

11.4.3 Ulfberht Swords

The Basics

Ulfberht Swords are all-steel swords from the Viking era that carry the inscription "Ulfberht" or variants thereof in big letters on the blade. The letters were mostly made from a thin twisted striped rods and hammered into the blade. The smith may have chiseled out the contours of the letters before he hammered them in or, more likely, he might have banged them into the hot blade just so. Consult [Mikko Moilanen's article](#) for details. Besides the Ulfberht swords we also know the "Ingelrii" swords ([here](#) is one) and a few more with inscriptions. Ulfberht and Ingelrii appear to be names but there are also (abbreviated) invocations like "in nomine domini" (in the name of the Lord). Sometimes something else, including symbols [as before](#), is found on the other side of the blade.

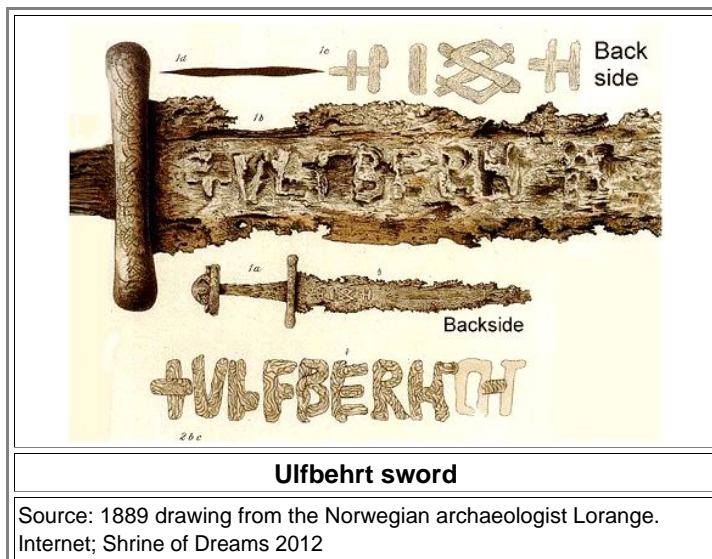
- What makes Ulfberht swords so fascinating can be stated in two sentences:
 - Swords with Ulfberht inscriptions were among the very best - *and* the very worst! They were neither surpassed nor underpassed by swords forged in the next 5 centuries or so; see the [figure](#) in the preceding sub-chapter.
 - The top-notch Ulfberht swords were made from (Indian) *crucible steel* and not from local bloomery steel.
- This is fascinating, indeed. So if you want to know all about the topic, my advice is:

Read Alan **Williams'** book:
[The Sword and the Crucible](#)

- There is nothing I can state here that goes beyond what he has written on the subject, based on his own metallographic work. I will therefore give you only a short account of the essentials. I do that by first going through the **W** questions

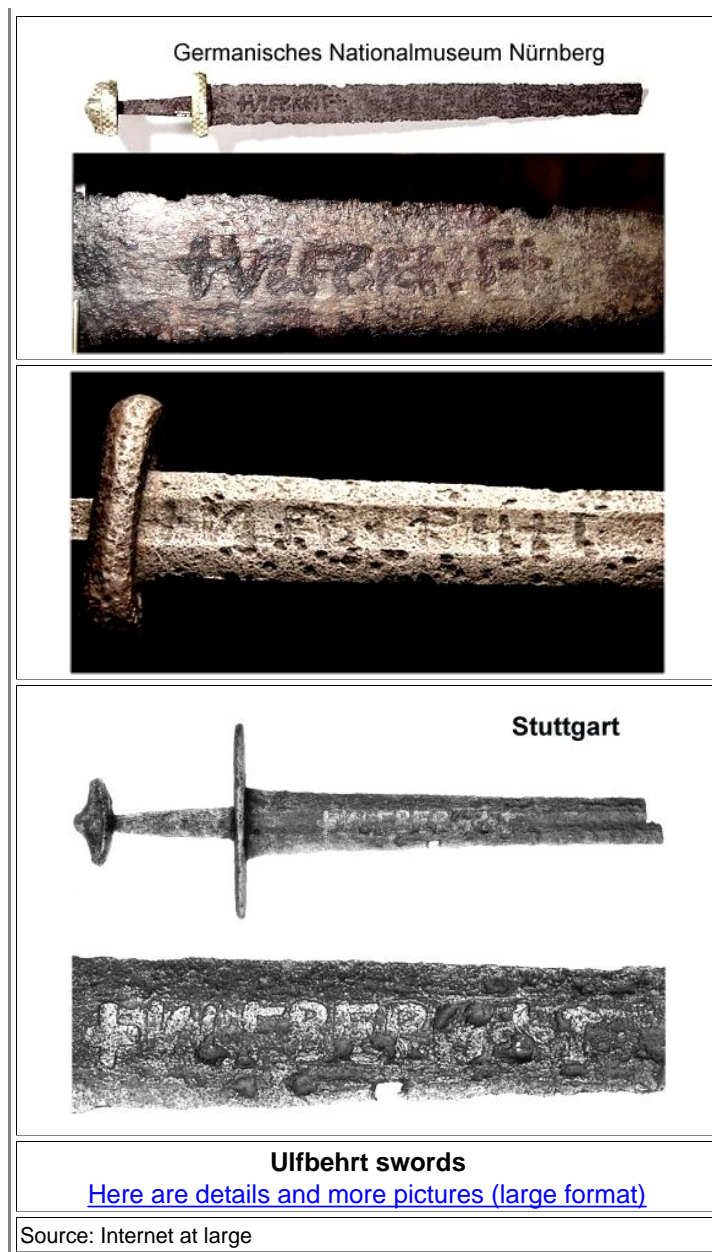
What are Ulfberht Swords?

