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Assessment of ingots from Saint Michaels Mount, Cornwall.

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Abstract

This report details exploratory non-destructive analysis of an assemblage of ingot fragments from Saint Michaels Mount, Cornwall, recovered in 2009 (SMM09), together with single finds of ingot fragments in 1995 (SMM95, Sewer trench, c235) and 2004 (SMM04 Footpath).

An initial batch of fourteen 'as found' ingot fragments from the 2009 assemblage was examined. These had received no cleaning or other treatment. A second batch of material included a further eleven fragments from the same 2009 assemblage, that had been cleaned to varying degrees by the finder. The collection was complemented by two further pieces: an ingot fragment found in the sewer trench of 1995 in a possible roundhouse fill together with a surface find from a footpath made in 2004.

The specimens were all analysed using a portable (handheld) X-ray Fluorescence instrument. The data were collected through varying thicknesses of corrosion and on uneven surfaces, so cannot be taken as being indicative of the bulk metal composition. A very approximate calibration technique was employed to provide analyses that are at best semi-quantitative indicative analyses. These demonstrated that the 2009 assemblage is relatively homogeneous, at least at this superficial level of investigation.

Fourteen pieces (eight cleaned, six as found) were of copper with low levels of other metals, with the analyses suggesting an average of 0.8% iron, 0.3% zinc, 0.4% arsenic, 1% lead and 0.1% silver, but less than 0.1%Sn (many of these elements are probably concentrated in the corrosion, compared with the metal). A further group of seven pieces (two cleaned, five as found) shows higher levels of iron, cobalt, arsenic and lead. These probably represent a similar metal composition to the first group, but with a more significant corrosion layer. Another piece shows a similar elemental profile to the second group but, in addition, shows higher levels of arsenic and antimony. The 2004 piece from the footpath is similar to this item, but the spectrum shows much higher levels of lead. Two pieces show a similar high level of arsenic, silver and antimony, but lack the high iron and cobalt of the previous examples. All of these materials might actually be rather similar metal, but with varying degrees and types of corrosion. Further detailed analysis is required to demonstrate how homogenous the collection might be.

One piece from the 2009 assemblage, the sole piece not forming a fragment from a plano-convex ingot, but being part of a lobate flow into charcoal, is of a leaded tin bronze. The 1995 ingot fragment also appears to be a metal of this type. Published analyses of this piece were made within a zone of superficial lead enrichment (below a thick lead-rich weathering crust) and suggested a very high lead but low tin content. The pXRF data suggest the tin content may actually be rather higher than stated and the piece may be similar to the single piece of bronze from the 2009 collection.

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Methods

The programme of analysis was focused on twenty five fragments of ingot from St Michaels Mount found in 2009. Fourteen of these formed the first batch of material investigated and were supplied in an 'as found' condition. A second batch of material comprises eleven ingot fragments that had received some degree of physical cleaning, plus two historic ingot finds from the area.

The specimens were analysed on a semi-quantitative basis using a Bruker Tracer III-SD portable X-Ray fluorescence spectrometer. The instrument was operated with the Bruker 'yellow' filter (300µm Al + 25µm Ti), at 40kV and 9.60 µA, with a filament current of 189 µA, for 100s.

The instrument was controlled by a PC running Bruker's S1PXRF with spectra stored as pdz files and csv files. The images presented in Figure 1 are produced from the csv output. The output was converted for measurement of net peak areas in Bruker's Spectra (Artax) software.

Since the irregular and corroded surface of the pieces precluded meaningful quantitative analysis, a crude calibration of the results was obtained through comparison of the net peak areas with those recorded by Nicholas and Manti (2014) on a series of copper alloy standards, using exactly the same instrument and settings. The potential errors associated with this procedure are large, but a more thorough calibration would not be justified at this stage. The results are sufficient to provide a broad classification of the materials. The raw net peak area values are provided in Table 1 and the calibrated analyses (using the above technique) are given in Table 2.

This project was undertaken for James Parry of the National Trust.

Material

This report details exploratory non-destructive analysis of an assemblage of ingot fragments from Saint Michaels Mount, Cornwall, recovered in 2009 (SMM09), together with single finds of ingot fragments in 1995 (SMM95, Sewer trench, c235) and 2004 (SMM04 Footpath).

