The Restless Earth

by

Tony Heyes

A Paradigm Shift

In our life time there was a Scientific Revolution

In the words of Thomas Kuhn:

a Paradigm Shift

Prior to the 1960s no one would get a job in a Geology Department if they believed in Continental Drift

After the 1960s no one would get a job in a Geology Department UNLESS they believed in Continental Drift

So what happened?

Please explain!

If you think that the shape of Africa fits neatly into the shape of South America, you are not alone

- Abraham Ortelius (1596)
- Theodor Christoph Lilienthal (1756)
- Alexander von Humboldt (1801 and 1845)
- Antonio Snider-Pellegrini (1858)

Continent

200m
Continental Shelf

Theodor Lilienthal
(1717 – 1781)

Theodor Lilienthal
(1717 –1781)

1756: ‘the facing coasts of many countries, though separated by sea, have a congruent shape, so that they would almost fill one another if they stood side by side; for example the southern part of America and Africa.’

In modern times the man who put the work in, not only comparing the shape of the coastline but comparing the rock types, the rock formations and the fossils on either side was….

Alfred Wegener
(1880 – 1930)

However he was

- A meteorologist
- A balloonist
- A polar explorer
- But not a **Geologist**

Alfred Wegener
(1880 – 1930)

- Wegener died during an expedition to Greenland. His companion buried the body with great care,leaving a pair of skis to mark the grave site

- The companion, Villumsen , thmed his journey to West camp.
- He was never seen again.

Alfred Wegener
(1880 – 1930)

- Wegener was the first to use the phrase "continental drift" (1912, 1915)[
- In fact, he and his followers were called

The Drifters

The Drifters

- Those of you of a certain age will recall that Cliff Richard's backing group was originally called The Drifters

- However, they changed their name to The Shadows when a US group called The Drifters had a major hit

Cliff Richard and The Drifters

The Drifters

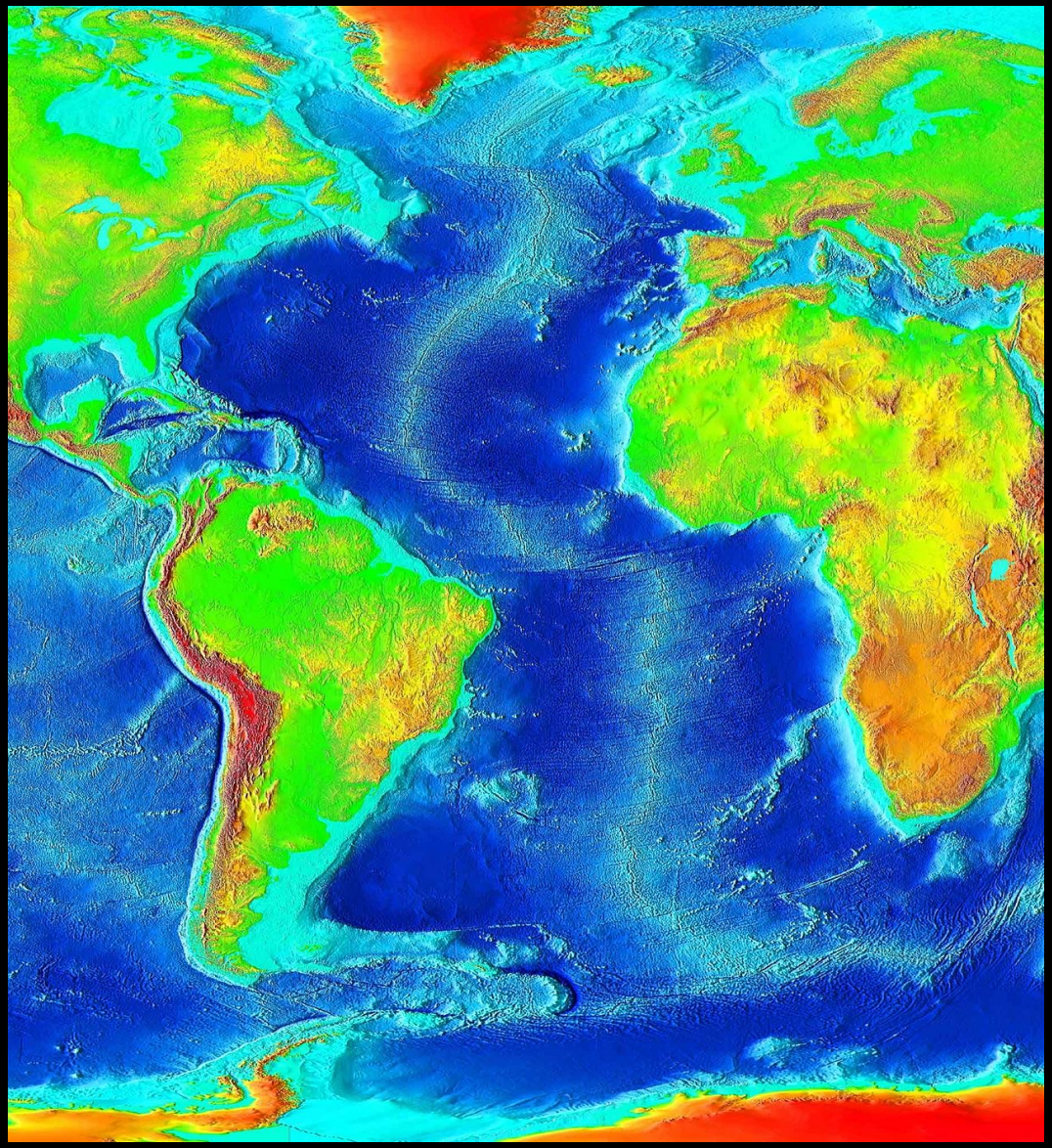
The Drifters

- I doubt that either group chose their name for Geophysical reasons
- However, I digress…
- Our Drifters

The Drifters

- Invented the concept of ocean floor spreading
- Identified the Mid-Atlantic ridge
- Found evidence from fossils and types of rock

Mid Atlantic Ridge



Thingvellir, Iceland

But still they won little support

- If the Atlantic was opening up
- Was the world getting bigger?
- How could the continents float apart?

The answer came

- In the 1960s

- From the work of a young Cambridge Geologist

Frederick Vine
(1939 –)

But first we must consider some Geomagnetism……..

