EPSC 201 - LECTURE 15 – MARCH 8, 2016

Practice Question: Which is the correct order of adjectives describing magma composition? (from more to less silica)

Answer: D. Felsic/intermediate/mafic/ultramafic

Review: extrusive rocks are erupted on the surface and then cooled, whereas intrusive cool underground. As the silica content increases so does the viscosity. Slower cooling means coarser grain – grains have more time to form larger sizes.

Practice Question: Why are there different magma compositions?

Answer: Considers the type of rock that is melting; 2 different magmas may come together in the magma chamber (mixed composition); Silica-rich magma melts first which can get separated from the rest resulting in a silica-rich vs. less-silica rock separation; hot magma is already formed which is melting the edges of the magma chamber which gets mixed in.

- Initial source rock compositions
- Partial melting
- Assimilation
- Magma mixing

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. Faster cooling = smaller/finer grains.
- Intrusive settings – cool at depth: lose heat slowly; crystals often grow large. Warmer so materials cool more slowly therefore grains have more time to grow so there are larger crystals forming in the rocks.

Extrusive Settings

- Lava flows cool as blankets that often stack vertically
- Lava flows exit volcanic vents and spread outward
- Low-viscosity lava (basalt) can flow long distances
- Lava cools as it flows, eventually solidifying

Magma will erupt outwards and flow away from the source. The low-viscosity (flows easily), often basalt, will flow much further away and end up in a thinner layer. Higher-viscosity lava will form thicker layers closer to the source. Lava cools as it flows and solidifies; the flow and viscosity ill impact how it cools.

- High-viscosity felsic magma erupts explosively – a large amount of volcanic ash which is ejected in the air and can travel very far – hazardous to flights and cities.

- Yield huge volumes of ash that can cover large regions
- Pyroclastic flow (includes ash, debris, and rocks) – volcanic ash and debris avalanche: races down the volcanic slope as a density current; often deadly.

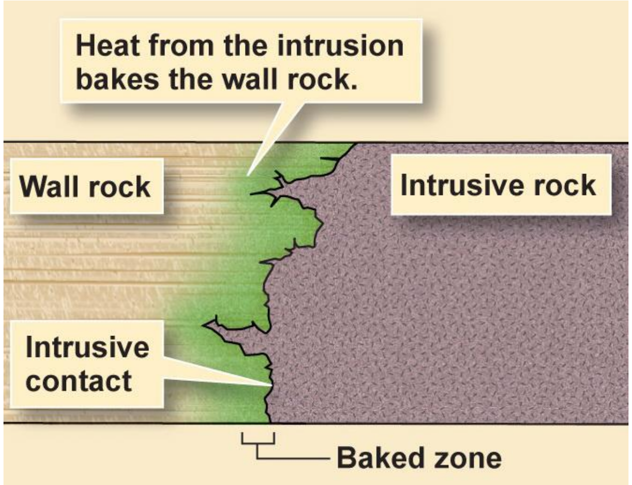
Intrusive Settings

-Magma invades pre-existing wall rock by:

- Percolating upward between grains
- Forcing open cracks

-The wall rock – magma-intrusive contact reveals high heat

- Baked zone – rim of heat-altered wall rock
- Chill margin – rim of quenched magma at contact



Magma (liquid rock) is flowing more easily and it can sort of invade the rock surrounding it by percolating between the grains as it solidifies which forces apart the existing rock.

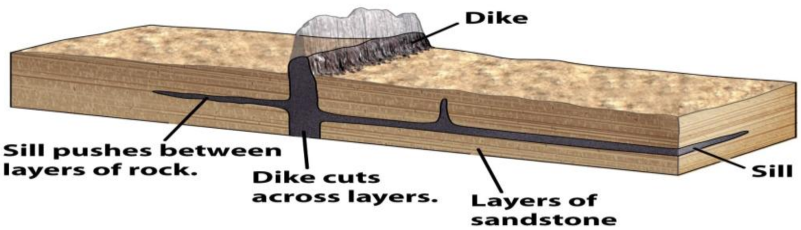
Wall rock = existing rock.
Baked zone = where hot material meets cold material. Cold material warms up because of the heat from the hot material.

-This seeping in of intrusive-magma can happen in different ways where geologists categorize intrusions by shape:

- Tabular (sheet) – planar with uniform thickness (horizontal or vertical)
- Blister-shaped – a sill that domes upward
- Balloon-shaped – blobs of melted rock

<u>Tabular Intrusions</u>

- Tend to have a uniform thickness
- Often can be traced laterally
- Have 2 major subdivisions: (1) Sill – injected parallel to existing rock layering (2) Dike – cuts across rock layering (vertical, perpendicular to rock layers)



