Metallurgical residues from Hartshill Copse

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Abstract

Metallurgical residues from Hartshill Copse include a small number of macroscopic slags. These are dominated by slags from iron smelting. Slag morphology indicates smelting in a non-slag tapping furnace, probably with a shallow slag-pit. Chemical analysis of the slags suggests that they were produced from the smelting of an iron oxide- rich ore, perhaps a weathered sedimentary iron ore. Dating of features bearing a rich assemblage of smelting residues suggests smelting was undertaken on the site at a point in the 5th – 6th centuries BC. The small quantity of such slags retrieved strongly suggests that the smelting activity lay outside the excavated area.

Micro-residues, including both spheroidal and flake hammerscale, was recovered from a wide variety of contexts in the IA enclosure. Almost all of these assemblages show high flake:spheroid ratios, suggesting unskewed assemblages. 28 contexts from Roundhouse B yielded hammerscale, but in very small quantities and not enough to suggest a direct relationship. Larger quantities of scale derive from features to the south and east of the roundhouse. In all, 11 contexts within the enclosure yielded >10 pieces of scale. A single sample from the enclosure ditch showed a high flake:spheroid ratio as did an assemblage from a pit to the west of the enclosure. Chemical analysis of spheroidal hammerscale from an assemblage yielding both macro- and micro-residues is broadly similar in composition to the smelting slags, so an origin during bloomsmithing is likely.

Hammerscale was also recovered from almost all postholes within roundhouses C and D (contexts apparently securely dated to the 10th century BC), as well as structure A.

The residues from roundhouses C and D include both spheroidal and flake hammerscale, with spheroidal hammerscale rather abundant (6 samples contained more than 10 spheroids and 3 samples more than 20). In comparison only 1 sample from within the enclosure yielded more than 10 spheroids. The processing of the microresidue samples was variable, so certain comparison of the hammerscale type ratios is slightly problematic. However, it is noteworthy that the ratio of flake:spheroidal hammerscale pieces in assemblages from the 7 assemblages with >10 pieces from roundhouses C and D was uniformly low. Structure A yielded 3 assemblages of >10 pieces; these had high flake:spheroid ratios, with only low numbers of spheroids present. These figures suggest that small quantities of a strongly skewed assemblage entered the postholes of roundhouses C and D, and it is interpreted that downward percolation of the microresidues produced this sorting. The abundance of spheroids would suggest a substantial deposit of hammerscale overlay this area. In contrast, larger "normal" assemblages entered the postholes of structure A.

Samples of the two hammerscale classes from Roundhouse D were subjected to chemical analysis. The flake hammerscale had a chemical composition similar to that of comparative material from other iron-working sites. In contrast, the spheroidal hammerscale composition was unlike the comparative material, but similar to the Iron Age material from the site interpreted as from bloomsmithing.

In conclusion it is suggested that iron making was undertaken on the site in the 5th –6th centuries BC. The focus of the smelting is unknown, but the distribution of fines suggests that the bloomsmithing (or at least disposal of the bloomsmithing waste) took place in the area of the earlier roundhouses, C and D.

Contents

Technique

The present report adds to the evaluation report (GeoArch report 2003/11) by the addition of chemical analyses of selected material, the description of many more micro-residue assemblages and the presentation of full discussion.

Chemical analyses were undertaken by the laboratories of the School of Earth, Ocean and Planetary Science, Cardiff University. Major element analysis was undertaken using induction-coupled plasma optical emission spectrometry (ICP-OES) and trace elements by induction-coupled plasma mass spectrometry (ICP-MS). Unfortunately the system was not able to measure Si in the samples, and for some samples rich in magnetite the acid dissolution was incomplete and the iron measured is a minimum content.

Description

Macroscopic slags

Physical description

Physical description of the individual macroscopic slags from the site was presented in the evaluation report (GeoArch report 2003/11), and so will not be repeated here. In summary, the assemblage included at least six fragments believed to come from a non-slag tapping iron smelting furnace, together with two smithing hearth cakes.

Chemical analysis

Five specimens of slags interpreted as smelting slags were analysed. The samples were derived from contexts 323, 407, 588, 821 and 1076. The chemical analyses are presented in Table 1. The analyses are all very similar, supporting the proposition that these are slags produced from a common process. Total iron, quoted as FeO varies from 62.8% to 74.0%. The slags are only moderately aluminous (Al_2O_3 varying from 3.2% to 4.4%), have low CaO (0.6% to 1.1%), low MgO (0.3% to 0.5%), moderate TiO_2 (0.2% to 0.3%) and moderate P_2O_5 (0.6% to 0.8%).

The trace element contents are also fairly tightly grouped. Elements worthy of comment include fairly low contents of Pb (7-10ppm), Ba (180-250ppm) and U (1.3-2.4ppm). Contents of some of the “immobile” elements are moderate, with Y at 40-56ppm, Nb at 4.7-5.4ppm, Th at 3.1-3.8ppm and total rare earth elements (ΣREE) of 140-210ppm.

The upper-crust normalised (after Taylor and McLennan, 1981) REE profiles are mainly humped (Figure 1), with Gd the most enriched (1.6 – 2.4 times upper crust). The heavy REE (HREE) are slightly less enriched (1.4 to 1.8 times upper crust for Lu, but slightly higher than the light REE (LREE) with 0.9 –1.4 times upper crust for La, with a very slight negative Ce anomaly.

In detail, the REE profiles show a spread from examples with a MREE “hump” through to examples with depletion of the LREE, which imparts an overall slope to the profile. The sample from (1076) is the most humped, with those from (323), (821) and (407) showing slightly lower LREE values, but with that from (588) showing a marked slope down to the LREE. A degree of variability is to be expected, even within slags from a single smelt, because of the inhomogeneity of the slag in a non-tapping furnace.

Distribution

The macroscopic slags were widely distributed across the site, with no clear focus.

