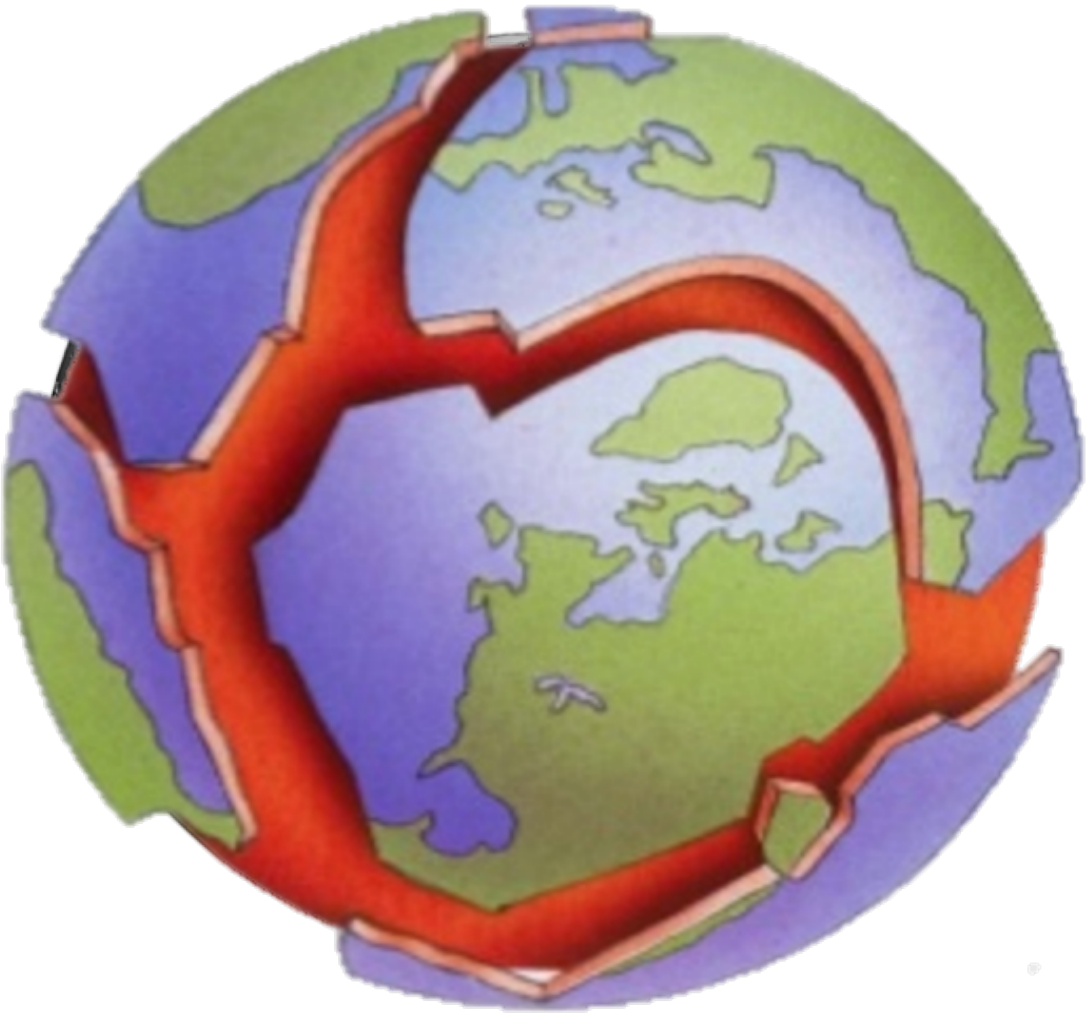
EARTH SCIENCE

KEY UNIT 4

DYNAMIC CRUST



YOUR PLANET

YOUR INHERITANCE

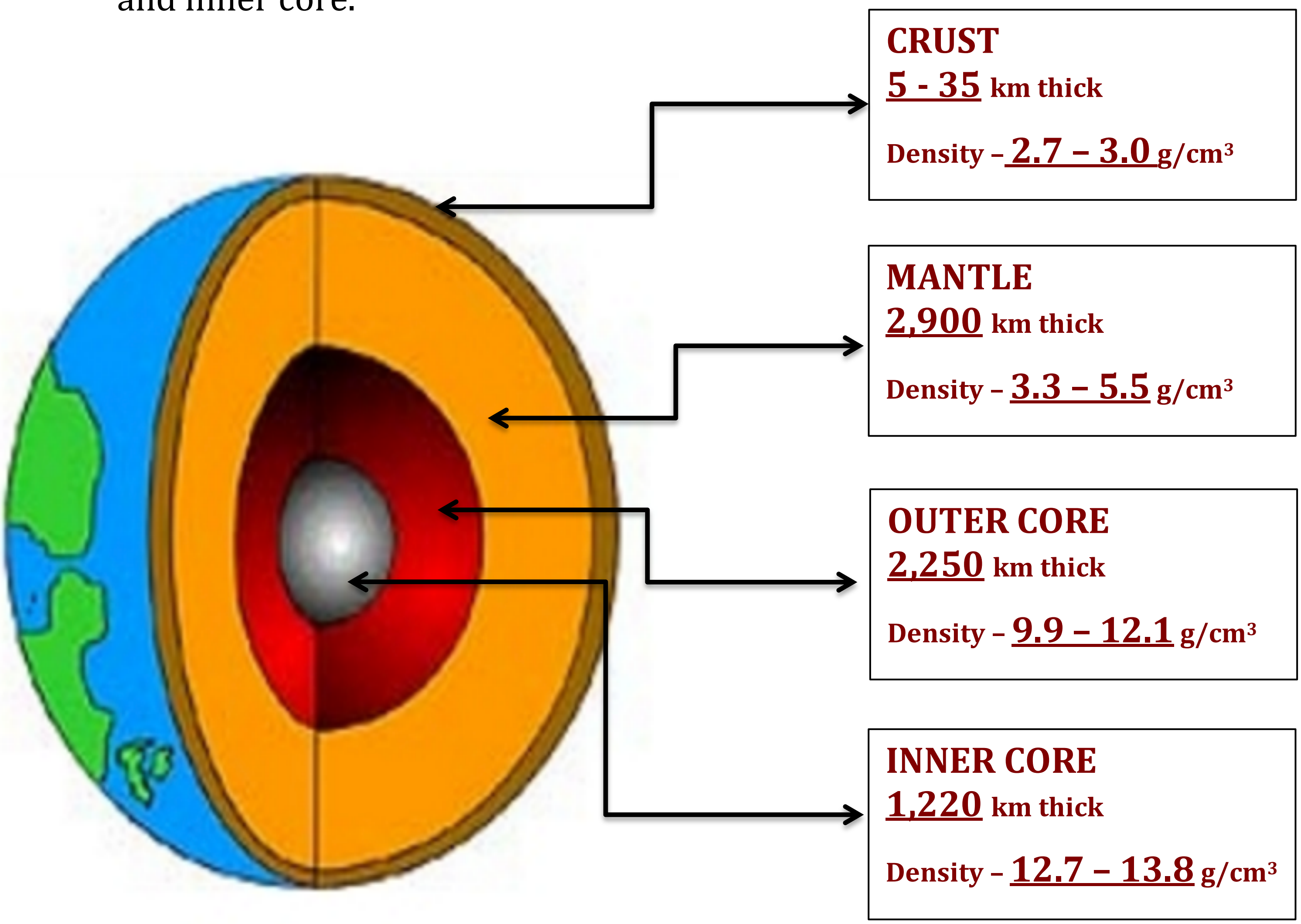
YOUR LEGACY

UPDATED AND ADAPTED FROM DAVID J. MILLS 2001

UNIT 4
THE DYNAMIC EARTH

I. **EARTH'S INTERIOR**:

1. Earth's structure / interior is divided into the crust, mantle, outer core, and inner core.



2. **EARTHQUAKE WAVES AND EARTH'S INTERIOR**:

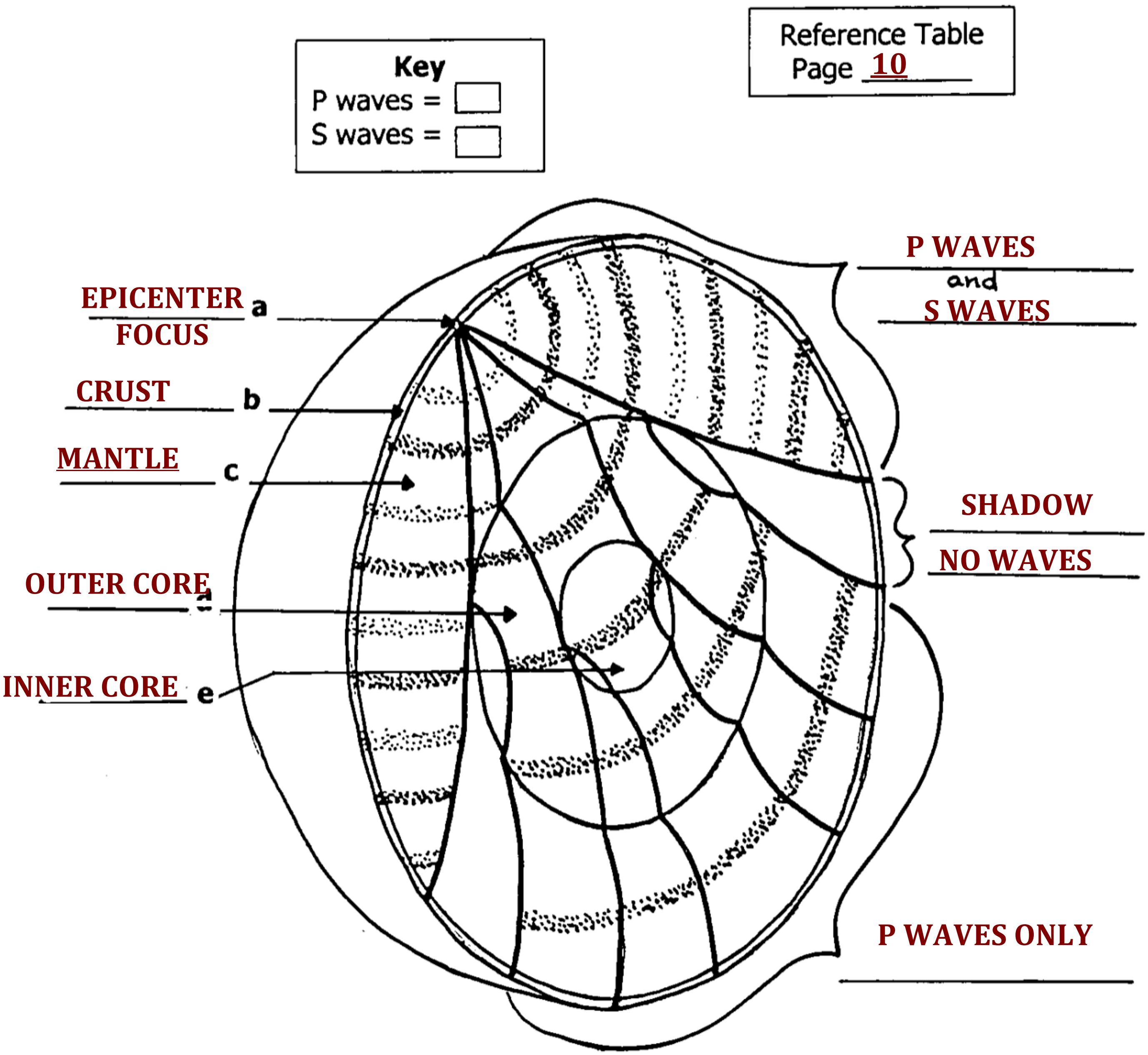
A. Analysis of seismic waves (P waves and S Waves) led scientists to infer the interior structure of Earth.

B. 1. P-Waves can travel through **SOLIDS** and **LIQUIDS**.

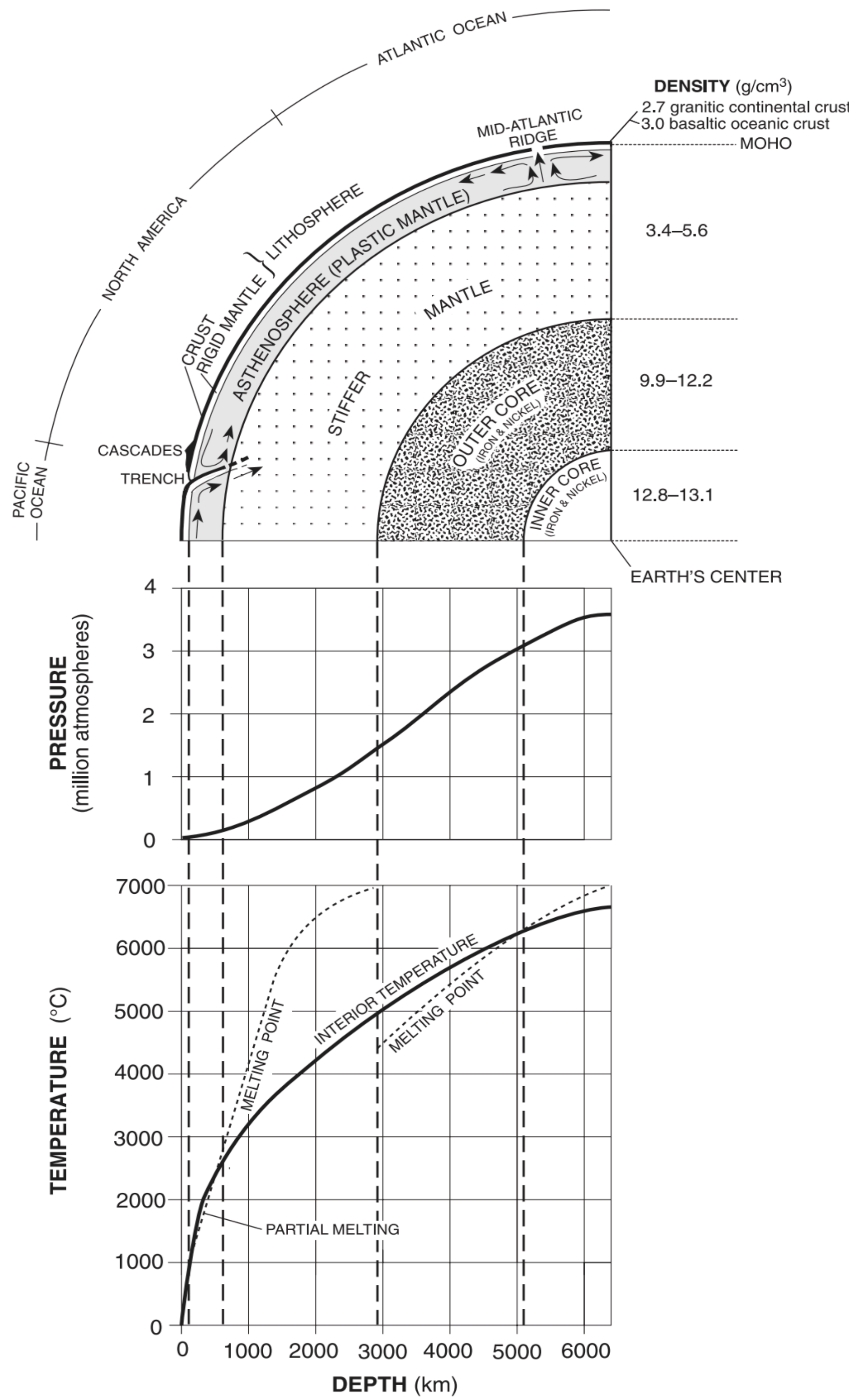
2. S-Waves can only travel through **SOLIDS**

3. Seismic waves **INCREASE** in velocity when traveling through materials that are more **DENSE.**

C.


