FINAL EXAM REVIEW (WITH ANSWERS!)

The final will consist of:

1. A series of short answer questions and definitions covering new material: earthquakes, plate tectonics and volcanoes

2. Two essay questions (with some degree of choice). One essay will be from previous material (minerals, rocks, groundwater and streams) and one will be from the new material.

Study questions for new material

> *N.B. These are brief answers designed to make sure that you are on the right track. You should use your notes and book to augment these answers. I do not want to see verbatim regurgitation of these answers on the exam. That would be plagiarism!*

Earthquakes

1. Describe the difference between elastic and plastic deformation in rocks. What happens in a brittle rock when the elastic limit is reached.

   When rocks deform elastically, they will return to their original shape after the deforming stresses are removed. In this sense, the strain is reversible. Plastic deformation is non-reversible. When the deforming stresses are removed, the rock remains deformed. Brittle rocks fracture when the elastic limit is passed.

2. Describe the elastic rebound model of earthquake mechanisms using a rubber band as an example.

   As the rubber band is stretched, it stores energy in the form of elastic strain (deformation). The lithosphere stores elastic energy as it is deformed by tectonic activity, particularly at plate boundaries. When the elastic limit is exceeded, the rubber band breaks and releases the energy in a very short period of time. When the lithosphere fails (rock breaks or a fault slips), an earthquake results and the strain energy is released in the form of seismic waves. It may take tens,, hundreds or thousands of years for the strain energy to build up, but the energy is release in seconds. Even in the largest earthquakes, the actual slip on the fault lasts no more than two minutes.

3. What is the difference between a magnitude and intensity scale of earthquake size? Name a magnitude and an intensity scale.

   An intensity scale measures the earthquake in terms of the effects at each location. Because these effects are also a function of the distance from the focus to the location, intensity is not a measure of the actual size of the earthquake. A magnitude scale corrects for distance from the focus and is thus a true measure of the earthquake's size. The Richter scale is a magnitude scale, the Mercalli scale is an intensity scale.

4. What basic quantity is measured to determine Richter magnitudes? How does this value change for a change of one integral unit of the scale? How does the energy released by the earthquake change for a change of one integral unit on the scale? Compare a magnitude 5.5 and 8.5 earthquake based on your answers to the preceding questions.

   The Richter magnitude measures the amount of ground displacement (motion) caused by an earthquake, as measured on a seismograph. An increase of one integer unit represents a 10 fold increase in ground motion. The energy release of the earthquake increases by a factor of approximately 30 for each integer unit on the Richter scale. A magnitude 8.5 earthquake would cause 1000 (10^3) times as much ground motion and release 27,000 (30^3)times the

energy of a magnitude 5.5 earthquake.

5. Where do earthquakes occur? Where do the largest earthquakes in the world occur?

   Earthquakes occur in the Earth's lithosphere. This is the only portion of the Earth that is brittle enough to experience brittle failure necessary for elastic rebound. Over 90% of all earthquakes also occur at or very near plate boundaries. These are the locations where plates are deformed and therefore store large amounts of elastic energy. The largest earthquakes occur in oceanic-continental subduction zones, at shallow depths along the underside of the continental plate. The two largest earthquakes in recorded history occurred in Chile and Alaska in this plate tectonic setting.

6. What are body waves? Describe two types of body waves. What are surface waves? Describe two types of surface waves.

   Body waves travel as rays through the interior of an object such as the Earth. P waves are the fastest elastic body waves. They are "longitudinal" waves which have vibration in the direction of wave motion. They are also "compressional" waves in that they distort the volume of the material. S waves are slower body waves which are "transverse", that is, the vibration of the wave is perpendicular to the direction the wave travels. S waves are also "shear" waves in that they propagate by distorting the shape (and the volume) or the material as they pass.

   Surface waves are waves which are confined to travel along or very near the surface of a body such as the Earth. Rayleigh waves are surface waves in which the ground moves in an elliptical orbit in a vertical plane. Rayleigh waves involve compression of rock, like P waves, and are the fastest surface waves. Love waves are surface waves that vibrate horizontally, perpendicular to the direction of wave travel, and like S waves, involve the shearing of rock.

