

USES0 2022

Open Exam

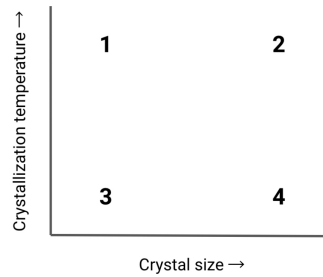
Section I - **KEY**



Instructions:

- Section I consists of 30 multiple choice questions. Each question is worth 2 points.
- Questions are **not** ordered by difficulty.

1. A petrologist infers that a rock cooled very quickly from a silica-rich melt. A rock represented by which labeled region(s) of the graph would be consistent with this inference?



- A. 1 only
- B. 2 only
- C. 3 only**
- D. 4 only
- E. Either 3 or 4

Solution: The rate of cooling is inversely related to crystal size; rocks that cool faster tend to have smaller crystals. As a magma cools and fractionally crystallizes, the remaining melt is silica-rich, so the crystallization temperature should have been relatively low.

2. Earth's early atmosphere, often referred to as its primary atmosphere, was largely produced by the outgassing of magma. How did the formation of oceans most significantly change the composition of this atmosphere?
- A. Increase in nitrogen
 - B. Increase in oxygen
 - C. Decrease in carbon dioxide**
 - D. Decrease in argon

Solution: Carbon dioxide, which still outgasses today in volcanically active regions, was once a major constituent of Earth's atmosphere until being dissolved and stored in oceans.

3. Flow between ocean basins, or interbasin transport, can have significant effects on the global ocean circulation. On average, interbasin transport brings freshwater *into* the Atlantic basin. If the magnitudes of freshwater flux from precipitation, evaporation, and runoff into the Atlantic are denoted P , E , and R respectively, which of the following must be true?
- A. $P - R = E$
 - B. $P + R = E$
 - C. $P - E + R > 0$
 - D. $P - E + R < 0$**
 - E. $P + E - R < 0$

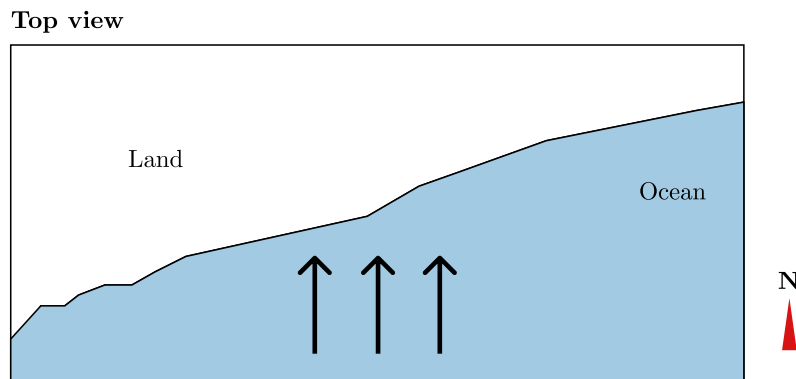
Solution: In any ocean basin in equilibrium, the net freshwater budget (and thus change in salinity) should be close to zero over long timescales. Since there is a net advective transport of freshwater into the Atlantic, there must be a net loss of freshwater via surface fluxes. Evaporation must dominate over precipitation and runoff, which both add freshwater. Hence the answer is D.

4. Although surface conditions on Venus are very different from those on Earth, aeolian features have also been observed on Venus's surface. However, some recent research indicates that aeolian features may be less common on Venus due to a lack of sediment. Which of the following *incorrectly* explains why this discrepancy may exist?

- A. Venus's thick atmosphere prevents meteorites from forming surface sediment.
- B. Venus's dense atmosphere slows winds, preventing sediment transport.**
- C. Venus has no liquid water or ice on its surface to erode rock.
- D. Venus has no plate tectonics to promote erosion.

Solution: The density of Venus's atmosphere promotes the movement of sediment. A denser fluid moving at the same rate will have more energy to pick up and transport loose sediment.

