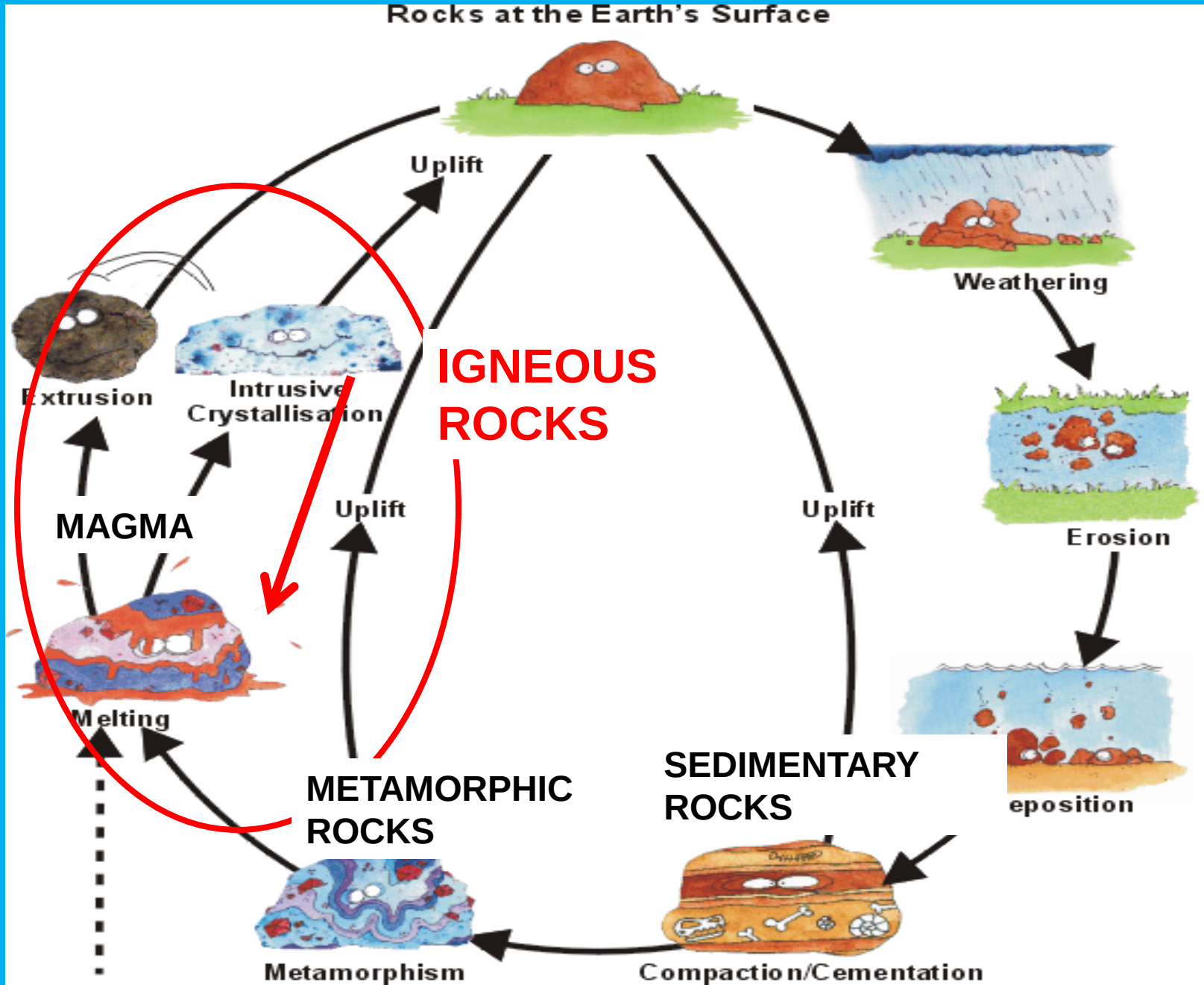
ROCK

- **Usually, an aggregate of mineral crystals or crystal fragments.**

- **May be composed of one or more minerals, in proportions *that vary*.**

- **May also be composed partly or entirely of rock fragments, or of organic remains.**

Rock Cycle

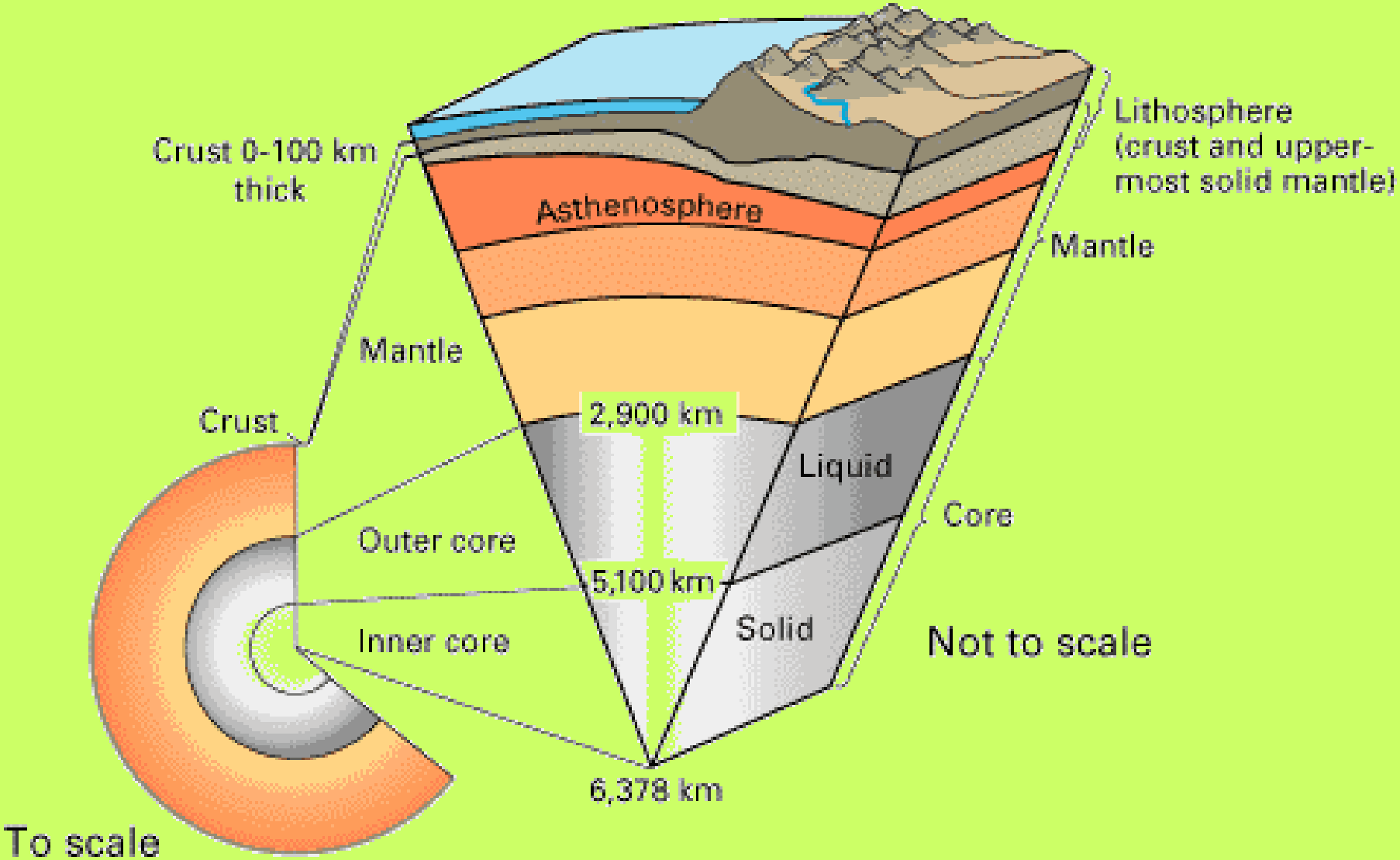

Rocks at the Earth's Surface
Uplift
Weathering
Extrusion
Intrusive
Crystallisation
IGNEOUS
ROCKS
MAGMA
Uplift
Uplift
Erosion
Melting
SEDIMENTARY
ROCKS
METAMORPHIC
ROCKS
eposition
Metamorphism
Compaction/Cementation

