11.3.3 Evolution of Pattern Welding

We still have three questions to deal with

9. The history of the *making* of pattern welded swords. Who made the first ones when and where? How did the technology develop and spread?
10. The history of the *discovery* of the pattern welded swords. How many have been dug out when and where. Where are they now? What kind of investigations took place? Why are the Danes so pissed about the Nydam treasure in Schleswig?
11. Most important: The *metallurgy* of the pattern welded sword. What do we know and what do we guess?

The last questions merits its own sub-chapter. I will deal with questions No. 9 and 10 right here.

History of Pattern Welding

I have put a lot of emphasize on the pattern welded swords found in Danish bogs. Almost all of them were from Roman work shops that were supposedly located somewhere in South Germany / France or along the river Rhine. The "Romans" who made them might have been Romans in the same way as the guys who produced the atomic bomb or rockets were Americans. The "Romans" in South Germany used to be members of Celtic tribes before they were coerced to become Romans. Later (after 200 AD, say) they gradually turned into Alemanni (more or less forcefully) before they became (very forcefully) Merovingians and then members of the Carolingian empire.
A number of bog-swords from around 300 AD where made with pattern welding skills that could not be improved upon then or now - provided you work with bloomery iron / steel and a manually wielded hammer. So let's consider 300 AD as the point in time when pattern welding technology climaxed.

- Looking at the history of pattern welding we thus need to ask two questions:

  1. What happened before 300 AD? How did pattern welding evolve?
  2. What happened after 300 AD? How did pattern welding go on and eventually decayed?

- Besides the history of pattern welding, there is also the history of *discovering* the pattern welding of old. It is one thing to find an old pattern welded blade, and quite another thing to recognize it for what it is. The basic concept of twisted striped rods is not so obvious if you (and everybody else you know) has never heard of that. I will give that topic a quick look, too.

How Pattern Welding Evolved Before 300 AD

How did pattern welding evolve? Who knows. There are no written records and what has been dug out of bogs and graves does not mirror the distribution of pattern welded swords 2000 years ago. There are far more Roman pattern welded swords in museums in Northern Europe than in Italy or Southern Europe because the barbarians up there sacrificed a lot of swords in bogs where iron was preserved *and* they put swords into the graves of the warriors. The Romans did neither. We need to go for educated guesses based on the few things we do know.
It is helpful to realize that here is a continuous transition from random structural piling to pattern welding of complex patterns. Since all cultures working with bloomery iron had to do some piling for making products, it was unavoidable that:

1. Structural and compositional *piling* developed, e.g. by using hard steel on the outside of a blade for the edges. The Roman "Thames" sword from the 1st / 2nd century AD offers a good example for a thoughtful way of structural and compositional piling that did *not* produce a pattern. It was essentially made from one broad striped rod.
2. Random *patterns* were produced on occasion and must have made people aware of the aesthetic potential of compositional piling.

Eventually striped rods became standard, producing not only a pleasing pattern but preventing sudden and complete fracture, especially in cold weather, for all swords employing phosphorous steel for the harder parts. Many in-between situations are imaginable and that means there is no definite beginning of pattern welding. The Celtic (La Tène) swords bear witness to this. Some swords had their iron / steel parts piled in such a way that a pattern might have resulted, possibly without the smith being aware of that. Contrariwise, another smith might have attempted to produce a certain pattern and failed.
At least one Celtic smith making a "La Tène sword" around 300 BC (No. 12 in the picture accessed by this link) produced a complex pattern welded sword that looks suspiciously like one of the the more complex pattern welded swords made about 600 years later. Far be it from me to doubt Pleiner's analysis of this sword. But this sword just doesn't make sense. It is possible that a particular talented La Tène smith was 500 years ahead of the rest, it's just not very likely.
Then again, in 2015 (after I had written this module), two Celtic swords (with anthropoid hilts) and pattern welded blades turned up in an auction catalogue! The pattern resulted from simple striped rods that might have been employed for increased fracture toughness but it sure looks like a pattern was clearly intended. Here is a detailed picture of one blade and here are the descriptions from the auction catalogue.
Yet more amazing is the celtic blade from the middle La Tène period (2nd century BC) that came up somewhat later in

an auction in April 2016. It definitely employs two very well made *twisted* stripes rods. Here is a picture and the description from the auction house.