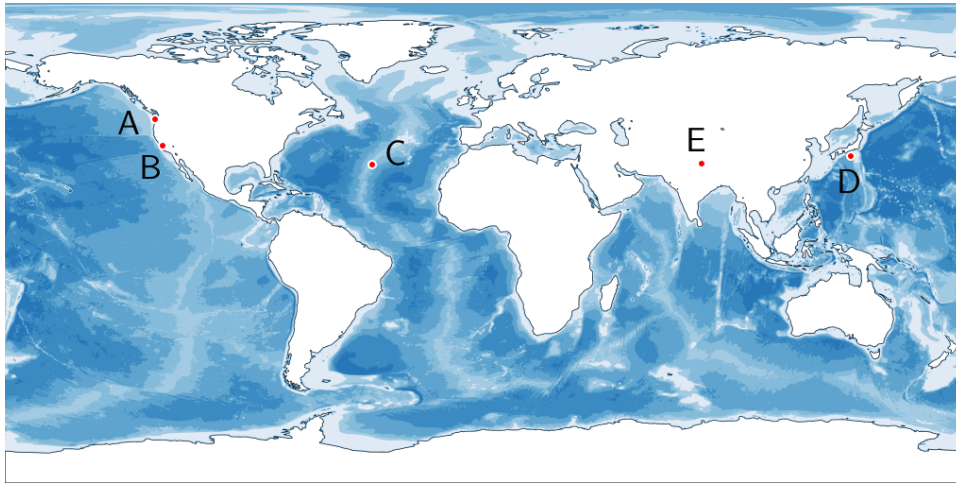
5. The following image shows a map of a coastal region in the Northern Hemisphere with wind blowing over the ocean towards land. Which of the following best describes what will happen to water at the surface and at depth, respectively?



- A. Moves parallel to the coast; upwelling**
- B. Moves parallel to the coast; downwelling
- C. Moves away from the coast; upwelling
- D. Moves away from the coast; downwelling

Solution: Ekman transport near the surface results in a deflection of approximately 45° to the right, which would mean water is still moving towards the coast and would result in a longshore current parallel to the coast. Ekman transport at depth results in a net transport 90° to the right of the wind, so the overall water flow is away from the coast and would result in upwelling.

6. Earthquakes with a hypocenter depth greater than 300 km are known as deep-focus earthquakes. Which of the locations on the bathymetric map below has the greatest concentration of deep-focus earthquakes?



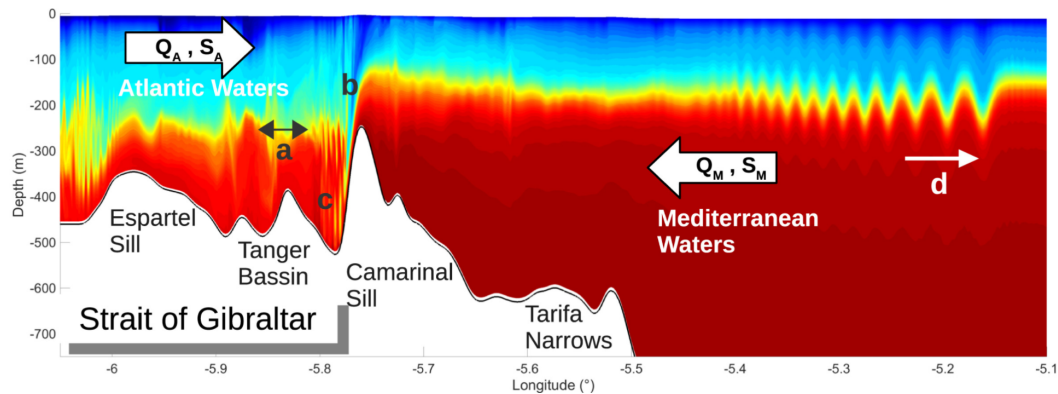
- A. A
- B. B
- C. C
- D. D**
- E. E

Solution: Deep-focus earthquakes almost always occur at subduction zones, so B, C, and E can be eliminated immediately. There is subduction at both A (Juan de Fuca plate) and D (Pacific plate), but the subducting Pacific plate is considerably older at D, thus subducting at a steeper angle and dipping deeper into the mantle. Hence **D** has the greatest concentration of deep-focus earthquakes.

7. A ridge on an upper-air map would dissipate most quickly if directly underlain on the surface by a:
- A. High-pressure region**
 - B. Low-pressure region
 - C. Ridge
 - D. Trough

Solution: Considering mass conservation, diverging air at a surface high would prevent divergence aloft, thus dissipating the ridge. Note that this system of high pressure above high pressure is not realistic because it would dissipate immediately.

8. Shown is a modeled density profile of the region around the mouth of the Mediterranean Sea (left - Atlantic; right - Mediterranean). On the Mediterranean side of the Strait of Gibraltar, internal waves are periodically generated and observable from satellites.



Select all of the following that are true.

