An Early to Middle Iron Age iron smelting site at Exeter Down, Stamford, Lincolnshire

Patrick Daniel and Roderick Mackenzie

ABSTRACT: Two small iron smelting furnaces were excavated close to an enclosed Iron Age farmstead, which pottery and radiocarbon dates indicate was occupied during the Early–Middle Iron Age (c5th–2nd centuries BC). The site lies on a belt of iron-rich sedimentary rocks (Jurassic ironstones), and there is plentiful evidence of pre-Industrial era ironworking nearby. Although the remains found at the site appear to be notably early, analysis of the slag has revealed the furnaces were operated in a very efficient way, with a relatively high proportion of iron extracted during smelting. The paucity of smithing residues suggests this process occurred elsewhere.

Introduction

In 2014 Wessex Archaeology carried out excavations at Exeter Down, Stamford, Lincolnshire (NGR 501000 307100), to comply with a planning condition relating to a commercial development. The site, which was located in an area of limestone geology, lay at approximately 65m OD on a low promontory just upstream of the confluence of the rivers Gwash and Welland, on the western edge of Stamford (Fig 1).

Geophysical survey and the analysis of cropmarks first identified the archaeological potential of the site, and this was confirmed by subsequent trial trench evaluation (SLR Consulting 2011a; 2011b; 2012; Wessex Archaeology 2014). The 2014 excavation targeted the two areas of highest archaeological significance (Wessex Archaeology 2017; Daniel forthcoming).

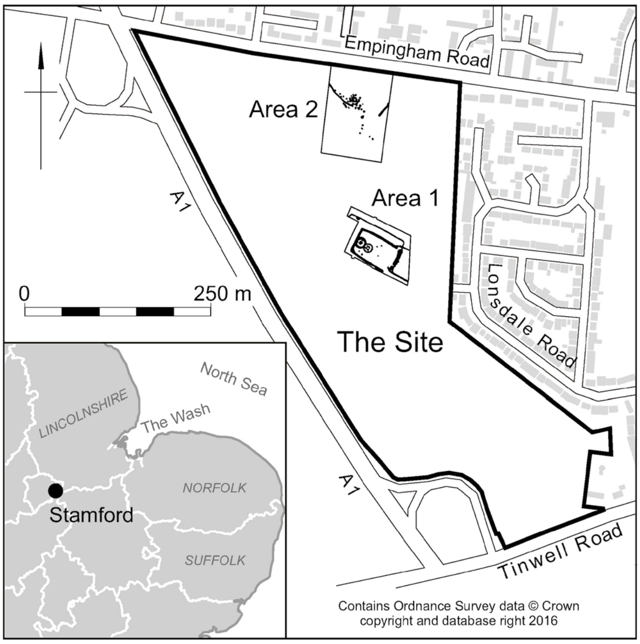

Figure 1: Site location.

Archaeological features

The furnaces

The plough-damaged remains of two iron smelting furnaces were discovered in Area 2, the northern of the two excavation areas, alongside field boundary ditches and a cluster of 41 pits (Fig 2).

