That which remains... Signs from Bloomery Iron Smelting
2 * - Initial Compaction

As a guide to field archaeologists excavating iron smelting sites, this series will illustrate the actual production of blooms using small direct process 'short shaft' furnaces. This should provide insight into the physical traces that might be expected, and how these relate to the various stages in the overall process from ore to bloom and into finished working bar.

Once a bloom is extracted from the smelting furnace, the next step is to undertake an initial surface cleaning and compaction process. The process of freeing the bloom from it's creation position in the slag bowl will determine how much slag still is clinging to the metal. There are a number of factors which will determine how compact the bloom itself is as it is as extracted, but generally the mass will have voids to collapse and internal slag to force out. All this is accomplished by hammering the surface, using some combination of large wooden mallets (typically called by modern workers 'troll' hammers) or two handed sledge hammers. It is critical to remember that the bloom will never again be as hot (so as easy to manipulate) as it is when it is first pulled from the furnace, so speed of working is important.

Because the heat required for this entire stage will be rapidly dropping once the bloom is removed from the furnace, the compaction area should be located reasonably close to the furnace itself, yet far enough away that there is clearance for the two different processes. This is most likely to be in a line from the extraction arch side (so away from bellows position), but obviously ground features and furnace construction details may determine the location. Ideally the compaction stub needs to be accessible from all sides, to allow room for a full working team.

After testing different compaction surfaces (metal anvils, stone blocks, wooden stubs) and hammering heights (ground mounted, raised at knee, or waist height surfaces) it has been found that the ideal is an elevated medium diameter wooden stub, of a size to encompass the circumference of the blooms being created. For the experimental work by the DARC team, these blooms have ranged from 3 to 8 kg (1), so a surface of 30 cm diameter has proved ideal. A round cross section of cut tree trunk is the most likely historically (as opposed to a squared section of beam). Digging the base of the stub into the ground will greatly increase stability, 10 to 20 cm depth has been found to be effective. With this mounting method, the base end of the timber need not be especially trimmed flat (this in relation to cutting tool effects, which change over time). These aspects, diameter, depth, profile, may be found archaeologically. Even if the stub was trimmed for a stable flat bottom, and merely set on the ground surface, there would be a clear void in accumulating debris marking it's location and size.

As hand hammers are being used, the stub top is set at standard 'blacksmithing' height. This distance from ground level is highly dependant on the physical stature of the workers. Members of the DARC team average around 170 – 180 cm, so for this group a stub surface at 70 – 80 cm tall is ideal (variations related to worker body size should be expected).

(figure i) Compaction stub currently in use at Wareham.
Red arrow marks direction of (figure ii)

The top of the timber needs to be initially trimmed relatively flat. The reason wood makes an ideal compaction surface is that the hot bloom will burn into the wood, helping to 'lock' the irregular bloom shape on to the stub. (In comparison, when testing with stone or metal anvils, the initial bloom can be extremely difficult to hold in place over harder materials). Over repeated uses, the top of the stub will actually burn into a convenient concave bowl shape, greatly improving this aspect. Although there certainly will be erosion of the stub over repeated uses, the endurance is for dozens of uses. Our testing could be considered ‘seasonal’ with typically 3 – 4 uses over a given year. It has been found that the natural effects of outdoor exposure, insects and normal rotting has been the reason any individual stub has needed to be replaced (typically after 5 – 10 years exposure to weather). It should be noted that there has been no special attempt to select for wood species for use durability or environmental endurance here.

Through repeated uses of the same stub, some observations may prove of value (2):

1) Debris Pattern

It has been seen there is a strong tendency for individual workers to take up similar positions around the stub each time:

a) The extraction requires the use of oversize iron tongs to grab, carry, then hold the bloom mass in place on to the stub. As this entire process is time dependant (and the mass is quite heavy), a ‘shortest distance’ travel to position comes into effect. The result is that the individual holding the bloom is most often in more or less the same location in relationship to the furnace.
b) Individual hammer wielders will space themselves evenly around the stub, based on that ‘holding’ position. The experience of the DARC team has been typically employing 3 strikers, primarily because a larger number simply can not work effectively in the confines around the stub. As might be expected with the ‘holder’ at a relatively standard position, this also places individual strikers at fairly consistent locations.
c) As with many team hammering exercises, the ideal would be for one individual acting as ‘master’, directing both the impact point, and also the relative stroke weight, of individual blows on the surface being worked. Individual strikers will then take turns applying single strokes based on this example. Although the relative position of the master does not matter, the easiest method is for strikers to work in a circular pattern around that starting point. An important factor for non-blacksmith observers is that <u>control</u> is far more important than power to effective compaction. (This level of directed hammering is often not seen by DARC, simply because of changing individuals and a general lack of blacksmithing training or experience.)
d) The bloom mass will need to be frequently re-positioned, both to ensure any clinging slag bowl remains are struck off, but also to control the effective compression of the bloom. If work proceeds quickly, this may extend beyond creating a simple flat disk, to shaping the metal for more rectangular sides, a process that may include slicing or even complete cutting into smaller working pieces. (see below)

