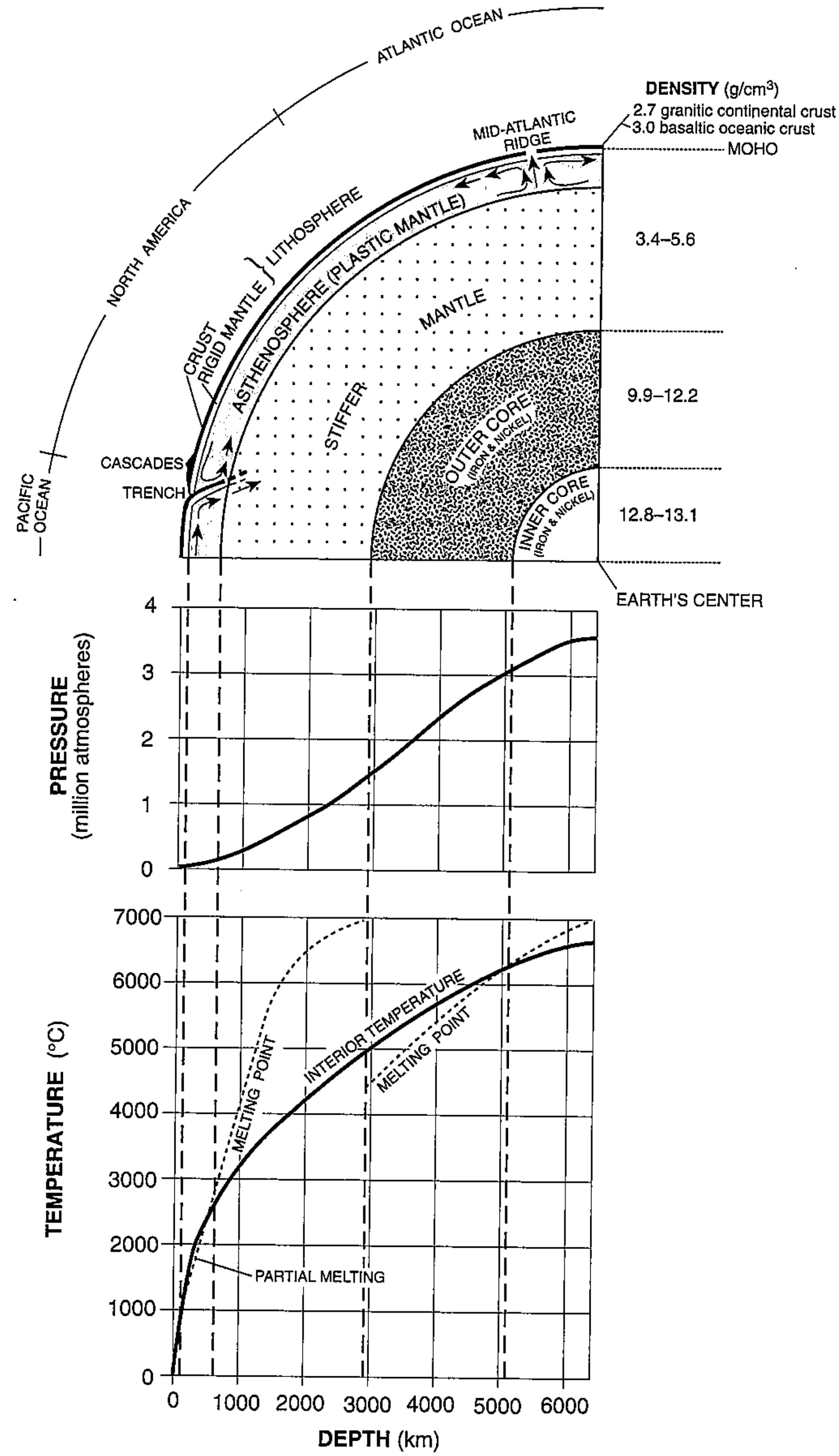
Inferred Properties of Earth's Interior



Overview:

If one could travel to the "Center of the Earth", it would be a rough trip. You would enter four different and distinct layers - the solid crust, the mantle, having a plastic and larger solid stiffer section, the liquid outer core, and the solid inner core. As you travel downward, the density constantly increases, while the temperature would rise to 6700°C, and the pressure would be measured in millions of atmospheres. Our understanding of the Earth's interior is mostly based on indirect knowledge since we have never completely penetrated through the crust. This is why the title contains the word "Inferred" - our best guess. Most of the information on the interior of the Earth has been slowly revealed by the study of seismic waves. Released by earthquakes and traveling deep into the Earth's interior, seismologists studying seismograms have detected changes in speed and direction as these waves enter different layers. Seismologists know that the seismic *S*-wave cannot pass through liquids. The *S*-wave is stopped at the beginning of the outer core, thus it must be a liquid. With more advanced technology, along with creative problem solving, new theories are being proposed and tested; giving better insight in the complexity and dynamics of the Earth's interior.

Earth's Cross-Section Chart:

The Crust – The Earth's outermost layer is the crust. It is relatively cold, thin and brittle, yet it supplies us with the valuable resources that make life possible. Earthquakes occur in the crust, generating destructive seismic waves. As shown on the upper right side, the crust is divided into the less dense granitic continental crust and the denser basaltic oceanic crust. The continental crust is much thicker compared to the oceanic crust. Under Density is the word MOHO. This term represents the boundary zone separating the crust from the rigid mantle.

The Lithosphere – The lithosphere (shown by the two lines) consists of the crust and the upper most part of the mantle referred to as the "rigid mantle." These joined parts collectively make up the plates. The diagram (lower left) shows the Pacific Ocean plate colliding with the North American continental plate, forming the Cascade Mountain chain. At this convergent zone, a trench is produced as the denser Pacific Ocean plate subducts under the overriding less dense North American continental plate. This area is known as a subduction zone. Shown at the Mid-Atlantic Ridge are hot convection currents, represented by the arrows, breaking through the lithosphere. Here and along other ocean ridges new lava emerges, quickly solidifies becoming part of the ocean floor. At these divergent plate boundaries the youngest ocean floor is found.

The Mantle – Geologist have subdivided the mantle into different sections – the rigid mantle, the asthenosphere, and the stiffer mantle. As already mentioned, the rigid mantle is the lower part of the plates. Under the rigid mantle lies the asthenosphere. The asthenosphere is the soft plastic-like section of the mantle that the plates move over and/or through. Major convection currents are found here, as shown by the arrows in the diagram. Hot rising convection currents are associated with ocean ridges, while cool sinking convection currents are associated with subduction zones. The mantle is the largest layer of the interior of the Earth in mass and volume. As a whole, the mantle is a solid in which both the *P* and *S* seismic waves travel through.

The Cores – The outer core is a liquid, having a composition of mostly iron and nickel. This liquid core prevents the seismic *S*-wave from traveling through. The inner core, being under so much pressure, remains a solid with an iron-nickel composition.

Density – Along the right side is the density section giving the density range for each layer. As the depth increases, so does the density.

The Graphs:

Depth axis – Located at the bottom of this page, the *x*-axis is the Depth scale (in km) with 0 being at the surface. The divisions of each Earth layer are shown by dash lines running down to the Depth axis. Use these lines and this axis to arrive at the distance from the surface of the crust to the other layers. For example, the outer core starts around 2,900 km and ends around 5,200 km, where the inner core starts.

Pressure graph – As the depth increases so does the pressure. For this graph, pressure is measured in millions of atmospheres. The dark graph line represents the pressure as the depth increases. To find the pressure at a specific layer, locate the dash line for that layer and follow it down until it intersects the pressure graph line. Read over to the Pressure axis for the answer. For example, what is the pressure at the start of the outer core? Following the dash line down from this position, it intersects the pressure graph line at 1.5 millions of atmospheres. To find the pressure at a certain depth, use the Depth (km) axis located at the bottom of the page. At the proper depth, move upward until it intersects the graph pressure line, then read over to the Pressure axis for the answer. For example, the expected pressure at 5000 km would be very close to 3 million atmospheres.

