

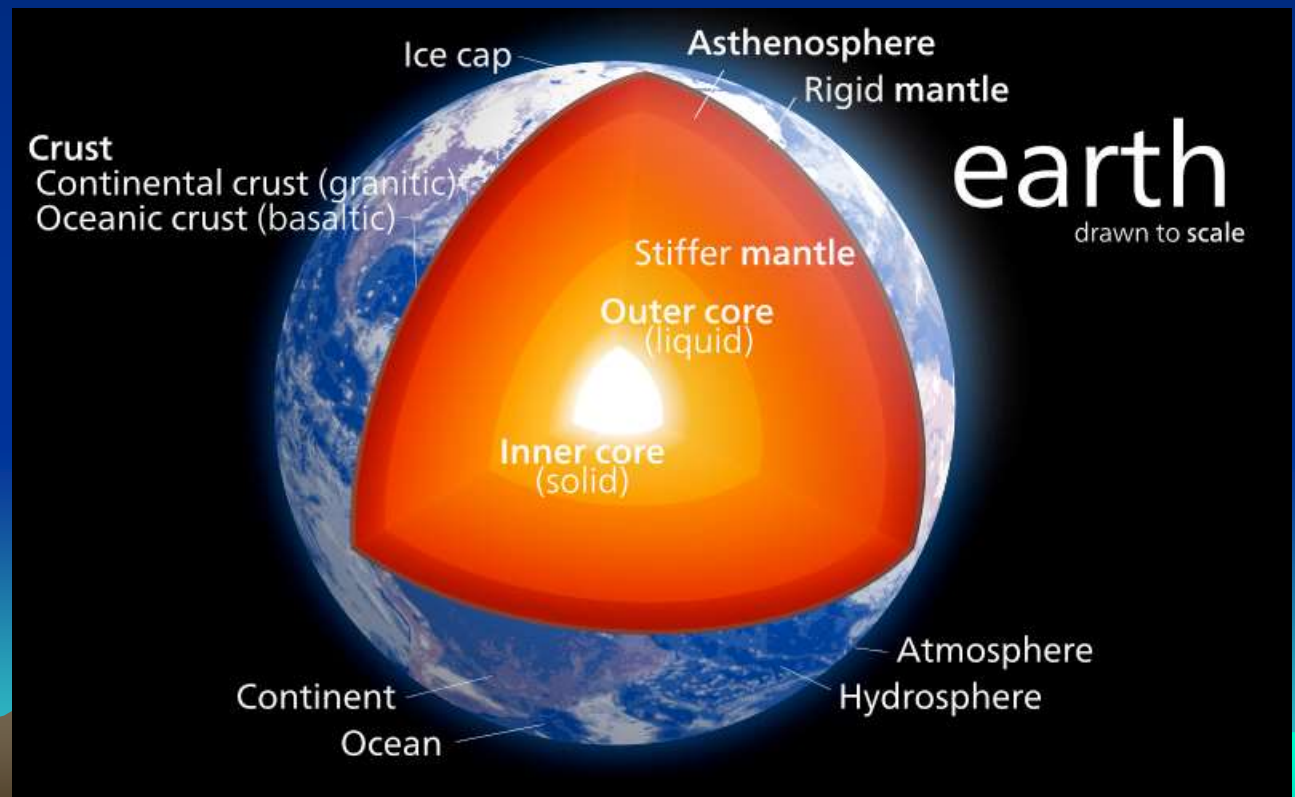
Earth's Magnetic Field

- Why does Earth have a **global** or world-wide magnetic field, while other similar planets either have no magnetic fields or very different kinds of fields?
- Why should we care about Earth's magnetic field? What does it do for us?



