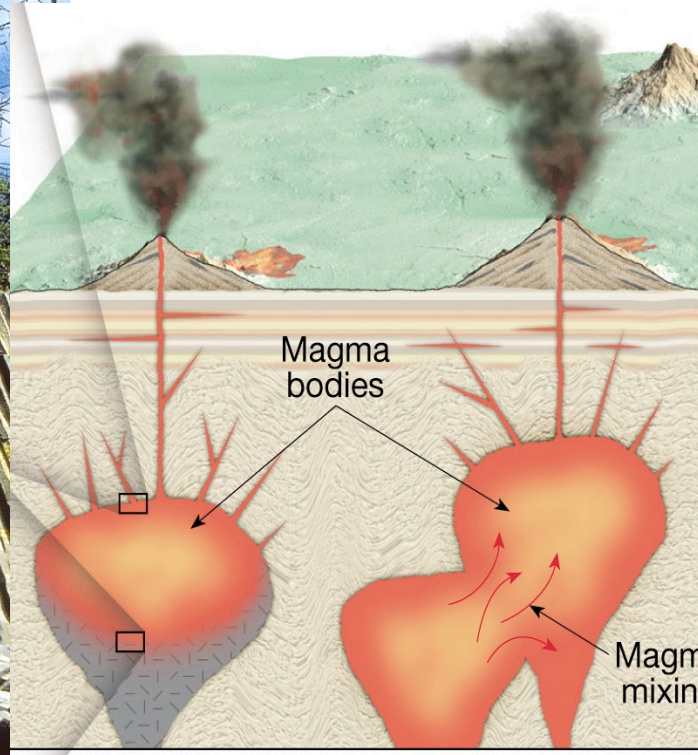
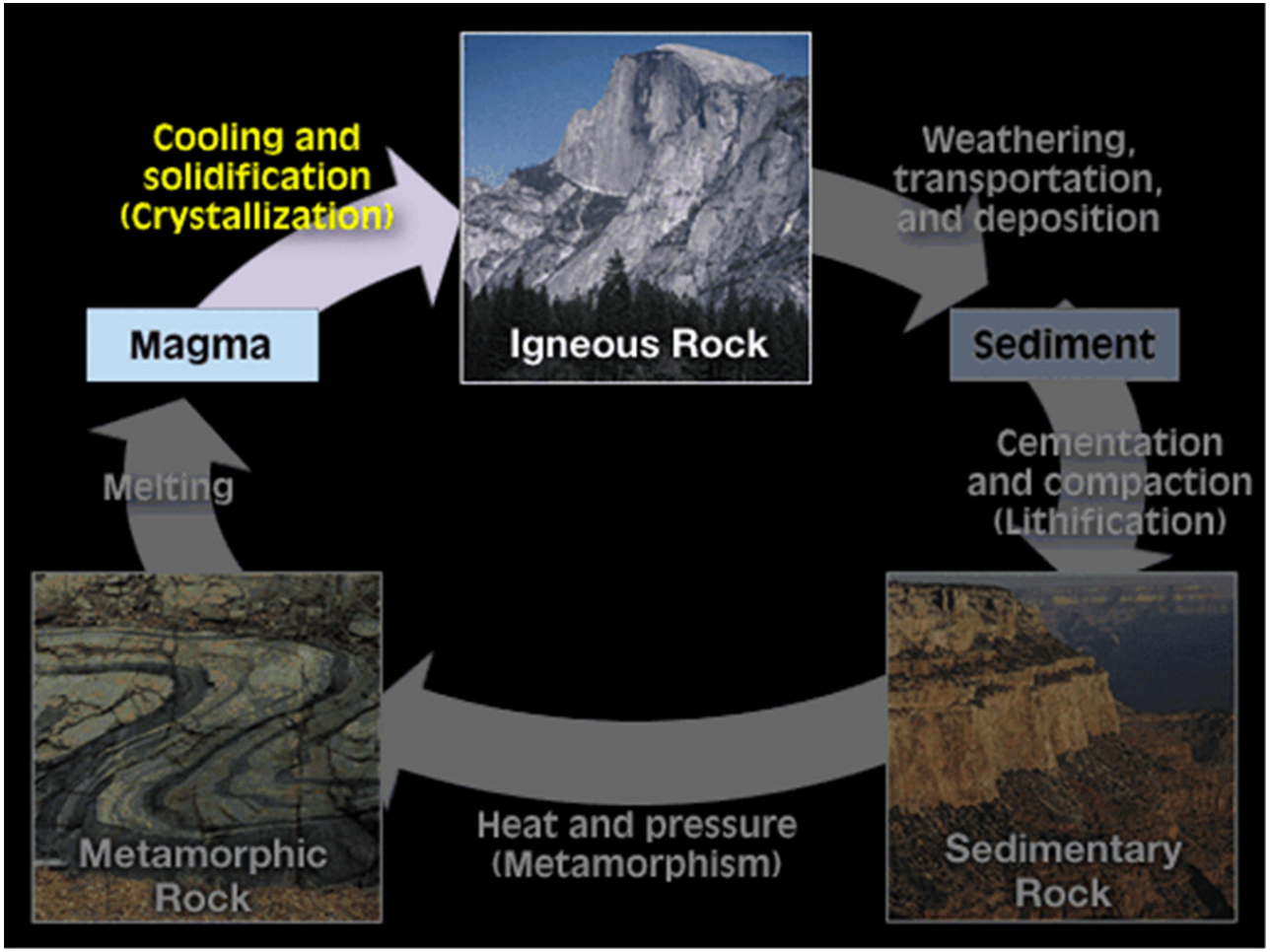
Chapter 4
Magmas, Igneous Rocks, and Intrusive Activity



Three Types of Rocks

Igneous
Sedimentary
Metamorphic



Magma and Igneous Rock

- **Magma** forms from the partial melting of rock in the subsurface.
  - Composed of mainly silicon and oxygen, so when it cools it crystalizes to an igneous rock composed of silicate minerals
  - Magma at the surface is called **lava**.
- **Igneous rock** forms as magma co
  minerals crystallize from the magn
  - Composed of silicate minerals

Magma Consists of Three Components

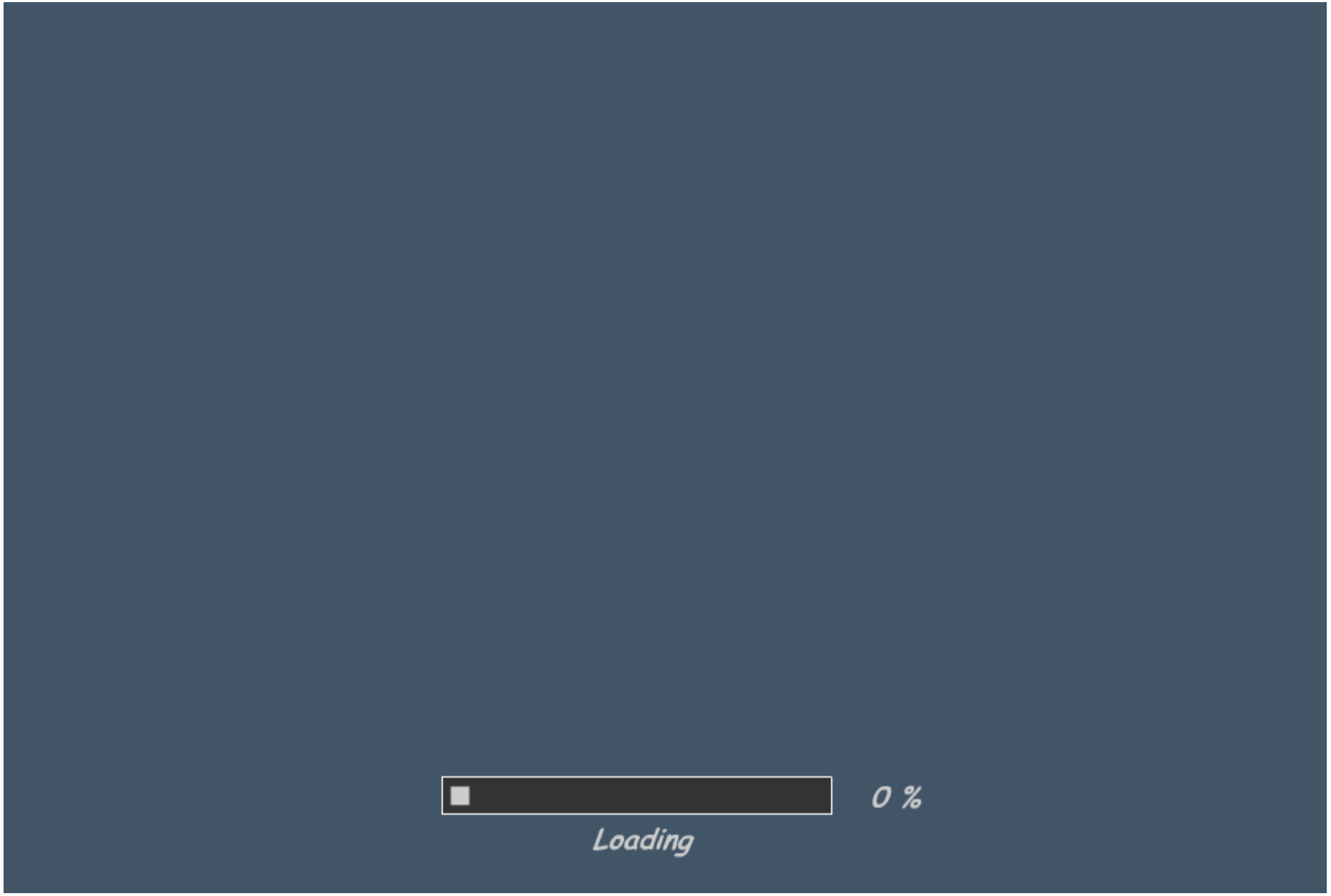
- **Liquid portion = the melt**
  - The liquid is a **silicate melt** (not water based)
  - Composed of mostly Si and O.
- **Solids**, if any, are crystals of silicate minerals
- **Volatiles -** dissolved gases in the melt that volatilize from the magma at low near-surface pressures

