

# IRON SMELTING

**“WOODFORD IRELAND” AUGUST 2018**

**EXPERIMENTAL ARCHEOLOGY**



*Hard working iron smelting furnace*

**An overview of four iron smelting days  
by Leo Moonen (Leo Ironsmelter)**

## PREFACE:

The “members of the iron smelting group” at the “Hunebed Centrum Borger” are already for some year’s now extracting iron from ore, following a method dated back to the “iron age”.

The “iron period” starts in western Europe around 800 BC and ends around the Roman period. Iron can be found as iron ore in rocks but also in the near subsurface as bog iron, transported as a solution by water and deposited. Depositing the iron goes quite fast - not centuries are needed but a few decades are sometimes enough for farmers to decide removing the iron containing banks, a few feet beneath the surface of their land.

Here in Holland, as in several other parts of Europe, the basic method of extracting iron from bog ore was very simple, using small sized smelting furnaces.

Keeping this practice and skills "alive" is done regularly at the "HunebedCentrum", at various other places in Europe - and also outside! There are only a few smelters per country and it is always a fest to meet in a festival and share our experiences.

So we did this year -2018- also in Woodford, Galway (Ireland) in August, a place with a rich history in producing iron. On a very nice field next to a small artificial lake. This reservoir was in the 17th century to power a blast furnace for iron production. Woodford was 'The Village of the Iron Mills.'



Our iron bloom

### The team members:

Leo Moonen Holland (Leo Ironsmelter on facebook),  
from the "Hunebed Centrum Borger" iron smelting team

Rudi Holmes UK, artist blacksmith - "Calderforge blacksmithing"

Audrey Smith UK

Gerlianne Paulus Luxembourg

Olivier Luxembourg

Romain Bohr Luxembourg, blacksmith

and

Maria Arians-Kronenberg, Germany, roasting first part of the ore , worked with the Polish team.

## CONTENTS:

page 5	"smelting" is not "melting" - the iron smelting process.
page 6	The bog ore, charcoal and the iron.
	Four days "ironsmelting":
page 7	day 1 Thursday, start building, walking and talking.
page 11	day 2 Friday, finishing the furnace.
page 13	day 3 Saturday, extra roasting, watching the bloom results of various teams.
page 18	day 4 Sunday, our smelting furnace at work -> result 15 kg iron bloom .
page 23	data

## INTRODUCTION:

To celebrate the heritage in Woodford, several Iron Smelting Teams of Europe gathered here in the center of Ireland for an iron smelting event.

The event was organized by Paul Rondelez in August, from Monday 20 until Sunday 26.

There must be something special with this Irish place and/or the ore we used because:

***ALL THE TEAMS WERE SUCCESSFUL IN PRODUCING IRON,***

some produced a spectacular large bloom of high quality almost clean iron, some a smaller good forgeable bloom ....

On Thursday I arrived and started to build my preferred type furnace. During four days there was plenty of time for walking, talking and recording until my own smelting day on Sunday. By Sunday, five experienced smelters and black smith's offered their help, joined into a team and made our smelt a big success! Our end result was a bloom of 15 kg iron (very homogenous), out of 56 kg bog ore.



## THE PROCES OF IRON SMELTING ("smelting" is not "melting")

In the iron age we could not reach the high temperatures for melting the iron as is done these days: above 2000°C .

The lowest temperature needed for melting the iron can be found in an "Iron-Carbon" diagram. It starts at around 1500°C for "clean" iron and is as low as 1130°C if the iron contains enough carbon molecules. Only above these temperatures iron is in a liquid state.

Burning charcoal in a small furnace does not give these high temperatures (at local spots sometimes). But, instead of melting the iron, the sand and rock material in the ore around the iron can be molten at around 1100°C and separated from the iron. You can see it as streaming "lava".

What goes into a basic small furnace from the top is the roasted \* ore (sand and rocky material with "rust") AND charcoal, often in the same mass quantities. Air is blown near the bottom, into the furnace where the burning coal gets hot enough for the sand to melt. The amount of air estimates the temperatures. The burning of the charcoal goes "very dirty". Much CO is produced and is present in the shaft. Already just beneath the top opening of the furnace, at temperatures above (~) 700°C, the CO is so aggressive, it removes the oxygen part (O<sub>3</sub>) of the rust (Fe<sub>2</sub>O<sub>3</sub>) and leaves the iron "clean" to drop deeper down to the hottest area in furnace (near the tuyere) where it may unite with other "clean" iron if the melting rock and sand flows further down. Although iron is heavier than the rock, the iron tends to stick together with other iron just beneath (or around) the tuyere and form a "bloom".

After a few hours the small smelting furnaces usually come into problems: "blocked" airstream..