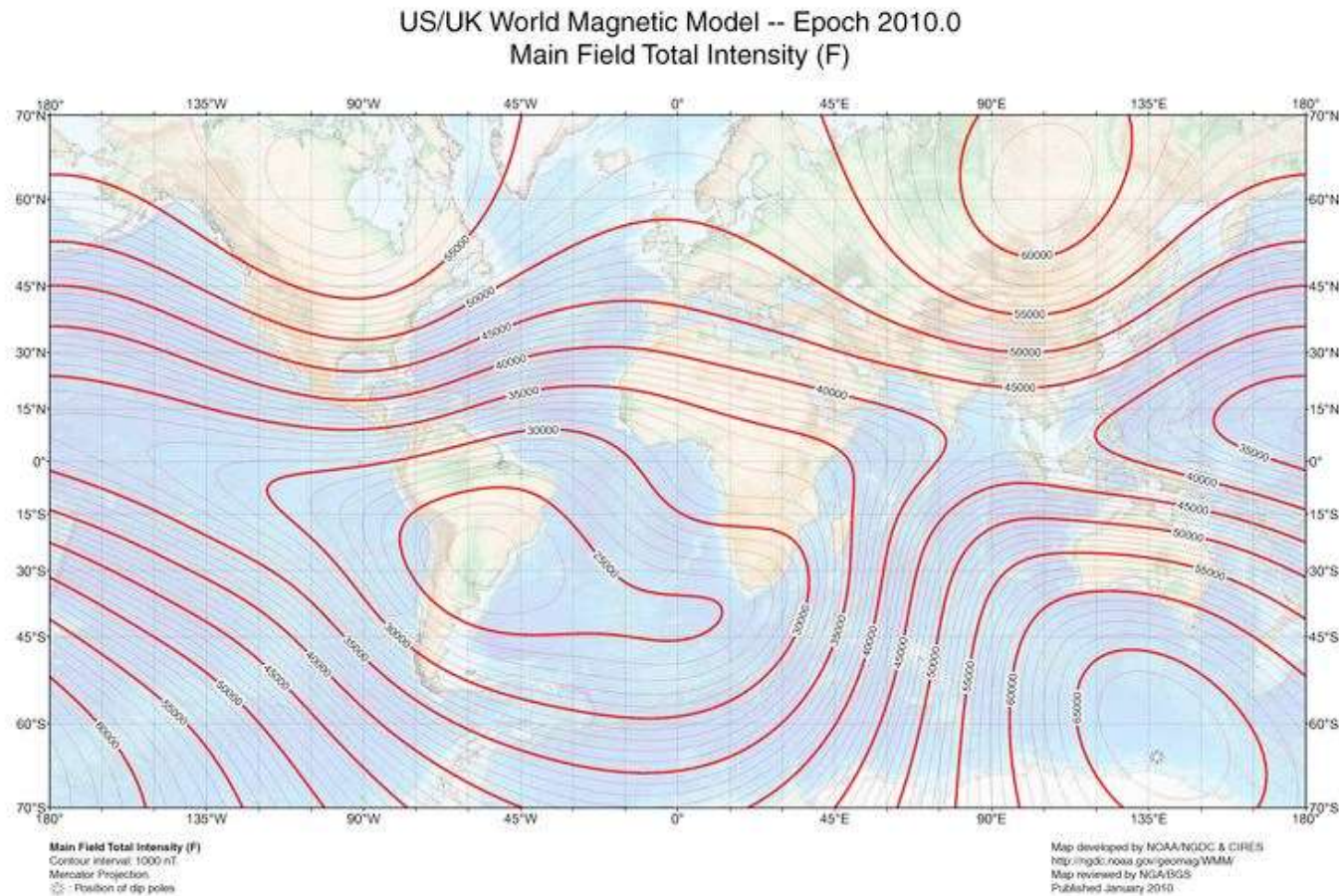
Earth's Magnetic Field

- Heat makes the outer core convect, which makes the Earth's magnetic field



Magnetic field variable

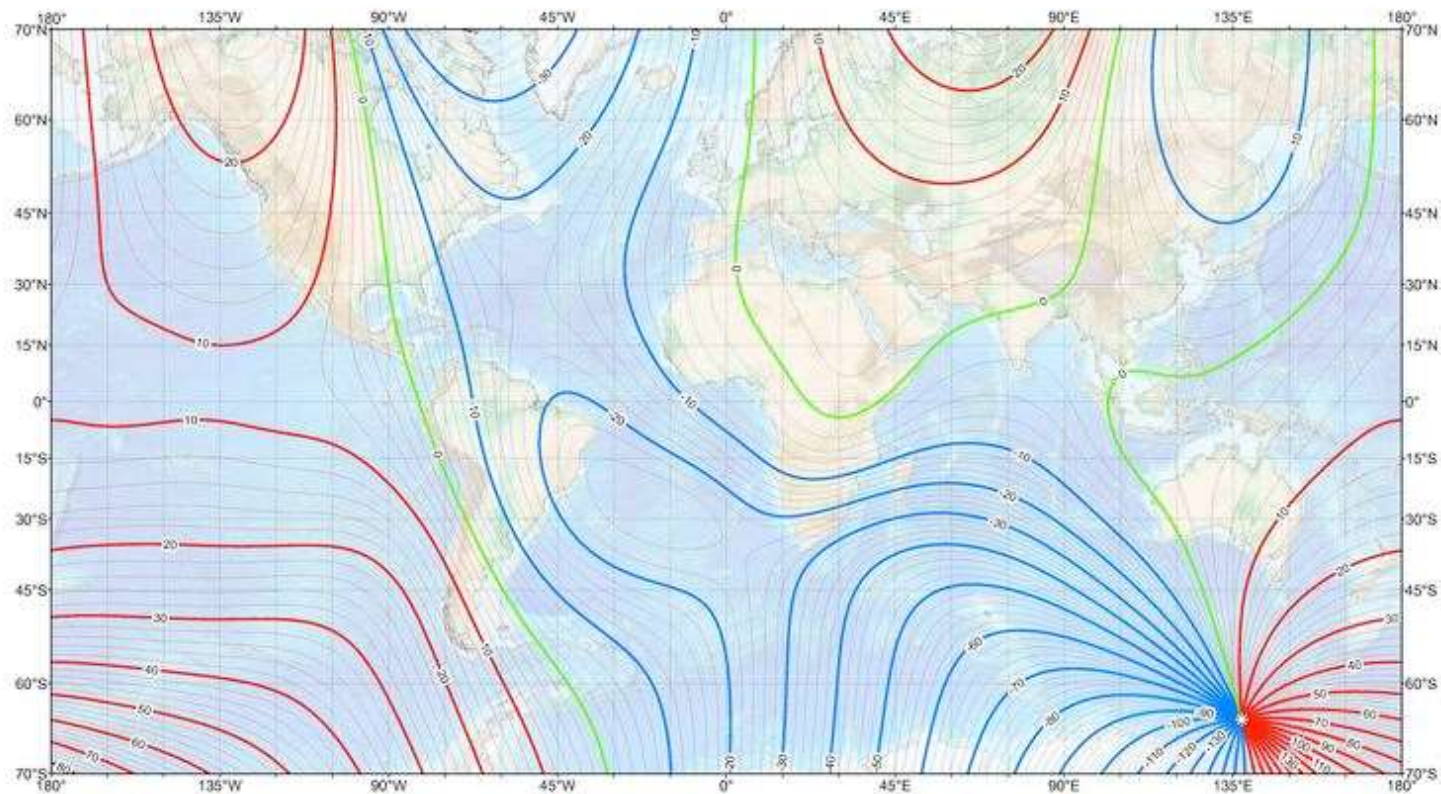
Space: Intensity



Magnetic field variable

Space: declination

US/UK World Magnetic Model -- Epoch 2010.0
Main Field Declination (D)



