200	8600	10600	8800	200	5200	30500	15500	101.4
Apr-16 (FA-55)	0.0422	86.1	3	1900	19	350	820	45	3500	70	1200	8400	12600	9000	170	5400	30000	15400	95.0
Apr-16 (FA-56)	0.0814	84.2	6	1900	17	300	800	45	3400	70	1200	8300	12500	8900	180	5400	29900	14700	93.0
Apr-16 (FA-57)	0.1095	84.1	7	2000	16	300	810	45	3500	70	1200	8400	12100	8900	170	5500	29700	14600	92.9
Jun-16 (J-33)	0.0655	85.5	27	1700	16	340	800	45	3400	90	1200	8200	8400	8700	170	5700	26600	15800	93.7
Jan-17 (K-27, HNO3)	0.0741	88.6	95	1800	20	370	780	45	3400	80	1200	8200	9800	8900	170	6700	28700	14900	97.1
Jan-17 (K-28, HCl)	0.0738	85.3	90	1700	19	300	760	45	3300	70	1100	7700	9400	8300	180	5600	28600	14400	93.5
Jul-17 (PB110-1)	0.0750	85.0	95	1700	20		770	40	3200	70	1200	8700	8200	8500	190	5900	25800	19300	93.4
Jul-17 (PB110-2)	0.0720	87.7	100	1700	17		780	40	3200	70	1200	8800	8200	8600	220	5900	26700	15300	95.8
Aug-17 (PB 110)	0.1038	81.5	75	1500	15	290	730	40	3100	70	1100	7700	7200	7900	130	5100	24800	14100	88.9
Oct-17 (OF-31)	0.1029	89.8	90	1800	18	340	750	45	3400	50	1200	8300	11400	8700	100	5500	34100	16200	99.0
Mar-18 (PB-110, 1/10)	0.0206	86.5	105	1600	15	370	760	45	3400	130	1200	8000	7300	8500	220	4500	27300	15200	94.4
Mar-18 (PB-110, 1/1)	0.0206	-	100	1500	14	240	710	40	3000	120	1200	7100	7100	7300	170	4100	23900	13300	-
Sep-18 (PB110)	0.1194	90.1	95	1600	19	260	780	45	3300	90	1200	8200	6800	8700	200	5600	26200	15700	98.0
May-19 (PB-110-B)	0.0635	86.8	95	1700	14	290	740	45	3300	70	1200	7800	8100	8200	170	5700	28300	16000	94.9
May-19 (PB-110-A)	0.0914	89.3	100	1500	16	330	750	40	2900	70	1200	8100	4400	8500	210	5900	16900	16600	96.1
Oct-19 (O-27)	0.0652	90.3	115	1900	15	310	800	45	3600	90	1300	8400	9400	8900	200	6000	31900	17500	99.3
Dec-19 (D-16)	0.0371	92.2	110	1700	20	340	780	45	3500	70	1200	8700	7500	8900	170	6300	27000	16000	100.5
Nov-20 (FI-13)	0.1522	95.1	110	1600	17	270	770	45	3400	70	1200	8400	7400	8500	60	4600	27100	15600	103.0
Oct-22 (PB-110)	0.0350	85.5	105	1900	15	300	820	50	3400	70	1200	7700	9000	8100	180	6000	30200	14700	93.9

