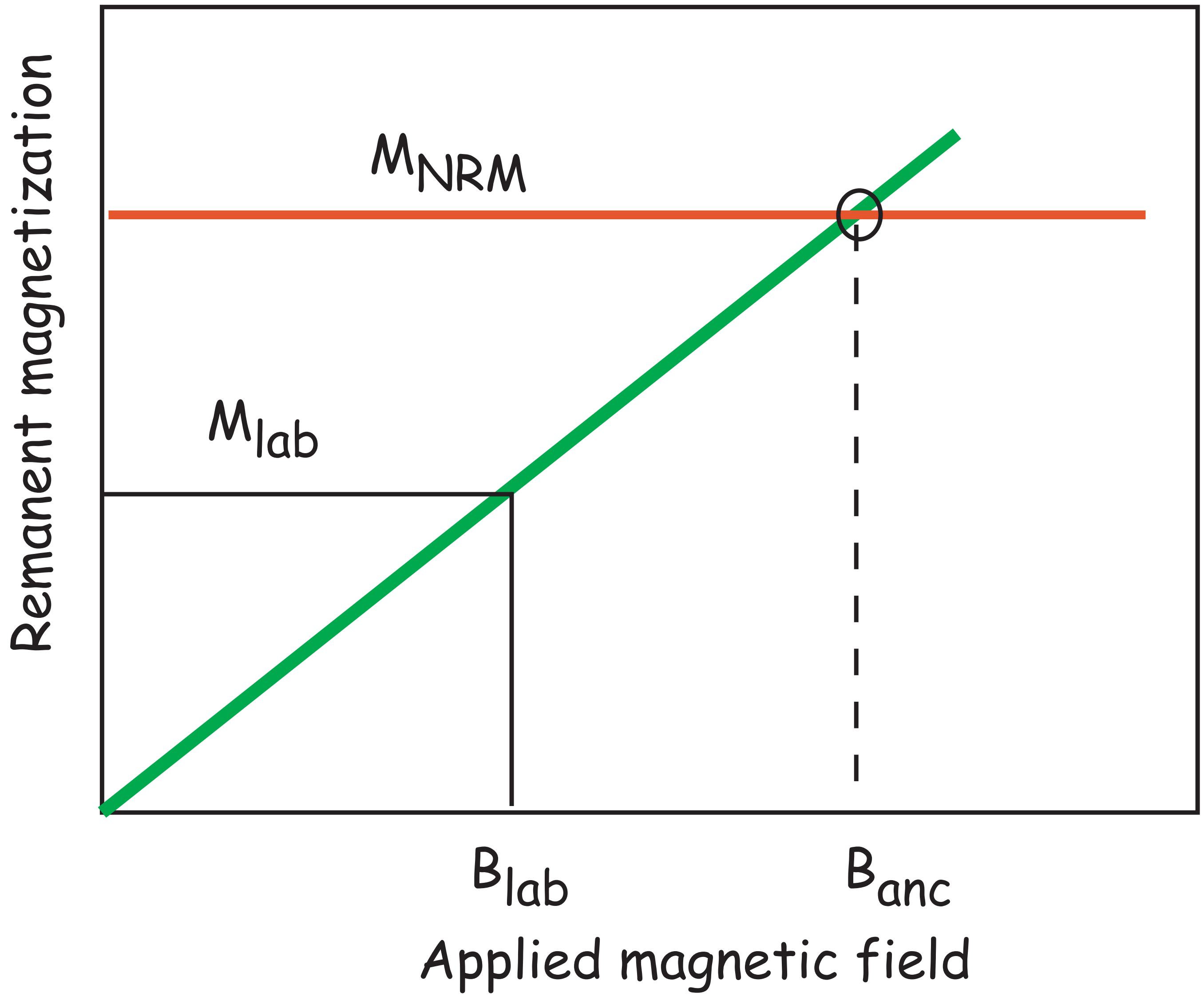
Lecture 14: Paleointensity

- Key assumptions
- Paleointensity with TRMs
- Paleointensity with DRMs
- Paleointensity with IRMs?

Key assumptions:

- The proportionality function between remanence and field is known (usually assumed to be linear)
- The proportionality constant can be approximated in the laboratory



$$B_{anc} = \frac{M_{NRM}}{M_{lab}} B_{lab}$$

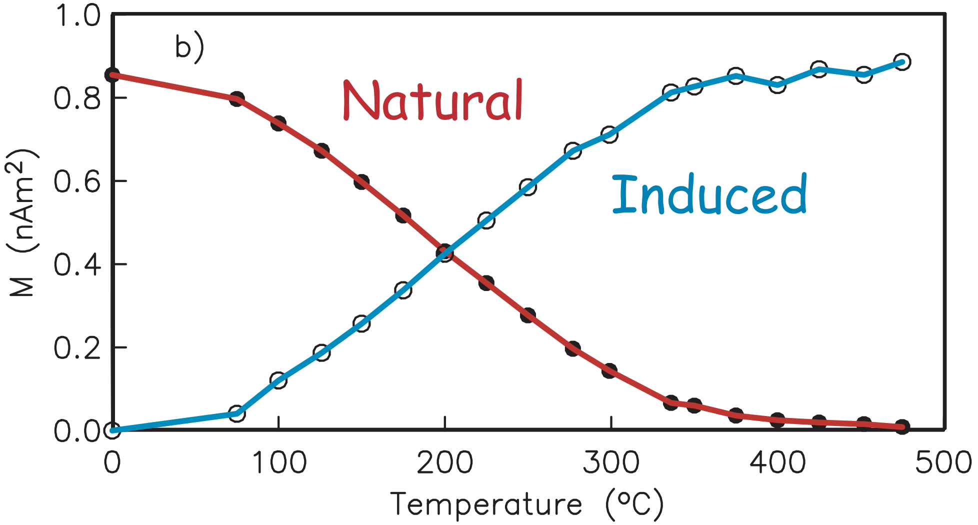
Sounds easy - BUT

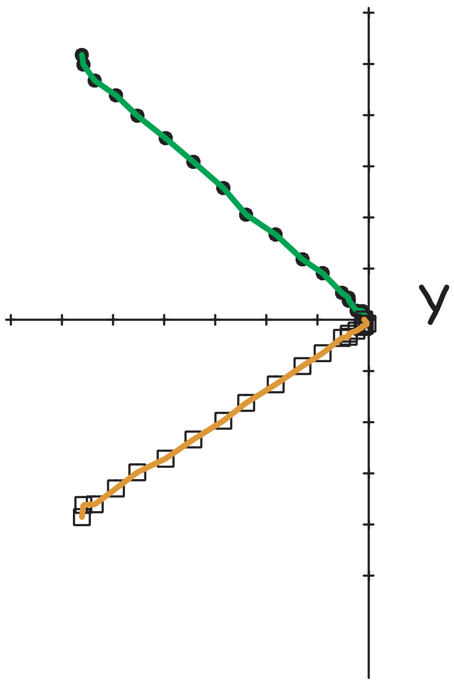
- Function may not be linear
- Specimen may have altered capacity to acquire remanence
- lab NRM may not be acquired by same mechanism (constant may be different)
- Anisotropy of remanence acquisition
- NRM may be multi-component

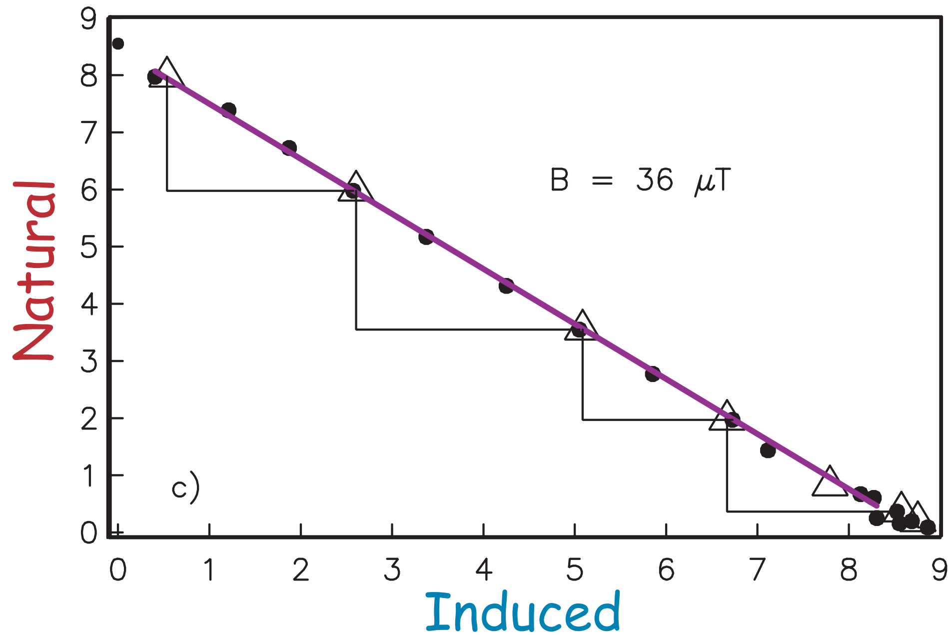
Paleointensity with TRMs: experimental design

- step-wise replacement of NRM with pTRMs (Thellier family of methods)
- step-wise replacement of NRM with microwave induced remanences
- replacement of NRM with total TRM and check for alteration
- many other methods (IRM normalization, multi-specimen approaches, new methods invented every month....)

