Gems

Gemstones - a mineral with special value

- Rare - formed by unusual geological processes
- Beautiful - strikingly unique color, clarity, and luster

Gem - a cut and polished stone created for jewelry

- Precious - stones that are particularly rare and expensive: Diamond, ruby, sapphire, emerald
- Semiprecious - less rare: topaz, aquamarine, garnet

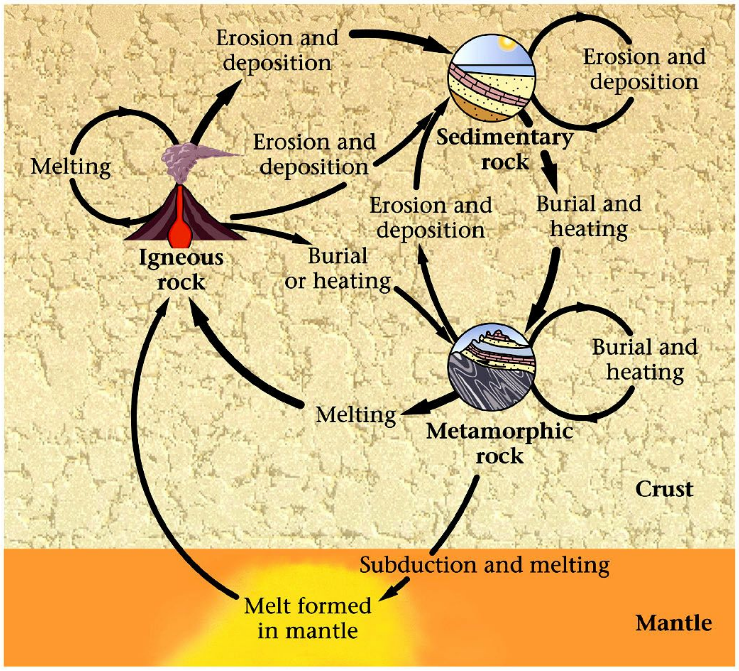
Gems are cut and polished stones used in jewelry

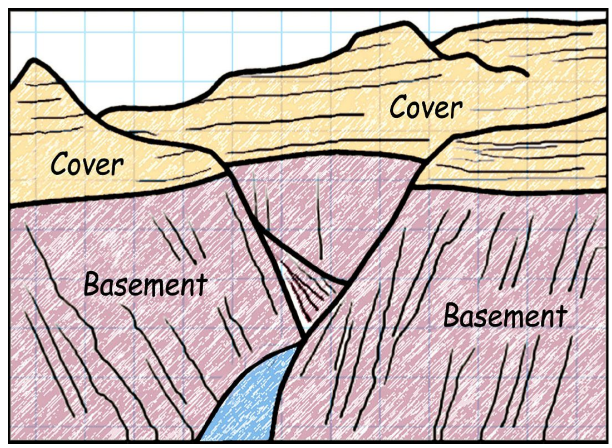
- Facets are ground onto a gem by a lapidary machine
- Faceting a gemstone takes a lot of time and effort
- Facets are not natural crystal faces

Sample midterm question: Dating of oceanic crustal rocks obtains ages that are no older than about 200 million years. Why?
My answer: Oceanic ridges continuously form new lithosphere and subduction zones continuously recycle old lithosphere. Therefore, as new ocean floor is being created, it is spreading the older ocean floor away from the ridge.
Sample answer: New oceanic crust is formed at spreading mid ocean ridges, and sinks back into the mantle at subduction zones. Crustal rocks get older with increasing distance from their source spreading ridge. There are no oceanic crustal rocks older than 200 million years because there is no oceanic plate material that is not already consumed in subduction back into the mantle by 200 million years after its formation on the spreading ridge.

Interlude A - Rocks!

Type of rocks: Igneous rocks, sedimentary rocks, and metamorphic rocks. The rock cycle is how we describe the transition between the different types of rock under different processes.





Regolith: broken chunks of rock that have been moved from their point of origin - they are not attached to the Earth's crust underneath them (they moved around)
Bedrock: attached to the Earth's crust - gives us a lot of clues as to what has happened geologically. Also, bedrock is typically covered by regolith.
Outcrop: un-vegetated rock exposure (exposed bedrock)
Basement: exposed bedrock

Outcrop examples: cliff (naturally), ridge (naturally), road cut (man-made), excavation (man-made), river or stream cut (e.g. grand canyon) (naturally).

