Two medieval bloomery sites in Shropshire: the adoption of water power for iron smelting

Tim Young and David Poyner
with contributions by V Bryant and A Clapham

ABSTRACT: Two bloomery sites in Stottesdon, Shropshire, were investigated to assess the local nature of medieval iron smelting and, in particular, the evidence for the use of water power. Topographical and geophysical surveys were followed by limited excavation to evaluate and date the sites, whilst avoiding significant structures. The 13th-century manually-blown bloomery at Ned's Garden lies on the outcrop of iron-stones within the coal measures. In contrast, the iron smelting at Cinder Mill, just off the outcrop of the ironstones, was probably sited to exploit the power of the water of the Fiddle Brook with smelting undertaken from late in the 14th century or early in the 15th, and possibly into the 16th century. The site is probably the 'bloomsmithy' recorded in mid-15th-century manorial accounts. The archaeometallurgical residues from the two sites were similar, being relatively iron-poor (46-62wt% FeO), with analyses from each site forming coherent compositional suites. Low-iron slags of the type described here form an important part of the current debate over whether later medieval water-powered furnaces mark a stage in an evolution towards the blast furnace. In this instance, it is argued that the introduction of water power appears to have had little effect on the chemistry of the smelting reaction.

Introduction

Over three decades ago Crossley (1981, 36) commented that 'The powered bloomeries of the 15th century have received little archaeological attention'; that situation has since changed little (Bayley *et al* 2008, Table 5). This contribution describes investigations of two bloomeries that exploited the same natural resources but one, of the 13th century, was manually-powered, whereas the other, constructed a century or more later, exploited the power of water.

The sites at Ned's Garden [SO 706840] and Cinder Mill [SO 705827] in the parish of Stottesdon, Shropshire, approximately 40km west of Birmingham, were identified during fieldwork by the Four Parishes Heritage Group. Topographical and geophysical surveys (Young 2007) were followed by trial excavation (Young 2008a; 2008b) and by detailed analysis of the iron-making residues recovered (Young 2011). The sites lie adjacent to small streams, approximately 1200m apart, on either side of a low ridge. The sites are close to (Cinder Mill), or on (Ned's Garden) the outcrop of clay-ironstones within the Carboniferous Coal Measures at a horizon just below the Brooch (or Broach) Coal (Fig 1).

Methods

Topographical surveys were undertaken by EDM. The magnetic susceptibility survey employed a Bartington MS2 meter with an MS2D loop on 2m spacings. The magnetic gradiometer surveys used a Geoscan FM256 fluxgate gradiometer on 0.5m sample- and 1.0m traverse-intervals.

Nine samples of archaeometallurgical residues from Ned's Garden (prefix NG) and ten samples from Cinder Mill (prefix FID) were analysed (Table 1). Electron microscopy was undertaken on the LEO S360 analytical electron microscope in the School of Earth and Ocean

Sciences, Cardiff University, with microanalysis using the system's Oxford Instruments INCA ENERGY energy-dispersive X-ray analysis system (EDS). All petrographic images presented are backscattered electron photomicrographs. The polished blocks were prepared in the Earth Science Department, The Open University. Bulk chemical analysis was undertaken using two techniques. The major elements (Si, Al, Fe, Mn, Mg, Ca, Na, K, Ti, and P) were determined on fused beads using the wavelength-dispersive X-ray fluorescence (WD-XRF) system in the Department of Geology, Leicester University (this also generated analyses for S, V, Cr, Sr, Zr, Ba, Ni Cu, Zn, Pb and Hf). Analysis for minor and trace elements (Sc, V, Cr, Co, Ni, Cu, Zn, Ga, Rb, Sr, Y, Zr, Nb, Mo, Sn, Cs, Ba, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Hf, Ta, Pb, Th, U) was undertaken on samples in solution using the ThermoElemental X-series inductively-coupled plasma mass spectrometer (ICP-MS) in the School of Earth and Ocean Sciences, Cardiff University.

The convention adopted here is to describe crystalline phases by their mineral names, as is common practice in archaeometallurgy, despite those names being strictly defined only for the natural occurrences of those phases. Olivine bearing Fe, Mg, Ca and Mn is described in terms

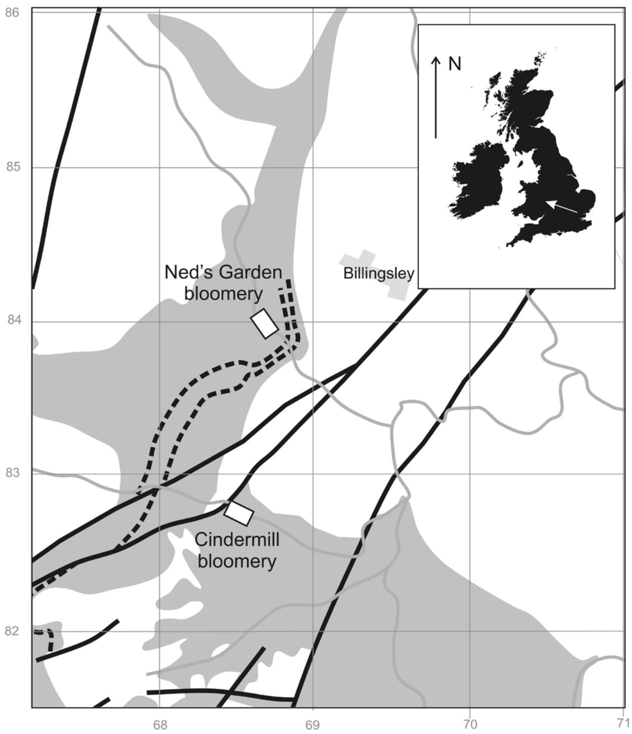

Figure 1: Location of Ned's Garden and Cinder Mill. National Grid 1km squares shown. Mid-tone shows outcrop of Coal Measures strata, with outcrop of major coal seams shown as dashed lines. Bold solid lines indicate faults Grey lines indicate rivers.

of an olivine on the forsterite-fayalite join (using the notation, for instance, of Fa95Fo5 for an olivine that is 95% fayalite and 5% forsterite) plus figures for the overall percentage replacement of iron and magnesium by calcium and manganese.

Ned's Garden

Historical background

Ned's Garden was an assart in 'Common Heath', Stottesdon. The adjacent Southall Bank Brook marks the parish boundary of Stottesdon with Billingsley and some of the evidence for iron-working lies on the east, Billingsley, side.

Late in the 12th century and early in the 13th, Stottesdon was a royal manor, held variously by the de Gamages and Pantulfs before being granted to John de Plessetis, later Earl of Warwick. In 1270, Henry de Plessetis gave the manor to John de Segrave. Although the dating of the bloomery is imprecise, the diversity of pottery (Appendix 1) hints at the period in the middle of the 13th century when John de Plessetis had pretensions to establish Stottesdon as a market town to rival its larger neighbours (obtaining grants of a market, an annual fair and free-warren; Purton 1933-34) and the manor was briefly of significance within the region. The encouragement of iron production in parallel with other revenue-generating activities, such as markets, is seen in other places at this time (*eg* Trellech: Howell 1995; 2000; Redknap and Young 1998, 114).

During the 18th century the area of Common Heath was again exploited for its iron and coal resources, as well as for quarrying the medieval slag for re-smelting. Notes written by Thomas Crump (late-19th-century copy of notes dated 1799, BGS: uncatalogued manuscript, Daniel Jones papers) describe the leasing of ironstone to Old Willey Furnace for eight years from 1707. Subsequently, in the 1730s, the mines supplied ironstone to Charlcotte Furnace (WA, BA 10470/4). Crump's manuscript also mentions the re-working of bloomery slag: 'There hath been in very antient times an old Furnace or Bloomery at the bottom of the Common Heath by the side of the Southal Bank Brook at a place called Ned's Garden where large quantities of furnace cinders or slag still remain and large quantities were carried from thence to Charlcot Furnace and iron extracted from them by stamping them and smelting over again'. Ironstone mining had largely ceased by the mid-1750s, but Crump makes clear that coal production continued later and mentions a water-wheel built to drive mine pumps on the Billingsley side of the brook.

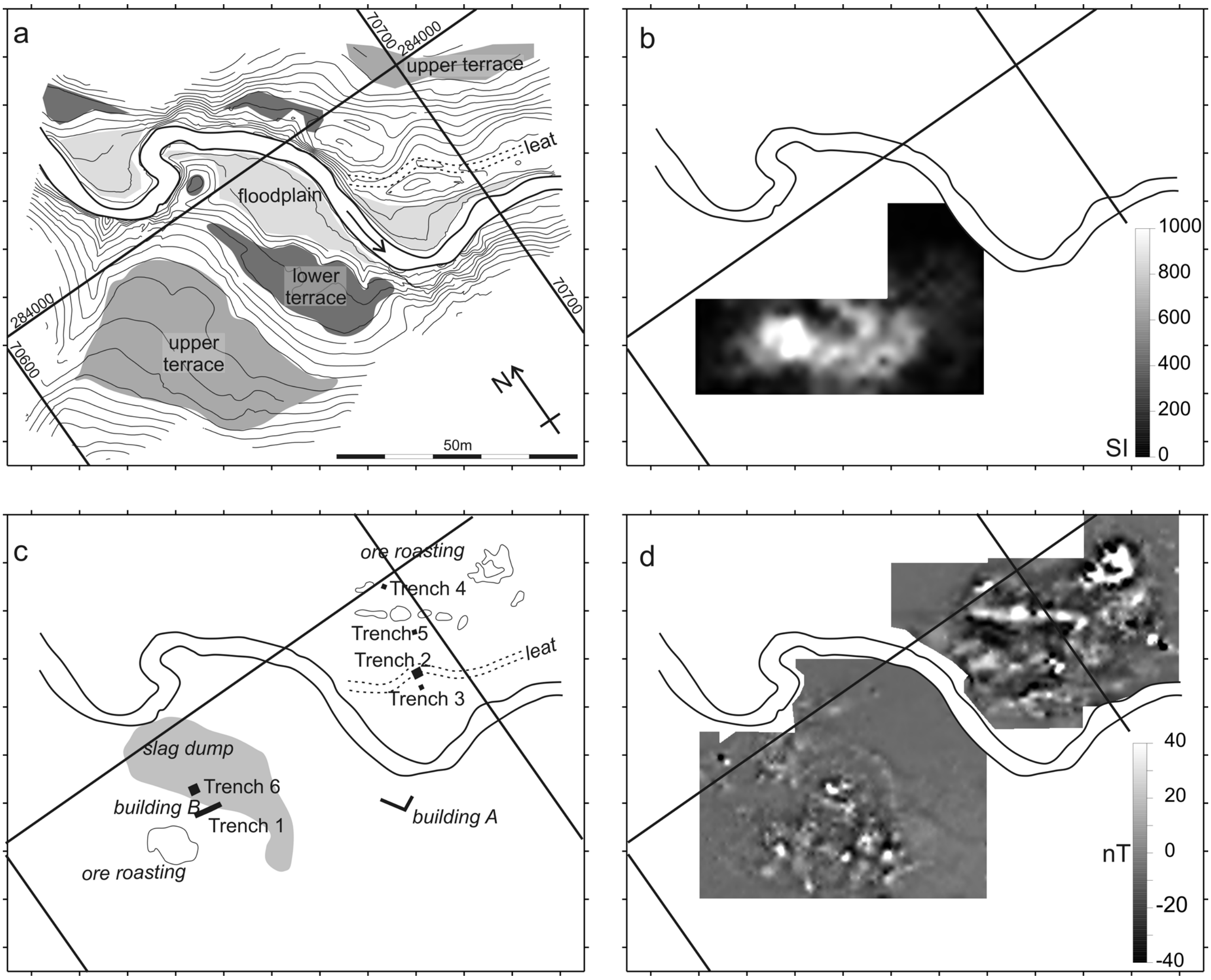

Figure 2: Ned's Garden. a) Geomorphology: pale tone = modern floodplain, dark tone = lower terrace, mid tone = upper terrace. Overlay is National Grid. Contours are at 0.5m intervals from the arbitrary site datum. b) Magnetic susceptibility survey results: Greyscale in dimensionless SI units. c) Summary interpretation. Pale tone = main western slag dump, dark fill = trenches. Unfilled outlines = peak magnetic gradient or peak measured magnetic susceptibility. d) Magnetic gradiometer survey: Greyscale -40nT (black) to +40nT (white).