  Most common volatiles in magma
  - **water vapor (H_2O)**
  - **carbon dioxide (CO_2)**
  - **sulfur dioxide (SO_2)**

Lava

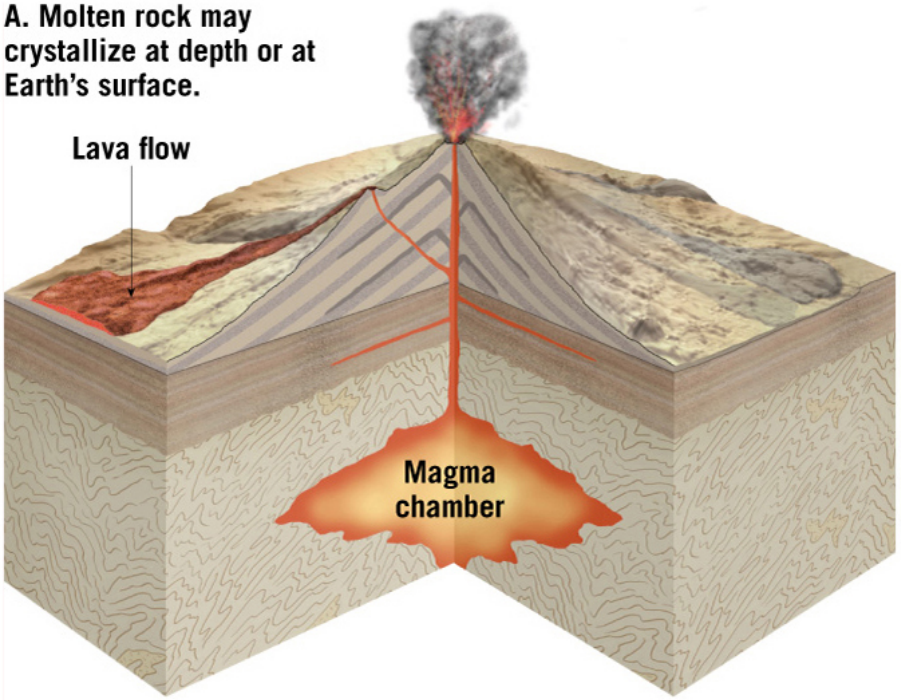
- Lava is magma that comes to the surface.
- Magma most often comes to the surface at
  - subduction zones
  - spreading margins
  - hot spots.

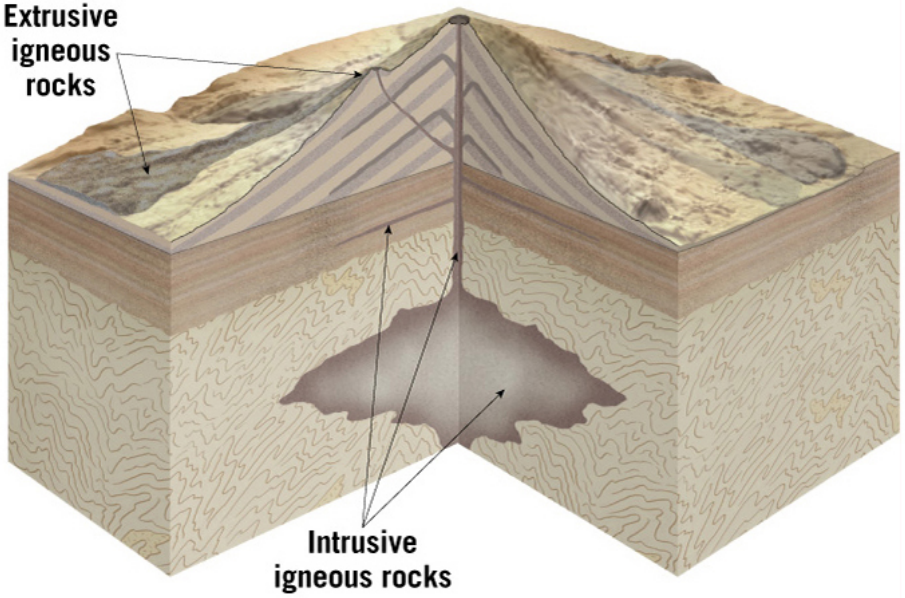
Formation of igneous rock from magma crystallization



The type of Igneous Rock depends on where it crystalizes (solidifies, turns to a solid)

- **Volcanic rocks** or **extrusive igneous rocks-** are rocks that formed from magma that crystalizes at the surface
- **Plutonic rocks** or **intrusive igneous rocks -** are rocks that formed from magma that crystalizes at depth

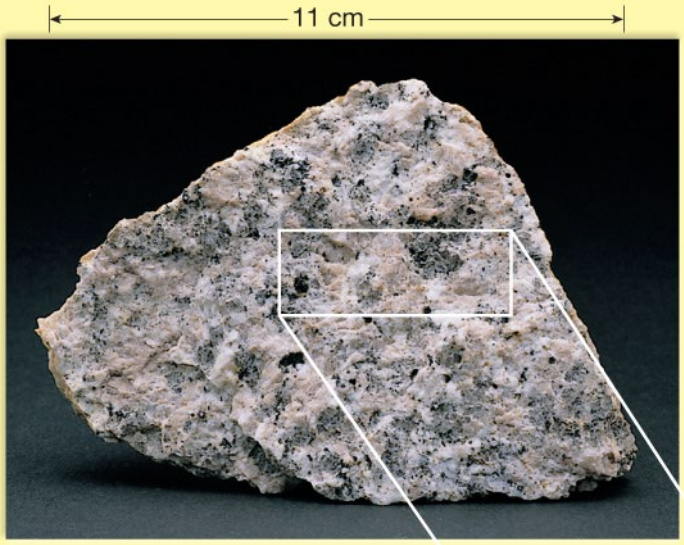




B. When magma crystallizes at depth, intrusive igneous rocks form. When magma solidifies on Earth's surface, extrusive igneous rocks form.

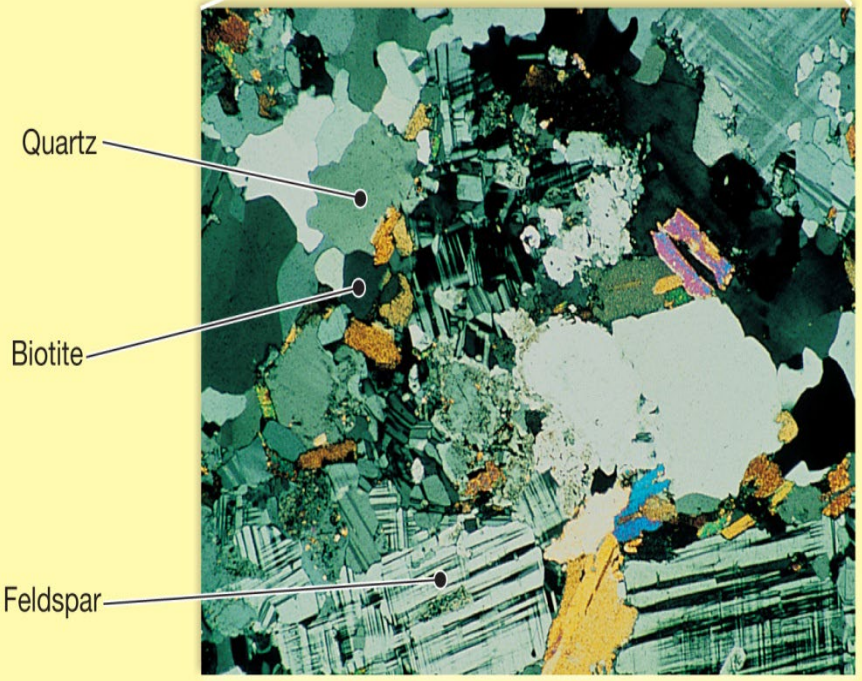
Crystallization occurs as magma cools and forms interlocking crystals.

We refer to these as crystals even though, in general, you cannot see individual crystal faces. When crystals grow in a confined space they grow into one another (interlock), so the crystal faces do not form.



