Announcements

- Please print out your safety training certificates if you have not already done so
- Sign up for a 2 hour block in the lab for the week after next. i’ll invite you to the Google calendar.

Lecture 7

Natural Remanences

or How Rocks get and stay magnetized

- Review from Lecture 6
- Different ways rocks get magnetized in nature
- A few "un-natural ways to magnetize rocks

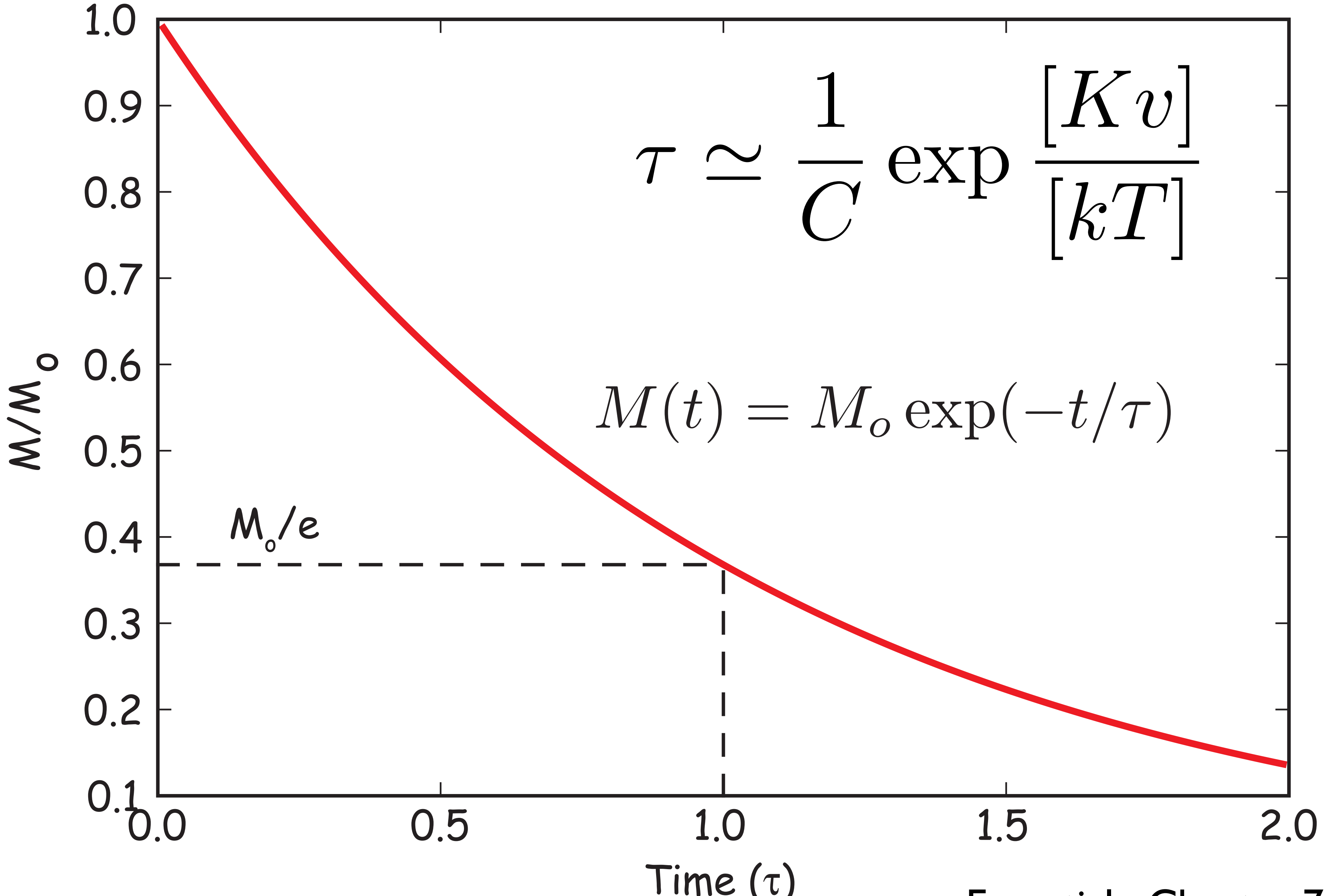
Review from last lecture

- How does the average moment of an assemblage of particles come into equilibrium with an applied field (so that net M is proportional to B and the direction is parallel to B)?
  - [Secret is "magnetic anisotropy energy" - certain directions within crystal are at lower energy than others]
- How does that net magnetization get frozen in so that we may measure it at some later time?
  - [Secret is that magnetic anisotropy energy can change from low, allowing magnetization to come into equilibrium with applied field to high, fixing the magnetization relative to thermal energy]

Need to understand two things

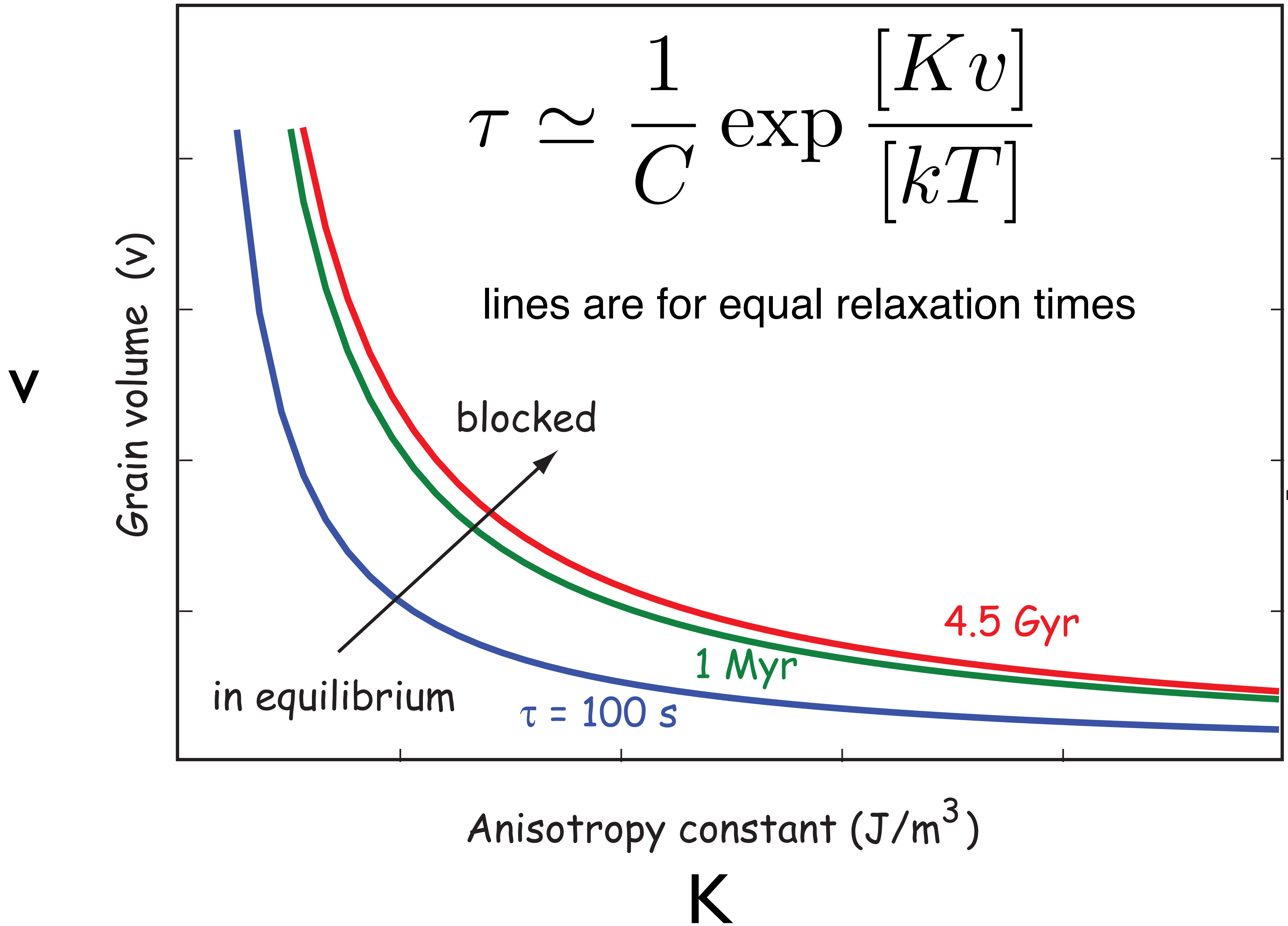
- Magnetic anisotropy energy (Kv)
- Magnetic relaxation time (τ)

Magnetic relaxation time:
time constant for decay of M in zero field. Reflects probability of magnetic moments jumping over anisotropy energy barriers between easy axes



