Rough Timeline of Metallurgy

- Chalcolithic (AKA Eneolithic, Copper Age)
  - Poorly defined transitional period
  - Copper, accidental bronzes
- Bronze Age
  - 4000 BC – 1000 BC
  - Bronze = copper + tin
- Iron Age
  - 1000 BC onwards

Basic Smelting Chemistry

- Very little native metal in the world
  - Gold, platinum, some copper, meteoric iron
- The rest is in the form of oxides, sulfides, etc.

- Smelting at its most basic:
  $2CuO + C = 2Cu + CO2$

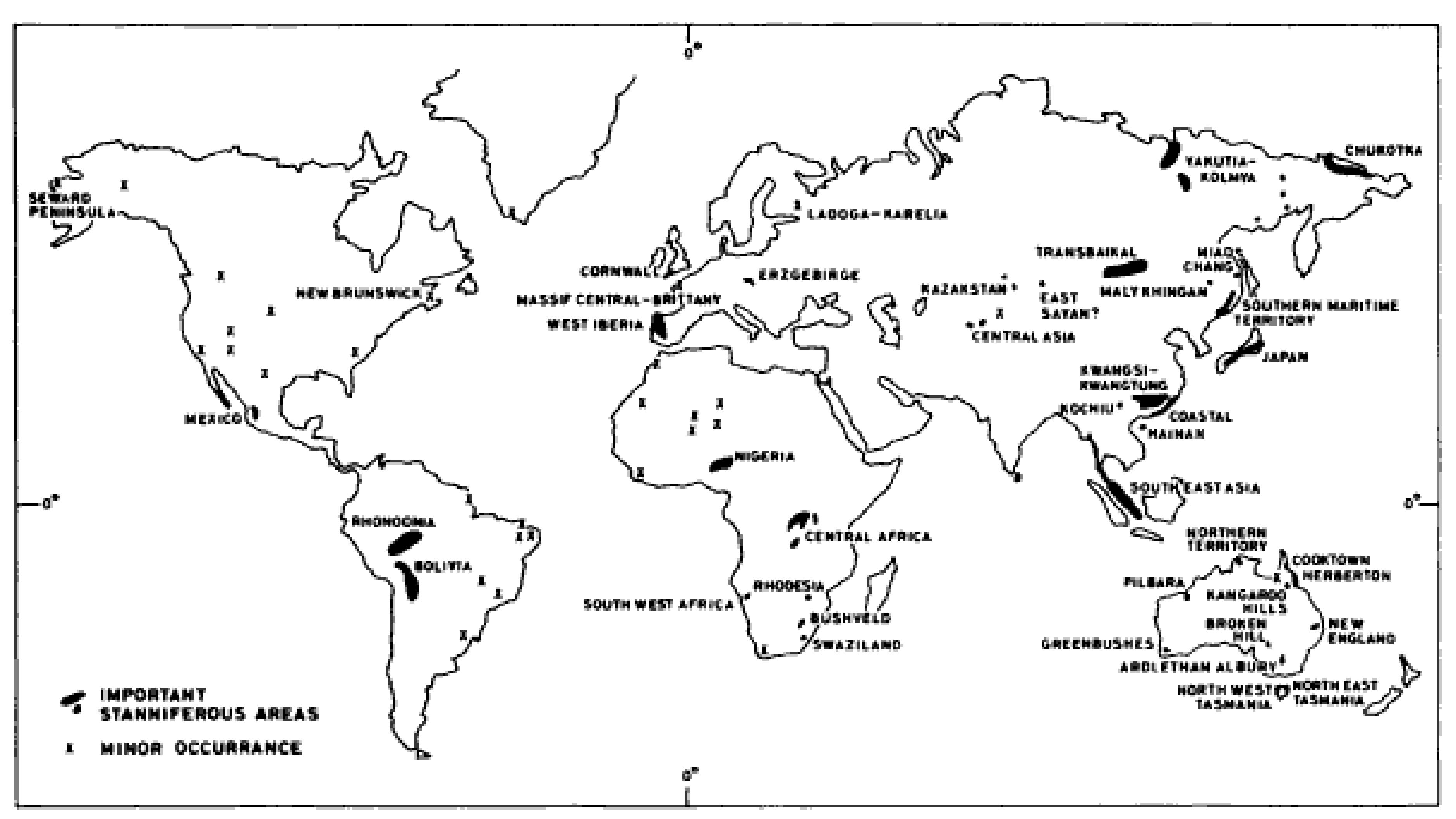
- Need heat and a reducing atmosphere

Timna

- Earliest archaeological record of smelting
- ~4000 BCE
- Simple bowl furnaces with goat-skin bellows

