Prehistorical File hewing and steel production

Reconstruction of The Mastermyr Find File

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Introduction:

Our aim in this project was to gain an insight into Viking Age blacksmith work. The Mastermyr Find is an extremely interesting archaeological find. It contains almost fully preserved tool kit of a Viking age blacksmith. We wanted to reconstruct the file from the kit. The file might sound a trivial tool, but in reality it has always been important tool in metal work. The file also has some kind of fascinating power over other materials. It "eats" steel, iron and other softer metals. By reconstructing the file we also had to face interesting special techniques, namely file hewing and carbonising of iron.

To get background information on file producing, we were in a lucky situation. The Mastermyr Find dates from the mid 9th century and we could find quite contemporary source from continent about producing files. In the beginning of the 12th century German monk Theophilus wrote a book about "Various Arts", where he introduces techniques of different crafts. There he has by medieval standards unusually precise descriptions for file hewing and carbonising of files.

File Hewing:

Four tools in The Mastermyr Find kit were categorised as files and two as rasps. The categorisation in the excavation report was done by outer criteria of form: Files were straight and rasps had a bend in the tong. This doesn't have anything to do with their real use. More real criteria to separate files and rasps is to look the amount of teeth. The finest file had 11 teeth/cm. It is clearly used for fine work, probably with softer metals like bronze. The coarsest had only 4 teeth/cm and it is definitely a rasp, maybe for wood working.

We started to copy the bigger rectangular file which has teeth on all four sides (Mastermyr find 22:32). Its overall length was about 22 cm. One of the sides was finer, but the report doesn't say which. From the picture we counted that the file had 7 teeth/cm. We assumed because of the lack of information, that the finer side might have something like 10 teeth/cm. The other copied file was much finer (Mastermyr Find 22:38). It was about 13 cm in length with 11teeth/cm. This was categorised as a rasp, because of its bend, but it is definitely a file for fine working.[1]

To hug a good file isn't so straightforward. There are many things which matter. From the illustration of Theophilus we got a clear idea for practical working arrangements (Picture 1). To fasten the file to the anvil with simple ropes. An interesting point is that the same working arrangement were still in use at the beginning of the 20th century (Picture 2). It is important to be cautious before using medieval pictures as direct sources. The other medieval picture represents more the monks or scribes idea of file hewing than real situation (Picture 3). Probably the drawer of the picture has never seen or done file hewing himself.


Picture 1


Picture 2


Picture 3


Niklas in work.

No details about angles and forms of teeth were available in descriptions of finds. We had to base our knowledge on modern technical information of file hewing, which is nearly a science itself. Naturally the Viking age blacksmith had no idea about theoretically perfect angles of teeth to file metal, but by practical experiences they probably came to the same result as modern science.

The form of the chisel is important to produce proper teeth. We tried different kind of angles of the chisel, but the best results of file hewing came, when we were using the angles given from Bacho Company. In this modern chisel angles were 22 degrees in the back side and 33 degrees in the front side of the chisel's edge. Together the edge was 55 degrees wide (clarifying picture). This form of chisel worked to hew both coarser and finer type of teeth. To produce a good long lasting chisel took a lot time. If the edge is too soft, it goes smooth after longer hammering against cold iron. If it is too hard, it is likely to break from the edge. We both made one chisel, which we had to release and harden several times, before the results were long lasting.

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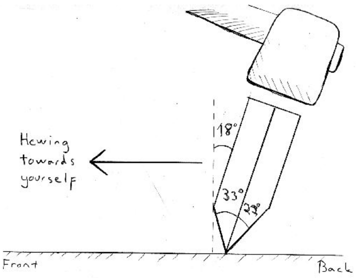
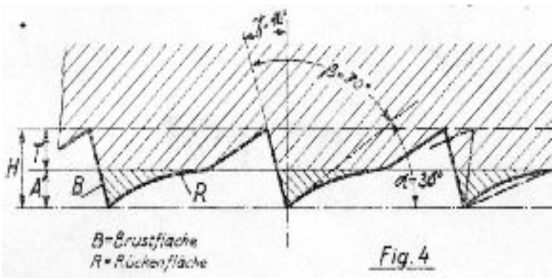
[1] *Mastermyr* s.12-13, 22-23

All Mastermyr Find files, were hewed at 90 degrees, what we also followed. To produce optimal teeth, the chisel should be held 18 degrees from yourself (clarifying picture).[2] It is important to hew towards yourself, starting hewing from the farther end of the file. Otherwise the new stroke spoils the tooth, which was last produced.