Site description

Ned's Garden (Fig 2a) lies in a valley with a markedly incised stream, the Southall Bank Brook. Two narrow impersistent terraces lie at about 71m and 74m OD, above the present narrow floodplain (at 69m OD) of the brook (68m OD). A ridge rising to about 71m OD and running transversely across the valley towards the west of the study area is suggestive of an artificial dam, but examination of the section on its northern side indicated that it is a natural erosional remnant of the lower terrace. The site was investigated through two test trenches on the west bank and four on the east (Fig 2a).

On the west side of the valley, Ned's Garden itself, rubble and wall fragments suggest the locations of two post-medieval buildings: Building A in the south of the site and Building B on the upper terrace. Evidence for iron-making on the west side of the valley includes a slag dump, which appears to have been tipped forward of the upper terrace, burying part of the lower terrace and locally spilling as far as the floodplain. The magnetic susceptibility survey (MS; Fig 2b) shows values of 400-800 (dimensionless SI units) over this slag dump, even where slag was exposed at the surface, but areas on the upper terrace showed values locally well in excess of 1200, indicative of the presence of roasted ore. The magnetic gradiometer survey (Fig 2d) showed some localised intense anomalies on the terrace, probably indicating the location of ore-roasting hearths. Above the upper terrace are the remains of mineral extraction pits.

Testing was undertaken with a 1m x 6m trench (Trench 1), running north east from the surface traces of Building B towards the slag dump on the upper terrace margin. A second small test pit was positioned over building debris slightly further north west (Trench 6).

The lowest archaeological deposits (Fig 3) in the eastern part of the Trench 1, below the later slag dump, were rich in slag (c116), whereas to the west, the proportion of charcoal fines, pottery and of roasted ore increased markedly (c117). This suggests a differentiation into a western working area, possibly also with domestic occupation, and an eastern slag dump. The pottery suggests a date in the 12th-13th centuries for the initial occupation. The slag dump in the eastern part of the trench had a preserved thickness of about 550mm. Pottery from the body of the dump is of the 13th-14th centuries, but towards the top is largely of late in the16th or into the 17th century, indicating later disturbance. To the west of the slag dump, a brown clayey deposit (c114), containing 13th-century pottery, may have accumulated during abandonment of the site.

These deposits were sealed by an extensive layer (c112) bearing small flecks of burnt stone and coal, either cut by, or accumulated against, the base of the wall of Building B (c109). The wall showed a well-built inner face, but a very poorly constructed outer rubbly face that contained late 16th to 18th century pottery; similar pottery also occurred in the coal-bearing layer outside the wall. The wall terminated within the trench, apparently at a doorway. The interior of the building was partly flagged and was overlain by a building collapse deposit (c103) with 18th-century pottery.

In Trench 6 a superficial scatter of stone blocks, derived from building B, overlay a dark slag deposit, similar to the upper part of the dump in Trench 1 and yielded 17th-18th century pottery and clay pipes, indicating disturbance during the period of occupation of the adjacent Building B. The lower slag deposits were not excavated.

On the east bank, a ridge with slag deposits abuts the modern floodplain, with a marked gully, apparently a leat, to its north east (Fig 2c). Above the leat the hillside rises, with small slag dumps associated with the lower terrace margin, towards the upper terrace, which again shows very high magnetic susceptibility, locally in excess of 2700 SI units. The magnetic gradiometer survey also shows strong anomalies on this terrace and it is interpreted as an area of ore roasting (Fig 2d). Above the upper terrace, the hillside is marked by numerous pits which are believed to be ironstone workings.

Testing included a 2m x 2m test pit (Trench 2) on the side of the leat and a 1m x 1m test pit on the crest of the bank between the leat and modern floodplain (Trench 3). Trench 4 was positioned on the edge of the upper terrace in an area interpreted as being associated with ore roasting and Trench 5 on the slope below the terrace edge; both trenches 4 and 5 were 1m x 1m test pits (Fig 2c).

In Trench 3, the earliest deposits were silty sands (c304) bearing slag fragments and yielding a single sherd of 13th-century pottery, which rested on weathered natural. These were not primary slag dump deposits, and show a similarity with a silty deposit running down the western edge of the leat in the adjacent Trench 2 (c211). Above these sands, Trench 3 showed two horizons of re-deposited pale natural clay separated by a thin silty horizon (c302/c303). In Trench 2 the silty deposits on the side of the leat were overlain by a rather patchy deposit of similar pale re-deposited natural clay (c204). The relationship between the deposits on the side of the leat in Trench 2 and those in its base are unclear; the lowest deposits in the leat show no direct relationship to the slope deposits, whereas subsequent water-lain deposits appear to have been deposited after the silty deposit on the flank. The upper layers in the leat were rich in medieval slag, but also yielded 18th-century pottery; the lower fills yielded no pottery. The base of the leat was only 0.5m above the brook level at the time of survey, so would have required only a very modest weir to raise water level sufficiently to divert flow.

In Trench 4 the topsoil rested directly on a hard, compact,

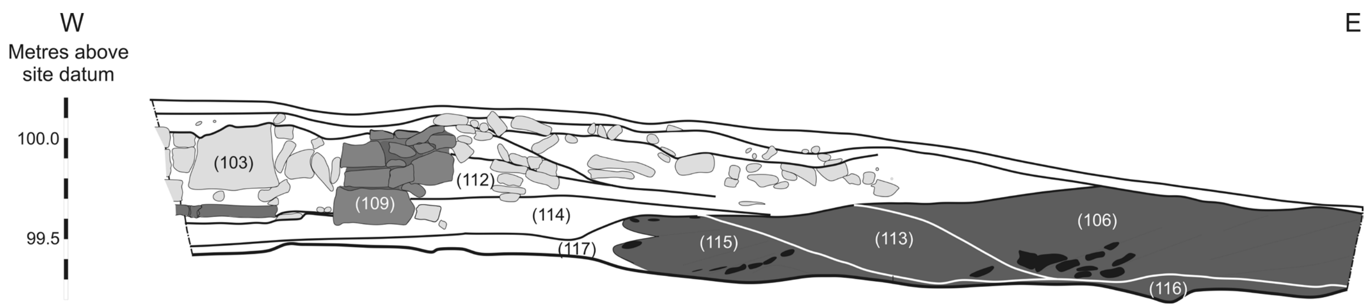

Figure 3: Ned's Garden: south-facing section of Trench 1. Dark tone = extent of slag dump with large slag pieces in black; mid tone = in-situ elements of the post-medieval building; pale tone = stone

clay surface with patches of reddening and local areas of impressed coal fragments. This surface is similar to the re-deposited clay surfaces recorded in trenches 2, 3 and 5. The burning raises the possibility that ore roasting had occurred upon it. The trench was closed without excavating through the surface.

Trench 5 was situated on a low rise to the east of Trench 2 and below Trench 4. The lowest observed context was a compact orange clay surface, which was overlain by deposits with slag, overlain in turn by a second clay surface, containing some slag, charcoal and coal. This surface was overlain by a dark brown soil and the modern topsoil. The upper contexts yielded pottery dated to the 16th to 18th centuries.

Site summary

The west side of the valley at Ned's Garden provided evidence for a medieval working area and slag dump associated with bloomery iron smelting. Pottery evidence suggests a 12th-13th-century age for the onset of smelting with cessation by early in the 14th century. The location of the slag dump on the margins of the upper terrace indicates that smelting is likely to have been undertaken well above any feasible location for water power. The upper part of the slag dump yielded late-16th/early 17th-century pottery, indicating disturbance associated with the occupation of Building B, which pottery evidence suggests was occupied until late in the 18th century and is interpreted as the cottage within 'Ned's Garden'.

On the east bank of the brook, although medieval pottery was located in several contexts, the majority of features appear associated with the post-medieval exploitation of iron ore, coal and slag. There were widespread surfaces of re-deposited natural clay, associated with abundant 16th-18th-century pottery. Some of these surfaces were probably used for ore-roasting. None of the deposits of iron-working residues on the east bank was necessarily *in situ*. There is no evidence to date the leat earlier than the 18th century and it probably supplied water to the waterwheel Crump described as having been employed for mine drainage early in the 18th century. Thus on neither side of the valley is there evidence for the medieval use of water power.

The survival of such an extensive early industrial landscape at Ned's Garden, with its areas of intensive pitting on both sides of the valley representing early ironstone extraction (including a medieval component) as well as later coal extraction and slag re-working, makes this a site of both regional and national importance.

Cinder Mill

Historical Background

It seems likely that the Cinder Mill bloomery was established while the Mowbrays, Dukes of Norfolk, held Stottesdon late in the 14th or early in the 15th century. It is not mentioned in accounts for Stottesdon covering 1442-5 (HRO: A63/I/398), but a bloomery was certainly in the possession of John Mowbray by 1455/6 when his steward paid John Grove, carpenter, 66s 8d for the making of a new pond with floodgates for the 'bloomsmithy'. The steward was also dispatched to the Forest of Dean to find a new bloomsmith and then to Sheffield. The accounts also record a new rent for mines of ironstone (Dyer 2005, 110; HRO: A63/I/399). Accounts for the manor of Stottesdon for 1479-81 make no mention of any receipts for ironstone or iron (BCM: BCM/D/5/74/21, BCM/D/5/74/22). The bloomery may then have been out of use, but as may have also been the case with the 1442-5 accounts, it may simply be hidden under the general rents.

The site was again documented during the 17th century when the dwelling of the Reynolds family, millers, was given as 'the Smythie' (1603) and 'Cynders Mill' (1653) (HRO, wills of John Warton, Stottesdon, 6th June 1603 and Adam Nicholls, Farlow, 15th November 1653). There seems little doubt that their dwelling was the structure on the platform at Cinder Mill, but whether the mill itself used the bloomery site or was situated on a leat to the south side of the brook is uncertain. Cartographic evidence indicates that the house was demolished before 1810 (SA: Kinlet estate map and terrier, MIC 207).

Site description

Cinder Mill bloomery lies within a curious bend of the Fiddle Brook (Fig 4a), which enters the survey area from the west, swings southwards across the valley floor, leaving the floodplain to become incised into the southern valley slope, passing to the south of a marked bedrock ridge within a shallow gorge, before re-entering the floodplain to the east of the site. The most likely interpretation of this unusual geomorphology is that the modern stream exploits (and has deepened) the course of an artificial spillway from the southern side of the pond. The surface level of the stream at the time of survey showed a 2m fall from the west of area to the outfall of the tailrace.

The most likely configuration of the site (Fig 4c) would be for the pond to have been held by a dam along the line of the modern river between the western end of the bedrock ridge and a prominent bedrock knoll on the north side of the valley. A spillway, probably with a sluice placed where the stream now enters the gorge, kept floodwaters away from the low-lying bloomery itself. The valley floor is occupied by a slag dump, 40m by 20m, and probably originally at least 1.5m thick in the centre. Most of the core of this dump has been quarried away, but it would have had an original volume of at least 800m^3.

The line of the tailrace is marked by a 5m-wide hollow along the base of the northern valley side. To the east there is a flat zone about 6m wide adjacent to the tailrace, below the hill-slope, which towards the west becomes overlain by slag (possibly a second slag dump), with an abrupt, possibly quarried eastern margin. To the west, the tailrace has been largely filled by material derived from the steeply-rising hillside to the north. The hillslope passes at the west of the area into an upstanding knoll of bedrock, with a hollow, possibly a small quarry to its west. To the north of the knoll and possible quarry, there is a platform that is apparently the site of the post-medieval dwelling. This platform extends eastwards into a narrow terraced path or track leading upslope.

The intensely-featured magnetic survey of the platform and adjacent hillside is difficult to interpret, but the rectilinear nature of some anomalies suggests that they may be contained within buildings. The large magnetic anomalies on the upper part of the slope are likely, as at Ned's Garden, to represent ore roasting sites. A single substantial positive anomaly (>200nT), 1.5m in diameter and close to the line of the tailrace, may indicate the furnace location.

