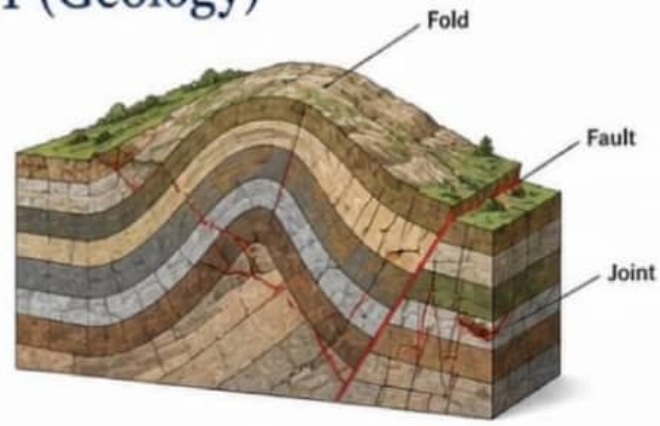
Mine Geology -1

Lecturer Note Prepared by

Sagar Krishna Pahi

Lecturer stage-1 (Geology)

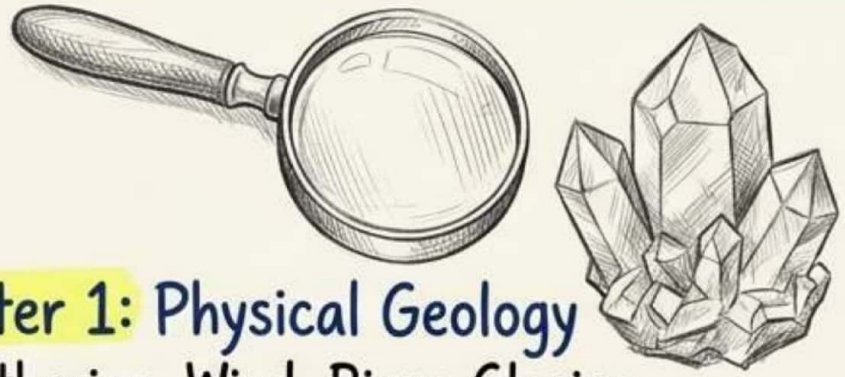






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Mine Geology I: The Definitive Study Guide



Chapter 1: Physical Geology
(Weathering, Wind, River, Glacier processes & landforms)

Chapter 2: Petrology
(Rock definitions, Igneous & Sedimentary textures/structures)

Chapter 3: Structural Geology
(Dip/Strike, Folds, Faults, Unconformity)

Chapters 4 & 5: Elements of Mineralogy
(Physical & Optical Properties)

Noteb

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Weathering & Erosion

Weathering process occurs at or near Earth's surface producing changes to landscape, influencing topography.
Weathering is physical disintegration or chemical alteration of rocks.
Erosion is the physical removal and transportation by water, wind, ice, or gravity.

Types of Weathering

Mechanical Weathering: Physical disintegration and size reduction of rocks without changing chemical composition.

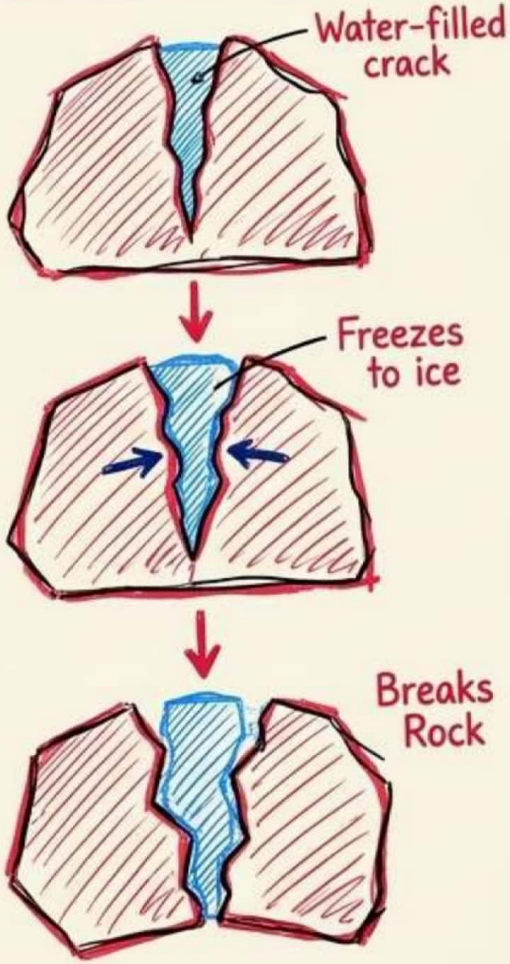
Exfoliation: Pressure released along parallel alignments near bedrock surface; layers/slabs break off and move downhill by gravity.

Abrasion: Rocks collide while transported (water, ice, wind, gravity). Weathers bedrock surface and breaks into individual grains.

Salt Wedging: Salts crystallize as water evaporates. Crystals grow, apply pressure, crack rocks. Common in dry climates (deserts).

Temperature Changes: Diurnal/seasonal. Warmer = expansion, cooler = contraction.
Weakens grains, rock breaks. Common in deserts (extreme fluctuations).
Accelerates other weathering.

Frost Wedging: Freeze-thaw action of trapped water. Water freezes → expands → applies pressure → cracks rock. (Repeated cycles).



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Chemical Weathering: Decomposes, dissolves, alters, or weakens rock through chemical processes to form residual materials.

Carbonation: CO_2 and rainwater chemically react to produce carbonic acid (weak acid), reacting with carbonate minerals. Weakens rock and removes materials.

$$CO_2 \text{ (air)} + H_2O \text{ (water)} \longrightarrow H_2CO_3 \text{ (carbonic acid)}$$

$$CaCO_3 \text{ (limestone)} + H_2CO_3 \longrightarrow Ca(HCO_3)_2 \text{ (calcium bicarbonate)}$$

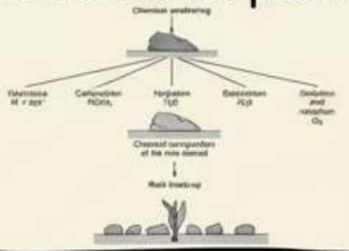
Hydrolysis

Reaction between H+ and OH- ions in water and rock minerals. H+ replaces minerals to produce weak acids.
Creates softer, weaker new compounds.

Hydration

Mineral forms weak bond with H_2O, expanding, creating stress and decay. Produces a new, larger mineral compound.

Example: Anhydrite ($CaSO_4$) absorbs two water molecules to become gypsum ($CaSO_4 \cdot 2H_2O$).



