Illustration

What did We Get?

In the Internet are plenty of sides from all those enthusiasts who procured the necessities for smelting (charcoal, ore, flux, clay, tuyeres, bellows, ..., beer), went out there, built a bloomery, run it, and hoped to find some iron inside. Here I will give excerpts from a random collection with particular regard to the result.

- Did they get a bloom of iron ? A good-sized one relative to the amount of iron ore used? Was it wrought iron or "carburized" iron?
  Most sites do not give precise quantitative data. That is just as it would have been 2000 years or so ago, when nobody would have told you the percentage of carbon in their bloom either. Nevertheless, looking at all the data provided, a clear result emerges: It is possible to smelt iron with a half-way defined carbon concentration (including low concentrations) in an efficient way - but you need to do everything just right! Going "by feeling" will not be good enough.
  My emphasizes in what follows.

A bit of Magic might help:
On an anthropological note, I was struck by how similar the tapping and extraction process was to *childbirth*: The slag pours out ("water breaks"), the tap arch (birth canal) is gradually enlarged, the bloom descends (the birth canal) and is finally extracted (not without difficulty) in an atmosphere of excited expectation and purposeful preparation and activity. This could not have been lost on ancient people and would no doubt have influenced and increased the significance of attendant *ritual and "magic".* We ourselves decorated the tap arch with a vulval symbol, fashioned a small Venus figurine from the tuyere clay, and *poured an "offering" of duty-free whiskey into the furnace* before charging began. It should never be forgotten in interpreting ancient sites that such things were equally "practical" to early technologists as ore and fuel quality or furnace design.
Source: http://iron.wlu.edu/reports/Eindhoven%20Smelt%20Report.htm

In 2012 Darrell **Markewitz** , a black smith running the **Wareham Forge**, applied for - and received - a grant from the Ontario Arts Council. The purpose of this Craft Project - Creation and Development Grant was defined : "... is to cover three months of dedicated time to allow me to develop a practical understanding of how to convert ten year's production of raw iron blooms into working bars". Here are some results:
The concentration at Smeltfest this year was in part on working with a *new magnetite ore*. On our first smelt, we did *not* produce any iron. After some consideration, the thought was that we had purified the ore (double magnetic sorting) too much, not leaving enough glass producing elements to create the correct working slag bath inside the furnace. On the second smelt, the result was a (quite surprising) *'white' cast iron*. Not what we expected at all. On the third smelt seen here, the result was a solid bloom of a *middle carbon steel*. Perfect!
Just to prove there is still more art than science in bloom smelting, our fourth attempt *should* have produced another flow of *high carbon cast iron*. The result? *Middle carbon steel again*, although not with the same yield or consistency as smelt 3. Hmm - some more consideration and experimentation seems in order here!
Source: http://warehamoacgrant.blogspot.de/2012_03_01_archive.html. Try also: http://www.warehamforge.ca/ironsmelting/ for plenty of data.

- Quite illuminating. Guys quite experienced with iron smelting vary just one parameter. What they produced - always against their expectations - is:

  1. Nothing
  2. Cast iron
  3. Middle carbon steel, i.e. around 0.4 % - 0.6 % (my guess)
  4. Middle carbon steel instead of high carbon steel

When completed, a section of the lower furnace was removed, and a frothy iron sponge-like material called a bloom (blástrjárn) was levered free of the furnace walls. The bloom was a mixture of *low-carbon iron*, slag, and charcoal. The surrounding slag and charcoal were knocked off, and the remaining material was compacted with sledges to consolidate the material. The bloom was refined by *folding it*, which mechanically served to homogenize the material and to drive out the impurities, such as slag. The folding process was *repeated multiple times* to create cleaner, more highly-refined material. The desired end result was a malleable *low-carbon iron*, ready to be forged to fabricate the required articles.
In the past, I believed that the quality of the iron obtained was highly variable because the smelting process was *difficult to control*. Yet modern smiths using replica Viking-age bloomery furnaces are routinely turning out high quality iron, which suggests they have good control of the process. Regardless, the process was *very inefficient* ; a lot of iron was left in the slag.
http://www.hurstwic.org/history/articles/manufacturing/text/bog_iron.htm

- Note that during the forging de-carburization takes place. Lots of folding means lots of surface through which carbon can diffuse out. The original bloom this might have had a somewhat higher carbon content.

