MUDIT JAIN

GEOMORPHOLOGY NOTES

DECODE ETHICS BOOK BY MUDIT JAIN AND 18 OTHER OFFICERS:

KBC-NANO

For Civil Services Mains Examination–2019

DECODE ETHICS

ETHICS, INTEGRITY AND APTITUDE

2013-2018
QUESTIONS SOLVED
by
19 Officers

TOPICWISE QUESTIONS
200 Diagrams

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PREFACE

Ethics, integrity and aptitude subject, better known as GS-4, has been a cause of concern for many aspirants of CSE. This book compiles the notes that the author gathered over the course of his preparation and which helped him manage 110+ thrice.

This book covers each and every term mentioned in the syllabus and solutions of all 6 Ethics papers so far (2103-2018). These papers have been solved by 19 officers from various services. The book also includes various applicable theories and sample questions.

The content is mentioned in bullets and points form that can be easily understood as well as reproduced in tricky questions that are asked in CSE.

This book includes 200 diagrams as part of answers and theories-concepts so that these can be used for answer writing. Also, there is a compilation of many quotes which are an asset for answer writing.

The author is sure that "Decode Ethics" will help the aspirants to decode the art of scoring high marks in Ethics paper. Happy reading!

Acknowledgements

I would like to express my gratitude to many people who saw me through this book. I am thankful to my family, teachers and mentors for making me capable enough to write this book.

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Geo morphology MUDIT JAIN

Relief is divided into 3 orders: 1st, 2nd, 3rd.

1st: Global view : continental crust / oceanic crust

2nd: belonging to both continental & oceanic [Mts, plateaus, ridges etc]

3rd: valleys, delta, submarine canyons [exogenetic feat.]

Relief is dynamic as it is subjected to 2 forces: Endo & Exo

Endo are developers of varian. Exo: levellers.

Geological time (chronological descripn)

Chronological desc of earth's history since T of its incepn is GT.

Approach of studying GT inc Relative & absolute time.

Relative T: a geological scale whr relief dev are outlined in ref to Pre & Post dev. It inc 4 principles:-

① Princi of superimposition:- funnel succn.
• low lying strata is always older than overlying strata.
This princi is complemented by princi of funnel succn which states that embedded fossil remains in low lying strata is less defined than overlying strata.

② Princi of cross bending relations:- Magma intrusn are always younger than rock stratas they intrude in. This justifies forman characteristics of Plutons.

③ Princi of fragmental inclun:- Rock fragment are younger thn non-eroded rock strata over which they are deposited → Rock weathering post forman.

Significance of relative time is restricted only in context of unconformities which are unexplained gaps b/w distinctive forman developed due to processes that LF is subjected to. To Analyze this absolute time scale was developed.

Absolute time: (1) Azoic Era : no visible life. 4000-600 mn yrs ago. Incorporates pre-cambrian epoch.

This era relates to origin of earth crust by initial cooling & solidifican of outermost layers of earth : solidified crust made up original relief forman of earth called shield or cratons. continental shield forms fundamental complex facilitating dev of present shape and size of continent. Dev relates to attachment of terranes, endogenetic dev & exogenetic dev.

cooling, solidifican → shields [illegible]

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Terranes are smaller, fragmental parts of original shields that with T accreted with bigger size shields. → shield enlargement + tectonic features. ex along eastern shoreline of Pacific ocean in vancouver island of north america & chiloe island of S. america, African shields, Eurassian shields, Aus shields. Also bcz of endogenetic forces of subsequent eras, size of continents increased

ERAS	Period	Epoch	Features
AZOIC	—	Pre-cambrian	
Paleozoic	Primary COSDCP Mount	Cambrian, ordovician, silurvian } lower Paleozoic Devonian, carboniferous, Permian } upper	old life 600 mn – 225 mn ago Important for mountain building coal bearing strata.
Mesozoic (silent tectonic wise)	secondary TJC X	Triasic Jurrasic cretaceous	Mid life 225 – 70 Silent tectonic Era.
cenozoic	Tertiary PEOMP Mount	Paleocene Eocene oligocene Meocene Pliocene	70 – 1 mnyr ago All young tectonic feat.
Neozoic APMC N	Quaternary PH	Pliestocene Holocene	• 1 mn – till date • sudden endo forces • Pliestocene imp 4 present day worldmap • Holocene for evolutn of hamosapiens • green areas on world map = neozoic era.

4600 – 600 – 225 – 70 – 1 – Present.

Factors influencing earth crust :-

- endo
  - diastrophism (slow)
    - periogenic — continent building (vertical)
    - orogenic — Mountain building (horizontal)
      - ← compren → Plastic deformatn (strain) → folds
      - ← Tension → faults ← reverse, normal, transform, transverse, thrust, overthrust (shearing)
  - sudden
    - volcano
    - earthquake
- exo
  - weathering
  - gradation — River, glacier, wind, sea waves, un water.

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Dynamic nature of relief feat of earth crust due to endo + exo as outlined by father of geomorphology davis. endo are variability developers while exo are levellers. endo are genesis of endo in interior of earth. (mn yr to vary surface)

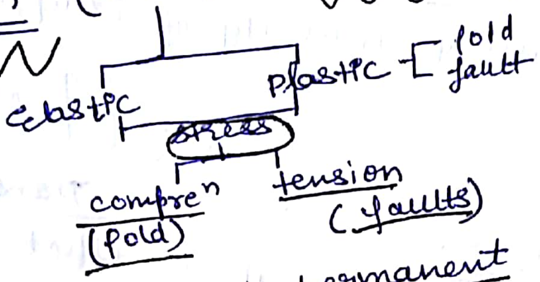
Types of endo < diastrophism (slow) / sudden forces

diastrophism inc Eperiogenic & orogenic.

Eperiogenic are continent building & vertical force, continental building is around fundamental complex (shields). These are applicable at sub-continental levels only.

Deformation (Strain) = change in shape & volume of rock)

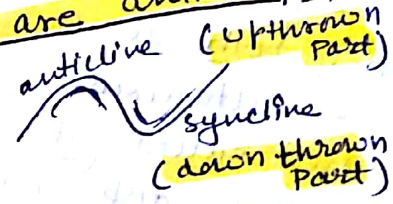
Deforman is Δ in shape & vol that rock strata is subjected to due to appⁿ of stress

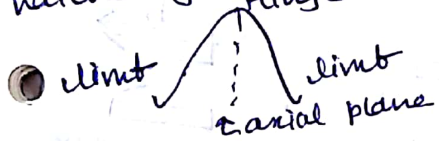


Plastic deforman are permanent & taken in a/c for geomorphological analysis. These are folds / faults.

folding is due to compreⁿ stress. inc limbs, Hinge, Axial Plane.

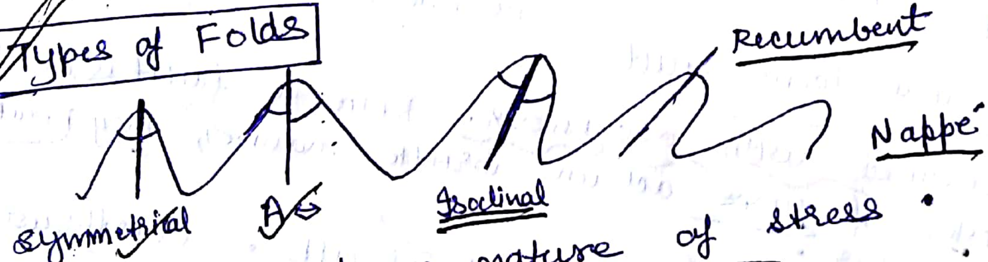
limbs: Part of fold. Hinge: line joining all hinges make axial plane. intersecⁿ pt of limbs. These 3 are analyzed to know nature of stress. In ref to relief, folds are anticline / syncline





limbs → hinge → axial Plain
studied for nature of stress → fold type

Types of Folds



Fold type depend on nature of stress. scale consideraⁿ divides folds into Major & Minor. inc

Major folds that can be outlined in global perspective (with axial plane).

1) symmetrical folds (limbs make equal ∠ & Andean cordilleras of N. America

ex: W. cordilleras of S. america.

2) Assymmetrical limbs make diff ∠s. ex Himalayan cordilleras & alpine ".

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③ Isoclinal Plane : largely denotes similar angular dip of limbs with ex himachal range of himalayan cordilleras

④ Recumbent : abs or near horizontal axial planes. ex at variable ranges of all 4 young fold mountain cordilleras.

⑤ Nappe : Broken fold. at either ends of himalayan cordilleras (|| mt ranges).

MINOR FOLDS : not recg at global scale. inc :

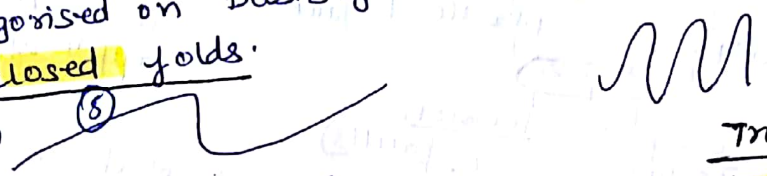
① Monoclinal : 1 limb only. No hinge / plane. anticline & syncline

② Chevron : lacks typical curvatures of represent Δ slopes. ^. multidirn compren stresses. It has

③ Fan folds : unique. anticlinorium & synclinoriums.

Minor folds categorised on basis of intensity of compren stress into open & closed folds. closed.

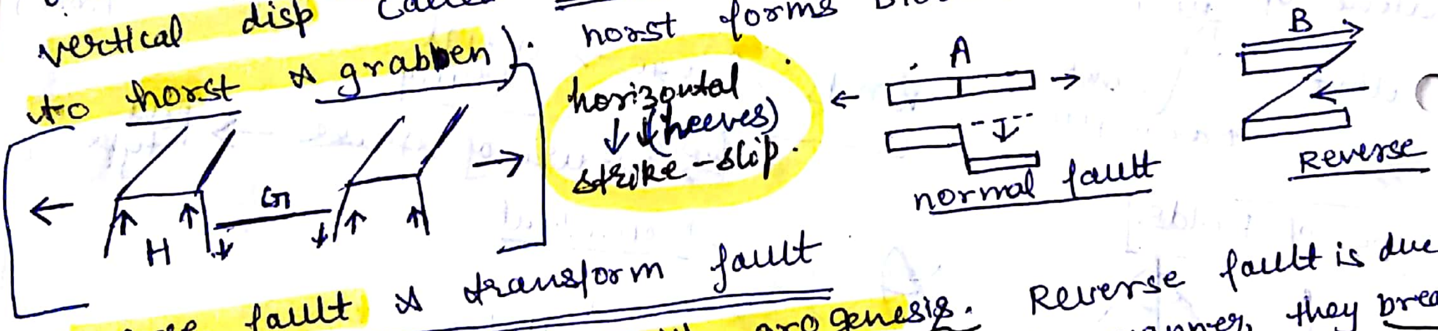
④ open ⑤



Faults by tensional stress. Transverse = shearing

Normal tensional stress has pulling apart effect while Transverse " " " shearing stress.

* In both dir of horizontal displacement generates fault & horizontal disp. Technically simultaneous orogenic effect. horizontal disp strike-slip faults while are called cheeves that generate Dip-slip fault (related vertical disp called throw generate graben form rift valley. to horst & grabben). horst forms block mt.

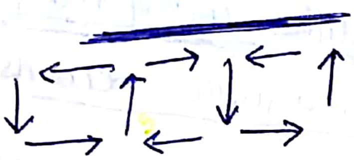


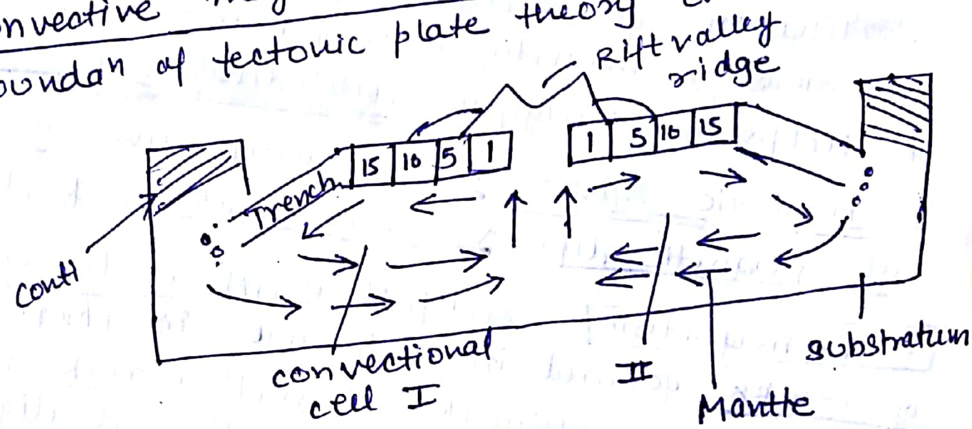
Reverse fault & transform fault

- largely not associated with orogenesis. Reverse fault is due to compren stress wher if rocks act in brittle manner, they break & ride over each other.
- Reverse fault inc overthrust & thrust faults. overthrust is absolute override of crustal slab over other while thrust represent some der of ∠.
- Transform fault represents type in which faulting occurs due to differential rate of movement of rocks. These are complementary developments relating to major crustal movements.

sea floor spreading — Harry Hess 1961

mapping of ocean floor became central theme in 1950s. These mapping evidences showed that sea-floor is equally active & conti crust in dev of tectonic feature. Hess, developed SFS on basis of evidences gathered by analyzing sub-marine topography emperically. He analyzed Albatross plateau of SE pacific & challenger ridge of S atlantic. He concluded both spreading & converging boundaries of sea floor. At spreading boundaries, magma from interiors of earth facilitate forman of submarine ridges. He also concluded presence of paired nature of rocks. → signify similarity of time of formation. Increasing age of rocks away from central ridge was an evidence. destrucn of existing oceanic crust at converging boundaries explains absence of azoic rocks. This conveyer belt aproach complemented CDT. Recgd convective magma currents outlined by Arthur Holmes. foundan of tectonic plate theory credited to him.





albatross' & challenger's bathymetry
conclusions

1. spreading & converging boundaries
2. MORs at spreading...
3. Paired nature of rocks at MORs.
4. ↑ing age away from MORs.
5. Absence of Azoic rocks due to converging boundaries.
6. complemented CDT by conveyor belt approach.
7. recgd convective magma currents of Holmes.

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Geomagnetism

Magnetic prop of earth identified by geomagnitism. Formal begining in study by william gilbert. He identified that ferrous interiors of earth forms the cause of magnetism as it is molten & mobile. He said, magnetic characteristic of earth is continuously generated & maintained by radioactive disintegran & gravity transfer of ferrous constituents in earth interior. 3 imp components of geomag:

① **Magnetic Declination**: horizontal component of GM. It is ∠ular inclination b/w geographic & magnetic poles. ∵ N. Mag pole is west of N. geog Pole & SMP is in east of SGP.

* This helps in distinguishing age of rocks.

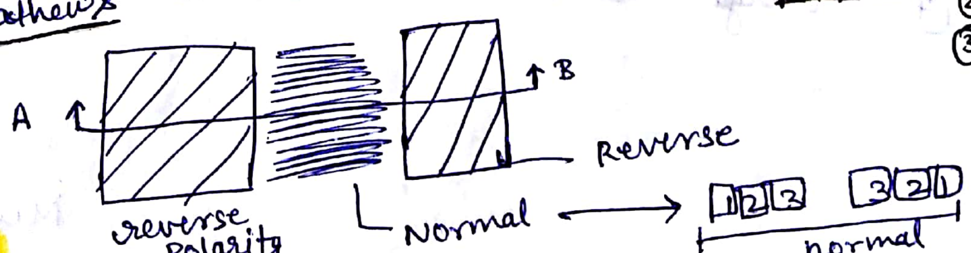
② **Magnetic Inclination / Dip**: vertical component. It is ∠lar inclination of freely suspended magnetic needle wrt proximal positions of magnetic & geog poles. It increases with ↑ in lat. (ii)

* Helps in identifying latitudinal locn of rock forman.

