Volcanoes and Other Igneous Activity

Objectives

After reading, studying, and discussing Chapter 9, you should be able to:

- List the factors that determine the violence of volcanic eruptions.
- List the materials that are extruded from volcanoes.
- Describe the various types of volcanoes and other features produced by volcanic activity.
- List and describe several intrusive igneous features.
- Discuss the role of heat, pressure, and volatiles in the origin of magma.
- Describe the relation between igneous activity and plate tectonics.

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Summary

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The following statements summarize the primary objectives presented in the chapter.

- The primary factors that determine the nature of volcanic eruptions include the magma's **temperature**, its**composition**, and the **amount of dissolved gases** it contains. As lava cools, it begins to congeal, and as **viscosity** increases, its mobility decreases. **The viscosity of magma is directly related to its silica content**. **Rhyolitic lava**, with its high silica content, is very viscous and forms short, thick flows.**Basaltic lava**, with a lower silica content, is more fluid and may travel a long distance before congealing. Dissolved gases provide the force that propels molten rock from the vent of a volcano.
- The materials associated with a volcanic eruption include **lava flows** (**pahoehoe** and **aa** flows for basaltic lavas), **gases** (primarily in the form of **water vapor**), and **pyroclastic material** (pulverized rock and lava fragments blown from the volcano's vent, which include **ash**, **pumice**, **lapilli**, **cinders**, **blocks**, and **bombs**).

- Successive eruptions of lava from a central vent result in a montainous accumulation of material known as a **volcano**. Located at the summit of many volcanoes is a steep-walled depression called a **crater**.**Shield**

cones are broad, slightly domed volcanoes built primarily of fluid, basaltic lava. **Cinder cones**have very steep slopes composed of pyroclastic material. **Composite cones**, or **stratovolcanoes**, are large, nearly symmetrical structures built of interbedded lavas and pyroclastic deposits. Composite cones produce some of the most violent volcanic activity. Often associated with a violent eruption is a **nuée ardente**, a fiery cloud of hot gases infused with incandescent ash that races down steep volcanic slopes. Large composite cones may also generate a type of mudflow known as a **lahar**.

- Most volcanoes are fed by **conduits** or **pipes**. As erosion progresses, the rock occupying the pipe is often more resistant and may remain standing above the surrounding terrain as a **volcanic neck**. The summits of some volcanoes have large, nearly circular depressions that exceed 1 kilometer in diameter called **calderas**. Although volcanic eruptions from a central vent are the most familiar, by far the largest amounts of volcanic material are extruded from cracks in the crust called **fissures**. The term **flood basalts** describes the fluid, waterlike, basaltic lava flows that cover an extensive region in the northwestern United States known as the Columbia Plateau. When silica-rich magma is extruded, **pyroclastic flows** consisting largely of ash and pumice fragments usually result.
- Igneous intrusive bodies are classified according to their **shape** and by their **orientation with respect to the host rock**, generally sedimentary rock. The two general shapes are **tabular** (sheetlike) and **massive**. Intrusive igneous bodies that cut across existing sedimentary beds are said to be **discordant**, whereas those that form parallel to existing sedimentary beds are **concordant**.

- **Dikes** are tabular, discordant igneous bodies produced when magma is injected into fractures that cut across rock layers. Tabular, concordant bodies, called **sills**, form when magma is injected along the bedding surfaces of sedimentary rocks. In many respects sills closely resemble buried lava flows. **Laccoliths** are similar to sills but form from less-fluid magma that collects as a lens-shaped mass that arches the overlying strata upward. **Batholiths**, the largest intrusive igneous bodies with surface exposures of more than 100 square kilometers (40 square miles), frequently compose the cores of mountains.

- Magma originates from essentially solid rock of the crust and mantle. In addition to a rock's composition, its temperature, depth (confining pressure), and water content determine whether it exists as a solid or liquid. Thus, magma can be generated by **raising a rock's temperature**, as occurs when a hot mantle plume "ponds" beneath crustal rocks. A **decrease in pressure** can cause **decompression melting**. Further, the **introduction of volatiles** (water) can lower a rock's melting point sufficiently to generate magma. Because melting is generally not complete, a process called **partial melting** produces a melt made of the lowest-melting-temperature minerals, which are higher in silica than the original rock. Thus, magmas generated by partial melting are nearer to the granitic (felsic) end of the compositional spectrum than are the rocks from which they formed.
- **Most active volcanoes are associated with plate boundaries**. Active areas of volcanism are found along mid-ocean ridges where seafloor spreading is occurring (**divergent plate boundaries**), in the vicinity of ocean trenches where one plate is being subducted beneath another (**convergent plate boundaries**), and in the interiors of plates themselves (**intraplate volcanism**). Rising plumes of hot mantle rock are the source of most intraplate volcanism.

Earth Science, 10th edition
Chapter 9: **Volcanoes and Other Igneous Activity**

I. Volcanic eruptions
  A. Factors that determine the violence of an eruption
    1. Composition of the magma
    2. Temperature of the magma
    3. Dissolved gases in the magma
  B. Viscosity of magma
    1. Viscosity is a measure of a material's resistance to flow
    2. Factors affecting viscosity
      a. Temperature (hotter magmas are less viscous)
      b. Composition (silica content)
        1. High silica B high viscosity (e.g., rhyolitic lava)
        2. Low silica B more fluid (e.g., basaltic lava)
      c. Dissolved gases (volatiles)
        1. Mainly water vapor and carbon dioxide
        2. Gases expand near the surface
        3. Provide the force to extrude lava
        4. Violence of an eruption is related to how easily gases escape from magma
          a. Easy escape from fluid magma
          b. Viscous magma produces a more violent eruption

