IGNEOUS ROCKS

*(follows note packet "**Igneous Rocks**" pgs. 1-11.)*

- **Rocks formed from the cooling and solidification of molten rock**
- **Form either *on* or *below* Earth's surface.**

Magma vs. Lava

Mt. Etna, Italy

Hawaii

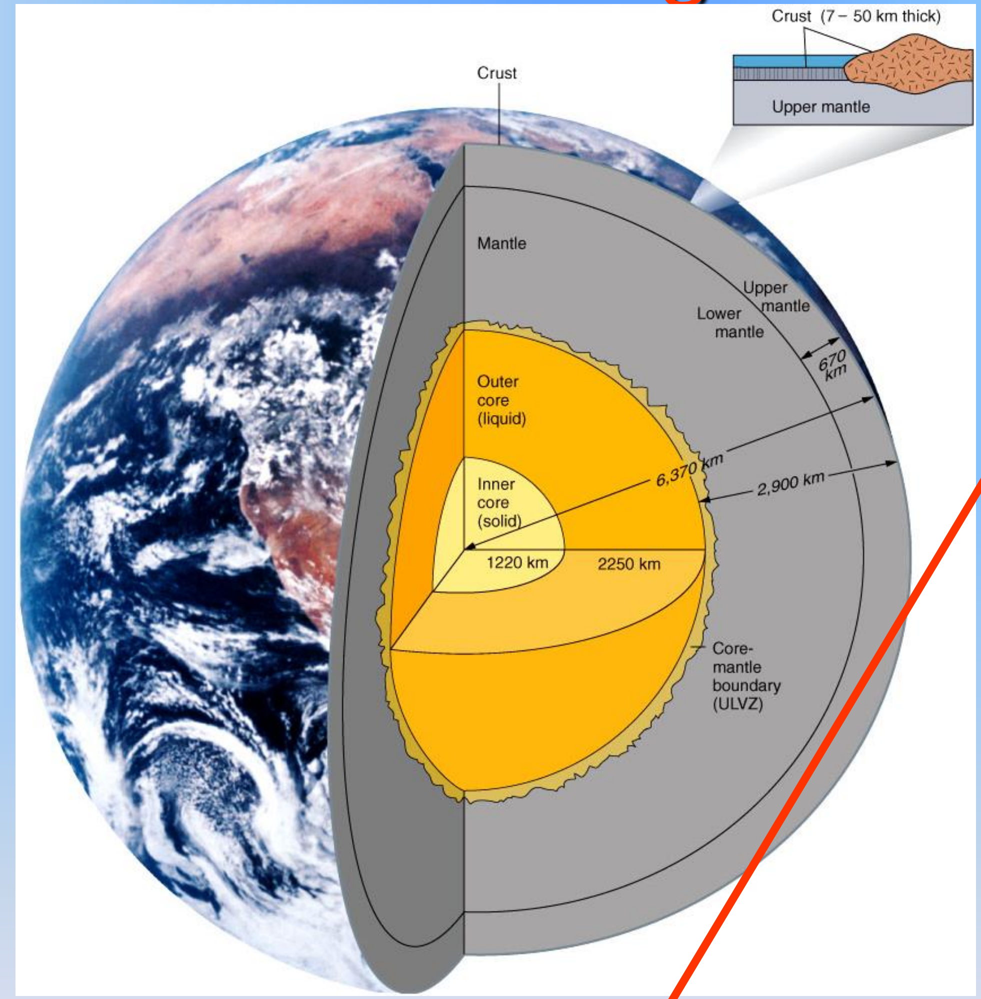
A. **<u>Magma</u>**:

1. **Magma vs. Lava**

a) _____**Magma**_____ is the term used for *all* hot and liquid (___**molten**___) rock.

b) _____**Lava**_____ is generally used for magma that flows on Earth's surface.

2. Where Does Magma Form?



} Lithosphere

a) Magma forms in Earth's **mantle** and **crust**.

b) Lava does ***not*** originate in Earth's core

Sources of Heat for Melting

a) ___Heat from below___ : Heat upward (by conduction and convection) from the very hot (>5000° C) core through the mantle and crust.

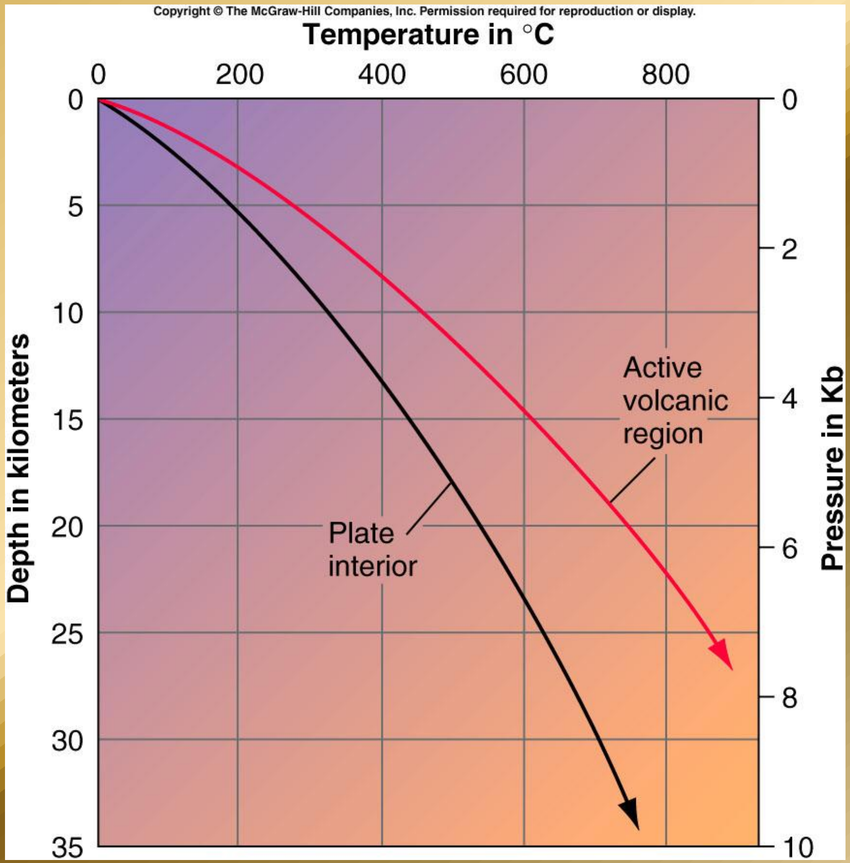
b. ___**Geothermal Gradient**_________ :

Heat moves upward (by conduction and convection) from the very hot (>5000° C) core through the mantle and crust.

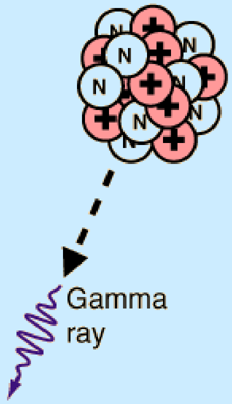
i. 3° C /100 m (30° C/km)

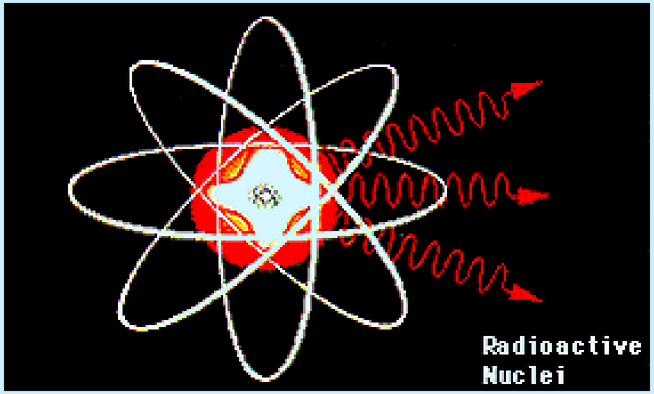
ii. At great depth temperature alone would melt rock <u>BUT</u> high pressure may cause it to remain solid.

iii. Not the same everywhere (i.e., It's higher in volcanic regions).



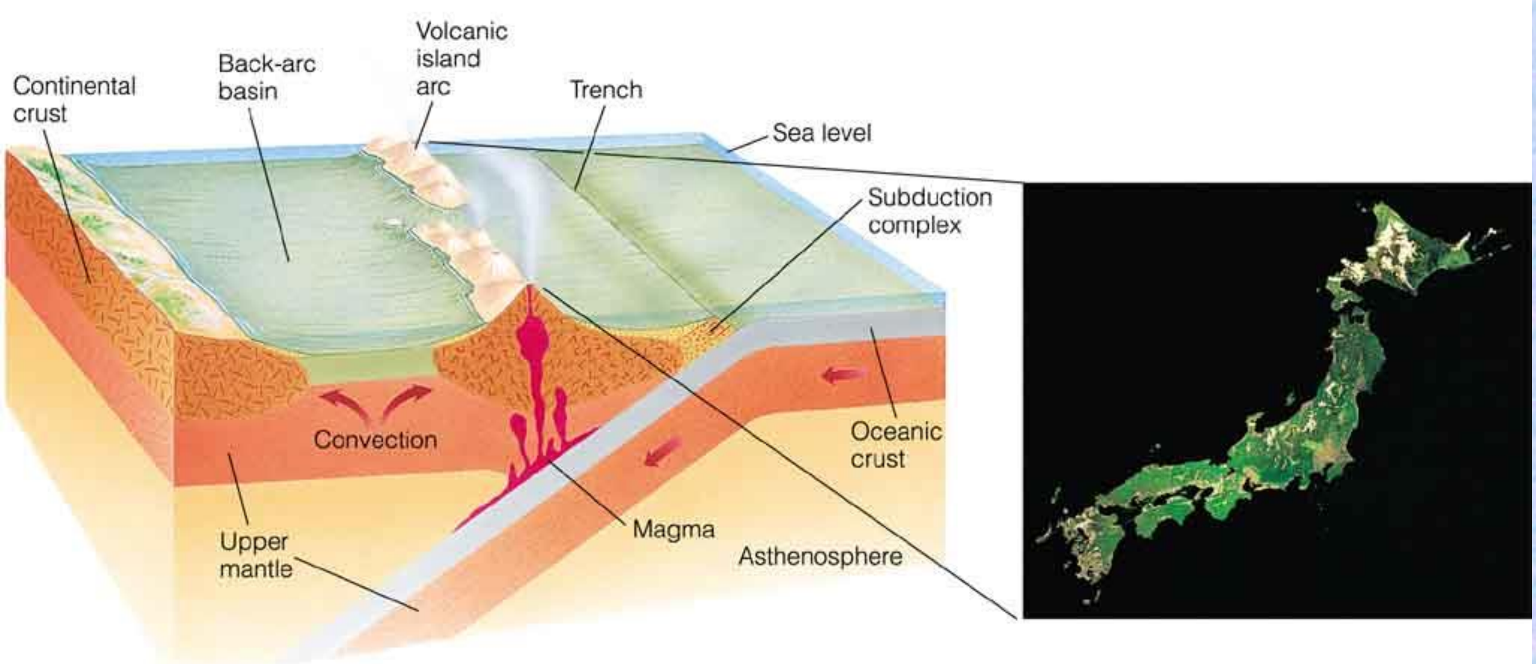
c) Radioactive Decay





- **Heat byproduct during decay.**
- **High concentration may cause temperature to increase with depth at a rate greater than the geothermal gradient.**

d) ____Friction____



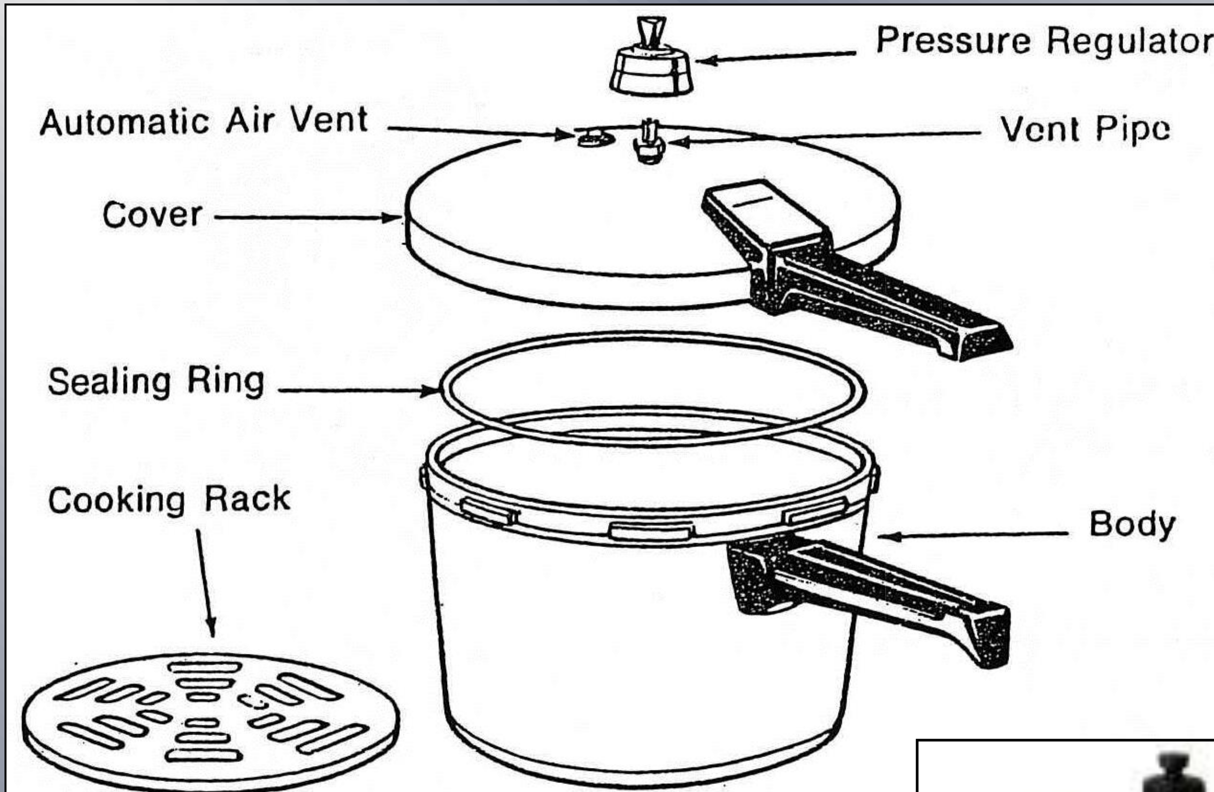
- Rock grinding past rock
- Active Mountain building regions. Friction of moving and shifting rock masses in regions of mountain building may combine with heat from other sources to melt rock.

B. Factors That Control Melting Temperatures

1. **Decompression Melting**

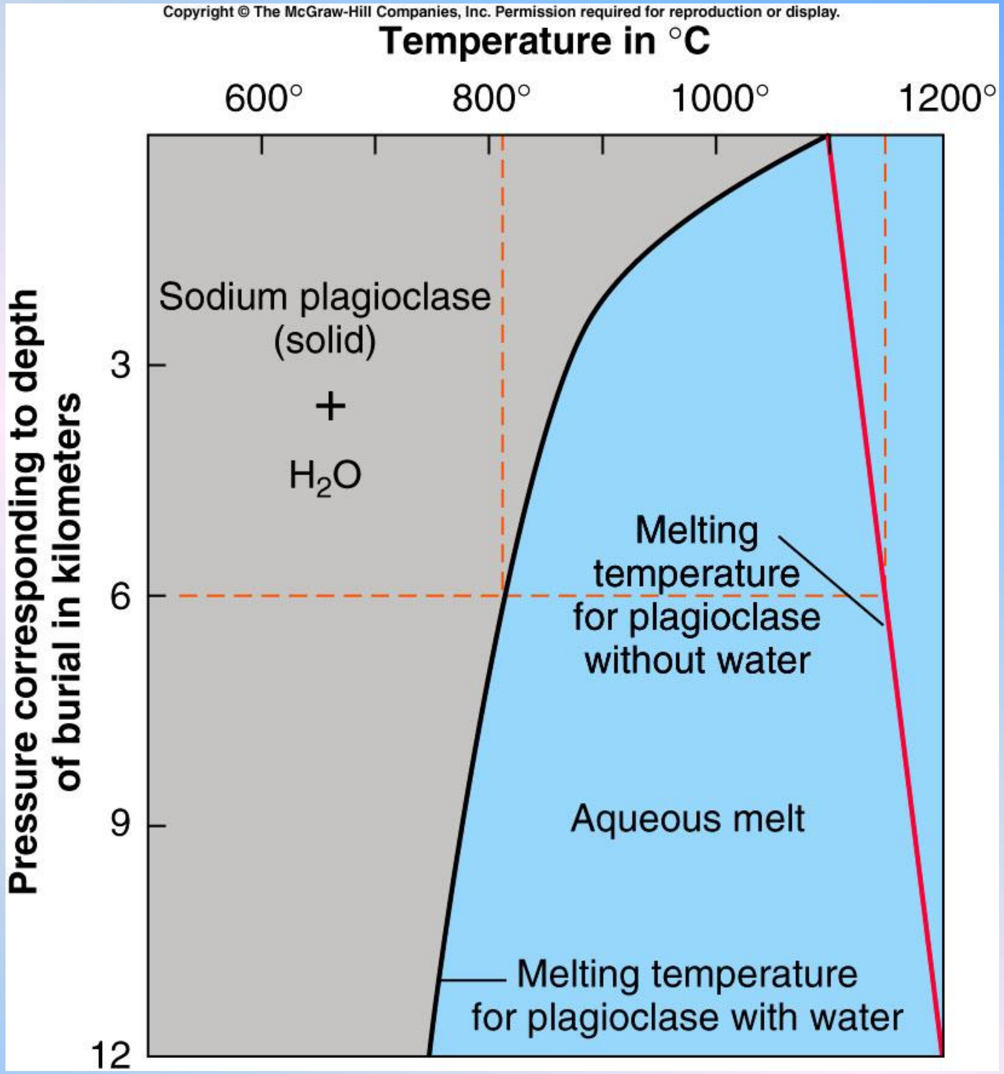
a) Increased pressure increases the melting point.

b) Reduction in pressure may cause melting.

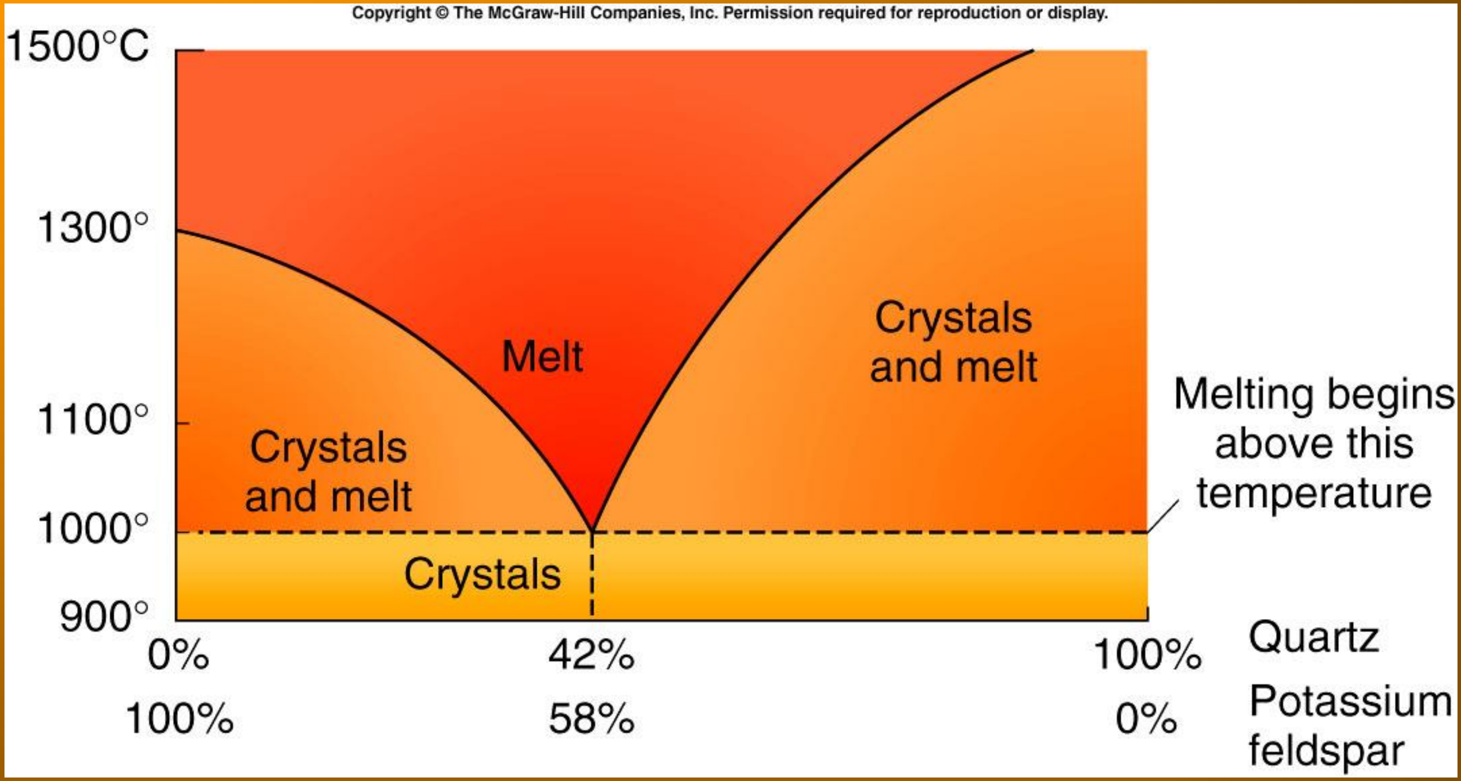

Pressure Regulator
Automatic Air Vent
Vent Pipe
Cover
Sealing Ring
Cooking Rack
Body

2. Water Under Pressure

- Water under pressure (water vapor entrapped in magma) lowers the melting point.



3. Effect of Mixed Minerals



- Different minerals have various melting temperatures. Some combinations of minerals may lower the overall melting temperature.

C. Types of Magma (Chemistry of Igneous Rocks)

- Approximately 99% of Igneous Rocks are comprised of only eight elements.
  - **Oxygen**
  - **Silicon**
  - **Aluminum**
  - **Iron**
  - **Calcium**
  - **Sodium**
  - **Potassium**
  - **Magnesium**

The amount of *silica* determines the mineral content and general color of igneous rocks

1) ___**Felsic**___ Magmas (also referred to as **sialic)**

a) Rich in silica and aluminum
b) They produce more quartz, potassium (orthoclase) feldspar, and sodium plagioclase.
c) The are generally ___**light**___colored and are usually *intrusive*

2. ___Mafic___ magmas

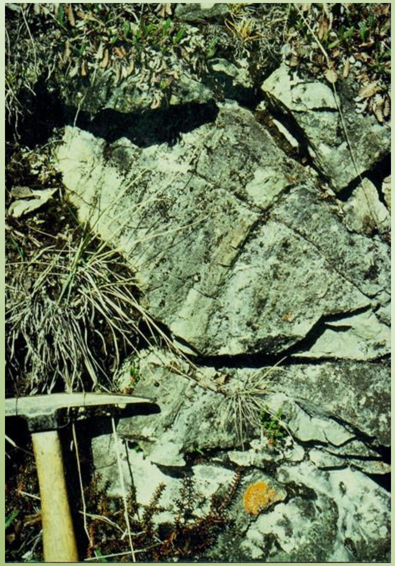
a) Rich in iron, magnesium, and calcium
b) Produce greater quantities of olivine, pyroxene, amphibole, and calcium plagioclase
c) They are generally ___dark___ colored because of the abundant dark ___ferromagnesian___ minerals.

3. ___Intermediate___ magmas

a) Chemical content between that of felsic and mafic rocks

b) Color is often ___green___ or___medium___ gray.

4. __Ultramafic__ magmas

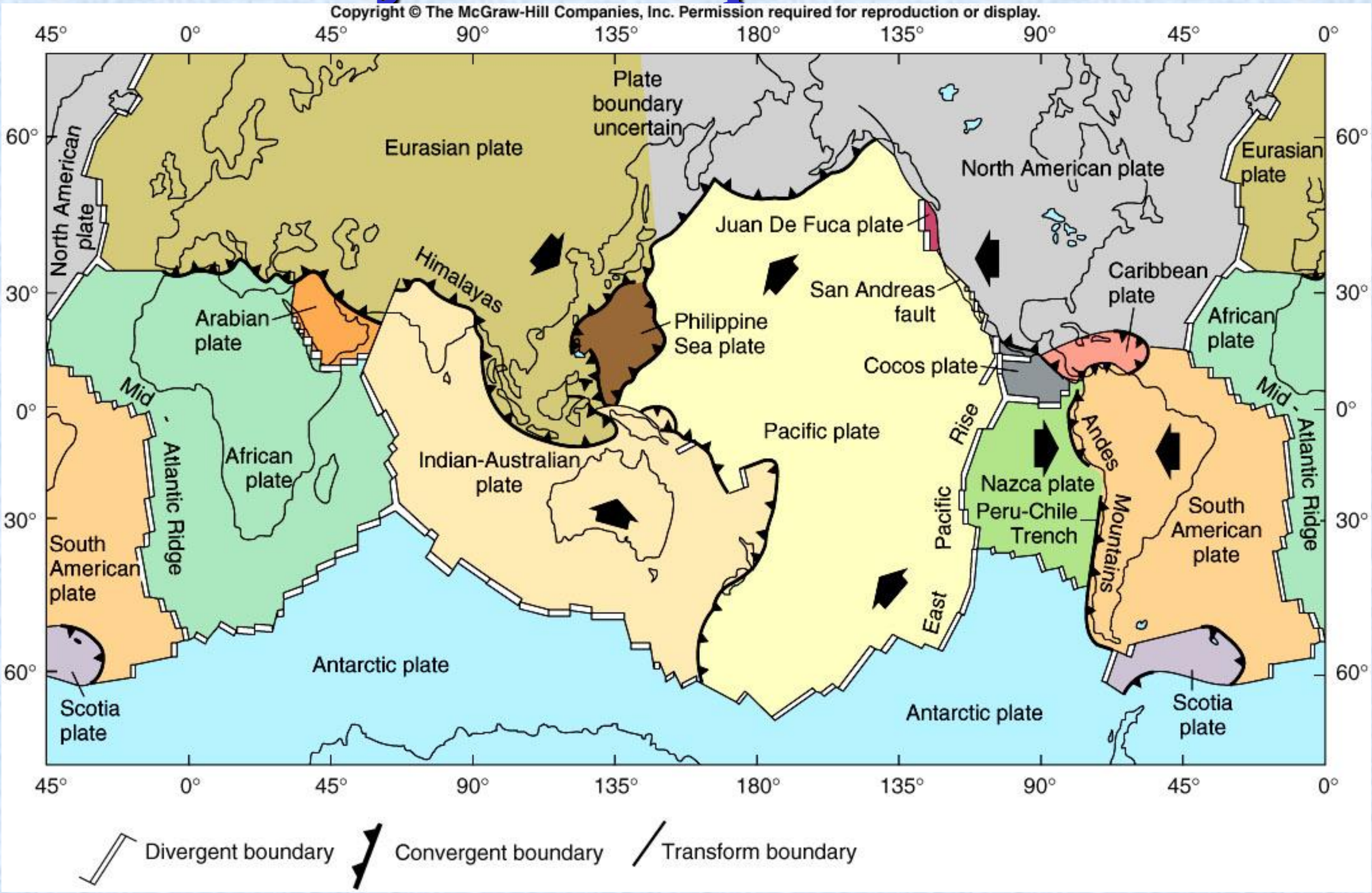


a) Composed entirely or almost entirely of ____**ferromagnesian**____ minerals.
b) No ____**quartz**____ or ____**feldspars**____ are present
c) Volcanic ultramafic rocks are very rare. They formed during Earth's early history (Hadean) when Earth's internal temperatures were high enough for them to form
d) Most come from the ____**mantle**____ rather than the ____**crust**____.

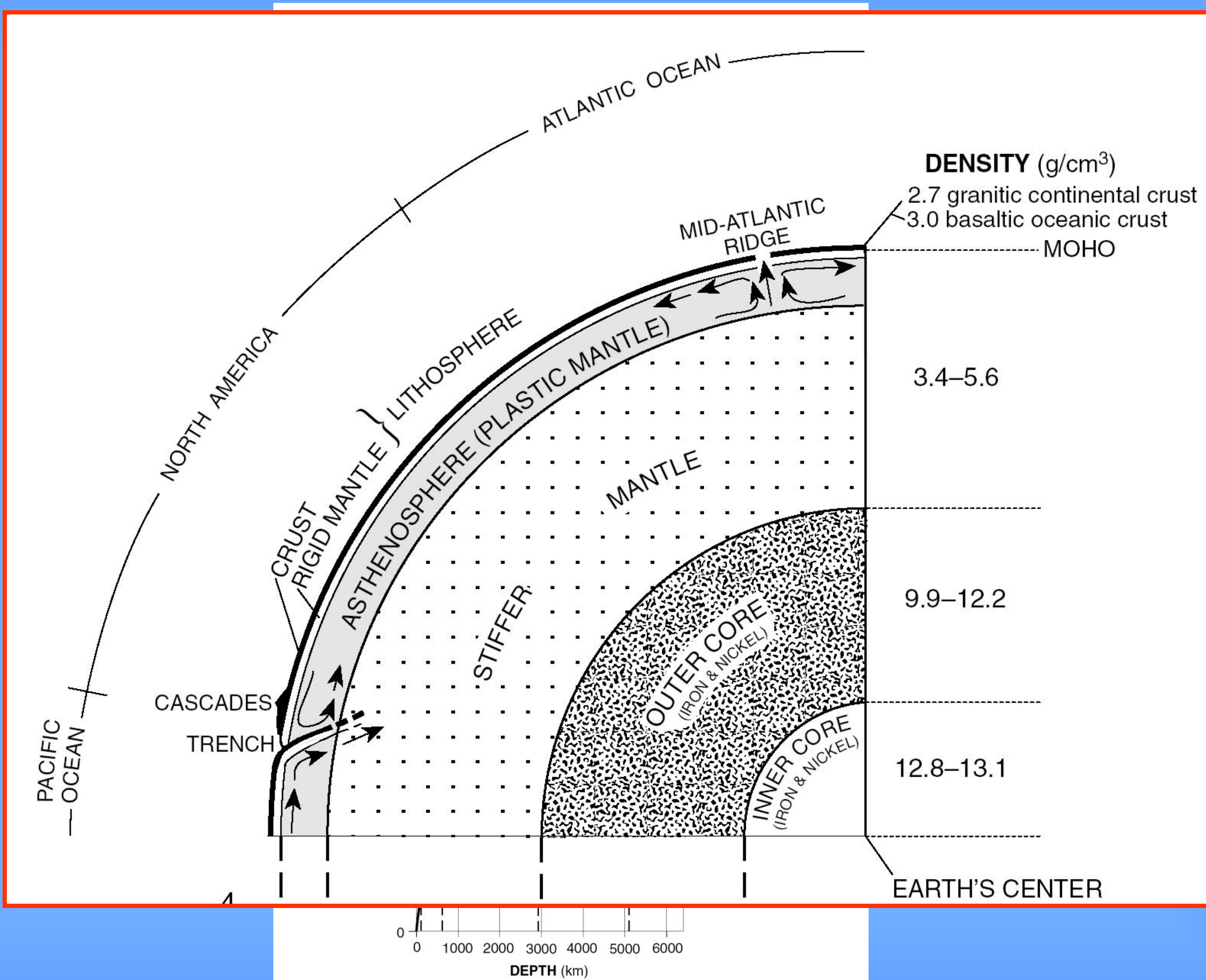
II. VOLCANIC ACTIVITY, IGNEOUS ROCKS AND PLATE TECTONICS

A. Plate Tectonics

Major Lithospheric Plates

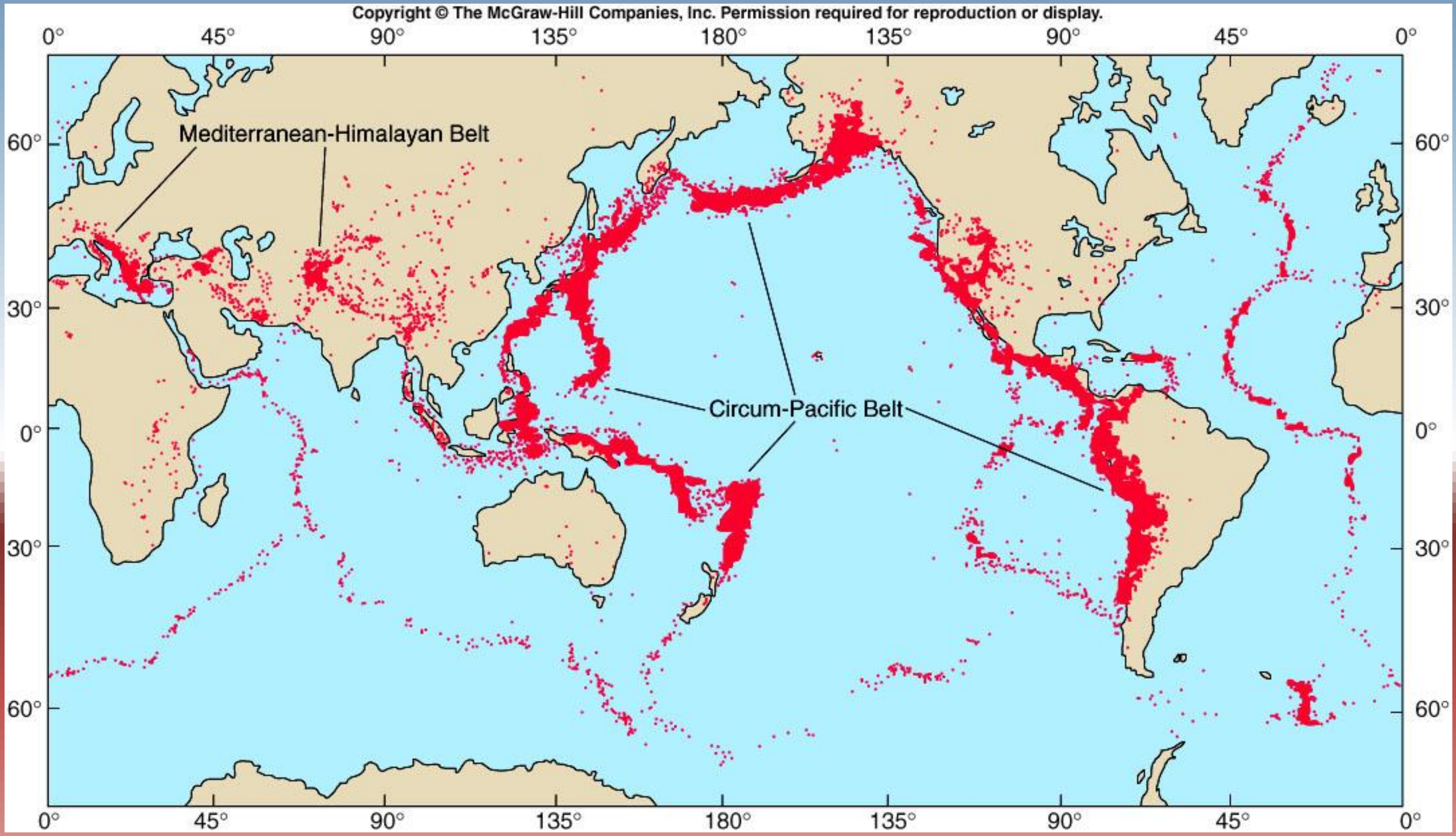


1. Lithosphere (**the upper mantle & crust**) is broken into **plates**.
2. Plates are moving relative to one another, sliding on the underlying **asthenosphere**, the partially molten plastic zone of the mantle.



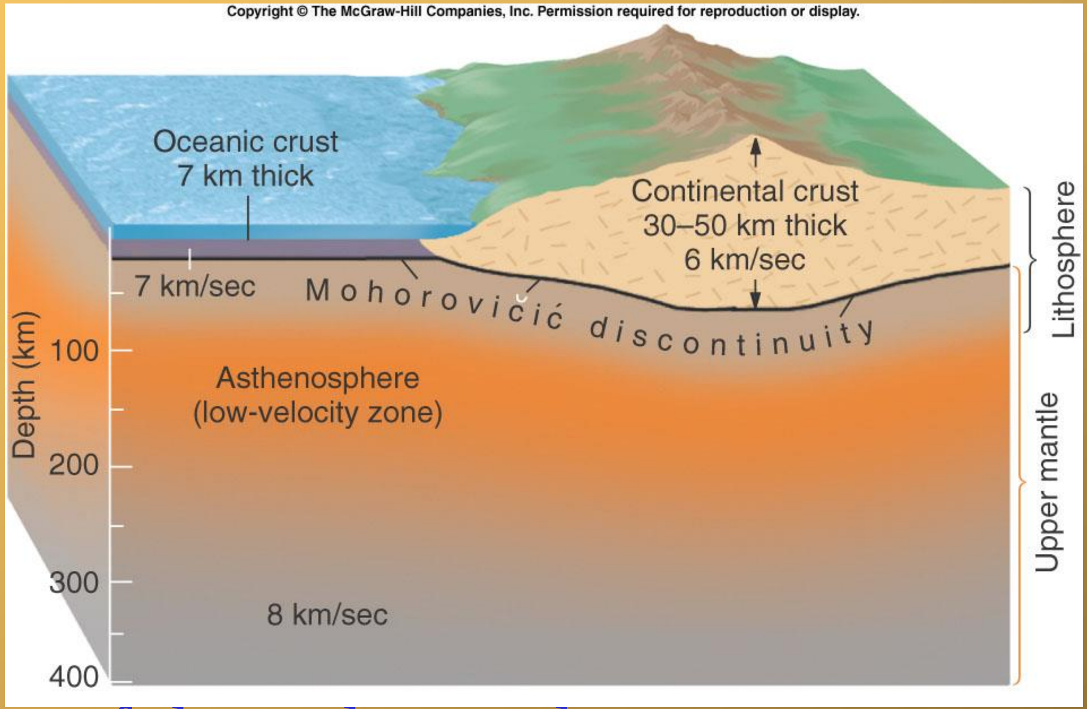
ATLANTIC OCEAN
NORTH AMERICA
PACIFIC OCEAN
DENSITY (g/cm3)
2.7 granitic continental crust
3.0 basaltic oceanic crust
MOHO
MID-ATLANTIC RIDGE
LITHOSPHERE
CRUST
RIGID MANTLE
ASTHENOSPHERE (PLASTIC MANTLE)
MANTLE
STIFFER
CASCADES
TRENCH
OUTER CORE
(IRON & NICKEL)
INNER CORE
(IRON & NICKEL)
3.4–5.6
9.9–12.2
12.8–13.1
EARTH'S CENTER
0
0 1000 2000 3000 4000 5000 6000
DEPTH (km)

World Distribution of Earthquakes



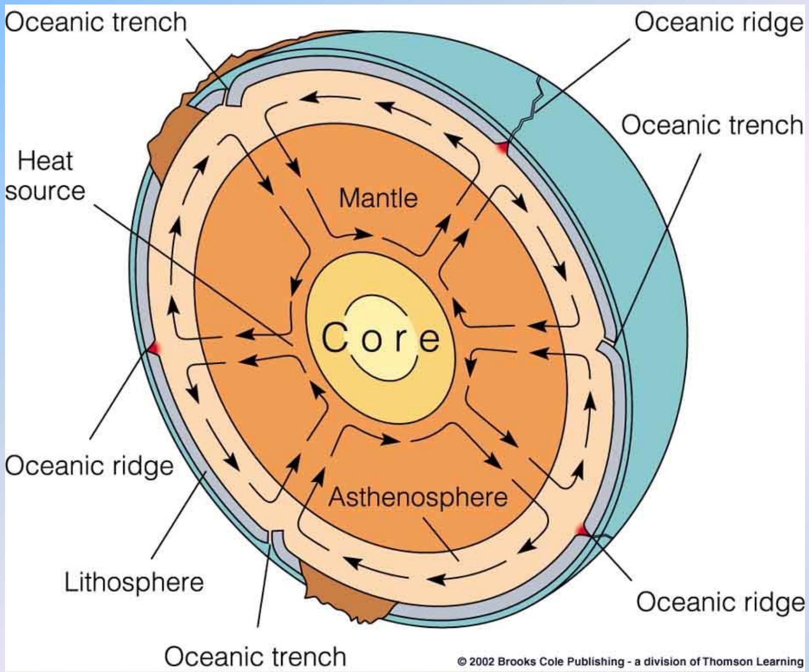
- Earthquakes with focal depths between 0 and 670 km
- Over a six-year period

The lithospheric plates overlie hotter and weaker semiplastic asthenosphere



- Movement of the asthenosphere
  - results from some type of heat-transfer system within the asthenosphere
  - and causes the plates above to move

Thermal Convection Currents

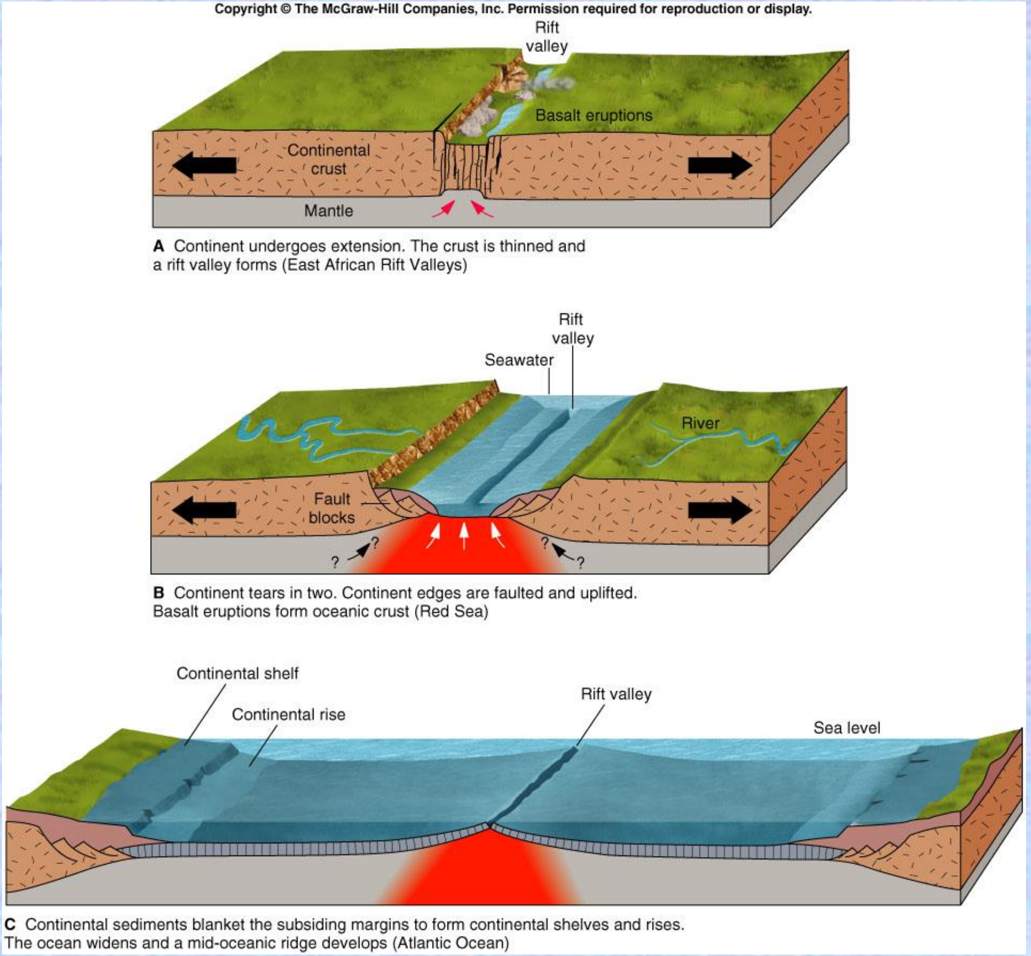


- In the asthenosphere but may possibly extend throughout the entire mantle.
- Drive the plates a few centimeters per year.