Key
P waves =
S waves =
Reference Table
Page 10
EPICENTER a
FOCUS
CRUST b
MANTLE c
OUTER CORE d
INNER CORE e
P WAVES
and
S WAVES
SHADOW
NO WAVES
P WAVES ONLY

Inferred Properties of Earth's Interior



1. Which two Earth layers are separated by the Moho boundary?

   A) rigid mantle and plastic mantle
   B) outer core and stiffer mantle
   C) stiffer mantle and asthenosphere
   D) crust and rigid mantle

2. Earth's outer core is best inferred to be

   A) liquid, with an average density of approximately 4 g/cm³
   B) liquid, with an average density of approximately 11 g/cm³
   C) solid, with an average density of approximately 4 g/cm³
   D) solid, with an average density of approximately 11 g/cm³

3. What are the inferred pressure and temperature at the boundary of Earth's stiffer mantle and outer core?

   A) 1.5 million atmospheres pressure and an interior temperature of 4950°C
   B) 1.5 million atmospheres pressure and an interior temperature of 6200°C
   C) 3.1 million atmospheres pressure and an interior temperature of 4950°C
   D) 3.1 million atmospheres pressure and an interior temperature of 6200°C

4. The inferred temperature and pressure of Earth's interior at a depth of 3,000 kilometers are approximately

   A) 1000°C and 0.5 million atmospheres
   B) 1000°C and 1.0 million atmospheres
   C) 5000°C and 1.5 million atmospheres
   D) 5000°C and 3.0 million atmospheres

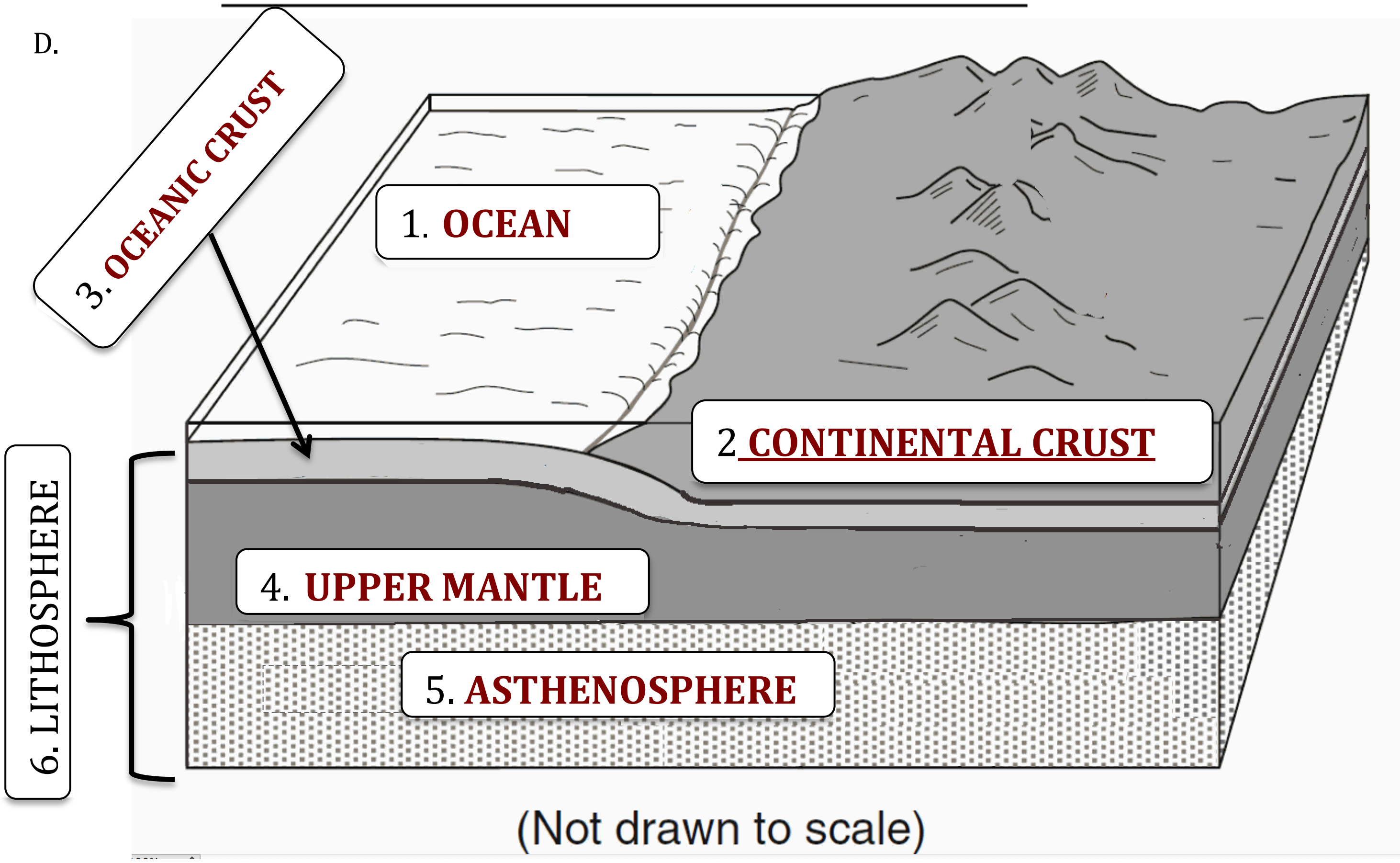
5. What happens to the density and temperature of rock within Earth's interior as depth increases?

   A) density decreases and temperature decreases
   B) density decreases and temperature increases
   C) density increases and temperature increases
   D) density increases and temperature decreases

6. Earth's inner core is inferred to be solid based on the analysis of

   A) seismic waves
   B) crustal rocks
   C) radioactive decay rates
   D) magnetic pole reversals

D.

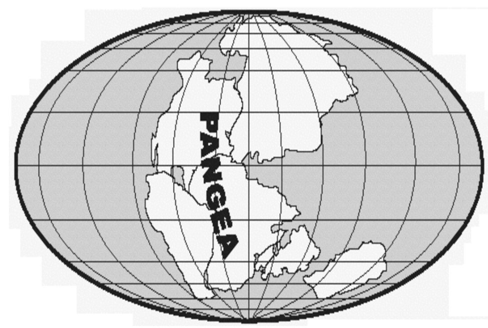


E. Density of: 1. Ocean (water) **1.0 g/cm³**
2. Granite (continental Crust) **2.7 g/cm³**
3. Basalt (oceanic crust) **3.0 g/cm³**
4. Rigid Upper Mantle }
5. Asthenosphere } **3.5 – 5.5 g/cm³**

3. **THEORY OF CONTINENTAL DRIFT**:

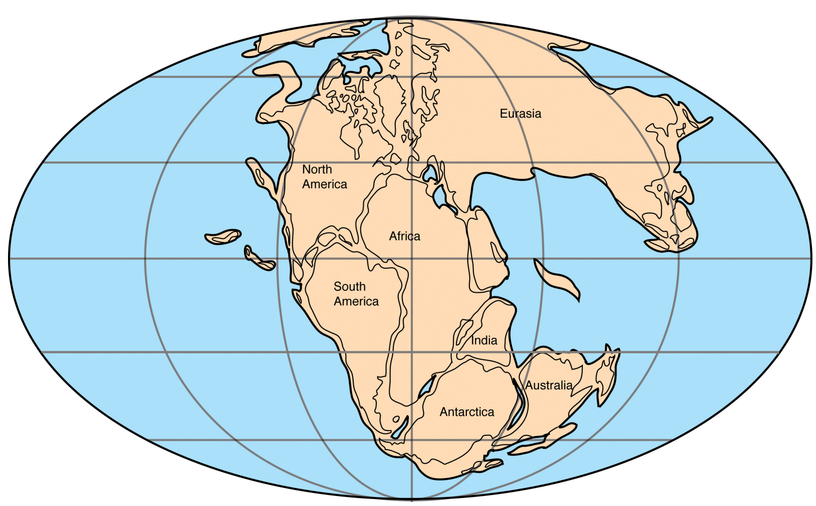
A. **ALFRED WEGENER** proposed the theory of Continental Drift in the early 1900's.

B. He proposed that approximate 200 million years ago, all of the continents existed as one large landmass which he called **PANGAEA**



4. **EVIDENCE FOR CONTINENTAL DRIFT**:

A. **Coastlines of the continents**:
For example, the east coast of **SOUTH AMERICA** fits well with the west coast of **AFRICA** – like pieces of a giant **JIGSAW PUZZLE**.

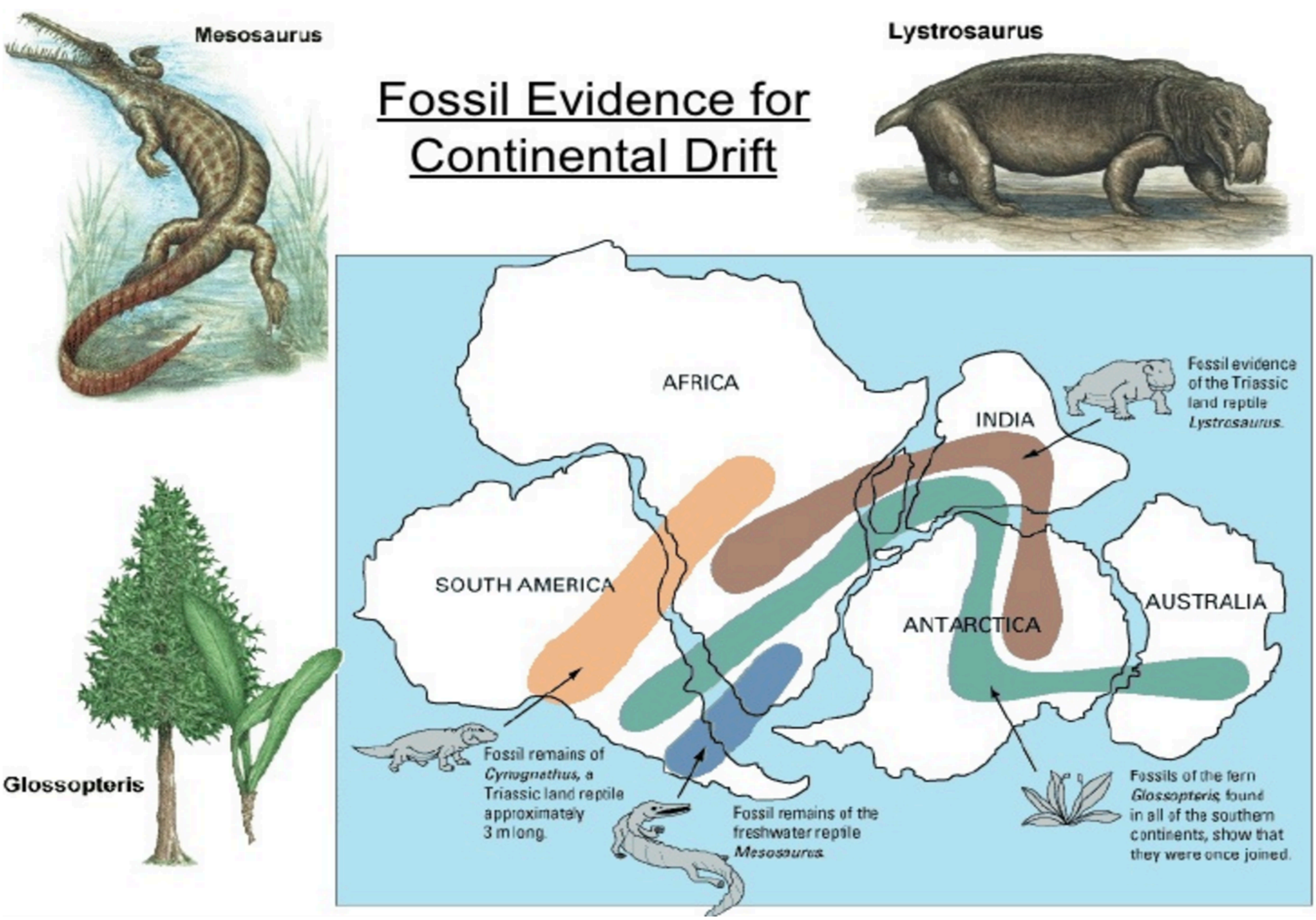


B. **Fossil Clues**:

Certain fossils of ancient life forms are found on widely separated continents.

Mesosaurus was a small freshwater reptile. it's fossils are found in **AFRICA** and **SOUTH AMERICA**.

Glossopteris was an ancient seed-fern (with very large, heavy seeds). It's fossils are found in **AFRICA** and **SOUTH AMERICA, INDIA, AUSTRALIA, and ANTARTICA**.



C. **Rock Clues**

1. The **APPALACHIAN** mountains of the eastern US are geographically similar to the mountains in Greenland and western Europe, which include the Caledonian Mountains of Scotland.

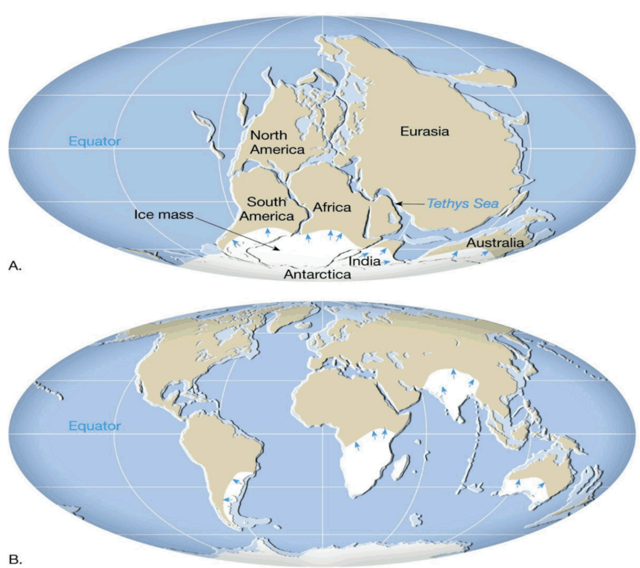
2. Structure, age, and mineral content of rocks are similar on the coasts of eastern **SOUTH AMERICA** and western **AFRICA**.

D. **Climate Clues**

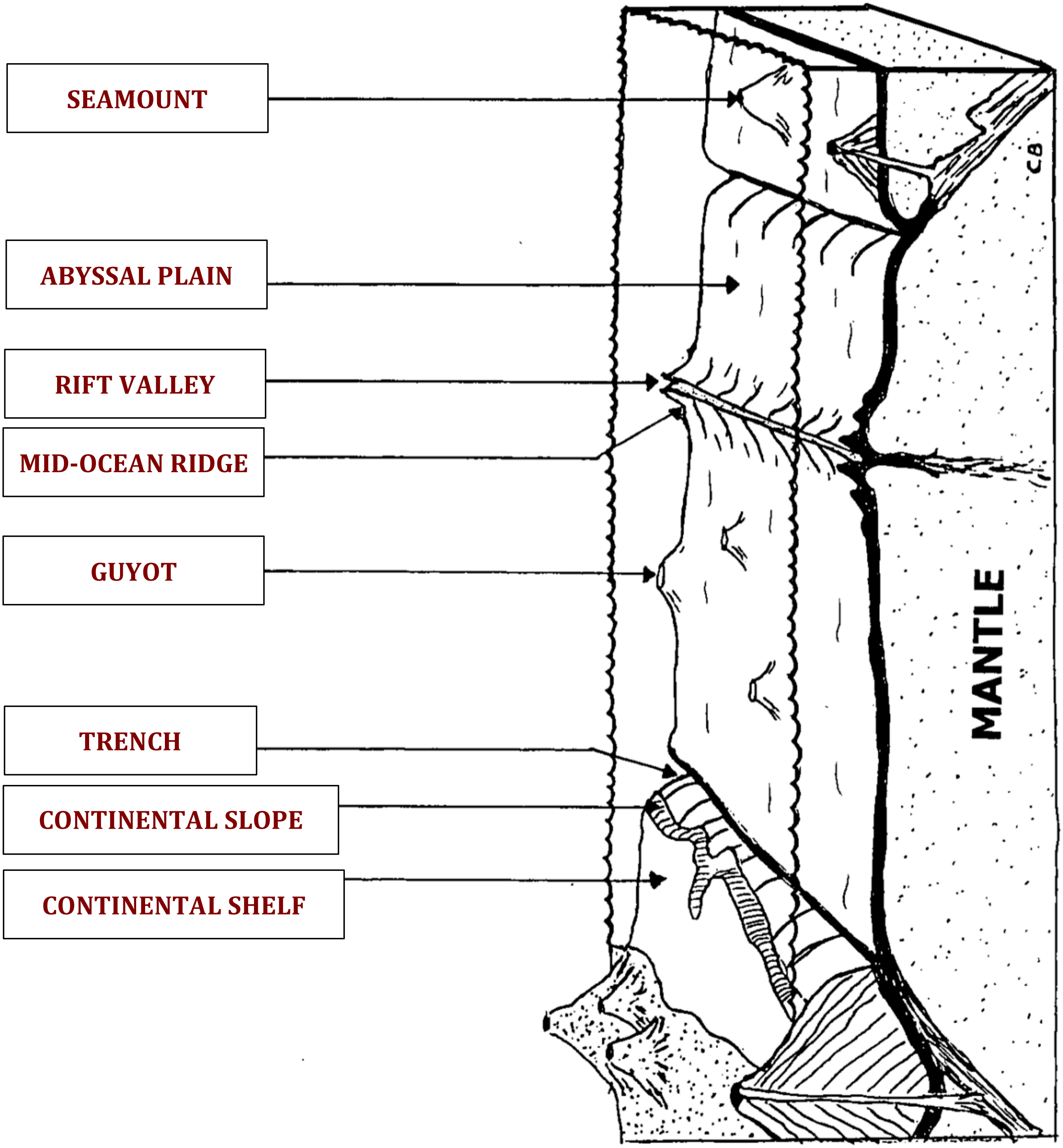
1. **Coal**, which forms from plants that grow in the warm, swampy environments, is found today in the colder climates of **NORTH AMERICA** and **ANTARTICA**.

2. **Coral Limestone**, containing the remains of coral, which once lived in warm seas, is found today in northern latitudes such as **NEW YORK STATE.**

3. Ancient rocks of the same age near the equator in South America, South Africa, and other southern landmasses, show evidence of glaciation.



