FINALIZED

GEOL 1010 - INTRODUCTION TO GEOLOGY
MIDTERM II STUDY GUIDE FALL 2012
Professor Bunds, Utah Valley University

READ THIS FIRST: this outline is not meant to be fully comprehensive. This lists all the major topics we discussed in class, but it does not completely cover everything involved with every topic, so use this as a guide to your notes, and to what to look at in the text.

WHAT THE EXAM WILL COVER: The exam will focus on igneous processes (including volcanoes, volcanic hazards, intrusive rock bodies), and sedimentary rocks (including weathering and erosion, transportation, deposition and lithification). You will be responsible for the corresponding chapters from your textbook (Ch. 4, 5 and 6).

WHEN THE EXAM WILL TAKE PLACE: The exam will take place on Friday 10/26 during regular class time. You must take the exam on 10/26 unless you have made other arrangements with Prof. Bunds.

INSURANCE: Insurance is due Friday 10/26 at 1 pm. To be eligible for insurance points, Ednet students must submit their insurance to their facilitator before taking the exam, and on campus students must submit insurance before taking the exam. Make yourself a photocopy of your insurance work and be sure to follow the directions to ensure you get full credit.

HANDOUTS AND POWERPOINTS: Available on our Canvas class site.

Simplified Outline of Topics Covered in Class. Refer to your notes and textbook for details.

1. **Formation of Magma and Volcanism**
    - **a. Be sure to look at the following 3 handouts on this topic:**
        - i. 'Volcanic Processes Summary' - a page of text
        - ii. 'Volcanic Processes Summary Table' -a table that relates magma formation to volcanic activity
        - iii. 'Magma Formation in the Earth' - illustrations of a divergent plate boundary and subduction zone with the locations and main aspects of magma formation labeled.
    - b. Magma forms by melting; virtually the entire mantle and crust are solid, but locally magma forms when rock underground (a few to 60 miles beneath the surface) is caused to partially melt.
    - c. **Partial melting**: When rock melts, especially mantle rock, the resulting magma is more felsic than the original rock that melted. For example, when ultramafic mantle rock partially melts, a mafic magma is produced.
    - **d. Magma formation at mid-ocean ridges and hotspots**
        - i. Melting mid ocean ridges and hotspots
            - 1) Magma forms by **Decompression melting**. In decompression melting, hot mantle rock rises towards surface. As it moves upwards it remains relatively hot but experiences greatly reduced pressure. Reduction in pressure causes it to partially melt.
            - 2) **Mafic** magma is formed because ultramafic mantle rock is partially melted.
        - ii. Volcanism at mid ocean ridges and hotspots
            - 1) The mafic magma is relatively hot, low viscosity, and low in dissolved gases.
            - 2) Consequently, volcanism tends to be **non-explosive** – although escaping gases can cause dramatic fountaining of lava.
            - 3) Large, shallowly sloped **shield volcanoes** can result at hot spots – for example, Mauna Loa on Hawaii.
            - 4) Decompression melting and basaltic volcanism can also result in **flood basalts** issuing from fissures. The **Columbia River basalts** are an example.
        - iii. Intrusive igneous activity at mid ocean ridges and hotspots
            - 1) The lower portions of all oceanic crust are made of gabbro, which is phaneritic mafic igneous rock (equivalent to basalt, but cooled slowly). Presumably there is gabbro under Hawaii, but it has not been seen and is unlikely that the overlying oceanic crust and volcanoes will ever be eroded away so that we can see it.
    - **e. Magma formation at subduction zones**
        - i. Melting at subduction zones
            - 1) Melting at subduction zones is caused by **water fluxing**. In water fluxing, water is carried downwards with the subducting oceanic crust. This water is released into the hot mantle rock above the subducting lithosphere/crust, which causes it to partially melt. Adding water to hot rock is analogous to adding salt to ice.
            - 2) **Intermediate composition** magma is formed. Initially, mafic magma is probably formed, but the magma that solidifies into plutons (and whole batholiths) in the overriding crust, and reaches the surface to form volcanoes is, on average, intermediate in composition. The originally mafic magma is made more felsic by differentiation and assimilation.
                - a) Differentiation occurs when, as the magma first begins to become solid, mafic minerals (rich in Fe (iron), Mg (magnesium) and Ca (calcium)) such as olivine and pyroxene crystallize, sink, and are

separated from the magma (recall from Bowen's Reaction Series that mafic minerals have higher melting temperatures than felsic minerals). The removal of mafic minerals from the magma leaves it depleted in those elements and enriched in Si (silicon).

