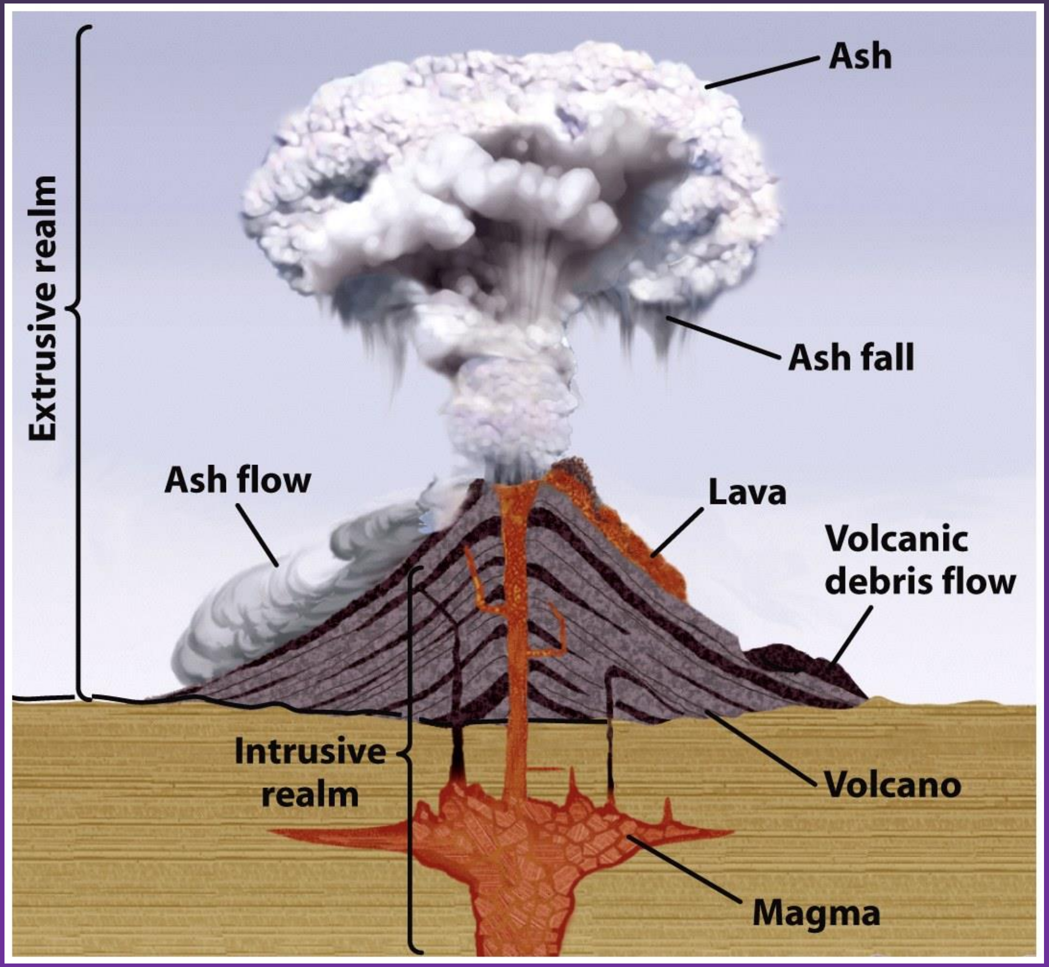
Igneous Rocks


Ash
Ash fall
Extrusive realm
Ash flow
Lava
Volcanic debris flow
Intrusive realm
Volcano
Magma

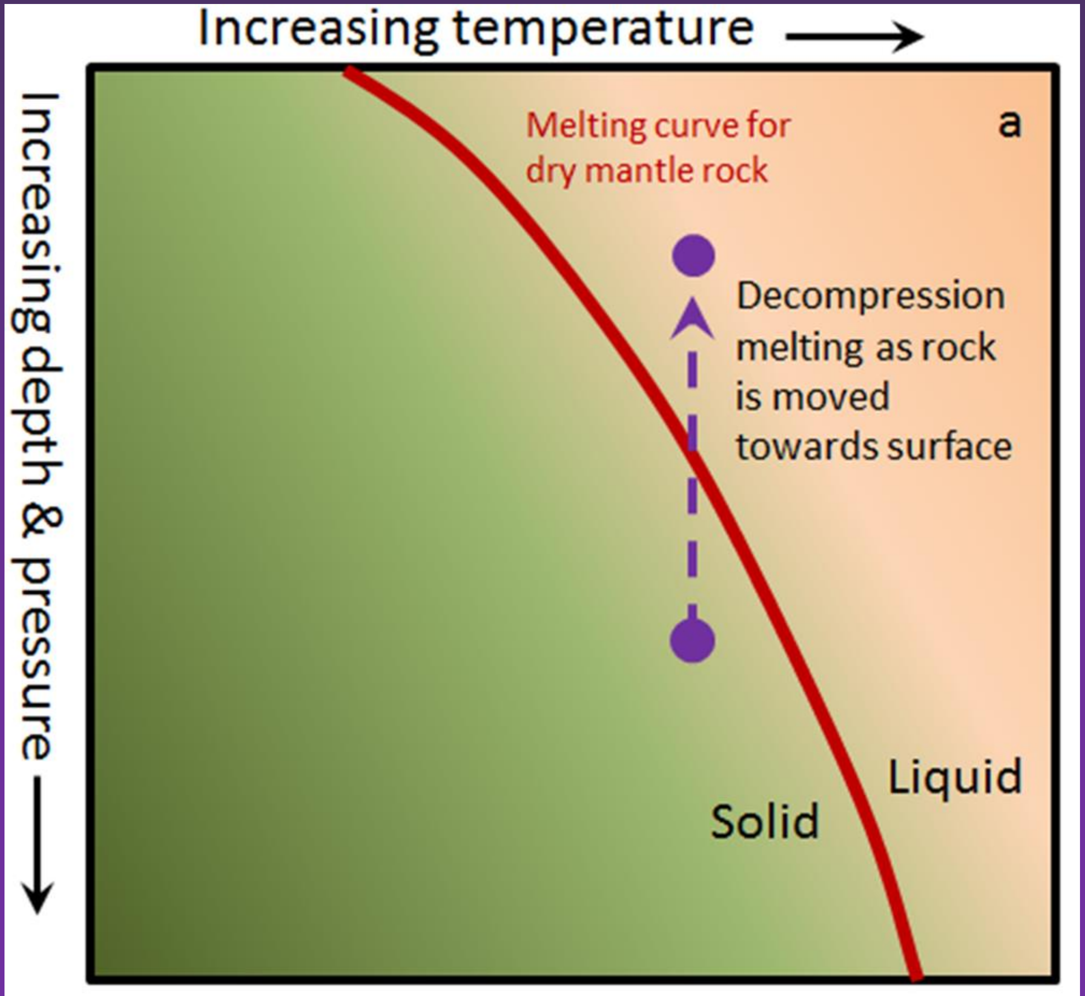
How do magmas form?

How do Magmas Form?

https://opentextbc.ca/geology/chapter/3-2-magma-and-magma-formation/

1. Decompression melting

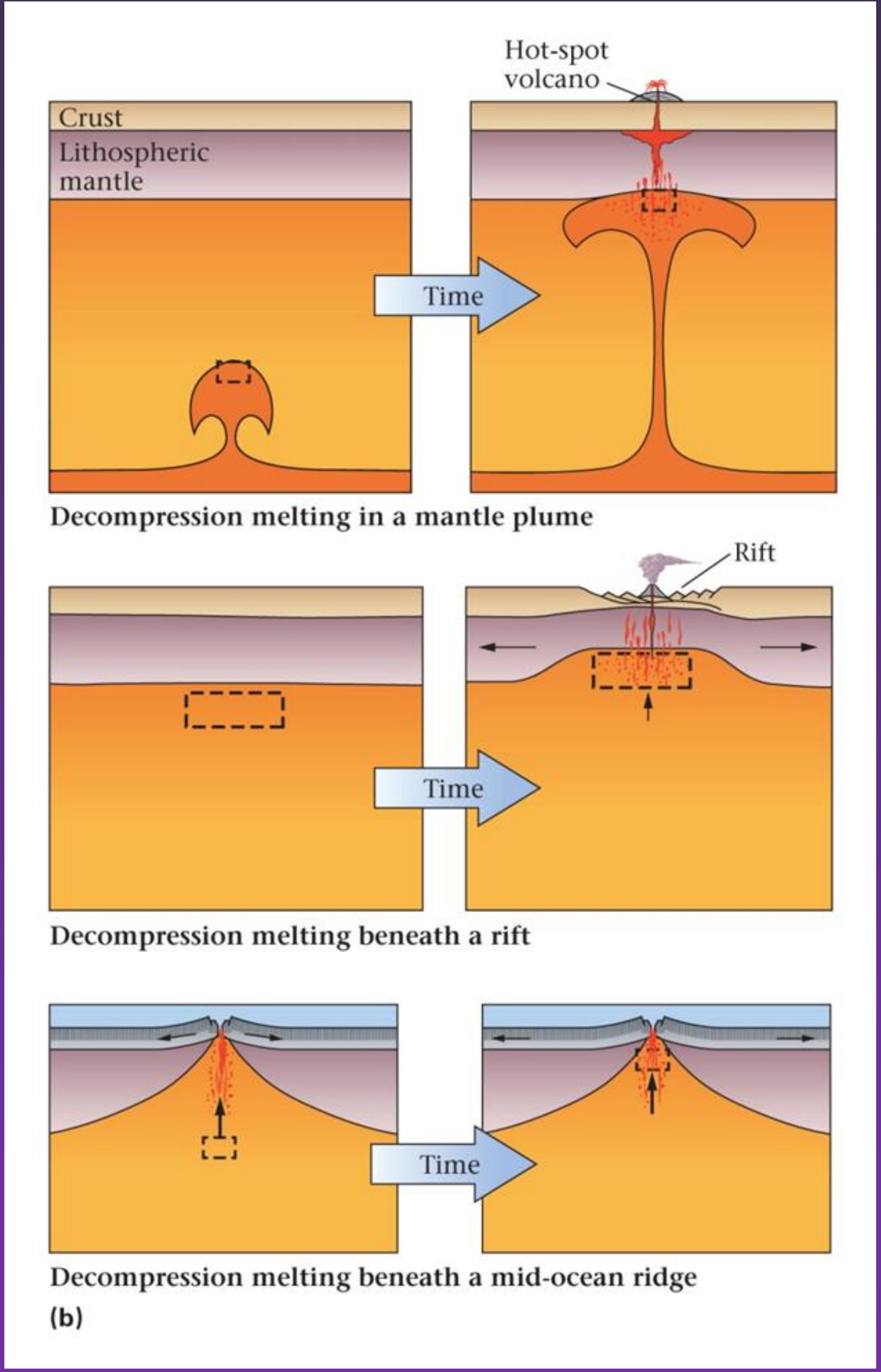
Decrease in pressure



How do Magmas Form?

1. Decompression melting

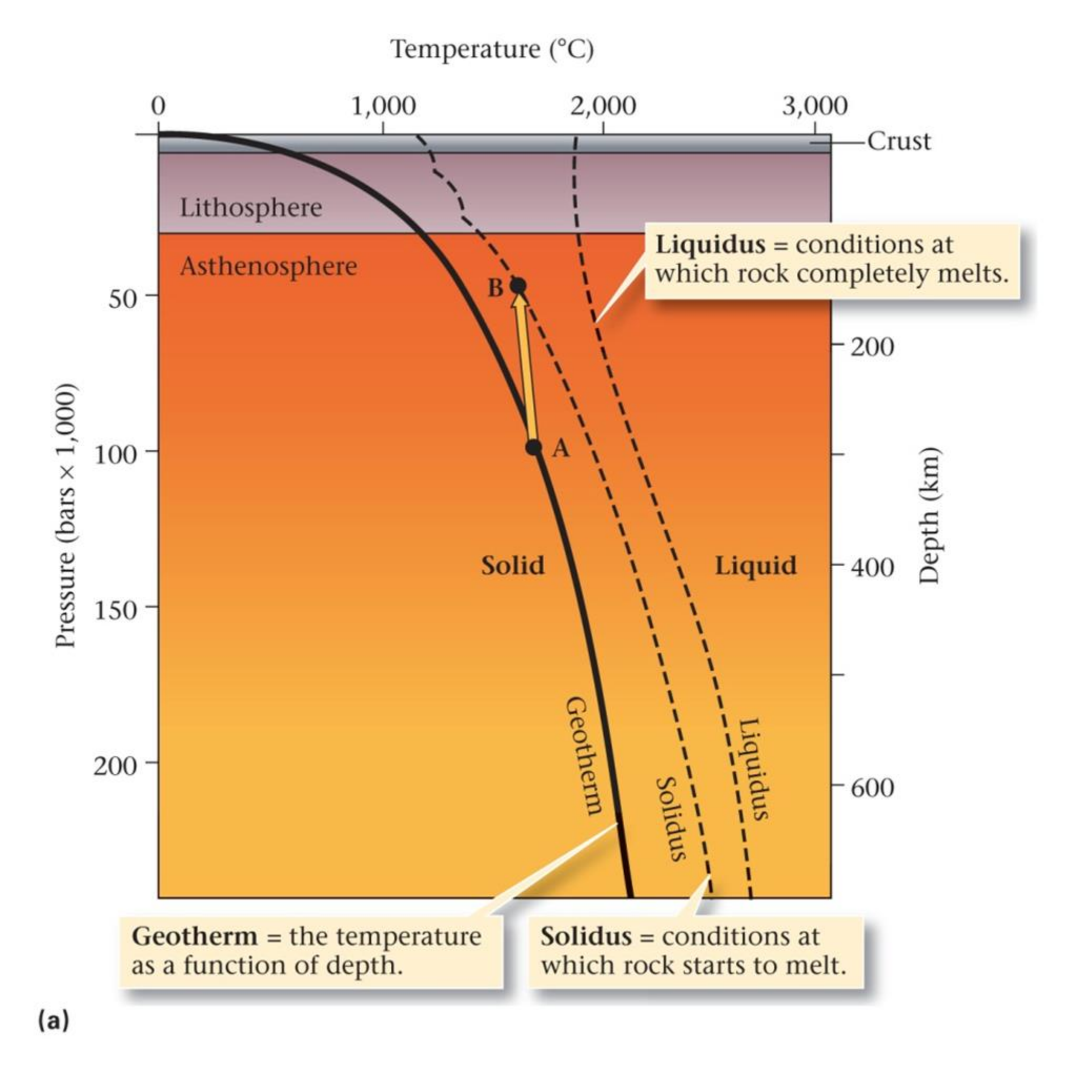
Decrease in pressure



How do magmas form?