B. Plate Boundaries are where two plates meet.

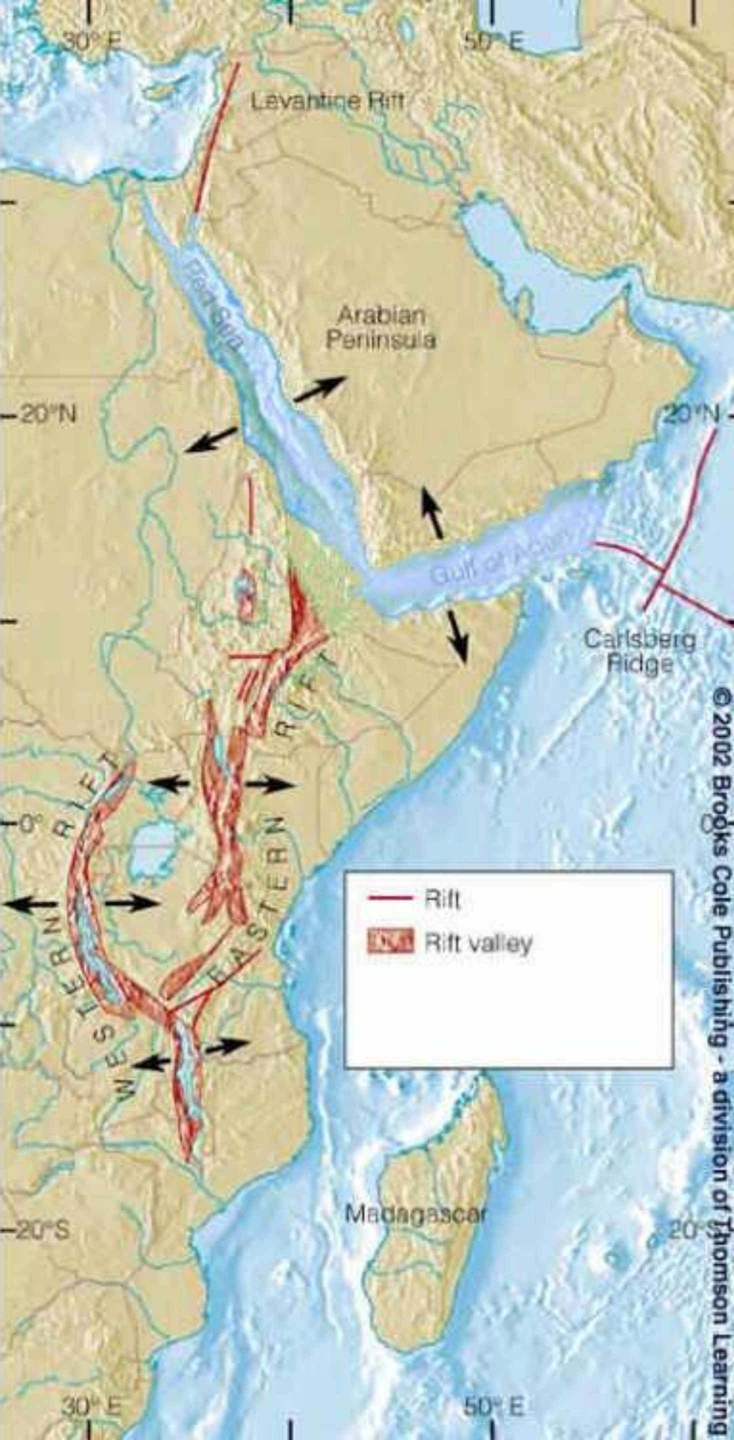
- Volcanoes are concentrated on two boundaries
  - Subduction zones and
  - Rifts

1. Divergent Boundaries

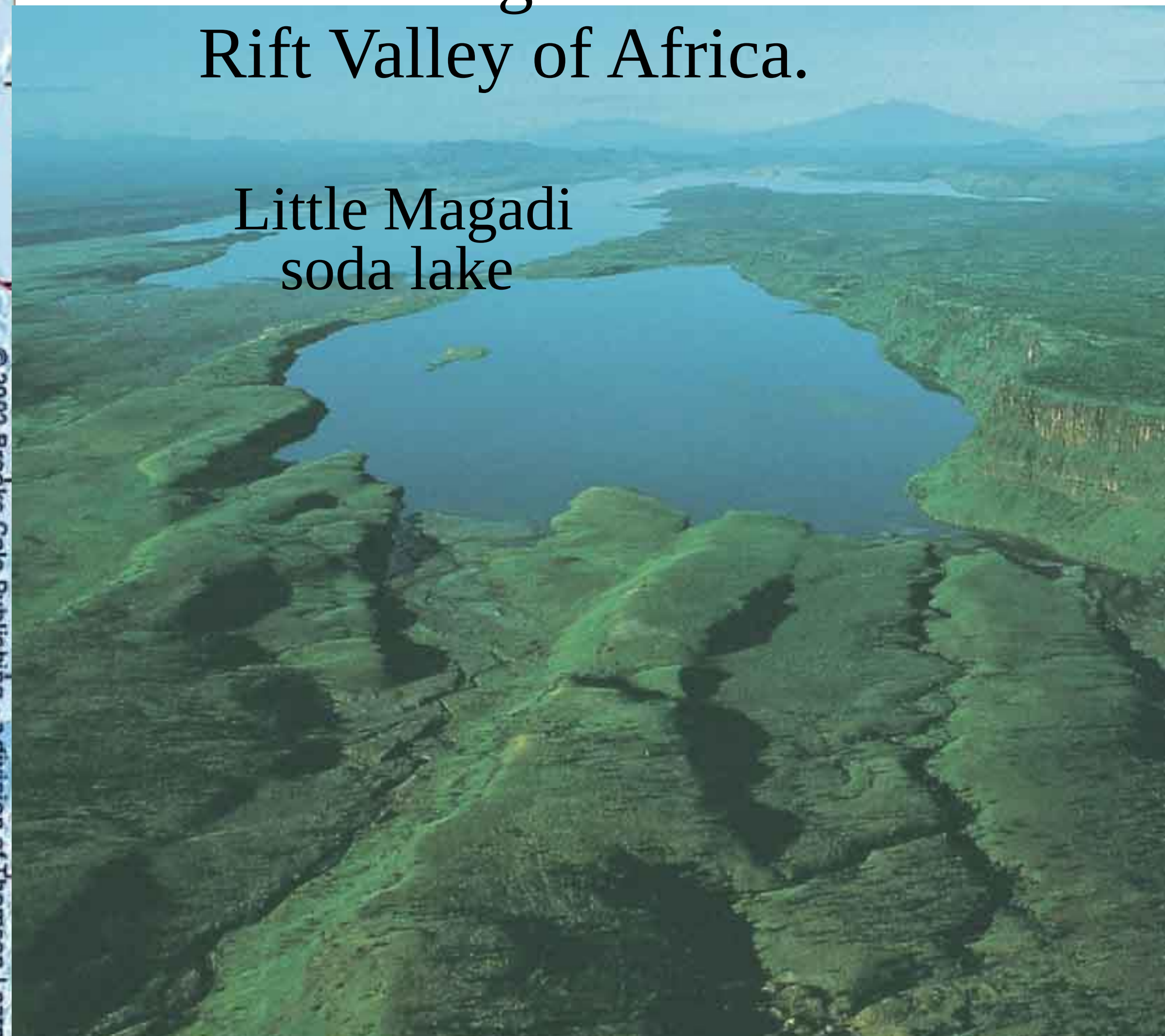


- Most coincide with mid-ocean ridges
- Forms 2.4 square kilometers of new seafloor per year
- An estimated 20 submarine eruptions occur each year

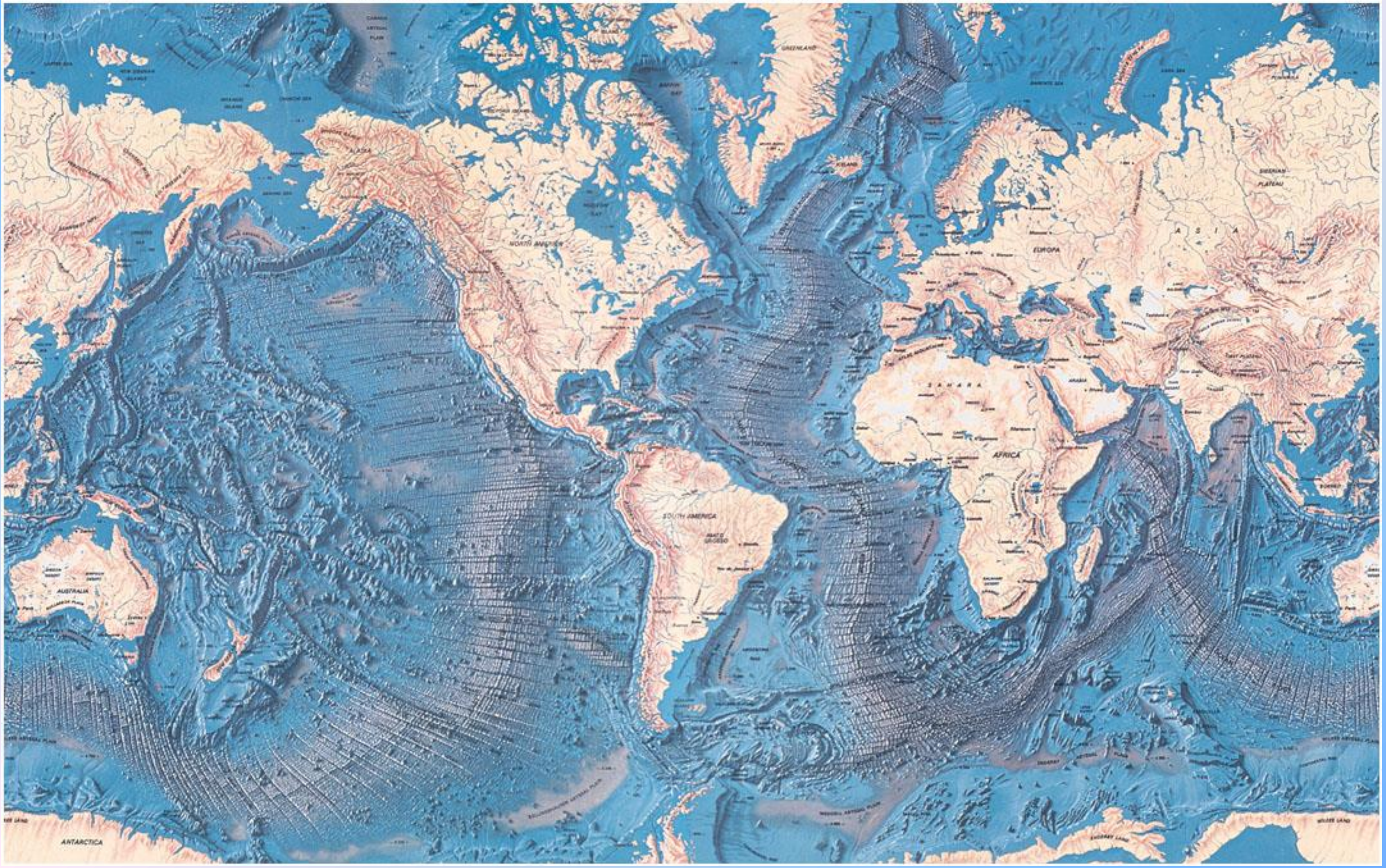
Modern Divergence



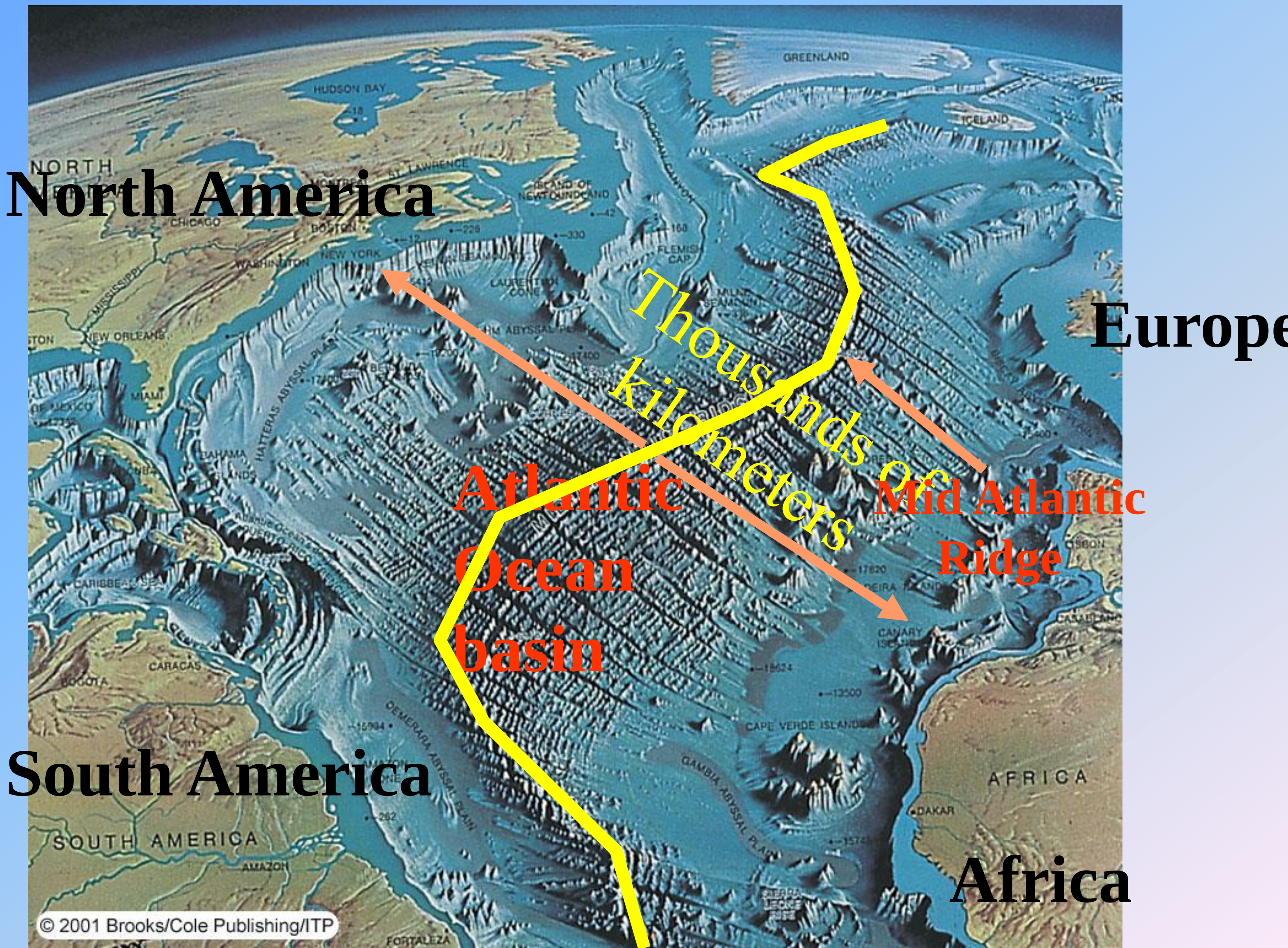
View looking down the Great Rift Valley of Africa.



The Ocean Floor

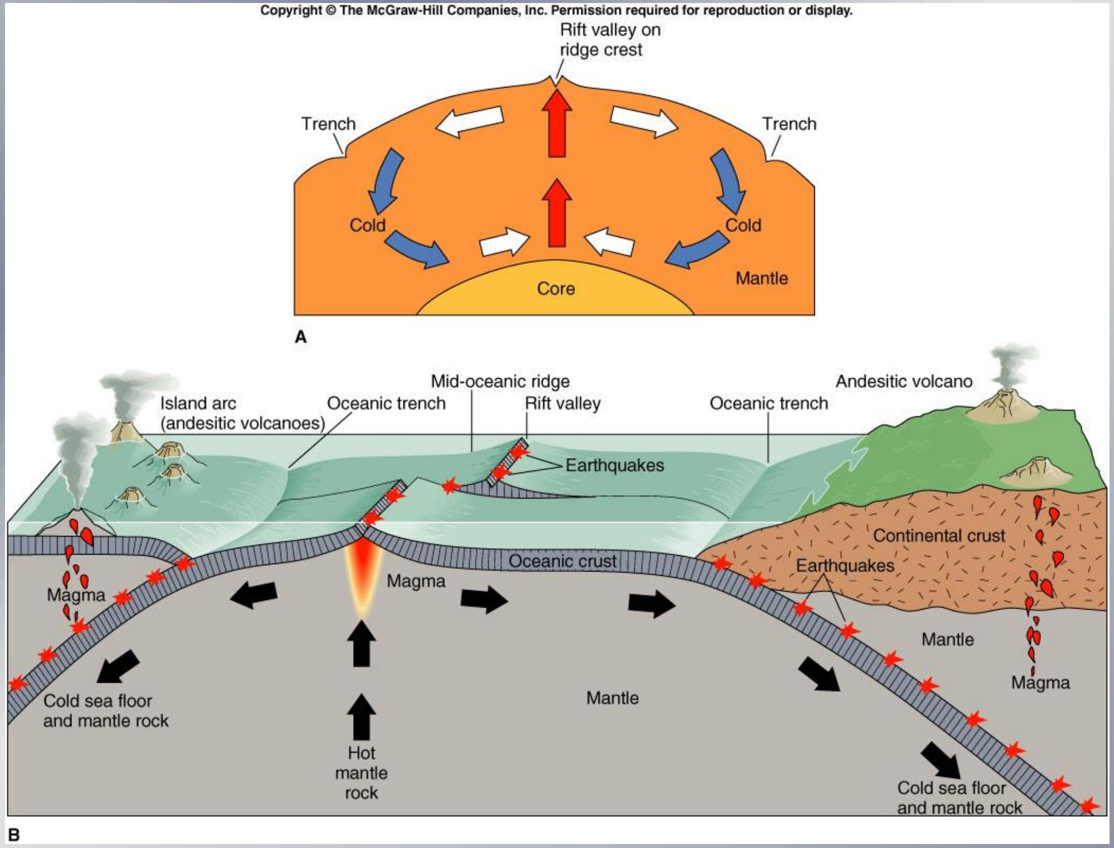


Atlantic Ocean Basin



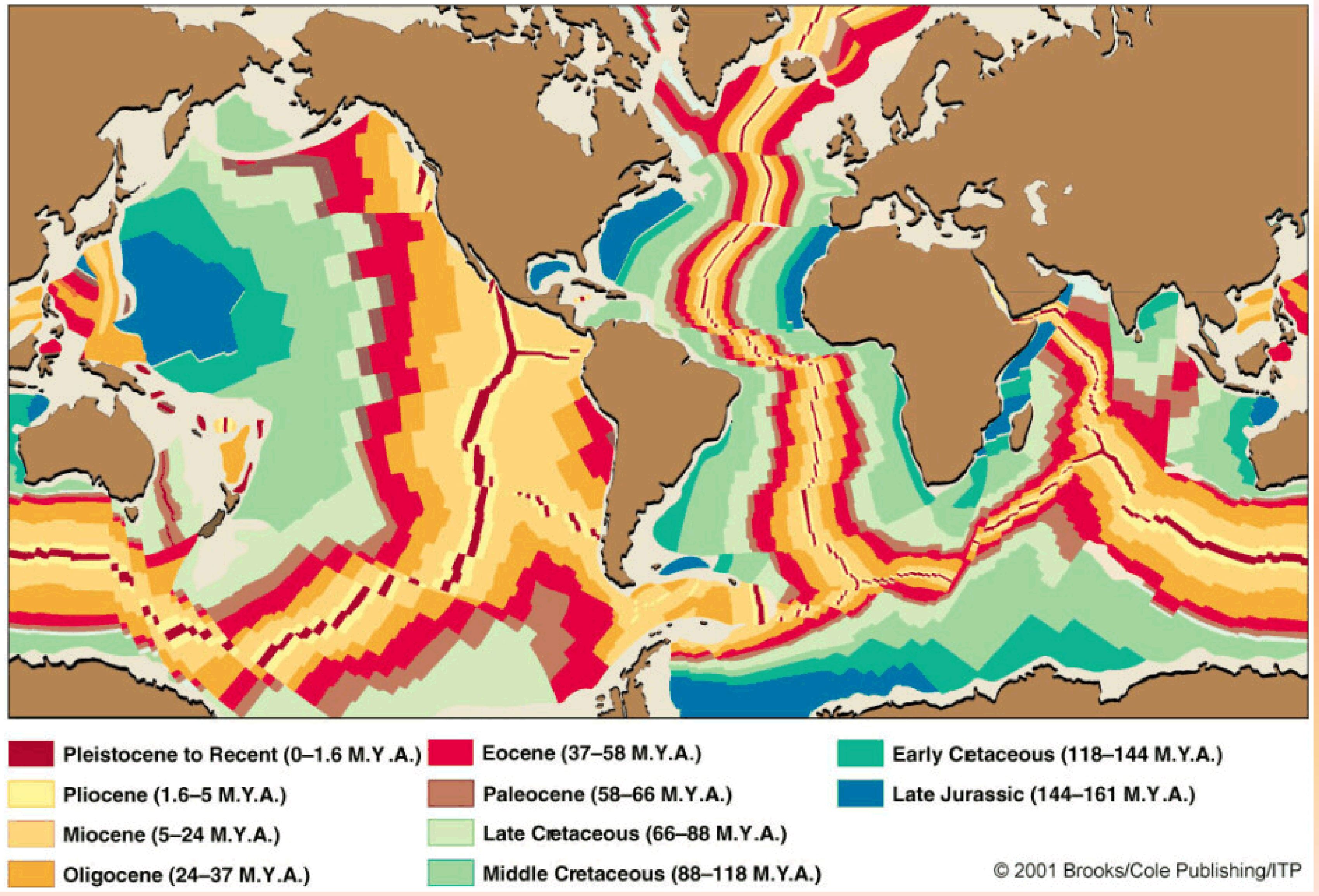
Oceanic Ridges

Divergent boundaries most commonly occur along the crests of oceanic ridges



- Ridges have:
  - rugged topography resulting from displacement of rocks along large fractures
  - shallow earthquakes

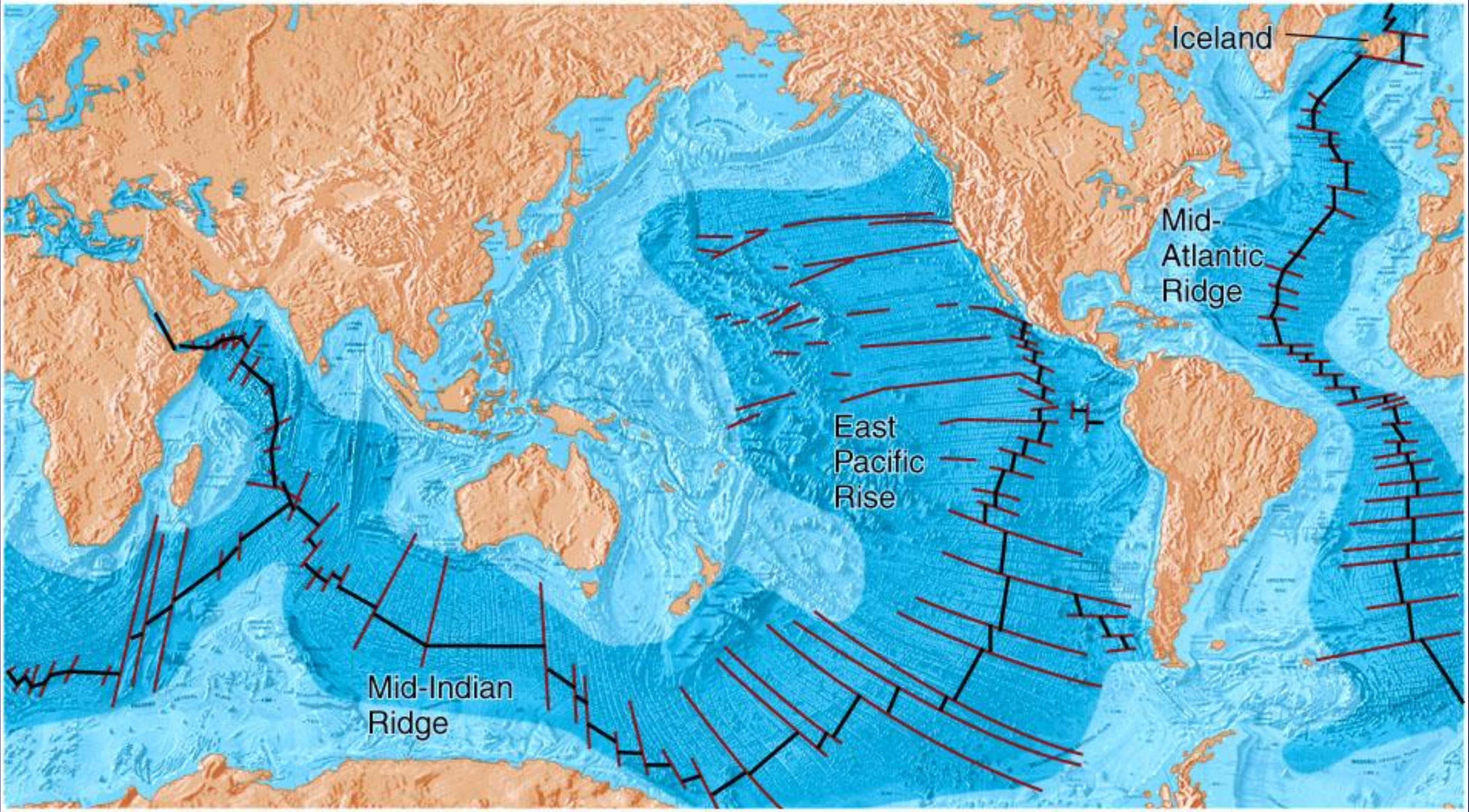
Age of Ocean Basins



2. **Transform Boundaries**

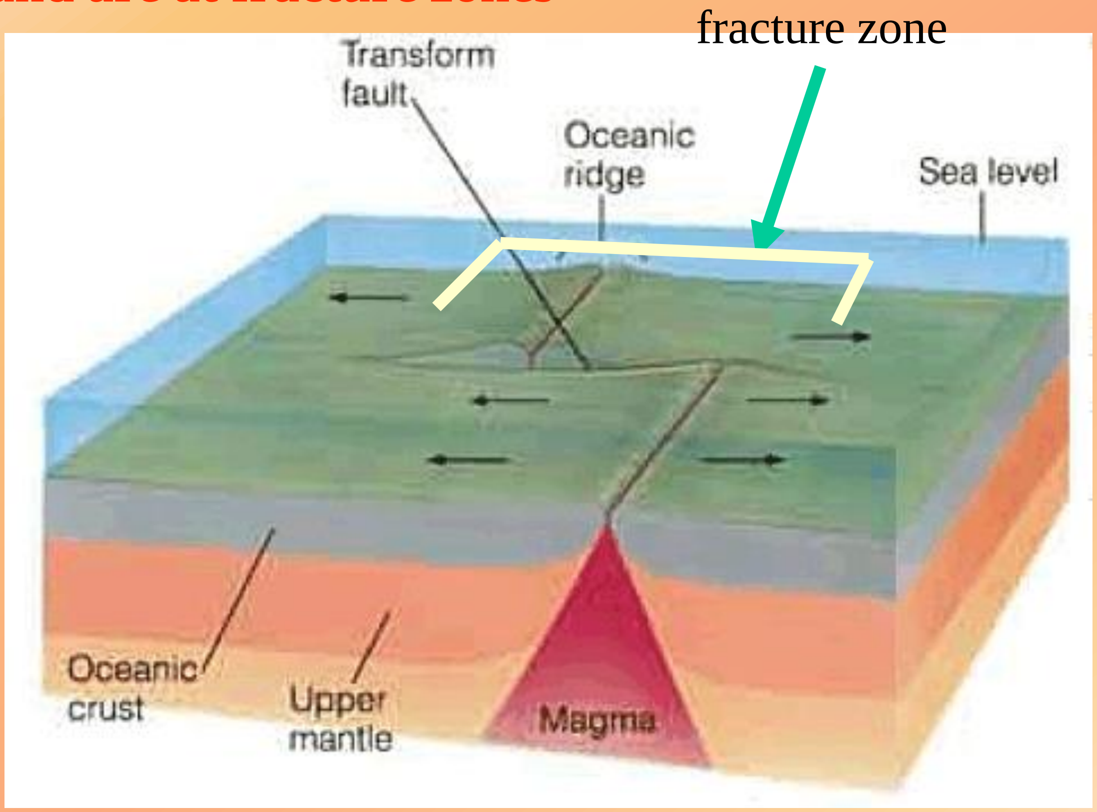
- Where adjacent plates slide past one another
- Not sites of igneous activity

Fracture Zones and Transform Faults



Transform Motion is not restricted to Plate Boundaries

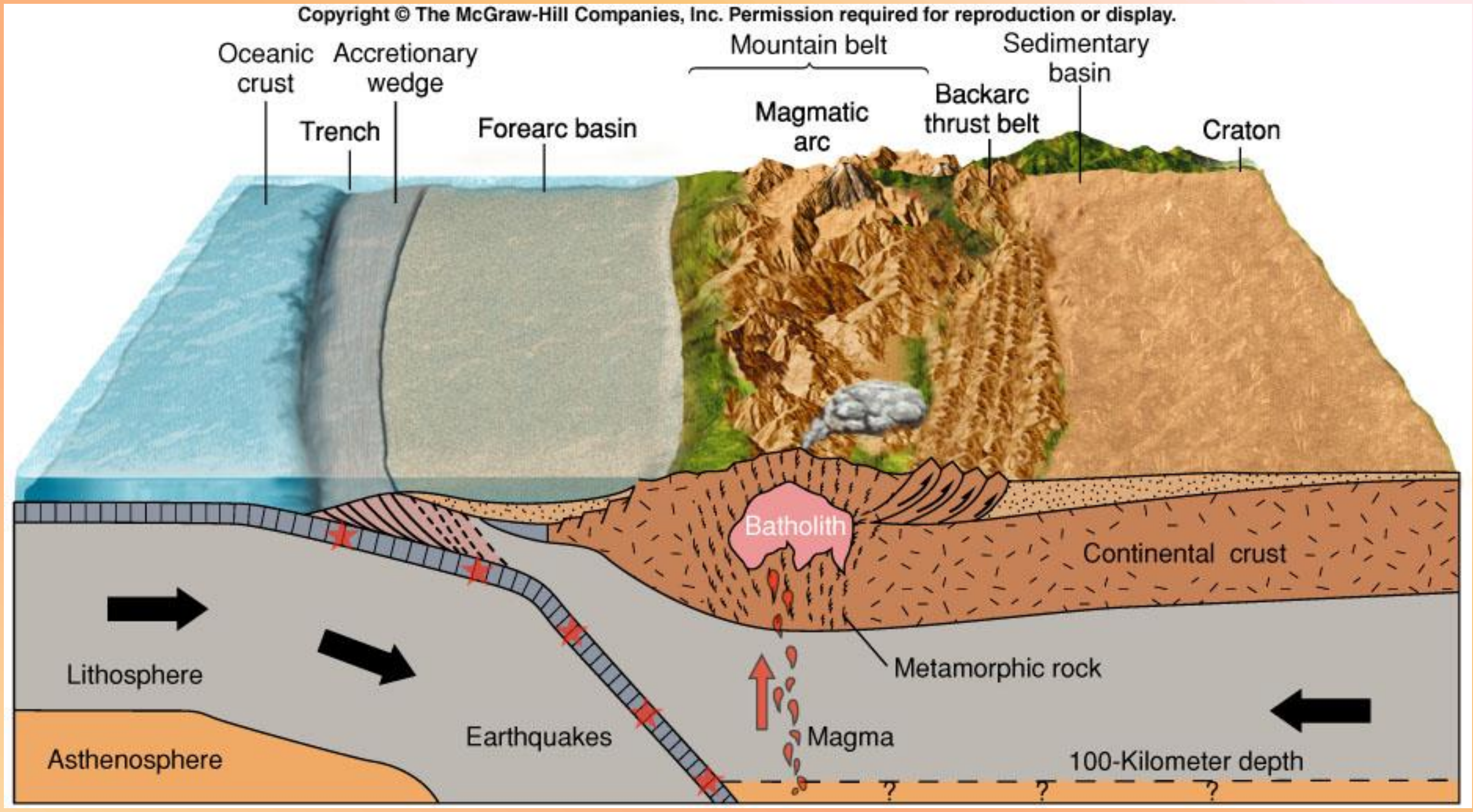
- **The majority of transform faults**
  - **connect two oceanic ridge segments**
  - **and are at fracture zones**



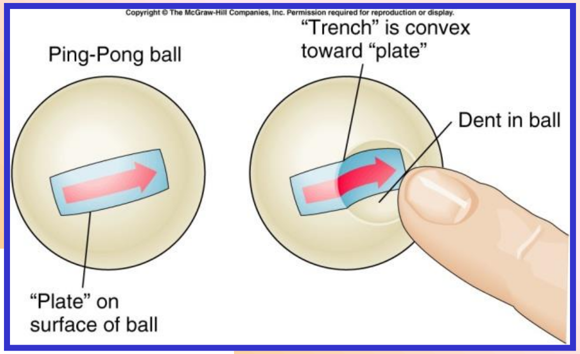
3. <u>Convergent Boundaries</u>

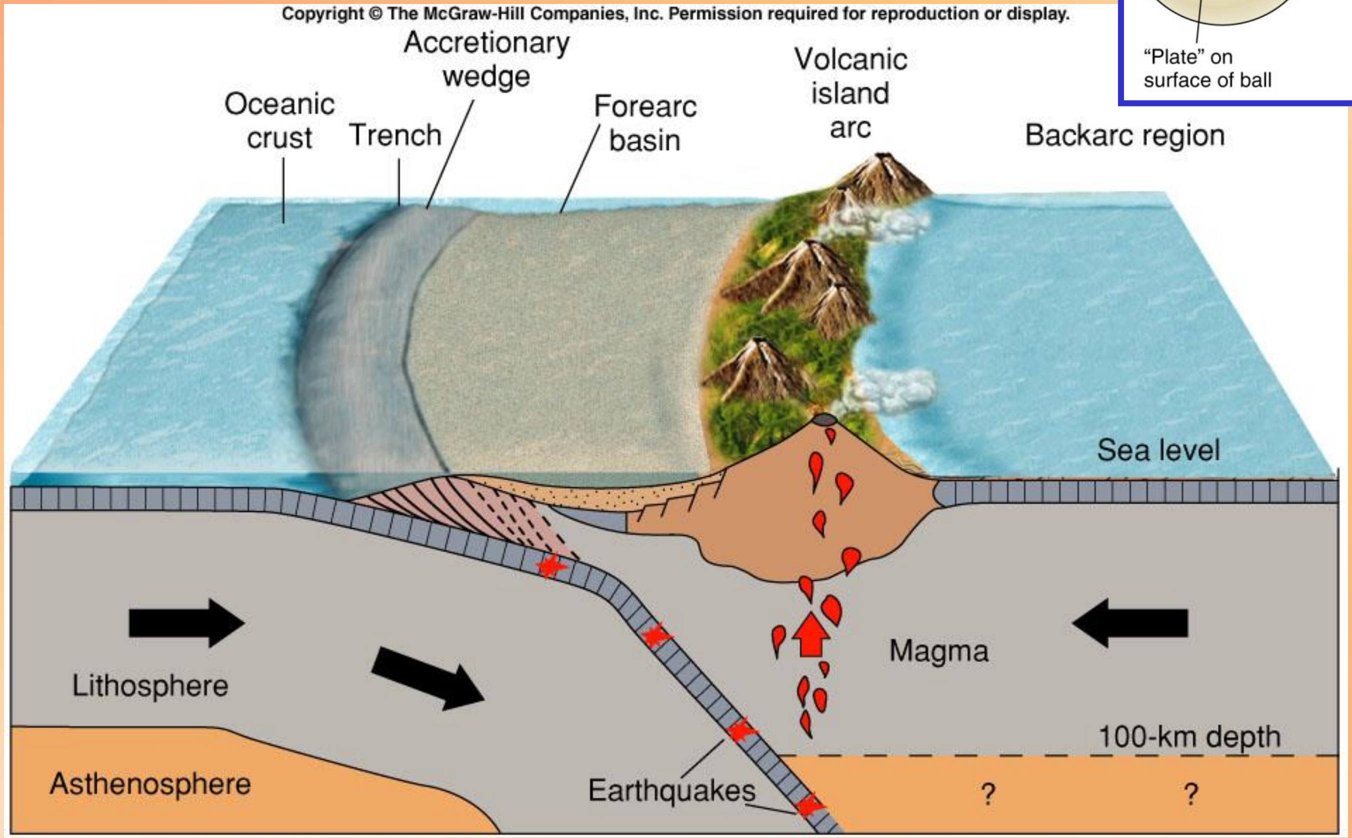
- **Plates move toward each other and collide.**

Ocean-Continent Convergence

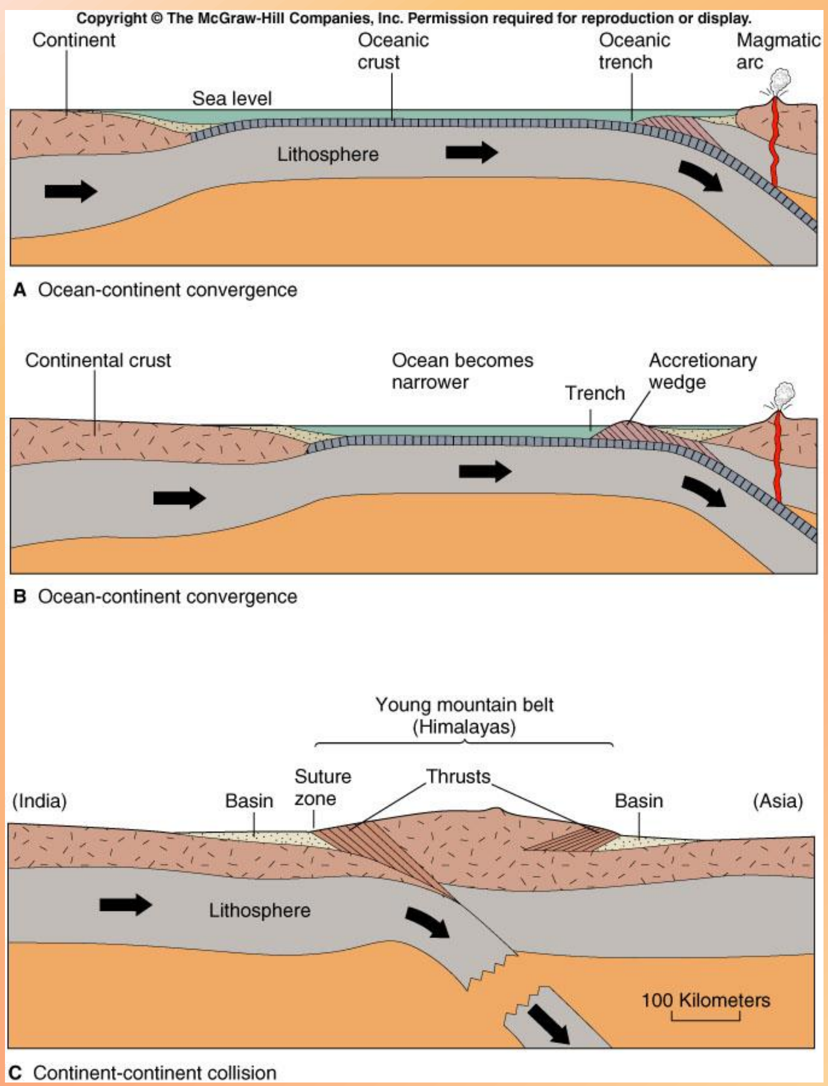


Ocean-Ocean convergence

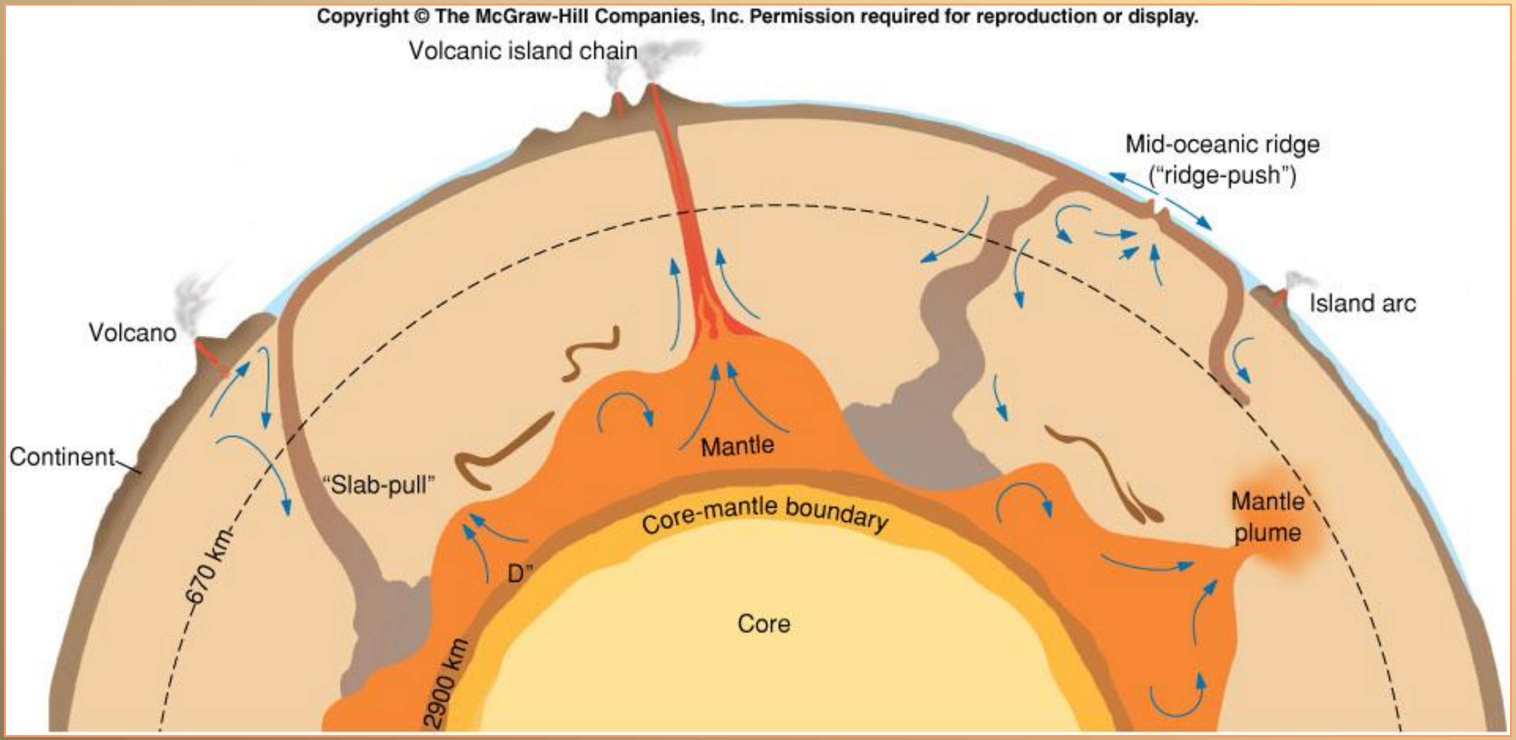


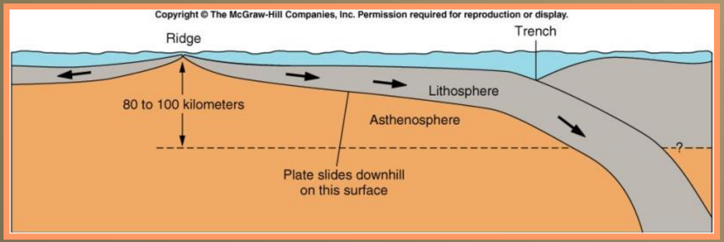


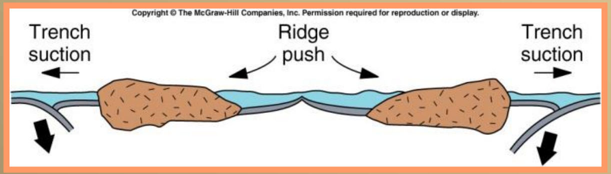
Continent-Continent Convergence



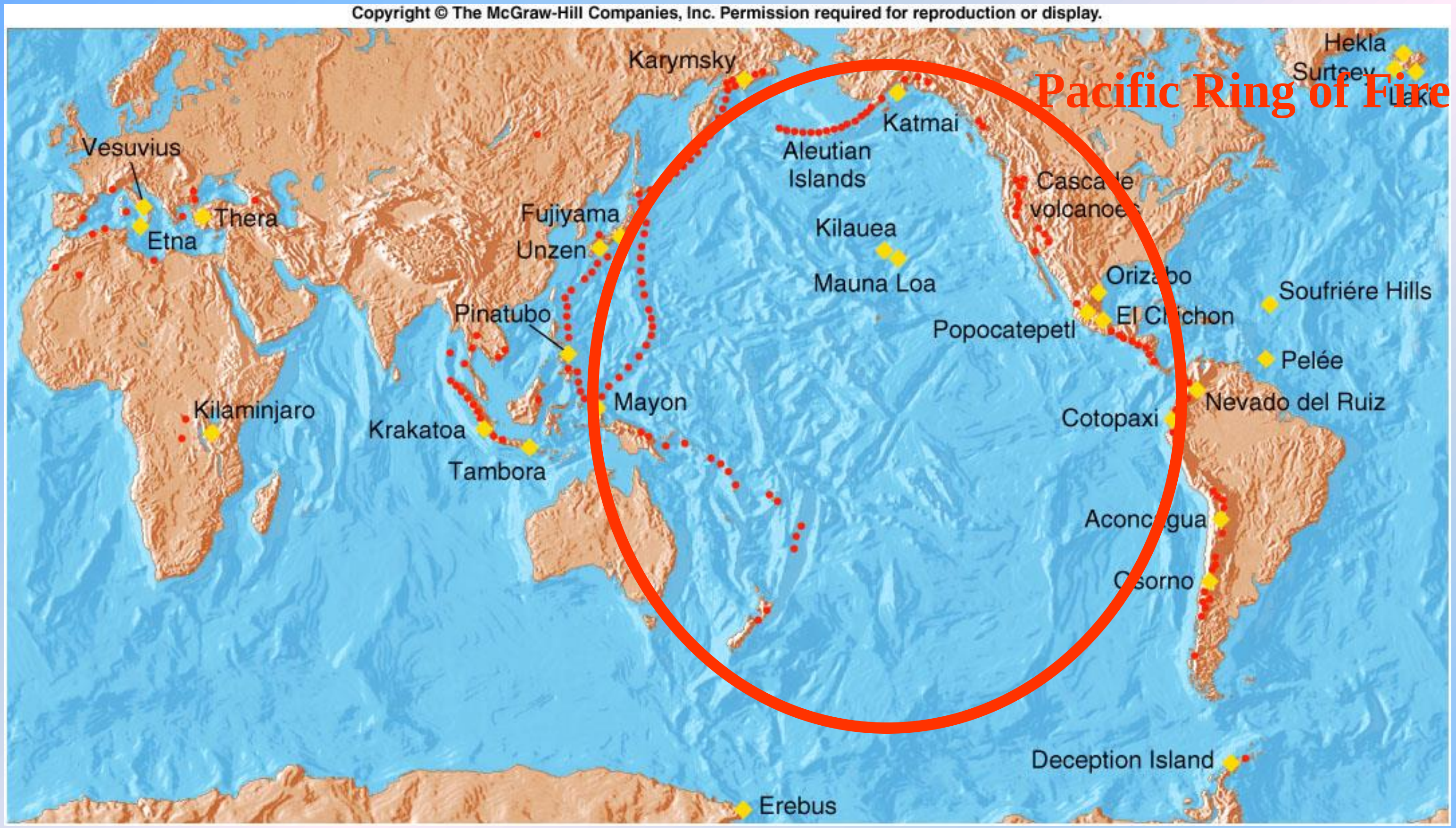
Mantle Convection and "*Ridge-Push*" and "*Slab-Pull*"







Subduction Volcanoes



Includes:

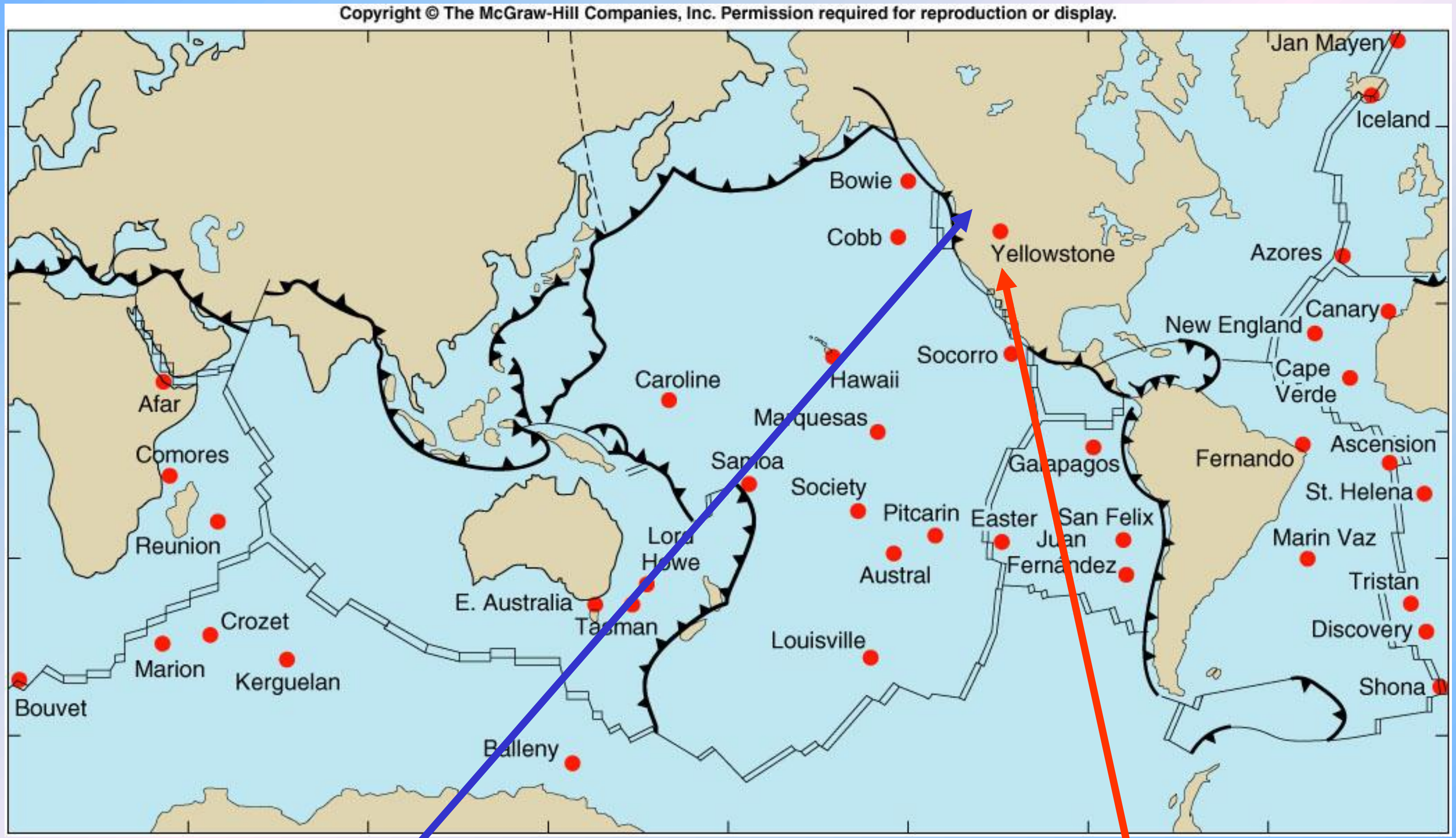
- Mt. St. Helens and the Cascade volcanoes of the U.S
- Mediterranean volcanoes of Greece and Italy

Cascade Range Volcanoes

C. Intraplate Igneous Activity

1. Volcanic activity at plate ____**interiors**____ not associated with ____**plate boundaries**____.
2. Location of hot mantle plumes (hot spots)
3. Columbia Plateau basalt in Washington and Oregon, and Yellowstone National Park.
4. Hawaiian Volcanism

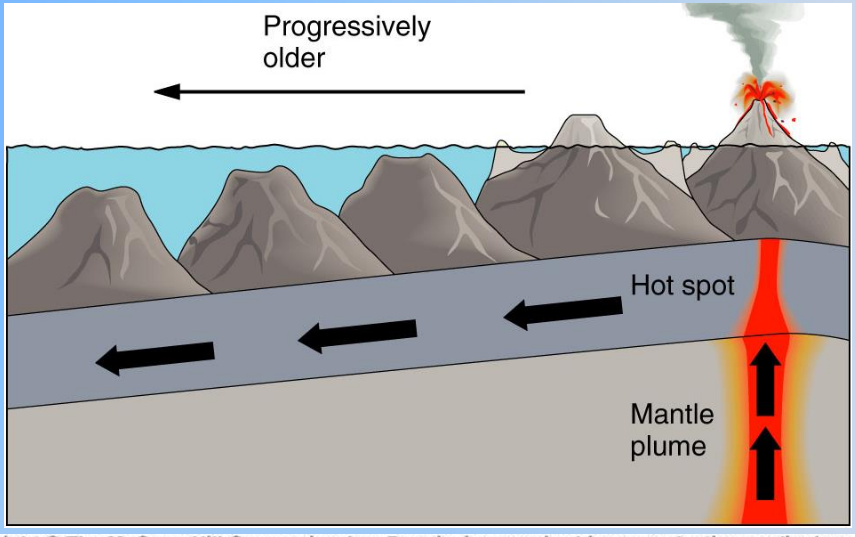
Mantle Hot Spots (Plumes)

