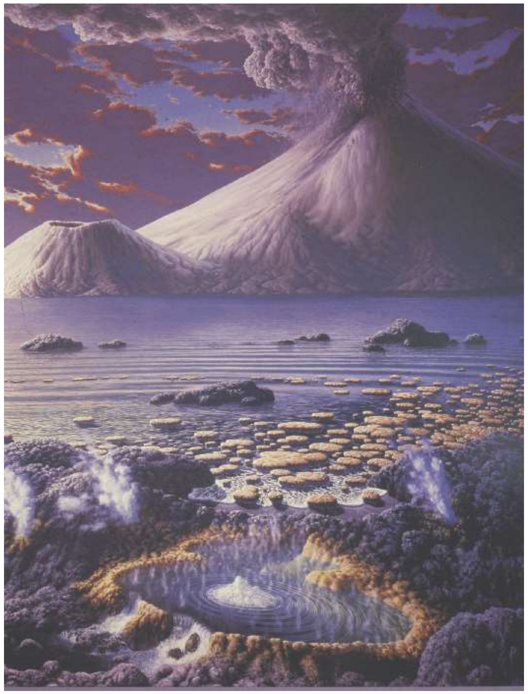
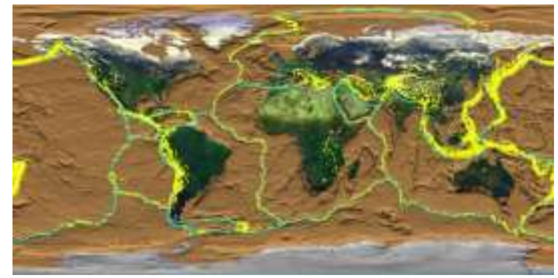
Earth

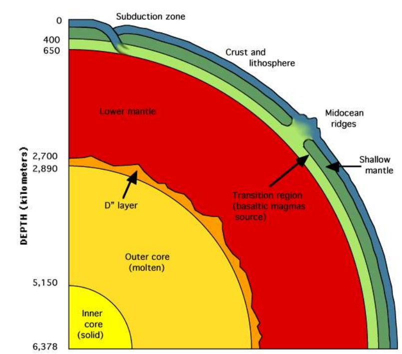


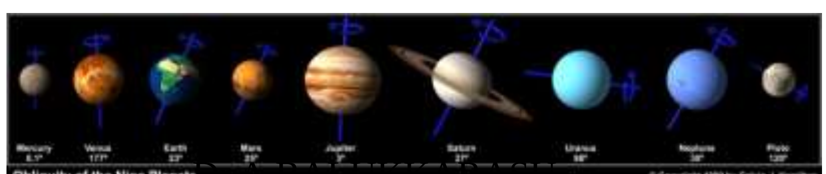
Early Archean

Blue Planet

Plate Tectonics







Earth Facts

- Distance from Sun: 150 million kilometers (93.2 million miles)
- Orbital period: 365.256 days
- Rotational period: 23.9345 hours
- Tilt of axis: 23.45 degrees
- Diameter: 12,756 kilometers (7,973 miles)
- Mean density: 5.515 g/cc
- Mean surface temperature: 15°C
- Atmospheric pressure: 1.013 bars
- Atmosphere composition: 77% N, 21% O and 2% other.
- Crustal rocks: Mid-ocean ridge basalt, andesites, granites, sandstones, shales, limestones, metamorphic.
- Magnetic field
- Plate tectonics
- Hydrosphere
- Biosphere

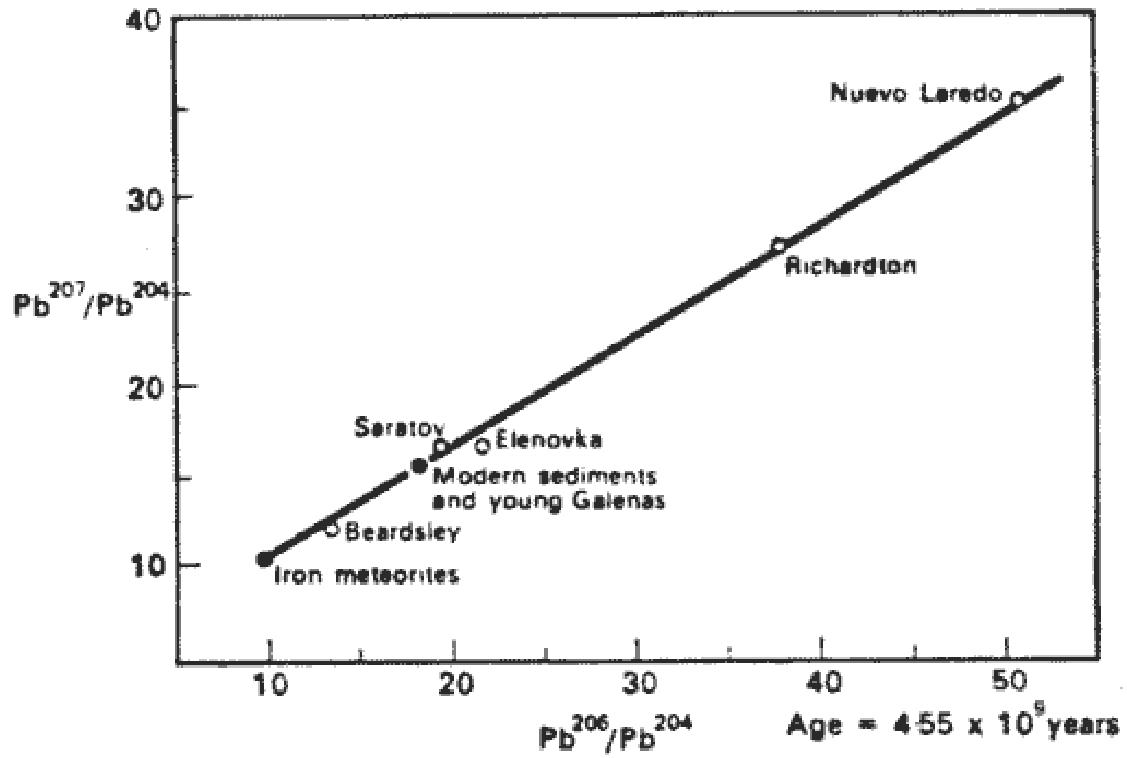
Age of the Earth

Estimated age for the Earth and the rest of the solar system is about 4.55 billion years comes from Lead isotope measurements.

The oldest Earth rocks: 3.8 to 3.9 billion years

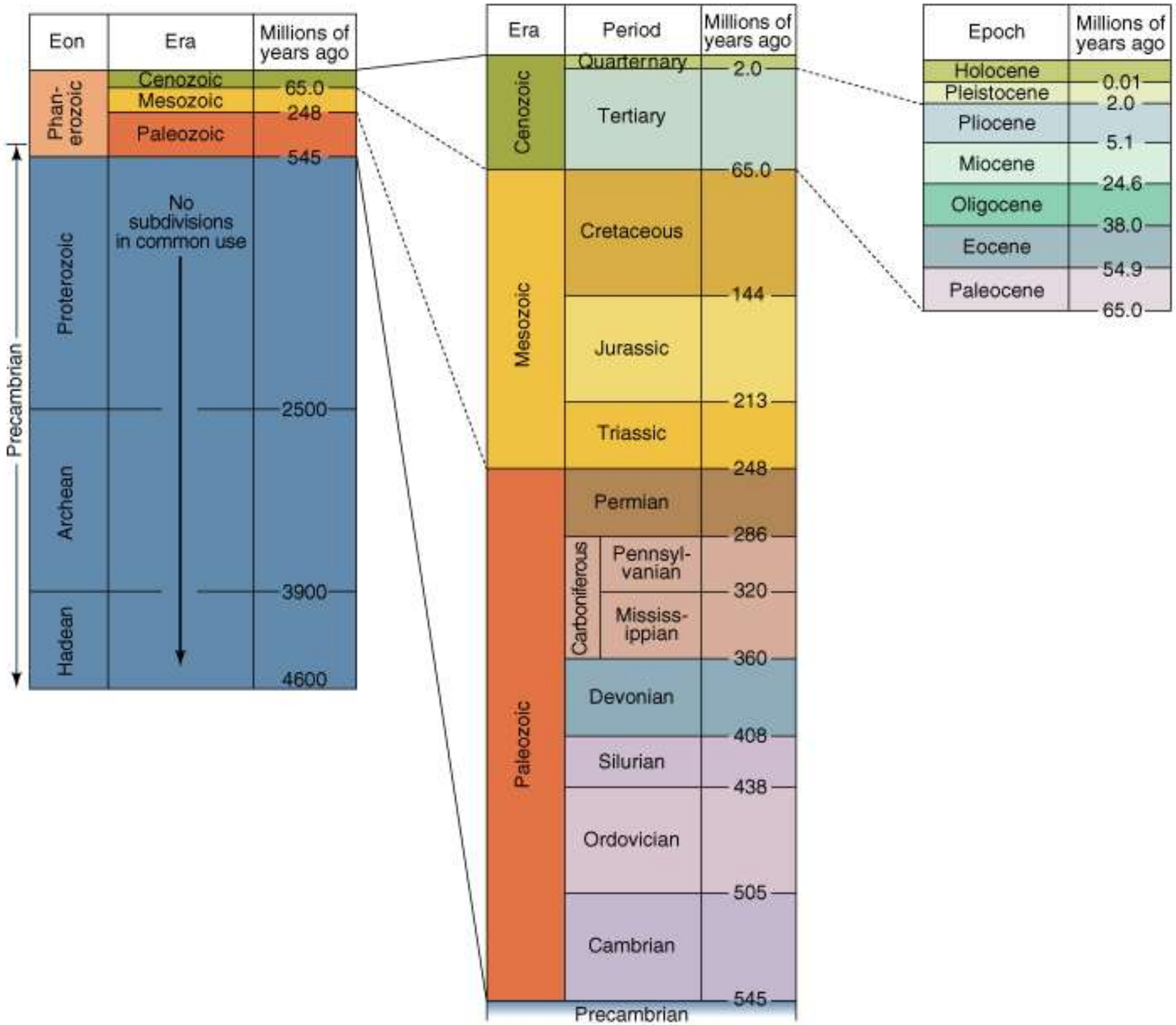
Oldest Earth minerals (zircons): 4.2 billion years

Oldest Moon rocks: 4.44 billion years



Early Earth Timeline

- About 5.5-6 billion years ago (BYA), the solar nebula begins to collapse
- About 4.6 BYA, Sun begins fusion
- About 4.5-4.56 BYA, Proto-Earth formed from planetesimals.
- 4.44+ BYA, Earth-Moon formed by giant impact. Earth melts, magma ocean.
- 4.2 BYA, Earth was completely differentiated.
- 4 BYA, earliest oceans formed, thick atmosphere exists
- 3.8 BYA, life develops
- 2.5-3 BYA, photosynthesis leads to O2 in ocean
- 2 BYA, O2 hits atmosphere



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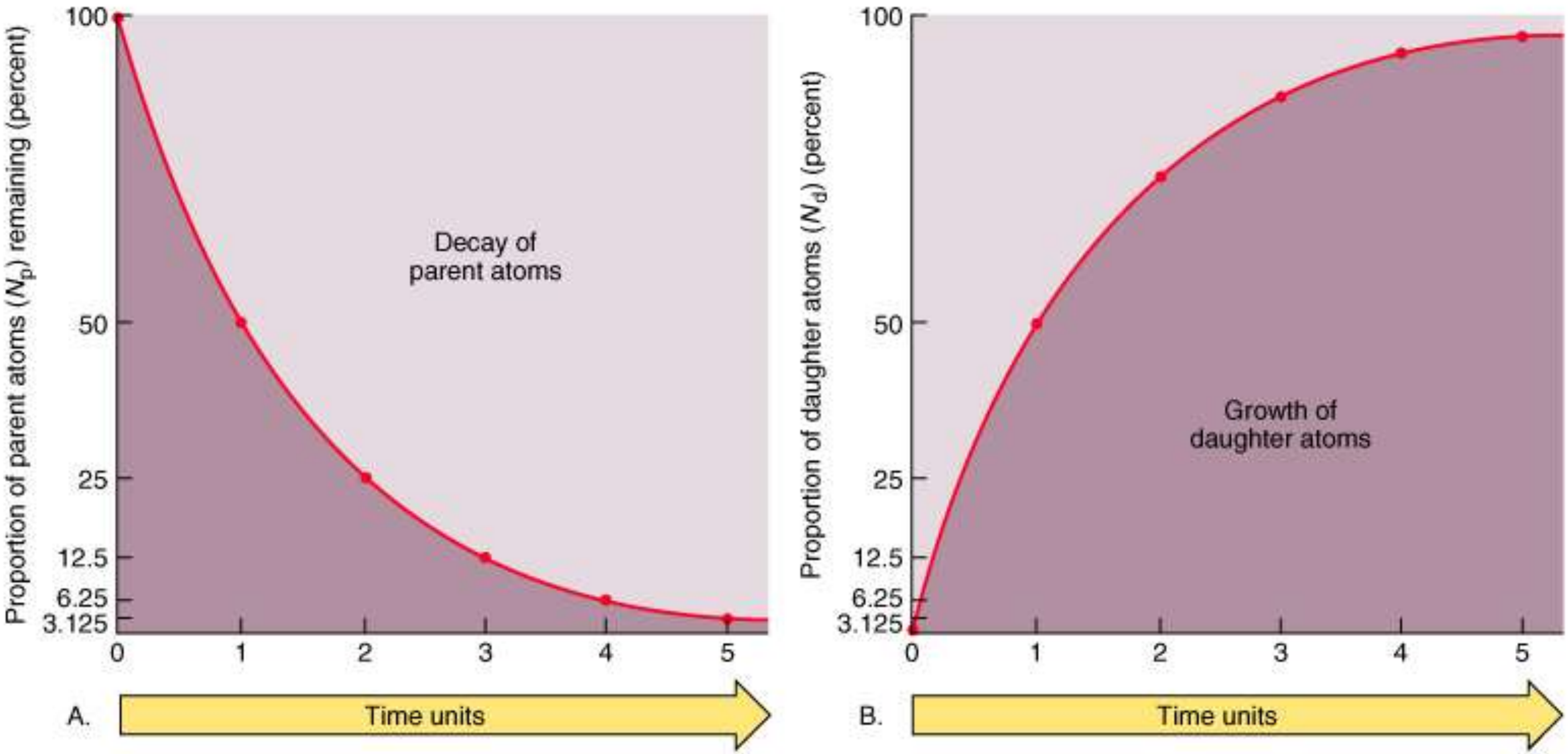
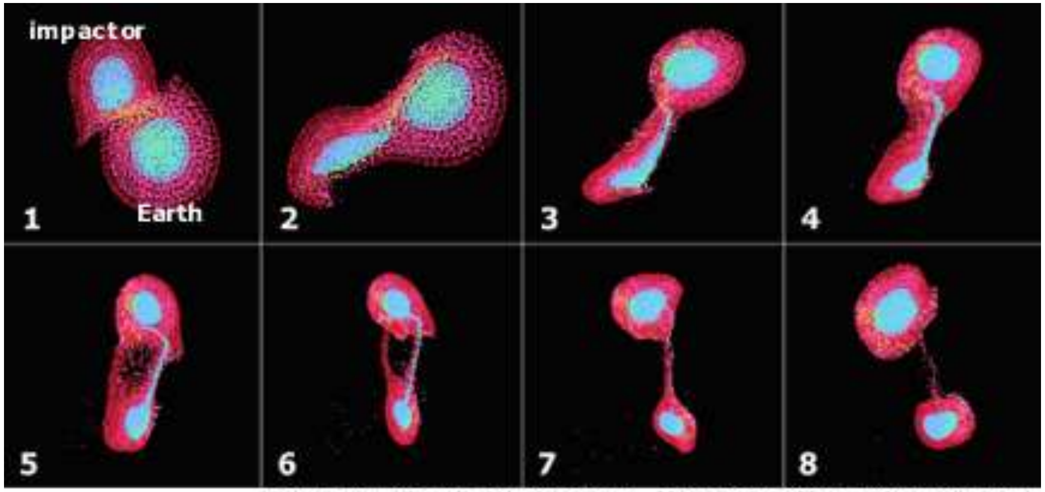


100
50
25
12.5
6.25
3.125
0
1
2
3
4
5
Proportion of parent atoms (N_p) remaining (percent)
Decay of
parent atoms
A.
Time units
100
50
25
12.5
6.25
3.125
0
1
2
3
4
5
Proportion of daughter atoms (N_d) (percent)
Growth of
daughter atoms
B.
Time units

Giant Impact Formation of Earth-Moon System

SHOW MOVIES!



