HISTORICAL METALLURGY SOCIETY (HMS)

2010 CONFERENCE at West Dean College **2-3 September 2010**

Project Secretary, Gillian Hovell, attended the two-day HMS conference at West Dean, Sussex, in September 2010.

Some 90 delegates attended, from America to countries throughout Europe (Spain, Italy, France, and the Netherlands) as well as every part of the British Isles (Wales, Ireland, Scotland and England).

Lectures were given on topics ranging from the history and personalities of the study of archaeometallurgy, the nature and issues of experimental archaeology, as well as overviews of specific studies in the discipline. One topic of discussion was the merits of pattern-welding swords (made by twisting different irons together with the result that the sword may or may not be harder/tougher/brittler and that it bears a quite beautiful pattern on the surface of the blade). Examples were handed around.

A substantial focus of the conference though was on the experimental archaeology carried out in the designated area of the college during the first afternoon and the second morning. Eight shaft furnaces had been constructed prior to the conference. They were fired up during the first day and there was much speculation about which would create a decent bloom of iron.

Any reasonable bloom was then given to an experienced smith/archaeometallurgist to work into a bar to test the quality of the iron. The smith’s forge was powered by charcoal and a traditional boom-operated style bellows.

In addition, a selection of bowl furnaces was prepared prior to and during the conference.

Similarly, one or two bowl furnaces were used to smelt a small amount of copper.

A small primitive steel-making furnace was built of clay, fired and tested on the second day.

Experimental Archaeology in Action

Charcoal was sieved in a central area before being given to the experimental teams. Despite the extreme muckiness of this job, the sieving was essential to prevent charcoal dust from choking and smothering the inside of the furnaces.

It was noticed that the charcoal that was poured into the furnaces was of fairly substantial sizes. This was not the one-inch spring wood charcoal which we suspect was used in Clocken Syke furnaces. It is known that the condition of every raw material creates a variable in the furnace experiments – what difference the charcoal size makes was not therefore identifiable but it should be noted for our purposes that it must have some impact.

Iron ore of medium to poor quality was sourced mainly from one geographical location and supplied in large iron-bearing blocks of stone (just within carrying weight). These were pounded by hand using basic unfashioned handheld stones (the modern tool users used regular hammers to do the same job and the consistency was noticeably different as a result) on flat stones and log ends until the ore fragments were about pea sized or slightly larger.

Wealden Ore – higher iron content - previously used. Section of resulting bloom

Raw ore used for conference experiments – ground on site. Resulting bloom

Both charcoal and iron ore were tipped into the furnaces from above throughout the day as the furnaces were constantly topped up.

Furnaces

Most furnaces were built of brick and covered inside (and in most cases, outside) with a single sourced clay that was mixed with materials according to each team's preference. Straw and dung were the main additions as far as I could discover. The open diameter of the furnaces was generally preferred to be 10 inches: previous experiments had apparently proven that this was a crucial factor – more or less and the bloom did not form. This seemed to be endorsed when one furnace, as a result of slumping sideways (due, the maker claimed, to substandard clay that simply wouldn't bond) was operated with an almost doubled diameter shaft due to its angle - the quality of the bloom was so dramatically affected that it turned out to be completely unusable.

Furnace 1

A particularly successful furnace was operated by an American team who had worked on Jamestown reconstructions. However, they used firebricks lined only internally by clay (which degraded between the bricks during the process). The furnace was built on the surface of the ground and these factors make it all very different to the archaeological evidence of sunken, stone-built medieval furnaces found on Iron-Age (Nidderdale) Project's site.

Generator-powered electricity was used to power air into the furnace. A successful bloom was achieved but the means were so far removed from those seemingly used in our medieval furnaces that the conditions are hardly comparable.

Furnace 2

A second successful furnace made by the Americans was thinner in shape and both lined and coated by clay. Its base seemed to have been set into the ground and insulated by brick.

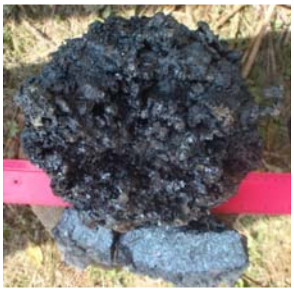
An electric air pump had been used for this furnace too.