Normalizing thermal remanence





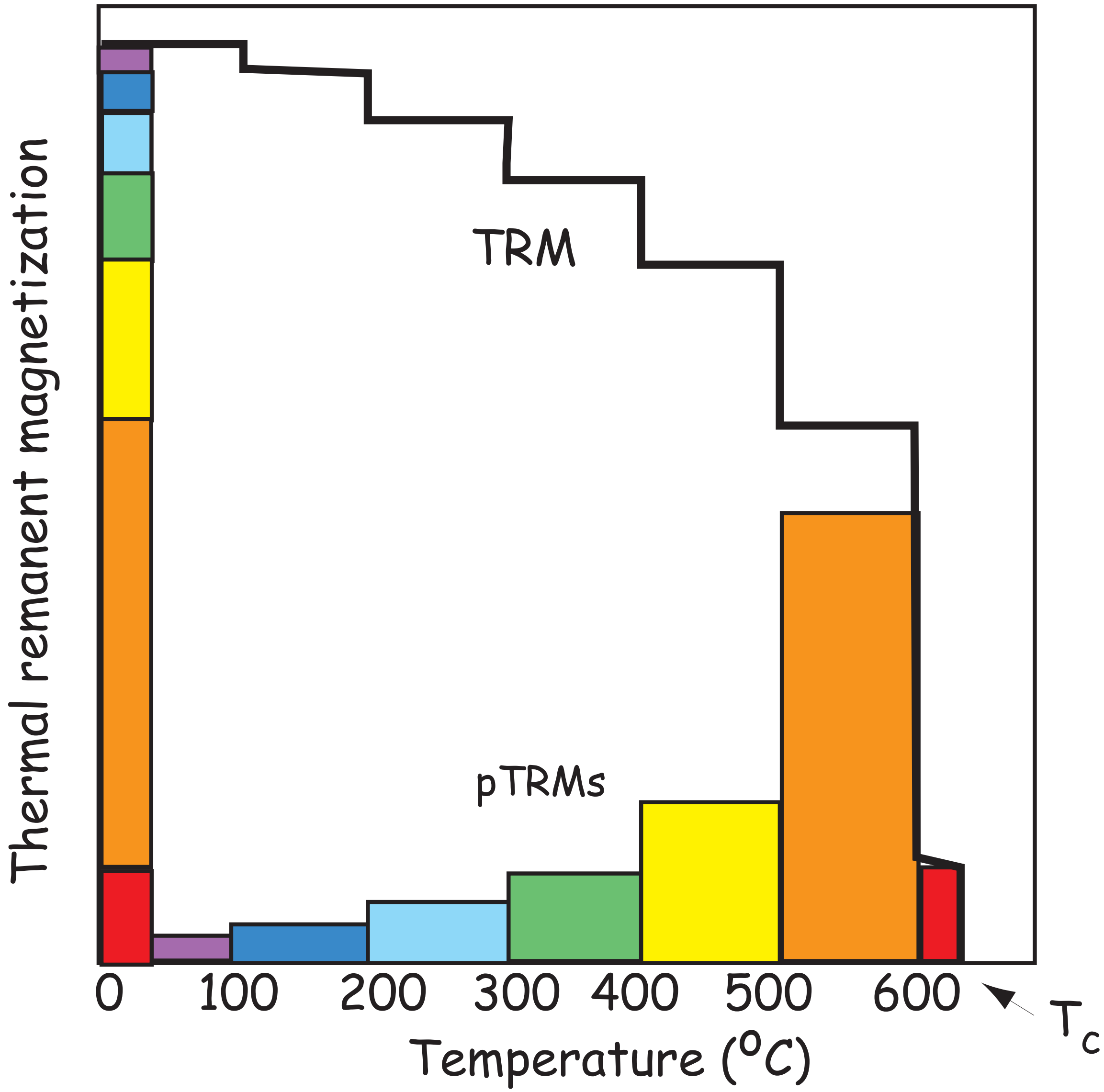


$$B_{ancient} = \frac{\text{Natural}}{\text{Induced}} B_{lab}$$

Assumptions

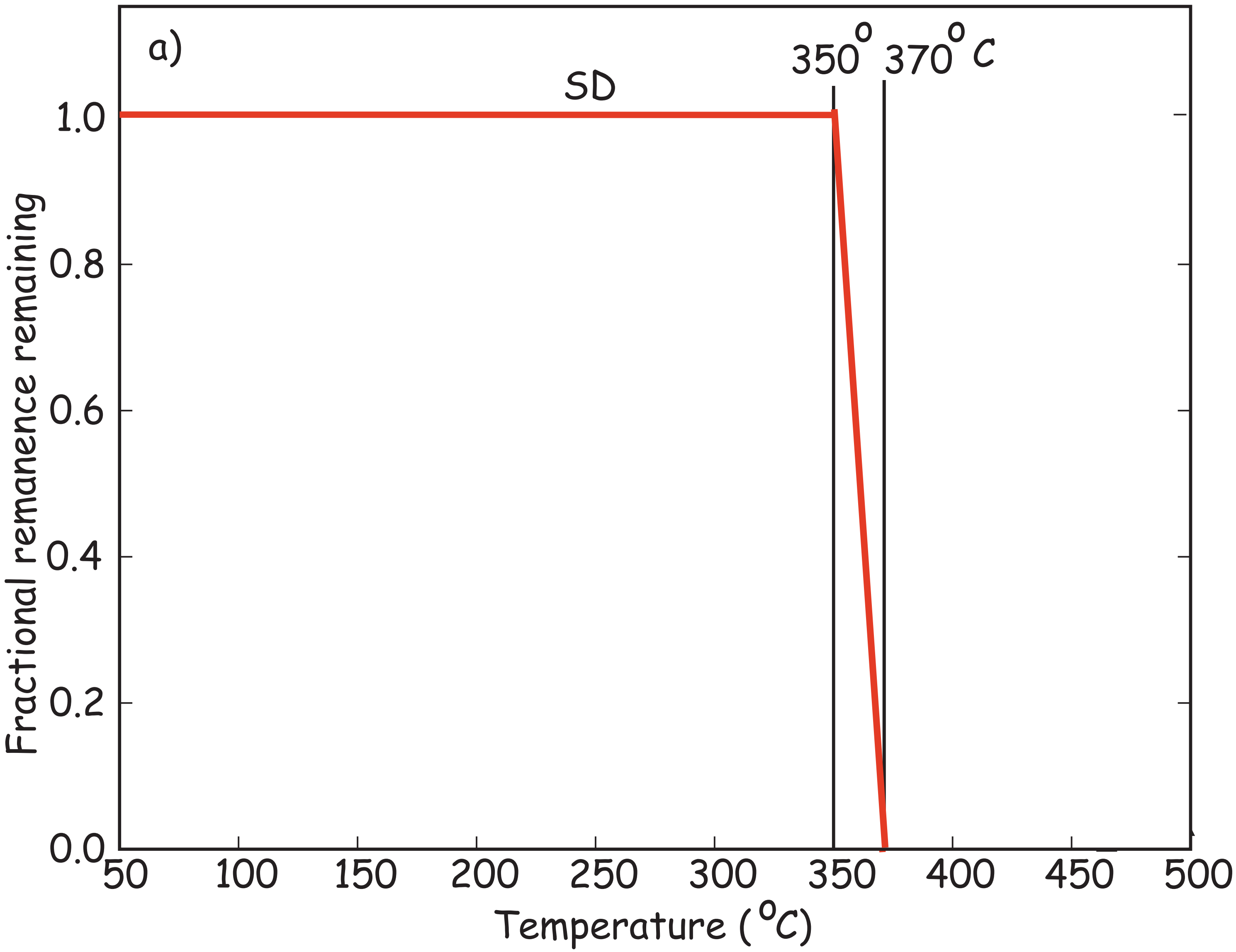
- pTRMs are additive (law of additivity)
- pTRMs acquired at Tb are removed at same temperature (Tb=Tub); law of reciprocity
- pTRM acquired in lab is equivalent to original
  - no lab alteration
  - linearity assumption?
  - cooling rate and anisotropy can be accounted for