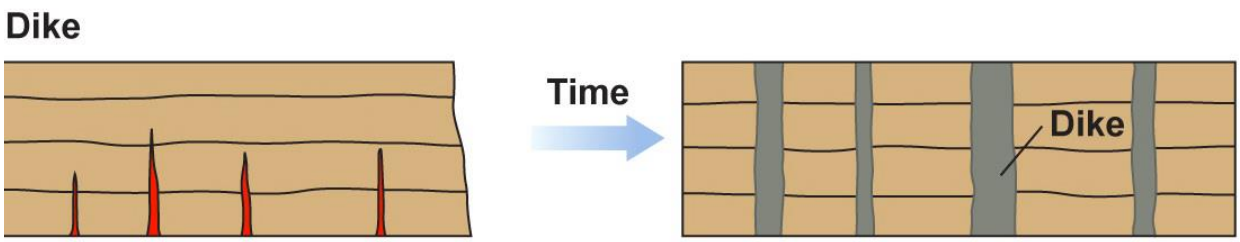
Tabular intrusions alter the rock since it forces it apart in some way causing it to expand, grow, and move. Also alters the rock thermally since it is warming to surrounding rock.

Dikes and sills modify invaded country rock.

- They cause the rock to expand and inflate
- They thermally alter the country rock

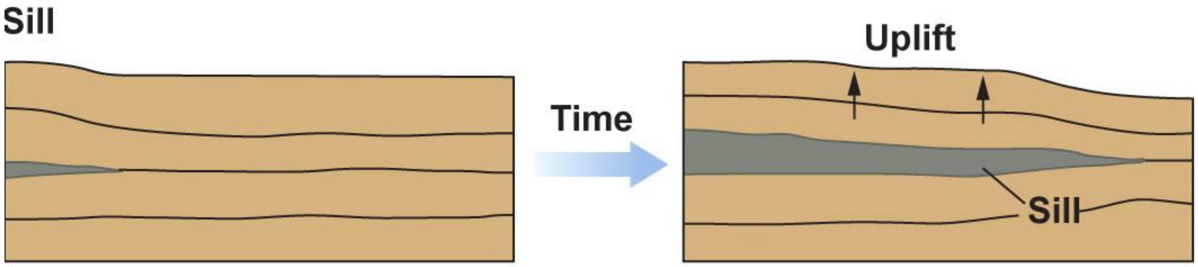
Dikes:

- Cut across pre-existing layering (bedding or foliation)
- Spread rocks sideways
- Dominate in extensional settings.



Sills:

- Are injected parallel to pre-existing layering
- Are usually intruded close to the surface

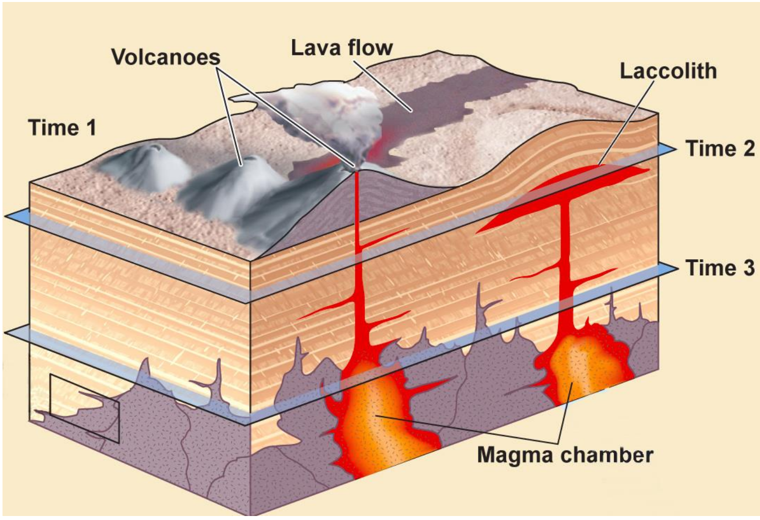


Both dikes and sills exhibit wide variability in:

- Size
- Thickness (or width)
- Lateral continuity

Intrusive rocks tend to be less susceptible to wethering and erosion. So over time, if you leave the setting that is not active and let it be wethered then the rock around the intrusive rocks will be wethered away and you will be left with spots of intrusive rock. Example: 3 dikes radiate away from Shiprock, New Mexico, and eroded volcanic neck.

Laccolith: Some intrusions start to inject in between layers but then dome upward, creating a blister-shaped intrusion known as laccolith.



It starts by spreading outwards like a sill and then balloons upwards. Shape like a mushroom cloud is called a laccolith. Example: Mount Royal in Montreal is a ~120Ma laccolith – it started as a sill and then ballooned upward.

Plutons: Irregular or blob-shaped intrusions, 10 m to 10 km across

Batholiths: multiple plutons, 100's km long x 100 km wide, example: Sierra Nevada Batholith

Plutonic Activity

Plutons may amass into a batholith:

- Immense volumes of intrusives
- Form above subduction zones (convergent boundaries) – parallel to the subductions zones is volcanic activity so there is a lot of magma there
- May add magma for tens of Ma
- Batholiths mark former subduction –EVIDENCE FOR AN OLD PLATE BOUNDARY

Intrusive

With erosion, progressively deeper features are exposed. We can see these rocks on the surface because all the surrounding rocks have eroded and wethered away.

- Vertical dikes
- Horizontal sills
- Mushroom-shaped laccoliths

Influence on the landscape: Continued uplift and erosion exposes the pluton.

