

EPSC 201 – LECTURE 14 – FEBRUARY 25 2016

Practice Question: What is the difference between magma and lava?

Answer: Location: the former is molten rock underground whereas the latter is molten rock at the Earth's surface.

Practice Question: In the upper crust of a continent, the geothermal gradient is about...

Answer: Continental crust is 10-20km thick. The geotherm describes the relationship between temperature and depth. The geotherm starts at 0°C at the surface and increases to ~500°C at the base of the crust. $\sim 500/10 = 50^\circ\text{C}/\text{km} = \text{answer C between } 20\text{-}30^\circ\text{C}$

Practice Question: Which of the following phenomena will cause melting to produce magma?

Answer: Transfer of heat from a hot magma into surrounding wall rock. Note: pressure can cause melting but it is a decrease of pressure – you can take rock from high pressure to low pressure like in a hot spot and get melting to occur.

Volcanoes are linked to plate tectonics, they are found at plate boundaries. E.g. ring of fire – ring of volcanoes along the subduction zones around the oceanic plate in the Pacific.

Where does the heat inside the Earth come from? Gravity bringing particles together and smashing into each other which generated a lot of energy and heat in the center of the Earth. 2 more ways to add heat into the center of the Earth: 1. Radioactive elements that decay which release heat 2. Meteorites hit the Earth adds heat to the Earth.

Sources of heat to the early Earth:

Remnant Heat:

- Planetesimal and meteorite accretion
- Gravitational compression: iron differentiation and early collision with planetoid

Ongoing heat generation:

- Decay of radioactive elements in the crust

Earth slowly loses heat to space. Eventually, Earth will solidify.

What is a rock?

Coherent:

- Holds together, can be broken into separated pieces, can form cliffs, be sculpted, etc.
- A pile of sand... not a rock.

Naturally occurring:

- Manufactured materials like concrete, brick... not rocks.

An aggregate of minerals or a mass of glass:

- Most are a collection of many mineral grains and/or crystals stuck or grown together.
- Some contain only one kind of mineral
- Some rock types are glass (not crystalline)

Magma viscosity and flow behaviour

Lava flows sometimes race down the side of a volcano, sometimes it builds up into a rubble-covered mound, and sometimes oozes out like toothpaste.

- Basaltic lava forms thin sheets (flows rapidly, easily)
- Andesitic lava tends to break up as it flows (thicker, flows less easily)
- Rhyolitic lava piles up at the vent as a dome (does not flow easily so it builds up, does not spread very far)

The viscosity (resistance to flow) of a lava depends on:

- Chemical composition
- Temperature
- Gas content
- Crystal content

High viscosity means it does not flow easily, low viscosity means it flows easily.

The surface texture of the basaltic flow, when it freezes, reflects the timing of freezing relative to how fast it was moving (ex. Pahoehoe or ropy lava).