pTRMs are additive - each cooling interval is independent of all others

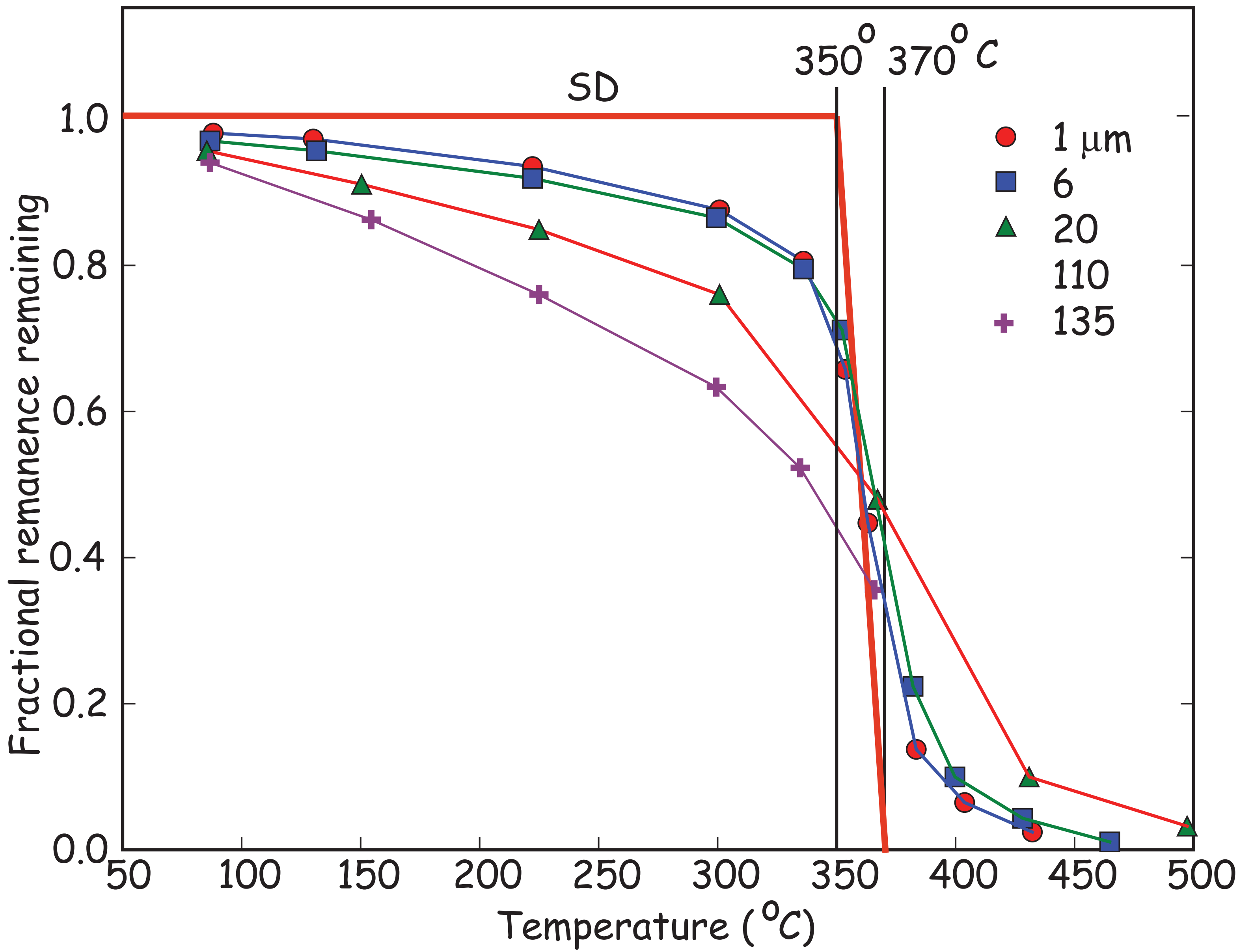


law of reciprocity

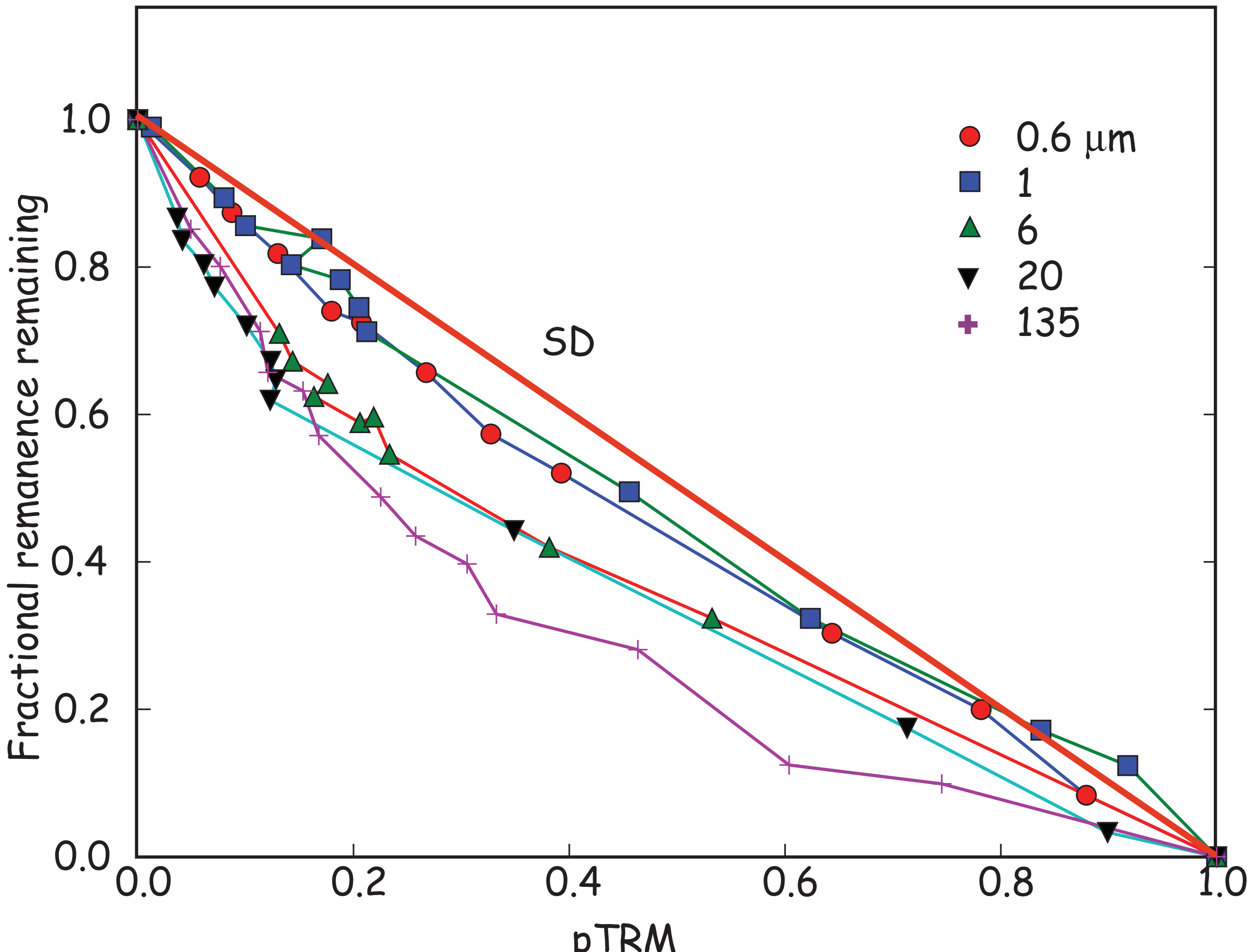
pTRM acquired between 350 and 370C is removed between 350 and 370C



only true for SD grains

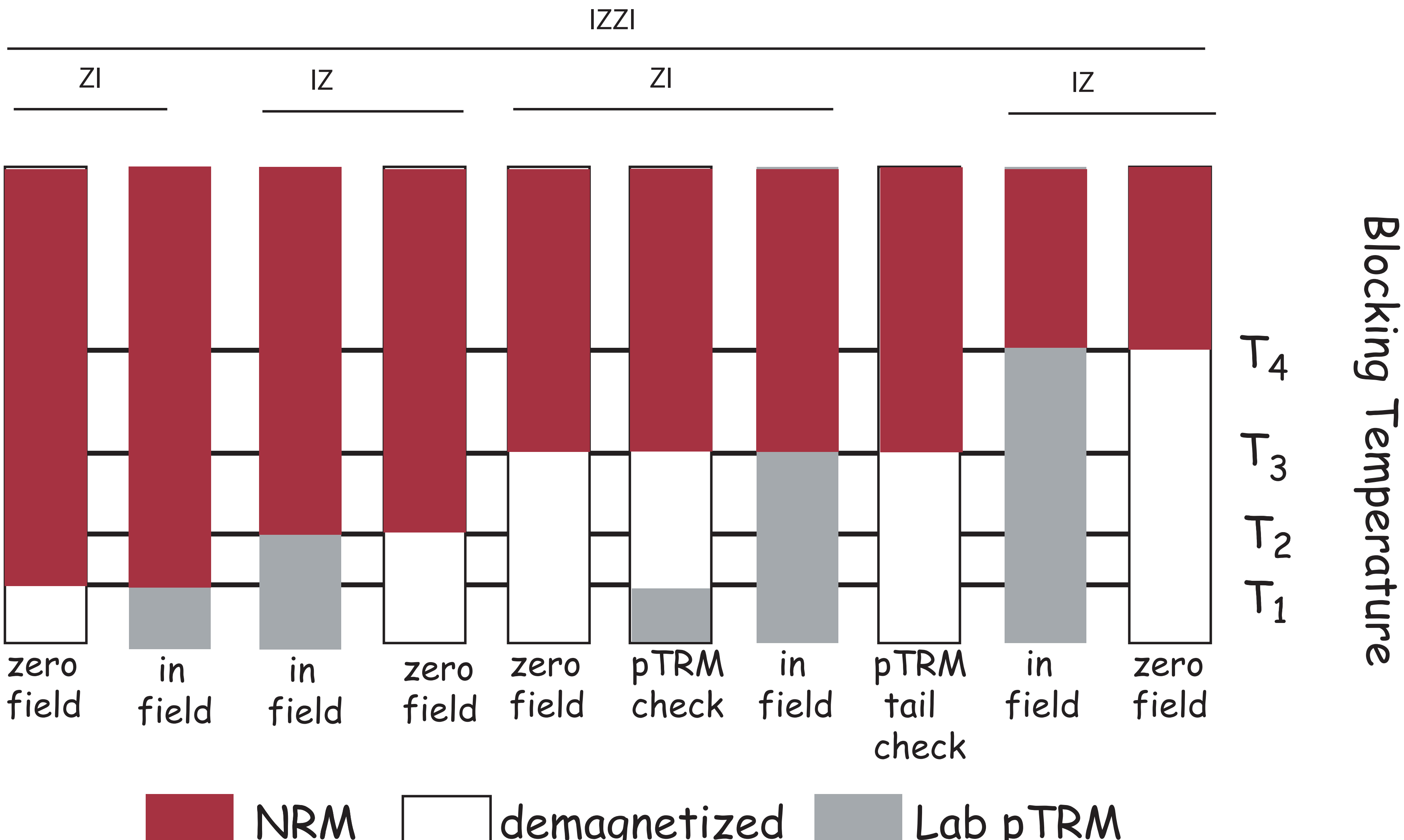


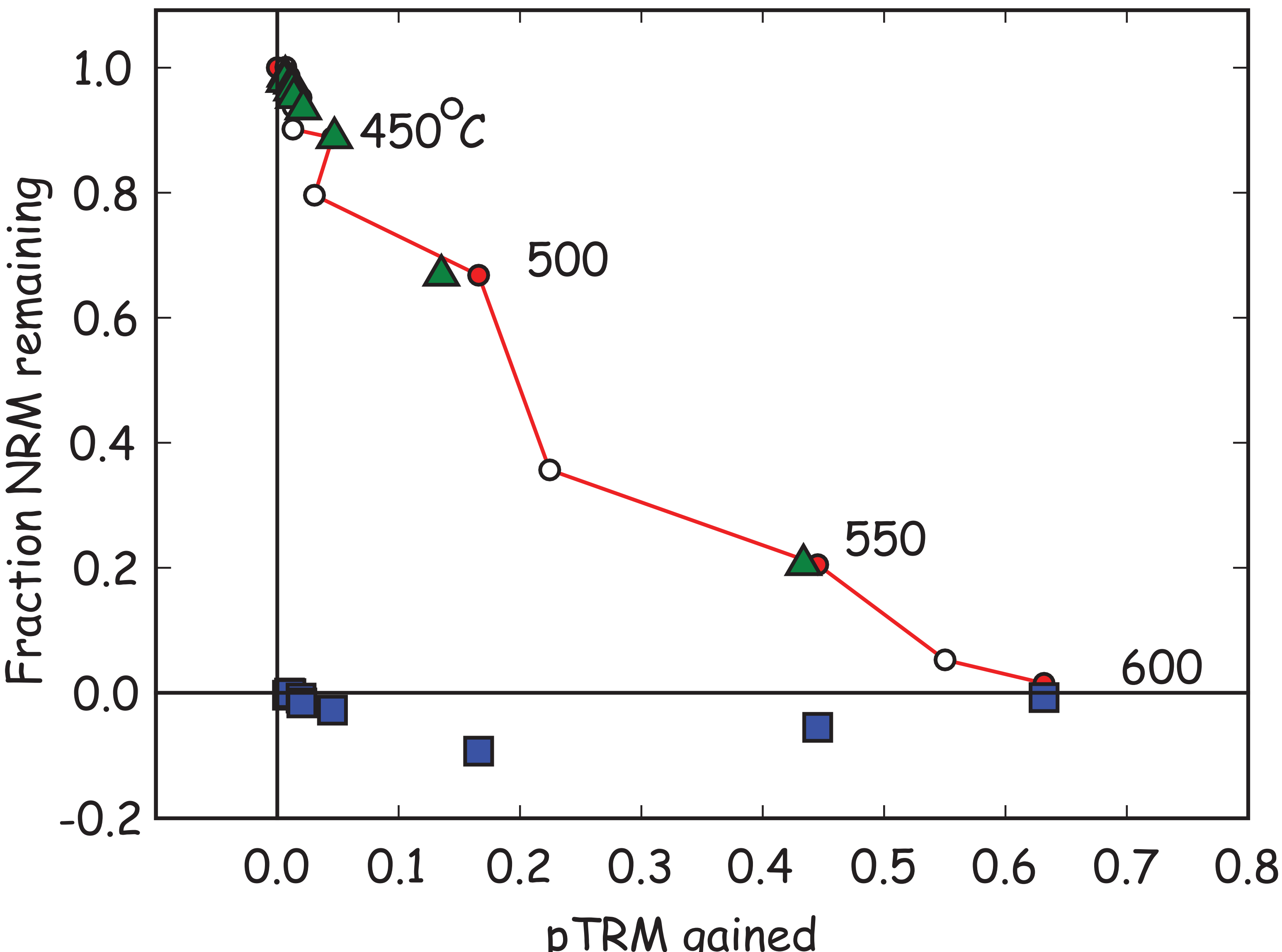
consequences in paleointensity experiments: saggy Arai plots



