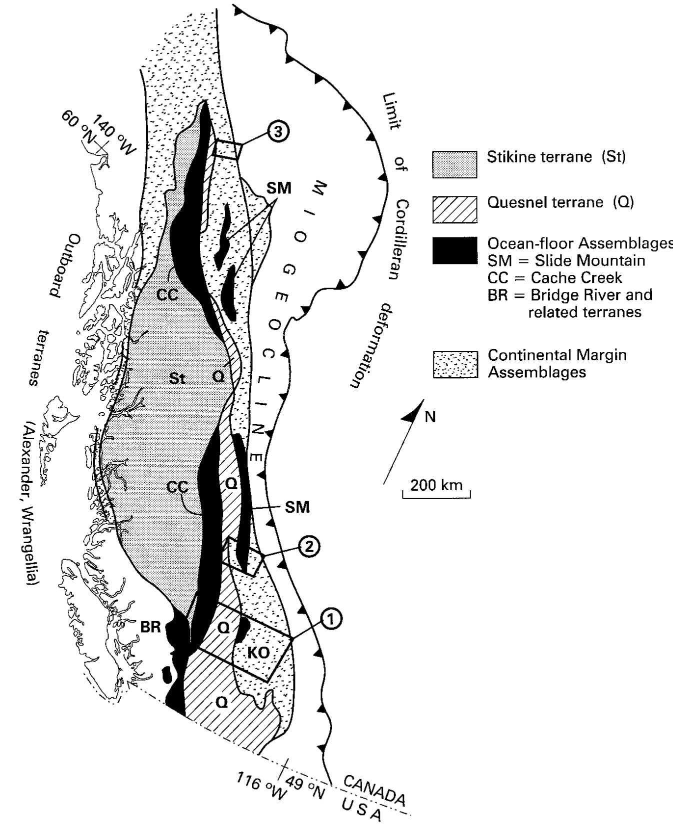
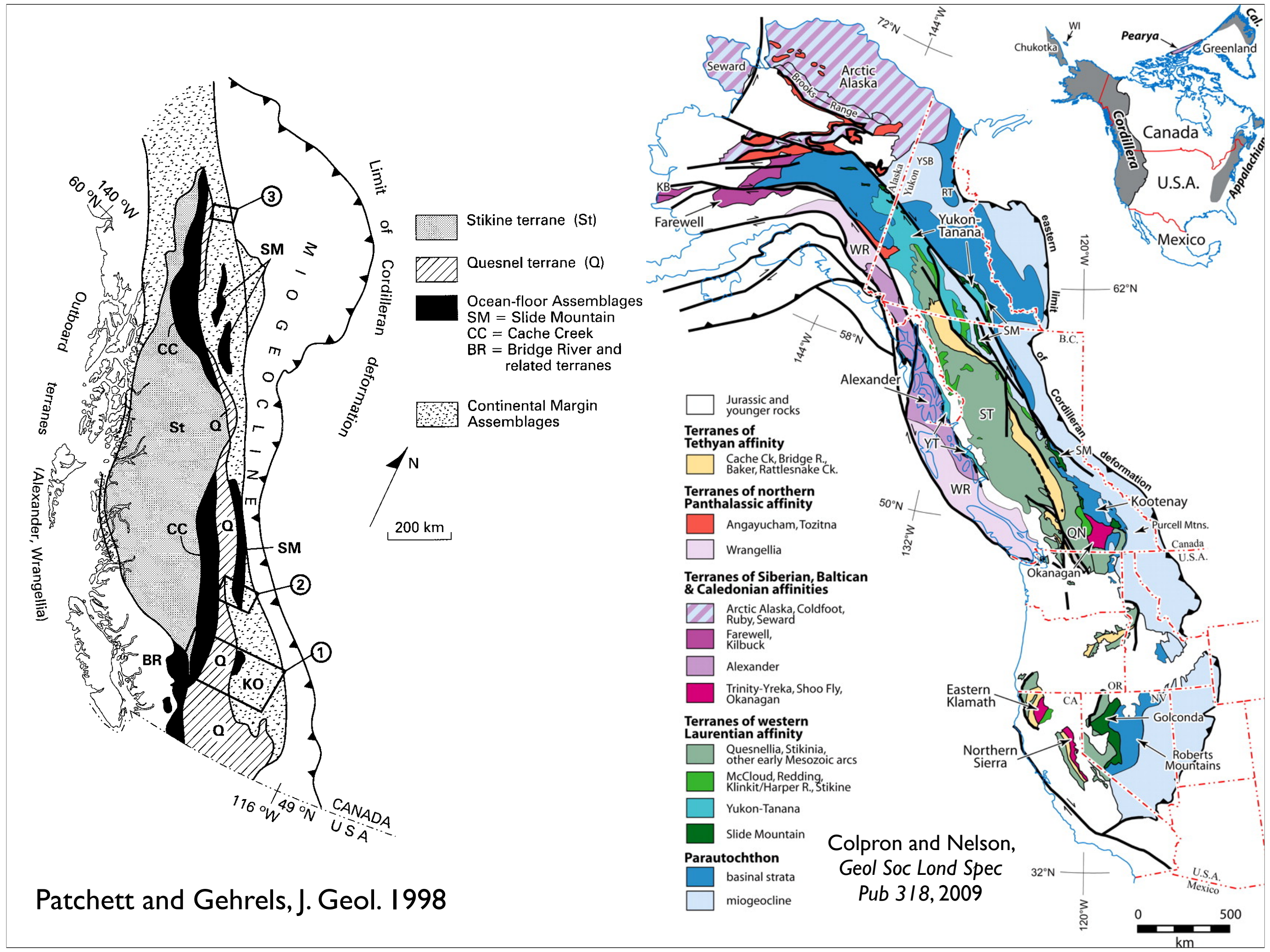
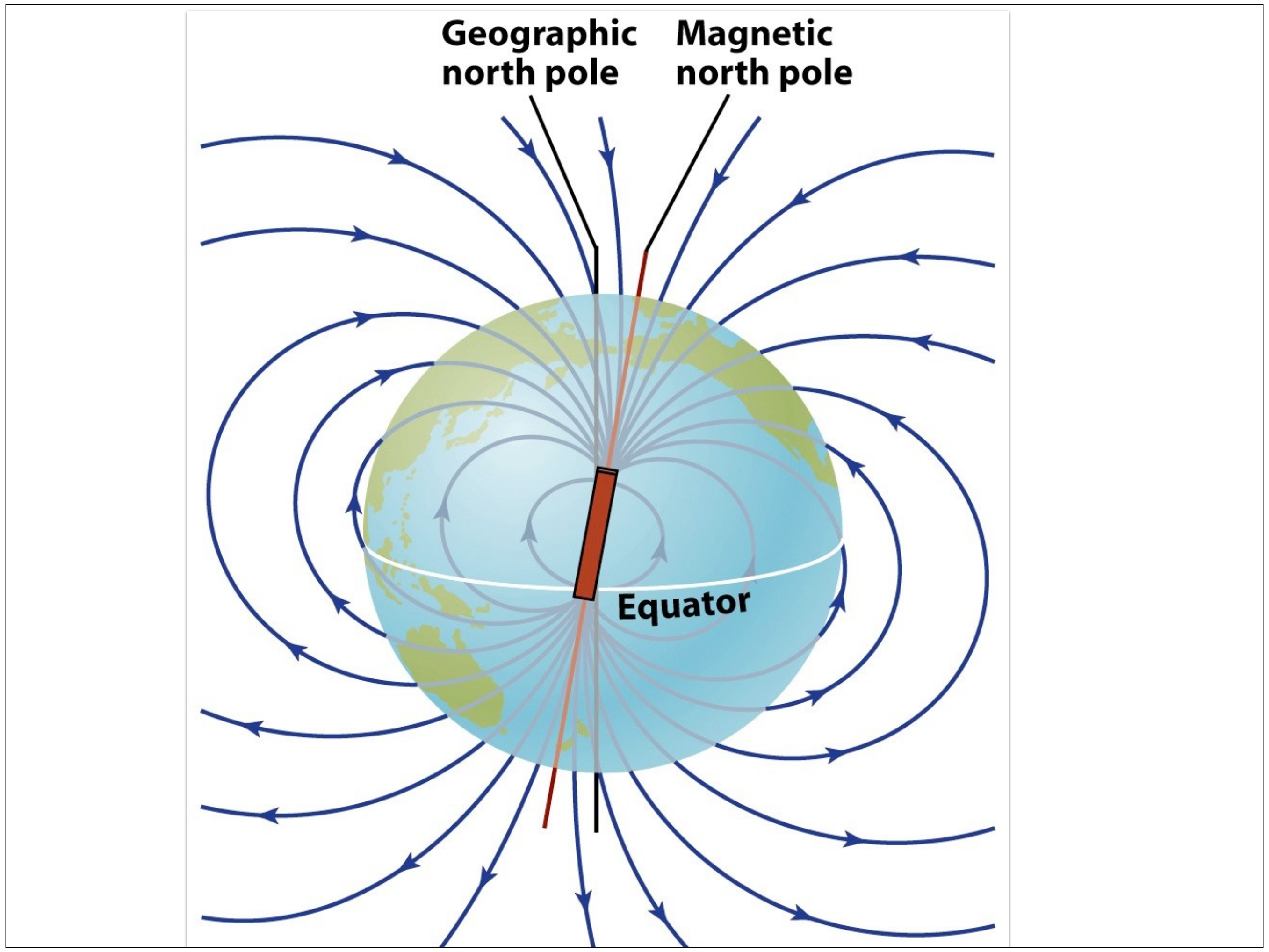
Figure 1. The Canadian Cordillera showing terranes studied here. Rectangles denote sampling regions: 1—southeastern British Columbia for Cache Creek, Quesnel, and Kootenay samples (KO = Kootenay terrane proper); 2—Wells-Barkerville region for Quesnel, Slide Mountain and Kootenay/Cassiar-equivalent samples; 3—Nisutlin assemblage at Little Salmon Lake, Yukon.



