Chapter 1
The Earth in Context

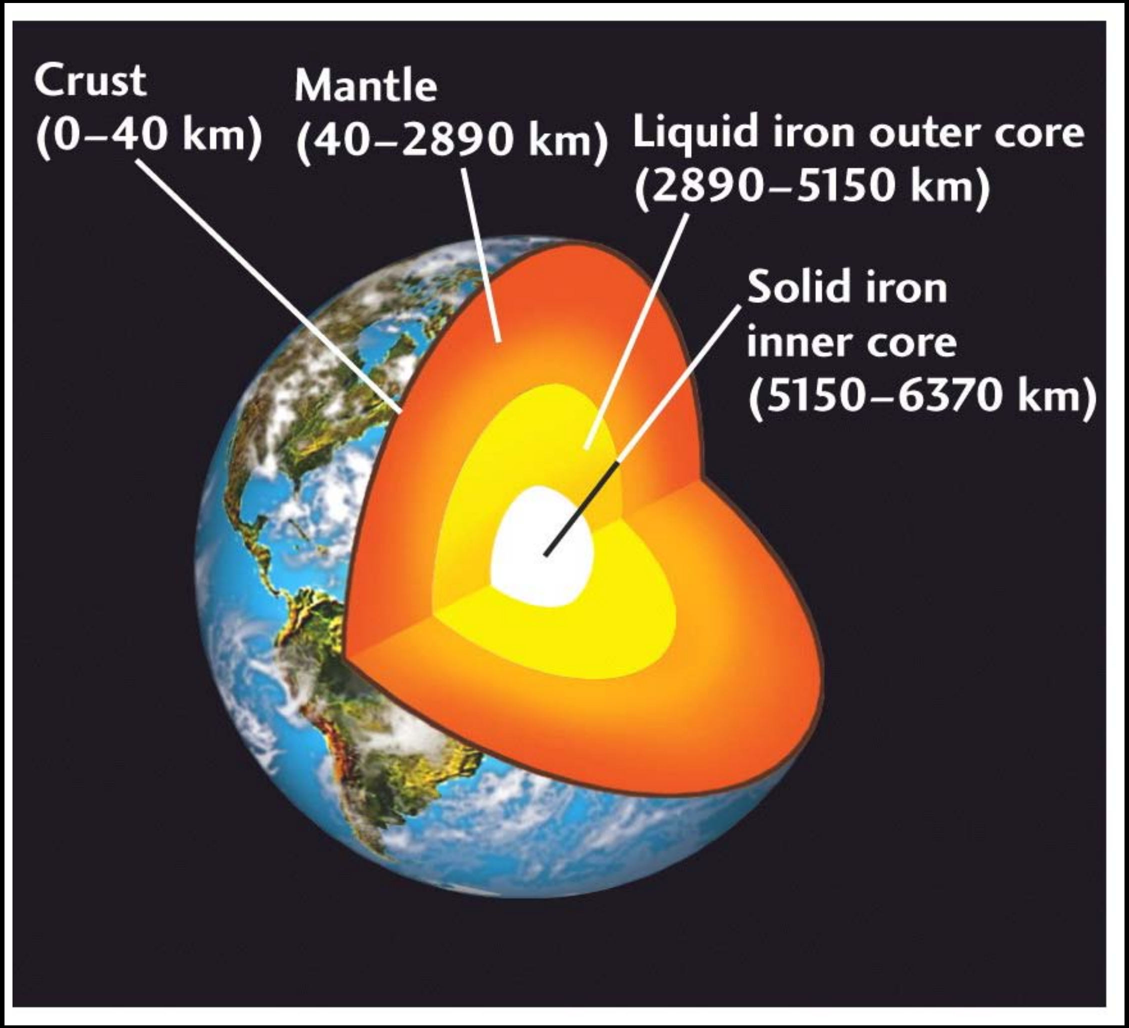
Structure of the Earth

<u>Chemically Different</u>

Crust
- Continental
- Oceanic

Mantle
- Upper mantle
- Lower mantle

Core
- Liquid outer core
- Solid inner core

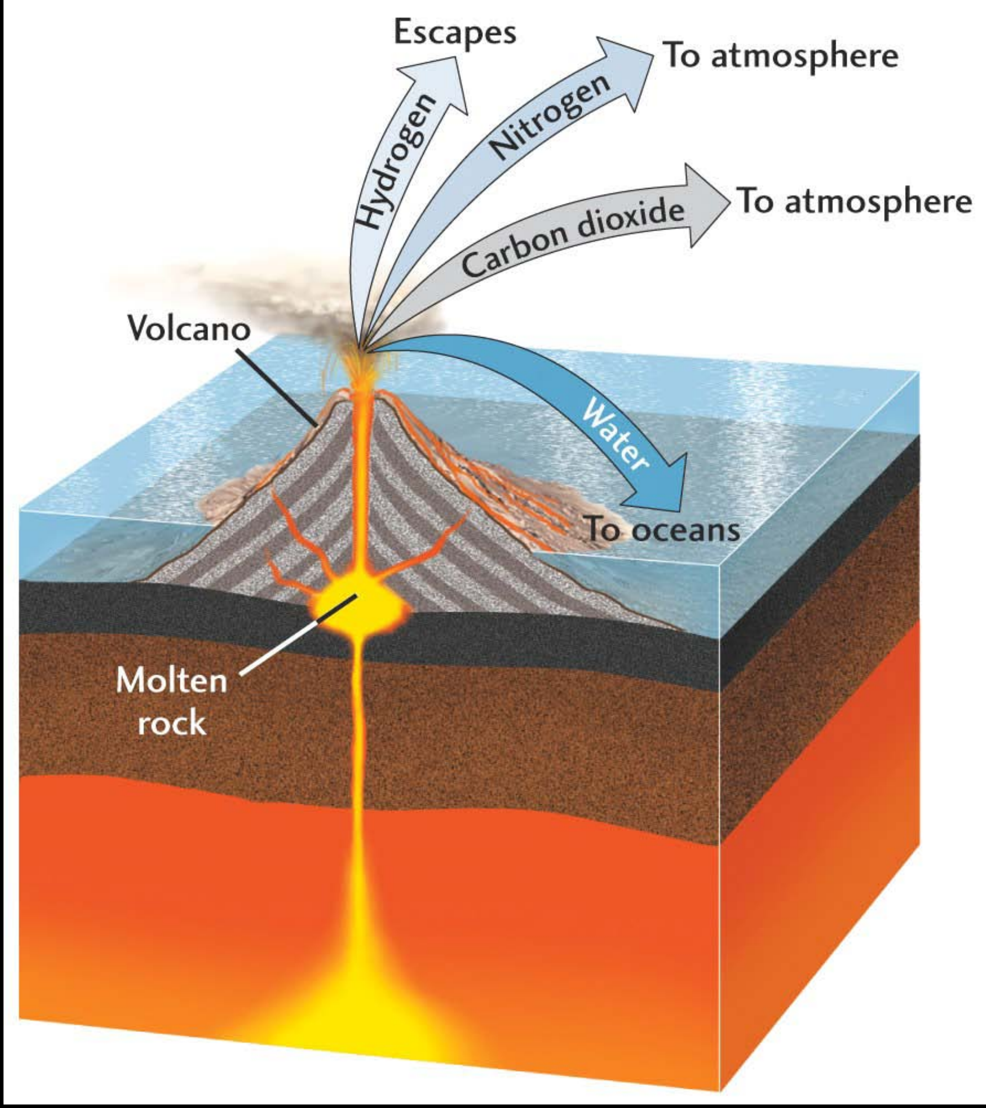


How did Earth's continents, atmosphere and oceans form?

Continents - form from the lighter molten materials rising to the surface solidified as it cools

Oceans and Atmosphere – 2 hypotheses

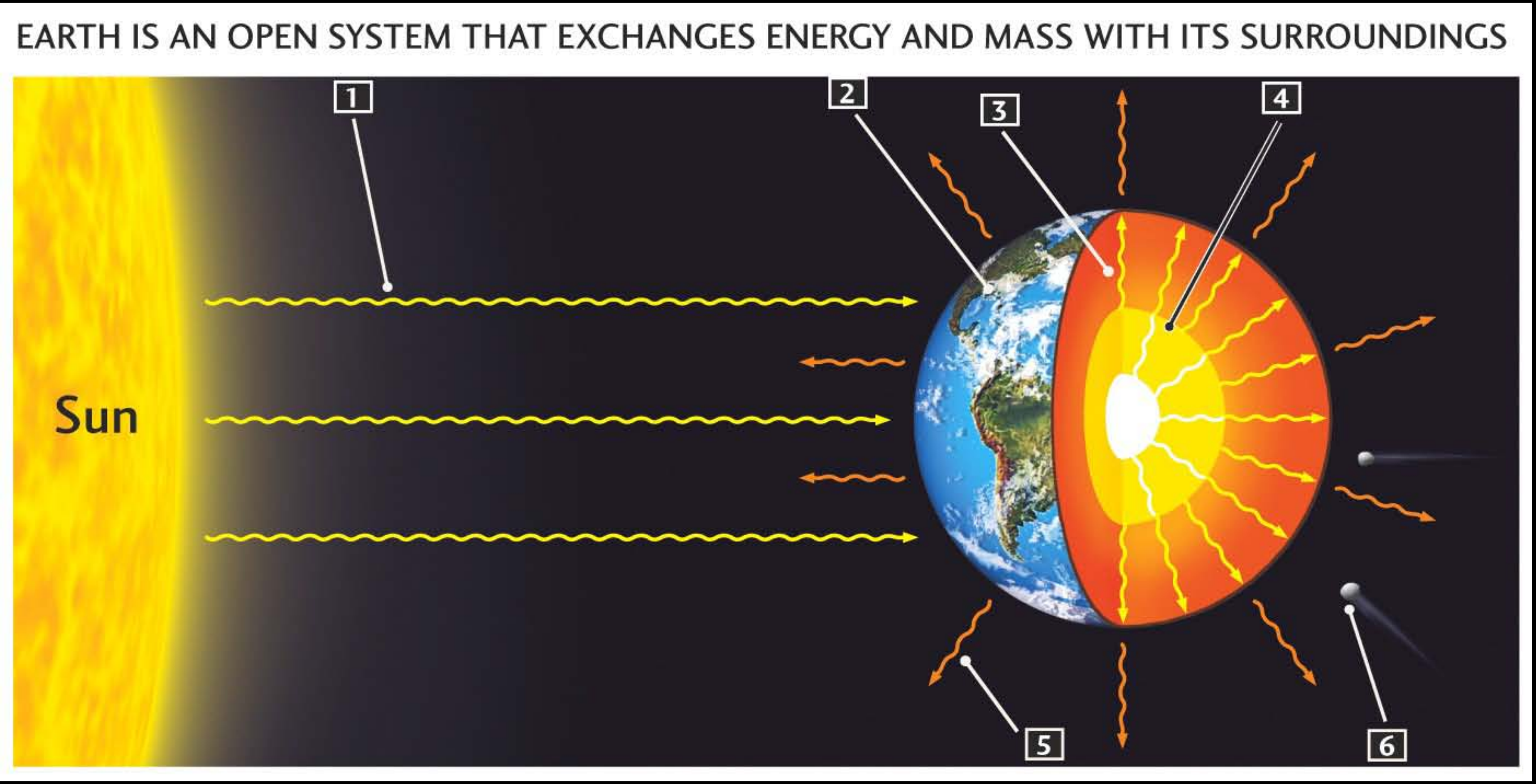
- resulted from impact of volatile-rich matter striking the Earth from space after it was formed - comets
- resulted from volatile tied up in planetesimals which formed the Earth. Volatiles released by volcanism

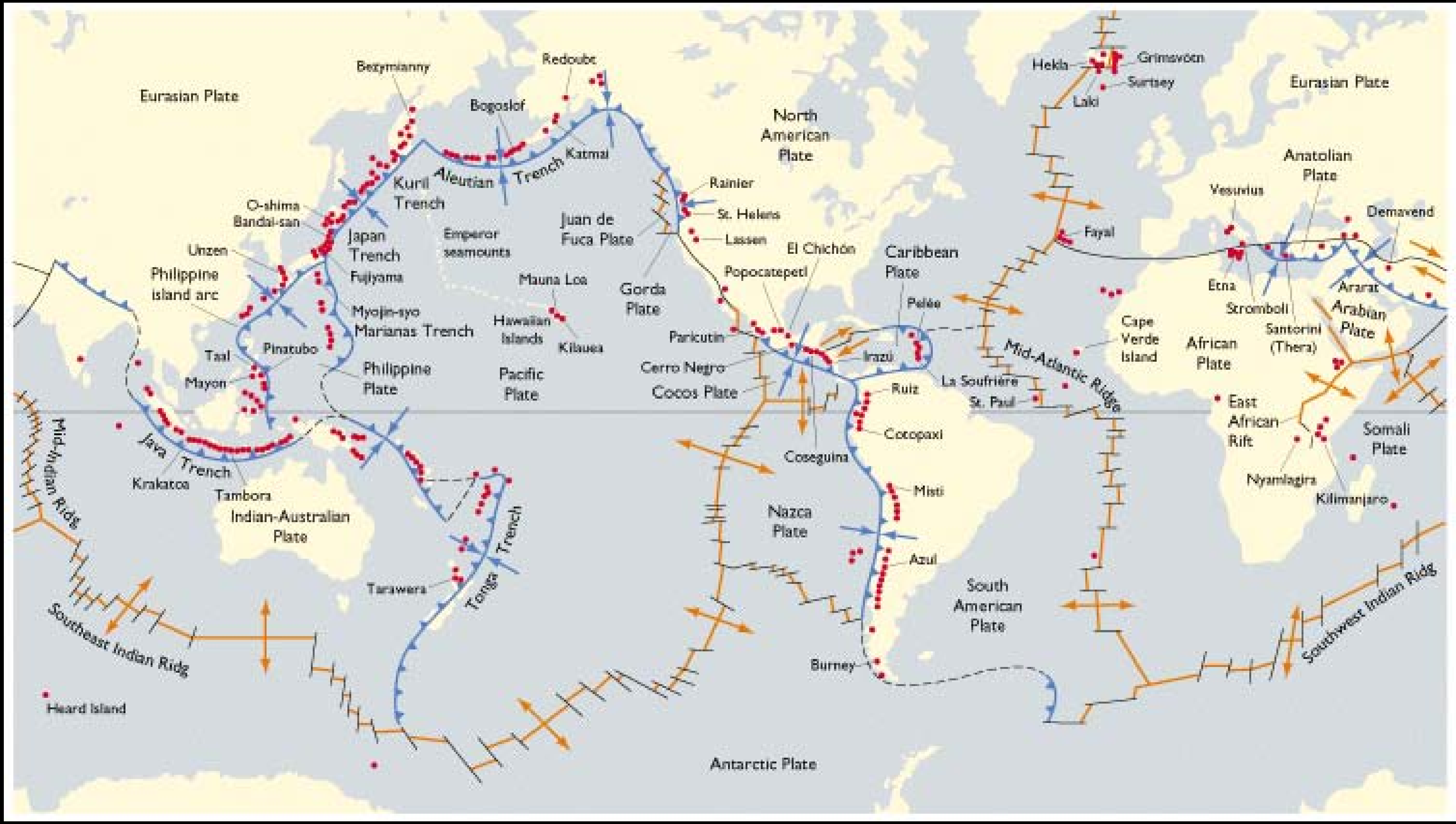


Earth Systems – 2 basic energy sources

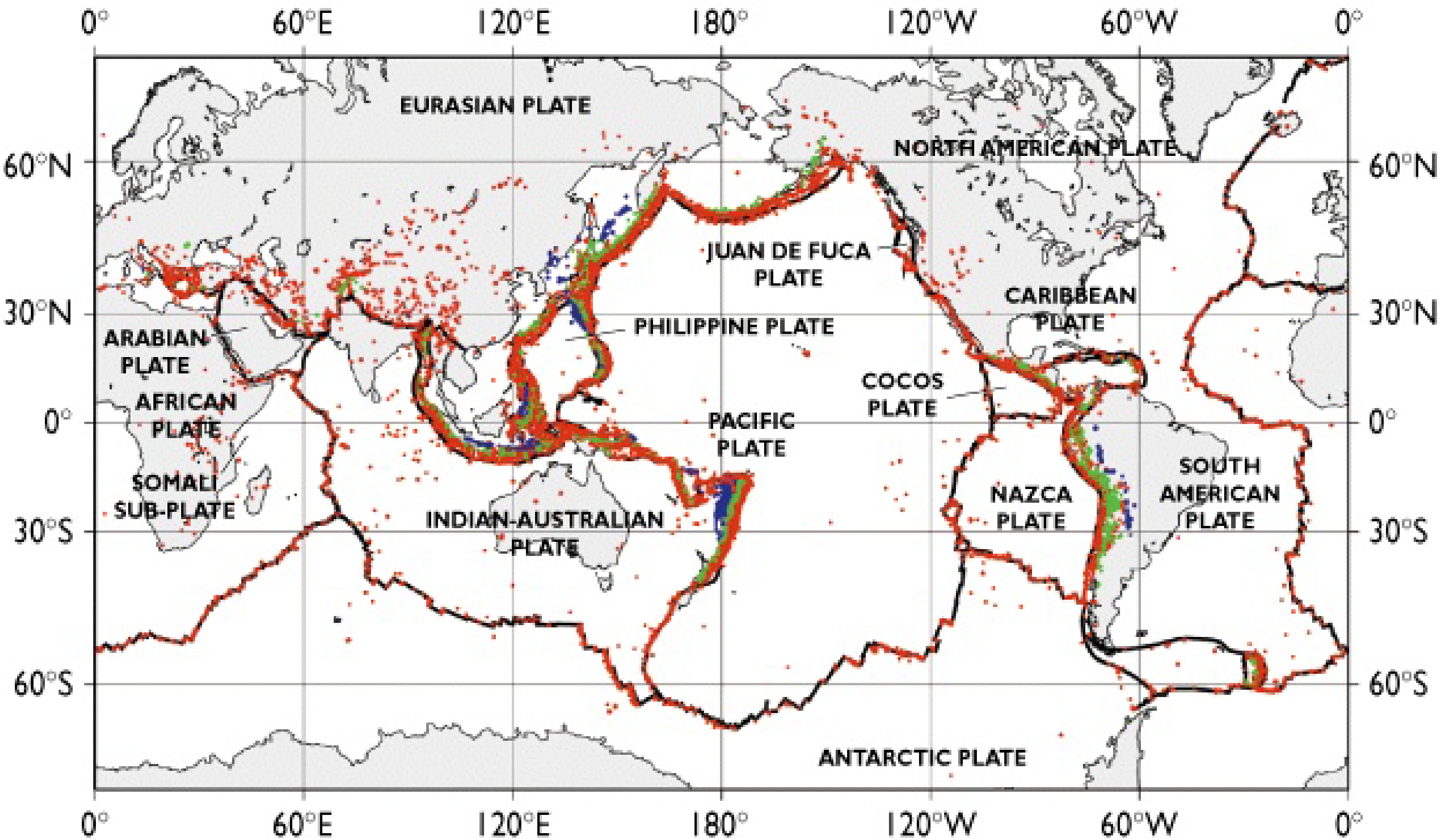
External heat engine - Solar Energy from the sun is the driving force powering the weather and climatic conditions. Solar energy affects the Atmosphere, Hydrosphere, and Biosphere

Earth's internal heat engine - is powered by heat energy trapped during planetesimal bombardment and heat generated by radioactive element decay deep within the Earth Affects Inner and Outer Core, Deep Mantle, Athensosphere, and Lithosphere





Active Volcanoes of the World



World Seismicity Map

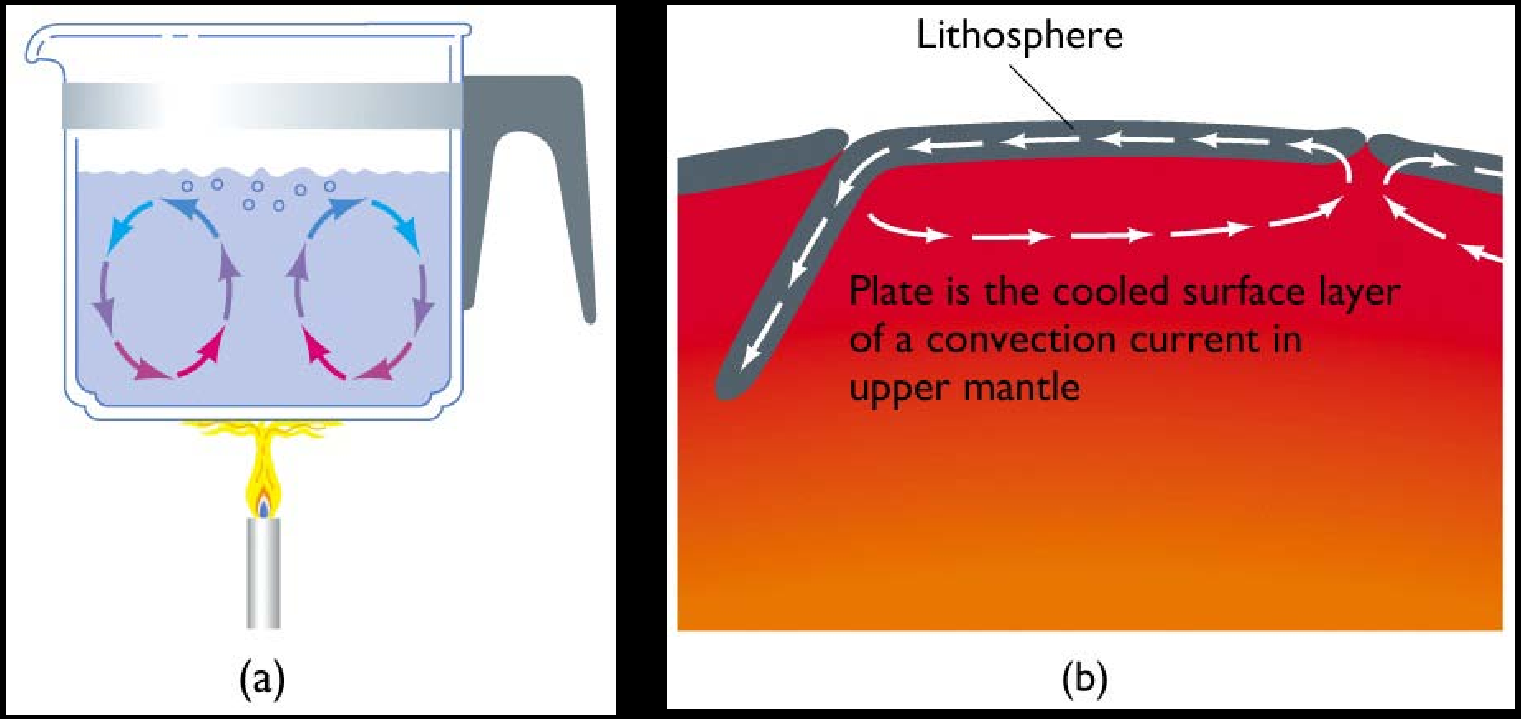
A Unifying Theory for Geology

- There is a pattern to the earth’s features such as earthquakes, volcanoes and mountain chains.
- Their location IS NOT RANDOM.
- Theory of Plate Tectonics

Plate Tectonic Model

- There are 3 major types of plate boundaries depending on **relative plate movement**.
- Plates move by convection – A process of heat transfer in which hot material rises (due to lower density) and cool material sinks.