An identifiable bloom was removed from a carefully made removable entrance at the base of the shaft. The slag closely resembled medieval slag found on Clocken Syke and the bloom was successfully worked by the blacksmith.

Furnace 3

Gerry McDonnell supervised a furnace which roared with fire and the flames, and sparks were very evident throughout the process (others tended to create high temperature heat hazes and smoke). While not set into the ground, a bank of soil (held in place with planks) had been built up around this furnace. This may have held the heat in and also enabled the slag and bloom to be pulled out from the front of the base of the furnace at ground level instead of into a slag pit.

The slag, however, was lumpy and full of impurities, and was stuck to large quantities of the lining clay which had come away with it. An expert declared that this was typical of Saxon slag: Roman slag comes away very cleanly, as does medieval slag.



Gerry's furnace also made use of the electric pump for the air flow. A worthy bloom was produced but I detected no great air of rejoicing about its quality, possibly due to impurities within it but I cannot be sure.

These furnaces had been protected by a temporary roof but two nearby furnaces had been built in an uncovered area.

Furnace 4 & 5

Two unusual furnaces were of note. One mini furnace, standing c50cm tall, produced no useable or even identifiable bloom. At no point did it seem to do what it was meant to do.

One tall, thin furnace (little more than a clay tube standing two metres high but powered by electrically produced air flow) churned out much heat and smoke was still burning at the end of the conference but there did appear to be some positive action occurring within it (admittedly after an unnerving and loud backfiring blast within the shaft).

An electric air pump provided a noticeably more reliable air flow for all these furnaces. This air flow could be measured (air per litres). There was some debate about the merits of scientific measurement combined with a determination to produce a bloom vs. the authenticity of ancient methods.

Two more furnaces and the bowl furnace area were situated in a separate area of the experimental zone. None of these had any protection from the weather (which, thankfully, stayed dry and even hot and sunny throughout the conference).

Furnace 6

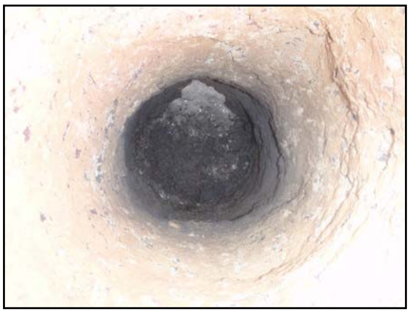
This was the slumped furnace. The clay was blamed for the furnace's slump, but the structure was otherwise sound, needing only occasional additions to the outer clay surface to keep it sealed where it cracked.

The furnace was powered by large bellows connected to the furnace by modern tubing which divided and entered the furnace at two points. The bellows were operated by a hand-controlled boom lever and, like all bellows, were hard and constant work, taken in shifts. The resulting bloom was not a great success, however, being mixed with large pieces of charcoal and slag. The slag itself, however, looked very similar to medieval slag we have encountered in Nidderdale.

The interior of the furnace was available for inspection later and this helped to give an insight into the deterioration and discolouring of the internal clay.

Furnace 7

The second open-air furnace provided a particularly masculine approach and prompted discussions on philosophy and the like (!) but despite an outwardly frivolous approach it was solidly and evenly built and it was, like those found on Clocken Syke, set into a hollow that had been dug in the ground. This certainly helped to seal the lower levels of the furnace and avoid temperature loss at the lower levels (an issue in some furnaces apparently). Two sets of bellows were simultaneously operated by hand, almost in the same manner we had witnessed in an anthropological film about native Africans smelting iron within the last century. The furnace had to be cut and broken / demolished to remove the slag but not before its interior was duly inspected and the remaining slag recorded. It definitely produced a bloom but its quality was never tested by the smith.



Remains of Furnaces

When the blooms had been removed, these open-air furnaces were demolished and the ground levelled. This was part of the experiment to see just what was left after a furnace had been removed.

Large quantities of charcoal that had covered the ground dispersed remarkably quickly and the broken chunks of the furnace itself were quite crumbly. Areas where the ore had been crushed were stained red but this would probably disperse quickly and completely as they were on the surface of the ground and barely trodden into it at all.