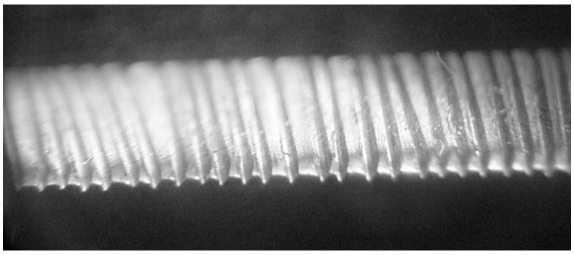


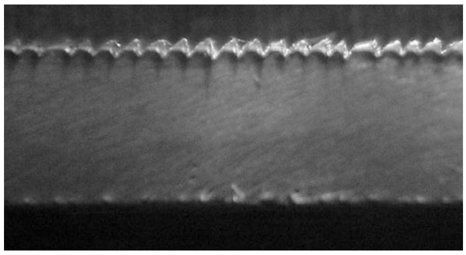
Clarifying picture?



The result of perfect hewing. Ideal teeth of a file.

Absolutely slavish following of given angles isn't necessary, but to produce good teeth of similar height, the angle of the chisel and the strength of the stroke should be the same all the time. This isn't so easy in practise and can be learned only by practising. The hammer should be heavy. It is easier to control force with a heavy hammer, when you don't have to strike the chisel, but you can let the hammer just "fall" against the chisel. The file has always been a practical tool, so the appearance of the old hand made files varied from hastily hewed to very fine examples. After training we could produce quite fine and workable files, so we didn’t have to shame our files in comparison what our ancestors have made.[3]





Pictures from the teeth of our file.

Carbonising:

To produce good quality steel in pre-historical times wasn’t an easy project. There is a lot written about Iron Age iron production, which in Europe was done in different kind of direct bloomeries (blästerugns), but about steel production there isn't much information.[4] It is quite interesting, because it is the steel, which is the most important material to produce sharp and long lasting tools and weapons.[5]

There are **at least three different methods to produce steel** in a "primitive" way, which all might have been in use in pre-historical and early medieval Europe, before the blast furnaces ("masugns") came to existence. These can be listed as **direct bloomery**, "**Theophilus** method" and "**Evenstad** method".[6]

One, maybe the most common way, has been having steel as a side product in **direct bloomeries**. In the produced iron, there can be some pieces, which contain a higher level of coal and can be hardened. It might be possible that pre-historical direct bloomery iron producers could have understood the ways of processing bigger amounts of steel in their bloomeries, but in my knowledge there haven't been any modern direct bloomery experiments, where the produced iron would have been containing higher amounts of steel. These experiments with direct bloomeries are totally out of the scope of our project, but we tried to produce steel in two other methods I mentioned.

Theophilus writes in context of files, how it is possible to make steel (calibe) from iron (ferro). We tried this method to carbonise our files. The Mastermyr Find files metal structure has never been analysed, but it is quite possible that they are carbonised with this method. To laminate steel around iron core to all four sides would have been quite a hard way to produce a practical tool such a file. Also the possibility of using full steel in these files sounds improbable, even Theophilus mentions full steel files. Most of the tools analysed in The Mastermyr Find are laminated. Even the quite small spoon-auger has a laminated steel edge. So steel in tools was used very sparingly.

Theophilus describes the **method of carbonising files** in the following way:
"…You make small files, square, round, half-round, triangular and flat ones from soft iron and you temper in this way.

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[2] Our information is from Bacho company

[3] Eg. The visit to the fågelsjö was interesting. The files of the skilled riffle smith were hugged amazingly poorly.

[4] Best overview about steel production can be found from the excursion in the book *Metalteknik.*

[5] As a curiosity, Caesar writes that Celts swords bend broken in battle meaning that they had iron swords. Whatever Caesar says, in practise weapons were made from steel.

[6] This is my own categorisation, because I haven't found any systematical research about the ways of European steel production before the blast furnaces came into existence.