Convection drives the plates!



The process which allows heat to escape from the interior of the Earth to the exterior is called **CONVECTION.**

CONVECTION – is the driving force of Plate Tectonic Theory. This process circulates heat and material in the solid mantle.

Chapter 2
The Way the Earth Works: Plate Tectonics

Continental Drift Hypothesis

What evidence supports Wegener's hypothesis of Pangaea?

- Continental fit
- Patterns of present day animal life
- Fossil evidence (Mesosaurus)
- Related rocks
- Ancient climates

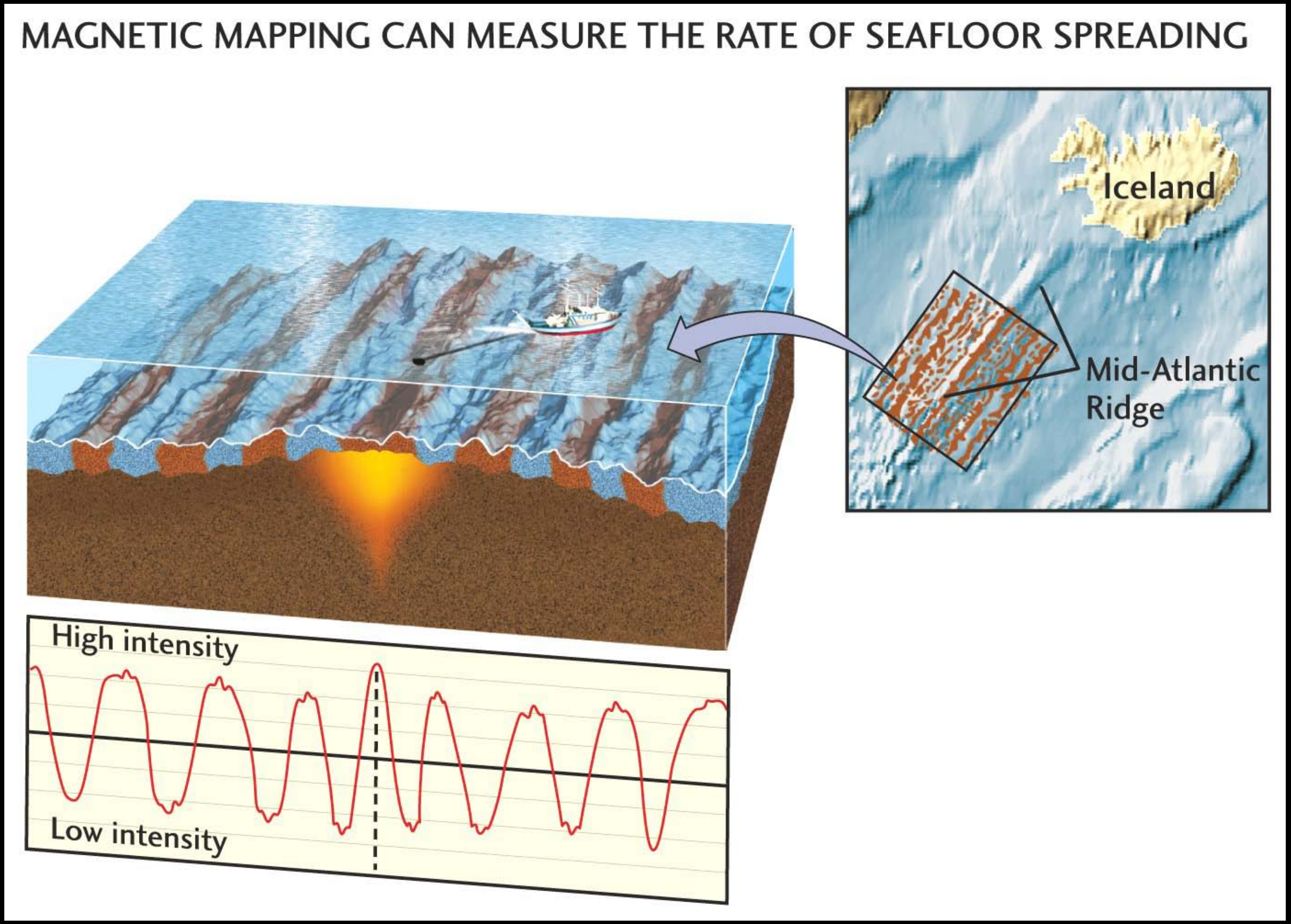
With so much evidence in support of the continental drift hypothesis, why was it not elevated as a theory until the 1960s?

- Wegener lacked a mechanism. He had no way to move the continents.
- He incorrectly believed that <u>only</u> the continents were moving.
- Continents are not independent plates. Plates are often made of both continental and oceanic lithosphere.

As implied by the use of the Scientific Method, a hypotheses is always being tested with the addition of new data.

Wegener’s original hypothesis had gaps, it was not until after WWII when there was extensive mapping of the oceans that lead to the discovery of a deep, cracklike valley (rift) along the ocean floor, combined with and the paired magnetic signature which was observed on each side of this “rift” that the answer emerged.

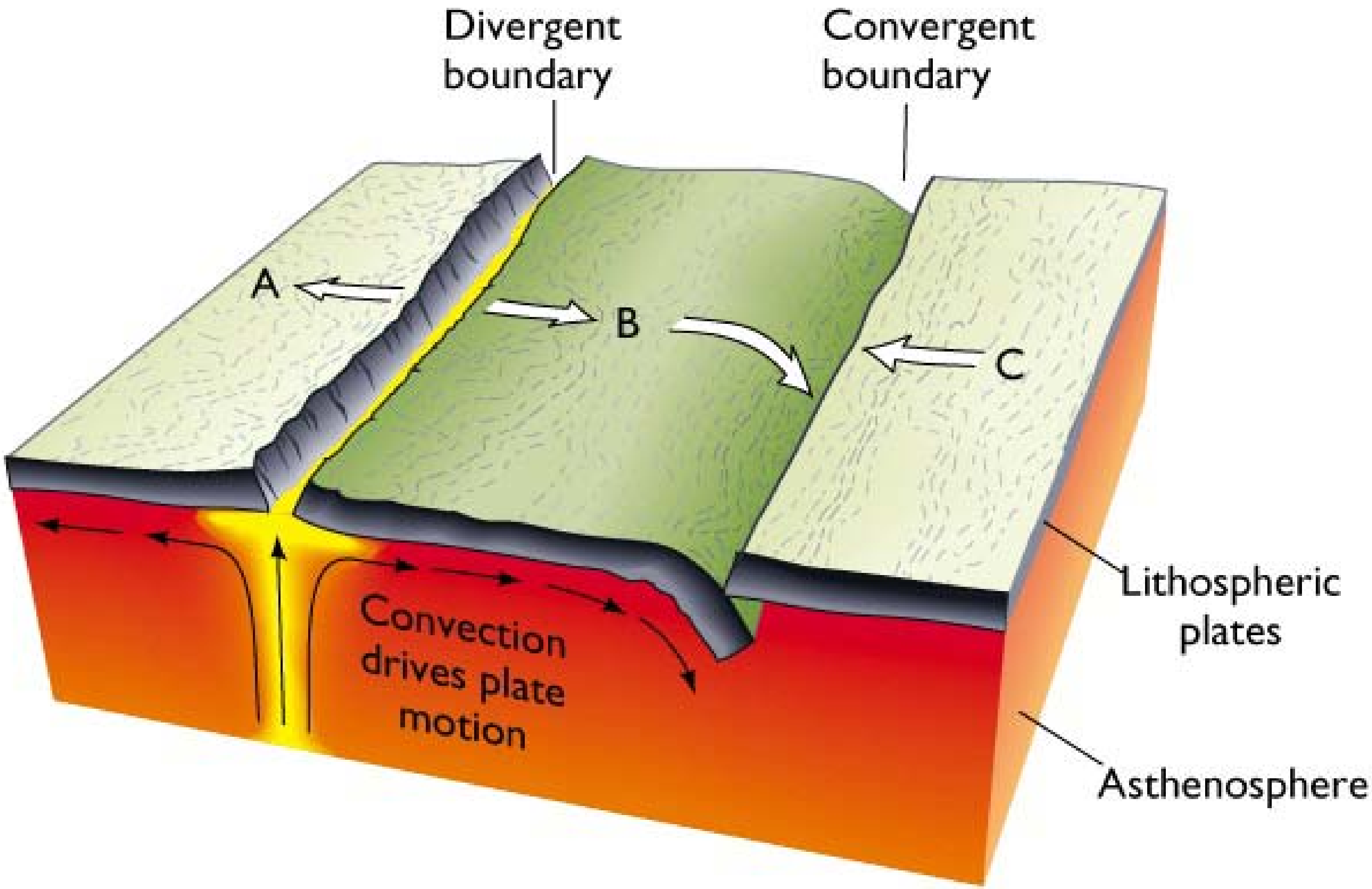
Finally, there was evidence how the continents could move.



Types of Plate Boundaries

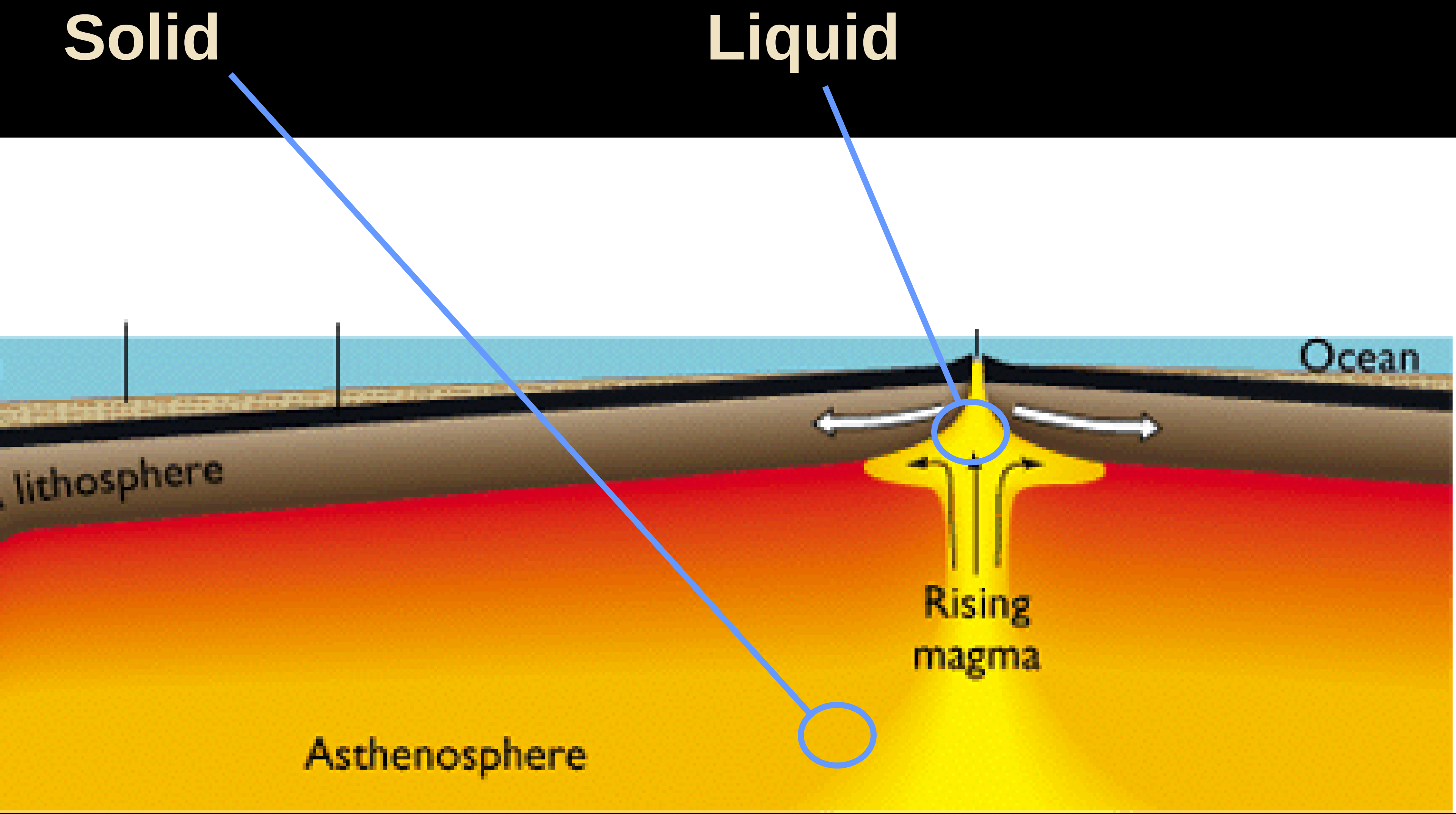
1. Divergent boundaries

- Plates move away from one another
- Rift-A crack like valley which allows molten rock to erupt from below.


Divergent boundary
Convergent boundary
A
B
C
Convection drives plate motion
Lithospheric plates
Asthenosphere
(a)

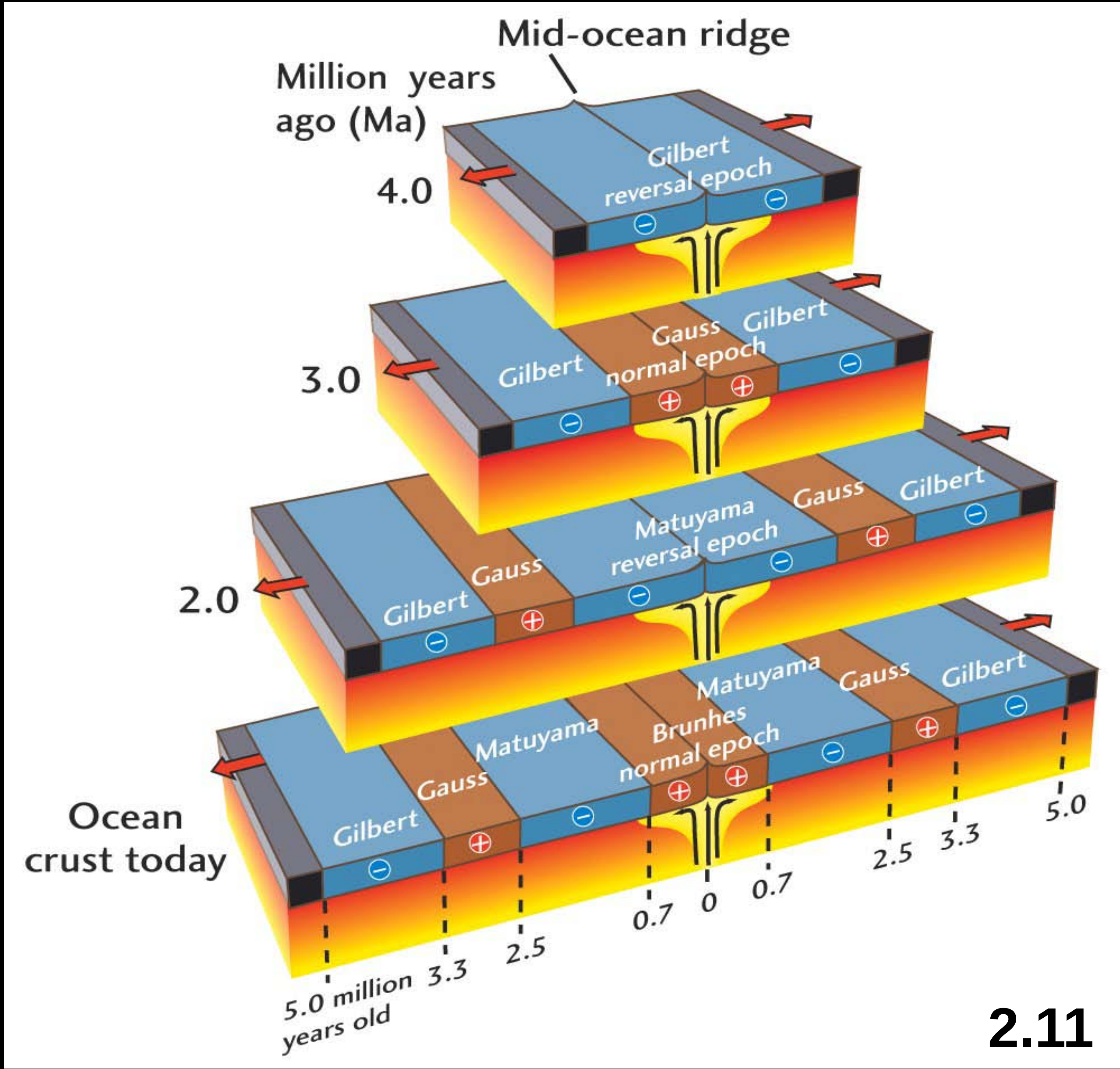
Decompression melting

- As mantle material rise toward the divergent plate boundary the pressure is drastically reduced which causes melting



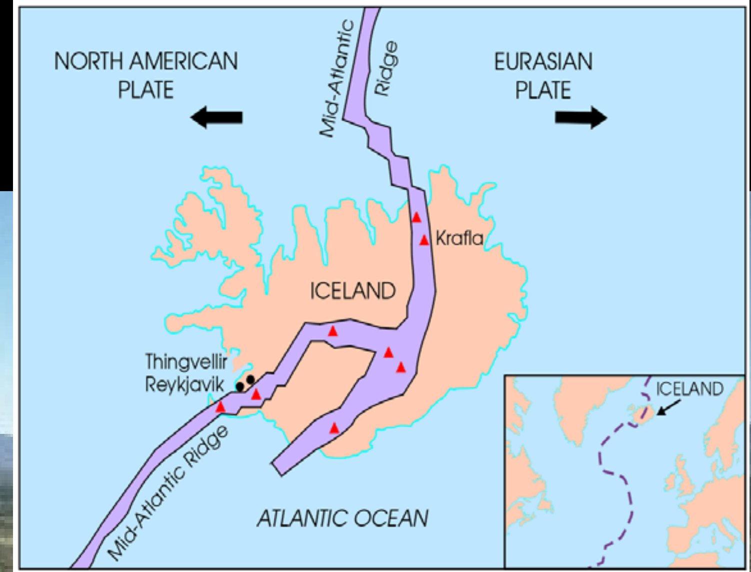
Magnetic striping (reversals) of the ocean floor

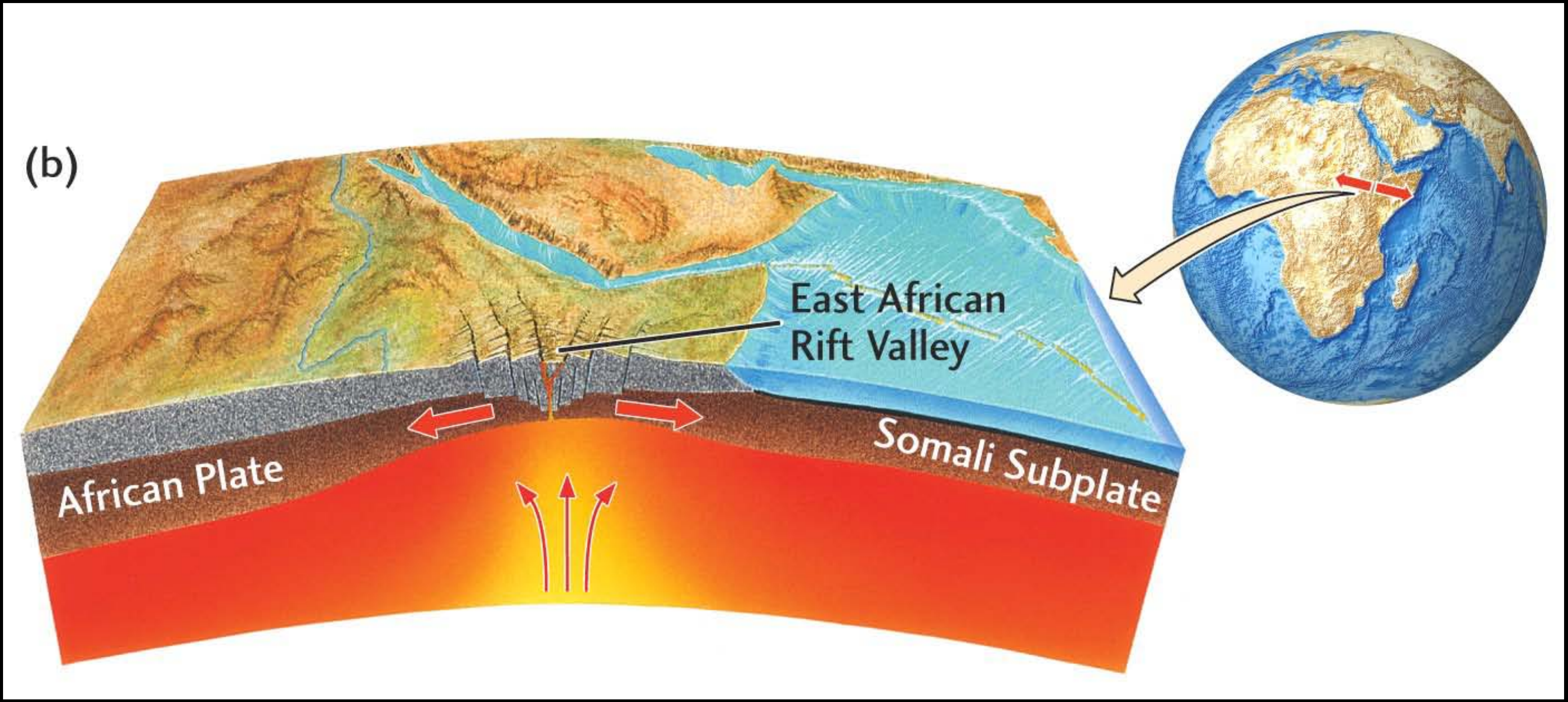
The detailed mapping of the magnetic reversals on land and in the ocean, combined with absolute age dating of the rocks allow a time scale to be developed for the ocean crust.