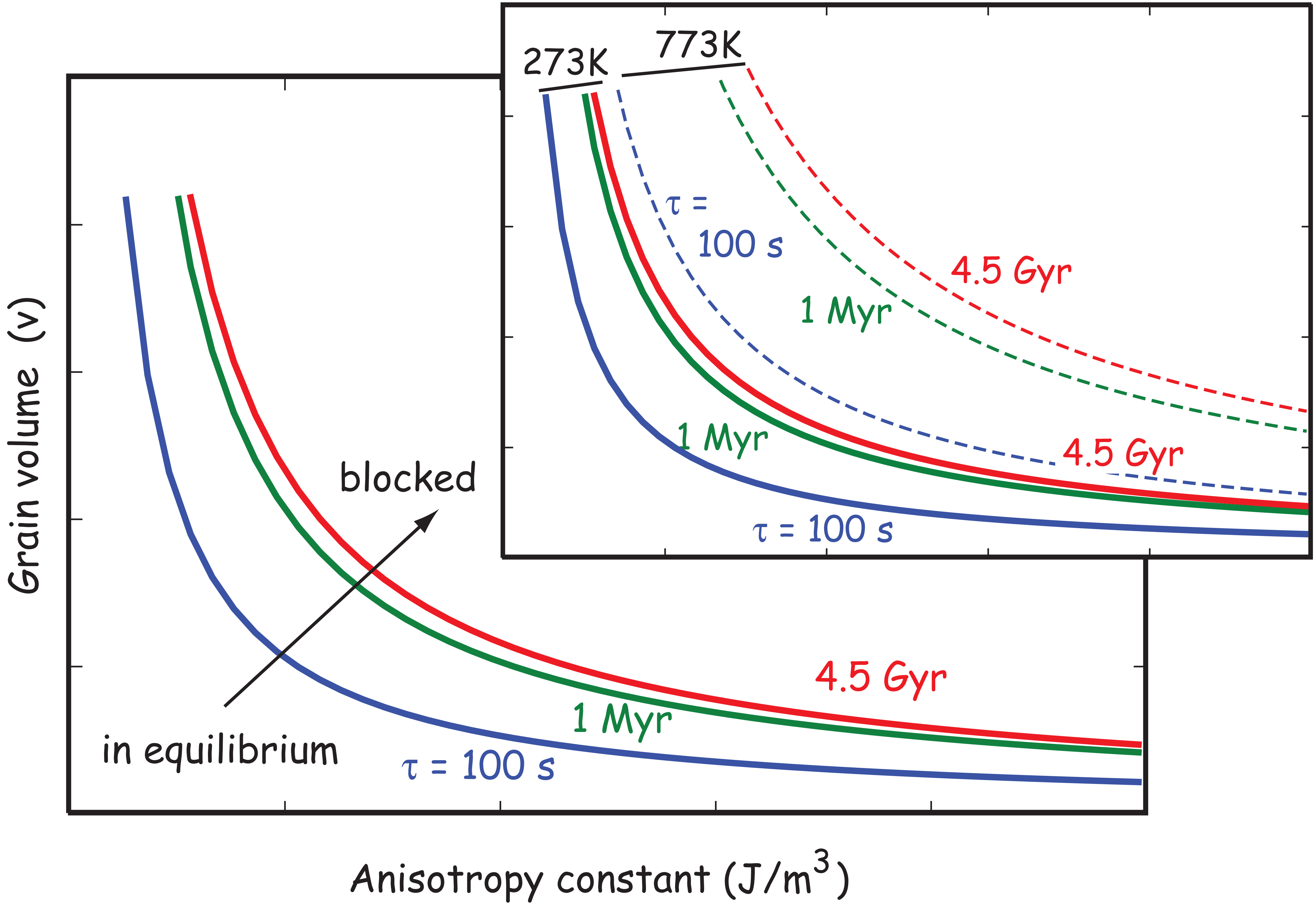
Essentials: Chapter 7

Another way to look at relaxation time

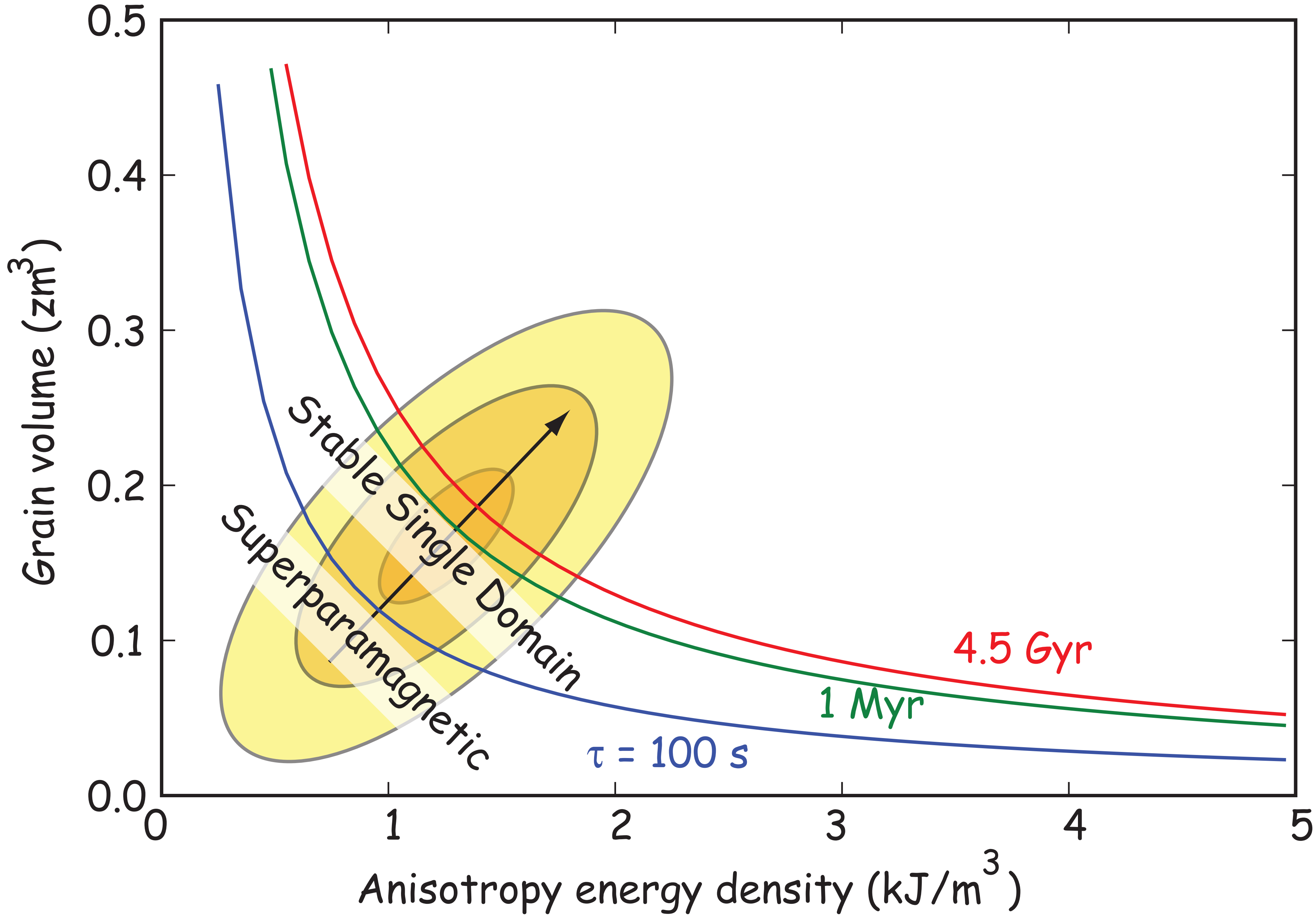


"in equilibrium" a.k.a. "superparamagnetic"

effect of temperature on relaxation time curves



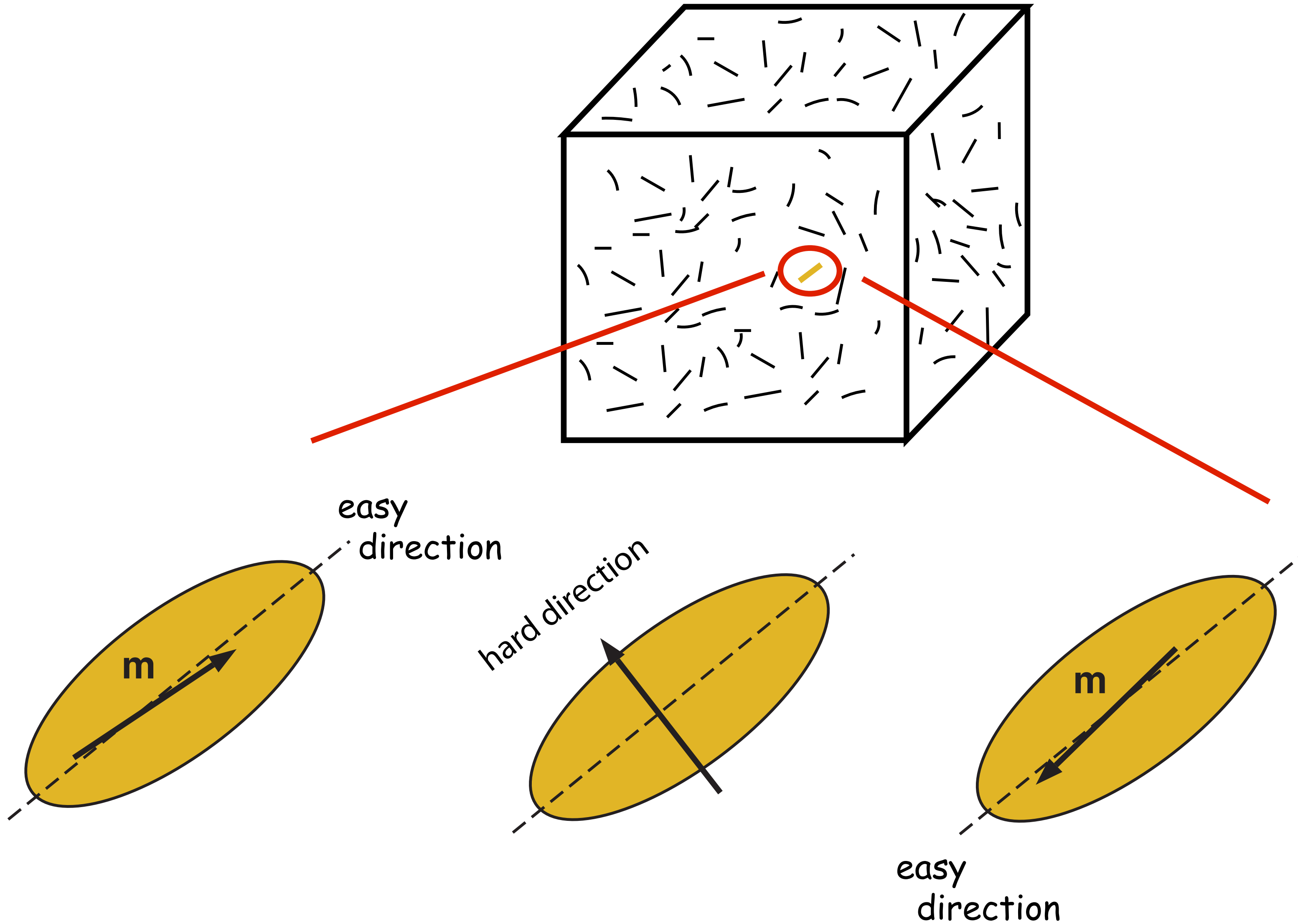
distributions of grain sizes



Sitting in a field:
Viscous remanent magnetization
(VRM)

- secret of remanence acquisition is lowering relaxation time to allow assemblage of magnetic minerals to approach equilibrium magnetization, then freeze it in by and raising relaxation time.
- can change relaxation time by changing temperature or volume, for example.
- but first, let's take another look at the remanence change as a function of time keeping all else constant
- this is "viscous" remanent magnetization (VRM)

Consider a magnetized block in zero field:

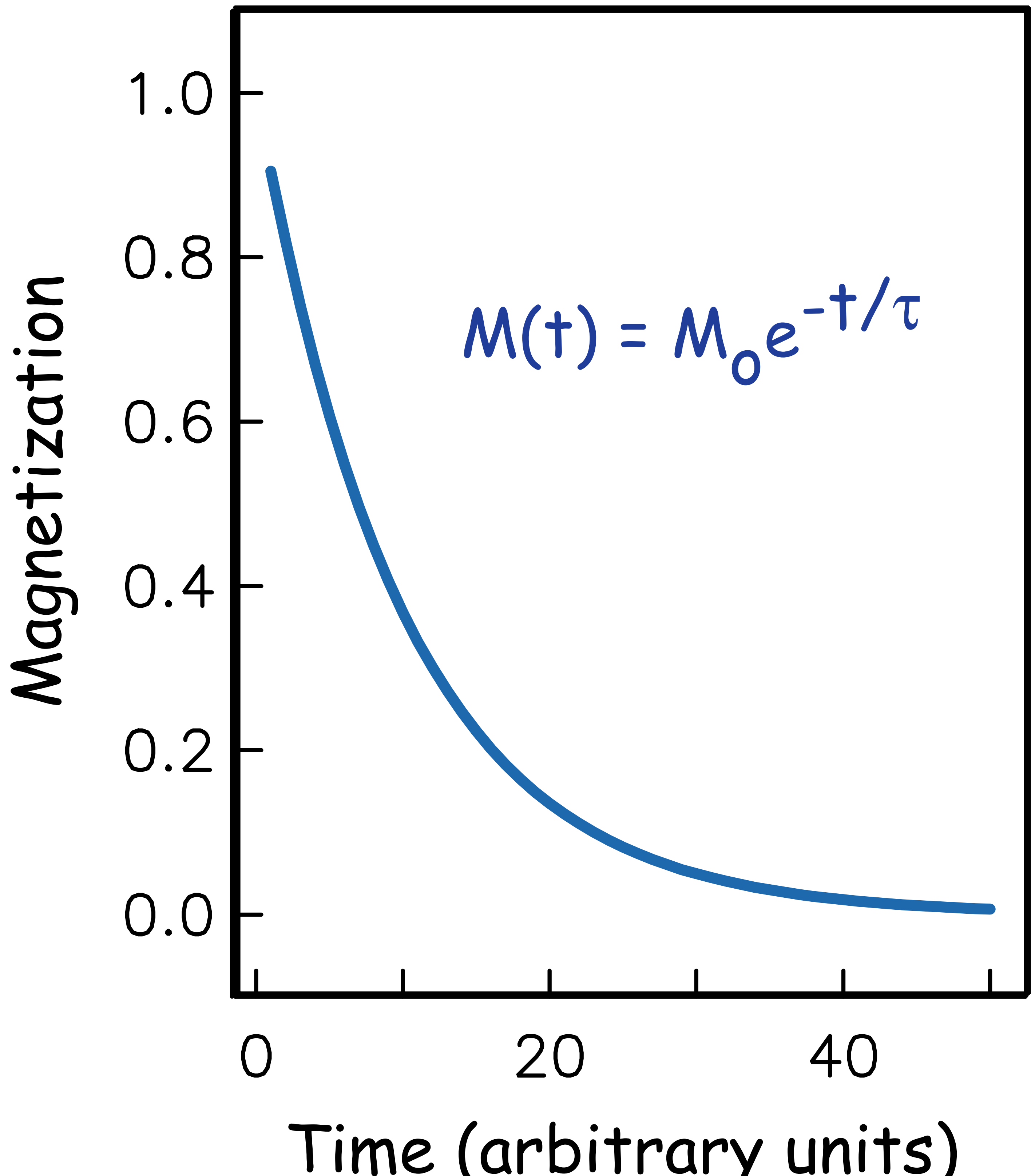


energy barrier to jump over hard direction: ΔE

probability of having that energy: $P = \exp \frac{-\Delta E}{kT}$

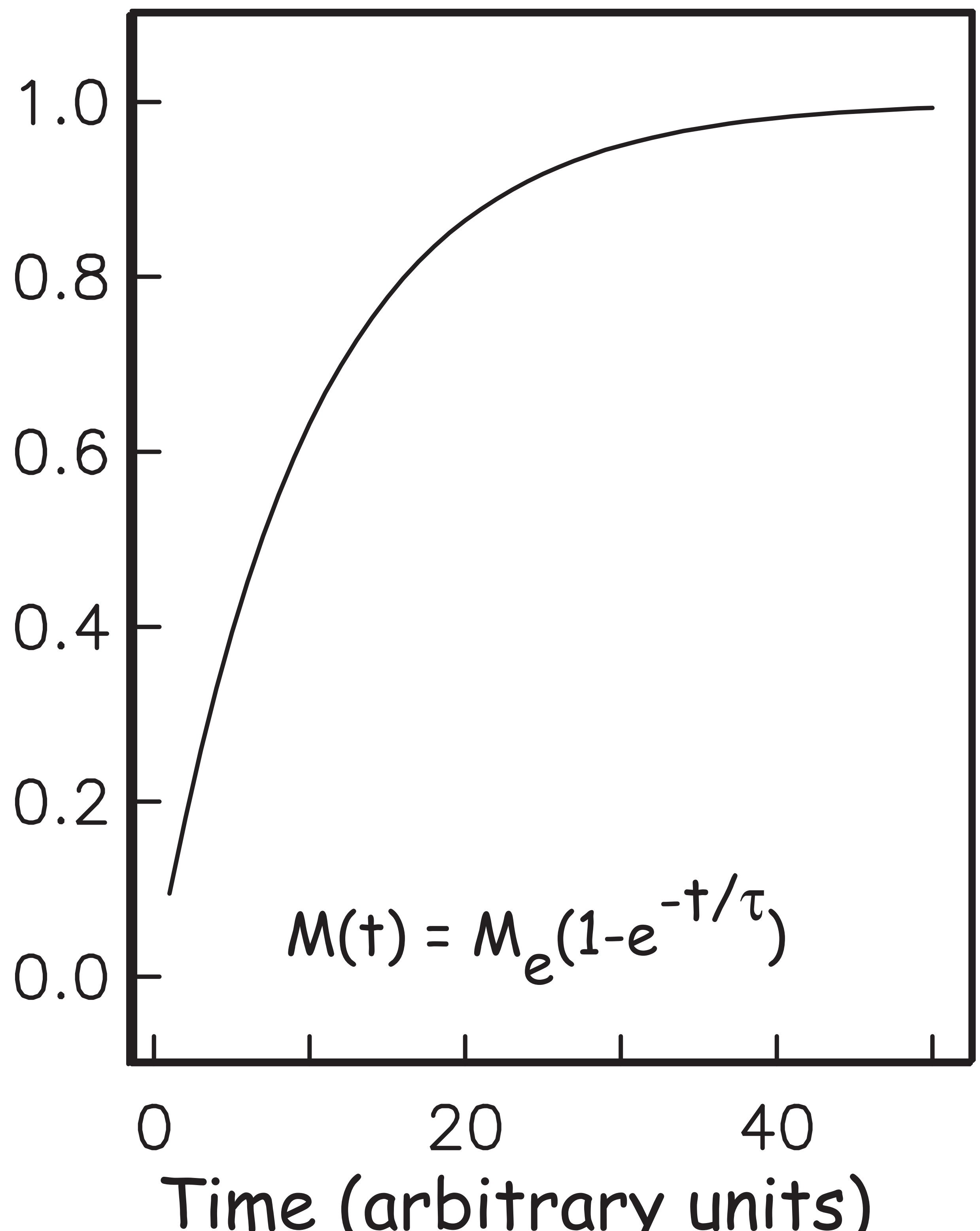
Two easy directions have equal energies, so no preference and: $M_e = 0$