5. THEORY OF SEA FLOOR SPREADING



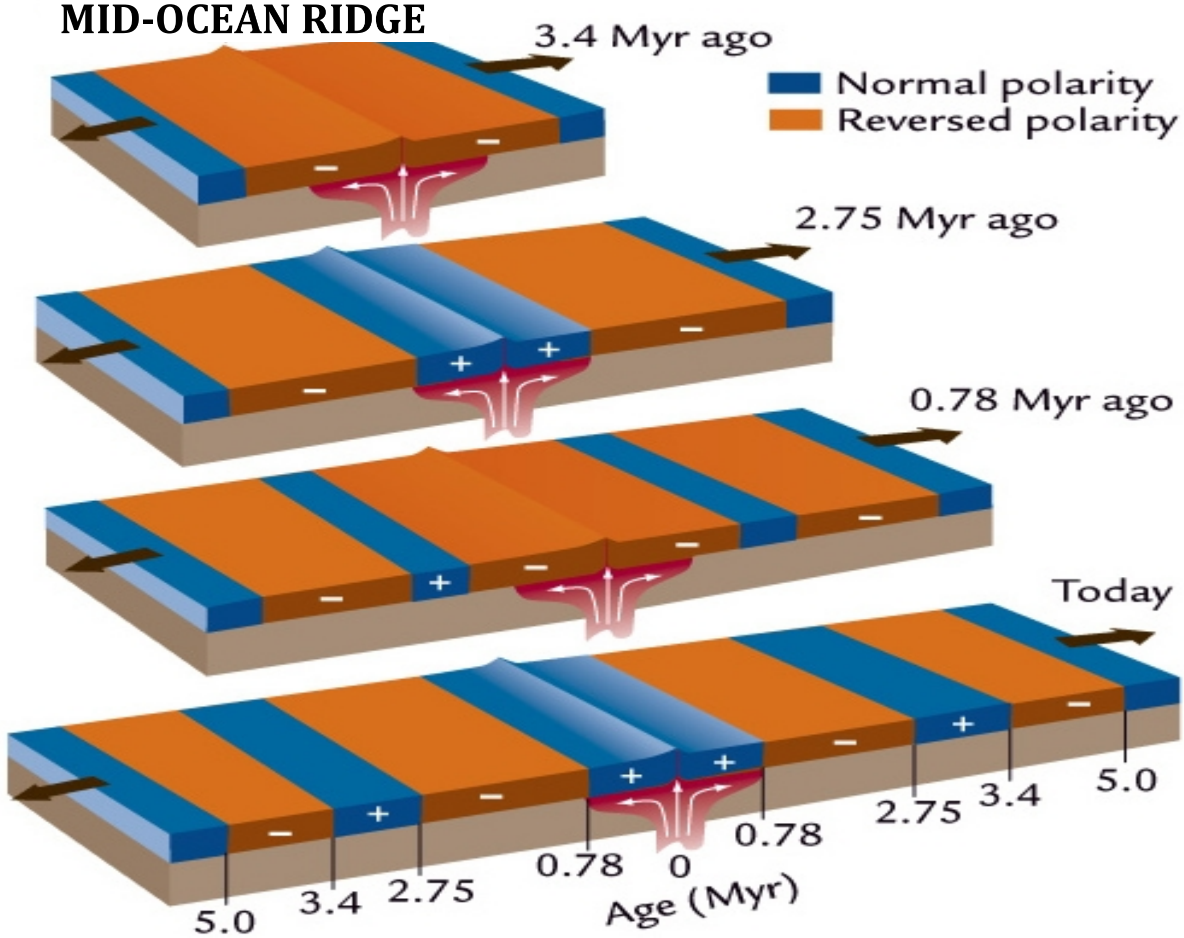
6. EVIDENCE OF SEA FLOOR SPREADING

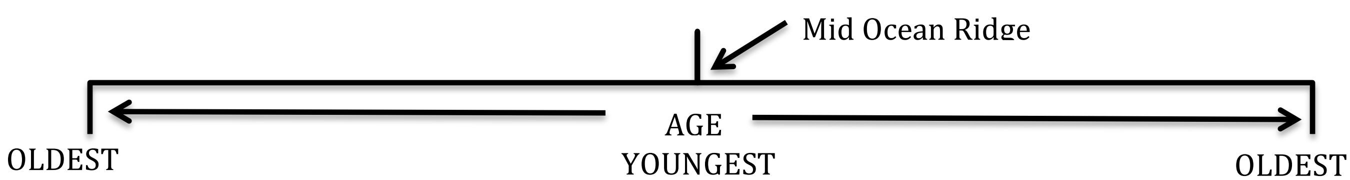
A. **<u>Age Evidence</u>**: Magma rising from the mantle fills in the gap between plates at the mid-ocean ridge. It solidifies into the extrusive Igneous rock **BASALT**.

Pressure pulling the plates apart constantly breaks the new rock in half – each part moving in different directions as new rock forms at the ridge.

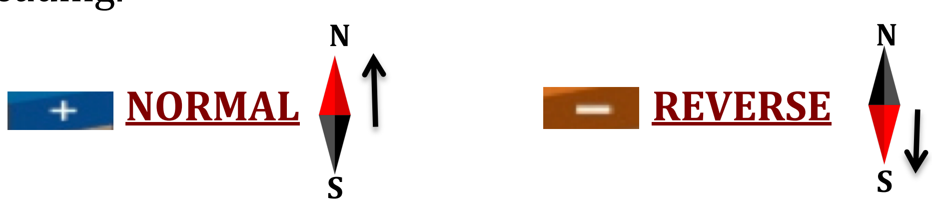
As the distance from the ocean ridge **<u>INCREASES</u>**, the **<u>AGE</u>** of the rock **<u>INCREASES.</u>**

MID-OCEAN RIDGE



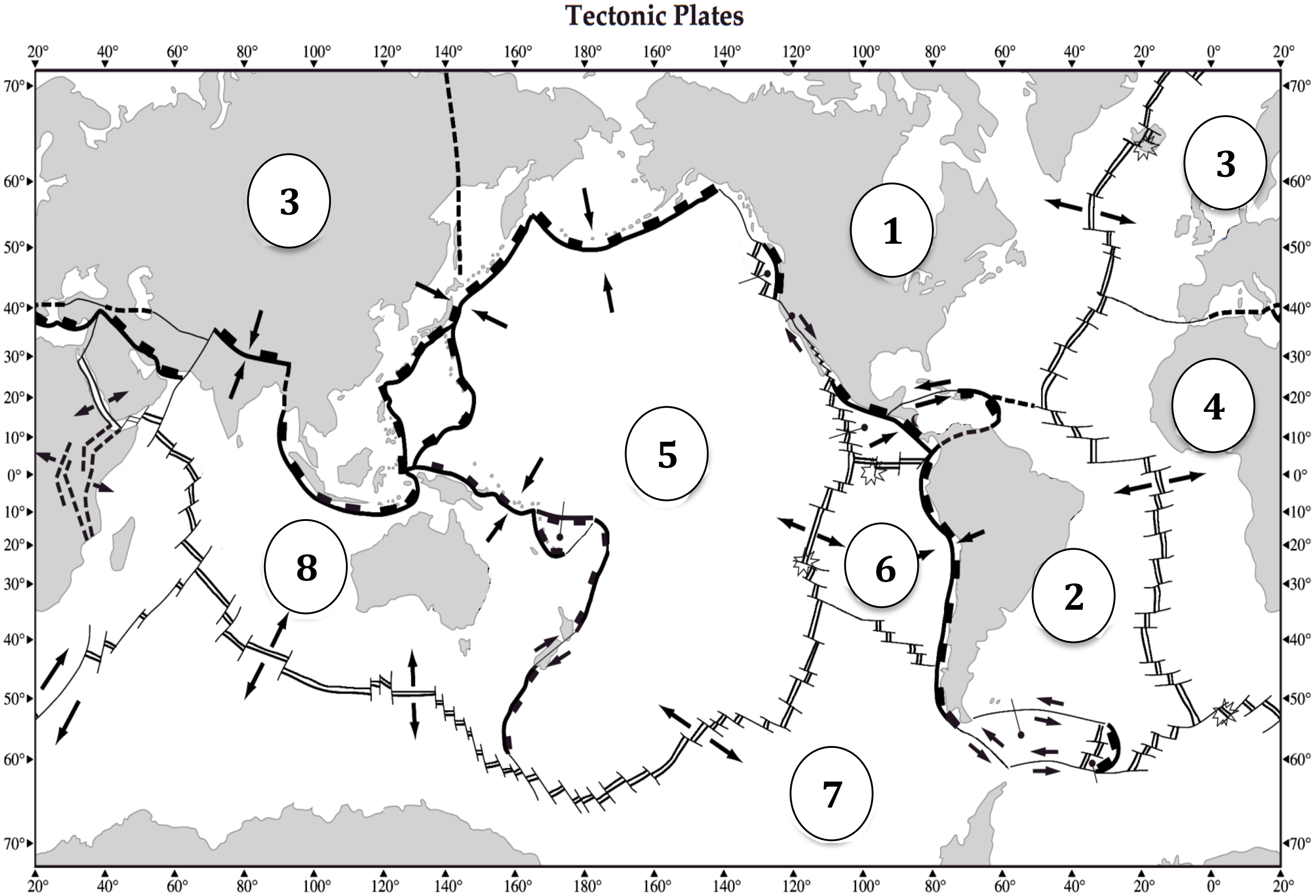


B. **Magnetic Evidence** (Paleomagnatism) – magnetic clues from the iron-bearing basalt rock of the ocean floor supports the theory of sea floor spreading.



6. THE THEORY OF PLATE TECTONICS

A. The theory of Plate Tectonics states that Earth's **LITHOSPHERE** (crust & upper mantle) is divided into sections called **LITHOSPHERIC PLATES**.



1. **NORTH AMERICAN PLATE**
2. **SOUTH AMERICAN PLATE**
3. **EURASIAN PLATE**
4. **AFRICAN PLATE**
5. **PACIFIC PLATE**
6. **NAZCA PLATE**
7. **ANTARCTIC PLATE**
8. **INDIAN – AUSTRALIAN PLATE**

B. **Plate Motion**: The Theory Of Plate Tectonics States That These Lithospheric Plates Are In Motion And "Float" or Ride On The **Asthenosphere**.

C. **Direction of Plate Movement**: The movement and interaction of the plates creates three types of plate boundaries: the arrows on the tectonic maps show the relative motion.

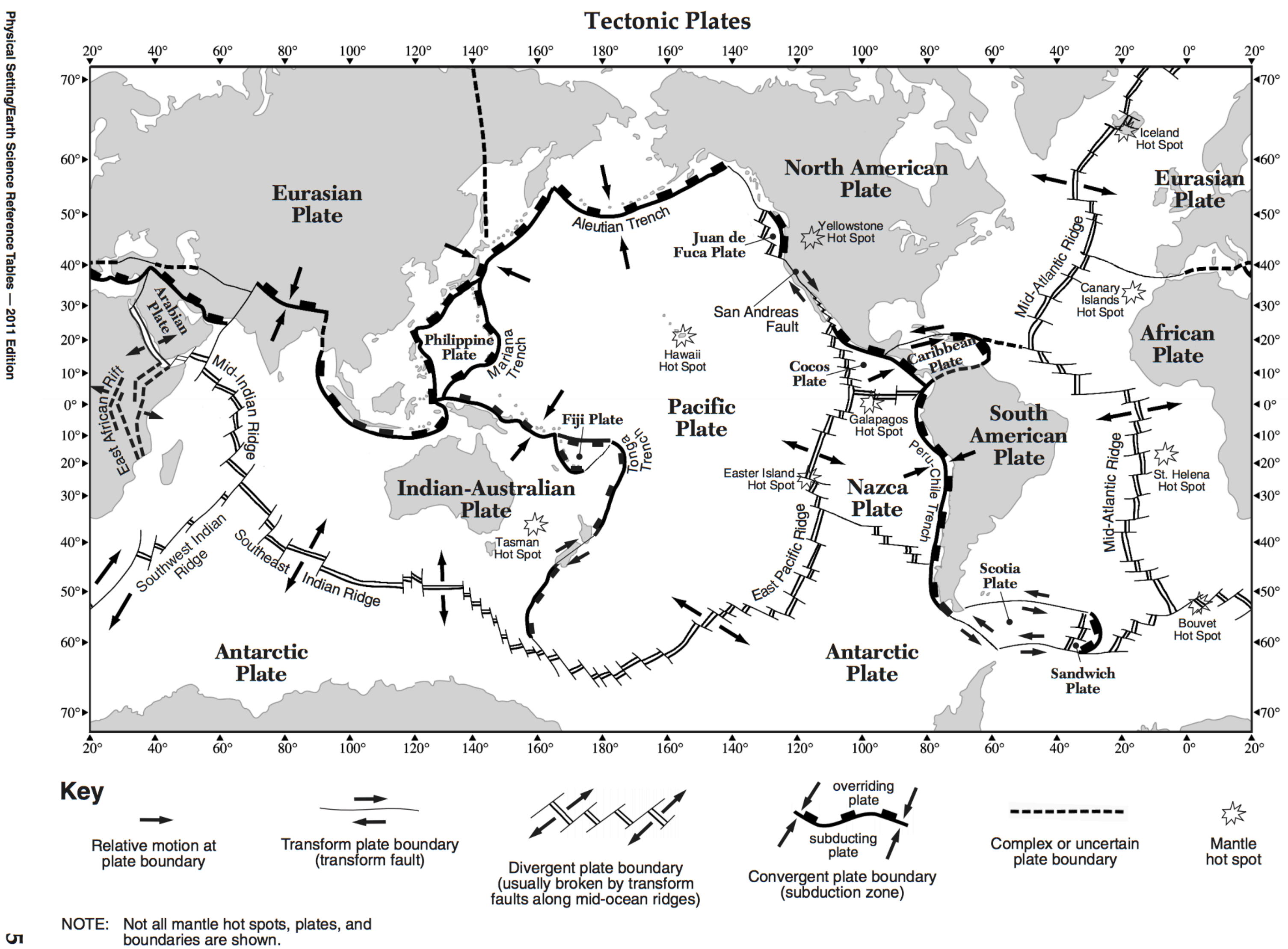


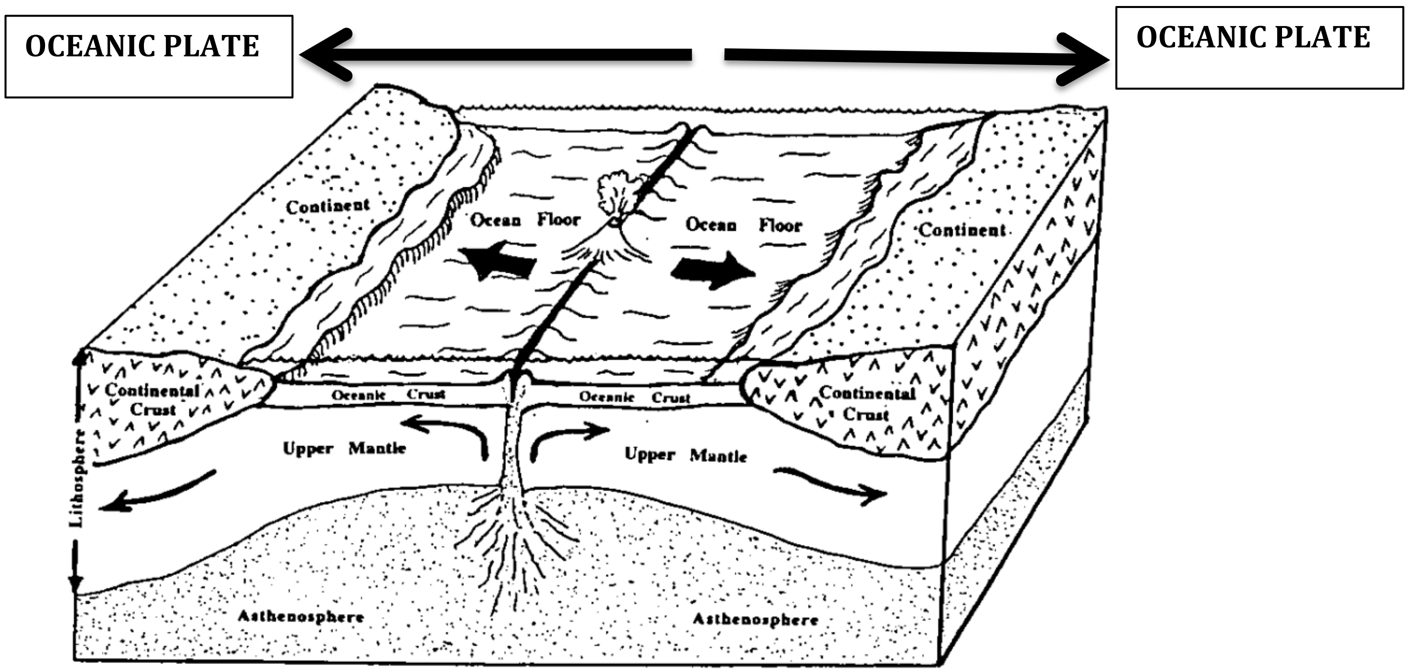
PLATE BOUNDARY	MOVEMENT	ARROWS ON MAP
DIVERGENT	**AWAY FROM EACH OTHER**	← →
CONVERGENT	**TOWARDS EACH OTHER**	→ ←
TRANSFORM	**LATERALLY / SIDEWAYS**	⇄

