Steel in the Derwent valley: but enlightenment?

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ABSTRACT: The author's 1980s excavation and research at Derwentcote are reviewed in the light of new information, and new ideas in archaeology more generally. The development of steelmaking in north-east England is seen as centered on the grafting of German and perhaps Swedish expertise on to the pre-existing English technology of cementation by William Bertram. The successful marketing of this product as 'German' steel involved an element of mystique and even deception as well as genuine innovation, and Derwentcote furnace can be seen as a projection of both sides of Bertram's character; its date may be slightly earlier than previously thought. A model of 'technological packages' for the development of steelmaking, with similarities to the 'punctuated equilibria' model of biological evolution, is briefly outlined.

Introduction

This paper presents a summary of the historical and archaeological research at Derwentcote steel furnace, Co Durham (Fig 1), in the late 1980s (Cranstone 1997). The discussion of the 1980s project is derived from that report, and from Barraclough (1984, 60–9), unless otherwise referenced. The conclusions are re-assessed in the light of new evidence, of the questions posed by Chris Evans in the Introduction to this issue and of more general developments in archaeology in the last 20 years, suggesting new directions for the historical archaeology of the iron and steel industries.

The 1980s project

My work at Derwentcote was carried out on behalf of English Heritage, who had taken the ruinous furnace into guardianship, and were conserving it for public display. The programme consisted of excavation, recording of the standing structures, historical research, a degree of landscape survey (by the then Royal Commission on Historical Monuments of England), and archaeo-metallurgical examination of slags and other process residues, broadly in that order. The excavation concentrated on the furnace, ancillary buildings, and their immediate exterior, with no investigation of the forge area, or of the slopes between the furnace and the forge which formed the main dumping areas for process residues, building debris, and artefact assemblages from the use of the furnace. In part this reflected the display purpose of the project—but it also reflected my own tight focus (and that of many historical metallurgists at the time) on technology and on functionalist interpretations.

The historical record

Medieval bloomery ironmaking was widespread in County Durham, using both the (phosphoric) Coal Measures ironstones of the central zone of the county and the (often non-phosphoric) replacement orebodies of the Weardale area to the west (Linsley and Hetherington 1978, 1–2). Within the Derwent valley there was a bloomery forge at Gibside (about three miles downstream from Derwentcote) by 1533; a new lease in 1613 gave permission for construction of a blast furnace, although there is no evidence that this was actually done (DRO: D/St/D5/1/66, /70). There was also a mid-16th-century blast furnace at Wheelbirks, just outside the Derwent catchment but only six miles west of Derwentcote (Linsley 1981–2). Intriguingly, there was a 17th-century attempt at steelmak-

Figure 1: Derwentcote furnace in 2007; the 'reverse-crowstepped' north gable (left) forms the only overtly non-functional element. The pantile roof is a modern replacement—the original handmade pantiles would have created a less coldly-uniform appearance than their modern machine-made replacements.

ing in the manor of Wolsingham (which covered most of Weardale west of Bishop Auckland, and its side-valleys); this produced good steel but was said in 1647 to have failed commercially 'these many yeares last past', due to its remote location. This attempt may have been by Sir John Zouch (presumably of Codnor, Derbyshire), who leased the 'mines, quarries, delfes and veynes of steel and ironstone' in the wastes and commons of Stanhope and the north side of Bedburn in 1631, with liberty to erect 'forges furnaces bloom smithies windless dammes poolls weares ...' (Kirby 1971, 152, 164). The technology of this works is not known: it was not necessarily a cementation furnace. However its existence indicates that the suitability of Weardale ores for steelmaking was known.

In the late 1680s, a partnership of south Yorkshire and Derbyshire ironmasters, dominated by Dennis Hayford (or Heyford), developed a blast furnace and forge at Allensford, *c* 6 miles south west of Derwentcote (Linsley and Hetherington 1978), and a steelworks at Blackhall Mill (one mile west of Derwentcote) and/or in Newcastle (Fig 2); in 1997 I saw the evidence as pointing specifically to Blackhall Mill. At the same time a substantial swordmaking company, later the Hollow Blade Sword Company, controlled by the wealthy Tyneside merchant William Cotesworth, was set up at Shotley Bridge, between Allensford and Blackhall Mill. Its workforce was dominated by immigrant German craftsmen from Solingen, and it concentrated on high-status rapiers. It is tempting to see this as an attempt to develop an integrated indigenous iron- and steel-making process, from ore to gleaming steel sword, a grand plan obscured, deliberately or otherwise, by the use of ostensibly-separate companies. If so, however, the iron end of the plan was unsuccessful, since, by the time detailed documentation appears, the steelworks was using imported Swedish bar iron. The reason may perhaps have been a failure to appreciate the difference between the non-phosphoric Weardale ores and the phosphoric Coal Measures ores local to Allensford, of which one seam was known locally as the 'German Band',

