

## EPSC 201 LECTURE 19 MARCH 24 2016

### MIDTERM REVIEW

1. How old is the Universe? According to the Big Bang Theory, what happened in the first 5 minutes of the birth of the Universe?
  - The Universe is 13.8 billion years old
  - According to the Big Bang Theory:
    - All matter and energy was initially packed into an infinitesimally small points;
    - $10^{-10}$  seconds, only quarks, subatomic particles could form;
    - $10^{-5}$  Proton and neutron forms;
    - Within a few seconds, hydrogen atoms could begin to form
    - Continue to expand and cool down.
2. Explain 2 lines of evidence that the universe is expanding.
  - The light of distant galaxies display red shift (Doppler effect);
  - Cosmic microwave background (Universe becomes neutrally charged)
3. Describe the Earth's magnetic field (you may draw a labeled representation of the field). How is the magnetic field created? What causes the aurorae borealis or "Northern Lights"?
  - The magnetic field of the Earth is created by the convection currents of molten metal inside the outer core.
  - Auroras are created by the interaction between electrically charged particles from the Sun colliding with gases in the atmosphere (e.g. Oxygen and Nitrogen). These charged particles get through the Earth's magnetic field and end up getting redirected to the poles. High latitudes because of the interaction of the charged particles with the Earth's magnetic field.
4. Our solar system and the solid Earth formed over 4.6 billion years ago and sometime later the moon formed and the Earth developed an atmosphere and an ocean. How did Earth's moon, atmosphere, and ocean form?
  - Moon formed with another smaller planet and Earth collided. Proto-Earth collides with another planet (Theia) and the debris flung into space coalesces to form moon
  - Volcanic gases fill the atmosphere
  - Over time, the atmosphere cools allowing water to condense
  - There is a minor contribution to oceans and atmosphere from comets

5. What is the highest mountain on the surface of the Earth, above sea level and how was it formed? What is the deepest part of the ocean?
  - Mt. Everest is located in the modern Himalayas, which is a result of the convergence of India and Asia. 2 Continental lithospheres colliding = orogenesis. ~8000 m
  - The Marianas Trench is located in the west Pacific near Guam and is at a subduction zone. ~11 000 m
  - \*Be careful about units and magnitudes.
  
6. Describe how the Hawaiian islands formed and which is the youngest island and why?
  - The Hawaiian Islands are formed from a mantle plume which is providing heat to the surface. The plume remains stationary but the overriding Pacific plate moves. The heat source is causing volcanic activity which results in a chain of volcanoes. This is why the youngest island (Hawaii) is at the end of the chain – it is currently sitting on top of the plume.
  
7. Describe where we find major divergent-margin ridge systems on Earth. Name 3 properties that vary moving away from a divergent ridge system and how and why they vary.
  - Mid-ocean ridges; in the center of ocean basins.
  - Age of crust – youngest closest to the ridge, gets older as you move further away, because new crust is being created at MOR.
  - Thickness of lithosphere – thicker moving away from the ridge because as the new crust cools, so does the mantle directly beneath it, becoming part of the lithosphere.
  - Heat-flux – will decrease moving away from the ridge, because hot magma comes out at the ridge and cools as it moves away.
  - Rate of cooling/lithospheric thickening – rate decreases with increasing distance from the ridge axis
  - Deepness of ocean – deeper moving further away from the ridge because as the lithosphere thickens, it sinks deeper into the mantle
  - Magnetic anomaly – alternating (symmetrically) polarity as you move away from the ridge, due to magnetic field reversals that happened as the seafloor was spreading.
  
8. What is the epicenter? Describe how a seismologist can determine the location of the epicenter.
  - The epicenter is the point on the surface of the Earth that lies directly above the focus of an earthquake.