Let's see what seems to be definitely known as we ascend upwards in time:

Sword Data; Time / Place	**Pattern / Structure**	**Source**
Middle Latène (250 BC - 150 BC) - Unknow location - Unknow location	Structural piling; face welding appears. - 2 striped rods (and anthropoid iron hilt) - 2 twisted striped rods First indications for twisting. Not in sci. literature	Pleiner; Lang & Ager - Antique trade - Antique trade
Late Latène (150 BC - 0) swords - Heiligenstein / Speyer (Germany) - Llyn Cerrig Bach/ Anglesey (England)	Three striped rods all through the blade. - Phosphor contrast.	Ypey Lang & Ager Antique trade
Late Latène Sword with full pattern welding - Cuvi (Italy)	First known example with twisted striped rods and complex structure in the sci. literature. This is the fully pattern welded No 12 sword of Pleiner	Ypey Maeder Pleiner
Latène swords found in - Wachock / Ilza (Poland) - Saône / France - Museum Rouen / France - Port Switzerland	Some pattern welding.	Ypey Maeder
No Roman pattern welded *swords* from the 1st century AD.		As stated by: Ypey
However, from the 1st half of the 1st century AD we have *Pugios* with stripe patterns from - Munich, Germany - Leuven, Nijmegen, Velsen (Netherlands); - Mainz (Germany)	Most Pugios, however, are *not* pattern welded. The ones that are seem to have pattern welded stripes only for decoration. Typically the "classic" 4/3 iron/steel layer package was used.	Ypey
Spathae, around 200 AD - around Oslo; (Norway) with Victoria/ Mars incrustations - South Shields / Durham (England) - Lauriacum / Linz (Austria) spatha	Fully pattern welded - 5/4 low/high phosphorous steel plates; some twisting. - 2 counter twisted rods. - 6 torsion strips on both sides!	Ypey Maeder
Around 300 AD Danish bog spatha	Climax of pattern welding technique	
500 AD - 1000 AD In England	Percentage of pattern-welded blades rose dramatically after ≈ 500 AD, peaked to ≈ 100 % during the 7th century, and fell again during the 9th / 10th centuries. After 800 AD swords with pattern-welded inscriptions appeared	; as far as investigated by Lang & Ager

That is not particularly illuminating. But what, exactly, is it that we want to know? It is quite simple. We want to know how the following three techniques originated and evolved:

- The *making of striped rods*; including the selection of "bright and "dark" steel.
- The *twisting* / grinding of the striped rods.
- *Faggoting* of the two materials *before* making a striped rod.

How, where and when? From the above one might guess that pattern welding evolved in Celtic regions north of the Alpes. But we simply know too little in general, and next to nothing about the use of faggoting in particular. And let me say it once more: If low / high phosphorous steel was used for the bright / dark parts, no clear pattern could result without first faggoting, i.e. homogenizing the phosphorous concentration, since phosphorous is always distributed rather inhomogeneously in the "raw" iron /steel. And phosphorous steel was used a lot!

Did you appreciate that I have hidden a contradiction in terms in the statements above? No? I thought so. Let me explain: If you are able to select the right steel grades *and* you can do faggoting, you do not need to go into pattern welding at all. You could make a superior all-steel swords right away. That pattern welding nevertheless dominated sword making (but not sax making) for about 3 centuries then tells us that:

- either the conditions above were not fully met, then pattern welding might have made sense,
- or they were met and pattern welding made no sense from an utility point of view - but people liked to have "pretty" swords.

The compromise was the full-steel sword with a pattern welded "veneer" that we find so often around and after 300 AD.

It is not clear to me when the first striped rod was made. The "Hermann Historica" sword shown here definitely shows two striped rods running the length of the blade. A (better preserved) second sword looks like it also incorporates striped rods but the catalogue picture are not conclusive.