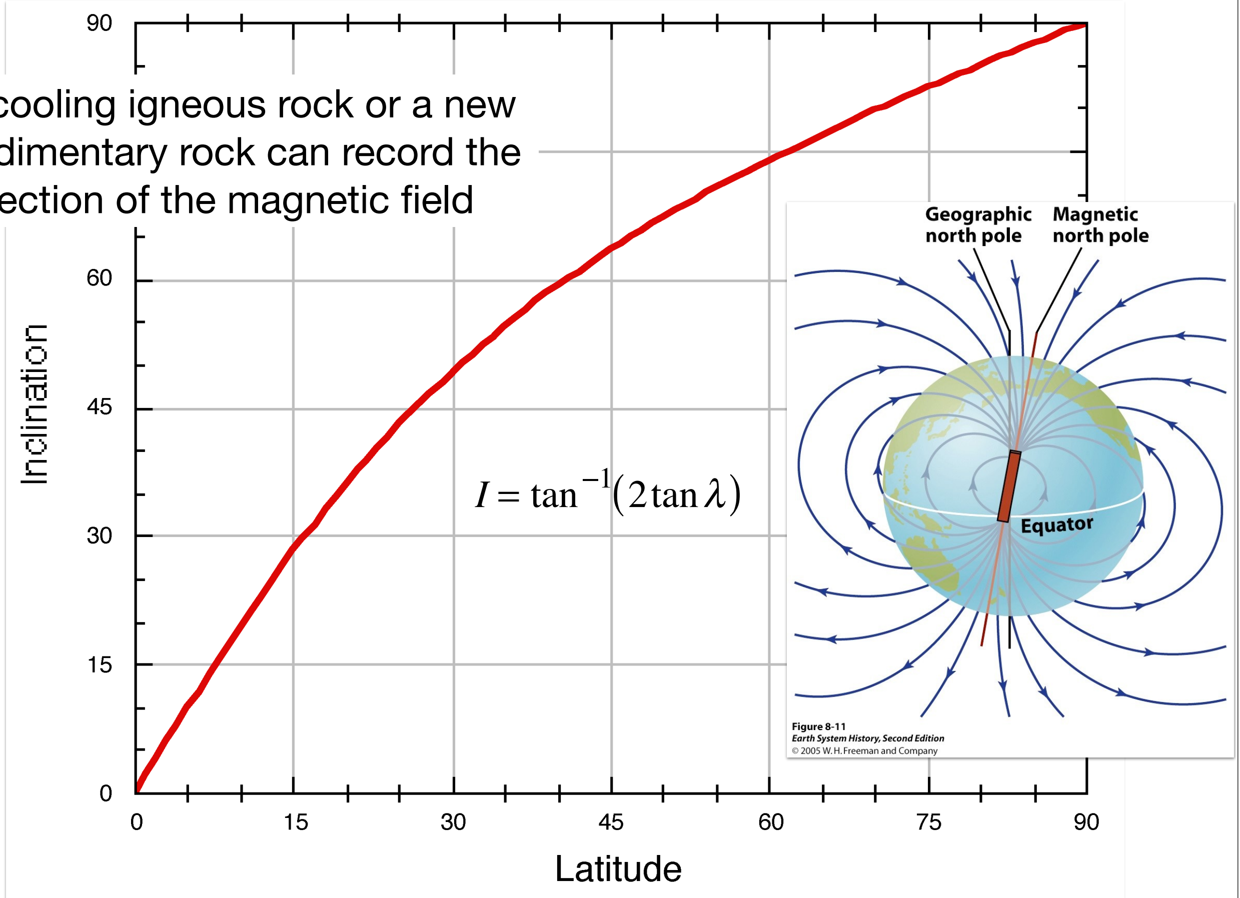
Patchett and Gehrels, J. Geol. 1998



Most terrane maps focus on Canada; map at right extends this into US

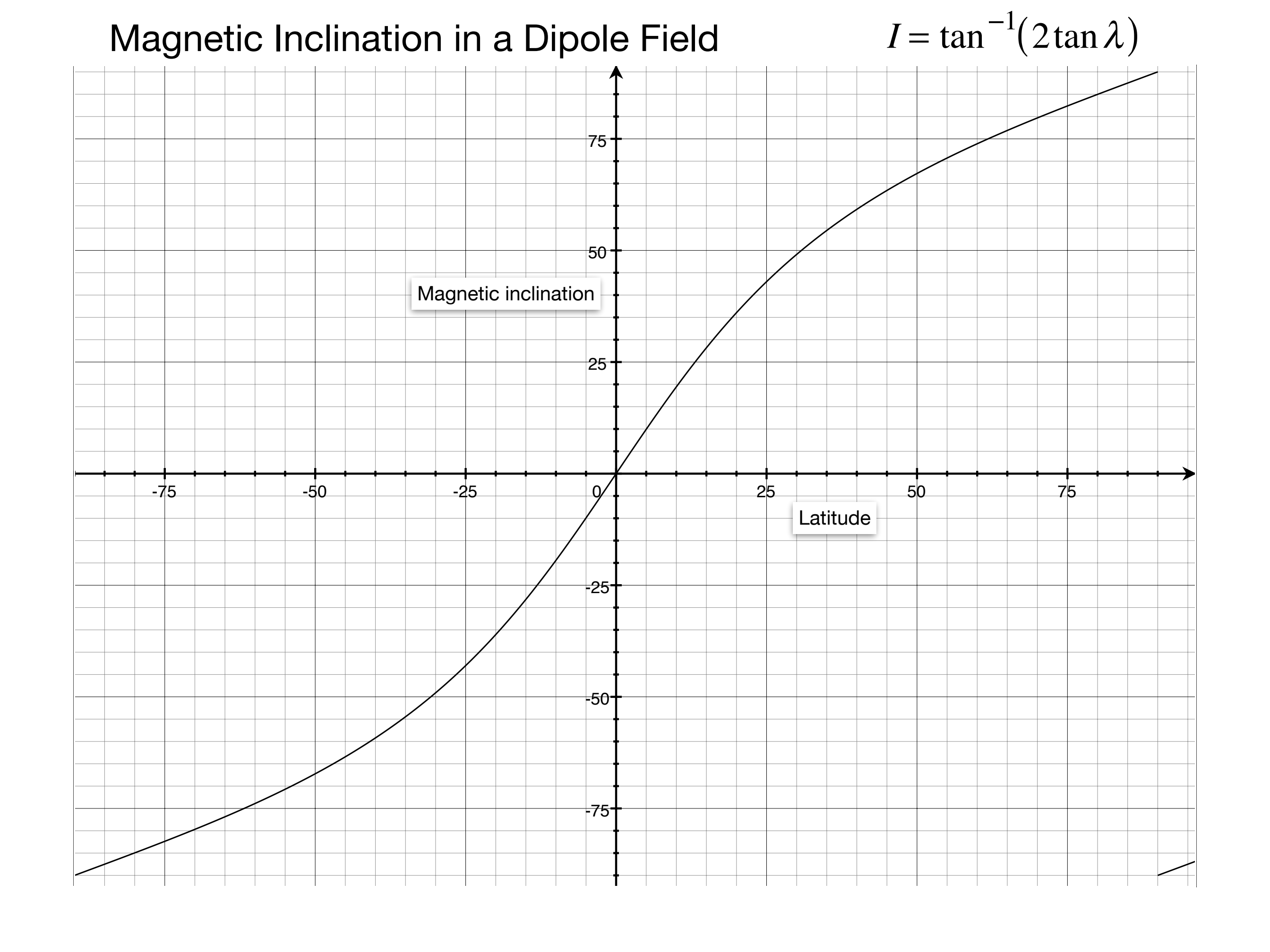

Geographic north pole
Magnetic north pole
Equator

Paleomagnetism and latitude



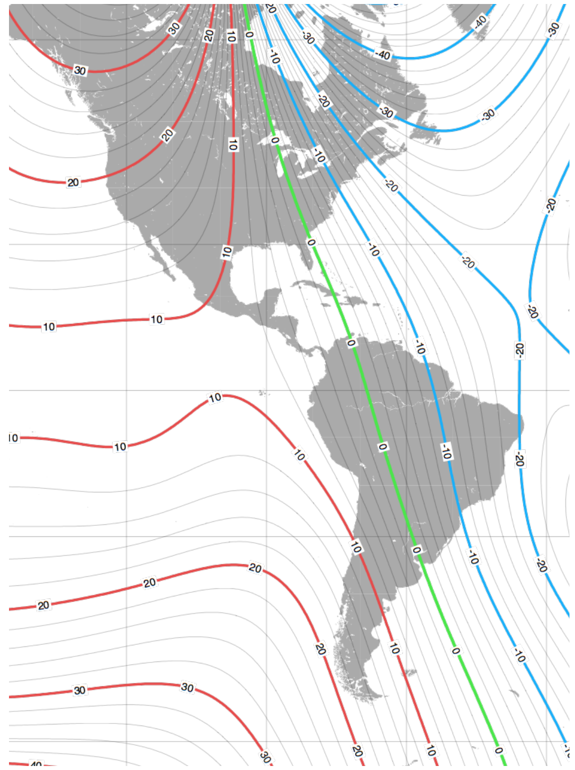
A cooling igneous rock or a new sedimentary rock can record the direction of the magnetic field

