1 ***Volcanoes & Volcanic Hazards***
Earth, Chapter 5
2 ***Chapter 5 – Volcanoes***
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6 **From the VolcanoCam, 12 September 2007**
7 **The Nature of Volcanic Eruptions**

- All eruptions involve magma
  - Magma is molten rock that usually contains some crystals and varying amounts of dissolved gases
  - Lava is erupted magma
- The behavior of magma is determined by:
  - Temperature of the magma
  - Composition of the magma
  - Dissolved gases in the magma
- The above three factors control the viscosity of a magma, which in turn controls the nature of an eruption.

8 **The Nature of Volcanic Eruptions**
9 **The Nature of Volcanic Eruptions**

- Viscosity is a measure of a material's resistance to flow.
  - The more viscous the material, the greater its resistance to flow.
  - For example, syrup is more viscous than water.
- Factors Affecting Viscosity
  - Temperature – hotter magmas are less viscous
  - Composition – silica (SiO_2) content
    - Higher silica content magmas are more viscous (rhyolitic and andesitic lavas)
    - Lower silica content magmas are less viscous (basaltic lavas)
    - Silicate structures (tetrahedra) start to link together in long chains early in the crystallization process.

10 **The Nature of Volcanic Eruptions**

- Factors Affecting Viscosity *(continued)*
  - Dissolved Gases
    - Dissolved water vapor in magma reduces viscosity by inhibiting formation of silica tetrahedra chains.
    - Gases expand within a magma as it nears Earth's surface due to decreasing pressure.
    - The violence of an eruption is related to how easily gases escape from magma.

11 **The Nature of Volcanic Eruptions**
12 **The Nature of Volcanic Eruptions**
13 **Materials Extruded During an Eruption**

- Lava
  - Lava Flows
    - ~90% of lava is basaltic lava
    - <10% of lava is andesitic lava
    - ~1% of lava is rhyolitic lava
  - Aa and Pahoehoe Flows
    - Composed of basaltic lava
    - Aa flows have surfaces of rough jagged blocks
    - Pahoehoe flows have smooth surfaces and resemble twisted braids of rope

14 **Materials Extruded During an Eruption**
15
16 **Aa lava flow**

17 **Aa lava flow**
18 **Materials Extruded During an Eruption**
19
20 **A pahoehoe (basaltic) lava flow**
21 **A pahoehoe lava flow**
22 ***A rhyolite (silicic) lava flow***
23 **Materials Extruded During an Eruption**

- Lava *(continued)*
  - Lava Tubes
    - Cave-like tunnels
    - Often form in pahoehoe flows
    - Previous conduits for lava
    - Form in the interior of a flow where the temperatures remain high long after the exposed surface cools and hardens.

24 **Materials Extruded During an Eruption**

- Lava *(continued)*
  - Block Lavas
    - Composed of andesitic and rhyolitic lava
    - Form short prominent flows
    - Upper surface consists of massive, detached blocks
  - Pillow Lavas
    - Formed from outpourings of basaltic lava underwater
    - The flow's outer skin freezes quickly, but interior lava squeezes out by breaking through
    - Flow is composed of tube-like structures stacked one atop the other

25 **Materials Extruded During an Eruption**
26 **Pillow Lavas in Hawaii**
27 **Pillow Lavas in the Grand Canyon**
28 **Materials Extruded During an Eruption**

- Gases
  - Volatiles (dissolved gases) make up 1–6% of the total weight of a magma
  - As the magma reaches the surface and the pressure is reduced, the gases expand and escape
  - Composition is about 70% H_2O, 15% CO_2 5% N, 5% SO_2, and 5% others
- Pyroclastic Materials
  - Volcanoes eject pulverized rock and lava fragments called pyroclastic materials
  - Particles range in size from fine dust, to sand-sized ash, to very large rocks

