

# ***FUNDAMENTALS OF EARTH SCIENCES***

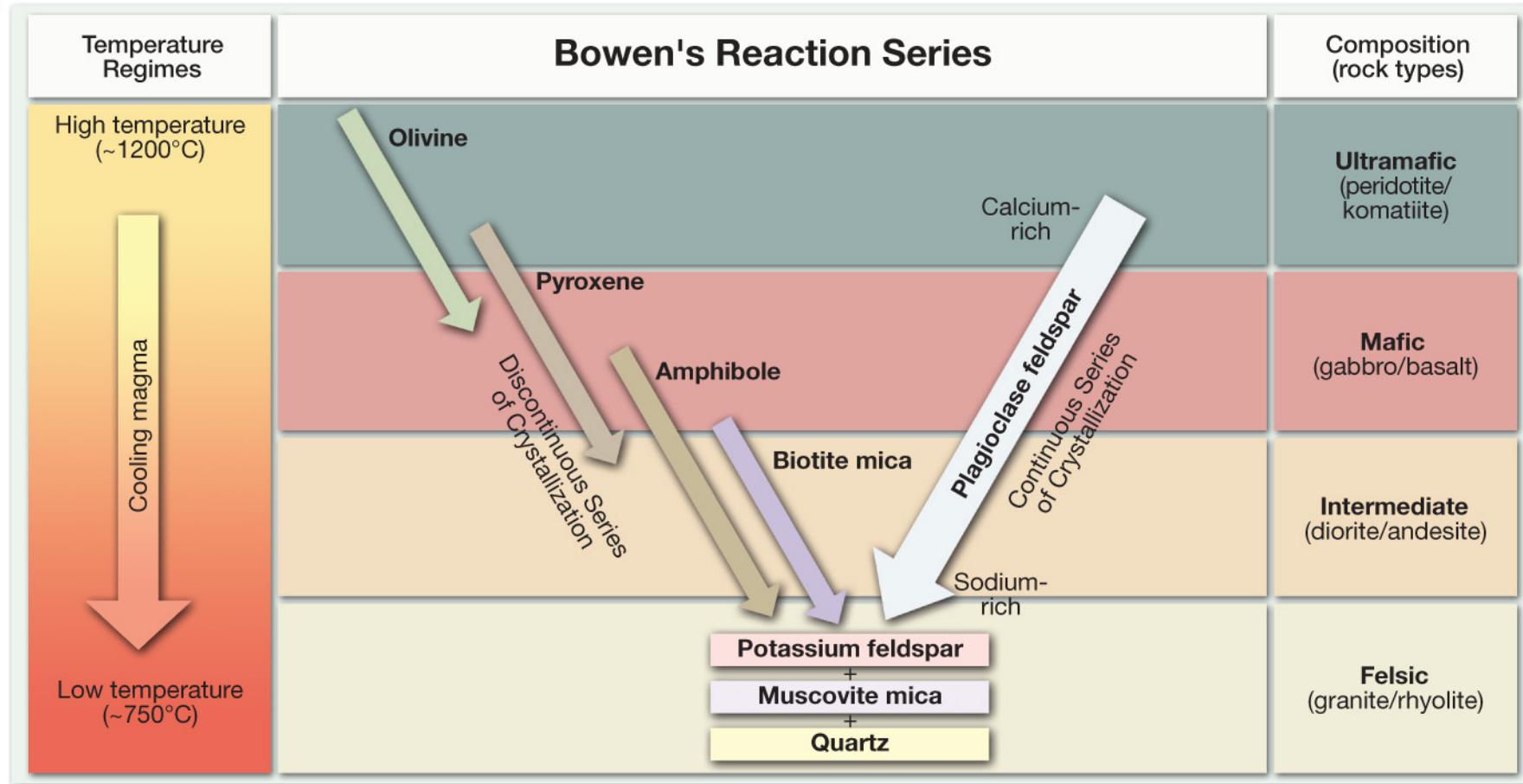
## **(ESO 213A)**

**DIBAKAR GHOSAL**

**DEPARTMENT OF EARTH SCIENCES**

**Volcanoes**

# Bowen's Reaction Series



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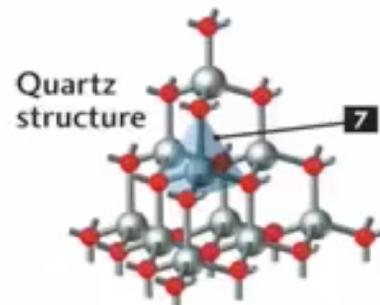
# Order of crystal formation depends upon silicate structure

## SILICATE AND SILICATE POLYMORPH MINERALS

(c) Silicate ion ( $\text{SiO}_4^{4-}$ )



Oxygen ions ( $\text{O}^{2-}$ )



(d) Isolated tetrahedra



(e) Single chains



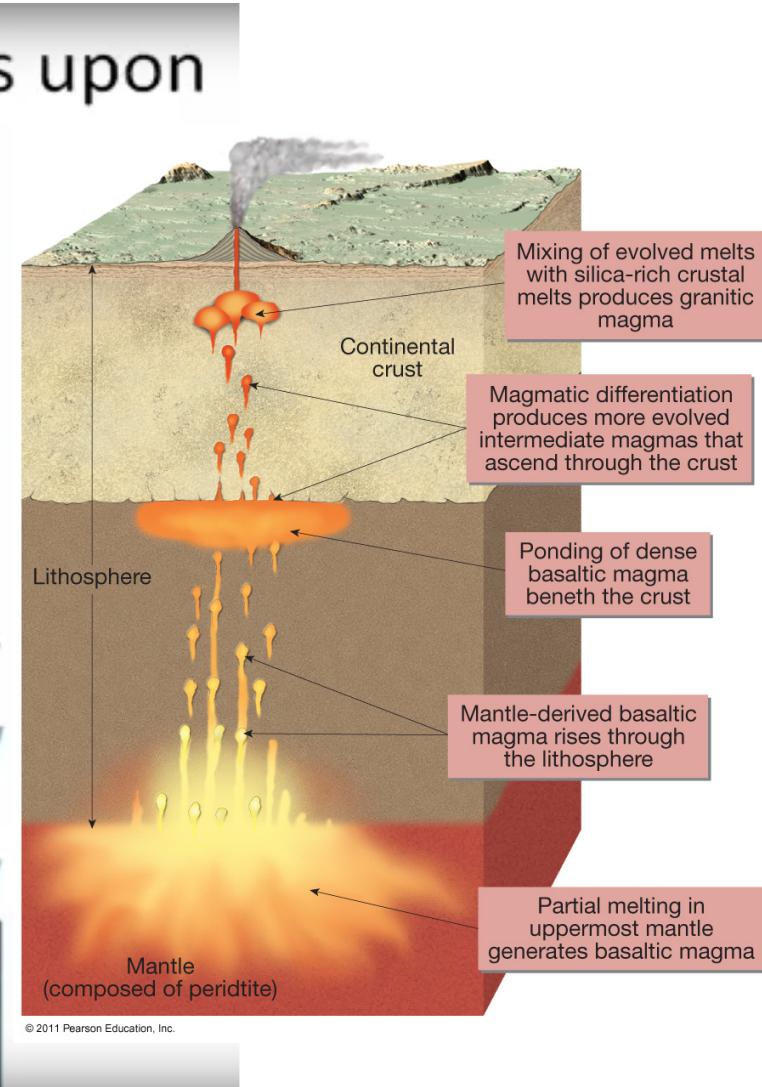
(f) Double chains



(g) Sheet



(h) Framework



# Volcanoes

An opening in Earth's crust through which molten rock, rock fragments, and hot gases erupt.

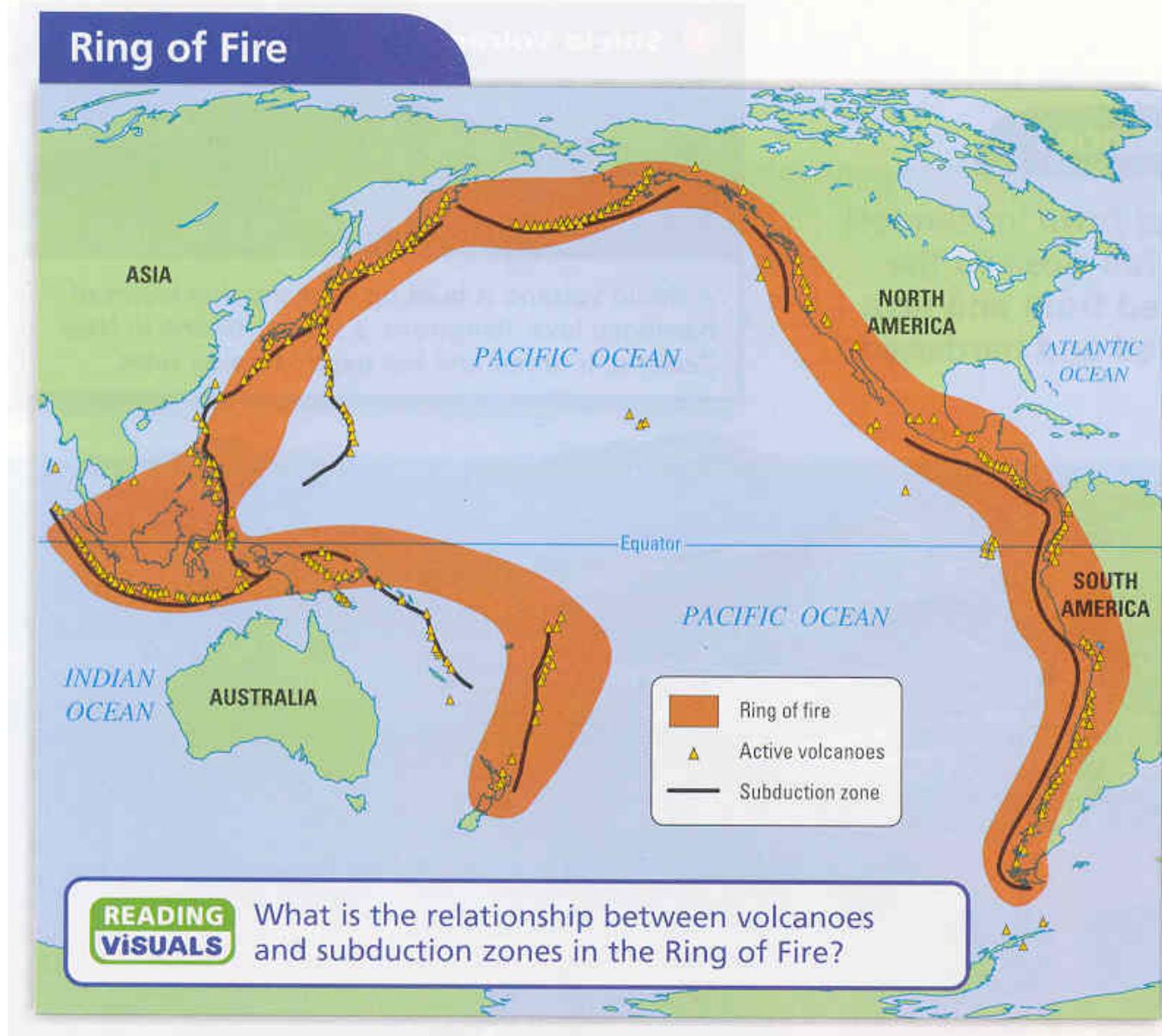


# Where do volcanoes occur?

Most form along plate boundaries

....

