GOVERNMENT POLYTECHNIC JAJPUR

Lecture Note on

Mine Geology-1

Prepared By :

MALAYA RANJAN JENA

(LECT. IN MINING)

DEPARTMENT OF MINING ENGINEERING

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PHYSICAL GEOLOGY

Remark

Weathering & erosion:-

- Weathering → process of causing rocks to be disintegrated physically & decomposed chemically because of exposure at or near the earth's surface.

Imp

- Erosion → is a process which includes the destruction of existing rocks & removal of the products from the site of destruction ("transportation" is important aspect - by means of glacier, river, wind)

Denudation = weathering + erosion

weathering & transportation result = Erosion

Imp

Factors Affecting Weathering & Erosion

- climate (physical disintegration - arid & tropical conditions. rock decomposition (humid climates)
- Temperature (diurnal & seasonal changes lead to expansion & contraction)
- Rainfall (promotes chemical weathering & physical also)

- Topography - (high relief area - erosion power & transporting power increases while prolonged weathering as marked on the area of low relief.)

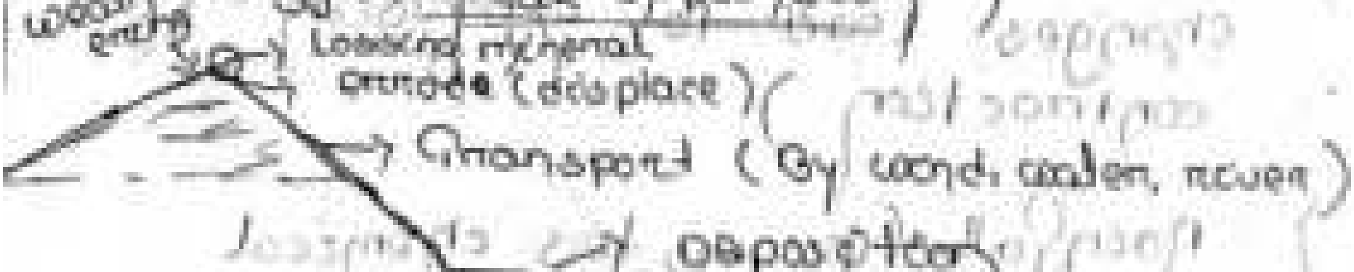
- Structure, texture & mineral composition - (joint, crack, fissures, - more weathering / fine grained rocks more susceptible to weathering)

- Vegetation cover - (W & E depends surface covered with vegetation & root system of trees)

- Time - longer period of time - maximum degree of weathering.

《Types of weathering》

1. Imp Physical weathering (exfoliation, crystal growth, freezing of water, differential expansion)



Q. chemical weathering (oxidation, Hydration, carbonation, Hydrolysis. Dissolution)

Imp short note

{Chemical weathering} ->

Is the decomposition of the rock mass (change in composition) by bio - & geo chemical processes. Rock decay is a function of mineral composition, pedo, micro environment, surface area available, & the capacity of the decomposing agent.

oxidation

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3. Biological weathering (plant, Bacteria & Animals, Anthropogenic)

It is divided in to 2 types

1. Biophysical process
2. Biochemical process

《Biophysical process》

Movement of plant roots, growing bet jointed blocks & along minute fractures bet them, then exert expansive force to widen the openings & sometimes create new fractures.

→ Insects like earth-worm, snail, microbes etc. & burrowing animals like rodents loosen the soil cover. It is also a kind of weathering.

→ Grazing of cattles also weather the grass land vegetation.

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{Biochemical process}

with decay & degeneration of dead remains of plants & animals, chemically substance are produced like CO_2, humic acid, together with traces of ammonia nitric acid etc.

*) These substance are capable of bringing about rock weathering

*) Man himself is an important agent of destruction. (Anthropogenic).

{Erosion} Imp

The agents which helps in erosion process is given below

* Gravitational force
* pore pressure
* Action of wind
* Action of river (even other water sources)
* Action of glacier

Imp
{GEOLOGICAL ACTION OF WIND}

Intro

-> Wind is defined as the natural movement of the air, esp. in the form of a "current of air blowing from a particular direction."

-> Arid Geomorphology is defined as the study of effects of wind erosion on the lithosphere.

-> Winds have a greater impact on the lithosphere in areas with sparse vegetation & unconsolidated or loose sediments.

-> It means that wind action prevails in the temperate region & more or less in the tropical region.

-> Wind erode, transport & deposit materials world wide.

Imp Imp
{Erosional Works of Wind}

-> Wind erosion mainly occurs due to mechanical weathering due to high day time, summer temp. & contraction consequent upon lower night & winter temp. causing in the disintegration of crystalline rocks with facilitates aeolian erosion.

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→ wind erosion is largely controlled determined by

i) wind velocity
ii) nature & amounts of sands, dusts & pebbles
iii) composition of rocks
iv) nature of vegetation
v) humidity, rainfall amount & temp.

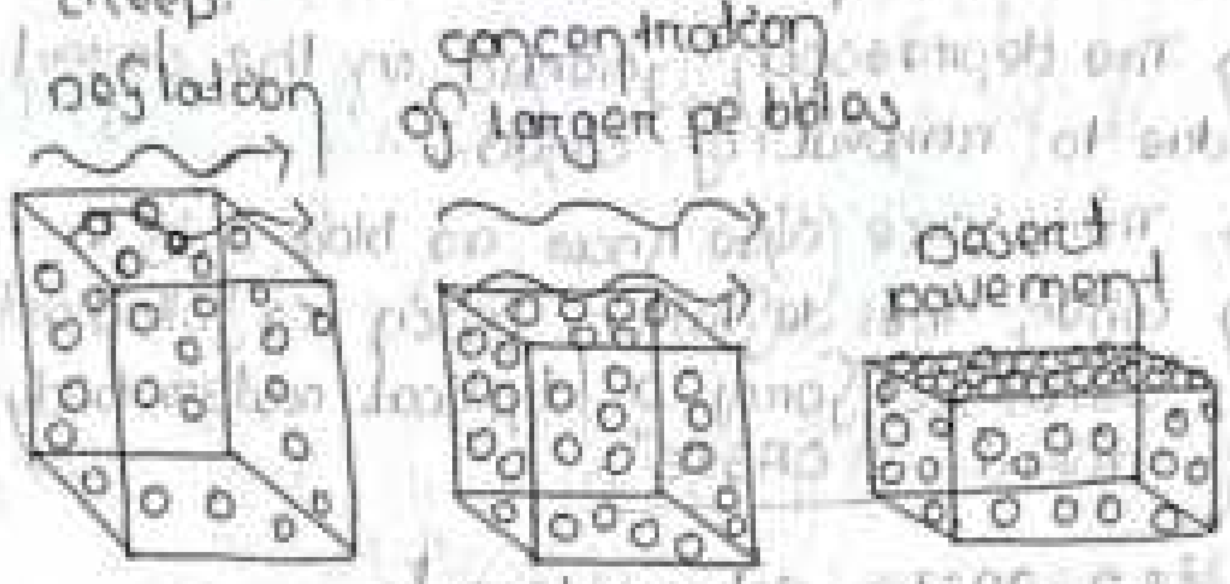
Wind Erosion occurs in three ways (Lolib →)

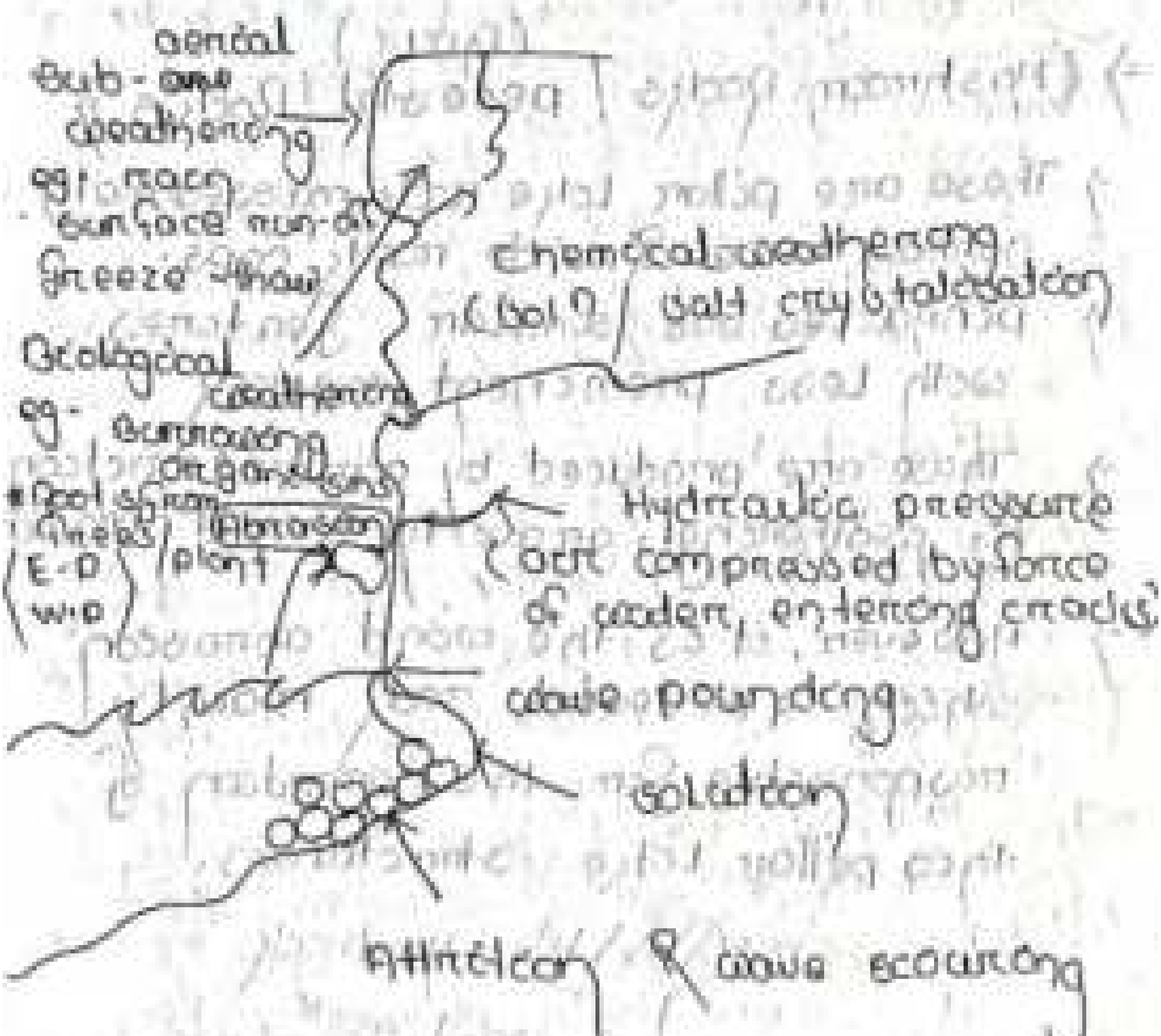
→ Deflation →
The process of removing, lifting & blowing away dry & loose particles of sand & dusts by wind.

→ Abrasion :-
Abrasion is the mechanical scraping of rock surface by friction bet rocks & moving particles during their transport by wind

→ Attrition →
Attrition involves mechanical wear & tear of the particles caused by themselves while they are being

transported by wind through the process of saltation & surface creep.





(EROSINAL LANDFORMS)

=> (Deflation Basin)

-> The depression formed in the desert due to removal of sands.

-> These are also know as blow outs.

-> When the deflation basin is filled with water, it form a typical water body called "OASIS"

Ex -> OASIS, Sahara desert.

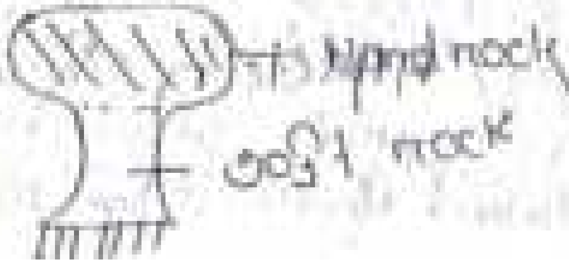
=> (Mushroom Rocks / pedestal Rocks (Gour))

-> These are pillar like rock masses with narrow base & wide rock caps.

-> pinnacles are similar features with less prominent cap rock.

-> These are produced by combined action of weathering, gravity & wind abrasion.

-> However, it is the wind abrasion which is pedestal rock mainly responsible for the formation of this pillar like structures.



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《Hamada》

-) A hamada is a type of desert Landscape consisting of largely barren, hard rocky plateaus, with very little sand.

-) It may sometimes also be called a reg through this more properly refers to a stony plain rather than a highland.

-) The area covered with small rocks & gravels are called "SERIRS". These are small version of hamadas

《Natural arch》

-) Typically formed by a combination of wind & water.

-) Narrow ridges are formed & the softer part of the rock is weathered first, forming a bridge / arch over head.

Ex - Natural arch (California, North America

《Insel berg》

-) These are isolated hill that stands above well developed plains and appears not unlike an island rising from the sea formed in the penultimate stage of arid cycle of erosion

-> These are also called bornhardts.
-> They are formed by volcanic processes that give rise to a rock resistant to erosion.

Ex - Bornhardt, germany

《Demoiselles》

-> These are the rock pillar having relatively resistant rock at the top & soft rocks at the bottom formed due to differential erosion of hard rocks & soft rocks.
-> They typically form within sedimentary rock & volcanic rock formation.

Ex -> Demoiselle of coode areal distribution, canada

《Zeugen》

-> A table shaped area of rock found in arid & semi-arid areas formed when more resistant rock is reduced at a slower rate than softer rocks made up of shale, mudstone etc.

-> It is generally formed in the areas showing alternate freeze & thawing mechanisms.

《Yardangs》

-> These are steep sided deeply undercut overhanging rock ridges separated from one another by long grooves or corridors.

-> These are also known as cockscomb.

-> Formed where alternate bands of hard & soft rocks are vertical or inclined to the horizontal planes.

《Ventifact》

-> created by wind erosion

-> wind carries fine particles that work like a sand blaster (i.e sand, silt, clay & ice particles)

-> The windward face of the rock is flattened & smoothed.

-> usually pebble to cobble sized.

-> These geomorphic features are most typically found where there is little vegetation to interfere with

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aeolian particle transport, where these are frequently strong winds, & where there is a steady but not overwhelming supply of sand.

-> The rock pieces having two abrade facets are called "zweikanter" & that having three are called "dreikanter".

«Ergs»

-> An erg (also sand sea or dune sea, or sand sheet if it lacks dunes) is a broad, flat area of desert covered with wind-swept sand with little or no vegetative cover.

«Stone Lattice»

-> Rocks that have been abraded, pitted, grooved, or polished by wind driven sands & other geomaterials.

-> These are extremely rough rock surface.

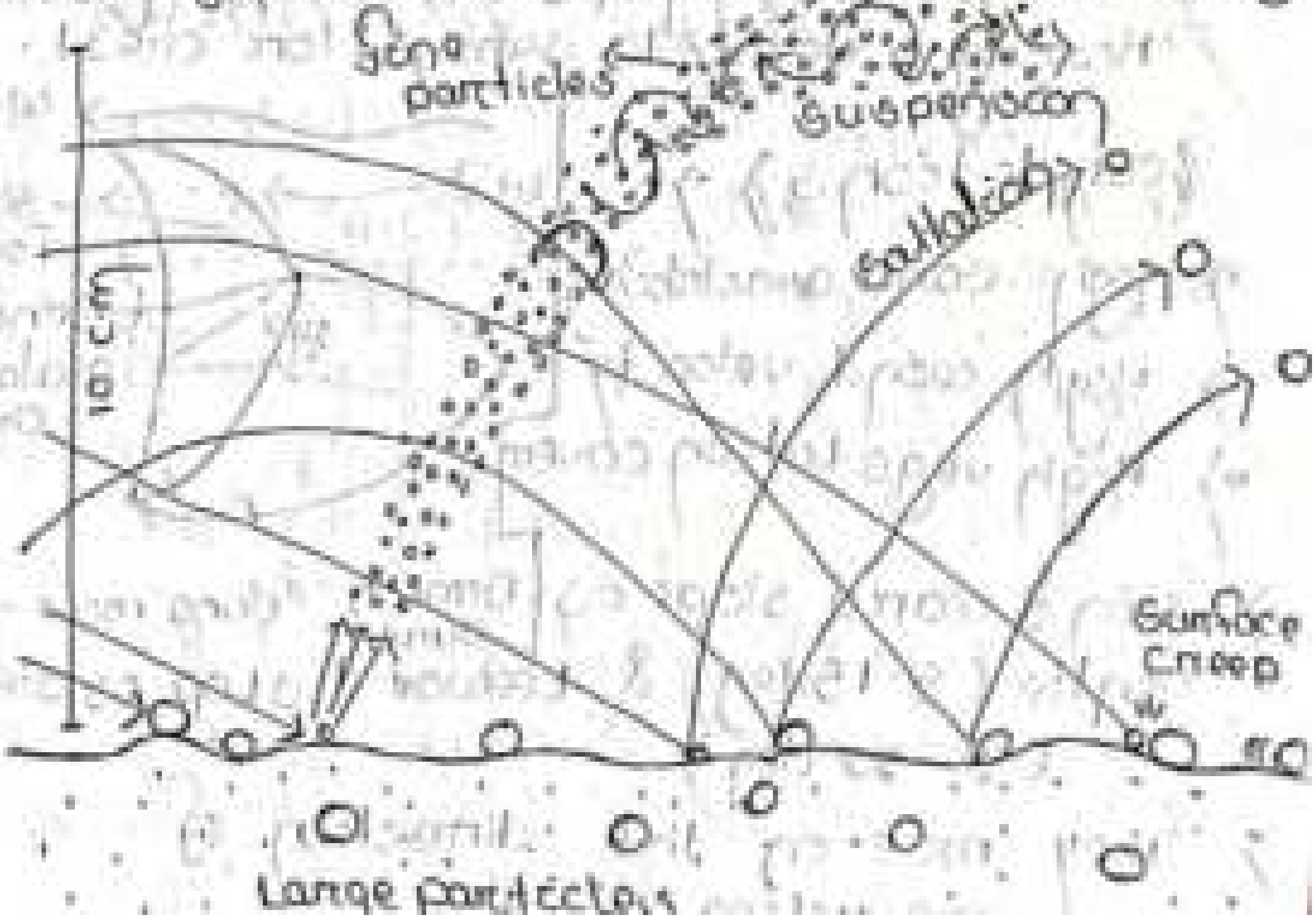
TRANSPORTATION WORK OF WIND

i) Involves the mechanism of :-

i) Suspension ->
Only the finest materials derived from silts & clay having a diameter less than 0.05mm are transported.

ii) Saltation ->
Medium sized particles having diameter betn 0.05mm to 2.0mm are transported through creeping, leaping & jumping.

iii) Traction ->
Large & heavy particles are transported through the process of rolling & creeping



《Depositional work of wind》 Imp

→ Depositional of wind blown sediment occurs due to marked reduction in wind speed & obstruction is caused by bushes, forests, marshes & swamps, lakes, bog, rivers, walls etc.

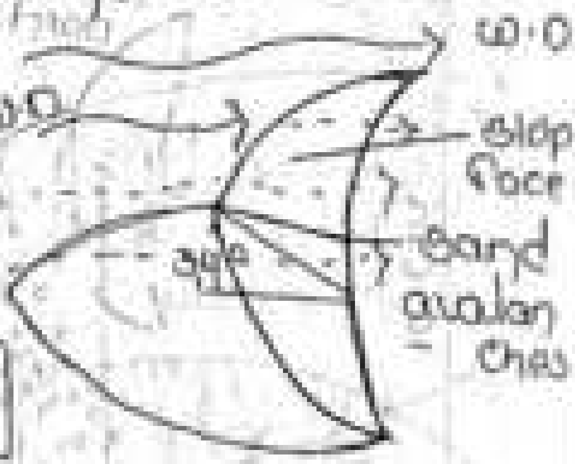
→ The accumulated sand mounds on either side of the obstruction are called sand shadows.

→ Accumulation of sand b/w obstacles are called sand drifts.

《Depositional features》 Imp

《Sand Dunes》 Heaps or mound of sands having a definite summit or crest.

《conditions》 →
i) High sand availability
ii) High wind velocity
iii) High vegetation cover



→ wind ward slope is gentle (5-15 deg) & Leeward slope is steep (20-30 deg)

Barchan Dune
dune move →

They move in the direction of prevailing wind.

《TYPES OF DUNES》

《Longitudenal Dunes》

-> These dunes are parallel to the wind direction

-> Formed in the inner parts of the continents.

Conditions

-> where high velocity winds are constant in one direction

-> Devoid of vegetation

《Transverse Dunes》

-> Transverse to the direction of prevailing wind.

《Conditions》

-> The effectiveness of wind (i.e along the coasts & margin of deserts.

《Parrabolic Dunes》

-> These dunes are formed form blowout dunes where the erosion of vegetated sand leads to a U-shaped depression.