29 **Materials Extruded During an Eruption**

- Pyroclastic Materials *(continued)*
  - Tephra
  - Volcanic ash – fine glassy fragments
    - *Welded tuff* – fused ash
  - Lapilli – walnut-sized material
  - Cinders – pea-sized material
  - Blocks – hardened or cooled lava >2.5 inches diameter
  - Bombs – ejected as hot lava >2.5 inches diameter
    - Because they are molten-semi molten, bombs take on a streamlined shape as they hurtle through the air

30 **Materials Extruded During an Eruption**
31 **Materials Extruded During an Eruption**

- Pyroclastic Materials *(continued)*
  - Tephra

- Volcanic ash – fine glassy fragments
  - Welded tuff – fused ash
- Lapilli – walnut-sized material
- Cinders – pea-sized material

32 **Ash**

33 ***Cinders***

34 **Materials Extruded During an Eruption**

- Pyroclastic Materials *(continued)*
  - Pumice – light gray or pink porous rock from frothy andesitic and rhyolitic lava
  - Scoria – reddish-brown porous rock from frothy basaltic lava

35 ***Pumice***

36 ***Scoria***

37 **Materials Extruded During an Eruption**

- Pyroclastic Materials *(continued)*
  - Blocks – hardened or cooled lava
  - Bombs – ejected as hot lava

38 ***Blocks***

39 **A volcanic bomb**

40 ***A volcanic bomb in Mojave Preserve (near Baker, California)***

41 **Anatomy of a Volcano**

- General Features
  - Fissure – a crack develops in Earth's crust as magma moves toward the surface
  - Conduit – a somewhat circular pathway from a fissure to the surface
  - Vent – the surface opening of a conduit
  - Volcanic cone – the cone-shaped structure created by successive eruptions of lava and pyroclastic material

42 **Anatomy of a Volcano**

43 **Anatomy of a Volcano**

- General Features *(continued)*
  - Crater – a funnel-shaped depression at the summit of most volcanic cones, generally less than 1 km in diameter
  - Caldera – a volcanic crater that has a diameter of >1 kilometer and is produced by a collapse following a massive eruption
  - Parasitic cones – a flank vent that emits lava and pyroclastic material
  - Fumaroles – a flank vent that emits gases

44 **Shield Volcanoes**

- General Features of Shield Volcanoes
  - Broad, slightly dome-shaped
  - Covers large areas
  - Produced by mild eruptions of large volumes of basaltic lava
  - Most begin on the seafloor as seamounts; only a few grow large enough to form a volcanic island
  - Examples include the Hawaiian Islands, the Canary Islands, the Galapagos, and Easter Island
  - Mauna Loa is the largest volcano on Earth

45 **Shield Volcanoes**

46 **Shield Volcanoes (Mauna Loa from Kilauea)**

47 **The "Big Island" of Hawaii**

48 **The "Big Island" of Hawaii**

49 **Cinder Cones**

- General Features of Cinder Cones
  - Also called scoria cones
  - Built from ejected lava fragments
  - Steep slope angle
  - Rather small size (30–300 m tall)
  - Frequently occur in groups
  - Sometimes associated with extensive lava fields—but these generally form in the final stages of the volcano's life span
  - Paricutin (located 320 km west of Mexico City) is an example of a cinder cone

50 **Cinder Cones**
51 **Cinder Cones**
52 **Cinder Cones**
53 **Cinder cone volcano**
54 **Cinder cone volcano**
55 **Vulcan's Throne, a cinder cone**
56 **Red Hill (cinder cone) and lava flow**
57 **Composite Volcanoes**

- General Features of Composite Volcanoes
  - Also called stratovolcanoes
  - Large, classic-shaped volcano (symmetrical cone, thousands of feet high and several miles wide at the base)
  - Composed of interbedded (generally andesitic) lava flows and layers of pyroclastic debris
  - Many are located adjacent to the Pacific Ocean in the Ring of Fire
  - Mount St. Helens and Mount Etna are examples

58 ***Anatomy of a composite, or strato- volcano***
59 **Composite Volcanoes**
60 **Mt. Shasta, California**
61 **Mt. Rainier, Washington**
62 **Mt. Lassen, California**
63
64 **Anatomy of a Volcano**
65 **Volcanic Hazards**

- Pyroclastic Flows
  - A pyroclastic flow is a mixture of hot gases infused with incandescent ash and lava fragments that flows down a volcanic slope.
  - Also called a nuée ardente
    - (Native Americans' name: "stone wind")
  - Propelled by gravity and move similarly to snow avalanches
  - Material is propelled from the vent at high speeds (can exceed 100 km [60 miles] per hour)
    - Pyroclastic flows are typically generated by the collapse of tall eruption columns.