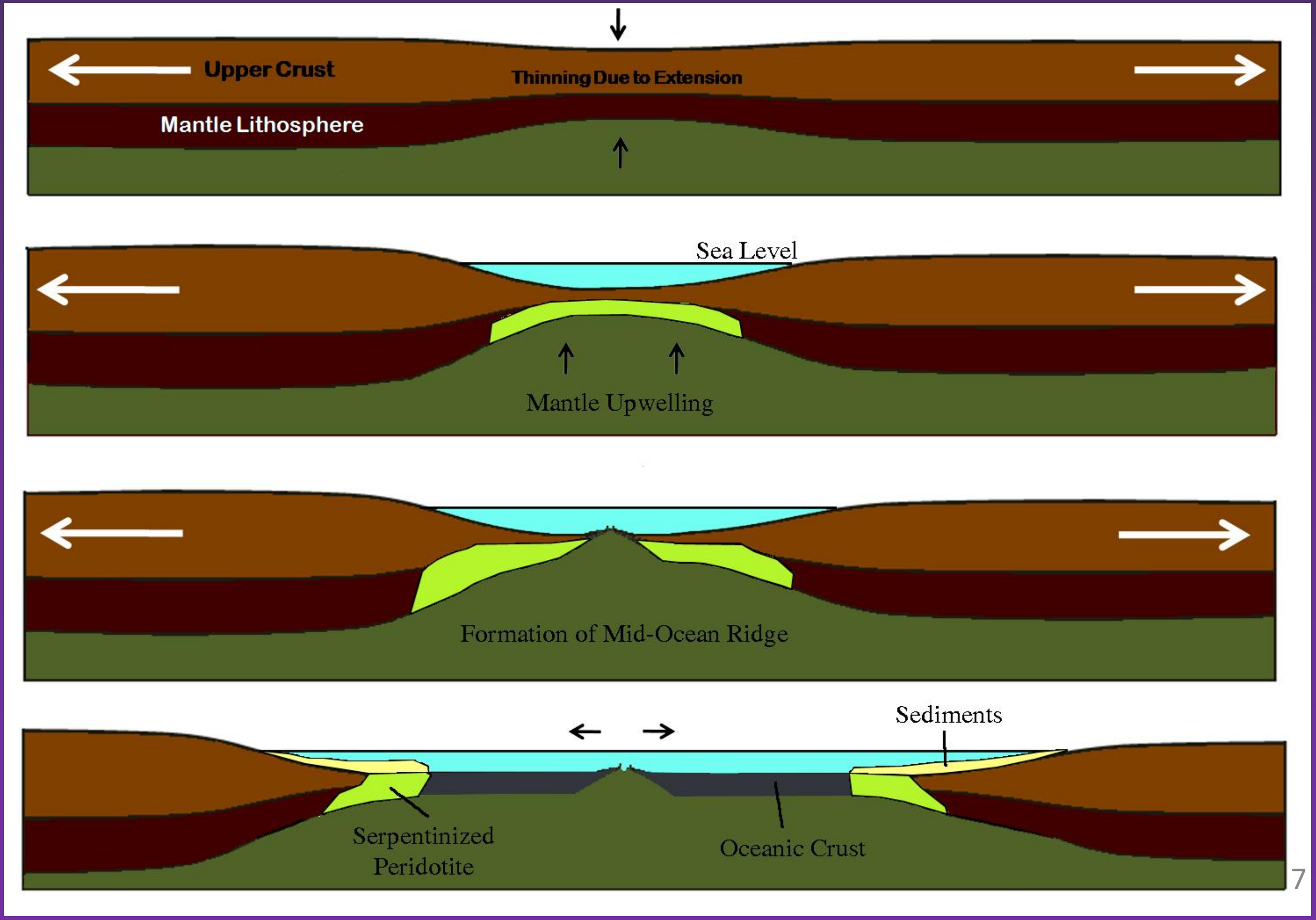
1. Decompression melting

- Geothermal gradient



Where Magma Forms

- Decompression
- Divergent margin



https://opentextbc.ca/geology/chapter/3-2-magma-and-magma-formation/

Divergent Margin

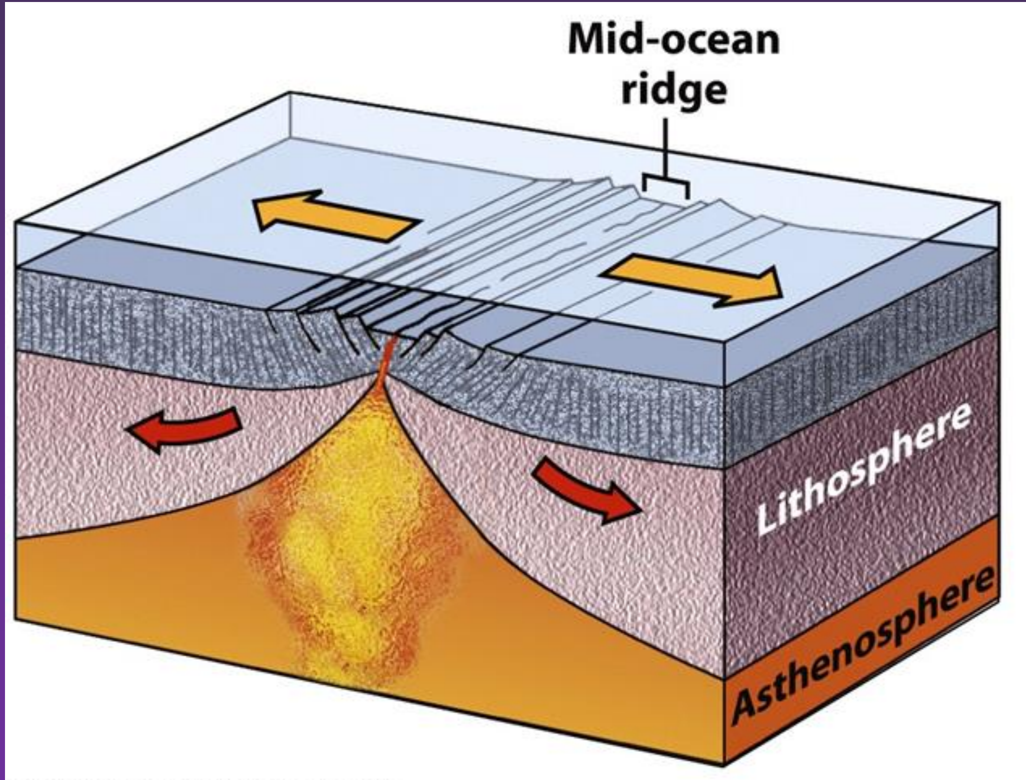
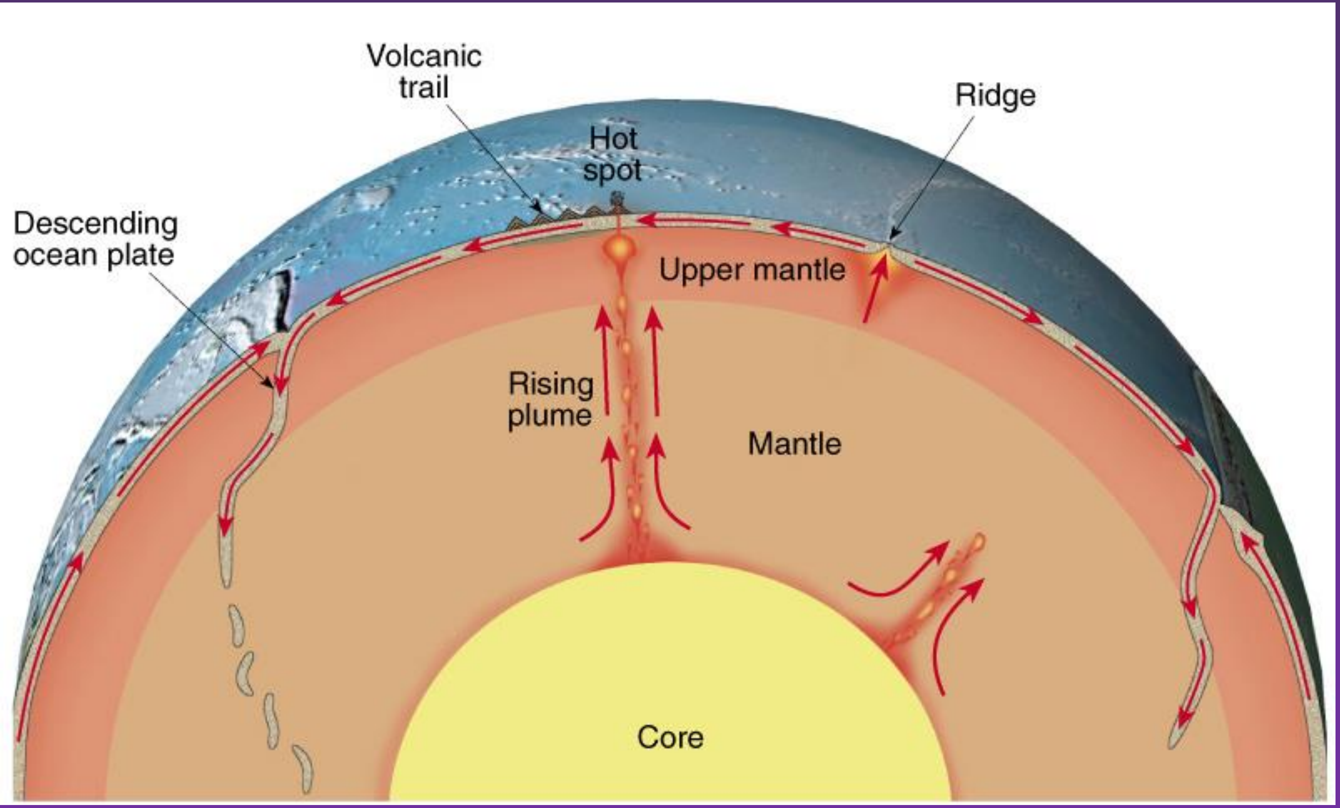


Figure 4-6a Earth: Portrait of a Planet 3/e

Where Magma Form

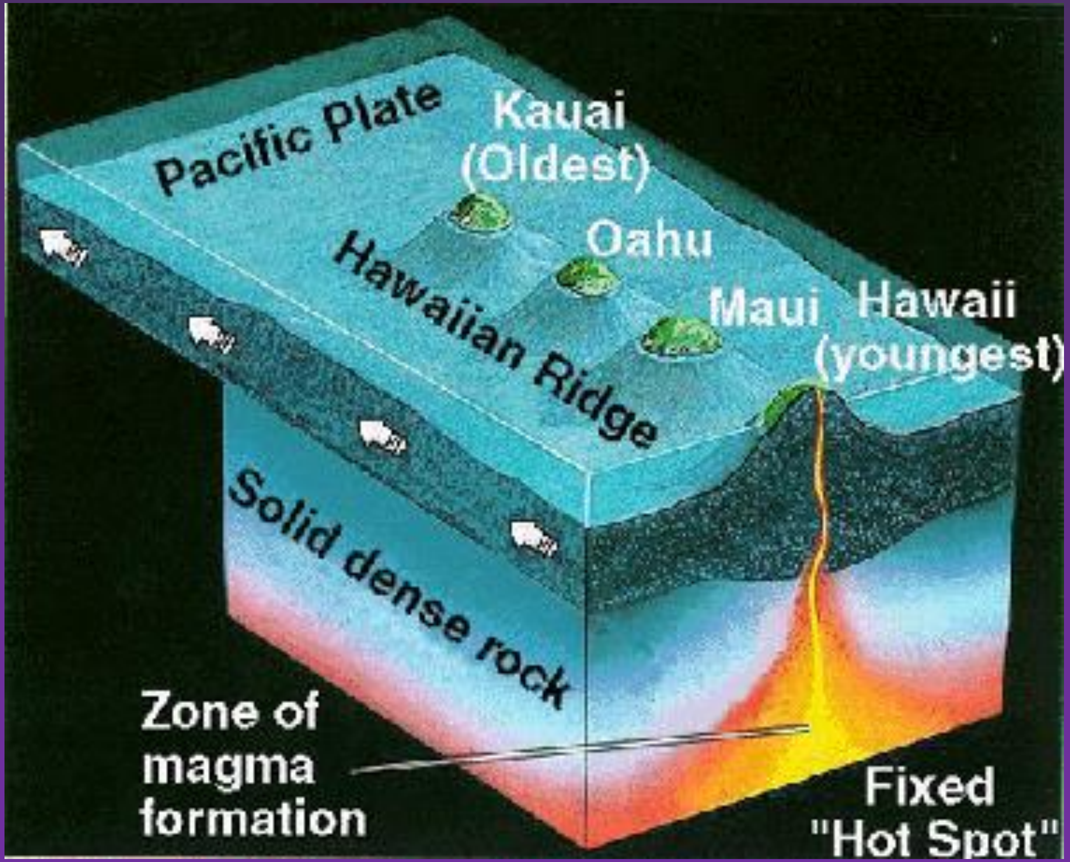
- Mantle Plumes
- “Hot Spots”



