



USESO 2024

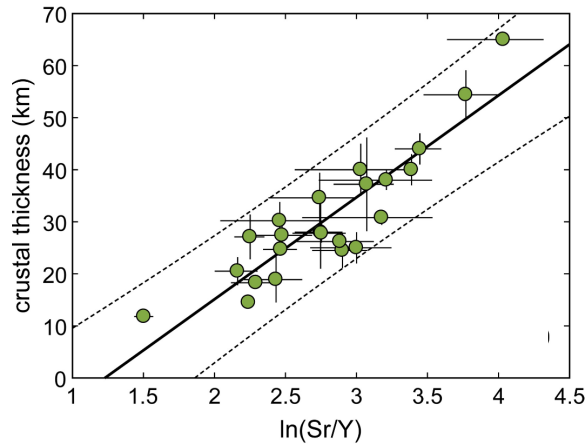
Training Camp Exam

Multiple Choice

Instructions:

- Section I consists of 30 questions that assess geoscience knowledge in the form of multiple-choice questions. Each question is worth 2 points.
- You have 1 hour and 15 minutes to complete this section.
- Any type of calculator is allowed.
- Participating in this exam is agreement to our Academic Integrity Policy.

1. Crustal thickness (H^{tot}) in volcanic arc regions can be estimated by interpreting the geochemical properties of surface igneous rocks through a process known as mohometry. A Sr/Y mohometer is shown below.



Let $H^{tot} = H + h$, where H represents the depth of the Moho discontinuity relative to sea level and h represents the elevation of the land surface. Which of the following statements is/are likely true?

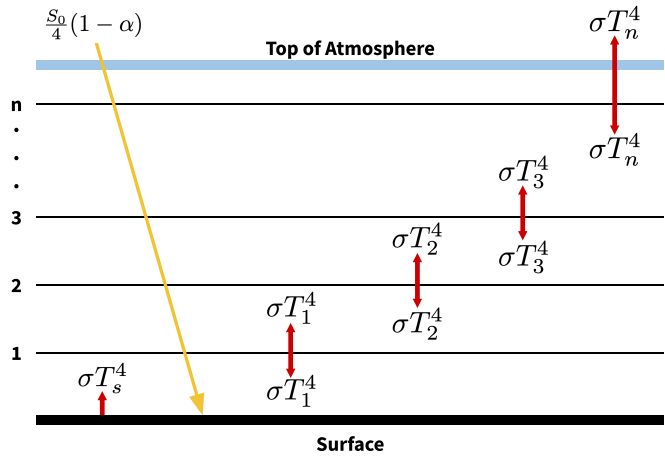
- I) H correlates negatively with h
 - II) Measured SiO_2 correlates negatively with H^{tot}
 - III) Strontium is incompatible at high pressures (i.e. it does not fit well into the crystal structure of most minerals) while yttrium is compatible
- A. II only
 - B. III only
 - C. I and II
 - D. I and III
 - E. None
2. Marc examines object X with circular orbit about star Y. He finds four different expressions for X's orbital velocity using each of the four methods described below.

- I) Equating the sum of X's kinetic and potential energy to X's total energy
- II) Equating the centripetal force exerted on X to the gravitational force exerted on X
- III) Dividing X's angular momentum by the product of X's orbital radius and mass
- IV) Dividing the distance X travels in a single orbit by X's orbital period

Marc realizes that by equating two of the derived expressions for X's orbital velocity and rearranging terms (without substitution), he can produce an expression for Kepler's third law. Which two expressions does he equate?

- A. I and III
- B. I and IV
- C. II and III
- D. II and IV
- E. III and IV

3. The model below describes an N-layer atmosphere transparent to incoming solar radiation in which each layer absorbs all outgoing terrestrial infrared radiation. If $\frac{S_0}{4}(1 - \alpha)$ equals the average incoming solar radiation across the planet and σT_i^4 represents blackbody radiation emitted by a given layer, which of the following is/are true regarding the model?



