The 18th International Earth Science Olympiad

Individual Theoretical Test Part 2

ID Number:

Answer Sheet (Do Not Detach)

45	46	47	48	49
50	51	52	53	54
55	56	57	58	59
60	61	62	63	64
65	66	67	68	69
70	71	72	73	74
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80	81	82	83	84

Do NOT open the test paper until the invigilator announces the start of the test.

Test Instructions

1. **Exam Duration**: The total duration of part 2 is **150 minutes**. Once the exam ends, you must **stop writing immediately** and wait for the test papers to be collected.
2. **Answer Submission**:
   - All answers must be transferred to the corresponding numbered boxes on the **cover page**. **Do not exceed the borders** of the answer area.
   - Only the **uppercase letter** (A, B, C, etc.) of the correct option should be filled in.
   - Even if you mark the correct answer beside the question, you will **NOT** receive any points unless it is copied onto the cover page.
   - If you need to modify an answer, **draw a single line through the original answer** and write the new one in the designated box (e.g., ~~ABC~~ AB).

Section G: Rocks and the earth systems

Question 45:

An ophiolite complex in a mountain belt has been studied by a group of geologists. The sequence includes (from bottom to top): serpentinized peridotite, layered gabbro, a dense zone of vertical mafic dikes, massive and pillow basalts, and radiolarian chert. The complex is tectonically emplaced onto continental crust. Nearby, metamorphosed sediments and blueschist-facies rocks are also observed.

Based on the full rock sequence described above, what can be reasonably inferred about the tectonic history of this region? (multiple correct answers)

A. The area once experienced active seafloor spreading.
B. The sequence likely formed in a subduction zone environment.
C. The ophiolite was uplifted through continental rifting.
D. The oceanic crust was thrust onto the continent during plate convergence.
E. The sequence formed terrestrially and subsequently submerged beneath the ocean.

Question 46:

Geochemical analysis of the ultramafic rocks at the base of an ophiolite suite reveals two important features:

- A high magnesium-to-iron (Mg/Fe) ratio, meaning there is more magnesium relative to iron than in typical mantle rocks.
- Very low concentrations of incompatible elements, such as potassium (K), barium (Ba), and cerium (Ce).

Note:

- During partial melting of the mantle, incompatible elements tend to enter the melt rather than stay in the solid phase.
- Iron (Fe) is more incompatible than magnesium (Mg).

Based on this information, which of the following interpretations is most reasonable? (multiple correct answers)

A. The rocks represent primitive mantle material that has not undergone melting.
B. The rocks were formed from a magma enriched in incompatible elements.
C. The rocks are residues left behind after partial melting of the upper mantle.

D. The rocks are likely associated with the formation of new oceanic crust at a mid-ocean ridge.

Question 47:

Suppose a fossil assemblage from the radiolarian chert layer at the top of the ophiolite is dated to ~160 million years ago (Jurassic).

What geological conclusion is most strongly supported by this data? (multiple correct answers)

A. The ophiolite was formed in or before the Jurassic at a mid-ocean ridge.

B. The entire ophiolite complex was emplaced onto the continent during the Jurassic.

C. The ocean floor above the ophiolite was still active until the end of the Jurassic.

D. The age of radiolarians gives the most recent time of ophiolite formation and not necessarily its emplacement.

Question 48:

Pillow basalts are commonly found at the top of well-preserved ophiolite sequences. These bulbous, rounded volcanic rocks form when magma erupts underwater and cools rapidly. In many pillow basalts, scientists also find evidence of hydrothermal alteration, including the presence of secondary minerals like chlorite and epidote, as well as chemical changes such as increased water content and mobility of certain elements.

Which of the following statements best explain the role of water-rock interaction during and after the formation of pillow basalts? (multiple correct answers)

A. Rapid cooling by seawater causes the outer surface of the lava to solidify, creating the round "pillow" shape.

B. Cold seawater infiltrates hot volcanic rocks, leading to chemical alteration and the formation of new minerals.

C. Water–rock interaction is only possible if the basalts are exposed to the atmosphere, not underwater.

D. Pillow basalts are typically formed in deep continental basins where groundwater replaces seawater.

Section H: The rock telling the story

You are analyzing a wind-blown sedimentary profile exposed in a region of northern China, near the Loess Plateau, an area known for its significant deposits of loess and sand dunes. Loess is a fine-grained, wind-blown deposit.

The profile contains several layers, each reflecting different periods of windy and moisture conditions. Your goal is to use the information in the profile to reconstruct the paleoclimate and environmental conditions at the time of deposition.

Question 49:

You are analyzing the lowermost layer of the wind-blown sediment profile. This layer consists of well-sorted, fine-grained sand with cross-bedding and well-rounded grains, indicating long-distance transportation. Overlying this layer is a thin loess layer containing fine particles, including silt and clay.

What does this suggest about the environmental conditions during the time of deposition? (single correct answer)

A. The region experienced strong winds with dry conditions during the deposition of sand, followed by a change in conditions that allowed for the deposition of loess

B. The region was humid with consistent rainfall, leading to the deposition of both sand and loess

C. The region was subject to tectonic instability, which caused both wind erosion and deposition of finer particles

D. The region was constantly cold with little to no moisture, which prevented the formation of loess

Question 50:

A middle layer in the profile consists of fine silt, with some layers showing calcareous cementation and evidence of bioturbation (plant root traces).

What can be inferred about the past environmental conditions? (single correct answer)

A. The region was consistently humid with frequent rainfall and plant growth.

B. The region was semi-arid, with periodic wet conditions allowing for soil formation and biological activity.

C. The region had stable, dry conditions, allowing only wind-driven deposition of fine particles.

D. The region was subject to frequent glaciation, which prevented the establishment of vegetation.

Question 51:

In the upper part of the profile, you find a transition from fine loess to coarse sand with well-developed cross-bedding. The grain size becomes more heterogeneous with occasional gravel layers.