- Intrusive rocks are usually more resistant to erosion
- Thus, intrusive rocks often stand high on the landscape
- "Unroofing" (exposure of intrusive rocks) takes long periods of geologic time

Describing Igneous Rock

-Igneous rock is used extensively as building stone: office buildings, kitchens
-Why? Durable & hard (does not wether away as much), Beautiful
-Often called “granite” – it is not always true granite

-Useful descriptions of igneous rock:

- color (light or dark)
- texture
- the size, shape and arrangement of the minerals:
  -Crystalline – interlocking crystals fit like jigsaw puzzle (size of crystal can tell us how fast the rock has cooled – fine vs. coarse)
  -Fragmental – pieces of pre-existing rocks, often shattered (shards of other rocks can be evidence of an explosion)
  -Glassy – made of solid glass or glass shards
- Texture directly reflects magma history

Crystalline Igneous Textures

Interlocking mineral grains from solidifying melt. Texture reveals cooling history:
Fine grained: rapid cooling, crystals do not have time to grow, extrusive.
Coarse grained: slow cooling, crystals have a long time to grow, intrusive.

Crystalline Textures

Texture reveals cooling history. Porphyritic texture – a mixture of coarse and fine crystals: indicates a 2-stage cooling history.

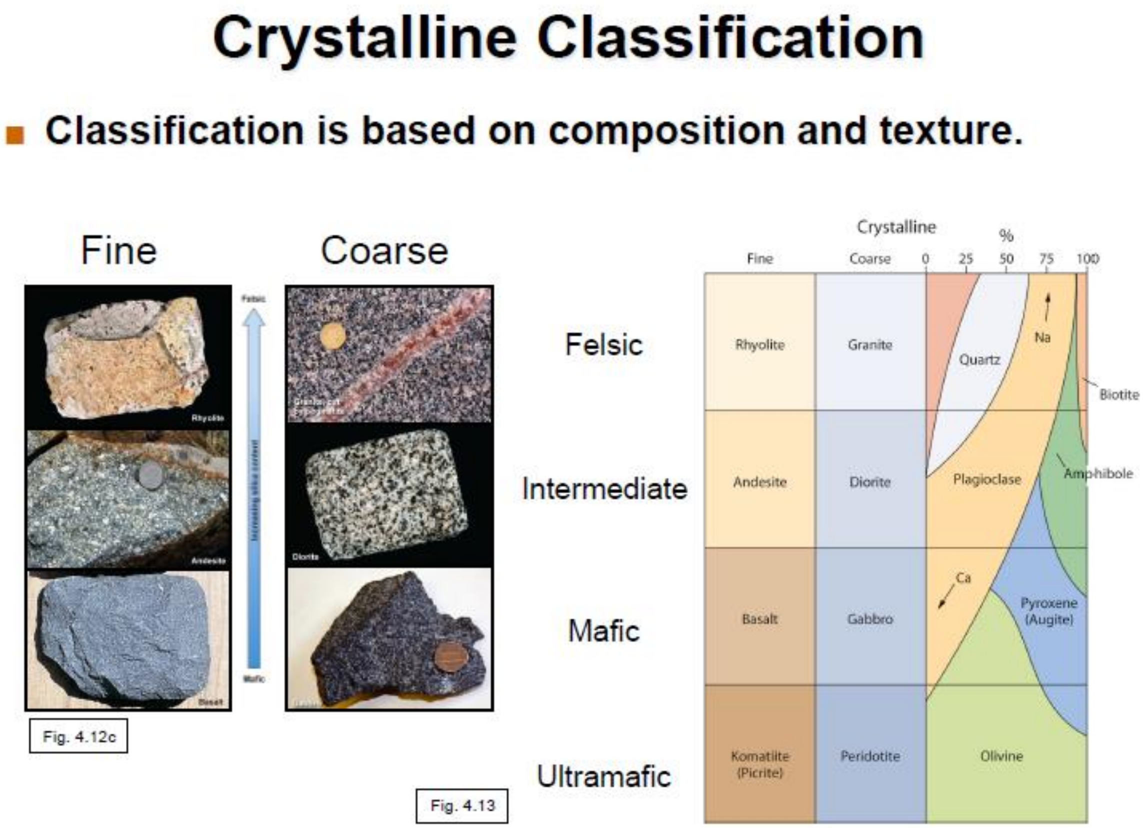
- Initial slow cooling creates large phenocrysts
- Subsequent eruption cools remaining magma more rapidly

Fragmental Textures

Pre-existing rocks that were shattered by eruption. After fragmentation, the pieces fell and are cemented.

Glassy Textures – Extrusive Igneous rocks – EXTREMEMLY FINE-GRAINED, cools really fast to keep fine-grained structure.