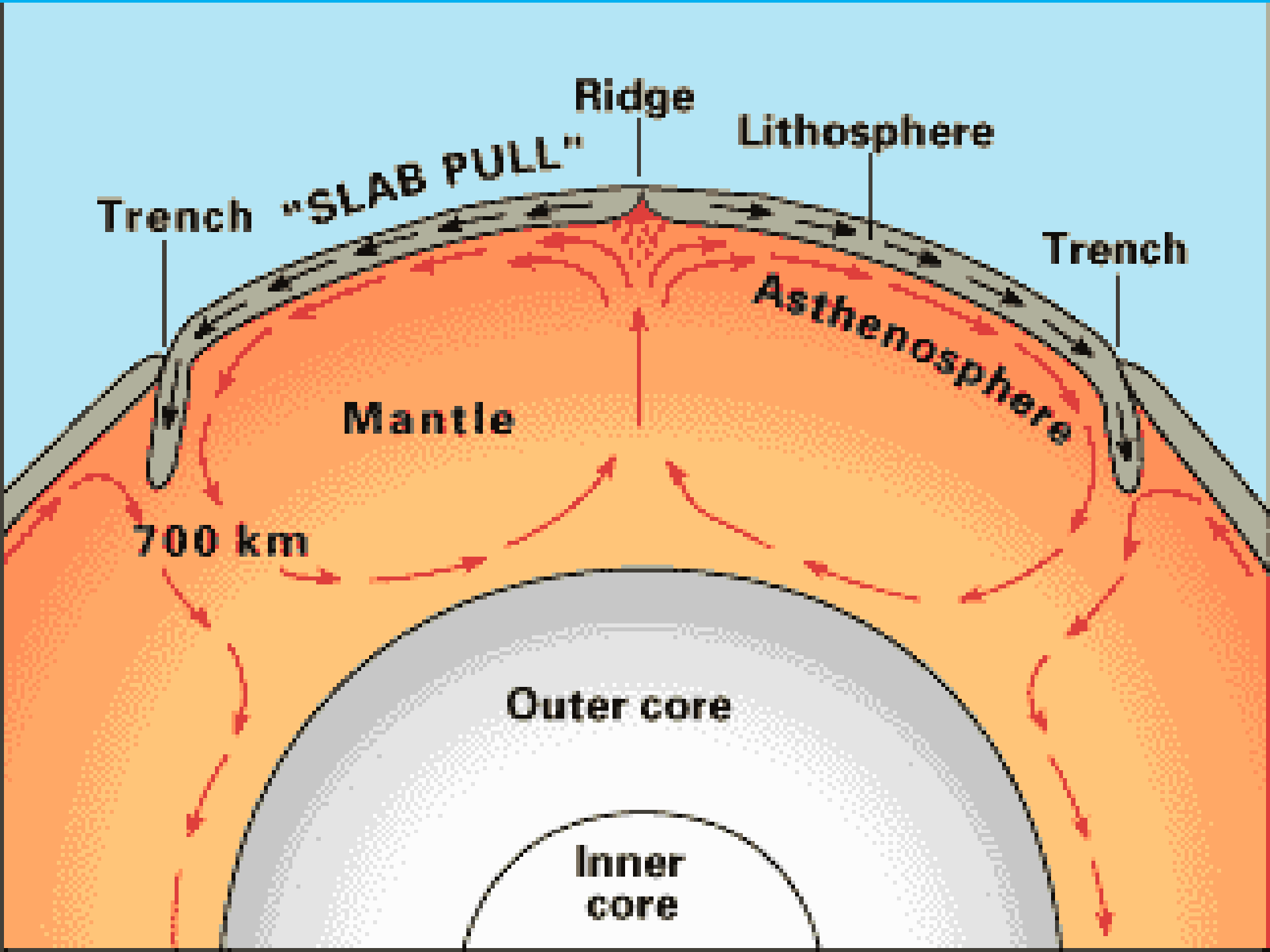
The Rock Cycle, or Geologic Cycle

- **What is most important about a rock is not the rock itself, but the process that made it.**
- **Rock-making processes are more important than the rocks they make.**
- **Rocks undergo sequences of process called the *geologic cycle*.**
- **Every rock contains information about how it was formed.**

The job of the Earth scientist is to "read" the rock in order to decipher its origin.

Structure of the Earth




Ridge
Lithosphere
"SLAB PULL"
Trench
Trench
Asthenosphere
Mantle
700 km
Outer core
Inner
core

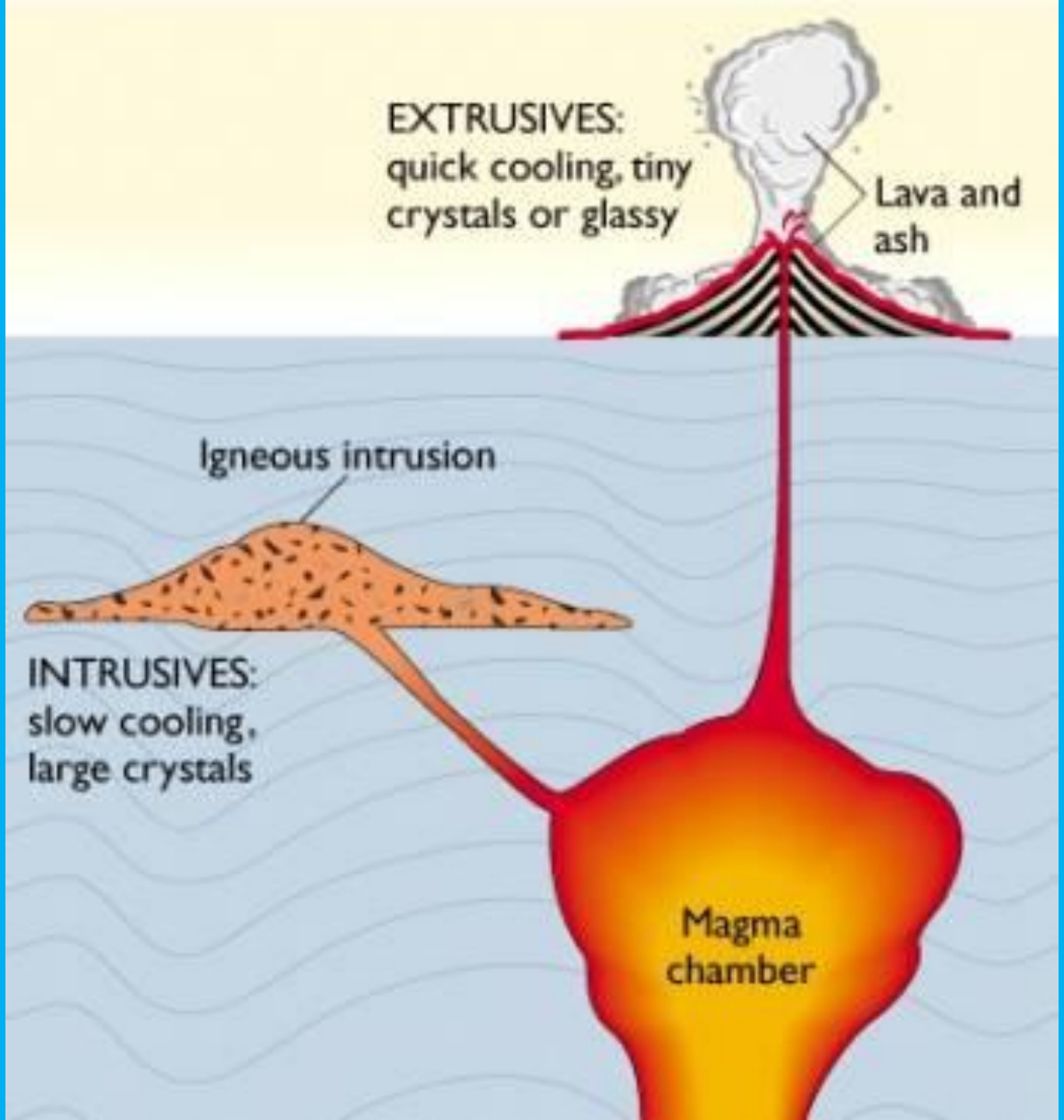
Formation of Magma

- Remember that the tectonic plates don't really float on a liquid asthenosphere, rather the asthenosphere is a ductile solid and is only melted in specific locations.

- Most magma/lava is not 100% liquid.
  - Magma/Lava is made of many compounds, all of which have different melting temps.
  - Only a few percent of liquid is required to make a melt.

- Other than a rise in temperature, what causes melting of rock within the Earth?

  Melting happens because of:
  - Decrease in pressure (decompression)
  - Addition of volatiles (H_2O, CO_2, etc…)
  - Heat transfer from rising magma


EXTRUSIVES:
quick cooling, tiny
crystals or glassy
Lava and
ash
Igneous intrusion
INTRUSIVES:
slow cooling,
large crystals
Magma
chamber

Magma

- Molten rock composed of varying amounts of
  - Liquid
  - Silicate (Si, O)
  - Ions of K, Na, Fe, Ca, Mg, Al
  - Solid
    - Minerals
  - Dissolved gas
    - H_2O, CO_2, SO_2
- Temperature: 600-1200^{o}C

Difference between lava and magma:

- **Magma = molten rock + dissolved gas.**
- **Most gas has escaped *from lava* at Earth's surface, where pressures are low.**

Types of Magma - Composition

Like rocks, not all magma is made of the same stuff

- **Magmas into groups by their composition**
  - **Felsic (Silicic): 66-76% Silica (SiO_2)**
    - **Most viscous, Least dense (~2.5 gm/cm^3), melting point 650-800^{o}C**
  - **Intermediate: 52-66% SiO_2**
  - **Mafic: 45-52% SiO_2, lots of MgO, FeO, and Fe_2O_3**
  - **Ultramafic: 38-45% SiO_2, abundant MgO, FeO, and Fe_2O_3**
    - **Least viscous, Most dense (~3.5 gm/cm^3), melting point up to 1300^{o}C**