- I) The Camarinal Sill likely generates most of the eastward propagating internal waves.
 - II) Internal waves are more prominent on the Mediterranean side due to a strong halocline.
 - III) Westward-propagating internal waves become more observable in the Atlantic when a strong thermocline is present.
- A. I only
 B. II only
 C. I and II
 D. I and III
E. I, II, and III

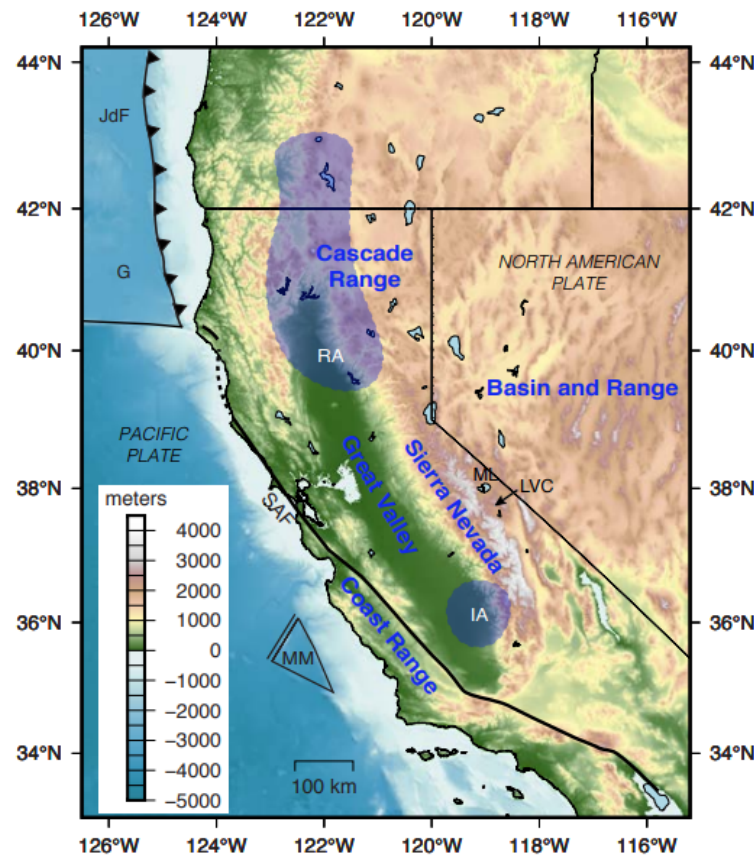
Solution: The Camarinal Sill is the easternmost sill, creating the eastward-propagating internal waves. Internal waves are located on the pycnocline, created by the strong halocline in the Mediterranean. Similarly, a thermocline also contributes to the density gradient at the pycnocline.

9. Katabatic winds are strong downslope flows that dominate the Antarctic surface wind field for much of the year. Which of the following statements are true?
- I) Coastal katabatic winds are typically strongest during austral (southern) winter
 - II) Katabatic winds are approximately in geostrophic balance

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

Solution: During winter, the temperature contrast between the ocean (near 0 °C) and ice sheet (typically far below 0 °C) is maximized; the horizontal pressure gradient force is also maximized, so I is true. Katabatic winds cannot be in geostrophic balance because of significant friction and topographic constraints.

10. The Isabella anomaly (IA) is an upper-mantle, high-speed P wave anomaly within California's southern Great Valley and the foothills of the Sierra Nevada. It is hypothesized to be either the sinking mafic root of the southern Sierra Nevada batholith or a fossil slab that is a continuation of the Monterey microplate translated beneath the Great Valley. Which of the following options are true *and* would support the second theory?



- I) The Isabella anomaly consists of relatively soft, hot material.
 II) The crust between the eastern portion of the mountains is thin.

