


1  **Igneous Rocks**

Earth, 9th edition - Chapter 4

2  **Igneous Rocks: summary in haiku form**


Olivine forms first;
quartz forms later, when it's cool.
Thanks Mister Bowen!

3  **Key Concepts**

- The nature of magma and lava, and the effects of cooling and crystallization.
- Textures of igneous rocks and their interpretation.
- Compositions of igneous rocks and their meaning.
- Naming, differentiating and comparing igneous rocks.
- The importance of Bowen's reaction series: Understanding magma processes and igneous rocks.
- The production and evolution of magma.

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6  **General characteristics**

of magma

- Igneous rocks form as molten rock cools and solidifies
- General characteristics of magma:
 - ☒ Parent material of igneous rocks
 - ☒ Forms from partial melting of rocks
 - ☒ Magma at surface is called lava

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General characteristics

of magma

- General characteristic of magma
 - ☒ Rocks formed from lava = extrusive, or volcanic rocks
 - ☒ Rocks formed from magma at depth = intrusive, or plutonic rocks

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General characteristics

of magma

- The nature of magma
 - ☒ Consists of three components:
 - ◆ Liquid portion = melt
 - ◆ Solids, if any, are silicate minerals
 - ◆ Volatiles = dissolved gases in the melt, including water vapor (H₂O), carbon dioxide (CO₂), and sulfur dioxide (SO₂)

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General characteristics

of magma

- Crystallization of magma
 - ☒ Cooling of magma results in the systematic arrangement of ions into orderly patterns
 - ☒ The silicate minerals resulting from crystallization form in a predictable order
 - ☒ Texture - size and arrangement of mineral grains

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Igneous textures

- Texture is used to describe the overall appearance of a rock based on the size, shape, and arrangement of interlocking minerals
- Factors affecting crystal size
 - ☒ Rate of cooling
 - ◆ Slow rate = fewer but larger crystals
 - ◆ Fast rate = many small crystals
 - ◆ Very fast rate forms glass

- 11 **Igneous textures**
 - Factors affecting crystal size
 - ☒ % of silica (SiO₂) present
 - ☒ Dissolved gases
- 12 ***Igneous Textures***
- 13 **Igneous textures**
 - Types of igneous textures
 - ☒ Aphanitic (fine-grained) texture
 - ◆ Rapid rate of cooling
 - ◆ Microscopic crystals
 - ◆ May contain vesicles (holes from gas bubbles)
 - ☒ Phaneritic (coarse-grained) texture
 - ◆ Slow cooling
 - ◆ Large, visible crystals
- 14 **Aphanitic texture**
- 15 **Phaneritic texture**
- 16 **Igneous textures**
 - Types of igneous textures
 - ☒ Porphyritic texture
 - ◆ Minerals form at different temperatures
 - ◆ Large crystals (phenocrysts) are embedded in a matrix of smaller crystals (groundmass)
 - ☒ Glassy texture
 - ◆ Very rapid cooling of lava
 - ◆ Resulting rock is called obsidian
- 17 **Porphyritic texture**
- 18 **Porphyritic texture:**
"Snowflake Porphyry"
(Vancouver Island, B.C., Canada)
- 19 **Glassy texture**
- 20 **Glassy texture: Obsidian**
- 21 ***Obsidian Arrowhead***
- 22 ***Obsidian Flow in Oregon***
- 23 **Igneous textures**
 - Types of igneous textures
 - ☒ Pyroclastic texture
 - ◆ Fragmental appearance produced by violent volcanic eruptions
 - ◆ Often appear more similar to sedimentary rocks
 - ☒ Pegmatitic texture
 - ◆ Exceptionally coarse grained
 - ◆ Form in late stages of crystallization of granitic magmas
- 24 **Pyroclastic Texture**
- 25 ***Pegmatitic Texture***
- 26 **Pegmatitic Texture**
- 27 **Igneous compositions**
 - Igneous rocks are composed primarily of silicate minerals
 - ☒ Dark (or ferromagnesian) silicates
 - ◆ Olivine, pyroxene, amphibole, and biotite mica
 - ☒ Light (or nonferromagnesian) silicates
 - ◆ Quartz, muscovite mica, and feldspars
- 28 **Igneous compositions**
 - Granitic versus basaltic compositions
 - ☒ Granitic composition

- ◆ Light-colored silicates
- ◆ Termed felsic (*f*eldspar and *s*ilica) in composition
- ◆ High amounts of silica (SiO₂)
- ◆ Major constituent of continental crust

29 **Igneous compositions**

- Granitic versus basaltic compositions
 - ☒ Basaltic composition
 - ◆ Dark silicates and calcium-rich feldspar
 - ◆ Termed mafic (*m*agnesium and *f*errum, for iron) in composition
 - ◆ Higher density than granitic rocks
 - ◆ Comprise the ocean floor and many volcanic islands

30 **Igneous compositions**

- Other compositional groups
 - ☒ Intermediate (or andesitic) composition
 - ◆ Contain 25% or more dark silicate minerals
 - ◆ Associated with explosive volcanic activity
 - ☒ Ultramafic composition
 - ◆ Rare composition that is high in magnesium and iron
 - ◆ Composed entirely of ferromagnesian silicates