What does this change suggest about the climate conditions at the time of deposition? (single correct answer)

A. The region transitioned from a humid environment to a more arid one, with decreased wind strength and coarser sediment deposition

B. The region became more humid, with frequent rainfalls leading to coarse sand deposition
C. The region was subject to tectonic uplift, which caused the coarsening of the sediments
D. The region experienced intense seasonal variations, with alternating periods of wet and dry conditions that caused grain size fluctuations

Question 52:
Further up in the profile, you find evidence of biological activity in the form of microfossils and plant root traces. This suggests a change in the environmental conditions.
Which of the following is the most plausible interpretation of these observations? (single correct answer)

A. The region transitioned to a more humid environment, where vegetation could establish and biological activity could occur
B. The region remained arid, but biological activity was still present during rare wet events
C. The region was cold and dry, preventing the establishment of vegetation but allowing for the preservation of microfossils
D. The region was subject to frequent disturbances, such as volcanic eruptions, which allowed plant roots to grow temporarily

Question 53:
Based on your analysis of the entire sediment profile, what can you deduce about the paleoclimate of the region during the time of deposition? (single correct answer)

A. The region experienced constant dry conditions, with little seasonal variation, and mostly wind-blown sand deposition
B. The region underwent alternating wet and dry conditions, with seasonal changes in wind strength and moisture availability
C. The region had a stable humid climate, with consistent rainfall and little wind influence
D. The region was characterized by intense seasonal flooding, which prevented the formation of wind-blown sediments

Section I: The hydrosphere and the earth systems

Students are recommended to read the following questions on the next page for the section FIRST, and then return to this information.

Figure I-1 describes eight landscapes of China marked A-H. China spans nearly 5,000 kilometers from west to east and hosts one of the most complex and varied physical geographies on Earth. Its landscape is characterized by a dramatic west-to-east elevation gradient. Towering mountain ranges and high plateaus dominate the western regions, while the terrain steps downward through basins and river valleys into low-lying plains and coastal zones in the east. This topographic structure—often described as "three steps"—is the result of long-term tectonic uplift, erosion, and sedimentary processes.

The westernmost regions consist of high-altitude deserts and enclosed basins (Regions A and B). These areas experience extremely dry conditions, with minimal rainfall and strong winds that shape sand dunes and deposit fine dust. Some of the basins in this zone have no outlet to the ocean; water collects temporarily and evaporates, often leaving behind salt flats or saline lakes.

To the south lies a vast highland plateau (Region C), the highest and largest of its kind on Earth. Its glaciers and snowfields give rise to many of Asia’s great rivers, including the Yangtze, Yellow, Mekong, and Yarlung Tsangpo. These rivers carve deep valleys into the plateau and carry sediment eastward through lower elevation regions. In some of these valleys (Region F), rapid erosion and tectonic uplift combine to produce rugged terrain and chaotic sedimentation patterns.

Moving eastward, a large mid-latitude plateau contains some of the thickest known deposits of wind-blown dust (Region D). This region, influenced by strong winter monsoons, accumulated loess sediments over thousands of years. Farther east, vast alluvial plains and deltas (Regions E and G) have developed at the mouths of major river systems, where sediment is deposited as river velocity decreases upon reaching the coast. These areas are shaped by fluvial, tidal, and wave-driven processes.

In the south and southeast, a subtropical to tropical climate prevails. Here, heavy summer rainfall, warm temperature, and marine influences produce diverse environments, including lowland river valleys, humid coastal plains, and shallow reef-fringed island systems (Region H). In some offshore zones, biological activity such as coral growth contributes directly to sediment formation in the form of carbonate reefs and lagoons.

Throughout these regions, sedimentation patterns are controlled by interactions among the Earth's spheres: atmospheric circulation, water flow, tectonic processes, and biological productivity. By analyzing the topographic map and applying your understanding of Earth system science, you will identify how different environments correspond to specific types of sedimentary processes.