1. in subduction zones (one plate sinks under another)
2. over hot spots
3. where plates are pulling apart



# *Materials Extruded from a Volcano*

## □ 1. Lava flows

- ~ 90% is basaltic in composition
- ~ 1% is rhyolitic in composition

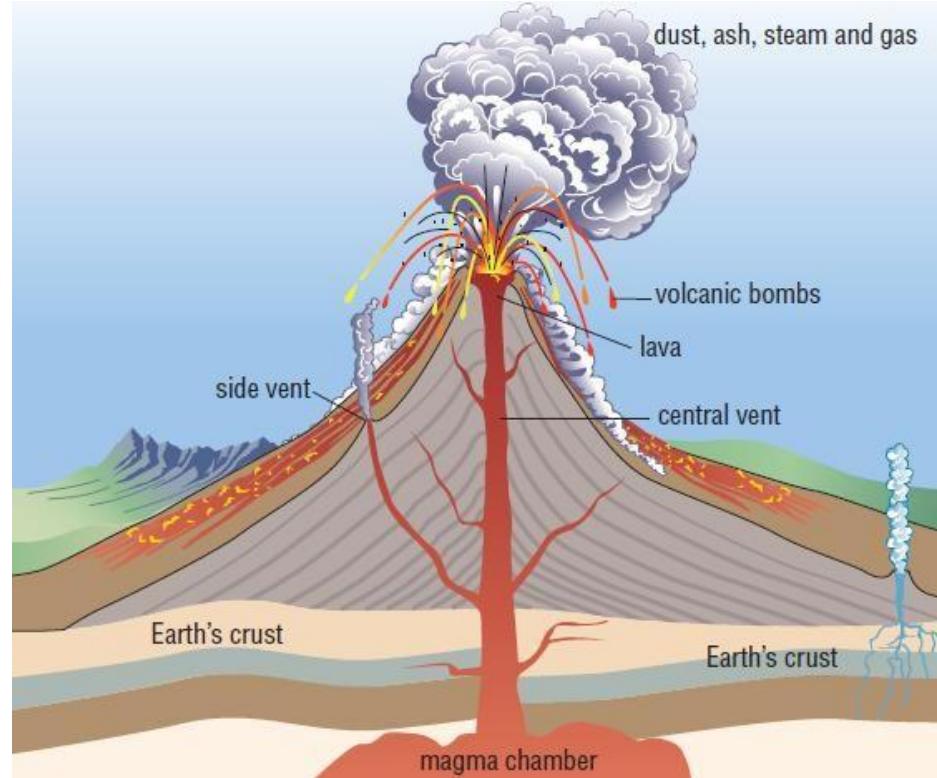
a) *Aa flows* – rough jagged blocks, sharp edges

b) *Pahoehoe flows* – smooth surfaces, more fluid

c) *Lava tubes*

d) *Block lavas* – common in case of andesitic and rhyolitic magmas

e) *Pillow lavas* – outpourings of lava on the ocean floor



## □ Factors affecting viscosity:

- Fluid basaltic lavas generally produce quiet eruptions.
- Highly viscous lavas (rhyolite or andesite) produce more explosive eruptions.

# *A Pahoehoe Lava Flow*



**B.**

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# *Materials Extruded from a Volcano*

## □ 2. Gases (volatiles)

- ~ 1 to 6 % of the total weight

- ~ 70% water vapor

- ~ 15 % carbon dioxide (CO<sub>2</sub>)

- ~ 5% nitrogen (N)

- ~ 5% sulfur dioxide (SO<sub>2</sub>)

- ~ 5% chlorine, hydrogen, and argon

- Natural source of air pollution

1. Water Vapor: more water=bigger explosion

2. Trapped gases (water and CO<sub>2</sub>):

Easy escape (low pressure)=quiet eruption

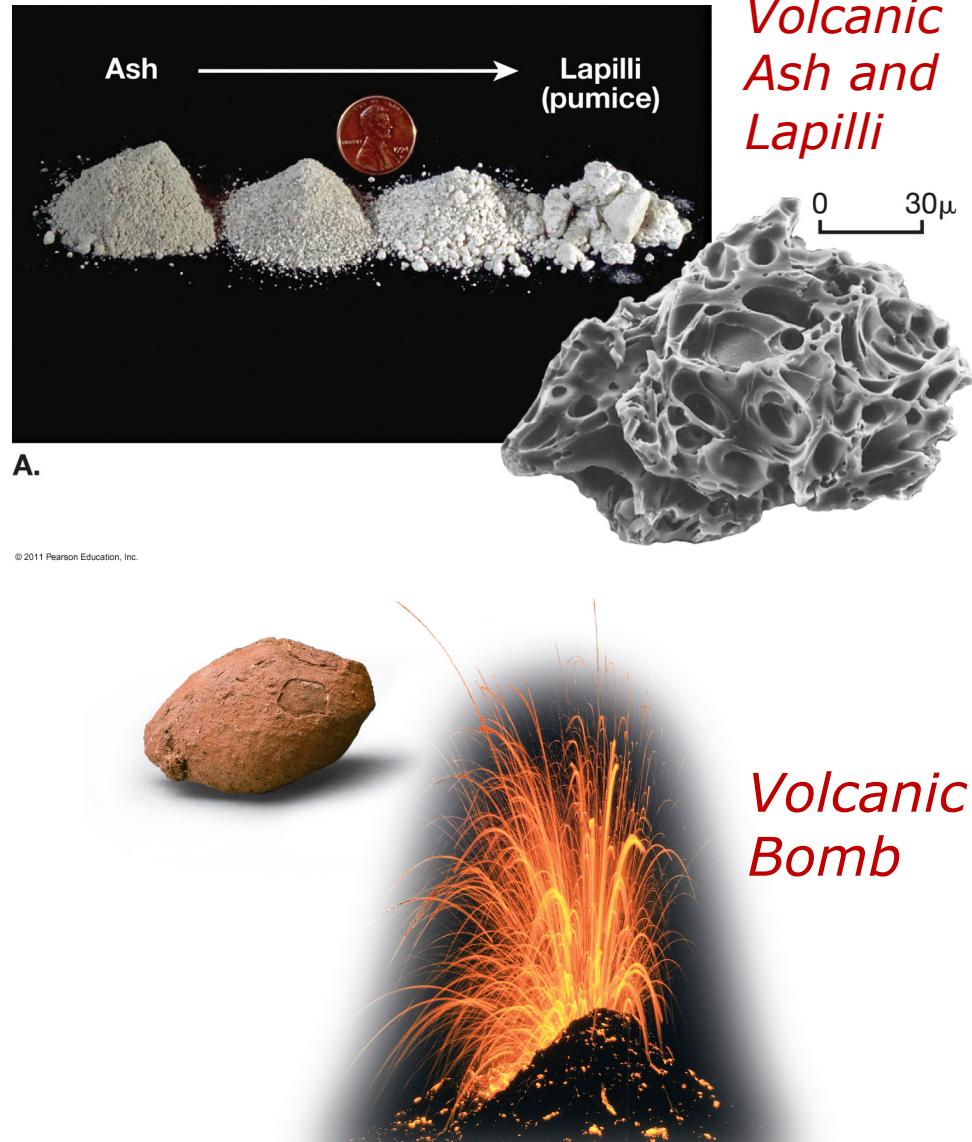
Difficult to escape (high pressure)=explosive/violent eruption

# *Materials Extruded from a Volcano*

## □ 3. Pyroclastic materials (fire fragments)

### Types of pyroclastic debris

- **Ash and dust** - fine, glassy fragments (welded tuff)
- **Lapilli** (little stones) - walnut-sized material
- Particles larger than lapilli
  - **Blocks** - hardened or cooled lava
  - **Bombs** - ejected as hot lava



### Vesicular rocks:

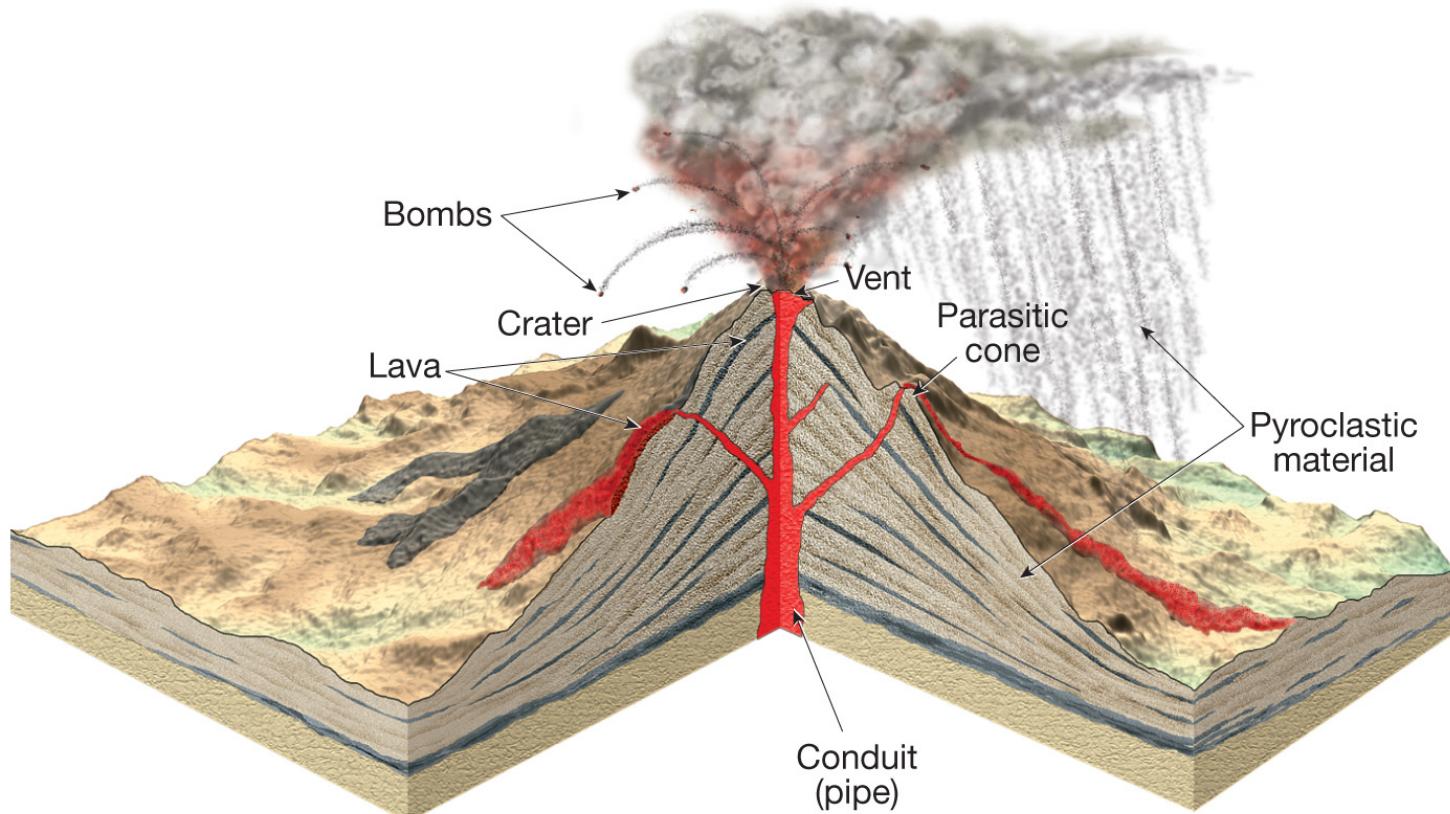
**Scoria** – vesicular ejecta that is a product of basaltic magma