<i>Sample name</i>	<i>Sample mass (g)</i>	<i>Cu</i>	<i>Ag</i>	<i>As</i>	<i>Au</i>	<i>Bi</i>	<i>Co</i>	<i>Cr</i>	<i>Fe</i>	<i>Mg</i>	<i>Mn</i>	<i>Ni</i>	<i>P</i>	<i>Pb</i>	<i>S</i>	<i>Sb</i>	<i>Sn</i>	<i>Zn</i>	<i>Totals</i>
<i>Oct-23 (BM-69)</i>	0.0415	87.2	120	1800	23	320	820	50	3700	90	1200	8900	9800	8500	280	6100	31500	15700	96.2
<i>Aug-24 (R-65, start)</i>	0.0926	88	115	1700	21	310	800		3500	80	1200	7200	8000	8200	240	5200	26300	15200	96
<i>Aug-24 (R-65, end)</i>	0.0926	91	130	1500	22	350	810		3500	70	1200	7300	7600	8300	270	5000	23900	15600	98
<i>Oct-25 (PB-110, start)</i>	0.0905	89.3	115	1800	< 25	340	810	45	3500	< 150	1200	9000	8600	9200	250	6700	29300	16000	98
<i>Oct-25 (PB-110, end)</i>	0.0905	91.0	115	1800	< 25	320	830	45	3500	< 150	1300	9200	9200	9400	260	7000	29500	16400	100
<i>Average recovery (%)</i>	0.1079	96.9		87		101	86		89	86	91	91	93	85	122	94	84	91	
<i>St.dev. recovery (%)</i>	0.1079	3.7		8		11	3		9	19	3	6	21	4	32	10	10	7	
Replicate analysis of same solution																			
CRV		90.44		1980		310	900		3390	90	1320	8980	9460	9950	150	5840	33060	17100	
<i>Oct-16 (PB110a)</i>	0.0966	85.5	100	1800	20	390	790	45	3500	70	1200	8000	10400	8800	100	5600	32300	17500	94.6
<i>Jul-17 (PB110a)</i>	0.0966	92.1	65	1500	22		830	45	3700	70	1300	9100	7200	9200	200	5800	21900	18700	100.0
<i>Aug-17 (PB110a)</i>	0.0966	90.8	70	1400	17	300	810	45	3600	80	1300	8600	7000	9000	200	5700	21400	18000	98.6
<i>Oct-17 (PB110a)</i>	0.0966	89.5	95	1700	17	350	760	45	3500	70	1200	8200	10300	8700	110	5300	31000	17700	98.4
<i>Mar-18 (PB110a)</i>	0.0966	86.9	105	1700	13	360	740	45	3500	80	1200	8100	8600	8700	150	5600	29700	17500	95.5
<i>Mar-18 (PB110a)</i>	0.0966	87.3	105	1700	16	340	760	45	3600	80	1200	8200	8700	8800	160	5700	30300	17700	96.0
<i>May-19 (PB110a)</i>	0.0966	87.2	95	1700	17	340	760	45	3500	70	1200	8000	8900	8600	200	5800	31100	19600	96.2
<i>Oct-19 (PB110a)</i>	0.0966	90.8	110	1700	15	360	820	50	3700	80	1300	8600	8800	9200	210	6100	28400	20700	99.8
<i>Nov-20 (PB110a, start)</i>	0.0966	89.8	105	1700	17	340	740	40	3400	70	1100	8100	8600	8400	60	5500	30000	17500	98.4
<i>Nov-20 (PB110a, end)</i>	0.0966	89.2	225	1700	50	330	740	45	3400	60	1100	8100	8700	8400		5500	30100	17400	97.8
<i>Oct-22 (PB110a)</i>	0.0966	84.6	100	1900	13	370	840	50	3500	70	1200	7700	9100	8300	160	6500	31400	17300	93.5
<i>Oct-23 (PB110a)</i>	0.0966	89.2	150	1900	20	370	830	50	3700	80	1300	8800	10100	8500	240	6100	32500	18300	98.5
<i>Average recovery (%)</i>		97.9		85		112	87		89	80	93	93	94	88	100	99	88	106	
<i>St.dev. recovery (%)</i>		2.5		8		6	5		3	7	4	5	11	3	47	5	12	5	

Table S.2: Elemental composition of MBH-CRM-CR32-PB110 as determined by ICP-OES analysis (in µg/g, except Cu and Totals in wt%), with recovery reported for each measurement