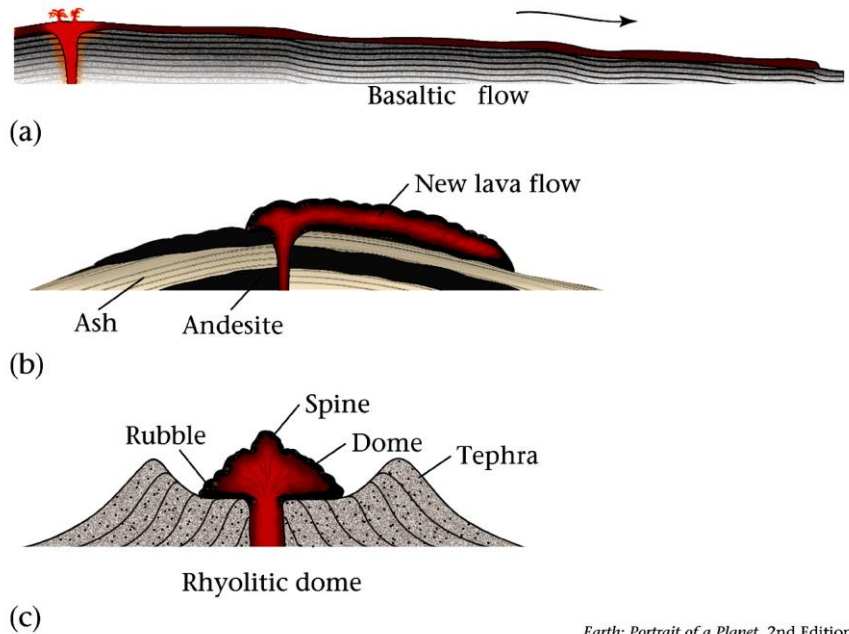
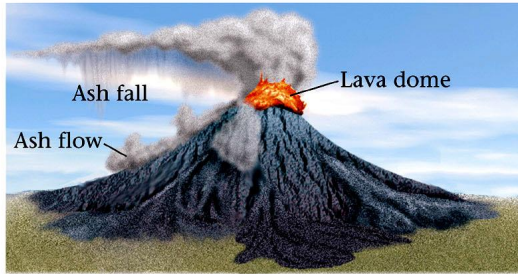


FIGURE 9.2

SHIELD VOLCANOE



(a)

STRATOVOLCANO



(b)

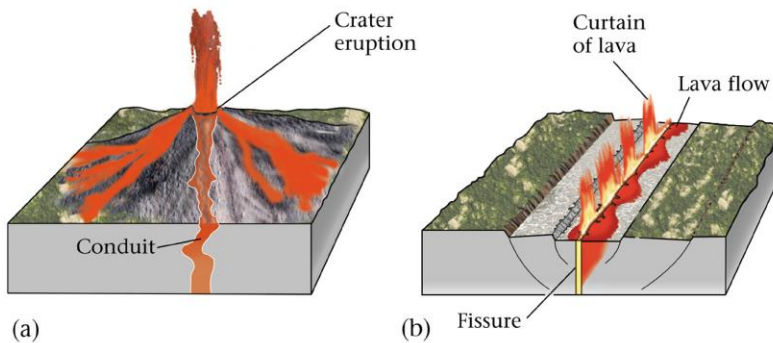
Not to scale



Shield volcano: lava flows quickly and faster, low viscosity. Forms a dome shape.

Stratovolcano: high viscosity, lava builds up forming a steeper peak similar to a mountain peak.

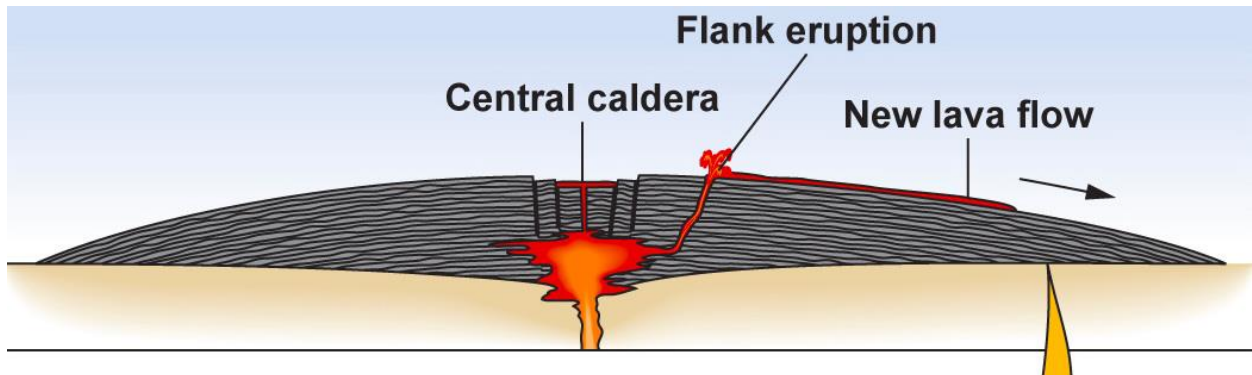
Shield Volcano Eruption: low viscosity lava that erupts from a circular vent or along a crack/fissure (line along the Earth). Examples: Piton de la Fournaise, Reunion; Mauna Loa, Hawaii (largest active volcano on Earth)