③ **Magnetic Equator**: imaginary line joining places with 0° of magnetic dip. ≠ geog equator. * identifies locn of rock formn.

Paleomagnetism: subfield of GM analyzing magnetic records of rocks formed in diff ages is PMG. molten rock material magma act as The ferrous constituents of needles & align themselves to earth's freely suspended magnetic polarity. This allignment is maintained in rock (even on deforman). Analysis of these rocks prove changing posin of the continents in geological past. contributors of PGM inc Runcorn, Fredvine & Mathews. Runcorn's contri since 1950. Attempted He concluded changing magnetic declinan in geog past. plotting Δ in N. magnetic poles posin in 500 mn from Hawain islands via siberia to present bathrust Island of canda. He concluded that rocks form at same geological T have diff LAT's Posin. He " jig-saw fit of North continents reviving CDT. Fredvine & Mathews contribon is largely outlined as zebra strips.

Runcorn: ① Δ declinan ② Jigsaw fit ③ rocks form at diff LATs at same T



Vine mathews: ① zebra strips ② Dip varian

↑ dist from Ridge, Anomalies ↑s.

In mapping ocean floor Vine & Mathews concluded existence of oceanic crustal rocks with variable magnetic allignment. They outlined it to alternating bands of normal & weak or reverse polarity. (zebra strips). At macro level these denote older crustal rocks with reverse polarity & newer due to ↑ing distance from SFS with normal polarity. At micro level, zebra strips are present magma rise → ↑ age, ↑ anamolies. at conti crust too but due to ↑ exogenic forces, original characteristics are not maintained.
* no exogenesis on oceanic crust. ∴ called base erosion level.

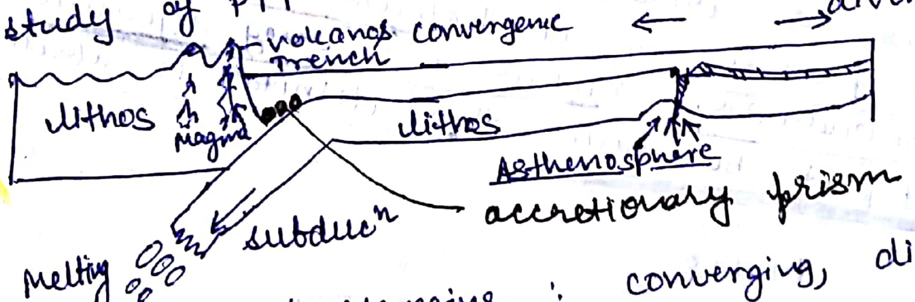
older → away from MOR, reverse polarity, ↑ anomalies

saw variable magnetic allignments → gave zebra strips.

Plate-Tectonic Theory

Parker, Morgan, Wilson etc.

In 1960s explained major endogenic activities. Prominent contributors are Tuzo-Wilson, Woolbudge, Morgan, Strahler, Harry Hess. Plate is division of lithosphere into oceanic i.e. heavier basaltic plate & continental i.e. lighter granitic plate. These plates move under effect of convective magma current over sub-stratum called asthenosphere in relation to each other. This movement causes tectonic activity at plate boundaries/margins
∴ study of PTT is study of plate boundaries.



Basalt → andesite → granite.

Plate boundaries/Margins : converging, diverging, Transverse (California plate).

converging : Most imp geomorphological plate boundary as these relate to conti crust at present. These are resp for earthquake & fold orogenesis. volcanic activity occurs only during destrucⁿ of existing plate. 3 subtypes:-
(destructive boundary)

① Ocean - continent covergence & major extenⁿ of mid-continental belt. young fold mts, volcanic activities & seismic activities relate to these locations. (Himalaya of mid-conti belt is C-C) (absence of subducⁿ → no volcanos). C-C is coliding boundary.
Entire circum pacific belt

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continuous collin of these granitic crusts have led to the doubling of crust in S. part of C. Asia (1 of d reasons of high height of Tibetian Plateau).

O-O is destructive & relates to sub-marine features. In these denser (largely, older oceanic crust) subduces developing destructive boundary → forman of volcanic island arc ex Scotia plate – Atlantic Plate → Island arcs of S. georgia & S. shetland.

diverging largely associated with sub-marine crust. collectivly called as oceanic divergence. Involve volcanism & earthquak as major tectonic activities. ex Mid atlantic rige, mid-I/O ridge etc.

* It's subtyp is intra plate divergence in N. Pacific ocean that correspond to Hawain hot-spots.

* on conti crust, diverging boundaries found at East Africa, Arabia. Divergence of minor plate somalia from main African plate forms ex of intra-plate divergence → tectonic ,, ,, also arabian plate – Africa ,, ,, ,,

Transverse / conservative It relates to sliding pass effect of shearing stress. All 3 tectonic plates resulting into dev of california plate – N. America plate tectonic activities associated. ex in W. cordilleras of N. America * Justifies existence of block mts

* PTT used to study tectonic features. theory emphasizes active boundaries → fails to explain forman processes of old tectonic features which are related to tectonic forces that not located on boundaries. But as PTT very dynamic this limitan is absolute. locational char of plate boundaries

Plates
- convergent
  - O-O
    1. oceanic crustal features
    2. Scotia-atlantic
    3. Volcanic islands.
  - C-C
    1. colliding boundary
    2. volcano
    3. Himalaya
  - O-C
    - lithos features (Mt, quakes, volcanoes)
    2. Mid-conti (-Him) & circum pacific
- divergent
  1. (oceanic largely) MORs: volcano quakes
     - inc intraplate divergence too (Hawain HS)
  2. conti at arabia-Somalia.
- Transverse (conservative)

Volcanism

on basis of locn of ejection of magma

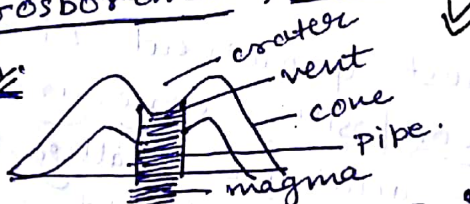
- extrusiv
  - fissure (basic) (mafic)
  - central (active)
    - Hawain (quiet)
    - Strombolian (quiet)
    - vesuvian (intense)
    - Pelean
- Intrusive (plutonic)
  - Tabular
    - concordant
    - discordant.
  - Massive

→ HSVP

Volcanism : sudden endo force having potentiality of developing surface LF features. It represent processes involving movement of molten rock material 4m earth interior to surface. Magma makes up most imp ejected matter. It is felsic & mafic Type

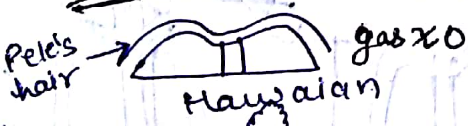
→ Felsic magma has 70% silica → ↑ viscosity → acidic magma.
→ intense activities compared to Mafic having 50% silica
→ more mobile/ less intense activities / basic magma. These also determine other ejeculants = gases, pyroclasts
nature & intensity of activity.

extrusive Volcanic activities co-relates to ejecn of molten rock material on surface of earth. Relates to fractures dev on earth surface. It generates fissure type of activity & magma is generally basic → travel long b4 solidifying → basaltic lava plateau. It's formed in active as well as transform. euthopian ex Plateau of Bosborema, Kordofan tableland, highland, deccan.



basic lava plateaus [Kordofan, Ethiopian, Deccan.] fissured features.

central type of extrusive volcano : ① along active boundary ② well specified passage (Pipe)
③ Pipe connected to molten interior of earth called volcanic cones
④ Relates to most reg volcanic feat of activity.
⑤ 4 types on basis of intensity HSVP



quiet ←

→ Intense

Hawaian | stromboli has ↓ trapped gases. Hawaian nearly 0.
→ quiet. Feat of Hawaian type is Pele's hair that compared to very quiet magma moving down the slope [gases + molten rock ejected] little more Intensity in strombolian justifying weak Intensity. Mudit Jain
gases ... move downslope

∴ condensn / Precipitan missing. Related to destructive & transverse plt

Vesuvian is ~~commonest~~ type. Throws gases to grt heights → condensan / Precipitan → Lahar (always). These are mass movements of water saturated pyroclasts downslope. This is economically good as volcanic soil layers develop at foot of the cone. Further intensified vesuvian bcms pelean.

Pelean (↑↑ destructive) throws magma patches to grt heights & generate → glowing / burning clouds. It blows up cone in pyroclasts. Lacks Lahar. only 2 ex are Karakatoa in gr Sunda E. India & Martinique (WI).

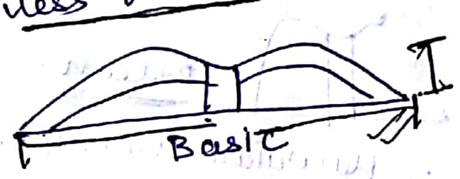
*Analysis of central type (Most common) bcms complete wd ref to PTT which justified activities based locational characteristics. In acc to theory, Hawaian type is related to oceanic divergence where gases are ↓ & magma travels ↓ distance ex Mt Mona Kea of Hawaian, visovian is wid destructive plate boundary. (cotopaxi (ecuador), Fuji, Mt Baker) at mid-continental. at circum pacific & (vesuvius, Merapi)

Volcanic LFs

① Lava Plateaus // fissured volcanoes
② Volcanic cones & associated feat. [central type HSVP.] } ext reliv
③ Intrusive feat.

② : **cones & feat** most prominent LF of volcanism. on basis of magma composin, cones are acidic | basic cones.

- Higher viscous magma → acidic cone [taller, steep slopes] + narrow base.
- Basic (Felsic) cone → gentle slope, ↓ height, broad base.
- Composite cones inc diff stratas of cone of diff compositional Magma.
- Cinder cones which marks filling up of its crater by unconsolidated pyroclast → conical shape.
- Parasitic cone has ≥ thn 1 openings of pipe → range of ancilleres within the same zone, ↓ height, less developed craters



Basic

composite

↑ acidic

show height

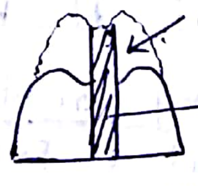
Parasitic

cinder

(Mt Mayon).

dormant plug dome

→



caldera

Plug dome

→

extinct

volcanic neck.

dev of well defined crator signifies to continuity of volcanic activity, for **dormant** volcano crator developes feature called **crater lake** ex Lake toba Indonesia. It is due to Pressure exerted by water accumulation in crator or due to lowering up of existing volcanic cone due to ↓ activity. This crator enlarges to form **Caldera**, **plug dome** is present and it is larger thn crator. solidified/exposed vent is seen. These are feat of eron → plug dome → rough volcanic rock)

extinct volcano

principle of cross bending relations

Intrusive features | **Plutonic**

- solidification of magma within existing lithos layers. Units movement towards earth, these solid intrusion rep newer features than the host rocks. Attain diff shapes/orientation. On size basis, Massive plutons differ from tabular plutons. Massive plutons are batholiths. Small batholith < 100 km² exposed characteristic is called **stock**. ex: Dartmoor range.

dyke — sill — Phacolith — laccolith — lapolith.

2 subcategories of tabular plutons

Acc to nature of developed beds of magma

① Con-cordant features

where magma solidifies in horizontal/near-horizontal profile. ex Pallisade sill along river Hudson

ex plutons called sills. solidified magma ex High veld.

Laccolith ∩ : dome shaped developed low lying table land.

Lappolith ∪ : saucer shaped. ex Bush veld plateau.

Phacolith ~ : when exposed wavy magma deposits incorporating crests & trough

② Discordant features vertical/near vertical.

Dykes ex Ukmes range in Zim.

(Horizontal) Sill ✓ Pallisade sill ✓

(wavy) Phacolith ∼ ✓ [redacted] ∪]

(saucer) Lappolith ∪ Bush veld ✓

(dome) Laccolith ∩ High veld ✓

(vertical) Dykes ✓ Ukmes range (Zim)

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Earthquake

deformed rocks → sudden energy release → sudden quacking

sudden endogenetic force that can modify existing lithos feat

It is sudden quacking of earth crust due to sudden release of accumulated energy in deformed rocks.

* Plutonic spot whr rocks begin to deform/shift : **focus**.
* Epicentre is pt on earth surface directly abv focus.
* Energy released at focus due to deforman of rocks is transmitted via adjacent rocks as energy waves called seismic
* seismic waves help in eqiury abt char of quake.

BSP — compreⁿ / distortion

seismic < **Body** — P (**compressional**), S(**Distortional**)
Surface — R (Rayleigh), L (Love)

Energy waves that moves via interiors of earth is Body waves generated at focus. These have compreⁿᵃˡ / distortionᵃˡ movements.

compreⁿᵃˡ waves (P) travel by compressing medium & rocks experience **alternate compreⁿ & expanⁿ**. These affect **vol of** medium n/t shape. Also called Primary waves being fastest & 1st to be recorded on seismograph. 7 km/sec

distortional waves (S). called so as they induce shearing stress on rocks; **Rocks pulled up & down** in wave direcⁿ/Propagan. as V= These affect shape of rocks. Also called secondary wave

(distorⁿ) S(shape) . P(volume) (compreⁿ)

3.5 km/s

* Body waves P & S help in studying earth's interior. Move on surface

surface waves register the dev at epicentre as geomorphic agent. at 2.5 km/sec : These justify earthquake as geomorphic imprints generated by these are :- 3

LHW

① GROUD SHIFT (GS)
- most identified geomorphic effect played by earthquake [R or L]
- 2 categories of GS on basis of kind of wave
- horizontal GS in case of whipping motion of L waves
- vertical " " " sea-swell " " R waves

R S V

② Liquifaction mass movement of withered, saturated mass movement due to quacking.
- enhancement of mass movement
- At elementary level quake triggers psblity of downslope movement of withered rock material which facilitates levelling.
- It also ↑es downslope movement of water saturated material specifically in terms of its velocity. → avalanches | solifluction.
- It also develops temp embankments at foot of tall raised figures which then develop temporary lakes → floods later.

* This is delayed imprint of natural hazard by quake.

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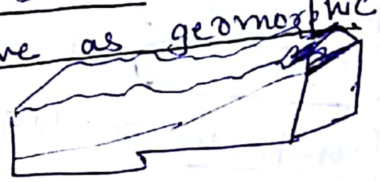
③ Tsunamis & seiches — water piles up at tectonically generated crustal depreⁿ.

In case of submarine quaks of ↑ intensity seismic sea waves called Tsunamis are generated. This can be called as strong vertical ΔS in ocean floor. → sequential whipping & rising of ocean / sea water level at tectonically generated crustal depreⁿ & sea water piles up at tectonically generated crustal depreⁿ. Here fast moving sea attempts to return to normal level. ↑ λ (160-180 km) waves called Tsunamis are generated. on reaching & extremely short wave height (.5-3 m only). shore thr is tremendous ↓ in velocity due to shallowness. water tends to pile up at shores. these waves have height of 15-30 m which develop extremely strong breakers & ∴ surfing effect → significant delay in backwash makes water gush in interiors.

3m to 15-30

Tsunamis of marginal water bodies called seiches represent same mechanism but it is more effective as geomorphic agent due to proximity to shoreline.



Behaviour of seismic waves & earth's interior

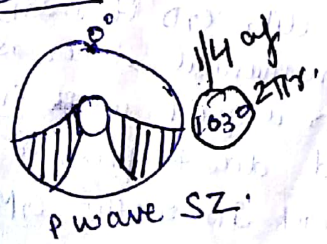
① study by Body waves only & not surface waves [R, L].

