SESSION EIGHT: COMPARATIVE PLANETOLOGY—THE EARTH

GEOLOGIC TIME AND THE EVOLUTION OF LIFE

Geologic Time Scale

Era	System & Period	Series & Epoch	Some Distinctive Features	Years Before Present
CENOZOIC	Quaternary	Recent	Modern man.	11,000
		Pleistocene	Early man; northern glaciation.	1/2 to 2 million
	Tertiary	Pliocene	Large carnivores.	13 + 1 million
		Miocene	First abundant grazing mammals.	25 + 1 million
		Oligocene	Large running mammals.	36 + 2 million
		Eocene	Many modern types of mammals.	58 + 2 million
		Paleocene	First placental mammals.	63 + 2 million
MESOZOIC	Cretaceous		First flowering plants; climax of dinosaurs and ammonites, followed by Cretaceous-Tertiary extinction.	135 + 5 million
	Jurassic		First birds, first mammals dinosaurs and ammonites abundant.	181 + 5 million
	Triassic		First dinosaurs. Abundant cycads and conifers.	230 + 10 million
PALEOZOIC	Permian		Extinction of most kinds of marine animals, including trilobites. Southern glaciation.	280 + 10 million
	Carboniferous	Pennsylvanian	Great coal forests, conifers. First reptiles.	310 + 10 million
		Mississippian	Sharks and amphibians abundant. Large and numerous scale trees and seed ferns.	345 + 10 million
	Devonian		First amphibians; ammonites; fishes abundant.	405 + 10 million
	Silurian		First terrestrial plants and animals.	425 + 10 million
	Ordovician		First fishes; invertebrates dominant.	500 + 10 million
	Cambrian		First abundant record of marine life; trilobites dominant.	600 + 50 million
	Precambrian		Fossils extremely rare, consisting of primitive aquatic plants. Evidence of glaciation. Oldest dated algae, over 2,600 million years; oldest dated meteorites 4,500 million years.	