Oxidation

Oxygen + water react with iron-rich minerals. Weakens structure. Changes color to "rusty" reddish-orange.

Solution

Minerals dissolve directly into water. Common on carbonates (limestone) or halite/rocksalt.

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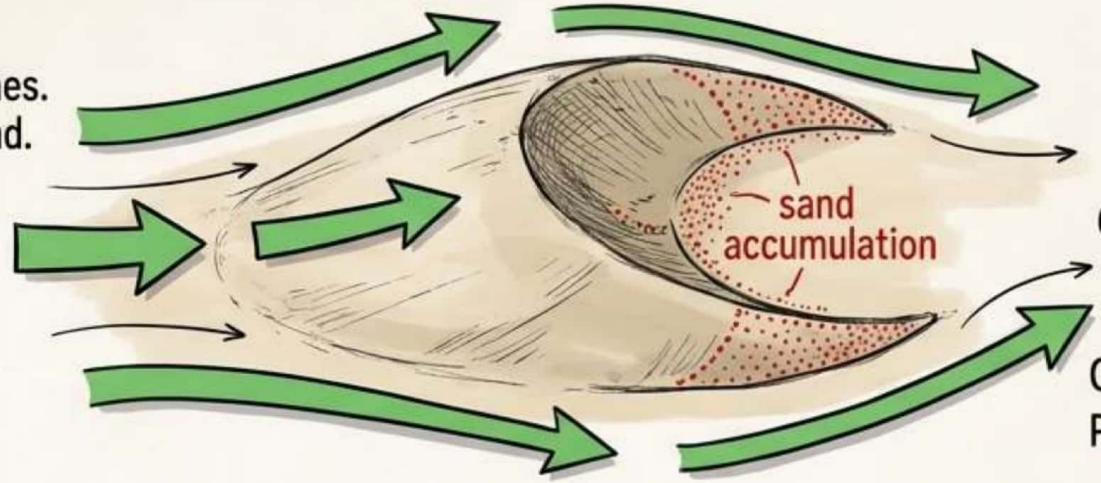
Landforms of Wind Deposition: When wind velocity/carrying capacity decreases, sand grains settle.

Dunes: Hills of sand formed by accumulation, shaped by wind movement.
Classifications: active (live, moving) vs inactive (fixed, rooted with vegetation).

Barchan Dunes:

Moon/crescent shaped live dunes.
Points/wings directed downwind.
Occur transversely to wind.

Windward side is convex & gently sloping; leeward side is concave & steep.



Windward side is convex & gently sloping; leeward side is concave & steep.

Crest moves forward as sand is driven up windward side and slips down leeward.

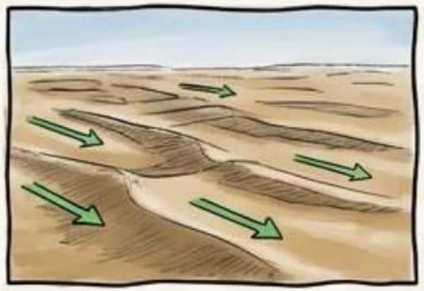
Can bury palm trees/houses.

Prevalent in Turkestan & Sahara.

Seif Dunes

Arabic for "sword".

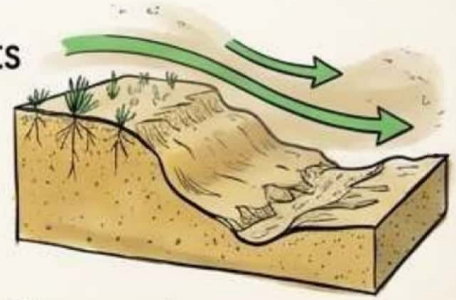
Long, narrow ridges of sand, often >100 miles long, lying parallel to prevailing winds.



Similar to barchan but with only one wing.
Crosswinds increase height/width.
Found in Sahara, West Australian, Thar deserts.

Loess

Fine dust blown beyond desert limits deposited on neighboring lands.



Yellow, friable, very fertile loam.
Rich in lime, extremely porous.
Water sinks readily, surface is dry.
Streams cut deep valleys -> badland topography.
Most extensive: north-west China (Hwang-Ho basin).

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Mechanics of Erosion

Tracking into water escalation

Splash erosion: Raindrop impact loosens soil particles.

Sheet flow/erosion: Water flows over surface not confined to channels. Significant erosion in arid/semi-arid regions where rainfall is torrential and vegetation is sparse.

Rill erosion: Concentration of flow in tiny, superficial, ill-defined channels.



Gully erosion: High intensity storms widen rills by absorption.



Fluvial Processes: Work of rivers (*fluvial* = Latin *fluvius*). Includes overland flow and stream flow. Constitutes largest proportion of terrestrial landscape development.

Streamflow (linear flow): Rill/gully develops into full drainage pattern. Length increases by elongation at heads (headward erosion).
Dynamics: Movement is laminar flow downhill. Gradual change in velocity/depth to compensate for bends/obstructions. Roughness reduces speed; turbulence is major eroding agent.

Discharge Formula

Energy depends on **volume & velocity (discharge)**.
Expressed in **cumecs** (cubic metres/sec).

Cumecs = rate of flow (m/s) × cross section (sq metres)

River Regimes:
Simple (one period of high/low water),
Double (two distinct periods),
Complex (largest rivers across multiple climates).

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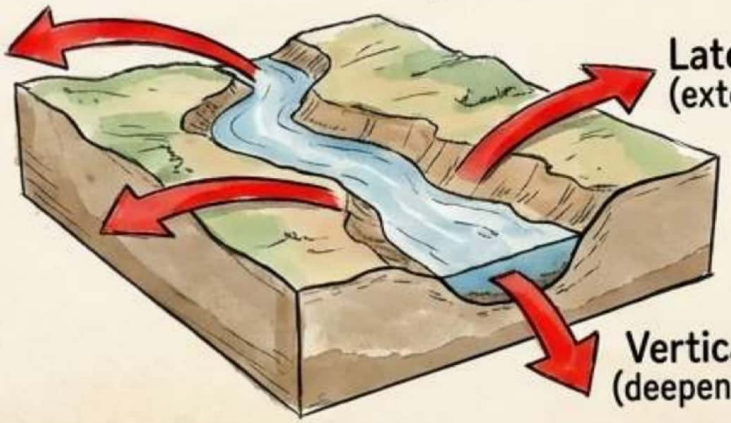
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The Work of Rivers: 3 interdependent activities that degrade land, carve valleys, create plains/deltas.

