
GEOMAGNETISM,
PALEOMAGNETISM,
MAGNETOSTRATIGRAPHY
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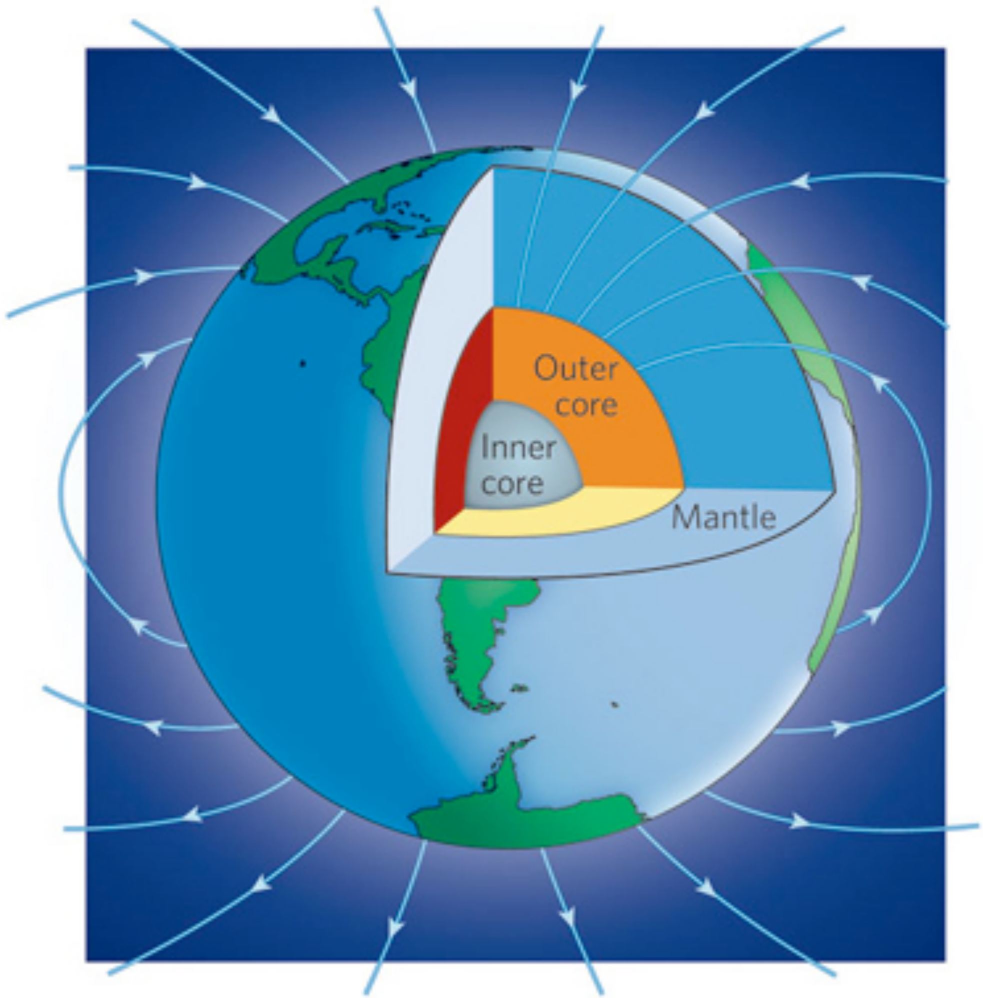
# definitions

- **Geomagnetism**
  – studies the current magnetic field of Earth
- **Paleomagnetism**
  – studies the ancient magnetic field of Earth, as recorded in rocks
- **Magnetic Stratigraphy**
  – takes advantage of magnetic properties of rocks to subdivide the rock record in distinct stratigraphic units

# Geomagnetism (a quick review)

- Studied when discussing Plate Tectonics
- Core, mantle, crust
- Outer core is made of spinning liquid iron:
  - metallic bond
  - electrons in motion generate electric current
  - electric current generates electromagnetic field