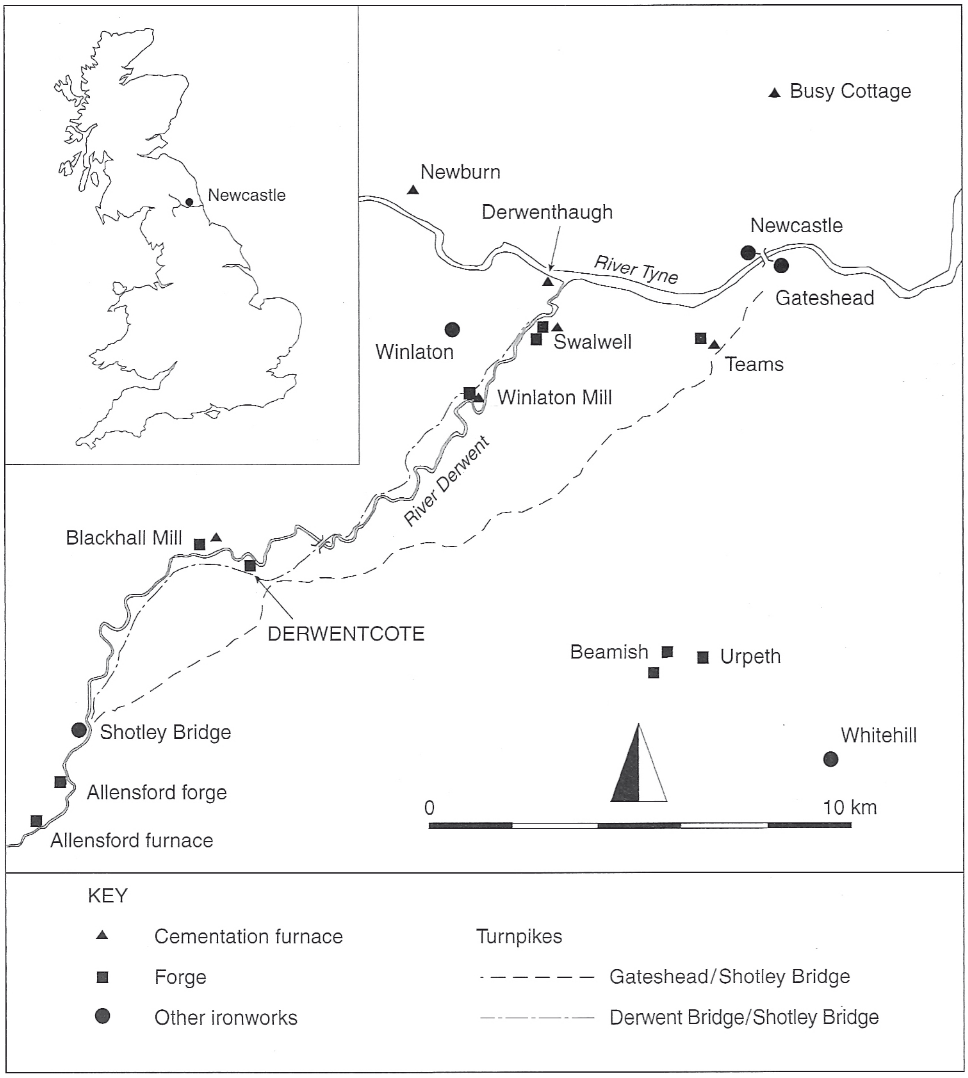

Figure 2: Derwentcote—location, showing the r elationship to the linked sites at Allensford, Shotley Bridge, Blackhall Mill, Teams, and Newcastle, and the Crowley iron- and steel-works at Winlaton Mill, Swalwell, and (from 1735) Teams. Other sites are of later date.

allegedly from its use by the German ironmakers.
From the 1690s onwards, one of Hayford's steel furnaces was operated by William Bertram, also a German, from Remscheid, and by 1720 Bertram was definitely the operator of Blackhall Mill. Although Hayford's company and the Swordmakers appear to have been formally separate operations, Hayford was certainly supplying steel to the Swordmakers, and it seems likely that the links were close. Bertram was clearly a cementation 'converter', and also seems to have introduced the manufacture of shear steel, produced by bundling highly-carburized blister steel bars into 'faggots', which were repeatedly forged down to produce an almost-homogeneous but finely-laminated product. Despite its alternative name of German Steel, the relatively large-scale production of shear steel by cementation and forging of faggots came to be known as the English Method, and Newcastle steel (*ie* steel exported via Newcastle from the Derwent valley, as well as any production in Newcastle itself) had an international reputation until it was eclipsed by Sheffield crucible steel in the middle of the 18th century.

A totally separate iron and steel business was set up in the 1690s further down the Derwent valley at Winlaton Mill, forming the initial nucleus of the Crowley ironworks (Flinn 1962; research by the writer on-going). In 1702, a further iron and steel works was set up at Swalwell, at the tidal mouth of the Derwent, by a partnership of Edward Harrison, William Bayliss, and John Wood. Harrison was a prominent Newcastle merchant who had close links with Crowley, Bayliss appears also to have been a Newcastle merchant, but Wood was from Masbrough near Sheffield (Flinn 1962, 52–4). The Swalwell works were taken over by the Crowley organisation in 1707. These Crowley works took a very different course from the Hayford-Bertram-linked works; the similarities and differences in their steel furnaces are discussed below.

The known history of Derwentcote itself is complex and convoluted. Partly this seems to reflect a genuinely complex sequence of partnerships, and of elliptical links with Blackhall Mill and the Swordmakers, but mainly it reflects the non-survival of any direct business or estate papers, so historical analysis has to rely on multifarious and often indirect records. The involvement with the iron industry probably began in 1718, in the form of a finery forge operated by Newcastle merchants Ralph Reed and William and Richard Thomlinson; Reed purchased forge plates from Hayford's Yorkshire partnership of ironmasters. Reed and the Thomlinsons, who became sole partners in 1721 following the death of Reed, also had ironworks, of unspecified nature, at Skinnerburn (Newcastle) and Teams; new evidence relating to these is discussed below. The Thomlinsons sold Derwentcote, described as 'an iron forge, warehouses, workinghouses and other buildings' in 1733, and the steel furnace was (I argued in the 1997 report) almost certainly built between 1733 and 1742, since it was not mentioned in the 1733 lease, but was mentioned in an abortive sale notice of the latter year. The partnership also held land at Shotley Bridge, and one of its members was a George Blenkinsopp, who is later known to have been manager of the Hollow Blade Sword Company. He ceased to be a partner in 1743, when he fell into dispute with his fellows. By the time of Angerstein's visit to the north east in 1754 (Berg and Berg 2001, 250–73), the Derwentcote partnership overlapped with that then running Blackhall Mill; Derwentcote was using Bertram's 'shear' trademark, and the steel converter was a former apprentice of Bertram. The forge continued to operate as a finery, using scrap iron, so seemingly not of particularly high quality, as well as forging the steel from the furnace. Both furnace and forge operated through the remainder of the 18th century, with more rapidly-changing partnerships; they may then have been mothballed early in the 19th century in favour of Blackhall Mill, before being re-opened in the 1830s when Blackhall Mill closed.

