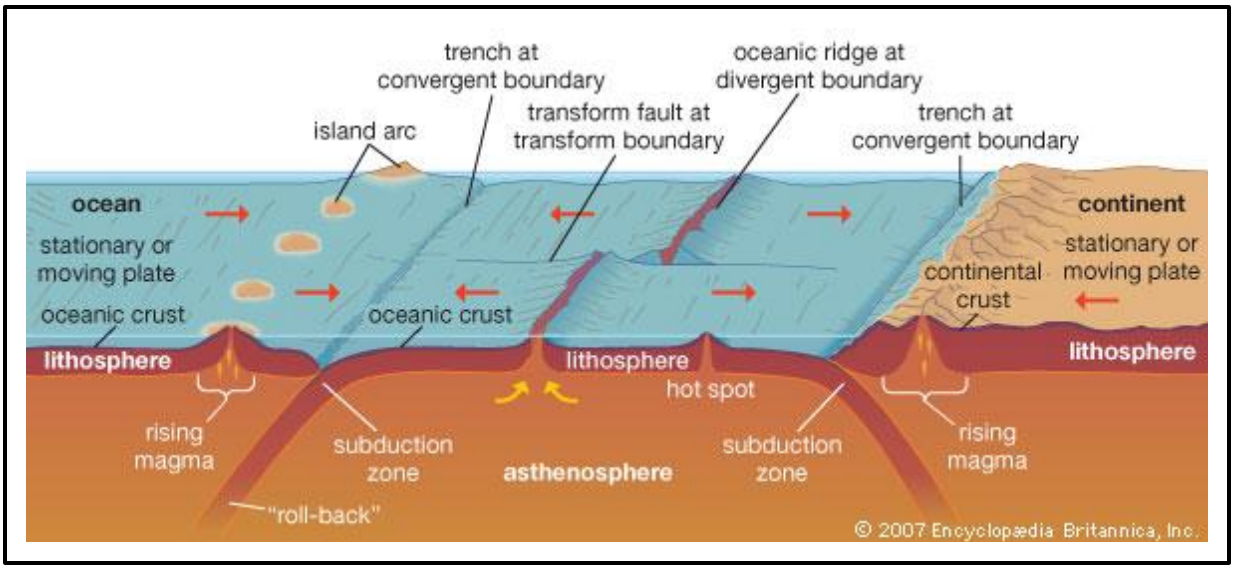
Part One: Multiple Choice (25 points total)

1. **C. Arc volcanism**
2. **D. all S-waves vanish because they cannot move through a liquid**
3. **C. are located near continental-oceanic boundaries due to magma generation in the Benioff Zone**
4. **B. Iapetus Ocean**
5. **A. Increase in cyanobacteria causes the great oxygenation event**
6. **C. elastic**
7. **B. The speed of seismic waves generally decreases with depth in a layer**
8. **B. the intensity of an earthquake**
9. **A. The movement of the continents**
10. **C. Are located where they are as a result of magma generation in the Benioff Zone**
11. **A. Magnetic patterns on the seafloor**
12. **D. The strength of the magnetic field is slightly weaker than usual**
13. **A. Occur in stripes parallel to mid-ocean ridges and offset along transform faults**
14. **A. Earth's crust is thicker than average**
15. **A. Rocks along spreading ridges all show normal polarity regardless of age**
16. **D. 25°C per kilometer**
17. **C. Pyroclastic flow**
18. **A. Steam and ash release – bulge on mountain – earthquake – landslide – lateral blast**
19. **D. Principle of stratigraphic superposition**
20. **C. eons, eras, periods, epochs**
21. **C. the outer core creates an electric current which induces a magnetic field**
22. **C. sediments – pillow basalts – sheeted dike complex – gabbro**
23. **C. Rodinia**
24. **A. an earthquake has only one magnitude but the intensity can vary**
25. **A. terrane**

Part Two: Short Answer (127 points total)