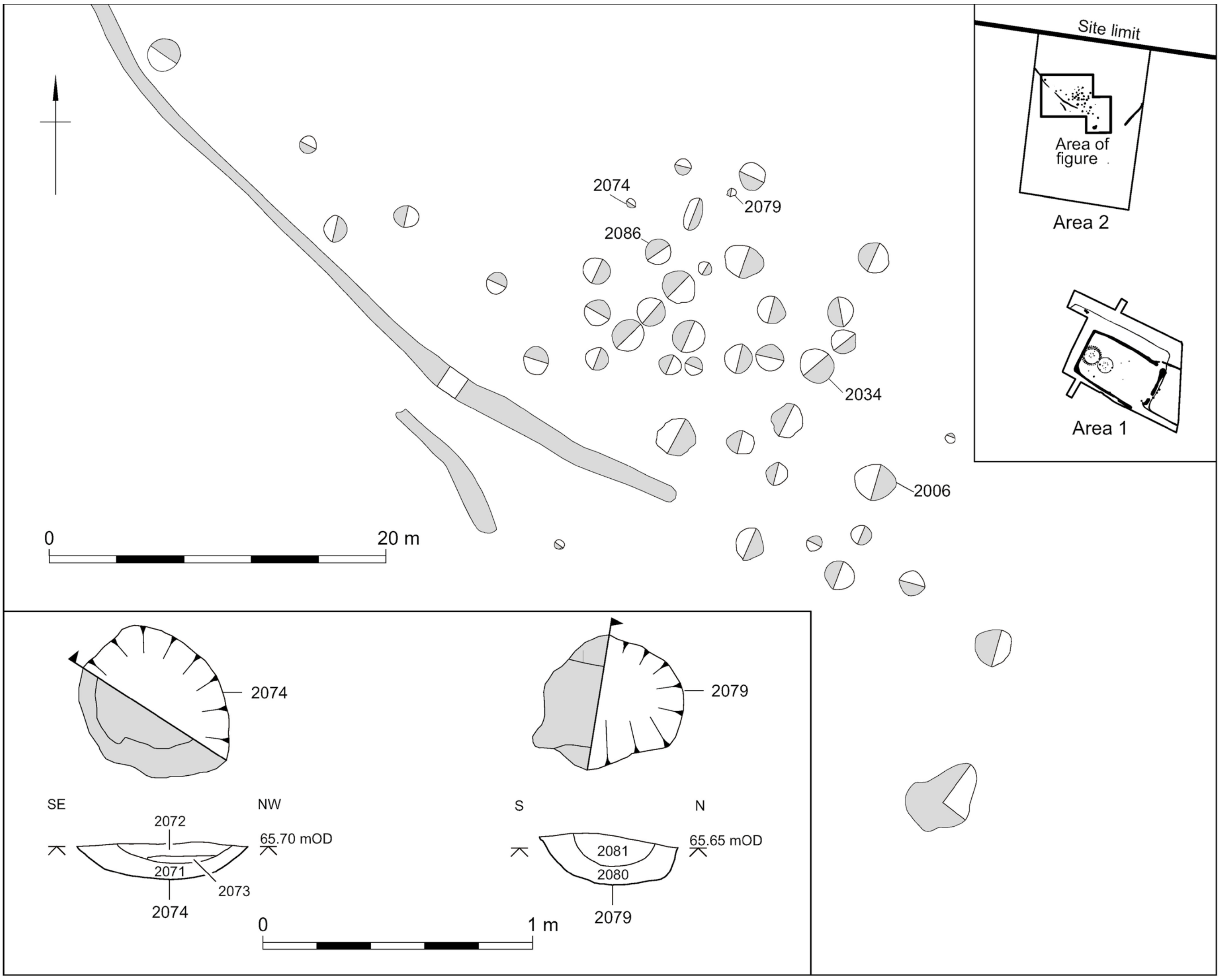

Figure 2: Plan of furnaces and associated features, with details of furnaces.

Furnace 2074 (0.4m max internal diameter, 0.07m deep) was almost circular in plan and had a shallow, U-shaped profile. Heat from its operation had scorched the surrounding substrate a pinkish red colour (Fig 3). It contained a brittle, dark grey deposit that may represent the collapsed-in walls of the furnace. Above this material was a dark grey-to-black clayish silt, which contained a single fragment (65g) of flow slag (see below).

Furnace 2079 lay 12m to the east. It was slightly more irregular in plan (0.34m by 0.51m internally and 0.13m deep) but similar in profile. The corona of scorching was less marked around this feature. It contained dark grey clayish silt, which also contained flow slag (six fragments totalling 280g).

No datable artefacts were recovered from the furnaces, but ironworking debris (including flow slag, slagged furnace lining, iron ore and possible hearth bottom slag) was found alongside Iron Age pottery in ten of the surrounding pits. The ceramics include Scored Ware, a regional pottery tradition belonging to the Middle and Late Iron Age. The fact that none of the pits or furnaces intercut, with each seemingly dug mindful of the position of the others, further suggests the group as a whole is broadly contemporary.