- Solid mass of glass or crystals surrounded by glass
- Fracture conchoidally
- Result from rapid cooling of lava



**Know this slide

<u>Glassy Classification:</u> More common in felsic igneous rocks

- Obsidian – felsic volcanic glass
- Pumice – frothy felsic rock full of vesicles; it floats
- Scoria – glassy, vesicular mafic rock

<u>Pyroclastic Classification:</u> Pyroclastic – fragments of violent eruptions

- Tuff-volcanic ash that has fallen on land
- Volcanic breccia – made of larger volcanic fragments

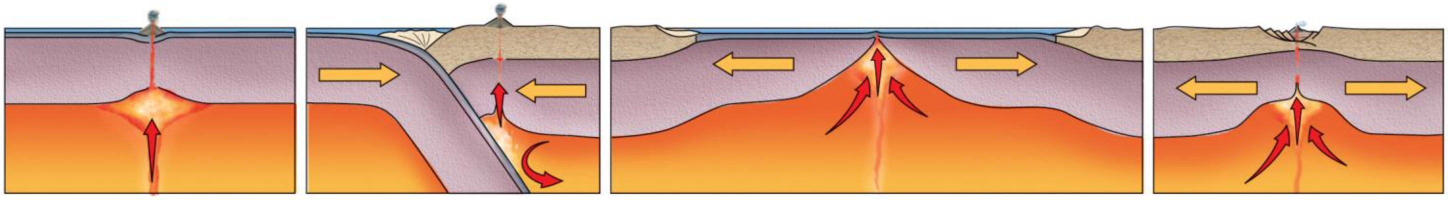
Where does Igneous Activity Occur (i.e. volcanic and magma activity)?

Igneous activity occurs in four plate tectonic settings:

- Volcanic arcs bordering deep ocean trenches

- Isolated hot spots
- Continental rifts (pulling part 2 pieces of continental plates)
- Mid-ocean ridges

They can occur at established or newly formed tectonic plate boundaries EXCEPT: hot spots which are independent of plates.



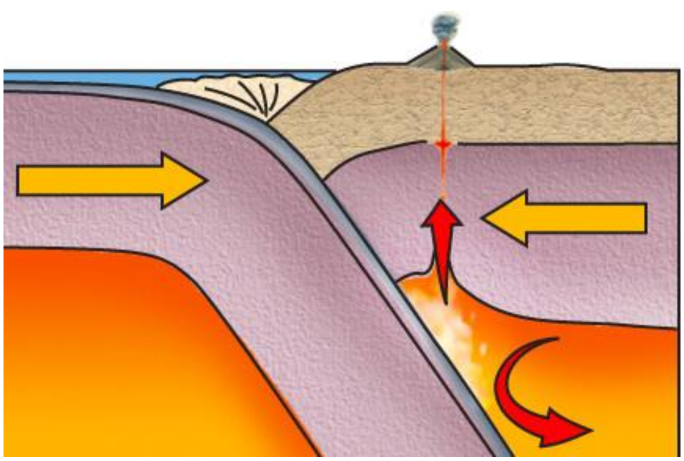
Mantle plume and a hot-spot volcano | Subduction yields a volcanic arc. | Melting occurs beneath a mid-ocean ridge. | Melting occurs beneath a continental rift.

<u>Volcanic Arcs</u>

-Most subaerial volcanoes on earth reside in arcs
-Mark convergent tectonic plate boundaries

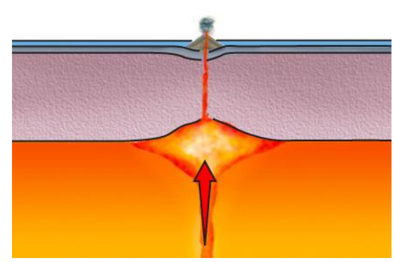
- Deep oceanic trenches and accretionary prisms
- Subducting oceanic lithosphere adds volatiles (water)
- Rocks of the asthenosphere partially melt
- Magma rises and creates volcanoes on overriding plate
- Magma may differentiate

Examples: Aleutian Islands, Japan, Java & Sumatra



In the diagram, we have an oceanic plate being subducted under a continental plate and it is bringing water with it. That water might melt the rock on the overriding plate which can cause magma to form and have volcanic activity at the surface. This results in a volcanic arc forming.

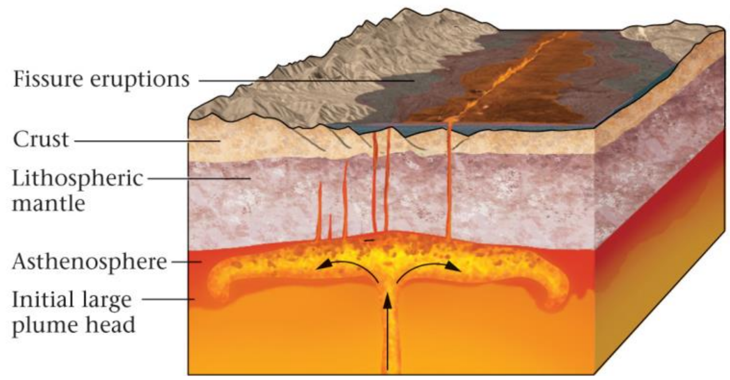
<u>Hot spots</u>: About 50-100 mantle-plume hot spot volcanoes exist. They are independent of tectonic plate boundaries.