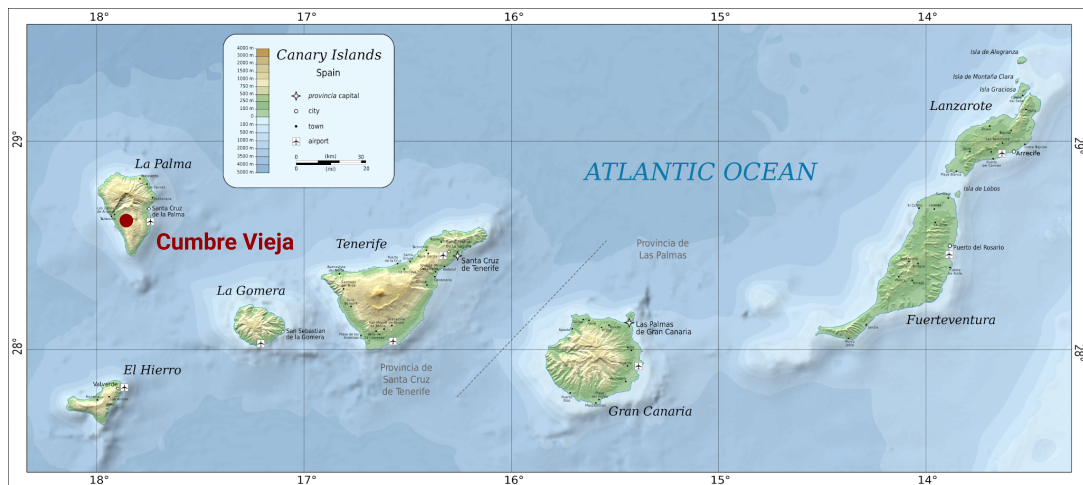
- A. I only
 B. II only
 C. I and II
 D. None

Solution: The Isabella Anomaly is a high-speed anomaly, indicating that it should be made of anomalously cold, incompressible material. Since mountains are typically associated with anomalously thick crust, a thinner crust could suggest delamination of the lithospheric plate; this supports the first theory.

11. Historical sunspot observations are one of the oldest and most continuous records in the earth and space sciences. Sunspot minima, during which few sunspots are counted, are associated with what climatic effect?
- Warmer temperatures only in the northern hemisphere
 - Cooler temperatures only in the northern hemisphere
 - Warmer temperatures in both hemispheres
 - Cooler temperatures in both hemispheres**

Solution: During a sunspot minimum, the reduced solar activity decreases overall insolation, cooling Earth's climate. Hemisphere generally does not change this effect.

12. The accompanying map is of the Canary Islands off the coast of Africa with the Cumbre Vieja volcano labeled. This volcano erupted over several months in 2021, forcing thousands to evacuate.



Identify all of the following statements that are likely true of Cumbre Vieja:

- The Canary Islands are located on a plate boundary.
- Only the western islands in the chain are volcanically active.
- The 2021 eruption involved andesitic magma.

- I only
- II only**
- III only
- I and III
- None

Solution: The Canary Islands are fed by a hot spot, which can be reasoned by the fact that the eastern islands appear older and more eroded while the western islands are being built up - I is false. The eastern islands likely formed above the hot spot that is feeding Cumbre Vieja and have since been pulled away by the African Plate, removing their source of magma and causing them to be eroded - II is true. Oceanic island magma is typically basaltic, because oceanic crust is too thin for significant differentiation to occur within the crust - III is false.

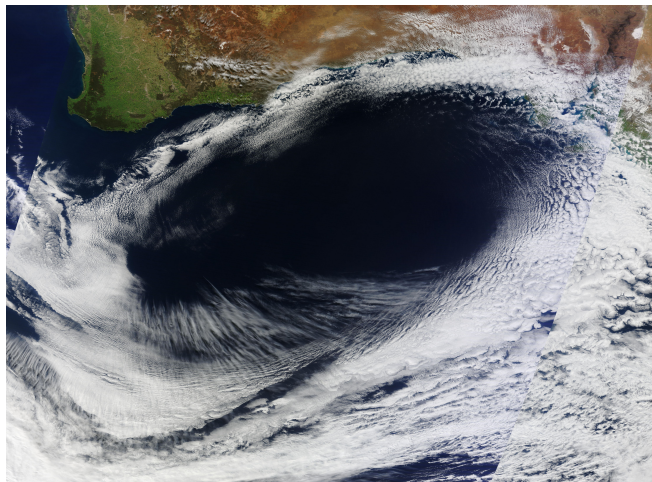
13. The complexity of silicate structures (e.g., complex network silicates to simple isolated tetrahedra) can influence the bulk properties of rock made from those silicate minerals. Which of the following trends is associated with increasing silicate complexity?

- I) Increasing melting point
- II) Increasing viscosity of magma

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

Solution: As seen in Bowen's reaction series, silicates with a more complex structure such as quartz and feldspar have lower melting temperatures than those with simple structures like olivine, so I is false. An increase in silica concentration in magma is associated with increasing complexity of silicates, increasing viscosity - only II is true.