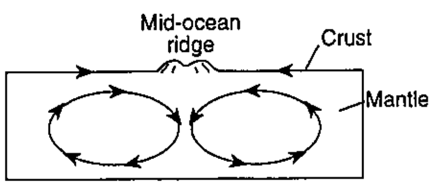
Temperature graph – As the depth increases, so does the temperature. The graph line, labeled Interior Temperature, starts near 0°C at the crust and increases to 6700°C at the Earth's center. Use the same procedure with this graph as we went over with the pressure chart. For example, what would the temperature be at the boundary between the stiffer mantle and the outer core? Locate this position and follow the given dash line downward until it hits the temperature graph line. At this intersection point, read over to the Temperature axis. The correct answer is 5000°C. The inferred Melting Point line is also plotted on this graph shown as a dash line. Within the mantle, the Melting Point line is higher than the Interior Temperature line. For this given condition, the mantle would be a solid. What about the outer core? Since the Interior Temperature line is higher than the melting point line, the outer core has experienced melting, becoming a liquid. In the inner core, the hottest temperature is found. However, due to the tremendous pressure, the inner core cannot melt and remains a solid.

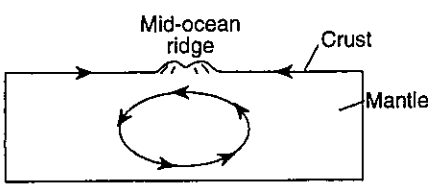
Additional Information:

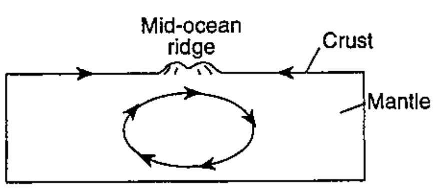
- The composition of most meteorites is iron and nickel. Scientists feel that the Earth's inner core would have a similar composition as meteorites.
- MOHO is named after its discoverer, Andrija Mohorovicic.
- We have very little direct evidence about the Earth's interior.
- The speed of seismic waves increase as they enter denser material.
- Astronauts left a working seismograph on the moon. From minor moonquakes (from space impacts), it has been revealed that the moon is completely solid throughout.

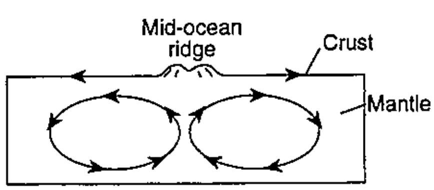
1. Earth's outer core is best inferred to be
   (1) liquid, with an average density of approximately 4 g/cm^3
   (2) liquid, with an average density of approximately 11 g/cm^3
   (3) solid, with an average density of approximately 4 g/cm^3
   (4) solid, with an average density of approximately 11 g/cm^3 1 _______

2. Which cross-sectional diagram of a portion of the crust and mantle best shows the pattern of mantle convection currents that are believed to cause the formation of a mid-ocean ridge?

(1) 

(2) 

(3) 

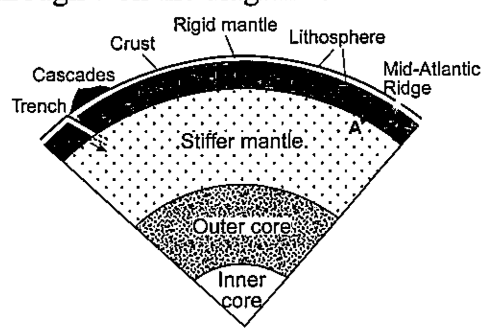
(4) 

2 _______

3. At which depth below Earth's surface is the density most likely 10.5 grams per cubic centimeter?
   (1) 1,500 km (3) 3,500 km
   (2) 2,000 km (4) 6,000 km 3 _______

4. What is the approximate temperature at the mantle-outer core boundary?
   (1) 1,500°C (3) 5,000°C
   (2) 4,500°C (4) 7,000°C 4 _______

Base your answers to questions 5 through 7 on the diagram below.