1. Erosion (Chemical & Mechanical)	2. Transportation	3. Deposition
- **Corrosion:** Soluble rocks (limestone) dissolve. - **Hydraulic action:** River cuts bed/sides via pure force of water (without pebbles/chemicals). - **Corrasion/Abrasion:** Rock fragments greatly increase erosive power, abrading bed/sides. - **Attrition:** Rock fragments collide and disintegrate into small, smooth, rounded pieces.	Depends on volume, velocity, gradient. - **Suspension/Solution:** Fine/small load floats or dissolves. - **Traction (Bed load):** Large, angular fragments roll/drag along river bed. Largest size moved = 'capacity'. Largest diameter = 'competence'. - **Saltation:** Intermediate material bounces/jumps along stream bed.	Starts when velocity decreases. Huge amounts of stony debris form sand/silt cones and fans. - **Diaras:** Slackening flow on level surface deposits sand/silt. - **Flood plain:** Flood waters overtop banks, depositing outside channel.

Forms of Erosion:

Headward
(increases upstream length)



Lateral
(extends width/sideways)

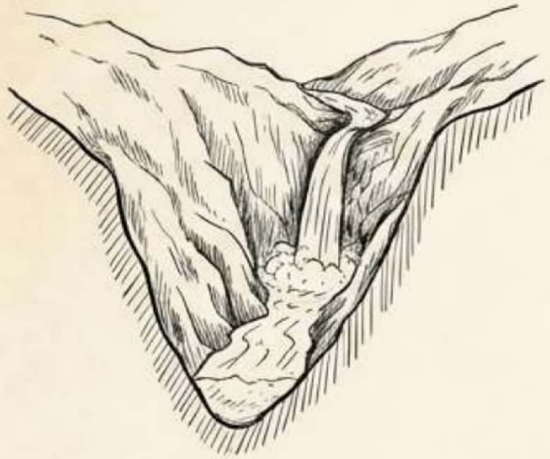
Vertical
(deepens base/channel)

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The Fluvial Cycle of Erosion: Three distinct stages of landscape development. (Point of origin = source; end = mouth).

Youth (Upper Course)



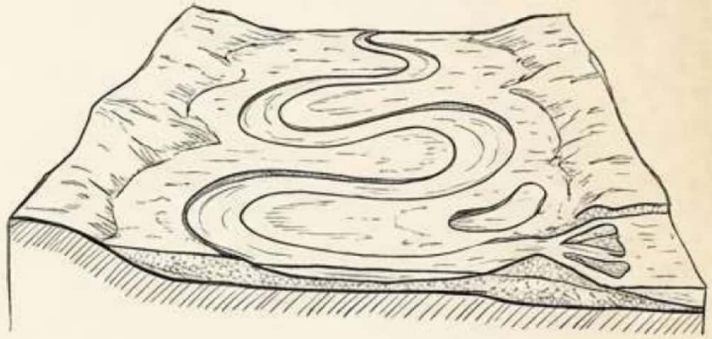
- Poor integration, steep gradients.
- Valley is deep, narrow, distinctly V-shaped.
- No floodplains (or very narrow).
- Downcutting (vertical) predominates over lateral corrasion.
- Features: Gorges, canyons, waterfalls, rapids, river capture. Example: Ganga above Hardwar.

Mature (Middle Course)



- Plenty of streams, good integration.
- Lateral corrasion replaces vertical corrasion.
- Valleys are still V-shaped but wider, deep due to active bank erosion.
- Trunk streams have wider floodplains, meanders confined within valley.
- Waterfalls and rapids disappear. Meander and slip off slopes are characteristic.

Old (Lower Course)

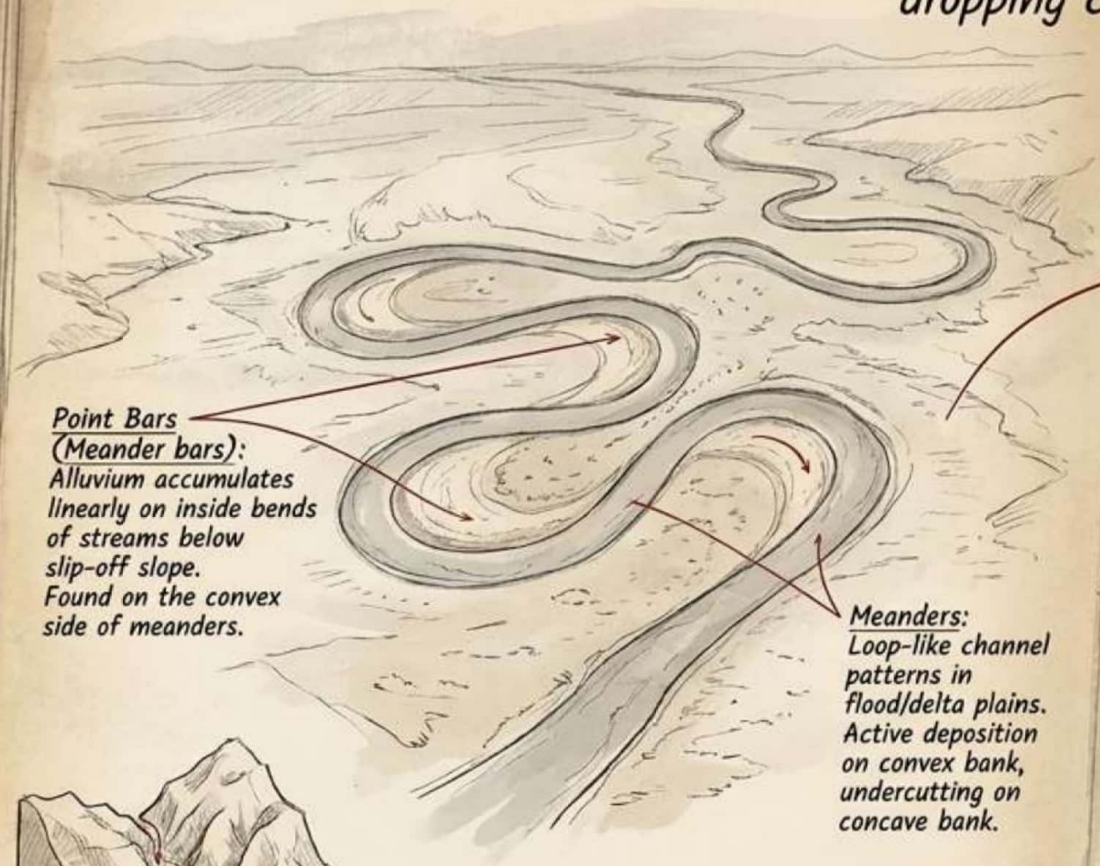


- Moves across broad level plain, heavy with sediments.
- Vertical corrasion ceases; lateral corrasion erodes banks further.
- Streams meander freely over vast floodplains. Depositional features predominate.
- Characteristics: Floodplains, oxbow lakes, natural levees, Delta. Example: Ganga below Rajmahal (plain tract)

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Fluvial Depositional Landforms: Lower course river loses velocity, reducing transporting power, dropping coarser materials first, then finer silt toward mouth.