Increasing SiO_2

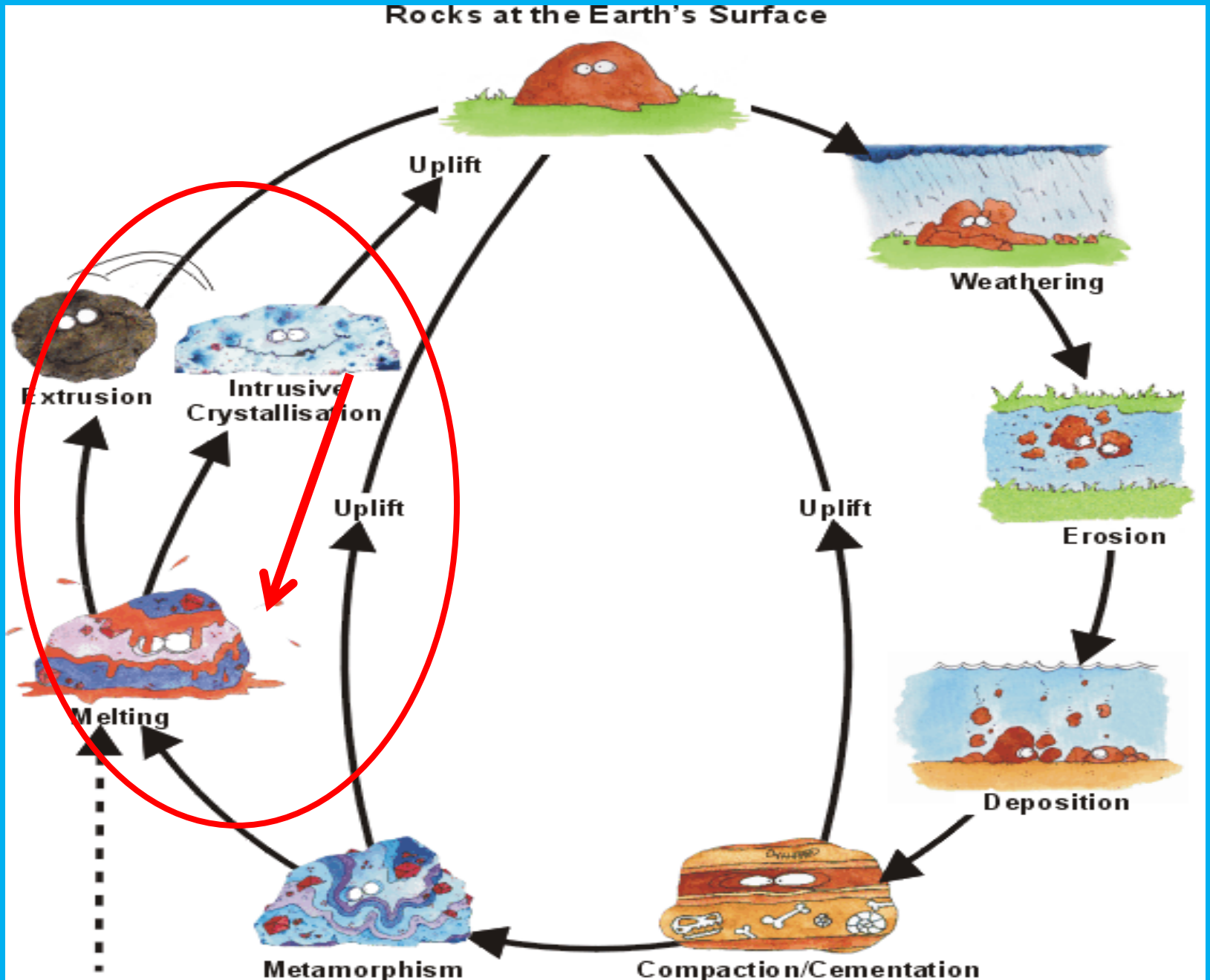
Increasing Fe, Mg

Magma Movement

- **If magma did not move, no extrusive/volcanic rocks would ever have formed**
- **Magma rises because:**
  - **hotter and less dense than the surrounding rock and therefore *buoyantly rises.***
  - **the weight of the overlying rock (lithostatic pressure) literally squeezes the magma out.**
    - ***Analogy: Think of stepping on a tube of toothpaste to force it out, or mud squishing through your toes when you step in a puddle***

- **Viscosity affects a magma or lava's ability to flow**
  - **Controlled by:**
    - **Temperature (high temp - low viscosity)**
    - **Volatile content (more volatiles – less viscous)**
    - **Silica content – silica tends to form silica-oxygen tetrahedrons that bond with each other to make long chains that ultimately resist flow (more silica – more viscous)**

Rock Cycle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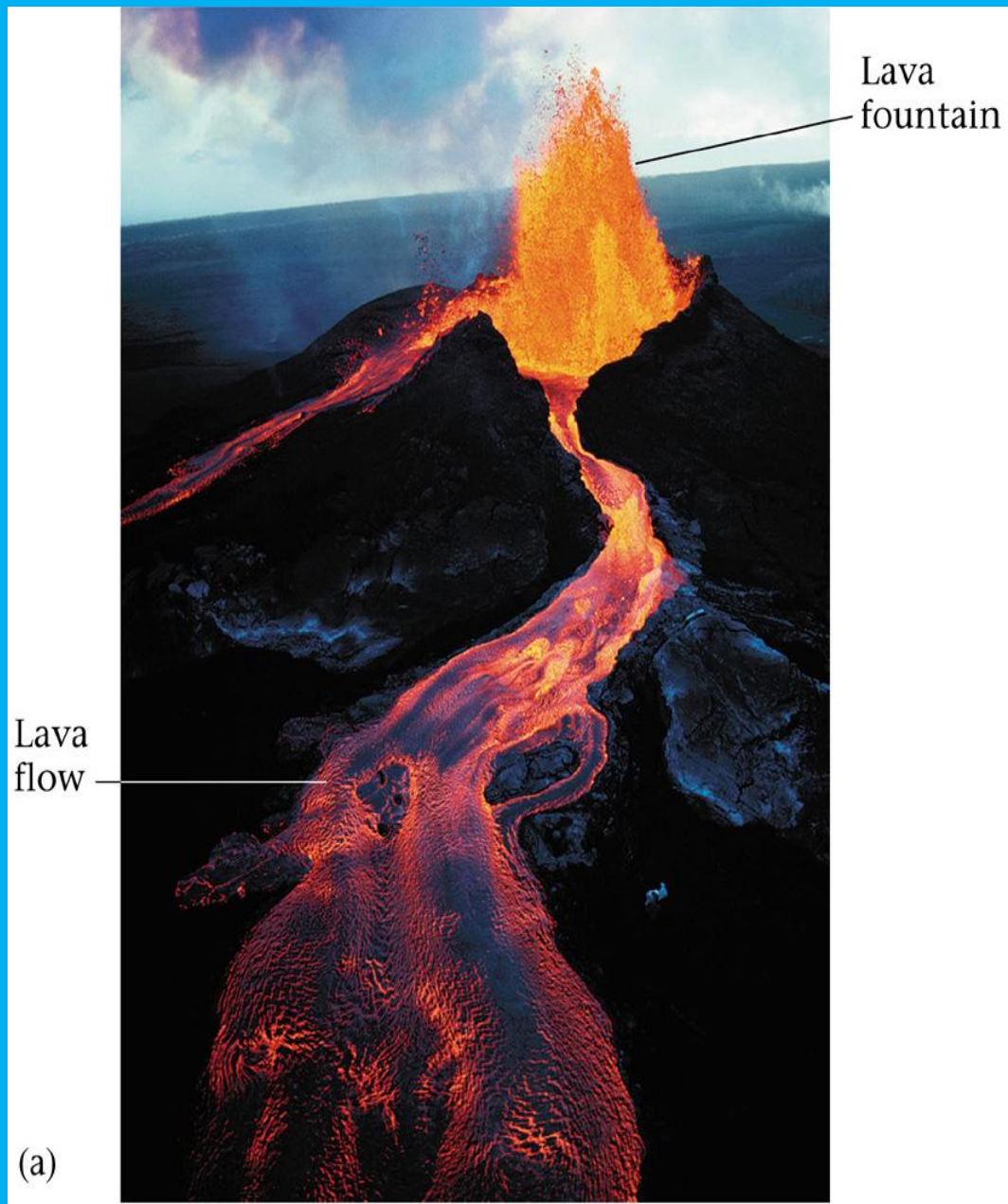
Uplift
Melting
Deposition
Metamorphism
Compaction/Cementation