- May erupt through oceanic or continental crust: oceanic – mostly mafic magma (basalt); continental – mafic and felsic (basalt and rhyolite)
- Burn a volcano chain through overriding tectonic plate which creates a hot-spot track

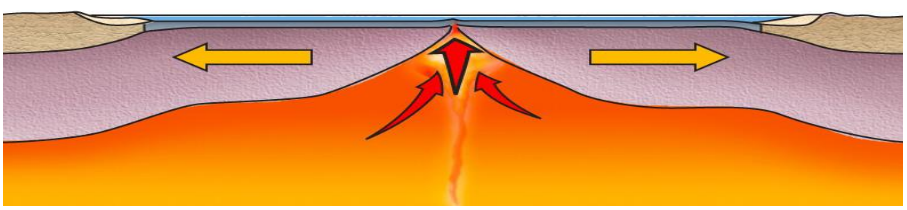
<u>Continental Rift</u>: Places where continental lithosphere is being stretched. Rifting thins the lithosphere.

- Causes decompressional melting of mafic rock (stretching the continent and moving the hot materials closer to the surface where it is thinner)
- Heat transfer melts crust, creating felsic magmas
- Example: East African Rift Valley



<u>Mid-Ocean Ridges:</u> Most igneous activity takes place at mid-ocean ridges. Area where new material is being formed so hot material is coming to the surface. Again, decompressional melting: taking hot rock which is lower below the surface and bringing it up, so less pressure causes the melting.

- Rifting spreads plates leading to decompression melting
- Basaltic magma wells up and fills magma chambers
- Solidifies as gabbro at depth
- Moves upward to form dikes or extrude as pillow basalt



<u>Large Igneous Provinces</u>

LIP's: unusually large outpourings of magma (large areas of igneous rocks spreading over a large area (over 100km) to accumulate over thick layers).

- Mostly mafic, include some felsic examples
- Mantle plume first reaches the base of the lithosphere
- Erupts huge volumes of mafic magma as flood basalts
  -Low viscosity
  -Can flow tens to hundreds of kms
  -Accumulate in thick piles

Practice Question: A ___________ is a tabular intrusion that cuts across layers, whereas a _____________ is one that intrudes between layers.

Answer: Dike/Sill (memory aid – window SILL = horizontal)

Practice Question: If you find an outcrop of coarse-grained igneous rock, you are probably looking at…

Answer: Slowly cooled magma in a large pluton that formed deep in the crust. If you have large grains = hotter temperature = cools slowly

Practice Question: In which of the following tectonic settings is magma formation not likely a consequence of decompression melting?

Answer: Convergent Plate Boundary – there is no mechanism to get material from deep depths to the surface (i.e. taking hot material and bringing it to the surface). This mechanism is characteristic of a divergent plate boundary and somewhat less characteristic of hot spots (but could still see decompression melting!)

Number and intensity of volcanic eruptions recorded in human history is not representative of all the volcanic eruptions from the start of geologic time.

<u>SEDIMENTARY ROCKS, e.g. Grand Canyon</u>

Sedimentary rocks form layers like the pages of a book – you can drill through the layers and pull out a record of what happened in the past. The layers record a history of ancient environments. The layers occur only in the upper part of the crust – sedimentary rocks are surface rocks.

Sedimentary rocks cover underlying basement rock. They happen by taking surface rocks, breaking them apart through wethering, moving them around the surface and then compressing them and forming new rocks. Break them apart, move them around (through water or wind, or putting a glacier over them, they settle and get compressed, and then a new rock forms).

Rock cycle: we looked at the igneous rocks, where there is a lot of melting. There were also extrusions of igneous rocks where some of the material may have wethered away. So the material that wethered away would have been the creation of sedimentary rocks.

Sedimentary rocks are erosion and deposition. It tells us about what is happening at the surface when the rock was created.