The site was tested with a single trench (Figs 4c and 5) which was located to avoid the probable location of the furnace and wheel-pit, but to determine whether the water power was associated with the bloomery, or with a separate phase of use of the site as a corn-mill. The trench lay across the course of the tailrace and upslope to its north. The wheel-pit is interpreted to lie between the excavation trench and the modern river bank 7m to the west. The tailrace was approximately 5m wide, but its full depth is unknown; it was excavated down to the water table at approximately 80.15m OD (1.85m below modern surface; the same level as that of the water in the stream immediately to the west).

In the north of the trench, metalled surfaces, initially of stone (c1023), later of slag (c1021), extended to within about 2.25m of the tailrace. To the south of these surfaces (and also progressively encroaching on to them) was a succession of alternating layers rich in charcoal and

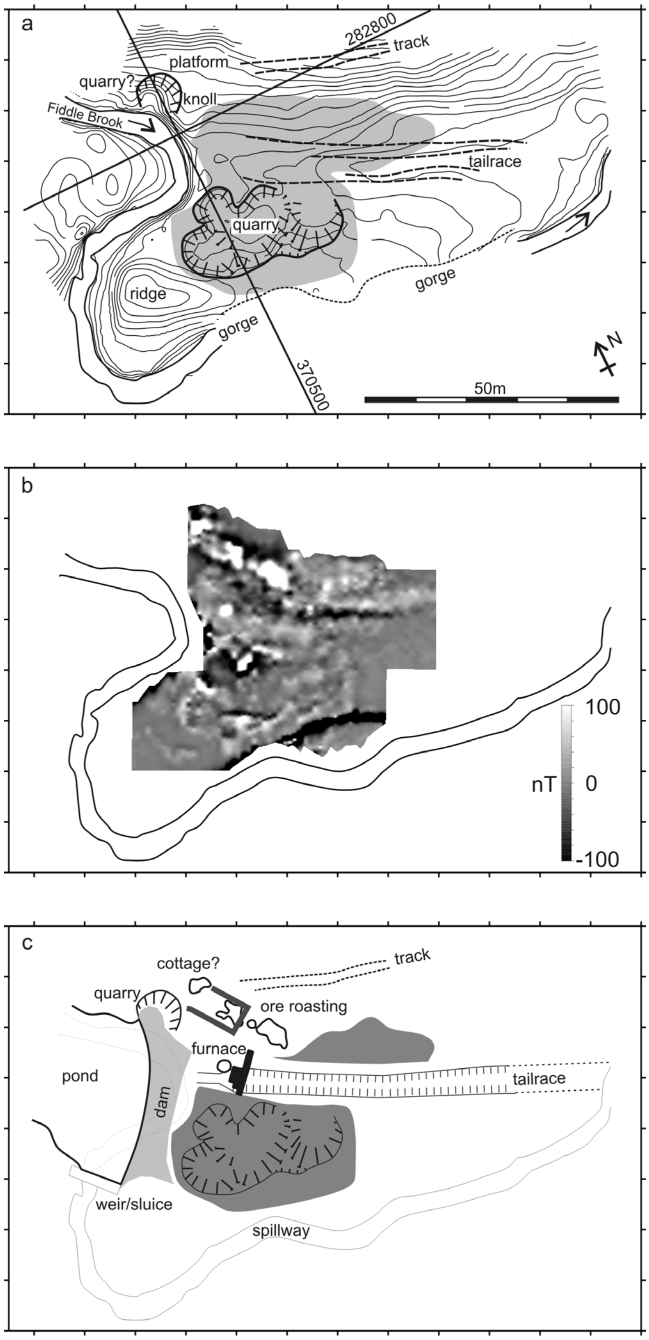

Figure 4: Cinder Mill. a) Geomorphology and surface features: The tone indicates the present slag spread. Overlay is National Grid. Contours are at 0.5m intervals based on the OS datum. b) Magnetic gradiometer survey: Greyscale -100nT (black) to +100nT (white). c) Summary interpretation: Dark tone = original slag dumps; pale tone = likely position of the (now-eroded) dam. Unfilled outlines = magnetic highs, interpreted as ore roasting areas and a possible furnace location.

iron ore fines. At least four sheets of very fine-grained ore particles occurred and are interpreted as being ore debris washed down from the upslope working surfaces. The intervening charcoal-rich deposits were clay-rich and are interpreted as 'background' accumulation. Midway between the metalling and the tailrace there was a shallow circular feature, which either cut through the earliest deposit of charcoal fines or had contained an

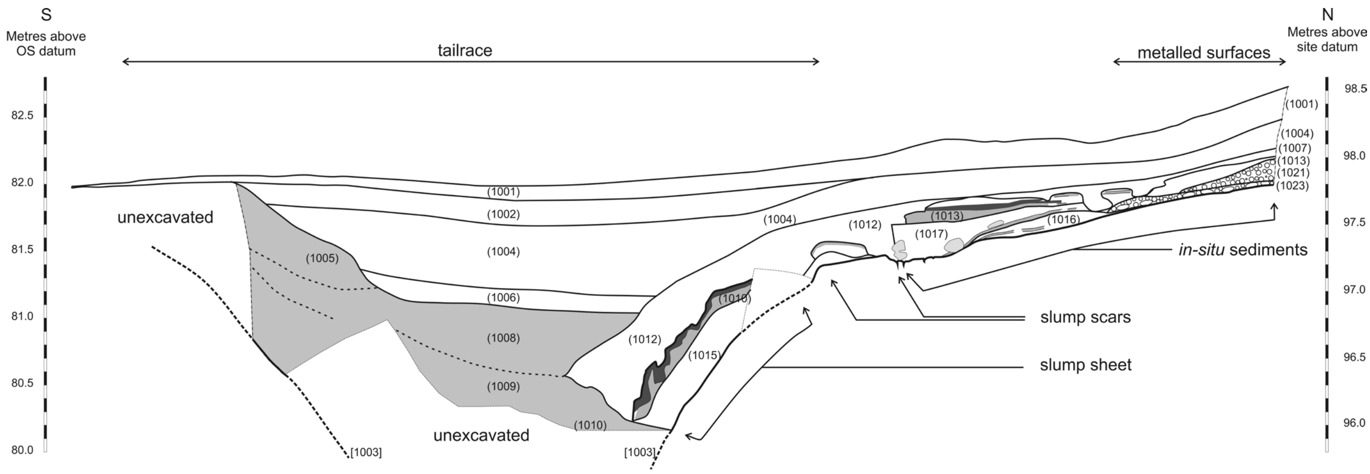

Figure 5: Cinder Mill: east-facing section of the excavation trench. Mid tone in the tailrace = extent of slag-rich deposits. Dark tone on north bank = charcoal-rich deposits; mid tone = deposits rich in ore-fines.

object (post?) which locally prevented its accumulation.

Close to the tailrace margin, the depositional sequence of the northern slope was interrupted by irregular, steep, cross-cutting discontinuities, interpreted as a slump scars. The corresponding detached slumped sheet was steeply inclined down into the northern side of the tailrace and showed abundant internal deformation. The angle of accumulation of the deposits immediately up-slope from the tailrace was too low for simple slope-wash, unless they supported or constrained at the down-slope end. Taken together with the subsequent slumping, this suggests that the tailrace was originally lined (or possibly even roofed) with a timber structure, the decay of which induced the failure of the adjacent deposits.

Small diameter round-wood birch charcoal from the lowest levels north of the tailrace (c1016) gave a radiocarbon date (Beta-311353) of cal AD1324-1345 (10.5%) or 1392-1443 (84.9%). There was very little pottery from the medieval deposits, but three sherds from the slump sheet are dated as 14th-16th century and one as 13th-14th century. Although correlation between the slump sheet and the *in situ* deposits on the north side of the tailrace is tentative, it is clear that two of the three sherds must come from low in the stratigraphic section, giving a *terminus post quem* in the 14th century for the interlayered stratigraphic sequence, broadly in agreement with the radiocarbon date. The lowest deposits in the tailrace yielded a substantial, if abraded, piece of chafing dish of 16th-century date (giving a *terminus post quem* for its infilling).

Much of the fill of the tailrace is a deposit of slag, probably derived from the dump to the south and possibly also representing collapse of the adjacent deposits after decay of the putative lining. The basal deposits in the tailrace were also slag-rich and must have been in place before the collapse of the northern side.

The deposits on the slope to the north of the tailrace were truncated by an irregular (rooted?) horizon with 16th-18th-century pottery. Within the tailrace, dark, slag-poor deposits (c1004, 1006), with abundant pottery and other domestic detritus mainly of 18th-century date, are interpreted as belonging to the garden of the post-medieval cottage. These deposits were overlain by further slag-rich material, suggesting some re-working or spreading of the slag dump late in the history of the site. There was no evidence that any post-16th-century deposits were associated with an active watercourse.

Site summary

The working areas of the Cinder Mill bloomery lay on the northern slope and platform, with waste disposal mainly on the low-lying valley floor. The excavation was specifically designed to avoid the likely furnace site, so there is no absolute certainty that the wheel powered the bellows. However, the presence of ore and charcoal fines in the sediments adjacent to the tailrace and the lack of any macroscopic or microscopic smithing residues from the excavation, strongly suggests that the water power was applied to a furnace and not a hammer. There is no evidence that the onset of iron-making pre-dated the watercourse and there is no evidence that the watercourse had been used to power a mill of a different (earlier or later) period.

It is likely that the tailrace within the excavated area was timber-lined and may have been culverted with a timber covering. The timber structures eventually decayed, with

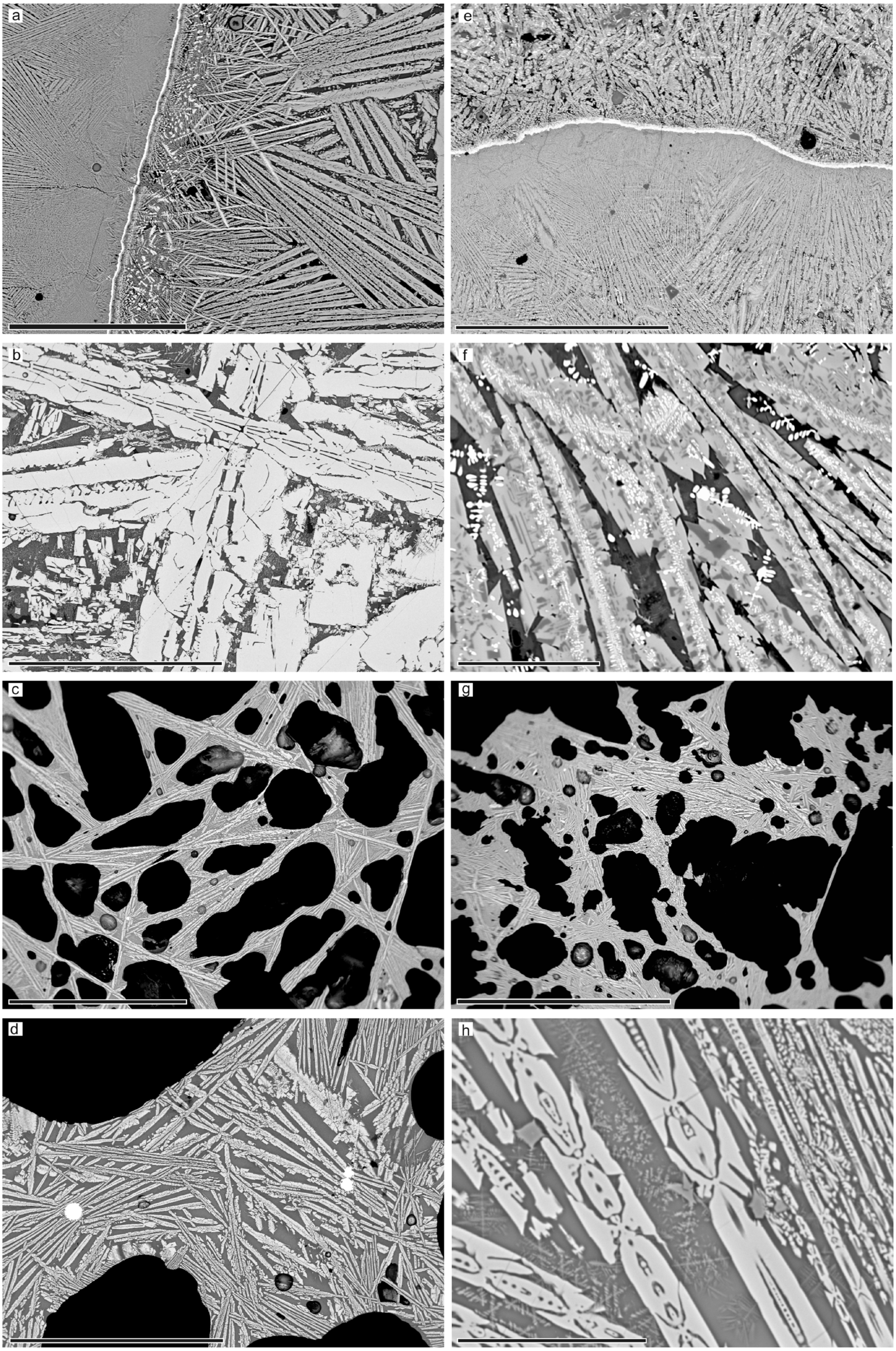

Figure 6: Back-scattered electron micrographs of slag samples. Left column are samples from Ned's Garden; right column are samples from Cinder Mill. Upper two rows show samples from slags with low-porosity; lower two rows show porous slags. a) Sample NG5 SOI4, scale bar 200µm. b) Sample NG3 SOI1, scale bar 600µm. c) Sample NG2 SOI4, scale bar 2mm. d) Sample NG2 SOI7, scale bar 600µm. e) Sample FID 12 SOI5, scale bar 600µm. f) Sample FID 12 SOI2, scale bar 100µm. g) Sample FID 4 SOI2, scale bar 4mm. h) Sample FID 1 SOI4, scale bar 50µm.