An initial batch of fourteen 'as found' ingot fragments from the 2009 assemblage was examined. These had received no cleaning or other treatment. A second batch of material included a further eleven fragments from the same 2009 assemblage, that had been cleaned to varying degrees by the finder. The collection was complemented by two further pieces: an ingot fragment found in the sewer trench of 1995 in a possible roundhouse fill, together with a surface find from a footpath made in 2004.

Results

The raw net peak area values are provided in Table 1 and the calibrated analyses (using the above technique) are given in Table 2. For convenience, the analyses have been divided into five groups:

1. Bronze (1 from the hoard and 1 other)
The ingot from the roundhouse (smm95-sewer-235-aa) was a tin bronze (Group 1) as was the copper flow (item23) from the hoard. Published analyses of this piece were made within a zone of superficial lead enrichment and also within a thick lead-rich weathering crust and suggested a very high lead but low tin content. Unfortunately the bulk composition of the bronze was not measured. The new pXRF data suggest the tin content may actually be rather higher than stated and the piece may be similar to the single piece of bronze from the 2009 collection.

2. Cu with high Ag, As, Sb (2 from the hoard)
Two pieces show a similar high level of arsenic, silver and antimony, but lack the high iron and cobalt of Group 3.

3. Cu with high Fe, Co, As, Ag, Sb, Pb (1 from the hoard and 1 other)
The earlier find from the footpath (smm04-ca) was an ingot fragment with a rich variety of trace elements at elevated concentrations (Group 3) broadly similar to one item from the hoard (smm-007-bi-39). These analyses re rather similar to those of Group 3, but lack elevated Fe and Co.

4. Cu with high Fe, Co (7 from the hoard)
A further group of seven pieces (Group 4; two cleaned, five as found) shows higher levels of iron, cobalt, arsenic and lead. These probably represent a similar metal composition to the first group, but with a more significant corrosion layer.

5. Cu with low traces (14 from the hoard)
Fourteen pieces (eight cleaned, six as found) were of copper with low levels of other metals (Group 5), with the analyses suggesting an average of 0.8% iron, 0.3% zinc, 0.4% arsenic, 1% lead and 0.1% silver, but less than 0.1%Sn (many of these elements are probably concentrated in the corrosion, compared with the metal).

These groupings are affected by both the state of alteration of the metal and the degree of cleaning, and actually hint at a rather low diversity of composition with the hoard. All of these materials might actually be rather similar metal, but with varying degrees and types of corrosion. Further detailed analysis of fresh metal is required to demonstrate how homogenous the collection might be. This part of the future analytical programme will be undertaken by ICP-MS.

Programme of works

The programme of works for investigation of these pieces will have two strands: chemical characterisation and lead isotope analysis.

For the full chemical classification of the material there are two possible approaches – analysis of a dissolved sample by ICP-MS and analysis of a polished surface by EDS/WDS, and/or by scanning µXRF, within the SEM. Arguably ICP-MS may provide the higher quality data (and is cheaper), but cannot analyse for all the desired elements (which include O, S, Mn, Fe, Co, Ni, Cu, Zn, As, Ag, Sn, Sb, Pb and Bi). The proposed protocol would be to investigate all analysed samples by SEM in order to gain the full range of elements, but to analyse representative examples across the compositional range by ICP-MS. The polished SEM

mounts would also be re-analysed by pXRF. For the most useful results the cuts need to be deep enough to be well away from the margin – to expose below the surface enrichment zone (the existing small chip from ingot from the sewer - smm95-sewer-235-aa – does not penetrate sufficiently deeply to do this). It is proposed that a cut sufficient to expose an area of approximately 10mm x 10mm is made from each of the sampled specimens (both to achieve this and to provide a sufficiently large area for pXRF). The removed piece would be mounted and polished for the SEM; the ICP-MS samples would be drilled from the cut surface of the remaining block. Such a large cut, whilst maximising the archaeological evidence, will disfigure the specimens, so specific permission is sought so to do. Ideally, the same sampling protocol would be followed for the two archive ingots (from 1995 and 2004), and again permission is sought to sample those two in the same manner.

For the lead isotope study, samples drilled from the cut surfaces would again be used – ideally with one drill hole providing both material for lead isotope and ICP-MS analyses.

With the above outline protocol, the objective would be to maximise the number of samples analysed within the available budget.