D. TYPES OF PLATE BOUNDARIES:

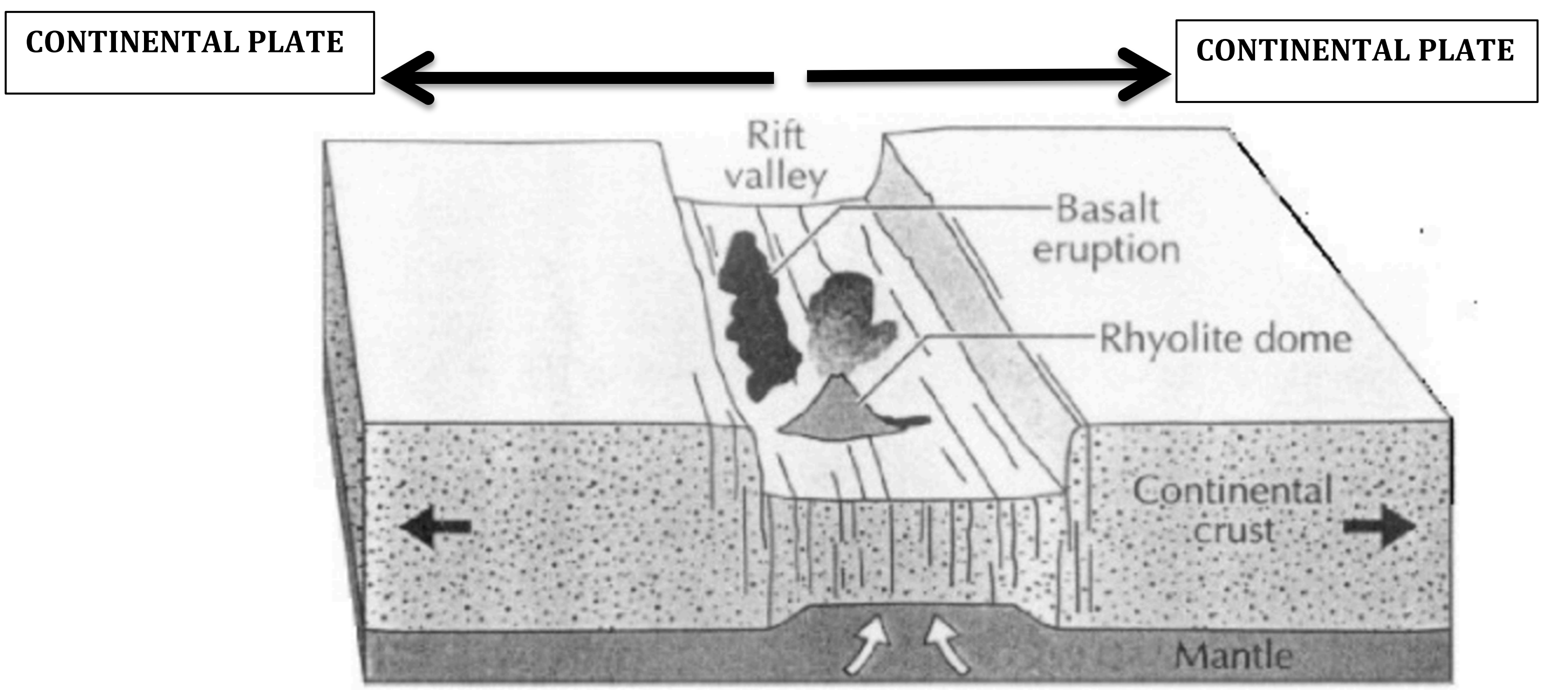
1. **Divergent Plate Boundaries**: **WHERE TWO PLATES ARE MOVING APART.** Plates can be Ocean or Continental

Examples Of Divergent Plate Boundaries:

a. **Ocean/ Ocean**: **MID–OCEAN RIDGE**



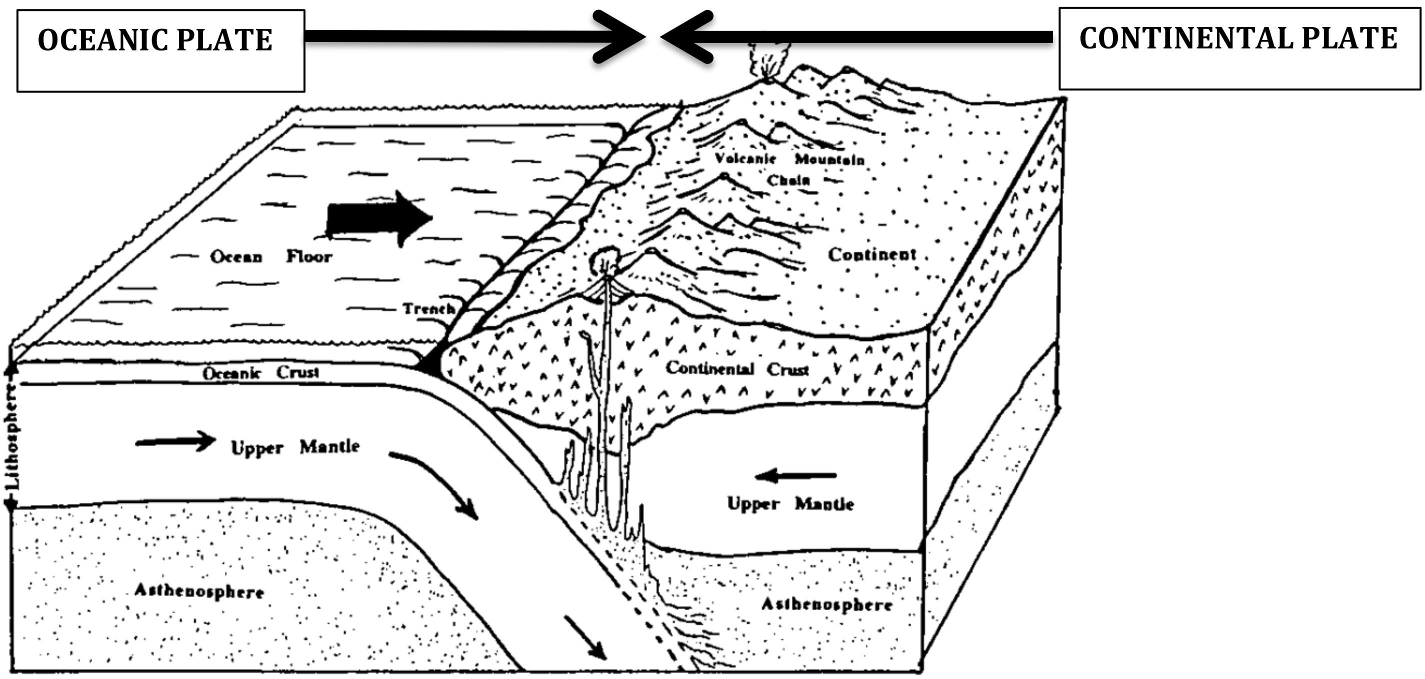
b. **Continental/Continental : GREAT RIFT VALLEY / AFRICA**



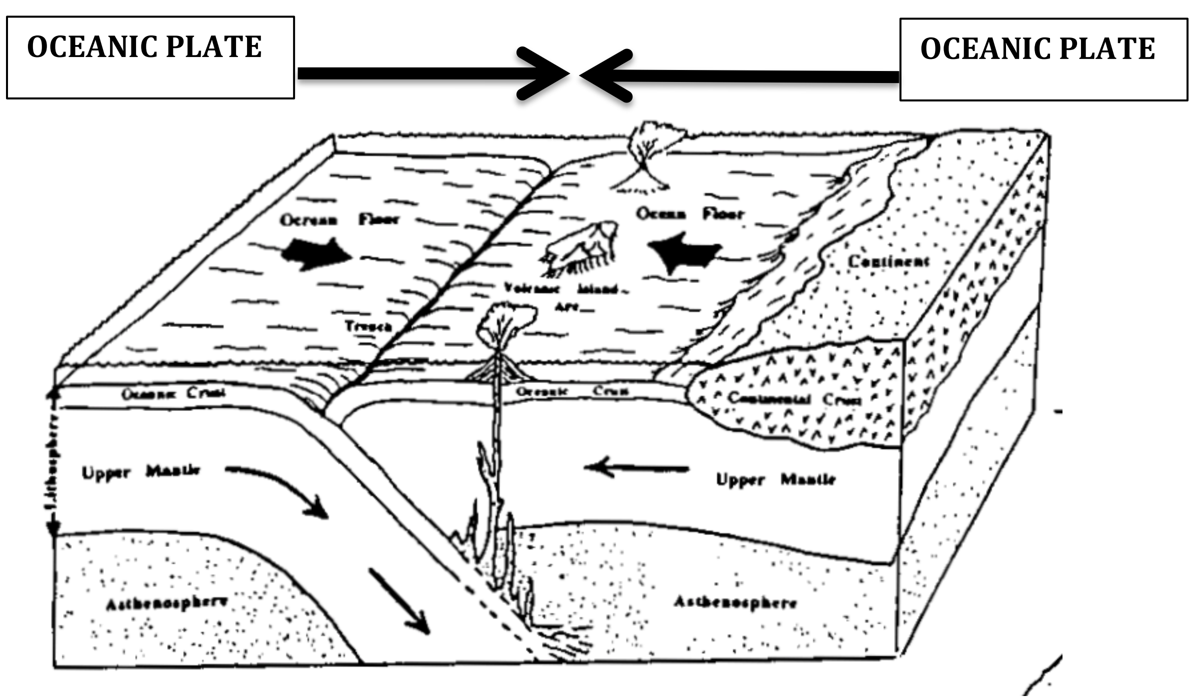
2. **Convergent Plate Boundaries**: **WHERE TWO PLATES COME TOGETHER (COLLIDE).**

Examples Of Convergent Plate Boundaries:

a. Oceanic / Continental: Pacific Plate (ocean) subducts (goes under) the South American Plate(continental) .

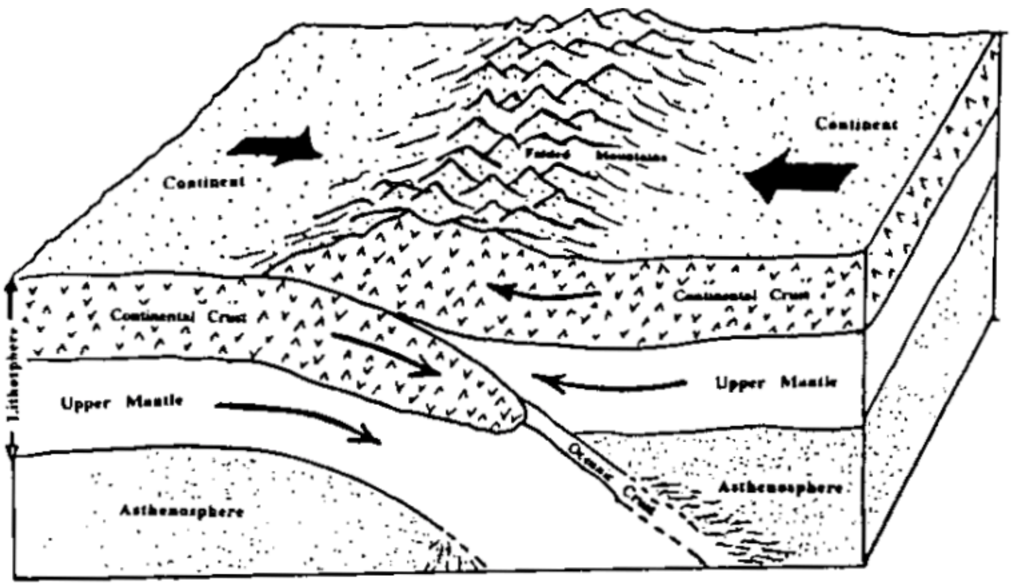


b. Oceanic / Oceanic: **Trenches and Island arcs of Japan and Aleutian Islands of Alaska.**



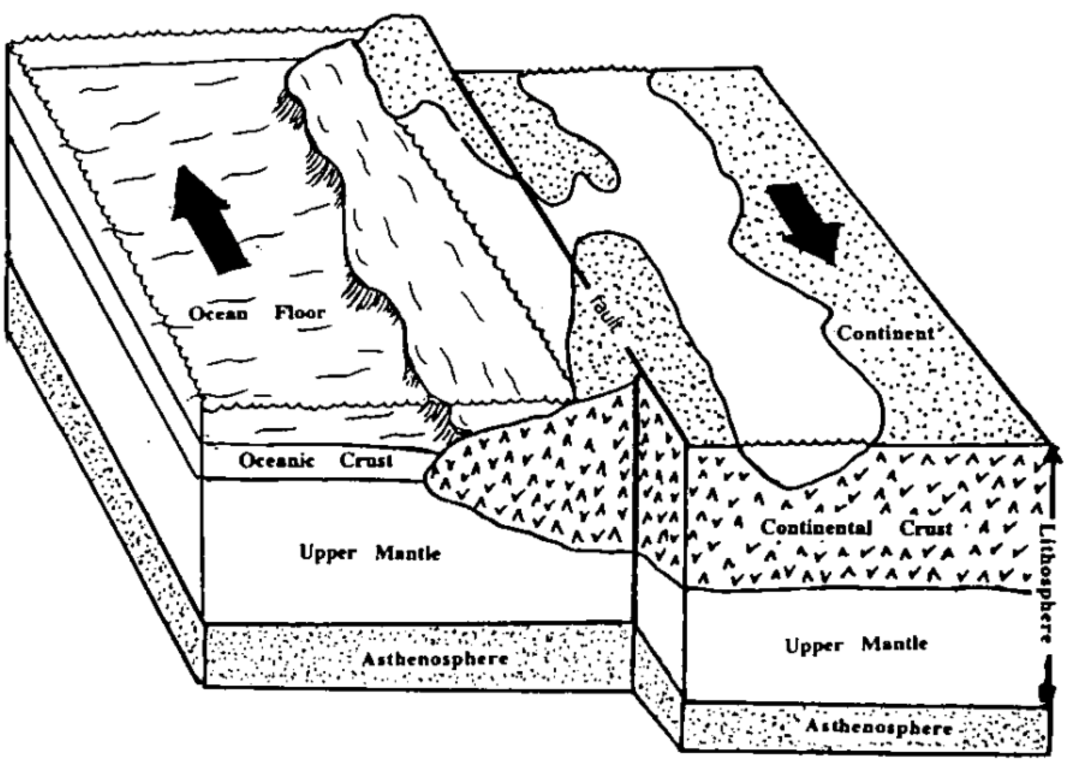
c. **Continental / Continental**: India colliding with Asia forming the Himalaya Mountains.

CONTINENTAL PLATE → ← **CONTINENTAL PLATE**



3. **Transform Plate Boundaries**: **WHERE TWO PLATES SLIDE PAST EACH OTHER).**

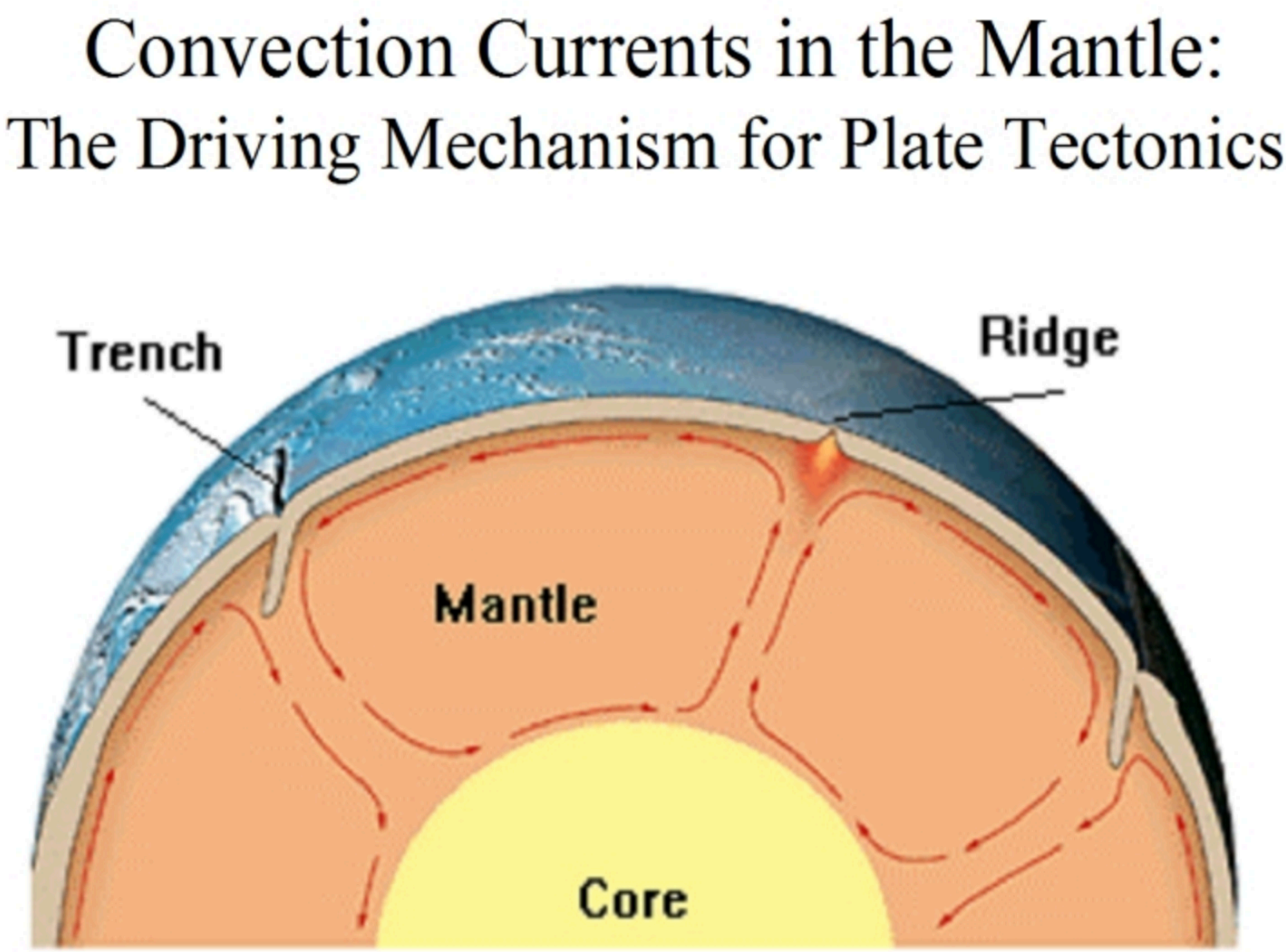
Examples Of Transform Plate Boundary: **SAN ANDREAS FAULT CALIFORNIA**



E. WHAT CAUSES TECTONIC PLATES TO MOVE?

a. **CONVECTION CURRENTS** – the driving force beneath plate tectonics.