# Earths' magnetic field today



- The magnetic field can be recorded in rocks

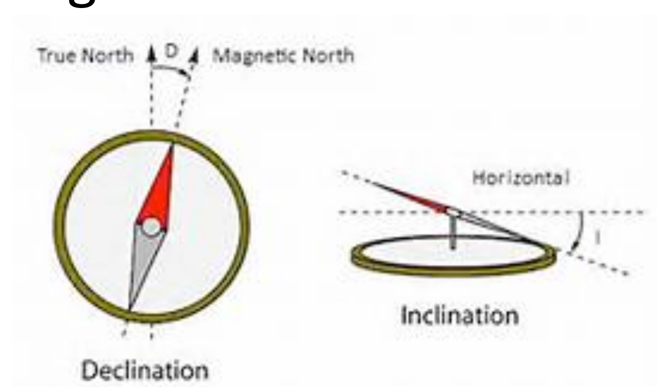
- Best record is in extrusive, Fe-rich igneous rocks

- Many rocks contain minerals that are naturally magnetic, such as
  - magnetite ($Fe_3O_4$)
  - hematite ($Fe_2O_3$)

# Magnetic properties recorded in rocks

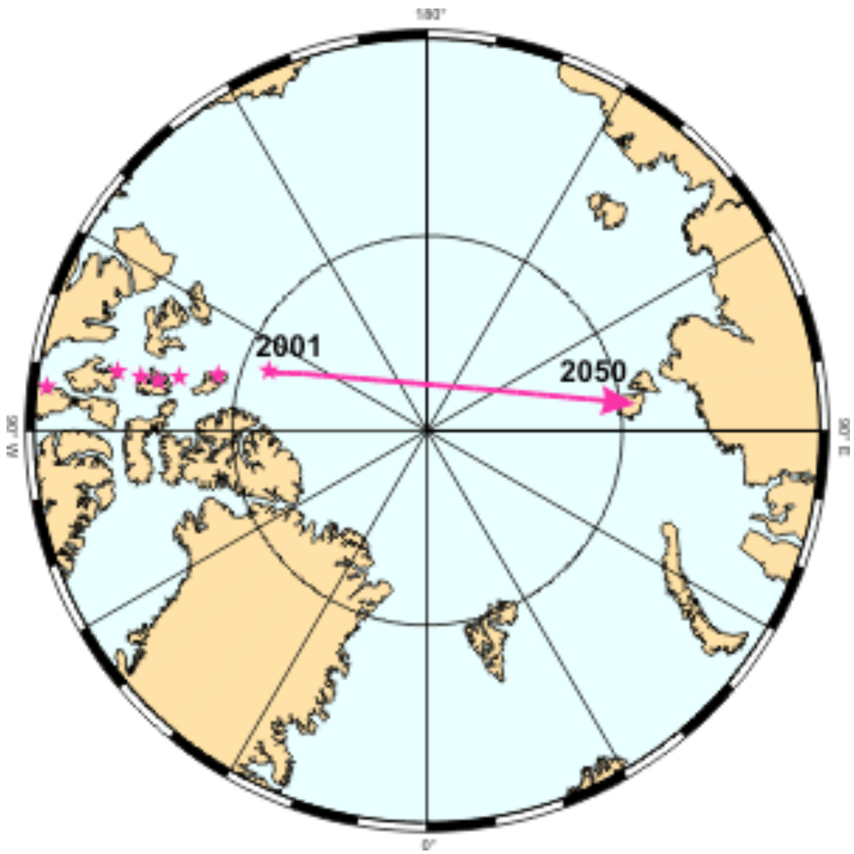
- Every single point on Earth is characterized by its own specific magnetic properties, which can be recorded in rocks

- Declination
  - angle between the true north (that is, the NP) and the magnetic North (NMP).
- Inclination
  - angle between the direction of the magnetic field and the horizontal surface
- Intensity
  - how strong the field is in a rock

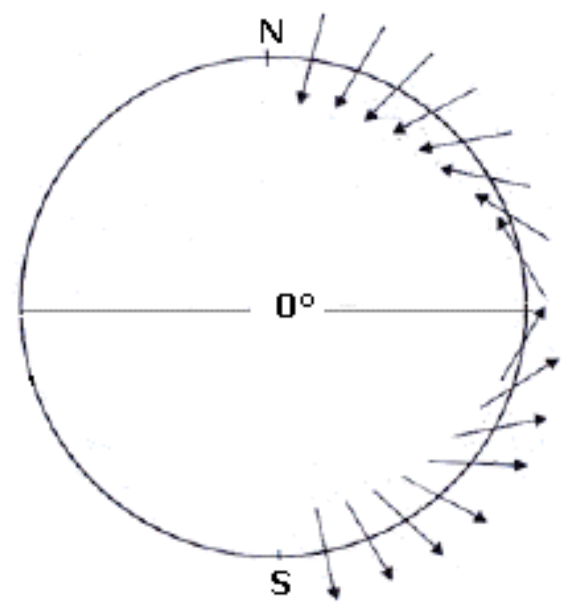


- The North Magnetic Pole (NMP) does not coincide with the geographic North Pole (NP)