Sample name	Sample mass (g)	Cu	Ag	As	Au	Bi	Co	Cr	Fe	Mg	Mn	Ni	P	Pb	S	Sb	Sn	Zn	Totals
CRV		90.44		1980		310	900		3390	90	1320	8980	9460	9950	150	5840	33060	17100	
Jan-16 (PB110)	0.1079	82.2	30	1700	30	300	750	45	3300	70	1100	7800	8700	8100	140	5200	29500	14700	90.4
Recovery (%)	0.1079	90.9		87		96	83		82	77	87	86	92	82	94	89	89	86	
Feb-16 (PB110)	0.1079	92.7	35	2000	3	340	810	5	3700	80	1200	8600	10600	8800	200	5200	30500	15500	101.4
Recovery (%)	0.1079	102.5		100		109	90		92	88	94	96	112	88	132	89	92	91	
Apr-16 (FA-55)	0.0422	86.1	3	1900	19	350	820	45	3500	70	1200	8400	12600	9000	170	5400	30000	15400	95.0
Apr-16 (FA-56)	0.0814	84.2	6	1900	17	300	800	45	3400	70	1200	8300	12500	8900	180	5400	29900	14700	93.0
Apr-16 (FA-57)	0.1095	84.1	7	2000	16	300	810	45	3500	70	1200	8400	12100	8900	170	5500	29700	14600	92.9
Recovery (%)	0.0422	95		97		112	92		104	77	94	94	134	90	116	93	91	90	
Recovery (%)	0.0814	93		98		97	89		101	77	93	93	132	90	118	92	91	86	
Recovery (%)	0.1095	93		99		96	89		102	80	94	93	128	89	115	94	90	85	
Jun-16 (J-33)	0.0655	85.5	27	1700	16	340	800	45	3400	90	1200	8200	8400	8700	170	5700	26600	15800	93.7
Recovery (%)	0.0655	95		83		109	88		85	93	92	92	89	88	113	98	81	92	
Jan-17 (K-27, HNO3)	0.0741	88.6	95	1800	20	370	780	45	3400	80	1200	8200	9800	8900	170	6700	28700	14900	97.1
Jan-17 (K-28, HCl)	0.0738	85.3	90	1700	19	300	760	45	3300	70	1100	7700	9400	8300	180	5600	28600	14400	93.5
Recovery (%)	0.0741	98		93		120	87		100	83	90	91	104	89	115	115	87	87	
Recovery (%)	0.0738	94		88		95	84		98	77	86	86	99	83	118	95	86	84	
Jul-17 (PB110-1)	0.0750	85.0	95	1700	20		770	40	3200	70	1200	8700	8200	8500	190	5900	25800	19300	93.4
Jul-17 (PB110-2)	0.0720	87.7	100	1700	17		780	40	3200	70	1200	8800	8200	8600	220	5900	26700	15300	95.8
Recovery (%)	0.0750	94		86			86		80	75	89	97	87	85	128	101	78	113	
Recovery (%)	0.0720	97		87			87		81	73	88	98	87	86	149	100	81	89	
Aug-17 (PB 110)	0.1038	81.5	75	1500	15	290	730	40	3100	70	1100	7700	7200	7900	130	5100	24800	14100	88.9
Recovery (%)	0.1038	90		77		92	81		79	76	85	86	76	79	85	87	75	82	
Oct-17 (OF-31)	0.1029	89.8	90	1800	18	340	750	45	3400	50	1200	8300	11400	8700	100	5500	34100	16200	99.0
Recovery (%)	0.1029	99		92		111	83		85	58	91	93	120	87	65	94	103	95	

<i>Sample name</i>	<i>Sample mass (g)</i>	<i>Cu</i>	<i>Ag</i>	<i>As</i>	<i>Au</i>	<i>Bi</i>	<i>Co</i>	<i>Cr</i>	<i>Fe</i>	<i>Mg</i>	<i>Mn</i>	<i>Ni</i>	<i>P</i>	<i>Pb</i>	<i>S</i>	<i>Sb</i>	<i>Sn</i>	<i>Zn</i>	<i>Totals</i>
<i>Mar-18 (PB-110, 1/10)</i>	0.0206	86.5	105	1600	15	370	760	45	3400	130	1200	8000	7300	8500	220	4500	27300	15200	94.4
<i>Mar-18 (PB-110, 1/1)</i>	0.0206	-	100	1500	14	240	710	40	3000	120	1200	7100	7100	7300	170	4100	23900	13300	-
<i>Recovery (%)</i>	0.0206	96		78		119	84		85	143	90	89	77	85	147	77	83	89	
<i>Recovery (%)</i>	0.0206	-		76		77	78		75	132	87	79	75	73	114	71	72	78	
<i>Sep-18 (PB110)</i>	0.1194	90.1	95	1600	19	260	780	45	3300	90	1200	8200	6800	8700	200	5600	26200	15700	98.0
<i>Recovery (%)</i>	0.1194	100		82		85	86		84	103	94	92	72	88	136	96	79	92	
<i>May-19 (PB-110-B)</i>	0.0635	86.8	95	1700	14	290	740	45	3300	70	1200	7800	8100	8200	170	5700	28300	16000	94.9
<i>May-19 (PB-110-A)</i>	0.0914	89.3	100	1500	16	330	750	40	2900	70	1200	8100	4400	8500	210	5900	16900	16600	96.1
<i>Recovery (%)</i>	0.0635	96		86		95	83		84	73	90	87	85	82	114	98	86	93	
<i>Recovery (%)</i>	0.0914	99		77		107	84		72	77	89	90	47	86	139	102	51	97	
<i>Oct-19 (O-27)</i>	0.0652	90.3	115	1900	15	310	800	45	3600	90	1300	8400	9400	8900	200	6000	31900	17500	99.3
<i>Recovery (%)</i>	0.0652	100		94		101	89		91	100	95	94	100	89	132	103	96	102	
<i>Dec-19 (D-16)</i>	0.0371	92.2	110	1700	20	340	780	45	3500	70	1200	8700	7500	8900	170	6300	27000	16000	100.5
<i>Recovery (%)</i>	0.0371	102		86		110	87		103	77	91	97	79	89	115	108	82	94	
<i>Nov-20 (FI-13)</i>	0.1522	95.1	110	1600	17	270	770	45	3400	70	1200	8400	7400	8500	60	4600	27100	15600	103.0
<i>Recovery (%)</i>	0.1522	105		78		87	86		86	75	90	94	78	85	43	78	82	91	
<i>Oct-22 (PB-110)</i>	0.0350	85.5	105	1900	15	300	820	50	3400	70	1200	7700	9000	8100	180	6000	30200	14700	93.9
<i>Recovery (%)</i>	0.0350	95		95		96	91		85	77	92	86	95	82	121	103	91	86	
<i>Oct-23 (BM-69)</i>	0.0415	87.2	120	1800	23	320	820	50	3700	90	1200	8900	9800	8500	280	6100	31500	15700	99.8
<i>Recovery (%)</i>	0.0415	96		89		102	91		103	101	95	99	103	85	190	105	95	92	
<i>Aug-24 (R-65, start)</i>	0.0926	88	115	1700	21	310	800		3500	75	1200	7200	8000	8200	240	5200	26300	15200	96
<i>Aug-24 (R-65, end)</i>	0.0926	91	130	1500	22	350	810		3500	74	1200	7300	7600	8300	270	5000	23900	15600	98
<i>Recovery (%)</i>	0.0926	98		85		99	88		88	82	89	80	85	83	160	89	79	89	
<i>Recovery (%)</i>	0.0926	100		78		111	90		89	82	90	82	80	83	181	85	72	91	
<i>Oct-25 (PB-110, start)</i>	0.0905	89.3	115	1800	< 25	340	810	45	3500	< 150	1200	9000	8600	9200	250	6700	29300	16000	98
<i>Oct-25 (PB-110, end)</i>	0.0905	91.0	115	1800	< 25	320	830	45	3500	< 150	1300	9200	9200	9400	260	7000	29500	16400	100
<i>Recovery (%)</i>	0.0905	99		91		110	90		103		91	100	91	92	167	115	89	94	
<i>Recovery (%)</i>	0.0905	101		91		103	92		103		98	102	97	94	173	120	89	96	

