Structure of Earth

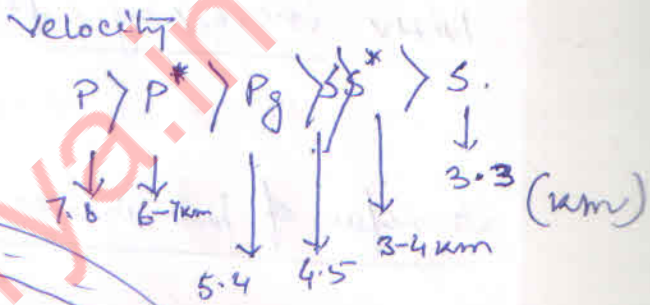
Temperature – Increases from the surface of the earth downward at rate of 2° to 3°c for 100 meters. Most part of the radio active minerals are concentrated in the uppermost layer of the earth, disintegration and decay of radio active materials generate more heat in crustal areas. Thus the rate of increase in temp downwards decreases with increasing depth.

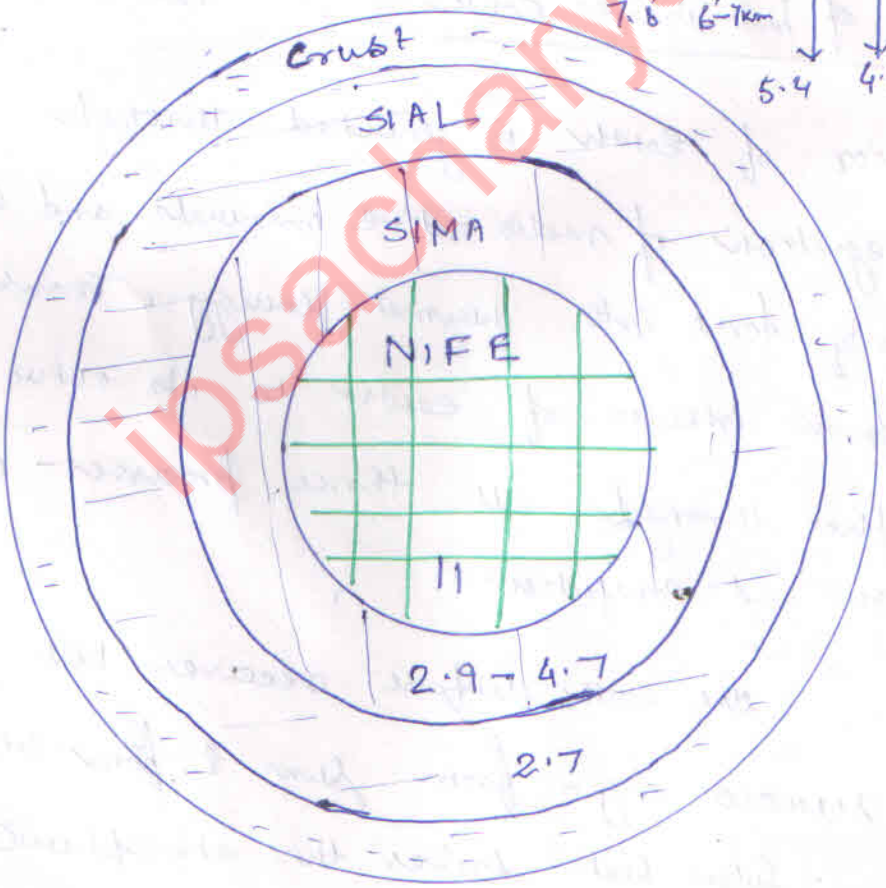
Transfer of heat inside Earth :- Heat inside the interior of Earth is generated through the disintegration of radio active minerals and conversion of gravity force into thermal energy. Transfer of heat from interior of earth to its outer part takes place through all three processes – conduction, radiation and convection.

The earth surface receives heat from two sources e.g – from sun & from interior part. Solar heat drives the atmospheric and hydrological processes and generate denudational

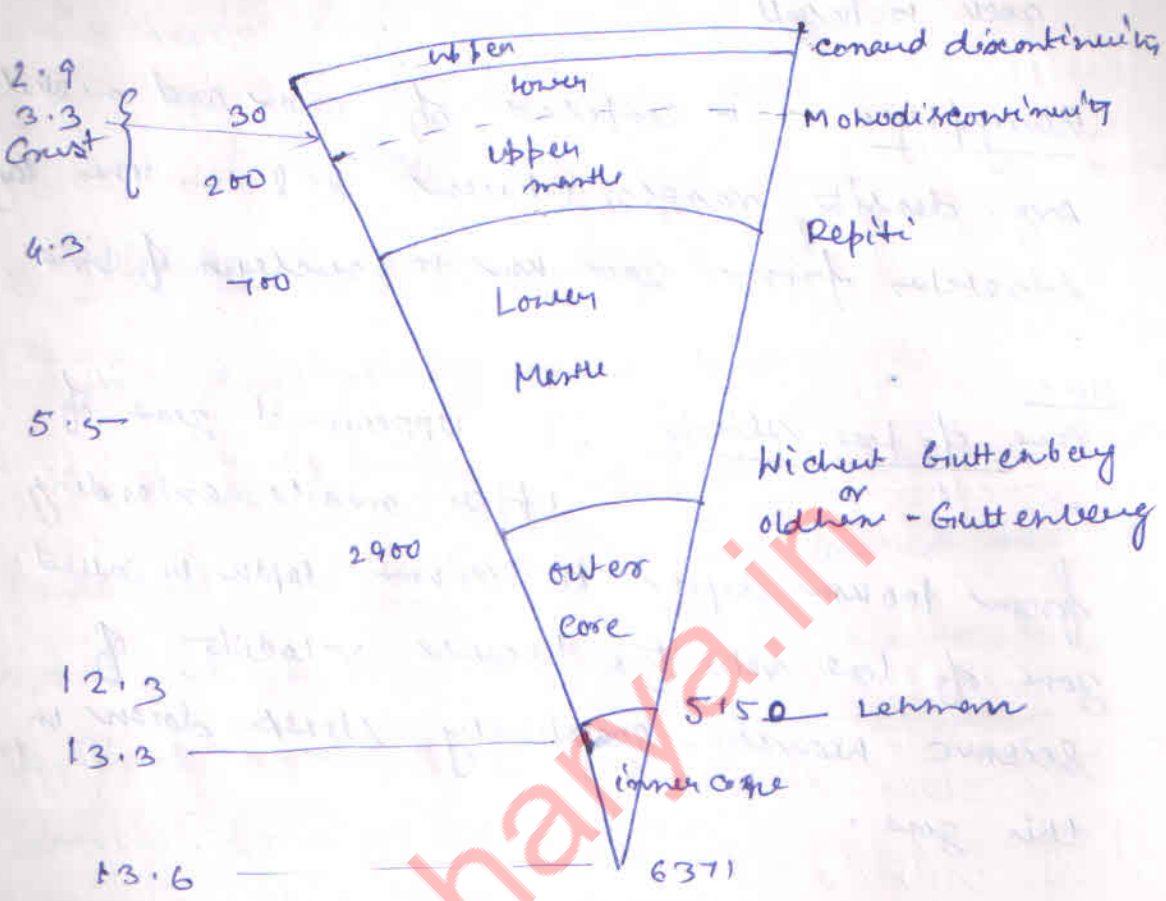
processes whereas the internal heat of the earth performs constructive works e.g - formation of mountain, plateau etc, volcanicity, seismic events and other tectonic events. In a real sense, the earth's internal heat engine builds mountains and its external heat engine, the sun, destroys them (F. Press and R Siever)

E. Suess





Conrad discontinuity — between oceanic and continental crust, velocity of P waves suddenly increases at lower Crust / after passing this discontinuity.



Diagramatic presentation of different zones of Earth on basis of International Union of Geodesy and Geophysics

General pattern

Lithosphere - With a thickness of about 100 km is mostly composed of granites. Silica and aluminium are dominant constituents. Avg. density is 3.5.

Pyrosphere - stretches for a thickness of 2780 km having avg. density of 5.6. Dominant rock is basalt.

Barysphere - is composed of iron and nickel. Avg. density ranges between 8 & 11. This layer stretches from 2800 km to nucleus of core.

Note

Zone of low velocity :- Uppermost zone of upper mantle extending from 100 km depth to 200 km depth is called zone of low velocity, because velocity of seismic waves relatively slows down in this zone.

Continents and ocean basin

Continental Drift theory by Taylor :-

F. B. Taylor postulated a horizontal displacement of the continents' in 1908.

↓

or (Drift or displacement theory)

Acc to him during cretaceous Laurasia & Gondwanaland were located near the north and south folls respectively. Acc to him Continents moved toward equator. The main driving force – tidal force.

i) equatorward movement

ii) Westward " , but the driving force responsible for both types of movement was tidal force of moon.

Consequently Baffin Bay, Labrador sea, Davis Strait were formed near north pole.

displacement of Gondwanaland from the South fell towards the equator caused splitting and disruption & Australian Bight, Ross Sea was formed.

Taylor assumed that landmasses began to move in lobe form while drifting through the zones of lesser resistance. Thus, mountains and island arcs were formed in the frontal part of moving lobes.

Criticism :- i) For mountain formation, displacement of land masses upto 32-64 km is sufficient. Contrary to this Taylor has described the displacement for thousands of kms.

ii) The mode of drift as suggested by Taylor as tidal force of moon is so enormous that it could displace the landmasses for thousands of kms, then it might have also put a break on the rotatory motion of the earth and thus the rotation of the earth might have been stopped.

But Taylor raised his voice against concept of permanency of continents & ocean basins.

Wegener

assumed all landmasses were united together in the form of one landmass - pangaea in carboniferous, surrounded by panthalasa.

Laurasia - present North America, Europe & Asia formed northern part of the pangaea while Gondwanaland - South America, Africa, peninsular India, Australia & Antartica. South pole was located near present Durban (near Natal in Southern Africa) during carboniferous.

Thus wegener does not describe the conditions during pre-carboniferous times.

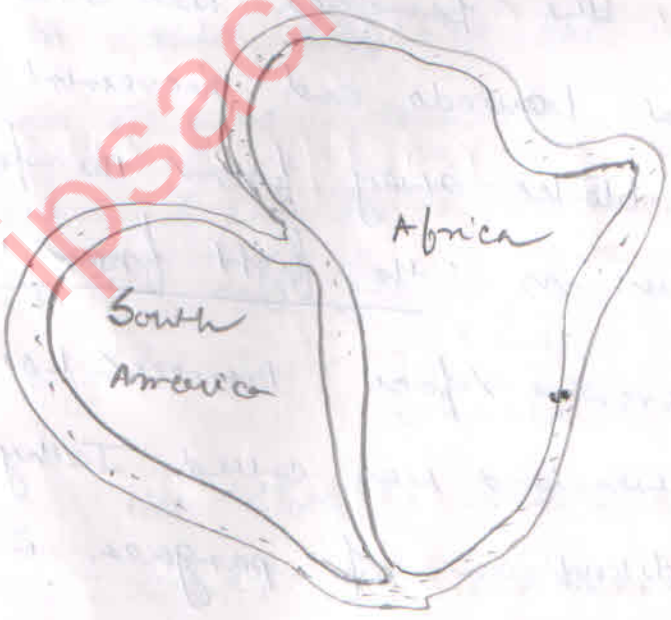
The pangaea was disrupted during subsequent periods and movement of the continental blocks away from the poles called by Wegener as 'the flight from the poles'.

The intervening space between Laurasia (Angaraland) and Gondwanaland was called Tethys sea. This phase of disruption of pangaea is called opening of tethys. The disruption, rifting and displacement of continental blocks continued

from carboniferous to pliocene, when the present pattern & arrangement of continents and ocean basin was attained.

Evidences in Support of Wegener

i) Acc to Wegener all the present day continents could be joined to form Pangaea. Both the opposing coasts of Atlantic can be fitted together in the same way as two cut-off pieces of wood can be refitted.



Jig-saw-fitting (Juxtaposition) of South America & Africa.

2) Geological evidences denote that the Caledonian and Hercynian mountain systems of the western and eastern coastal areas of Atlantic are similar.

The appalachians of the north-eastern region of North America are compatible with the mountain systems of Ireland, Wales and north western Europe.

3) Du Toit, after detailed study of eastern coasts of South America and western coast of Africa has said that the geological structure of both the coasts are more or less similar.

4) There is marked similarity in the fossils and vegetation remains found on eastern coast of South America and western coast of Africa.

5) Geodetic evidences showed that Greenland is drifting westward at the rate of 20 cm per year.

6) The distribution of glossopteris flora in India, South Africa, Australia, Antarctica, Falkland Islands etc proves the fact that all the landmasses were previously united.

7) The lemings (small sized animals) of the northern part of Scandinavia have a tendency to run westward & drowned in Atlantic. This behaviour of lemings proves the fact that the land masses were united in the ancient times and the animals used to migrate to far off places in western direction.

8) The evidences of carboniferous glaciation of Brazil, Falkland, South Africa, peninsular India, Australia and Antartica further prove the unification of all landmasses in one landmass (Pangaea) during carboniferous.

Forces Responsible for the Drift

Ace to Wegener continents moved in two direction — i) equatorward movement
ii) westward movement

The equatorward movement was caused by gravitational differential force and force of buoyancy. As lighter sialic materials were floating on relatively denser sima,

Equator and movement of Sialic blocks would depend on the relation of centre of gravity & centre of buoyancy of floating continental mass.

The westward movement of the continents was caused by the tidal force of the Sun and the moon, which was maximum when the moon was nearest to earth.

Origin of Mountains & island arcs

Acc to Wegener, the frontal edges of westward drifting continental blocks of North & South America were folded against the resistance of the rocks of the sea floor and thus the western cordilleras (Rockies & Andes) were formed. Similarly, the Alpine ranges of Eurasia were folded due to equatorward movement of Eurasia & Africa.

When the asiatic block was moving westward, the eastern margin of could not keep pace, consequently island arcs were formed consisting of Sakhalin, Kurile, Japan, Philippines etc. Similarly some portions of North & South America, left behind to form island arcs of West Indies & Southern Antilles.

Criticism of Wegener

1) Acc to Morgan and Wooldridge, the tidal force as invoked by Wegener need to be 10,000 million times as powerful as it is at present to produce the required drift of Continents. If it had such a value, it would have stop Earth's rotation completely in a year.

Similarly, the differential gravitational force & force of buoyancy are also not adequate to cause equatorward movement of Continents. Instead the force, if so enormous might have caused the concentration of Continents near equator.

2) Though Wegener initially consider Sialic mass, freely floating over 'Sima', but later he described forceful resistance offered by 'Sima' to explain the origin of mountains along frontal edges of floating Continents. Acc to J. A. Steers, it is difficult to show how the sial blocks, on their passage through Sima, would crumple at their frontal edges and produce mountains.

3) Both the coasts of the Atlantic Ocean cannot be completely refitted. Thus the concept of juxtaposition or jig saw fit can not be validated.

4) Wegener has not elaborated the direction and chronological sequence of the displacement of the continents. He did not describe the situation of pre carboniferous times.

PLATE TECHTONIC

The rigid lithospheric slabs or rigid and solid crustal layers are technically called 'plates' (J. T. Wilson, 1965). The whole mechanism of the evolution, nature and motion of plates and resulted reactions is called plate techtonics

This theory is based on —

1) Concept of continental drift.
2) " " sea floor spreading.

6 major & 20 minor plates.