(a)

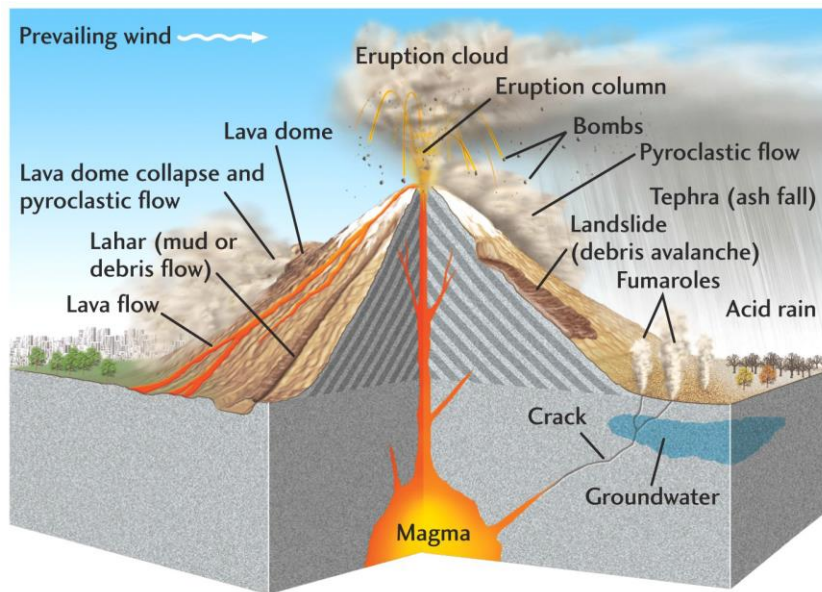
(b)

Flank eruption: sometimes lava can travel up a different area. Because this happens, you may end up with lava erupting along a linear tear (a fissure). Fissure eruptions may display a “curtain of fire”.



Stratovolcano Eruptions: Large, cone-shaped ones. Typically form from medium to high viscosity lava (andesitic), often leading to explosive volcanism. Because you have something that is harder to flow, they are more eruptive – spew out more dramatically. More pressure blocking the way so when it’s finally released it shoots higher up. Examples: Mt Fuji, Japan; Pinchincha, Ecuador; Karymsky, Kamchatka, Russia.

Stratovolcanoes are large, cone-shaped volcanoes with steep slopes made of alternating layers of felsic lava, tephra, and debris. Often symmetric, they can acquire odd shapes following landslides, etc.



Eruption cloud: All the stuff that comes out

Pyroclastic flow: bits of rock and cooled lava – hard bits that are flowing down (cooled debris on the bottom and lava flow flows on top of it).

Lava flowing down

Lahar: when you have ice and snow on the mountain that is melting very rapidly as it is suddenly heated (similar to a flood) – travel very

quickly if there is ice on top of the mountain

Volcanic ash: little bits of crystallized glass which can be inhaled = dangerous

Volcanoes erupt large quantities of fragment – volcaniclastic deposits. The material includes pyroclastic debris, pre-existing rock, landslide debris, and lahars.

Order of eruption components: lahar – flows very fast, pyroclastic debris, then the lava.

Acidic lakes can form around volcanic eruptions because of the gases which are released. CO₂ released can actually lead to increased lake acidity.

Silicate Structures: Silica tends to link into long chains and these increase the lava viscosity.

