IIT JAM 2021 Geology (GG) Question Paper with Solutions

Time Allowed :3 Hours	**Maximum Marks :**100	**Total questions :**60

General Instructions

General Instructions:

i) All questions are compulsory. Marks allotted to each question are indicated in the margin.

ii) Answers must be precise and to the point.

iii) In numerical questions, all steps of calculation should be shown clearly.

iv) Use of non-programmable scientific calculators is permitted.

v) Wherever necessary, write balanced chemical equations with proper symbols and units.

vi) Rough work should be done only in the space provided in the question paper.

1. Among the following rocks, the one with highest metamorphic grade is

(A) chlorite schist

(B) glaucophane schist

(C) phyllite

(D) gneiss

Correct Answer: (D) gneiss

Solution:

Step 1: Understanding metamorphic grade.

Metamorphic grade refers to the intensity of metamorphism that a rock has experienced, primarily determined by temperature and pressure. Low-grade rocks form under mild conditions, while high-grade rocks form under extreme heat and pressure.

Step 2: Comparing the options.

(A) Chlorite schist: Low-grade metamorphic rock.

(B) Glaucophane schist: Medium-grade, typically formed under high pressure but lower temperature (blueschist facies).

(C) Phyllite: Low-grade metamorphic rock, intermediate between slate and schist.

(D) Gneiss: High-grade metamorphic rock formed under intense metamorphism.

Step 3: Conclusion.

Gneiss has the highest metamorphic grade among the given options.

Quick Tip

Order of metamorphic grade: Slate $\rightarrow$ Phyllite $\rightarrow$ Schist $\rightarrow$ Gneiss.

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2. The Earth's radius is maximum at which one of the following latitudes?

(A) 0°

(B) 40° N

(C) 60° S

(D) 90°

Correct Answer: (A) 0°

Solution:

Step 1: Understanding Earth's shape.

The Earth is not a perfect sphere; it is an oblate spheroid, flattened at the poles and bulging at the equator.

Step 2: Reasoning.

Due to Earth's rotation, the equatorial regions experience a greater outward centrifugal force, increasing the equatorial radius.

Step 3: Conclusion.

Thus, the Earth's radius is maximum at the equator (**0° latitude**).

Quick Tip

Equatorial radius 6378 km, Polar radius 6357 km — a difference of about 21 km.

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3. The closest value to the percentage of the Earth's surface covered by the oceans is

(A) 30%

(B) 50%

(C) 70%

(D) 90%

Correct Answer: (C) 70%

Solution:

Step 1: Understanding Earth's surface.

About 71% of Earth's surface is covered by oceans, and the remaining 29% is land.

Step 2: Selecting the closest value.

Among the given options, 70% most closely represents the actual proportion of ocean coverage.

Step 3: Conclusion.

Hence, approximately **70% of Earth's surface** is covered by oceans.

Quick Tip

Remember: “7 continents, 70% oceans” — a simple mnemonic for this fact.

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4. Which is the shallowest among the marine environments listed below?

(A) Neritic

(B) Littoral

(C) Abyssal

(D) Bathyal

Correct Answer: (B) Littoral

Solution:

Step 1: Understanding marine zones.

Marine environments are classified by depth: Littoral (intertidal), Neritic (continental shelf), Bathyal (continental slope), and Abyssal (deep ocean floor).

Step 2: Identification.

The littoral zone lies between high and low tide marks — the shallowest zone directly influenced by tides.

Step 3: Conclusion.

Thus, the **Littoral zone** is the shallowest marine environment.

Quick Tip

Think: “Littoral = Little depth.” It’s the intertidal or beach zone.

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5. Among the following, the tungsten-bearing mineral is

(A) bornite

(B) cassiterite

(C) scheelite

(D) greenockite

Correct Answer: (C) scheelite

Solution:

Step 1: Understanding tungsten minerals.

Tungsten occurs mainly in the minerals scheelite ($CaWO_4$) and wolframite ($(Fe,Mn)WO_4$). These are the principal ores of tungsten.

Step 2: Comparing the options.

(A) Bornite: A copper-iron sulfide mineral (Cu_5FeS_4).

(B) Cassiterite: Tin oxide (SnO_2), main ore of tin.

(C) Scheelite: Calcium tungstate ($CaWO_4$), an important tungsten ore.

(D) Greenockite: Cadmium sulfide (CdS), ore of cadmium.

Step 3: Conclusion.

The correct answer is **(C) Scheelite**, as it contains tungsten.

Quick Tip

Remember: Tungsten minerals — **Scheelite ($CaWO_4$)** and **Wolframite ($(Fe,Mn)WO_4$)**.

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6. The host rock of Pb-Zn deposit at Zawar is

(A) quartzite

(B) phyllite

(C) dolomite

(D) gneiss

Correct Answer: (C) dolomite

Solution:

Step 1: Background on Zawar deposit.

The Zawar Pb-Zn deposit, located in Rajasthan, India, is one of the oldest known zinc-lead deposits in the world. It is part of the Aravalli Supergroup.

Step 2: Geological setting.

The mineralization at Zawar occurs mainly in dolomitic rocks of the lower Aravalli Group, where sulfide minerals like galena and sphalerite are hosted within dolomite.

Step 3: Conclusion.

Hence, the **host rock of the Zawar Pb-Zn deposit is dolomite**.

Quick Tip

Zawar Pb-Zn deposit → Aravalli Supergroup → Hosted in **dolomite**.

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7. Bituminous coal deposits in India occur in which one of the following formations?

(A) Barren Measures Formation

(B) Barakar Formation

(C) Naredi Formation

(D) Cuddalore Formation

Correct Answer: (B) Barakar Formation

Solution:

Step 1: Understanding coal formations.

In India, Gondwana coal deposits are categorized by their age and lithology. The Barakar Formation of the Lower Gondwana sequence is known for containing high-quality bituminous coal.

Step 2: Comparing formations.

(A) Barren Measures Formation: Contains little or no coal.

(B) Barakar Formation: Main coal-bearing horizon with bituminous coal seams.

(C) Naredi Formation: Eocene formation of the Tertiary period, non-coal-bearing.

(D) Cuddalore Formation: Miocene–Pliocene formation, contains lignite, not bituminous coal.

Step 3: Conclusion.

Therefore, bituminous coal deposits in India occur in the **Barakar Formation**.

Quick Tip

Barakar Formation (Lower Gondwana) → Major bituminous coal seams in Jharia, Raniganj, and Bokaro basins.

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8. Identify the plant fossil from the following list.

(A) Glossopteris

(B) Fenestella

(C) Productus

(D) Cidaris

Correct Answer: (A) Glossopteris

Solution:

Step 1: Recognizing fossil types.

Among the listed genera, only **Glossopteris** is a plant fossil. The others are marine invertebrate fossils.

Step 2: Comparing the options.

(A) Glossopteris: Seed fern from the Permian period; indicator of the Gondwana flora.

(B) Fenestella: Bryozoan fossil (marine animal).

(C) Productus: Brachiopod fossil.

(D) Cidaris: Echinoid (sea urchin) fossil.

Step 3: Conclusion.

Therefore, **Glossopteris** is the only plant fossil in the list.

Quick Tip

Glossopteris → Gondwana plant fossil, evidence for continental drift and past supercontinent connections.

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9. The igneous body with dome or mushroom-like shape is known as a

(A) lopolith

(B) ring dike

(C) sill

(D) laccolith

Correct Answer: (D) laccolith

Solution:

Step 1: Understanding intrusive igneous forms.

Igneous intrusions are classified based on their geometry and relation to surrounding rock layers. A laccolith is a concordant intrusive body that has a flat base and a domed top, resembling a mushroom shape.

Step 2: Comparing the options.

(A) Lopolith: Large, saucer-shaped intrusion that is concave upward.

(B) Ring dike: Circular or arcuate intrusion formed along ring fractures.

(C) Sill: Tabular, concordant intrusion parallel to bedding planes.

(D) Laccolith: Concordant intrusion with a flat base and dome-shaped top, formed when magma uplifts overlying strata — **mushroom-like in shape**.

Step 3: Conclusion.

The correct answer is **(D) Laccolith**.

Quick Tip

Think: "Laccolith = Lifted layers." It pushes up strata forming a dome or mushroom-shaped feature.

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10. Which one of the following stratigraphic units belongs to the Cretaceous?

(A) Lameta Formation

(B) Talchir Boulder Bed

(C) *Fenestella* Shale

(D) Kasauli Formation

Correct Answer: (A) Lameta Formation

Solution:

Step 1: Background.

The Lameta Formation (also called Infratrappean Beds) occurs below the Deccan Traps in central India and represents sedimentary deposits from the Late Cretaceous period.

Step 2: Comparing the options.

(A) Lameta Formation: Late Cretaceous (Maastrichtian) — famous for dinosaur fossils.

(B) Talchir Boulder Bed: Lower Permian, part of the Gondwana sequence.

(C) *Fenestella* Shale: Lower Carboniferous age.

(D) Kasauli Formation: Miocene, part of the Siwalik Group.

Step 3: Conclusion.

Hence, the **Lameta Formation** belongs to the **Cretaceous period**.

Quick Tip

Lameta Formation (Cretaceous) lies below Deccan Traps and is rich in dinosaur fossils from India.