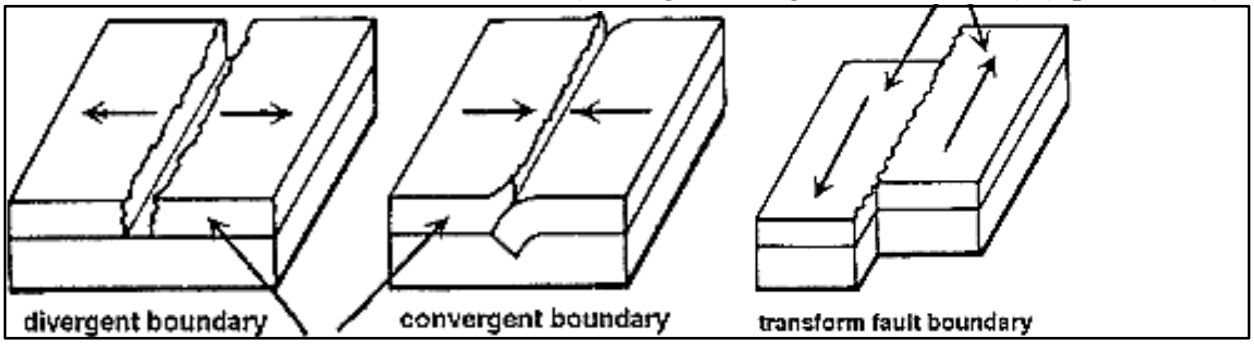
1. Draw a diagram depicting seafloor spreading. Label and show direction of plates **(15 points total)**



- Features that must be included: ridge, trench, abyssal plain, subduction zone, continental plate **(1 point each, 5 total)**
- Plate movement: arrows pointing away from ridge, continental plate moving toward ridge **(2)**
  a. What mechanisms drive these plate movements? Describe each mechanism.
     - At convergent/subduction zone: slab pull, at divergent: ridge push **(1 point for each named, 2 total)**
     - Slab pull: As lithospheric plates move away from midocean ridges they cool and become denser. They eventually become more dense than the underlying hot mantle. After subducted, cool, dense lithosphere sinks into the mantle under its own weight. This helps to pull the rest of the plate down with it. **(1 point for correct description)**
     - Ridge push: lithosphere thickens with distance away from the midocean ridge. The result of this thickening with distance from the ridge is that the lithosphere/asthenosphere boundary slopes away from the ridge. The weight of the lithosphere on this sloping surface produces a downslope force. Since the asthenosphere is weak, the weight of the lithosphere near the ridge sliding down the "slippery slope" of the asthenosphere "pushes" the older part of the plate in front of it. **(1 point for correct description)**

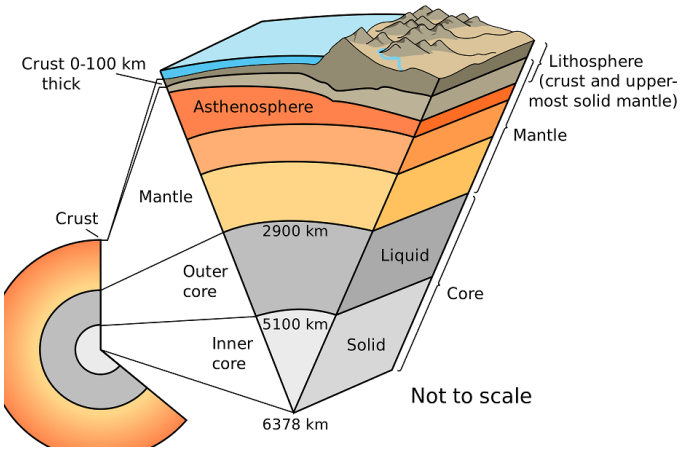
  b. Does volcanism occur anywhere in your cross section? If so, mark on your diagram. What type of volcanism occurs at each of the locations you marked
     - Yes **(1 point)**
     - Occurs at two locations: at mid-ocean ridge and at subduction zone **(1 point for each)**
     - Volcanism at mid-ocean ridge: possible answers include mafic, effusive, mid-ocean ridge volcanism, ocean basin environment **(1 point)**
     - Volcanism at subduction zone: possible answers include mafic, explosive, arc volcanism, arc environment **(1 point)**