Archaeological recording

The excavation and structural recording investigated the furnace and ancillary buildings in considerable detail. The furnace (Figs 3 and 4) is a complex structure, consisting basically of an axial ashpit and firegrate along its north-south axis, the cementation chamber, which was occupied by two coffin-like chests of refractory sandstone, bedded in an array of flues carrying the flames from the firegrate round and over the chests, and an upper chimney space occupying the cone of the furnace, into which flames and fumes vented from the cementation chamber by a further set of flues. In plan it is a buttressed rectangle at ground level, becoming more oblong with rounded ends at cementation chamber level, then passing into an oval at cone level. There were four small openings in the end walls at chamber level, for passing iron bars in and blister bars out. A 'spy-bar' hole, by which a bar could be withdrawn for testing during the course of the firing, is a later alteration. There are four slightly larger openings in the side walls, for passing sand and charcoal in and out. Originally these were too small for man-access, the only way in being by climbing up through the fire-grate, though later two of the side-openings were blocked, and the other two enlarged to be just big enough for human access. There were also vent flues from over each end of the firegrate into the cone, an entrance door into the cone on the east side, and a small opening into the cone on the south-east side just above the roof of the ancillary building, possibly to carry the control rod for a damper in the cone, or the rope for a pulley to lift heavy slabs of chest sandstone during major repairs. To add to the complexity, the four buttresses on the end walls are wedge-shaped in plan whereas the six on the side walls are rectangular, and the latter are block-keyed into the main structure in order to allow for differential thermal movement; and the 'shoulder' of the furnace was strengthened by an external collar of strapping beams, also to resist thermal stresses. The furnace is built of a good-quality hard sandstone, carefully shaped and coursed, but not cut to ashlar neatness.

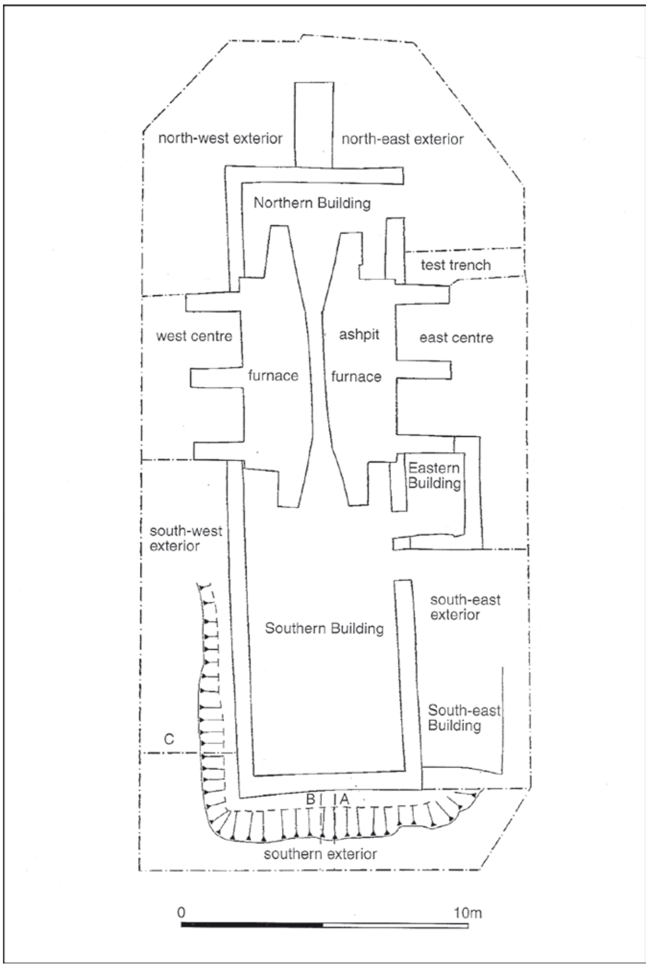

Figure 3: Derwentcote—overall plan of the furnace, ancillary buildings, and excavation areas; furnace planned at ground/ashpit level.

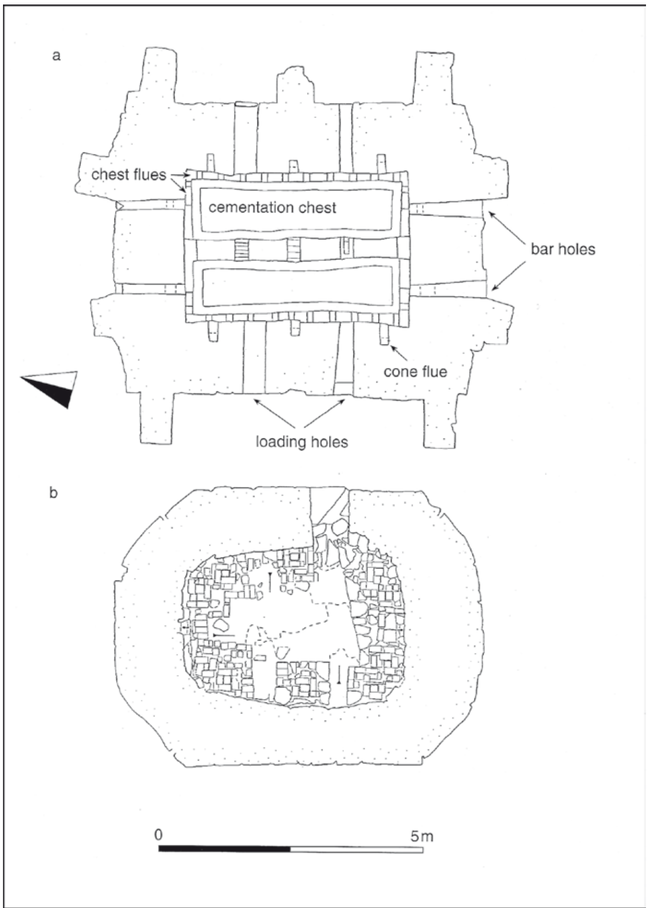

Figure 4: Derwentcote—plans of furnace at: a)—chest compartment level; b)—cone floor level.

The ancillary buildings were less complex, and the southern building had been extensively rebuilt, probably within the 18th-century period of use and perhaps after a fire. A later floor was not removed in the northern building during the excavation. In the southern buildings the floor levels were excavated, revealing traces of successive beaten earth surfaces with some ironworking debris: the cast-iron base-plates (I think) of a charcoal-grinding mill and a massive posthole and a small tree-stump, perhaps the mountings for a hammer and anvil respectively. The putative anvil lies the same distance from the south wall of the furnace as the length of the internal chests, suggesting that it may have held a mounted chisel for cutting the iron bars to length. Outside the main stone buildings there were timber-framed sand stores on either side of a buttress on the north end, and traces of a shelter over the loading area outside the east wall of the furnace.