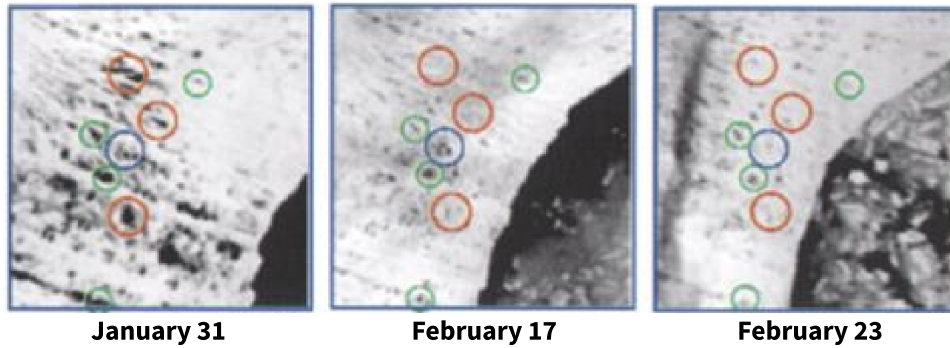
- I) The top of the atmosphere has a radiative balance given by $\frac{S_0}{4}(1 - \alpha) = \sigma T_n^4$
 - II) The planetary surface has a radiative balance given by $\frac{S_0}{4}(1 - \alpha) + \sigma T_1^4 = \sigma T_s^4$
 - III) Each individual layer has a radiative balance given by $2\sigma T_i^4 = \sigma T_{i-1}^4 + \sigma T_{i+1}^4$
- A. I only
 - B. II only
 - C. I and II
 - D. II and III
 - E. I, II, and III

4. Below are three structures formed by deformation. Which of the following best characterizes the stress that likely produced each structure?



- A. Compressional; extensional; compressional
- B. Compressional; extensional; extensional
- C. Shear; compressional; compressional
- D. Shear; compressional; extensional
- E. Extensional; extensional; shear

5. The 2002 Larsen B calving event was distinctive due to its splinter-style calving. Based on ice loss data and images of the calving areas, which of the following processes was most likely responsible for ice loss during this event?



Circled dark areas are melt ponds.

Date	Ice Loss
Jan 31 - Feb 17	611 km ²
Feb 17 - Feb 23	164 km ²
Feb 25 - Mar 5	1973 km ²

- A. Higher albedos led to more melting, which led to further melting of the ice
- B. Ocean water intruded into the ice sheet, which split apart the ice
- C. Meltwater formed and solidified, which wedged apart the ice
- D. Meltwater infiltrated beneath existing fractures, which weakened the ice

6. The four Galilean moons, listed in order of increasing distance from Jupiter, are Io, Europa, Ganymede, and Callisto. Which of the following statements is/are likely true of these moons?

- I) Meteorites strike Io and Europa more often than Callisto and Ganymede due to inward focusing of debris caused by Jupiter
- II) Io and Europa have more internal heat than Callisto and Ganymede because their larger masses allow them to maintain a higher geotherm

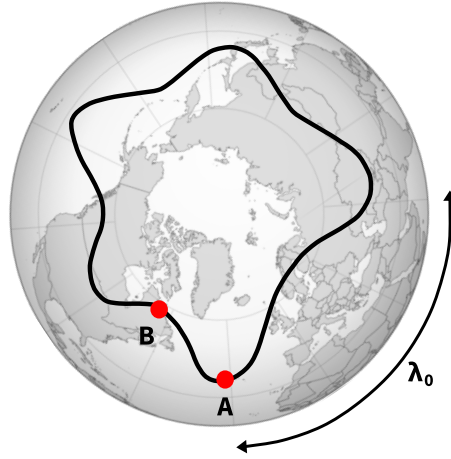
- A. I only
- B. II only
- C. I and II
- D. None

7. A geologist studying a lava lake is interested in the settling rates of cooling crystals. Which of the following rock formations would be of most use to the geologist?

- A. Large, closely packed olivine crystals in an intermediate groundmass that is finest near the top
- B. Ripples of lava trending from higher to lower elevation that grow blockier as they progress downslope
- C. Layers of rock fading from light to dark in repeated patterns that increase in thickness toward a central region
- D. Repeated vertical intrusions separated by baked contacts

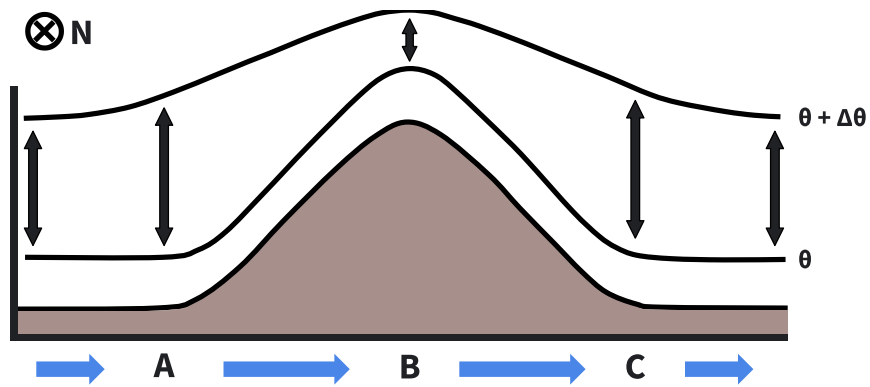
The following two questions should be approached sequentially.