-> well know in coastal deserts.

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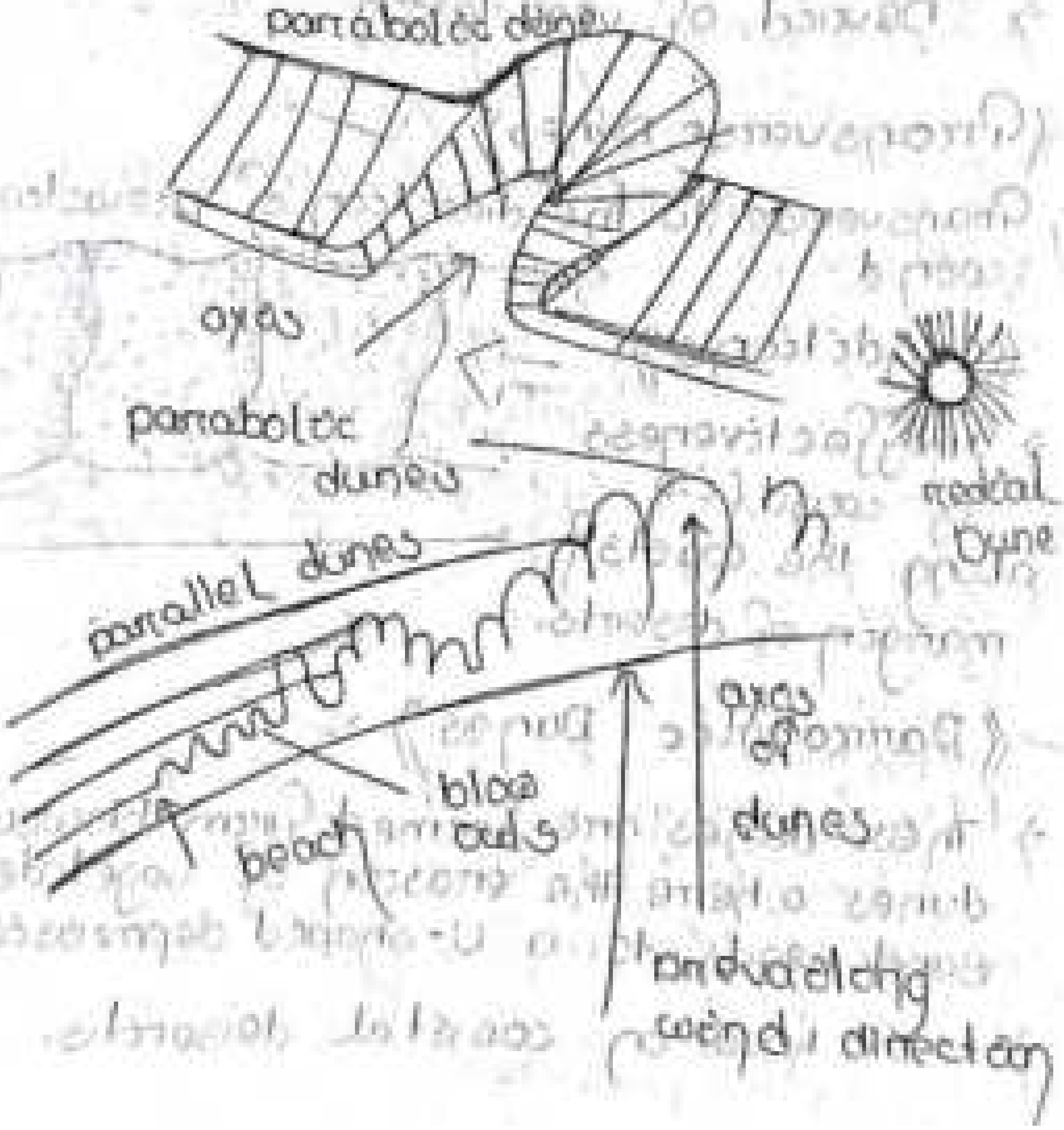
-> The elongated arms are help in place by vegetation

-> elongated arms extend upward.

-> parabolic dunes are dependent on the vegetation that covers them - grasses bushes, and trees, which help anchor the trailing arms

-> The grains are well-sorted, very fine to medium grained.



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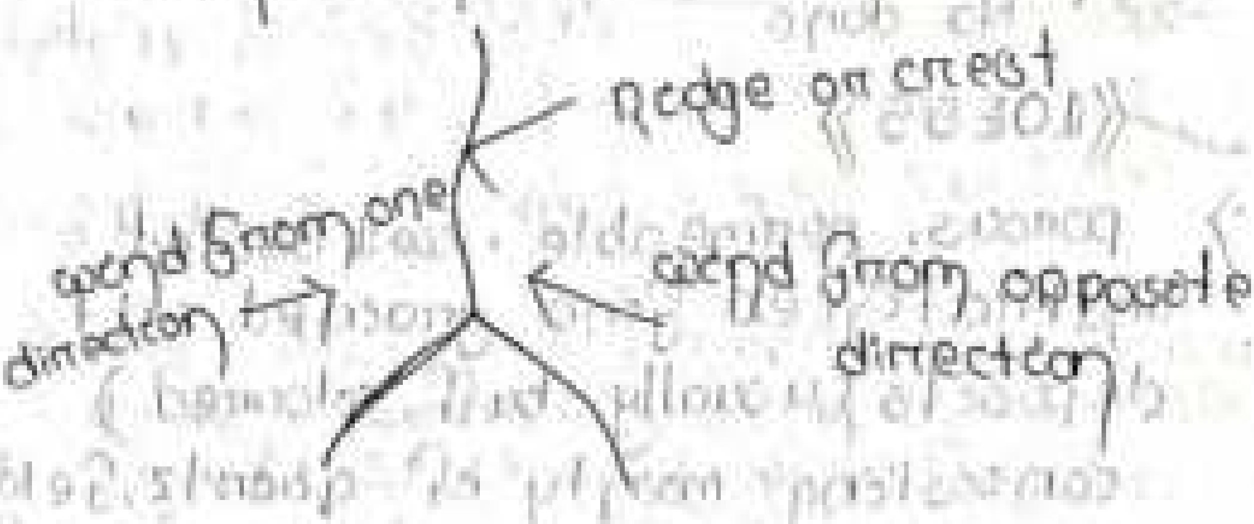
《Star dunes》

- → Dunes having multiple slip faces, high central peak, radially extending three or more arms
- → multi directional wind regimes.
- → grow upward rather than laterally.

《Reversing dunes》

- → formed when wind blowing from opposite directions are balanced in strength & duration.
- → typically have major & minor slipface oriented in opposite direction.



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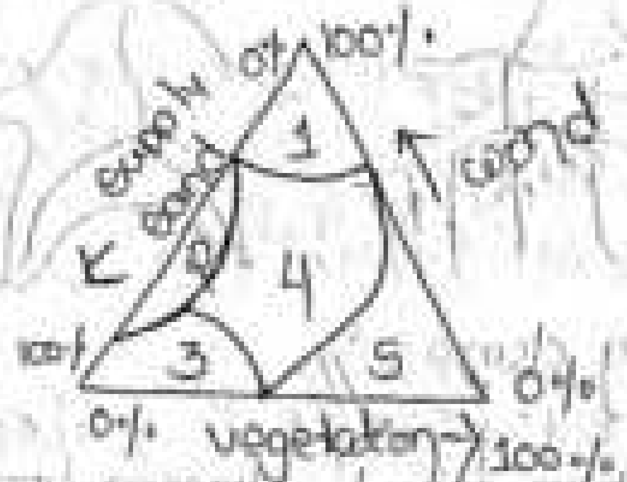
《Whale back dune》

→ smooth, elongated mound or hill of desert sand shaped generally like a whale's back, formed by passage of a succecession of longitudenal dunes along the same path.



1 = longitudenal dune
2 = Barchan dune
3 = Trauseverise dune
4 = parabolic dune
5 = No dune

《LOESS》

→ porous, permeable, well sorted, unstratified fine grained silt deposits (usually buff coloured) consisting mainly of quartz, feldspar calcite, dolerite etc.

-> occurs at distant places away from places away from their source area.

STREAM

Stream

A stream is a body of water that carries rock particles & dissolved ions & flows down slope along a clearly defined path, called a channel. Thus, streams may vary in width from a few centimeters to several kilometers. Streams are important for several reasons.

-> Streams carry most of the water that goes from the land to the sea, & thus are an important part of the water cycle.

-> Streams carry billions of tons of sediment to lower elevations, & thus are one of the main transporting mediums in the production of sedimentary.

-> Stream carry dissolved ions, the products of chemical weathering, into the oceans & thus make the sea salty.

-> Stream are a major part of the erosion process, working in conjunction with

-> weathering & mass wasting. Much of the surface landscape is controlled by stream erosion, evident to anyone looking out of an airplane window.

-> Stream are a major source of water & transportation for the world's human population. Most population centers are located next to stream.

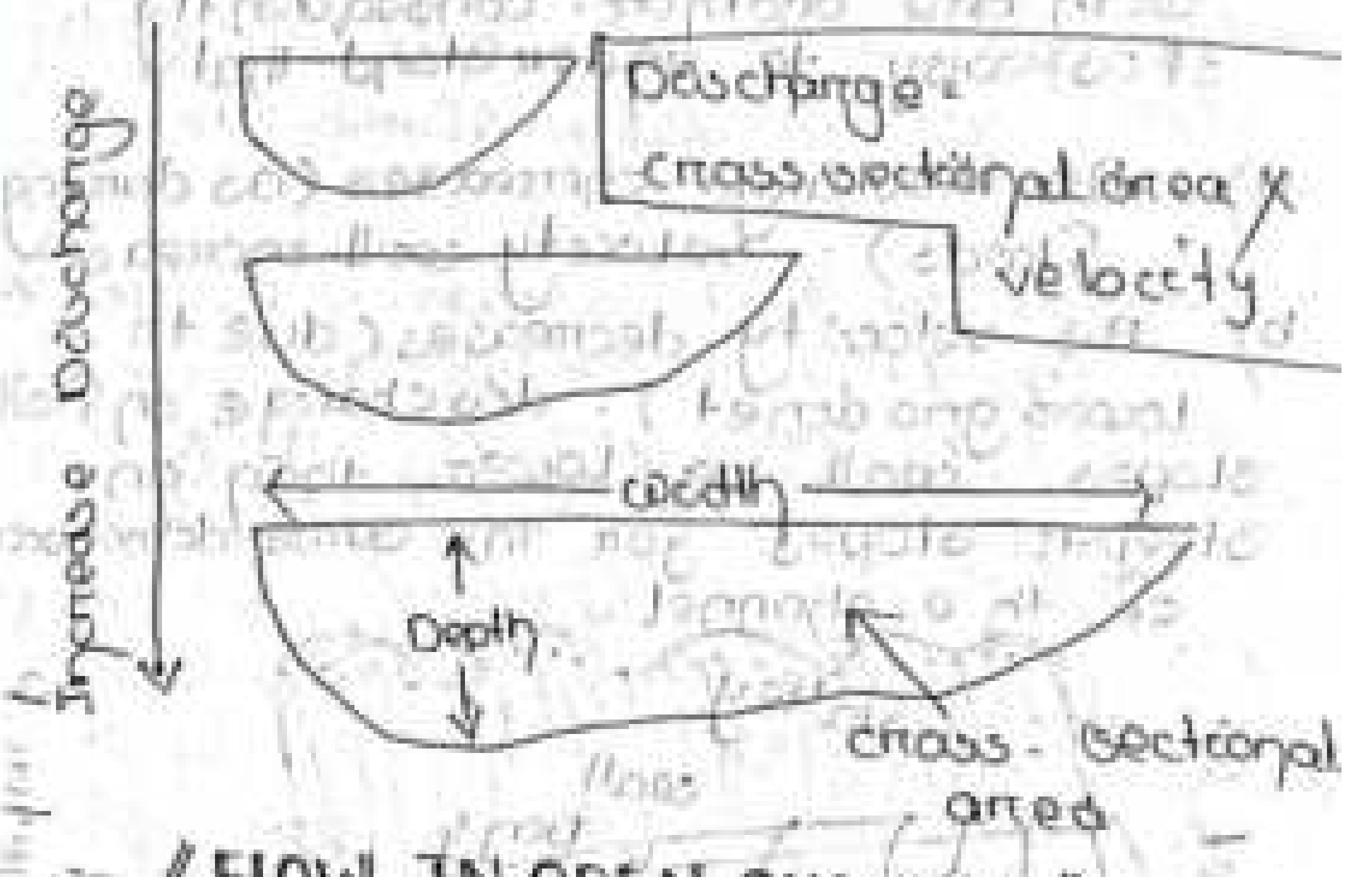
Geometry & Dynamics of stream channels

The stream channel is the conduct for water being carried by the stream. The stream can continually adjust its channel shape & path as the amount of water passing through the channel changes. The volume of water passing any point on a stream is called the discharge.

-> Discharge is measured in units of volume / time (m³/sec)

《Cross Sectional shape》 — Imp!

varies with position in the stream, & discharge. The deepest part of channel occurs where the stream velocity is the highest. Both width & depth increase downstream, because discharge increases downstream. As discharge increases, the cross sectional shape will change, with the stream becoming deeper & wider.



《FLOW IN OPEN CHANNEL》

Stream flow is a rate of the amount of water moving past a give location per-unit of time.

Discharge (Q) at a cross-section of a stream is a function of

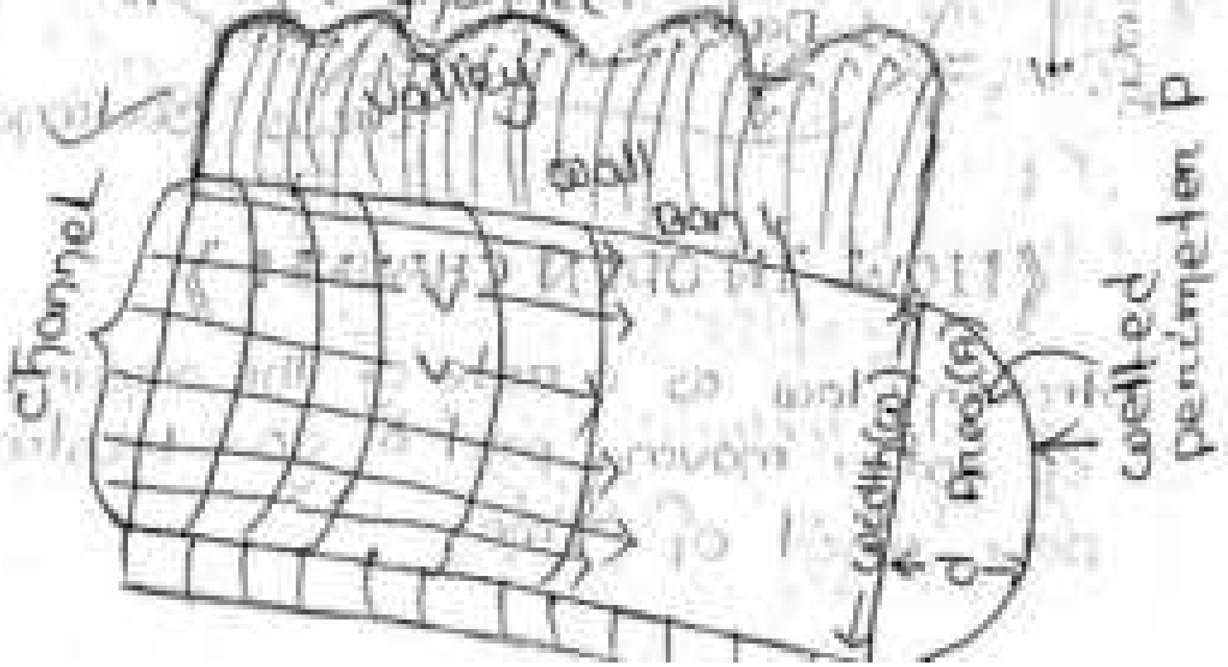
- stream width (w)
- depth of channel (d), &
- flow velocity of (v) **Q = wdv**

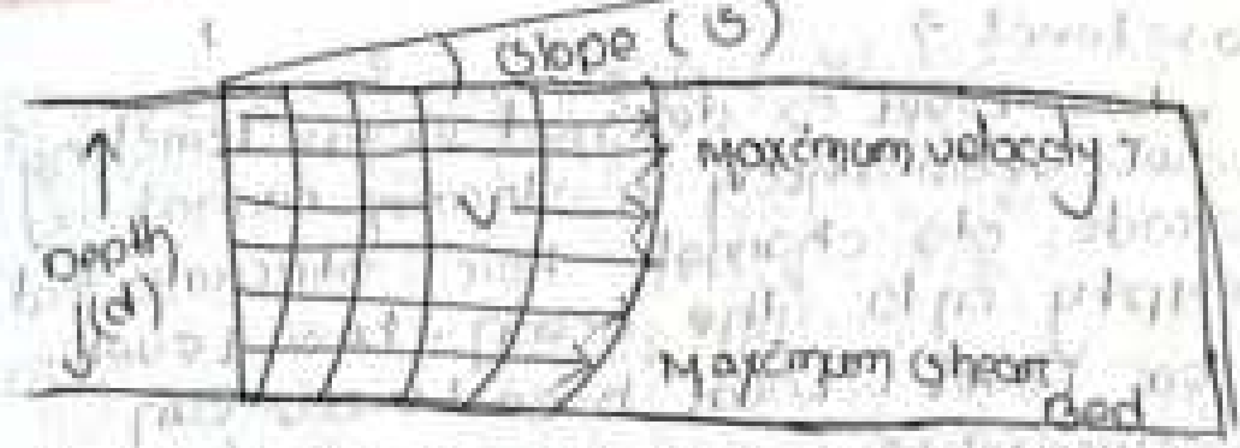
(assuming laminar flow)

Q & V have a direct linear relationship with one another. Consequently it is easy to understand that

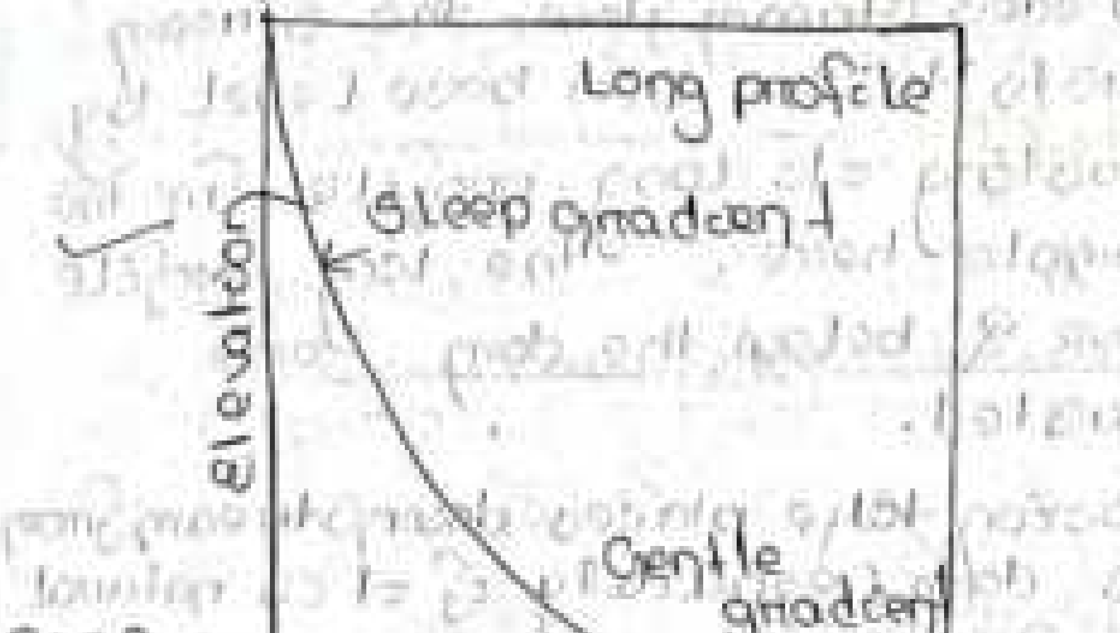
a) As discharge increases (as during floods), velocity will increase

b) As velocity decreases (due to lower gradient), discharge on flatter slopes will be lower than on steeper slopes for the same dimensions of the channel.





Long profile - a plot of elevation versus distance. Usually show a steep gradient near the source of the stream & a gentle gradient as the stream approaches its mouth



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Base Level →

Base Level is defined as the limiting level below which a stream cannot erode its channel. For streams that empty into the ocean, base level is sea level. "Local" base levels can occur where the stream meets a resistant body of rock, where a natural or artificial dam impedes further channel erosion, or where the stream empties into lake.

When a natural or artificial dam impedes stream flow, the stream adjusts to the new base level by adjusting its long profile. In the example here, the long profile above & below the dam are adjusted.

