# CEEES/SC 10110-20110 The Wrath of Vulcan: Volcanic Eruptions

Redoubt Volcano, Alaska. 1989-1990 eruption.



### **Catastrophic Volcanic Eruptions**



# Krakatoa, Indonesia

Large quantities of water may seep into magma chamber and produce a Phreatic Eruption or explosion.

Krakatoa, 1883 - blew material halfway around the world!

Island 9  $\times$  5 km - swelled up to 800 m above sea level.

- 1883 violent eruption. The island vanished, 80 km<sup>3</sup> of material gone.
- Left a hole 6 km wide, 300 m below sea level. Blocks of 50 tons blown 35 km.
- Explosion heard 5,000 km away in Australia. Tropical vegetation from Krakatoa found in African deserts.
- Ash blown around the world several centimeters settling on on the decks of ships in the Pacific.

Earth's annual mean temperature lowered.

Tsunami 40 meters high killed 36,000 people & destroyed 300 towns.

### **Destruction of Pompeii, A.D. 79, by Vesuvius**



a.m. 79 AD.
 km high ash cloud.
 Pyroclastic fall and debris flow.

Buried in a 6 m thick layer of ash.

20,000 people in Pompeii.





### Vesuvius



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# Vesuvius





### Destruction of Pompeii

# Ash Cloud was FAST!





### **Products of Volcanic Eruptions**



#### Products of Volcanic Eruptions: Lava Flows





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### **Lava Flows**



# **Lava Flows**



### Lava Tubes



Lava tubes are conduits for basaltic lava.

### **Lava Flows**



### <u>Lava F</u>lows



Andesite

Higher silica content = slower moving flows (1-5 m/day), steeper volcanoes. Can break up into a pile of rubble.

#### **Rhyolite**



Ash

Builds a steep lava dome. Sticky magma doesn't flow. If magma freezes in the neck, a spine can get pushed out.

Rhyolitic dome Rubble forms because lava shatters as the interior fills with fresh material

Tephra: unconsolidated pyroclastic deposits.

# **Rhyolitic Lava Flows**



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# **Pyroclastic Debris**



# **Pyroclastic Debris**

**Dust/ash** = finest.

Cinders = sand grains.

**Bombs/blocks** = largest. Bomb = ejected as lava and streamlined in air as it cools.





Tuffs = rock composed of fine-grained pyroclastic particles. Can be cemented or welded. Air fall tuff or water lain.



Hyaloclastite = Lava erupts under water/ice and shatters. Fragments become cemented/welded.

Volcaniclastic Sediment: reworked pyroclastic debris.

Volcanic Breccia = rock composed of larger pyroclastic materials.

## Santorini





# **Pyroclastic Debris**





Pyroclastic Flow (Nueé Ardente)





**Ignimbrite**: welded tuff from pyroclastic flow.





Lahars: mud flows from remobilization of ash. 21

# **Volcanic Gas**

#### $CO, H_2O, CO_2, SO_2, H_2S, HF.$

Can form sulfuric acid, which forms aerosols that stay airborne.

Form vesicles in lava.





Water  $(H_2O)$ —the most abundant Carbon dioxide  $(CO_2)$ —second in abundance Sulfur dioxide  $(SO_2)$ —creates rotten egg smell

# **SUMMARY**



# **CALDERA FORMATION**

When a magma chamber drains, leaves a void & the top of the volcano tends to collapse downwards.

Caldera: large, steep-sided, circular or oval "crater" several kilometers in diameter.

For example, Crater Lake National Park, Orgeon created 6,600 years ago. Also Yellowstone.

Magma often solidifies in the magma chamber = INTRUSIVE.

Can also form by huge explosions.

Crater: circular depression at top of volcano (200-500 m across).

**Caldera**: huge circular depression - much bigger than crater.



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### **CALDERA**



Crater Lake, Oregon, is actually a caldera, not a crater. 26

# **FISSURE ERUPTIONS**

Flood lavas from long fissures.

Very hot mafic lavas = flood basalts, which form plateaus (e.g., Columbia Plateau – Oregon and Idaho; Deccan Traps, India).

Can form on land (*continental flood basalts*) or in the sea (*oceanic plateaus*). For example, Ontong Java Plateau, SW Pacific; Iceland. Environmental Effects.