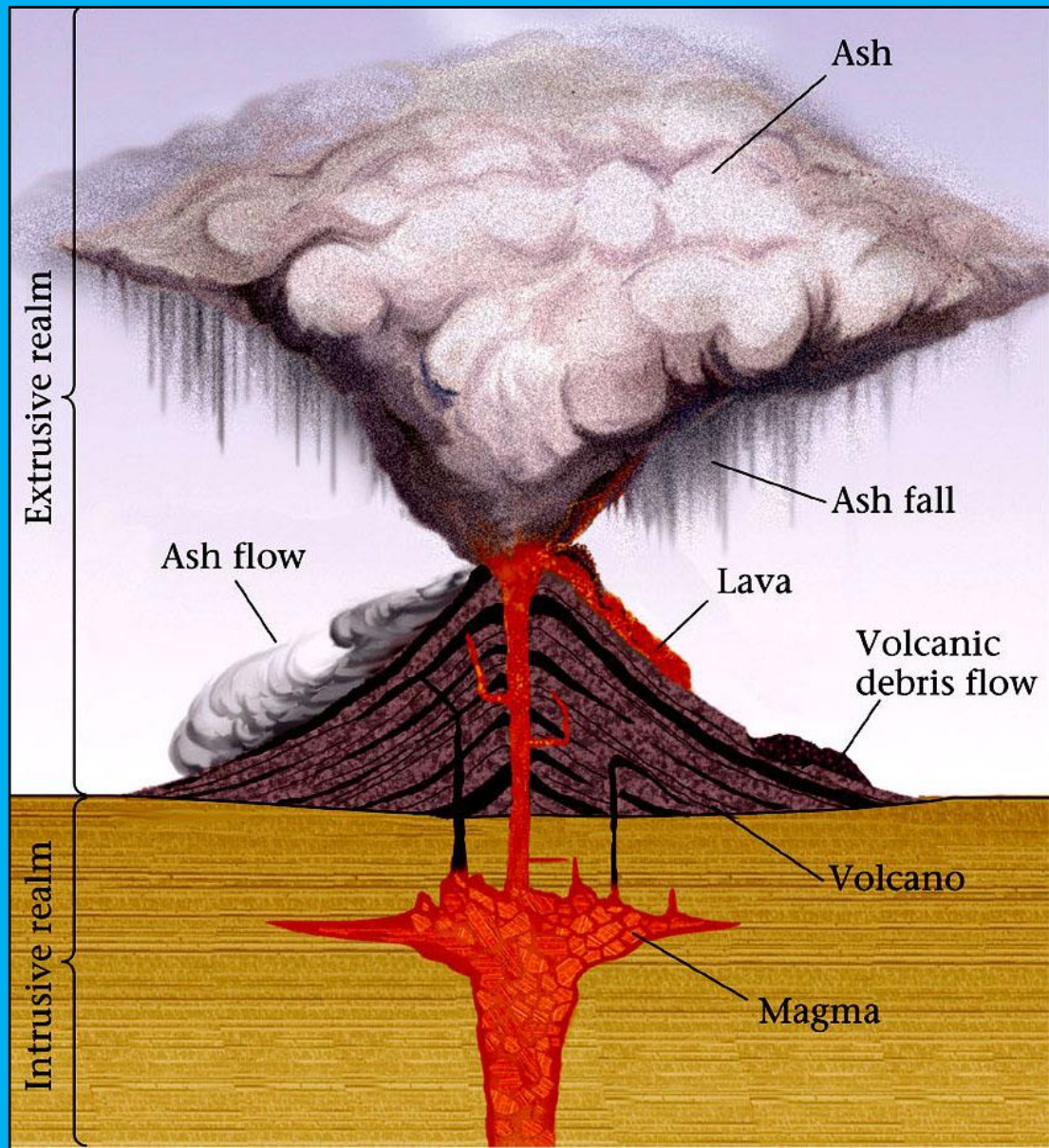
Igneous Rocks- The Basics

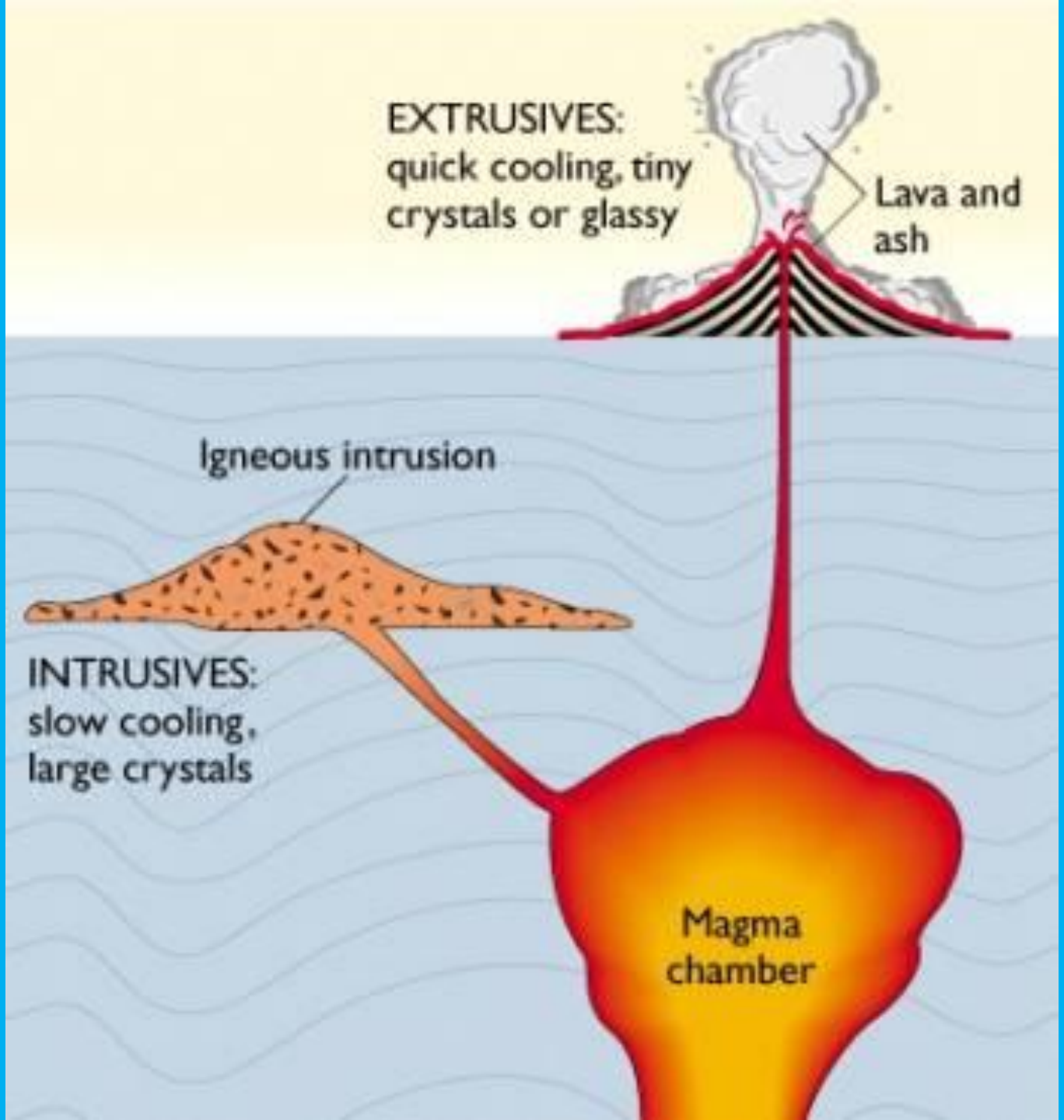
- **Solidified molten rock (which freezes at high temp).**
  - **1,100°C to 650°C.**
  - **Depends on composition.**
- **Earth is mostly igneous rock.**
  - **Magma: Subsurface melt.**
  - **Lava: Melt at the surface.**
- **Magma erupts via volcanoes.**



Igneous Rocks are classified by Texture and Composition – BOTH are used.

- In general, there are two basic types of igneous rocks
  - **Extrusive/Volcanic:** Igneous rocks that form due to the freezing of melts above the surface of the Earth
    - Includes rocks made of volcanic ash (pyroclastics)
  - **Intrusive/Plutonic:** Form by freezing of melts below the surface of the Earth.

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slow cooling,
large crystals
Magma
chamber

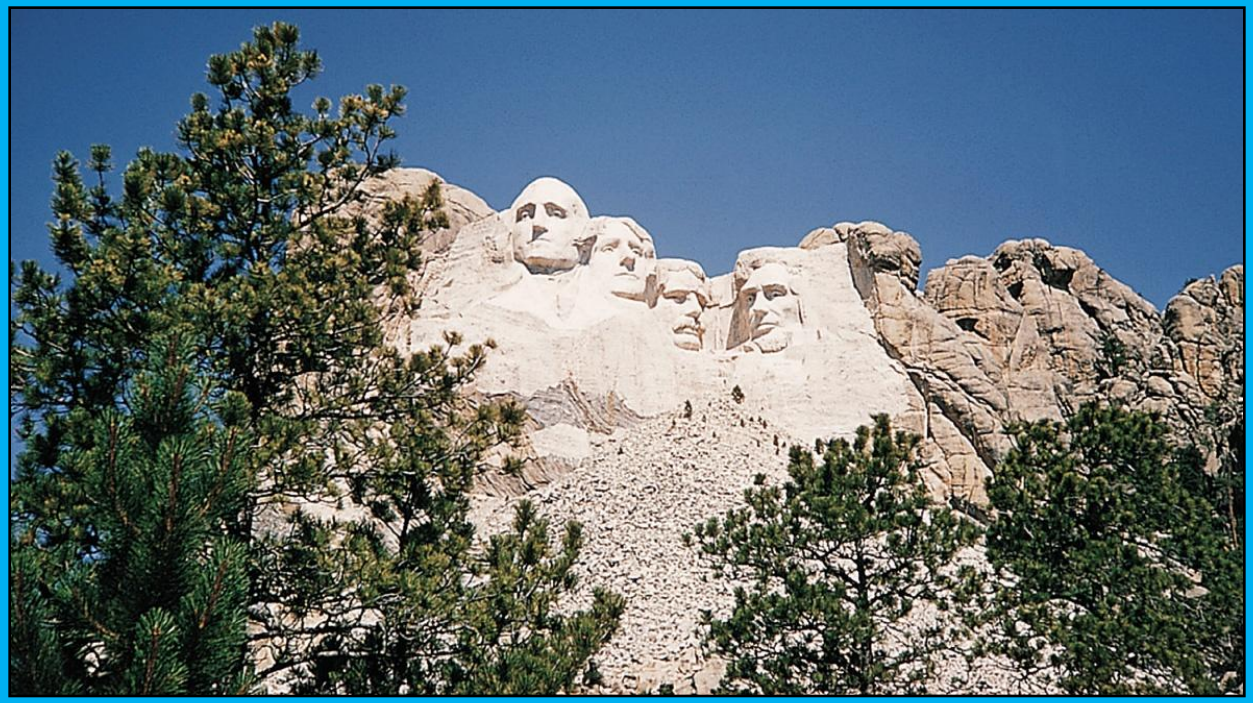
Extrusive Igneous Rock Environments

- **Explosive eruptions generally occur when source magma is:**
  - **High in silica (felsic-intermediate)**
  - **Low temp**
  - **High in volatiles**
- **These volcanoes form**
  - **Lava domes**
  - **Ash clouds and ash flows**