Here are some statistics from an 2008 Iron Smelt Experiments done by Lee Sauder and Skip Williams, by now real experts. There are far more data on their pages. Note the rather large variation of the results
http://www.warehamforge.ca/ironsmelting/smelt/smelt08/index.html

Experiments in the same kind of bloomery					
No.	CC [kg]	Ore [kg]	Time [hr]	Bloom [kg]	Comments
1	45	23	4½	5.5	Soft iron, some C
2	60	30	5½	1.7	High carbon
3	68	59.5	5½	7.2	Soft iron
4	34	18	4½	2	Workable iron
5	13	15	2½	None	11.5 kg high-iron content slag
6	12	7.8	2¼	None	no iron produced
7	30	20	3¼	1.9	workable iron
8	67	35	6	9.5	workable iron
9	46	23	6½	4.9	workable iron
10	48	24	5	4.25	workable iron
CC = charcoal weight					

The ore that was available to the Eindhoven participants was a *bog ore* from North Western Germany. Previous analysis carried out by Dr. Arne Espelund indicated that most samples were of relatively low iron content, and *high in phosphorus*. Based on the quantity of iron that would necessarily be reacted with the silicates and end up as slag, it was his *prediction that this ore should not produce much if any iron*, despite previously reported success. As a means of enriching this bog ore, *Skip Williams* requested a supply of hammer-scale (magnetite).
The blower was turned off, and a rod was driven through the top of the tap arch until the pockets of slag were found. This drained off into a previously prepared depression that had been lined with a layer of charcoal fines. The slag was fully molten and fluid, running out into quickly cooling blocks that were removed with a shovel. This slag proved to be *weakly magnetic*, probably owing to the inclusion of particles of reduced iron and/or magnetite.
Product: Of the *four* smelts, *two* produced *successful blooms*. Both used bog ore enriched with magnetite. These blooms were roughly lens shaped (plano-convex), with the more convex surface oriented downwards in the furnace. The first bloom weighed seven kilos and was cut into two major pieces. The second bloom was sectioned through after I returned to Buffalo, New York using an industrial power hacksaw. Interestingly, large interior voids in this bloom were mostly empty rather than being filled with slag as expected.
Spark testing on a grinding wheel showed the starburst, secondary sparking characteristic of *high carbon material*, specifically steel, on some *exterior zones*, but the *interior* produced the long, non-branching sparks typical of *wrought iron*.
http://iron.wlu.edu/reports/Eindhoven%20Smelt%20Report.htm

- Two out of four runs give blooms. At least one bloom changes strongly in compositions from the inside to the outside.
  The page gives a lot of data, including metallographic pictures.

Then like the birth of a dragon (*interesting variation of the theme from above*) the bloom emerged. The chimney fell over and lay in glimmering ruin, as we struggled with the *white hot* bloom. Owen grasped the refulgent bloom in his tongs and dragged it to an anvil that was set near the chimney; we took turns hammering it with a great striking mall. The bloom was *unconcerned by our petty knocking* and absorbed the hammer force with little notice, glowing and brooding, full of potential.
This bloom is *full of carbon*, which means it is steely-iron, the magical stuff swords and knives were made of during the Iron Age.
http://jakepowning.blogspot.de/2011_04_01_archive.html

White hot and not given to plastic deformation by hammering? Maybe it was cast iron?

Bei diesem Verhüttungsprozess wurden insgesamt ca. *70kg Holzkohle und 16kg Eisenerz* verarbeitet. Das Gewicht der gewonnenen Luppe betrug *4kg*. Um einen verwendbaren Eisenbarren zu erhalten muss die Luppe im nächsten Arbeitsschritt mehrmals gefaltet und feuerverschweißt werden.
Nach der Langen Nacht der Museen stand unserem Rennofen noch ein langer Winter bevor. Er wurde nicht abgerissen, sondern konnte im Innenhof des Museums stehenbleiben. Ziel dieser Aktion war es, den Verfall eines solchen Rennofens zu dokumentieren. Einerseits ging es uns darum, zu ermitteln, wie gut er - ohne Überdachung - Wind, Wetter und Winter standhalten konnte. Andererseits wollten wir die taphonomischen Prozesse dokumentieren und nach dem Abtragen des Ofens im Frühling festhalten, wie sich der Befund im Boden abzeichnet, zumal solche Spuren einen wichtigen Teil der Hinweise darstellen, die von der Archäologie noch von einem ehemaligen Rennofen wahrgenommen werden können.
http://exparchvienna.blogspot.de/2010/04/lange-nacht-und-langer-winter-fur-einen.html