A. Hand sample of granite

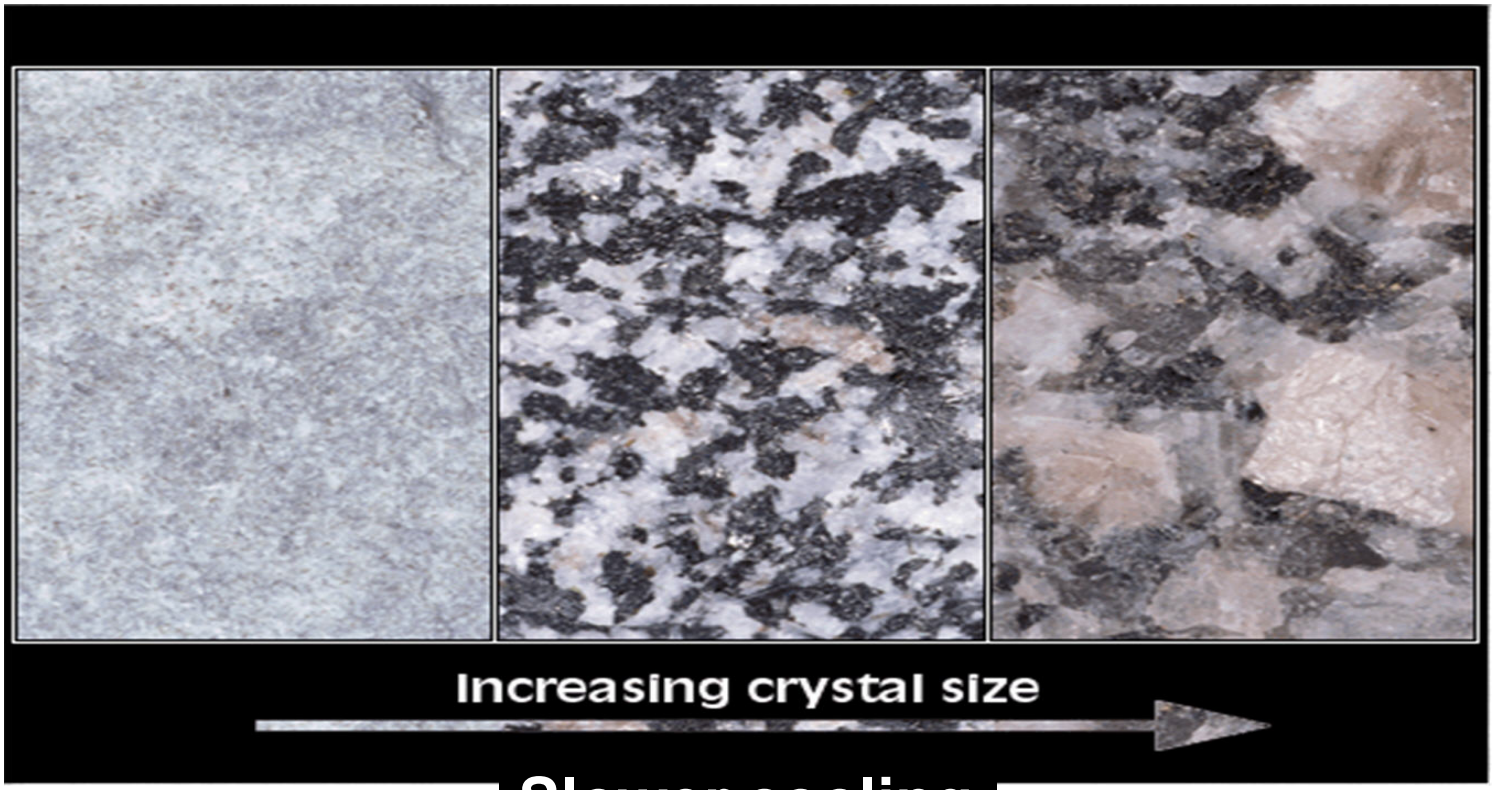
B. Thin section



C. Photomicrograph taken with polarized light magnified about 27 times.

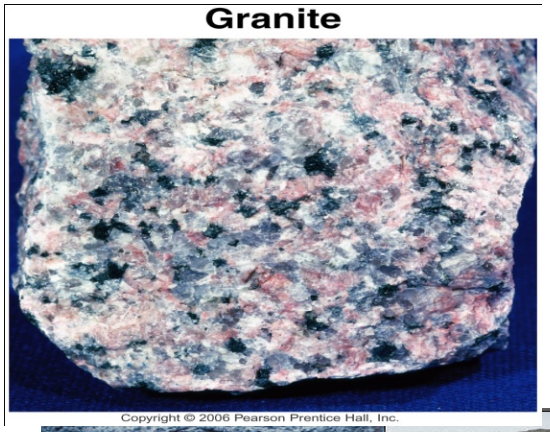
The size of the interlocking crystals gives information on the rate of crystal growth

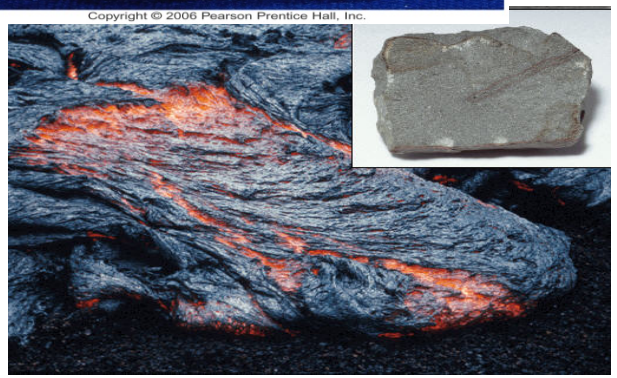
The slower the magma cools, the slower the crystals form, and thus the larger they can grow.

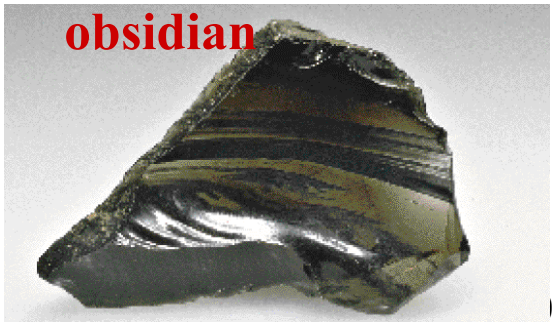


The size of the interlocking crystals gives information on depth of origin

- Large crystals form in intrusive igneous rocks, because they crystalize at depth and thus cool very slowly
- Small crystals (you can barely see without magnification), form in extrusive igneous rocks because the magma can cool rapidly.
- Glass (no crystals) forms in extrusive igneous rock subjected to extremely fast cooling
  - This occurs when lava is ejected into the air or flows into water
  - Obsidian, pumice, volcanic ash, scoria





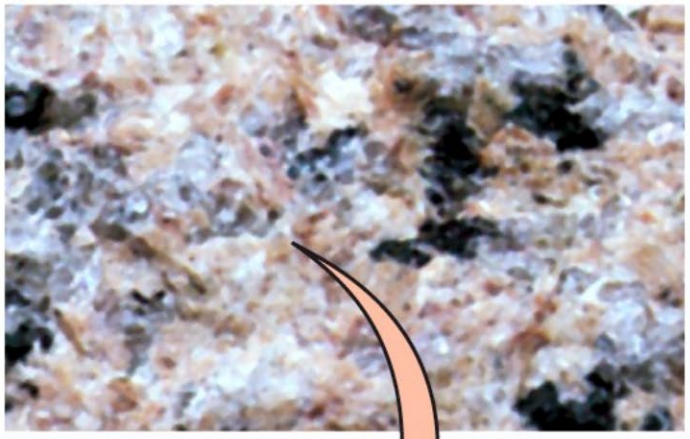


Intrusive
large crystals

Extrusive
small crystals

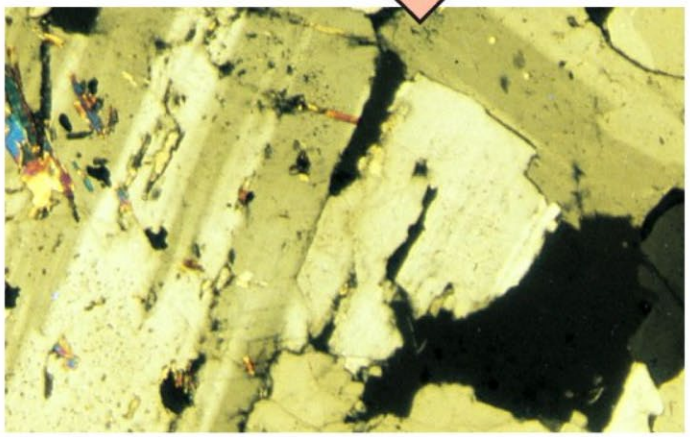
Granite

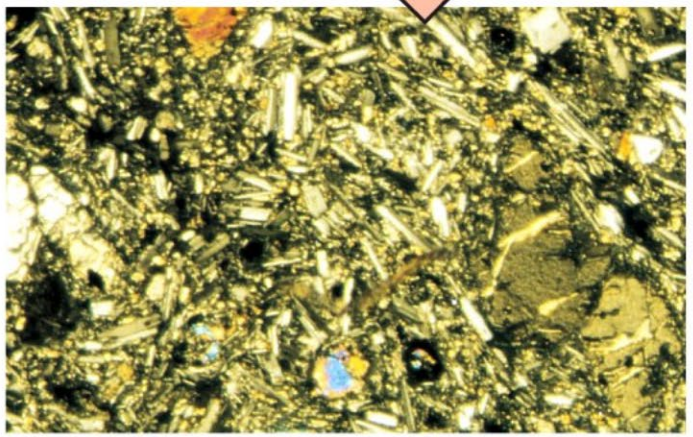
Basalt



Seen with a magnifying glass

1 cm





Seen through a polarizing microscope

1 mm

Types of glassy volcanic rocks

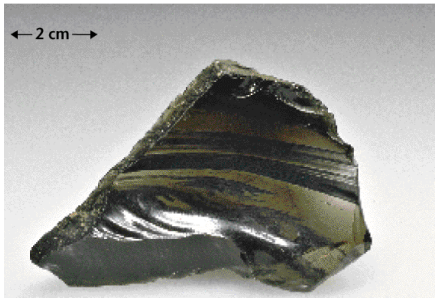
Obsidian - volcanic glass
formed as lava flows into water and cools quickly

Pumice - intertwined glass ejected from the volcano

Scoria – extremely vesicular volcanic ejecta

Volcanic Ash – very small loose pieces of volcanic glass ejected from volcano

Tuff – a rock formed from compacted volcanic ash

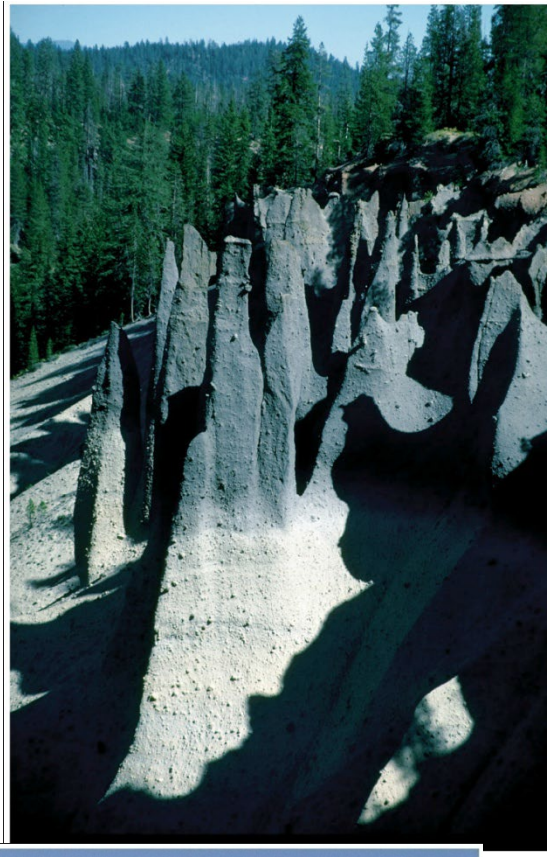



C. Glassy (pumice)

Volcanic ash

Pyroclastic

- Pyroclastic is any rock fragment ejected from the volcano
- pumice, scoria, ash, cinder, volcanic bombs
- can be fine ash mixed with large angular blocks embedded in the ash