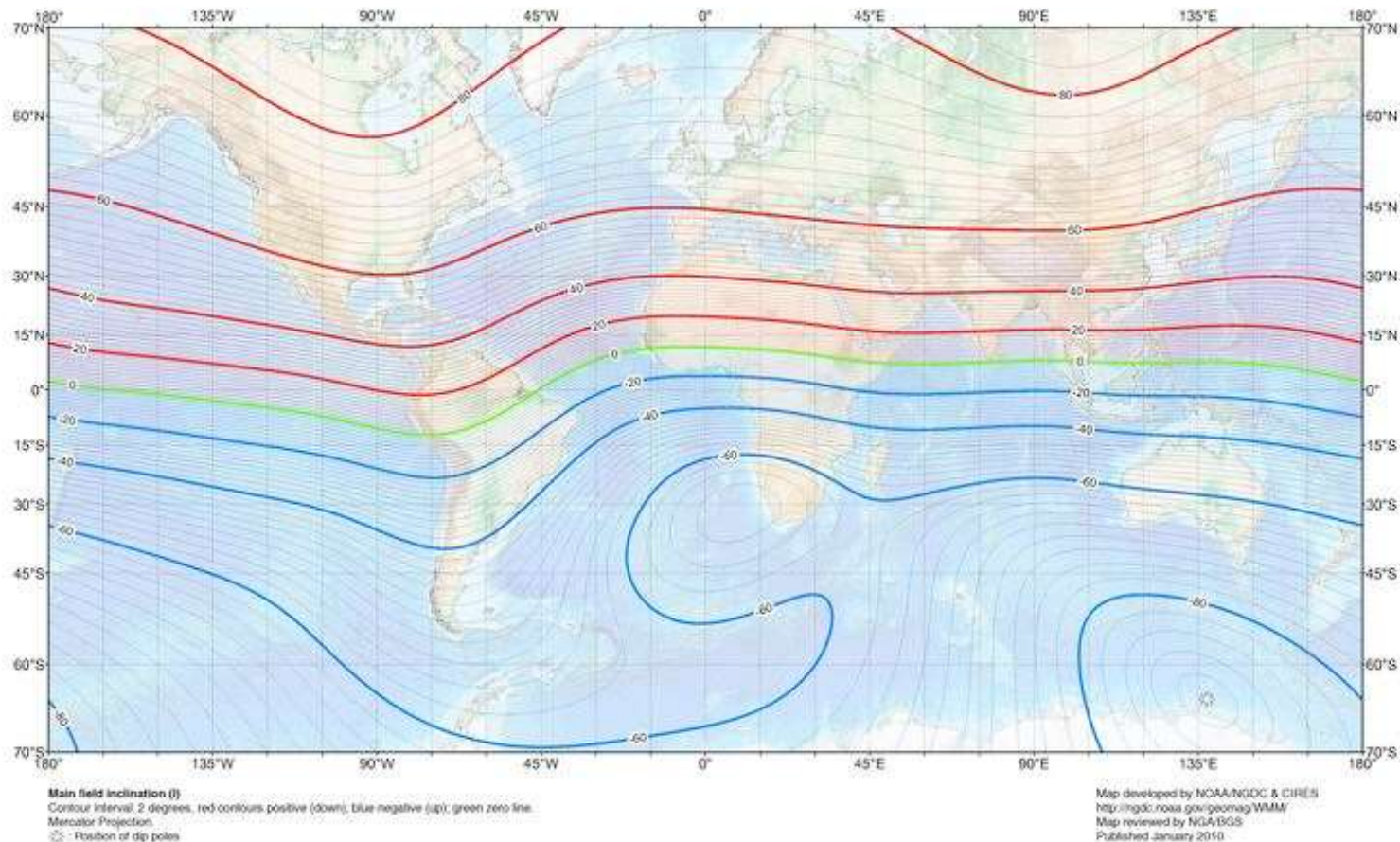
Main field declination (D)
Contour interval: 2 degrees, red contours positive (east), blue negative (west), green (agonic) zero line
Mercator Projection
Position of dip poles

Map developed by NOAA/NGOC & CIRE
<http://ngdc.noaa.gov/geomag/WMM/>
Map reviewed by NOAA/BGS
Published January 2010

Magnetic field variable

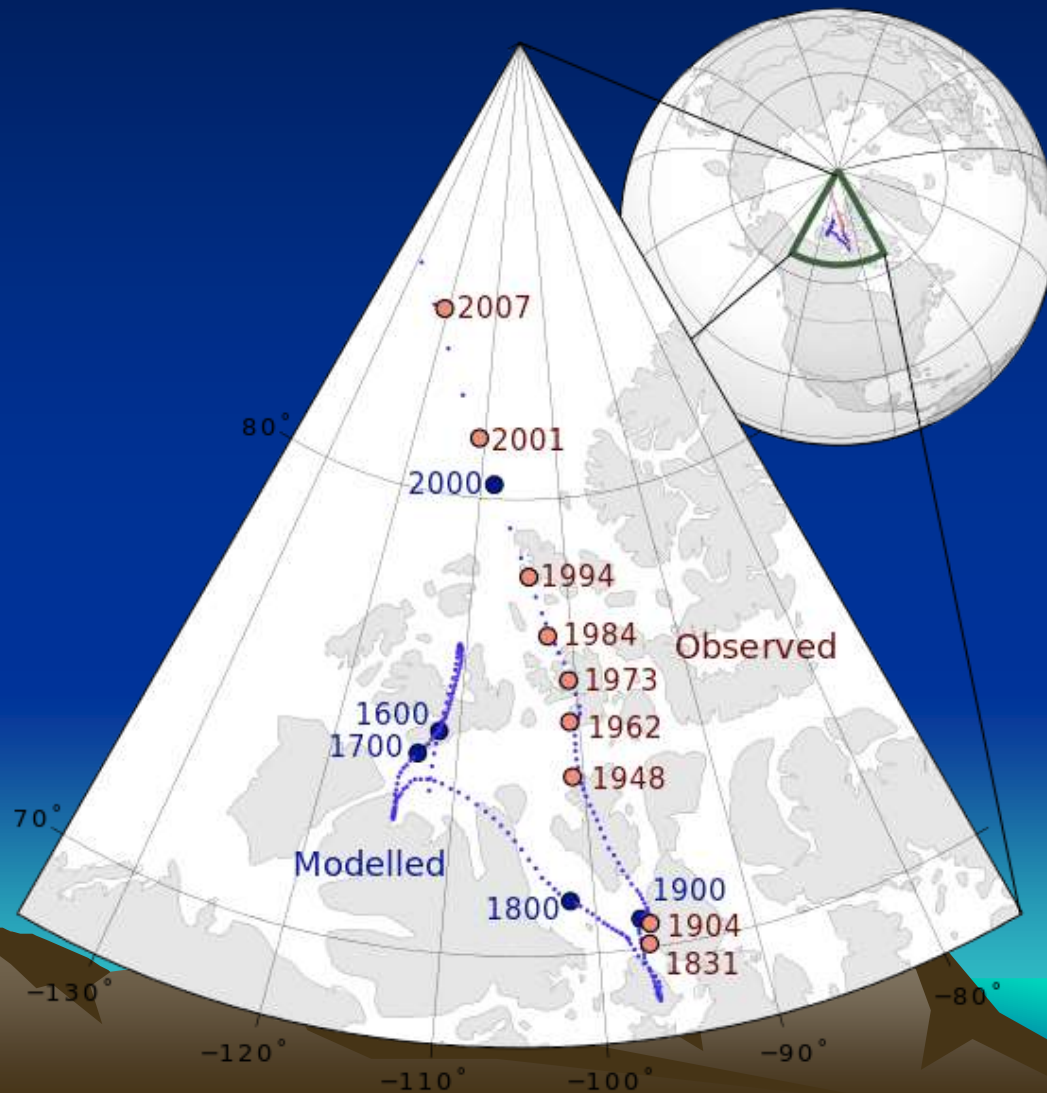
Space: Inclination

US/UK World Magnetic Model -- Epoch 2010.0
Main Field Inclination (I)