As the positions of the workers has been found to be fairly consistent between uses, the ‘spray’ of debris from the hammer strokes has also been found to develop noticeable patterns over time. Most commonly, hammer impacts will push material to the right and left sides of the stroke, rather than away from and towards the worker, with both stub and the worker also providing a block to any distribution in those directions.

(figure ii) Showing the usual position of holding (yellow) and strikers (red). Note the distinctive lobe pattern to the debris scatter around each striker.

2) Distinctive slag types and fragment sizes

As archaeological features, beyond the suggested circular mounting hole, what will remain are scattered traces of the various slag wastes stuck off during the compaction process :

a) Slag Bowl pieces
- The extraction process employed can greatly effect just how much slag bowl material remains clinging to the bloom mass. This material will be composed of black iron rich slag, which may be somewhat ‘frothy’ (small gas bubbles), but generally is

quite dense. There may be pieces of charcoal embedded on pieces that come from the outside surfaces of the original bowl. In some cases (where the entire bowl has been pulled loose) there may also be a layer of clay wall material attached on one side of some. The slag bowl material is fragile under hammering, and also cools relatively quickly. Pieces will shatter off as struck, ranging from 'fist' sized and downwards, with 'hen's egg' sized pieces the most common.
These larger pieces are a significant burn injury risk to the workers. For that reason, the DARC team always includes a 'safety', who has the job primarily of quickly scooping up any larger pieces and tossing these outside the working area (in our case into a metal bucket). Smaller fragments accumulate as they fall. This kind of sorting, for the same reasons, should be expected historically.

(figure iii) Slag Bowl fragments - the pieces above were gathered while hot and dropped into a water filled bucket (for safety), resulting in some pieces shattering and some fast surface rusting.

b) Gromps
As the bloom develops, there is a halo of lacy metallic material around particularly the sides of the more solid bloom. Gromps are defined as fragments that may contain as much slag as metal, knocked off during the compaction sequence. Typically the fragments range from 'hen's egg' size or less (any larger accumulations tend to be compressed down on to the surface of the bloom as it is hammered). These can be

distinguished afterwards by appearance and density, clearly containing iron, but normally of a size and consistency that would make any attempt to forge down into useful bar difficult to impossible. If the metallic content of a piece is uncertain, tapping it with a hammer will cause the contained iron to distort and even break to show a bright silver crystal inner texture (where glassy slag simply shatters into sharp fragments).

It is suggested here that as the difference between gromps and glassy slag is easily made, even historically these pieces would be gathered up, to be added into future smelts to recover the contained iron. (3) Practically, this means any gromps much smaller than ‘peanut’ sized are likely to remain where they fell. (This team sweeps the compaction area with a magnet to recover even small particles, a method not available to ancient workers.)

(figure iv) Gromps – these larger pieces were also collected hot and dropped into water, later sorted from the other fragments by weight (density) and appearance. Note the greater surface rust, this after only two days immersed.

c) Liquid Slag

The bloom itself is a spongy mass, which may still contain small amounts of liquid slag internally (amount is dependent on ore used and the smelting process undertaken). As the mass is compressed, this slag may dribble out as pockets are broken, or be forceably ejected under hammer blows. In both cases, this material will be dense, black, and iron rich. When allowed to dribble out, the result most closely resembles small tendrils of tap slag, and can be expected to be found close to the base of the stub. When ejected, the slag will form small rounded blobs (even tiny spheres) – which may travel a considerable distance (1 – 2 meters has been seen). All these fragments are likely to be small enough to require collection by screening.

(figure v) Liquid Slag droplets – collected from the base of the stub, with dark coloured and smooth 'melted' looking surfaces.

Example – Smelt # 91 – June 2022

(see : http://www.warehamforge.ca/ironsmelting/iron2022/june-2022/june-22.html)

A reference video was shot by **Anita Herbert** of an entire compaction process. **Neil Peterson** is holding the bloom and directing what surfaces are being compacted. **Richard Schweitzer** is leading the hammering sequence, seen initially using the wooden troll hammer. **Maxim Fedetsov** and **Isabelle Wigglesworth** are the two other strikers. **Kelly Probyn-Smith** is safety.