- Ulfberht swords are swords like these:



- This is about the best "picture" I could find. The real swords look like this:





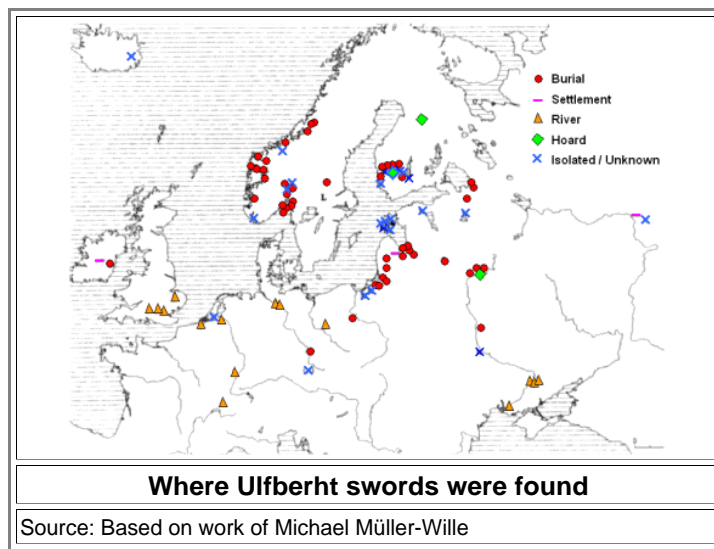
- The top one is more typical than the other two ones. In other words: the inscription is mostly barely recognizable. These swords may or may not be "true" ones; I'll get to that. In what follows I also count swords under "Ulfberht swords" that have a completely garbled inscription like "VLFBEH" or "VLGPIR".

When do we encounter Ulfberht Swords?

- Strangely enough, Alan Williams seems not to supply clear dates. So let's turn to the other big Ulfberht person: **Anne Stalsberg¹⁾**. Anne states "[Ulfberht blades are found on handle types from around AD 800 to the 11th. century, possibly also as late as from the 12th century](#)". Dating was only done by looking at the hilt and that always leaves some uncertainty because old blades might have been fitted with a new hilt. Nevertheless, it is likely that Ulfberht swords were made over a time span of up to 300 years and that tells us for sure that it wasn't just *one* master smith but a lot of smiths; possibly not all of them "masters", who made blades with some kind of Ulfberht inscription.

Where did one encounter Ulfberht Swords?

- We have two questions here: Where did we *find* Ulfberht swords and where have they been *made*? What we know rather well is where modern people *found* them. The following map gives an idea about that.



Obviously the about 170 known Ulfberht swords (Anne Stalsberg counted 166 but a few more have been found in the meantime) were mostly found *in graves* in Scandinavia or in the Baltic region. Actually, 44 out of 166 known Ulfberht swords have been found in Norway, plus some 2500 normal swords and around 650 saxes from the Viking time. That does not mean that they were most prominent there, only that it was more likely that they ended up in a grave. As [noted before](#), burying people with their stuff went out of style in the Frankish empire already in the 8th century because grave goods were contrary to Christian doctrine (you were supposed to give your precious to the church). Only the pagan Vikings and other unbelievers in the North / East stuck to the old custom for a while longer. Anne Stalsberg in her paper gives many maps concerning details¹ but the basic fact remains: From the supposed Frankish heartland of advanced sword makings we have only a few finds, mostly from riverbeds, and therefore without any context. That makes all but certain that only a very small percentage of Ulfberht swords has been found, and that many thousands must have existed 1000 years ago.