Summary

The analyses suggest that the main group of ingots may potentially be homogeneous. All the analyses are within a range of variation that might be expected from variably altered material, analysed by pXRF in imperfectly standardised conditions (rough surfaces with variable corrosion).

The programme of analysis proposed would use the groups of material identified here to select appropriate specimens for sampling, with as many samples investigated as possible within the budget.

A recommended campaign of analysis would be:

- Prepare polished mounts of specimens from each of the 25 ingot fragments
- Undertake µXRF on each polished mount
- Undertake pXRF on each polished mount
- Drill samples from cut faces of a subset of 8 samples
- Undertake ICP-MS analysis of each drill sample
- Undertake lead isotope analysis of each drill sample

The pXRF triage of the hoard produced five groups of copper analyses and one of bronze. This indicates that the minimum number of detailed analyses should be six.

The outline costings have been submitted as a separate document for discussion.

Reference

HERRING, P. 2000. *St Michael's Mount Archaeological Works, 1995-8*. Truro: Cornwall Archaeological Unit:

- *Fragment of plano-convex copper ingot*, P. Herring 46-47 with Figs 17,18 on p66
- *Appendix 5 Analysis of a small copper ingot*, pp. 196-198

NICHOLAS, M & MANTI, P. 2014. Testing the applicability of hand held portable XRF to the characterisation of archaeological copper alloys. *In* J. Bridgland (ed) *ICOM-CC 17th Triennial Conference Preprints, Melbourne, 15–19 September 2014*. Paris: International Council of Museums.

Table 1: net peak areas for the pXRF analyses

	Element	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Rh	Rh	Ag	Ag	Cd	Cd	Sn	Sn	Sb	Sb	Pb	Pb
	Line	K12	K12	K12	K12	K12	K12	K12	K12	K12	L1	K12	L1	K12	L1	K12	L1	K12	L1	L1	M1
1. Bronze																					
smm95-sewer-235-aa-1	clean	449	718	148292	4926	220	311711	2365	94207	22369	111	1376	432	2135	0	92578	929	0	1210	1236088	635
smm95-sewer-235-aa-2	clean	242	513	65092	1692	352	251013	867	129709	21652	120	1244	447	5370	0	77534	1104	164	816	2047938	1807
smm95-sewer-235-aa-3	clean	417	145	22020	1187	2081	2021367	6294	32345	14786	193	1334	470	758	0	90076	2052	468	1149	629535	994
smm95-sewer-235-aa-4	clean	262	210	951	8011	269	409310	1244	6687	31665	149	7990	570	381	0	19968	285	122	338	123124	285
smm95-sewer-235-aa-5	clean	422	112	6872	7507	284	61068	340	14702	31913	174	7597	500	740	0	87382	1835	837	1016	248700	552
item23 pt1	batch 1	165	111	10607	829	1362	3046077	9790	13555	16543	173	2417	599	411	0	205602	1788	1651	652	214379	407
item23 pt2	batch 1	65	154	21223	1420	309	2209134	8455	24673	16420	179	1727	715	590	0	134493	72	1195	752	452111	522
item23 pt3	batch 1	328	315	16155	724	426	1270339	5149	20857	12589	151	1505	464	535	0	82511	766	644	583	349224	463
2. Cu with high Ag, As, Sb																					
smm09-007-au-1	batch 2	292	149	15407	929	1	5012716	16584	380900	14819	343	11211	1005	142	1	1849	0	11263	754	216158	192
smm09-007-au-2	batch 2	324	805	21864	1502	1	4970432	17817	255850	14723	477	12051	906	174	0	2051	0	12217	947	178086	286
item24 pt1	batch 1	340	179	20062	1356	304	5313589	20899	5042	13121	384	6137	982	49	1	521	0	6604	972	5888	269
item24 pt2	batch 1	171	623	37825	2351	1	4323446	18728	14061	13388	485	3976	800	174	0	516	0	3703	1086	38925	243
item24 pt3	batch 1	39	504	102417	6553	469	5024869	22471	17064	14739	458	5275	860	135	0	739	0	6248	914	60271	281
3. Cu with high Fe, Co, As, Ag, Sb, Pb																					
smm04-ca-footpath-1	batch 2	140	698	460248	57085	2946	1955182	11090	456111	16960	200	8577	843	140	48	1432	0	2661	1192	229450	252
smm04-ca-footpath-2	batch 2	230	111	242235	11950	1	2883953	11589	393954	15423	291	12639	639	125	0	1370	0	2053	694	280696	269
item39 pt1	batch 1	225	239	367543	13057	68	2264934	10216	321964	17777	367	45063	578	31	1	2613	0	52431	1851	78751	453
item39 pt2	batch 1	159	78	191013	7591	1	4414684	16922	39373	15468	396	3668	669	63	1	625	0	6220	943	69382	311
smm-007-bi-39-cx958	batch 2	1	356	186133	7210	1	5135214	19059	35600	15351	426	3535	908	32	0	560	0	6474	1012	77269	169
4. Cu with high Fe, Co																					
item42 pt1	batch 1	84	323	393156	72796	1825	3301592	11789	32839	13776	386	2738	692	152	0	1077	0	678	748	68787	230
item42 pt2	batch 1	108	111	369904	73590	3043	4114193	19493	118338	13659	387	3948	819	172	0	1498	0	1249	799	47230	238
item44 pt1	batch 1	219	415	45853	2475	1	4333712	17035	19619	14711	554	1471	785	228	0	2195	0	38	824	31551	306
item44 pt2	batch 1	410	700	356569	13524	1	3532211	21364	21624	14822	361	1183	891	206	0	713	0	285	896	25593	177
smm09-007-130-2	batch 2	183	860	137731	8288	1	4103275	20188	56265	15413	299	5461	789	103	98	821	0	458	913	29423	228