The process-residues included distinctive vitrified refractory sandstone from the cementation chests, large amounts of fritted sand from the sealing of the chests during a firing (the local equivalent of Sheffield 'crozzle'), small amounts of glazed red sandstone, perhaps from earlier internal linings—the surviving final phase of these was entirely of firebrick. There was a stamped piece of 'Hoop L' blister bar (perhaps with hindsight a deliberate sample or display piece), also crucible sherds and lids from a crucible melting plant in the forge area, but this was a 19th century addition.

Twenty years on—a re-consideration

So, with 20 years of hindsight, new information and new ideas since the start of the project, how should my original interpretations of Derwentcote now be re-assessed, and how can they contribute to current research issues?

Steelmaking sites and their ownership

To start within the technocentric and functionalist focus of the 1997 report, the full publication of Angerstein's diary (Berg and Berg 2001; 250–77 for his visit to Tyneside) rather than the pre-publication extracts used by Barraclough, and the discovery of a detailed 1718 plan of the Crowley works at Winlaton Mill and Swalwell (now TWAS 2644), allow a reconsideration of the early Tyneside steel industry, and of Derwentcote's place within it. It is now clear that in 1754 there was a furnace 'just outside the town' of Newcastle, operated by Hall and Co in conjunction with Blackhall Mill, where the younger Bertram was his steelmaker (Berg and Berg 2001, 250, 252). Barraclough's claim that the older Bertram was operating a steel furnace for Hayford in Newcastle *c* 1700 is therefore probably correct. In 1997 I doubted the existence of a separate Newcastle furnace, as opposed to other furnaces in the broader Newcastle area (and I suspect that some confusion remains in both the contemporary and the modern literature). As suggested by Barraclough (1984, 65), the Newcastle furnace may be one of the smoking chimneys on his Figure 11 (Berg and Berg's Figure 233), though this is not in fact stated in the text: the right-hand chimney is conical on close examination, and the left-hand chimney fits the location of Elswick lead/silver works, also described by Angerstein. This would put the location of the steelworks at the mouth of the Skinnerburn valley, *c* 300m outside the city walls. The first specific mention of a Hayford/Bertram steel furnace at Blackhall Mill appears to be *c* 1720 (Barraclough 1984, 209), when it was clearly well-established.

By 1720, William Reed and William and Richard Thomlinson were operating Derwentcote forge, Skinnerburn, and Teams (Cranstone 1997, 18–19). All were described as 'ironworks' with no mention of steelmaking, but the case for a steel furnace at Skinnerburn has been made above, and Teams had 'slitting-mills, steel furnaces, other mills, forges, workhouses etc' when it was

Figure 5: Winlaton Mill—Furnace No 1 and attached 'teesing houses' (numbers 71–73 on plan), already disused by 1718 (TWAS 2644).

leased by the Rev Robert Thomlinson to the Crowleys in 1735; these plurals may be legalese, but it was clearly a substantial works with at least one steel furnace (Flinn 1962, 79). In view of the Thomlinsons' substantial involvement in steelmaking, which was not appreciated in the 1997 report, my dating of Derwentcote furnace to after the Thomlinsons' sale in 1733 must be re-considered. The non-mention of the steel furnace in the 1733 sale notice remains strong evidence for the later date, but the steel furnace, as perhaps at Skinnerburn and/or Teams if these sites had furnaces in 1720, could have been operated by a separate partnership. An alternative construction date for Derwentcote of *c* 1720 does now seem a viable alternative interpretation.

The date of construction and ownership of the pre-1750 cementation furnaces in the area now seems to be as follows:

Newcastle (Skinnerburn?): probably 1690s, Hayford/Bertram (though confusion with Blackhall Mill in the pre-1750 references remains possible); Reed and Thomlinsons 1720; Hall and Co by 1754.

Winlaton Mill: 1701, Ambrose Crowley (Flinn 1962, 48–9, 167; Barraclough 1984, 200–1); by 1718 (Figs 5 and 6) the old No 1 Furnace (probably that built in 1701) had been replaced by the conjoined No 2 and No 3 Furnaces (TWAS 2644); these in turn had closed by 1754, when the Crowleys' steelmaking was concentrated on Swalwell and Teams (although other parts of the Winlaton Mill works remained very much in use).

Swalwell: before 1718 (TWAS 2644). The works was set up by Harrison, Bayliss and Wood in 1702 and acquired by Ambrose Crowley in 1707; the style of depiction of the furnace on the 1718 plan (Fig 7) is very different from that of the Winlaton Mill furnaces, suggesting that this was copied from an earlier plan pre-dating the Crowley takeover. A second furnace had been added by 1754.

Blackhall Mill: first definitely documented *c* 1720, Hayford/Bertram (Barraclough 1984, 209); earlier references not definitely associated with Blackhall Mill as opposed to Newcastle. Hall and Co by 1754.

Teams: before 1735, Thomlinsons (see above); acquired by Crowleys 1735, one steel furnace still in use 1754, for re-cementing steel form Swalwell.

Derwentcote: either Thomlinsons (with or without Reed) *c* 1720 or Smith, Wasse, Harle, Blenkinsopp and (from 1734) Moncaster 1733–1742; Hodgson and Co by 1754.