NOTES

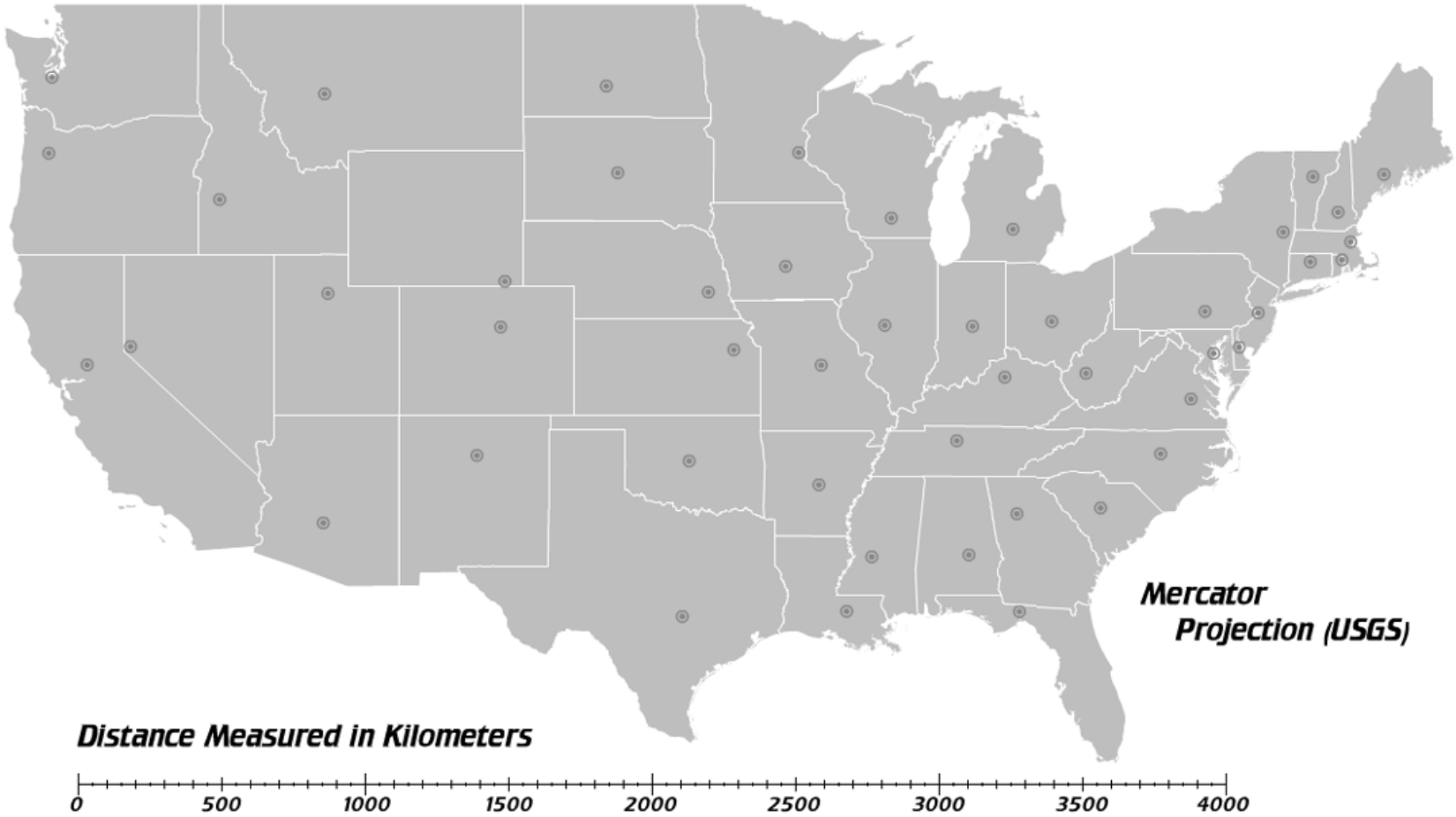
Name_____ Date_____ Moravian University

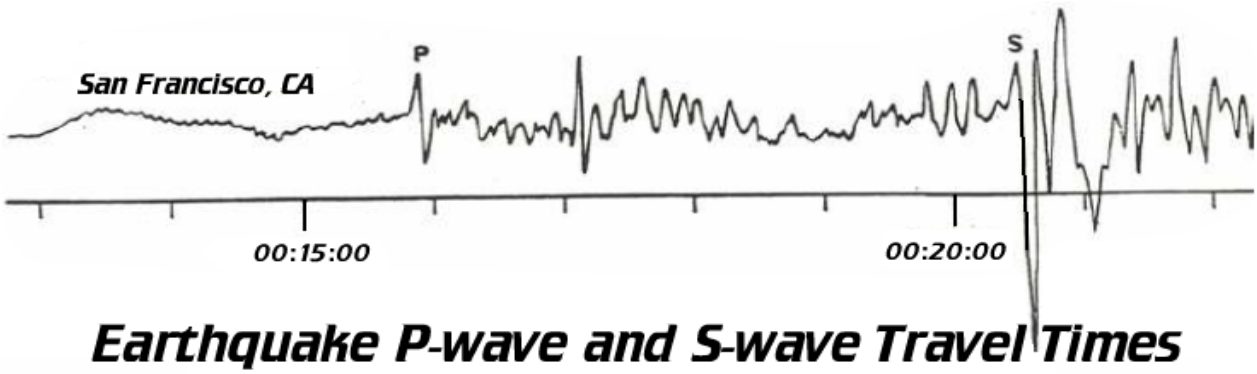
Find the Epicenter of the Earthquake

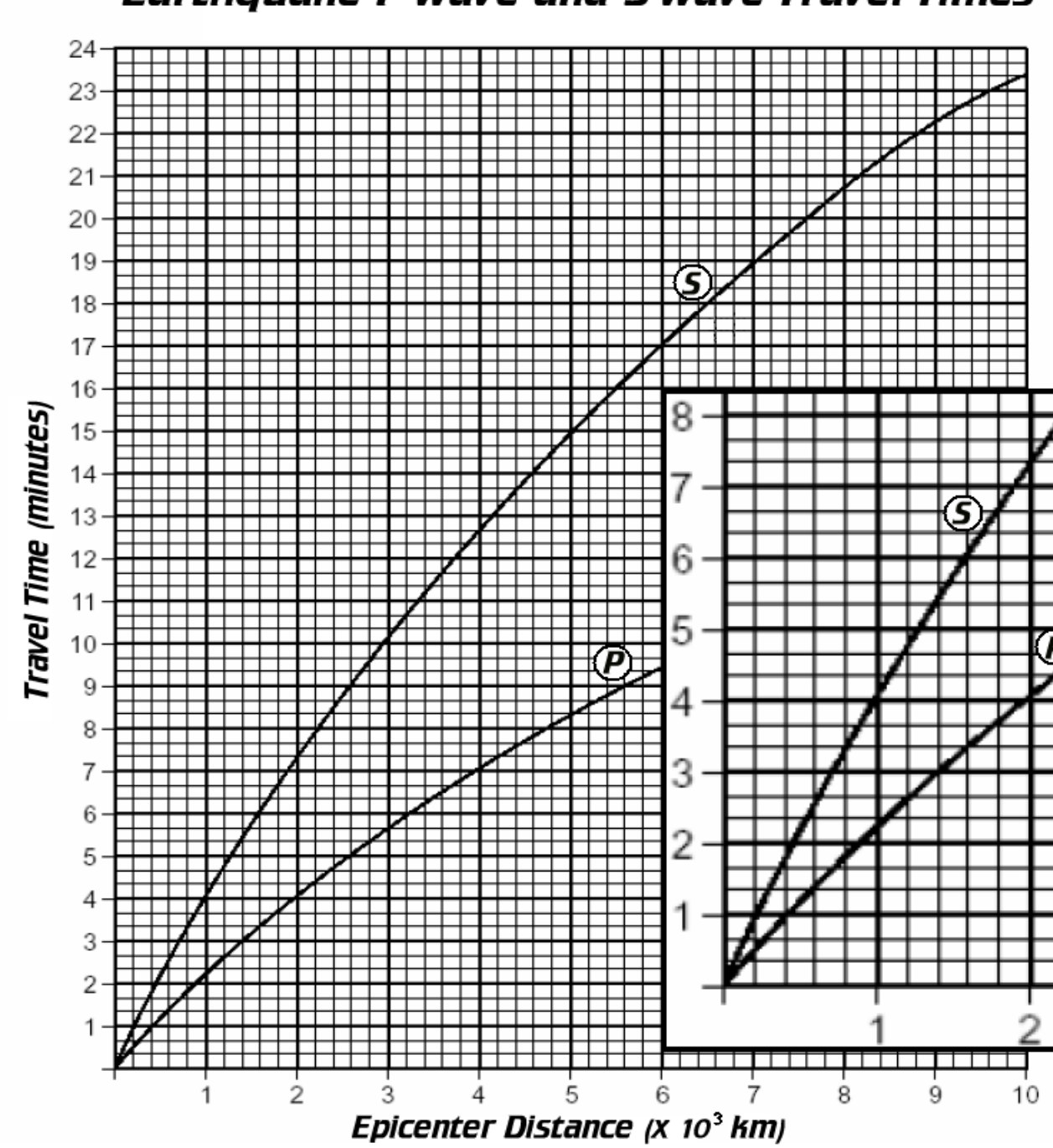
(5 points)

Time Delay P-wave/S-wave Reception EC=Epicenter: location on the Earth's surface over which the quake took place

1. Harrisburg, PA to EC: **P/S** = 4m 37s
2. Austin, TX to EC: **P/S** = 3m 05s
3. Sacramento, CA to EC: **P/S** = 2m 07s
4. Madison, WI to EC: **P/S** = 3m 08s
5. Olympia, WA to EC: **P/S** = 2m 02s
6. Tallahassee, FL to EC: **P/S** = 4m 09s
7. Columbus, OH to EC: **P/S** = 3m 57s
8. Santa Fe, NM to EC: **P/S** = 1m 58s
9. Bismarck, ND to EC: **P/S** = 1m 42s




San Francisco, CA
P
S
00:15:00
00:20:00


Earthquake P-wave and S-wave Travel Times
Travel Time (minutes)
Epicenter Distance (x 10³ km)
S
P
S
P

Name _____ Date _____ Moravian University

Name _____ Name _____

PLATE TECTONICS EXERCISE

(10 Points)

Instructions: The Earth is composed of a series of moving plates, floating on a denser, but plastic upper layer of the mantle called the asthenosphere. All of the major land and seafloor formations owe their characteristics to this global operation called plate tectonics. Based upon the maps which have been given to you, identify the processes occurring at the locations specified, or why the region looks the way it does.