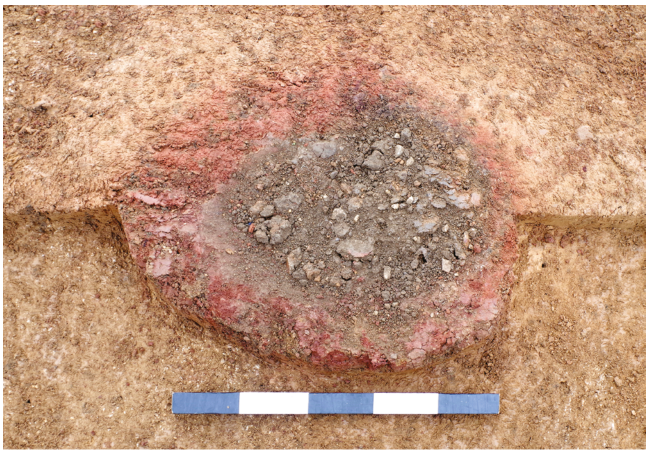

Figure 3: Furnace 2074. Scale bar 0.5m.

Table 1: Radiocarbon dates

Lab ref	Feature	Material	Date BP	δ13C	δ15N	C:N	95% confidence	Posterior density estimate
SUERC-61769	Main enclosure ditch	Cattle bone	2153±34	-22.1‰	8.3	3.2	360–90 cal BC	*360–150 cal BC*
SUERC-61684	Roundhouse posthole	Sheep/goat bone	2359±34	-21.7‰	6.5	3.3	520–380 cal BC	*510–370 cal BC*
SUERC-61685	Roundhouse	Sheep/goat bone	2229±34	-21.3‰	5.0	3.3	400–190 cal BC	*390–210 cal BC*
SUERC-61689	Main enclosure ditch	Sheep/goat bone	2204±34	-21.5‰	6.4	3.3	390–170 cal BC	*390–240 cal BC*
SUERC-61690	Main enclosure ditch	Pig bone	2232±34	-21.4‰	5.4	3.3	400–190 cal BC	*360–200 cal BC*

The settlement

The second excavation area, Area 1, lying some 250m south of the furnaces, contained an Iron Age farmstead comprising a succession of three roundhouses, the latest of which was set within a 0.3-hectare rectangular enclosure defined by a ditch with a probable internal bank (Fig 4). Pottery evidence indicates that the furnaces were probably contemporary with the final, enclosed, phase of the settlement. However, ironworking debris (including roasted and unroasted iron ore, iron furnace slag, possible furnace lining and iron furnace bottom slag) was recovered from features from all phases of the settlement. The radiocarbon evidence, which is not at odds with the pottery dates, suggests that the settlement had begun by the 5th century BC, and possibly slightly earlier. It was occupied for about two centuries from the end of the Early Iron Age into the earliest part of the Middle Iron Age, ending either before or by the early 2nd century BC. The radiocarbon dates (Table 1) derive entirely from the settlement; further details are available within the final site report (Wessex Archaeology 2017).

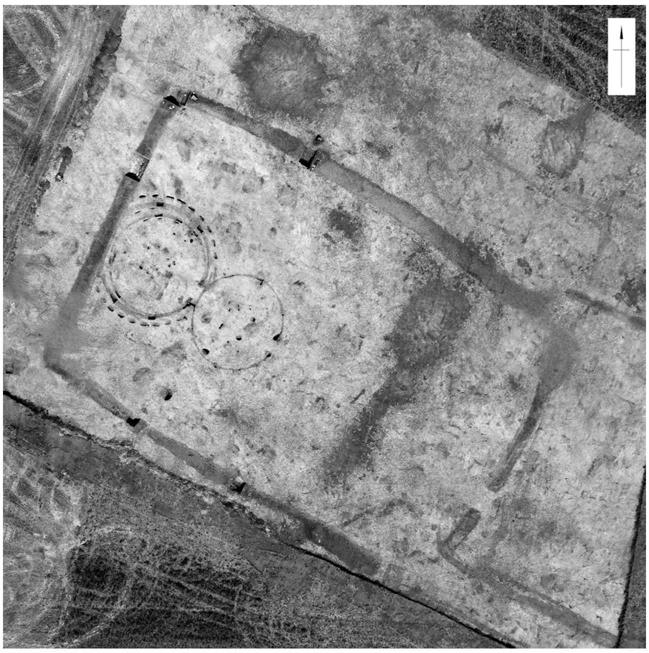

Figure 4: Aerial photograph of the settlement area.