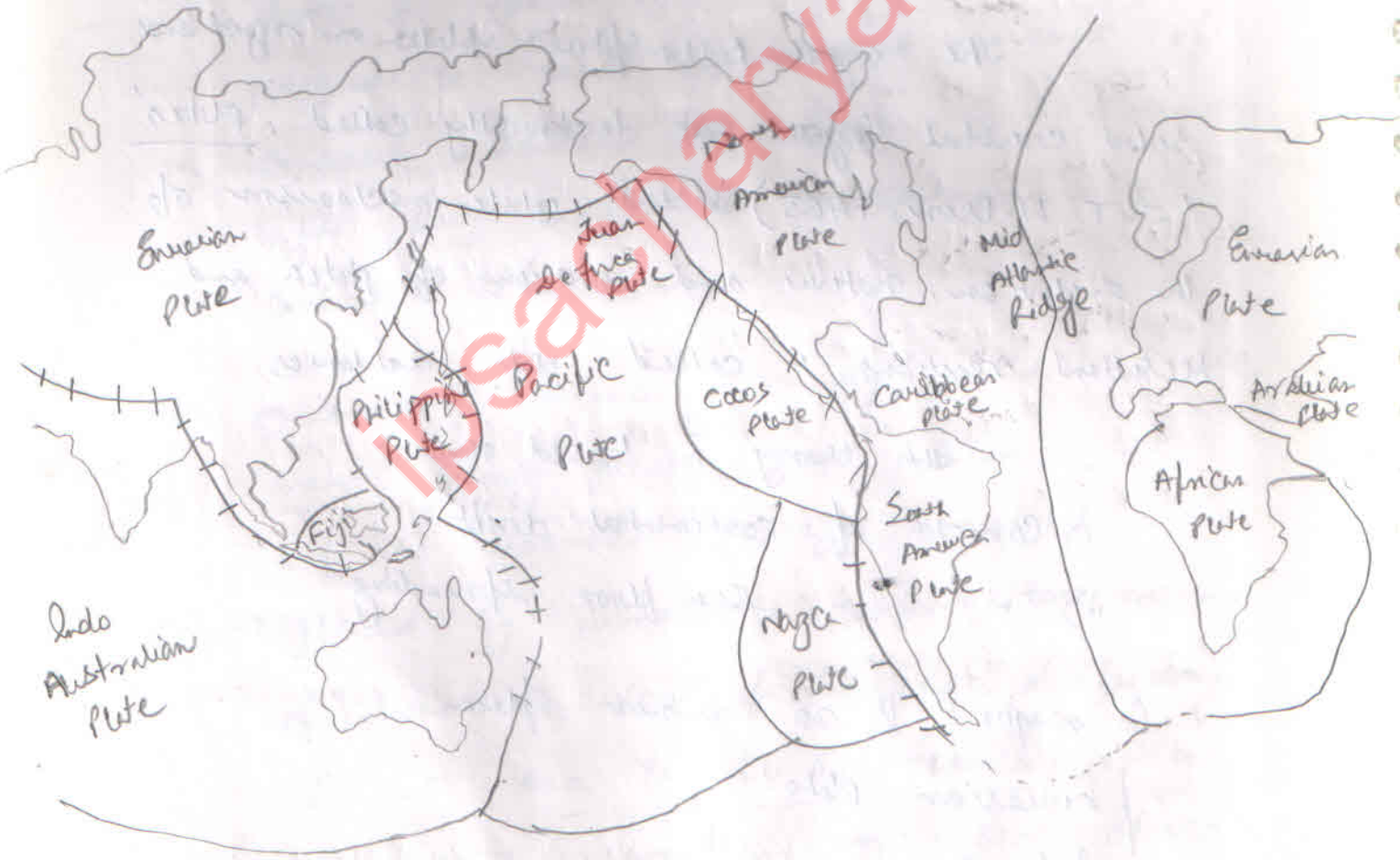
- Eurasian plate
- Indo-Australian "
- American plate "
- pacific "
- African "

first write

McKenzie and Parker (1967). based on Euler's Geometrical theorem, postulated a paving stone hypothesis wherein the oceanic crust was considered to be newly formed at mid oceanic ridges.

Isacks and Sykes confirmed this hypothesis.

(2nd)* W.J. Morgan and Le Pichon elaborated the various aspects of plate tectonics in 1968.

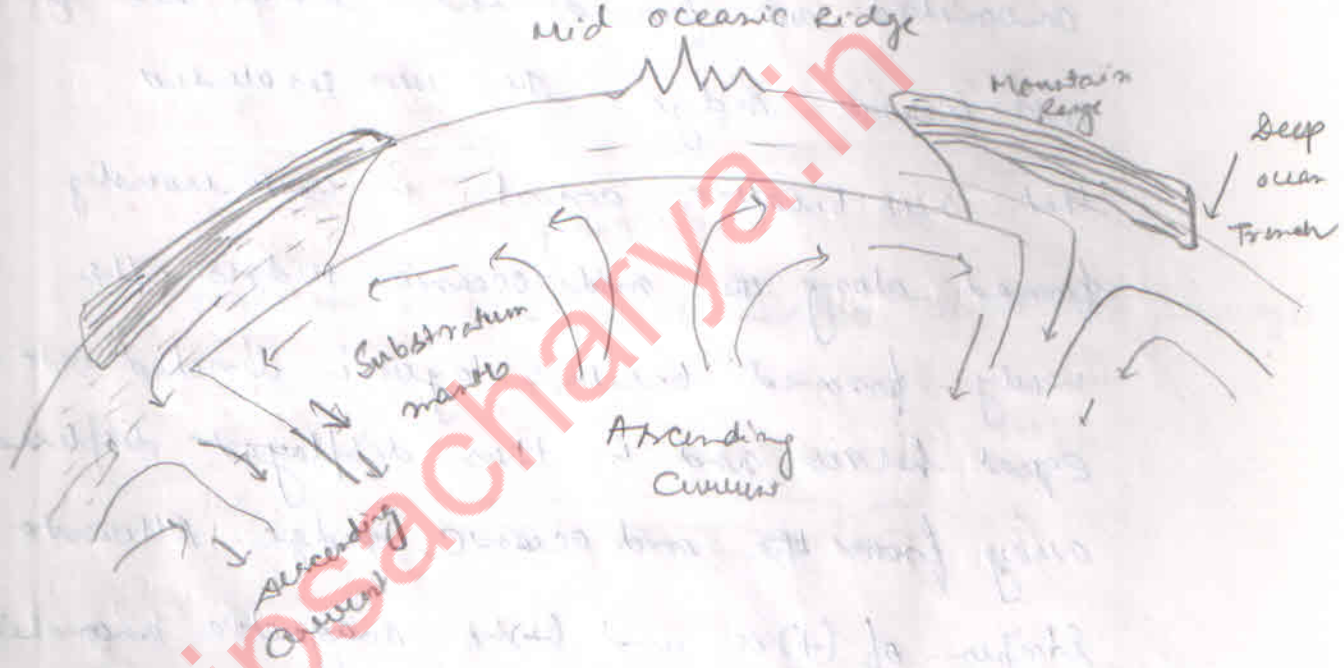


+++ convergent boundary

— divergent "

- Constructive / divergent / accelerating plate margins
- Destructive / consuming / convergent " "
- Conservative / Transform plate " "

Plate tectonic theory is based on the evidences of 1) Sea floor Spreading ⟹ Alok's Note
2) Paleomagnetism.



Paleomagnetism & Geomagnetic Reversal

W.G. Vine and Matthews conducted the magnetic survey of the central part of Carlsberg Ridge in Indian ocean in 1963 and compared the magnetic profiles on the basis of ground magnetism.

due to them, when molten hot lavas come up with the rising thermal convection current along mid-oceanic ridges and get cooled and solidified, these (lavas) also got magnetized according to the geomagnetic polarity of that time. thus alternate band or stripes of magnetic anomalies are formed on either side of mid-oceanic ridge. It was concluded that new basaltic crust is continuously formed along the mid-oceanic ridges. The newly formed basaltic layer is divided into two equal halves and is thus ~~displayed~~ displaced away from the mid oceanic ridge. Alternate stripes of (+)ve and (−)ve magnetic anomalies are found on either side of ridges. Such magnetic anomalies are formed because of temporal reversal in geomagnetic field.

The rate of sea floor spreading is calculated on two bases -

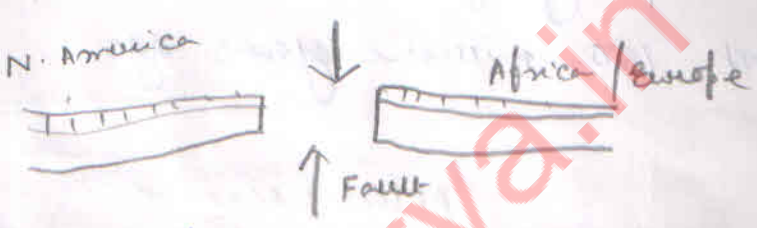
e.g i) ~~one~~ on the basis of the age of isochrons.

(*) **ISOCHRONS** — are those lines which join the points of equal dates of the magnetic stripes plotted on the map.

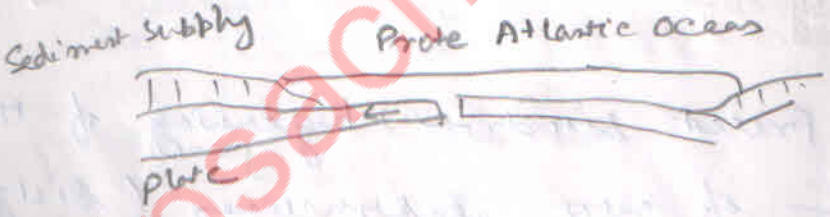
It's on basis of distance between two isochrons.

Evolution history of Atlantic ocean

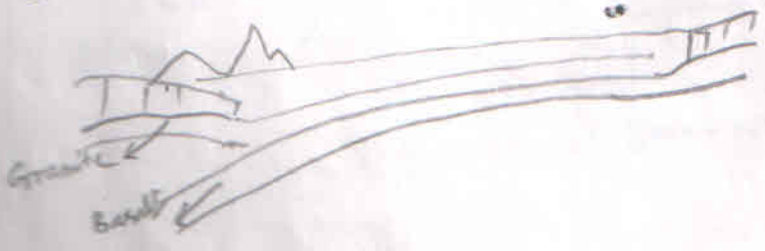
(for the past 700 million years)



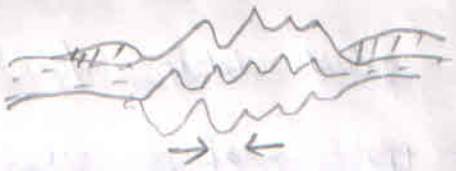
① Formation of new ocean basins 700 million years ago



② Deposition of miogeocline and eugeocline on the margins about 500 million years ago

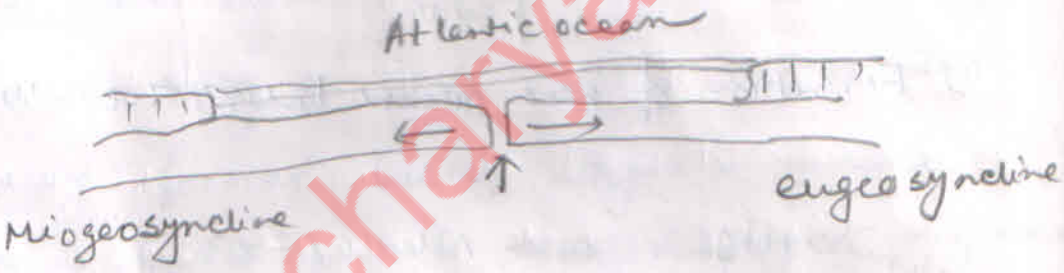


③ Closing of the Atlantic ocean and formation of part of the Applachians due to convergence of Eurasian & American plate 400 million years ago.



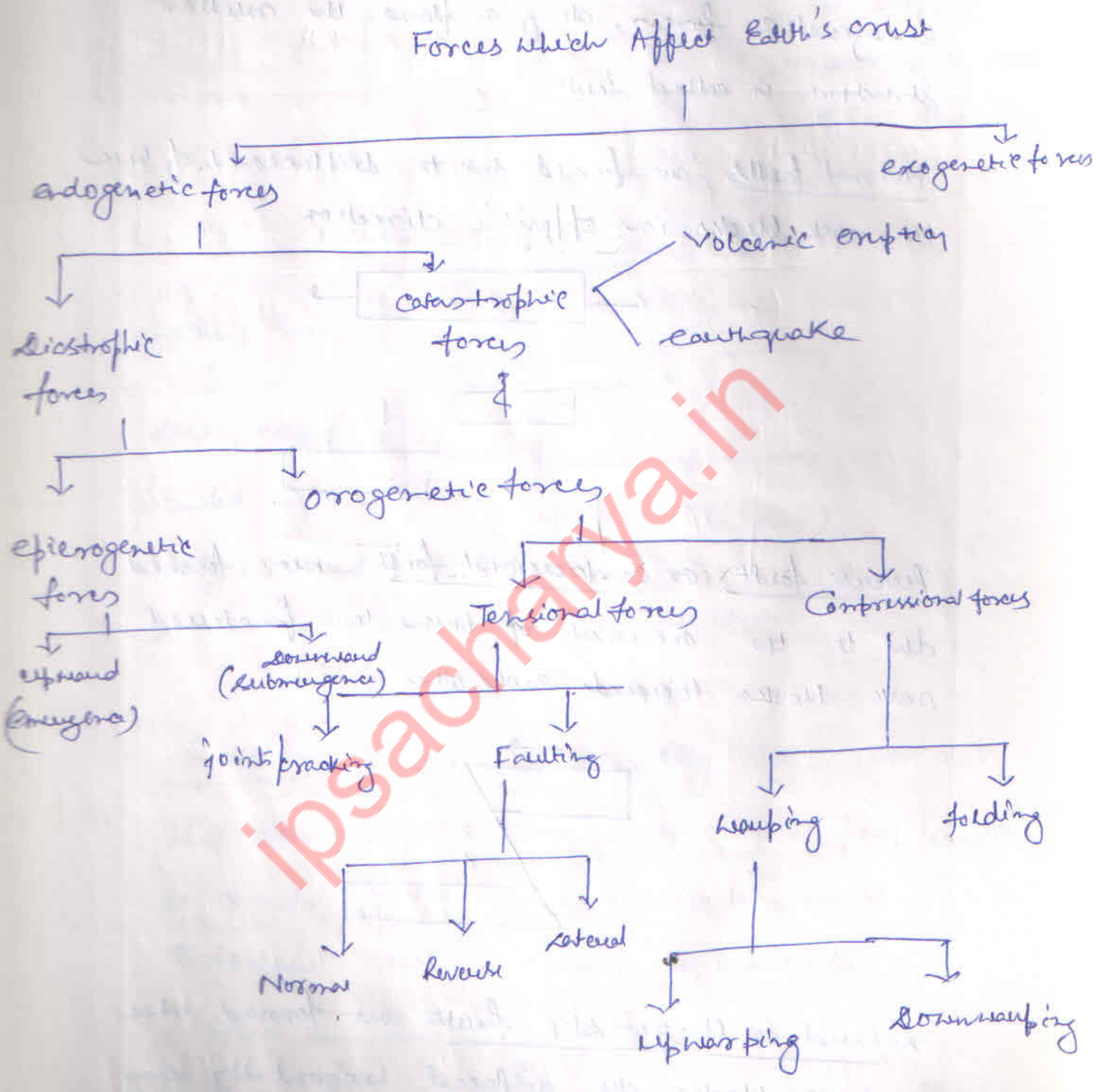
(4) Atlantic closed completely and the formation of Applachians of North America and Hercynian mountains of Europe was completed 300 million years ago

(3) Reopening of Atlantic due to plate motion about 150 million years ago



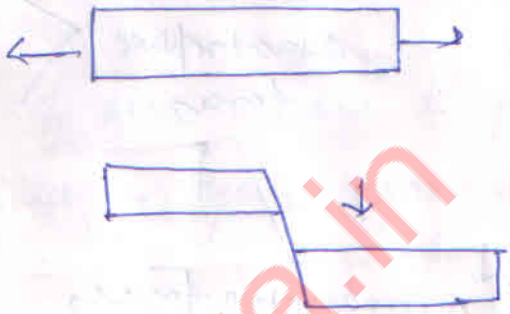
(6) Present situation, beginning of the formation of new geosynclines (Dietz, 1973)

EARTH'S MOVEMENT

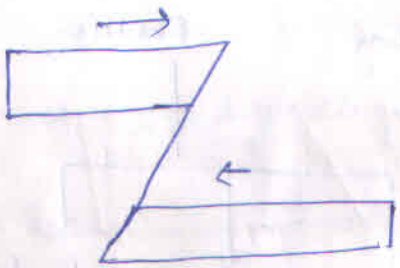


Fault – When the crustal rocks are displaced due to tensional movement caused by endogenetic forces, along a plane the resultant structure is called fault.