2.11

Example: Iceland




(b)
East African
Rift Valley
African Plate
Somali Subplate

Example:

Baja California

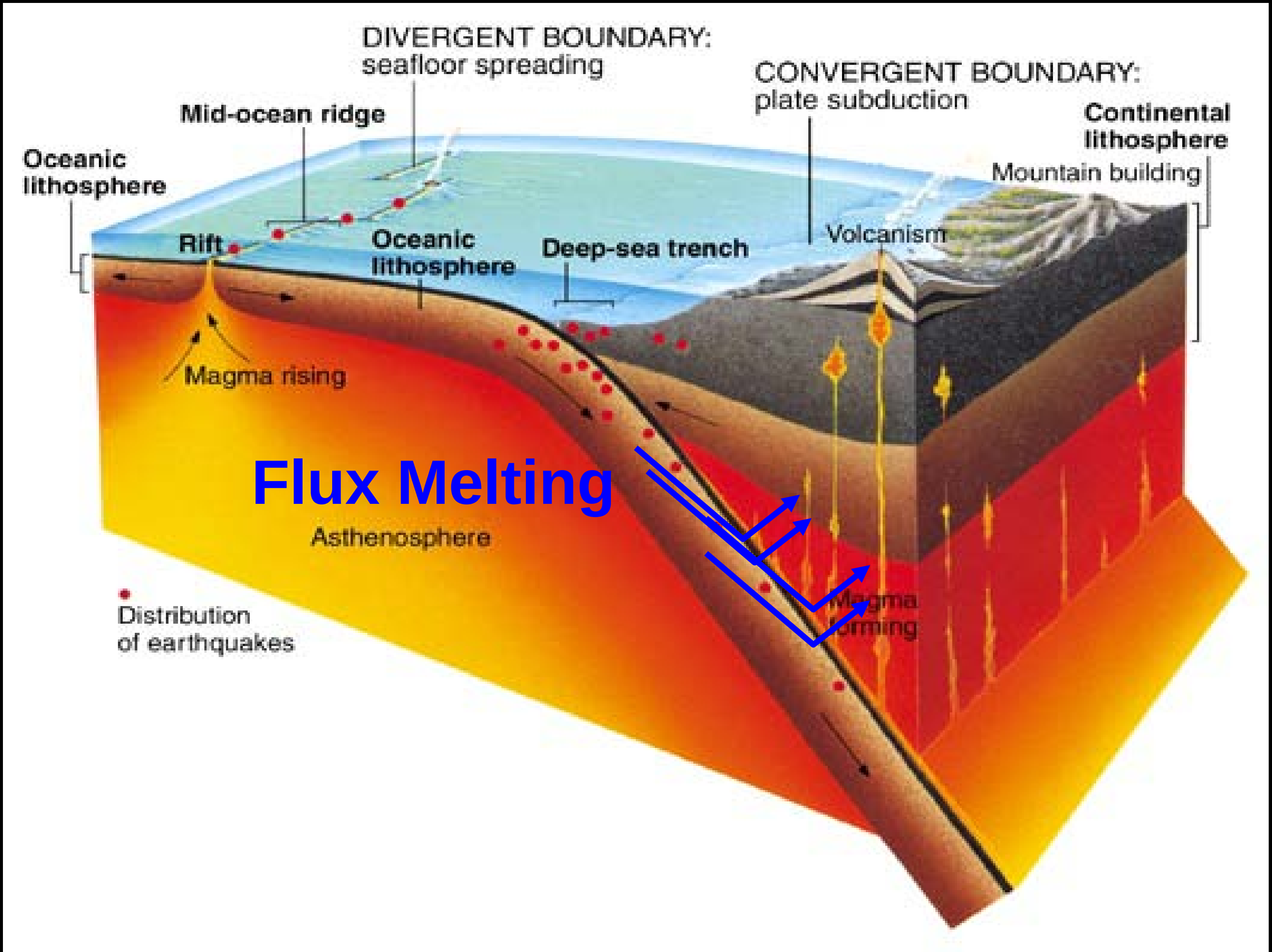
(Mexico)

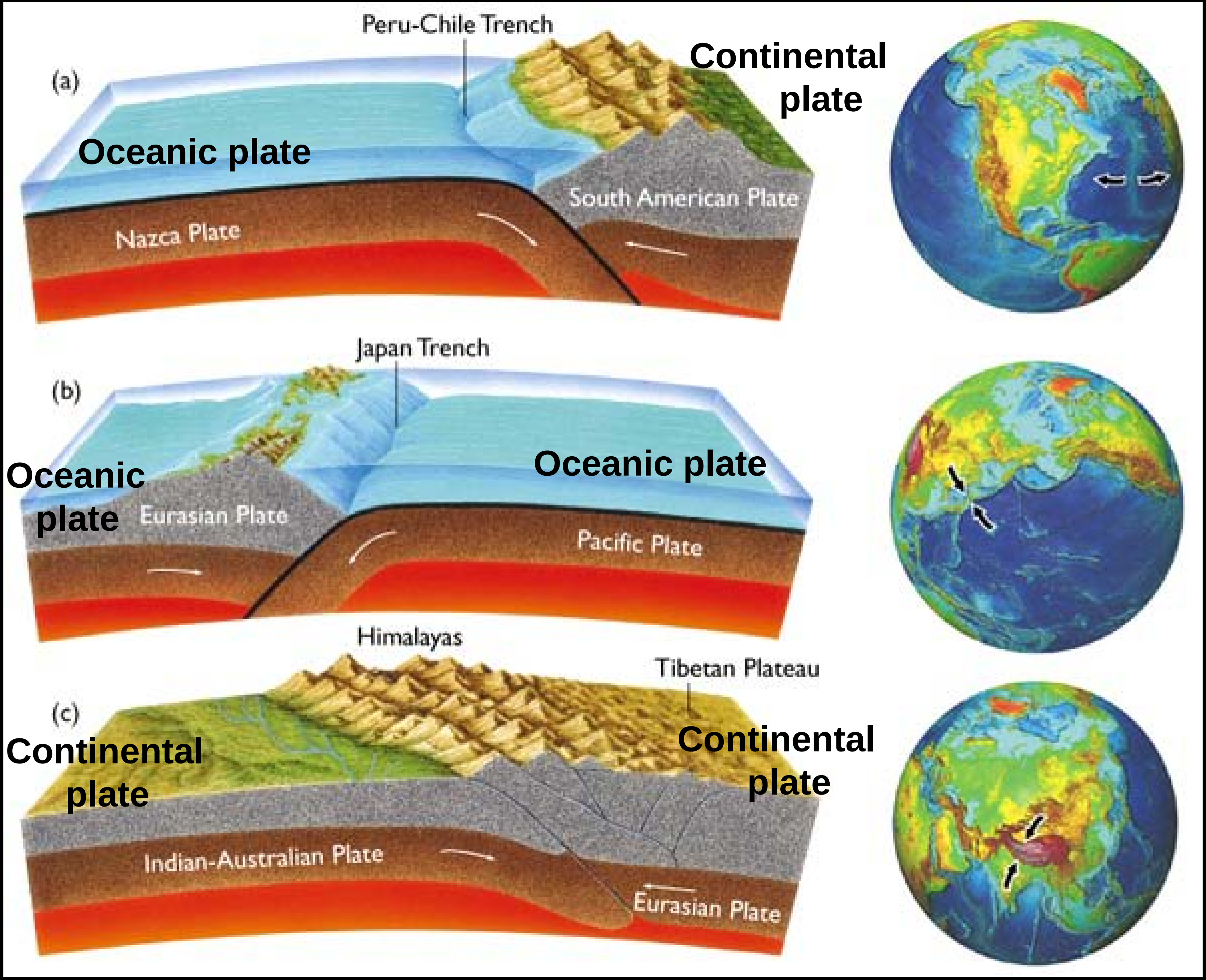
Types of Plate Boundaries

2. Convergent boundaries

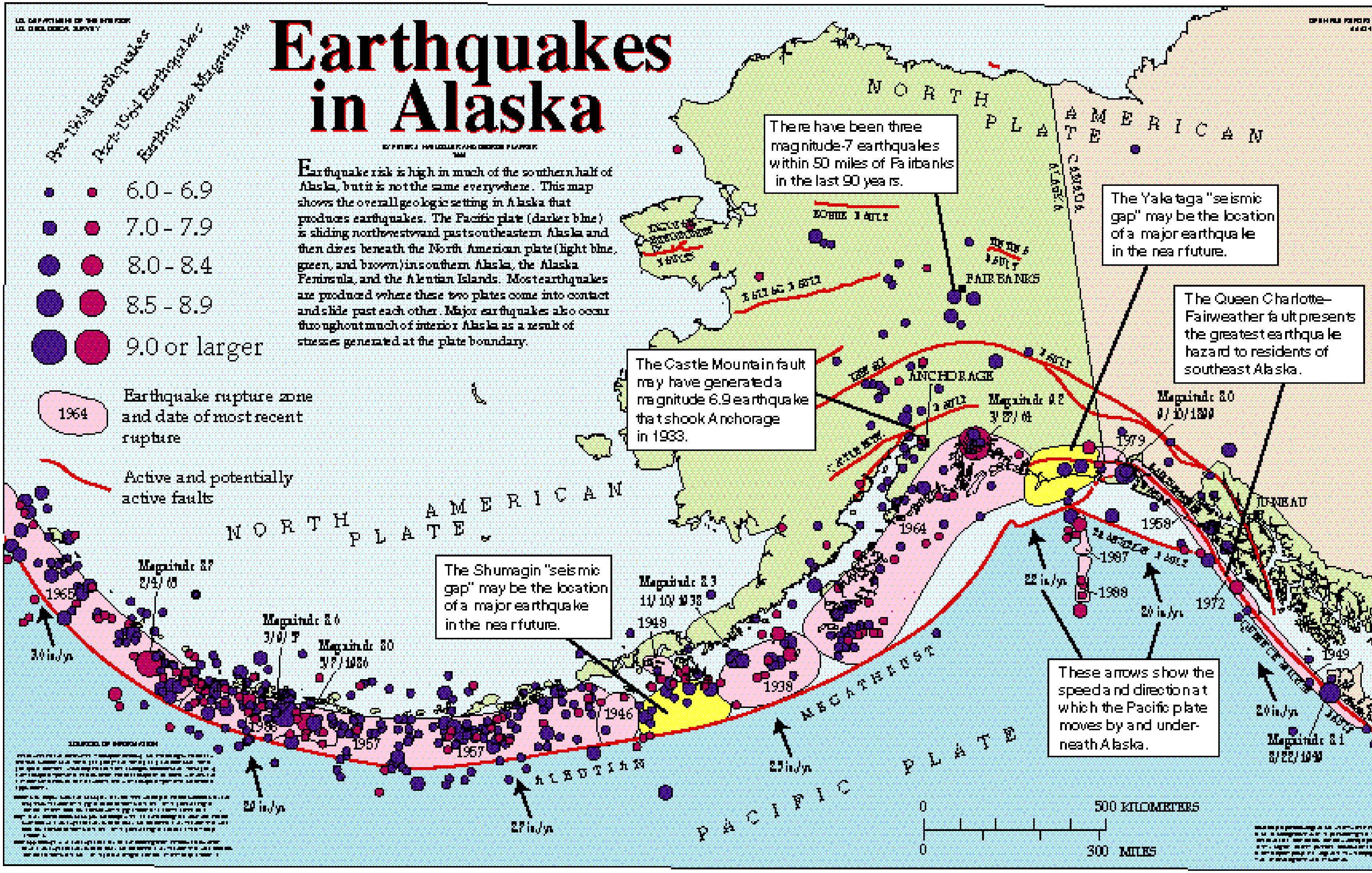
- Plates move towards one another
- Collision or Subduction occurs.

Subduction is where one plate sinks beneath the other plate. What determines which plate will sink?

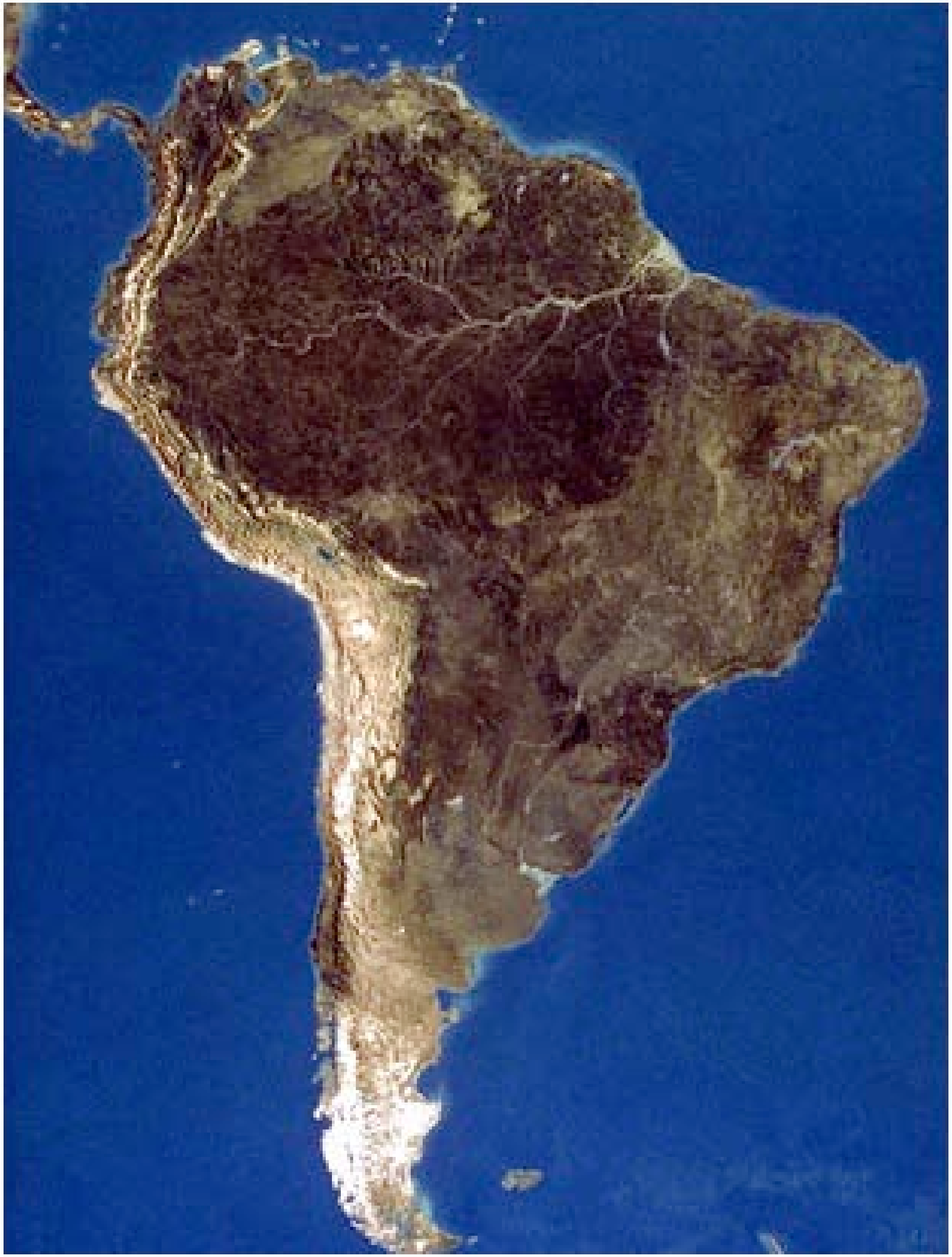

DIVERGENT BOUNDARY:
seafloor spreading
CONVERGENT BOUNDARY:
plate subduction
Mid-ocean ridge
Oceanic
lithosphere
Continental
lithosphere
Mountain building
Rift
Oceanic
lithosphere
Deep-sea trench
Volcanism
Magma rising
Flux Melting
Asthenosphere
Magma
forming
Distribution
of earthquakes


Peru-Chile Trench
(a)
Continental plate
Oceanic plate
South American Plate
Nazca Plate
Japan Trench
(b)
Oceanic plate
Oceanic plate
Eurasian Plate
Pacific Plate
Himalayas
Tibetan Plateau
(c)
Continental plate
Continental plate
Indian-Australian Plate
Eurasian Plate

2.9

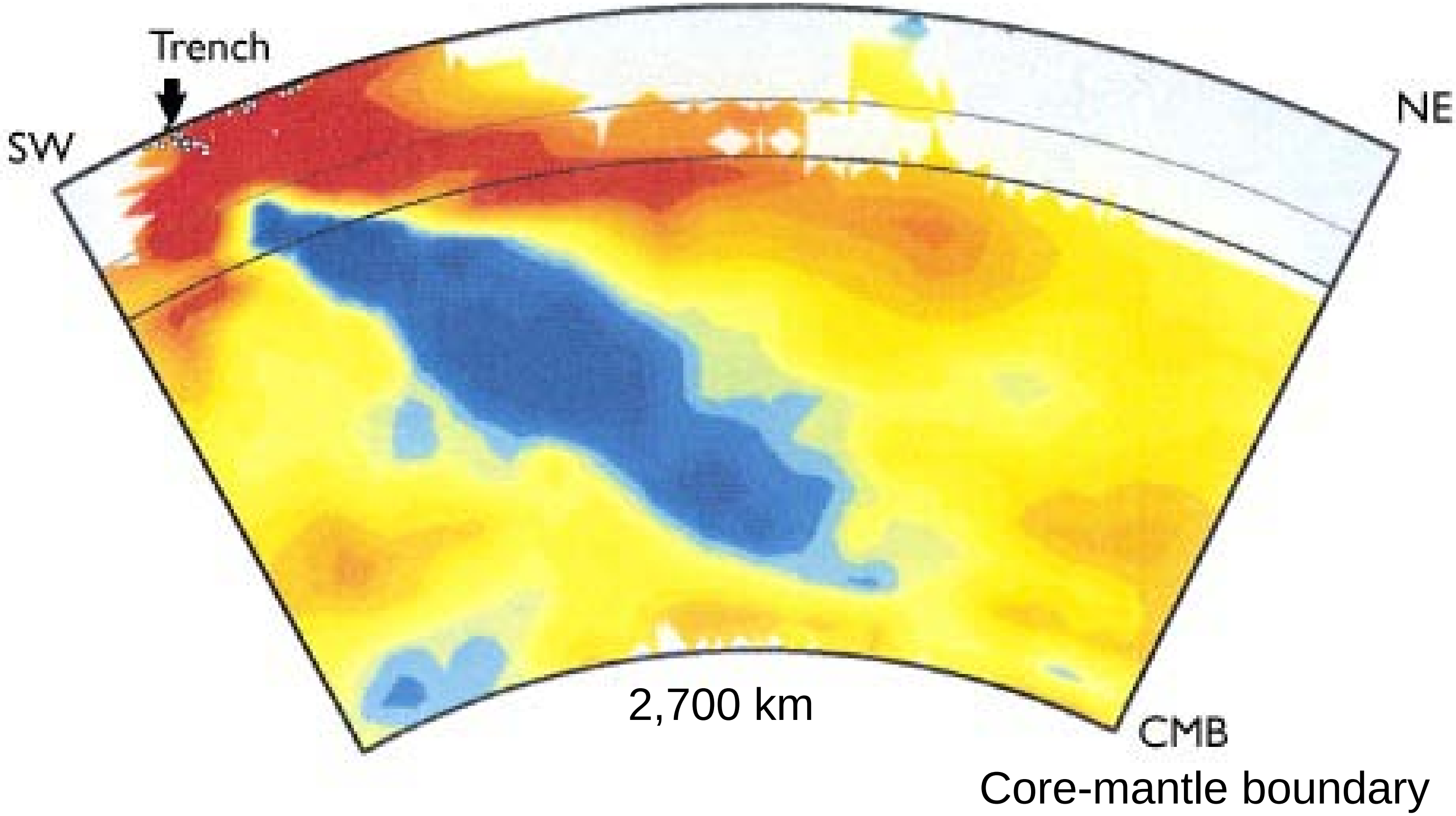


Earthquakes in Alaska
Earthquake risk is high in much of the southern half of Alaska, but it is not the same everywhere. This map shows the overall geologic setting in Alaska that produces earthquakes. The Pacific plate (darker blue) is sliding northwestward past southeastern Alaska and then dives beneath the North American plate (light blue, green, and brown) in southern Alaska, the Alaska Peninsula, and the Aleutian Islands. Most earthquakes are produced where these two plates come into contact and slide past each other. Major earthquakes also occur throughout much of interior Alaska as a result of stresses generated at the plate boundary.
Pre-1964 Earthquakes
Post-1964 Earthquakes
Earthquake Magnitude
6.0 - 6.9
7.0 - 7.9
8.0 - 8.4
8.5 - 8.9
9.0 or larger
1964
Earthquake rupture zone and date of most recent rupture
Active and potentially active faults
NORTH AMERICAN PLATE
PACIFIC PLATE
ALEUTIAN MEGATHRUST
There have been three magnitude-7 earthquakes within 50 miles of Fairbanks in the last 90 years.
The Yakataga "seismic gap" may be the location of a major earthquake in the near future.
The Queen Charlotte–Fairweather fault presents the greatest earthquake hazard to residents of southeast Alaska.
The Castle Mountain fault may have generated a magnitude 6.9 earthquake that shook Anchorage in 1933.
The Shumagin "seismic gap" may be the location of a major earthquake in the near future.
These arrows show the speed and direction at which the Pacific plate moves by and underneath Alaska.
FAIRBANKS
ANCHORAGE
JUNEAU
ALASKA
CANADA
1964
1965
1957
1946
1938
1948
1958
1972
1979
1949
1987
1988
3.0 in./yr.
2.9 in./yr.
2.7 in./yr.
2.5 in./yr.
2.2 in./yr.
2.0 in./yr.
0
500 KILOMETERS
300 MILES