<u>Rock classification:</u>
Igneous: form from freezing (solidification) of molten rock or melt (magma or lava).
Sedimentary: form from either cementation of fragments of pre-existing rocks or by precipitation of minerals out of water (inorganic or biogenic) - a coming together of fragment of pre-existing rocks. E.g. when North America was covered by an ice-sheet 20 000 years ago and it started to retreat, well that might have moved rocks around or ejected sediments.
Metamorphic: form when pre-existing rocks change in response to a change in pressure/temperature and/or deformation.

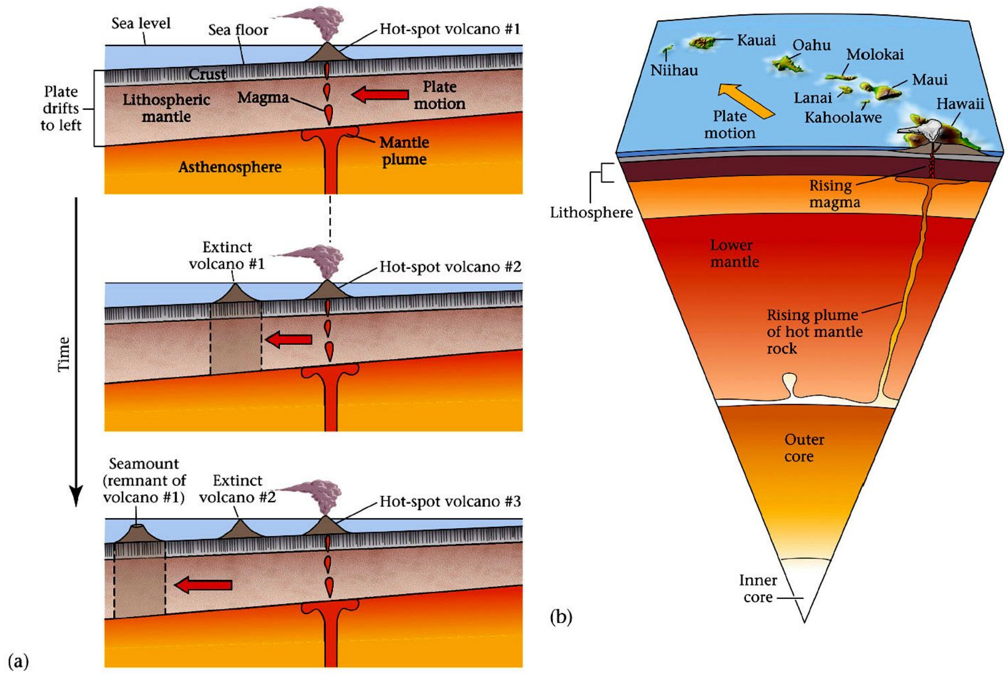
<u>Magma and Igneous Rocks - Volcanoes</u>

Volcano: a vent where molten rock comes out of the Earth, e.g. Kilauea Volcano, Hawaii

- Hot (~$1200 \circ C$) lava pools around the volcanic vent
- Hot, syrupy lava runs downhill as a lava flow
- The lava flow slows, loses heat, and crusts over
- Finally, the flow stops and cools, forming an igneous rock

Note: Magma = inside the Earth, Lava = outside the Earth

Reminder: Hot spot volcano which formed the Hawaiian islands. Hot spot stays in the same place as the plate moves over it.



<u>Igneous Rocks</u>

Igneous rock is formed by cooling from a melt

- Magma - melted rock below ground
- Lava - melted rock once it has reached the surface

Igneous rock freezes at high temperature (T)

- $1100 \circ C$ -$650 \circ C$ depending on composition

There are many types of igneous rock

Melted rock can cool above or below ground

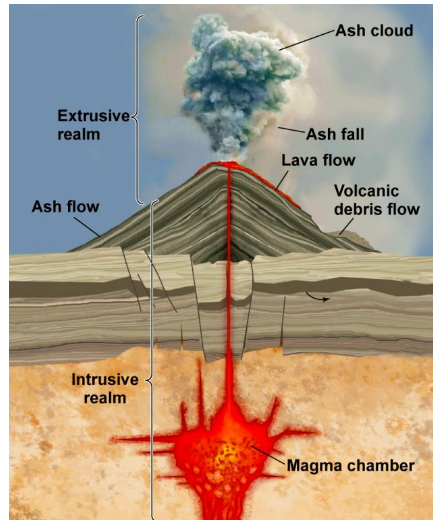
- <u>Extrusive igneous rocks</u>: cool quickly upon exposure of lava (or pyroclastic debris) at the surface. Cools from a lava. e.g. volcano explosion. More readily observable on the surface, more spectavular. - we see extrusive rocks more often.
- <u>Intrusive igneous rocks</u>: cool out of sight, underground from a magma. Typically found in much greater volume than extrusive igneous rocks. Intrusive rocks cool at a much

slower rate than extrusive rocks. Cools from a magma. May have a magma chamber below the surface which cools to form igneous rocks.