**Pumice** – vesicular ejecta that is a product of andesitic and rhyolitic magmas

# Volcanoes

## General features

- **Crater**—A steep-walled depression at the summit, generally less than 1 km in diameter.
- **Caldera**—A summit depression typically greater than 1 km in diameter and produced by a collapse following a massive eruption.
- **Vent**—An opening connected to the magma chamber via a **conduit (pipe)**.
- **Volcano** – successive eruption of lava and pyroclastic material



# Magma Composition

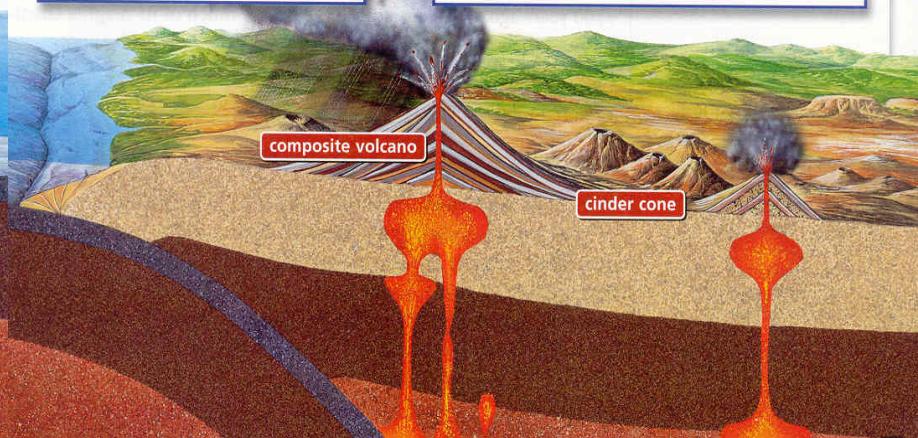
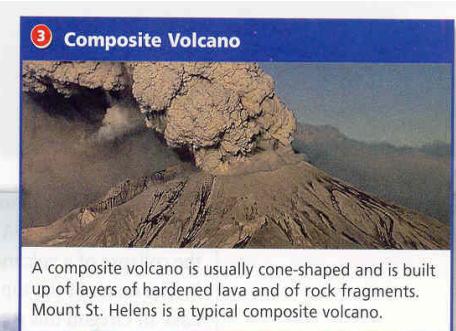
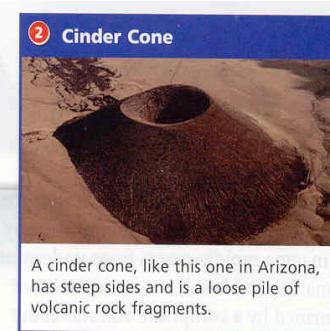
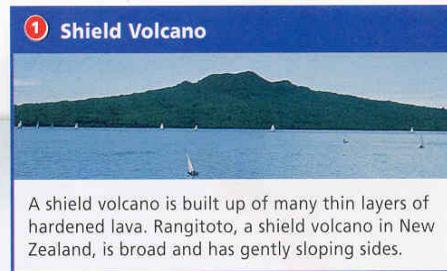
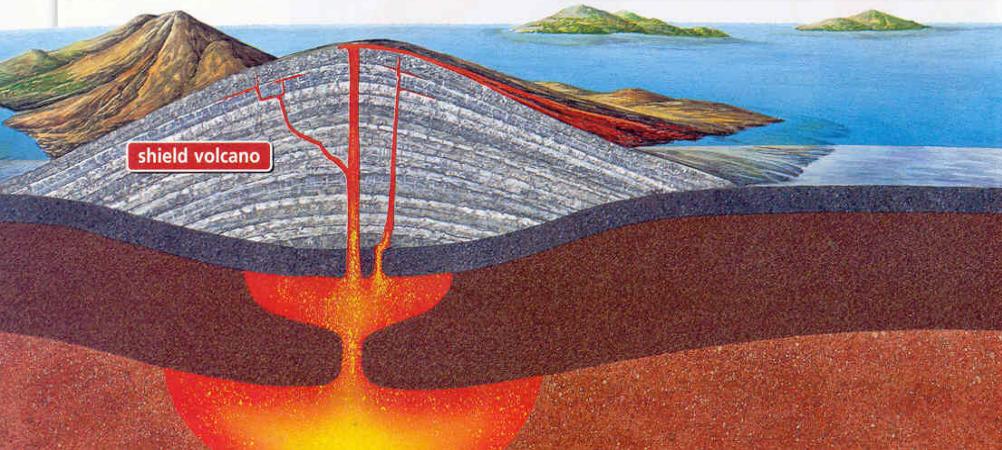
- Basaltic lava
  - Hawaiian Volcanoes, including
    - Kilauea
    - Mona Loa
  - Iceland
    - Heimaey
    - Hekla
- Granitic volcanoes are
  - Yellowstone Caldera
    - It is a super volcano!
  - Katmai, Alaska
    - Last eruted in 1912.
- Andesitic Lava
  - Mount Pelee, Martinique (Famous for the May 8, 1902 eruption which killed 29,000 people and destroyed the city of St. Pierre. This is the largest number of causalities for a volcanic eruption this century).
  - Mayon, Phillipines (It is the most active volcano in the Philippines. Since 1616, Mayon has erupted 47 times.
  - It's 1814 eruption killed 1,600.)

# Basic Volcano shapes

The shape and size are determined by the type of magma feeding it.

## Three Types of Volcanoes

Two types of material form volcanoes:  
rock fragments that fall close to the  
openings they erupted from and lava  
flows that have cooled and hardened.

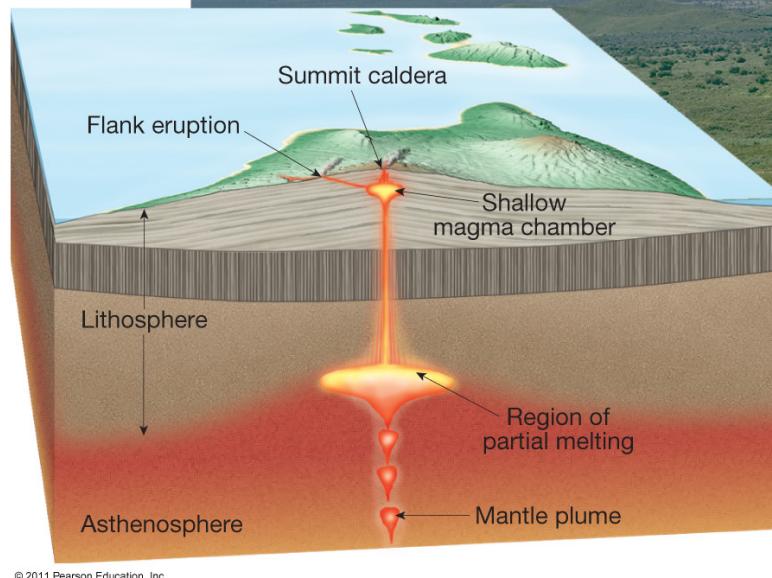
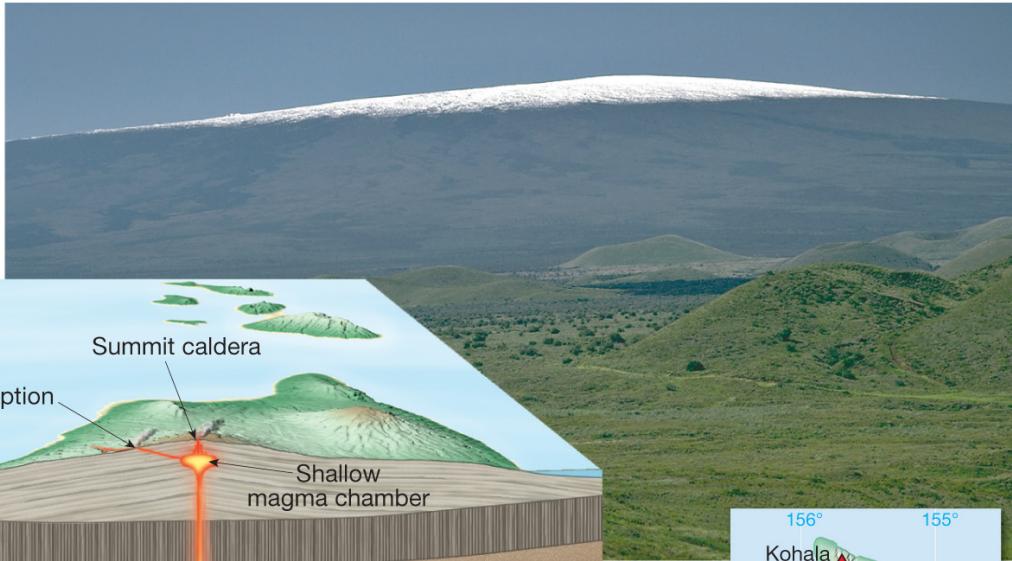


# *Types of Volcanoes*

## 1. Shield volcano

- Formed by quiet eruptions of slow-moving lava flows
- Basaltic lava builds up in flat layers
- Largest with gently sloping sides
- Broad, slightly dome-shaped
- Generally covers large areas
- Majority begin on the ocean floor as seamounts
- Produced by mild eruptions of large volumes of lava
- Mauna Loa in Hawaii is a good example.