Archaeometallurgical analysis
by Roderick Mackenzie

Overview of assemblage

A site visit by the author confirmed the presence of two iron smelting furnaces and significant quantities of smelting slag and iron ore. All residues thought to relate to metal production were collected during the excavation, and the complete assemblage has been assessed and quantified by type of residue (Wessex Archaeology 2017, 130–42).

The most abundant types of material in the assemblage are iron smelting slag (858 pieces, 60kg) and iron ore (887 pieces, 54kg), whereas only three pieces (1.2kg) appear to be more characteristic of iron smithing. The smelting slag is predominantly composed of fragments that appear to have formed and remained in the furnace or to have been manually removed from it, rather than tapped.

As well as the metalliferous slag and ore, there are 76 fragments of fuel ash slag (0.4kg) and 46 fragments of fired clay (5.2kg), possibly the clay lining of hearths or furnaces. The fuel ash slag appears to be wood-derived rather than coal-derived, suggesting that it may be a by-product of the two charcoal-fired furnaces at the site (Fig 2), although it could be connected with ore roasting or pyrotechnical processes unrelated to the production of metal.

Methodology

Four fragments of slag were analysed (Table 2). Specimens 1 and 2 derive from fragments of *in situ* flow slag from each of the two furnaces. The other samples of slag comprise specimen 3, a sample from a lump

Table 2: Analysed smelting slag specimens.

Specimen	Context	Type
1	2072 (furnace 2074)	Flow slag
2	2081 (furnace 2079)	Flow slag
3	2035 (pit 2034)	Furnace slag (possible furnace bottom)
4	2007 (pit 2006)	Flow slag

of furnace slag with limestone inclusions which was recovered from 2035 (the fill of pit 2034), and specimen 4, a sample of flow slag found in 2007 (the fill of pit 2006) (Fig 2) which were chosen as representative of the other smelting slag morphologies found at the site. Within this report, the term flow slag describes slag that had become fluid enough to trickle down through the furnace charge during smelting. The term furnace slag has been used to describe larger pieces of slag that appear to have accumulated and solidified in the base of the furnace.

The specimens were removed from the samples of bulk slag by a combination of fracturing and diamond-blade cold-disc cutting. They were then mounted in cold-setting resin, before being ground and polished in the conventional manner (Vander Voort 1999), with the final stages of polishing carried out using 1 µm diamond paste.

The polished specimens were examined using reflected light microscopy, before being carbon coated for further examination and analysis using an analytical scanning electron microscope with energy dispersive spectrometer (SEM-EDS). The microstructures of the specimens were recorded as back-scattered electron images where components with a high atomic mass, such as iron, appear brighter than those with a lower average atomic mass. The bulk composition of each specimen was determined by taking the average of three scans of areas approximately 650 by 400 microns. Spot analyses were also carried out to aid identification of individual phases, or determine the composition of small spots of metal within the slag matrix.

Results

The results of the SEM-EDS analysis (Table 3) show that the general composition of all specimens approximates to that of fayalite (Fe_2SiO_4). The microstructures of all four specimens are predominantly composed of three mineral phases: primarily laths of fayalite (Fe_2SiO_4) sit within an interstitial glassy matrix, and iron oxide in the form of dendritic wüstite (FeO) is also present in most specimens. Other phases present in relatively small amounts include hercynite ($FeAl_2O_4$) and kirschsteinite ($CaFeSi_2O_6$).

The three analysed pieces of flow slag all share the solidified viscous flow-like morphology characteristic of this slag type. The fresh fracture surfaces of the pieces reveal a dense, dark graphite-grey surface, with a relatively low abundance of randomly distributed fine (<1mm) vesicles. The microstructure of specimen 1 has a very low abundance of dendritic wüstite (Fig 5a). Specimen 2 has more dendritic wüstite present than specimen 1, but the dendrites are relatively thinly dispersed in localised areas within the specimen. Occasional small spots of metallic iron (typically <40 microns in size) are present and spot analysis revealed that these are composed of

Table 3: SEM-EDS analyses of slag specimens (wt%).

		MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	TiO_2	MnO	FeO
Specimen 1	area1	-	6.54	28.44	-	0.96	3.98	1.02	0.68	58.39
	area 2	0.18	5.37	28.74	0.19	0.87	3.37	0.70	0.65	59.92
	Average	0.09	5.96	28.59	0.10	0.92	3.68	0.86	0.67	59.16
	Std Dev	0.13	0.83	0.21	0.13	0.06	0.43	0.23	0.02	1.08
Specimen 2	area 1	0.29	6.94	29.00	0.34	1.27	4.95	0.67	1.21	55.34
	area 2	0.40	6.94	28.69	0.47	1.28	4.75	0.40	0.87	56.21
	area 3	0.33	7.34	30.34	0.17	1.14	4.99	0.87	0.89	53.93
	Average	0.34	7.07	29.34	0.33	1.23	4.90	0.65	0.99	55.16
	Std Dev	0.06	0.23	0.88	0.15	0.08	0.13	0.24	0.19	1.15
Specimen 3	area 1	0.54	8.47	35.03	0.27	0.80	3.98	0.72	-	50.19
	area 2	0.48	8.37	32.90	-	1.09	4.58	0.63	0.73	51.22
	area 3	0.66	8.75	30.14	0.24	0.78	4.02	0.70	0.73	53.97
	Average	0.56	8.53	32.69	0.17	0.89	4.19	0.68	0.49	51.79
	Std Dev	0.09	0.20	2.45	0.15	0.17	0.34	0.05	0.42	1.95
Specimen 4	area 1	0.37	9.18	38.21	0.55	0.75	4.66	0.88	-	45.41
	area 2	0.28	8.57	40.71	0.19	0.60	4.36	0.78	0.60	43.91
	area 3	0.42	9.36	39.70	0.07	0.80	4.91	0.80	-	43.94
	Average	0.36	9.04	39.54	0.27	0.72	4.64	0.82	0.30	44.42
	Std Dev	0.07	0.41	1.26	0.25	0.10	0.28	0.05	0.42	0.86

