Please do not write on these figures.

Figure 1

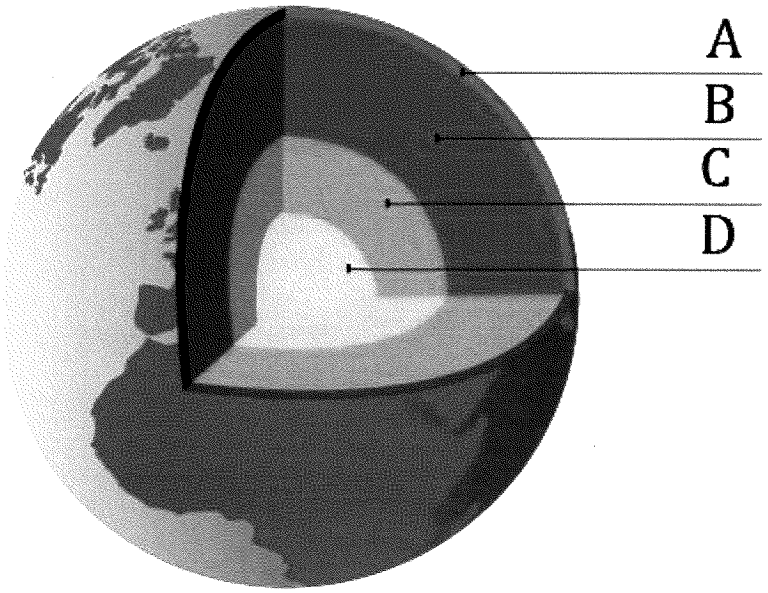


Figure 2

<-- West East -->

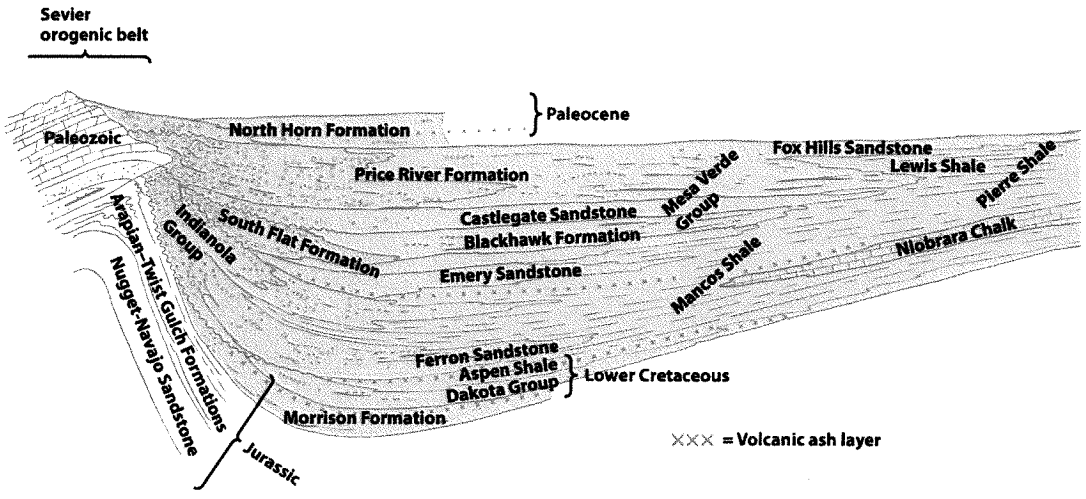
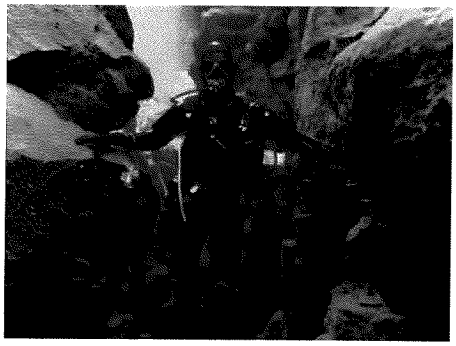


Figure 17-23
Earth System History, Third Edition

Please do not write on these figures.

Figure 3



Source:
https://www.kidsdiscover.com/quick-reads/silfra-crack-divers-can-touch-two-continents/

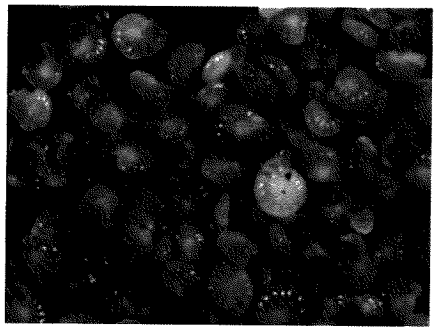
Figure 4

Source:
https://geology.com/world/map/map-of-iceland.gif

Figure 5

Source:
https://upload.wikimedia.org/wikipedia/commons/3/36/BlankAmericas.png

Figure 6



This image shows 0.3 mm foraminifera made up of a single cell surrounded by a limestone shell. (Credit: © Jan Pawlowski, UNIGE)

Figure 7

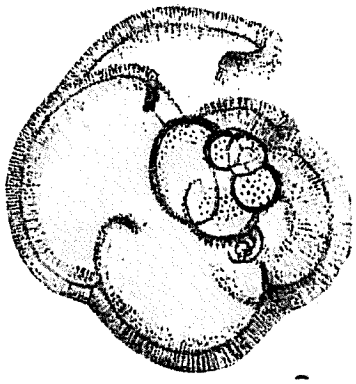


Image source: Cushman, J.A. 1914. A Monograph of the Foraminifera of the North Pacific Ocean. Part IV. Chilostomellidae, Globigerinidae, Nummulitidae. Bull. U.S. Nation. Mus 71: vi+46 pp.+19 pls.

Please do not write on these figures.

