

USESO 2021 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 non-graphing, non-programmable calculator is allowed; show all work for calculations
- Recommended time management: 30 minutes on each section

Section I

1. (2 points) You discover a planar vein of quartz exposed from a perfectly vertical roadcut on flat ground, as shown in the figure below. The thickness on the ground is 0.25 m, while the thickness on the wall is 0.40 m.



Which of the following is closest to the true thickness, in meters?

- A. 0.05 m
- B. 0.10 m
- C. 0.15 m
- D. 0.20 m
- E. $0.25~\mathrm{m}$
- 2. (2 points) Bouguer gravity anomaly profiles can be used to study geologic structures by detecting underground density variations. Positive anomalies occur in regions where density is relatively high compared to surrounding country rock, while negative anomalies occur in regions where density is relatively low.



Assuming any hanging walls are **left** of center, match the above Bouguer gravity profiles to their corresponding structure.

- A. 1 normal fault, 2 mafic dike, 3 reverse fault, 4 sedimentary basin
- B. 1 reverse fault, 2 mafic dike, 3 normal fault, 4 sedimentary basin
- C. 1 normal fault, 2 sedimentary basin, 3 reverse fault, 4 mafic dike
- D. 1 reverse fault, 2 sedimentary basin, 3 normal fault, 4 mafic dike
- E. 1 mafic dike, 2 sedimentary basin, 3 reverse fault, 4 normal fault

- 3. (2 points) Which of the following is consistent with a tectonic environment in which very old oceanic crust subducts under an island arc?
 - A. A relatively narrow forearc basin and a steeply-dipping Wadati-Benioff seismic zone
 - B. A relatively narrow forearc basin and an abundance of granulite facies
 - C. A relatively wide forearc basin and back-arc compression
 - D. A shallow-dipping Wadati-Benioff seismic zone and an abundance of granulite facies
 - E. A shallow-dipping Wadati-Benioff seismic zone and back-arc extension
 - F. A steeply-dipping Wadati-Benioff seismic zone and back-arc compression
- 4. (2 points) Geosphere dynamics may affect climate in interesting ways. Which of the following is **not** true about the interaction of the geosphere with the global climate?
 - I) Greenhouse climates tend to be associated with faster mid-ocean ridge spreading rates than icehouse climates
 - II) The eruption of supervolcances like Yellowstone initially cools the planet
 - III) The weathering of silicates is a net carbon sink
 - A. I only
 - B. II only
 - C. III only
 - D. II and III
 - E. I, II, and III
 - F. None
- 5. (2 points) Which of the following tectonic environments is most likely depicted by the geotherm and solidus curves shown below?



Temperature

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

Refer to the figure below for questions 6 and 7. The figure below divides Earth's surface into three regions according to the seismic waves (or lack thereof) that are observed in each after an earthquake. Note: the arrow points to a portion of region Y seen on the other side of the globe.



- 6. (2 points) Where, approximately, did this earthquake most likely occur?
 - A. Southeast Asia
 - B. Off the coast of South America
 - C. Near the Mediterranean
 - D. The North Pole
 - E. The South Pole

7. (2 points) Consider if the radius of the outer core was increased. Which of the following would be true?

- I) Only P-waves would be observed in Y
- II) Y would move towards X
- III) Surface waves would be observed in Z
- IV) Z would expand
 - A. I only
 - B. II only
 - C. I and III
 - D. II and IV
 - E. II, III, and IV

8. (2 points) Three drill cores, each of 800 m depth, are drilled in a line, each spaced 200 meters apart. The width of each core can be neglected. Let δ represent the true dip. Assume no overturning unless otherwise stated.



Different geologic beds are denoted as different colors and are labeled A-G.

- (a) Which of the following best describes the structure immediately surrounding the fault?
 - A. Rightward dipping planar beds
 - B. A syncline above the fault plane with an anticline below the fault plane
 - C. A single syncline split by the fault
 - D. An anticline above the fault plane with a syncline below the fault plane
- (b) Which of the following most accurately describes the fault?
 - A. A normal fault with $\delta \geq 69.4$ degrees
 - B. A normal fault with $\delta \leq 20.6$ degrees
 - C. A normal fault with $\delta = 20.6$ degrees
 - D. A reverse fault with $\delta \geq 69.4$ degrees
 - E. A thrust fault with $\delta \leq 20.6$ degrees
 - F. A thrust fault with $\delta = 20.6$ degrees

9. (2 points) The figure below shows the multibeam bathymetry of Astoria Canyon, a structure off the Northwest Coast of the United States.



Based on the tectonic and depositional setting, which of the following best describes the sandstone found in Astoria Canyon?

- A. Greater than 25 percent feldspar, poorly sorted, angular grains
- B. Almost entirely composed of quartz, well sorted, rounded grains
- C. Greenish color from abundant glauconite mica and other clay minerals, fossil-rich, rounded grains
- D. Mostly carbonate mineral grains and calcareous shell fragments cemented together
- E. Angular quartz grains, feldspar grains and rock fragments surrounded by a clay matrix, poorly sorted
- 10. (2 points) Which of the following is **false** regarding contact metamorphism around an igneous intrusion?
 - A. The contact aureole commonly exhibits granoblastic texture
 - B. Metamorphic grade decreases with increasing distance from the intrusion
 - C. As the magma's latent heat of crystallization increases, contact aureole size decreases
 - D. Assuming the intrusion is below the water table, higher country rock permeability allows for greater rates of heat transfer
 - E. None of the above (All of the statements are true)

Section II: Problem 1

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

Deltas are fascinating environments at the land-water interface to study. Occurring throughout the world, their diverse morphologies uniquely reflect the interplay of terrestrial, hydrologic, and climatic processes on multiple scales.