b) Assimilation occurs when felsic rock from the crust the magma is rising through is melted and incorporated into the magma. This makes the magma less mafic.

ii. Volcanism at subduction zones

1) The intermediate to felsic composition magma that is erupted at subduction zone volcanoes is relatively cool, high viscosity (thick), and rich in dissolved gases.
2) Consequently, volcanism tends to be explosive; gases escape violently from thick lava and shoot columns of gas and **pyroclastic rock** miles into the air. Ash also can cascade down the sides of volcanoes in destructive, deadly, 100 – 300 mph **pyroclastic flows** (nue ardente).
3) **Strato – volcanoes** (also called **composite**) result. They consist of layers of lava that managed to ooze out of the volcano and layers of pyroclastic material that has been compacted and glued into pyroclastic rock
4) Examples are Mts St Helens, Rainier, Baker, Hood, Shasta etc. in the U.S. northwest, as well as numerous volcanoes around the rim of the Pacific (Andes, Japan, Alaska, Philippines, etc.).
5) Know about the eruption at Mt. St. Helens (e.g., the warning signs, aspects of the eruption that were typical of strato-volcanoes and the unusual aspects).

iii. Intrusive igneous activity at subduction zones

1) Large volumes of magma cool and solidify within the continent beneath the continental volcanic arcs that form over subduction zones.
2) Most or all of the true, large batholiths in the world formed over subduction zones. The batholiths are made of many individual plutons that were emplaced over the life of the subduction zone (tens of millions of years), and they are intermediate to felsic in composition on average.

f. Volcanism – some general information

i. **Lava** - relation between composition, temperature, viscosity, gasses

1) **Basaltic** is hotter, lower viscosity, flows faster, less explosive, forms mostly at divergent boundaries, hot spots. Lots gets erupted each year (on average), since much of all new oceanic crust is made of it, as are hot spot islands which are really big volcanoes.
2) **Rhyolite** is cooler, much more viscous (mostly because it's cooler), barely flows at all, can be very explosive. Intermediate is in between, generally doesn't flow all that well.

ii. **Gasses**. Magma has a lot of gas, especially H_2O and CO_2, dissolved in it, which need to escape when the magma erupts as lava and pressure is released. Relate this to viscosity, fountaining, big explosions like Mt. St. Helens etc. Creates vesicles in lava.

iii. Volcano Types

1) **Shield** - basaltic, layered, very big, hot spots, main and side vents are common, see book. Hawaii.
2) **Composite/Strato** Volcanoes - andesitic to rhyolitic, smaller, alternating layers of lava and pyroclastic flows, explosive (thick, viscous lava), volcanic arcs like the Cascades, Andes. Mts. St. Helens, Ranier, Shasta, etc.
3) **Cinder cones**
4) Basalt also sometimes comes out in huge quantities through fissures kilometers long to make '**flood basalts**,' such as the Columbia River Basalts (164,000km^2 in area!)

iv. Volcanoes and Plate Tectonics

1) Most volcanoes are at plate boundaries.
2) Composite volcanoes form at convergent plate boundaries (have a rough idea of a side view of a subduction zone with volcanoes over the subducting slab, plutons forming under the volcanoes, say like figure 4.26). "Ring of Fire" around the Pacific, figure 4.22
3) Shields form at hot spots (figure 4.25).
4) Lots of basaltic volcanism at divergent boundaries (mid-ocean ridges), but nearly all is undersea.