Often flows have columnar jointing upon cooling (relatively slow cooling in thick lava flows (e.g., Giants Causeway, Ireland; Fingles

Cave, Scotland).



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# **FISSURE ERUPTIONS**

Fissure eruption may form several central vents.

Mid-ocean ridges - Iceland. MOR + Hot Spot.





Large Igneous Provinces.



# **FISSURE ERUPTIONS**





Hot spot volcanism follows flood volcanism.

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### **Types of Volcanoes**





# **Olympus Mons**



Largest Shield Volcano in the Solar System 32



Largest Shield Volcano on Earth



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### **Cinder Cone**



Small volcanoes with slopes ~30°. Seldom >500 meters high. Made up of loose fragments ("pyroclasts") ejected by firefountaining, because of gas content, from a central vent:

Very fine ash; Blocks, angular solid material; Cinders; Bombs – molten material rounded during travel.

Short life span (gas exhausted) and easily eroded. For example, Craters of the Moon, Idaho. Violent – due to gas content of the magma. Can form from any magma composition.

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 $FIGURE \ 4.20$  Cerro Negro, a cinder cone in Nicaragua. (A) View from the air; (B) nighttime eruption of pyroclastics at the summit.

**Cinder Cone, Nicaragua** 



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### **COMPOSITE / STRATOVOLCANO**

Intermediate slope angle, very large, sometimes >1,000 meters.

Alternating layers of lava and pyroclasts.

Lava layers inhibit weathering and erosion.

Magma composition = intermediate, with a variable gas content (lava + pyroclasts).

Very long-lived.

For example, Mt. Fuji, Japan. Mt. Vesuvius, Italy. Mt. Ranier (andesite); Mt St Helens (rhyolitic).







### **Volcano Size and Shape**



### **Eruptions**

#### Effusive

Basaltic lava flows. Lava tubes. Shield volcanoes.

#### **Explosive**



Cinder cones, fire fountains, volcanic bombs. Calderas. Ash. Pyroclastic flows. Pumice.

**Phreatomagmatic**: water gets in the magma chamber - causes explosion because of steam.

Viscosity and gas content determines the general type of eruption.



### **Recognizing Old Volcanoes**



**Eruption Style** 



An explosive eruption.

# **Eruption Style**

Strombolian eruption





# **Eruption Style**





Surtseyan eruption

### **Hazards Related to Volcanoes**



### **Hazards Related to Volcanoes**

#### Iceland – sits on a MOR. One big volcano!

Lava flows are always a hazard. Heimaey, 1973 – controlled lava flow by cooling it with water to divert flow from blocking up the harbor. Fortunately the lava was moving slowly.



### **Hazards Related to Volcanoes**

Lava general not that hazardous because it moves relatively slowly in most cases.

It is HOT! Will burn things in its way.

Don't build on slopes of volcanoes - lava flows downhill!

BUT volcanic soils are very fertile and because of the infrequency of eruptions causes people to forget the volcano is active (e.g., Mt St Helens).



### **Volcanic Hazards**



Goma, W. Africa - basalt lava traveled 50 km. 2 m of lava in Goma.







Wahalua Visitors' Center Aflame in Hawaii

Ruins of the Visitors' Center After Lava Cooled



### Volcanic Hazards

Pumice, Ash, and Lapilli



Fragments ~0.01 mm across.



Falling roofs. Hazard to aircraft.



Lahars

### Lahars

E.g., Pinatubo, Mt. St Helens.

Mudflows choke river channels – flow like water and set with the consistency of concrete.

Form initially by volcano melting snow and ice on summit.

May also form by heavy rains washing ash into rivers.

Can be long term hazards (decades) because of diverted drainage and continued erosion of loose ash.





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### **Volcanic Hazards**

#### **Pyroclastic Flows**

May 8<sup>th</sup>, 1902: Nueé Ardente (glowing cloud) erupted. Temperature ~700 °C; cloud was comprised of ash & pyroclastics (volcanic rocks fragmented by explosion) on a cushion of air.

St. Pierre was incinerated, 28,000 people killed, 2 survivors.





### **Montserrat Ash Cloud**



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### **Volcanic Hazards**

#### **The Blast**



#### Gas

Lake Nyos, Cameroon. August 21, 1986. 1 km<sup>3</sup> of  $CO_2$  belched forth.