Normal faults are formed due to displacement of both the rock blocks in opposite direction



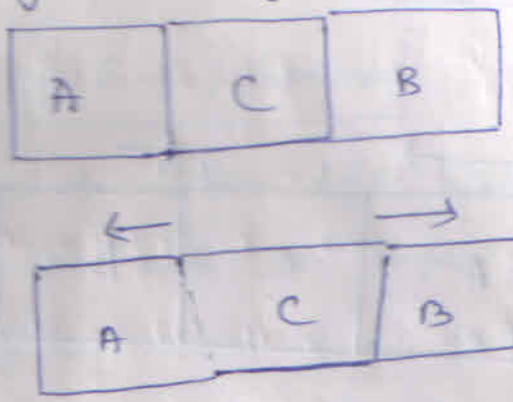
Reverse fault or compressional fault are formed due to the movement of both the fractured rock blocks towards each other.



Lateral or strike-slip faults are formed when the rock blocks are displaced horizontally along the fault plane due to horizontal movements.

Origin of Rift valleys

① Tensional hypothesis / Keystone hypothesis based on the 'dropped keystone of the arch' of a building

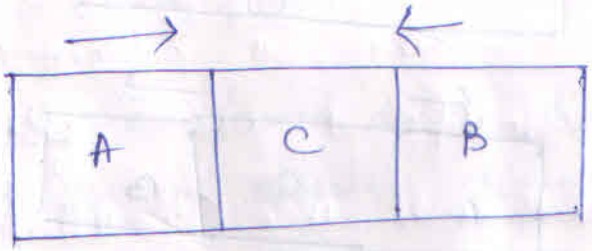


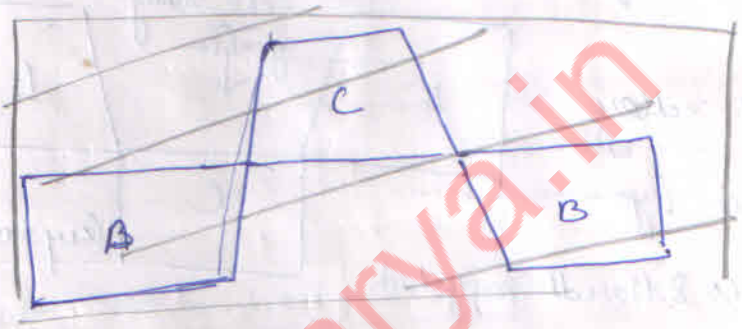
eg
~~Eg Rift valley~~
↓
Rhine valley
bounded by
Vosges & Haardt mountain
at one side and Black forest at other

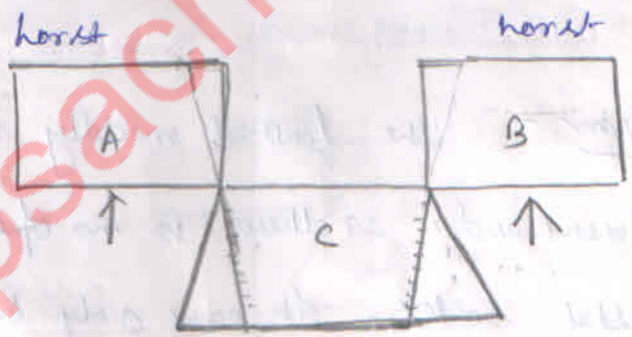
Criticism - The faulted middly block can not sleep downward, as there is no open space beneath the crustal rocks. It can only be slipped downward when it would be able to displace the magma lying below the crustal blocks. If this process is accepted, then formation of rift valley must be followed by volcanic activities, but it was observed that rift valley formation is not necessarily always associated with volcanic eruptions.

(2) Compressional hypothesis

by Wayland, Baily, D. Smith.





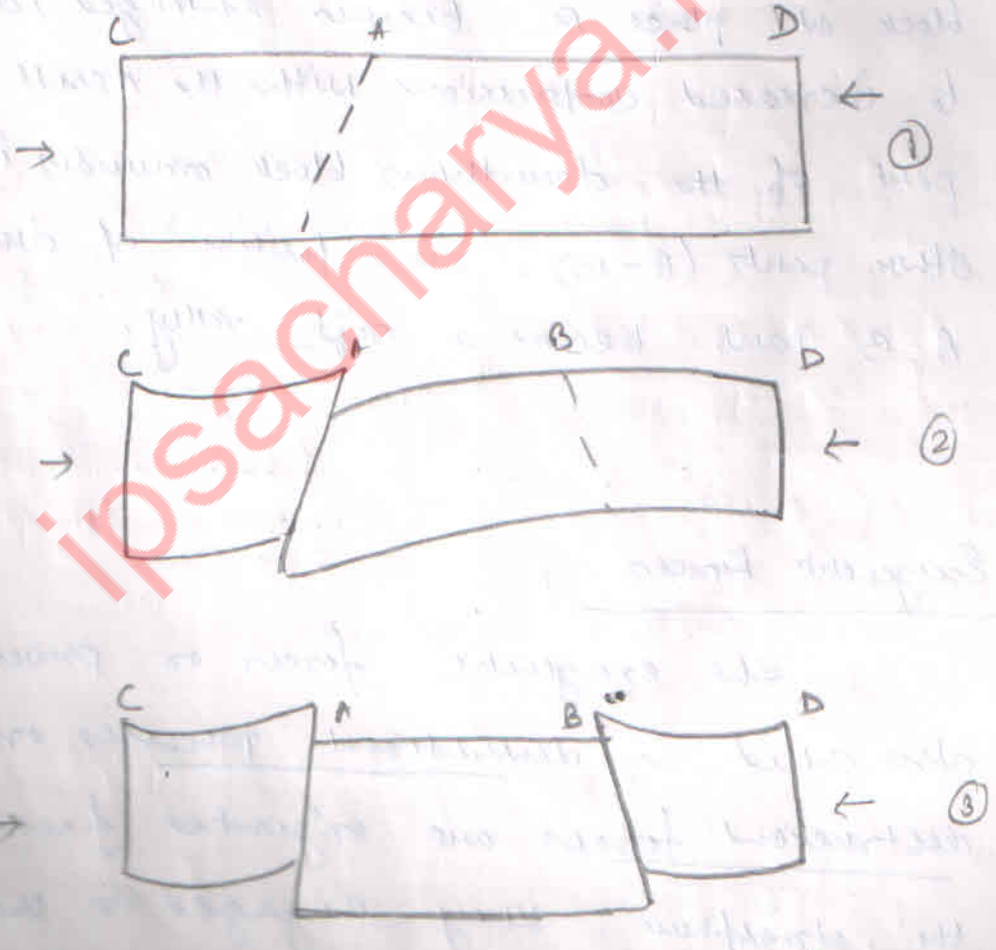


Due to intense compression the side blocks are thrown up along the thrust faults in the form of horsts. These upthrown blocks are overthrusting rift blocks. The middle portion is forced to slip downward because of the pressure resulting from rising side blocks. Thus the downward slipping middle portion between two faults

is called rift block which is narrow upward but broader downward.

③ Hypothesis by E. C. Bullard

Acc to him rift block can not slip downward under the impact of gravity, like a keystone of an arch of a building. Thus the rift valley can be formed only due to compression coming from two sides



First stage - There is compression in the crustal rock beds of the rigid part of a plateau due to active horizontal movement. When the compression

become so enormous that it exceeds the strength of the rock, a crack is developed (A in fig 1).

2nd: Due to formation of the crack one portion overrides the other. This is known as thrusting. Due to upthrusting of the side block (A-C), the downthrust block (A-D) develops crack (B in fig 2)

3rd: The crack developed in downthrust block at place B, becomes enlarged, due to increased compression with the result B-D part of the downthrust block overrides it to other parts (A-B). Thus position of downthrust A-B part becomes a rift valley.

Exogenetic Forces

The exogenetic forces or processes, also called as denudational processes or destructional forces are originated from the atmosphere. They engaged in the destruction of the relief features created by endogenetic forces thru their weathering, erosional and depositional activities. Exogenetic

processes are therefore floatation processes.

Denudation — Weathering + erosion

↓

[removal + transportation dynamic]

↙ exsitu

↓

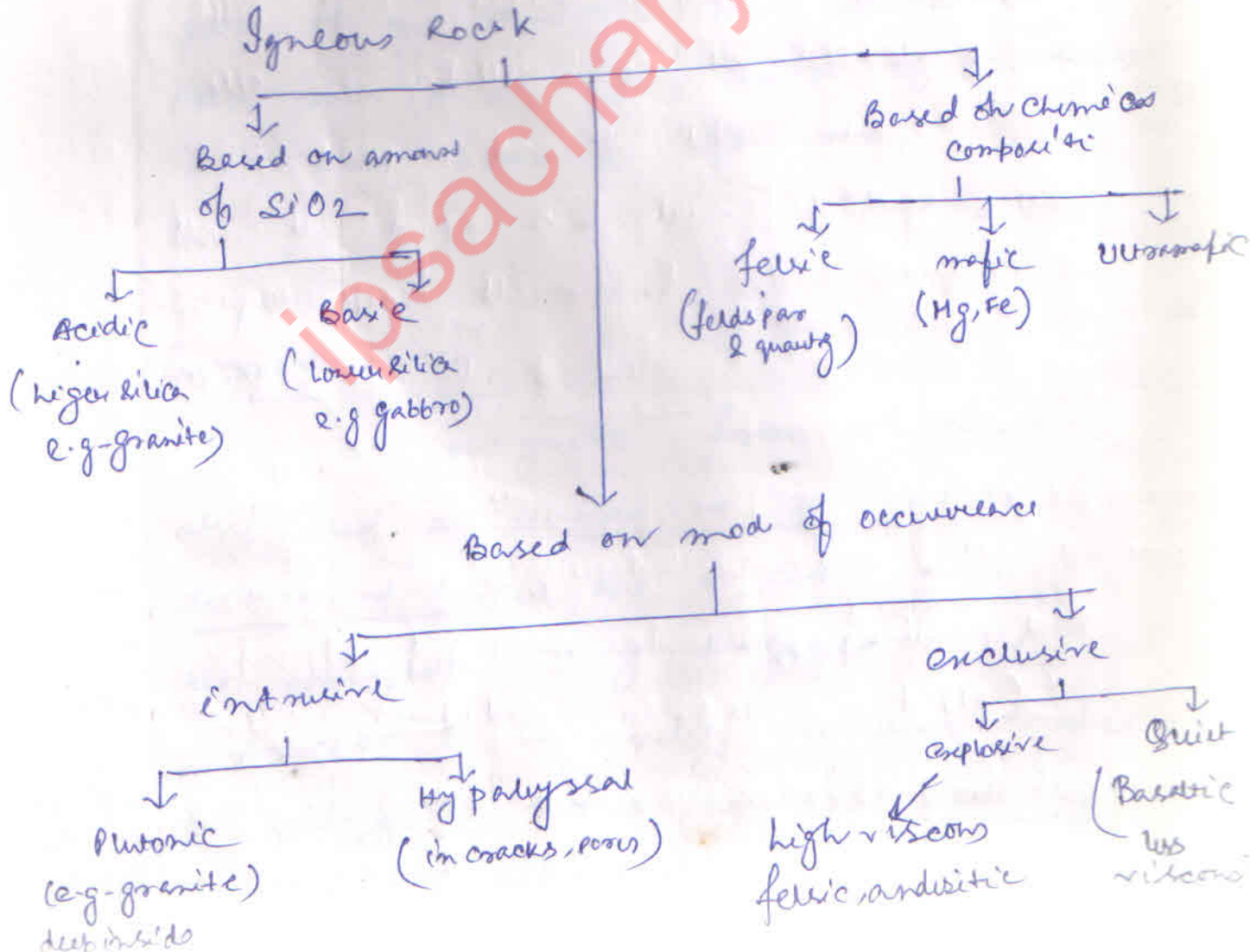
disintegration & decomposition (insitu & static)

Weathering → Physical or mechanical
→ chemical
→ Biological

ROCKS

Whole Earth — Iron – 35%.
Oxygen – 30%.
Silicon – 15%.
Magnesium – 13%.

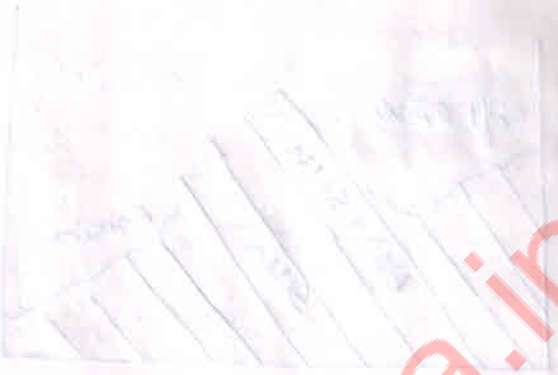
Earth crust — oxygen 46%.
Silicon – 28%.
Aluminium – 8%.
Iron – 6%.



Hypabyssal

Batholiths | Laccoliths | Phacoliths | Lopoliths | Sills | Dykes

Fig-



Classification of Igneous rocks based on chemical composition

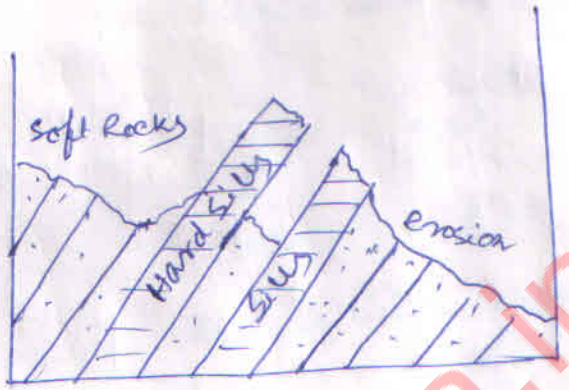
① Acidic – Silica content 65-85%, Density - 2.75 to 2.8
e.g – Quartz, Feldspar, Granite → good building material.
lack in – Fe, Mg

② Basic – Silica – 45-60% – Density 2.8 - 3.0
Dominated by ferro-magnetism.
Heavy in weight – Basalt, gabbro, dolerite

③ Intermediate – between basic & acidic
e.g- Diorite, andesite

Ultra basic — Silica less than 45%.
e.g. Peridotite.

Cuestas & Hogback

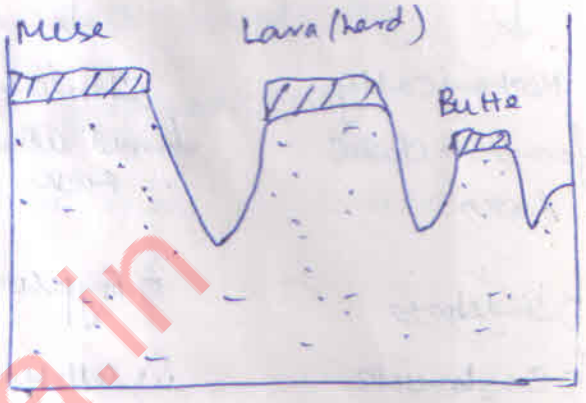


When hard igneous rocks in form of sills are intruded in the tilted or inclined sedimentary rocks, the latter are eroded more than the former and thus resistant sills project above the general ground surface as Cuestas and hogbacks

Mesas and Buttes

The differential erosion of the basaltic cap rocks produces interesting features like mesas and buttes. Mesas (a table) is such a hill which is characterized by almost

flat and regular top-surface but very steep slopes. When mesas are reduced in size due to continuous weathering and erosion, they are called buttes. Mesas are locally called as pats or patland on Chottonagpur plateau. e.g — Jamira pat, Netarhat pat, Khamar pat, Raldami pat.