http://www.uoguelph.ca/geology/geol2250/glossary/HTML%20files/mantleplume.html

How Magma Forms

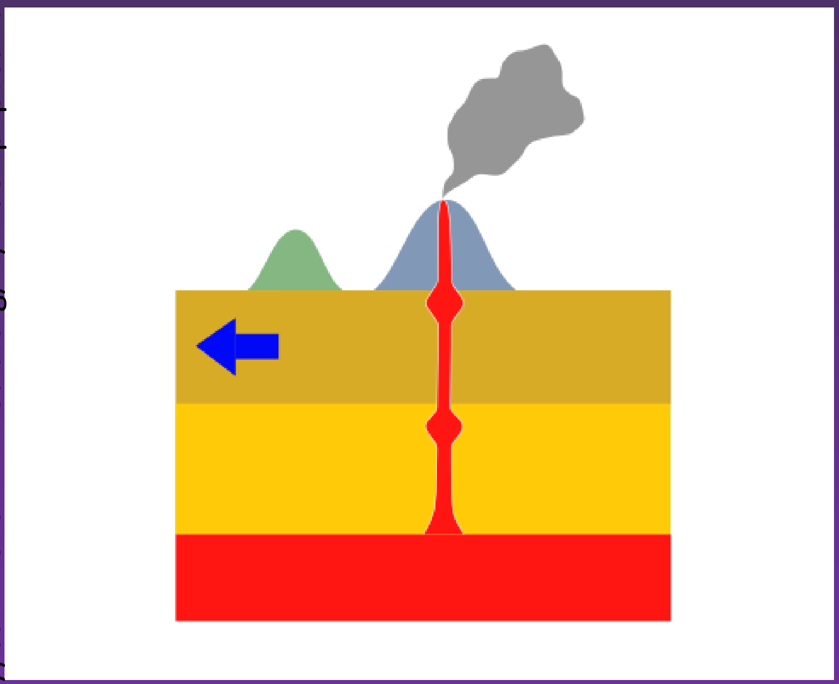
- Mantle Plumes (Hot Spots)
- Decompression

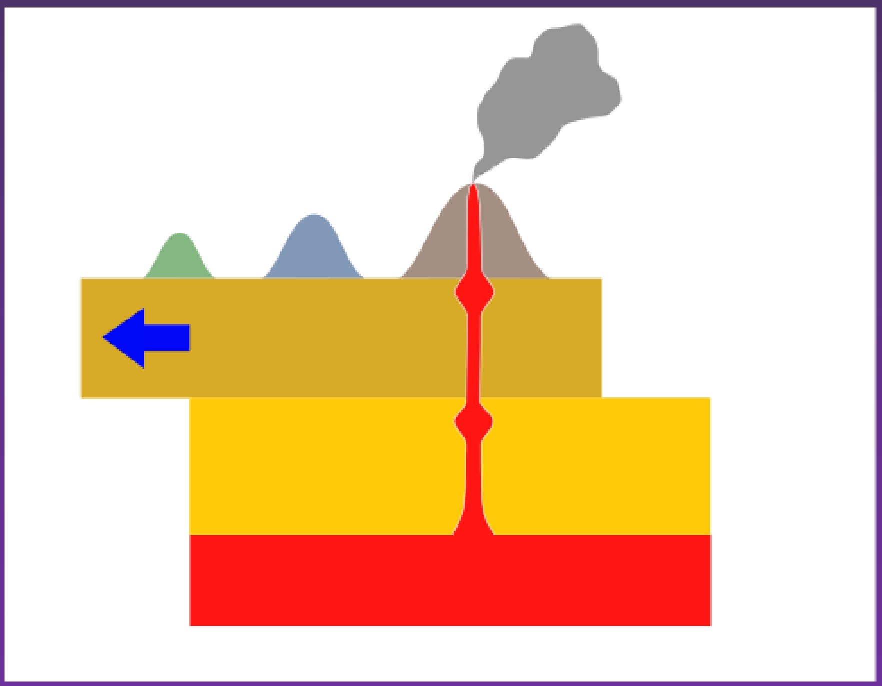


volcano.oregonstate.edu

Hotspots

By Los688 - myown work, Public Domain,
https://commons.wikimedia.org/w/index.php?curid=4618531





How do Magmas Form?

2. Addition of volatiles

Water lowers melting temperature at a given pressure (depth)

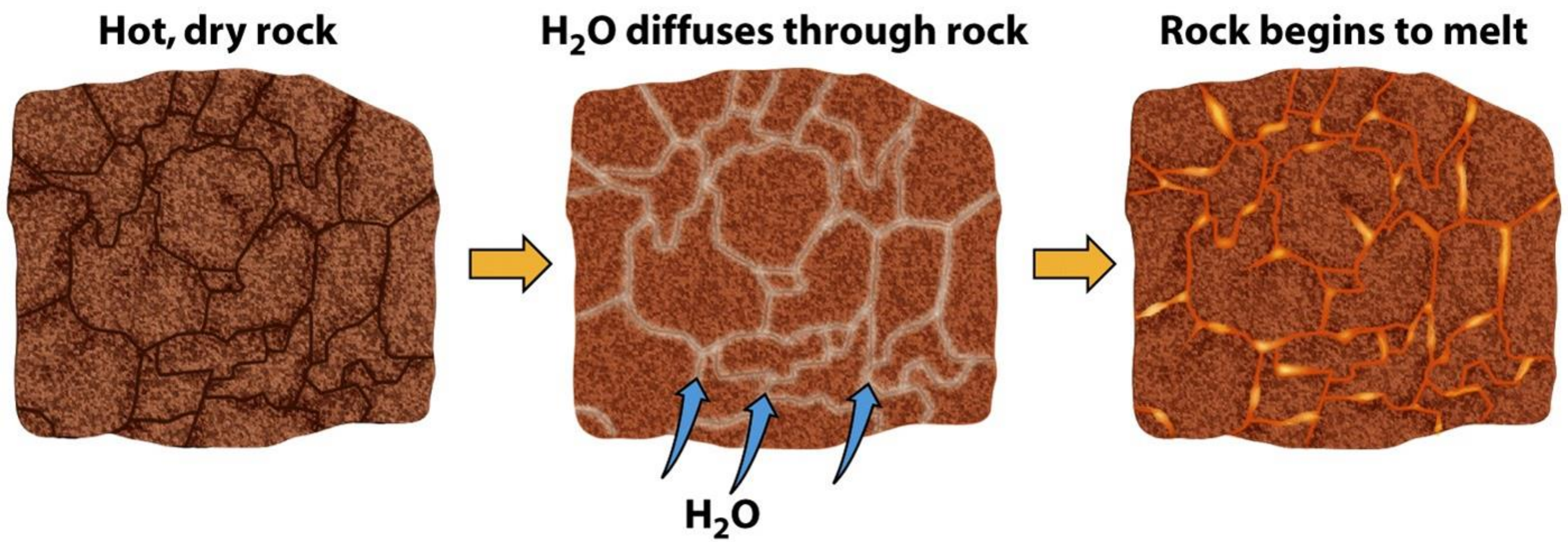
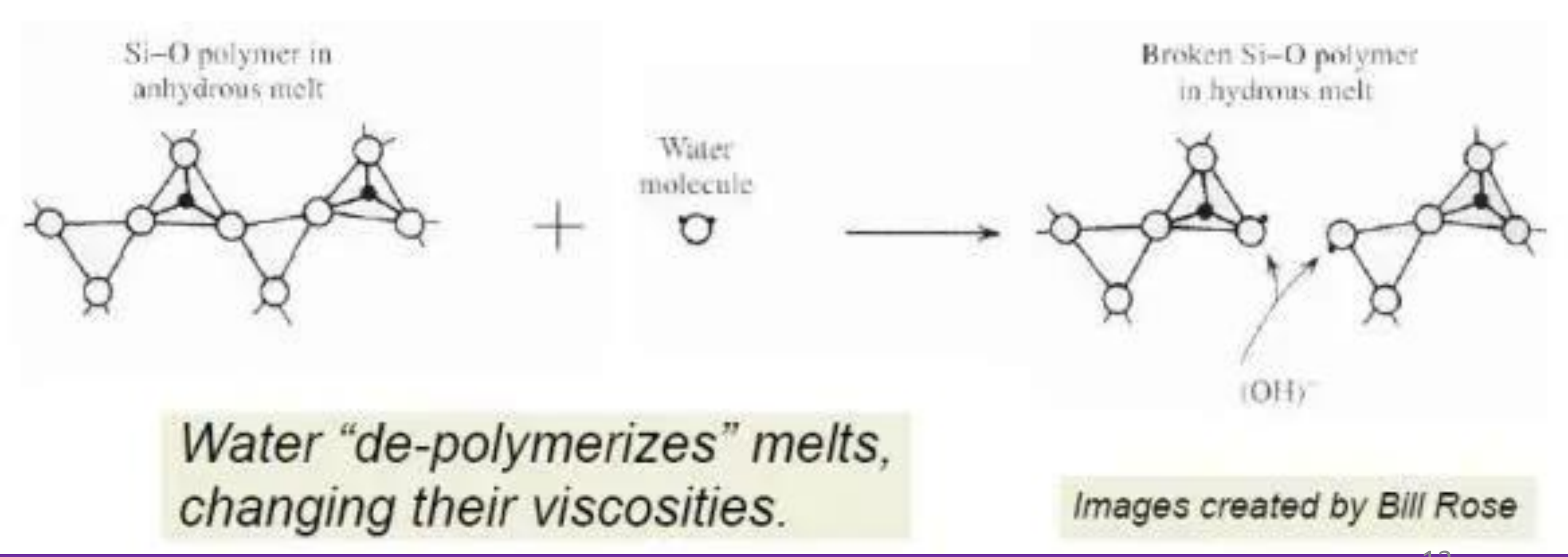


Figure 6-4b Earth: Portrait of a Planet 3/e

How Magma Forms

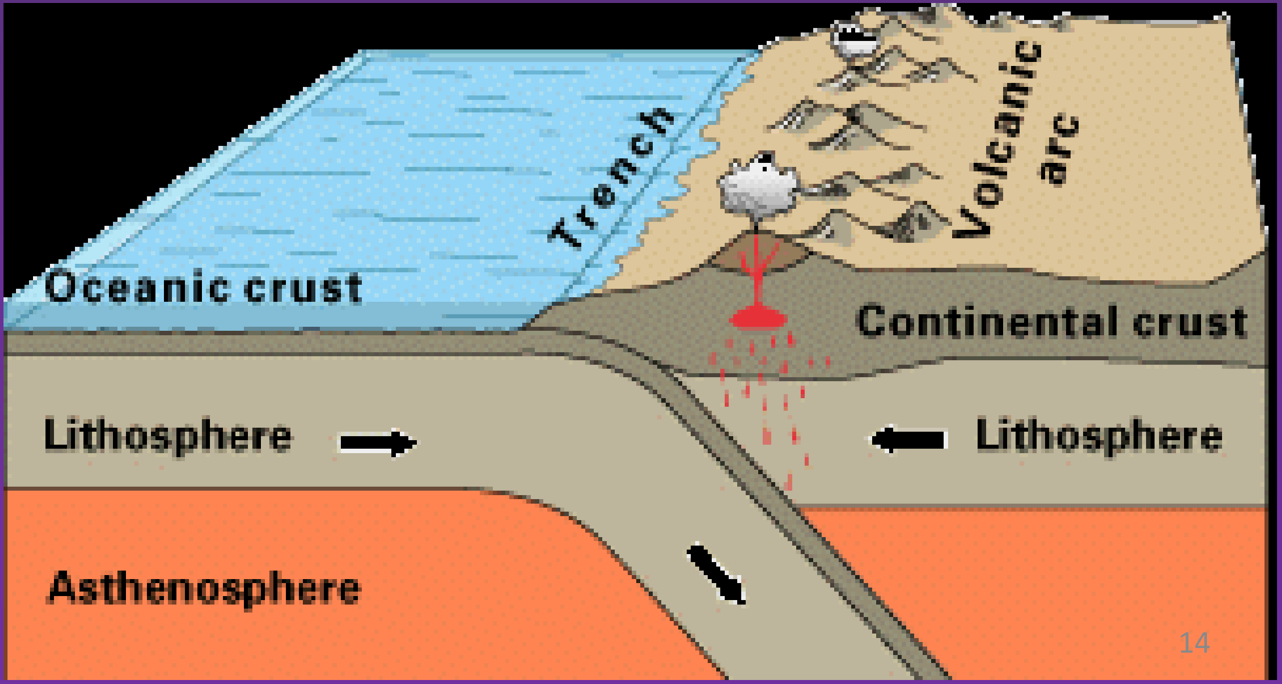
- 2. Addition of volatiles (e.g. water, carbon dioxide)
- Volatiles break silica bonds allowing the material to flow



https://bubblesbigidea.wordpress.com/6-7/

How Magma Forms

- 2. Addition of volatiles (e.g. water, carbon dioxide)
- Water comes from rocks subducted
- Convergent margins