v. **Other types of volcanic features** see book, notes

1) **Calderas** .
2) **Columnar jointing**
3) Volcanic necks
4) Fissure eruptions

vi. Volcanic Hazards

1) Lava flows
2) Pyroclastic flows
3) Lahars
4) Gasses
5) Ash fall
6) Earthquakes

vii. **Volcano case studies**
1) Mt. St. Helens (see textbook; erupted about 1 to 2 km^3 or 0.24 to .5 cubic miles of ash)
2) Long Valley Caldera and Mammoth Mtn. (see handout on class website)
3) Yellowstone
a) 2 million years ago erupted 600 cubic miles (2500 km^3) of ash and formed a large caldera that is hard to see today due to erosion and more recent volcanic activity
b) 630,000 years ago erupted 240 (1000 km^3) cubic miles of ash and formed a large caldera that is fairly readily visible today
c) There have been numerous smaller eruptions in addition to the huge "supervolcano" events listed above. Still active today – magma is present a few miles beneath the park!

g. Intrusive (igneous) Rock Bodies
i. **Plutons** - all encompassing term for intrusive rock bodies
ii. **dikes**, **sills**, **laccoliths**, **volcanic necks**, **batholiths** (these are in the book; be able to name them from a picture). Know that dikes cut pre-existing layers whereas sills parallel them, but that both formed by magma flowing into a (big) crack. It is not necessarily true that dikes are vertical and sill are horizontal, because the country rock layering is not necessarily horizontal. Know that laccoliths are 'poofed up' sills. Know approximate time required for formation. Know idea of batholiths – they comprise many individual plutons, consequently take millions to tens of millions of years to form, and mostly form over subduction zones (beneath the chains of volcanoes that form over subduction zones). Sierra Nevada batholith is a nearby and well-studied example. The Sierra Nevada batholith formed over tens of millions of years.
a) Where do they occur?
iii. wide spread, but mostly at plate boundaries (or places that were plate boundaries in the past). Especially **batholiths** - they tend to form under the volcanic arcs that form over subduction zones (e.g., Sierra Nevada batholith). Know about batholiths – where they occur with respect to plate boundaries, how long they take to form, an example of one, etc.
iv. Emplacement - **how does the magma rise thru the crust?** The basic driving force is **buoyancy** - the magma is less dense than the surrounding rock because it is hotter; less dense material wants to rise like a hot air balloon. Think of the lava lamp.
v. Examples:
1) Dikes and sills are widespread and so common that few are given special names
2) Stocks: there are several in the Wasatch Mountains. The Alta Stock (makes up much of the Alta and Brighton ski resorts) and Little Cottonwood stocks (in the lower, western portion of Little Cottonwood Canyon) are probably the best-known. The "Temple Granite" used in the LDS SLC temple and meeting hall was taken from the Little Cottonwood Stock. Most of the stocks in the nearby Wasatch mountains have precious metals such as copper, silver, lead and zinc associated with them.

2. **Sedimentary Rocks -** Thing to do here is know **weathering, erosion, transportation, deposition** and **lithification**. Then you are in like flint. You should be able to draw a sketch to illustrate the spatial (where) and temporal (when, relative to other steps) relationships of these 5 steps in the formation of sedimentary rocks.

a. **Weathering** - minerals stable deep in the Earth are not necessarily stable at the surface. They break down in place - which is weathering
i. **Mechanical** - freeze-thaw, organic, abrasion, heating+cooling
ii. **Chemical** - solution (getting fully dissolved and then can be carried away in the water), and chemical reactions to form new minerals that are more stable at the surface of the Earth (clays and rust-like minerals are common products). Oxidation (e.g., rusting) is another common type of chemical weathering that involves chemical reactions of this type. Note also that both solution and the formation of new minerals can result essentially simultaneously. Limestone is very susceptible to being dissolved, whereas quartz is not. Understand why water is so powerful at dissolving substances, especially ionically bonded substances.
iii. Rocks weather at different rates, which gives rise to lots of neat landforms. Many neat patterns in the layered sedimentary rocks throughout southern Utah result from this.