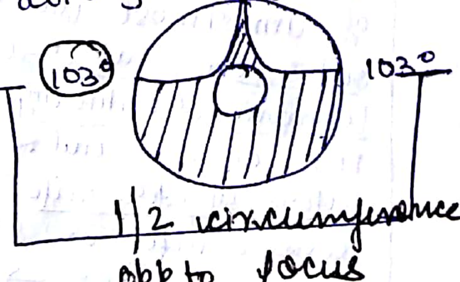
② Primary wave capable of moving via both mediums which in interior of earth. It is inelasticity of liquid medium & deviaⁿ in flow direcⁿ. (P) justifies ↓ in velocity of wave thru liquid.

③ S waves do not travel thru liquid facilitated link b/w seismic wave behaviour & earth's interior [here Body waves are not recorded]. shadow zones.

④ In 20th cent, shadow zone of S waves occurs half the circumference of earth on opposite side of focus justifying its disapperance beyond certain depth in interior. [Gutenberg calc 2900 km]. This marks boundary b/w mantle & core (M-C). S waves till Gutenberg justifying outer core to be in liquid state. quarter of circumference

⑤ shadow zone of P waves runs via interior of earth causes shadow. Refracted coarse of P waves via liquids. P waves shadow zone inspite its ability to move due to its refracted course.





shadow zone of S-wave.

liquid → ×S
P (↓vel, dirⁿ changed).

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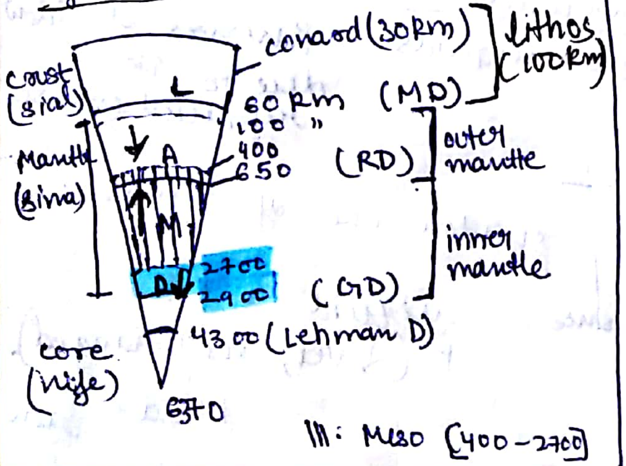
formaⁿ of earth incorps imp imprints of sorting or differentiaⁿ
→ 3 compositional layers are distinct.

CRUST outermost. depth 60 km from earth surface. In case of conti cratons ≈ 50 km. Skin of earth. depth of crust in mt region it can be 70 km. Sialic composⁿ. however in mt region it can be 70 km. This compositional layer is density (2.8) g/cm3, This compositional layer at 60 km distinguished from subsequent compositional layer. Crust / brittle that corresponds to Mohorovicic discontinuity demarcated by outer layer divided into outer n inner at ≈ 30 km. Conrad discontinuity, Moho &

Mantle : 80% of earth Vol. 60 km - 2900 km has well gutenberg discontinuity respectively. Mantle

* compositional layers : sial, sima, nife
* Mechanical " : lithos, Asthenos, Mesos.

reference i.e Repetti discontinuity demarcated sub-division of compositional called at 650 km ≈ outer & inner mantle. it is divided into lithos, ~~In terms of mechanical layers~~ lithos layer (100km) inc complete crust asthenos, Meso & D layer. → upper rigid outerlayer of earth & upper 40 km of mantle. no significance of Moho in determining seismic wave justifying sub-strata behaviour. Below lithos is partially molten low velocity zone Asthenosphere upto depth of 400 km. It is (decrease in velocity). Reacceleraⁿ for both body waves (80% decrease) Mesosphere. As beyond 400km justifies mechanical layer & radioactive (↓) this layer lies in transition b/w effect of frictional drag disintegraⁿ, related temp ↑. From inner boundary of mesophere (2700km) to gutenberg (2900km) thr is existence of IInd substratum of mantle called D layer. Here also body wave's velocity ↓.



Innermost layer of earth, core b/w (2900-6370 km). compositionally this is nife layer, densest of all layers. subdiviⁿ of innermost layer demarcating inner n outer core at 4300 km depth marked by Lehman discontinuity. like GD it demarks both compositional & mechanical layer as outer lighter nife is liquid while inner denser nife is solid due to pressure of overlying layer → imp in earth's GM.

||Exogenesis Process||

Normal cycle | davisian concept | fluvial cycle

WM davis, American geologist propounded concept of normal cycle of erosion. Based on empirical observation he attempted to generalize role played by water as an active agent of gradation. In dev of LF features he developed approach on foll assum.

1. It is after endogenesis, that exogenesis begins.
2. exogenic downcutting relates to formation of well specified stages of LF development
3. climatic condition in specified location are static
4. end product of cycle of erosion → featureless lowland Peneplain

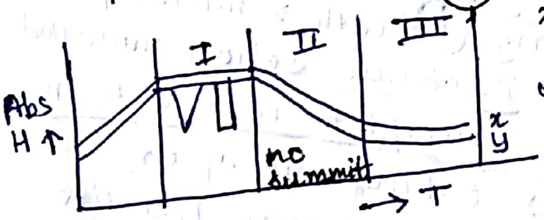
∴ He outlined landscape is function of str, process & stages

$LF = f(S, P, St)$

- With term [structure] he attempted to outline constituents of relief feat. Used str to emphasize on fact that str is dominant control factor in evolution of LF. Relief wid less resistant construct accelerates the cycle of erosion while opp is also true. He inc all major characteristics like joints / permiability of rocks etc.
- With [Process] he attempted to outline endo / exo process where endo were variability developer & exo are levellers recognizing 5 diff levellers. All these ↑ relative height ito facilitate ↓ in abs height. He also highlighted diff in effectiveness in diff location, forming exogenetic agents as per the diff LF.
- Term [stage] inc ② 3 stages: young, Mature & old

Levellers: ↑ rel H
↓ abs H

x = water divide / summit
y = valley floor.



[Young state] begins with completion of endogenetic upliftment. River starts developing long profiles of channels. River also marks dev of variable set of features relate to valley deepening, widening & deposition. Here V-Deeping features as V, I shaped valleys, rapids, cascades waterfalls are dominant. Stage also marks dev of ungraded long profiles of diff channels. The cutting of summit and then its complete removal by these channels mark begining of mature stage along with dev of graded long profiles. Ther is ↓ in abs height [which is dependent on str of water divide, drainage density & mutual distance b/w channels].

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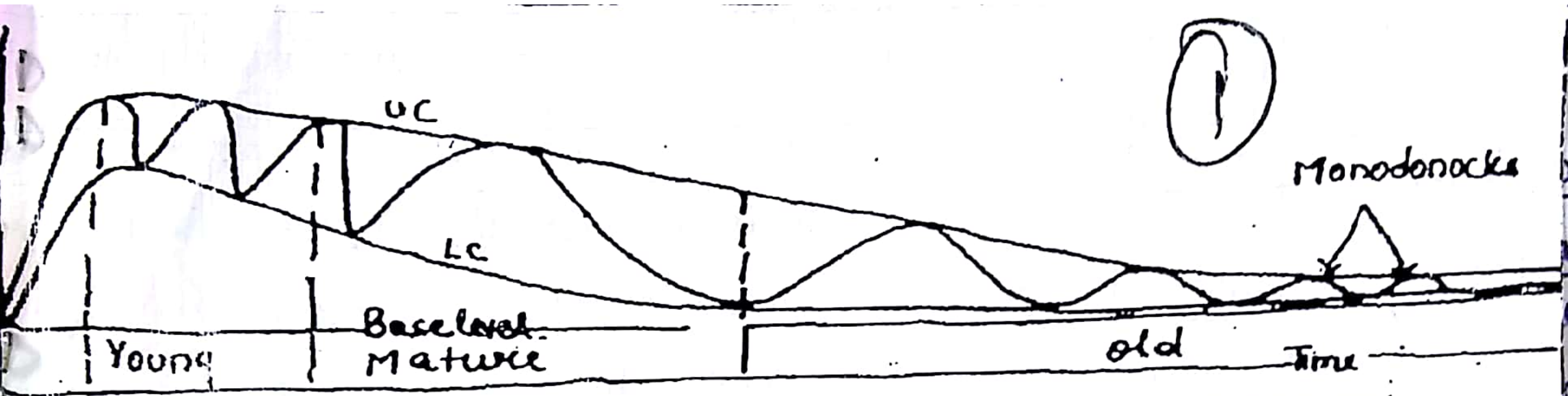
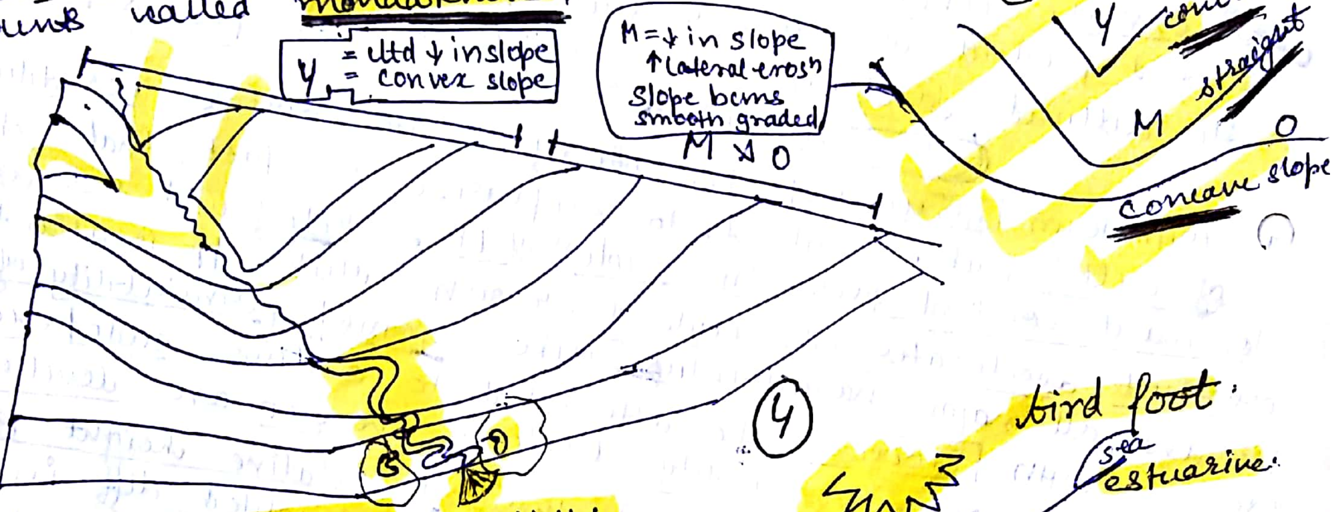


DAVISIAN NORMAL CYCLE OF EROSION

Mature stage : The ↓ in abs H & resultant ↓ in available gradient makes valley deepening significantly weaker as compared to prev stage. there features related to valley widening develop like flood plains, meanders, graded long profile among tributaries is highlighted as transin to IIIrd state.

old stage : It rep near complete removal of variabilities best induced by endo forces. ∴ ther is ↑ depositional activities represented as (deltas). Cycle of eron marks terminan in dev of featureless lowland plains in locan of long profiles of channel (peneplain) dotted with some resistance, thus remnant mounts called monadknocks.



* delta: Δ lobate, cuspate (tooth), (digitate), bird foot, sea estuarine. (5)

critical appraisal

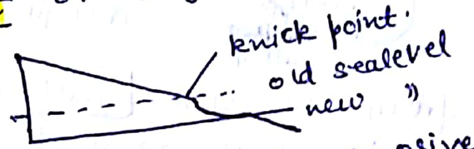
1st version has running water as agent, subsequently he intro glacial cycle & coastal cycle. simple approach. Use of sequential descripn of LF features development. Approach widely followed criticised by german scholar Penck. He propounded endo upliftment (morphological system) & episodic erosion with exo downcutting being complementary. (1) death → misinterpre restricted validity of this approach. Davisian school maintand dominance till 1960s, (2) T opened the concept to wide criticism. upliftment is significantly (3) slow process taking mn of yrs to generate recg feature ∴ levellers cant remain inactive till that time. (4) T taken to complete exogenic cycle have been questioned. Endogenic interrupn in exogenic effectivity relates to approach of Rejuvenation. (5)

Rejuvenation

This approach in geomorphology is related to approach of gilbert who identified that LF features represent dynamic equilibrium b/w tendencies towards variabilities & tendency towards uniformity.

LF has equilibrium in tendency towards variabilities & uniformity.

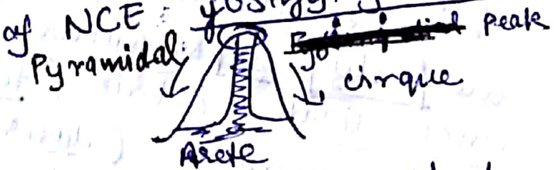
equilibrium b/w 2 processes generate present nature of LFs.
2 types of (endogenic interference in exogenic interference) / rejuvenation are:
① Positive endogenic interference facilitating levelling task ↓↑ either by land subsidence or by rising of oceanic crust. ② Negative on other hand rep endogenic interference that delays levelling task by rising of land or subsidence of oceanic crust. (-ve) It formed incised meanders ① Negative R^n steepen the ② slope so that active downcutting is ③ renewed. A fall in sea level leaves ④ flood plain at ↑sd altitude River with renewed vigour cuts the former flood plain leaving behind terraces ⑤ on both sides. ⑥ Thr is break in graded profile of river marked by rapids. Pt where old & new profile meet is called knick pt ⑦ or rejuvenated land.
ex colorado river in US.



+ve will submerge land, drown valleys & weaken erosive power the flow is checked & large quantities of sediments will b dropped
incised meanders, floodplains, terraces, rapids,
-ves ↓MSL, ↑land level, exposes hitherto sub-sea surface, at higher altitude, ~~knick points, steepen d slope.~~ 2 storeyed valleys

(Glacial cycle of erosion)

moving mass of snow & ice is glacier. snowfields are areas where snowfall always surpasses magnitude of ablation (melting process of snow & ice) resulting into accumulation. Alpine glacier continent glaciers related to ↑ lat are bigger masses of snow & ice but are not identified with stages of erosion. on other hand are lesser mass of snow & relate to favourable availability of gradients & ∴ demarcated stages of eroⁿ cycle. Davis presented GCE as special case of NCE justifying absence of clarity of base level of erosion.



① Young stage
(a) after compleⁿ of endogenic upliftment, dev of snowfield & in relation to it's glacial mass. Begining of moving of glacier sets in cycle of glacial erosion. process of eroⁿ, transportⁿ & depositⁿ reeq in alpine glaciers. However due to dominating presence of developed mt ranges, this stage is

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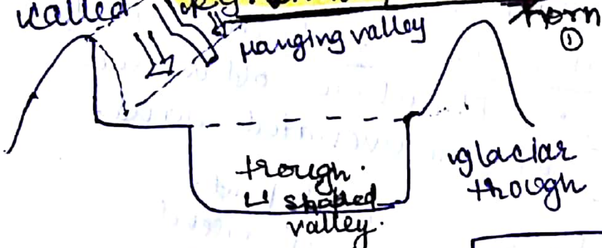
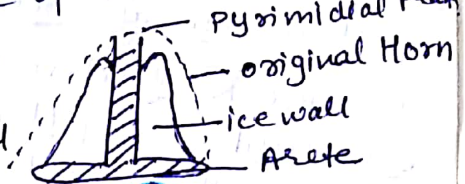
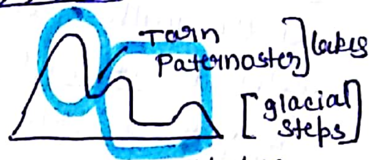
typically identified with dev of horn topography. The upelevated part of mountain rep horn & its steeper gradient restricts fuller accumulan of snow & ice ; downward movement of glacier → valley deepening & Basal sapping (ll retreat of backwall) → arm chair topography due to this dual effect. It has steep standing backwall & depren at base. This is cirque. If 2 or > cirque form along same horn → knife-edge ridges b/w cirque called Arete. rough peak In case of more thn 1 arete along slope of horn, called pyrimidical peak is formed.