pubs.usgs.gov

Convergent Margin

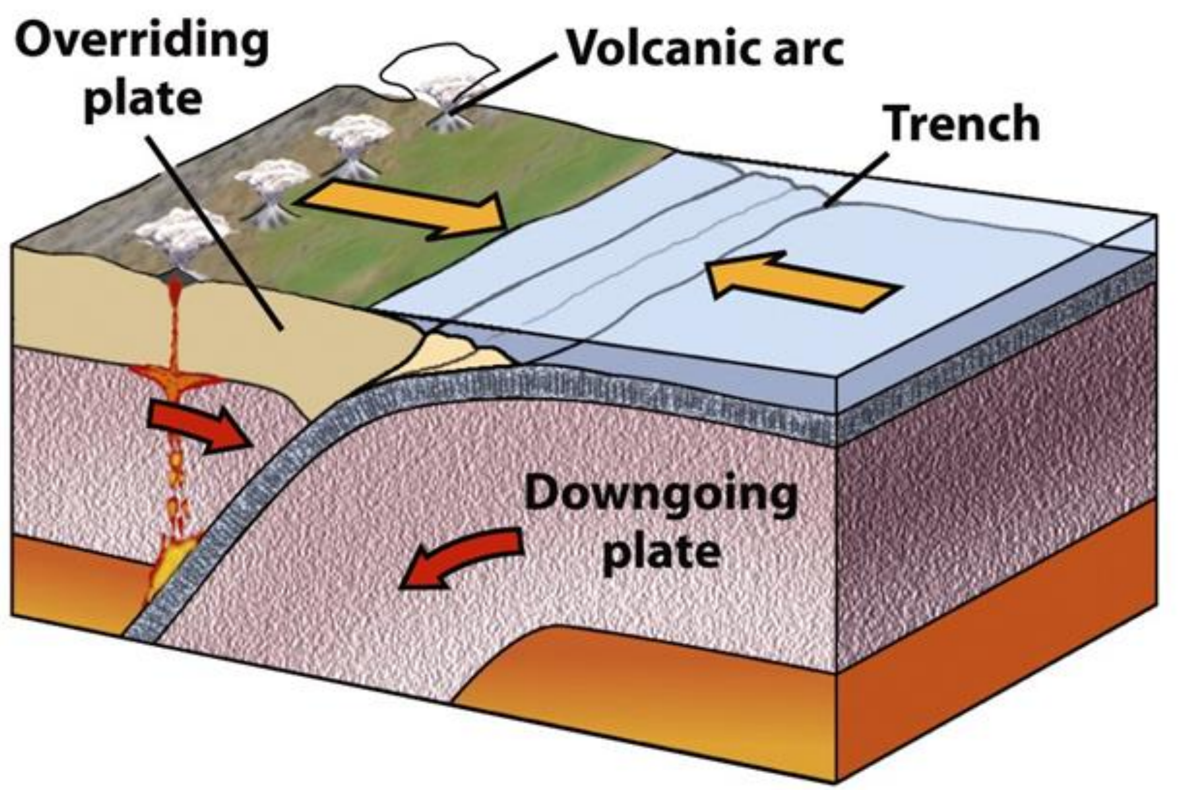
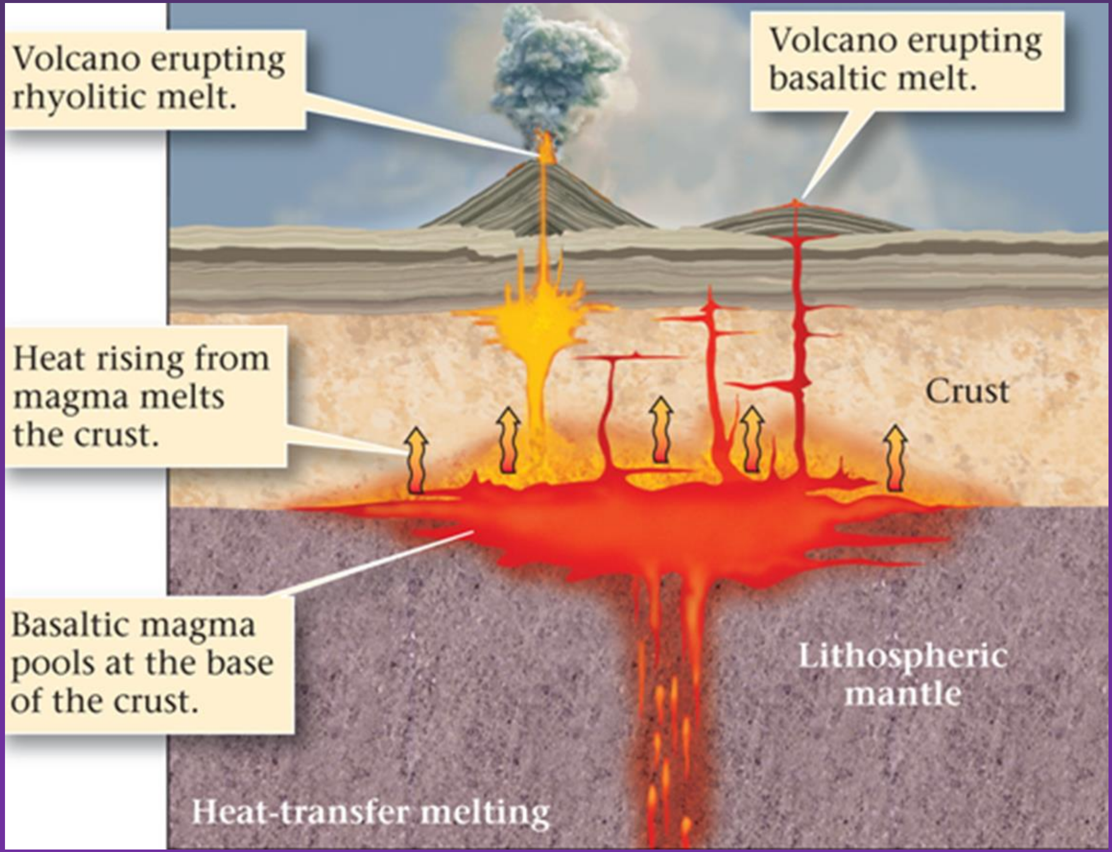


Figure 4-6b Earth: Portrait of a Planet 3/e

How do Magmas Form?

3. Heat transfer from rising magma



Igneous Rocks

- Cooling magma similar to freezing process
- Different magmas “freeze” at different temperatures (650° – 1100° C)

Magma Composition

- Expressed as oxides
  - Silicon (SiO_2)
  - Aluminium (Al_2O_3)
  - Iron (Fe0/Fe_2O_3)
  - Magnesium (MgO)
  - Calcium (CaO)
  - Potassium (K_2O) and sodium (Na_2O)
  - And “volatiles”(H_2O, CO_2)
- Other elements in minor amounts

Classifying Igneous Rocks

- Amount of Silica
  - Felsic 66-76% SiO_2
  - Intermediate 52-66% SiO_2
  - Mafic 45-52% SiO_2
  - Ultramafic 38-45% SiO_2

Igneous Minerals

Mafic Minerals

- Olivine $(Fe, Mg)_2SiO_4$
- Pyroxene $(Fe,Mg)SiO_3$
- Amphibole (Fe,Mg)Al Si0
- Biotite (FeMg)KAlSi0

Felsic Minerals

- Plagioclase feldspar $(Ca,Na)(Al,Si)_4O_8$
- Quartz SiO_2
- K-feldspar $KAlSiO_3$
- Muscovite

Bowen's Reaction Series

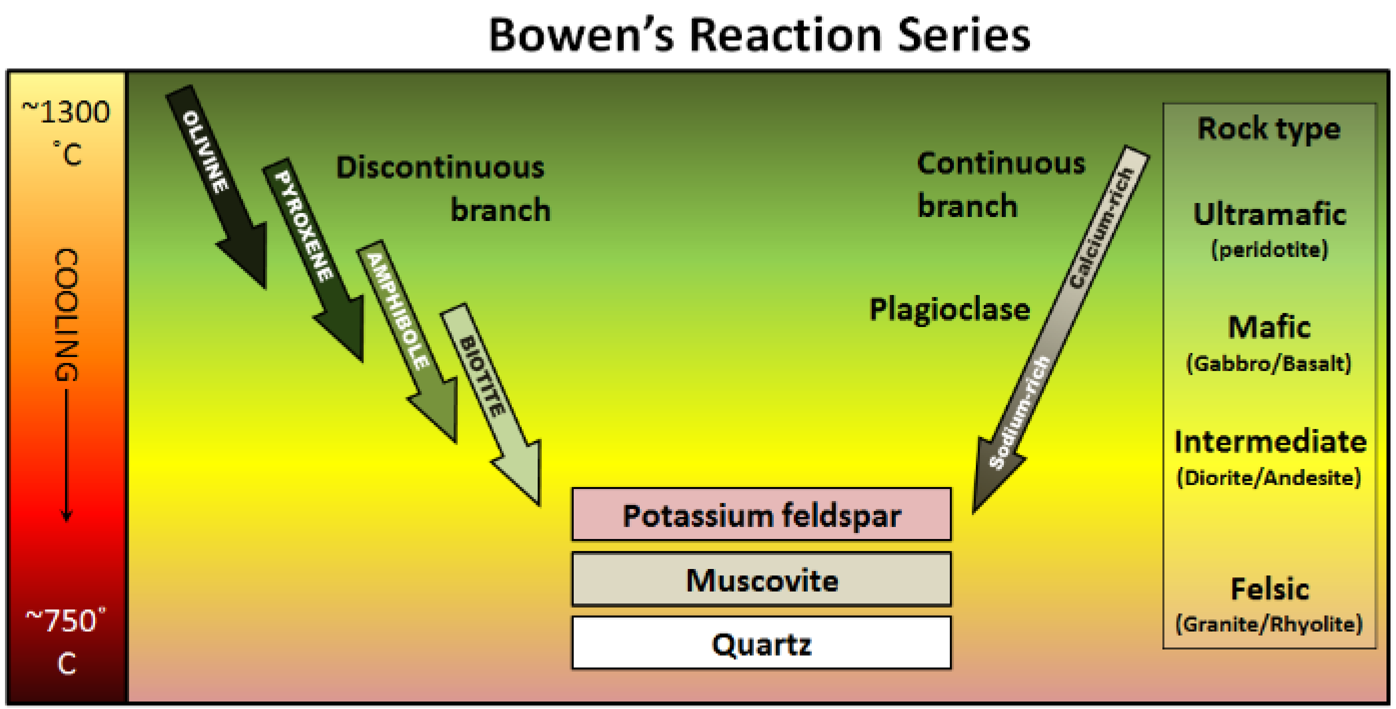
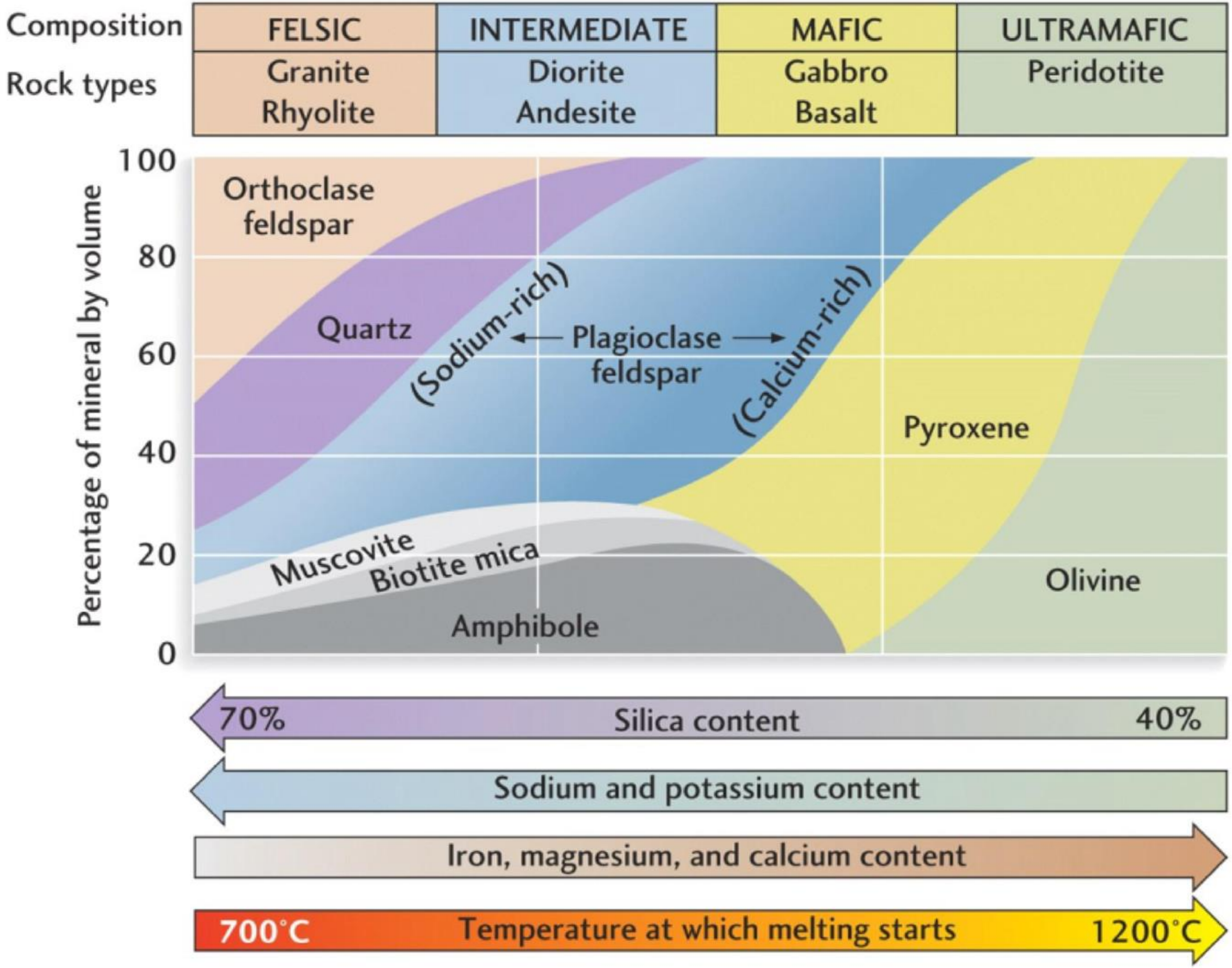


Figure 3.3.1 The Bowen reaction series describes the process of magma crystallization.