- The magnetic poles are not located at the ends of the axis on which the Earth turns ie. The North Pole and the South Pole

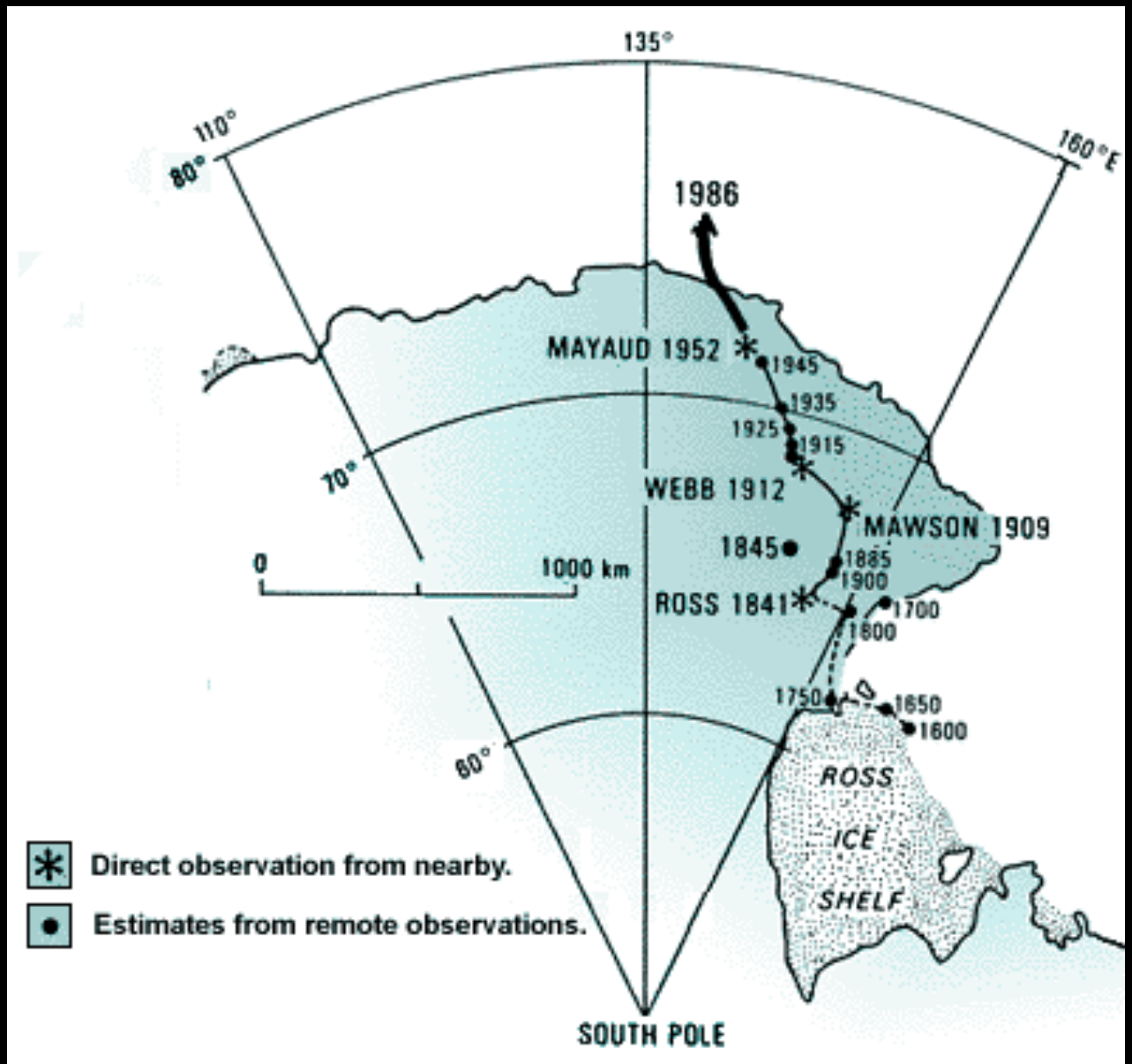
- What is more, the magnetic poles do not stay in one place – they drift

Geomagnetism

- When Sir Douglas Mawson trekked to the South Magnetic Pole in 1909 it was on a high ice plateau.
- It is now in the sea!

- We think of the North Magnetic Pole as being in Canada. Well, it is heading rapidly for Siberia.