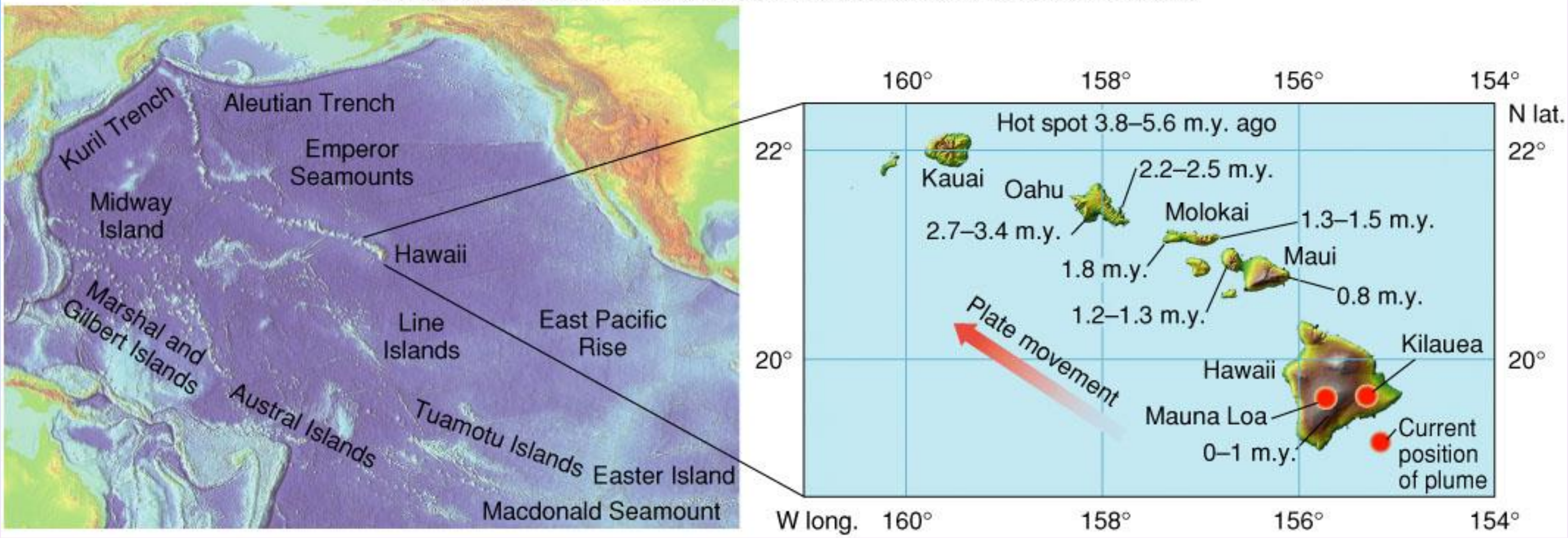


Columbia Plateau in Washington and Oregon

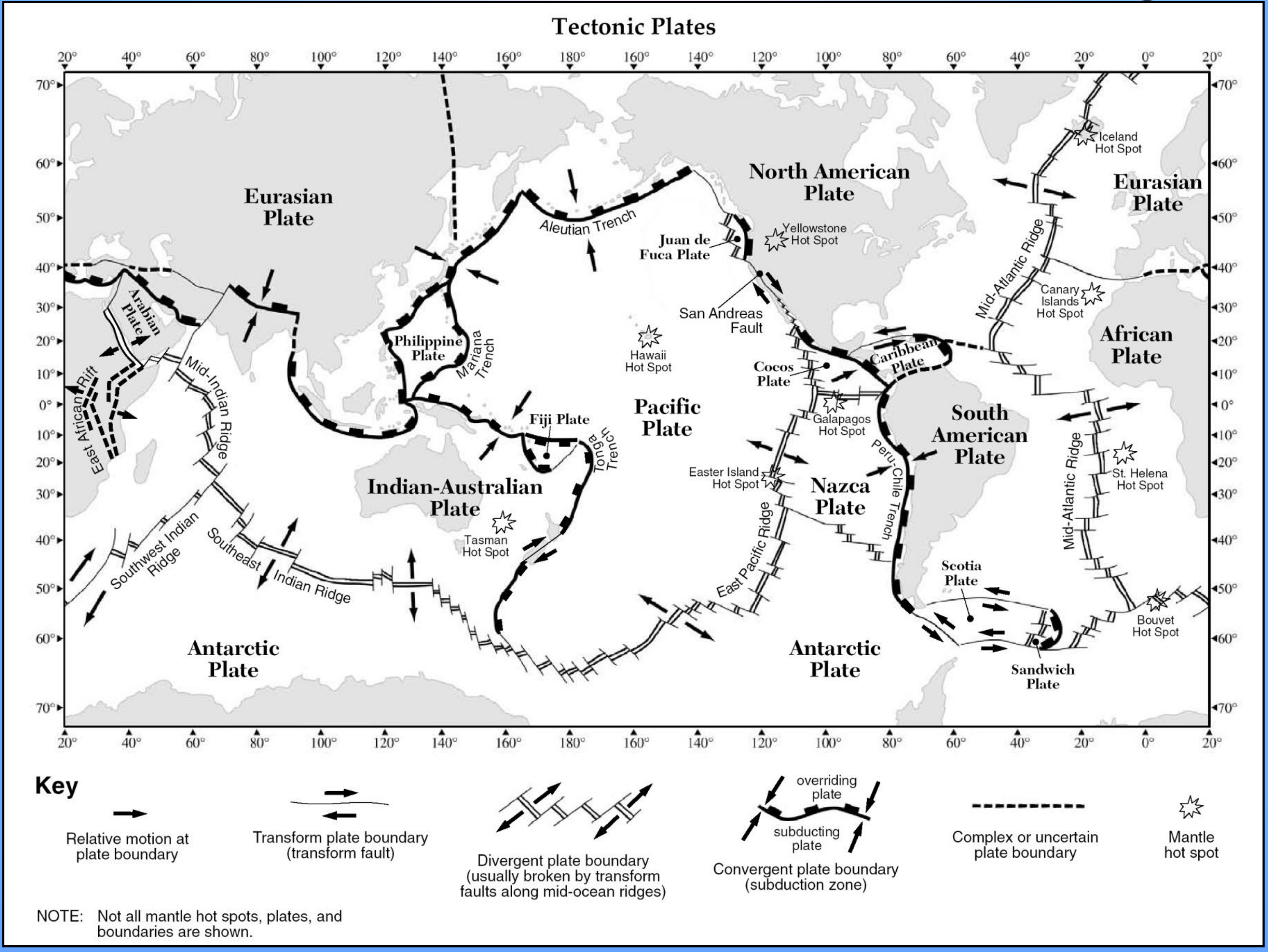
Yellowstone National Park, WY

Hawaiian Volcanism

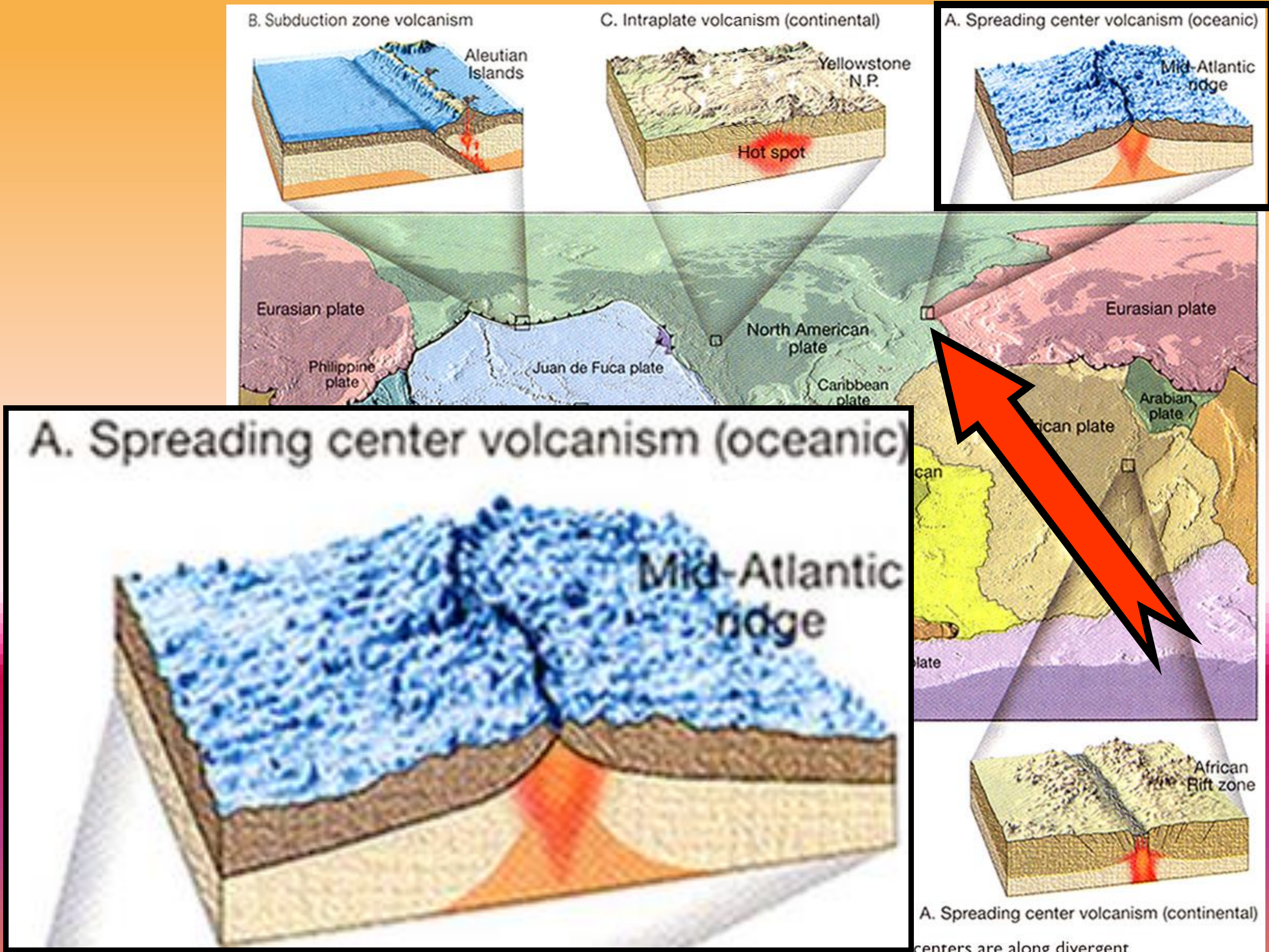




Earth Science Reference Tables Map



Summary of Tectonic Setting Where Volcanism Occurs



centers are along divergent plate boundaries. **B.** Subduction zones are along convergent plate boundaries. **C.** Intraplate volcanism occurs in isolated places within plates, away from boundaries.

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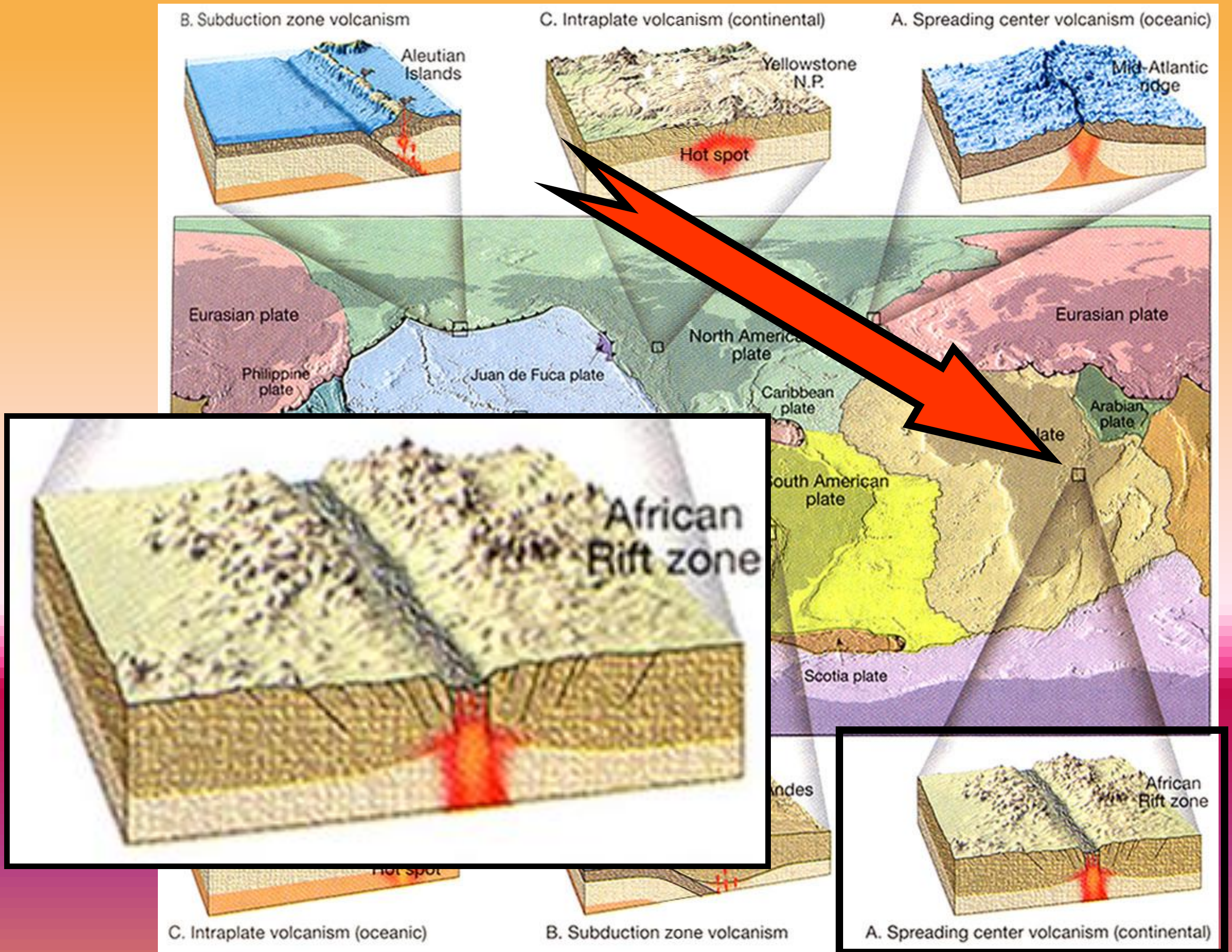

Three settings where volcanism occurs (two examples of each). **A.** Spreading centers are along divergent plate boundaries. **B.** Subduction zones are along convergent plate boundaries. **C.** Intraplate volcanism occurs in isolated places within plates, away from boundaries.

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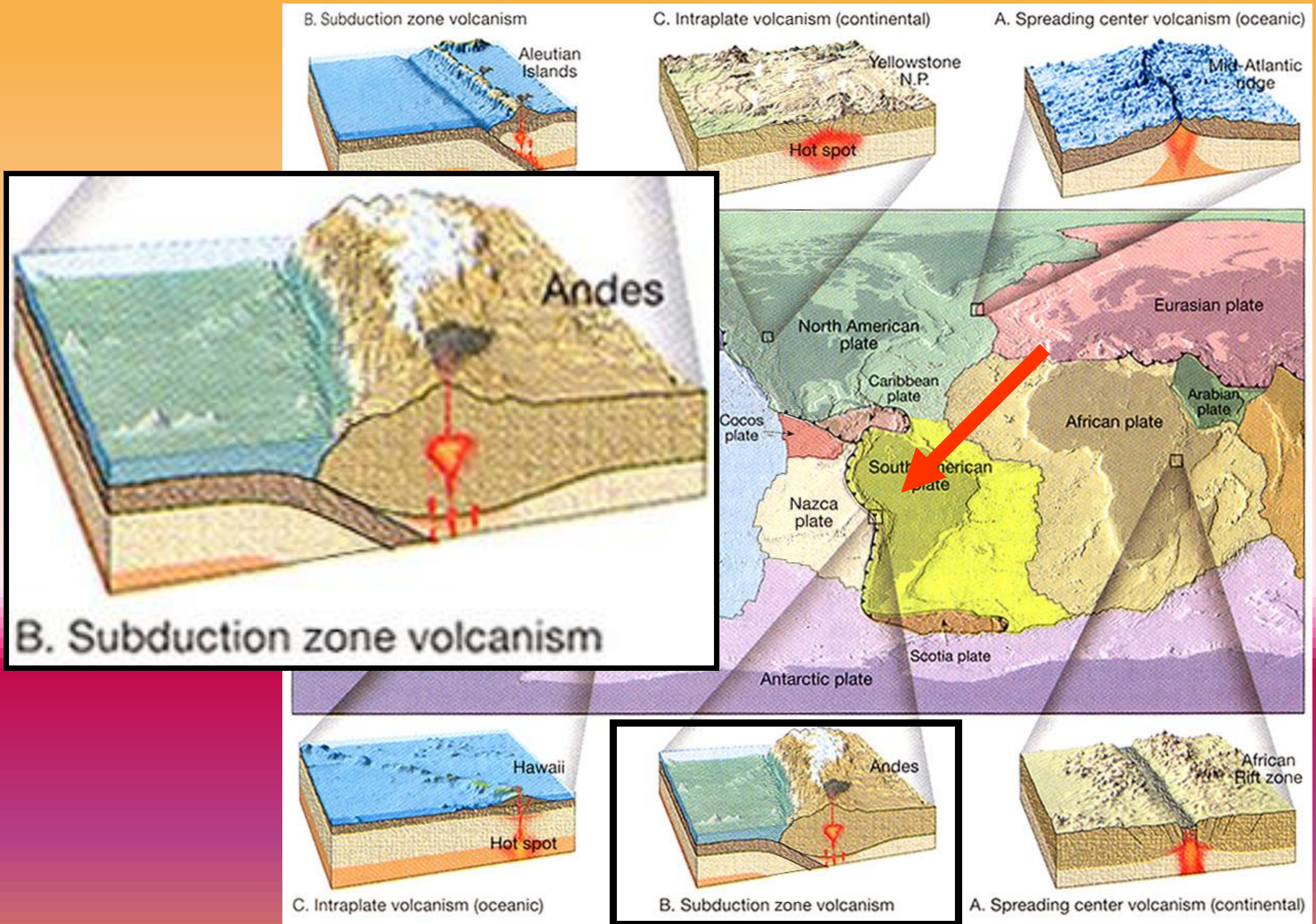

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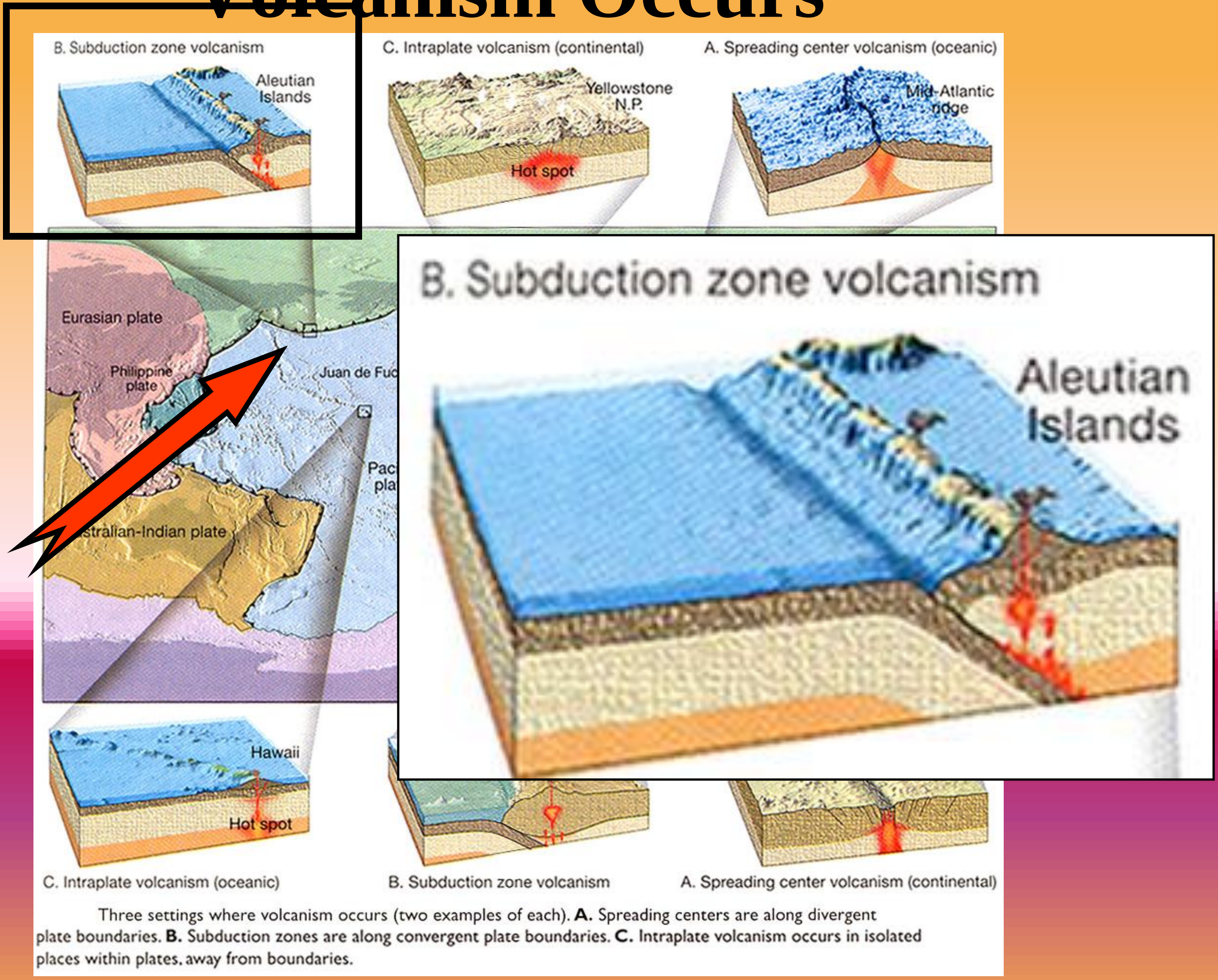
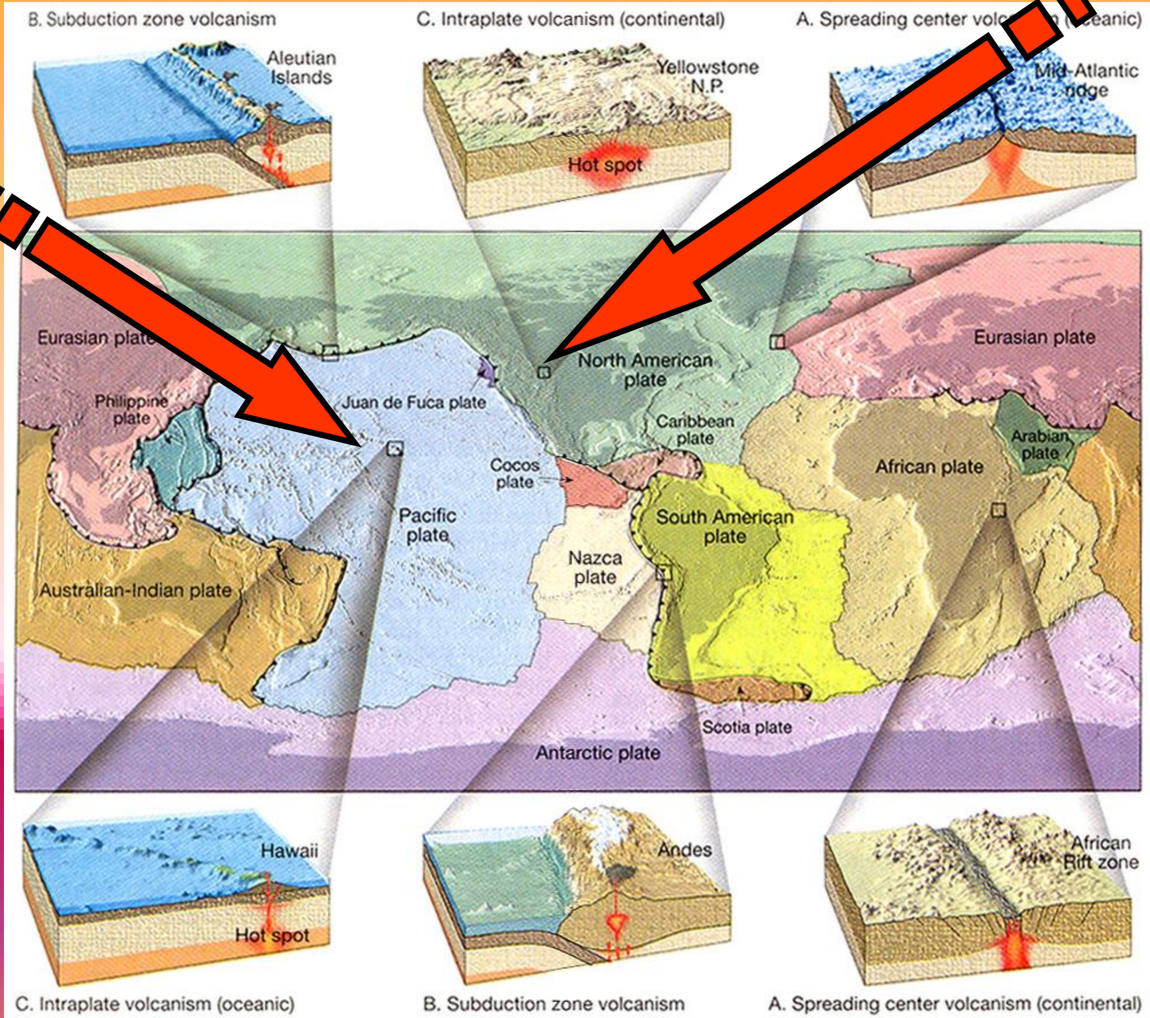


Summary of Tectonic Setting Where Volcanism Occurs

Yellowstone

Hawaii



Three settings where volcanism occurs (two examples of each). **A.** Spreading centers are along divergent plate boundaries. **B.** Subduction zones are along convergent plate boundaries. **C.** Intraplate volcanism occurs in isolated places within plates, away from boundaries.

Identification of Igneous Rocks

A. __**Texture**____:This refers to the size, shape, and boundary relations between adjacent minerals in a rock mass.

1. Textures of igneous rocks develop primarily in response to the magma's ***rate of cooling*** and its viscosity.

a) Generally, the __**slower**__ the cooling of the magma, the larger the grain size. Atoms in a very viscous lava cannot move as freely as those in a very fluid lava. As a result, more viscous lavas are more likely to have larger grain sizes.

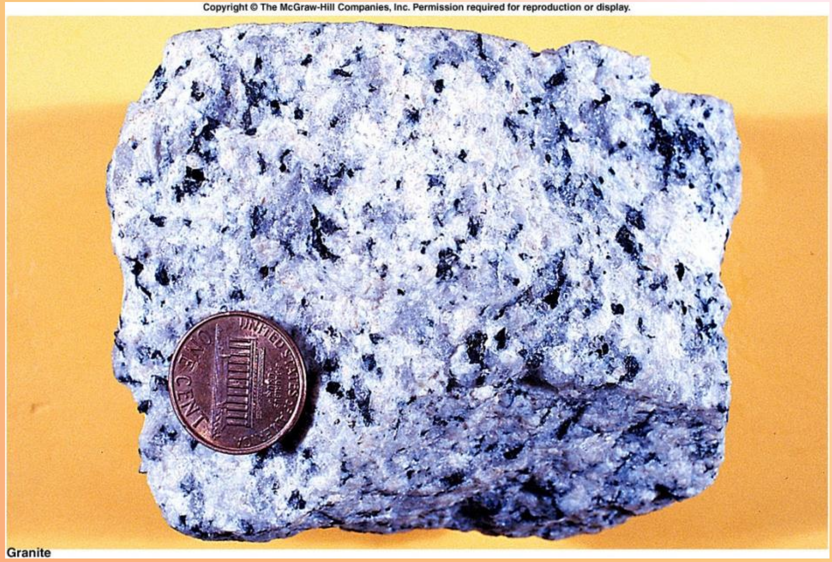
b) As a result, more *viscous* lavas are more likely to have *larger* grain sizes.

2. **Intrusive** (PLUTONIC) IGNEOUS ROCKS:

- Magmas deep within Earth's crust cool very slowly. Individual crystals are more or less uniform in size and may grow to 2 centimeters or more in diameter.

a)__**Coarse Grained**___(Phaneritic)

- Individual minerals are large enough to be plainly visible
- 1 mm or larger



Granite

Gabbro

b) Very Coarse Grained

- *Pegmatites consist of large crystals*
- *Measured in centimeters or even meters*
- *Usually granitic*

3. ___Extrusive___ (Volcanic) Igneous Rocks

- A magma extruded out onto Earth's surface cools rapidly and the crystals have only a short time to grow.
- Crystals from such a magma are typical so small that they can rarely be seen without the aid of a microscope.
- The rock appears massive and structureless.

a) Fine grained (aphanitic)

- Crystals can't be seen without a microscope
- Contain small interlocking crystals

Basalt

b) <u>**Glassy**</u> Extremely rapid cooling.

- Non-crystalline
  - Metamict mineraloid composition
- Appearance of
  - Ordinary glass
  - Thread-like mesh

B. Color

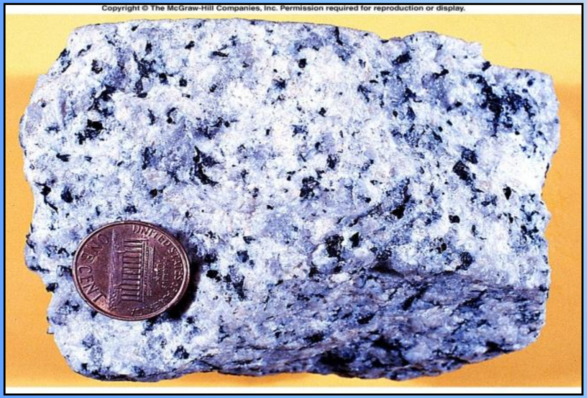
a) **Color is based upon the *mineral composition* of the rock.**

Generally the lighter colored igneous rocks are **felsic** and the darker igneous rocks are **mafic**.

a) *Light* Colors: White, tan, gray, pink, red
b) *Intermediate* (Medium) Colors: darker gray, green
c) *Dark Colors*: dark green, dark gray, black.

2. **Colors result from Magmas of Different Composition**

Comparing Color: Intrusive Rocks



Light (Granite)

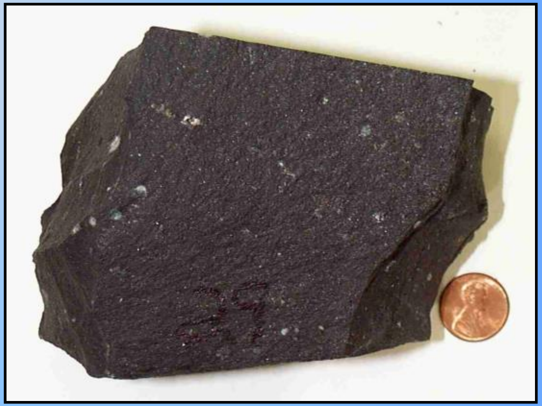
Intermediate (Diorite)

Dark (Gabbro)

Comparing Color: Extrusive Rocks

Light
(Rhyolite)

Intermediate
(Andesite)

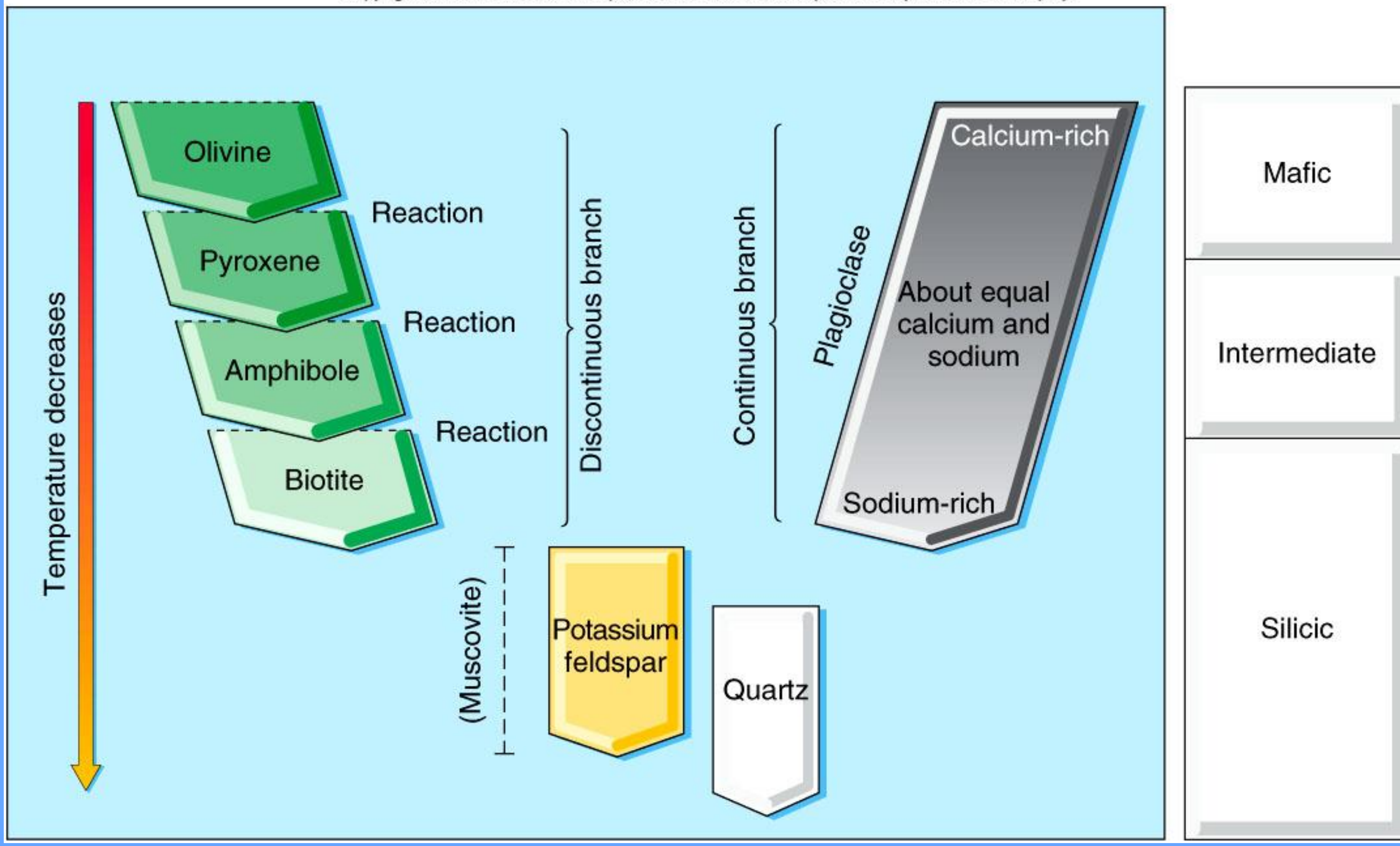


Dark
(Basalt)

a) **Differentiation**

- The process by which different ingredients separate from an originally homogeneous mixture
- **Bowen's** Reaction Series

Bowen's Reaction Series

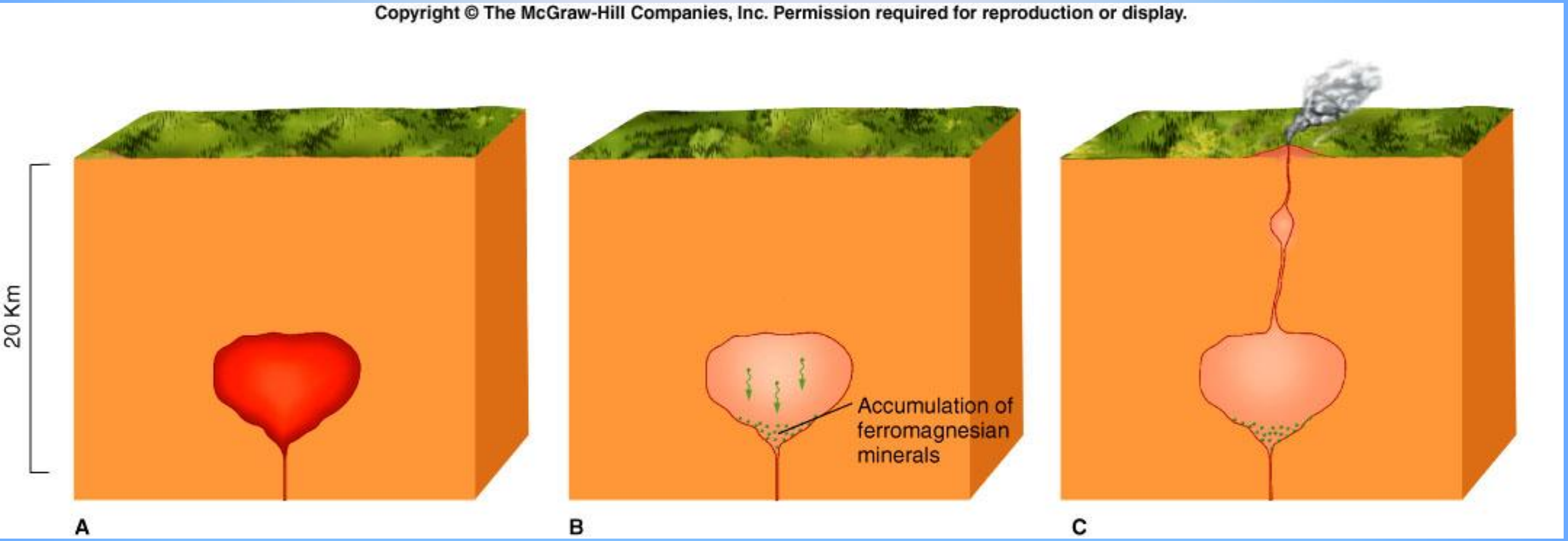


b) Partial Melting

- As a rock melts, the first portion of the rock melts.

- Liquid with the chemical composition of quartz and potassium feldspar is “sweated out.”
- It can accumulate into a pocket of felsic magma.
- Mafic rock can also sweat out at higher temperatures.

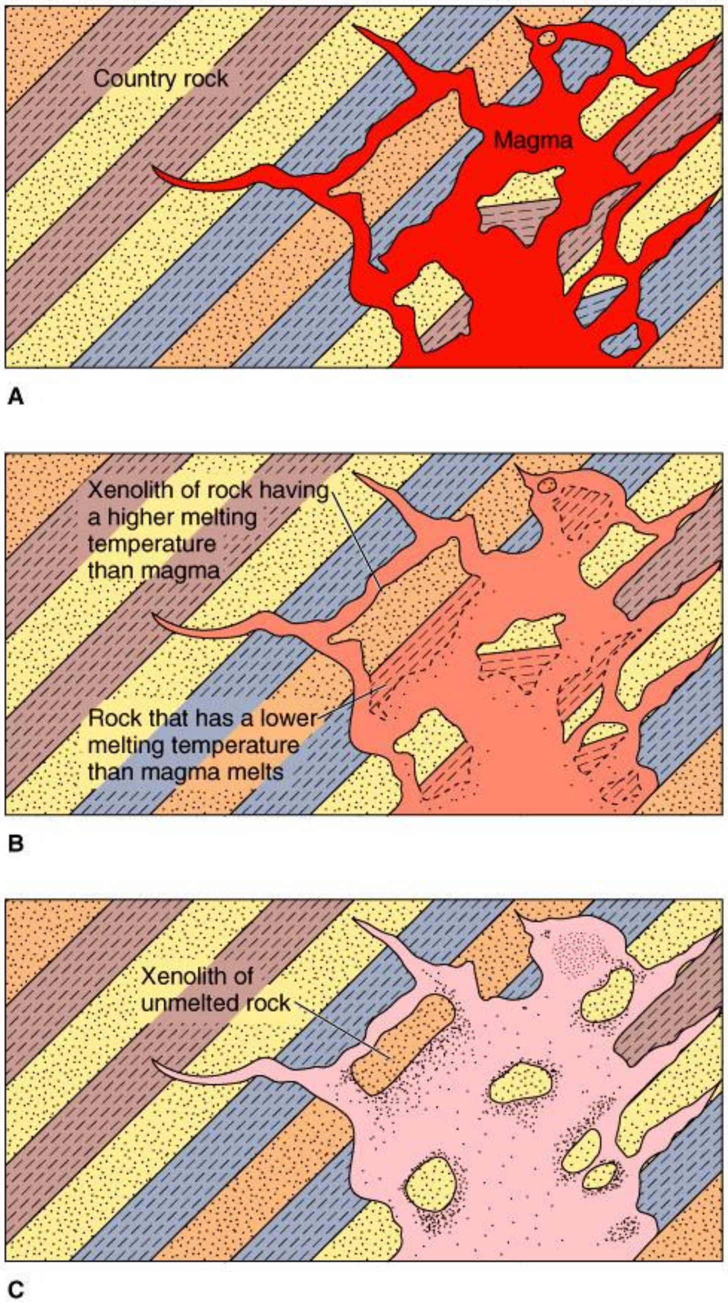
c) Crystal Settling



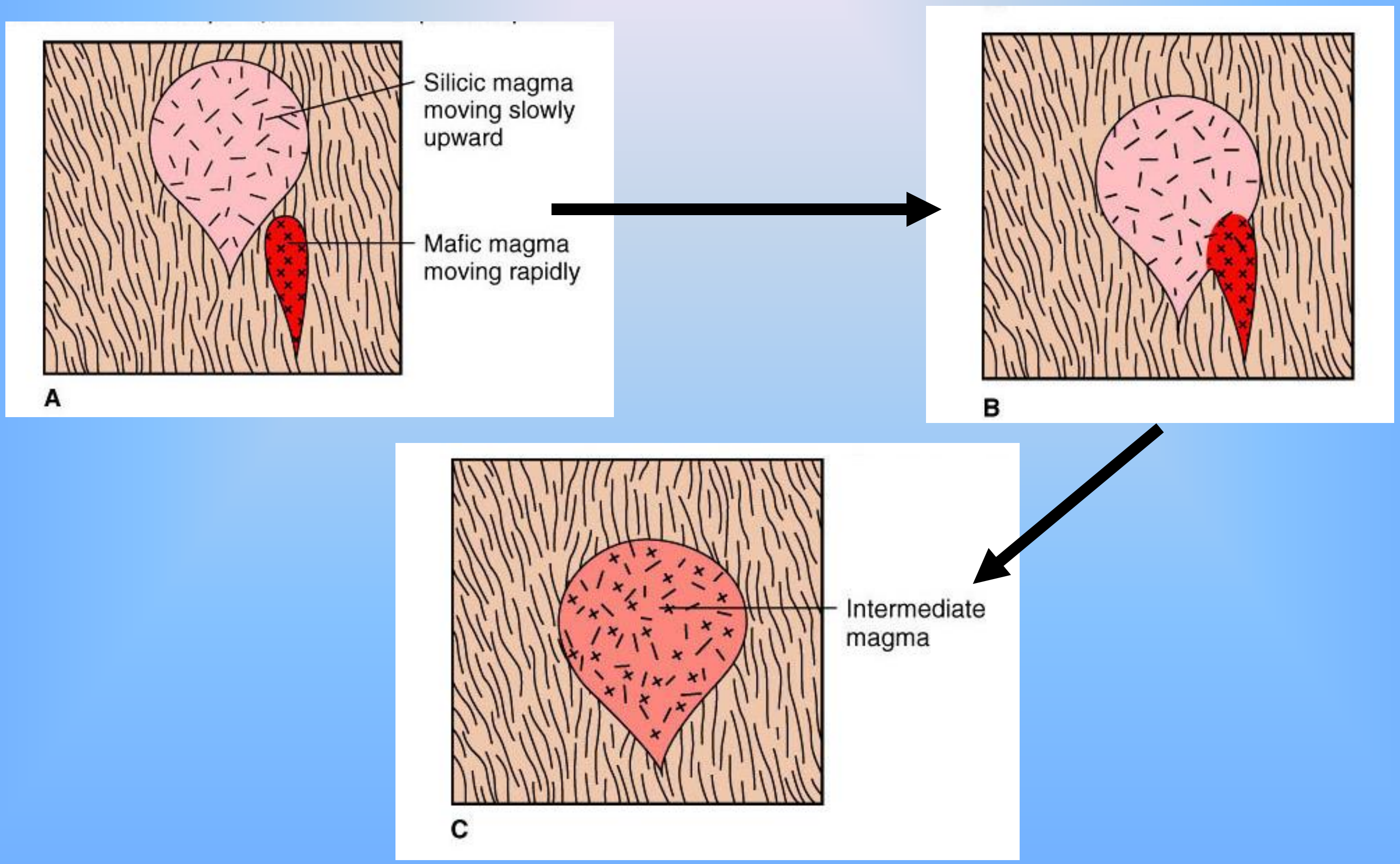
- When only the original basaltic magma cools slowly.
- The *earliest* formed minerals physically separate.
- Being *denser*, these minerals settle to the bottom of the magma.

d) Assimilation

- Very hot magma comes into contact with surrounding older rock (called *country rock”*).
- Some of the country rock melts and becomes part of the newly molten material.
- If basalt from the mantle comes into contact with granite country rock it will become richer in silica.
- This may be how intermediate magmas form (andesite and diorite).

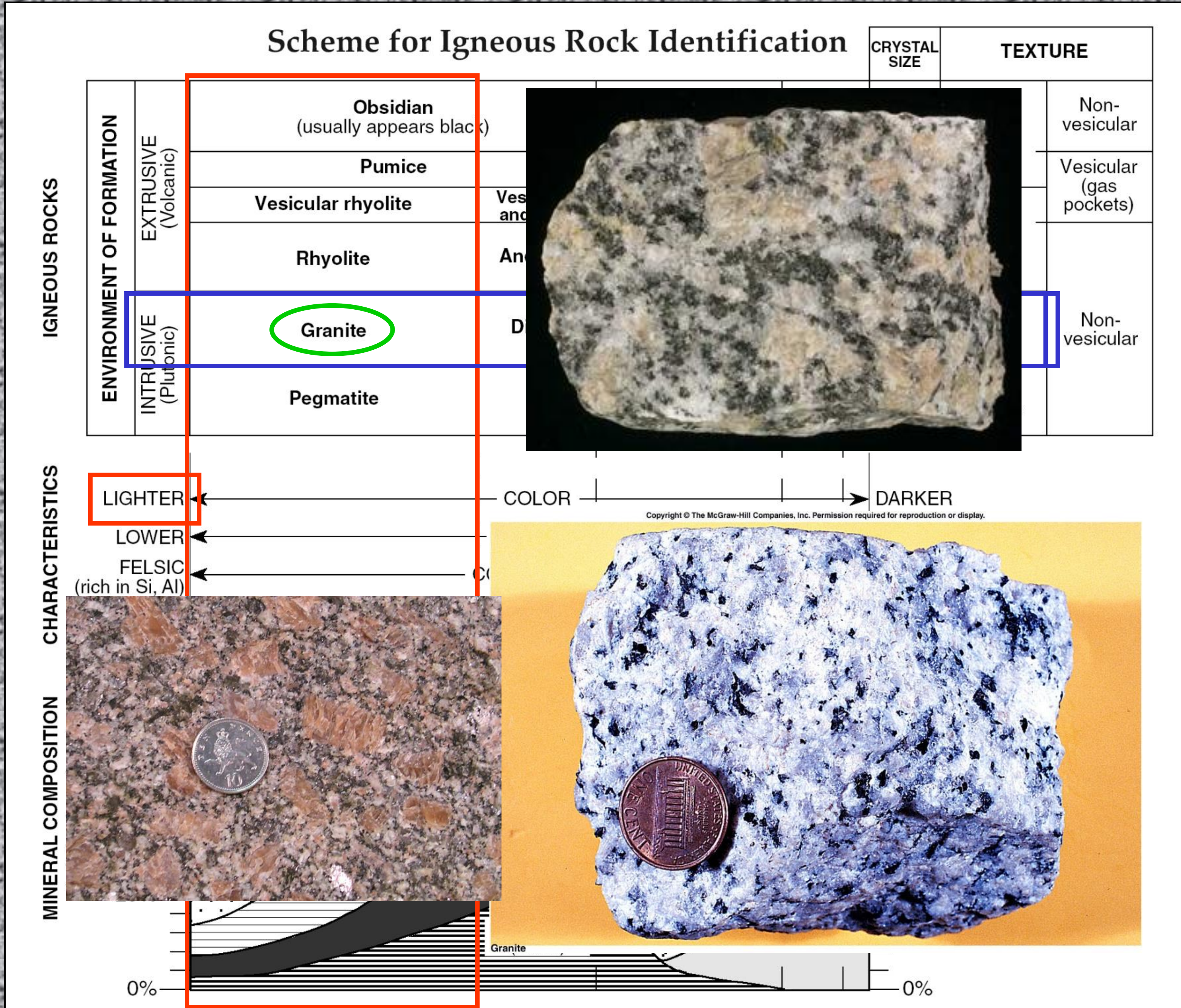


e) Mixing of Magmas



- Two magmas meet and merge in the crust.
- The combined magma will be *intermediate*.