Sedimentary Rocks

Basis of nature of Sediments

- Mechanically formed or Clastic Rocks
  - i) Sandstones
  - ii) Conglomerate
  - iii) Clay rock
  - iv) Shale
  - v) Loess
- Chemically formed sedimentary Rocks
  - i) Gypsum
  - ii) Salt rock
- Organically formed
  - i) Limestone
  - ii) Dolomite
  - iii) Coals
  - iv) Peats

Basis of transporting Agents

- Argillaceous or Aqueous Rock
  - i) Marine Rocks
  - ii) Lacustrine Rocks
  - iii) Riverine Rocks.
- Aeolian Rocks
  - i) Loess
- Glacial Rocks
  - i) Till
  - ii) Morains

S.N

Conglomerates - are formed due to cementation and consolidation of pebbles of various sizes together with sands. The term Conglomerate is applied to cemented fragmental rocks containing rounded fragments such as pebbles and boulders; if the fragments are angular ~~and~~ or subangular, the rock is called breccia.

Tyk

Types of Metamorphism

- Process of metamorphism
  - i) Physical
  - ii) ~~or~~ chemical
  - iii) Physio-chemical
- Nature of Agents
  - i) Thermal (Heat) — Due to
  - ii) Dynamic (Pressure)
  - iii) Hydro (Hydro-static Pressure)
  - iv) Hydro-thermal (Water & heat)
- Place or Area
  - i) Contact Metamorphism (localized)
  - ii) Regional (Larger Area)
- composite
  - Contact or thermal
  - Dynamic and Regional
  - Hydro
  - Hydro-thermal

Rock	Metamorphed Rock
Limestone	Marble
Clay	Schist
Shale	Slate
Granite	Gneiss
Sandstone	Quarzite

World Distribution of Volcanoes.

Circum Pacific belt

Mid continental belt

Basaltic Plateau

① Circum Pacific Belt : It is also known as volcanic zone of the convergent oceanic plate margins. This volcanic belt also known as fire girdle of the pacific or the fire ring of the pacific. This belt begins from Erebus mountain of Antartica and runs northward through Andes and Rockies mountain of South & North Americas to reach Alaska, from where

this belt turns towards eastern Asiatic coast to include the volcanoes of island arcs and festoons (e.g Sakhalin, Kamchatka, Japan, Philippines etc).

Here volcanic eruptions are primarily caused due to collision of American and Pacific plates and due to subduction of Pacific plate below Asiatic plate.

(2) Mid Continental Belt : also known as the volcanic zones of convergent continental plate margins. It includes the volcanoes of Alpine mountain chains and the Mediterranean Sea and the volcanoes of fault zone of East Africa. Here, volcanic eruptions are caused due to convergence and collision of Eurasian plates and African and Indian plates.

e.g- famous volcanoes of mediterranean Sea, such as Stromboli, Vesuvious, Etna etc.

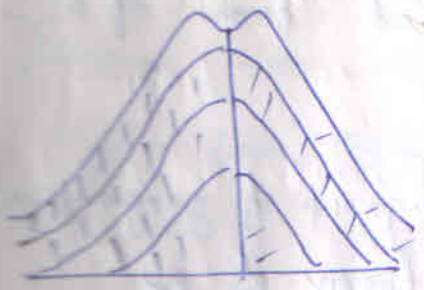
This belt does not have the continuity of volcanic eruptions as several volcanic-free zones, are found along the Alps and Himalayas because of compact and thick crust formed due to intense folding activity.

(3) Mid-Atlantic belt - includes the volcanoes mainly along mid-Atlantic ridge which represents the splitting zone of plates. e.g - Iceland, which is located in mid-Atlantic ridge, Lesser Antilles, Southern Antilles, Azores, St. Helena etc.

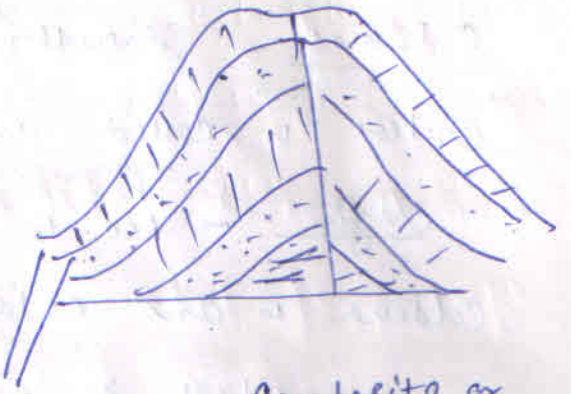
(4) Intra-plate volcanoes :- Besides, the plate boundaries, scattered volcanoes are also found in the inner parts of the continents. Such distributional patterns of volcanoes are called as intraplate volcanoes.
e.g - volcanoes of pacific plate - Hawaii to Kamchatka
fissure eruption in north-western part of North America during Miocene period
fissure flows of lavas in peninsular India
Parana of Brazil and Paraguay.

Why volcanoes in convergent plate boundaries are explosive in nature??

When two convergent plates collide along Benioff zone (subduction zone) comparatively heavier plate margin is subducted beneath comparatively lighter plate boundary. The subducted plate margin, after reaching a depth of 100 km or more in the upper mantle, is melted and thus magma is formed. This magma is forced to ascend by the enormous volume of accumulated explosive gases and thus magma appears as violent volcanic eruption. Such type of eruption is common along destructive plate boundaries - e.g. - Circum pacific belt and mid-continental belt. The volcanoes of the island arcs and festoons (off the east coast of Asia) are caused due to subduction of oceanic crust (pacific plate) below the continental plate (asiatic plate) near Japan trench.



Cinder or ash cone

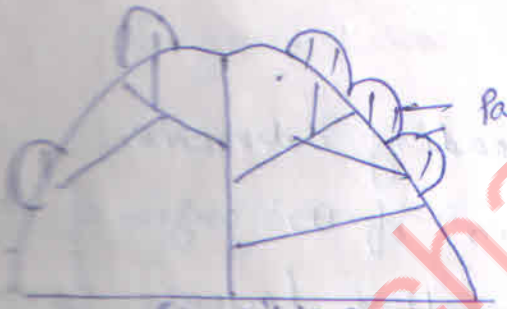


diff layers

Composite or Strato cone

e.g. – Fuzi yama (Japan)

Cotopaxi (Ecuador)



Parasite cone

Parasitic cone

e.g. – Mt. Shasta (US)

Basic

~~Hawaiian~~ type

Hawaiian

Acid lava

Strombolian type

Vulcanian type is similar to this (Strombolian), but they are extremely violent in explosion

to a particular cone are found not only
near the concerned caldera but also found
several kms away from the caldera.
e.g. - Lake Toba of Sumatra.

Geysers

Geysers in fact is a special type
hot spring which spouts hot water from
to time.
These are hot springs from which
of hot water and steam
-ged at intervals, s
heights of hund

S. N.

Calderas – Generally enlarged form of a crater is called caldera.

Origin – Acc to one group of geographers caldera is an enlarged form of a crater and it is surrounded by steep walls from all sides. The caldera is formed due to subsidence of a crater. This concept has been propounded by US geological survey.

2nd group

Daly, the leading advocate of 'eruption hypothesis' of the origin of calderas, believes that the topographic features formed by subsidence are volcanic sinks, while not calderas are formed due to violent and explosive eruptions of the volcanoes.

Acc to this hypothesis, if calderas are formed due to subsidence, there should not be any deposit of pyroclastic materials and volcanic ashes related to a particular volcanic cone near the caldera, but evidences have revealed that the remains of volcanic materials related

to a particular cone are found not only near the concerned caldera but also found several kms away from the caldera.

e.g – Lake Toba of Sumatera.

Geysers

Geysers, in fact, is a special type of hot spring which sports hot water from time to time.

Geysers are hot springs from which a column of hot water and steam is explosively discharged at intervals, sporting in some cases to heights of hundreds of feet (Arthur Holmes).

e.g- Old Faithful Geyser of Yellow Stone National Park, USA

Geysers → Pool type (sports water from an open & relatively large pool)

→ Nozzle type (sport water & vapour from a small & constricted vent.

Emitted materials are deposited around the geyser vent & new geyser cones are formed.

The diff between hot springs & geysers lies in the fact that there is continuous spouting of hot water from the former where there is intermittent (with interval) spouting of water & gas from the latter. A geyser spouts water from a small & narrow vent which is connected by a circuitous pipe with the underground aquifers. The pipe is called as geyser pipe, or tube.

Fumaroles

means such a vent thru which there is emission of gases and water vapour. It is believed that gases and vapours are generated due to cooling & contraction of magma after the termination of the eruption of a volcano. It may be pointed out that fumaroles are the last signs of the activeness of a volcano.

e.g - Fumaroles near Katmai volcano of Alaska. Here fumaroles are found in groups & the valley is known as 'Valley of Ten thousand Smokes'

Fumeroles dominated by sulphur are called Solfatara or sulphur fumaroles.

Vulcanicity - The term vulcanicity covers all those processes in which molten rock material or magma rises into the crust or is poured out on its surface, there to solidify as a crystalline or semicrystalline rock

EARTHQUAKES

Causes of Earthquakes

① **Vulcanicity** - The explosive violent gases during the process of vulcanicity try to escape upward and hence they push the crustal surface from below with great force and thus is caused as severe earth tremor of high magnitude

② **Faulting and Elastic Rebound Theory**

The horizontal and vertical movements caused by endogenetic forces result in the formation of faults and folds which in turn cause isostatic disequilibrium in the crustal rocks which ultimately causes earthquake of varying magnitudes. e.g. - the 1950 Earthquake of Assam.

Acc. to **Elastic rebound theory** by H. Reid (based on San Francisco earthquake, 1906), the underground rocks are elastic like rubber and expand when stretched and pulled. The rocks continue to be stretched as long as the tensile forces do not exceed the elasticity of the rocks, but

as tensile forces exceed the rock's elasticity, they are broken and then broken rock blocks try immediately to occupy their previous position. All these processes occur so rapidly that the equilibrium of the concerned crustal surface is suddenly disturbed & hence earth tremors are caused.

③ Hydrostatic pressure & Antropogenic Causes

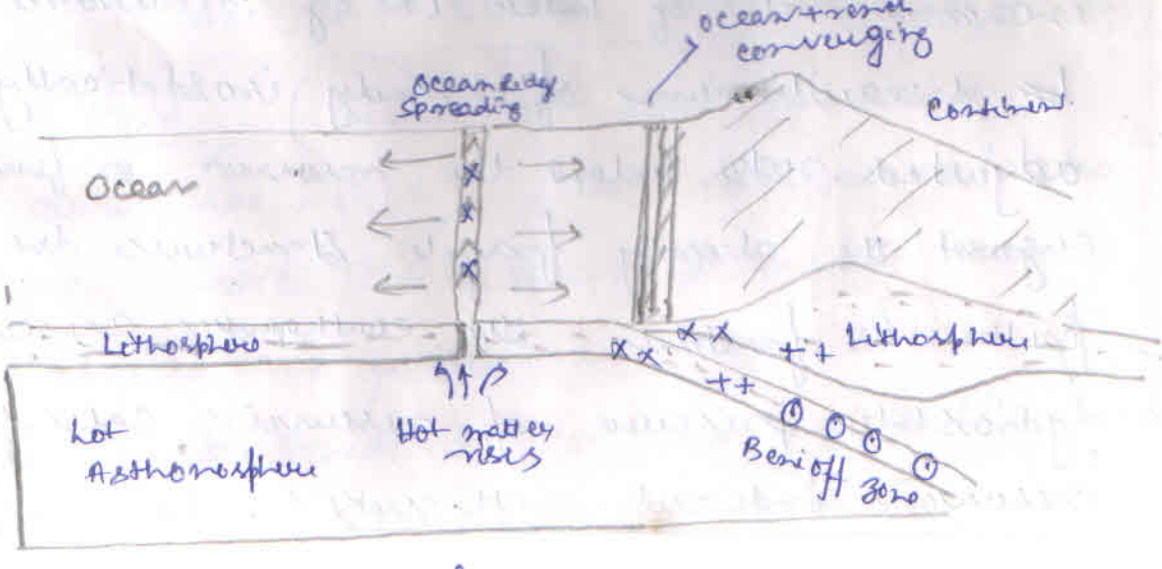
Human activities such as pumping of ground water & oil, deep underground mining, blasting of rocks, nuclear explosion, storage of huge vol. of water in reservoir can cause earthquake.

The introduction of additional artificial superincumbent load thru the construction of large dams and impounding of enormous vol. of water in big reservoirs cause disequilibrium of already isostatically adjusted rocks below the reservoir or further augment the already fragile structures due to fault & fractures. The earthquakes caused by hydrostatic pressure of reservoirs called 'reservoir induced earthquake'. For e.g Koyna earthquake, 1967.

(4) Plate Techtonic Theory

Moderate earthquakes, or shallow focus eq. are caused along the constructive plate boundaries, because the rupture of the crust and consequent movement of plates away from the mid-oceanic ridges is rather slow & the rate of upwelling of lavas due to fissure flow is also slow.

Eq. of high magnitude and deep focus are caused along the convergent or destructive plate boundaries because of collision of two plates & subsequent subduction of one plate boundary along the benioff zone. This explains earthquake of varying magnitudes & along ring of fire of pacific, or circum pacific belt, and mid Continental belt - along Alpine Himalayan Chain.



× × → shallow focus eq + + → medium

World Distribution of Earthquakes

(1) Circum pacific Belt surrounding the pacific ocean

(2) Mid-Continental belt representing epicentres located along the Alpine-Himalayan chains of Eurasia and Northern Africa and epicentres of East African Fault-zones.

(3) Mid-Atlantic Belt representing the earthquakes located along the Mid-Atlantic ridge and its offshoots.

Note

The Indian subcontinent has deformed at places due to the Indian ocean floor spreading process. India folds at places and when the energy reaches the elastic limit, the rocks break up and trigger strike-slip and thrust fault earthquake.

The Himalayan fault zone is not actually one fault but a broad system of interactive faults. The eq. belt extends from Sulaiman & Kirthar Shear zones in the west, the Himalayas in the north and the Burmese arc in the east. These tectonic events caused by plate movement. Causes eq. in the northern

and north-eastern part of India. Even the earthquakes of peninsular India have been related to the active faults below deccan trap.

Mercalli Scale – measure the degree of destructiveness or intensity of earthquake in 1–12 scale.

Richter magnitude scale – measure the magnitude of energy released by an earthquake. The scale has no upper limit of no. because it is a logarithmic scale.

PLATEAU

Division based on Mode of origin

(1) Glacial Plateaus :- The pre-existing plateaus modified by glacial actions are called glacial plateau. e.g — Garhwal plateau

'Marg' of Kashmir is supposed to have been formed of glacial moraines.

(2) Fluvial Plateaus — are formed due to continuous deposits of fluvial sediments brought by the rivers, their consolidation and stratification into sedimentary rocks of great thickness. e.g — Kaimur plateau

(3) Aeolian Plateau — is formed because of deposition of fine sediments brought by winds. e.g — Potwar plateau of Pakistan and Loess plateau of Pakistan.

(4) Structural Plateau - are surrounded by mountains almost from all sides. Generally they are formed due to upwarping of middle portion of the geosynclines known as median mass, after the formation of mountain ranges

along both the margins of the geosynclines.
e.g – Tibetan, Bolivian Plateau

(5) Piedmont Plateaus – are formed at the foot hill zone of extensive mountains. These are flanked by mountain on one side while by plain or coastal plain on other side. e.g – Patagonian plateau of South America.