$$I = \tan^{-1}(2\tan\lambda)$$

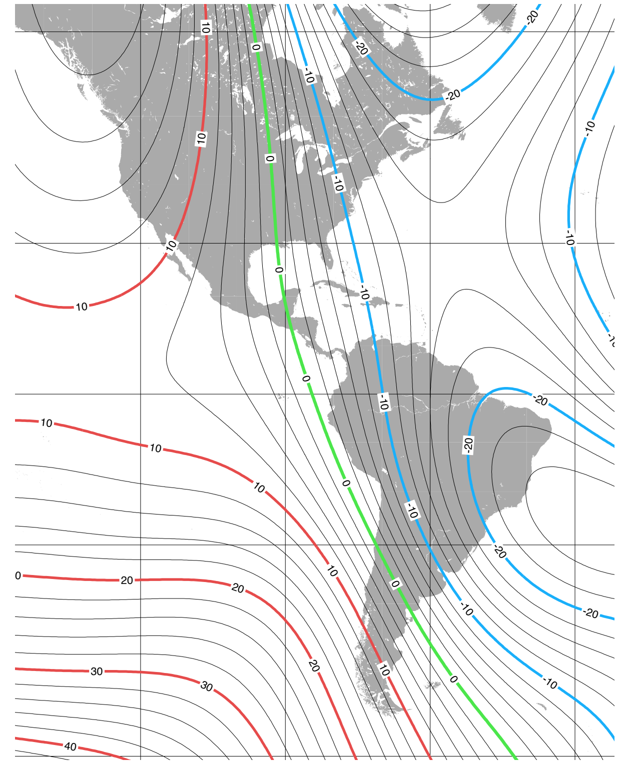

Magnetic Inclination in a Dipole Field
$I = \tan^{-1}(2\tan\lambda)$
Magnetic inclination
Latitude
75
50
25
0
-25
-50
-75

Magnetic Declination

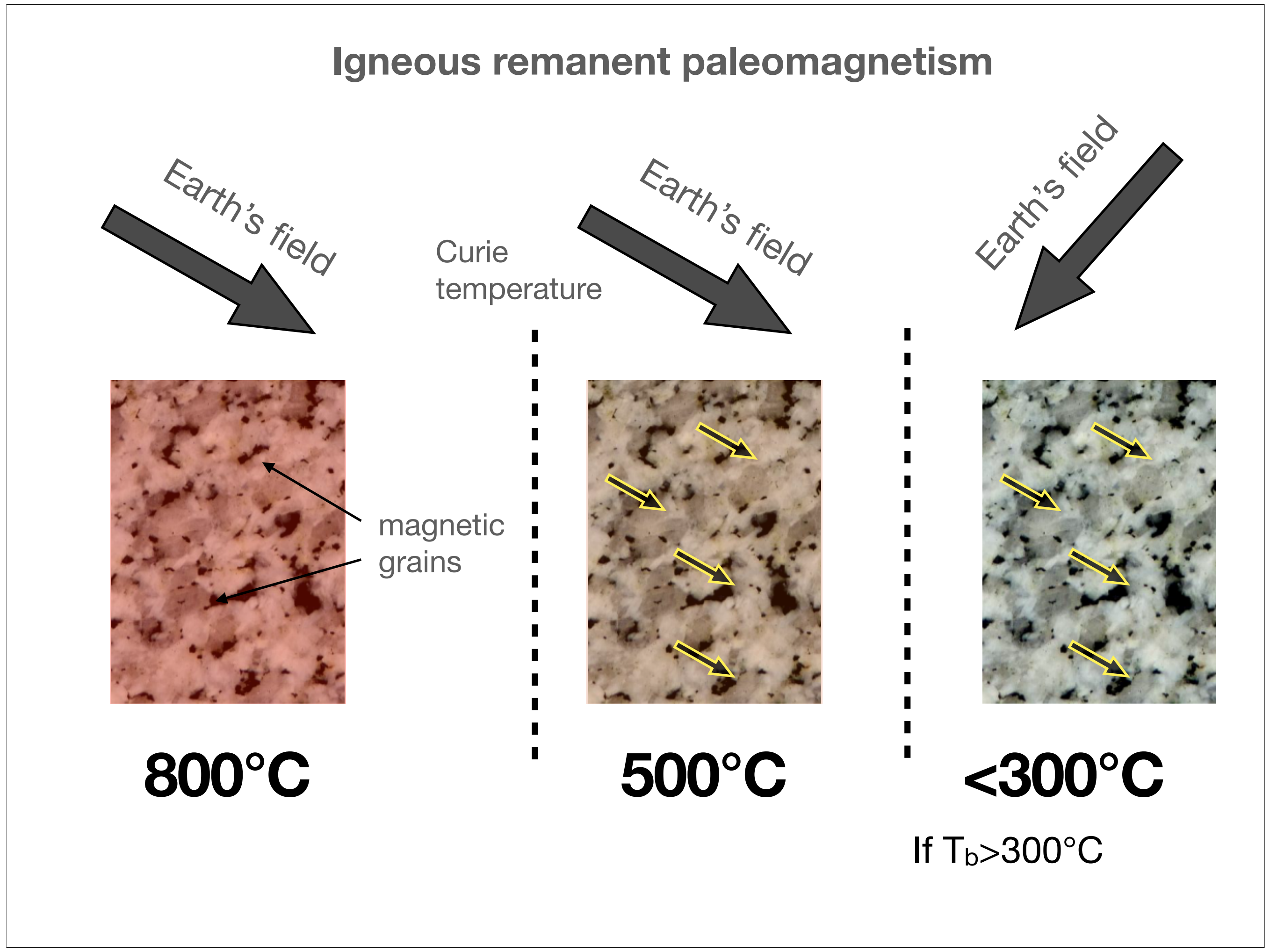
1945



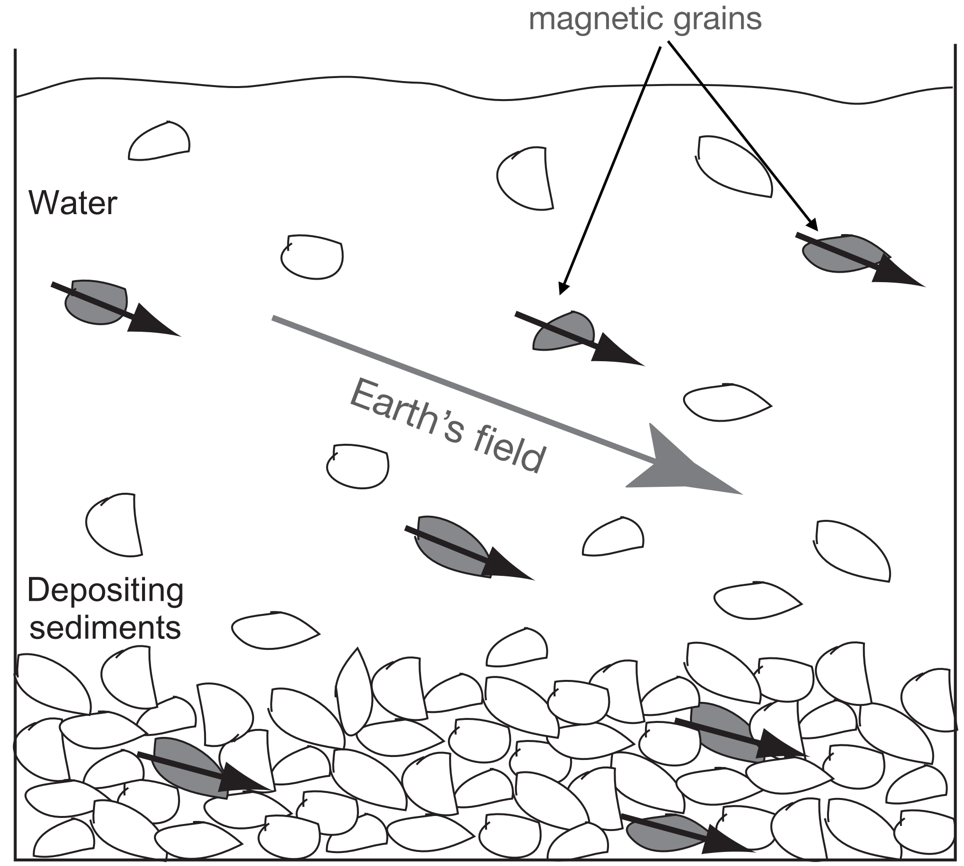
2020



https://www.ngdc.noaa.gov/geomag/data/mag_maps/pdf/


Igneous remanent paleomagnetism
Earth's field
Curie
temperature
Earth's field
Earth's field
magnetic
grains
800°C
500°C
<300°C
If Tb>300°C