Classifying Igneous Rocks



Scheme for Igneous Rock Identification
CRYSTAL SIZE
TEXTURE
IGNEOUS ROCKS
ENVIRONMENT OF FORMATION
EXTRUSIVE (Volcanic)
INTRUSIVE (Plutonic)
Obsidian
(usually appears black)
Pumice
Vesicular rhyolite
Rhyolite
Granite
Pegmatite
Non-vesicular
Vesicular (gas pockets)
Non-vesicular
CHARACTERISTICS
LIGHTER
COLOR
DARKER
LOWER
FELSIC
(rich in Si, Al)
MINERAL COMPOSITION
0%
0%
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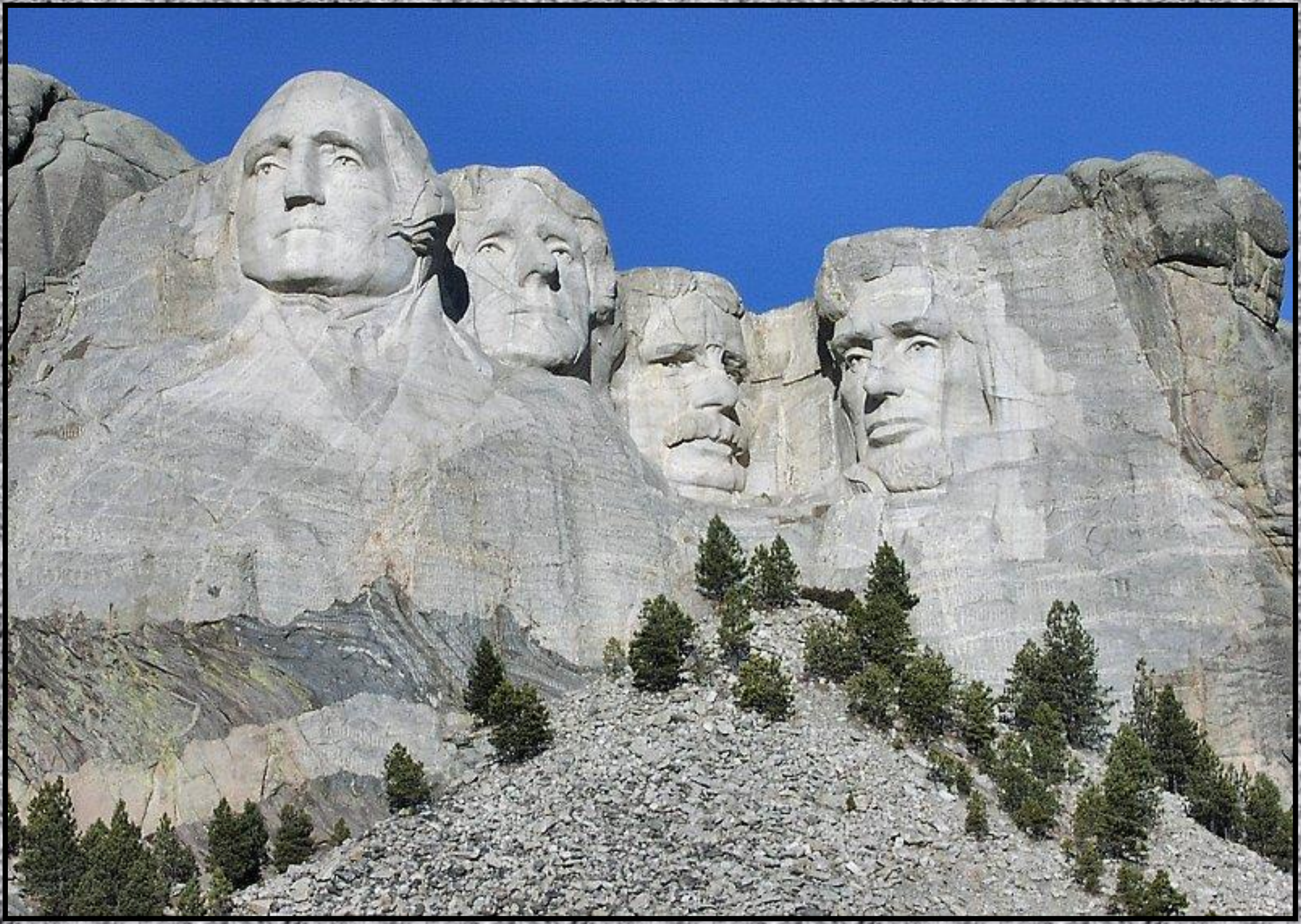
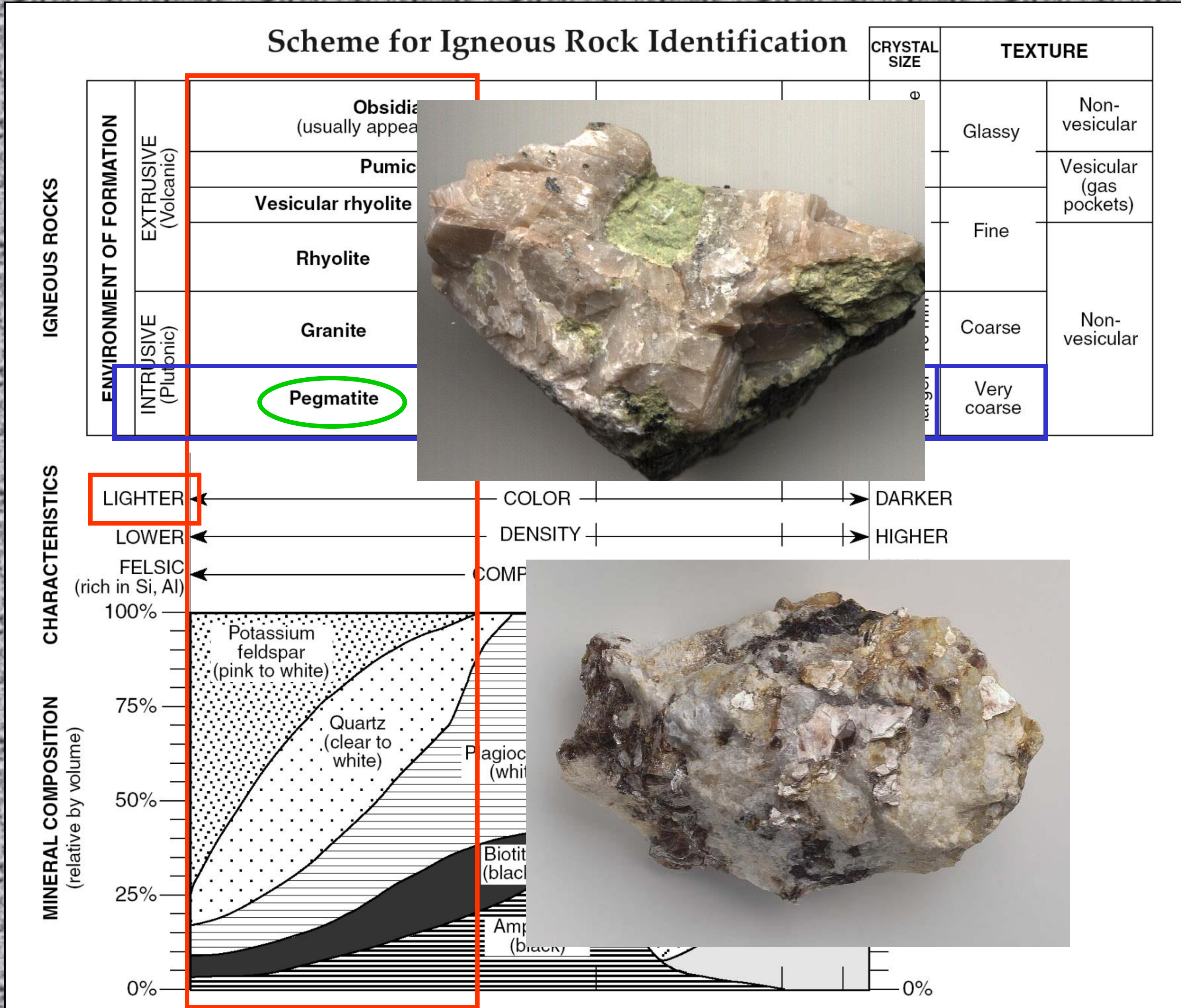
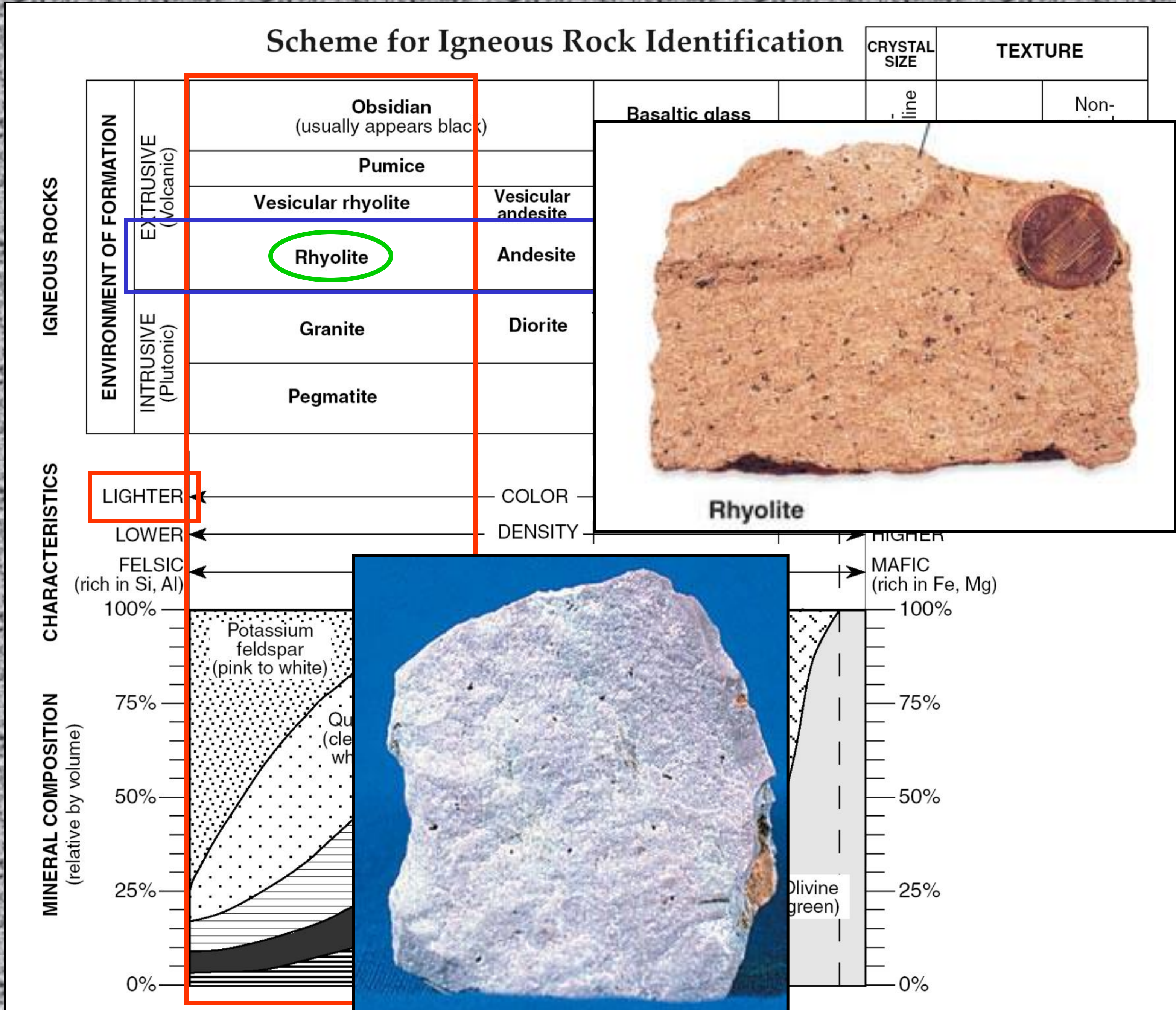
Granite

Mt. Rushmore National Monument

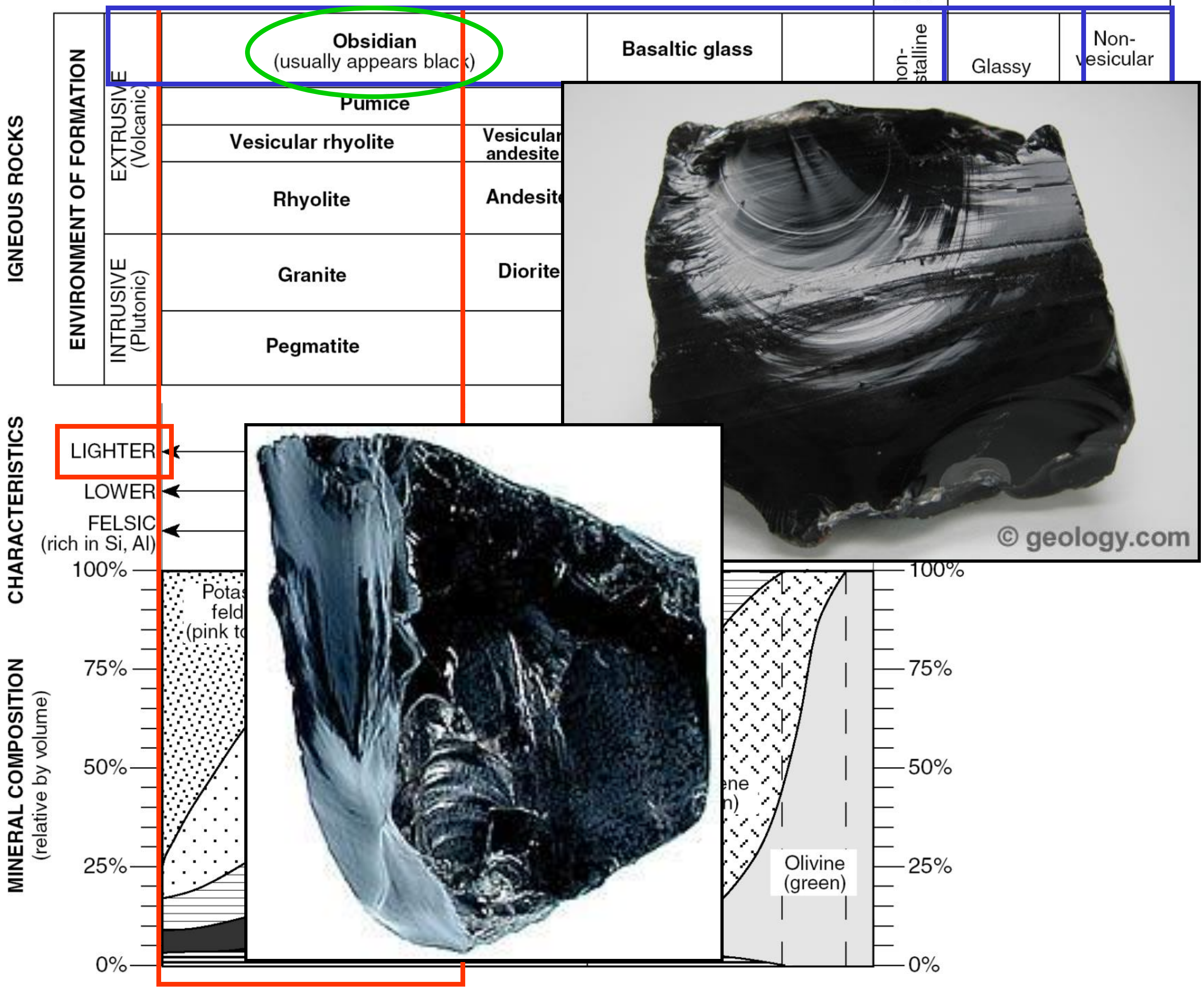


- Carved from granite in the Black Hills of South Dakota


Scheme for Igneous Rock Identification
CRYSTAL SIZE
TEXTURE
IGNEOUS ROCKS
ENVIRONMENT OF FORMATION
EXTRUSIVE (Volcanic)
INTRUSIVE (Plutonic)
Obsidia
(usually appea
Pumic
Vesicular rhyolite
Rhyolite
Granite
Pegmatite
Glassy
Non-vesicular
Vesicular (gas pockets)
Fine
Coarse
Non-vesicular
Very coarse
CHARACTERISTICS
LIGHTER
COLOR
DARKER
LOWER
DENSITY
HIGHER
FELSIC
(rich in Si, Al)
COMP
MINERAL COMPOSITION
(relative by volume)
100%
75%
50%
25%
0%
0%
Potassium feldspar (pink to white)
Quartz (clear to white)
P agioc
(whi
Biotit
(black
Amp
(black)


Scheme for Igneous Rock Identification
CRYSTAL SIZE
TEXTURE
Non-
IGNEOUS ROCKS
ENVIRONMENT OF FORMATION
EXTRUSIVE (Volcanic)
INTRUSIVE (Plutonic)
Obsidian
(usually appears black)
Basaltic glass
Pumice
Vesicular rhyolite
Vesicular andesite
Rhyolite
Andesite
Granite
Diorite
Pegmatite
Rhyolite
CHARACTERISTICS
LIGHTER
COLOR
LOWER
DENSITY
HIGHER
FELSIC
(rich in Si, Al)
MAFIC
(rich in Fe, Mg)
MINERAL COMPOSITION
(relative by volume)
100%
75%
50%
25%
0%
Potassium
feldspar
(pink to white)
Olivine
green)

Scheme for Igneous Rock Identification



Scheme for Igneous Rock Identification

Obsidian (usually appears black)	Basaltic glass	non-crystalline	Glassy / Non-vesicular
Pumice	Scoria		Vesicular (gas

IGNEOUS ROCKS

ENVIRONMENT OF FORMATION

CHARACTERISTICS

MINERAL COMPOSITION (relative by volume)

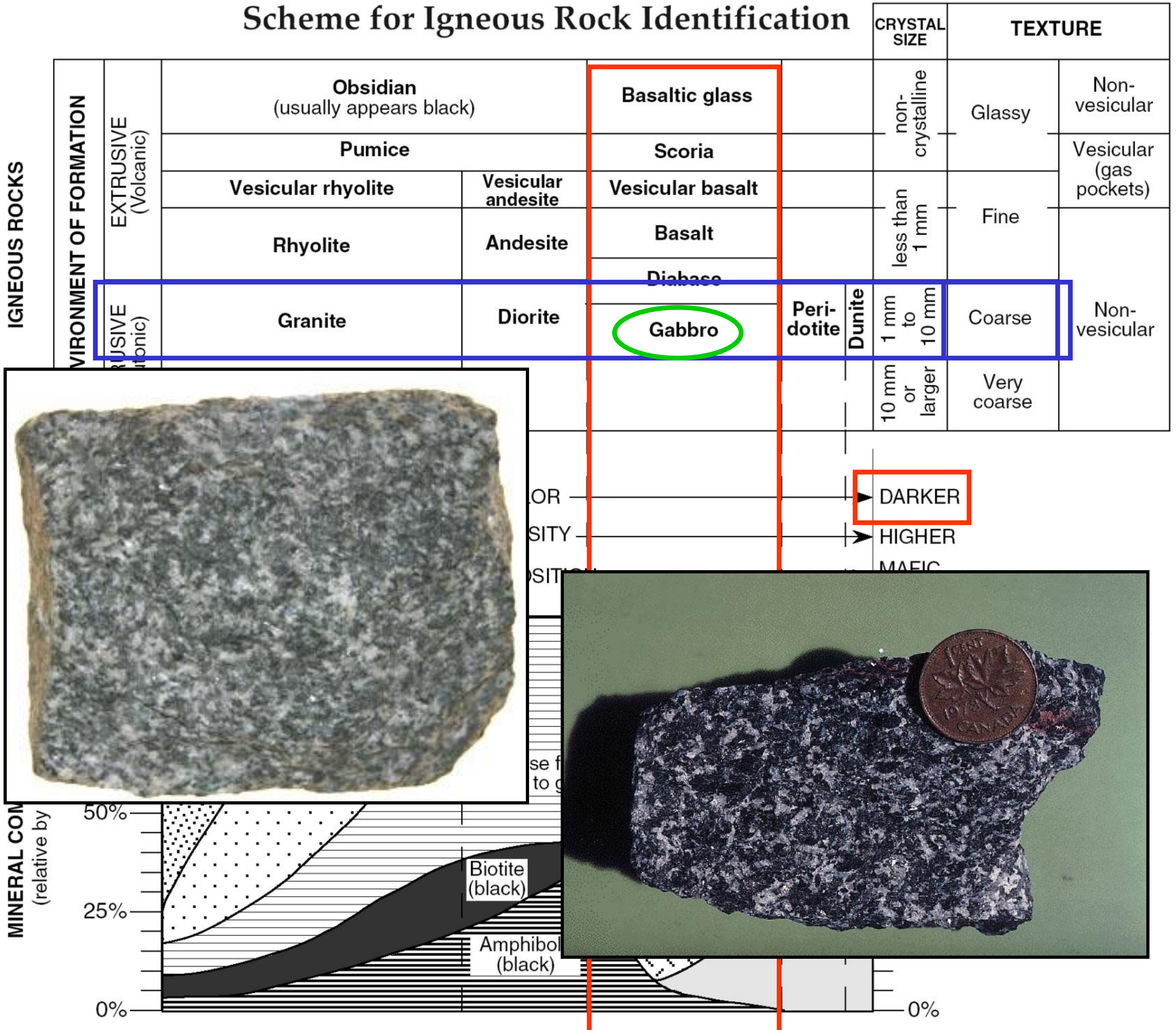
(rich

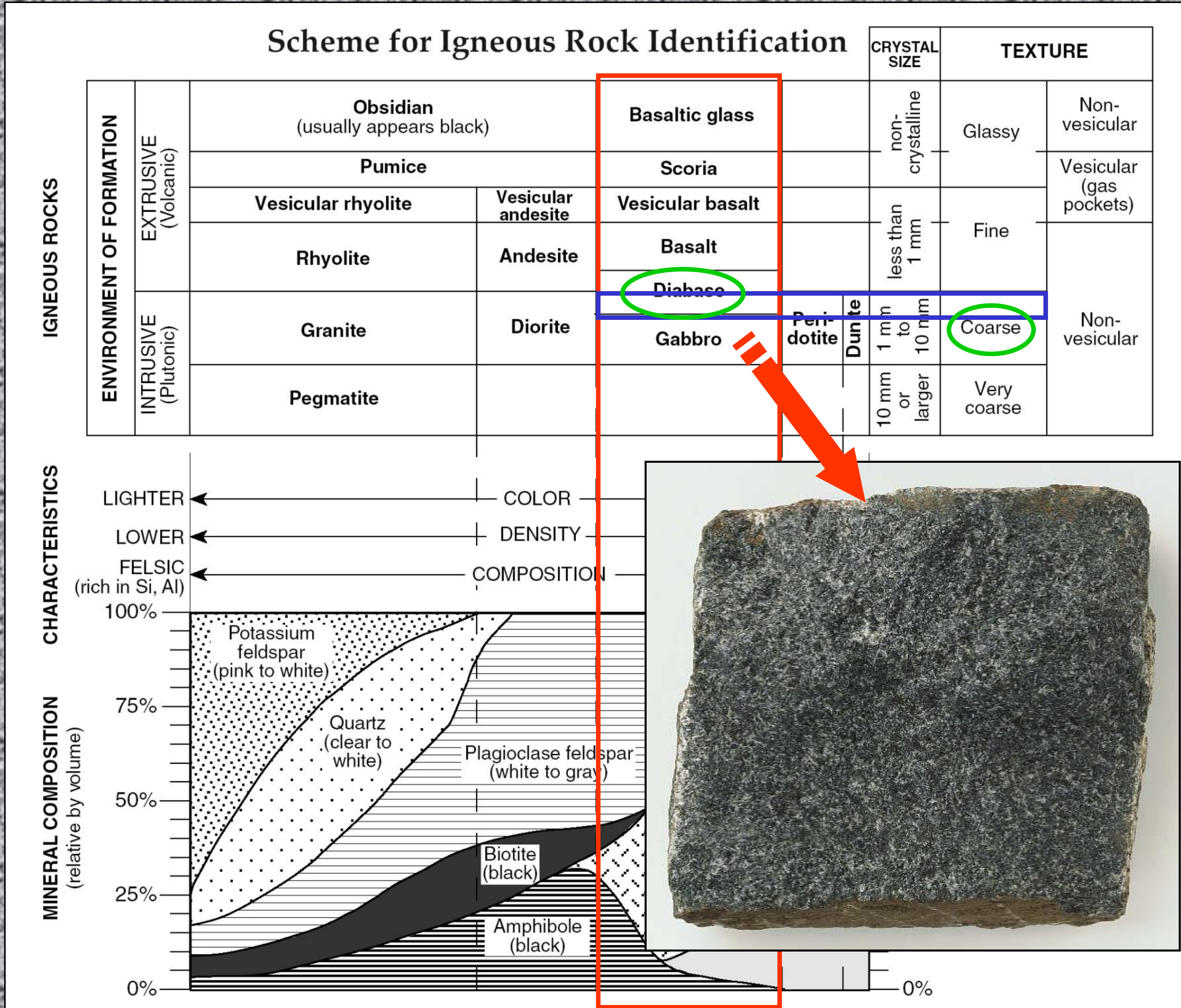
(black)

0%

0%

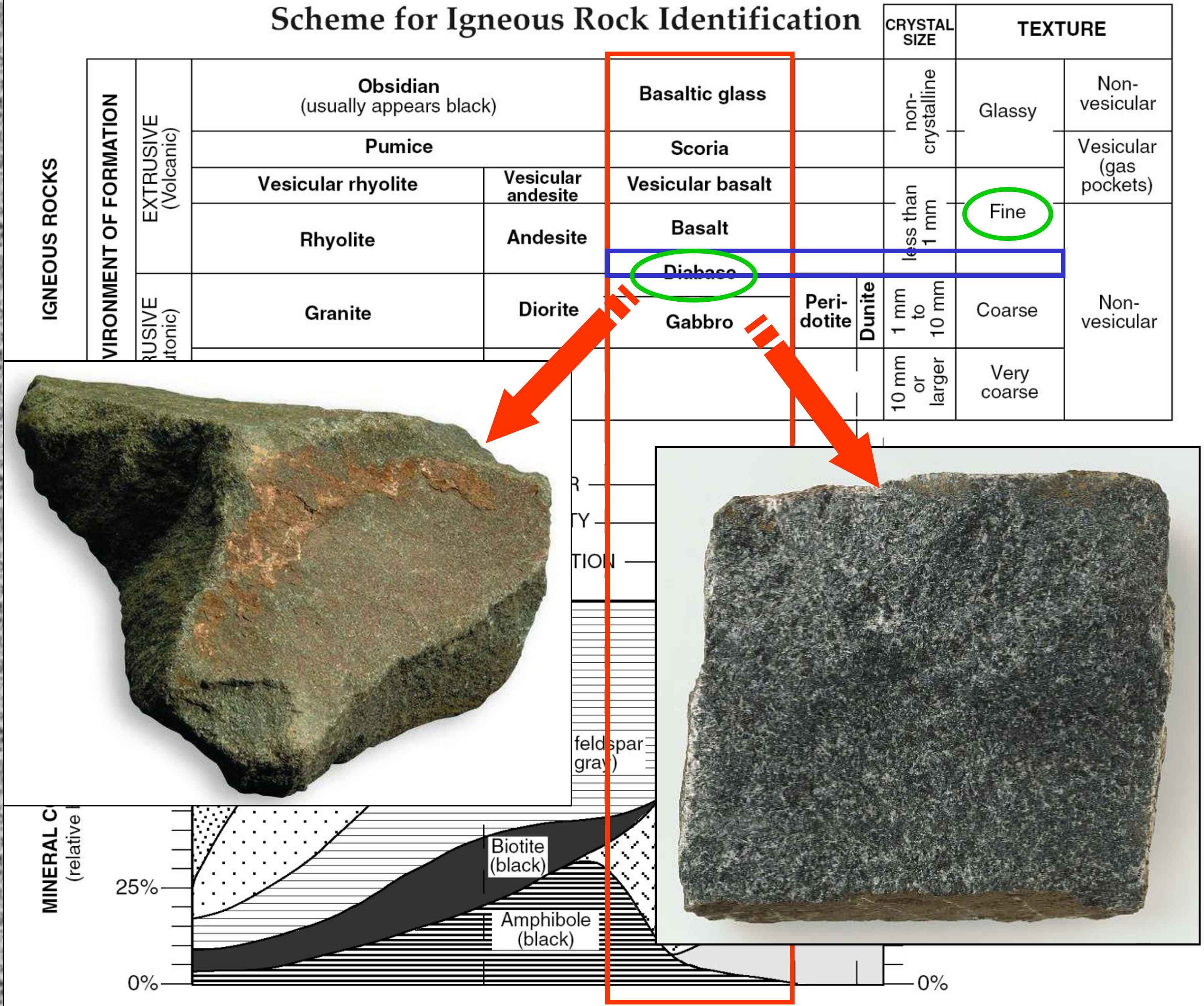
Scheme for Igneous Rock Identification





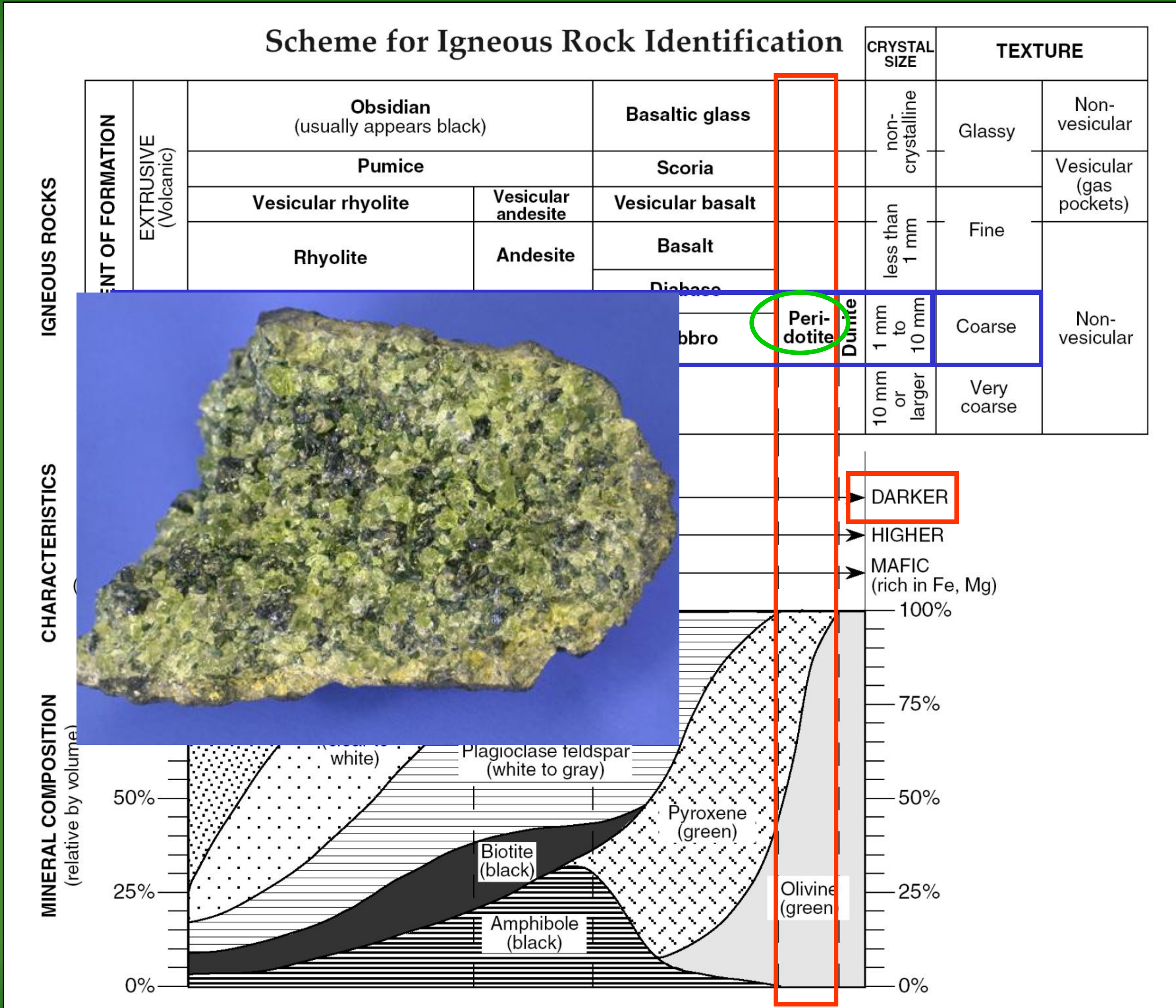
Scheme for Igneous Rock Identification
CRYSTAL SIZE
TEXTURE
IGNEOUS ROCKS
ENVIRONMENT OF FORMATION
EXTRUSIVE (Volcanic)
INTRUSIVE (Plutonic)
Obsidian (usually appears black)
Basaltic glass
Pumice
Scoria
Vesicular rhyolite
Vesicular andesite
Vesicular basalt
Rhyolite
Andesite
Basalt
Diabase
Granite
Diorite
Gabbro
Peri-dotite
Dunite
Pegmatite
non-crystalline
less than 1 mm
1 mm to 10 mm
10 mm or larger
Glassy
Fine
Coarse
Very coarse
Non-vesicular
Vesicular (gas pockets)
Non-vesicular
CHARACTERISTICS
LIGHTER
COLOR
LOWER
DENSITY
FELSIC (rich in Si, Al)
COMPOSITION
MINERAL COMPOSITION (relative by volume)
100%
75%
50%
25%
0%
Potassium feldspar (pink to white)
Quartz (clear to white)
Plagioclase feldspar (white to gray)
Biotite (black)
Amphibole (black)
0%

Scheme for Igneous Rock Identification

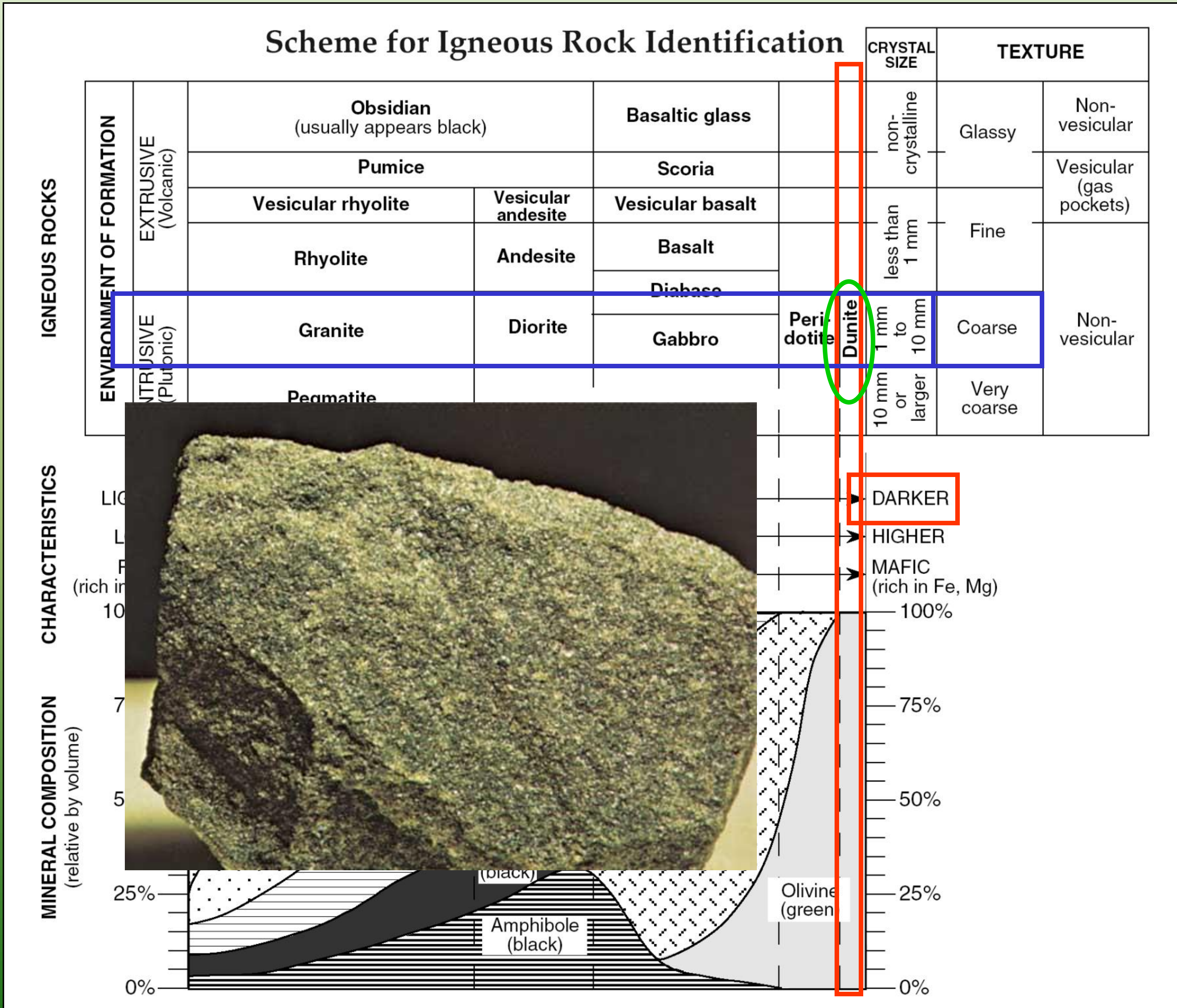


Ultramafic Rocks

- Enriched in minerals with magnesium and iron
  - Pyroxene
  - Olivine
- Greenish color

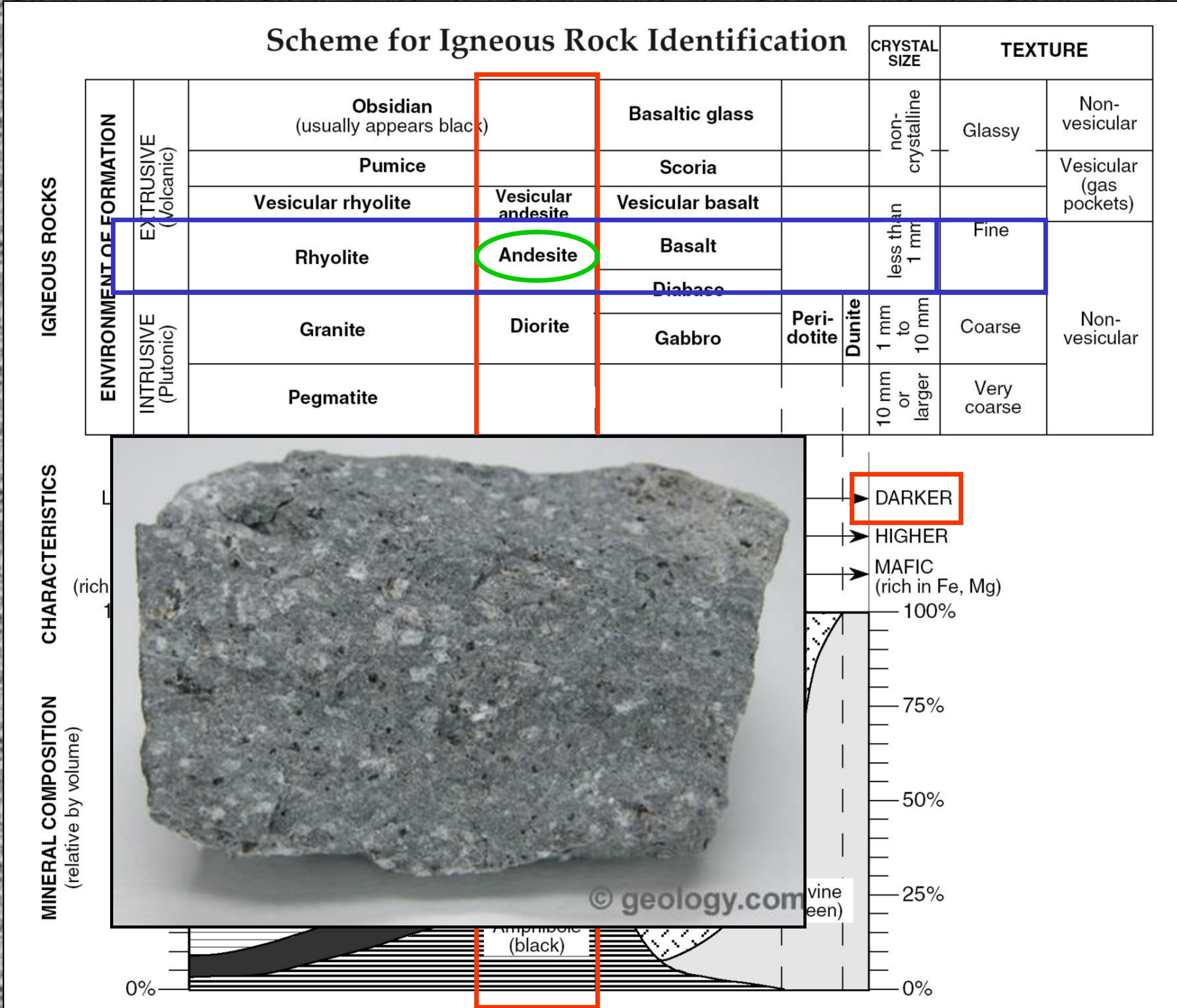


Scheme for Igneous Rock Identification
CRYSTAL SIZE
TEXTURE
IGNEOUS ROCKS
EXTRUSIVE (Volcanic)
Obsidian (usually appears black)
Basaltic glass
Pumice
Scoria
Vesicular rhyolite
Vesicular andesite
Vesicular basalt
Rhyolite
Andesite
Basalt
Peri-dotite
Dunite
non-crystalline
less than 1 mm
1 mm to 10 mm
10 mm or larger
Glassy
Fine
Coarse
Very coarse
Non-vesicular
Vesicular (gas pockets)
Non-vesicular
CHARACTERISTICS
DARKER
HIGHER
MAFIC (rich in Fe, Mg)
MINERAL COMPOSITION (relative by volume)
100%
75%
50%
25%
0%
white)
Plagioclase feldspar (white to gray)
Biotite (black)
Amphibole (black)
Pyroxene (green)
Olivine (green



Scheme for Igneous Rock Identification
CRYSTAL SIZE
TEXTURE
IGNEOUS ROCKS
ENVIRONMENT OF FORMATION
EXTRUSIVE (Volcanic)
Obsidian (usually appears black)
Basaltic glass
non-crystalline
Glassy
Non-vesicular
Pumice
Scoria
Vesicular (gas pockets)
Vesicular rhyolite
Vesicular andesite
Vesicular basalt
Rhyolite
Andesite
Basalt
less than 1 mm
Fine
Diabase
Granite
Diorite
Gabbro
Peridotite
Dunite
1 mm to 10 mm
Coarse
Non-vesicular
Pegmatite
10 mm or larger
Very coarse
CHARACTERISTICS
DARKER
HIGHER
MAFIC (rich in Fe, Mg)
MINERAL COMPOSITION (relative by volume)
100%
75%
50%
25%
0%
Olivine (green)
Amphibole (black)

Rocks with Intermediate Composition



Scheme for Igneous Rock Identification
IGNEOUS ROCKS
ENVIRONMENT OF FORMATION
EXTRUSIVE (Volcanic)
INTRUSIVE (Plutonic)
Obsidian (usually appears black)
Basaltic glass
Pumice
Scoria
Vesicular rhyolite
Vesicular andesite
Vesicular basalt
Rhyolite
Andesite
Basalt
Diabase
Granite
Diorite
Gabbro
Peri-dotite
Dunite
Pegmatite
CRYSTAL SIZE
TEXTURE
non-crystalline
less than 1 mm
1 mm to 10 mm
10 mm or larger
Glassy
Fine
Coarse
Very coarse
Non-vesicular
Vesicular (gas pockets)
Non-vesicular
CHARACTERISTICS
DARKER
HIGHER
MAFIC (rich in Fe, Mg)
MINERAL COMPOSITION (relative by volume)
100%
75%
50%
25%
0%
(black)
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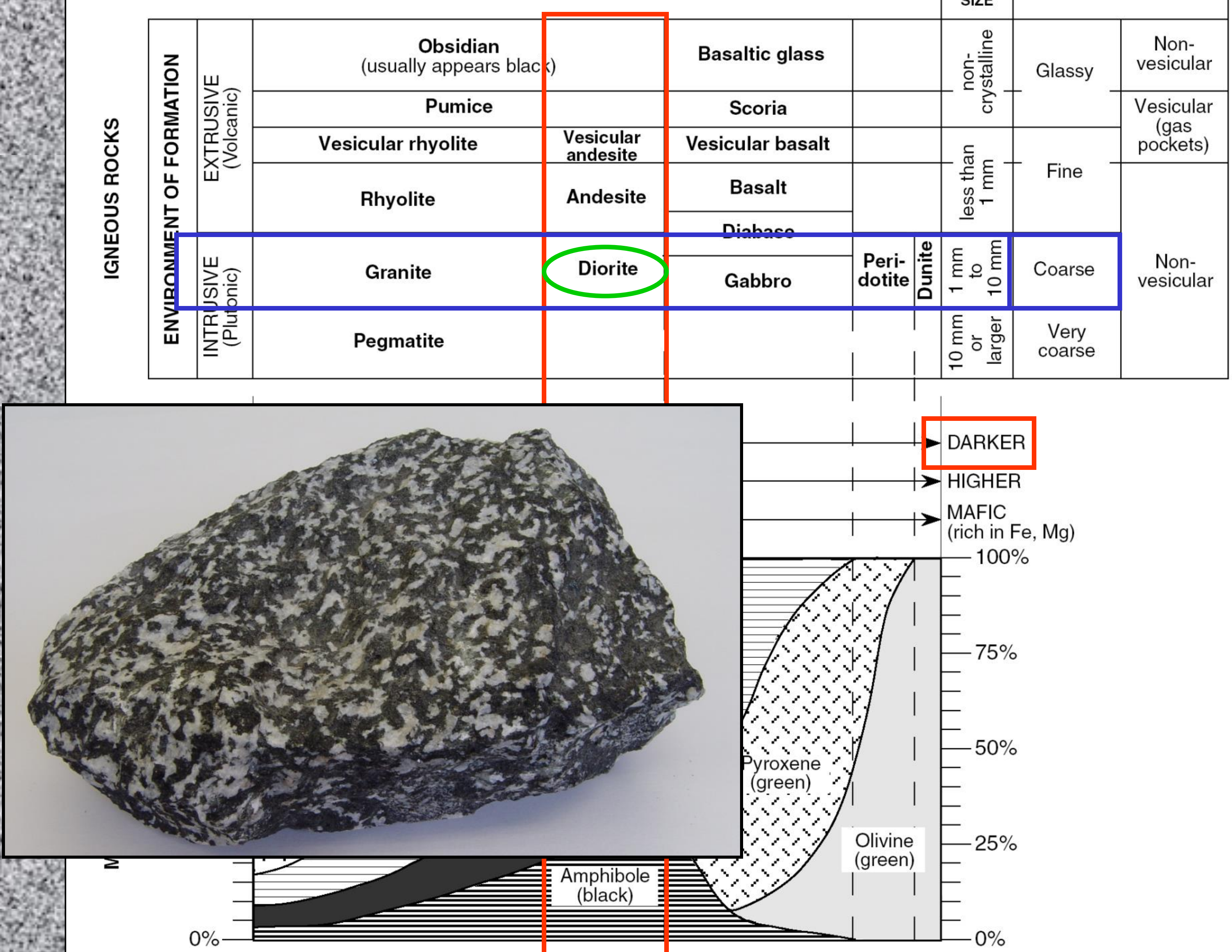
Scheme for Igneous Rock Identification



Now Try:

- **Igneous Rocks Worksheet Practice**
- **Then … Lab 2-3 Igneous Rocks**

C. Igneous Rocks with Special Textures

(Bottom of Page 5 in note packet)

1. **Porphyritic** Texture

Phenocrysts

site (porphyritic)

2. **Vesicular**

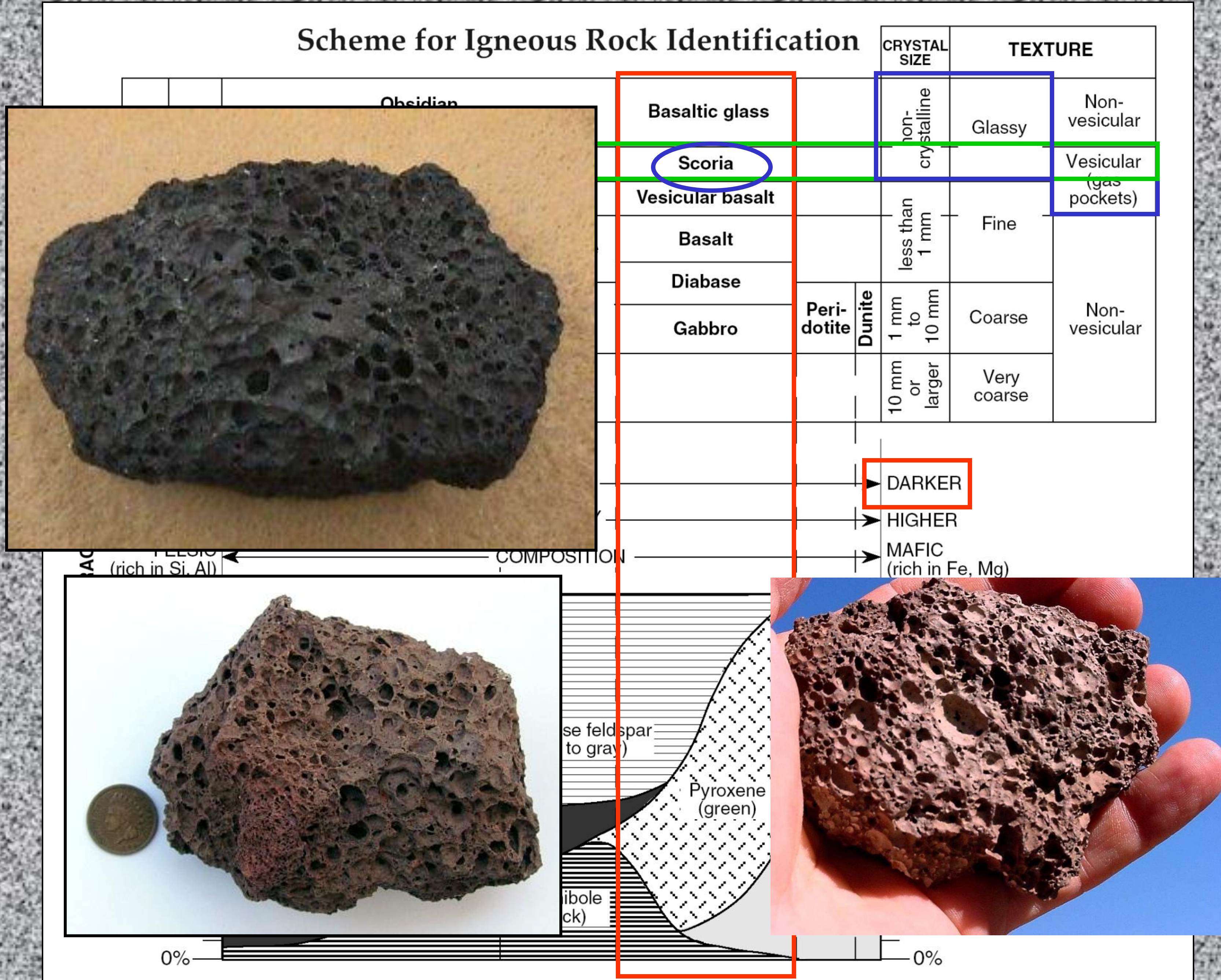
a) Characterized by many spherical openings called **vesicles**.

b) From trapped gas bubbles in cooling lava.

c) Vesicular rocks

(i) **Scoria**:

- Has so many vesicles that it resembles a sponge.
- Most scoria is noncrystalline.