II. Materials associated with volcanic eruptions
  A. Lava flows
    1. Basaltic lavas are more fluid
    2. Types of lava
      a. Pahoehoe lava (resembles braids in ropes)
      b. Aa lava (rough, jagged blocks)
  B. Gases
    1. One to 5 percent of magma by weight
    2. Mainly water vapor and carbon dioxide
  C. Pyroclastic materials
    1. "Fire fragments"
    2. Types of pyroclastic material
      a. Ash and dust B fine, glassy fragments
      b. Pumice B from "frothy" lava
      c. Lapilli B "walnut" size
      d. Cinders B "pea-sized"
      e. Particles larger than lapilli
        1. Blocks B hardened lava
        2. Bombs B ejected as hot lava

III. Volcanoes
  A. General features
    1. Conduit, or pipe caries gas-rich magma to the surface
    2. Vent, the surface opening (connected to the magma chamber via a pipe)
    3. Crater
      a. Steep-walled depression at the summit
      b. Caldera (a summit depression greater than 1 km diameter)

4. Parasitic cones
5. Fumaroles

B. Types of volcanoes
1. Shield volcano
a. Broad, slightly domed
b. Primarily made of basaltic (fluid) lava
c. Generally large
d. Generally produce a large volume of lava
e. e.g., Mauna Loa in Hawaii
2. Cinder cone
a. Built from ejected lava fragments
b. Steep slope angle
c. Rather small size
d. Frequently occur in groups
3. Composite cone (or stratovolcano)
a. Most are adjacent to the Pacific Ocean (e.g., Mt. Rainier)
b. Large size
c. Interbedded lavas and pyroclastics
d. Most violent type of activity
e. Often produce nuée ardente
1. Fiery pyroclastic flow made of hot gases infused with ash
2. Flows down sides of a volcano at speeds up to 200 km (125 miles) per hour
f. May produce a lahar, a type of mudflow

IV. Other volcanic landforms
A. Calderas
1. Steep walled depression at the summit
2. Formed by collapse
3. Nearly circular
2. Size exceeds one kilometer in diameter
B. Fissure eruptions and lava plateaus
1. Fluid basaltic lava extruded from crustal fractures called fissures
2. e.g., Columbia Plateau
C. Volcanic pipes and necks
1. Pipes are short conduits that connect a magma chamber to the surface
2. Volcanic necks (e.g., Ship Rock, New Mexico) are resistant vents left standing after erosion has removed the volcanic cone

V. Intrusive igneous activity
A. Most magma is emplaced at depth
B. An underground igneous body is called a pluton
C. Plutons are classified according to
1. Shape
a. Tabular (sheetlike)
b. Massive
2. Orientation with respect to the host (surrounding) rock
a. Discordant B cuts across existing structures
b. Concordant B parallel to features such as sedimentary strata
D. Types of igneous intrusive features
1. Dike, a tabular, discordant pluton
2. Sill, a tabular, concordant pluton
a. e.g., Palisades Sill, NY

b. Resemble buried lava flows
c. May exhibit columnar joints

3. Laccolith
   a. Similar to a a sill
   b. Lens shaped mass
   c. Arches overlying strata upward
4. Batholith
   a. Largest intrusive body
   b. Often occur in groups
   c. Surface exposure 100+ square kilometers (smaller bodies are termed stocks)
   d. Frequently form the cores of mountains

VI. Origin of magma

A. Magma originates when essentially solid rock, located in the crust and upper mantle, melts

B. Factors that influence the generation of magma from solid rock

1. Role of heat
   a. Earth=s natural temperature increases with depth (geothermal gradient) is not sufficient to melt rock at the lower crust and upper mantle
   b. Additional heat is generated by
      1. Friction in subduction zones
      2. Crustal rocks heated during subduction
      3. Rising, hot mantle rocks
2. Role of pressure
   a. Increase in confining pressure causes an increase in melting temperature
   b. Drop in confining pressure can cause decompression melting
      1. Lowers the melting temperature
      2. Occurs when rock ascends
3. Role of volatiles
   a. Primarily water
   b. Cause rock to melt at a lower temperature
   c. Play an important role in subducting ocean plates
4. Partial melting
   a. Igneous rocks are mixtures of minerals
   b. Melting occurs over a range of temperatures
   c. Produces a magma with a higher silica content than the original rock

VII. Plate tectonics and igneous activity

A. Global distribution of igneous activity is not random

1. Most volcanoes are located on the margins of the ocean basins (intermediate, andesitic composition)
2. Second group is confined to the deep ocean basins (basaltic lavas)
3. Third group includes those found in the interiors of continents

B. Plate motions provide the mechanism by which mantle rocks melt to form magma

1. Convergent plate boundaries
   a. Deep-ocean trenches are generated
   b. Descending plate partially melts
   c. Magma slowly rises upward
   d. Rising magma can form
      1. Volcanic island arcs in an ocean
         a. Basaltic composition
         b. e.g. the Aleutians
      2. Continental volcanic arcs

a. Andesitic or rhyolitic composition
b. e.g. Andes Mountains

2. Divergent plate boundaries
   a. The greatest volume of volcanic rock is produced along the oceanic ridge system
      1. Lithosphere pulls apart
      2. Less pressure on underlying rocks
      3. Partial melting occurs
      4. Large quantities of fluid basaltic magma are produced
3. Intraplate igneous activity
   a. Activity within a rigid plate
   b. Plumes of hot mantle material rise
   c. Form localized volcanic regions called hot spots
      1. Associated with Hawaii and the
      2. Columbia Plateau in the northwestern United States