Rocks

(Part II of our study of the Lithosphere)

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Types of Rock

- Rocks are *heterogeneous mixtures* of different minerals
- Three types of rock:
  - ***Igneous*** – forms when magma cools and solidifies
  - ***Sedimentary*** – forms from the weathering products of other rocks and Earth materials
  - ***Metamorphic*** – forms when other types of rock undergo change through heat and pressure
- ***Rock Cycle*** – shows the interrelationships between different types of rocks and the geologic processes by which they change into one another

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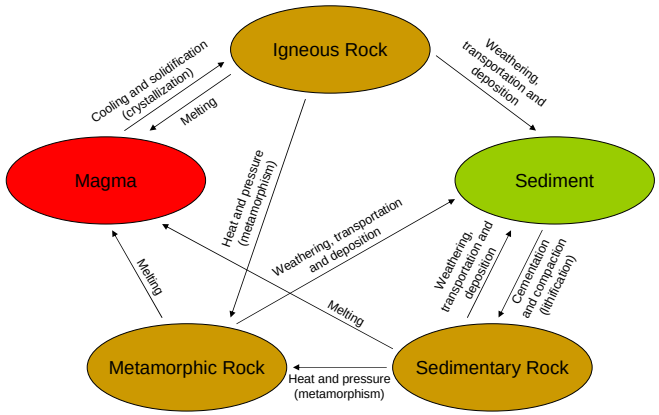
Rock Cycle



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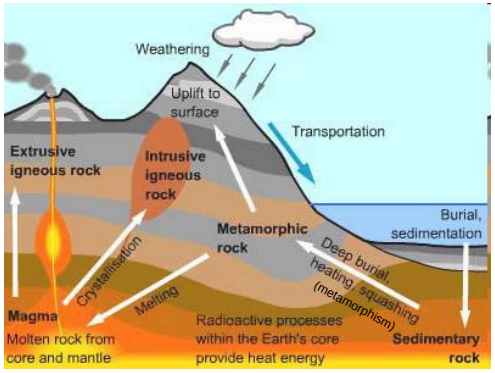
Rock Cycle



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Igneous Rock

- Forms when magma crystallizes (cools and solidifies)
- Type of igneous rock determined by
  - Type of magma that formed it:
    - ***Mafic***
    - ***Intermediate***
    - ***Felsic***
  - Rate at which that magma cooled
    - Slow – ***Intrusive*** (plutonic) – forms large crystals
    - Fast – ***Extrusive*** (volcanic) – forms small or no crystals

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Types of Magma

- Magma is described by ***temperature/viscosity*** and ***composition/mineral content***
- ***Viscosity***: resistance to flow
  - Viscosity of magma is strongly controlled by silica content.
  - Viscosity is influenced by temperature.
  - Trapped gases (or volatile components) also affect viscosity.
- ***Mafic*** (dark in color)
  - 45-52% silica (quartz) with considerable Fe, Mg, Ca; some Na, K
  - Higher melting temperatures and lower silica content than felsic – LOW VISCOSITY
- ***Intermediate*** (intermediate in color)
  - 53-65% silica
- ***Felsic*** (usually light in color)
  - >65% silica, high Na, K, Al; low Fe, Mg, Ca
  - Lower melting temperature, higher silica content, more dissolved gases than mafic – HIGH VISCOSITY

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Classification of Igneous Rock

- Classified two ways:
  - By COMPOSITION – determined by *location/temperature of cooling*
    - Mafic [**Ma**gnesium and **Fe** (iron), contains magnesium and iron]
    - Felsic [**Fel**dspar and **Si**lica (quartz)]
  - By TEXTURE – determined by the *rate of cooling*
    - Coarse-grained (large crystals – cooled SLOWLY)
    - Porphyritic (large crystals embedded in fine-grain)
    - Fine-grained (small crystals – cooled QUICKLY)
    - Glassy (no crystals – cooled INSTANTANEOUSLY)
- See http://www.uky.edu/AS/Geology/howell/goodies/elearning/module03swf.swf for igneous rock animation