Magnetic field variable

Time: Secular Variation



Magnetic field variable

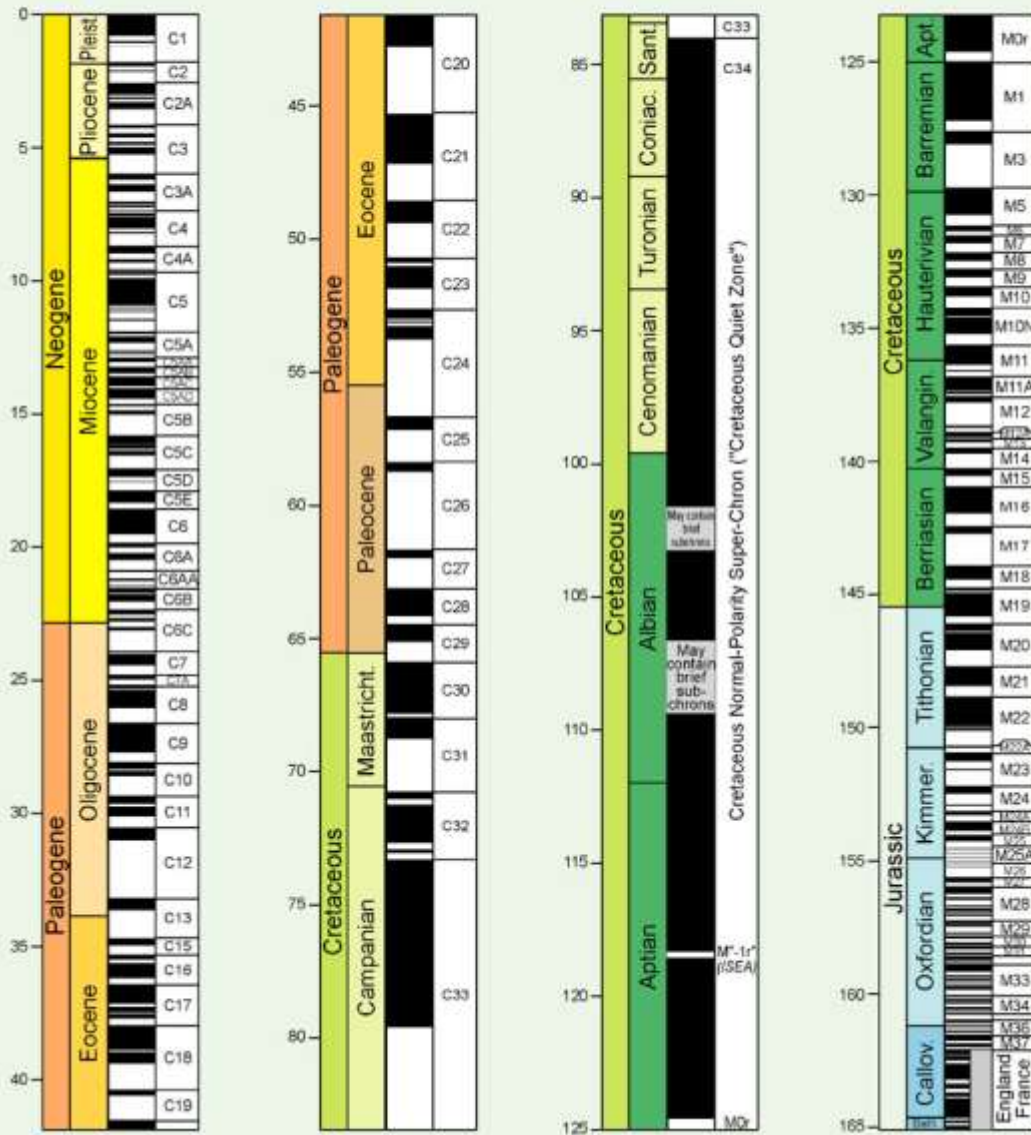
Time: Secular Variation

Declination, inclination, and intensity change...



Geomagnetic Polarity Time Scale

C-Sequence and M-Sequence



Geomagnetic Polarity Time Scale

modified from Concise Geologic Time Scale (Ogg et al., 2008)

Period	Series	Stage	Geomagnetic Polarity
Neogene	Quaternary	Quaternary	C1
		Quaternary	C2
	Pleistocene	Calabrian	C2A
		Gelasian	C2B
	Pliocene	Placenzian	C3A
		Zandean	C3B
	Miocene	Messinian	C4A
		Tortonian	C4B
	Pliocene	Serravalian	C5A
		Langhian	C5B
Paleogene	Oligocene	Burdigalian	C5C
		Aquitanian	C5D
	Eocene	Chattian	C6A
		Rupelian	C6B
	Eocene	Priabonian	C7A
		Bartonian	C7B
	Eocene	Lutetian	C8A
		Ypresian	C8B
	Paleocene	Thanetian	C9A
		Selandian	C9B
Paleogene	Paleocene	Danian	C10A
		Danian	C10B