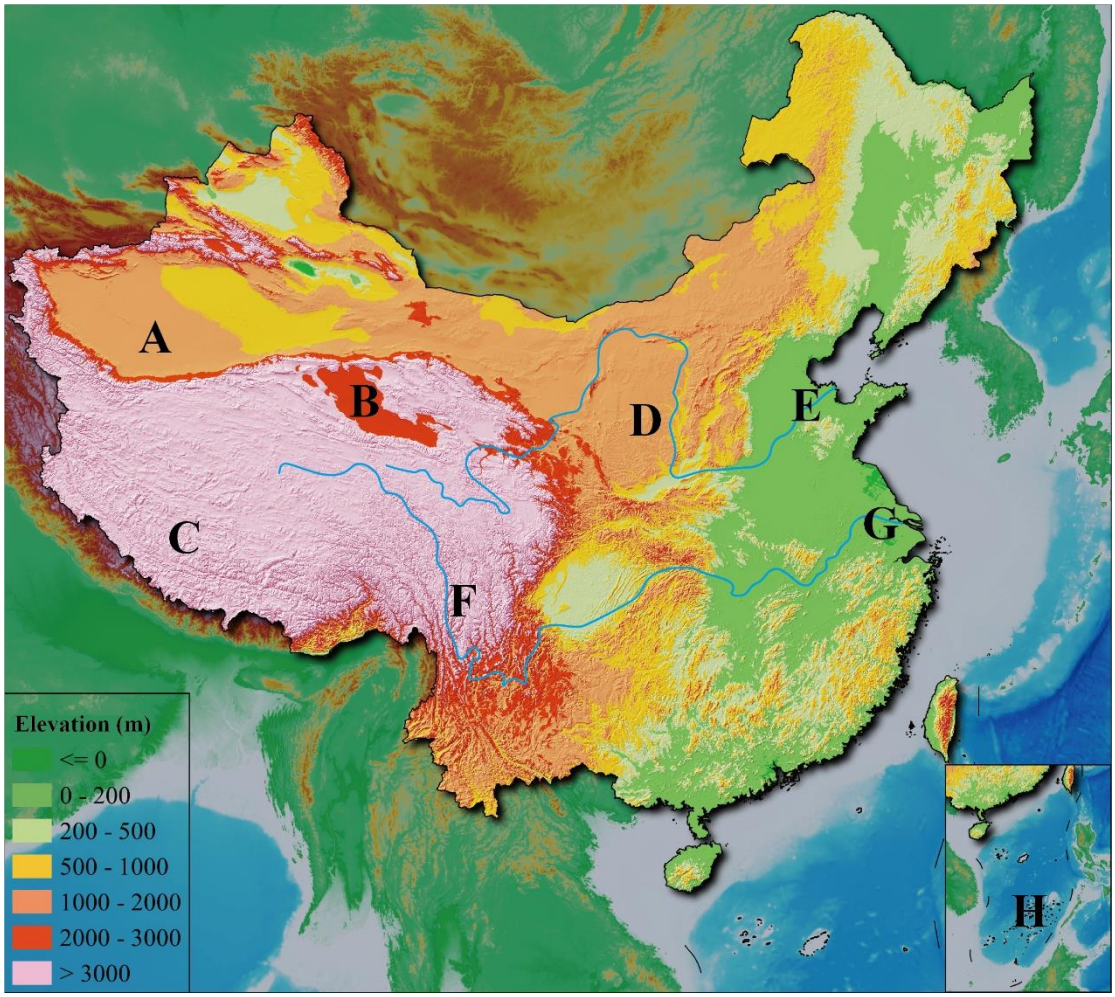

Figure I-1. Topographic Map of China

Question 54:
Which locations on the map show sedimentation patterns that are primarily influenced by interactions between the atmosphere and the lithosphere? (multiple correct answers)
Refer to the labeled map for options A–H.
Answer: **ABD**

Question 55:
Which location on the map shows sedimentation that is primarily controlled by the interaction of the hydrosphere, biosphere, and lithosphere? (single correct answer)
Refer to the labeled map for options A–H.
Answer: **H**

Question 56:
Which of the following locations on the map illustrate sedimentation primarily driven by direct physical interactions between the hydrosphere and the lithosphere — such as fluvial erosion, transport, and deposition — without major contributions from atmospheric or biological processes? (multiple correct answers)
Refer to the labeled map for options A–H.

Answer: **EFG**

Question 57:
Sorting describes the distribution of grain sizes in sedimentary deposits. The degree of sorting reflects the energy and consistency of the transport processes.
In which of the following depositional environments are very poorly-sorted sediments most likely to be found? (multiple correct answers)
Refer to the labeled map for options A–H.
Answer: **CF**

Question 58:
Terrigenous saltwater lakes are typically formed under specific environmental conditions.
Based on the map and your understanding of regional geography, which of the following locations are likely to host terrigenous saltwater lakes? (multiple correct answers)
Refer to the labeled map for options A–H.
Answer: **AB**

Question 59:
Lagoons are shallow coastal water bodies partially separated from the open sea, often influenced by both seawater and freshwater input.
Based on your understanding and the map, which location is most likely to support brackish lagoon environments rather than freshwater systems? (single correct answer)
Refer to the labeled map for options A–H.
Answer: **H**

Question 60:
Karst landscapes are formed by the chemical interaction between water and soluble rocks.
Which of the following bedrock types is most likely to develop karstic features through this process? (single correct answer)

A. Marl
B. Dolomite
C. Schist
D. Granite

Question 61:
Which of the earth systems are interrelated (directly and indirectly) to form karstic landscape? (single correct answer)

A. Only the Geosphere and Hydrosphere.
B. Only the Hydrosphere and Biosphere.
C. Only the Biosphere and Geosphere.
D. Only the Hydrosphere, Atmosphere, and Biosphere.
E. Only the Hydrosphere, Geosphere, and Biosphere.
F. The Atmosphere, Hydrosphere, Biosphere, and Geosphere.

Question 62:

At a site along the middle reaches of the Yellow River, a meandering river segment shows highly curved bends, low gradient, and fine-grained floodplain deposits. This region is characterized by seasonal variation in discharge and clear erosion–deposition patterns.

Which of the following statements about river sinuosity is correct? (single correct answer)

A. River sinuosity refers to the degree of bending in a river, typically expressed as the ratio of channel length to valley length.

B. Higher sinuosity indicates faster flow velocity.

C. River sinuosity is independent of erosional processes.

D. River sinuosity is solely influenced by topography, not discharge.

Question 63:

In a mountain valley of the eastern Tibetan Plateau, geologists have identified multiple levels of river terraces along the valley sides. These terraces lie above the modern floodplain and show clear stratigraphic separation, with some surfaces capped by loess.

Which of the following statements about river terraces is **not** correct? (single correct answer)

A. River terraces are step-like landforms resulting from fluvial deposition and incision.

B. River terraces can reflect tectonic uplift or climatic change.

C. The formation of river terraces is unrelated to fluvial deposition.

D. A greater number of terrace levels indicates more tectonic uplift events.

Question 64:

Near the First Bend of the Yangtze River, field observations show well-developed point bars on the inner curves of the meander bends, and lateral bars forming along the straight channel segments downstream. Both are visible at low flow stages.