(6) Domeshaped plateau are generally formed due to endogenetic forces mainly during volcanic activity e.g – Chotanagpur plateau

(7) Diastrophic plateau – The upland raised by horizontal and vertical earth movements caused by endogenetic forces is called diastrophic plateau. while very extensive plateau are called continental plateau. e.g – Deccan plateau, Arabian, Australian plateau.

(8) Volcanic Plateau : are those plateau which are formed due to accumulation of thick layers of basaltic lavas. e.g – Peninsular Plateau of India, Columbian pl. of USA.

PLAINS

Cryoplain :- the plains formed by the process of cryoplanation in periglacial areas are called cryoplains.

Etchplain - The plain surfaces formed by etching process of deep chemical weathering in Savanna region is called etchplain.

Outwash plain - the plain formed due to deposition of glacial sediments after the deletion of glaciers and ice sheets is called outwash plain.

Panplain - the plain having flat and almost even surface formed due to coalescence of numerous flood plains is called panplain (by C.H. Crickmay)

Till plain - the plain formed by the deposition of finer glacial materials, called as till, is called till plain.

Wind eroded plains - are called reg, serir, and hamada in Sahara and are naked stony surfaces formed by the joint actions of wind erosion and sheet erosion during occasional floods.

Pedeplain - the extensive erosion surface of concave slope formed due to coalescence of several pediments in the arid and semi arid region is called pedeplain. (L.C. King)

Peneplain - represent low featureless plains having undulating surface and remnants of convexo-concave residual hills. These are infact, the end product of normal cycle, as proposed by Davis.

WEATHERING AND MASS MOVEMENT

Weathering refers to the breakdown or disintegration and decomposition of rocks *insitu* through mechanical and chemical changes in the rocks provided that there is no large-scale transport of weathered products by denudational processes except mass movement of rockwastes, down the slope under the impact of gravity.

Controlling factors

- Composition & structure of rocks (joint, layering, faulting, folding)
- Nature of Ground slope (Rocks in steep slope easily disintegrated due to mechanical weathering)
- Climatic variations (Chemical → humid tropical areas
  Mechanical → semi-arid areas)
- Floral effects → (partly a factor of weathering - breaking rocks by roots and partly a protector of rocks.

Types & Agents

① Physical or mechanical Weathering
Agents — Moisture & water
frost
insolation
Wind

② Chemical Weathering
Agents — Oxygen, CO_2, Hydrogen

③ Biological Weathering
Agents — vegetation
Animals, mainly micro organism.

Physical Weathering

① Block disintegration due to temperature change.
— Crystalline rocks, like granites are affected by temp changes & these particles expand and contract with increase and decrease of temp, which causes tension & stresses along parallel joints in the rocks.

② Granular disintegration
If the rocks are coarse grained and are of diff colours, the different parts of the same rock mass receive and absorb different amount of insolation. Consequently differential expansion & contraction

disintegrated the rock in smaller particles.

③ Block disintegration due to frost :

Sedimentary rocks are most affected by frost action.

The disintegration of rocks due to diurnal freeze-thaw cycles in periglacial areas is called frost weathering or congelifraction which forms landforms like frost-riven polygons.

④ Exfoliation :- refers to peeling off concentric shells of rocks due to combined actions of heat and wind in hot arid and semi-arid regions. More common over crystalline rocks. e.g. - Kanke dome near Ranchi.

⑤ Disintegration and exfoliation due to unloading

- Sheeting - refers to the development of cracks and fractures parallel to the ground surface caused by removal of superincumbent load resulting into reduction of confining pressure. Occurs in granites, quartzites etc.

Camberring - refers to fracturing of brittle sandstone beds along vertical joints due to expansion caused by unloading of superincumbent load and consequent release of confining pressure. Reported in limestones.

Spalling — refers to development of platy rock fragments, in the rocks due to unloading of superincumbent load.

⑥ Other types

Dirt cracking - When the boulders containing 'dirt' are fractured.

Slaking — disintegration of rocks due to alternate wetting and drying.

Salt weathering. Disaggregation of rocks due to growth of salt crystals from solution is called salt weathering, which generally occurs in hot & arid areas.

Chemical Weathering :- decomposition & disintegration due to chemical reaction.

Processes involved :-

(1) Solution – gave birth to karst topography.

(2) Oxidation – reaction of atmospheric oxygen with rock, to form oxides.

$$Fe + H_2O + O_2 \rightarrow Fe_2O_3, 3H_2O$$

(3) Carbonation – is the reaction of carbonate or bicarbonate ion with minerals

$$CO_2 + H_2O \rightarrow H_2CO_3$$

$$CaCO_3 + H_2CO_3 \rightarrow Ca(HCO_3)_2$$

(4) Hydration – Addition of water to minerals. The process of hydration changes feldspar mineral into kaolinite clays, the process being known as kaolinization

(5) Hydrolysis is chemical reaction between mineral & water, that is between H^+ ion and OH^- ion.

(6) Chelation – is a complex process by which metallic cations are incorporated into hydrocarbon molecules. In other words, chelation means holding of an ion, usually a metal, within a ring structure of organic origin. It is a form of chemical weathering by plants. Plants extract

minerals or nutrients from the soils with the result, minerals lattices are disrupted and crystal lattices are fragmented and thus mineral weathering takes place at much faster rate.

Biotic Weathering

① Faunal Weathering
② Floral Weathering
③ Anthropogenic Weathering

Geomorphic Importance of Weathering

① **Production of rock wastes** :- Weathering help in soil formation, expose minerals, economic extraction of minerals etc. These weathered materials lying over the unweathered fresh rocks are called **regoliths**.

② **Weathering helps in erosional processes**

– Weathering loosens the rocks by disintegrating and decomposing them and thus paves the way for erosional processes to operate easily.

Mass movement / Mass wasting

Mass movement is the detachment and downslope transport of soil and rock material under the influence of gravity. Mass movement includes both, detachment of rock materials and their downslope transport. The collective term for gravitational or downslope movements of weathered rock debris is **masswasting**.

The rocks, debris coming through mass movement are deposited at the foot-hill zones as **scree or talus**. The deposit of large boulders in conical shape is called **talus cone**.

Classification of mass movement

1. Vertical movement
   - (A) Fall
     - Rock falls
     - Earth fall
     - Debris fall
     - Topple (Rotational fall)
   - (B) Subsidence or Sinking
     - Collapse (of roofs of underground caves)
     - Settlement (collapse of ground surface)

(2) Lateral Movement

(A) Slides

a) Block slide – downslope movement of single large block

(B) Spreading – displacement of series of block

(3) Diagonal movement

(A) Creeping (downslope movement of earthern materials at slow velocity)

- Soil creep
- Rock "
- talus "

(B) Slide (Rapid rate of downslope movement)

- Rock slide
- Debris "
- Slumping (movement of fine material along a curve path)

(C) Flows (downslop transport of water - soaked fine debris)

- earth flow
- Debris "
- mud "

Factors of Mass Movement (D. J. Vaunes, 1978, R J Chorley, 1985)

Factor which increases shear strength

1. Removal of lateral support
   a) Natural
      - erosion
      - Weathering
      - Rockfall, slide, faulting
   b) Anthropogenic
      - Construction of pits, canals
      - alteration of water table

2. Loading of slope
   - Wt. of rain, snow, canals
   - vegetation, trees
   - Seepage pressure of percolating water

3. Endogenetic processes
   - earthquakes
   - vibration, blasting, traffic ..

4. Removal of underlying support
   - Undercutting by rivers, waves
   - Solution at depth
   - mining

5. Lateral pressure
   - water in cracks
   - freezing of water
   - hydration.

Factors which decreases shear strength of material

(1) Weathering and other physico-chemical reactions
- physical disintegration of granular rocks
- drying
- removal of cement by solution
- hydration of clay mineral causing decrease in particles cohesion, swelling

(2) Changes of structure
- remoulding of loess, sand and sensitive clay

(3) Organic
- burrowing animals
- decay of roots

Land slides

All types of mass movements of rock wastes including soils and ice are collectively called as landslides. On ~~an~~ average, landslides (based on downslop movement) are divided into five major categories

(1) Falls
- instantaneous fall of weathered rock materials
  - Rock fall
  - debris fall

② Slides

Mass wasting wherein a mass of rock or weathered debris moves downhill along discrete shear surfaces is defined as slide

- Slumping — involves intermittent sliding of rock fragments, block along a curved plane caused by rotational movement

- Rock slide

- Debris slide - occurs at larger scale than slump, but there is little amount of water

③ Flows

- Downslope movement of rock fragments and soil along sliding plane with enough water, is called flow

① Debris flow - involves downslope movement of enormous amount of viscous soil and boulders, occuring mostly along river valley sides. Debris flow of volcanic material saturated with water is called lahar

② Earth flow - promoted by excessive water, and more common on planar hillslides or valley slides having alluvium.

③ Mud flow - differs from earthflow as the former is much more frequent than earth flow. The necessary condn for mud flow

- Steep & vertical slope
- presence of unconsolidated material on upper surface
- Supply of sufficient water as lubricant
- Absence of vegetation.

Spatial characteristics

- mudflows of arid region
- Alpine mud flow
- volcanic mud flow.

Diff between debris, earth, mud flow is related to size of particles and amount of water. The size of particles decreases from debris flow to mud flow, where content of water increases from debris flow to mud flow

④ Creep

very slow and imperceptible downslope movement of materials is called creep

Soil Creep - is also called Solifluction, which occurs in variety of climatic condⁿ ranging from tropical humid to periglacial.

J. Andersson (1906) proposed the term Solifluction (Solum - soil) for slow movement of debris, soaked with water from higher to lower slope.

Congelifluction (J Saylik, 1951) was defined as soil flow of Periglacial climate having perma frost below an active layer. Recently gelifluction is also used in place of congelifluction.

Cryoturbation

include all types of mass movement of regoliths under periglacial environment.

Rock Creep - involves downhill movement of rock debris having great depth (upto 300m) but the movements is very slow and ranges between one meter to ten meters per year.

FLUVIAL LANDFORMS

Law of erosion states that the rate of and amount of erosion increases before the attainment of equilibrium between the transporting capacity of the rivers and the load, while it decreases after the attainment of their equilibrium condition. Thus, erosion becomes maximum when the river carries load according, according to its transporting capacity

> Normally
> erosional power $\propto$ (velocity of the stream)^2

Types of Fluvial erosion

(1) Solution or Corrosion – the soluble materials are removed from the parents rocks and are mixed with the running water of the stream.

(2) Abrasion or Corration – involves the removal of loosened materials of the rocks of valley walls and valley floors with the help of erosional tools or drilling tools. (boulders, pebbles, cobbles etc.)

③ Attrition – is the mechanical tear and wear of the erosional tools, against each other themselves

④ Hydraulic Action – involves the breakdown of the rocks of valley sides due to the impact of water currents of channel.

Base Level of erosion

J. W. Powell (1875) postulated the concept of base level. There is a limit for maximum vertical erosion by a river, beyond which it cannot degrade its valley. This limit of maximum downward erosion by a river is called base level of erosion.

① Grand base level – is also called general or ultimate or permanent base level, which is determined by the sea level. This imaginary smooth curve of the grand base level denotes the limit of maximum downward erosion by a particular river.

② Temporary base level: Temporary base level can be present in a particular river due to presence of lakes, different beds of hard & soft rocks etc.

③ Local base level: is the level of the confluence of a tributary stream with its receiving master stream. The tributary streams first erode their valleys according to the level of their confluences and ultimately the sea level becomes the grand base level of erosion for the entire drainage system.

Changes of Base Level

Sea level changes are generally of two types –

i) eustatic changes — which have global impact
ii) local changes.

Changes in sea level and base level are grouped into two categories.

Positive change – occurs when either there is a subsidence of the coastal land in relation to the sea level or there is a upheaval of the sea floor.

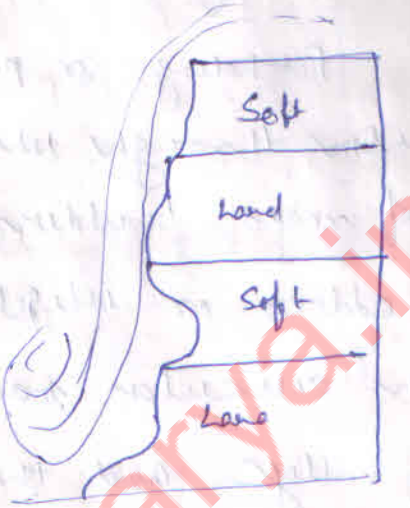
Negative change – occurs when either there is a emergence of the coastal land in relation to the sea level or there is subsidence of sea floor.

Erosional Landforms

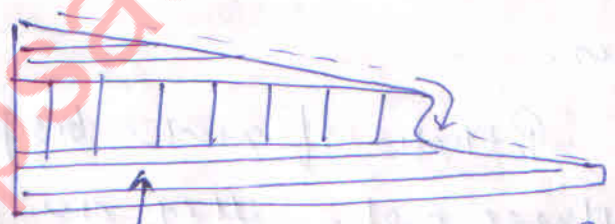
① Geoges

② Canyons – are extended form of geoges

③ Waterfall



④ Rapids. – much smaller dimension than waterfall



e.g. - Bhagavati fall on krishna river

⑤ Knick point fall – The breaks in channel gradient caused by rejuvenation (either due to uplift-ment or fall in sea level) are called knick point or heads of rejuvenation. This knickpoints denote sudden drops of elevation in the longitudinal profile of the rivers and allow water to fall down vertically giving birth to water falls. eg – Hudson fall on Sabarna rekha river.

(6) Pot holes and Plunge pools

The kettle like small depression in the rocky beds of the river valleys are called potholes which are usually cylindrical in shape. Generally formed in coarse-grained rocks such as Sandstones and granites.

Pot holing or pothole drilling is the mechanism through which the grinding tools (fragment of rocks, boulders .etc) when caught in water eddies or whirling water start dancing in circular manner and drill the rock bed of valleys and thus form small holes, which are gradually enlarged. The depth of potholes are far more than their diameters.

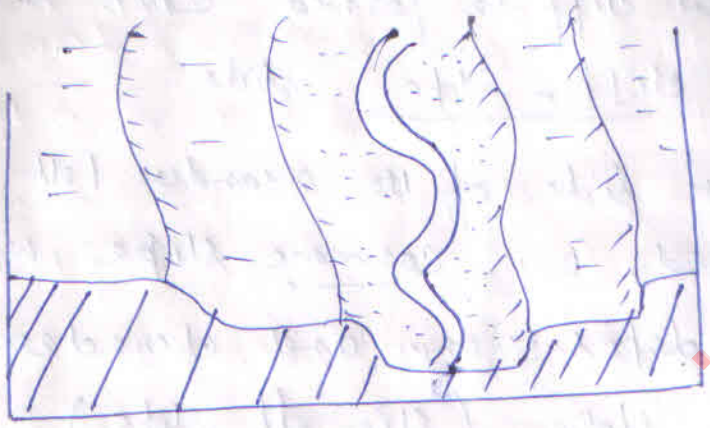
Potholes of much bigger size, are called plunge pool. They are generally formed at the base of waterfalls.

e.g - Bed of Gaur nadi (east of Jabalpur, MP) present magnificent view of pot holes.

① River Terraces

① paired Terraces

② Unpaired Terraces



Paired Terraces

Unpaired

River Meanders

refers to the beds of longitudinal courses of the river. The beds of sinous rivers have been named after. On the basis of Meanders river of Turkey.

Each bend of a meander belt has

two types of slopes.