(Not drawn to scale)

5. The arrows shown in the asthenosphere represent the inferred slow circulation of the plastic mantle by a process called
   (1) insolation (3) conduction
   (2) convection (4) radiation 5 _______

6. The temperature of rock at location *A* is approximately
   (1) 600°C (3) 2,600°C
   (2) 1,000°C (4) 3,000°C 6 _______

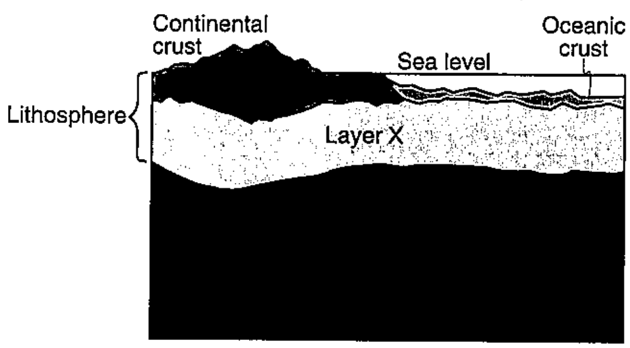
7. Which part of Earth is composed of both the crust and the rigid mantle?

____

8. Compared to Earth's crust, Earth's core is believed to be
   (1) less dense, cooler, and composed of more iron
   (2) less dense, hotter, and composed of less iron
   (3) more dense, hotter, and composed of more iron
   (4) more dense, cooler, and composed of less iron   8 ______

9. What is the density of the continental crust?
   (1) 3.0 g/cm³   (3) 2.7 g/cm³
   (2) 2.5 g/cm³   (4) 6.2 g/cm³   9 ______

10. The accompanying cross section shows a portion of Earth's interior. Layer *X* is part of Earth's interior. Identify the part of Earth's lithosphere represented by layer *X*.



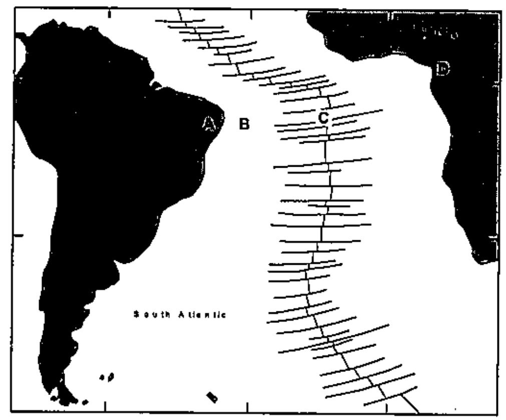
(Not drawn to scale)

Layer *X* = ______________________

11. Which part of the given cross-section would the largest convection currents be located in?

____

12. The diagram shows South America, the ocean between them, and the ocean ridge and transform faults.
Locations *A* and *D* are on the continents.
Locations *B* and *C* are on the ocean floor.



The hottest crustal temperature measurements would most likely be found at location
   (1) *A*   (3) *C*
   (2) *B*   (4) *D*   12 ______

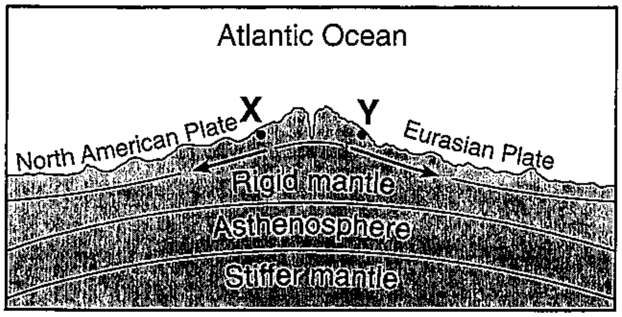
13. What is the pressure at the center of the Earth?
   (1) 3 millions of atmospheres
   (2) 3.2 millions of atmospheres
   (3) 3.5 millions of atmospheres
   (4) 5200 millions of atmospheres
   13 ______