Erosion take places downstream from the dam (especially if it is natural dam & water flow over the top), just upstream from the dam the velocity of the stream is lowered so that deposition of sediment occurs causing the gradient to become lower.

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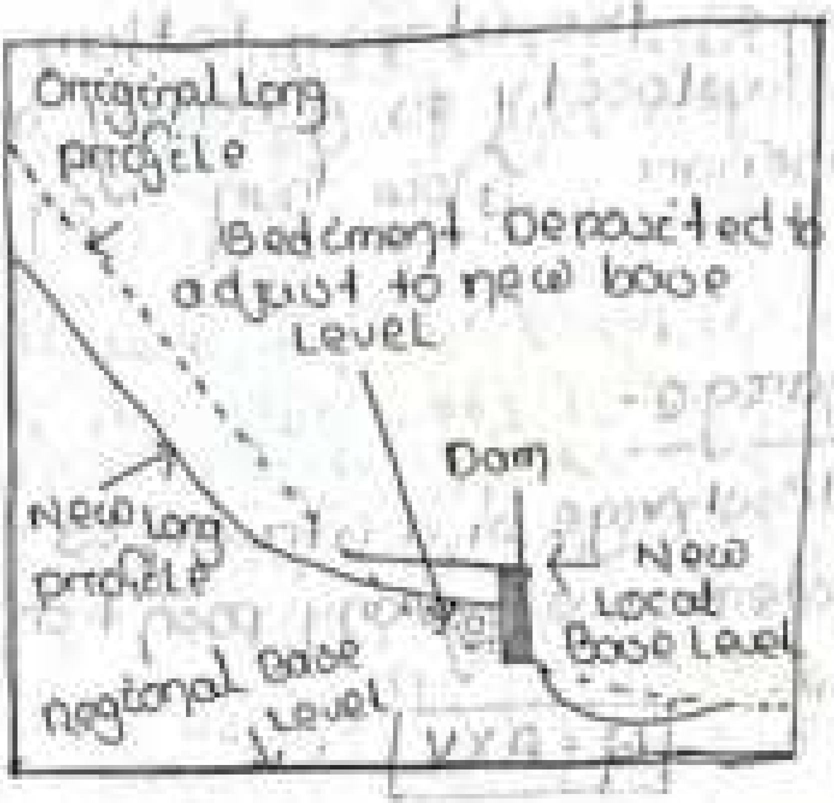

Velocity -

A stream's velocity depends on position in the stream channel, irregularities on the stream channel caused by resistant rock & stream gradient. The average velocity is the time it takes a given particle of water to traverse a given distance. Stream flow can be either laminar, in which ~~in individual particles~~ all water molecules travel along similar, parallel paths, or turbulent, in which individual particles take irregular paths. Turbulent flow can keep sediment in suspension longer than laminar flow & aids in erosion of the stream bottom, Average linear velocity is generally greater in laminar flow than in turbulent flow.

Discharge-

The discharge of a stream is the amount of water passing any point in given time.

$$Q = A \times V$$

Discharge (m^3/sec) = cross sectional Area (width x average depth) (m^2) x Average velocity (m/sec)

As the amount of water in a stream increases, the stream must adjust its velocity & cross sectional area in order to form a balance.

Discharge increase as more water is added through rainfall, tributary stream or from ground water seeping into the stream. As discharge increase, generally width, depth, & velocity of the stream also increase.

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Laminar flow   Turbulent flow

Load ->

The rock particles & dissolved ions carried by the stream are called the stream's load. Stream load is divided into three parts.

Suspended Load ->

particles that are carried along with the water in the main part of the streams. The size of these particles depends on their density & the velocity of the stream. Higher velocity currents in the stream can carry large & denser particles.

Bed Load

coarser & denser particles that remain on the bed of the stream most of the time but move by a process of saltation (jumping) as a result of collision b/w particles & turbulent eddies. Note that sediment can move b/w bed load

& Suspended Load as the velocity of the stream changes.

Dissolved Load →
ions that have been introduced into the water by chemical weathering of rock. This load is invisible because the ions are dissolved in the water. The dissolved load consists mainly of HCO_3^- (bicarbonate ion), Ca^{+2}, SO_4^{-2}, Cl^-, Na^{+2}, Mg^{+2} & K^+.

→ These ions are eventually carried to the oceans & give the ocean their salty character.
→ Stream that have a deep underground source generally have higher dissolved Load than those whose source is on the Earth's surface.

Changes Downstream

As one moves along a stream in the downstream direction

Discharge increases, as noted above, because water is added to the stream from tributary stream or groundwater.

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As discharge increase, the width, depth, & average velocity of the stream increase. The gradient of the stream, however, will decrease.

It may seem to be counter to your observations that velocity increases in the downstream direction, since when one observes a mountain stream near the headwaters where the gradient is high, it appears to have a high velocity than a stream flowing along a gentle gradient.

But the water in the mountain stream is likely flowing in a turbulent manner, due to the large boulders & cobbles with make up the streambed.

If the flow is turbulent, then it takes longer for the water to travel the same linear distance, & thus the average velocity is lower.

Also as one moves in the down stream direction, the size of particles that make up the bed load of the stream tends to decrease.

Even though the velocity of stream increase downstream, the bed load particle size decreases mainly because the large particles are left in the bed load at higher elevation & abrasion of particles are left in the bed load at higher elevation & abrasion of particles tends to reduce their size.

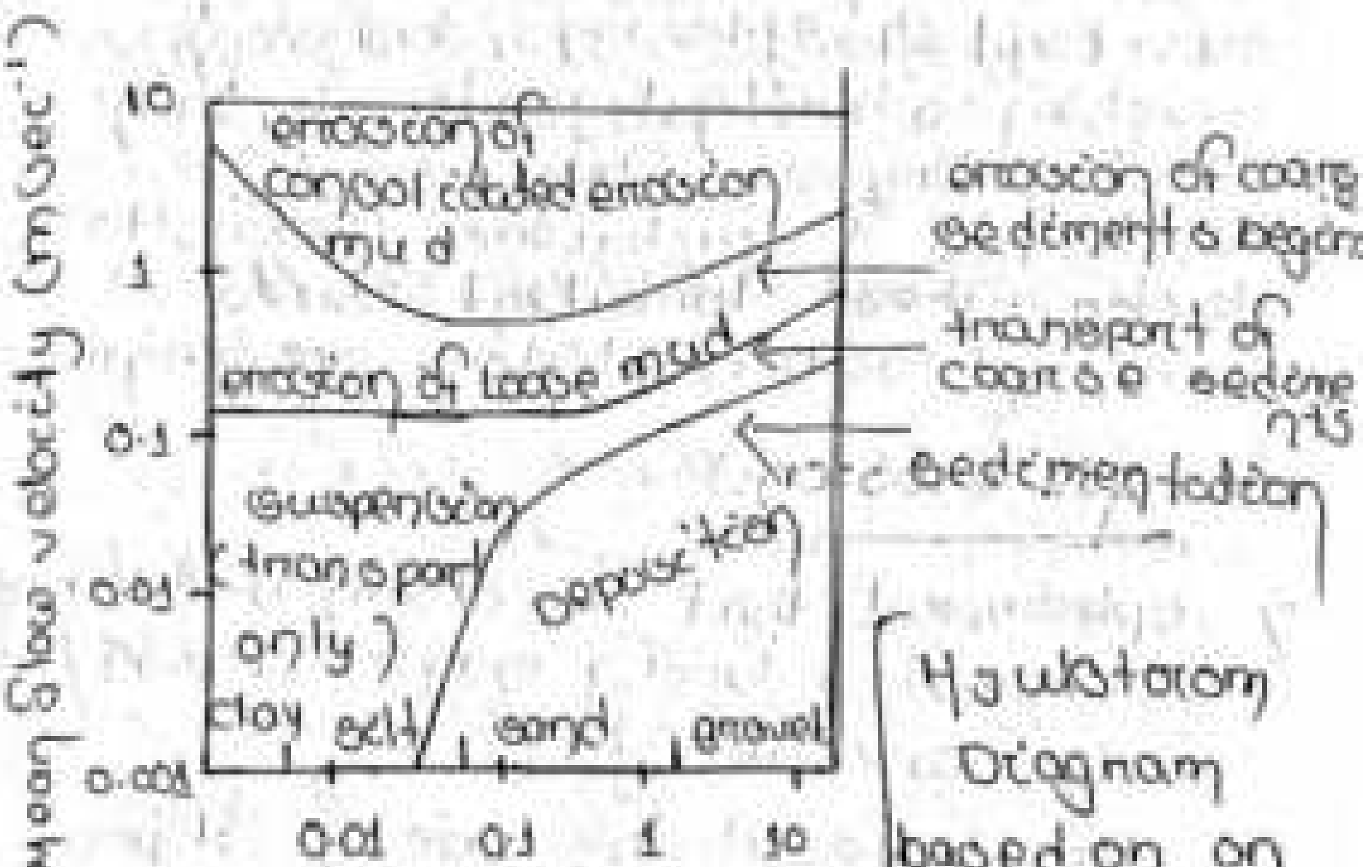
The composition of the particles in the bed load tends to change along the stream as different bed rock is eroded & added to the stream's load

Floods

Floods occur when the discharge of the stream become too high to be accommodated in the normal stream channel. When the discharge becomes too high, the stream widens its channel by over topping its banks & flooding the low-lying area surrounding the stream. The areas that become flooded are called

↳ **Floodplains**.

Irrespective of the original nature of the original channel, the resulting geometry, dimensions & form of the channel will be a modified version of the original, depending upon several parameters & contributors.



Hjulstrom Diagram based on on experimental flow of 1m depth

Water - driven erosion

« Raindrop impact & Splash erosion »

-> force of rain drops on bare soil causes disaggregation of surface soil

-> displacement of soil by rain drops, creating small craters on bare soil

-> on slope the splash is asymmetrical (mostly results in sheet - wash)

Sheet wash (rain wash)

-> entrainment of loose particles in overland flow

overland flow deepens downslope, reaching a critical gradient such that laminar flow cannot be maintained & turbulence begins to develop. These turbulent eddies suspend soil particles, creating rills

Rill erosion

-> ephemeral that is, it can be destroyed & recreated during major storms / each seasonal cycle.

-> terminate at the base of slopes & thus are not part of the regional drainage network.

Water Regimes

→ Based on seasonal variance in water availability, 4 types:

→ Snow & ice melt dominated
→ Temperate environment
→ Tropical, non-equatorial river system
→ Equatorial rivers

Flow regime	Nature of flow	common occurrence	Erosional potential	Depositional potential
Flashy	Turbulent	Floods	[illegible]	[illegible]
steady rate & continuous	mixed but dominantly laminar	Glacial system	+	-
subdued	Laminar	dry season / base-flow	0	+
static	??	oceanic / Lacustrine	+/-	+/-

« Channel geometry »

Stream / river channel is the fundamental alignment along which the water flowing down-slope moves bet^n two points on its course.

cross-section of a channel is normally a curvilinear one with slope on either side confluencing at a common point.

A channel may be :- (i) Linear or
(ii) curvilinear
= (meandering)

A channel may have a portion that is
i) simple (singular) or
ii) braided

« FLOW IN OPEN CHANNEL »

Wetted perimeter (P) is the surface the channel that is in direct contact with water during the flow of water through it (Also called channel base)

P = 2d + w (assuming a perfect triangular shape)

P = πd (assuming a perfect ~~triangular~~ semi-circular shape)

Due to friction betⁿ the water & the substrate, the velocity across a channel & along the wetted perimeter will be the lowest for a laminar flow.

Hydraulic Radius (R) of a channel is computed on the basis of the ratio of the cross-sectional area (A) to the wetted perimeter:

$R = A/P$

Hydraulic radius provides a direct count of the efficiency of the channel to transmit water.

=> Greater the P, lower the R & thus hence lower the efficiency

(River System - terminology)

Imp

Head/Source:
uplands/upper reaches
Downcutting

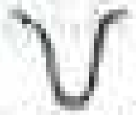
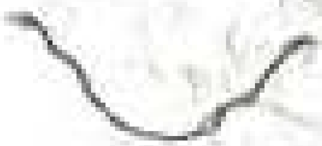
Mid course:
Slope/Slope-base
Transition/Bypass

plains:
Flood plains/Lower reaches
Bypass/Deposition

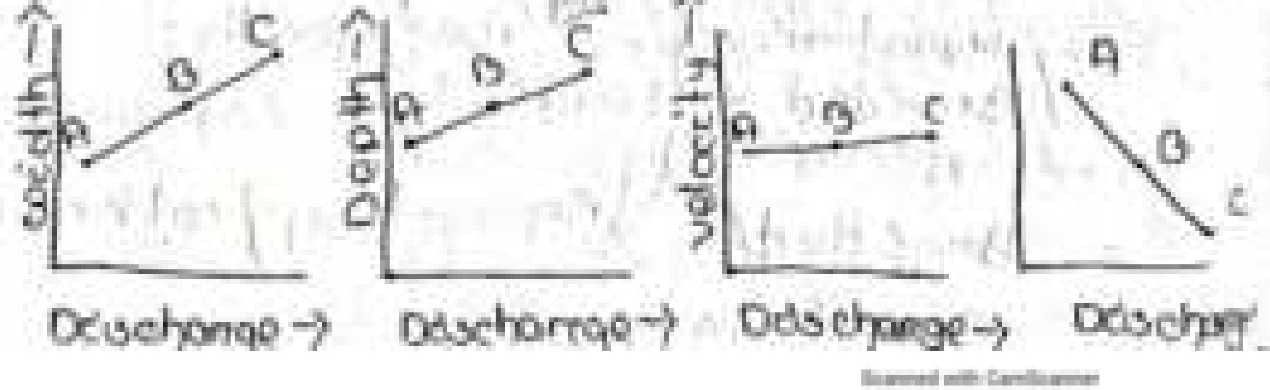
Tide/mouth:
Lowlands/estuary
delta
Deposition/outreach

Progressive loss of gradient →

⟪River System - Stages⟫

Transverse profile		
 W < H	Active/youthful draining/eroding	Head/Source upland/upper reaches
	Slope-change Slope-base/fans Terraces	Mid-course Slope-base
W≈H	(rejuvenated - terraces - ...)	
 W > H	Mature/ Monadnoc Alluvial plains bars/Levees	Plains: Flood plains
 W >>> H	Mature/Senile Delta at estuaries deposits	Sea/mouth: delta/estuary

⟪River system - Stages & discharge⟫



《River system - Landforms》

In upper Reaches
- channels are narrow,
- channels tend to be linear, simple types.
- slopes are steep.
- incision along channels is active.
= Dissected Mountain terrain

At slope Bases / Mountain fronts
- channel suddenly widen out.
- channel tend to be gently sinous
- slope becomes gentler
- in balance b/w vertical & horizontal erosion by streams
- May deposite large sediment dumps at inflection points yielding
= Alluvial fans

《River system - Landforms》

immediately below mountain fronts
- channels becomes braided
- slope becomes flatter
- incision by streams is more into its own deposits (alluvium) than the

bedrock

-> channel captures & diversions are common (particularly during flood)

= over bank terraces, levees, marshlands & grasslands

10 mark

《EROSIONAL LANDFORM》

(Waterfall) Imp

-> waterfalls are formed when rivers flow over area of hard & soft rocks.

-> The river erodes the soft rock, but can not erode the hard.

-> The river erodes the soft rock but cannot erode the hard rock. This creates a step where the water stands to fall over.

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-) The falling water erodes deeper on to the bed. The river's load creates a "plunge pool" as it falls.

《V-shaped Valley》

-) V-shaped valleys get their name from their shape. The river erodes the landscape & creates a valley in the shape of the english letter 'V'.

-) This occurs because of vertical erosion. The river cuts down into the river bed making it deeper. It creates a narrow into the river bed. making it deeper. It creates a narrow deep valley. Mechanical weathering & mass movement create the V shape.

《Gorges》

-) Narrow & deep river valleys which develop in hard rocks are "gorges".

《Meanders》

Meanders are bends or curves along the river. They are formed by erosion & deposition. Erosion occurs on one side of the river while deposition occurs on the opposite side. This continues, making the bends sharper.

«Ox-bow lake»

- An ox-bow lake is a horseshoe shaped lake found beside a river. Ox-bow lake are formed when continued erosion & deposition create a very pronounced meanders.
- Eventually the river cuts through the neck of the meander. Deposition then occurs which leaves the ox-bow-lake separated from the river.

« DEPOSITIONAL LANDFORMS »

(Alluvial fans)

- The alluvial material which flows down from mountains, accumulates at foot hills where the stream enters a plain. The deposition occurs due to abrupt change in the gradient of river valley.
- Such deposit spread out in the shape of flat fans & are called "Alluvial fan".

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coarse material are dropped near the base of the slope while finer materials are carried further out on the plain.

《Flood plain》

-> A flood plain is the flat area of land on either side of river. After heavy rain the sometimes flood. The water spreads out over the land on either side of the river.

-> When the river retreated leaves behind a thin layer of alluvium. After many floods a thick layer of alluvium is created. Thus is very fertile soil.

《Natural Levees》

-> Levees are raised banks of deposited materials found along the banks of the river.

-> When the river floods & spreads out over flood plain, the heaviest material is deposited close to the river over time & after many periods of flooding this deposited material forms "levees" along the banks of river.

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《Delta》

→ A delta is a triangular shaped piece of land which is formed at the mouth of the river. As the river enters the sea it drops off all the remaining material it is carrying.

→ This material builds up to form new land. The river is forced to break up into smaller channel called "distributaries".

《GLACIER》

Types of glaciers)

There are three kinds of glaciers:

(i) valley glaciers
(ii) piedmont glaciers 《& [illegible]》
(iii) ice glaciers

(i) 《valley glaciers》

The glaciers which originated near the crests of high mountains & move along the valleys just like rivers, are called "valley glaciers".

(ii) 《piedmont glaciers》

At the end of a hilly region, a number of valley glacier may unite to form a comparatively thick sheet.

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of ice such a compound glacier is called piedmont glacier.

(iii) ⟪Ice sheets/glaciers⟫

These are massive accumulation of ice covering extensive areas. Two such glaciers that exist today are the green land & Antarctic ice sheets. The greenland ice sheet covers an area of about 1.7 million square kilometers & is over 1500 meter thick.

⟪MOVEMENT OF GLACIERS⟫

Most of glacier move at the rate of a few meters per day. They move partly by plastic flow & partly by shear movement. In the most gradient valleys a mountain glacier flows down the slope much like a stream of water under gravity.

But on basin-shaped, flat or upland areas where the ice can not move under gravity, the glaciers move as a result of differential pressure with in the ice mass. The first type of movement is called "gravity flow".

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& the second "extrusion flow". A mountain glacier may have gravity flow in one part of its course & extrusion flow in another, depending upon the irregularities present in the path.

In a moving glacier two zones can be identified : ① zone of flow &
② zone of fracture

① zone of flow

The "zone of flow" is found in the deeper layers of ice. Here the weight of the overlying ice is great, & the ice behaves plastically.

② zone of fracture

However, the upper layers of a glacier have little pressure on them & therefore the surface ice behaves as a brittle mass. It often develops cracks known as "crevasses". This upper zone is called the "zone of fracture".

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«GLACIAL EROSION»

The glaciers cause erosion in three ways

(i) by plucking or quarrying
(ii) by abrasion &
(iii) by frost wedging

(i) plucking or quarrying

while flowing over a jointed rock surface, the glacial ice adheres to blocks of jointed bedrock, pulls them out & carries them along.

(ii) Abrasion

The moving ice grinds & polishes the rock surface with the help of rock fragments which are held firmly within the body of the glacier. The abrasion produces striations & grooves on the bed rock surface. A polished surface results when the glacier performs abrasion by fine silt-sized sediment. The ground up rock produced by the grinding effect of the glacier is called "rock flour".

(iii) Frost Wedging

Thawing & freezing of water in the cracks & joints of rocks

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break them by wedge action. In this manner rock fragments of all sizes are added onto the glacier.