(Courtesy of A. G. W. Cameron, Harvard College Observatory.)

Lunar Magma Ocean

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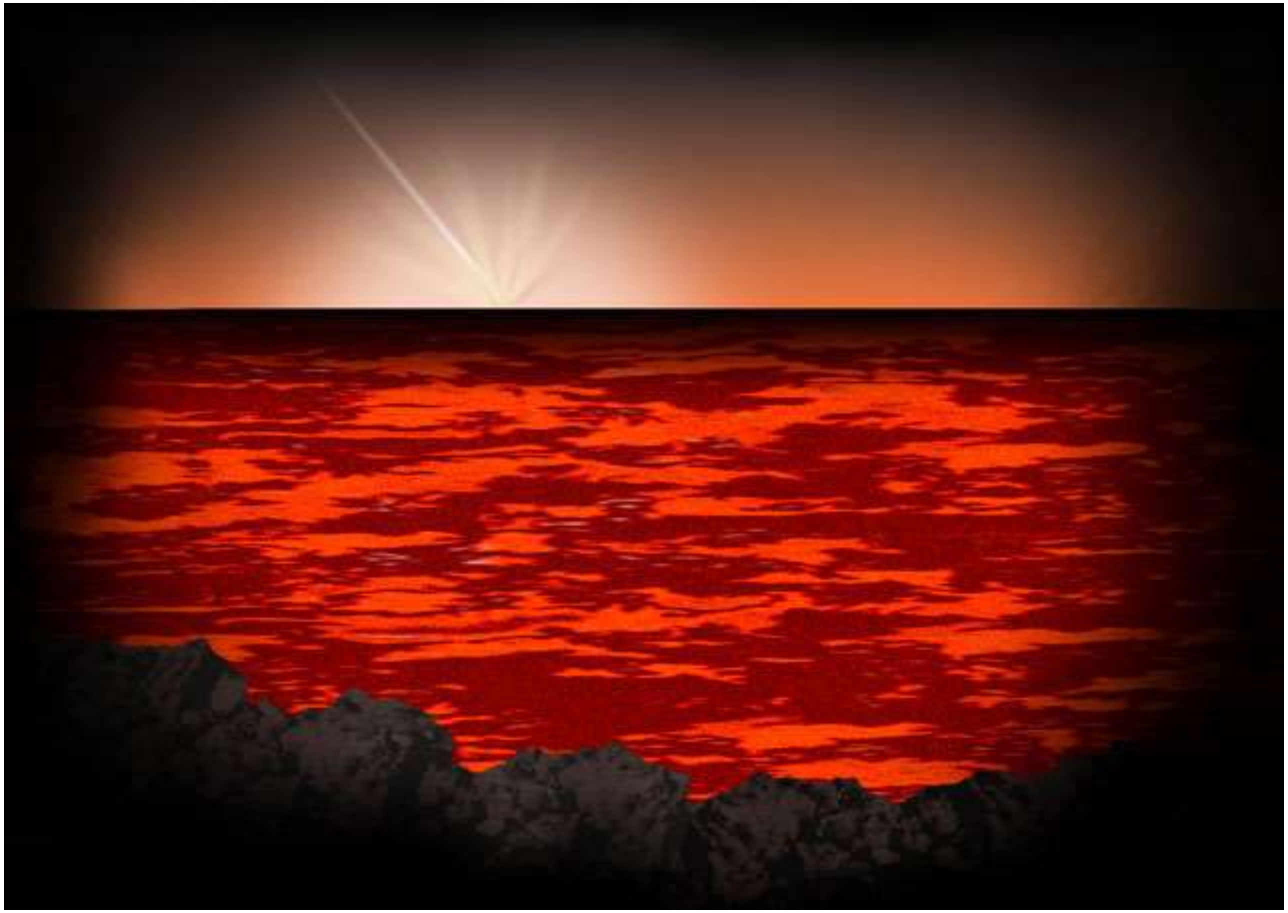
Early Earth's Magma Ocean



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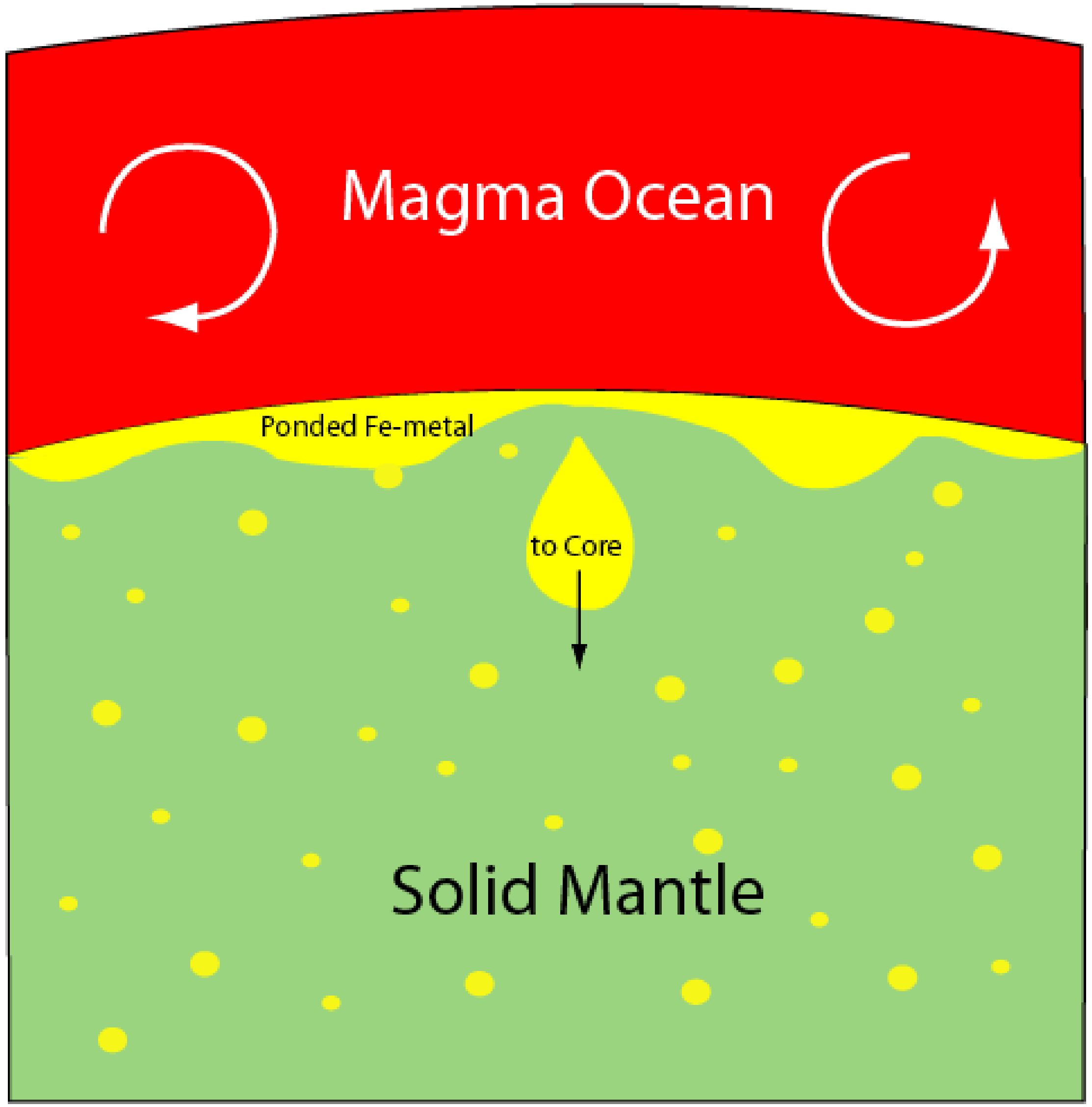
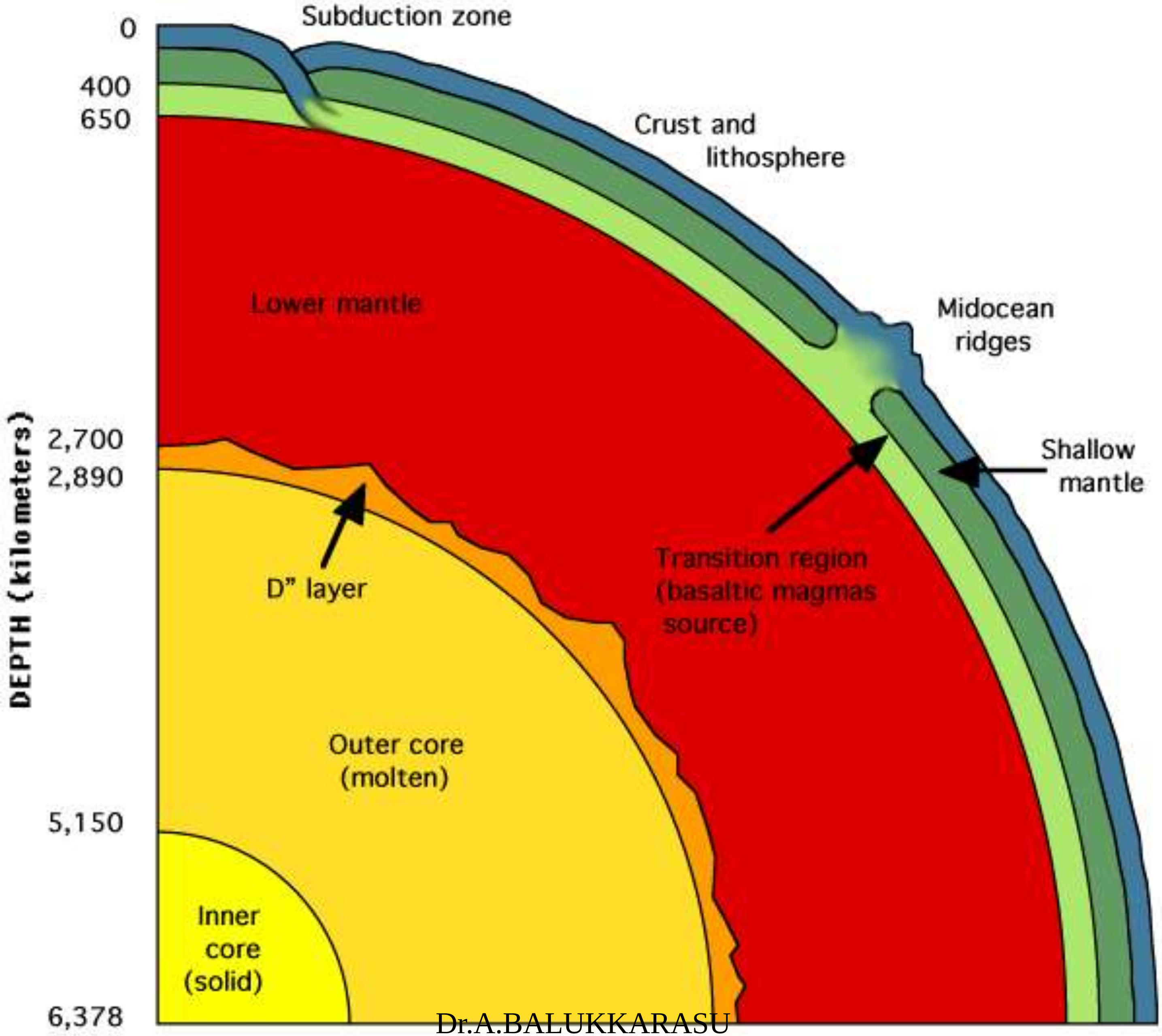


1000 km ?



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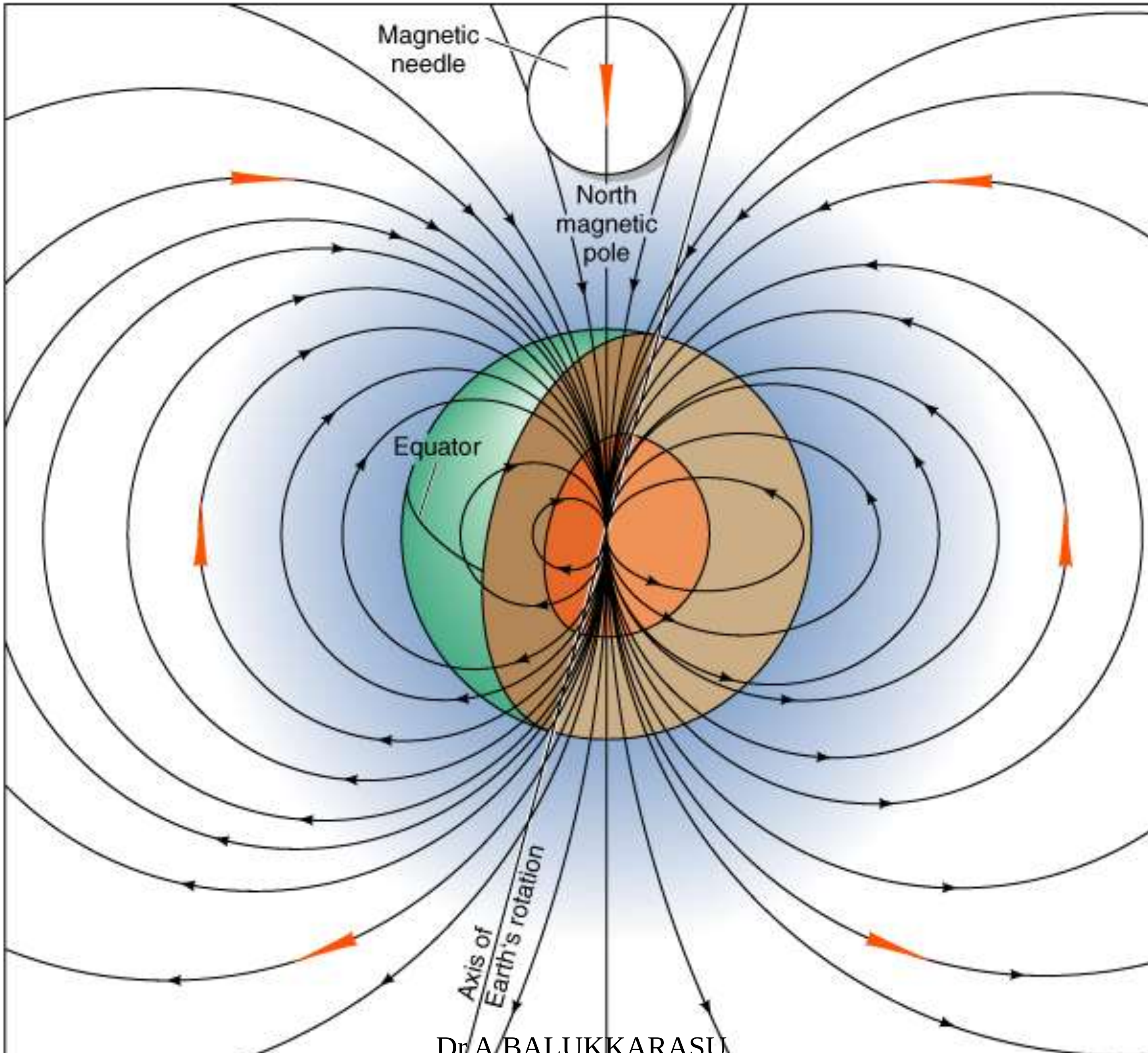
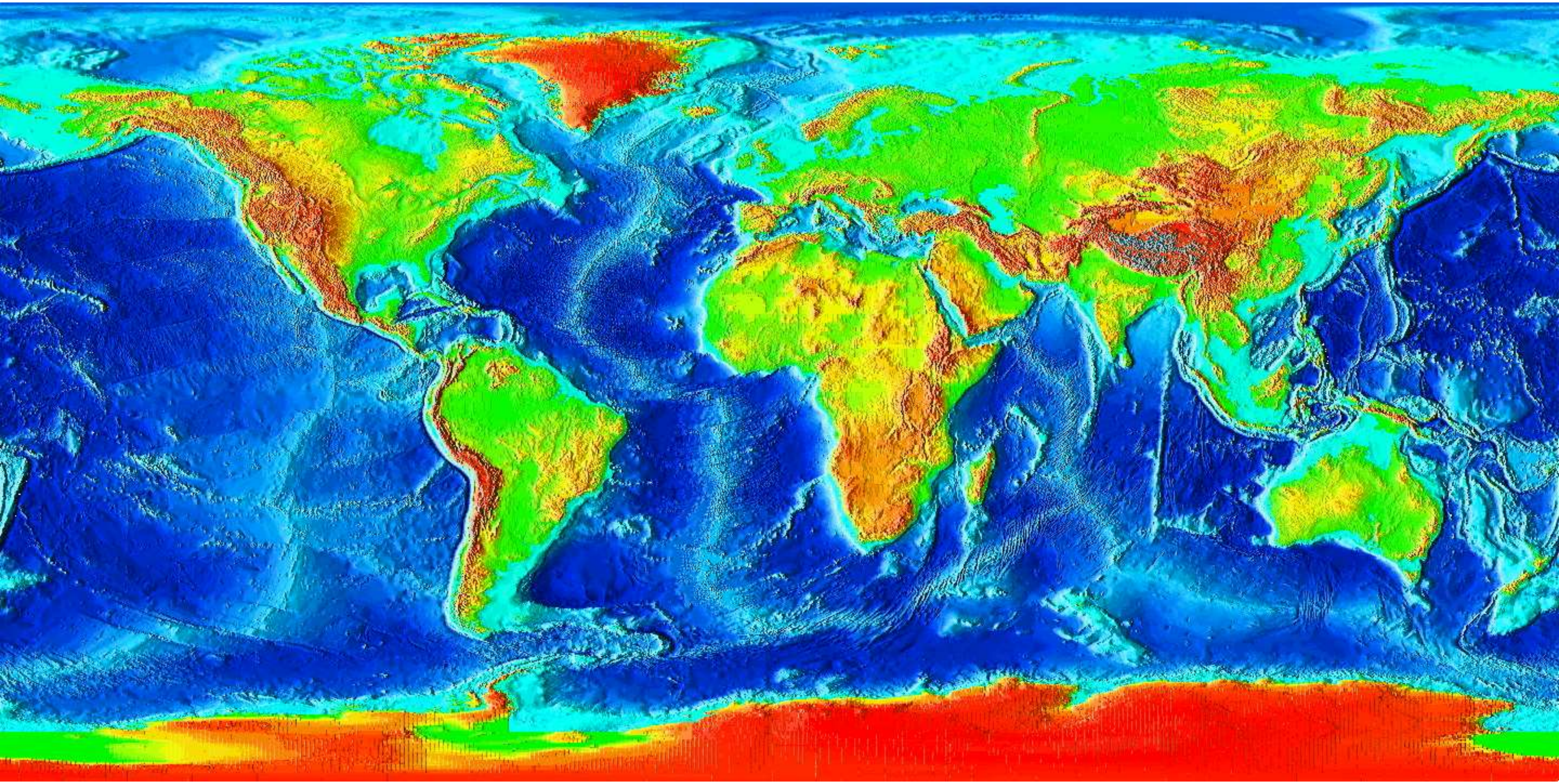

