

**Final Exam, Earth 50 Fall 2006**      Name \_\_\_\_\_ **KEY**  
**3 Hours (200 points total + 15 pts possible extra credit)**

Multiple Choice (2 pts each)

1. In an igneous rock a porphyritic texture indicates:
  - A) quenching underwater
  - B) two stages of cooling**
  - C) rapid cooling
  - D) slow cooling in the deep subsurface
  
2. Radiolarian ooze is typically found in:
  - A) marshes associated with major rivers
  - B) beach environments
  - C) reef environments
  - D) the deep sea**
  
3. Which of the following is NOT a mineral in the strict definition of the term?
  - A) salt
  - B) diamond
  - C) coal**
  - D) graphite
  
4. The Moho discontinuity represents:
  - A) the base of continental or oceanic crust**
  - B) a phase transition at 670 km
  - C) the zone of partial melting
  - D) the boundary between inner and outer core
  
5. The Himalayas are, on *average*, 5 km above sea level. If you remove 3 km from the top of this mountain range, what would be the approximate *average* elevation of the mountains, *not* their peaks, after isostatic adjustment relative to sea level?
  - A) 4 km**
  - B) 5.5 km
  - C) 5 km
  - D) 3 km
  - E) 2 km
  
6. The sedimentary rock layers in Europe can be correlated with those in North America by using:
  - A) the principle of superposition
  - B) tracing their physical continuity
  - C) fossils and the notion of faunal succession**
  - D) the principle of uniformitarianism
  
7. Excessive pumping of a water well:
  - A) will enhance production of adjacent wells
  - B) has no effect on the local water table
  - C) will increase the flow from artesian wells
  - D) will create a cone of depression**
  - E) is unrelated to saltwater invasion in coastal areas

8. Groundwater erodes rocks by:
- A) **solution**
  - B) high velocity flow
  - C) headward erosion
  - D) saltation
  - E) abrasion
9. Which of the following characteristics is NOT associated with a texturally mature sediment? Increased particle rounding, increased particle sorting,
- A) increased particle rounding
  - B) **presence of widely varying particle sizes**
  - C) increased particle sorting
  - D) decrease in proportion of clay minerals
10. Building a dam causes the river upstream to:
- a. down cut to its new base level
  - b. **deposit sediment as its base level is raised**
  - c. has no effect on the river's base level
  - d. increase its capacity to carry sediment
  - e. convert from a meandering stream to a braided stream

**Short Answer (6 pts each, answer 10 of 13 of these)**

1. What are three geologic features or lines of evidence that show that California was on a convergent margin during the Mesozoic?

**Remnants of the old volcanic arc—the Sierra Nevada/Peninsular Ranges**

**The Forearc Basin—Central Valley**

**The accretionary wedge—Calif Coast Ranges**

**Blueschist and serpentine indicating past subduction**

**Accreted terranes indicating past subduction**

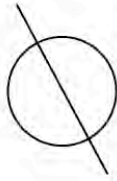
2. Eruptions of andesitic and rhyolitic lavas tend to be much more explosive than those of basaltic lavas. What factors are responsible for this difference in eruptive style?

**The more silica rich lavas are more viscous than basalt preventing slow degassing. Rhyolitic and andesitic melts also have more water (i.e., they have a higher water solubility - the water might come from partial melting of pre-existing rocks with significant amounts of water). When these water-rich, silica-rich and low-temperature melts come to shallow depths, rapid expansion of gases out of solution in rhyolites and andesites produces explosive eruptions. Gas escapes easily from low-silica, runny basaltic lavas so these tend not to produce violent eruptions.**

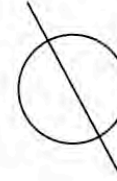
3. Using a simple sketch of the Sun-Earth system, explain the origin of seasons.

**The earth's north pole is tilted toward the sun in Northern hemisphere summer and away from the sun in N. hemisphere winter**

Northern Hemisphere Winter



Northern Hemisphere Summer



4. What are two key factors (there are lots more than two) that control how rapidly rocks weather and erode: Fully explain what you mean. A two word answer will receive little credit.

**Rainfall, elevated temperature (as in the tropics) and abundant plant cover: increasing the rate of chemical weathering; Uplift to expose fresh rock, faulting and fracturing to increase exposure of minerals to water, rocks composed of minerals high on Bowen's reaction series**

5. Volcanic arcs and the associated subduction zones typically have an arcuate shape. Briefly explain why these features are arc-shaped.

**Due to subduction on a sphere. Bending a plate on a sphere will produce a arc-shaped tear in the planet surface and hence an arc-shaped volcanic arc in the overlying plate**

6. In what part of the modern ocean would you find the oldest bottom water? Please briefly explain your reasoning.

**The Pacific—Pacific water is at the end of the transit of deep waters from their sites of formation in the Atlantic.**

7. During construction of the Aswan High Dam across the Nile River, some 500 km from the present outlet of the river into the Mediterranean, Russian engineers discovered a huge buried canyon beneath the present-day river. The oldest sediments filling the canyon were deposited shortly after the period when the Mediterranean dried up. How could such a deep canyon have been cut in the past considering that the current Nile river is very near its base level? Explain the process involved.