Figure 8

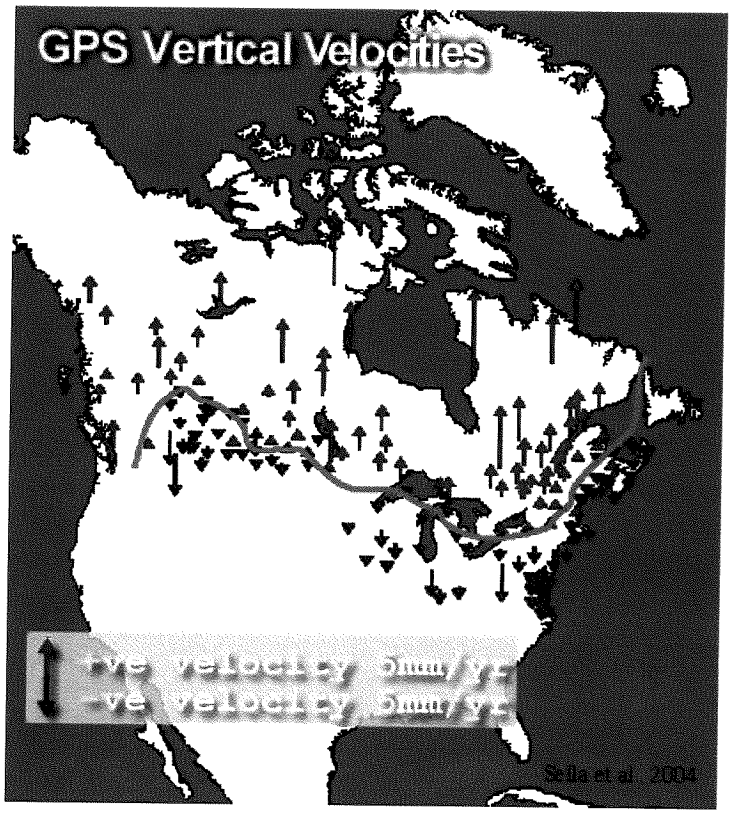
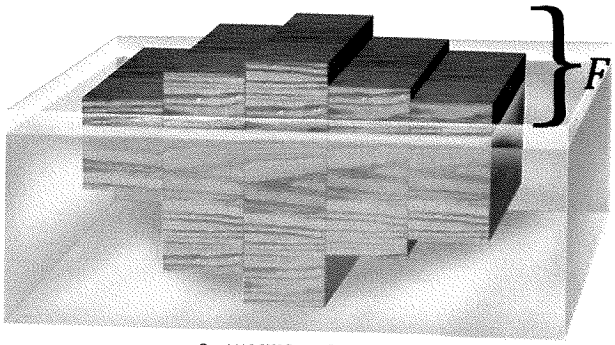
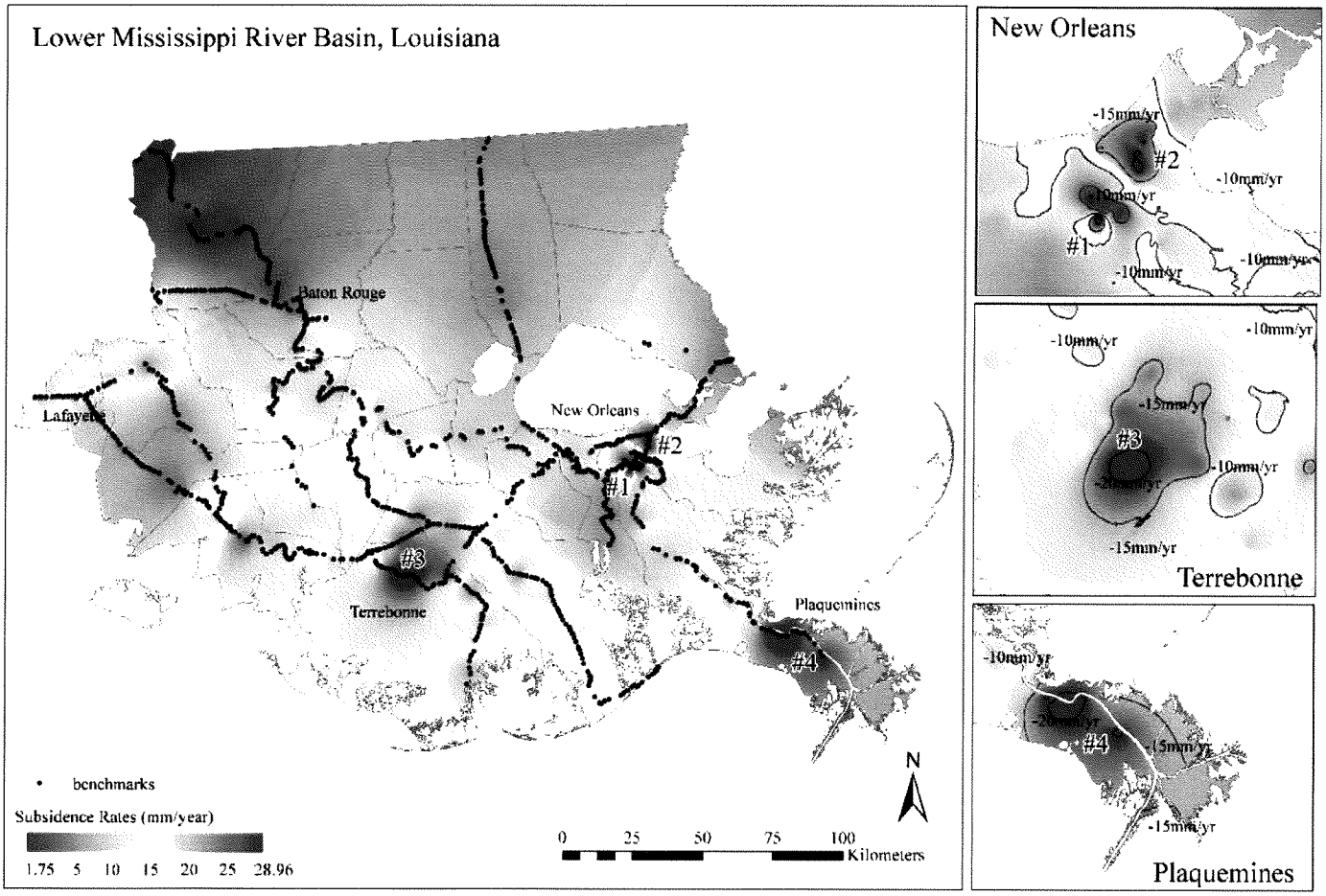


Figure 9



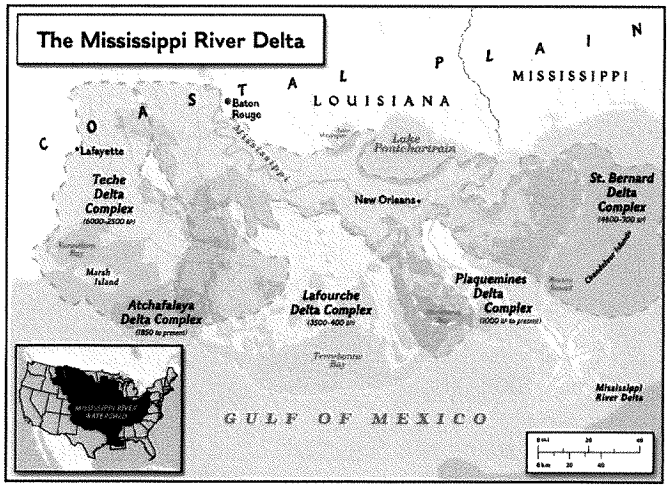
Please do not write on these figures.

Figure 10



Credit: Zou et al. 2015

Figure 11



Please do not write on these figures.

