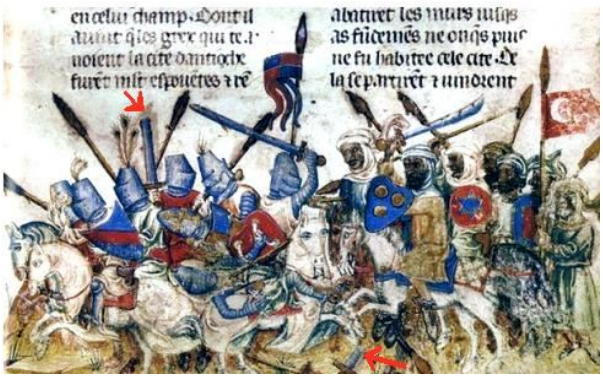
Medieval and Modern Texts Concerning Crucible Steel

Crusades to About 1500

Advanced

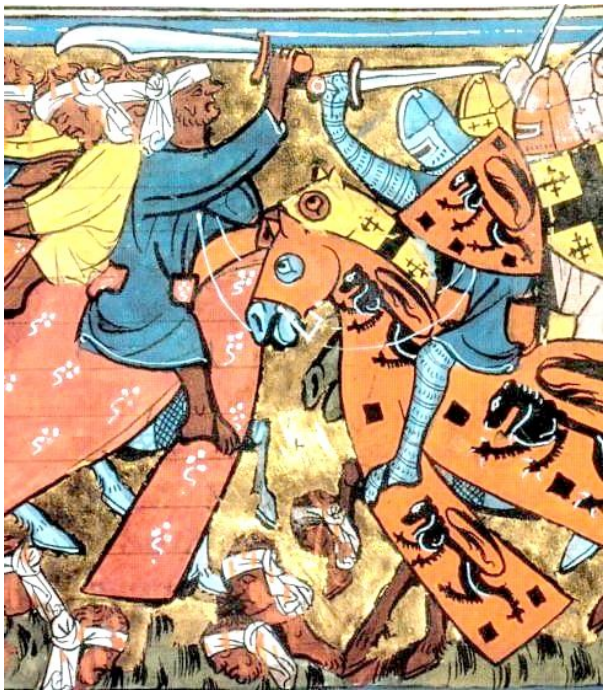
- What did people write about crucible steel "late" in history. With the early writings I have already dealt with in this module.
- Let's start at 1095 AD - the time of the first **crusade**. "Our" knights encountered wootz blades then and until 1272, when the last crusade ended. What written accounts do we have mentioning wootz blades and Indian steel from the Western side? None, it seems.
  - That well-know tale of King Richard "Lionheart" comparing swords with Sultan Saladin is *pure fiction!* There are no authentic writings. This is certainly due - up to a point - to the fact that "our" knights were essentially illiterates. But enough literate clergy was around to record what was going on. They just never remarked on wootz blades.



Moslems are winning. Note broken crusader swords (arrows)

Source: Internet at large; unidentified old "illuminated" manuscript.

- In contrast, the Islamic world provides plenty of writings about Indian steel and the trade of crucible steel and finished weapons from before, throughout and after the crusades. Places of origin are compared and sword qualities were ranked. There is no doubt that South Asian steel (meaning mostly India and Sri Lanka) figured heavily in the "Islamic" world and in the spreading of Islam in the 7th and 8th century (by the word and the sword). Recipes for making crucible steel were known and used outside India - there is evidence that crucible steel was made in Egypt and Syria, for example. The quality of the steel and the blades made from it were appreciated. For example, **Al-Idrisi** or in full splendor, Abu Abd Allah Muhammad ibn Muhammad ibn Abd Allah ibn Idris al-Idrisi, (ca.1100 AD - 1166 AD), a well-known Muslim scientist, praises Indian sabres for their sharpness: "it is impossible to find anything to surpass the edge".
  The prevalence of Indian steel in the "arabic" world is not just due to the high quality of crucible steel. Lack of trees and thus charcoal simply prevented large parts of the Arabic world from sustaining a sizeable iron industry of their own as pointed out before.
  - What we also learn from Islamic writing is that "Frankish" or European swords were quite common in the Arabic world. Al-Kindi, whom we have encountered before, remarks already in the 9th century on the "river-like appearance" of the center of Frankish blades, and that they were made from two kinds of iron / steel". He must have seen pattern-welded blades, it seems.
    One Ibn Hodeil in the 14th century wrote a book entitled "Equipment for Knights and Insignia of the Brave". There we read: "The Arabs claim that the fabrication of (Frankish swords) is the *work of Genies*. They are more resistant to blows one gives with them even during *cold weather*, while the hindy (wootz) sabre often breaks when the weather is cold...". It seems that the wootz swords had a "cold-short" problem, most likely caused by phosphorous.
    China, by the way, was aware of the Indian steel in the Middle Ages, but seemed not to have been very impressed either. There are no indications of major trading or other interactions.