Table 1: Slag sample descriptions categorised by broad degree of vesicularity.

	Ned's Garden	**Cinder Mill**
High Porosity	NG2 (Fig 7c-d) - dominated by olivine in long thin crystals in glass - olivine Fa94-97 with up to 0.6% Ca and 2.1-2.5% Mn - interstitial glass bears droplets of iron. NG6 - dominated by olivine in long (<20mm) thin crystals - olivine Fa96- 98 with 1.0-1.7% Ca and 2.2% Mn substitution - clear textural similarities with NG3	FID4 (Fig 7g) - dominated by olivine in long (<5mm) thin crystals - olivine: Fa86-90, with 0.6-0.8% Ca and 2.6% Mn - interstitial glass bears a few dendritic outgrowths from the olivine, together with small angular dendrites of hercynite with about 6% magnetite.
Medium Porosity		FID1 (Fig 7h) - main texture has long thin olivine crystals (<1mm long) forming a meshwork, within which there are bundles of smaller crystals. - olivine Fa89-91 with 0.3-0.6% Ca and 1.3-1.6% Mn. The interstitial spaces occupied by glass bearing fine equant crystals and finer dendrites of hercynite with 7-8% magnetite, with 2% Ti and 1% Mn plus low levels of Cr and V - rare small blebs of iron.
Low Porosity	NG3 (Fig 7b) - large olivine crystals (< 20mm) mainly perpendicular to the base of internal units. - main phase olivine grades from Fa94 with 0.3-0.7% Ca and 1.4% Mn substitution, through to Fa98-Fa99 with similar substitutions. - a second generation of olivine, typically Fa99-100 with 0.9-1.3% Ca and 1.3% Mn substitution, forms skeletal crystals and dendrites within the interstitial areas. - This late olivine is intimately associated with small (10µm) equant grains and dendrites of hercynitic spinel with cores rich in magnetite (44-47%), but decreasing to about 28% magnetite outwards with low levels of Mn and Ti substitution. These late minerals occur within an interstitial glass which bears a third, even finer, generation of dendritic growths, too small to analyse, but probably of olivine and hercynite.	FID12 (Fig 7e-f) - the flow lobes showed chilled oxide margins (probably largely magnetite) closely associated with 10-15µm euhedral hercynite (with 9% magnetite). - the hercynite is overgrown by sparse dendrites of magnetite with approximately 33% hercynite, followed by fine-grained olivine (Fa90 with 0.9% Ca and 2.1% Mn substitution). - the interstitial glass bears a very fine crystalline phase – possibly an olivine. - within the cores of the flow lobes the texture is slightly heterogeneous: again, the primary phase appeared to be euhedral hercynite, with a grain size of up to at least 80µm and with zonation from cores with around 8% magnetite to 13% magnetite near the margins. The distribution of hercynite shows a strong relationship to that of early wustite dendrites, which show arrays of up to about 500µm. This was the only specimen to contain wustite. These two early phases are followed by sheaves of long (locally >1mm) fayalite crystals which contain cotectitic wustite and hercynite.
	NG5 (Fig 7a) - largest olivine crystals (300µm wide by several mm in length) in the lobe cores show centres of Fa91with 0.5% Ca and1.8% Mn margins of Fa97 with 0.8%C a and 1.7% Mn. - the interstitial areas have fine olivine dendrites of Fa98-100 with 1-4% Ca and 1.5-1.9% Mn and hercynite dendrites with 20-30% magnetite. - the margins of the flow lobes have an altered surficial layer, possibly including magnetite (maximum 5% hercynite) over olivine (Fa91 with 1.6-1.9% Ca and 2.5-2.6% Mn). The chilled surface also supports inward-growing dendrites of magnetite with 21-22% hercynite.	FID11 - with cotectic olivine and hercynite. - olivine: Fa94 with 0.8% Ca and 1.3% Mn substitution in centre, Fa100 with 3.8% Ca and 1.0% Mn substitution on margin - euhedral equant hercynite contains 4-16% magnetite (increasing outwards), sometimes with continued outwards growth into a blocky intergrowth of hercynite with about 23% magnetite and a titaniferous spinel (magnetite with 38% hercynite and 15% ulvopsinel). - late spinels are associated with rounded grains of leucite and overgrown by elongate crystals of rhönite - remainder of the interstitial space is occupied by late-stage calcic olivine (typically Fa100 with 12.5% Ca and 1.0% Mn substitution), a finely lamellar (?)calcium phosphate and glass. - some vesicles are surrounded by areas rich in leucite

subsequent failure of deposits which had accumulated against or upon them to the north and possibly to the south as well.

The radiocarbon date for the earliest deposits north of the leat might indicate either a date in the second quarter of the 14th century, or a date between the last decade of that century and middle of the 15th century. The small amount of pottery also suggests occupation from the 14th century at the earliest; there is no overlap in the medieval pottery fabrics from Cinder Mill with those from the earlier Ned's Garden site, suggesting there was no overlap in date. The 16th-century pottery from the base of the tailrace provides the earliest date at which the tailrace could have become infilled. The archaeological evidence is thus compatible with the historical evidence for the 'bloomsmithy' being in existence in the mid-15th century. A building, presumably that on the platform, was occupied from at least the beginning of the 17th century, but it is not known whether this building was a survivor from the medieval bloomsmithy.

Despite the possible loss of the dam from river erosion, the potential survival of a water-powered bloomery furnace and ancillary structures gives this site, too, regional and national significance.

Archaeometallurgical residues

Slag description

The morphology and structure of the slags tapped from the smelting furnaces at Ned's Garden and Cinder Mill are broadly similar (Table 1). Dense tap slags of 'conventional' appearance (with well-preserved small flow lobes) occur, but are associated with much larger volumes of slag that are moderately to highly vesicular and with some that are extremely vesicular (frothy; the 'honeycomb' texture of Dungworth 2010).

The moderately to highly vesicular slags frequently form flows with broad, low-convexity flow lobes, or simply slag puddles with flat tops. These, flat-topped slag cakes have iron contents in the centre of the compositional range. They have moderately dense lower parts, sometimes with tubular vesicles, but the vesicularity often increases abruptly upwards and is capped by a rather thin upper chilled surface. These features suggest that the vesicular slag was the result of the tapping of a large

Table 2: Major element chemical analyses (by XRF) expressed as wt% oxides.

sample		context	SiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	LOI	total
NG2	slag	106	39.38	8.12	46.44	41.80	1.19	1.21	1.47	<	1.15	0.50	0.17	-3.58	99.81
NG3	slag	113	27.53	5.81	60.57	54.51	0.78	0.80	1.11	<	0.88	0.36	0.25	-5.69	98.38
NG4	slag	113	34.05	7.33	51.50	46.35	0.98	1.20	1.34	<	1.16	0.43	0.21	-5.04	98.51
NG5	slag	115	28.40	7.40	56.68	51.02	1.02	1.34	1.79	<	0.95	0.40	0.31	-5.13	98.48
NG6	slag	115	32.42	6.37	55.41	49.87	0.87	0.96	1.15	<	0.84	0.41	0.39	-5.13	99.01
NG9	slag	301	26.62	7.81	57.72	51.95	0.81	1.53	1.36	0.01	1.10	0.46	0.47	-5.22	98.12
NG10	clay	114	63.40	23.93	4.13	3.72	0.08	0.94	0.25	<	1.94	1.26	0.04	2.48	98.65
NG11	ore	111	12.46	6.13	56.23	50.61	1.07	0.18	0.17	<	0.17	0.08	0.03	22.49	99.07
NG12	ore	U/S	32.58	5.69	41.91	37.72	0.69	0.67	0.34	<	0.55	0.26	0.25	15.21	98.31
FID1	slag	1005	31.87	10.24	48.13	43.31	1.15	1.67	2.80	0.03	1.68	0.53	0.53	-4.64	98.91
FID4	slag	1008	33.18	11.76	44.37	39.93	1.37	2.04	3.01	<	1.93	0.59	0.61	-4.16	99.36
FID5	slag	1008	35.24	11.64	44.88	40.39	1.00	1.86	1.59	<	1.49	0.58	0.36	-3.73	98.97
FID10	slag	1015	25.63	10.80	54.01	48.61	1.28	2.51	1.96	<	1.06	0.44	0.78	-1.60	98.72
FID11A	slag	1017	25.69	8.02	59.27	53.35	0.70	1.34	1.88	<	1.18	0.41	0.68	-5.67	99.52
FID11B	slag	1017	25.61	8.20	58.30	52.47	0.69	1.24	1.99	0.01	1.25	0.43	0.69	-5.78	98.78
FID11C	slag	1017	24.80	7.60	58.70	52.83	0.74	1.53	1.79	0.01	1.02	0.40	0.64	-5.67	97.57
FID12	slag	1021	21.73	8.39	63.50	57.15	0.98	1.72	1.56	<	0.87	0.41	0.68	-4.47	100.06
FID13	clay	1008	62.77	22.54	8.40	7.56	0.12	0.61	0.19	<	1.01	1.16	0.09	0.83	97.99
FID14	clay	1015	57.07	16.84	11.60	10.44	0.18	0.67	0.64	<	1.02	0.88	0.08	9.85	99.28
FID27	ore	1013	18.61	4.02	67.83	61.05	1.04	0.33	0.23	<	0.37	0.24	0.27	4.61	98.09
FID6	ore	1010	41.84	15.76	32.46	29.21	0.34	0.80	0.39	<	1.17	0.75	0.12	5.13	99.19

Notes: Columns in tone indicate values recalculated with the iron expressed as FeII. LOI = loss on ignition. < = below detection.