Sedimentary remanent paleomagnetism



Ziegler and Kodama, *Terrestrial Depositional Systems,* 2017

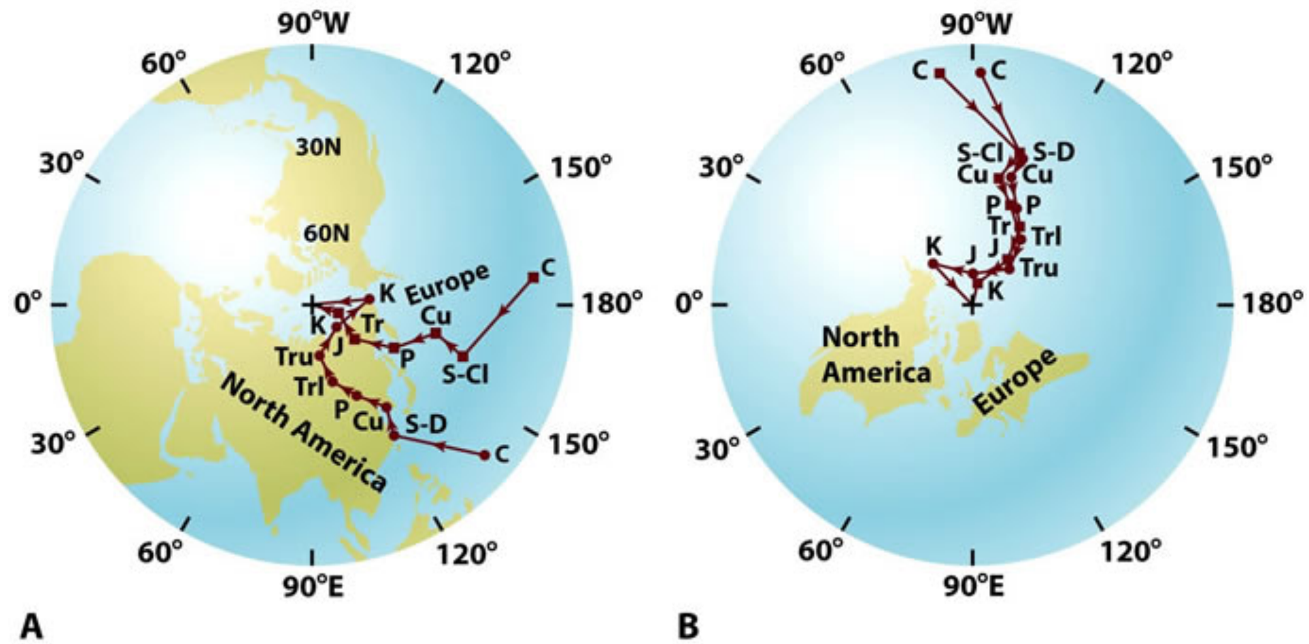
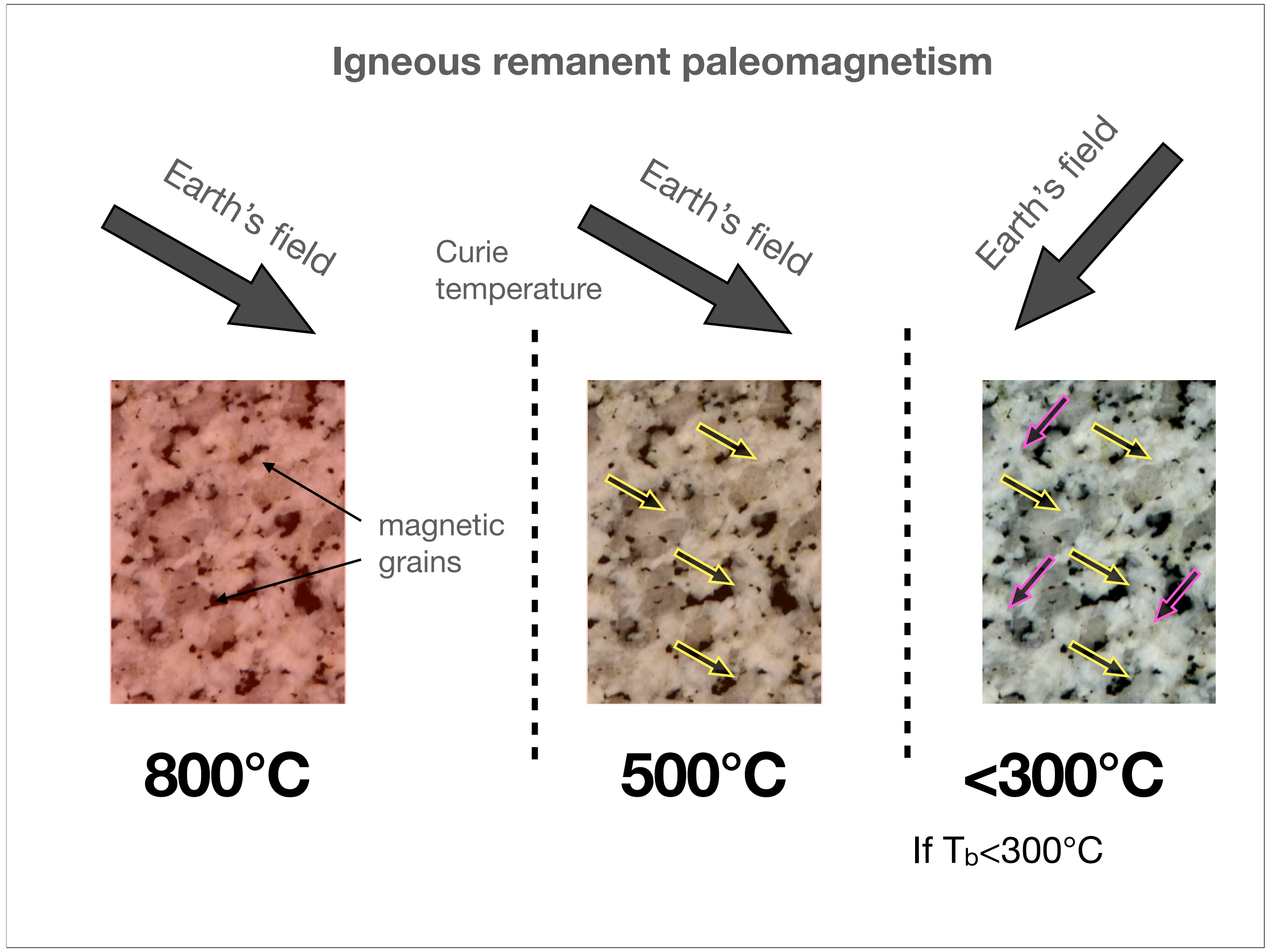
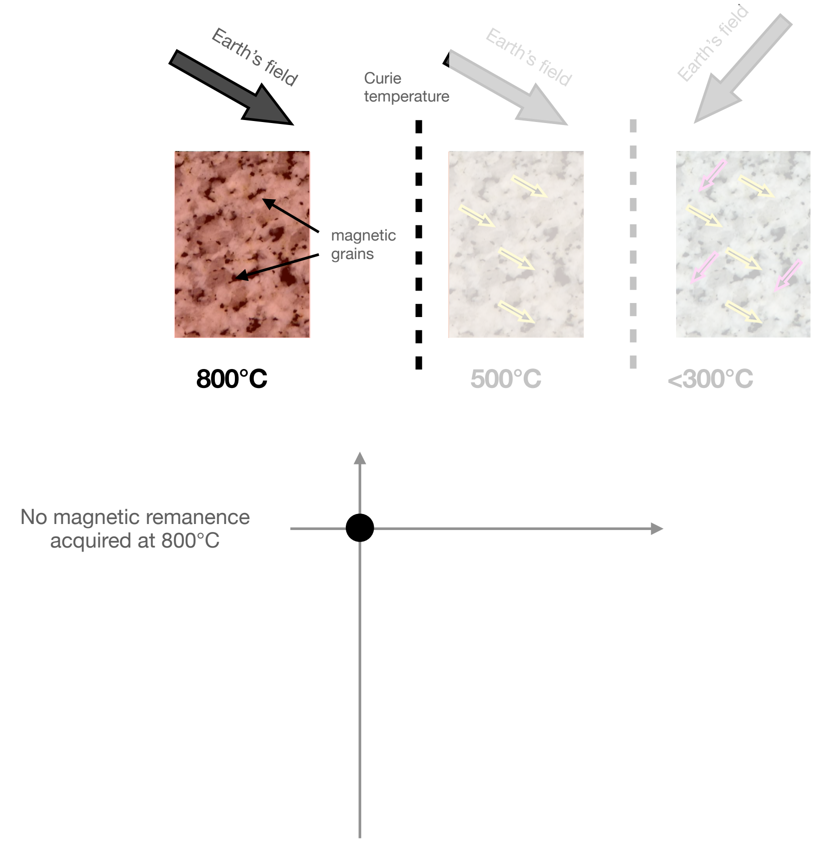


Figure 8-12
Earth System History, Second Edition

Mineral	Composition	Curie Point	Origin
Magnetite	Fe_3O_4	580°C	Magmatic, occasional metamorphic and chemical
Titanomagnetite	$Fe_2\ Fe_x\ Ti_{1-x}O_4$	150-580°C	"
Hematite	α-Fe_2O_3	675°C	Often sedimentary, chemical, sometimes magmatic, metamorphic
Maghemite	γ-Fe_2O_3	590-675°C —goes to hematite above 250-750°C	Chemical
Pyrrhotite	FeS_{1+x}, $0<x\leq 0.14$	320°C	Magmatic, chemical
Goethite	α-FeOOH	120°C (dehydrates 100-300°C)	Chemical (weathering)
Lepidocrocite	γ-FeOOH	Below room temperature (dehydrates 250°C to maghemite)	Chemical (weathering)
Greigite	Fe_3S_4	~330°C	Chemical (anoxic sediments)


Igneous remanent paleomagnetism
Earth's field
Earth's field
Earth's field
Curie temperature
magnetic grains
800°C
500°C
<300°C
If Tb<300°C