Unfortunately no provenance is given for these swords. They are supposed to be Celtic and from the middle La Tène period (3rd century BC). While there can be no doubt about the Celtic origin of these remarkable swords, the dating is not beyond reproach since Celtic swords with an anthropoid hilts are typically assigned to the late La Tène (1st century BC) period.
We thus can be sure that Celtic smiths understood and used pattern welding with striped rods as early as about 100 BC, possibly earlier. We don't know, however, if Celtic smiths invented pattern welding with all that implies or if they imported the technology from somewhere else. While I'm not aware of pattern welding being practiced outside of Europe in the first few centuries before the common time, that doesn't mean much. We may not have discoverd the relevant artifacts or we may not have given them proper attention. Having said all this, I nevertheless like to state:

Pattern welding was invented by Celtic smiths sometime between 300 BC and 100 BC.

The Celts used the technology, and so did the Romans. Around 300 AD pattern welding was routine and "Roman" blades with incredibly complex strucures were routinely made. However, we do not know much about the time between 100 BC and 300 AD.

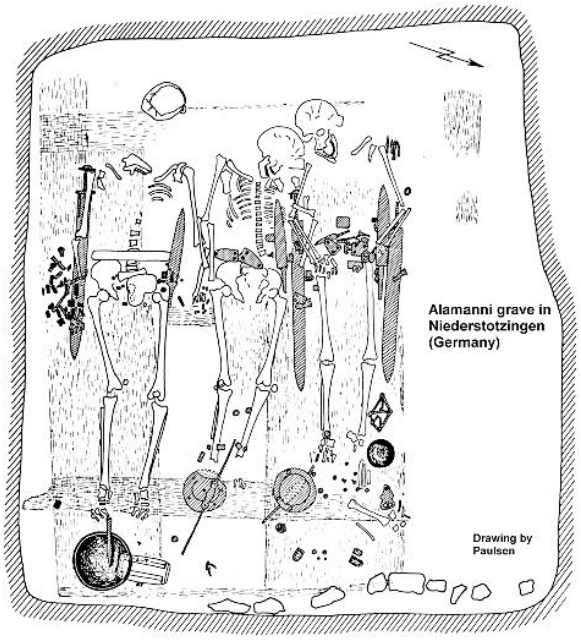
Let's stop here and look at the second point from above: What happened to pattern welding *after* 300 AD?

How Pattern Welding Matured Between 300 AD - 600 AD

Good headline - I just don't know much about the topic. All I could figure out so far is that "late" pattern welded swords were found in graves all over (Northern) Europe. I have no idea about statistics (percentage of graves with swords, percentage of pattern welded swords, where and when) and thus will give you only a few numbers from one tiny area for the beginning:

Area of "Sindelfingen swords"