Point Bars (Meander bars): Alluvium accumulates linearly on inside bends of streams below slip-off slope. Found on the convex side of meanders.

Meanders: Loop-like channel patterns in flood/delta plains. Active deposition on convex bank, undercutting on concave bank.

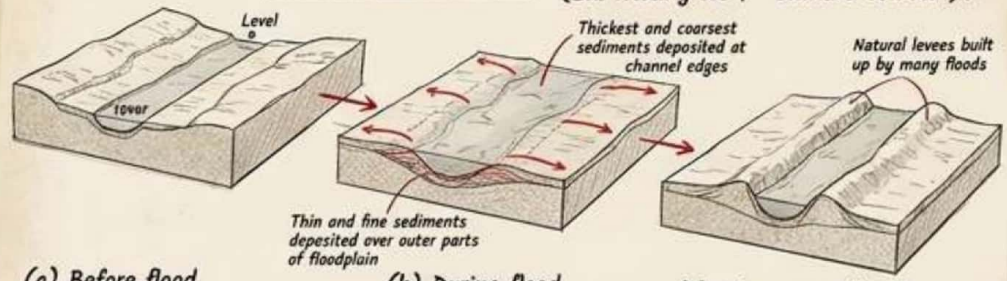


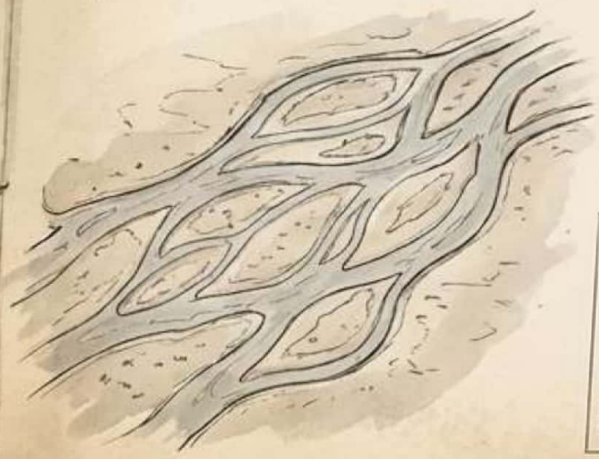
Alluvial Fans: Cone-shaped deposit built by heavy sediment load streams flowing from mountains onto level surfaces. Humid areas = low cones, gentle slope.
Arid = high cones, steep slope.

Natural Levees

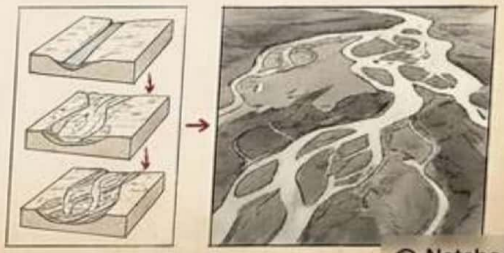


Natural Levees: Low, linear, parallel ridges of coarse deposits on both banks of large rivers. Formed when flood waters spill over banks and suddenly lose speed. Minimizes flood risk, but sudden bursts cause disasters (Ex: Hwang Ho / "China's sorrow").





Braided Channels: Formed by deposition and lateral erosion. Central bars divert flow toward banks, widening valley. Water column reduces, materials deposit as islands/lateral bars, creating multiple separate channels.



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Glacier: Large mass of ice persistently moving under own weight over land or down mountains in broad trough-like valleys. Flows like very slow rivers (centimetres to metres a day).