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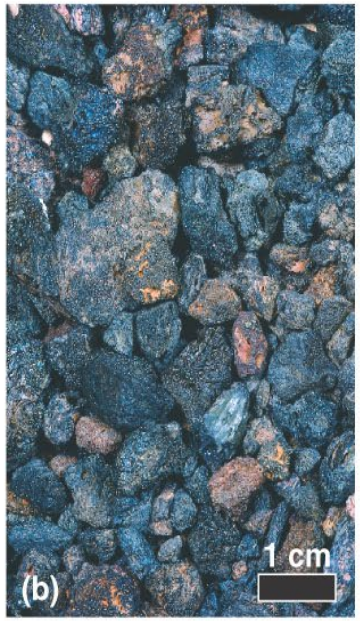
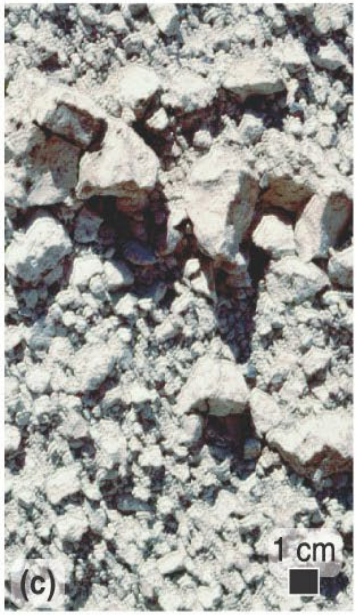
Pyroclastics



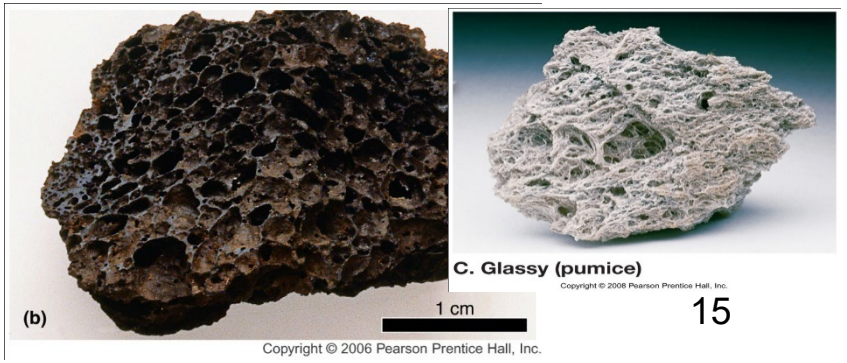


Bombs **Cinder** **Pumice** **Ash**

- Volcanic bomb – a steamlined pyroclastic fragment ejected from the volcano while still semi-molten
- Cinder – ejected lava that forms pea- to walnut-sized fragments

Vesicular Texture

- Vesicular texture describes a rock with numerous vesicles
  - vesicles are small holes resulting from the magma hardening around bubbles of escaping gas
  - Vesicles only form in extrusive volcanic rocks because the rapid pressure decrease upon extrusion allows the volatiles to escape
- Vesicles result in an extremely lightweight (low density) rocks that in some cases can float in water.
- Examples of extrusive volcanic rocks with vesicular texture
  - vesicular basalt, pumice, scoria



Igneous rock compositions

- Igneous rocks are composed of silicate minerals
- For describing igneous rocks we separate the silicate minerals into two groups.
  - **Dark or ferromagnesian silicate minerals**
    - Have the dominant cations: **Fe-Mg rich**
    - Examples: olivine, pyroxene, hornblende, biotite mica
    - These are referred to as **mafic minerals**
  - **Light or *non*ferromagnesian silicate minerals**
    - Have the dominant cations: **Na-Ca-K rich** (compared to Fe-mg)
    - Examples: quartz, muscovite mica, and feldspars
    - These are referred to as **felsic minerals**
    - (note: light in this case means light in color, not in weight)

Mafic/felsic minerals and rocks

- **Mafic mineral** is a dark colored silicate mineral where Fe and Mg dominate
  - **Mafic rock (or basaltic rock)** is composed of predominantly mafic minerals (although there will be some felsic minerals in it)

- **Felsic mineral** is a light colored silicate mineral where Na, K and Ca dominate
  - **Felsic rock (or granitic rock)** is composed of predominantly felsic minerals (although there will be some mafic minerals in it.

Igneous Rock types

(classified on whether intrusive or extrusive and on composition)

Composition	Intrusive (Plutonic)	Extrusive (Volcanic)
Granitic (felsic; rhyolitic)	Granite	Rhyolite
Andesitic (intermediate)	Diorite	Andesite
Basaltic (mafic)	Gabbro	Basalt
Ultramafic	Peridotite	

Granite

- **Granitic/felsic composition**
- **Minerals**
  - **Quartz, feldspar, hornblende (or biotite)**
- **Predominantly light-colored nonferromagnesian silicate minerals**
  - **felsic stands for *fe*ldspar and *si*lica rich**
  - **High silica (SiO_2) content**
- **Major constituent of the continental crust**