Crusaders are winning as evidenced by the head count.

Source: Internet at large; unidentified old "illuminated" manuscript.

- In the same vein, *Ibn Miskawayh* (932 - 1030) or Abu 'Ali Ahmad ibn Muhammad ibn Ya'qub Ibn Miskawayh, a Persian philosopher and historian makes an interesting comment concerning the times when the "Rus" (=Vikings), who originated in Scandinavia, lost their predominance in a part of their south-eastern territory: "the Muslims opened their graves and took out a number of swords, that are in high demand until today because of their sharpness and excellent quality".
  I owe this to **Stefan Maeder**, whom we will encounter extensively in the next chapter.
- "During all of the Middle Ages there is little evidence other than the Islamic to indicate that Indians were making high-quality steel or that they were shipping iron and steel to other countries", to quote Bennet Bronson[1)] once more. This might be taken as indirect evidence that the Islamic / Arabic / Persian "wootz sword" with a typically curved blade by then was not superior to the typically straight bloomery steel blades of Europeans. The Western knights certainly stuck to their straight double-edged swords. To some extent that might have been just good old-fashioned conservativeness ("what was good enough for my Dad and Grandpa is good enough for me"), also known as plain old stupidity. It is just like people who know about German beer but still drink ..... , for example. You only switch your behavior if the foreign stuff is a *lot* better; just a bit better won't do.
  We might conclude that the average wootz sword might have been "better" than the average Western sword - but not a lot. At this point we may also want to consider that the value of a sword for its owner came not only from its "mechanical" behavior in battle but also from the spiritual strength it imparted to its owner. You were just about invincible if you wielded the sword of the Prophet, a Saint, a famous King, and so on, or if your sword had been blessed by the Pope or one of his representatives. If it contained a holy relic it was well-nigh magical.
  For Moslems, the "water patterns" on their swords may have symbolized the *Waters of Paradise*. "Just as a blade could simultaneously save a life while taking a life, water symbolized both life (clear sweet water) and death (dark brackish water). In Islamic poetry, to drink the water of the sword was to die and begin everlasting life in Paradise. The blade was the means by which a warrior would transmute from this life to the next. Thus, the water pattern on a blade was a very significant symbol of life, death, rebirth, and a constant reminder that dying in battle would result in being reborn into Paradise" writes Anne Feuerbach in 2012 for the American Chemical Society.
  - The quality of a sword, by the way, is not a fixed thing but must be seen in context. The scimitar of the guy at the left in the picture above might be much sharper than the knights sword but that will not be an important advantage against his fully armored opponent. The crusaders sword may not be as sharp but is still good enough to sever plenty of heads.
- About the first time that the "West" learned about famous "Indian" swords was around **1215** from the "Wigalois" of *Wirnt von Grafenberg*; a popular and long book / saga about one Wigalois, a knight of King Arthur's round table. It's rather long and contains these lines: "In inner India / there is a steel (=sword) for battle / that has red marking of gold / and is so hard / that it cuts stone / right as (soft) iron". That looks rather like hearsay (not just India but *inner* India!) and not like a first-hand experience from a crusade.