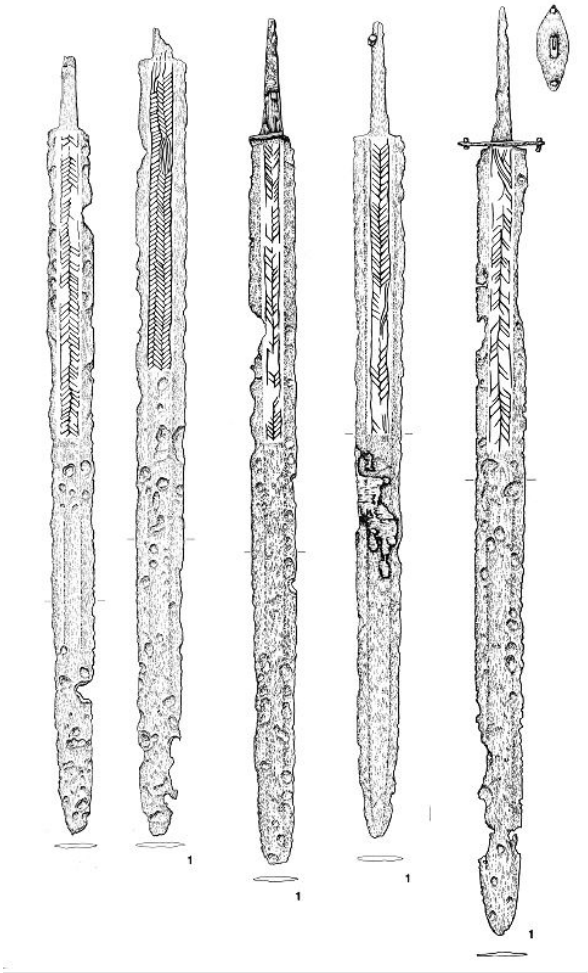
- Sindelfingen is a town about 15 km south-east of Stuttgart, sporting a large Mercedes plant. It is likely to be an Alemannic settlement like all towns in South-West Germany with names ending on "-ingen". The Allemani graves in the Sindelfingen area are by no means special; there are plenty similar ones all over South Germany. I only focus on them because **Dorothee Ade** compiled a detailed analysis of what has been found in the Sindelfingen area in her 2012 PhD thesis. Most of the stuff is from ancient cemeteries, some from single graves.
  Starting about 1860 people payed some attention to artifacts from old times other then treasure that were occasionally dug up, and some of the stuff ended up in museums. Nowadays the location of several ancient cemeteries are known but the graves are left alone for future generations of archaeologists. We already know of another Alemannic cemetery in Pleidelsheim, just to the North in the map above, and unexpected finds are made all the time, too (see below).
  - I'm talking mostly about Alemanni graves here. The Alemanni, as pointed out before, coming from the North (and East), crossed the Roman Limes, the fortified boundary "wall", in 260 AD and occupied parts of what is now South Germany, Switzerleand and France. After the official end of the Roman empire in the second half of the 5th century, the Alemanni were more or less dominated by Ostrogoths in the East or the Frankish Merowingians in the West. The Alemanni were nevertheless a culture that has left deep traces until their nobility was wiped out for good at the "**blood court at Cannstatt**" (Blutgericht zu Cannstatt) in 746. What happened was that **Carloman**, the eldest son of **Charles Martel**, Charlemagne's grandfather, invited all nobles of the Alemanni to a council at Cannstatt (close to Stuttgart). Carloman arrested the several thousand noblemen who had followed his invitation, accused them of taking part in the uprising of Theudebald, Duke of Alamannia and Odilo, Duke of Bavaria, and summarily executed them all for high treason. The action eliminated virtually the entire tribal leadership of the Alemanni and ended the independence of the duchy of Alamannia, after which it was ruled by Frankish dukes. Things like that happen when you neglect to invade Gaul (now called "France") from time to time!
- Anyway , the Alemanni buried their mighty ones with their weapons, and that included pattern welded swords. Here is an especially interesting burial in **Niederstotzingen** from around 600:



Alamanni grave in Niederstotzingen / South Germany (about 600 ±)
Large picture plus a picture of the real things

Source: Old drawing shown in many places, e.g. here or in Menghin's book

- Three warriors, each fully equipped with a big sword, a sax, and many smaller items. And one of those warriors was - surprise! - a woman as a relatively recent DNA analysis proved [2)].
  Here is what those swords might have looked like:



"Sindelfingen swords"
Large picture with more examples

Source

You don't want to see drawings but the real thing? OK - here are some of the newest ones:

Arian (left) und Tarik Wissendaner show what they found in 2012 while perusing an Altingen construction site.

Source: Local newspapers

Altingen is on the edge of the circled area in the map above. While South-German museums are full of (pattern welded) Alemanni swords, there seem to be very few pictures around. Manfred Sachse showed a good one in his book, and this link hub leads to a few more.
I have also started to take pictures myself; here is one (large scale) example. Even more pictures can be found in this link

So what do we know about the Alemanni swords found in the "Sindelfingen" area? Here is a list of what was found in just a few places in the area investigated:

Place	No. graves	Graves with Spatha		Graves with Sax		Time Horizon
Hailfingen	661	25	3.8 %	41	6.2%	500 - 525
Schretzheim	630	105	16.7%	82	13.4%	500 - 525
Holzgerlingen	302	12	4.0%	?	?	≈ 550
Nusplingen	278	15	5.4%	?	?	≈ 550
Marktoberdorf	238	24	10.1%	68	28.6%	≈ 550
Esslingen-Simau	222	16	7.2%	52	23.4%	≈ 550
Sontheim	197	17	8.6%	26	13.2%	550 - 600
Heidelberg-Kirchheim	149	10	6.7%	13	8.7%	≈ 500
Güttingen	113	9	8.0%	22	19.5%	≈ 590
Sindelfingen	?	(21)	?	28	?	450 - 500
Sums / Averages	**2.790**	**233**	**8.35%**	**332**	**15.02%**	**450 - 600**