7. What are strong, major and great earthquakes. About how often does each of these size earthquakes occur?

   Strong earthquakes have Richter magnitudes between 6.0 and 6.9, major earthquakes have Richter magnitudes between 7.0 and 7.9 and great earthquakes have Richter magnitudes above 8.0. On the average, there are two strong earthquakes a week (100/year), one major earthquake every three weeks (18/year) and about 1 great earthquake each year.

8. What is the focus of an earthquake? The epicenter? How deep are the deepest earthquakes?

   The focus, or hypocenter, of an earthquake is the point within the earth where the rupture on the fault begins. The deepest hypocenters occur in subducting plates at depths of 700 km. The epicenter (epi means "on top of") is the point on the Earth's surface beneath which the earthquake begins.

9. What is seismic moment. What is a moment-magnitude, and how does it differ from other measurements of magnitude. For what earthquakes are moment-magnitudes most important.

   Seismic moment is the best physical measure of the size of an earthquake. The moment is in units of force x distance (dyn-cm). The moment is equal to the area of the fault times the amount the fault moves (slip) times the strength of the rock in which the fault is located. These three quantities are the real physical parameters which control the size of the earthquake. The moment is measured using all of the data in seismograms from the earthquake. For earthquakes above magnitude 7.5, traditional magnitude measures (local and surface wave magnitudes) underestimate the size of the earthquake. The moment magnitude is a magnitude determined from the seismic moment which is more accurate for these largest of earthquakes. For example, the 1964 Good Friday Alaska earthquake is the second largest earthquake ever measured. Its Richter magnitude is 8.4, but its moment magnitude is 9.2. Moment magnitude is abbreviated M_w, and should be used whenever

possible.

10. In a simple sketch, show the difference between the appearance of a seismogram recorded near an earthquake, and a seismogram recorded thousands of km away from the epicenter. Be able to describe the way earthquake magnitudes are measured from each of these types of seismograms.

    Refer to the handout from class for the appearance of seismograms.

    Local seismograms are short in duration, usually less than a minute. The P wave is clear as the first arrival, but the S waves and surface waves combine into a large decaying series of peaks called the coda. Local magnitudes, M_L, are based on measuring the largest peak amplitude in the coda. This is the method that Richter pioneered.

    On distant seismograms, the P, S and Surface waves are spread out over many minutes of the seismogram. For most small to moderate sized distant earthquakes, the magnitude is obtained by measuring the amplitude of the surface waves at a particular period (20 seconds). This is called the surface wave magnitude, M_s.

    Explosions (atomic and otherwise) and deep earthquakes produce little in the way of surface waves, and so their magnitude is measured using the body waves to obtain a body wave magnitude, m_b.

    For large earthquakes, the moment magnitude, M_w, is calculated from the measured seismic moment. The seismic moment is measured using the entire seismogram and thus gives the most accurate picture of the earthquake magnitude.

Plate tectonics

1. Compare and contrast continental and oceanic crust in terms of density, composition, thickness and variability.

   Continental crust is variable in thickness and composition, ranging from 10-70 km thick with an average of about 25 km, and ranging in composition from felsic to mafic. Oceanic crust is extremely uniform, with a thickness of about 5-6km and a mafic composition, the upper crust composed of basalt and the lower crust composed of gabbro.

2. How does plate tectonics account for the observation that no ocean crust is more than 400 million years old? About what fraction of the age of the Earth is that?

   Oceanic crust, unlike continental crust, is ultimately destroyed by subduction. Currently, the oldest oceanic crust is in the western Pacific. This crust is about 1/12 the age of the Earth.

3. What is the lithosphere? What is the asthenosphere? How are they related to the compositional layers of the Earth?

   The lithosphere is the outer, rigid shell of the earth. It consists of the crust and the rigid uppermost portion of the mantle. The lithosphere varies in thickness, but on the average it is about 100 km thick. It is thinner under mid-ocean ridges, and somewhat thicker under continents. The asthenosphere is the soft, plastic layer of the mantle that lies directly beneath the lithosphere. The asthenosphere is not molten, but it is close to melting and therefore very soft. These are physical (or mechanical) layers of the Earth. They do not coincide directly with the compositional layers of the Earth (crust, mantle and core) which are based on chemical makeup rather than mechanical properties.