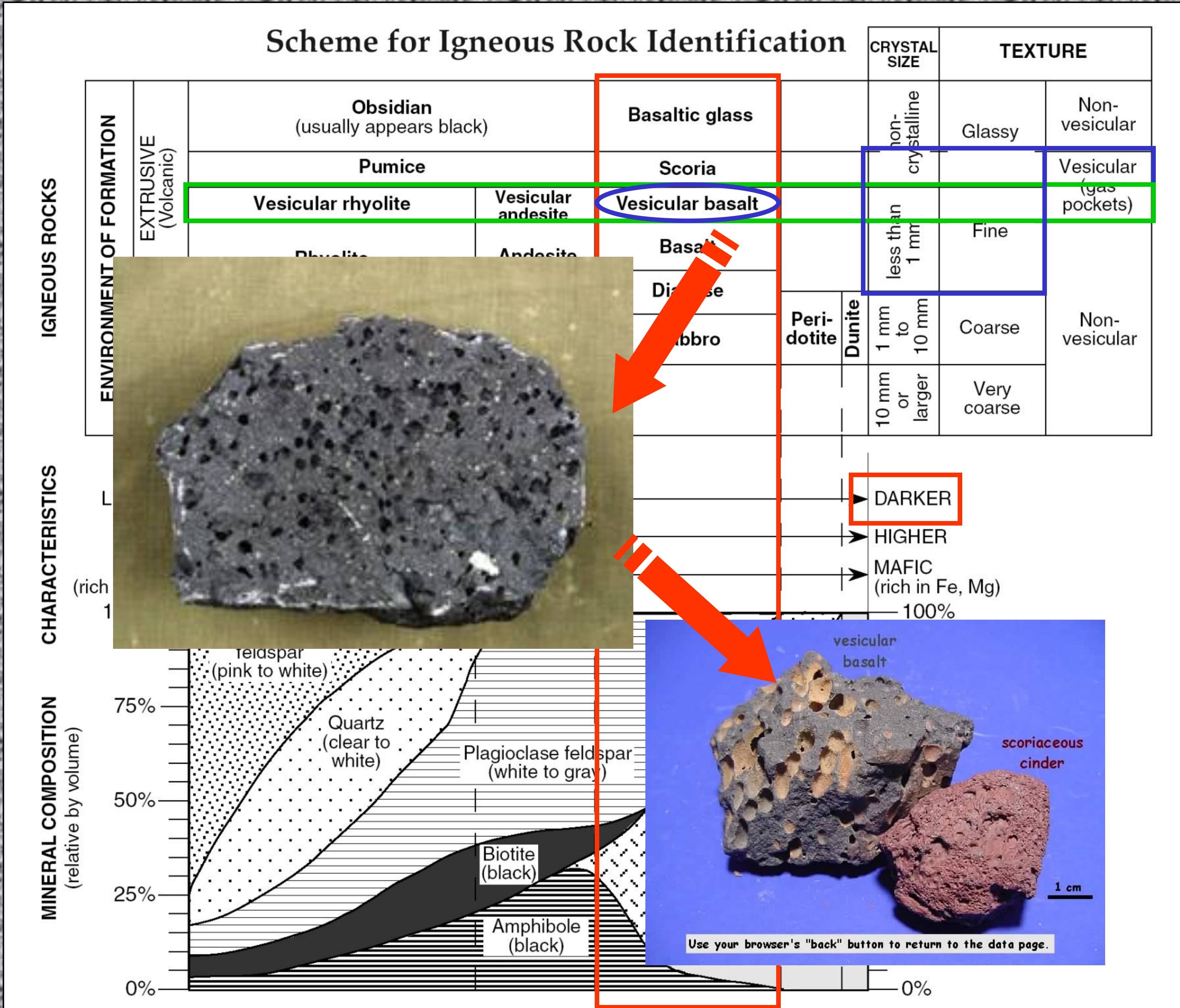


Scheme for Igneous Rock Identification
CRYSTAL SIZE
TEXTURE
Basaltic glass
Scoria
Vesicular basalt
Basalt
Diabase
Gabbro
Peri-dotite
Dunite
non-crystalline
less than 1 mm
1 mm to 10 mm
10 mm or larger
Glassy
Fine
Coarse
Very coarse
Non-vesicular
Vesicular (gas pockets)
Non-vesicular
DARKER
HIGHER
COMPOSITION
(rich in Si, Al)
MAFIC (rich in Fe, Mg)
Pyroxene (green)
0%
0%

Vesicular Textures

(ii) __Vesicular Basalt__

- Fine-grained
- Vesicles do not make up most of the rock.

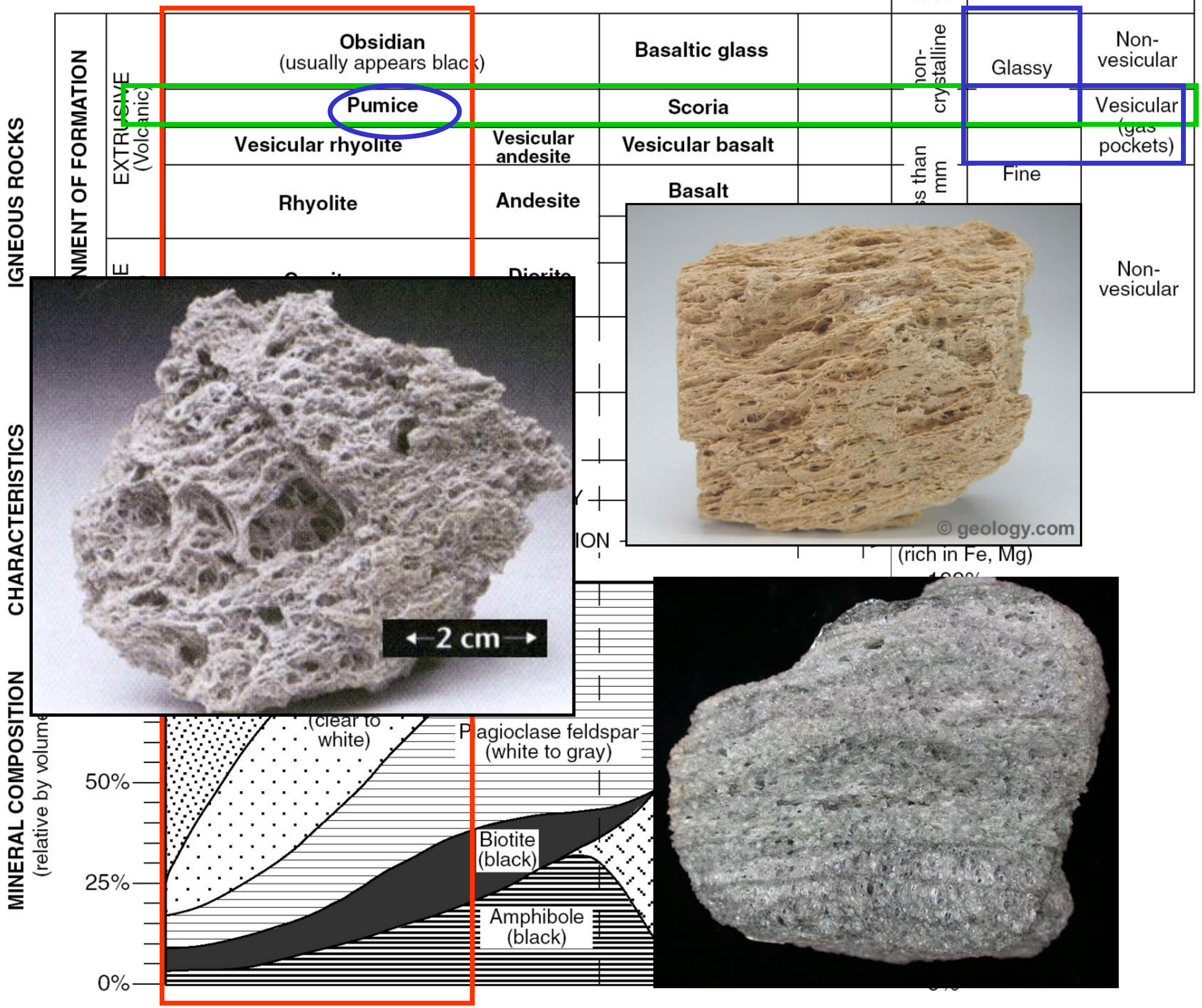

Scheme for Igneous Rock Identification
CRYSTAL SIZE
TEXTURE
IGNEOUS ROCKS
ENVIRONMENT OF FORMATION
EXTRUSIVE (Volcanic)
Obsidian
(usually appears black)
Basaltic glass
Pumice
Scoria
Vesicular rhyolite
Vesicular andesite
Vesicular basalt
Basalt
Peri-dotite
Dunite
non-crystalline
less than 1 mm
1 mm to 10 mm
10 mm or larger
Glassy
Fine
Coarse
Very coarse
Non-vesicular
Vesicular (gas pockets)
Non-vesicular
CHARACTERISTICS
DARKER
HIGHER
MAFIC
(rich in Fe, Mg)
100%
MINERAL COMPOSITION
(relative by volume)
75%
50%
25%
0%
(pink to white)
Quartz (clear to white)
Plagioclase feldspar (white to gray)
Biotite (black)
Amphibole (black)
0%
vesicular basalt
scoriaceous cinder
1 cm
Use your browser's "back" button to return to the data page.

Vesicular Textures

(ii) __Pumice__

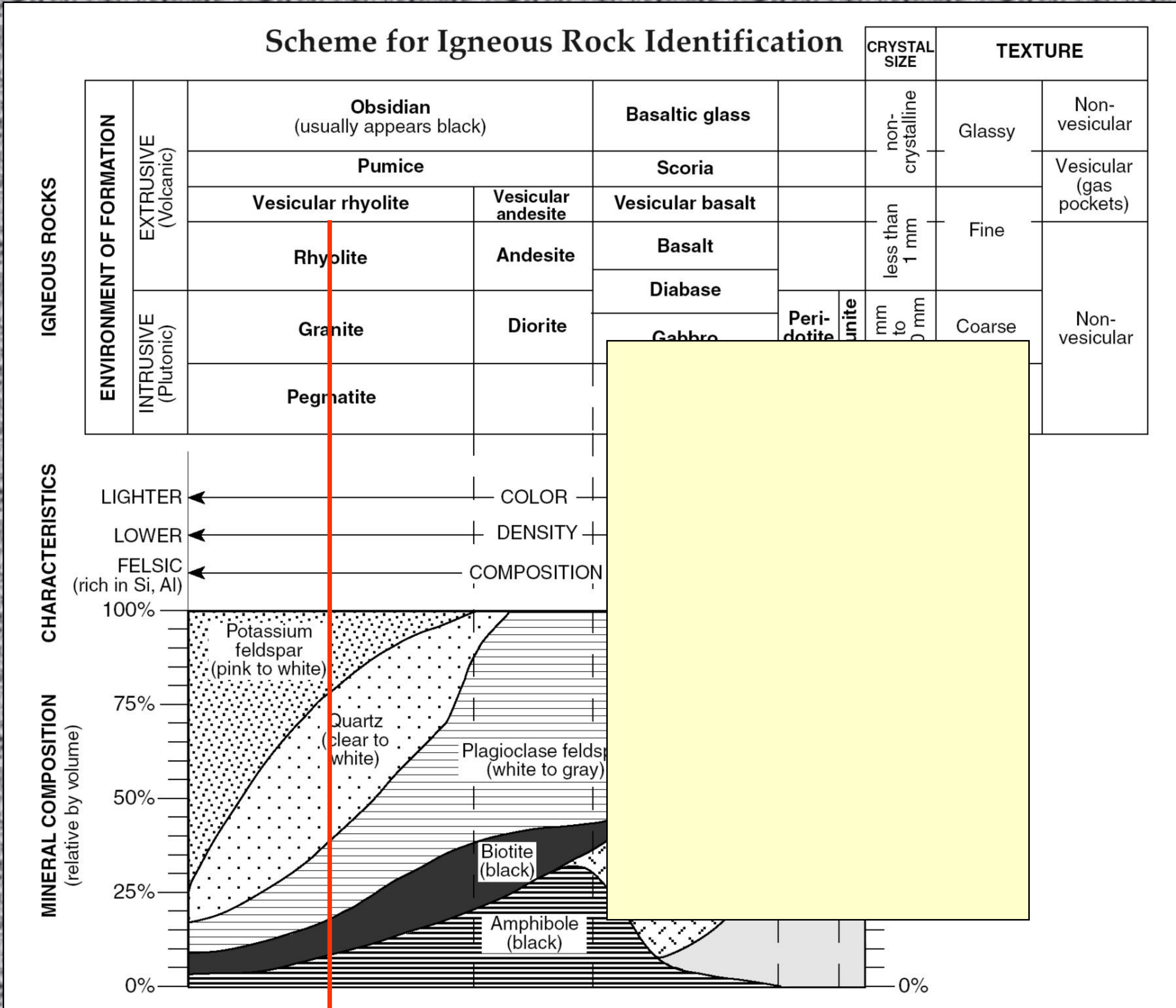
- Glassy
- Has so many tiny vesicles that it resembles a frothy meringue.
- Will float in water

Scheme for Igneous Rock Identification



Pumice

A


Scheme for Igneous Rock Identification
CRYSTAL SIZE
TEXTURE
IGNEOUS ROCKS
ENVIRONMENT OF FORMATION
EXTRUSIVE (Volcanic)
INTRUSIVE (Plutonic)
Obsidian (usually appears black)
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Vesicular rhyolite
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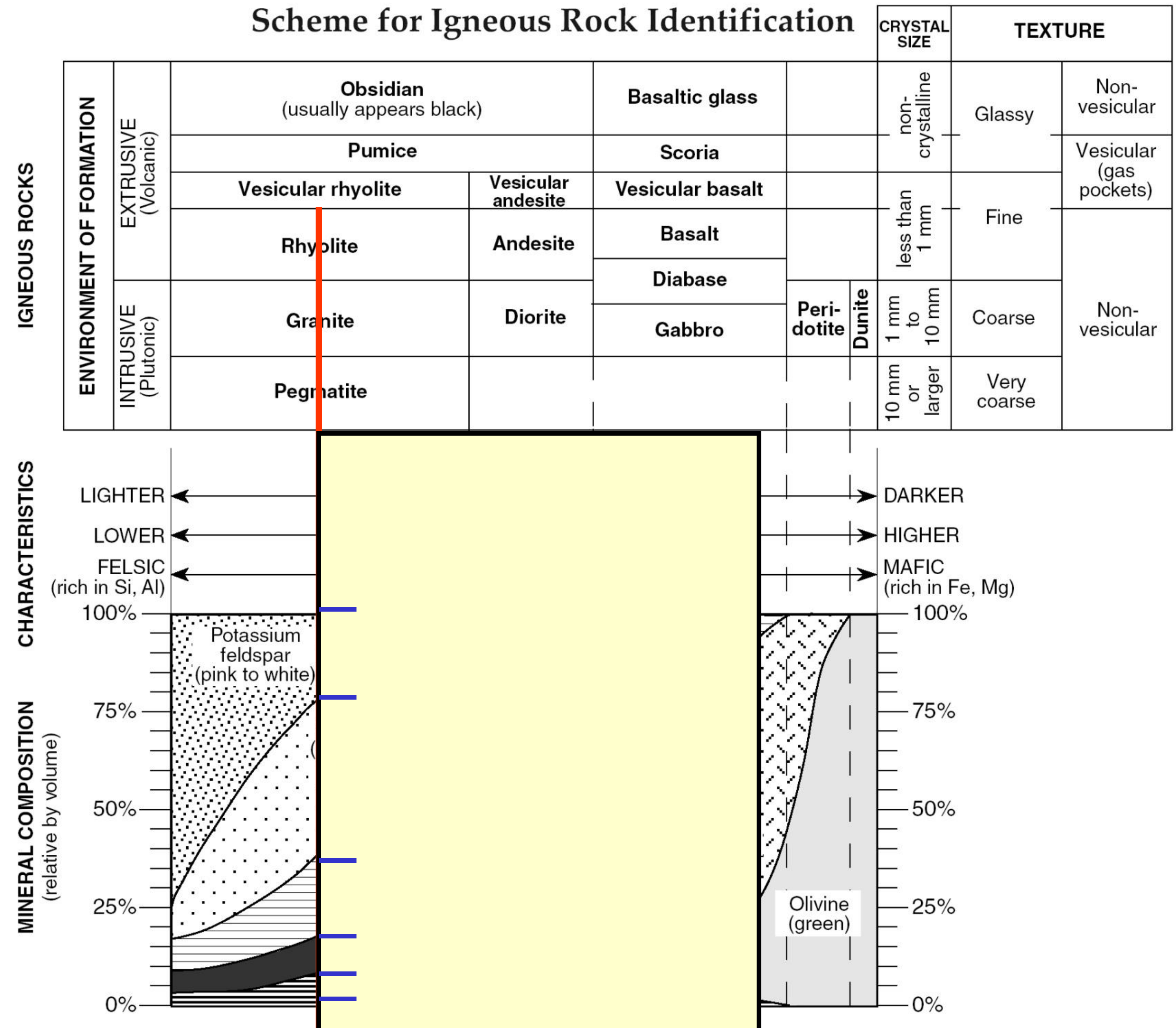
Vesicular basalt
Rhyolite
Andesite
Basalt
Diabase
Granite
Diorite
Gabbro
Peri- dotite
unite
Pegmatite
non- crystalline
less than 1 mm
mm to 0 mm
Glassy
Fine
Coarse
Non- vesicular
Vesicular (gas pockets)
Non- vesicular
CHARACTERISTICS
LIGHTER
COLOR
LOWER
DENSITY
FELSIC (rich in Si, Al)
COMPOSITION
MINERAL COMPOSITION (relative by volume)
100%
75%
50%
25%
0%
0%
Potassium feldspar (pink to white)
Quartz (clear to white)
Plagioclase felds (white to gray)
Biotite (black)
Amphibole (black)


Scheme for Igneous Rock Identification
CRYSTAL SIZE
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IGNEOUS ROCKS
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Obsidian (usually appears black)
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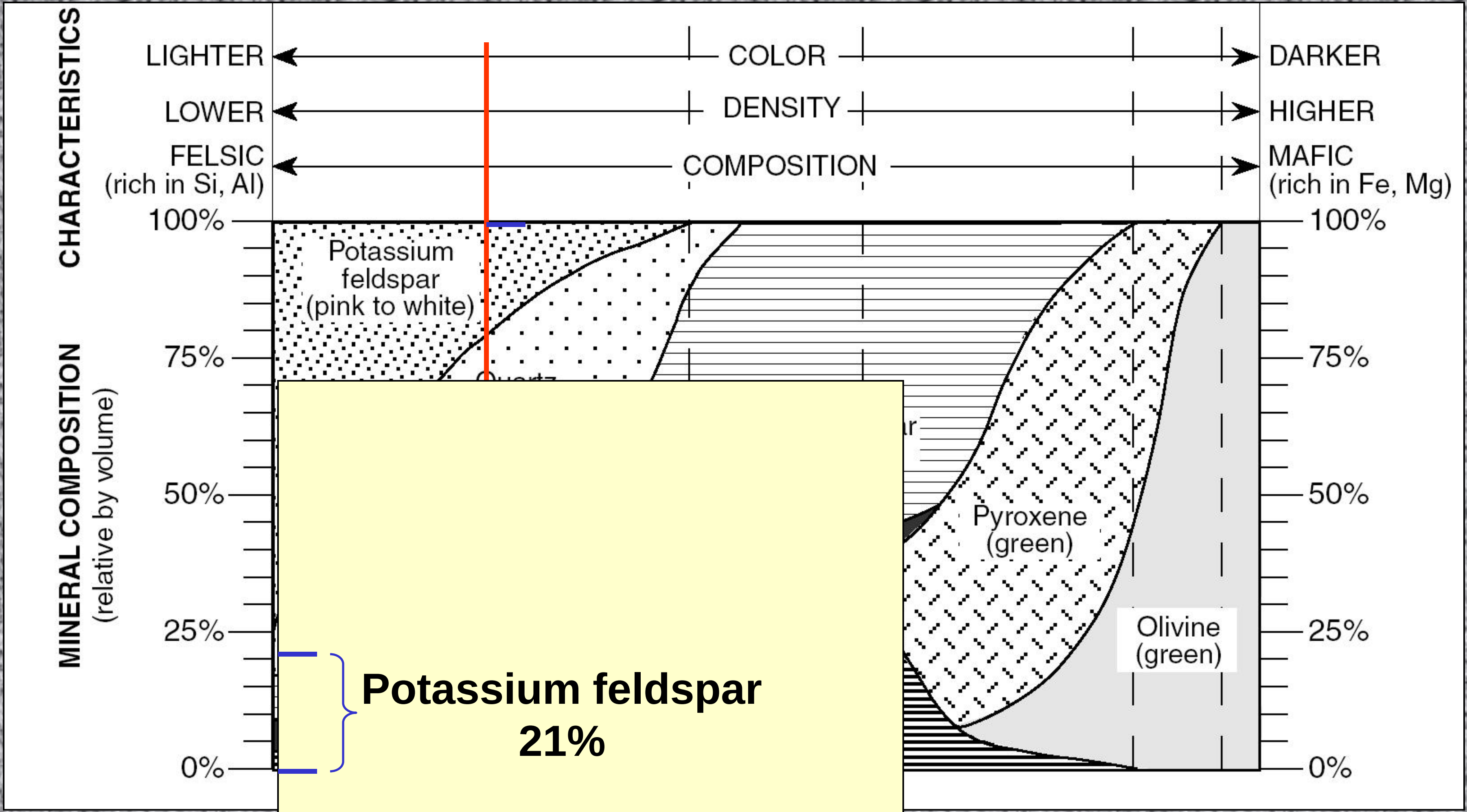
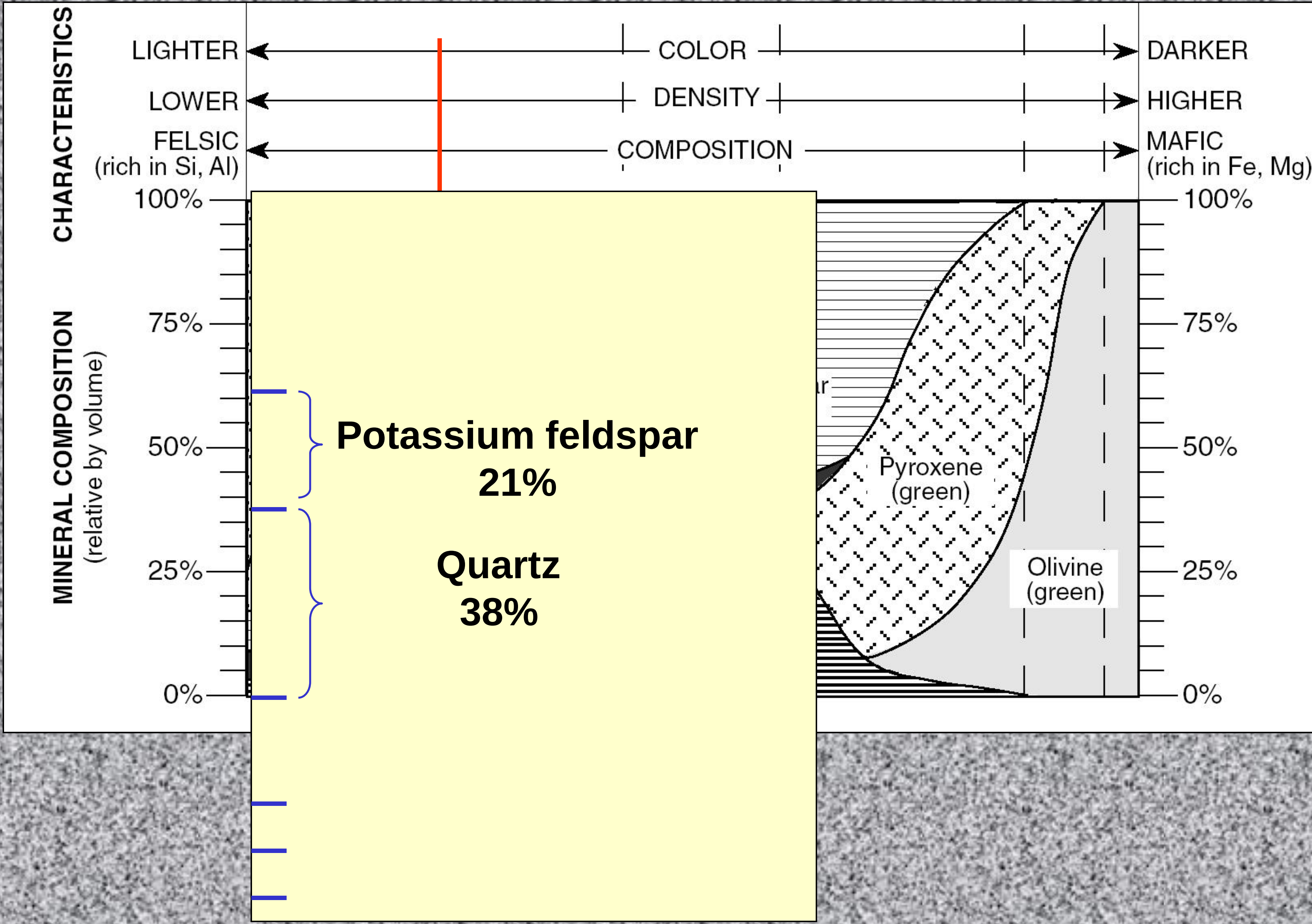
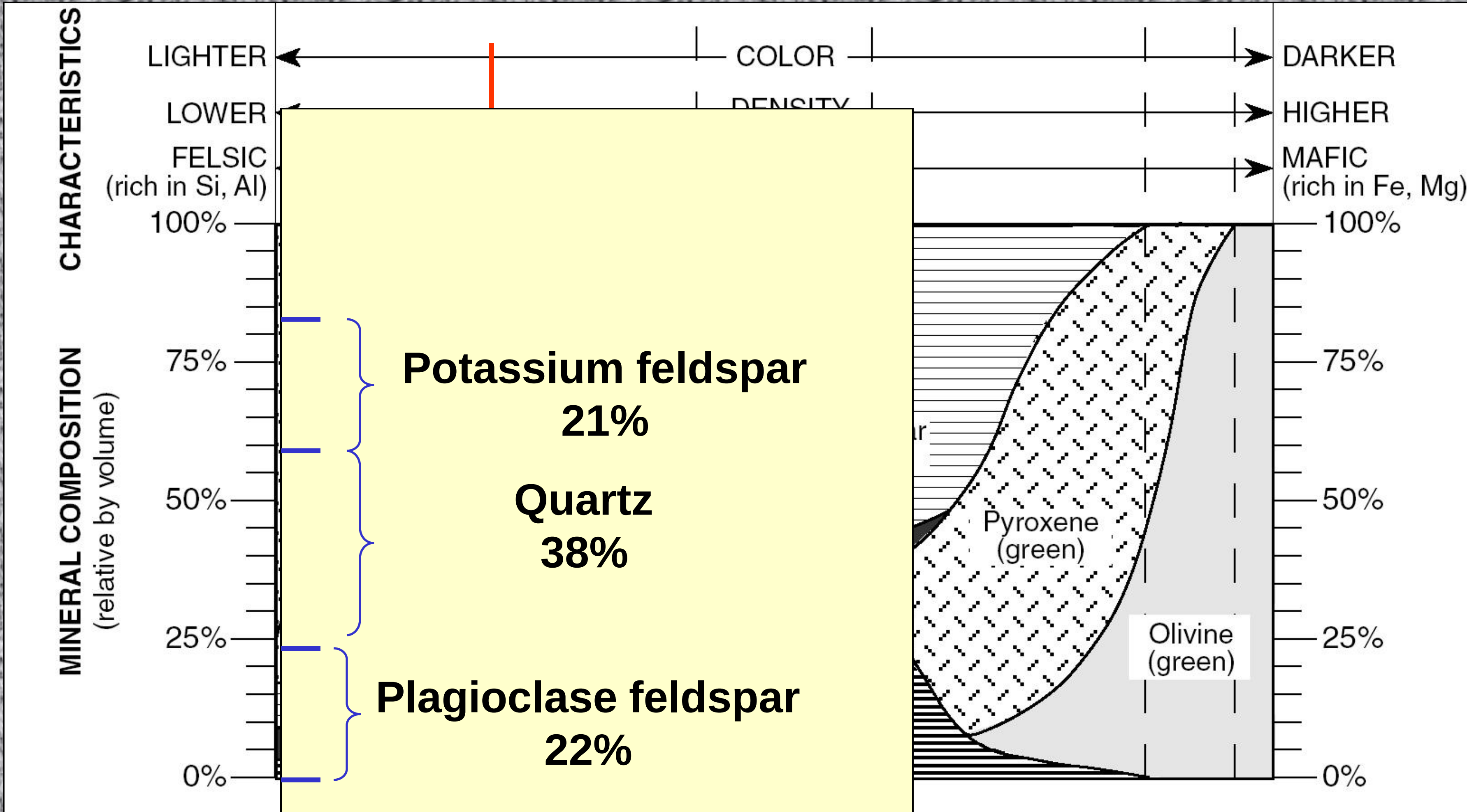
Pumice
Scoria
Vesicular rhyolite
Vesicular andesite
Vesicular basalt
Rhyolite
Andesite
Basalt
Diabase
Granite
Diorite
Gabbro
Peri-dotite
Dunite
Pegmatite
non-crystalline
less than 1 mm
1 mm to 10 mm
10 mm or larger
Glassy
Fine
Coarse
Very coarse
Non-vesicular
Vesicular (gas pockets)
Non-vesicular
CHARACTERISTICS
LIGHTER
LOWER
FELSIC (rich in Si, Al)
DARKER
HIGHER
MAFIC (rich in Fe, Mg)
MINERAL COMPOSITION (relative by volume)
100%
75%
50%
25%
0%
Potassium feldspar (pink to white)
Olivine (green)



Potassium feldspar
21%

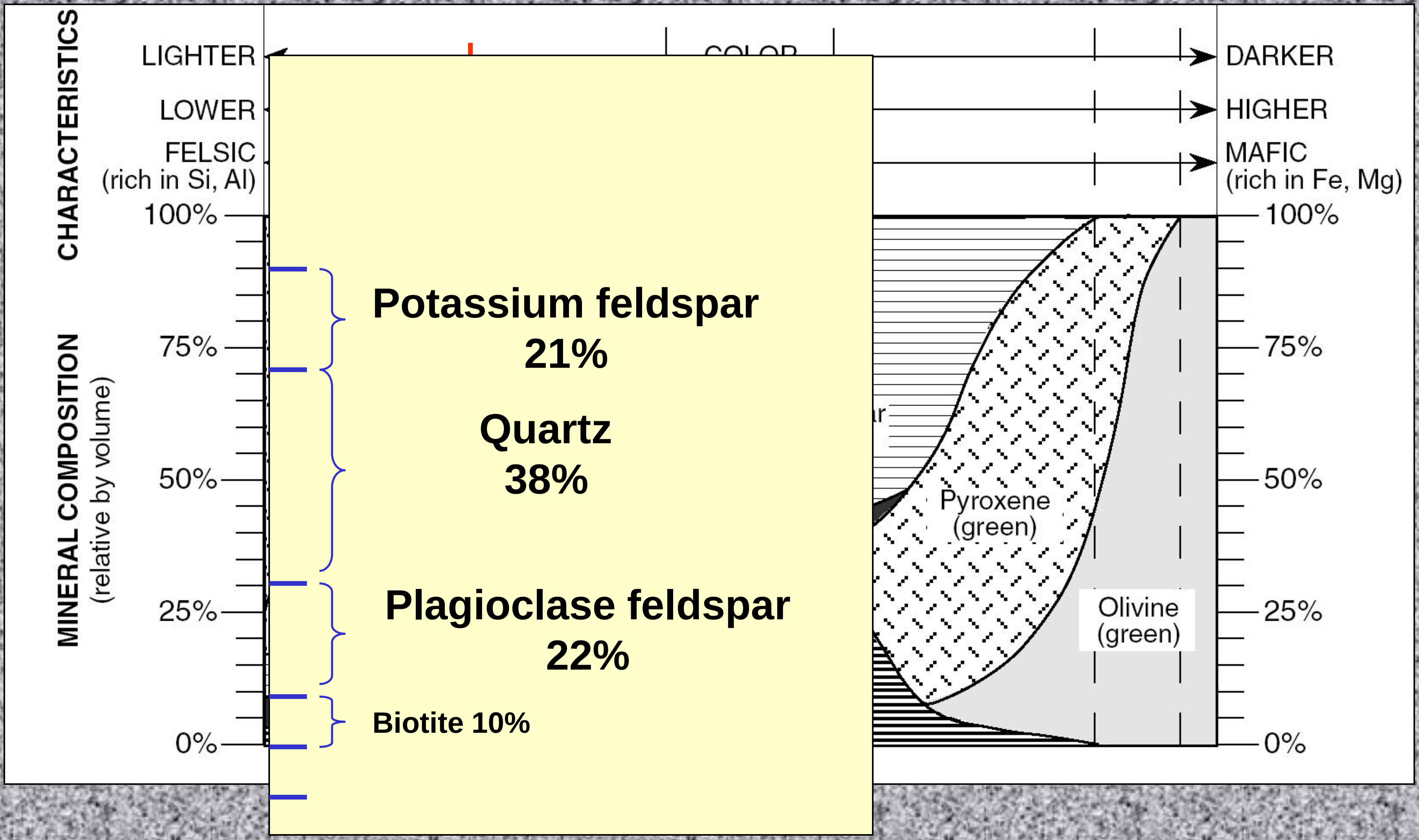

CHARACTERISTICS
LIGHTER
COLOR
DARKER
LOWER
DENSITY
HIGHER
FELSIC
(rich in Si, Al)
COMPOSITION
MAFIC
(rich in Fe, Mg)
MINERAL COMPOSITION
(relative by volume)
100%
75%
50%
25%
0%
Potassium feldspar
21%
Quartz
38%
Pyroxene
(green)
Olivine
(green)

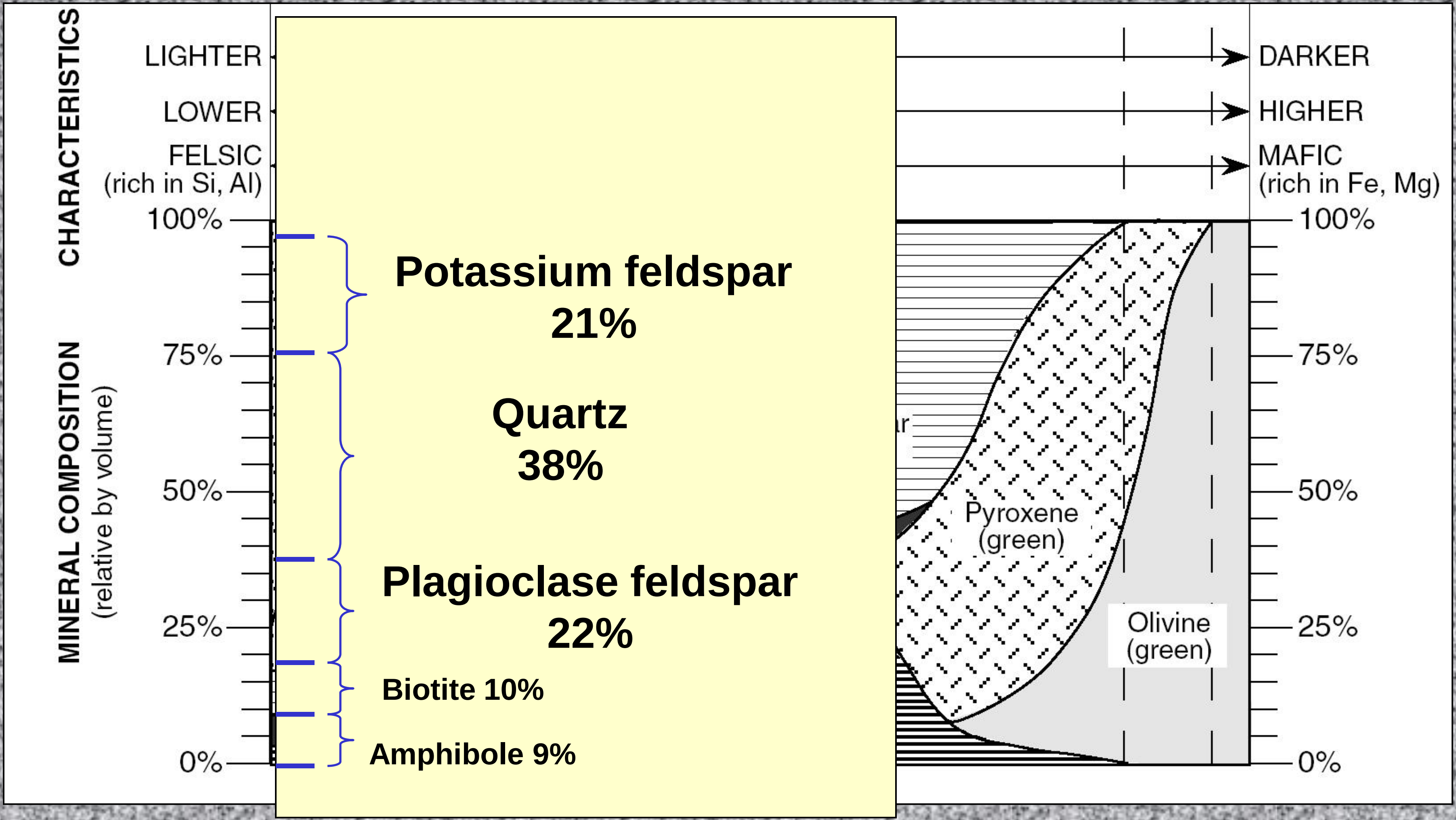


Potassium feldspar
21%

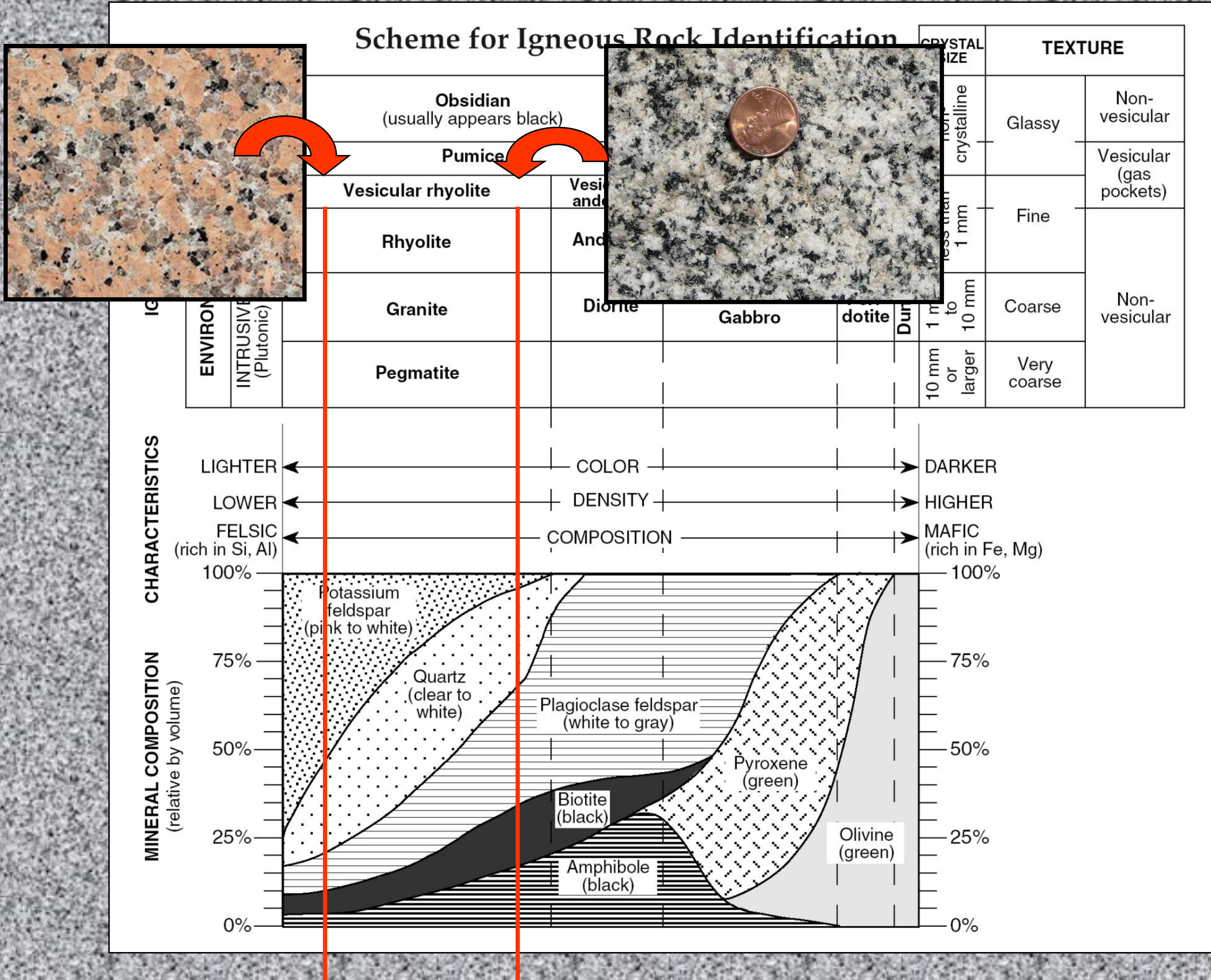
Quartz
38%

Plagioclase feldspar
22%

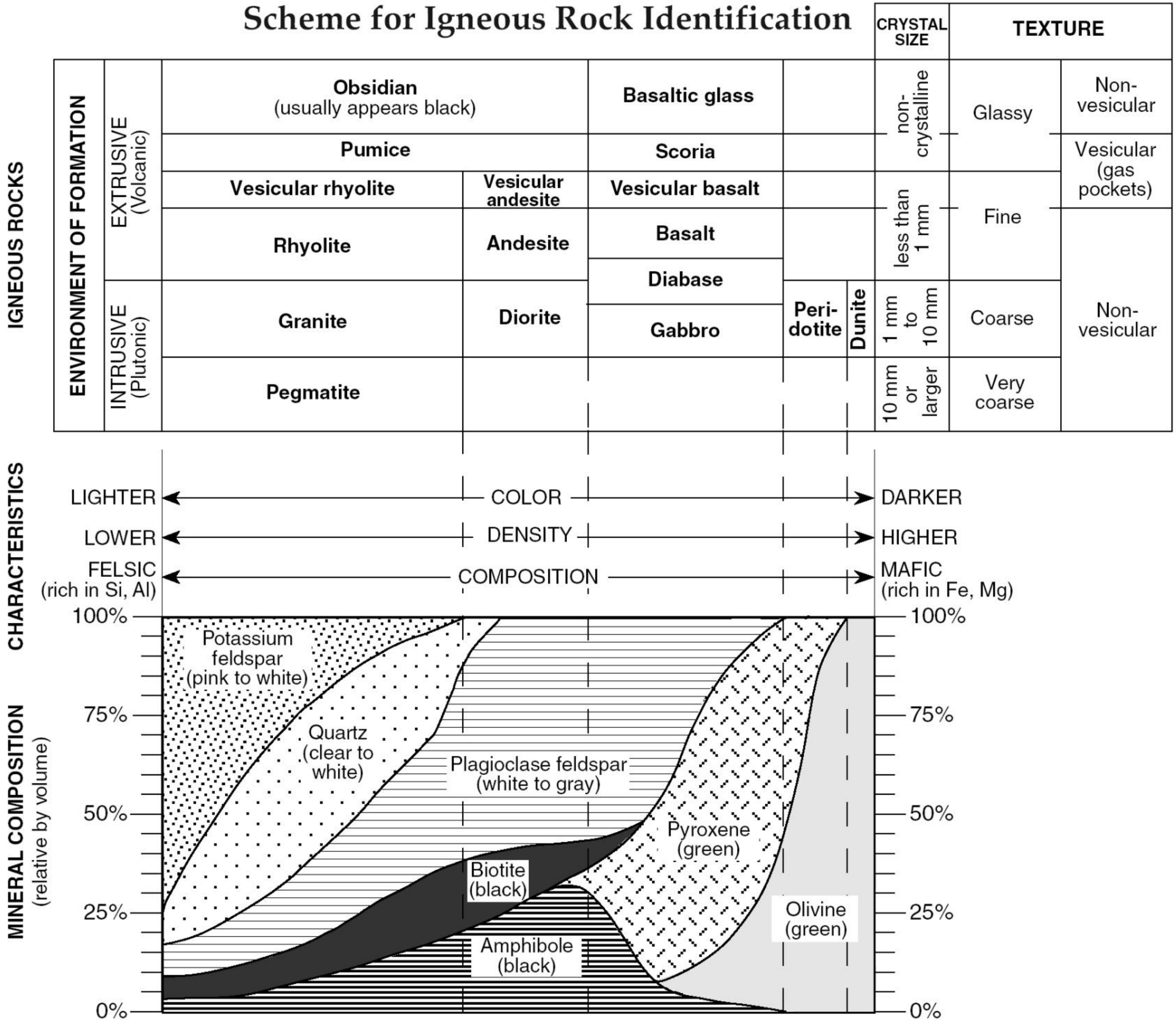

CHARACTERISTICS
LIGHTER
DARKER
LOWER
HIGHER
FELSIC
(rich in Si, Al)
MAFIC
(rich in Fe, Mg)
MINERAL COMPOSITION
(relative by volume)
100%
75%
50%
25%
0%
Pyroxene
(green)
Olivine
(green)
Potassium feldspar
21%
Quartz
38%
Plagioclase feldspar
22%
Biotite 10%


CHARACTERISTICS
LIGHTER
DARKER
LOWER
HIGHER
FELSIC
(rich in Si, Al)
MAFIC
(rich in Fe, Mg)
MINERAL COMPOSITION
(relative by volume)
100%
75%
50%
25%
0%
Potassium feldspar
21%
Quartz
38%
Plagioclase feldspar
22%
Biotite 10%
Amphibole 9%
Pyroxene
(green)
Olivine
(green)

Varieties of Granite


Scheme for Igneous Rock Identification
CRYSTAL SIZE
TEXTURE
Obsidian
(usually appears black)
Pumice
Vesicular rhyolite
Rhyolite
Granite
Pegmatite
Diorite
Gabbro
dotite
ENVIRON
INTRUSIVE (Plutonic)
crystalline
1 mm
10 mm
10 mm or larger
Glassy
Fine
Coarse
Very coarse
Non-vesicular
Vesicular (gas pockets)
Non-vesicular
CHARACTERISTICS
LIGHTER
COLOR
DARKER
LOWER
DENSITY
HIGHER
FELSIC (rich in Si, Al)
COMPOSITION
MAFIC (rich in Fe, Mg)
MINERAL COMPOSITION (relative by volume)
100%
75%
50%
25%
0%
Potassium feldspar (pink to white)
Quartz (clear to white)
Plagioclase feldspar (white to gray)
Biotite (black)
Amphibole (black)
Pyroxene (green)
Olivine (green)

Scheme for Igneous Rock Identification

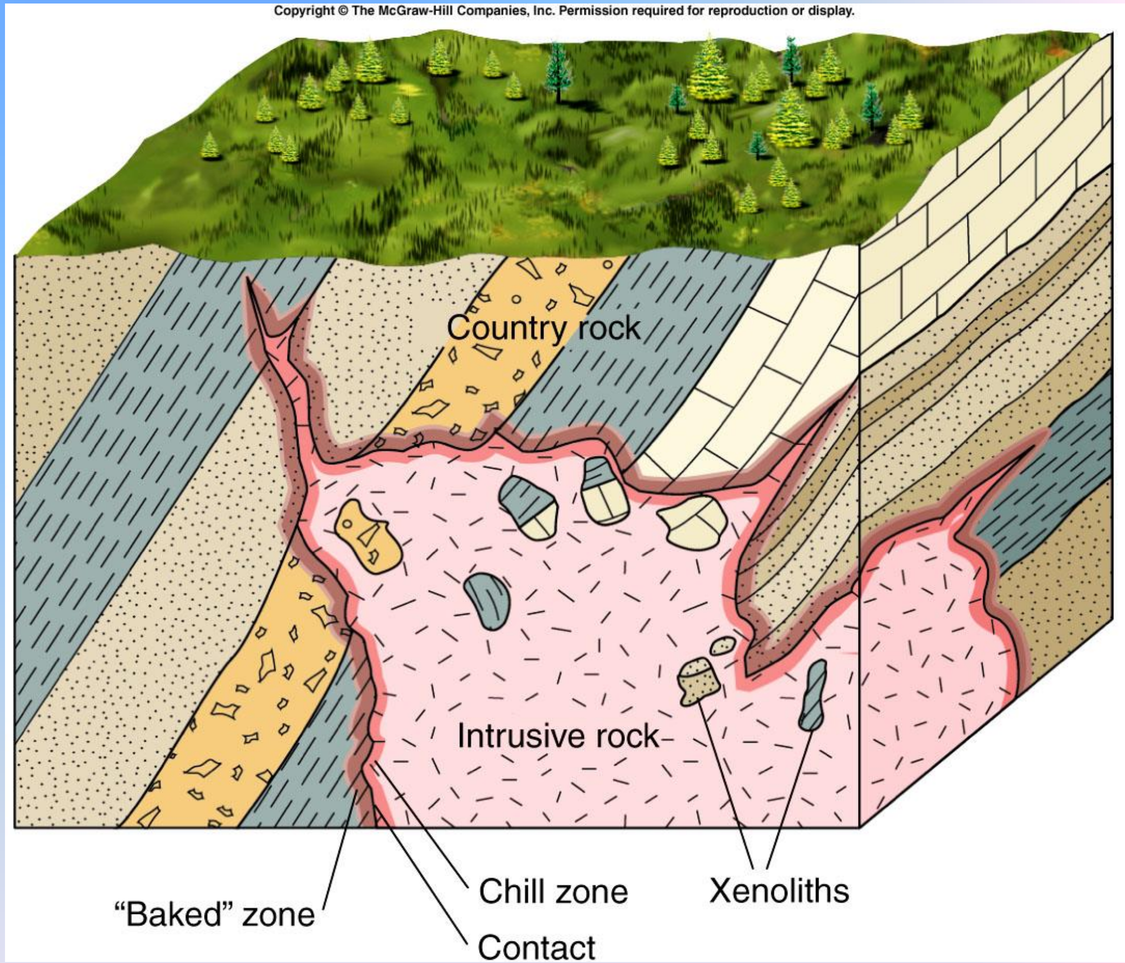


IV. Intrusive Activity and Igneous Rocks

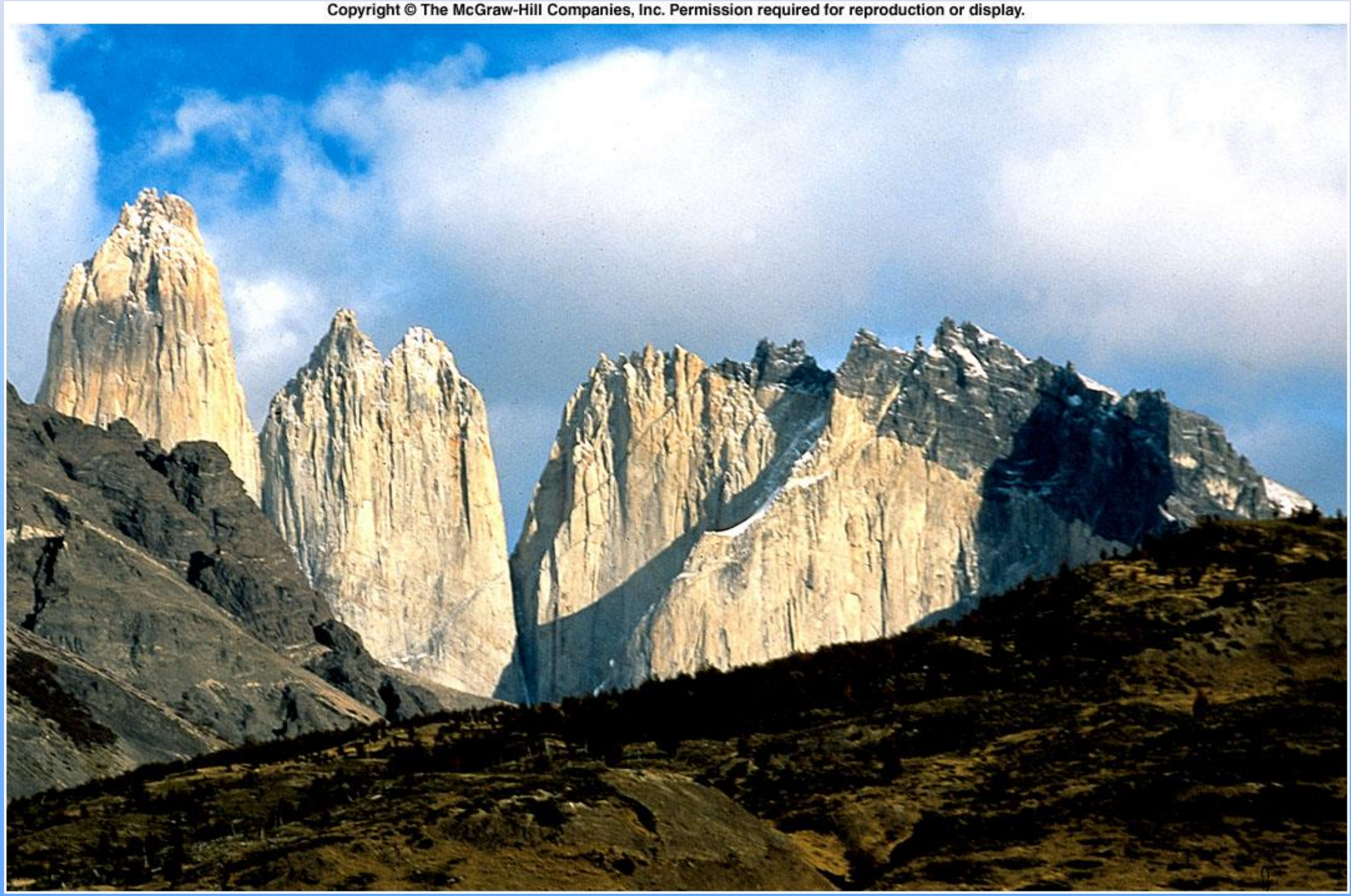
- ***Country Rock***:
  Any older, preexisting rock into which an igneous body has intruded.