Magnetic needle
North magnetic pole
Equator
Axis of Earth's rotation
Dr.A.BALUKKARASU

Earth



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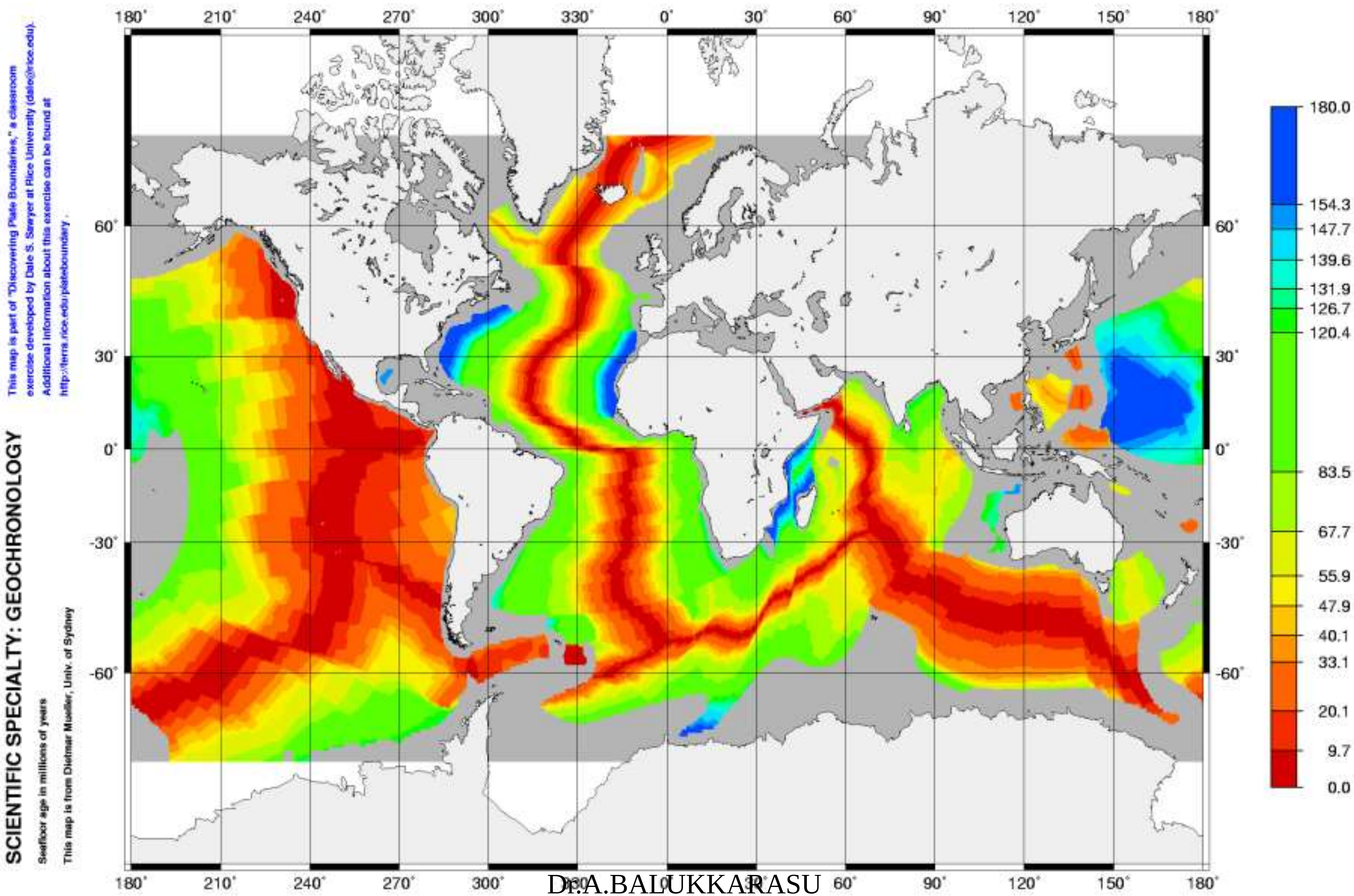
Age of the Oceanic Crust



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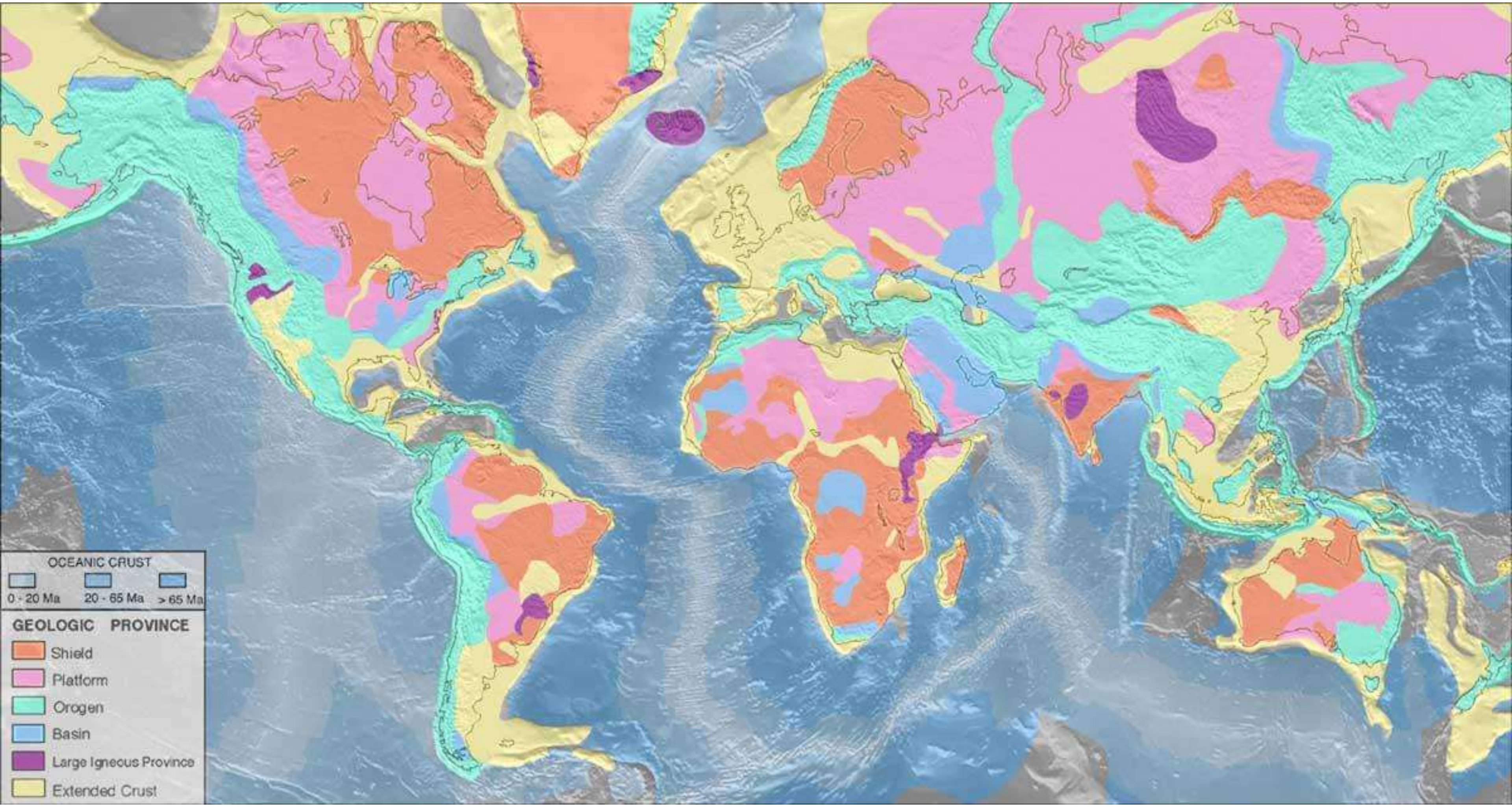
Geologic Provinces



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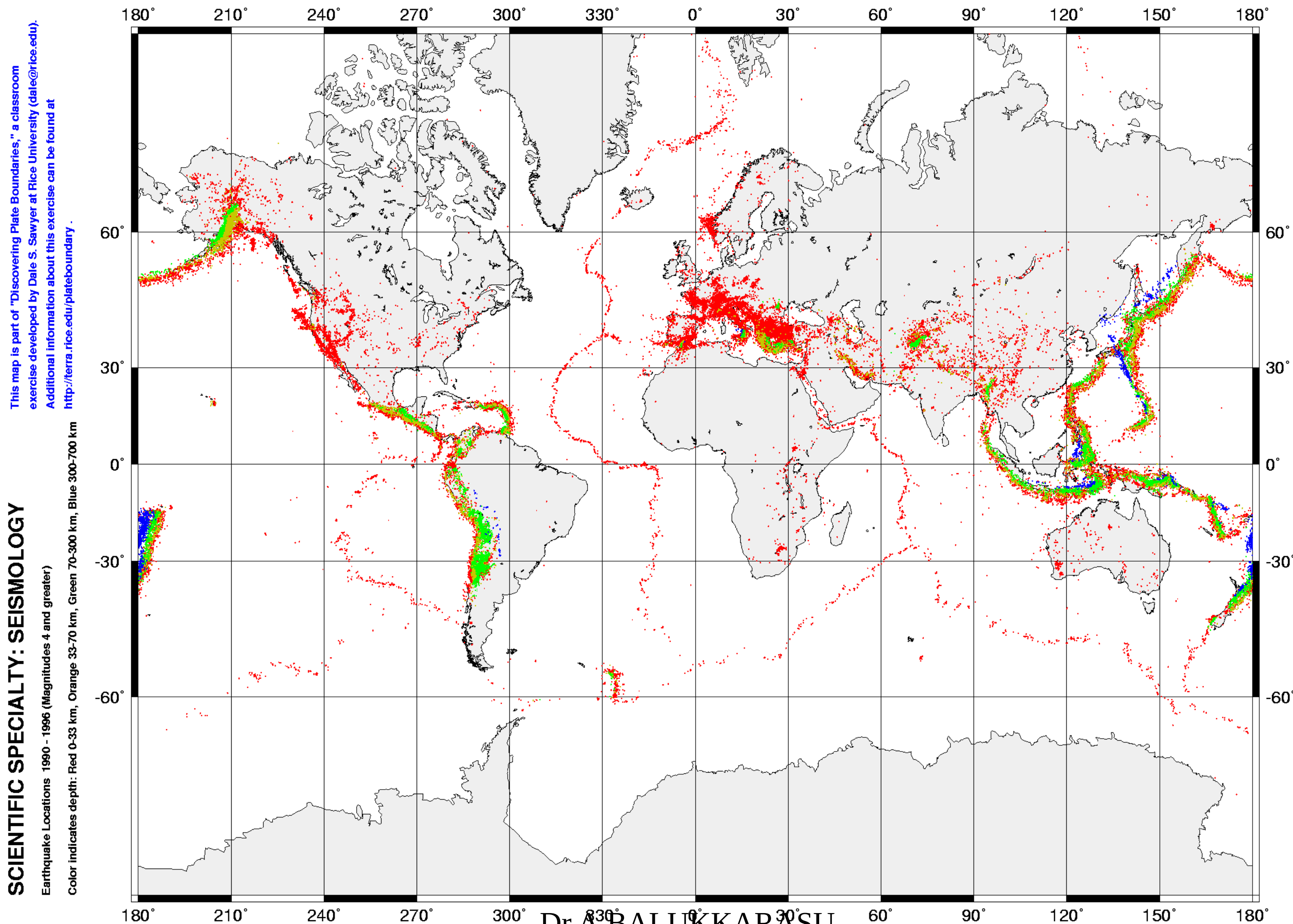
Earthquake Epicenters