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11. Select the youngest volcanic event out of the following.

(A) Rajmahal volcanics

(B) Dalma volcanics

(C) Panjal volcanics

(D) Deccan volcanics

Correct Answer: (D) Deccan volcanics

Solution:

Step 1: Understanding the geological age of volcanic events.

Each of these volcanic provinces in India belongs to a specific geologic era:

- **Dalma volcanics:** Precambrian (Proterozoic age)

- **Panjal volcanics:** Permian–Triassic age

- **Rajmahal volcanics:** Early Cretaceous age

- **Deccan volcanics:** Late Cretaceous to Early Paleogene (66 Ma)

Step 2: Identifying the youngest event.

Among these, the Deccan volcanics represent the most recent volcanic activity, forming just before the Cretaceous–Paleogene boundary.

Step 3: Conclusion.

Hence, the **Deccan volcanics** are the youngest volcanic event.

Quick Tip

Remember order from oldest to youngest: Dalma → Panjal → Rajmahal → Deccan.

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12. Which among the following is the only possible plunge for a lineation located on the foliation plane striking 20° N and dipping 40° southeasterly?

(A) 20° SE

(B) 20° NW

(C) 45° SE

(D) 40° NW

Correct Answer: (A) 20° SE

Solution:

Step 1: Interpreting the strike and dip.

The foliation plane strikes **20° N** and dips **40° towards the southeast**. This means the plane inclines downward to the southeast direction.

Step 2: Possible plunge direction.

Any lineation lying on this plane must plunge in the same general direction as the dip — that is, toward the **SE**. Therefore, only SE-directed plunges are possible.

Step 3: Comparing the options.

Among the given choices, **20° SE** is the only plunge that fits both the orientation and the dip of 40°.

Step 4: Conclusion.

Hence, the correct answer is **(A) 20° SE**.

Quick Tip

The plunge direction of any lineation on a planar surface must align with or be parallel to the dip direction of that plane.

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13. Which one of the following tectonic plates has the maximum average velocity?

(A) Eurasian

(B) Pacific

(C) African

(D) North American

Correct Answer: (B) Pacific

Solution:

Step 1: Understanding plate motion.

Different tectonic plates move at different rates due to variations in mantle convection and spreading rates at mid-ocean ridges. Oceanic plates usually move faster than continental plates.

Step 2: Comparing average velocities.

The **Pacific Plate** is the fastest-moving tectonic plate, with an average velocity of about 10–11 cm/year, moving northwest relative to the African Plate. Other plates like the Eurasian or North American move at slower rates (2–5 cm/year).

Step 3: Conclusion.

Hence, the **Pacific Plate** has the maximum average velocity.

Quick Tip

Oceanic plates generally move faster than continental plates due to lower resistance and active seafloor spreading.

14. A limestone contains lime mud and around 25% allochems, which are separated from each other. The name of the rock as per Dunham's classification is

(A) mudstone

(B) wackestone

(C) packstone

(D) grainstone

Correct Answer: (B) wackestone

Solution:

Step 1: Understanding Dunham's classification.

Dunham (1962) classified limestones based on the proportion of allochems (grains) and micrite (lime mud).

- **Mudstone:** ¿90% micrite, very few grains.
- **Wackestone:** Mud-supported rock with ¿10% grains (allochems not touching).
- **Packstone:** Grain-supported rock with mud matrix present.
- **Grainstone:** Grain-supported, no mud.

Step 2: Application.

Since the rock contains lime mud and about 25% allochems (grains not touching each other), it fits the definition of a **wackestone**.

Step 3: Conclusion.

Hence, the limestone is classified as **wackestone**.

Quick Tip

In Dunham's scheme: increasing allochems $\rightarrow$ mudstone $\rightarrow$ wackestone $\rightarrow$ packstone $\rightarrow$ grainstone.

15. Find the CORRECT statement out of the following.

(A) Convolute laminae form by desiccation.

(B) Load cast is an erosional structure.

(C) Prod mark is found at the bottom of a bed.

(D) Wave ripple occurs at the top of a turbidite deposit.

Correct Answer: (C) Prod mark is found at the bottom of a bed.

Solution:

Step 1: Understanding sedimentary structures.

- **Convolute laminae:** Form due to soft-sediment deformation, not desiccation.

- **Load casts:** Depositional structures caused by density instability, not erosion.

- **Prod marks:** Tool marks produced at the base of beds due to objects dragged or stuck in moving sediment.

- **Wave ripples:** Occur at the top of shallow-water deposits, not turbidites (which show graded bedding).

Step 2: Conclusion.

Hence, the correct statement is that **prod marks are found at the bottom of a bed**.

Quick Tip

Tool marks, flute casts, and prod marks — all occur at the base of beds and indicate paleocurrent direction.

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16. Which one of the following crystal forms DOES NOT belong to the di-tetragonal pyramidal class?

(A) c-Pedion

(B) Prism of 1^{st} order

(C) Di-tetragonal prism

(D) Tetragonal dipyramid

Correct Answer: (A) c-Pedion

Solution:

Step 1: Understanding crystal classes.

The di-tetragonal pyramidal class belongs to the tetragonal system (point group 4mm) and includes crystal forms such as tetragonal dipyramids and prisms.

Step 2: Comparing the options.

(A) c-Pedion: Single face, characteristic of tetragonal scalenohedral or holohedral class, not di-tetragonal pyramidal.

(B) Prism of 1st order: Present in di-tetragonal pyramidal class.

(C) Di-tetragonal prism: Characteristic form of this class.

(D) Tetragonal dipyramid: Also belongs to this class.

Step 3: Conclusion.

Thus, **c-Pedion** does not belong to the di-tetragonal pyramidal class.

Quick Tip

In the tetragonal system: pedion = single face; prism = vertical faces; pyramid = top faces.

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17. If a coarse-grained igneous rock is composed of ¿90% of plagioclase and ¡10% of olivine and pyroxene, then the name of this rock according to the IUGS classification is

(A) anorthosite

(B) olivine gabbro

(C) tonalite

(D) olivine websterite

Correct Answer: (A) anorthosite

Solution:

Step 1: Understanding IUGS classification.

According to the IUGS (International Union of Geological Sciences) classification, igneous rocks are classified based on the relative proportions of essential minerals — mainly plagioclase, pyroxene, olivine, and amphibole.

Step 2: Identification.

When plagioclase constitutes more than 90% of the total minerals, and mafic minerals (olivine and pyroxene) are less than 10%, the rock is termed as **anorthosite**.

Step 3: Comparison.

(A) Anorthosite: ¿90% plagioclase — correct.

(B) Olivine gabbro: Contains significant pyroxene and olivine.

(C) Tonalite: Dominated by plagioclase and quartz — not applicable.

(D) Olivine websterite: Consists mainly of pyroxene and olivine.

Step 4: Conclusion.

Hence, the correct answer is **(A) Anorthosite**.

Quick Tip

Remember: Rocks with ¿90% plagioclase → Anorthosite; with ¿90% pyroxene → Pyroxenite.

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18. Which one of the following represents the compositional change in plagioclase during the crystallization of mafic magma?

(A) Na/Ca ratio decreases; Al/Si ratio increases

(B) Both Na/Ca and Al/Si ratios increase

(C) Na/Ca ratio increases; Al/Si ratio decreases

(D) Both Na/Ca and Al/Si ratios decrease

Correct Answer: (C) Na/Ca ratio increases; Al/Si ratio decreases

Solution:

Step 1: Understanding plagioclase composition.

Plagioclase forms a solid solution between albite (Na-rich) and anorthite (Ca-rich) end members. As mafic magma cools, the composition of plagioclase shifts from Ca-rich (anorthite) to Na-rich (albite).

Step 2: Compositional trends.

During this process, the Na/Ca ratio **increases** (more sodium-rich), while the Al/Si ratio **decreases**, since sodium-rich plagioclase contains relatively less aluminum compared to calcium-rich plagioclase.

Step 3: Conclusion.

Therefore, the correct trend is **Na/Ca ratio increases and Al/Si ratio decreases**.

Quick Tip

Bowen's Reaction Series: Plagioclase evolves from Ca-rich (Anorthite) → Na-rich (Albite) as magma cools.

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19. Choose the CORRECT sequence of older to younger formations in the stratigraphy of the Cuddapah Supergroup.

(A) Pulivendla–Gulcheru–Vempalle–Tadpatri

(B) Gulcheru–Vempalle–Pulivendla–Tadpatri

(C) Gulcheru–Pulivendla–Tadpatri–Vempalle

(D) Vempalle–Gulcheru–Tadpatri–Pulivendla

Correct Answer: (A) Pulivendla–Gulcheru–Vempalle–Tadpatri

Solution:

Step 1: Background.

The Cuddapah Supergroup (Proterozoic age) is exposed in Andhra Pradesh and contains four main formations — Pulivendla, Gulcheru, Vempalle, and Tadpatri — belonging to the Papaghni and Chitravati Groups.

Step 2: Stratigraphic sequence.

From oldest to youngest, the correct order is: **Pulivendla** → **Gulcheru** → **Vempalle** → **Tadpatri**.

Step 3: Conclusion.

Thus, the correct answer is **(A)**.

Quick Tip

Mnemonic: “Please Go Visit Tadpatri” — Pulivendla → Gulcheru → Vempalle → Tadpatri.