**When sea level dropped during the Med Sea desiccation event, base level dropped several thousand meters. The Nile cut down rapidly to the new base level and then, when sea level rose again, filled in the canyon that had just been cut.**

8. The “oil window” is the temperature range from 80-160°C over which buried organic matter in “source rocks” is converted to oil. At higher temperature, oil is converted into

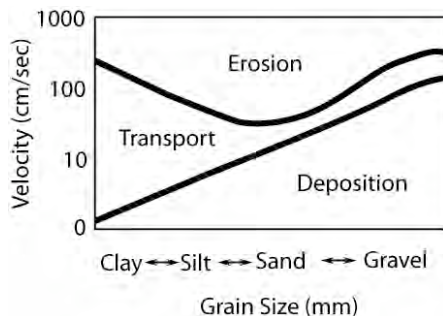
gas. Still, many large productive oil fields are located in areas where all source rocks are currently buried at depths where the temperature far exceeds 160°C. Why are such fields still productive for oil even if all the source rocks are now at temperatures far above the “oil window”?

**Oil migrates to shallower depths after it is formed. Hence, even while the source rocks are being buried to depths where the temperatures are above 160°C, oil that was previously generated from these source rocks can migrate out of the formation to shallower and cooler formations.**

9. The United States east coast is a classic “passive margin” that rifted from NW Africa about 250 my ago. As a USGS geologist, you propose to drill a test well through the current marine sediments into the underlying crust. Based upon your knowledge of the evolution of a passive margin from its initial rifting, what sequence of rocks would you expect to find in the borehole and what kind of crust is likely to be present at the bottom of the hole?

**The bottom of the hole likely starts in stretched continental crust, overlain by non marine sediments [alluvial fans, lake deposits, stream deposits (mostly texturally and compositionally immature)] overlain by salt (formed during the first marine inflow) and then normal marine sediments (limestone, marine sandstone, shale and siltstone).**

10. Experiments show that it takes a higher velocity flow in a stream to erode clay and gravel than to erode fine sand as shown in the diagram below. Explain.



**Clay is cohesive because of electrostatic attraction between clay particles and therefore requires more erosive power to erode sediment than silt or fine sand.**

11. Streams and rivers carry sediment in a number of different ways:  
a. What is the difference between suspended load, dissolved load and bed load?  
**Suspended load: fine grained material material kept in suspension whereas bed load is material (mostly coarse grained) that bounces or rolls along the bottom of a stream. Dissolved load consists of ions and chemicals dissolved in water**

b. How does the relative volume of sediment load differ between (1) a braided stream and (2) a meandering stream? **Sediment load is higher in a braided stream for a similar volume of water than in a meandering stream.**

12. Large hurricanes rarely strike Tropical West Africa, England or South Africa (all on the east side of the Atlantic), yet are common in the Caribbean and SE United States. Why are there more hurricanes in the western tropical Atlantic than anywhere else in the Atlantic basins?

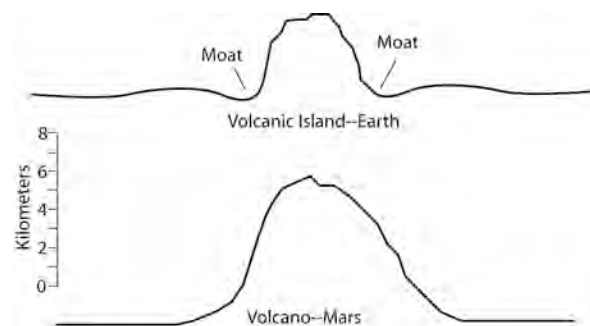
**Western tropical basins have warmer surface waters than the eastern basins (where cold water upwelling prevails). The heat is needed to promote evaporation and the formation of strong winds that fuel storms.**

13. The figure below shows the topography of two large basaltic shield volcanoes—on Earth (the top profile) and one on Mars (bottom profile). Unlike Earth, Mars is not known to have plate tectonics and the lithosphere is believed to be very thick and cool. The Earth volcano is associated with a depression or moat around the base of the island, whereas nothing like this is observed on Mars. How does isostasy explain:

a. why there a moat around the Earth volcano?

**The volcano depresses the crust around the volcano forming a moat**

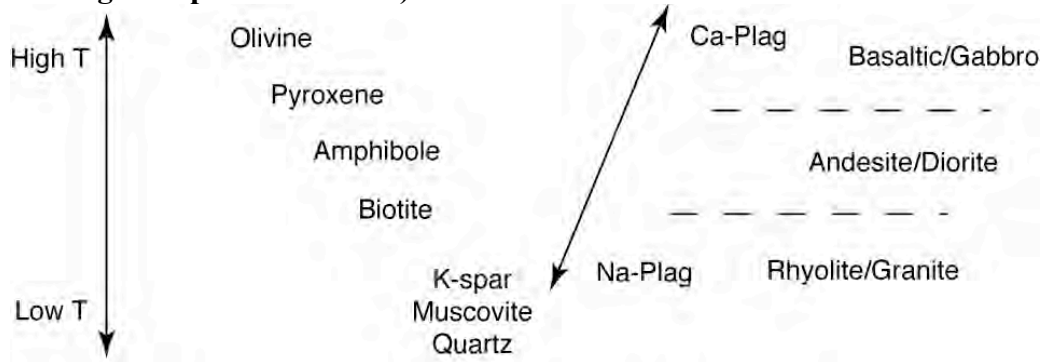
b. why a moat does not develop around the Mars volcano, even though this volcano is larger and more massive than the one on Earth? **The crust is too thick to be bent by the large volcano.**