- The viewing angle is approximately the same as in figure ii.
- Note the inaccuracy of 'heat colours' recorded by the camera over that perceived by the human eye (the camera always showing too 'bright').
- This was the first time at a smelt – or attempting striking, for Max and Isabelle (!)

For reasons of space, readers are directed to view the full video sequence available on YouTube : https://youtu.be/7YD0-dwo-wY

The final bloom weight from the experiment above was 7 kg, from 24.5 kg of red oxide analog (Fe_2O_3) ore. (4) It should be noted that this bloom was considered very spongy as it was compacted, with more liquid slag pockets than are typical for this team.

Individual screen captures seen below are taken from the video, with descriptions :

(figure vi) Part way through the first hammering sequence. In this case the entire slag bowl encasing the bloom was extracted, resulting in a much larger starting block than is typical for this team, about 25 cm in diameter and 20 cm top to bottom. A large piece of encasing slag bowl material can be seen flaking off, exposing the much hotter metallic bloom surface underneath.

(figure vii) At the end of the second round of hammering, the mass being shifted to expose a different side for hammering. Roughly fist sized pieces of slag bowl are being moved clear of the work area, while several (hot!) egg sized fragments can be seen still on the ground to the right.

(figure viii) About half way through the compaction process, the bottom of the bloom now uppermost. Hammering has cracked open an internal pocket, ejecting liquid slag, which can be seen running out and dribbling as small pieces down on to the ground.

(figure ix) About two thirds way through compaction. The clinging slag cools much faster, and as it is struck off, the visibly hotter bloom core becomes obvious. In this position, the bloom is on one edge, with the original top surface to the right, already showing slightly flattened edges from the classic 'planno-convex' shape of artifact blooms.

The white colour of the larger slag pieces (to left and lower right) are surfaces of broken away clay furnace wall.

(figure x) At the end of the initial compaction sequence. The bloom at this point has been formed into a rough cube through repeated hammering, but has cooled down below a temperature where any further work would be effective without re-heating (actually into a 'red' colour to the eye).
Even with repeated removal of the larger hot pieces of slag that had been broken away, the circle of debris created is obvious.

Notes :

** Summer 2022 - This series is being written in a somewhat random order. The individual segment numbers are thus tentative as separate articles are produced.*

1) At point of writing, I have led, or participated in, over 90 bloomery iron smelts, and have observed half again as many by others. Members of the **Dark Ages Re-Creation Company**, a group of Viking Age re-enactors, have assisted with 36 experimental or public demonstration smelts. The full experimental series is documented on the web site : http://www.warehamforge.ca/ironsmelting
For information on DARC, see : http://www.darkcompany.ca/

2) When these images were taken, this stub had been used for 18 compaction sequences. It was set in 2015, a replacement for an earlier timber mounted in roughly the same location. It should be noted that this is a natural grassed area, so fine details of fallen debris are somewhat obscured. The larger pieces (as detailed) are cleared away and removed from the immediate smelting area.

3) – **Arne Espelund** proposed a ‘partial product’ method were ancient iron makers would deliberately limit a smelt to generate gromp like metallic foils embedded in slag, which would be collected up cold and subjected to a second full smelting sequence. The concept was presented to a group of working bloomery iron makers at the ‘Iron Making Seminar at Thy’ (Heltborg, Denmark – 2008 : http://www.warehamforge.ca/ironsmelting/HELTBORG/index.html) – and was universally considered unlikely. Although there is certainly archaeological evidence for the collection of gromps (Espelund, '*The Evidence and the Secrets of Ancient Bloomery Ironmaking in Norway*'), it remains my opinion (and that of others) that this merely represents the collection of obviously iron rich remains intended to be added as later enrichment (a process demonstrated experimentally in #81, November 2018 : https://warehamforgeblog.blogspot.com/2018/10/the-espelund-method-saturday-nov-3.html)

4) I have employed a wide range of iron ore types over the years, mainly because of the simple problem that there is no naturally occurring iron ore anywhere close to Wareham in Ontario. Starting in 2008, an analog to simulate primary bog iron ore was developed by DARC, comprised of industrial red iron oxide powder with 10% wheat flour as a binder. This has become the standard ore used, providing dependable and comparative results. (see : http://www.warehamforge.ca/ironsmelting/ores.html)

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