Microscopic residues

Physical description

The sampled spheroidal hammerscale from contexts 1402/1667 had a size range of 100 – 1900µm, with a mean of 660µm, that from 1543/1669 had a range of 200 – 1000µm, with a mean of 480µm. The hammerscale from other contexts appears broadly similar, although no detailed measurements of size distribution have been made. The one exception is the deposit rich in smelting debris (422/323) in which a proportion of significantly larger spheroids were present; it is possible these may have a separate origin with the smelting furnace.

Flake hammerscale assemblages were all rather degraded. It is possible however, that coarser materials were not retrieved by the sampling regime.

Chemical analysis

Hartshill Copse Material

Three samples of micro-residues were selected for analysis, together with five samples of comparative material, since there are no published chemical analytical studies of hammerscale. For all of the samples the analytical technique required sample sizes greater than single particles. In order to attain a suitable bulk samples size the sample of spheroidal hammerscale from an IA context contained 8 spheroids from context 422, the sample of spheroidal hammerscale from LBA contexts contained 33 spheroids from contexts 1402/1667 and 1543/1660, and the sample of flake hammerscale from LBA contexts contained 23 pieces from contexts 1402/1667, 1543/1660 and 1425/1665. All the LBA contexts from which the samples were drawn are postholes within Roundhouse D.

The analyses of the two sets of spheroidal hammerscale are rather similar, and strongly dissimilar to the flake hammerscale. The flake hammerscale shows low concentrations of all elements (except iron). The upper-crust normalised REE profile of the flake hammerscale is fairly flat, but those of the two spheroidal samples show relative deletion of the LREE (Figure 1), giving a profile close to that of macroscopic smelting slags.

Comparative material

Hammerscale of each of the two classes was sampled from existing collections from two sites. Firstly the 4th century smithy within the basilica at Caerwent, Gwent, context CWT2835 (>200µm fraction), and secondly material from an early Medieval (probably 8th century) smithy at Abernant, Gwent, context ANC099A (1-2mm fraction of magnetic residues). In addition, magnetic spheroids produced in a corn-drying kiln in the Iron Age settlement of Bornish, South Uist (context 269, samples 5967 and 5991), were analysed as an example of non-metallurgical magnetic spheroids.

The flake hammerscale from Caerwent contains over 96% iron expressed as magnetite. For the Hartshill and Abernant specimens the laboratory reported problems in getting all the magnetite into solution, so those iron totals are too low. For other elements the flake hammerscale shows lower concentrations than found in the spheroidal hammerscale. The upper-crust normalised REE profiles for the samples from Abernant and Caerwent are approximately parallel, with the REE relatively enriched by 1.5 to 2 times in the spheroidal scale (Figure 2).

The material from the corn-drier at Bornish showed a surprisingly low iron content given its strongly magnetic properties. The material was markedly different from the iron-working residues in many aspects of its composition, and it will not be discussed further here.

Distribution

Micro-residues, including both spheroidal and flake hammerscale, was recovered from a wide variety of contexts in the IA enclosure. 28 contexts from Roundhouse B yielded hammerscale, but in very small quantities. Only 4 of those contexts exceeded 10 pieces of scale, and those have variable, but high flake:spheroid ratios (5, 6, 30, ∞). Significant quantities of scale derive from features to the south and east of the roundhouse. In all, 11 contexts within the enclosure yielded >10 pieces of scale and these showed high flake:spheroid ratios (6, 8, 8, 10, 12, 15, 20, 25, 30, ∞, ∞) . A single sample from the enclosure ditch showed a high flake:spheroid ratio (15).

Outside the enclosure to the east hammerscale was recovered from almost all postholes within roundhouses C and D (contexts apparently securely dated to the 10th century BC), as well as structure A.

The residues from roundhouses C and D include both spheroidal and flake hammerscale, with spheroidal hammerscale rather abundant (6 samples contained more than 10 spheroids and 3 samples more than 20). In comparison only 1 sample from within the enclosure yielded more than 10 spheroids. The processing of the microresidue samples was variable, so certain comparison of the hammerscale type ratios is slightly problematic. However, it is noteworthy that the ratio of flake:spheroidal hammerscale pieces in the 7 assemblages with >10 pieces from roundhouses C and D was uniformly low (0, 0.1, 0.2, 0.2, 0.4, 0.6, 0.8).

Structure A yielded 3 assemblages of >10 pieces; these had high flake:spheroid ratios (23, 31, 100), with only low numbers of spheroids present.

There are some problems with normalising the distribution data to sample volume, given the uncertainties over the comparability of sample processing between batches; figure 3 shows the distribution of samples with different flake:spheroid ratios for both samples poor (Fig. 3 : upper) and relatively rich (Fig. 3 : lower) in hammerscale.

Interpretation

Chemical analyses suggest that the macroscopic smelting slags were the product of smelting quite a rich iron ore. The contents of CaO and MgO are low, suggesting it was not a carbonate ore, The P_2O_5 is moderate, suggesting a sedimentary ore. The most likely solution is that the ore was a sedimentary iron oxide, probably goethite. Iron oxide pellets were present in the magnetic residues, suggesting they had been heated – so smelting of a highly weathered greensand is possible.

The match between the REE profiles of the spheroidal hammerscale and the macroscopic slags suggests that they were likely to have been derived during bloomsmithing, and the expulsion of residual smelting slags from the raw bloom. Some spheroids may be produced in the smelting furnace too, but the context of much of the Hartshill material suggests against that in this case.