<i>Sample name</i>	<i>Sample mass (g)</i>	<i>Cu</i>	<i>Ag</i>	<i>As</i>	<i>Au</i>	<i>Bi</i>	<i>Co</i>	<i>Cr</i>	<i>Fe</i>	<i>Mg</i>	<i>Mn</i>	<i>Ni</i>	<i>P</i>	<i>Pb</i>	<i>S</i>	<i>Sb</i>	<i>Sn</i>	<i>Zn</i>	<i>Totals</i>	
Replicate analysis of same solution																				
<i>Oct-16 (PB110a)</i>	0.0966	85.5	100	1800	20	390	790	45	3500	70	1200	8000	10400	8800	100	5600	32300	17500	94.6	
<i>Recovery (%)</i>	0.0966	95		91		125	87		88	78	94	89	110	89	66	97	98	103		
<i>Jul-17 (PB110a)</i>	0.0966	92.1	65	1500	22		830	45	3700	70	1300	9100	7200	9200	200	5800	21900	18700	100.0	
<i>Recovery (%)</i>	0.0966	102		73			92		92	80	96	101	77	92	134	100	66	110		
<i>Aug-17 (PB110a)</i>	0.0966	90.8	70	1400	17	300	810	45	3600	80	1300	8600	7000	9000	200	5700	21400	18000	98.6	
<i>Recovery (%)</i>	0.0966	100		71		96	89		91	87	96	96	74	91	135	97	65	105		
<i>Oct-17 (PB110a)</i>	0.0966	89.5	95	1700	17	350	760	45	3500	70	1200	8200	10300	8700	110	5300	31000	17700	98.4	
<i>Recovery (%)</i>	0.0966	99		85		113	84		87	80	91	92	108	87	76	91	94	103		
<i>Mar-18 (PB110a)</i>	0.0966	86.9	105	1700	13	360	740	45	3500	80	1200	8100	8600	8700	150	5600	29700	17500	95.5	
<i>Mar-18 (PB110a)</i>	0.0966	87.3	105	1700	16	340	760	45	3600	80	1200	8200	8700	8800	160	5700	30300	17700	96.0	
<i>Recovery (%)</i>	0.0966	96		84		115	83		88	84	92	91	91	88	103	97	90	103		
<i>Recovery (%)</i>	0.0966	97		85		109	84		89	84	93	92	92	88	110	97	92	103		
<i>May-19 (PB110a)</i>	0.0966	87.2	95	1700	17	340	760	45	3500	70	1200	8000	8900	8600	200	5800	31100	19600	96.2	
<i>Recovery (%)</i>	0.0966	96		88		110	85		87	76	92	89	94	87	137	99	94	115		
<i>Oct-19 (PB110a)</i>	0.0966	90.8	110	1700	15	360	820	50	3700	80	1300	8600	8800	9200	210	6100	28400	20700	99.8	
<i>Recovery (%)</i>	0.0966	100		84		114	91		92	87	98	96	93	92	142	104	86	121		
<i>Nov-20 (PB110a, start)</i>	0.0966	89.8	105	1700	17	340	740	40	3400	70	1100	8100	8600	8400	60	5500	30000	17500	98.4	
<i>Nov-20 (PB110a, end)</i>	0.0966	89.2	225	1700	50	330	740	45	3400	60	1100	8100	8700	8400		5500	30100	17400	97.8	
<i>Recovery (%)</i>	0.0966	99		84		108	82		85	72	86	90	91	85	39	95	91	102		
<i>Recovery (%)</i>	0.0966	99		84		107	82		85	70	86	90	92	85	-8	94	91	102		
<i>Oct-22 (PB110a)</i>	0.0966	84.6	100	1900	13	370	840	50	3500	70	1200	7700	9100	8300	160	6500	31400	17300	93.5	
<i>Recovery (%)</i>	0.0966	94		94		120	94		87	79	94	85	96	83	110	112	95	101		
<i>Oct-23 (PB110a)</i>	0.0966	89.2	150	1900	20	370	830	50	3700	80	1300	8800	10100	8500	240	6100	32500	18300	98.5	
<i>Recovery (%)</i>	0.0966	99		93		118	92		94	88	96	98	106	85	159	105	98	107		