When they have been incised with the hammer or chisel, or with a knife, smear them with old hog's lard, bind them round with straps cut from goat-skin, and tie them up with flaxen thread. Afterwards cover each one separately with kneaded clay leaving the handles bare. When they are dry, put them in a fire and blow vigorously until the skin is burnt. Then remove then quickly from the clay, quench them evenly in the water, withdraw them and dry them at the fire.[7]

We followed this description quite strictly. By thinking of the Scandinavian situation during the Iron Age, we replaced the old hog's lard with elk lard and goat skin with elk skin. Medieval texts have a tendency to be very concrete level. A good example of this concreteness is when Theophilus means that urine is better than water to harden tools, he says: "*Tools are also given a harder tempering in the urine of a small, red-headed boy than in ordinary water*." This comment has also its background. When knowledge has been based on practical experiences, this kind of concrete thinking is perfectly logical.

Theophilus says that files should be covered with clay. It was quite clear beforehand that pure clay wouldn't stand the heat. We made experiences with three different clay mixtures. Pure clay didn't work, neither the mixture of clay (1/2) and quartz sand (1/2). They crumbled away in heat. The best solution is the recipe used in bronze-casting. It contains 3 part clay, 5 parts quartz sand and 7 parts horse shit. It worked well in high heat.

When the files are covered with lard, skin and clay, they have to be dried. In a warm place one night is enough. Horse shit ties the clay so well, that fast drying didn't really increase the risk of breaking.

Here are all the phases of file hewing and preparing of carbonising. From left to right: Hammer and two chisels, plain polished file for hewing, ready hugged file, file covered with elk lard and skin, file covered with clay.

When the clay forms are dried they are ready for carbonising. Theophilus isn't so exact in timing and heating. He only says that they should be put to a fire, which should be blown vigorously until the skin is burnt. This we interpretated to mean quite a short time. This is quite different from more modern methods of carbonising, when files are in coal damn. Normally it's recommended to have them in heat for several hours or even a half day.[8]

In the first attempt we had the file in forge 5 minutes. Clay was glowing yellow, but the iron tong of file was quite cold, having a dim red colour. After breaking the burned clay we dipped the file in water and tried to file with it. The first try wasn't successful. The iron wasn't carbonised enough. The coal level in iron has to rise over 0,40% so it can be hardened.

The second attempt worked better. We were planning to heat the form in high temperature for at least two hours. After the form was warmed up, we maintained a very high heat. The clay form was glowing white and the iron tong had a yellow colour. It was important to roll the form often, otherwise it would have been burnt through in high heat. After 15 minutes, the clay form broke. To save our file we took it out from a forge and dipped it to the water. When testing the file, it was proven to be steel and working well. In high heat the clay had become glass on the surface, having bright green and black colours.

The third attempt went also well. The file was again in high heat for 15 minutes until the clay started to crack, but it was enough and the file was hardened and worked well.

The Fourth attempt we heated the forge in extreme. Without having the protecting layer of clay, the iron would have probably started to burn. After 7 minutes the clay began to brake. When the file was taken out of the forge, the clay was acting like soft glass. After dipping the file to the water, it was tested. It worked well to file, but in some places the steel was too hard, so it cracked. Theophilus says that after hardening the files should be dried at fire. In the fourth file the coal level is probably so high, that it would need a little bit of releasing.[9]

These attempts to carbonise by the Theophilus method proved to be extremely interesting. We gained new knowledge that the time for carbonising can be very short. Instead of hours, a couple of minutes were enough to make a sufficiently deep and hard steel layer on the surface of file. Organic materials, like lard and skin, can react more efficiently than pure coal. It is known that carbonising can be made more effective with soda or potash. Similar kind of substances can be found from organic materials.[10]

Here is the ready made files from left to right. Over chisel the clay pieces of the first unsuccessful attempt. Then first, second and third attempt. In the side of files there is the burned clay forms.

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[7] *Theophilus s.72-73*

[8] *Järn smidesboken s.?*

[9] We tried to test the hardness of files in Sveg Mineral, but the meter worked only in industrially polished plain surfaces.

[10] *Metalteknik* s.216-217. Also from Sveg's Mineral Company we heard, that burned skin contains nitrates, which are very effective in the carbonising process. Some of those nitrates are used even nowadays in steel production.

