Lecture 5: Igneous Rocks

1. Big Island Field Trip. Sign-up by Friday Sept. 11

2. Extra credit

iClicker assignments – pick yours up

<table>
<thead>
<tr>
<th>001 Abreu</th>
<th>003 Agena</th>
<th>004 Albert</th>
<th>006 Araki</th>
<th>091 Atiburcio</th>
<th>008 Buck</th>
<th>010 Byce</th>
<th>011 Clements</th>
<th>012 Colle</th>
<th>067 Peahu</th>
<th>068 Santiago</th>
<th>069 Shigemitsu</th>
<th>070 Soares</th>
<th>084 Teramura</th>
<th>086 Tomaszek</th>
<th>073 Wu</th>
<th>074 Yamamoto</th>
<th>075 Yanagi</th>
<th>077 Yokota</th>
<th>079 Zoller</th>
</tr>
</thead>
</table>
Learning Objectives (LO)

Lecture 5: Igneous Rocks

What we’ll learn today:

1. Describe igneous rock
2. Identify the information revealed by igneous texture
3. Identify how igneous rock color relates to chemical composition
4. Describe the process of igneous evolution and the role of plate tectonics in it
5. Describe the environments where basalt accumulates
Quick Facts

- Earth’s crust is 4/5 igneous rock
- Every igneous rock begins life as magma
- As magma migrates toward the surface, some of it chills & hardens underground into various types of igneous rocks
- Magma that makes it to the surface erupts in either flowing or explosive volcanoes, generating lava or pyroclastic debris
Igneous rock is formed when molten, or partially molten, rock solidifies.
Fundamental Rock Types

- **Igneous Rocks:** form when magma solidifies

- **Sedimentary Rocks:** form when sediment becomes cemented into solid rock

- **Metamorphic rocks:** form when heat, pressure, or hot water alter any preexisting rock
The Rock Cycle

- **Def.:** All rocks change slowly from 1 of 3 rock types to another
- Rocks are created, changed, and recycled
Igneous rocks are the foundation of the **Rock Cycle**
Igneous Rocks = Magma

- **Magma**: solid rock that is melted (high temperatures) to form molten liquid

- Magma rises toward Earth’s surface & cools, solidifies
Igneous Rock-Forming Environments
Types of Igneous Rocks

- **Extrusive** (volcanic)
  - forms when magma erupts & solidifies on the surface

- **Intrusive** (plutonic)
  - forms when magma solidifies within the crust
## Cooling of Magma

<table>
<thead>
<tr>
<th>Size of Magma Body</th>
<th>Time for Cooling</th>
<th>Type of Magma</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 mm</td>
<td>1 second</td>
<td>lava splatter</td>
</tr>
<tr>
<td>10 mm</td>
<td>1 minute</td>
<td>lava flow</td>
</tr>
<tr>
<td>100 mm</td>
<td>1 hour</td>
<td>magma chamber</td>
</tr>
<tr>
<td>1 m</td>
<td>5 days</td>
<td></td>
</tr>
<tr>
<td>10 m</td>
<td>1 year</td>
<td></td>
</tr>
<tr>
<td>100 m</td>
<td>100 years</td>
<td></td>
</tr>
<tr>
<td>1 km</td>
<td>10,000 years</td>
<td></td>
</tr>
<tr>
<td>10 km</td>
<td>1 Myr</td>
<td></td>
</tr>
<tr>
<td>100 km</td>
<td>100 Myr</td>
<td>oceanic lithosphere</td>
</tr>
</tbody>
</table>

Cooling is VERY SLOW for large magma bodies.
Extrusive Igneous Rocks

- **Lava**: fluid magma that flows from a crack or volcano onto Earth’s surface

- Magma cools quickly = less time for crystals to form

- Ex.: Basalt - common volcanic rock, ocean crust, few crystals
Intrusive Igneous Rocks

- Magma cools **slowly**, more time for **crystals** to form
- Ex. Granite: most abundant rock in continental crust
  medium- to coarse-grained crystals

Granite

Gabbro
Igneous intrusions occur in a variety of shapes and sizes.
Igneous intrusions occur in a variety of shapes and sizes.
Basalt forms at spreading centers & hotspots

Spreading centers

hotspots

Pillow basalts
Pillow lavas form where erupting lava interacts with water

http://www.youtube.com/watch v=DdlIUuUY0L9c
Lava erupting beneath ice forms volcanoes with flat tops and steep sides. Called a “Tuva”.