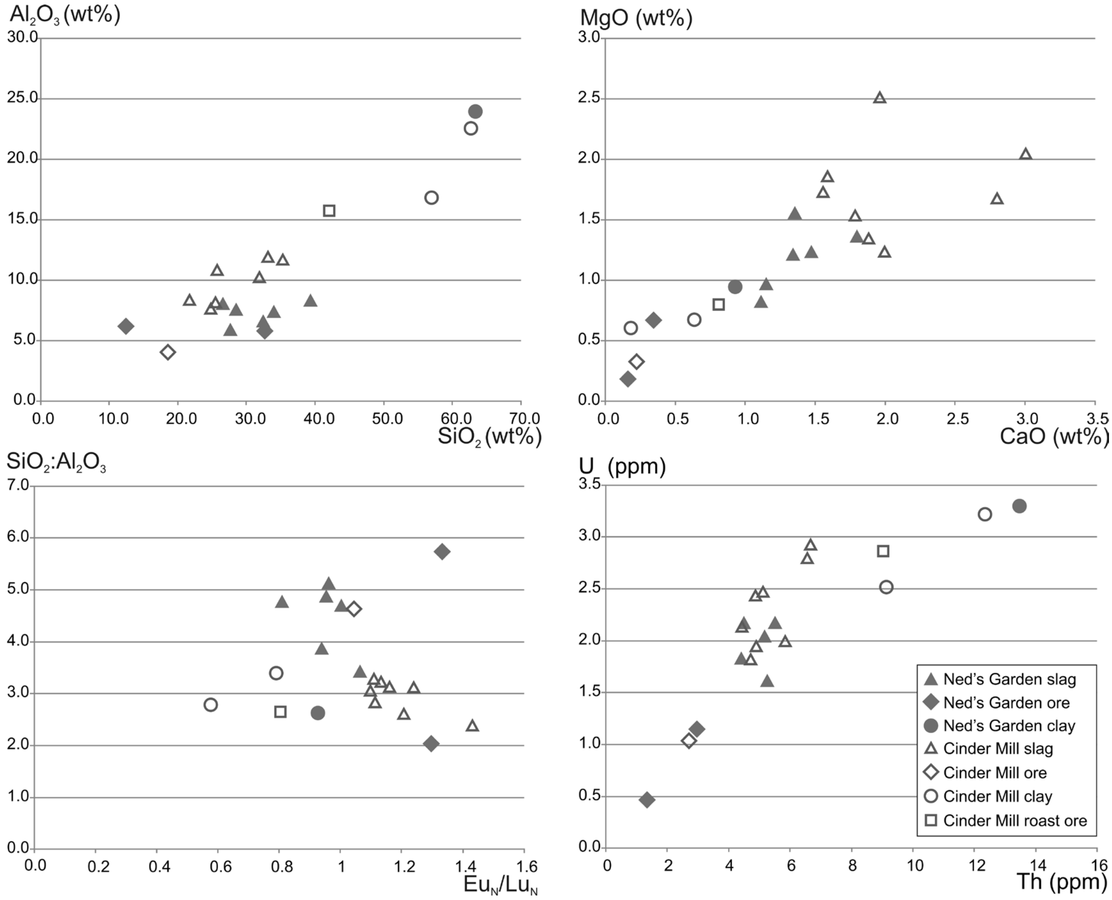

Figure 7: Binary scatter plots illustrating aspects of the bulk chemical composition. E_N is the upper crust normalised concentration of element E.

volume of gas-rich highly fluid (high-temperature?) melt. Degassing destroyed any primary flow textures within the body of the cake, although flow lobes are sometimes preserved on the base and lateral margins, but chilling of the upper surface appears to have prevented complete gas escape. In some cases denser (less vesicular) tap slags of more conventional appearance (with narrow, high-convexity flow lobes), can be observed to have flowed over the top of the vesicular slag to form a composite cake. The occurrence of tap slags of more conventional appearance later in the smelt might be due to a change in slag composition – but equally might simply be due to improved degassing at lower rates of slag production.

Extremely vesicular slags form rounded masses, often of very low density, suggesting flows of a much more viscous nature. Some of these pieces are of runner-like form, others are more globular and sometimes hollow. The extremely vesicular slags tend to be mainly greenish to greenish-yellow in colour (as opposed to the denser slags that are grey) and lie at the iron-poor end of the compositional range.

Most tapped slags are highly fragmented, but some rare individual examples are reasonably complete, one of which, a tapped slag cake of composite texture (moderately vesicular, flat-topped puddle, overlain by conventional dense flow-lobed slags) from within the leat at Cinder Mill, weighed approximately 8.5kg.

The slag microstructures are illustrated in Figure 6 and key features given in Table 2. The low-density, iron-poor slags show simple microstructures in which the porosity is created by the interstices of a texture dominated by long, narrow olivine crystals (Figs 6c-d, 6g-h). These are associated with minor hercynite in the interstitial glass and in some cases with rather abundant iron droplets. The medium-density slags are texturally similar, apart from the lower degree of porosity.

The dense slags tend to show slightly more complicated paragenesis, with common spinels and, in the case of one sample from Cinder Mill, a range of late-stage minerals including a calcium phosphate, rhönite and leucite (Figs 6a-b, 6e-f).

Chemical composition

The smelting slags from the two sites form two suites of compositions differentiated particularly by their silica:alumina ratio, which is higher (Fig 7, upper and lower left) for slags from Ned's Garden (3.4-5.1) than

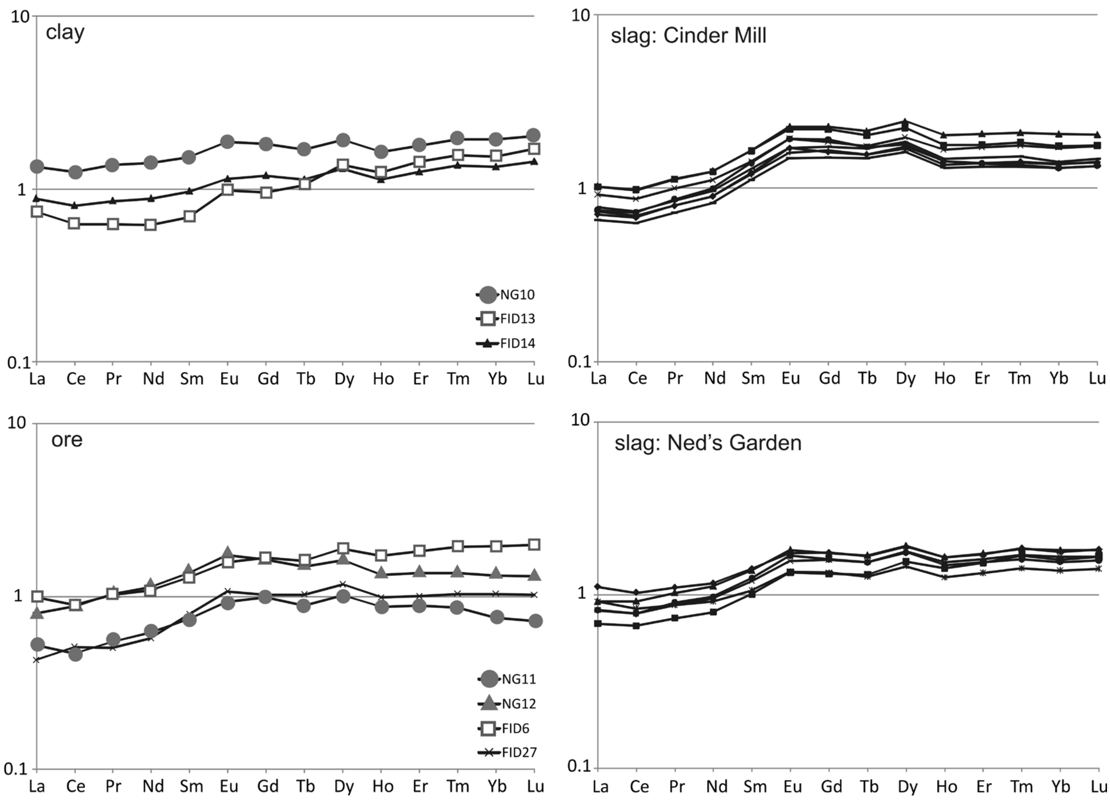

Figure 8: Upper crust normalised rare earth element profiles for furnace ceramics, ore and slag samples (normalisation factors after Taylor and McLennan 1981).

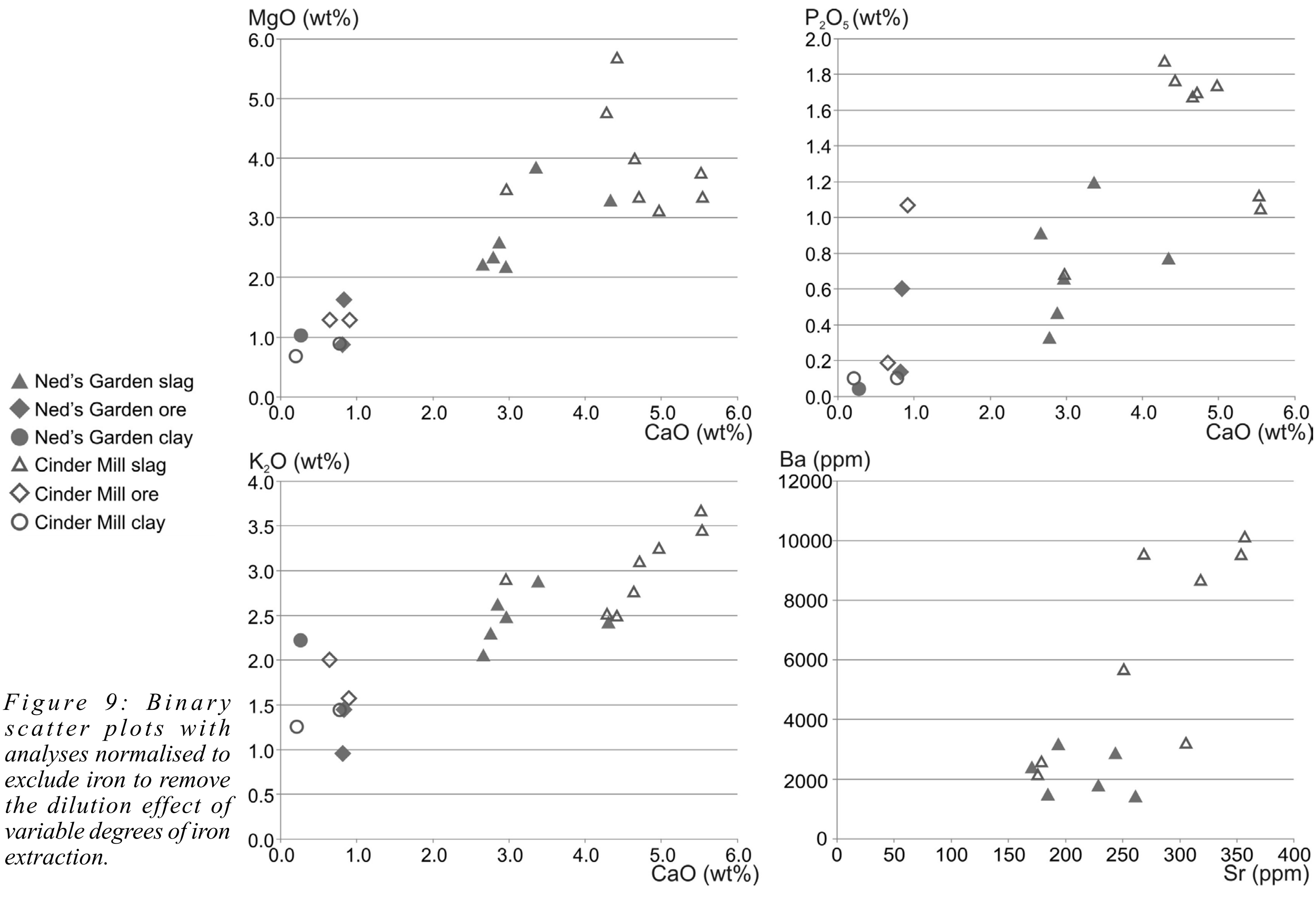

Figure 9: Binary scatter plots with analyses normalised to exclude iron to remove the dilution effect of variable degrees of iron extraction.