4. What happens at a convergent boundary? Why can't continental lithosphere subduct?

At convergent boundaries, one of two things happens. If one or both of the plates are oceanic plates (i.e. they have ocean crust) one of the plates sinks into the asthenosphere in the process known as subduction. This is then the site of significant volcanic activity, metamorphism of rock and earthquake generation. If both plates are continental, a continental collision takes place creating a massive mountain range such as the Himalayas..

5. Describe the forces that propel oceanic lithosphere. What is the ultimate cause of plate tectonics?

   Oceanic plates are propelled primarily by their own density. The thick leading edge of the plate sinks under its own weight at a subduction zone and drags the rest of the plate along behind. The thin part of the plate near the mid-ocean ridge slides down the ridge providing some push as well. The ultimate cause of plate tectonics is convection in the Earth's mantle driven by the Earth's internal heat, and gravity. Plate tectonics is the Earth cooling off..

6. Discuss the correctness of the statement: "The lithosphere floats on the asthenosphere."

   Continental plate floats, because the thick, low density continental crust cannot sink. Young ocean plate, near the mid-ocean ridge also floats, but old thick ocean plate sinks at subduction zones providing one of the main driving forces for plate tectonics..

7. Draw a cross-section of an oceanic-continental subduction zone. Label the crust, mantle, lithosphere and asthenosphere, and label relevant thicknesses. Indicate where magma forms and where magma chambers could be found. Describe the major mechanism thought to generate magma at this plate tectonic setting. What type of magmas reach the surface at this type of plate boundary?
8. What is a hot spot? What type of magmas are generated at hot spots? What type of lavas are erupted at hot spots? Give two examples of hot spots with different eruptive activities.

   Hot spots are sources of magma beneath the lithosphere. We know they are beneath the lithosphere because they do not move with the plates. Hot spots produce mafic magmas beneath the lithosphere. If the overlying plate is an ocean plate, mafic magmas are erupted forming island chains such as Hawaii. If the overlying plate is a continental plate, erupted magmas are bimodal, mafic and felsic, causing both basalt flows and explosive caldera style eruptions such as at Yellowstone NP.

9. Be able to discuss the mechanism of formation of magma at each major plate tectonic setting. Be able to discuss the types of lavas erupted, and the processes that alter magmas prior to eruption.

   see table

Volcanoes

1. What is a volatile? Name the most abundant volatile in magmas. Name another volatile common in magmas.

   A volatile is a substance, dissolved in the magma, that does not go into minerals when the magma cools. Water is the most abundant volatile in magmas, but other common volatiles are SO_2, H_2S and CO_2. Volatiles escape quietly from mafic magmas due to their low viscosity. Volatiles cannot easily escape from thick, viscous felsic and intermediate magmas, giving them their explosive behavior.

2. Contrast the properties of felsic, intermediate and mafic magmas and explain how that effects their eruptive behavior.

   Felsic magmas are relatively low temperature (around 700^{o}C), viscous (thick) and have a relatively large amount of volatiles causing them to be very explosive. Mafic magmas are

relatively high temperature (around 1000^{o}C), very fluid, and have lower volatile content resulting in quiet flowing eruptions. Intermediate magmas are intermediate. The can erupt as flowing fluids or as explosive pyroclastic blasts. This accounts for the structure of stratovolcanoes built from intermediate magmas.

3. Be able to discuss the mechanism of formation of magma at each major plate tectonic setting. Be able to discuss the types of lavas erupted, and the processes that alter magmas prior to eruption.

   see table

Exploration Seismology

1. Be able to interpret a simple set of seismograms from a refraction seismic experiment.

   just remember that the slopes give velocities of the upper and lower layers, and the intersection indicates the thickness of the upper layer.

Review Essay Questions - be prepared to write on one of these (your choice)

1. What is a mineral? How are minerals classified into groups. Be familiar with the major rock forming minerals and their groups and the details of the crystal structures of several minerals, including the role of different types of bonds in that structure.

2. What is a rock? What are the three genetic rock types? Describe the classification of igneous and sedmentary rocks, and be familiar with the following specific rocks: granite, gabbro, diorite, andesite, basalt, rhyolite, shale, quartz sandstone, mica schist, gneiss and marble.