- More to the point was *Bertrandon de la Brocquiere*, a French guy, who in **1455**, wrote about his travels to the Middle East in 1432–33. He wrote the book at the request of Philip the Good, Duke of Burgundy, for the purpose of facilitating a *new crusade*. Constantinople had fallen to the 21-year-old Ottoman Sultan Mehmed II in 1453 and a new crusade was certainly called for.
  Brocquiere wrote: "Damascus blades are the handsomest and best of all Syria... I have nowhere seen swords cut so excellently. They are made at Damascus, and in the adjoining country..."
  That seems to be the source of the faulty notion that swords made from crucible steel and possibly with a water pattern were made in Damascus.

The British and India

- If we want to understand how crucible steel or "wootz steel became a big issue in the 18th and 19th century and why the British produced complete chaos around this topic, we must consider very briefly the history of the British - Indian relations. With "Indian" I mean the whole general area, not just present-day India.
- Since I credited you with a halfway decent education, you know that it was a bad day for the *American* Indians when they discovered **Christopher Columbus** in **1492**. You also know that Columbus (1451 – 1506) was a Portuguese subject who worked for the Spanish crown, and that his idea was to get to the *East Indies* by sailing *West*. The Spanish crown supported him in a kind of gambling game, hoping to outdo other powers like England in the contest for the lucrative *spice trade* with Asia / India.
  - It follows that Europeans knew about the treasures of India in the 15th century and wanted them. Spices, jewels, silk, gold and silver, dyes like indigo, and so on. Crucible steel, however, was not on the "Wanted" list.
    What is now called America was in Columbus' way, and the American natives, wrongly called "Indians", had to suffer ever since for causing that bit of unpleasantness.
- **1498**, **Vasco da Gama**, another Portuguese, finally discovered the much sought-after sea route from Europe to India. Serious trade along the lines "gold for glass pearls" could now commence. The Portuguese profited hugely because they now controlled the spice trade (first pepper and cinnamon a but then many more) for a while. Vasco's grateful superiors named him "Governor of India" under the title of a Viceroy in 1524. The (proper) Indians weren't asked if they needed a new Governor.
  - Vasco da Gama sailed with an armada - armed ships - and not with research vessels. He knew why, and the Portuguese soon were able to set up trading posts in Goa, Daman, Diu and Bombay. The French, British, and so on - but not the Germans - quickly followed suit and grabbed whatever was still available. Eventually, however, they lost most of their territories in India to the British.
- In **1600** the **English East India Company** (known as "the Company") was founded to get the trade with India going in style and quickly took over parts of India. It not only subdued, bribed and blackmailed local authorities by doing business as usual, but fought outright wars. It employed its own soldiers / mercenaries and removed uncooperative Indian rulers or other European powers that were in the way. In effect it ruled most of India after 1700 or so.
  In the beginning mostly finished goods like fine cotton and silk was exported from India (made in parts in factories put up there) but as time went by the focus shifted to raw materials, which chiefly consisted of raw cotton, opium, and indigo, and more or less forcing the Indians / Asians to buy back the finished goods.
  - Once more plenty of trade - but iron and steel is not mentioned. Opium, for example, was the big issue in the early 19th century.
- In **1857** the Indians rebelled against the Company's rule. They were so brutally suppressed that the British government was "forced" to take control of the Company *and* of India. It favored the princely states that helped suppress the rebellion, and tended to favor Muslims (who were less rebellious) against the Hindus who dominated the rebellion. The British ruled almost 100 years until **1947**.
  British rule might have been better for many Indians compared to the more or less despotic rule of their local maharajahs. But the main goal of the British was not to make the Indians happier but to make some Britons richer.
  - What I wanted to make clear is that the British had ample opportunities in more than 300 years to see crucible steel made, learn all its secrets, and export as much as they wanted to the motherland. But most of the time they didn't.
    Early traders around 1615 and later commented on the iron going to Southeast Asia and other places, but not to Europe. These records make clear that there was a sizeable Indian iron and steel industry and that plenty of the stuff was exported - but no specific mention of crucible steel or superior quality of the steel seems to have been made.
- In **1679** Jean Baptiste Tavernier, obviously a French subject, makes the first remarks on wootz steel: "The Persians are excellent artists at Damasquing with Vitriol, or engraving Damask-wise upon Swords, Knives, and the like. But the nature of the Steel which they make use of, very much contributes to their Arts, in which regard they cannot perfom the same work neither upon their own steel nor ours. This steel is brought from Golconda (=Haiderabad), and is the only sort of steel which can be damasqu'd."
  He goes on and comments on the special forging (low temperatures, no hard quenching), and that the steel was rather cheap. Than he writes: "I speak thus to undeceive these people who think our scimitars and Cut-lasses are made of steel of Damascus, which is a vulgar error; there being no steel in the world but that of Golconda that can be