Which of the following statements about fluvial bars is **not** correct? (single correct answer)

A. Both point bars and lateral bars are formed by fluvial deposition.

B. Point bars are located on the inner side of meander bends, whereas lateral bars are found along the channel margins.

C. The grain size of sediments in point bars and lateral bars is identical.

D. The formation of point bars and lateral bars is influenced by river discharge and flow velocity.

Question 65:

Satellite imagery of a lowland river in eastern China reveals curved sandbar structures and shallow point bar growth. Field students are tasked with using geomorphic indicators to determine the direction of water flow in this area.

Which of the following landforms can help indicate river flow direction? (multiple correct answers)

A. Point bars

B. Lateral bars

C. River terraces

D. Floodplains

Question 66:

Across China's diverse terrain, rivers display a wide range of channel patterns. In the central plains, some rivers develop highly sinuous single channels with broad floodplains. In mountainous regions such as the Tianshan or Hengduan Ranges, others form wide, shallow channels that constantly shift due to unstable flow conditions. In certain vegetated lowlands, rivers split into multiple fixed branches separated by muddy islands and levees. These differences reflect complex interactions among slope, sediment load, discharge variability, and vegetation, shaped by the combined influence of the hydrosphere, lithosphere, and biosphere.

Such channel forms are commonly classified as:

Meandering rivers*: single, curved channels in low-gradient areas.*

Braided rivers*: networks of shifting shallow channels in high-energy environments.*

Anastomosing rivers*: multiple, vegetated channels with long-term stability.*

Which of the following statements about meandering, braided, and anastomosing rivers are correct? (multiple correct answers)

A. Meandering rivers typically develop in areas with gentle slopes and fine sediments.

B. Braided rivers are typically associated with coarse sediment load and large fluctuations in flow, leading to frequent channel rearrangement.

C. Anastomosing rivers are transitional between meandering and braided rivers, with stable channels and minimal branching.

D. The formation of meandering and braided rivers is independent of river discharge and solely controlled by topography.

Section J: The groundwater and the earth systems

Geogenic groundwater contaminants (GGCs) include arsenic (As), fluorine (F), selenium (Se) and uranium (U). The global distribution of GGCs is controlled by basin geology and tectonics, with GGC enrichment in both orogenic systems and cratonic basement rocks (Fig. J-1). This regional distribution is broadly influenced by climate, geomorphology and hydrogeochemical evolution along groundwater flow paths. Volcanic eruptions along volcanic arcs can deposit rhyolitic glass, volcanic ash and metastable, high-temperature minerals that undergo chemical weathering in rapidly (on geological timescales) uplifted mountain chains to become the source of allochthonous sedimentary detritus.

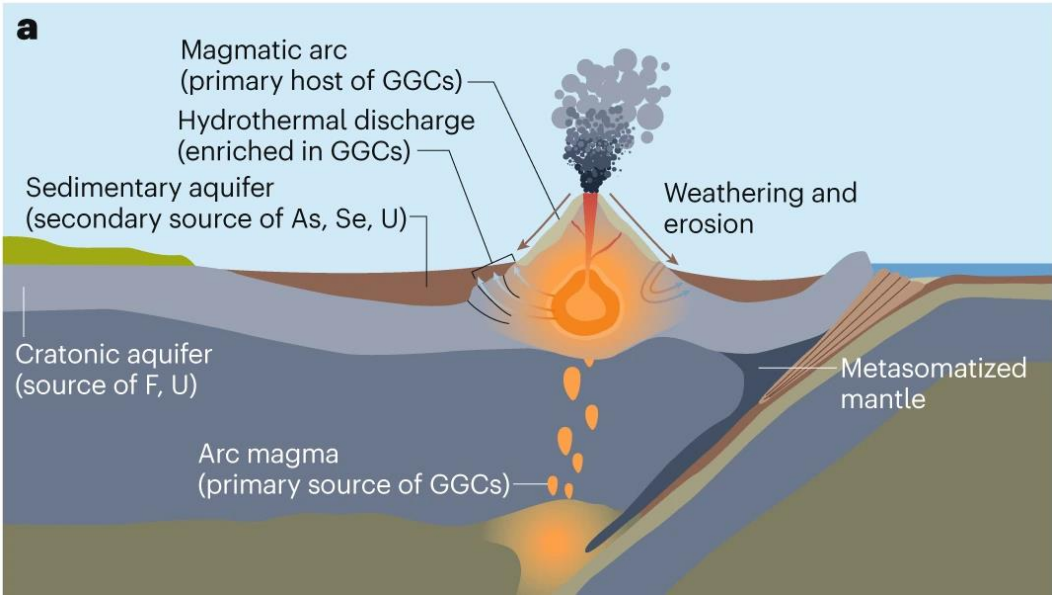

Figure J-1 Not to scale.

Question 67:

Based on the distribution of geological units in Fig. J-1, which of the following pollutant migration pathways best represents the complete geochemical cycle of GGCs? (single correct answer)

A. Magma → hydrothermal activity → sedimentary aquifer

B. Craton basement → weathering → hydrothermal system

C. Metasomatized mantle → sedimentary aquifer → surface runoff

D. Volcanic ash deposits → erosion → deposition

Question 68:

Fig. J-2 shows the global water fluxes (×1000 km^3 per year) in brackets and water storage (×1000 km^3). The upward arrows show annual evaporation from the ocean and terrestrial evapotranspiration. Global groundwater withdrawal is set at 1000 km^3 per year. (Antarctica was not included in the terrestrial water balance.)