Note: - = not detected

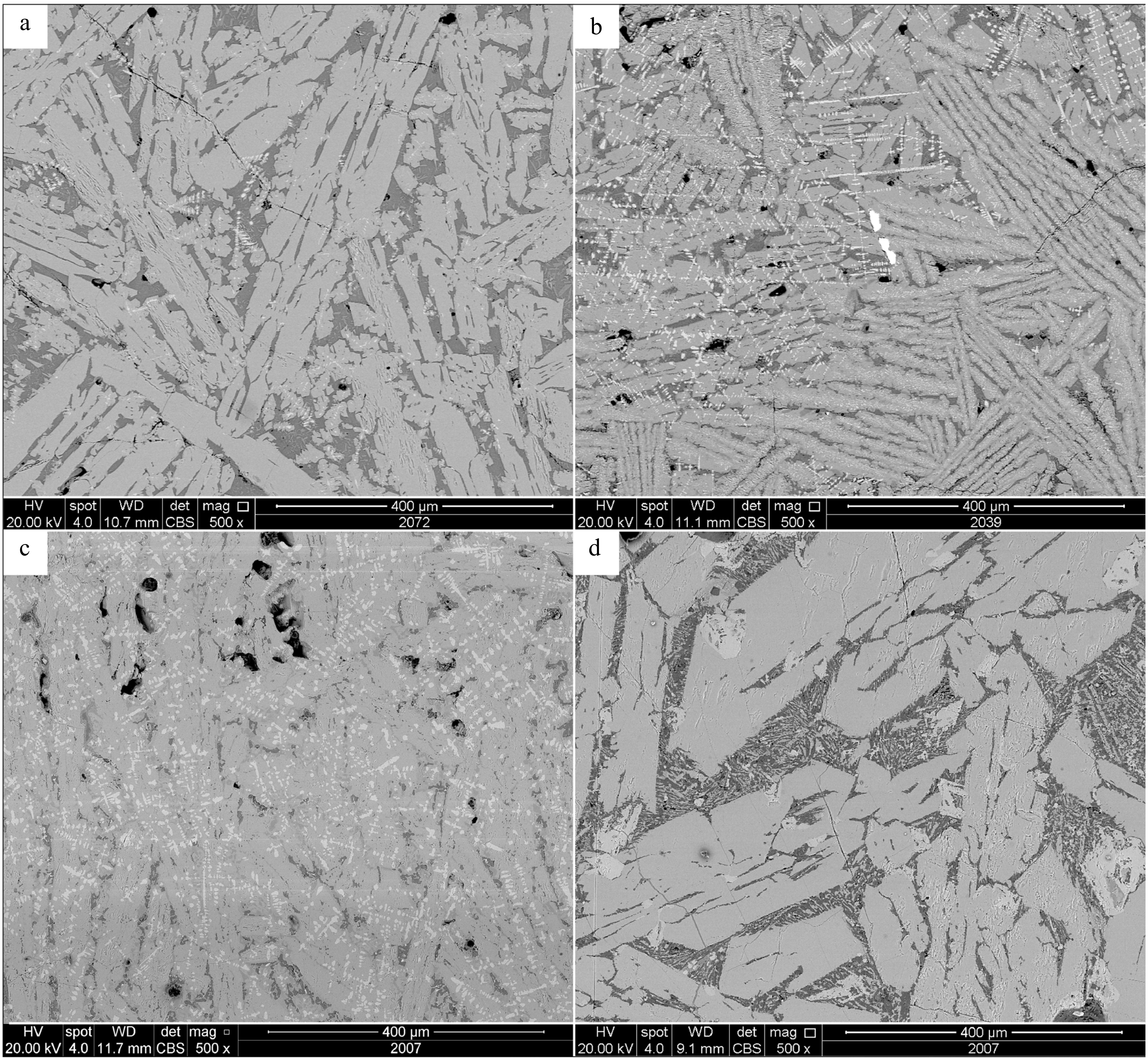

Figure 5: Backscattered electron images of specimens 1–4. a) Specimen 1: fayalite laths (mid-grey) in a glassy matrix (dark grey) with sparse dendritic wüstite (light grey); b) Specimen 2: fayalite laths (mid-grey), overlying wüstite dendrites (light grey) and metallic iron (white); c) Specimen 3: fayalite (mid-grey), wüstite dendrites (light grey) and voids (black); d) Specimen 4: large fayalite laths (mid-grey) with some hercynite (lighter grey).

almost 100% iron (Fig 5b). Specimen 4 has larger more blocky laths of fayalite than specimen 1 and 2, and some hercynite. There is a very low abundance of dendritic wüstite in this specimen (Fig 5d).

The fracture surface of specimen 3, a furnace slag, reveals that the texture of the slag is more varied than the flow slag specimens, the most obvious difference being the larger number of vesicles in the fracture surface. The predominant phase in the microstructure of the specimen 3 is fayalite. Wüstite dendrites are also present (Fig 5c) and these are more abundant and evenly distributed than in the flow slag specimens.

Discussion of the slag

The microstructure and chemical composition of the flow slag (Specimens 1, 2 and 4) are generally very similar; they are within the expected range typically seen in bloomery furnace flow slags. The comparatively low levels of the mineral phase wüstite suggests that the furnaces were being operated in an efficient way to reduce the amount of free iron being lost into the slag, and extract the maximum amount of useable iron from the ore.

The appearance of the fragment of slag that specimen 3 was removed from suggested that it may have collected within the base of a furnace before cooling and solidifying. The microstructure of specimen 3 suggests that the slag has cooled at a slower rate than the flow slag specimens, which is what might be expected in a slag that has been left to cool *in situ* within the base of a furnace. Although there is more free iron in specimen 3, it is still comparatively low for an iron smelting slag produced during the Iron Age.

The similarities in the microstructure of the slag specimens are reflected in their chemical composition, which suggests that, if the specimens are from different smelting events, the same (or very similar) ore and fuel sources were used on each occasion.

Discussion

The site lies on a large geological belt of iron-rich deposits (Jurassic ironstones) that runs through the Midlands to the north-east of England. Surveys of pre-industrial iron industry in the area have indicated extensive activity during the Late Iron Age to Roman-British period (Bellamy *et al* 2000; Schrüfer-Kolb 2004), and there are several significant ironworking sites within approximately 25km of Stamford. Although no dates were obtained from the furnaces, finds of pottery alongside ironworking debris from the pits surrounding the features, and the presence of further ironworking debris from deposits associated with the roundhouses, confirm that iron production occurred whilst the settlement was in use, *ie* probably within the Early to Middle Iron Age (5th to 3rd centuries BC). The furnaces found at the site therefore appear to be amongst the earliest examples in the area. Furthermore, analysis of the slags has suggested that a good level of expertise already existed locally at this time.