«Features of glacial Erosion»

Striations

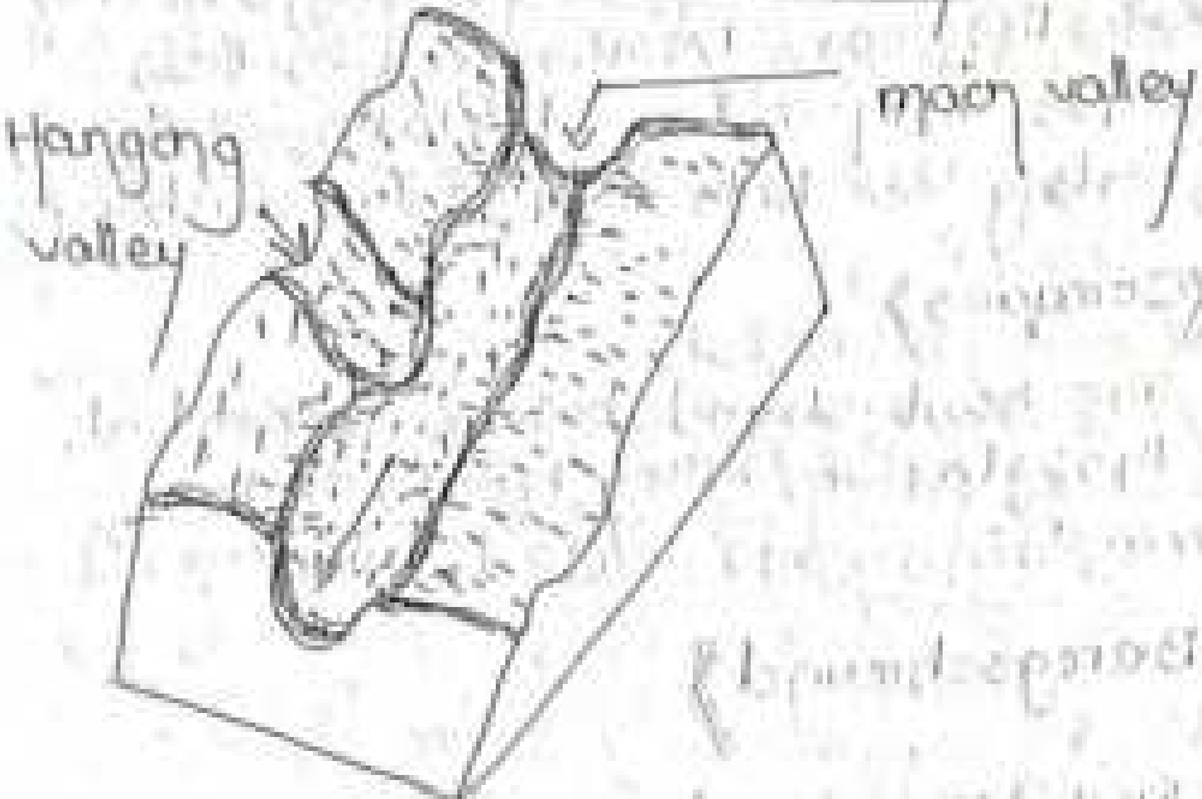
Glaciers carry rock fragments firmly embeded in the ice. They scratch, grind or groove the rock surface over which they move. These scratches & grooves left on bedrock & boulders, are called "Striations". The striations indicate the direction of ice movement.

U-shaped valleys

As glaciers occupy valleys & flow down hill, As they erode their valleys both laterally & vertically, U-shaped valleys with steep walls & flat floor & produced.

Hanging valley

Since the magnitude of the glacial erosion depends upon the thickness of the ice, main glaciers cut their valley deeper than those of their tributaries. As a result, at the junction where a tributary joins the main glacier, the floors of their valleys do not meet at the same level. The valley of the tributary stands at a higher elevation than that of the main valley; such valleys are called "hanging valleys".



When the glacier disappear, the hanging valleys are occupied by streams, which discharge into the main valley forming waterfalls.

《Icebergs》

Where a valley glacier terminate on Land, the streams of melt-water flowing on & under the glacier meet downstream to form a single river. The glaciers that end at the sea coast, discharge huge cliffs of ice into the sea. Because ice is less dense than water, it floats. Such floating ice hills are called icebergs.

《Cirques》

The bowl-shaped hollows present at the glacier valley heads on the mountains, are called "cirques".

{Bergschrund}

They are formed mainly by the quarrying & frost-wedging action of ice. In cirques a little gap is generally left be-tween the head of the glaciated valley & the mass of the glacier ice. This gap is known as the "bergschrund".

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《Serrate Ridges》 (i)

As the adjacent cirques, along the opposite side of mountain are enlarged the space bet^n them becomes narrow. As a result sharp divides are formed. such divides which have jagged, serrated & narrow crest" are called "serrate ridges".

《Horn》

~~[illegible]~~ When three or more cirques surround a mountain summit, a pyramid-like peak is formed; such a peak is called "horn". (ii)

Roche Mountonness ✓ write

Fiords ✓ write

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((Transport by glaciers))

Glaciers acquire a huge amount of rock debris by plucking, abrasion & frost wedging, the material is transported in three ways.

(i) Super glacial Load

The debris that falls from the valley walls on the surface of the glacier, is transported as a conveyor belt such debris is called "super glacial load".

(ii) Englacial Load

Sooner or later a part of the debris as glacier is moving is engulfed into crevasses. This material which is enclosed within the ice is called "englacial load".

(iii) Subglacial Load

The debris present at the bottom of the glacier is called "subglacial load". The subglacial load includes the material plucked from the rocky floor & a portion of the debris that reaches the base from above.

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← Glacial Deposits →

« Depositional Landforms »

« Moraines » ✓ Imp

Ridges or layers of till are called "moraines".
They are four types:

(i) ground moraines (iii) medial moraines
(ii) lateral moraines (iv) terminal moraines

(i) Ground moraines
A layer of till deposited beneath the moving ice on the ground is called the "ground moraine". Ground moraines fill low spots & old stream channels thereby creating a levelling effect.

(ii) Lateral moraines ✓
The material that falls from the valley walls, accumulates on the sides of a glacier. When the glacier disappears these materials are left as ridges along the sides of the valley.

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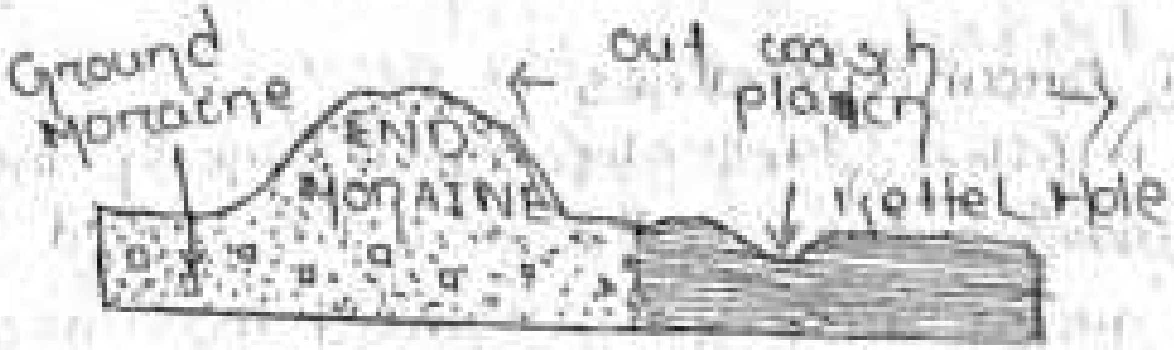
such deposits are called "Lateral moraines"

(ii) Medial Moraines

when two glaciers meet, a medial moraine is formed by the union of two lateral moraines.

(iii) Terminal Moraines

At the terminalus of a glacier where the ice starts melting, the rock debris is deposited in the form of a ridge which extends across the valley. Such deposits are called "terminal moraines" or "end moraines"



《Outwash plains》

In front of the end moraines, streams of meltwater deposit sediment producing stratified deposits of sand, silt & gravel. such deposits constitute "outwash plains".

《Drumlins》

"Drumlins" are small, smooth, elliptical hills of till that lie parallel to the direction of ice movement. Unlike roche moutonnees the uphill side of the drumlins are steep & the downhill sides are gently sloping.

-) They may be 20-30 meters high & a kilometer long. Drumlins are not found singly but they occur in clusters, thereby forming drumlin fields. They are believed to have formed by a subglacial shaping of an accumulated till into streamlined forms.

《Eskers》

Eskers are long winding ridges of stratified drift found in the middle of ground moraines. They run for kilometers in a direction more or less parallel to the direction in which ice moved. Eskers are formed due to deposition of gravels & sand by the englacial & subglacial stream.

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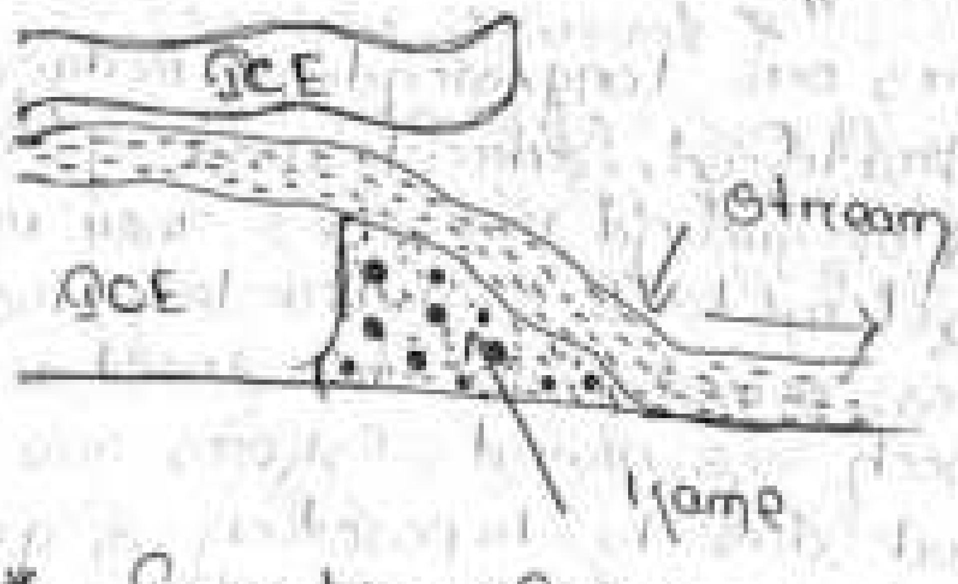
In many areas they are mined for sand & gravel.

Local melting of ice of glaciers produces streams of water. If these streams flow beneath the glaciers, they are called "sub glacial streams" & if these flow on or within the glaciers they are called "englacial streams".

«Kames»

Kames are hillocks of stratified drift which are formed at the edge of the retreating ice by glacial streams. These streams fall from a height & deposit sand & gravel along the margin of the glacier as alluvial cones.

«ESD/103»



* Formation of a kame.

Varves

Varves are thinly laminated deposits formed in glacial lake. They consist of alternation of light coloured bands of silt & dark coloured bands of clays. The former gets deposited during the summer season while the latter in winter. Thus each pair of varves corresponds to one year of deposition. The thickness of a varve may vary from a very small fraction of a centimeter to 0.75 centimeter.

Buried valley — Imp

Buried valley are the ancient deep valley which are excavated in the bedrock by glacier erosion & and filled back subsequently with glacial drift. The present day surface topography gives no clue to their existence. The rivers which are flowing in these areas may have no relation to the buried valley. Such valley creat unexpected problems for the civil engineers.

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« Elements of Mineralog »
|CH → 1|5

1. Def of Mineral ? Imp

A mineral is a naturally occuring homogeneous substance which has a more or less definite chemical composition & definite atomic structure.

→ The mineral are usually formed by inorganic process.

The mineral may be divided into two broad groups :

① (rock-forming mineral) Imp

"Rock forming minerals" are those which are found in abundance in the rocks of the earth's curst

② (ore forming mineral)

"Ore forming minerals" are those which are of economic value & which do not occur in abundance in rocks.

« Mineral Group »

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Imp.

S. No	Mineral Groups	Examples
1.	Oxides →	quartz, magnetite, Hematite, Limonite.
2.	silicates →	Felspars, Mica, Hornblende, Augite, olivines etc;
3.	carbonates →	calcite, Dolomite, siderite, etc.
4.	sulfides →	pyrites, galena, sphalerite etc.
5.	sulfates →	gypsum etc
6.	chlorides →	Rock salt etc;

« physical properties » Imp 7 mark

The physical properties of minerals can be determined readily by inspection or by simple test. Because the physical properties are determined in hand specimens, they are important in the recognition of minerals in the field. The chief physical properties are, colour, streak, lustre, hardness, habit, cleavage, fracture, odour, feel, tenacity fluorescence, phosphorescence, magnetism, specific gravity & crystal form.

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《Colour》

It depends upon the absorption of some & reflection of other of the coloured rays which constitute white light. Some minerals show distinctive colours as follows.

a) white → calcite, barite, magnesite, aragonite, opal, jade, chalk

b) Blue → azurite, sodalite, covellite, lazulite, lazurite, apatite

c) Green → fluorite, beryl, olivine, chlorite, serpentine

d) yellow → sulphur, marcasite, quartz, [illegible]

e) Red → realgar, jasper, pyrope, orthoclase.

f) Lead gray → galena, graphite, molybdenite

g) steel gray → hematite

h) Brass yellow → pyrite

i) colour less → halite, quartz, calcite, zeolite.

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Variation of colour may be due to
(i) surface alteration
(ii) difference in composition
(iii) presence of impurities
(iv) inclusion of foreign matter.

(Streak) Imp

It is the colour of the powder of a mineral in small amount & sometimes it is quite different from the colour of the mineral in mass. For example
(i) siderite shows the streak colour as white.
(ii) hematite shows the streak colour as cherry red.
(iii) chalcopyrite shows black streak colour.

(Lustre)

It is the appearance of the surface of a mineral in reflected light. Lustre also depends upon absorption & reflection of light. Lustre of mineral differ both in intensity & kind depending upon the amount & manner of reflection respectively. Lustre may be of the following types.

a) Metallic Lusture → Gold, silver, copper, galena, graphite, molybdenite etc.

b) Non-metallic Lusture

(i) vitreous lusture → It is the lusture of a broken glass. eg → quartz

(ii) Greasy lusture → It is lusture of an oily glass. eg → Nepheline

(iii) Resinous lusture → The lusture of resin as in ophalonite.

(iv) Silky lusture → It is shown by minerals possessing fibrous structure like asbestos, fibrous gypsum, fibrous calcite etc.

(v) Admantine lusture → It is the lusture of a diamond.

(vi) Pearly lusture → It is the lusture of a pearl, as in talc, opal, gypsum, kynite etc.

(vii) Earthy/Dull lusture → It is dull lusture as of kaoline, chalk.

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when the degree of lusture is more, the surface shines like a mirror & it is known as splendent or brilliant lusture.

What is Lusture

Lustre is a very characteristic & useful properties of mineral. It's a measure of the reflective of the mineral surface. The lusture may be defined as the general appearance of a mineral surface in reflected light.

《Hardness》

Hardness is the most useful diagnostic properties of a mineral.

-> It is defined as the resistance of a mineral to abrasion or scratching. Hardness is determined by rubbing a mineral of unknown hardness against one of known hardness.

-> A numerical value is obtained by using the "Mohs scale of hardness".

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-) In this scale there are ten mineral which are arranged in the order of their increasing hardness.

Imp «Mohs Scale of Hardness»

Hardness	Mineral	Remark
1	Talc	Scratched by a finger nail.
2	Gypsum	
3	calcite	Scratched by a knife
4	Fluorite	
5	Apatite	
6	Orthoclase	Scarcely scratched by a knife
7	Quartz	
8	Topaz	Not scratched by a knife.
9	corundum	
10	Diamond	

« Habit »

'Habit' of a mineral may be defined as the size & shape of the crystals & the structure or form by the

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10	Diamond	

« Habit »

'Habit' of a mineral may be defined as the size & shape of the crystals & the structure or form by the crystal aggregates & cryptocrystalline masses. The chief habits shown by minerals are as follows.

1) Accicular
Minerals showing needle like crystals. For example -> natrolite

2) Fibrous
Minerals showing an aggregate of long thin fibres, for example -> asbestos & satin spar.

3) Foliated
Minerals with platy habit commonly occur as foliated aggregates containing thin separable sheets. for ex -> muscovite & biotite

4) Bladed
Minerals showing bladed habit occur as small knife blade, for, ex -> kyanite

5) Tabular
Minerals showing broad flat surface. for ex -> feldspar

6) columnar
Minerals showing columnar crystals for example -> (tourmaline)

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7) <u>Botryoidal</u>)
Minerals showing aggregate of rounde masses resembling bunch of grapes.
Ex -> Chalcedony

8) <u>Reniform</u>)
Minerals showing kidney shaped form. Ex -> kidney iron-ore

9) <u>Granular</u>)
Minerals ~~showing~~ which occur as aggregate of equidimensional grains.
Ex -> Chromite

10) <u>Pisolitic</u> ->
Mineral which occur as aggregate of rounded grains of a pea size,
Ex -> Bauxite

11) <u>Oolitic</u>
Mineral showing an aggregate of bodies resembling fish ore
In case the rounded grain are of the size of a small pinhead

12) <u>Massive</u> »
when noncrystalline or crypto—

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crystalline minerals occur as structureless mass. their habit is described as "massive", for ex- flint

《Cleavage》

This is the property that some minerals exhibit of breaking along definite smooth planes.

The presence of these planes is a simple indication of the difference in strength of bonds bet^n atoms in the crystal.

Thus the property of cleavage is intimately connected with the atomic structure of mineral.

《Fracture》

Mineral which do not exhibit cleavage, break with an irregular surface.

The nature of this broken surface is called "fracture".

》《Odor》

Some minerals gives a characteristic smell when rubbed, breathed upon or heated.

① Arsenical ⇒ The arsenical odor like the odor of garlic.

orpiment & other arsenic minerals given arsenical odor.

2) Sulfurous → This odor is like the odor of burning sulfur. pyrite gives sulfurous odor.

3) Argillaceous ⇒ This odor is like the odor of clay. Kaolin gives argillaceous odor.

《Feel》

The feel is the sensation upon touching or handling minerals.

The different type of feel are

(i) greasy → feel is talc
(ii) soapy → feel is kaolin
(iii) rough → feel is bauxite
(iv) harsh →

《Tenacity》

Tenacity of mineral denotes denotes the degree or character of cohesion

(i) sectile → minerals which may be cut with knife but pieces are not malleable.

(ii) malleable → minerals which flatten under the hammer.

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③ Flexible -> minerals which may be bent
④ elastic -> minerals which spring back after bending
⑤ Brittle -> minerals which break easily. Brittle is the opposite of tough.
⑥ Friable -> minerals which crumble easily.
⑦ pulverulent -> minerals which are powdery & have little or no cohesion.
eg -> clay or chalk.

《**Fluorescence**》

~~Some mineral glow & emit light when they are~~

Some minerals when exposed in sunlight or ultraviolet light produce a colour quite different from their own. Thus green or colourless fluorite shows a blue or purple colour in ultraviolet light. This property of minerals is called "fluorescence".

ex -> calcite & scheelite.

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《 Phosphorescence 》

Some minerals glow & emit light when they are placed in ultraviolet light or certain other electrical radiation. The glow induced in the mineral may continue for a few seconds or minutes after the removal of the cause. This property of minerals is called " phosphorescence ".

ex → diamond & sphalerite.

《 Magnetism 》

A few mineral are attracted by a magnet of these minerals magnetite & pyrrhotite are the most common examples. The magnetic that possesses attracting power & polarity is called "lodestone".

《 Specific Gravity 》

" Specific gravity " is a number which represents the ratio of weight of a mineral to the weight of an equal volume of water.

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→ Thus a mineral with specific gravity 4.0 is four times as heavy as water.

→ The specific gravity of common silicate mineral is about 2.65 & those of ore mineral varies bet^n 4.5 to 10.0.

→ A rough estimate about the specific gravity of minerals can be made by hefting them in our hand.

《 Determination of Specific Gravity 》

The common methods of determining specific gravity of solids are based on the fact that the loss in weight of a body immersed in water, is the weight of an equal volume of water.

If W_1 is the weight of the mineral in air & W_2 its weight in water, its specific gravity will be as under.

$$\text{Specific Gravity} = \frac{W}{W_1 - W_2}$$

Long (7) march — Imp

《 Silicate Mineral Structures 》

The silicate mineral group is of great importance because they constitute about 90% of the earth crust.

→ They are found in all the common rock expect limestones.

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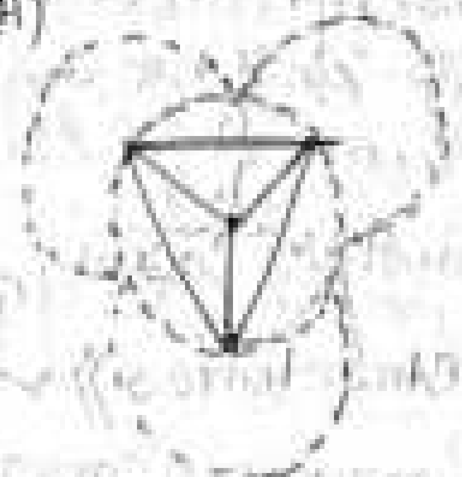
→ In order to understand the difference bet major silicate mineral group, it is necessary to study their structure.

→ Every silicate mineral contains oxygen & silicon & all exp except quartz, contain one or more additional elements to complete their structure.