Figure 12

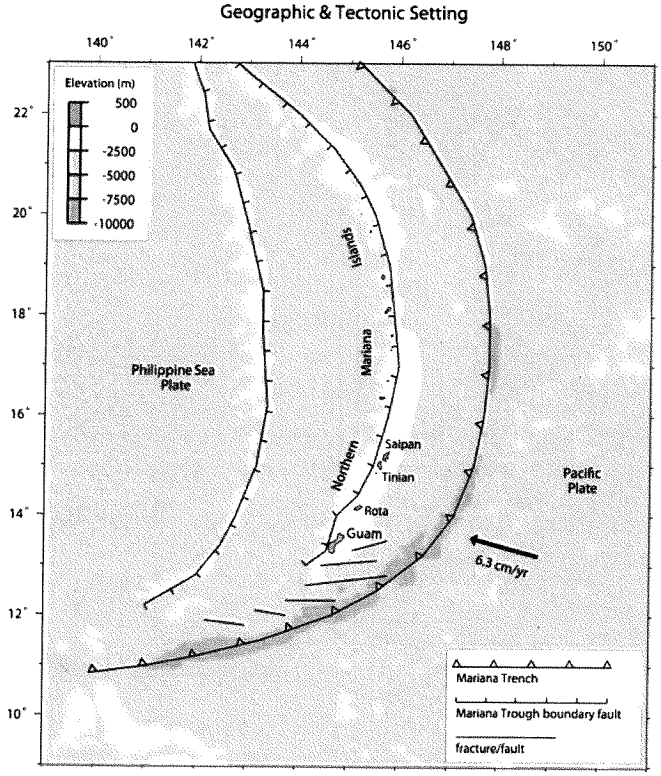


Figure 13

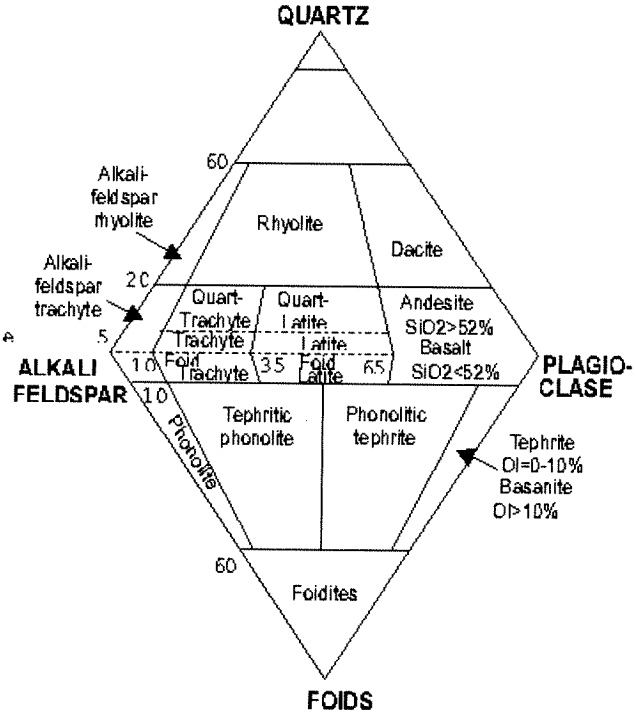
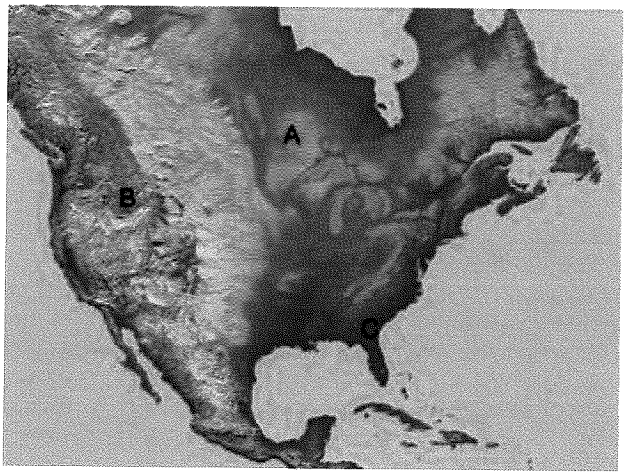


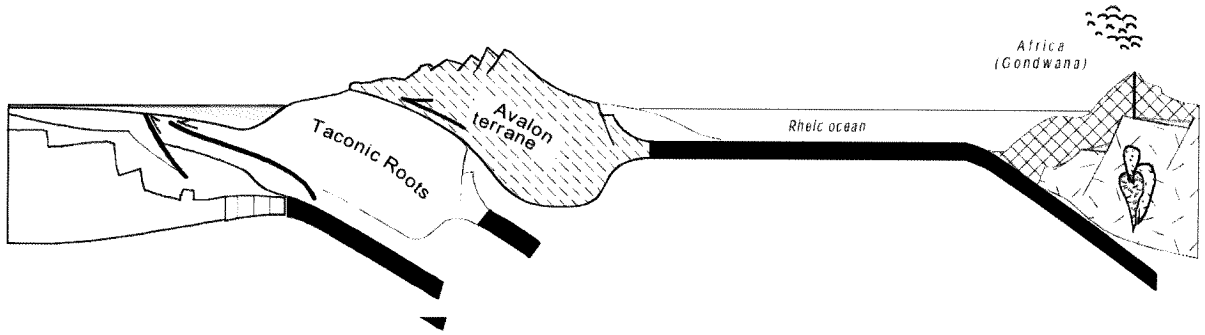
Figure 14



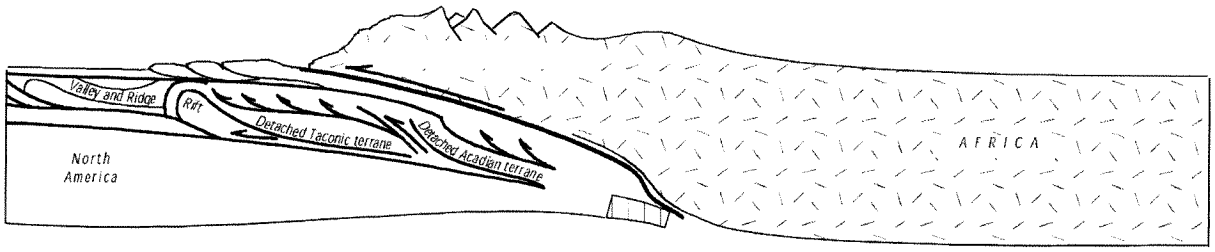
Please do not write on these figures.

Figure 15

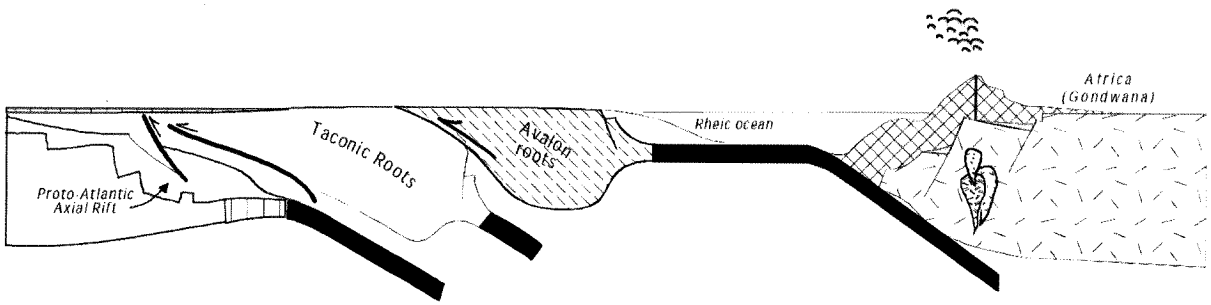
A.



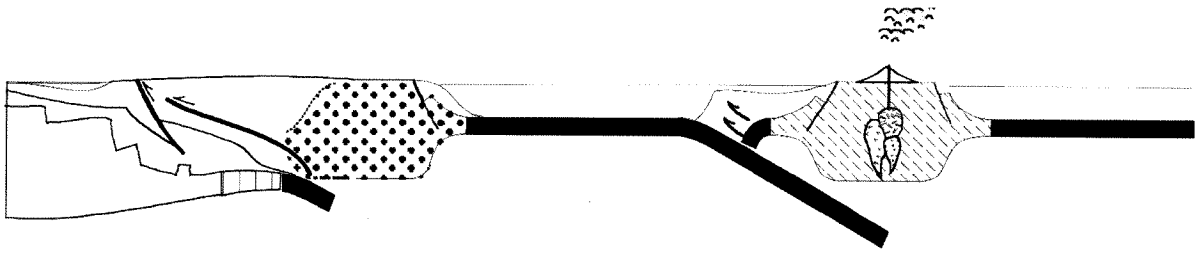
B.