	Element	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Rh	Rh	Ag	Ag	Cd	Cd	Sn	Sn	Sb	Sb	Pb	Pb
	Line	K12	K12	K12	K12	K12	K12	K12	K12	K12	L1	K12	L1	K12	L1	K12	L1	K12	L1	L1	M1
smm09-007-aw-1	batch 2	519	1415	333862	12538	337	3837292	17888	6060	13158	356	1771	847	135	0	801	0	150	768	10322	168
smm09-007-aw-2	batch 2	153	1048	50706	3259	48	5122094	28507	10367	13951	363	1224	1017	166	0	688	0	202	1031	32227	222
item34 pt1	batch 1	267	536	100972	30631	785	4414476	21028	28958	12898	413	2216	846	169	0	666	0	621	806	16900	200
item34 pt2	batch 1	267	536	100972	30631	785	4414476	21028	28958	12898	413	2216	846	169	0	666	0	621	806	16900	200
item34 pt3	batch 1	276	161	276036	31141	658	2815456	14152	151420	12792	281	2474	579	169	0	608	0	1417	729	89589	162
item35 pt1	batch 1	221	1466	320550	19670	583	3674545	19184	16510	15218	290	4326	744	302	0	754	0	185	834	13537	254
item35 pt2	batch 1	186	166	53814	2799	1	3319930	14463	12578	13056	386	4115	686	100	0	1223	0	148	776	10369	160
item36 pt1	batch 1	114	772	106823	38601	1262	4259849	21142	27035	14793	291	3768	928	205	0	1091	0	784	977	162791	171
item36 pt2	batch 1	357	451	209380	37943	1129	2850324	13649	54413	15498	236	4976	537	277	0	1691	0	484	625	174900	78
5. Cu with low traces																					
smm09-007-av-1	batch 2	16	899	19681	1322	690	6521237	20396	6447	14136	398	2863	1027	191	0	607	43	341	573	20627	77
smm09-007-av-2	batch 2	128	511	34054	2133	194	5527298	21338	18841	14745	370	2017	788	228	0	655	27	243	1508	122002	213
smm09-007-ax-1	batch 2	380	599	22150	2145	422	5734240	22587	5741	12649	397	3918	1163	50	0	428	-1	358	562	8627	257
smm09-007-ax-2	batch 2	243	36	28681	2255	1	4985064	21651	23415	12980	418	6457	970	307	0	415	0	438	691	27661	175
smm09-007-bf-1	batch 2	244	305	12793	1066	9	4975681	24243	16942	12170	355	807	909	208	0	1080	0	101	364	17527	248
smm09-007-bf-2	batch 2	279	275	12687	945	1	6090656	18148	25033	13568	520	1260	1294	247	1	2221	0	99	539	28985	232
smm09-007-bj-1	batch 2	130	425	31687	1726	1865	5959421	23114	26818	15184	506	1191	1044	195	0	549	0	179	721	57122	181
smm09-007-bj-2	batch 2	247	1	10415	1264	14283	5578220	15567	72979	15296	1012	1430	699	159	1	684	0	99	403	17233	308
smm09-007-bk-1	batch 2	66	366	30538	1886	568	5783392	26514	5865	13256	467	1107	984	233	1	487	0	75	654	11719	387
smm09-007-bk-2	batch 2	186	834	73582	4510	325	4887945	24272	10964	14253	313	1437	951	145	0	556	0	89	752	32089	129
smm09-007-bm-1	batch 2	76	262	64281	2964	1	5327761	22058	11204	13538	484	2608	926	188	0	467	0	51	773	20523	353
smm09-007-bm-2	batch 2	102	310	37539	2039	246	5113442	26955	8752	12697	530	2805	774	162	1	545	0	52	473	7078	371
smm09-007-bo-1	batch 2	108	484	79110	4557	1	5228446	28574	13852	14427	453	1625	892	356	0	2092	4	149	669	5298	115
smm09-007-bo-2	batch 2	416	1134	31895	2235	1	6285955	28288	6284	13696	449	1567	854	285	0	1402	0	184	687	3801	228