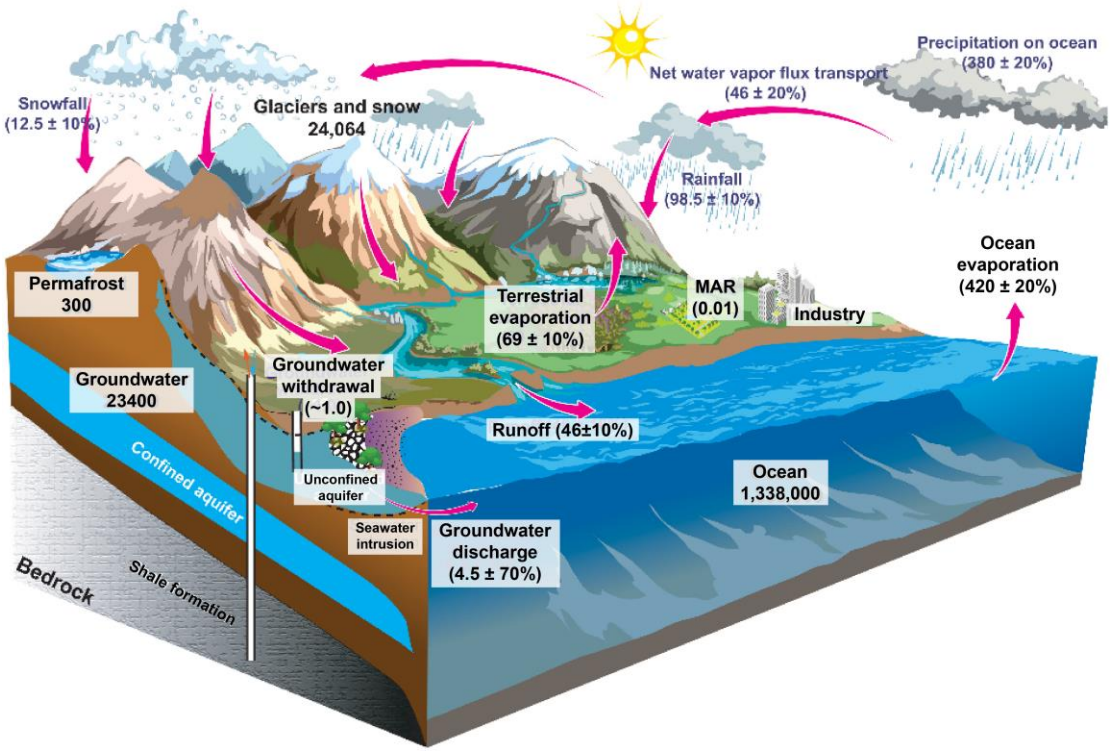

Figure J-2 Diagram showing water fluxes (×1000 km^3 per year; given in parentheses or brackets) and water storage (×1000 km^3) in the different earth systems.

Based on the global water cycle shown in Fig. J-2, calculate the annual water balance of the oceans using the given average annual water volume (unit: 10^3 km^3/year), and select the closest net change and its direction from the options given below. (single correct answer)

A. Gains approximately 10 × 10^3 km^3 of water annually.

B. Gains approximately 20 × 10^3 km^3 of water annually.

C. Loses approximately 20 × 10^3 km^3 of water annually.

D. Loses approximately 35 × 10^3 km^3 of water annually.

E. Maintains a dynamic balance and experiences no net change in water volume annually.

F. Gains approximately 40 × 10^3 km^3 of water annually.

Question 69:

Coastal areas often undergo land reclamation and urbanization. Land reclamation can change groundwater levels and the position of the saltwater-freshwater interface. Urbanization, especially high-rise building construction, involves dewatering and building deep foundations, which affect groundwater flow (Fig. J-3).

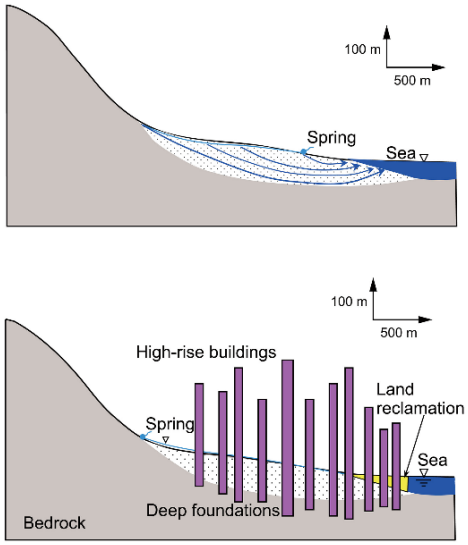

Figure J-3

During urbanization in coastal areas, what is the impact of deep foundations (for high-rise buildings) on groundwater flow? (single correct answer)

A. Promotes horizontal groundwater flow
B. Does not affect groundwater flow
C. Raises the groundwater level
D. Accelerates groundwater flow velocity on average
E. Causes groundwater to flow toward the sea

Section K: The Carbon Cycle and the Earth Systems

Chemical weathering changes the composition of rocks, often transforming them when water interacts with minerals to create various chemical reactions. Chemical weathering is a gradual and ongoing process as the mineralogy of the rock adjusts to the near-surface environment. It changes the mineralogy of the rocks over time that makes them to wear away, dissolve, or disintegrate. The end result is the formation of new materials that contribute to the creation of pores and fissures in the rocks which, in turn, accelerate disintegration. Chemical weathering involves various processes.

Question 70:

Chemical weathering not only contributes to landscape formation but also plays a key role in the material cycles among Earth's subsystems.