Higher silicate content = more viscous

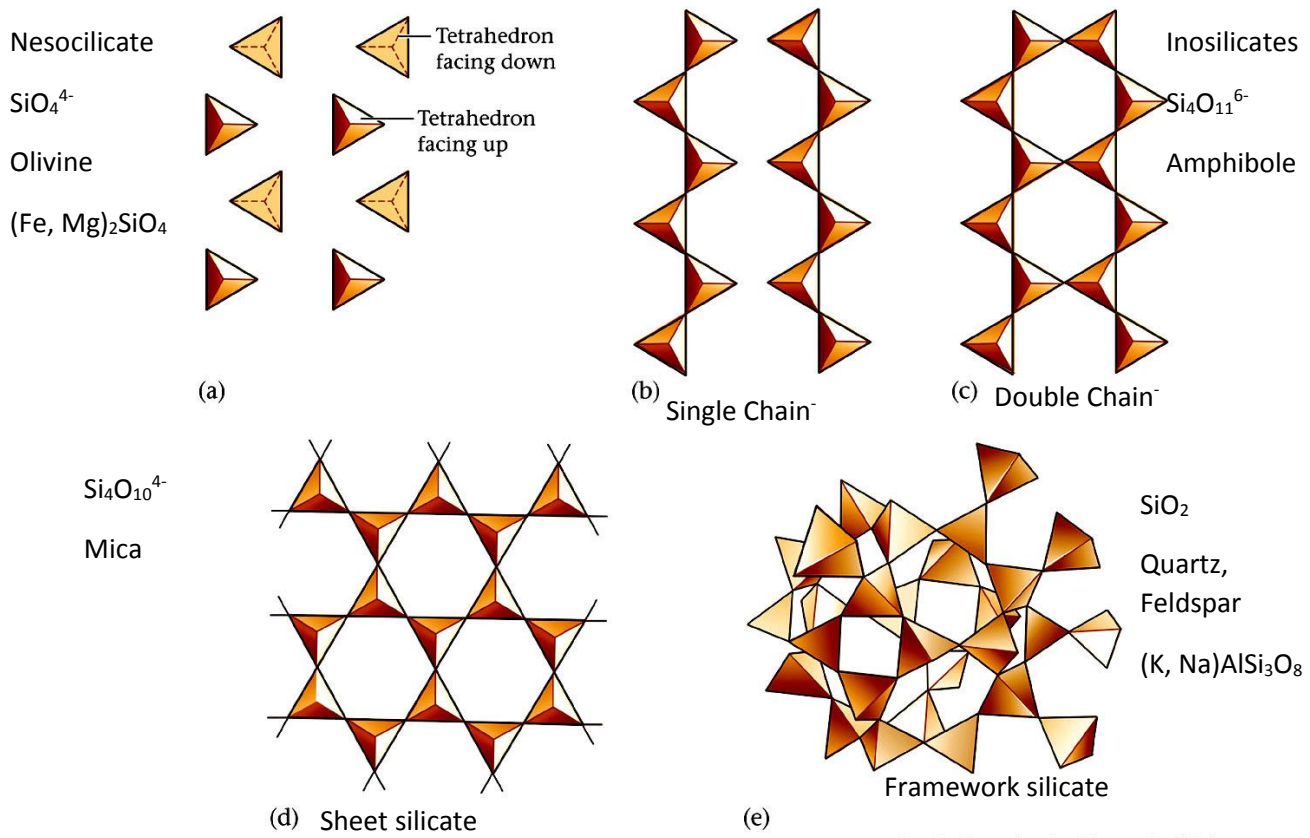


FIGURE 5.24

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Major types of magma: there are 4 types of magma based on their % silica content (SiO₂)

- Felsic (feldspar and silica) : 66%-76% SiO₂
- Intermediate : 52%-66% SiO₂
- Mafic (Mg- and Fe-rich) : 45%-52% SiO₂
- Ultramafic : 38%-45% SiO₂

Classification of Igneous Rocks

Extrusive Igneous Rocks: Cooled on the surface very rapidly so they have finer grains