Movement of the South Magnetic Pole

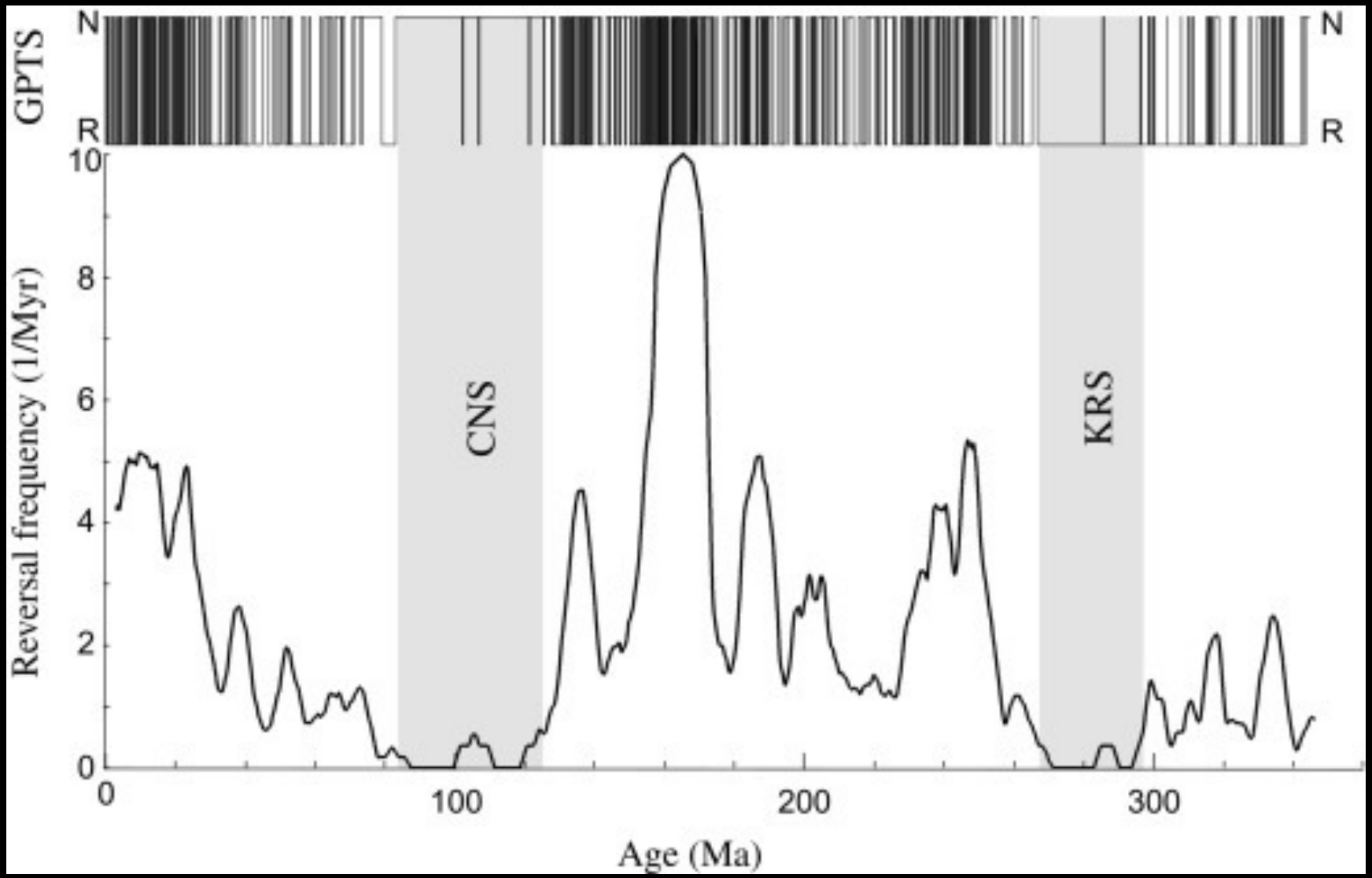


Geomagnetism

- Somewhat more alarming the Magnetic Poles change places from time to time

- There have been numerous times during which the North seeking end of a compass would point to what Paul Keating referred to as the "Arse end of the world"

Magnetic Reversals



Magnetic Reversals

- When magnetic material is cooled after being heated above the Curie Temperature the magnetic dipoles within the material freeze having been aliened with the earth's magnetic field

- We know the history of the reversals because many volcanic rocks freeze to form crystals which align themselves with the earth's magnetic field

Magnetic Reversals

- Until recently it was thought that a magnetic reversal had never happened during the time that humans have been on earth!
- However there was a brief but large magnetic excursion some 42,000 years ago and it was recorded in a stone fireplace near Lake Mungo

The Laschamp Excursion

- The **Laschamp Excursion o**ccurred 41,400 (±2,000) years ago during the end of the Last Glacial Period it was first recognised from a geomagnetic excursion discovered c. 1969 in the Laschamps lava flows in the Clermont-Ferrand district of France

The Laschamp Excursion

- From this, and other locations (eg. NZ) we now know…

- The magnetic field was reversed for approximately 440 years, with the transition from the normal field lasting approximately 250 years

Kauri
(*Agathis australis)*

Alan Hogg
University of Waikato

- This huge, lonely tree grew for some 1700 years across a remarkable period in our planet's history when the Earth's magnetic field flipped some 42,000 years ago; the Laschamp Excursion
- This period of low magnetic field has been termed the **Adams Event**. During this period, Earth's magnetic field dropped to below 6% of the current level, Carbon-14 production increased, ozone levels decreased, and atmospheric circulation changed. This loss of the geomagnetic shield was also claimed to cause extinction of Australian Megafauna extinction of the Neandertals, and appearance of cave art.

The Adams Event

https://www.youtube.com/watch?v=Qs1dLe3GsQY

The Adams Event

Vine and his colleagues proposed

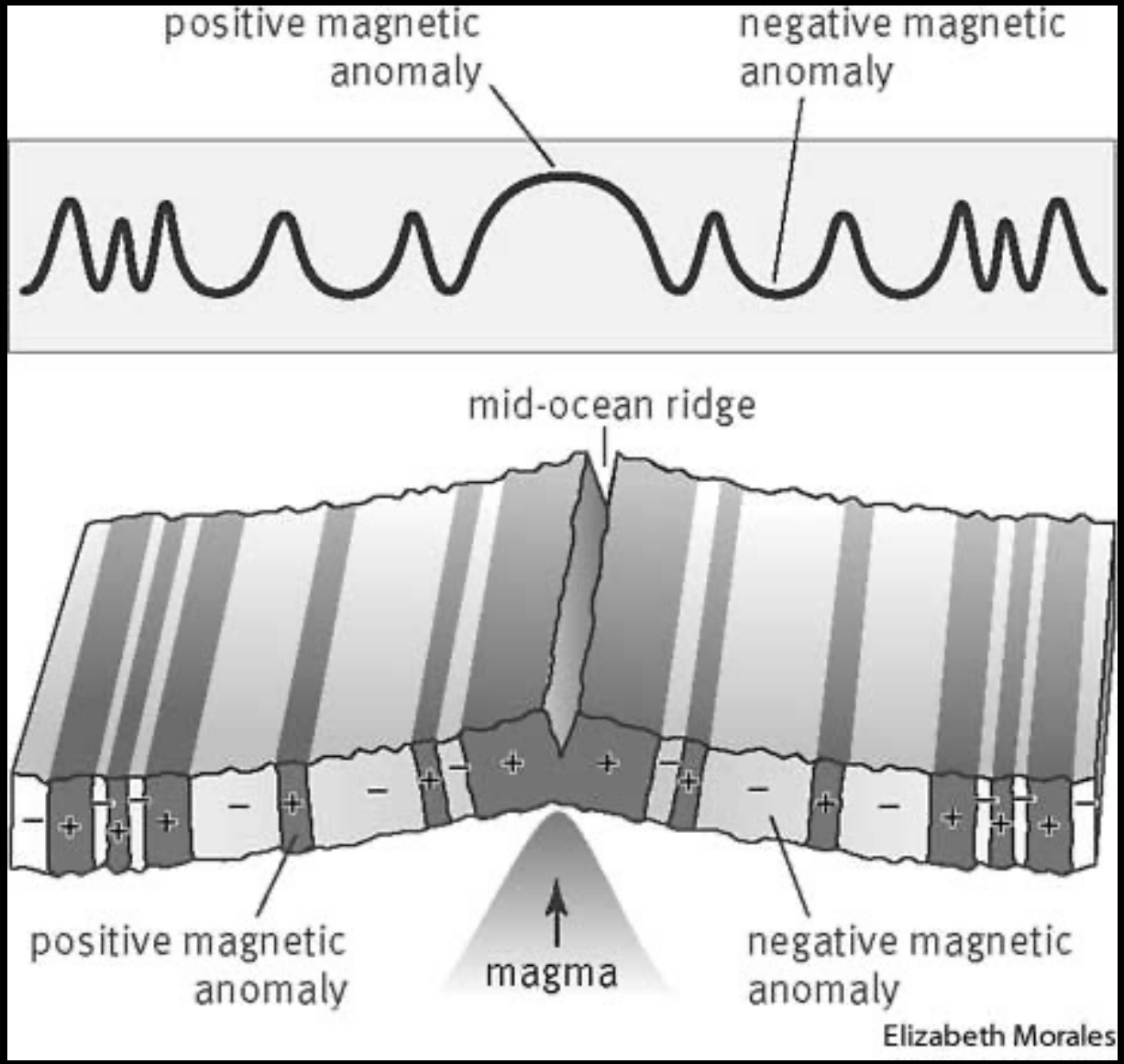
- That the sea floor either side of the Mid-Atlantic ridge should be composed of rock which showed the direction of the earth's magnetic field corresponding to when it was laid down, AND