1. The continental shelf of North or South America (eastern sides of the continents):

2. Mid-Atlantic Ridge:

3. Peru-Chile Trench:

4. The Andes Mountains:

5. The Rocky Mountains:

6. Mariana Trench in the Pacific:

7. Volcanoes in the Caribbean Sea:

8. The Alps of Europe:

9. The Himalayan Mountains:

10. The Islands of Hawaii:

11. The Anchorage, Alaska Earthquake of 1964 which measured 9.7 on the Richter Scale:

12. The type of mountains which compose the Aleutian Islands of Alaska:

13. Seismic (Earthquake) activity in Yellowstone National Park, or for that matter, around Flagstaff, Arizona (near the Grand Canyon):

14. Baja California:

15. The East African Rift Zone:

EARTH FORMATION AND STRUCTURE

A. Major forces that shaped the solar system. Stars and planets form in clusters, not by themselves. Events that generate star formation.
   1. **Supernovas:** triggers massive shock fronts that expand for tens of thousands of years and have been shown by the Hubble Space Telescope to create new stars.
   2. **OB Associations:** Young, hot cluster stars emit high energy radiation which creates collects matter and creates shock fronts which lead to the formation of new clusters. The Orion nebula is the best example.
   3. **Interactions between galaxies:** Creates turbulence which forms shock fronts and create new star generation in the form of clusters.

B. The early solar system was a rough and tumble place.
   1. **Matter was differentiated** into refractory materials near to the sun and volatiles in the outer solar system. Heat from the formation of the sun and strong magnetic fields probably played a significant role in causing the inner solar system to be purged of volatiles which were then driven outward to form the major planets.
   2. **Grains**, very small particles, were the first manner in which matter collected. These were melted into spherical chondrules in huge solar outbursts as the sun was stabilizing it thermonuclear output. Chondritic meteorites are the best example of how early solar system materials gathered.
   3. **Planetesimals** were the next step in size as grains physically bumped into one another to create larger objects. These objects continued to grow through collisions with one another.
   4. **Protoplanets** were the next stage in the development of the Earth and the rest of the solar system. These objects had a strong enough gravitational pull to attract other objects from a distance greater than their own size.
   5. **Planets:** Protoplanets collide in massive impacts rapidly building up the planets that we have in our present. In the case of the terrestrials, Mercury through Mars, these objects were probably molten throughout in their very early histories.
   6. **Formation of the moon:** A Mars-sized object struck or sideswiped the Earth sending crustal and mantle material into orbit around Earth. This debris rapidly coalesced into the moon.

C. Differentiation of Earth's internal structure:
   1. **Period of major bombardment** ends about 3.85 billion years ago.
   2. **Earth cools from exterior** to interior.
   3. **Heavier crystals migrate towards the interior** and melt leaving less dense rocky material nearer to the surface or migrating to the surface.
   4. **Densest materials, mainly iron and some nickel form the core**

CAN YOU ANSWER THE FOLLOWING QUESTIONS/STATEMENTS ABOUT THE EARTH?

ATMOSPHERE OF EARTH

1. The three basic chemical components of the Earth's atmosphere are _____, _____, and _____.

2. Plant biology is responsible for the artificially high concentration of _____ in the Earth's atmosphere which equals approximately _____ percent.

3. The bulk of the Earth's atmosphere is _____. It probably resulted from the eruptive processes of volcanoes spewing NO (nitrogen oxide), NO_2 (nitrogen dioxide), and HNO_3 (nitric acid) into the air. Its abundance in the atmosphere is approximately _____ percent.

4. Volcanic eruptions are also thought to have supplied most of the water vapor which condensed and fell as rain to form the Earth's oceans. Other sources of water may have come from _____ which hit Earth during its early history. Carbon dioxide (CO_2) and Carbon monoxide (CO) emitted during volcanic eruptions are also indirectly responsible for producing the carbonate rocks which contain _____ within their atomic structures, such as limestone ($CaCO_3$).

5. The decay of radioactive Potassium 40 into _____ has made it possible for this gas to be brought to the surface of the Earth by _____ eruptions to produce the _____ percent of this gas which is found in the atmosphere.