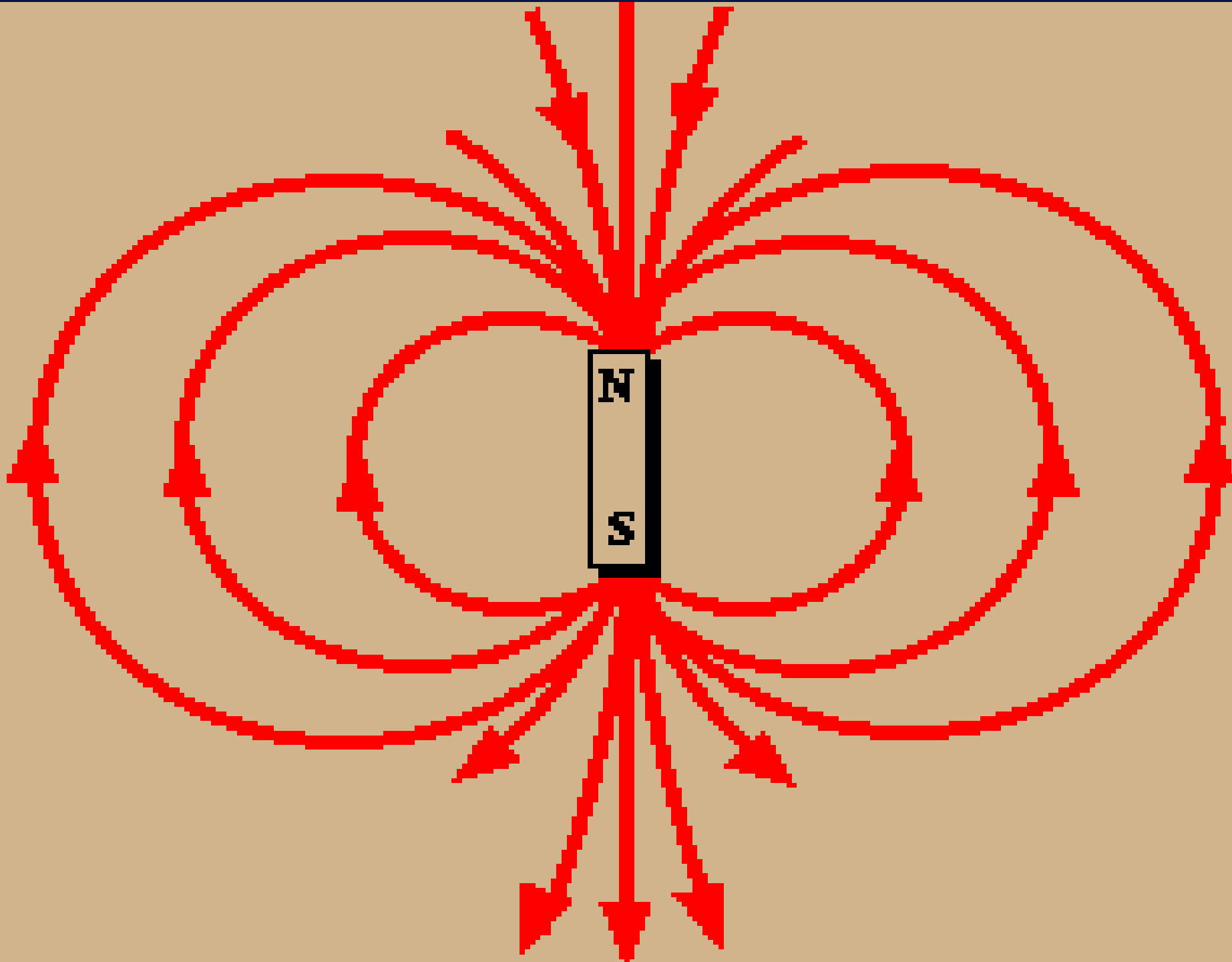
Period	Series	Stage	Geomagnetic Polarity
Cretaceous	Late	Maastrichtian	C30
		Campanian	C31
	Late	Santonian	C32
		Coniacian	C33
	Early	Turonian	C34
		Cenomanian	C35
	Early	Albian	C36
		Aptian	C37
	Early	Barremian	C38
		Hauterivian	C39
Jurassic	Late	Valanginian	C40
		Berriasian	C41
	Middle	Tithonian	C42
		Oxfordian	C43
	Middle	Callovian	C44
		Bathonian	C45
	Early	Bajocian	C46
		Aalenian	C47
	Early	Toarcian	C48
		Pliensbachian	C49
Triassic	Late	Sinemurian	C50
		Hettangian	C51
	Late	Rhaetian	C52
		Norian	C53
	Middle	Camian	C54
		Ladinian	C55
	Middle	Anisian	C56
		Olenekian	C57
	Early	Olenekian	C58
		Olenekian	C59

Period	Series	Stage	Geomagnetic Polarity
Permian	Lopingian	Changhsingian	C60
		Wuchiapingian	C61
	Lopingian	Capitanian	C62
		Wordian	C63
	Lopingian	Roadian	C64
		Kungurian	C65
	Lopingian	Artinskian	C66
		Sakmarian	C67
	Lopingian	Asselian	C68
		Gzhelian	C69
Carboniferous	Pennsylvanian	Kasimovian	C70
		Moscovian	C71
	Pennsylvanian	Bashkirian	C72
		Serpukhovian	C73
	Pennsylvanian	Visean	C74
		Tournaisian	C75
	Pennsylvanian	Famennian	C76
		Frasnian	C77
	Pennsylvanian	Givetian	C78
		Eifelian	C79
Devonian	Middle	Emilian	C80
		Pragian	C81
	Middle	Lochkovian	C82
		Lochkovian	C83
	Middle	Katlian	C84
		Sandbian	C85
	Middle	Dartmuthian	C86
		Dapingian	C87
	Middle	Floian	C88
		Tremadocian	C89
Silurian	Llandovery	Stage 10	C90
		Stage 9	C91
	Llandovery	Stage 8	C92
		Stage 7	C93
	Llandovery	Stage 6	C94
		Stage 5	C95
	Llandovery	Stage 4	C96
		Stage 3	C97
	Llandovery	Stage 2	C98
		Fortunian	C99

Earth's Magnetic Field

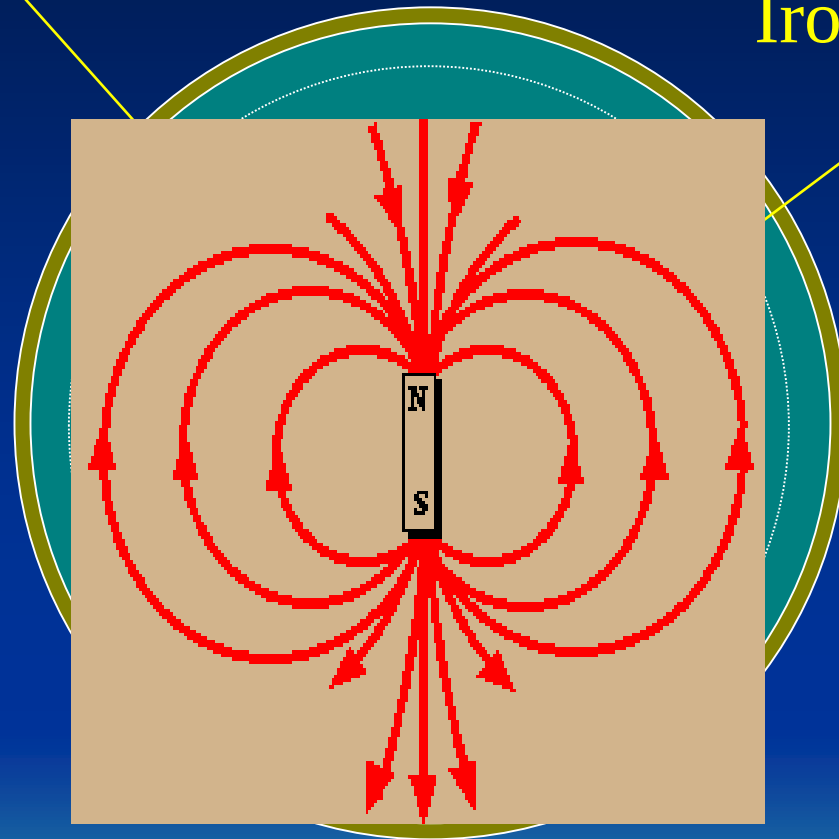
- Magnetic fields are made wherever there is an electric current, that is the movement of electrons.
- In a regular bar magnet, the magnetic field comes from the electrons orbiting around the nuclei of the iron atoms. All the electrons orbit in the same direction.





Solid Inner Core
2400 km diameter
Iron & Nickel

Liquid Outer Core
2270 km thick
Iron & Nickel



Earth's Magnetic Field

- In the earth, electrical currents run through the molten iron core. Friction within the molten, flowing iron knocks electrons off iron atoms.
- The molten iron flows at about 0.8 inches per second, but the electrical currents can flow faster.