C.

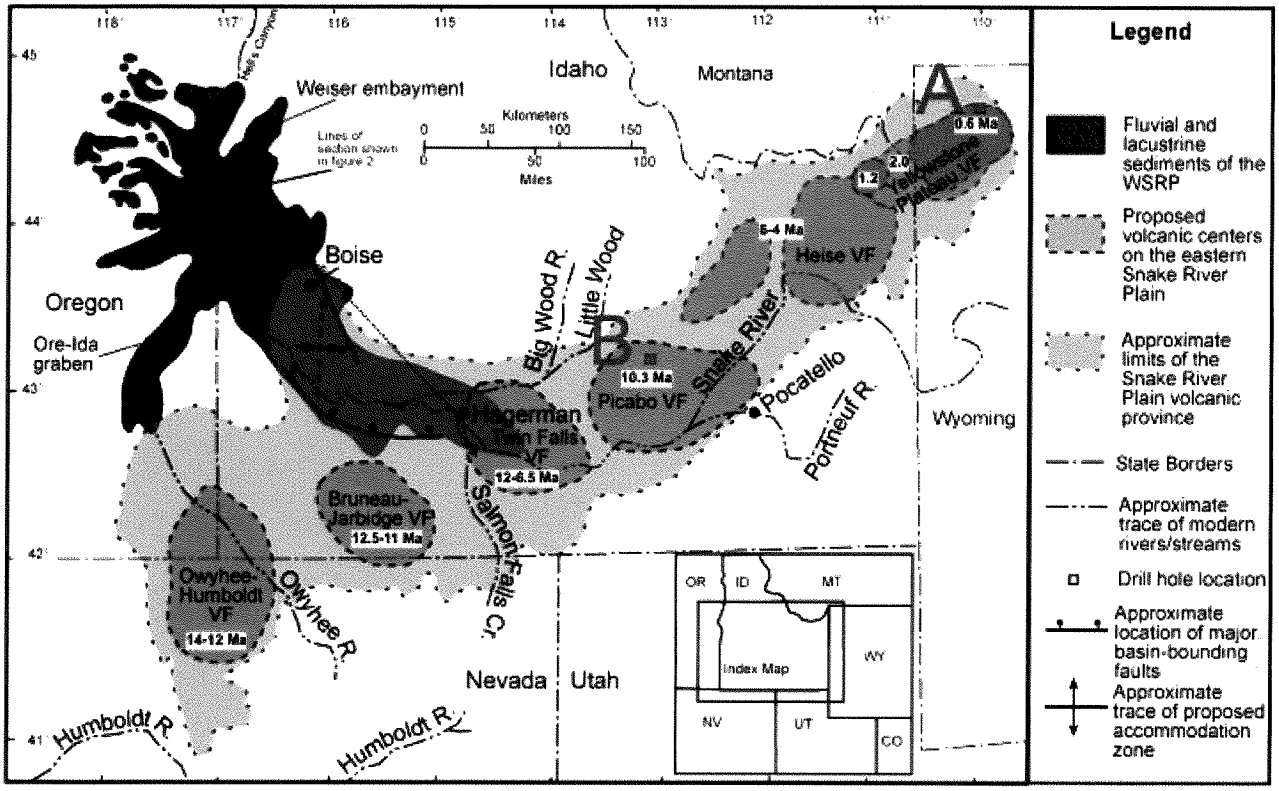


D.



Please do not write on these figures.

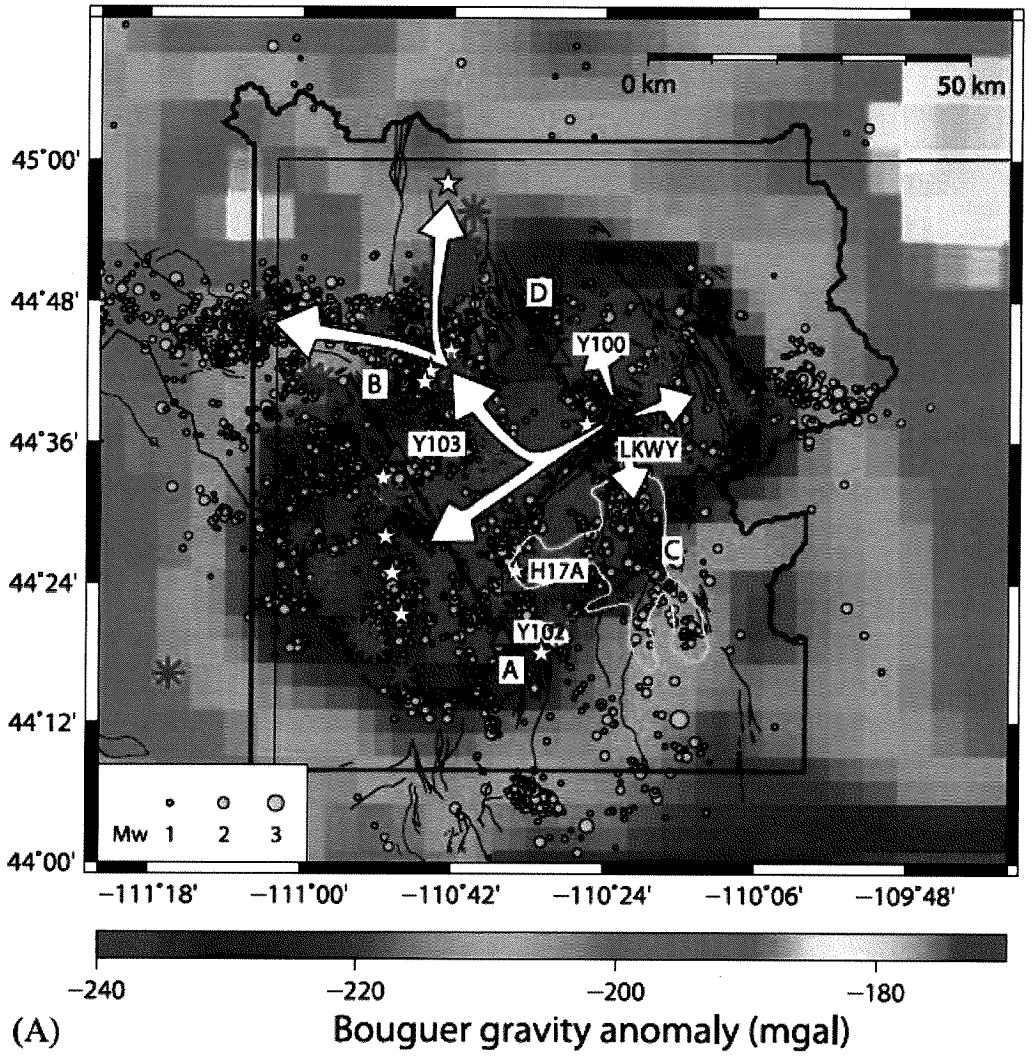
Figure 16



Credit: http://geology.isu.edu/Digital_Geology_Idaho/Module11/mod11.htm

Please do not write on these figures.