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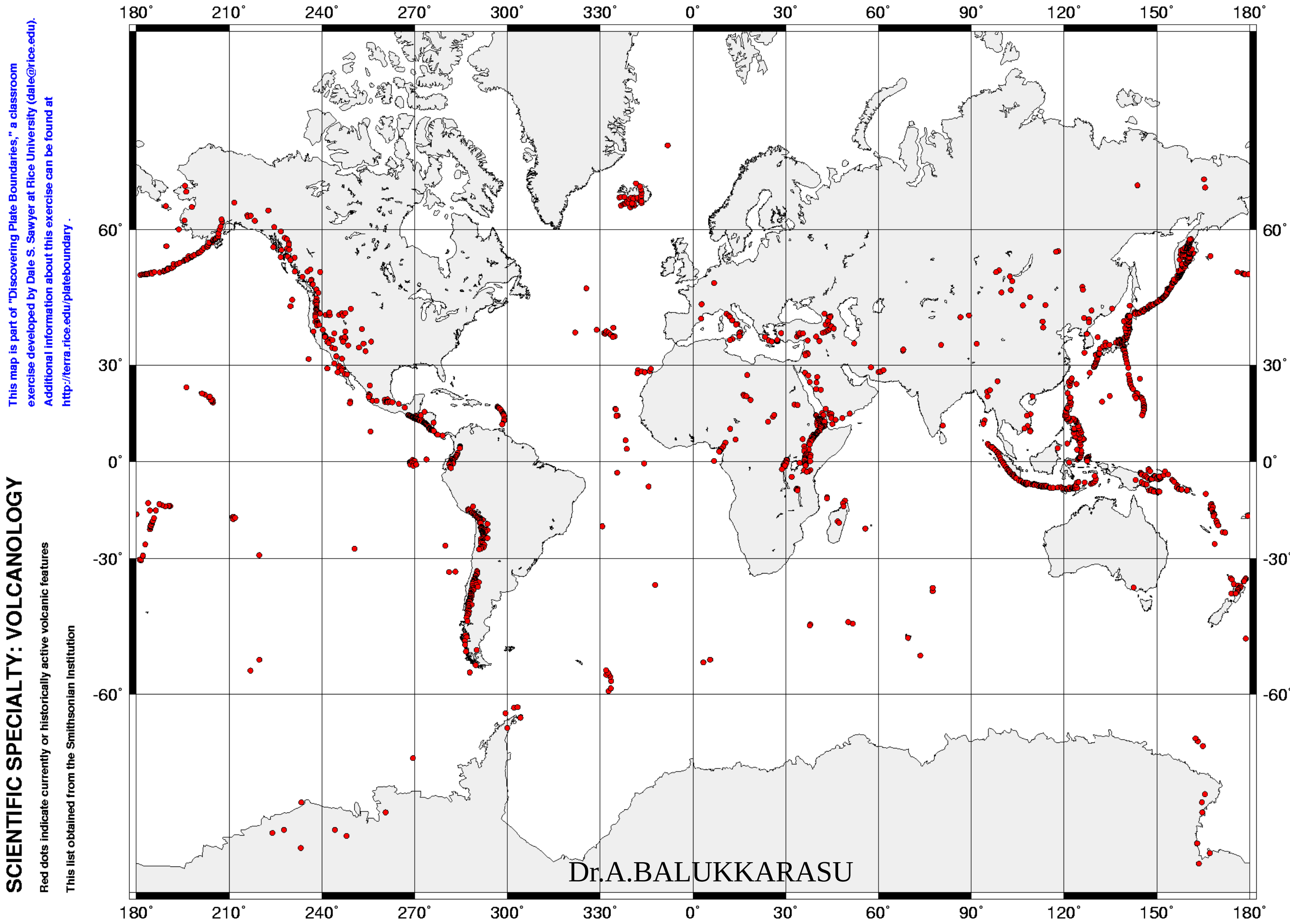
Recent Volcanism



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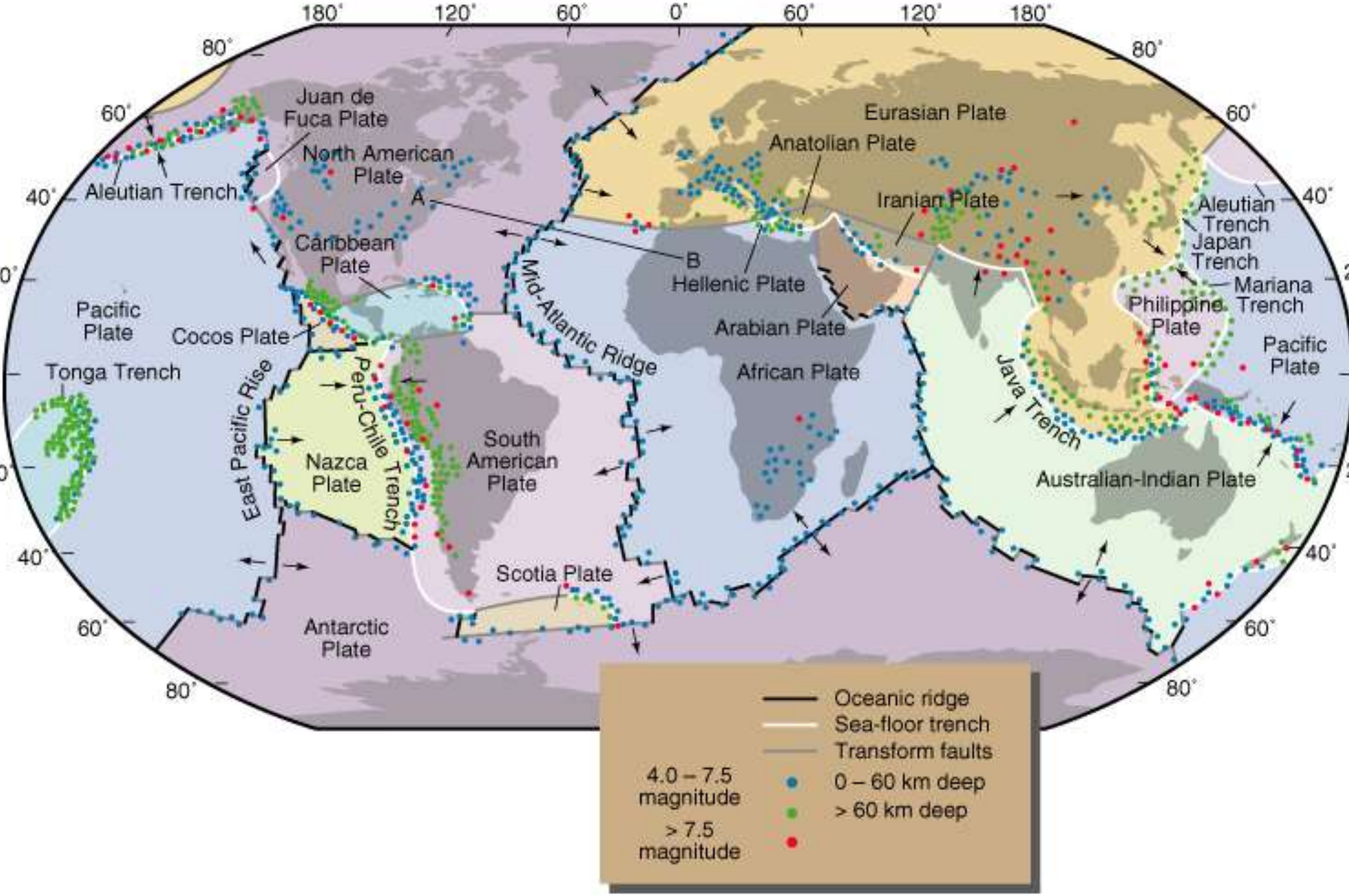
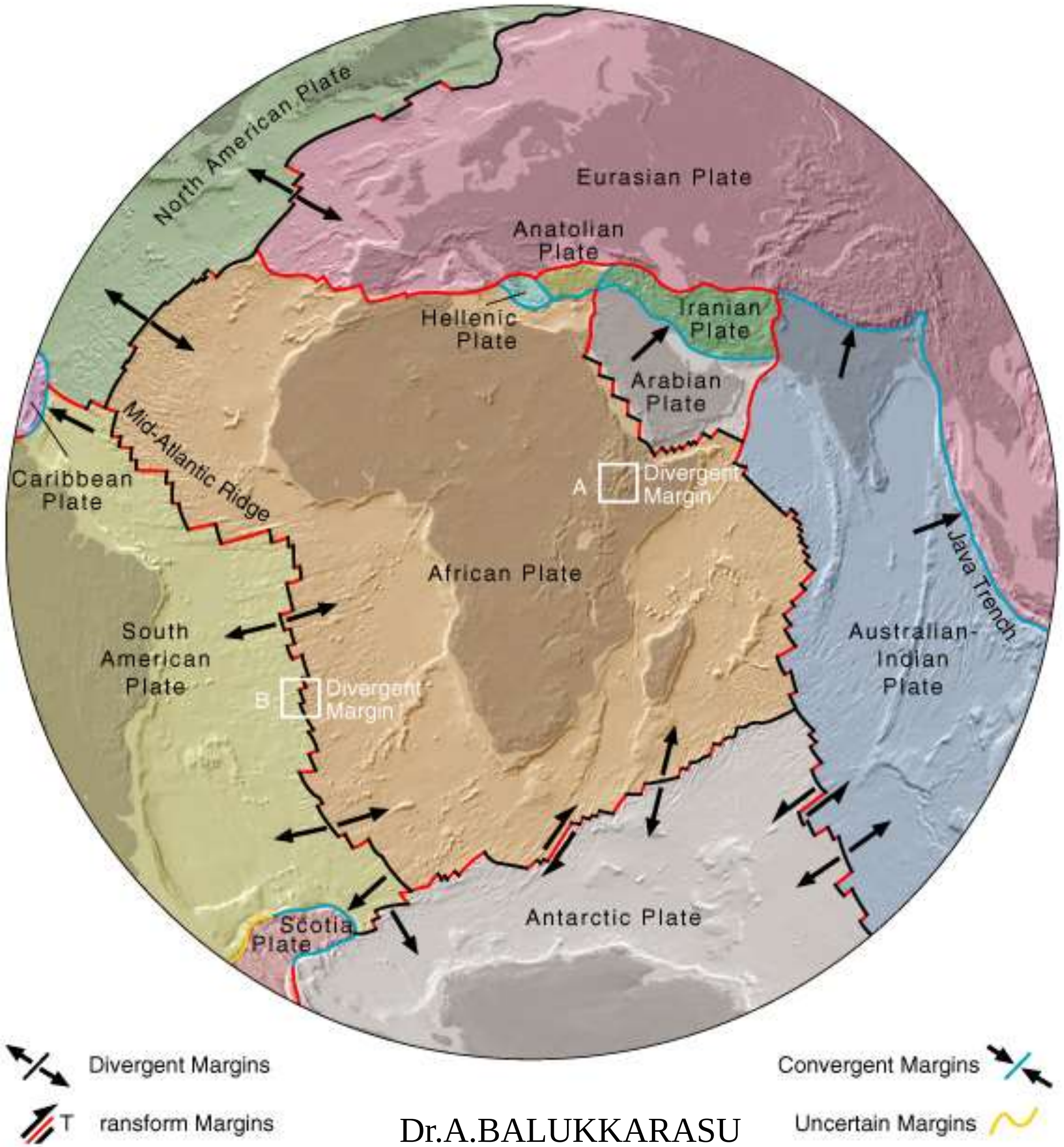

180° 120° 60° 0° 60° 120° 180°
80° 60° 40° 20° 0° 20° 40° 60° 80°
Juan de Fuca Plate
North American Plate
Aleutian Trench
A
B
Caribbean Plate
Pacific Plate
Cocos Plate
Tonga Trench
East Pacific Rise
Peru-Chile Trench
Nazca Plate
South American Plate
Mid-Atlantic Ridge
Scotia Plate
Antarctic Plate
Eurasian Plate
Anatolian Plate
Iranian Plate
Hellenic Plate
Arabian Plate
African Plate
Aleutian Trench
Japan Trench
Mariana Trench
Philippine Plate
Pacific Plate
Java Trench
Australian-Indian Plate
Oceanic ridge
Sea-floor trench
Transform faults
4.0 – 7.5 magnitude
0 – 60 km deep
> 60 km deep
> 7.5 magnitude



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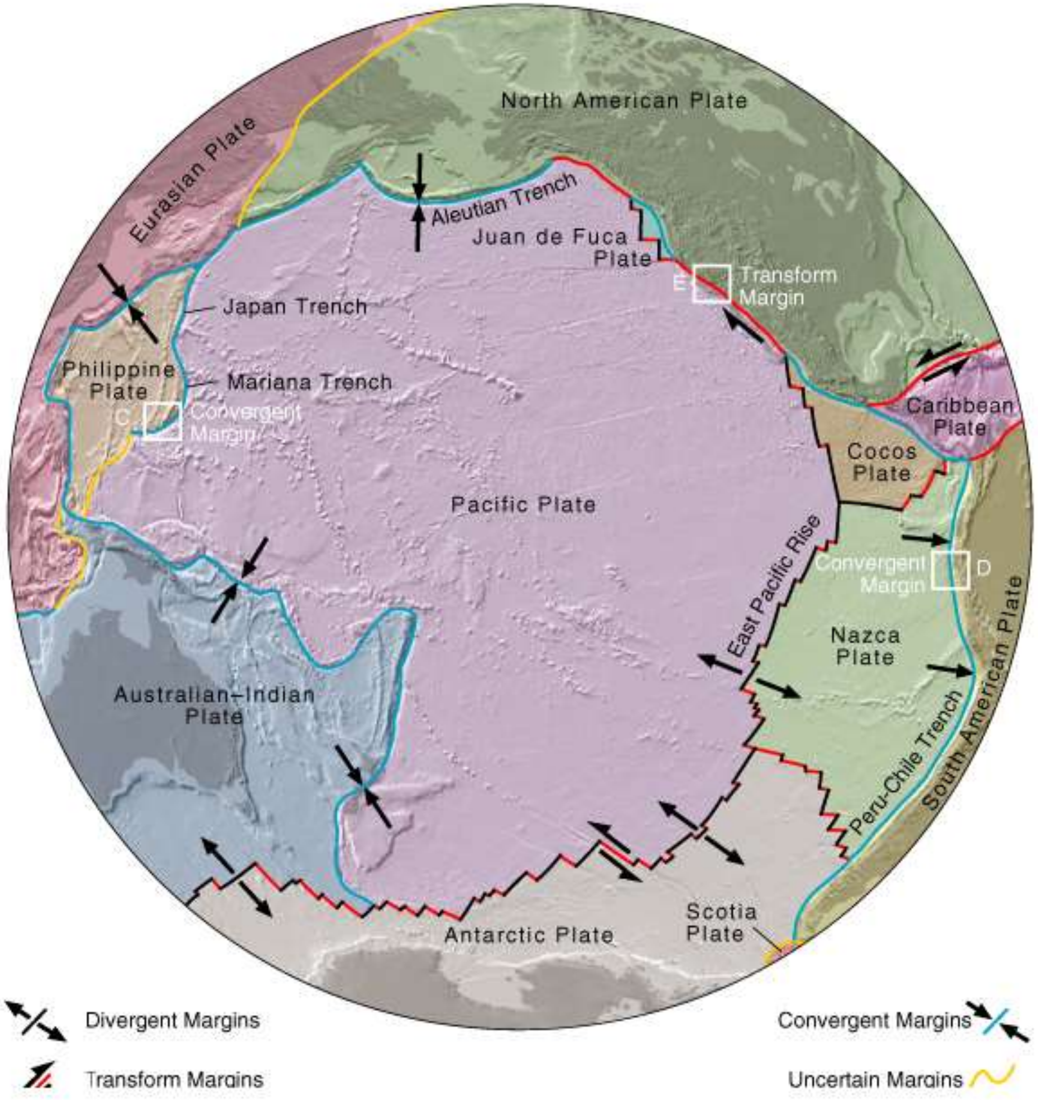
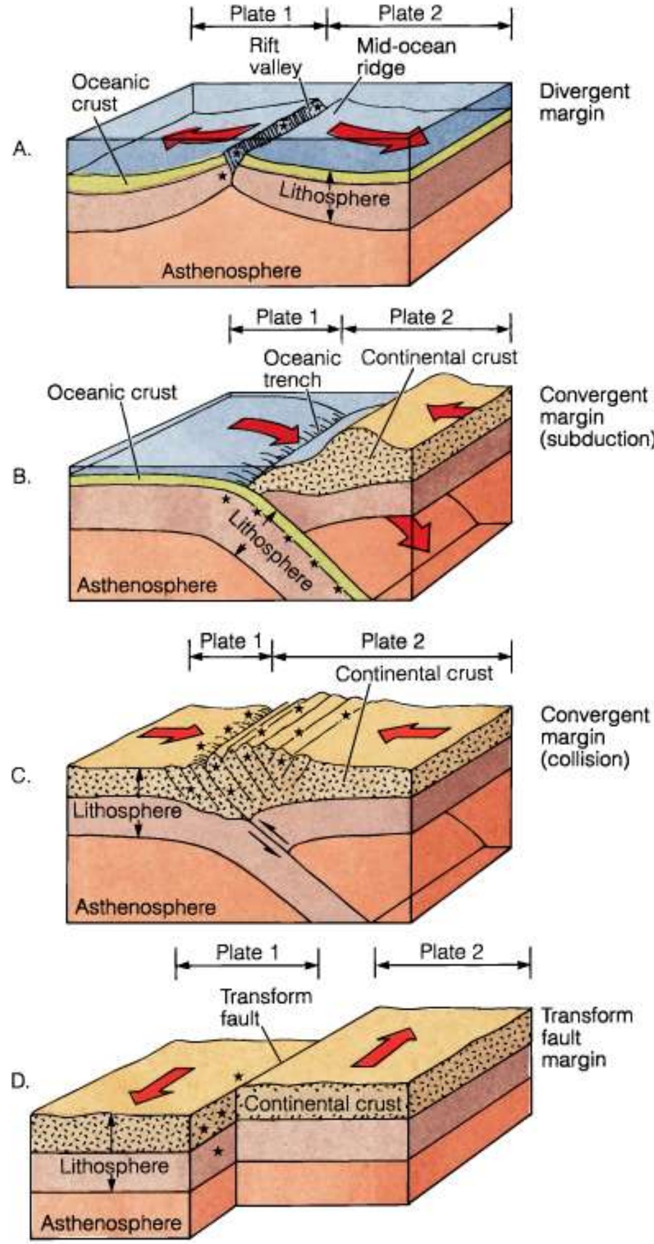