	Element	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Rh	Rh	Ag	Ag	Cd	Cd	Sn	Sn	Sb	Sb	Pb	Pb
	Line	K12	K12	K12	K12	K12	K12	K12	K12	K12	L1	K12	L1	K12	L1	K12	L1	K12	L1	L1	M1
smm09-007-bp-1	batch 2	227	461	33017	2362	412	5765953	19576	6860	13404	522	3342	882	110	0	597	0	364	890	7651	68
smm09-007-bp-2	batch 2	172	422	155731	6174	461	4883860	11344	17707	15463	546	10306	620	394	0	1093	0	364	884	27425	240
item28 pt1	batch 1	1	484	26744	1550	1	5070885	21534	17002	13136	322	1438	918	80	0	2045	24	504	751	17998	215
item28 pt2	batch 1	80	413	105260	4556	1	2751619	14213	116256	13603	265	4547	735	292	0	20673	328	4755	1089	83112	76
item29 pt1	batch 1	395	766	45369	3399	1	4748284	23761	23285	13807	401	1989	938	83	0	1897	5	234	873	19840	55
item29 pt2	batch 1	413	627	36237	2402	1	4285620	22589	15820	13988	374	1507	872	326	1	1360	17	130	559	16248	213
item31 pt1	batch 1	121	524	26233	1923	428	5724276	22351	5580	13768	455	2004	975	189	0	554	0	197	750	12691	225
item31 pt2	batch 1	226	313	43039	2678	1	3397542	13982	13809	12636	422	5943	776	142	1	813	-1	385	616	46916	129
item32 pt1	batch 1	203	920	50961	4563	1	5616223	20450	7012	14434	591	2137	738	230	0	794	0	140	891	14890	263
item32 pt2	batch 1	266	204	21476	2346	1	4716564	15716	11669	13344	434	2367	783	213	1	541	-1	34	628	11536	149
item32 pt3	batch 1	212	1	16630	1198	1	5823020	19198	3637	14059	583	1596	940	327	0	624	-1	19	717	3346	276
item37 pt1	batch 1	1	167	18596	1491	1	4223023	14719	14268	13244	431	1874	786	200	0	451	0	232	707	9057	116
item37 pt2	batch 1	464	309	40457	2409	1	4234272	15816	20997	13654	355	1720	798	73	0	527	0	167	794	8061	109
item38 pt1	batch 1	588	451	42808	2804	1801	5193872	25120	13145	14518	392	2306	813	154	1	472	0	474	811	32114	172
item38 pt2	batch 1	457	1156	49359	2599	1393	4782839	18583	20917	14540	326	2179	948	198	0	702	0	275	989	30947	165