→ The basic unit in all silicate minerals is the silicon-oxygen tetrahedron

→ The structure is composed of four oxygen atoms with the silicon atom at its centre

(A)



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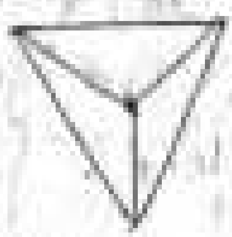

Diagrammatic representation of SiO_4 tetrahedron

The SiO_4 tetrahedron (four large spheres represent oxygen & dark one represents a silicon atom)

i) 《Neosilicates》
The structure is that of independent (SiO_4) - tetrahedron
Ex-> olivene, zircon, garnet etc.

ii) 《Sorosilicates》
Two tetrahedra sharing one oxygen i.e Si_2O_7.
Ex-> Melilite

iii) 《 cyclo- silicates 》
These are closed rings of tetrahedra sharing two oxygen a. i.e the ratio betn 'Si' & 'O' is 1:3

* 3-tetrahedra sharing an oxygen atom
* 4- " " " " -> Benitoite
* 6- " " " " -> Axinite
-> Beryl

iv) 《Ino-silicates》
These are also known as chain structure.
① i) Single-chain structure ->
In this case two oxygen atoms of silicon - tetrahedron are shared Si : O = 1 : 3
Ex -> pyroxene

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(iv) Double-chain structure → These are continuous double chain of tetrahedra alternately sharing two & three oxygen. The ratio of silicon to oxygen is 4:11

Ex → Amphibole.

v) ((Phyllo silicates))

These are continuous sheets of tetrahedra sharing three oxygens, ratio of silicon to oxygen is 4:10.

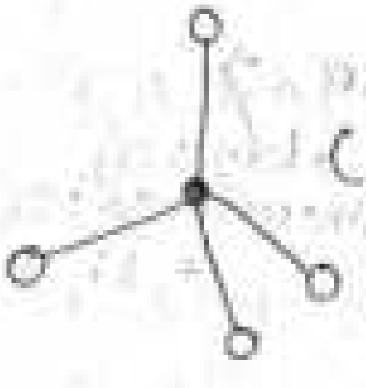
Ex → mica

vi) ((Tekto silicates))

These are three-dimensional framework of tetrahedra with all four oxygen atoms shared. Ratio of silicon to oxygen is 1:2

Ex → quartz, Feldspar.

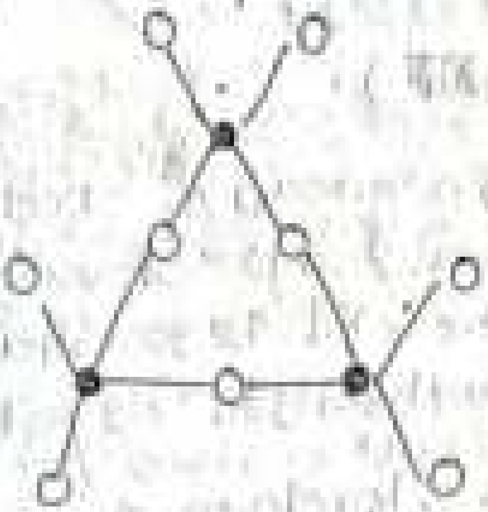
((Drawing))



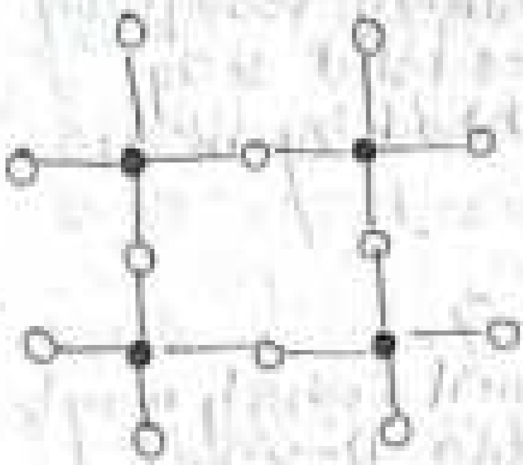
(Neo silicate)

○ → oxygen
● → silicon

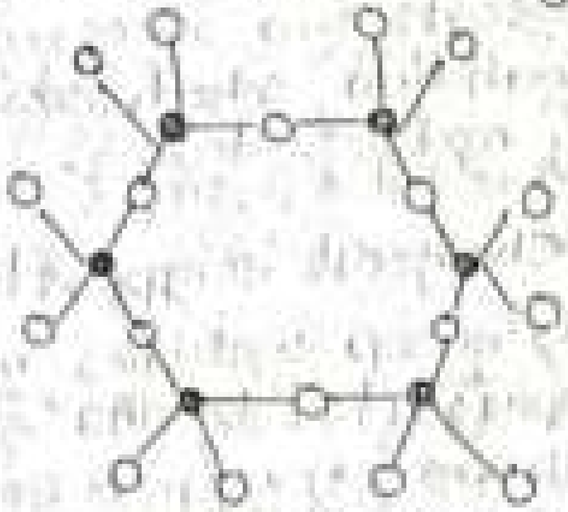
(Sorosilicate) (cyclosilicate)



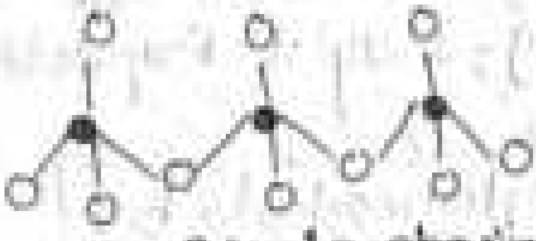
3-member ring



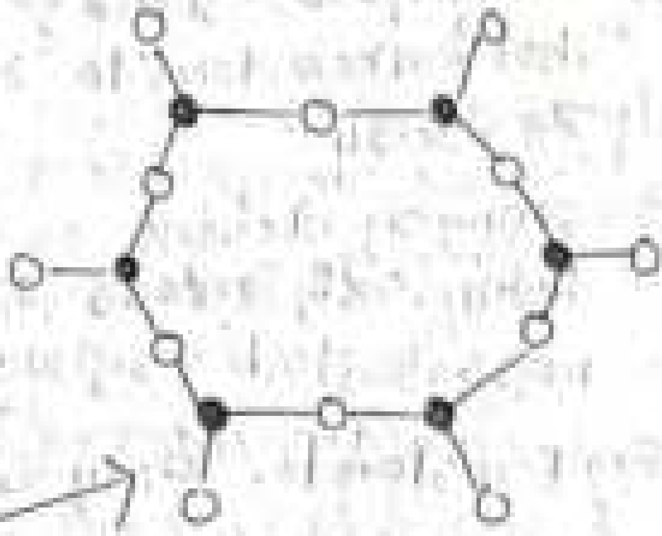
4-member ring



6-member ring



Single chain



Double chain

chain Structure

Imp «OLIVINE»

This is a group of rock-forming silicates. The minerals are olive-green or brown in colour. All these minerals crystallise in orthorhombic system.

Atomic structure →
These are neo-silicates which essentially consists of a series of isolated SiO_4 tetrahedra which are linked by means of metal cations.

Chemical composition →
The group includes minerals which may be represented by the formula R_2SiO_4, where R = Mg or Fe.

→ The members of this group belong to a continuous series of solid-solution bet^n forsterite Mg_2SiO_4 & Fayalite Fe_2SiO_4

→ common olivine is intermediate bet^n them with excess Mg & the formula is represented as $(Mg, Fe)_2SiO_4$.

Ex→ Forsterite, chrysolite, Hortonolite, Fayalite.

«allied mineral»

Knebelite $(FeMn)_2SiO_4$

Monticellite $(CaMgSiO_4)$

Ophorite Mn_2SiO_4, Larsenite $PbZnSiO_4$

《physical properties》

1. crystal system → orthorhombic
2. colour → olive green
3. streak → colourless
4. Lustre → vitreous lustre
5. Hardness → 6.5 to 7
6. cleavage → Absent
7. Sp. gravity → 3.2 to 4.3
8. Fracture → conchoidal
9. Twinning → none

《optical properties》

(i) colourless & non-pleochroic
(ii) Ref. index. High positive relief
(iii) Bi-refringence strong 0.037
(iv) extinction straight

《Varieties》

The gem-quality of olivines are referred to as peridot.

《Occurrence》

It characterises the ultra-basic igneous rocks as dunites, peridotites serpentinite & basic rocks like norite, gabbro, dolerite basalt etc.

Ex → chromite, spinel, pyrope

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(PYROXENES)

These rocks forming silicates contain the Si_2O_6 single chain structure (inosilicate). These are anhydrous silicates of Mg & Fe & thus are predominantly found in ferro-magnesian rocks i.e. in basic & ultrabasic rock.

1. Orthorhombic

a. Enstatite - $MgSiO_3$
b. Bronzite - Fe
c. Hypersthene - Mg, Fe SiO_3
d. Ferrosilite - $FeSiO_3$

A) 2. Monoclinic

a. Diopside - $CaMgSi_2O_6$
b. Clino-enstatite - $Mg_2Si_2O_6$
c. Hedenbergite - $CaFeSi_2O_6$

B) Alkali-pyroxenes

a. Aegirine - $NaFeSi_2O_6$
b. Jadeite - $NaAlSi_2O_6$
c. Spodumene - $LiAlSi_2O_6$

3. (Triclinic)

They are commonly known as pyroxenoids & include minerals like wollastonite ($CaSiO_3$), pectolite [$CaNaH(SiO_3)$] & rhodonite ($MnSiO_3$), bustamite [$MnCa(SiO_3)_2$].

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《Physical properties》

These are usually prismatic crystals

1. colour → Nearly black or green of various shades.
2. Lustre → vitreous to subvitreous. Hypersthene shows a kind of metallic-pearly lusture termed "schillerization".
3. Cleavage → 2 sets, prismatic at angles 87° & 93°.
4. Hardness → 5 to 6
5. Sp. gravity → low to moderate
6. Twinning → contact twins in case of monoclinic members

《Optical characteristics》

a) orthopyroxenes	b) clinopyroxenes
i) green & pleochroic	i) colourless to pale green & pleochroic
ii) ref. index. High. optically +ve	ii) ref. index. Higher than canada Balsam
iii) Interference colour. 1st order	iii) Int. colour. 2nd order
iv) Extinction. parallel	iv) Extinction. Inclined, 45°

《Varieties》

i) Diallage
ii) omphacite
iii) Kunzite
iv) Hiddenite

《Occurrence》

Mostly found in basic rocks like gabbro & their hypabyssal & volcanic equivalent, ultrabasic rocks like - peridotite, pyroxenite also contain predominantly pyroxenes.

《FELDSPARS》 Imp. 7 marks

This is the most important group of the rock-forming silicates. They constitute about 2/3rd of the igneous rock.

1. orthoclase & microcline $KAlSi_3O_8$
2. Albite $NaAlSi_3O_8$
3. Anorthite $CaAl_2Si_2O_8$
4. Celsian $BaAl_2Si_2O_8$

The three isomorphous series are
(i) Anorthoclase series → bet^n a-K & a-Na feldspar
(ii) Hyalophane series → bet^n a-K feldspar & a-Ba feldspar with 10%
(iii) Plagioclase series → bet^n albite & anorthite
i) Albite iii) Andesine
ii) Oligoclase iv) Bytownite

《Physical properties》

(i) crystal form → orthoclase is monoclinic. microcline & plagioclases are triclinic.

(ii) colour → orthoclase → flesh-red
Microcline → green
plagioclases → white to gray

(iii) Lusture → vitreous or pearly

(iv) cleavage → 2 sets - one parallel to (001) face & other to (010)
Angle in cleavage's is 90° & orthoclase is less than 90°.

(v) Hardness → 6

(vi) sp. gravity → 2.5 to 3

(vii) 《Microscopic characteristics》

1. form → subhedral to anhedral
2. cleavage → 2 sets.
3. bi-refringence - weak
4. Twinning (i) orthoclase → simple twinning
(ii) Microcline → cross-hatched twinning
(iii) plagioclase → polysynthetic
5. Extinction angle → 15 to 60°

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《Varieties》

1. Sanidine → A high temp. potassium feldspar
2. Adularia → Low-temp. orthoclase
3. Moon stone → opalescent adularia or albite.
4. Aventurine → gem variety of albite
5. Amazon stone → bright green microcline.

《Occurrence》

Alkali-feldspars i.e orthoclase, microcline & albite are common in acid igneous rocks like granite, grano-diorite, syenite etc.

《QUARTZ》 — Imp

Quartz is a member of silica group of minerals, which have tecto-silicate structure & the chemical composition of SiO_2. The atomic structure as is found in crystalline varieties does not apply to silica glass.

(i) quartz (ii) tridymite

(iii) cristobalite (iv) coesite

(v) stishovite (vi) keatite

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physical ~~props~~ characteristics

1. Form → while quartz as a member of the hexagonal system.
2. Streak → white
3. Lusture → vitreous to sub-vitreous
4. Hardness → 7 (seven)
5. Cleavage → No cleavage
6. Sp. gravity → Low, i.e 2.65
7. Occurring →

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《PETROLOGY》 Chapter - 2

《Rock》

Rocks from a major part of the earth's crust. They may be defined as aggregates of minerals. Some rocks such as quartzite (quartz) & marble (calcite), contain grain of one mineral only, but most are composed of a variety of different minerals.

The rock are broadly classified into three groups:

1. Igneous
2. Sedimentary
3. metamorphic

《Igneous Rock》

Igneous Rock are formed by cooling & solidification of magma.

Ex-) granite & basalt.

《Sedimentary Rock》

Sedimentary rocks are formed by consolidation & cementation of sediments ~~that~~ deposited under water.

Ex-) sandstone, limestone.

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«Metamorphic Rock»

Metamorphic rocks are formed when the pre-existing rocks have been changed in texture & composition by increased temp & pressure.

Ex → Schist & gneiss

«Rock cycle»

→ The rock cycle shows the relationship bet the three types of rocks, that is igneous sedimentary & metamorphic rocks.

→ One type of rock change slowly to another type.

→ Erosion produces sediment which is transported & deposited into deep basins under the sea. Then it hardens to form sedimentary rocks.

→ If these rocks are deeply buried, the temp. & pressure turn them into metamorphic rocks.

→ Intense heat at great depths melts metamorphic rocks & produces magma. The magma may rise up & reach the earth's surface where it cools to form igneous rock and it.

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At the surface, igneous rocks are exposed to weathering & erosion, & the cycle begins again.

«IGNEOUS ROCK»

→ Approximately 90% of the earth's crust is composed of igneous rocks but their great abundance is hidden on the earth's surface by a relatively thin layer of sedimentary & metamorphic rocks.

→ Igneous rocks are formed by cooling & solidification of magma. Magma is a hot viscous, siliceous melt containing water vapour & gases. It comes from great depth below the earth's surface.

→ It is composed mainly of O, Si, Al, Fe, Ca, Mg, Na & K. When magma comes out upon the earth's surface, it looses its gases. Such a magma is called "Lava".

«Chemical composition»

The chemical composition of igneous rocks depends upon the composition of magma from which they are originated.

The chemical composition of igneous rocks exhibit a fairly limited range. The largest oxide component is SiO_2 which in common igneous rocks ranges from 40 to 75% by weight.

The % of Al_2O_3 generally ranges from about 10-20% & each of the other major components (oxides of Ca, Mg & Fe) seldom exceed 10%.

On the basis of silica % present, igneous rocks are classified into the following groups →

(i) Ultrabasic rocks → These contain less than 45% silica. eg → peridotite

(ii) Basic rocks → These contain silica betn 45% & 55% eg → gabbro, basalt

(iii) Intermediate rocks → These contain silica betn 55% & 65% eg → diorite

(iv) Acid rocks → These contain more than 65% silica. eg → granite.

{ Igneous rocks are light in colour, low in specific gravity (< 2.7) & have high proportion minerals like quartz, alkali feldspars.

Acid rocks are also called the "felsic rock". Ex → granite

colour → dark
sp. gravity → 3.2

Basic rocks are also called mafic rocks".
eg → basalt.

classified as →
(i) Oversaturated rocks
(ii) Saturated rocks
(iii) undersaturated rocks

(i) oversaturated →
These rocks crystallize from melts containing higher amount of silica. They contain abundant quartz & alkali felspars.

(ii) Saturated rocks →
These rocks are formed when the amount of silica present in the melt is just sufficient to from silicate minerals. Saturated igneous rocks do not contain quartz.

(iii) Undersaturated rocks →
These rocks crystallize from a melt which is deficient in silica & high in alkalies & aluminium oxide.

→ Such rocks contains silica poor minerals, such as felspathoids. & lack quartz.

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Occurrence of Igneous Rocks »

Magma is produced deep in the earth's crust where temp. are of the order of (900°-1600°c). It being lighter than the surrounding rocks works its way towards the surface.

Two types of igneous rocks

① «extrusive Rocks »

when magma reaches the earth's surface it causes a volcanic eruption. This eruption generates extensive lava. The rocks formed due to solidification of lava are called extrusive rocks.

→ The extrusive rocks are also called the volcanic rocks.

⑪ «Intrusive Rocks»

Intrusive rocks are formed when magma crystallizes beneath the earth's surface. Depending on depth of formation, intrusive rocks are two types.

① «plutonic Rocks »

Rocks crystallized at great depth are called "plutonic rocks".

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② {Hypabyssal Rocks}

Hypabyssal rocks are formed when magma solidifies close to the earth's surface.

《TEXTURES》

Textures means the size, shape & arrangement of mineral grains in a rock. The grain size of an igneous rock depends on the rate of cooling of magma.

In general, slower is the rate of cooling the coarser is the grain of rock.

The points are →

(i) degree of crystallization
(ii) size of grains
(iii) shape of crystals
(iv) mutual relation betn mineral grains

《Degree of crystallization》

On the basis of degree of crystallization textures of igneous rocks can be divided into following groups

→ ① Holocrystalline texture →
When a rock is made up entirely of crystals, its texture is described as holocrystalline.

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→ (i) Holohyaline texture →
when a rock is composed entirely of glassy material, its texture is called holohyaline.

→ (ii) Merocrystalline texture →
when a rock is composed partly of crystals & partly of glass, the texture is called merocrystalline texture.

《 **Size of Grains** 》

The size of grains in an igneous rock varies considerably. The slow cooling gives crystals time to grow to sizes greater than 5 mm. In rapid cooling, the mineral grains crystallize quickly as a mass of tiny crystals which are generally less than one millimeter in size.

→ Igneous rocks whose constituent mineral grains can be seen with the naked eyes, are described as "**phaneric**", while those whose mineral grains are too small to be seen with the naked eyes, are called **aphanitic**.

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Types

(i) Coarse Grained Texture →
If the grains of a rock are more than 5 mm in diameter, its texture is said to be "coarse grained".

(ii) Medium Grained Texture →
If the size of grains are bet 1 mm & 5 mm the rock is described as medium grained.

(iii) Fine Grained Texture →
If the grains are like granulated sugar where their diameter is less than one millimeter, the texture of the rock is called "fine grained".

(iv) Microcrystalline Texture →
In an aphanitic rock, if the mineral grains can be distinguished under a microscope, the rock is said to be microcrystalline.

(v) cryptocrystalline Texture →
In a cryptocrystalline texture, the individual crystals are very small. They are not visible under the microscope but their presence can be felt as they react to the polarized light.

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«Shape of crystals»

* The grains of an igneous rock are called "euhedral" if they show well developed crystal faces.

* If the crystal faces are partly developed, they are described as "subhedral".

* The term "anhedral" is used for those grains in which crystal faces are absent.

«Mutual Relations of grains»

Depending on mutual relations of grains the textures of igneous rocks may be classified into four major groups

1. equigranular texture
2. inequigranular texture
3. directive texture
4. Intergrowth texture.

«Equigranular Textures»

Igneous rocks containing mineral grains of more & less equal size are said to have an "equigranular textures".

(i) panidiomorphic texture →
when most of the grains are euhedral, the texture of rock is called "panidiomorphic"
ex → lamprophyres

(ii) Hypidiomorphic texture →
when most of the crystals are subhedral, the texture is called "hypidiomorphic"
ex → granites, & syenites

(iii) Allotriomorphic texture →
when most of the crystals are anhedral, the texture is called "allotriomorphic".
ex → aplites

(iv) microgranular texture →
microcrystalline igneous rocks may also have an equigranular texture. The crystals of these fine grained rocks are commonly anhedral or subhedral, such a texture is called "microgranular texture".

(v) orthophyric texture →
some highly feldspathic rocks such as orthophyres & plagiophyres, possess a fine grained panidiomorphic texture. this is called "orthophyric texture".

(vi) Felsitic texture →
A igneous rock containing a uniform mass or cryptocrystalline matter is said to have a "felsitic texture".

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Inequigranular Texture →

Igneous rocks showing variations in the size of mineral grains are said to have the "inequigranular texture".

① porphyritic Texture →
when an igneous rock contains large crystals of some minerals set in a matrix which is much finer grained or even glassy, the texture is called "porphyritic".

→ The large crystals are called phenocrysts.
→ The finer grained material called groundmass

② Glomero-porphyritic →
Here phenocrysts gather at one spot.

③ vitrophyric →
when the groundmass is glassy in a porphyritic texture, it is called vitrophyric texture.

④ poikilitic Texture →
when in a rock smaller crystals are enclosed within larger crystals without common orientation the texture is called "poikilitic texture".