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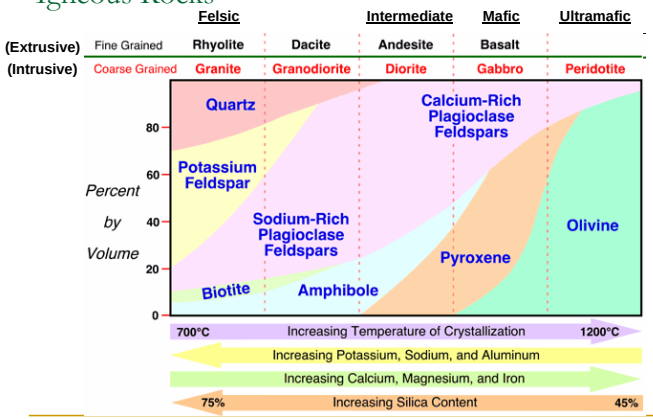
Bowen's Reaction Series – Mineral Composition of Igneous Rocks



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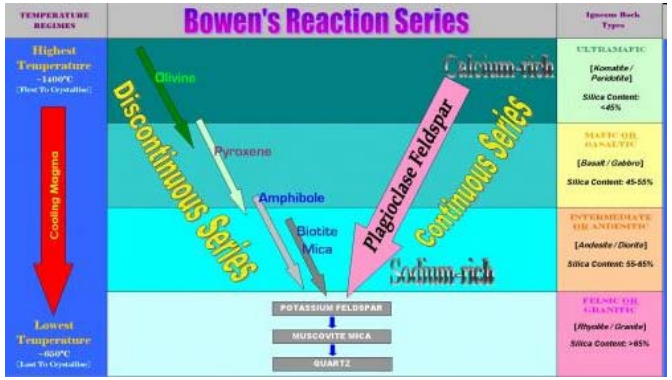
Bowen's Reaction Series



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Classification of Igneous Rocks (cont'd)

	Felsic (Granitic)	Intermediate (Andesitic)	Mafic (Basaltic)	Ultramafic
Coarse-grained (Intrusive)	Granite	Diorite	Gabbro	Peridotite
Fine-grained (Extrusive)	Rhyolite	Andesite	Basalt	Komatite
Mineral Composition	Quartz, Potassium Feldspar, Sodium Feldspar	Hornblende, Sodium Feldspar, Calcium Feldspar	Calcium Feldspar, Pyroxene	Olivine, Pyroxene
Minor Mineral Constituents	Muscovite, Biotite, Amphibole (Hornblende)	Pyroxene	Olivine, Hornblende	Calcium feldspar
Rock color Based on % dark (mafic) minerals	Light-colored, Less than 15% dark minerals	Medium-colored, 15-40% darm minerals	Dark-gray to black, More than 40% dark minerals	Dark-green to black, Nearly 100% dark minerals

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	Intrusive/ Plutonic	Extrusive/Volcanic		
	Coarse-grained	Fine-grained	Frothy/ Bubbly	Glassy
Mafic	 Gabbro	 Basalt	 Scoria	
Intermediate	 Diorite	 Andesite	 Tuff	
Felsic	 Granite	 Rhyolite	 Pumice	 Obsidian

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Formation and Location of Sedimentary Rocks

- Formed from ***sediment***: the weathering products of other rocks and Earth materials
- Weathering takes place by the following agents:
  - Gravity
  - Erosional agents (wind, running water, waves, glacial ice)
- Sedimentary rocks make up only 5% of rocks in the outer 10-mile layer of Earth.
- Sedimentary rocks form a ***thin*** layer that covers a large portion of the crust *because they form on the surface.*

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Classification of Sedimentary Rocks

- Sedimentary rocks are classified based on the source of the sediment from which they form:
  - ***Clastic*** (detrital): form from solid particles produced by physical weathering (pieces of broken-down rocks)
  - ***Non-clastic***:
    - Chemical: form from precipitation of dissolved minerals/rocks
    - Organic: form from materials generated by living organisms (i.e. corals, mollusks)

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Clastic Sedimentary Rocks

- Chief minerals: clay minerals and quartz
- Distinguished by particle size:

Sediment Name	Size Range (mm)	Clastic Rock Name
Gravel	>2	***Conglomerate*** or ***Breccia***
Sand	1/16 – 2	***Sandstone***
Silt	1/256 – 1/16	Siltstone
Clay	<1/256	***Shale***

(Note that rock names in bold italics depict samples we have studied in class.)