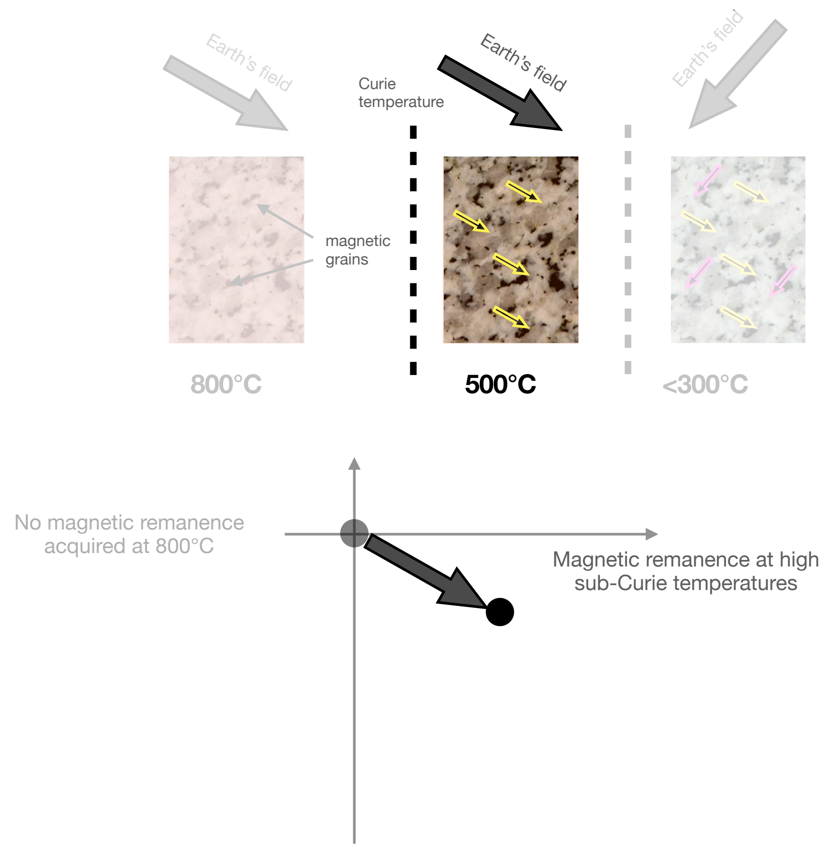
Igneous remanent paleomagnetism



$$M(t) = M_0 e^{-t/\tau}$$

$$\tau = \frac{1}{C} e^{\left(\frac{vK}{kT}\right)}$$

Igneous remanent paleomagnetism



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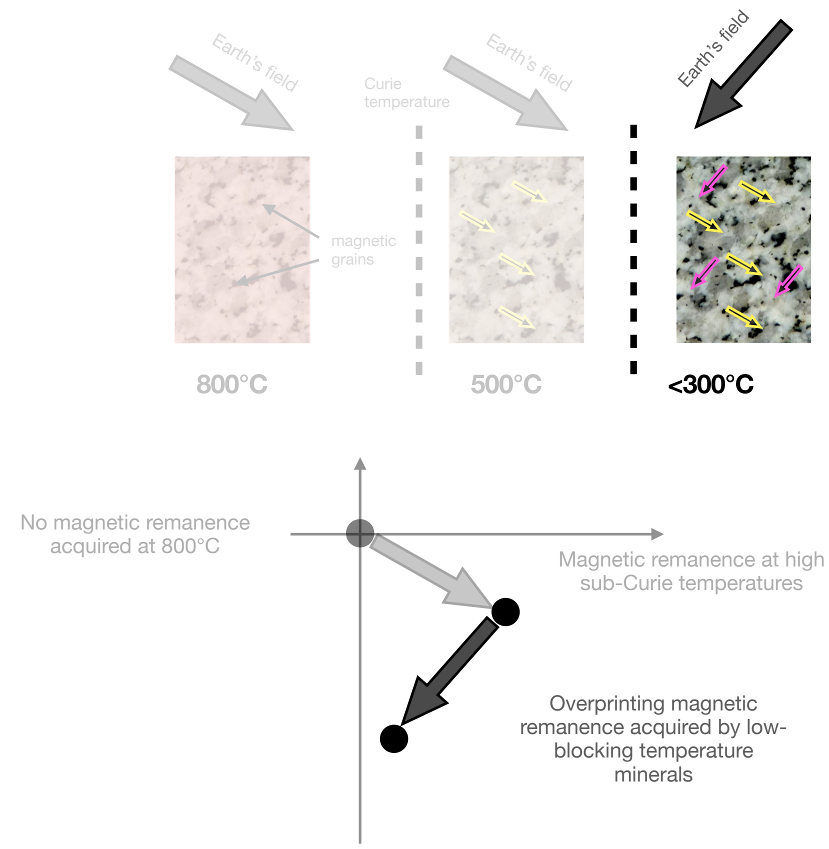
Igneous remanent paleomagnetism



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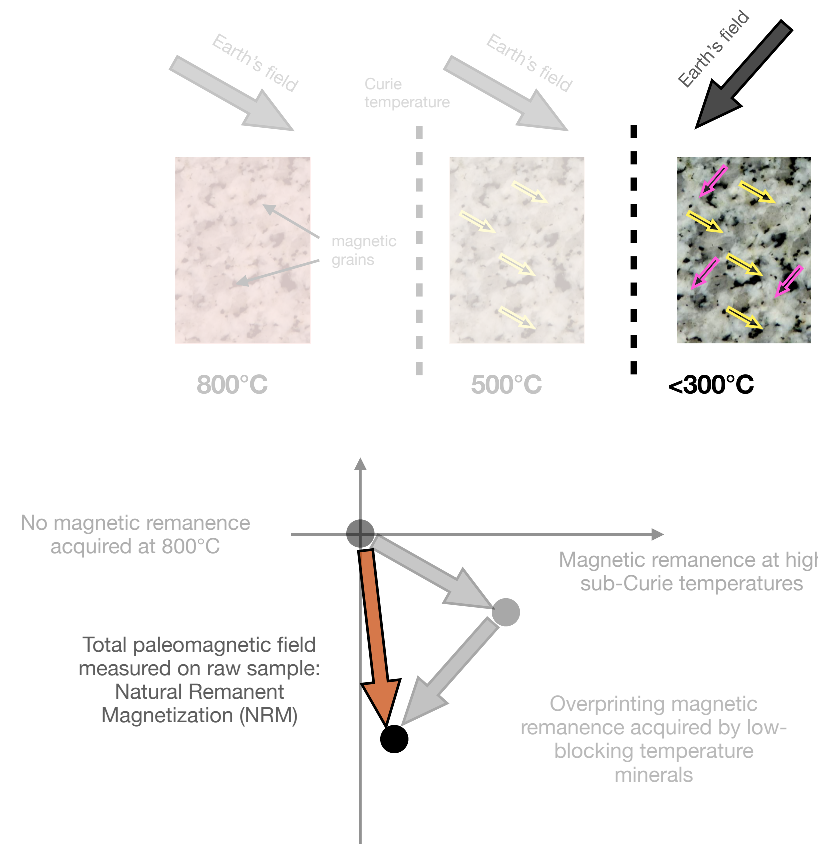
$$\tau = \frac{1}{C} e^{\left(\frac{vK}{kT}\right)}$$

Igneous remanent paleomagnetism



$$M(t) = M_0 e^{-t/\tau}$$

$$\tau = \frac{1}{C} e^{\left(\frac{vK}{kT}\right)}$$

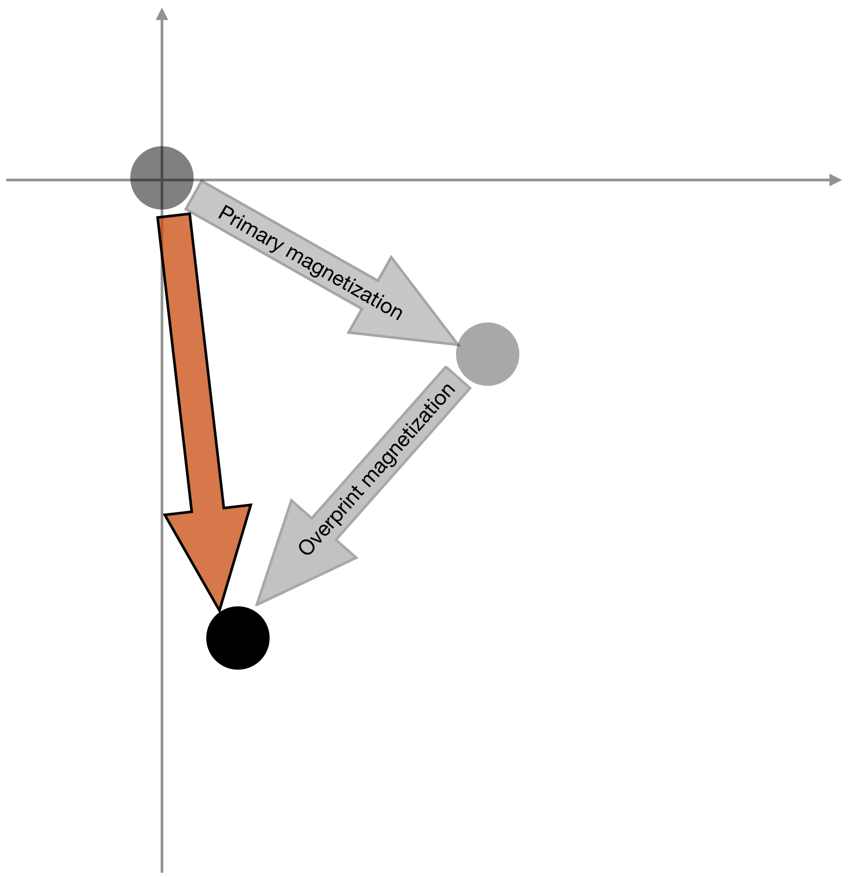
Igneous remanent paleomagnetism

So raw measurements of rocks rarely reveals the "original" primary magnetization.