Figure 17



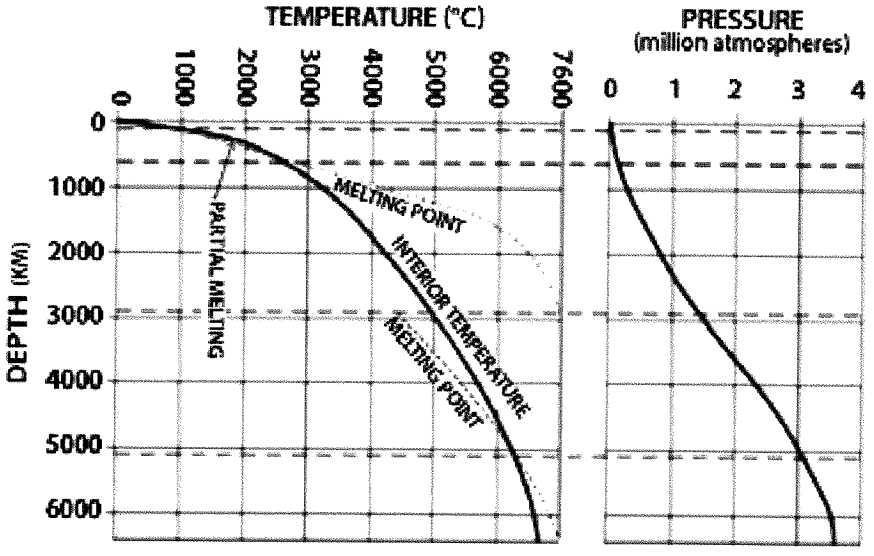
http://web.gps.caltech.edu/~jackson/Research.html,
http://web.gps.caltech.edu/~jackson/pdf/Chu_2009GL041656.pdf
https://sites.ualberta.ca/~unsworth/UA-classes/224/notes224/B/224B5-2006.pd

Please do not write on these figures.

Figure 18

Credit: http://www.iris.edu/hq/inclass/downloads/optional/759

Figure 19



Please do not write on these figures.

Figure 20

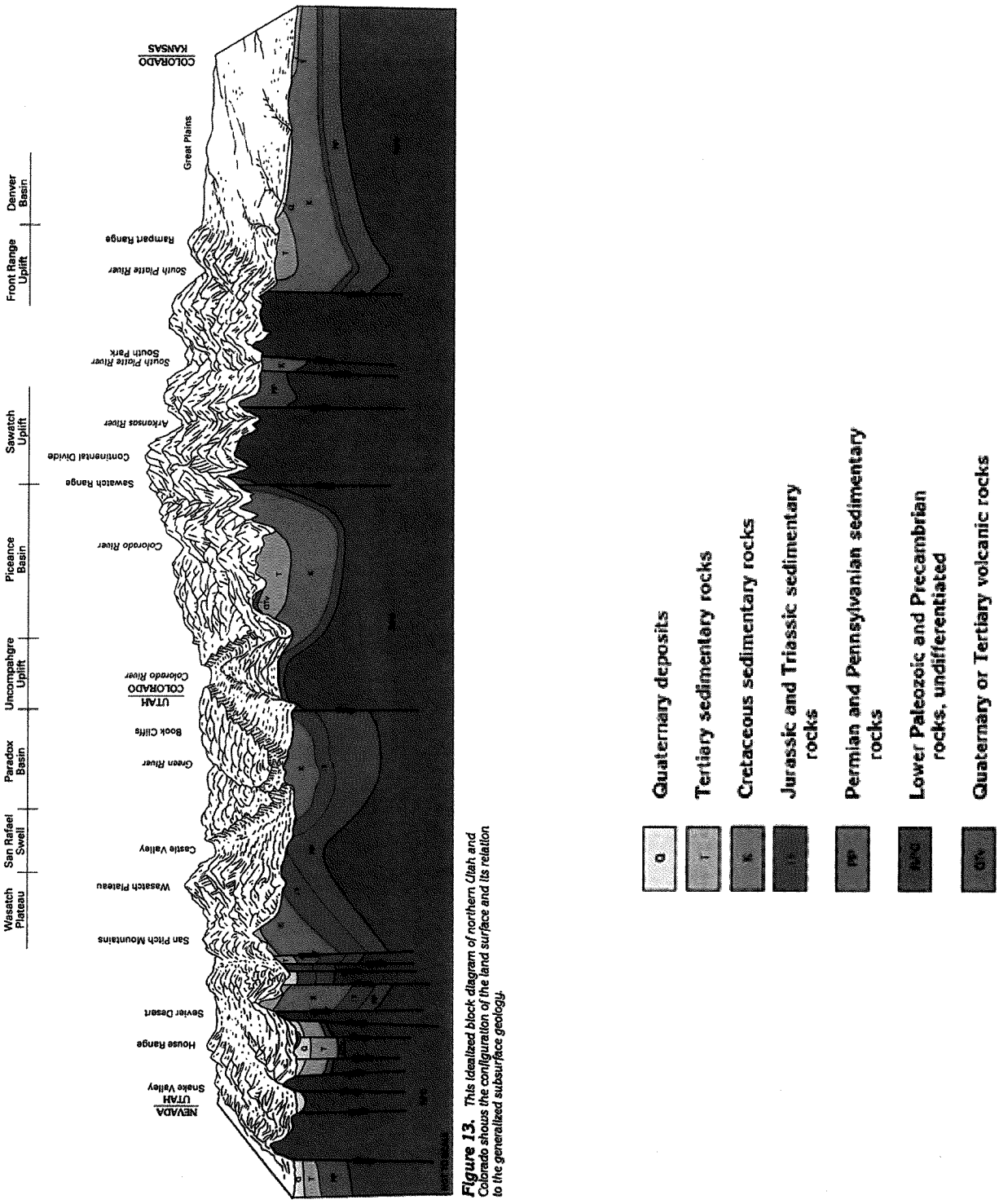


Figure 13. *This idealized block diagram of northern Utah and Colorado shows the configuration of the land surface and its relation to the generalized subsurface geology.*

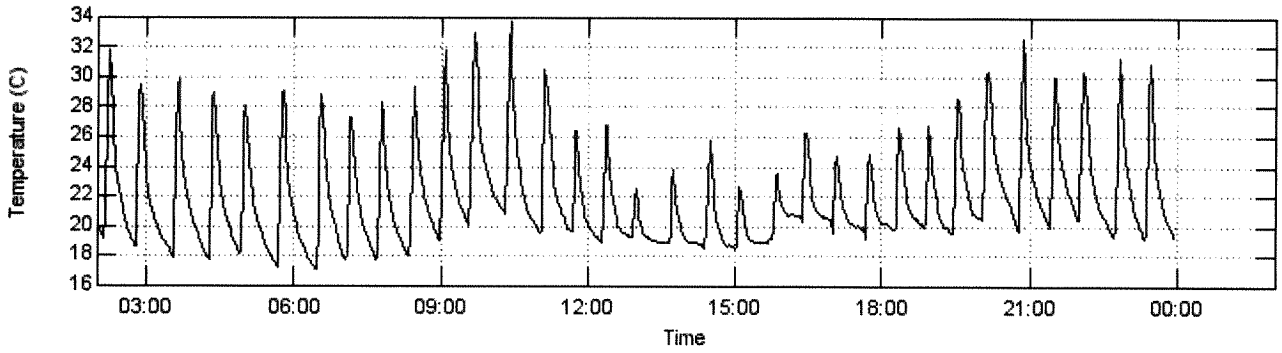
Please do not write on these figures.