Intrusive Igneous Rocks: Cool underground and slower so they have coarser grains

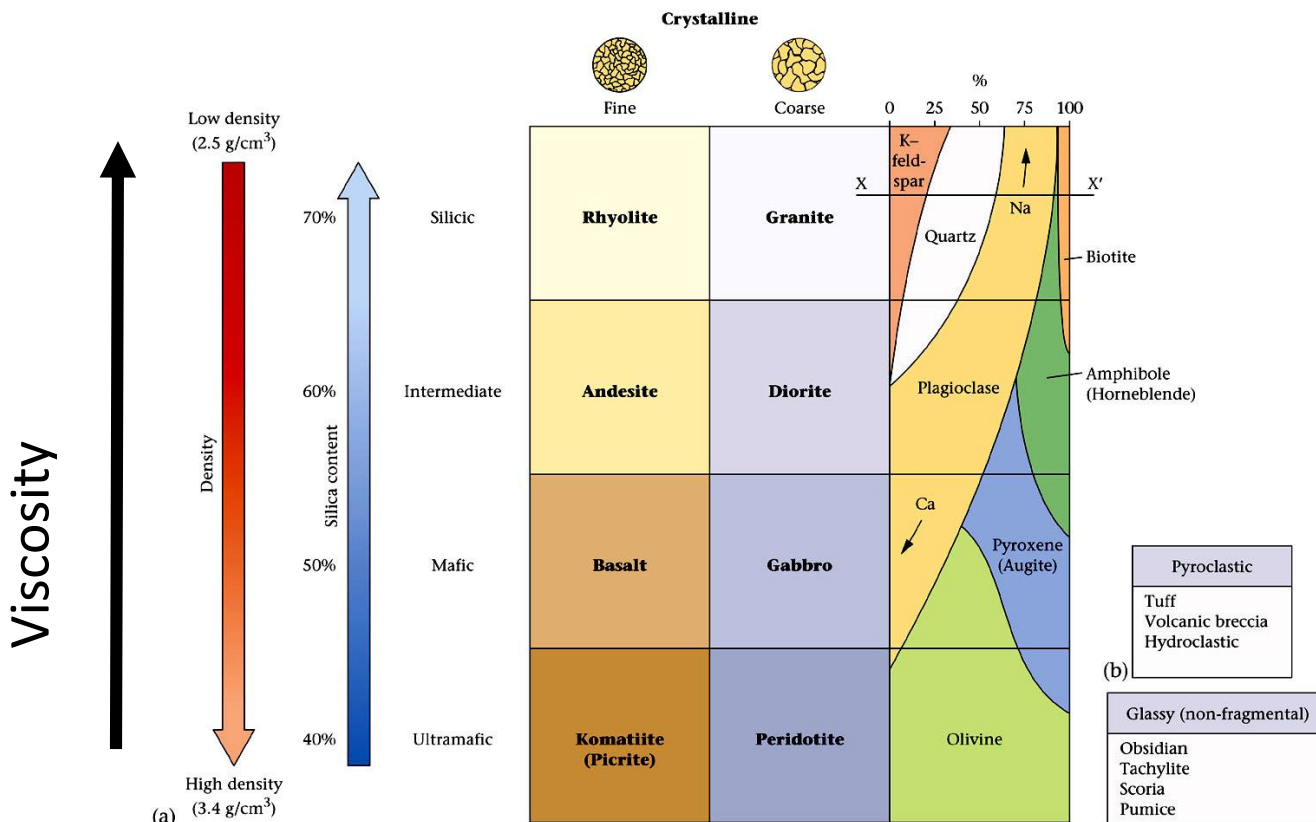


FIGURE 6.18

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**know this table...

Major types of magma

-Why are there different magma compositions?

-Magmas vary chemically due to:

- Initial source rock compositions – where does the rock come from? Is it mantle rock that melted and is rising to the surface? Is it rock near the surface that is melting?
- Partial melting – degree to which it melts (different materials have different MP)
- Assimilation – magma from the mantle starts to melt other rocks
- Magma mixing

Magma Variation

Source rock dictates initial magma composition.