Demagnetization seeks to run the acquisition of magnetization backwards…

Thermal demagnetization is perhaps most intuitive

$$T_1 \ln C\tau_1 = T_2 \ln C\tau_2$$



Igneous remanent paleomagnetism

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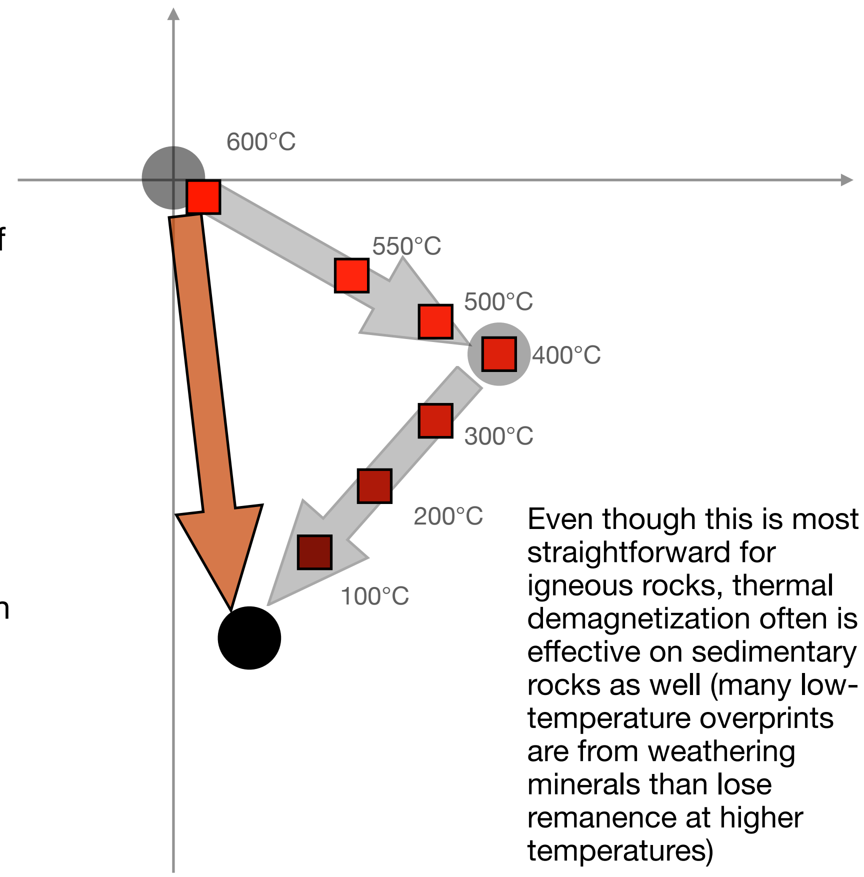
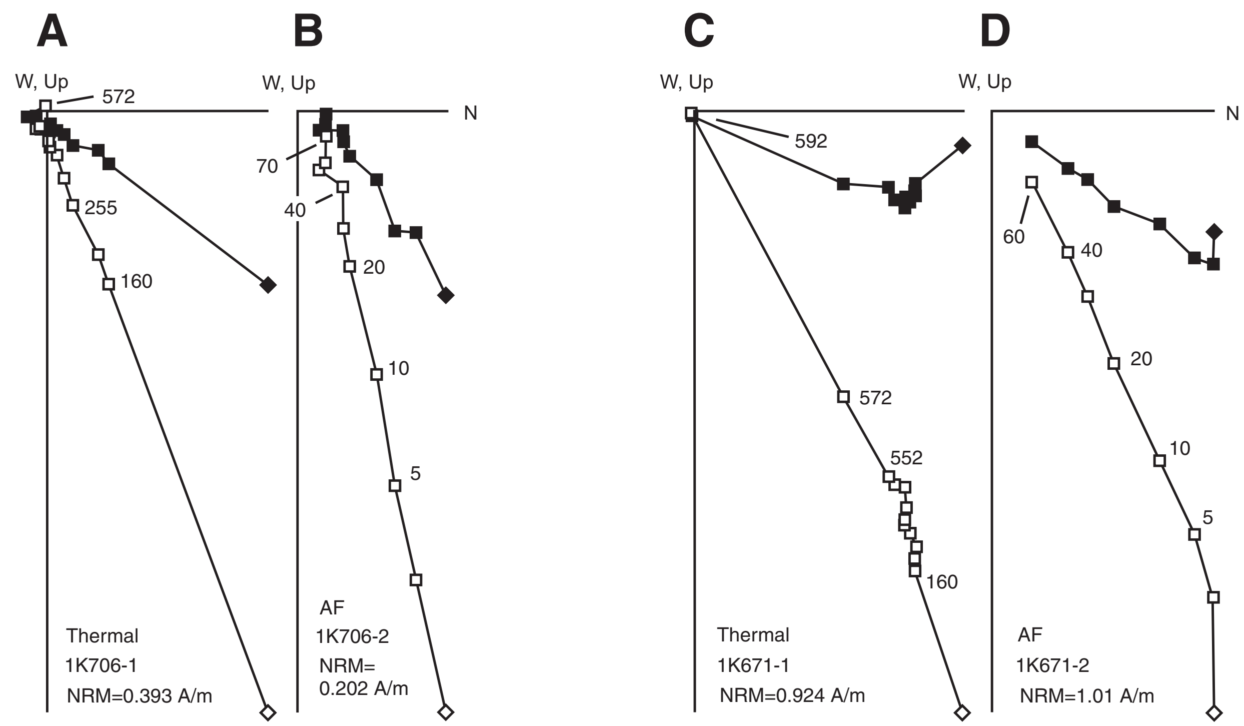


Even though this is most straightforward for igneous rocks, thermal demagnetization often is effective on sedimentary rocks as well (many low-temperature overprints are from weathering minerals than lose remanence at higher temperatures)

Demagnetization Curves

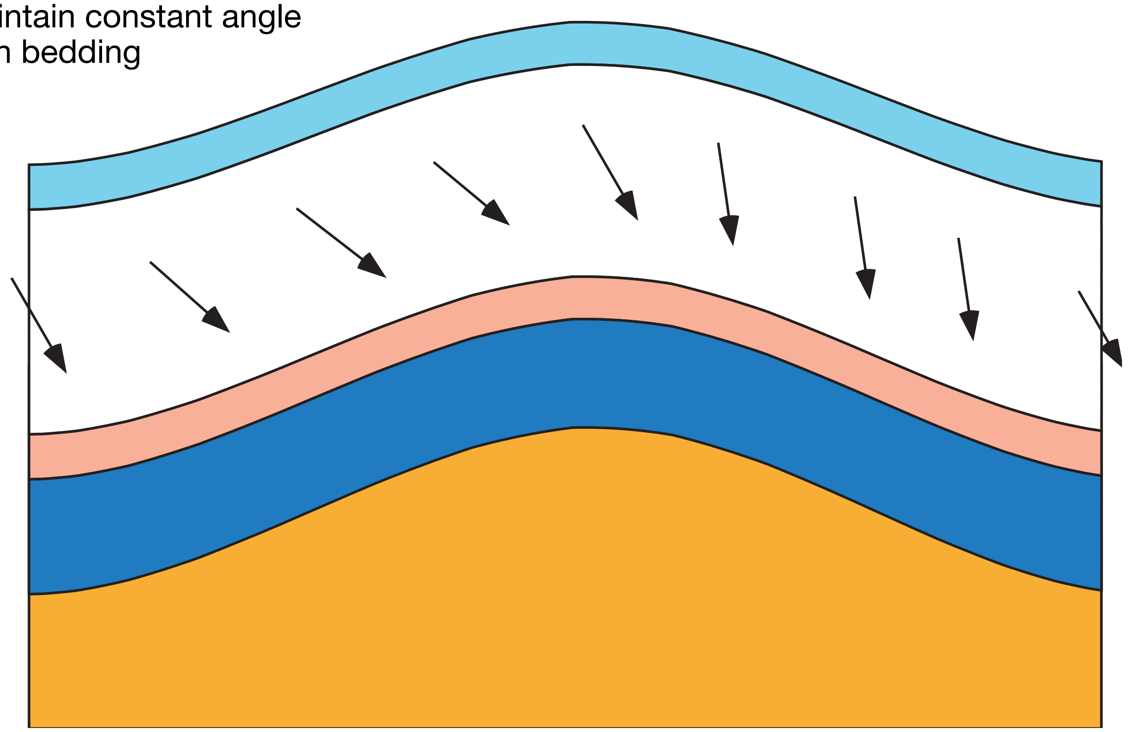


Rusmore et al., *Lithosphere*, 2013
Solid are horizontal projection, open are vertical.

Paleomagnetism tests

Fold test:

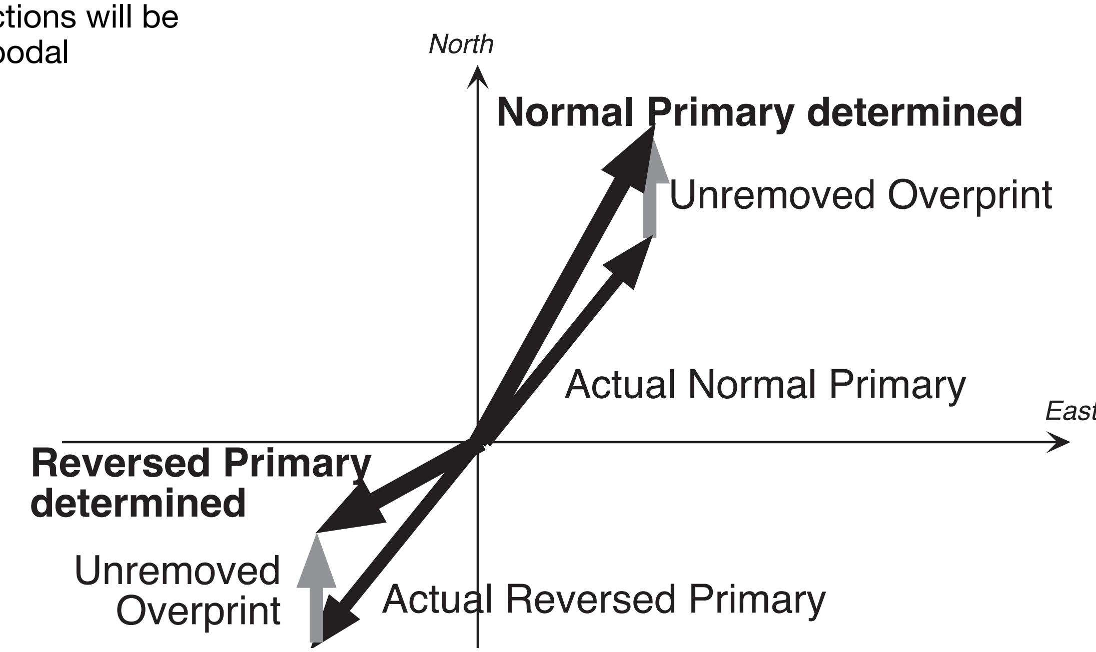
Magnetization acquired at deposition will maintain constant angle with bedding