only true slope is red line

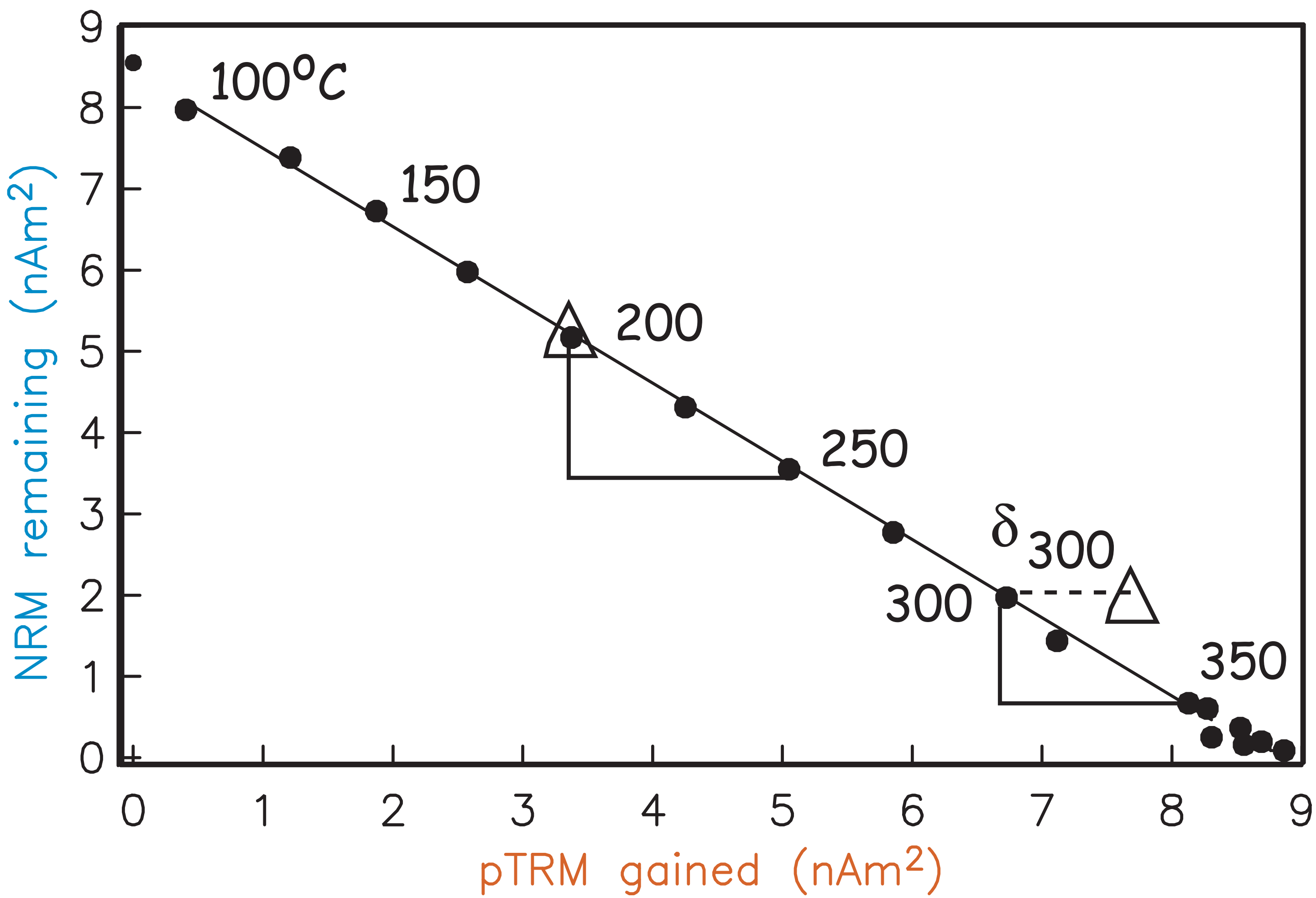
check with “IZZI” or pTRM tail checks



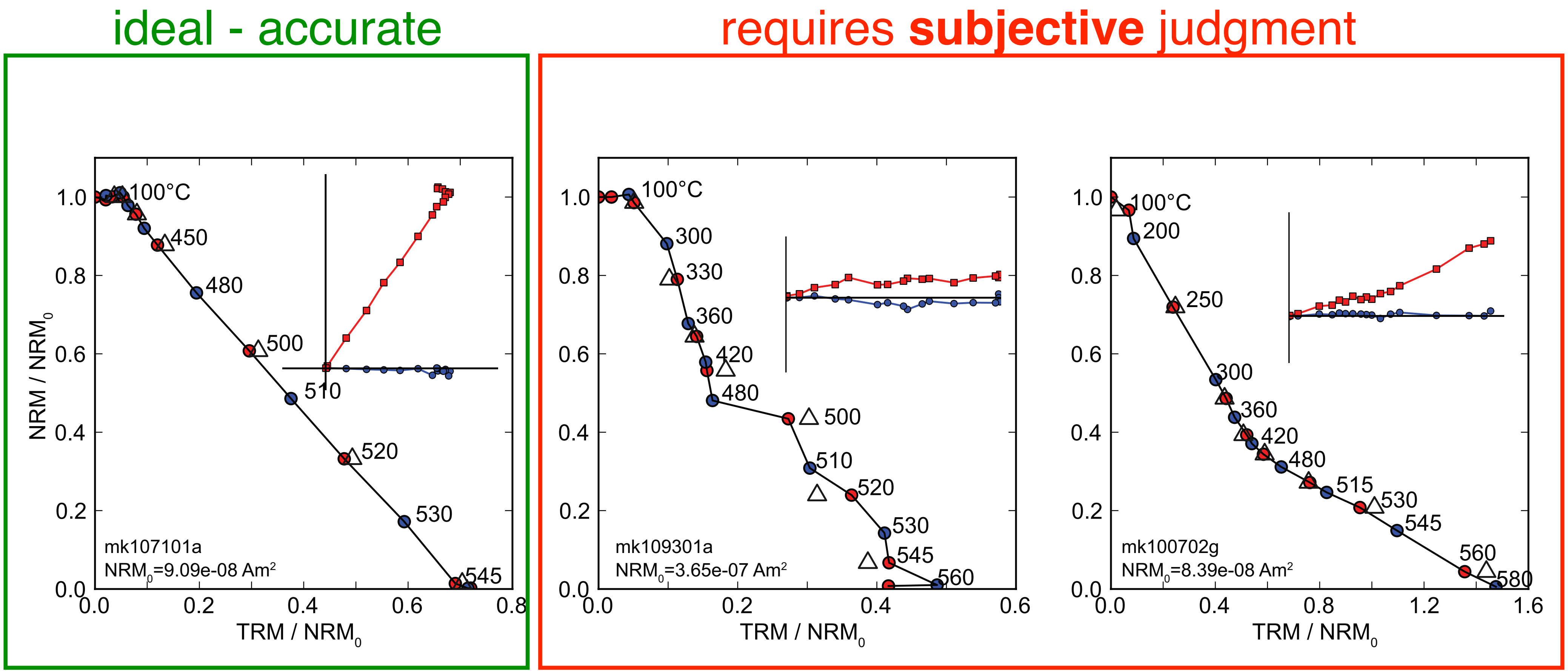


Fraction NRM remaining
pTRM gained
450°C
500
550
600
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8

problem of alteration during experiment



can be checked with "pTRM checks"



Need a magic mix of selection criteria:
exclude the 'bad' data
select the 'good' data

http://www.paleomag.net/SPD/home.html

Arai plot:

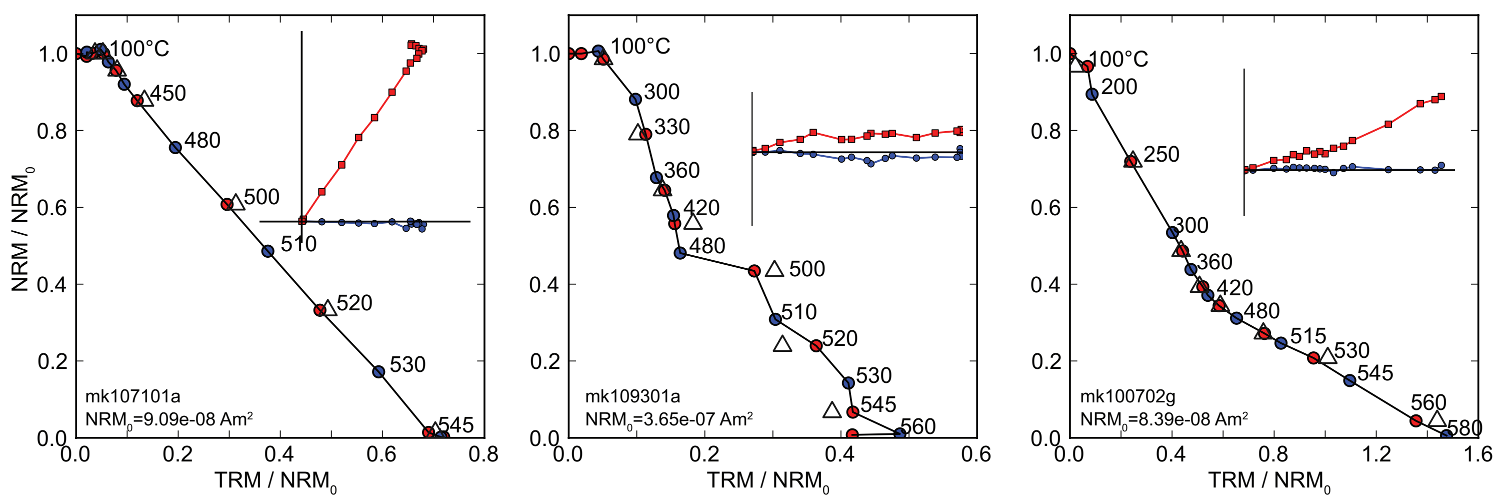
ancient field : $|b| \times B_{lab}$ where $|b|$ is the slope

standard error: σ_b scatter: $\beta = \frac{\sigma_b}{|b|}$

FRAC: fraction of NRM used K_{rv} : curvature

Zijderveld plot:

MAD: directional scatter DANG: deviation from origin



How things go wrong

- failure of single domain assumption
- failure of linearity assumption
- anisotropy of TRM
- cooling rate

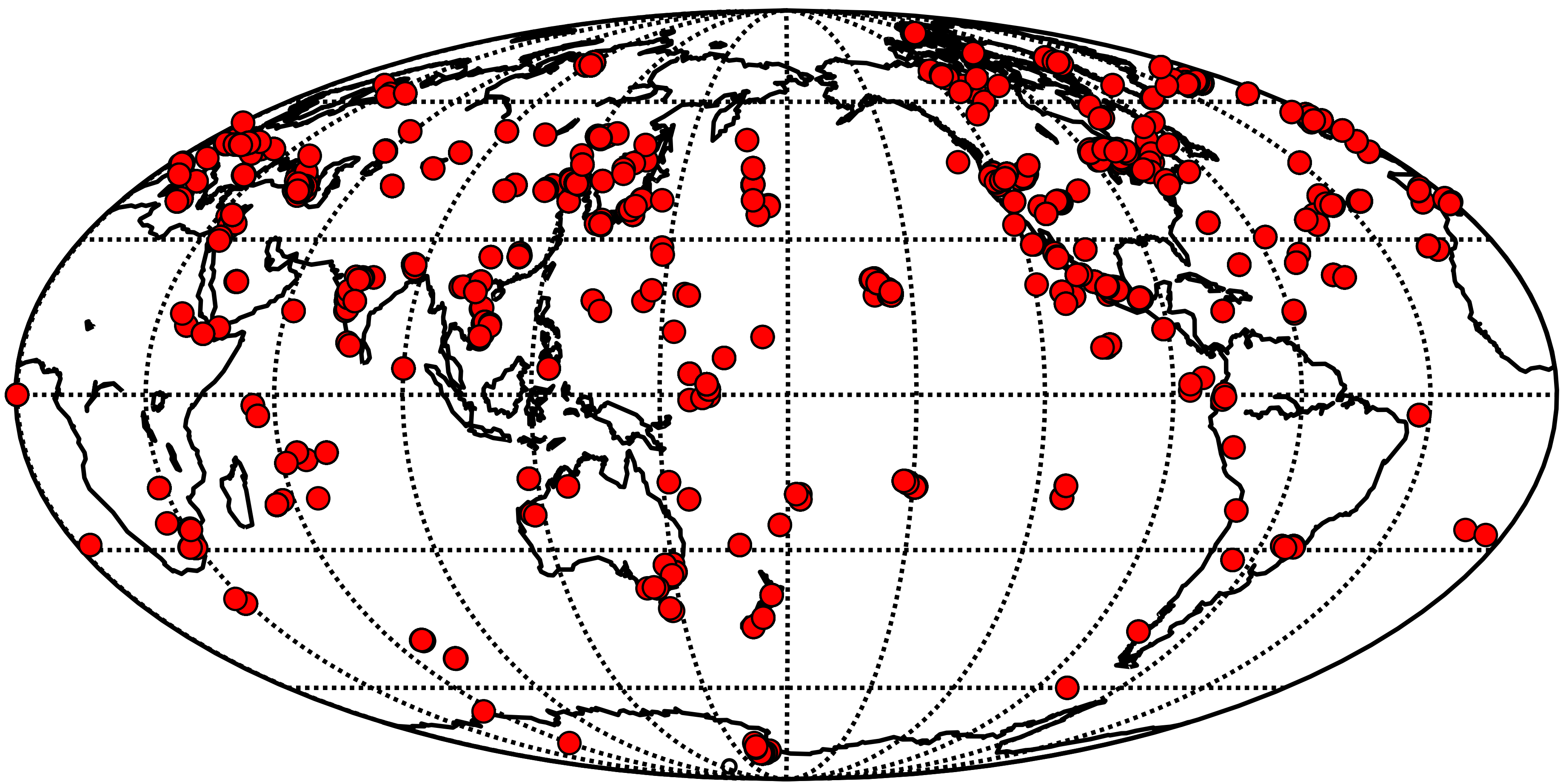
Whatever method you use

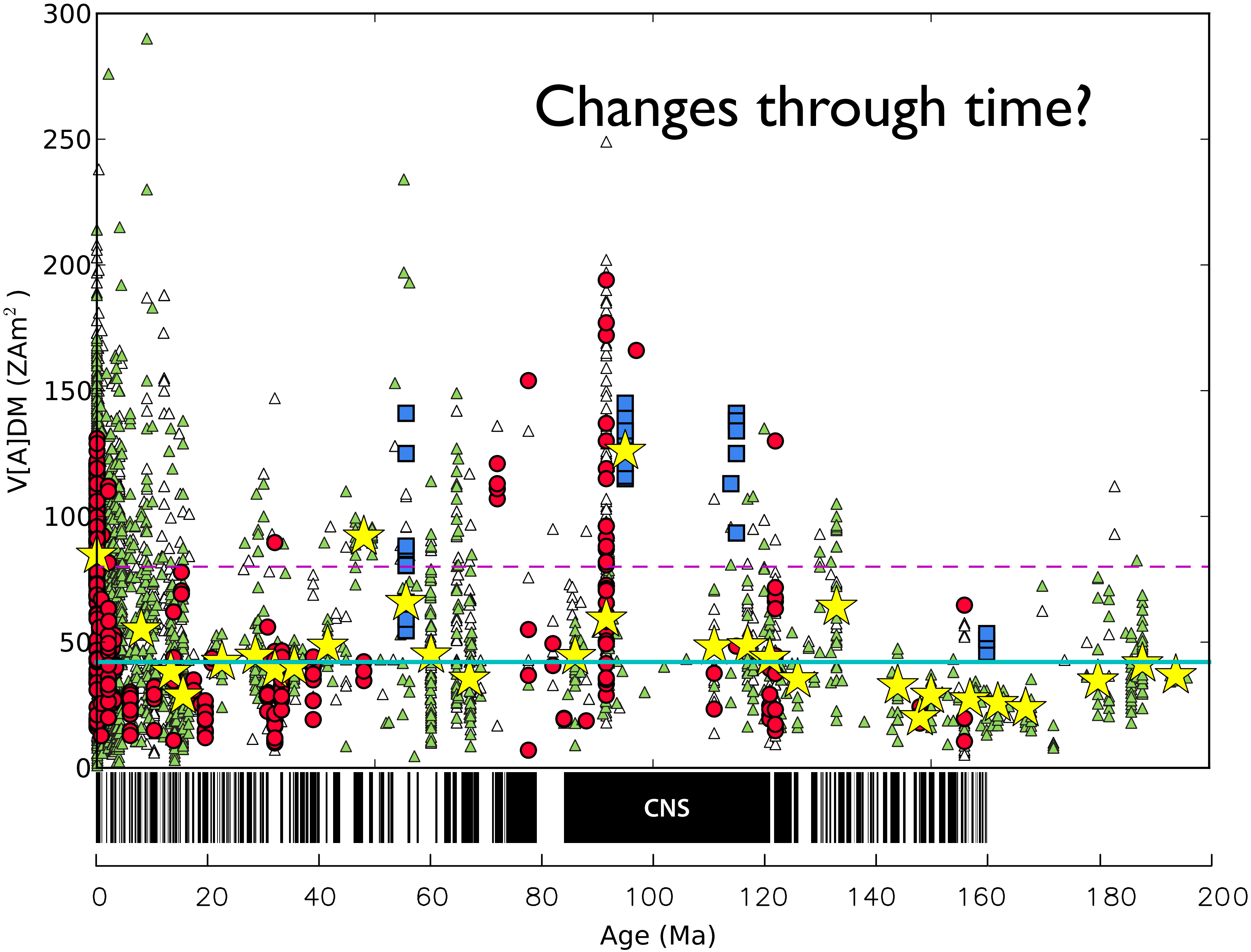
- Must build in checks of fundamental assumptions
- Must have some tests for quality assurance (statistics, acceptance criteria)

State of the database:

http://earthref.org/MagIC/search

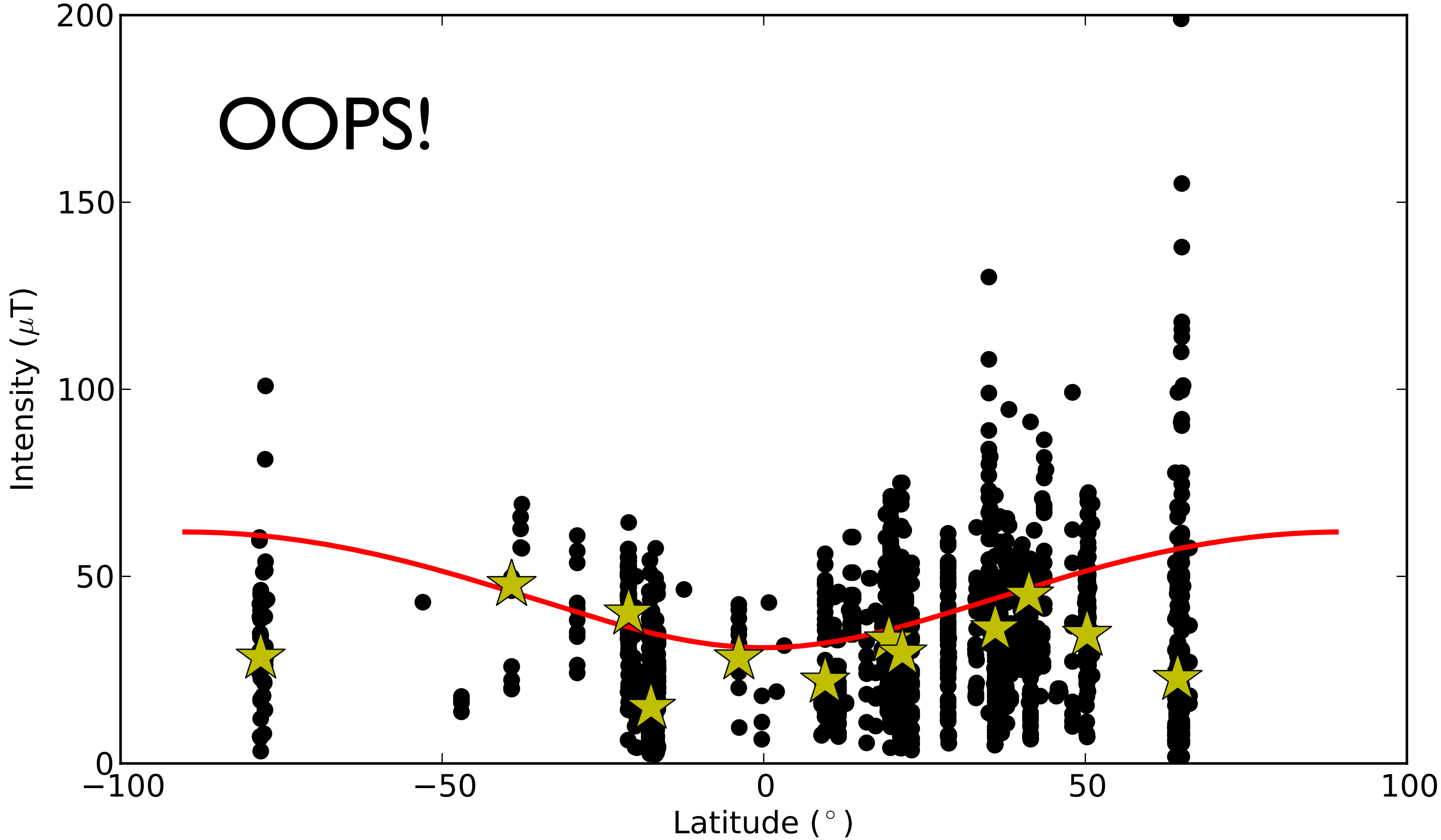
Over 20,2000 sites with "absolute" paleointensity in database (method codes: LP-PI and NOT LP-PI-REL)



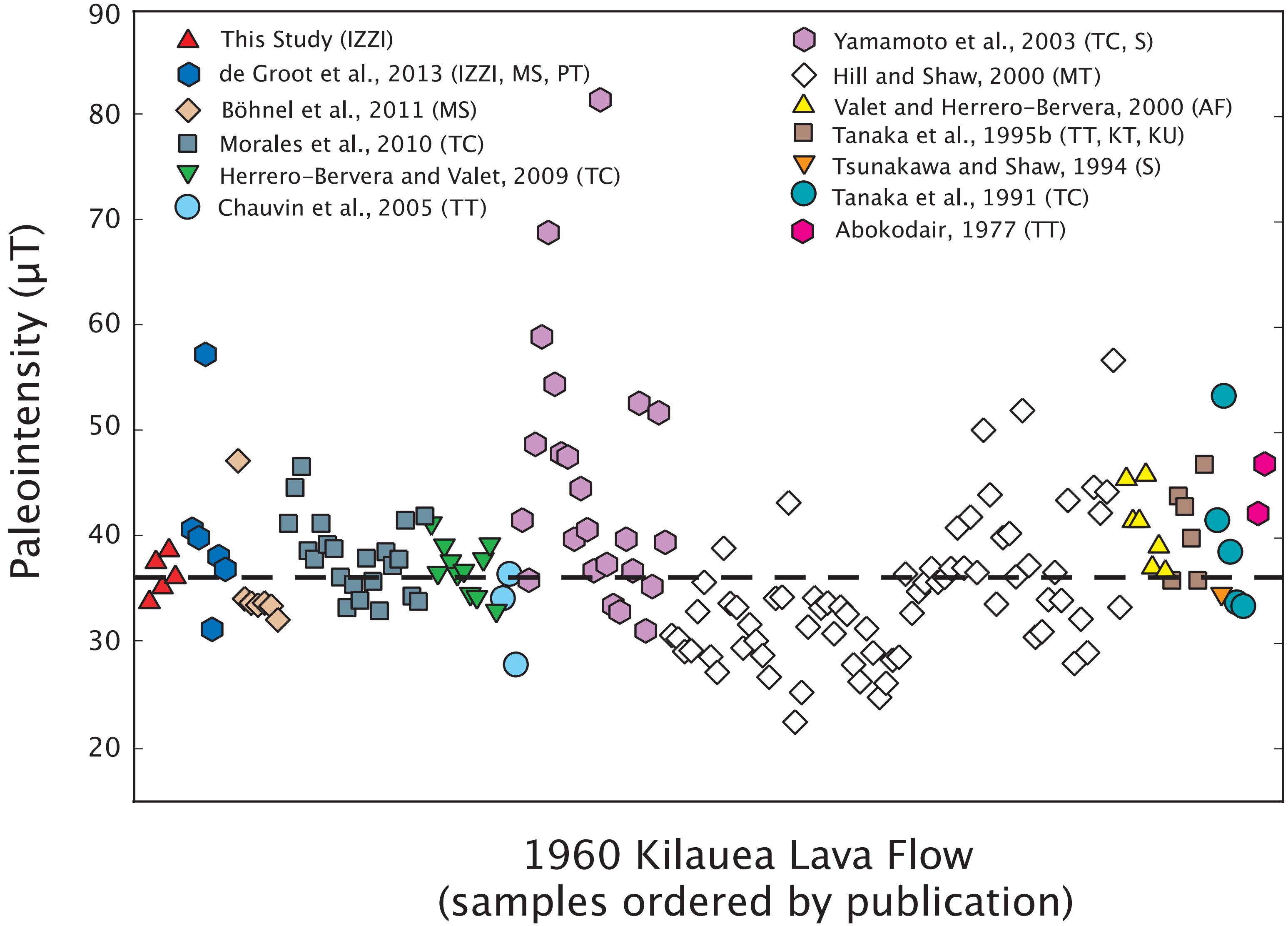


Changes through time?
300
250
200
150
100
50
0
V[A]DM (ZAm²)
CNS
0
20
40
60
80
100
120
140
160
180
200
Age (Ma)

2013 MagIC database: 0-5 Ma
N=2180



Worse news!
Data from a single lava flow span the entire range of intensities on Earth!



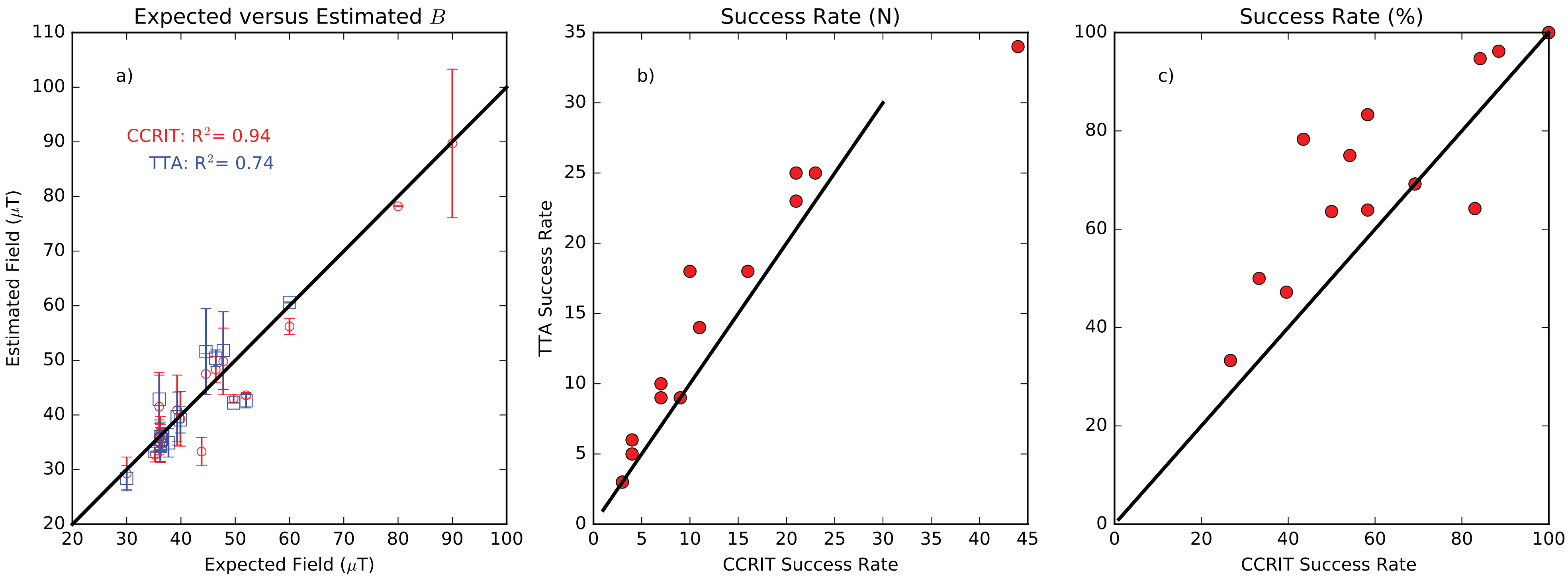
Cromwell et al. (submitted)

Without measurements

- No way to quantify alteration tests because there is no standard pTRM check statistic
- No way to tell if non-linear Arai plot or even what fraction of data are used
- No way to tell if MD “sag” is present
- No way to make sure in linear TRM range
- No way to know if cooling rate or anisotropy are problems

With measurements

- Can use "SCAT" to filter out altered, scattered data
- Can use Krv to quantify sagging.
- Can use IZZI method to quantify pTRM 'tails'
- Can repeat total TRM as a function of field to test for non-linearity of TRM acquisition
- Can test for cooling rate dependence and correct for anisotropy