- Mantle source: ultra-mafic and mafic magmas (low silicate content)
- Crustal source: mafic, intermediate, and felsic magmas (high silicate content)

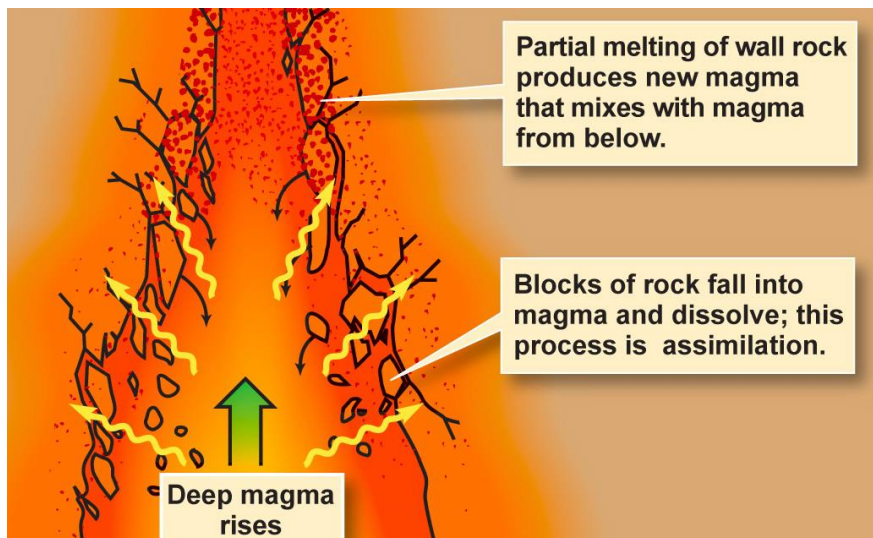
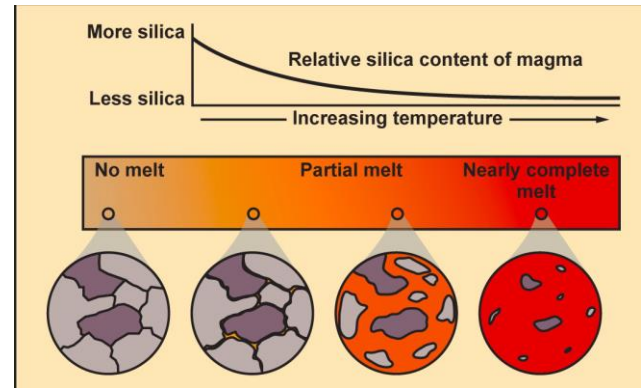
Partial Melting

Upon melting, rocks rarely dissolve (melt) completely. Instead, only a portion of the rock melts.

- Si-rich minerals melt first, Si-poor minerals melt last
- Partial melting, therefore yields a silica-rich magma
- Removing partial melt from its source creates felsic magma and mafic residue

Assimilation: If you have a magma chamber, you are also melting the rocks surrounding the magma chamber.

- Magma melts the wall rock it passes through
- Blocks of wall rock (xenoliths) fall into magma
- Assimilation of these rocks alters magma composition



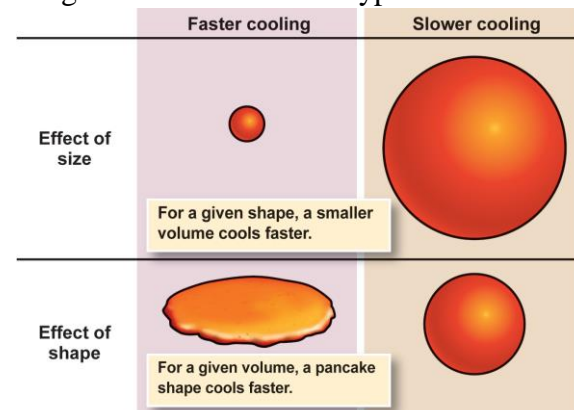
Magma Mixing: Different magmas may blend in a magma chamber. The result combines the characteristics of the two. Often magma mixing is incomplete, resulting in blobs of one rock type (xenolith) suspended within another.