Now we know where the swords were found but we still need to consider where *the blades* were made. We do not worry about the hilts. These quite likely were made locally (at least the vast majority of the not-so-fancy hilts). Well, the blades most likely were forged in the Frankian empire for the [reasons given before](#) plus the fact that the letters are not done with runes but in a kind of "Carolingian Minuscule", a script form developed by you guess who. Ulfberht, as a name, can also be traced to the Frankish realm, where it has been recorded in many versions like "Uolfberht" or "Wolfbert". There was no standard spelling by then and Monks (the usual writers) wrote names as they felt was right. However, as we shall see later, Alan Williams has some doubts about this.

Who was Ulfberht?

What we can state with some certainty is that there was one original "Ulfberht" and a lot of copy cats. We don't know, however, if "Ulfberht" was a person or an organization. Even if "Ulfberht" was a person, he needn't have been the master smith who personally made the blades. Just as well he could have been the boss of some enterprise that produced the swords. Christian Dior did not stitch together the garments sold in his name all by himself either, for example. Anne Stalberg makes a detailed case for the latter alternative. She goes even further and suggests that Ulfberht was a Bishop or other high dignitary of the church, and that Ulfberht swords were perhaps made in **abbeys or monasteries**. Those were big industrial enterprises in the good old days. We know that **Alcuin**, Charlemagne's Anglo-Saxon adviser, was the abbot of four abbeys which owned more than twenty thousand **slaves**.

Why?

There is not just one "why" question but several:

1. Why "signing" a blade at all?
 2. Why not just straight with the name "VLFBERHT" but like this: +VLFBERH+T (the Latin V is our modern U)?
 3. Why are there a lot of variations in the spelling?
 4. Why using coarse iron letters instead of nicely encrusted gold or silver?
- The fourth question [I have already answered](#). I only might add here that there is actually an "Ulfberht" with silver instead of iron letters:



Ulfberht type sword with silver lettering - a fake?

Source: "[Neues Museum](#)"; Internet at large; and [here](#)

- It appears that the "letters" are made from silver, "damascened" into grooves cut with a chisel. Then it would be an obvious fake for an illiterate customer. However, as Ingo Petri assured me, who had the opportunity to analyze this sword in some detail, this is a "true" +VLFBERH+T sword. An over-eager custodian of the museum, some time ago, "painted" some silver color over the insets he could recognize, muddling up the lettering and the appearance in this process.

VLFBERHT Variants and Blade Quality

Let's give some thought to why one would want to have some symbols or signatures on a sword blade. Reasons might be:

1. Showing off. That was an important reason for pattern welding, after all. More [modern swords](#) often have highly embellished blades for that reason. However, the always visible hilt is a better object for showing off than the usually covered blade.
2. Magic. Some special signs or symbols, like a Victoria or a Mars on [Roman swords](#), might bring luck. Invocations or quotes from Holy books became popular much later too, for essentially the same reason.
3. Identifying the owner or the organization. The blade is the important part of a "working" sword and thus a better place for an identifier than the hilt.
4. Identifying the maker. That only makes sense if the sword is not a standard issue, run-of-the-mill weapon. For reasons [given before](#), that necessitates to make the inscription on the blade during forging. It also necessitates to use iron / steel letters and to make them rather large.
5. Impressing or better scaring your opponent in a sword fight. That necessitates that the inscription is as large as possible and well visible. Since those guys were typically illiterate and had no time to spell out a word during a sword fight anyway, its general appearance should be instantaneously recognizable

- From this and all I have written before, it is clear that points 4 and 5 apply to Ulfberht swords. Point 3 might come in when one looks at the backside of Ulfberht swords where often only [symbols](#) are displayed.

[Alan Williams](#) set out to investigate as many as possible Ulfberht swords as closely as possible. In his book he describes 55 swords in some detail. While each sword is unique, it can be assigned to one of five quality groups, essentially determined by the carbon content of the steel, which are:

1. Blade made from (one?) piece of hypereutectoid steel, i.e. the carbon concentration is larger than 0.8 %.
2. Blade made from eutectoid steel (carbon concentration about 0.8 %).
3. Hardened steel (around 0.4 % carbon) for the edges with a softer core.
4. Unhardened steel (around 0.4 % carbon) for the edges with a (wrought) iron core.
5. Wrought iron (less than 0.2 % carbon) throughout.