8. The absolute vorticity η of an air column is a measure of rotation calculated as $\eta = \zeta + f$, where ζ represents relative vorticity (derived from the column's rotation) and f represents planetary vorticity (derived from Earth's rotation). Absolute vorticity is conserved in the case of atmospheric Rossby waves. This explains why they move in sinuous patterns with wavelength λ , as shown below by a contour of constant η .



At position A, f is _____ than f at position B. In the Northern Hemisphere, ζ is negative when rotation is _____.

- A. greater; cyclonic
 - B. greater; anticyclonic
 - C. smaller; cyclonic
 - D. smaller; anticyclonic
9. Air bounded by two isentropes, surfaces of constant potential temperature (θ), flows adiabatically over the Rockies at 45°N as shown below.

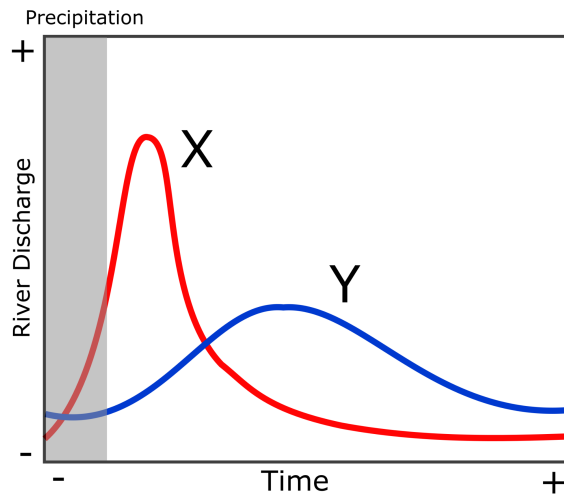


The circled cross indicates that north is directed into the page.

The potential vorticity (Q) of an air column is a measure of rotation calculated as $Q = \eta/H$, where H represents column height. Because Q accounts for stretching and contracting of the column, it is conserved regardless of column height (i.e. Q remains constant from A to B to C in the diagram above). Considering your answer to the previous question, which of the following statements is/are likely true?

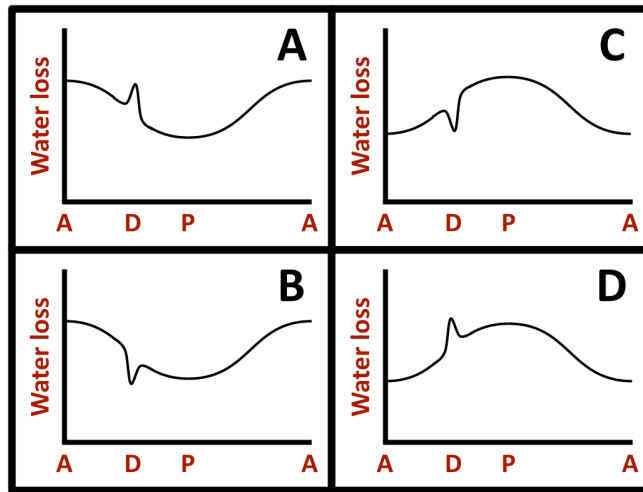
- I) An atmospheric ridge develops at C
 - II) Northerly geostrophic winds develop between B and C
- A. I only
 - B. II only
 - C. I and II
 - D. None

10. Shown below are two different hydrographs representing river discharge after a precipitation event. Which of the following drainage basin changes would result in a shift from hydrograph X to Y? Assume that the total amount of precipitation that enters the basin is constant.