Elemental analysis of CHARM standards

To our knowledge, the elemental composition of the different CHARM standards, designed to be used as external calibration standards for XRF analysis, has not been measured as a QA/QC standard for ICP-OES analysis of archaeological materials (although OES was among the techniques used to validate the CHARM standards' composition by MBH: Heginbotham et al. 2015). Such compositional analysis was never the focus of the research presented here, and not consistently conducted for all batches, but results are included in the Supplementary Materials as they can aid the interpretation of the corresponding Pb isotope ratios measured in this study.

While recoveries are within tolerance for most elements in the copper alloys, there are some notable variations in recovery, particularly for silver, lead, antimony and tin (and two outliers for arsenic and bismuth). In some cases, the variation appears related to very low sample mass and thus object heterogeneity (e.g. 32X SN5 A (2)), yet similarly low recoveries are sometimes observed for higher sample masses. Occasionally strong variations in measured lead concentrations are observed, for example, in leaded bronze standards 32X LB15 E and 32X LB17 A, with sometimes low recoveries of silver, antimony and tin, particularly for 32X LB17 A. This may be attributed at least in part to heterogeneity on the micro-scale.

It is notable that silver recovery for standards with silver concentrations > 0.1 wt% is more variable. Similarly, tin recovery is not consistent across different standards. Heterogeneity seems to play a role, with lower recovery often (though not consistently) noted for samples smaller than the recommended 30-50 mg. On the other hand, the frequent inclusion of tin as tin oxide in standards (which does not affect their performance for XRF calibration) impacts its solubility during acid digestion and thereby lowered recovery. Similarly, lead and bismuth have been noted as oxide inclusions in several standards, with an example shown in Figure S.1 and Table S.3 below. A detailed examination of element compositional variability within the CHARM standards is beyond the scope of this paper. Similarly, the results of elemental (re-)analysis of residual samples of the early Egyptian copper alloys from the British Museum and their comparison to earlier AAS/ICP-OES data (Cowell 1987), discussing the effects of sample size on elemental analysis, is the subject of ongoing research by the authors, and intended for future publication.