Everest

“Orogeny” = a mountain-building event



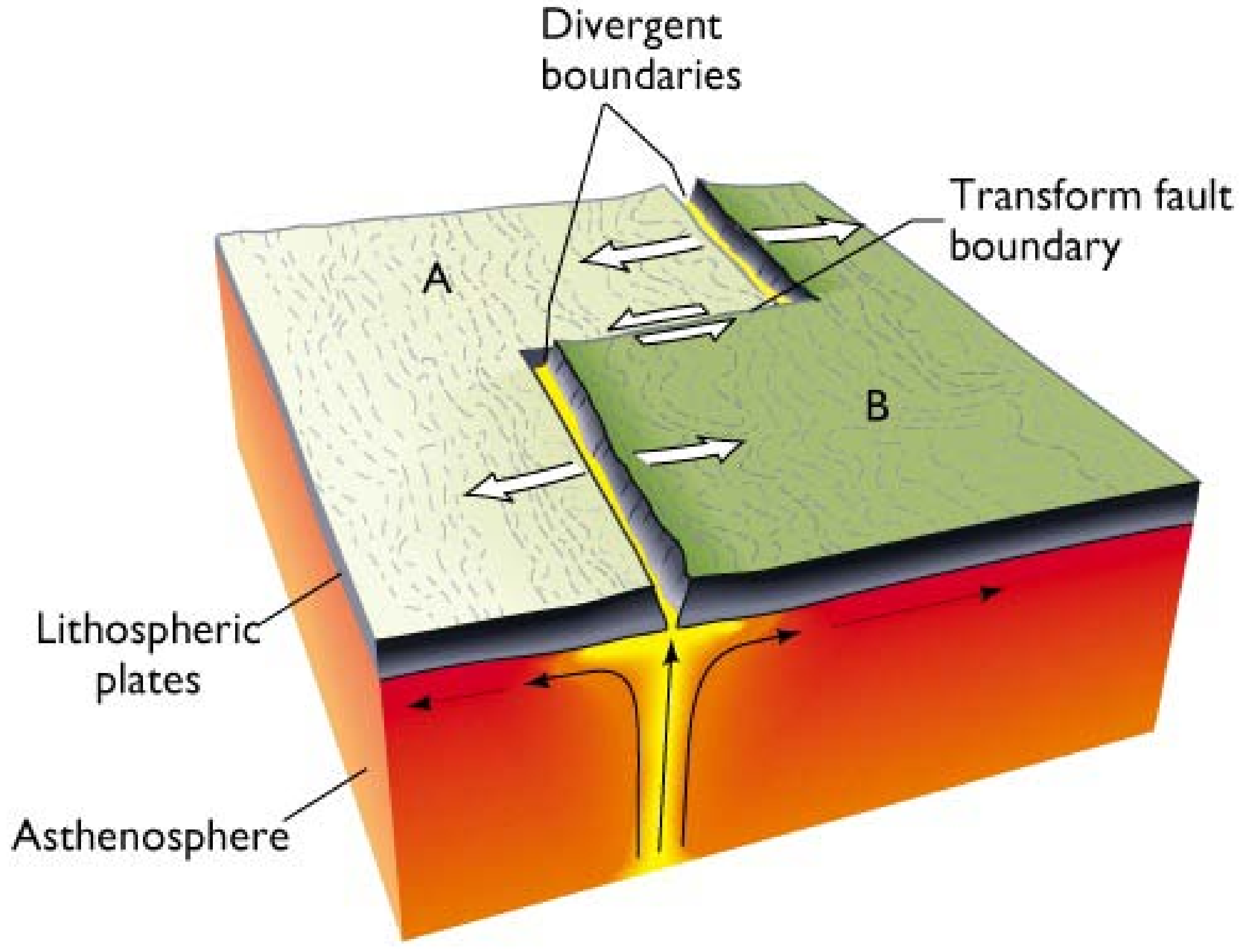
Seismic tomography records variations in P-wave velocity, which correlate with the temperatures of matter in Earth's interior.

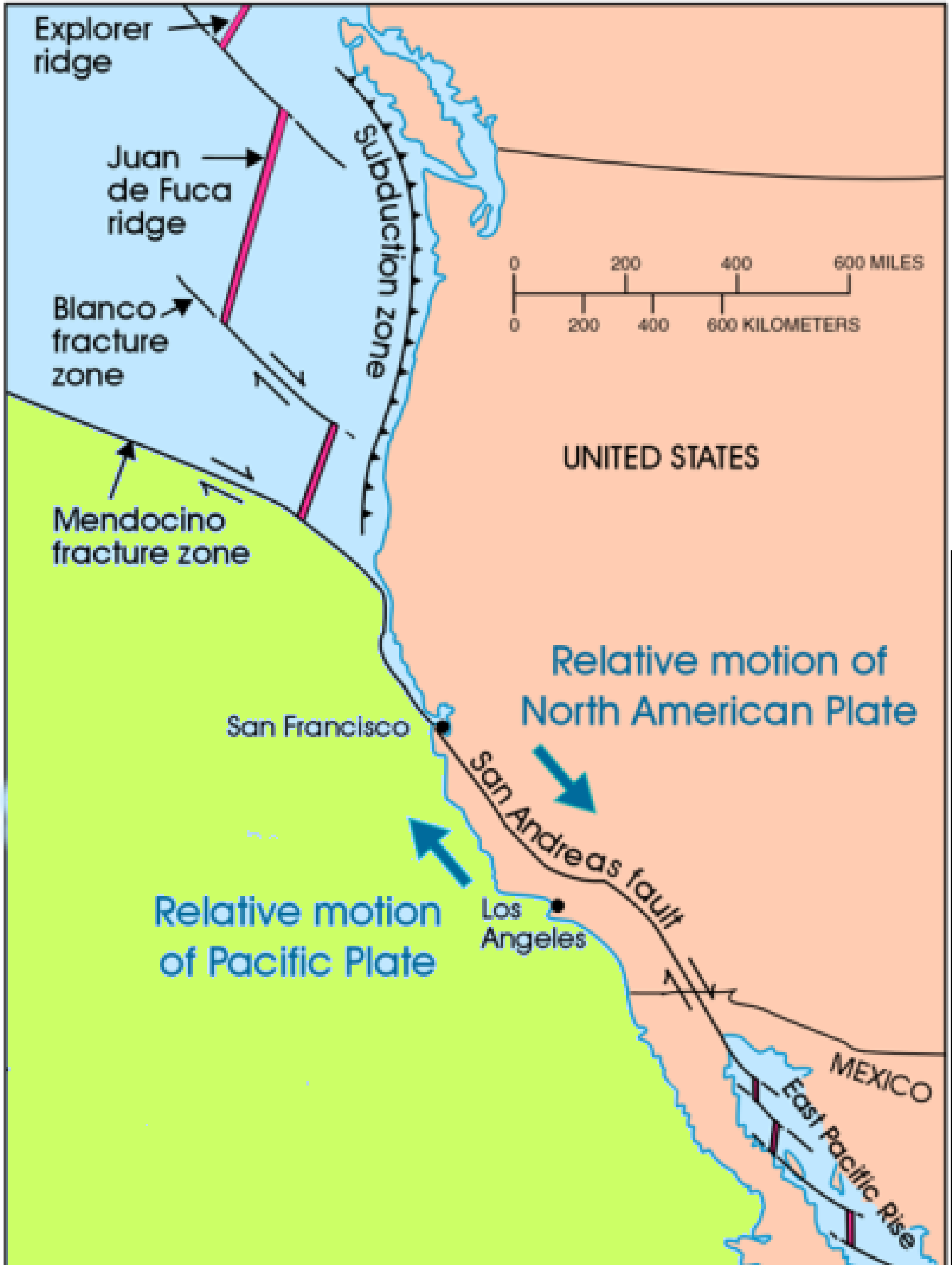
- Slower P waves, indicating warmer-than-average matter
- Average-speed P waves, indicating average-temperature matter
- Faster P waves, indicating cooler-than-average matter
- No data

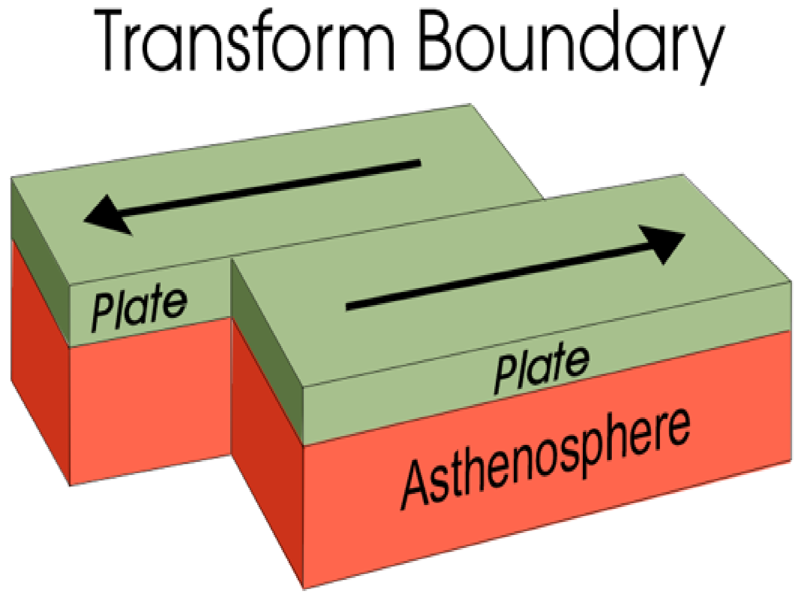
Types of Plate Boundaries

3. Transform boundaries

- Where plates slide past one another.

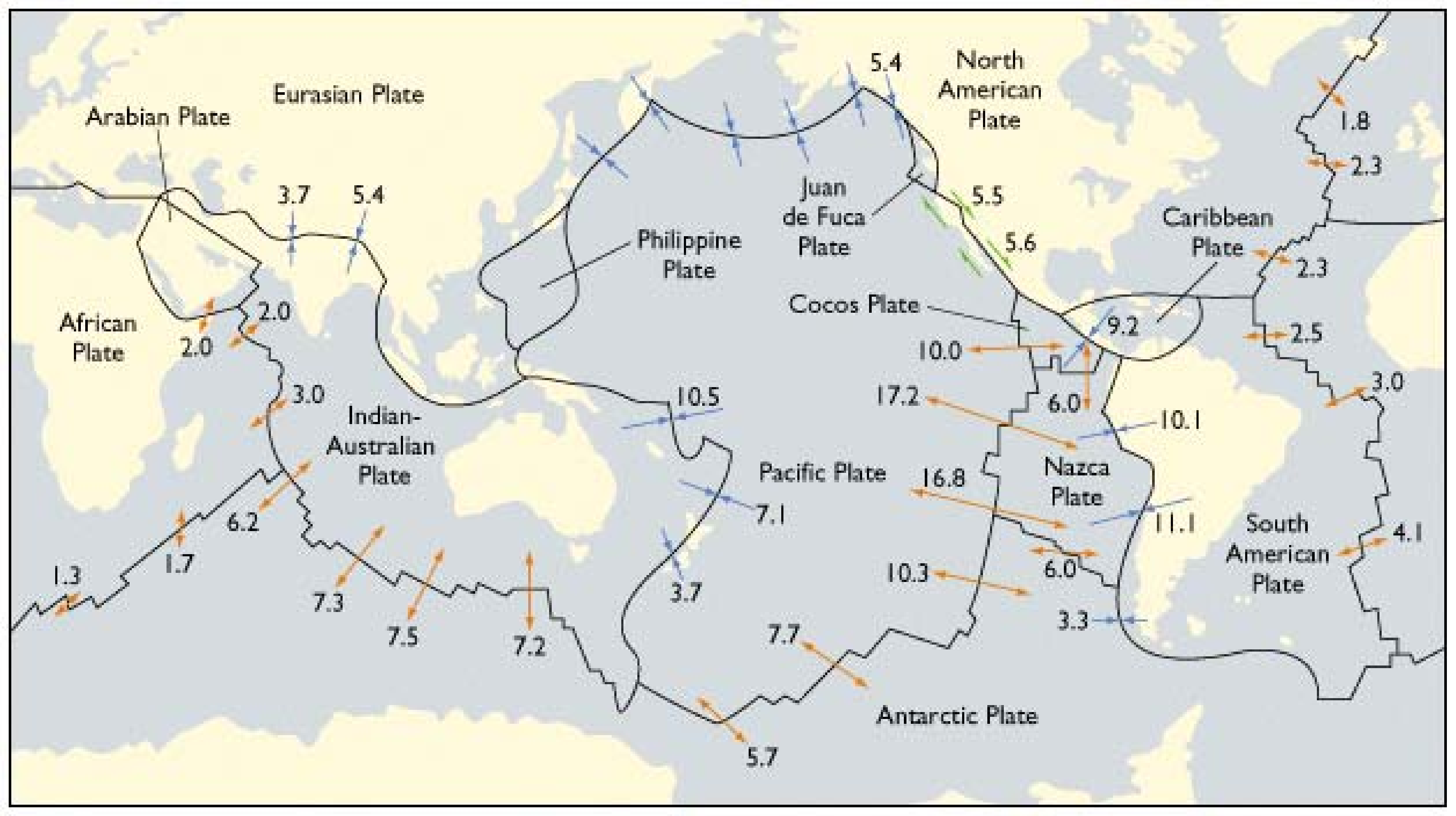

Divergent boundaries
Transform fault boundary
A
B
Lithospheric plates
Asthenosphere
(b)



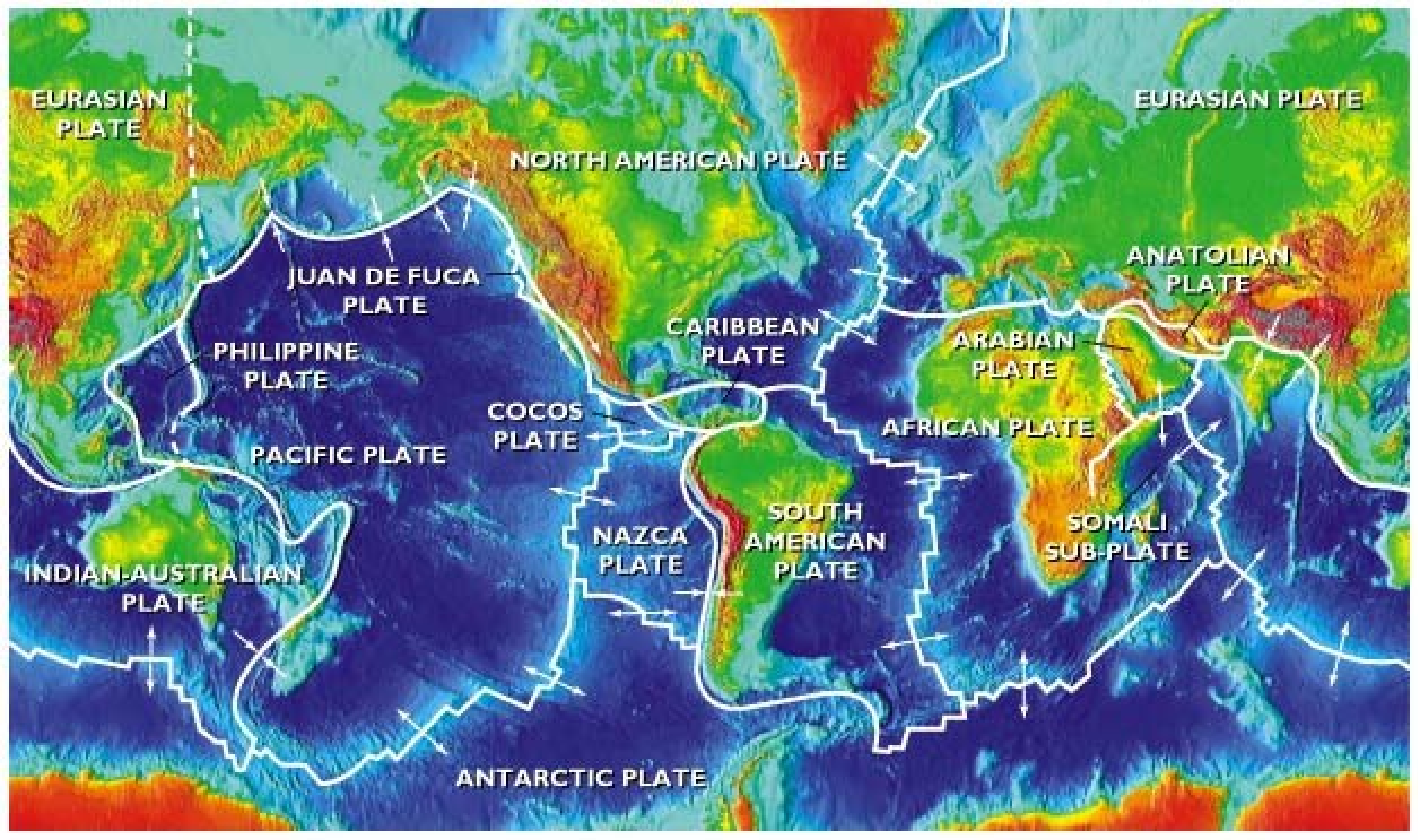


~ 5.5 cm/year

At this rate, LA will reach San Francisco in 9-10 million years.



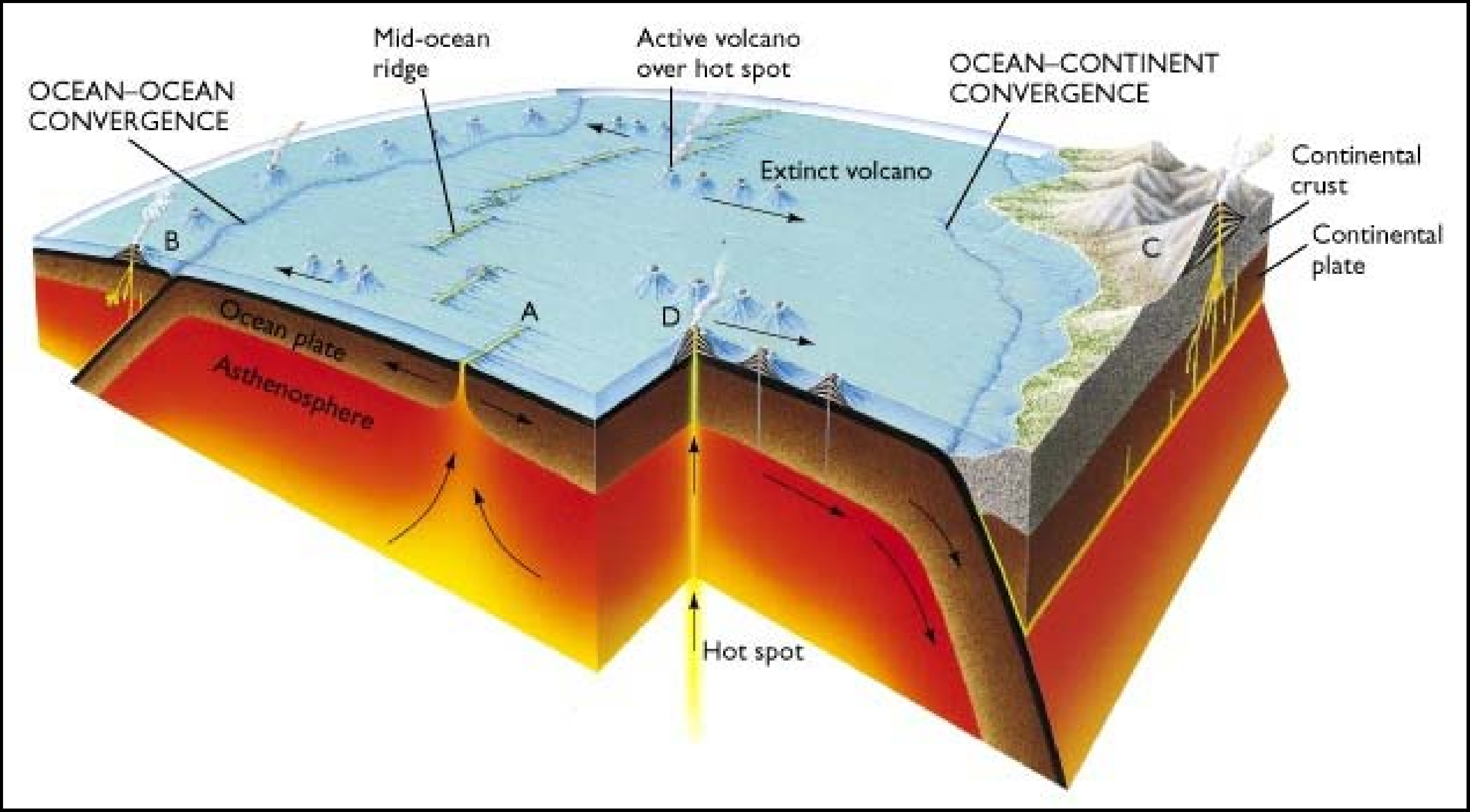
Relative Plate Velocities (cm/yr)


EURASIAN
PLATE
EURASIAN PLATE
NORTH AMERICAN PLATE
JUAN DE FUCA
PLATE
ANATOLIAN
PLATE
CARIBBEAN
PLATE
ARABIAN
PLATE
PHILIPPINE
PLATE
COCOS
PLATE
AFRICAN PLATE
PACIFIC PLATE
SOUTH
AMERICAN
PLATE
NAZCA
PLATE
SOMALI
SUB-PLATE
INDIAN-AUSTRALIAN
PLATE
ANTARCTIC PLATE