Figure 21

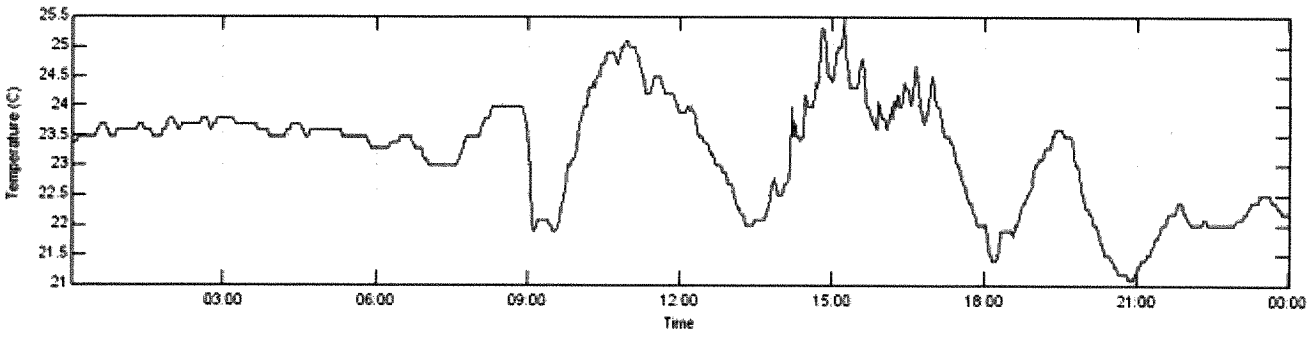
Mammoth Hot Springs, Yellowstone National Park (Credit: K. Gervase)

Figure 22

A.



B.



https://volcanoes.usgs.gov/volcanoes/yellowstone/monitoring_norris_temp.html

QUESTIONS 1-4: No figures needed.

#1 (1 pt): In 1963, two British geologists and a Canadian geophysicist theorized that:

As tectonic plates spread and new Earth crust was formed, _____ would have developed that would align with Earth's _____. Choose one:

A. a magnetization, geomagnetic field
B. striations, oceanic currents
C. mineral DNA, magma content
D. dense crystals, polarization

#2 (1 pt): The theory of continental drift was proposed by Alfred Wegener, but it was criticized early on because:

A. plant and animal fossils found on distant continents did not support the theory.
B. many scientists thought that ocean crust was too firm for continents to move through.
C. his proposed mechanism for continental drift estimated the velocity of continental motion to be too high (250 cm/year).
D. his writings were often mistranslated from German to English.

#3 (1 pt): During World War I, sonar-equipped ships provided support for plate tectonic theory because:

A. the sonar on the boats could measure the rate of continental drift as the boats moved through the ocean.
B. sonar enabled the discovery of mid-ocean ridges along continental boundaries.
C. ships had to adjust their sonar capabilities with respect to the movement of continental plates.
D. crew members began to notice that sonar waves took longer to come back to the boat when there was volcanic activity in the area.

#4 (1 pt): Why is the Theory of Plate Tectonics considered the unifying theory of geology?

A. Tectonic plates sometimes stick together and unify to form continents.
B. Plate Tectonic Theory was developed before other theories, unifying the scientists who were discovering evidence that supported the theory.
C. The ideas of Plate Tectonics are considered law, and scientists are no longer debating the evidence that supports Plate Tectonics.
D. Plate Tectonics Theory explains the relationship between seemingly unrelated phenomena, such as volcanoes and earthquakes, topographic features, etc.

QUESTIONS 5-9: No figures needed.

#5 (1 pt): Approximately what percent of the Earth's mass is made of the crust?

#6 (1 pt): Approximately what percent of the Earth's mass is made of the mantle?

#7 (1 pt): Approximately what percent of the Earth's mass is made of the core?

#8 (1 pt): The _____ is composed of the crust and the upper mantle.

#9 (1 pt): The _____ is composed of the lower mantle and core of the Earth.

QUESTIONS 10-13: Use Figure 1.

#10 (1 pt): In Figure 1, what layer of the Earth is indicated by A?

#11 (1 pt): In Figure 1, what layer of the Earth is indicated by B?

#12 (1 pt): In Figure 1, what layer of the Earth is indicated by C?

#13 (1 pt): In Figure 1, what layer of the Earth is indicated by D?

QUESTIONS 14-20: No figures needed.

#14 (1 pt): What type of plate boundary occurs on the west coast of Washington and Oregon in the United States?

#15 (1 pt): What type of plate boundary occurs on the west coast of California?

#16 (1 pt): **True** or **False**: The eastern margin of the US is a convergent boundary.

#17 (1 pt): The Himalayan Mountains are a result of tectonic forces. What type(s) of plates are involved?

A. a continental plate and a continental plate
B. a continental plate and an oceanic plate
C. an oceanic plate and an oceanic plate
D. a continental plate and a rift valley

#18 (1 pt): The plate boundary along which the Himalayan Mountains exist is a _____ boundary.

#19 (1 pt): A craton is a mostly [**stable** or **unstable**] part of a continent.

#20 (1 pt): The North American craton is made mostly of:

A. sedimentary rocks
B. igneous rocks
C. metamorphic rocks

*** Remember to write your answers on the separate answer sheet ****

QUESTIONS 21-22: No figures needed.

#21 (4 pts): Briefly (in a few words or a couple sentences) describe how thermal convection cells work. *Write your answer on the separate answer sheet.*

#22 (4 pts): On the blank figure in the separate answer sheet, draw the following things:

- a tectonic plate, extending from the ridge
- a trench where the plate descends into the mantle
- a convection cell, located in the proper place within the interior of the Earth
- arrows to show the cell's direction of motion

QUESTIONS 23-27: Use Figure 2.

#23 (1 pt): What type of tectonic basin was this package of sedimentary rock deposited within?

A. Aulocogen
B. Foreland Basin
C. Forearc Basin
D. Passive Margin

#24 (1 pt): Another name for this package of sediments is:

A. Melange
B. Clastic Wedge
C. Ophiolite

#25 (1 pt): In what direction is the source area for these sediments?

A. East
B. West

#26 (1 pt): Which sediments are most likely marine?

A. Indianola Group
B. Niobrara Chalk

#27 (1 pt): Which sediments are most likely deposited on land?

A. Indianola Group
B. Niobrara Chalk

QUESTION 28: No figures needed.

#28 (1 pt): Which of the following describes the start of the Wilson Cycle?

A. a plate thins from a rising plume of magma
B. an ocean basin opens
C. an ocean basin closes
D. continents collide

*** Remember to write your answers on the separate answer sheet ***

QUESTIONS 29-32: Use Figures 3 and 4.

#29 (2 pts): The diver shown in Figure 3 is in the Silfra crack in Iceland, touching 2 tectonic plates at the same time. What are the names of the 2 plates that the diver is touching?

#30 (1 pt): The two plates that the diver is touching are _____.