- ***Xenoliths***:
  Fragments of country rock often break off and are enclosed in the intrusion.

- ***Chill Zone***:
  Finer-grained rocks adjacent to contacts with country rock are often evidence magma solidified more quickly due to the rapid loss of heat to cooler rock.



Granite Intrusion:
Exposed by Erosion in Torres del Paine, Chile



Dark colored country rock the sedimentary rock shale.

A. Shallow Intrusive Structures

1. Solidified near Earth's surface (most likely at depths less than 2 km).
2. Associated with subsurface volcanic activity
3. Are likely to be fine-grained because of shallow locations and relatively cool country rock into which they intrude.
4. Smaller than bodies formed at great depths (also a reason for rapid cooling rates)

5. Types of Shallow Intrusive Structures

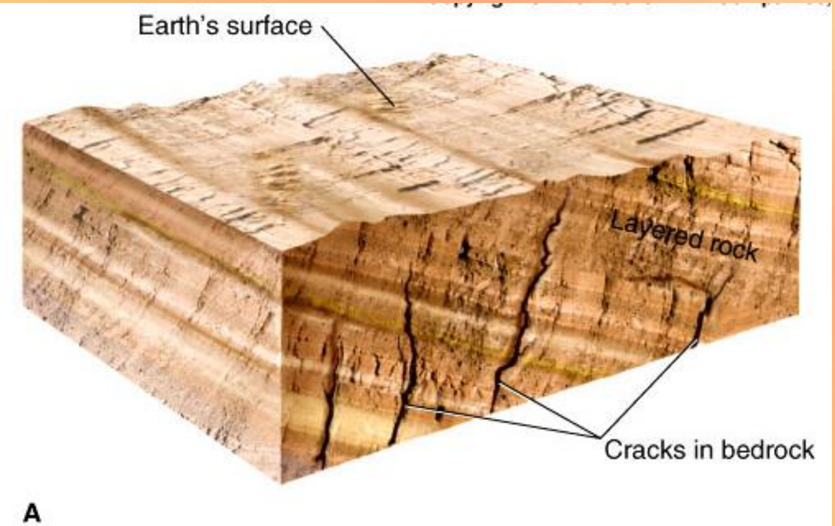
Dikes and Sills

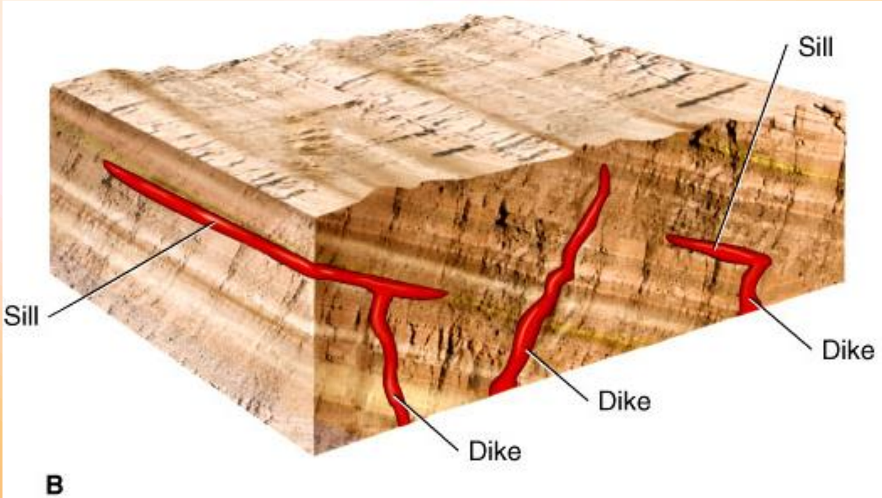
a) **Dike**

- i A tabular shaped structure
- ii Cuts across older country rock (*discordant*)

b) **Sill**

- i Tabular intrusive structure that is *concordant* (parallel to any planes or layers of older country rock)
- ii Originates as magma that has been squeezed in between older layers solidifies.





Dikes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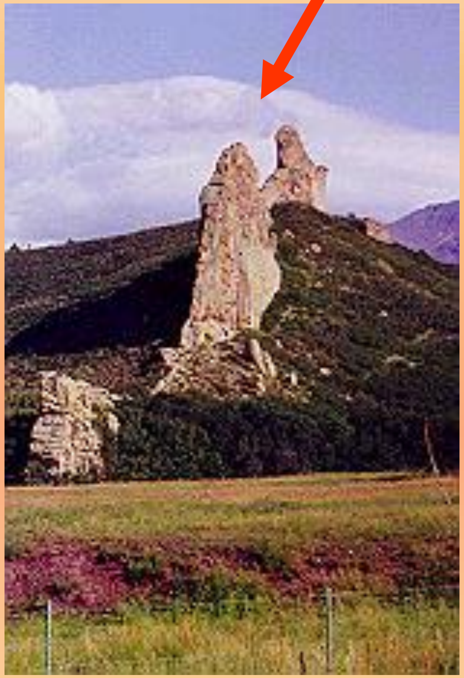
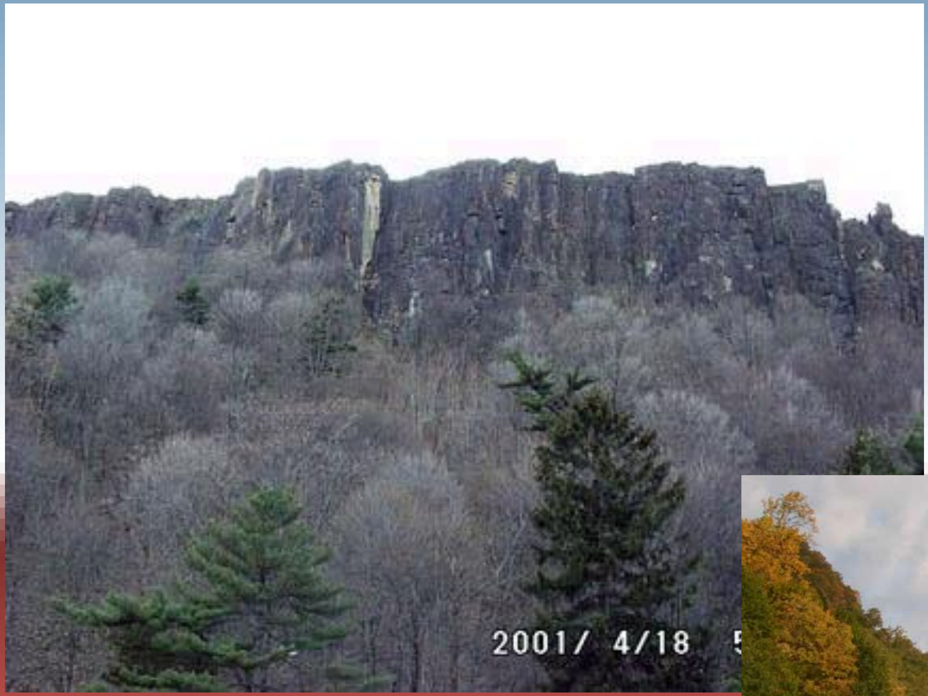
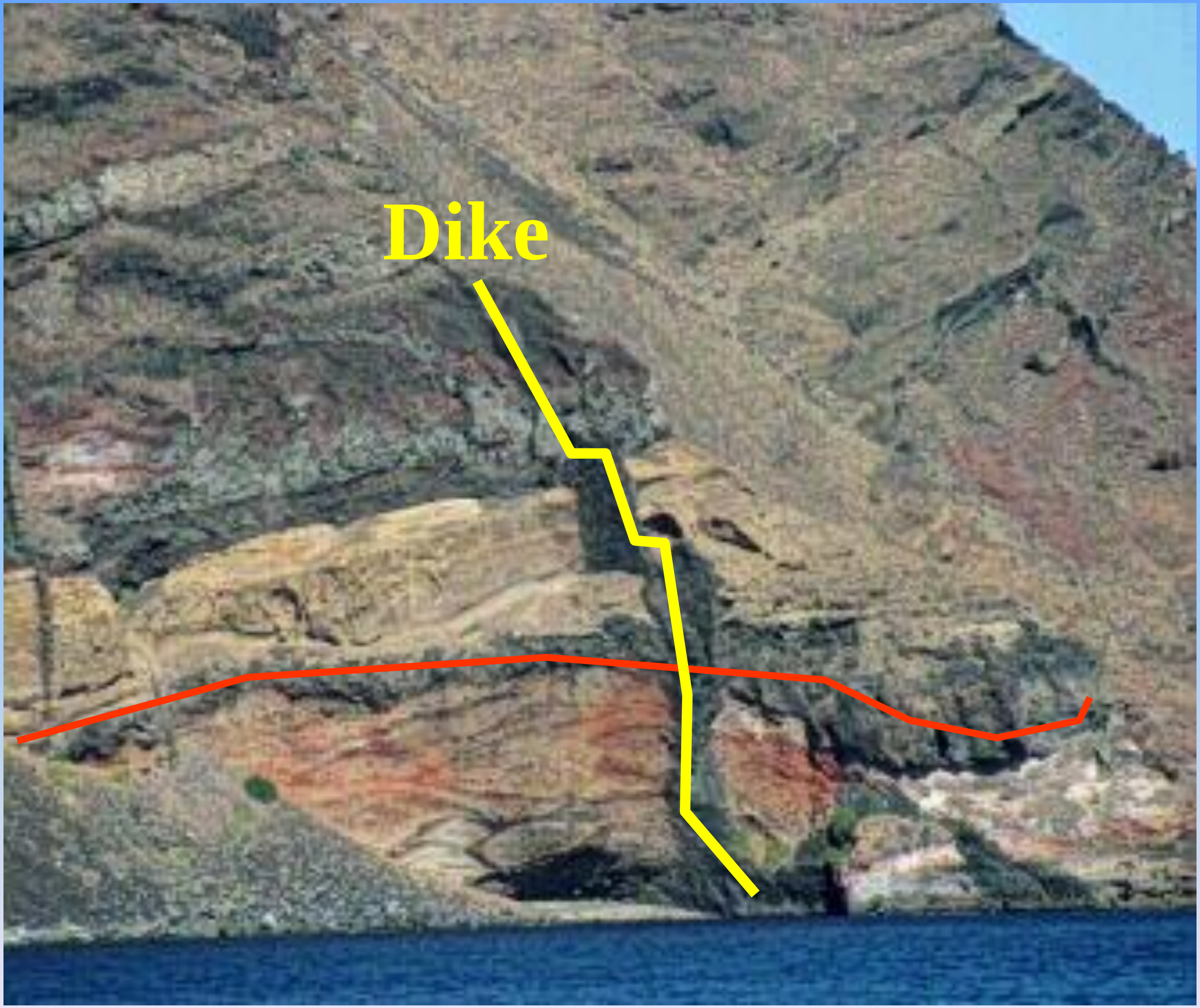


Sills

- Top Photo
  - Basaltic sill in Glacier National Park, Montana
- Bottom Photo
  - Palisades Sill along the Hudson River

Palisades Sill

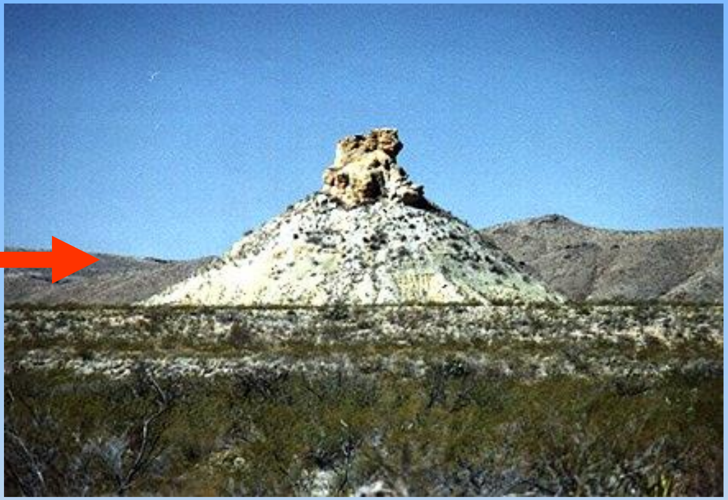




Can you see the sill? **How about the dike?**

c) Volcanic Neck (Plug)

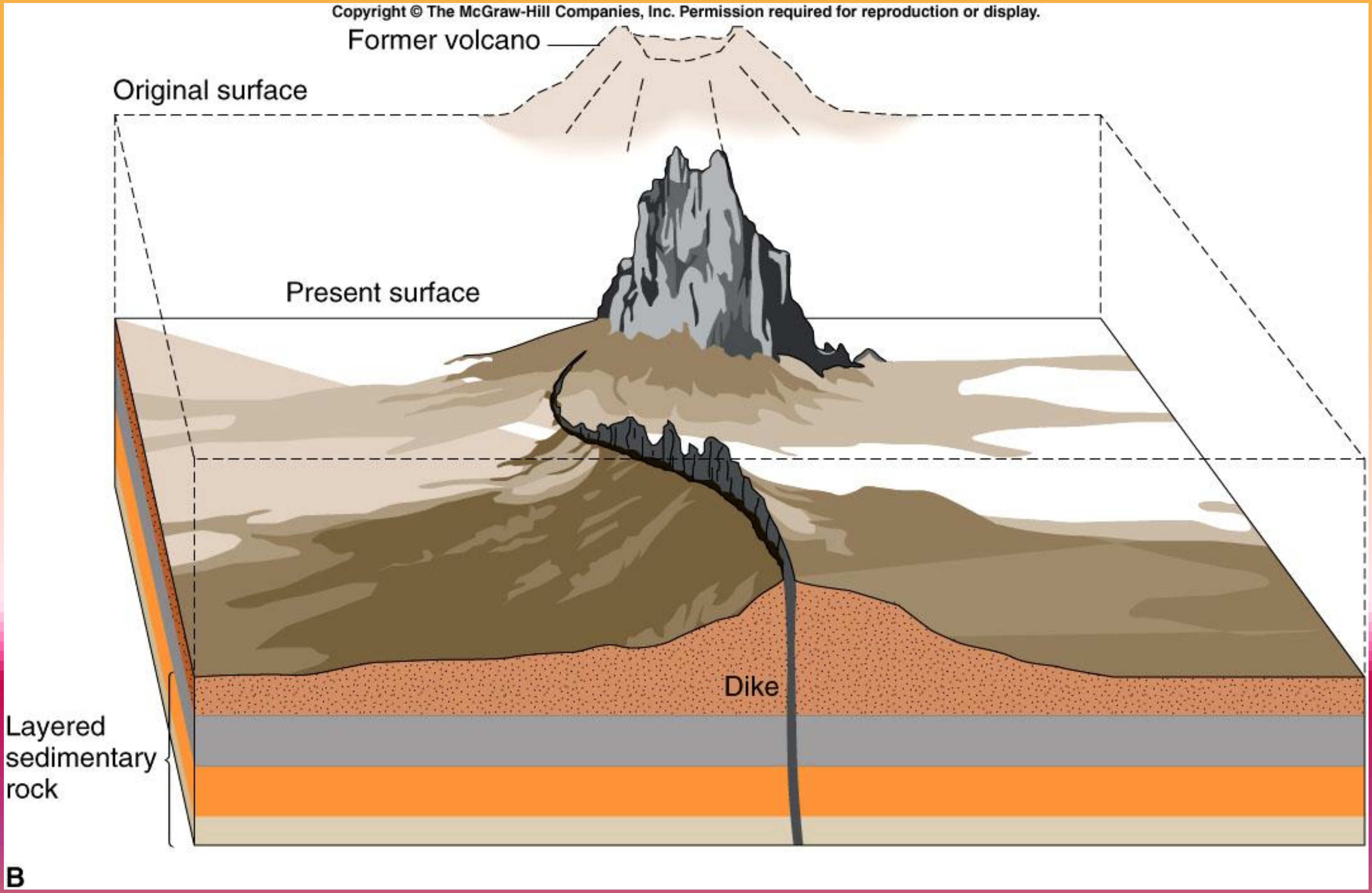
Erosion



i. Form from magma that solidifies in the pipe of a volcano

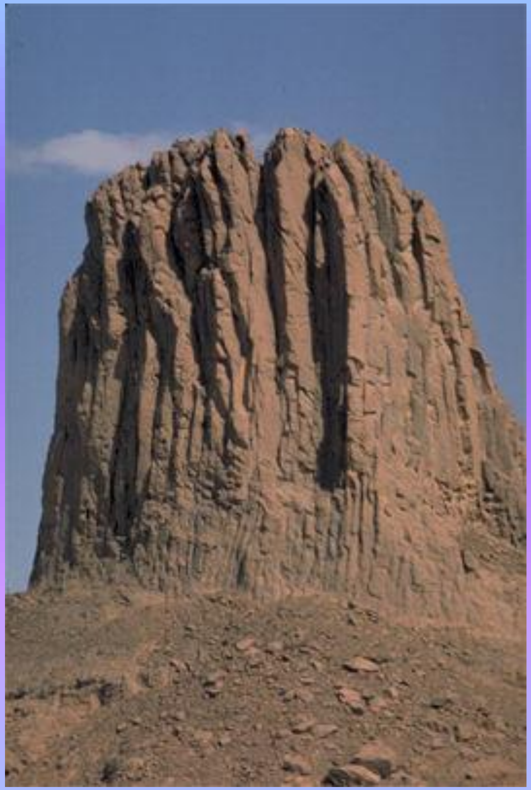
ii Shiprock, New Mexico is an example.

Ship Rock in New Mexico



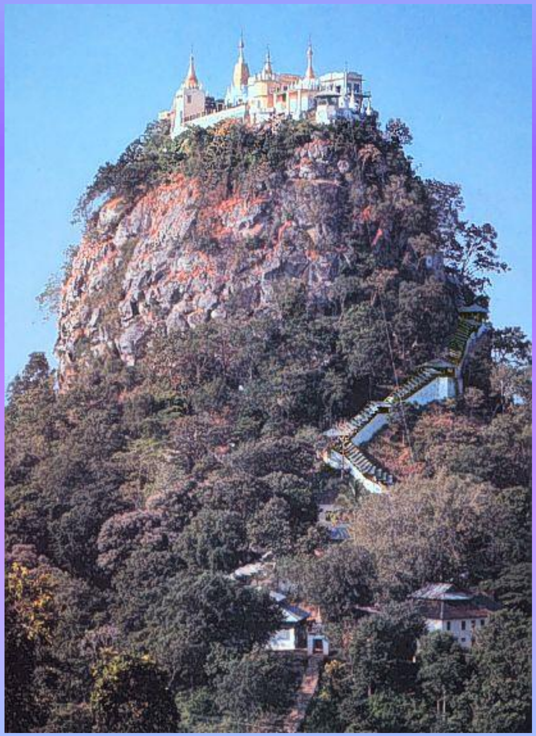
Height is
420 m
(1,400 ft.)

Volcanic Necks



Algeria

Monument Valley
AZ/UT, USA



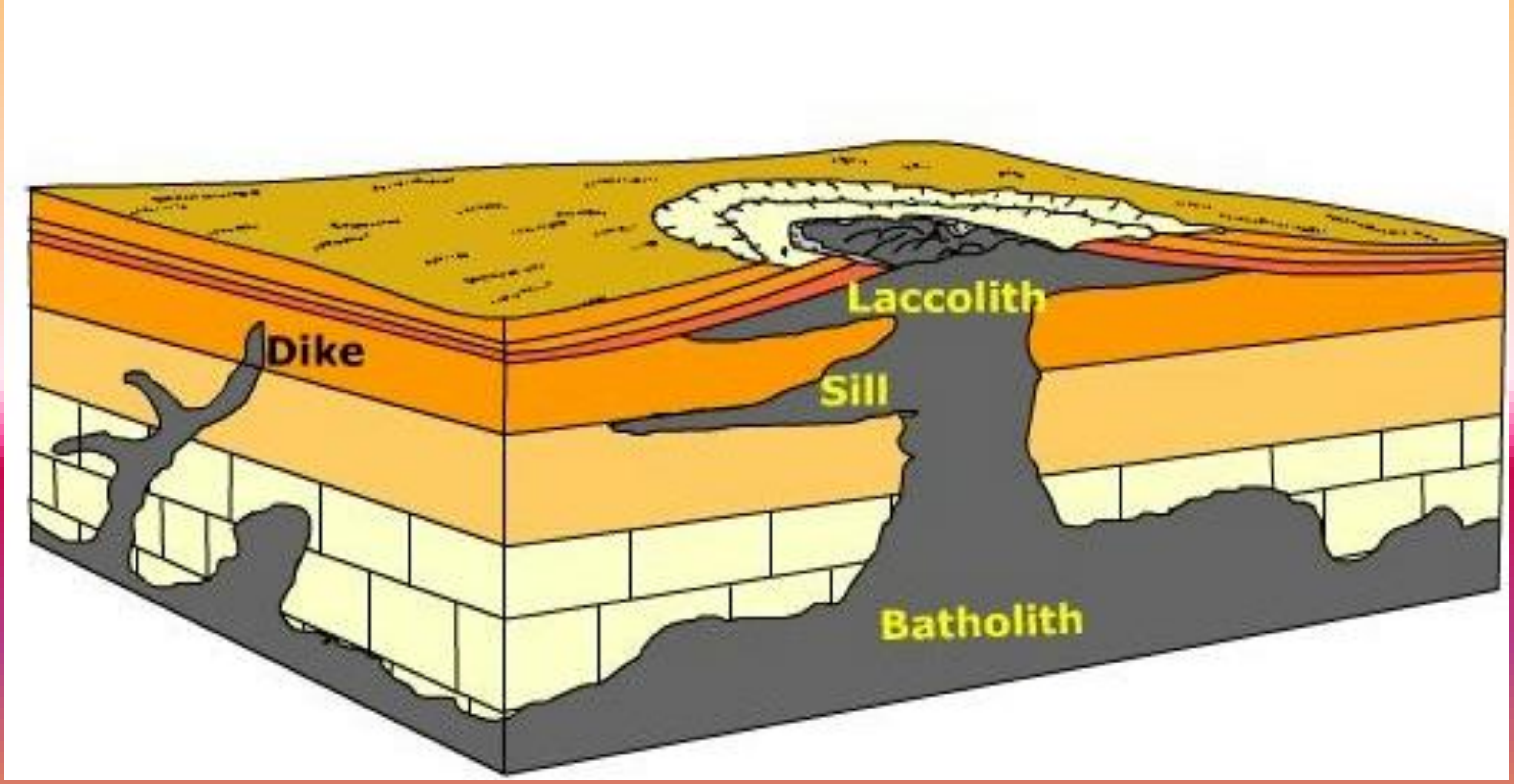
Burma

d) Laccolith

i Similar to a sill but the central portion is thick and domed upward.

ii “Mushroom-like” appearance

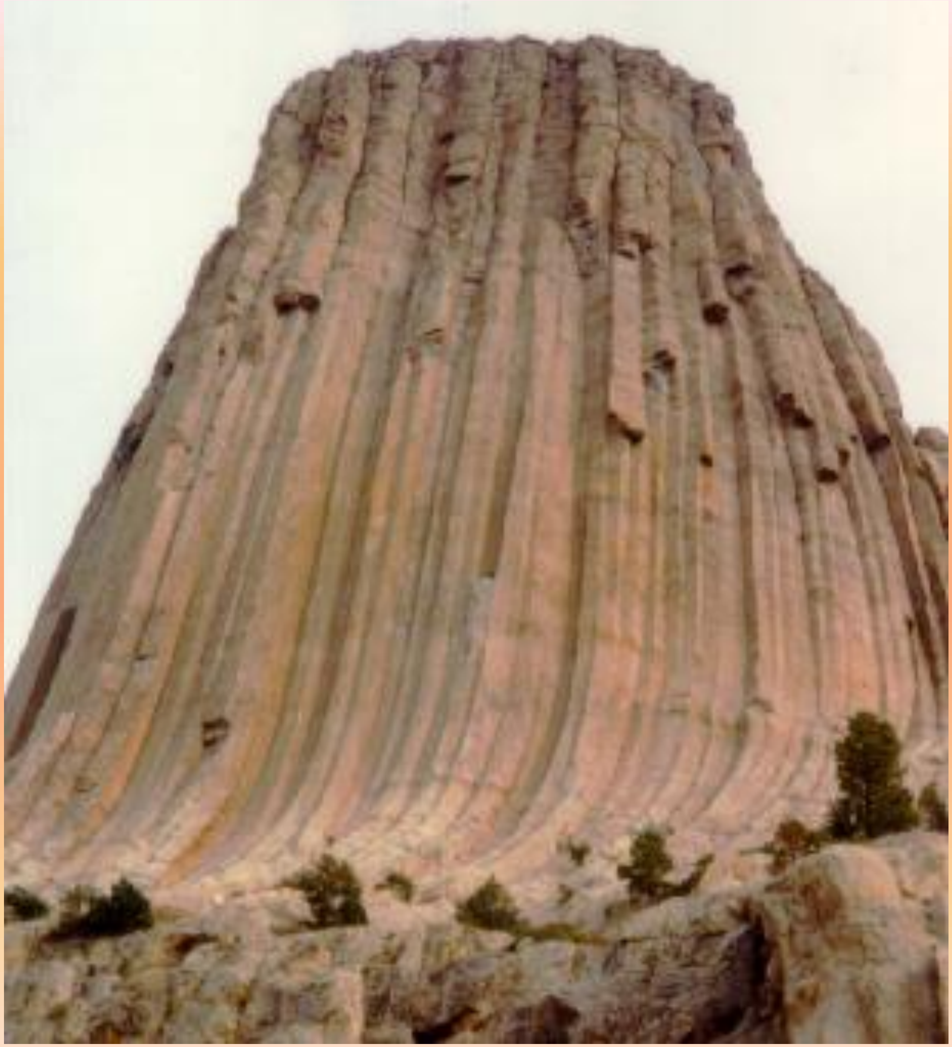
iii Not common



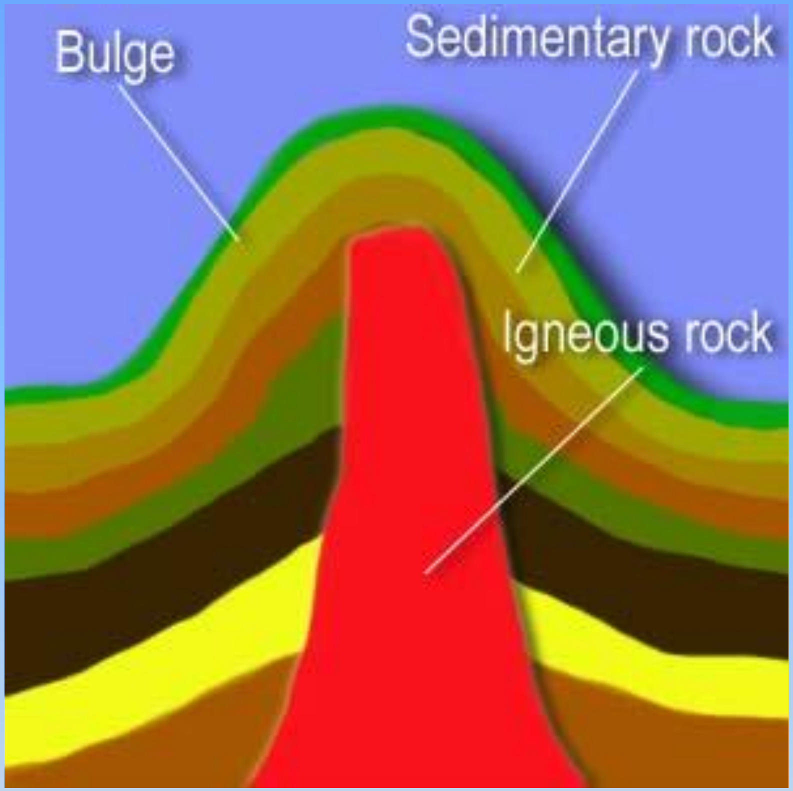
Laccolith

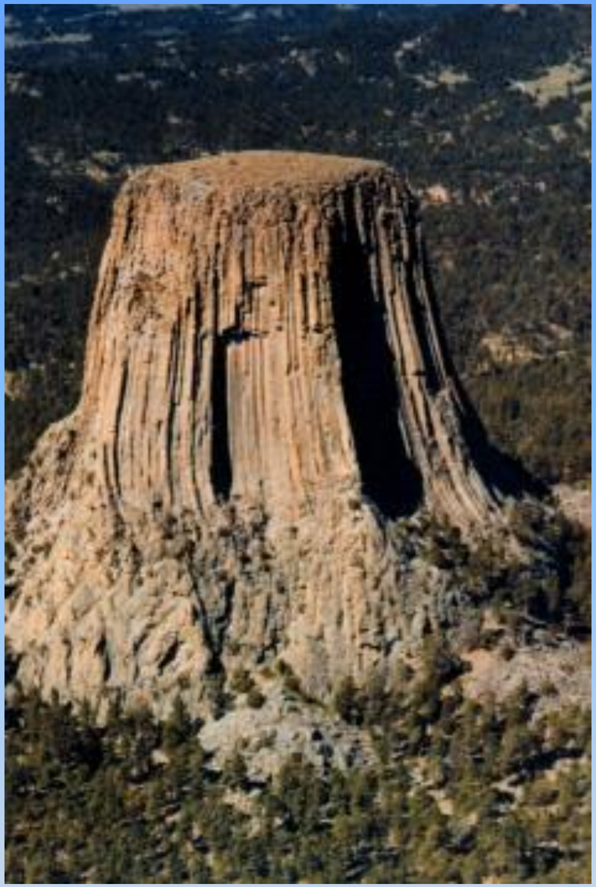
South Dakota laccolith exposed by erosion

Devils Tower, WY
Volcanic Neck or Laccolith?



- Most of the evidence suggests that Devil's Tower isn't the remains of an extinct volcano
- There is no trace in the surrounding countryside of other geological phenomena that might be associated with a volcano such as ash or lava flows.





- **A more likely theory is that Devil's Tower is a steep-sided laccolith**

Good Morning
3.27.12

- **Finish Ring of Fire (10 mins) please find your DVD ditto**
- **Go over UPCO HW**
- **PPT Notes Igneous Intrusions**
- **HW: Finish Lab 4-4, Vocab. Lab 2-3 Wednesday**

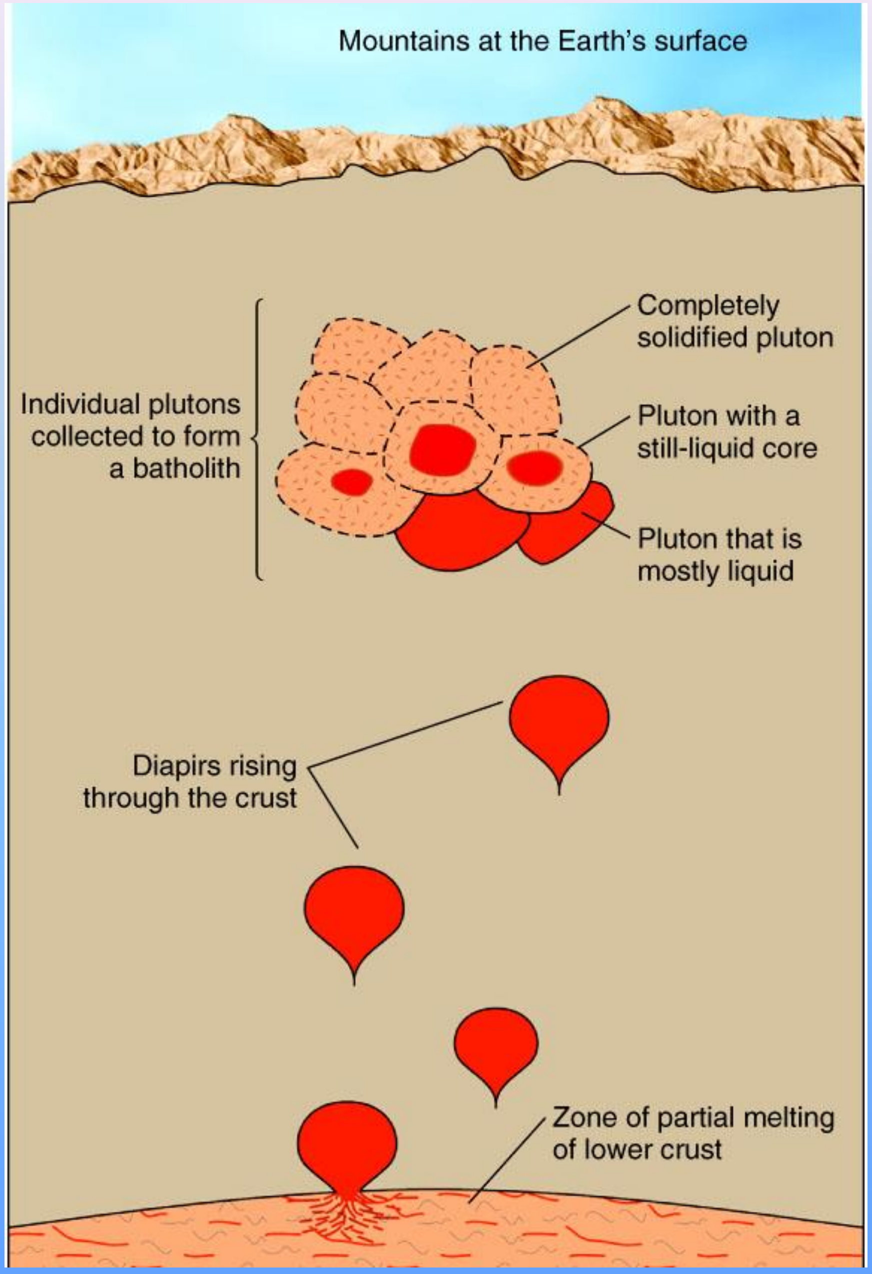
B. Intrusions that Crystallize at Great Depths

1. __**Pluton**__

   a) A body of magma or igneous rock that crystallizes at considerable depth within Earth's crust.

   b) Unlike dikes and sills, most plutons have no particular shape.

Formation of a Pluton



2. *Types of Plutons*

a) **Batholith**

i A large *discordant* pluton

ii Outcrop area of greater than 100 square km (most are larger)

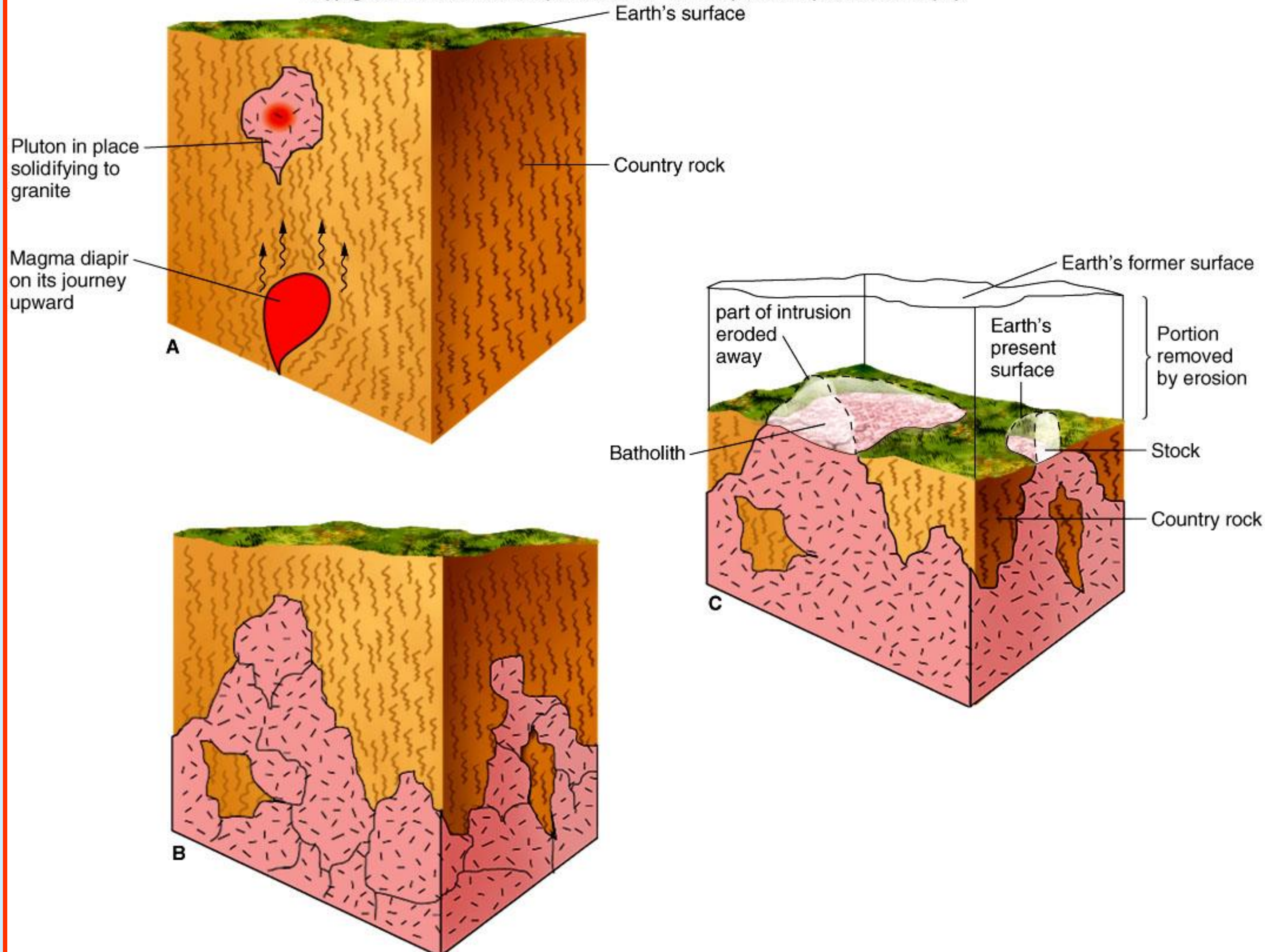
iii Most are predominantly granitic although they often contain mafic and intermediate rocks

iv They are formed many coalesced plutons. These large blobs of magma, called **diapirs**, that melt their way upward and collect 5 to 50 km below the surface.

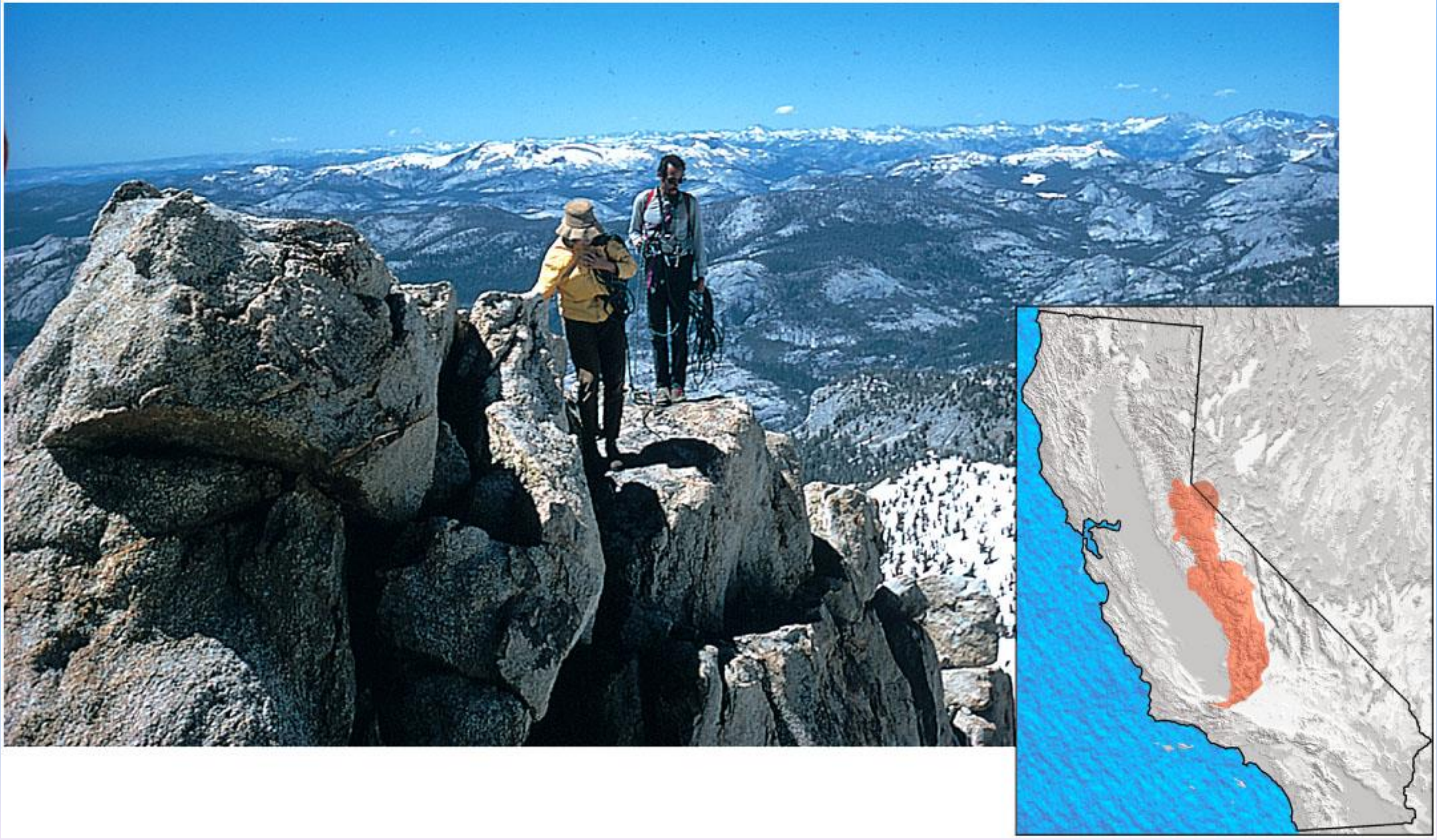
b) **Stock**

i Small *discordant* pluton

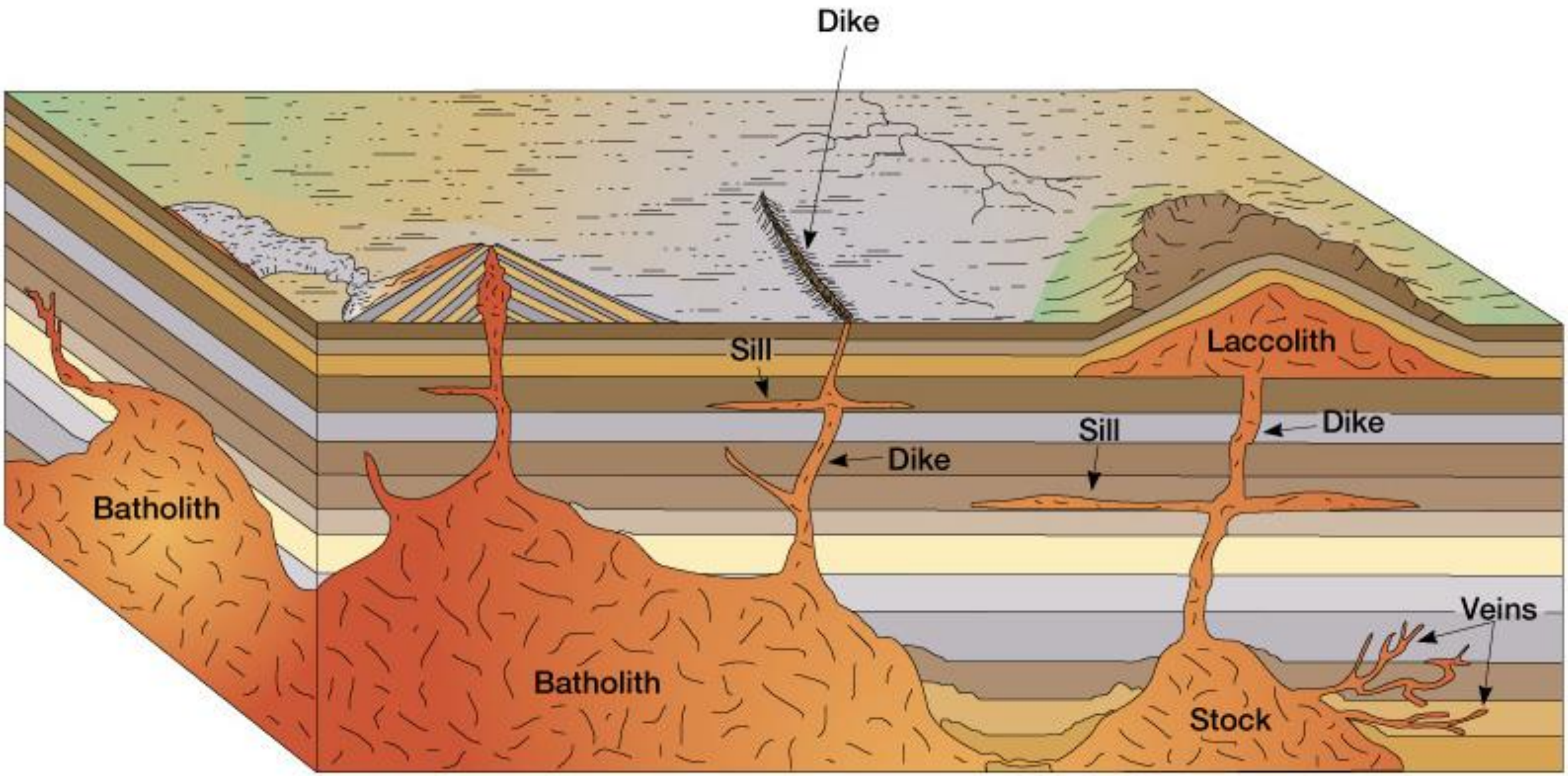
ii Outcrop area less than 100 km


Earth's surface
Pluton in place solidifying to granite
Country rock
Magma diapir on its journey upward
A
B
Earth's former surface
part of intrusion eroded away
Earth's present surface
Portion removed by erosion
Batholith
Stock
Country rock
C

Sierra Nevada Batholith



Igneous Intrusions: Summary



V. **Volcanic Products**

- A volcano is a vent or fissure through which solid, liquid (molten), and gaseous material pass upward to Earth's surface.