Furnace design

The form of the furnaces seems to reflect two different traditions. Blackhall Mill, Derwentcote, and all three furnaces at Winlaton Mill were square in ground-plan (with projecting buttresses at Blackhall Mill and Derwentcote, but seemingly not at Winlaton Mill), whereas both Swalwell furnaces were circular. The plan-form of Newcastle and Teams is not definitely known. In view of the close links between Newcastle and Blackhall Mill a square plan seems likely in this case. The rectangular furnace illustrated by Jars in 1767 (Barraclough 1984, pl 5 no 4) cannot have been at Swalwell since the latter was circular; since Teams operated closely with Swalwell and seems to have been controlled by the Swalwell

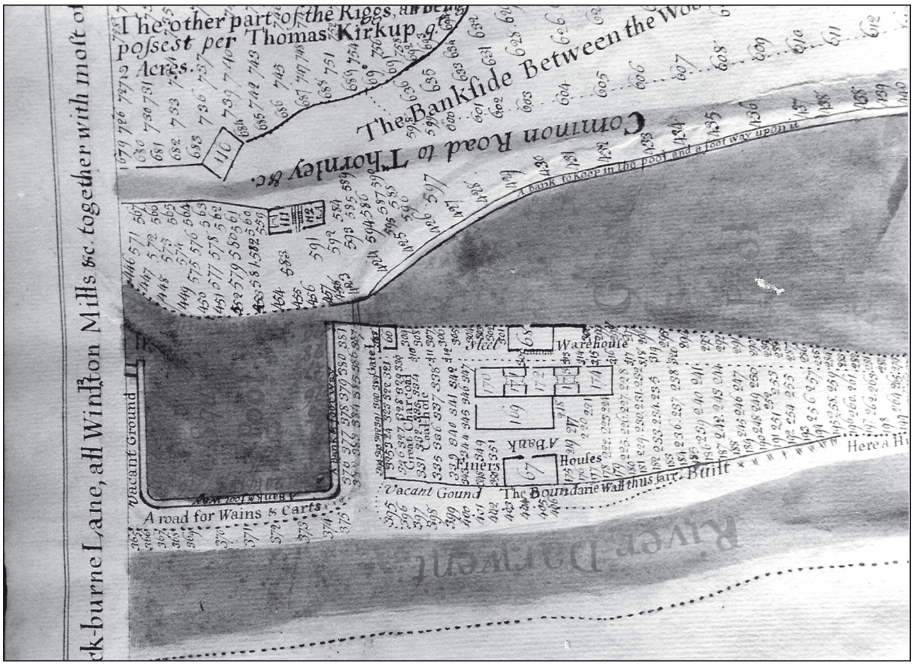

Figure 6: Winlaton Mill—Furnaces Nos 2 and 4 and attached 'teesing houses' (numbers 170–174 on plan) in 1718 (TWAS 2644).

steelmaster in 1754 (Berg and Berg 2001, 258–9), the furnace depicted by Jars may well have been Teams, in which case (with its little internal chimneys on the vents from the chest compartment into the interior of the cone) Teams was strikingly similar to Derwentcote. Since one of the Swalwell partners, John Wood, was from Masbrough (Flinn 1962, 53), the circular form probably derives from Sheffield practice: the earliest illustration of a Sheffield cementation furnace, in 1737, shows two conjoined circular furnaces (Barraclough 1984, Plate 4a; David Crossley, pers comm). The square plan of the Winlaton Mill furnaces is more surprising, since in 1701 Ambrose Crowley (III) was clearly in discussion with his father, Ambrose II, who had had his own 'steelhouse' in Stourbridge since 1682; 17th-century West Midlands steel furnaces normally seem to have been circular, following on from the initial Coalbrookdale furnaces (Belford and Ross 2007; Belford, this volume; Plot 1686, 374–5, quoted in Barraclough 1984, 154). However in 1701 Ambrose II appears to have been taking advice from his son on the reconstruction of his 'great furnace' (Flinn 1962, 13), rather than *vice versa*. The clue may lie in the name of Ambrose III's steelmaker, Thomas Eckerhood. As noted by Flinn (1962, 187) the name is probably German, and Crowley may well have recruited him from the Hayford/Bertram operation at Newcastle and/or Blackhall Mill.

This suggests that the origin, or introduction, of the square tradition may have lain with William Bertram. According to his son, as reported by Angerstein in 1754 (Berg and Berg 2001, 267–8), Bertram was from Remscheid in Germany, the next town to Solingen, in the Siegerland area, but had married a Swedish (or possibly Swedish-Jewish) wife. His ship was blown off course to Shields while attempting to return to Germany, and he was presumably recruited by Hayford to set up his steelworks. The German origin and the sojourn in Sweden are confirmed by Kalmeter in *c* 1720 (Barraclough 1984, 209), although the 'accidental' arrival in Shields seems an unlikely coincidence, at just the time when Hayford was trying to supply steel to the Solingen-derived swordmakers at Shotley Bridge. Bertram's German Steel was also produced by forging 'blister' (cementation) steel, whereas genuine German shear steel was produced by the finery process and not by cementation (Berg and Berg 2001, 268–9). Cementation was not even used in the Remscheid area (assuming this was genuinely Bertram's home-town), though it was used in some other areas of what is now Germany (Knau pers comm); it was arguably first developed in Nuremberg (Bavaria) early in the 17th century (Barraclough 1984, 48–50). Assuming that Bertram was genuinely from Remscheid, and we only have his son's word to Angerstein on this, his expertise may therefore have derived from Sweden, where at least four cementation furnaces had been established by *c* 1700 (Barraclough 1984, 124), rather than Germany, though his workmen do seem to have been German. To complicate matters further, Hayford was also a partner with John Fell in the Sheffield steel trade from at least 1699 to 1727. However their cementation steelmaking was contracted out, and Hayford's involvement with Bertram, and as supplier to the Hollow Blade Sword Company, seems to have started before his partnership with Fell (Barraclough 1984, 69–74). It may therefore be that Bertram introduced the rectangular design of furnace (whether this was of German, Swedish, or his own origin), and the use