- Measuring the difference between P-wave and S-wave arrival time on a seismogram gives information about the distance of a seismometer and the epicenter.
  - Using the S-P arrival time difference measured from the seismogram, find the time difference on a plot of travel-time curves (x-axis = distance from epicenter, y-axis = time) to determine the distance of the seismometer from the epicenter
  - Get the distance from at least 3 seismic stations and draw the distance radius around each in order to triangulate the location of the epicenter, where the 3 circles intersect.
9. In the context of plate tectonics, name 3 types of locations where we can expect to see shallow earthquakes. Name one location where we can expect to have deep earthquakes. What drives earthquakes there? How deep can earthquakes occur, and what prevents them from happening deeper than this?
- Locations with shallow earthquakes include all plate boundaries: transform boundaries, divergent boundaries, and convergent boundaries. Also acceptable: MOR, continental rifts, continental collision zones, and intra-plate fault zones.
  - Deep earthquakes occur at convergent plate boundaries, where the down-going slab is sinking into the mantle and the interior of the plate is still cool enough to break as it is sinking (Wadati-Benioff zone). Earthquakes here can be caused by extension, shearing of sinking plate with the asthenosphere, or volume changes from olivine's phase change.
  - The maximum depth for deep-focus earthquakes is 660 km deep (boundary between the upper mantle and the lower mantle), where the rocks are all hot enough that they will flow plastically and not break.
  - Note! Mantle is solid rock, not a liquid. It flows like a very viscous fluid on geological time scales. Even hot spots are still solid rock.
10. What is a tsunami? How do they form? How do they differ from storm waves?
- Tsunami – a wave produced by displacement of the sea floor
  - Causes – earthquakes, volcanic eruptions, submarine landslide
  - Wind waves: influence the upper ~100m; have wavelengths of several tens to hundred meters; wave height and wavelength related to wind speed; wave velocity maximum several tens of km per hour; waves break in shallow water and expend all stored energy
  - Tsunami waves: influence the entire water depth; have wavelengths of several ten to hundreds of kms; wave height and wavelength are unrelated to wind speed; wave velocity maximum several hundreds of km per hour; water arrives as a raised plateau that pours onto the land with no dissipation

11. According to a geologist, what is a mineral? List 4+ properties of minerals. Why is glass not a mineral?

- The geological definition of a mineral: naturally occurring, formed geologically, solid, crystalline structure, definite chemical composition, inorganic (few exceptions)
- Glass is not a mineral because it does not have a crystalline structure, not because it is man-made. Obsidian is a volcanic glass, formed when felsic (high SiO<sub>2</sub> content) lava cools too rapidly with no or minimum crystal growth.



12. What is the chemical composition of diamond and graphite? How do they differ and why?

- Both are composed of Carbon.
- Difference: hardness, color, etc. Diamond is the hardest mineral. Reason: covalent bond tetrahedron (strong) vs. covalent bond within sheet and ionic bond between sheets (weak).

13. What is the composition of a silicate mineral? How common are silicates on Earth? On what basis do mineralogists organize silicate minerals into distinct groups?

- Silicate minerals are all partly or fully made of silicon-oxygen tetrahedrons (SiO<sub>4</sub><sup>4-</sup> anionic unit): 4 O atoms bonded around a central Si atom.
- Silicates are the most common minerals on Earth.
- Mineralogists organize silicate minerals into distinct groups based on their structure: how many tetrahedrons are linked to each other or the number of oxygen atoms shared between tetrahedrons. It defines if their structure is independent (nesosilicates), single or double chained (inosilicates), sheeted, or in frameworks.
- Many said silicate minerals are grouped based on their silica content or their density (felsic or mafic). Those terms are more usually used to define rocks rather than silicate minerals.

14. Describe 3 difference between a shield volcano and a stratovolcano. Give an example on earth of each of these types of volcanoes.

Shield volcanoes	Stratovolcanoes
<ul style="list-style-type: none"> <li>• Wide and flat shape</li> <li>• Low-viscosity lava (lava flows are faster and are spread to form the wide and flat shape)</li> <li>• Mafic lava (low silica content)</li> <li>• Low amount of volcanoclastic debris (usually only lava flows) and often non explosive</li> <li>• Eruptions may happen along a crack/fissure</li> <li>• Examples: Hawaiian volcanoes, Icelandic volcanoes, Piton de la Fournaise (Reunion), Olympus Mons (Mars)</li> </ul>	<ul style="list-style-type: none"> <li>• High with steep slopes (cone-shaped form)</li> <li>• Medium to high viscosity lava (lava flows are slower)</li> <li>• Felsic lava (high silica content)</li> <li>• Often explosive with high amount of volcanoclastic debris, landslides, lahars, pyroclastic flows, ashes, ...</li> <li>• Eruptions usually happen from a crater</li> <li>• Examples: Mt Fuji (Japan), Mt St. Helens (Washington), Mt Vesuvius and Mt Etna (Italy)</li> </ul>
	