In conclusion, only parts of the structure which had been beneath the surface had any chance of survival, even within hours of the demolition. The tuyeres were all, naturally, above the ground level and so no evidence of them would remain. The racking out of the slag left only a tiny amount behind. Apart from the slump in the ground above the hollow of the base of the furnace (due to soil settlement) it is not surprising that some of our furnace sites have little more than the degradation of the heated soil to show that they were there.



In conclusion:

The experimental furnaces were varied in nature and the operators varied in their approach to the reconstructions. The procedures and results prompt a number of conclusions that may be applicable to any reconstruction undertaken by the Iron-Age Project.

- Charcoal must be sieved before use to avoid choking the furnace.

- Ore must be pounded into lumps to maximise its surface area and avoid clogging the furnace.

- It is universally agreed that different ores would, inevitably, produce different qualities of bloom. Higher iron content ores had been used with much greater success to achieve a decent bloom - and the Americans showed comparative examples of previous ores and blooms.

  It would be sensible for our own experiments to use local ore, so that any reconstruction avoids too great a variable and is as close to the original conditions as possible.

- The experimental area was sited in an enclosed wooded area. There was virtually no breeze, let alone the almost continuous wind that blows across Clocken Syke's furnace area. The bellows and air flow proved to be one of the hardest factors to maintain in this airless experimental site.

  It seems likely to me that a windy site would make a vast difference to the work required to maintain air flow through the furnace, although few of those at the conference seemed to consider it a major factor or even of any importance at all, despite the sheer effort required by them to maintain an air flow. Movement of air must have made a vast difference to the air flow through the bloomery furnaces on our site – after all, the point of a chimney is to draw the air upwards through the furnace and this is most effective in steadily windy conditions.

- Some furnaces at the conference used modern methods and materials to improve their chances of creating a quality bloom. Others tried to stay true to the archaeological records. An electrically operated air flow significantly improved the quality of the bloom but this was not sufficient in itself to guarantee success. It was notable that the operators of the two open-air furnaces which used more traditional methods were both keen to exchange views and ideas and they were interested in attending and learning from our own proposed reconstruction. Those using modern machines and materials tended to dismiss reconstructions unaided by modern equipment as doomed to failure!

- Using springwood charcoal will be different to the mainstream archaeometallurgy experiments currently in vogue. However, there is no sign of bulk charcoal having been used on our site. And I believe using springwood charcoal would keep any reconstruction we undertake as close as possible to the original medieval furnaces.

- Poor clay seems to have been a crucial factor in the failure of the conference furnaces, and it would be wise in future experiments to use clay sourced from close to the archaeological remains of furnaces: the charcoal could be sourced elsewhere (brought as springwood on pack horses and made on site) and the ore, once broken up, would not degrade in transport. The clay, it seems, however, had to be damp and dense and this would be incredibly difficult to transport. Maybe this is why bloomery furnaces are sited in particular areas?

  A thought: is this one reason why Roman and medieval furnaces have slag which is clean of clay, while Saxon furnaces, sited on virgin territory (therefore maybe not sited for their proximity to a good source of clay?) produce slag mixed with the clay lining?

- Running repairs to the external clay were needed throughout the day on all furnaces. A supply of ready-mixed clay will be necessary for any experimental reconstruction.

- To my knowledge, none of the experimental furnaces were built with stone. Surely the thermal properties of stone vs brick would have an impact on the worth of the experiment? By using stone in any Project's reconstruction, we shall be able to see how this affects the operation of the furnace but also it will reveal how the stone degrades during the firing and what is left of the sandstone after the furnace has been demolished – on our site we find some stone remaining from the below-ground structure but, in some places there is only some reddened/yellowed sand left to say the sandstone was there at all. Would a reconstructed stone furnace reproduce this effect?

- A question: does the size of the charcoal pieces poured into the furnace have an effect? The slag pulled from the conference furnaces all contained large pieces of charcoal set within it and even the blooms had visible lumps within it. Would springwood charcoal do the same? We have seen no sign of slag containing charcoal on Clocken Syke.

