Lecture 11

- Environmental toolkit
- Applications
Toolkit

- Images (a picture is worth 1000 words)
- Critical Temperatures (Curie, Verwey, etc.)
- Magnetic susceptibility
- Remanent magnetizations
- Ratios
Critical temperatures (Table 8.1)

- Curie (Neel) temperature ($T_c$)
- Blocking temperature ($T_b$) and Median destructive temperature ($MDT$) [and $H_c$ and Median destructive field while we are at it.]
- Hopkinson effect
- Various crystallographic transition temperatures
Curie balance in the SIO lab

- Electromagnet
- Thermocouple
- Specimen
- Water jacket
- Pickup coil
- Oven
Estimating Curie Temps

Temperature ($^\circ$C) M/M$_s$ = 593

Tc = 589$^\circ$ C

d$^2$/d$T^2$

d$M$/dT

Temperature ($^\circ$C)
Know your Curie Temperatures!

Listed in Table 6.1
Verwey Temp (from Chapter 4)
coercivity spectrum and MDF for sister specimen
Guess which mineral this is....
Magnetic susceptibility

- Measurement
- Directional dependence (anisotropy – see Chapter 13)
- Temperature dependence
- Frequency Dependence
Magnetic susceptibility
Temperature dependence

- Diamagnetic (none)
- Paramagnetic (1/T)
- Ferromagnetic (depends on domain state (SP/SD/MD))

Biggest effect is change from SD => SP (jumps by factor of 27) known as Hopkinson effect
Frequency dependence

Because the definition of SP depends on time scale, can go from SD to SP by lengthening time span of observation.

Measure susceptibility fast, could behave as stable (low susceptibility)

Measure same specimen slow, could behave as SP (high susceptibility)
Susceptibility (m$^3$/kg) vs. Frequency (Hz)

- $B = 30 \, \mu T$
- $T = 300 \, K$

The graph shows the relationship between susceptibility and frequency, indicating a decrease in susceptibility as frequency increases.
Susceptibility (m$^3$/kg)

Temperature (K)

Susceptibility (m$^3$/kg)

Temperature (K)

$B = 30 \, \mu T$
outcrop measurement of susceptibility
Magnetic remanences

- Isothermal remanence (IRM)
- Anhysteretic remanence (ARM)
- Gyromagnetic remanence (GRM)
The joys of IRM

- Acquisition
- Destruction
- DC fields
- AC fields
- thermal demagnetization
Review of two ways to give IRMs

Chapter 5

Chapter 7
Neat application

![Graph showing Isothermal Remanent Magnetization vs. Applied Field](image)

- LAP
- GAP
- DP

$\mu_0 H_{1/2}$

Coercivity (mT)

Applied Field (mT)
crossover: non-interacting SD versus interacting (MD)
3D IRM technique

Temperature (°C)

IRM (Am⁻¹)

Temperature (°C)

B₁

B₂

B₃

lab arrow

(2.0 T)

(0.4 T)

(0.12 T)
ARM – what’s it good for

- Strong function of grain size
- Strong function of concentration (particle interaction)
Magnetic Susceptibility
Anhysteretic Remanence

onset of Agriculture
baseline
decreasing grain size
little ice age

Banerjee et al., 1981
ARM/sIRM vs. $B_{dc}$ (mT) with increasing concentration.
Ratios (and differences)

- Mr/Ms versus Hcr/Hc (Day plot)
- ARM versus magnetic susceptibility (Banerjee plot)
- see Table 8.2 in the book for more....
Lots more applications in Chapter 8

Assignment

Problems 8.1 and 8.3 in Chapter 8 of Essentials of Paleomagnetism