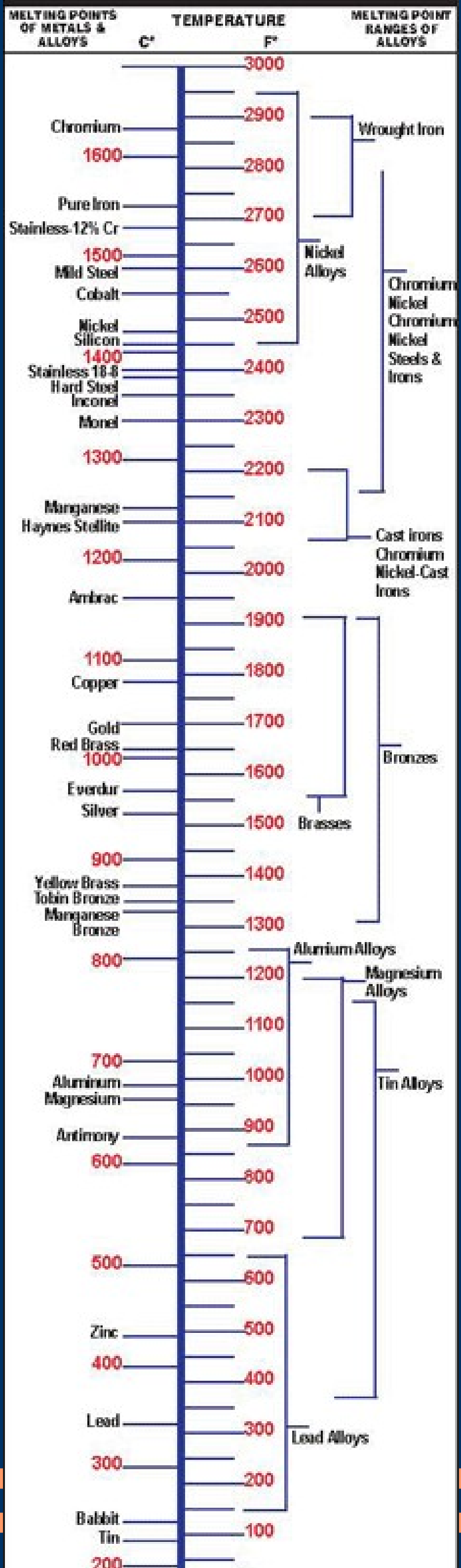
Backyard copper smelting

Global source of tin



Iron

- Iron ore is everywhere
- Early furnaces were nowhere near hot enough to melt iron
- Instead, a porous mass called a bloom forms
- Contains lots of chunks of charcoal and slag
- Removed from the furnace and then hammered down to force out some of the impurities
- Very labor intensive



http://www.bradford.ac.uk/archsci/depart/resgrp/amrg/Rievaulx02/Rievaulx.htm

Flickr user: Stellar Muddle

Wrought Iron

- Resulting wrought iron has banded layers of differing carbon content, making it moderately resistant to corrosion
- In modern terms, 'mild steel'
- Don't confuse the name with wrought iron as a style of metalwork
- Distinctive 'grain' pattern if you know what to look for

Flickr user: neilalderney123

Blacksmithing

- Two basic operations:
  - drawing out: making longer and narrower (easy)
  - upsetting: making thicker and shorter (hard)
- Welding is possible at very high temps
- But riveting is easier and preferred if possible
- Surprisingly easy to do in an urban setting :)

Cast iron

- Takes very high temps, so you need good bellows or a good power source
- First achieved in China around 300 BCE
- China used box-bellows
- Added water power around 30 AD
- Didn't spread to Europe until the 15th century
- Europe stuck with accordion bellows, which suck