Special case

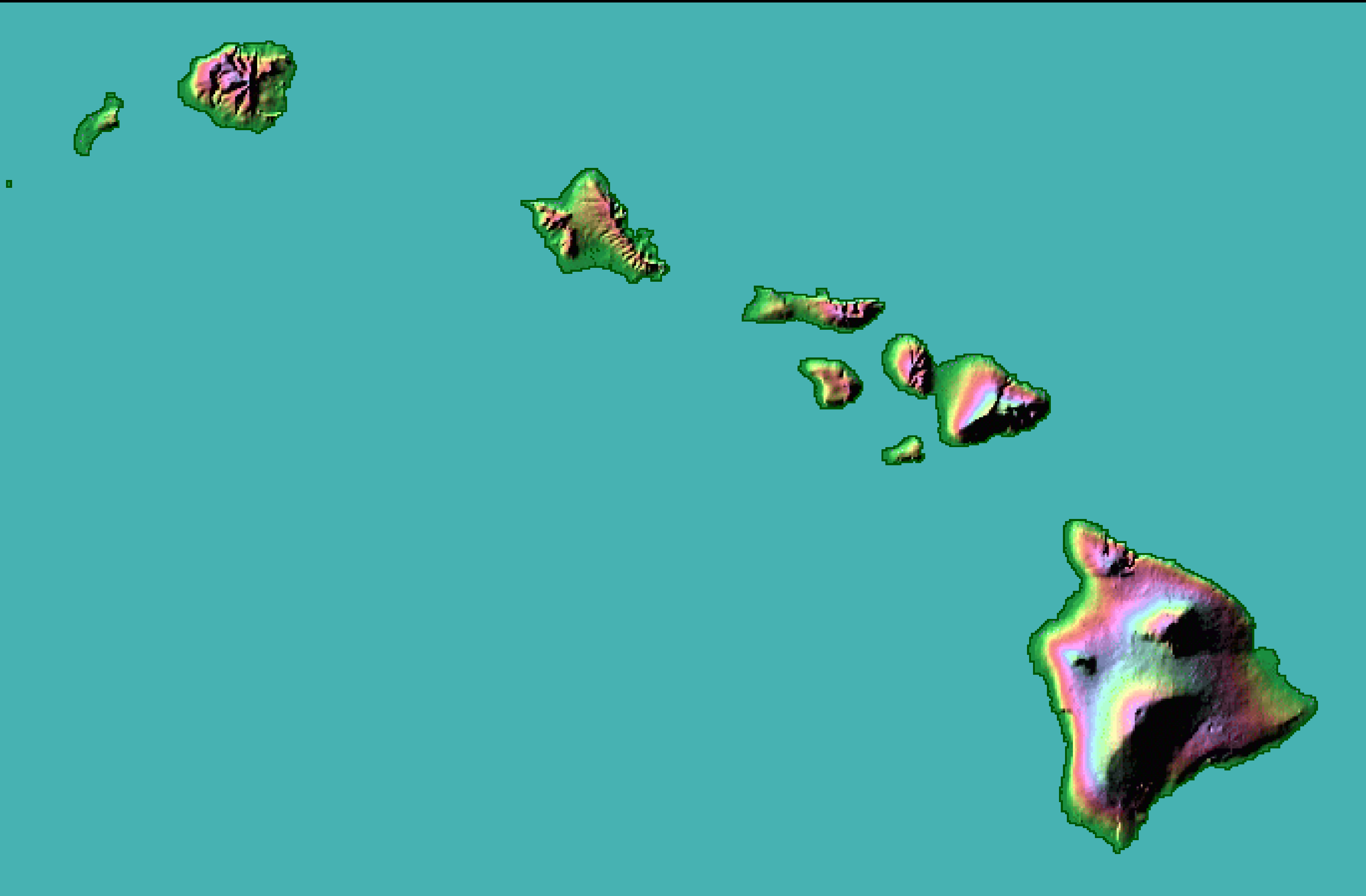
Hot Spots

- Stationary, surface expression of volcanic activity.
- Result of a **thermal plume**, a localized source of rising heat energy from the mantle-core (?) boundary.



Mid-ocean ridge
Active volcano over hot spot
OCEAN–OCEAN CONVERGENCE
OCEAN–CONTINENT CONVERGENCE
Extinct volcano
Continental crust
Continental plate
B
C
A
D
Ocean plate
Asthenosphere
Hot spot

Hawaii hotspot and island arc



A whole chain of “Yellowstones” have been left behind as the N America plate has moved west.

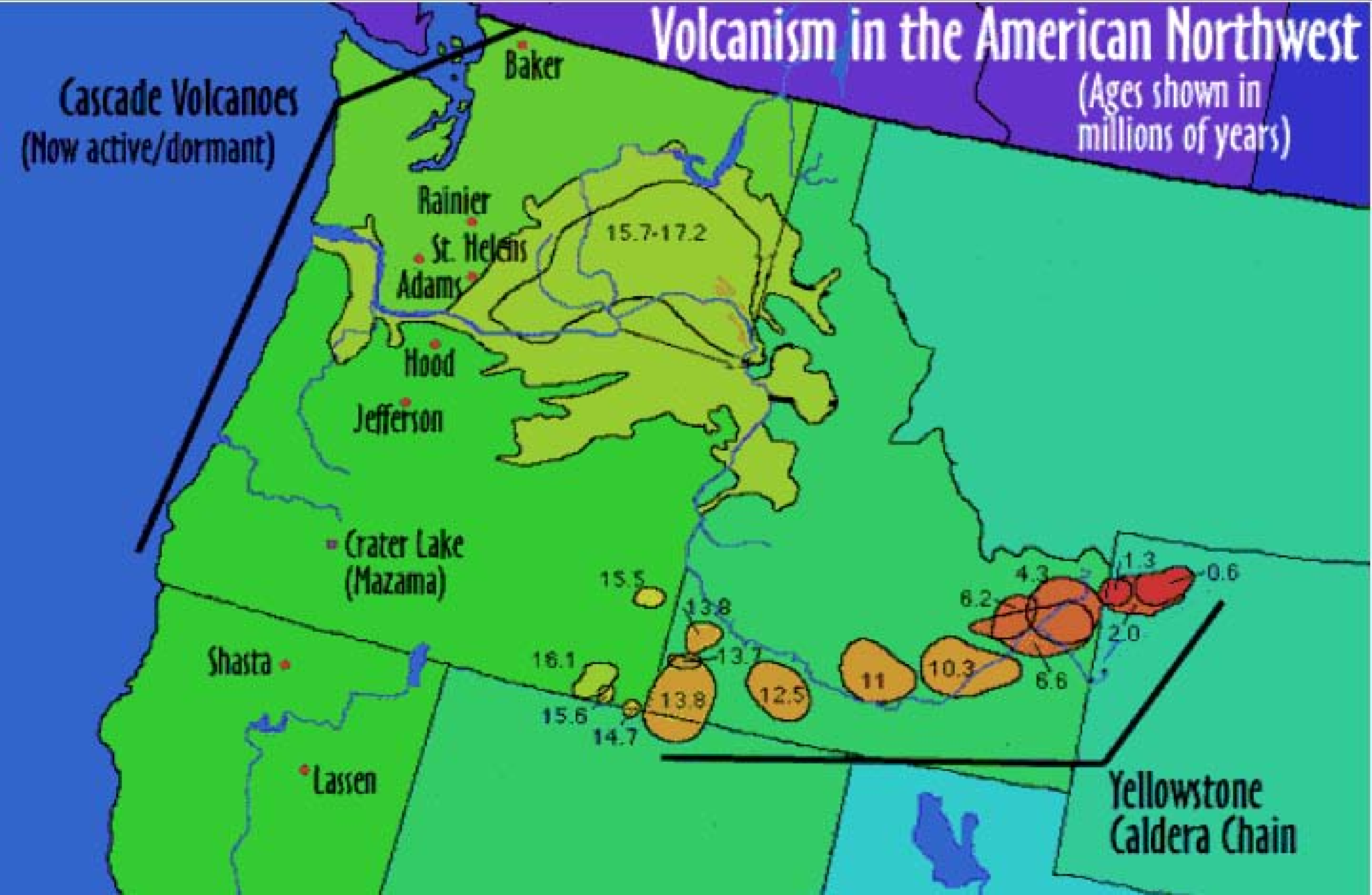
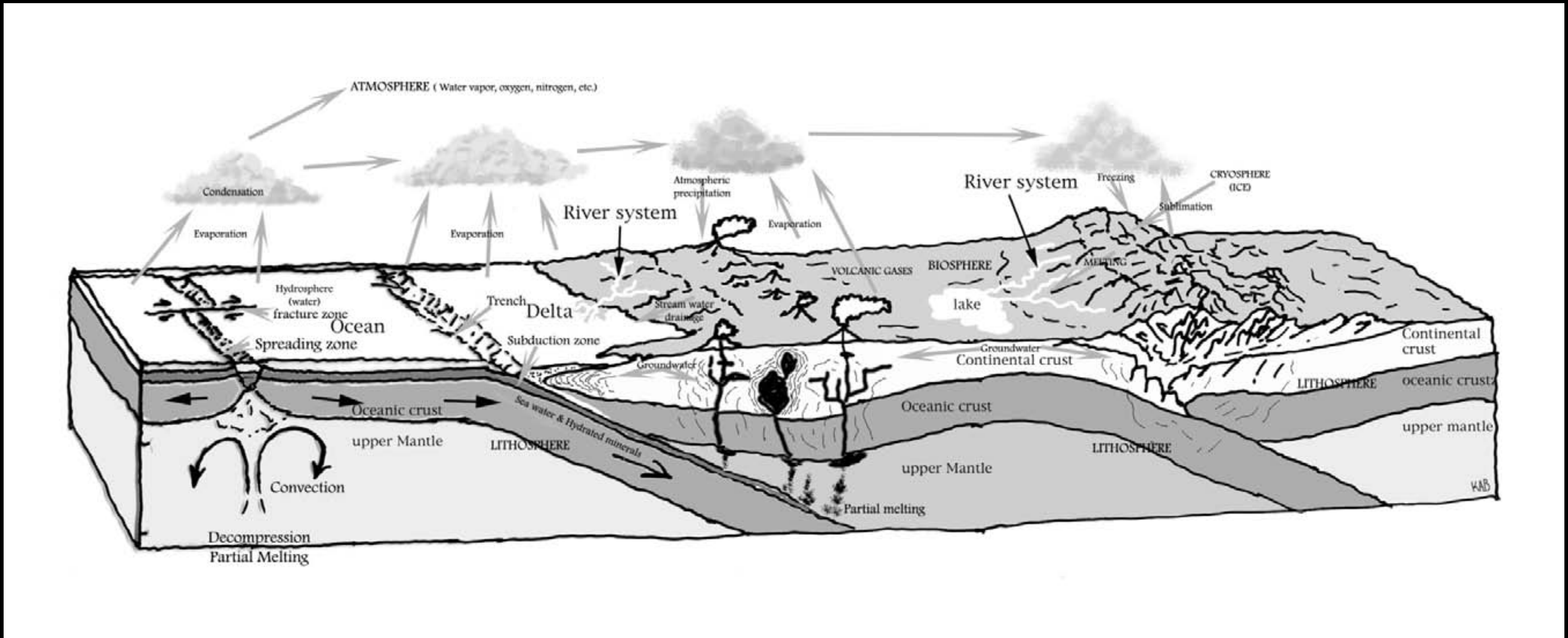


Plate boundaries



How does the curst of the Earth form?

Divergent boundaries

- Decompression melting – forming oceanic crust

Convergent boundaries (with subduction zones)

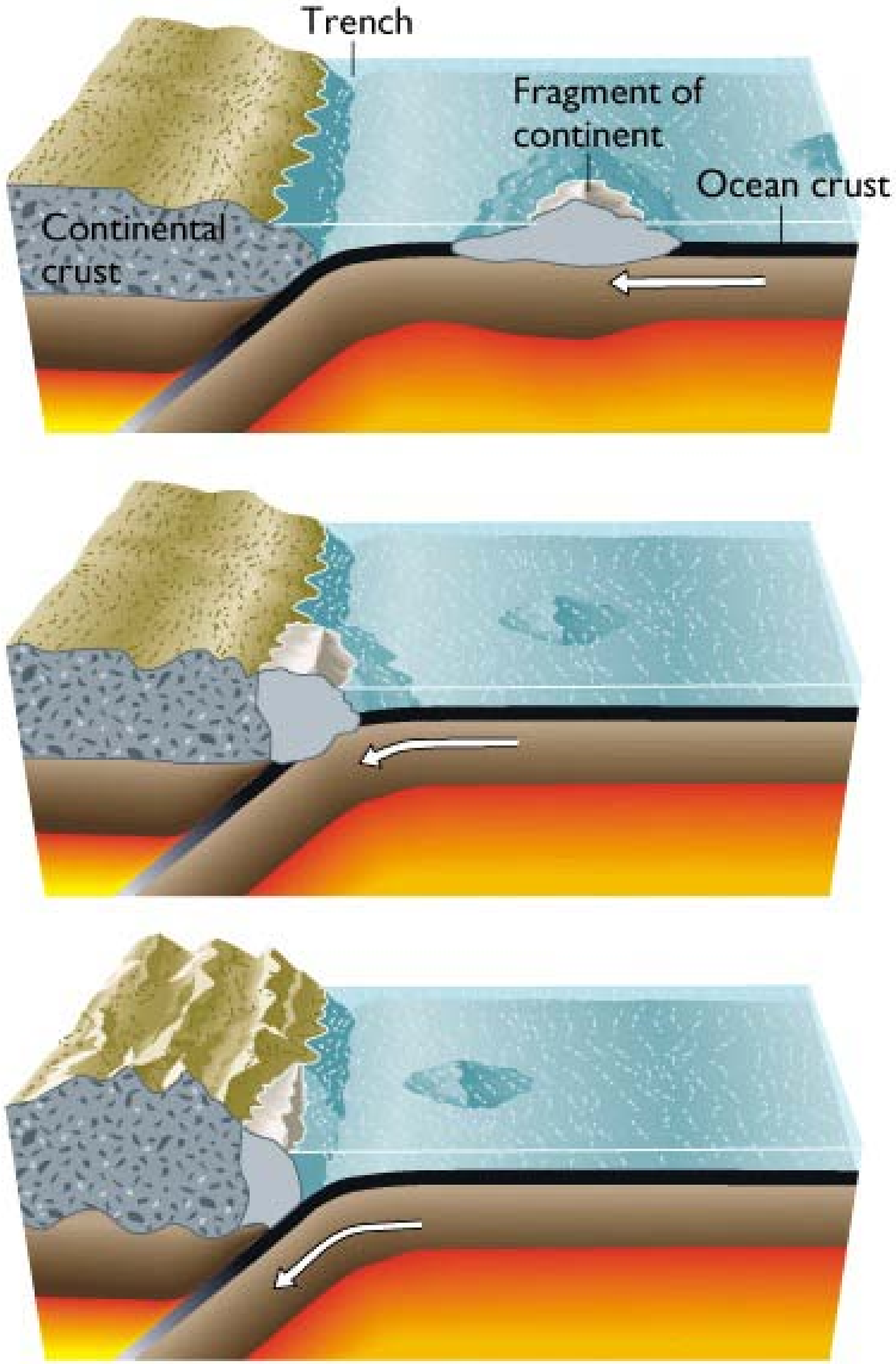
- Flux melting – partial melting in a subduction zone
- This forms new land through volcanism
- Land is attached to the continents by accretion.

Convergent boundaries (without subduction zones)

- Continents change shape during collisions by suturing landmasses together.

What about transform? Hot spot?

Accretion


Trench
Fragment of continent
Ocean crust
Continental crust

Have there have been many orogenies in N. America?

Chapter 3
Patterns in Nature: Minerals

What is a Mineral?

- naturally occurring
- inorganic - no organic carbon
- crystalline solid - atoms are arranged in a particular structure (ex: a cube)
- Specific chemical compound - contains particular elements in a set ratio.
  - H_2O has a set ratio. Is it a mineral? What about mineral water? Ice?

Isotopes

- All carbon atoms have 6 protons (atomic number).
- The # of neutrons may change = isotope.
- Ex: Carbon 12, Carbon 13 and Carbon 14 are Carbon isotopes.

Ionic Bonding

- Transfer of electrons.
- Form when shells are nearly empty or nearly full.
- Weak bond.

Covalent Bonding

- Sharing of Electrons
- Form when shells are about half full
- Strong bond

Diamond

- How does this affect the physical properties of diamonds?

Uncut diamond (left) and cut diamond (right)

Geology 2nd ed. - Chernicoff

What Mineral Will Form?

- Available Elements
- Ionic Substitution
- Conditions of Crystallization
  - Polymorphs (same composition but different crystal structure)
    - Ex: Diamond and Graphite

How do Minerals Form?

Chemical reactions between elements.

Crystallization – the growth of a solid from a gas or liquid whose constituents come together in the proper chemical proportions and crystalline arrangement

What conditions cause minerals to form?

- Lower the temperature of a liquid below its freezing point
- Liquids evaporate from a solution forming a supersaturated solution and results in precipitate
- When atoms and ions in a solid become mobile and rearrange themselves at high temperature (>250 °C)

Mineral Properties

Color

- least reliable - do not use alone
- Color depends on the presence of certain ions, such as iron, chromium, cobalt

Luster

- How the surface reflects light.
- Metallic vs. Non-metallic

Streak

- Color of a mineral in powdered state.

Cleavage or Fracture?

Cleavage

- The tendency of mineral’s to break along planes of weakness.

Fracture

- Breaks randomly.

Fig. 3.18

Hardness

- A mineral’s resistance to scratching & abrasion.
- Based on Moh’s Hardness Scale

Table 3-2 Mohs Scale of Hardness

Mineral	Scale Number	Common Objects
Talc	1	
Gypsum	2	— — — Fingernail
Calcite	3	— — — Copper coin
Fluorite	4	
Apatite	5	— — — Knife blade
Orthoclase	6	— — — Window glass
Quartz	7	— — — Steel file
Topaz	8	
Corundum	9	
Diamond	10	

Things that affect hardness

1. The structure
2. The kind of bonds – covalent is stronger
3. The types of atoms involved

SiO_2	PbO_2
Hard	Soft

Specific Gravity (SG)

- Ratio of weight to an equal volume of water.
- Basically, how heavy it feels relative to other minerals.

Things that affect density

- Atomic weight of the atoms
- Crystal structure

Crystal Habit

- Characteristic shape as it grows

Ex. Quartz (6 sided)

Special Properties of Select Minerals

Smell and Taste

- Sulfur or Halite

Fluorescence

- Some minerals glow under UV rays.

Magnetism

- Magnetite

Effervescence

- Calcite reacts with HCl (acid).

The 4000+ minerals are divided into Mineral Groups

Silicates

- Most abundant mineral group in the crust
- Dominates all three rock types
- Composed of Silicon and Oxygen= silica (SiO_2)

Silicates


Framework
Sheet
Isolated
Framework
Single chain
Double chain

Non-Silicates

Carbonates, Oxides, Sulfides, Sulfates, Native elements

$CaCO_3$	Fe_2O_3	FeS_2	$CaSO_4$	Au
Calcite	hematite	pyrite	gypsum	gold

Asbestos, What’s the deal?

- Asbestos is commercial definition for minerals that are flexible, chemically and thermally resistant and can be woven.
- Fiberous crystal form
- Previously used in building products (tiles, etc.) and insulation products.
- Heavy exposure to **some types** of asbestos has been linked to lung cancer.
  - Mesothelioma

Asbestos, Do we need to spend $50,000,000,000 to $150,000,000,000 to get rid of it?

Crocidolite

- Forms sharp fibers (needles) that can puncture lungs

Chrysotile

- Fibers dissolve more easily (not sharp)
- Has never been shown to cause lung related diseases.
- The only type of asbestos that is currently mined.
- The most commonly used type of asbestos in N. America.

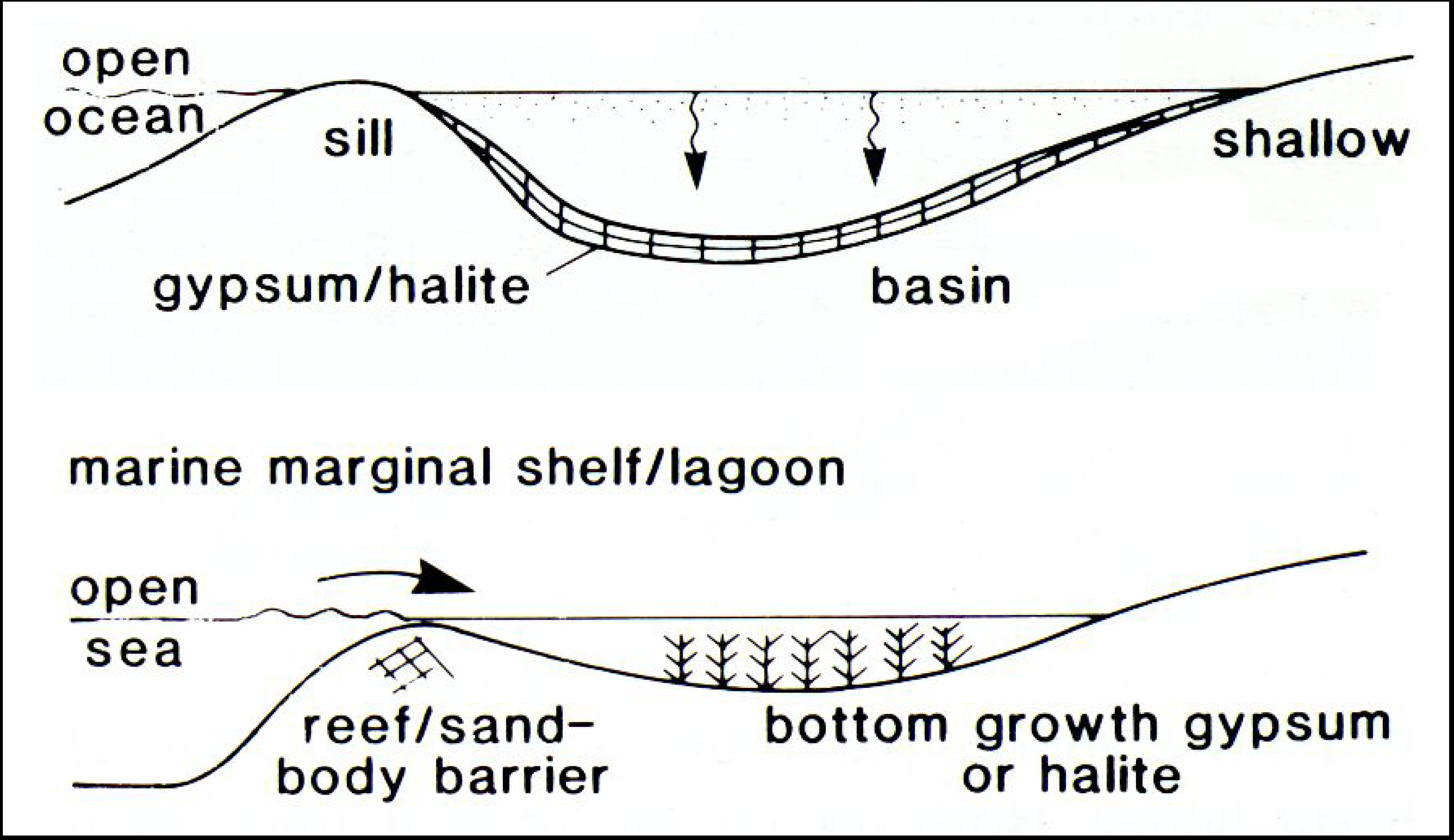
How do Minerals Form?