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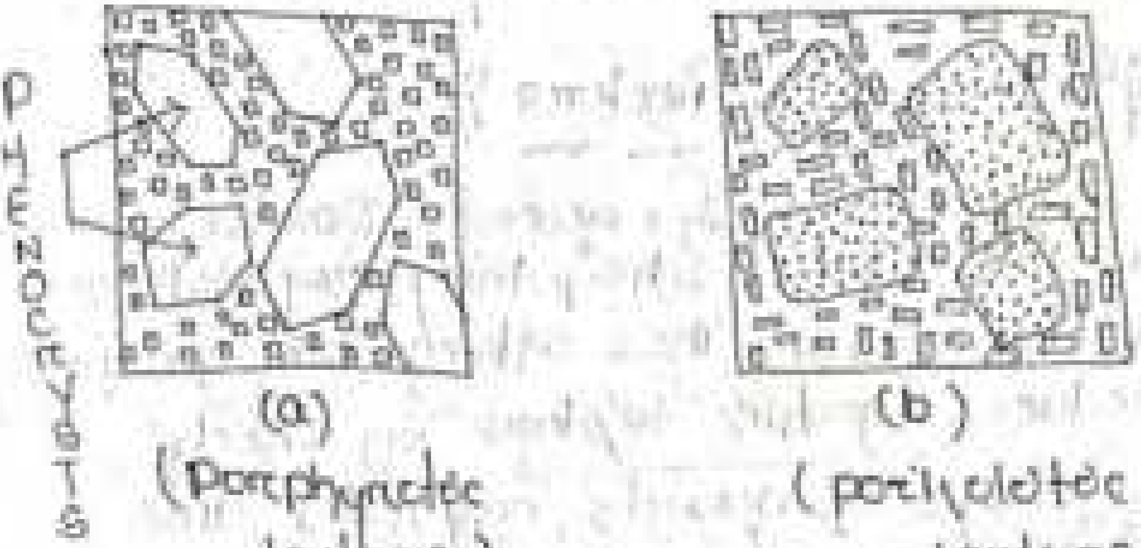
Ex → Syenites & monzonites

② «Ophitic Texture»

"Ophitic texture" is a special type of poikilitic texture in which bigger crystals of augite enclose smaller laths of plagioclase.

Ex → dolerites



(a) (Porphyritic texture)

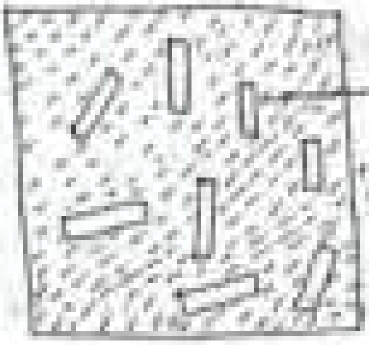
(b) (poikilitic texture)

«Directive Textures»

The textures produced as a result of flow of lavas during their consolidation are called "directive textures".

c) «Trachytic Texture»

Certain volcanic rocks, such as trachyte contain feldspar laths arranged in lines parallel to the direction of flow of lava. Such a texture is called the "Trachytic Texture".



(ii) Hyalopilitic Texture →
In a volcanic rock if felspar laths are found intermixed with glass, the texture is called "hyalopilitic".

《Intergrowth Texture》

The intergrowth of quartz & orthoclase may take place when they crystallize simultaneously. This intergrowth frequently produces "graphic texture" in which skeletons of quartz crystals are embedded in the orthoclase.

→ The two intergrowth minerals have the same optical orientation over large areas. A variety of granite called the "graphic granite" show the graphic texture.

SEDIMENTARY

«Sedimentary Rock»

→ The total amount of sedimentary rock is that exists in the upper 16 km of the earth's crust is estimated to be only about 5%. These rocks are found chiefly as an extensive cover over the continents.

→ "Sedimentary rocks are formed by consolidation & cementation of sediments deposited under water". Sedimentary rocks also include the rocks formed by accumulation of chemically precipitated or organically derived material. Sedimentary rock occurs in layers & frequently contain fossils.

Form

The formation of sedimentary rocks takes place in three stages

(i) weathering & erosion of preexisting rocks

(ii) sedimentation

(iii) lithification & diagenesis.

«Weathering & Erosion»

During weathering & erosion, the preexisting rocks & their constituent minerals are broken down. The material thus produced is called the "sediments".

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The sediments are usually transported & deposited in areas of accumulation by the action of water or less frequently by glacial or wind action.

« Sedimentation »

The process of accumulation of sediments at a site of deposition is called the "sedimentation".

« Lithification & Diagenesis »

Lithification is a process by which soft & loose sediments are converted into hard & firm rocks. This process is also called "consolidation". During this process many physical & chemical changes take place within the sediment. Such changes are called the diagenetic changes & the process is described as "diagenesis".

The diagenesis includes three processes:

(i) compaction
(ii) cementation
(iii) recrystallization

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i) 《Compaction》

compaction occurs when the weight of overlying layers compresses the sediments below. As the grains of sediments are pressed closer & closer together, there is considerable reduction in pore space & volume.

ii) 《Cementation》

When water circulates through the pores of coarse grained sediments, dissolved mineral matter is precipitated between the grains which causes cementation.

→ The most common cementing materials are silica, calcium carbonate, iron oxides & clay minerals.

iii) 《Recrystallization》

Although most sedimentary rocks are lithified by compaction, cementation or a combination of both, some are consolidated chiefly by the recrystallization of their constituents.

Ex → limestones, dolomites, salt & gypsum.

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((Classification))

The sediments form which sedimentary rocks are formed may be devided into two major groups.

i) clastic sediments
ii) Non-clastic sediments

((Clastic sediments))

"clastic sediments" are broken fragments of preexisting rocks ranging in size from minute clay particles to very large boulders. Clastic rocks are formed by the mechanical accumulation of grains of clastic sediments

→ The clastic rock are classified into three groups-)

i) ((Rudaceous Rocks))

These rocks are formed by accumulation of bigger rock fragments such as gravels, pebbles & boulders if the grains are rounded, the rock is called "conglomerate". & if they are angular the rock is termed as breccia.

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i) 《Arenaceous Rocks》

These rocks are composed almost entirely of sand grains. When individual grains are rounded, the rock is called "sandstone" and grit if the grains are angular.

ii) 《Argillaceous Rocks》

These rocks are made up of very fine-grained sediments; "shale" & "mudstone" are typical argillaceous rock which are composed of clay-sized sediment.

《Nonclastic sediments》

Nonclastic rocks include those sedimentary rocks which are formed by chemical precipitation of minerals from water ~~mainly because~~ or by accumulation of remains of animals and plants.

They are classified into two groups

i) chemically formed rocks

ii) organically formed rocks

i) 《carbonate Rocks》

• "Limestones" & "dolomites" are the most abundant carbonate rocks. They are formed by the chemical precipitation of calcium carbonate from sea water.

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ii) ((Salt Rocks))

Evaporation is the major process involved in the deposition of of chemical precipitates. The salt deposit formed by the evaporation of saline lakes are called "evaporites".

iii) ((Ferruginous Rocks))

This group includes those rocks which are formed by the chemical precipitation of iron oxides. Such rocks contain a high proportion of iron-bearing mineral such as siderite, hematite, chamosite & pyrite. "Iron-stone" is an example of ferruginous rocks.

iv) ((Siliceous Deposits))

Siliceous rocks are formed when silica is precipitated form water.

Ex → flint, chert, jasper & agate

((Organically formed Rocks))

These rocks are composed mainly of remains of animals or plants. Organically formed rocks are subdivided into two groups.

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i) ⟪Biochemical Rocks⟫

The biochemical rocks which sediment is produced when plants & animals living under water, extract from it dissolved mineral matter, usually calcite to form shells or other hard parts.

Ex → shell - limestone

ii) ⟪ Organic Rocks ⟫

Rocks containing organic matter belong to this group.

Ex → coal

→ These are also called the carbonaceous rocks".

⟪ Texture ⟫

"Texture" means the size, shape & arrangement of grains in a rock. As sediments contain particles of various size, grain size is an important factor of the description of sedimentary rocks. Depending upon the size, particles of sediments are classified into pebbles, gravels, sand, silt & clay & each of these gives rise to a particular type of rock.

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《Structural Features》 Imp

The important structural features of sedimentary rocks are stratification, lamination, graded bedding, current bedding & ripple marks. Besides these, there are some minor structures such as mud cracks, rain prints, tracks of terrestrial animals etc.

《Stratification》

All sedimentary rocks are, in general, characterized by stratification. Deposition of sediments into layer or beds is called the stratification.

《Lamination》

Thin bedding, less than one centimeter in thickness, are called "Lamination". Lamination is usually found in very fine grained rocks, like shale & gives them the characteristic property of fissility.

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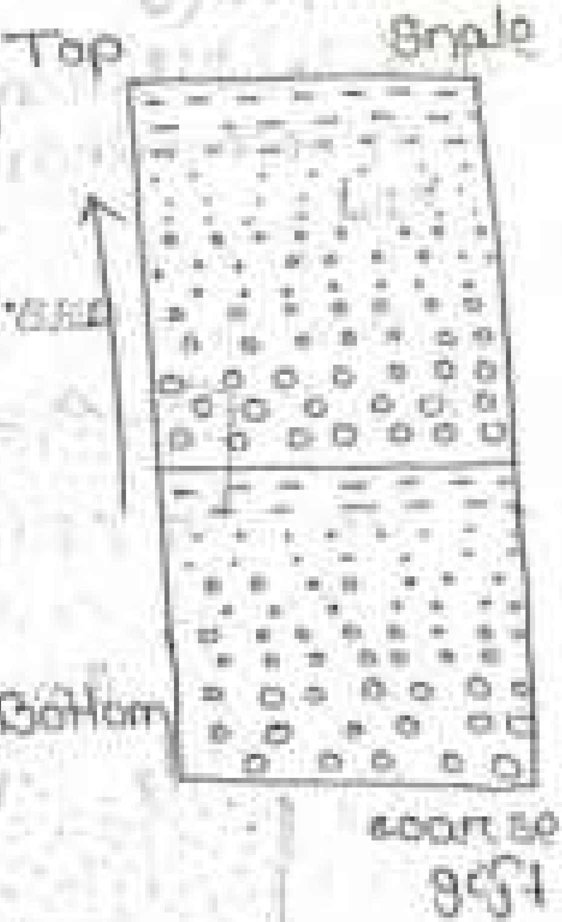
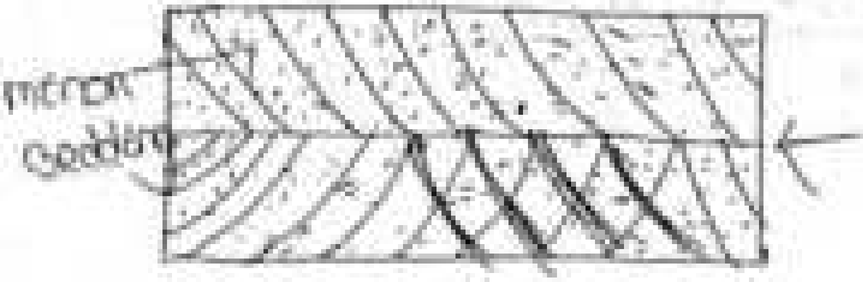
《Graded Bedding》

In "graded bedding" each bed shows a gradation in grain size, from coarse below to fine above. The graded bedding results from rapid sedimentation in water.



《Current Bedding》

"current bedding" is also called the "cross" bedding.
→ In this structure minor beds or laminations lie at an angle to the planes of general stratification.
→ current bedding is commonly found in shallow water & wind formed deposits.



《Ripple Marks》 Imp

Ripple marks are the wavy undulation seen on the surface of bedding planes. They are produced by the action of wave & current in shallow water.

Ripple marks are two types →

(i) asymmetrical or current ripple marks

(ii) symmetrical or oscillation ripple marks

The oscillation ripple marks are useful in determining top & bottom of deformed beds.

(symmetrical)

(A)

《Asymmetrical》

(B)

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ELEMENT OF CRYSTALLOGRAPHY

→ What is crystallography?

Crystallography is a branch of mineralogy which deals with the study of crystals & the laws that govern their growth, external shape & internal structure.

Crystal →

A solid which possesses a regular geometrical shape, is called crystal.

Zone →

In many crystals a group of faces are arranged in such a manner that their intersection edges are parallel to each other such face constitute a zone.

Edges →

Edges are formed where two adjacent faces meet...

Solid Angle →

Solid Angle is formed where three or more edges meet.

Zone axis →

A line which passes through the centre of the crystal and is parallel to the line of the face intersection is called the zone axis.

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Interfacial Angle

In a crystal the angle bet adjacent faces is called "interfacial angle".

Crystallographic Axes

In order to describe the faces & symmetry of crystals, a set of three or four reference axes are established. These imaginary reference lines are called "crystallographic axes".

* The length,

Axial Ratio

The "unit lengths" of crystallographic axes are length of the unit cell edges. These are expressed as a, b, & c.

& the crystallographic angles are expressed as

$+c + b = \angle\alpha$

$+c + a = \angle\beta$

$+a + b = \angle\gamma$

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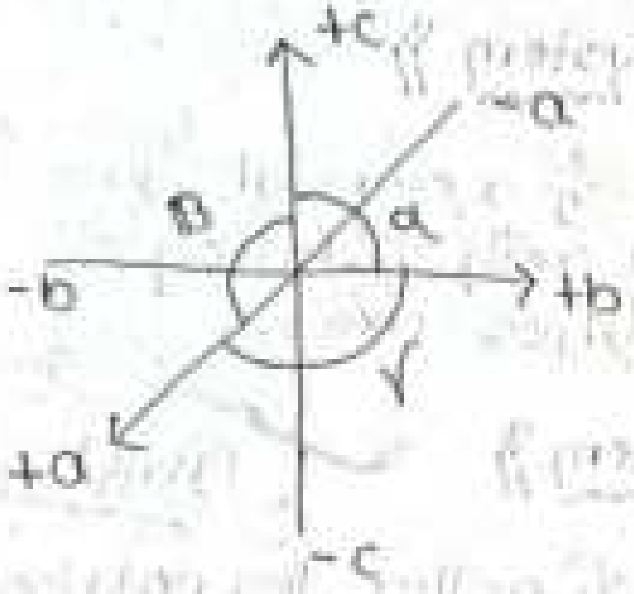
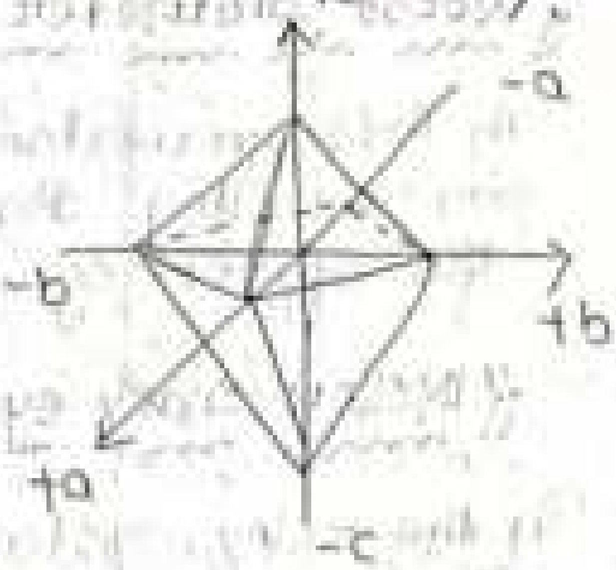


a) (crystal face)



b) Miller indices

Parameters

The parameters of a crystal face may be defined as the intercepts made by the crystal face on the crystallographic axes

Crystallographic Notation

The slope of crystal faces can be described with reference to the intercepts they make on the crystallographic axes.

The methods that are commonly used for expressing the intercepts of crystal face are
(i) Weiss parameter system
(ii) Miller index system

« Weiss parameter system »

In this parameters of a crystal face are written along with notation of the crystallographic axes.

Small

« Miller index system » Imp

In the index system of miller, the notations of crystal faces are called "miller indices".

-> The miller indices of a face consists of a series of whole number that have been derived from the parameters by taking their reciprocals & then by clearing of fractions. The no. of the miller indices are always written in the axial order.

Forms

A "form" consists of a group of crystal faces all of which have the same relation to the elements of symmetry. The no. of faces in a form is determined by the symmetry of the crystal class.

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1. Closed & open form

A "closed form" is that whose faces enclose space & can exist alone.

Ex → cube

Faces of an "open form" do not enclose space.

Ex → prism

2. Holohedral & Hemihedral forms

In a crystal system, each form of the normal class is called "holohedral form".

→ However in the lower symmetry classes there are some forms which contain half the no. of faces found in the corresponding holohedral form. Such a form is called "hemihedral forms".

3. Hemimorphic form

In the lower symmetry classes of some system, there are some crystal forms in which face occur only one end of the vertical crystallographic axis, such form are called "hemimorphic forms".

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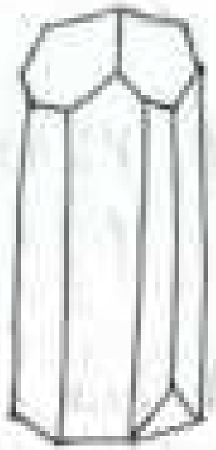

Tourmaline crystal showing (hemimorphism)

《Enantiomorphous forms》

crystal which do not possess plane & centre of symmetry, contain a form that occurs in two positions & which are mirror image of eachother.

→ These two positions are related in the same way as right & left hand & are not interchangeable. such a form is called "Enantiomorphous form"

Symmetry Elements

Imp — small

Every crystal possesses a certain symmetry element are used to describe this symmetry.

plane of symmetry

A plane of symmetry is an imaginary plane which devides a crystal into two halves, each of which is the mirror image of the other.

Axes of symmetry

It is an imaginary line through the crystal about which if the crystals is rotated, it gives the observer exactly the same view more than once in a single rotation

→ If the same view is repeated 2, 3, 4 or 6 times, the axis of symmetry is referred to as two-fold, three-fold, four-fold, or six-fold respectively.

centre of symmetry

If each face on a crystal is duplicated by a similar parallel face on the opposite side, it is said to have a centre of symmetry

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⟪Six crystal systems⟫ — Imp

All crystals that occur in nature can be grouped into six major crystal system.

i) ⟪Cubic or Isometric system⟫

The crystals belonging to this system have three mutually perpendicular axes of equal lengths. These axes are designated as a_1, a_2 & a_3.

ii) ⟪Tetragonal system⟫

The crystal of this system are referred to three mutually perpendicular axes. The two horizontal axes are equal (a_1 & a_2) & the vertical axis is longer or shorter than the other two.

iii) ⟪Hexagonal system⟫

In the crystals of the hexagonal system there are four crystallographic axes. Three of these are of equal length & lie at angle of 120° to each other in the horizontal plane. These are designated as a_1, a_2 & a_3. The fourth axis is vertical & is either longer or shorter than the other axes.

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iv) 《Orthorhombic system》

The crystals of this system have three mutually perpendicular axes of different lengths. They are designated as a, b & c.

v) 《Monoclinic system》

In the crystals of this system, there are three unequal crystallographic axes. The 'a' & 'c' axes are inclined to each other at an oblique angle & the 'b' axes is perpendicular to the plane of the two.

vi) 《Triclinic system》

There are three unequal axes all intersecting at oblique angles.

《Cubic or Isometric system》

Some of the most - common minerals that crystallize in the cubic system are galena, garnet, fluorite & magnetite.

《Crystallographic axes》

Crystals of the cubic system are referred to three mutually perpendicular equal axes. These axes are interchange - able & are designated as a_1, a_2 & a_3.

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《Classes》

There are five classes in the cubic system of these the most important classes are

(i) Galena type (ii) pyrite type

(iii) Tetrahedrite type

《Galena type》 Imp

It is the normal class of the cubic system which possesses the highest degree of symmetry.

Symmetry → The symmetry elements of this class are as follows

planes 9 { 3 axial
6 diagonal

Axes 13 { 3 crystallographic axes of 4-fold symmetry
4 diagonal axes of 3-fold symmetry
6 diagonal axes of 2-fold symmetry

A centre of symmetry

i) «Cube (100)»

This form is composed of six square faces that make 90° angles with each other. Each face intersects one of the crystallographic axes and is parallel to the other two.

ii) « octahedron » (111)

octahedron is composed to eight equilateral triangular faces. Each face intersects the three crystallographic axes at equal lengths.

iii) « Dodecahedron » (110)

This form is composed of 12 rhomb shaped faces. Each face intersects the two crystallographic axes equally & is parallel to the third.

iv) « Trapezohedron » (hll)

This form is composed of 24 trapezium shape faces. Each face intersects one crystallographic axis at unit distance & the other two at equal multiples. The most common trapezohedron is (211).

v) « Tetrahexahedon » (hk0)

The tetrahexahedron is made up of 24 faces, each of which is an isosceles triangle. Each face intersects one axes at unity, the second axis at some multiple of unity & is parallel to the

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third. The most common tetrahexahedron is (210)

6) « Trisoctahedron » (hhl)

The form is composed of 24 triangular faces. Each face intersects two crystallographic axes at unity & the third at some multiple of it. The most common trisoctahedron is (221)

7) « Hexoctahedron » (hkl)

This form is made up of 48 triangular faces. Each face intersects ~~the crystallographic axes at unity~~ & all the three crystallographic axes at unequal distances. A common hexoctahedron is (321)

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Structural Geology

Dip & Strike — Imp

The beds of undisturbed sedimentary rock formations generally occur in horizontal deposition.