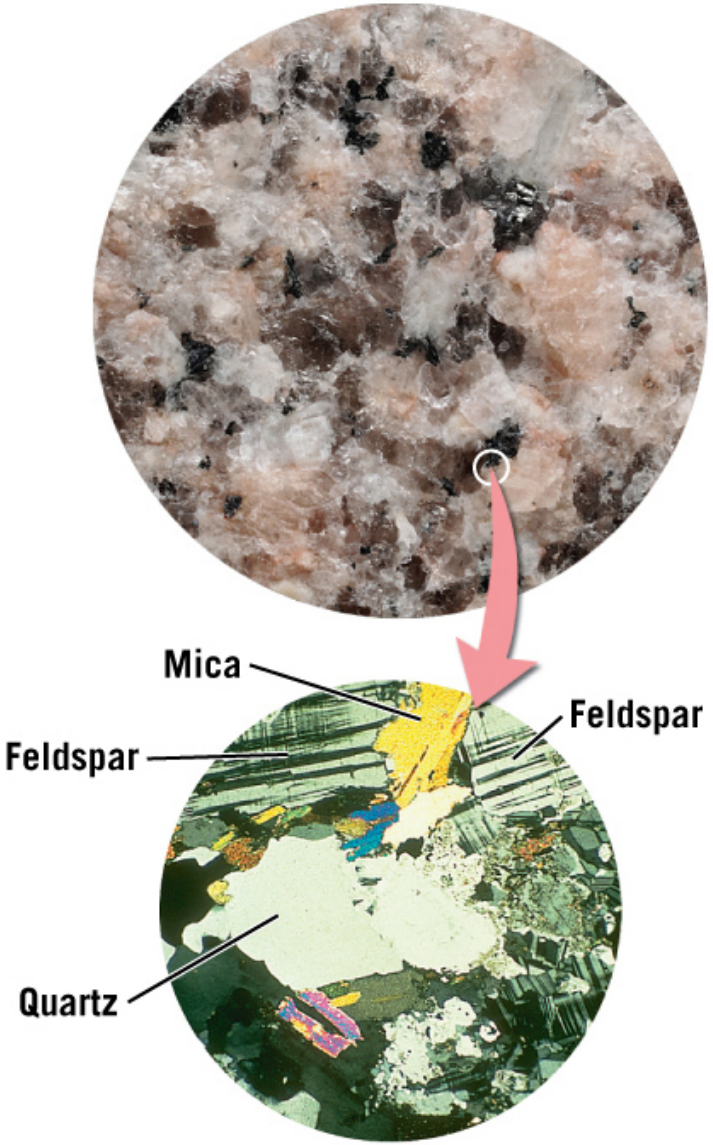
Granite

Basalt

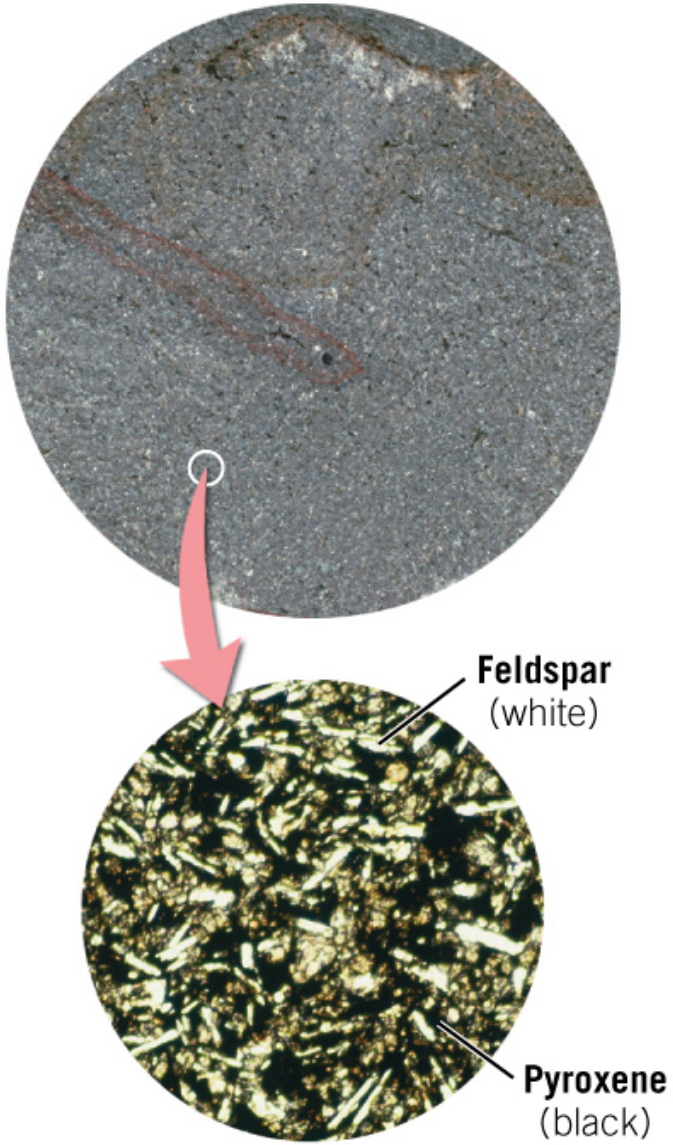

Basalt

Basaltic/mafic composition

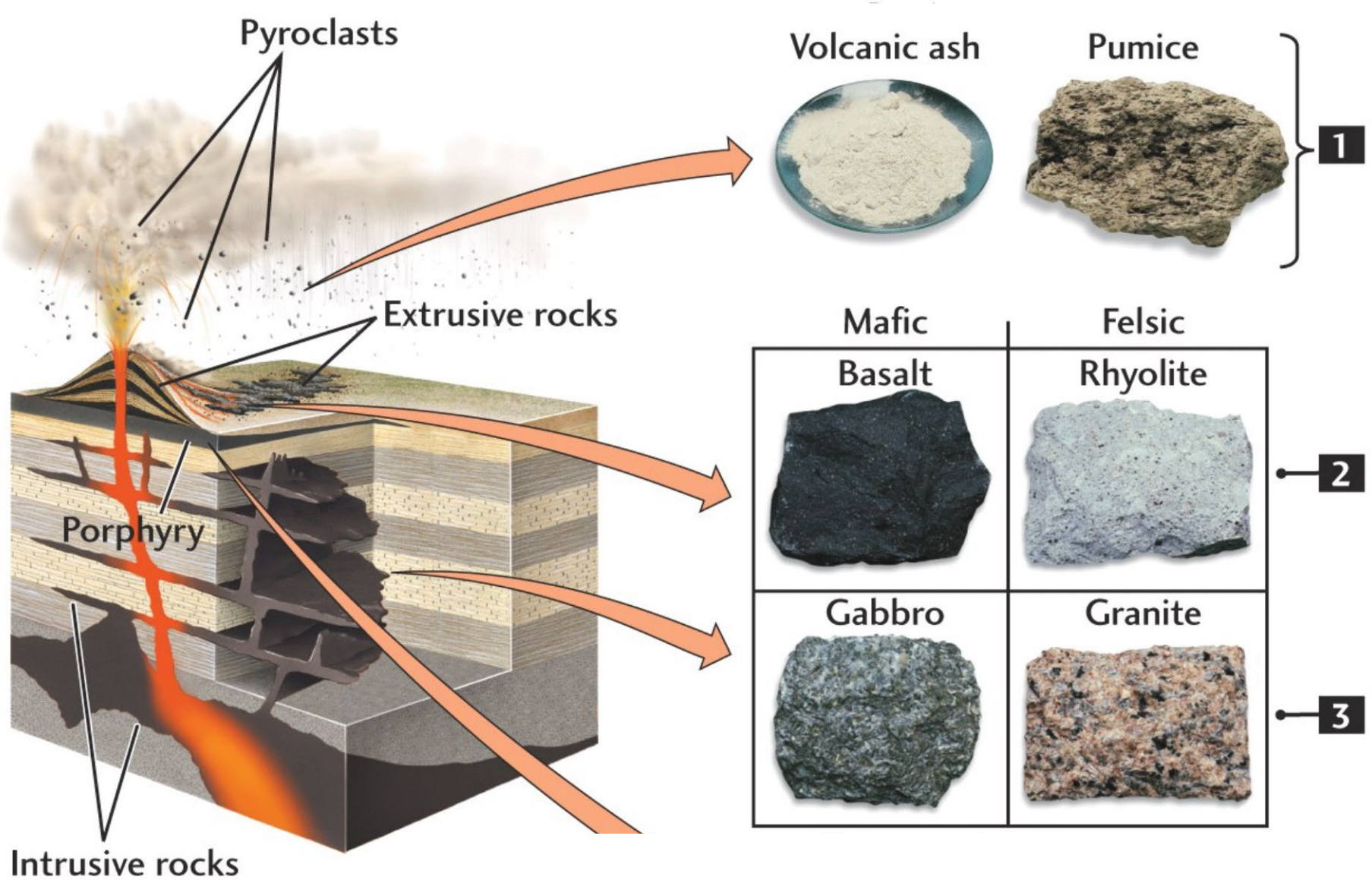
- **Minerals**
  - **Predominantly dark ferromagnesian silicates minerals**
  - **The termed mafic is for *ma*gnesium and *f*errum, for iron**
  - **Higher density than granitic rocks**
- **Comprise the ocean floor and many volcanic islands**



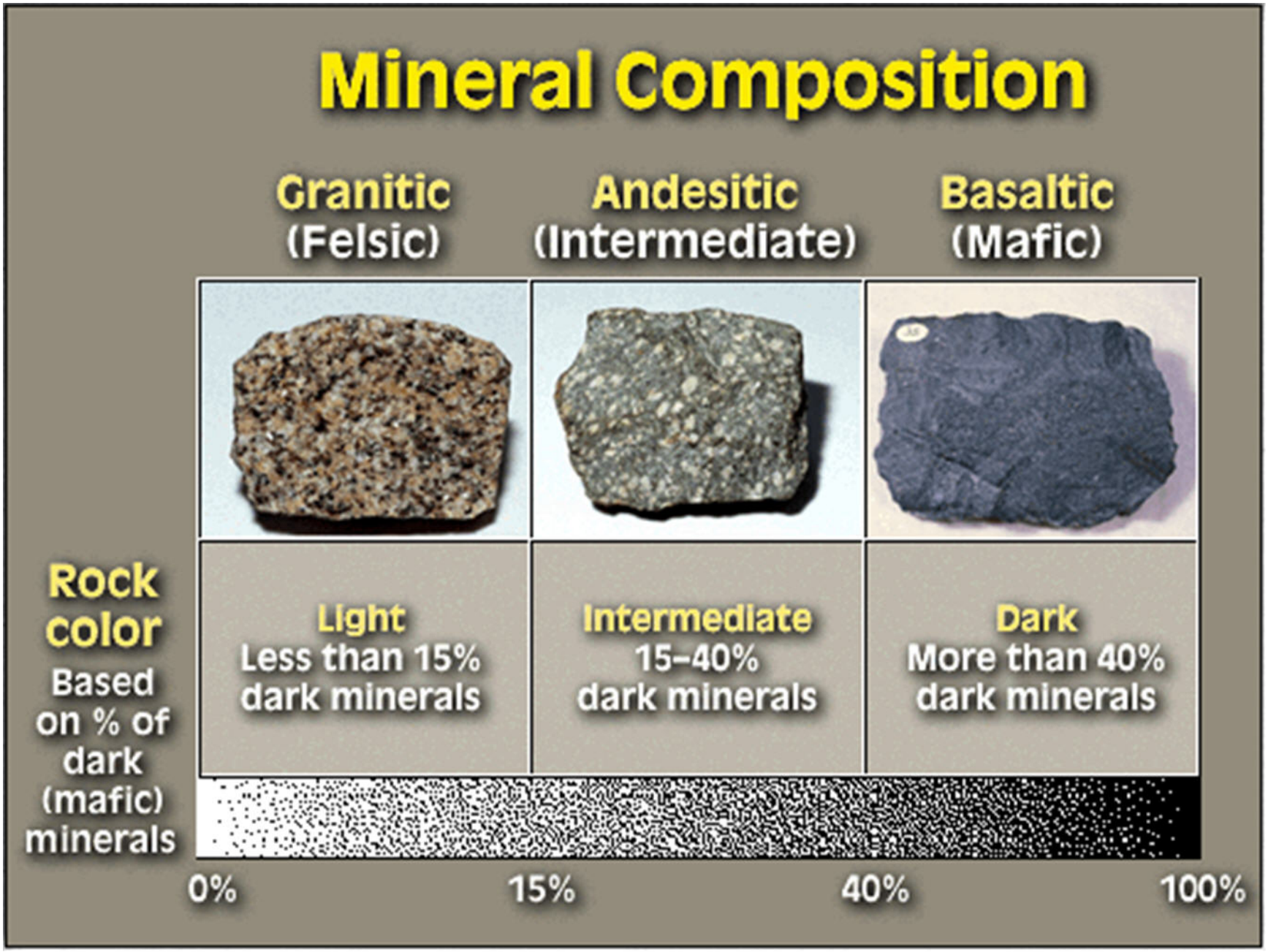
A. Granite is a felsic, coarse-grained igneous rock composed of light-colored silicates—quartz and potassium feldspar.



B. Basalt is a fine-grained mafic igneous rock containing substantial amounts of dark colored silicates and plagioclase feldspar.