Chemical reactions between elements.

Crystallization – the growth of a solid from a gas or liquid

Where do minerals come from?

2. Evaporites – Liquids evaporate from a solution causing minerals to precipitate



What makes a gem?

Ruby

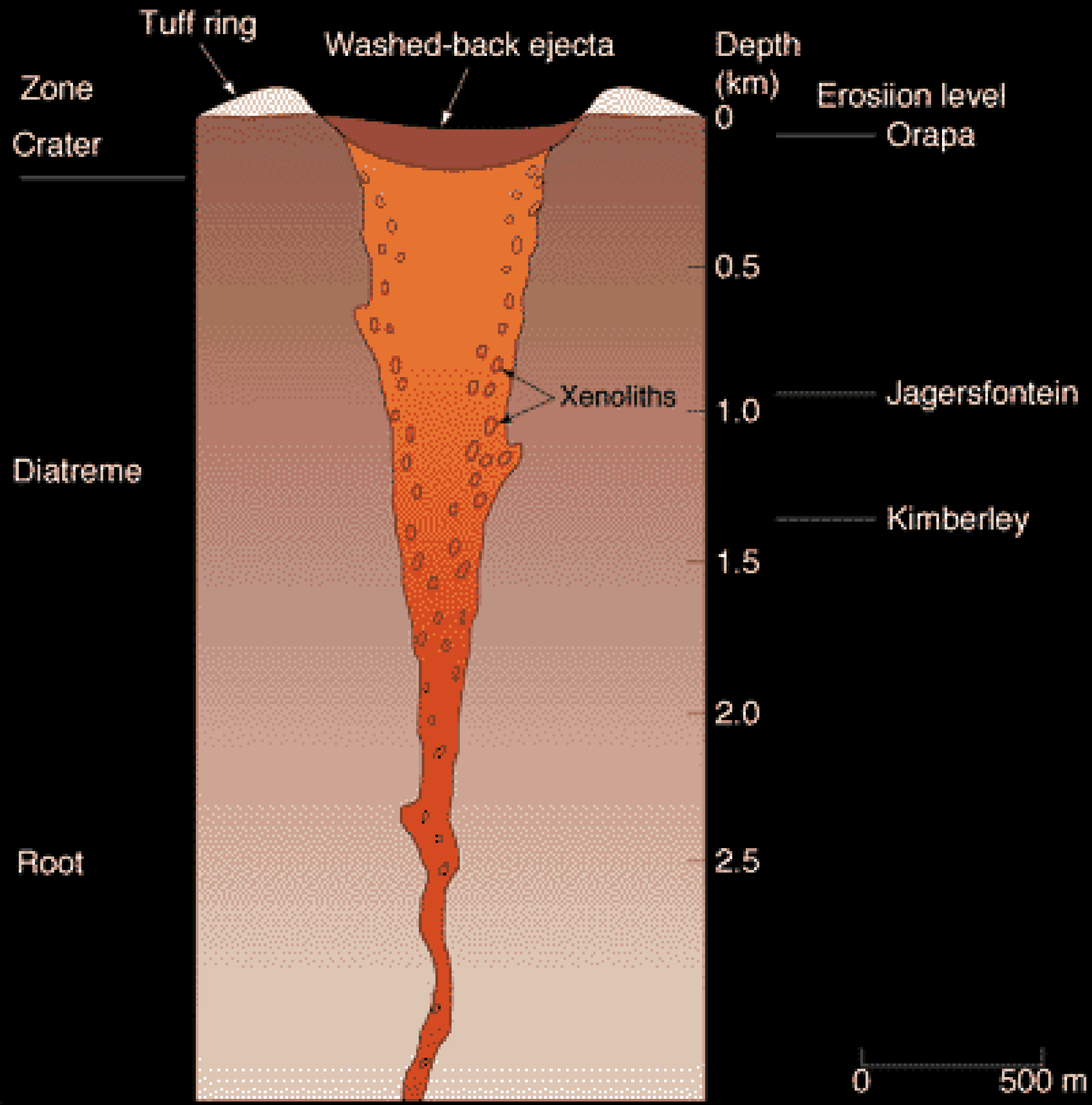
Al_2O_3

- Beauty – as reflected by color and luster
- Transparency,
- Brilliance – enhanced by cutting and polishing
- Durability – based on hardness
- Rarity or perceived rarity

Diamonds

- Covalent bonds
- 10 on hardness scale
- Polymorph of carbon along with graphite
- Form in the mantle
- Most are believed to be very old (most about 3 billion years old).
- Brought to the surface through kimberlite pipes.
- Can be found as placer deposits.
- Uses: Gems, Cutting and Polishing

Cross-Section of a Kimberlite Pipe

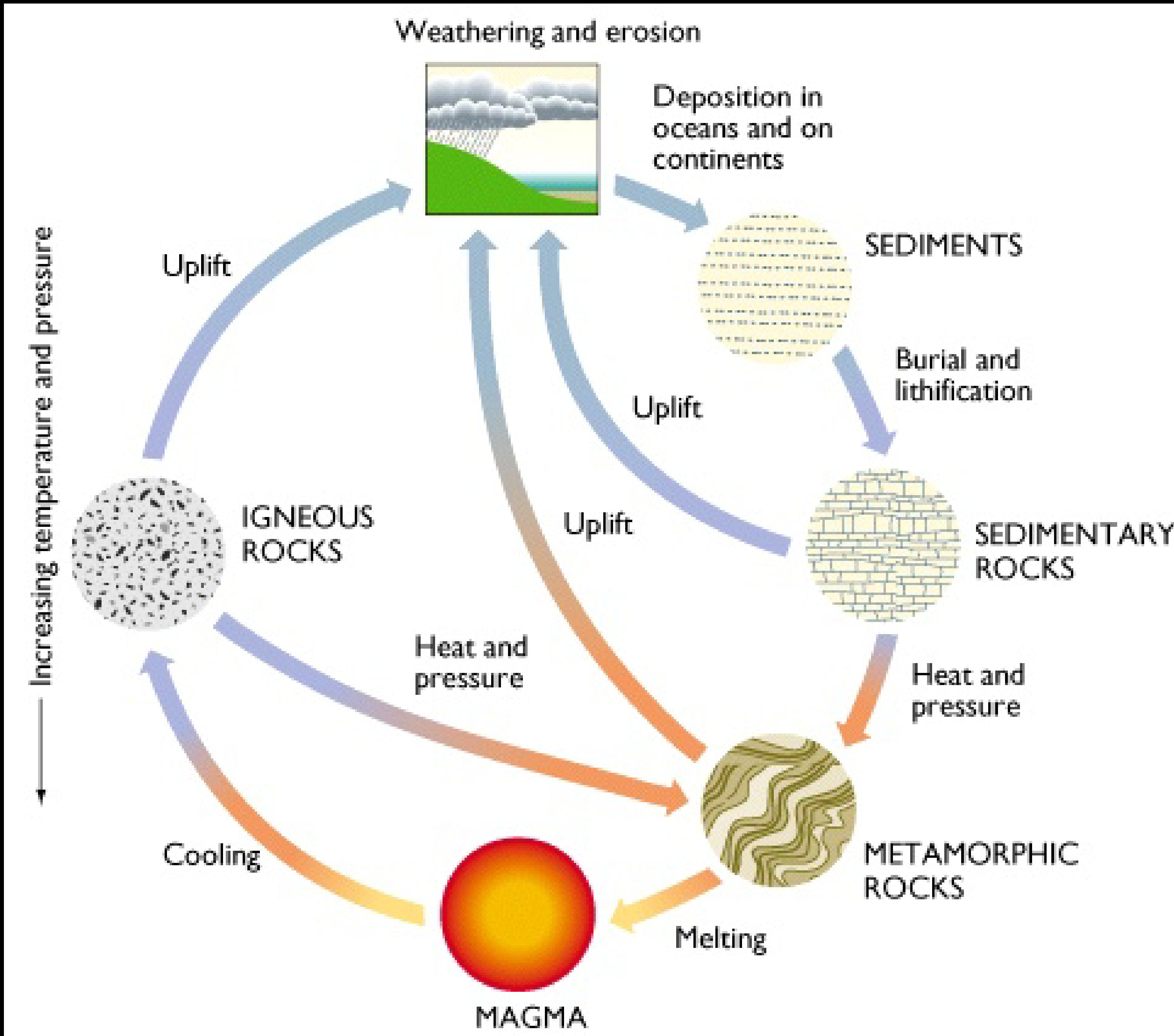


Chapter 4
Up from the Inferno: Magma and Igneous Rocks

Minerals to Rocks

- Now we can combine one or more minerals to form different rocks!

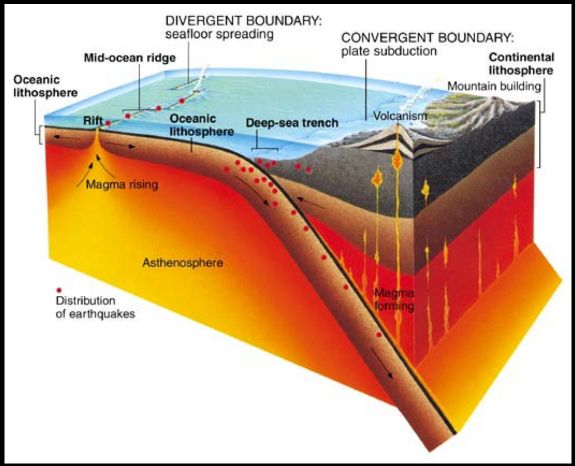
The Rock Cycle



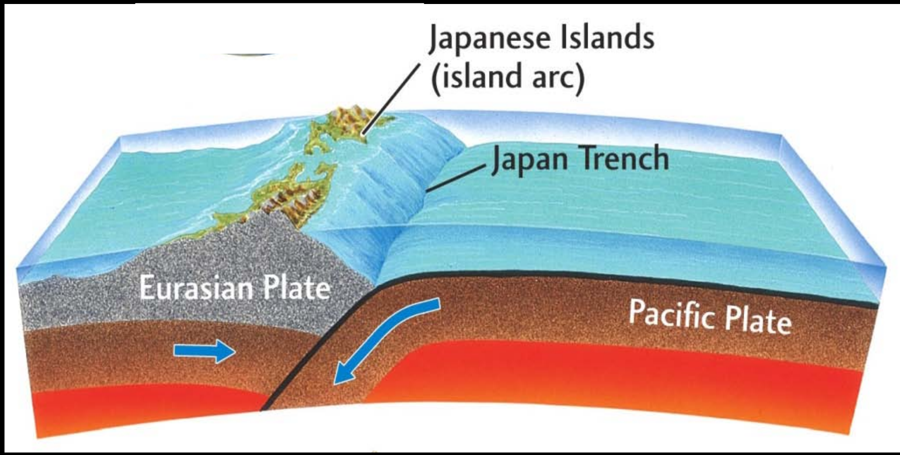
(from M Fouch ASU)

Generation of Magma

- Convergent boundaries
  - oceanic-continental

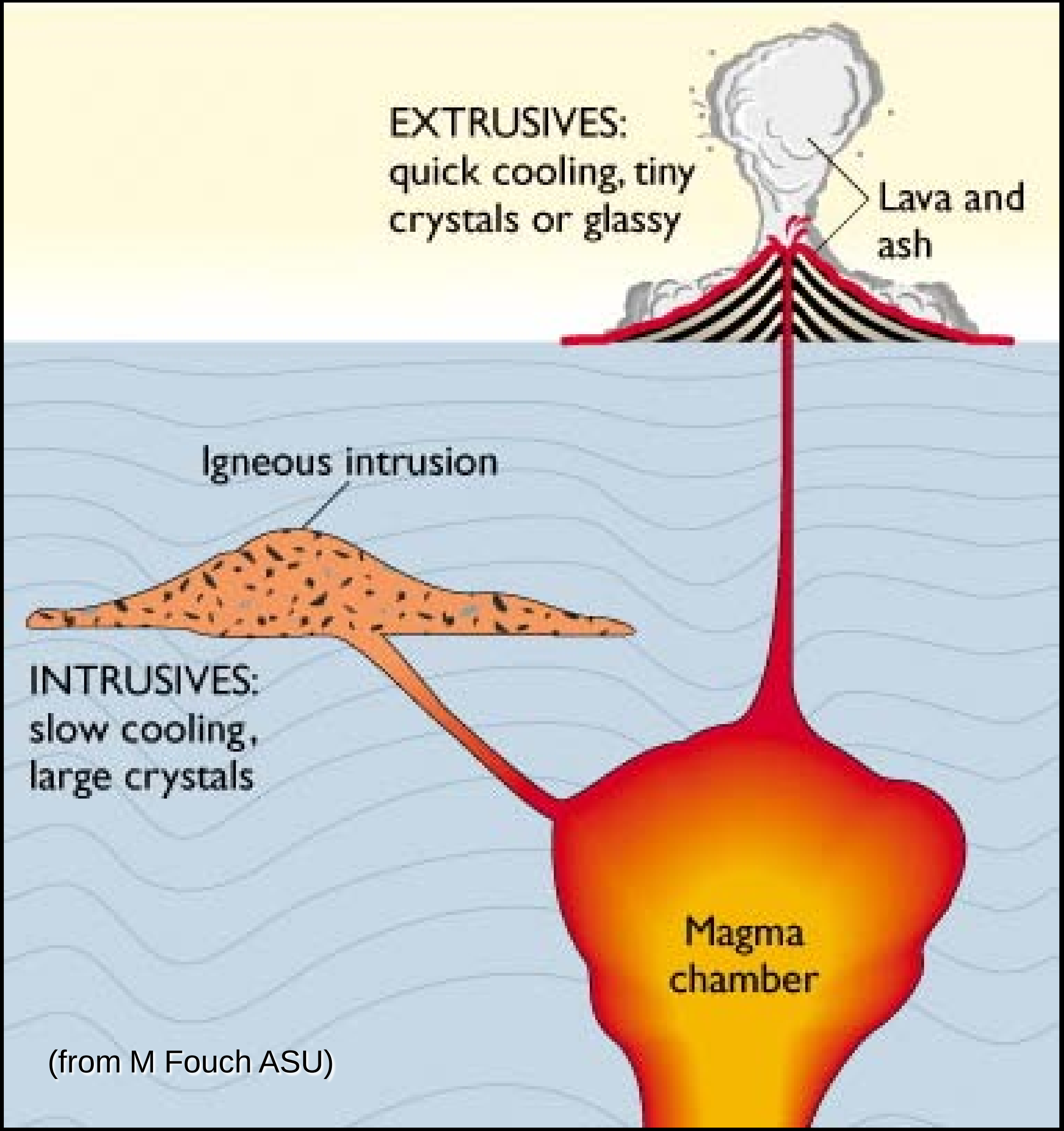


  - oceanic-oceanic



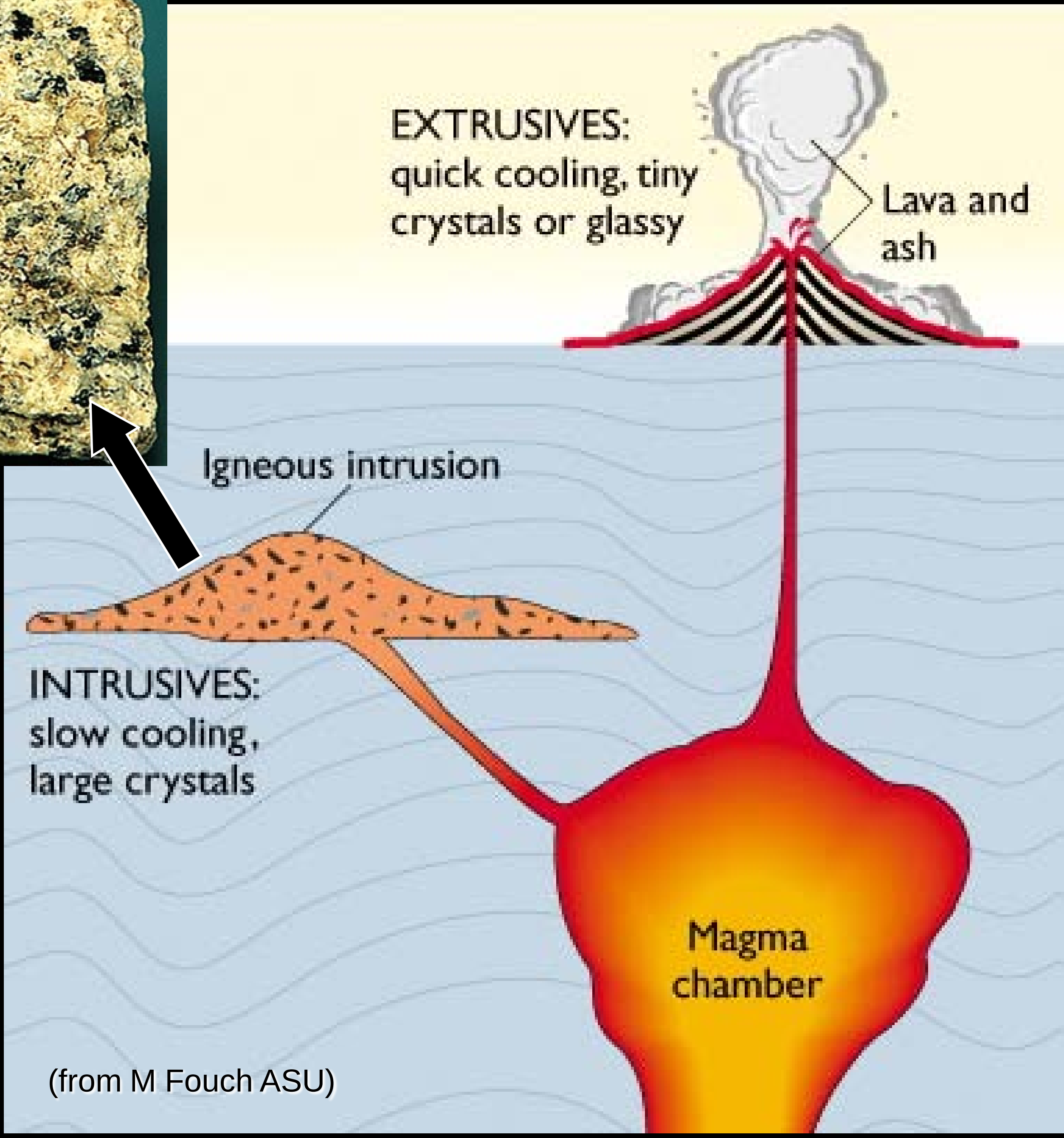
Igneous Rocks

Intrusives and Extrusives

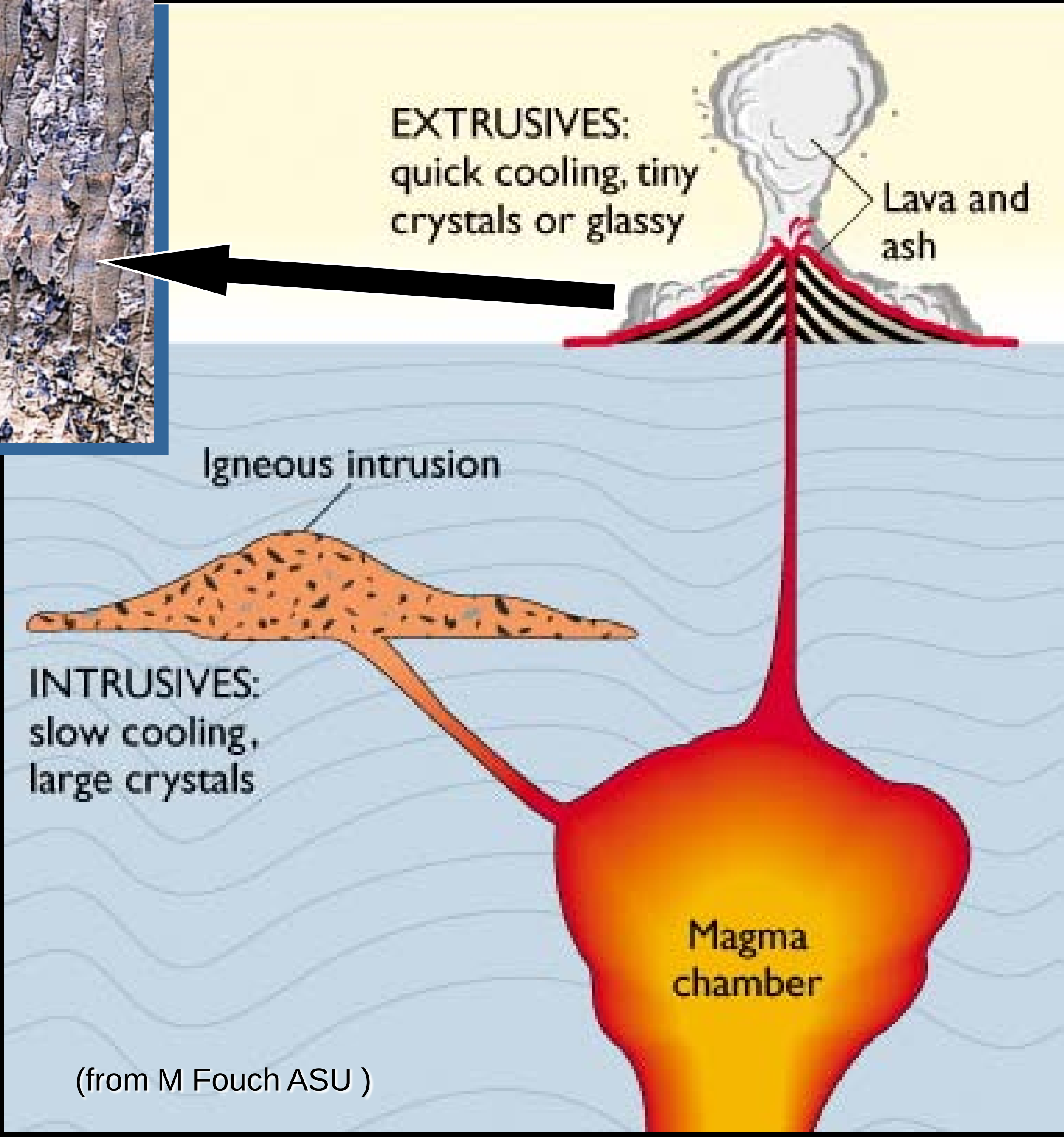


Intrusive Granite

(large crystals)



(from M Fouch ASU)



Extrusive Basalt

(small crystals + glass)

(from M Fouch ASU)

Extrusive Textures

Aphanitic

- Crystals are too fine to be distinguished without a microscope.