That is the "grade" scale for the 10th century swords that I have referred to in a [preceding figure](#).

- Grade 1 swords are supposed to be top-notch swords, far better than anything made before or after for hundreds of years. That is not just due to hypereutectoid steel as material but also to the observation that this steel was rather slag-free and forged in the "right" way. Grade 1 Ulfberht swords, in other words, were made from [crucible steel](#) by someone who knew how to work with this difficult material. I'll come to that.

Grade 5 swords were extremely bad; worse than anything made in later centuries and, with some restrictions, also earlier centuries

Alan made two sensational discoveries:

1. Crucible steel was used for some - the grade 1 - Ulfberht swords. That is a sensational discovery - provided it is true. I have no reason at all to doubt Alan's analysis but as a scientist I only accept sensational results if there is an independent confirmation.
2. The quality is tied to the accuracy in spelling "Ulfberht". The correct rendering is: +VLFBERH+T, and the two crosses are important

The following table supplies some data and examples from Alan Williams' and Anne Stalsberg's work. "Early", "Middle" and "Late" mean, according to Anne::

- *Early Viking Age*; sword blades with their main existence in the 9th. century.
- *Middle Viking Age*; swords with their main existence in the 10th. century.
- *Late Viking Age*; swords with their main existence in first half of the 10th. century - 11th. century.

Anne's time ranges are a tad unclear in the middle but the general time sequence is clear.

Alan Williams' Table			Anne Stalsberg's table			
Grade	No of swords	Spelling examples	Spelling	Early	Middle	Late
1	9	6: +VLFBERH+T 3: Close	+VLFBERH+T	11 25%	20 45%	1 30%
2	5	2: +VLFBERH+T 3: close, missing cross	+VLFBERHT+	15 68%	4 18%	3 14%
3	14	+VLFBERH, VLFBERN+	VLFBERH+T	1-2	0	4-3
4	16	Many wrong variants, e.g.VLFBER++, VLFBPH T, and completely garbled	+ VLFBERH- - T	4 44%	4 44%	1 12%
5	11	Very wrong ("VLEHBA"), non-latin letters, symbols instead of letters	+VLEBERHIT +VLFBEHT+ +VLFBERH*	6 42%	4 29%	4 29%

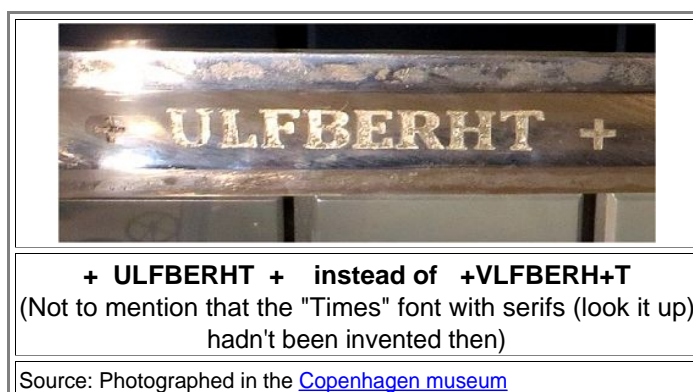
Anne Stalsberg distinguishes between 7 spelling variants (including "non-definable") for the Ulfberht signature *and* the backside symbols but doesn't tie that to blade quality. The table above with only 5 variants does not include the "undefinables" and a group with only 2 undatable specimen.

She does interpret the crosses as part of the signature of church chieftains. Indeed, some Bishops or other high church officials still put a cross in front of their signature up to this very day.

Taking everything together, one possible scenario emerges: Somehow crucible steel from the "East" must have made it to the North, and some sword smiths figured out or learned from others how one had to deal with the stuff. Swords superior to anything known so far were made from the crucible steel and became an expensive high-prestige weapon for a few.

It goes without saying that as soon as "true" **Ulfberht swords** acquired some fame, **Ulfberht fakes** were produced all over the place. The fakers made an all-steel blade and added an Ulfberht inscription. Since they probably had never seen an original, were illiterate anyway, and might have been taken in by an inscription that was already a fake, the whole thing deteriorated. In the end only meaningless symbols were put on a blade.