Iron production at the site was facilitated by the local availability of suitable ores. A significant background spread of what appeared to be fragments of weathered ironstone was noted across the site at the fieldwork stage, and British Geological Survey maps show ironstone deposits within 1km of the site, with outcrops in the immediate surrounding area (BGS 1974; Dixon 1979, 34). Given such close proximity of ore deposits and the relatively small scale of the iron production that appears to have been carried out at the site, it seems highly likely that the ore would have been sourced locally.

The degree of truncation of the two furnaces, probably from ploughing, makes it impossible to be certain about the furnace types. The absence of features resembling slag tapping channels or pits suggests that, if they were shaft-type furnaces, they were of the non-tapping variety. The absence of any fragments of tap slag in the slag assemblage also points to the furnaces being of the non-tapping type.

When taken as a whole, the archaeological evidence of smelting at the site is suggestive of relatively small-scale iron production. Only a small amount of smithing slag (around 2% of the slag assemblage) was recovered during fieldwork. It is possible that the iron produced by the furnaces was smithed just outside the excavated area, or that the archaeological evidence of smithing has been destroyed by later ploughing. Condron suggests that the expertise needed to forge and smith iron may have led to the development of specialised smithing centres in the area (1997, 5 and 10); this raises the possibility that blooms of iron from the furnaces may have been smithed elsewhere.

Despite the evidence for efficient iron smelting occurring on the site, its inhabitants were farmers first and foremost: furnaces aside, the settlement resembles other Iron Age farmsteads in the region. Plant remains, the animal bone assemblage and finds of quernstones combine to provide a picture of mixed subsistence agriculture overall, with an emphasis on livestock (cattle and sheep/goat, with some pig). Cereals grown include the barley and spelt wheat typical of the region and period.

It is uncertain whether the farmstead excavated during the project was the only contemporary settlement in the immediate vicinity of the furnaces: due to disturbance from modern housing and road construction, it cannot be established if people once lived in closer proximity to the north. If it is assumed that the farmstead stood in isolation, then the smelting would indeed have been peripheral (approximately 250m to its north). The furnaces may have been so-positioned for reasons of safety, or their apparent remoteness may be due to the proximity of ore and fuel, or clay for the furnace superstructures. However, it would be unwise to interpret the remains from a purely modern and functionalist standpoint, as other social or symbolic factors may have influenced decision-making here in the past. For example, the separation of the furnaces from the settlement may be due to some taboo: the presence of a large human skull fragment and a dog burial from pits 2006 and 2086 within the iron making area (Fig 2) might indicate that such a novel and transformative process, of likely high social and economic importance, was bound up with the ceremonial world of the site's inhabitants. Alternatively, the ironworkers may have wished to limit access to their activities, and so control the dissemination of their skillset, possibly to maintain their own status. Such a scenario might indicate a closed 'caste' of itinerant ironworkers, for which there are ethnographic parallels (*eg* Okafor 2004, 52–3). There are, however, numerous counter-examples of Iron Age smelting occurring in close proximity to settlement, *eg* Eversley Quarry, Berks (Cotswold Archaeology 2012) and Bryn y Castell, Gwynedd (Crew 1987).

Conclusion

Overall the archaeological investigations at the site have made a useful contribution to improving the understanding of how the area was settled and farmed during the Early to Middle Iron Age transition, and the part it played in the local introduction of iron production. The evidence of iron production is significant as it is one of the earliest smelting sites excavated in the area, if not the earliest. Due to the nature of the excavation, there were limitations on the scope of the scientific analysis, although examples of slag, ore and related residues are available at The Collection, Lincoln for future academic research. Such work might usefully involve analysis of the iron ore found during the excavation, alongside fresh samples of unweathered local ore to investigate the efficiency of the furnaces. This could lead to a better understanding of the furnace technology used at the site. More generally, the social circumstances of iron production have also been identified as meriting further study.

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