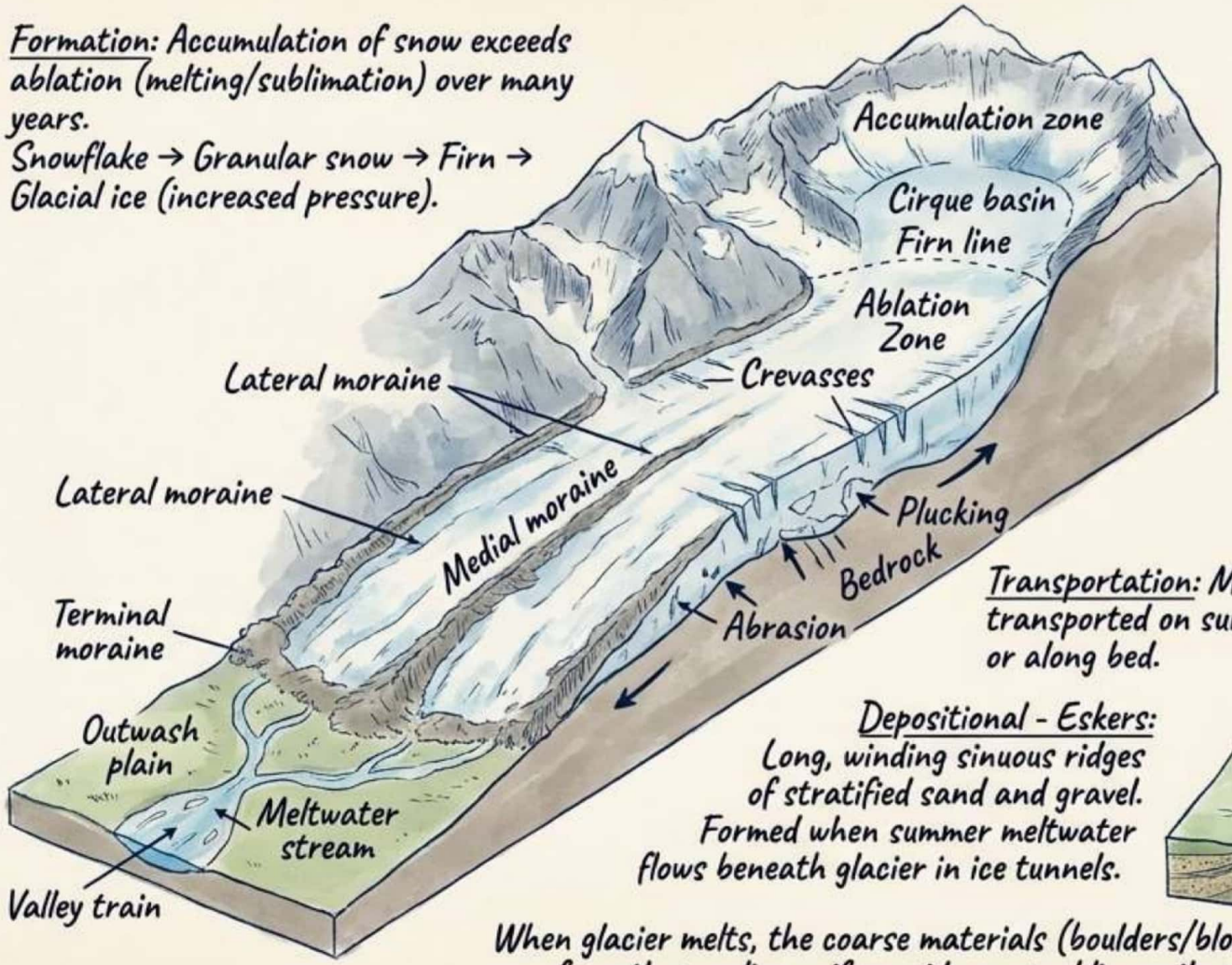
90% air

Snow | 50% air

Firn | 20-30% air

Glacial ice
(20% air as bubbles)

Formation: Accumulation of snow exceeds ablation (melting/sublimation) over many years.
Snowflake → Granular snow → Firn → Glacial ice (increased pressure).

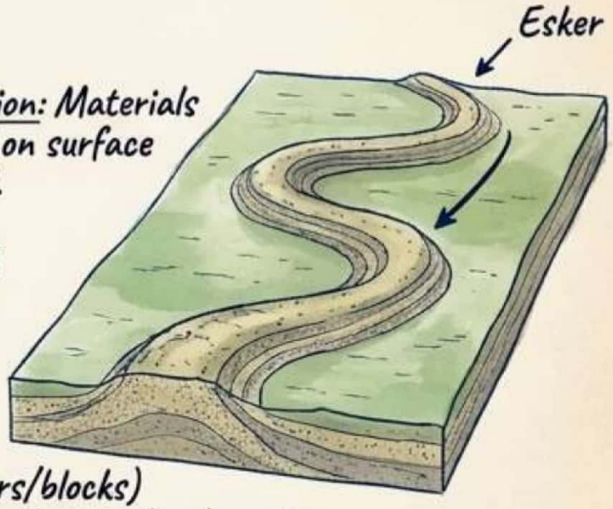


Glacial Erosion:
Abrasion: Basal ice is armed with sharp angular rock fragments. Polishes, scratches, cuts grooves (striations) in rock floor.

Plucking: Quarrying/joint-block removal. Freezes to parent rock and removes large fragments without movement of parent rock.

Transportation: Materials transported on surface or along bed.

Depositional - Eskers:
Long, winding sinuous ridges of stratified sand and gravel. Formed when summer meltwater flows beneath glacier in ice tunnels.



When glacier melts, the coarse materials (boulders/blocks) form the peculiar uniform ridge, resembling railway embankments.

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Why Study Rocks? Contain clues about past Earth. Assemble historical record, trace events, answer if there was a lake, mountain, or hot/cold climate. "Every rock has a story to tell..." - helps us coexist with nature.

Textures of Igneous Rocks: Based on glass vs. mineral grains proportions, sizes, shapes, mutual arrangements. Provides cooling history! (Fabric = arrangement/orientation of grains).

Petrology: Crystallinity & Granularity

Crystallinity (Degree of crystallisation): Ratio between crystallised matter and glass (0-100%). ①

↳ **Crystallites**: Embryo of crystals.
- Longulites (cylindrical rods).
- Globulites (minute spherical drops).
- Margarites (globulites aligned like beads).
- Scopulites (rods with divergent plumes).
- Trichites (filamentous/hair-like).

② **Factors Controlling Crystallinity:**
- **Rate of cooling**: Faster cooling = finer crystals / volcanic glass. Slower = larger crystals.
- **Depth & Volume**: Higher depth = slower cooling. Larger volume = slower cooling.
- **Composition/Viscosity**: Highly viscous (rhyolite/siliceous) favous non-crystalline/glass. Less viscous (basaltic/mafic) gives crystalline rocks.

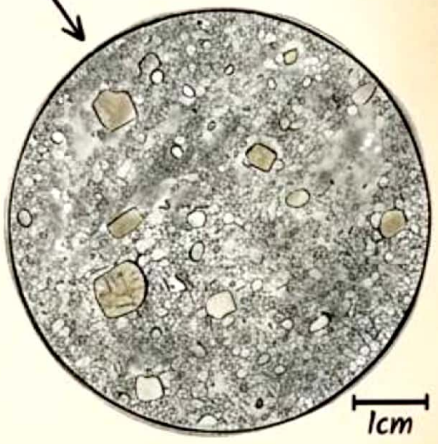
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- Less viscous (basaltic/mafic) gives crystalline rocks.

③ **Granularity**: Grain size variation.



Phaneritic (coarse-grained, seen with unaided eyes).



Aphanitic (fine-grained, requires microscope).

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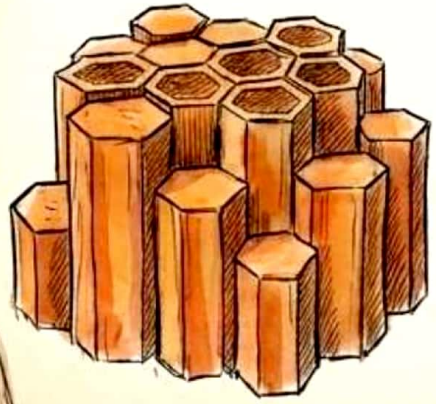
Igneous Structures



Platy and Sheet:
Parallel partings/joints giving rise to plates of rock mass.
Horizontal joints = sheet structure.

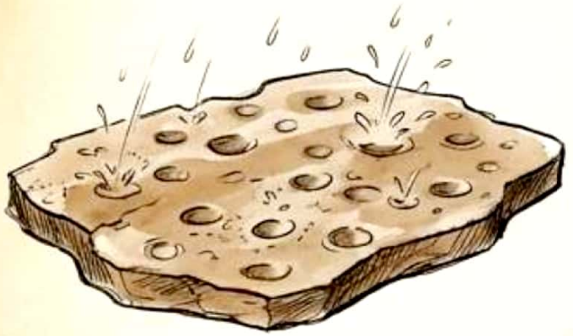
Pillow Lava:
Peculiar ellipsoidal pillow-shaped structures in basic/mafic lavas.
Formed by extrusion of lava under water (logged sea water, sediment, rain-soaked air, ice-sheets).
Vesicular crust, glassy skin (chilled margins from sudden cooling).