Earth's Magnetic Field

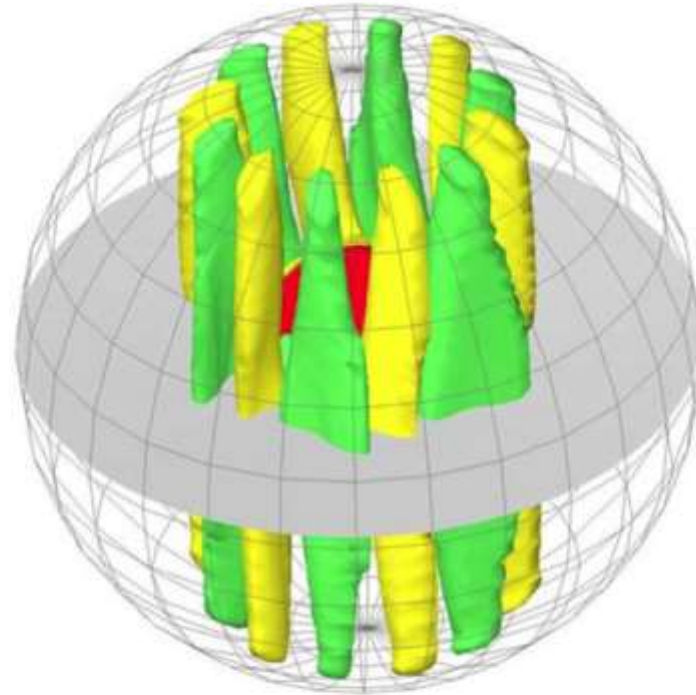


Figure 2. Snapshot of convection cells aligned nearly parallel to the rotational axis, visualized by the isosurfaces of the z component of vorticity $\mathbf{W}$. The yellow ($W_z > 0$) and green ($W_z < 0$) surfaces indicate cyclonic and anticyclonic convection cells. Reproduced from *Kageyama and Sato [1997c]*, with the permission of the authors and the publisher (American Physical Society).

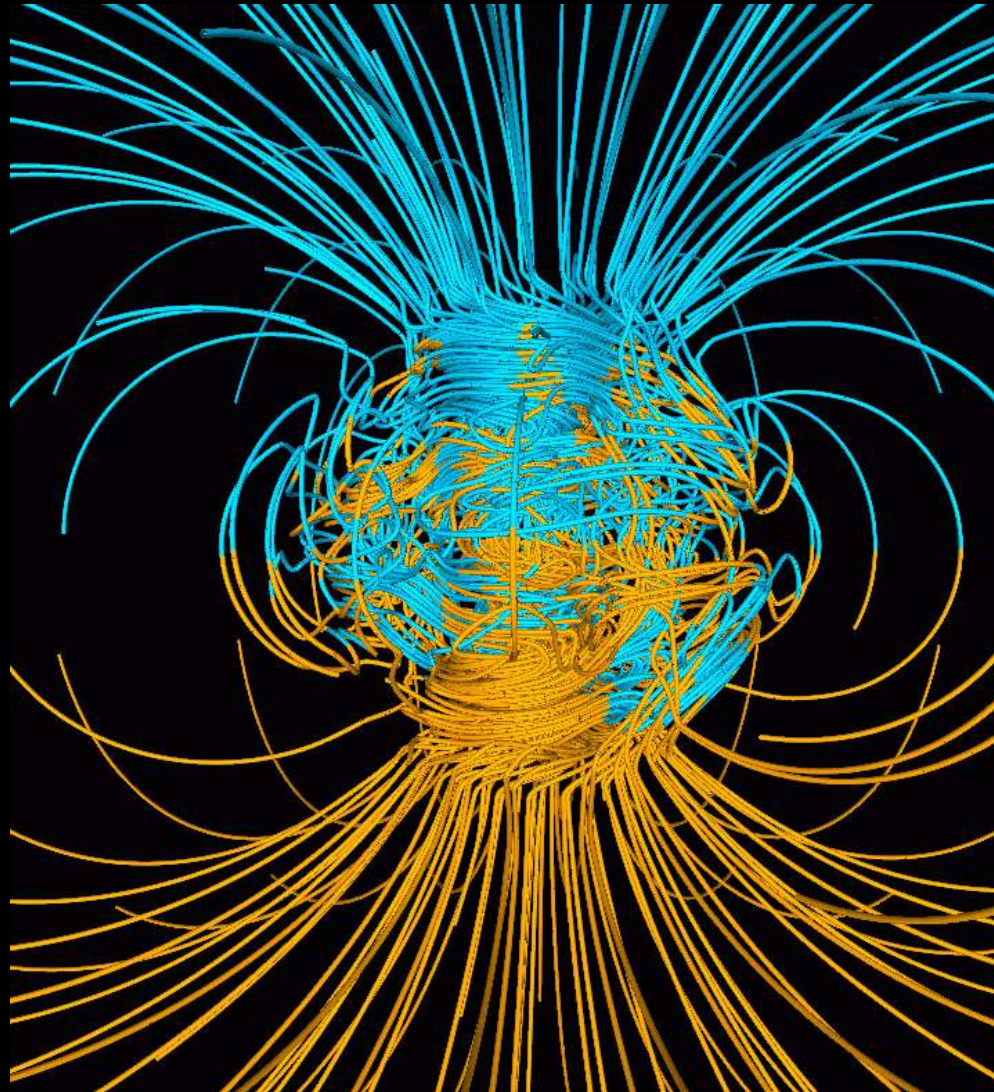
Earth's Magnetic Field

- The electrical currents within the earth cause earth to act like a gigantic electromagnetic generator.
- This is called the **Dynamo Theory** of magnetic field generation.



