

Igneous Rock and Processes



The Nature of Igneous Rocks

- Form from Magmas and Lavas
 - Hot, partially molten mixture of solid, liquid and gas
 - Minerals form in the magma making a "slush"
 - Gases - H_2O , CO_2 , etc. - are dissolved in the magma
 - Magma is less dense than solid rock

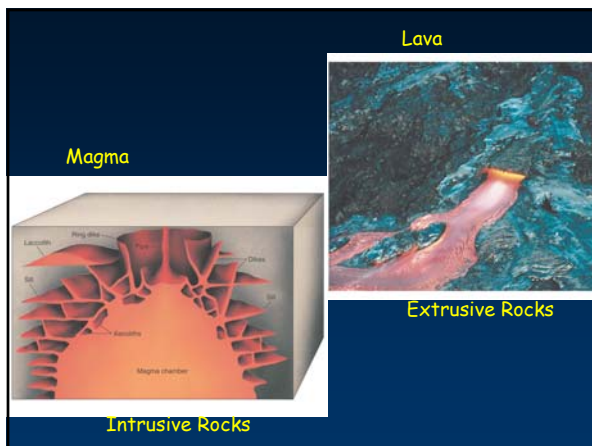
The Nature of Igneous Rocks Magma vs. Lava

Magma

1. molten rock beneath the surface
2. Forms intrusive igneous rocks

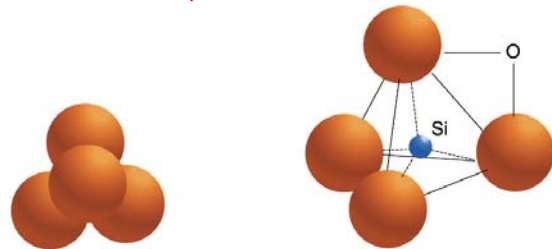
Lava


1. molten rock that reaches the surface
2. Forms extrusive igneous rocks



The Nature of Igneous Rocks

- Composition varies widely
 - Generally a silica (SiO_2) melt



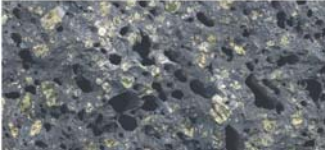


Mafic Magmas

- ~ 50% Silica
- High concentrations of Fe, Mg and Ca
- High temperature of molten magma
 - 1000° to 1200°C

• Major minerals

- Olivine
- Ca Plagioclase
- Pyroxene



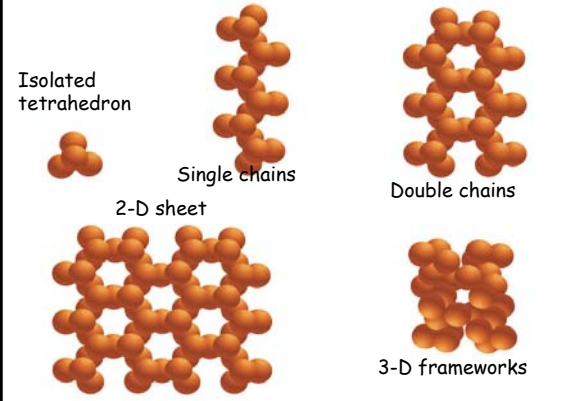

Silicic Magma

- 65-77% Silica
- High Al, Na and K
- Lower temperature magmas
 - Less than 850°C
- Major minerals
 - Feldspars
 - Micas
 - Quartz



Magma Viscosity

- Controlled by silica, water content, and temperature
- As magma cools, silica tetrahedron form links
- Linkages increase viscosity




Isolated tetrahedron

Single chains

Double chains

2-D sheet

3-D frameworks



Magma Viscosity

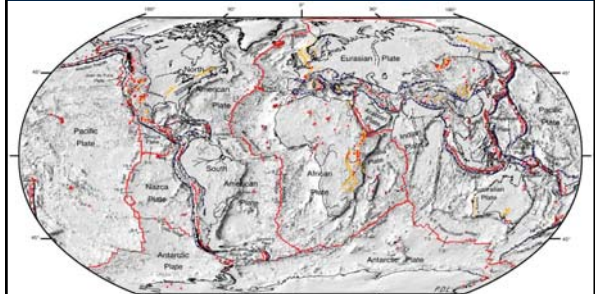
- Water and volatiles influence viscosity
- H₂O and CO₂ make up 90+% of dissolved gases in magmas
- Typical range of dissolved gases is 0.1 to 5%
 - Up to 15% is possible
 - High volatile content may cause explosive eruptions

QuickTime™ and a Cinepak decompressor are needed to see this picture.