Rocks may look different if they are cooled under vs. above ground. E.g. form coarser grains if cooled more slowly and form fine grain if cooled faster.

Extrusive igneous rocks - cool quickly at the surface

- Lava flows - streams or mounds of cooled melt
- Pyroclastic debris - cooled fragments of rock: volcanic ash - fine particles of volcanic glass (little particles that go into the air); volcanic rock - fragmented by eruption (e.g. piece of rock from the surface that is emitted away from the surface as part of the explosion.)

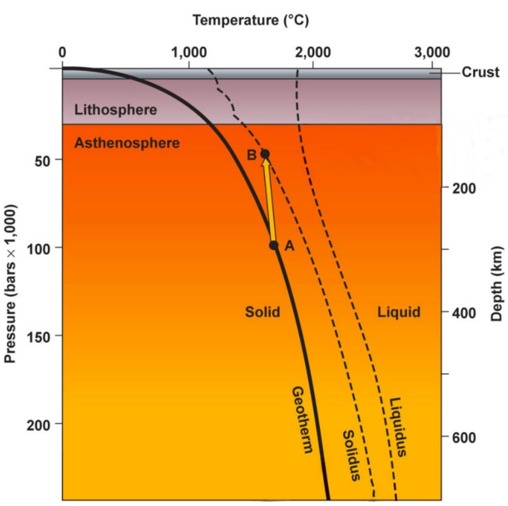


Intrusive igneous rocks - cool out of sight, underground.

- Much greater volume than extrusive igneous rocks
- Cooling rate is slower than for extrusives: Large volume magma chambers; smaller volume tabular bodies or columns.

<u>Why does magma form?</u>

- Magma is not everywhere below the Earth's crust
- Magma only forms in special tectonic settings:
  -Partial melting occurs in the crust and upper mantle
  -Melting is caused by: pressure release (decompression of material can cause melting); volatile addition (e.g. water); heat transfer (hot material can rise to melt material closer to the surface).

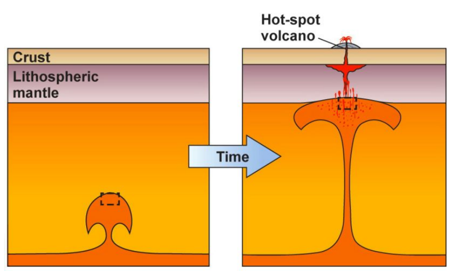


<u>Decrease in Pressure (P) - decompression</u>

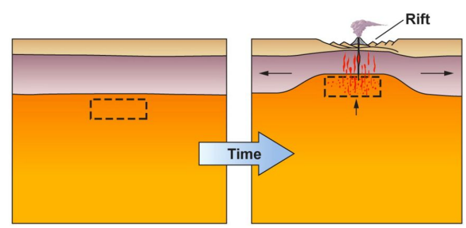
- The base of the crust is hot enough to melt mantle rock
- but, due to high P, the rock does not melt
- Melting will occur is P is decreased.
- P drops when hot rock is carried to shallower depths: mantle plumes (shoots of hot material rising up into the Earth), beneath rifts (continents pulling apart and rifting in the middle) , beneath mid-ocean ridges.

- Geotherm indicates temperature versus depth. In this case, geotherm indicates pressure vs temperature. Pressure increases as depth increases (i.e. deeper = higher pressure)
- Solidus line = dotted line. To the left of the solidus = solid material. To the right of the solidus = liquid material
- At point A at depth equivalent to ~100 000 bars, we are to the left of the solidus which means there is solid material. If we move this material up in the Earth towards the surface, to a depth equivalent to ~50 000 bars (decrease in pressure), at point B, we get conditions where it can melt - this is <u>decompression melting</u>.