North American Plate
Eurasian Plate
Aleutian Trench
Juan de Fuca
Plate
Transform
Margin
E
Japan Trench
Philippine
Plate
Mariana Trench
C
Convergent
Margin
Caribbean
Plate
Cocos
Plate
Pacific Plate
East Pacific Rise
Convergent
Margin
D
Nazca
Plate
South American Plate
Peru-Chile Trench
Australian–Indian
Plate
Scotia
Plate
Antarctic Plate
Divergent Margins
Transform Margins
Convergent Margins
Uncertain Margins



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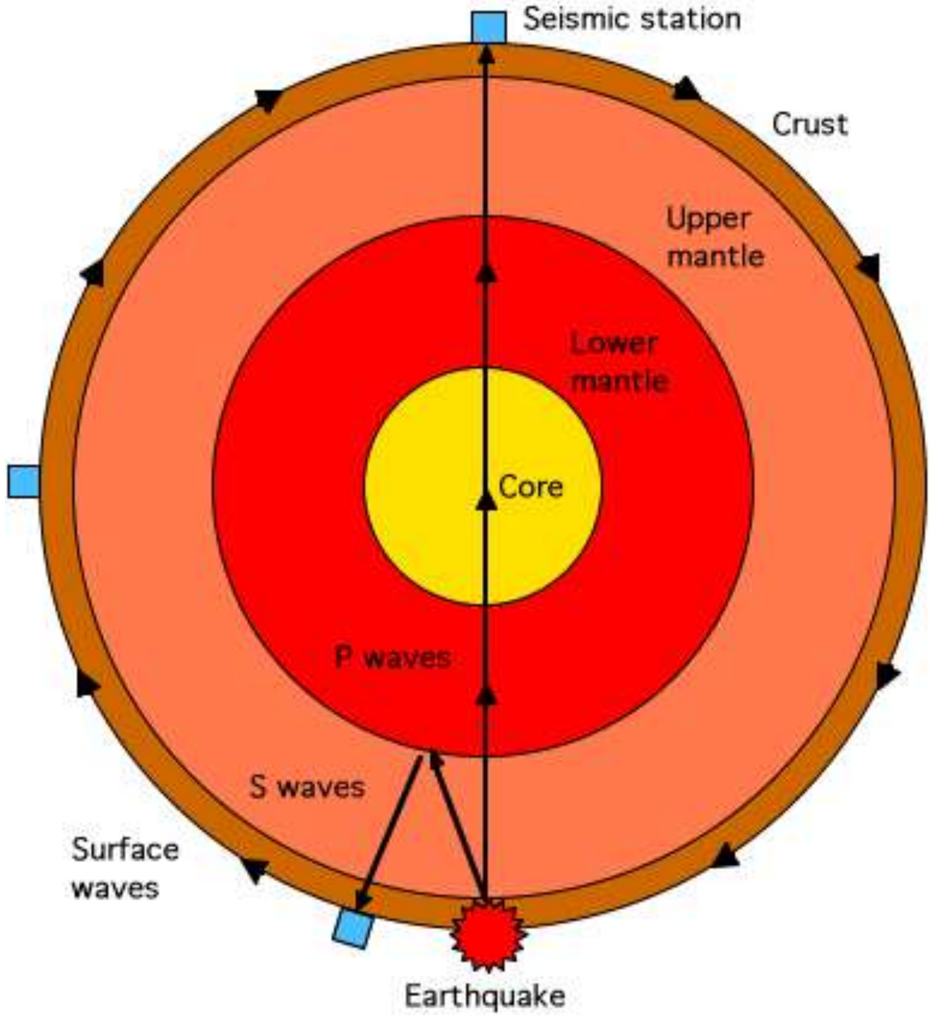
Imaging the Earth’s Interior



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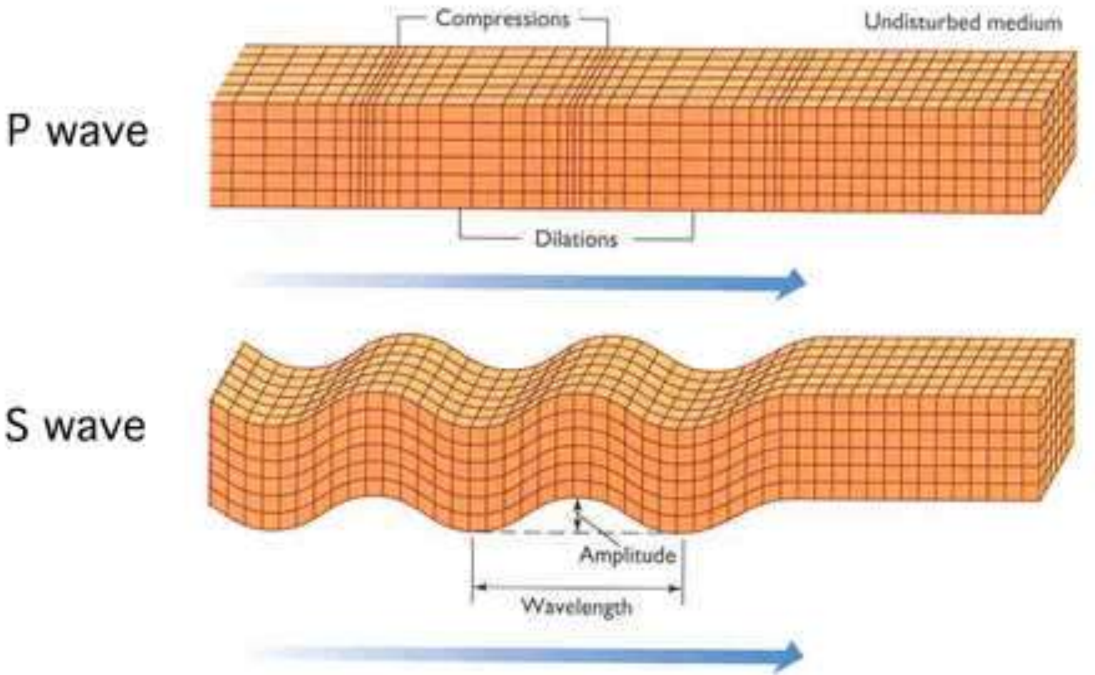
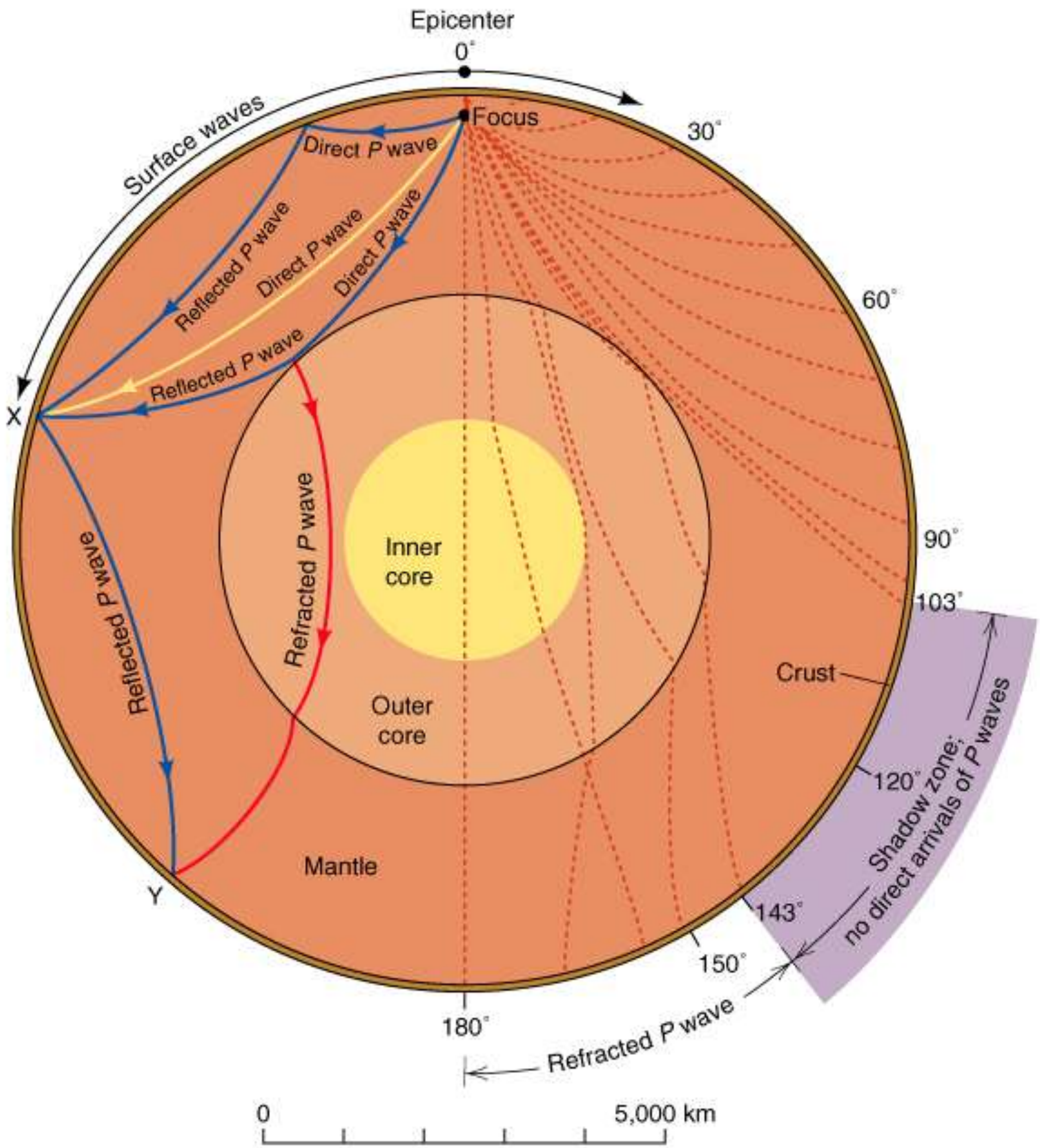
TWO TYPES OF SEISMIC WAVES

P OR *COMPRESSIONAL* WAVES - VOLUME CHANGES
MATERIAL COMPRESSED OR EXPANDED IN DIRECTION WAVE PROPAGATES



S OR *SHEAR* WAVES - DISTORTION WITHOUT VOLUME CHANGES - MATERIAL SHEARED IN DIRECTION NORMAL TO WAVE PROPAGATES
P WAVES TRAVEL FASTER (ABOUT 1.7X) THAN S WAVES