approach to equilibrium is viscous decay

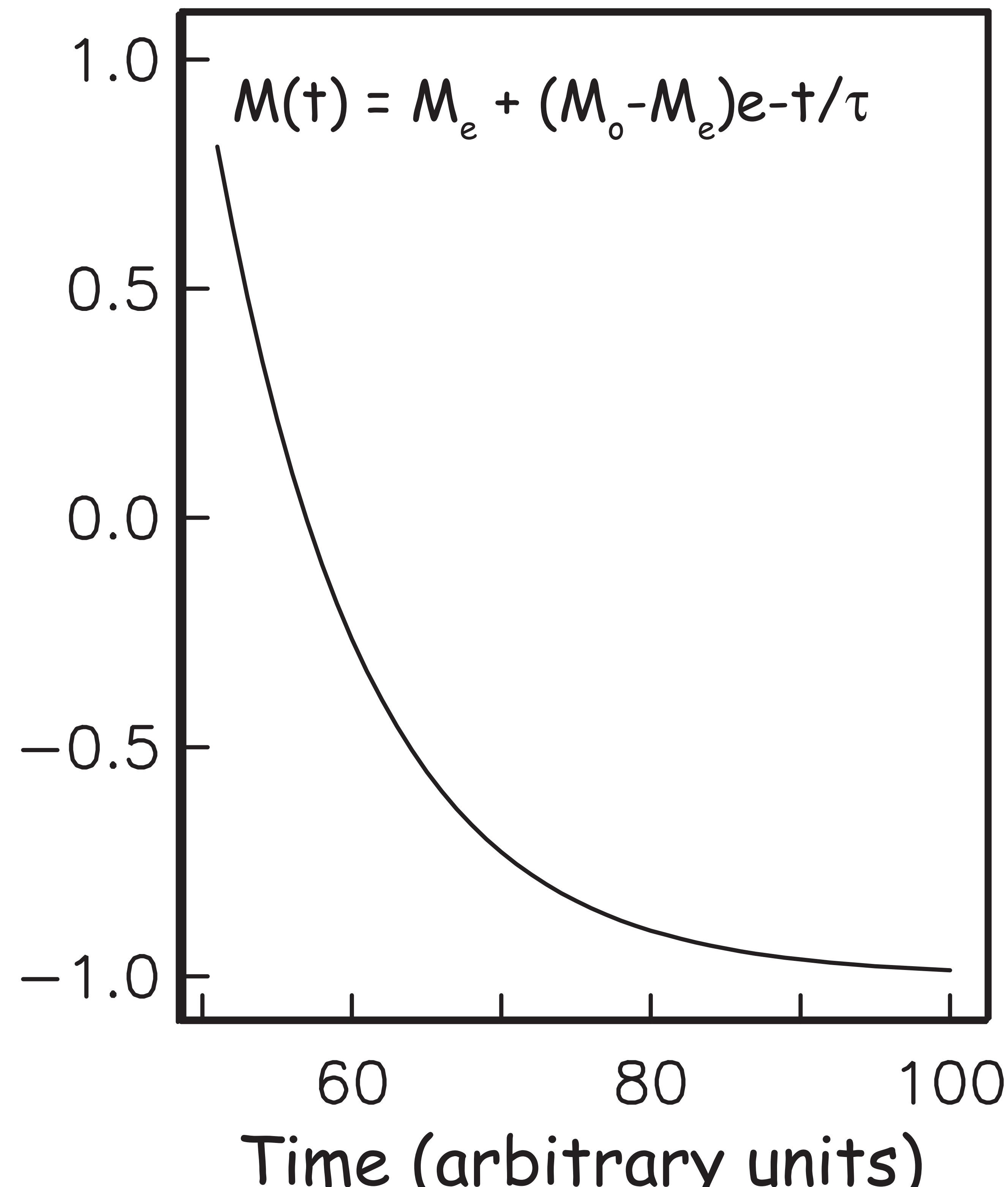


saw this in last lecture

demagnetized sample placed in a field

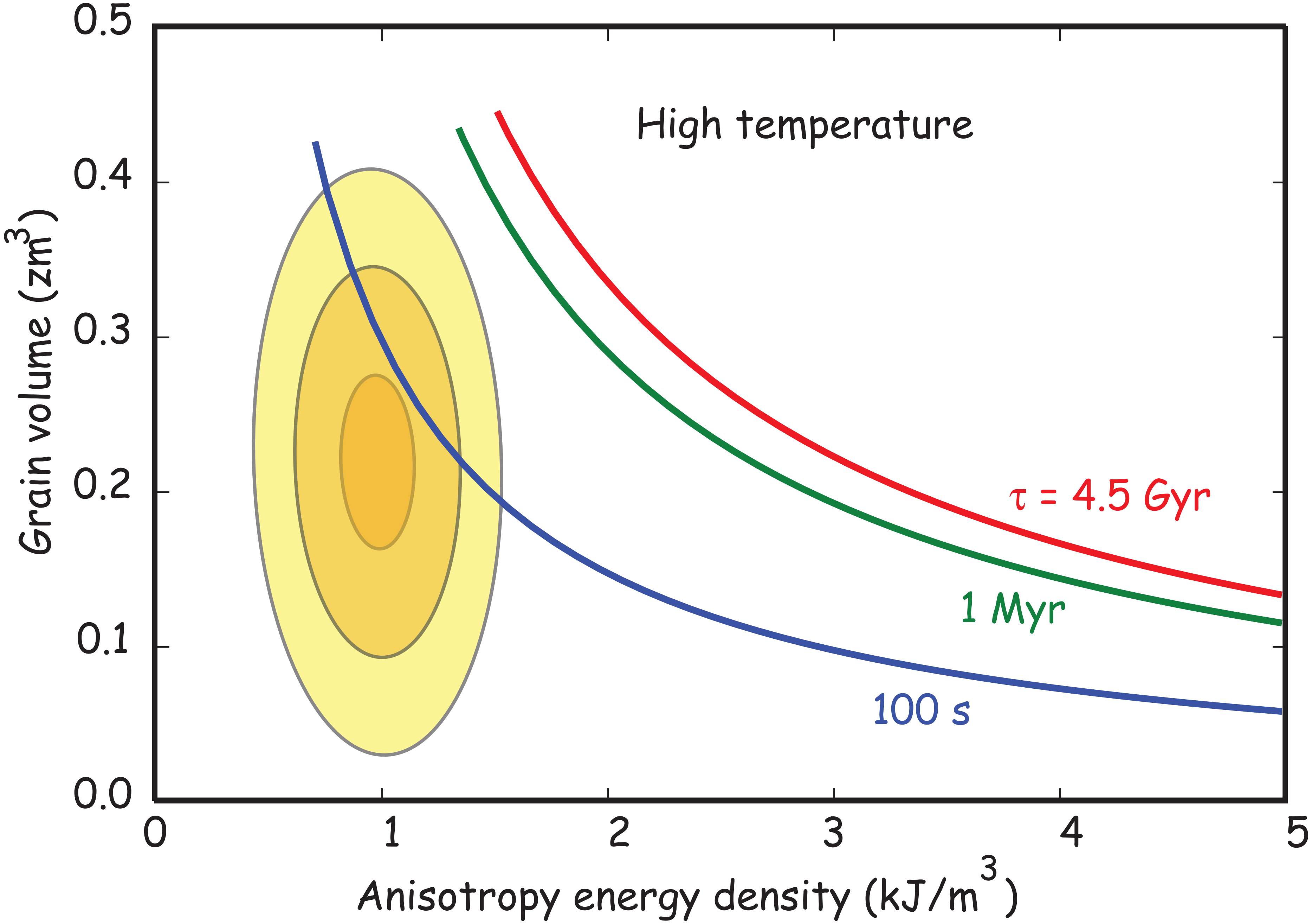


general case



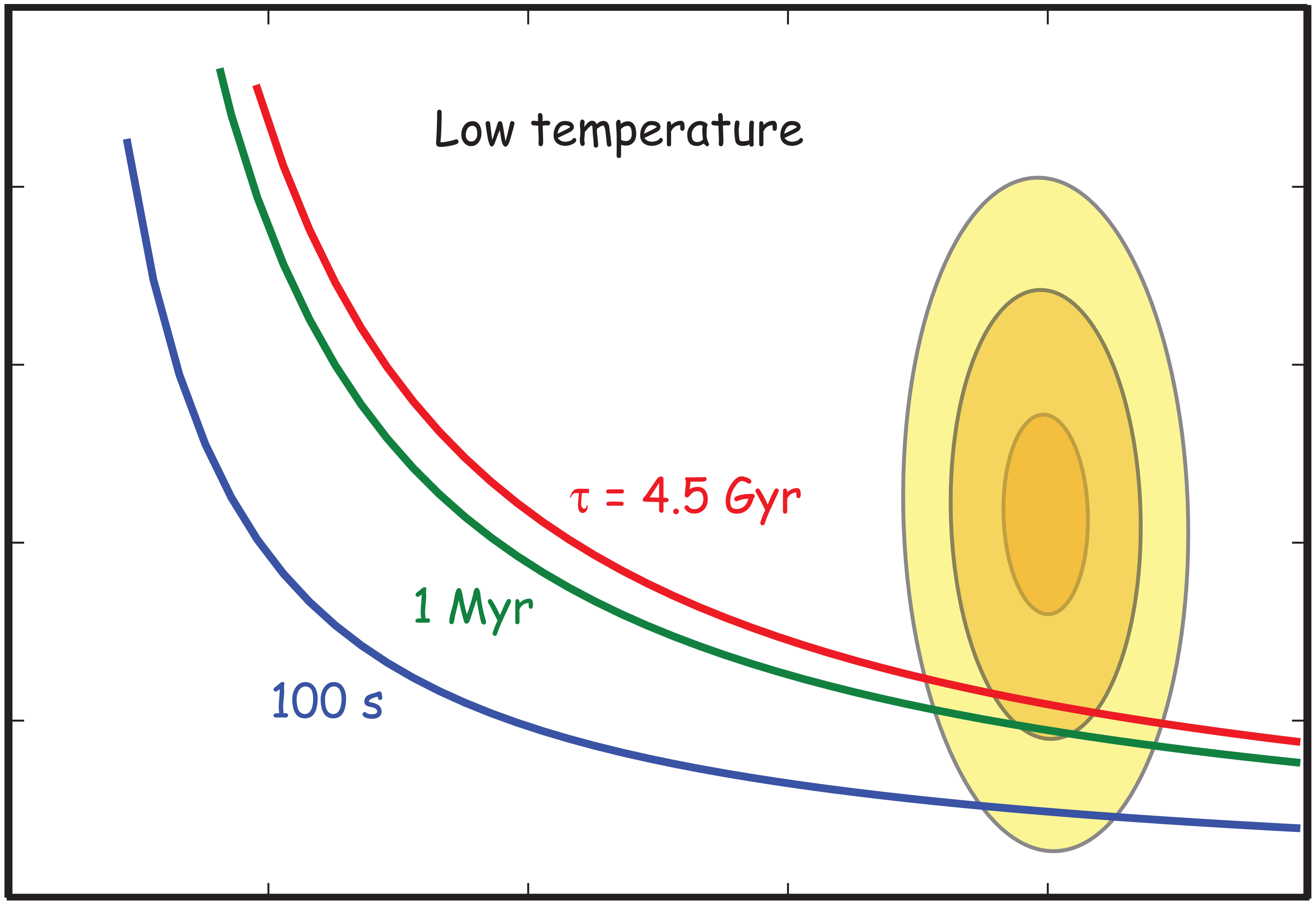
Cooling in a field:
Thermal remanent magnetization
(TRM)

back to effect of temperature on relaxation time curves

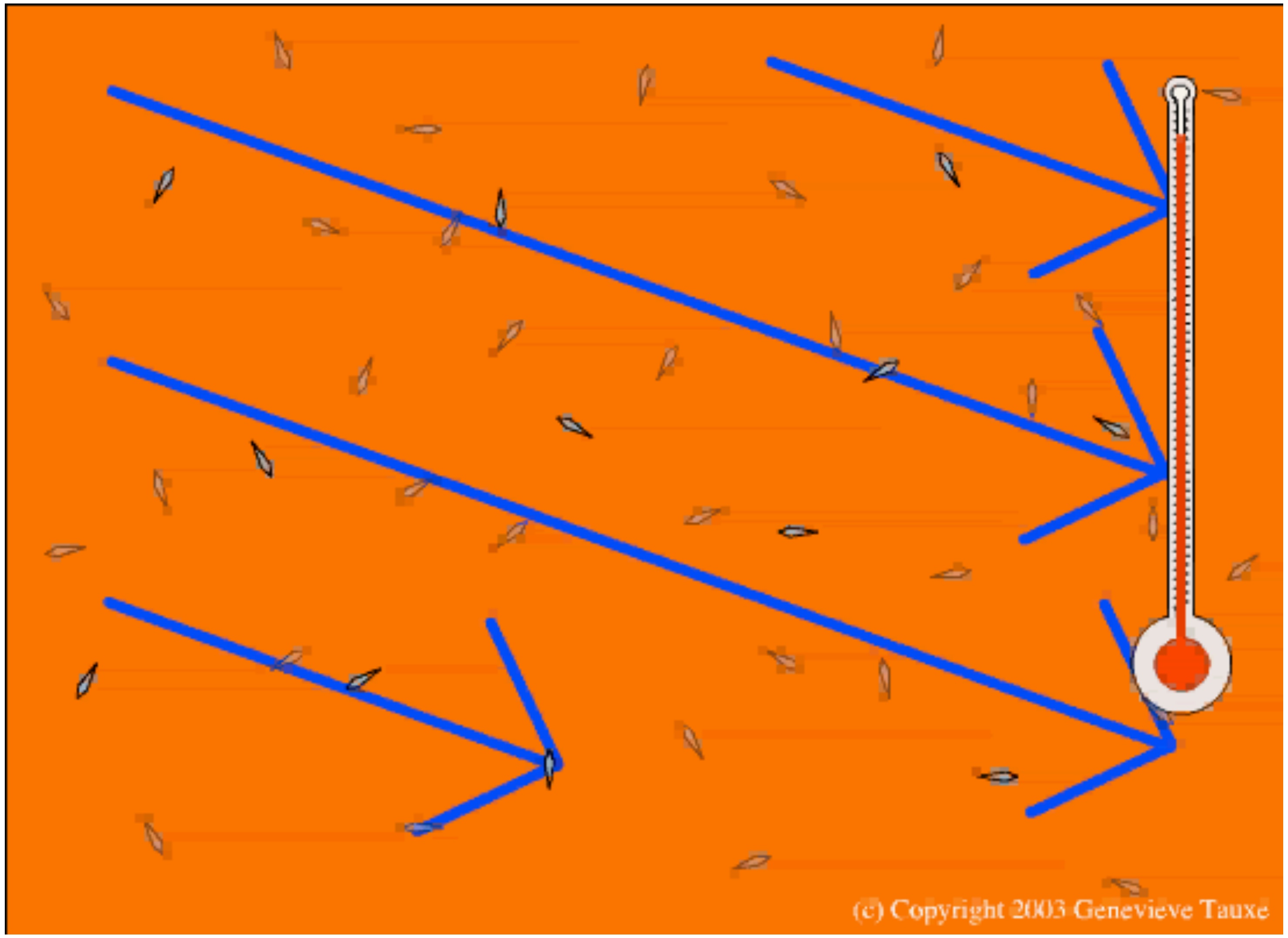


High T: all grains are below Curie temperature, but moments are in equilibrium with applied field (taus ~100 s)

back to effect of temperature on relaxation time curves



Low T: most grains are "blocked" (taus ~Gyr)