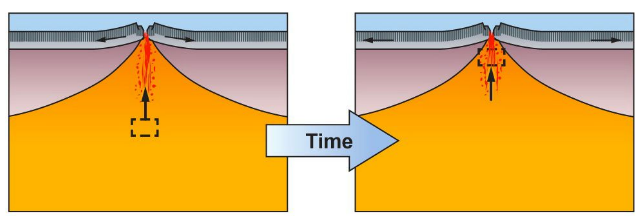
a. <u>Mantle Plume:</u> Taking hot material from the mantle and bringing it closer to the surface.
b. <u>Rifting:</u> Pull apart a continent and it starts to thin so the base starts to come up, which means hot material from the mantle is closer to the surface - another example of decompression
c. <u>Under mid-ocean ridges</u>: where mantle material comes up to form new crust, thus brining hot material to the surface



a. Decompression melting in a mantle plume



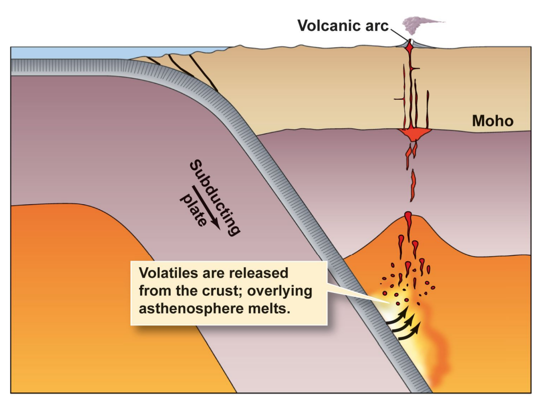
b. Decompression melting beneath a rift

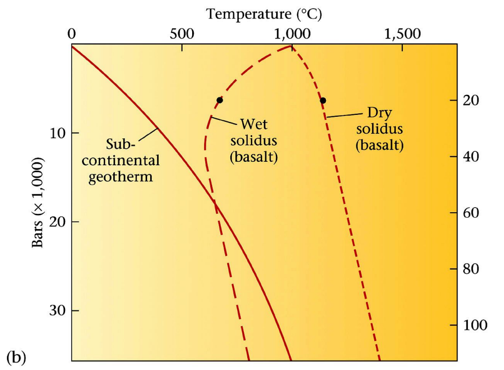


c. Decompression melting beneath a mid-ocean ridge

<u>Addition of volatiles (flux melting)</u>

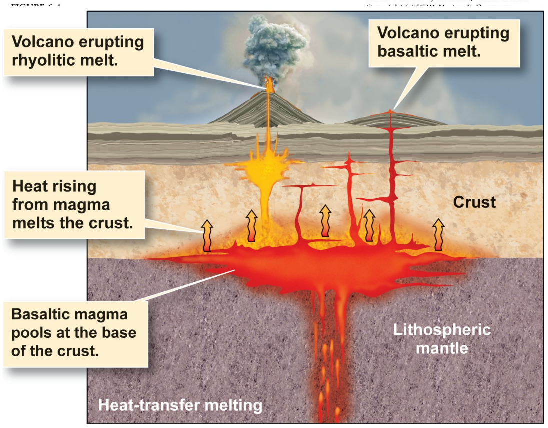
- Volatiles lower the melting T of a hot rock - if you add a volatile, it will lower the melting T of that rock
- Common volatiles include H_2O and CO_2
- Subduction carries water into the mantle, melting rock - oceanic crust subducting under the Earth, so when an oceanic crust subducts, it brings water down with it which will cause melting. Melting then rises to the surface.





Earth: Portrait of a Planet, 2nd Edition

<u>Hydration Melting - subduction zones</u>
(Similar plot as above)
If water is added, the solidus shifts to the left, therefore for a lower temperature at a particular depth you can get melting. So if point A is the right dot, and water is added, then point B would be the left dot, thus melting at a lower temperature.



<u>**Heat transfer melting**</u>

- Rising magma carries mantle heat with it
- This raises the T in nearby crustal rock, which then melts
- Piece of material in deep part of the Earth is hotter than surface material and then it rises up, thus bringing heat with it.
- Magma rises and might melt the crustal rock around it. This case would be melting of the crust as opposed to melting in the mantle. This would happen if you have a magma chamber melting the crustal rock, thus you would get different compositions of magma based on melting and incorporating material from the crust within in. - Important to consider if trying to understand the composition of igneous rocks.

<u>Practice Question</u>: How does the addition of water lead to melting? Define and discuss the geotherm and the solidus in your answer.
<u>My Answer:</u> The addition of water is considered as the addition of a volatile material in which is decreases the melting temperature of the rock, For example, when an oceanic crust subducts beneath a continental crust, it brings water with it, thus decreasing the temperature of melting. If analyzing a geotherm and solidus plot, the addition of water shifts the solidus to the left, crossing the geotherm. (Draw sketch of plot with 2 dots horizontally and arrow moving left).
Note: on midterm, define geotherm, axes, etc.