**Long Answer Questions (Answer 12 of 15 for 10 pts each):**

1. Using Bowen's reaction series,

- a. Briefly explain the basic mineralogy of the three major igneous rock types (please provide both intrusive and extrusive rock names for these rock types). This is probably best accomplished using a sketch and suitable labels. **(At the low temp/high silica end) Rhyolite/granite: composed of quartz, k-spar and mica; Andesite/diorite: plagioclase, amphibole, and pyroxene; Basalt/Gabbro: pyroxene, olivine, and Ca-Plagioclase (at the high temp/low silica end)**



- b. Which types of minerals/rocks are most resistant to weathering?  
**Rocks on the low temp/high silica end of Bowen's reaction series**

- c. Which types of rocks are likely to be produced by partial melting of lower continental crust? **Intermediate magmas like andesite/diorite**

2. During subduction, most water trapped in pore spaces within deep sea sediments and lavas is squeezed out of the subducting slab within less than ~50 km of the slab's descent into the mantle, yet most melt generation fueled by introduction of water into the asthenosphere occurs at depths of >100 km in the mantle.

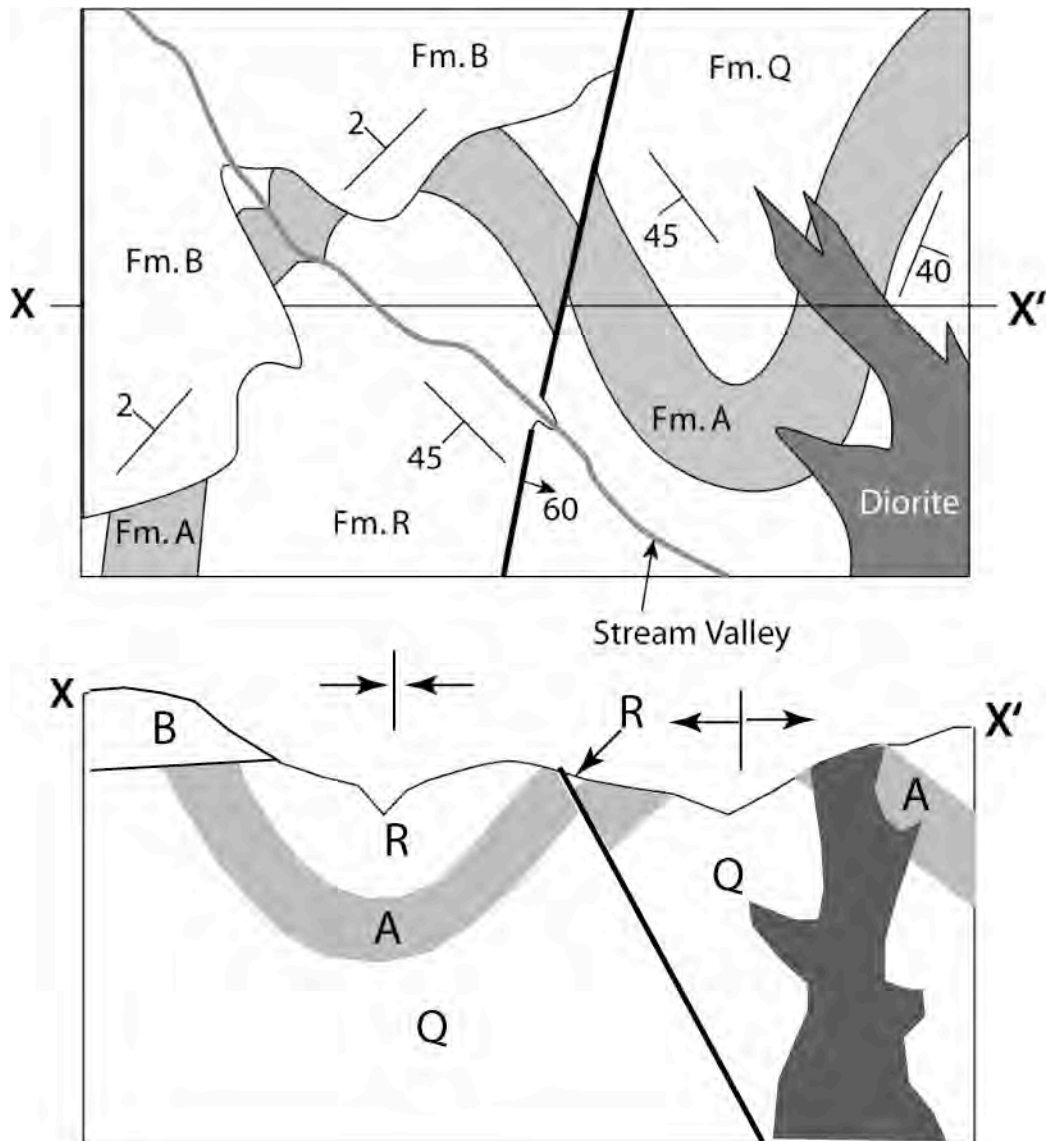
- a. Where does the water come from that promotes mantle melting?

**Dehydration of amphibole and mica**

- b. **How** does the addition of water contribute to melting of the asthenosphere beneath a continent?