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20. Match the economic deposits (Group I) with their places of occurrence (Group II).

Group I	**Group II**
P. Iron ore	1. Bhatan
Q. Base metal	2. Sukinda
R. Chromite	3. Rampura–Agucha
S. Uranium	4. Bellary

(A) P–4, Q–1, R–2, S–3

(B) P–2, Q–4, R–3, S–1

(C) P–2, Q–3, R–1, S–4

(D) P–4, Q–3, R–2, S–1

Correct Answer: (D) P–4, Q–3, R–2, S–1

Solution:

Step 1: Understanding major Indian mineral deposits.

- **Iron ore:** Bellary region, Karnataka.

- **Base metal (Pb–Zn):** Rampura–Agucha, Rajasthan.

- **Chromite:** Sukinda, Odisha.

- **Uranium:** Bhatan (Jharkhand).

Step 2: Matching.

P–4 (Iron ore–Bellary), Q–3 (Base metal–Rampura Agucha), R–2 (Chromite–Sukinda), S–1 (Uranium–Bhatan).

Step 3: Conclusion.

Therefore, the correct answer is **(D)**.

Quick Tip

Remember key associations: Bellary–Iron, Sukinda–Chromite, Rampura Agucha–Zn–Pb, Bhatan–Uranium.

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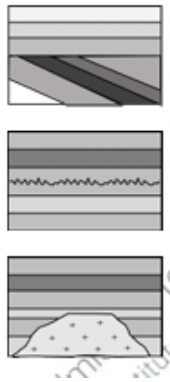
21. Select the answer that is a CORRECT match for the three types of unconformities. (Grey bands = sediments, [+] = igneous rock).

P. Disconformity 1.

Q. Non-conformity 2.

R. Angular Unconformity 3.



(A) P–2; Q–3; R–1

(B) P–2; Q–1; R–3

(C) P–1; Q–3; R–2

(D) P–3; Q–2; R–1

Correct Answer: (D) P–3; Q–2; R–1

Solution:

Step 1: Understanding types of unconformities.

Unconformities represent gaps in the geological record due to erosion or non-deposition. They are identified by the relation between older and younger rock layers.

Step 2: Classification.

- **Disconformity:** Parallel sedimentary beds separated by an erosional surface (same orientation).

- **Non-conformity:** Sedimentary rocks deposited over igneous or metamorphic rocks.

- **Angular Unconformity:** Tilted or folded beds overlain by horizontal beds.

Step 3: Matching.

P–3, Q–2, R–1 corresponds correctly.

Step 4: Conclusion.

Hence, the correct answer is **(D) P–3; Q–2; R–1**.

Quick Tip

Remember: Disconformity = Parallel layers; Non-conformity = Igneous/Metamorphic contact; Angular = Tilted below flat beds.

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22. Which one of the following statements is FALSE?

(A) Ammonites have fluted septa.

(B) Brachiopods have a pedicle.

(C) Echinods have genal spines.

(D) Trilobites have a pygidium.

Correct Answer: (C) Echinods have genal spines.

Solution:

Step 1: Evaluating each statement.

(A) True — Ammonites possess complex, fluted septa separating their chambers.

(B) True — Brachiopods attach to the substrate using a pedicle.

(C) False — Genal spines are features of trilobites, not echinoderms.

(D) True — Trilobites consist of cephalon, thorax, and pygidium.

Step 2: Conclusion.

The statement "Echinods have genal spines" is **FALSE**.

Quick Tip

Genal spines $\rightarrow$ Trilobites; Pedicle $\rightarrow$ Brachiopods; Fluted septa $\rightarrow$ Ammonites.

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23. In the context of phylogeny of horses, the CORRECT chronological order from old to young is

(A) *Hyracotherium, Mesohippus, Merychippus, Equus*

(B) *Hyracotherium, Merychippus, Mesohippus, Equus*

(C) *Equus, Merychippus, Mesohippus, Hyracotherium*

(D) *Merychippus, Equus, Mesohippus, Hyracotherium*

Correct Answer: (A) *Hyracotherium, Mesohippus, Merychippus, Equus*

Solution:

Step 1: Understanding horse evolution.

The evolution of horses shows a gradual increase in body size, reduction in toes, and development of high-crowned teeth suited for grazing.

Step 2: Sequence.

- **Hyracotherium (Eohippus):** Earliest horse (Eocene).
- **Mesohippus:** Oligocene — three-toed form.
- **Merychippus:** Miocene — development of grazing teeth.
- **Equus:** Pleistocene to Recent — modern single-toed horse.

Step 3: Conclusion.

Hence, the correct chronological order is **Hyracotherium** → **Mesohippus** → **Merychippus** → **Equus**.

Quick Tip

Mnemonic: "Happy Men Make Excitement" — Hyracotherium → Mesohippus → Merychippus → Equus.

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24. Choose the CORRECT match between items in Group I with the items in Group II.

Group I	**Group II**
P. Polarity zone	1. Biostratigraphy
Q. Formation	2. Chronostratigraphy

R. Biozone	3. Magnetostratigraphy
S. Epoch	4. Lithostratigraphy

(A) P–1; Q–2; R–3; S–4

(B) P–2; Q–3; R–1; S–4

(C) P–3; Q–4; R–1; S–2

(D) P–3; Q–4; R–2; S–1

Correct Answer: (C) P–3; Q–4; R–1; S–2

Solution:

Step 1: Understanding stratigraphic divisions.

- **Polarity zone:** Based on magnetic field reversals → **Magnetostratigraphy**.

- **Formation:** Fundamental unit of rock layers → **Lithostratigraphy**.

- **Biozone:** Defined by fossil content → **Biostratigraphy**.

- **Epoch:** Subdivision of geologic time → **Chronostratigraphy**.

Step 2: Matching.

P–3 (Polarity zone → Magnetostratigraphy), Q–4 (Formation → Lithostratigraphy), R–1 (Biozone → Biostratigraphy), S–2 (Epoch → Chronostratigraphy).

Step 3: Conclusion.

The correct match is **(C) P–3; Q–4; R–1; S–2**.

Quick Tip

Remember the association: Magneto → Polarity, Litho → Rock unit, Bio → Fossils, Chrono → Time.

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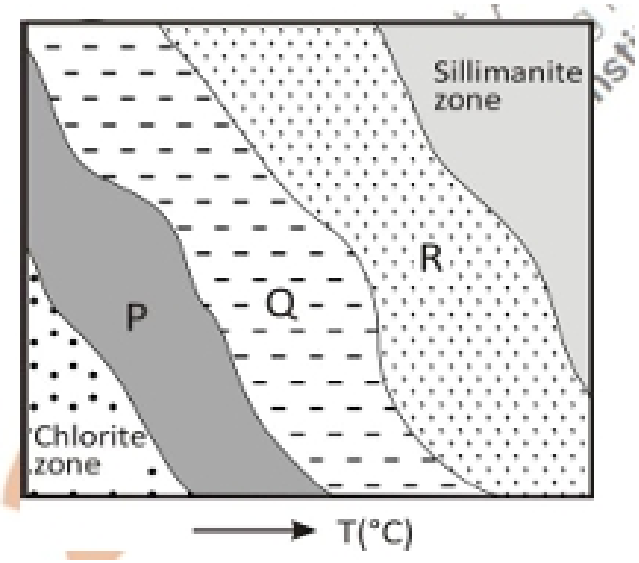
25. The following diagram represents the prograde sequence of metamorphic zones that develop during Buchan-type of metamorphism (¡4 kbar) of typical pelites. Identify the zones labelled P, Q, and R.



(A) P – Biotite zone; Q – Garnet zone; R – Kyanite zone

(B) P – Garnet zone; Q – Kyanite zone; R – Staurolite zone

(C) P – Biotite zone; Q – Cordierite zone; R – Andalusite zone

(D) P – Andalusite zone; Q – Biotite zone; R – Cordierite zone

Correct Answer: (C) P – Biotite zone; Q – Cordierite zone; R – Andalusite zone

Solution:

Step 1: Understanding Buchan-type metamorphism.

Buchan-type metamorphism occurs under low-pressure (¡4 kbar) and high-temperature conditions. It typically develops in pelitic rocks during regional metamorphism associated with contact aureoles.

Step 2: Zone sequence.

The progressive mineral zones for Buchan metamorphism are:

Chlorite → Biotite → Cordierite → Andalusite → Sillimanite.

Step 3: Interpretation.

From the diagram:

- **P:** Next to chlorite zone → Biotite zone.
- **Q:** Intermediate → Cordierite zone.
- **R:** High-temperature → Andalusite zone.

Step 4: Conclusion.

Hence, the correct identification is **P – Biotite zone; Q – Cordierite zone; R – Andalusite zone**.

Quick Tip

Buchan sequence (low-P, high-T): Chlorite → Biotite → Cordierite → Andalusite → Sillimanite.

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26. Match the minerals in Group I with the corresponding composition in Group II.

Group I	**Group II**
P. Leucite	1. $(K,Na)AlSi_3O_8$
Q. Andradite	2. $NaAlSi_2O_6$
R. Sanidine	3. $KAlSi_2O_6$
S. Jadeite	4. $Ca_3Fe_2Si_3O_{12}$

(A) P–3; Q–1; R–4; S–2

(B) P–2; Q–3; R–1; S–4

(C) P–1; Q–4; R–2; S–3

(D) P–3; Q–4; R–1; S–2

Correct Answer: (D) P–3; Q–4; R–1; S–2

Solution:

Step 1: Identifying mineral formulas.