Which of the following processes is most effective in removing carbon dioxide from the atmosphere and thereby reducing atmospheric CO_2 levels? (single correct answer)

A. Carbonate weathering
B. Silicate weathering
C. Sulfide oxidation
D. Evaporite dissolution

Question 71:

Which reaction of olivine (Mg_2SiO_4) weathering contributes more to CO_2 sequestration? (single correct answer)

A. $Mg_2SiO_4 + 4CO_2 + 4H_2O \rightarrow 2Mg^{2+} + 4HCO_3^- + H_4SiO_4$
B. $Mg_2SiO_4 + 2H_2O \rightarrow 2Mg(OH)_2 + SiO_2$
C. $Mg_2SiO_4 + O_2 \rightarrow 2MgO + SiO_2 + CO_2$
D. $Mg_2SiO_4 + 2CO_2 \rightarrow 2MgCO_3 + SiO_2$

Question 72:

To mitigate the rising concentration of atmospheric carbon dioxide, Enhanced Rock Weathering (ERW) has been proposed as a carbon removal strategy. It helps address climate change by capturing CO_2 from the atmosphere and storing it in solid mineral forms. One widely used approach involves the application of crushed basalt.

The underlying principle is: (single correct answer)

A. Increasing the availability of calcium and magnesium ions
B. Increasing the availability of sodium and potassium ions
C. Increasing the availability of iron and aluminum oxides
D. Increasing the availability of sulfate and nitrate ions

Question 73:

In the ERW (Enhanced Rock Weathering) process, what factors may enhance the rate of this process? (single correct answer)

A. Increased temperature

B. Increased grain size of crushed rock

C. Decreased precipitation
D. Decreased runoff

Question 74:
Which of the following is **not** a possible consequence of scaling up enhanced weathering for carbon removal? (single correct answer)
A. Limited global reserves of suitable rocks
B. Energy costs of mining and grinding rocks
C. Competition with agricultural land use
D. A possible mass extinction

Question 75:
Due to the ocean's absorption of large amounts of anthropogenic carbon dioxide, significant ocean acidification has occurred since the Industrial Revolution.
How might enhanced weathering indirectly mitigate ocean acidification? (multiple correct answers)
A. By reducing atmospheric CO_2 concentrations
B. By releasing cations (e.g., Ca^{2+}, Mg^{2+}) into rivers
C. By increasing oceanic dissolved oxygen levels
D. By adsorbing carbonate ions from seawater

Question 76:
How do human activities disrupt geological-scale carbon cycling? (single correct answer)
A. Mining carbonate rocks for construction reduces the long-term capacity of weathering as a carbon sink
B. Burning fossil fuels releases ancient carbon faster than it can be reabsorbed by weathering processes
C. Acid rain enhances limestone dissolution, temporarily accelerating carbon sequestration
D. Agricultural expansion increases soil erosion, promoting the burial of organic carbon

Question 77:
Changes in various components of the global carbon cycle can shift the Earth's climate system away from its steady state. Because different carbon sources have distinct carbon isotope signatures, marine carbon isotopes can partially record global carbon cycle changes in Earth's history. Note:

$$\delta^{13}C = \left[\frac{\left(\frac{^{13}C}{^{12}C}\right)_{sample}}{\left(\frac{^{13}C}{^{12}C}\right)_{standard}} - 1 \right] \times 1000‰$$

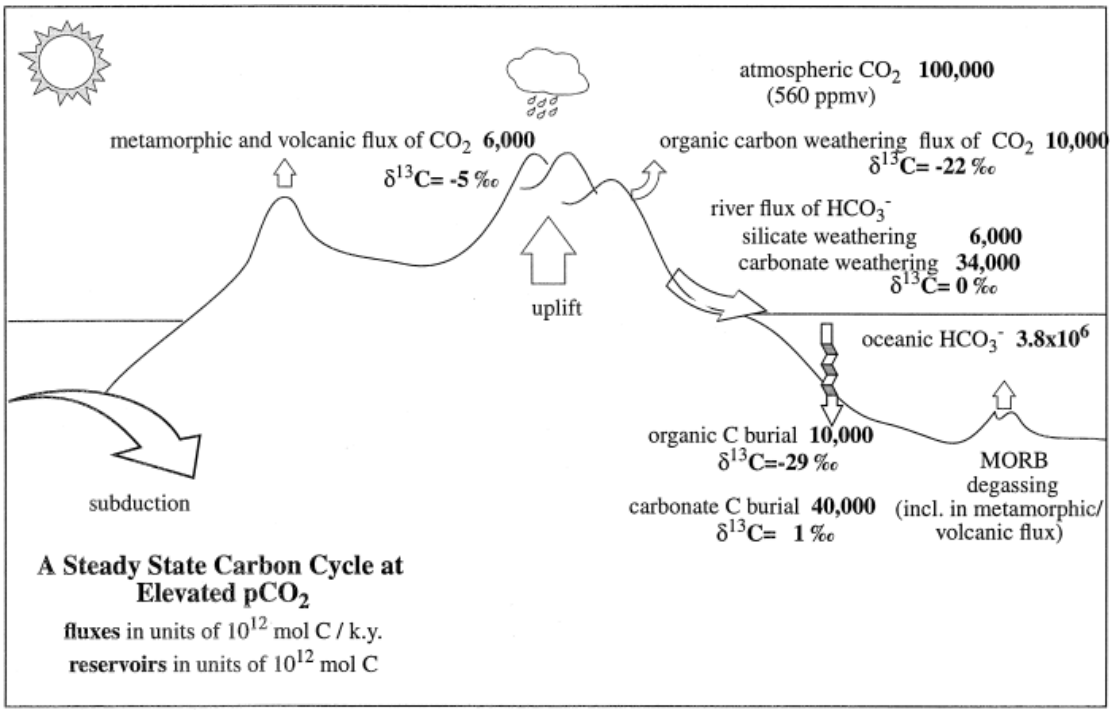

Figure K-1$\delta^{13}C$ values associated with different carbon sources. k.y. = thousand years

Which of the following factors could explain negative excursions in marine $\delta^{13}C$ during Earth's history? (multiple correct answers)