Making Igneous Rock

Cooling rate – how fast does magma cool?

-Depth-deeper is hotter; shallower is cooler:

- Deep plutons lose heat very slowly; take long time to cool
- Shallow flows lose heat more rapidly; cool quickly

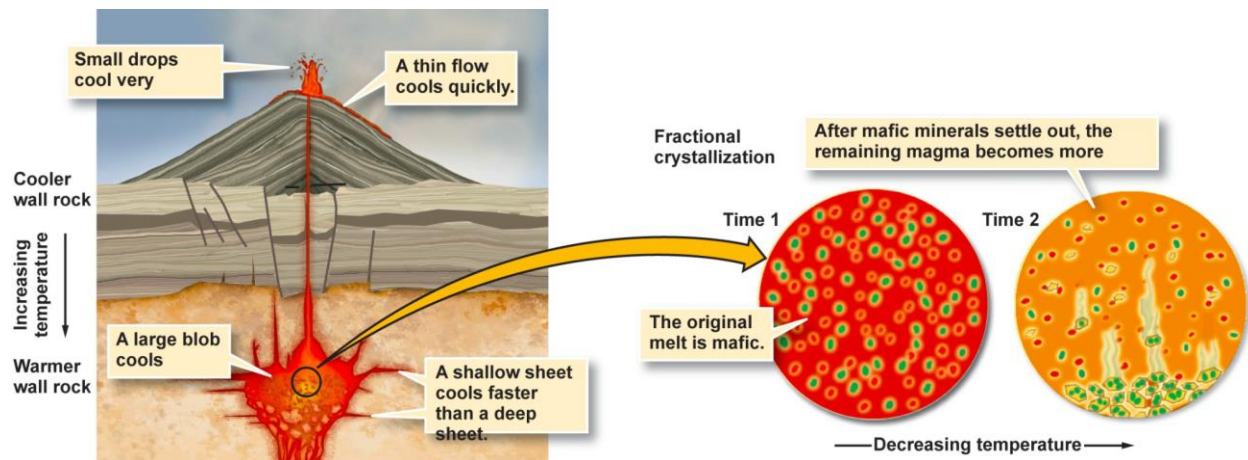


-Shape – spherical bodies cool slowly; tabular faster – more surface area is exposed to the cooler air therefore losing heat more rapidly.

-Groundwater – circulating water removes heat

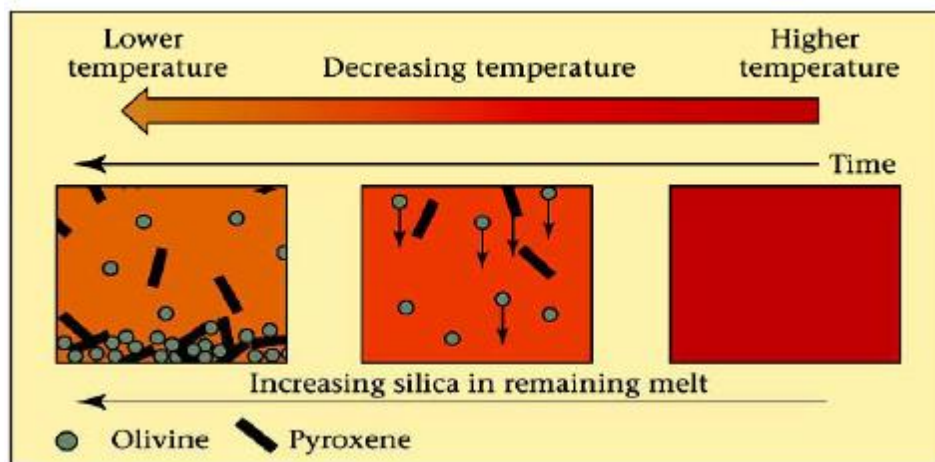
-Changes with cooling:

- Fractional crystallization – early crystals settle by gravity
- Melt composition changes as result
 - Fe, Mg, Ca are removed as early mafic minerals settle out
 - Remaining melt becomes enriched in Si, Al, Na, and K



Fractional Crystallization

When magma cools, mafic minerals that have a greater melting point will form first. As a result, the remaining magma becomes more felsic (Si-rich) as it cools → fractional crystallization

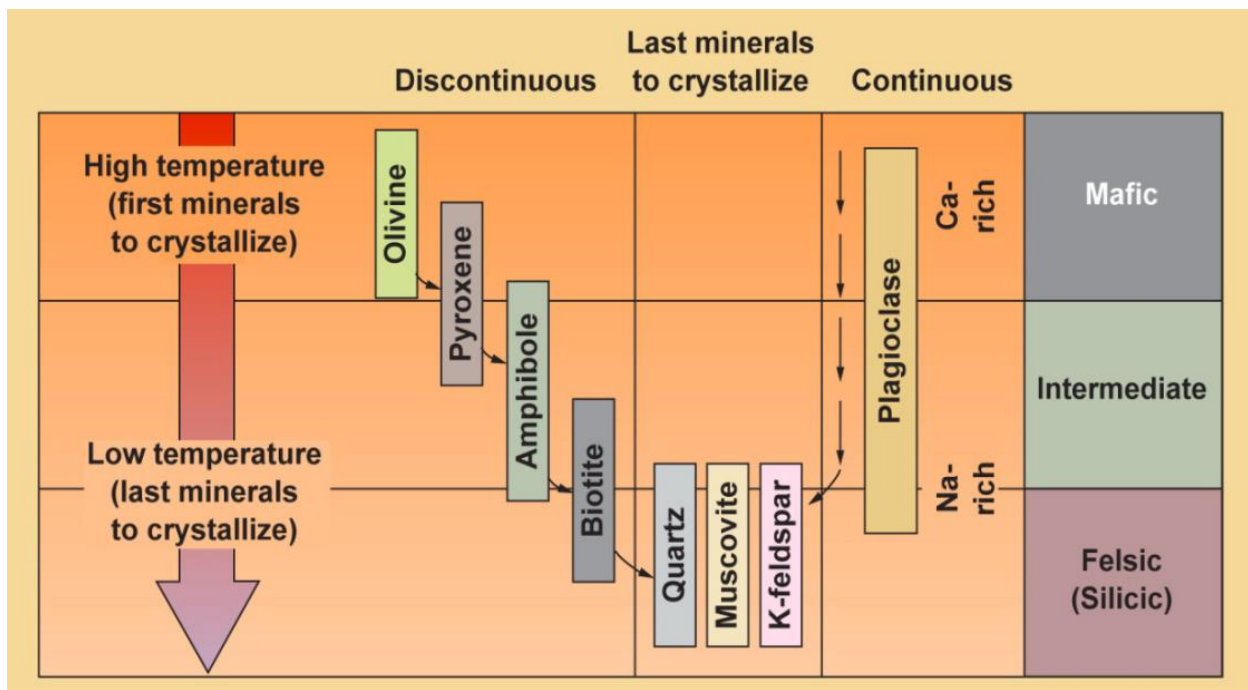


As cooling occurs, certain materials begin to solidify and create a layer. They will sink to bottom of magma. The top materials will be materials that solidify at lower temperatures. This results in different compositions in the bottom versus top layers.

Bowen's reaction series

N.L. Bowen devised experiments cooling melts (1920s). He determined at that temperature different materials solidify. Mafic materials solidify first at higher temperature and felsic materials cool slower at lower temperature.

- Early crystals settled out, removing Fe, Mg, and Ca
- Remaining melt progressively enriched in Si, Al, and Na



Igneous Environments

Two major categories – based on cooling locale.

-Extrusive settings – cool at or near the surface.

- Cool rapidly.
- Chill too fast to grow big crystals

-Intrusive setting – cool at depth

- Lose heat slowly
- Crystals often grow large