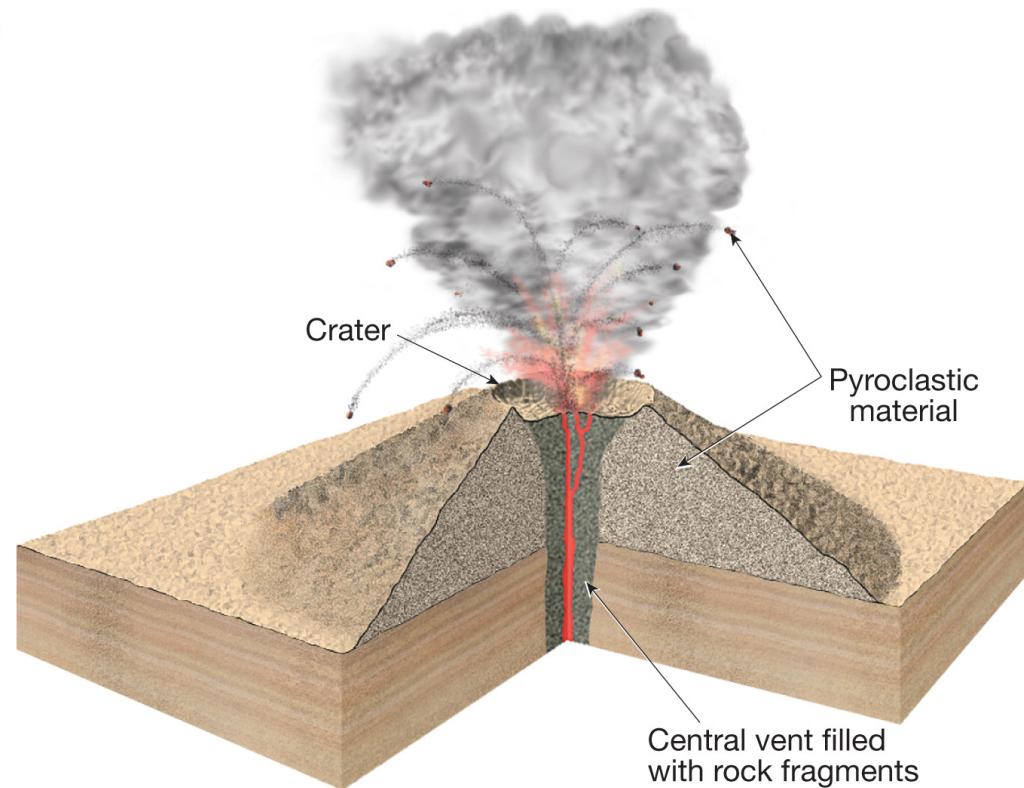
## *Mauna Loa—A Shield Volcano*



# *Types of Volcanoes*

## 2. Cinder (scoria) cone

- Built from ejected lava (mainly cinder-sized) fragments. Lava cools into different sizes of volcanic material called tephra.
- Steep slope angle ( $\sim 30^{\circ}$  –  $40^{\circ}$ )
- Rather small size and usually  $< 300$  m in height
- Frequently occur in groups
- Presence of large, deep craters
- Generally produced by a single, short-live eruptive event (95% - less than 1 year)



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Example: Parícutin Volcano in Mexico

# *Types of Volcanoes*

- **Composite cone (stratovolcano)**
  - Most are located adjacent to the Pacific Ocean (e.g., Mount Fujiyama and Mount St. Helens) (Ring of Fire).
  - Large, classic-shaped volcano (thousands of feet high and several miles wide at base)
  - Composed of interbedded lava flows and layers of pyroclastic debris
  - Associated with **SUBDUCTION ZONES**

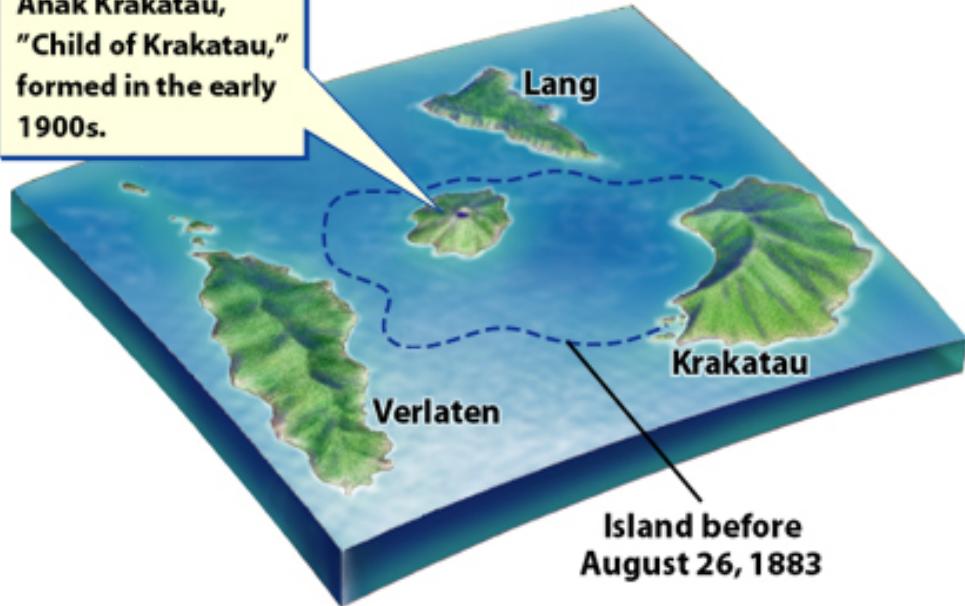
## *Mount Fujiyama—A Composite Volcano*



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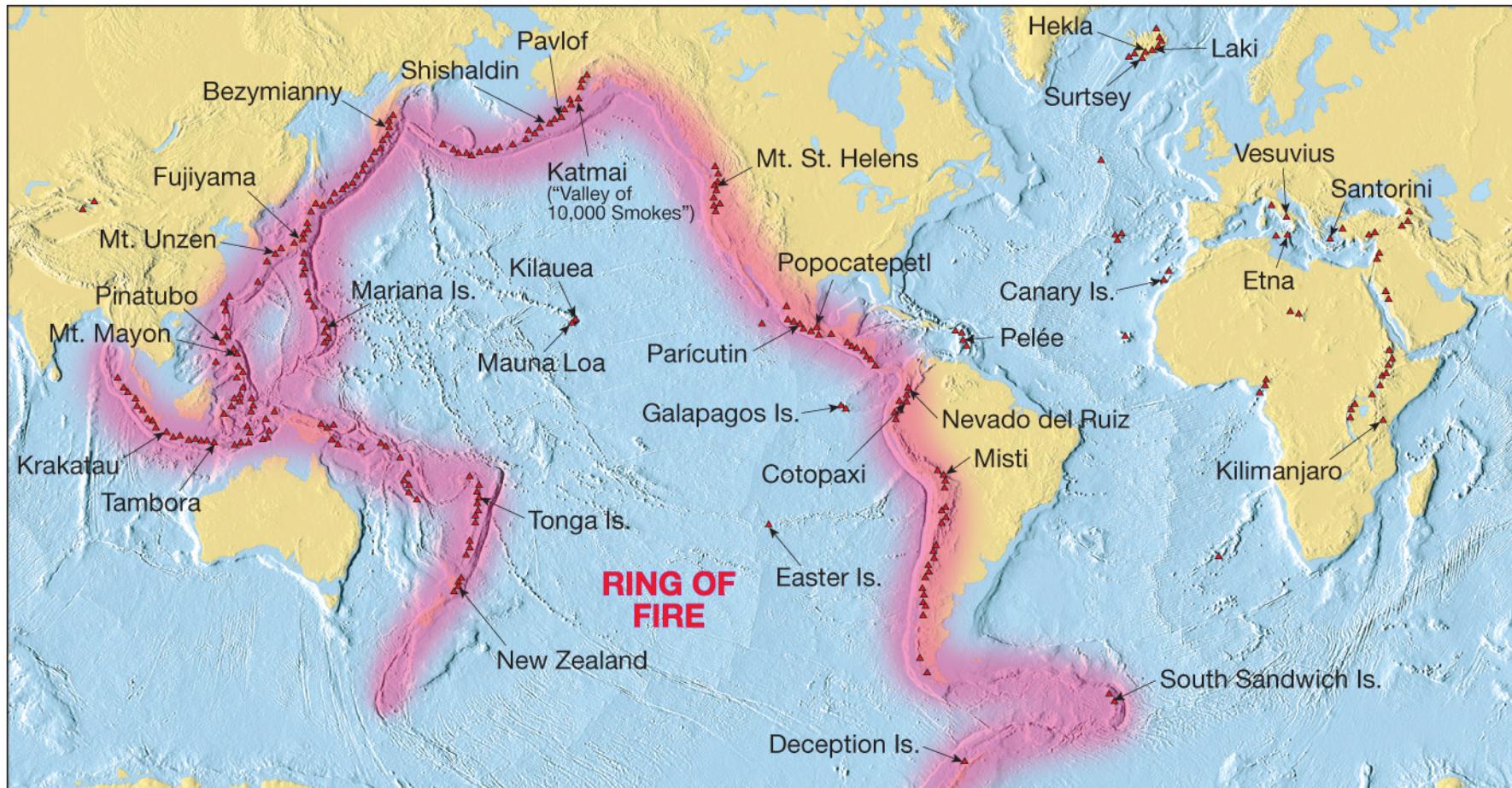
# Example of Composite Volcano

Anak Krakatau,  
"Child of Krakatau,"  
formed in the early  
1900s.



