Chapter 4
Igneous Rocks and Intrusive Igneous Activity

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Chapter Outline
Introduction
LO1 The Properties and Behavior of Magma and Lava
LO2 How Does Magma Originate and Change?
LO3 Igneous Rocks: Their Characteristics and Classification
LO4 Intrusive Igneous Bodies: Plutons
LO5 How Are Batholiths Intruded into Earth’s Crust?

Learning Outcomes
After reading this unit, the students should be able to do the following:
LO1 Describe the properties and behavior of magma and lava
LO2 Explain how magma originates and changes
LO3 Identify and classify igneous rocks by their characteristics
LO4 Recognize intrusive igneous bodies, or plutons
LO5 Explain how batholiths intruded into Earth’s crust

Chapter Summary
- Magma is the term for a molten rock material below Earth’s surface, whereas the same material at the surface is called lava.
- Variation in silica content distinguishes mafic (45–52% silica), intermediate (53–65% silica), and felsic (>65% silica) magmas.
• Magma and lava viscosity depends mostly on temperature and composition: The more silica, the greater the viscosity.

• Minerals crystallize from magma and lava when small crystal nuclei form and grow.

• Rapid cooling accounts for the aphanitic textures of volcanic rocks, whereas comparatively slow cooling yields the phaneritic textures of plutonic rocks. Igneous rocks with markedly different-sized minerals are porphyritic.

• Igneous rock composition is determined mostly by the composition of the parent magma, but magma composition can change so that the same magma may yield more than one type of igneous rock.

• According to Bowen’s reaction series, cooling magic magma yields a sequence of minerals, each of which is stable within specific temperature ranges. Only ferromagnesian silicates are found in the discontinuous branch of Bowen’s reaction series. The continuous branch of the reaction series yields only plagioclase feldspars that become increasingly enriched with sodium as cooling occurs.

• A chemical change in magma may take place as early ferromagnesian silicates form and, because of their density, settle in the magma.

• Compositional changes also take place in magma when it assimilates country rock, or one magma mixes with another.

• Geologists recognize two broad categories of igneous rocks: volcanic or extrusive and plutonic or intrusive.

• Texture and composition are the criteria used to classify igneous rocks, although a few are defined only by texture.

• Crystallization from water-rich magma results in very large minerals in rocks known as pegmatite. Most pegmatite has an overall composition similar to granite.
Instructor’s Manual

Chapter 4

GEOL

Igneous Rocks and Intrusive Igneous Activity

- Intrusive igneous bodies known as plutons vary in their geometry and in their relationship to country rock: Some are concordant, whereas others are discordant.

- The largest plutons, known as batholiths, consist of multiple intrusions of magma during long periods of time.

- Most plutons, including batholiths, are found at or near divergent or convergent plate boundaries.

Lecture Suggestions

1. Bowen’s reaction series can be compared to changing two given brick walls into two new walls. In one case—the discontinuous series—the bricks are individually removed and a new wall is simultaneously built from the bricks, but in a new pattern. The constituents of olivine, for example, are thus recreated into the new structure of pyroxene. In the second case—the continuous series—bricks are individually removed from the wall and replaced by different bricks, having, perhaps, a different color, but retaining the original pattern. For plagioclase, an original constituent (calcium) is replaced by a new constituent (sodium), but the structure is never torn down.

2. Bowen’s reaction series is a very powerful tool for explaining more than one facet of rock formation. The series helps us understand why some minerals are typically found together in igneous rocks (e.g., olivine and pyroxene with calcium plagioclase; or quartz, biotite, and orthoclase with sodium plagioclase), but others are not (e.g., olivine and pyroxene with sodium plagioclase and orthoclase). Bowen’s reaction series also explains temperature relations (why mafic magmas are hotter than felsic ones). It can also be seen why a mafic magma, by giving up heat, can partially melt material to form felsic magma, but the reverse isn’t possible. Later, when weathering is discussed, Bowen’s reaction series will help to explain the greater stability at Earth’s surface of the lower temperature minerals (e.g., quartz) and lesser stability of the higher temperature ones (e.g., olivine).

3. Crystal settling may be explained by analogy with a series of salts that precipitate as saltwater evaporates while the remaining water becomes increasingly saturated in the remaining salts. Precipitation from a solution and crystallization of magma are not the same thing, of course.