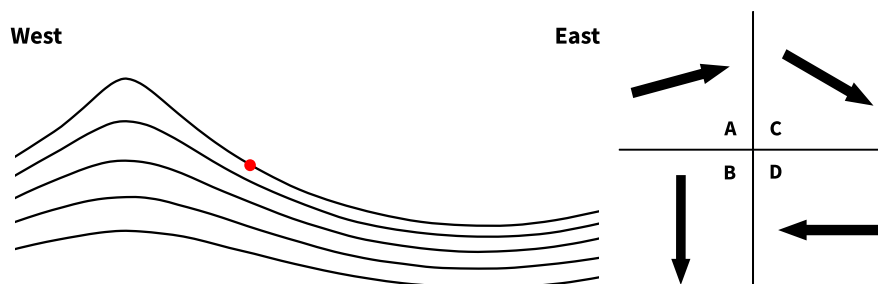
- A. Increase in impervious surface area
 - B. Increase in basin elongation
 - C. Increase in basin slope
 - D. Decrease in surface plant cover
11. One of the leading models for mantle convection is known as the double-layered model, which describes the mantle as having two distinct convection cells separated by a mid-mantle boundary at a depth of around 660 km. Which of the following observations would support the double-layered model?
- I) Subducting tectonic plates in the boundary region typically create compressional earthquakes
 - II) Mid-Atlantic Ridge Basalts are generally depleted in volatile elements while Hawaiian Ocean Island Basalts are generally rich in volatile elements
- A. I only
 - B. II only
 - C. I and II
 - D. None

12. Mars' lower atmosphere contains a small amount of water vapor that is slowly lost over time. A group of researchers measured the rate of Mars' water loss throughout a full orbit from November 2017 to October 2019. They found that the most extreme values occurred at aphelion (labeled A), at perihelion (labeled P), and during a violent dust storm (labeled D) that occurred during May 2018. Which of the graphs below would likely be closest to the researchers' observed results?



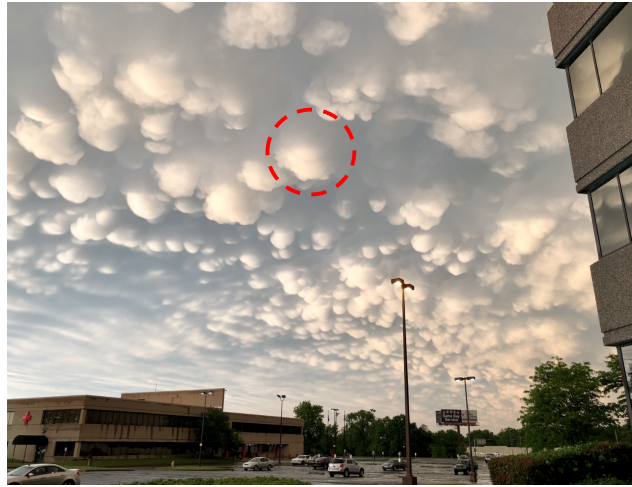
- A. A
- B. B
- C. C
- D. D

13. The cross-section of a surface wave moving westward in the North Atlantic Ocean is shown below. Which of the following arrows best approximates the direction of net force on the water particle marked in red?



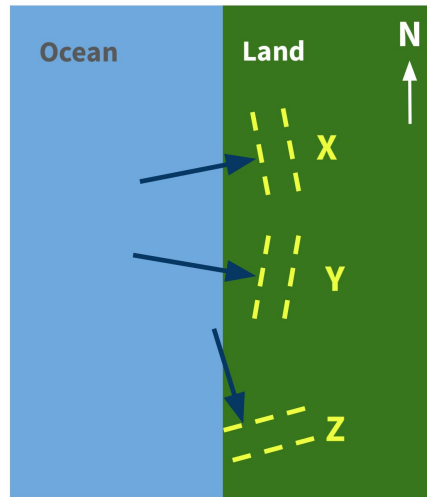
- A. A
- B. B
- C. C
- D. D

14. Mammatus clouds are typically observed following the passage of thunderstorms and form underneath storm anvil clouds as shown below.



- (a) Which of the following best characterizes the primary direction of motion of air in the circled region?
- A. Upward
 - B. Downward
 - C. Lateral
- (b) Considering the conditions favorable for cloud development, which of the following choices regarding energy balance in the circled region best supports a potential mechanism for mammatus cloud formation and sustenance?
- A. Less heat energy is consumed by evaporation of precipitation than is released by adiabatic heating
 - B. More heat energy is consumed by evaporation of precipitation than is released by adiabatic heating
 - C. Less heat energy is consumed by adiabatic cooling than is released by condensation of water vapor
 - D. More heat energy is consumed by adiabatic cooling than is released by condensation of water vapor
15. Since zircon incorporates almost no lead (Pb) upon formation, the ratio of ^{206}Pb to ^{207}Pb can be used to date the crystal. ^{206}Pb forms from ^{238}U with a half-life of 4.468 billion years and ^{207}Pb forms from ^{235}U with a half-life of 703.8 million years.
- A scientist discovers a zircon crystal that she believes formed 500 million years ago and lost some of its lead to external sources. When the crystal formed, the ratio of ^{238}U to ^{235}U on Earth was approximately 91.0. Which of the following ratios of ^{206}Pb to ^{207}Pb would the researcher expect to find in the crystal if 50% of Pb was lost during an event 250 million years ago?
- A. 15.86
 - B. 17.47
 - C. 18.09
 - D. 19.52