## Krakatau

- One of the most violent eruptions in recent times occurred on an island in the Sunda Straits near Indonesia in August of 1883.
- Krakatau, a volcano on the island, erupted with such force that the island disappeared.
- Killed 36,000 people most were killed by a giant tsunami and destroyed 160 villages
- Fine ashes from the eruption were carried by upper level winds as far away as New York City
- Volcanic dust lowered global temperatures for five years, this caused



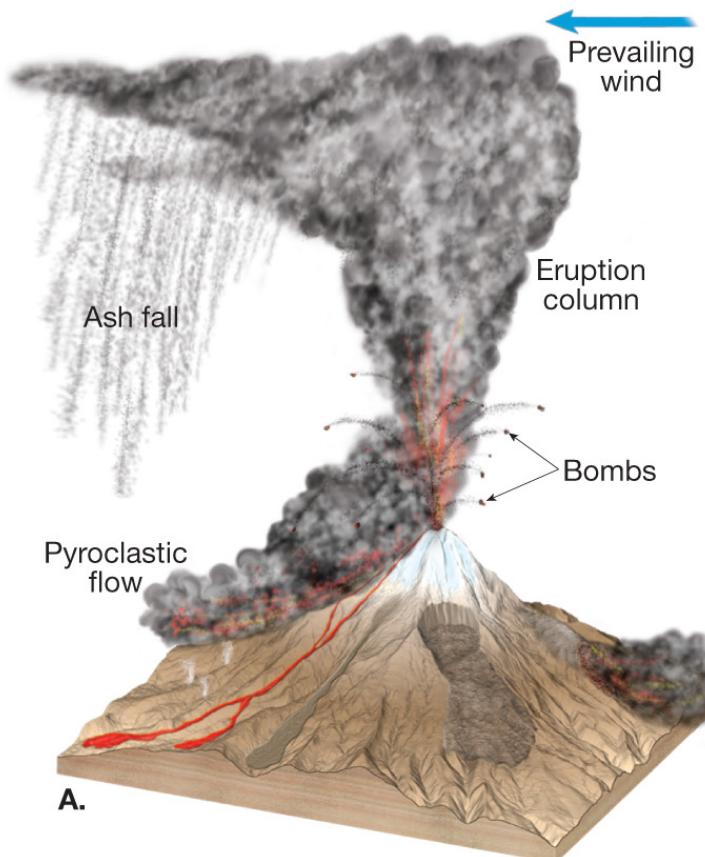
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# **Volcanoes**

- **Composite cones**

- Most violent type of activity (e.g., Mount Vesuvius)
- Often produce *nueé ardentes* (glowing avalanches)
  - Fiery pyroclastic flows made of hot gases, infused with ash and other debris
  - Move down the slopes of a volcano at speeds up to 200 km per hour
  - May produce a *lahar*, which is a volcanic mudflow
    - » Volcanic debris becomes saturated with water and rapidly moves down steep volcanic slopes

# *A Pyroclastic Flow*



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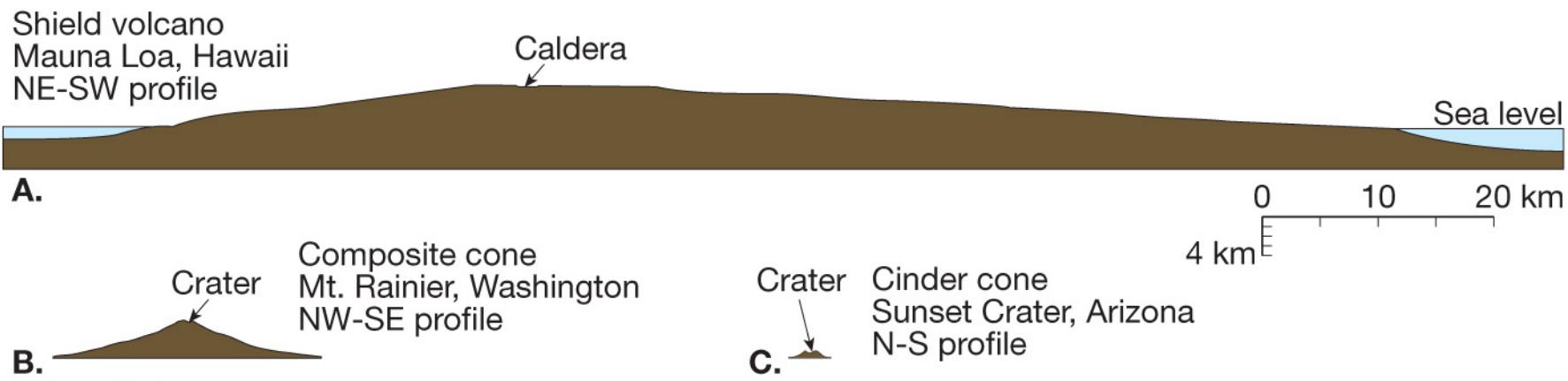
A.

The remains of human victims were quickly buried by falling ash and subsequent rainfall caused the ash to harden. Over the centuries, the remains decomposed which created cavities discovered by nineteenth-century excavators. Casts were then produced by pouring plaster into the voids.



B.

# *A Size Comparison of the Three Types of Volcanoes*



# Volcano Eyjafjallajokull (from Iceland)

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shield volcano

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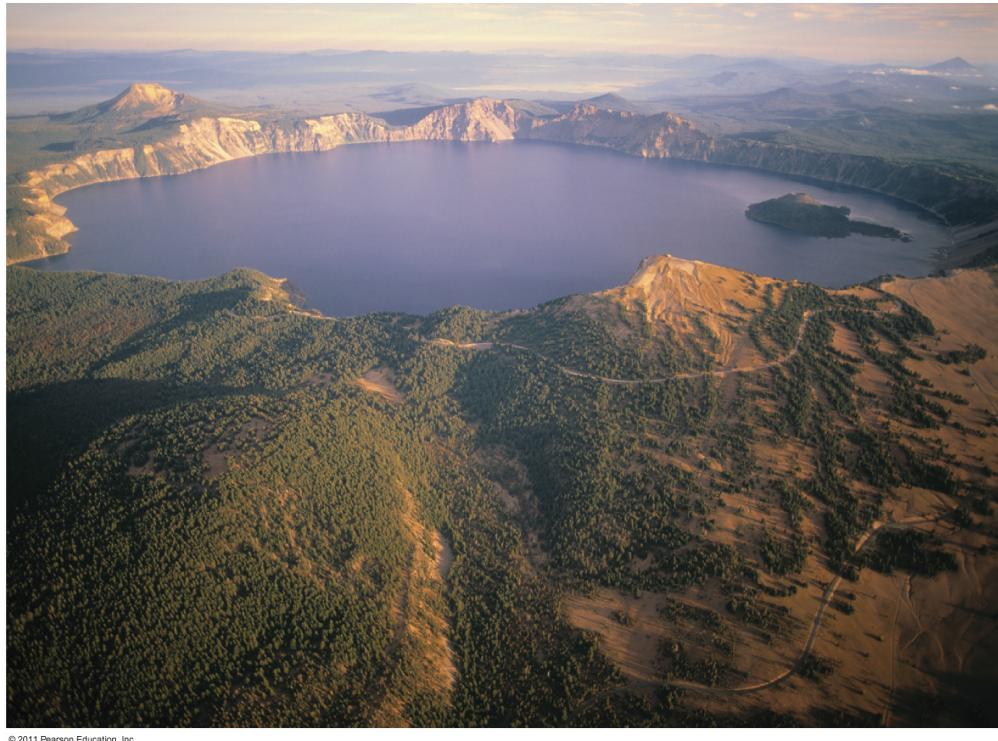
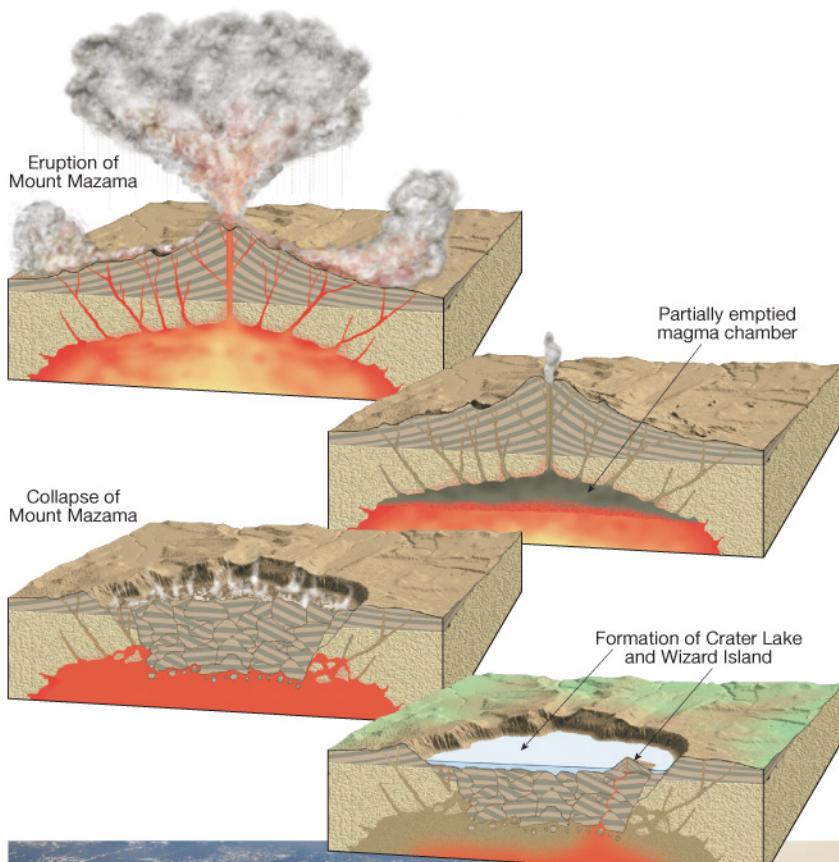
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# *Other Volcanic Landforms*

## □ 1. Calderas

- Steep-walled depressions at the summit
- Size generally exceeds 1 km in diameter
- 3 types:
  - » **Crater Lake-type calderas** (collapse of the summit of a composite volcano after an explosive eruption)
  - » **Hawaiian-type calderas** (formed by gradual subsidence as magma drained laterally from the magma chamber)
  - » **Yellowstone-type calderas** (the collapse of a large area, caused by the discharge of colossal volumes of silica-rich pumice and ash along ring fractures)

# *Crater Lake—A Caldera in Oregon*



- 10 km diameter
- 1175 m deep

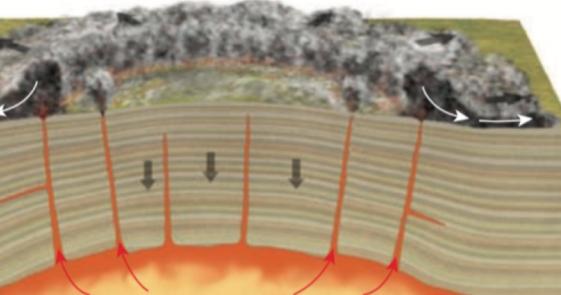
# Caldera-Yellowstone type

## Formation of Yellowstone-type Calderas

Ring fractures

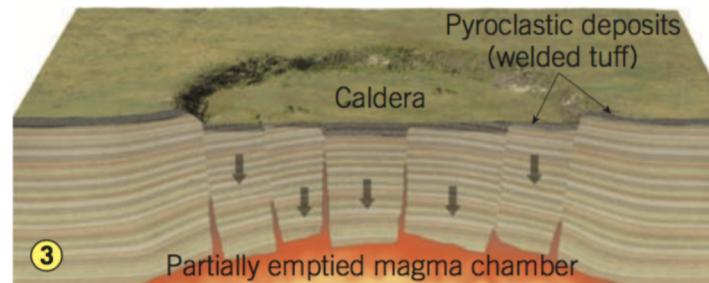
Magma chamber

The emplacement of silica-rich magma causes the layers of rock above to bulge and crack, producing a set of *ring fractures*.