The chemical analyses of the microresidue from the LBA contexts leaves no room for doubt that they indeed from iron-making or –working. Although there is doubt over the proper collection of hammerscale from the earlier-processed residues, the certain LBA contexts appear to yield an odd assemblage, dominated by spheroidal hammerscale. To achieve a more normal ratio, several hundred pieces of flake hammerscale would have had to have been discarded from these samples – and it seems unlikely that so much material would have been overlooked. The extremely early proposed date of this material seems also to be problematic. Iron smelting of 10th century BC age has not yet been recognised in western Europe, although the process may have been undertaken in Eastern Europe at this time. Given these two causes of concern, it seems more likely that the "LBA" assemblages have arisen by a different route. It is suggested that downward percolation of the microresidues from an overlying (now removed) could have produced this sorting. The abundance of spheroids would suggest a substantial deposit of hammerscale overlay this area.

In contrast, larger "normal" assemblages apparently entered the postholes of structure A. It is possible that this structure therefore is IA in date.

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References

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Table 1: catalogue of hammerscale

context	sample	batch	spheroidal	flake	notes	volume	sph/10l	flk/10l	flk/sph	description	fill of	same as	E	N
Roundhouse A														
141	3	batch3	1	2		6	1.7	3.3	2.0	fill of posthole	140		166	495
177	10	batch3	1	31		20	0.5	15.5	31.0	fill of posthole	140	141	166	495
165	8	batch3	0	1		4	0.0	2.5	infinity	fill of posthole	164	178	166	493
145	4	batch3	0	4		8	0.0	5.0	infinity	fill of posthole	144	176	167	496
176	9	batch3	0	7		20	0.0	3.5	infinity	fill of posthole	144	145	167	496
183	14	batch3	0	5		20	0.0	2.5	infinity	tertiary fill of pc	154	159	170	498
159	6	batch3	2	200	approx. 200 flake	35	0.6	57.1	100.0	tertiary fill of pc	154	183	170	498
205	19	batch3	0	4		10	0.0	4.0	infinity	primary fill of p	154	155	170	498
147	5	batch3	0	0		8	0.0	0.0	infinity	fill of posthole	146	179	168	497
179	12	batch3	4	90	approx. 90 flake	20	2.0	45.0	22.5	fill of posthole	146	147	168	497
Roundhouse D														
1371	113	batch1	2	8		10	2.0	8.0	4.0	fill of post pipe	1370		151	496
1374	112	batch2	1	2		30	0.3	0.7	2.0	fill of pit	1373	1669	147	498
1669	192	batch1	15	2		70	2.1	0.3	0.1	fill of hearth	1373	1374	147	498
1383	114	batch1	7	2		30	2.3	0.7	0.3	fill of posthole	1382	1664	153	493
1402	117	batch1	20	11		30	6.7	3.7	0.6	fill of posthole	1401	1667	153	491
1404	120	batch2	2	0		20	1.0	0.0	0.0	fill of posthole	1403	1576	149	489
1412	121	batch2	4	0		20	2.0	0.0	0.0	fill of posthole	1411	1575	149	484
1678	193	batch1	0	0		10	0.0	0.0	infinity	fill of posthole	1415	1416	152	489
1665	190	batch1	26	6		10	26.0	6.0	0.2	fill of posthole	1424	1425	155	494
1433	?	batch2	3	0		?			infinity	fill of ditch	1432		146	489
1437	127	batch1	5	0		10	5.0	0.0	0.0	fill of posthole	1436	1626	145	491
1440	125	batch1	7	0		30	2.3	0.0	0.0	fill of posthole	1439	1663	154	497
1454	128	batch2	1	0		10	1.0	0.0	0.0	fill of posthole	1453	1627	144	492
1460	132	batch1	5	2		10	5.0	2.0	0.4	fill of posthole	1459	1681	152	499
1462	133	batch2	0	0		20	0.0	0.0	infinity	fill of posthole	1461		145	495
1649	184	batch2	5	0		10	5.0	0.0	0.0	fill of posthole	1488	1489	145	497
1503	142	batch2	0	1		10	0.0	1.0	infinity	fill of postpipe	1502		149	493
1679	194	batch1	11	0		10	11.0	0.0	0.0	fill of posthole	1504	1505	151	489.5
1510	144	batch1	7	2		10	7.0	2.0	0.3	fill of posthole	1509	1680	152	489
1645	180	batch1	6	5		10	6.0	5.0	0.8	fill of posthole	1526	1527	155	494
1529	148	batch1	7	2		10	7.0	2.0	0.3	fill of posthole	1528	1646	156	495
1628	168	batch1	2	0		10	2.0	0.0	0.0	fill of posthole	1533	1534	144	495
1541	152	batch2	0	1		10	0.0	1.0	infinity	fill of posthole	1540		150	497
1543	153	batch1	12	5		10	12.0	5.0	0.4	fill of posthole	1542	1660	150	496
1545	155	batch2	1	0		10	1.0	0.0	0.0	fill of posthole	1544		145	495
1563	157	batch2	0	0		10	0.0	0.0	infinity	fill of posthole	1562		149	491
1568	160	batch1	7	9		20	3.5	4.5	1.3	fill of pit	1564	1574	152	491
Roundhouse C														
200	156, 149, 16	batch1	22	4		10, 40, 30	2.8	0.5	0.2	fill of pit	199	202; 204	176	495
1208	103	batch2	1	1		10	1.0	1.0	1.0	primary fill of pc	1207	1340	176	493
1340	105	batch2	0	0		10	0.0	0.0	infinity	fill of posthole	1207	1208	176	493