Paleomagnetism tests

Reversal test:

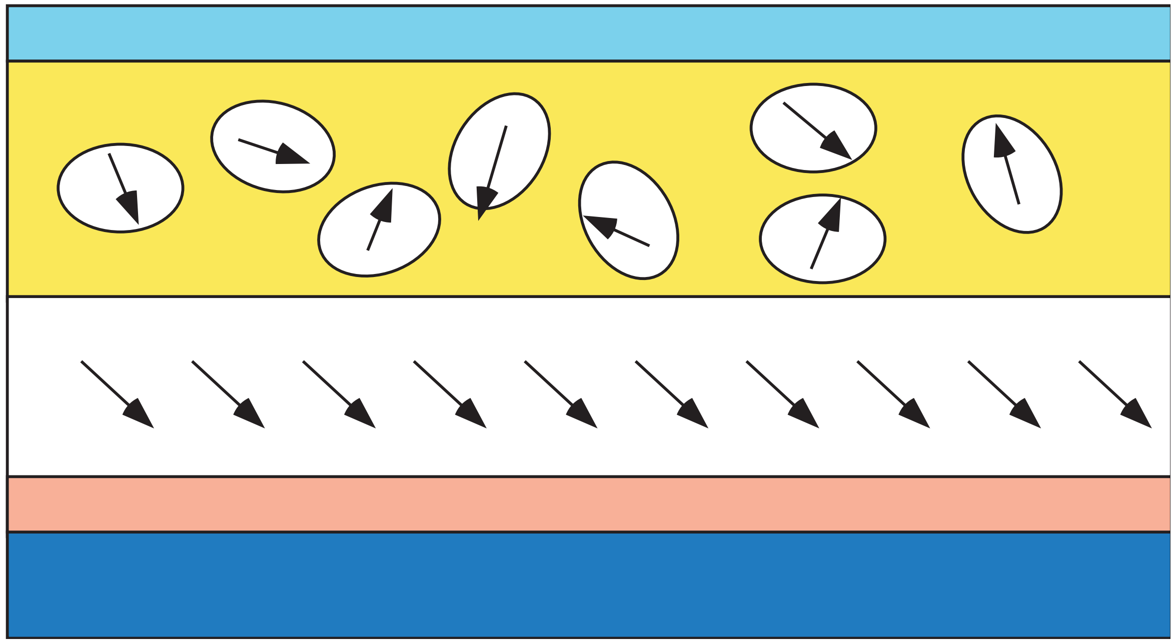
Normal and reversed directions will be antipodal



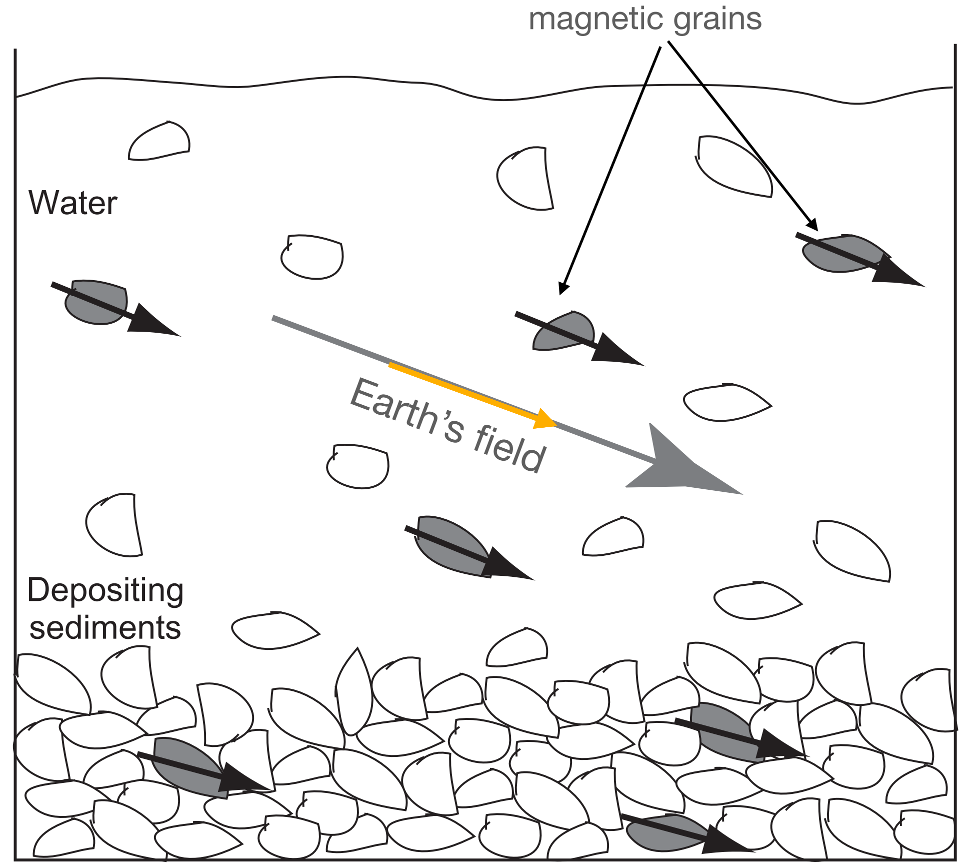
Paleomagnetism tests

Conglomerate test:

Magnetization in cobbles will be random if not overprinted

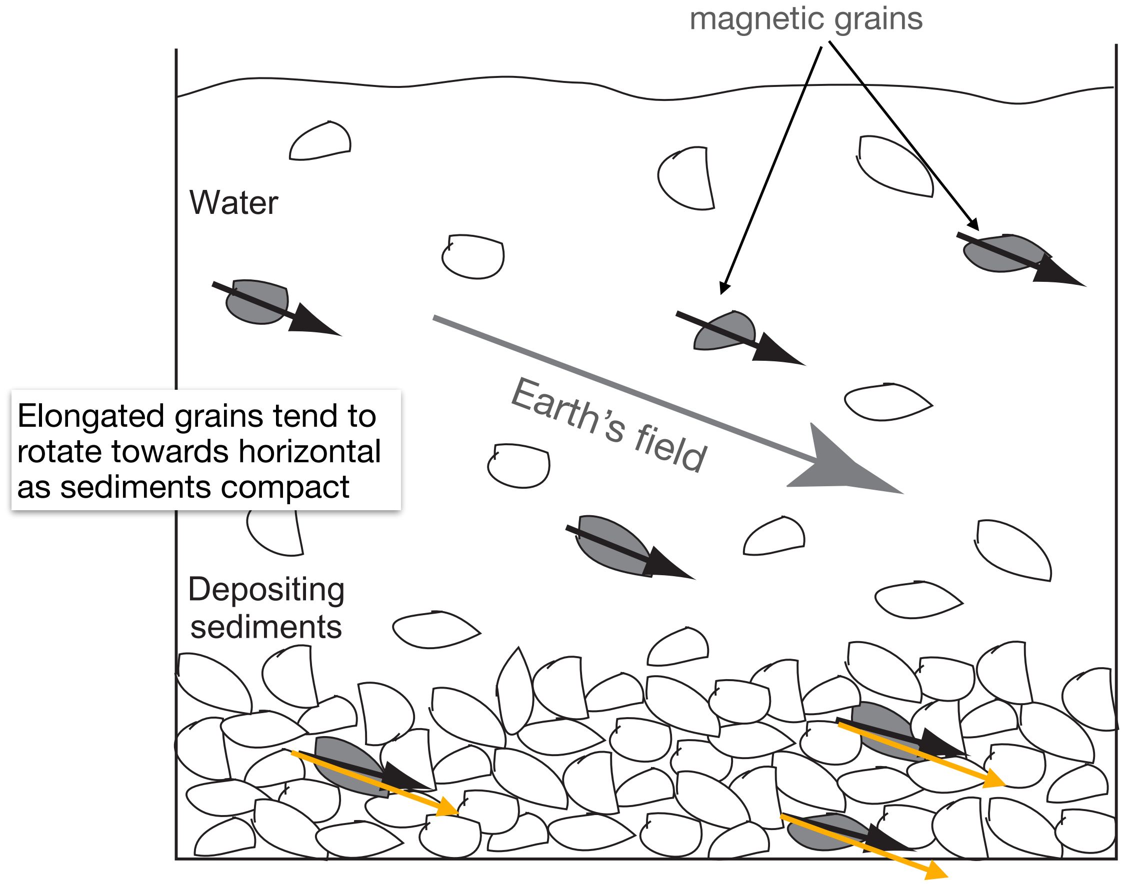


Sedimentary remanent paleomagnetism: Flattening



Ziegler and Kodama, *Terrestrial Depositional Systems,* 2017

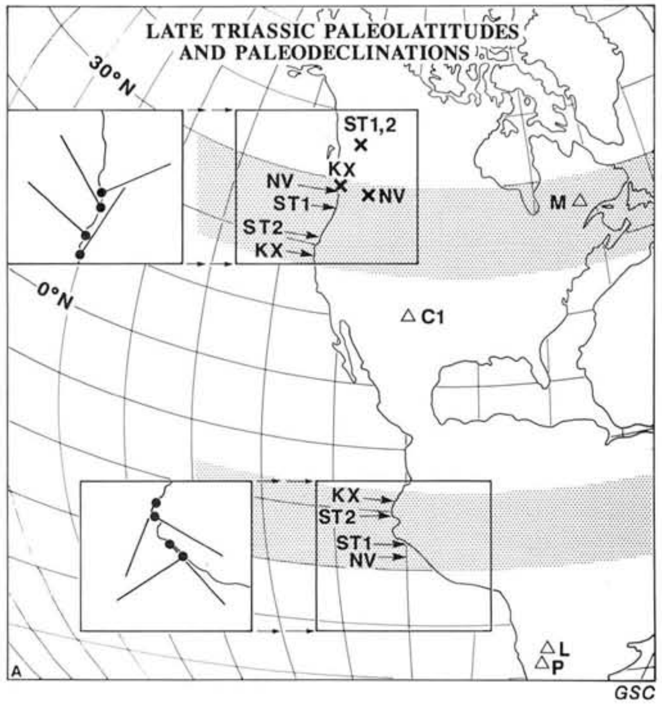
Sedimentary remanent paleomagnetism: Flattening