- 1. (1 point) In the most fundamental sense, deltas exist because rivers deposit their sediment load where they meet a larger body of water. Within a deltaic setting, which of the following is deposition best attributed to?
 - A. Decrease in competence as fast-moving river water slows
 - B. Frequent delta switching as distributaries form more stable paths
 - C. Lower capacity from the river splitting into distributaries
 - D. Shallower grade creating more resistance to river flow
 - E. Point of maximum discharge located at the river mouth



Figure 1 (left): Stratigraphic column labeled A-E representing a set of generic deltaic deposits. Figure 2 (right): An overhead view of the present delta from which the column in Figure 1 represents. Distinct deltaic and surrounding depositional regions are labeled 1-5. Note that 1-2 are above water while 3-5 are below water.

2. (a) (2 points) Match each letter (A-E) in Figure 1 to *one* of the regions numbered 1-5 in Figure 2. Each number may be used more than once or not at all.

(b) (3 points) The degree of mixing between river outflow and the larger body of water depends partly on the density contrast of the two waters. If the density contrast was increased while all other factors remain constant, explain why the area of region 4 in Figure 2 might expand outwards.

In your answer, be sure to consider the following: Would a higher density contrast increase or decrease mixing? How does mixing affect flow velocity? How is flow velocity related to deposition?

- 3. (2 points) Rivers are often the most significant source of sediment at shorelines. Select all of the following that accurately describe the general relationship between sedimentation and passive margins. (*)
 - A. Regions of nondeposition are being uplifted because of isostatic adjustment
 - B. Delta-derived sediments are currently widening continental shelves
 - C. Erosion and deposition balance in deltas as passive margins increase in age
 - D. Much of the sediment output is captured by oceanic trenches parallel to shore
 - E. Relatively cool oceanic lithosphere tends to create sedimentary basins
 - F. Sediment accumulation results in lithospheric subsidence



Figure 3: Sea level curve for the last 240,000 years.

- 4. (a) (3 points) Assuming that the course of the river remains unchanged, what is a reasonable location of its delta active approximately 15,000 years ago *relative* to the presently active delta? Answer in terms of the horizontal (landwards/seawards) and vertical dimensions (higher/lower elevation). Provide a justification for this shift in location using the sea level curve in Figure 3.
 - (b) Depositional sequences often preserve incised valleys where rivers and distributaries downcut in the past.
 - i. (2 points) Choosing from A-D, from which time would one *least* expect to observe valleys being incised? Briefly explain.
 - ii. (2 points) In one sequence of a particular locality, a stratigrapher finds incised valleys that correlate to this time interval. Propose *one* physical process that accounts for evidence of downcutting. Give your reasoning for this apparent contradiction.

Section II: Problem 2

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

Baekdusan (Chinese: Changbaishan, $\underline{\mathsf{K}} \dot{\boxminus} \underline{\mathsf{U}}$) is a large active stratovolcano on the China-North Korea border. Explaining its volcanism has proved to be quite enigmatic: it appears to be intraplate, there are no geochemical signs of flux melting, and there is no seismic signature of a deep mantle plume (hotspot).



Figure 1: (a) Backdusan as viewed from space; its caldera lake is covered with ice in the picture. (b) Tang et al. model of Northeast China intraplate volcanism.

- 1. One model is given by Tang et al. (2014), where a gap in the subducted Pacific plate has led to mantle upwelling and decompression melting.
 - (a) (2 points) Why does the subducted slab flatten out at 660 km?
 - (b) (2 points) Geochemical evidence has shown that magmatism at Baekdusan is associated with the partial melting of clinopyroxene-rich eclogite. What does this suggest about the upwelling in the Tang et al. model?

Jeju Island, a nearby volcanic island in the East China Sea, tells a different story.



Figure 2: subsurface stratigraphy of Jeju Island. Monogenetic scoria cones are small vents that form from a single eruption. Letters A and B denote rocks generated by two separate stages of volcanism.

- 2. (a) (2 points) Jeju Island is a ______volcano generated from _____
 - A. Shield; a hot-spot
 - B. Shield; subduction of the Pacific plate
 - C. Composite; a hot-spot
 - D. Composite; subduction of the Pacific plate
 - (b) (2 points) The lava flows on Jeju Island are mostly composed of a plagioclase clinopyroxene phyric (i.e., phenocryst-bearing) basalt. Briefly discuss what the presence of phenocrysts indicates about the cooling history of the basalts.
 - (c) (1 point) The eustatic sea level during the petrogenesis of B was ______than now.
 - A. Higher
 - B. Lower
 - C. Not enough information
 - (d) (2 points) Justify the above answer.

- 3. The most common volcanism on Earth happens out of sight, deep in the oceans. Ophiolites, remnants of oceanic lithosphere that have been emplaced onto land, allow us to study mid ocean ridge volcanism in more detail. Obduction is one mechanism by which ophiolites are displaced onto land, where compressive forces thrust the ocean floor onto continental crust.
 - (a) (2 points) Which of the following is true about ophiolites?
 - I) Obduction occurs more commonly for young oceanic crust than for old oceanic crust
 - II) Obducted mantle peridotite is usually enriched in incompatible elements
 - III) Ophiolites are often heavily metamorphosed
 - A. I only
 - B. II only
 - C. III only
 - D. II and III
 - E. I and III
 - F. I, II, and III
 - (b) (2 points) Briefly discuss how variation in the global mean spreading rate at mid-ocean ridges can cause variation in the eustatic sea level.

END OF EXAM