**Reduces the melting temperature of the asthenosphere**

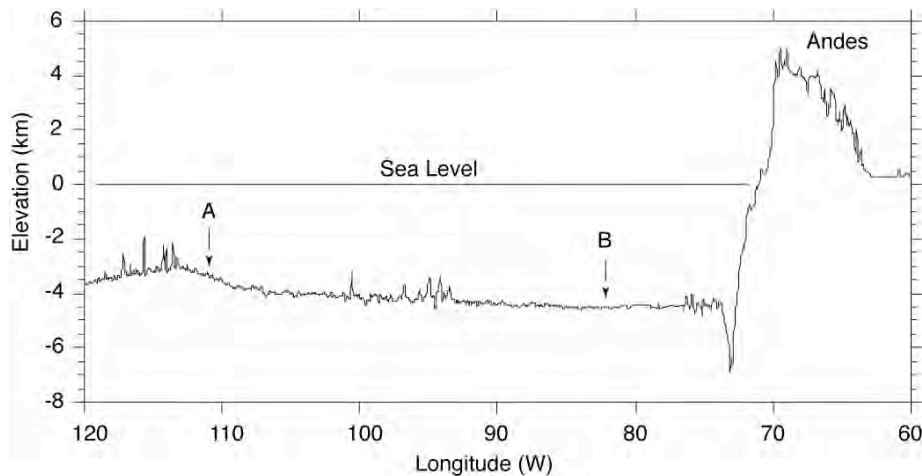
3. Construct the Geologic Structure Section and answer the questions. Note that the heavy line is a fault contact.



- a. In the cross section, does the fault have mainly normal, strike-slip, or reverse movement? **Normal Fault**
- b. State the correct age relationships from youngest to oldest between the four sedimentary formations (Fm. A, Fm. B, Fm. Q, and Fm. R), the Diorite and the Fault. Assume that Fm. B contains pebbles derived from the Diorite.
- Youngest:   Fault     B     Diorite     R     A     Q   Oldest
- c. What kind of fold exists on the right side of the fault? **Anticline**

4. The plot below shows an E\W topographic profile (at ~20°S) across the eastern Pacific from the East Pacific Rise spreading center to the Andes.

- At what longitude would you most likely find recent basaltic lava flows?  
~115°
- At what longitude would you most likely find recent andesitic lava flows?  
~65-70°
- At what longitude would you most likely have the largest earthquakes?  
~68-70°
- At what longitude would you most likely have earthquakes associated with normal faulting?  
~115° (or 110-120°)
- If the calcium carbonate compensation depth is presently at 4000m, what type of sediment might you expect to be currently accumulating at sites A and B? Please briefly explain your reasoning.  
**A: carbonates (above the CCD), B: red clay or siliceous ooze (below the CCD)**



5. Mid-ocean ridges spread at rates ranging from about 2 cm/yr (slow-spreading) to about 15 cm/yr (fast-spreading).

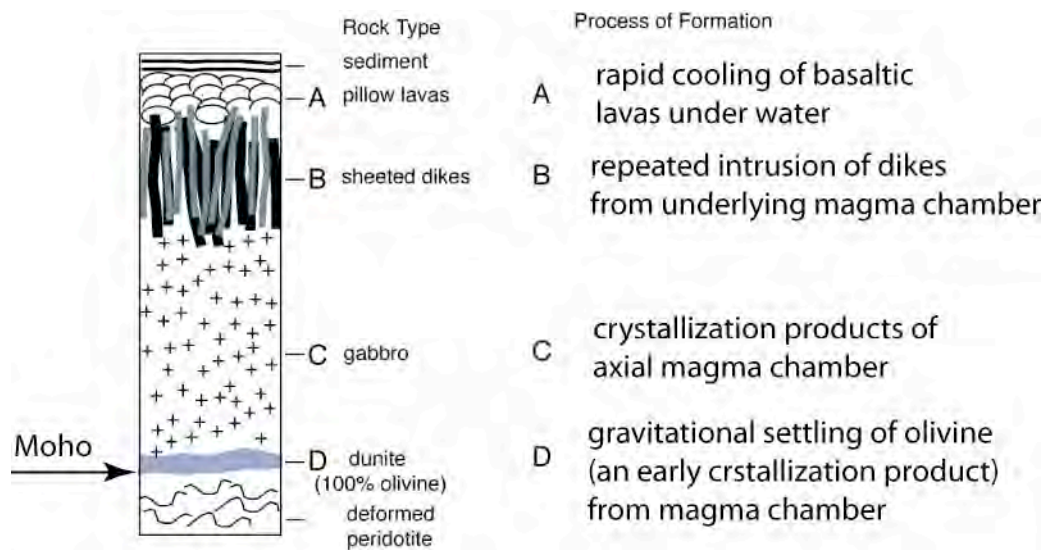
- How does the topography differ between a slow-spreading and a fast-spreading ridge? **Rougher, steeper on a slow spreading ridge**
- How would magma chambers likely be different at slow and fast spreading ridges? **Smaller or non-steady state at a slow spreading ridge**
- Fast- and slow-spreading ridges show the same rates of subsidence. What accounts for the similarity of subsidence rates? **Subsidence related to rate of cooling of the crust, same rate in both ridges**

6. The diagram below shows a typical ophiolite sequence and likely is similar to the structure of the oceanic crust.

a. In the column at the right briefly explain the process by which the labeled rock types form. Note that unit D is a special rock type composed only of olivine, so you'll need to speculate on how such a unit might form.

b. Indicate the approximate location of Moho on the diagram. **Just below D**

c. Provide a depth scale for the diagram to indicate the approximate thickness of the oceanic crust.