Even if half the graves were for (unarmed) females, it is clear that not all men and women had a sword. But whoever had a sword was very likely also in possession of a sax. Some, however, had only a sax. By the way, the town names ending in "ingen" signal Alemannic origin. In contrast, the ending "Heim" (=home) signal Merovingian dominance. From some towns it is known that the name changed after the Merivigians took over, e.g. from Hessingen to Hessigheim.

Pretty much all of the swords in the table above were pattern welded. The first blades without pattern welding were from the beginning of the 7th century and their number increases towards the end of the 7th century. As far as one can tell, exclusively twisted striped rods were used for pattern welding, producing simple herring bone patterns (like in the picture above or here) or more complex ones like in the "Ingersheim sword" (almost in the area discussed above). No complex chevron or palmette patterns have been found.
So much for the larger Sindelfingen area. But what about the rest of Europe? And for times after about 600 AD, when Sindelfingen ends? Tall questions with very short answers:

- As far as sword *blades* are concerned, the technology appears to have been about the same everywhere in (Northern) Europe. Pattern welding was the standard. However, I have yet to see blades that surpass the 350± Nydam / Illerup blades. Around 600 AD the first sword blades that are not pattern welded but made by laminating pieces of supposedly faggoted steel appear in some areas (like South Germany). In other areas (like England) that transition might have happened somewhat later. Pattern welding, however, never went quite out of style for another 400 or 500 years.
- We need to be a bit careful about the statement above. A corroded pattern welded blade might just *appear* not to be pattern welded. Look a the one right below or the ones in the link. Was pattern welding involved in the one below? It doesn't look like it but only X-ray pictures or metallographic investigations will tell for sure. Indeed, more recent X-ray investigations did produce evidence that pattern welding was used for blades that did not show it. Contrariwise, a blade with a clearly visible pattern could have been made from solid steel while the pattern was only encrusted, inlayed or "damascened" into the surface of the blade.
- In contrast, while there are some pattern welded *saxes*, the majority of that "utility weapon" seems to have been made without pattern welding. To what extent piling and faggoting was used I can't tell.
- What had happened with respect to making pattern welded blades between - very roughly - 400 AD and 700 AD was and is totally eclipsed by what had happened to the *hilt*. That was true then and is true now. There are far more papers in the present literature about hilt details than about blades for that time span.
- In other words: For the top-of-the line "show-off" swords the hilt became the distinctive part; it also must have been far more expensive than the blade. That doesn't mean that the blade was not top; it just means it wasn't used for fighting. You don't use your Porsche, Mercedes or Bentley four-wheel drive luxury off-road car to actually go off-road either. For menial jobs you have other cars, not to mention people, for God's sake. But your Porsche would be up to the job! We just don't have all that many *fighting* swords from that period, not to mention that warriors might have used a sax for that.

In other words: As far as steel technology and pattern welding is concerned, the technology was established and didn't change much for several centuries. That the focus shifted to the hilt was then to be expected. Basic car technology with respect to the "mechanics" of cars became an established technology around 1980. Gone are the times when young men (like me and my buddies) discussed at length and with a lot of emotions the relative advantages and shortcomings of suspension systems (Längslenker, Querlenker, Schräglenker, Raumlenker... there are no English terms because the American car industry has yet to discover those techniques). Nowadays the sound system of your car is far more interesting than the suspension system.
In other words:

Decadence!

Gold hilt spatha, Stotzingen, Germany; Ellwangen museum

Source: Left: Ellwangen / Germany museum
Right: "Photobucket", Matt Bunker's (medicusmatt) picture

Is that a pattern welded blade? It doesn't look like one but one must be careful in making such a judgement. It was certainly a sword for showing off. Gold was and is in short supply in Northern Europe, and the little that was panned around the Rhine must have been very precious. I doubt very much, however, that a sword with such a hilt would have been any good in a fight. It has no pommel, must be badly balanced, and easily slips out of your hand.