16. Wind turbines are most efficient when oriented perpendicular to the wind. Suppose you are deciding where to place rows of wind turbines (oriented according to the dashed lines) in a forested region. The map below shows three possible wind vectors and corresponding sets of turbines.



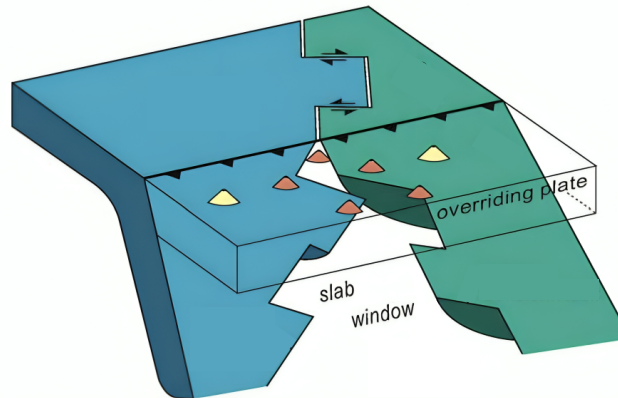
- (a) On a warm, sunny day in the Northern Hemisphere, which wind turbine placement would be most efficient?
- A. X
 - B. Y
 - C. Z
- (b) As the winds move onshore, what happens to them?
- A. They converge and turn slightly to the left
 - B. They converge and turn slightly to the right
 - C. They diverge and turn slightly to the left
 - D. They diverge and turn slightly to the right
17. Hydrostatic pingos are typically found in regions underlain by permafrost. They form as trapped groundwater freezes and expands, creating ice cores that exert an upward pressure on overlying sediments. Identify all of the following environments that would be favorable for the development of hydrostatic pingos.
- I) A still-water lake that has been recently infilled with sediment
 - II) A sloping hill underlain by coarse gravel
 - III) A compacted ground moraine deposited by a valley glacier
- A. I only
 - B. I and II
 - C. II and III
 - D. I and III
 - E. I, II, and III

18. The Bowen ratio B is the ratio of sensible heat flux (SHF) to latent heat flux (LHF), defined to be positive in the surface-to-atmosphere direction. Given that SHF is relatively small and more uniform across latitudes compared to LHF, which of the following can be inferred about B ?

- I) If the air is warmer than the surface and net evaporation is occurring, B is negative
- II) If the surface is warmer than the air, decreasing soil moisture in a dry atmosphere lowers B
- III) On average, B decreases with increasing latitude

- A. I only
- B. II only
- C. I and II
- D. I and III
- E. II and III

19. A slab window, depicted below, is a gap formed when a mid-ocean ridge subducts and both divergence at the ridge and convergence at the subduction zone continue.

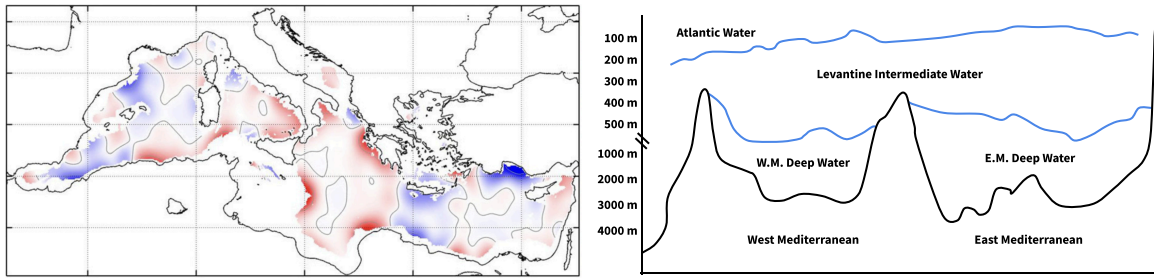


Which of the following statements is/are likely true?