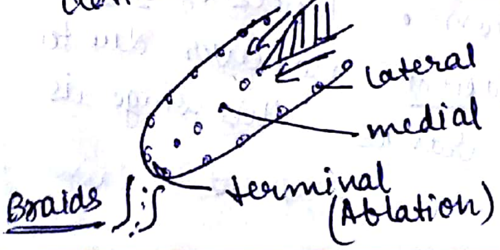
horn T → arm chair T ② (backwall (cirque) (arete) (P-Peak)) ① ↓ col topography ③

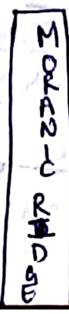




Transin from young to mature is marked by some collapse of pyrimidical peak → ↓ abs H, Transin is > prominent when at identified in context of dev of glacial mass. Mature stage has dominating forman of col topography comprising glacial trough (Ushapped valley) developed by vertical abran carried out by glacier. significant attachment called hanging valley that are less developed troughs of tributary glaciers. Horn topography is also recgd with col, collectively making glacial steps. These erosional depren are identified with var size fresh water lakes sourced by melting glacier. Tarn are lakes specific to cirque while collectively lakes are called Paternoster lakes. Mature stage associates with further thinning of backwall of cirque → complete collapse of horn → old stage.

The old stage's remnant glacier has stronger rate of ablation due to ↓ abs H & thus the terminan of fav climatic condition These remnants facilitate dev of Morainic Ridges (Moraines are only depo features of alpine glaciers) (These are unsorted, unconsolidate debris, tongue shaped), diff types on basis on posin of moranes (lateral, medial, Terminal). These fill all existing depren → end cycle → featureless lowland cryoplain dotted with remnant mounts Nunataks.



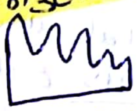


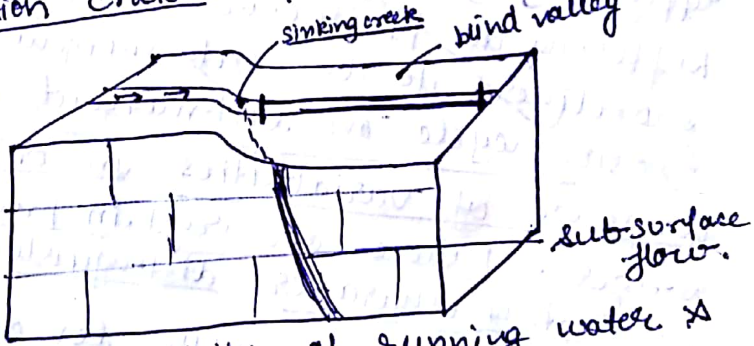
Beede & Cvizic

(Karst cycle)

Beede & Cvizic foll davisian approach and gave karst cycle of erosion. It is spl case on basis of parameters like absence of base level of erosion, specifican of geological str, required climatic conditions. Requires par-moist climate + thick bed on limestone exposed on surface. Simplicity of cycle vissible in homogenity of str, single process of erosion (solution) Probs: absence of base level of eron & absence of clarity of movements of sub-surface water.

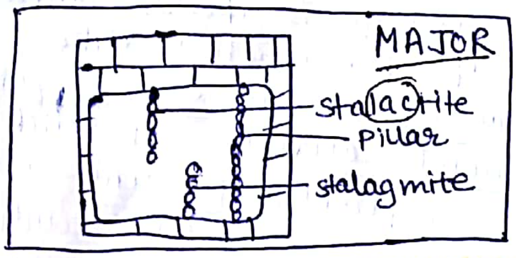
Young stage begin with begining of surface solotion carried by rainwater + running water. Solution incorps broad range of corrosional features. for this stage common are Lappies, clefts, sinkholes with associated features. Lappies rep pinnacled topography developed on coron of vertical bed of limestone. These arent common. In case of horizontal beds, joints form clefts which are enlargement of joints due to corron → depn of blocks of limestone from each other. commonest feat wid jointless horizontal limestone beds r called sink holes. dev of surface sol crator identified in such strata are distinguished in ref to their respective sizes. In the ↑ing size it inc sinkholes, doline, uvala & Poljes: Acc to their sizes they develop verticle profile which marks dev of karst windows availing view of inner layers. Karst window rep ↑ in rel H of given topography. Remnant surface bed b/w surface solution crators form karst bridge.





Young state also marks corassion. Effectivity of running water & relates to forman of sinking creek [when surface run off sinks to bcm sub-surface water & beyond "valley devoid of water forms blind valley. Transin from Y to M stage is highlighted with disappernce of all major surface runoff. ∴ Mature study is study of underground water as active agent of gradation. Karst cave is only dominating erosional feature. caves are defined as sub-surface solutional hollow developed either by sub-surface flow or rainwater. cave features are together called speleothems inc stalactite, stalagmite, immature variants. Mudit Jain

Speleothems



mature stage terminates with collapse of ceiling wall of cave → ↓ abs H → Old stage starts. ∴ reveals simultaneous effect of surface & sub-surface solution alongwith callapse of unstable karst bridges. This leads to reappearance of surface runoff, concluding the cycle. Stalactites are destroyed, but as ground of cave is exposed, remnant of stalagmites forms calcium carbonate mounts generating undulations called Homs. Fresh begining on exposed surface. These are end product of cycle not formally regd. of cycle is likely, ∴

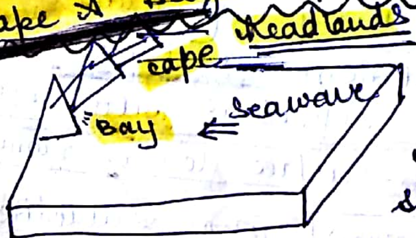
Cave pearls, Flowstones

Dropstone, Banded draperies.

(coastal cycle of erosion)

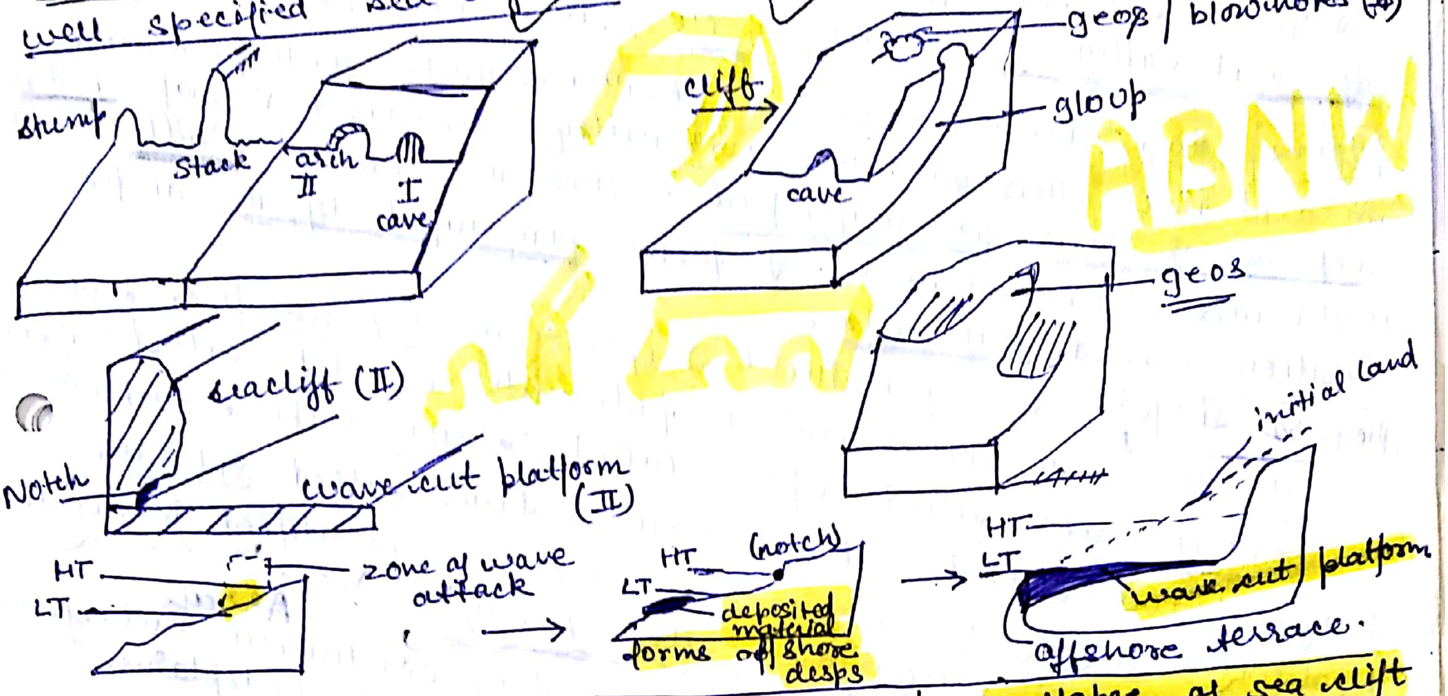
(1) sea wave as an active agent of eron in coastal areas. sea waves caused by drag effect of wind. Davis outlined coastal cycle on lines of normal cycle. effectivity of sea waves in coastal cycle identified. Reffering to Pliestocene Ice age terminat, the shorelines to be submergent type in global perspective. Erosion cycle on submergent coast is determined by presence of variabilities in on-shore locan. Davis gave stages. [there dev regd in preediciing stage makes up dominating character distinguishing from other cycles.] dev of present nature of coastal areas.

young stage begins with dev of present erosional features. seawaves erosion generate commonest erosional features that represent differential rate of erosion. It is called cape & Bay topography. dev of erosional features regulated by range of structural controls. whr the headlands are tall coastal mt with significant horizontal expan, coastal cave is developed which results in other features in next stages. caves represent cutting down of front wall of mt with less resistant rocks.



These differ from features made due to similar resistances like coastal notch. demarcation of Y to M only on basis of dev of subsequent features.

In **Mature stage** coastal caves pave way for coastal arches (coastal bridge) or blow holes (geos). More narrowing of headlands develop broader bays. Projected dev of notch marks well specified sea-cliff & wave cut platforms.

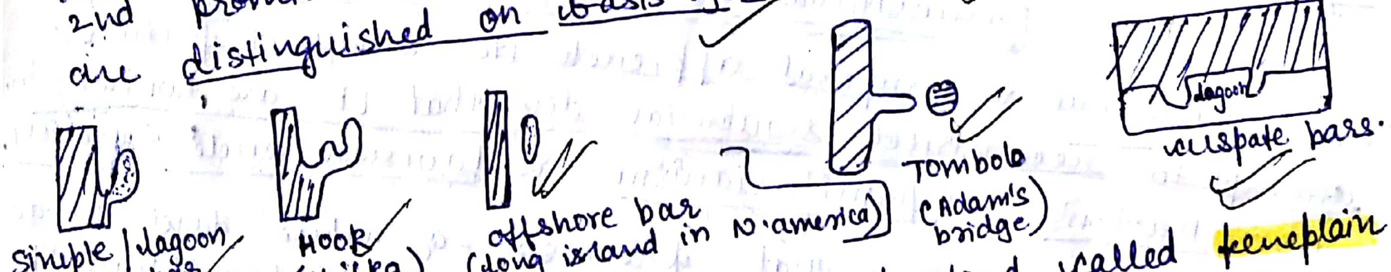


old stage ↓ in abs H. this corresponds to collapse of sea cliff due to cutting down of coastal mountain at notch or collapsing of ceiling wall at arch generating coastal pillar called stack. (onshore & offshore deposits).

Deps features are also prominent, an outcome of backwash.

onshore deps are called beaches b/w shoreline & coastline. These are unsorted dump deposits. Beach cusps when over 2 types on basis of locn of its deposition. Beach ridges when developed over headlands & when over wave cut platforms.

offshore deposits related to effect of long-shore drift makes 2nd prominent category of deps features. These Bar deposits are distinguished on basis of shapes, locn wrt mainland:



end product is featureless coastal lowland called peneplain alongwith coastal monadnocks.

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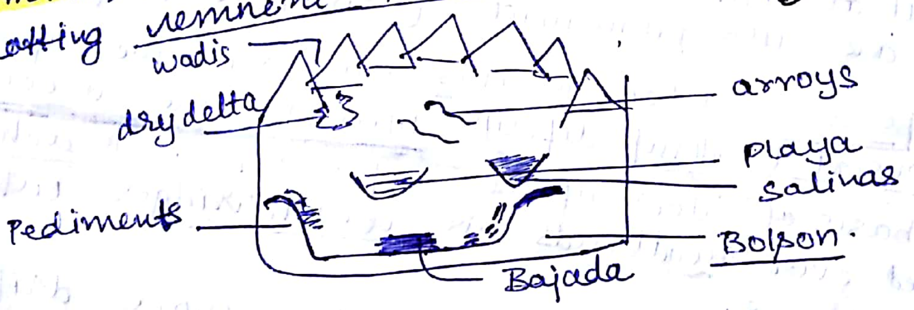
Eolian cycle of Eron

on the lines of normal cycle of eron, eolian cycle made by LC King
In tropical & sub tropical deserts of world wind is most effective agent of erosion. But Due to absence of wind's effecivity specifica, eolene cycles take into the effect of flash-flood water sourced from sudden torrential rains. This water moves down the slope → erosional effectivity to mts. This denudational is app only to arid-valley surrounded by Mt, called Bolson.

Young stage begins by vertical abran carried by flash-flood water in arid mts. This generate river valleys similar to V shape but is deprived off river for major part. These are called wadis. water carries sediment load. It forms fan shaped deposits at foot location called dry-delta.

Mature stage has prominent imprint of Bolson-floor. It inc dev of erosional planes called pediments & deps called Bajadas. Temporary water filled depren called Playas lake. Evaporan of Playa leaves behind salt rich crustal layer called Salinas. Horizontal abran by seasonal streamlets is identified in this stage. These waterless valleys are called ARROYS. Arroys:

Old stage Transin from M-O marked by continuous enlargment of pediments, retreat of Mt wall → featurless pedeplains with dotting remnent mount called Inselbergs.



Denudational chronology & cycles of eron

DC is historical & temporal approach to study LF features & attempt to reconstruct sequential dev that LF are subjected to based on Hutton's uniformitarianism & davisian cycle of erosion.
Hutton's approach outlines that processes of nature dont change with change in time & the way present topography marks it's development, older topography was subjected to similar process
Davisian concept of sequential series of dev of LF is applied.

As said by RJ. Small DC is to reconstruct development denudan & redevelopment of topography. He demarcated out tertiary relief as they experience initial level of development. ~~present~~ topography.
Small identified 3 determinants in dev of topography.

① Age of features : older features will be low lying than the younger counterparts. This is justified with regn of elevan of palazoic mt when compared to Azoic stable land.

② Relative hardness of rocks : / structure ↑ hardness → ↑ delay in denudation. validated by conical remenant of shields as Aghar Mt of algeria & Hamersley range in Aus.

③ exogenic forces : effectivity of running water is not just fn of structure of relief but also vol of water, drainage density

Limitan ptd by Bloom. ∴ highly deductive, generalises devlopment restricted to Ltd geog expanse ex process of features, Tectony reupliftment goes unnoticed in DC. Applaichians.

EROSIONAL SURFACES

ES are end products of erosional cycles which are largely featureless lowlands with gently undulating characteristics. Davis called them peneplains. Elaborating Davisian approach, small defined ES as EF features which are direct outcome of denudan wid complete absence of depositional activities". He differed b/w ES & erosional features. EF makes up structurally controlled relief that sequentially paves way to dev of ES. Small gave types of ES:

① Local pene-plain forms 1st stage of dev of peneplains where either due to strong erosion or weak structure, Erosion cycle completes much ahead of rest of locations. These facilitate dev of regional pene-plains.