Occurrence of Igneous Rocks

- Global
- Discrete geologic settings

- Convergent plate margins
- Divergent plate margins
- Mantle plumes



- Convergent plate margins
- Intrusions and overlying volcanoes



USGS Photo by Austin Post, May 18, 1980

- Divergent plate margins
- Mid-ocean ridges and continental rifts



Mantle plumes



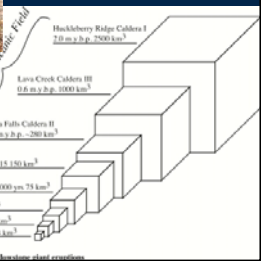
EXPLANATION

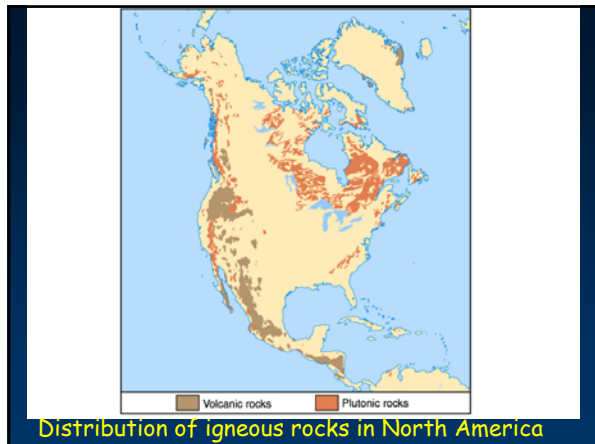
- Divergent plate boundaries—Where new crust is generated as the plates pull away from each other.
- Convergent plate boundaries—Where crust is consumed in the Earth's interior as one plate dives under another.
- Transform plate boundaries—Where crust is neither produced nor destroyed as plates slide horizontally past each other.
- Plate boundary zones—Broad belts in which deformation is diffuse and boundaries are not well defined.

Selected prominent hotspots

A map of the Pacific Ocean region showing hotspots as red dots. Labeled hotspots include Hawaii, Galapagos, Azores, Iceland, and Yellowstone.

Mantle plumes





Igneous Textures

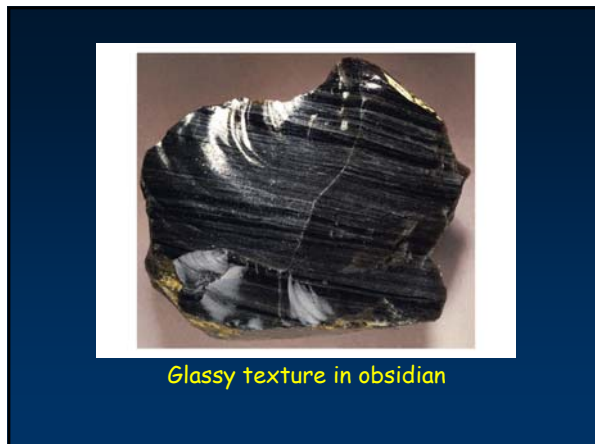
- Texture - size, shape and relationship of Xtals and minerals in the rock
- Related to cooling history of the magma or lava
- Crystal size increases as rate of cooling slows

Crystalline Textures

- Crystal growth requires time for ions to form minerals
- Slow cooling provides time for crystal growth
- Crystals grow until melt is quenched or is completely solidified

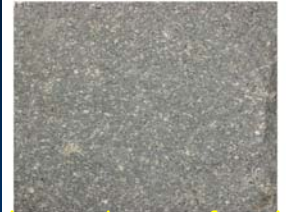
Glassy Texture

- Very rapid cooling - quenched
 - Volcanic glass, e.g. Obsidian
 - Conchoidal fracture
- No apparent crystals
- Dark color, generally silicic composition



Aphanitic Texture

- Fine grained texture
- Few crystals visible in hand specimen



- Relatively rapid rate of cooling
- Vesicles may be formed by gases trapped in cooling magma