Columnar/Prismatic Structure:
Uniform cooling and contraction in homogeneous magma. Forms 4, 5, or 6-sided columns due to contraction at equally-spaced intervals on cooling surfaces.

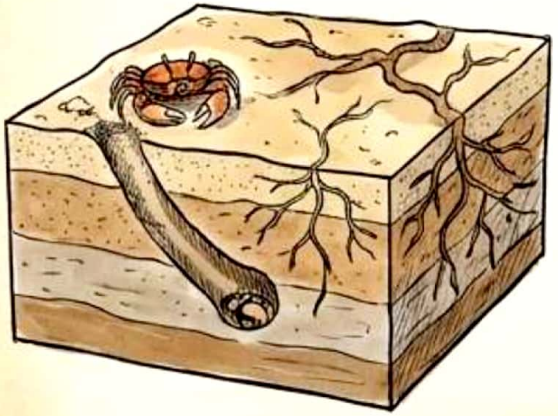
Important Sedimentary Structures



Rain prints/drop points:
Pits created by falling rain on exposed sediment.

Tracks and Trails:
Formed when organisms move, walk, crawl, or drag body parts across sediment.





Burrow marks: Formed by any organism that burrows into sediment.

Rootlets: Marks left by plant roots in sediment.

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Metamorphic Structures (Macrotextures):

Texture/Fabric: Penetrative small-scale features. **Structure** = larger-scale (hand-sample/outcrop). Microstructure replaces "texture" for microscopes.

Slaty cleavage: Pervasive, parallel foliation of fine-grained platy minerals (chlorite) perpendicular to max stress. (Slate, phyllite).

Schistose: Lepidoblastic foliation defined by oriented micas, or nematoblastic (prismatic minerals like amphiboles).

Gneissic: Complex banded texture; alternating schistose bands.

Granoblastic: Granular, interlocking equidimensional grains; no preferred orientation.

Hornfelsic: Fine-grained, interlocking grains of variable shapes; no preferred orientation.

Cataclastic: Produced under stress without high temp. Durable minerals survive crushing ("porphyroclasts").
Highly crushed fine-grained rocks = **mylonites.**

Chapter 3: Structural Geology

Study of 3D geometry of rocks from micro to macro scale to explain deformation processes.
Helps understand mountain building, faulting, folding. Important for bridge/building design!

Geometry (shape, orientation, size)	Motion (paths of particles—deformation)	Mechanics (why geometry/motion are as they are)

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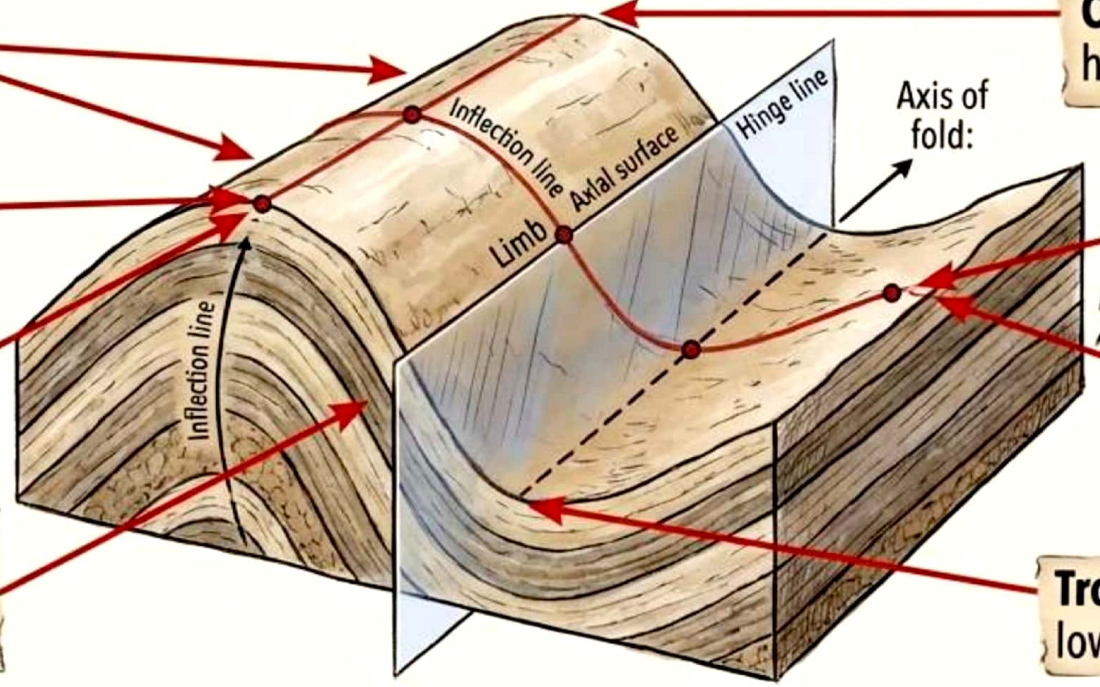
Fold: Undulations, bends, or curvatures developed in crust rocks from time-to-time stresses. (Process = **FOLDING**).

Limbs: Sides of a fold.

Hinges: Maximum curvature point where limbs start/end.

Hinge line: Sequence of joined hinge points.

Axial surface: Planar or non-planar surface tracing the hinge line through depth.

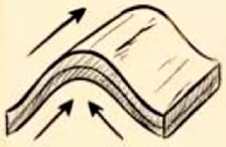


Crest: Line running through highest points in up-arched fold.

Axis of fold: Line drawn parallel to hinge line.

Plunge of a fold: Angle of inclination of fold axis with horizontal.

Trough: Line running through lowest points in down-arched fold.



Basic Types - Anticlines:
Strata are up-arched, convex upwards. Geologically older rocks in interior, youngest at outermost flank. Limbs dip away from each other.



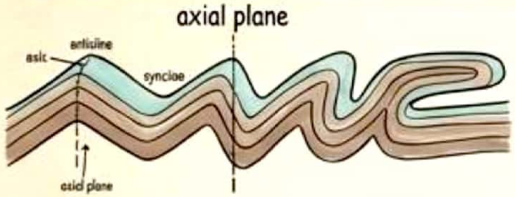
Basic Types - Synclines:
Down-arched, convex downwards. Younger rocks in core, older rocks form outer flanks. Limbs dip towards a common center.