1

Massive amounts of magma erupt, producing fiery clouds of ash and gases called *pyroclastic flows* that devastate the surrounding landscape.

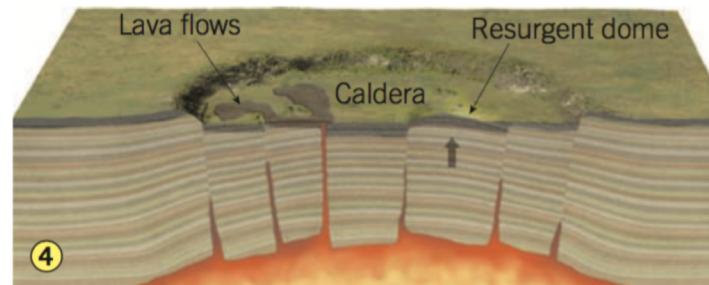


3

Partially emptied magma chamber

Pyroclastic deposits (welded tuff)

With loss of support, the roof of the magma chamber collapses forming a large caldera.



4

Following the eruption, the caldera floor experiences a long period of slow upheaval that produces an elevated central region, called a *resurgent dome*.

# *Other Volcanic Landforms*

## **2. Fissure eruptions and basalt plateaus**

- Massive amount of fluid basaltic lava extruded from crustal fractures called fissures
- Columbia River Plateau – 200,000 km<sup>2</sup>
- Deccan Traps – 500,000 km<sup>2</sup>
- Ontong-Java Plateau (submarine)



B.

***The Columbia River Basalts***

## Exposure of Deccan lava flows in the Western Ghats



# Deccan trap formation

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(1) 1.5 billion years of Plate

youtube.com/watch?v=llnwyAbczog&t=170s

scotese plate tectonics paleogeography & ice ages

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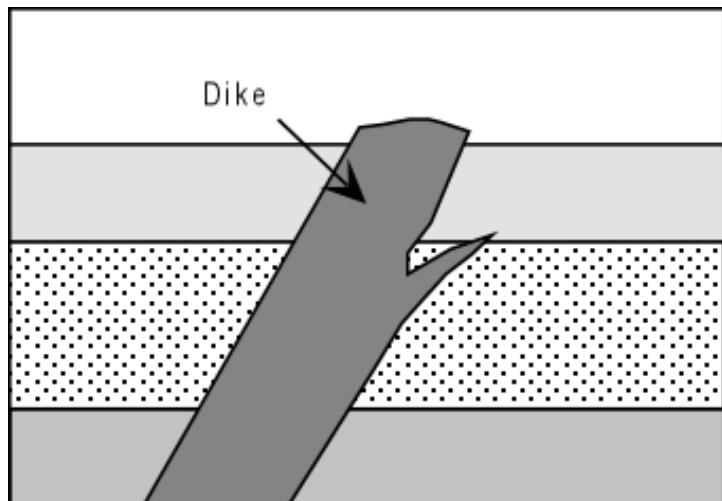
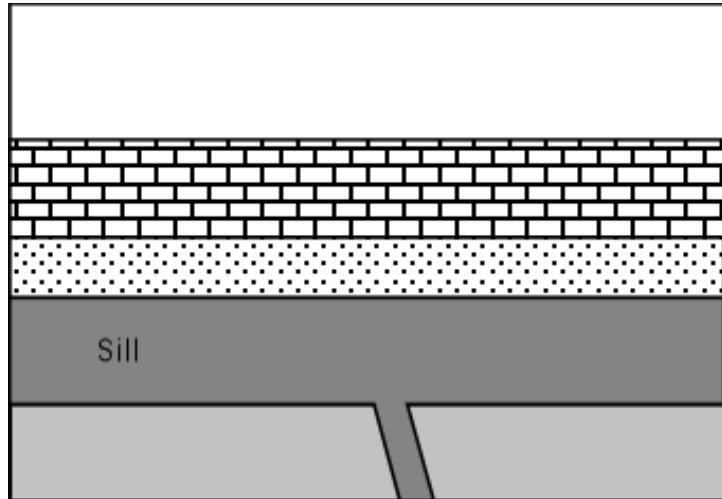
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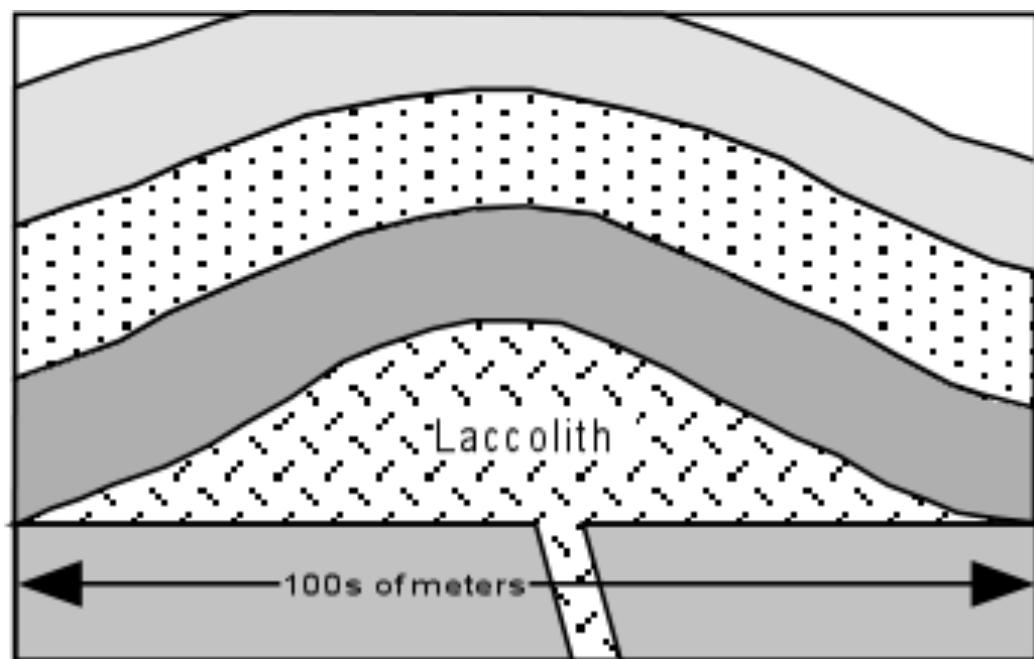
What's the Longest Drivable Distance on Earth?  
Half-eo-Interactions 4:46