② Regional pene-plains group of erosional sub-surfaces as peneplain of fluvial cycle, crynoplains, Etch plains of savannah cycles. These mark completn of exogenic ~~activitie~~ levelling.

③ Uplifted Rejuvenated peneplains. ex labrador plateau of Azoic canadian shield. canada reps paleozoic reupliftment to Labrador plateau / Mohak valley. also Mohak valley of USA. Labrador plateau of normal cycle is an

Acc to crick may, end product of several flood plains

④ Panplain, formed due to coalescence of meandering rivers. result of lateral eron by

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DC : based on palimpsest topography which represent topography of a region which has been dev, denuded & reder several times.

-ves: ① ↑↑ deductive.
② unknown events are guessed.
③ ↓↓ evidences available.

It is important, however, to distinguish between erosion/planation surfaces from rock cut structural benches. Erosion surfaces cut across geological formation and structures while structural surfaces are structurally controlled. For example, if a horizontal soft rock bed overlies horizontal resistant rock beds, soft rock beds are more or less uniformly eroded and thus are almost entirely removed and underlying relatively hard rock beds are exposed to environmental processes. The surface of such lithological formation is called structural surfaces. On the other hand, erosion surfaces are formed due to erosion of different rock types (hard and soft) and different geological structures (folded faulted) alike. However, as

(Hill slope dev)

Study of LF features include Hill slope analysis as 1 of constituent. It considers 2 aspects : Hill slope segments/elements & hill slope forms.

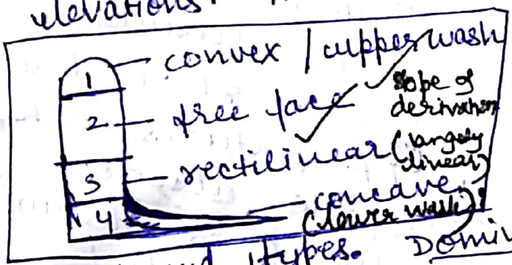
segments : ideal has 4 wid distinct characterists. convex element, free face, rectilinear element & concave element.

convex element is hill crest. It justifies effectivity of endo forces to be dominant thn exo. It grows in H wid endo forces & registers development of its dimensions due to exo downcutting. This element is also called upper wash face slope.

free face is wall like element complety deprived of broken rock material like convex element. endo is dominating. called as slope of derivan which facilitates || retreat or backwasting of Mts.

Rectilinear forms hill slope. largely straight/linear & is transin between convex/free face & concave element. slope is constant/regular & rock debri rest on it. (debris-slope).

concave/foot Represents exogenetic levelling largely deprived of vertical elevations. Also called lower wash slope.



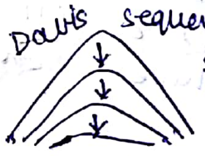
Hill slope forms

- actual slope profile.
- combi of HSS/E.

Represent actual slope profile of relief. Every HSF represent combination of >thn 1 hill slope elements & ∴ are always complex compound types. Dominating element is taken into ref to differ them. In classifican of HS on temporal basis, young Mts will rep dominating convex / freeface elements whr as old will have concave

Approaches of slope dev study

Davis sequential slopes.



Penck's || retreat.

① slope decline theory of davis

He said that like cyclic LF dev, hill slopes also undergo process of cyclic modification by progresiv decline in slope angle & sequential transin from convex to concave. In young stage of cycle of hill slope dev, steep convex slope evolves as per effective vertical abrassion or valley deepening. Till abs height dsnt ↓, slope ∠ & slope donot ↓ rather other is ↑ In relative dimension of slope. But as abs H ↓, both slope & slope ∠ ↓. there is continuous genesis of rectilinear with horizontal abraⁿ. other is concave slope is developed due to cutting of all H. with mark of old age, concave slope. In context of str, he said that concave form do inc resistant remanents of convex element.

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Slope Replacement approach

credited to german Penck who outlined that development of hill slope represents corresponding influence of endogenetic upliftment & exogenic downcutting. He presumed existence of homogenous structural cliff with presence of non-eroding & non-depositing river at its foot. weathering of cliff generates broken rock material → masswasted due to nature of gradient. It is transported further by existing river. with continuing process, homogenous cliff experiences || retreat declining in slope & converts slope from free-face to concave. This approach is validated in ref to seawave action as well as alpine glacial effectivity forming wavecut platform & cirque.

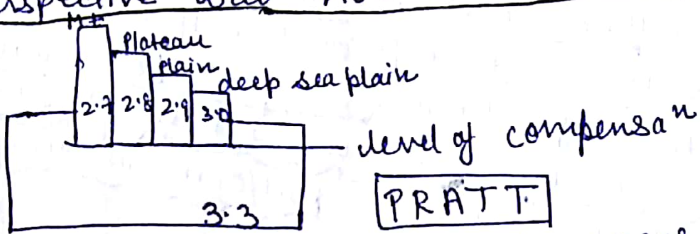
Pratt, diff density, level of compensaⁿ, inter, intrax

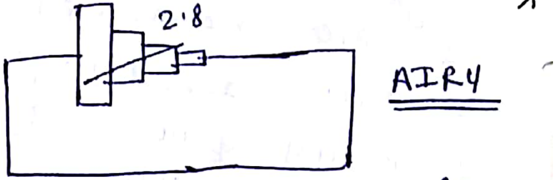
ISOSTACY

It is concept of equilibrium which takes into a/c causes which facilitate balance b/w tall raised & deep seated lithos features on fast spinning earth. Begining of research traces back to 1st half on 19th century when Sir George Everest concluded variaion in calcⁿ of distance b/w different places in ref to diff methods of survey. It was concluded that mighty Himalayas are not exerting the weight that they are likely to in accordance to their height & size. This was concluded by 1 of proponder of isostacy, PRATT. He outlined concept of level of compensation. All lithospheric constituents are identified to be made up of diff density material & exert weight accordingly. Isostatic features persists as taller ~~material~~ features are made equilibrium b/w these features & deep seated features are made of lighter density material. He identified existence of level of compensaⁿ in Asthenosphere wher all density differences get compensated. This explains balancing b/w continental & oceanic crustal features but fails to explain balance b/w either oceanic crustal features & contl. as density diff within these crust is not identified.

Hayford & Joly followed this school. Airy objected this approach and gave Mountain - Root concept. In acc to this, all lithos features are identified to be made of same density material & equilibrium is developed acc to depth of roots. Taller features have deeper roots & r in equilibrium wid deep seated features with shallow roots. It can be applied in intra-crust perspective but not inter-crust.

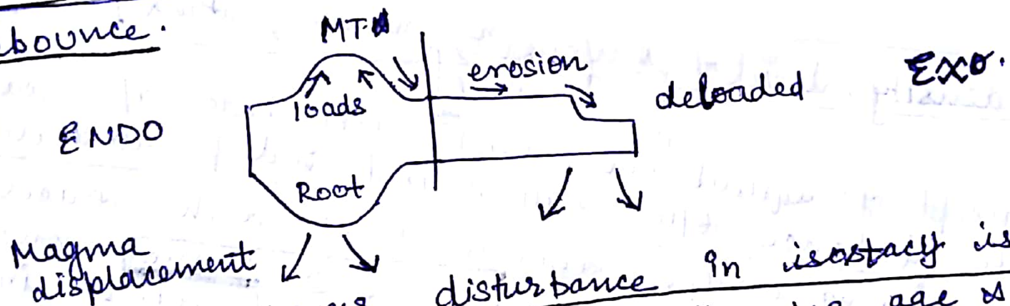
intra-crust ✓ inter-crust ✗



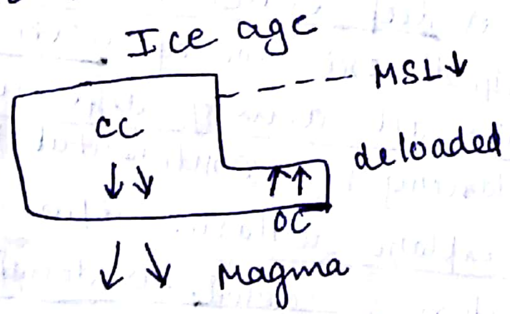


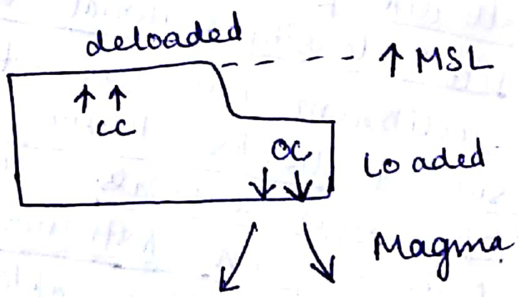
Dynamics of lithospheric processes justify that equilibrium is continuously disturbed & reestablished. Disturbances are induced by both climatic & geomorphic agents. Geomorphic agent like endogenic upliftment induces crustal loading & hinders isostatic equilibrium. This is compensated by simultaneous readjusting equilibrium. displacement of magma from MT root locan

During exogenic downcutting of MT, isostacy is disturbed due to bouncing back of MT root. Displacement of magma compensates this rebounce.



In climatologic terms disturbance in isostacy is related to prominent change in climate like ice age & its termination. During ice age loading of conti crust causes it's sink and in order to maintain isostacy, magma displacement is outlined. Whr as after termina^n of ice age it is loading of oceanic crust that sinks & rebounces deloaded conti crust. Here magma displacements occur under oceanic crust.





Penck cycle of Erosion

explained process of dev of LF in fluvial geomorphological region. so Model is thought as an opposite effort to Davis' model. the replaced 'cycle' term of Davis & used Entewickelung (dev)

Assumpⁿ ① LF is exprenⁿ of mutual interacⁿ b/w exo & endo.
② Most of tectonic movements begin & end slowly.
③ Initial quiescence surface (Primarrumpf) follows slow long duration upheaval & gradaⁿ immediately after upheaval. i.e upheaval & eroⁿ occur simultaneously.

Primarrumpf (initial featureless surface) is gradually uplifted & exposed to denudaⁿ → featureless plain associated with some residual monadnock (Peneplain). 3 phases are involved* Entwickelung (dev). It inc waxing (↑sing dev of LF), uniform entwickelung. dev of LF & absteigende (wanning) (↓ng dev of LF) absteigende.

Waxing Primarrumpf remains featurless for some period but as rate of upliftment ↑es, rivers begin to cut deep valleys through vertical incicion & V-shaped valleys are produced. upliftment of both crest n valley bottom are continuously increasing up. relief Δ b/w abs H & relief of river valley. Rate of upheavel ≯ incⁱⁿ of river valley increases. Slope is convex.

Uniform dev of LF curve of ridge summit & bottom of river valley are ∥ but have different inclination in different parts of stage. subdivided into 3 phases. LF dev takes place at constant rate. depending on ratio of upliftment & eroⁿ.

Phase 1 acceleraⁿ of upliftment but lower rate than previous. both upliftment of summit & river bottom are at uniform rate. Rate of summit eroⁿ & valley deepening are similar thus vally sides are straight. Absolute H ↑es.

Phase 2 upliftment is accelerated wrt summit of divide & river valley bottom. Upliftment = rate of summit eroⁿ & deeping. summit neither ↑ or ↓. Absolute H is max.

Phase 3 stopping of upheaval, lowering of summit, valley deepening, Relief remains constant as in 1 & 2 as Rate of deepening rate. But Absolute H ↓es.
erosion =

Wanning continuous declining summit due to denudaⁿ. Due to lowering of slope, valley deepening is reduced.

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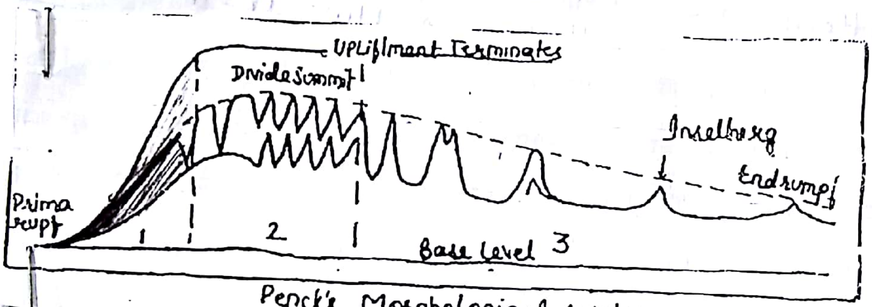
Lateral erosion becomes dominant. Absolute H ↓. Relief ↓ stage has 2 parts on basis of slope & summit curve (crest). upper part (Boshe steilwand)/gravity slope is steep & maintain its angle by ∥ retreat. lower part is Haldenhang or wash slope which is very gentle. Sharp Break pt exist b/w them (Knick point). wash slope extends at expense of gravity slope crest lowers to form inselbergs, river is completely graded. End product is Endrumpf (Peneplain)

Evaluatn

(1) removed probs with Davis' model of rate & period of upliftment.
(2) considered simultaneous action of erosion & upliftment.
(3) More practical than Davis'.
(4) But his emphasis is only on development of slopes in evolutn of LF & didnt take care of structure of rocks & or lithological characteristics.



Penck's Morphological system

Boshe steilwand/ gravity slope (steep) ∥ retreat

Haldenhang (wash slope) gentle

waning abSteigende → slopes ⟨ Upper wash (gravity) Boshe ~~haldenhan~~ Steilwende or
lower wash haldenhang

(Geosyncline & mt building)

geosyncline effect is 1 of elemenentary geomorphological effect in studies of endogenetic forces. It relates to analyses of forman processes of fold mts. GEOSYNC approach dedicated to Hall & Dana who identified it as shallow - sinking sea bed. Dana outlined geosync to refer a gradually deepening & filling basin resulting from this concept of crustal contracn due to cooling of earth's crust. This represents classical approch to study of mt building of applaichian. Prominent contributors adding to char of classically defined geosync include Haug, evans & Schuchert.

Haug applied geosync concept to global perspective. He is credited of recognising mesozoic geosync which wr bounded by large no. of stable masses. He gave ex of tethys sea, circum pacific location. & among stable masses, N/S america, Afro-Indian masses etc. In ref to him, dev & filling of mesozoic geosync facilitated forman of cenozoic mt ranges along boundries of stable landmasses. Evans on basis

Evans & Schuchert attempted classifican of geosync. water front GS (tethys) & landfront GS (circum pacific). This classifican was elaborated by Shuchert of locan of GS gave in ref to mountain building process. He classified them as Mono GS & poly GS. Mono represents single episode of deposin & folding (as ref in most old fold mts) while poly reps many episodes of sedimentan & folding (young cordilleras) has 2 categories:-

deepening seabed geosynclines developing along conti margins, moutain building material mostly limestones, dolomite, shale (sedimentary strata). There

① Miogeosynclines is complete absence of magma ex himalayan cordilleras which is only young fold mt devoid of volcano.

② Eugeosynclines develop along marine boundaries & represents mt building material as sedimentary strata + marine lava/magma generated due to destrucn of existing oceanic crust. This is common GS as 3 major young fold mt of world show.