4. Dust off the lava lamp that you relegated to the attic and bring it to class. You can use it to illustrate points about how densities vary with temperature, how gravity is the driving force in a rising magma, and what shapes are assumed by the rising bodies as they deform and shoulder aside the other material. You may want to note that unlike the lava lamp example, plutons, once they ascend, do not later descend back into the same rocks through which they rose.
Enrichment Topics

**Topic 1. Igneous Rock Classification.** There are lots of ways to classify igneous rocks. Grab a handful of igneous rocks, preferably with their chemical analyses, and explore some of those ways: color-texture, modal, normative. [http://csmres.jmu.edu/geollab/Fichter/IgnRx/IgHome.html](http://csmres.jmu.edu/geollab/Fichter/IgnRx/IgHome.html)

![Igneous Rock Classification Diagram]

**Topic 2. Devil’s Tower.** Geologists do not agree on whether Devil’s Tower is the neck of a long-dead volcano or an igneous intrusion. How could geologists tell the difference? [http://www.nature.nps.gov/views/Sites/DETO/HTML/00G_Overview.htm](http://www.nature.nps.gov/views/Sites/DETO/HTML/00G_Overview.htm)

Common Misconceptions

Misconception: Once they accept the fact that magmas can exist within Earth’s crust, many students believe that these bodies of liquid are squeezed into surrounding rocks, or squirited out at the surface by some unknown forces acting in a manner like the squeezing of toothpaste from a tube.
Fact: Magma bodies rise and intrude in response to the simple pull of gravity. Liquid rock—magma—has a lower specific gravity than solid rock. This causes the magma to rise and
perhaps, over time, even to deform other rocks. As the magma approaches the surface and the pressure decreases, there is the additional “push” provided by the expansion of the dissolved gases coming out of solution.

Consider This

1. If small bodies such as dikes (e.g., basalt dikes) and sills cool rapidly and are thus usually fine grained, how is it possible for pegmatites having crystals several feet in length to form in these small bodies?

2. Batholiths are believed to have been emplaced and solidified several kilometers underground, yet we can see them exposed in mountain ranges today. What has happened to all of the rocks that must have been above the batholiths?

3. How can a single volcano erupt distinctly felsic composition lavas in one event and distinctly mafic lavas in another?

Key Terms

aphanitic texture  laccolith  pyroclastic (fragmental) texture
assimilation  lava  pyroclastic materials
batholith  lava flow  sill
Bowen’s reaction series  mafic magma  stock
concordant pluton  magma  stoping
country rock  magma chamber  vesicle
crystal settling  magma mixing  viscosity
dike  mantle plume  volcanic neck
discordant pluton  phaneritic texture  volcanic pipe
felsic magma  plutonic texture  volcanic (extrusive igneous) rock
hot spot  pluton  porphyritic texture
igneous rock  plutonic (intrusive igneous) rock
intermediate magma
Internet Sites, Videos, Software, and Demonstration Aids

Internet Sites

   This University of North Carolina website was developed to help undergraduate students understand igneous and metamorphic rocks.

2. Rob’s Granite Page: http://uts.cc.utexas.edu/~rmr/
   An introduction to granitic rocks from the University of Texas.

Videos

1. Journeys from the Center of the Earth: Architecture. Insight Media (2004, 50 min.)
   Rocks and how they determined the structures that could be built by ancient civilizations.

2. Intrusive Igneous Rocks. Insight Media (1999, 19 min.)
   The formation of intrusive igneous rocks.

3. Rock Cycle. Insight Media (2003, 30 min.)
   How minerals form rocks and rocks change into other types of rocks.

   (1992, 30 min., free video):
   - #14: Intrusive Igneous Rocks. The processes that create intrusive rocks and the types of intrusive rocks that are found on Earth.

Software

   Photos of rocks and the rock cycle for Mac or Windows.

   An interactive exploration of minerals and rocks and the geological processes that form them.

   Includes 53 minerals and 27 common rocks for lab simulation.

Slides and Demonstration Aids

1. Rocks, Minerals and Resources (Mac/Windows CD-ROM)
   Mineral and rock types and resources discussed and identified.

Slide set including many topics important to introductory geology courses.

   Digital images of intrusive and metamorphic rocks from the continental core.

4. Science Stuff, [http://www.sciencestuff.com/](http://www.sciencestuff.com/), has an assortment of rock and mineral collections, including:
   - Introductory Earth Science Rocks and Minerals.
   - Igneous Rock Collection.
   - Metamorphic Rock Collection.
   - Sedimentary rock Collection.
   - Advanced Rock and Minerals Collection.