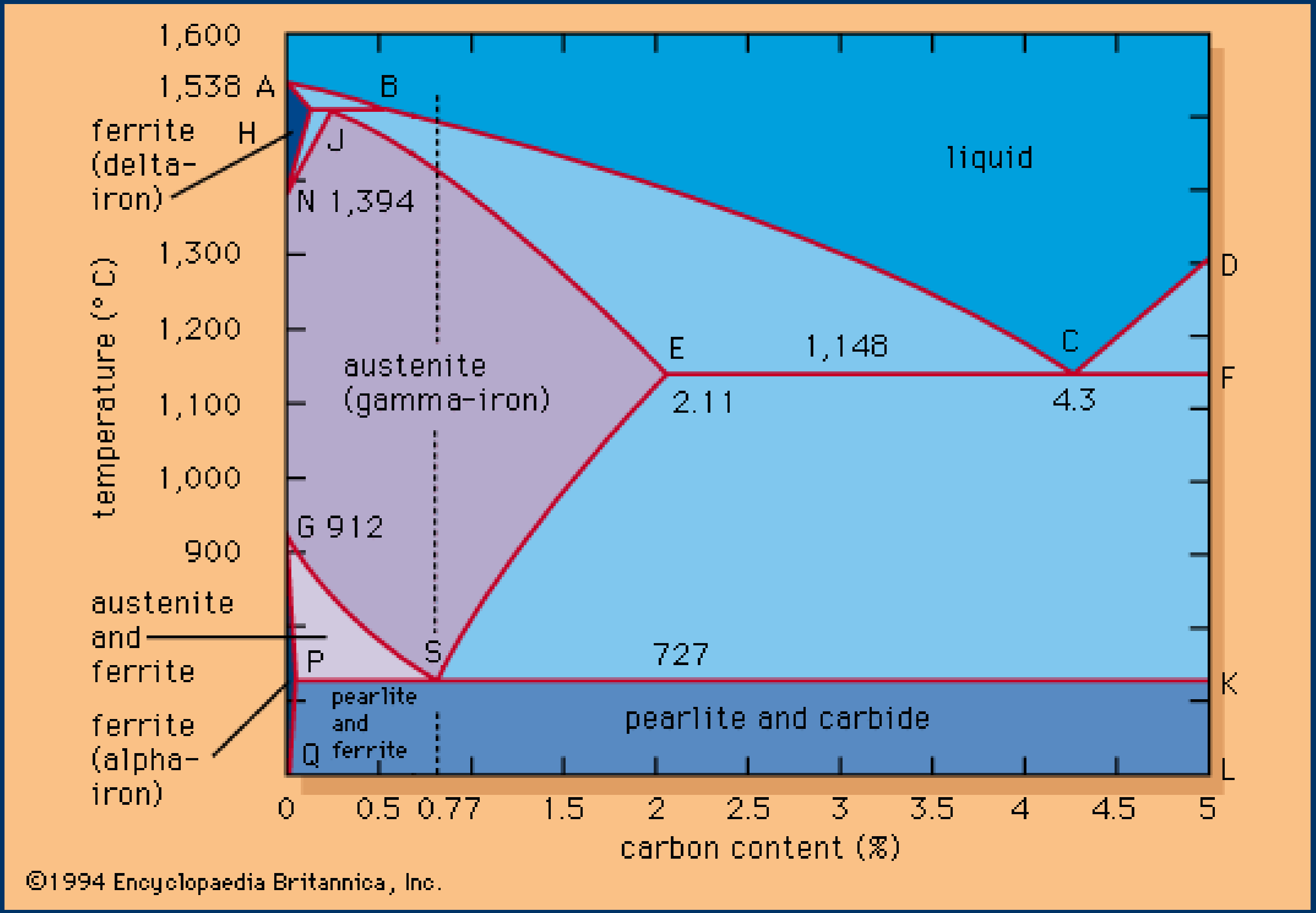
Steel smelting

- Wootz
- Tamahagane
- Blister steel
- Crucible steel (1740)
- Puddling (1784)
- Bessemer Process (1855) (Youtube Video)
- Linz-Donawitz process (1952)