7. Please identify which of the following rocks are intrusive, extrusive, metamorphic, or sedimentary?

- a. Chert pebble conglomerate
- b. Porphyritic orthoclase biotite granite
- c. Olivine basalt
- d. Blueschist
- e. Claystone
- f. Rhyolite tuff
- g. Quartz feldspar mica gneiss
- h. Texturally mature quartz sandstone
- i. Garnet mica schist
- k. Brachiopod trilobite limestone
- l. Porphyritic Mica amphibole plagioclase diorite
- m. Salt
- n. Non-foliated, olivine-bearing marble
- o. Serpentinite
- p. Olivine gabbro

Rock type:

- \_\_\_ Sedimentary \_\_\_
- \_\_\_ Intrusive \_\_\_
- \_\_\_ Extrusive \_\_\_
- \_\_\_ Metamorphic \_\_\_
- \_\_\_ Sedimentary \_\_\_
- \_\_\_ Extrusive \_\_\_
- \_\_\_ Metamorphic \_\_\_
- \_\_\_ Sedimentary \_\_\_
- \_\_\_ Metamorphic \_\_\_
- \_\_\_ sedimentary \_\_\_
- \_\_\_ Intrusive \_\_\_
- \_\_\_ Sedimentary \_\_\_
- \_\_\_ Metamorphic \_\_\_
- \_\_\_ Metamorphic \_\_\_
- \_\_\_ Intrusive \_\_\_

8. The diagram below illustrates two sea surface magnetic anomaly profiles that cross a spreading ridge system that is oriented N-S. Given the magnetic polarity time scale and sea surface magnetic anomaly profiles, answer the following questions:

a. At what position (in km) does the spreading center (ridge crest) occur on profile C-D?

**45 km (based on symmetry of magnetic anomalies about this point)**

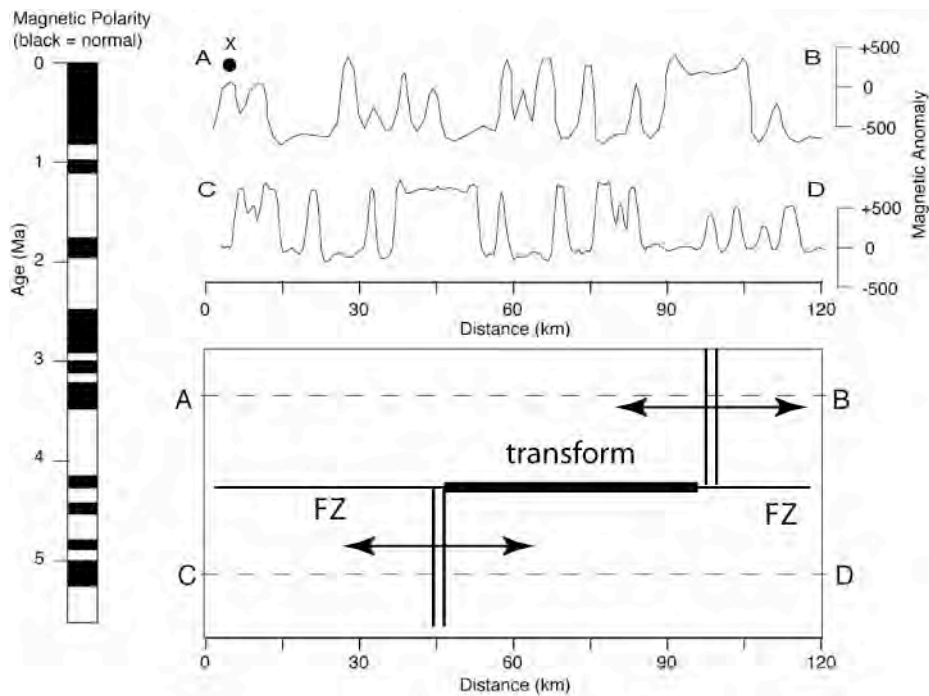
b. What is the spreading rate of this ridge crest system? i.e. how many km of new seafloor are produced per million years?

**full spreading rate of 26 km/million years (45km to ~112km or ~67km on east flank in 5 m.y. or ~13km/m.y on one flank; double this to account for the other flank)**

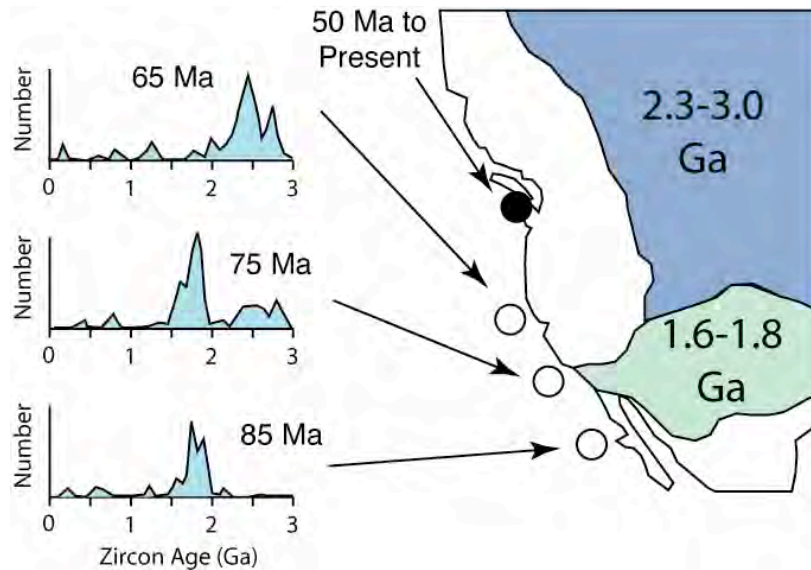
c. How could you estimate the age (in millions of years) of crust at point X?