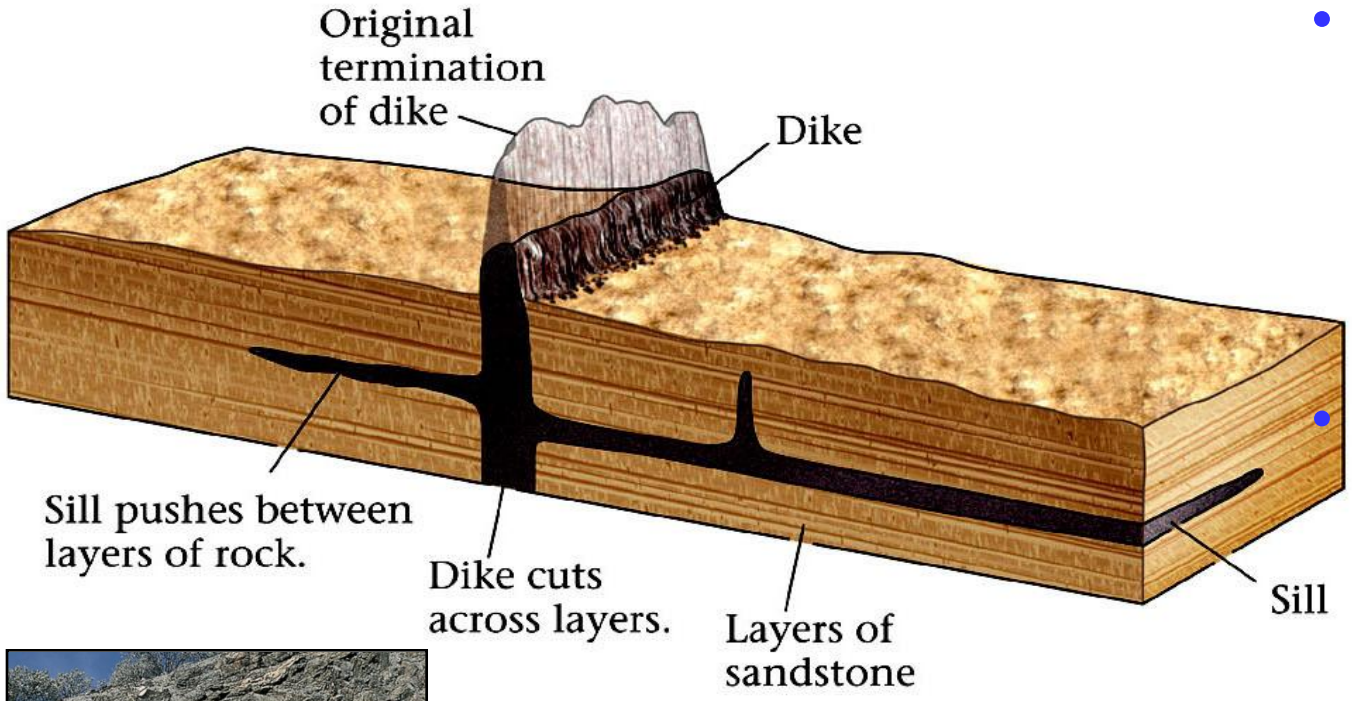
- **Effusive eruptions** generally occur when source magma is:
  - Low in silica (**mafic**)
  - High temp
  - Low in volatiles
- These volcanoes form
  - **Fluid lava flows**
  - **Fire fountains (if volatiles), lava tubes**

Intrusive Igneous Rock Environments

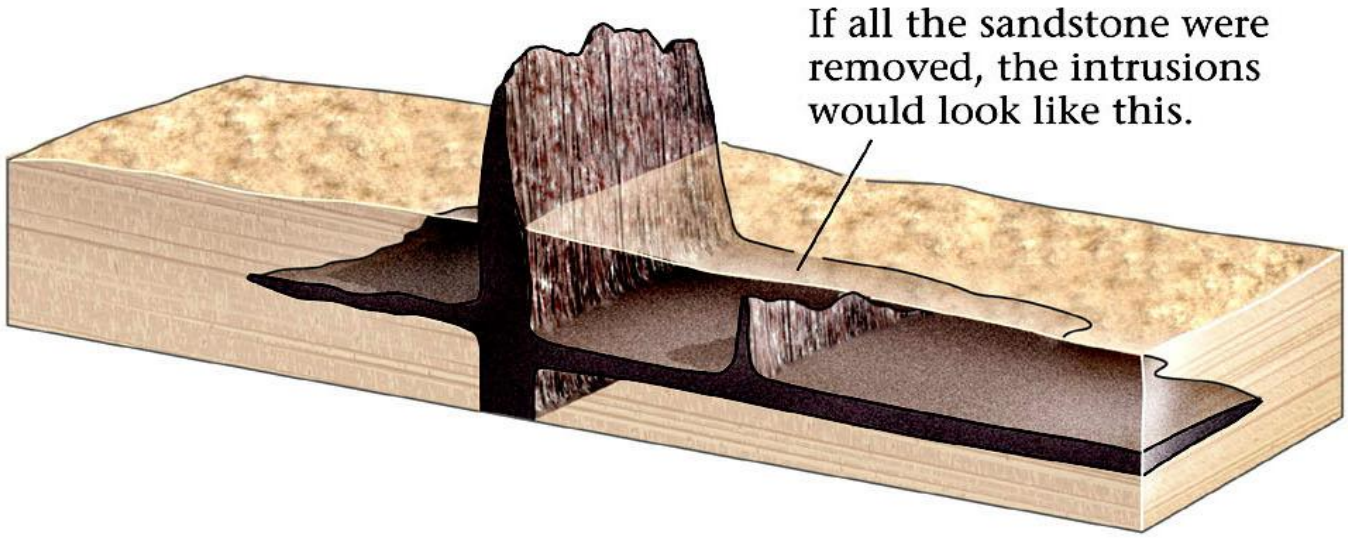
- Magma rises by percolating between grains and/or by forcing open cracks in the subsurface
- The magma that doesn't reach the surface of the Earth cools into intrusive igneous rocks
  - *Country rock or wall rock:* The pre-existing rock that magma intrudes into
  - *Intrusive contact:* The boundary between the igneous intrusion and the wall rock
- Tabular intrusions: **Dike, Sill, Laccolith** (pseudo-tabular, or sheet-like)
- Non-tabular intrusions: **Pluton, Batholith**