Ziegler and Kodama, *Terrestrial Depositional Systems,* 2017

Remanent paleomagnetism: Hemispheric ambiguity

In tectonically active areas, large rotations about a vertical axis are possible, so could be in either hemisphere.



Irving and Wynne, DNAG v. G-2, 1991

Igneous remanent paleomagnetism: Paleohorizontal ambiguity

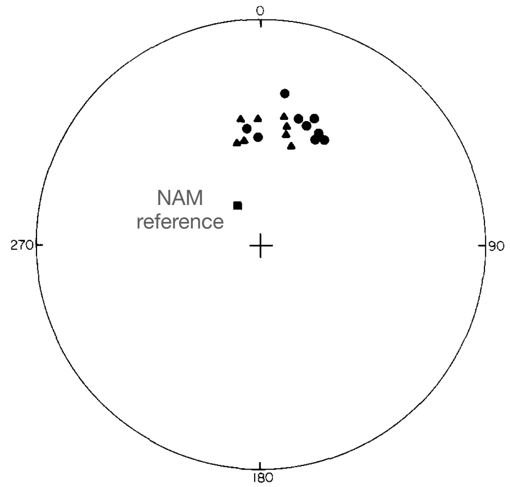
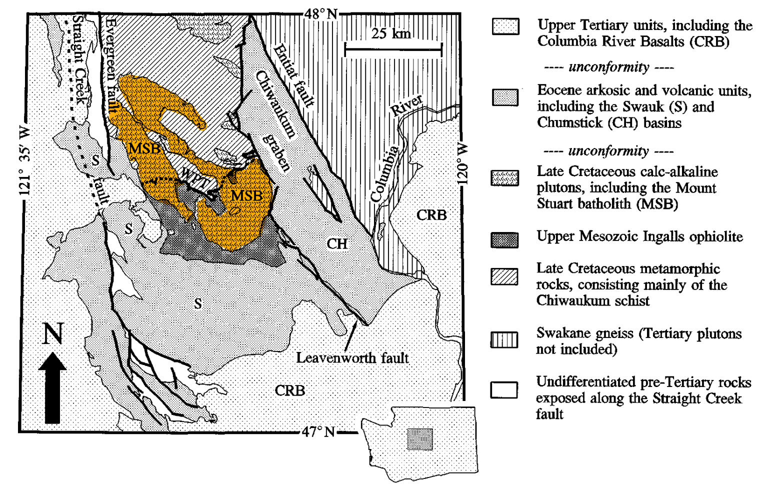


Fig. 3. Equal-area projection on the lower hemisphere, showing site-mean directions of magnetism for the Mt. Stuart batholith. Symbols are keyed to Fig. 4; eastern sites are shown by triangles, western sites by circles. The solid square represents the Cretaceous expected direction at the present latitude and longitude of the Mt. Stuart rocks, calculated from Mankinen [19].

Beck et al., EPSL, 1981

AGUE AND BRANDON



Ague & Brandon, GSA Bull, 1996

Attention focused on one pluton for what could be wrong in pmag...

Igneous remanent paleomagnetism: Paleohorizontal ambiguity

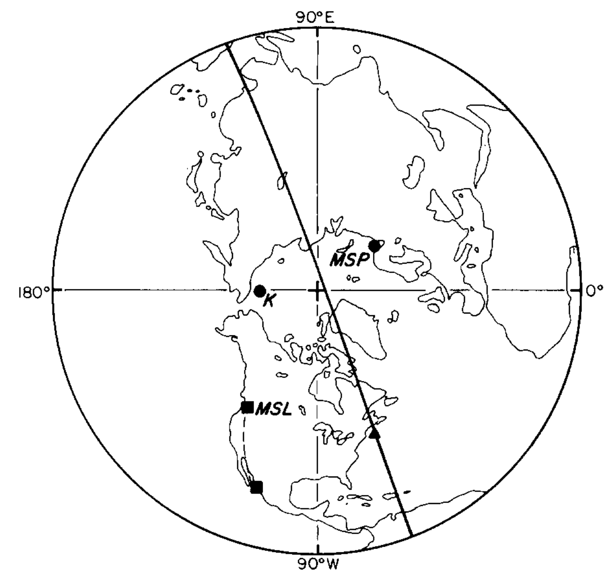


Fig. 5. A tectonic-transport ("microplate") solution. *MSL* = location of Mt. Stuart Batholith; *MSP* = Mt. Stuart paleomagnetic pole; *K* = Cretaceous reference pole for North America. The heavy curve bisects the distance between *K* and *MSP* and therefore is the locus of all possible Euler poles about which *K* can be displaced to *MSP* by a single finite rotation. The triangle shows the unique rotation pole that results from assuming that the Mt. Stuart Batholith originated on the edge of North America. *MSL* is shown rotated back to western Mexico about this pole.

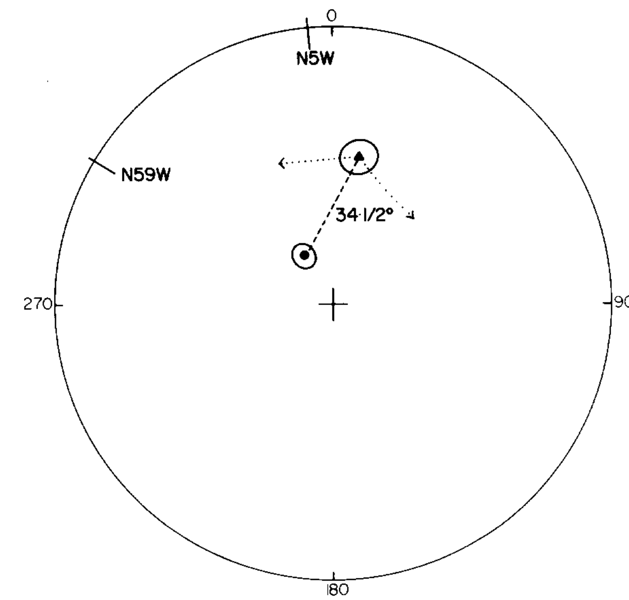
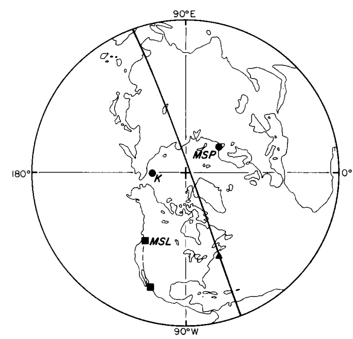


Fig. 6. A tilt solution. Circle is the Cretaceous expected direction, with circle of confidence; triangle is the observed direction for the Mt. Stuart Batholith, also with circle of confidence. A rotation of 34.5° about a fold-axis trending N59W will bring the two into coincidence. Tilt to the southeast or west does not reduce the discordance.

Beck et al., EPSL, 1981

could translate or tilt....

Igneous remanent paleomagnetism: Paleohorizontal ambiguity



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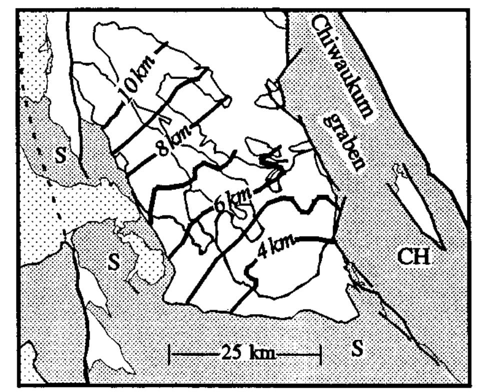


Undifferentiated Upper Tertiary units

---- *unconformity* ----

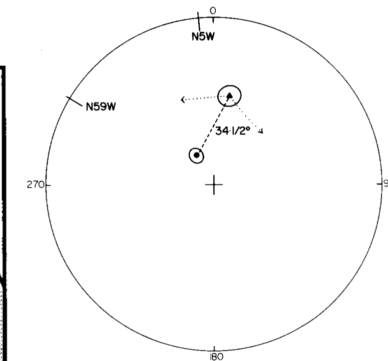
Eocene arkosic and volcanic units, including Swauk (S) and Chumstick (CH) basins

---- *unconformity* ----

Undifferentiated pre-Tertiary rocks

Figure 10. Depth contours computed from the best-fit paleosurface by determining the intersection of the present topography with surfaces of constant crystallization depth (cf. text and Fig. 2A).

Ague & Brandon, GSA Bull, 1996



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Beck et al., EPSL, 1981