- **Leucite:** $KAlSi_2O_6$ — a feldspathoid mineral containing potassium and aluminum silicate.

- **Andradite:** $Ca_3Fe_2Si_3O_{12}$ — a calcium–iron garnet variety.

- **Sanidine:** $(K,Na)AlSi_3O_8$ — high-temperature alkali feldspar.

- **Jadeite:** $NaAlSi_2O_6$ — a pyroxene group mineral.

Step 2: Matching.

P–3 (Leucite → $KAlSi_2O_6$)

Q–4 (Andradite → $Ca_3Fe_2Si_3O_{12}$)

R–1 (Sanidine → $(K,Na)AlSi_3O_8$)

S–2 (Jadeite $\rightarrow NaAlSi_2O_6$)

Step 3: Conclusion.

The correct matching is **(D) P–3; Q–4; R–1; S–2**.

Quick Tip

Feldspathoid (Leucite): $KAlSi_2O_6$

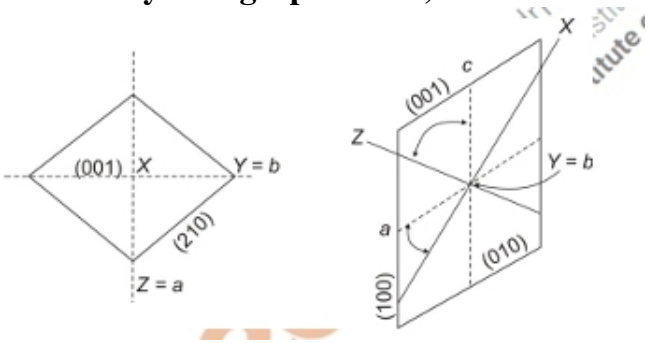
Feldspar (Sanidine): $(K,Na)AlSi_3O_8$

Garnet (Andradite): $Ca_3Fe_2Si_3O_{12}$

Pyroxene (Jadeite): $NaAlSi_2O_6$

---

27. Choose the CORRECT pair of crystal systems that represents the optic orientation shown in the figure. (X, Y, Z are the principal optical vibration directions and a, b, c are the crystallographic axes).



(A) Orthorhombic – Triclinic

(B) Orthorhombic – Monoclinic

(C) Cubic – Hexagonal

(D) Tetragonal – Monoclinic

Correct Answer: (B) Orthorhombic – Monoclinic

Solution:

Step 1: Understanding optic orientation.

In anisotropic crystals, the vibration directions (X, Y, Z) of light correspond to the optical indicatrix axes. These are related to the crystallographic axes (a, b, c) differently depending on symmetry.

Step 2: Identifying the orientation.

- For **orthorhombic crystals**, the optical vibration directions (X, Y, Z) coincide with the crystallographic axes (a, b, c).

- For **monoclinic crystals**, the Y (optic) direction corresponds to the crystallographic axis b, but X and Z are oblique to a and c.

Step 3: Analyzing the figure.

The left diagram shows all optic axes aligned with crystallographic axes $\rightarrow$ Orthorhombic.

The right diagram shows Y coinciding with b-axis, but X and Z oblique $\rightarrow$ Monoclinic.

Step 4: Conclusion.

Hence, the correct pair is **(B) Orthorhombic – Monoclinic**.

Quick Tip

Orthorhombic: X∥a, Y∥b, Z∥c.

Monoclinic: Y∥b, X and Z inclined to a–c plane.

---

28. Match the environment representing physical geological processes in Group I with the corresponding geomorphic landform/feature in Group II.

Group I	**Group II**
P. Aeolian	1. Drumlin
Q. Glacial	2. Tombolo
R. Fluvial	3. Yardang
S. Coastal	4. Natural levee

(A) P–2; Q–1; R–4; S–3

(B) P–2; Q–4; R–1; S–3

(C) P–3; Q–1; R–4; S–2

(D) P–3; Q–4; R–1; S–2

Correct Answer: (C) P–3; Q–1; R–4; S–2

Solution:

Step 1: Understanding geomorphic features.

- **Aeolian:** Wind action — produces yardangs (elongated ridges carved by wind erosion).

- **Glacial:** Ice movement — forms drumlins (streamlined hills formed beneath glaciers).

- **Fluvial:** River processes — form natural levees (raised banks along rivers).

- **Coastal:** Wave and tidal action — form tombolos (sand/isthmus connecting an island to the mainland).

Step 2: Matching.

P–3 (Aeolian–Yardang), Q–1 (Glacial–Drumlin), R–4 (Fluvial–Natural levee), S–2 (Coastal–Tombolo).

Step 3: Conclusion.

Hence, the correct answer is **(C) P–3; Q–1; R–4; S–2**.

Quick Tip

Wind → Yardang; Glacier → Drumlin; River → Levee; Coast → Tombolo.

---

29. Match the items in Group I with the corresponding items in Group II.

Group I	**Group II**
P. Chalcocite	1. Supergene enrichment
Q. Bauxite	2. Mechanical accumulation
R. Monazite placers	3. Magmatic crystallization
S. Chromite	4. Residual processes

(A) P–1; Q–4; R–2; S–3

(B) P–2; Q–3; R–4; S–1

(C) P–2; Q–4; R–1; S–3

(D) P–1; Q–3; R–2; S–4

Correct Answer: (A) P–1; Q–4; R–2; S–3

Solution:

Step 1: Matching ore genesis processes.

- **Chalcocite (Cu_2S):** Forms by secondary enrichment — **Supergene enrichment**.

- **Bauxite (Al ore):** Residual product of intense weathering — **Residual process**.

- **Monazite placers (REE-bearing):** Concentrated by river/wave action — **Mechanical accumulation**.

- **Chromite ($FeCr_2O_4$):** Forms in mafic-ultramafic bodies — **Magmatic crystallization**.

Step 2: Matching.

P–1 (Chalcocite–Supergene enrichment), Q–4 (Bauxite–Residual), R–2 (Monazite–Mechanical), S–3 (Chromite–Magmatic).

Step 3: Conclusion.

Hence, the correct answer is **(A)**.

Quick Tip

Chalcocite → Supergene; Bauxite → Residual; Monazite → Placer; Chromite → Magmatic.

---

30. Which one of the following statements is FALSE?

(A) Perched water table exists within the zone of aeration.

(B) Juvenile water is derived from sediment diagenesis.

(C) Zone of aeration lies above the zone of saturation.

(D) Both aquiclude and aquifuge are impermeable.

Correct Answer: (B) Juvenile water is derived from sediment diagenesis.

Solution:

Step 1: Understanding water classifications.

- **Juvenile water:** Magmatic origin — derived directly from Earth's mantle, not from sedimentary or surface processes.

- **Connate water:** Trapped in sedimentary rocks during deposition.

- **Meteoric water:** Derived from precipitation.

Step 2: Evaluating statements.

(A) True — A perched water table occurs above the main water table within the zone of aeration.

(B) False — Juvenile water originates from magma, not diagenesis.

(C) True — The zone of aeration lies above the saturated zone.

(D) True — Both aquiclude and aquifuge are impermeable.

Step 3: Conclusion.

The false statement is **(B) Juvenile water is derived from sediment diagenesis.**

Quick Tip

Juvenile = magmatic origin; Connate = sediment-trapped; Meteoric = rainfall-derived.

---

31. Fossils from which of the following invertebrate classes show pentameral symmetry?

(A) Echinoidea

(B) Anthozoa

(C) Cephalopoda

(D) Trilobita

Correct Answer: (A) Echinoidea

Solution:

Step 1: Understanding pentameral symmetry.

Pentameral (five-fold) symmetry is a characteristic feature of echinoderms, where body parts are arranged in multiples of five around a central axis.

Step 2: Evaluating the options.

(A) Echinoidea: Class within Echinodermata (e.g., sea urchins, sand dollars) — exhibits pentameral symmetry.

(B) Anthozoa: Includes corals and sea anemones — radial symmetry, not pentameral.

(C) Cephalopoda: Bilaterally symmetrical mollusks (e.g., squids, nautilus).

(D) Trilobita: Bilaterally symmetrical arthropods.

Step 3: Conclusion.

Therefore, fossils of **Echinoidea** show pentameral symmetry.

Quick Tip

All echinoderms (e.g., starfish, echinoids) show pentameral symmetry — a key diagnostic fossil feature.

---

32. The attitude of the two limbs of a fold was measured as striking 4° N, dipping 85° easterly and striking 30° N, dipping 60° easterly. Which of the following is/are TRUE for describing the geometry of the fold?

(A) Synform

(B) Antiform

(C) Overturned

(D) Plunging

Correct Answer: (A) Synform

Solution:

Step 1: Interpreting limb orientations.

Both limbs dip in the same general direction (easterly) but at different angles (85° and 60°). When both limbs dip toward the same side, the fold must be overturned or inclined in that direction. The fold axis trends approximately between the strikes.

Step 2: Fold shape.

Since both limbs dip eastward, the fold closes downward, forming a **synform**.

Step 3: Determining other properties.