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Clastic Sedimentary Rocks

Conglomerate

Breccia

Sandstone

Shale

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Clastic Sedimentary Rocks

- Particle size is related to formation of rocks.
- Currents of water or air separate particles by size:
  - Strong currents carry larger particles as well as small ones.
  - Weak currents only carry small particles.
  - Which rock type was formed by stronger currents – conglomerate or sandstone?
- Sandstones are associated with sand dunes, river deposits and beaches.
- Silts and clays settle very slowly and are associated with quiet lakes, lagoons, swamps, etc…
  - Imagine you are an historical geologist. If you found and outcropping of shale, what type of land feature would you guess used to occupy that location?

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Non-clastic Sedimentary Rocks

- Chemical sediments come from materials that are carried in solution (not as solid particles) to lakes and seas.
- Non-clastic sedimentary rocks form when one of two things happen:
  - A solution becomes concentrated to the point that minerals start precipitating out of the water. (CHEMICAL sedimentary rocks)
    - Temperature and concentration changes (***Limestones***)
    - Evaporation of water (Forms *evaporites* – Examples include halite and gypsum)
  - Water-dwelling life forms extract the dissolved minerals from the surrounding water and use them to form shells and other parts. (ORGANIC or Biochemical sedimentary rocks)
    - ***Coquina***
    - Chalk
    - Many limestones
    - Coal

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Non-clastic Sedimentary Rocks

Coquina

Limestone

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Lithification

- ***Lithification***: processes by which sediments are transformed into solid rock
  - ***Compaction***: new sediment deposits bury older sediments, and over time the weight compresses the old sediment deposits and reduces pore space. (Most significant lithification process for fine-grained sedimentary rocks.)
  - ***Cementation***: water percolates through pores inbetween sediments, carrying dissolved cementing materials with it. As water evaporates, the cementing materials precipitate out of solution and act like glue.

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Metamorphism

- ***Metamorphism***: transformation of pre-existing rock
- Changes that can occur:
  - Textural
  - Mineralogical (compositional)
- Change comes from ***agents of metamorphism***:
  - Heat
  - Pressure
  - Chemically active fluids
  - Any combination of the above factors

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Where and when does metamorphism happen?

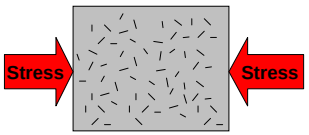
- ***Regional metamorphism*** occurs during mountain building (either at plate boundaries or mid-continent).
  - Main agent of metamorphism: PRESSURE
  - Most metamorphic rock forms this way.
- ***Contact metamorphism*** occurs when rock comes in contact with or near a magma chamber.
  - Main agent of metamorphism: TEMPERATURE
  - Surrounding rock is effectively "baked."

Grades of Metamorphism

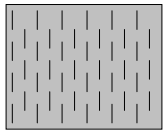
- ***Low-grade metamorphism***: rocks are subjected to temperatures and pressures only slightly above those of lithification of sediments.
  - Example: shale to slate
- ***High-grade metamorphism***: rocks are subjected to extreme conditions close to those at which rocks melt.
  - Example: limestone to marble
- Degree of metamorphism is reflected in texture and mineral content.

Texture of High-Grade Metamorphic Rocks

- During high-grade metamorphism, some minerals in rocks recrystallize and form large grain crystals.
- ***Nonfoliated texture***: crystals do not display a preferred direction – appear more like a coarse-grained igneous rock.
  - Example: marble
- ***Foliated texture***: crystals that form are directional and create a banded appearance.
  - Example: gneiss (pronounced "nice")



Before metamorphism



Foliated texture after metamorphism

Metamorphic Rocks

Slate
(was shale)

Marble
(was limestone)

Quartzite
(was sandstone)

Biotite Gneiss
(was granite – high)

Mica Schist
(was granite – medium)

Phyllite
(was granite – low)

Anthracite
(was peat)

Resources from Rocks and Minerals

- Many important accumulations of metals in the Earth are generated by igneous and metamorphic processes.
- Metal resources = ***ores***. (See Table 1.5, p. 54) Ores are generated in 3 ways/locations:
  - From hydrothermal solutions (associated with cooling magma)
  - Vein deposits (look like veins running through the rock; see Fig. 1.29, p. 55)
  - Disseminated deposit (distributed through rock mass)
- Nonmetallic resources
  - Building materials
  - Industrial minerals

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