Damasq'd.

There you have the source of the notion that the only kind of crucible steel that can produce a pattern comes from Golconda, the present day Haiderabad.
What makes Tavernier special is that he admired the Indian / Asian culture and didn't look down on it as was then the common attitude in the "West".

There are other reports from around this time about swords made in Persia with Indian steel. While there are contradictions and uncertainties, we can be sure that patterned blades were made in the 17th century at least in Persia, and that plenty of Europeans knew about that. Nobody seems to have been particularly impressed however. And we should be aware of two points in this context:

- Pretty much all those guys roaming around in India / Asia carried a sword and knew how to use it. But they obviously did not consider to exchange their Western sword against water-patterned wootz blades.
- They nevertheless could admire the elegance and beauty of a wootz samshir or scimitar. You might admire the elegance and beauty of a Lamborghini or Porsche but stick to your pick-up truck or VW for surviving in the rough terrain where you make your livelihood.

It was actually the other way around. Since the first contacts in 1600, the English exported their swords to India, in rather large quantities. Some Indians commented negatively on these "ill swords" but the trade nevertheless increased. One native trader expressively wanted more of the British-made "crooked swords" and long knives which could "bowe almost round and com straight again of themselves".
The European products even sold well in the "high-end" market where competition from India-made blades should have been most severe.
This is a first hint that European swords by then were just as tough and flexible as the wootz swords, which were *supposedly* unbeatable in the "bowing around your body without fracture " discipline. The Europeans, contrariwise, describe Indian swords as rather brittle, given to fracture when bend. Actual tests of wootz swords (I'll get to this in more detail later) seem to support this view.

But let's not get carried away. Swords from crucible steel, like all other swords, came in a wide range of qualities. Wootz swords of exceptional quality as well as mediocre ones must have been made, and it is hard to tell from a few tests what kind of quality could be attained for the top products.
There are also hints that Indian smiths had problems with their own steel. "Bad" Indian blades have been found, and the fact that Persian smiths could sell swords they made from Indian wootz steel back to the Indians supports this view. On the other hand, English connoisseurs around 1875 remarked on Indian steel products as being unsurpassed, resisting blows on granite without being chipped. We must always bear in mind that "a few hundred" years are a long time. The British (no to mention the French) right now, for example, cannot make decent cars but that was not always so. Rolls Royce (presently a BMW in drag), for example, did enjoy a respectable image less than hundred years ago.

It is fair to say that between 1500 - 1600 Asia was the technological equal of Europe. The Europeans did not see it that way since facts count for nothing relative to believes, especially if they are based on religion. This situation changed around the mid-seventeenth century, when the technology gap between Europe and Asia actually had widened and kept widening. The irony is that at times when the West was really ahead, "products of the Orient began to attract widespread admirations not just for their richness and rarity but for the technological skills they embodied", writes Bronson. Europeans now were bent on discovering the "secrets" of the Orient - witness the craze for "China" or porcelain in the 17th century and the race to figure out how it was made. The winners were Johann Friedrich Böttger and Ehrenfried Walther von Tschirnhaus, who made the first European "china" in 1708 in Dresden / Meißen.