14. The following image shows an unusual weather system off the southern coast of Australia.



Identify all of the following statements that are likely true of this weather system:

- I) The system rotates counterclockwise at the surface.
- II) A 500 mbar isobaric map would show this region as high pressure.
- III) The lack of clouds in the center is due to adiabatic cooling.

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

Solution: The cloud-free center of the weather system reveals that air is likely sinking, since adiabatic warming would lower relative humidity—III must be false. Sinking air is indicative of convergence at a low pressure region aloft, making II false. In the southern hemisphere, surface highs rotate counterclockwise—I is true.

Refer to the following for questions 15–16: Marine ice sheet instability refers to a positive feedback loop that amplifies ice mass loss. It involves ice flow over the grounding line, which marks the interface between the ice sheet, bedrock, and ocean.

15. Which of the following best describes how a landward shift in the grounding line would change ice flux (the volumetric rate of ice flow) over it?

- A. Increased ice flux, since the ice sheet generally thickens landward.
- B. Decreased ice flux, since the ice sheet generally thickens landward.
- C. Increased ice flux, since the ice sheet generally thins landward.
- D. Decreased ice flux, since the ice sheet generally thins landward.

Solution: Since ice sheets tend to be thicker towards land, a landward shift of the grounding line corresponds to an increase in the thickness of overlying ice. The volumetric rate of ice passing over this new grounding zone increases with ice thickness, so as the grounding line moves inward, ice flux is greater.

16. Does a landward shift of the grounding line favor or work against this positive feedback loop?

- A. Favors
- B. Works against
- C. Neither for or against

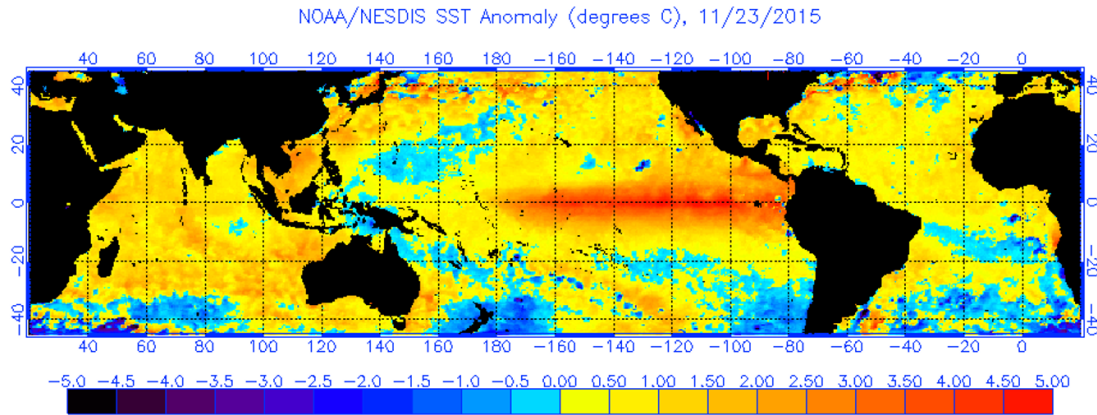
Solution: As noted in the first part of the question, landward shifts in the grounding line are related to increases in ice flux over the grounding line. This positive flux causes the ice sheet to lose mass, resulting in thinning and therefore reduced weight that allows the ice sheet to lift off from the bed at the grounding line, moving the grounding line further inland.

17. Kirkwood gaps in the asteroid belt are cleared by orbital resonances with Jupiter. Given that Jupiter is on average 5.20 AU from the sun, at which of the following distances would we be most likely to find a Kirkwood gap?

- A. 1.73 AU
- B. 2.50 AU
- C. 2.60 AU
- D. 2.88 AU
- E. 3.46 AU

Solution: Kirkwood gaps are expected to be found at fraction multiples of Jupiter's orbital period. By Kepler's third law we know that $T^2 \propto a^3$, hence, we can divide each answer choice by 5.20 AU, take the $3/2$ power, and look for simple fractions. We find that $\frac{2.50}{5.20}^{3/2} \approx \frac{1}{3}$, so the answer is **B**.

18. Consider the sea surface temperature anomaly map given.



During this time, a high surface air pressure anomaly is expected to be found in the _____ Pacific, and easterly trade winds are _____.

- A. Western; weaker
- B. Western; stronger
- C. Eastern; weaker
- D. Eastern; stronger

Solution: El Niño is characterized by anomalously warm sea surface temperatures in the tropical Eastern Pacific, where upwelling of colder water is limited by the weakened trade winds caused by the surface high (rather than the typical low) in the Western Pacific.