1341	106	batch2	1	4		10	1.0	4.0	4.0	primary fill of p	1209	1210	179	492
1342	107	batch2	0	0		10	0.0	0.0	infinity	secondary fill c	1209	1328	179	492
1295	93	batch1	2	0		10	2.0	0.0	0.0	secondary fill o	1213	1296	179	489
1299	99	batch2	1	2		10	1.0	2.0	2.0	fill of posthole	1215	1216	179	487
1222	94	batch1	1	0		10	1.0	0.0	0.0	fill of posthole	1221	1298	178	485
1224	86	batch1	2	0		10	2.0	0.0	0.0	fill of posthole	1223	1270	175	484
1271	88	batch1	7	1		20	3.5	0.5	0.1	fill of posthole	1227	1228	172	485
1230	140	batch1	2	1		10	2.0	1.0	0.5	fill of posthole	1229		173	487
1372	111	batch2	3	0		10	3.0	0.0	0.0	fill of posthole	1231	1232	171	486
1234	108	batch2	0	1		20	0.0	0.5	infinity	fill of posthole	1233	1354	171	487
1354	109	batch2	2	0		15	1.3	0.0	0.0	fill of posthole	1233	1234	171	487
1236	126	batch1	1	0		10	1.0	0.0	0.0	fill of posthole	1235	1455	171	489
1455	129	batch2	0	1		10	0.0	1.0	infinity	fill of posthole	1235	1236	171	489
1458	131	batch1	0	0		10	0.0	0.0	infinity	fill of posthole	1237	1238	170	489
1240	135	batch2	0	1		40	0.0	0.3	infinity	fill of posthole	1239	1485	172	490
1485	136	batch1	0	0		40	0.0	0.0	infinity	fill of pit	1239	1240	172	490
1242	89	batch1	1	1		10	1.0	1.0	1.0	fill of posthole	1241	1272	171	491
1246	92	batch2	1	0		10	1.0	0.0	0.0	fill of posthole	1245	1310	173	493
1518	146	batch2	4	0		10	4.0	0.0	0.0	fill of posthole	1517		180	489
Roundhouse c (or A?)														
1238	130	batch3	0	1		10	0.0	1.0	infinity	fill of posthole		1458	170	489
others outside encl to E														
1105	78	batch3	0	4		40	0.0	1.0	infinity	fill of pit	1104		142	508
1254	88	batch3	1	1		20	0.5	0.5	1.0	fill of posthole	1253		144	484
1263	84	batch1	0	1		40	0.0	0.3	infinity	fill of pit	1262		146	515
1282	91	batch3	0	0		20	0.0	0.0	infinity	fill of posthole	1281		144	510
Roundhouse B														
231	22	batch3	0	3		15	0.0	2.0	infinity	fill of posthole	230		89	545
426	24	batch1	0	0		25	0.0	0.0	infinity	fill of posthole	230	231	89	545
426	24	batch3	0	0						fill of posthole	230	231	89	545
288	39	batch3	0	8		10	0.0	19.0	infinity	fill of posthole	287	517	86	547
288	39	batch3	0	11						fill of posthole	287	517	86	547
290	34, 35	batch1	0	0			0.5	15.0	30.0	fill of posthole	289	516	87	546
290	34	batch3	1	30		10				fill of posthole	289	516	87	546
290	35	batch3	0	0		10				fill of posthole	289	516	87	546
449	28	batch3	1	8		20	0.5	4.0	8.0	fill of posthole	291	292	90	546
449	28	batch1	0	0						fill of posthole	291	292	90	546
294	29	batch3	0	0		18	0.0	0.0	infinity	fill of posthole	293	490	91	546.5
878	75	batch3	0	1		10	0.0	1.0	infinity	fill of posthole	299	878, 300	95.5	547.5
500	36	batch3	?1	1		18	0.6	0.6	0.9	fill of posthole	301	302	93	548.5
500	36	batch1	0	0						fill of posthole	301	302	93	548.5
545	51	batch3	0	0		6	0.0	0.0	infinity	fill of posthole	314	315	85	550
319	52	batch3	0	0		10	0.0	0.0	infinity	fill of posthole	318	603	85	551
343	54	batch3	1	1		10	1.0	1.0	1.0	fill of posthole	342	621	86	552
343	54	batch1	0	0		10				fill of posthole	342	621	86	552
358	56	batch1	0	0		10	0.0	0.0	infinity	fill of posthole	357	634	86.5	553
634	57	batch3	0	1		15	0.0	0.7	infinity	fill of posthole	357	358	86.5	553
380	60	batch3	0	3		15	0.6	2.0	3.3	fill of posthole	379	657	87.5	553.5
380	60	batch2	1	0						fill of posthole	379	657	87.5	553.5
657	61	batch3	0	5		30	0.0	1.7	infinity	fill of posthole	379	380	87.5	553.5
732	64	batch1	0	0		20	0.0	0.0	infinity	fill of pit	379		87.5	553.5
395	65	batch3	0	1		10	0.0	1.0	infinity	fill of posthole	394	735	88	553.5
735	66	batch3	0	0		10	0.0	0.0	infinity	fill of posthole	394	395	88	553.5
401	68	batch1	0	0		10	0.0	0.0	infinity	fill of posthole	400	778	89	553.5
778	69	batch3	0	1		10	0.0	1.0	infinity	fill of posthole	400	401	89	553.5
403	70	batch1	0	0		12	0.0	0.0	infinity	fill of posthole	402	788	91	554.5
403	70	batch3	0	0						fill of posthole	402	788	91	554.5
788	71	batch3	1	4		20	0.5	2.0	4.0	fill of posthole	402	403	91	554.5
856	73	batch3	0	2		20	0.0	1.0	infinity	fill of posthole	404	405	91.5	553.5
856	73	batch1	0	0						fill of posthole	404	405	91.5	553.5
542	49	batch3	0	7		15	1.3	4.7	3.5	fill of posthole	406	407	93	552
542	49	batch1	2	0						fill of posthole	406	407	93	552
409	41	batch3	0	10		15	1.3	8.0	6.0	fill of posthole	408	505	93.5	550
409	41	batch3	1?	2						fill of posthole	408	505	93.5	550
409	41	batch1	1	0						fill of posthole	408	505	93.5	550
505	42	batch3	2	9		20	1.0	4.5	4.5	fill of posthole	408	409	93.5	550
521	47	batch3	0	1		5	0.0	2.0	infinity	fill of posthole	526		93.5	550
1126	81	batch3	1	1		40	0.3	0.3	1.0	fill of pit	1125		94.5	548.5