- Common terminology indicates some kind of mountain or dome being formed but volcanic plateaus as well mountains can form.

A. Gases

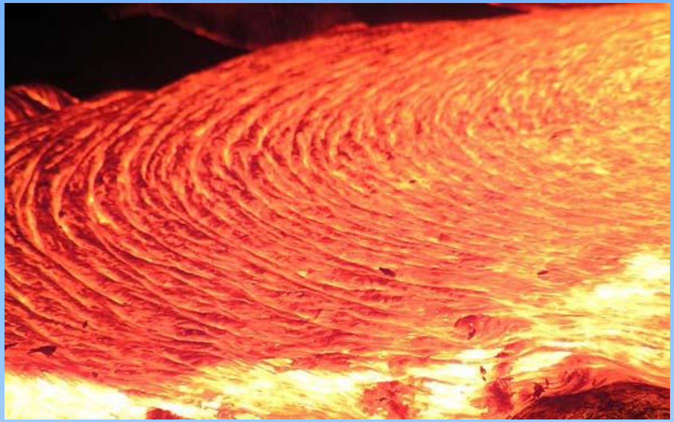
1. Water Vapor
   a) Most of the gases released during eruptions (50 % to 95%)
   b) Condenses as steam

2. Other gases include: carbon dioxide, sulfur dioxide, hydrogen sulfide (rotten egg smell) and hydrochloric acid

B. ___Liquids___ (Lava)

1. ___Pahoehoe___ Lava (*pah-hoy-hoy*)
   a) Hawaiian name for basaltic lava that cools quickly and was fully liquid
   b) Cools with a smooth ropy or billowy surface

Pahoehoe Lava



C. <u>**aa** (*ah-ah*) Lava</u>

a) Hawaiian name for basaltic lava cool enough to have partially solidified
b) Moves as a slow, pasty mass
c) Solidified front of flow moves as a pile of rubble
d) Has a rough and jagged surface

Lava - aa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3. **Pillow** Lava (Pillow Structures)

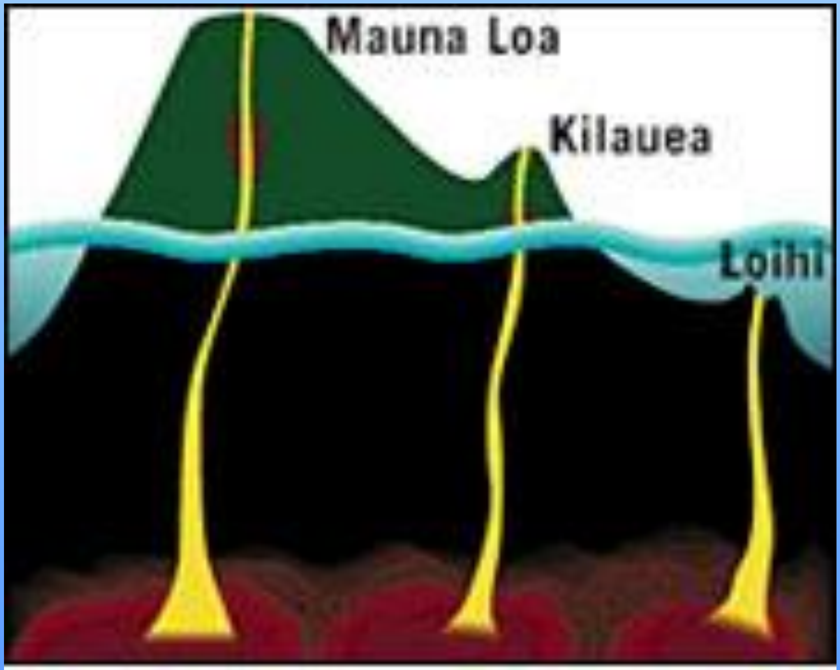
a) Basaltic lava flows under water
b) Occur as pillow-shaped rounded masses that are closely fitted together
c) Blobs of lava are squeezed out of a thin skin of solid basalt over a lava flow.
d) The surface of the blob quickly chills and becomes solid while a new blob forms as more lava breaks out.
e) Most pillow basalt forms at mid-ocean ridge crests although they can form in lakes and rivers.

Pillow Structures

Pillow Structures in CA

Show: How Earth was Made:
Hawaii chap. 5 Lo'ihi (~5 mins.)

- Outcrop along the beach in Cayucos
- Closer view of pillow structures



4. Types of Magma Affect the Types of Volcanic Eruptions

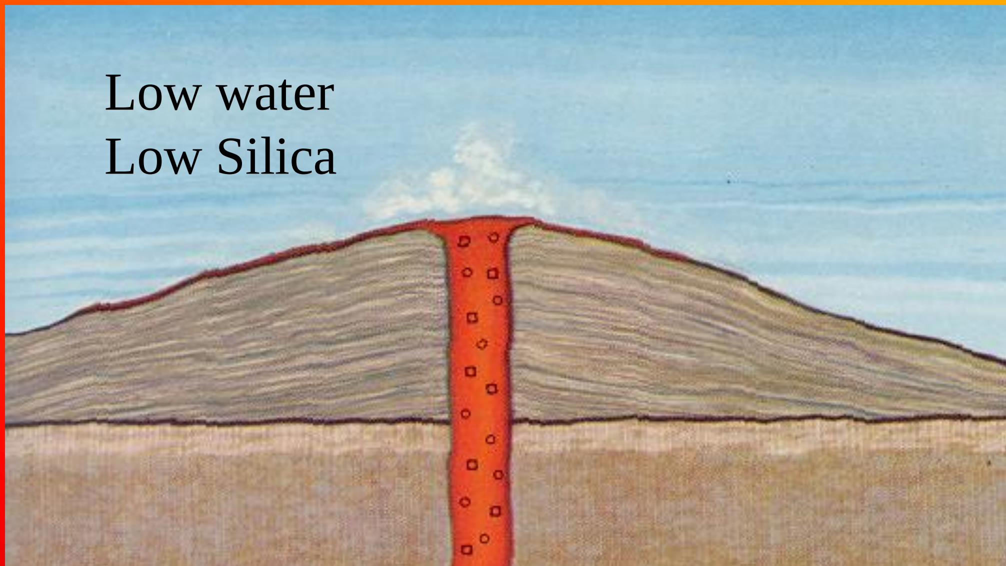
a) The violence of an eruption depends on two components; ___**silica**___ and ___**water**___.

b) The concentration of silica determines the viscosity of the molten rock.

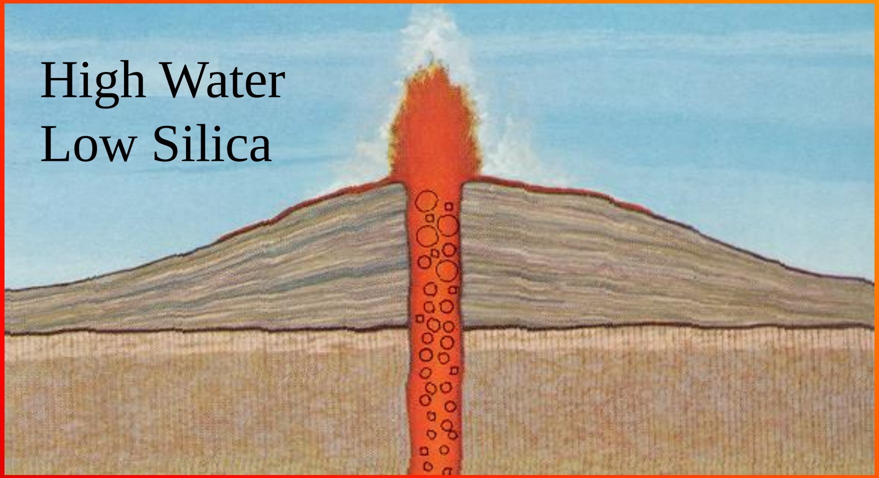
c) Water in magmatic solution provides the explosive potential of steam.

d) Types . . .

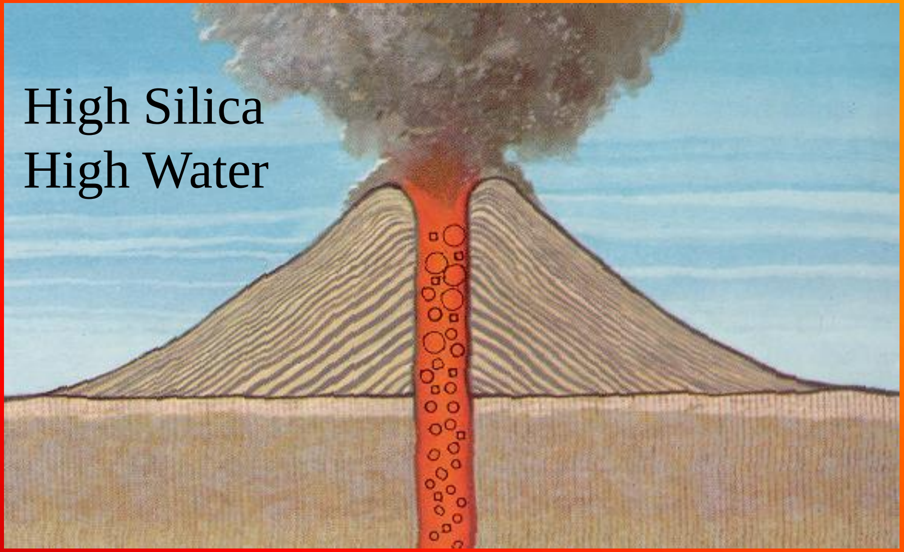
I. ***<u>Quiet Runny Lava</u>***



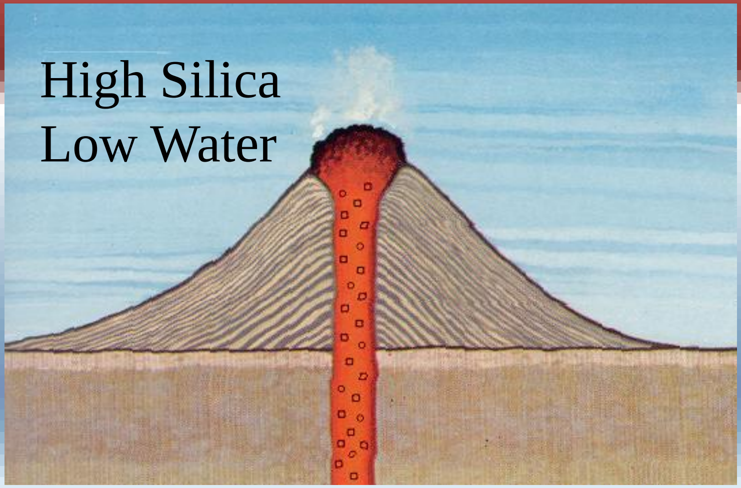
II. ***Fire Fountains***



III. ***<u>Gas Expolsions</u>***

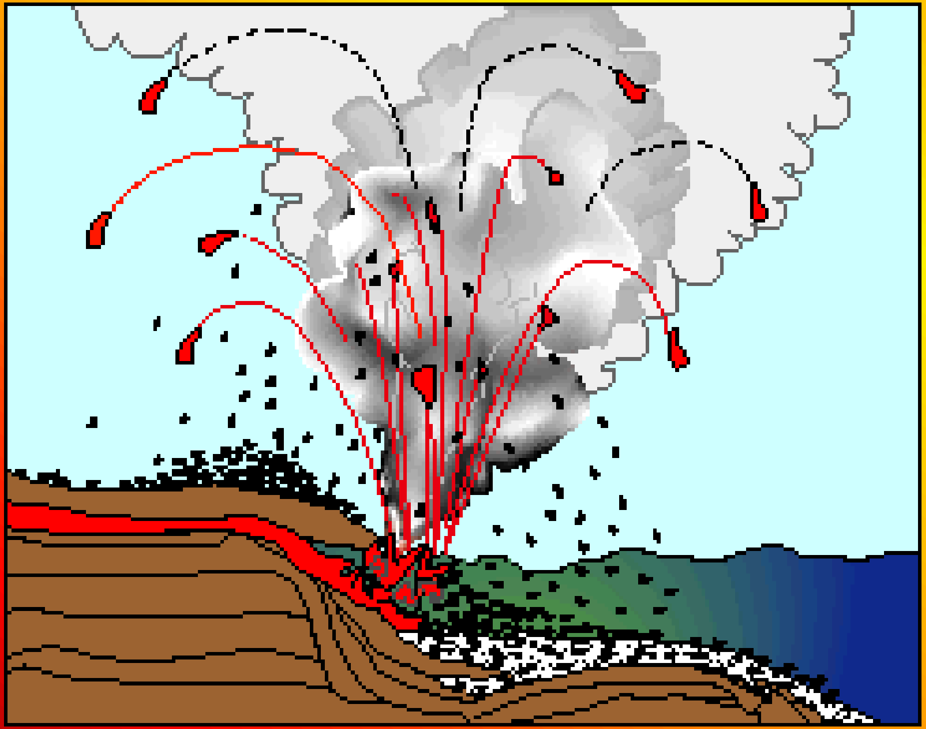


IV. ***Lava Domes***



C. **Solids**

1. __**Pyroclasts**__________ (also called *tephra* or *ejecta)* are solid fragments formed by volcanic explosions



2. Pyroclasts are classified by __**size**__.

a) ***Dust***: Smaller than 1/8 mm
b) ***Ash***: 1/8 to 2 mm
c) ***Cinders***: 2 to 64 mm
d) ***Blocks***: greater than 64 mm and are solid
e) ***Bombs***: greater than 64 mm and is plastic

Volcanic Ash

Block

During violent eruptions, blocks of up to several meter size can be thrown to several km distance.

- **During the Minoan eruption (ca. 1645 BC) of the Santorini volcano in Greece, <u>meter-sized blocks</u> were thrown to <u>up to 7 km horizontal distance</u>.**

- **Impacted violently into the ground, destroying houses of ancient settlements.**

- **The time these blocks spent on their trajectories = around 30-40 seconds**
- **Traveled at speeds of typically 200-300 m/s.**

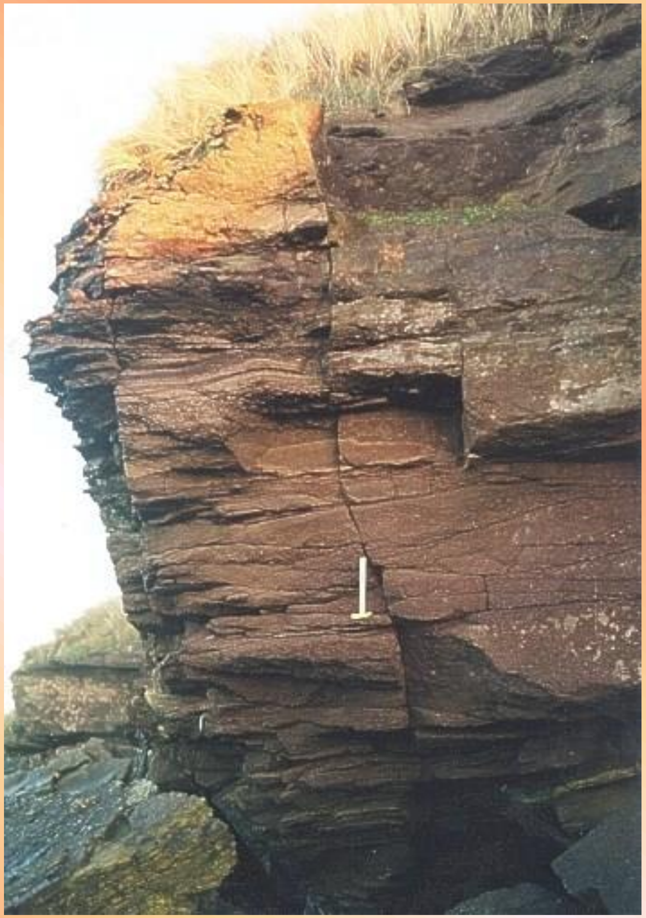
Bomb

- Blobs of lava that have been ejected from a volcano during eruption.

•Being somewhat gooey, airflow often molds them into aerodynamic shapes, producing teardrop or “flying saucer” shapes.

•Some bombs cool and harden before hitting the ground; however, this one was still viscous, and its sharp leading edge (left) was curled over on impact.

Rocks Formed from Pyroclastic Material: Tuff

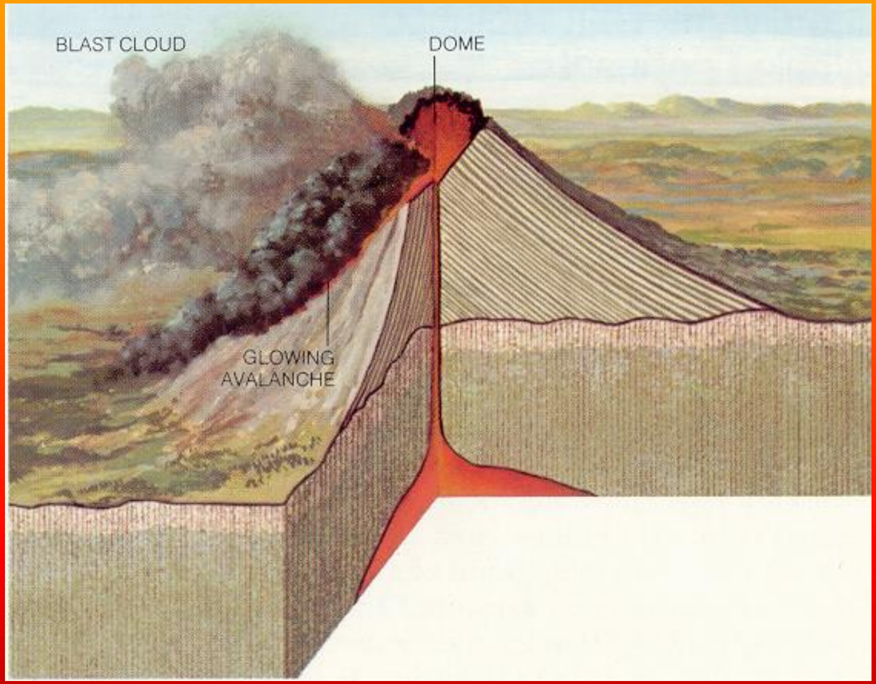


Tuff Cliff in Northern Ireland

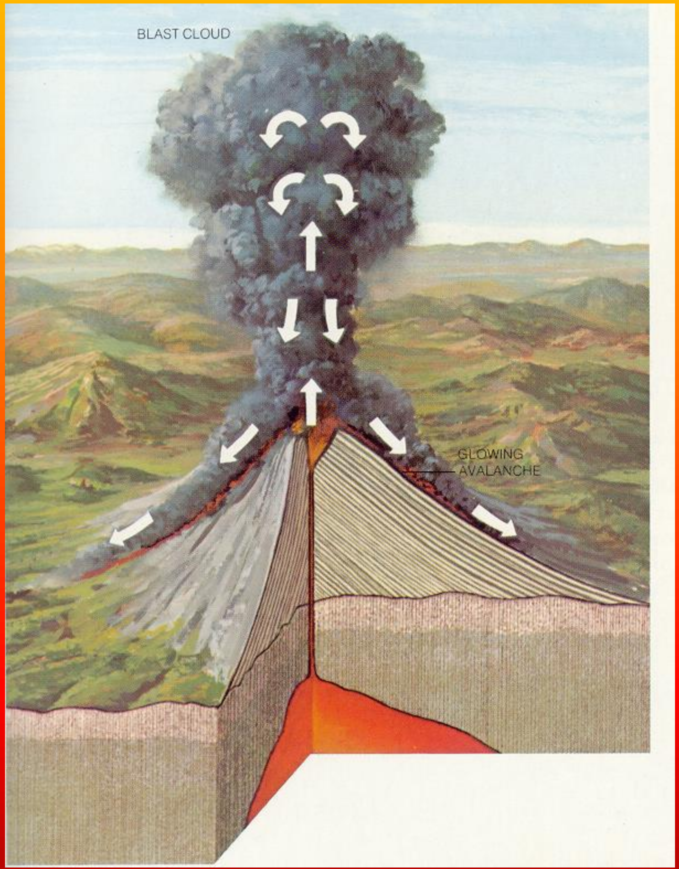
Rocks Formed from Pyroclastic Material: Breccia

Pyroclastic Flows Combined with Gases

Glowing Avalance (*Nuée Ardente*)



Exploding froth of gas and magma blasts out from a solid or viscous plug



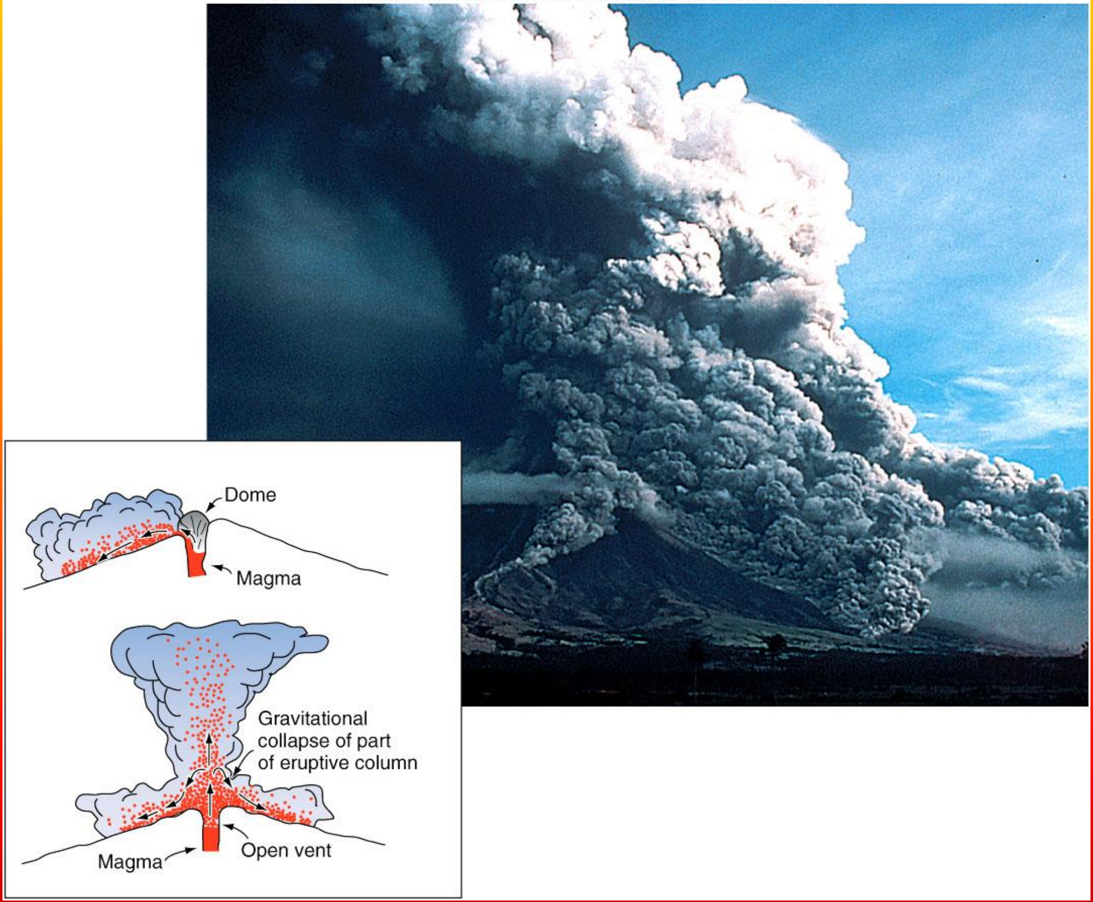
Vertically blasted gases and pyroclasts collapse due to gravity

Glowing Avalance (Nuée Ardente)

Mt. St. Helens

Mt. Pinatubo

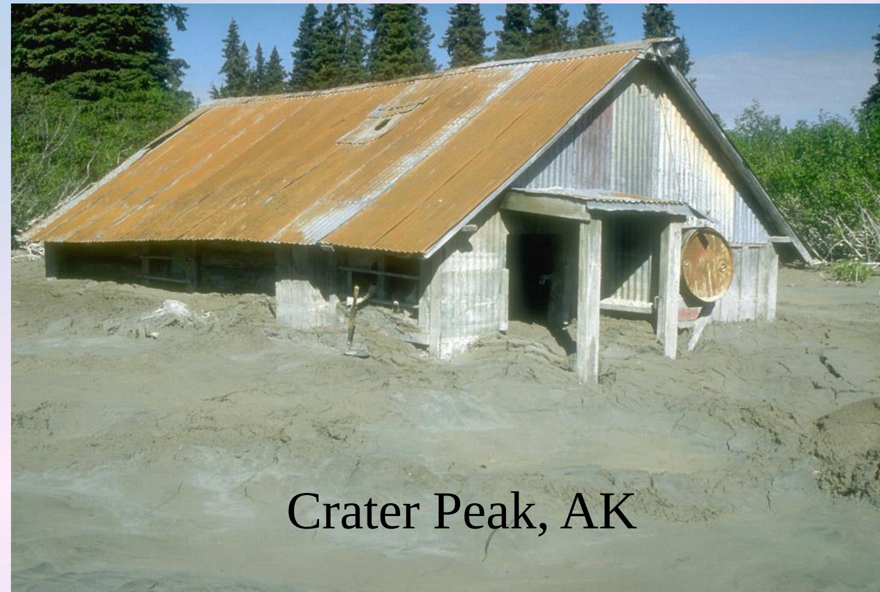
Pyroclastic Flow



- **Mayon Volcano, Philippines**
- **1984 Eruption**

Lahars

Mount Ruapehu, New Zealand



Crater Peak, AK

a) Pyroclastic flows combined with water
b) Form from heavy rains wash down loose ash from eruptions or more frequently from an eruption that ejects a crater lake or melts snow and ice on a volcanoes high summit
c) Mudflows are formed as the floods of water surge down the flanks of the volcano
d) Larger rocks a boulders can be picked up as the entire mass crashes down the valleys like a torrent of wet concrete.

Lahars

Mt. Pinatubo

Mt. St. Helens

Volcanoes Create New Landforms

Overall, volcanism is a *constructive* geologic process

Surtsey forms in 1963

VI. Volcanic Landforms

A. __**Vent**_______: Opening through which an eruption takes place

B. The __**conical shape**______ typical of volcanoes originates from volcanic material deposited and ejected around a central vent

C. __**Crater**______: Basin-like depression over a vent at the summit of a volcano

D. __**Caldera**_______: A volcanic depression much larger than the original crater with a diameter of at least one km.

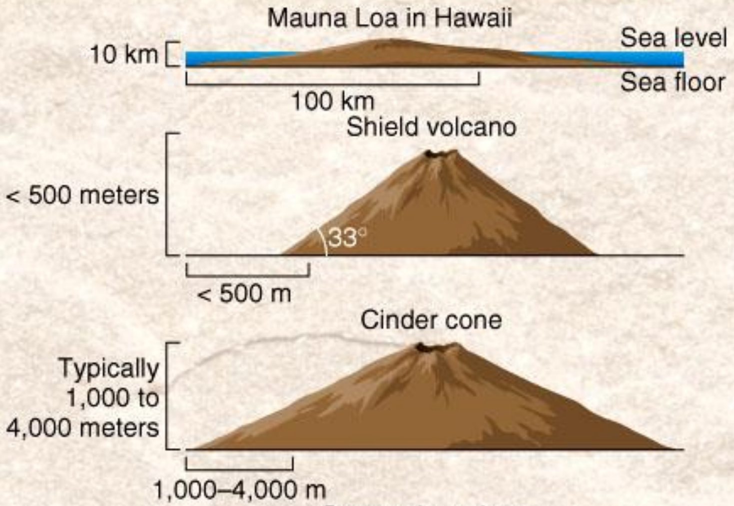
E. __**Flank**______ Eruption: When lava flows from a vent on the side of a volcano instead of from a central vent.

Types of Volcanoes

Volcanoes differ in size, shape, composition

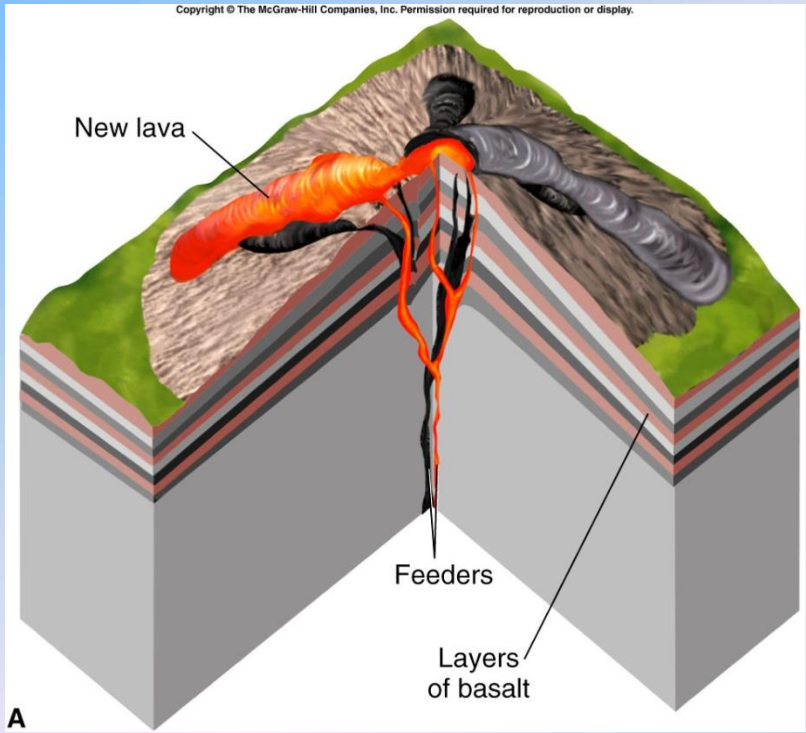
Table 4.2

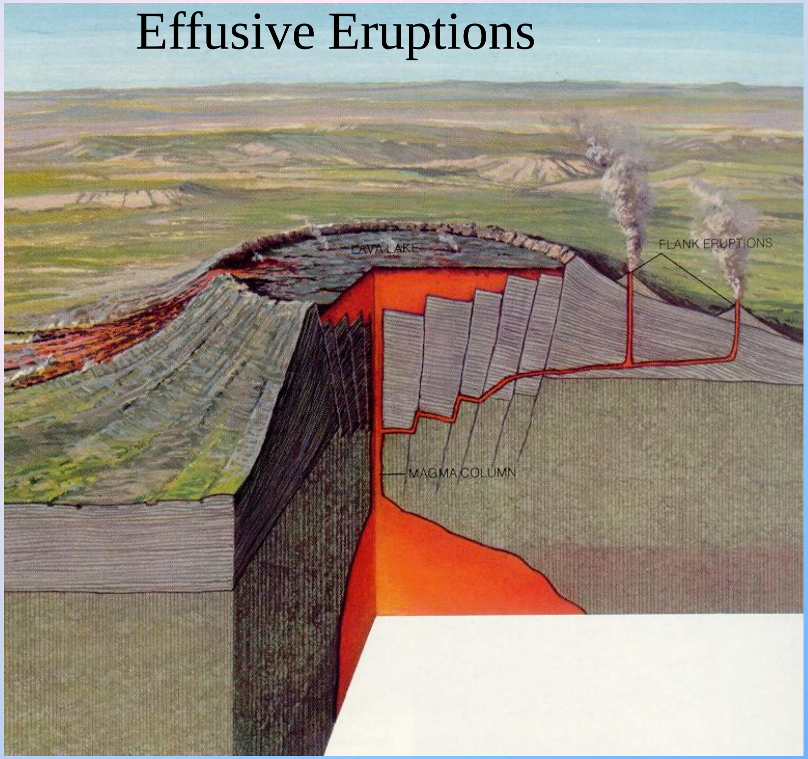
Comparison of the Three Types of Volcanoes



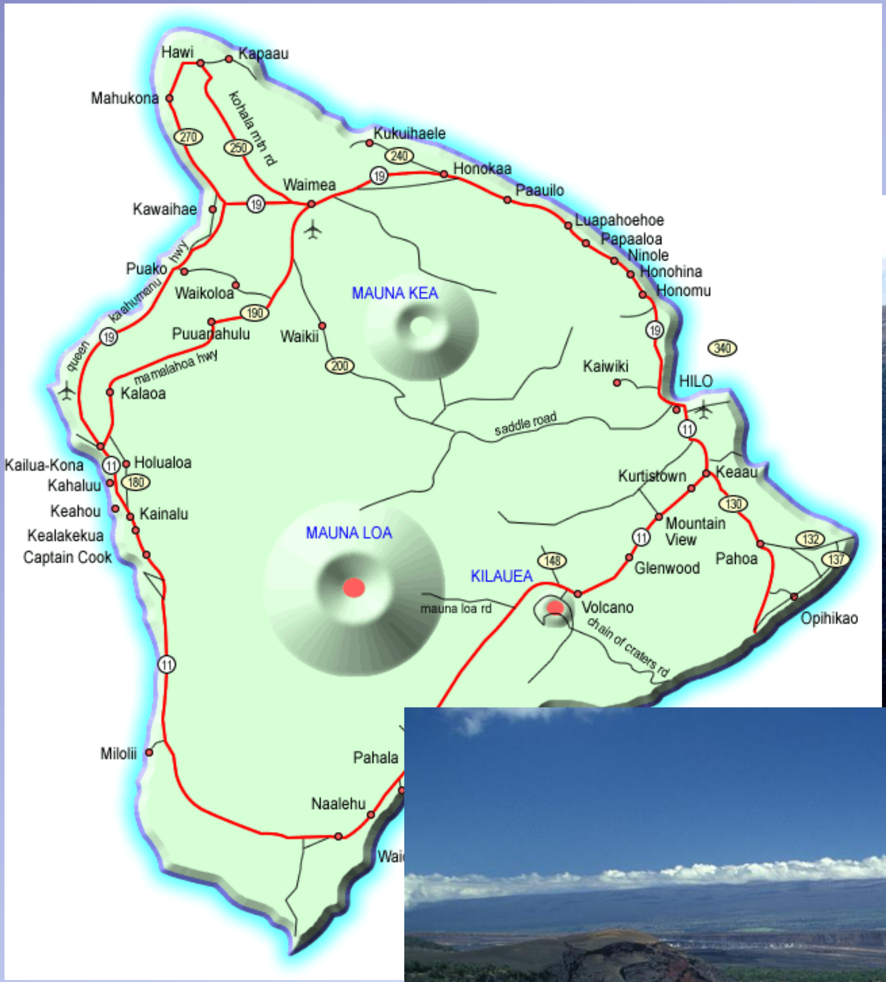
Profile of Volcano	Description	Composition
Shield volcano	**Shield Volcano** Gentle slopes—between 2° and 10°. The Hawaiian example rises 10 kilometers from the sea floor.	Basalt. Layers of solidified lava flows.
Cinder cone	**Cinder Cone** Steep slopes—33°. Smallest of the three types.	Pyroclastic fragments of any composition. Basalt is most common.
Composite volcano	**Composite Volcano** Slopes less than 33°. Considerably larger than cinder cones.	Layers of pyroclastic fragments and lava flows. Mostly andesite.

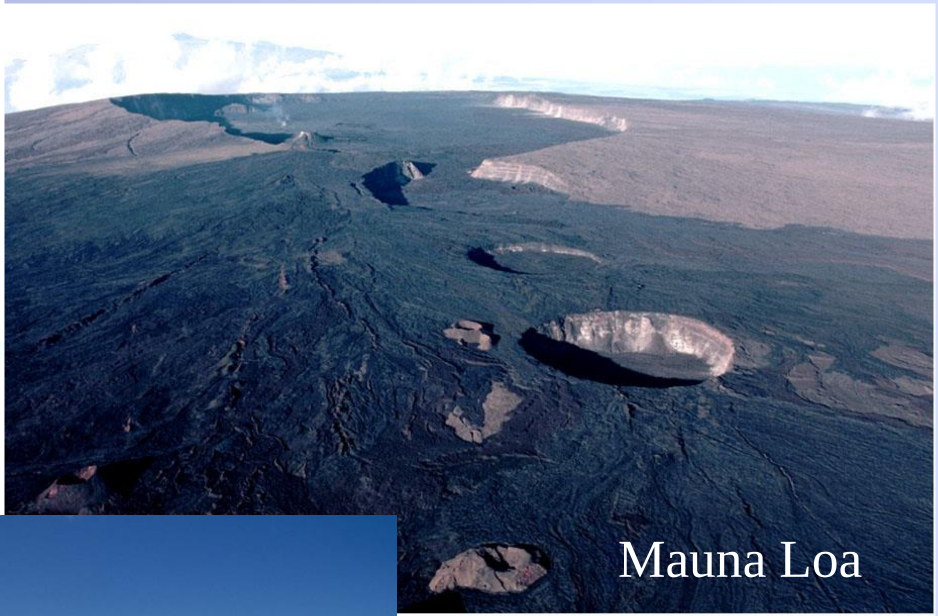
Shield Volcanoes (*Hawaiian* Type)





Hawaii

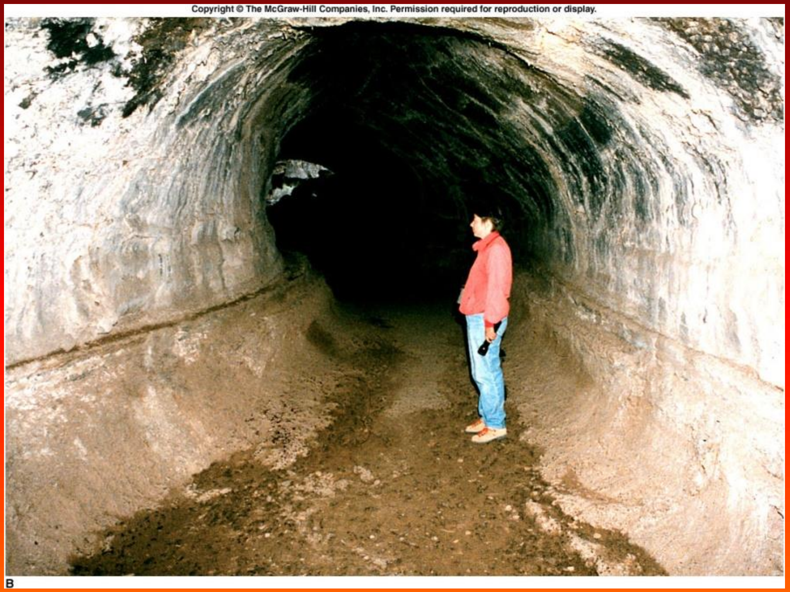



Mauna Loa


Halema'umu'u Crater

Mauna Kea, Hawaii (13,796 ft. SL)

Lava tube with collapsed roof



Lava Tube

Lava Fountain, 1969

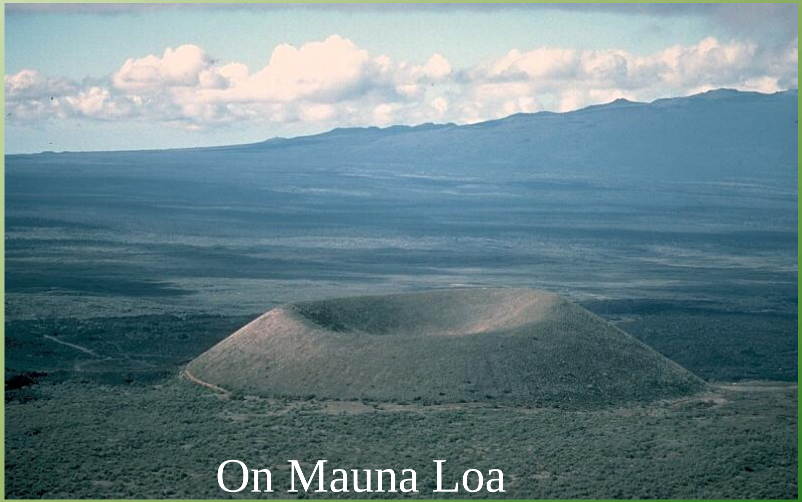
Spatter Cone

Kaui, Hawaii

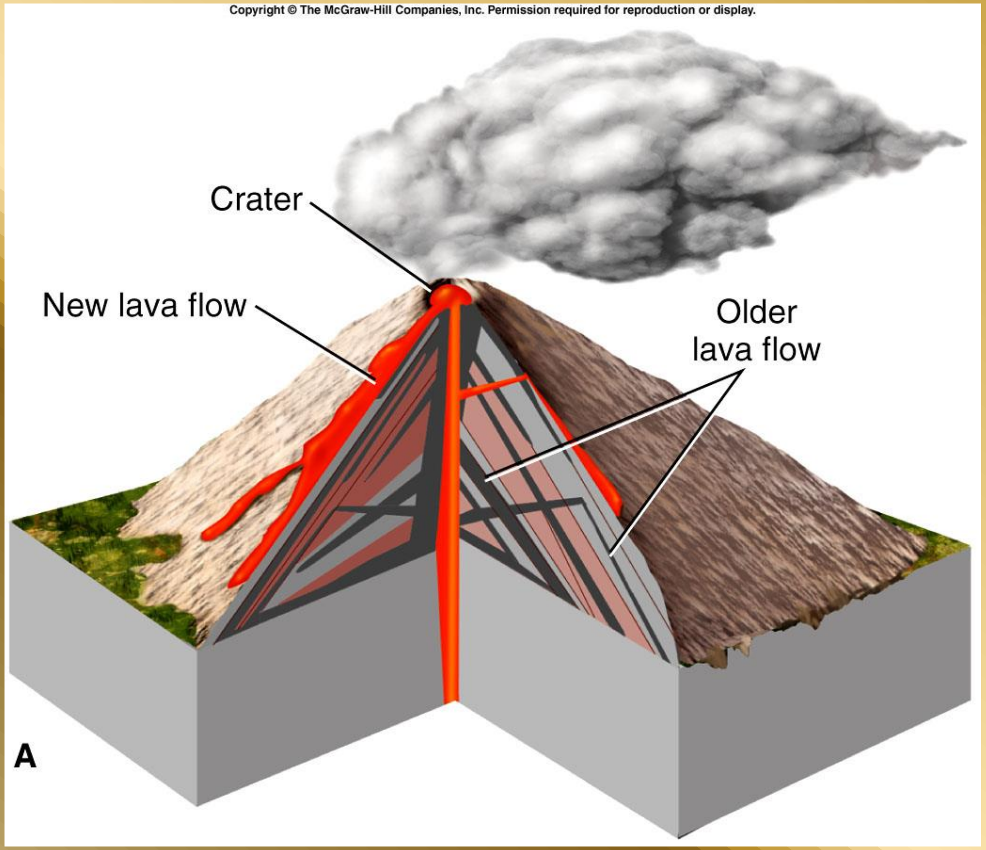
Black Sand Beach

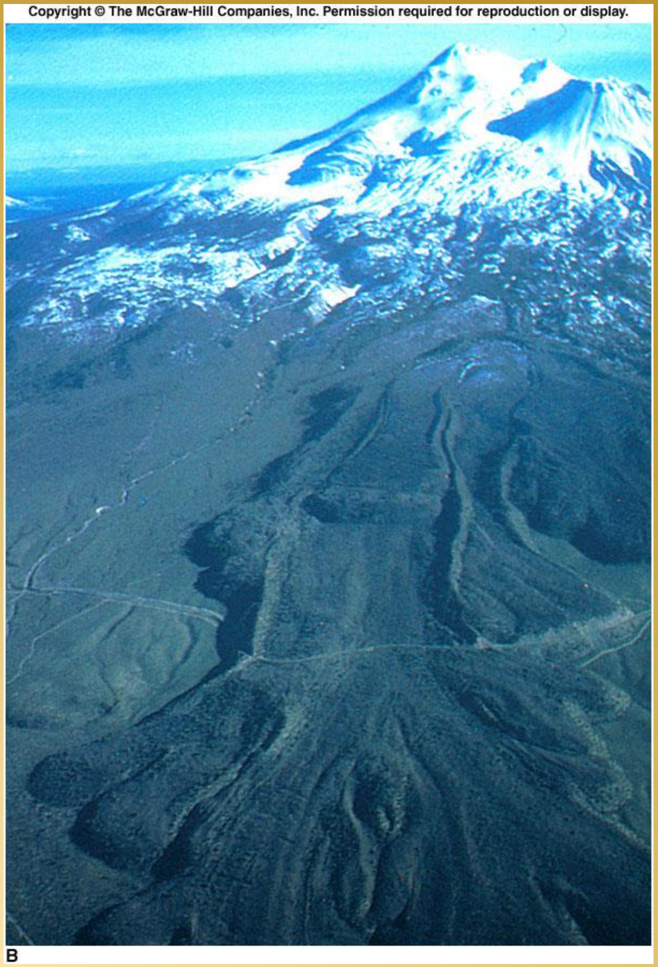
Waimea Canyon
("Grand Canyon of the Pacific")

Cinder Cones



Composite Volcano (Stratovolcano)





Mt. Shasta, CA

Composite Volcanoes

Mt. Ranier, CA

Fuji, Japan

Rebdoubt Volcano, AK

Popocatépetl (“Popo”), Mexico

Mt. Etna, Italy

Lava Floods and Flood Basalt

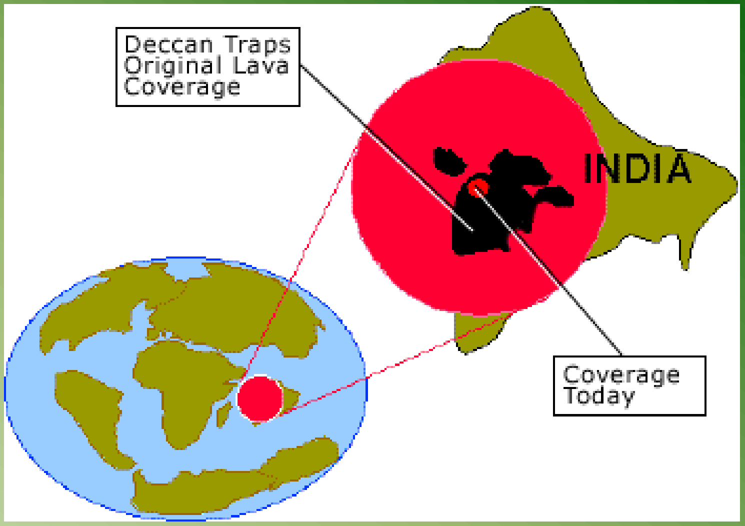
- **Massive outpourings of lava**
- **Rock formations 1000's of meters thick**
  - **Individual layers 15 to 100 m thick**
- ***Columnar Structure* (jointing) is common**

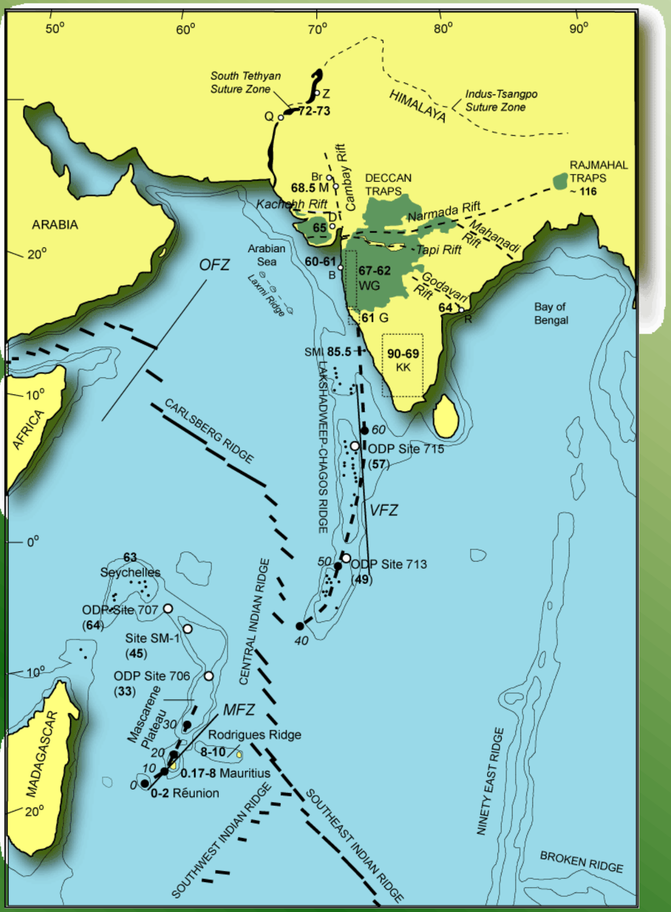
Columnar Jointing
Devil’s Postpile, CA

- Basalt contracts *after* solidifying
- Cooling can’t pull in the edges
- Tension fractures rock into hexagonal pattern