- I) Mantle within slab windows exhibits increased water content
- II) Slab windows can be identified by the presence of positive P wave velocity anomalies
- III) The degree of decompression melting within slab windows decreases away from the subduction zone

- A. I only
- B. III only
- C. I and II
- D. II and III
- E. I, II, and III

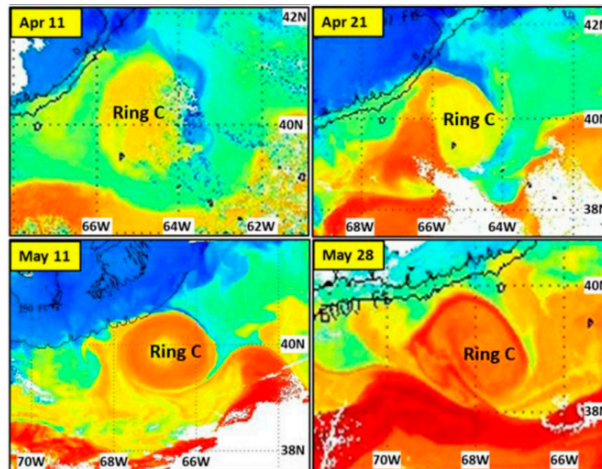
20. An oceanographer finds a map of the Mediterranean Sea with colors corresponding to an unknown property (shown on the left). To help determine the identity of this property, they roughly sketch an east-west cross-section of the sea and label the major water masses (shown on the right).



Which of the following best characterizes the unknown property?

- A. Sea surface conductivity; blue shading corresponds to regions of low conductivity
- B. Sea surface conductivity; blue shading corresponds to regions of high conductivity
- C. Temperature at 300 m; blue shading corresponds to regions of low temperature
- D. Vertical velocity at 1000 m; blue shading corresponds to regions of downward velocity
- E. Vertical velocity at 1000 m; blue shading corresponds to regions of upward velocity

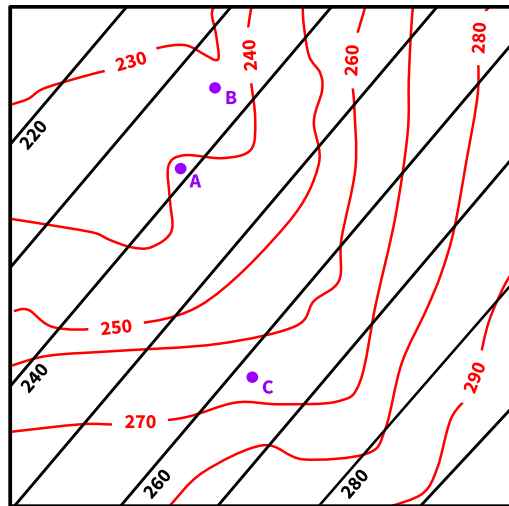
21. The Gulf Stream can create large circulating water masses known as eddies. The diagram below depicts the evolution of multiple eddies, with red regions indicating high sea surface temperatures (SSTs) and blue regions indicating low SSTs. Identify all of the following statements that are likely true regarding Ring C:



- I) Water within Ring C rotates counterclockwise
- II) The center of Ring C has abnormally low productivity
- III) Hurricanes passing over Ring C would strengthen

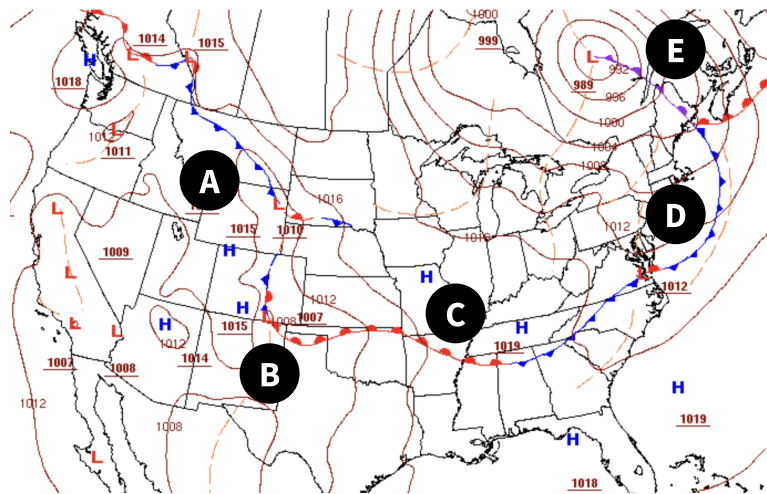
- A. I only
- B. III only
- C. I and II
- D. I and III
- E. II and III

22. Consider the following topographic map. The black contours describe the elevation of a coal seam and the red contours describe the surrounding topography. At which of the three labeled points is the seam likely to outcrop?