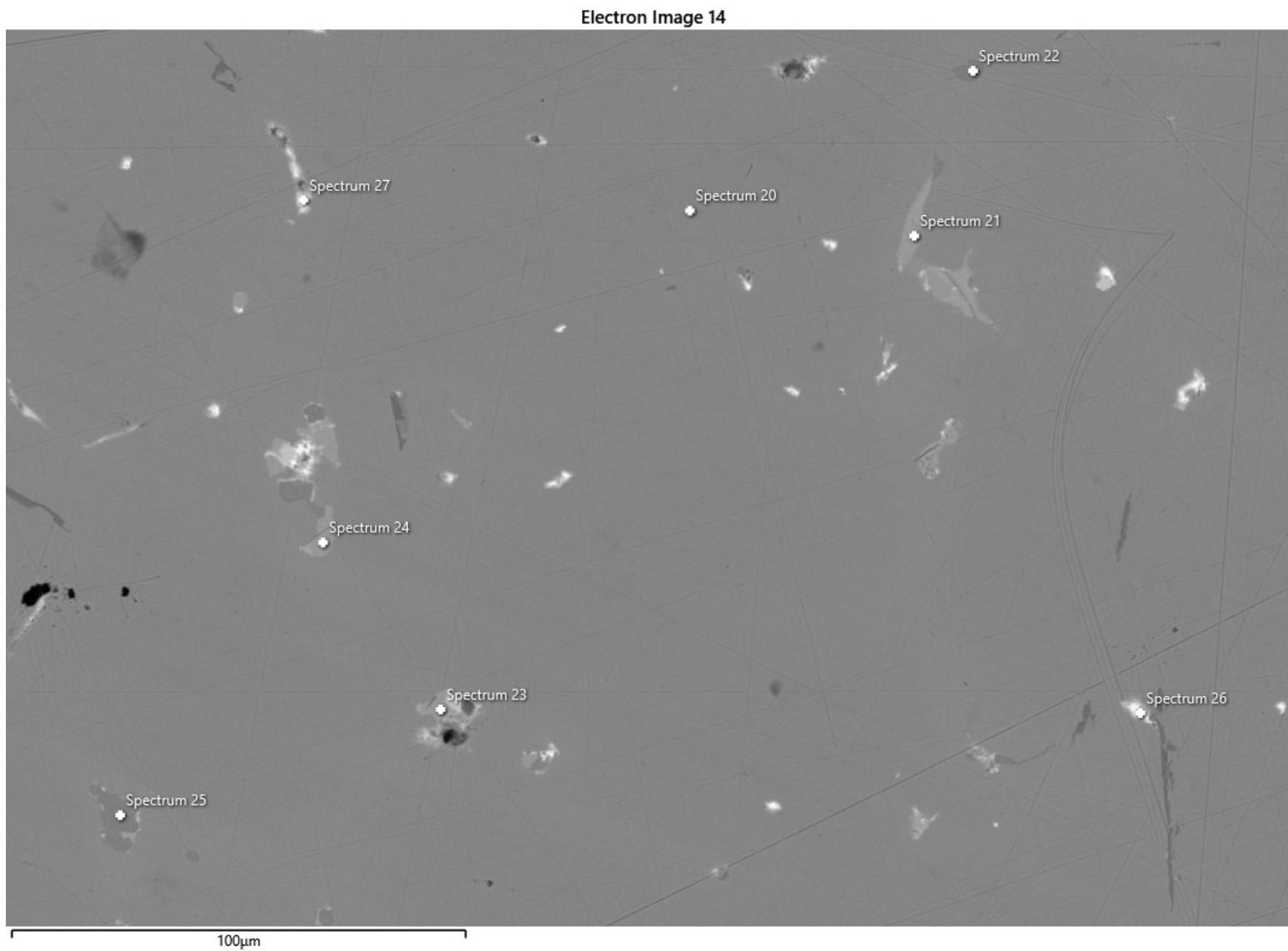


Figure S.1: Micrograph of 32X SN5 A and corresponding micro-compositions provided in Table S.3.

Table S.3: Micro-phase composition (in wt%) determined by SEM-EDS (20 kV, 12 mm working distance, Aztec standard calibration, all elements, normalised) for micrograph in Figure 2. For corresponding larger area analyses of CHARM standards by SEM-EDS, see Rademakers et al. (2023).

Spectrum Label	O	Si	P	Mn	Fe	Co	Ni	Cu	Zn	As	Ag	Cd	Sn	Sb	Pb	Bi	Total
Spectrum 20					0.15	0.46	0.20	72.99	25.93				0.26				100.00
Spectrum 21		0.16	0.37	0.39			0.68	57.95	18.16		1.98	2.03	9.43	8.84			100.00
Spectrum 22			9.76				0.73	76.96	6.95	4.38			0.30	0.92			100.00
Spectrum 23								58.87	19.82		2.37	0.88	16.45	1.61			100.00
Spectrum 24								57.76	20.13	0.73	4.20	1.26	10.28	5.64			100.00
Spectrum 25			9.96				0.37	77.35	6.66	3.62	0.89	0.45		0.71			100.00
Spectrum 26	3.00				0.17	0.32		17.81	7.75		1.44	0.82	1.52	2.21	61.38	3.59	100.00
Spectrum 27	2.47							19.92	7.42		1.26	0.68	2.86	4.14	58.67	2.58	100.00

Table S.4: Elemental composition of selected CHARM standards as determined by ICP-OES analysis (in µg/g, except Cu and Totals in wt%). Au concentrations (in italics) are overestimated due to manganese interference.