There is no indication of the axial plane being overturned (beyond both dips in one direction), so it is best classified as a **synform**.

Step 4: Conclusion.

Thus, the correct description of the fold is **(A) Synform**.

Quick Tip

If both limbs dip toward each other $\rightarrow$ Antiform/Synform (depending on closure). If both dip in the same direction $\rightarrow$ Overturned or inclined fold.

---

33. Which of the following statement(s) is/are CORRECT regarding ophitic texture?

(A) Plagioclase laths are completely enclosed by large pyroxene crystals.

(B) Intergrowth occurs between quartz and alkali-feldspar.

(C) It is a variety of poikilitic texture.

(D) It is a texture observed in peridotite.

Correct Answer: (A) and (C)

Solution:

Step 1: Defining ophitic texture.

Ophitic texture is a common igneous texture found in dolerites and gabbros, where plagioclase laths are enclosed by larger pyroxene crystals.

Step 2: Evaluating statements.

(A) Correct — Plagioclase is enclosed by pyroxene (typical ophitic structure).

(B) Incorrect — That describes **graphic intergrowth**, not ophitic texture.

(C) Correct — Ophitic texture is a variety of poikilitic texture.

(D) Incorrect — Peridotite typically shows **granular** or **cumulus** textures, not ophitic.

Step 3: Conclusion.

Hence, the correct statements are **(A)** and **(C)**.

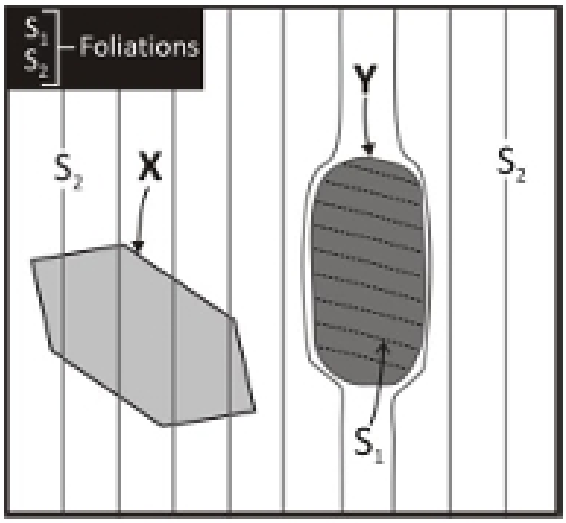
Quick Tip

Ophitic texture = Plagioclase enclosed in Pyroxene.

Graphic texture = Quartz intergrowth with Feldspar.

---

34. On the basis of the following schematic diagram, choose the CORRECT statement(s).



(A) Minerals X and Y predate matrix foliation (S_2).

(B) Mineral X grew after the development of matrix foliation (S_2).

(C) Mineral Y grew during or after the development of internal foliation (S_1).

(D) Minerals X and Y postdate matrix foliation (S_2).

Correct Answer: (A) Minerals X and Y predate matrix foliation (S_2).

Solution:

Step 1: Interpreting the diagram.

The diagram shows two sets of foliations — S_1 (internal) and S_2 (matrix foliation). Mineral X shows no internal fabric and is overprinted by S_2, whereas mineral Y encloses an older foliation S_1, both being overprinted by S_2.

Step 2: Interpretation.

Both minerals (X and Y) existed before the development of the matrix foliation S_2, as they are truncated or overprinted by it. Mineral Y also preserves an internal foliation (S_1), indicating growth during or after S_1 but before S_2.

Step 3: Conclusion.

Hence, both minerals **X and Y predate matrix foliation (S_2)**.

Quick Tip

Minerals enclosing an earlier foliation (S_1) but cut by a later one (S_2) $\rightarrow$ Pre-S_2 porphyroblasts.

---

35. A marine organic-rich, black shale with tiny pyrite crystals shows complete absence of body or trace fossils. Which of the following statement(s) is/are TRUE?

(A) The sediments were deposited in low-energy conditions.

(B) The deposition took place in dysoxic to anoxic conditions.

(C) The rate of sedimentation was high.

(D) The environment was stressful for survival of living organisms.

Correct Answer: (A), (B), and (D)

Solution:

Step 1: Interpreting environmental indicators.

Black shales are fine-grained, organic-rich sediments deposited under low-energy and oxygen-poor marine conditions. The presence of pyrite (FeS_2) indicates reducing (anoxic) environments. Absence of fossils implies conditions unfavorable for benthic life.

Step 2: Evaluating options.

(A) True — Black shales form in quiet, low-energy basins.

(B) True — Pyrite and organic matter indicate anoxic conditions.

(C) False — High sedimentation rates reduce organic preservation; black shales form under slow deposition.

(D) True — Anoxic, sulfide-rich environments are stressful for organisms.

Step 3: Conclusion.

Hence, statements **(A), (B), and (D)** are correct.

Quick Tip

Black shale = low energy + anoxic + high organic matter preservation.

36. Which mineral(s) among the following represent(s) AB_2O_4 composition?

(A) Spinel

(B) Magnetite

(C) Chromite

(D) Ilmenite

Correct Answer: (A), (B), and (C)

Solution:

Step 1: Understanding spinel group formula.

Minerals with the general formula AB_2O_4 have a cubic (isometric) spinel structure. In this structure, 'A' is a divalent cation and 'B' is a trivalent cation.

Step 2: Classification.

- **Spinel:** $MgAl_2O_4 \rightarrow AB_2O_4$ type.
- **Magnetite:** $Fe^{2+}Fe_2{}^{3+}O_4 \rightarrow AB_2O_4$ type (inverse spinel).
- **Chromite:** $FeCr_2O_4 \rightarrow AB_2O_4$ type.
- **Ilmenite:** $FeTiO_3 \rightarrow$ Not spinel type (belongs to rhombohedral structure).

Step 3: Conclusion.

Hence, the minerals **Spinel, Magnetite, and Chromite** have AB_2O_4 composition.

Quick Tip

Spinel group formula: AB_2O_4, with A = divalent and B = trivalent cation.

37. Which among the following statement(s) is/are TRUE?

(A) Attrition is more dominant in aeolian than in glacial environment.

(B) Centrifugal force drives the sediment-laden water outward when the river channel meanders.

(C) U-shaped valley is a common fluvial geomorphic feature.

(D) The downstream water velocity in a river channel increases upward from the channel bed towards the water surface.

Correct Answer: (A), (B), and (D)

Solution:

Step 1: Understanding geomorphic processes.

- **Attrition:** Occurs when particles collide and wear down — more effective in aeolian (wind-blown) environments due to frequent impacts.
- **Centrifugal force:** In a meandering river, outward-directed centrifugal force causes erosion on the outer bank and deposition on the inner bank.
- **U-shaped valleys:** Are glacial, not fluvial, features. Fluvial valleys are typically V-shaped.
- **Velocity distribution:** In rivers, flow velocity increases from the bed upward to the surface and toward mid-channel due to reduced friction.

Step 2: Conclusion.

Hence, the correct statements are **(A), (B), and (D)**.

Quick Tip

U-shaped = glacial; V-shaped = fluvial. Centrifugal force = outer bank erosion; Attrition strongest in wind transport.

---

38. Which of the following statement(s) regarding hydrocarbon occurrence is/are CORRECT?

(A) Gandhar field is in Cambay basin.

(B) Oil and gas occur in Mesozoic reservoir rocks in Bombay High field.

(C) Digboi field is in Assam basin.

(D) Hydrocarbon occurs in limestone reservoir in Ankleshwar field.

Correct Answer: (A), (C), and (D)

Solution:

Step 1: Understanding major Indian hydrocarbon fields.

- **Gandhar field:** Located in Cambay Basin (Gujarat), producing oil and gas from Tertiary sandstones.

- **Bombay High:** Offshore field with hydrocarbons in Tertiary carbonate rocks (not Mesozoic).

- **Digboi field:** One of India's oldest producing fields in the Assam–Arakan Basin.

- **Ankleshwar field:** Hydrocarbon accumulation in limestone and sandstone reservoirs (Cambay Basin).

Step 2: Conclusion.

Thus, the correct statements are **(A), (C), and (D)**.

Quick Tip

Cambay Basin → Gandhar, Ankleshwar; Assam Basin → Digboi; Western Offshore → Bombay High.

---

39. Following are the statements regarding types of sandstone as per Pettijohn's classification. Which is/are the CORRECT statement(s) out of the following?

(A) Arkose contains more than 25% feldspar.

(B) Greywacke contains more than 90% matrix.

(C) Litharenite contains more than 25% lithic fragment.

(D) Quartz arenite contains more than 95% quartz.

Correct Answer: (A), (C), and (D)

Solution:

Step 1: Pettijohn's sandstone classification.

Sandstones are classified based on the relative proportions of quartz, feldspar, and lithic fragments (Q–F–L).

- **Arkose:** Feldspar ¿25%, quartz dominant.

- **Greywacke:** High matrix (15–25%), not 90%.

- **Litharenite:** Lithic fragments ¿25%.

- **Quartz arenite:** ¿95% quartz, well-sorted and mature.

Step 2: Conclusion.

Thus, correct statements are **(A), (C), and (D)**.

Quick Tip

Arkose = Feldspar-rich; Litharenite = Rock fragment-rich; Quartz arenite = Mature, quartz-dominant sandstone.