Table 1: catalogue of hammerscale (continued)

Pit V area

492	32	batch3	2	20	lots of fired clay	40	0.5	5.0	10.0	fill of pit	491		85	532
499	38	batch3	0	6		15	0.0	4.0	infinity	fill of posthole	498	1634	96	532
1634	172	batch3	0	120	approx. 120 flake	30	0.0	40.0	infinity	fill of posthole	498	499	96	532
1634	172	batch1	0	0						fill of posthole	498	499	96	532
514	45	batch3	1	30		10	1.0	30.0	30.0	fill of pit	513	1635	92	534
514	45	batch3	0	0						fill of pit	513	1635	92	534
1635	173	batch3	8	200	approx. 200 flake	30	2.7	66.7	25.0	fill of pit	513	514	92	534
1635	173	batch1	0	0						fill of pit	513	514	92	534
773	67	batch3	0	2		30	0.0	0.7	infinity	fill of pit	772	1642	87	536
1642	177	batch1	0	0		10	0.0	0.0	infinity	fill of pit	772	773	87	536

SE RH B

221	20	batch3	0	4		20	0.0	2.0	infinity	fill of pit	220	?7	103	545
323	21	batch3	1	80	approx. 80 flake	10	13.0	80.0	6.2	fill of posthole	322	422	108	537
323	21	batch1	12	0						fill of posthole	322	422	108	537
422	23	batch3	0	100	approx. 100 flake	10	0.0	100.0	infinity	fill of posthole	322	323	108	537

others in enclosure

489	31	batch3	1	12		25	0.4	4.8	12.0	fill of pit	488	1633	72	548
1633	171	batch1	1	0		20	0.5	0.0	0.0	fill of pit	488	489	72	548
494	33	batch1	0	0		40	0.0	0.0	infinity	fifth fill of pit	493	1636	61	528
504	46	batch3	0	26		8	0.0	32.5	infinity	primary fill of p	493		61	528
504	46	batch1	0	0						primary fill of pi	493		61	528
1640	176	batch3	0	20		20	0.5	10.0	20.0	secondary fill c	677	679	77	523
1640	176	batch1	1	0						secondary fill o	677	679	77	523
941	76	batch3	0	2		10	0.0	2.0	infinity	fill of posthole	940		79	518
976	82	batch3	1	8		40	0.3	2.0	8.0	fill of pit	975		101	513.5
1103	77	batch3	0	2		10	2.0	2.0	1.0	fill of posthole	1102		99	511
1103	77	batch1	2	0						fill of posthole	1102	1643	99	511
1643	178	batch3	0	30	approx. 30 flake	10	0.0	30.0	infinity	fill of posthole	1102	1103	99	511
1643	178	batch3	0	0						fill of posthole	1102	1103	99	511
1119	79	batch3	0	2		20	0.0	1.0	infinity	fill of pit	1118	1121	117.5	517.5
1121	80	batch3	0	8		20	0.0	4.0	infinity	fill of pit	1118	1118	117.5	517.5

enclosure ditch

746	197	batch3	0	15		40	0.3	3.8	15.0	fill of ditch	745		91	509
746	197	batch1	1	0						fill of ditch	745		91	509

Far SW

28	2	batch3	3	2	also lots of ?rust	5	6.0	4.0	0.7	fill of pit	27	1632	29	492
28	2	batch1	0	0						fill of pit	27	1632	29	492
1632	170	batch3	2	7		10	2.0	7.0	3.5	fill of pit	27	28	29	492

just ouside encl to W

1639	175	batch3	1	80	approx. 80 flake	30	0.3	26.7	80.0	secondary fill c	493	497	60	520
639	59	batch3	0	1		20	0.0	0.5	infinity	fill of pit	638		42	530
639	59	batch1	0	0						fill of pit	638		42	530
640	58	batch3	0	2		20	0.0	1.0	infinity	fill of pit	638		42	530

Near pit Q in South

1406	119	batch3	0	4		10	0.0	4.0	infinity	post pipe	1405		105	474
1409	118	batch3	0	0		40	0.8	0.0	0.0	fill of pit	1441		84	470
1409	118	batch1	3	0						fill of pit	1441		84	470

146 samples ***totals:*** ***267*** ***1319***

Table 2a: Major elements by ICP-OES

	SiO2	Al2O3	FeO	Fe3O4	MnO	MgO	CaO	Na2O	K2O	TiO2	P2O5	total Fe as FeO	total Fe as Fe3O4
Abernant flake	no data	1.04	59.96	64.40	0.03	0.16	0.25	1.73	0.14	0.13	0.18		68.06
Abernant spheroids	no data	2.35	37.18	39.93	0.27	0.35	0.47	1.57	0.43	0.24	0.42		46.03
Bornish spheroids	no data	9.14	6.33	6.80	0.17	4.28	8.70	1.88	2.07	0.75	1.90		35.69
Caerwent flake	no data	0.86	89.86	96.52	0.02	0.17	0.42	1.75	0.13	0.09	0.21		100.17
Caerwent spheroid	no data	1.74	56.42	60.60	0.03	0.37	0.65	1.67	0.41	0.15	0.23		65.85
hcb 1667-flake	no data	0.95	14.64	15.72	0.05	0.26	1.27	1.56	0.35	0.37	0.32		20.86
hcb 1667-spheroid	no data	1.18	46.83	50.30	0.04	0.24	0.64	4.08	0.20	0.26	0.48		57.43
hcb 422-spheroid	no data	3.27	67.93	72.97	1.31	0.54	0.74	1.57	0.03	0.31	1.22		81.96
323-sm	no data	3.87	62.80	67.45	1.01	0.49	0.64	1.68	1.07	0.25	0.73	74.58	
407-sm	no data	3.16	70.68	75.91	0.69	0.29	0.83	1.69	0.54	0.22	0.63	80.75	
588-sm	no data	3.51	64.19	68.94	0.93	0.45	0.63	1.67	0.48	0.27	0.65	74.76	
821-sm	no data	4.37	68.52	73.59	1.10	0.36	1.10	1.29	0.65	0.22	0.75	80.50	
1076-cake	no data	3.37	73.97	79.45	0.75	0.29	0.69	1.61	0.55	0.22	0.64	84.17	