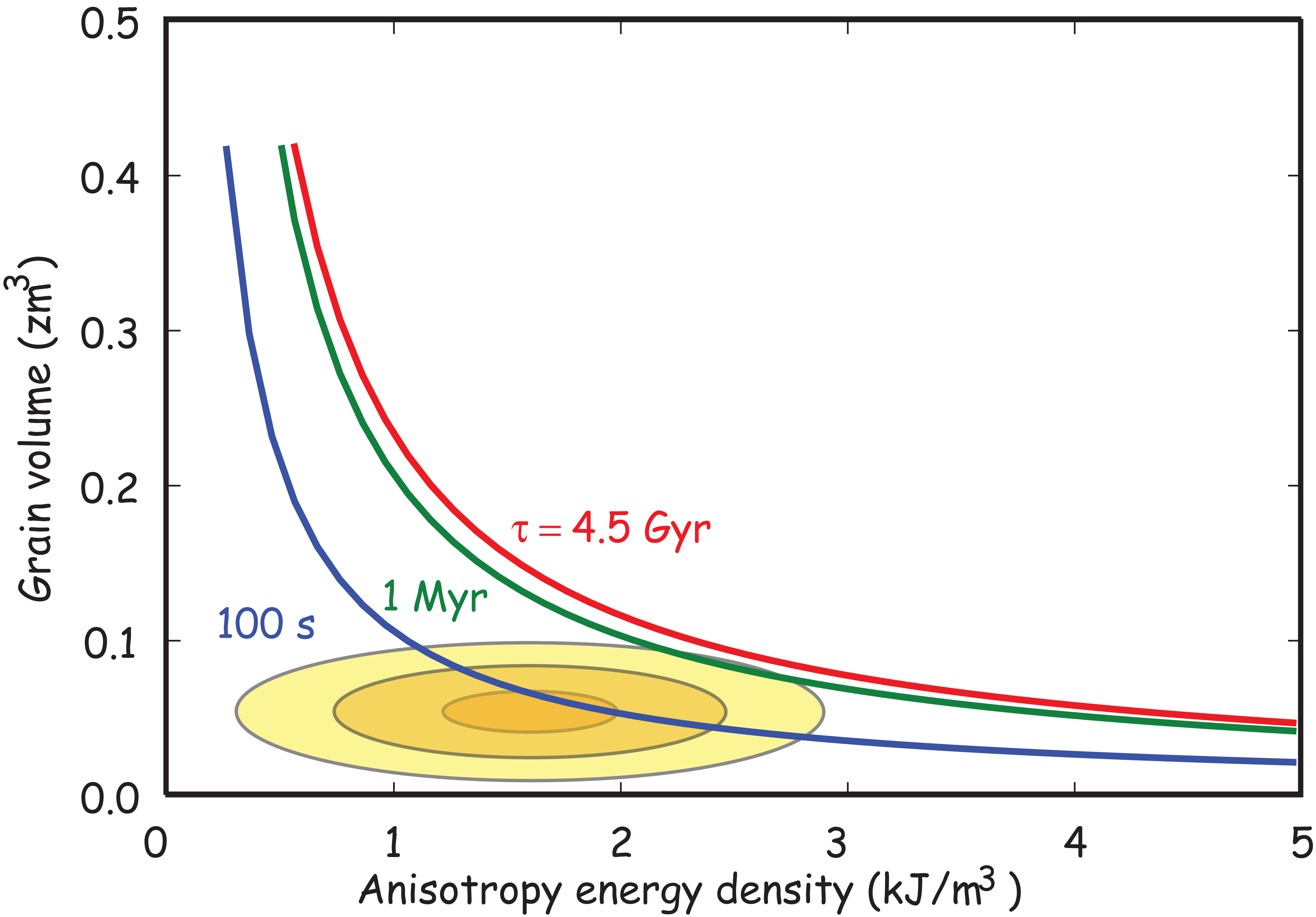


http://magician.ucsd.edu/Lab_tour/movs/TRM.mov

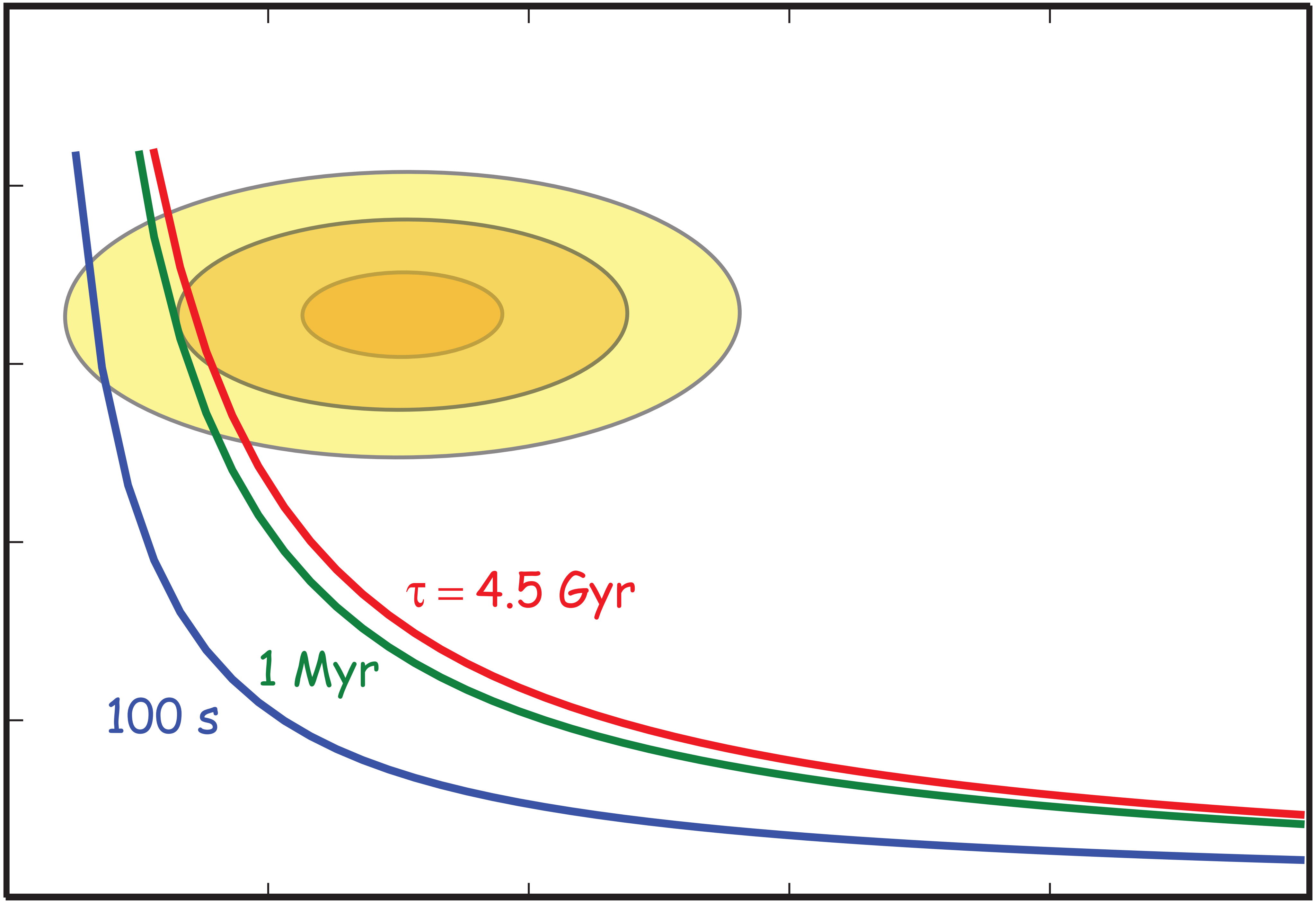
Genevieve Tauxe

growing in a field:
Chemical remanent magnetization
(CRM)

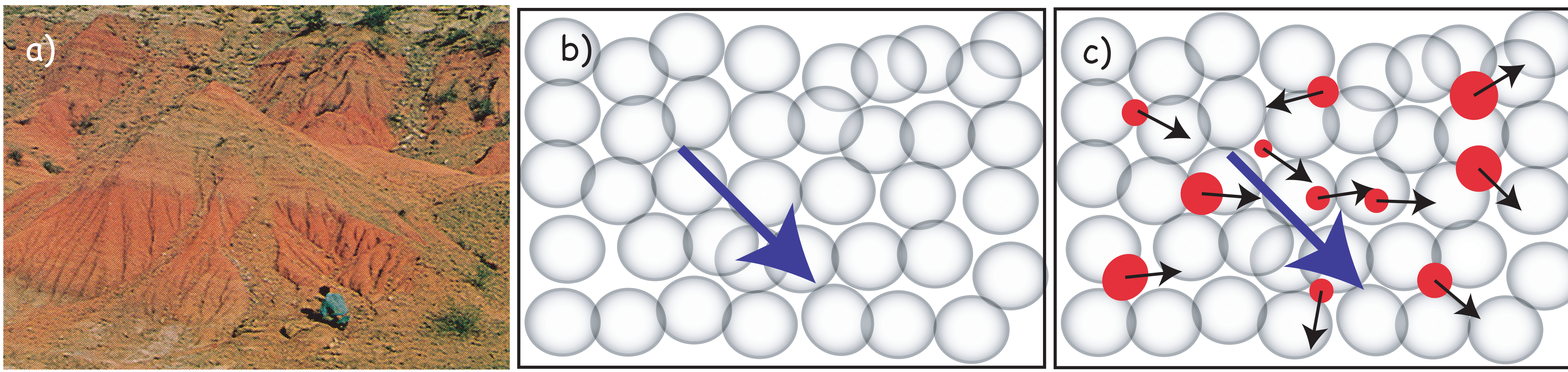
now for the effect of volume:



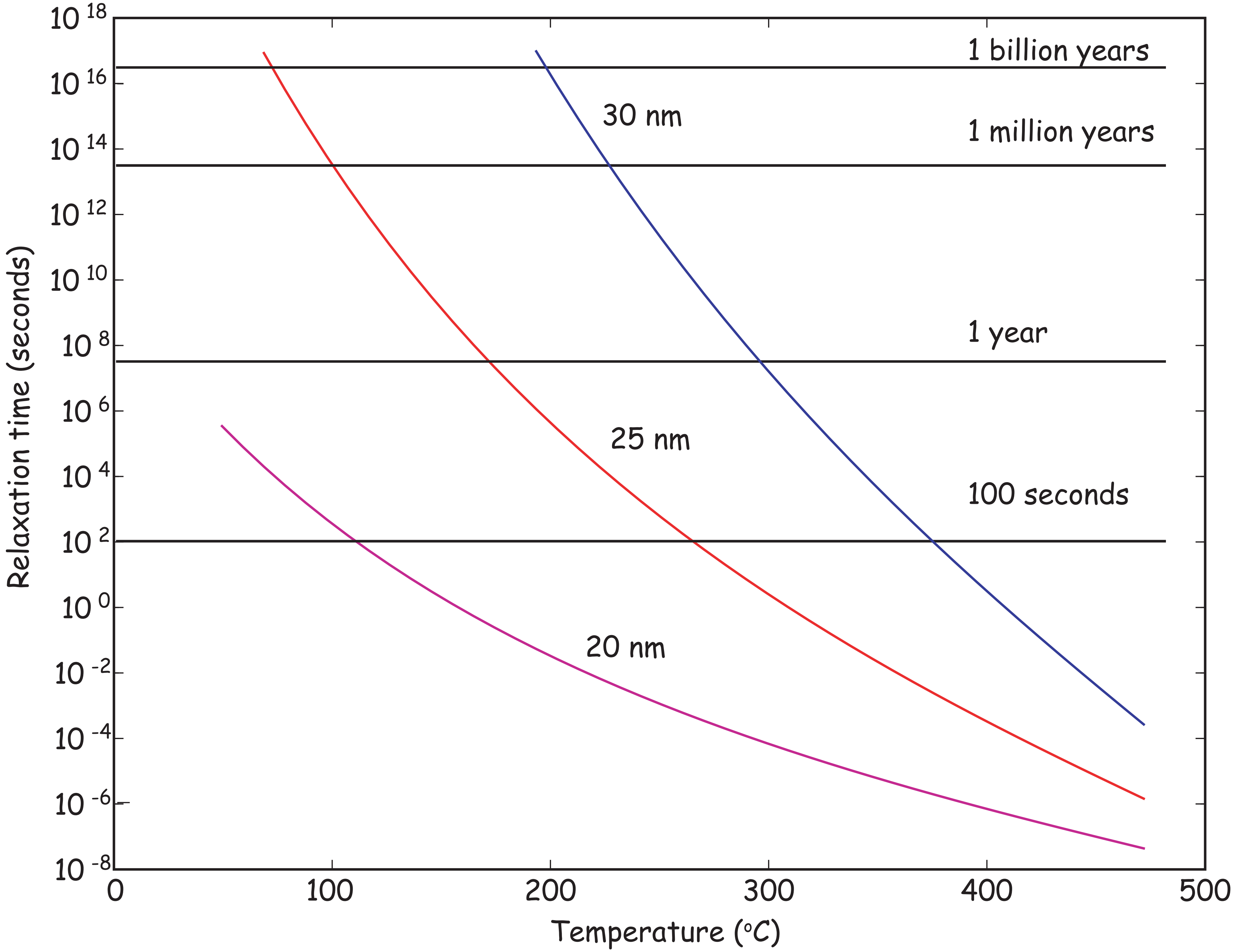
making grains bigger can take them from equilibrium to blocked: CRM now for the effect of volume:



making grains bigger can take them from equilibrium to blocked: CRM


a)
b)
c)

concept of blocking temperature and volume



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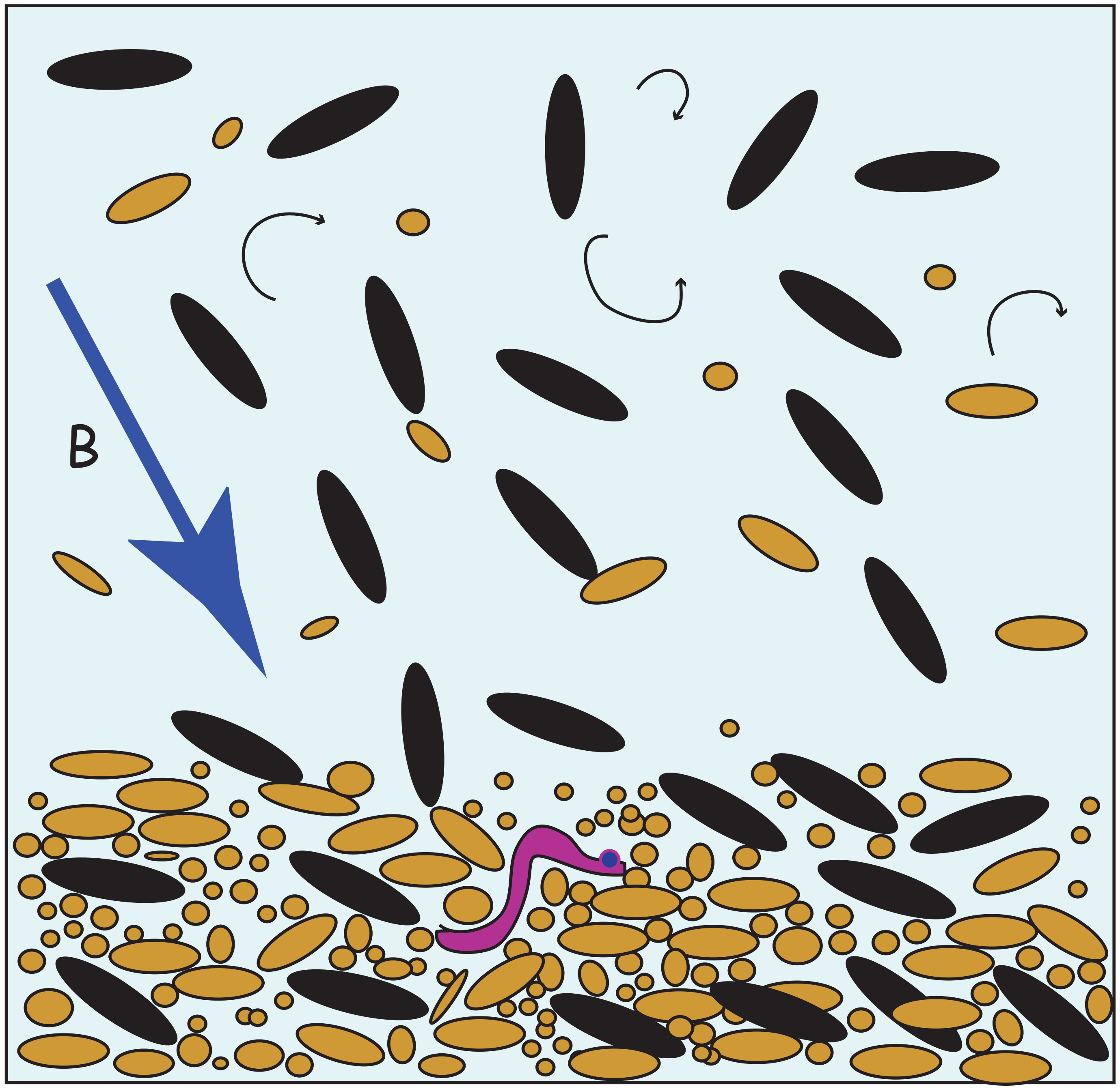
Settling in a field: Depositional remanent magnetization (DRM)

Standard concept of depositional remanence



Turbulent Water

Still water or
laminar flow

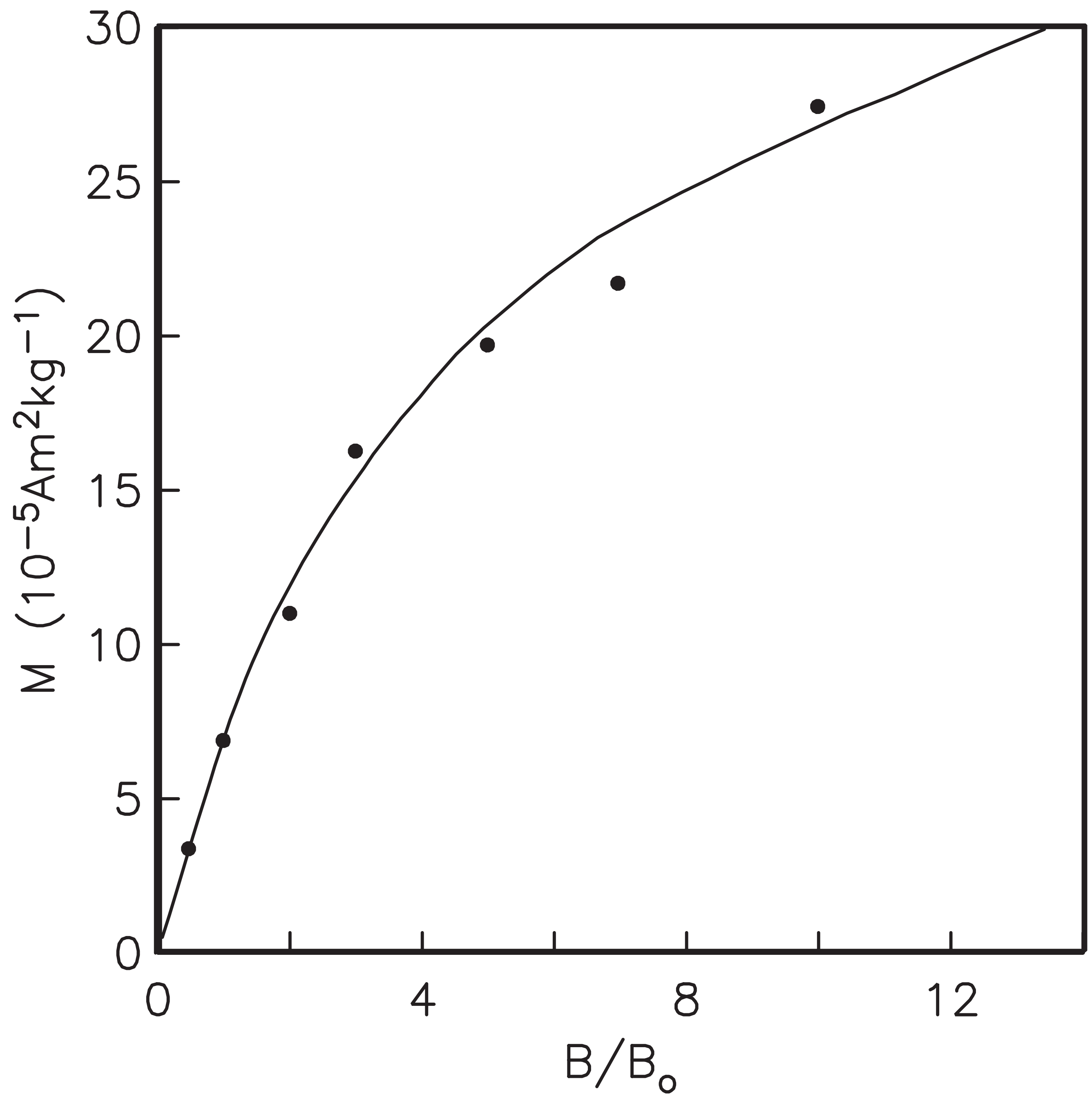
sediment/water
interface
bioturbation
consolidation
"lock-in depth"

compaction

Key points

- Magnetic particles are already magnetized and relaxation time stays constant
- When free to rotate, they will physically rotate such that their moments are in equilibrium with the magnetic field
- This physical rotation gets blocked somehow, fixing the DRM
- Free magnetic particles will align themselves almost instantaneously with the magnetic field, so the magnetization SHOULD be at saturation

But almost all redeposition studies show that DRM is NOT at saturation (far from it)

