USESO 2022

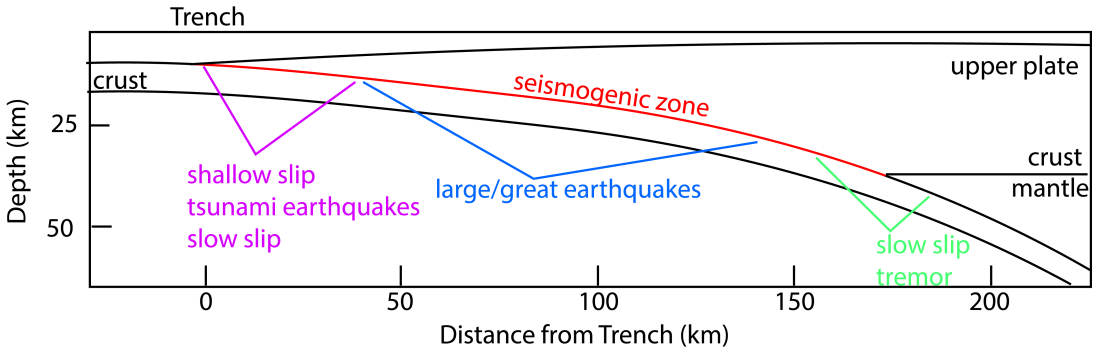
Geosphere

Instructions:

- Section I consists of 10 multiple choice questions, with each question worth 2 points. There is only one correct option on multiple choice questions
- Section II consists of 2 multipart free response questions
- A calculator is allowed; show all work for calculations unless otherwise stated
- Recommended time management: 30 minutes on each section

Section I

1. Almost all high-magnitude earthquakes occur at megathrust faults, and their significant displacement means they have a high likelihood of generating tsunamis. The strongest earthquakes occur with greater seismic coupling (i.e. high friction); faults slip slowly and aseismically where seismic coupling is weaker.



(Bilek et al., 2018)

Increasing which of the following would make strong megathrust earthquakes more likely?

I) Increasing the age of the subducting slab

II) Increasing the convergence rate of the subduction zone

III) Increasing fluid pressure at the subduction zone

A. II only

B. III only

C. I and II

D. II and III

E. None

2. Below are three sedimentary structures. Which of the following corresponds to the likely directions of the currents that produced each?

A. Right, right, left

B. Right, left, right

C. Left, left, right

D. Left, right, left

E. Left, right, right

3. Most modern coal formed in wetlands after a global glaciation. Which of the following are effects of glaciation that lead to coal-forming conditions?

I) Newly exposed continental shelf led to the formation of more wetlands.

II) Lower water availability prevented plant matter from decomposing.

III) Lower temperatures led to slower biodegradation.