The bloom inside is still quite "dirty", containing pieces of rock and charcoal. It has to be taken out as hot as possible. On a block of wood (so it doesn't cool fast) it will be hammered upon: compacted. If you only hit it "on top" it will get more flat - and break into pieces. If you watch this in a movie\* you will see the trick of hitting also sideways to keep the bloom in one piece. Before the bloom gets too cold and difficult to handle you want to split it for further treatment by the blacksmith ... or you have to reheat the bloom again.

Further on in this report you will see various images I took from five other iron smelting teams: Lee Sauder, Bill Trainer, Robert Funkenschläger, Owen Bush and Katie Surridge. There were more teams on the field with often more than one furnace.

\*You may find a video clips of these furnaces at work and blooms being compacted on my facebook page "Leo Ironsmelter".

## The bog ore and charcoal

Three different types of bog ore were used in this Woodford smelt. At the start of the festival, two types of bog ore were available: light colored from Derryarkin Co. Offaly (A) and the dark colored of Kilchreest Co. Galway (B). Later in the week another 10 bags of dark colored bog ore from near Mountshannon (C) were added.

Type A had an iron ("rust") content of almost 90 % (!?), type B of 50-70 %, type C unknown.

The smelters using type A, all produced a very nice bloom with high iron content. Users of type B and C had a more "usual" good quality bloom.

We used 40 kg of roasted bog ore type A from Derryarkin (light brown) , all that was the "left over" by other teams, and 16 kg roasted type C (dark brown) from Mountshannon, in total 56 kg bog ore. The charcoal was produced local - you may find more on this on the facebook page of Paul Rondelez.

## The method of extracting iron from the ore was:

First the ore is roasted on a "good" fire. All organic material is broken down and the ore gets brittle. The remaining iron is mostly "rust":  $\text{Fe}_2\text{O}_3$ . As it sticks to a magnet, the rusty iron can be sorted out of roasted ore. This way you leave some non-magnetic iron behind in the roast... The final size of the pieces must be small enough to allow the CO to do the work and large enough not to be blown out of the furnace during charging.

After the furnace has reached the desired temperature, equal amounts (weights) of ore and charcoal are loaded through the top of furnace. The rate is often in the order of (0,5 kg ore + 0,5 kg charcoal) per 5 a 7 minutes. This continues for a few hours, until you run out of ore, but most likely earlier because the system gets blocked.

The German type Rennofen can be opened at the bottom to let the fluid rock flow out. Another (Dalfsen) type may have a 40-50 cm hole beneath the tuyere, initially filled up with branches, to collect the molten rock.

I built a German type "Rennofen".

## DAY ONE - Thursday, August 23

### *(1) a "Lee" type furnace:*

Lee was already smelting and as I was still at the very beginning of building my furnace, there was plenty of time for some video, some pic's .... and talking. I noticed a few things like: Lee and his team built a "narrow" tall furnace (110cm H x 26cm W inside) with one tuyere - slightly higher positioned as I expected. He applied a rather high burning rate, of 2 kg charcoal + 2 kg ore every 11 minutes - almost twice as fast as I am used to. Watching him producing a nice bloom at this rate, I decided to also go for a high burning rate. Not too fine chopped charcoal and ore was used.



At around 1100 - 1150 C rock becomes fluid and drips/flows down (lava at small scale)

Ingredients: charcoal and roasted bog ore from Derryarkin

Lee Sauder's smelting furnace at work



Opening the bottom of the furnace



Bloom sticks just beneath the tuyere (top right)



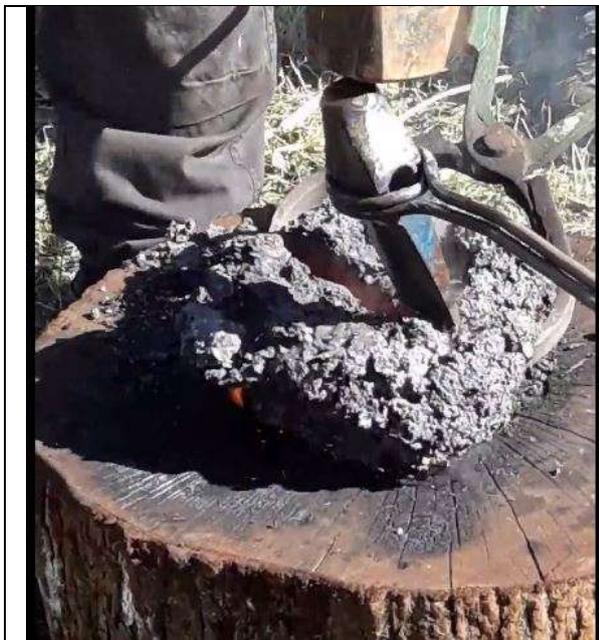
Grip on the bloom



There it is...



cleaning by compacting (hammers)



Already a little bit too cold for splitting



Preparing for re-heating

So far this smelting exercise from Lee and his team ...