The [Copenhagen museum](#) provides a nice example for not paying close attention while faking. Its museum store offers Ulfberht replicas that look like this:

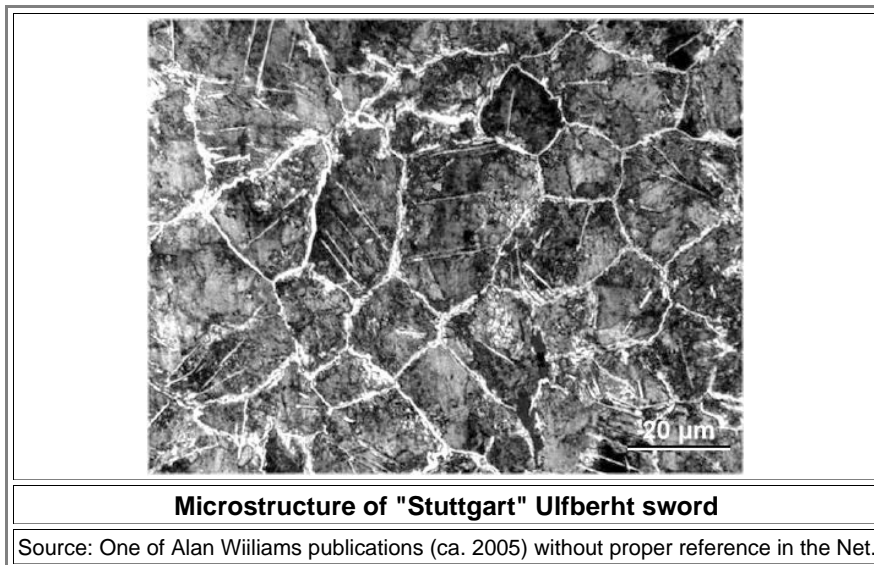


● If the museum couldn't get it right, you can't blame ancient black smiths for goofing.

Now would be a good moment to read up the essentials of [crucible steel](#). Here I will only refresh your memory by enumerating the crucial points:

1. Crucible steel was molten once and thus does not contain slag inclusions. That is a huge advantage relative to bloomery steel.
2. Crucible steel is always hypereutectoid steel with a carbon concentration typically well above 1 %. It is thus perfectly brittle and useless, except if "tricks" like spheroidizing the cementite are used during forging.
3. After the cementite is spheroidized you must forge the steel at *low* temperatures. If you ever exceed the transition temperature to austenite around 730 °C (1346 °F), most of the cementite dissolves and upon cooling you are back to the brittle stuff.
4. Wootz blades made from crucible steel employ very special forging technique. The cementite must be kept from lining the grain boundaries (as it does [here](#)) and induced to "spheroidize" (as shown [here](#)). This can be achieved in various ways.

● I don't think that a Northern smith could figure this out all by himself. In fact, the metallographic analysis does show that some if not all "true" Ulfberht swords did *not* consist of the good spheroidized cementite but contained "bad" cementite encased pearlite grains and cementite needles as shown below for the Stuttgart sword:



● What we see are grains completely encased in cementite plus some cementite needles inside the grains. It does look a lot like the [structure of crucible steel](#) right after solidification. Of course, one picture does not prove that the whole sword had a microstructure like this. It is likely, however, and would make for a rather brittle sword. What that means is that the sword would fracture as soon as the elastic limit is reached. However, since there are no slag inclusions, the elastic limit is at a relatively high level and the sword might still have been better than the bloomery steel swords of the time. Or maybe not; it is an open question. Its broken end may indicate that the blade broke because it was brittle. This sword thus is not comparable to the "wootz" blades of a later time.

One might conclude that exporting crucible steel to the North made only sense together with a manual of how to work it, possibly in the form of a slave. However, the makers and users of crucible steel might not have figured out the best way of forging it at the Viking time either.

So which of the cultures / empires around the Frankish empire or the Viking infested Northern area could have traded crucible steel? If you look at [this map](#) long enough and then compare it to [this map](#), two possibilities emerge:

1. We know that the Vikings got down the river Dnieper all the way to the Black Sea and possibly beyond quite early. One Viking actually scratched a graffiti (in runes) into a marble balustrade in the Hagia Sophia in Istanbul (or Byzanz as it was called then). From there it is not so far to sources of crucible steel, and they might well have taken some back. They certainly took [silver coins](#) from the Samanid empire (today's Iran) all the way back to what now is Sweden, where plenty of these coins have been found. In this case the "true" crucible steel Ulfberht's might have been forged in Eastern Europe and not somewhere in the Frankish Rhine area. Alan Williams seems to favor this scenario.



- The Franks had many dealings - bloody and otherwise - with the "Moors" in Spain. The Moors were the medieval Muslims that inhabited large parts of what is now Spain. They were in turn connected (bloodily and otherwise) to the "Caliphate" of the Abbasides that ruled much of North Africa, Arabia, the Middle East, Iran and so on - look at [this map](#). There was a lot of trade and crucible steel may well have made it to the Frankish sword forging centers along the Rhine.