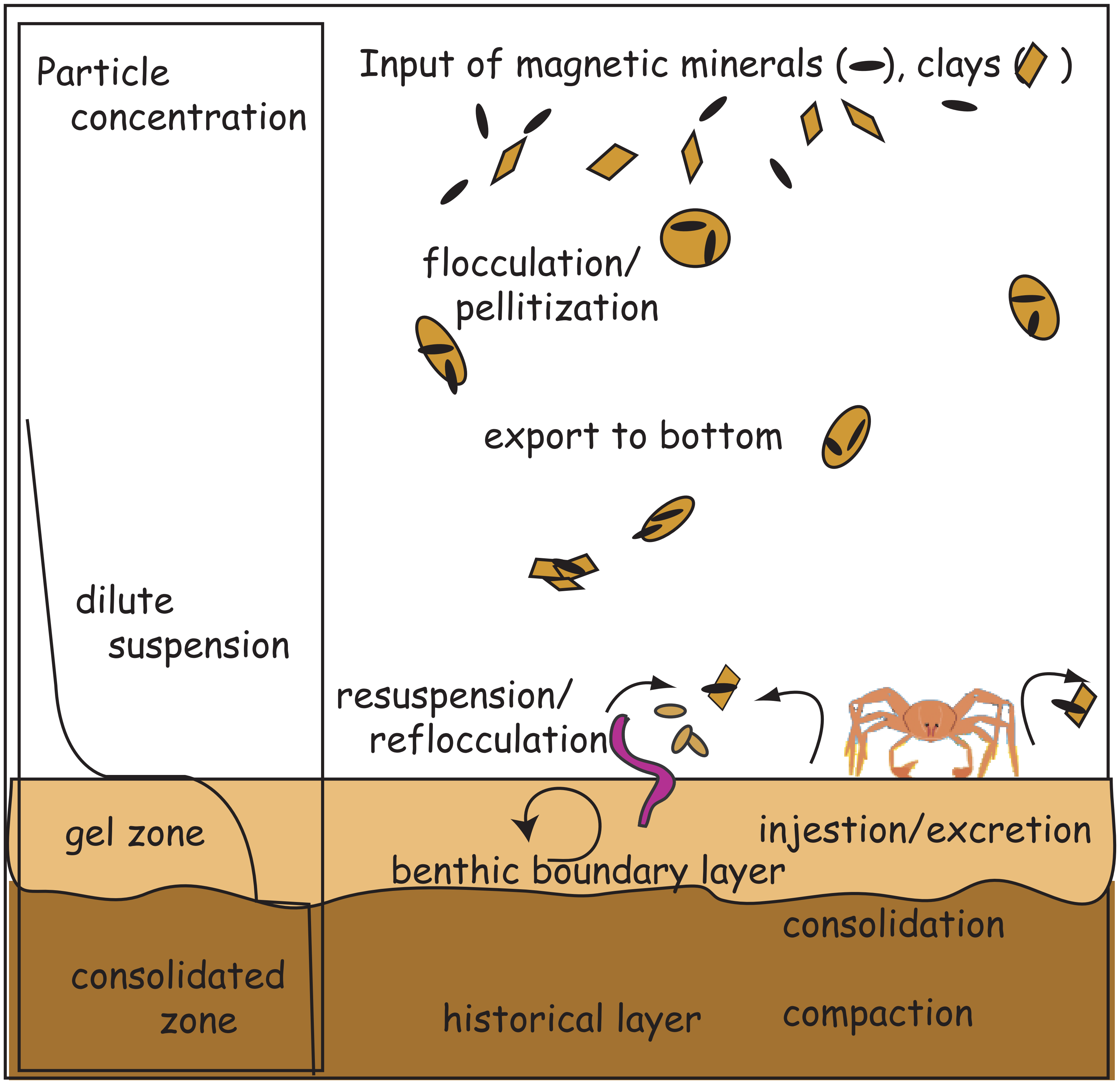


Johnson et al. 1948

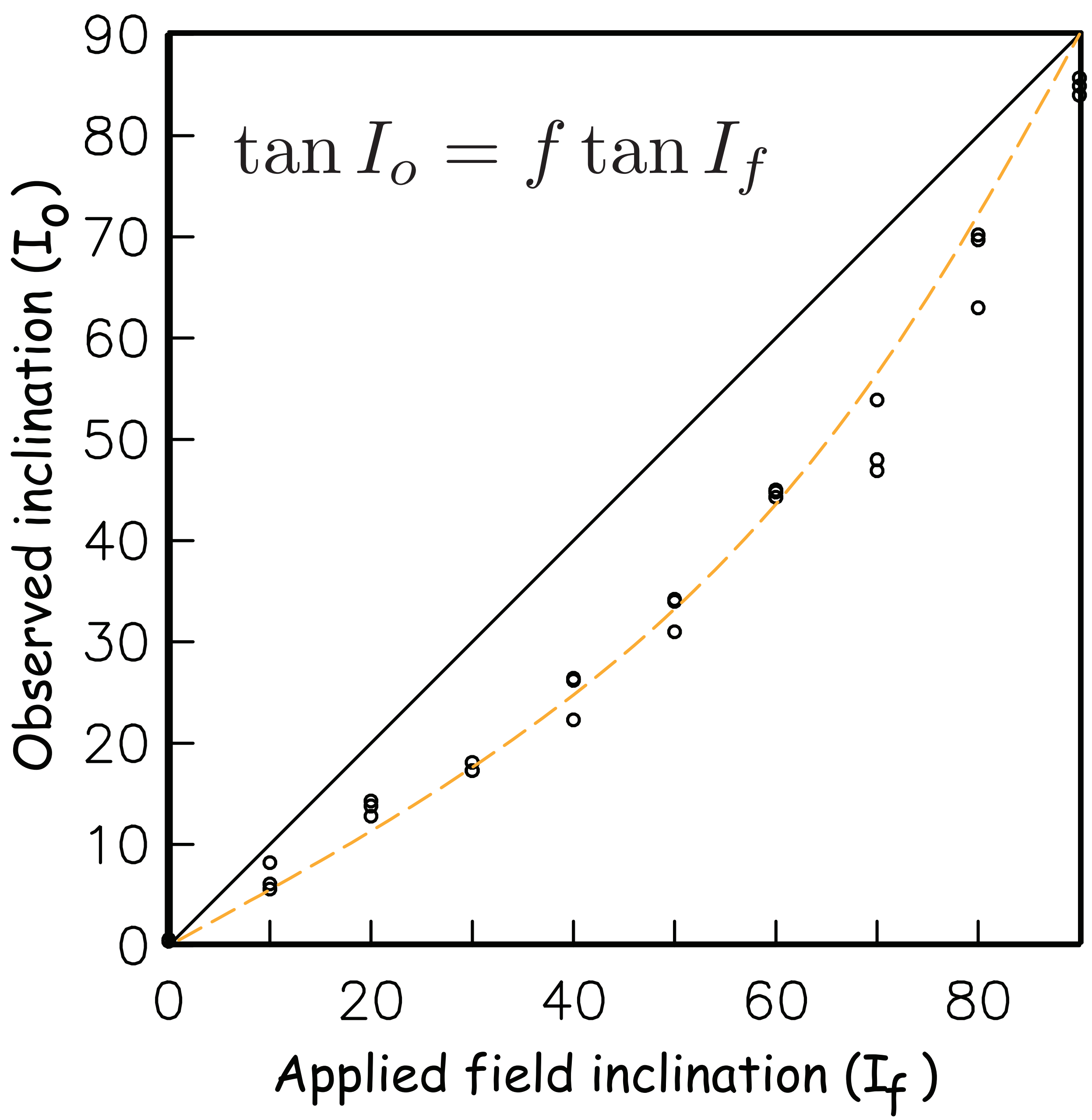
So what is the secret?

- Lots of ideas in the literature
- best one is that the magnetic grains are not isolated, but are embedded in large “snow flakes” of clay (flocs)

Modern view of DRM (in flocculating environments)



Beware of inclination shallowing in sediments!



Getting zapped by a large field

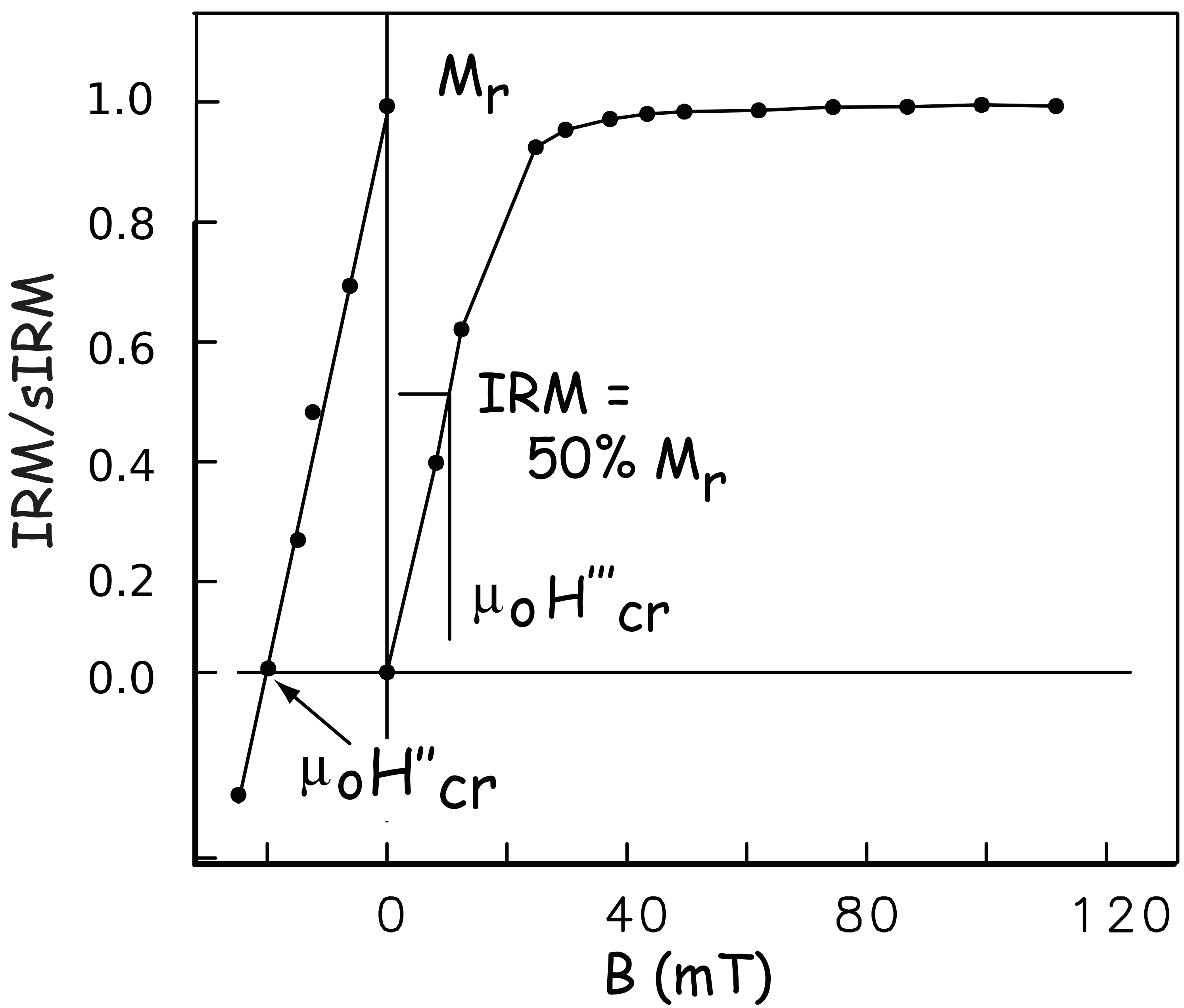
Isothermal remanent magnetization

(IRM)