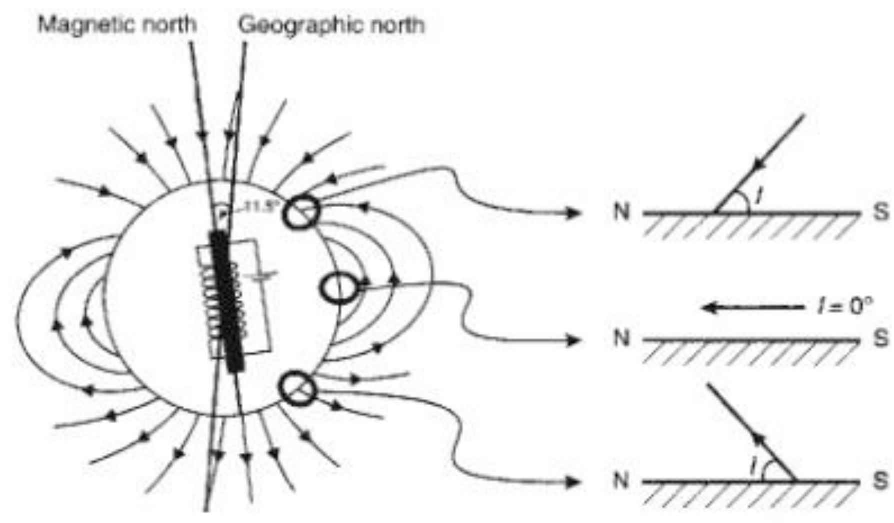
- The position of the NMP varies yearly



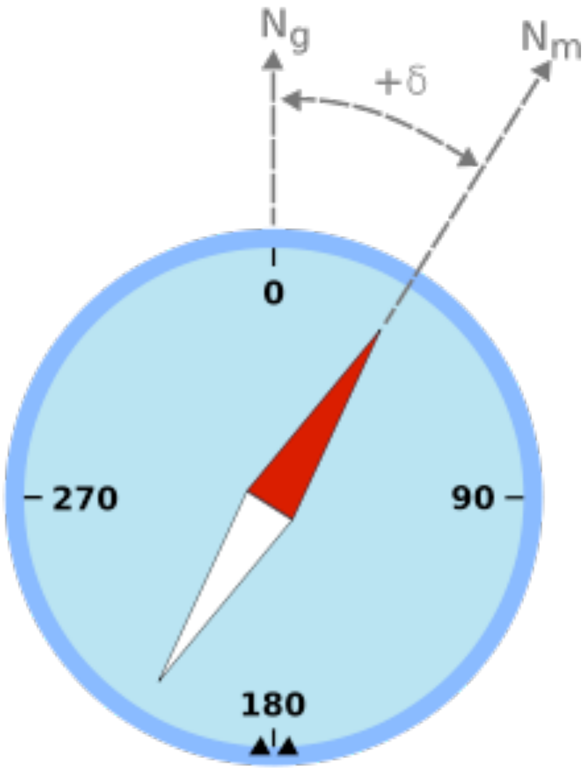
# Inclination

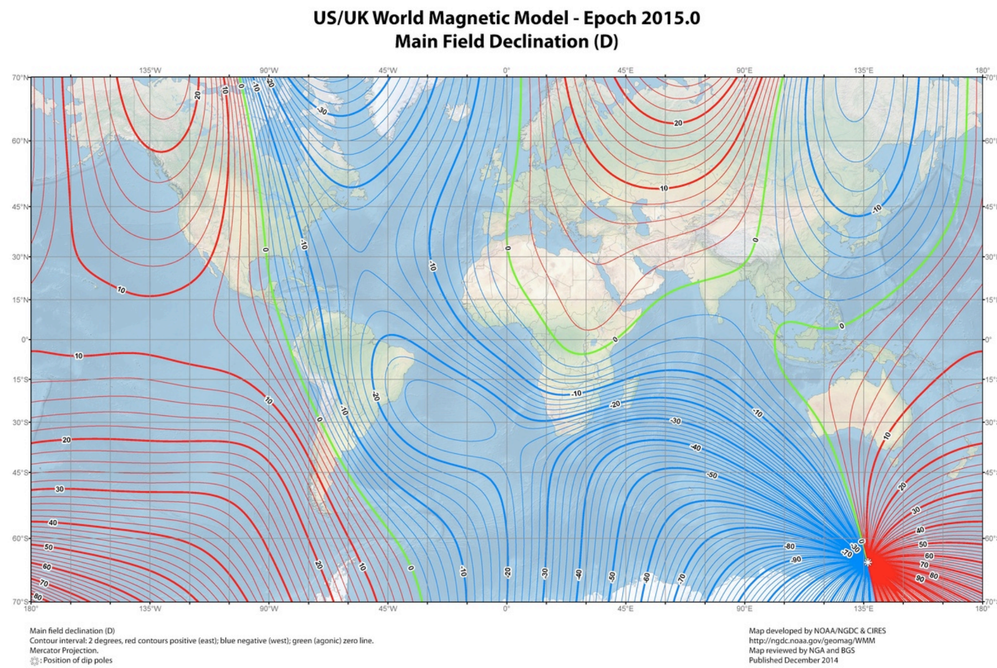



**Magnetic inclination related to