Is it answer 1 or answer 2? It is too early to tell. While I have no reason to doubt Alan Williams' pronouncement that the "original" Ulfberht swords were made from crucible steel, it is good scientific practice to wait for an independent confirmation before something is considered certain.

Since only a few of all the Ulfberht swords were made from crucible steel, we might surmise that the supply was limited and probably only available for a short period of time. While many efforts to emulate the "true" Ulfberht swords failed, some quite miserably, it might have triggered a new look into making iron and steel in bloomeries, leading slowly to progress in the technology.

Is It True?

Much has been made about the "Super" weapons of the Vikings in the form of the "true" Ulfberht sword, made from "wootz" steel. Some quotes:

- Although some have been identified as sloppy counterfeits, the real thing was obviously a fabulous piece of work. They were stable, weightless and particularly lethal.
Web: "Medieval Histories"
- Ganz Europa schätzte die Superwaffe. Die Klingen der sogenannten Ulfberht-Schwerter zählten vor tausend Jahren zur Hochtechnologie der Rüstungsmanufakturen des fränkischen Reichs. Das Kampfgerät war stabil, besonders leicht und damit hocheffizient.
Süddeutsche Zeitung, July 30th, 2014.
- The Vikings were among the fiercest warriors of all time. Yet only a select few carried the ultimate weapon of their era: they feared Ulfberht sword. Fashioned using a process that would remain unknown to the Vikings' rivals for centuries, the Ulfberht was a revolutionary high-tech tool as well as a work of art. Considered one of the greatest swords ever made, it remains a fearsome weapon more than a millennium after it last saw battle.
From the NOVA broadcast, 2012.

As I'm writing this, the "Süddeutsche Zeitung", one of Germany's leading daily newspapers, has an [Ulfberht on page 1](#), pointing to a major article in its science part. In the (surprisingly good) article some doubts are expressed about the "super steel" from the East" hypothesis. The "Süddeutsche" is already quoted above. In its July 30th, 2014 article, with the heading: "Ulfberht"-Swords - wonder weapons from monasteries", the paper is all stricken with the super weapon.

So is that true? The claims to the superior qualities certainly are not! The weight and "feel" of the Ulfberht swords was no different from that of others made to corresponding dimensions, of course. A sloppy wrought iron sword was just as lethal as a steel sword if used against unprotected civilians. One of the greatest swords ever made? How the hell can those guys tell this from a micrograph showing the structure of a tiny part of the blade?
And be aware of a little detail: While true Ulfberht's might have been made from crucible steel, they are not akin to the famous "wootz" blades that show a ["water pattern"](#) and were also made from crucible steel.

On a more serious note I need to mention that Alan Williams' insights are not universally accepted by all and sundry. This is especially true for claims that Alan did not even make himself but which "evolved" somehow in the media and in follow-up work.

Here are my comments on some topics that are maybe not all that clear.

1. Is "+VLFBERHT+" the original correct way of the inscriptions followed (later) by "+VLFBERHT+" and all the other variants?

Anne Stalsberg disagrees. As the [table above](#) clearly shows, 68% of the +VLFBERHT+ variants are dated to the early Viking period - but only 25 % of the +VLFBERHT+'s.

Since +VLFBERHT+ makes a lot more sense than +VLFBERHT+, one might speculate that the latter resulted from a mix-up of a cross and a T / t.

2. The "originals" - whichever they are - were made from **crucible steel** that originated somewhere in "India" or thereabout!

There is no reason to doubt Alan Williams' analysis. The pictures in his book support his view (of course!). However, Alan only shows that a few tiny areas of the blades consist of hypereutectoid high-carbon steel with no or little slag inclusions.

There is no reason to accept his analysis as eternal truth either as long as there is no independent metallurgical analysis done by other researcher that corroborate Alan's work. Moreover, it is all but sure that hypereutectoid high-carbons steel have been [made in Europe](#), too, albeit in a bloomery and not in a crucible. What this means is that small sword fragments that look a lot like crucible steel Ulfberht's under the microscope may actually be European bloomery-steel swords. More to that in what follows.

3. Are swords made from crucible steel always **much better** than swords made from bloomery steel?

This is certainly wrong. Some confusion comes from equating crucible steel swords with "[wootz](#)" swords, the famous (and considerably later) swords with a "[water pattern](#)" on their blade. While all "wootz" blades were made from crucible steel, most blades made from crucible steel are not "wootz". The first and decisive difference is that in wootz blades the cementite has been spheroidized (=balled up) in a tricky process, while in regular crucible steel it lines the grain boundaries and extends into the grains as needles. Just as in the "Stuttgart" Ulfberht sword [shown above](#) and in others according to the (not very good) pictures in Alan Williams' book.