Gold hilt spatha were in use from about 450 AD – 490 AD and are seen by some as derivatives of Romano-Byzantine designs. Alemanni mercenaries, serving in the army of the Byzantine empire, might have brought them home as a kind of memorials and show-off piece. after they This link, this one, and in particular this one gives a few more pictures. King Childeric's sword from about 480 AD embodies the culmination of the gold hilt sword and also leads over to the lavish use of almandine (red garnet) and gold adornments in the time span from (roughly) 500 AD - 700 AD.
The gold hilt swords could be seen as the first step into the new fashion of emphasizing the hilt. This is not so interesting to us here (we are into steel, not gold, after all), so I only give you a (long and lavishly illustrated) special module on the hilt business.

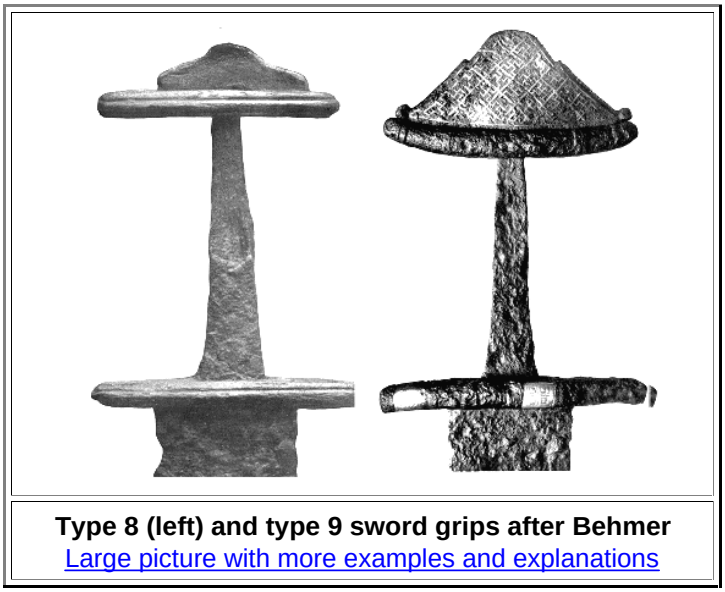
Illustr. Module

Fancy Hilts

Hilt fashion development, however, is good for something: dating swords! Hilt fashions changed more quickly with time than blade fashion, just look at the years before about 300 AD. Certain types then are seen as typical for certain times and areas. Fancy hilts, containing gold, silver or bronze, corrode far less than iron or organic materials and often these parts are about all that has been left.
The reference for hilt fashions is still the 1939 book of **Elis Behmer**. He sifted through much of what has been found in connections with swords, in particular the metal pieces left from hilts and scabbards. Pommels, cross-guards, chapes, lockets and so on in later "migrations period" years. Behmer's successor, up to a point, is **Wlifried Menghin** with his book "Das Schwert im frühen Mittelalter" (Swords during the Early Middle Age).
It's all in the special module. We now look at:

The Years After 600 AD

As far as hilts are concerned, one can see In Behmer's systematic that hilts and pommels became less fancy once more. Here are two examples from Behmer's book:



Type 8 (left) and type 9 sword grips after Behmer
Large picture with more examples and explanations

- As far as blades are concerned, we have a (slow) transition from the Merovingian / Vendel / ... pattern welded "fancy hilt" sword to the Frankish / Viking non-nonsense (laminated/piled) all-steel sword. This took quite some time (400+ years) The new kind of sword will be dealt with in the next chapter.

The History of Discovering the Pattern Welded Swords of the 1st Millennium AD

People must have unearthed 1st millennium swords all the time without looking for them. Farmers unearth things, and so do builders, peat diggers and children. But interest in old things other than treasures was not large before about 1750, when serious archaeology started by dedicated digging in Pompeii and Herculaneum. It took another 100 years before old rusty iron found some interest, and yet another 100 years needed to go by before the science of iron and steel had developed to a point where one could try to figure out what old iron / steel artifacts could tell us.
Let's play the old game and ask:

Who first noticed that he was looking at the result of pattern welded twisted striped rods when he contemplated an old sword? When was that?