Illustrious names became enamored with the the Orient: Voltaire, Leibnitz, Diderot, Watteau, Goethe, ... In this general befuddlement the myth of the superior "damascene sword" was born. Why the term "damascene" was used for blades with a "water" pattern throughout the later history is not really clear; I will comment on that later in more detail. Here it is sufficient to note that the much-admired water-patterned sword made from Indian crucible steel had nothing whatsoever to do with the city of Damascus except that you could buy one there, like in all other "Asian" cities.
Significantly enough, the appreciation of wootz swords as superior weapons did not start with the Europeans who lived in the Orient and were exposed to these weapons on occasions but with the couch potatoes at home. As intellectuals are wont to do, they read up on the topic - in all those old (Islamic) writings then becoming available - and payed no attention to direct evidence. Just take the classical archeologist as example.

Before and parallel to that, Western smiths and scientist did try on occasion to work a piece of crucible steel. One Joseph Moxon remarked in the 1670s that it is difficult to work with but "keeps the strongest edge" of any, steel. Once more sharpness, always related to hardness, is the topic, and products were not swords but punches, files, and such.

It wasn't just the urge to do science that triggered all these and many other guys to look into the "steel issue". There was a lot of money in it, too. Réaumur was payed quite handsomely by Philippe II, Duke of Orleans, to get a better grasp on iron and steel because the French iron and steel industry was seriously backward by then and that was an impediment in conquering the world.
It was thus straightforward thinking to look at "super" steel of others. Indeed, Réaumur was induced to look at the steels "from which the famous Damascus swords are made".He received some samples via the French consul in Egypt and found them hard to forge.

Nothing more remarkable followed. This might just indicate that Réaumur was not aware that some smiths in France knew exactly how to work with wootz. He was a member of the upper class and simply might not have had any contact to the "working" part.

Whatever happened in detail, by the end of the 18th century two developments could be noticed:

1. General public interest in "exotic" stuff, including exotic steel, was becoming a fad or obsession.
2. Scientists were increasingly interested in iron and steel science and technology for various reasons.

As one might expect, there was some interaction between the two and scientists then as now were not always above making some money even if that meant to compromise scientific integrity a bit or altogether. The public wants Damascus steel for their cutlery? So let's give it some - just keep the ingredients secret. Maybe silver steel would sell? Sounds classy, doesn't it? Must be good. Or how about Peruvian steel? As long as nobody knows the difference, you can name your steel as you like.
To quote Bronson: "Some may have been good enough scientists not to allow the possibility of getting rich to lead them into actually falsification of evidence, but a degree of suppression and obfuscations can be expected in the writings of all specialists of the period who worked on the problems of wootz and damascus steel"

One noticeable event was caused by Helenus Scott, who lived in Bombay around the end of the 18th century. He send some samples of wootz steel to Sir Joseph Bank, the President of the august Royal Society, asking his opinion about that steel that "was in high esteem among the Indians". He also remarks on the excessive hardness of the stuff, that this makes it useful for a number of tools and uses (swords, however, are not mentioned it seems), and that it couldn't be welded to regular iron / steel. Banks passed samples on to scientists who were affiliated with the Society (and thus being top notch by definition) and others. Their response is of some interest to us:

- **George Pearson**, a British physician and celebrated chemist was first to voice an opinion in his paper: "Experiments and Observations to Investigate the Nature of a Kind of Steel Manufactured at Bombay and there called Wootz", published 1795 in the Philosophical Transaction of the Royal Society. We learn nothing of much interest from this paper but he was the *first* to use the word "**wootz**" in print.
- **J. Stodart**, a cutlery maker who worked with Faraday, also got a sample. He made (with problems) a penknife from his sample that he found quite good. He had immediate commercial interests at stake and got *Faraday* involved who was working on steel in a general way. They tried to show that wootz was an alloy of iron and aluminum or various other metals. That was a kind of obsession but understandable since Faraday had started to alloy iron with various metals, especially noble metals, in the quest for that better steel.
- **David Mushet** , a Scottish metallurgist and a big name in early iron / steel mass production also got some "cakes". Officially in 1804 but he probably had access to wootz before that. He reported on his results in 1805. Before that he filed a patent for making crucible steel in 1800. The Pearson from above found it remarkable that Mushet's patented process was "in principle, and I may add even in practice too, identical with that by which the Hindoos have from ancient times prepared their wootz". One might be inclined to view Mushet's 1805 comments as a bit biased - he had a patent to protect.