Dikes and Sills

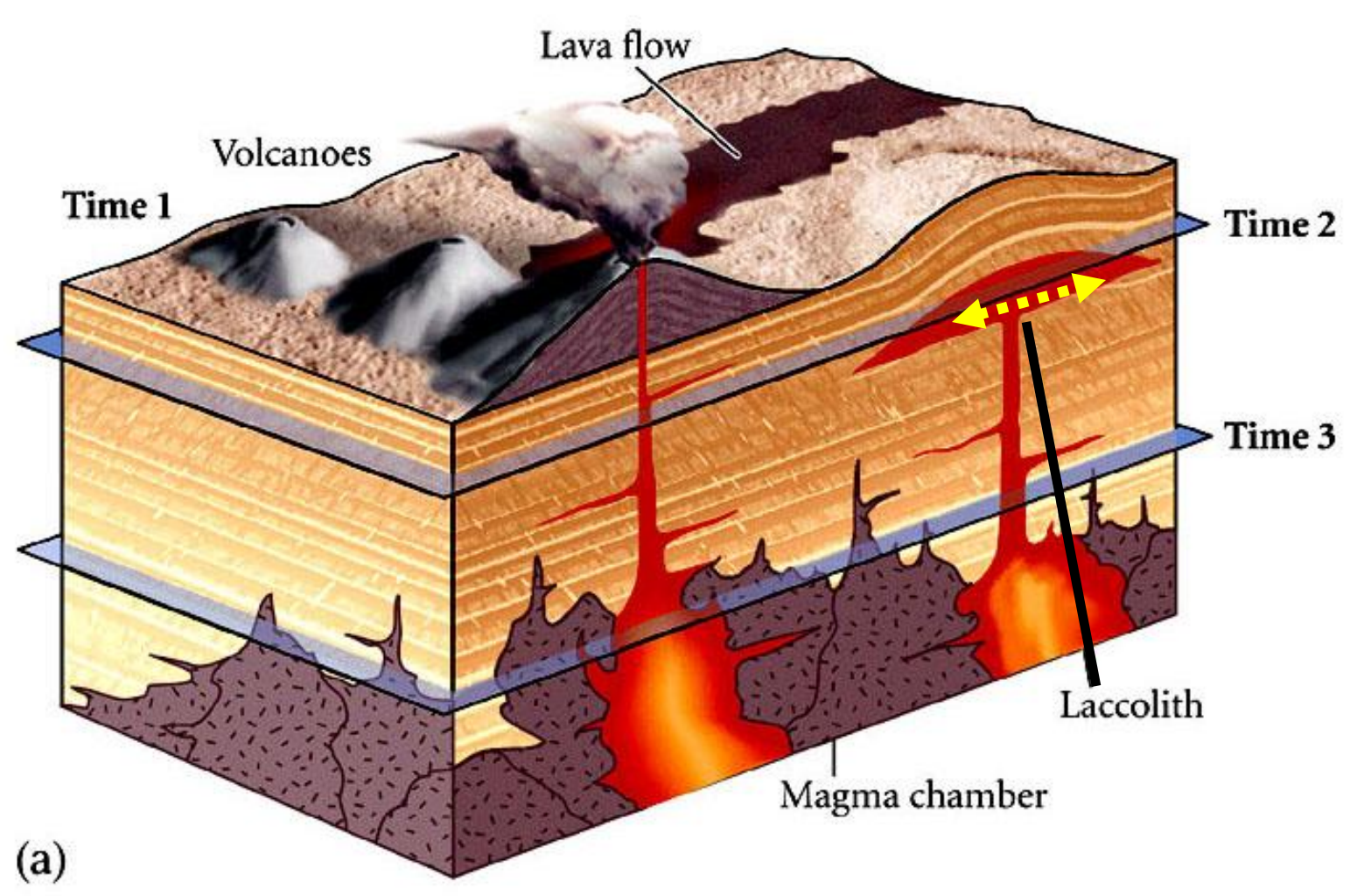


- **Dikes:** igneous intrusions that cut across layering, i.e. discordant
- **Sills:** igneous intrusions that follow layering, i.e. concordant

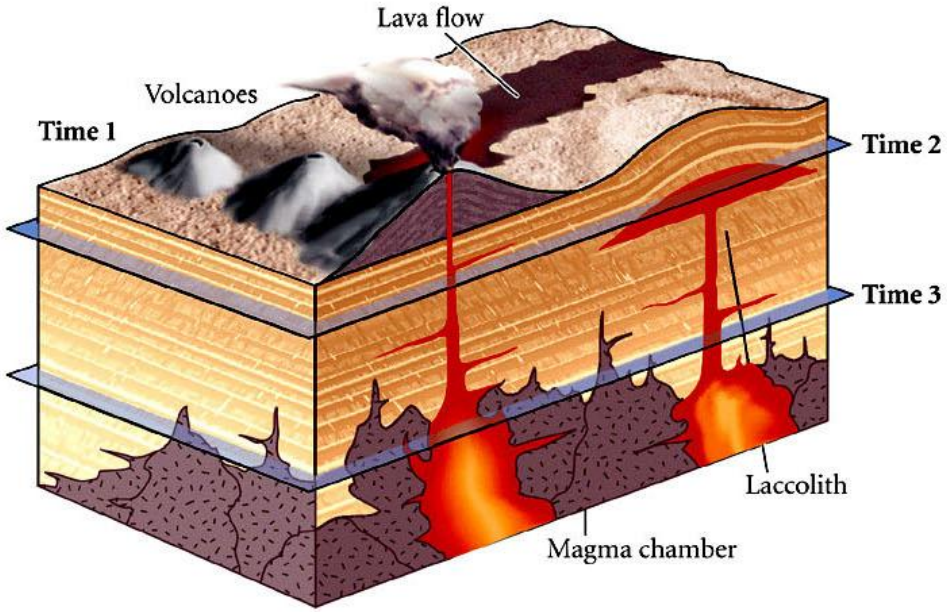


Laccoliths

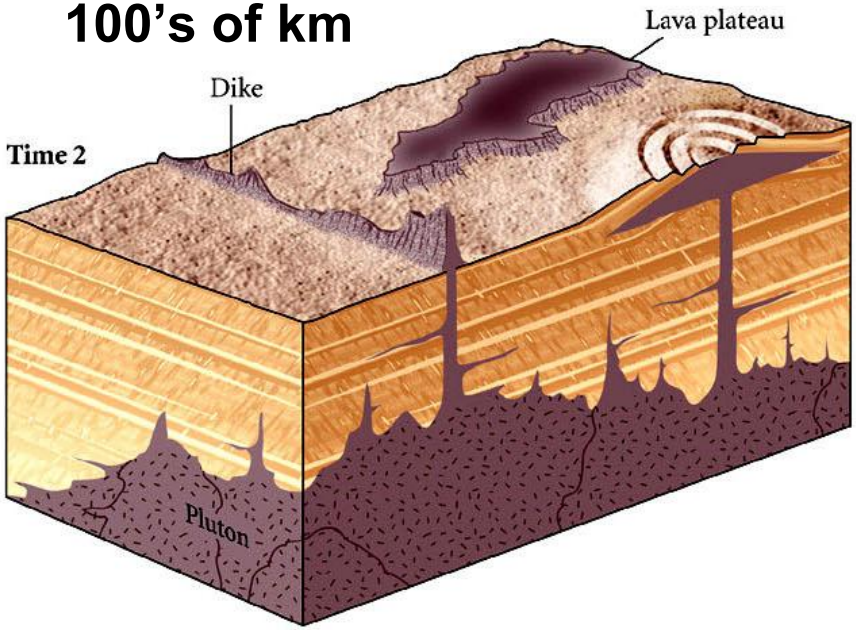
- **Laccolith: a dome-like *sill* that bends the layers above it into a dome shape**

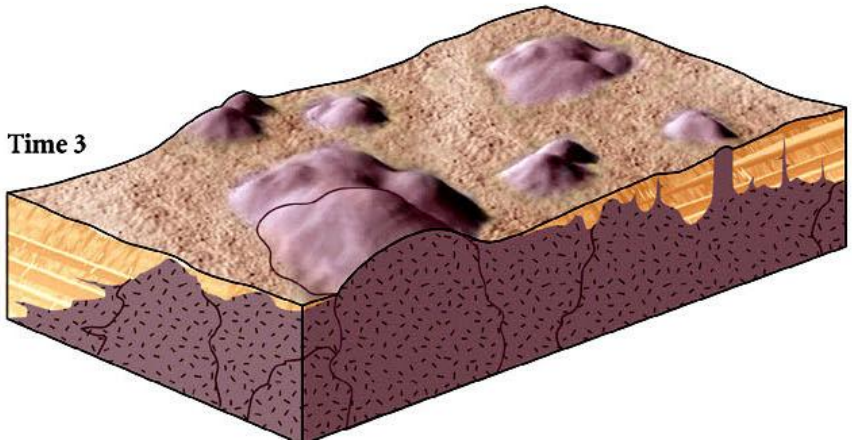


Non-Tabular Intrusions: *Plutons*



- **Pluton:** **Irregular blob-shaped discordant intrusions that range in size from 10's of m, to 100's of km**

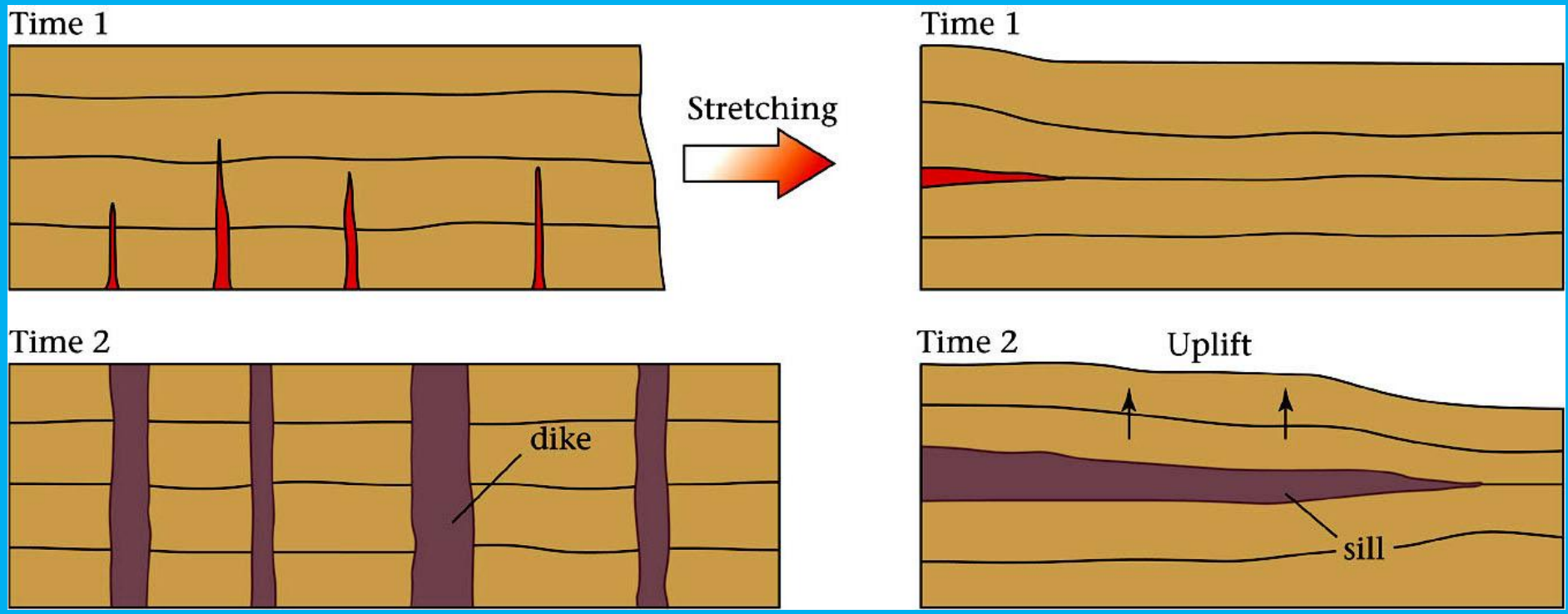




- **Batholith:** **A pluton that is 100 km^2 in surface exposure**

Effects of Intrusions

- **Dikes form in regions of crustal stretching**
- Sills may cause **uplift** at the surface of the Earth