- It was clear that producing a bloom was only half a success – there were tales of how another seemingly good bloom had been produced elsewhere but had proved utterly useless when given to even a very experienced smith. The real test is the quality of the final product.

<u>And Finally</u> …

Producing a bloom is dependent on a great variety of factors: raw materials and their preparation, furnace dimensions, air-flow, tuyere angle and height, the operator's approach and even his mood on the day which could affect his attention to detail.

A professional approach and a lifetime of practical experience and acquired hands-on knowledge (ie. 'craft' combined with 'skill') are essential to produce usable iron. Prolonged concentrated hard physical work is required at every stage: the preparation of the raw materials, the construction of the furnace, the working of the bellows, the charging of the furnace with charcoal and ore and the eventual removal of the bloom all required a consistent dedication and attention to detail for any chance of success.

And while we are accustomed to buying iron items we need from a hardware shop or even from a supermarket, we must remember that a bloomery furnace and all the work that went into it would produce little more than enough for a small blade - hence the pattern-welded swords which made use of several separately smelted irons (potentially of different qualities). Such work required great craftsmanship. Even a single sword was the result of a vast amount of work and several smeltings, as well as the smith's skill and experience.

Both iron and copper acquired a genuine respect during the two days of experiments. While we had begun by admiring the workmanship and beauty of a pattern-welded sword, by the end, the sheer existence of a sword with so much iron in it was a source of wonder. No wonder the Roman army, clad in iron, was so revolutionary and why swords acquired names (a la *Excalibur*).

PART 2

Bowl Furnaces

At least three bowl furnaces for smelting iron were made, lined with clay and loaded with charcoal and ore. Simple hand-operated drum bellows were used throughout the day(s) and the furnaces needed frequent recharging with charcoal. In one, small ‘dungballs’ (ore mixed with dung) were used while others used the crushed ore as in the bloomery furnaces.

None of the bowl furnaces were covered with anything, although one had turf up its sides and another had a clay edging, but not nearly enough to account for the clay debris found within the bowl furnaces on Clocken Syke. Perhaps not surprisingly as the air was not restricted, none of the conference’s bowl furnaces produced any kind of iron whatsoever.

Copper bowl furnaces

The bowls for the furnaces were dug out by hand and also puddled with clay by hand.

Quantities of copper ore (malachite) were laboriously crushed by hand using handheld stones. A bowl furnace, blown with a pair of bag bellows and fired with charcoal was used to smelt the ore which had been placed in a lidded crucible (to contain the tiny amount of ore available for use).

Hard physical work with the bellows produced some tiny prills (solidified droplets) of copper. This sandy ore had to be carefully hand picked and then a further heating was used with a flux to help the copper prills to coalesce to form metal.

These copper prills would then be able to be melted in a crucible and then cast into an ingot. However, the tiny quantity achieved was too small for this.

The experiment made everyone appreciate how very valuable copper and especially bronze would have been.

Steel making furnace

The Americans bided their time once their bloom had been produced from the shaft furnaces by making a tiny clay furnace on the end of a log. Its size reminded me of our 'hearths' set down in stones – and now I know why the stone is there: the log caught fire … But apart from its flammable base, the clay furnace was a wonderful example of how such hearths can be used. Apparently they are/were commonly used by the American Indians to turn iron bars into steel.

The clay furnace was shaped (and had a 'porch' in this instance to take the bulky electric generated tuyere) and then dried by burning kindling wood around and inside it for a considerable time (an hour or more? Maybe much more – I wasn't always present). Once dry, it was loaded with charcoal until the temperature rose to an intense level. When I asked how they knew it was ready he shrugged and said they didn't – a classic case of knowing by practised instinct. Several iron rods were brought over and he predicted it would take less than fifteen minutes to reduce them to steel as a melted 'button' in the base of the furnace.

The bars were introduced vertically, one by one and they each sank into the charcoal as the base melted. The furnace was allowed to burn down and the remaining charcoal scooped out so that the button could be lifted out with tongs. On testing the metal, it was determined that it hadn't worked as well as they hoped and that nearly half the metal had been lost in the process, but it was an indication of how the process worked.

Oh yes, West Dean's gardens were great too …

Gillian Hovell
September 2010