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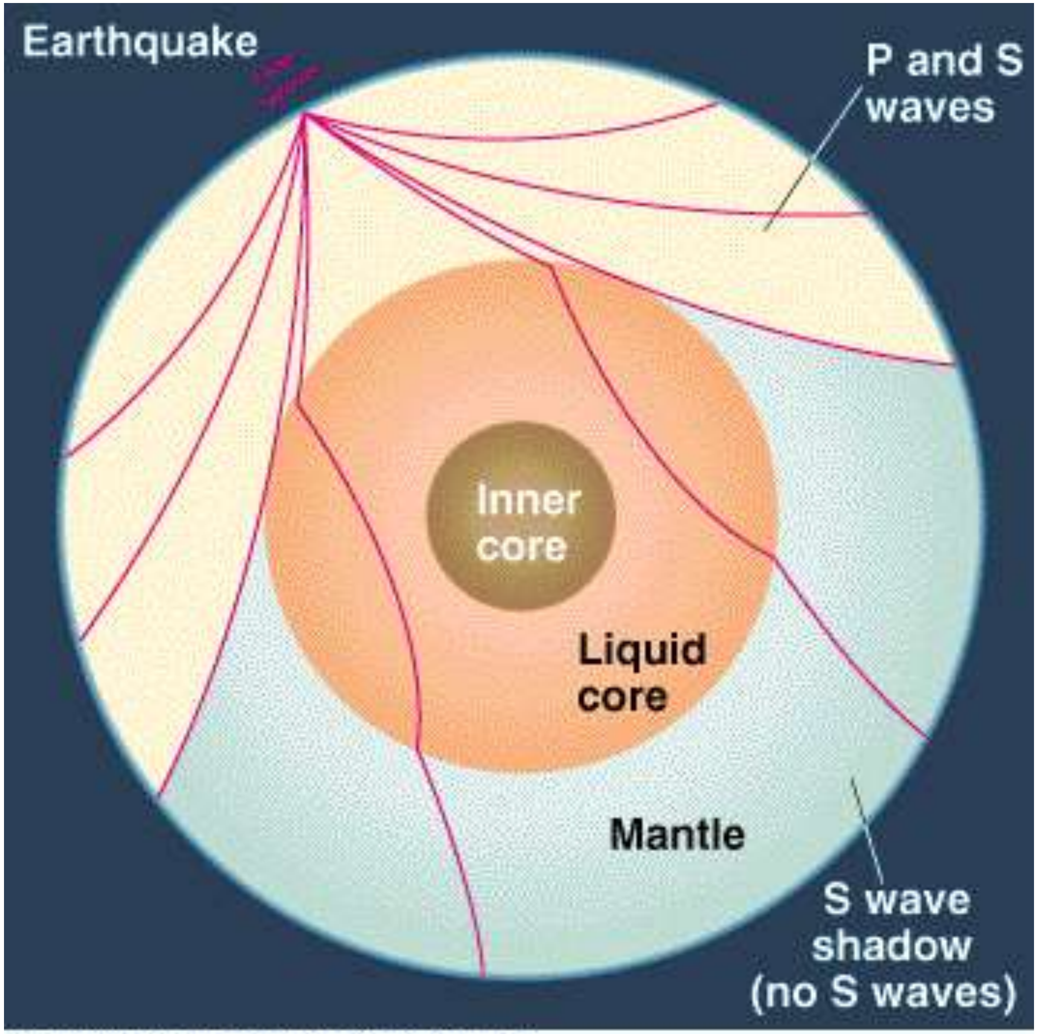
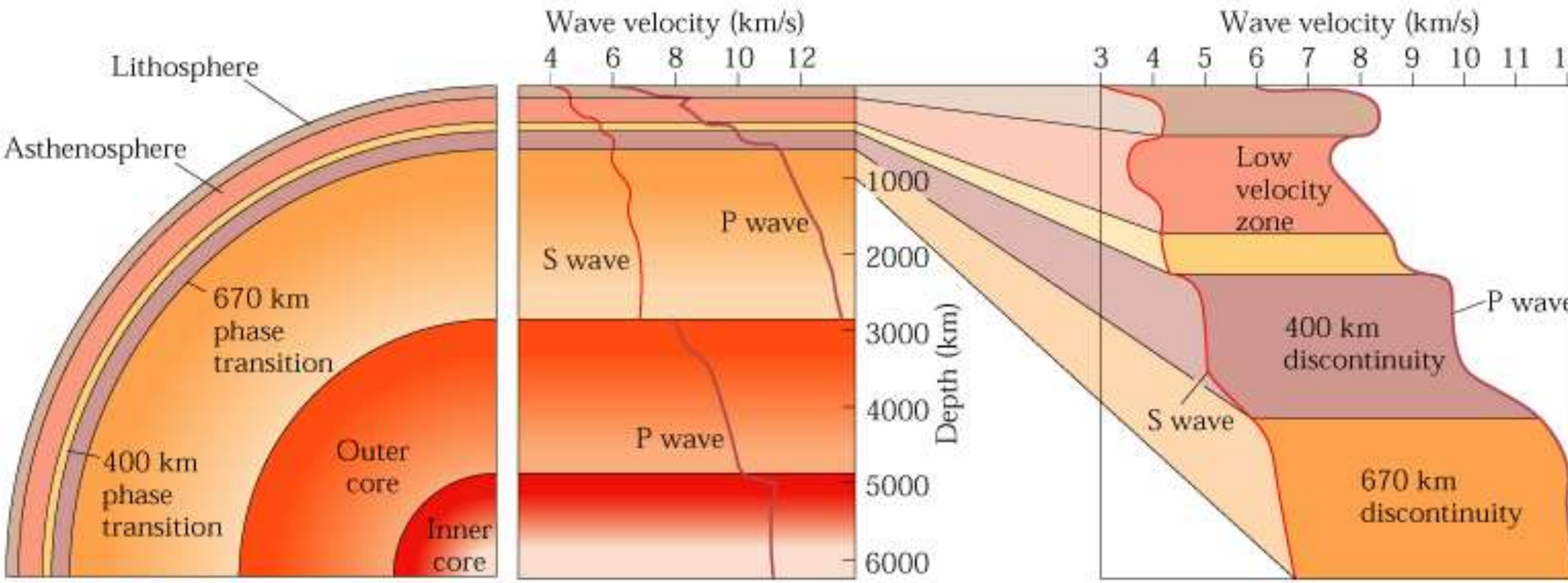
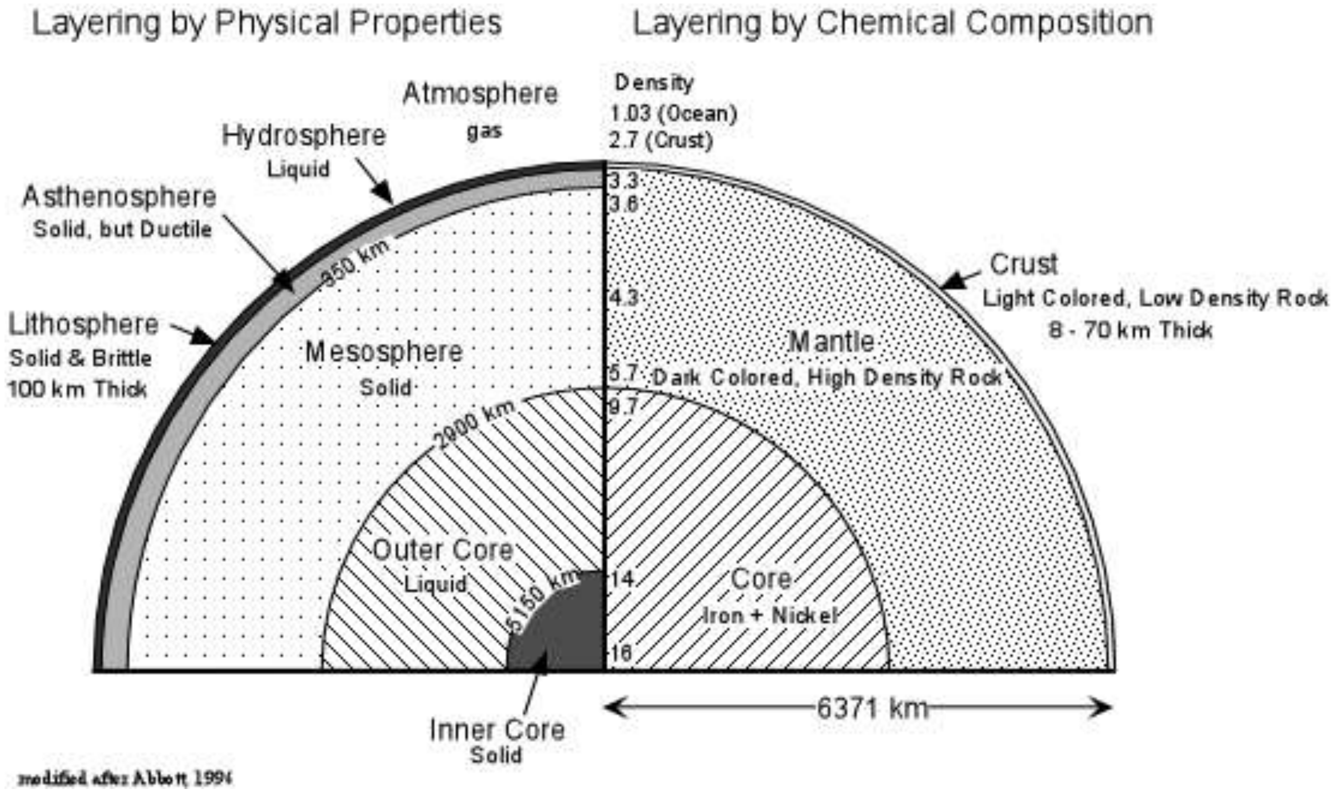
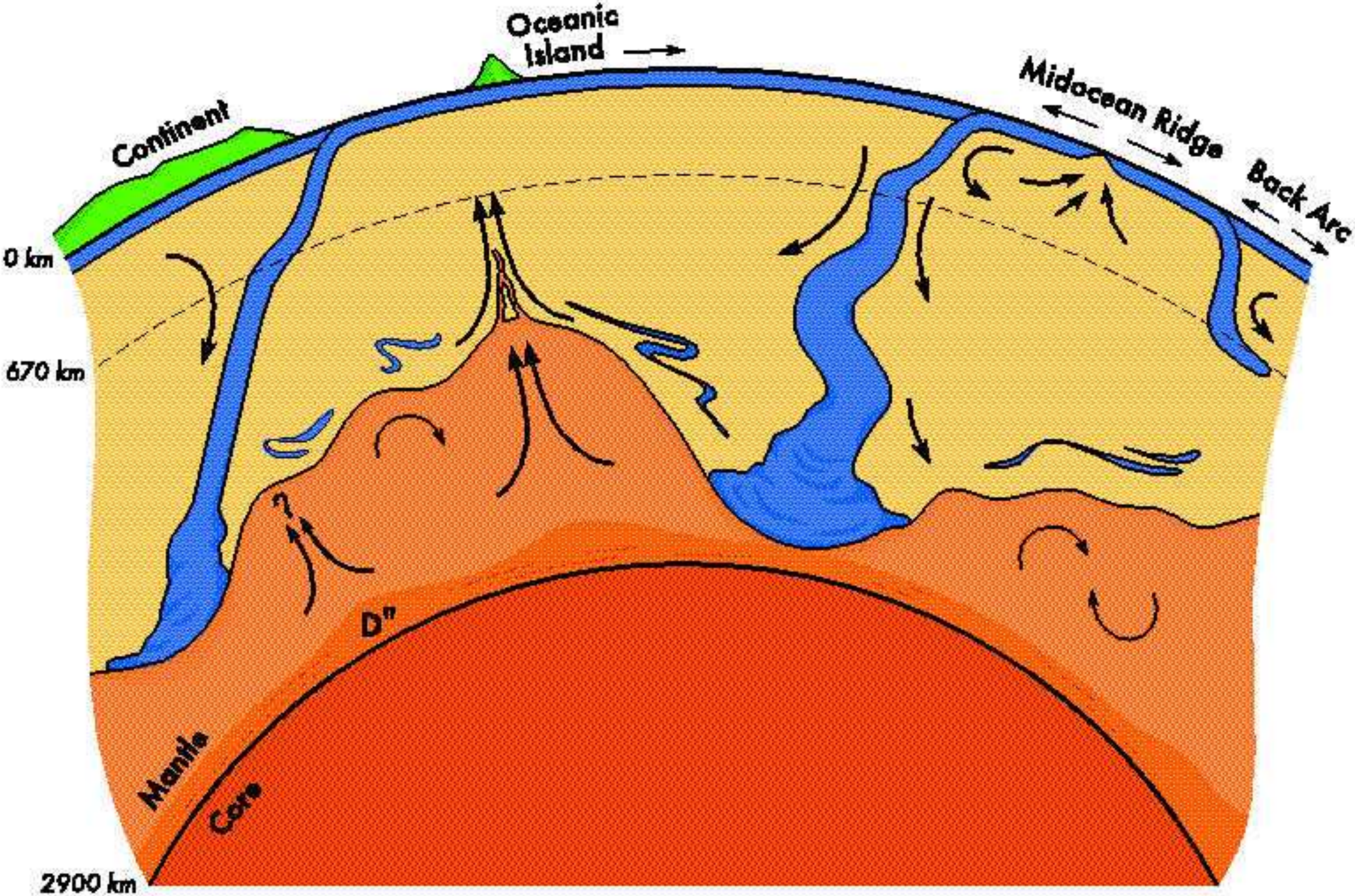
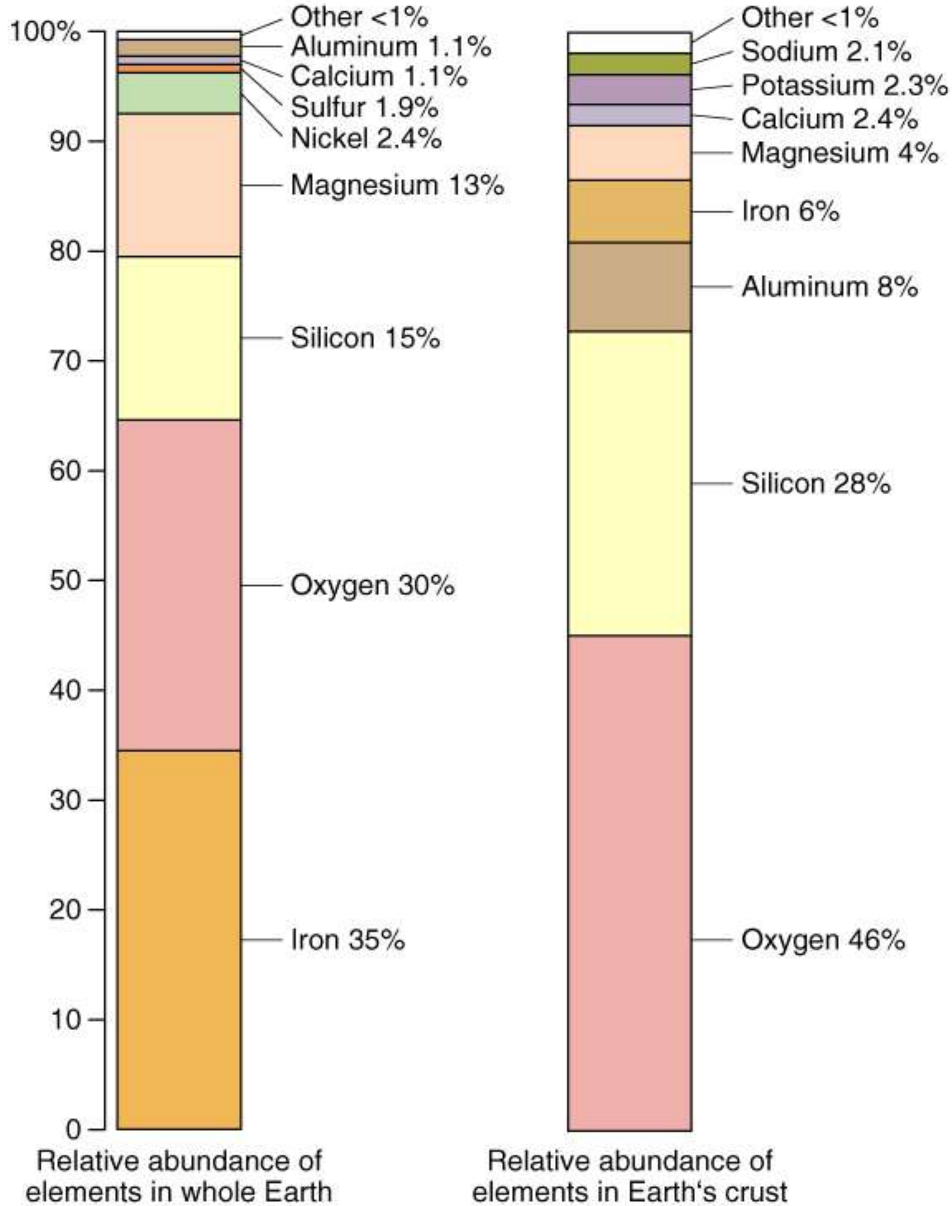

Earthquake
P and S waves
Inner core
Liquid core
Mantle
S wave shadow (no S waves)

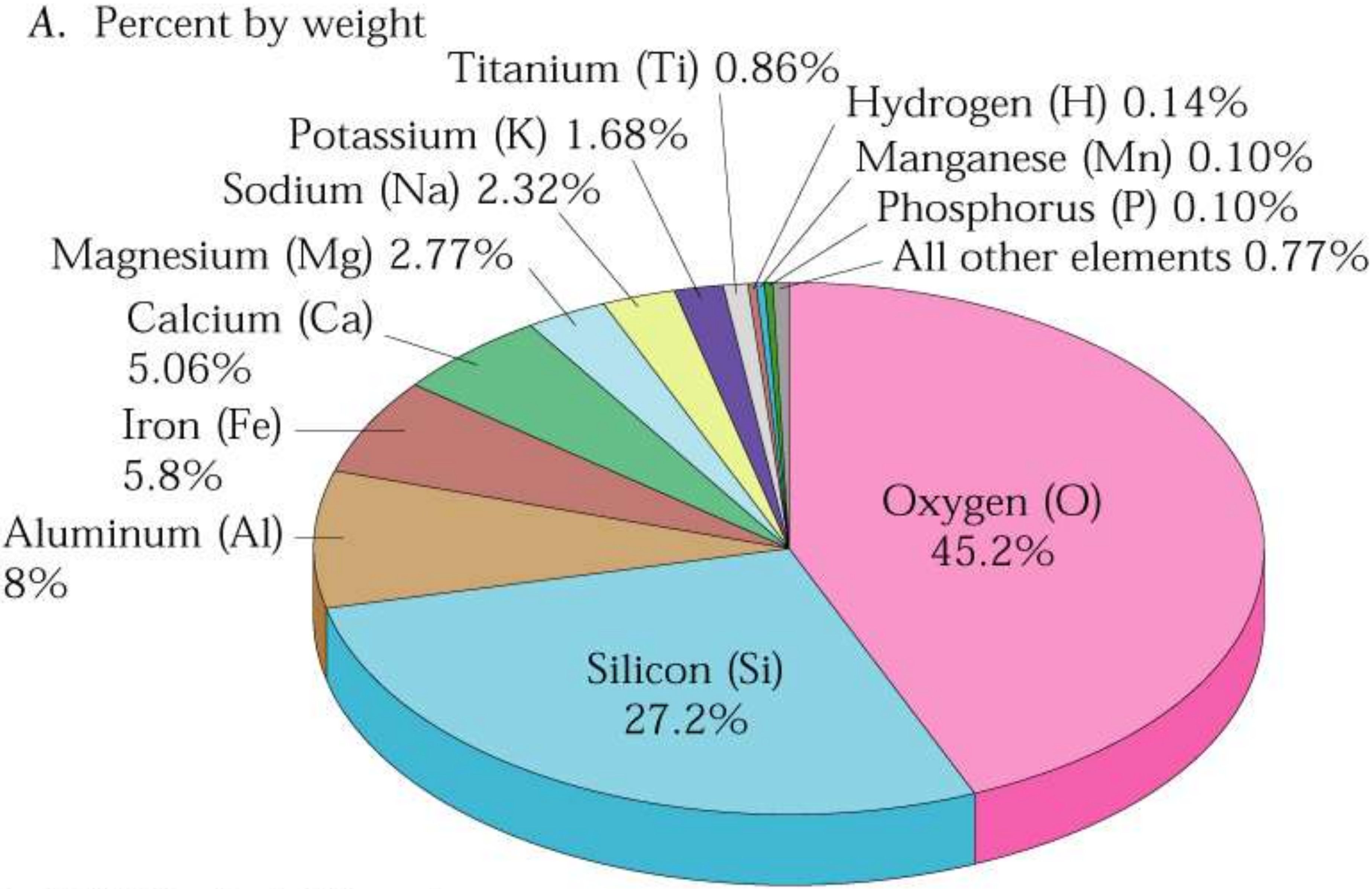


Lithosphere
Asthenosphere
670 km phase transition
400 km phase transition
Outer core
Inner core
Wave velocity (km/s)
4 6 8 10 12
S wave
P wave
P wave
1000
2000
3000
4000
5000
6000
Depth (km)
Wave velocity (km/s)
3 4 5 6 7 8 9 10 11 12
Low velocity zone
400 km discontinuity
670 km discontinuity
P wave
S wave