19. A sandstone enthusiast has an extensive collection of sandstones from all over the world, and decides to plot feldspar content against the range of grain size for each rock. One would expect to find:

- A. A positive correlation
- B. A negative correlation
- C. No significant correlation; negligible change in one variable
- D. No significant correlation; points scattered randomly

Solution: Higher feldspar content indicates minimal weathering of the sediment before it was deposited. Being poorly sorted is also typical of minimal transport and weathering. Thus, there is likely a relationship with increasing feldspar content and increasing grain size range.

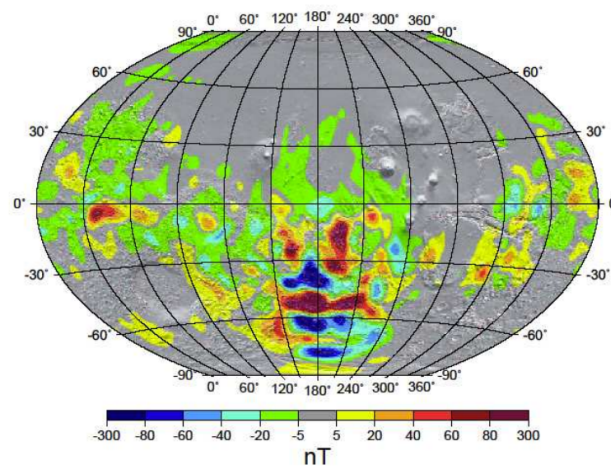
20. Alice Springs (latitude 24°S, longitude 134°E) is located in central Australia. Based on its location, which of the following can be reasonably inferred about the climate in Alice Springs?

- I) Daily temperature ranges are greater in Alice Springs than in coastal locations of Australia.
- II) June is typically wetter than December due to seasonal shifts in global winds.
- III) The prevailing wind direction is southwest.

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

Solution: Due to its location in the center of the continent, away from large bodies of water, and its proximity to a high-pressure belt around 30°S, Alice Springs typically experiences a dry climate. Since proximity to water and increased moisture in the air would moderate temperature variations, the lack of these would result in higher daily temperature ranges. The ITCZ, a belt of low pressure, shifts north of the equator during June and south during December, so the ITCZ is closer to Alice Springs during December, resulting in increased precipitation. According to the three-cell model of atmospheric circulation, prevailing winds between 0° and 30°S are southeast trade winds, since they blow towards lower pressure and are deflected towards the left in the Southern Hemisphere by the Coriolis effect.

21. Though Mars does not currently generate a magnetic field, parts of its crust are magnetized. The map shows the remanent magnetization present on Mars's surface.



Which of the following does the map suggest?

- I) The lack of magnetization in impact basins is attributed to large impacts and thermal events erasing preexisting remanent magnetization.
 - II) The northern lowlands are thought to have experienced sedimentary or volcanic resurfacing.
- A. I only
 - B. II only
 - C. I and II
 - D. None

Solution: The impact basins appear gray on the image, indicating little magnetic field due to large impacts. The Northern Plains also have little magnetic field as well, suggesting that new crust overlays the older magnetized crust. Similarly, sedimentary and volcanic resurfacing overlays the old magnetized crust in those areas. Thus choice **C** is the answer.

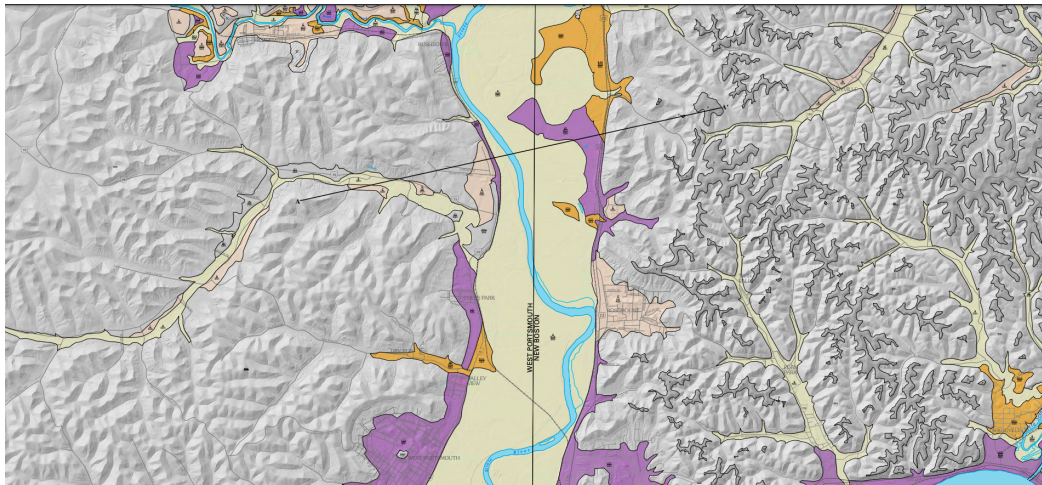
22. Which of the following statements about lake temperature are true?