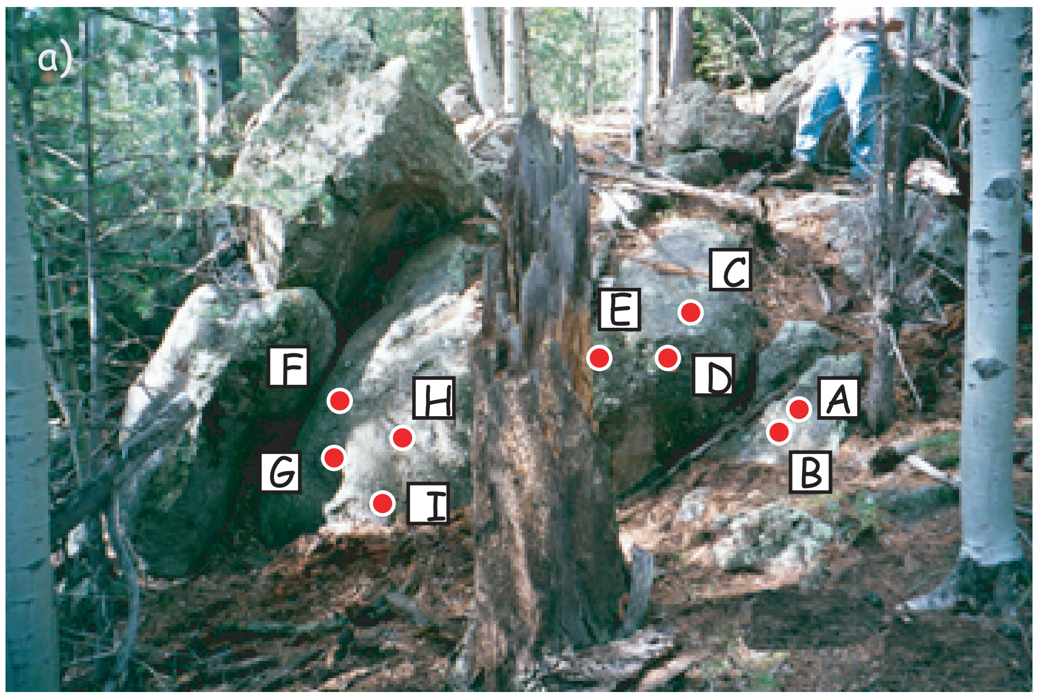
Isothermal Remanent

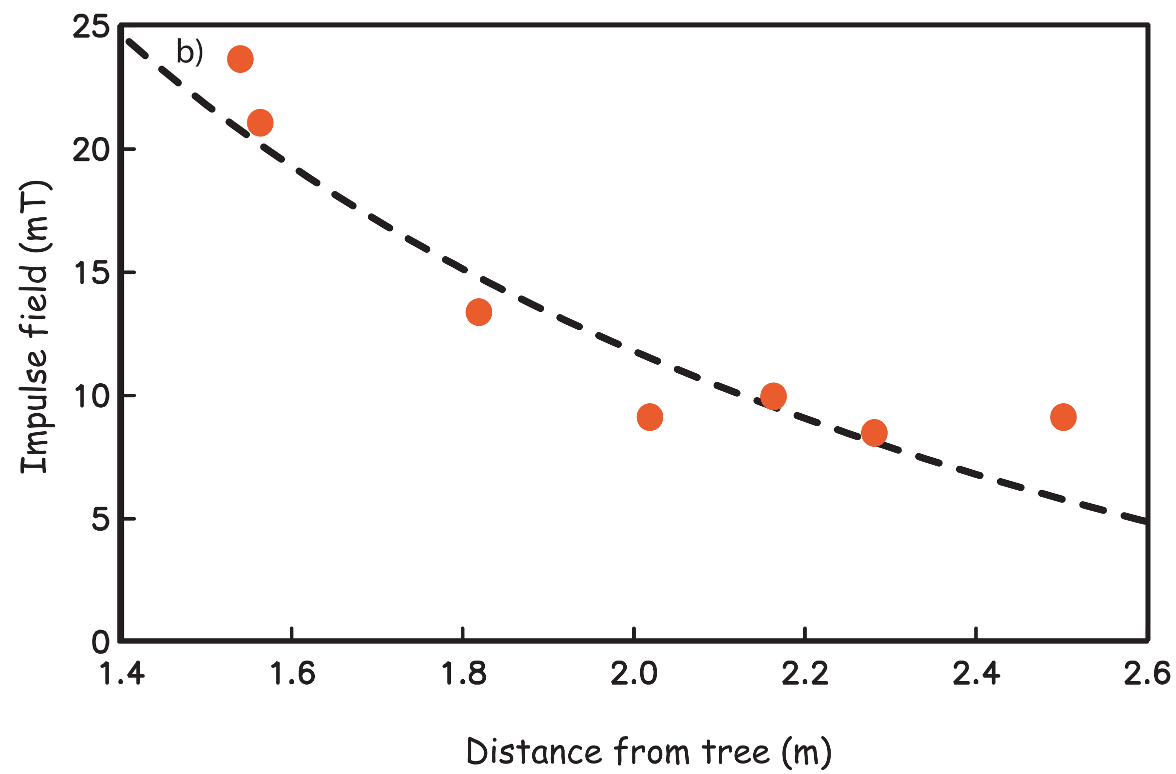
- Acquired when $H > H_c$
- In nature, associated with lightning strikes
- In the lab, acquired in large lab fields
- you met this before in the hysteresis lecture as, for example M_r

Example of IRM acquisition curve in the lab



IRM in nature





Summary of properties of natural remanence

VRM

- Acquired by sitting in a field over time
- Associated with the least stable (lowest relaxation time) particles
- Doesn't really effect the most stable particles much

TRM

- Acquired parallel to (except for self-reversal! or highly anisotropic rocks) and proportional to external field
- is the equilibrium magnetization

CRM

- Theoretically the same as TRM (but hasn't really been tested much since late 80s early 90s)
- Acquired parallel to applied field
- Acquired during diagenesis, so could have happened long after formation of rock (stay tuned)

DRM

- Very complicated
- Can be acquired parallel to and proportional to applied field
- But can suffer from inclination shallowing

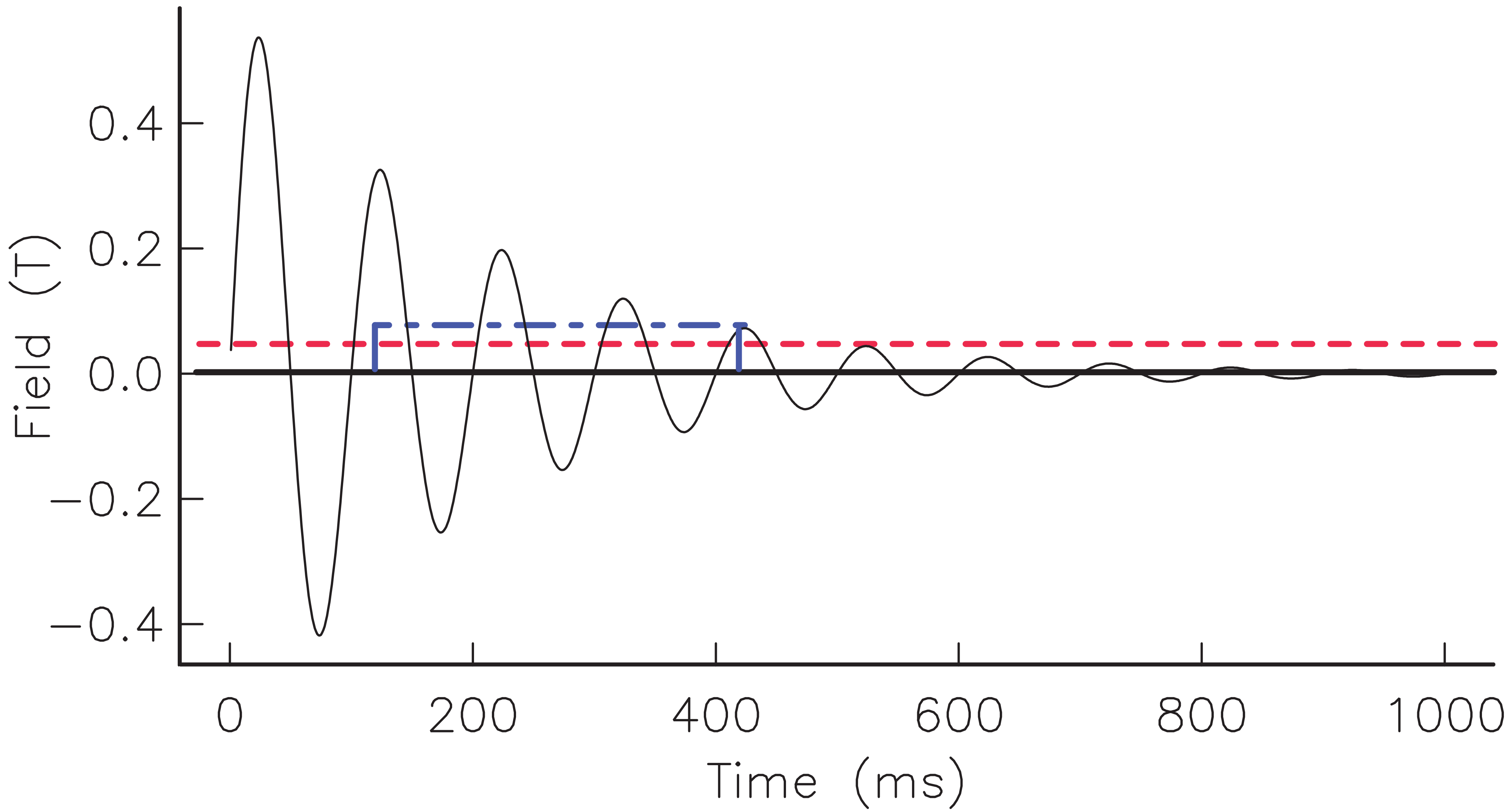
IRM

- In nature, get it from lightning strikes
- Ruins your whole day

An un-natural one:

Sitting in a decaying alternating field
Anhysteretic remanent magnetization
(ARM)

One last remanence: Anhysteretic remanent magnetization (ARM)



Take home message

- Rocks get and stay magnetized by changing the conditions from being in equilibrium with the applied field to being blocked.
- This is accomplished by a number of mechanisms

Assignment

- Problems 7.2 and 7.4 in the online textbook