Magmatism and Igneous Rocks

MAGMATISM AND IGNEOUS ROCKS

MAGMA:

Magma is a mixture of liquid rock, crystals, and gas. Characterized by a wide range of chemical compositions, with high temperature, and properties of a liquid.

MAGMATISM AND IGNEOUS ROCKS

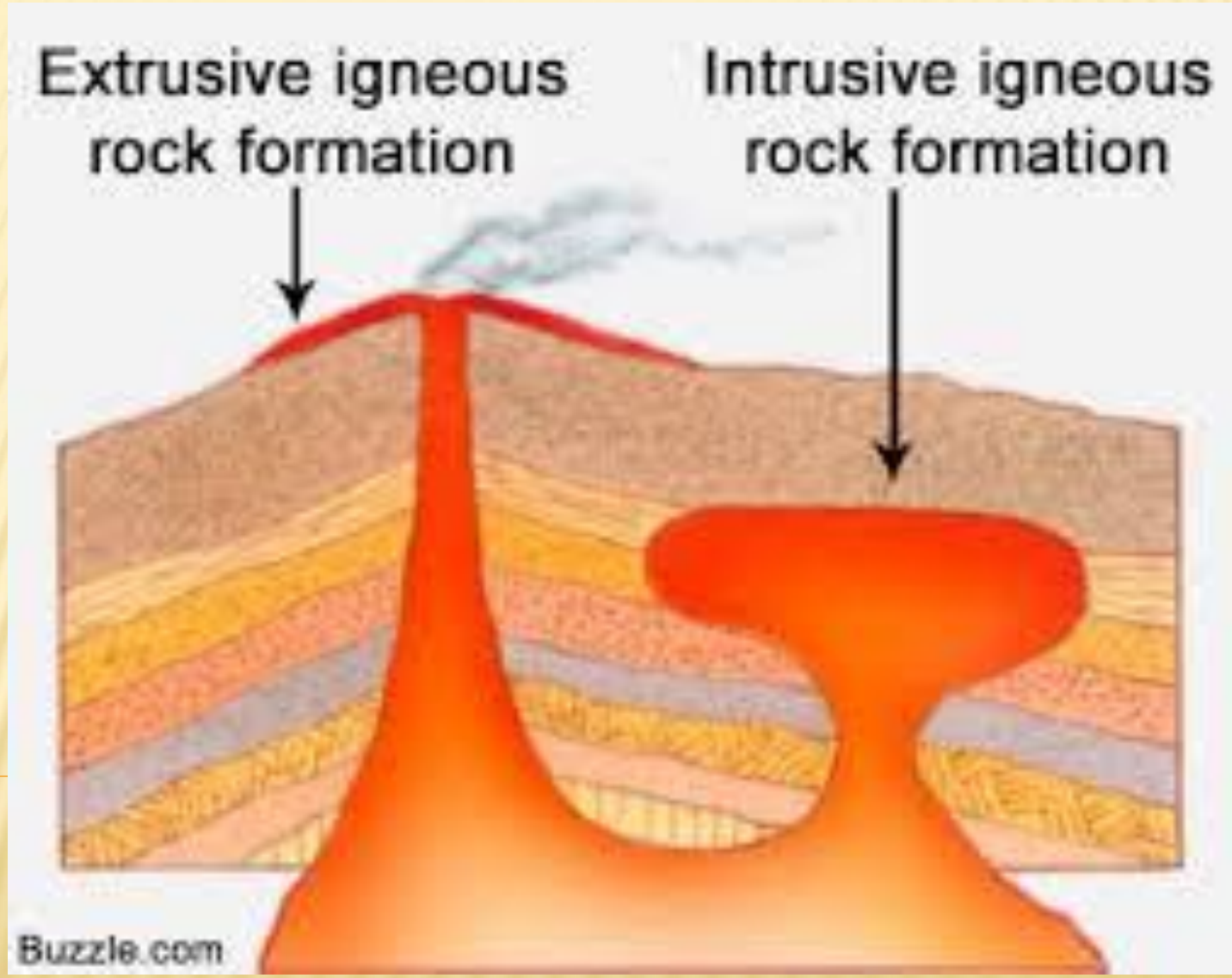
MAGMA:

Igneous Rocks are formed by crystallization from a liquid, or magma. They include two types

Volcanic or extrusive igneous rocks form when the magma cools and crystallizes on the surface of the Earth

Intrusive or plutonic igneous rocks wherein the magma crystallizes at depth in the Earth.

Magmatism and Igneous Rocks



MAGMATISM AND IGNEOUS ROCKS

MAGMA:

Magmas are less dense than surrounding rocks, and will therefore move upward. If magma makes it to the surface it will erupt and later crystallize to form an extrusive or volcanic rock. If it crystallizes before it reaches the surface it will form an igneous rock at the depth called a plutonic or intrusive igneous rock.

MAGMATISM AND IGNEOUS ROCKS

Types of Magma

Chemical composition of magma is controlled by the abundance of elements in the Earth. Si, Al, Fe, Ca, Mg, K, Na, H, and O make up 99.9%. Since oxygen is so abundant, chemical analyses are usually given in terms of oxides. SiO_2 is the most abundant oxide.

1. Mafic or Basaltic-- SiO_2 45-55 wt%, high in Fe, Mg, Ca, low in K, Na

2. Intermediate or Andesitic-- SiO_2 55-65 wt%, intermediate. in Fe, Mg, Ca, Na, K

3. Felsic or Rhyolitic-- SiO_2 65-75%, low in Fe, Mg, Ca, high in K, Na.

MAGMATISM AND IGNEOUS ROCKS

Types of Magma

Gases - At depth in the Earth nearly all magmas contain gas. Gas gives magmas their explosive character, because the gas expands as pressure is reduced.

- Mostly H2O with some CO2
- Minor amounts of Sulfur, Cl , and F
- Felsic magmas usually have higher gas contents than mafic magmas.

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Temperature of Magmas:

- Mafic/Basaltic - 1000-1200°C
- Intermediate/Andesitic - 800-1000°C
- Felsic/Rhyolitic - 650-800°C.

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Question:

Why Mafic/basaltic rocks have higher melting temperature than Felsic/rhyolitic rocks?

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Viscosity of Magmas

Viscosity is the resistance to flow (opposite of fluidity). Depends on composition, temperature, & gas content.

- Higher SiO_2 content magmas have higher viscosity than lower SiO_2 content magmas
- Lower Temperature magmas have higher viscosity than higher temperature magmas.

MAGMATISM AND IGNEOUS ROCKS

Summary Table

Magma Type	Solidified Volcanic Rock	Solidified Plutonic Rock	Chemical Composition	Temperature	Viscosity	Gas Content
Mafic or Basaltic	Basalt	Gabbro	45-55 SiO_2 %, high in Fe, Mg, Ca, low in K, Na	1000 - 1200 ^oC	Low	Low
Intermediate or Andesitic	Andesite	Diorite	55-65 SiO_2 %, intermediate in Fe, Mg, Ca, Na, K	800 - 1000 ^oC	Intermediate	Intermediate
Felsic or Rhyolitic	Rhyolite	Granite	65-75 SiO_2 %, low in Fe, Mg, Ca, high in K, Na	650 - 800 ^oC	High	High

MAGMATISM AND IGNEOUS ROCKS

Origin of Magma:

As we know that the only part of the Earth that is liquid is the outer core. But the core is not likely to be the source of magmas because it does not have the right chemical composition. The outer core is mostly Iron, but magmas are silicate liquids. Thus, since the rest of the earth is solid, in order for magmas to form, some part of the earth must get hot enough to melt the rocks present. We know that temperature increases with depth in the earth along the ***geothermal gradient***.

MAGMATISM AND IGNEOUS ROCKS

Origin of Magma:

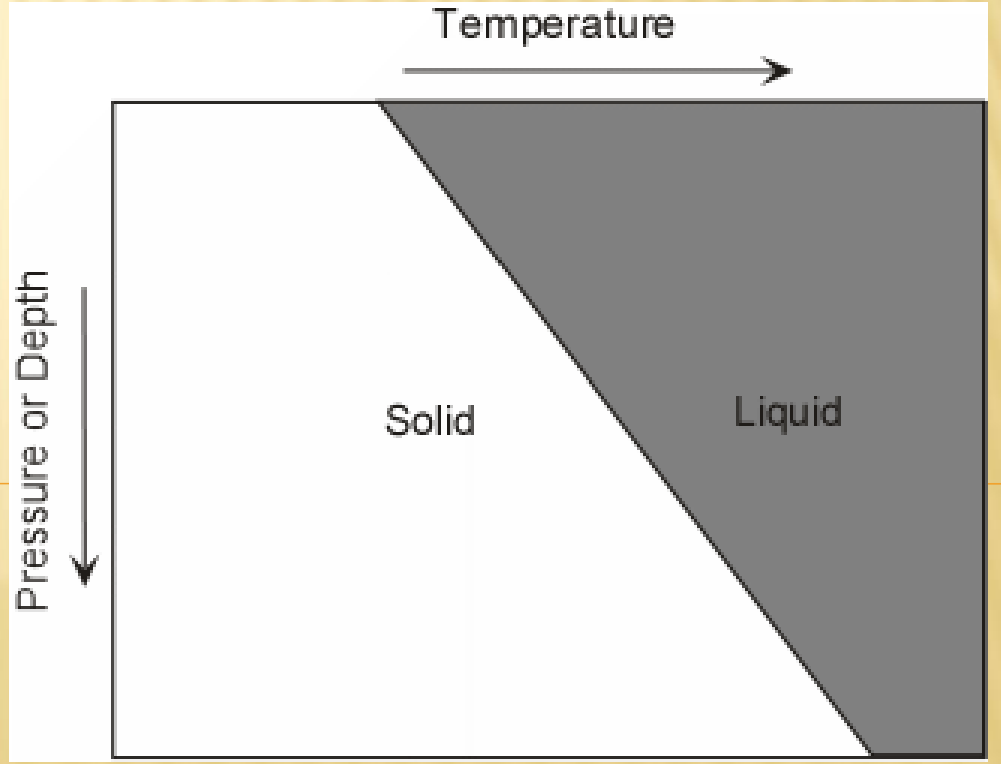
The Earth is hot inside due to heat left over from the original accretion process, due to heat released by sinking of materials to form the core, and due to heat released by the decay of radioactive elements in the Earth. Under normal conditions, the geothermal gradient is not high enough to melt rocks, and thus with the exception of the outer core, most of the Earth is solid. Thus, magmas form only under special circumstances. To understand this we must first look at how rocks and mineral melt.

Magmatism and Igneous Rocks

Origin of Magma:

As pressure increases in the Earth, the melting temperature changes as well. For pure minerals, there are two general cases.

For a pure dry (no H2O or CO2 present) mineral, the melting temperate increases with increasing pressure.

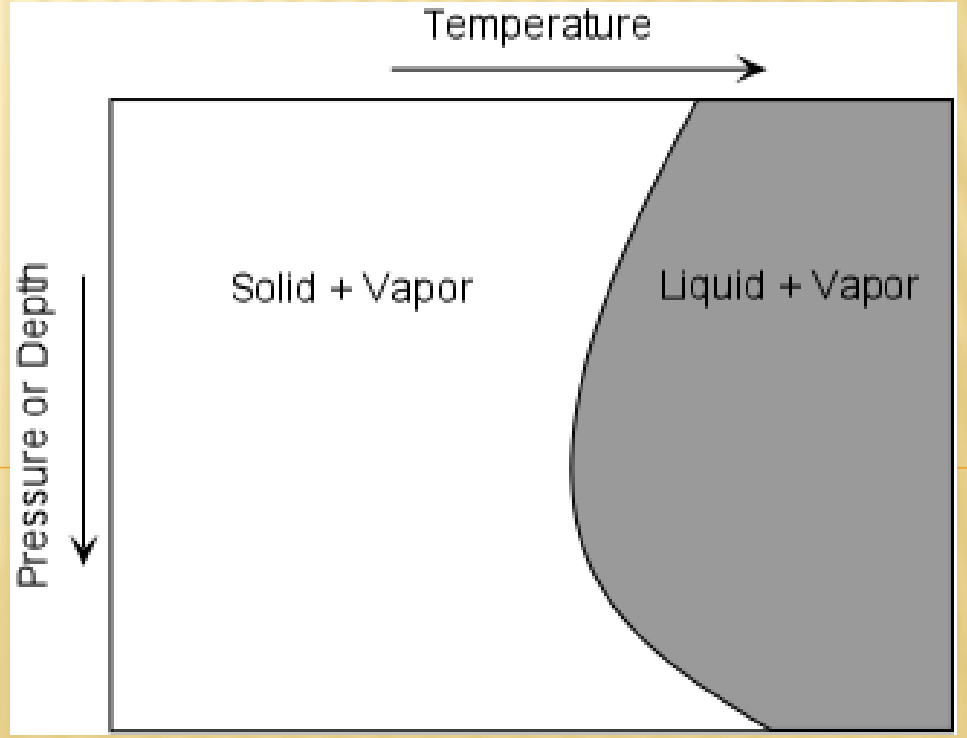


Magmatism and Igneous Rocks

Origin of Magma:

As pressure increases in the Earth, the melting temperature changes as well. For pure minerals, there are two general cases.

For a mineral with H2O or CO2 present, the melting temperature first decreases with increasing pressure



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Origin of Magma:

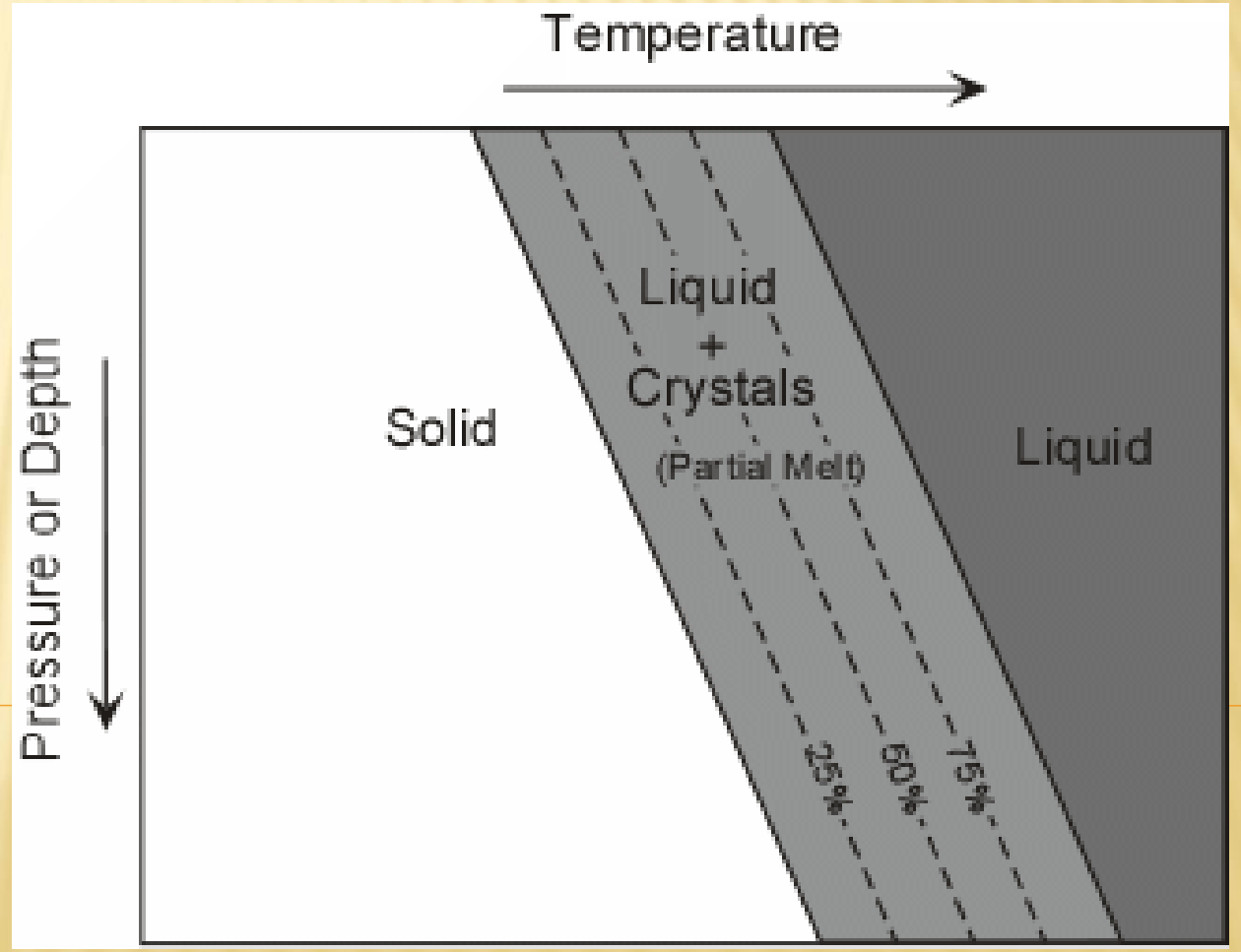
Since rocks are mixture of minerals, they behave somewhat differently. Unlike minerals, rocks do not melt at a single temperature, but instead melt over a range of temperatures. Thus, it is possible to have partial melts from which the liquid portion might be extracted to form magma.

