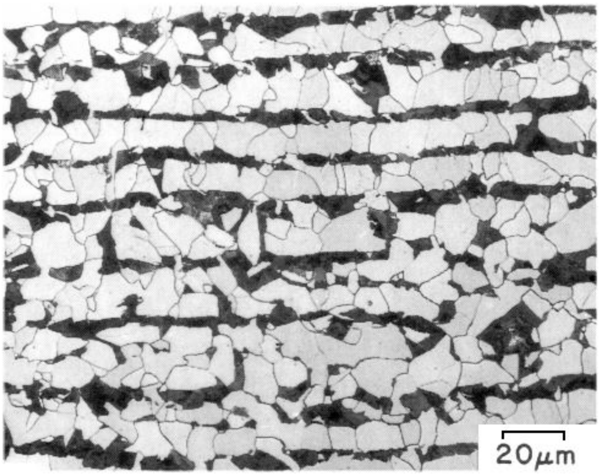
Banding

Illustration

In the backbone I stated: "running a (hot) piece of *any* steel through a roller mill, reducing its thickness, almost always produces banded structures with a nicely staggered sequence of carbon-lean, carbon-rich, carbon-lean, ... , layers. This is generally not appreciated". **Badeshia**, well-known to us by now, expresses it thusly: "Although these cellular networks of carbides are broken up by subsequent deformation, they spread out to form the *infamous* banding" [1)]

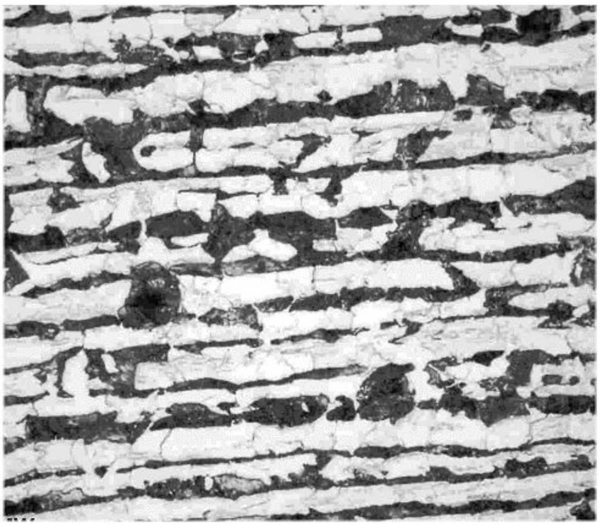
In this module I will show a few pictures of banded structures and look into explanations.

- Here are three pictures showing banding in various steels. Pearlite appears always dark



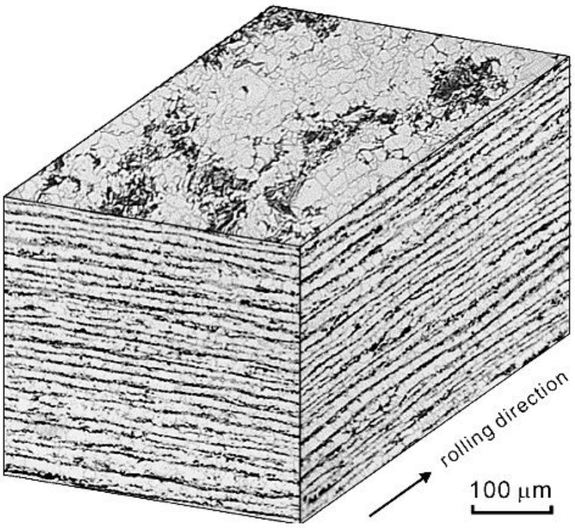
Banding in low carbon steel. Some rolling might be assumed but no details are given