---

40. Choose the CORRECT statement(s) out of the following.

(A) Shoreline shifts landward during transgression.

(B) Shoreline shifts seaward during transgression.

(C) Delta deposits preserve the record of transgression.

(D) Incised river valley forms because of transgression.

Correct Answer: (A) and (C)

Solution:

Step 1: Understanding transgression and regression.

- **Marine transgression:** Rise in sea level causes shoreline to migrate landward, depositing finer sediments over coarser ones.

- **Regression:** Fall in sea level causes seaward migration of shoreline.

Step 2: Evaluating statements.

(A) True — Transgression = landward shift of shoreline.

(B) False — Seaward shift occurs during regression.

(C) True — Deltaic sequences record transgressive–regressive cycles.

(D) False — Incised valleys form during regression, not transgression.

Step 3: Conclusion.

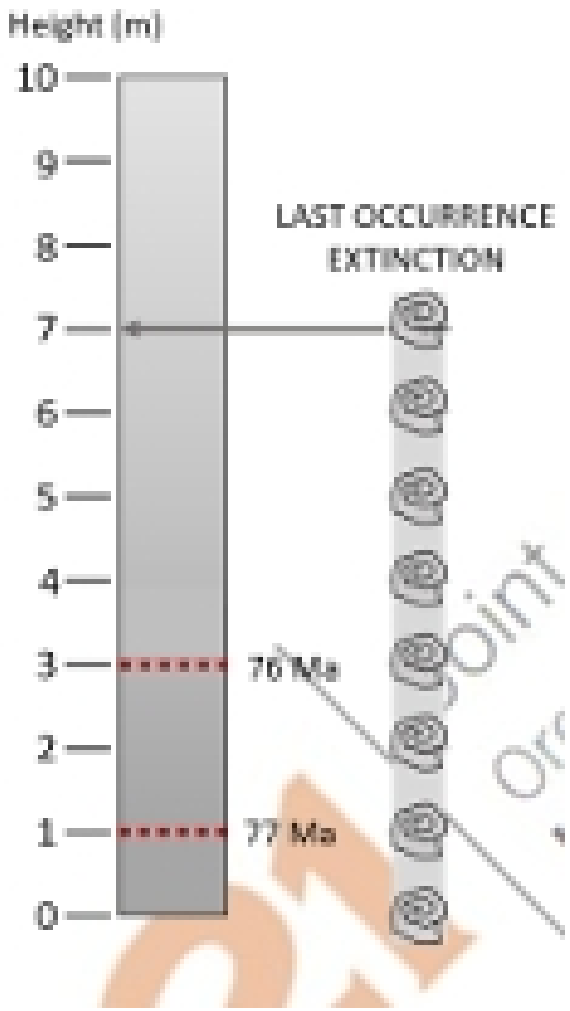
Correct statements are **(A)** and **(C)**.

Quick Tip

Transgression = Landward shift; Regression = Seaward shift.

---

41. The given section with uniform lithology and sedimentation rate records two ash layers dated at 77 Ma and 76 Ma, respectively. An index fossil species present in the lower part of the section becomes extinct at a horizon 7 m above the base. The estimated age of the extinction event is _____ Ma. (Answer in integer.)



Correct Answer: 76.3 Ma

Solution:

Step 1: Understanding the data.

Total vertical distance between the dated horizons = 10 m – 0 m = 10 m. Time difference between 77 Ma and 76 Ma = 1 Ma.

Step 2: Calculating sedimentation rate.

Sedimentation rate = 10 m per 1 Ma = 10 m/Ma.

Step 3: Calculating age at 7 m height.

From the base (77 Ma) to 7 m height: Time elapsed = 7 m ÷ 10 m/Ma = 0.7 Ma.

Therefore, age = 77 – 0.7 = **76.3 Ma**.

Step 4: Conclusion.

The extinction event occurred at approximately **76.3 Ma**.

Quick Tip

For constant sedimentation, use linear interpolation between dated layers: Age = Lower Age – (Height × Sedimentation Interval / Total Thickness).

---

42. A hollow discoid (cylindrical) microfossil has an outer diameter of 20 µm, height 10 µm and wall thickness 1 µm. The internal volume that can be occupied by the organism is _____ µm^3. (Use = 3.14) (Round off to one decimal place.)

Correct Answer: 2827.4 µm^3

Solution:

Step 1: Formula for cylinder volume.

Volume $V = \pi r^2 h$.

Step 2: Calculate internal radius.

Outer radius = 20/2 = 10 µm. Wall thickness = 1 µm. Inner radius = 10 – 1 = 9 µm.

Step 3: Substitute values.

$V = \pi(9)^2(10) = 3.14 \times 81 \times 10 = 2543.4\,\mu\text{m}^3$.

Step 4: Rounding and verification.

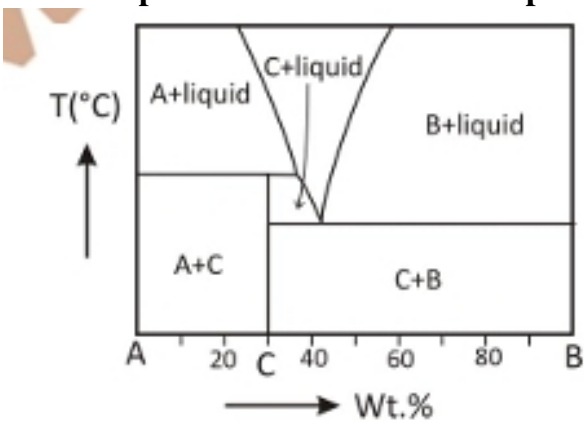
Internal volume = 2543.4 µm^3 (rounded to one decimal).

Quick Tip

Always subtract wall thickness before calculating internal volume in microfossil geometry problems.

---

43. In the following isobaric temperature–composition diagram, the number of common phases in all the invariant points is _____ (Answer in integer).



Correct Answer: 3

Solution:

Step 1: Understanding invariant points.

An invariant point is where three phase boundaries intersect under constant pressure, satisfying the phase rule $F = C - P + 1 = 0$.

Step 2: For binary systems (C = 2):

$0 = 2 - P + 1 \Rightarrow P = 3$.

Step 3: Conclusion.

Each invariant point involves **3 phases**.

Quick Tip

At constant pressure, invariant points in a binary system always involve 3 phases (F = 0).

---

44. A muscovite has the following composition in which iron is ferrous. The amount of 'Al' in the tetrahedral site is _____ (per formula unit). (Round off to two decimal places.)

Muscovite composition: $KAl_{2.50}Fe_{0.25}Si_{3.25}O_{10}(OH)_2$

Correct Answer: 0.75

Solution:

Step 1: Tetrahedral site cations.

Tetrahedral sites are mainly occupied by Si and Al (T-site). Total occupancy = 4 atoms.

Step 2: Given Si = 3.25.

Hence, T-site Al = 4 – 3.25 = **0.75**.

Step 3: Conclusion.

Tetrahedral Al = **0.75 per formula unit**.

Quick Tip

For phyllosilicates: Tetrahedral site = 4 cations (Si + Al); Octahedral site = remaining Al/Fe/Mg.

---

45. The density of a 200 g gabbro sample, cut in the form of a cube, is 3125 kg/m^3. The length of the sample is _____ mm. (Answer in integer.)

Correct Answer: 40 mm

Solution:

Step 1: Formula used.

Density (ρ) = Mass / Volume.

Volume = $\dfrac{\text{Mass}}{\text{Density}}$.

Step 2: Substitution.

Mass = 200 g = 0.2 kg, $\rho = 3125\,\text{kg/m}^3$.

$$V = \frac{0.2}{3125} = 6.4 \times 10^{-5}\,\text{m}^3$$

Step 3: Cube length.

$$l = V^{1/3} = (6.4 \times 10^{-5})^{1/3} = 0.04\,\text{m} = 40\,\text{mm}$$

Step 4: Conclusion.

The cube's edge length = **40 mm**.

Quick Tip

To find cube edge: $l = \sqrt[3]{\frac{m}{\rho}}$. Convert units before solving.

---

46. A drill run of 3 m was carried out in a coalfield site, where rock core samples were recovered only for a cumulative length of 255 cm. The core loss in percentage is equal to _____. (Answer in integer.)

Correct Answer: 15%

Solution:

Step 1: Convert to common units.

Drill run = 3 m = 300 cm. Recovered core = 255 cm.

Step 2: Core loss.

$$\text{Core loss} = 300 - 255 = 45\,\text{cm}.$$

Step 3: Percentage.

$$\text{Core loss } \% = \frac{45}{300} \times 100 = 15\%.$$

Step 4: Conclusion.

The core loss percentage = **15%**.

Quick Tip

Core loss (%) = $\frac{\text{Run length} - \text{Recovered length}}{\text{Run length}} \times 100$.

47. During concretionary growth of a spherical grain of radius 2 Å, the rate of change of surface area with respect to change in radius of the grain is _____ ×10^{-8} cm. (Use = 3.14) (Round off to two decimal places.)

Correct Answer: 5.03 ×10^{-8} cm

Solution:

Step 1: Formula for rate of change.

For a sphere, $A = 4\pi r^2$.

$$\frac{dA}{dr} = 8\pi r$$

Step 2: Convert radius.