Table 2b: Trace elements by ICP-MS

	V	Cr	Co	Ni	Cu	Ga	Rb	Sr	Y	Zr	Nb	Ba	Hf	Ta	Pb	Th	U
Abernant flake	19.2	29.4	28.0	75.9	22.8	4.2	3.0	15.8	5.6	188.1	3.4	135.5	5.1	0.3	25.1	1.3	0.4
Abernant spheroids	59.8	51.0	18.4	42.5	141.7	5.3	13.1	34.1	10.2	286.4	5.2	247.1	7.7	0.5	14.5	2.8	1.7
Bornish spheroids	78.4	69.7	13.8	75.0	58.4	11.8	25.8	849.6	16.8	541.7	8.9	418.8	14.2	0.8	22.1	3.4	4.1
Caerwent flake	16.7	17.7	12.7	74.5	72.8	5.0	2.1	52.3	4.4	130.1	2.3	145.6	3.6	0.2	7.2	1.0	0.5
Caerwent spheroid	25.4	21.0	11.6	119.3	29.2	5.7	11.3	154.1	9.0	187.3	3.4	219.7	5.2	0.3	11.2	1.8	0.7
hcb 1667-flake	43.1	77.3	41.4	181.6	185.9	5.6	6.6	74.9	5.9	696.1	9.6	488.6	20.0	0.9	37.5	2.2	0.5
hcb 1667-spheroid	42.6	47.5	33.3	110.4	21.9	4.7	35.0	33.0	37.9	357.5	12.0	281.6	4.3	0.8	16.0	3.6	0.9
hcb 422-spheroid	112.9	101.3	7.1	11.3	97.8	4.6	19.6	33.4	57.9	206.5	5.6	188.0	5.6	0.5	9.3	3.0	1.9
323-sm	85.8	71.7	5.4	36.4	33.0	4.7	39.8	37.0	56.8	198.6	5.4	250.5	5.3	0.4	9.9	3.4	2.4
407-sm	69.5	80.7	3.4	31.2	35.4	4.2	22.1	36.9	39.6	217.3	5.0	179.2	5.7	0.4	8.7	3.8	1.3
588-sm	83.9	64.4	5.7	3.8	20.4	4.4	17.8	27.7	45.1	199.3	5.2	157.8	5.5	0.4	8.3	3.1	1.6
821-sm	62.8	79.6	5.9	11.2	57.1	4.2	23.1	46.5	50.1	150.9	4.5	183.5	4.1	0.3	7.2	3.7	1.3
1076-cake	69.3	79.2	9.0	20.4	40.9	4.1	21.9	43.0	43.1	211.2	4.7	179.5	5.7	0.4	8.7	3.5	1.5

Table 2c: REE by ICP-MS

	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Total REE	Total REE no La
Abernant flake	no data	8.8	1.3	5.1	1.2	0.3	1.2	0.2	0.9	0.2	0.5	0.1	0.5	0.1		20.1
Abernant spheroids	no data	14.2	1.8	6.8	1.8	0.4	1.9	0.3	1.6	0.3	0.9	0.1	0.9	0.1		31.0
Bornish spheroids	no data	47.7	5.5	19.8	3.8	1.0	3.5	0.5	2.6	0.5	1.4	0.2	1.5	0.2		88.3
Caerwent flake	no data	7.7	0.9	3.4	0.8	0.2	0.8	0.1	0.7	0.1	0.3	0.0	0.3	0.1		15.4
Caerwent spheroid	no data	15.5	2.0	7.4	1.6	0.4	1.7	0.2	1.4	0.3	0.7	0.1	0.6	0.1		31.9
hcb 1667-flake	no data	14.0	1.3	4.2	0.8	0.2	0.9	0.1	0.7	0.2	0.5	0.1	0.4	0.1		23.4
hcb 1667-spheroid	18.2	38.8	5.3	21.3	5.5	1.9	6.1	1.0	6.3	1.3	3.4	0.5	3.4	0.5	113.3	95.2
hcb 422-spheroid	25.5	50.0	5.8	22.8	5.7	1.3	6.8	1.2	7.6	1.7	4.8	0.7	5.0	0.8	139.7	114.2
323-sm	41.6	78.6	9.7	37.9	8.8	2.1	9.2	1.4	8.1	1.6	4.2	0.6	4.0	0.6	208.4	166.8
407-sm	no data	47.8	7.3	26.9	6.1	1.3	5.9	0.9	5.2	1.0	2.8	0.4	2.8	0.4		109.0
588-sm	27.7	52.2	6.3	24.6	5.9	1.4	6.3	1.0	6.1	1.3	3.6	0.5	3.7	0.6	141.1	113.3
821-sm	37.8	66.9	9.3	35.0	7.8	1.8	7.6	1.2	6.7	1.3	3.6	0.5	3.5	0.5	183.6	145.8
1076-cake	no data	69.6	9.3	34.8	7.5	1.7	7.5	1.1	6.1	1.2	3.1	0.4	3.0	0.5		145.8