2. Draw cross sections of the three boundaries (convergent, divergent, and transform). **(9 points total)**



- **1 point for each correctly drawn boundary, 3 total**
  a. What type of stress operates within each boundary? (directional stress) On each of your cross sections draw the direction these forces are acting in.
     - tensional stress at divergent **(1 point)**, compression at convergent **(1 point)**, shear at transform **(1 point)**
     - **3 points for each correct direction that is drawn**

3. Refer to the following cross section of Earth's interior. Label each layer. **(12 points total)**
    - Must include inner core, outer core, mantle, asthenosphere, lithosphere **(5 points total)**
    - If student lists asthenosphere and lithosphere as crust only, award **1 point instead of 2**



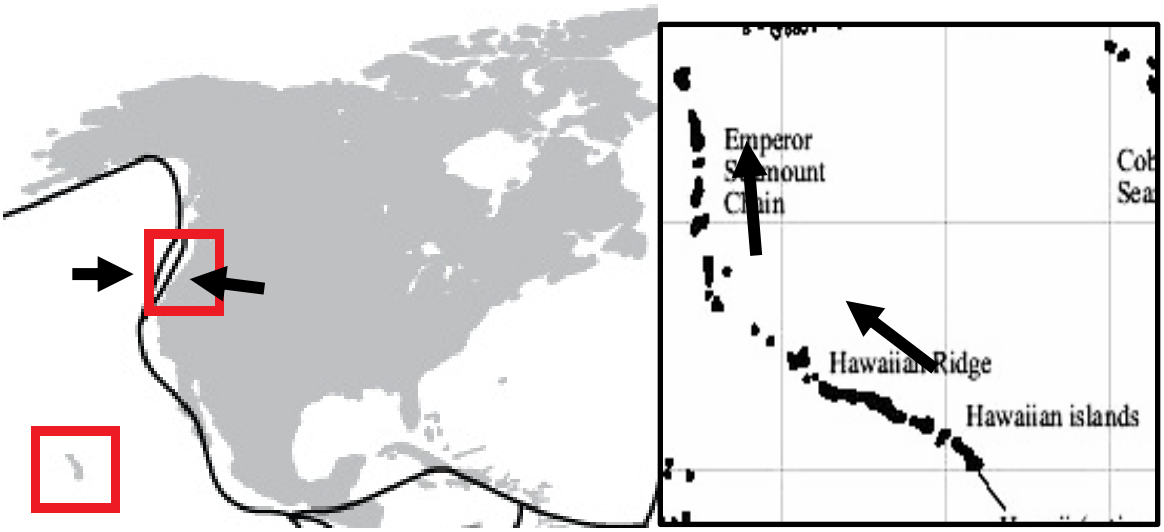
a. Which layer is molten? What evidence was used to prove this?
    - Outer core **(1 point)**
    - seismic waves reflect off the core **(1 point)**
    - magnetic field: generated by circular flow of electrically charged particles in the liquid outer core **(1 point)**

b. When Earth was first formed, the layers that exist today were not present. Explain the process that created Earth's layers. In which geologic eon did this occur?
    - core differentiation **(1 point)**
    - The interior of Earth is hot and very soft: it can easily flow, so metals sink downward to form the Fe/Ni core, silicates migrate upward to form the mantle **(1 point for defining and 1 point for providing mechanism)**
    - Hadean Era **(1 point)**