6. The four basic layers of the Earth's atmosphere, stated in their correct order from the lowest to the highest levels, are the _____, the _____, the _____, and the _____.

7. These four atmospheric layers are defined by their decrease or increase in _____ with increasing altitude.

8. The temperature in the lowest segment of Earth's ocean of air becomes _____ with increasing elevation because there is less pressure from overlying atmosphere, and the air expands.

9. Above the first layer of the Earth's atmosphere, called the _____, the temperature begins to _____, yet the atmospheric pressure is still decreasing.

10. This second layer of atmosphere mentioned in the last sentence is called the _____. The reason for the change in temperature results from the absorption of _____ radiation by ozone molecules (O_3). This region can also be called the _____ layer. Chlorofluorocarbons, which in the past were used as the propellants in aerosol cans, helped to deplete this protective region by blocking the formation of the O_3 molecule after ultraviolet energy had broken the ozone apart.

11. The _____ lies above the second layer. The atmosphere in this region simply cools as the air _____ due to decreasing air pressure with altitude. There is no effective absorption of energy in this layer.

12. The top layer of Earth's atmosphere, the _____, increases in temperature with increasing altitude because hard _____ energy is absorbed at this level.

13. In essence, Earth's four atmospheric layers are defined by their decrease or increase in _____.

14. On Mars, daily temperatures vary to a much GREATER/LESSER (circle one) extent than on the Earth because the Martian atmosphere is extremely _____; and therefore, it cannot retain much heat during the night.

CIRCULATION OF THE ATMOSPHERE

15. The region of the Earth which receives the most energy from the sun is the _____, while the areas of Earth which receive the smallest amounts of solar energy are the _____.

16. The most basic reason for the major wind patterns on the Earth, or for that matter any planet, is the _____
_____

17. One might expect the major wind zones of Earth to operate in a strictly north to south configuration; however, this is not the case. The Earth's _____ deflects the circulating air, causing the major wind systems to blow from either the _____ or the _____ directions.

18. The deflection mentioned in the previous problem is called the _____ effect or "force," and on Earth, it produces basically ONE/TWO/THREE (circle one) major climatic zonal regions.

19. An air mass in the northern hemisphere, moving from a lower to a higher latitude position, will be deflected to the RIGHT/LEFT (circle one).

20. An artillery shell fired towards the equator from a southern hemispheric position will be deflected towards the LEFT/RIGHT (circle one) of its assumed strike position unless there is a directional compensation.

21. Based upon the "Orbital and Physical Characteristics of the Planets" sheet on the first page of Session Seven, why should Venus' global wind circulation reflect a single cell which simply transports warmer air from the equator to the poles and cooler air back from the poles to the equator?

    _____

    _____

22. Conditions on Jupiter favor a much more complicated multicellular circulation pattern because of Jupiter's _____. This is the reason why the planet presents a striped or zebra-like pattern to telescopic observers. Similar situations are evident for the other Jovian worlds, but their appearance is less distinct because of hazier atmospheres.

THREE MAJOR ROCK GROUPS

23. The three most common elements contained within the Earth are _____, _____, and _____.

24. The three major rock groups are **i** _____ , **s** _____, and **m** _____ rocks.

25. _____ rocks form from the cooling of any molten material, either at depth, near the surface, or on the surface. Granites and basalts are two representatives of this major classification of rock.

26. _____ rocks form from the **dep** _____ of other rocks which have been eroded by wind, water, and weathering, or from the chemical **pre** _____ of minerals in saturated solutions of water. An example of the former is sandstone while a good example of the latter is limestone.

27. _____ rocks form when sedimentary or igneous rocks undergo a period of **h** _____ or **c** _____ which changes the structural arrangement of that rock's molecules. Limestone can be changed into marble, shale to slate, and graphite into diamonds when these materials are subjected to the appropriate conditions.

28. Of the three major rock types, _____ rocks would not be expected to be found on the airless and waterless moon.

INTERIOR OF EARTH

29. The four basic layers of the Earth from surface to interior are called the _____, _____, _____, and _____.

30. The various layers of Earth are based upon differences in **c**_____, **d** _____, **t** _____, and **p** _____.

31. The various layers of Earth were created as the result of a molten body which cooled. As rock crystallized the denser minerals _____, while the less dense materials _____.