b. **Erosion** - removal of weathered rock
i. water, wind, glaciers. **Rivers** are by far biggest agent.
ii. when you have weathering but little or no erosion, coupled with organic activity you get **soil**. **Soil** can also form where sediments have been deposited, say by floods along rivers. **So soils are weathered rock + organic material**. Soils take time to form, and can be completely and indefinitely lost when vegetation is removed, as in many rain forests.
iii. **Soil**: know what it is, how it forms.

c. **Sedimentary rocks**:
i. **Detrital** (know the various types of detrital rocks)
ii. **Bio-chemical** (know the various types of bio-chemical rocks, such as coal, chert, limestone, evaporites)

d. **Transportation**.

i. **Detrital** sediments (bits of rock fragments, like pieces of sand) are transported by streams, wind, glaciers and waves. Weathering continues during transportation, and detritus is rounded (amount of rounding of detritus can indicate the transportation distance). Wind and streams have a bed load, suspended load and a dissolved load.

ii. **Dissolved** rock is transported primarily by water, although CO_2 (a constituent of calcite in limestone and important to global warming) is transported by wind.

e. **Sedimentation/Deposition**. Need to talk separately about detrital and chemical sediments.

i. Detrital material

1) comes in several **sizes - gravel, sand, silt, clay** (see book).
2) When detrital material (ground up rock) is **deposited**, it forms layers of **sediment** (its not rock yet!).
3) fine material is deposited in low **energy** environments (e.g. quite water like out in the ocean or in a bay, coarse material (sand, or especially gravel) gets deposited in energetic water (fast river or creek, right on a beach). Think about the jug I brought in. Important thing here is the grain size of sediment or a sedimentary rock tells you a LOT about where it was deposited (the **depositional environment**).
4) **Sorting** also results from the deposition environment; beach sands tend to be very well sorted because they are subjected for a long time to a particular amount of water '**energy'** (energy is sort of like turbulence).
5) **Sorting** and **rounding** together are the important detrital sedimentary **textures**
6) Detrital structures - geometric features in the rock. They tell you about how the rock formed: **cross bedding, ripples, mudcracks, etc.** see book, notes.

ii. Chemical material mostly forms **calcite** ($CaCO_3$), **dolomite** ($CaMg(CO_3)_2$, **gypsum**, and good ol' **salt** (NaCl). When water - especially water that was 'salty' to begin with, like seawater - evaporates, it leaves a bunch of bio**chemical sediments** (mostly gypsum and salt) behind.

iii. Also must consider **organic** or **biochemical sediments**, such as accumulations of calcite shells which form **coquina**, leaves and other vegetation which make **peat** (can become **coal** with proper heating and compaction), or silica (SiO_2) shells which can form **chert**.

iv. **Depositional Environments –**

1) examples are alluvial fans, lakes, rivers, oceans (beach, near shore, reef/offshore, deep sea), glacial, sand dunes, evaporite basins (where a lake or sea evaporates, like the salt flats)
2) Determining the environment that sediment was deposited in is like detective work; depositional environments are generally identifiable by **sedimentary structures** and features in a sedimentary rock..
   a) features include chemical vs detrital sediment, grain size + sorting + rounding (for detrital).
   b) structures include mudcracks, ripples and cross-beds.
   c) An example: the very fine grained, very will sorted sandstones with very thick (3 to maybe 20+ meters) cross-beds (and a few dinosaur footprints) in southern Utah are mostly ancient sanddunes.

f. **Lithification** - transformation of sediment into rock by compaction and cementation. Fundamental driving force here is the burial of the sediment under more and more layers of sediment. For example, there are maybe 4km of sediments in the Salt Lake Valley, so the sediments at the bottom are under a lot of pressure (think how heavy a 2.5 mile tall pile of dirt must be!!), and they are a bit warm, maybe 80oC.

