Steel in the Derwent valley – but Enlightenment?

This paper starts by presenting a brief summary of the historical and archaeological research at Derwentcote steel furnace, Co. Durham, in the late 1980s (fully published in Cranstone 1997; the remainder of this section is derived from this publication, and from Barraclough 1984a, 60-69, unless otherwise referenced). It then re-assesses these in the light of the questions posed by Chris Evans in the Agenda for this colloquium, and of developments in archaeology more generally in the last twenty years, and attempts to suggest some new directions for the historical archaeology of the iron and steel industries, and of industrialisation more generally. Since it is intended to stimulate new thinking rather than to report substantial new research, it is deliberately written in fairly informal style.

My work at Derwentcote was on behalf of English Heritage, who had taken the ruinous furnace into guardianship, and were conserving it for public display. It consisted of excavation, recording of the standing structures, historical research, a degree of landscape survey (by the then Royal Commission on Historical Monuments), and archaeo-metallurgical examination of slags and other process residues, more-or-less in that order. Since the excavation was targetted on the needs of conservation and public display, rather than academic priorities, it focussed entirely 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 any artefact assemblages from the use of the furnace.

Let's start, as we so often do in reports, with the historical evidence. 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 3 miles downstream from Derwentcote) by 1533; a new lease in 1613 gave permission for construction of a blast furnace, though there is no confirmation 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 c 6miles west of Derwentcote (Linsley 1981-2). There was also a mid-17th century attempt at steelmaking somewhere in Weardale (Linda Drury, Durham University Special Collections, *pers. com.*); this appears to have produced good steel but to have failed commercially due to its remote location. 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 1680s and 1690s, a partnership of south Yorkshire and Derbyshire ironmasters, dominated by Dennis Hayford, developed a blast furnace and forge at Allensford (c 6 miles SW of Derwentcote), and a steelworks at Blackhall Mill (1 mile west of Derwentcote); he may also have had a steel furnace in Newcastle. At the same time, a substantial swordmaking company (later the Hollow Blade Sword Company, and controlled by 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 conentrated on high-status rapiers. It is very 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 grand plan was unsuccessful, since by the time that detailed documentation appears the steelworks was clearly using imported Swedish bar iron. The reason may have been a failure to appreciate the difference between the phosphoric ores local to Allensford and the non-phosphoric Weardale ores.

From the 1690s onwards, one of Hayford's 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 in fact close. Bertram was clearly a cementation 'converter', and also seems to have introduced the manufacture of shear steel (produced by bundling highly-carburised blister steel bars into 'faggots', which were repeatedly forged down to produce an almost-homogenous 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 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 mid 18th century.

A totally-separate iron and steel business was also set up in the 1690s further down the Derwent valley at Winlaton Mill, and forming the initial nucleus of the Crowley ironworks (Flinn 1952; ongoing research by the present author). In 1701, a further iron and steel works was set up at Swalwell, at the mouth of the Derwent, by yet another company; this was taken over by the Crowley organisation in 1707. By 1718, an 'old' square-footprint steel furnace at Winlaton Mill had been replaced by two working rectangular furnaces and ancillary buildings, on a ground-plan very similar to a 'double-Derwentcote'; however the single Swalwell furnace was of circular plan. These works took a very different course from the Hayford-Bertram-linked works, and and did not share the links either at management or (so far as is known) at workforce level; they are not discussed further.

The known history of Derwentcote itself is consistently complex and convoluted; partly this does seem 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 records – the historical anaylsis had therefore to rely on multifarious and often indirect records. The involvement with the iron industry began in (probably) 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, though there is no indication of any closer link. A new partnership took over in 1733, and the steel furnace was almost certainly built between 1733 and 1742. The partnership also held land at Shotley Bridge, and one of its members (until 1743, when he fell into dispute with the other partners) was a George Blenkinsopp, who is later known to have been manager of the Hollow Blade Sword Company. By the time of Angerstein's visit to the Northeast in 1754 (Berg and Berg 2001, 250-273), 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's. The forge continued to operate as a finery (using scrap iron, so seemingly not of any particular 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 in the early 19th century in favour of Blackhall Mill, before being reopened in the 1830s with the closure of Blackhall Mill.