- During earth movements, the strata may be tilted out of the horizontal. Such inclined rock beds are said to have a 'dip'.
- The object of measuring dip & strike of rocks is to obtain information on their three dimension position.

Dip — Imp — Smart

The angle of inclination of a rock bed with the horizontal plane is called "Dip".

- It is measured in a plane perpendicular to strike.
- The dip angle is measured with clinometer & its direction is measured with a compass.

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True Dip

True Dip

Imp

The "true dip" is defined as the maximum angle of dip on a rock bed. It is measured in the direction at right angle to the strike.

Apparent Dip

Imp

A Dip measured in any other direction than the true dip, is called the apparent Dip.

An apparent Dip will always have a value less than the true dip.

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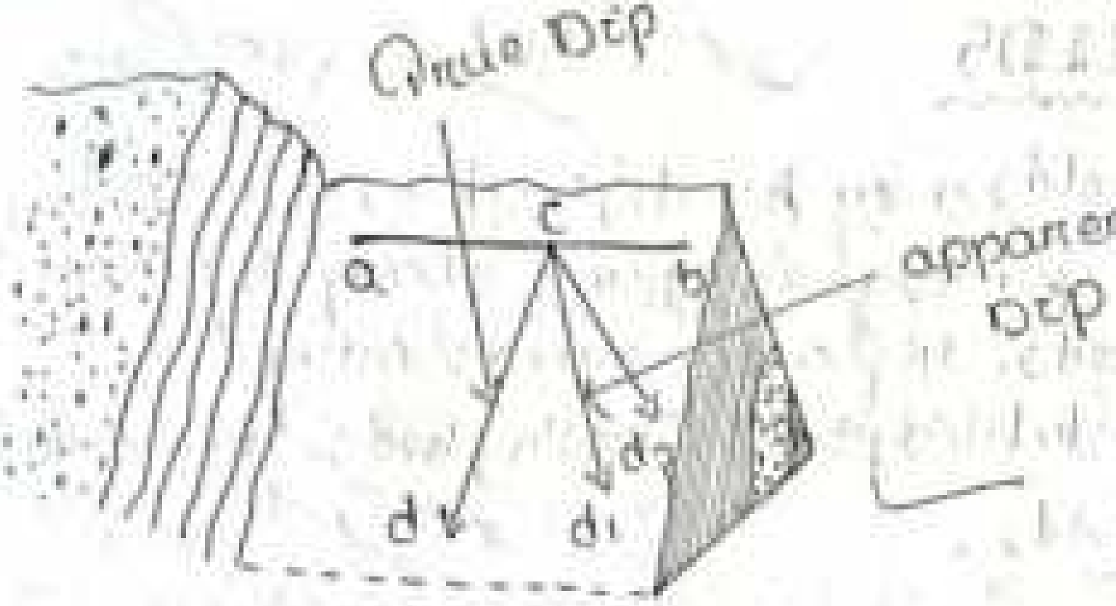

Strike Dip

The trend of a rock bed on the ground surface is called the strike.

→ The strike may be defined as the direction of a line formed by the intersection of bedding plane & horizontal plane.

→ The strike is always at right angle to the true dip direction.

→ Thus the strike is horizontal line on a surface of rock beds.

→ The direction of the strike is measured by compass with reference to the true north & south.

FOLDS — Imp — 16 mark

Folds may be defined as a curved or zig-zag structure shown by rock beds. In order words wavy undulations the rock beds are called folds.

- They consist of arches & troughs in alternat manner.
- They are displayed by the sediment any rocks.
- The size of folds vary greatly.

Elements of folds

Anticline & syncline

An "anticline" is an up-fold where the limbs dip away from the axis of fold on either side.

- A "syncline" is a down-fold where the limbs dip towards the axis of fold on either side.

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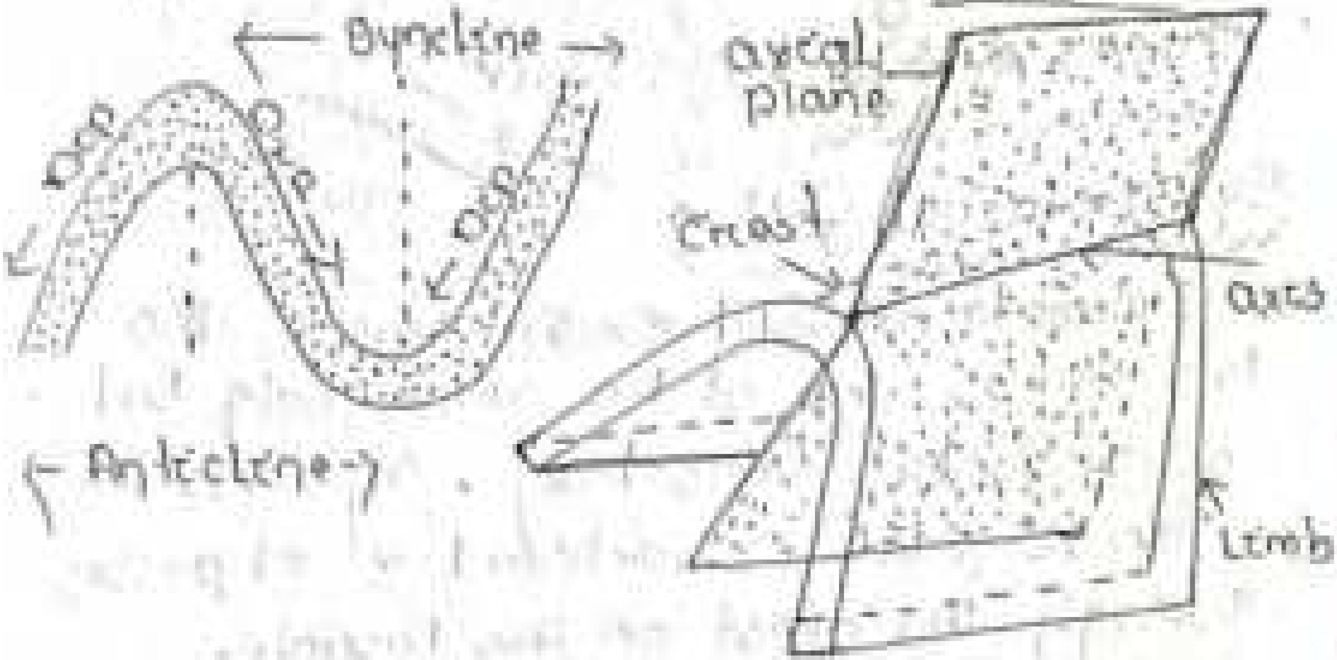
the highest point on the arch of an anticline is called the "crest" of the fold & the lowest point on the syncline is called the "trough".



Limbs

The sloping sides of fold from crest to trough are called the "Limbs".

Axial plane

The imaginary plane or surface which divides a fold into two equal halves.

Axial of fold

An axial of fold is defined as the line of intersection bet^n the axial plane & the surface of any of constituent rock bed.

plunge of fold

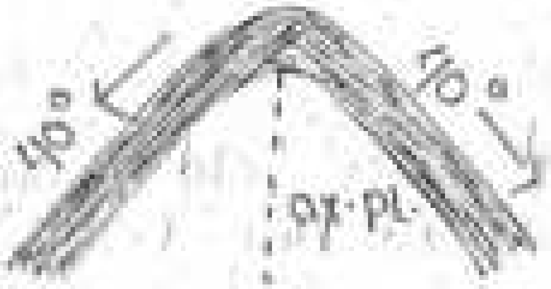
Folds having inclined axes are called plunging fold.

Types of Fld :

Imp to mark

Symmetrical fold →

A symmetrical fold is one where the two limbs dip at the same angle but in opposite direction. In case the axial plane is vertical & it passes through the crest or trough.



Asymmetrical fold

An "asymmetrical fold" is one where the limbs dip at unequal angles in opposite directions. In this case the axial plane is inclined & it not necessarily passes through the crest line.

Overturned Fold

It is an asymmetrical fold whose one limb is turned past the vertical. In this case the axial plane is inclined & both the limbs dip in the same direction. In the overturned fold the lower limb is turned upside down.

Recumbent Fold

In "recumbent folds" the folding is so intense that both the limbs become almost horizontal. In this case the axial plane also becomes nearly horizontal & the lower limb gets overturned. In recumbent folds fractures usually develop across bends to produce over thrusts.

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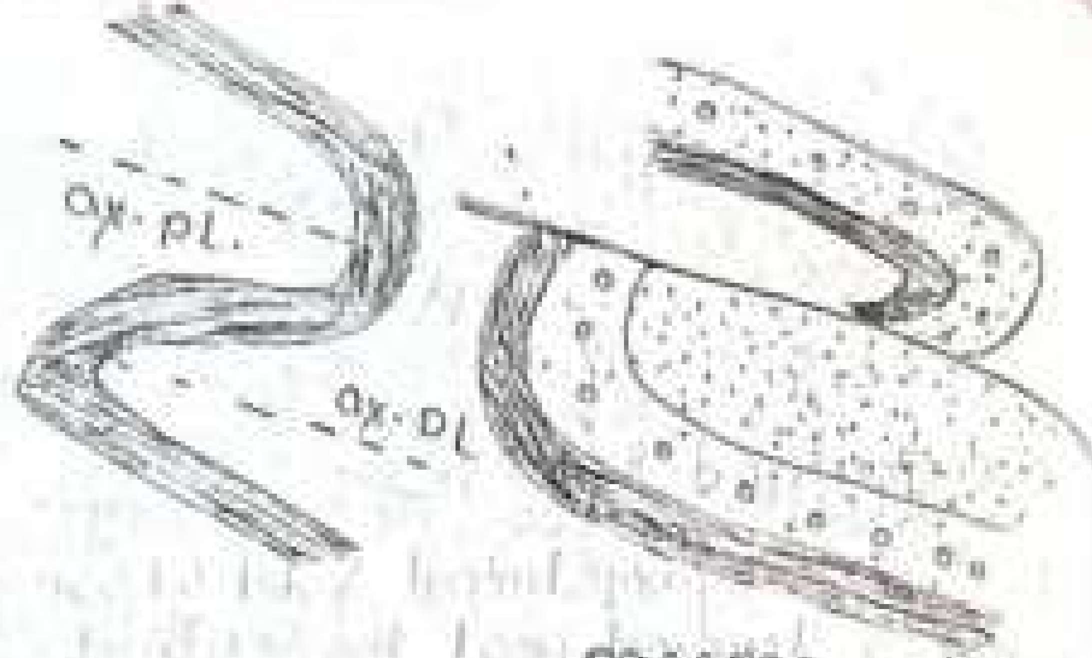
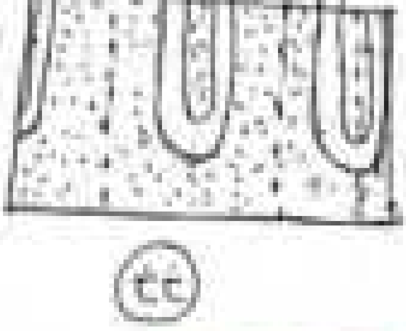


Isoclinal Fold

Folds that have parallel limbs are called "isoclinal folds". In this case limbs dip at the same angle & in the same direction. Isoclinal folds are of three types

(i) Inclined isoclinal folds
(ii) vertical isoclinal folds
(iii) recumbent isoclinal folds



(ii)

(i)

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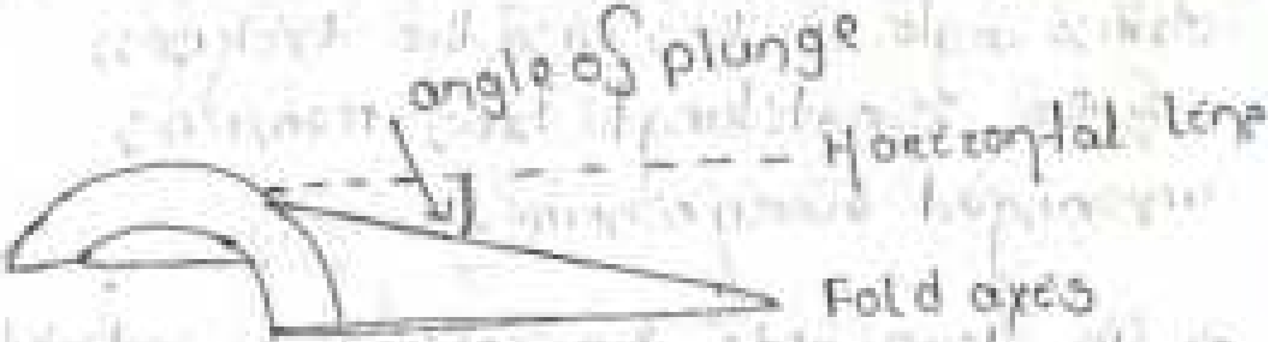
Nonplunging & plunging Folds (Imp)

The axes of fold may be horizontal or inclined. Anticlines & synclines whose axes are horizontal are said to be "nonplunging".

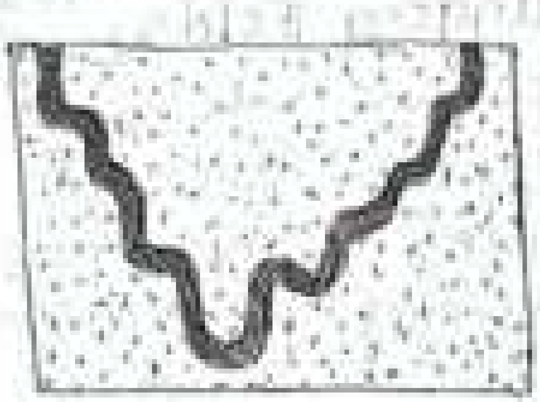
-) Folds having inclined axes are called the "plunging folds"

-) The angle of inclination of the axes measured from the horizontal is called the "angle of plunge".

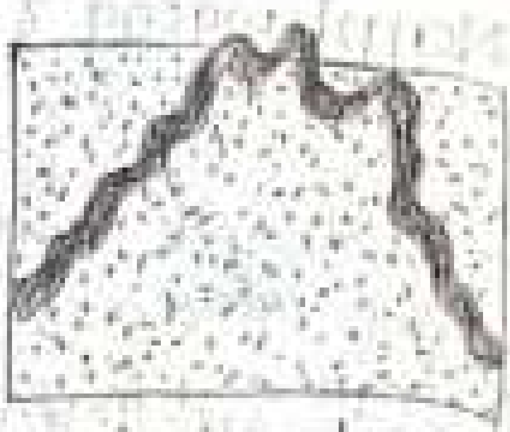


«Anticlinorium & synclinorium»

These are the complex large folds of general anticlinal & synclinal form. An "anticlinorium" is a large anticline with a no. of secondary folds of smaller size developed on it. A "synclinorium" is a large syncline of similar nature.



Synclenorceam



Anteclendreum

Open & close Folds

In "open folds" the folding is mild & therefore the limbs meet at bends at an obtuse angle. In this case the thickness of the constituent beds remains unchanged everywhere.

-> In "close folds" the folding is so tight that the incompetent strata flow plastically towards the crests & troughs. This causes thinning at the flanks & thickening at the crests. Thus close folds develop under great stresses.

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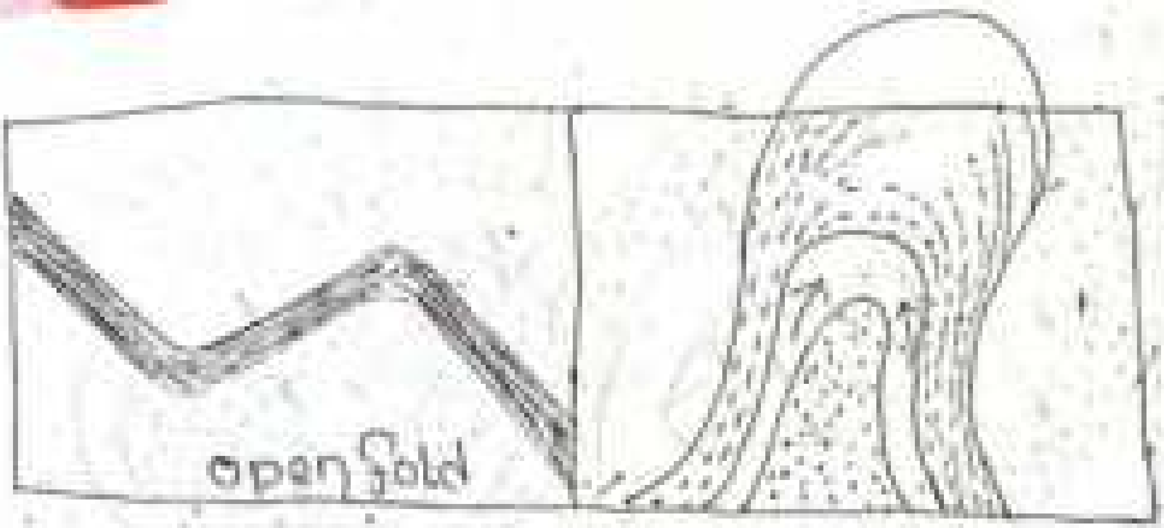

Close fold

Dome & Basin

when the strata have been subjected to folding in two direction at right angles. each anticline is converted into a dome & each syncline into a basin. these folds are about as wide as wide as they are long. Thus a "dome" may be defined as an upfold where the beds dip radically outward in all directions from the centre. In such a case the strata are said to have a quaquaversal dip. A basin may be defined a down-fold where the beds dip radically inward toward the centre.

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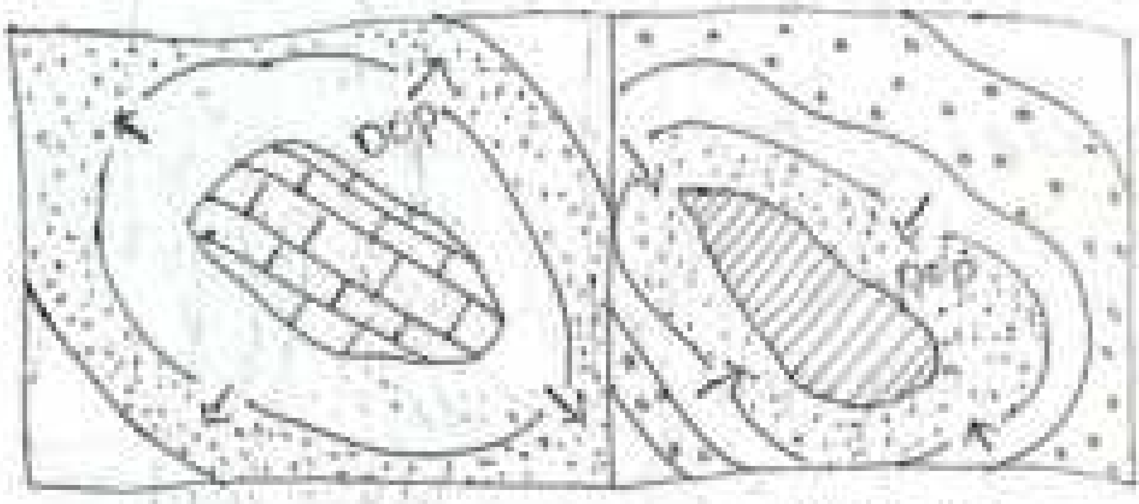
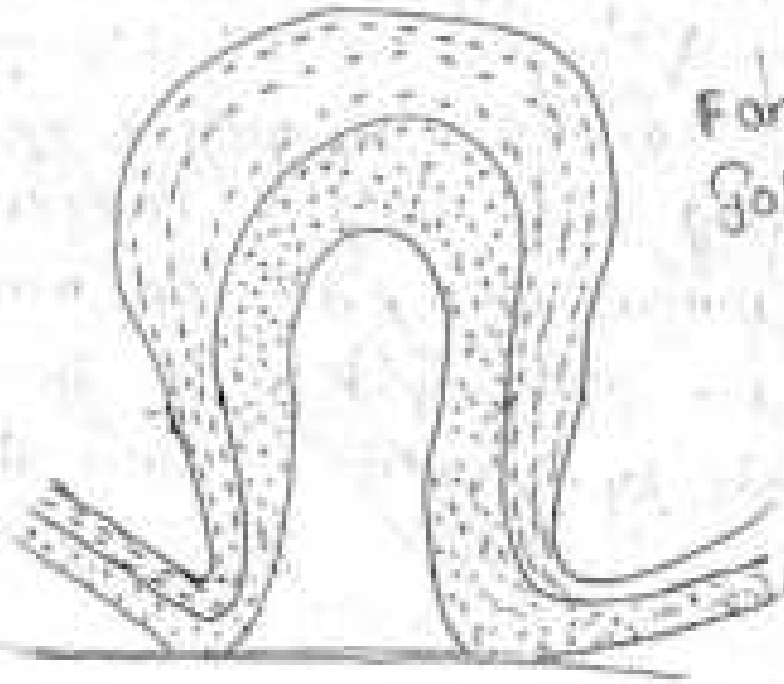


Dome Basin

Fan Folds

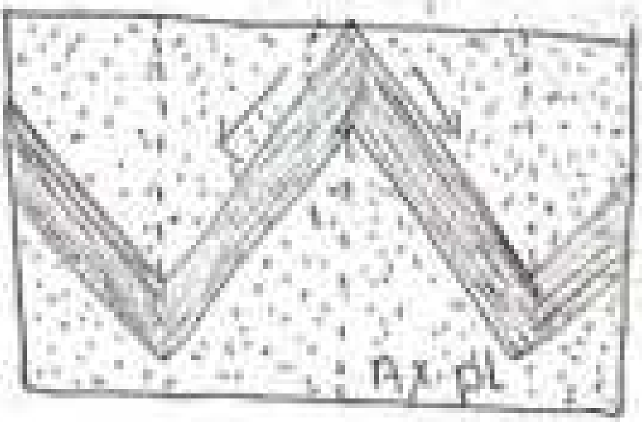
A "fan fold" is an upright fold in which both the limbs are overturned. In anticlines limbs dip towards the axial plane & in synclines they dip away from it.