latitude**



# Declination



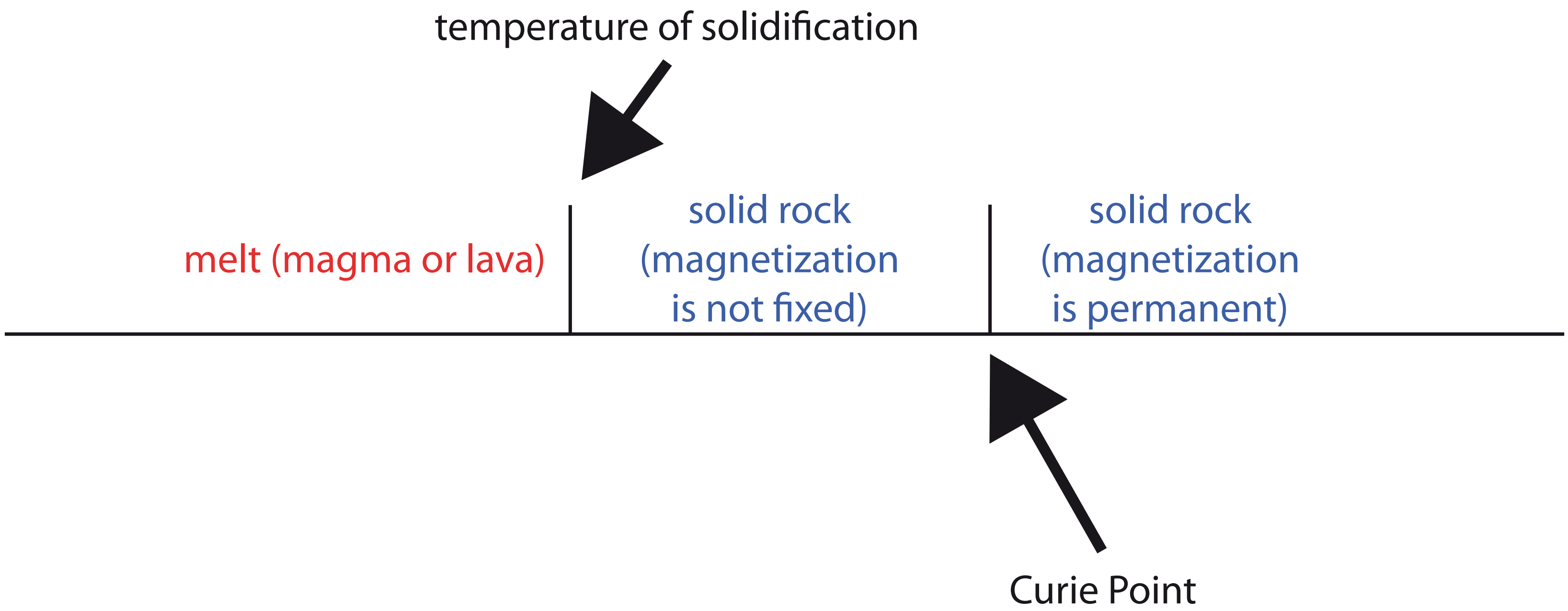



- When minerals become oriented in the direction of the magnetic field of the time, they are said to have acquired a **PERMANENT MAGNETIZATION**