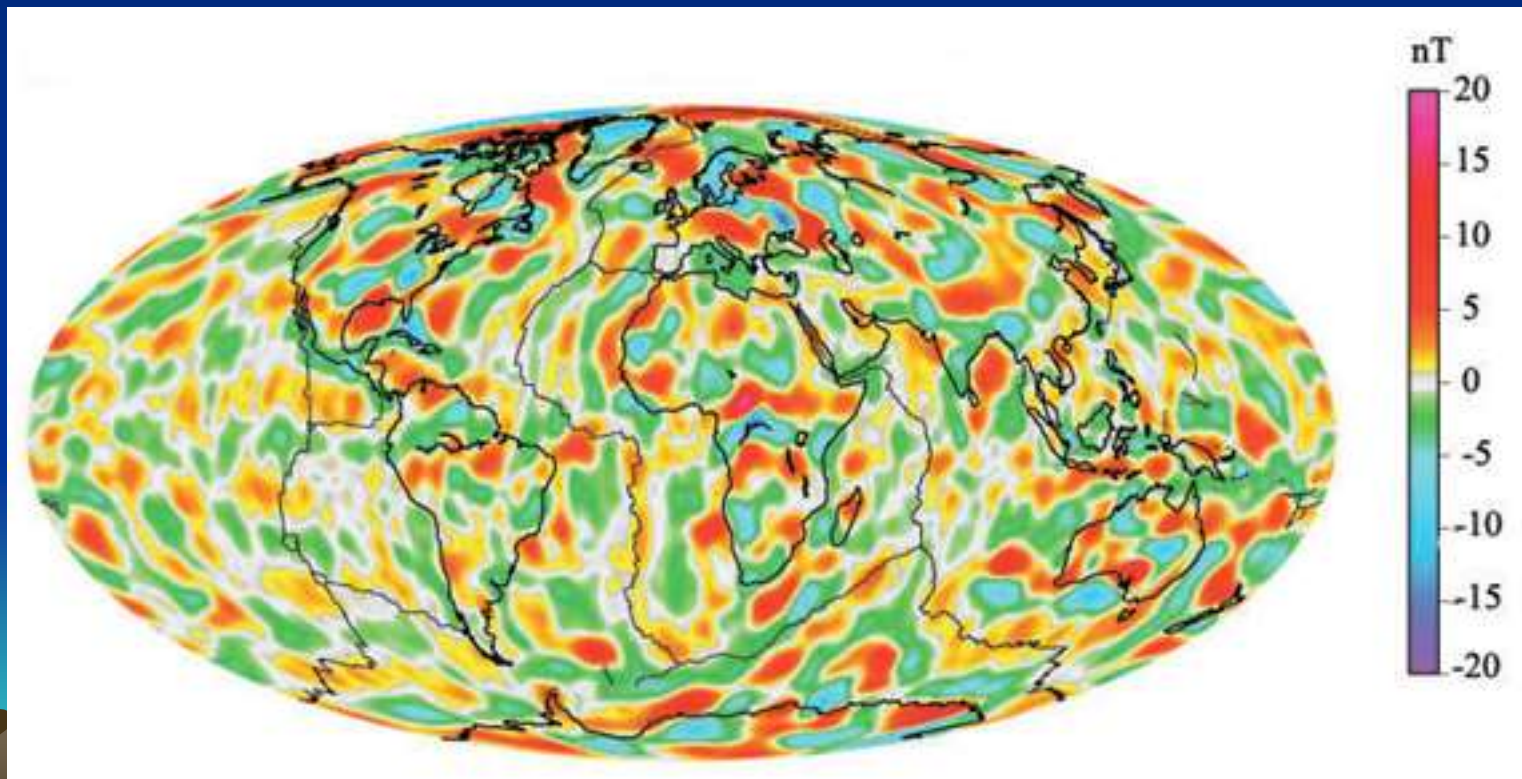
Earth's Magnetic Field

Global Field



Earth's Magnetic Field

- “local” field: Lithospheric Magnetic Anomalies.



A little more info...

- The earth's magnetic field isn't strong enough for us to feel, but many animals can sense it and even use it to navigate. It's only about 0.4 Gauss, much weaker than a small magnet you can hold in your hand.



The poles “flip”

- Every so often, what was the North magnetic pole suddenly becomes the South magnetic pole.



The poles “flip”

- how long does the process take?
thousands of years?



Hypothesized triggers

We used to think that these flips are triggered by external events that directly disrupt the flow in the Earth's core.

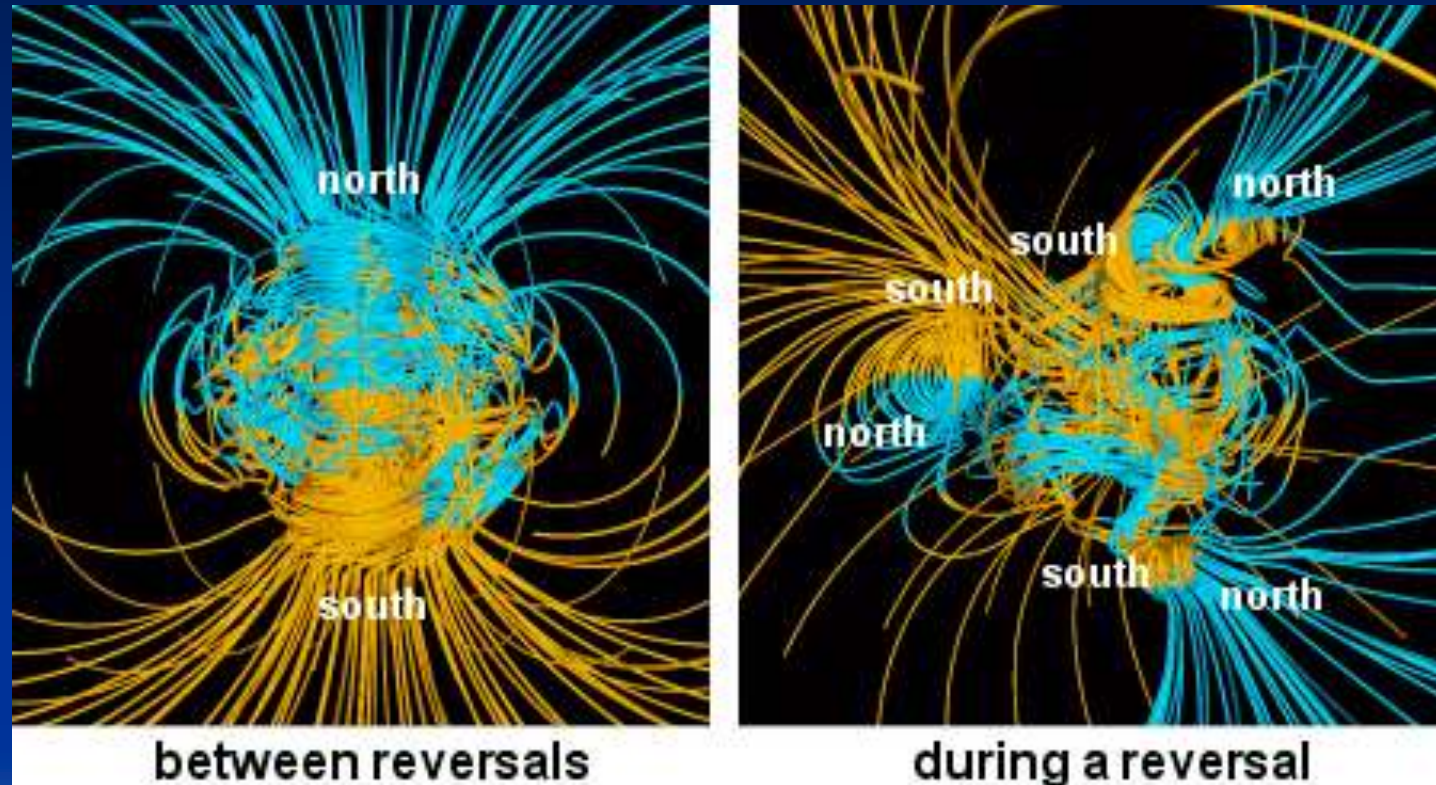
- impact events
- internal events such as the arrival of continental slabs carried down into the mantle
- or the initiation of new mantle plumes from the core-mantle boundary.