Composition
Rock types
FELSIC
Granite
Rhyolite
INTERMEDIATE
Diorite
Andesite
MAFIC
Gabbro
Basalt
ULTRAMAFIC
Peridotite
Percentage of mineral by volume
100
80
60
40
20
0
Orthoclase feldspar
Quartz
(Sodium-rich)
Plagioclase feldspar
(Calcium-rich)
Pyroxene
Olivine
Muscovite
Biotite mica
Amphibole
70%
Silica content
40%
Sodium and potassium content
Iron, magnesium, and calcium content
700°C
Temperature at which melting starts
1200°C

Igneous Rocks

- Intrusive
  - Form from magma
  - Cool underground
  - Coarser grained
- Extrusive (“volcanic”)
  - Form from lava
  - Cool above ground
  - Fine-grained or aphanitic

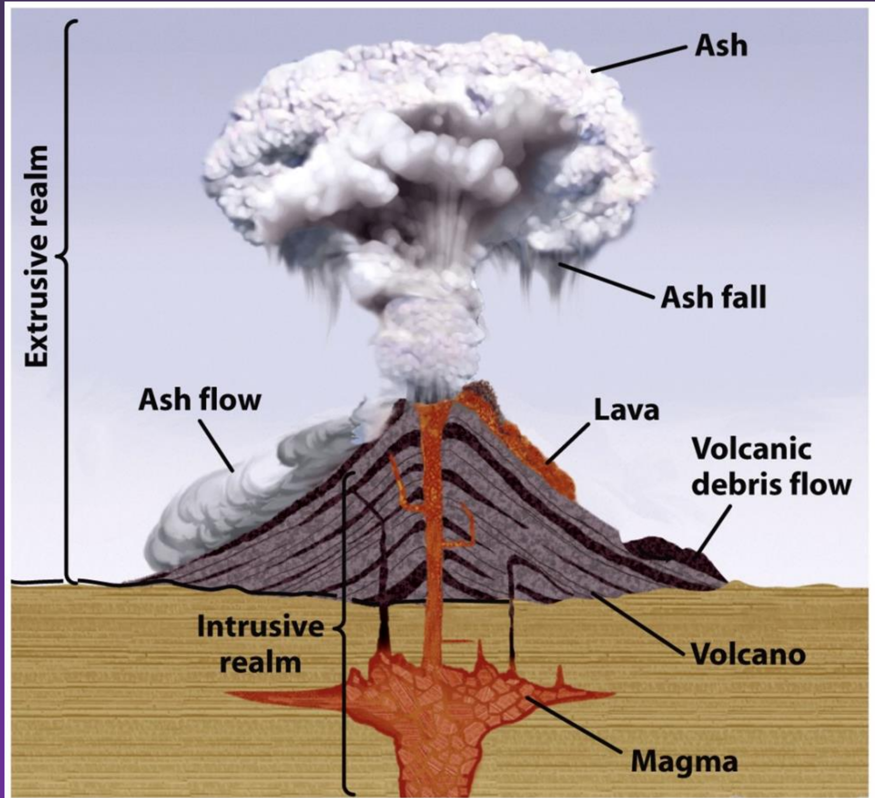


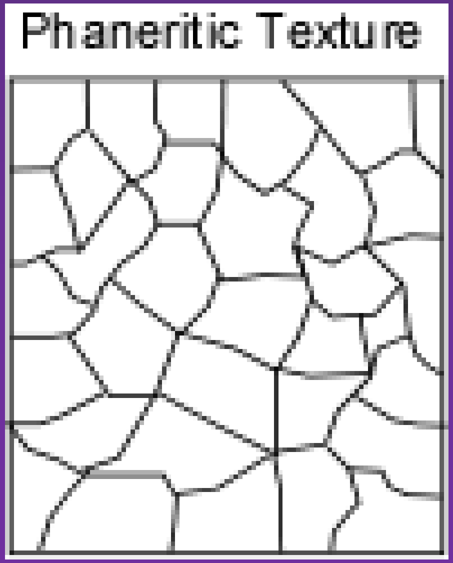
Figure 6-2 Earth: Portrait of a Planet 3/e

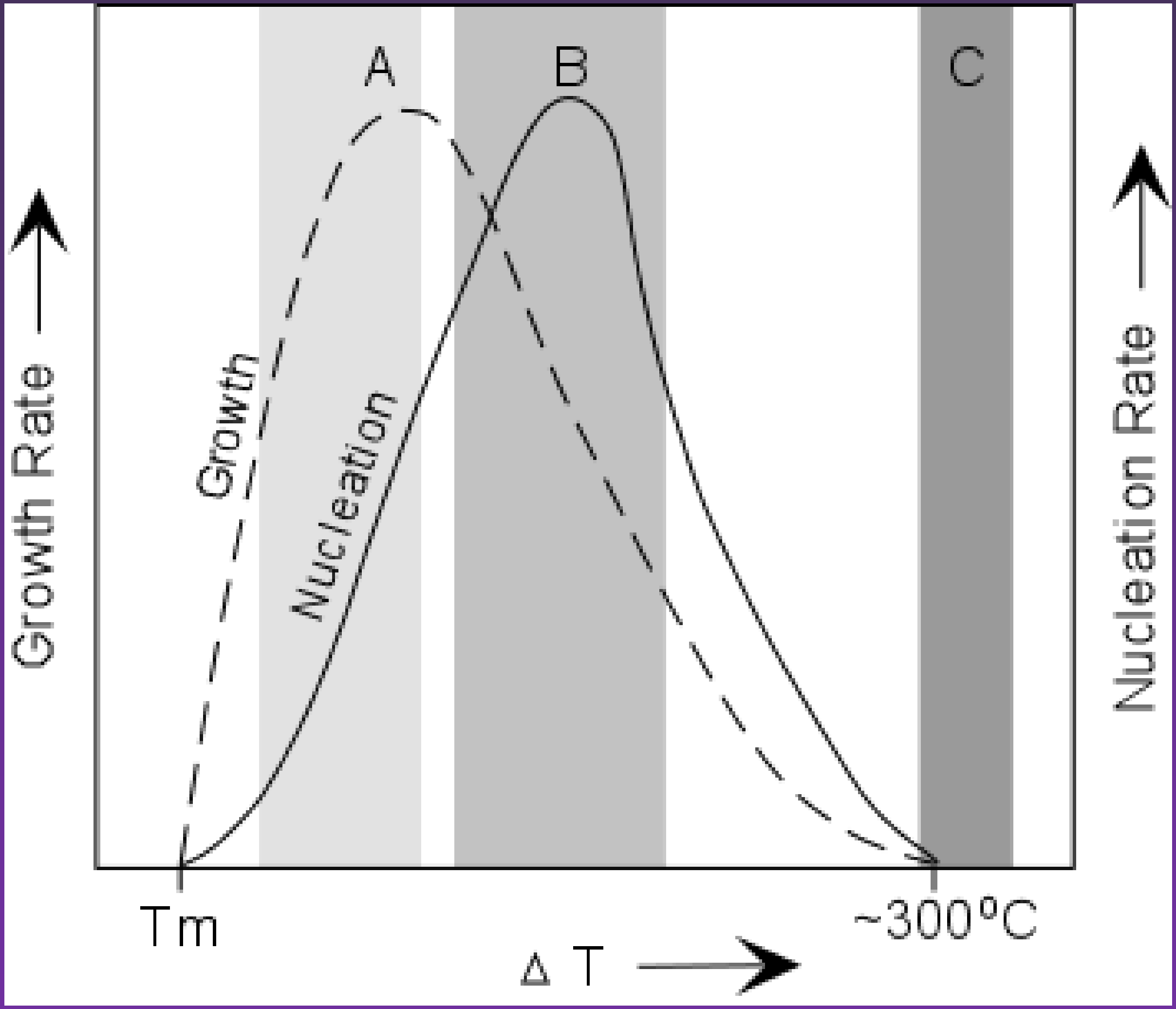
Factors Controlling Texture

- **Cooling rate** ($\Delta T/\Delta t$)
- Diffusion rate
- Rate of nucleation of new crystals
- Rate of growth of crystals

Phaneritic Textures

- A.