- I certainly don't know. I have sifted through 100+ old papers but couldn't figure out who exactly had made the first decisive step in the right direction. But as we shall see, it will be sufficient to look a the work of just a few prominent old researchers to arrive at a surprising insight:

Something went spectacularly wrong!

Let's start with **Conrad Engelhardt** and the Danish bogs. Systematic digging there started in 1859 - 1863, look up the special modules for details. Pattern welded swords were found and recognized as such by Engelhardt. So what did Engelhardt state with respect to pattern welding?

- Engelhardt published his findings in 1886 (in English) and referred to the swords unearthed in Nydam as being "damascened". This was quite natural if unfortunate. Now let's see how Engelhardt described the process of "damascening" in 1886.

"The Nydam swords are of iron, long, straight, and two-edged; the blades are for the most part - ninety out of a hundred - richly damascened in various patterns, and afford good illustrations of the poet's sword, " the costliest of irons, with twisted hilt, and variegated like a snake" (**Beowulf**). Iron wires, arranged in patterns, have been laid in grooves made in the surface of the blade, and then the whole has been welded together, so that the surface must originally have been smooth. That we now see the patterns raised is probably owing to unequal oxidation. Among the many elegant and ingenious patterns represented on Plates VI and VII, I would call special attention to Fig. 5 and 5a, with borders of flowers freely rendered in twisted iron wire."
Page 52

- That is a description of "tauschieren ", and there is no proper English word with exactly that meaning; words like inlaying, incrustation come close. The proper word would be "damascening" but that is now misleading since it was misused as another word for "pattern welding" (mostly by Germans). Whatever - we note that Engelhardt in 1886 was obviously not aware of the twisted striped rod technique.

Now lets move up to 1939 and look at what **Behmer** has to say. He studied the literature quite carefully, and if the "twisted striped rod technique" was generally known by then, he would most certainly refer to it.

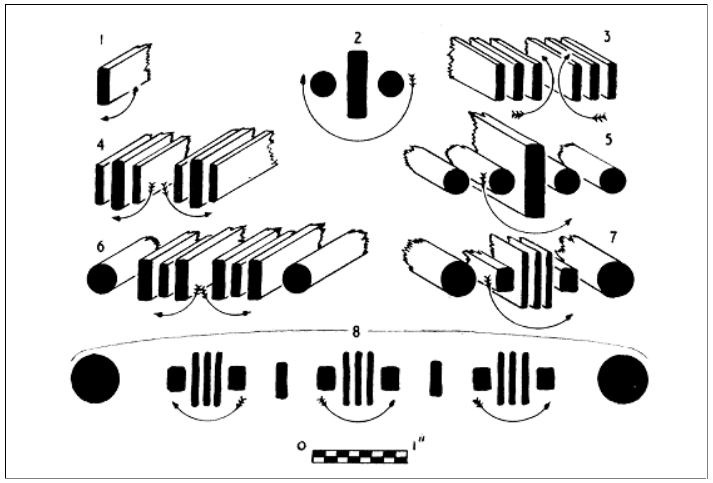
- Here is the decisive paragraph from his book:

"Im Zusammenhang mit den Blutrinnen tritt so gut wie stets Damaszierung auf. In jeder Rinne sind dann auf dem Grunde längs der ganzen Klinge lange, parallele, einander kreuzende, gebogene oder wirbelförmig gewundene Drähte, vermutlich aus Stahl, eingelegt, die in das Schmiedeeisen der Klinge eingehämmert sind. Klingen, die keine Blutrinnen aufweisen, sind oft in ähnlicher Weise damasziert. Der Zweck dieser „unechten" Damaszierung, die von der morgenländischen „echten" Damaszierung, mit der das Abendland erst in der Zeit der Kreuzzüge bekannt wurde, wohl zu unterscheiden ist, dürfte der gewesen sein, durch Einhämmern von Stahlstreifen in ein weicheres Material dieses	"In connection with fullers we find pretty much always damascening. Each fuller groove contains hammered-in wires down its whole length, probably made from steel, running in parallel or wavy, crossing each other or forming eddies. Blades without fullers are often damascened in a similar way. The purpose of this "untrue" damascene, that one should strictly distinguish from the "true" damascene, that was only known to the West after the crusades, might have been to render the soft material more strong and elastic by

stärker und elastischer zu machen." Page 38	hammering in steel wires" My translation

54 years went by since Engelhardts publication, and nothing has changed! It is mostly but *not* completley pure BS, mind you, since some swords have been "patterned" this way.