- That the pattern of magnetic results should be symmetrical each side of the ridge

Magnetic Reversals

When magnetometer measurements were taken from East to West across the mid-Atlantic range one found……

Ocean floor spreading



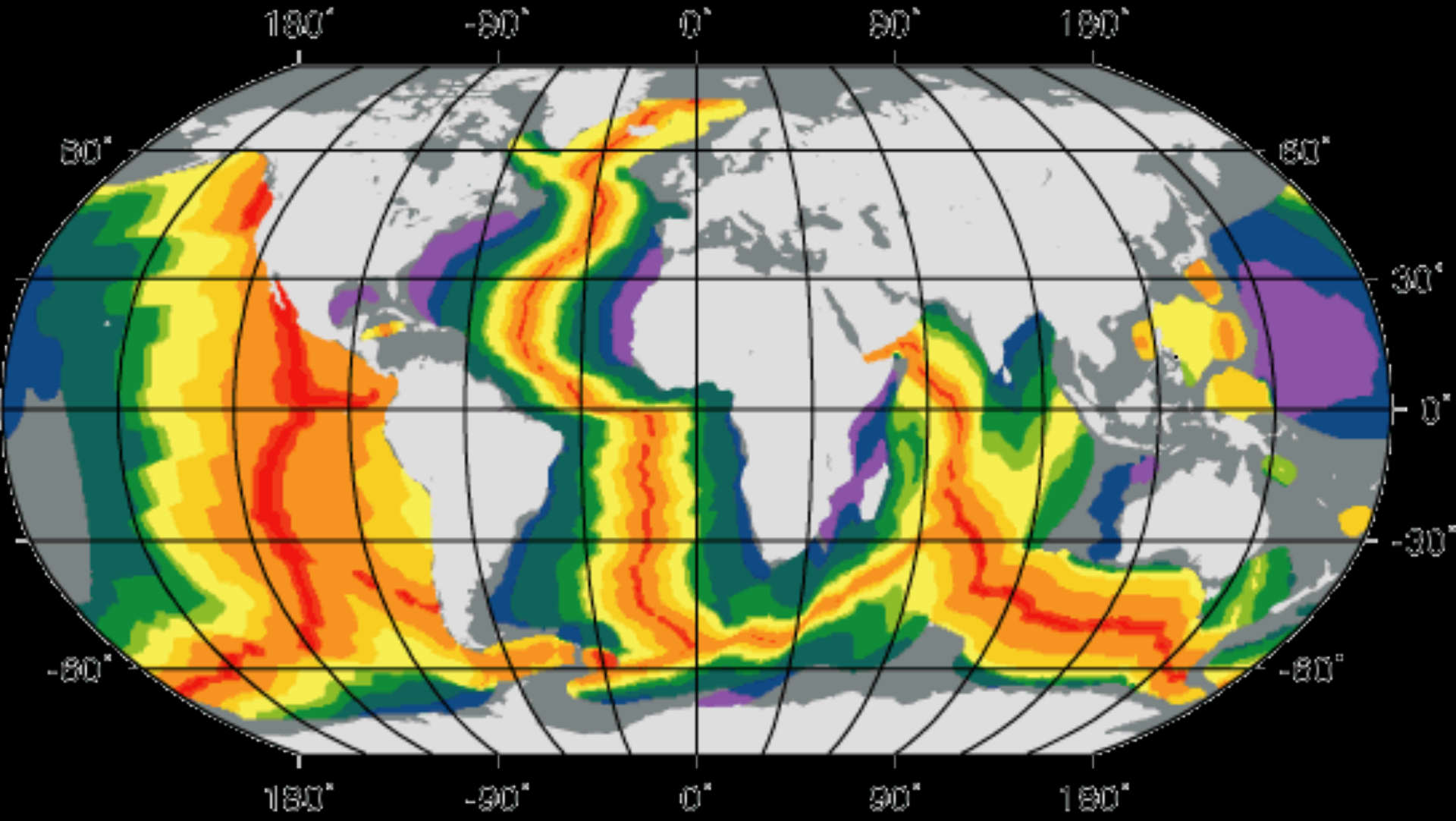
Ocean floor spreading

We now understand that the mid-Atlantic range is just one of many places where the ocean floor is spreading