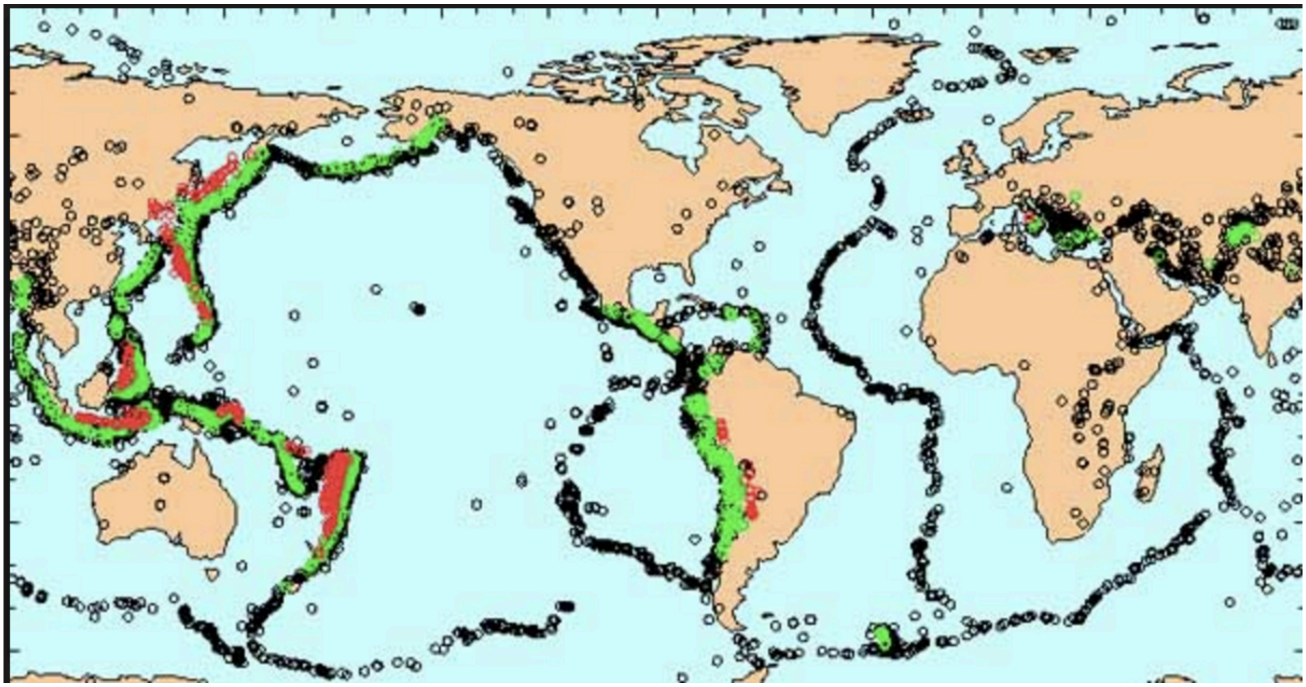
Hot, **LESS** dense material from deep within earth's mantle rises. When this material cools near the surface, it becomes **MORE** dense and sinks. The resulting convection flow of this material in the mantle **CARRIES / MOVES** lithospheric plates across the surface of the earth.



III. EARTHQUAKES:

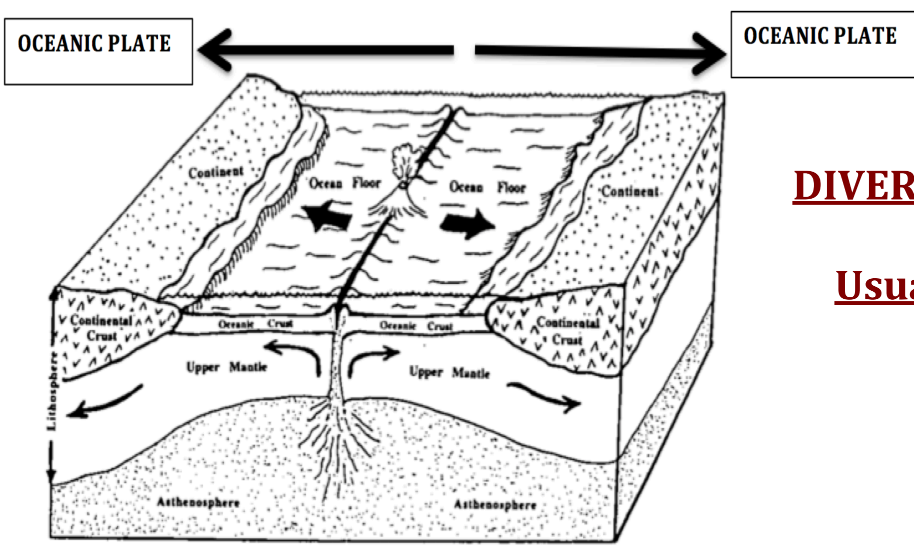
A. SEISMOLOGY – The branch of science that studies earthquakes

B. Earthquake regions on earth:



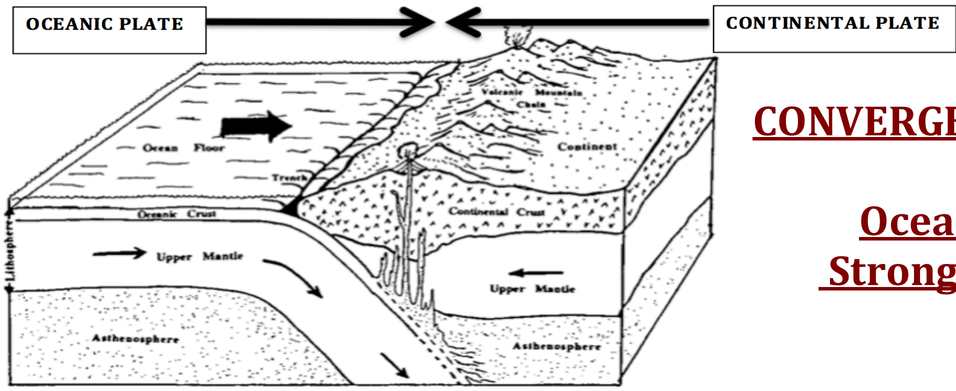
C. Causes of earthquakes: - Sudden movement of Earth's crust at plate boundaries and faults.

1. **PLATE BOUNDARIES**



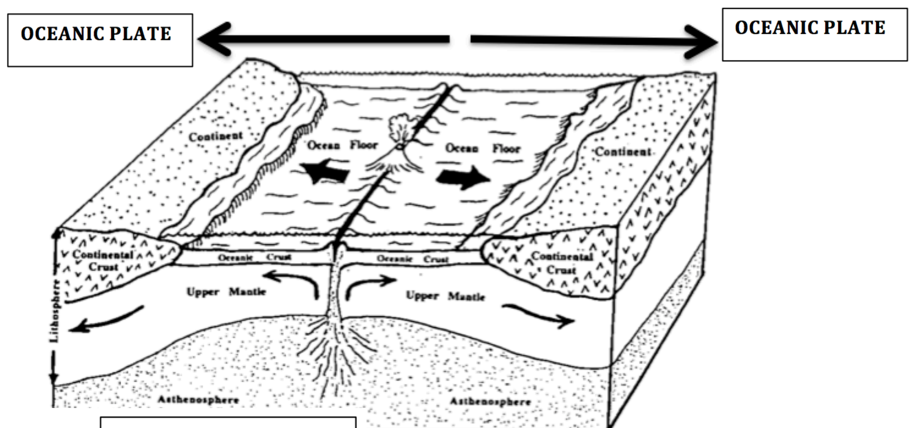
<u>DIVERGENT BOUNDARIES</u>

<u>Usually minor quakes / shallow</u>



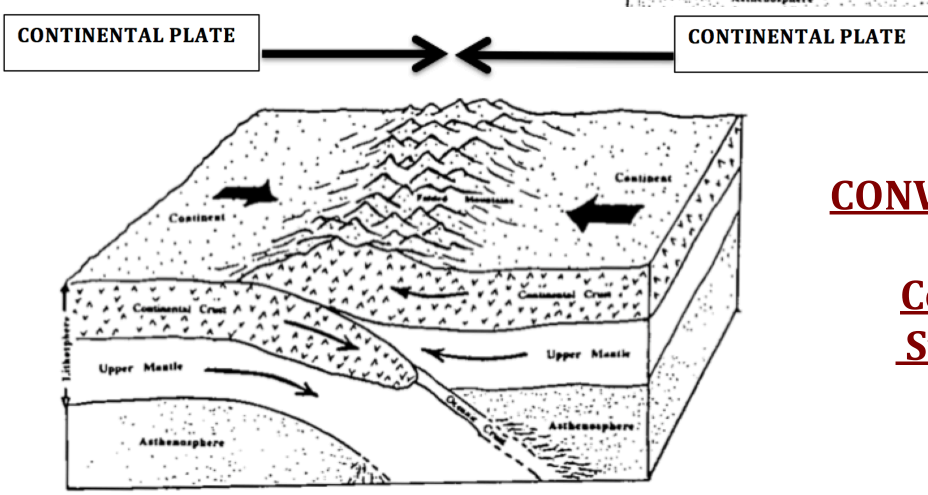
CONVERGENT BOUNDARY

Ocean – Continent
Strong / Deep Quakes



CONVERGENT BOUNDARY

Ocean – Ocean
Strong / Deep Quakes

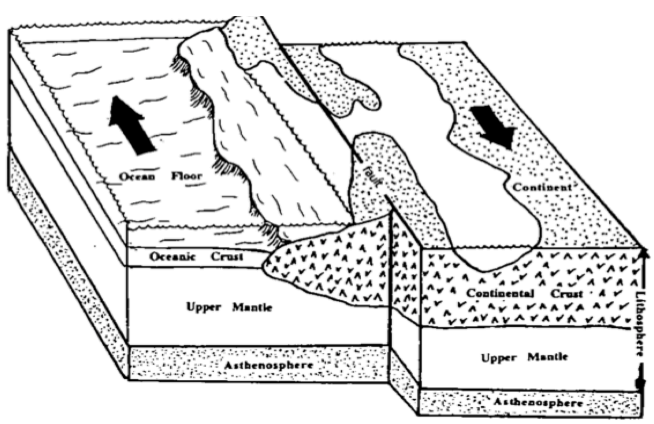


CONVERGENT BOUNDARY

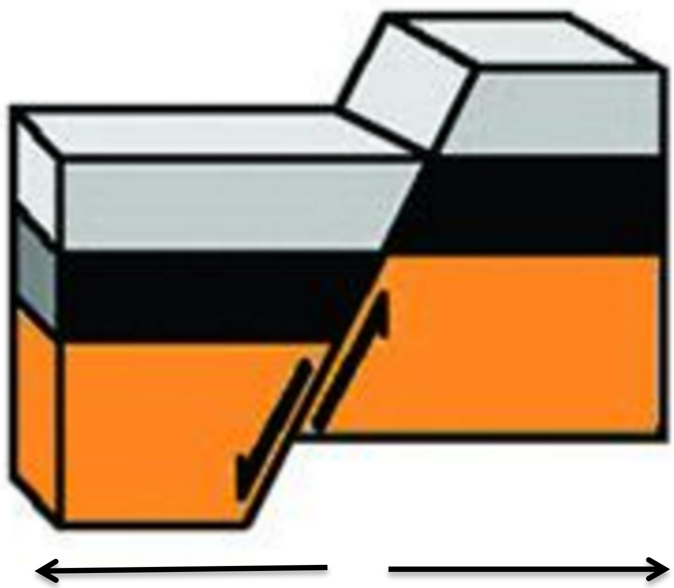
Continent – Continent
Strong / Deep Quakes