**My own furnace design is a "one off" - to be dismantled at the end of the smelt.**



**Start with the bottom of my furnace**

After collecting a wheelbarrow load of fireproof bricks I started to build a German type "Rennofen". Dimensions (inside): width 42 cm at the bottom, 25+ cm at the top, height 115cm. One tuyere, just above the first stone layer at 20 cm. My preferred basic dimensions are: bottom 35 cm, top 25 cm, height 120 cm. Two tuyeres, one at 15 a 20 cm above the other. Start using the bottom one, the moment the airflow gets seriously blocked, switch to the one above.

During the construction I turn the round piece of trunk a few times in the wet loam so it doesn't stick to the wall and I get a nice hole.



**Roasting the light-brown ore**

**After roasting - "all" sticks to the magnet - high quality!**

## DAY TWO - Friday, August 24

My second day at the festival started very damp, all the grass and other stuff to burn was wet. It took some time to get a nice fire burning inside the furnace.

Drying the furnace I build yesterday by burning local peat:

	
<p>A very damp start of the day - "finally" burning around 11h30</p>	<p>A piece of local peat - good fuel, typical smell.</p>

from (<http://ireland2050.ie/past/peat/>) :

... Peat harvested from local bogs has been used for centuries for cooking and heating in Ireland. With the depletion of this country's natural woodland in the 1600s (\*), peat became an important source of indigenous fuel for households .... many households continue to burn peat, either as peat briquettes or privately harvested turf.....

(\* ) wood for the iron industry?

		
<p>Around 18h: the eyes are 200 years old remains</p>	<p>Air inlet with glass for heat color check</p>	<p>Blower connected</p>

The smelting event was held on a very nice field just next to a small artificial lake:



Also Woodford: green and sunshine.....

A few teams spent some time in nicely decorating their furnaces.  
The one on the right managed to produce the biggest bloom: 26 kg!



From Katie - UK



From Robert - German



From Mathias -German



From Pawel - Polish



Forgot the name.... UK

## DAY THREE - Saturday, August 25

This day was the BIG SMELTING DAY for most participants, for me a day of preparation for our smelt tomorrow.

The furnace is ready. Paul asked all us if we could put something extra in the construction: from the remains of the Iron Industry here in Woodford, two centuries ago. I used to little shiny pieces for the eyes in the furnace, giving it a kind of character I guess...

There was not enough ore roasted for this smelt so I started yesterday afternoon grabbing and roasting all the remaining ore.



Me, finishing the furnace and the late roast of the other "dark colored" ore from Mountshannon.



## **(2) a square "Catalan" type furnace:**

There was a team with a "Catalan" type furnace, impressive and spectacular (video on facebook):  
The furnace was made by Josh, James, Jesus and Owen. Bloom weight was 16 kg.



A "Catalan" type furnace:



Zoom in on the bloom of 16 kg

Three big hammers:



Compacting the bloom

### ***(3) a furnace with heat from peat:***

One German team ran the furnace on peat and made a huge bloom. It didn't stay in one big solid piece. The separate remaining pieces were forged. Members were: Bill, Mathias and Bernhard.



Dismantling the furnace



Mathias compacting the hot bloom



Impressive bloom



Hammer of wood, big but "soft"



In a few large useful pieces

### ***(4) a furnace on a hairdryer:***

And then the special decorated smelting furnace from Katie. Also special was the blower she used - a hairdryer! And it did the job very well. We tried once a hairdryer and could not reach the desired temperature. Must be some magic involved...



**Getting the bloom out**



**compacting**



**Bloom on the smith's anvil**



**Katie's hairdryer**

### ***(5) a furnace as a piece of art - a face***

The biggest bloom came the German team from Robert Funkenschläger: 26 kg bloom from 66 kg ore  
The other team members: Lennart, Tatjana and Kamala.



**Difficult to get the bloom out**



**Hot**



**A very BIG bloom**



**-26 kg**

## DAY FOUR - Sunday, August 26

This day was the big day for black smiths - and our day for ironsmelting



After a wet night. Our furnace is working!



Air regulating box (by Romain)

Temperature check by color: too bright is "fine"

The airflow can be regulated by varying the voltage over the blower (variac), but also by this box Romain made: at the same time, shutting off the entrance to the furnace, you open up an escape gate. This way the air blower maintains the air flow and the pressure inside the box. ( and stays cool)

## Log file of the ironsmelt of Leo and team on August 26:

**Start: one charge (load) = (1 kg ore + 1 kg charcoal)** into the furnace (in Dutch "een ertsgang") first we put the ore in the furnace (\*), directly followed by the charcoal to cover the ore.