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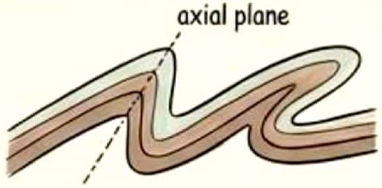
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Classification of Folds

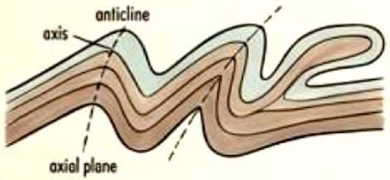
Based on Axial Plane Position



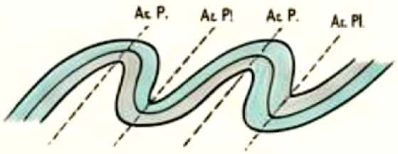
1. **Symmetrical**: Axial plane vertical. Limbs equal in length, dip equally in opposite directions. (Normal/upright).



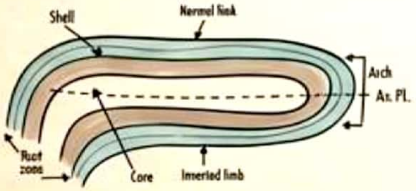
2. **Asymmetrical**: Limbs unequal in length, dip unequally.



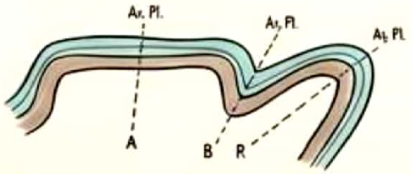
3. **Overturned**: Inclined axial planes; both limbs dip in same direction.



4. **Isoclinal**: All axial planes are parallel. Limbs dip at equal amounts.



5. **Recumbent**: Axial planes acquire almost horizontal attitude.

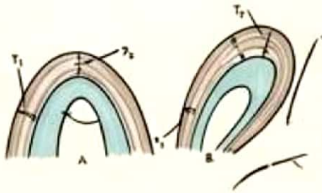


6. **Conjugate**: Pair of folds with mutually inclined axial planes.

Based on Compression/Depth



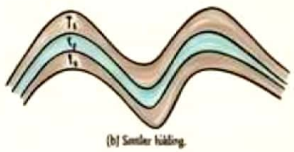
- **Open fold**: Bend without causing appreciable variation in thickness.



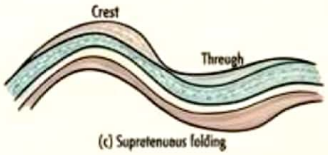
- **Closed fold**: Severe forces cause plastic movement, resulting in thinner limbs and thicker crests/troughs.



- **Concentric folds**: Thickness of layers remains uniform/constant even after folding.



- **Similar folds**: Degree of folding is similar for indefinite depths (thin limbs, thick crest/trough).



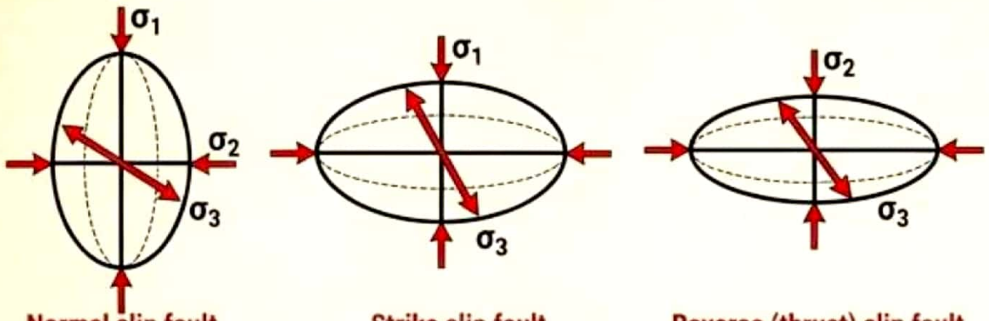
- **Supratenuous folds**: Differences in thickness at crestal/trough regions, induced by erosional/depositional processes, not folding process.

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Faults and Faulting: Fractures (cracks) along which relative movement of blocks has occurred.

Causes: Rock withstands stress up to a limit (cohesive strength/internal friction). When limit is crossed, rock yields by fracturing. Blocks suddenly displace.



Relationship Between Principal Stress, and Type of Faulting
(a) Maximum Principal Stress σ_1 is vertical, (b) Intermedian Principal Stres. σ_1 is vertical
(c) Least Principal Stress σ_3 is vertical

Important Parts:

Fault plane: Planar surface of fracture which displacement takes place.

Hanging wall: Faulted block lying on upper surface of fault plane.

Dip: Inclination of fault with horizontal.

Foot wall: Faulted block lying on under surface of fault plane.

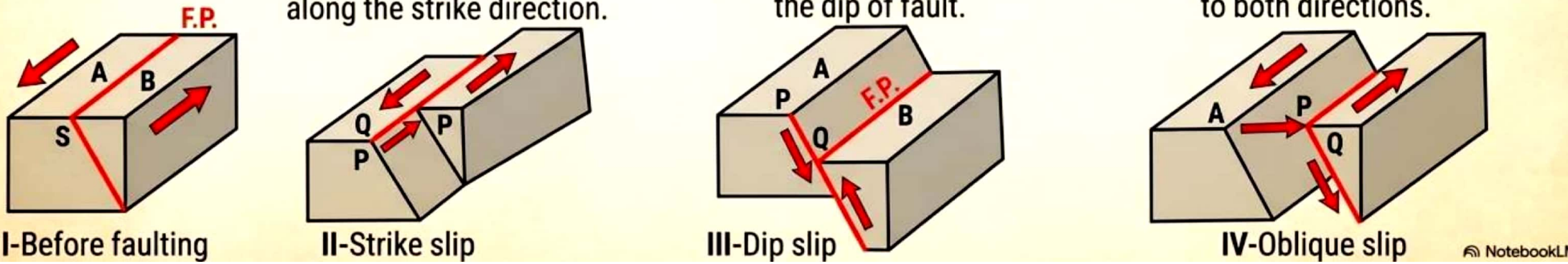
Hade: Angle of fault with vertical.

Slip (Separation): Relative displacement of 2 points.

Strike slip: Displacement along the strike direction.

Dip slip: Displacement along the dip of fault.

Oblique-slip: Takes place oblique to both directions.