TRANSFORM BOUNDARY

Strike-Slip Fault
Moderate / Shallow Quakes

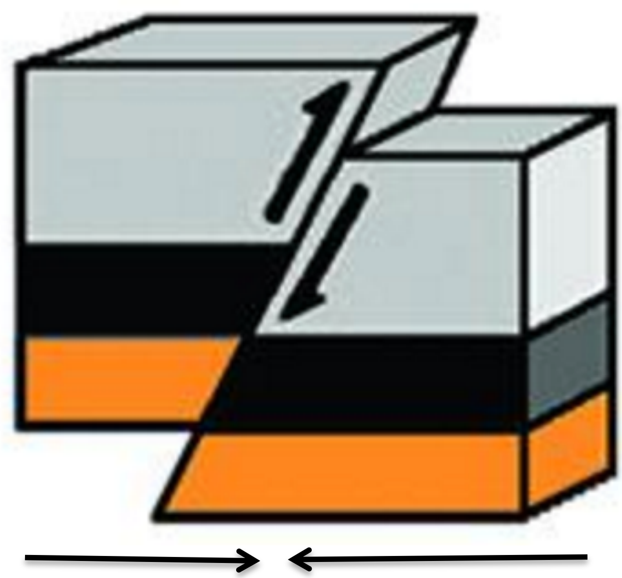


2. FAULTS



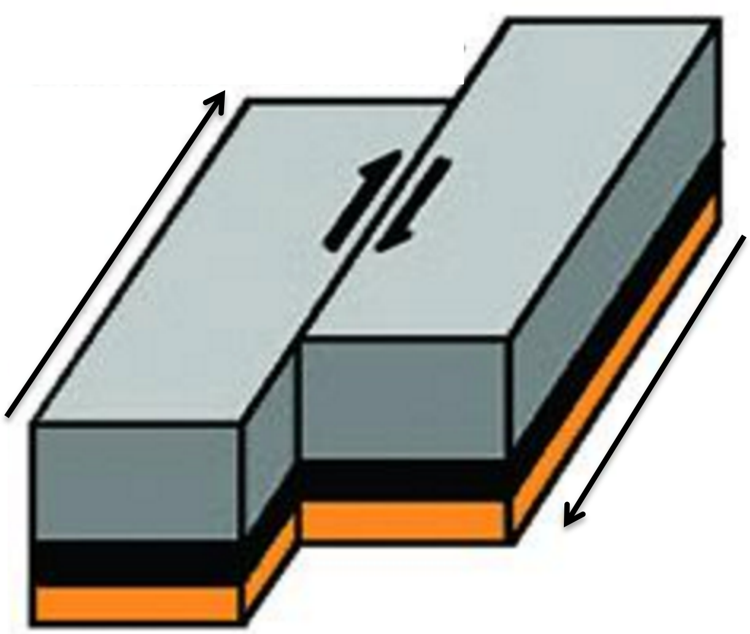
NORMAL
Caused when plates diverge

Common along mid-ocean ridges



REVERSE
Caused when plates converge

Common in subduction zones at island arcs

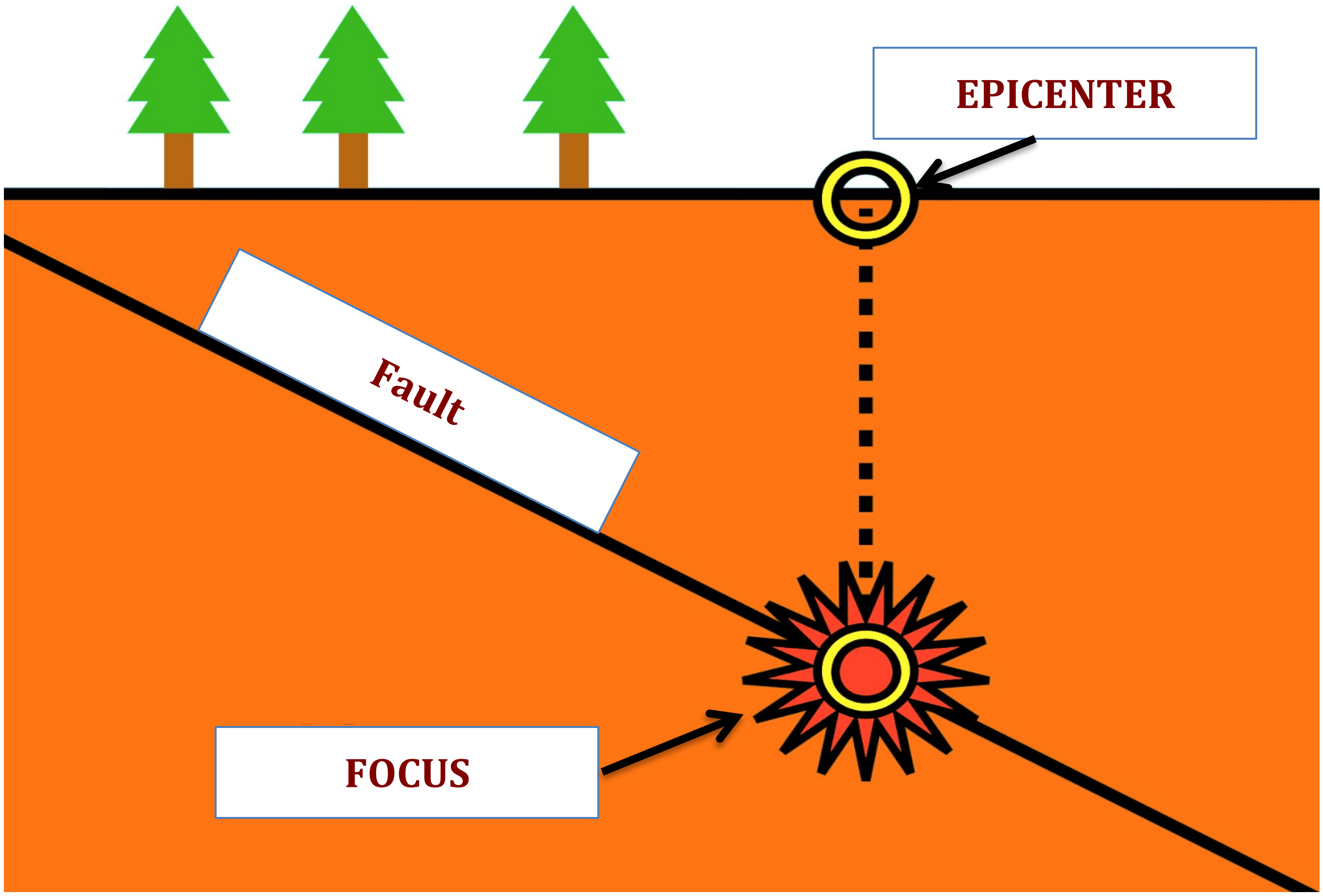


STRIKE-SLIP
Caused by Transform boundaries

Caused when plates slip passed each other with little up or down motion.

3. EARTHQUAKE WAVES

A. Origin And Map Location



FOCUS – **THE POINT BENEATH EARTH'S SURFACE WHERE FAULT MOVEMENT RELEASES SEISMIC WAVES (ENERGY)**

EPICENTER – **POINT ON EARTH'S SURFACE DIRECTLY ABOVE THE FOCUS**

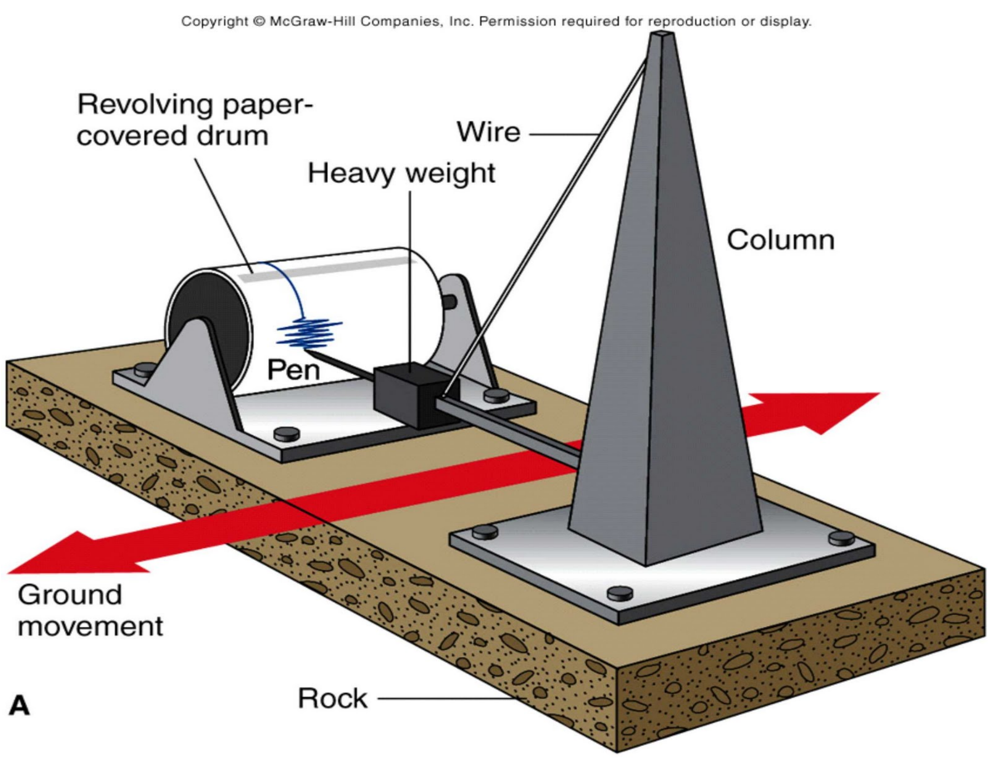
B. TYPES OF SEISMIC WAVES

	PROPER NAME	TRAVEL SPEED
P WAVES	**PRIMARY WAVE**	**6 MPS**
S WAVES	**SECONDARY WAVE**	**4 MPS**

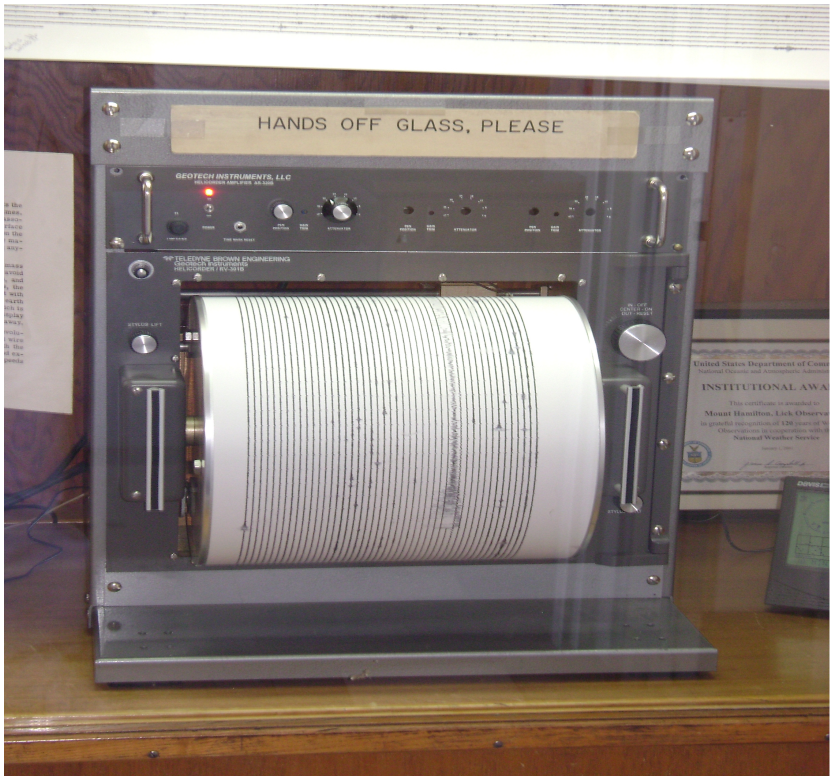
C. **<u>SEISMOGRAPH / SEISMOMETER</u>** – Measures and records earthquake waves

ANCIENT SEISMOGRAPH (2000 years old) – Each dragon held a metal bead in it's mouth. When the ground "quaked", the metal bead dropped from the dragon's mouth to the frog.

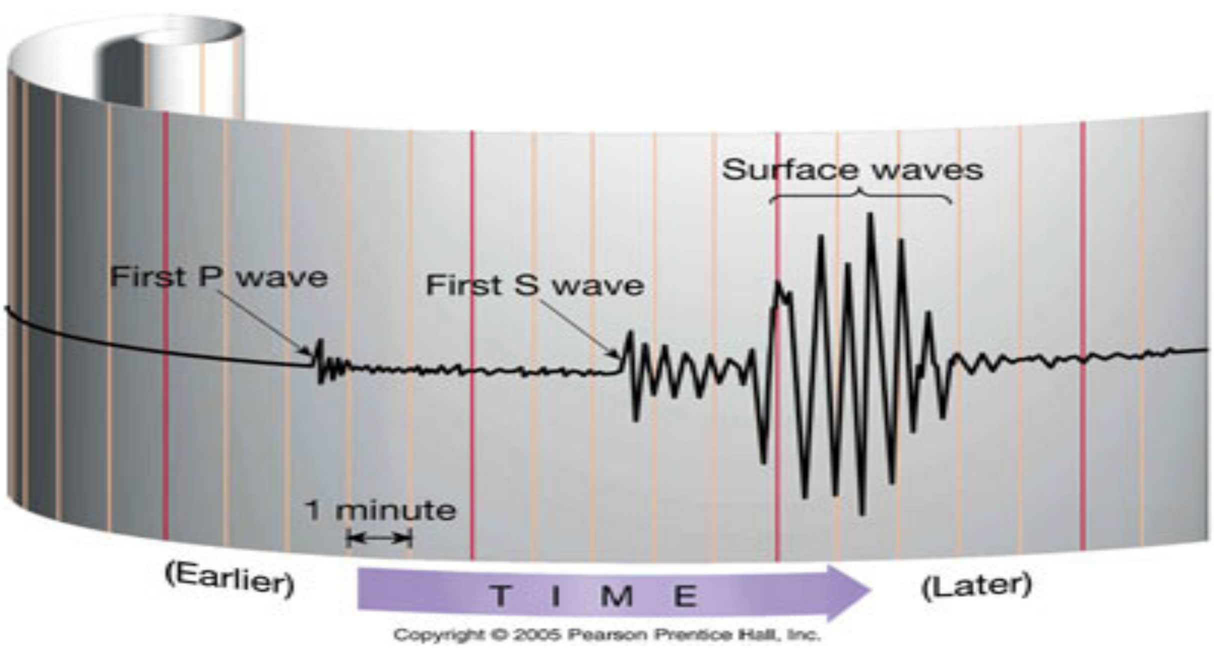
<u>EARLY SEISMOGRAPHS</u> – A heavy weight with a pen attached sways when the earth quakes, making marks on the paper rolling beneath.



<u>MODERN SEISMOGRAPHS</u> – Computerized. Record movement detected by wired and rods buried beneath the earth's surface



SEISMOGRAM: The readout from seismograph



D. LOCATING THE EPICENTER OF AN EARTHQUAKE – EXAMPLE 1

1. Houston, Texas

2. Chicago, Illinois

3. Seattle, Washington

SEISMOGRAPH STATION	ARRIVAL TIME P-wave	S-wave	DIFFERENCE IN ARRIVAL TIME	DISTANCE TO EPICENTER
HOUSTON	13 MIN	16 MIN	3 MIN : 0 SEC	1900 KM
CHICAGO	15 MIN	19 MIN	4 MIN : 0 SEC	2600 KM
SEATTLE	12 MIN	14 MIN 20 SEC	2 MIN:20 SEC	1400 KM

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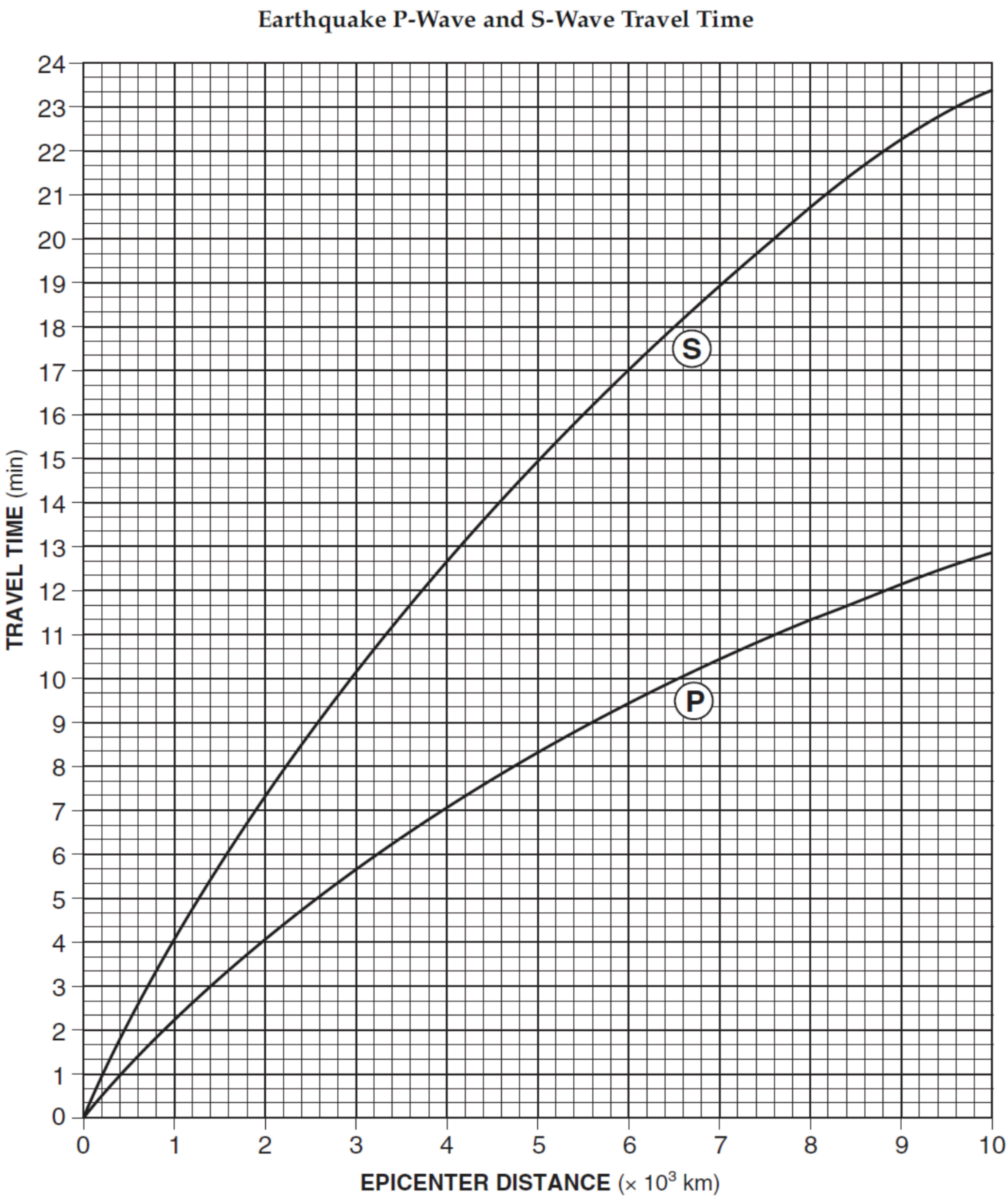
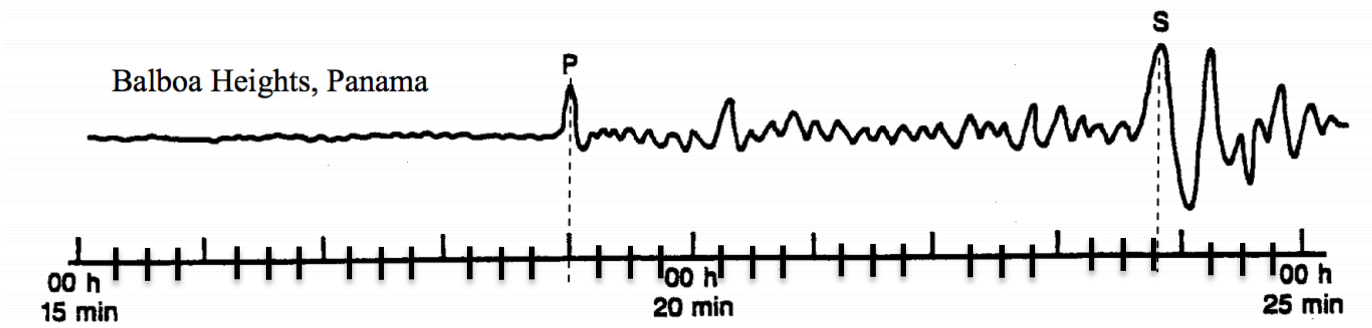
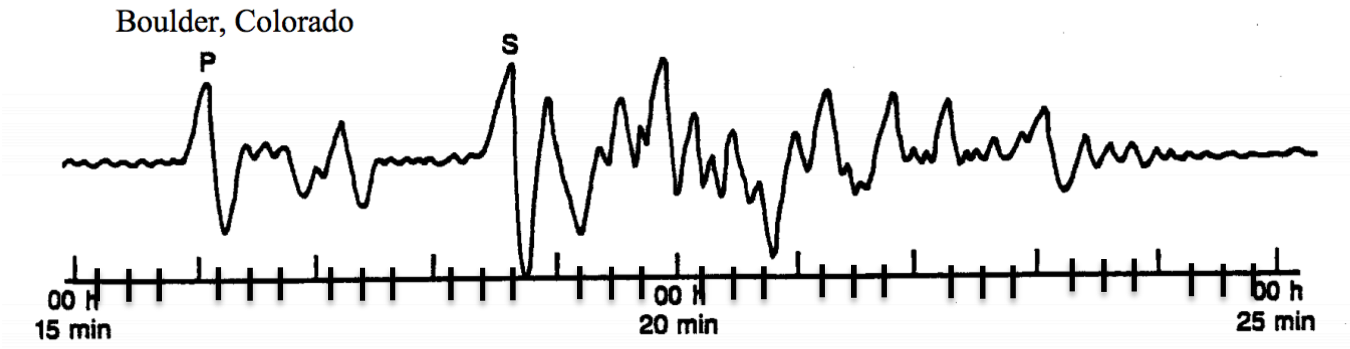
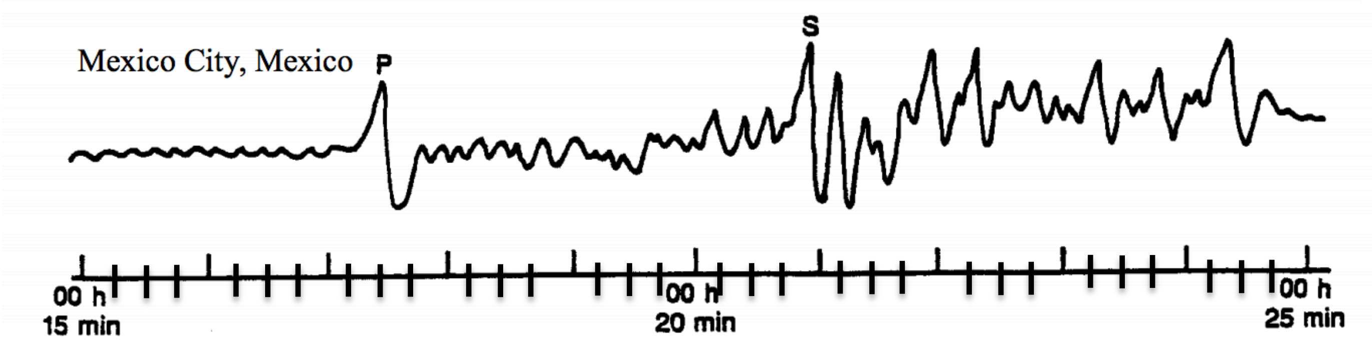