i. Compaction - sediment typically is 15 to 90% pore space (voids in the rock, usually filled with water or air). When the sediment gets buried under layers of more sed., the weight compacts the sediment, usually to where it has 5 to 15% pore space. Remember that there is a lot of weight on a rock that is buried a mile or two deep in the Earth.

ii. Cementation - basically the sediment grains get glued together. The cement minerals commonly are calcite, silica or clay. The glue is either material from the sed. grains that gets dissolved off the sharp tip of a sed. grain and precipitates next to the sharp tip, or its material that is carried by water flowing through the rock (say water getting squeezed out of sediments buried even deeper).

g. Sedimentary rock resources

i. Coal, oil, natural gas, sand & gravel, gypsum, uranium (Moab), etc.

ii. Coal comes from plant material (peat), whereas oil primarily is derived from plankton in marine sediments. Oil migrates from a source rock into a trap ('reservoir'). Each must be cooked to the correct respective temperature to become valuable coal or oil.

iii. see the handout on sedimentary rock resources

Study Questions

If you want to turn these in, **please be sure to answer them on separate sheets of paper and staple everything together!** Be sure to answer these and the book questions in **complete sentences, using sketches where appropriate or useful.** Note that if you score below C- on the exam you can receive points equivalent to a C- by doing these questions **AND** the suggested problems from the back of the appropriate chapter **AND** turning them all in **before the end of the testing period**. The suggested chapter problems are listed on the course syllabus.

1. In relation to the types of plate boundaries, where do felsic to intermediate igneous rocks tend to form?
2. In relation to the types of plate boundaries, where do mafic igneous rocks tend to form?
3. What type of volcanic rock is most common at hot spots (especially hot spots the form in oceanic crust)?
4. What types of igneous rocks compose most of the crust beneath the oceans?
5. Name and explain the two primary ways that magma forms in the Earth (natural processes that cause melting). Use a sketch like the one in your class handout in your explanation.
6. Which of the two main processes that cause melting and magma to form operates along subduction zones?
7. Why do **mafic** igneous rocks result from upward movement of the mantle under midocean ridges (i.e., why does melting happen, and why does the melting produce magma/lava that is mafic in composition).
8. What is the probable initial composition of the magma that forms when melting happens at a subduction zone, and what composition typically is erupted from volcanoes above subduction zones? What happens to change the composition of the magma as it moves towards the surface before it erupts?
9. Which of the two main processes that cause melting and magma to form operates along divergent plate boundaries?
10. In which layer of the Earth does most initial magma formation occur?
11. What process causes magma to form under Hawaii?
12. If you had to guess, at which of the following location do you think there might be a batholith forming: under Utah with it's Wasatch fault or under western Oregon and Washington, which is over a subduction zone?
13. Using a sketch, explain the series of events that led to Mt. St. Helens eruption on 18 May, 1980.
14. In what ways was the eruption of Mt. St. Helens in 1980 typical of volcanoes of its type?
15. In what ways was the eruption of Mt. St. Helens in 1980 atypical of volcanoes of its type?
16. How much larger was the eruption in Yellowstone that created the caldera visible today relative to the eruption of Mt. St. Helens in 1980? How much ash was eruption when the Long Valley Caldera formed in eastern California?
17. List 3 warning signs of an impending eruption.
18. What is the initial cause of magma formation in the asthenosphere beneath Yellowstone?
19. What probably happens in the crust beneath Yellowstone to produce so much felsic magma?
20. Explain what a caldera looks like and how they form. Draw a series of sketches to go with your explanation.
21. Imagine that a real estate agent mentions that the neighborhood you are considering moving into is located next to a very young caldera. Is that a cause for concern, and if so, why?
22. Explain what a lahar is and why they are dangerous.
23. Explain what a pyroclastic flow is and why they are dangerous.
24. Why does magma tend to rise through the crust?
25. We discussed the Long Valley Caldera, which is located in eastern California, in class. What is it called, where is it located, when did the caldera form, and how much magma was erupted to form the caldera? (there is a handout on this on the class website).
26. Briefly explain the concept of flood basalts, and give an example of some.
27. Name a batholith. What I mean is, right down the name of a batholith that someone else named. Where is the batholith you named, and about how big is it? (Now you can give it a name of your choosing, if you wish).
28. Describe and explain the formation of major batholiths such as the one in California. In your description, include information such as the type of rock (both chemical composition and grain or crystal size), a rough estimate of the size of the batholith, and its shape. Your explanation of its formation should include information such as its relationship to plate tectonic processes and other igneous processes, a rough estimate of how long it took to form, and an example of a location where a batholith probably is forming today.
29. How does a dike differ from a sill?
30. Are there any plutons in the Wasatch Mountains? Where could you find one?
31. Imagine you find a stock while hiking in the mountains, and it turns out no one else has ever found it and marked it on a map. What economic benefit might be associated with your discovery?
32. What is a laccolith? Are there any laccoliths in Utah? How do laccolith's form?
33. How can you distinguish an intrusive igneous rock from an extrusive igneous rock? What is the cause of the obvious visual difference between intrusive and extrusive igneous rocks? What are the names given to the appearances of each?
34. Which happens first - erosion or weathering?