Extrusive Textures (continued)

- Pyroclastic material- Fragments of material ejected explosively into the air.
  - Pumice
  - Ash
  - Tuff

Extrusive Textures (continued)

Glassy – no minerals present (Obsidian)

Pyroclastic (Fragmental) Texture: Pumice or Tuff

Extrusive Textures (continued)

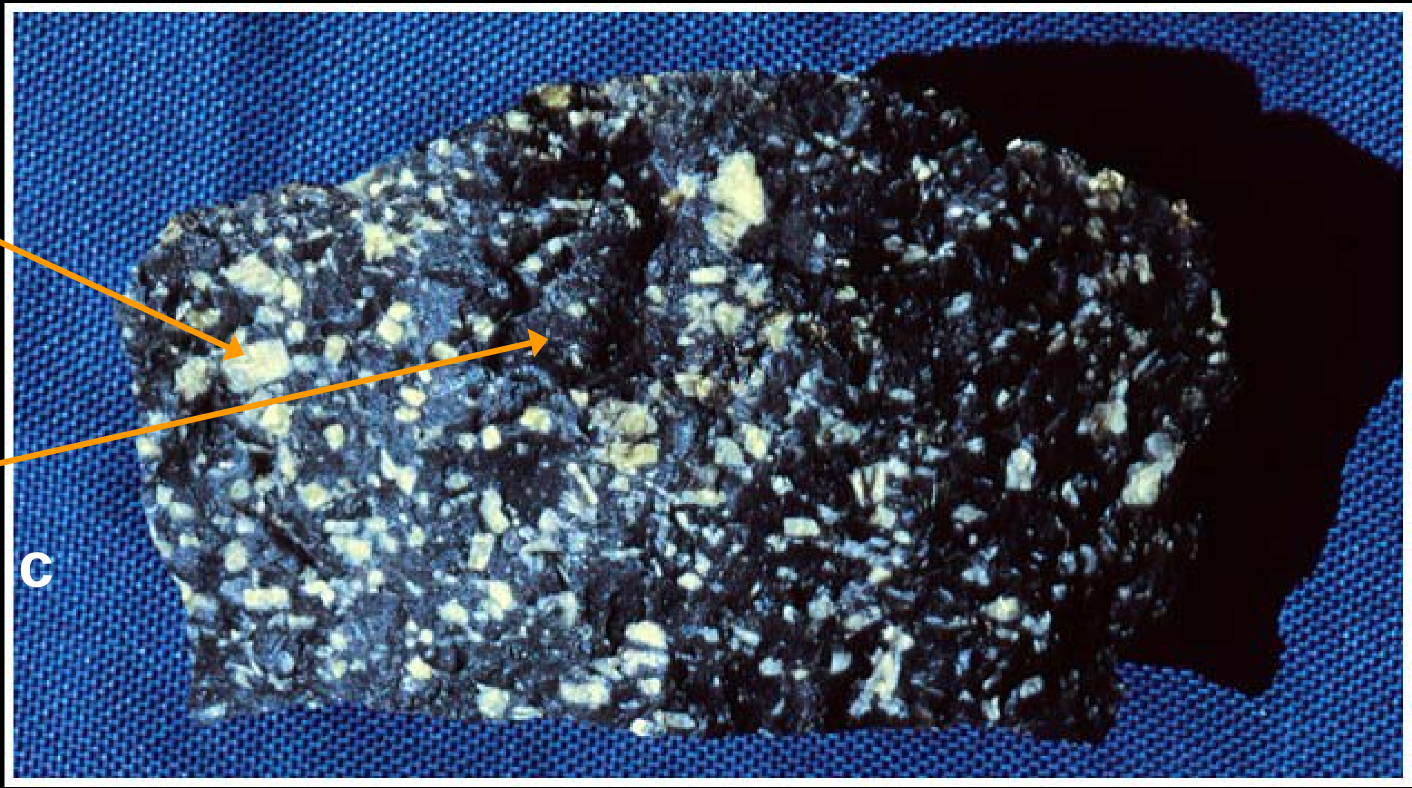
- **Vesicular – Void spaces that where gas bubbles**

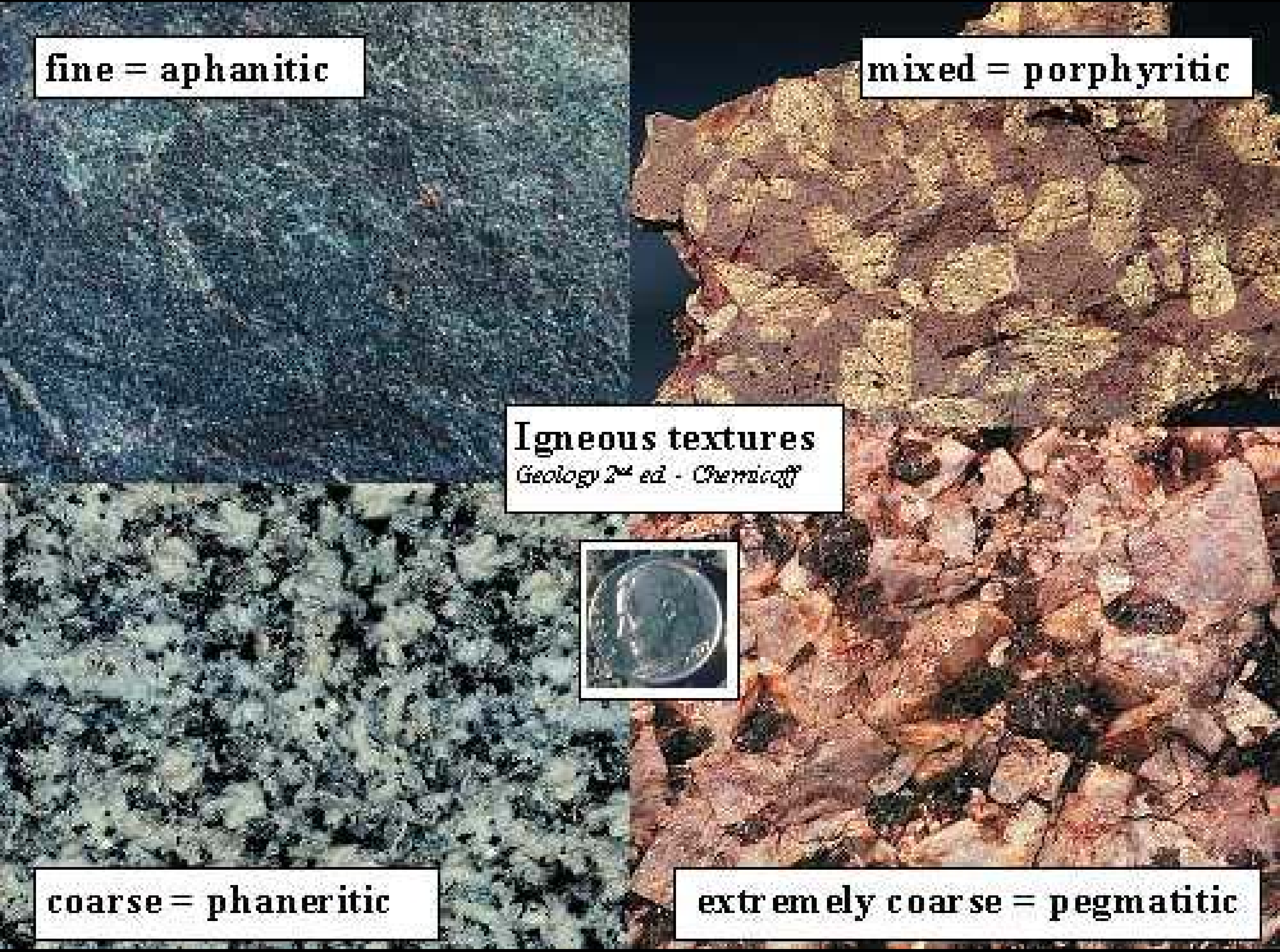
Mixed Texture

- Porphyritic – 2 distinct crystal sizes.
- What does this indicate about the rate of cooling?

Phenocrysts (big crystals)

Matrix is aphanitic




fine = aphanitic
mixed = porphyritic
Igneous textures
Geology 2nd ed. - Chernicoff
coarse = phaneritic
extremely coarse = pegmatitic

Composition

Ultramafic –lowest % silica, dark colored (green)

Mafic – low % silica, dark colored (green/brown/black)

Intermediate – intermediate % silica, intermediate color (grey, grey/green)

Felsic – high % silica, light color (white, light grey, pink)

The composition of the magma is a reflection of where the melting took place

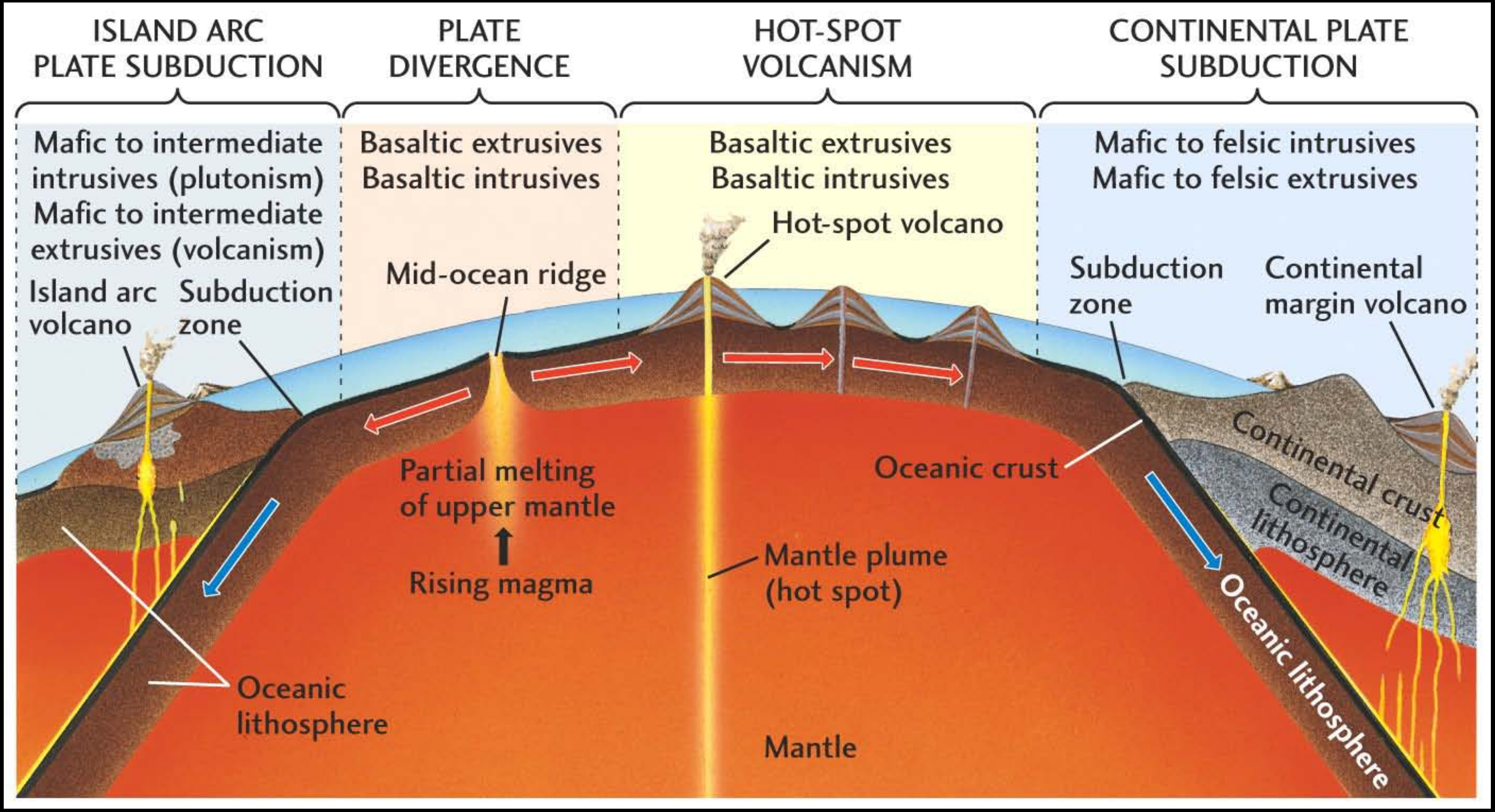
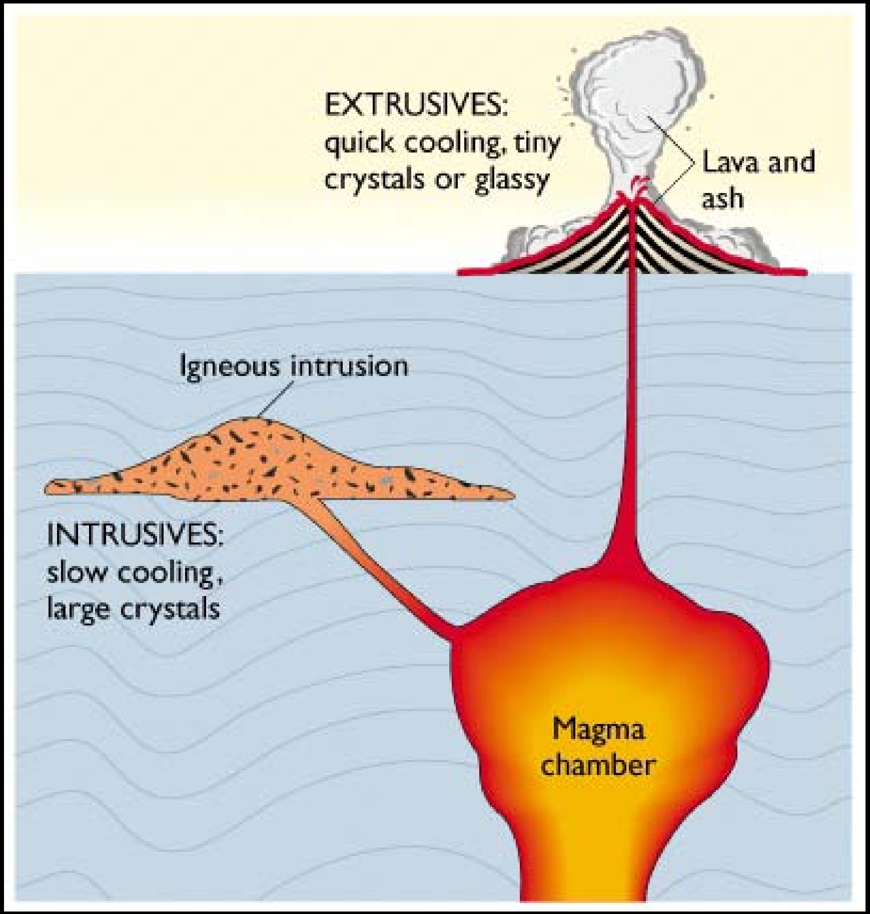


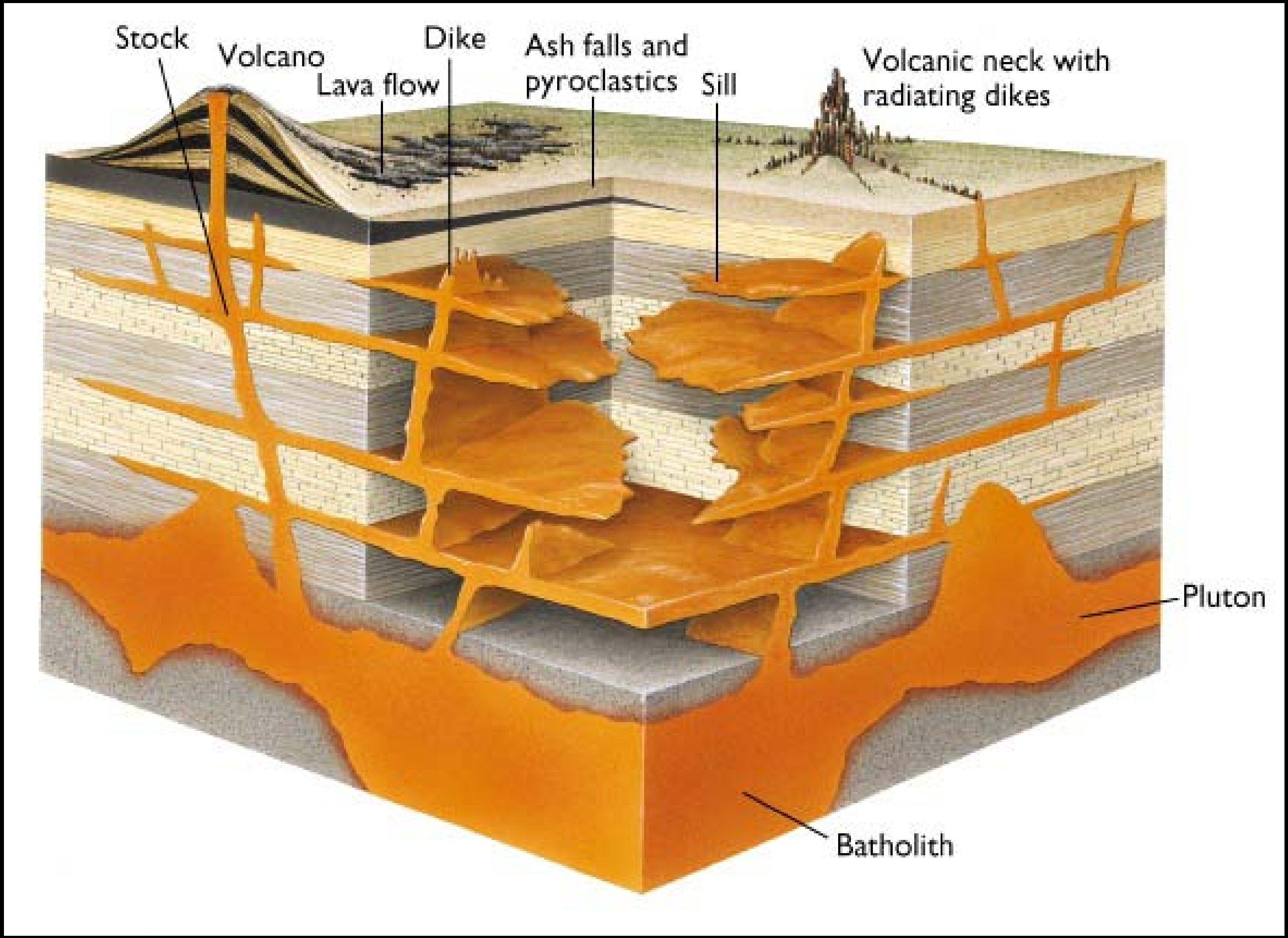
Fig. 5.11

Extrusive vs. Intrusive: types and shapes

- Volcano – A hill or mountain that forms from the accumulation of lava that erupts at the surface.

- Plutons – Large igneous bodies that cool underground (intrusive).




Stock
Volcano
Dike
Lava flow
Ash falls and pyroclastics
Sill
Volcanic neck with radiating dikes
Pluton
Batholith

Plutons

Sill: Horizontal intrusions.