A. I only

B. II only

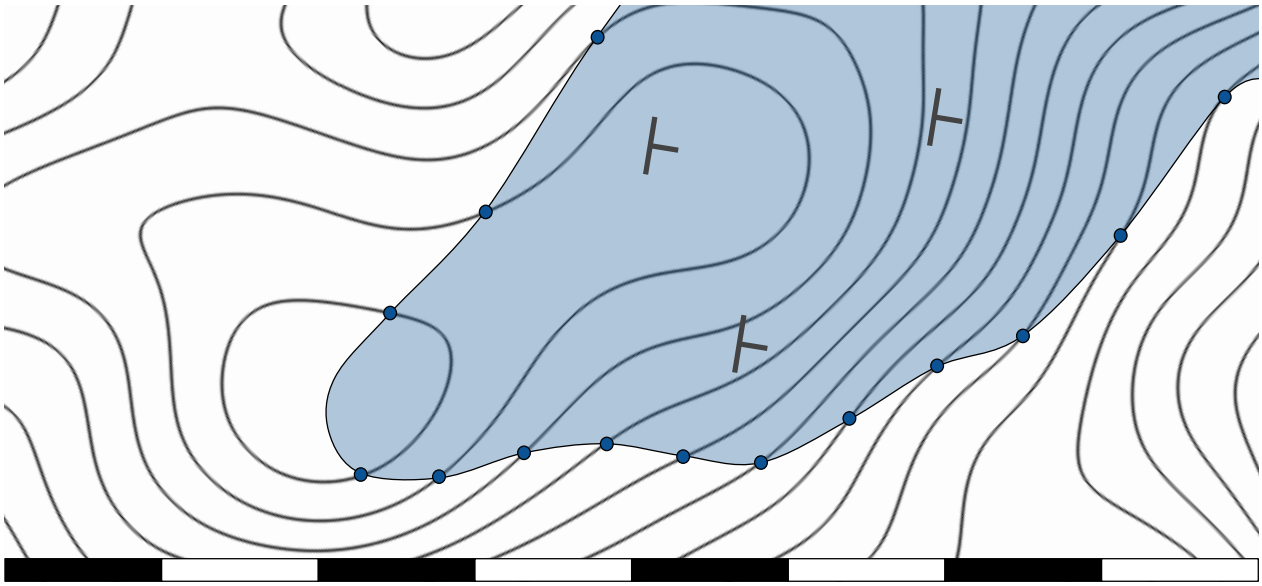
C. III only

D. II and III

E. I, II, and III

F. None

4. Consider the contour map below. The contour interval of the map is 10 m, and each rectangular bar on the bottom the image is 100 m. The border of the shaded region shows the area where a uniform planar bed has been exposed by weathering. The strike at any point on the bed is N10E.



Which of the following is closest to the dip angle of this bed?

A. 2°

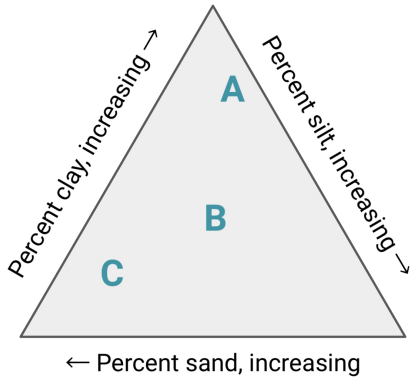
B. 6°

C. 11°

D. 22°

E. 32°

5. Consider the simplified soil texture triangle shown below. The letters A, B, and C represent the compositions of three different soil samples.



Which of the following is/are true of these samples?

I) Of the three soil samples, soil A is best suited for plants requiring high soil moisture.

II) Of the three soil samples, soil B is most likely to be found in a low-energy depositional environment .

III) If soil B is subjected to wind erosion, the resulting soil composition would be closer to soil C.

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

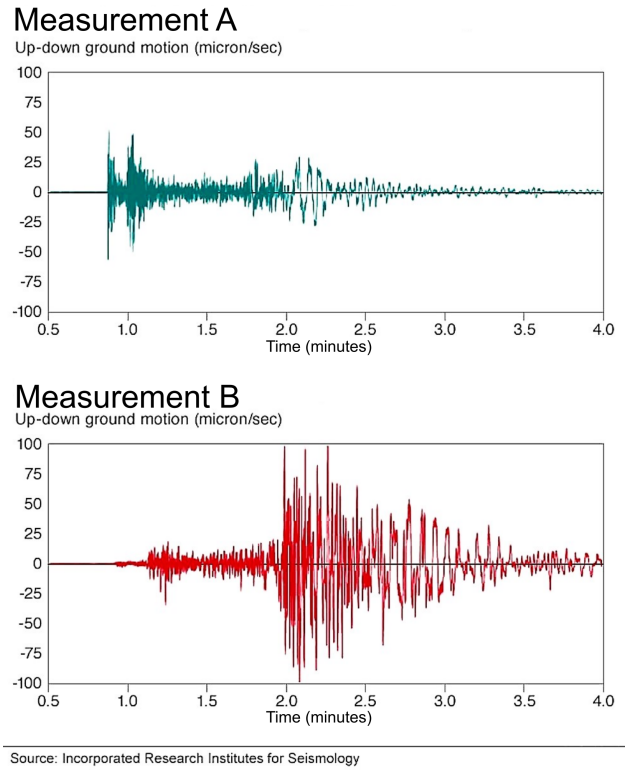
6. Even though metamorphic reactions are reversible in theory, retrograde metamorphism is rarely observed. Which of the following may explain this?