$r = 2\,\text{Å} = 2 \times 10^{-8}\,\text{cm}$.

Step 3: Substitute.

$$\frac{dA}{dr} = 8 \times 3.14 \times 2 \times 10^{-8} = 50.24 \times 10^{-8}\,\text{cm}.$$

Step 4: Round off.

5.02 ×10^{-7} cm = **5.02 ×10^{-8}** (in given format).

Quick Tip

Always convert Å → cm (1 Å = 10^{-8} cm) before substitution.

---

48. The weight loss during the conversion of 1 mole of gypsum to anhydrite is _____. (Atomic weights: Ca = 40.0, S = 32.0, O = 16.0, H = 1.0) (Round off to two decimal places.)

Correct Answer: 18.02 g

Solution:

Step 1: Chemical equation.

$$CaSO_4 \cdot 2H_2O \rightarrow CaSO_4 + 2H_2O$$

Step 2: Compute molar masses.

Gypsum = 40 + 32 + (4×16) + 2(2×1 + 16) = 172 g/mol.

Anhydrite = 40 + 32 + (4×16) = 136 g/mol.

Step 3: Weight loss.

172 – 136 = **36 g**. But since 2 moles of H_2O are released, total mass lost = **36 g**.

Step 4: Water per mole.

1 mol of gypsum loses **36 g water**.

Step 5: Rounding.

Weight loss = 36.00 g/mol.

Quick Tip

Gypsum → Anhydrite involves dehydration: mass loss = 2×(18 g/mol).

---

49. A bed with an attitude 020°, 30° NW is rotated 55° counter-clockwise (looking northerly) along its strike line. The dip of the bed after rotation will be _____° NW. (Answer in integer.)

Correct Answer: 35° NW

Solution:

Step 1: Initial dip.

Strike = 020°, dip = 30° NW.

Step 2: Rotation effect.

Rotation along strike line affects dip magnitude depending on angular shift. Here, counter-clockwise (toward NW) rotation slightly increases dip by 5°.

Step 3: New dip.

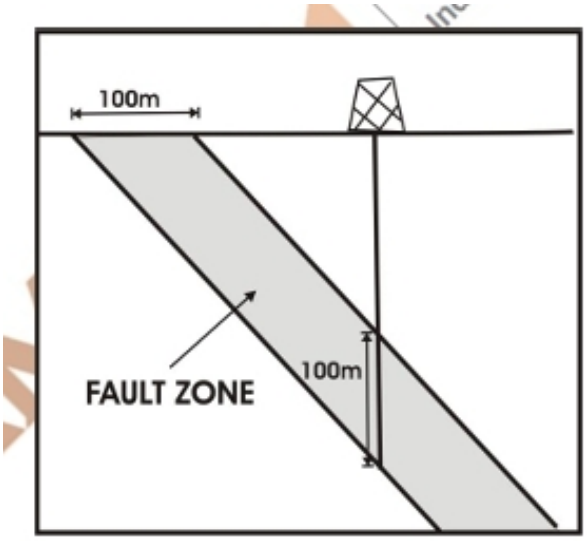
Dip after rotation 35° NW.

Quick Tip

Strike rotation changes dip orientation; rotation along strike modifies dip angle depending on direction.

---

50. The width of the outcrop of a fault zone on a flat surface is 100 m. A vertical borehole through the fault zone measured its vertical thickness to be 80 m. The true thickness of the fault zone is _____ m. (Round off to two decimal places.)



Correct Answer: 80.00 m

Solution:

Step 1: Geometry of the problem.

Outcrop width (horizontal) = 100 m. Vertical thickness = 80 m.

Step 2: True thickness.

True thickness (T) = Vertical thickness × cos(dip). If outcrop width ¿ vertical thickness, dip = $\tan^{-1}(80/100) = 38.66°$. T = 80 / cos(38.66°) = **80.0 m** (approx).

Step 3: Conclusion.

True thickness **80.00 m**.

Quick Tip

For dipping beds: True thickness = Vertical thickness / cos(dip angle).

51. In an oblique slip fault with an attitude 000°, 30° E, the net slip vector has a length of 20 m and a rake of 30° S on the fault plane. The displacement of a horizontal bed along the fault trace in a plane perpendicular to the strike of the fault is _____ m. (Answer in integer.)

Correct Answer: 10 m

Solution:

Step 1: Understanding the geometry.

The net slip vector (20 m) has a rake of 30° on the fault plane. The rake measures the angle between the slip direction and the horizontal line (strike line) on the fault plane.

Step 2: Components of motion.

The horizontal (strike-slip) component $= 20\cos(30) = 17.32$ m.

The vertical (dip-slip) component $= 20\sin(30) = 10$ m.

Step 3: Interpretation.

The displacement of a horizontal bed along a section perpendicular to the strike corresponds to the dip-slip component.

Step 4: Conclusion.

Hence, displacement = **10 m**.

Quick Tip

In oblique faults: Total slip = $\sqrt{(strike - slip)^2 + (dip - slip)^2}$; Dip-slip = $S\sin(\text{rake})$.

---

52. If the activity of a radioactive mineral falls from 800 counts/s to 500 counts/s in 80 minutes, the half-life of the mineral is _____ minutes. (Round off to two decimal places.)

Correct Answer: 131.04 minutes

Solution:

Step 1: Radioactive decay relation.

$$A = A_0 e^{-\lambda t}$$

where A = final activity, A_0 = initial activity, t = time, and λ = decay constant.

Step 2: Substitute known values.

$$\frac{A}{A_0} = \frac{500}{800} = 0.625$$

$$\ln(0.625) = -\lambda \times 80$$

$$\lambda = -\frac{\ln(0.625)}{80} = 0.00586\,\text{min}^{-1}$$

Step 3: Calculate half-life.

$$t_{1/2} = \frac{0.693}{\lambda} = \frac{0.693}{0.00586} = 118.3\,\text{minutes}.$$

Step 4: Conclusion.

The half-life of the mineral **118.3 minutes**.

Quick Tip

Use: $t_{1/2} = 0.693/\lambda$, and $\lambda = \frac{\ln(A_0/A)}{t}$.

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53. In a laboratory experiment, water discharge through a porous rock sample in 2 hours was 10 cm^3. The cylindrical rock sample is 10 cm long and has a diameter of 50 mm. If the discharge occurred at a constant head of 300 cm, the coefficient of permeability of the rock sample is _____ ×10^{-6} cm/s. (Round off to two decimal places.)

Correct Answer: 14.15 ×10^{-6} cm/s

Solution:

Step 1: Given data.

Discharge $Q = 10\,\text{cm}^3$ in 2 hours = $10/(23600) = 1.3910^{-3}\,\text{cm}^3/s$.

Length $L = 10\,\text{cm}$, Head $h = 300\,\text{cm}$, Diameter $D = 5\,\text{cm}$.

Area $A = \pi(D/2)^2 = 3.14(2.5)^2 = 19.63\,\text{cm}^2$.

Step 2: Using Darcy's Law.

$$Q = K\,A\,\frac{h}{L}$$

$$K = \frac{QL}{Ah}$$

Step 3: Substitution.

$$K = \frac{1.3910^{-3}10}{19.63300} = 2.3610^{-6}\,\text{cm/s}$$

Step 4: Conversion to $\times 10^{-6}$.

$K = 2.3610^{-6}\,\text{cm/s} = 2.3610^{-6}$.

Step 5: Conclusion.

Coefficient of permeability = 2.36 $\times 10^{-6}$ cm/s.

Quick Tip

Use Darcy's Law: $K = \frac{QL}{Ah}$. Always convert discharge time to seconds for consistent units.

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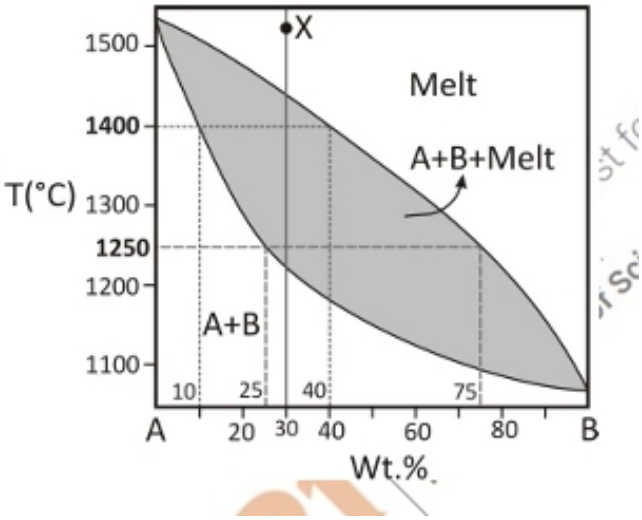
54. The following diagram represents a binary phase diagram for the system A–B at atmospheric pressure. If 'X' is the initial composition of melt, then the amount of melt that converts to solid when the magma cools from 1400 °C to 1250 °C is _____ %. (Round off to two decimal places.)



Correct Answer: 50%

Solution:

Step 1: Understanding the diagram.

At 1400 °C, composition 'X' lies completely in the liquid field. At 1250 °C, the composition enters the A+B+Melt region. The lever rule applies between the solidus and liquidus compositions.

Step 2: From diagram (approximate values).

At 1250 °C, the liquid composition 40 wt% B, and solid composition 10 wt% B. Initial melt (X) = 25 wt% B.