Sample name	Standard	Sample mass (g)	Cu	Al	Ag	As	Au	Bi	Co	Cd	Cr	Fe	Mn	Ni	P	Pb	S	Sb	Sn	Zn	Totals
Batches 2023 & 2024																					
CRV	36X CUAS3 A		96.74			29000				3		10		7		12			5000		100
Std. drill	BM-46	0.0721	93.0	<dl	< 100	27500	< 20	<dl	<dl	0	< 20	< 1000	< 10	6	< 100	1	< 250	< 25	1200	10	96
Std. drill	BM-48	0.0681	90.8	<dl	< 100	27400	< 20	170	<dl	0	360	8500	22	30	< 100	< 1	< 250	< 25	1200	14	95
Std. drill	R-55	0.0621	94.5	< 125	< 125	27800	< 25	180	< 10	2	5	85	< 10	7	< 125	14	< 125	< 250	1100	< 50	97
Precision (%)			2			1				141		98		77		87			4	17	
Recovery (%)	BM-46		96			95				0				86		8			24		
Recovery (%)	BM-48		94			94				0		85000		429		< 8			24		
Recovery (%)	R-55		98			96				67		850		100		117			22		
CRV	33X GM20 A		87.58	10	1410	1960		310	382	229	150	5700	2190	9990	630	1060		20040	40700	38700	100
	BM-49	0.0185	80.5	<dl	1400	1700	25	300	350	220	170	6200	1900	9400	750	750	< 250	17200	29100	34600	91
	BM-50	0.0071	76.8	<dl	1300	1600	25	320	320	210	150	5600	1800	8800	650	700	< 250	16200	27100	32500	86
	BM-51	0.0148	84.1	<dl	1400	1600	30	290	360	220	170	6000	2000	9500	700	740	< 250	16800	28000	35300	94
	R-57	0.0837	85.9	< 125	390	1000	35	300	350	230	160	4500	1900	8100	470	720	100	7100	18900	35100	94
Precision (%)			4		38	19		4	4	3	5	12	4	6	16	3		29	16	3	
Recovery (%)	BM-49		92		99	87		97	92	96	113	109	87	94	119	71		86	71	89	
Recovery (%)	BM-50		88		92	82		103	84	92	100	98	82	88	103	66		81	67	84	
Recovery (%)	BM-51		96		99	82		94	94	96	113	105	91	95	111	70		84	69	91	
Recovery (%)	R-57		98		28	51		97	92	100	107	79	87	81	75	68		35	46	91	
CRV	32X LB17 A		74.83	3880	9110	15100		2200	83	1510	8	4880	2960	4650	510	98300		41000	59700	6340	100
	BM-52	0.0584	72.2	3700	3100	11600	40	2300	75	1400	< 20	4600	2700	4500	580	104100	< 250	26900	33100	6100	92
	BM-53	0.0057	67.8	3700	7200	13100	40	2200	70	1300	12	5000	2500	4200	660	74800	< 250	42100	47000	5700	88
	BM-54	0.0559	73.3	3800	1100	13700	40	2400	75	1400	< 20	5200	2700	4600	670	100000	< 250	42200	48700	6200	96
	R-58	0.0945	74.5	3900	3600	10900	45	2000	75	1400	8	3200	2600	3600	460	46700	220	15900	28400	6000	87
Precision (%)			4	2	59	9	5	7	3	3	20	17	3	9	14	28		35	22	3	
Recovery (%)	BM-52		97	95	34	77		105	90	93		94	91	97	114	106		66	55	96	