Plate Tectonics 750Ma to Today

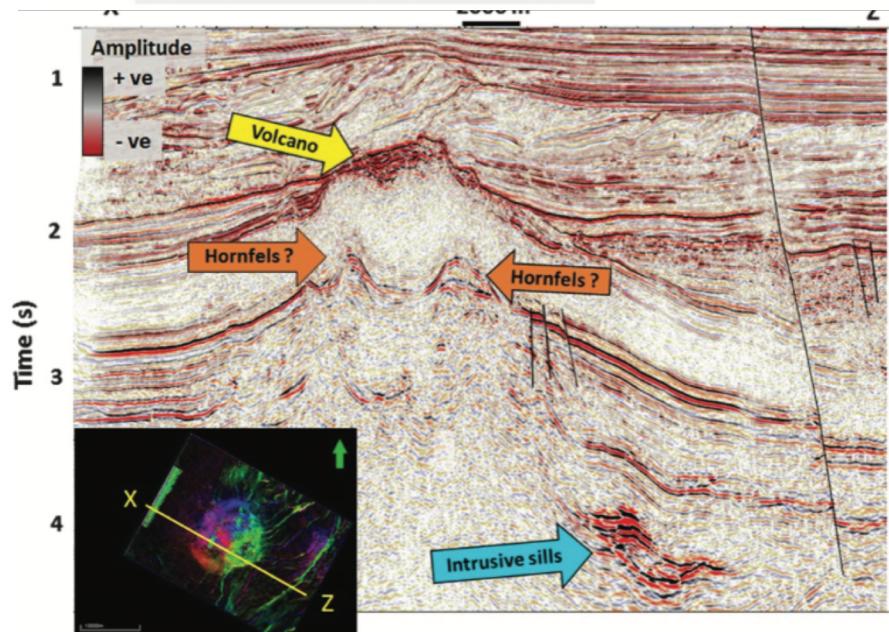
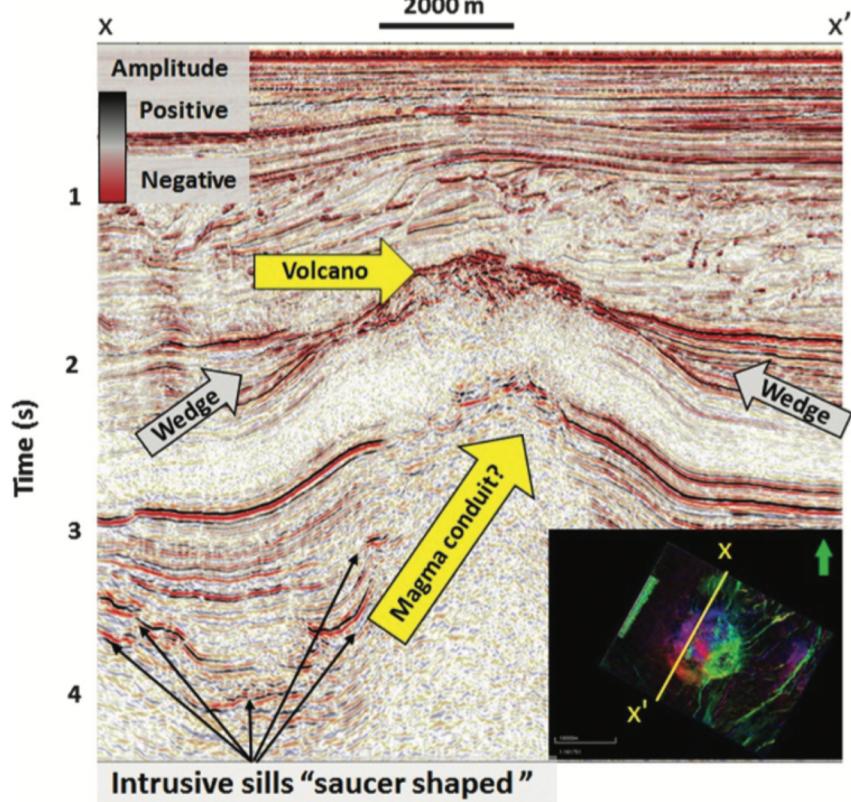
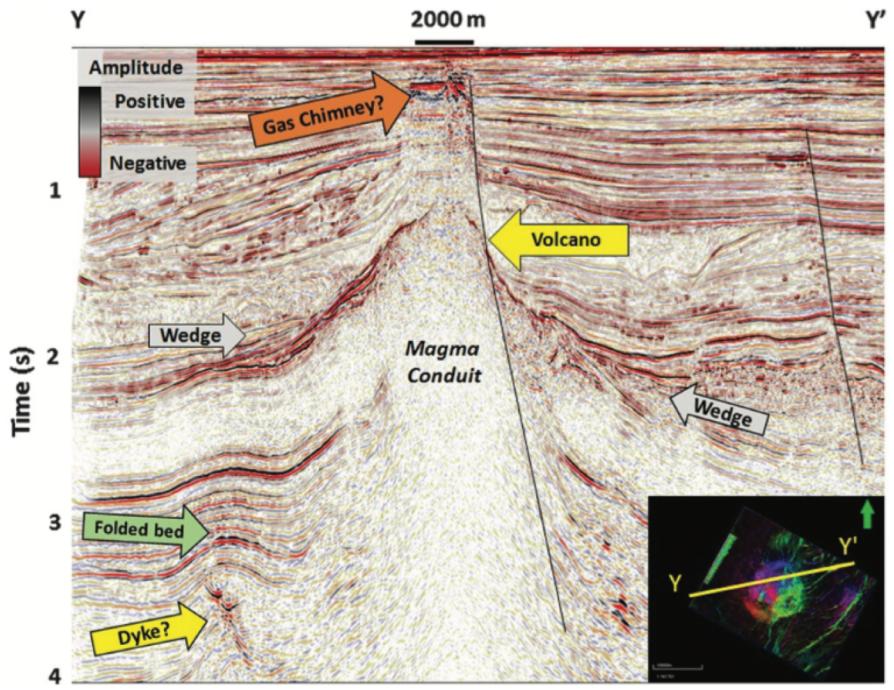
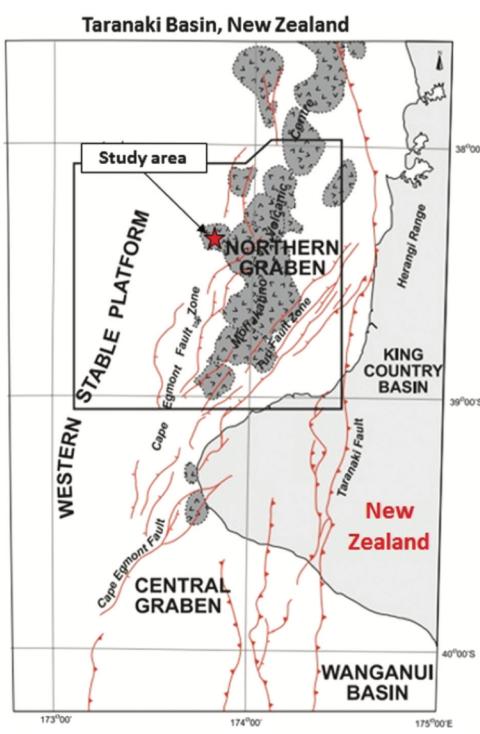
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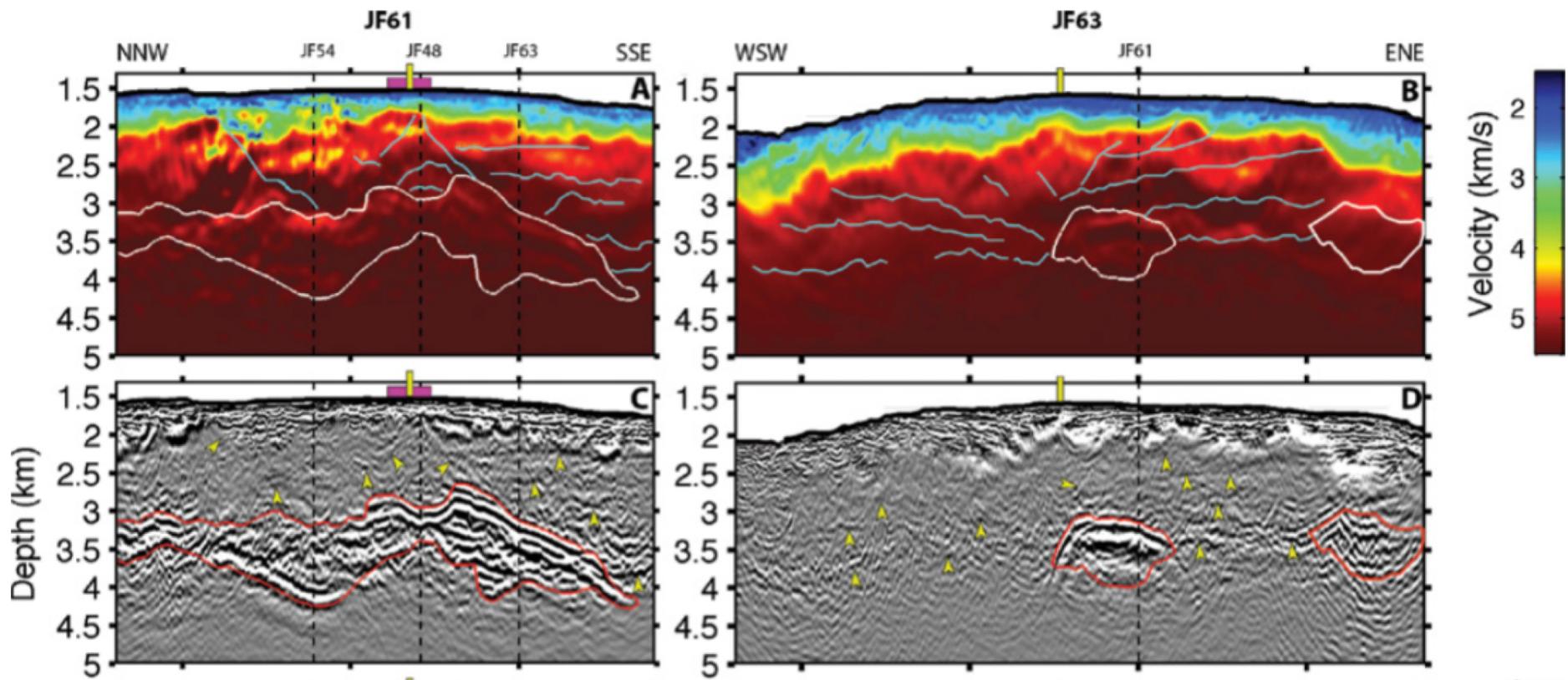
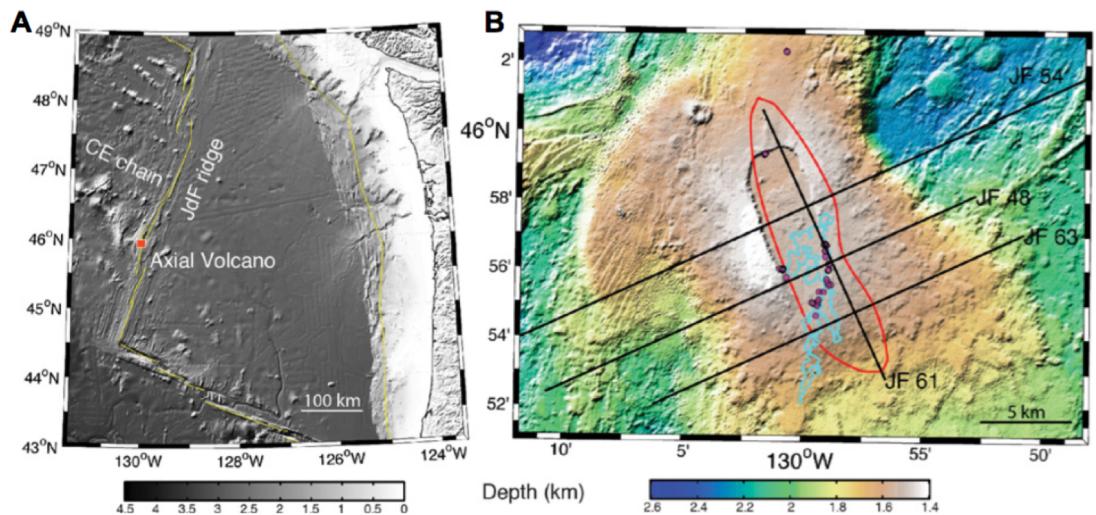
## Dike/Sill/Laccolith



# Examples of Submarine buried volcanoes



# Example of an Active volcano from a divergent plate margins



# Materials From Volcanic Eruptions Affect Earth

## Land

## Air

## Water

Lava

Poisonous Gases\*

Hot Springs

Volcanic Ash\*

Adds to Acid Rain

Geysers

Landslides (can cause tsunamis)

Haze

Fumaroles

Mudflows

Lower Temperature

Deep -Sea Vents

\*These can get in the jet stream and affect the weather around the world for months or years