15. Describe the 3 processes that are responsible for the formation of magma, and a location on Earth where we can expect each process to occur.

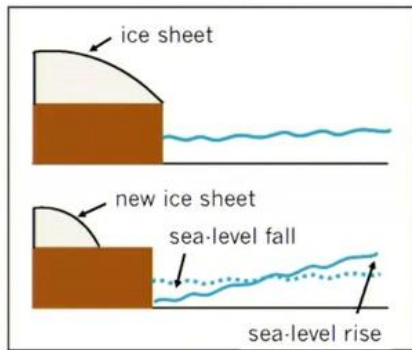
- Decrease in pressure: the base of the crust is hot enough to melt mantle rock, but due to high pressure, the rock doesn't melt. Melting will occur if hot rocks are carried to shallower depths. (Mantle plumes, beneath rifts, beneath mid-ocean ridges). Taking a hot rock from below and bring it to the surface → decompressing which allows it to melt
- Addition of volatiles: volatiles such as H<sub>2</sub>O and CO<sub>2</sub> lower the melting temperature of rocks. Subductions may carry water and gas into the mantle which will cause the overlying asthenosphere to melt. (Beneath subduction zones, oceanic plate being subducted into the mantle)
- Heat transfer: Rising magma carries mantle heat and raises the temperature in nearby crustal rock, which then melts. (Beneath any types of volcanoes or in any magma chamber)

## SEA-LEVEL LECTURE CONTINUED

What happens to water levels when ice melts?

Bath tub model is incorrect. If Greenland melts, the largest sea rise is observed in the southern hemisphere, and there is a sea level drop near the ice sheet. This phenomena is due to gravity. Sea level falls near a retreating ice sheet by ~10 m. An ice sheet exerts a gravitational attraction on the water around it. Water goes where gravity tells it to. If you melt an ice sheet, you reduce

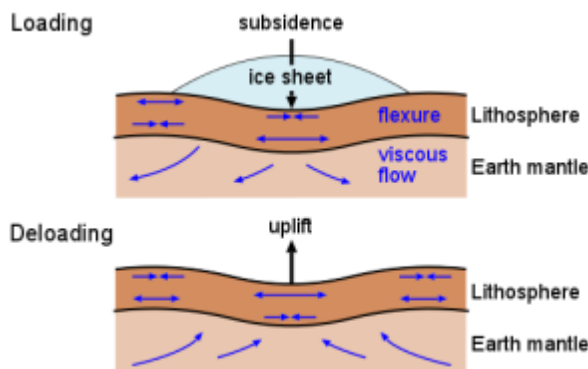
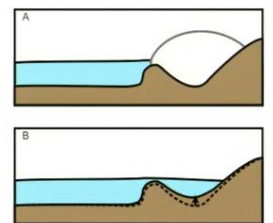
## Gravity!



its mass, so its gravitational force on the water weakens. That causes the sea surface to drop locally. Because you are dropping water locally, you get greater than average sea level further away.

Earth can deform because of an ice sheet. Because of the mass of the ice sheet, the earth beneath it can deform (e.g. weight in the middle of a trampoline, or memory foam mattress). When the ice sheet is removed, the earth “rebounds” and pops up due to “viscoelastic”. The earth will go back to its original shape over time.