**Point X has anomalies that are older than the oldest anomalies on the polarity time scale shown. Spreading rate is quite constant back to 5 Ma so we could extrapolate this rate back to date point X.**

d. On the lower plot (a map view), sketch the approximate location of the ridge crests and the intervening transform fault and fracture zone. Clearly label the location of the transform fault and fracture zone(s).



9. A series of Late Cretaceous (85-65 Ma) sedimentary rocks are exposed on Vancouver Island (black dot). These rocks have been postulated (based on magnetic inclination data) to have been formed far to the south and to have traveled northward during the Cretaceous, reaching their final position by about 50 Ma. The figure below shows the distribution of zircon ages from three intervals (at 85, 75, 65 Ma) from this sedimentary sequence and the paleomagnetically determined latitudes of this terrane at these times (open circles). Dominant zircon ages on stable North America are also shown.



- a. Do the sedimentary zircon ages support the magnetically -determined northward transport?

**Yes. The sediments have zircons with ages similar to the 1.6-1.8Ga source area as the site passes closest to this source.**

- b. Geologists have identified many “exotic terranes” along the western margin of North America like the rocks on Vancouver Island. How might an exotic terrane be recognized in the rock record [aside from the paleomagnetic data and zircon ages noted above]?

**Fossils (flora/fauna characteristic of another latitude)**

**Sediment type characteristic of another latitude**

**Faults with documented motion comparable to that inferred from magnetics**

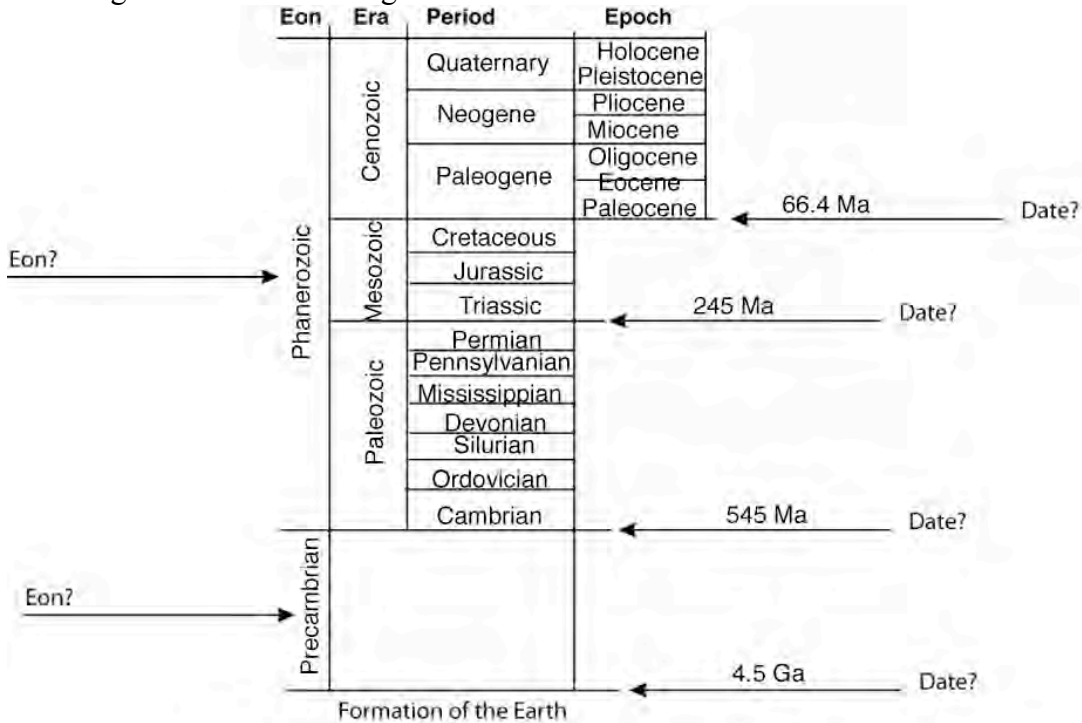
**Different origin for rocks on the other side of a fault**

**Rocks did not form where they are presently found.**

- c. The Atlantic was formed by rifting of Africa and Europe from North and South America about 250 my ago. Would you expect to find exotic terranes along the margins of the Atlantic that are younger than 250 my? Why or why not?

**No. Rifted passive margins would not have exotic terranes. Convergent and/or transform margins are required to provide relative transport of the terranes.**

10. Fill in at least 20 of the blanks (1/2 pt each) in the time scale using a subset of the choices given below including dates where indicated.