I) Reactions between solid phases are typically slow and require a catalytic fluid to proceed.

II) Slow uplift to the surface allows the rock to equilibrate to surface conditions.

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

7. The following image shows two seismograms, one of a nuclear test and one of an earthquake. Which of the following correctly identifies the earthquake and gives the best evidence to support the claim?



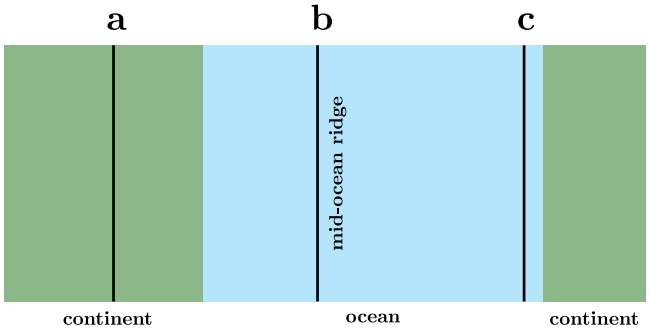
A. Measurement A is the earthquake, as evidenced by the clear gap between the arrival times of P and S waves at 0.8 and 1 minute respectively.

B. Measurement A is the earthquake, as evidenced by the much greater magnitude of P and S waves as compared to the surface waves.

C. Measurement B is the earthquake, as evidenced by the clear gap between the arrival times of P and S waves at approximately 1.1 and 1.9 minutes respectively.

D. Measurement B is the earthquake, as evidenced by the sudden increase in magnitude at the arrival of the surface waves after the arrival of P and S waves.

8. Terranes are crustal fragments that are transported across ocean basins and accrete onto the margins of continents. The figure below shows continental crust (green), oceanic crust (blue), and three tectonic boundaries labeled A, B, and C. Boundary B is a mid-ocean ridge. Boundaries A and C are either rifting or subduction zones. For continental crust fragment on the left to eventually accrete onto the continent on the right, which of the following conditions must be true?



I) Boundary A is an extensional environment.

II) The rate of rifting/subduction of Boundary A exceeds that of Boundary B.

III) The rate of rifting/subduction of Boundary C exceeds that of Boundary B.

A. II only

B. III only

C. I and II

D. I and III

9. Which of the following sets of features is associated with continental margins that contain accreted terranes?

A. Uplift and earthquakes

B. Uplift and coastal aquifers

C. Subsidence and flooded valleys

D. Subsidence and marine terraces

10. The marine organisms are better recorded in the fossil record than terrestrial organisms. Which of the following about marine environments provides the best explanation?

A. Oceanic lithosphere is younger on average compared to continental lithosphere.

B. Deep sea sediments accumulate more slowly than alluvial sediments.

C. Marine environments more readily form calcareous deposits.

D. Marine deposits are exposed to less wind and running water.

Section II: Problem 1

Question	1	2	3	4	Total
Points	3	7	2	3	15 (30%)

The chemical weathering of silicate minerals plays an important role in regulating the carbon cycle, thereby affecting other Earth systems. In this problem we will consider the impacts of silicate weathering on oceans, and on geologic timescales, the climate.

While uncommon, wollastonite ($CaSiO_3$) is a simple mineral that exemplifies a pattern of silicate weathering. The chemical equation for this weathering is as follows:

$$2\,H_2O + CO_2 + CaSiO_3 \longrightarrow 2\,HCO_3^- + Ca^{2+} + SiO_2$$

1. (a) (1 point) The carbon produced from silicate weathering is transported into the ocean. Marine organisms cannot use the bicarbonate produced directly from weathering, yet are able to incorporate the carbon into calcium carbonate. What chemical change must bicarbonate undergo?

   (b) (2 points) A signficant amount carbon dioxide produced by human activity enters the ocean, where it reacts with water to form carbonic acid (H_2CO_3). How might an increase in carbonic acid inhibit the reaction that forms calcium carbonate as described in part (a)?