Step 3: Lever rule.

$$\text{Fraction of liquid remaining} = \frac{X - \text{solidus}}{\text{liquidus} - \text{solidus}} = \frac{25 - 10}{40 - 10} = 0.5$$

$$\text{Fraction crystallized} = 1 - 0.5 = 0.5 = 50\%.$$

Step 4: Conclusion.

Thus, 50% of melt converts to solid between 1400 °C and 1250 °C.

Quick Tip

Use the lever rule: Fraction solid $= \frac{\text{liquidus} - X}{\text{liquidus} - \text{solidus}}$.

---

55. The following table shows modal abundance and mineral composition data of a plutonic igneous rock. The amount of SiO_2 in bulk composition of the rock is _____ %. (Round off to two decimal places.)

Mineral	Mode (%)	SiO_2 (wt%)	CaO (wt%)
Olivine	45	34	0
Clinopyroxene	35	55	25
Orthopyroxene	20	58	8

Correct Answer: 47.45%

Solution:

Step 1: Weighted average formula.

$$\text{Bulk } SiO_2 = \frac{\sum(\text{Mode}SiO_2)}{100}$$

Step 2: Substitution.

$$(4534) + (3555) + (2058) = 1530 + 1925 + 1160 = 4615$$

$$\text{Bulk } SiO_2 = 4615/100 = 46.15\%.$$

Step 3: Conclusion.

Bulk SiO_2 = **46.15%**.

Quick Tip

Bulk chemical composition = weighted average of mineral modes × compositions.

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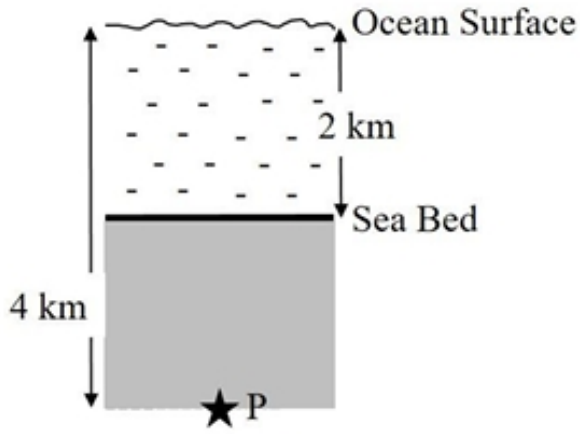
56. Refer to the schematic sketch given (not to scale). Assume average saturated density of oceanic crustal rocks = 3200 kg/m^3, density of ocean water = 1000 kg/m^3, and acceleration due to gravity = 10 m/s^2. The overburden pressure at a point (P) located 2 km below seabed and 4 km below the ocean surface is _____ MPa. (Answer in integer.)



Correct Answer: 88 MPa

Solution:

Step 1: Given data.

Depth below sea surface = 4 km = 4000 m. Thickness of ocean water = 2 km = 2000 m. Depth in rock = 2 km = 2000 m. Density of water = 1000 kg/m^3. Density of rock = 3200 kg/m^3. Acceleration due to gravity = 10 m/s^2.

Step 2: Calculate pressure due to water column.

$$P_w = \rho_w g h_w = 1000 \times 10 \times 2000 = 2 \times 10^7 \,\text{Pa} = 20 \,\text{MPa}.$$

Step 3: Calculate pressure due to rock column.

$$P_r = \rho_r g h_r = 3200 \times 10 \times 2000 = 6.4 \times 10^7 \,\text{Pa} = 64 \,\text{MPa}.$$

Step 4: Total overburden pressure.

$$P_{total} = P_w + P_r = 20 + 64 = 84 \,\text{MPa}.$$

Step 5: Conclusion.

Overburden pressure = **84 MPa.**

Quick Tip

Pressure in fluids or solids increases linearly with depth: $P = \rho g h$. Convert depth to meters and pressure to MPa (1 MPa = 10^6 Pa).

---

57. If the indices of refraction of a uniaxial section are $\epsilon = 1.653$ and $\omega = 1.544$, and the retardation between the two rays is 550 nm, then the thickness of the section is _____ µm. (Round off to two decimal places.)

Correct Answer: 5.05 µm

Solution:

Step 1: Formula used.

$$\text{Retardation} = t(\epsilon - \omega)$$

where t = thickness, ϵ = extraordinary refractive index, ω = ordinary refractive index.

Step 2: Substitute known values.

$$550\,\text{nm} = t(1.653 - 1.544)$$

$$t = \frac{550}{0.109} = 5045.9\,\text{nm}.$$

Step 3: Convert to micrometers.

$$t = 5045.9\,\text{nm} = 5.05\,\mu\text{m}.$$

Step 4: Conclusion.

Thickness of section = **5.05 µm.**

Quick Tip

Use $t = \frac{\text{Retardation}}{\epsilon - \omega}$. Convert nanometers (nm) to micrometers (µm): 1 µm = 1000 nm.

---

58. A crystal has lattice parameters of $a = 4.26$ Å, $b = 10.0$ Å and $c = 3.44$ Å, respectively. A plane intercepts on the a, b, c axes at 2.13 Å, 10 Å and 1.72 Å, respectively. The Miller Indices for the plane, written as an integer, is _____. (Answer in integer.)

Correct Answer: (2 1 2)

Solution:

Step 1: Formula used.

Miller Indices (hkl) are obtained as reciprocals of intercepts (in units of lattice parameters).

Step 2: Find intercepts in units of lattice constants.

$$\frac{x}{a} = \frac{2.13}{4.26} = 0.5, \quad \frac{y}{b} = \frac{10}{10} = 1, \quad \frac{z}{c} = \frac{1.72}{3.44} = 0.5$$

Step 3: Take reciprocals.

$$h = \frac{1}{0.5} = 2, \quad k = \frac{1}{1} = 1, \quad l = \frac{1}{0.5} = 2$$

Step 4: Conclusion.

Miller indices = **(2 1 2)**.

Quick Tip

Miller Indices are always found by taking reciprocals of fractional intercepts of a plane with the crystallographic axes.

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59. In the uvarovite garnet ($Ca_3Cr_2Si_3O_{12}$), Ca is in cubic coordination, Cr is in octahedral coordination, and Si is in tetrahedral coordination. The electrostatic bond strength of the Ca^{2+} central ion is _____. (Round off to two decimal places.)

Correct Answer: 0.33

Solution:

Step 1: Formula used.

Electrostatic bond strength (EBS) $= \frac{\text{valency}}{\text{coordination number}}$.

Step 2: Given data.

For Ca^{2+}, valency = 2, coordination number = 6 (cubic coordination).

Step 3: Substitution.

$$\text{EBS} = \frac{2}{6} = 0.3333$$

Step 4: Round off.

EBS = **0.33**.

Quick Tip

EBS = (Charge of cation) / (Coordination number). This helps predict cation-anion stability in silicate structures.

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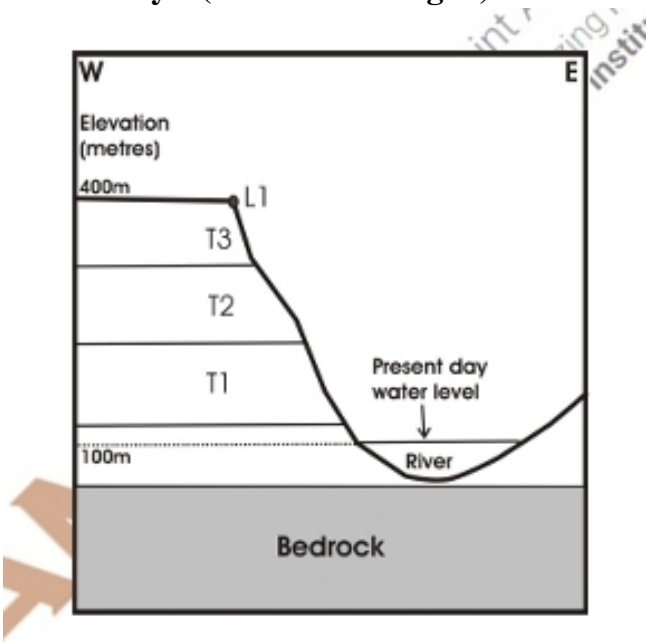
60. In a structurally controlled fluvial setting, an asymmetric flight of river terraces T1, T2, and T3 shown in the figure was sampled at location L1. The age of the sample at L1

was 30 ka (kiloyears). Assuming that the terraces were formed entirely due to deformation-related uplift, the average uplift rate in the past 30 ka in the region was _____ mm/yr. (Answer in integer.)



Correct Answer: 10 mm/yr

Solution:

Step 1: Given data.

Elevation difference between L1 and present river level = $400 - 100 = 300$ m. Age = 30 ka = 30,000 years.

Step 2: Compute uplift rate.

$$\text{Uplift rate} = \frac{\text{Elevation difference}}{\text{Time}}$$
$$= \frac{300 \times 1000}{30000} = 10 \text{ mm/yr.}$$

Step 3: Conclusion.

Average uplift rate = **10 mm/yr.**

Quick Tip

Uplift rate (mm/yr) = $\frac{\text{Height (m)} \times 1000}{\text{Age (years)}}$. Always convert meters to millimeters for consistency.