None of these guys mentioned the "water pattern" that was supposedly obtainable with wootz in their reports .
Before I go on I need to exorcise one little demon that permeates about every paper I have read about the subject:

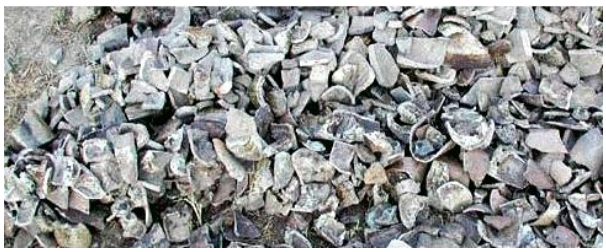
The 18th / 19th century scientists were *not* really interested in figuring out the secrets of crucible or wootz steel. They were interested in figuring out the secrets of steel!

Steel itself was mysterious. Any steel or any form of iron. The differences between Sheffield steel, Solingen steel, blister steel, puddle steel, and so on ad infinitum were just as puzzling as the differences between all of those and crucible steel. Consider that

- Atoms, while existent for billions of years, had not been "invented" yet.
- It was not before 1781 that Torben Olof Bergman noticed that it was essentially carbon that turned iron into steel. He was not so sure, however, what carbon (he called it plumbago) actually is.
- That's because the notion of chemical elements first came up 1789 in Lavoisier's seminal book. But elements weren't well established then; Lavoisier's list was both incomplete and faulty when **Michael Faraday** did his investigations.
- You can't really analyze what iron is alloyed with if you don' know all the major elements and have no good analytical tools.
- It was not before 1831 that somebody (actually the Russian scientist Anosov; see below) looked with a microscope on the surface of some steel.

Faraday, certainly one of foremost scientists of his days, together with Stodart, his black smith so to speak, actually did come up in 1820 with the observation that wootz could produce a "water" pattern, realizing that excess carbon in the steel and slow cooling rates played a role a in this.

Many more people tried their hands with wootz samples during the 19th century. And quite a lot watched it being made in India and reported about that. Crucible steel making, after all, was a major industry in India until about 1900 and and "up to this day, massive heaps of broken crucibles cover the outskirts of several Indian villages, and are testimony to a time in the eighteenth and early nineteenth centuries when Indian wootz ingots were sold by the shipload to European and Arabian merchants, serving international markets", writes Thilo Rehren. Here is a picture from his homepage illustrating this:



Heaps of broken crucibles.

Bronson lists 18 credible accounts of crucible steel making, dismissing a number of suspicious ones. The process, or better the processes, were rather well known. They were quite different in many details and also in major points. The source of carbon, for example, could be plants, wood, charcoal or even cast iron.

It's time to stop. Going into the intricacies of who did what and when, and why that conflicts with other sources; who might have cheated a bit or just didn't get it, and why interest was lost eventually, would fill many more pages. All I'm going to do now is to give a few more highlights, selected completely subjectively, plus my opinion on some points.

1. Not everything proclaimed to be "wootz" was crucible steel. In the 19th century people could make all kinds of good steel in other ways too - and that includes Indians in India. Cylindrical wootz "cakes" with flat bottoms are actually a bit suspicious; a wootz "egg" is more to the point since most crucibles did not have flat bottoms. Some of the wootz distributed by Sir Joseph Bank at the end of the 18th century might have been such a "pseudo" wootz.