32. The process mentioned in the previous problem is called chemical, crustal, or planetary _____.

33. The two most familiar types of seismic (earthquake) waves are known as the _____ and the _____ waves. A synonym for each of the above words would be _____ waves and _____ waves.

34. _____ waves travel faster than _____ waves. Therefore, the time delay between the detection of these two types of seismic activity tells the seismologists the _____ to the epicenter of the earthquake from the seismic station. The epicenter represents the location on the _____ of the Earth over which the earthquake occurred. The true location of the earthquake beneath the epicenter is called the _____.

35. Seismologists theorize that the Earth's outer core is liquid because _____ do not penetrate liquids. Therefore, when an earthquake occurs, certain seismic stations record both the _____ and the _____, while other stations record only the _____. The inescapable conclusion is that the Earth's outer core must be liquid. The ratio of these zones to the Earth's surface area allows geologists to calculate the _____ of Earth's core.

36. A material may be kept in its solid state, when its temperature is much higher than its melting point, if there is a sufficiently high amount of _____ to maintain the crystalline structure of the rock.

37. The Earth's inner core is SOLID/LIQUID (circle one). Increasing temperatures are no match for the increase in _____ which dominates the 11,000 °F (6000 K) temperatures of this region and changes the phase (solid, liquid, gas) of the material from a _____ to a _____.

THE DYNAMIC EARTH—PLATE TECTONICS

38. Give several reasons why continental drift is currently accepted as the overall theory of Earth's evolution. Consider below (a) continental shapes, (b) fossil records, and (c) magnetic pole reversals
    a. _____
    _____
    b. _____
    _____
    c. _____
    _____

39. The Earth's crust is broken into a number of _____, which like ice cubes, jostle for position over a denser but plastic asthenosphere which is slowly moving. In the case of ocean plates, the motion may be more gravity driven, the plates sliding from higher to lower seafloor elevations pulled over period of tens of million of years by the plate boundaries which are thicker, denser, and therefore, heavier.

40. The location of the denser asthenosphere is just below the _____ and above the _____. The asthenosphere, however, is considered a part of the uppermost _____.

41. The Earth is a dynamic planet with new crustal material being created in regions where material is upwelling. The best example of this phenomenon is along the _____. These regions of seafloor spreading are called _____ plate.

42. In locations where new crust is being regenerated, active _____ are found. State the name of a country which lies in such an active region of Earth's crust and is relatively close to North America. _____

43. Since the Earth has a finite surface area, any region where there is crustal material being formed, precludes that there must be a location or locations where surface material is being destroyed. Regions such as these are called _____ zones.

44. In such a region, one plate is sliding under another plate. The plates build up energy, then jerk past each other, creating _____. The increase in the pressure of the material in the plate that is being forced under the other plate causes an increase in the temperature of the material. This melts the rock of the plate and creates an area behind the boundary prone to _____. In front of the plate boundary a deep _____ results.

45. One region of the world which meets the conditions expressed in the last two problems is _____.

46. In California the North American plate is pressing southwestward against the Pacific plate. The Pacific plate is moving northwestward toward Alaska. Why does this spell trouble for the Los Angeles basin and the area around San Francisco?
    _____
    _____

47. The action of two plates crashing into each other results in the formation of _____. Two examples which support this contention are as follows:
    a. _____
    b. _____

48. The type of geological structure which formed the Hawaiian Islands is called a _____. The location of the heat source is found deep within the _____.

49. As the Pacific plate moves towards the northwest, it passes over a plume of _____ in the middle of the Pacific Ocean basin which for the past 30 million years has produced a series of volcanoes known today as the Hawaiian Islands. This is the type of volcanism that has occurred on Mars and Venus.

50. Hotspots can also occur under continents where they can build up pressure for hundreds of thousands of years and more. The best example of a hotspot under the North American plate can be found in _____ National Park.

51. The statement that the continents are really floating over the upper portion of the Earth's _____ is true. The continental crustal material is less _____ than the material which is below it, so it can only be floating over a denser asthenosphere which is pliable.

52. Based upon the last statement of a floating crust, the regions of the world where the crust is thickest are found under _____, while the areas where the crust is thinnest are found under _____.

53. If magma works its way towards the surface and domes up a region, the surface area becomes LARGER/SMALLER (circle one). Eventually, the upward pressure becomes so great that _____ occurs. This releases the pressure by creating more _____ area.