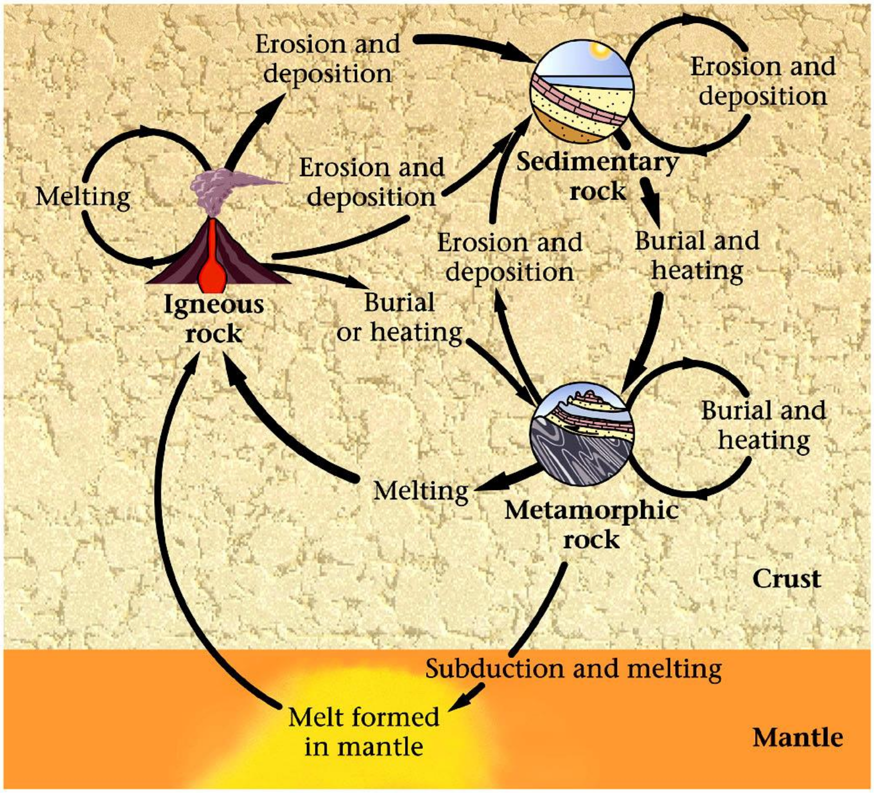


FIGURE B.1

Earth: Portrait of a Planet, 2nd Edition

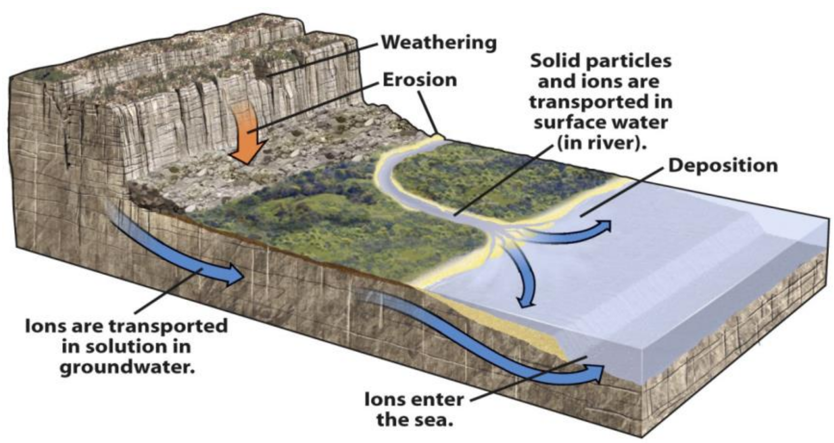
Weathering, Sediments, and Sedimentary Rocks

Weathering: Chemical decay & physical fragmentation of rock at/near the Earth surface

Erosion: Incorporation and transport of material by a mobile agent (water, wind, ice).

Mass-wasting: transfer (transport) of rock material downslope under the influence of gravity (rockfalls/rock slides, landslides, slumps, avalanches, debris flow, mud flows, creep, etc).

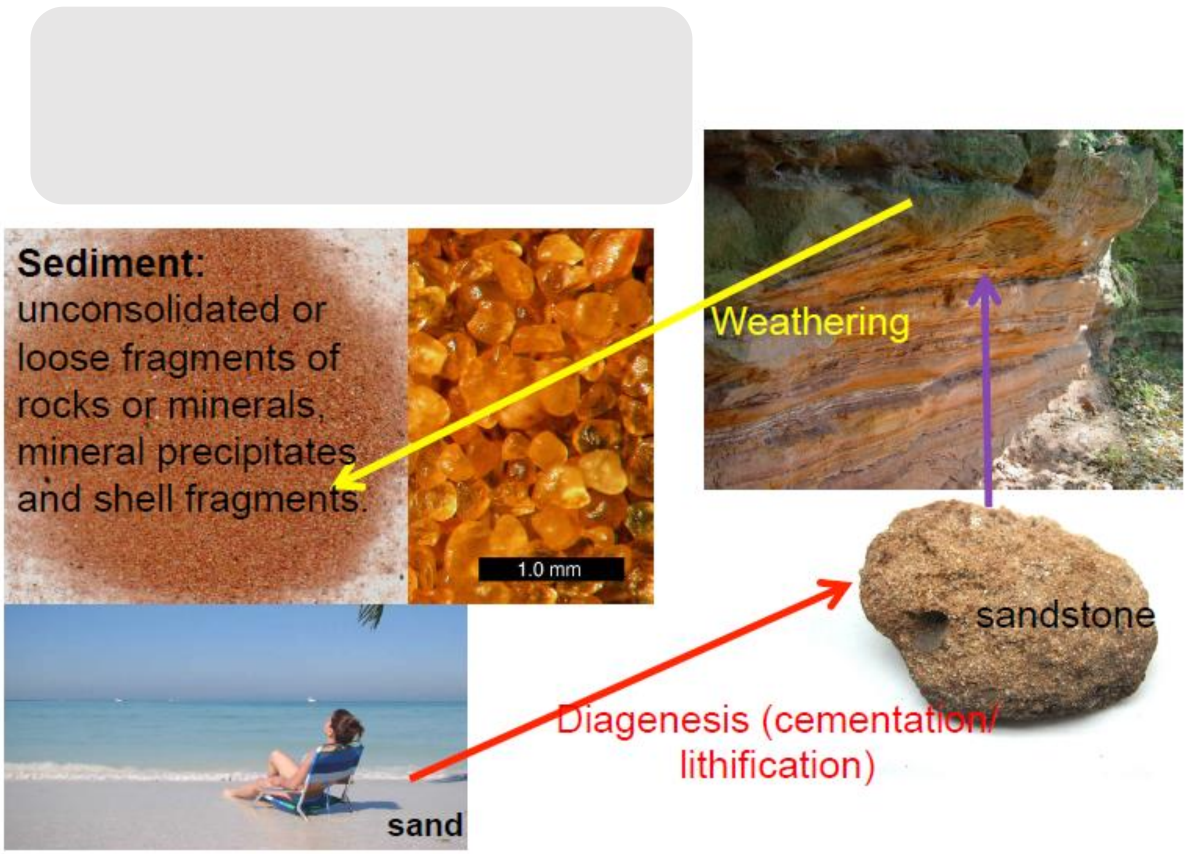
Weathering cannot be totally dissociated from erosion and mass-wasting because, as weathering breaks rocks apart, it facilitates the movement of rock debris by erosion and mass-wasting and by removing the products of weathering, erosion and mass-wasting expose fresh, unaltered rock to weathering.