14. What is the depth to the boundary of the outer core and the inner core?
   (1) 5200 km   (3) 2900 km
   (2) 6300 km   (4) 5000 km   14 ______

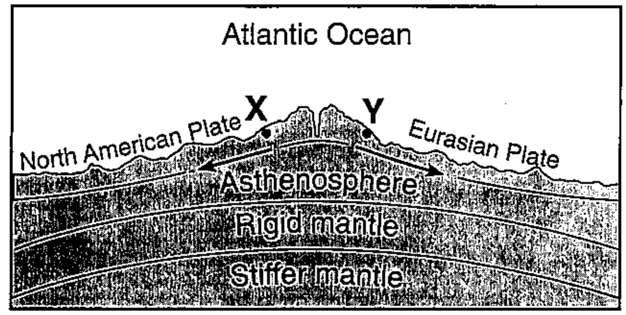
15. State the density of the oceanic plate.

______________________ g/cm³.

16. Which cross section best represents the relative locations of Earth's asthenosphere, rigid mantle, and stiffer mantle? (The cross sections are not drawn to scale.)



(1)



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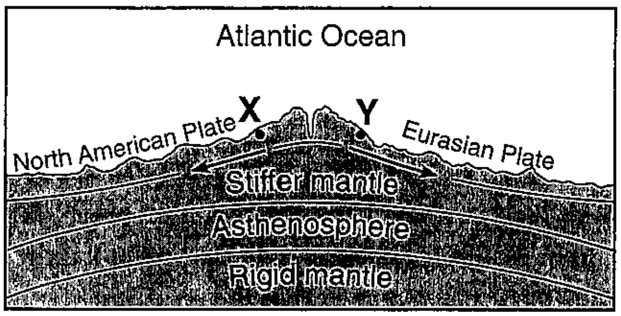

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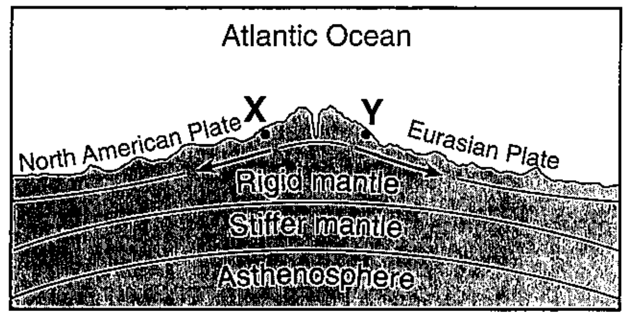
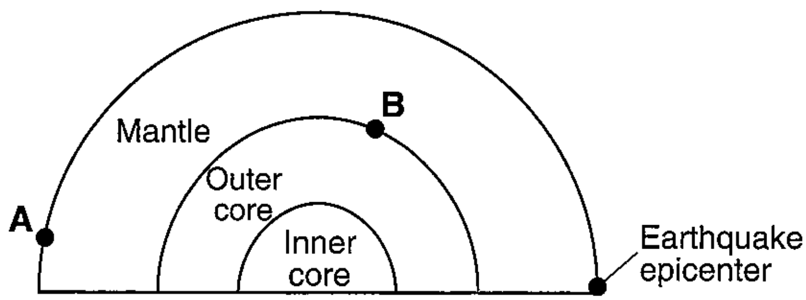


(4)

16 ______

Base your answers to questions 17*a* and *b* on the accompanying cross section, which shows a portion of Earth's interior layers and the location of an earthquake epicenter. Letter *A* represents a seismic station on Earth's surface. Letter *B* represents a location in Earth's interior.



(Not drawn to scale)

17. *a*) Explain why seismic station *A* receives *P*-waves but not *S*-waves from this earthquake.

____

____

b) What is the approximate temperature at location *B*? ______________________