Geosync - mt building

Based on classical categories of geosync, 1st mt building aproach attempted by Kober reeg GS to be sinking sea bed. Developed fold orogenesis concept to explain young fold mts. He gave 3 Stages:-

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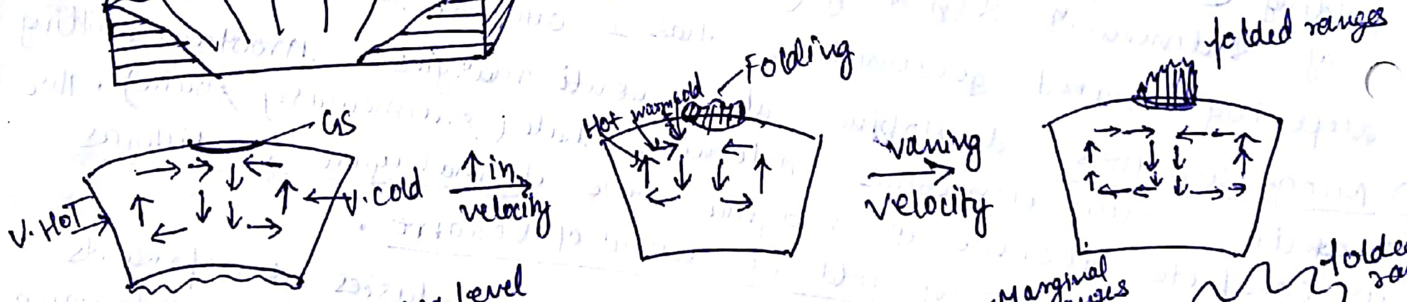
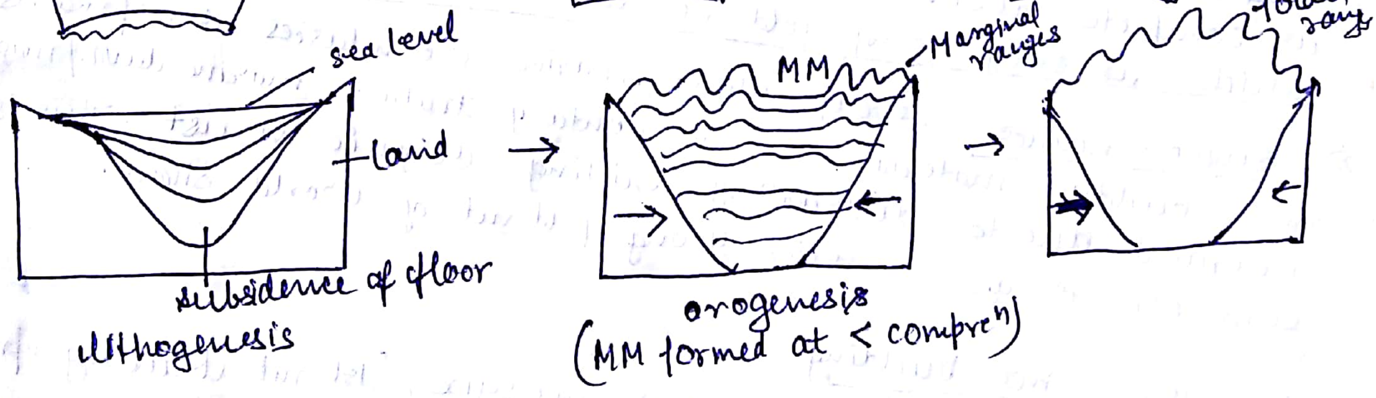
① Lithogenesis
• deposiⁿ of eroded material in to the GS. This facilitates shallow linear GS to continuously sink. This enhances depositⁿ psbilities & converts GS to deep & narrow.

② orogenesis : begining of orogenesis relates to convergence of stable masses due to narrowing down of GS. Folding of deposited material marks begining of mt building process wher 2 ranges are formed with low lying central median mass. Kober recg MM to be a plateau or plain that represents lesser intensity of compreⁿ thn adjoining mountains. Tibetian plateau & hungarian plane are ex of inter-montane features.

③ Glyptogenesis : Marked by further ↑ in height of developed relief, complete folding of GS sediments & closing down of GS.
This descriptive approach of kober is applied to analyz formaⁿ of himalayas. Approach remains valid as refered in the context of correⁿ attempted by Holmes. In his aproach of convective magma currents, he justified deepening process of GS & ① genesis of compressional stress to magma currents. He outlined psblity of GS remaining open ② even after dev of folds. This has helped in elaborating practical validity of concept.
* collectively for orogenesis however these theories are incompre & PTT offers descripⁿ for all types of mts.





continental drift theory

from 19th cent, visual fit of S. Atlantic shoreline attracted analysis attempted by scholars like Humboldt, F B Taylor. german climatologist Alfred wegener's work is identified most in this respect. wegener was attempting Paleoclimatic studies that was with objective of analzing nature of Δ in climatic condn in diff continents. In the refrnce of fact that global climatic regions have been static in their respective posn. He concluded drift of continents.

To explain drift he outlined :-

- sial / sima
- equatorwards (gravity)
- westward (tidal forces).

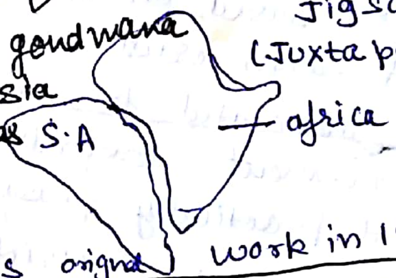
① free float of sial over sima.
② equatorward movement due to gravitational
③ westward movement due to tidal force by moon & sun.

On applying abv 3, he concluded existence of supercontinent & a superocean called Pangea till carboniferous epoch. & a ~~angaraland~~ Panthalasa. disintegran formed northern part angaraland (N america + Eurasia) & S. part comprising present S. continents (gondwanaland) along with S. part of asia. water body b/w these 2 was called tethys sea. gondwanaland & angaraland continued to further disintegrate developing present day map.

* highlighted movements inc: N.ward movement of disintegrated gondwana → developing Arctic ocean. eurasia developing I/O & S.ward move of N & S america forming atlantic & contracting
* westward drift of panthalasa to form Pacific.

Northwards gondwana
South → Eurasia
west → Americas

Jigsaw fit (Juxtaposin)



Evidences of CDT

① Jigsaw fit ② Paleoclimatic evidences.

wegener gave range of evidences for his orignal work in 1912 upto 4th edin of his text in 1930s. among these Jigsaw fit is most imp & convincing, eventualy suported by geomorphologists. It means fitting shorelines of present day continents esp s.america / atlantic shoreline by wegener. 3 fold orientan of JSF inc fit of shape, fit of str, fit of process.

under fit of shape, wegener highlighted match of s.america & africa This was supported by edward Bullard in 1960s by computer fit upto depth of 1000 m from mean sea level. He also noted unconformities due to processes applied on shoreline with time. like tensional wear-tear, sea wave erosion, delta forman

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* In ref of fit of structure wegener provided evidence like princi of superimposn, faunal succen to justify continuity of geological str from 1 atlantic shoreline to other. ex: gold rich strata on either sides, fossils of mesosauraus.
* In ref of fit of process, contribon of subsequent geomorph... are more significant in context of normal tensional stress generated due to disintegran & formatn of range of horst on either shoreline & graben in b/w justifies drift. This rift enlarged forming basin of atlantic.

ex Paleozoic block mt along shoreline of S. america has serra-de-montiquera & along africa Admauwa? highlands serra-de-montiquera justify CDT.

Paleoclimatic evidence by analyzing sample rocks of variable continents of world to derive out nature of climatic condin in geological past. He concluded glacian for gondwana & tropical condin for angara ∵ opposite of present day. He emphasized fit of continents forming gondwanaland & their posin to S. polar region. & angara in significantly warmer lats.

limitaton of theory Mechanisms of movement, failure to explain tectonic developments (2nd order), treating oceanic crust as passive.

- CDT based on free float sial over sima. Sial makes upper 60 km of earth crust & continues till depth of 100 km (inc upper sima) (Lithos). ∴ advocated free float is unlikely.
- Movement towards equator & westward due to gravity pull & tidal forces to drift continents not practically feasable as these forces are very weak. It explains theory gets restricted in absence of 2nd order reliefs.
- relative posin of continents & oceans (1st order).
- treatment of oceanic crust as passive tectonically was overruled in 1960s as ocean floor is as active as continents in movements.

The Puzzling Fossil Record

Wegener also found evidence for continental drift in the distribution of certain fossils. For example, identical species of the Permian reptile *Mesosaurus* had been found on both sides of the South Atlantic. Although it was a marine reptile, Mesosaurus was not thought to be a strong swimmer and, like the modern alligator, would not have been able to swim across an entire ocean. Similarly, fossils of the Triassic reptile *Cynognathus* had been found in South America and Africa, while those of the Triassic reptile *Lystrosaurus* had been found in Antarctica, Africa, and India. Today these continents are separated by major oceans. While it is conceivable that *Lystrosaurus*, a sheep-sized, land-dwelling reptile, could have walked from Africa to India, it certainly could not have crossed the polar ocean to Antarctica.

Mesosaurus, cynognathus in S.A

Lystrosaurus in Africa & India

Wegener found similar evidence in the distribution of an unusual, apparently stunted assemblage of fossil ferns known as the *Glossopteris* Flora. Characterized by a small number of readily identifiable species, this unique flora of Late Paleozoic ferns had been found in South America, South Africa, India, Australia, and Antarctica, as well as in the Falkland Islands and Madagascar. Because the seeds of *Glossopteris* were several millimeters across, they could not have been carried great distances by the wind and are unlikely to have been able to float. As birds had not yet evolved to carry the seeds.

glossopteris S.A, africa, India, Aus

The seemingly paradoxical distribution of fossil species such as *Mesosaurus*, *Cynognathus*, *Lystrosaurus* and the *Glossopteris* Flora was also readily accounted for on Wegener's maps which reassembled the southern continents into a single landmass by closing the intervening oceans. Without oceans to cross, the distribution of these and other species posed no dilemmas. But those opposed to continental drift were forced to advocate the improbable existence of former "land bridges" that had at one time connected the present continents but which had now sunk below the surface of the oceans.

1

Triassic 2

3
Jurrasic

4
Cretaceous

Present
5

The break up of Pangea arrows shows motion of lithospheric plates and dots shows oceanic rifts and ridges

Hotspots

- Not well explained by PTT.
- Existence proposed by Tuzo Wilson.
- These are relatively small areas of higher than average heat flow associated with volcanoes.
- These form volcanic islands that become extinct.
  → reefs → attols → seamounts.
- Only some lie on plate boundaries & most on interior reg.
  ∴ not associated with boundary mechanisms rather giant plumes of heat welling up from deep mantle [mantle plumes] [By Morgan] → push against lithos → blister
- Plate is moving while hotspot is fixed → series of sea mount chain is formd. on oceanic plates
  bristtes. ∴ On
- Other theories : extra-terrestrial impacts, shallower source beneath plates.
- Types < oceanic / continental.

oceanic hotspots

- ex Hawaii, emperor sea-mount (SMC) chain in Pacific, bora; reunion etc.
  Bora, society islands, azores
- SMC provide evidence of dirn & speed of plate.

Continental

- Conti-HS play role in determining posn of certain plate boundaries.
- Theory :- Plume / hotspots drive wedge that splits continents apart first dooming & then cracking crust into Y shape rifts which meet at triple point. ex: Euthopia's Afar Δ.

2 ~~types~~ rifts among Y widen & one weaken & bcm inactive. [failed rift or aulacogen (later filled with sediment)]

Mudit Jain

Scanned by CamScanner

which reaches as far as the Aleutian trench, a distance of 2500 km (1550 mi). Adding the Emperor Seamounts produced a bend in the chain which Jason Morgan, in keeping with his idea of mantle plumes, attributed to a change in the direction of movement of the Pacific plate at the age of the seamount at the bend, about 40 million years ago. Because hotspots remain more or less stationary, seamount chains provide evidence of the direction and speed of the plate on which they sit, while past plate configurations can be reconstructed by sliding the plate back towards the present hotspot along the seamount track. Hence the bend between the Hawaiian and Emperor chains suggested to Morgan that the presently northwest-moving Pacific plate had been moving directly north prior to 40 million years ago. This idea has since been borne out by dating, the progressive northwestward

So large continents are thought to trap mantle heat. The number of hotspots is also uncertain stimates ranging from 20 to 120 depending on such criteria as the level of activity, lava stry, and degree of doming.

Two types of hotspots, oceanic and continental, are distinguished on the basis of the type of n which they occur. While the origin of the two types may be the same, there are major nces in the nature of their volcanism.

c Hotspots

nown of all the world's hotspots is Hawaii. The Hawaiian-Emperor seamount chain marks sage of the Pacific plate over a plume for the past 70 million years. The oldest seamounts

Scanned by CamScanner

oceanic ridge, accounting for the large number of hotspots located at or close to the Mid-Atlantic Ridge and the mid-oceanic ridges of the southern Indian Ocean

In contrast to hotspots like Hawaii, continental hotspots must burn their way through many kilometers of granitic continental crust. As a result, their record of activity suggests long volcanic silences and short cataclysmic explosions of pyroclasstic material. The reason for this is that mantle-derived basaltic magma is sufficiently hot to melt the granitic continental crust during its ascent. Melting of continental crust produces magma with the same composition as granite. This gas-rich magma is less dense but more viscous than basalt, so that although it rises more rapidly, it retains its gases allowing pressures to build explosively. Bulging beyond capacity, the ground above the magma chamber finally cracks, releasing the pressure and triggering a catastrophic eruption. Only after this does the deeper basaltic magma flood out as lava flows.

Such is the history of the Yellowstone hotspot in Wyoming, which is manifest at the Earth's surface today by hot springs, geysers, and other hydrothermal activity. Although we do not associate

Plate driving mechanisms

imagined. And while there may be many forces influencing plate motion, the main driving mechanism is clear. It is the flow of heat from the interior of the planet to its surface. Basically, plate movement occurs as a result of the convective circulation of the Earth's heated interior and is powered by the decay of naturally occurring radioactive elements in the mantle. This convective circulation locally causes plates to move apart or spread, to come together or collide, or to slide past each other in translation. However, how convection actually makes the plates move is still poorly understood.

convective circulation of earth's heated int... & powered by radioactivity → moves plates

In the Pacific Ocean, the plates may be self-propelled. The Marianas-type subduction typical of the western Pacific occurs because of the gravitational instability of old, dense oceanic crust. As the leading edge of the plate subducts, its weight pulls the rest of the plate when enough hangs over the edge. This force is called **slab pull** and occurs because the subducting lithosphere is denser and heavier than the asthenosphere through which it is sinking. But plate motion also occurs in the Atlantic where there is very little subduction. Yet it is clear that the opening of the Atlantic Ocean has resulted in the westward drift of North and South America, and the eastward drift of Europe and Africa. Here the plates may be partially propelled by sliding off the Mid-Atlantic Ridge. This gravitational force is called **ridge push**, the elevated position of the ridge allowing the plate to simply slide downhill like a toboggan. Deep-seated convective circulation may also drive the plates, the hot mantle rising beneath ridges and spreading out laterally below the lithosphere, propelling the plates as it circulates. In this case the plates move like rafts in a moving stream. The force by which this motion of the asthenosphere may carry the plates along (or slow them down) is called **mantle drag**.

Mantle drag.

Pacific ① Slab pull during subduction
Atlantic ② Ridge push during MOR sliding
③ deep seated convection (Mantle d

The most important of these forces appears to be slab pull because the fastest moving plates, like the Cocos and Nazca plates of the eastern Pacific, are those with the greatest lengths of subducting edges in relation to their size pulling the plate along. On the other hand, because non-subducting plates like that of the North American plate also move, ridge push may also be important. The role of mantle drag is uncertain. If it was a major driving force, those plates with the largest surface areas over which the force could operate, should be the fastest moving.

The fact that they are not suggests that it is a drag force which opposes slab pull and ridge push and slows the plates rather than carries them. The presence of continental crust also slows plates down. The deep roots of the continental lithosphere may exert a drag as they plough through the asthenosphere, much like a sea anchor slows the movement of a boat.