The two general cases are:

MAGMATISM AND IGNEOUS ROCKS

Origin of Magma:

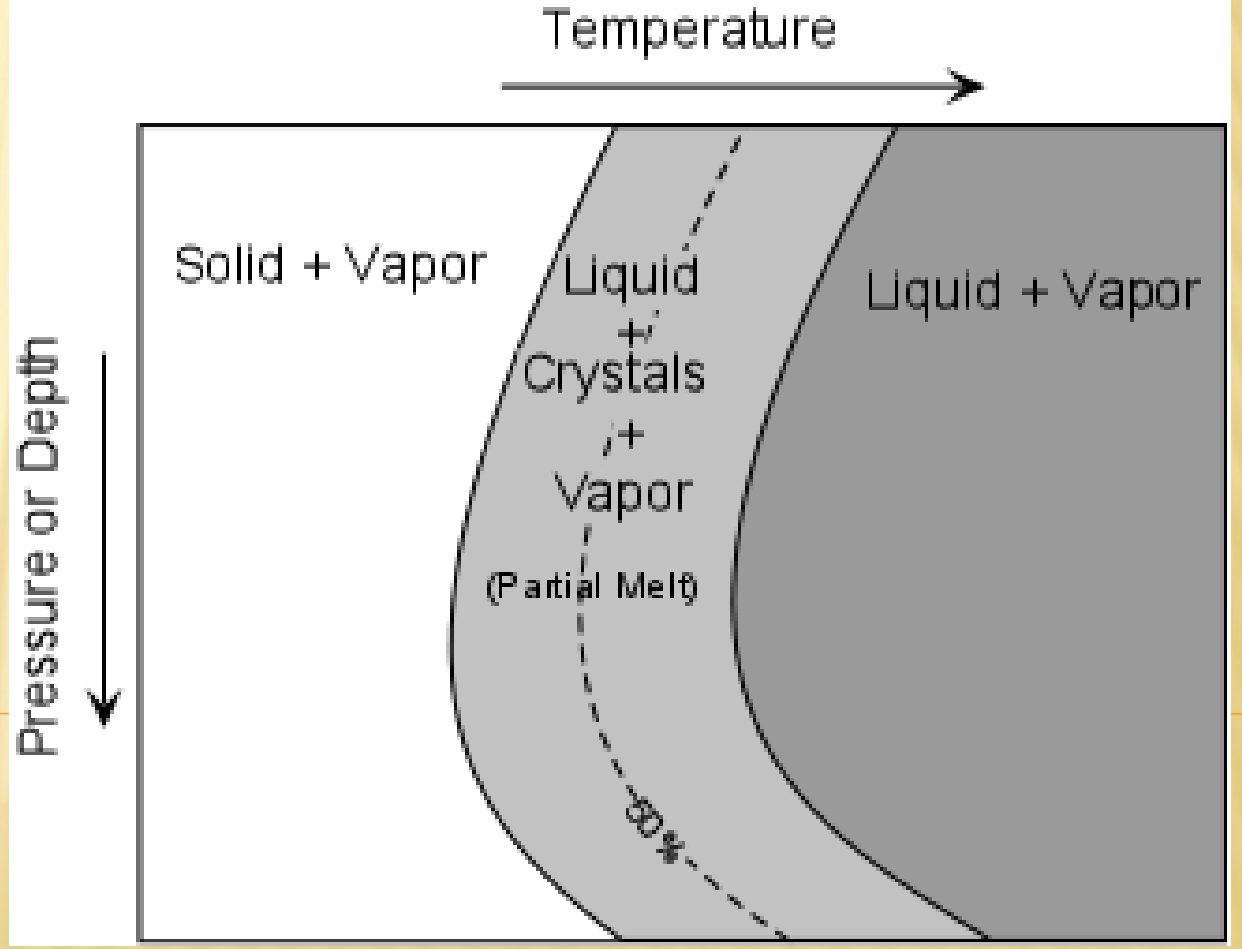
Melting of dry rocks is similar to melting of dry minerals, melting temperatures increase with increasing pressure, except there is a range of temperature over which there exists a partial melt. The degree of partial



MAGMATISM AND IGNEOUS ROCKS

Origin of Magma:

Melting of rocks containing water or carbon dioxide is similar to melting of wet minerals, melting temperatures initially decrease with increasing pressure, except there is a range of temperature over which there exists a partial melt.



MAGMATISM AND IGNEOUS ROCKS

Three ways to Generate Magmas:

1. Decompression Melting ;

Under normal conditions the temperature in the Earth, shown by the geothermal gradient, is lower than the beginning of melting of the mantle. Thus in order for the mantle to melt there has to be a mechanism to raise the geothermal gradient. Once such mechanism is convection, wherein hot mantle material rises to lower pressure or depth, carrying its heat with it.

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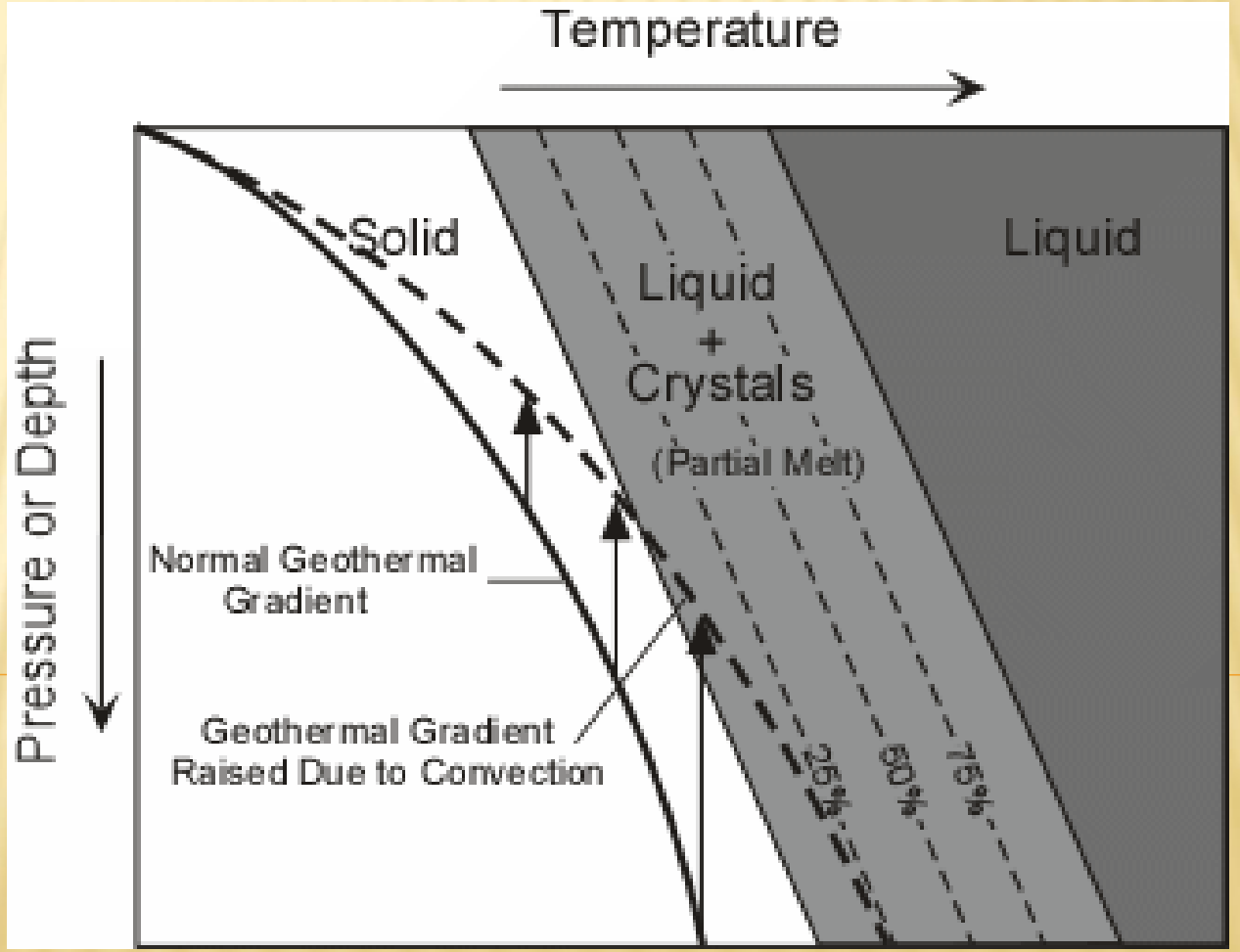
Three ways to Generate Magmas:

1. Decompression Melting :



MAGMATISM AND IGNEOUS ROCKS

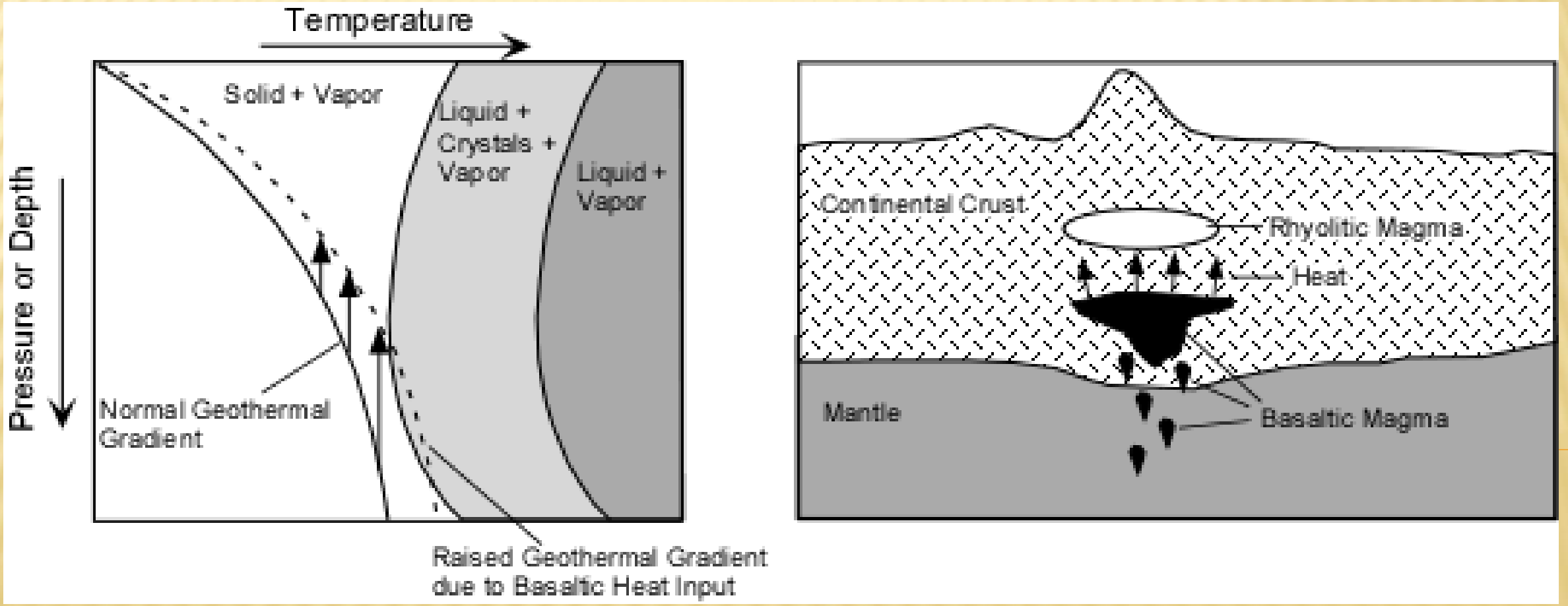
Three ways to Generate Magmas:

2. Transfer of Heat ;

When magmas that were generated by some other mechanism intrude into cold crust, they bring with them heat. Upon solidification they lose this heat and transfer it to the surrounding crust. Repeated intrusions can transfer enough heat to increase the local geothermal gradient and cause melting of the surrounding rock to generate new magmas.

Magmatism and Igneous Rocks

Three ways to Generate Magmas:



MAGMATISM AND IGNEOUS ROCKS

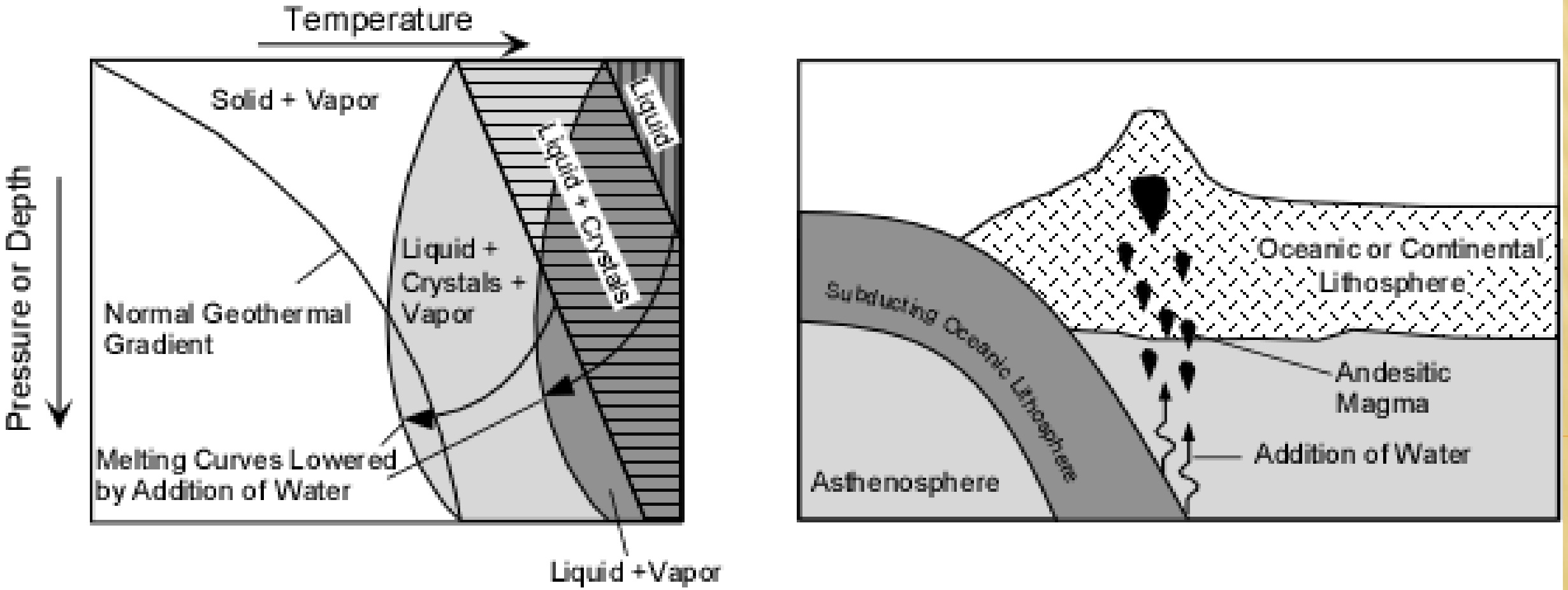
Three ways to Generate Magmas:

3. Flux Melting ;

If the addition of water or carbon dioxide takes place deep in the Earth where the temperature is already high, the lowering of melting temperature could cause the rock to partially melt to generate magma. One place where water could be introduced is at subduction zones. Here, water present in the pore spaces of the subducting sea floor or water present in minerals like hornblende, biotite, or clay minerals would be released by the rising temperature and then move in to the overlying mantle. Introduction of this water in the mantle would then lower the melting temperature of the mantle to generate partial melts, which could then separate from the solid mantle and rise toward the surface.

Magmatism and Igneous Rocks

Three ways to Generate Magmas:



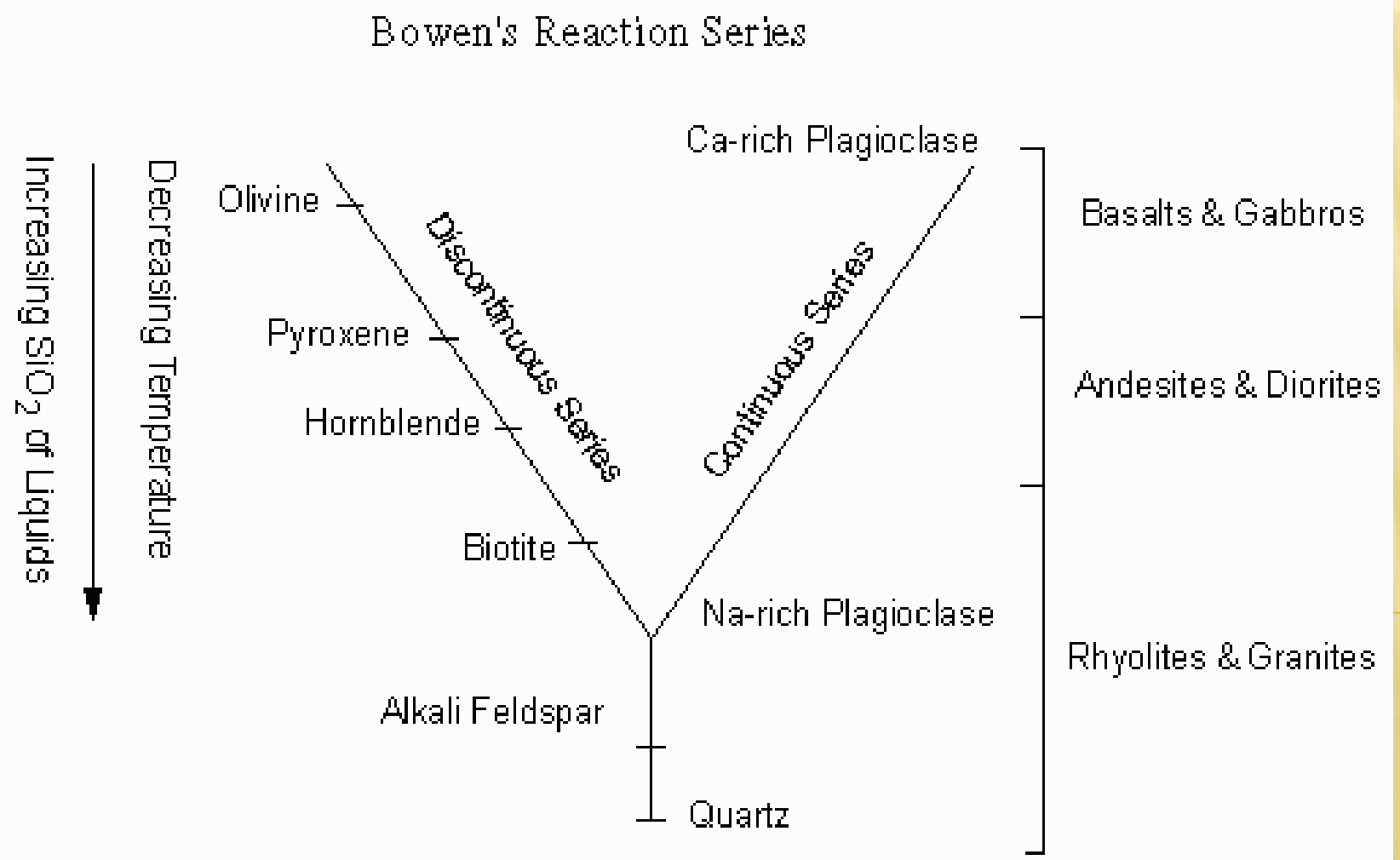
MAGMATISM AND IGNEOUS ROCKS

Bowen's Reaction Series:

Bowen found by experiment that the order in which minerals crystallize from a basaltic magma depends on temperature. As a basaltic magma is cooled Olivine and Ca-rich plagioclase crystallize first. Upon further cooling, Olivine reacts with the liquid to produce pyroxene and Ca-rich plagioclase react with the liquid to produce less Ca-rich plagioclase. But, if the olivine and Ca-rich plagioclase are removed from the liquid by crystal fractionation, then the remaining liquid will be more SiO_2 rich. If the process continues, an original basaltic magma can change to first an andesite magma then a rhyolite magma with falling temperature.

Magmatism and Igneous Rocks

Bowen's Reaction Series:



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Igneous Environments and Igneous Rocks:

The environment in which magma completely solidifies to form a rock determines:

1. The type of rock
2. The appearance of the rock as seen in its texture
3. The type of rock body.

In general there are two environments to consider:

MAGMATISM AND IGNEOUS ROCKS

Igneous Environments and Igneous Rocks:

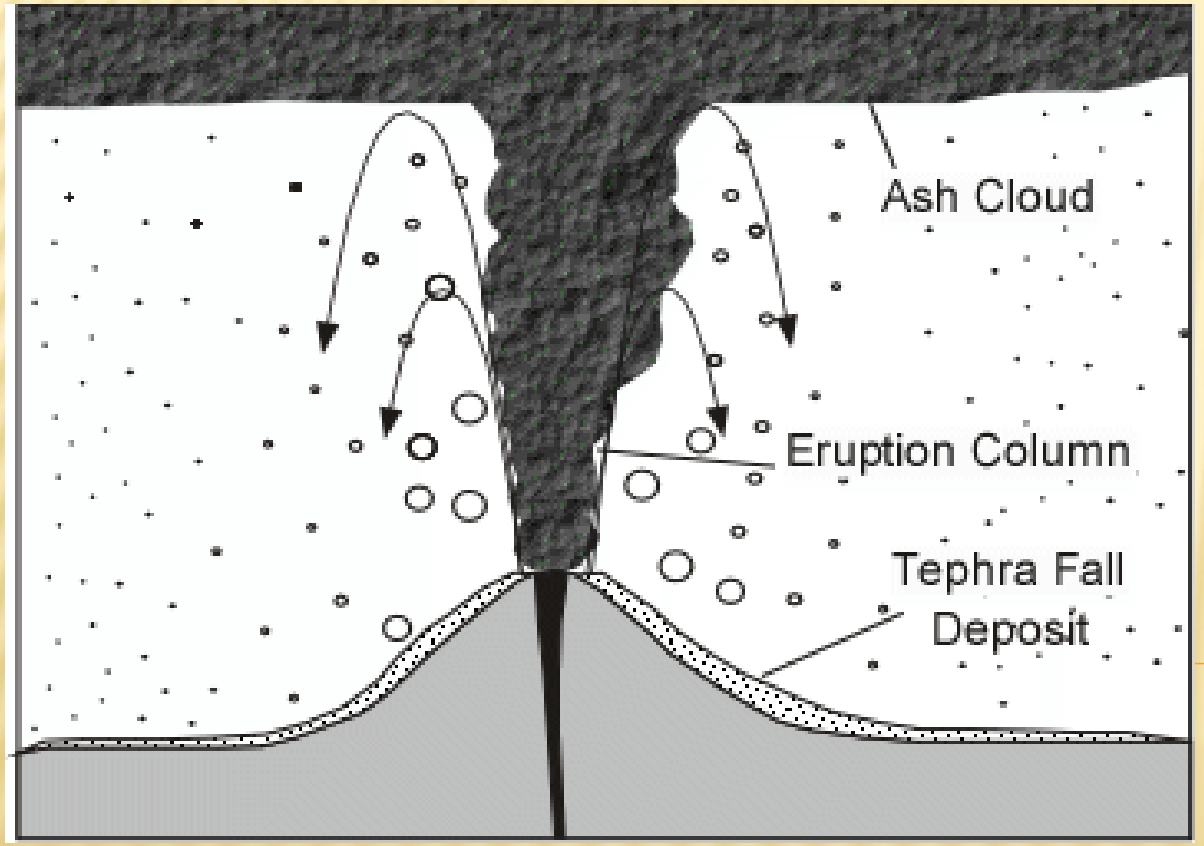
1. Extrusive Environments

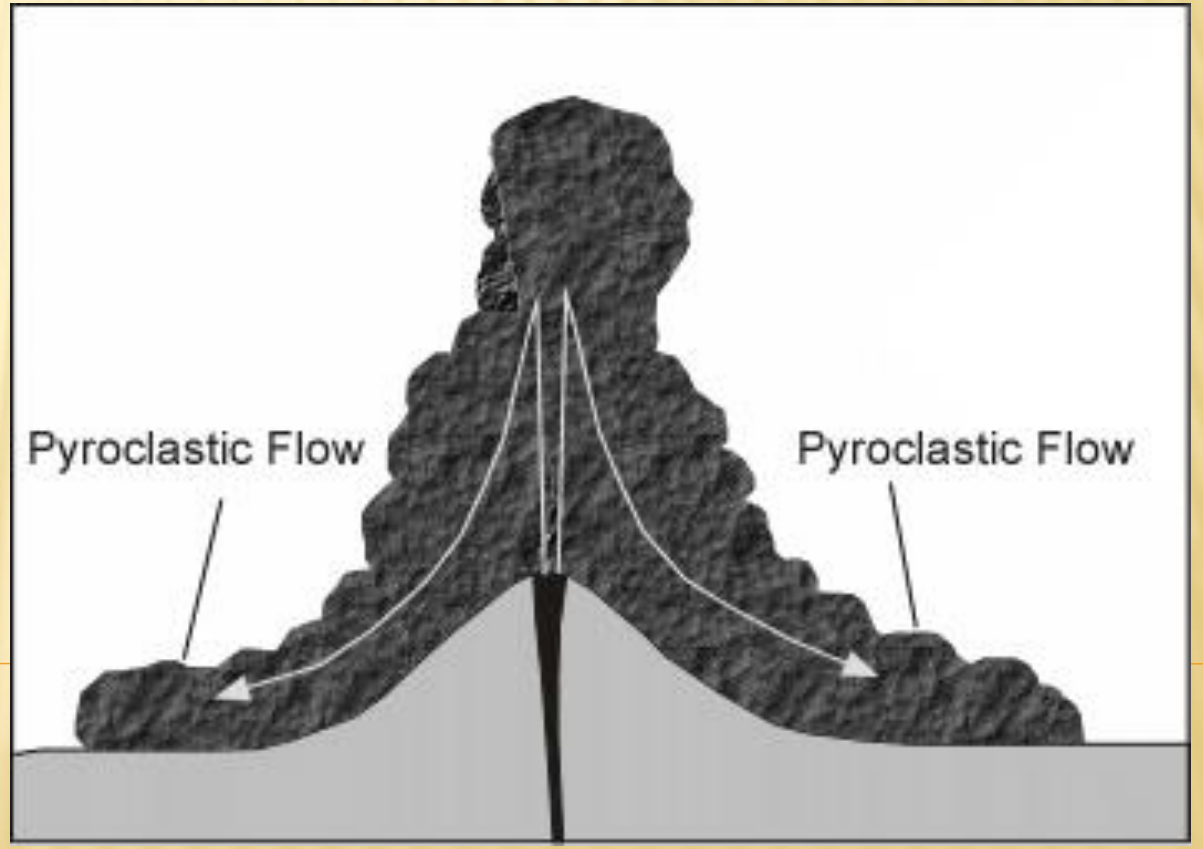
When magmas reach the surface of the Earth they erupt from a vent called a volcano. They may erupt explosively or non-explosively.

- Non-explosive eruptions are favored by low gas content and low viscosity magmas (basaltic to andesitic magmas and sometimes rhyolitic magma).
- Explosive eruptions are favored by high gas content and high viscosity (andesitic to rhyolitic magmas).