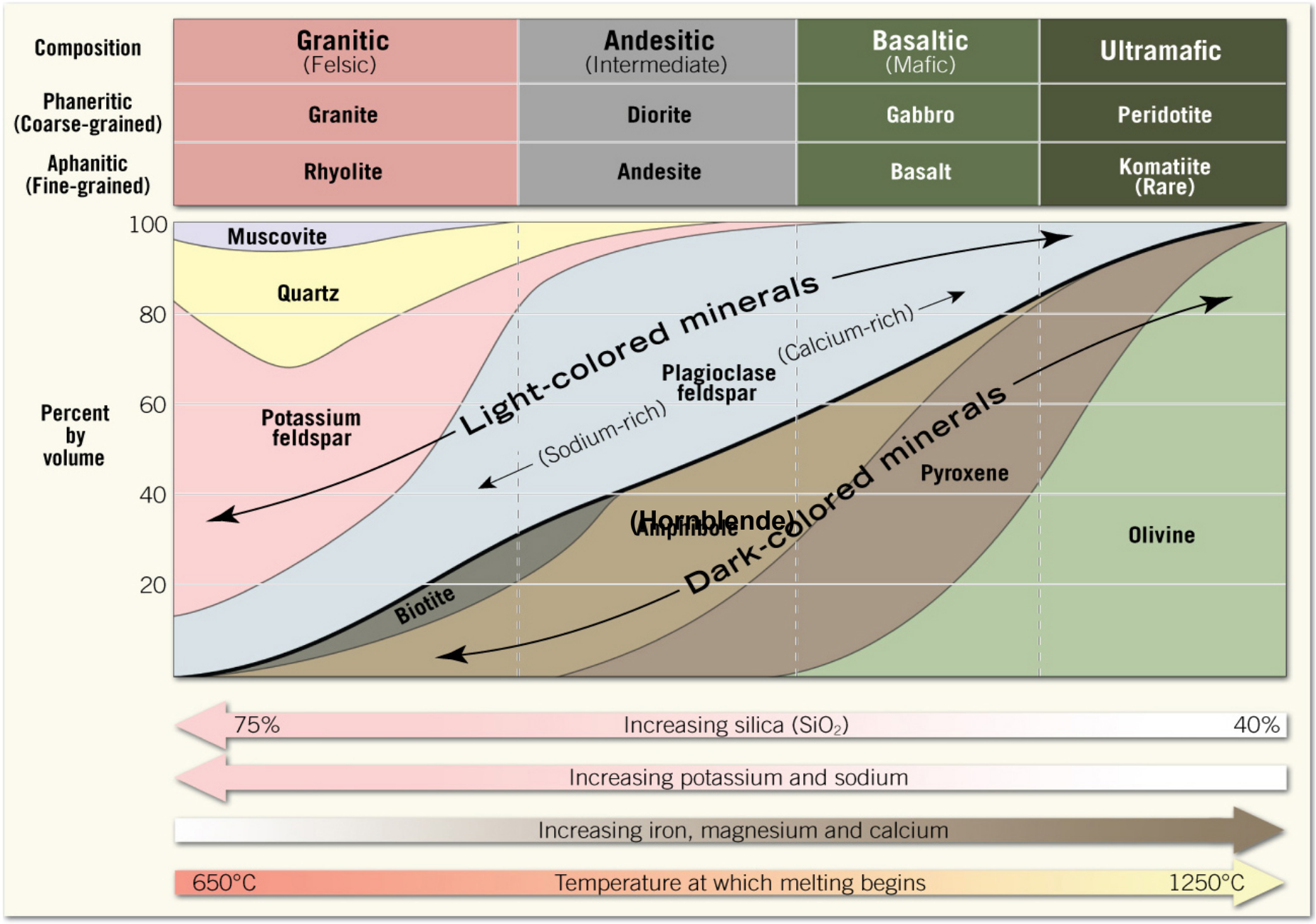

Pyroclasts
Volcanic ash
Pumice
1
Extrusive rocks
Mafic
Felsic
Basalt
Rhyolite
2
Porphyry
Gabbro
Granite
3
Intrusive rocks

Mineral Composition



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**
    - **Peridotite of the mantle is ultramafic**


Composition
Granitic (Felsic)
Andesitic (Intermediate)
Basaltic (Mafic)
Ultramafic
Phaneritic (Coarse-grained)
Granite
Diorite
Gabbro
Peridotite
Aphanitic (Fine-grained)
Rhyolite
Andesite
Basalt
Komatiite (Rare)
Percent by volume
100
80
60
40
20
Muscovite
Quartz
Potassium feldspar
Light-colored minerals
Plagioclase feldspar
(Calcium-rich)
(Sodium-rich)
Dark-colored minerals
Pyroxene
Amphibole (Hornblende)
Olivine
Biotite
75%
Increasing silica (SiO_2)
40%
Increasing potassium and sodium
Increasing iron, magnesium and calcium
650°C
Temperature at which melting begins
1250°C

Review
Igneous Rocks Classified by

- Texture
  - crystal size
  - glassy
  - vesicular
- Chemical Composition
  - % SiO_2 Na, K
  - % Fe, Mg
- Mineral Composition
  - felsic
  - intermediate
  - mafic
  - ultramafic

Review Igneous Rock types

Composition	Intrusive (Plutonic)	Extrusive (Volcanic)
More Si, Na, K rich; lower melting temperature		
Granitic (felsic; rhyolitic)	Granite	Rhyolite
Andesitic (intermediate)	Diorite	Andesite
Basaltic (mafic)	Gabbro	Basalt
More Fe, Mg rich; higher melting temperature		

Review

Texture	Composition		
	Felsic (Granitic)	**Intermediate** (Andesitic)	**Mafic** (Basaltic)
(course-grained)	 Granite	 Diorite	 Gabbro
(fine-grained)	 Rhyolite	 Andesite	 Basalt

Review - silicate minerals in igneous rocks

ferromagnesian minerals

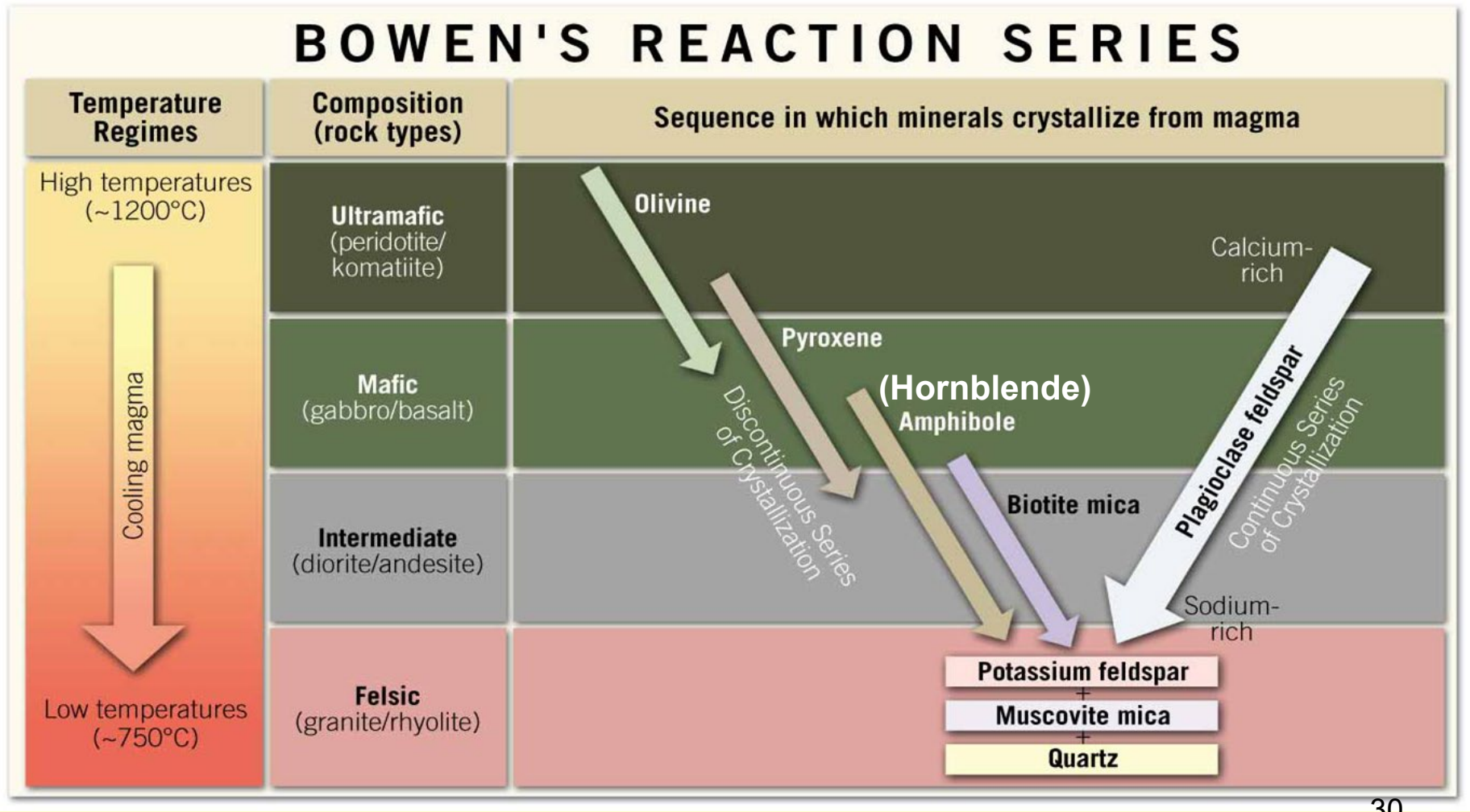
- olivine
- pyroxene
- amphibole group
  - (hornblende)
- biotite mica

nonferromagnesian minerals

- quartz
- muscovite mica
- feldspars
  - plagiclase (Na-Ca feldspar)
  - orthoclase (K feldspar)