Deccan Traps, India

- One of six major lava floods in the last 200 million years.
- 66 million years ago
- 500,000 mi^3 of lava

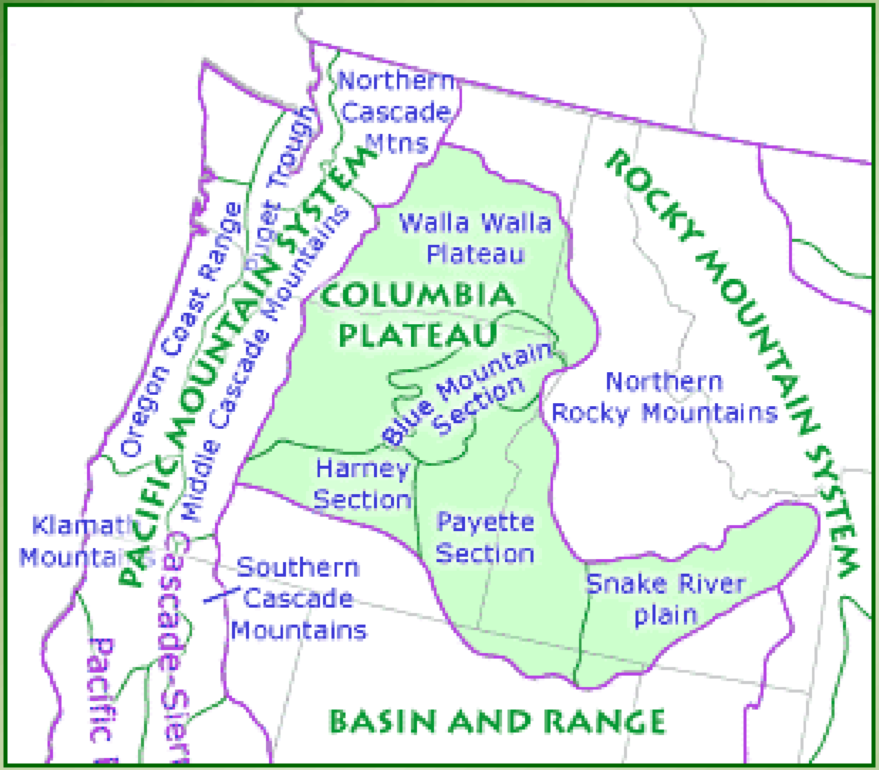


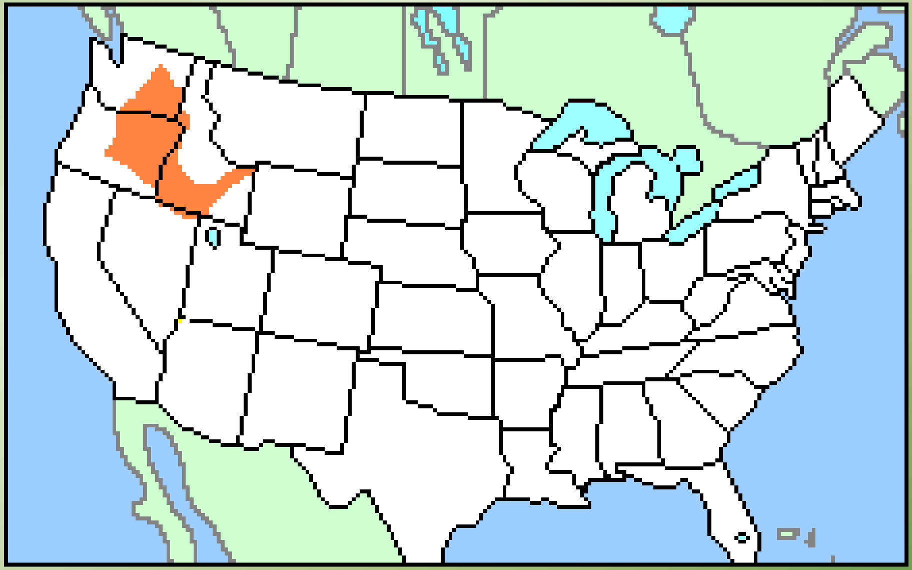


Deccan is from Sanskrit for "southern"
Trap is Dutch for "staircase"

Deccan Traps

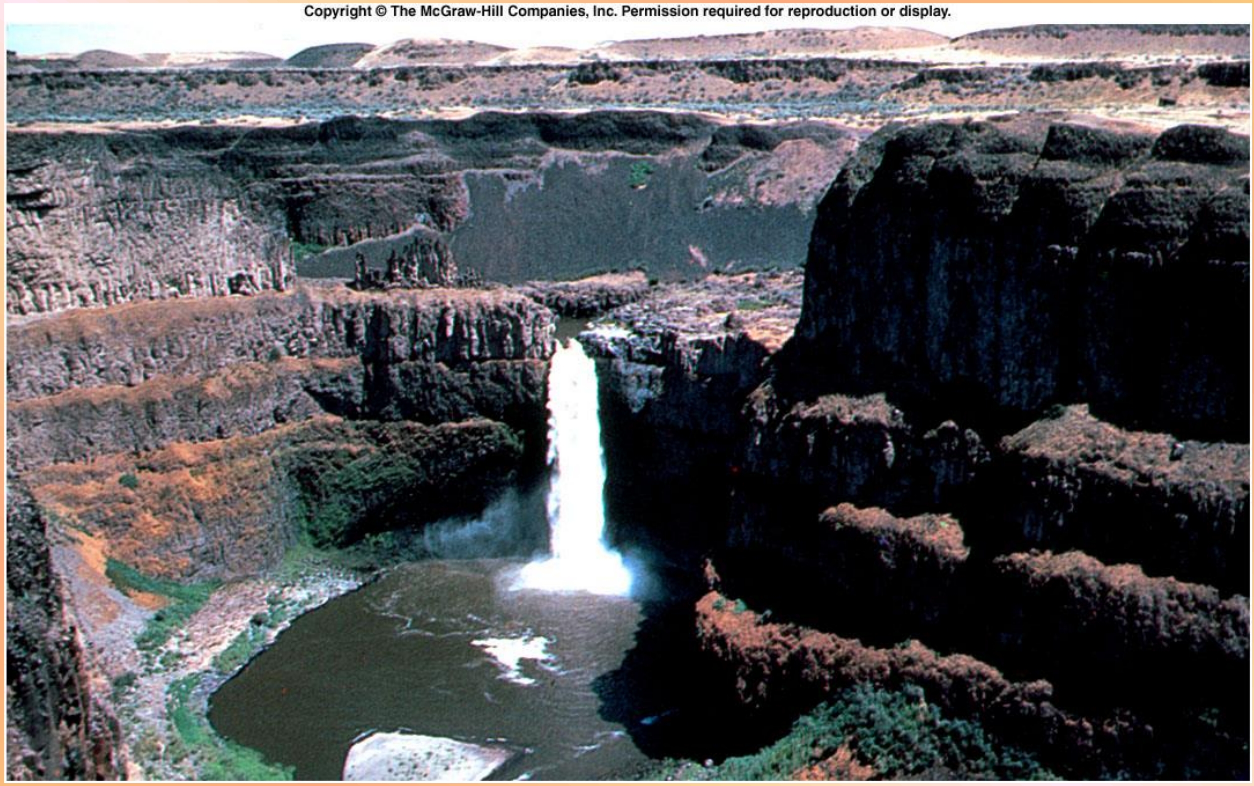
Columbia Plateau, USA





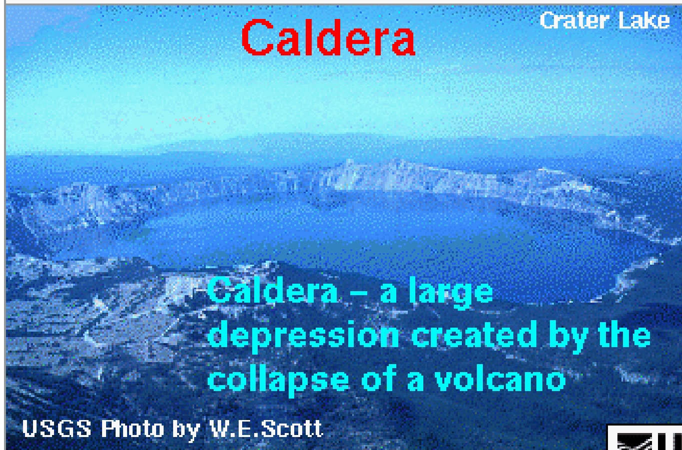
- **Last flood lava episode**
- **Ended about 15 million years ago**

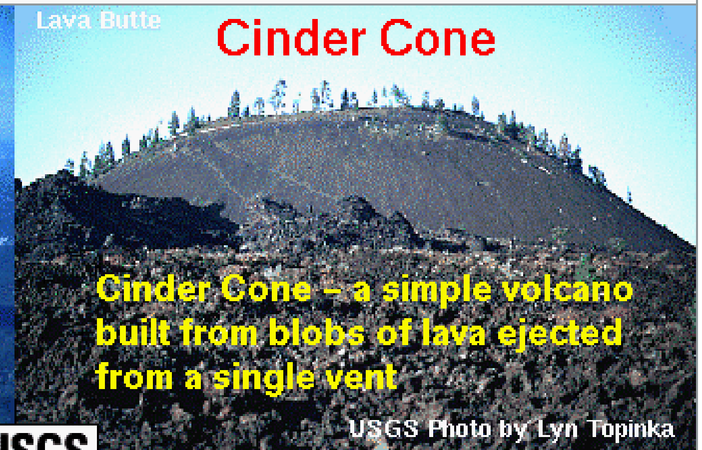
Plateau Basalts

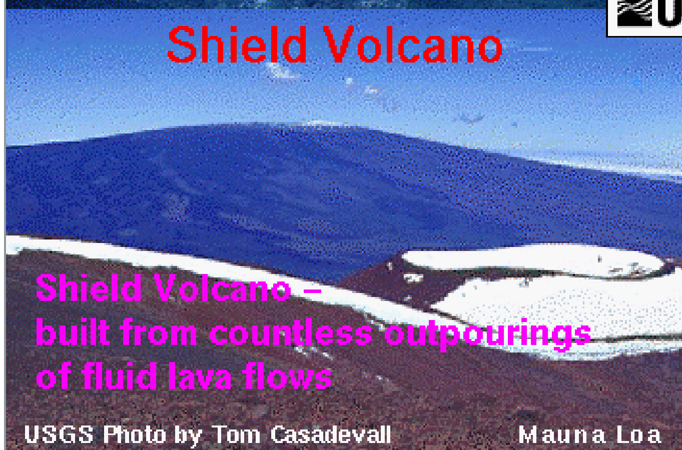


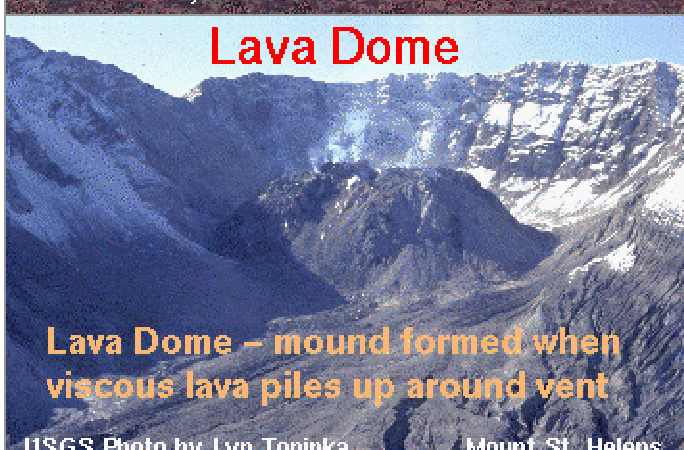
- **Columbia Plateau area of Washington is pictured**
- **Area covers 400,000 km^2 of WA, ID, and OR**
- **As thick as 3,000 meters in places (individual lava flows of 15 to 100 meters thickness)**

Five Major Types of Volcanoes





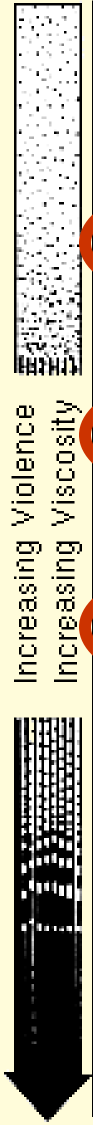


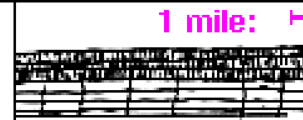
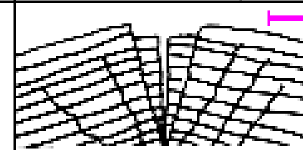
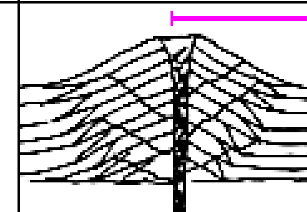
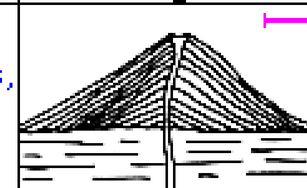
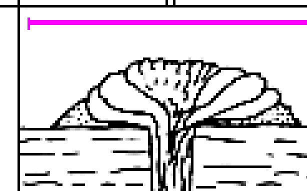
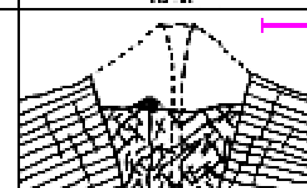


1. Caldera
2. Cinder Cone
3. Shield Volcano
4. Stratovolcano
5. Lava Dome

Lyn Topinka, USGS/CVO, 1998

Types of Volcanoes



Volcano Type	Characteristics	Examples	Simplified Diagram
Flood or Plateau Basalt	Very liquid lava; flows very widespread; emitted from fractures	Columbia River Plateau	
Shield Volcano	Liquid lava emitted from a central vent; large; sometimes has a collapse caldera	Larch Mountain, Mount Sylvania, Highland Butte, Hawaiian volcanoes	
Cinder Cone	Explosive liquid lava; small; emitted from a central vent; if continued long enough, may build up a shield volcano	Mount Tabor, Mount Zion, Chamberlain Hill, Pilot Butte, Lava Butte, Craters of the Moon	
Composite or Stratovolcano	More viscous lavas, much explosive (pyroclastic) debris; large, emitted from a central vent	Mount Baker, Mount Rainier, Mount St. Helens, Mount Hood, Mount Shasta	
Volcanic Dome	Very viscous lava; relatively small; can be explosive; commonly occurs adjacent to craters of composite volcanoes	Novarupta, Mount St. Helens Lava Dome, Mount Lassen, Shastina, Mono Craters	
Caldera	Very large composite volcano collapsed after an explosive period; frequently associated with plug domes	Crater Lake, Newberry, Kilauea, Long Valley, Medicine Lake, Yellowstone	

USGS

Topinka, USGS/CVO, 1997, Modified from: Allen, 1975, Volcanoes of the Portland Area, Oregon, Ore-Bin, v.37, no.9

LANDMARK VOLCANIC ERUPTIONS

Nevado del Ruiz Volcano (1985)

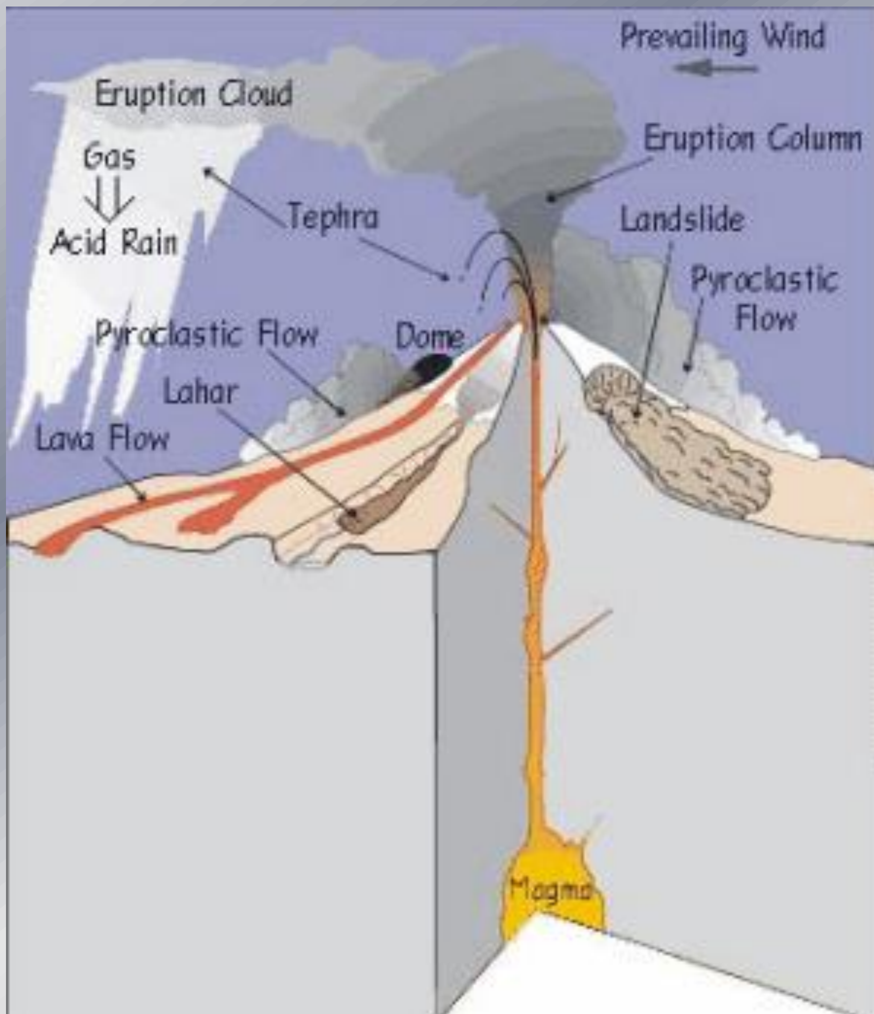
- Columbia, Central America
- Mudflows caused by hot pyroclastic flows killed about 1000 peopl
- The town of Armero, located at the end of the Lagunillas Valley in which mudflows moved at 40 to 60 km/hour, was swept away.
- The mudflows spilled out at about 30 meters high and spread out to dense floods 3 to 5 meters deep.
- A one meter deposit of dried mud was left covering and area of about 40 km^2 (15 mi^2).

El Chichón Volcano (1982)

- Southern Mexico
- Ash and gas clouds rose to heights of 20 to 25 km.
- Pyroclastic flows killed 2,000 to 3,000 people.

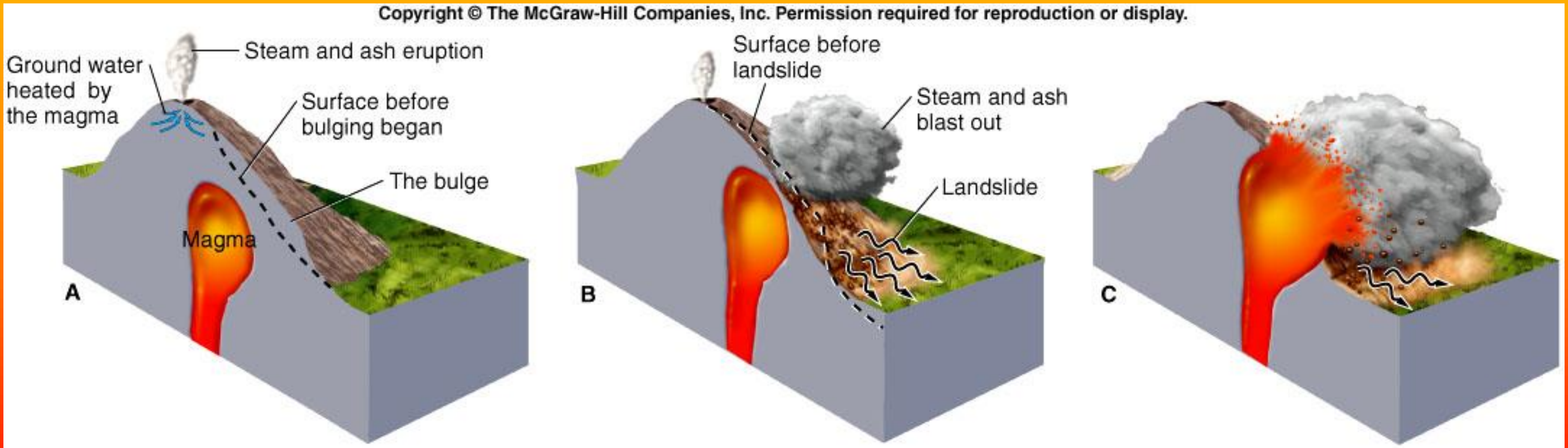
Mt. St. Helens (1980)

Steam (Phreatic) Eruption

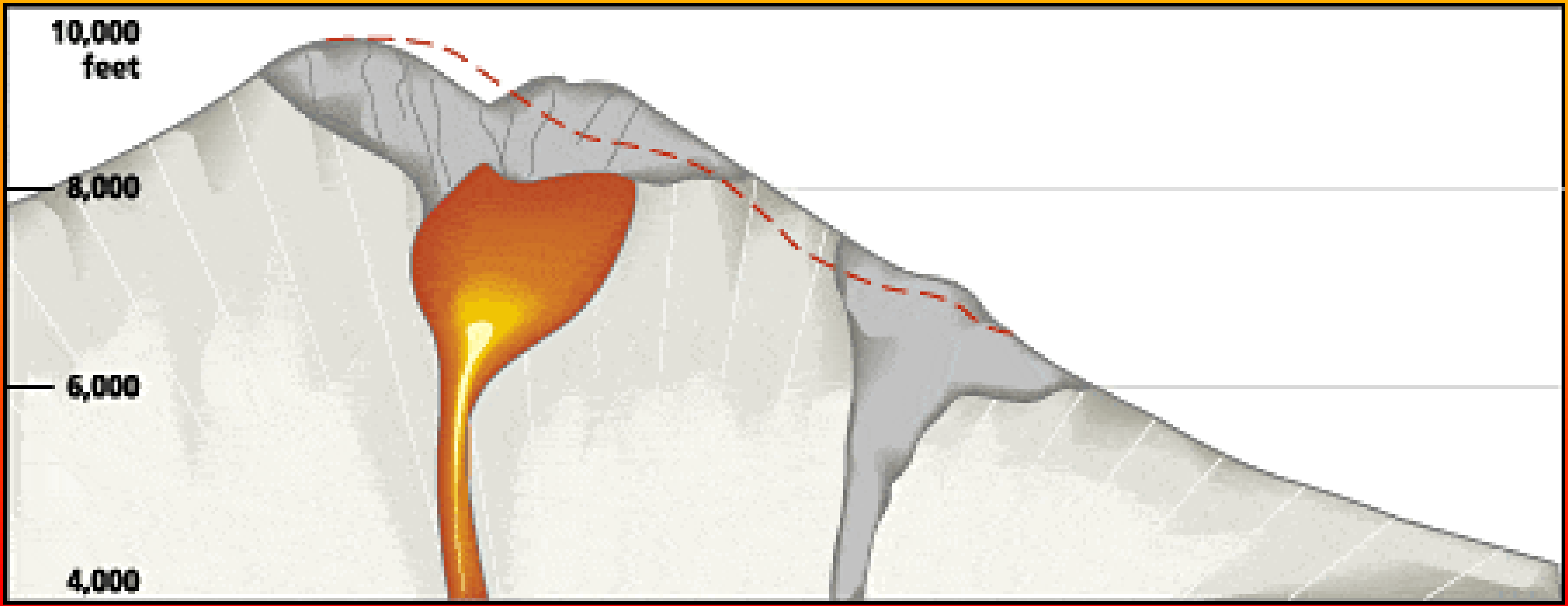


Mt. St. Helens
Before and After May 18, 1980

The Eruption

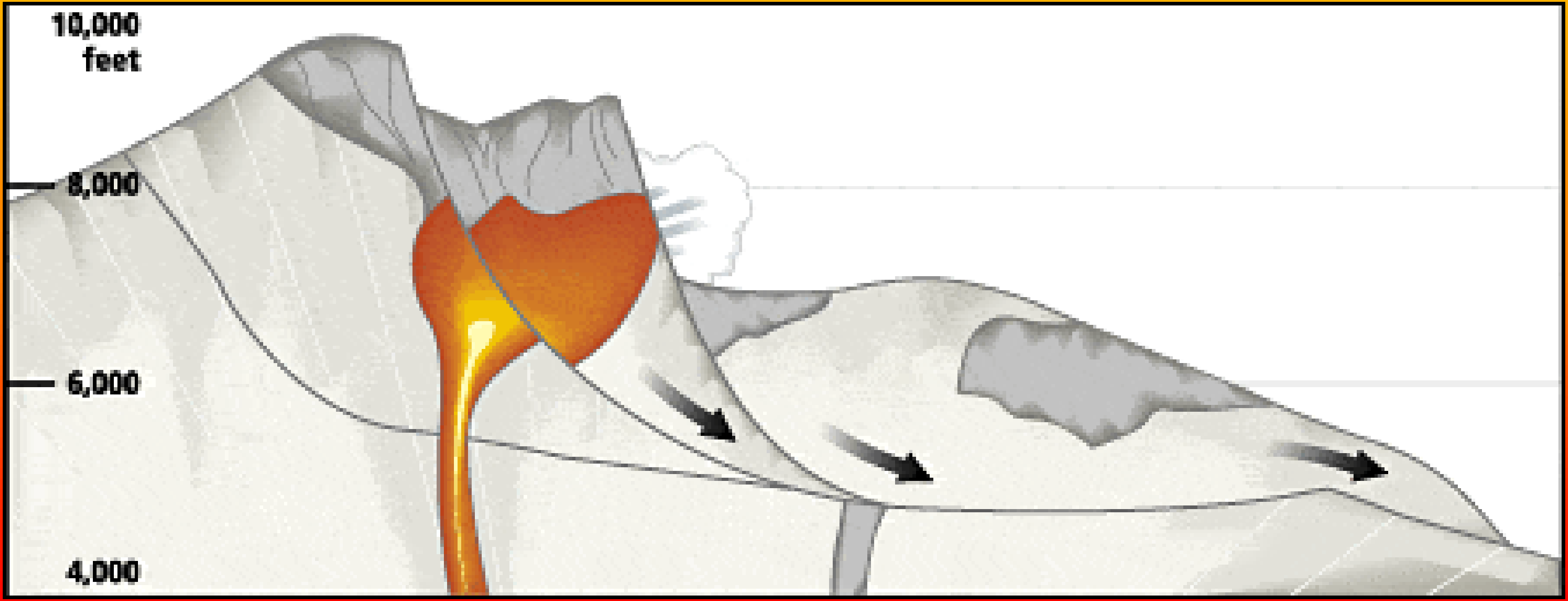


May 18, 1980 at 8:32:00 a.m.



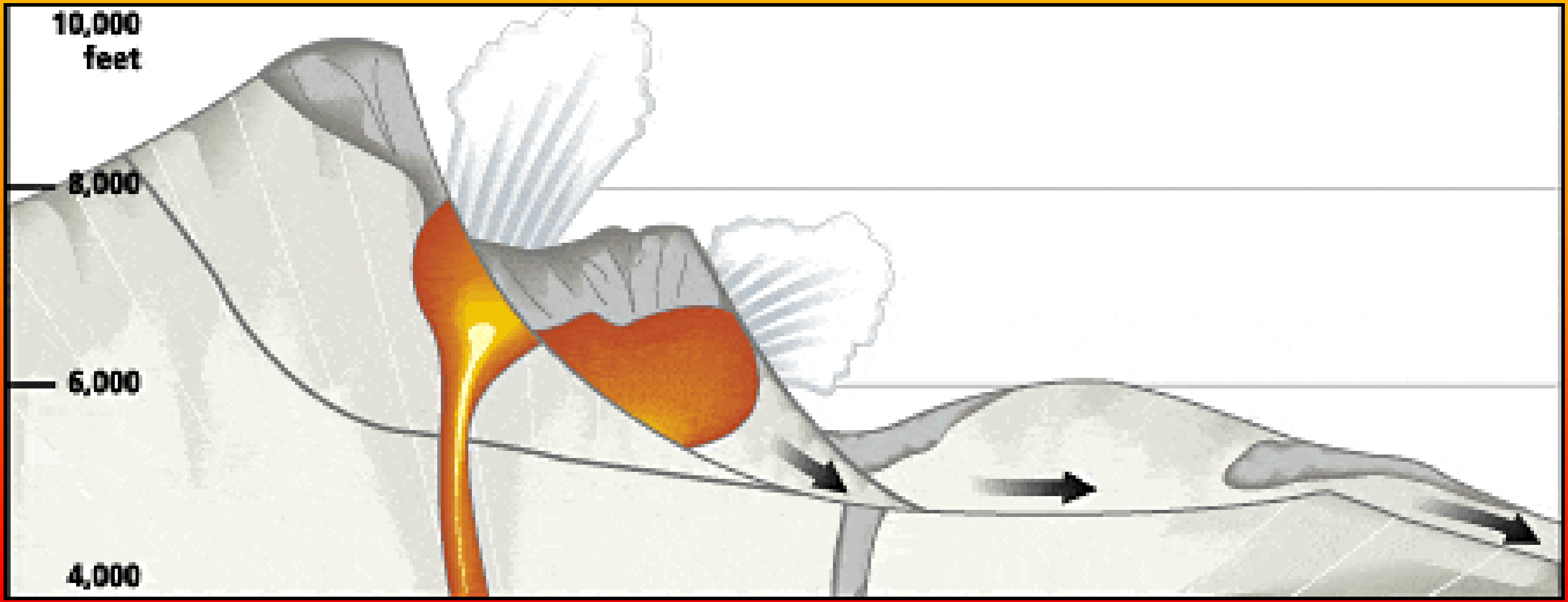
- The bulging north flank that geoscientists had watched develop since March is intact. It had clearly grown by 450 feet in some areas, and by late April was estimated to be growing at five feet a day.

May 18, 1980 at 8:32:10 a.m.



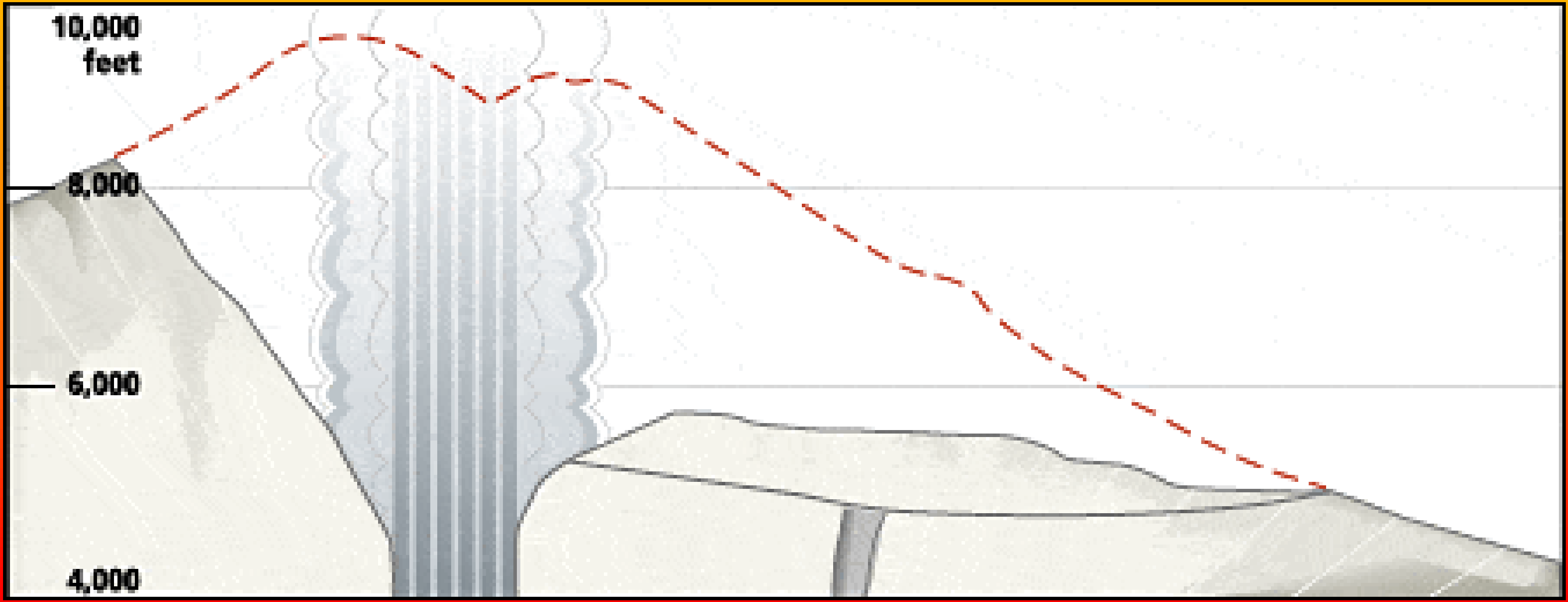
- A 5.1 magnitude earthquake about 1 mile beneath the mountain causes the north flank to slide. Tendrils of steam burst from the mountain, releasing pressure bottled up in magma below.

May 18, 1980 at 8:33:00 a.m.

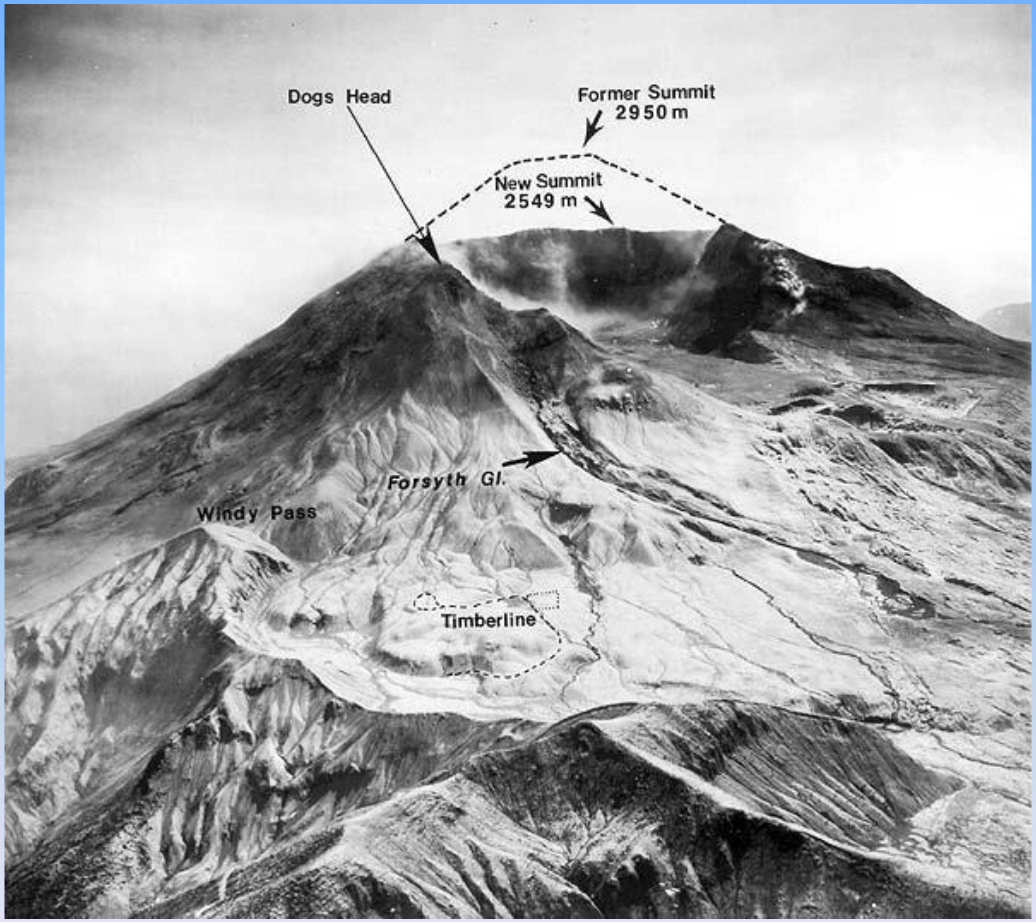


- A cubic mile of mountain gives way, traveling at 70 to 150 mph, and superheated rocks in the volcano's core are suddenly exposed, shooting a lateral blast of gas north, incinerating everything in its path. Huge glaciers on the mountain's peak melt instantly.

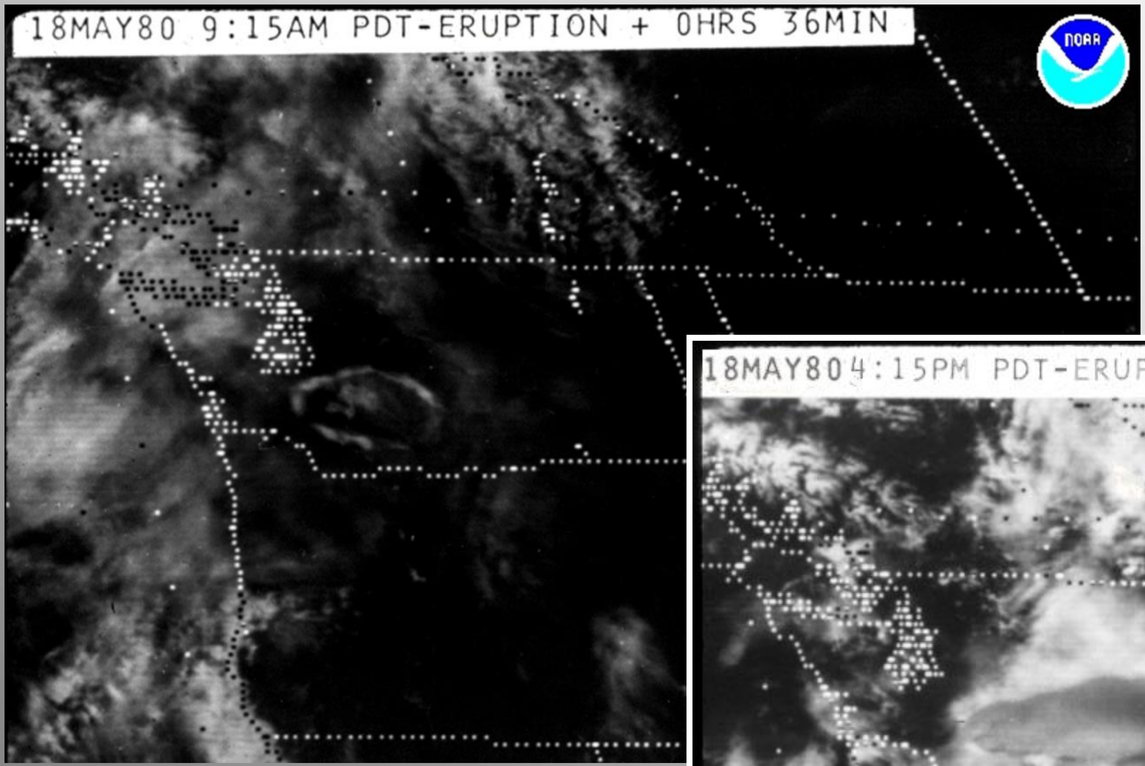
May 18, 1980 at 8:33:20 a.m.

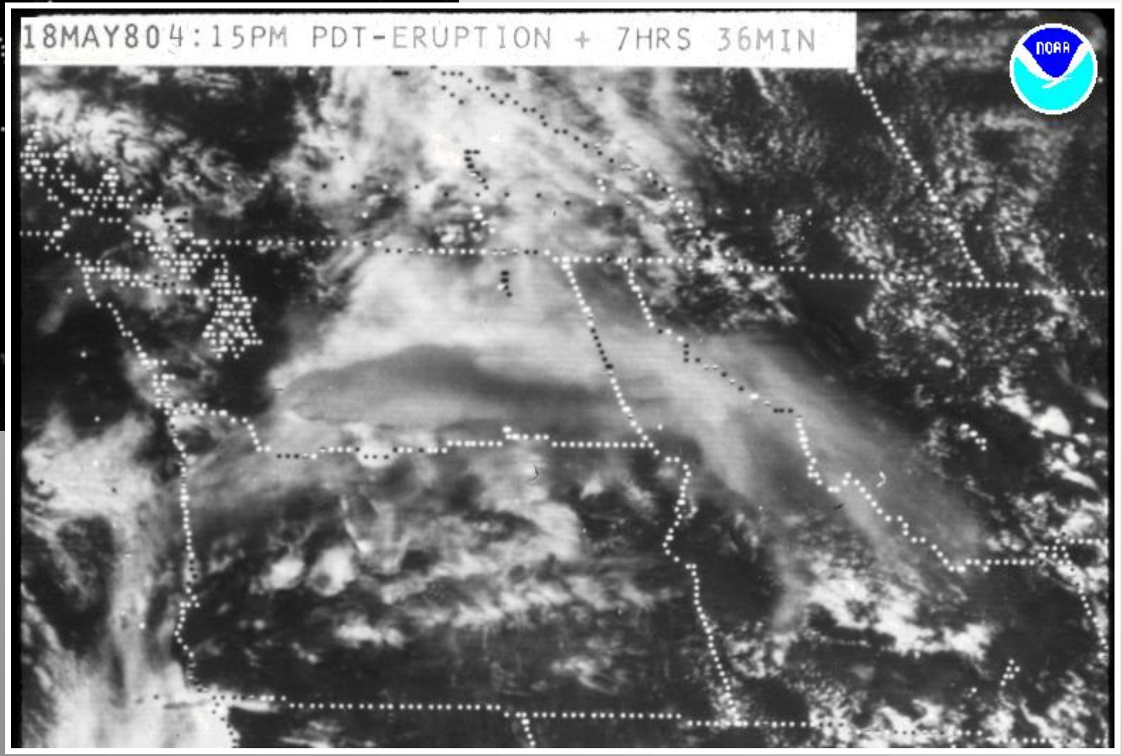


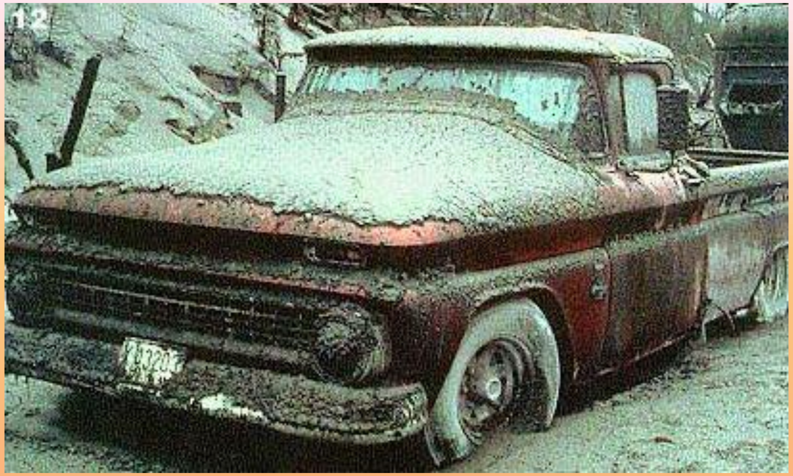
- The blast is over but the mountain begins to pulverize as the eruption vents its full fury, sending a thick, 3-mile-wide ash cloud 80,000 feet into the sky.


Dogs Head
Former Summit
2950 m
New Summit
2549 m
Forsyth Gl.
Windy Pass
Timberline

Ash Plume


18MAY80 9:15AM PDT-ERUPTION + 0HRS 36MIN


18MAY80 4:15PM PDT-ERUPTION + 7HRS 36MIN



USGS Cascades Volcano Observatory

- Mt. St. Helens Information

http://vulcan.wr.usgs.gov/Volcanoes/MSH/framework.html

Mt Pelèe (1902)

- West Indies island of Martinique in the Caribbean Sea
- Port City of St. Pierre was destroyed by pyroclastic flows after a period of dome growth.
- The pyroclastic flows with temperatures of about 700o C (approx 1,290o F) burned or suffocated 28,000 people.
- There were only four survivors (one a condemned prisoner in a poorly ventilated dungeon).

Krakatoa (1883)

- Island in western Pacific
- Composed of three volcanoes which blew apart the island (1/3 remained after the eruption)
- 13 km^3 (estimated) of rock collapsed into the emptied magma chamber creating a 300 m deep underwater depression
- Tsunamis were generated that killed over 34,000 people around the Pacific basin.

Mt. Vesuvius (A.D. 79)

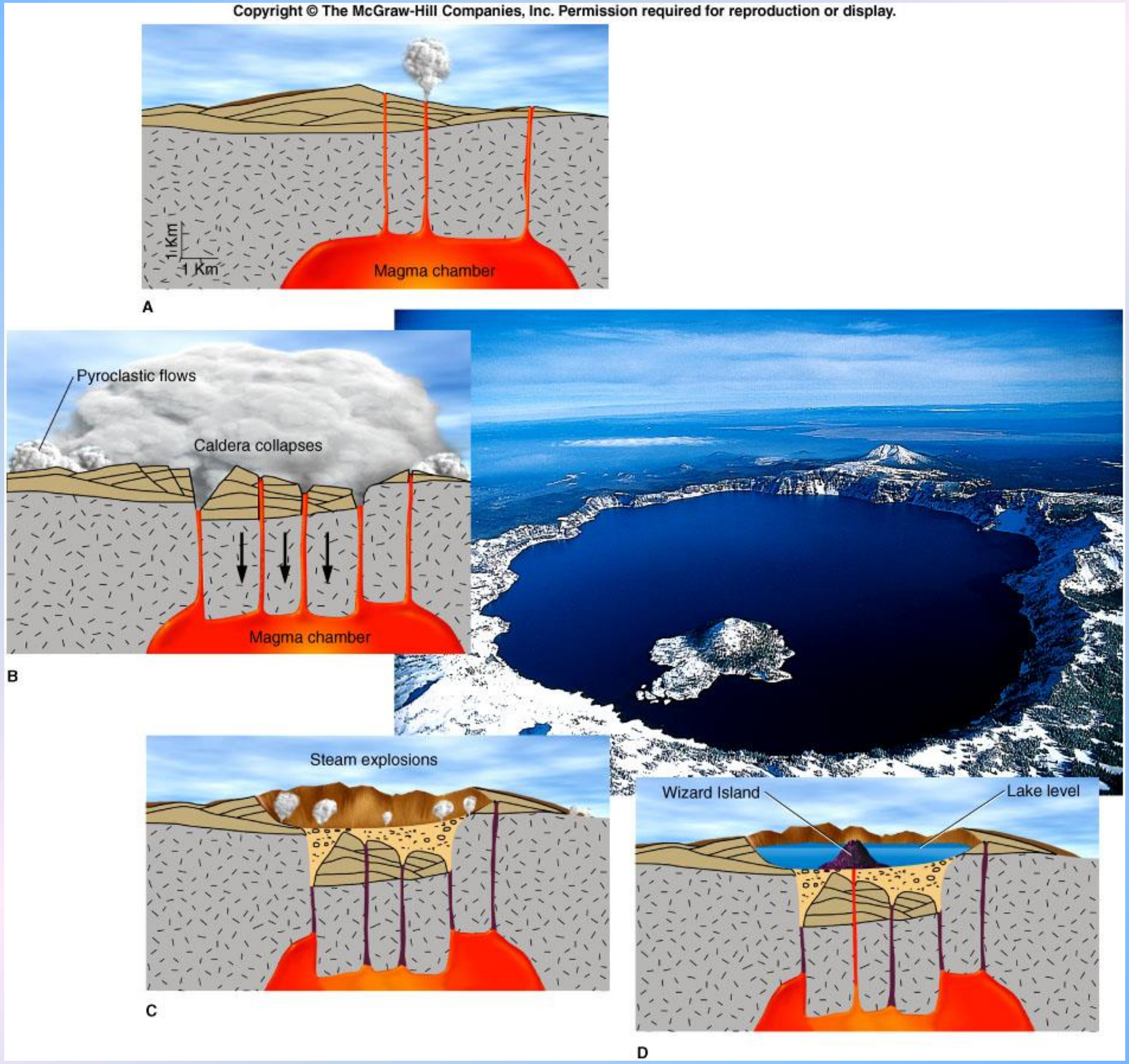
- Near Naples, Italy
- The Roman city of Pompeii and at least four other towns were destroyed
- *Plinian* explosion (named for the naturalist Pliny the Elder who was killed in the eruption)
  - extremely gas rich, viscous magma exploded deep within the volcano.
  - The vent acted like a gun barrel with a vertical blast twice the speed of sound. An ash column extended an altitude of more than 30 km (20 miles).
  - Pompeii was buried under 5 to 8 meters (up to 26 feet) of ash

Pompei





Crater Lake, Oregon (6,600 years ago)



Crater Lake

- At 1,932 ft. deep it's the deepest lake in the U.S. (7^{th} deepest in the world)
- 12 cubic miles of rock blasted away
- 5 x 6 miles (8.0 x 9.6 km) wide

Wizard Island, a cinder cone, rises about 800 ft. above the lake surface.

Iceland Volcanism on Heimaey Island