- I) A temperate lake is typically most stratified during summer months.
- II) In winter, a dimictic lake is approximately isothermal and isopycnal.

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

Solution: Temperate lakes occur in the mid-latitudes, where increased solar radiation warms the uppermost layer of the lake to a higher temperature than underlying water - I is true. Dimictic lakes are stratified in the winter, and so density (which mainly depends on temperature for freshwater lakes) changes with depth - II is false.

23. Based on the geologic map shown, if large-scale glaciation occurred, which of the following would most likely happen?



- A. Increased deposition, hydrological cycle would slow down due to more water being in glaciers.
- B. Nickpoint created, forming a waterfall due to a layer of hard, durable rock.
- C. Lakes form and the river would have more meanders in order to adjust to the change in base level.
- D. River starts downcutting, which could lead to the meanders becoming incised.**

Solution: With glaciation, sea level drops due to significant storage of water in ice sheets. This leads to a decrease in the ultimate base level (sea level), then downcutting, which can create incised meanders and river terraces. Answer choices relating to deposition or meanders are incorrect because the river would have a higher gradient and thus higher velocity.

24. Although the fractions of silicon isotopes in diatoms is based on temperature, silica isotopic ratios are not as useful as oxygen isotopic ratios for paleoclimate proxies. Which of the following may explain this difference? (The atomic weight of Si is 28.086 and its major isotopes are ^{28}Si , ^{29}Si , ^{30}Si .)

- I) Isotopes other than ^{28}Si are too rare to be useful.

- II) There are varied sources of Si, which decreases the constraints Si isotopes can provide as a paleoclimate proxy, while the atmosphere provides a well-mixed, dominant source of oxygen in oxygen isotope proxies.
- III) Biogenic silica is mainly precipitated from diatom tests while oxygen isotope data may also use the tests of calcareous forams.

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

Solution: ^{29}Si and ^{30}Si are relatively common, given that the molar mass has a positive deviation from the expected mass of 28 from just ^{28}Si . Silicon from weathering and erosion brought to the ocean by rivers or as dust have different compositions from upwelled nutrients or silicon from hydrothermal vents. This is a significant issue since a change in isotopic ratios may also then be attributed to nutrient shifts. Diatoms deposit silica while forams deposit calcite. Both contain oxygen and so both can give oxygen isotope data, while only diatoms can yield silicon isotope data. This heavily restricts data sets to mostly around the Southern Ocean, where diatoms bloom regularly.

25. Jill digs a core and finds this order of rocks, from bottom to top: sandstone, shale, limestone, shale, sandstone. Why might this be the case?

- A. The sequence was formed between two interglacial periods separated by a glacial period.
- B. The sequence was formed between two glacial periods separated by an interglacial period.**
- C. The sequence was formed during the transition from a glacial to an interglacial period.
- D. The sequence was formed during the transition from an interglacial to a glacial period.

Solution: The relative energy of the depositional environment for sandstone is greater than shale, which is greater than limestone. Hence the sequence represents a deepening followed by a shallowing. This may occur as sea level rises during an interglacial period and subsequent fall during a glacial period.

Note: this question was not graded due to a wording error. The final release copy has been updated with the correct wording.

26. Which of these statements are true regarding winds and tropical cyclones (TCs)?

- I) Most TCs originate near the equator due to low pressure created by converging surface trade winds.
- II) Weak winds aloft and at the surface favor TC formation with all other favorable conditions present.
- III) Minimum central pressure more reliably predicts maximum TC wind speed than the pressure gradient within the eyewall.

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

Solution: TCs rarely form at or near the equator because the Coriolis force is very weak near the equator, limiting rotational wind patterns. Uniformly weak winds in the troposphere favors TC development as lack of vertical wind shear minimizes structural disruptions to the developing cyclone. Finally, wind is a consequence of pressure gradients, and wind speed is directly proportional to pressure gradient. While lower minimum central pressures correlate to some extent to stronger winds, this is due to the higher pressure gradients in the eyewall (where the most intense TC winds occur) rather than the absolute value of the minimum pressure.