Steel chemistry

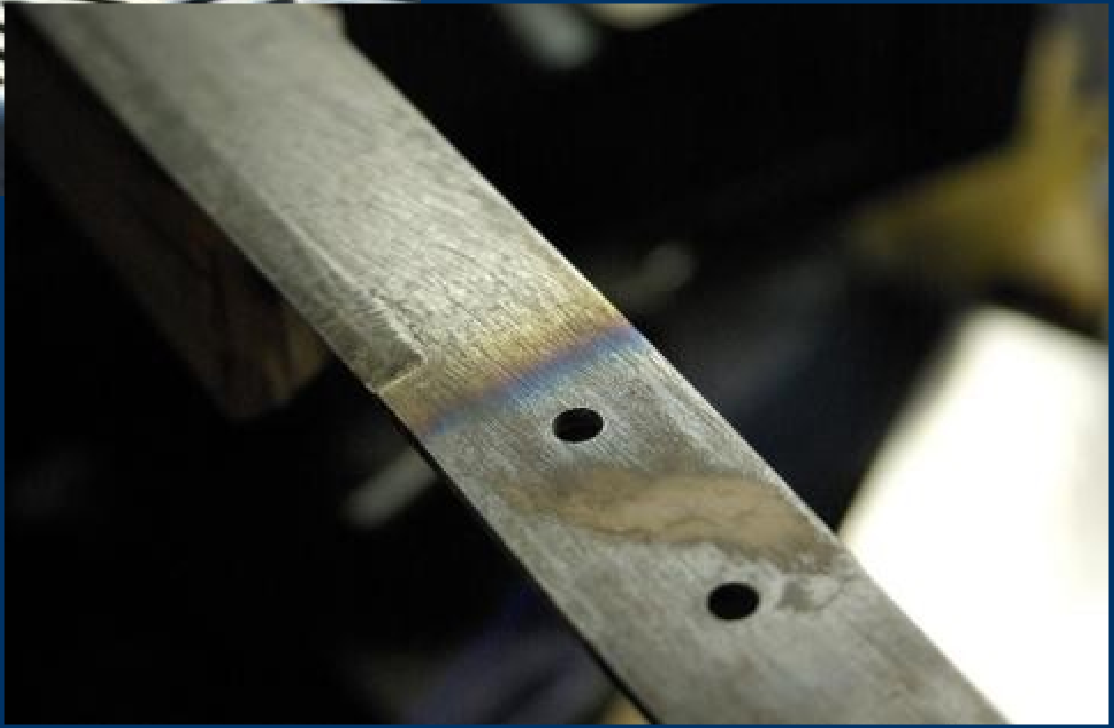
- Steel == alloy of iron + carbon
- Anything beyond about 1% carbon just makes it brittle – this is what cast iron is
- Different molecular structures at different temps
  - Ferrite: Pure iron, body-centered cubic lattice, low carbon solubility
  - Cementite: Iron carbide, brittle cast iron
  - Austenite: Face-centered cubic lattice, high carbon solubility
  - Martensite: Metastable result of rapidly cooled austenite
  - Pearlite: Combination of ferrite and cementite

Phase diagram



Heat treatments

- All heat treating of steel is just manipulation of the phase diagram
- Normalizing/annealing == slowly cooling from over the critical temp to release stresses and remove all hardening
- Quenching == rapidly cooling to lock the steel into martensitic structure
- Tempering == partially degrading hard/brittle structures through the application of (much lower) heat (martensite to cementite)

Quenching Myths

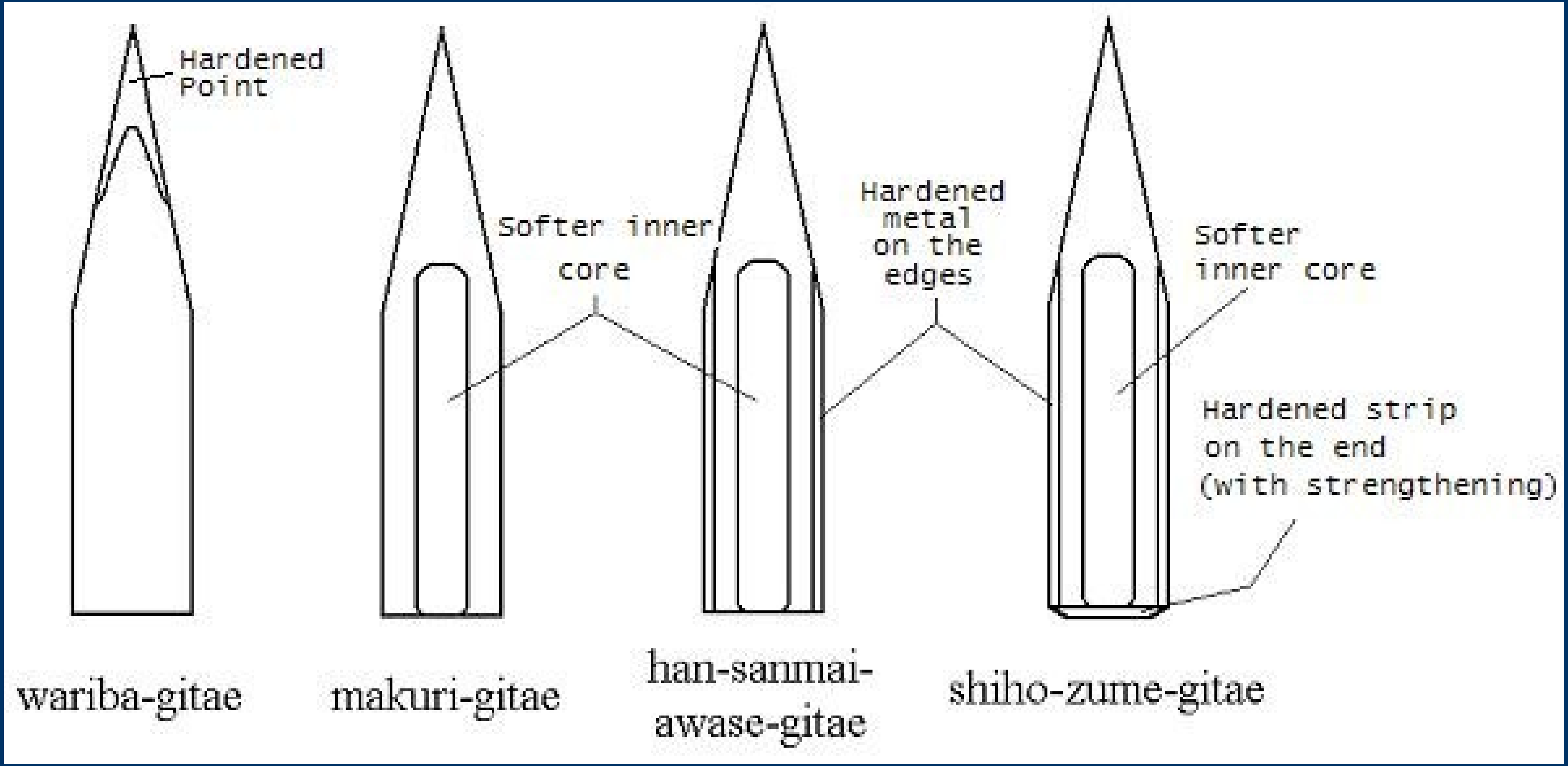
- The ONLY function of the quenchant is to change how quickly the steel cools down
- The faster it cools down, the harder and more brittle it will be
- Different quenchants remove heat at different speeds, due to bubble formation and boiling point
- Oil < water < brine
- Use the correct quenchant for the alloy, RTFM
- USING SNOW IS BULLSHIT