We now call such places

Plate Boundaries

Opening Plate Boundaries



Opening Atlantic

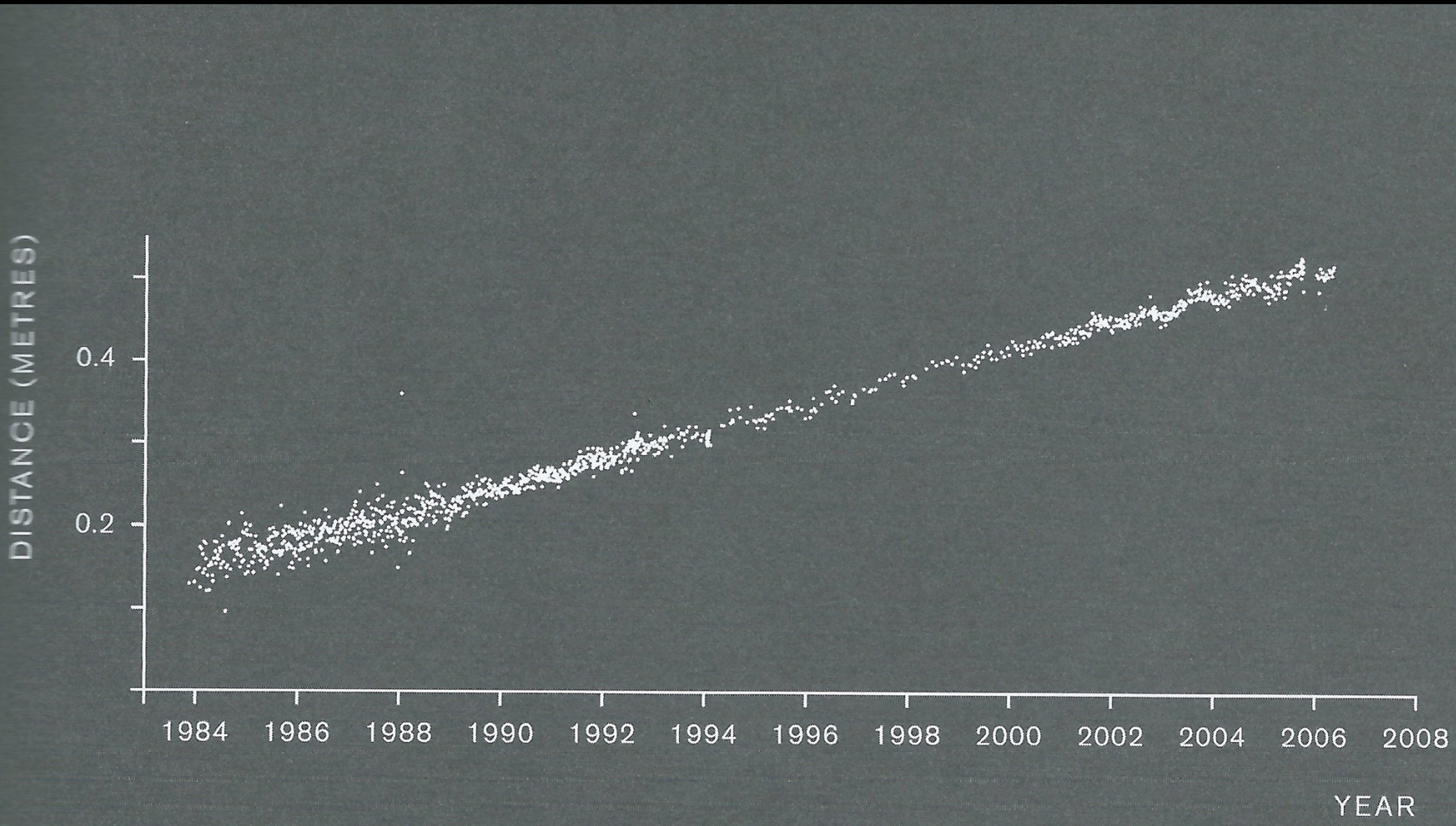


Plate Tectonics

- Continents sit on plates
- It’s the plates that drift
- But does this mean that the world is getting bigger?
- NO, Plates subduct