- In general, there are three different ways in which permanent magnetization can be obtained:
  - Thermal Remanent Magnetization (TRM)
  - Detrital Remanent Magnetization (DRM)
  - Chemical Remanent Magnetization (CRM)

# TRM

- During the process of igneous rocks solidification, magma (or lava) cool to a solid state
- Every mineral solidifies at its own temperature
- After solidification, cooling may continue below a threshold value, called the **Curie Point**
- In the interval between the solidification temperature and the Curie Point, magnetization can be changed
- Below the Curie Point, it becomes permanent




- in a mafic igneous rock, crystals (such as amphiboles and pyroxenes) will orient themselves in the direction of the magnetic field upon cooling

- when temperature drops below the Curie Point, that is it: magnetization is LOCKED in the crystal

- TRM is very important in basaltic lavas because:
  - they are rich in iron
    - that means a lot of magnetic indicators
  - they cool quickly
    - that means that the time frame is very short

# DRM

- Sedimentary rocks can acquire a DRM when magnetic grains (for instance, sand grains of magnetite) are eroded, transported and then deposited

- for instance, in a river bar, grains of magnetite can be realigned in the direction of the magnetic field

- DRM is always weaker than TRM

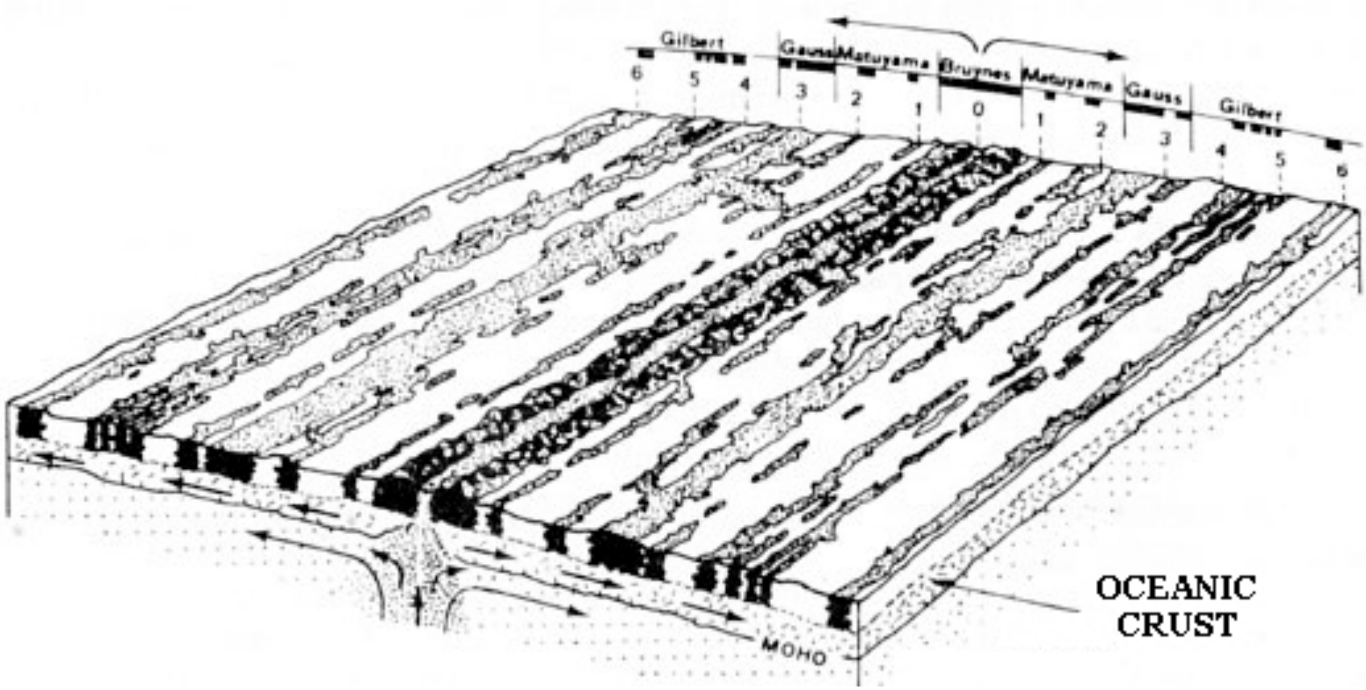
# CRM

- When hematite is deposited as a cement or is moved around during metamorphism, it can acquire the direction of the magnetic field
- Notice that in this case, the CRM belongs to the cement, and not the original sediment (or rock)