Magmatism and Igneous Rocks

Igneous Environments and Igneous Rocks:





Extrusive Environments

MAGMATISM AND IGNEOUS ROCKS

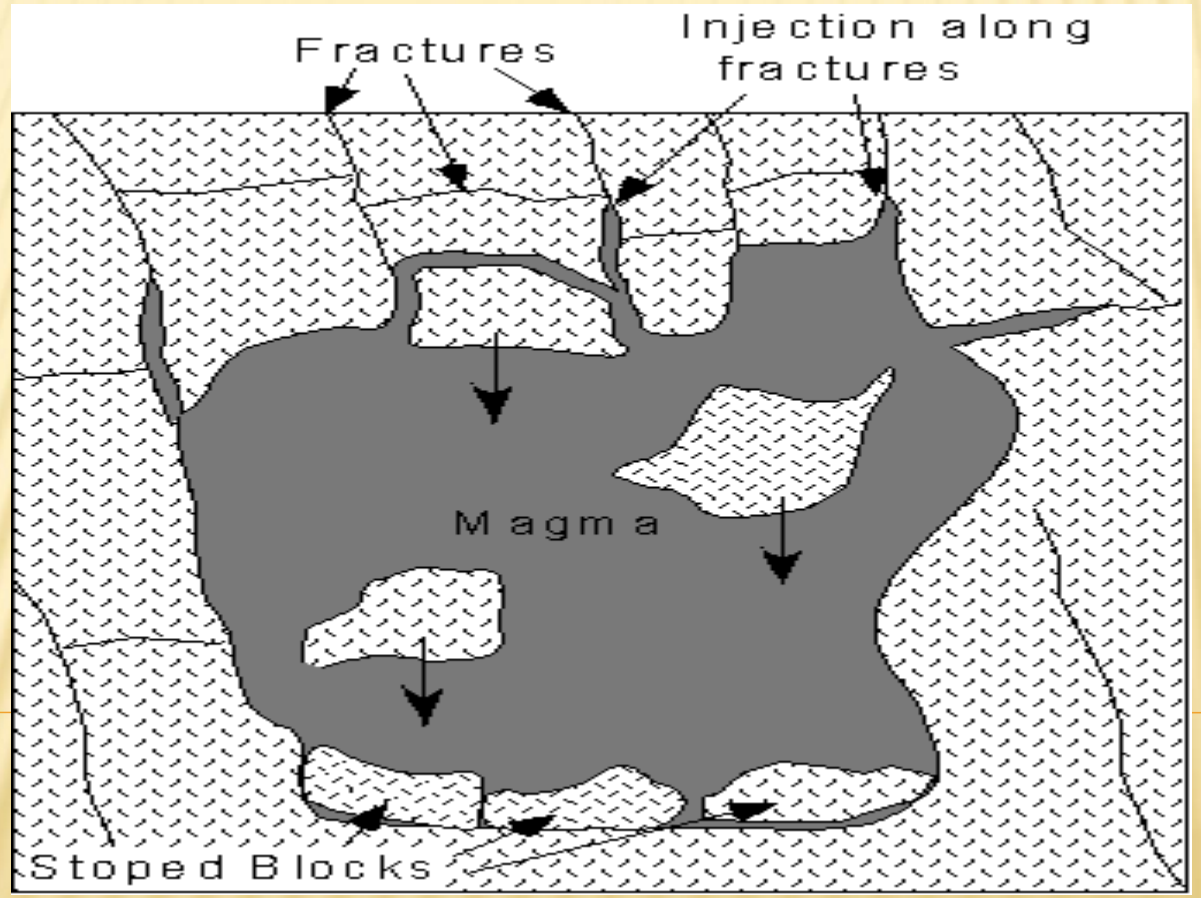
Igneous Environments and Igneous Rocks:

2. Intrusive Environments

Magma that cools at depth form bodies of rocks called intrusive bodies or plutonic bodies also called plutons. When magma intrudes it usually affects the surrounding rock and is also affected by the surrounding rock. It may metamorphose the surrounding rocks or cause hydrothermal alteration. The magma itself may also cool rapidly near the contact with the surrounding rock.

Magmatism and Igneous Rocks

Igneous Environments and Igneous Rocks:



Intrusive Environments

MAGMATISM AND IGNEOUS ROCKS

Classification of Igneous Rocks:

Igneous rocks are classified on the basis of texture and chemical composition, usually as reflected in the minerals that from due to crystallization.

1. Extrusive/Volcanic Rocks

Basalts, Andesites, and Rhyolites are all types of volcanic rock distinguished on the basis of their mineral assemblage and chemical composition. These rocks tend to be fine grained to glassy or porphyritic. Depending on conditions present during eruption and cooling, any of these rock types may form one of the following types of volcanic rocks.

MAGMATISM AND IGNEOUS ROCKS

Classification of Igneous Rocks:

1. Extrusive/Volcanic Rocks

- ***Obsidian*** - dark colored volcanic glass showing concoidal fracture and few to no crystals. Usually rhyolitic .
- ***Pumice*** - light colored and light weight rock consisting of mostly holes (***vesicles***) that were once occupied by gas, Usually rhyolitic or andesitic.
- ***Vesicular*** rock - rock filled with holes or vesicles that were once occupied by gas. Usually basaltic and andesitic.
- ***Pyroclasts*** hot, broken fragments. Result from explosively ripping apart of magma. Loose assemblages of pyroclasts called ***tephra***. Depending on size, tephra can be classified as bombs. lapilli, or ash.

MAGMATISM AND IGNEOUS ROCKS

Classification of Igneous Rocks:

2. Intrusive/Plutonic Igneous Rocks

Coarse grained rocks, formed at deeper levels in the earth include gabbros, diorites, and granites. Note that these are chemically equivalent to basalts, and esites, and rhyolites, but may have different minerals or different proportions of mineral because their crystallization history is not interrupted as it might be for extrusive rocks.

Pegmatites are very coarse grained igneous rocks consisting mostly of quartz and feldspar as well as some more exotic minerals like tourmaline, lepidolite, muscovite. These usually form dikes related to granitic plutons.

Magmatism and Igneous Rocks

Distribution of Igneous Activity:

Igneous activity is currently taking place as it has in the past in various tectonic settings.
These include diverging and converging plate boundaries, hot spots, and rift valleys.

MAGMATISM AND IGNEOUS ROCKS

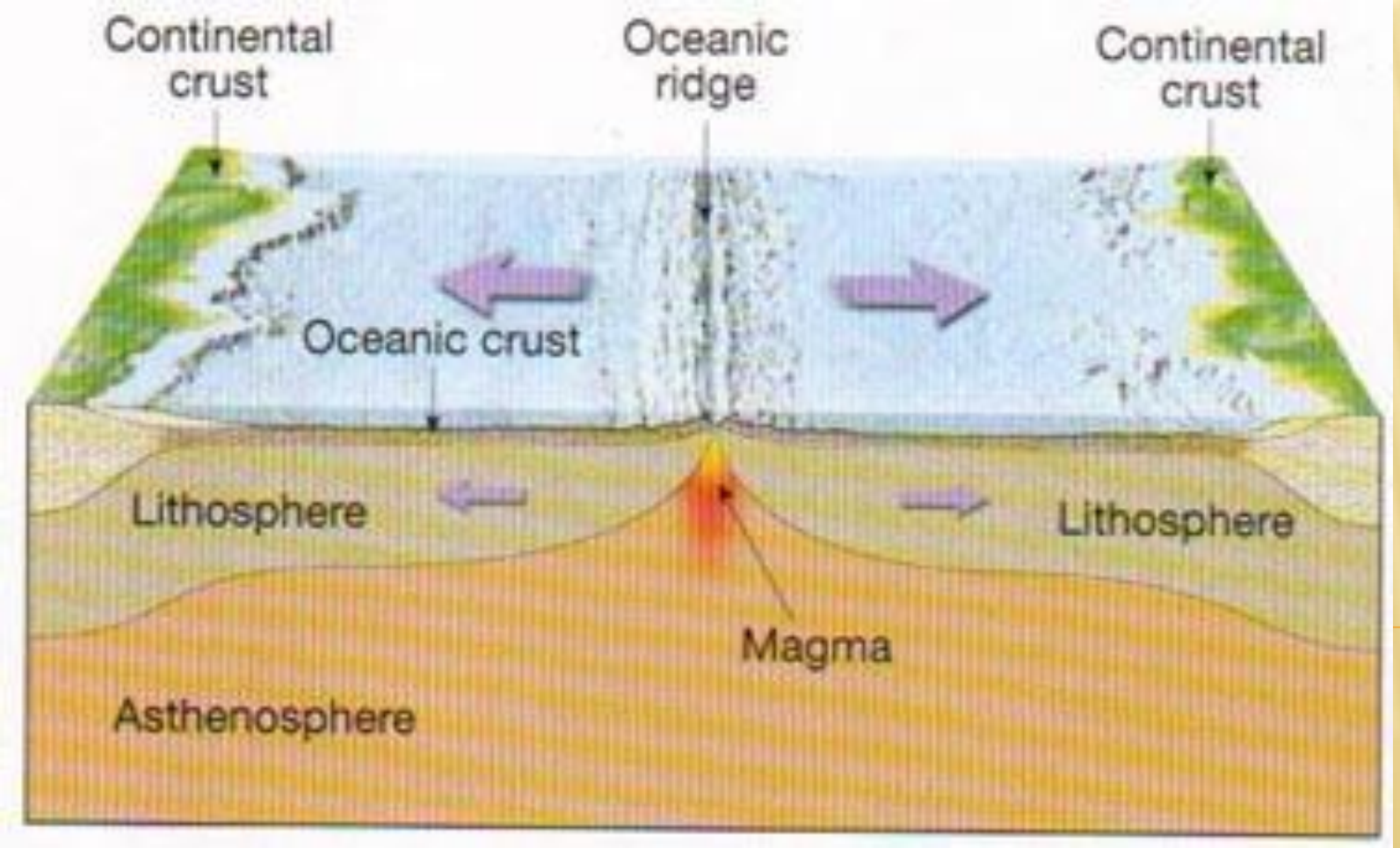
Distribution of Igneous Activity:

Divergent Plate Boundaries:

When a divergent boundary occurs beneath oceanic lithosphere, the rising convection current below lifts the lithosphere producing a mid-ocean ridge. Extensional forces stretch the lithosphere and produce a deep fissure. When the fissure opens, pressure is reduced on the super-heated mantle material below. It responds by melting and the new magma flows into the fissure. The magma then solidifies and the process repeats itself

Magmatism and Igneous Rocks

Distribution of Igneous Activity:



MAGMATISM AND IGNEOUS ROCKS

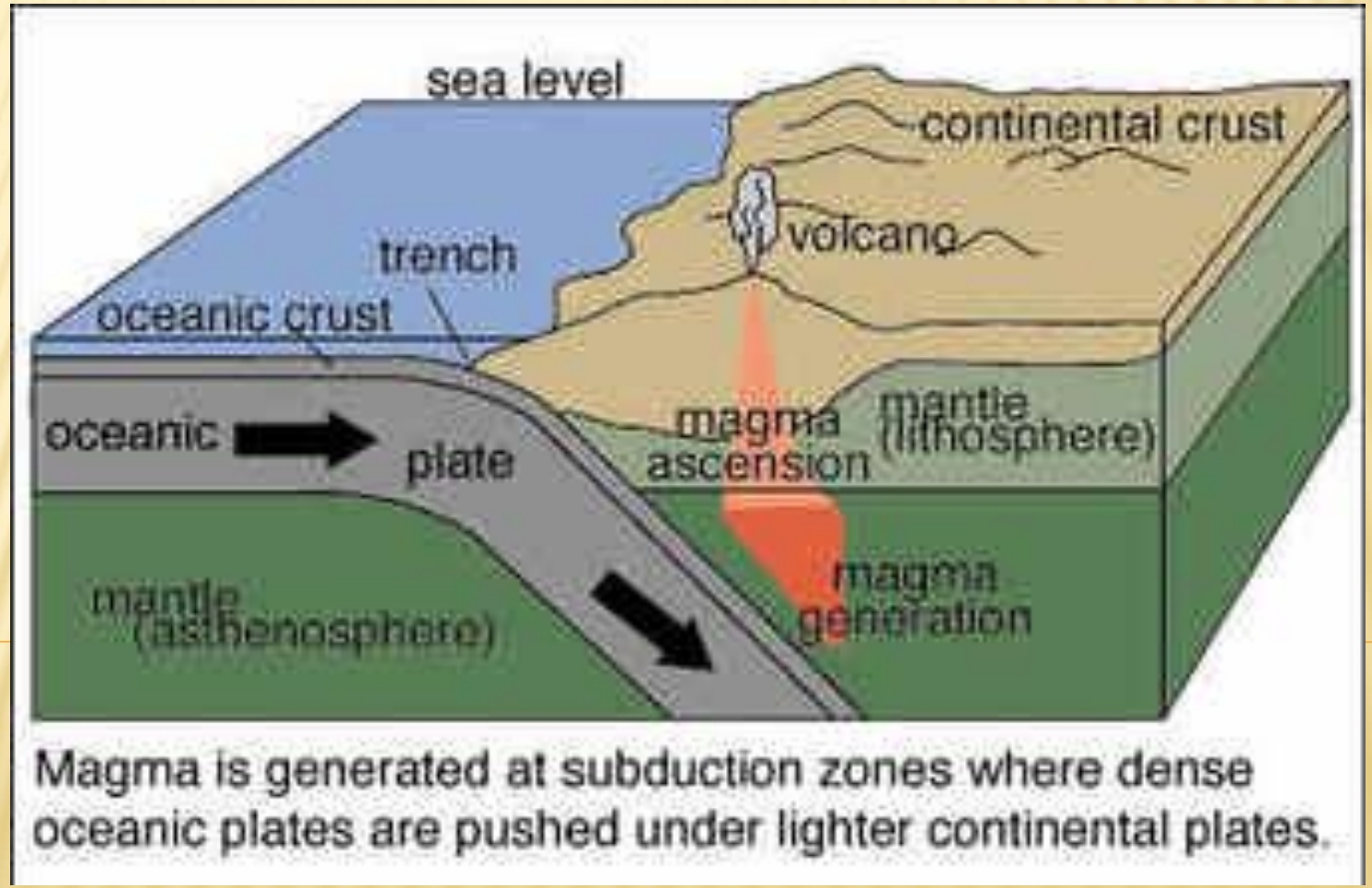
Distribution of Igneous Activity:

Convergent Plate Boundaries:

When continental and oceanic plates collide the thinner and more dense oceanic plate is overridden by the thicker and less dense continental plate. The oceanic plate is forced down into the mantle in a process known as "subduction". As the oceanic plate descends it is forced into higher temperature environments. At a depth of about 100 miles (160 km) materials in the subducting plate begin to approach their melting temperatures and a process of partial melting begins

Magmatism and Igneous Rocks

Distribution of Igneous Activity:



Magma is generated at subduction zones where dense oceanic plates are pushed under lighter continental plates.

MAGMATISM AND IGNEOUS ROCKS

Distribution of Igneous Activity:

Hot Spots:

Hot spots are places within the mantle where rocks melt to generate magma. The presence of a hot spot is inferred by anomalous volcanism (i.e. not at a plate boundary), such as the Hawaiian volcanoes within the Pacific Plate.

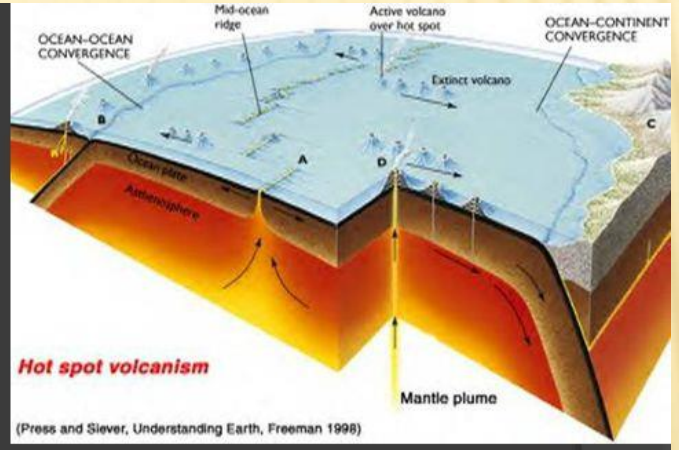
Magmatism and Igneous Rocks

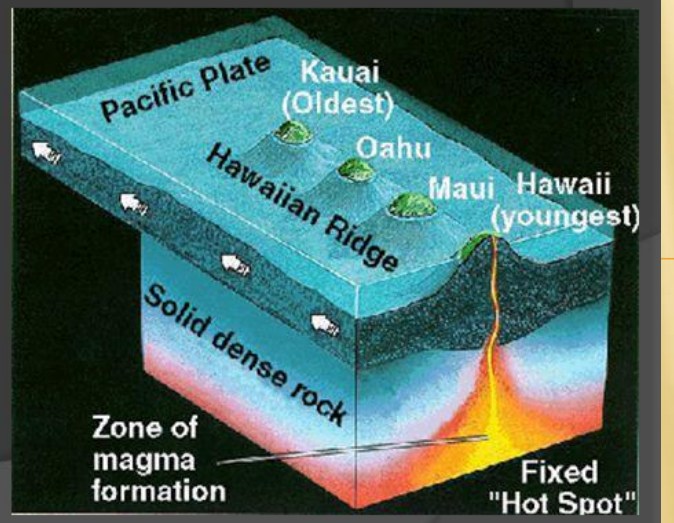
Distribution of Igneous Activity:

Intraplate Volcanism

The volcanic mountains that make up the Hawaiian Islands have formed as the Pacific plate moves over a hot spot.

The age of each volcano indicates the time when it was over the hot spot. Kauai is the oldest while the most recently formed island has two volcanoes; Mauna Loa and Kilauea.





MAGMATISM AND IGNEOUS ROCKS

Major Igneous Rocks:

Igneous rocks are formed from the solidification of molten rock material. There are two basic types.

Intrusive igneous rocks crystallize below Earth's surface, and the slow cooling that occurs there allows large crystals to form. Examples of intrusive igneous rocks are *diorite, gabbro, granite, pegmatite, and peridotite*.