Producing files by the Theophilus method was successful and our **goal** in the project **was accomplished.** Still it is a quite specific way of producing steel to specific uses. When thinking in practical level about the work of the Viking Age blacksmith, we have to face still quite undiscussed question, how they got their steel to laminate tools and weapons?[11] Producing steel in bigger amounts in direct bloomeries hasn't been, in my knowledge, successful so far. Even if it works, it's probably very difficult to steer the final coal level of the steel. That's why the simple method, which was written down by Ole **Evenstad** in 1782, is very interesting. The idea in this steel production is very simple and possible to do in the normal forge. Soft iron is melted through coal layers to the bottom of the forge to carbonise it to steel. It could be possible to speculate that the Viking age blacksmiths could have been using this method when needing acutely special type of steel. Here is the translation from the original text:[12]

*About **Fine Iron's Smelting to Steel***

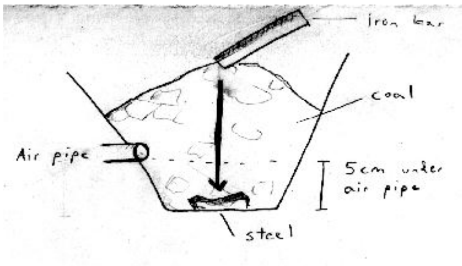
After having used the ash to smelt the iron for a whole day, so it has become thoroughly hot. The forge should be cleaned, digged up and hammered like it was for iron making. It should be two thumbs [about 5 cm] deep under an air-pipe, so that the air won't touch the steel when it has fallen down to the ash. Then the forge is filled high up over the edges with pine coal.

Then you need a piece of iron. As much as you have resmelted in one melting. That should be cut into two pieces and then welded together again and hammered to the rectangular shaped iron bar on the anvil. The iron bar is placed on the coals, which have been ignited. When the iron bar is very hot at one end, it should be taken with tongs and held closely above the blowing air stream, but high enough that the blowing air won't touch it.

The fire must be strong and lasting, so you have to blow forcefully all the time. This makes the iron smelt and fall gradually down into the ash and become steel. During the smelting you should throw sand onto the fire 2 to 3 times. After the iron is smelted the strong heat is maintained. Sand is thrown onto the fire until the steel has become solid, so that it can be taken up with tongs. This should be done very carefully so that the piece wouldn't break.

As soon as it is taken from the ash, it had to be softly hammered until it becomes smooth. Then it's split up into small strips with the axe, hammered out and welded together where the steel is leaky. Then it's ready for further processing. You have about half the amount of steel from the iron you smelted.

Evenstad's description isn't fully clear, but I tried to follow it as well as possible. In my **first attempt** I hammered a small tong (about 7*5mm) from soft Lancaster iron. I built the forge so that there was about 5cm of coal below the air-pipe. I had the strong fire in a forge and I held the tong above the air stream. When the iron started to sparkle I threw sand onto the fire to protect the metal from burning. By doing this couple of times the iron melted down. After this I threw more sand onto a fire. Then I dug up the coals and on the bottom of the forge I found melted pieces of metal. I dipped them in water and by proving to file them it was proved that they had turned to hardened steel. The first attempt was in a way successful, but the pieces were all too small to try to hammer or weld them to something useful.



Working arrangements to produce steel.

Steel piece from the third attempt

In a **second attempt** I hammered a coarser tong (about 15*10mm) to produce more steel. I also build up the forge with tiles to spare the charcoal. The process of melting went quite similarly to the first try. Now the iron was smelted to one bigger piece, which was easier to take up. When dipped in water it turned out, that it was mostly iron. About one third was steel. The Reason for this was most probably, that the piece hadn't fall totally to the bottom of the forge. Half of the piece was directly in the air-stream. The direct air stream probably stopped the carbonising process or decarbonised the piece. When hammering the piece flat, the small parts having steel crumbled mostly away and the result was mostly iron.

In a **third attempt** the material was similar to the second try. After the melting I could find two bigger pieces of hard steel. Other one wasn't melted totally and was probably carbonated only from surface. The other piece was

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[11] Lots of archaeo-metallurgy books have been written about furnaces and iron production, but the next step to produce it to steel has been forgotten. E.g. recontructions of "Viking age knives" have been done from soft self made iron (Early Iron production s.27-36) or laminated knives have been forged from self made iron, but the steel has been bought (Blästbruk s.224).

[12] This is my translation from old danish (Thanks to Sofie and Jene) from the book *Bondejern i Norge*. Full English translation is done by Jensen 1968.

successful and full steel. In further processing to laminated knife I will see how good quality it really became. In a **fourth try** I ran out of the soft Lancaster iron and I had to try with unidentified modern soft iron. It turned out to be extremely hard to melt. After half an hour very heavy heating I had to give up. The iron had only started to burn, but not melt.

Evenstad method was proven to work in practise. By more training it would be quite a practical way of producing small amounts of steel for laminating tools.

In these last lines the writer Toni Turunen and Niklas Alexanderson thanks the reader who has managed to read this far.

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