The excavation and structural recording investigated the furnace and ancillary buildings in considerable detail. The furnace is a complex structure, consisting basically of an axial ashpit and firegrate along its north-south axis, the actual cementation chamber, 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 a conning-tower-like 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), and 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 access being by climbing up through the firegrate, though later two of the side-openings were blocked, and the other two enlarged to just big enough for human access, as demonstrated by Paul Belford. 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 SE 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, carefuly shaped and coursed, but not cut to ashlar neatness.

The ancillary buildings were less complex, and the southern building had been extensively rebuilt, probably within the 18th century period of use, perhaps after a fire. A later floor was not removed in the northern building; in the southern buildings the floor levels were excavated, revealing traces of successive beaten earth surfaces with some ironworking debris, the base-plates of (I think) a charcoal-grinding mill, and a massive posthole and 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 sandstone 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), and a stamped piece of 'Hoop L' bar – and also crucible sherds and lids from a crucible melting plant in the forge area, but this was a 19th century addition.

So, with twenty years' hindsight and development in understanding and ideas, what do I now think about Derwentcote, and can it contribute to the questions that Chris Evans posed in his agenda for this colloquium, and to other current research issues?

My own, perhaps ididcyncratic, perspective on the post-1970s intellectual development of archaeology, and specifically the archaeology of the later 2nd millenium 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 own views very briefly:

- The fundamental debate in archaeology has been between 'processualism' and 'post-processualism'; these broadly corresponds to 'modernism' and 'post-modernism' in the humanities, with the twists that 'processualism' involved an attempt to relocate archaeology into the sciences rather than the humanities, and 'post-processualism' a counter-move back to the humanities, and 'processualism' an assertion of disciplinary independence from history.

- 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, though to me this 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' is still often misused in its North American sense of 'Later 2nd millenium archaeology'; in its literal (and, to me, correct) usage as 'the archaeology of literate (or externally-documented) societies', it involves a developing debate on the relationship between the material record of archaeology, and the written/oral record of history (Andren 1998, Funari 1999).

- My own take on 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 automatically to fit the archaeological and historical evidence in to a single seamless synthesis, as I did at Derwentcote, 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 past actors.

- Related to this, I believe we as archaeologists need to consider the precise '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. In particular, I would stress the role of archaeology and archaeological science in elucidating the processes and mechanisms of incremental development – the progressive, often 'bottom-up', improvements, learnings-from-mistakes, etc of industrial practice, rather than the sudden top-down 'invention' that tends to dominate the documentary record.

So how would I apply these ideas to Derwentcote?

Firstly symbolism. In my 1997 report, I treated the furnace very much as a functional and pragmatic piece of design, 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 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 and more elegant 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?

Of course, other symbolisms are possible. This is the problem with symbolic arguments – how do we distinguish what was real (consciously or subconsciously) in the past from our own projections? For example Belford (*pers. com.* November 2007) has noted the resemblance of the 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 coincidential. 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 (I believe the word 'cementation' is derived by at least some linguists from 'semen', though I have been unable to relocate my reference for this). I am not seriously suggesting that this was a factor in the design of the structure, certainly not consciously – 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, thrusting coal into the ever-demanding orifice of the furnace that towered over them, the working environment may have been highly charged.

Moving into slightly calmer waters, Derwentcote is not a good site for developing the rigorous dialogue between historical and archaeological data that I have advocated, due to the very fragmentary and often circumstantial nature of the survivng 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. However this almost certainly reflects the tightly conservation-focussed nature of the excavation; a future excavation targetted on the rubbish dumps below the furnace might yield a very different picture.