4. Suppose this glacier melts/retreats. As a result of the glacier's removal, what would you expect to happen? Explain why this process occurs. **(4 points total)**
    - When the glacier is removed, the crust will gradually rise **(1 point)**
    - Process is called isostatic rebound **(1 point)**
    - Mantle is able to flow, so the crust will deform when there is an increase of pressure/gravity on crust. Specifically, the crust/mantle adjusts for the glacial ice and the crust sinks. **(1 point)**
    - When glacial ice is removed, there is no longer a force pushing down on the crust, so the mantle subsequently flows back and the crust rebounds. **(1 point)**

5. Consider the Rocky Mountains and the Appalachian Mountains. Which of the two ranges is older? Justify your answer. **(3 points total)**
    - Appalachian Mountains are older **(1 point)**
    - Can tell by size, Appalachians were once as tall as Rocky Mountains **(1 point)**
    - Erosion occurs at both ranges, but Appalachian have been eroding for a longer time **(1 pt)**

6. Consider the two volcanoes on the map: Mt. St. Helens and the Hawaiian Chain. **(21 points total)**



a. On the map above, draw arrows to illustrate the direction of plate movement at each location.

- Arrows on map above, **1 point for each correct direction (2 points total)**

b. What type of volcano would you expect at each location, and what type of volcanism is the volcano associated with? **(4 points total)**

i. Mt. St. Helens: either stratovolcano or cinder cone **(1 point),** arc volcanism **(1 point)**

ii. Hawaii: shield volcano **(1 point),** hotspot volcanism **(1 point)**

c. Consider Mt. St. Helens and Hawaii. Compare/contrast the magma properties.

- **1 point for each correct property, 10 total**

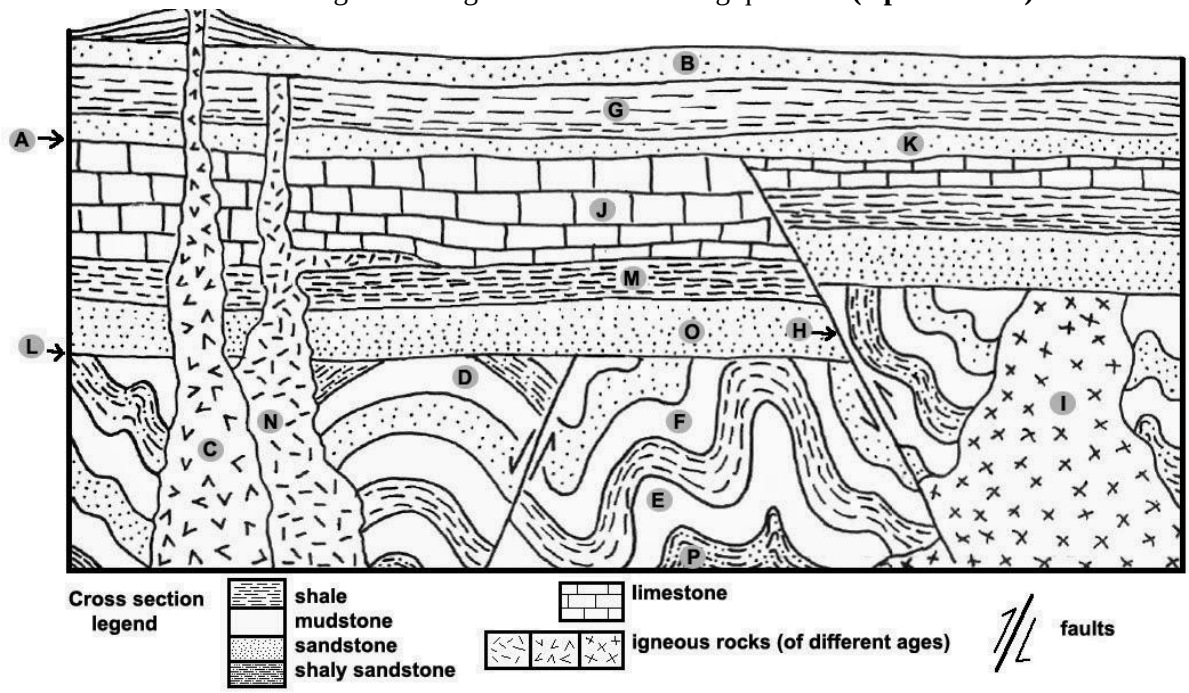
	Mt. St. Helens	Hawaiian Chain
Composition	Felsic or high Si content	Mafic or low Si content
Viscosity	High viscosity	Low viscosity
Cooling temperature	Low temp (or near 700 C)	High temp (or 1000-1200)
Eruptive style	Explosive	Effusive/gentle
Geologic setting	Arc environment	Ocean basin environment