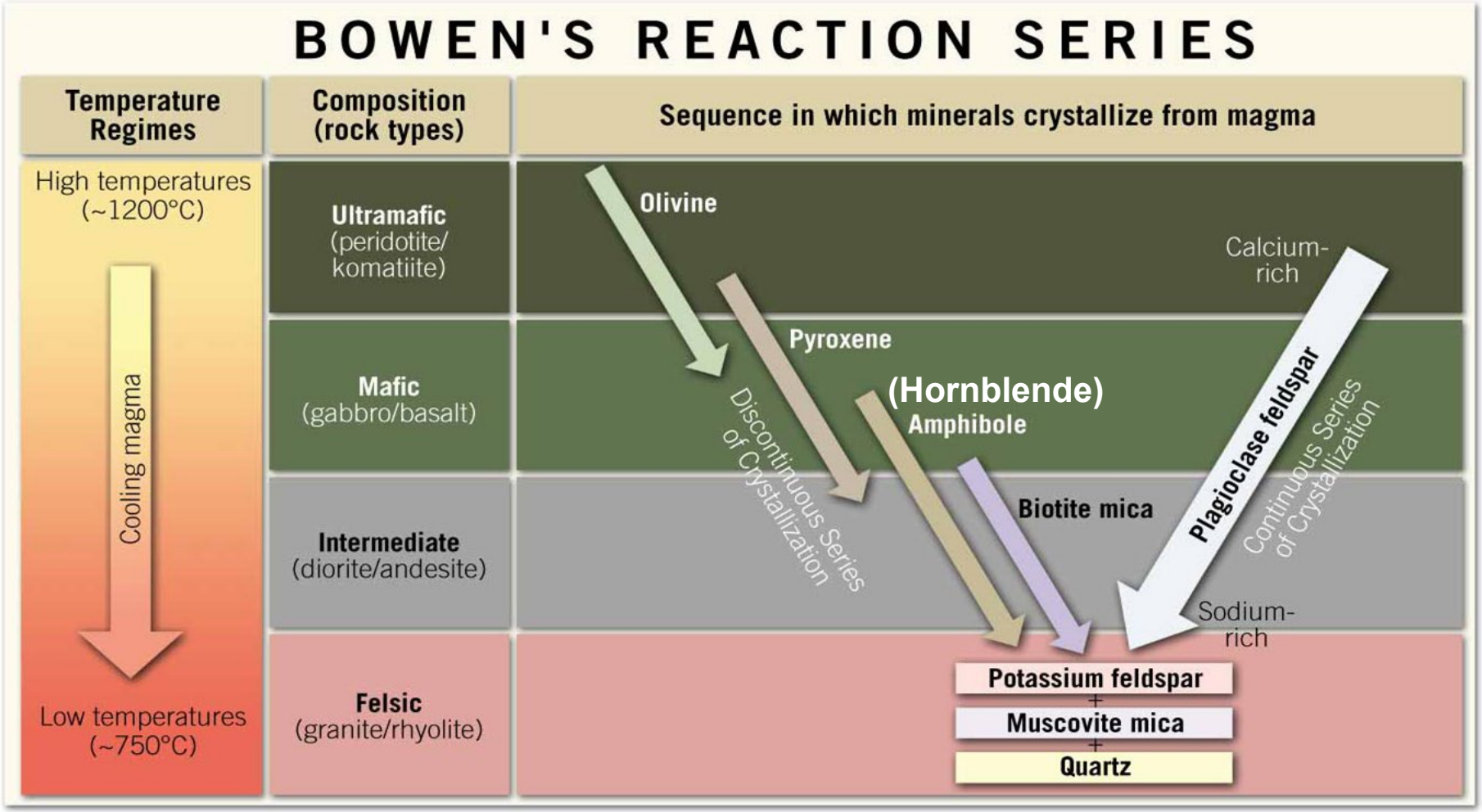
Bowen's Reaction Series

- Gradual cooling of basaltic magma results in a sequence of mineral crystallization called the Bowen's Reaction Series

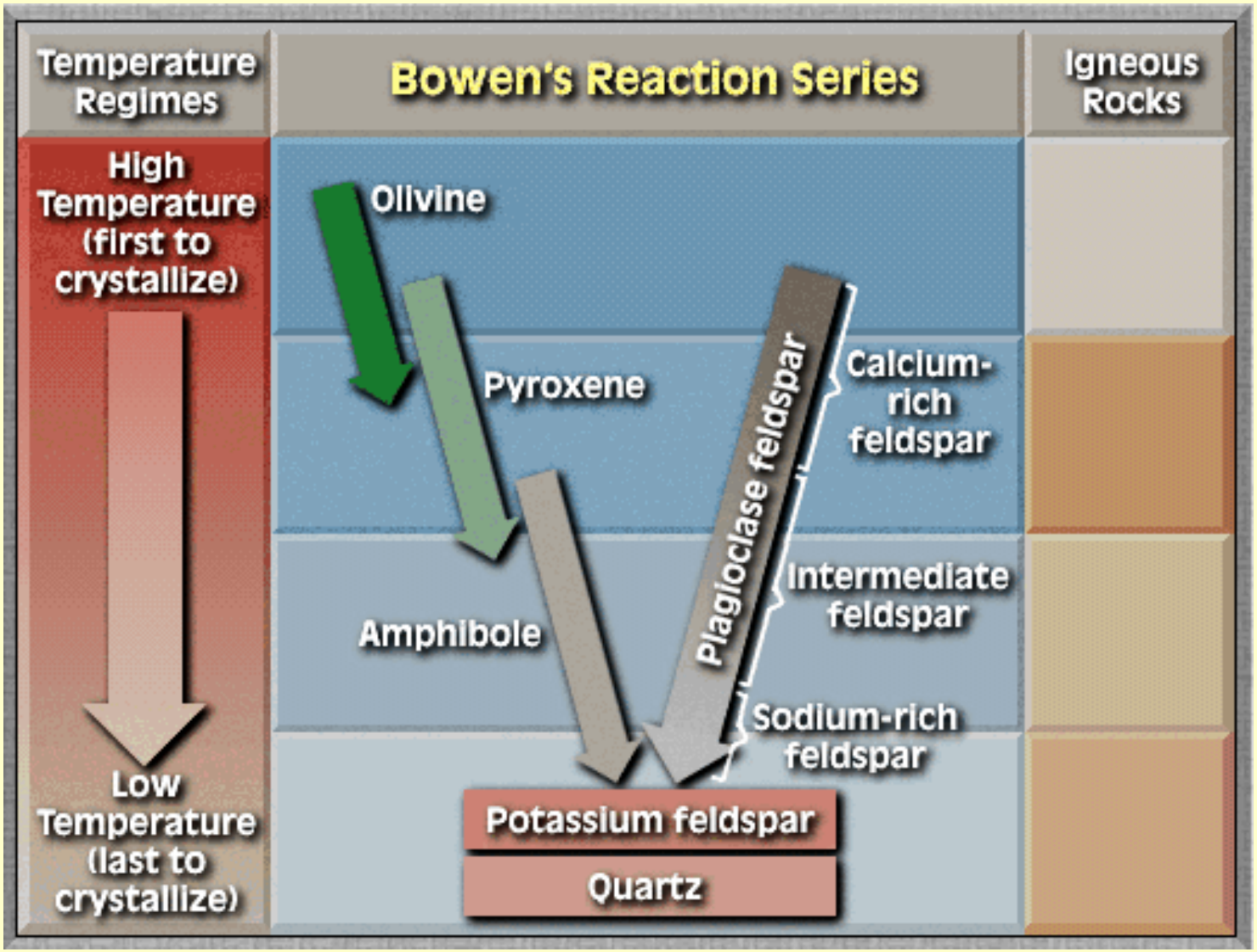


Predicts Minerals found together in Igneous Rock

- Minerals that form in the same temperature regime are generally found together in the same igneous rocks

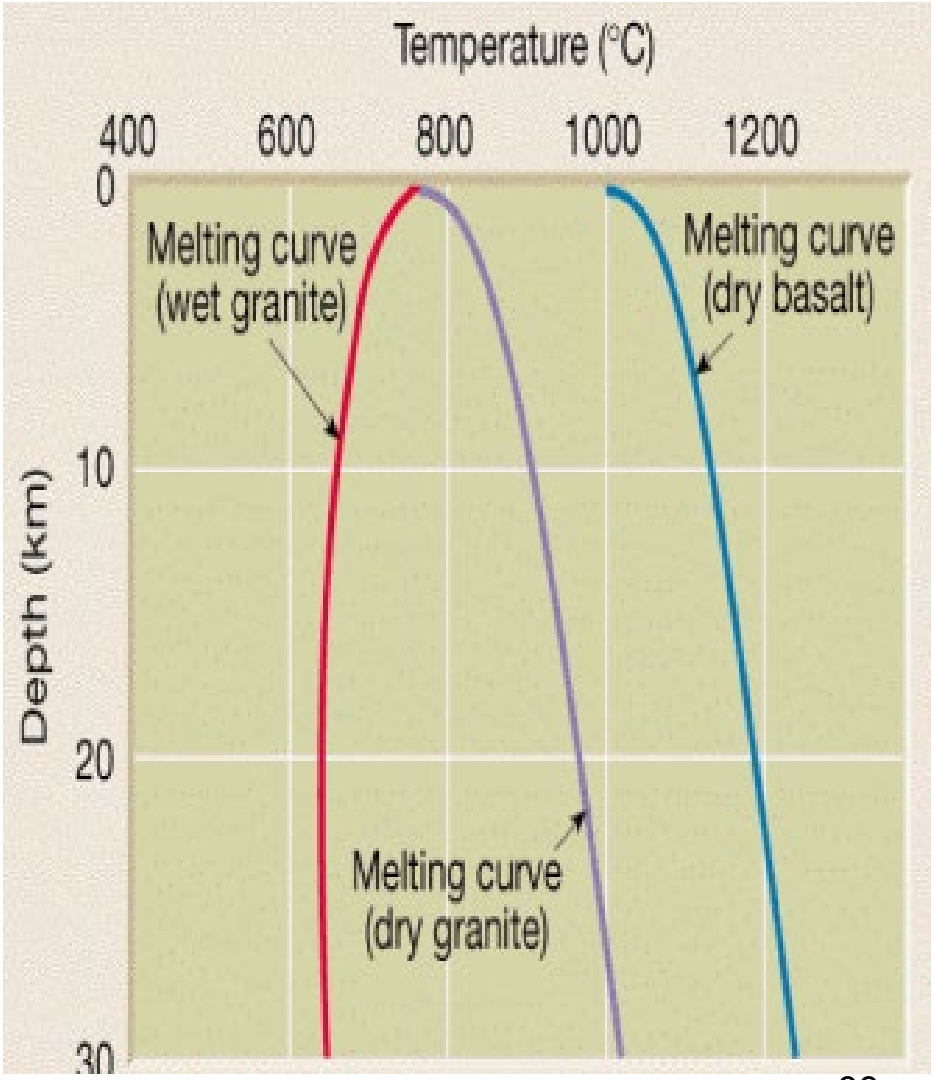


Minerals formed over the same temperature range are found together in the same rock



How does magma form? Why rock melts.