Swords with such a structure must have been rather hard but also quite brittle. If some phosphorous was involved (often the case with crucible steel), they were also prone to [cold shortness](#). It is hard to judge how well they would hold up in a fight with a capable but conventionally armored opponent, but it is almost certain that they could not have been *a lot* better than a well-made bloomery steel sword with a hardened edge like the [Moravian swords](#) - if they were better at all!

Alan's claim that even "an imperfectly homogenised crucible steel would have been considerably better than the fragments of bloomery steel" (page 25) is unsubstantiated, to say it politely.

4. The crucible steel for the "true" Ulfberht's came from India or some related place **via trade routes running along major rivers in the East** (today's Russia) and the **Ulfberht's were forged somewhere in the East too**. True?

The first part is not unlikely. A lot of oriental stuff, in particular coins, did make it this way to the far North. However, here is another possibility, too. The Frankish empire had close relations with the "Caliphate" in Spain and in other places. While not much seems to be known about the steel type used by Muslim warriors in Spain, it is not unlikely that they had access to crucible steel blades and crucible steel. From there it could have made it to Frankish smiths. This is just a possibility with no direct proof at present. But this hypothesis has not been disproved either.

5. **Ulfberht is the name of the smith who made the first and "true" Ulfberht's some time around 850. A lot of other smiths made inferior forgeries for 200+ years to come. True?**

This is rather unlikely. It is all but certain that most of the "true" +VLFBERTH+T (or is it +VLFBERTHT+; see above) swords have not been found, and that the number of all the Ulfberht swords made exceeds the capacity of one smith by far. I would rather go with Anne Stalsberg's hypothesis that Ulfberht was for swords what Enzo Anselmo Ferrari (1898 - 1988) was for Ferrari's. I believe I need not explain to you guys out there, including the part with cheap and not-so-cheap [copies](#).

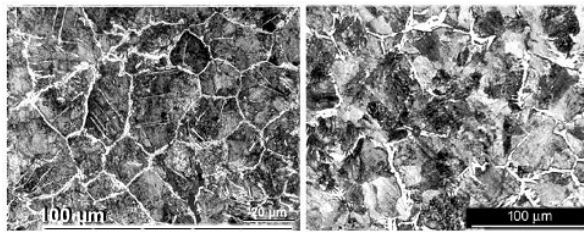
The Ulfberht manufacturing business might well have taken place in monasteries as Anne supposes. They simply were the major "industrial" centers in the Viking time period, just look at their [size of the work force](#)!

All things considered, it is perfectly reasonable to doubt the major thesis that "true" Ulfberht's were made from Indian crucible steel. If stripped down to the essentials, Alan Williams bases his claim on just two points: A *very high-carbon steel* with *no slag inclusions* can only be crucible steel. This is true but only if both conditions are met *simultaneously* and for a *large* piece of the material. In particular, just having a very high-carbon steel doesn't prove anything. It is rather clear by now that this kind of steel was also produced in Europe around 800 AD and later. While European UHCS was never completely slag-free, it is not impossible to find areas in a blade where slag inclusions are not obvious. Buchwald's two books contain a lot of structural pictures that do not show obvious slag, for example [2](#). Since Alan, to the best of my knowledge, has not shown that large areas of the swords investigated were free of slag, there are some general doubts as well.

Personally, I consider it absolutely possible that high-carbon steel with very little slag inclusions has been made inside the Frankish empire or [somewhere else in Europe](#). If you look at the new and rather [breathtaking findings](#) of the iron and steel smelting development on the "Schwäbische Alb" (the old haunts of the Alemanni) between 500 AD and 1100 AD, I would not be surprised to learn that on occasion they made the kind of steel typically associated with crucible steel. That is pure speculation, though.