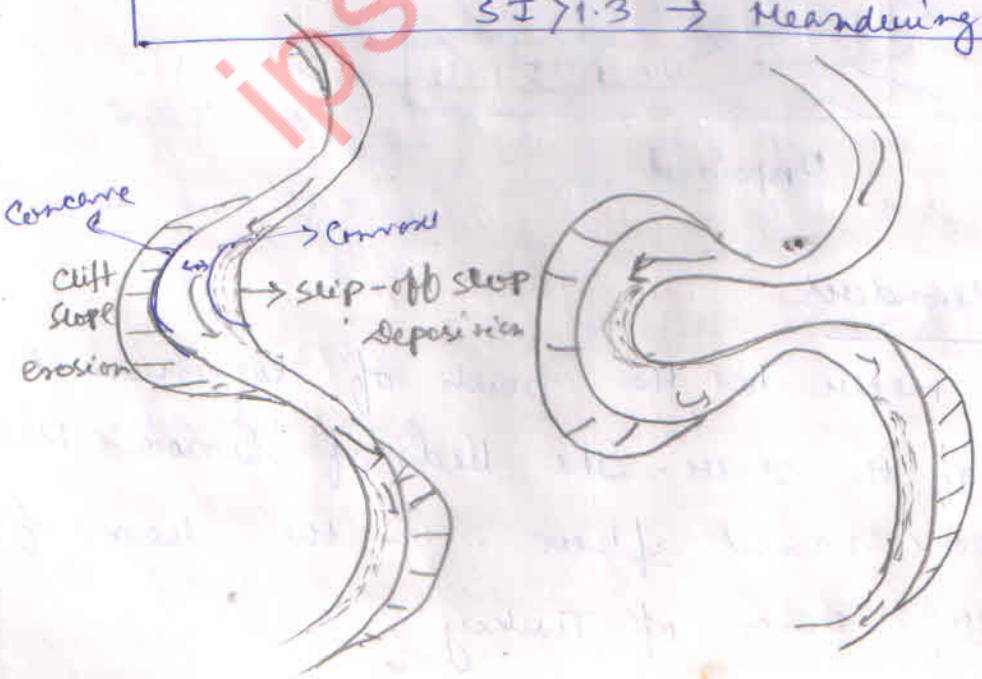
(1) one side is characterized by concave slope, where the channel strike to valley sides directly, as a result severe erosion takes place and vertical cliff is formed. This side is also called cliff - slope side.

(2) the other side of the meander belt is characterized by convex slope, which receives deposition and characterized by gentle slope (slip-off slope)

The ratio of observed path (actual course of a stream) to the expected path (theoretical straight course), is known as sinuosity index which tells magnitude of meandering

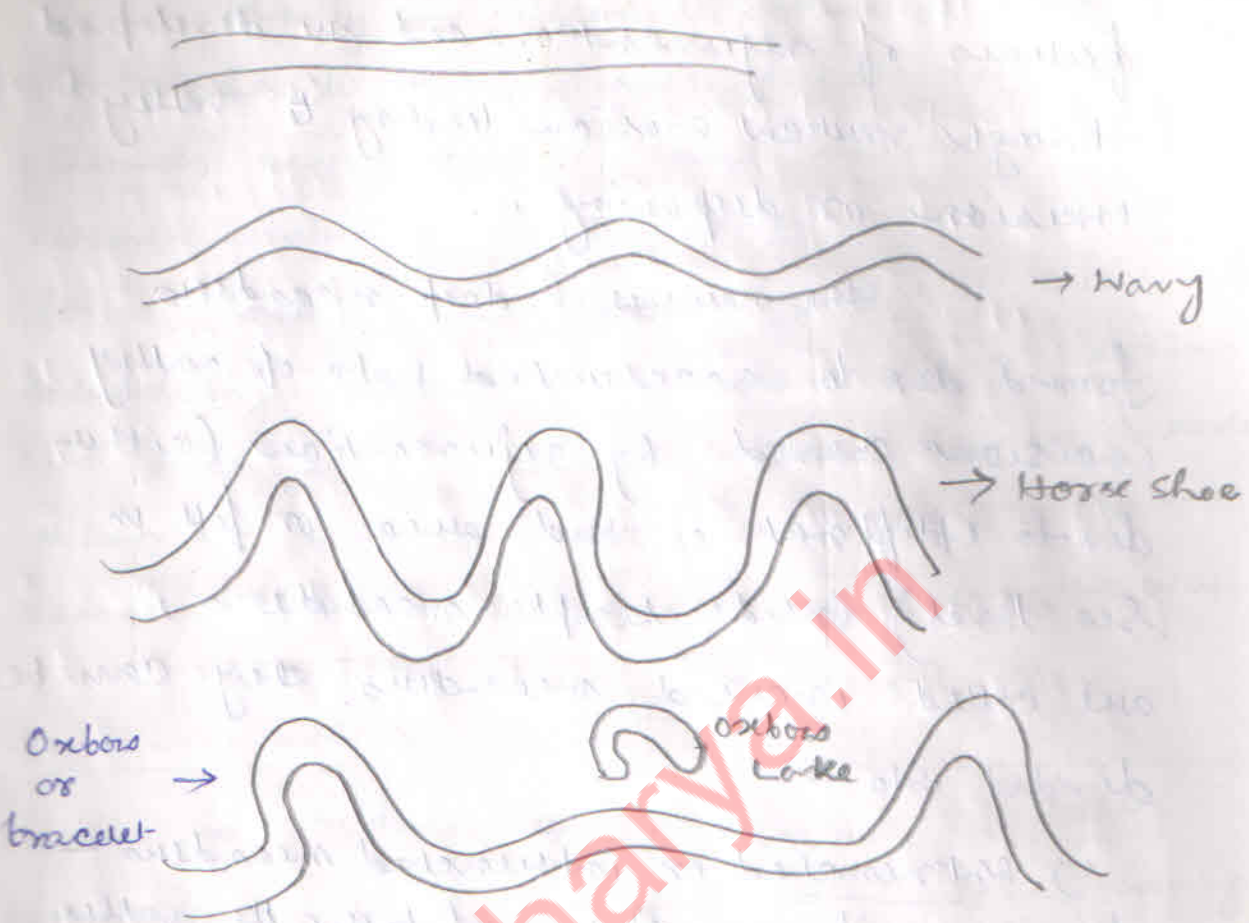
$1 < SI < 1.3$ → Sinuous

$SI > 1.3$ → Meandering



e.g. → Gomati river of UP

Ganga between Allahabad and Varanasi



Types

(1) Simple Meander — developed during first cycle of erosion. These are formed by lateral erosion during mature stage (*) of river stream. The most ideal condn req. for development of meanders are alluvial plains, gentle slope, sufficient amount of precipitation and general absence of vegetation. Generally divided into 3 types

- Wavy meander
- horse shoe type
- oxbow or bracelet type

(*) Not in old stage (transportation) or young (valley deepening) stage.

② Incised Meanders — are the representative features of rejuvenation and are developed through vertical erosion leading to valley incision or deepening.

The narrow & deep meanders formed due to accelerated rate of valley incision caused by rejuvenation (either due to upliftment of land area or fall in sea level) inside simple meanders, are called incised meanders. They can be divided into —

i) entrenched or intrenched meanders — having uniform slopes of both the valley sides of meander loop.

ii) Ingrown meanders, which have unequal slopes of valley sides. One side of the valley (concave side) is deeply indecent and the other side (convex / slip off) is characterized by gentle slope valley and deposition of sediments.

Misfit meanders

When by any reason, the volume of water in the concerned rivers decreases, substantially, the channels become narrow. These narrow channels becomes unable to fit themselves in the broader former valleys and hence they develop their own meandering course of narrow valleys within the older wider meanders. Such narrow meanders within the wider meanders are called misfit meanders, because they can not fit with the later.

The end product of normal fluvial cycle, is represented by low featureless plain having undulating surface and remnants of convexo-concave residual hills. These plains are known by various names

Peneplain - W.M Davis	Pediplain - L.C. King
Endplain - W. Penck	Etchplain - Pugh & Thomas
Panplain - C.H. Crickmay	Panfan - A.C. Lawson.

Transportation

G. K. Gilbert's Sixth power law

Transportation power $\propto$ (Stream velocity)^6

River transport their load in diff ways

(1) Saltation involves the transportation of rock pieces and boulders of bigger size which move as bedload close to the channel floor by rolling or sliding

(2) The bedload does not always touch the valley floor and gravels pebbles, cobbles of comparatively smaller size are then transported by the process of traction

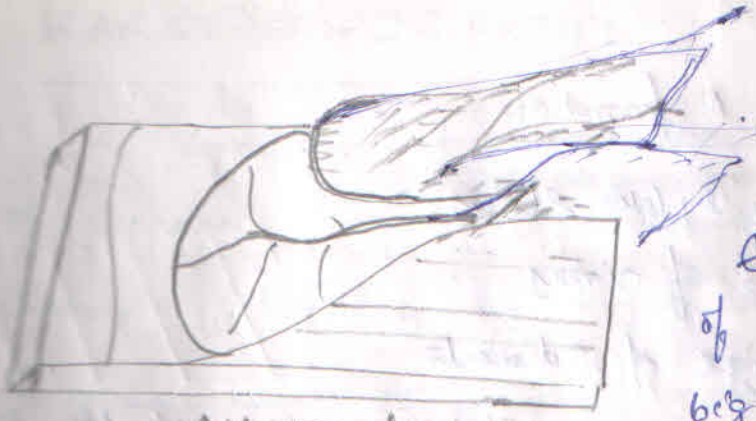
(3) The materials of medium size are suspended in water due to its buoyancy. Such load is called suspended load and process of transportation is by suspension.

(4) The soluble materials are transported by solution.

Depositional Landform

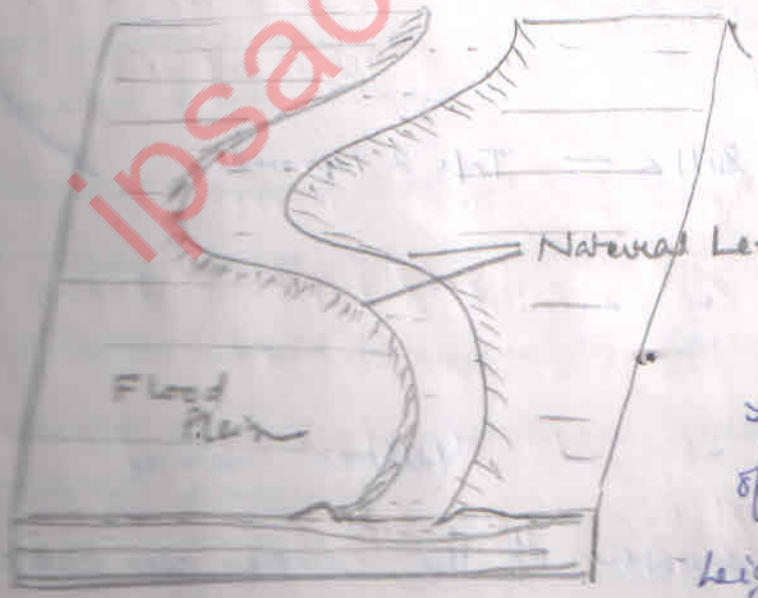
- Alluvial fans & cones
- Natural Levees
- Delta

Alluvial fan and cones are formed at the base of foothills where there is abrupt drop in channel gradient. Load consisting of finer to coarser and big sized materials coming from upstream is deposited at the point of break in slope or foothill zone thus alluvial fans are formed. Shapes are generally semi-circular or arcuate. Alluvial cones have relatively steeper slopes than alluvial fans and made up of coarser material. Bhabar zone composed of fan & cone.



Alluvian fan

Alluvian cone



The narrow belt of ridges of low height built by the deposition of sediments, on either bank of the stream is called Natural Levee.

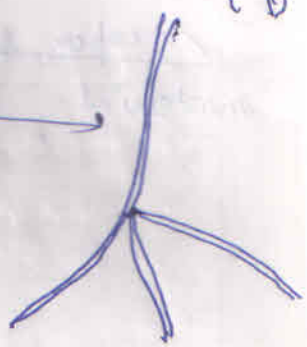
Delta

Condition for Δ formation

- Shallow sea & lake shores
- long courses of rivers
- medium size of sediments
- relatively calm or sheltered sea at the mouths of the rivers
- large amount of sediment supply
- accelerated rate of erosion in the catchment area
- stable condⁿ of sea coast & ocean bottom.

e.g. - Arcuate delta — Nile, Ganga

Bird Foot — River Mississippi →



Estuarine delta — Tapi & Narmada

Truncated " —

Abandoned " — Yellow river.

(#) Those mouth of the rivers are called Estuaries which are submerged under marine water & sea waves and oceanic currents remove the sediments bought by the rivers.

KARST TOPOGRAPHY

Landforms produced by chemical weathering of carbonate rocks (mainly calcium carbonate, $CaCO_3$, limestone) and magnesium carbonate (dolomites) by surface and sub surface water are called karst topography, named after karst region of southern Yugoslavia situated along the eastern margin of Adriatic Sea.

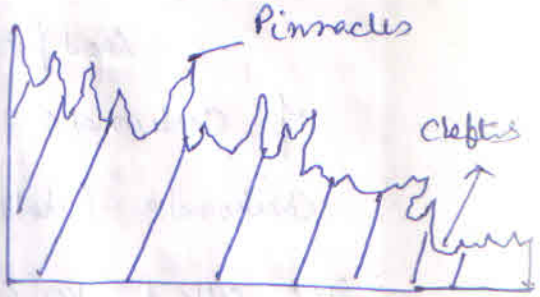
In India, limestone topography can be observed Robat cave & Tafu between temple near Dehra Dun, Panchmarhi (MP), Bastar (Chh), Sahasradhara, Coastal area near Visakhapatnam.

Cond^{n} for development

- The limestone must be massive, thickly bedded, well cemented & well bedded
- Limestone should not be porous and permeability is largely controlled by joints
- Limestone should be above the ground water table
- Should be widely distributed both in areal & vertical dimension
- There should be enough rainfall
- Limestone should be highly folded, fractured & faulted.

Erosional Landform

① Lapies



are generally formed due to corrosion of limestone do along their joints.
The highly corrugated & rough surface of limestone lithology characterized by low ridges & pinnacles, clefts & numerous solution holes is called lapies. The weathering residues left at the surface are called terra rosa which means residual soil or red earth.

② Solution Holes & Associated Features

Chemically active rainwater dissolve limestone & numerous type of solution holes are developed.
Smaller one called Sink holes

Sink hole < Swallow hole < Doline < Solution pan < Uvala < Poljes

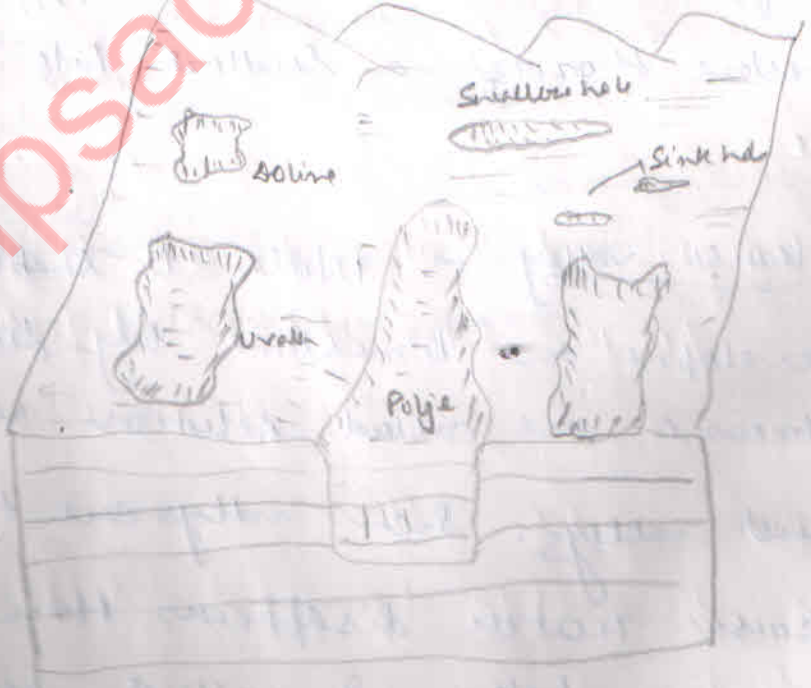
Solution pan is almost similar to Doline but of shallow depth & larger areal extent.