Subducting Plate Boundary

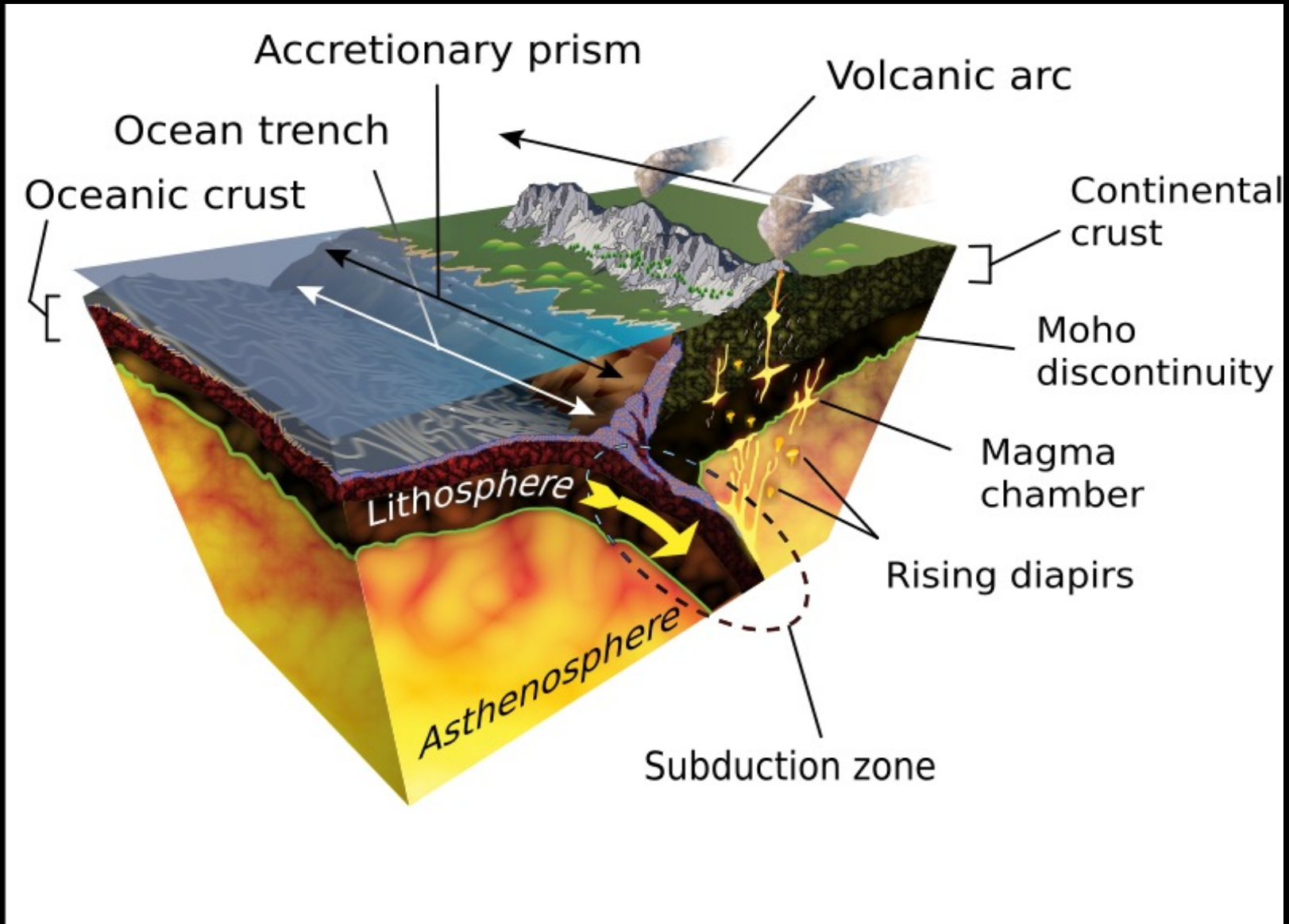


Plate Tectonics

- Most earthquakes happen near plate boundaries
- Plates can slide past each other eg. the San Andreas fault in California
- Colliding plates build mountains eg. the Himalayas and cause volcanos
- Australia is heading North

Plate Tectonics

- The movement of plates can have a huge affect on the Earth's climate
- A major Ice Age followed when the South American Plate collided with the North American Plate and prevented the ocean currents flowing between the Pacific and the Atlantic
- It is speculated that having a land mass at the South Pole is responsible for our benign epoch

Ice Ages

- But there is more to Ice Ages than Plate Tectonics
- The main factor is the heat we receive from the Sun
- Ice Ages begin not when Winters get colder but when Summer temperatures fail to melt all the snow that fell the previous Winter

The Sun

- Fortunately the energy output from the Sun is remarkably constant
- It does vary depending on the number of Sun spots and the occurrence of Solar Flares but the variation is small
- What DOES vary is the Earth's position with respect to the Sun

The Sun – Earth System

- It has long been known that the Earth's orbit is subject to fluctuations:
- Orbital eccentricity (100,000-year cycle - Johannes Kepler, 1609)
- Axial tilt (41,000-year cycle - from 22.1° to 24.5°; Presently, the Earth's tilt is 23.5° - Ludwig Pilgrim, 1904)
- Orbital precession (23,000-year cycle - Hipparchus, 130 BC)

The Sun – Earth System

The man who did the mathematics to calculate the effect these parameters had on the amount of the Sun's energy reaching various parts of the Earth's surface was a Serbian polymath

Milutin Milankovitch (1879 – 1958)

Milankovitch Cycles

Milankovitch's detailed mathematical analysis of the effect of these three periodic parameters has resulted in them becoming known collectively as

Milankovitch Cycles

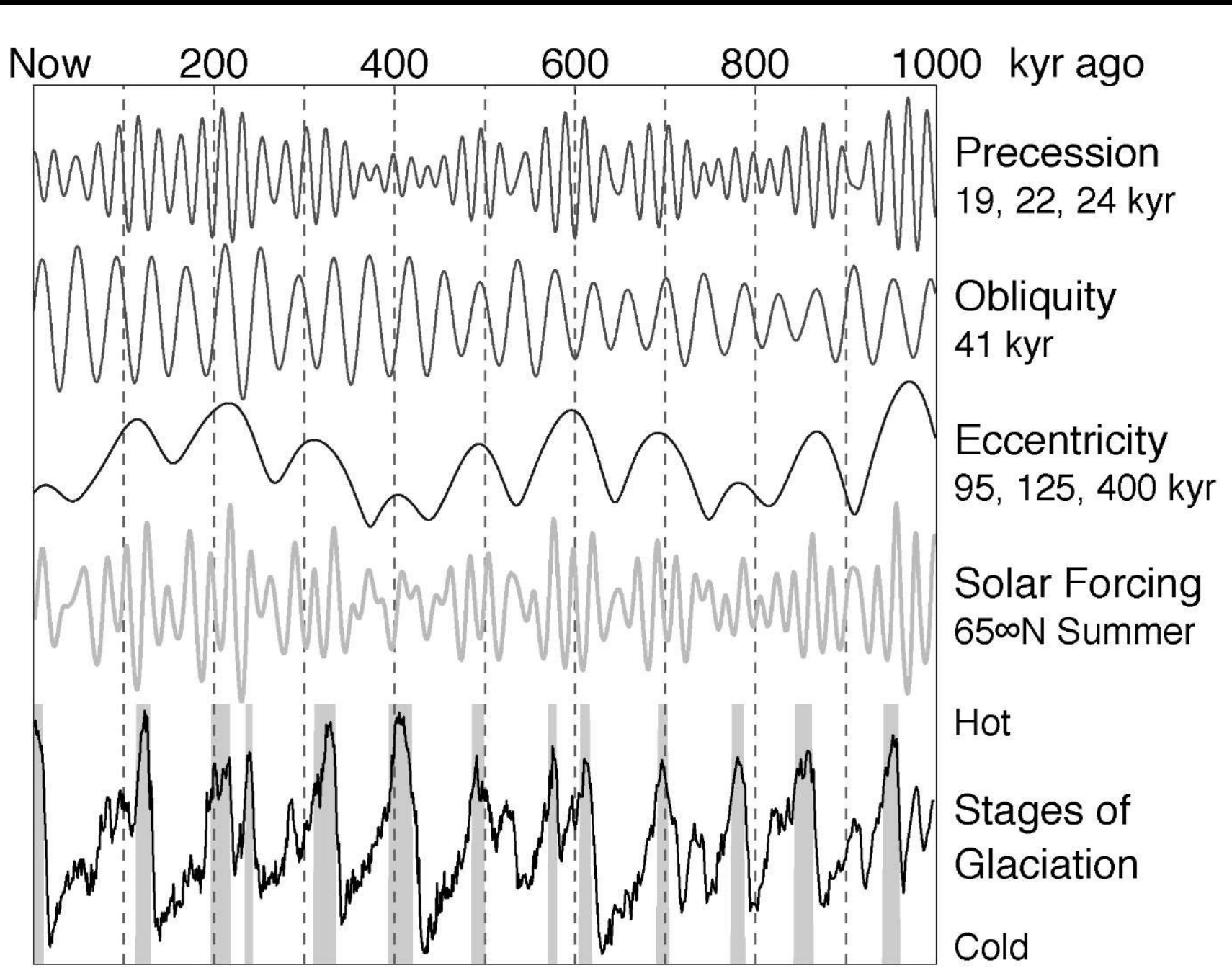
Milutin Milankovitch (1879 – 1958)