Igneous Textures

- **Glassy Texture:** A solid mass of glass or tiny crystals surrounded by a glass matrix
  - Matrix: the smaller stuff in a rock (relative term)

- **Interlocking Texture** ***(Phaneritic)***: Rock made of interlocking crystals that grew as the melt solidified. Commonly called *crystalline igneous rocks*

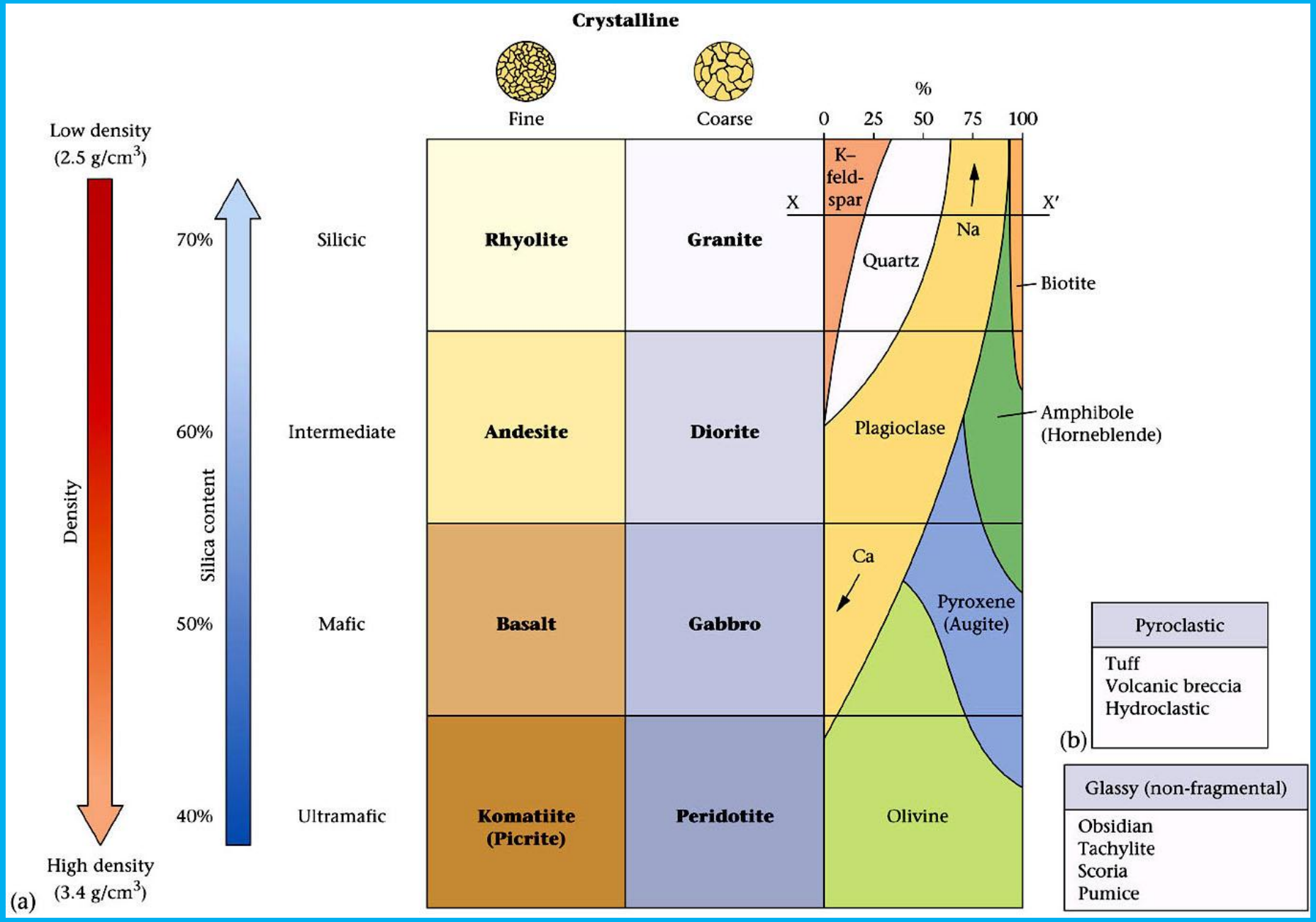
li

- **Fragmental Texture:** Volcanic rocks that are made of various types of fragments that form from volcanic eruptions.
  - Fragments can be:
    - Crystals
    - Xenoliths (from volcano walls)
    - Glass

A Welded Tuff – white specks are fragments, grey is ash

Volcanic Breccia – angular pieces of fragments entrained in the eruption

Crystalline Igneous Rocks



Glassy Igneous Rocks

- **Obsidian:** Mass of solid felsic glass; conchoidal fracture
- **Tachylite:** mafic, bubble-free mass of >80% glass (very rare)
- **Pumice:** glassy felsic volcanic rock that contains abundant open pores called vesicles (it grey to tan in color). Occasionally less dense than water (it floats!)
  - Vesicle: a open space left over from a gas bubble in a lava or magma
- **Scoria:** glassy mafic volcanic rock with abundant vesicles (>30%). Grey, black, or red in color.
  - Typically has larger and rounder vesicles than pumice

Fragmental Igneous Rocks

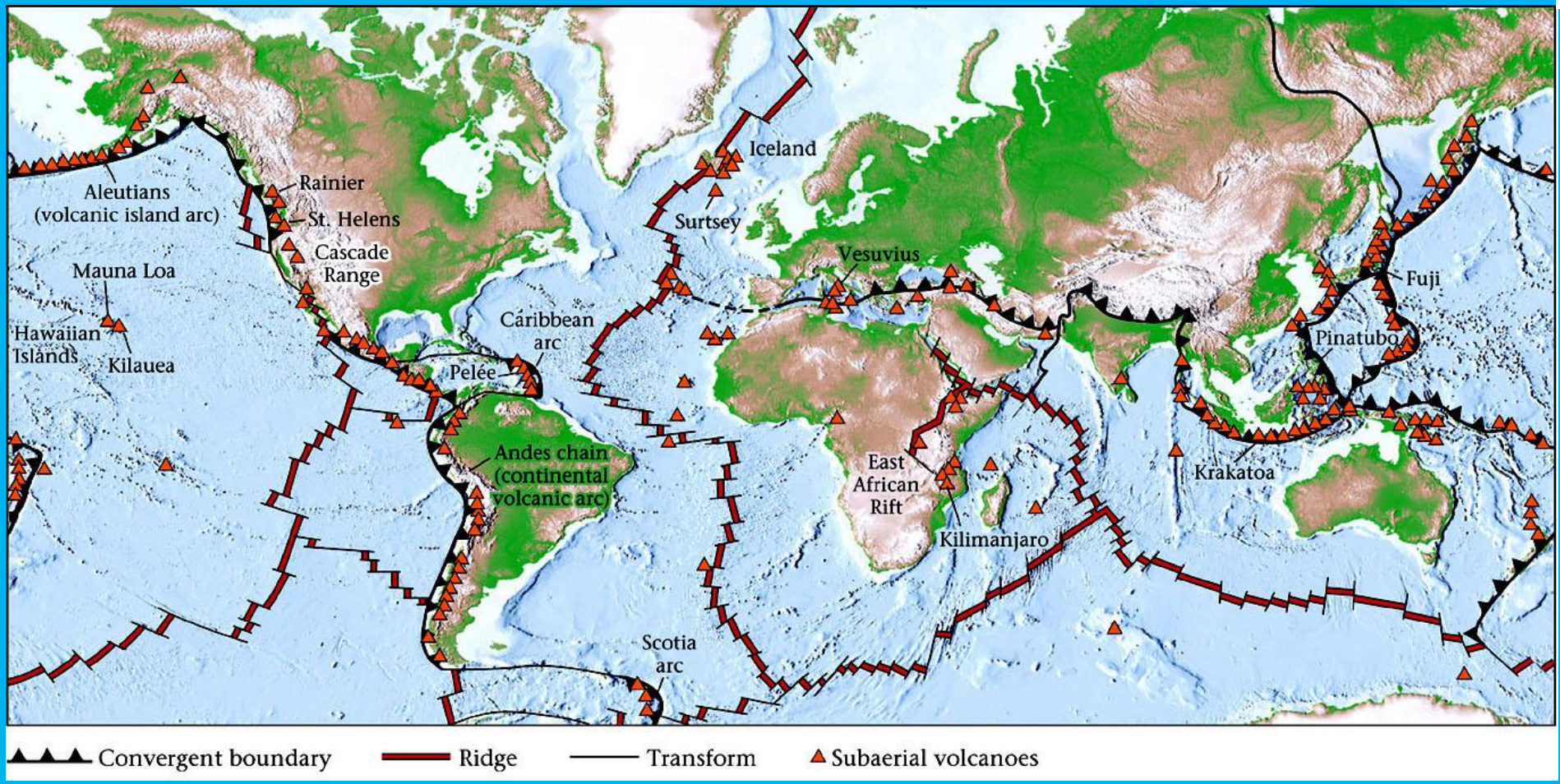
{ Rocks blasted out of volcanoes…commonly called *pyroclastic* rocks }