Karst window is formed due to collapse of upper surface of sink holes or dolines. These enable to observe subsurface drainage & other features.

Extensive depressions are called uvalas. They are formed by —

- due to coalescence of several dolines or sink holes
- due to collapse of upper roof of large cavities formed underground.

③ Poljes — Most extensive depressions are called poljes. They are believed to be formed due to downfolding and downfaulting of limestone areas due to earth movement.



④ Valleys of karst region

The upper surface having several sink holes in the region of limestones having horizontal beds of or slightly inclined beds is called karst plain on which surface drainage system develop different types of valleys —

① Sinking Creek – When surface water disappears through numerous sink holes located in a line, the resultant feature is called sinking creek.

② Blind valley – Refers to the valley of that surface stream which disappears in limestone through a shallow hole or sink hole.

③ Karst valley – Wide U shaped valleys developed on limestone by surface streams are called solution valleys or karst valleys. Such valleys are temporary because water disappears thru shallow or sink holes & valleys become dry.

(5) Caves or Caverns

are voids of large dimension below the ground surface. e.g - Carlsbad & Mammoth Caves of USA, Bora cave of Araku valley.

Depositional Landforms

All types of deposits in the caverns are collectively called Speleothems of which calcite is the common constituent.

Travertines - Banded calcareous deposits

Dripstones - Deposit from dipping of water in dry caves

Stalactites - Deposits hanging from cave ceiling

Stalagmites - " growing upward from cave floor

Cave pillar - When Stalactites & Stalagmites meet together.

Drapes / curtains - Numerous needle shaped dripstone hanging from ceiling

Helictites & Heligmites - Drip stones growing sideward from Stalactites & Stalagmites

Globulites - Helictites of globular structure

Eg-

Karst Cycle of Erosion

The concept of cycle of erosion was applied to limestone regions by J. W. Beede and J. Cvijic.

WM Davis regarded karst cycle of erosion as a special phase of the normal fluvial cycle of erosion characterized by the development of surface drainage, disappearance of surface drainage underground and re appearance of subterranean drainage as surface drainage.

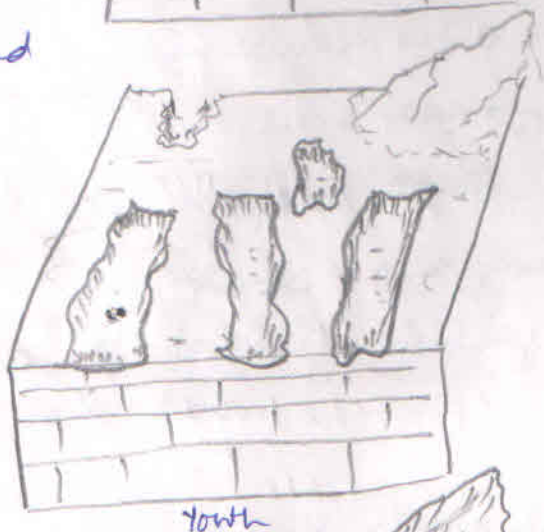
① Youthful stage

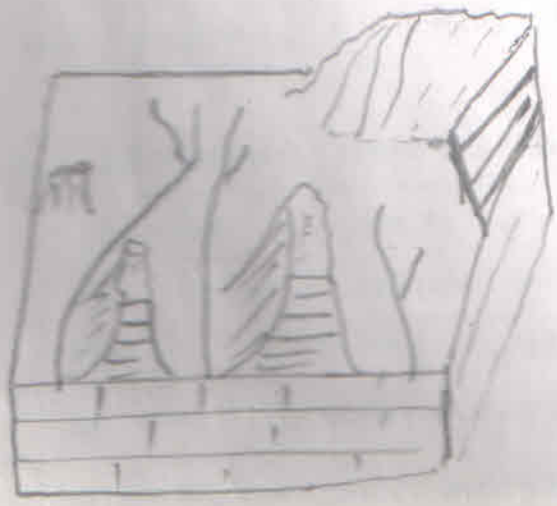
Rainwater mixed with atmospheric CO_2 reacts with limestones and thus form sink hole, swallow holes, dolines through the mechanism of solution process. The characteristic geomorphic features of this stage are sink holes, swallow holes, dolines, lapies, blind valleys, sinking creeks, caves and caverns of small dimension. The termination of youth stage is marked by total disappearance of surface drainage.

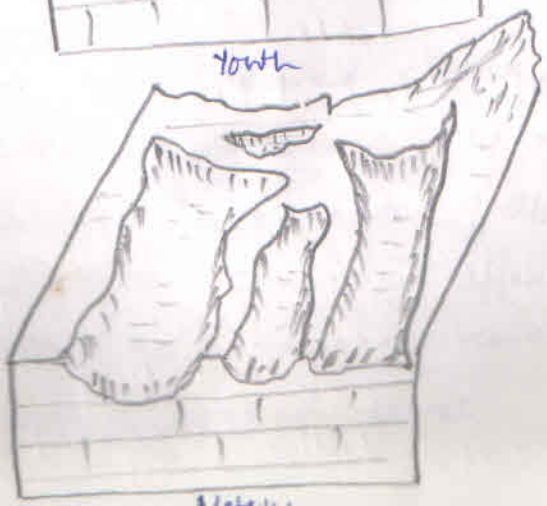
② Maturity

Initiation of this stage is heralded by total disappearance of surface drainage, thus ground surface is characterized by dry waterless condition. The process of underground solution and abrasion increases because of development of subterranean drainage. The thinning of cave roof causes their collapse giving birth to uvalas, poljes, and karst window.

③ Old Stage - The cave roofs are totally collapsed. The residual carbonate rocks slightly projected above the ground are called Lums. Most of the ground surface is levelled and thus resembles the peneplain of normal fluvial cycle.







The subterranean drainage again appears on the ground surface. Nearly all of the karst valleys, solution holes & sinking creeks are eliminated. The second karst cycle of erosion may start with fresh upliftment of karst plain.

AEOLIAN LANDFORMS

S.N.

Tafoni – is a typical cavernous topography developed in siliceous rocks mainly sandstone in the tropical deserts. Amorphous network of holes are developed in sandstones due to decomposition of rocks. Such tafoni are found in Jodhpur – Ajmer part of Thar Desert.

Wind erosion occur in three ways.

① Deflation – The process of removing, lifting and blowing away dry and loose particles of sands and dusts by wind is called deflation.

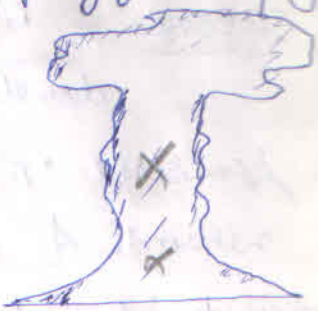
② Attrition – involves mechanical tear and wear of the particles suffered by themselves while they are being transported by ~~with~~ wind through the process of saltation and surface creep. Saltation involves movement of sands and gravels through the mechanisms of bouncing, jumping and hopping by turbulent air flow.

③ Abrasion / Sand blasting – Wind armed with sand grains as tools of erosion attacks the rock and erodes them. Under the mechanism of abrasion, flaking, grooving, polishing the combined effects, ~~is~~ are collectively known as abrasion or sand blasting. Abrasion is minimum in ground level.

Erosional Land forms

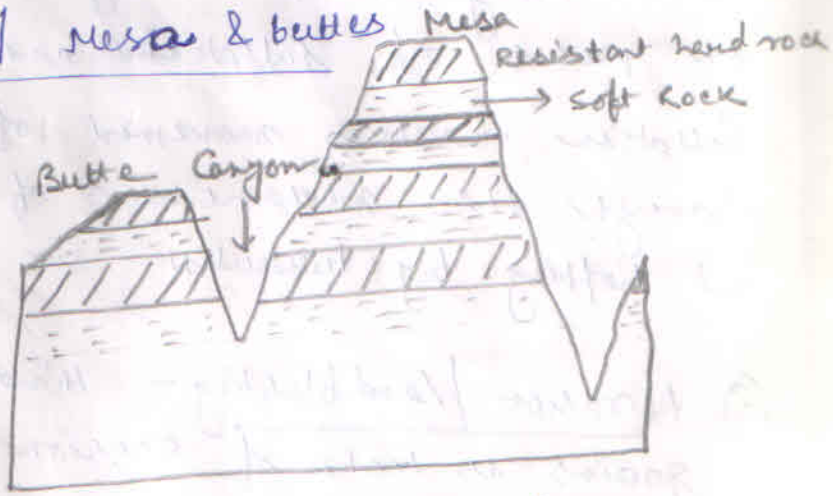
(1) Deflation Basin

(2) Mushroom rocks / pedastal rocks / pilz felsen / gaur



(3) Inselberg / bornhardts - Residual hills and mounds of relatively resistant rocks
e.g - Kalahari desert

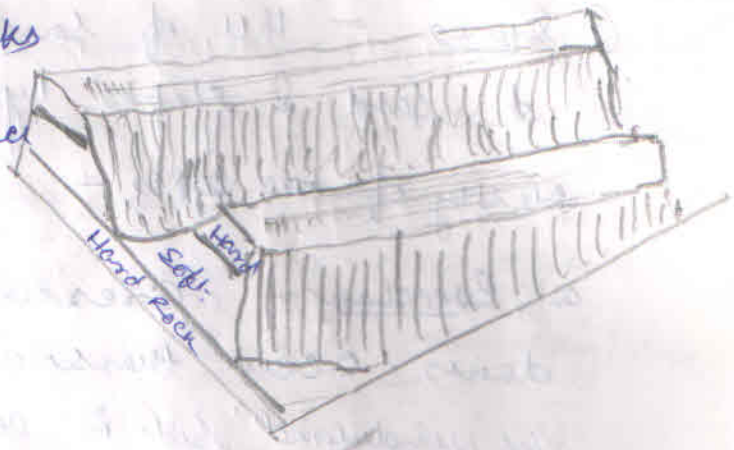
(4) Demoiselles / Mesa & buttes



Mesa is a Spanish word, meaning table. It is flat, table-like land mass with a very resistant horizontal top layer. Continued denudation through the ages may reduce mesas, so that they become isolated flat-topped hills called buttes. e.g - Table mountain, Cape Town, South Africa

⑤ Zeugen - (Ridge & furrow topography)

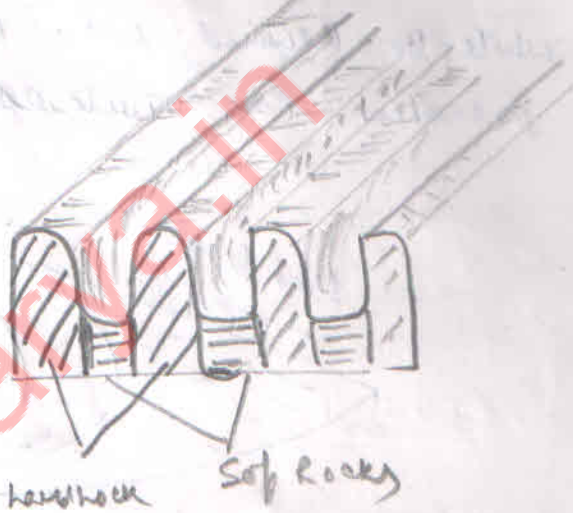
These are tabular masses which have a layer of soft rocks lying beneath a surface layer of more resistant rocks.



⑥ Yardangs

Soft & hard rocks are lying as vertical bands

e.g - Atacama desert.



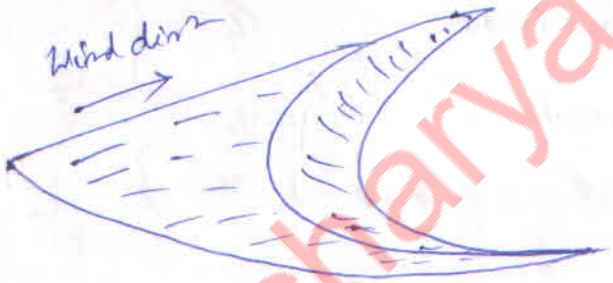
⑦ Ventifacts or dreikanter

These are pebbles shaped & thoroughly polished by sand blasting. Among the ventifacts those with three wind faceted surfaces are called dreikanter.

Depositional Landform

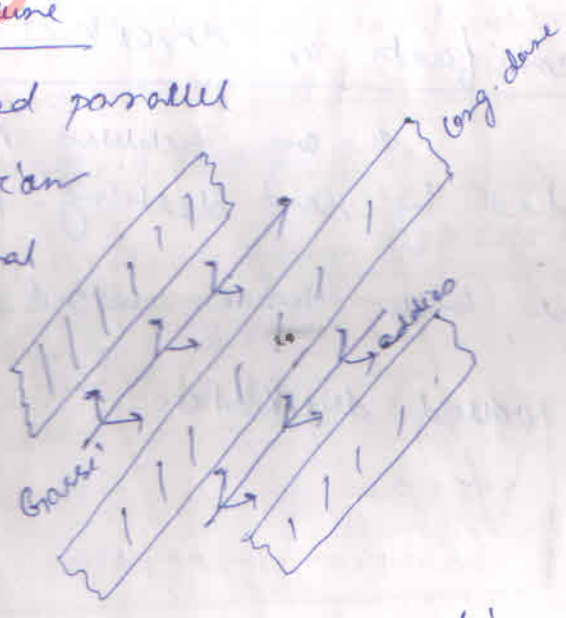
① Dunes – Hill of sand formed by accumulation of sand & shaped by the movement of wind. Mostly of two types –

a) Barchan – Crescentic or moon shaped dunes, occur transversely to the wind. The windward side is convex and gently sloping while the leeward side is concave & steep. prevalent in Turkistan & Sahara desert.



b) Seif or longitudinal dune

Sand dunes formed parallel to the wind direction are called longitudinal dunes. Sand free corridors between parallel dunes are called Gassi ② in Sahara. prevalent in Sahara, Australia, Thar desert.



② also called reg or hammada.

③ Loess - (fine loam, loose or unconsolidated material) represents thick deposits of unstratified, very coherent, extremely porous, fine grained sediments consisting of quartz silt, with small clay fraction & higher content of calcareous minerals. Loess is readily eroded in humid climate & thus dense network of rills & gullies (Badland topography) are formed.

Desert Loess - Most extensive in North-West China, Huang-Ho basin

Glacial Loess - 'Limon' in France & Belgium.
'Adobe', Mississippi basin, USA.

FLUVIAL DESERT LANDFORM

① Badland Topography - The regions of weak sedimentary formations are extensively eroded by numerous rills and channels, which are occasionally developed due to fluvial erosion. ~~Further~~ ~~Which~~ These rills & channels are further enlarged into ravines & gullies, which are divided by numerous narrow ridges. Such type of landscape is called badland topography. e.g - Huang Ho basin
Chambal basin

Bolsons & Playas. The intermontane basin in arid or semi arid. Some water collects in the centre of the bolsons and form temporary lakes. Such temporary lakes are called playas. (& saline due to high evaporation)

Salinas - Salt covered playa bed.

Bajada - Gently sloping depositional plain between pediments and playa is called bajada. Bajada is formed due to coalescence of several alluvial fans. Thus it is a depositional feature.

Pediments - (G. K Gilbert, 1882)

Pediments situated between mountain front and bajada in intermontane basin are broad, extensive and gently sloping areas of rocket surfaces.

Development of Pediments

① Lawson's recession theory: Dec to A.C Lawson (1915) pediments are formed becoz of gradual recession of mountain front caused by weathering & erosion.

② Sheet Flood theory (by McGee)

– Acc to W. J. McGee, pediments are formed due to erosion of weathered bedrocks by sheetfloods originating from occasional torrential rainfall in deserts

③ Lateral erosion theory (G. K. Gilbert)

The formation of pediments is initiated by active down cutting of mountain front, (inner zone) resulting into rapid erosion. The eroded materials are removed & deposited by ephemeral streams. Thus several alluvial fans are formed on the lower segment of hillslopes. These fans gradually coalesce to form bajadas. Rock fans are formed in, between the mountain front and margin of intermontane basins, due to lateral erosion by streams. These rock fans gradually extends to become pediment.