## Solid Earth Deformation

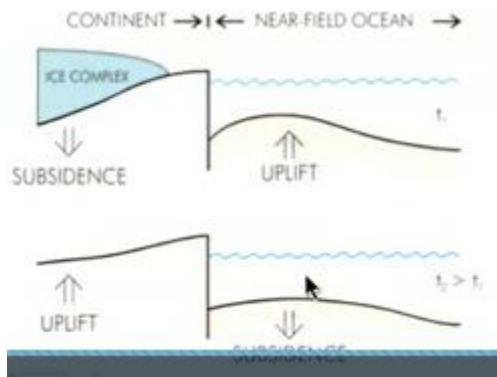


Lithosphere responds elastically. The mantle below flows viscously and eventually there will be uplift. Earth is still deforming over 1000 of years. The ground may still be uplifting from ice sheets which melted thousands of years ago. We are still experiencing the deformation of the Earth because of that.

When a mass is removed from the Earth, the Earth’s rotation axis is actually impacted, which shifts the water around the Earth → results in bulges of water around the Earth.

21 000 years – we were in a glacial maximum (covering 30% of continent surface, today 10% coverage). The large retreat of ice sheets that covered North America ended roughly 6000-7000 years ago. The oceans rose ~130 m after the North American ice sheets melted. The land is still deforming today because of this change. The peak ice sheet was centered around Hudson’s Bay – this region is uplifting about 1cm per year (shorelines are receding).

There are peripheral bulges around the ice sheet... Sea level fall over the area covered by ice, and sea level rise as the land goes down.



Ocean syphoning: peripheral bulges are making room for more water and so water from the equator is being pulled in to fill the peripheral bulges. Evidence: exposed coral reef in equatorial regions. Corals grow at a specific depth, and when sea level falls, the corals are exposed and die. We can date when they died (e.g. dated back to the deglaciation event 20 000 years ago).

Things that happened in the past is what is changing sea level now, so it is important to know what happened in the past. All modern observations of sea-level related quantities are impacted by past ice and ocean loading changes.

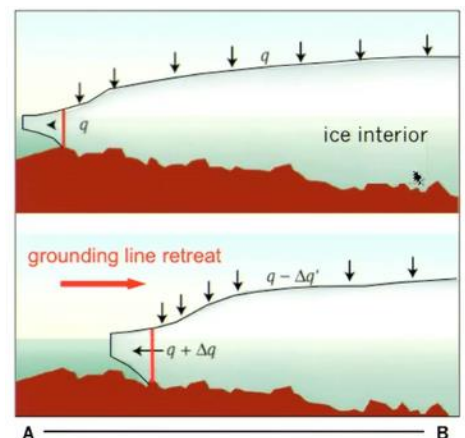
Review:

- Sea-level changes following changes in ice distribution are highly geographically variable due to gravitational, rotational, and deformational effects. (sea level varies in different regions around the globe)
- Ice sheet changes in the past impact sea level in the present through viscous deformation of the solid earth
- Sea level falls (rises) in the vicinity of a retreating (advancing) ice sheet on both short and long timescales.
- Feedback of sea-level changes on marine ice sheet stability and evolution

### Instability of marine ice in Antarctica

Marine ice sheets – ice sheets sitting on bedrock which is below the water.

The diagram on the right is a cross-section of an ice sheet. The solid surface is brown, the faint shading is the water surface. Ice sheets look like a pile of honey on a plate. There is snowfall accumulating on its surface, growing in mass. It flows outward under its own weight. It then loses ice (mass) through a grounding line. Grounding line is where ice on land becomes thin enough to



float on the water. The grounding line is that point where ice floats and is not resting on the ground. The system is in equilibrium if the mass it is accumulating is the same as the mass it is losing through the grounding line.

The solid ground surface tilts down as it goes further into the ice sheet. If the ice sheet is warmed a little bit and the grounding line is retreated a little bit... First we are gaining mass through snowfall accumulation – but a little bit less than before since the ice sheet retreated a little. It turns out that the flow of ice across the grounding line is dependent on the depth of water. This comes to a point where we are losing more ice than we are gaining and the retreat is going to continue. The grounding line feedback causes it to retreat. This is happening in the West Antarctic. If the grounding line is retreating, the sea level falls → rise of the sea floor → sinking of the sea surface. On top of this feedback, there is a counter force which is the sea level fall. The uplifting of the ground surface when the ice sheet retreats slows down the retreating rate.