2. Even among real wootz large differences must be expected with respect to the carbon concentration and whatever else was in the iron. In the 18th and 19th century it must have been possible to raise temperatures in a wootz kiln to degrees that could melt ordinary steel and not just high-carbon steel. That allowed to make "wootz" with less than 2 % carbon, easier to work with but still quite hard. Then, as always, a bit of phosphorous, manganese, sulfur, silicon and so on would also have made a difference. This simply means that the quality of a wootz steel could vary considerably.

3. All things considered, crucible steel was foremost a high-carbon steel, or in modern lingo actually a Ultra High Carbon Steel (***UHCS***) with a carbon concentration between 1 % and 2 %. These steels are used nowadays whenever extreme hardness is good - but they still occupy only a niche market. While proper forging or processing (nowadays with powder metallurgy, for example) does exorcise the inherent extreme brittleness of UHCS to some extent, you cannot expect miracles. Pulad eggs or wootz are "dirty" UHCS and will not be susceptible to miracles either.
On the other hand, UHCS is still a material good for a few surprises. It will exhibit *superplasticity* at high tempratures, for example, if its structure is right

- **4.** *All* high carbon steels have the potential to show a surface pattern caused by inhomogeneously distributed cementite particles. Not all UHCS, however, can be coerced to produce a *nice* pattern. What exactly is needed for pattern formation in general and for nice patterns in particular, will be dealt with in the next chapter.
- **5.** Sword bearers in the 19th century tended to go for *showy* swords. They were typically officers who *carried* but did not use a sword (except in a duel). Regular grunts did neither carry nor *use* swords anymore. That's why there was a certain revival of the pattern-welded "damascene" sword and all this interest in wootz and "true damascene" in the 19th century. It was just more fancy.
  While scientists at least tried to analyze the wootz *cakes*, rigorous tests of wootz *swords* are suspiciously absent until 1924, when Zschokke tested four wootz swords and found them to be inferior to standard-issue blades. With your wootz sword you might have been able to cut that silk handkerchief, definitely impressing the Ladies and assorted couch potatoes, but not necessarily your enemy on the battle field.
- **6.** All that experimenting with crucible steel was certainly helpful in getting on with *Western* science and technology of iron an steel, but those Western scientist and engineers would have come up with all their insights and inventions without wootz too. Maybe a little later, maybe with a few more dead ends - but there is no doubt that this would have happened. Contrariwise, having had a "superior" iron / steel technology for more than 1000 years did not do much for *Eastern* Science, and I include China here.
- **7.** There is still a tremendous lot of BS published about wootz. Even modern scientists contribute directly or lead you astray by "unfortunate" wording. Here are two examples from an otherwise very good article (that shall remain anonymous):
  "The early European blacksmiths failed to duplicate Damascus blades because they were in the practice of forging only low carbon steels at white heat, which have a *higher melting point*. Biswas mentions that the forging of wootz at high heat would have led to the dissolution of the cementite phase in austenite so that the steels were found to be brittle enough to crumble under the hammer." This is complete BS. The melting point is irrelevant for forging; and austenite is neither brittle nor does it crumble under the hammer.
  "Ultrahigh carbon steels could be both superplastic at warm temperatures and strong and ductile at room temperatures". Superplastic? Wow! Sounds certainly good. Would you have guessed that "warm temperatures" mean a least 700 ^{O}C (1300 ^{O}F)?

Russia and Wootz

Everybody who looked into the "wootz" issue just a little bit knows that some Russians had unveiled its "secret" before anybody else. And that's about it. There seem to be not too many details around of what, exactly, was done in Russia. Here are some bits of information; mostly from Anna Feuerbach's thesis:

- "During the **18th century**, *Tsar Alexei Mihailovich* sent three artisans to Astrakhan to learn the art of forging Damascus steel" writes Anna. "However, what happened after they were sent there was not recorded" she continues. Small wonder because Tsar Aleksey Mikhailovich (1629 – 1676) was the Tsar of Russia during some of the most eventful decades of the *mid-17th century* and not the 18th century..
- The most notable (wootz) researcher was General **Pavel Petrovich Anosov** (1799-1851) who attempted to improve steel and replicate the Damascus steel pattern. Exactly when Anosov started his crucible steel research is not known but it was after **1819** when he was made supervisor of the damascene weapons department of a *small arms factory* in Zlataoust. He actually headed that factory until 1847.