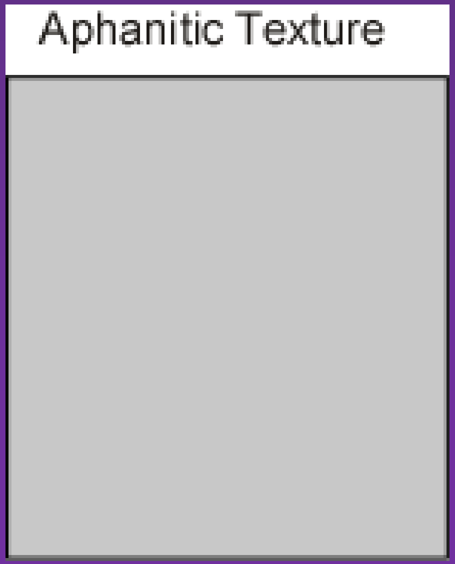


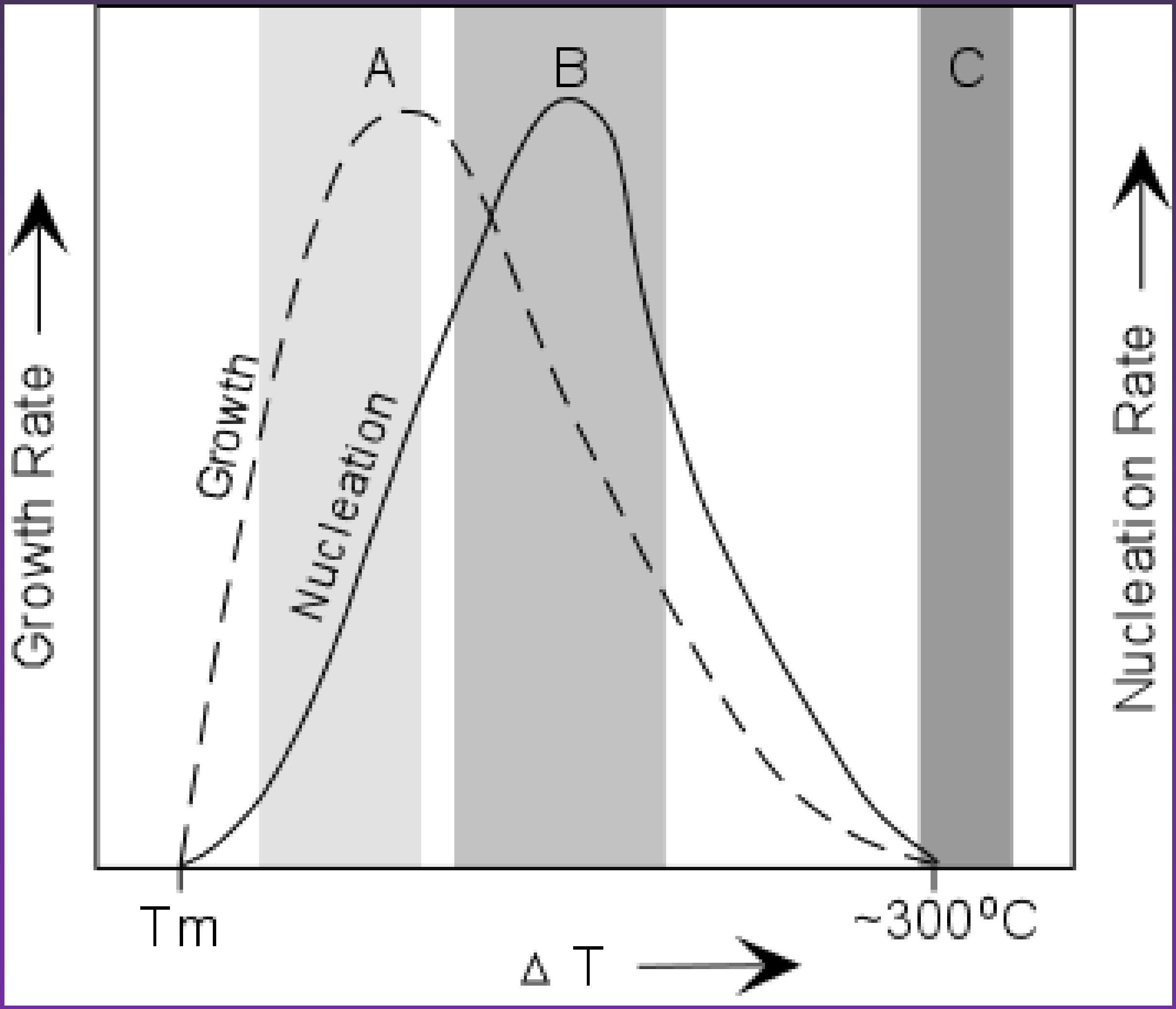


https://www2.tulane.edu/~sanelson/eens212/textures_igneous_rocks.htm

Aphanitic Texture

- B

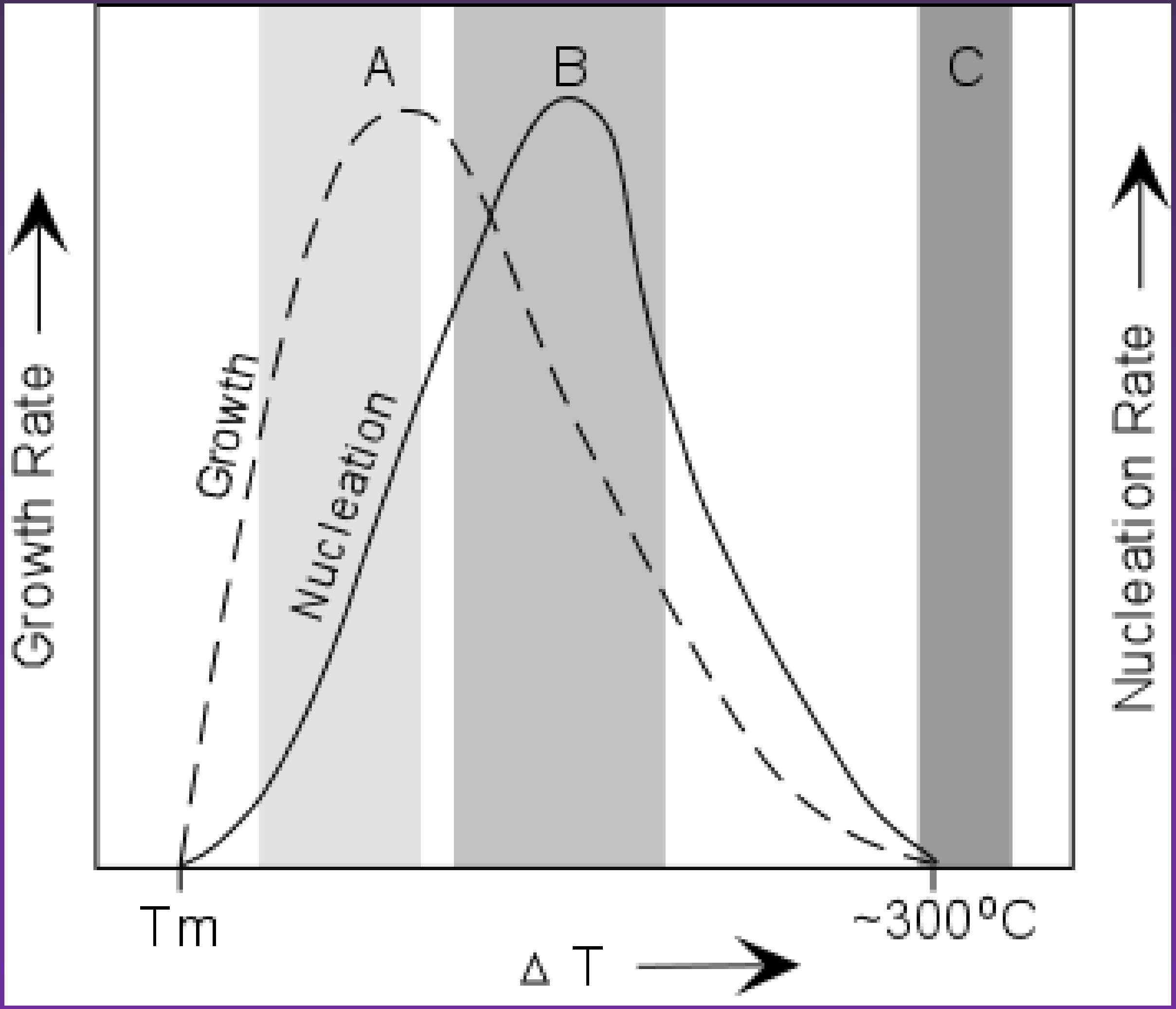




https://www2.tulane.edu/~sanelson/eens212/textures_igneous_rocks.htm

Holohyaline (glassy) Texture

- C



https://www2.tulane.edu/~sanelson/eens212/textures_igneous_rocks.htm

Intrusive Rocks

- Slow cooling magmas because of insulation by country rocks
- Relatively coarse-grain size (>1mm)

Classification by Texture

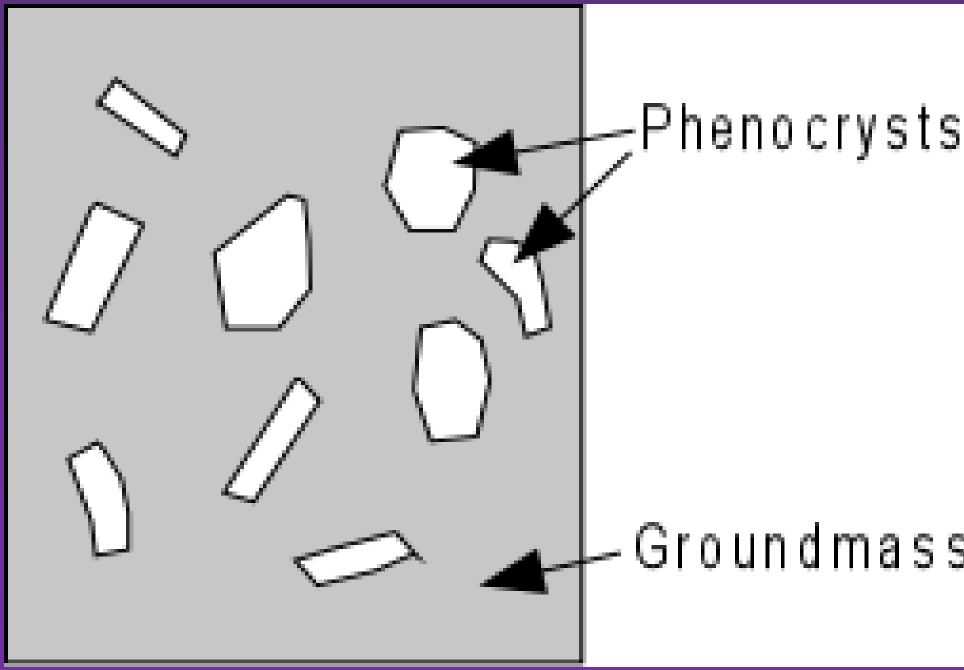
- Intrusive textures (slow cooling)
  - Crystalline
    - Grain size – are grains large or small?
      - Fine-grained (<1mm)
      - Medium-grained
      - Coarse-grained (>5mm)
    - Equigranular – grains are the same size

Classification by Texture

- Extrusive (or rapidly cooled intrusive rocks)
  - Aphanitic
    - crystals cannot be distinguished with a hand lens)
  - Holohyaline
    - glassy

Textures

- Porphyritic (both intrusive and extrusive)
  - mix of large, euhedral grains, and fine-grained or aphanitic groundmass



https://www2.tulane.edu/~sanelson/eens212/textures_igneous_rocks.htm

Why do magmas move?

- Buoyancy
- Weight of overlying rocks

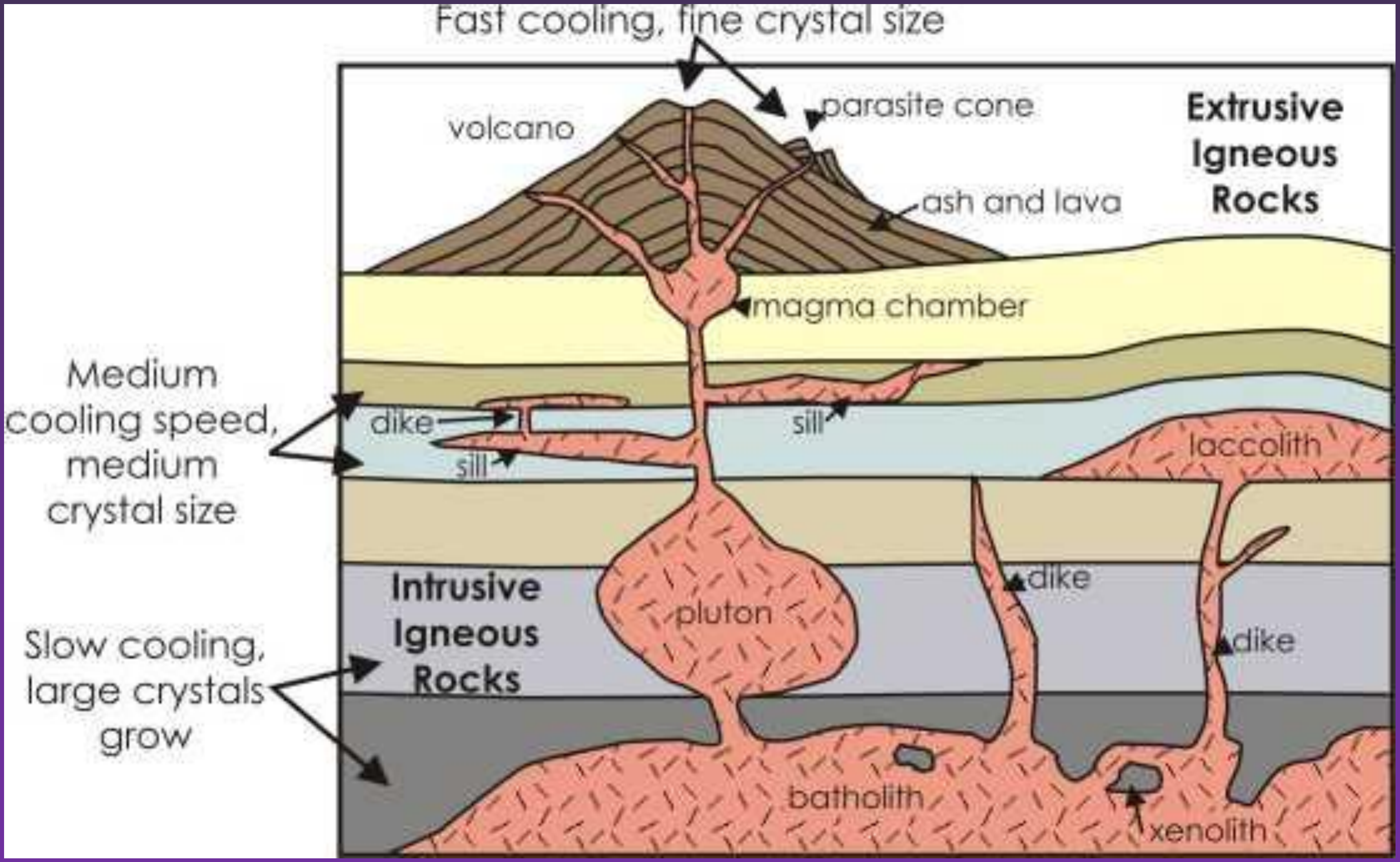
Speed of magma?

- Determined by viscosity
- Controlled by
  - Temperature
  - Silica content
  - Volatiles

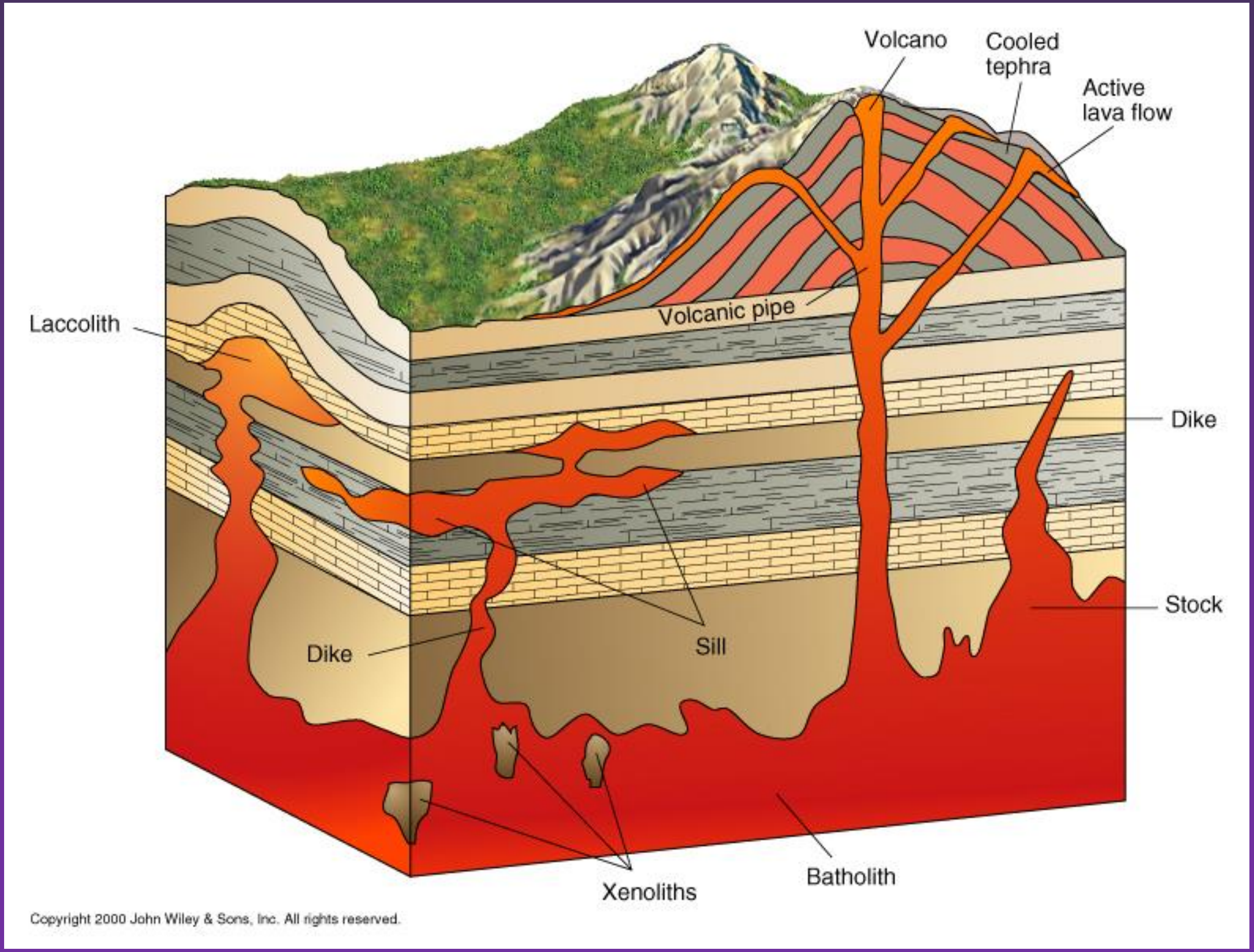
“Freezing”