- By 1914 he was well established as an engineer, a mathematician and a scientist
- He chose to go to Austro-Hungary for his honeymoon and was there when WW1 started
- As a Serbian he was interned

Milutin Milankovitch (1879 – 1958)

- Strings were pulled on his behalf and he was allowed to remain under 'house arrest' in Budapest

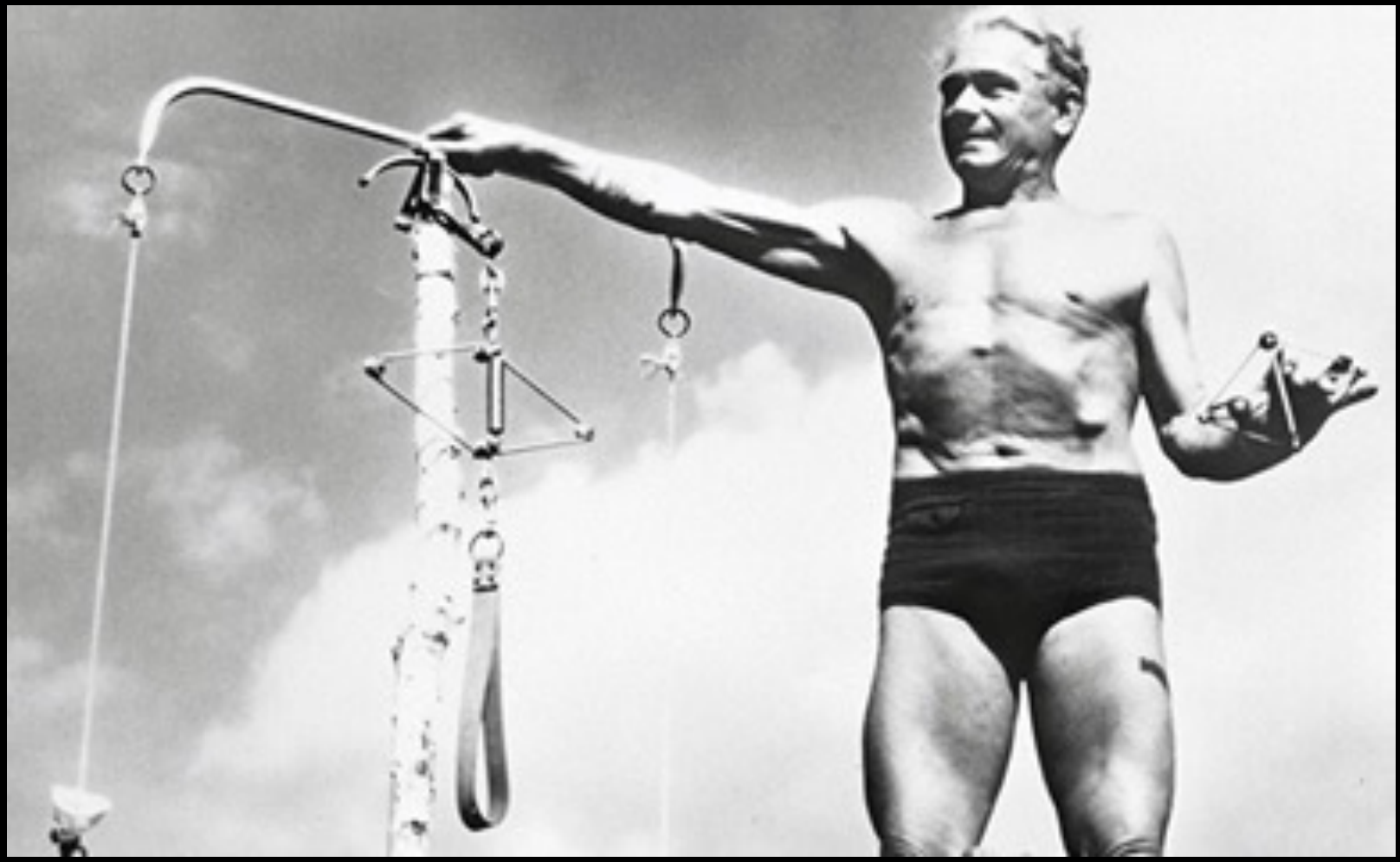
- He spent the war years in the library of the Hungarian Academy of Science doing his celestial mechanical calculations


Now
200
400
600
800
1000
kyr ago
Precession
19, 22, 24 kyr
Obliquity
41 kyr
Eccentricity
95, 125, 400 kyr
Solar Forcing
65∞N Summer
Hot
Stages of
Glaciation
Cold

One is reminded of another First World war Internee

- A German who happened to be in the UK at the outbreak of WW1
- Was interned in the Isle of Man
- And spent his time developing
- Who knows?

Joseph Pilates (1883 – 1967)



Milankovitch Cycles

- But I digress… Again
- I am now going to show a film about Milankovitch Cycles
- There is a lot of information but the essentials are……

Milankovitch Cycles

- The Sun – Earth distance does not affect the temperature much so whether the orbit is a circle or an ellipse is not too important
- The axis tilt determines the intensity of the seasons and is all important with respect to the summer melting of winter snow
- The precession of the axis – also called the precession of the equinox – upsets the calendar and affects the timing of the seasons but is of less importance

Milankovitch Cycles

- Milankovitch showed that the combined effect of the three variable did, from time to time, produce conditions likely to trigger an Ice Age

- Although not taken especially seriously in his lifetime, modern ice core measurements have, to a large extent, confirmed his analysis

Milankovitch Cycles

- Today we understand it is the position of the tectonic plates at the time of a solar energy minimum – as determined by the Milankovitch Cycles – that determines whether of not we have an Ice Age.

What about Astrology?