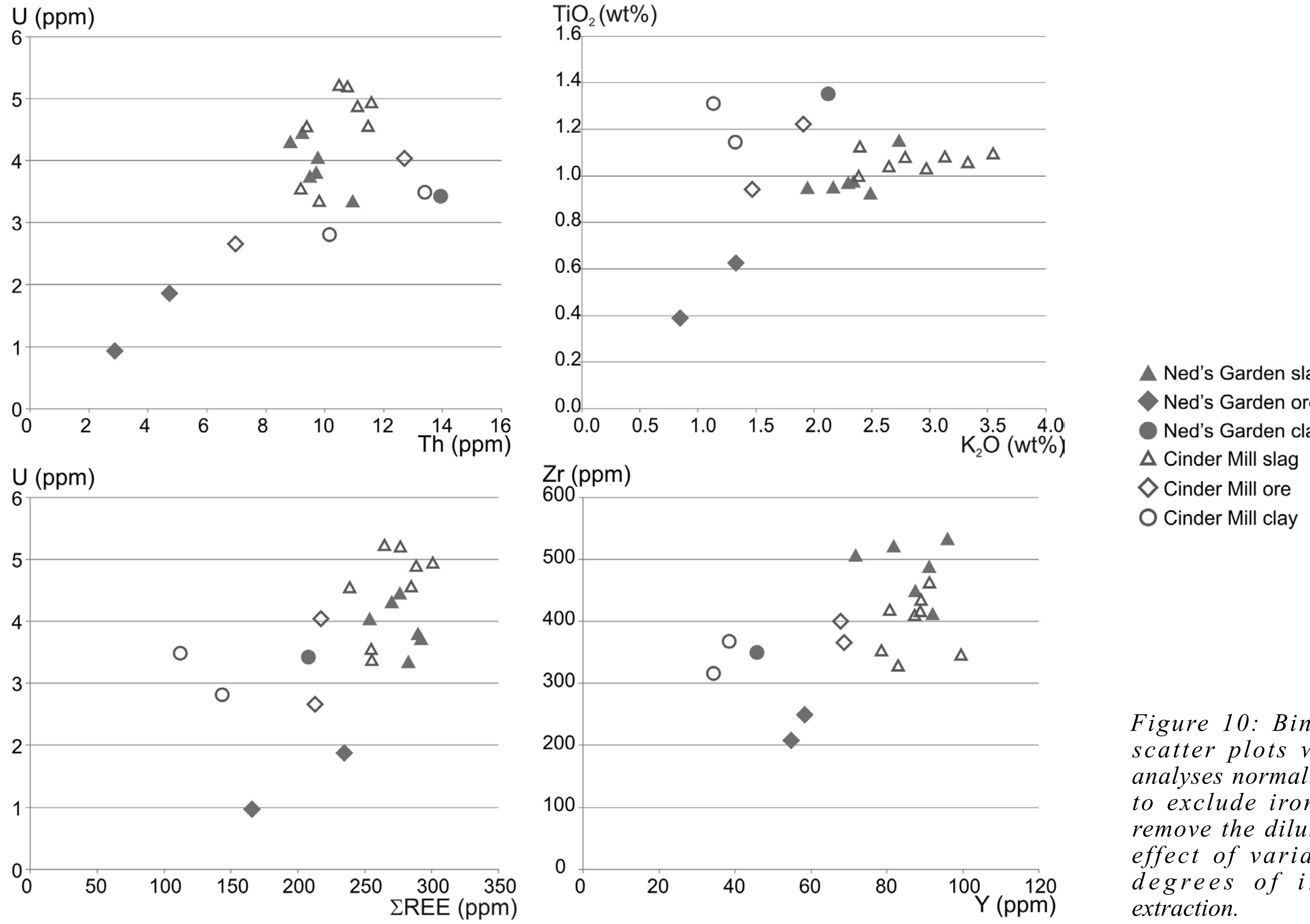

Figure 10: Binary scatter plots with analyses normalised to exclude iron to remove the dilution effect of variable degrees of iron extraction.

for those from Cinder Mill (2.3-3.3). The Si:Al ratio of a smelting slag is controlled by the relative proportions of these elements in the both the ore and the furnace lining, together with the mix of these components in the slag-forming reaction (Thomas and Young 1999a; 1999b). Interpretation is hampered by the rather variable and probably unrepresentative analyses of ore particles. In contrast, the small numbers of analyses of technical ceramic from the two sites cluster closely in terms of silica and alumina contents. It is likely, therefore, that the dominant control on the Si:Al ratio of the slag will have been the ore composition; that utilised at Ned's Garden being more relatively siliceous than that at Cinder Mill. The Si:Al ratio of a coal measures ironstone will be very sensitive to the grain-size of the host sediment (siltstones typically having a higher Si:Al ratio than claystones). Confirmation of this would, however, require the acquisition of analyses of more representative ores. The Cinder Mill slags are also richer in Mg, Ca, Ba and P than those from Ned's Garden (*eg* Fig 7 upper right).

The upper-crust normalised rare earth element (REE) profiles (Fig 8) of the two suites are also slightly different, with those from Cinder Mill showing a slight middle REE (MREE) hump, whereas for Ned's Garden the profiles are approximately horizontal through the MREE and the heavy REE (HREE). The ceramic samples show inclined profiles with progressive depletion towards the light REE (LREE). The ore samples show relatively flat MREE/HREE for the rich Cinder Mill sample, an inclined profile close to the ceramic samples for the clay-rich roasted ore from Cinder Mill, and with more humped profiles for samples from Ned's Garden – again emphasising how the ore samples are a mismatch with the slag samples.

The interpretation of the bulk analyses (Fig 7) is complicated by inter-sample variation in iron content. To allow more direct comparison of the non-ferrous component of the slags, the binary plots in Figures 9 and 10 are for analyses normalised to exclude iron. These plots show more clearly the relationship between the two slag suites. For many 'immobile' trace elements (U, Th, REE, Y, Zr) there is substantial overlap between the two sites – presumably reflecting the broad similarity of the ores and their host sediments. For the alkali and alkaline earth elements (K, Mg, Ca, Ba) there is much less overlap. indicating a more significant difference between the sites (see below).

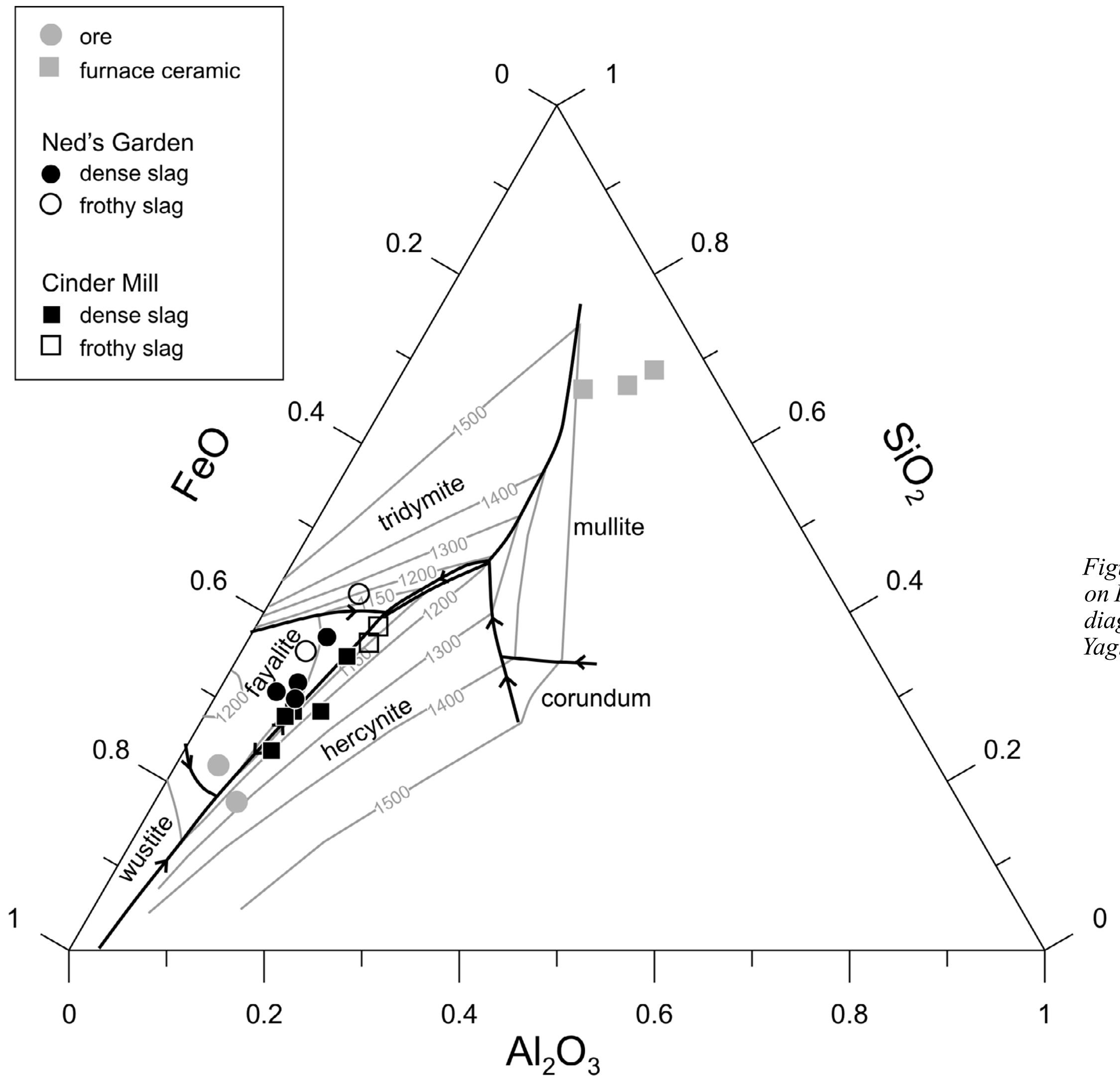

Figure 11: Analyses plotted on FeO–SiO_2–Al_2O_3 ternary diagram (after Schairer and Yagi 1952, fig 6).

Interpretation

The total of the contents of alumina, silica and iron oxide amounts to approximately 90% of the slag analyses, allowing the use of the ternary system SiO_2-Al_2O_3-FeO as a reasonable basis for the discussion of slag chemistry (Fig 11). Other elements will modify slightly the phase relationships and liquidus temperature, but the broad relationships will hold.

Smelting may be modelled as firstly a mixing of ore and furnace lining to produce a theoretical mixture, lying on the join between those components and close to the composition of the ore. This is followed by extraction of iron from the mixture (as a metal), leading to the production of slag with composition along a trendline from the mixture composition directly away from the FeO pole. The suites of slags from Ned's Garden and from Cinder Mill each form such a linear array – with those from Ned's Garden lying mainly within the fayalite field and those from Cinder Mill lying along the fayalite-hercynite eutectic.

Given the uncertainties over the ore composition, it is not possible to construct a robust mass balance of the smelting reaction. However, if any furnace lining contribution is ignored, the production of slags with 46-62% FeO from an ore with 73% FeO implies removal of 40-63% of the iron in the ore. The actual extractive efficiency, once the furnace lining contribution to the mix is taken into consideration, would be rather lower than this. This level of extractive efficiency is broadly comparable with that derived by Thomas (2000) for smelting from much richer ores in the Bristol Channel Orefield. These figures can be used to provide a very approximate model for the iron yield: the range of 46-62% FeO indicates the use of 2.2kg to 1.5kg of roasted ore per kg of slag produced, yielding between 460g and 540g of iron.

The subtle differences between the silica:alumina ratio of the two suites of slags is likely to reflect a variation in the grain size of the sediment hosting the iron ore. The Ned's Garden ores are the more siliceous – and indeed the low grade ores noted on the surface in Ned's

Garden East were siltstones and fine sandstones. The more aluminous Cinder Mill ores would have been more clay-rich – which would also be likely to lead to enhanced concentrations of, amongst others, potassium and titanium.

The higher levels of calcium and magnesium in the Cinder Mill ores are a slight, but important feature. Elevated contents of these elements in bloomery slag have usually been explained by one of three approaches.

Firstly, that limestone has been deliberately added to the smelt as a flux. This has been particularly favoured by those who see the later evolution of the bloomery as approaching the blast furnace. Morton and Wingrove (1969-70) favoured a small addition of lime as the best explanation for the composition of the slags from the early post-medieval site at Rushall (West Midlands). Dungworth (2010) reinvestigated material from this site, made the same compositional observations, but urged caution in their interpretation. In this case, the observed elevation in magnesium and calcium in the slag would be equivalent to adding less than 2% of dolomite to the charge, a figure that would appear too low to be credible as a deliberate act.

A second possibility is that these elements were derived from the fuel ash, and that their increased abundance in some sites indicates a higher degree of capture of the fuel ash into the slag. The pattern of elemental enrichment, particularly of magnesium, does not, however, actually match the composition of wood ash (Thomas 2000).