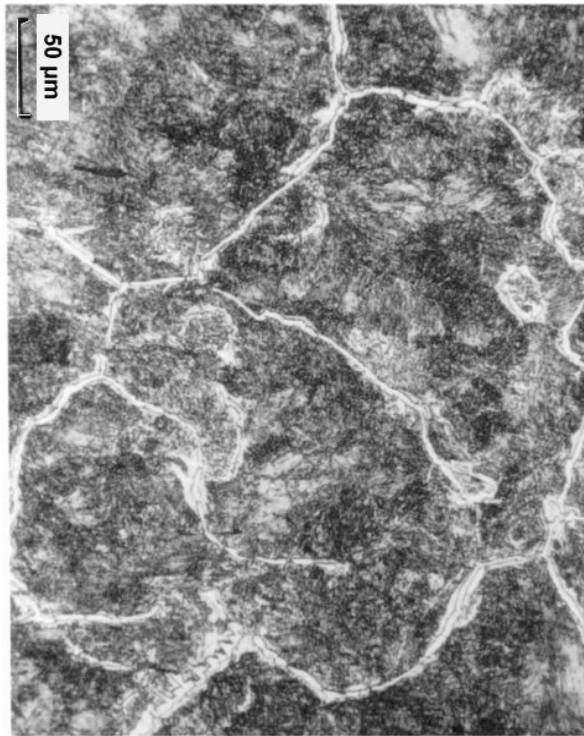
That (probably) normal Frankish swords contemporary to the Ulfberht's show (in parts) a [microstructure](#) that looks very much like that of the [Stuttgart Ulfberht](#) is a fact, however.

For the sake of the argument, let's assume that very high carbon steel from *bloomeries* was available. In contrast to true crucible steel, however, it must be expected to contain some slag. The amounts might have been small, however, and so much broken up during [faggoting](#), that the slag inclusions are not always visible in typical micrographs. Here are examples:



Ulfberht

Frankish



Upper left: Microstructure of Stuttgart Ulfberht (supposedly crucible steel).
 Upper right: [Frankish sword](#) made from bloomery steel.
 Bottom: Svedish axe blade; around 1000 AD. Pearlitic grains enveloped in cementite; i.e. hypereutectoid steel. No visible slag ([Buchwald](#); p. 308)
[Large picture](#) of hypereutectoid bloomery steel with no visible slag
[More pictures](#) of European hypereutectoid bloomery steel

- In any case, the arguments for a Frankish origin of the "true" Ulfberht swords, though not irreproachable, are still far stronger than the arguments in favor of an Eastern origin. Very recently (2014), a [new "Ulfberht"](#) has been found in the river Weser, North Germany. There was some lead in its pommel that could be traced to the "Rheinisches Schiefergebirge", not far from the old and powerful monasteries of Fulda and Lorsch. While that finding doesn't *prove* anything it does make the Frankish origin of Ulfberht's a bit more likely.

[Alfred Geibig](#), known to us from before, the author of a 1991 book about swords of the middle ages, and certainly one of the top German authorities on swords, is also sceptical according to the "[Süddeutsche](#)", and considers a local origin of high carbon steel as possible. Robert Lehmann from the University Hannover who analyzed the Weser sword (and found the lead connection mentioned above), based on his (not yet published) analysis also votes for a local origin of the steel.

 - Add to this that at least one of his analysis is most likely wrong. The Hamburg Ulfberht sword, while a true Ulfberht and counted among the crucible steel Ulfberht's by Alan Williams, shows clear "striations" along its edges. So it was most likely made from fagotted and piled bloomery steel. Judge for yourself by contemplating the picture below and [this picture](#).



Hamburg's Ulfberht sword with striated edges.

[Large size](#)

● If the sword would have been made from crucible steel, there would not have been a reason for faggoting and piling. The [new "Ulfberht"](#) from the Weser also shows some striations in an corroded edge part, possibly also indicating faggoted steel.

▶ Nothing helps. If we want to find out what really happened in the Viking era to the iron and steel industry, we need far more metallographic investigations of regular swords, and in particular a clearer picture of the progress made in smelting technologies. It also wouldn't hurt to know more about the kind of swords that the Islamic Moors carried in Spain, and if and how technology transfer took place at the border to the Christian empires. And so on. I doubt very much that the last word has already been spoken with regard to Viking era swords including Ulfberht's.

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- 1) Anne Stalsberg (Museum of Natural History and Archaeology, The Norwegian University of Technology and Science, Trondheim, Norway): "The Ulfberht sword blades reevaluated", 2008 Internet source: [Jenny-rita.org.](#), Stavanger.
 - 2) We find many pictures in [Buchwald's book](#) that do not show obvious slag. That does not mean that the steel was slag-free, only that the area in question was slag-free or at least did not contain slag particles large enough to be recognizable. Some examples :of such "slagless" steel are:
Buchwald I: Figs.: 118, parts of 122, 174, 245, 270, 330, 334
Buchwald II: Figs.: 12 (most parts), 16, 17, 53, 95, 129 (parts), 259, 304, 306, 356, 376.
To be sure, there are more pictures that clearly do show slag inclusions.