d. If there is no plate boundary at Hawaii, explain how a volcano can still form. **(5 points total)**

- Forms through hotspot volcanism **(1 point)**
- Mantle plume rises from base of mantle, mantle plume is much hotter than surrounding mantle so it rises **(1 point for naming mantle plume)**
- Mantle plume head reaches surface and melts crust **(1 point)**

- When plume tail reaches the surface, hotspot volcanism occurs **(1 point for naming plume tail)**
- Tectonic plate continues to move over hotspot, leaving a track of volcanoes **(1 point)**

7. Refer to the following block diagram for the following question. **(8 points total)**



a. Using the laws of original horizontality, superposition, and cross-cutting relationships interpret the order of the formation of the features in this cross section (oldest to youngest)

1. P	5. I	9. J	13. G
2. E	6. L	10. H	14. N
3. F	7. O	11. A	15. B
4. D	8. M	12. K	16. C

- **0.5 point for each correct letter, total possible is 8**
- **If a large portion of the letters are in the correct order but are not assigned to the correct numbers in the list, consult the head grader on how to distribute points.**

8. Considering the following: An ice sheet is imposed on a continental block, causing the continent to sink. Assuming the two are in isostatic equilibrium, it is possible for one to calculate the thickness of the ice sheet given the value of total isostatic rebound. The buoyancy pressure on the continental block equals the pressure that is imposed by the ice sheet. For the following problems, assume that the density of the ice sheet is always 1000 kg/m^3 and that the density of the asthenosphere is 3300 kg/m^3
    a. Calculate the displacement of the asthenosphere when the ice sheet has a thickness of 3.3 kilometers.
        - (ice thickness)(density of ice) = (displacement of asthenosphere)(density of asthenosphere) **(1 point for equation)**
        - 3300 m * 1000 = (displacement) (3300) **(1 point for set up)**
        - Displacement = 1000 m **(1 point for correct answer)**

b. Calculate the thickness of the ice sheet when the displacement of the asthenosphere is equal to 0.85 kilometers.
   - (ice thickness)(density of ice) = (displacement of asthenosphere)(density of asthenosphere) **(1 point for equation)**
   - (ice thickness)(1000) = (850)(3300) **(1 point for set up)**
   - Ice thickness = 2805 m **(1 point for correct answer)**

9. Considering the following questions about plate convergence.
   a. At an oceanic-continental convergent boundary, the oceanic plate typically sinks. Explain why subduction of the oceanic plate is favored.
      - Oceanic plate is cooler and more dense than the continental plate **(1 point)**
   b. Is it possible that a geologic process, other than subduction, can occur at this convergent boundary?
      - Yes **(1 point)**
      - Called abduction **(1 point for correct name)**
   c. If so, what is this process's effect on the convergent boundary?
      - The oceanic plate overrides the continental boundary, and is pushed under the oceanic plate **(1 point)**
      - This causes the oceanic plate to buckle and usually results in a new mid ocean ridge forming **(1 point)**
10. Consider the different types of tectonic basins, and answer the following questions.
   a. Where are rift basins typically located?
      - Found on all passive (Atlantic-type) continental margins, found between mountain ranges **(1 point)**
   b. What can be inferred from studying rift basins?
      - Provide a record of the early stages of continental breakup **(1 point)**
   c. What geologic basins are associated with back arc basins?
      - Island arcs and subduction zones, convergent plate boundaries **(1 point)**
   d. Describe the formation of foreland basins.
      - Form because the immense mass created by crustal thickening associated with the evolution of a mountain belt causing the lithosphere to bend **(1 point)**, by a process known as lithospheric flexure **(1 point)**
   e. Where are forearc basin regions typically located?
      - Between an oceanic trench and the associated volcanic arc, at convergent margins **(1 point)**
11. The Wilson Cycle describes the overall cycle of the rifting, drifting, and colliding of tectonic plates. In the spaces provided, number each event in order of their occurrence. **(9 points)**