### 11h38 Start iron smelting

#### 1 11h40 1 charge

2	11h48	„
3	11h50	„
4	12h00	„
5	12h01	„
6	12h10	„

switch to time increment ~ 5 minutes / load

7	12h17	„
8	12h22	„
9	12h22	„
10	12h34	„
11	12h39	„
12	12h45	„
13	12h50	„
14	12h55	„
15	13h01	„
16	13h05	„
17	13h10	„
18	13h15	„
19	13h20	„
20	13h25	„

up to now we added 20 kg iron ore and 20 kg charcoal in 1 hour and 45 minutes

**-> average burning rate => 1 kg ore / 5.5 minutes**

21	13h30	„
22	13h36	„
23	13h41	„
24	13h46	„
25	13h51	„
26	13h55	„
27	14h00	„
28	14h05	„
29	14h10	„
30	14h15	„

up to now we added in total 30 kg iron ore and 30 kg charcoal.

**-> burning rate has increased to almost 1 kg ore / 5.3 minutes**

31	14h20	„
32	14h25	„
33	14h30	„
34	14h35	„
35	14h41	„
36	14h48	„
37	14h53	„

at 15h44 the bottom of the furnace was punched: 1e time liquid stone flowing

**-> we now increase the load by 50%, one "charge" = (1.5 kg ore + 1.5 kg charcoal)**

#### 38 15h00 1 charge (1.5 +1.5) kg

39	15h05	„
40	15h11	„
41	15h21	„ hose connection, blower to tuyere, disconnected for a short time
42	15h30	„
43	15h37	„
44	15h45	„
45	15h55	„
46	16h00	„
47	16h13	„
48	16h17	„
49	16h25	„
50	16h30	„

#### 51 16h42 last charge (1.5 + 1.5)kg

Stopped charging the furnace

Over the last hour and 42 minutes, we loaded  $14 \times 1.5 = 21$  kg iron ore -> **1kg ore / 5.2 minutes**

The furnace is still working fine - but we ran out of ore! -> so we had to stop after **56 kg ore total.**

(\*) Useful remark from Romain: as we use only one tuyere it is best to gently put the ore into the furnace, on top near the side of the tuyere position - not at random, somewhere in the middle.



Audrey, charging the furnace



Romain and Gerliane discussing



Opening the furnace around 17h00



The bloom



Bloom compacting



Romain, Olivier and Rudi, cutting off the bloom

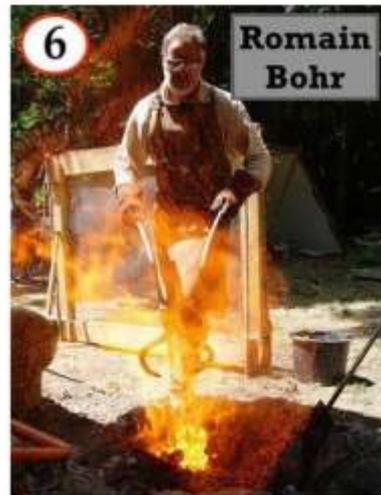


Sparks and also punching confirm that the iron is locally harder, locally softer...





The team, left to right: Gerliane, Audrey, Romain, Leo, Rudy and Olivier



www.furnaceproject.org :

The smelting teams for the Furnace Festival 2018 in Woodford, Co. Galway (25-26 Aug)



The "light" colored very high quality ore (~90% iron !?) originates from Derryarkin.  
 The "dark" colored good quality ore (~52 - 70% iron) originates from Kilchreest.  
 From near Mountshannon, also dark colored bog ore, 10 bags, added later on the field. (no data)

Fe <sub>2</sub> O <sub>3</sub>		SiO <sub>2</sub>	P <sub>2</sub> O <sub>5</sub>
1664,4 KCps		11,3 KCps	0,6 KCps
89,7 %		7,12 %	0,279 %
BaO		Fe <sub>2</sub> O <sub>3</sub>	CoO
0,2 KCps		1437,9 KCps	2,5 KCps
445 PPM		51,8 %	0,115 %
		ZrO <sub>2</sub>	BaO
		0,5 KCps	5,0 KCps
		0,00579 %	0,712 %
		Al <sub>2</sub> O <sub>3</sub>	SiO <sub>2</sub>
		4,2 KCps	21,9 KCps
		2,80 %	12,6 %
		MnO	Fe <sub>2</sub> O <sub>3</sub>
		342,7 KCps	2063,1 KCps
		12,8 %	69,6 %
Derryarkin, Co. Offaly (light)		Kilchreest, Co. Galway (dark)	

- The End -