- **increase temperature**
  - geothermal gradient – temperature increases as go deeper in the earth
- **add water** to the rock
  - lowers melting temperature
- **decrease pressure (decompression melting)**
  - lowers melting temperature
  - pressure decreases as decrease weight of overlying rock



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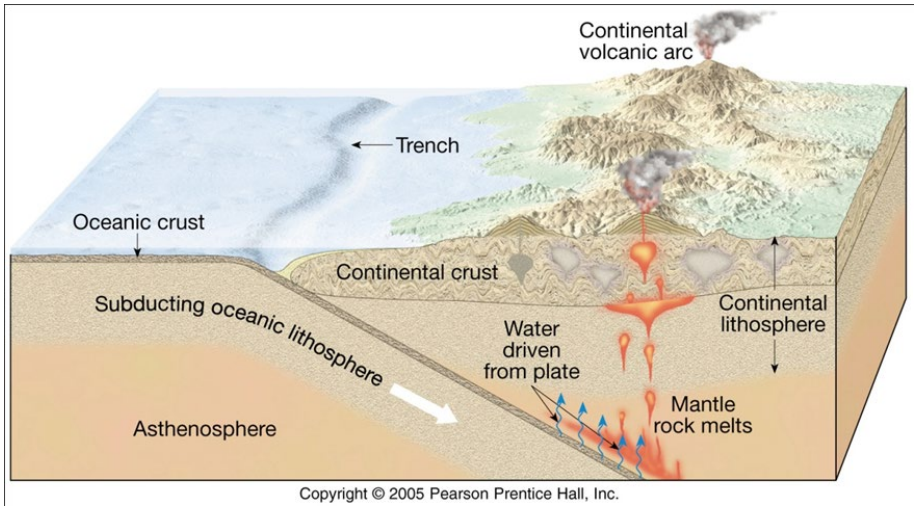
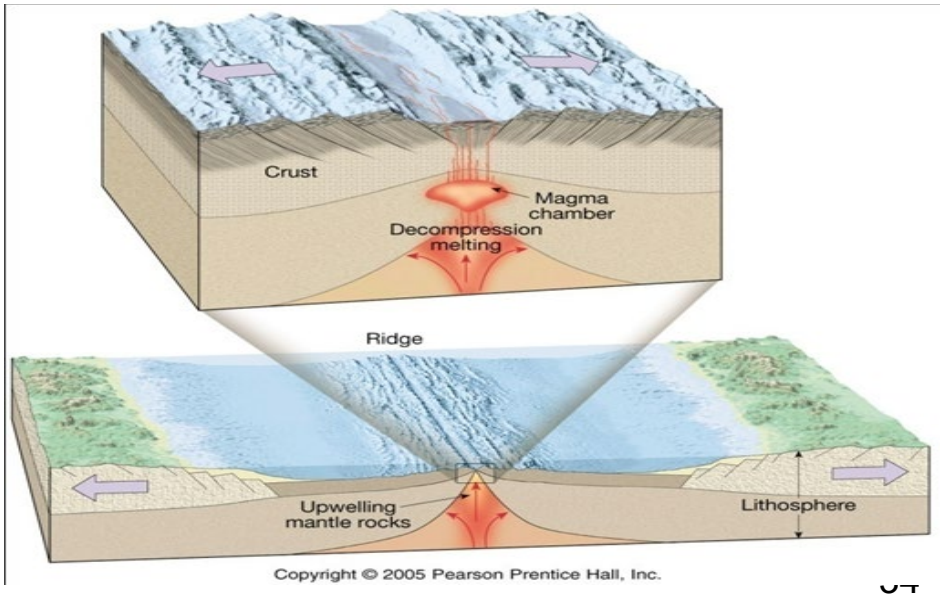
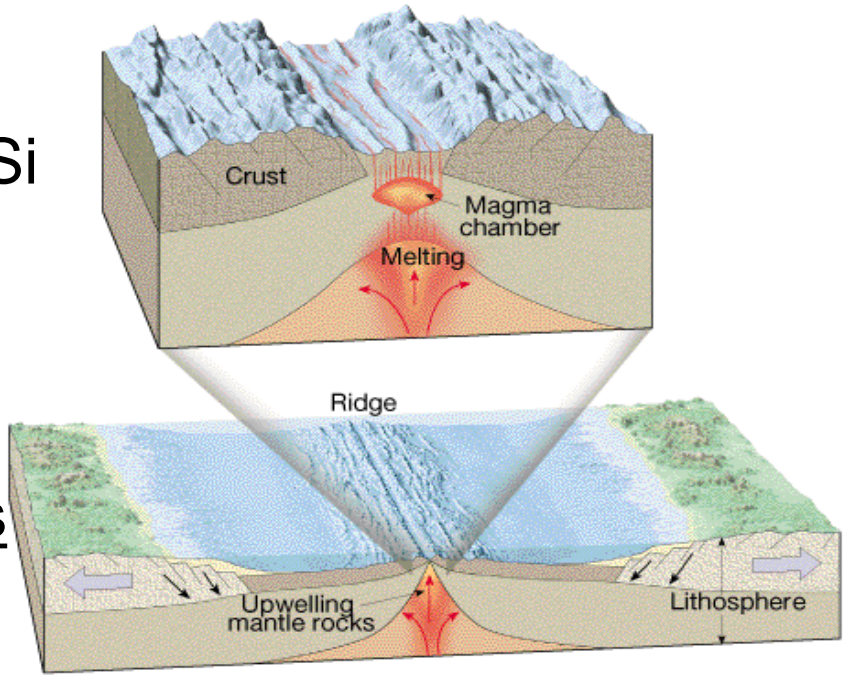




Origin of Basaltic Composition Magma

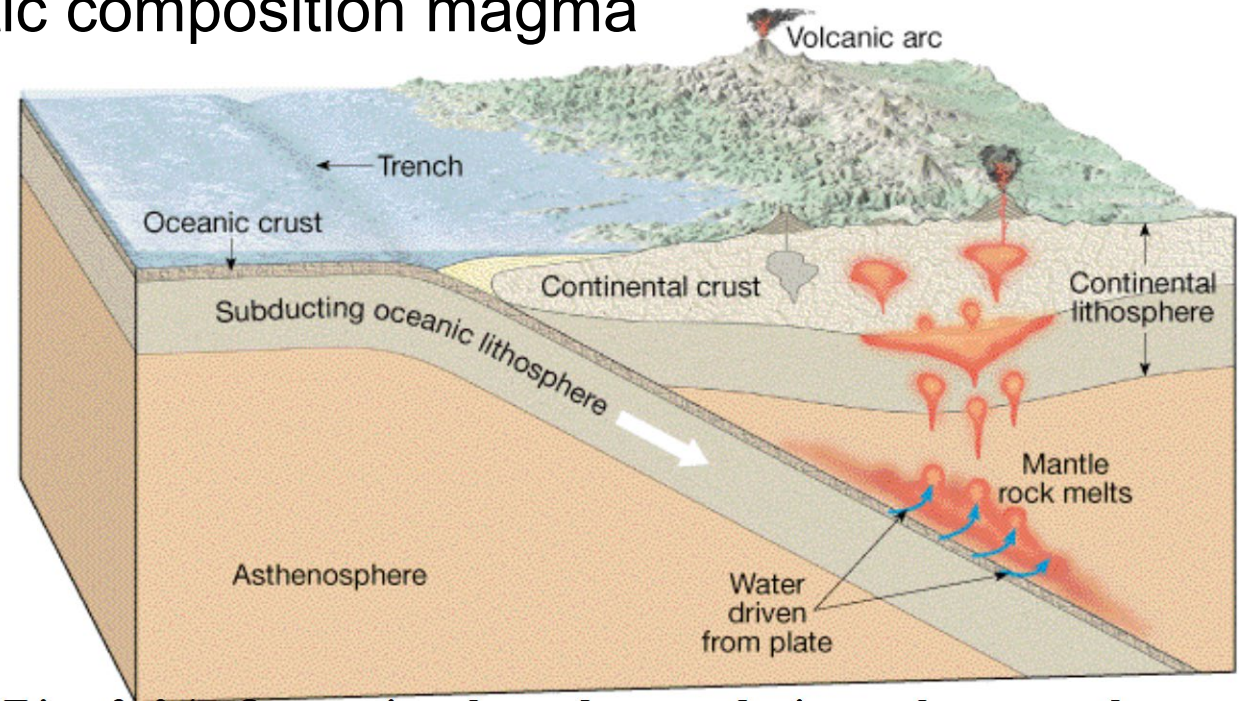
- Partial melting of upper mantle
  - mantle is Mg-Fe rich and Si poor so produces basaltic composition magma
- Found at:
  - oceanic spreading centers (oceanic ridges)
  - Oceanic hot spots



Basaltic mantle ascends but does not solidify as it cools because of decreasing pressure.[2]

Origin of Intermediate to Granitic Composition Magma

– Melt a mixture of oceanic crust (basaltic) and continental crust (granitic)
  - Forms intermediate (andesitic) composition magma
– Melt continental crust
  - Forms granitic composition magma
– Forms at
  - subduction zones
  - Continental hot spots



Importance to Volcanic Processes

Basaltic magma

- silica poor
- low viscosity
- more fluid
- **quiet eruptions**

Granitic-Intermediate magma

- silica rich
- high viscosity
- less fluid
- **violent eruptions**

the end