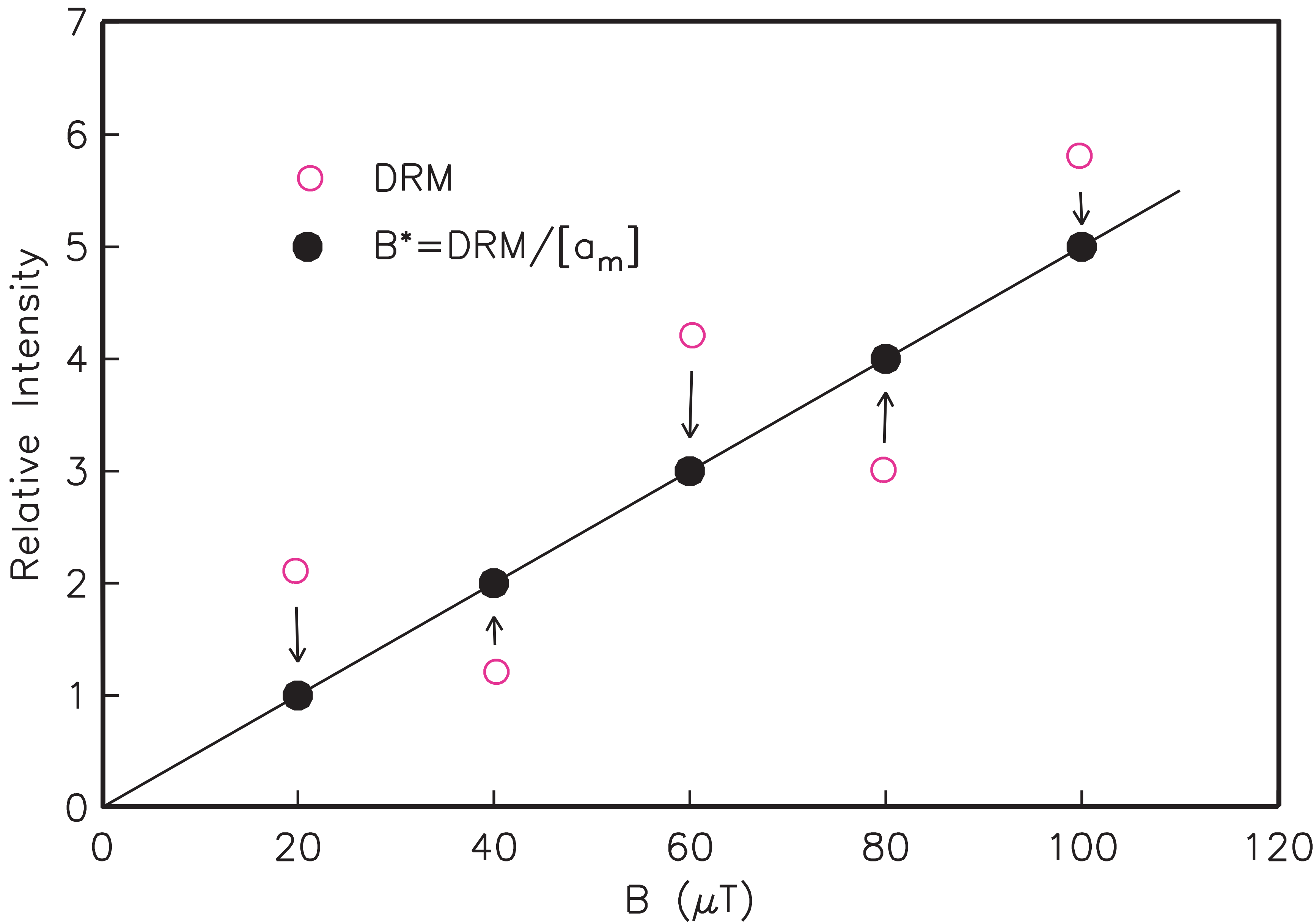
Comparing two sets of selection criteria on results of known answer

CCRIT: Cromwell et al. 2015
TTA: Leonhardt et al. 2004

Paleointensity with DRMs: same two key assumptions

- The proportionality function between remanence and field is known (usually assumed to be linear)
- The proportionality constant can be approximated in the laboratory

In graphical form:



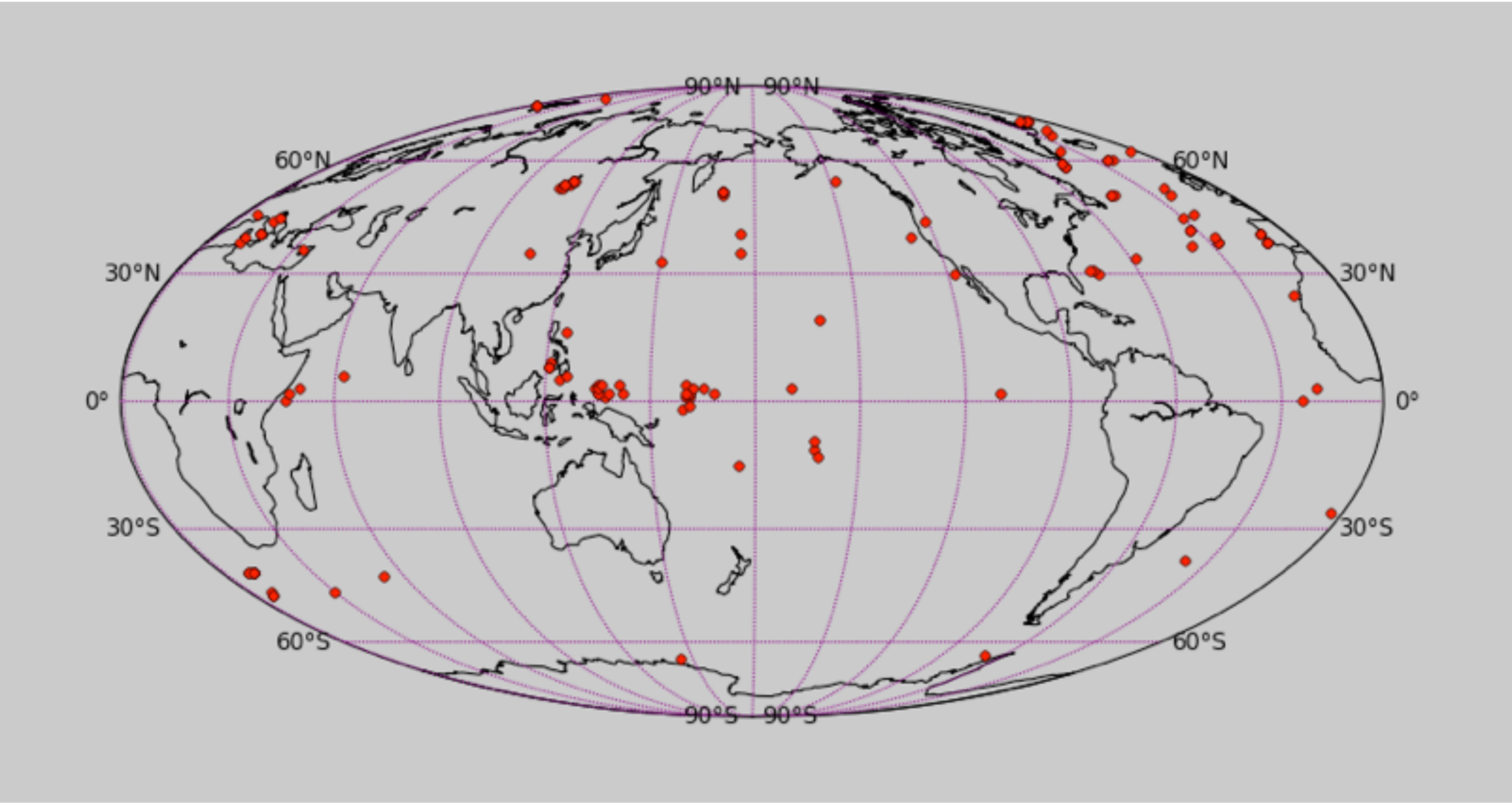
Usual procedure:

- Establish (or assume) DRM origin of ChRM
- Establish magnetic carrier (should be magnetite!)
- Establish homogeneousness of bulk properties (linear relation between ARM, IRM, susceptibility) to rule out changes in magnetic grain size
- Establish maximum bounds for changes in concentration (no more than ~10x)
- Choose bulk normalizer
- (Rarely) compare nearby records

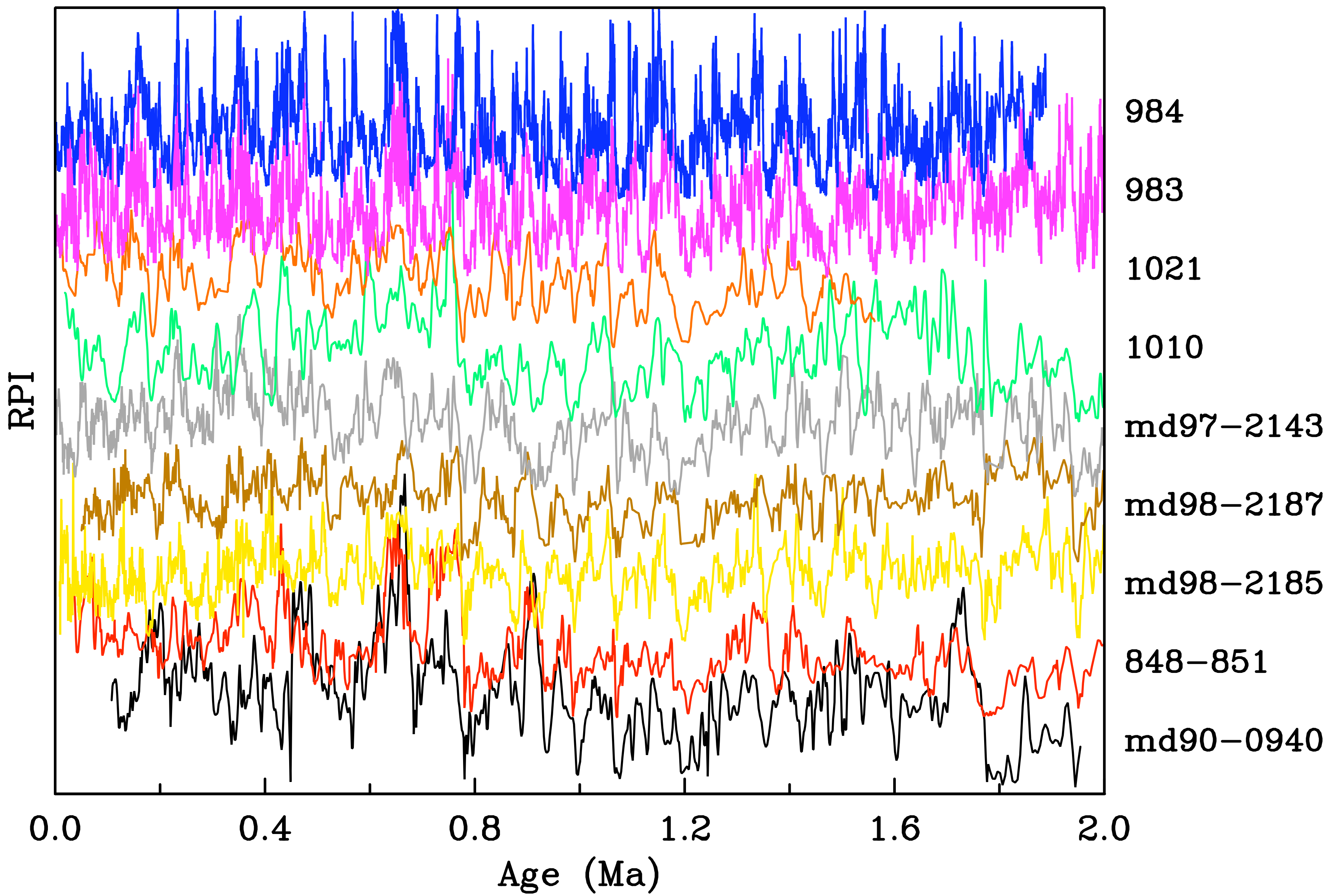
State of the database:

First the good news

Over 100 "relative" paleointensity papers in database

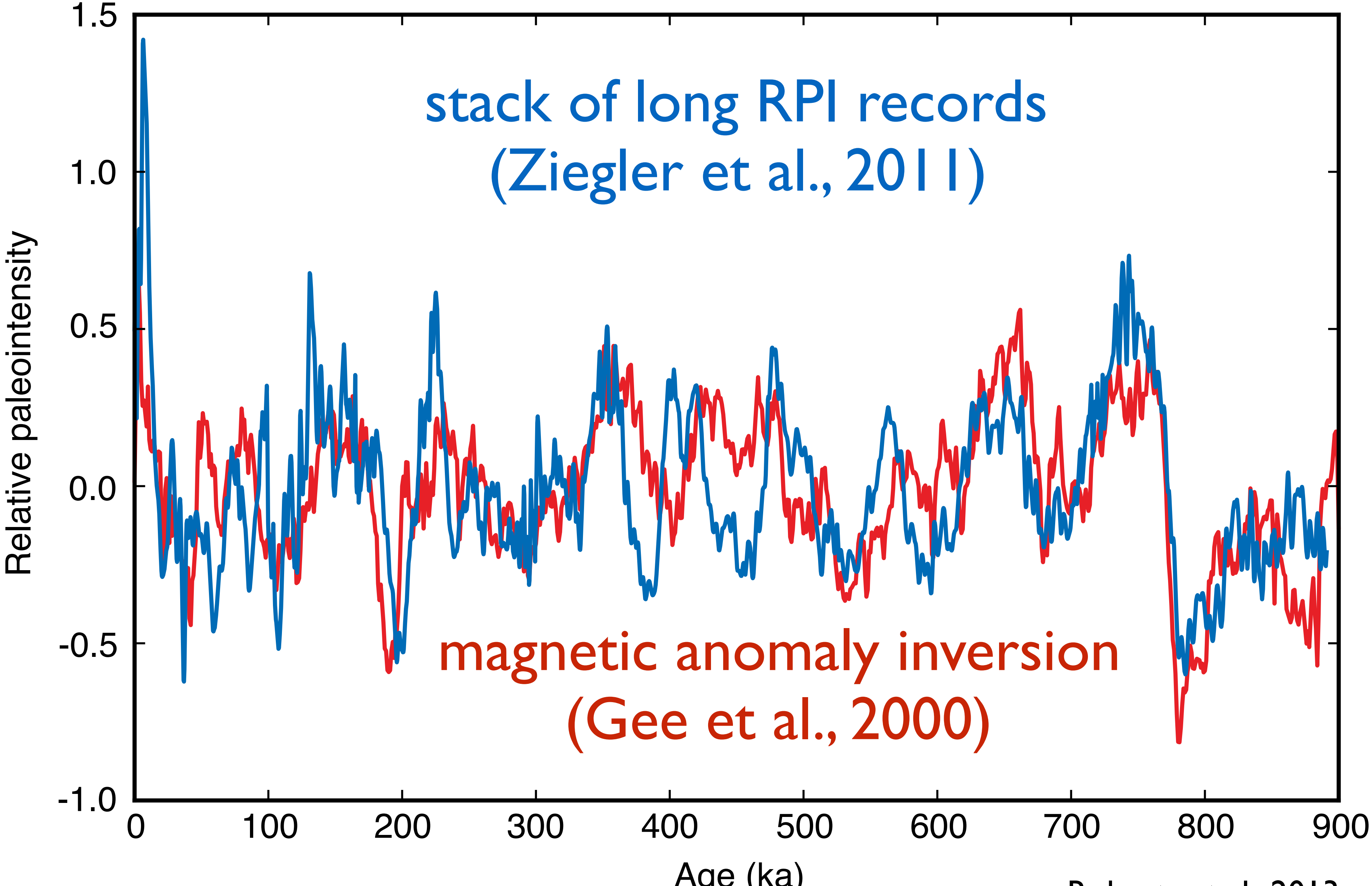


Examples of long records from deep sea sediments



Ziegler et al. (2011)

RPI works?

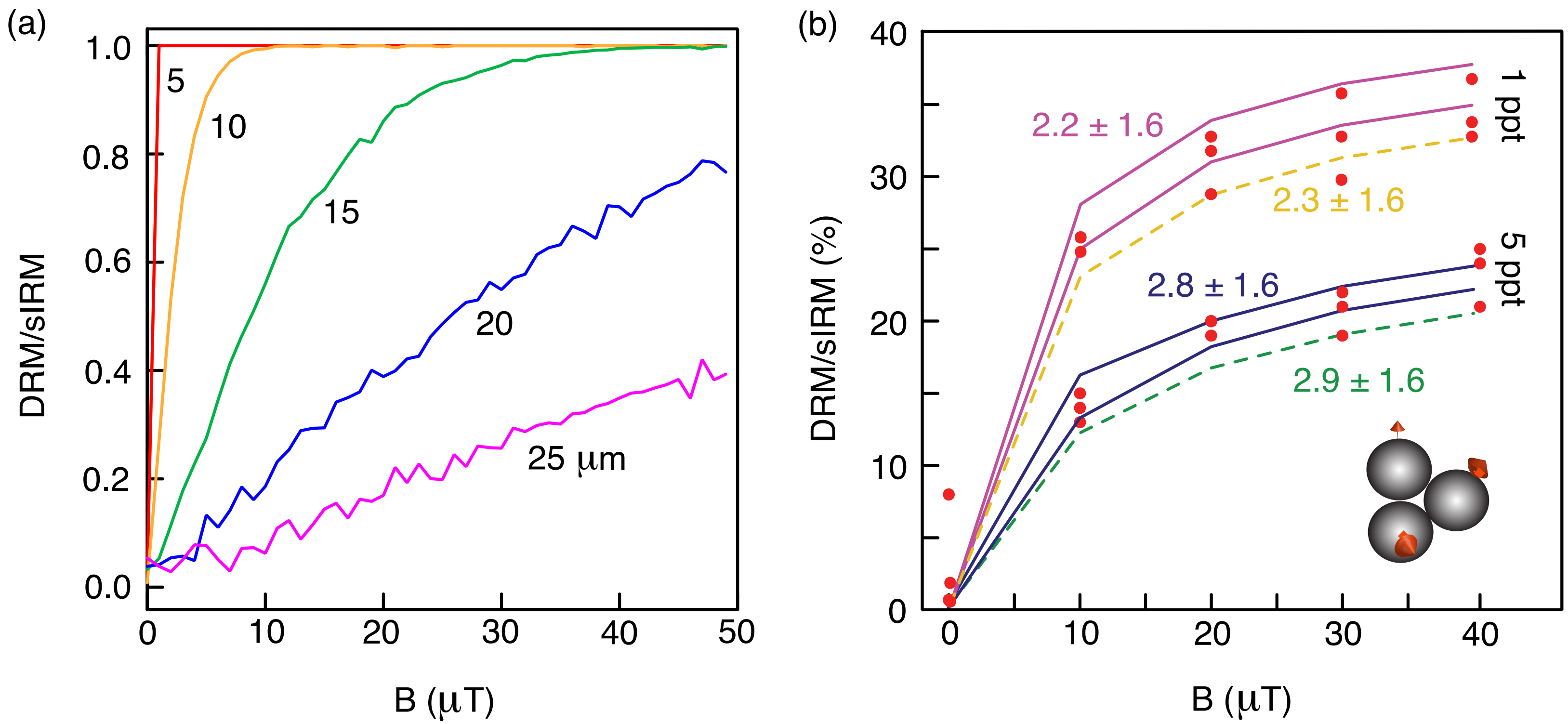


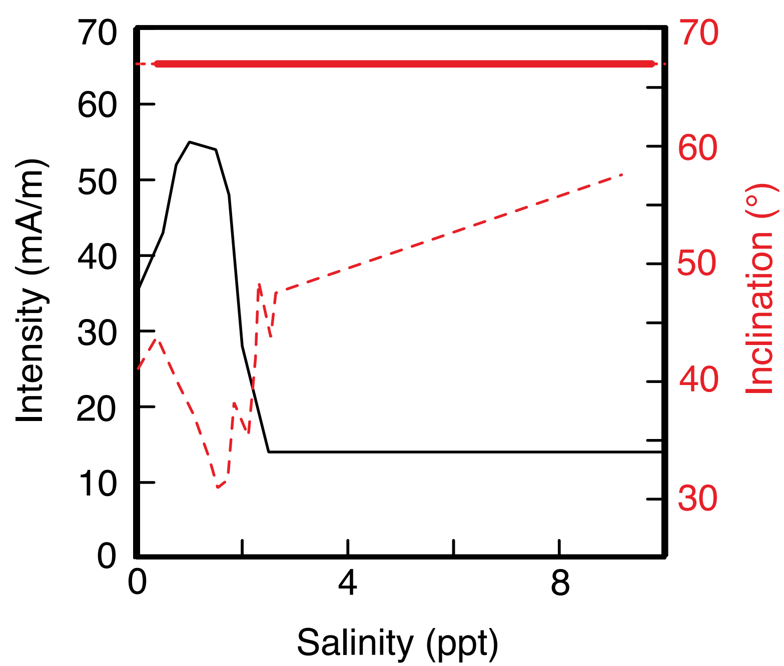
Roberts et al., 2013

How things go wrong

- failure of linearity assumption
- sensitivity of DRM to environmental conditions (salinity, particle size, mineralogy)

Where things can go wrong:





In database

- No way to know effect of flocculation on relative paleointensity
- No way to make sure in linear TRM range
- No consistent approach to data quality

In summary

- Theory is getting better and better
- Need to apply theoretical understanding to data selection
- Need access to all the experimental data - not just what gets published.