I-Before faulting

II-Strike slip

III-Dip slip

IV-Oblique slip

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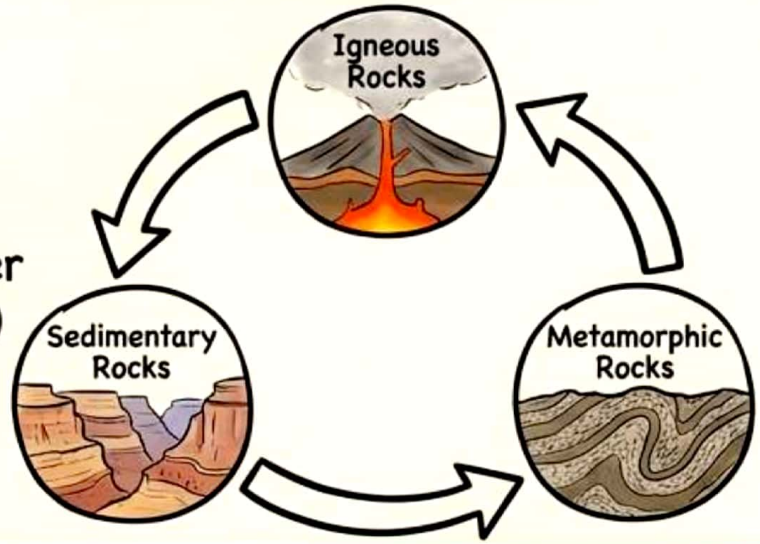
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What is Unconformity?

A buried erosion surface separating two rock masses or strata of different ages. Indicates discontinuous sediment deposition.
Older layer was exposed to erosion before younger deposition.
A break in sedimentary geologic record! (Missing local record/time).

Types:

- **Disconformity** (wavy, thin conglomerate above)
- **Nonconformity** (sedimentary over intrusive igneous/metamorphic)
- **Angular** (lack of parallelism, apparent radial contrast)
- **Paraconformity**



Stages of Development:

1) Formation of older rocks
2) Uplift & Erosion
3) Deposition of younger strata

Rocks Involved: Sedimentary, Volcanic, Plutonic, Metamorphic.

Recognition & Distinguishing from Faults (Crucial!)

- Effort needed to observe actual contact in field.
- In unconformity: Small ridges of older rock project into younger rocks. Conglomerate with older rock fragments lies above contact.
- Fault indicators (ABSENT in unconformity): Slickensides, gouge, and breccias. Some faults have sharp, knife-like contacts devoid of these.

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Physical Properties of Minerals

Lustre

- Metallic (Galena/Gold/Pyrite)
- Sub-metallic (Hematite/Chromite/Magnetite)
- Vitreous/glass (Quartz/Feldspar)
- Sub-vitreous (Pyroxenes)
- Pearly (Talc/Muscovite mica)
- Silky (Asbestos)
- Resinous (Opal/Agate)
- Greasy (Graphite)
- Adamantine/diamond (Garnet/Diamond)
- Earthy/dull (Bauxite/Magnesite)

Fracture (Random broken surface)

- Even (Magnesite/Chalk)
- Uneven (Hornblende/Bauxite)
- Hackly/irregular (Asbestos/Kyanite)

Transparency

- Transparent (Muscovite/Rock crystal)
- Translucent (Agate/Calcite)
- Opaque (Galena/Pyrite)

Cleavage (Tendency to break along parallel weak planes)

- One set (Mica/Chlorite/Talc)
- Two sets (Feldspars/Pyroxenes/Amphiboles)
- Three sets (Calcite/Dolomite/Galena)
- Four sets (Fluorite)
- Six sets (Sphalerite)
- No cleavage (Quartz/Olivine/Garnet)

Specific Gravity/Density

- Low <2.5 (Gypsum, Graphite)
- Medium 2.5-3.5 (Quartz, Feldspar)
- High >3.5 (Chromite)

Special Properties

Talc = smooth/soapy feel.
Graphite = marks paper easily.
Pyrolusite = soils fingers.
Halite = saline taste.
Magnetite = strongly attracted by magnet.
Chalk = rough feeling on tongue, adheres strongly.

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Optical Properties (Under Polarizing Microscope)

Relief

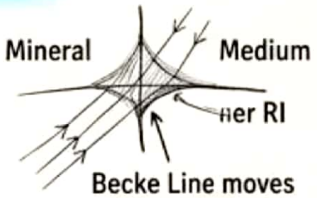
Effect making mineral stand out. Function of RI (Refractive Index) difference between mineral and surroundings (Canada Balsam CB = 1.537). High relief = distinct fractures/cleavages.

Relief = |RI(mineral) – RI(surroundings)|.



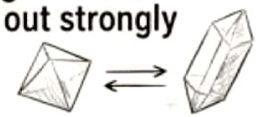
Becke Line

Bright fringe of light along boundary. Rule of thumb: Medium with higher RI acts like bi-convex lens, converges light to center when stage is lowered.



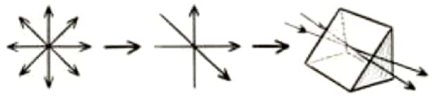
Twinkling

In anisotropic minerals (Calcite). Relief changes with crystallographic orientation as stage is turned. Appears to stand out strongly and disappear.

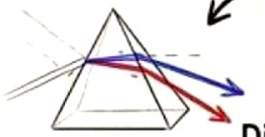


Polarization

Light forced to vibrate in single plane (linear polarization).
Methods: Reflection/refraction (Brewster law),
Absorption (Dichroic minerals, herapatite),
Double refraction (Nicol prism separates fast/slow rays).



Dispersion

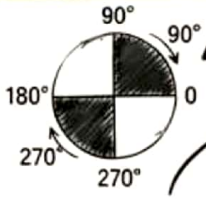


Blue rays refracted closer to normal than red rays.

Dispersion = n(blue) - n(red)

Extinction

No light vibrates passing through analyser. Complete darkness every 90° revolution. "Mottled extinction" = tiny specks of illumination (Micas).

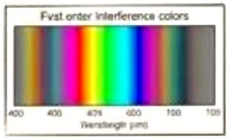


Retardation & Birefringence

Difference in relative ray velocities.
Birefringence = RI1 – RI2.
Interference colours result from complementary phases of rays. Patchy birefringence = epidote.

Retardation (Δ) = $t \times (RI_1 - RI_2)$

Birefringence = $|\varepsilon - \omega|$ or $|\alpha - \gamma|$



Opaque minerals

Do not transmit light.
Studied via reflection microscopes (Magnetite, Pyrite, Ilmenite).



Pleochroism

Color of transparent mineral depends on absorption of light vibrating parallel to E-W direction. Color changes as stage rotated. (Compositional zoning = concentric coloring).



Pleochroism in anisotropic minerals.

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