Source: Texbook "Constitution and Properties of Steel", p. 11



Banding in hot rolled 0.27 % carbon, 1.25 % manganese steel

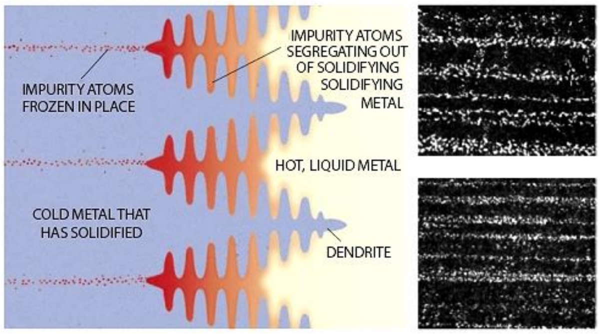
Source: RK Nichols contribution in the Bladesmith's Forum: March 2005



Banding in rolled (low carbon?) steel with manganese

Source: H. K. D. H. Bhadeshia, Graduate Institute of Ferrous Technology (GIFT); Internet site: Interpretation of the Microstructure of Steels

- The picture above looks a lot like the picture in this link and that tells us that one might be able make blades that show a kind of nice wootz pattern - except that the pattern is not due to cementite banding but to pearlite banding. **Ann Feuerbach** discusses this in her papers and in particular in her thesis in some length.
  - So far I have not found a picture of such a "pearlite pattern" for old swords and therefore will not go deeper into this.
- Here is the picture Verhoeven published in the Scientific American in 2001. It does insinuate that the banding of cementite in real wootz blades as shown on the right comes right from bands of "impurity atoms frozen in place" during solidification between the dendrites that extend extend into the liquid from left to right.



Verhoeven's "banding by dendrites" picture
The dendrites are the blue structures by the way.

Source: see the text

  - This is an oversimplification, to say it politely, as explained in some detail in the backbone.
    Mind you, I don't blame Verhoeven for this. It is simply impossible to explain to a *general* readership what really happens between impurity segregation during freezing and the appearance of banding in the finished product since even the very basics of freezing and segregation are far too complicated for lay persons. It is also impossible to explain to an *expert* readership what really happens between impurity segregation during freezing and the appearance of banding in the finished product for the simple reason that nobody knows. Verhoeven tried and failed; read the details here.

- Maybe other steel experts can explain banding? H. K. D. H. Bhadeshia from above, a top authority on steel structures, offers the following (simplified) explanation for banding:
    - The vast majority of commercial steels contain manganese and are produced by casting under conditions which do not correspond to equilibrium. There are as a result, manganese-enriched regions between the dendrites. Any solid-state processing which involves *rolling-deformation* is then expected to smear these enriched regions along the rolling direction, thus building into the steel bands of Mn-enriched and Mn-depleted regions.
    - Aha. Dendrites again. But the decisive process is the *"smearing of the enriched regions during rolling"*. This is to be expected, indeed, for the simple geometric reasons discussed here. However, this simple change of the geometry alone cannot account for "nice" or pronounced banding.
- I have not found a convincing explanation for banding in the literature I consulted, This may have several reasons. Maybe I wasn't looking hard enough. Maybe I'm too stupid to understand the finer points some authors were making. I still believe, however, that banding is simply not yet fully understood.
    - My own "explanation" goes as follows: Consider a grain or part of a grain in some steel that runs through rollers (or gets hit by a hammer in a way that makes it longer and thinner). A volume increment somewhere in the grain then must move forward and inward. It will do so because it feels stress from various directions, to which it responds by deforming and net movements forward and inward. How exactly it does so depends on its internal structure. Now grains or parts with *different* structures respond differently to stress. If they would be on their own, the would deform differently then when they hang together. Hanging together means that they all experience the same deformation in the rolling direction. You might also say that they must move with the same *velocity* in the rolling direction, if they like it or not.
    However, this is not necessary in directions *perpendicular* to the rolling direction. All parts must move inwards to some extent, the material gets thinner after all. "Harder" parts, like cementite particles or pearlite grains might do that differently from soft parts like ferrite grains. The result could be banding.
    Not very clear and not very convincing. And, of course, a far cry from being a detailed explanation. But we have encountered the basic effect - different deformation in different parts of a specimen - before, when we considered necking. That was complex enough but what I'm considering here is far more complex. So I won't go on. Time will tell.

[1)] H.K.D.H. Bhadeshia: "Steels for Beaqrings"; Progress in Materials Science 57 (2012) 268-435.