Table 2: Calibrated pXRF results in elemental wt%

	Element	Mn	Fe	Ni	Cu	Zn	As	Pb	Sn	Sb	Ag
1. Bronze											
smm95-sewer-235-aa-1	clean	0.04	3.81	0.01	7.94	0.04	2.77	76.12	9.27	0.00	
smm95-sewer-235-aa-2	clean	0.02	1.15	0.01	4.39	0.01	2.61	86.48	5.33	0.02	
smm95-sewer-235-aa-3	clean	0.01	0.56	0.05	50.98	0.11	0.94	38.36	8.93	0.06	
smm95-sewer-235-aa-4	clean	0.05	0.12	0.03	51.41	0.11	0.97	37.37	9.86	0.08	
smm95-sewer-235-aa-5	clean	0.02	0.67	0.03	5.90	0.02	1.64	58.08	33.20	0.44	
item23 pt1	batch 1	0.00	0.24	0.03	68.98	0.16	0.35	11.73	18.30	0.20	
item23 pt2	batch 1	0.01	0.55	0.01	56.75	0.15	0.73	28.06	13.58	0.17	
item23 pt3	batch 1	0.02	0.65	0.02	51.08	0.14	0.97	33.93	13.04	0.14	
2. Cu with high Ag, As, Sb											
smm09-007-au-1	batch 2	0.00	0.25	0.00	82.24	0.19	7.20	8.57	0.12	1.00	0.42
smm09-007-au-2	batch 2	0.03	0.38	0.00	85.21	0.21	5.05	7.38	0.14	1.14	0.47
item24 pt1	batch 1	0.01	0.37	0.01	98.02	0.27	0.11	0.26	0.04	0.66	0.26
item24 pt2	batch 1	0.03	0.84	0.00	95.71	0.29	0.36	2.08	0.04	0.44	0.20
item24 pt3	batch 1	0.02	1.93	0.01	93.76	0.29	0.37	2.72	0.05	0.63	0.22
3. Cu with high Fe, Co, As, Ag, Sb, Pb											
smm04-ca-footpath-1	batch 2	0.04	13.07	0.08	55.06	0.22	14.80	15.61	0.16	0.41	0.55
smm04-ca-footpath-2	batch 2	0.00	5.66	0.00	66.85	0.19	10.52	15.72	0.12	0.26	0.67
item39 pt1	batch 1	0.01	10.29	0.00	62.89	0.20	10.30	5.28	0.29	7.90	2.85
item39 pt2	batch 1	0.00	3.95	0.00	90.52	0.24	0.93	3.44	0.05	0.69	0.17
smm-007-bi-39-cx958	batch 2	0.01	3.34	0.00	91.54	0.24	0.73	3.33	0.04	0.63	0.14
4. Cu with high Fe, Co											
item42 pt1	batch 1	0.02	10.09	0.05	84.08	0.21	0.96	4.23	0.11	0.09	0.16
item42 pt2	batch 1	0.00	7.81	0.06	86.14	0.29	2.86	2.39	0.12	0.14	0.19