Case Hardening

- Pack the piece in carbon and heat for a long time
- Much like blister steel, but non-destructive
- Creates a high carbon zone maybe 1 mm deep
- Good for bearing surfaces, but not blades

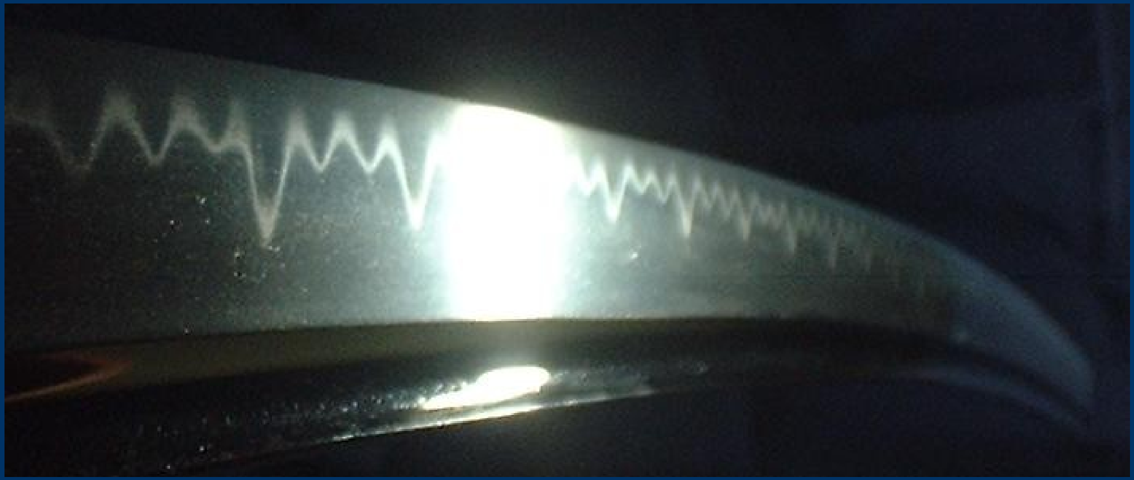
Composite sword design

- The ideal blade has a very hard edge, but is still flexible over the whole length
- Can approximate this with tempering
- Another way is to combine steels of different carbon contents
- This also lets you use lower carbon steel, which traditionally was much cheaper
- Classic example: the katana
- (The folding 10,000 times thing? Bullshit.)


Hardened Point
Softer inner core
Hardened metal on the edges
Softer inner core
Hardened strip on the end (with strengthening)
wariba-gitae
makuri-gitae
han-sanmai-awase-gitae
shiho-zume-gitae

Differential quenching and hamon

- To make the edge even more durable, you can quench different parts at different rates
- Coat the parts you want softer with a clay mixture
- When quenched, those parts cool slower, thus harden less
- Forms a *hamon* when polished properly



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