54. When the sides of a fracture zone move away from each other, the center collapses, creating a fault known as a _____. When continents start breaking apart, similar to what is happening in eastern Africa, _____ valleys are formed. These areas also have volcanism associated with them because they are positioned along a **d** _____ plate boundary. Eventually, these valleys will be flooded by _____ as the continent breaks apart.

55. The viscosity of a liquid is an indication of its resistance to flow. Lava with a high viscosity will flow _____, while lava with a low viscosity will flow _____.

MAGNETIC FIELDS

56. A _____ is a force generated by some condition or property of matter that goes beyond the boundary of the matter generating it. In turn, this matter will affect other _____ that happens to be positioned within the boundary of the force.

57. Two good examples of forces generated by a condition or property of matter would be a _____ field and a _____ field.

58. A magnetic field may be created if the spin axes of innumerable _____ are made to point in the same direction. This is **not** how the magnetic field of the Earth and most other planets are generated, but it does approximate the mechanism that allows Mercury, with a solid core, to maintain a magnetic field.

59. A _____ is a hot gas composed of positively charged ions and electrons.

60. A flow of electrons will produce an electric current as well as a _____. In fact particles in motion, whether positively or negatively charged, will create a magnetic field. In the outer core where Earth's magnetic field is generated, only the _____ are free to move from atom to atom.

61. A charged particle approaching a field line will have difficulty penetrating the field and will most likely yield to the field by beginning to _____ around it.

EARTH'S MAGNETIC FIELD

62. The Earth's magnetic field is produced by a directional flow of _____ within the outer liquid core. The Earth's _____, sculpted by the Coriolis effect, shapes this flow into a series of loops which amplify the magnetic field, allowing it to extend into space and affect charged particles in the neighborhood of the Earth. Earth's magnetic field is self-generated.

63. If the electrical currents in the Earth's interior were flowing in random directions, all of the individual fields generated would _____ each other.

64. A magnetic field affects the matter in the space which surrounds it. Thus, if an electron or an ion approaches the Earth's magnetic field, the charged particle will be made to _____.

65. Plasma is continuously streaming away from the sun, and this phenomenon is known as the _____. This plasma is composed mostly of _____, _____, and the nuclei of helium atoms.

66. Almost all of the plasma leaving the sun which reaches Earth is TRAPPED/DEFLECTED (circle one) by Earth's magnetic field.

67. As an electron approaches the magnetic field of Earth, it first encounters the _____ where it begins to feel the influence of Earth's field. In this region the solar magnetic field is STRONGER/WEAKER (circle one) than Earth's field.

68. At the point mentioned in the last statement, the velocity of the plasma is abruptly reduced, causing more plasma to "pile" up behind it. This creates a _____.

69. As the electron gets closer to the Earth, it may eventually reach a position where the solar and terrestrial magnetic fields are equal. This region is called the _____.

70. Once beyond this neutral region, the electron is under the influence of the magnetic field of _____.

71. If the particle is energetic enough and penetrates the field, it will now become trapped within the _____ of Earth. The particle, depending upon its charge, will begin to move toward one of two regions of intensified field strength above the Earth's surface. These regions are called the _____ belts.

72. The force of the solar wind pushing against the magnetosphere causes this teardrop shaped field to wiggle like _____. Ripples or waves at the boundary of the zone may engulf and trap solar wind plasma also bringing it into the magnetosphere.

73. Occasionally, energetic coronal mass ejections, CMEs, triggered by solar flares shower the Earth's magnetic environment with bursts of high energy plasma. These distort the magnetosphere, overloading the Van Allen belts, causing them to dump huge amounts of plasma directly into the upper atmosphere surrounding the north and south magnetic poles. These events produce the _____ and the _____. The electricity flows into the Earth’s upper atmosphere as a direct electrical current. It can light up the air within an average altitude of 60 to 200 miles above Earth’s surface.

74. The magnetosphere of Earth still allows very few charged particles to reach the Earth's atmosphere or its surface. This effectively blocks our planet from receiving most of the harmful effects of the _____.