	Element Line	Mn	Fe	Ni	Cu	Zn	As	Pb	Sn	Sb	Ag
item44 pt1	batch 1	0.02	1.03	0.00	96.23	0.26	0.50	1.69	0.19	0.00	0.07
item44 pt2	batch 1	0.03	8.98	0.00	88.27	0.37	0.62	1.55	0.07	0.04	0.07
smm09-007-130-2	batch 2	0.04	3.15	0.00	93.00	0.32	1.47	1.61	0.07	0.06	0.28
smm09-007-aw-1	batch 2	0.06	7.96	0.01	90.73	0.30	0.17	0.59	0.07	0.02	0.10
smm09-007-aw-2	batch 2	0.04	0.97	0.00	96.80	0.38	0.23	1.47	0.05	0.02	0.05
item34 pt1	batch 1	0.02	2.20	0.02	95.59	0.32	0.72	0.88	0.06	0.07	0.11
item34 pt2	batch 1	0.02	2.20	0.02	95.59	0.32	0.72	0.88	0.06	0.07	0.11
item34 pt3	batch 1	0.01	7.92	0.02	80.18	0.28	4.97	6.16	0.07	0.22	0.16
item35 pt1	batch 1	0.07	7.92	0.01	90.06	0.33	0.47	0.80	0.07	0.02	0.24
item35 pt2	batch 1	0.01	1.58	0.00	96.53	0.29	0.42	0.73	0.14	0.02	0.27
item36 pt1	batch 1	0.03	2.23	0.03	88.26	0.31	0.65	8.15	0.09	0.09	0.18
item36 pt2	batch 1	0.02	5.90	0.03	79.64	0.27	1.75	11.81	0.19	0.07	0.32
5. Cu with low traces											
smm09-007-av-1	batch 2	0.03	0.30	0.01	98.42	0.22	0.11	0.75	0.04	0.03	0.10
smm09-007-av-2	batch 2	0.02	0.58	0.00	93.64	0.25	0.37	4.99	0.04	0.02	0.08
smm09-007-ax-1	batch 2	0.02	0.38	0.01	98.63	0.27	0.11	0.36	0.03	0.03	0.15
smm09-007-ax-2	batch 2	0.00	0.56	0.00	96.95	0.29	0.52	1.30	0.03	0.05	0.29
smm09-007-bf-1	batch 2	0.01	0.25	0.00	98.05	0.33	0.38	0.83	0.08	0.01	0.04
smm09-007-bf-2	batch 2	0.01	0.21	0.00	97.80	0.20	0.46	1.12	0.14	0.01	0.05
smm09-007-bj-1	batch 2	0.01	0.52	0.03	96.35	0.26	0.50	2.23	0.03	0.02	0.04
smm09-007-bj-2	batch 2	0.00	0.18	0.25	97.07	0.19	1.46	0.72	0.05	0.01	0.06
smm09-007-bk-1	batch 2	0.01	0.52	0.01	98.46	0.32	0.12	0.48	0.03	0.01	0.04
smm09-007-bk-2	batch 2	0.03	1.46	0.01	96.27	0.33	0.25	1.53	0.04	0.01	0.06

	Element Line	Mn	Fe	Ni	Cu	Zn	As	Pb	Sn	Sb	Ag
smm09-007-bm-1	batch 2	0.01	1.18	0.00	97.24	0.28	0.24	0.91	0.03	0.01	0.11
smm09-007-bm-2	batch 2	0.01	0.73	0.00	98.20	0.36	0.19	0.33	0.04	0.01	0.12
smm09-007-bo-1	batch 2	0.02	1.48	0.00	97.35	0.37	0.30	0.24	0.15	0.02	0.07
smm09-007-bo-2	batch 2	0.03	0.50	0.00	98.73	0.31	0.11	0.14	0.09	0.02	0.06
smm09-007-bp-1	batch 2	0.02	0.57	0.01	98.52	0.23	0.14	0.32	0.04	0.03	0.13
smm09-007-bp-2	batch 2	0.02	3.04	0.01	94.53	0.15	0.39	1.28	0.08	0.04	0.45
item28 pt1	batch 1	0.02	0.52	0.00	97.69	0.29	0.38	0.84	0.15	0.05	0.06
item28 pt2	batch 1	0.02	3.20	0.00	82.86	0.30	4.03	6.05	2.45	0.78	0.31
item29 pt1	batch 1	0.03	0.93	0.00	96.90	0.34	0.55	0.98	0.15	0.03	0.09
item29 pt2	batch 1	0.03	0.83	0.00	97.27	0.36	0.41	0.89	0.12	0.02	0.08
item31 pt1	batch 1	0.02	0.45	0.01	98.48	0.27	0.11	0.53	0.04	0.02	0.08
item31 pt2	batch 1	0.02	1.21	0.00	94.39	0.27	0.44	3.15	0.09	0.06	0.38
item32 pt1	batch 1	0.03	0.90	0.00	97.90	0.25	0.14	0.63	0.05	0.01	0.08
item32 pt2	batch 1	0.01	0.45	0.00	98.29	0.23	0.28	0.58	0.04	0.00	0.11
item32 pt3	batch 1	0.00	0.29	0.00	99.17	0.23	0.07	0.14	0.04	0.00	0.06
item37 pt1	batch 1	0.01	0.44	0.00	98.26	0.24	0.38	0.51	0.04	0.03	0.10
item37 pt2	batch 1	0.01	0.94	0.00	97.63	0.26	0.56	0.45	0.05	0.02	0.09
item38 pt1	batch 1	0.02	0.81	0.03	96.91	0.33	0.28	1.45	0.03	0.05	0.10
item38 pt2	batch 1	0.04	1.00	0.03	96.48	0.26	0.49	1.51	0.06	0.03	0.10

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