Intrusive igneous rocks revealed by erosion and weathering is now subjected weathering:

- Weathering is the response of earth material changing environment
- The mass crystalline rock, which formed in high temperature, higher pressure environment perhaps several kilometers below ground, is now subjected to a very different and comparatively hostile surface environment. In response, this rock mass will gradually change until it is once again in equilibrium, or balance, with its environment = weathering.

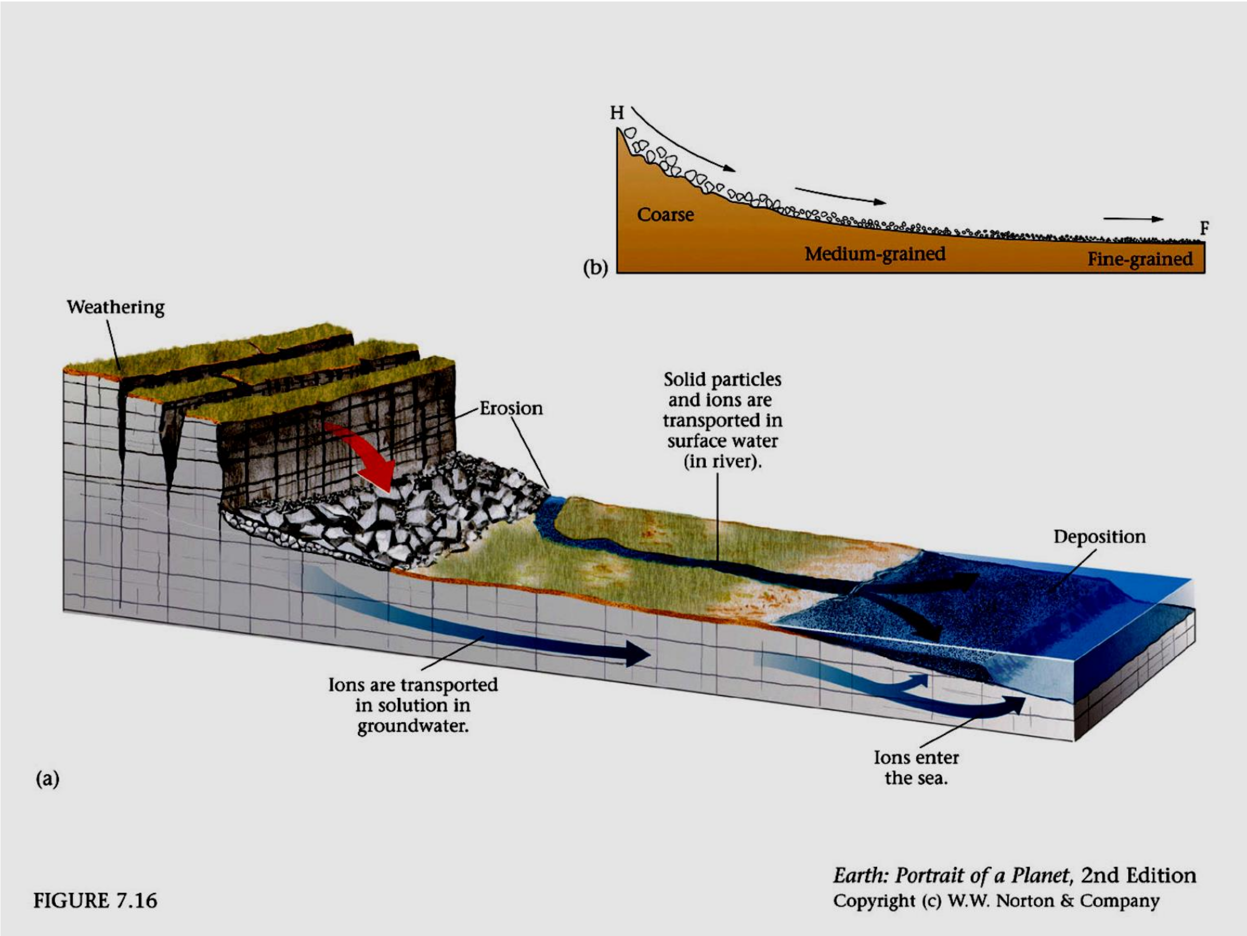
Weathering: processes that break up and corrode solid rock, transforming it into sediment