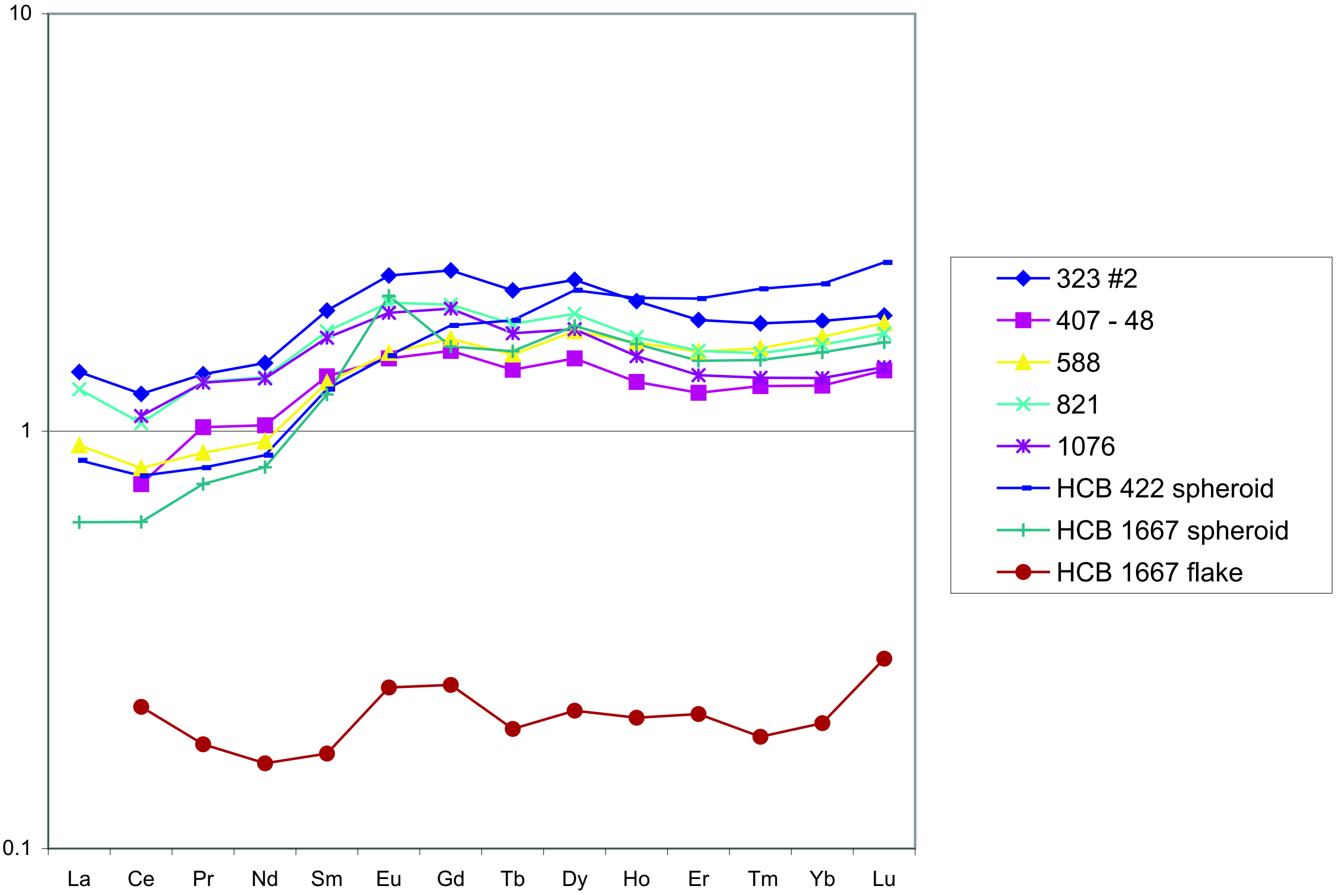

Figure 1. Upper Crust-normalised REE profiles for slags and microresidues from Hartshill Copse