Phaneritic Texture

- Coarse grained texture
- Slow rate of cooling

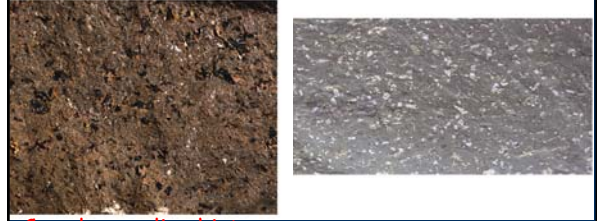


- Equigranular, interlocking crystals
- Slow cooling = crystallization at depth

Granite

Porphyritic Texture

- Well formed crystals (phenocrysts) in fine grained matrix (groundmass)



- Complex cooling history
 - Initial stage of slow cooling
 - Large, well formed crystals
 - Later stage of rapid cooling - groundmass

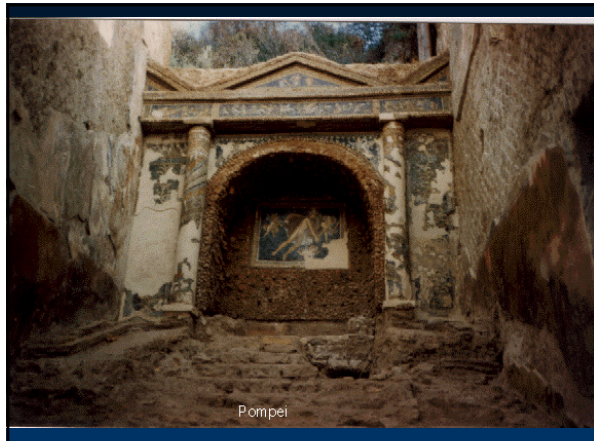
Pyroclastic Texture

- Produced by explosive volcanic eruptions



- Appears porphyritic but Crystals show distortion
- Matrix may be dominated by glassy fragments
 - Hot fragments may "weld" together

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Pompeii

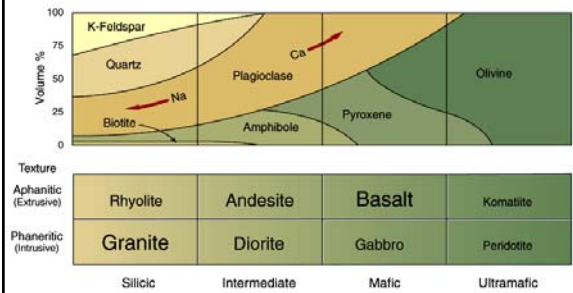
So How and Why do we Categorize Igneous Rock Types?

Classification of Igneous Rocks

- Texture
 - Aphanitic
 - Phaneritic
- Composition
 - Silicic
 - Intermediate
 - Mafic
 - Ultramafic

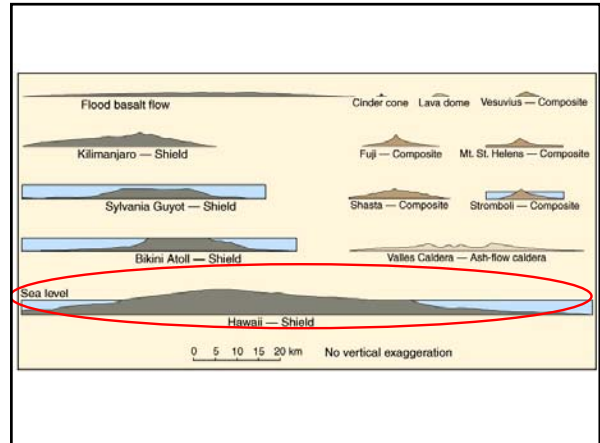
****Combination of Texture and Composition produces rock name****