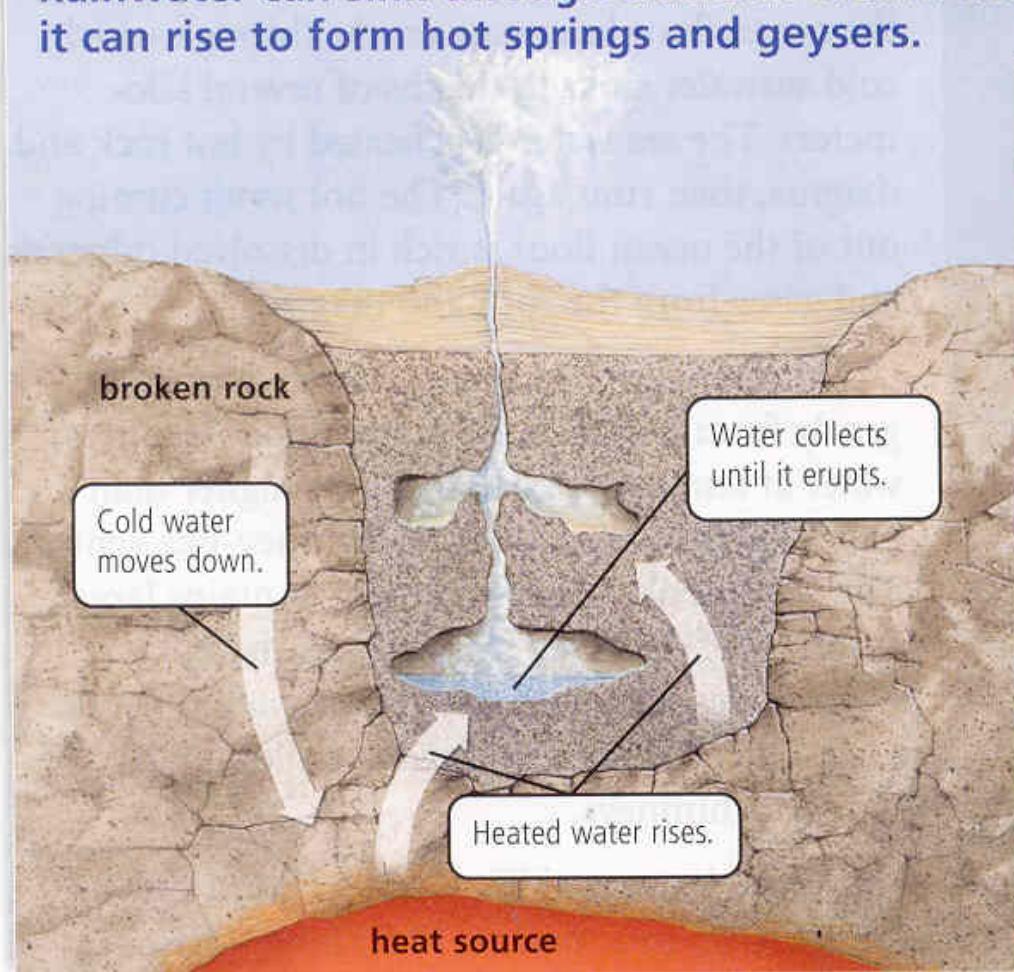
\*\*There can be benefits: richer farmland and beautiful landscapes

# Volcanoes Affect Earth's Land, Air, and Water



## Geysers

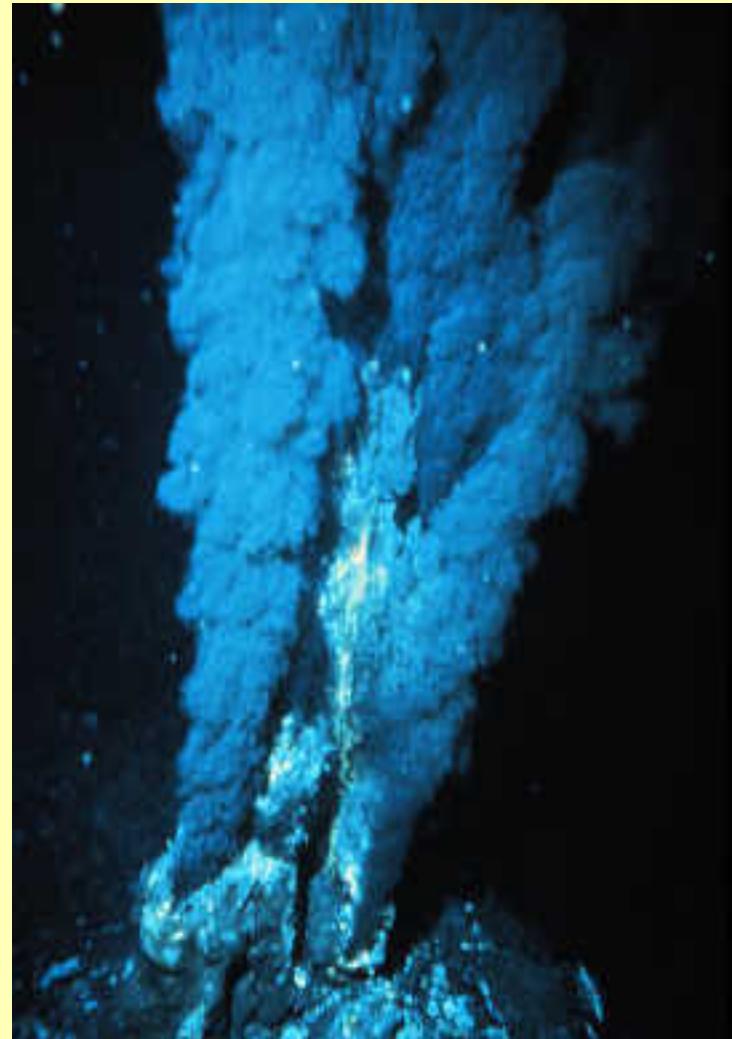
Rainwater can sink through cracks in rock. If it is heated within Earth, it can rise to form hot springs and geysers.



Old Faithful geyser in Yellowstone National Park erupts more often than any other large geyser. Heated water is forced up into the air through a narrow channel.

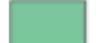
# Deep-Sea Vent

# Hot Spring

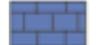


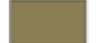
 Porphyry intrusion

 Breccia

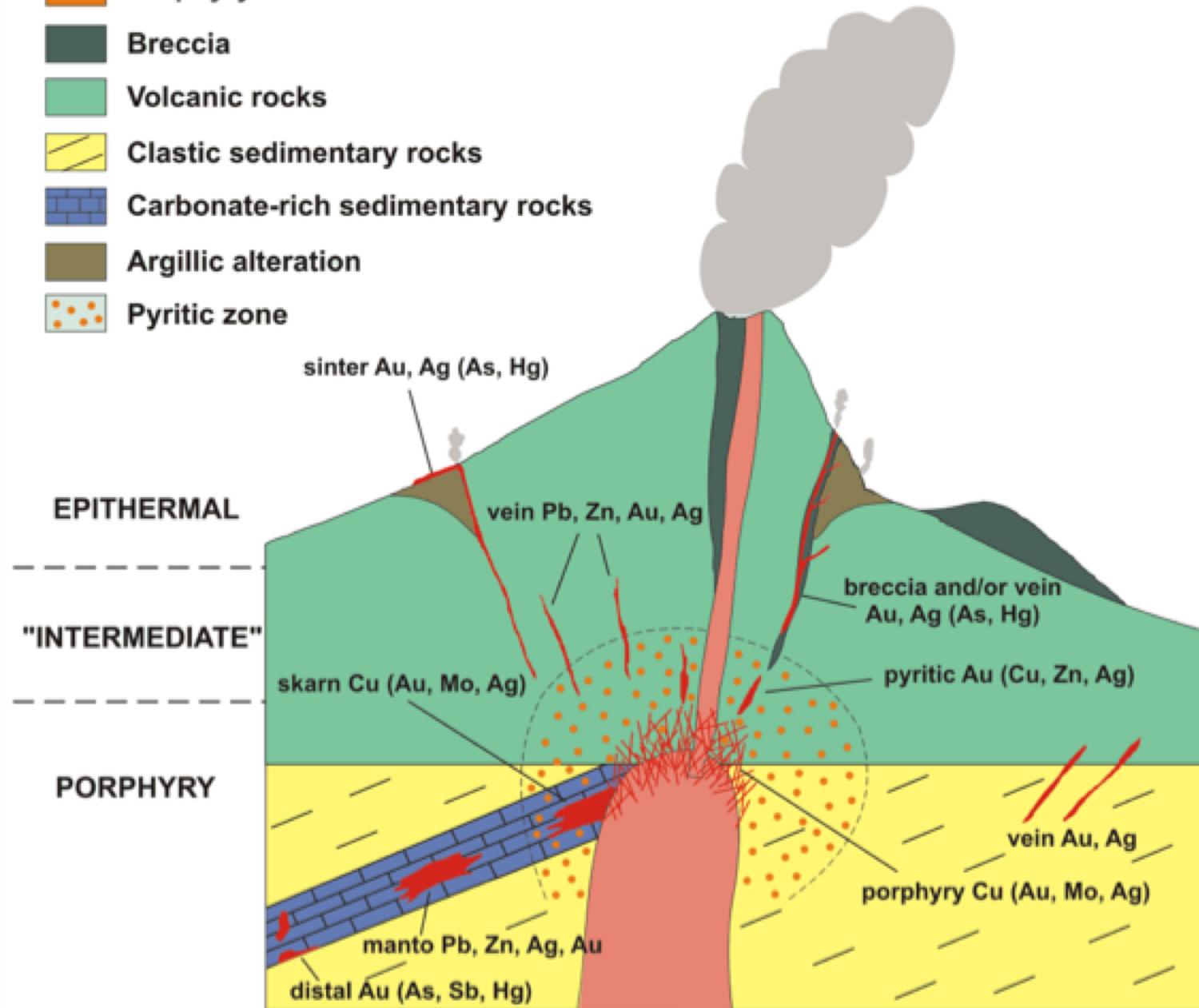
 Volcanic rocks

 Clastic sedimentary rocks

 Carbonate-rich sedimentary rocks

 Argillic alteration

 Pyritic zone



## ***Earth Science current events:***

### ***Earthquakes:***

<http://www.iris.edu/seismon/>

### ***Volcanic eruptions:***

<http://www.swisseduc.ch/stromboli/livecams/index-en.html>

### ***Local weather:***

<http://www.srh.noaa.gov/mfl/>

### ***Hurricanes on the way?***

<http://www.nhc.noaa.gov/>

# Questions

Q1: \_\_\_\_\_ is the dominant lava erupted from volcanoes on Hawaii and Iceland.

- A) Rhyolite
- B) Andesite
- C) Peridotite
- D) Basalt

Q2: Which of the following is associated with deep mantle hot spots?

- A) Vesuvius and the other volcanoes of Italy
- B) the volcanoes of Hawaii and the recent activity in Yellowstone National Park
- C) the very young cinder cones scattered across the southwestern United States
- D) Mt. St. Helens and other volcanoes of the Cascade Mountains

Q3: \_\_\_\_\_ tend to increase the explosive potential of a magma body beneath a volcano.

- A) High viscosity and dissolved gas
- B) High viscosity; low dissolved gas content
- C) Low silica content, low viscosity
- D) Low viscosity; low dissolved gas content

Q4: Which region has the greatest concentration of currently active volcanoes?

- A) the coastal plain of western Africa
- B) European Russia and Siberia
- C) the area surrounding the Red Sea
- D) the circum-Pacific area

Q5: Kilauea and Mauna Loa are \_\_\_\_\_.

- A) explosive, rhyolitic volcanoes
- B) andesitic stratovolcanoes
- C) basaltic shield volcanoes
- D) small, basaltic cinder cones