66 **Volcanic Hazards**

  - A *surge* is a small amount of ash that separates from the main body of the pyroclastic flow.
    - Occasionally, these surges have enough force to knock over buildings and move automobiles.
  - In 1902, the town of St. Pierre was destroyed by a pyroclastic flow from Mount Pelée

67 **Volcanic Hazards**
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69 **Volcanic Hazards**
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71 **A nueé ardente on Mt. St. Helens**

72 **A nueé ardente on Mt. St. Helens**

73 **Volcanic Hazards**

- Lahars
  - A lahar is mudflow on an active or inactive volcano
  - Volcanic debris becomes saturated with water and rapidly moves down a volcanic slope
  - Some lahars are triggered when magma nears the surface of a volcano covered in ice and snow and causes it to melt
  - When Mt. St. Helens erupted in 1980, several lahars were generated
  - In 1985, lahars formed during the eruption of Nevado del Ruiz, killing 25,000 people

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75 **Volcanic Hazards**

76 **Volcanic Hazards**

- Other Volcanic Hazards
  - Volcano-related tsunamis
    - Destructive sea waves can form after the sudden collapse of a flank of a volcano
  - Volcanic ash – a hazard to airplanes
    - Jet engines can be damaged when flying through a cloud of volcanic ash
    - In 2010, the eruption of Iceland's Eyjafjallajokull created a thick plume of ash over Europe, stranding hundreds of thousands of travelers
  - Volcanic gases – a respiratory health hazard
    - Volcanoes can emit poisonous gases, endangering humans, and livestock

77 **Volcanic Hazards**

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80 **Volcanic Hazards**

- Effects of Volcanic Ash and Gases on Weather and Climate
  - Ash particle released from volcanoes can reflect solar energy back into space causing cooling.
    - The 1783 Laki eruption in Iceland brought the longest period of below 0 temperatures to New England in 1784.
    - The ash from the eruption of Mount Tambora in 1815 led to the "year without summer" (1816).
    - The El Chichon eruption in Mexico (1982) produced an unusually large amount of SO_2 that reacted with water vapor to produce clouds of tiny sulfuric acid droplets.

81 **Other Volcanic Landforms**

- Calderas
  - *Calderas* are circular, steep-sided depressions with a diameter >1 km
  - Three different types:
    - *Crater Lake-type calderas*: Form from the collapse of the summit of a large composite volcano following an eruption; these calderas eventually fill with rainwater
    - *Hawaiian-type calderas*: Form gradually from the collapse of the summit of a shield volcano following the subterranean drainage of the central magma chamber
    - *Yellowstone-type calderas*: Form from the collapse of a large area after the discharge of large volumes of silica-rich pumice and ash; these calderas tend to exhibit a complex history

82 **Formation of Crater Lake-Type Calderas**

83 **Crater Lake (Oregon)**

84 **Crater Lake (Oregon)**

85 **Crater Lake and Wizard Island, 2001**

86 **Mt. Mazama profile**

87 **Mt. Mazama profile**

88 **Hawaiian-Type Calderas**
89 **Halemaumau**
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a crater within Kilauea Caldera

(enlarged considerably in 2018!)
90 **Halemaumau, within Kilauea Caldera**
91 **Halemaumau, within Kilauea Caldera**
92 **Formation of Yellowstone-Type Calderas**
93 **Formation of Yellowstone-Type Calderas**
94 **Yellowstone-type Caldera formation**
95 **Yellowstone-type Caldera formation**
96 **Yellowstone-type Caldera formation**
97 **Yellowstone-type Caldera formation**
98 **Yellowstone: pyroclastic deposits**
99 **Yellowstone: pyroclastic deposits**
100 **Other Volcanic Landforms**
- Large Igneous Provinces
  - Large igneous provinces cover a large area with basaltic lava
  - Basaltic lava extruded from fissures blanket a large area, called a large igneous provinces or basalt plateaus
  - The Columbia Plateau and the Deccan Traps are two examples