Fan folds

chevron Fold

"The folds which have straight or nearly straight limbs, their crests to a troughs become sharp & angular such zig zag folds are called "chevron fold"



Homocline

when beds dip uniformly with the same angles & in the same direction for a distance of the order of a kilometer or more. the structure is called a "homocline".

monocline

A local warping in the horizontal strata is called the monocline.

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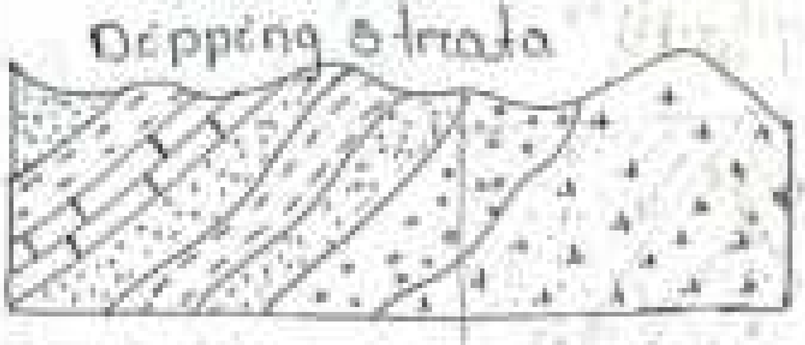
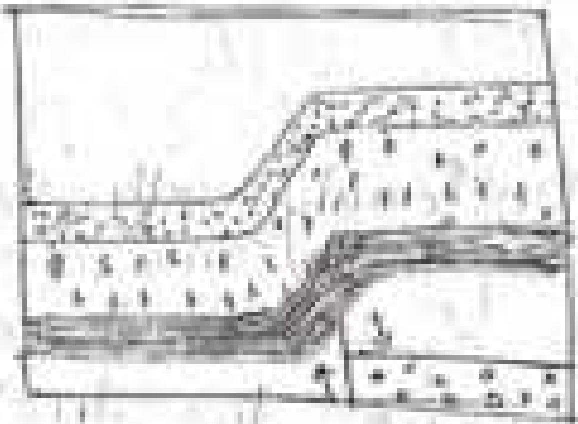
Structural terrace

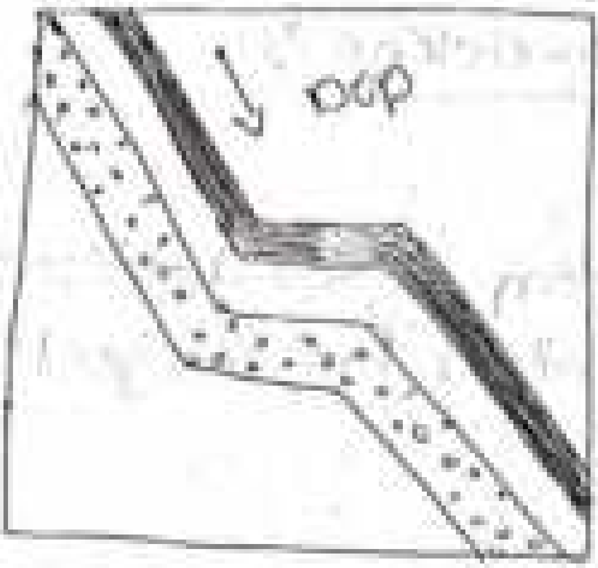
A local flattening in an otherwise uniformly dipping beds is called the "structural terrace".



ⓐ Homocline



ⓑ Monocline



ⓒ structural terrace

Drag Flds

The "drag folds" may be defined as minor folds developed within the body incompetent beds during the process of major folding.

FAULTS Imp Imp

A "fault" may be defined as a fracture along which blocks of rock have been displaced relative to each other. This planar discontinuity originates by tectonic force acting regionally. The displacement along a fault may be less than a meter, several hundred meters or many kilometers, faults result from tensional as well as compressional force.

Fault terminology

Fault plane

The fracture surface along which relative movement has taken place is called a "fault plane".

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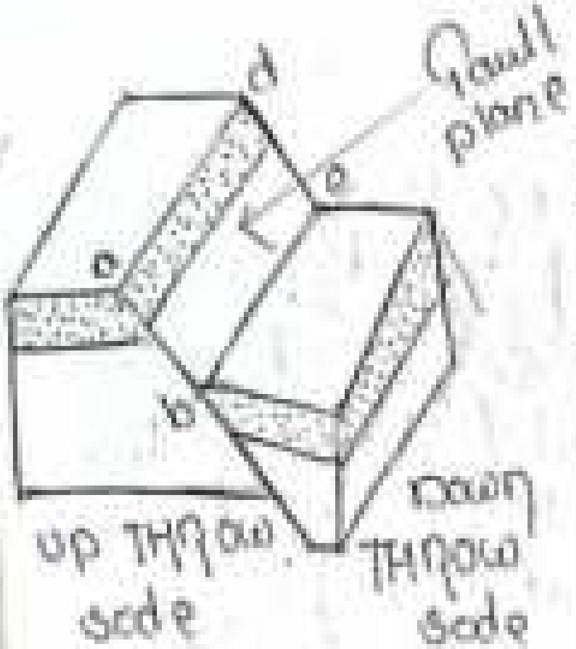

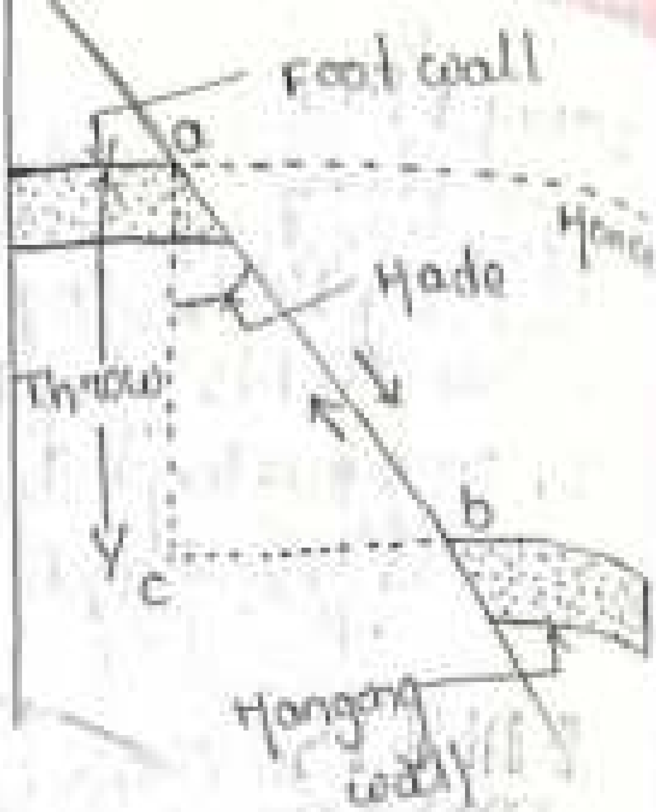

Hade

The 'hade' of a fault is the angle of inclination of fault plane measured from the vertical. It includes both the angle & the direction.

Dip

The dip is the angle the fault plane makes with a horizontal surface.

Thu

Strike

The strike of a fault is the direction of its continuity on the ground surface.

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Throw

The vertical component of the displace-
ment of fractured rock block is
called throw of fault.

Heave

The horizontal component of the
displacement of a fault is called the
"heave".

Net slip

The total displacement measured along
the fault plane is called the "net slip".

Strike slip & Dip slip

Dip slip is movement parallel to the
direction of dip of the fault plane. The
movement which is parallel to the strike
of the fault plane is called "strike slip".

Fault scarp

A fault scarp is the cliff formed
initially along the up-throw side
of a fault.

Hanging wall & Foot wall

If the fault plane is not vertical, the block of rock lying above it is known as the "hanging wall".

→ the block below the fault plane is known as the foot wall.

vertical fault have neither hanging wall nor footwall.

Fault zone

Most fault planes are associated with a zone of crushed or altered rock. This zone is called the "fault zone".

Classification of faults

Bedding fault

Imp 7 marks

A bedding fault is one which occurs along a contact bet^n beds of different or same Lithology. The bedding faults are difficult to recognize.

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Oblique fault

A fault which runs oblique to the strike & dip directions of strata is called the "oblique faults".

Parallel fault

A series of faults that have the same strike & dip are called the "parallel faults". Such faults run parallel to one another & all hade in the same direction with the same angle.

Peripheral fault

The curved faults which have nearly circular or arc-like outcrops on level surface, are called "peripheral faults".

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Unconformities — Imp!

when the sedementary rock beds are found to have been deposited without in-terruption they are said to be "conformable".

- Unconformeties are formed when there is break in sedementation. This creates a gap in the geological record.

Unconformeties

Major breaks in sedementation are called unconformeties.

Types of Unconformeties | Imp

Unconformeties are three types

(i) angular unconformeties
(ii) disconformity
(iii) non conformety

Angular unconformety

The rock beds on opposite sides of an angular unconformety are not parallel.

The angular unconformeties occur where

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the older series of beds have been tilted, deformed & eroded before the deposition of younger beds.

Disconformity

The rock beds on a opposite sides of beds on opposite sides of a disconformity are parallel.

Disconformity occur where the strata of the older series have not been tilted or deformed in any way before the younger rock beds were deposited above them.

Nonconformity

when bedded sedimentary rocks overlie the non-bedded igneous mass, the structure is called the nonconformity.

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JOINTS

Diff. bet. joints & faults (comm.)

Joints - A fracture in a rock where no observable amount of displacement occur is known as joint.

* Joints are formed due to →
(i) Shrinking caused by cooling & desiccation of rock body
(2) Drying
(3) Contraction
(4) Compressive forces due to earth movement
(5) Fluid injection

→ Different from fault, there is no dislocation of blocks.
→ Found in all types of rocks
→ Joints surface may be
(i) curve (ii) planner (iii) smooth
(4) jagged (5) striated

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joint terminology

joint set

A group of parallel joints of common origin is called joint set.

joint system

Two are more jointset consist a joint pattern is know as joint system.

Trace of joint

The part of joint plane which is exposed over the surface is called as trace of joint.

- joint may be open are closed
- joint can run in 1. vertical
  2. horizontal
  3. inclined direction

- joint may be filled with quartz, calcite, dolomite, clay, etc.

- joint space varies widely from few cm to several meters.

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Classification of joints: Imp 10 marks

classification according to their attitude & geometry

-> strike joint (s)
strike of joint parallel to strike of rock bed.

-> Dip joint (d)
strike of joint parallel to dip of the country rock

Geometry

-> oblique / diagonal joint (o)
joints that strike at an angle to the direction of dip & strikes of rock bed

-> Bedding joints (b)
joints parallel to the bedding of associated rock

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Strike joints

The joints which are parallel to the strike of the rock.

Dip joints

The joints which are parallel to the dip of the rock.

Oblique joints

Joints which are neither parallel to the strike nor to the dip of the layer in which they occur.

Bedding joints

In stratified rocks some joints may develop essentially parallel to the bedding plane. These are called bedding joints.

Genetic

Two type of joints are recognised

(a) tension joints

(b) shear joints

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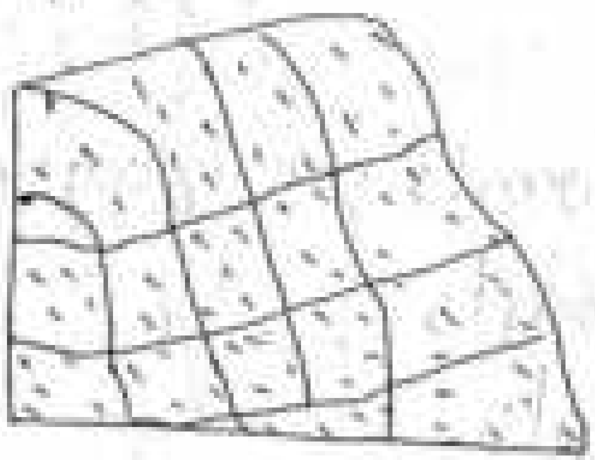
Tension joint in Igneous Rock

Mural joints

- As cooling & solidification progress, magma or lava become rigid & ultimately rupture & crack occurs
- This system is typical in granite
- Mural joints consists of 3 almost equally spaced mutually perpendicular joint, bisecting the rock mass into cubical block.

Significance

- Easy identification of mural joint by looking cubical block
- Joint plane allow natural weathering



Mural joints in granite

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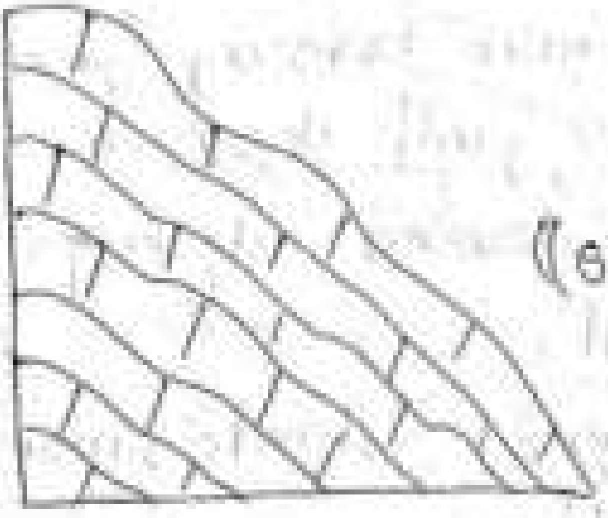
2- sheet joint

- typical of granite & other plutonic rock
- consists of one set prominent joint parallel to the ground surface
- Bisect rock mass into sheet like blocks.
- Lens like form due to pinch & swelling
- due to layering rocks are thinner near the surface & thicker at depth.



(sheet joint in granite)

3- columnare joint

- typical of basalt & other volcanic igneous rock consists of both horizontal & vertical cross joints

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-) Devide the whole in to polygon, hexagon, prismatic column.

-) formed by cooling of horizontal flow of lava due in development of weak plane by radeus contraction

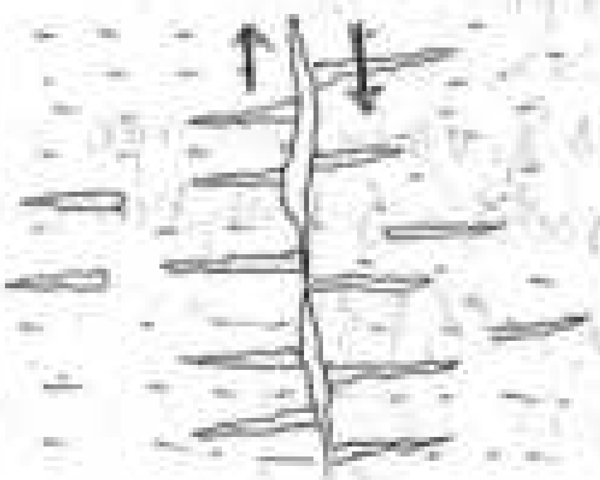
-) In form of dyke, sill, lava flow on dyke

4- feather joint

-) feather joints are tension fracture formed due to fault displace.

-) they commonly develop adjacent to major fault

-) the feather joint indicate a movement of any fault.



feather joint on faults

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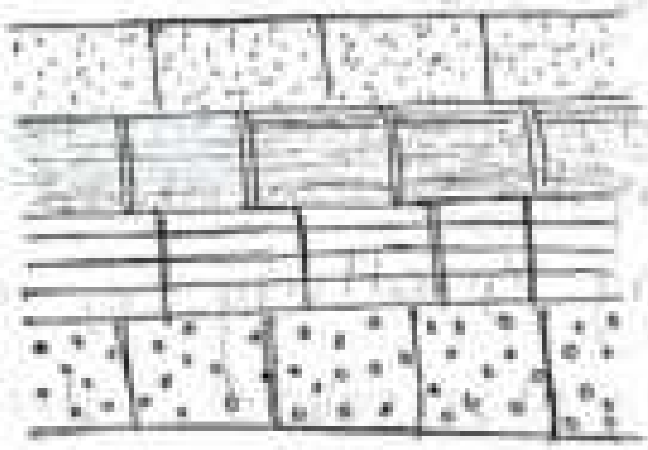
Reason joint in sedimentary rock

- As sediments become more & more consolidated, it compressed & occupy less volume so pressure increases & finally ruptured
- joint set produces right angle to each other.

1- Master joints

- Typically sandstone - limestone & consist of a set mutually perpendicular joints
- persist of long distance with regularly spacing & width, it is called master joint
- In shale this joint is very close.

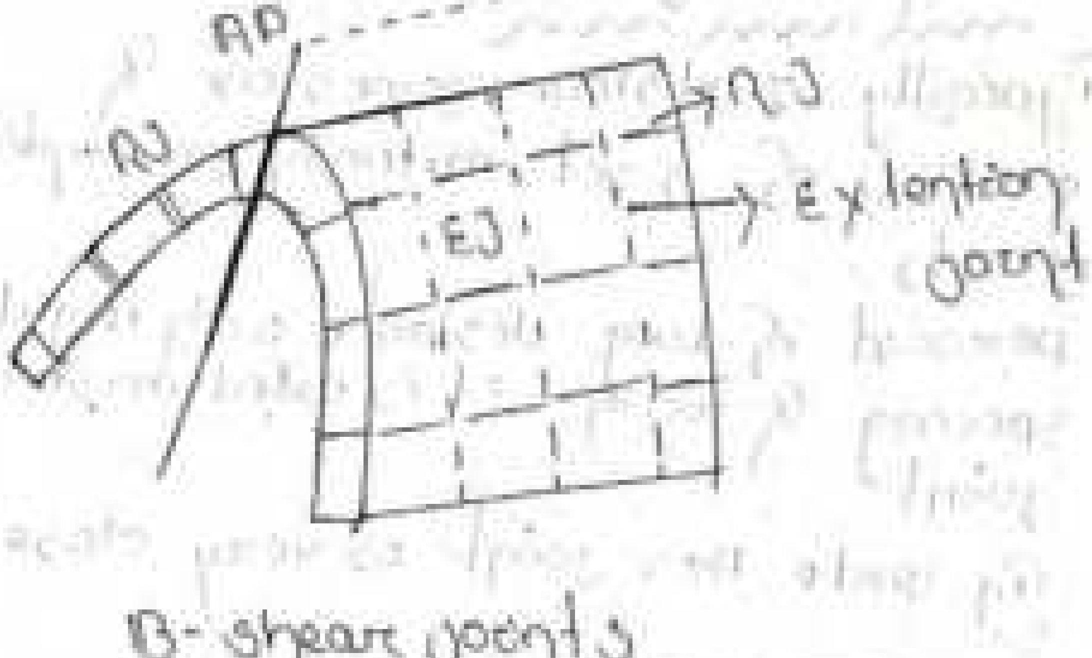


Master joints in sedimentary rocks

Extension & Release joints

-> In folded strata tension joints are in crestal region either parallel or perpendicular to axial plane

-> parallel to axial plane is release joints perpendicular to axial plane is extension joint



B- Shear joints

-> These joints are formed due to compressional force involved in the folding faulting of rocks

-> These joints also called diagonal joints

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→ It also contain
  → strike joints
  → dip joint
  → diagonal joints
  → conjugate joints system

→ Shear joints occur in two sets which intersect at a high angle to form a conjugate joint system.

Significance

→ Influences blasting & quarrying
→ Rocks are unstable & weak.
→ controls ground water drainage system
→ Exploration of water well sites.

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