2. (a) (2 points) Consider a hypothetical scenario in which strengthened mantle convection increases the spreading rate at a mid-ocean ridge. Briefly explain how faster seafloor spreading would likely affect the average global temperature.

   (b) (3 points) Explain how the effect of seafloor spreading on climate in part (a) is connected to the carbonate-silicate cycle.

   (c) (2 points) The strengthening of mantle convection also increases the rate of subduction, resulting in larger mountain ranges and island arcs. What effect does this have on climate? Briefly explain.

3. (a) (1 point) The most important aspect of the carbonate-silicate cycle is its dependence on global temperature. Suppose that human CO_2 emissions increase Earth's temperature significantly and last long enough to affect geologic processes. Describe how the weathering of silicates would change in rate in response to anthropogenic warming.

   (b) (1 point) On long timescales, what kind of feedback is exhibited by the temperature dependence of silicate weathering?

   A. Positive

   B. Negative

   C. Both positive and negative

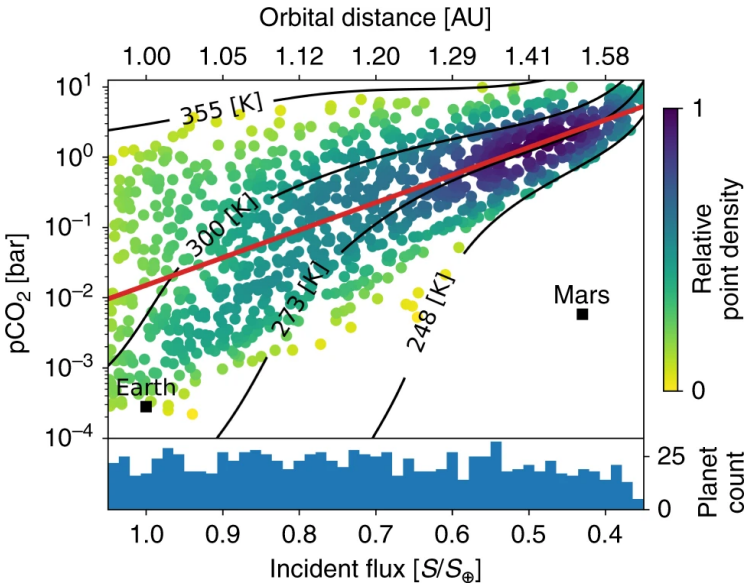


Figure 1: Expected distribution of Earth-like exoplanets in pCO_2 and orbital distance. (Lehmer et al., 2020)

4. (3 points) In Earth's infancy, the Sun was likely only about 70% as bright as it is now. All else the same, Earth would have been too cold to sustain a liquid ocean at a temperature of about 248 K. However, there is strong evidence for the presence of oceans during this time, indicating that Earth had a much stronger greenhouse effect than today. Explain how the carbonate-silicate cycle could have played a role in keeping Earth's temperature more consistent throughout its evolution.

Section II: Problem 2

Question	1	2	3	4	5	6	7	Total
Points	4	2	1	2	2	1	3	15 (30%)

The Himalayas form the longest mountain range in Asia. This problem explores its crustal deformation in a cross section and the Main Himalayan Thrust.

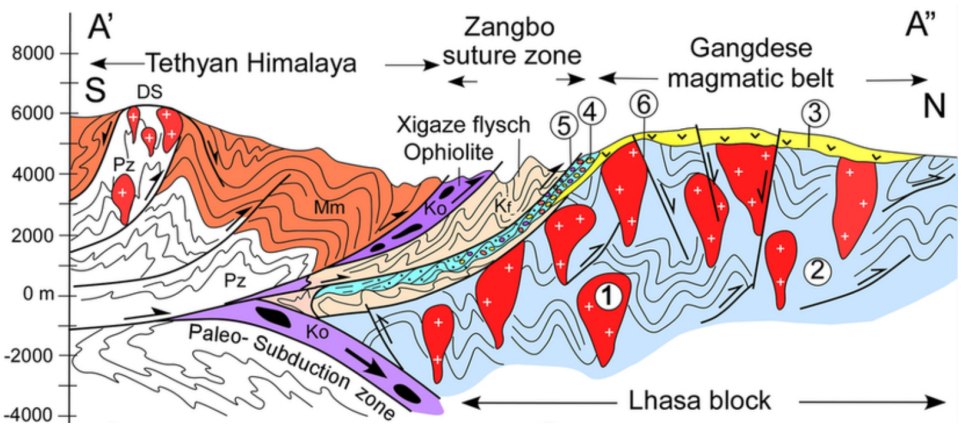


Figure 1: Cross section of Himalayas. (Wang et al., 2015)