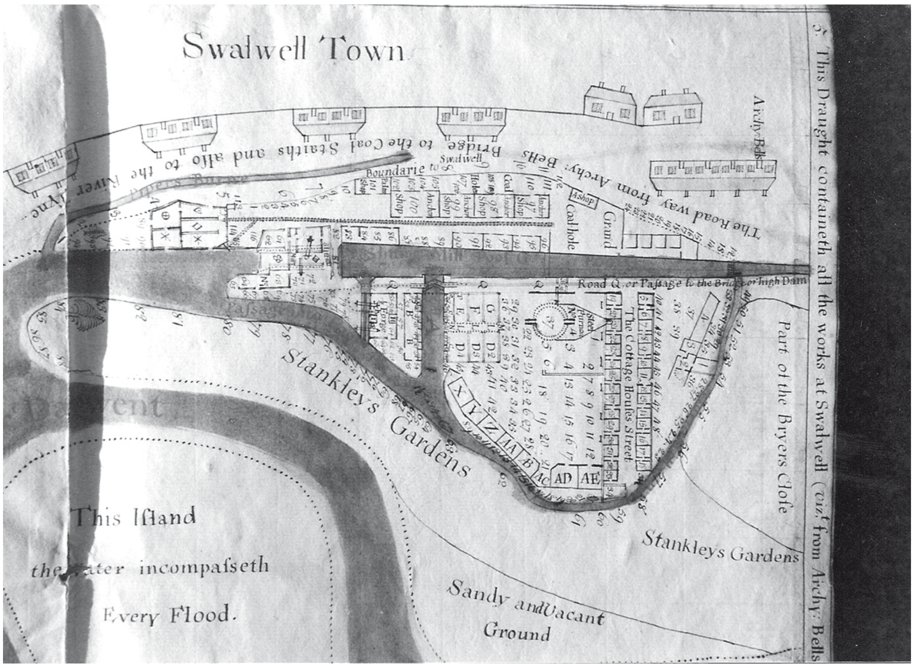

Figure 7: Swalwell—Furnace No 4 in 1718; note the circular form without attached buildings, and the very different stye of depiction from the Winlaton Mill plan (TWAS 2644).

of specific 'marks' of high-grade Dannemora/Oregrund Swedish iron to Hayford and to England.

Steelmaking and religion

In the light of Belford's fairly radical re-assessment (this volume) of the connections between religion and early industrialisation, it is tempting to suggest that the strong recusant and, after 1688, Jacobite sympathies of much of rural north-east England were a factor in the early development of its steel industry, especially as both the Crowley and Hayford involvement started during the turmoil of James II's return to Catholicism and its overthrow by the 'Glorious Revolution' of 1688. At first sight the history of the Crowley organisation might seem to support this: Ambrose Crowley's first venture into the region, at Sunderland, a strongly Puritan town in contrast to most of Co Durham (Meikle and Newman 2007), involved the importation of Catholic workmen from Liège, whose hostile reception on account of their religion prompted a petition to King James and perhaps Crowley's re-location to Winlaton Mill after the Glorious Revolution (Flinn 1962, 40–1). However Ambrose Crowley III was raised a Quaker before becoming an active Anglican by 1687 (Flinn 1962, 15–18, 43–4), and Hayford was of Puritan stock (Riden 1993, 102). The original religious affiliations of Bertram and his fellow-Germans are unclear, although their appearance in parish registers indicates that by the 18th century they were at least outwardly Conformist. The case for a confessional factor in the development of the north-east England steel industry is therefore ambiguous on present evidence, but would repay further research.

Theoretical issues

The issue of religion leads from relatively factual updates towards broader and more theoretical issues. My own, perhaps idiosyncratic, perspective on the post-1970s intellectual development of archaeology, and specifically the archaeology of the later second millennium and of industrialisation, remains broadly as published elsewhere (Cranstone 2004, 2005); the volumes in which these appear (Barker and Cranstone 2004; Casella and Symonds 2005), together with the Association for Industrial Archaeology's recent research framework (Gwyn and Palmer 2005), form part of a developing and much-needed debate. To summarise my views:

- The fundamental debate in archaeology has been between processualism and post-processualism; these broadly correspond with modernism and post-modernism in the humanities, with two twists: processualism was in part an assertion of disciplinary independence from history and, with its emphasis on mathematical models and hypothesis testing, involved an attempt to relocate archaeology into the sciences rather than the humanities. Post-processualism was a counter-move back to the humanities.
- Processualism looked for underlying processes (hence the name) and down-played the role of the individual as agent, while many post-processual approaches have actively sought the individual in the archaeological record (and, in consistency with this, have encouraged a more personal and less formal style in archaeological writing).
- To an extent, the processual/post-processual dichotomy has been resolved by the development of

'cognitive archaeology' in the broad sense used by Whitley (1998); and also by the concept of 'social archaeology', as championed by the Association for Industrial Archaeology, although I find this latter formulation tends to err into over-synthesis and therefore to be less stimulating.

- The relationship between archaeology and history, and between archaeological and historical evidence, has become a focus for debate. The term historical archaeology should, in my view, be used to mean the archaeology of literate (or documented—the two are not quite synonymous) societies generally; it should not be confined to the North American definition as the archaeology of the later 2nd millennium, except within areas where the two definitions definitely coincide. It involves a developing debate on the relationship between the material record of archaeology, and the written/oral record of history (Andren 1998, Funari et al 1999).
- My position in this debate is to stress the relationship between the historical record of 'what people said (or more often wrote)', and the archaeological record of 'what people (not always the same people) actually did'. Rather than trying to fit the archaeological and historical evidence into a single seamless synthesis, as I did for the 1997 Derwentcote report, this involves an analysis that pays active attention to discrepancies, and may even see discrepancies as the most informative route into the mind-sets of groups and individuals in the past.
- Related to this, I believe archaeologists need to consider the precise origin or 'authorship' of all elements of the archaeological record, be it structure, wear-mark, layer, artefact, or process residue; who produced it or controlled its production, and what does it tell us about him/her?
- In the historical archaeology of industry and production, we need to apply these concepts particularly to the processes of invention and development, stressing the role of archaeology and archaeological science in elucidating the processes and mechanisms of incremental development: the progressive, often 'bottom-up', improvements, the learnings-from-mistakes, etc of industrial practice, rather than the sudden top-down 'invention' that tends to dominate the documentary record.

So, 20 years on from the main fieldwork and research, how do I now apply these ideas to Derwentcote? Firstly and unfortunately, Derwentcote is not a good site for developing the rigorous dialogue between historical and archaeological data that I have advocated, due to the fragmentary and often circumstantial nature of the surviving historical record. Nor can current 'consumption studies' approaches to archaeological artefact assemblages contribute much to a social or cognitive archaeology of the workforce, since the domestic artefact assemblage from the 1980s excavation was very limited. This almost certainly reflects the tightly conservation-focused nature of the excavation; a future excavation targeted on the rubbish dumps below the furnace might yield a very different picture. There are however a few areas of theory that can be explored.