A. converging
B. diverging
C. sliding past each other

#31 (1 pt): Iceland is one of the few above-ground areas of the world's longest mountain range. What is the name of this mountain range?

A. Mid-Atlantic Ridge
B. Himalaya
C. Rockies
D. Appalachians

#32 (1 pt): This diver is in a:

A. rift valley
B. trench
C. caldera
D. geyser

QUESTION 33: No figures needed.

#33 (1 pt): Orogenic belts occur _____.

A. towards the active edges of continents
B. in the farthest interior parts of continents
C. on abyssal plains
D. within Earth's mantle, transporting heat from the core to other parts of the Earth's interior

*** Remember to write your answers on the separate answer sheet ****

QUESTIONS 34-35: Use Figures 5-7.

#34 (1 pt): Scientists have extracted sediment layers from up to 6 million years ago from the drill sites (red dots) shown on the map in Figure 5. Scientists found the same species of foraminifera (shown in Figure 6) in the drill cores at both sites.

Why was this marine species found on both sides of the isthmus?

A. The land bridge between the Americas enabled easier transport of the organisms by ancient travelers and traders.
B. Oceans were connected at one time, before the land bridge between the Americas formed.
C. The presence or lack of the isthmus is not related to the same species being found at the two drill sites.

#35 (1 pt): Figure 7 shows another kind of foraminifera called *Pulleniatina*. Unlike the species foraminifera mentioned in Question #34, *Pulleniatina* is only found in the cores from the Pacific Ocean side of the isthmus.

What is the most likely explanation for the presence of *Pulleniatina* only on the Pacific Ocean side?

A. Atlantic Ocean predators likely ate all the *Pulleniatina.*
B. *Pulleniatina* developed in freshwater streams only on the east side of the isthmus and were flushed to the ocean during abnormally wet periods with heavy rainfall.
C. *Pulleniatina* did not appear until after the land bridge formed a boundary between the two oceans.

QUESTIONS 36-37: Use Figure 8.

#36 (1 pt): Which area is showing isostatic rebound?

A. North of the green line (red arrows)
B. South of the green line (blue arrows)

#37 (1 pt): What is the major change in the last 2 million years that has led to isostatic rebound in the areas shown in Figure 8?

A. Large dinosaurs are no longer walking around, changing the Earth's surface with their weight.
B. Ice caps in Canada have grown.
C. Ice sheets melted.
D. The Earth's magnetic field has changed and impacted the amount of isostatic rebound.

QUESTIONS 38-40: Use Figure 9 for reference.

In geology, freeboard refers to the height to which crust that sits in the mantle is elevated above a hypothetical zero line.

As an example, Figure 9 shows an illustration of freeboard, with wooden blocks sitting in water, where the water line is the hypothetical zero line. In geology, the wooden blocks would be crust and the water would be the mantle. Figure 9 does not have any questions directly about it. Figure 9 is just to help you understand what freeboard means.

Freeboard is determined by this equation:

Given: $F = \frac{a(d_2 - d_1)}{d_2}$

where variables are:

- *F = freeboard*
- *a = thickness of the crust*
- *d_2 = density of mantle*
- *d_1 = density of material (crust) floating in mantle*

and constant values are:

- *density of continental crust = 2.7 g/cm^3*
- *density of oceanic crust = 3.0 g/cm^3*
- *density of mantle = 3.3 g/cm^3*

#38 (2 pts): According to the equation shown above, the freeboard (height) of continental crust that is 10 km thick is 1.8 km while the freeboard (height) of oceanic crust that is 10 km thick is 0.9 km. Why does continental crust have a greater freeboard (height)?

#39 (1 pt): Which do you think would have a greater freeboard (height): continental crust that is 10 km thick or continental crust that is 30 km thick?

#40 (2 pts): Using the information shown in the freeboard equation, why would the crust with the thickness you chose in Question #39 have a greater freeboard and float higher?

QUESTIONS 41-42: Use Figures 10 and 11.

Figure 10 shows an area of southern Louisiana, including the cities of New Orleans and Baton Rouge where the land is moving vertically. Figure 11 is an orientation map for reference.

#41 (1 pt): What is the maximum rate of subsidence in the Plaquemines area?

A. < 10 mm/year
B. 10-15 mm/year
C. 15-20 mm/year
D. > 20 mm/year

#42 (2 pts): In a short answer on the separate answer sheet (you only need a few words), briefly explain why the area around Plaquemines might be subsiding.

QUESTION 43: No figures needed.

#43 (1 pt): Of the following, which is not a natural hazard associated with plate tectonics?

A. hurricanes
B. tsunamis
C. volcanic eruptions
D. earthquakes

QUESTION 44: Use Figure 12.

#44 (2 pts): Figure 12 shows the island of Guam and some smaller islands. In a short answer on the separate answer sheet, briefly describe why Guam may, or may not, be subject to earthquakes.

QUESTIONS 45-51: No figures needed.

#45 (1 pt): Melting of crust material results in magma that has [**higher** or **lower**] silicate content than magma that originates directly from the mantle.

#46 (1 pt): What layer of the Earth's interior melts to form magma at divergent plate boundaries? Choose one.

A. crust
B. upper mantle
C. middle mantle
D. lower mantle, close to the core

#47 (3 pts): In a short answer on the separate answer sheet, briefly explain why portions of the Earth's interior melt at divergent plate boundaries.

QUESTIONS 48-51: Use the table below. Remember to write your answers on the separate answer sheet.

At subduction zones, two layers of Earth's interior may form magma. Which two layers may form magma at subduction zones? Why do these layers form magma at subduction zones? You may write on the table below if you need scratch space, but remember to record your answers on the separate answer sheet!

Layer that may form magma at a subduction zone Choose from: core, lower mantle, upper mantle, crust	**Why does this layer form magma at a subduction zone?**
#48 (1 pt):	**#49 (2 pts)**:
#50 (1 pt):	**#51 (2 pts)**:

QUESTIONS 52-54: Use Figure 13.

Hawaii is at a hot spot; Mount St. Helens is near a convergent boundary. Hawaii experiences relatively quiet eruptions that involve flowing basaltic lava. Mount St. Helens often experiences violent eruptions that involve exploding lava of rhyolitic composition.

Use the diagram in Figure 13, which shows composition of volcanic rocks and the geographic settings described above to help you answer these questions. **Remember to write your answer on the separate answer sheet.**

#52 (2 pts): What is *one* difference in terms of mineral composition between rhyolite and basalt?

#53 (2 pts): Think about how the magma forms in the areas of Hawaii and Mount St. Helens. What is *one* reason why the lavas at Mount St. Helens and Hawaii so different in terms of their compositions?

#54 (2 pts): Why do rhyolitic lavas experience more violent eruptions than basaltic lavas?

*** Remember to write your answers on the separate answer sheet ***

QUESTION 55: Use Figure 14.

#55 (1 pt): In the map shown in Figure 14, which letter is located on the North American craton?

QUESTIONS 56-57: No figures needed.

#56 (1 pt): Which of the orogenies listed below contributed to the building of the Appalachian Mountains? *Choose all that apply.*

A. Laramide
B. Taconic
C. Sevier
D. Acadian
E. Alleghenian

#57 (1 pt): In which of the orogenies that created the Appalachian Mountains did Africa collide with North America?

QUESTION 58: Use Figure 15.