- A. A only
- B. B only
- C. A and B
- D. A and C
- E. B and C

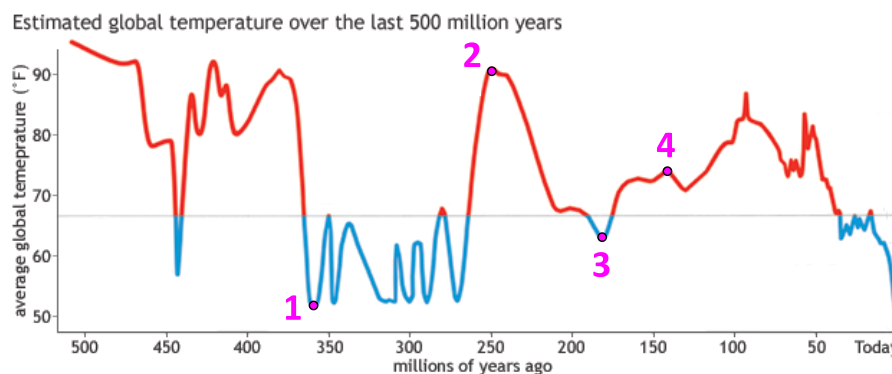
23. Refer to the following surface air map.



At what location would you most likely expect to find mid-to-high altitude clouds, such as altostratus and cirrus?

- A. Location A
- B. Location B
- C. Location C
- D. Location D
- E. Location E

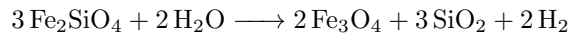
24. Jupiter and Saturn share similar structures due to commonalities in their formation and composition. They are, however, not entirely the same. Which of the following correctly contrasts properties of these two planets?
- Jupiter's higher mass results in it having more liquid metallic hydrogen than Saturn
 - Jupiter's stronger magnetic field results in it having a higher density than Saturn
 - Tidal forces from Ganymede induce storms on Jupiter while Titan's magnetic field inhibits storms on Saturn
 - Jupiter's magnetic field is produced from the convection of iron and nickel while Saturn's magnetic field is produced from the convection of silicate material
25. Jason samples and analyzes four ice cores on a research trip to the Arctic. He finds that cores A, B, C, and D are increasingly enriched in ^{18}O . He also knows that each core was taken from one of the four points in time indicated below.



Which of the following statements is/are likely true?

- Core C was taken from Point 4
 - Core D was taken from Point 1
 - An ocean sediment core taken from the same time as Core D would also be significantly enriched in ^{18}O
- I only
 - II only
 - I and III
 - II and III
 - None
26. Tidal height is recorded at two locations on Earth's surface when the Moon is at a declination of 23°N . Location A is at 10°N latitude while Location B is at 60°N latitude. Assuming equilibrium tides, which of the following best categorizes the expected tidal patterns at Location A and Location B, respectively?
- Diurnal; diurnal
 - Diurnal; mixed semidiurnal
 - Semidiurnal; mixed semidiurnal
 - Mixed semidiurnal; diurnal
 - Mixed semidiurnal; semidiurnal

27. Serpentinization is an important metamorphic process that may have played a role in the development of early life on Earth. Although there are multiple pathways, one of the basic serpentinization reactions involves Fe_2SiO_4 , the iron-rich endmember of the olivine solid solution:

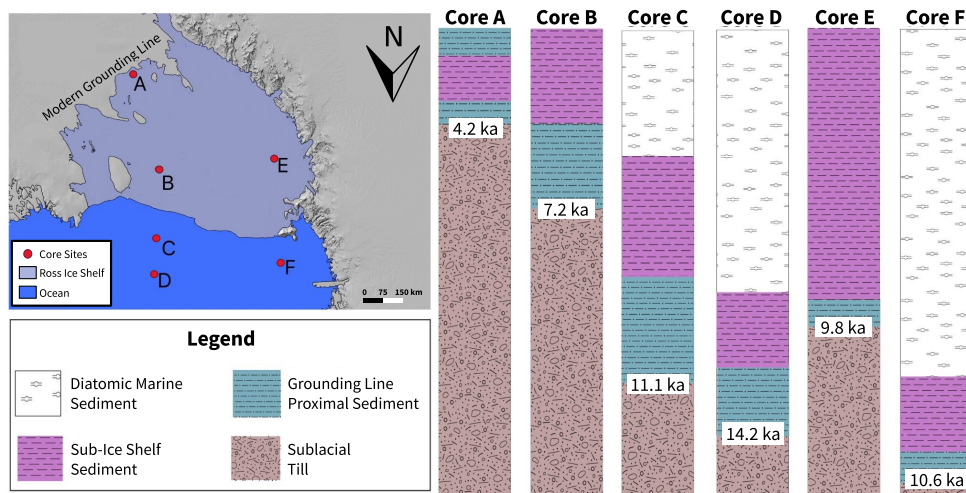


Which of the following statements is/are likely true?