It was **Herbert Maryon** in 1940 who coined the term "**pattern welding** " and, as far as I can tell, had almost the right ideas about the striped rod twisting.
Next, in 1954, the year Germany won the soccer championship for the first time, J.W. Anstee and L. Biek published "A study in pattern welding" [3)] and related their results of attempts to replicate an old pattern welded sword by forging. Those were probably the first attempts in "experimental archaeology" with respect to pattern welding. They did use a kind of twisted striped rod and experienced big problems with fire welding. They did not only use striped rods but also wires. The idea was to fill the grooves of the screw-like spiral obtained after twisting with a wire to obtain a smoother surface in order to facilitate welding.
The essential picture of the paper tells it all:



Anstee's and and Biek's geometries

We do not need to go into details. It is clear that Anstee and and Biek came close but weren't quite there yet. Here are a couple of interesting quotes:

- "Alternate strips of carbon-free and low carbon metal have been thought necessary to produce such a pattern, and up to 0.6% of carbon has been reported in some material. As the present work shows, however, patterns are obtained *even with strips of the same, virtually carbon-free, iron*".
  The role of phosphorous iron in pattern welding was not known by the authors. Here we probably have the source of the myth that patterns could be produced with one kind of steel. That a pattern was obtained probably relates to their problems with welding:
- "Some of the difficulties inherent in this natural and apparently simple method of construction were revealed when a number of such rods were made in the Laboratory. No welding was then possible; the twisted rods were merely flattened, soft-soldered and ground away to varying levels to reveal the consequent changes in pattern."
  What that means is that their weld seams, if "taking" at all, were likely full of oxides and thus could have shown a "pattern".
- "Furthermore, the herringbone and other patterns observed, either on the surface or (on X-radiographs) within this type of blade, could evidently be produced by (the remains of) composite rods, each pile-forged from thin strips of iron, and adjacent ones twist-welded in opposite directions"
  That is the correct idea.
- "The answer to the problem of scale removal was now clear. As during the work the oxide layer became thicker (and duller) it was forced from all surfaces by the twisting stress. The best solution was to allow the scale to form, twist a little, then tap the hot bundle with the hammer. In this manner the strips were finally screwed up on to themselves, the whole length being traversed in short sections altogether four times-twice up and down. Even so, much fine scale was left in the joints; nevertheless, all internal welds there appeared to be perfect, except at one or two points where lumpy particles had been trapped."
- So twisting makes welding easier!?

I do *not* know when finally everything was right - must have been around 1960. I do know something else, however:

The twisted striped rod technique was an industrial standard in 1850 and earlier!

I have dealt with that already - not so long ago. All of the guys named above must have seen pattern welded contemporary objects like guns for hunting and military (dress) swords in their time. In the larger German-speaking areas (including Denmark, etc.) these pattern welded objects were called *damascened* and were standard issue stuff. While many smiths or companies employed the technique, mass production of twisted striped rod stuff took place in Belgium.

- How Engelhardt and Co. could miss that is beyond me and that's why I say that something went spectacularly wrong. However, they were men of the pen and not the sword and therefore might have become early victims of the "damascene" confusion, believing that the "damascened" gun barrels and swords they must have seen were made by "tauschieren"=inlaying, encrusting; just as described by Engelhardt and Co.

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1) Dorothee Ade: "Funde aus frühmittelalterlichen Gäberfeldern auf der Gemarkung Sindelfingen und aus dem nördlichen oberen Gäu"; PhD Thesis 1991; on-line 2012 in two installments

2) Tobias Schneider: "Mehrfachbestattungen von Männern in der Merowingerzeit", ZAM (Zeitschrift für Archäologie des Mittelalters), Jahrgang 36, 2008; Verlag Dr. Rudolf Habelt GmbH, Bonn

3) J.W. Anstee and L. Biek: "A study in pattern welding", Medieval Archaeology /1954) p.6