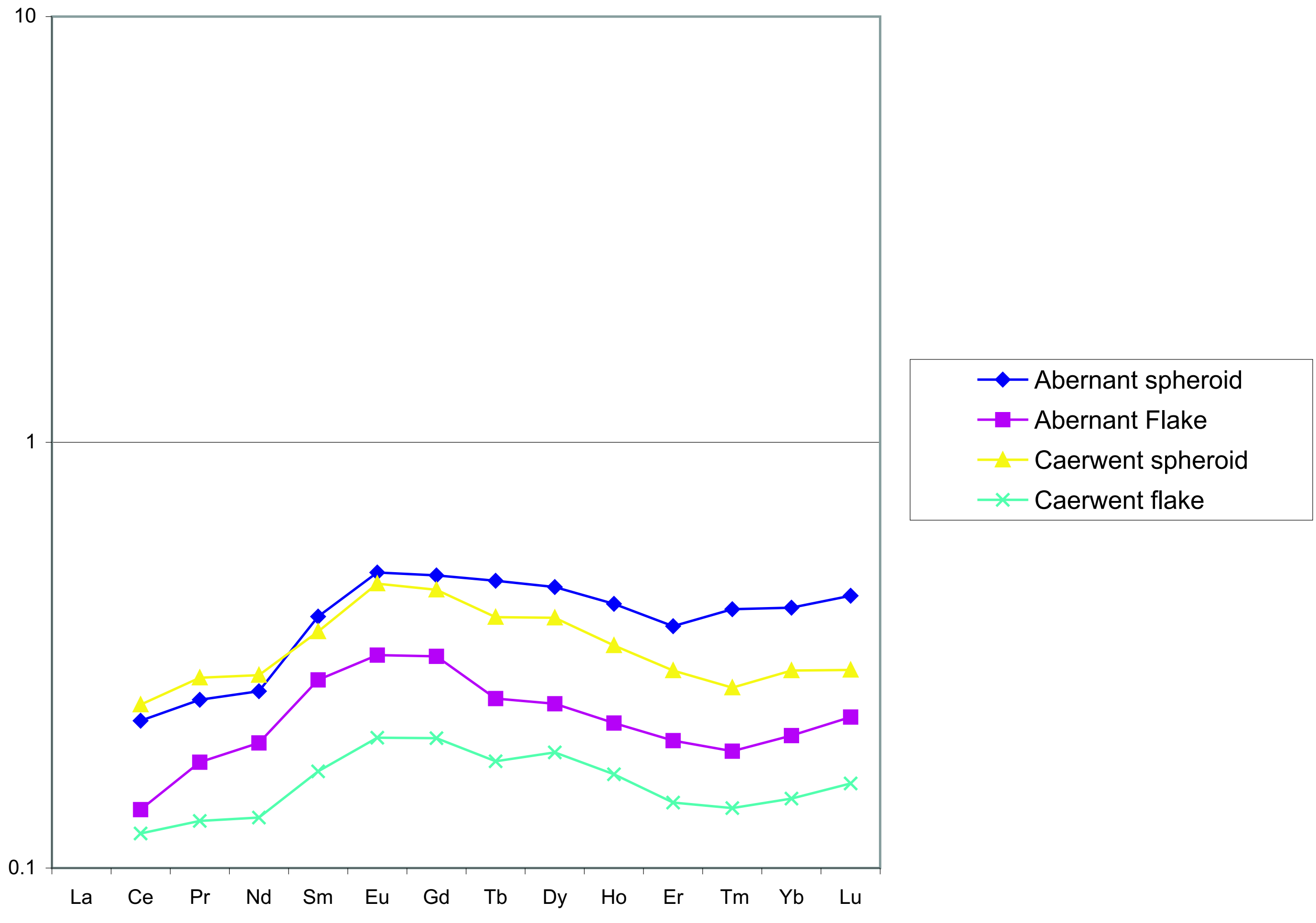

Figure 2. Upper Crust-normalised REE profiles for comparative samples of hammerscale from Abernant and Caerwent.

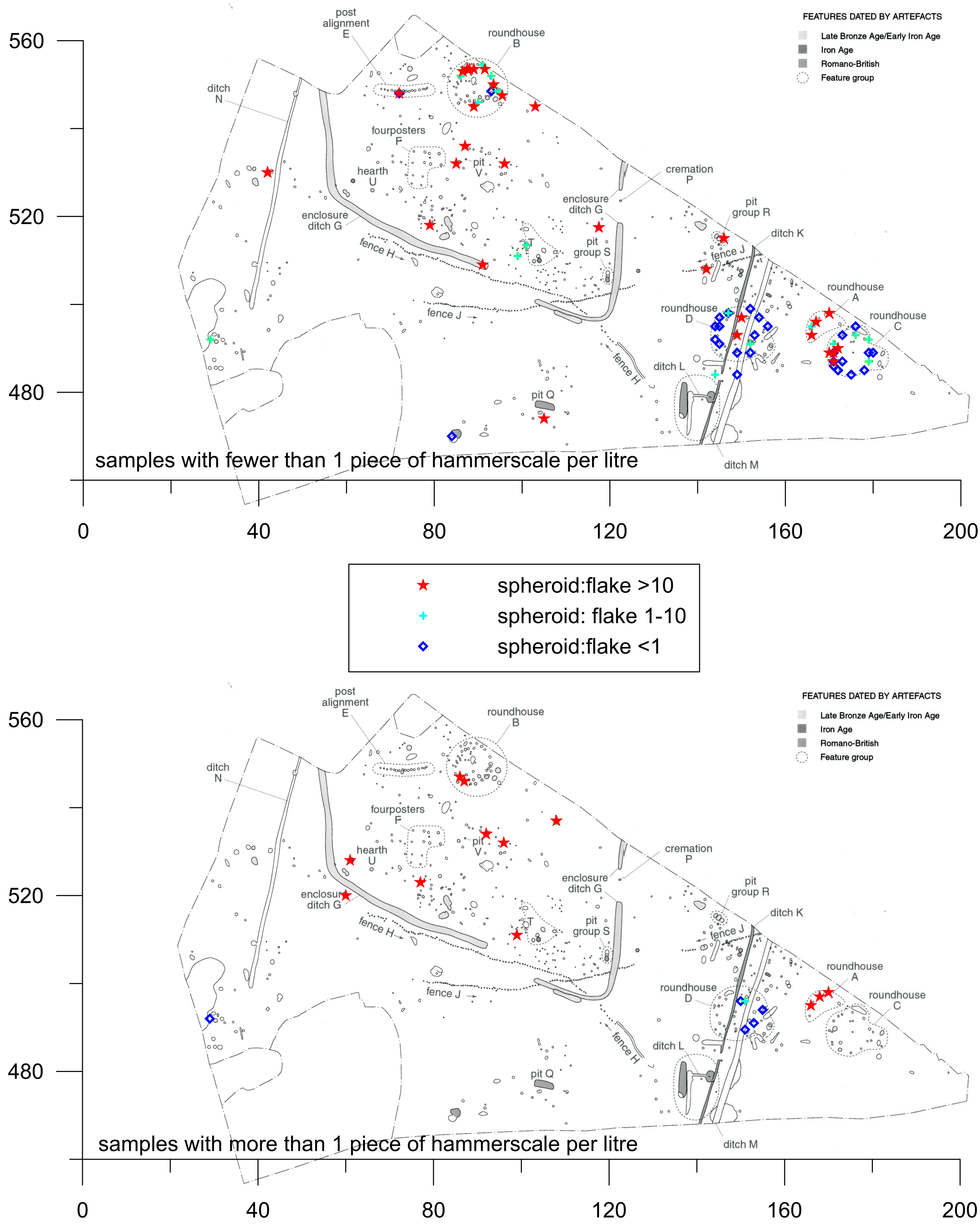

Figure 3. Distribution of microresidue samples showing the ratio of flake to spheroidal hammerscale. Upper diagram shows samples with fewer than 1 piece of hammerscale per litre of sampled deposit, the lower shows those with more than 1 piece per litre. The scale type ratio in small samples is likely to be less reliable.