- I) Crust undergoing serpentinization generally increases in volume
- II) Serpentinized rocks are commonly found in ophiolite structures
- III) Infiltration of silica-rich groundwater would hinder serpentinization

- A. I only
- B. II only
- C. II and III
- D. I and II
- E. I, II, and III

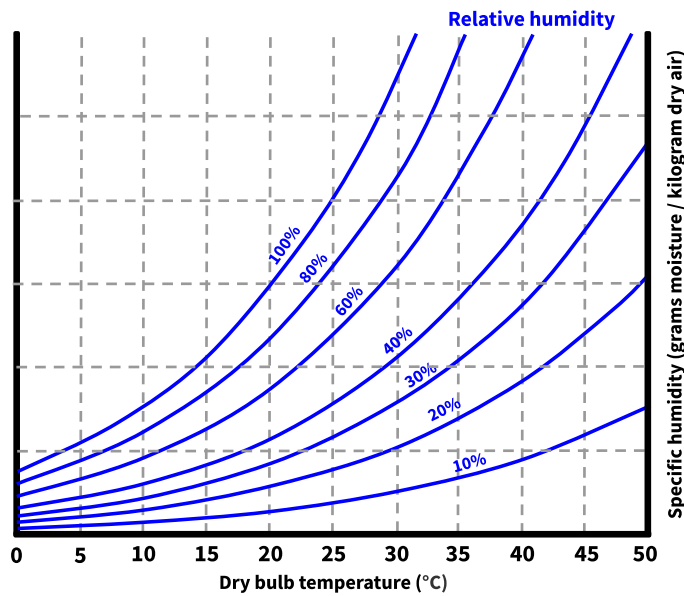
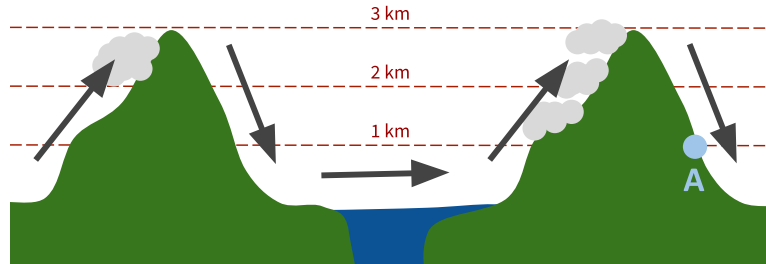
28. Sediment cores A-F were collected in the Ross Sea in Antarctica. The corresponding sedimentary sequences can be used to understand changes in grounding line position, where ice shifts from being in contact with land to floating on the ocean. Which of the following statements about Ross Sea deglacial history are supported by the sediment cores? Assume sedimentation rates are equal at all sites.



- I) The grounding line retreated more rapidly in the Western than the Eastern Ross Sea
- II) The grounding line retreated past its modern extent, then readvanced to its current position
- III) The grounding line remained near site C longer than any other site

- A. I only
- B. I and II
- C. I and III
- D. II and III
- E. I, II, and III

29. An air parcel moves across two mountains with a lake between them. Clouds begin forming at an altitude of 2 km while crossing the first mountain and 1 km while crossing the second mountain. The air parcel begins at the surface with an initial temperature of 25°C, does not change in temperature while crossing the lake, and does not change in specific humidity while descending. Using the psychrometric chart below, if the dry adiabatic lapse rate is 10°C/km and the moist adiabatic lapse rate is 5°C/km, which of the following is closest to the relative humidity at point A?



- A. 10%
 - B. 20%
 - C. 30%
 - D. 40%
30. Large shield volcanoes are common on the surfaces of Venus and Mars. Although these volcanoes have similar compositions and structures, they are significantly shorter on Venus than on Mars. Which of the following processes best explains this difference?
- A. Rapid weathering by Venus' atmosphere
 - B. Underground magma chamber collapse
 - C. Isostatic adjustment
 - D. Fracturing of magma pathways

END OF MULTIPLE CHOICE