3_____ An ocean basin is formed between the two continents.
6_____ Most of the ocean basin has subducted.
1_____ A stable continental craton exists. A hotspot rises up under the craton, causing it to split.
7_____ In the subduction zone, magma is generated and rises to the surface, forming volcanoes that later build into a mountain range
5_____ A subduction zone forms somewhere within the ocean basin.
9_____ The mountains begin to erode, and the foreland continent returns to Earth's surface.

2_____ A new divergent plate boundary is created.
8_____ The two continents collide.
4_____ As the ocean basin widens, the divergent continental margins begin to cool and sink below sea level

(1 point for each correct, 9 total)

12. Answer the following questions concerning Earth's orogenic belts.
    a. Define orogeny.
        - the building of continental mountains by plate-tectonic processes that squeeze the lithosphere **(1 point)**
    b. Give at least five examples of the processes that occur during orogeny.
        - Possible answers: Distinctive patterns of deposition, deformation, metamorphism, intrusions, volcanic activity, seismic activity **(1 point each, 5 total)**
    c. Which orogenic belt is considered to be the most dramatic?
        - Between the Indo-Australian Plate and African Plate to the South and the Eurasian Plate to the North/ along the Himalayas **(1 point)**
13. Match each scientist to his or her contribution to the field of geology.

(1 point, 14 points total)

a. Abraham Ortelius	b. Alfred Wegener	c. Arthur Holmes	d. Hugo Benioff
e. Alexander du Troit	f. Sir Edward Bullard	g. Milutin Milankovitch	h. J. Tuzo Wilson
i. Ingo Lehmann	j. James Hutton	k. Nicolas Steno	l. Charles Lyell
m. William MacLure	n. Harry Hess		

---

n_____ Studied mid-ocean ridges and concluded that seafloor spreading continually adds new material to the ocean floor
g_____ Credited with calculating eccentricity, precession, and obliquity
a_____ First noted the close fit of the shorelines of the Americas with those of Africa and Europe
f_____ Demonstrated that a better fit between the continents could be made if the continental shelf/slope boundary at a water depth of 1000 meters was used instead of the coastlines of the continents
i_____ Discovered the outer core by studying seismograms from earthquakes in New Zealand; observed that the seismic waves reflected off the boundary of the inner core
h_____ Proposed that plates might move over fixed "hotspots" in the mantle, forming volcanic island chains like Hawaii
j_____ Proposed the theory of uniformitarianism
b_____ Portrayed the breakup of Pangaea and the movement of the continents to their present positions in his book *The Origins of Continents and Oceans*
m_____Considered the "Father of American Geology" for making the earliest geologic map of the United States
c_____ First suggested that thermal convection currents in the mantle are the force moving the continents
l_____ Author of *Principles of Geology*, which caused controversy during the science v. religion debate of the 1800s
d_____ Plotted the location of deep earthquakes around the Pacific Ocean, which revealed they were concentrated along well-defined lines (subduction zones)
e_____ Theorized that there were two great landmasses called Laurasia and Gondwana
k_____ Studied the formation of rock layers/strata and published his findings in his book *Prodromus*