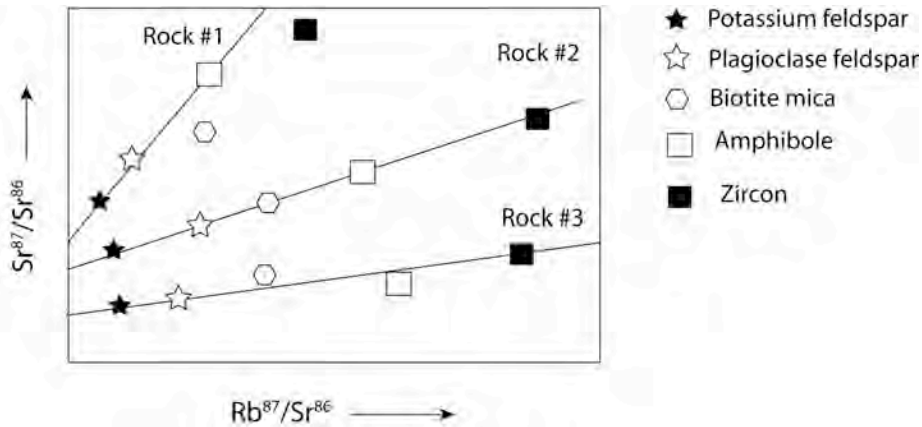
Dates: 2 Ma, 10.2 Ma, 40.5 Ma, 66.4 Ma, 104 Ma, 245 Ma, 350 Ma, 545 Ma, 854 Ma, 1.2 Ga, 2.5 Ga, 4.5 Ga, 6.5 Ga

Periods, epochs, eras, eons: Precambrian, Miocene, Cambriocene, Cambrian, Cenozoic, Permian, Devonian, Silurian, Eocene, Mesozoic, Hadiozoic, Paleozoic, Marzipan, Pleistocene, Triovinian, Pennsylvanian, Marylandian, Mississippian, Phanerozoic, Ordovician, Jurassic, Siluriocene, Holocene, Pliocene, Cretaceous, Paleocene, Triassic, Oligocene

11. Glaciers are common in mountain areas and as large ice sheets. Explain how a glacier moves, what forces are involved in producing movement, and how movement is manifested in either the structure of the glacier or features made by the glacier. Include in your explanation “Ablation”, “Accumulation”, “Equilibrium line”. A sketch may help.

**Glaciers move by the accumulation of snow at the upper end, compaction of snow to firn and ice, and flow of ice (by a combination of shearing/deformation of ice crystals, and flow over wet basement) to the point at which ice is melted or undergoes ablation. The equilibrium line is the point on the glacier where loss of ice by ablation is balanced by accumulation. Glaciers will retreat if ablation exceeds accumulation and will advance if the reverse is true.**

12. Rb-Sr Radiometric dating of minerals in three granite samples produces the isochrons below. The key to the types of minerals dated is shown to the left of the isochron diagram. Please *explain your answer* to each of the following:



a. Which of the three rocks is the oldest *and why*?

**Rock #1. Various minerals would initially have well mixed constant  $87Sr/86Sr$  ratio and with time the points evolve up and to the left (slope of -1) as parent is replaced by daughter.**

b. Which of the three rocks had the highest initial ratio of daughter product *and why*?

**Rock #1. The initial  $87/86$  ratio is given by the intercept of the isochron (left edge of diagram at  $87Rb = 0$ ).**

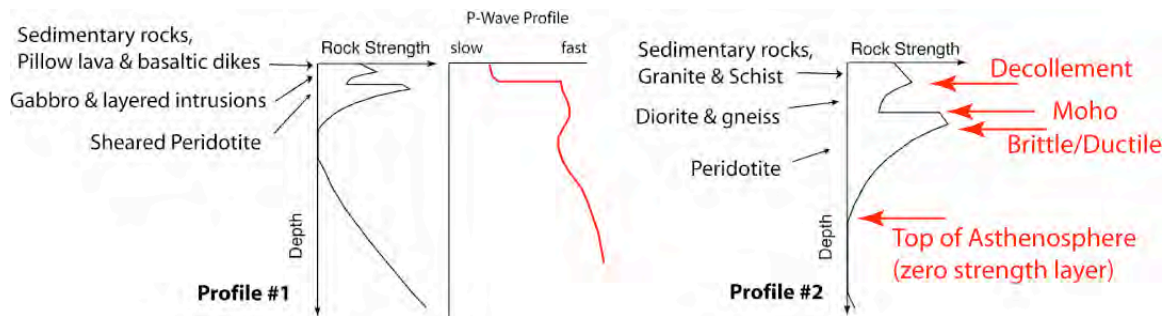
c. Which mineral has the highest Rubidium content *and why*?

**Zircon has the highest Rb content. It plots furthest to right on Rb axis.**

d. Which date is most reliable *and why*?

**Rock#2. All points fall on single line with little scatter.**

13. The two profiles below show the major lithologies and rock strength of two sections through the Earth's crust and upper mantle.



a. Which profile represents continental crust and its underlying mantle?

**Profile #2 represents continental crust and underlying mantle (note rock types and thicker crust than in profile #1)**

- a. On Profile #2, use arrows and labels to show the location of
  - a. the Moho.
  - b. the top of the asthenosphere.
  - c. the brittle/ductile transition in the mantle lithosphere.
- b. On Profile #2 indicate the relative depth where you expect to find décollements (=detachment faults) where normal faults turn into low angle shear zones?