Clearly, there is much to be learned about the driving mechanisms behind plate motion. At a more fundamental level, however, we know it is some form of thermal convection in the mantle that is ultimately responsible for their movement. Thermal convection is a pattern of circulation in a fluid in which hot material rises and cools while cold material sinks and is heated. In the mantle, upwelling of hot mantle material to hotspots or ridges is coupled by rigid plate motion to the downwelling of cold oceanic lithosphere at subduction zones. In this sense, plate motion is simply a near-surface manifestation of mantle circulation.

length of plate & subducting w.r.t its size ↓ slab pull ex Cocos & Nazca.

N. America & Ridge Push.

In summary, the principle of isostasy describes the state of buoyant equilibrium that exists in the Earth's crust. It accounts for the contrasting elevations of the continents and ocean floors, and the striking relationship between the crustal thickness and surface elevation of the continents. It also demonstrates that the Earth's crustal fragments and the plates in which they are embedded effectively "float" on a pliable mantle below. Crustal erosion is consequently compensated by isostatic rebound. This rebound not only drives the rock cycle but has also eliminated entire mountain belts that may have once rivaled the Himalayas. In the process, the crust may be uplifted by as much as 50 km (30 mi). Yet this distance is tiny compared to the horizontal distances moved by plates. Because plates effectively "float" they are also free to move sideways and can be carried in this way for thousands of kilometers by circulating currents within the Earth's heated interior. This is the motion that drives plate tectonics, and it is to this movement and the plate boundaries along which it occurs that we now turn.

rigid, interlocking slab like fragments

PLATE BOUNDARIES

Recall that according to plate tectonics, the Earth's lithosphere is broken into rigid, interlocking slabs like fragments of a cracked eggshell. All plates are curved because they are part of a spherical Earth. But unlike the cracked eggshell, the lithospheric fragments we call plates float on a dense, pliable asthenosphere, and are therefore free to move relative to each other like rafts floating on a stream. As a consequence, all plates must interact with neighboring plates along their mutual boundaries. In the simplified case of Figure, movement of plate A to the left requires it to slide along its top and bottom margins, while an overlap is produced in front and a gap is created behind. The margins of Plate A therefore *simultaneously* experience three types of motion. At the rear, its motion relative to Plate B is one of separation and **extension**. At the front, it is one o convergence and **compression**. Along its top and bottom margins, it is one of translation or **shear**.

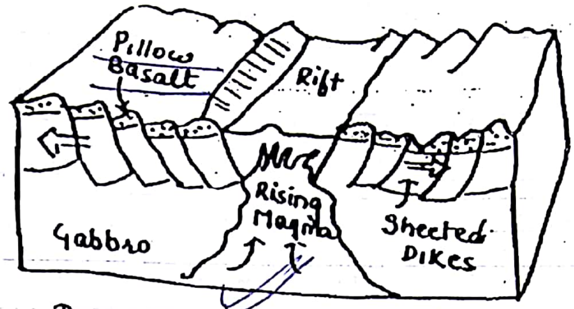
Actual plate boundaries behave in much the same way as Plates A and B: separating, colliding, or sliding past each other. The three types of plate boundaries that result from these interactions are termed divergent, convergent, and transform boundaries depending on their sense of movement. As reasoned by Vine and Matthews, **divergent plate boundaries**, where two plates move apart, are marked by spreading centered on a mid-oceanic ridge and create new oceanic lithosphere. Because these boundaries form new crust, they are often called **constructive** margins. **Convergent plate boundaries**, where two plates are in collision, are marked by subduction zones along which one plate is forced beneath the other and consumed. These boundaries are also termed **destructive** plate margins. **Transform plate boundaries**, where two plates slide past each other in translation, are marked by great crustal fractures. Transform boundaries neither create nor destroy lithosphere

transform plate's crustal fractures.

but form links between one plate boundary and another. They are also known as **conservative margins.**

Divergent Boundaries Creating Oceans

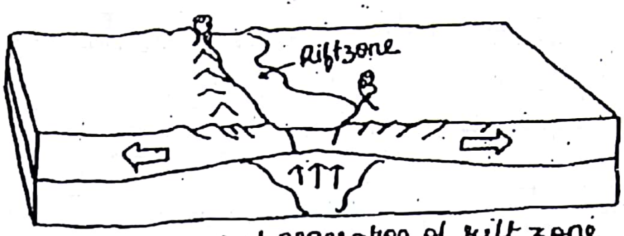
At divergent plate boundaries, where plates move apart, continents may be torn in two to form new oceans. Where these occurs new oceanic lithosphere is created by sea floor spreading at mid-oceanic ridges as the lavas and the rocks beneath them cool and thicken to form a rigid layer. The birth of oceans starts on dry land with the breakup of a continent. When two plates start to separate, basaltic magma rises from the mantle below, and the overlying lithosphere bulges. As more magma is inserted into the continental crust like wedges into wood, the crust stretches and thins. Rising batches of magma create a line of separation, and in the early stages of rifting, continental blocks settle into faults in much the same way that the keystone of an arch would settle if the arch was pulled apart. This settling of subsidence forms a steep-walled rift valley. This new valley commonly becomes a pathway for major streams. As a result stream and lake deposits accumulate on the floor of the valley in addition to flows of basaltic lava. When the rift has torn completely through the continent and reaches a coastline, seawater floods in and the first shallow marine sediments are deposited on the rift floor. As the continental plates separate further, more water flows in and upwelling magma starts to build new basaltic ocean floor. A small but progressively widening ocean develops between the now drifting continents. The thinned margins of the continents slowly subside as they move away from the heat source at the zone of divergence, and are progressively flooded and covered by unfaulted sedimentary rocks to form continental shelves.



Divergence Ophiolite Complex

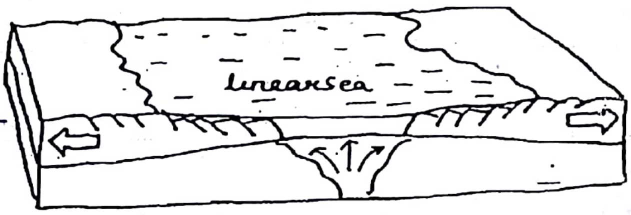
In this way, continental rifting creates two plates from one and produces an ocean centered along the original line of separation. Once the two continents have separated and oceanic crust has developed between them, the divergent plate boundary between the two plates is a **mid-oceanic ridge**, a submarine mountain chain buoyed by underlying mantle heat. At the highest point of the ridge, basaltic ocean crust is created by sea-floor separating. As the plates move apart, fractures open in the rift valley at the ridge crest and are continually filled but magma derived from the hot, partially molten mantle below. The near-vertical sheets of basalt that are produced by the filling of fractures are called dikes. In this way, new oceanic crust is continually inserted at the summit of the ridge, and all previously formed ocean floor is progressively wedged further and further apart. This implies that the crust is newest at the spreading ridge and gets progressively older with increasing distance from the ridge crest. The process is like inserting a series of books into the center of a bookshelf such that the newer books push the older ones apart. As older ocean floor is carried away from the ridge, it cools, contracts, and subsides as it does so, and a full ocean thousands of kilometers across is opened as a result.

Over the past 200 million years, just such a process created the Atlantic Ocean. The present-day, Atlantic can therefore be visualized as a giant expanding bath-tub, bordered by the Americas to the west, and by Europe and Africa to the east, with a continuous ridge running down its center that is anchored to the base of the bathtub and rises to within a few inches of its water surface.



Divergence and generation of rift zone

A similar process in its early stages can be seen operating in East Africa, where the Great Rift Valley cuts across Ethiopia southward to Mozambique, a distance of 4500 km (2800 mi). Along this divergent plate boundary a slab of continental lithosphere known as the Somali plate, may one day split from Africa. As rifting takes place, magmas rise to fill the fissures so that volcanoes are commonplace, the largest, Mt. Kilimanjaro in Kenya, rising over 5750 m (19,000 ft) to form Africa's highest mountain. To the north, where the rift system is flooded by the Red Sea and the Gulf of Aden, separation has reached the next stage with the birth of a new ocean between Africa and the Arabian Peninsula. All three arms of the rift system meet in Ethiopia's "Afar Triangle" to form a Y-shaped plate junction known as a **triple point**.



Generation of Linear sea

The Earth's system of divergent plate boundaries form a network of **mid-oceanic ridges** that girdle the globe like a seam on a baseball. The rates of divergence on this system vary significantly, ranging from a rapid 17 cm/year Rift Valley. Mid-oceanic ridges are found in all of the world's major oceans and form an interconnected system of undersea mountains that rarely break the surface, but which rise two to three km (6500 to 10,000 ft) above the surrounding sea floor and stretch continuously for 65,000 km (40,000 mi). Typically their summits are one to five km (0.6 to 3 mi) below the ocean surface.

The mid-oceanic ridges constitute the greatest mountain range on Earth. They are mountains because they rise above the abyssal plains of the surrounding ocean floor, although their summits rarely stand above sea level so they are mostly hidden from view by a cover of ocean water. Only in Iceland does a significant portion of a mid-oceanic ridge (the Mid-Atlantic Ridge) rise above the surface of an ocean.

Mid-oceanic ridges on land, however, are quite unlike the more familiar mountain ranges on land, which owe their origin to compression and thickening of continental crust along zones of plate convergence. Mid-oceanic ridges are, by contrast, the products of extension and separation. The rift valley at their summits, where basaltic lavas erupt to create new oceanic crust as the sea floor spreads, is evidence of this extension. They are therefore high not because they are being compressed, but because they are swollen with heat, being thermally buoyed by the hot mantle beneath. As sea-floor spreading carries the oceanic crust away from a ridge, the cooling seabed subsides and ultimately becomes part of the flat abyssal plain of the deep ocean. So mid-oceanic ridges are broad areas of thermal uplift. In consequence, they tend to be far wider than most continental mountain belts, and as they are thermally buoyed, they do not require a crustal root to support their weight. Unlike continental mountains, therefore they are not in isostatic equilibrium like an iceberg, but rather are in thermal equilibrium, being only as high as they are hot.

Rift valleys continue to develop at the crests of mid-oceanic ridges for the same reason that they form where continents are tearing apart. The influence of mantle heat not only uplifts the mid-oceanic ridge, it also stretches the oceanic crust, causing settling or subsiding. The mechanism of subsidence can be likened to the collapse of a row of unsupported books on a bookshelf. If an additional book is inserted into the middle of the row, and the row has no bookends, the books will tip over and slide against each other as they fall. The pattern formed by the fallen books is similar to that produced by the collapse of fault blocks at mid-oceanic ridges.

Although only a few hundred kilometers of the mid-oceanic ridge system has been directly explored, it has been extensively probed by geophysical instruments and is known to form high, jagged peaks in the Atlantic and smoother, broader ranges in the Pacific, abruptly changing from one shape to the other in the Indian Ocean. Differences in ridge topography reflect variations in the rate of sea-floor spreading. As oceanic crust spreads away from mid-oceanic ridges it cools and subsides. How far the crust moves away from the ridge before it subsides to the level of the abyssal plain, however, depends on the spreading rate. Along slow-spreading ridges, the ocean floor does not move far before cooling so that the subsidence occurs close to the ridge. Along fast-spreading ridges, in contrast, the ocean floor can move much further from the ridge before it cools and subsides. Thus the slow-spreading Mid-Atlantic Ridge is narrow and steep whereas the fast-spreading East Pacific Rise is broad and gentle.

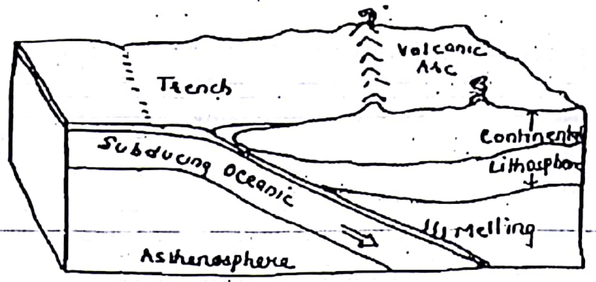
The internal structure of the oceanic crust has been determined by studying earthquakes at mid-oceanic ridges, and from the results of deep sea drilling and the study of suites of rocks on land that are thought to preserve fragments of ancient ocean floor. As previously mentioned, the vast majority of the ocean floor is hidden from direct observation by a cover of ocean water. It is also rarely preserved in the geologic record as a result of the efficient recycling floor by subduction. In rare instances, however, sections of oceanic crust may break way from the subducting slab as it descends and attach themselves to the edge of the overriding plate. Fragments of ocean floor preserved in this way are called **ophiolites**, from the Greek *ophis* meaning "serpent", because of the blotchy green, snake-like appearance of some of the rocks they contain, many of which are altered peridotites.

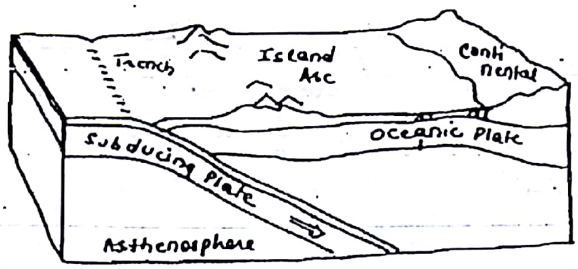
Some ophiolites, like the Troodos Complex of Cyprus, preserve a complete cross section of sea floor that demonstrates how the oceanic crust is constructed. At the top of the sequence are deep-ocean sediments laid down in the ancient sea. Next come bulbous **pillow lavas**, which formed when basalt magma was extruded onto the seabed. Then there is a layer of basalt that solidified in conduits leading from the magma chamber to the surface to form dikes. The repeated opening of fractures by sea floor spreading produces a complex of **sheeted dikes**. Below these lie slowly cooled, coarse-grained basaltic rocks called gabbros that once filled the magma chamber of a mid-oceanic ridge. At the base of the sequence, dark, heavy, magnesium and iron-rich mantle rocks called peridotites were once part of the bottom layer of the lithosphere. Some of these peridoties are thought to have formed on the floor of the magma chamber that fed the overlying dikes and lavas. Here heavy crystals settling out of the magma chamber as it cooled would have slowly accumulated to produce concentrated layers of early crystallizing magnesium-and iron-rich minerals. Some of the other peridotites, however, are truly upper mantle rocks left behind after partial melting had extracted the basaltic magma to form the overlying oceanic crust.

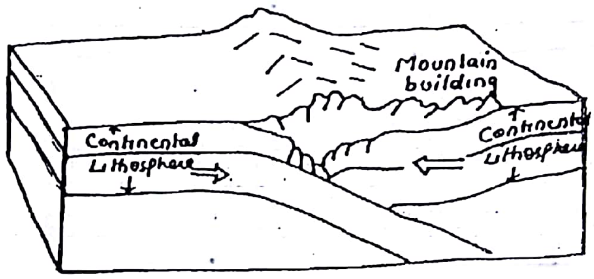
Hence, divergence plate boundaries are those along which plates separate. They are responsible for the rifting of continents, the opening of oceans, the development of mid-oceanic ridges, and the creation of new oceanic crust. They are constructive plate margins, producing new ocean floor that spreads away from the high-standing mid-oceanic ridges, cooling and subsiding as it does so. But where does all this oceanic crust go? We must examine another type of plate boundary that associated with plate collision. It is to these convergent plate boundaries where oceanic crust meets it fate, that we now turn.

Convergent Boundaries - Recycling Crust and Building Continents

Assuming the size of the Earth to be constant, the creation of new lithosphere must be balanced by the destruction of old lithosphere. The contrast in the maximum ages of continental crust (up to 4 billion years) and oceanic crust (less than 200 million years) suggest that the oceanic lithosphere is preferentially destroyed. The destruction of lithosphere is accomplished at convergent plate boundaries where two plates overlap. What happens at such boundaries depends on whether the overlapping plates are continental or oceanic. Because of this, three type of convergent plate boundary are possible: ocean-ocean, ocean-continent, and continent-continent. The two types of plate boundaries that consume oceanic lithosphere, ocean-ocean, and ocean-continent, have quite different characteristics and we will examine each in turn. But first, we must see how the overlap between two plates is actually achieved, to do this, we turn to the process responsible, that of subduction.