- The Precession of the Equinox which has rather messed up Astrology. For example:
- My birthday is in early April
- When this nonsense was first cooked up the Sun was 'in' the constellation Aries in early April
- Thus they tell me that my Star Sign is Aries
- But since those days, the Precession of the Equinox has changed the position of the sun with respect to the constellations

Astrology

- These days, in early April, the Sun is ‘in’ the constellation Cetus- the Whale
- Oddly, those who believe in Astrology do not believe me when I tell them that my Star Sign is Cetus the Whale

Astrology

- https://www.youtube.com/watch?v=j0H4xTla_M8

Sheldon's view of Astrology

Milankovitch Cycles

And now the film

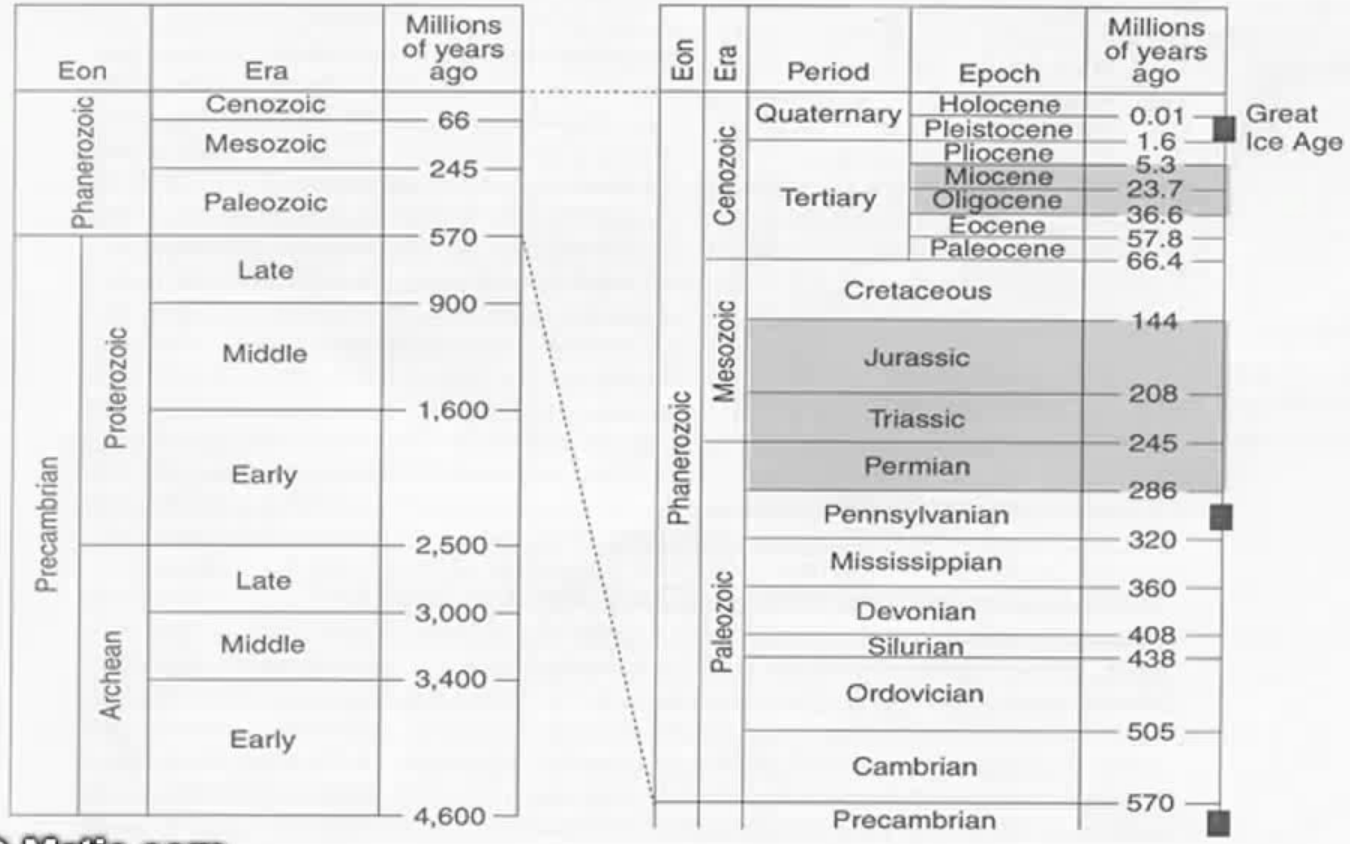
Enjoy the animations…..

Milankovitch Cycles

- https://www.youtube.com/watch?v=xQSHxY5ZR6w

Milankovitch Cycles

Table 1 This geologic time scale shows how recent and short-lived the Great Ice Age was in comparison to the age of the earth. Periods and epochs for which no deposits are known in Illinois are shaded in blue at right. Rectangles along the right scale indicate the times of major ice ages in earth's history. (After Palmer 1983)

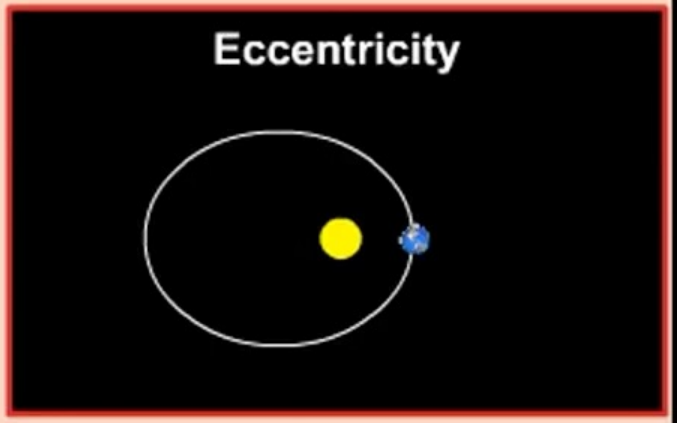


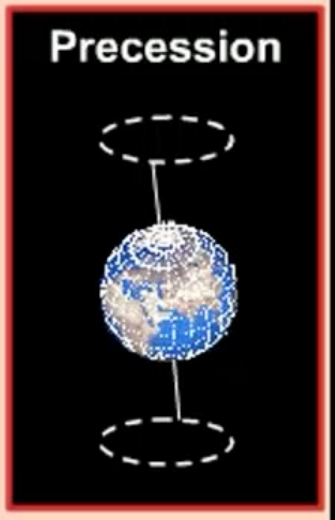
Milankovitch Cycles

Introduction

The shape of the Earth's orbit (**eccentricity**), the tilt of its axis (**obliquity**), and direction of its axis (**precession**) change slowly and periodically over time. These cycles cause variations in the amount of solar energy reaching the Earth. These **Milankovitch Cycles** are named after the Serbian mathematician, Milutin Milankovitch, who used them to explain the advance and retreat of the polar ice caps. Many scientists believe these cycles play a role in the Earth's climate.

In this tutorial you will learn about eccentricity, obliquity, and precession and how they change through time. You will also learn how these changes may influence the Earth's climate.





The End