- While the NMP oscillates around the NP, statistically (on a geological time scale) it can be said that the two coincide

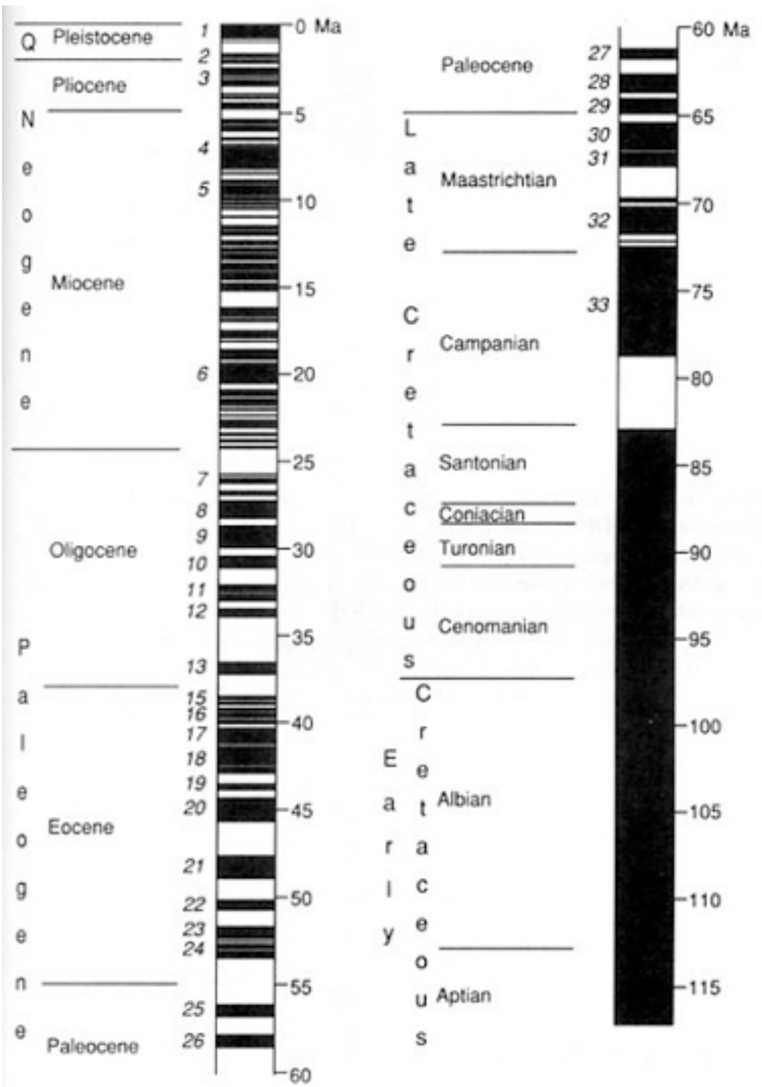
- But, the magnetic field “flips”
  - the NMP switches with the SMPO, and viceversa
  - the needle of a compass would point South instead of North