④ Composite Theory – (WM Davis, Kirk Bryan, R. P. Sharp)

Acc to this theory first the mountain front is disintegrated due to mechanical weathering, and the weathered materials are transported

downslope by sheetfloods. These twin process causes gradual recession of mountain front and consequent development of rocket pediment surface - It is evident that this theory takes into account all the three theories discussed above.

Landforms of glaciations

The terms glacierization means the coverage of an area by moving glacial ice while glaciation refer to the action of moving ice on land. Glaciation may include both the processes of occupation of land by ice masses & erosional and depositional works by advancing glaciers.

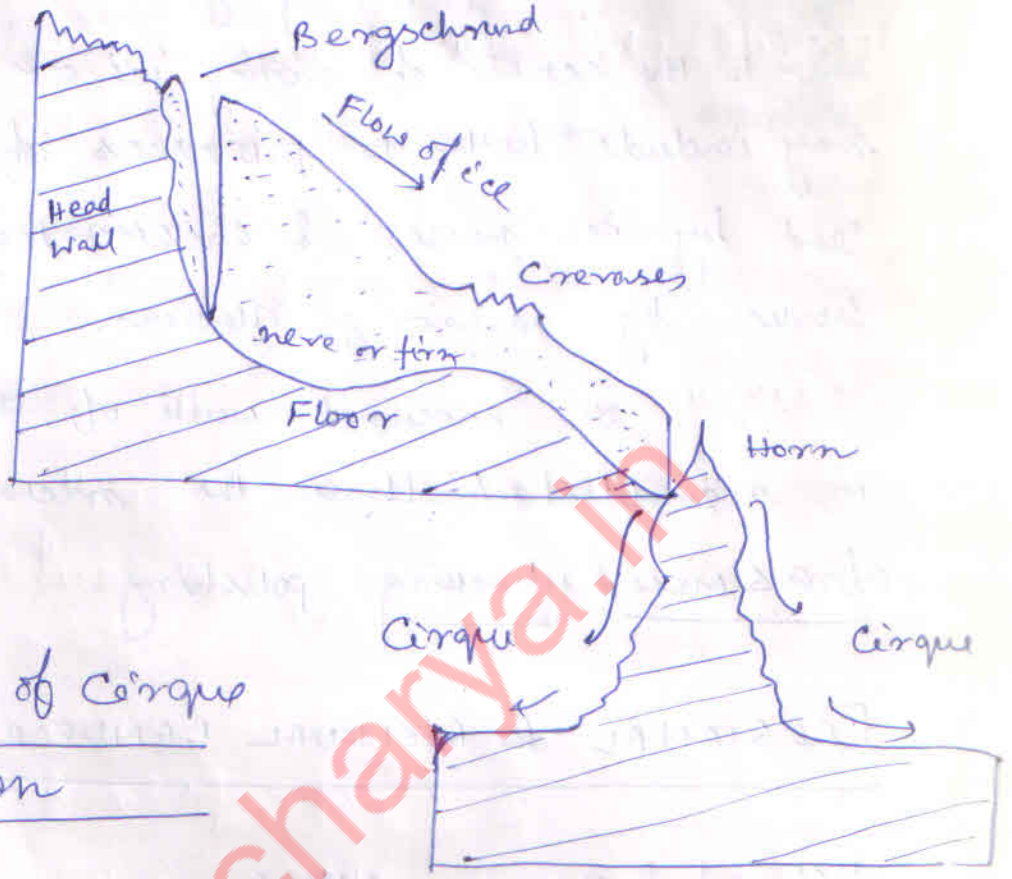
The erosional work of the glaciers is accomplished thru the mechanisms of abrasion, plucking, polishing.

EROSIONAL & RESIDUAL LANDFORMS

U shaped & Hanging Valleys - The cross section of glacial valleys or glacial troughs of mountain glaciers is U shaped, which is characterized by steep valley walls. Some times, U-shaped valleys are associated with tributary valleys called hanging valleys.

Cirques - The armchair-shaped or amphitheatric cirque or corrie is a horseshoe-shaped, steepwalled depression representing a glaciated valley head. Cirques are variously

named in different countries, e.g Corrie in Scotland, kar in Germany, botn in Norway etc.



Theories of Cirque formation

① Glacial Protection theory (Gardwood)

According to this theory, depression are formed by frost action and water-erosion and soil creep during interglacial period before the formation of cirques. These depression are later modified by glaciers to form corries. In fact, glacial ice offers protection to corries.

② Bergschrund Theory (D. W. Johnson)

Acc to this theory basal sapping is the most active process of corrie excavation. At the head of glacier, where it begins to leave the snowfield of a corrie, a deep vertical crack opens up, called a bergschrund or rimaye.

Alternate freeze and thaw at the intersecting point of the cirque wall and bergschrund causes mechanical disintegration of rocks and thus deepens the depression. This mechanism is called basal sapping. Gradual increase in the bergschrund & consequent acceleration of basal sapping result into well developed corries.

Criticism - i) Most of the bergschrunds are very small & they dont reach the rock wall or head wall.
ii) most of the glaciers contain very few bergschrunds

③ Glacial Erosion Theory or Cyclic Theory of cirque formation. (W. H. Hobbs). Hobbs

advocated that cirques are formed according to the various stages of the cycle of mountain glaciation.

First a small hollow is formed. Later this hollow increases in size due to glacial erosion acc. to bergschrund theory. Gradually the wall of the hollow recedes & ultimately semi circular armchair shaped depression is formed.

Col, Aretas, horn, pyramidal peak

Where three or more cirques cut back together, their ultimate recession will form an angular horn or pyramidal peak.

Note

Basket Board topography.

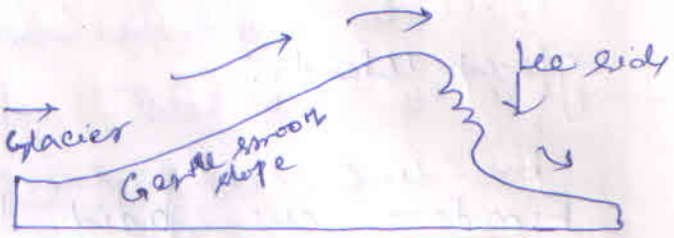
A high plateau or a mountain range after being eroded rather incompletely by glaciers mainly through the process of cirque recession remains as remnants between the steep, concave glaciated forms. Such imperfectly glaciated upland surface is called scalloped upland or biscuit board topography. The scalloped upland is transformed into fretted upland by complete dissection of the terrain thro cirque recession.

Nunatak – The higher peaks and ~~mountain~~ mounds surrounded by ice from all sides are called nunataks. They look like scattered islands amid extensive ice masses, thus are also known as glacial islands.

Fiords – are glacial troughs, which have been occupied by the sea. In fact, fiords are the arms of the sea which have occupied U-shaped glaciated valleys which were dug out below sea level through the mechanisms of abrasion and plucking by valley glaciers descending from coastal mountains.

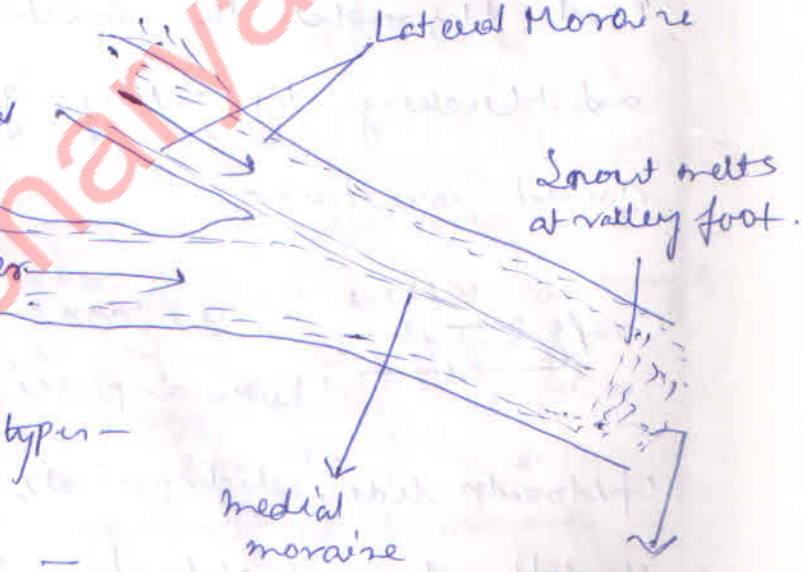
Crag & Tail – The crag is a mass of land rock with a precipitous slope on the ~~upstream~~ side, which protects the softer leeward slope from being completely worn down by moving ice. It therefore has a gentle tail. Such landforms are developed over old volcanic or basaltic plugs above the ground surface as resistance knots

Roches moutonnees — This is resistant residual rock has hummock. The surface at the upstream side is smoothed by abrasion and its downstream side is roughened by plucking.



Depositional Landforms

Moraines are ridge-like depositional features of glacial tills. They are of four types—



① **Terminal moraines** — are formed due to deposition of glacial till across the moving ice sheets of glaciers after ablation of ice. The recession of glaciers or ice sheets results in the deposition of several irregular ridges, mounds separated by basins. Such

landscape is called 'Knob and basin' topography.

④ Lateral Moraines are parallel ridges of till on either side of the glacier.

⑤ Medial moraines are formed due to deposition of glacial sediments along the internal margins of two glaciers at their confluence.

⑥ Ground Moraines are formed when glacial sediments are deposited at the floor of glacial valley.

Drumlins

Drumlins are elliptical or ovoid hills, resulting from the deposition of glacial till. They generally posses a steeper upglacier slope, with an elongated downglacier tail. Usually these occur in cluster and typical pattern. Such topography is called 'Basket of egg topography'. Colonies of drumlins are found in Finland, Northern Ireland.

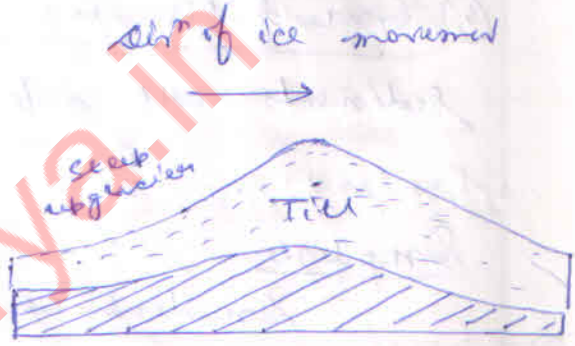
Origin of drumlins

① Several recessional terminal moraines parallel to each other are formed due to recession of glaciers during interglacial period. During next glacial period, the advancing

glaciers erode the upglacier sides of preexisting terminal moraines and deposit the eroded material on the downglacier side

② Acc. to another view point, when the glacier is overloaded with sediments, these are not carried upto the snout but are deposited below the ice & form mounds. These ice mounds grow in size & become drumlins

③ The 3rd group of geomorphologists is of the view that drumlins are formed due to fluvial erosion. Acc to them mounds are formed due to deposition of huge amount of boulder clay during glacial period. These mounds are later modified by fluvial erosion during interglacial period.



GLACIO - FLUVIAL DEPOSITION

The deposition of sediments after the ~~ab~~ deglaciation (melting of glaciers) is called glacio-fluvial deposits and landform resulting from such deposits is called glacio-fluvial landforms.

① Eskers - These are long narrow, sinuous ridges composed of sand & gravel which mark the former sites of sub-glacial melt-water streams.

② outwash plains - These are made up of fluvio-glacial deposits washed out from the terminal moraines by the streams and channels of the stagnant ice mass. e.g. - North European plains.

Kames : Small rounded hillocks of sand & gravel may cover part of the plain. Where the deposition takes the form of alternating ridges and depressions, the latter may contain Kettle lakes and give rise to characteristics Knob & kettle topography.

S.N

① Periglacial region

Periglacial areas are those which are in permanently (perennially) frozen condition but without permanent ice cover on the ground surface. Periglacial areas are characterized by permanently frozen Subsoil (~~peat~~ permafrost), seasonally thawed topsoil (active layer), frequent changes of temperature (Avg annual 1°C to -15°C) and an incomplete vegetation cover.

Permafrost are the permanently frozen ground without permanent ice cover. The greatest depth (600m) of permafrost has been discovered in northern Siberia. Permafrost are of 3 categories.

- Continuous
- discontinuous
- Sporadic.

Active layer or the top layer of permafrost is characterized by diurnal freeze (during night) & thaw (during day time) cycle during the intervening periods of summer & winter seasons. It is completely frozen during winter & thawed during late summer.

② Congelifraction

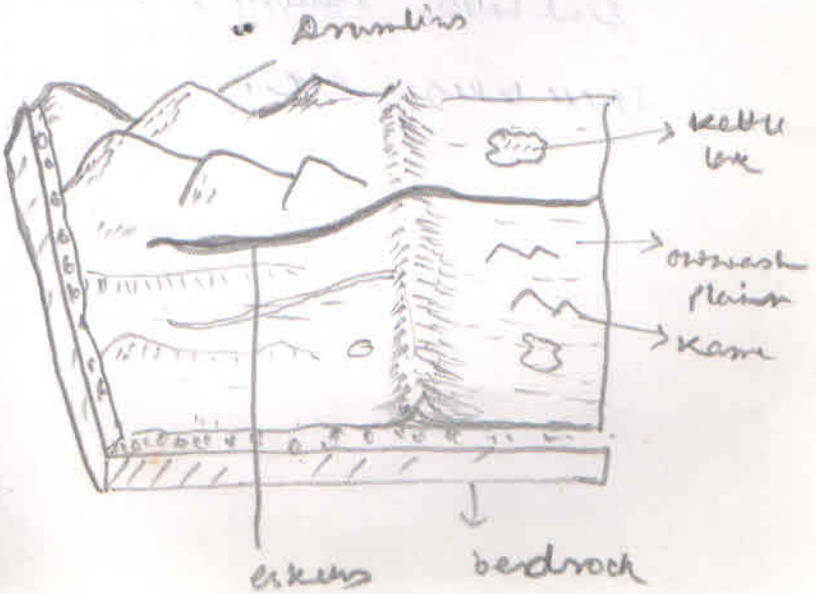
Congelifraction, simply known as frost weathering includes freezing of moisture and water during night and subsequent thawing during daytime (in summer) making a complete 'diurnal freeze thaw cycle', which disintegrates the rocks because of continuous alternate expansion and contraction.

③ Frost Heaving

Frost heaving is connected with freeze-thaw cycle but it is given separate entity as it helps in moving the coarse grains upward. Frost Susceptible grains in the active layer are frozen during night in Summer and therefore, they expand their sizes. Vertical. Repitition of this mechanism brings larger particles on the ground surface & it appears as if ground vomits stones. This vertical thrust gives rise to the formation of patterned ground including stone circles, stone polygons, stone nets etc.

④ Nivation

is a wide term which includes variety of subprocesses related to the snow patches either immobile or semipermanent. The process of nivation includes the subprocesses of weathering under a snow-patch, meltwater erosion from beneath a snow patch & downhill erosive creep of wet or saturated snow.



⑤ Thermokarst

Thermokarst, though similar to the karst topography of carbonate rocks in appearance, vary significantly from the karstic landforms because the latter are formed due to chemical reactions of water and consequent dissolution of carbonate rocks, whereas thermokarsts are formed due to thawing of frozen ground in permafrost areas because of changes in thermal conditions. In fact, thermokarst refer to negative landforms (sinks & depression) which are formed due to collapse of ground surface because of thawing of ice of the active layer. Thus karstic landforms are lithologically controlled, whereas the thermokarstic landforms are thermally controlled.

Thermokarsts include surface pits, sinks, sink holes, hollows, ravines, dry valleys, caves, thaw lakes, etc.