- **Tuff: Fine-grained rock, composed of lithified volcanic ash and/or fragmented lava and pumice. Formed from ash fall from the air, or from hot material that avalanches down the side of a volcano.**
  - **If material is still very hot (gooey) it may get squished upon landing and weld with other particles forming a *welded tuff***

- **Volcanic Breccia: Large angular chunks of material from either volcanic debris flows (blocky lava flow) or air fall (bombs).**

- **Hyaloclasite: formed when lava erupts under ice of water and cools so quickly that it shatters into fragments that weld or cement together.**

Where Does Igneous Activity Occur?



Most volcanoes occur at plate boundaries or Hot Spots

Most igneous rocks *crystalline*.

Crystal sizes record cooling rates.

Coarse (Phaneritic) -- every crystal visible to naked eye. Grew slowly.
Intrusive; formed at depth,

where magmas, insulated by

overlying rocks, cool slowly.

Phaneritic Texture

- **Phaneritic (Intrusive)**
  - **Phaneritic rocks are coarse-grained rocks which form below the Earth's surface.**
  - **The individual crystals are relatively even-sized and large enough for scientists to identify the different mineral grains that compose the rock.**

Granite rock with a phaneritic texture

Fine (Aphanitic)-- easily seen only with magnifying glass. Had little time to grow.

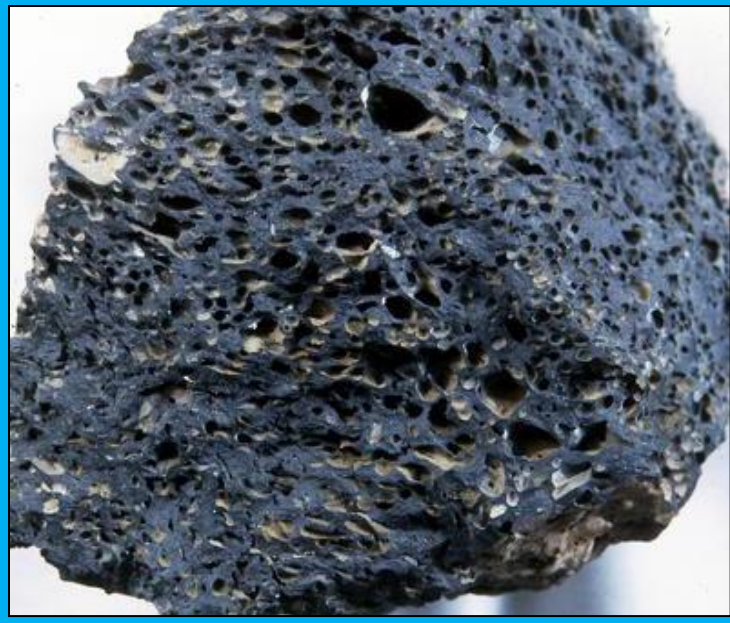
Extrusive; cooled rapidly at Earth's surface.

Glassy: cooled too fast for even small crystals to form.

Aphanitic Texture

- **Aphanitic (Extrusive)**
  - Aphanitic rocks are very fine-grained and contain crystals that are too small to distinguish without the aid of a magnifying lens.
  - Aphanitic rocks are often described by how light or dark the rock appears. Lighter colored aphanitic rocks contain mostly non-ferromagnesian silicate minerals. Darker colored aphanitic rocks contain mostly ferromagnesian silicate minerals.
  - Aphanitic rocks may also contain vesicles of remnant gas that give the rock a vesicular texture. Vesicles form when the rock cools very quickly and preserves the openings formed by the expansion of trapped gas bubbles.

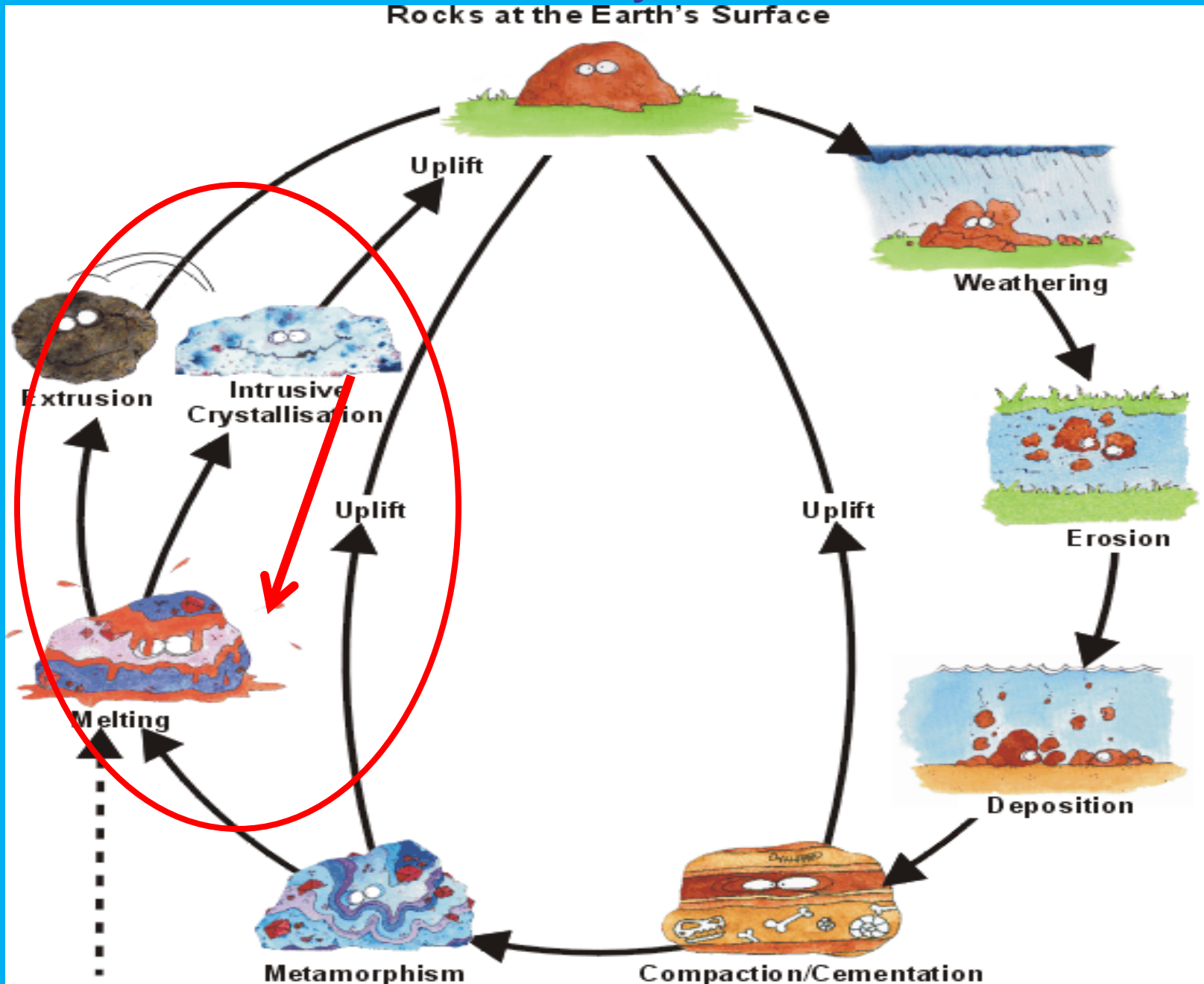
Basalt rock with an aphanitic and vesicular texture



- **Glassy (Extrusive)**
  - Glassy textured rocks are formed by very rapid cooling of magma.
  - Glassy rocks often form from magmas with high silica content that arranges into long chainlike structures before crystallization occurs. These sili chains increase the viscosity of t magma and it once it eventually cools it forms a glassy textured rock.
  - Glassy rocks can be considered amorphous because they have no crystalline structure.
  - Glassy rocks are classified by the amount of glass contained by the rock:
    - Glass-bearing: 0-20% glass
    - Glass-rich: 20-50% glass
    - Glassy: 50 – 100% glass
  - **Obsidian is a common glassy rock.**

Obsidian rock with a glassy texture and conchoidal fractures

Rock Cycle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