So the Russians actually produced their own wootz and made weapons from it as early as 1819, when English researchers had not achieved very much yet except to produce some confusion? It just doesn't seem to be quite believable.

Anosov, besides being a general, was obviously a good scientist. His interest, it appears was the "damascus" pattern on sword blades that he must have perceived as sign of high quality. His steel research was centered on reproducing it by making suitable steel. Two of his actions are noteworthy:

1. He investigated not just wootz cakes but actual *blades* with a "water" pattern. What exactly he did with those blades, I don't know.
2. He appears to have been the first scientist who in **1831** used a microscope to look at a metal - three years before Henry Clifton *Sorby,* who is usually given credit for this achievement. What he saw I don't know.

Pavel Petrovich Anosov

- What he did *not* do is to find the secret of wootz / damascus steel because there never was a secret beyond the general secret of steel at this time. He did, however, find *four* ways to produce crucible Damascus steel with the characteristic pattern:

  1. Direct reduction from the ore.
  2. Decarburization of cast iron with iron oxide.
  3. Melting and casting steel into a mould.
  4. Reacting iron and carbon (Probably in a crucible)

Knowing only this it becomes clear that Anosov "simply" found the major ways to make steel, including high carbon steel plus ways to process (some of) the products in such a way that a "water" pattern could develop. He was aware, for example, that the cooling rate was important - *slow cooling* is necessary for a "damascene" pattern, plus *repeated* forging at *low* temperatures. He also looked into methods of producing *different* patterns.
This was a momentous achievement in its time. It was by necessity completely empirical. Anosov and anybody else around this time could not possibly have *understood* the role of carbon in iron and *why* cooling rates make a difference. The first more or less tentative phase diagrams did not appear before 1875, after all.

- The list above, while clear in principle, leaves many open question. How did Anosov control a *direct reduction* process? Bloomeries by then had made iron and steel by carbon monoxide (CO) reduction for more than 2000 years by then, but making *high* carbon steel with a defined amount of carbon this way was at best a matter of luck. That is not an easy thing to do. What kind of steel did he melt for reacting it with carbon? And so on.
  It doesn't matter much, however. What Anosov did was to produce halfway homogeneous (=melted once) steel that contained enough carbon to allow pattern formation by distributing cementite particles inhomogeneously. There is no mystery in this. The difficulty or "mystery" in the old times was that everything in a long chain of processing steps needed to be done "just right".
  Anosov communicated with or even met many of the other big guys in steel research in the early 19th century, and actually gave some of them (e.g. Faraday) "damascene" swords made by him. Those swords are languishing somewhere, collecting dust. Unfortunately he only managed to write one short paper on the topic, entitled "On the Bulat". It was published in 1841 and is about all we have besides surviving swords (some of which are now being analyzed [2)]).
  Most people, however, like simple mysteries far better than complicated facts. In a recent (2008) paper from Russia [2)] we read for example that "the *secret of obtaining bulat steel* was partially lost after the death of Anosov". Come on! A whole factory in Zlataoust, wherever that might be, is making the stuff in large quantities and then suddenly the folks there didn't know how to do it any more? Might it not be just as likely that interest was lost because Anosov's UHCS was simply not so great for making serious steel thing like guns? My guess is that the market for showy officer swords collapsed when the bloody Crimean war started in 1850.

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1) Bennet Bronson: "The making and selling of wootz, a crucible streel of India", Archeomaterials, Vol1, No. 1 (1986) p. 13 - 51

2) V. M. Schastlivtsev et al.: "Structure of Three Zlatoust Bulats (Damascus-Steel Blades)"; The Physics of Metals and Metallography, Vol 106 No. 2 (2008) p. 179