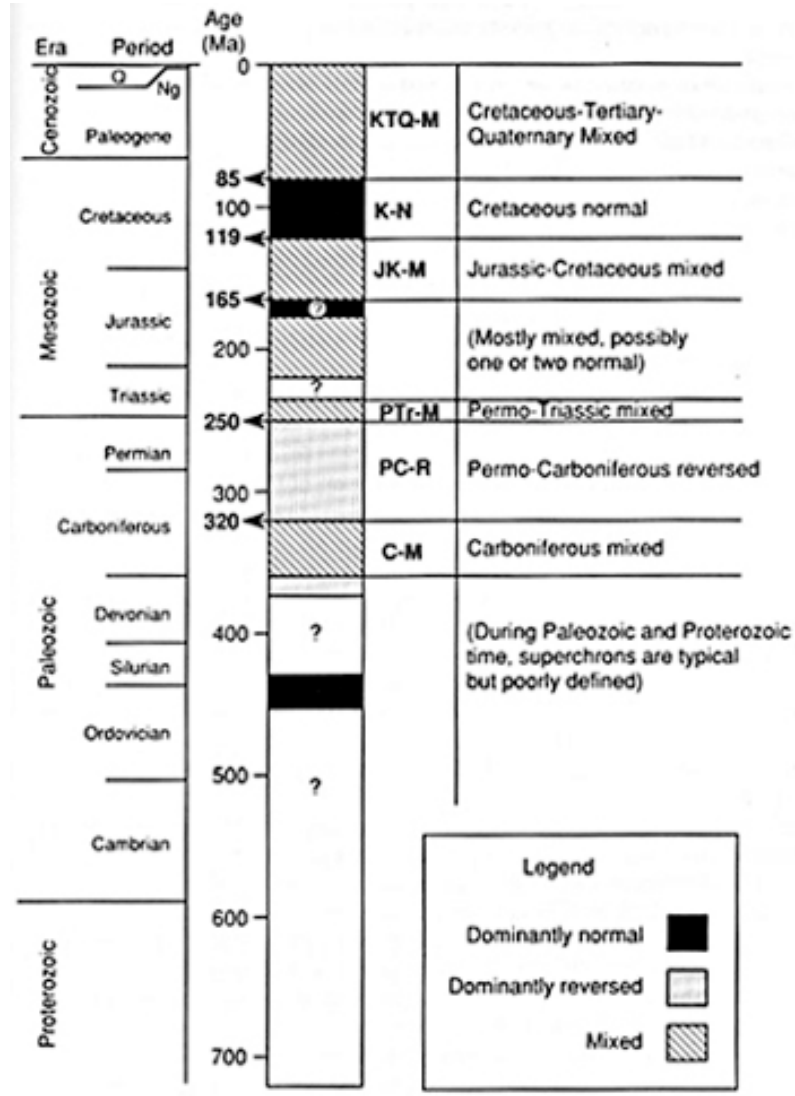
- Today, the compass needle points North
  - we call this a Normal Magnetic Field
- At times in the past, the compass needle pointed South
  - we call this a Reverse Magnetic Field