#58 (1 pt): The diagrams in Figure 15 show portions of the sequence of geologic events that led to the formation of the Appalachian Mountains. The figures are out of order. Put them in order by ordering the letters from earliest to latest in time.

QUESTION 59: No figures needed.

#59 (1 pt): Between approximately 2 million years ago and 500,000 years ago, the Yellowstone area experienced _____ major caldera-forming volcanic eruptions.

A. two
B. three
C. twenty
D. eight hundred

QUESTIONS 60-64: Use Figure 16.

#60 (1 pt): In Figure 16, what is the age of the far eastern side of the Yellowstone Plateau at Location A?

A. 0.6 million years old
B. 6 million years old
C. 10 million years old
D. 15 million years old

#61 (1 pt): In Figure 16, what is the approximate age of the Picabo VF at Location B?

A. 0.6 million years old
B. 1.2 million years old
C. 10.3 million years old
D. 12.5 million years old

The Yellowstone Hot Spot and geological features associated with it can be used to estimate (1) the direction in which the North American plate is moving and (2) how fast it is moving.

#62 (1 pt): Examine Figure 16 and the ages and locations of geologic features in the figure.

Towards what direction is the North American plate moving, based on information about the Yellowstone Hot Spot and geological features associated with it? Choose from NW, N, NE, E, SE, S, SW, W. Assume North is to the top of the map in Figure 16.

#63 (6 pts): Compute the approximate distance in kilometers between points A and B on the map in Figure 16.

- ***Use this test booklet as scratch paper if you need it.***
- ***Show your work in the space provided on the separate answer sheet.***
  - ***You must show your work on the separate answer sheet to get full credit for this question. You may also get partial credit if you show your work.***
  - ***Remember: only answers on the separate answer sheet will be scored!!***
- ***Remember to include units of kilometers or km on your final answer.***

#64 (8 pts): Compute the rate (in cm/year) at which the North American Plate is moving using information in Figure 16. (Hint: also use information from Questions 60, 61, and 63).

- ***Use this test booklet as scratch paper if you need it.***
- ***Show your work in the space provided on the separate answer sheet.***
  - ***You must show your work on the separate answer sheet to get full credit for this question. You may also get partial credit if you show your work.***
  - ***Remember: only answers on the separate answer sheet will be scored!!***
- ***Remember to include units of cm/year on your final answer.***
- ***Round to the nearest tenth of a cm/year on your final answer.***

QUESTION 65: Use Figure 17.

#65 (1 pt): Figure 17 shows Bouguer gravity anomaly values in and around Yellowstone National Park. In Figure 17, the density of the subsurface material at Location Y103 (red triangle) is most likely to be [**higher** or **lower**] than at Location B (white square).

QUESTIONS 66-72: No figures needed.

#66 (1 pt): **True** or **False**: Strain is the amount of force applied to an object, per unit area of that object.

In the table below, provide the terms that match the types of deformation, as well as the type of strain (reversible or irreversible). You may write on the table but ***remember to record your answer on the separate answer sheet!***

For deformation terms, choose from brittle, ductile, or elastic.

Type of Deformation	**Deformation Term or Name**	**Irreversible or Reversible Strain?**
rocks break in pieces in response to stress	**#67 (1 pt):**	**#70 (1 pt):**
When stress is removed the material will return to its original position or shape.	**#68 (1 pt):**	**#71 (1 pt):**
rocks flow or bend in response to stress	**#69 (1 pt):**	**#72 (1 pt):**

QUESTION 73: Use Figure 18.

#73 (2 pts): Fill in the blanks: The rocks in the photo in Figure 18 have undergone _____ deformation over a long period of _____. Choose from: brittle, ductile, stress, fracturing, elasticity.

QUESTIONS 74-75: Use Figure 19.

#74 (1 pt): In the graphs in Figure 19, at what depth would you expect to observe the greatest seismicity?

A. 5000 km
B. 3000 km
C. 1000 km
D. 200 km

#75 (1 pt): Why would you expect to observe the greatest seismicity at the depth you chose in Question #74?

A. The confining pressure is higher than at other depths, which results in many fractures.
B. The confining pressure and temperatures are lower at this depth, which allows fractures to form.
C. Fractures form easily at this depth because the temperature the melts rock.
D. The confining pressure and temperature at this depth inhibit nearly all fractures from forming.

QUESTIONS 76-77: No figures needed.

#76 (1 pt): Magnetic anomalies can be used to analyze:

A. fault locations.
B. topography.
C. seafloor spreading.
D. A and B
E. A and C

#77 (1 pt): True or **False:** Raw gravity measurements can be used to learn about the detailed structure and characteristics of geologic features.

QUESTION 78: No figures needed.

#78 (2 pts): The US Geological Survey (USGS) is leading an effort to develop a "ShakeAlert" system that is based on a network of seismometers. In a few words, briefly explain one reason why using a network of seismometers is better than using a single seismometer. *Write your answer on the separate answer sheet.*

QUESTIONS 79-83: Use Figure 20.

Put the statements of geological events that are shown below in order by assigning them numbers. 1 is the earliest event in time, and 4 is the latest or most recent event in time.

You may write on the table below, but remember to *record your answers on the separate answer sheet.* Only answers on the separate answer sheet will be scored.

Event	**Question**	**Number** (1=earliest, 4 = latest or most recent) *** remember to record your answers on the separate answer sheet **
Permian and Pennsylvanian sedimentary rocks were deposited	**#79 (1 pt)**	
Faulting occurred between the San Pitch Mountains and the Sevier Desert	**#80 (1 pt)**	
Layers between the San Pitch Mountains and Book Cliffs warped	**#81 (1 pt)**	
Cretaceous sedimentary rocks were deposited	**#82 (1 pt)**	

QUESTIONS 83-86: No figures needed.

#83 (1 pt): A gravimeter measures which of the following?

A. gravitational acceleration
B. Coriolis Force
C. gravitational velocity
D. gravity thickness

#84 (1 pt): A compass is a simple type of what kind of geophysical tool?

A. gravimeter
B. direction-o-matic
C. gravitational wave sensor
D. magnetometer

#85 (1 pt): **True** or **False**: Much of the world's hydrocarbon deposits are located along transform plate boundaries.

#86 (1 pt): Much of North America's major metallic ore deposits, such as copper, are associated with _____ plate boundaries.

A. convergent
B. divergent
C. transform
D. spreading

QUESTIONS 87-88: Use Figure 21.

#87 (1 pt): What is the source of the water in the hydrothermal feature shown in the photo in Figure 21?

A. Water from Earth's core
B. Rain and snow that melted and ran overland to the hydrothermal feature
C. Rain and melted snow that flows through the subsurface along fault systems
D. Water pumped into the feature by humans

#88 (1 pt): The rocks of the hydrothermal feature in the photo in Figure 21 are formed by calcium carbonate mineral precipitation. What is the most likely source of the carbonate minerals that help to form the spring?

A. Sedimentary rocks
B. Igneous rocks
C. Metamorphic rocks

QUESTIONS 89-90: Use Figure 22.

#89 (1 pt): Which graph (A or B) of water temperature is from a hydrothermal feature that was impacted by rain?

#90 (1 pt): Which graph (A or B) shows water temperature in outlet channel that drains water that flows from an erupting geyser?

*** Remember to write your answers on the separate answer sheet ***