Earthquake P-Wave and S-Wave Travel Time
TRAVEL TIME (min)
EPICENTER DISTANCE (× 10³ km)
S
P
0 1 2 3 4 5 6 7 8 9 10
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24


0
1000
2000
Kilometers
Chicago
Houston
Seattle
Epicenter

D. LOCATING THE EPICENTER OF AN EARTHQUAKE – EXAMPLE 2







City	P-wave Arrival Time	S-wave Arrival Time	Difference Between P-wave and S-wave	Distance to Epicenter
Balboa Heights	**19:00**	**23:45**	**5:45**	**4,200 KM**
Boulder	**16:00**	**18:45**	**2:45**	**1,800 KM**
Mexico City	**17:30**	**21:00**	**3:30**	**2,200 KM**

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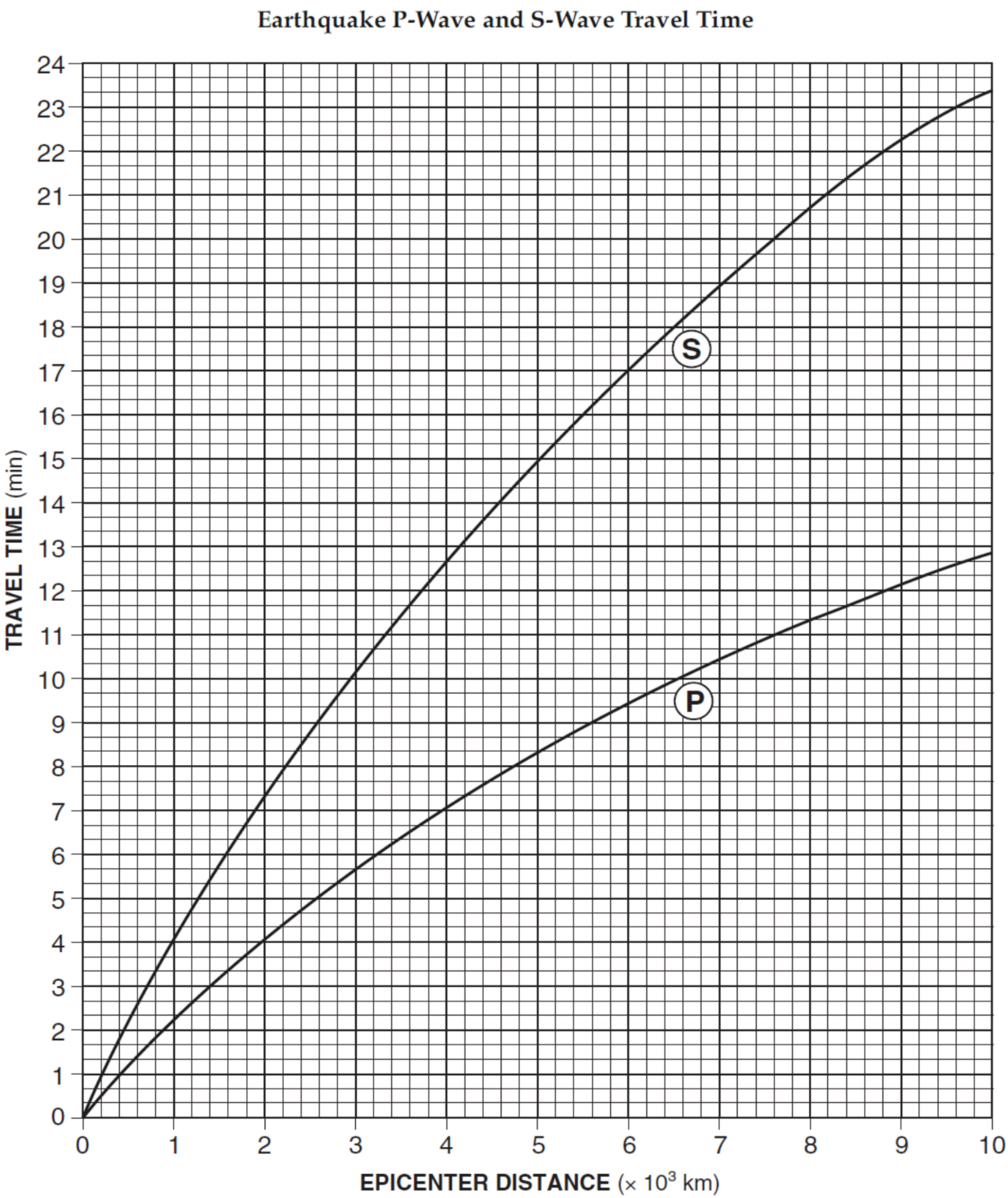

Earthquake P-Wave and S-Wave Travel Time
TRAVEL TIME (min)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
S
P
EPICENTER DISTANCE (× 10³ km)
0
1
2
3
4
5
6
7
8
9
10


GREENLAND
ALASKA
CANADA
UNITED STATES
BC
MEXICO
MC
BH
0
1000
2000
3000
4000
SCALE (KILOMETERS)
SOUTH AMERICA

E. MEASURING AN EARTHQUAKE

1. **RICHTER SCALE**- a scale used to express the **STRENGTH** or **ENERGY** an earthquake releases by assigning a number from 1 to 10. Each of the numerical steps represents a ten-fold increase in the amount of energy. For example, a reading of 3 indicates 10 times more energy than a reading of 2.

RICHTER SCALE

Magnitude	Description	What it feels like	Frequency
Less than 2.0	Micro	Normally only recorded by seismographs. Most people cannot feel them.	Millions per year.
2.0–2.9	Minor	A few people feel them. No building damage.	Over 1 million per year.
3.0–3.9	Minor	Some people feel them. Objects inside can be seen shaking.	Over 100,000 per year.
4.0–4.9	Light	Most people feel it. Indoor objects shake or fall to floor.	10,000 to 15,000 per year.
5.0–5.9	Moderate	Can damage or destroy buildings not designed to withstand earthquakes. Everyone feels it.	1,000 to 1,500 per year.
6.0–6.9	Strong	Wide spread shaking far from epicenter. Damages buildings.	100 to 150 per year.
7.0–7.9	Major	Wide spread damage in most areas.	10 to 20 per year.
8.0–8.9	Great	Wide spread damage in large areas.	About 1 per year.
9.0–9.9	Great	Severe damage to most buildings.	1 per 5-50 years.
10.0 or over	Massive	Never Recorded.	Never recorded.

2. **MERCALLI SCALE** – A scale which assigns a numeral from I to X to show the **DAMAGE** to people and property caused by an earthquake

Modified Mercalli Intensity Scale

I	Instrumental: detected only by instruments	VII	Very strong: noticed by people in autos Damage to poor construction
II	Very feeble: noticed only by people at rest	VIII	Destructive: chimneys fall, much damage in substantial buildings, heavy furniture overturned
III	Slight: felt by people at rest Like passing of a truck	IX	Ruinous: great damage to substantial structures Ground cracked, pipes broken
IV	Moderate: generally perceptible by people in motion Loose objects disturbed	X	Disastrous: many buildings destroyed
V	Rather strong: dishes broken, bells rung, pendulum clocks stopped People awakened	XI	Very disastrous: few structures left standing
VI	Strong: felt by all, some people frightened Damage slight, some plaster cracked	XII	Catastrophic: total destruction

3. SOME MAJOR EARTHQUAKES:

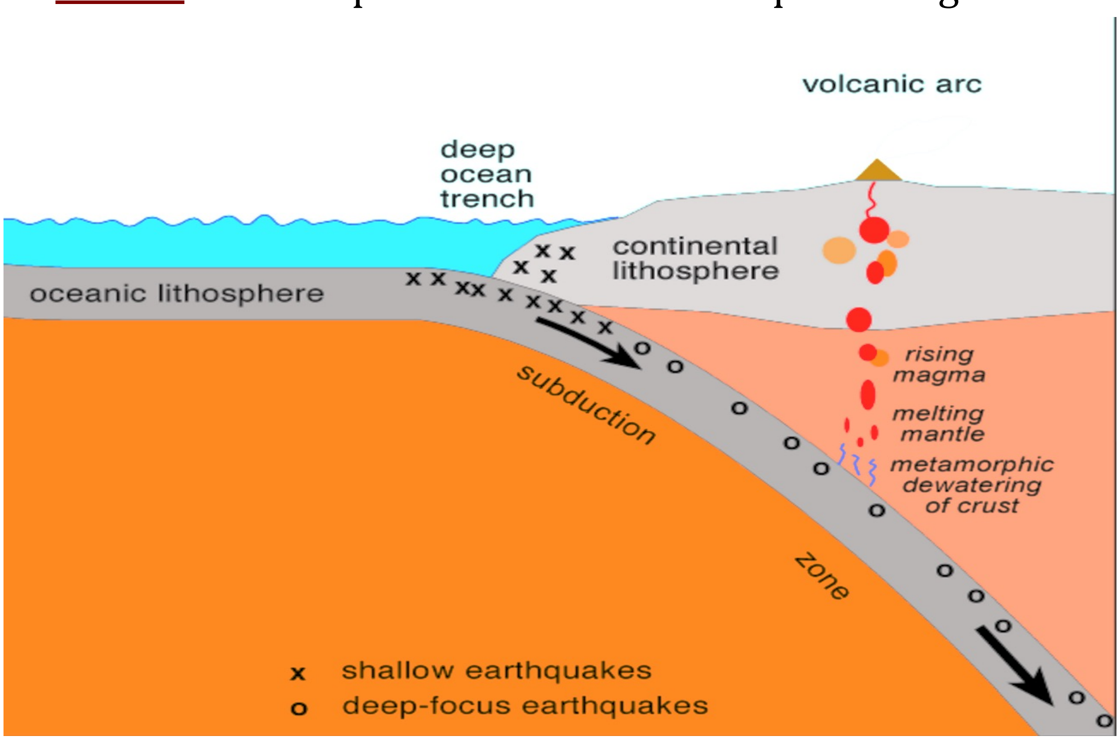
Number of Earthquakes Worldwide for 2000 - 2010

Located by the US Geological Survey National Earthquake Information Center

Magnitude	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
8.0 to 9.9	1	1	0	1	2	1	2	4	0	1	1
7.0 to 7.9	14	15	13	14	14	10	9	14	12	16	19
6.0 to 6.9	146	121	127	140	141	140	142	178	168	141	137
5.0 to 5.9	1344	1224	1201	1203	1515	1693	1712	2074	1768	1872	1646
4.0 to 4.9	8008	7991	8541	8462	10888	13917	12838	12078	12291	6815	8593
3.0 to 3.9	4827	6266	7068	7624	7932	9191	9990	9889	11735	2903	3786
2.0 to 2.9	3765	4164	6419	7727	6316	4636	4027	3597	3860	3015	3832
1.0 to 1.9	1026	944	1137	2506	1344	26	18	42	21	26	25
0.1 to 0.9	5	1	10	134	103	0	2	2	0	1	0
No Magnitude	3120	2807	2938	3608	2939	864	828	1807	1922	18	28
Total	22256	23534	27454	31419	31194	30478	29568	29685	31777	* 14808	* 18067
Estimated Deaths	231	21357	1685	33819	228802	88003	6605	712	88011	1787	226888

4. Earthquakes Tell Us About Earth's Surface Movement.

FOCUS – The Depth At Which An Earthquake Originates

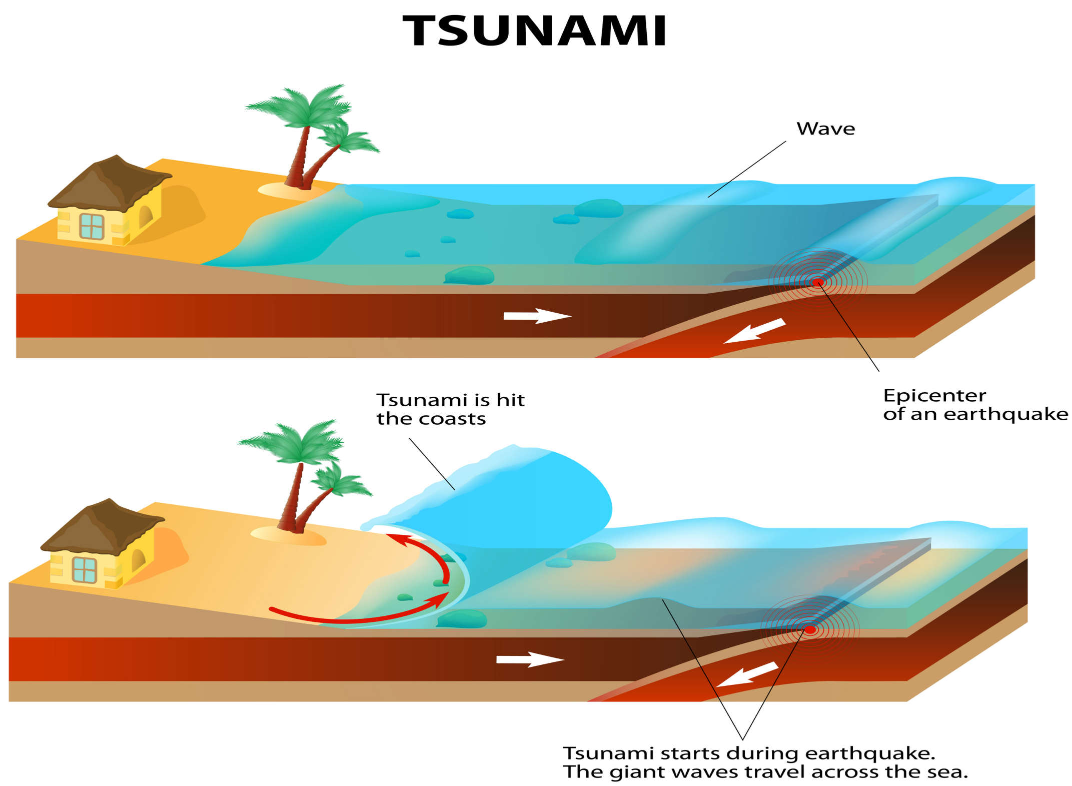


5. Earthquakes can cause other disasters:

TSUNAMI – gigantic sea waves

Characteristics – Speed – **400 – 500 mph**

Height – **50 – 100 feet**

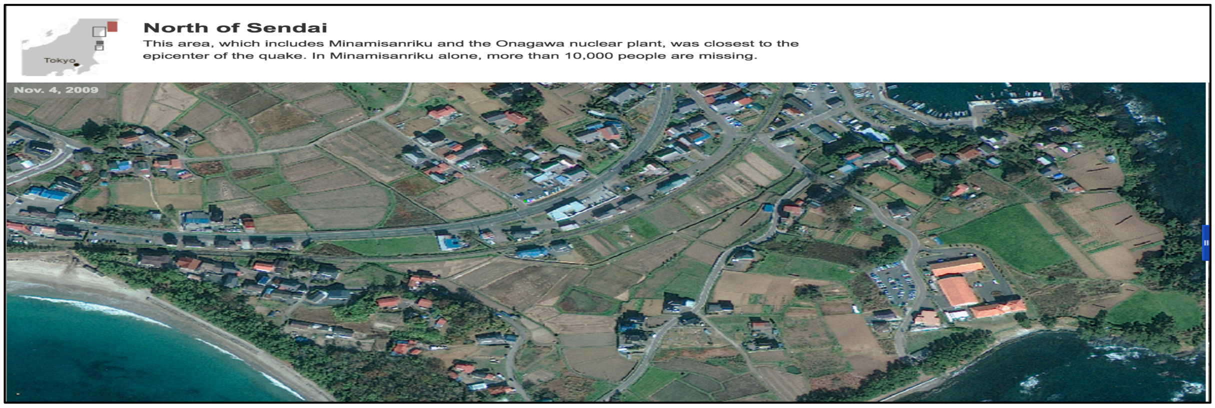


INTERACTIVE TSUNAMI BEFORE AND AFTER PICTURES –

http://www.nytimes.com/interactive/2011/03/13/world/asia/satellite-photos-japan-before-and-after-tsunami.html?_r=5&