Herðubreið, Iceland
What Happens When Lava Meets Ice?

https://www.youtube.com/watch?v=yvSmPqqZB3Q
Igneous rocks are classified based on their composition and texture

Composition: assemblage of minerals (Si vs. Mg)
Texture: size and arrangement of crystals (cooling history)
The Major 7 Types of Igneous Rocks

- Rhyolite
- Andesite
- Basalt
- Granite
- Diorite
- Gabbro
- Peridotite
Composition Types

- **Felsic:** Feldspar & Silica
  Granite (large grains), Rhyolite (small)

- **Mafic:** Magnesium & Iron (Fe)
  Gabbro (large), Basalt (small)

- **Ultramafic:** High Mg & Fe
  Peridotite (mantle material, rare)

- **Intermediate:**
  Andesite
Bowen’s Reaction Series Describes the Crystallization of Magma

As magma crystallizes, a network of interlocking minerals forms
Mafic minerals crystallize early and Felsic minerals crystallize late in magma

Minerals at the TOP of the series:
- Dark in color
- Mafic to ultramafic
- Fe & Mg

Minerals at the BOTTOM of the series:
- Light in color
- Felsic
- Na & K
Composition vs. Color

Igneous color (gray scale) is used to estimate chemical composition.

less → More Mg/Fe content → less
more ← Si/O content ← less

Using visual color to estimate composition can be misleading.

Obsidian is Felsic!
Igneous rocks are classified based on their composition and texture.

Composition: The assemblage of minerals (Si vs. Mg)

Texture: the size and arrangement of minerals (cooling history)
Texture is a Record of the Crystallization History

**TABLE 5.2 Common Igneous Textures**

<table>
<thead>
<tr>
<th>Texture</th>
<th>Definition</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aphanitic</td>
<td>Minerals too small to see</td>
<td>Rhyolite</td>
</tr>
<tr>
<td>Phaneritic</td>
<td>Minerals large enough to see with unaided eye</td>
<td>Granite</td>
</tr>
<tr>
<td>Glassy</td>
<td>No obvious minerals</td>
<td>Obsidian</td>
</tr>
<tr>
<td>Pyroclastic</td>
<td>Fused, glassy volcanic rock fragments and ash from explosive volcanic eruption</td>
<td>Tuff</td>
</tr>
<tr>
<td>Vesicular</td>
<td>Many holes or pits in rock surface caused by escaping gas</td>
<td>Vesicular Basalt</td>
</tr>
<tr>
<td>Porphyrytic</td>
<td>Two distinct mineral sizes</td>
<td>Porphyritic Basalt</td>
</tr>
</tbody>
</table>

**Diagram:**
- Pyroclastic texture
- Aphanitic texture
- Phaneritic texture
- Porphyrytic texture
Texture Styles

**Phaneritic:**
- Slow cooling, larger crystals
- Coarse texture
- Intrusive or plutonic

**Aphanitic:**
- Rapid cooling, smaller crystals
- Finer texture
- Extrusive or volcanic

Other textures are **glassy**, **pyroclastic**, **vesicular**, and **porphyritic**
Phaneritic
large minerals

Large crystals had a long time to crystallize.

Therefore, this is an intrusive rock

Example: Granite
Texture

Aphanitic
mineral grains too small to see with the unaided eye

Small crystals had a short time to crystallize. Therefore, this is an extrusive rock

Example: Basalt
Vesicular
many pits from gas escape

Extrusive rock

Example: Basalt
Texture

Glassy
no obvious
minerals

No crystals.

This is an **extrusive** rock that cooled VERY quickly

Example: Obsidian
Extrusive rock (made during an eruption)

Example: Tuff

Pyroclastic
Fused rock fragments & ash from an explosive eruption

Texture
Texture

Porphyritic
2 distinct grain sizes, large & small

Two phases of cooling:
Intrusive phase: large crystals
Extrusive phase: fine crystals

Example: Andesite
The Major 7 Types of Igneous Rocks

- **Felsic**
  - Volcanic or Extrusive (aphanitic)
    - Rhyolite
  - Plutonic or Intrusive (phaneritic)
    - Granite

- **Intermediate**
  - Andesite

- **Mafic**
  - Basalt
  - Diorite
  - Gabbro
Igneous rocks are named based on their texture & composition.

Seven major types of igneous rocks:
- Extrusive (volcanic):
  - Rhyolite
  - Andesite
- Intrusive (plutonic):
  - Granite
  - Diorite
  - Basalt
  - Gabbro
  - Peridotite
Green Sand Beach, Big Island is made of Olivine.

True or false?
Olivine is also the most common mineral in the upper mantle.

A. True
B. False
Many Uses of Igneous Rocks

- Pumice stone
- Arrowheads
- Countertops
- Walls of lava rock
- Building materials
The Rock Cycle

- Weathering
- Uplift and exposure

- Transportation
- Deposition
- Sediments
- Lithification (compaction and cementation)

- Sedimentary rocks
- Metamorphism
- Metamorphic rocks

- Igneous rocks (intrusive)
- Igneous rocks (extrusive)

- Pyroclastic materials
- Lava

- Consolidation
- Melting
- Magma
Igneous rock is a ubiquitous component of Earth’s crust because it evolves as a product of tectonic processes.

**ubiquitous**

/yəˈbɪkwɪtəs/

adjective

present, appearing, or found everywhere.

“his ubiquitous influence was felt by all the family”

synonyms: omnipresent, ever-present, everywhere, all over the place, pervasive, universal, worldwide, global; More
What you should know from today:

1. Describe igneous rock
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