Classification of common igneous rocks



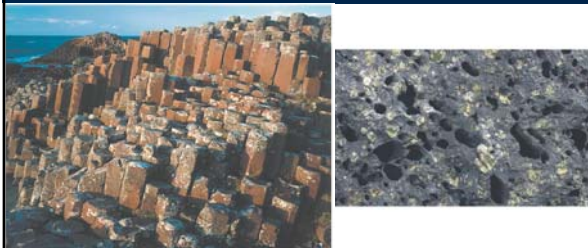
Extrusive Rock Bodies

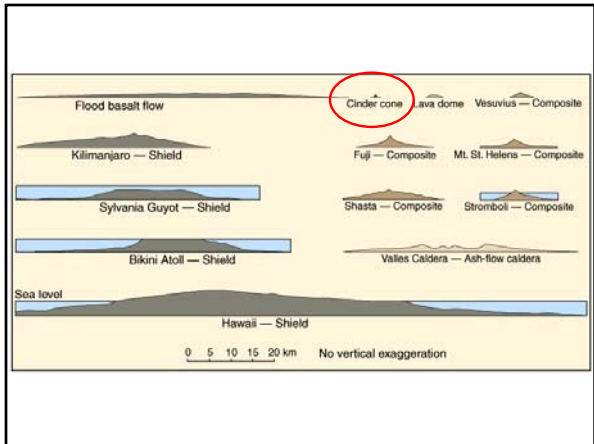
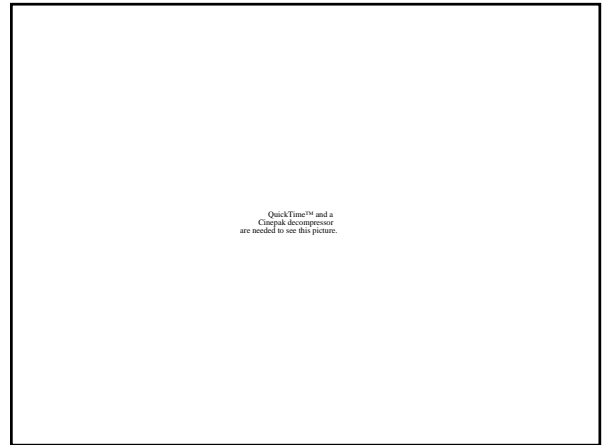
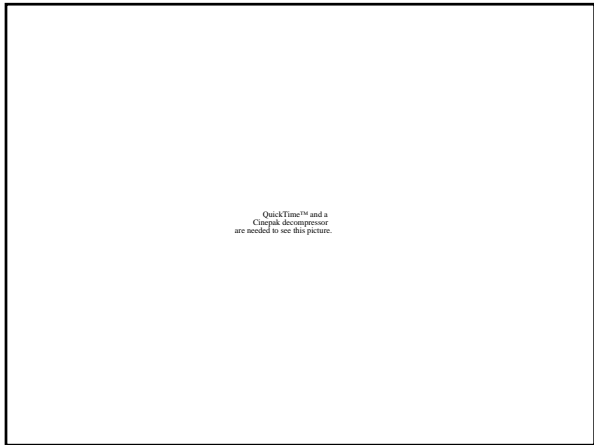
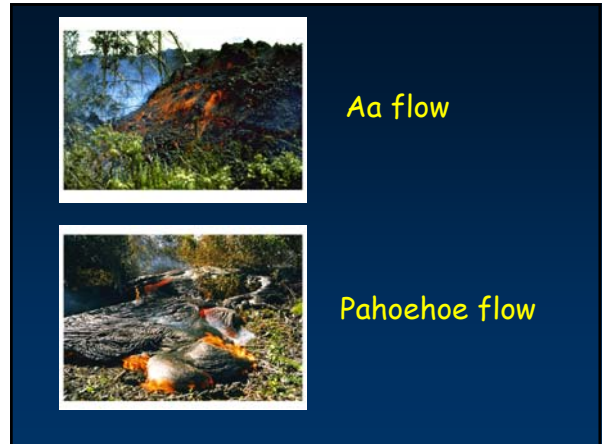
- The form of extrusive deposits influenced by magma properties
 - Composition
 - Silica content
 - Viscosity
 - Volatile content
 - Temperature