Sample name	Standard	Sample mass (g)	Cu	Al	Ag	As	Au	Bi	Co	Cd	Cr	Fe	Mn	Ni	P	Pb	S	Sb	Sn	Zn	Totals
Recovery (%)	BM-53		91	95	79	87		100	84	86	150	102	84	90	129	76		103	79	90	
Recovery (%)	BM-54		98	98	12	91		109	90	93		107	91	99	131	102		103	82	98	
Recovery (%)	R-58		100	101	40	72		91	90	93		66	88	77	90	48		39	48	95	
CRV	32X SN5 A		78.96	4740	990	619	102	970	1380	1450	585	12000	7200	5020		2590	9	6640	160500	4940	100
	BM-55	0.0486	74.0	4300	660	650	190	1000	1300	1400	540	12900	6500	4900	550	2000	< 250	6700	134000	4500	92
	BM-56	0.0011	66.7	5700	2500	950	160	830	1200	1400	500	17400	6300	4700	340	2000	< 250	4300	85800	4700	80
	BM-57	0.0179	75.8	4400	1100	550	190	970	1400	1500	570	13900	6800	4900	580	2200	< 250	6900	147000	4600	95
	R-56	0.0381	75.0	4400	850	760	210	1000	1300	1500	520	11300	6600	3900	440	2100	150	7000	143000	4500	93
Precision (%)			5	12	57	20	10	7	5	3	5	16	3	9	20	4		18	19	2	
Recovery (%)	BM-55		94	91	67	105	186	103	94	97	92	108	90	98		77		101	83	91	
Recovery (%)	BM-56		84	120	253	153	157	86	87	97	85	145	88	94		77		65	53	95	
Recovery (%)	BM-57		96	93	111	89	186	100	101	103	97	116	94	98		85		104	92	93	
Recovery (%)	R-56		95	93	86	123	206	103	94	103	89	94	92	78		81		105	89	91	
Batch 2019 & 2024																					
CRV	32X SN6 A		86.39		11590	7640	73	1580	6550		74	990	24	2030		15590	180	3230	73100	11700	100
	D-17	0.0115	83.0		3100	6600	65	1500	5700		60	680	19	1800	125	12000	250	2700	64000	8400	94
	R-59	0.0566	83.5	365	2800	6700	80	1600	6100	859	80	880	19	1600	< 125	11700	270	2700	60900	10800	94
Recovery (%)	D-17		96		27	86	89	95	87		81	69	79	89		77	139	84	88	72	
Recovery (%)	R-59		97		24	88	110	101	93		108	89	79	79		75	150	84	83	92	
CRV	31X 7835.8 A		69.93		4630	1430			3130			1000	930	1580	1220	31500		1150	5160	248300	100
	D-18	0.0092	72.1		2100	1300	19	1100	2600		7	870	820	1300	1200	27800	100	990	5900	240000	101
	R-60	0.075	68.4	< 150	350	1400	21	1200	2900	846	< 10	930	820	1200	1100	25600	150	1100	4900	171000	90
Recovery (%)	D-18		103		45	91			83			87	88	82	98	88		86	114	97	
Recovery (%)	R-60		98		8	98			93			93	88	76	90	81		96	95	69	
CRV	31X B26 F		63.2		500	1200		1000	1200			6500	4000	14000	600	9500		1000	14000	300000	99
	D-19	0.0064	67.4		590	1200	55	1000	1000		100	6100	3900	13000	730	8700	65	960	15000	301000	103

Sample name	Standard	Sample mass (g)	Cu	Al	Ag	As	Au	Bi	Co	Cd	Cr	Fe	Mn	Ni	P	Pb	S	Sb	Sn	Zn	Totals
	R-61	0.0662	61.0	9729	450	1100	60	1100	1100	150	89	6000	3800	11000	580	7500	105	720	10800	191000	85
Recovery (%)	D-19		107		118	100		100	83			94	98	93	122	92		96	107	100	
Recovery (%)	R-61		97		90	92		110	92			92	95	79	97	79		72	77	64	
CRV	32X LB15 E		73.6		217	273		1300	51			12		1230	35	214200	320	1270	45100	640	100
	D-20	0.0164	70.9		220	260		660	50		5	35	2	1100	95	95000	320	1200	43000	880	85
	R-62	0.1146	70.8	< 150	250	330	< 25	720	45	4	< 10	55	< 10	980	< 125	266000	380	1200	40000	660	102
Recovery (%)	D-20		96		101	95		51	98			292		89	271	44	100	94	95	138	
Recovery (%)	R-62		96		115	121		55	88			458		80		124	119	94	89	103	
CRV	83X PR8 (C)		0.0660		5050	1550	82	11860						20		1000000		2590	6030		103
	D-21	0.0118	0.0883		160	1500	20	12000						25		951000		400	1200	20	97
	D-21	0.0694	0.0122	< 150	3000	1300	19	11100	< 10	2050	< 10	19	< 10	17	< 125	573000	55	1500	1400	< 50	59
Recovery (%)	D-21		134		3	97	24	101						125		95		15	20		
Recovery (%)	D-21		18		59	84	23	94						85		57		58	23		
CRV	85X ANTH (E)		0.0291		71	2170		194				10		62		1000000	36	60500	14500	7	108
	D-22	0.0091	0.0328		50	1800		240				35		50		878000		39000	1400		92
	R-64	0.0676	0.0205	< 150	70	1000	< 25	105	< 10	42	< 10	40	< 10	40	< 125	538000	65	10000	300	< 50	55
Recovery (%)	D-22		113		70	83		124				350		81		88		64	10		
Recovery (%)	R-64		70		99	46		54				400		65		54	181	17	2		