A. Large-scale volcanic activity releases ^{13}C-depleted magmatic CO_2

B. Methane hydrate dissociation emits extremely light carbon

C. Expansion of terrestrial vegetation increases soil organic carbon burial

D. Glacial retreat enhances silicate weathering, delivering ^{13}C-enriched material

E. Ocean warming suppresses the biological pump, reducing organic carbon burial

Section L: Carbon cycle in the ocean

The ocean is the Earth's largest active carbon reservoir, regulating atmospheric CO_2 levels through air-sea gas exchange. The CO_2 flux between the ocean and atmosphere depends primarily on seawater temperature (via solubility) and biological processes. Meanwhile, the total dissolved inorganic carbon (DIC) in seawater is governed mainly by physical processes, including ocean circulation and the hydrological cycle. Because the concentration of CO_2 in the atmosphere has increased through human-made CO_2 emissions, the ocean has taken up an increasing amount of CO_2 (about 25% of the emissions).

Marine phytoplankton consume CO_2 through photosynthesis, driving a mechanism known as the *biological pump*. This process facilitates the ocean's absorption of over 10^{11} kg of carbon from the atmosphere daily. However, this carbon does not directly reach the deep ocean. Instead, it fuels metabolic activities of consumers and decomposers in surface waters, while particulate organic carbon undergoes gradual sinking before long-term sequestration in the deep sea. The biological carbon pump annually supplies $5\text{-}10 \times 10^{12}$ kg of carbon to the oceans, driving long-term sequestration and providing energy for deep-sea ecosystems.

Question 78:

Fig. L-1 illustrates the process of the biological pump.

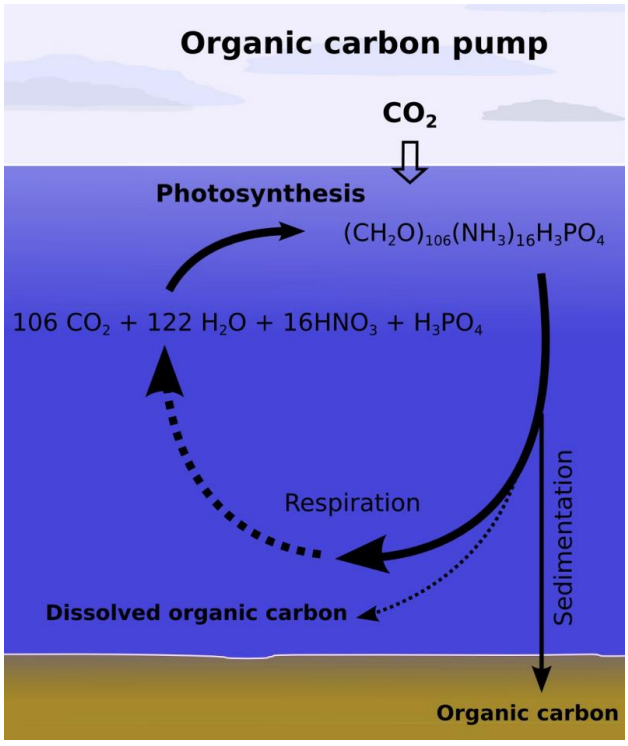

Figure L-1

Regarding the fundamental processes of the marine biological pump, which of the following statements is **not** correct? (single correct answer)

A. Photosynthesis by phytoplankton converts dissolved inorganic carbon (DIC) into particulate organic carbon (POC).

B. The biological pump's carbon export efficiency depends on the sinking rate of POC from the euphotic zone to the deep ocean.

C. Remineralization in the mesopelagic zone (200-1,000 m) reduces the carbon flux reaching the deep ocean. (Remineralization refers to the microbial breakdown of sinking particulate organic carbon (POC) back into dissolved inorganic carbon (DIC) as it descends.)

D. Deep sea sediments permanently sequester biologically exported carbon and no longer participate in the carbon cycle.

Question 79:

Which of the following factors would enhance the efficiency of the biological pump in a given region (i.e., increase the export of carbon to the deep ocean)? (multiple correct answers)

A. Strong upwelling (e.g., off the coast of Peru)

B. Strong stratification in the surface ocean

C. Favorable conditions for the formation of rapidly sinking large particles (e.g., fecal pellets)

D. Extremely high surface temperatures

Question 80:

Fig. L-2 presents global patterns of ocean productivity (as indicated by chlorophyll concentration, Chl), sea surface temperature (SST), surface nitrate concentration (N), and surface phosphate concentration (P).