- Occurs due to
  - Cooling
  - Loses volatiles
- Rate of cooling
  - Depth
  - Shape and size
  - Groundwater

Intrusive Rocks



Intrusive Rocks



- *Amount Of Silica:* *(Intrusive / Extrusive)*
- **Felsic** - 66-76% silica (granite / rhyolite)
  - high viscosity - less dense
  - Light colour - solid @ 650C +/-
- **Intermediate** - 52-66% (diorite / andesite)
  - interm viscosity - mod density
  - interm colour - 900C+/-
- **Mafic** - 45-52% (gabbro / basalt)
  - low viscosity - dense
  - dark colour - >1000C
- **Ultramafic** - 38-45% (peridotite/komatiite)
  - (1300C+/-)
  - very low viscosity - very dense - dark coloured

Volcanic (Extrusive) Rocks

- Two main groups of volcanic rocks
  - Lava flows
  - Pyroclastic rocks

Classifications

- Textures
    - Obsidian- volcanic glass- dark, sharp
    - Pumice - felsic, “frothy”, vesicles, light colour, floats
    - Scoria -mafic, vesicles, dark colour, dense

  – Fragmented – Pyroclastic – extrusive
    - Depends on size of fragments
    - Tuff – fine (ash)
    - Volcanic breccia – fragments of volcanic debris (coast fabrics)

Bowen’s Reaction Series

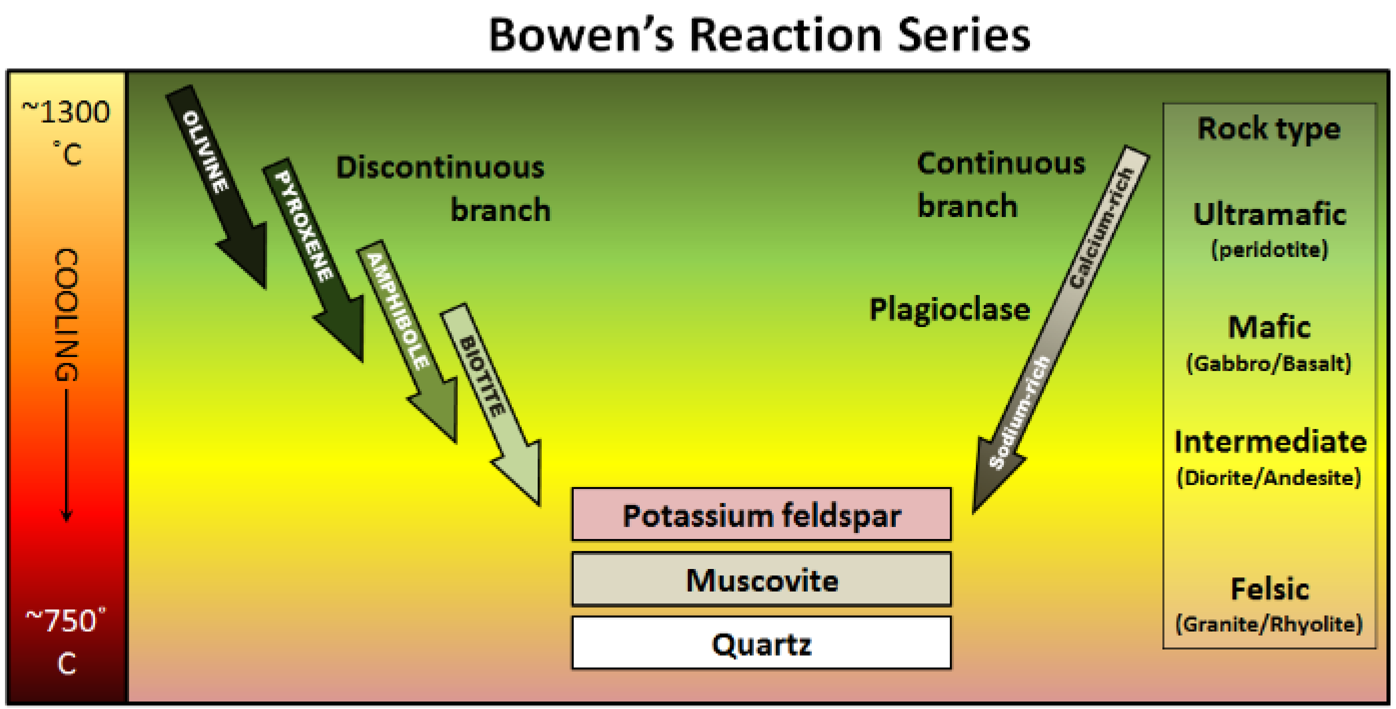
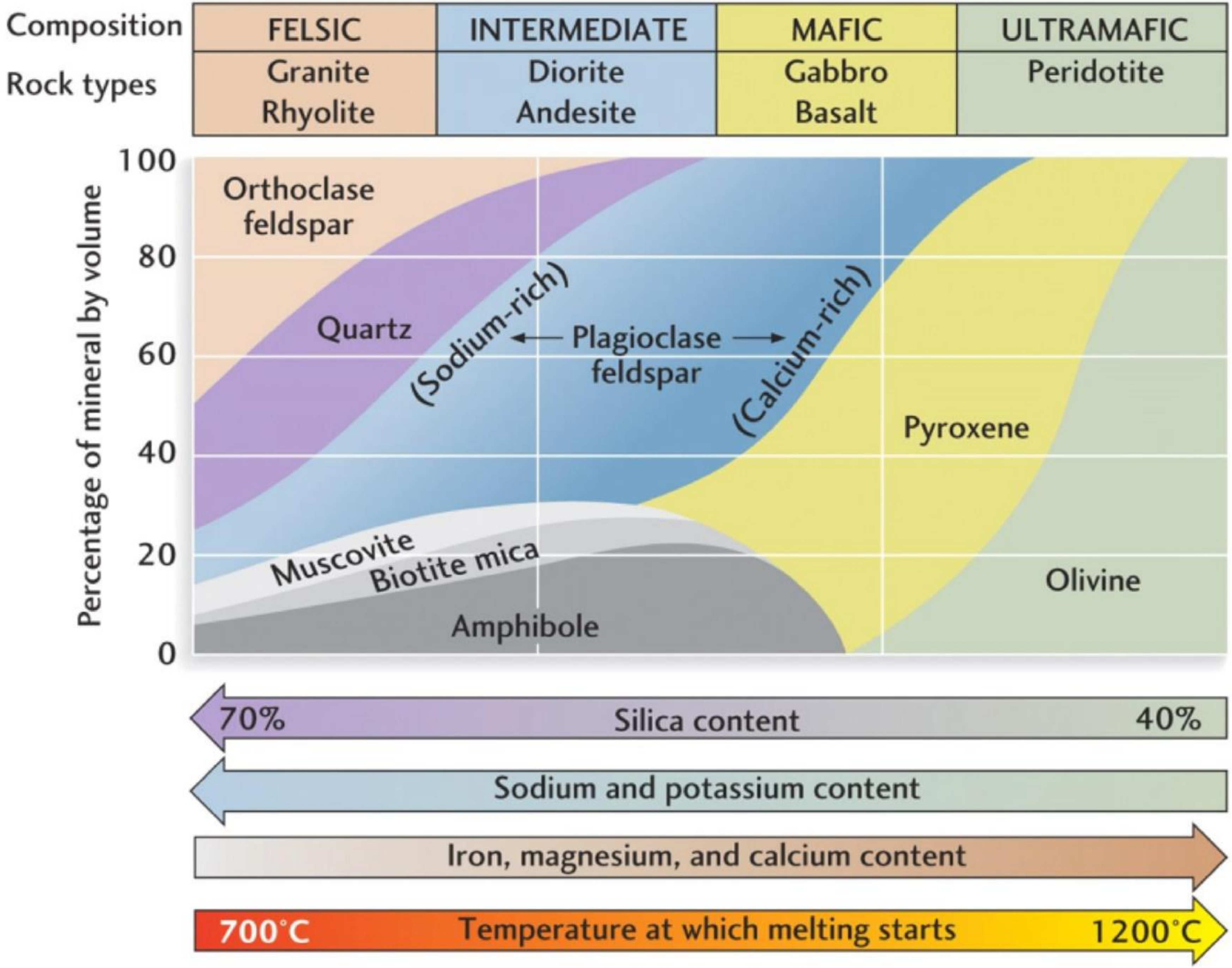
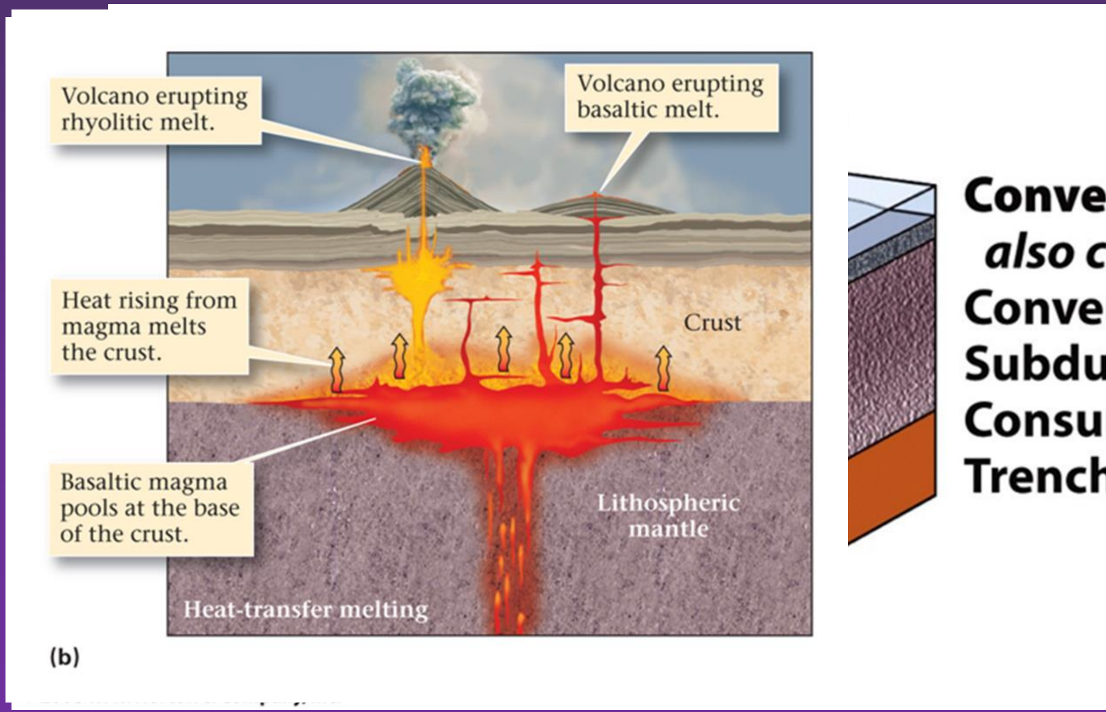


Figure 3.3.1 The Bowen reaction series describes the process of magma crystallization.