#### **Earthquakes**

Movement of magma generates earthquakes, which can generate landslides and even promote eruption.



### **TOXIC GASES**

Gases emitted by volcanoes can be toxic and deadly  $(SO_2, HCl, CO, CO_2)$ .

Cameroon,  $21^{st}$  August, 1986: Lake Nyos sits along a rift zone known for volcanic activity. Massive cloud of CO<sub>2</sub> emitted and suffocated 1,742 people/6,000 cattle. CO<sub>2</sub> is denser than air.





### **Volcanic Hazards**

#### Landslides

Mt. St. Helens: 8 billion tons of debris slid 20 km at 250 km/hr.

#### Tsunamis

Generated by massive landslides and huge explosions.











### **Climate & Atmospheric Chemistry**

Dust/ash into the atmosphere can block out the sun and reduce global temperatures.

**Krakotoa**, **1883**: Global temperature decreased by 0.5°C and effects persisted for 10 years.

Tambora, Indonesia, 1816: Produced "year without a summer".

**El Chichon, Mexico, 1982**: put a lot of sulfur-rich gas into the upper atmosphere, which produced clouds of sulfuric acid droplets – blocked out the sun and produced acid rain.

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### **Climate & Atmospheric Chemistry**

Mt. Pinatubo, 1991: climatic effects measured by scientists – dust and  $SO_2$  pumped into the atmosphere.

SO<sub>2</sub> stays airborne for years, hence the long effects.

Cooling ~0.5°C, but greatest effect in the mid-latitudes of N. Hemisphere. Temperatures had rebounded by 1994.

 $SO_2$  emissions into the atmosphere also erode the ozone layer.



# **Tracking the Path of Sulfuric-Acid Mist**



### **Issues in Predicting Volcanic Eruptions**

#### **Activity Classification**

Active: volcano has erupted in recent history;

**Dormant**: inactive at present, but with the potential to become active at any time;

**Extinct**: very unlikely to erupt again.

Precise rules for putting volcanoes into these categories do not exist. For example, on average active volcanoes erupt every 220 years, but 2% erupt less than once every 10,000 years.

300-500 active volcanoes - cannot monitor all of them.

Vesuvius had been regarded as extinct – then it destroyed Pompeii in 79 A.D.

# **Volcanic Precursors**

Seismic activity, due to the upward-moving magma, earthquakes becoming shallower and more numerous as the magma gets closer to the surface and eruption nears.

The shock of a larger earthquake may release the eruption (e.g., Mt. St. Helens).

Bulging of the volcano's surface.

Cannot precisely say when the volcano will erupt.



### **Other Areas for Concern**

#### **Yellowstone National Park:** Doming is starting to occur. Eruption imminent?



### **Other Areas for Concern**

#### **Cascade Region**

Lots of active volcanoes (e.g., Mount St. Helens, 1980). Mount Baker, 1870; Mount Hood, 1865; Mount Shasta, sometime in the last 200 years; Mount Ranier, 1882.



#### Mudflows from Mt. Rainier



### **Summary**

Catastrophic Volcanic Eruptions: Krakatoa, Pompeii.

Lava Flows: Basalt (Pahoehoe, A' a, Lava Tube, Columnar Jointing, Pillow Basalts). Andesite. Rhyolite.

**Pyroclastic Debris**: Ash, Lapilli, Cinders, Bombs/Blocks, Tuffs, Hyaloclastites, Volcanic Breccia, Volcaniclastic Sediments, Ignimbrite, Lahar, Nueé Ardente.

Gas: Vesicles.

Caldera Formation.

Fissure Eruptions: MOR, Ht Spots, LIPs.

Types of Volcano: Shield, Cinder Cone, Spatter Cone, Composite/ Stratovolcano.

Eruptions: Effusive, Explosive, Phreatomagmatic.

Volcanic Hazards: Lava Flows; Pumice, Ash, Lapilli; Lahars; Pyroclastic Flows; Blast; Earthquakes; Gas; Landslides; Tsunamis; Climatic Effects.

Activity Classification: Active, Dormant, Extinct.

**Volcanic Eruption Precursors.** 

Areas for Concern: Yellowstone, Mt. Hood, Mt St. Helens. Mt. Ranier.