Extrusive igneous rocks erupt onto the surface, where they cool quickly to form small crystals. Some cool so quickly that they form an amorphous glass. These rocks include *andesite, basalt, obsidian, pumice, rhyolite, scoria, and tuff.*

Magmatism and Igneous Rocks

Major Igneous Rocks:

Lets discuss one by one

MAGMATISM AND IGNEOUS ROCKS

Major Igneous Rocks:

Andesite:

Andesite is the name used for a family of fine-grained, extrusive igneous rocks that are usually light to dark gray in color. They often weather to various shades of brown, and these specimens must be broken for proper examination. Andesite is rich in plagioclase feldspar minerals and may contain biotite, pyroxene, or amphibole. Andesite usually does not contain quartz or olivine.

Magmatism and Igneous Rocks

Major Igneous Rocks:

Andesite:

MAGMATISM AND IGNEOUS ROCKS

Major Igneous Rocks:

Basalt:

Basalt is a dark-colored, fine-grained, igneous rock composed mainly of plagioclase and pyroxene minerals. It most commonly forms as an extrusive rock, such as a lava flow, but can also form in small intrusive bodies, such as an igneous dike or a thin sill. It has a composition similar to gabbro. The difference between basalt and gabbro is that basalt is a fine-grained rock while gabbro is a coarse-grained rock.

Magmatism and Igneous Rocks

Major Igneous Rocks:

Basalt:

MAGMATISM AND IGNEOUS ROCKS

Major Igneous Rocks:

Diorite:

Diorite is the name used for a group of coarse-grained igneous rocks with a composition between that of granite and basalt. It usually occurs as large intrusions, dikes, and sills within continental crust. These often form above a convergent plate boundary where an oceanic plate subducts beneath a continental plate.

Magmatism and Igneous Rocks

Major Igneous Rocks:

Diorite:

MAGMATISM AND IGNEOUS ROCKS

Major Igneous Rocks:

Gabbro:

Gabbro is a coarse-grained, dark-colored, intrusive igneous rock. It is usually black or dark green in color and composed mainly of the minerals plagioclase and augite. It is the most abundant rock in the deep oceanic crust. Gabbro has a variety of uses in the construction industry. It is used for everything from crushed stone base materials at construction sites to polished stone counter tops and floor tiles.

Magmatism and Igneous Rocks

Major Igneous Rocks:

Gabro:

Magmatism and Igneous Rocks

Major Igneous Rocks:

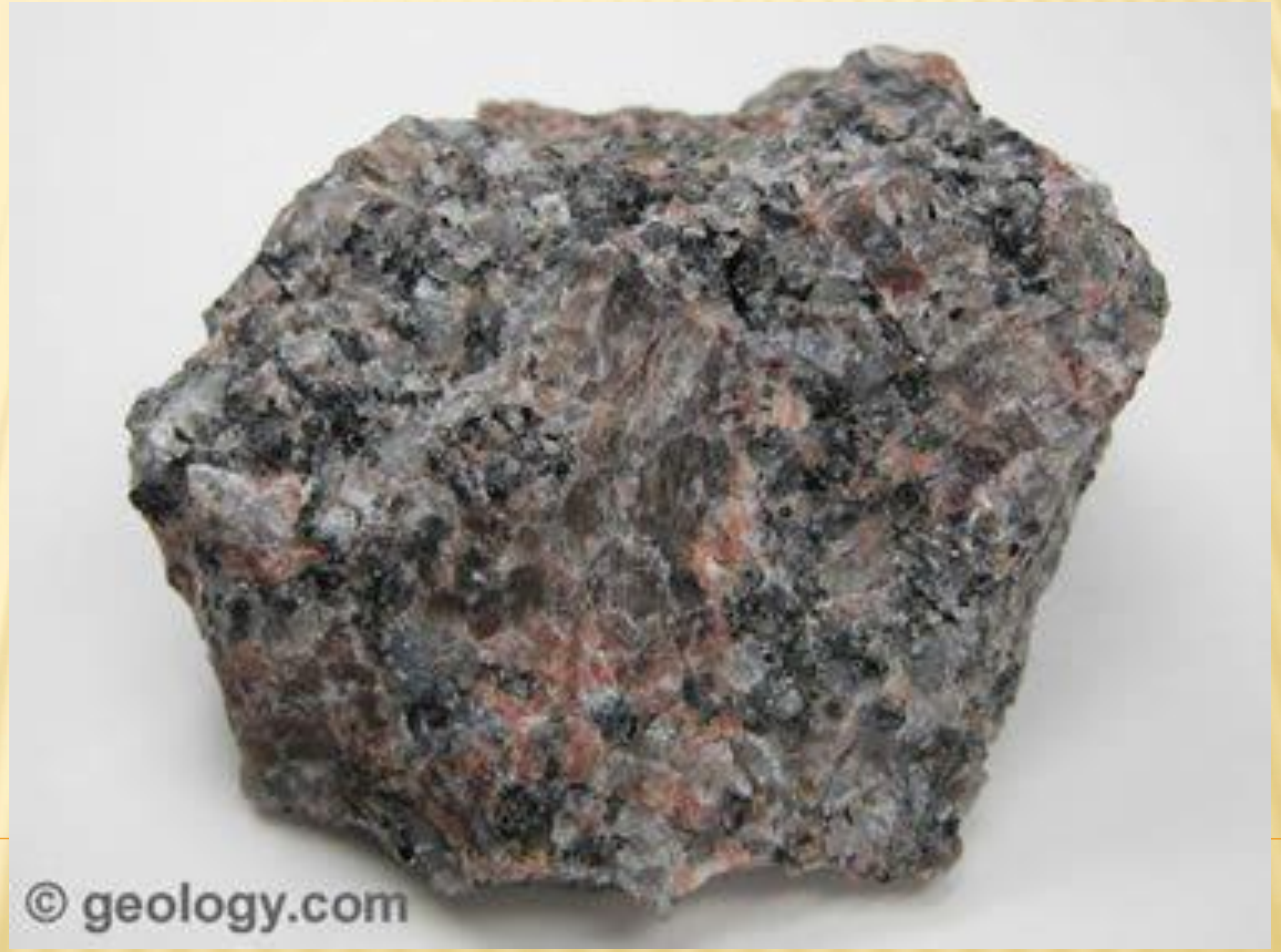
Granite:

Granite is a light-colored igneous rock with grains large enough to be visible with the nacked eye. It forms from the slow crystallization of magma below Earth's surface. Granite is composed mainly of quartz and feldspar with minor amounts of mica, amphiboles, and other minerals. This mineral composition usually gives granite a red, pink, gray, or white color with dark mineral grains visible throughout the rock.

Magmatism and Igneous Rocks

Major Igneous Rocks:

Granite:



MAGMATISM AND IGNEOUS ROCKS

Major Igneous Rocks:

Obsidian:

Obsidian is an igneous rock that forms when molten rock material cools so rapidly that atoms are unable to arrange themselves into a crystalline structure. It is an amorphous material known as a "mineraloid." The result is a volcanic glass with a smooth uniform texture that breaks with a conchoidal fracture (see photo).

Magmatism and Igneous Rocks

Major Igneous Rocks:

Obsidian:

Magmatism and Igneous Rocks

Major Igneous Rocks:

Pegmatites:

Pegmatites are extreme igneous rocks that form during the final stage of a magma's crystallization. They are extreme because they contain exceptionally large crystals and they sometimes contain minerals that are rarely found in other types of rocks.

Magmatism and Igneous Rocks

Major Igneous Rocks:

Pegmatite:

MAGMATISM AND IGNEOUS ROCKS

Major Igneous Rocks:

Pumice:

Pumice is a light-colored, extremely porous igneous rock that forms during explosive volcanic eruptions. It is used as aggregate in lightweight concrete, as landscaping aggregate, and as an abrasive in a variety of industrial and consumer products. Many specimens have a high enough porosity that they can float on water until they slowly become waterlogged.

Magmatism and Igneous Rocks

Major Igneous Rocks:

Pumice:

Magmatism and Igneous Rocks

Major Igneous Rocks:

Rhyolite:

Rhyolite is an extrusive igneous rock with a very high silica content. It is usually pink or gray in color with grains so small that they are difficult to observe without a hand lens. Rhyolite is made up of quartz, plagioclase, and sanidine, with minor amounts of hornblende and biotite. Trapped gases often produce vuggs in the rock. These often contain crystals, opal, or glassy material.

Magmatism and Igneous Rocks

Major Igneous Rocks:

Rhyolite:


Any
Questions?

MAGMATISM AND IGNEOUS ROCKS

Questions?

1. What is magma? Describe its type?
2. Why mafic/basaltic rocks have high melting points than felsic/rhyolitic rocks?
3. How viscosity depends upon temperature?
4. Describe the ways of generation of magma?
5. What Bown's reaction series describe?
6. What is meant by distribution of igneous activity?
7. Describe any four common igneous rocks?


THANKS FOR LISTENING
I HOPE I WASN'T TOO BORING