Symbolism of the structure

In my 1997 report, the furnace was treated very much as a functional and pragmatic piece of design, with the only nod towards formalism or symbolism being the 'reverse-crowstepping' of the northern gable (a semi-polite element of the local vernacular architecture). In many ways that is true; the furnace is most emphatically designed for a purpose, and its form follows function. But does it actually overdo it—are all those complexities of three-dimensional form really necessary or actively beneficial, or are they over-complex? Later Sheffield cementation furnaces managed to achieve the same functional ends with much cleaner lines. Is the Derwentcote furnace actually making the statement: 'this is a practical building in which form follows function; the form is extremely complex and difficult to build; therefore the function is also very complex and takes intricate skill to master'—in other words, projecting the art and mystery of cementation steelmaking rather than the rationalist science?

Of course, other symbolisms are possible. This is the problem with symbolic arguments—how to distinguish what was real (consciously or subconsciously) in the past from our own projections? For example Belford (pers comm November 2007) has noted the resemblance of the Derwentcote buildings to a church, with the southern building as nave, the furnace itself as tower or spire, and the northern building as chancel. Physically this is true, though my own opinion is that the resemblance is entirely coincidental. More plausibly (to me) the furnace itself can also be seen as charged with sexual symbolism, even as a precursor of the Temple of Venus at West Wycombe so embarrassedly described by Tony Robinson in a recent *Time Team* programme: the rounded superstructure over an oval opening with curved ridges on each side, leading to an enclosed chamber in which iron was impregnated to form steel (Figs 8, 9). I am not seriously suggesting that this was a factor in the design of the structure, certainly not consciously (though see below), but I do seriously suggest that the (consistently all-male) workforce and visitors may have been aware of the resonance; for a workforce in the confined space of the ancillary building (a gendered all-male space), thrusting coal into the ever-demanding orifice of the furnace that towered over them, the working environment may have been highly charged.

Authorship

The obvious related question is who built the furnace or, more precisely, who determined its detailed form? The furnace was certainly not an architect-designed 'polite' structure; it was designed for, and therefore probably by, a working steel converter. Given the historical links with Bertram and Blackhall Mill, and the extremely close similarities between Derwentcote and Blackhall Mill (as known from an early 20th century photograph taken before its demolition), I would suggest that the furnace was probably designed and built, or at least closely supervised, by Bertram (father or less probably son, depending on the precise date), although clearly under the instructions and budgets of his employing company. If so, the symbolic statements (conscious and, perhaps, subconscious) are Bertram's, and the statement of the art and complexity of cementation steelmaking could perhaps be read as Bertram staking-out his expertise and indispensableness to his masters. And could the sexual symbolism of the furnace be an allusion to the idea of the furnace as a 'fickle mistress', hard to humour?

This chimes surprisingly well with Angerstein's comments (Berg and Berg 2001, 267–70) on 'old' Bertram, the only steelmaker, and one of the few individuals, that he describes in any detail (clearly his son sold the Bertram family story and image very successfully to Angerstein). Bertram had clearly undertaken considerable experimentation on different 'marks' of bar iron, on the cementation process and on subsequent selection and forging of the blister steel to produce a 'German Steel' which (at least on the English market) was accepted as the equal of genuine finery-process Remscheid steel. However in Angerstein's assessment 'he would perhaps never have succeeded if he had not been a German and if the English had not persuaded themselves to believe that he used the same raw materials and methods of production as common in Remscheid'. An element of deliberate mystique and even dissemblance in Bertram's design of Blackhall Mill and Derwentcote would be very much in character with Angerstein's judgement.

The process residues can also be considered as the product of the workforce, although in this case not exclusively of Bertram himself, and not, presumably, making any conscious statements. Again, the nature of the excavation limits the information that could be gained by re-examination of the existing assemblage: although large, it contains very little stratigraphic depth. However, as with the artefacts,

Figure 8: The Temple of Venus, West Wycombe: rampant lust veiled in Enlightenment neo-classicism. Compare with Figure 9. (©NTPL/Alasdair Ogilvie).

a future research excavation on the rubbish dumps downslope could produce large assemblages from throughout a deep and well-controlled stratigraphic sequence, and this, combined perhaps with further work on *in situ* materials and deposits in the structure, could allow a detailed study of the incremental development, or perhaps the extreme stability, of the process, in the form of an 'archaeology of practice' of the working steelmaker and forgeman (Photos-Jones *et al* 2008). With careful cognitive research design, this could also illuminate the mindset and 'scientific' beliefs of the workforce—what did they think they were doing to the materials they were handling, and why did they attempt (or not attempt) to resolve problems in that way, as well as the modern archaeometallurgical understanding of what they were doing? And, if suitable samples of the various grades of Bertram's 'German steel' can be obtained and compared with actual German steel of comparable date and quality, can the role of Bertram in the development of rationalist steelmaking, and the validity (or otherwise) of his claims to be replicating the quality of the finest German steels, be determined? Archaeometallurgy is increasingly able and willing to address such issues (*eg* Mackenzie and Whiteman 2006), and recent work in related areas of archaeological science such as glassmaking (Dungworth and Cromwell 2006) offers further pointers to the methods and strategies that may be appropriate.

Technological packages

In the Introduction to this issue, Evans draws attention to 'key turning points' and the time-lags in their widespread use. I believe that some of these time-lags may reflect the delays between 'invention' or 'introduction' and the incremental development of practice to produce

Figure 9: Derwentcote: south face of furnace within ancillary building. In use, the ashpit (behind modern railings) would be covered iron plates, and without the modern lighting the red glow would form a strong visual focus between the projecting buttresses (photo Paul Belford).

consistent, reliable and cost-effective production: part of the 'archaeology of practice' already mentioned. This can be investigated by large-scale well-designed archaeometallurgy, in conjunction with excavation. But I think there may be another factor involved, the concept of 'technological packages'.