31 **What's Wrong Here?**

32 **What's Wrong Here?**

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35 **Igneous compositions**

- Silica content as an indicator of composition
 - ☒ Exhibits a considerable range in the crust
 - ◆ 45% to 70%
- Silica content influences magma behavior
 - ☒ Granitic magmas
 - ◆ high silica content and viscous
 - ☒ Basaltic magmas
 - ◆ much lower silica content and more fluid-like behavior

36 **Igneous compositions**

- Naming igneous rocks – granitic rocks
 - ☒ Granite
 - ◆ Phaneritic
 - ◆ Over 25% quartz, about 65% or more feldspar
 - ◆ Very abundant - often associated with mountain building
 - ◆ The term granite includes a wide range of mineral compositions

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41 **Igneous compositions**

- Naming igneous rocks – granitic rocks
 - ☒ Rhyolite
 - ◆ Extrusive equivalent of granite
 - ◆ May contain glass fragments and vesicles
 - ◆ Aphanitic texture
 - ◆ Less common and less voluminous than granite

42 **Rhyolite**

43 **Igneous compositions**

- Naming igneous rocks – granitic rocks
 - ☒ Obsidian
 - ◆ Dark colored
 - ◆ Glassy texture
 - ☒ Pumice
 - ◆ Volcanic
 - ◆ Glassy texture
 - ◆ Frothy appearance with numerous voids

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Igneous compositions

- Naming igneous rocks – intermediate rocks
 - ☒ Andesite
 - ◆ Volcanic origin
 - ◆ Aphanitic texture
 - ☒ Diorite
 - ◆ Plutonic equivalent of andesite
 - ◆ Coarse grained

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Andesite

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Diorite

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Igneous compositions

- Naming igneous rocks – basaltic rocks
 - ☒ Basalt
 - ◆ Volcanic origin
 - ◆ Aphanitic texture
 - ◆ Composed mainly of pyroxene and calcium-rich plagioclase feldspar
 - ◆ Most common extrusive igneous rock

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Basalt

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Igneous compositions

- Naming igneous rocks – mafic rocks
 - ☒ Gabbro
 - ◆ Intrusive equivalent of basalt
 - ◆ Phaneritic texture consisting of pyroxene and calcium-rich plagioclase
 - ◆ Significant % of the oceanic crust

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Gabbro

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Igneous compositions

- Naming igneous rocks – pyroclastic rocks
 - ☒ Composed of fragments ejected during a volcanic eruption
 - ☒ Varieties
 - ◆ Tuff = ash-sized fragments
 - ◆ Volcanic breccia = particles larger than ash

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A Welded Tuff Deposit

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Welded Tuff Deposits, plus...

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Figure 4.11

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Figure 4.12

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Origin of magma


- Highly debated topic
- Generating magma from solid rock
 - ☒ Role of heat
 - ◆ Temperature increases in the upper crust (geothermal gradient) average between 20°C to 30°C per kilometer

- ◆Rocks in the lower crust and upper mantle are near their melting points
- ◆Any additional heat may induce melting


60  **Origin of magma**

- Generating magma from solid rock (continued)
 - ☒Role of pressure
 - ◆Increases in confining pressure cause an increase in a rock's melting temperature
 - ◆When confining pressures drop, decompression melting occurs
 - ☒Role of volatiles
 - ◆Volatiles (primarily water) cause rocks to melt at lower temperatures
 - ◆Important factor where oceanic lithosphere descends into the mantle

61  **Decompression melting**

62  **Evolution of magmas**

- A single volcano may extrude lavas exhibiting very different compositions
- Bowen's reaction series
 - ☒Minerals crystallize in a systematic fashion based on their melting points
 - ☒During crystallization, the composition of the liquid portion of the magma continually changes

63  **Bowen's reaction series**

64  **Evolution of magmas**

- Processes responsible for changing a magma's composition
 - ☒Magmatic differentiation
 - ◆Separation of a melt from earlier formed crystals
 - ☒Assimilation
 - ◆Changing a magma's composition by the incorporation of surrounding rock bodies into a magma


65  **Evolution of magmas**

- Processes responsible for changing a magma's composition
 - ☒Magma mixing
 - ◆Two chemically distinct magmas may produce a composition quite different from either original magma

66  **Assimilation, magma mixing, and magmatic differentiation**

67  **Evolution of magmas**

- Partial melting and magma formation
 - ☒Incomplete melting of rocks is known as partial melting
 - ☒Formation of basaltic magmas
 - ◆Most originate from partial melting of ultramafic rock in the mantle at oceanic ridges
 - ◆Large outpourings of basaltic magma are common at Earth's surface


68  **Evolution of magmas**

- Partial melting and magma formation
 - ☒Formation of andesitic magmas
 - ◆Produced by interaction of basaltic magmas and more silica-rich rocks in the crust
 - ◆May also evolve by magmatic differentiation

69  **Evolution of magmas**

- Partial melting and magma formation
 - ☒Formation of granitic magmas
 - ◆Most likely form as the end product of crystallization of andesitic magma
 - ◆Granitic magmas are more viscous than other magmas so they tend to lose their mobility before reaching the surface
 - ◆Tend to produce large plutonic structures

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71  **End of Chapter**