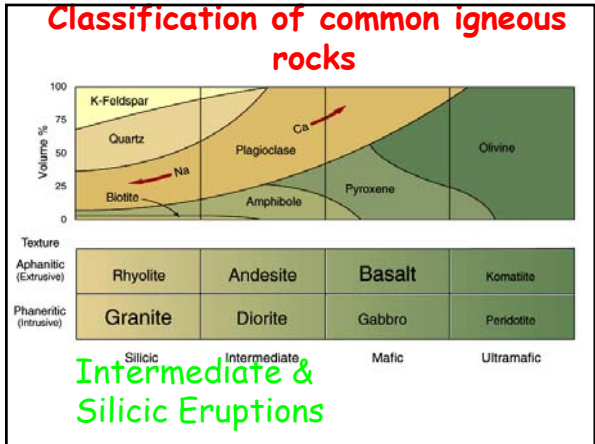
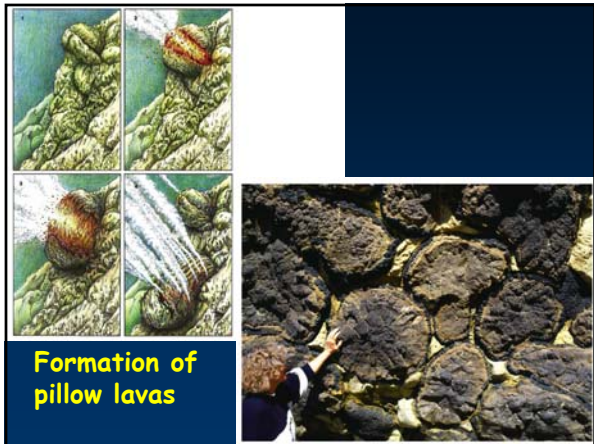
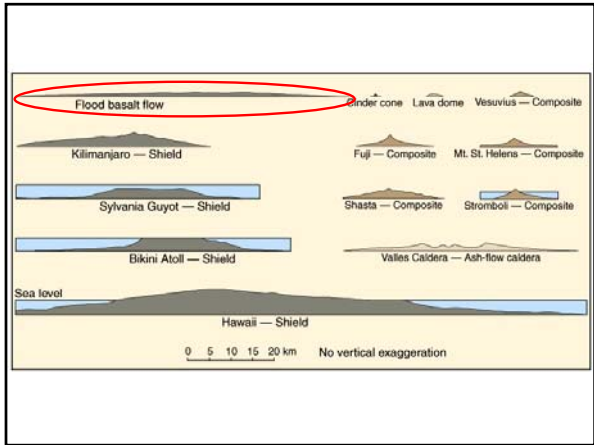
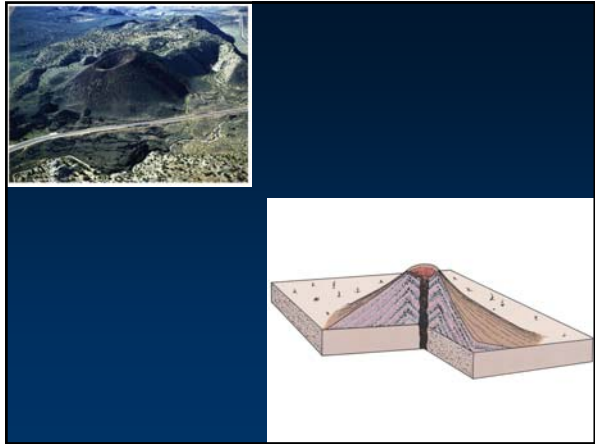


Basaltic Eruptions

- Low Silica + High T = Low Viscosity
- What kind of deposits are produced by basaltic eruptions?