In this model, a technological package consists of a linked group or sequence of processes, all of which fit well with each other, in terms of the scale of each process and the usability of one product in the next link of the *chaine operatoire* and with the society in which they occur, in terms of the demands made on the operators and on society more generally, and the ability of the quality and scale of production to meet the demands of society. A good technological package will initiate a period of relative technological stability or even conservatism, since changes to one part will tend to have adverse effects on other links in the chain; conversely a package whose links do not work so well together, or one that has become ill-adapted to resource constraints or the changing demands of society, may reach a 'tipping point' that sets off a period of rapid evolution, as change in one area forces changes in the other links of the chain, until a new stable package is developed.

Applying this concept to steelmaking, I suggest that the take-off of cementation steelmaking in Britain in the 1680s and 1690s reflected both incremental improvements in technique over the decades since its introduction, and also the completion of a 'technological package' or *chaine operatoire* including the use of imported Swedish bar iron as feedstock for the cementation process, and the shear steel process for converting the blister steel into consistently high-quality end products. However the links in the chain were not very well matched; the scale of shear steelmaking did not really match the scale of blister steel production, and neither the scale of end-production nor the consistency of the product really met the developing requirement of 18th-century Enlightened society. The package was only completed by the development of crucible melting, and it was only at this point that the technology stabilised and production really took off.

This analysis is tentative and empirical and I offer it for scrutiny and development; looking beyond the steel industry, it would appear to be highly applicable to the development of British ironmaking (from the Iron Age to the 20th century, in perhaps four major packages?), but I would not assume that it can be usefully applied to all industries. The concept has similarities to the 'punctuated equilibria' model of biological evolution developed by Stephen Jay Gould and others (Malik 2000, 167), and may form a more useful way of applying evolutionary theory to technological development (a comparison that is surely valid in principle) than the Dawkinsian 'meme'-based approaches so far attempted (*eg* Shennan 2002). It would certainly broaden the range of the developing cognitive archaeology of industry.

Conclusion

In many ways, the cementation process can be seen as very much an 'Enlightenment' phenomenon, capital- rather than labour-intensive compared with other steelmaking processes, relatively predictable and replicable, even routine, and demanding much less individual 'art and mystery' on each bar produced. This may have been precisely what Bertram sought to conceal from his masters and customers. However the shear steel process that followed cementation was very much the reverse; only with the development of crucible steel-melting was the *chaine operatoire* from iron bar to steel artefact fully recast into an 'Enlightened' form. It is interesting that, despite the reputation and dominance of Newcastle steelmaking early in the 18th century, the crucible process took off in Sheffield rather than Tyneside and the Derwent valley. This may reflect either the rural and relatively remote location of the north-eastern steelworks, and/or the mindset of 'art and mystery' proclaimed by the furnace structures, whereas the urban atmosphere of Sheffield or London (Evans this volume) was better suited to the interchange of ideas that leads to new innovation—but all these ideas require more rigorous exploration and testing.

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Bibliography

Archive sources

DRO: Durham Record Office.
TWAS: Tyne and Wear Archive Service.

Published works

Andren A 1998, *Between artifacts and texts: historical archaeology in global perspective* (New York and London).

Barker D and Cranstone D (eds) 2004, *The Archaeology of industrialisation* (Leeds: Society for Post-Medieval Archaeology Monograph 2).

Barraclough K C 1984, *Blister steel: the birth of an industry* (London).

Belford P and Ross R A 2007, 'English steelmaking in the seventeenth century: the excavation of two cementation steelworks at Coalbrookdale', *Historical Metallurgy* 41/2, 105–123.

Berg T and Berg P (trans) 2001, *R R Angerstein's illustrated travel diary, 1753–1755* (London).

Casella E and Symonds J (eds) 2005, *Industrial archaeology: future directions* (New York).

Cranstone D 1997, *Derwentcote steel furnace; an industrial monument in County Durham* (Lancaster).

Cranstone D 2004, 'The Archaeology of Industrialisation - New Directions', in Barker and Cranstone 2004, 313–320.

Cranstone D 2005, 'After Industrial Archaeology?', in Casella and Symonds 2005, 77–92.

Dungworth D and Cromwell T 2006, 'Glass and pottery manufacture at Silkstone, Yorkshire', *Post-Medieval Archaeology* 40/1, 160–190.

Flinn M W 1962, *Men of Iron* (Edinburgh).

Funari P P A, Hall M and Jones S 1999, *Historical archaeology: back from the edge*, (London and New York).

Gwyn D and Palmer M 2005, *Understanding the workplace: a research framework for industrial archaeology in Britain* (*Industrial Archaeology Review* 27/1).

Kirby D A 1971, *Parliamentary Surveys of the Bishopric of Durham. Volume I* (Gateshead: Surtees Society 183 for 1968).

Linsley S 1981–2, 'Furnace Rediscovered – Provisional Note', *Industrial Archaeology Review* 6/1, 69–72.

Linsley S and Hetherington R 1978, 'A Seventeenth Century Blast Furnace at Allensford, Northumberland', *Historical Metallurgy* 12/1, 1–11.

Mackenzie R J and Whiteman J A 2006, 'Why pay more? An archaeometallurgical investigation of 19th-century Swedish wrought iron and Sheffield blister steel', *Historical Metallurgy* 40/2, 138–149.

Malik K 2000, *Man, Beast and Zombie: what science can and cannot tell us about human nature* (London).

Meikle M M and Newman C M 2007, *Sunderland and its origins: monks to mariners* (Chichester).

Photos-Jones E, Dalglish C, Coulter S, Hall A J, Ruiz-Nieto R and Wilson L 2008, 'Between archives and the site: the 19th-century iron and steel industry in the Monklands, Central Scotland', *Post-Medieval Archaeology* 42/1, 157–180.

Plot R 1686, *The Natural history of Staffordshire* (Oxford).

Riden P 1993, *A gazetteer of charcoal-fired blast furnaces in Great Britain in use since 1660* (2nd edition Cardiff).

Shennan S 2002, *Genes, memes, and human history: Darwinian archaeology and cultural evolution* (London).

Whitley D S 1998, 'New Approaches to Old Problems: Archaeology in Search of an Ever Elusive Past', in Whitley D S (ed) 1998, *Reader in archaeological theory: post-processual and cognitive approaches* (London and New York), 1–28.

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