Sedimentary rocks are formed at Earth's surface by cementing together weathered fragments of pre-existing rock, fragments of shells, organic matter, or mineral precipitates – through a process known as **diagenesis,** sediment particles become **lithified or cemented together.** Under pressure, the air and liquid (water) is squeezed out until it bonds and forms rocks.

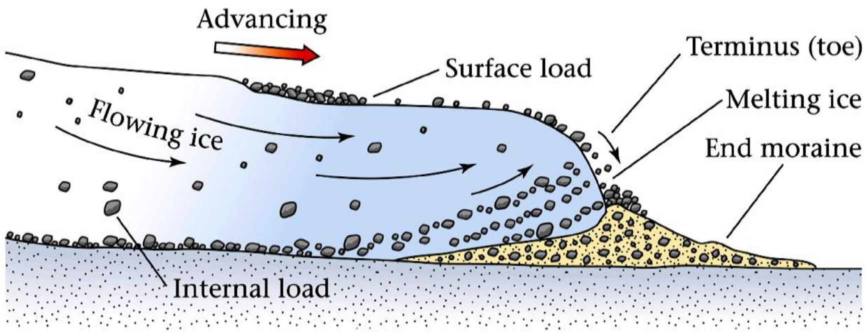
Sediments are sedimentary rocks only occur in the upper part of the crust and they often preserve evidence of their mode of origin in the nature of the sediment grains that comprise the rock and the cements that bind those grains together.

Products of weathering do not always remain at the site of origin but are eventually transported by various means to their final resting place in the ocean basins. Coarse grains need a more turbulent flow to get transported longer distances whereas fine-grains can get transported longer distances with a less turbulent flow.



Sediment is transported in many ways. It may slide down a hillside or be carried by wind, by glacier, or by flowing water. In each case, when transport ceases, the sediment is deposited in a fashion characteristic of the transporting agent. When sediment is transported by sliding or rolling downhill the result is generally a mixture of particles of all sizes.

Unsorted particles in a moraine or till: When a glacier eventually melts, the pebbles, boulders and finer particles carried by the glacier are left behind (e.g. glacier erractics) and creates a distinctive layer of sediment, **glacial till**, at the foot of the glacier.

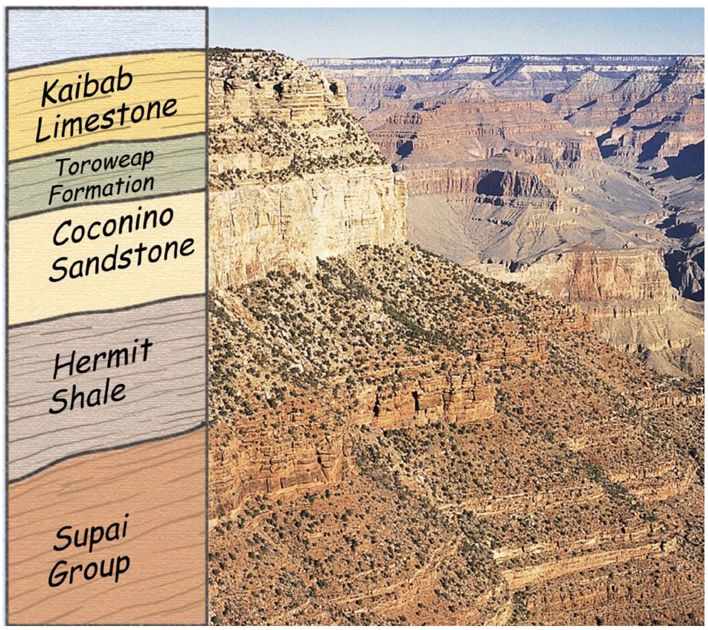


The extent of ice tells us how cold it was. We can use the sediments deposited by the glaciers which are no longer there to tell us how far and when was this glacier here, when did we have a warming climate, what happened? There is a specific way glacial flow will deposit sediments when it advances and retreats. The deposits are classed glacial moraine or till.

If the sediment particles are transported by wind or water, deposition occurs when the flowing water or moving air slows to a speed at which particles can no longer be carried. The grain size tells us about the speed of the wind or the water. The more turbulent the flow, the easier we can transport bigger pieces of rock. Also the more the rocks can get mushed up together, giving them a more uniform shape – they smooth out as they break apart into smaller pieces. We end up with layers of sedimentary rocks.

Sedimentary bedding and stratigraphic formations

Sedimentary rock contain a record of Earth's history and environmental changes, and many sedimentary rocks are economically important since they host resources.



These layers happened at different times in the geologic past. These layers tells us about the different processes that were active at that time.