The third and most likely explanation is that variation in these elements is due to their variation in the ore. The substitution of manganese, magnesium and calcium into siderite is very variable (Young 1993, table 9.1), both between ores and within an individual concretion (*eg* Young 1993, table 9.5). Oxidation of the siderite through weathering or roasting may also lead to preferential loss of calcium and magnesium leading to a significant range in calcium and magnesium content, even from a single ore horizon. The ores recovered on archaeological sites may also show more weathering than in their 'as-mined' state, thus potentially leading to an underestimate of the calcium and magnesium contents of the furnace feedstock.

In summary, the slags from the water-powered site at Cinder Mill cannot be differentiated from those from the manually blown site at Ned's Garden by texture nor by any chemical characteristic, that cannot be attributed to a slight difference in ore chemistry. The ore used at Cinder Mill was probably slightly more ankeritic and had a finer-grained host sediment; that at Ned's Garden was closer to end-member siderite and was hosted in a slightly coarser-grained sediment.

Discussion

The natural resources of Stottesdon included abundant iron ore, woodland for charcoal production and narrow valleys suitable for small water-powered works. Within this setting, the timing of bloomery iron-making is significant. The drive to raise the revenue-earning capabilities of manors in the 13th century led to the creation of markets and fairs, as well as to the more thorough and efficient exploitation of natural resources. The evidence provided by the wood charcoal (Appendix 2) suggests that the fuel employed at Ned's Garden was dominantly hazel and at Cinder Mill it was birch. In both cases, these species are followed in importance by oak and other species that comprise the major trees of the modern woodland. The species selected for coaling therefore appear to be those of the under-storey, suggesting that the woodland was managed as coppice-with-standards, possibly an indication of the thoroughness of exploitation of the woodland resource for both charcoal and timber.

This burst of activity may have been cut short by the crises of the 14th century, with its famines and plagues, and when demand for iron rose again later in the 14th and 15th centuries, new technologies were adopted to exploit the resources. Water power allowed efficiencies of scale, but required capital for the creation of the more complex infrastructure. It was this economic change, more than any change in the iron-making reaction, that foreshadowed the major developments in the iron industry in the 16th century. Then, the arrival of the blast furnace forced the concentration of industry on to sites suitable for harnessing water power on a larger scale. The natural resources of Stottesdon were still exploited for iron-making in the blast furnace period, but were carted to furnaces constructed on more suitable sites elsewhere.

The evidence suggests that the essential bloomery reaction remained unchanged in this area with the introduction of water power. The tapping of the furnaces on the Stottesdon sites to form multiple slag cakes during a single smelt, means that, in the absence of information on the furnace structures, there is no direct evidence here for any change in scale of the process with the change in power. The maximum slag cake size at Cinder Mill of approximately 8.5kg may provide evidence for the tapping regime, but not for smelt size. Nonetheless, the bloom size is very likely to have increased; documentary evidence supports an approximately ten-fold increase over the period of introduction of water power (Crew 2013, fig 5). It should be noted, however, that this increased productivity could be achieved whilst maintaining manual blowing (*eg* Clun Park, Llantrisant, was producing two blooms per day, each of approximately 50kg, in the 1530s; NA SPI/66/262).

The suites of slags from the two sites probably indicate variation within the residues produced during normal smelting; the composite slag cakes demonstrate some of that variation within a single tapping event and it is likely that individual smelts, with multiple tappings, may have produced slags across an even wider range of the compositional spectrum. This should sound a note of caution against any attempt to use individual analyses, or small numbers of analyses, to characterise such a smelting regime.

These compositional suites also call into question the utility of the concept of 'optima' (and the attendant 'choices') in iron-making (*sensu* Charlton *et al* 2010 and Rehren *et al* 2007). The slag suites from both Shropshire sites range from close to 'Optimum 2' (surrounding the melting point minimum of the fayalite-wustite-hercynite system) to close to 'Optimum 1' (surrounding the melting point minimum of the fayalite-tridymite-hercynite system) of Rehren *et al* (2007). Early research on bloomeries paid close attention to the liquidus of the smelting system, but more recent work has clearly demonstrated that the core temperature of a bloomery furnace is much higher than previously envisaged, several hundred degrees above the liquidus of the slags, making the slight variation of liquidus temperature along the field of these compositional suites almost irrelevant to the smelting reaction (although not, perhaps, to the tapping regime). What is more important is that the liquidus temperature rises very rapidly at compositions more iron-rich than 'Optimum 2' and more iron-poor than 'Optimum 1'. Viewed this way, the 'optima' are not really optimal conditions, but are merely close to the bounding limits of compositions with suitable liquidus temperatures; anything between them is an equally viable slag composition.

Both Charlton *et al* (2010) and Rehren *et al* (2007) discussed the concept of 'choices' in iron-making, but it is clear that, given the composition of the local ore, in this case there was no choice, no possibility of smelting with the production of a slag bearing a significant level of wustite because the ore compositions already lie further from the iron oxide apex of the FeO-SiO2-Al2O3 system than does 'Optimum 2'. The medieval exploitation of coal measures ironstones (Morton and Wingrove 1969-70; 1972) inevitably produced slags with a low-iron content.

It has been suggested (*eg* Charlton *et al* 2010; Rehren *et al* 2007; Sauder and Williams 2002) that wustite (or iron II oxide present within the silicate melt) plays an important role in the control of carbon in the nascent bloom; thus for reactions producing low-iron slags there is a greater potential for the production of high carbon 'steely' blooms or even of cast iron. On the basis of the range of composition of the slags from the two sites described here, this is no likelier a scenario at the water-powered Cinder Mill than it had been at the manually-powered Ned's Garden site.

The principal contribution of this study is to demonstrate that similar slags were generated by the earlier manually-blown bloomery at Ned's Garden and by the later, water-powered, site at Cinder Mill. There is no reason necessarily to posit, therefore, a different form of iron product from the two sites. Whilst the discussion of the implications of the introduction of water-power to smelting is very important, it is necessary to separate the evidence for water-power from that for the expansion of bloomery smelting into areas with lean, aluminous ores. Many of the attributes of slags that have been suggested to indicate the use of water power were already present in the earlier manually-blown bloomery exploiting the same ores. The introduction of water power was, however, very likely to have permitted a change in the scale of smelting operations.

Acknowledgements

This work forms a component of the 'Medieval Ironmaking' project of the Four Parishes Heritage Group, supported by grants from the Local Heritage Initiative, Cleobury and Rural Local Joint Committee, Kinlet and Stottesdon parish councils, with additional support from the Shropshire Archaeological and Historical Society. The support of members of the Four Parishes Heritage Group at all stages of this project is very gratefully acknowledged.

We wish to thank Roger Holmes, Roger Harris, Stewart Corry, Ray and Hillary Benton and Natural England for access to their land. We are also grateful to James Lawson for discussions.

Appendix 1: Medieval pottery

Victoria Bryant

This is an abridged version of the archive report (Bryant 2008), restricted to an account of the pottery relevant to the dating of the bloomeries. Fabrics are referenced to the Shrewsbury fabric series (Bryant 2002) or Worcestershire County fabric series (Bryant 2004; www.worcestershireceramics.org).

Ned's Garden

The medieval pottery assemblage from Ned's Garden consisted of 113 sherds weighing 897g. The lack of published reports on medieval ceramics from the South Shropshire/North Worcestershire region means that, despite its small size, the group is important enough to be reported on in some detail. The medieval pottery assemblage as a whole is similar to sites of this period in both Shrewsbury (Bryant 2002, 104-95) and Bridgnorth (Ratkai 1996), both in the wares present and in the relative proportions of sherds from cooking pots and jugs. It is, however, unusual that the cooking pots found on this small rural site came from such a wide range of production areas.

Worcestershire Fabric 56/Shrewsbury Fabric 10, Malvernian unglazed ware; late 12th to 13th century

The sherds (13 pieces, 272g) from Ned's Garden were all from cooking pots dating to the 13th century (Bryant 2002, fig 53 no 3). Pottery of this type was produced in Worcestershire between the Malvern Hills and the River Severn and was distributed widely outside Worcestershire particularly in the 13th century (Vince 1977) (c114, c115, c117).

Shrewsbury Fabric 80, local unglazed sandy ware; late 12th to 14th century

This fabric is quite hard fired and generally reduced to a dark grey to black throughout although a few sherds are orange to brown. All the vessels (24 sherds, 200g) in this fabric from Ned's Garden are cooking pots with infolded rims (Bryant 2002, fig 53 no 2). This fabric was identified at Shrewsbury and was considered to be a local ware although no kilns have been identified. Cooking pots of this type are common in Shropshire (Barker 1970), have been noted at Bridgnorth (Ratkai 1996) and would seem to be the products of many local potteries producing cooking pots in a regional style. It is possible that the cooking pots found at Ned's Garden are from the Shrewsbury area but some may come from, as yet unidentified, kilns closer to Stottesdon (c114, c115, c117, plus nine unstratified sherds).

Stottesdon unglazed micaceous sandy ware; 12th to 14th century

A coarse-tempered, iron-poor fabric, that is quite hard fired and buff/orange to pale grey with a dark grey surface. Some sherds are black throughout. This fabric has not been identified before. The inclusions are: frequent, well-sorted, rounded quartz <0.25mm across; moderate, well-sorted, rounded quartz *c*0.5mm across; moderate, well-sorted, grog fragments *c*0.25mm across; frequent well-sorted flecks of white mica *c*0.01mm across; and occasional, ill-sorted, charcoal fragments *c*1.0mm across. All the vessels (represented by 12 sherds, 148g) from Ned's Garden are cooking pots (see Fig 12). Individual finds of sherds in micaceous fabrics have been noted from Ludlow (medieval jugs and cooking pots; Vince 1984, vol 3), Kidderminster (16th-century forms; Vince 1984, vol 1, p.120) and Bridgnorth (medieval jugs; Ratkai 1996, 60) but it is not possible to be certain that these are the same fabric as the pottery recovered from Ned's Garden. It is possible the cooking pots found at Stottesdon are the products of a kiln site in North Worcestershire or South Shropshire. Ceramic cooking pots of this basic type were produced from the 12th to the 14th century in the West Midlands (c116, c117 plus one unstratified sherd).

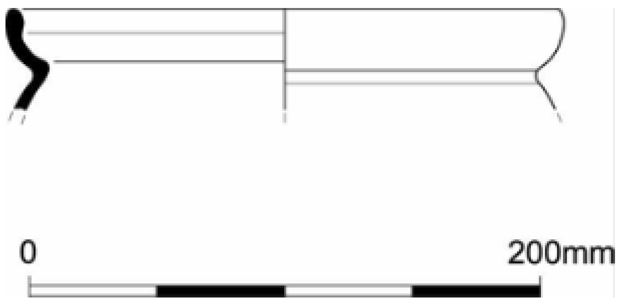

Fig 12: Stottesdon unglazed micaceous ware, cooking pot rim (context 117).

Shrewsbury Fabric 3, early glazed sandy ware; late 12th to early 13th century

The one sherd (4 pieces, 61g) from Ned's Garden was an abraded rim from a pitcher or large jug (c117).

Shrewsbury Fabrics 14, 19, 63, local sandy ware; 13th to 15th century

The sherds from Ned's Garden are from glazed jugs (Fabrics 14 and 63; 2 sherds, 10g)) and un-glazed cooking pots (Fabric 19; 12 sherds 95g) dating from the

13th to early 14th century. The majority of the cooking pot sherds from Ned's Garden may all come from the same vessel (in context 115) and show no signs of being heated over, or next to, an open fire unlike most cooking pots of this date. The pot may have been used for storage (Bryant 2002, 95). This type of pottery is found in quantity in Shrewsbury (Bryant 2002) and at Haughmond Abbey; the later wares (not seen on this site) have been identified at Bridgnorth (Ratkai 1996). No kiln sites producing this fabric have been identified (c115, c117, c304).

Shrewsbury Fabrics 67, 79 buff wares; 13th to 14th century
Sherds (9 pieces, 64g) of fabrics 67 and 79 come from glazed jugs. Pottery of this type has been identified in Shrewsbury (Bryant 2002, 98-99) and possibly in Kidderminster (Hurst, Pearson and Ratkai 1997, 4) but no kiln site has yet been located (c106 plus six unstratified sherds).