What about the Chicxulub impact, at the Cretaceous–Paleogene boundary?
Is there a reversal?

What about the 20+ reversals in the past 5 my? Do we have evidence of impact events?



The poles “flip”



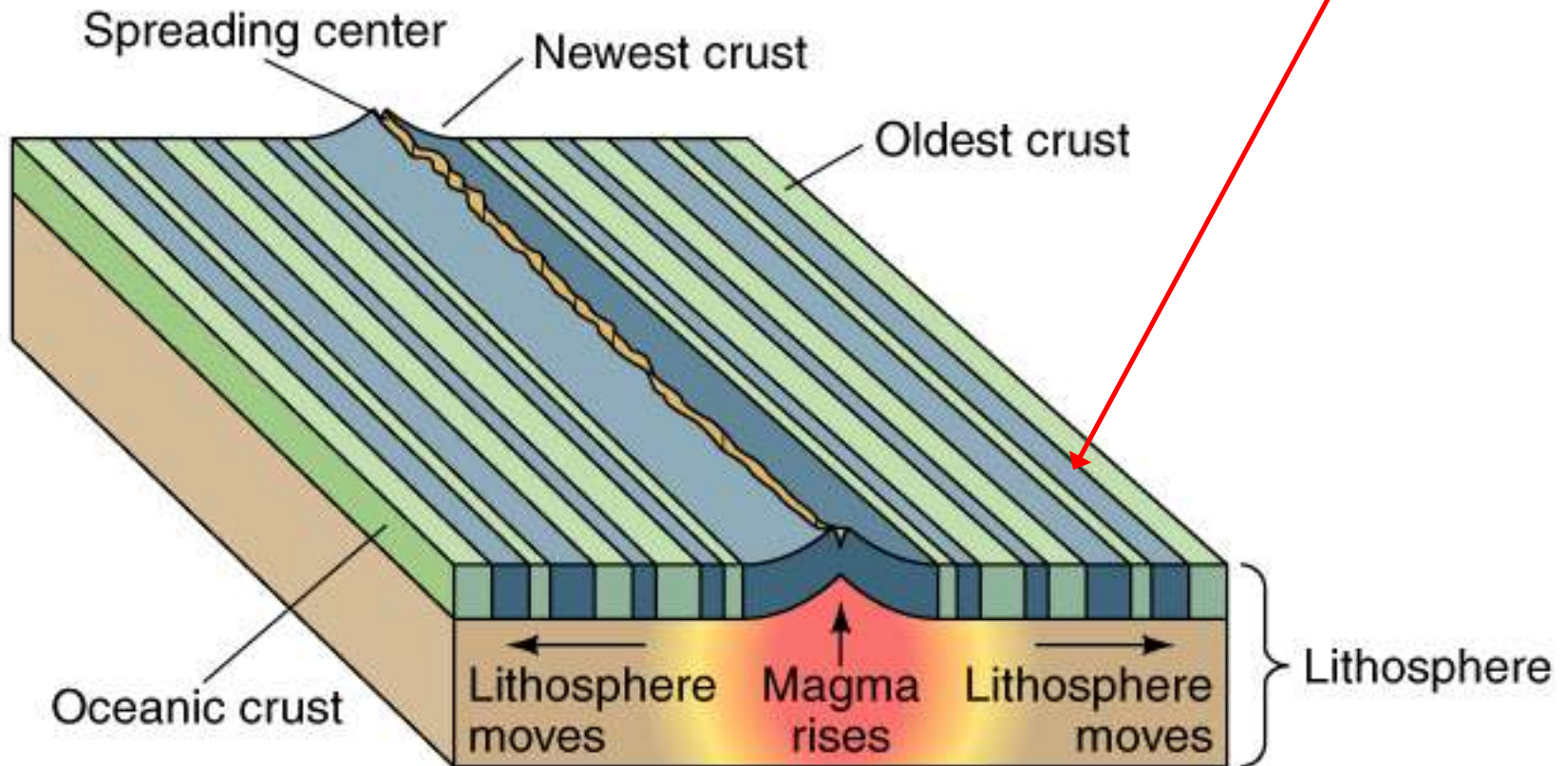
NASA computer simulation using the model of Glatzmaier and Roberts.^[28] The tubes represent magnetic field lines, blue when the field points towards the center and yellow when away. The rotation axis of the Earth is centered and vertical. The dense clusters of lines are within the Earth's core.

The poles “flip”

- Lava that cools quickly on the sea floor records these flips and lets us date them.



Stripes of different magnetic polarity form in the rocks as the lava from the mid-ocean ridge cools.



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Strange Things Going On

- Earth's magnetic field is **NOT** aligned with its rotational axis.
- The magnetic field is tilted 12° to the rotational axis, and doesn't even pass directly through the center of the earth.
- Does this mean that the electrical currents don't flow evenly and uniformly inside the earth? Is there turbulence inside?



Magnetic Fields in Space

- Earth's magnetic field extends 7-10 times the earth's diameter outward from the earth.
- The earth's magnetic field would be spherical, but the solar wind compresses it on the side closest to the sun, and stretches it out into a long tail on the side opposite the sun.
- Overall, it's kind of tadpole shaped.



Why do we care?

- Earth's magnetic field isn't just "there" with no purpose. Without it, you and I and every living thing on this planet would be dead (including the cockroaches!)
- The magnetic field channels away the solar wind.
- It also prevents erosion of the atmosphere.



Solar Wind

- So what is the solar wind anyway?
 - It's radiation: extremely hot, high-energy, fast-moving charged particles (ions) given off by the sun. Most of these particles are protons.
 - If you were exposed to it for just a few hours without protection, your skin and every organ in your body would be burned, and you'd have a fatal dose of radiation poisoning.



How does the magnetic field protect us?

- The magnetic field captures the solar wind and channels much of it into a donut of radiation around the earth.
- This donut (actually 2 layers – one inside the other) is called the Van Allen Radiation Belt (V.A.R.B.)