101 **Other Volcanic Landforms**
- Fissure Eruptions and Basalt Plateaus
  - Fluid basaltic lava extruded from fissures blanket a large area, called a large igneous province or basalt plateau.
  - Flood basalts appropriately describes these eruptions
  - The Colombia Plateau and the Deccan Traps are two examples

102 **Fissure eruptions**
103 **Other Volcanic Landforms**
104 **Other Volcanic Landforms**
- Lava Domes
  - A lava dome is a small dome-shaped mass composed of rhyolitic lava.
  - As thick lava is squeezed out of a vent, it produces a dome-shaped mass.

105 **A lava dome**
106 ***A lava dome near Mono Lake***
107 **Salton Buttes:**
lava domes in our back yard…
108 **Obsidian Butte, a lava dome**
109 **Other Volcanic Landforms**
- Volcanic Necks and Pipes
  - A volcanic neck is the remains of magma that solidified in a volcanic conduit.
    - Shiprock, New Mexico, is an example
  - A pipe is a rare type of conduit that originated in the mantle at depths exceeding 150 km.
    - Kimberlite pipes, for example

110 ***Shiprock, New Mexico***
111 **Formation of a volcanic neck**
112 ***Devil's Tower, Wyoming***
(neck vs. laccolith?)
113 ***Kimberly, South Africa***
114 **Plate Tectonics and Volcanic Activity**

- Volcanism at Convergent Plate Boundaries
  - Occurs at subduction zones, where two plates converge and the oceanic lithosphere descends into the mantle.
  - *Volcanic arcs* develop parallel to the associated subduction zone trench
    - The Aleutians, the Tongas, and the Marianas are examples of volcanic island arcs
    - The Cascade Range is an example of a continental volcanic arc
  - Most active volcanoes are found along the circum-Pacific Ring of Fire
  - Eruptions tend to be explosive and associated with volatile-rich, andesitic magma

115 **Plate Tectonics and Volcanic Activity**

116 **Convergent Plate Volcanism**

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120 **Plate Tectonics and Volcanic Activity**

- Volcanism at Divergent Plate Boundaries
  - 60% of Earth's yearly output of magma is from spreading centers
  - Characterized by a vast outpouring of fluid, basaltic lavas.

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122 **Plate Tectonics and Volcanic Activity**

- Volcanism at Divergent Plate Boundaries
  - East African Rift Zone

123 **Plate Tectonics and Volcanic Activity**

- Intraplate Volcanism
  - Volcanoes that occur thousands of kilometers from plate boundaries
  - Occurs when a mantle plume ascends towards the surface.
  - Large mantle plumes, dubbed *superplumes*, are thought to be responsible for flood basalts.
  - Examples include the Hawaiian Islands, the Columbia River Basalts, and the Galapagos Islands.

124 **Plate Tectonics and Volcanic Activity**

125 **Plate Tectonics and Volcanic Activity**

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129 **Track of the Yellowstone Hot-spot**

130 **Monitoring Volcanic Activity**

- Why? To provide scientific data and to assess hazards
- Most notable changes in a volcanic landscape:
  - Changes in patterns of earthquakes
  - Inflation of the volcano related to rising magma
  - Changes in the amount and/or composition of gases released from the volcano

131 **Monitoring Volcanic Activity**

- Remote sensing devices greatly enhance ability to monitor volcanoes
  - Limited-accessibility volcanoes
  - Eruptions in progress
  - Ground deformation and SO_2 emissions
- A volcano must be monitored for a long time to recognize a difference between "resting state" and "active state."

132 **Monitoring Volcanic Activity**

133 **Distribution of some of the world's major volcanoes**

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136 **End of the Road (and Chapter)**