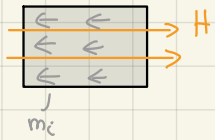
Magnetic properties of materials

Atomic-scale origin of magnetism
→ unpaired electrons in orbital shells (outer) ↑↓ ↑↓ ↑
→ symmetries in crystal lattice structure

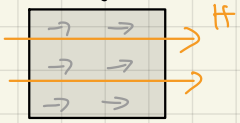
This leads to three different magnetic groups
Dia-, Para-, Ferromagnetism

Diamagnetism



- weakening effect because $\vec{m}_i$ align antiparallel to external field
- if field is removed, then the thermal disorder takes over and magnetization is removes
- $k<0$ and small
- Quarz, Calcite, ...
- WEAK magnetism

Paramagnetism



- reinforcing effect ($k>0$, smallish)
- Volume magnitization is lost if external field is removed
- gold, copper, ...

Ferromagnitism

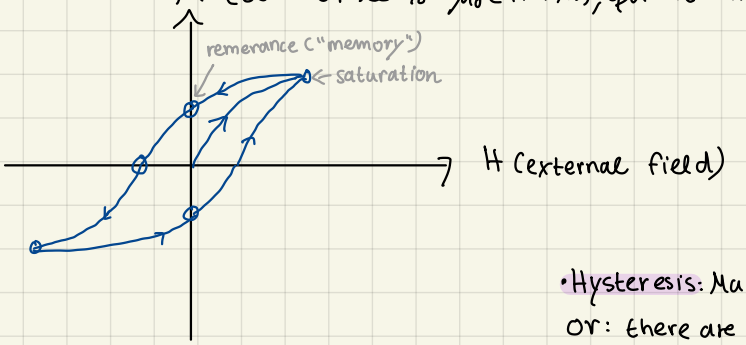
aligned regions with a net magnetic moment already in absence of ext. field

- reinforcing effect
- $k >> 0$ (large values, strong magn.)
- iron nickel

Remanence & Paleomagnetism

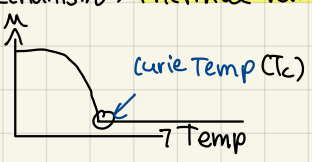
M (sometimes $B = \mu_0(H+M)$, qualitatively similar)

remenence = magnetization without ext. field



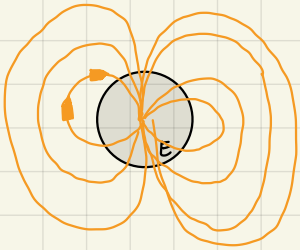
- Hysteresis: Material has memory of magnetization history
  or: there are two remanent states for $H=0$ and other H
- materials can "store" the magnetic field orientation via remanence because this is a strong effect
  also: Ice shields of Antarctica and rising sea level

Important mechanism: Thermal remanent magnetization (TRM)

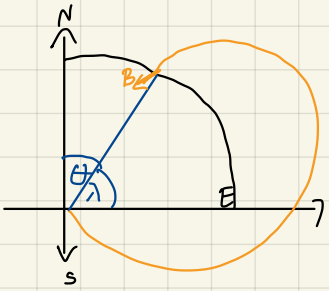


igneous rocks: hematite, magnetite

At Temperatures $< T_c$ remanent magnetization can be locked in igneos rocks parallel to $\vec{B}$ at that location and time.



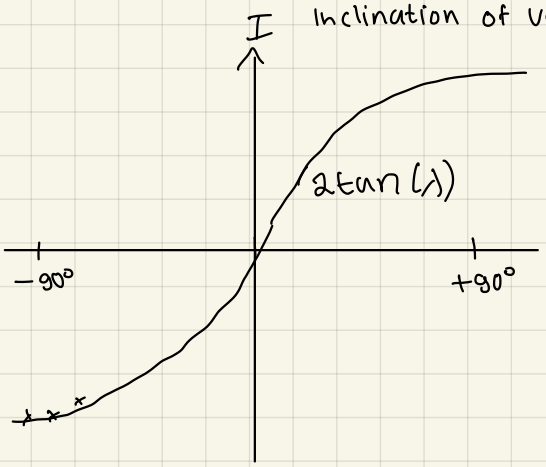
Hypothesis: TRM inclination should follow dipole fieldlines which are latitude dependent



λ : latitude

θ : co-latitude

$\tan(I) = \frac{B_r}{B_\theta} = 2\tan(\lambda)$

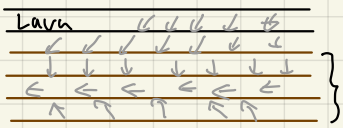


Observation: Inclination of Plio-Pleistocene rocks fit very well with magnetic dipole parallel to earth's axis.

This means: The long term (tens of thousands of years) Earth magnetic field is a dipole at Earth's center and parallel to rotation axis.

Continue with older rocks

Buns structural geology



not in line with todays magnetic field

Hypothesis: Magnetic pole wandered in the past hence incl. changes with depth / time

magnetic pole

Ap Polar Wanderpath (APW)

Alternatives: Continents moved and pole stayed the same

Outcome: Different locations at different continents show different APW (location of North Pole)

Ex. A: Multiple magnetic field which is time dependend

Ex. B: Continents moved

⇒ Explaination B + plate tectonic theory is what we believe today