Composition
Rock types
FELSIC
Granite
Rhyolite
INTERMEDIATE
Diorite
Andesite
MAFIC
Gabbro
Basalt
ULTRAMAFIC
Peridotite
Percentage of mineral by volume
100
80
60
40
20
0
Orthoclase feldspar
Quartz
(Sodium-rich)
Plagioclase feldspar
(Calcium-rich)
Pyroxene
Olivine
Muscovite
Biotite mica
Amphibole
70%
Silica content
40%
Sodium and potassium content
Iron, magnesium, and calcium content
700°C
Temperature at which melting starts
1200°C

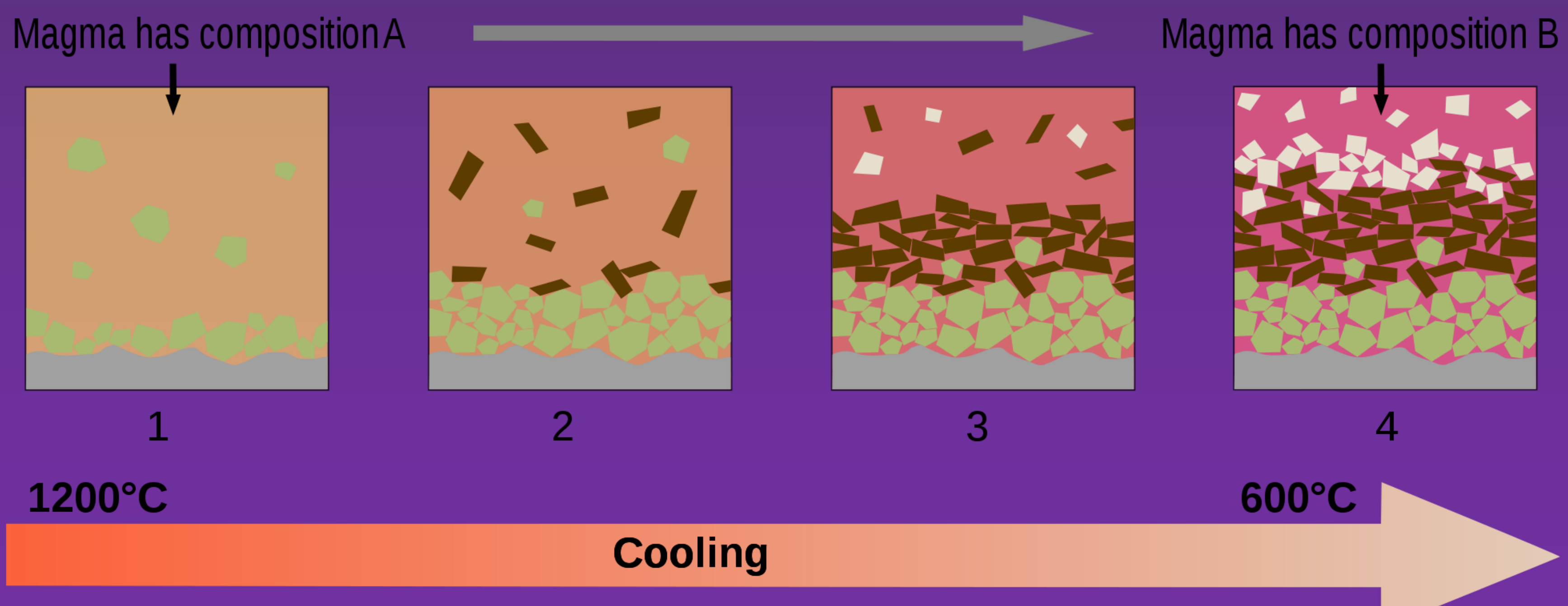
Why are there different types of Igneous Rocks?

- Source rock
- Crystal Fractionation
- Partial Melting
- Assimilation
- Magma mixing



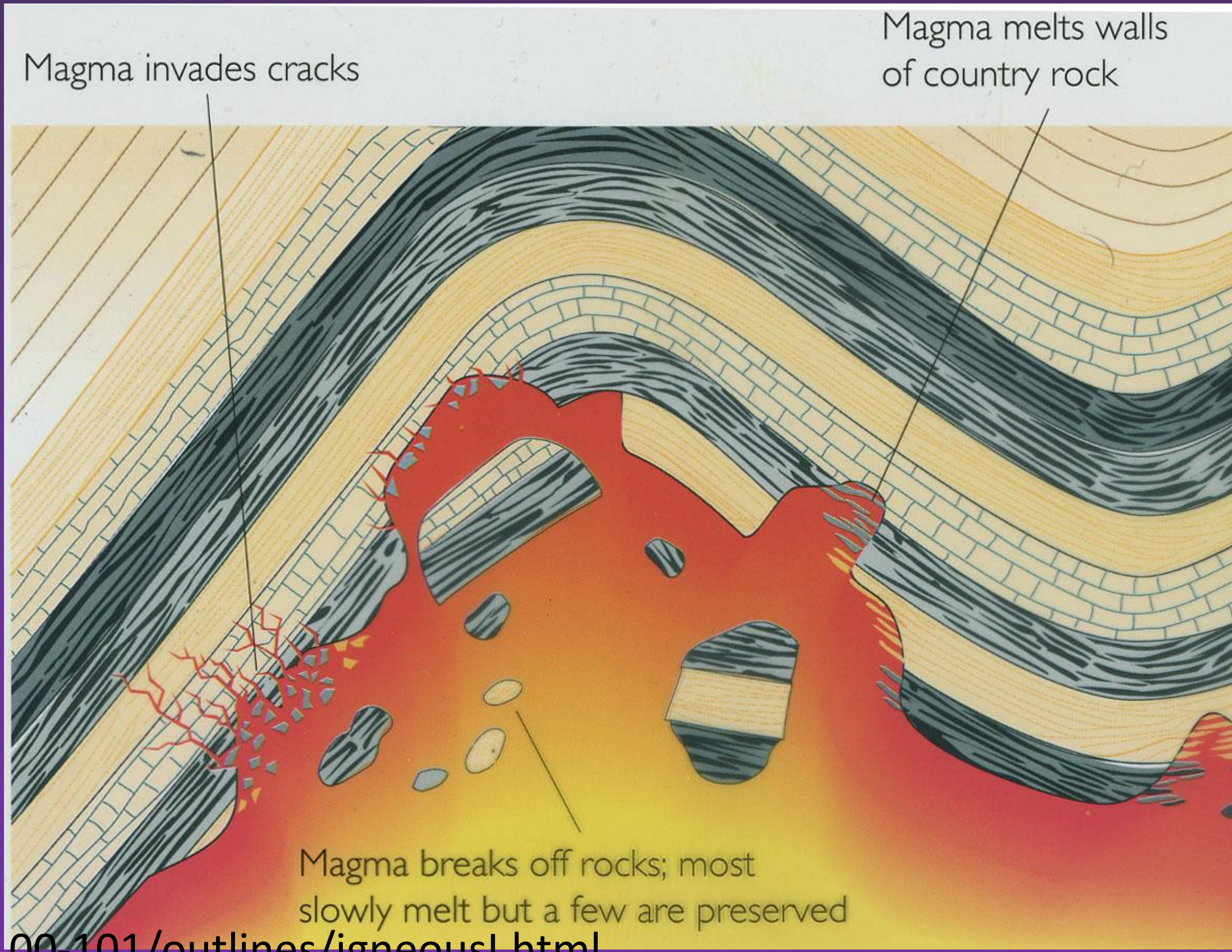
Crystal Fractionation

- Mafic minerals crystallize first
- More dense crystals fall out, leaving a more silica-rich magma



Assimilation

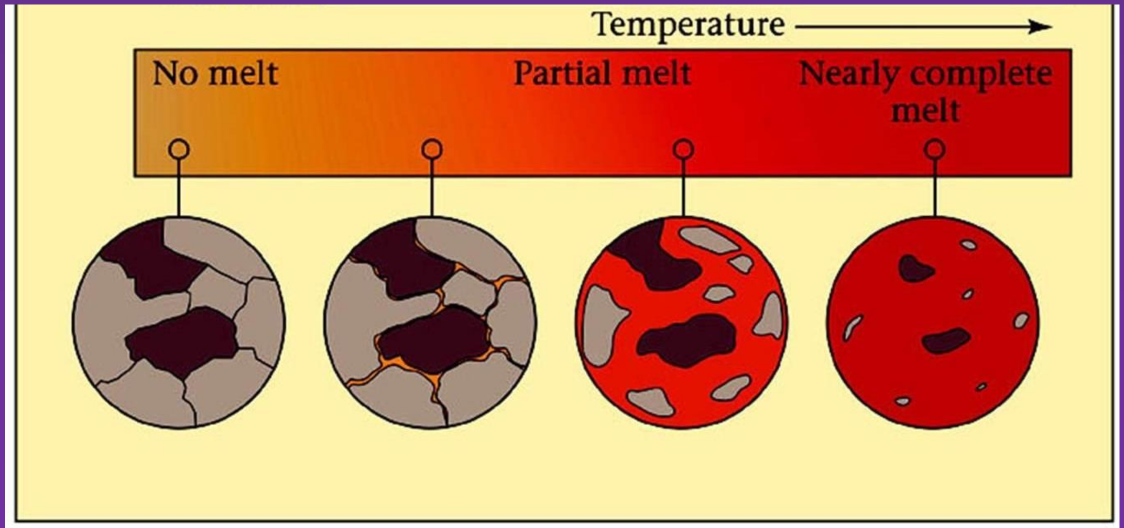
- Add elements from the surrounding rocks



http://jan.ucc.nau.edu/~nrr/GLG100-101/outlines/igneousI.html

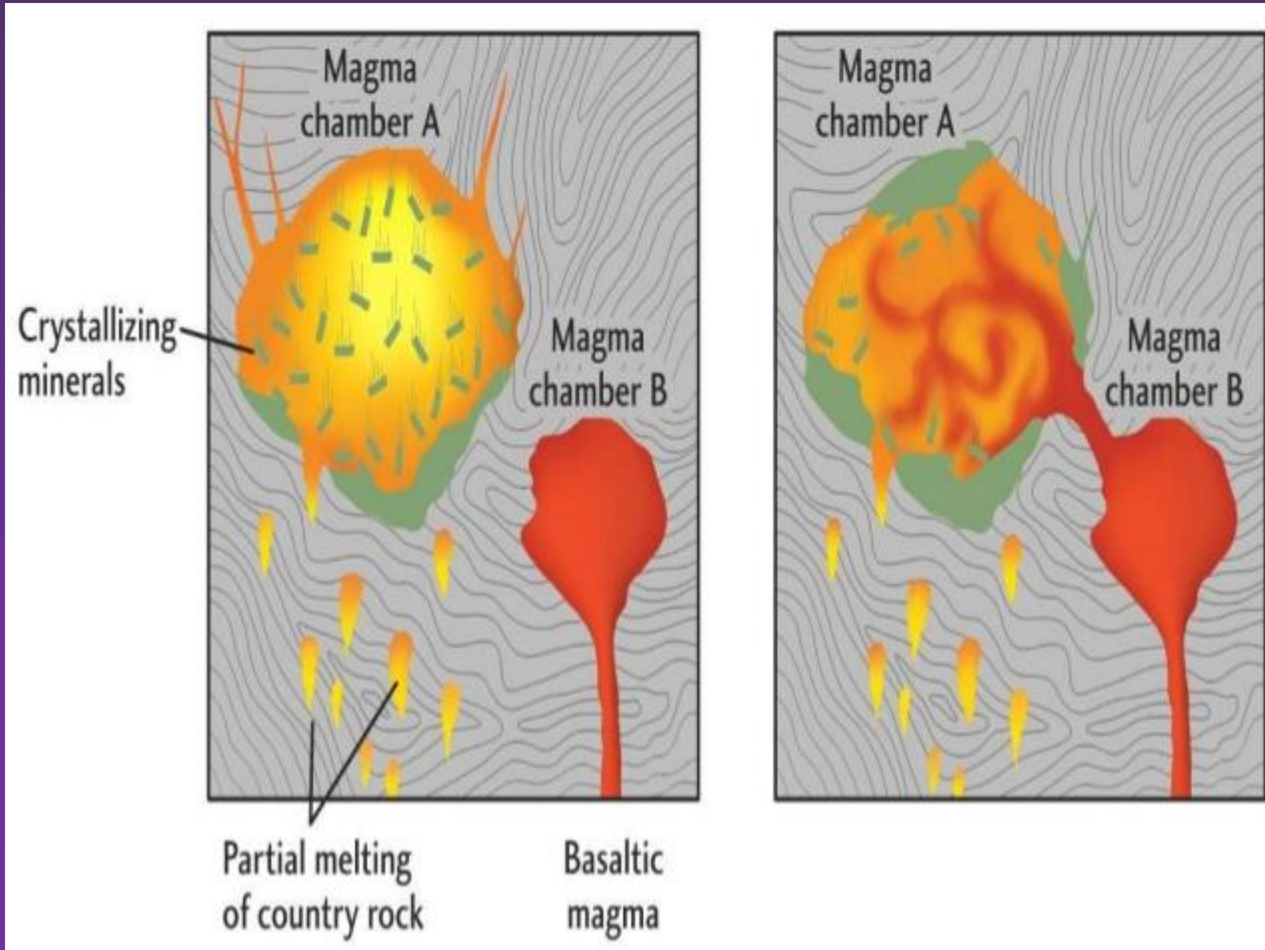
Partial Melting

- Silica-rich minerals melt first
- Partial melting produces melts with more silica
- Remove melt:
  - Silica-rich melt
  - Mafic residue



Magma Mixing

- Magmas of different compositions mix together, producing a magma of intermediate composition



Magma Composition

- Silicon (Si)
- Oxygen (O)
- Al
- Mg, Fe
- Ca, K, Na
- And water! (H_2O)
- Other elements in minor amounts

Classifying Igneous Rocks

- Amount of Silica
  - Felsic 66-76% SiO_2
  - Intermediate 52-66% SiO_2
  - Mafic 45-52% SiO_2
  - Ultramafic 38-45% SiO_2

Classifying Igneous Rocks

- **Amount of silica** **Intrusive/Extrusive**
- Felsic Granite/ Rhyolite
  - High viscosity – less dense
  - Light colour – solid @ 650°C
- Intermediate Diorite/ Andesite
  - Intermediate viscosity and moderate density
  - Intermediate colour – solid @900°C
- Mafic Gabbro/ Basalt
  - Low Viscosity – dense
  - Dark colour - >1000°C
- Ultramafic (intrusive only)
  - Very low viscosity – very dense – dark colour 1300°C

Geochemistry of Rocks

GRANITE CHEMISTRY

SiO_2	70.24
TiO_2	1.21
Al_2O_3	13.23
FeOt	2.21
MgO	1.49
CaO	1.11
Na_2O	3.50
K_2O	5.43
P_2O_5	0.13
LOI	2.60

LOI = Loss on Ignition
FeOt = total iron