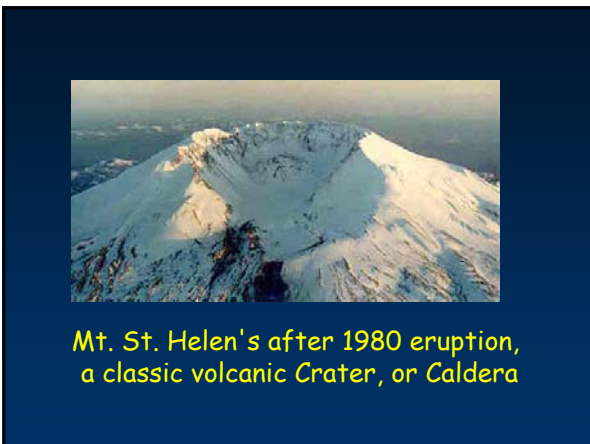
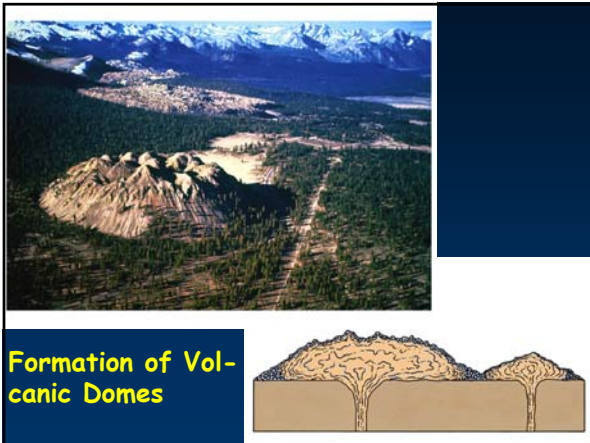
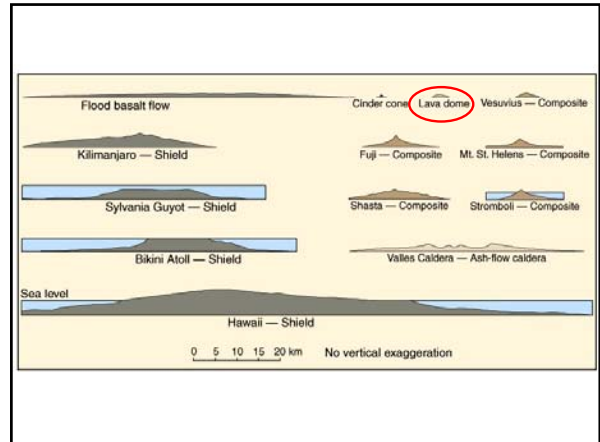


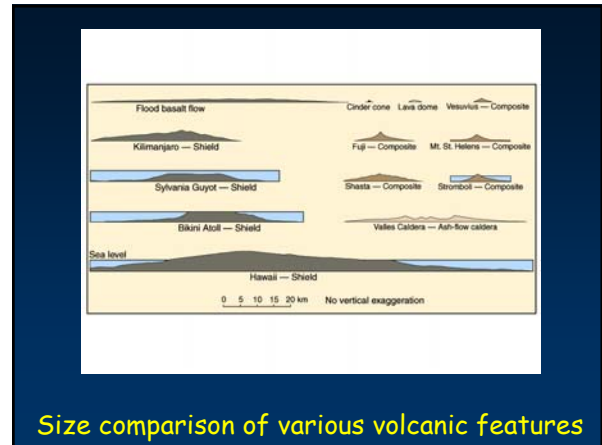
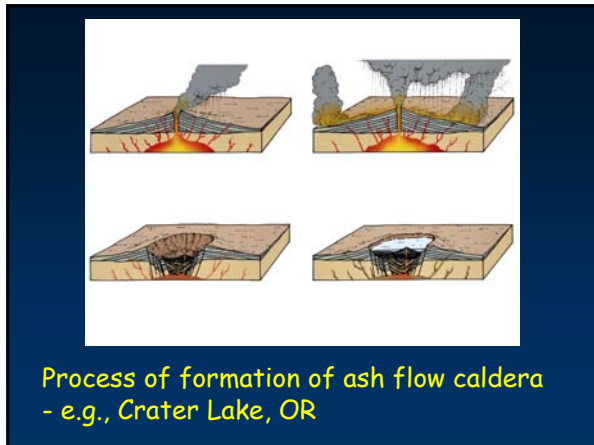
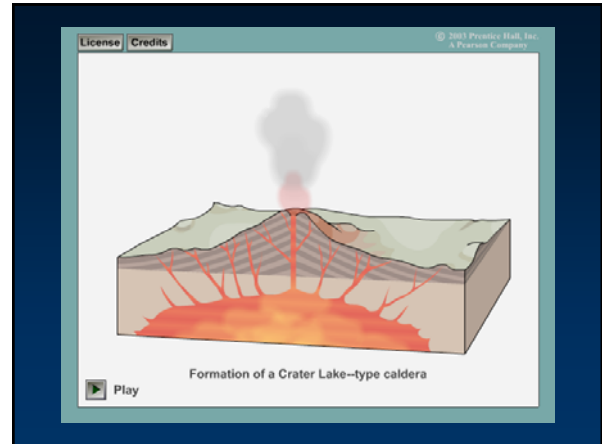