70 kg charcoal and und 16 kg ore produce just a 4 kg bloom

Insgesamt hat die Ofenreise sehr gut geklappt. Wir haben ca. alle 15 Min. 600 Gramm Holzkohle und 300 Gramm von unserem neuen Raseneisenerz zugegeben. Insgesamt haben wir in 21 Chargen ca. *6,3 Kg Erz* verhüttet. Einen Schlackeanstich haben wir versucht, kam aber nichts. Die gesamte Ofenreise inkl. Vorheizen und Ausbrennen ging, wenn ich mich recht entsinne, 5-6 Stunden. Geerntet haben wir eine schön kompakte Luppe von *1950 Gramm*. Also fast eine 1/3 Ausbeute. Die Luppe lag genau in der Mitte vom Ofen knapp unter Düsenhöhe. Unter der Luppe gab es einen schönen Schlackesee, an der Luppe selbst klebte allerdings kaum Schlacke. Besonders schön bei dieser Ofengröße finde ich, dass man eine handhabbare Luppe erntet und die gesamte Reise relativ schnell vonstatten geht. Ist stressfrei an 1,5 Tagen zu machen. Wenn man sehr früh anfängt, könnte man es wohl auch an einem Tag schaffen.
http://schmiededaseisen.de/forum/rennoefen_im_viking_center_ribe-7456505-t.html

6,3 kg ore yield a 2 kg bloom.

Wir haben von ca. 18:00 Uhr an gefeuert und die Nacht durch bis etwas 6:00 Uhr, dann hatten wir kein Erz mehr. Bis 7:00 Uhr haben wir dann durchbrennen lassen und von diesem Zeitpunkt an nur noch gewartet, dass der Ofen abkühlt.
Die Luppe kann nur aus dem Ofen geholt werden, wenn man diesen abbaut, bzw. umstößt. Daher sollte man auch tunlichst Lehm als Mörtel nehmen. Bis 8:30 Uhr waren die Öfen noch heiß, so dass wir nur einen geöffnet haben. Auch von diesem kam uns noch eine deutliche Gluthitze entgegen. Die Luppe hatte sich unterhalb des Belüftungsrohrs gebildet, war ein riesig verbackener Kloß, der nur mit heftigen Stößen einer Eisenstange vom Mauerwerk abbrach. Nach dem Auskühlen (am nächsten Tag) konnten wir mit einem Trennschleifer Stücke von der Luppe trennen. Im Vergleich waren die Ergebnisse beider Öfen ähnlich, wir haben *sehr große Luppen* erhalten. Wir lagen mit der Temperatur bei ca. *1100 Grad Celsius, was wir zu Beginn nachgeprüft haben*. Mit dem Gebläse kann man die Temperatur erhöhen oder erniedrigen. Wichtig ist es aber, nicht zu heiß zu werden, denn der Rennofen versintert das Eisen nur, es schmilzt das Eisen nicht.
Wir haben, so Herr Crampen als Schmied, ein *Gusseisen* erzeugt. Dieses ist schlecht schmiedbar und müsste „aufgefrischt“ werden, d.h. in einer Thomasbirne unter Sauerstoffeinblasung zu reinem Eisen überführt werden. Dies kann uns aber nicht gelingen, so dass wir mit dem Eisen vorsichtig eine Schmiedearbeit beginnen werden. Hier kann nur noch der Schmied sein Kunst beweisen.
http://www.waldorf-ideen-pool.de/index.php?katid=297

A High-School project. *Cast iron* was produced, according the smith, who was a professional.
The temperature, however, was measured (?) to be around *1100 ^{O}C* (2012 ^{O}F); a bit low for making cast iron.