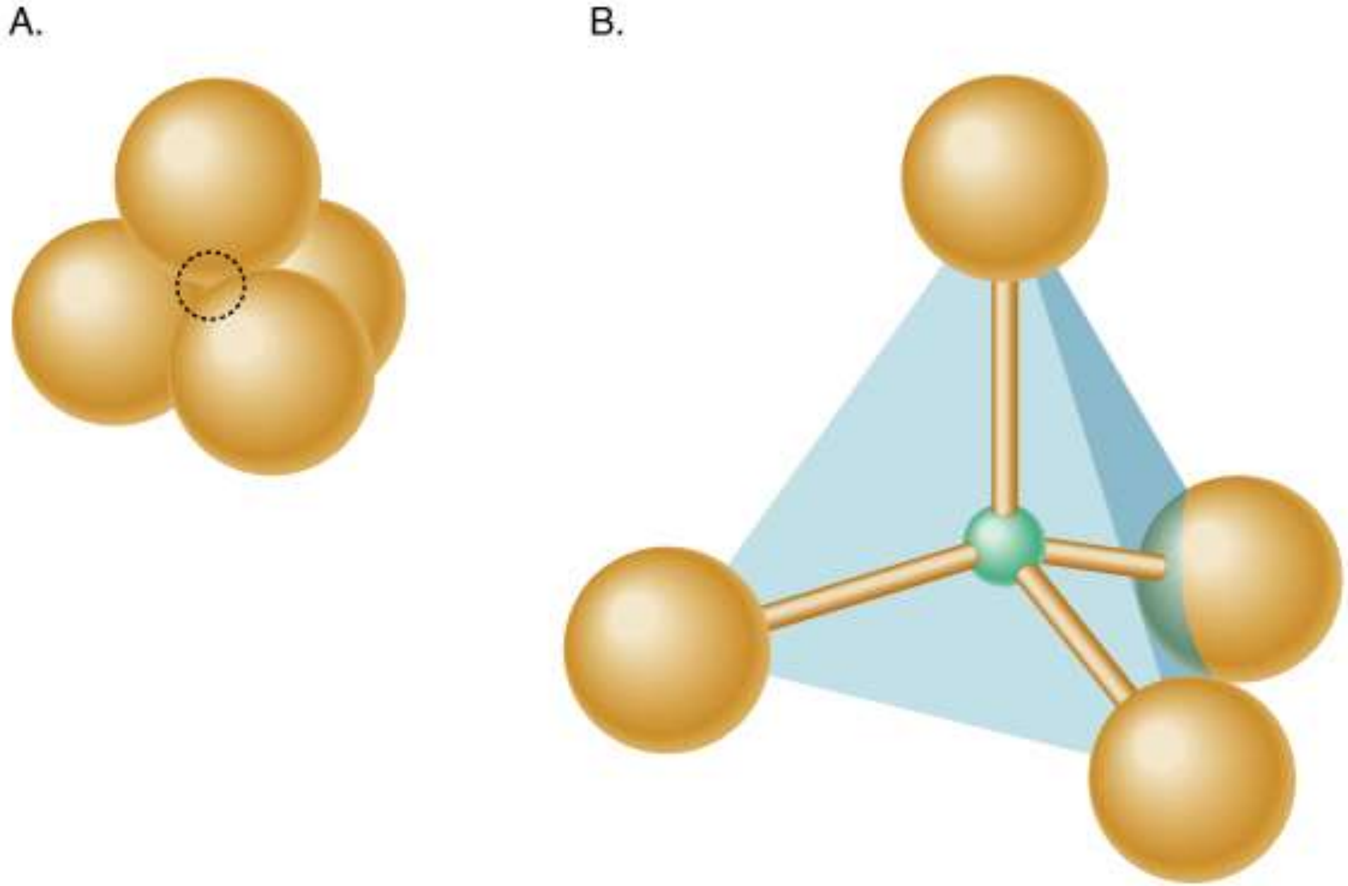

Layering by Physical Properties
Layering by Chemical Composition
Atmosphere
gas
Hydrosphere
Liquid
Asthenosphere
Solid, but Ductile
Lithosphere
Solid & Brittle
100 km Thick
350 km
Mesosphere
Solid
2900 km
Outer Core
Liquid
5150 km
Inner Core
Solid
Density
1.03 (Ocean)
2.7 (Crust)
3.3
3.6
4.3
5.7
9.7
14
16
Crust
Light Colored, Low Density Rock
8 - 70 km Thick
Mantle
Dark Colored, High Density Rock
Core
Iron + Nickel
6371 km
modified after Abbott, 1994

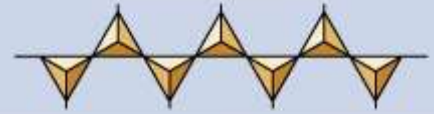
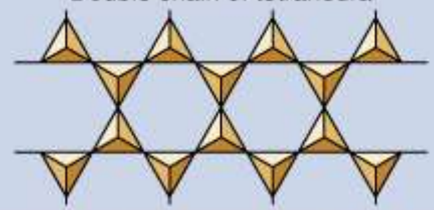
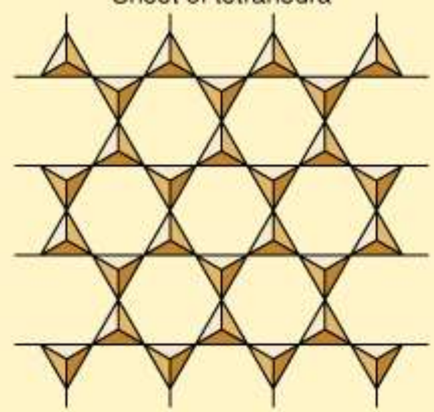

Oceanic Island
Continent
Midocean Ridge
Back Arc
0 km
670 km
D"
Mantle
Core
2900 km


100%
90
80
70
60
50
40
30
20
10
0
Other <1%
Aluminum 1.1%
Calcium 1.1%
Sulfur 1.9%
Nickel 2.4%
Magnesium 13%
Silicon 15%
Oxygen 30%
Iron 35%
Relative abundance of elements in whole Earth
Other <1%
Sodium 2.1%
Potassium 2.3%
Calcium 2.4%
Magnesium 4%
Iron 6%
Aluminum 8%
Silicon 28%
Oxygen 46%
Relative abundance of elements in Earth's crust


A. Percent by weight
Titanium (Ti) 0.86%
Hydrogen (H) 0.14%
Potassium (K) 1.68%
Manganese (Mn) 0.10%
Sodium (Na) 2.32%
Phosphorus (P) 0.10%
Magnesium (Mg) 2.77%
All other elements 0.77%
Calcium (Ca) 5.06%
Iron (Fe) 5.8%
Aluminum (Al) 8%
Oxygen (O) 45.2%
Silicon (Si) 27.2%

Silicate Tetrahedron



Mineral	Formula	Cleavage	Structure
Olivine	$(Mg,Fe)_2SiO_4$	None	Isolated tetrahedra 
Garnet	$Mg_3Al_2(SiO_4)_3$	None	
Pyroxene	$CaMg(SiO_3)_2$	Two planes at 90°	Chain of tetrahedra 
Amphibole	$Ca_2Mg_5(Si_4O_{11})_2(OH)_2$	Two planes at 120°	Double chain of tetrahedra 
Mica	$KAl_2(Si_3Al)O_{10}(OH)_2$	One plane	Sheet of tetrahedra 
Clay	$Al_4Si_4O_{10}(OH)_8$		
Feldspar	$KAlSi_3O_8$	Two planes at 90°	Three-dimensional network too complex to be shown by a two-dimensional drawing
Quartz	SiO_2	None	

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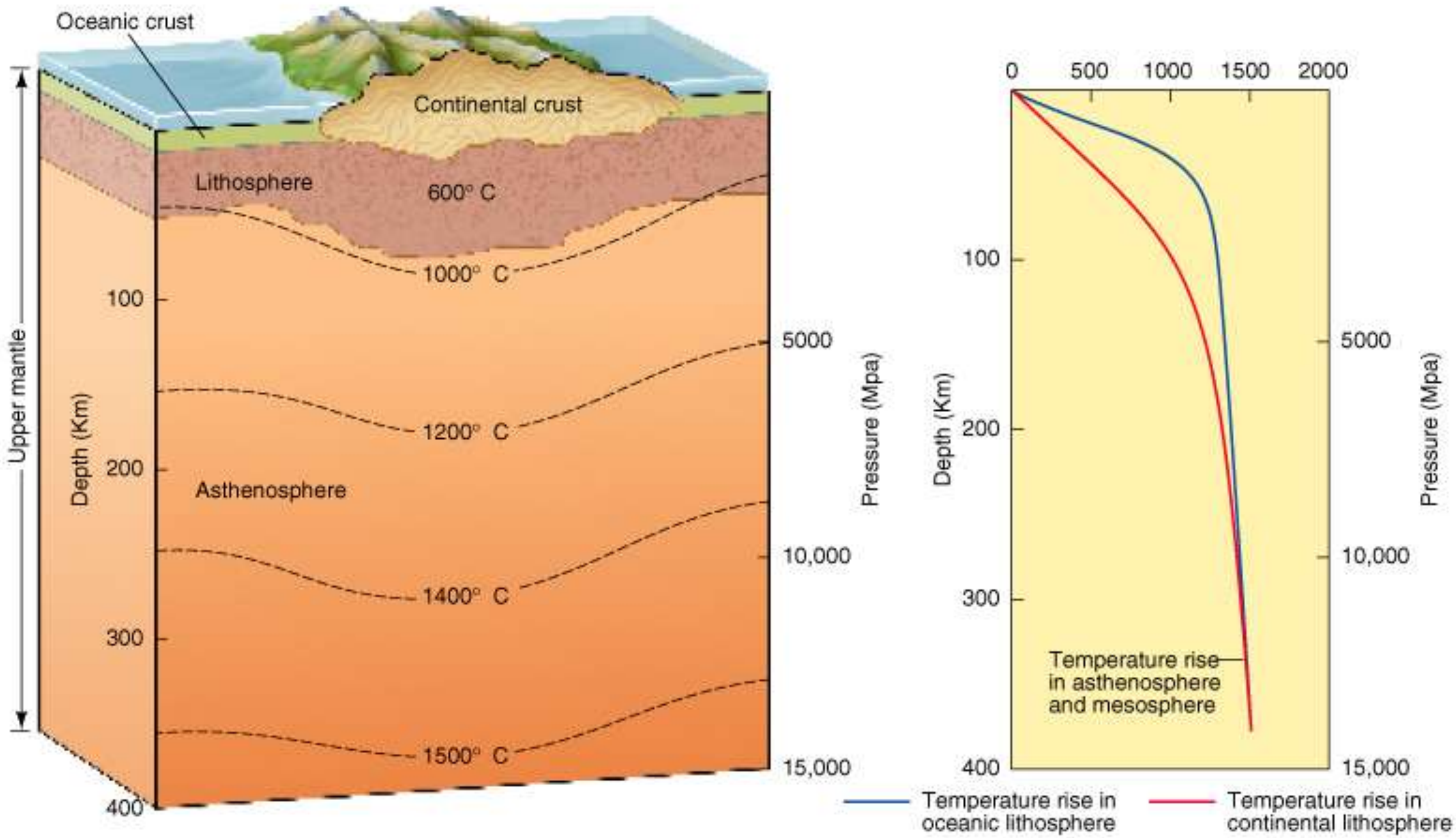
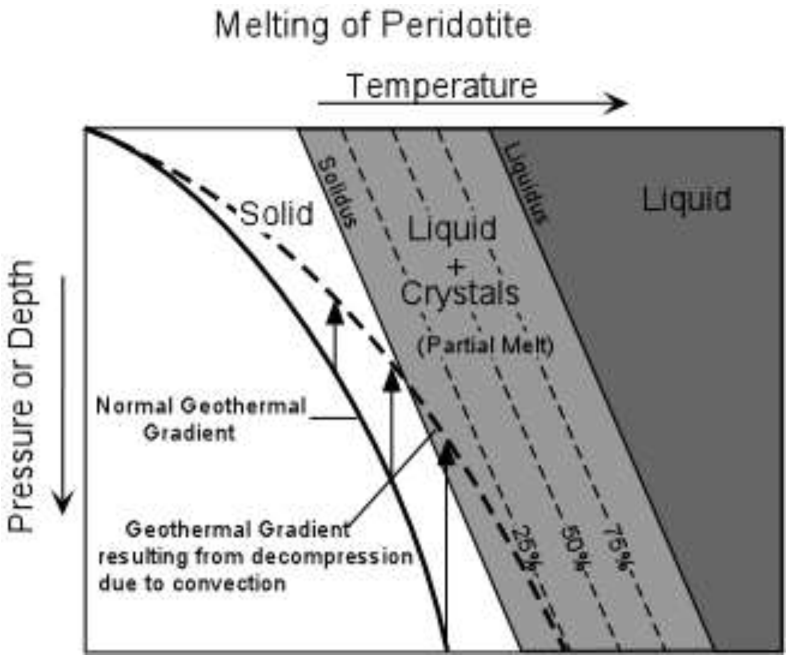
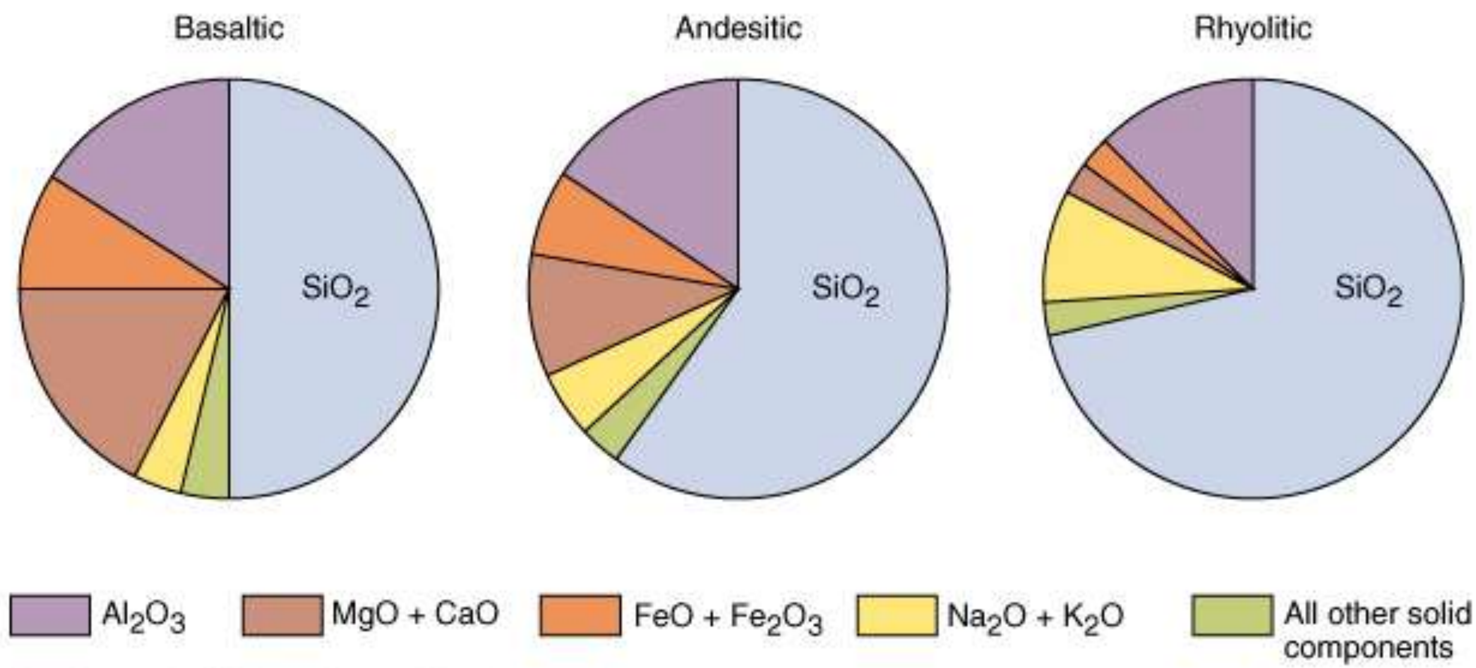
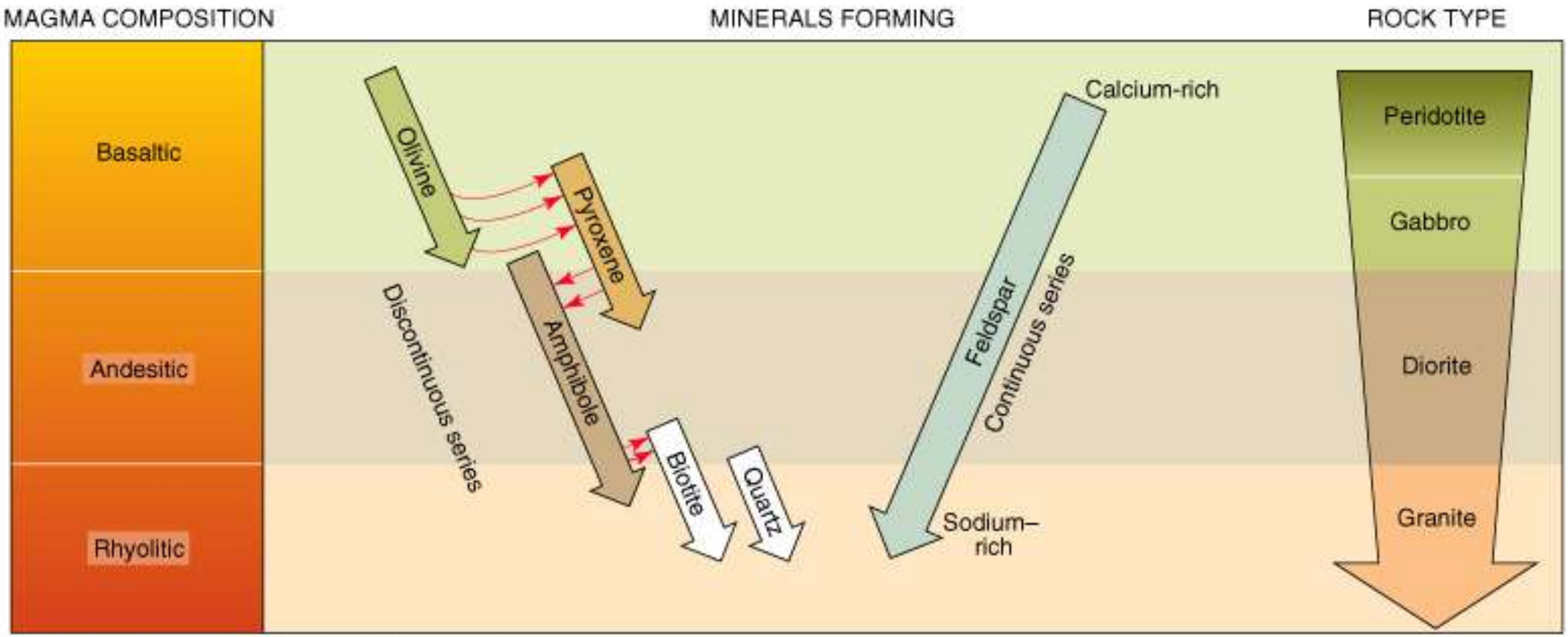