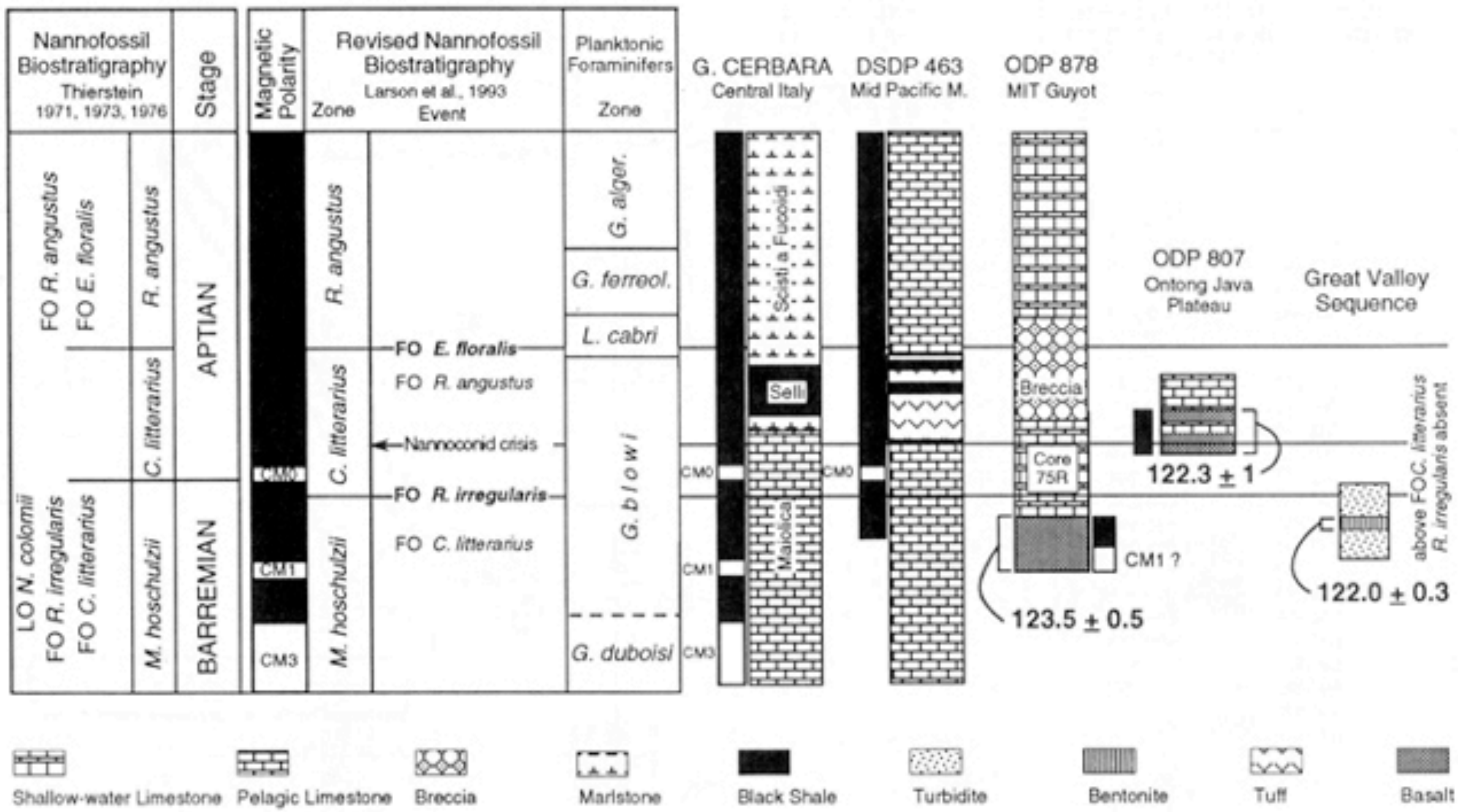

Gilbert
Gauss
Matuyama
Brunhes
Matuyama
Gauss
Gilbert
6
5
4
3
2
1
0
1
2
3
4
5
6
MOHO
OCEANIC
CRUST

- Reversal are of great utility in geology because:
  - they are synchronous
    - they happen at the same time at all locations
  - they are global
    - the whole world is affected at the same time

- As such, reversals are a great tool for CORRELATION
- A geomagnetic scale has been established
- The basic unit is called a Chron
- Chron starts form today (Chron 1 Normal, or C1N) and go back in time


Q
Pleistocene
Pliocene
Neogene
Miocene
Oligocene
Paleogene
Eocene
Paleocene
1
2
3
4
5
6
7
8
9
10
11
12
13
15
16
17
18
19
20
21
22
23
24
25
26
0 Ma
5
10
15
20
25
30
35
40
45
50
55
60
Paleocene
Late Cretaceous
Maastrichtian
Campanian
Santonian
Coniacian
Turonian
Cenomanian
Early Cretaceous
Albian
Aptian
27
28
29
30
31
32
33
60 Ma
65
70
75
80
85
90
95
100
105
110
115


Era
Period
Age (Ma)
Cenozoic
Q
Ng
Paleogene
Mesozoic
Cretaceous
Jurassic
Triassic
Paleozoic
Permian
Carboniferous
Devonian
Silurian
Ordovician
Cambrian
Proterozoic
0
85
100
119
165
200
250
300
320
400
500
600
700
?
KTQ-M
Cretaceous-Tertiary-Quaternary Mixed
K-N
Cretaceous normal
JK-M
Jurassic-Cretaceous mixed
(Mostly mixed, possibly one or two normal)
PTr-M
Permo-Triassic mixed
PC-R
Permo-Carboniferous reversed
C-M
Carboniferous mixed
(During Paleozoic and Proterozoic time, superchrons are typical but poorly defined)
Legend
Dominantly normal
Dominantly reversed
Mixed


Nannofossil Biostratigraphy
Thierstein 1971, 1973, 1976
Stage
Magnetic Polarity
Revised Nannofossil Biostratigraphy
Larson et al., 1993
Zone
Event
Planktonic Foraminifers
Zone
G. CERBARA
Central Italy
DSDP 463
Mid Pacific M.
ODP 878
MIT Guyot
ODP 807
Ontong Java Plateau
Great Valley Sequence
FO R. angustus
FO E. floralis
R. angustus
C. litterarius
LO N. colomii
FO R. irregularis
FO C. litterarius
M. hoschulzii
APTIAN
BARREMIAN
CM0
CM1
CM3
FO E. floralis
FO R. angustus
Nannoconid crisis
FO R. irregularis
FO C. litterarius
G. alger.
G. ferreol.
L. cabri
G. blowi
G. duboisi
Scisti a Fucoidi
Selli
Maiolica
Breccia
Core 75R
CM1 ?
122.3 ± 1
123.5 ± 0.5
122.0 ± 0.3
above FOC. litterarius
R. irregularis absent
Shallow-water Limestone
Pelagic Limestone
Breccia
Marlstone
Black Shale
Turbidite
Bentonite
Tuff
Basalt