Intermediate & Silicic Eruptions

- Higher Silica + Lower T = Higher Viscosity
- Produce
 - Composite or Stratovolcanos
 - Lava Domes
 - Ash Flow Calderas



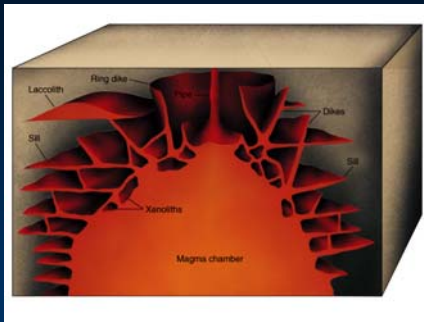


Intrusive Rock Bodies

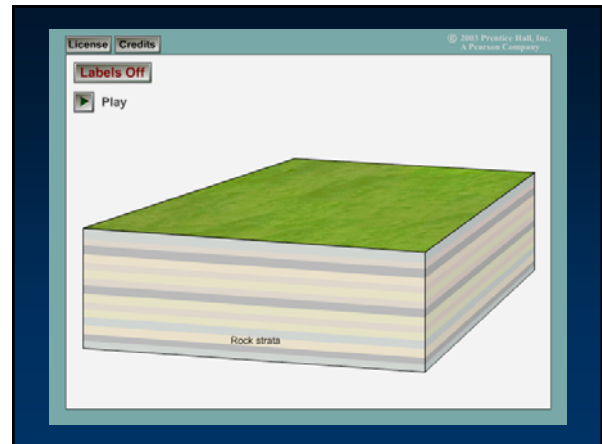
- Less dense magmas rise through the crust
- Rising magmas slowly cool
 - Viscosity increases
 - Density increases
- Intrusions form as magma solidifies beneath the surface

Intrusive Rock Bodies

- Intrusions are classified by their size, shape and relative age
- Large intrusions
 - Batholiths
 - Stocks
- Small intrusions
 - Dikes
 - Sills
 - Laccoliths



Types of magmatic intrusions



Origin of Magmas

- Solid rock is at equilibrium with its surrounding
- Changes in the surroundings may cause solid rock → magma
 - Raising T
 - Lowering P
 - Changing composition

Origin of Magmas

- Lowering P
 - Mantle convection moves deep mantle rocks upwards
- Raising T
 - Hot mafic magma intrudes into the crust
- Changing composition
 - Adding small amounts of water

Magma Differentiation

- Magmas, and the resulting igneous rocks, show a wide range of compositions
- Source Rock
 - variations cause major and minor variations in the magma
- Magma Mixing
- Assimilation

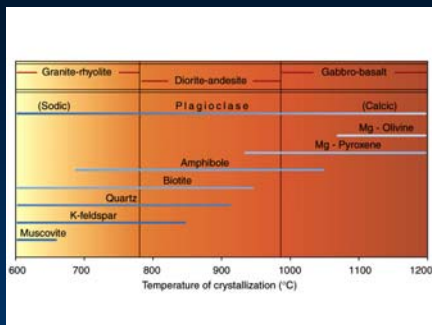
Processes of magma differentiation

Magma Differentiation

- Partial Melting
 - Individual minerals within source rock melt at different T
 - Resulting magma is enriched in many elements, especially SiO_2
 - Resulting magma is less dense than source rock

Magma Differentiation

- Fractional Crystallization
 - Individual minerals precipitate from magma at different T
 - Bowen's Reaction Series
 - Remaining magma is enriched in many elements, especially SiO_2
 - Remaining magma may migrate



Bowen's reaction series

Plate Tectonic Setting of Igneous Rocks

- Divergent Plate Boundaries
 - Partial melting of mantle produces basaltic magma
- Convergent Plate Boundaries
 - Subduction and partial melting of wet basalt, sediments and the surrounding mantle
 - Andesitic and rhyolitic magma generated through fractional crystallization
 - Ascending magma may assimilate lower crustal material

Plate Tectonic Setting of Igneous Rocks

- Mantle Plumes
 - Partial melting of rising plumes of solid mantle material
 - Distinctive basaltic magma is produced
 - Rising magma may produce
 - Intraplate island chains
 - Flood basalt
 - Basalt plateaus and rhyolitic calderas

End of Chapter 4