This leads into the theme of 'authorship'. The obvious question here 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, the extremely close similarities between Derwentcote and Blackhall Mill (as known from an early 20th century photo before its demolition), and the lack of steelmaking expertise on behalf of any of the known partners, I would suggest that the furnace was probably designed and built (or at least closely supervised) by Bertram, though clearly under the instructions and budgets of his employing company. If so, the symbolic statements 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 indispensibility to his masters.

The process residues can also be considered as the product of the workforce, though in this case not exclusively of Bertram himself, and not (presumably) making an conscious statements. Again, the nature of the excavation limits the information that could be gained by reexamination of the existing assemblage – although large, it contains very little stratigraphic depth. However, as with the artefacts, 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. 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 archaeo-metallurgical understanding of what they were doing? With modern scientific techniques, and much more sophisticated scientific, cognitive, and humanistic questions, the first enabling and the second requiring far more, and more detailed, analyses than was either possible or needed twenty years ago. These approaches have yet to be developed in detail (so far as I know) for steelmaking, though recent work in related areas of archaeological science such as glassmaking (Dungworth and Cromwell 2006) offer pointers to the methods and strategies that may be appropriate.

Finally, to return briefly to some of Chris Evans' questions in the Agenda. In many ways, the cementation process can be seen as very much an 'Enlightenment' phenomenon; capital- rather than labour-intensive compared to 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! However the 'shear steel' process that followed-on from 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 in the early 18th century, the crucible process was developed in Sheffield rather than Tyneside and the Derwent valley.** This may possibly reflect either the rural and relatively remote location of the Northeast steelworks, and/or the mindset of 'art and mystery' proclaimed by the furnace structures; whereas the urban atmosphere of Sheffield was better for the interchange of ideas that leads to new innovation. But I would like to see these ideas explored more rigorously!

Turning to Evans's 'key turning points', I would suggest that some of the time-lags that he identifies may reflect the delay between 'invention' or 'introduction' and the incremental development of ptractice to produce consistent, reliable and cost-effective production. This can be investigated by large-scale and well-designed archaeo-metallurgy, in conjunction with excavation. But I think there may another factor involved, and I will finish with a sketch-analysis in terms of the concept of 'technological packages', a concept related to current biological thinking on 'saltatory evolution' (on which I am only beginning to read up!).

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 proces,

and the usability of one product in the next linkof 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 change); 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, will initiate 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.

To apply this analysis to steelmaking: I would suggest that the take-off of cementation steelmaking in Britain in the 1680s and 90s 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, since the scale of shear steelmaking did not really match the scale of blister steel production, and both the scale of end-production and the consistency of the product did not really meet the developing requirement of 18th century 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.

Is this analysis helpful?

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Bibliography

Andren, A. 1998, *Between Artifacts and Texts: Historical Archaeology in Global Perspective*, New York and London: Plenum Press

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

Barraclough, K C, 1984a. *Blister Steel: the birth of an industry* (London: The Metals Society)

Barraclough, K C, 1984b. *Crucible Steel: the growth of technology* (London: The Metals Society)

Berg, T, and Berg, P (trans.), 2001. *R R Angerstein's Illustrated Travel Diary, 1753-1755* (London: Science Museum)

Casella E and Symonds, J, (eds) 2005. *Industrial Archaeology: Future Directions* (New York: Springer)

Cranstone, D, 1997. *Derwentcote Steel Furnace; an industrial monument in County Durham* (Lancaster: Lancaster Imprints)

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

Cranstone D, 2005. 'After Industrial Archaeology?', in Casella E and Symonds, J, (eds) 2005, *Industrial Archaeology: Future Directions* (New York: Springer), 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: Edinburgh University Press)

Funari, P. P. A., Hall, M., and Jones, S, 1999, *Historical Archaeology: back from the Edge*, London and New York: Routledge

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

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

Whitley, D. S. 1998, 'New Approaches to Old Problems: Archaeology in Search of an Ever Elusive Past', in Whitley, D. S. (ed) 1998a, *Reader in Archaeological Theory: Post-Processual and Cognitive Approaches* (London and New York: Routledge), 1-28