27. Jerry found a meteorite that he identifies to be an iron meteorite due to its high density and metallic luster once cut open. Which of the following would NOT be expected of this iron meteorite?

- I) It contains many vesicles and vugs.
 - II) There are shallow indentations on unweathered surfaces indicative of ablation.
 - III) The meteorite is nonmagnetic due to a thick fusion crust.
- A. I only
 - B. III only
 - C. I, II, and III
 - D. I and II
 - E. I and III**

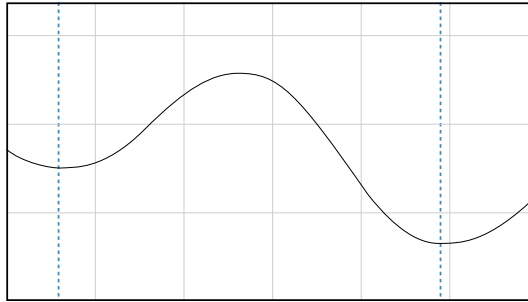
Solution: Vesicles, vugs, and amygdules indicate high gas content, which is indicative of terrestrial rather than meteorite origins. Ablation occurs as a meteorite begins its descent into the atmosphere; these form regmaglypts (the shallow indentations) and a fusion crust. Most meteorites tend to be magnetic since they contain metallic iron, which the fusion crust does not affect significantly.

28. A planet's equilibrium temperature is the temperature that it would have if it were a blackbody radiating away all incident energy absorbed from its parent star. Earth's equilibrium temperature is about 255 K (about -18 °C), but average global surface air temperature (GSAT) is about 290 K (about 12 °C). What primarily accounts for this discrepancy?

- A. Equilibrium temperature fails to account for the Earth's albedo.
- B. Greenhouse gases re-radiate outgoing radiation back to the surface.**
- C. The average global ground temperature, unlike average GSAT, is much closer to the equilibrium temperature.
- D. Earth also receives energy from other stars outside of the solar system.

Solution: The equilibrium temperature is calculated from *absorbed* radiation, which already accounts for reflected radiation. The surface air temperature is affected by the presence of an atmosphere, which contains greenhouse gases that reradiate energy back to the surface—this is the primary reason for why Earth's average GSAT is considerably greater than its equilibrium temperature.

29. A harbor experiences a mixed semidiurnal tide, shown below. Two low tides are marked with dashed lines.

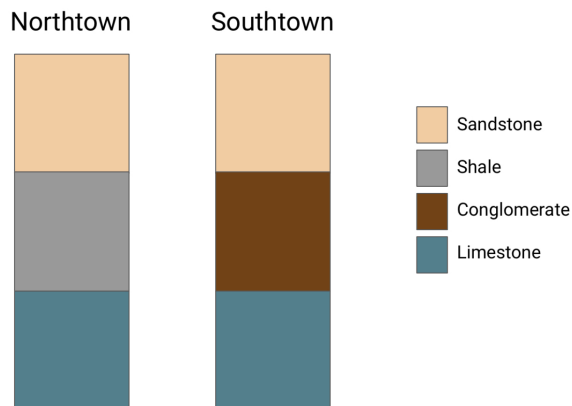


If the first low tide occurs on Tuesday at 1:50 PM, at what time does the second low tide occur?

- A. Wednesday at 1:50 AM
- B. Wednesday at 2:15 AM**
- C. Wednesday at 1:50 PM
- D. Wednesday at 2:15 PM
- E. Wednesday at 2:40 PM

Solution: The period of a semidiurnal tide is 12 hr 25 min.

30. Shown below are stratigraphic columns for the coastal towns Northtown and Southtown. Assume they are the same distance from the coast.



Which of these can be inferred from the columns above?

- I) In both columns, groundwater in sandstone is less saline than groundwater in limestone.
- II) The column at Northtown contains a confined aquifer.
- III) The column at Southtown contains a confined aquifer.

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

Solution: Because saltwater is more dense than freshwater, saltwater is located beneath freshwater in coastal areas. In the Northtown column, shale has a relatively low permeability, so it acts as a confining bed above the limestone, which is a confined aquifer. In the Southtown column, conglomerate has a relatively high permeability. Sandstone also has a relatively high permeability, so groundwater from the surface can infiltrate rather easily into the limestone, which is not a confined aquifer.