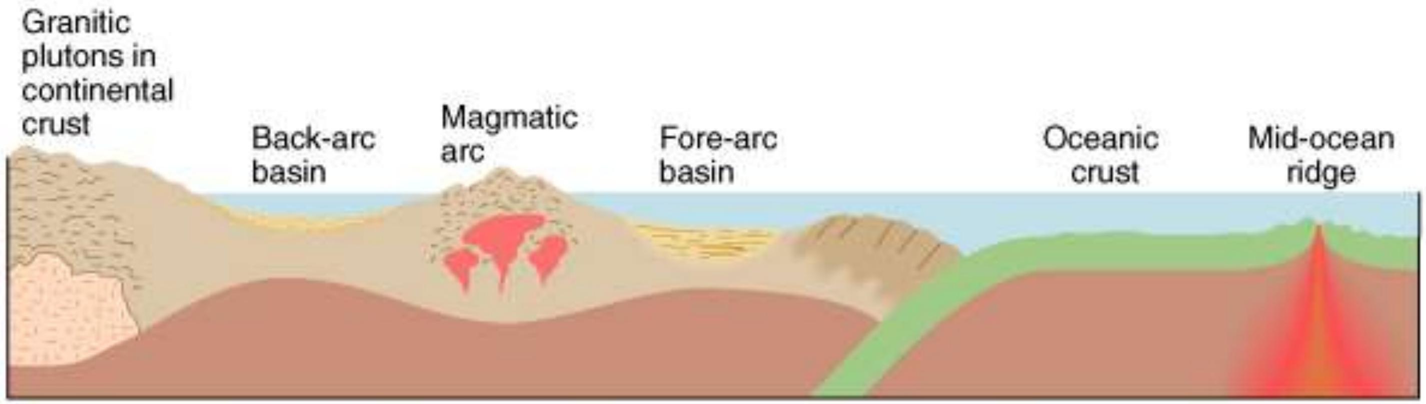
Oceanic crust
Continental crust
Lithosphere
600° C
1000° C
1200° C
1400° C
1500° C
Asthenosphere
Upper mantle
Depth (Km)
100
200
300
400
5000
10,000
15,000
Pressure (Mpa)
0
500
1000
1500
2000
Temperature rise in asthenosphere and mesosphere
Temperature rise in oceanic lithosphere
Temperature rise in continental lithosphere



Melting of Peridotite
Temperature
Pressure or Depth
Solid
Solidus
Liquidus
Liquid
Liquid
+
Crystals
(Partial Melt)
Normal Geothermal
Gradient
Geothermal Gradient
resulting from decompression
due to convection
25%
50%
75%


Basaltic
Andesitic
Rhyolitic
SiO2
SiO2
SiO2
Al2O3
MgO + CaO
FeO + Fe2O3
Na2O + K2O
All other solid components


MAGMA COMPOSITION
MINERALS FORMING
ROCK TYPE
Basaltic
Andesitic
Rhyolitic
Olivine
Pyroxene
Amphibole
Biotite
Quartz
Discontinuous series
Calcium-rich
Feldspar
Continuous series
Sodium–
rich
Peridotite
Gabbro
Diorite
Granite



Metals	Tin Tungsten Bismuth Copper	Copper Zinc Gold Chromium	Copper Gold Silver Tin Lead Mercury Molybdenum	Lead Zinc Copper	Chromium	Manganese Cobalt Nickel	Copper Zinc
Deposits	Vein: contact metamorphic	Volcanogenic massive sulfide, stratabound, evaporites.	Porphyry copper; veins	Stratabound in sediments	Magmatic chromite	Manganese nodules	Volcanogenic massive sulfide

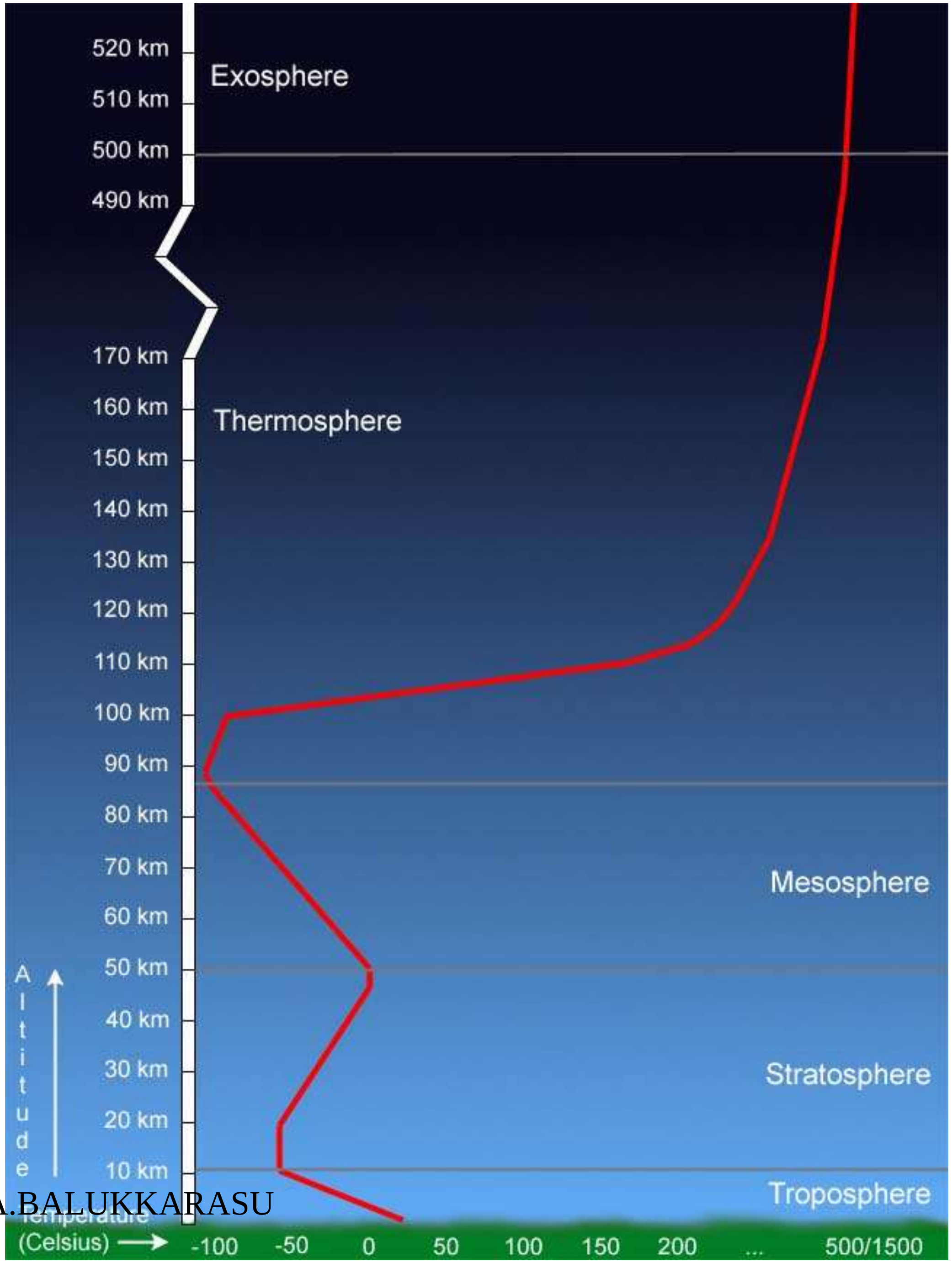
Earth’s Atmosphere

The gaseous area surrounding the planet is divided into several concentric spherical strata separated by narrow transition zones.

The upper boundary at which gases disperse into space lies at an altitude of approximately 1000 km above sea level.

More than 99% of the total atmospheric mass is concentrated in the first 40 km from Earth's surface.

Atmospheric layers are characterized by differences in chemical composition that produce variations in temperature



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Primordial Atmosphere

Studies of the chemical abundance in the solar system points to the fact that our atmosphere is not a primordial atmosphere but rather a secondary atmosphere.

When the Earth (and other planets) formed, it must have been surrounded by a primordial atmosphere (mainly **H2**, **He**).

The primordial atmospheres of the inner planets were probably wiped out completely during the stage when the sun evolved to the stage of a *T-Tauri* star.

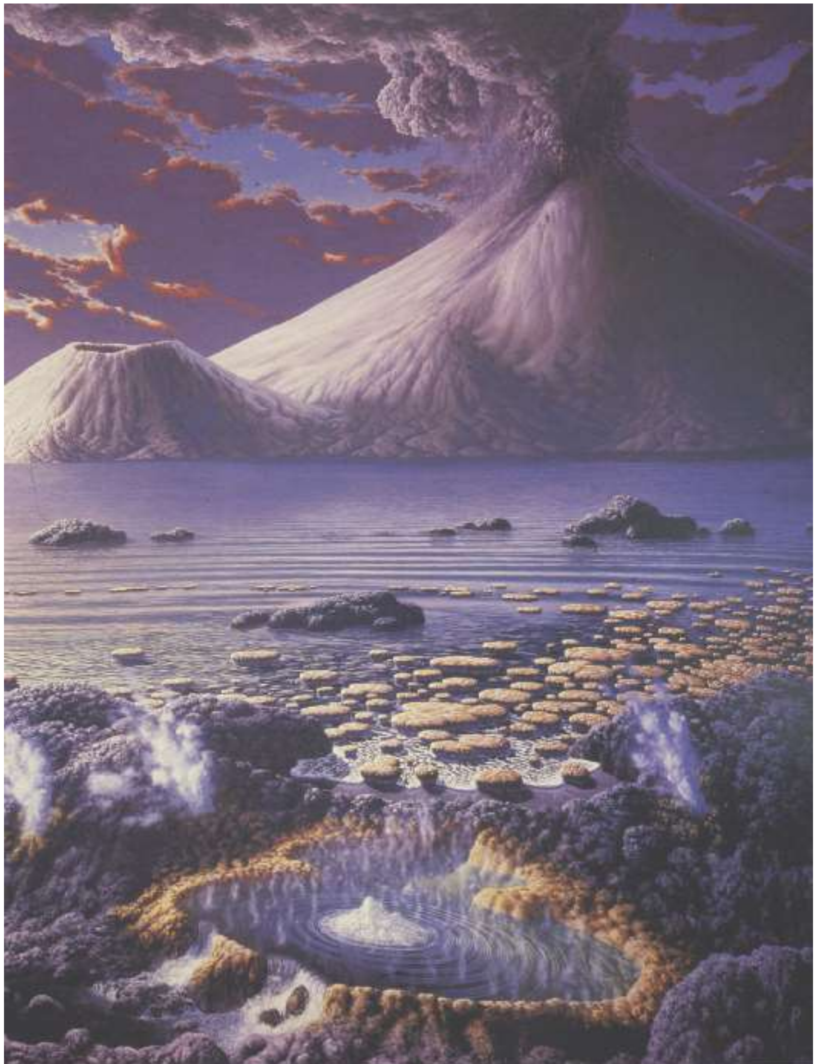
This was probably caused by the sun ejecting substantial mass from its surface in form of violent solar winds. These winds were effective in eroding the primordial atmospheres of the terrestrial planets.

This atmosphere erosion may have been enhanced by the lack of a strong magnetic in the early Earth.

Also, Earth's gravity (compared to Jovian planets) is not strong enough to prevent escape of **H2** & **He**.

Secondary Atmosphere

Produced by *volcanic out-gassing*



Gases produced were probably similar to those created by modern volcanoes (H_2O, CO_2, SO_2, CO, S_2, Cl_2, N_2, H_2) and NH_3 (ammonia) and CH_4 (methane).

No free O_2 at this time (not found in volcanic gases).

Ocean Formation - As the Earth cooled, H_2O produced by out gassing could exist as liquid in the Early Archean, allowing oceans to form.

Evidence - pillow basalts, deep marine seds in greenstone belts.

Addition of O_2 to Atmosphere

Oxygen Production

Photochemical dissociation

Breakup of water molecules by ultraviolet radiation

Produced O2 levels approx. 1-2% current levels

At these levels O3 (Ozone) can form to shield Earth surface from UV

Photosynthesis

CO2 + H2O + sunlight = organic compounds + O2 – first produced by Archean cyanobacteria, and eventually higher plants - supplied the rest of O2 to atmosphere.

Removal of CO_2 from Atmosphere

Silicate Weathering – Carbonate Precipitation

(In the presence of water)

$$CO_2 + CaSiO_3 \rightarrow CaCO_3 + SiO_2$$

Carbon dioxide | Silicate minerals | Limestone | Chert

CO2 is removed from the atmosphere during silicate weathering and buried as limestone (CaCO3) where it is sequested for a long time (millions of years) until subduction and metamorphism release it.

Removal of CO_2 from Atmosphere

Photosynthesis

$$CO2 + H2O \rightarrow CH2O + O2$$

Carbon dioxide Water vapor Organic matter Oxygen

Phytoplankton – oceans

Plants – land

Burial of organic matter reduces the level of CO2 in the atmosphere

Removal of CO_2 from Atmosphere

Once the water vapor in the atmosphere condensed to form an ocean, it became a “sink” for dissolved CO2.

Biochemical production of limestone by sedimentation of skeletal foraminifera from sea water further sequesters CO2 in the solid Earth.

There is 60 times more CO2 dissolved in sea water than in the atmosphere, and 3000 times more CO2 buried in sedimentary rocks than in the oceans.

Nitrogen build up in the early atmosphere was enhanced because of its low solubility in sea water.

	VENUS	EARTH	MARS
SURFACE PRESSURE	100,000 mb	1,000 mb	6 mb
		COMPOSITION	
CO_2	>98%	0.03%	96%
N_2	1%	78%	2.5%
Ar	1%	1%	1.5%
O_2	0.0%	21%	2.5%
H_2O	0.0%	0.1%	0-0.1%