Dike: Vertical or semi-vertical intrusion

Chapter 5
The Wrath of Vulcan: Volcanic Eruptions

Volcanic Eruptions

Effusive

Pyroclastic

Effusive

- gentle eruptions
- Lava dominates
- magma/lava generally low in silica (mafic)
- low viscosity
- release gas
- occur commonly at divergent boundaries and hot spots
- Ex: Kilauea, Hawaii, Mid-Atlantic Ridge

Pyroclastic

- Violent eruptions
- Mostly pyroclastics
- Lava high in silica (intermediate to felsic)
- High viscosity
- Gas is trapped
- Occur commonly at convergent boundaries and hot spots

Landforms produced by different styles of volcanic eruptions

Effusive

Fissure eruption

- Flood Basalts

Central eruption

- Shield Volcanoes
- Cinder Cones
- Spatter Cones

Pyroclastic

Central eruption

- Composite Volcanoes
- Cinder Cones
- Calderas

Landforms from Effusive Eruption

Flood Basalts

- **Primarily fissure eruptions**
- **Mafic lava**
- **Generally flat layers**
- **Cover 100-1000s of Km^2**

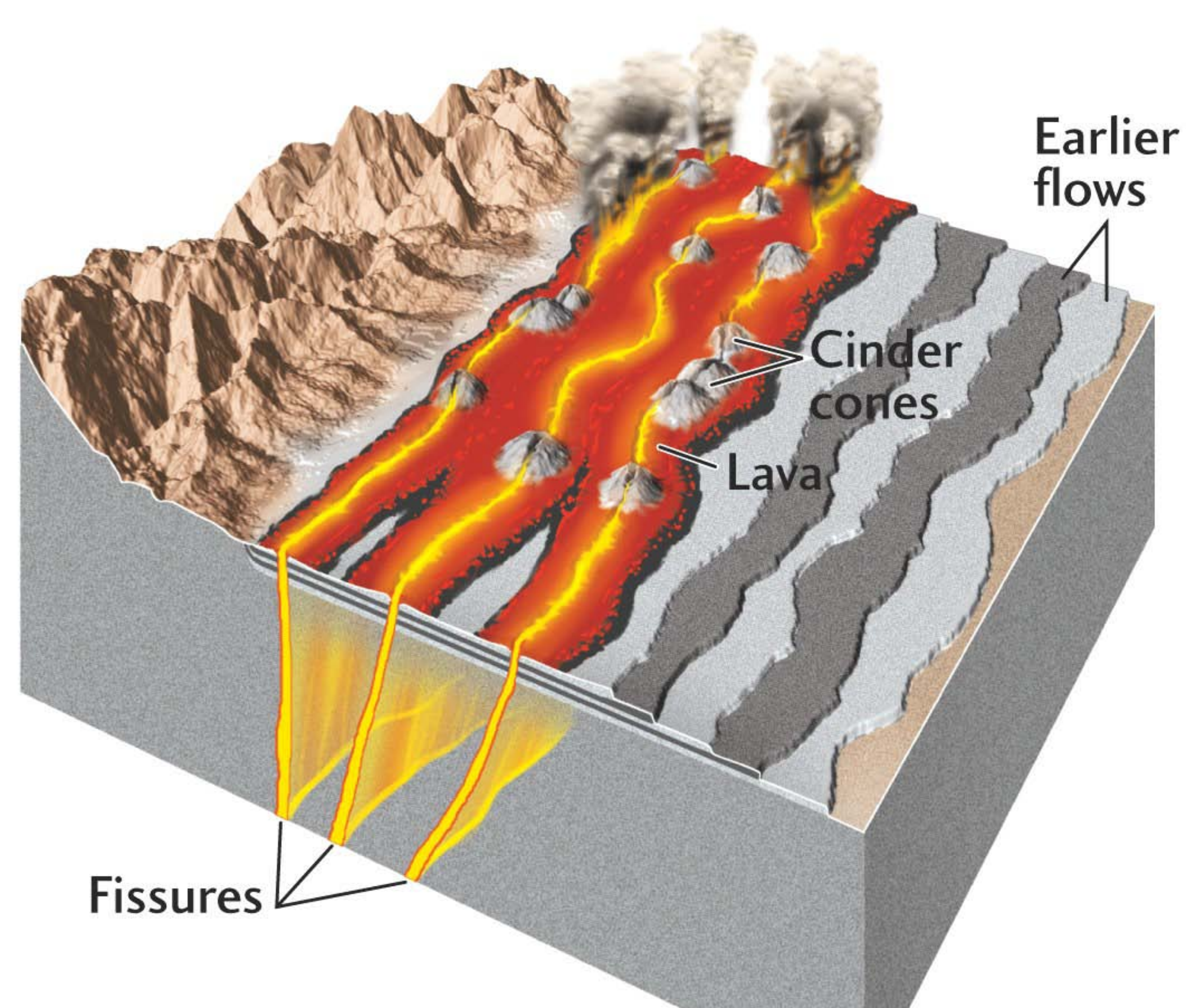
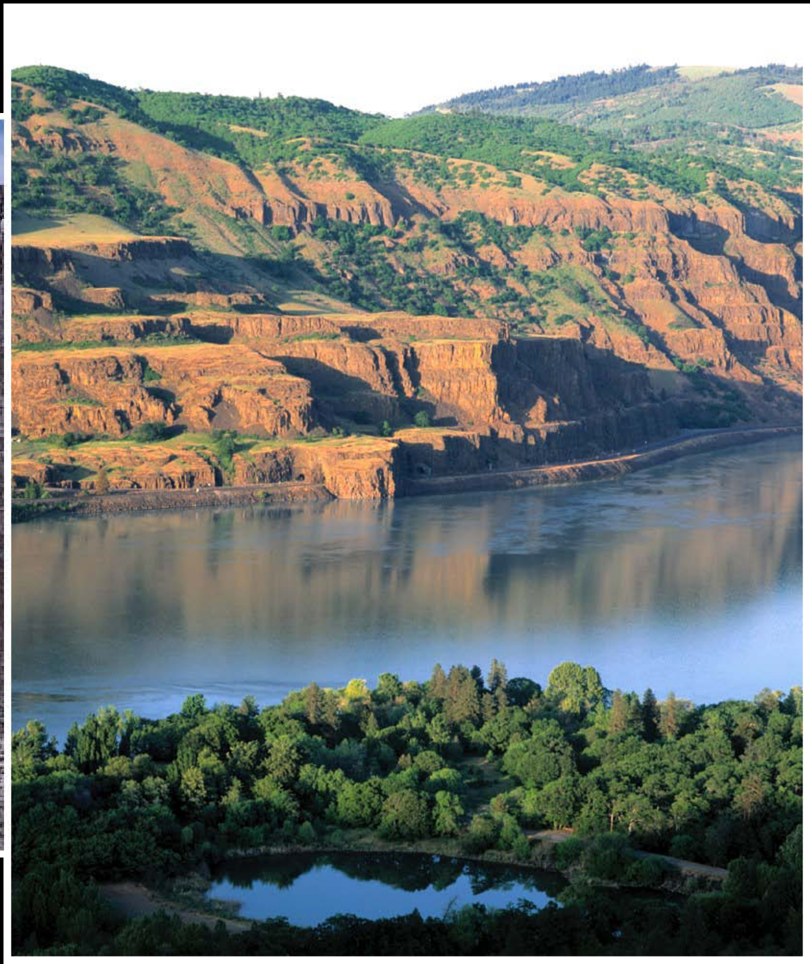


Fig. 6.13

Flood Basalts

Ex: Columbia River Basalts



Shield Volcano

(d) Composite volcano

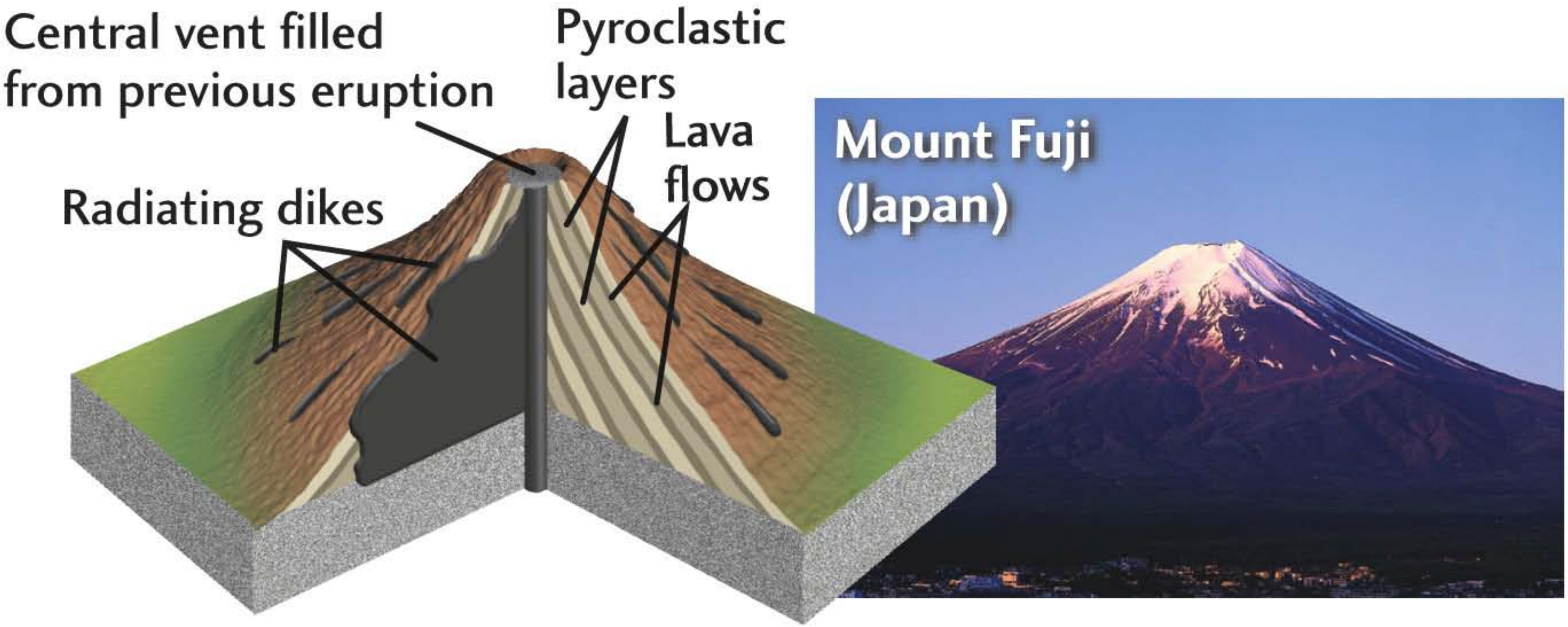


Fig. 6.9d

Composite Volcanoes

Ex:

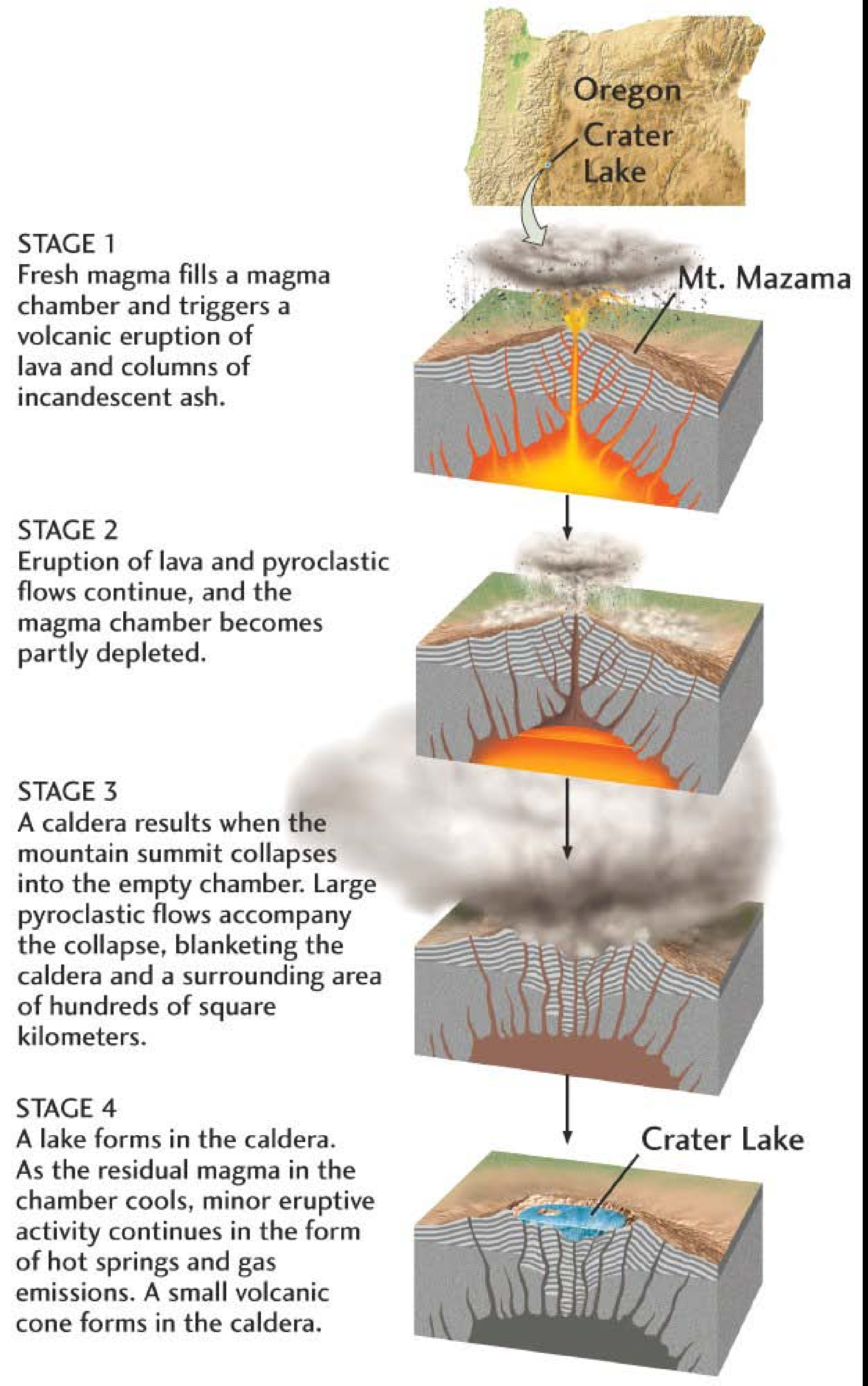
- Cascade Volcanoes (Mt. Rainier, Mt. St. Helens, etc.)
- Volcanoes of the Japan Ocean Island Arc
- Andes Volcanoes

Landforms from Pyroclastic Eruptions

Calderas

- Central Vent
- Extremely large explosive eruption causes the COLLAPSE of the summit into an empty magma chamber
- Primarily felsic pyroclastic rocks
- 10s Km across
- Ex: Crater Lake, OR and Yellowstone NP

Stages in caldera formation



Caldera Ex: Crater Lake, OR

Wizard Island is a Cinder Cone

Other Textures/Products created by volcanoes

Basaltic Lava (mafic)

- Pahoehoe – ropey
- Aa – blocky
- Lava tube
- Pillow lava – spherical shape, characteristic of underwater volcanic eruptions.
- columns

Aa

Pahoehoe

Summary: Mafic volcanic hazards

Lava flows

Volcanic Gases

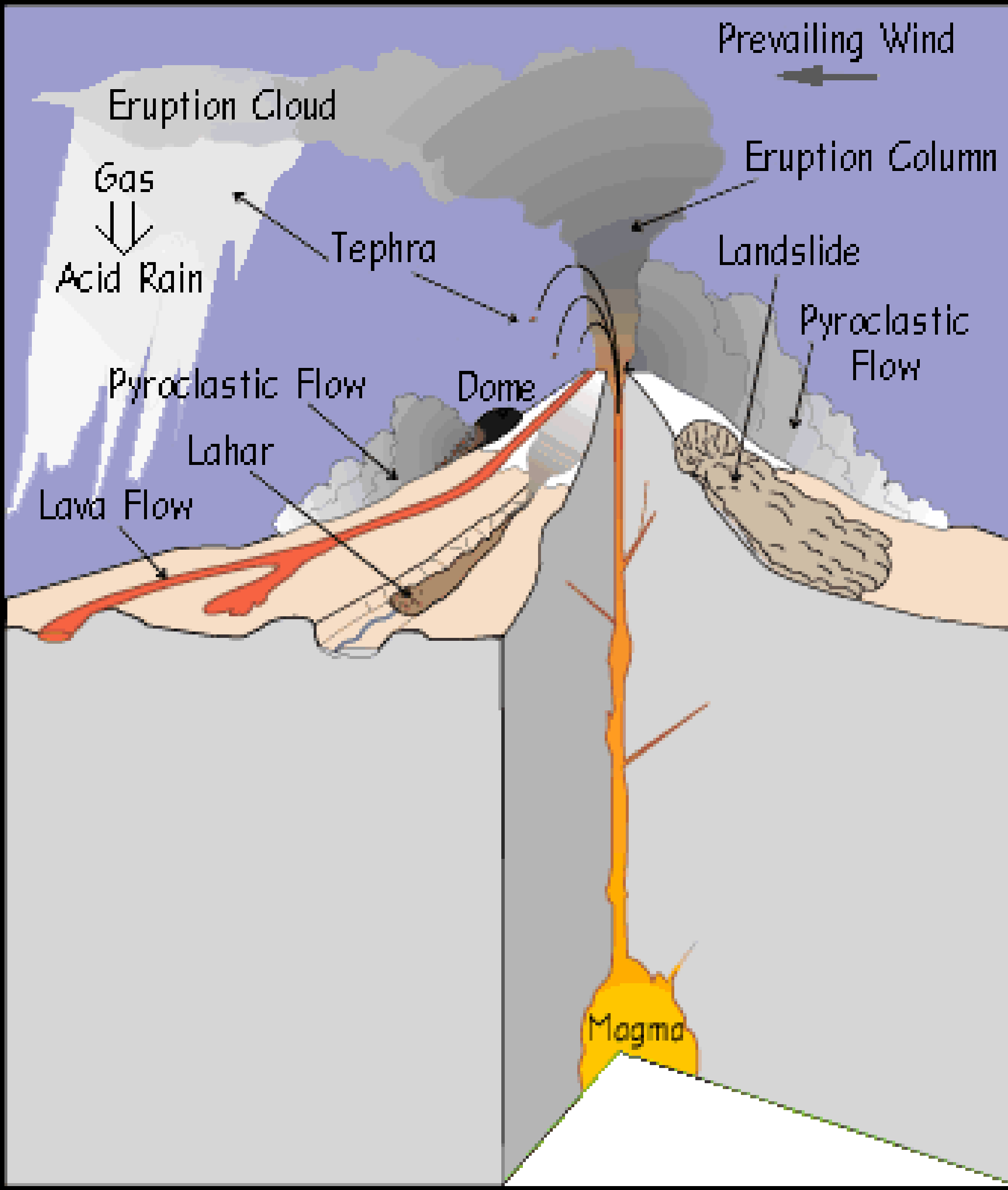
Flank collapse – extremely large landslide that could create a tsunamia

In general, basaltic lavas pose a relative low risk to human life. People have enough warning that they can get out of the way. The greatest risk is to property that can not be moved

Intermediate/Felsic (composite and caldera) volcanic hazards

- Tephra Fallout
- Pyroclastic Flows
- Lahars (mudflows)
- Lava Flows
- Gases

Other: Landslides
Climate change



(diagram from http://volcanoes.usgs.gov/Hazards/What/hazards.html


pyroclastic flow

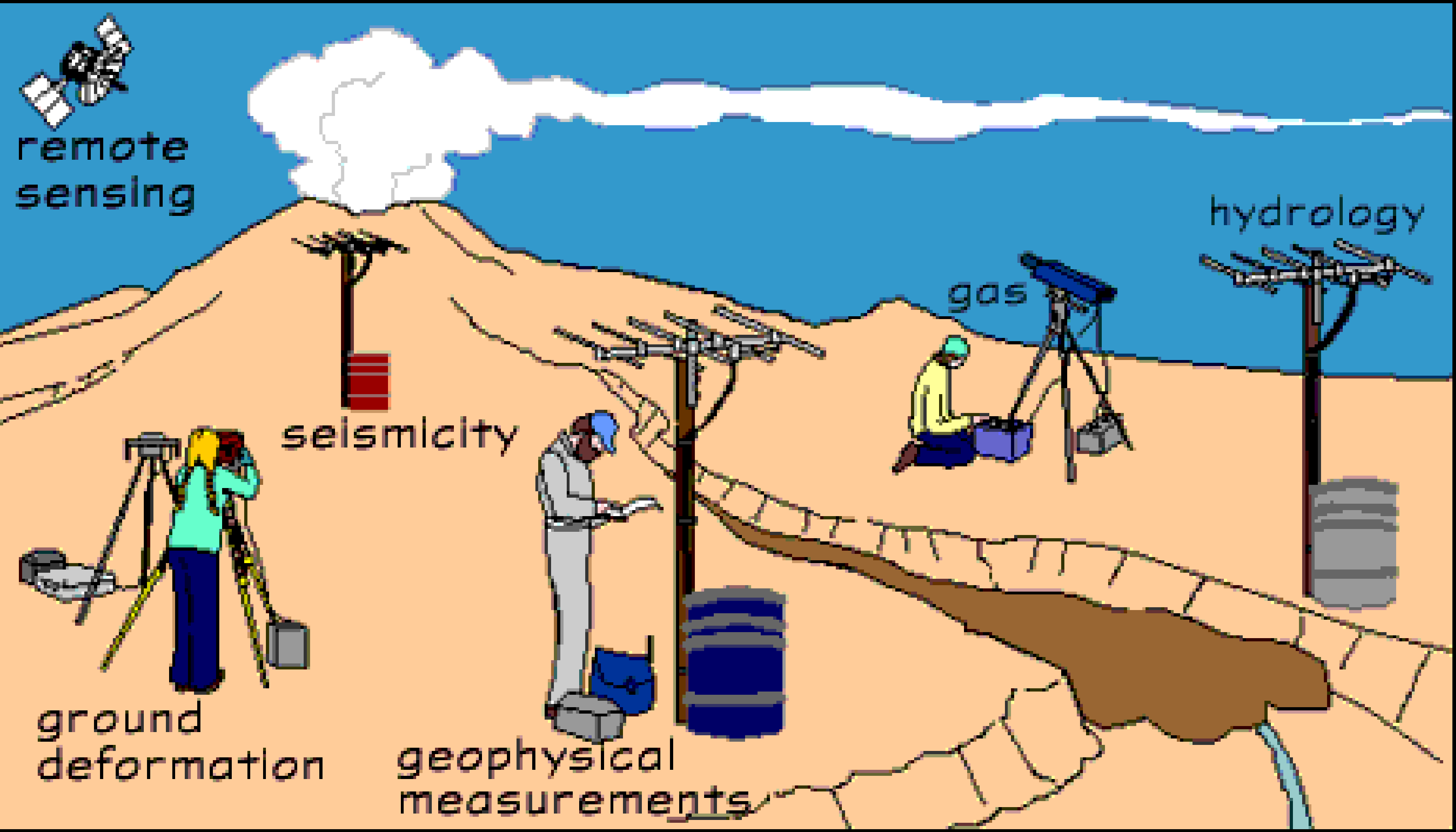
Lahar

Video: Perilous Beauty – The Hidden Dangers of Mount Rainer

Mudflows and Lahars

- Mudflows can be triggered for numerous reasons (look for these in the video).
- Lahars are a type of mudflow that results from mountain snow and ice melting during a volcanic eruption.

Volcano monitoring:



Step-wise process – monitoring is not emplaced everywhere – it is added where needed