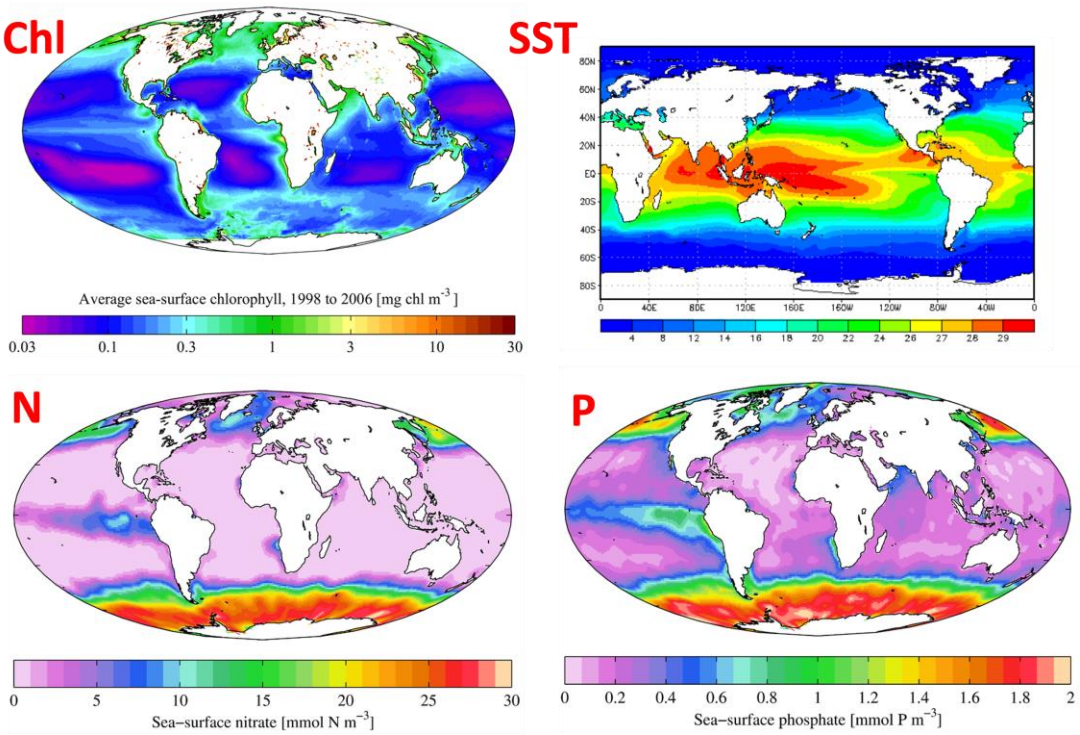

Figure L-2

In the subtropical open ocean regions (typically between 20° and 40° latitude in both hemispheres), the efficiency of the biological pump is generally low. What are the likely reasons for this? (multiple correct answers)

A. Surface nutrients (nitrogen and phosphorus) are extremely scarce, limiting phytoplankton growth (oligotrophic conditions).

B. Sea surface temperatures are too low, inhibiting photosynthesis.
C. The deep euphotic zone allows sinking particles more time to be decomposed before reaching the deep ocean.
D. These regions lack deep oceans and cannot store carbon.

Question 81:
The biological pump is a process whereby CO_2 in the upper ocean is fixed by primary producers and transported to the deep ocean as sinking biogenic particles (particulate organic matter, POM) or as dissolved organic matter (DOM) (Fig. L-3).

How might climate change (e.g., global warming) affect the efficiency of the ocean biological pump? (multiple correct answers)
A. Enhanced ocean stratification reduces nutrient upwelling, potentially lowering productivity in some regions.
B. Ocean acidification promotes phytoplankton calcification, increasing carbon export.
C. Shifts in phytoplankton community composition (e.g., more small-sized algae) may reduce sinking efficiency.
D. Accelerated deep ocean currents enhance carbon release from sediments.
E. Increased glacial meltwater delivers more nutrients, improving the efficiency of the global biological pump.

Question 82:
Which of the following physical factors does **not** control the global pattern of biological pump efficiency? (single correct answer)
A. Wind-driven upwelling that transports deep nutrients to the surface
B. Stratification strength, which regulates nutrient diffusion into the euphotic zone
C. Infrared radiation directly enhances the degradation of particulate organic matter (POM)
D. Ocean circulation patterns that influence nutrient residence time.

Question 83:
Previous studies have shown that the organic matter produced by marine phytoplankton has a statistically consistent atomic C:N:P ratio, known as the Redfield ratio (C:N:P = 106:16:1). If the annual flux of sinking organic phosphorus in a certain region is 0.5 mol $m^{-2} \cdot yr^{-1}$, which of the following statements correctly describe the associated organic matter fluxes? (multiple correct answers)
A. The organic carbon flux is approximately 53 mol $m^{-2} \cdot yr^{-1}$
B. The organic nitrogen flux is 16 mol $m^{-2} \cdot yr^{-1}$
C. For every 1 mol of phosphorus exported, 6.6 mol of CO_2 is consumed
D. If the measured nitrogen flux is 9 mol $m^{-2} \cdot yr^{-1}$, the sinking particles are nitrogen-enriched

Question 84:

Direct injection of CO_2 into the ocean is a potentially effective carbon sequestration strategy. Sequestration would be accomplished by injecting CO_2 stripped from the flue gases of fuel-burning power plants into the bottom waters (~3000 m) of the deep-sea, where the circulation time of the world ocean would prevent CO_2 out-gassing to the atmosphere for centuries, thereby mitigating the peak atmospheric CO_2 levels expected during the next 200-300 years.

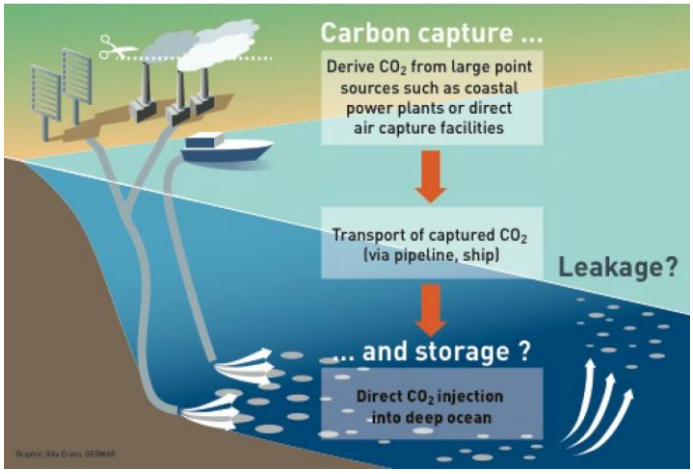

Figure L-3 Schematic diagram of direct CO_2 injections into the deep ocean

Which effect is anticipated to arise as a result of elevated CO_2 concentrations in the deep ocean on marine organisms? (single correct answer)

A. change in deep-sea pH

B. interference with consumers' feeding patterns

C. erode calcareous components of marine organisms

D. ecosystems with enhanced biological activity are likely to form