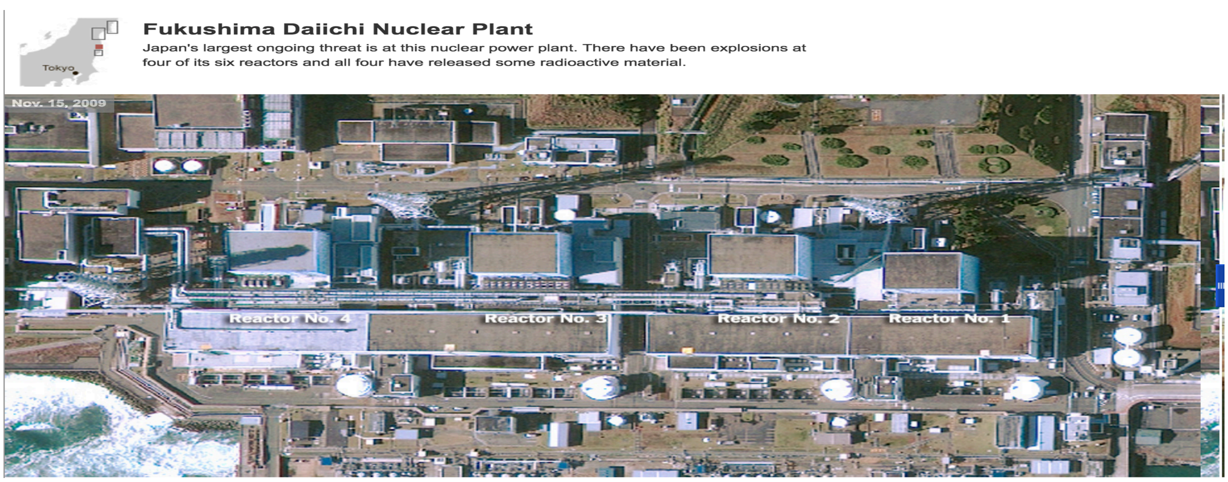
JAPAN TSUNAMIS:

Before

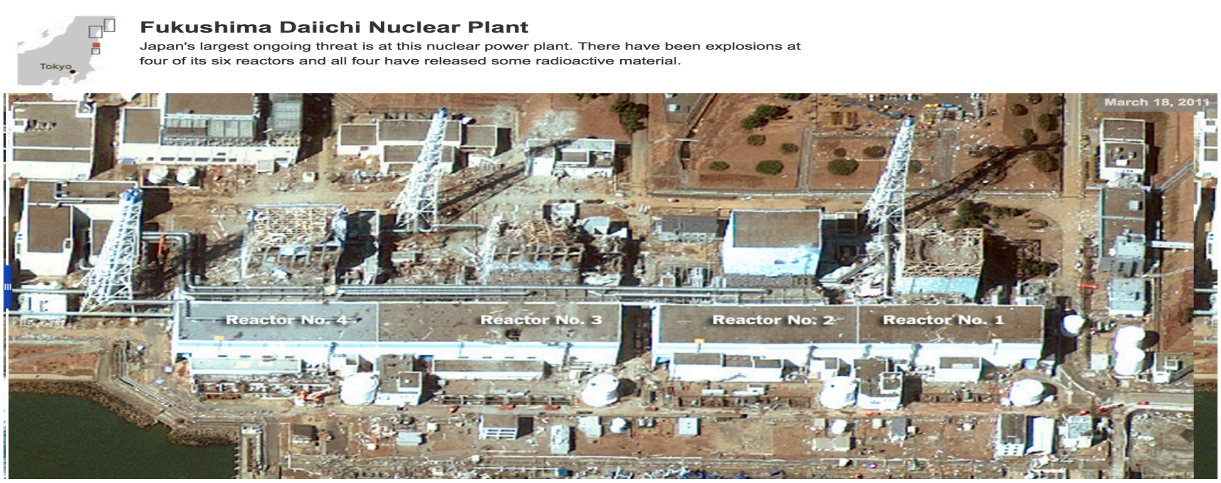


After

Before

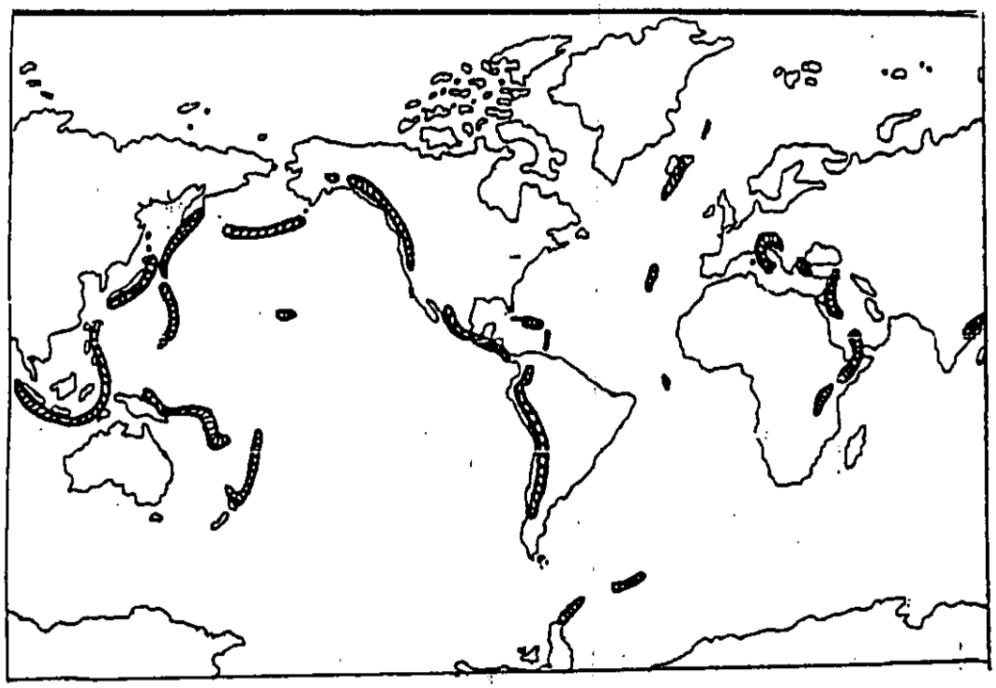


After



F. VOLCANOES

A. Volcanic regions on earth

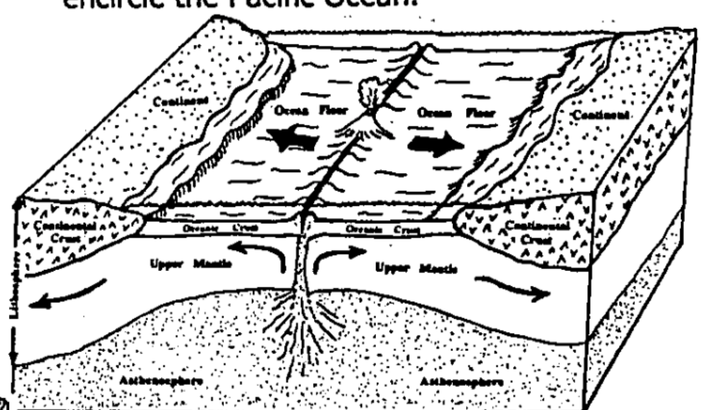


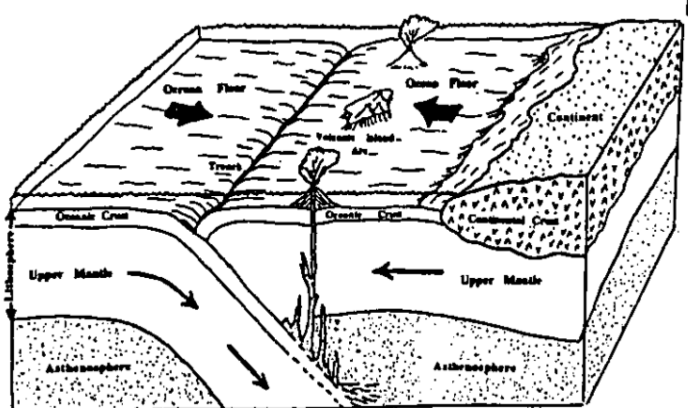
RING OF FIRE ___ = region of volcanoes that encircle the Pacific Ocean.

B. Causes of Volcanic Activity

1. Plate Boundaries

DIVERGENT



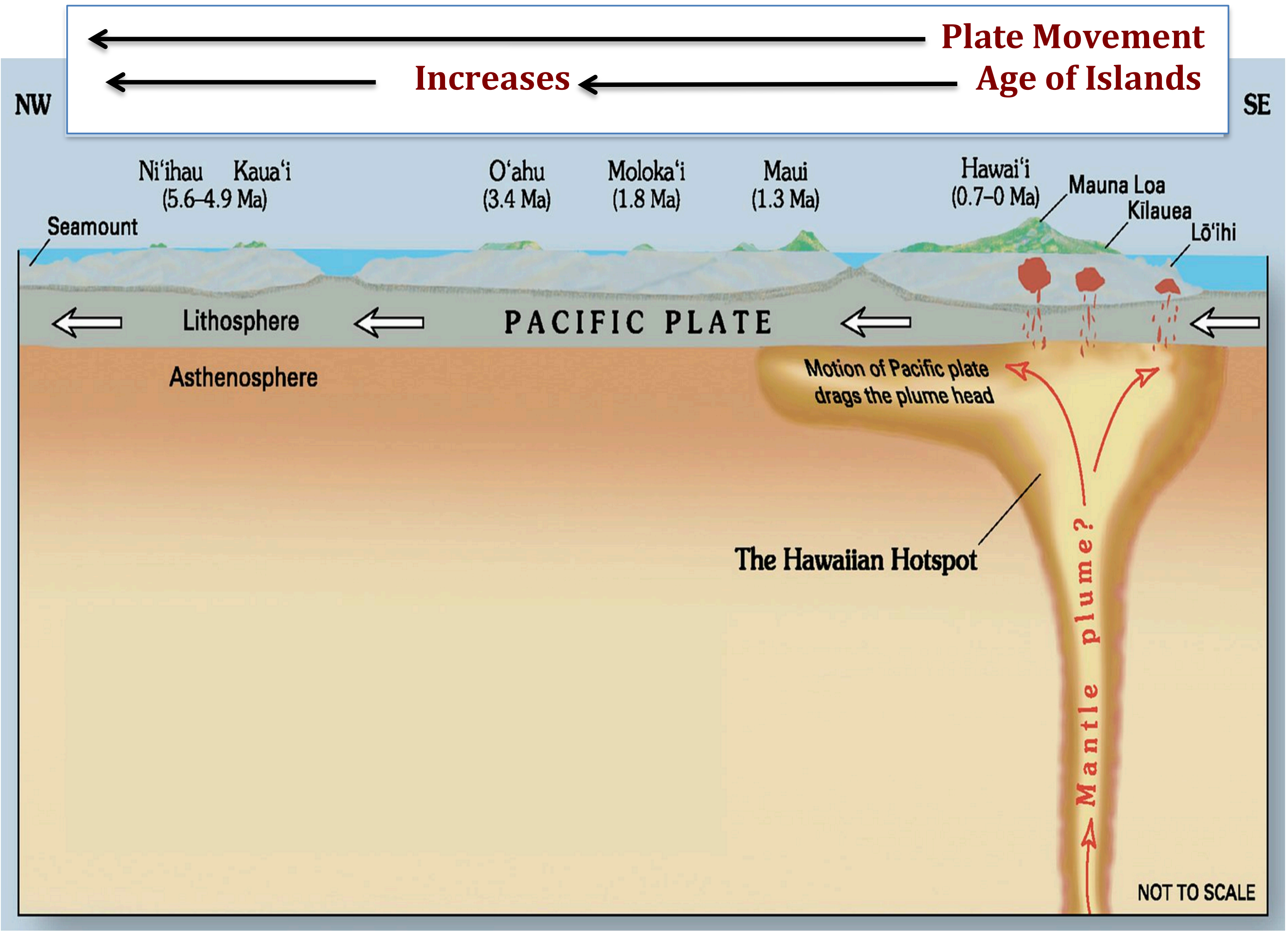


CONVERGENT

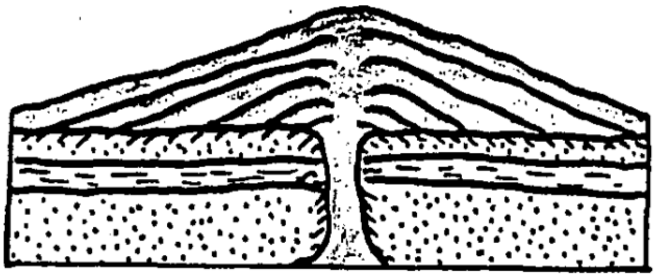
2. Hot Spots

A place deep within the **Earth** where **hot** magma rises to just underneath the surface, creating a bulge and volcanic activity. The chain of Hawaiian Islands (see Hawaii) is thought to have been created by the movement of a tectonic plate over a **hot spot**.

Hawaiian Islands

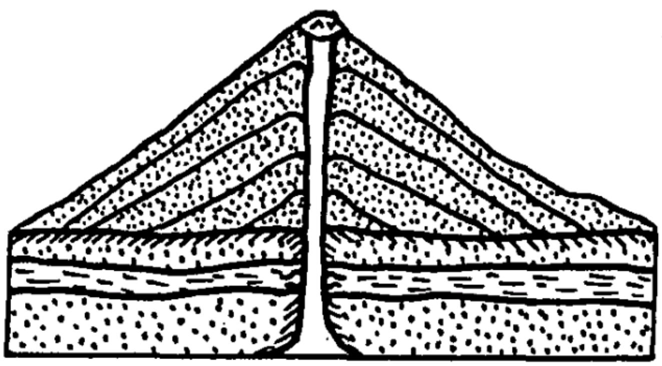


C. Types of Volcanoes



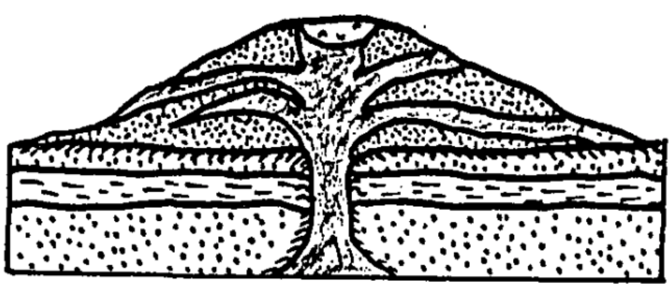
SHIELD Cone

- nonexplosive eruptions
- built from repeated lava flows
- gentle slopes
- example **MAUNA LUA**



CINDER Cone

- explosive eruptions
- built from tephra (lava is blasted into the air and solidifies as it falls to the ground as ash or cinders)
- steep slopes
- example ___ **PARICUTIN**



COMPOSITE Cone

- repeated nonexplosive and explosive eruptions
- built from alternating layers of lava and tephra
- moderate slopes
- example **Mt. FUJI**

UNIT 4 EXAM TOPICS

- Earth's Interior
  - **ESRT p. 10**
  - Continental vs Oceanic crust
  - Why "Inferred" properties?
  - S-Waves and the outer core
- Continental Drift
  - Evidences used to prove:
    - Coastal shape
    - Fossils
    - Rocks
    - Mountain Ranges
    - Climate
- Se-Floor Spreading
  - Age
  - Magnetic Polarity
- Volcanoes
  - Locations
  - Hot Spots
- Plate Tectonics
  - **ESRT p. 5**
  - 3 types of plate boundaries
    - what occurs
    - how they move
    - what moves them
    - subduction
- Earthquakes
  - **ESRT p. 11**
  - Depth
  - Locating the epicenter (triangulation)
  - Distance to epicenter
  - Travel Time
  - Velocity of waves

UNIT 4 EXAM VOCABULARY