35. What are the two main effects of chemical weathering?
36. What types of minerals are common products of chemical weathering?
37. What common rock type is particularly susceptible to being dissolved by water?
38. Why is water such a powerful solvent?
39. Is quartz susceptible to chemical weathering?
40. Explain the relative susceptibility of the common igneous minerals to chemical weathering in relation to their position on Bowen's Reaction Series.
41. Name 4 main causes of mechanical weathering, and give the name of the material produced by mechanical weathering.
42. List the different types of detritus in order from smallest grain size to largest.
43. What are the two main types of sedimentary rock? How do they relate to the types of weathering?
44. How are detrital (or clastic) sedimentary rocks classified (i.e., named)?
45. Name 5 common types of bio-chemical sedimentary rocks. For each, explain how they form, and what type of environment they form in.
46. What is meant by a 'high energy' depositional environment?
47. Give an example of a type of sedimentary rock that is deposited in a high energy environment.
48. There is a great deal of limestone in the Wasatch Mountains near Orem. Much of it is approximately 300 to 340 million years old. What was the geography of Utah like at that time (desert, ocean, lakes, etc.)? Be as specific as you can.
49. As you walk along a sedimentary bed (one layer of rock formed at the same time by the same process), you notice that the large sand grains get more and more angular. Are you getting closer or further from where the sand grains were eroded?
50. Above the sedimentary bed of sandstone mentioned above (which clearly formed near an ocean beach, since it contains marine clam fossils) you find a pair of thick layers of salt (NaCl) and gypsum ($CaSO_4$*H20). What do those rocks tell you probably happened in the past (how did the salt and gypsum layers probably form?).
51. Above the salt and gypsum, you find a layer of rock that contains boulders as well as sand and even flour-sized grains. The boulders are moderately well rounded. In what sort of environment was the layer formed?
52. The Entrada Sandstone (a thick layer/horizon of sandstone) in Arches National Park was deposited as *sanddunes*. One of the reasons we know this is that it contains very large cross-beds. Sketch crossbedding (like we did in class), and explain how it can be created by sand dunes. An additional sketch will aid your explanation. How does the shape of cross-bedding relate to the law of superposition and identifying younger and older layers of sedimentary rock in nature?
53. Describe what an alluvial fan is, and how one can be recognized by its shape and location (as seen from a distance) and by the sediment it consists of.
54. List 2 depositional environments (other than the ones described above), and list some sedimentary rock features that would be indicative of deposition in each of the environments.
55. Describe what must have happened to the sand in the Entrada to transform it from sand in sand dunes (i.e., sediment) into sandstone?
56. Briefly describe what a sedimentary basin is, and give an example of one.
57. Describe the origin and formation of coal.
58. List three other resources that humans get from sedimentary rock (i.e., other than coal and oil).