**see plot**

- c. On Profile # 1 sketch the P-wave profile that corresponds to the rock strength profile.

**see plot**

14. Features that are believed to be related to hotspots are abundant on the surface of the Earth.

- a. Explain what a hotspot is and how it is manifested at Earth's surface.

**A hotspot is a deep seated melting anomaly (plume of hotter, more buoyant mantle)  
Age progressive volcanic chain, Topographic swell, Flood basalts/oceanic plateaus**

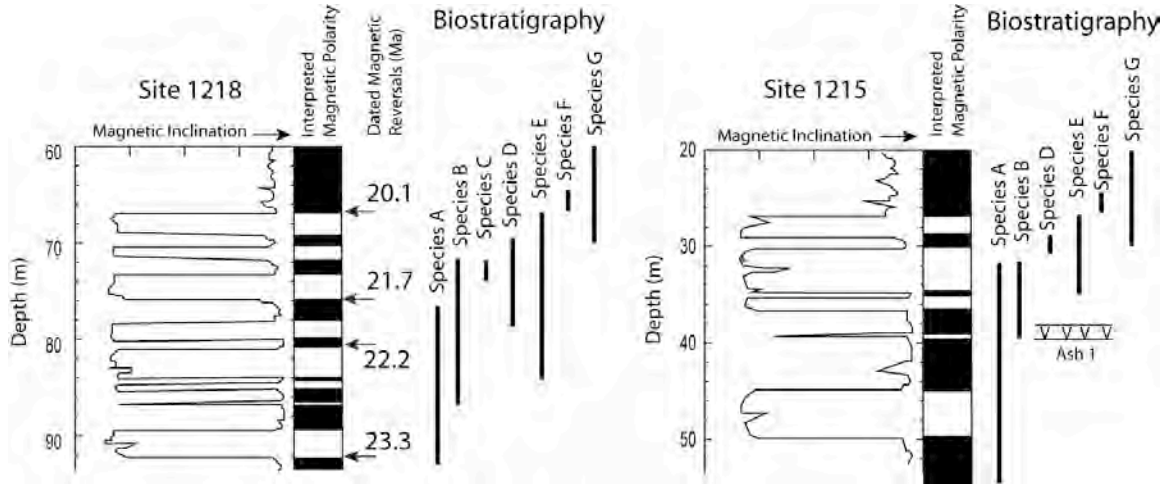
- b. How can radiometric dating be used to support the idea that a hotspot is involved in the formation of one of these surface features?

**If ages of volcanoes change systematically with distance along chain.**

- c. How can magnetic inclination data be used to test the "fixed hotspot" model?

**If plume is stationary (fixed), then the surface volcanic expression will form at the same latitude and thus the magnetic inclination will be the same for all volcanoes in a chain derived from a stationary plume.**

15. The pattern of magnetic reversals and biostratigraphic events is shown for two deep sea sediment cores (Site 1218 and 1215) from the Pacific. The magnetic anomalies have been partly dated in Site 1218. Assuming that the record in Site 1218 is accurate and correctly dated, answer the following:



a. There is an unconformity in Site 1215. Approximately what depth in this site is the unconformity?

**32 meters**

b. About how much time is missing in the unconformity?

**~0.75 m.y. (from about 22.4 to 21.1 Ma)**

c. What is the approximate sedimentation rate in Site 1218 (in meters/million years)?

**25m in 3.2 m.y. or ~8m/m.y.**

d. If you were to radiometrically date Ash 1 in Site 1215, about what age would you expect it to be based upon the biostratigraphy and magnetostratigraphy in Site 1218?

**~22.7 Ma**

**Extra Credit Essay Question (15 pts):** On the back of this page, describe the rock cycle in light of the theory of Plate tectonics: How are different types of rocks formed by heating, pressure, melting and erosion, how does erosion, weathering, metamorphism, and melting transform one type of rock into another, and what kinds of rock are typically found in the major plate tectonic settings. (You can use drawings to help)

**The rock cycle involves the formation of rocks by magnetic activity, metamorphism and sedimentation. The formation of melts (often by partial melting or ultramafic peridotites) in a spreading ridge or the upper mantle associated with a subduction zone generates intrusive magma bodies that may erupt to the surface to form**

extrusive volcanic rocks. At ridges, these rocks are gabbros (in the cooled magma body) and basalts erupted onto the ocean floor. In volcanic arcs, the plutons are typically diorites or granite and their extrusive equivalents, andesite and rhyolite. Intrusion of magmas in the arcs causes metamorphism of the surrounding rocks (regional metamorphism at depth, contact metamorphism near the surface). Metamorphic rocks can also be formed in subduction zones (where it is usually high pressure/low temperature) and by water-rock interaction (mostly greenschist and zeolite grade metamorphism) in spreading zones. Any of these types of rocks (as well as other sedimentary rocks) can be weathered and eroded at the surface. Erosion is typically most pronounced in the tropics and in areas of large mountains there is tectonic uplift during collisions between plates or exposure of fresh rock in continental rifts. Transform faults can also generate large mountains and their associated sediments. Chemical weathering and erosion reduces the amount of mafic minerals and increase the relative proportions of clay and quartz sand. Most sediments are deposited in areas of active mountain building (volcanic arcs, collision zones, transform faults on land, rift zones). Deep sea sediments are typically biogenic (oozes) or form atmospheric dust (red clay).