    Note: An additional source of particles for the Van Allen radiation belts may be very high energy cosmic rays (electrons, protons, helium nuclei, etc.) from supernova events. Because of their high energies, they move unimpeded through the magnetosphere and shatter air molecules in the upper atmosphere. Some of the neutrons from these collisional

events head away from the Earth, but within the magnetosphere they can spontaneously decay into an electron and a proton, adding additional plasma to the magnetospheric environment. The average life of a free neutron is about 15 minutes.

75. Venus does not possess a magnetic field, even though it is assumed to have an iron core (density 5.4 gm/cm^3). What Venus lacks is either a _____ core or a rapid enough _____.

ANSWERS TO SESSION EIGHT QUESTIONS

ATMOSPHERE OF EARTH

1. nitrogen, oxygen, argon
2. oxygen, 21
3. nitrogen, 78
4. comets, carbon
5. argon, volcanic, one
6. troposphere, stratosphere, mesosphere, thermosphere
7. temperature
8. cooler
9. troposphere, rise
10. stratosphere, ultraviolet, ozone
11. mesosphere, expands
12. thermosphere or ionosphere, ultraviolet
13. temperature
14. GREATER, thin

ATMOSPHERIC CIRCULATION

15. equator or tropics, poles
16. exchange of heat from warmer regions of the Earth to colder regions of the planet.
17. rotation, west, east
18. Coriolis, THREE
19. RIGHT
20. LEFT
21. The rotation of Venus is so slow that the Coriolis effect is much weaker.
22. rapid rotation

THREE MAJOR ROCK GROUPS

23. oxygen, silicon, iron
24. igneous, sedimentary, metamorphic
25. igneous
26. sedimentary, deposition, precipitation
27. metamorphic, heating, compression
28. sedimentary

INTERIOR OF EARTH

29. crust, mantle, outer core, inner core
30. composition, temperature, pressure
31. sank towards the center of the planet, while less dense materials either remained in their positions or moved toward the surface.
32. differentiation
33. primary, secondary, primary (P-waves, push-pull, longitudinal, “phast”), secondary (S-waves, slower, transverse)
34. primary, secondary, distance, surface, focus

35. secondary waves, primary waves, secondary waves, primary waves, diameter (extent)
36. pressure
37. SOLID, pressure, liquid, solid

THE DYNAMIC EARTH—PLATE TECTONICS

38. a. The continents are in many respects like a jigsaw puzzle which can be fit together along boundaries where they were once joined.
    b. Fossils of extinct species of animals are found in locations separated by large bodies of water, indicating these continents were once joined.
    c. Magnetic properties of ocean basins reveal a zebra pattern of pole reversals indicating continental separation.
    d. Techniques in radio astronomy utilizing Very Long Baseline Interferometry have shown North America to be separating from Europe by about 1¼ inches (3 cm) per year.
39. plates
40. crust, mantle, mantle
41. Mid-Atlantic Ridge, divergent
42. volcanoes, Iceland
43. subduction
44. earthquakes, volcanism, trench
45. Japan or New Zealand or the Aleutian Islands or the Caribbean Islands or the west coast of South America or the Philippines, etc.
46. Los Angeles and San Francisco are near the boundaries of the North American plate and the Pacific plate. This region is prone to seismic activity as the Pacific plate yields to the pressures being exerted against it by the North American plate.
47. mountains
    a. Alps: Italy slamming into Europe
    b. Himalayas: India colliding with Asia
    c. Andes: Nazca plate subducting under the South American plate
    d. Rockies: N American plate pushing against the Pacific plate
48. volcano, mantle
49. magma
50. Yellowstone
51. mantle, dense
52. mountains, oceans
53. LARGER, faulting or fractures, surface
54. graben, rift, divergent, ocean water
55. slowly, rapidly

MAGNETIC FIELDS

56. field, matter
57. gravitational field, magnetic field
58. atoms
59. plasma
60. magnetic field, electrons
61. spiral

EARTH'S MAGNETIC FIELD

62. electricity (electrons), rotation
63. cancel
64. deflect around the Earth's magnetic field or change its direction of motion
65. solar wind, protons, electrons
66. DEFLECTED
67. bow shock, STRONGER
68. shock front
69. magnetopause
70. Earth
71. magnetosphere, Van Allen
72. Jell-O
73. aurora borealis or northern lights, aurora australis or southern lights
74. solar wind
75. liquid, rotation

August 24, 2021

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