Shrewsbury Fabric 70? possible Sneyd Green-type ware, 14th century
One jug rim sherd (9g) which may be from this source was recovered from Ned's Garden. The Sneyd Green kiln is in north Staffordshire and its products have been identified at Shrewsbury (Bryant 2002, 100). White wares have been identified in some numbers at Bridgnorth (Ratkai 1996) and some may be from this source.

Cinder Mill

The medieval to 16th century pottery assemblage from Cinder Mill consisted of just 6 sherds weighing less than 250g.

Worcestershire Fabric 55, Worcester sandy ware
Represented by a single sherd of cooking pot (40g). Wares in this fabric are the products of a number of kilns, none identified, but probably in the area of Worcester. The distribution seems at present to be largely confined to the Worcestershire but sherds have been found in Hereford and Gloucester. The production of this ware starts late in the 11th century, with a floruit in the 12th and 13th centuries; production stops during the 14th century (c1007).

Worcestershire Fabric 64.1, Worcester-type sandy glazed ware
A single very hard fired sherd (49g) of a jug. Vessels in this fabric are the products of a number of unidentified kilns in and around Worcester and were probably produced at the same kilns as fabric 55. Sherds of this fabric are commonly found all over Worcestershire but the distribution of different forms varies. Jugs have been found in Wales, Shrewsbury, Hereford and Gloucester although few are found south of Gloucester. The fabric first occurs very late in the 11th or into the 12th century but the main floruit of the industry dates to the 13th to 14th centuries (c1015).

Worcestershire Fabric 69, late Malvernian ware.
A single large, abraded sherd from a 16th-century chafing dish (146g; cf. Bryant 2004, fig 188.10), together with a tiny abraded sherd (2g) from a different context. Archaeological and documentary evidence indicates that pottery in this fabric was produced in the parish of Hanley Castle. Vessels in this fabric are found mainly in the valleys of the Severn and the Wye and the distribution has been discussed by Vince (1977). By the 16th century and early in the 17th the distribution extended south of Bristol and along the south Wales coast (c1010, c1014).

Worcestershire Fabric 78, black-glazed redwares
Three sherds are present: one from a slipware dish (22g; late in the 17th to early in the 18th century), one from a cup or tankard (1g; 16th century) and one from a bowl or jar (4g; late in the 17th to early in the 18th century). The source of this fabric has not been identified but is within the West Midlands (c1007, c1012).

Appendix 2: The charcoal

Alan Clapham

Samples totalling 196 pieces from a total of 27 deposits of medieval date were examined (15 contexts from Ned's Garden and 12 from Cinder Mill). The material is described more fully in the archive report (Clapham 2011). Where possible the diameter of the round-wood was measured and the number of annual rings counted, in order to determine any indication of woodland management.

Ned's Garden

A total of 15 samples consisting of 112 fragments were provided for charcoal analysis. Taxa identified included beech (*Fagus sylvatica*), oak (*Quercus* sp), birch (*Betula* sp), hazel (*Corylus avellana*), lime (*Tilia* sp), willow/poplar (Salicaceae), cherries (*Prunus* sp), apple/pear/whitebeam/hawthorn (Maloideae) and maple (*Acer* sp); six fragments of bark were present in c117. The commonest taxon was hazel, followed by oak, willow/poplar, lime, and apple/pear/whitebeam/hawthorn. Single finds of beech, cherry and maple were also present.

Of the 112 fragments identified, 44 fragments provided diameter measurements and 58 provided annual ring counts. The majority of the fragments exhibited 10 annual rings, suggesting that woodland management was practiced with harvesting after 10 years.

Cinder Mill

A total of 12 samples and 84 fragments were identified from Cinder Mill. The taxa identified from Cinder Mill include possible sweet chestnut (? *Castanea sativa*), oak, birch, alder (*Alnus glutinosa*), hazel, willow/poplar, apple/pear/whitebeam/hawthorn and maple. In contrast to Ned's Garden the commonest taxon was birch, followed by oak, apple/pear/whitebeam/hawthorn, hazel, willow/poplar, alder, sweet chestnut and maple. Of the 84 fragments, 33 provided diameter measurements and 40 annual ring counts.

The annual ring distribution of all taxa at Cinder Mill is wider than at Ned's Garden, suggesting that apart from coppiced wood, there may have been some larger timbers used at the site. The ring distribution for birch is skewed with the main range between 6 and 12 rings with outliers at 17 and 26 rings. The greatest number of fragments was recorded at 10 and 12 rings, suggesting that birch may have been harvested on a 10 and 12 year cycle.

Summary

The charcoal remains suggest that coppicing was practised and that the average harvesting period was 10 years for hazel at Ned's Garden and 12 years for birch at Cinder Mill. The taxa identified are all common coppice species, apart perhaps from lime, which may indicate the remains of pollarding.

References

Manuscript Sources

BCM: Berkeley Castle Deeds, Gloucestershire.
BGS: British Geological Survey Records Office, Keyworth, Daniel Jones papers (uncatalogued).
HRO: Herefordshire Record Office.
NA: National Archives, London.
SA: Shropshire Archives, Shrewsbury.
WA: Worcestershire Archives, Worcester.

Published Sources

Barker P A 1970, *The medieval pottery of Shropshire from the Conquest to 1400* (Shrewsbury: Shropshire Archaeological and Historical Society Monograph Series 1).

Bayley J, Crossley D and Ponting M (eds) 2008, *Metals and metalworking: A research framework for archaeometallurgy* (London: Historical Metallurgy Society Occasional Publication 6).

Bryant V 2002, 'The pottery from the Queen Anne House site', in N Baker (ed), *Shrewsbury Abbey*, (Shrewsbury: Shropshire Archaeological and Historical Society Monograph Series 2), 87–112.

Bryant V 2004, 'Medieval and early post-medieval pottery', in H Dalwood and R Edwards, *Excavations at Deansway, Worcester 1988-89. Romano-British small town to late medieval city* (London: CBA Research Report 139), 281–339.

Bryant V 2008, Report on the pottery and building material from the Ned's Garden complex, Stottesdon and Billingsley, Shropshire (Report 1645, Historic Environment and Archaeology Service, Worcestershire County Council).

Charlton M F, Crew P, Rehren T and Shennan S J 2010, 'Explaining the evolution of ironmaking recipes – An example from northwest Wales', *Journal of Anthropological Archaeology* 29, 352–367.

Clapham A J 2011, Charcoal from Ned's Garden, Cinder Mill and Little Down Bloomery sites, Shropshire (Report 1860, Historic Environment and Archaeology Service, Worcestershire County Council).

Crew P 2013, 'Twenty-five years of bloomery experiments: perspectives and prospects', In D Dungworth and R Doonan (eds), *Accidental and experimental archaeometallurgy* (London: Historical Metallurgy Society Occasional Publication 7), 25-50.

Crossley D W 1981, 'Medieval iron smelting', in Crossley D W (ed), *Medieval industry* (London: CBA Research Report 40), 29–41.

Dungworth D 2010, 'The possible water-powered bloomery at Goscote (Rushall), Walsall, West Midlands', *Historical Metallurgy* 44(1), 15–20.

Dyer C 2005, *An age of transition? Economy and society in England in the later Middle Ages* (Oxford).

Howell R 1995, 'Ironworking at the medieval borough of Trelech, Gwent', in P Crew and S Crew (eds), *Iron for archaeologists (Abstracts)* (Plas Tan Y Bwlch), 25–27.

Howell R 2000. 'Development by Design: an Investigation of thirteenth-Century Industrialization and Urban Growth at Trelech, Gwent', *Studia Celtica* 24, 211–222.

Hurst D, Pearson E and Ratkai S 1997, Evaluation of land at Mill Street Kidderminster (Report 545, Worcestershire County Archaeological Service).

Morton G R and Wingrove J 1969-1970, 'Metallurgical considerations of early bloomeries in south Staffordshire', *Transactions of the South Staffordshire Archaeological and Historical Society* 11, 64–6.

Morton G R and Wingrove J 1972, 'Constitution of bloomery slags: Part II: Medieval', *Journal of the Iron and Steel Institute* 210, 478–488.

Purton R C 1933-4, 'Stottesdon', *Transactions of the Shropshire Archaeological Society* 47, 139-49.

Ratkai S 1996, 'The medieval and post-medieval pottery', in I M Ferris (ed), 'Excavations at Bridgnorth Franciscan Friary, Shropshire in 1989', *Transactions of the Shropshire Archaeological and Historical Society* 71, 58-61.

Redknap M and Young T P 1998, 'The iron industry of south-east Wales in the 13th century', In N Nayling, *The Magor Pill medieval wreck* (London: CBA Research Report 115), 112-115.

Rehren T, Charlton M, Chirikure S, Humphris J, Ige A and Velhuijzen H A 2007, 'Decisions set in slag: the human factor in African iron smelting', in S La Niece, D Hook and P Craddock (eds), *Metals and mines: Studies in archaeometallurgy* (London), 211-218.

Sauder L and Williams S 2002, 'A practical treatise on the smelting and smithing of bloomery iron', *Historical Metallurgy* 36(2), 122-131.

Schairer J F and Yagi K 1952, 'The system FeO-Al2O3-SiO2', *American Journal of Science, The Bowen volume*, 471–512.

Taylor S R and McLennan S M 1981, 'The composition and evolution of the continental crust: rare earth element evidence from sedimentary rocks', *Philosophical Transactions of the Royal Society* A301, 381-399.
Thomas G 2000, A chemical and mineralogical investigation of bloomery iron-making in the Bristol Channel Orefield, UK. Unpublished PhD thesis, Cardiff University.
Thomas G R and Young T P 1999a, 'Bloomery furnace mass balance and efficiency', in A M Pollard (ed), *Geoarchaeology: exploration, environments, resources* (London: Geological Society of London Special Publication 165), 155-164.
Thomas G R and Young T P 1999b, 'A graphical method to determine furnace efficiency and lining, a contribution to Romano-British bloomery iron-making slags (Bristol Channel Orefield, UK)', in S M M Young, P D Budd, R A Ixer and A M Pollard (eds), *Metals in Antiquity* (Oxford: BAR IS 792), 223-226.
Vince A 1977, 'The medieval and post-medieval ceramic industry in the Malvern region: the study of a ware and its distribution', in D P S Peacock (ed), *Pottery and early commerce, characterisation and trade in Roman and later ceramics* (London), 257-305.
Vince A 1984, The medieval ceramic industry of the Severn Valley. Unpublished PhD thesis, University of Southampton.
Young T P 1993, 'Sedimentary Ironstones', in R A D Pattrick and D Polya (eds), *Mineralization in the British Isles* (London), 446-489.
Young T P 2007, Topographic and geophysical survey of two bloomery sites near Highley, Shropshire (GeoArch Report 2007/03).
Young T P 2008a, Excavations at Ned's Garden, Shropshire (NG08): Data Structure Report (GeoArch Report 2008/34).
Young T P 2008b, Excavations at Cinder Mill, Shropshire (FID08): Data Structure Report (GeoArch Report 2008/35).
Young T P 2011, Archaeometallurgical residues from Ned's Garden & Cindermill, Shropshire (GeoArch Report 2011/10).

The authors

Tim Young runs the GeoArch consultancy, providing a service in archaeometallurgical analysis, as well as other aspects of archaeological science. His personal research interests are mainly in ferrous archaeometallurgy of all periods.
Address: GeoArch, Unit 6 Block C, Western Industrial Estate, Caerphilly, CF83 1BQ.
e-mail: Tim.Young@GeoArch.co.uk

David Poyner is chair of the Four Parishes Heritage Group, a community archaeology and history group based around the parishes of Highley, Kinlet, Billingsley and Stottesdon in south Shropshire.
Address: 136 Hoo Road, Kidderminster, DY10 1LP.
e-mail: David@D-Poyner.freeserve.co.uk

Victoria Bryant is Worcestershire Archive and Archaeology Service Manager.
Address: Worcestershire Archive & Archaeology Service, The Hive, Sawmill Walk, The Butts, Worcester, WR1 3PB.
e-mail: vbryant@worcestershire.gov.uk

Alan Clapham is an archaeobotanist with Worcestershire Archaeology.
Address: Worcestershire Archive & Archaeology Service, The Hive, Sawmill Walk, The Butts, Worcester, WR1 3PB.
e-mail: aclapham@worcestershire.gov.uk