1. (a) (2 points) Contemporary sinking near the Zangbo suture zone is causing the Gangdese magmatic belt to rise. Explain how this motion is an example of isostatic adjustment.

   (b) (2 points) Within the Zangbo suture zone is flysch composed of folded units that transition from turbidites to dark shales to coarse fluvial deposits. Describe the changes in depositional environment reflected in this flysch in relation to the collision of the Indian subcontinent with Asia.

2. (2 points) Around 20 million years ago, monsoons around the Himalayas intensified. How might this have affected the vertical movement of the Himalayas?

3. (1 point) A geologist finds pillow basalt in the Himalayas. In which region(s) of this cross-section could the geologist potentially be in?

   I) Tethyan Himalayas

   II) Zangbo Suture Zone

   III) Gangdese Magmatic Belt

   A. I only

   B. II only

   C. III only

   D. I and III

   E. None

4. (2 points) Some of the Tethyan Himalaya is strongly folded but is only weakly metamorphosed. How can igneous intrusions create these conditions?

5. (2 points) Some of the igneous rocks in the Gangdese magmatic belt are derived from basaltic melts. Meanwhile, the yellow unit on surface has a different composition from the rest of the belt. Briefly explain the process that created the yellow unit.

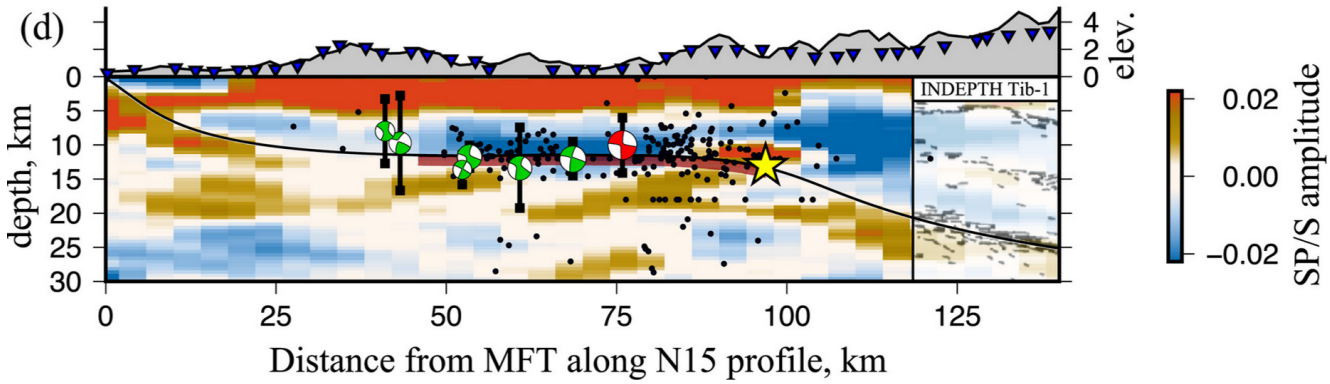


Figure 2: The Main Himalayan Thrust, a basal detachment fault, (Duputel et al., 2016)

6. (1 point) Relative to the bottom half of the image, towards what direction is the top half of the image moving?

   A. Right

   B. Left

   C. Neither

7. (a) (2 points) At depths between 10-15 km is a low-velocity zone, an area of anomalously slow seismic wave velocity that may be caused by the introduction of water. Describe two mechanisms that explain how subducted material acts as a source of water to the mantle.

   (b) (1 point) Another low-velocity zone is present deeper in the mantle. This structure is thought to be a result of which of the following phenomena?

   A. Volatiles at depth

   B. Partial melting

   C. Metamorphism

   D. Faulting