Subduction

Along convergent plate boundaries, two plates come together and one angles down beneath the other in a process known as **subduction**. The inclined zone along which this happens is called a **subduction zone**. In general, it is the denser plate that is subducted beneath the lighter, more buoyant one. Because of this, it is usually oceanic lithosphere that is consumed. The broadly granitic rocks of the continental crust are less dense and, hence, far more buoyant than the dense basalts of the ocean floors. So if one of the colliding plates is continental, the denser oceanic lithosphere angels downward beneath it. Such is the case today along the western margin of South America where the oceanic Nazca plate plunges beneath the continental South American plate. Because of their contrast in density, oceanic lithosphere created at mid-oceanic ridges tends to be destroyed and recycled, whereas buoyant continental crust is preserved.

It two oceanic plates converge, it is again the denser plate that is preferentially consumed. However, in this case, the outcome is often determined by the relative age of the converging plates. Because oceanic crust cools and becomes denser as it ages, ocean-ocean convergence tends to preferentially destroy the older oceanic lithosphere. In this way, old oceanic lithosphere is preferentially recycled and the age of the ocean floor is kept young. Many examples of this style of subduction occur today in the western Pacific Ocean.

Such continent-continent convergence is ultimately inevitable if the subduction of oceanic lithosphere consume the ocean floor between two continents. When the two continents eventually meet, the one on the subducting plate will be dragged down into the subduction zone. But continental lithosphere is too buoyant to be subducted completely. As a result, the process of subduction eventually comes to a halt following the collision of continents. But the effects of continental collision are dramatic, when we turn our attention to the process of mountain building.

Prior to the terminal development of collisional mountains, however, other major features are characteristic of the subduction process. All subduction zones, for example, are marked by earthquakes, deep ocean trenches, and volcanoes. But whereas some create curved chains of islands, others produce explosive volcanoes on land.

Characteristics of Subduction Zones

The downgoing oceanic slab in a subduction zone is cold and rigid, and so may penetrate deep into the mantle before it is consumed. Because earthquakes occur in cold brittle rock, those associated with subduction may therefore occur at much greater depths than the earthquakes associated with spreading ridges. (Recall that at a spreading ridge, hot magma sits relatively close to the surface, rendering the crust less rigid at relatively shallow depths). In fact, earthquakes within a subducting slab may come from depths as great as 600 km (375 mi), in contrast to the very shallow (often less than 5 km) depths typical of earthquakes at mid-oceanic ridges. Subduction zone earthquakes also have a variety of sources.

Some subduction zone earthquakes are generated where the cold, and therefore brittle, oceanic plate bends before it subducts. Others occur if the downgoing slab breaks up before it is consumed in the mantle. But most are produced by slippage along the subduction zone itself, where the two plates rub together. Because rocks conduct heat very slowly, it takes a long time for the subducting plate to heat up and become soft. Until this occurs, the downgoing slab maintains its rigidity and so is capable of breaking along brittle, earthquake-producing fractures within it unlike the far hotter and more pliable asthenosphere that surrounds it. In fact, it is only in subduction zones that earthquakes can originate from depths of more than 100 km (62mi). Subduction zone earthquakes, like those of the Japanese volcanic arc, are consequently confined to the descending lithosphere, so their points of origin or "foci" become deeper in the direction of subduction. The existence of these inclined zones of earthquakes foci was known before the advent of plate tectonics, and they are often referred to as **Benioff zones** after the American geophysicist Hugo Benioff, who pioneered their study.

The site of subduction is also marked by a deep ocean trench where the oceanic plate bends before sinking. Ocean trenches are produced by frictional drag between the colliding plates which causes the subducting plate to pull the edge of the overriding plate down with it, creating some the deepest points on the ocean floor. At more than 11,000 m (36,000 ft) below sea level and some 5,500 m (18,000 ft) below the adjacent seabed, the floor of the Mariana Trench in the western Pacific is the deepest point of the Earth's surface.

Subduction is also marked by volcanoes, which tower above the trench and are fueled by melting and the ascent of magmas released in or above the downgoing slab as it plunges into the Earth's interior. Where the overriding plate is oceanic, the volcanoes form a curved line of islands that run parallel to the adjacent trench, like those of the Aleutian Islands in the northern Pacific. These curved chains of volcanic islands are called **island arcs**. The curvature of island arcs reflects the spherical shape of the Earth, and therefore the curvature of the surface of the subducting slab. Where the overriding plate is continental, however, magma rising from the subduction zone causes uplift of the continent's leading edge to produce a volcanic mountain range parallel to the coast, like that of the Andes Mountains in South America.

O/O : Island arcs   C/O : Volcanic Mt parallel ranges

Where the subducting oceanic lithosphere is very old, the subduction zone is commonly steep because the downgoing slab is too dense to be supported buoyantly. As a result, the slab collapses into the asthenosphere, rolling back oceanward as it does so. The action of this "roll back" may pull the overriding plate behind the arc, causing its oceanic crust to crack. As molten rock in the mantle rises to fill the crack, a small spreading zone is created behind the island arc, like a miniature version of a mid-ocean ridge. This process is called **back-arc spreading** and the basin it opens behind the arc is a **back-arc basin** floored by oceanic crust. Much of the western Pacific Ocean has been affected by back-arc spreading, which accounts for the seas that occur between the islands of the western Pacific and the coastline of Asia. The floors of the Sea of Japan and the Philippine Sea, for example, were formed by such a process.

Types of Subduction

As lithosphere plates may be oceanic or continental, subduction zones can be of two types: ocean-ocean and ocean-continent. Ocean trenches and volcanic islands like the Aleutians mark the sites of present-day ocean-ocean subduction, whereas ocean trenches and volcanic mountains like the Andes mark the sites of ocean-continent collision. These differences produce marked variations in the characteristics of subduction zones as we will now discover by examining the two types in more detail.

Ocean-Ocean Convergence

When two oceanic plates converge, the denser plate is generally subducted. Typically, the denser plate is also the older one, because the density of oceanic crust increases as the crust colder with age. In fact, old oceanic lithposphere will ultimately become denser than the underlying asthenosphere so that its eventual subduction is inevitable. The main resistance to the subduction of old oceanic lithosphere is its own rigidity. But this resistance is eventually overcome as the plate's density increases. Like a tablecloth sliding off a table, once initiated, the subduction of old oceanic lithosphere can become very rapid indeed, often resulting in "roll back" of the subduction zone and the development of a back-arc basin.

The product of subduction is the formation of a deep ocean trench, produced as the subducting plate pulls the edge of the overriding plate down with it, and a volcanic island arc like that of the Aleutians. The curvature of island arcs is parallel to that of the neighboring deep ocean trenches, implying a direct relationship to the subduction process. The curvature of both the arc and trench is caused by the spherical shape of the Earth. The subduction zone plunges into the Earth's interior like a knife cuts into an apple, forcing the trench to adopt a curved shape, just as a dent in a ping-pong ball adopts a circular outline. As a result, both curvatures are always convex toward the subducting plate.

The volcanoes that make up the island arc are the product of subduction and occur into the Earth's interior it is heated and, when the temperatures become high enough, its ocean-floor basalts start to melt. The slab also releases water and other gases formerly trapped in minerals and fractures in the subducting ocean floor. These fluids rise into the wedge-shaped area of mantle (or **mantle wedge**) above the subduction zone where they promote melting of the mantle rocks. Those magmas derived from the mantle wedge, like all melts from the mantle, are basaltic in composition. Those produced by melting of the subducting slab itself are somewhat more silica-rich and are termed "basaltic andesites" because they are transitional in composition between basalts and andesites. Both types of magma rise through the overriding oceanic plate and may reach the surface where eruptions build an arcuate line of largely basaltic volcanoes parallel to the trench.

The gap between the trench and the arcuate line of volcanic islands (the "arc-trench gap") reflects the angle of subduction. Magmas can not be produced until the downgoing slab becomes hot enough to melt; a situation that usually occurs only after the slab has reached depths of 100 km (62 mi) or more. The volcanoes, which form above the point at which melting first occurs, are consequently offset from the treneh. Because steeply dipping subduction zones attain this depth closer to the trench than shallow-dipping ones, magmas rising from steep subduction zones generate arcs that are closer to trench. In either case, however, the relative position of the arc and trench can be used to determine the direction or **polarity** of subduction, because subduction that starts at a trench will always be directed toward and beneath the neighboring volcanic arc.

In summary, Benioff zones of earthquakes, deep ocean trenches, volcanic island arcs, and back-arc basins are all features typical of ocean-ocean convergence. Volcanism is largely basaltic and the distance between the trench and arc reflects the subducting plate's of descent. Some of these features are also typical of ocean-continent convergence but, as we shall now see, others differ markedly.

Ocean-Continent Convergence

Unlike ocean-ocean collision, subduction beneath continents results in volcanic eruptions that are often highly explosive and, produces mountains. Ocean-continent convergence also shrinks oceans, as dense basaltic ocean floor is subducted beneath more buoyant continental lithosphere. This kind of subduction generates some of the Earth's most violent internal actions.

Seventy-five percent of the Earth's active land volcanoes lie alongside the offside trenches that reveal the lines of ocean-continent collision surrounding the Pacific Ocean. The edge of the Pacific is under attack, its floor shrinking as it is consumed beneath as many as six different plates along the subduction zones that rim this ocean. The volcanoes fueled by the subduction of its ocean floor from the 48,000 km- (30,000 mi-) long **Pacific Ring of Fire.** As is the case for convergence between oceanic plates, the magmas produced above these subduction zones are mainly basaltic, and are formed by partial melting of either the downgoing oceanic slab or the overlying mantle wedge where melting is triggered by the addition of water and riding plate is continental, however, these fluid-charged magmas must punch their way through the continental crust. The ascending fluid-charged magma is an efficient transporter of heat, and promotes partial melting of the overlying continental crust to produce granitic melts. These coexisting but compositionally contrasting magmas may then mix. Unlike basalt magmas which are very fluid and permit their dissolved gases to escape easily, continental crustal melts are more viscous or sticky because they are richer in silicon and poorer in iron and magnesium. They are generally andesitic or rhyolitic in composition, and are charged with liquefied gases under tremendous pressure. As the pods of melt rise to fill near surface magma chambers, these gases expand, fracturing the overlying rock and giving vent to explosive volcanic eruptions. Magma chambers can be likened to pressure cookers with lids of brittle crust. As the pressure within the chamber builds, cracks appear in the crustal lid through which the over-pressured magma surges upwards and escapes violently at the surface in the form of a pyroclastic eruption.

The devastating pyroclastic eruption of Mt. Pinatubo in the Philippines in June 1991, exemplifies the often explosive volcanism associated with ocean-continent collision. This eruption, the largest in over 80 years, blasted 5.5 cubic km (1.3 cubic mi) of ash and some 20 million tons of sulfur dioxides into the atmosphere in a matter of hours. By blocking out sunlight, this blanket of gas dust cooled the planet by degree or so for several years.

The eruption of Mount St. Helens in Washington State in May 1980, was significantly smaller than that of Mt. Pinatubo, ejecting a mere 1.0 cubic km (0.2 cubic mi) of material into the atmosphere.

Nevertheless, it tore almost 400 m (1300 ft) from the summit of the volcano, and devastated an area of 200 square km (75 square mi).

Both of these devastating eruptions are examples of subduction zone volcanism and stand in sharp contrast to the generally quiescent volcanism of mid-oceanic ridges. Mid-oceanic ridges do not form such serious 'pressure cookers" because they lack a thick crustal lid and the basalt magmas they produce are both less viscous and less gas-charges than the magmas of subduction zones. Mid-oceanic ridge are also highly fractured areas that facilitate that ascent of magma rather than allowing the build up of pressure. Mid-oceanic ridge volcanism is exemplified by the lava fountains and fast-flowing lava flows witnessed on the island of Iceland, which sits astride the Mid-Atlantic Ridge.

The explosive volcanism characteristic of ocean-continent convergence represents only a small fraction of the magmatism associated with subduction. Most magma never reaches the surface, but instead cools to form vast bodies of plutonic rock within the overriding continental plate. This influx of hot buoyant magma together with the compression that often accompanies plate convergence uplifts the leading edge of the continental plate into a range of mountains parallel to the offshore trench. As a result, the volcanoes associated with ocean-continent collisions occur within coastal mountain ranges like those of the Andes or Cascades.

Volcanic mountains rather than island arcs are therefore typical of ocean-continent convergence. At the same time, volcanism tends to be explosive and is generally of a more silica-rich andesitic or rhyolitic composition rather than basaltic. Each of these characteristics reflects the presence of a continental plate above the subduction zone.

Controls on Subduction: Marianas vesus Andean

Subduction at continental margins does not always cause crustal compression. The Andes, for example, preserve a more complex history. Some 150 million years ago, back-arc basin spreading occurred in the southern Andes, opening up a back-arc basin that later closed. This shows that the behavior of a subduction zone can change with time. Indeed, we sometime talk of a continuum between two end-member types of subduction Marianas and Andean. One end-member (Marianas type) is related to the more-or-less passive subduction of old, dense oceanic crust, which typically occurs in oceanic settings. The other (Andean-type) is related to the forceful subduction of oceanic crust beneath continental plate margins.

During **Marianas-type subduction**, named after the Marianas Islands of the western Pacific, a very old and heavy oceanic plate willingly dives beneath younger, more buoyant ocean floor so that the process of subduction is fairly passive. The two plates consequently meet with less force so that major earthquakes are few, roll-back of the sinking plate is common so that back-arc basins form, and the angle of subduction is steep. In fact, part of the heavy downgoing slab may even become detached and sink into the mantle.

This situation clearly contrasts with the situation in the modern Andes where there is no back-arc spreading and mountains have developed instead, during **Andean-type subduction**, named after the modern Andes, young buoyant ocean floor is "forced" to subduct. The plates consequently meet with great force so that earthquakes are frequent and strong (releasing a hundred times more energy than Marianas-type systems), the angle of subduction is shallow, and compression rather than roll-back occurs, creating a mountain belt parallel to the oceanic trench.

Although the Andes today are the example of Andean-type subduction, evidence in the Andes for back-arc spreading (a feature of Marianas-type subduction) some 150 million years ago, demonstrates that this was not always the case. This shows that the types of subduction are not mutually exclusive but may change from one to the other.

Modern Japan, for example, is now part of an Andean-type system as its recent history of destructive earthquakes testifies. Prior to 20 million years ago, however, Japan was part of a Marianas-type system with active back-arc spreading forming the floor of the Japan Sea. Indeed, Japan was once attached to the Russian coast of Asia, but was spalled off by back-arc extension and drifted oceanward as the Japan Sea opened.

One cause for this change in the character of subduction with time is a progressive decrease in the age of the subducting ocean floor. When subduction first starts, ancient oceanic crust is consumed which collapses into the mantle and rolls back, giving rise to Marianas-type subduction. As subduction continues, however, the subducting ocean floor becomes younger and more buoyant. It must therefore be forced to subduct, causing compression, which closes the back-arc basin and gives rise to Andean-type subduction. A progressive decrease in the dip of the subduction is steep whereas that of Andean-type systems is typically shallow. Where this occurs, the site of magma generation also changes with time, adding to the complexity of the subduction zone.

Subduction and the Growth Continents

A progressive evolution from Marianas to Andean-type subduction may be expected to accompany the closure of an ocean, because the age of the subducting ocean floor should decrease as the mid-oceanic ridge approaches the subduction zone. As a result, ocean-continent subduction along the margins of a closing ocean is likely to become increasingly Andean-type with time. The magmas generated by this subduction will be added to the continent above the seduction zone. Similarly, island arcs, initially generated by Marianas-type subduction within the ocean basin, will continue to grow as the ocean shrinks, but must ultimately collide with a continental margin as the ocean closes. In this way, subduction must ultimately contribute to the growth of continents.

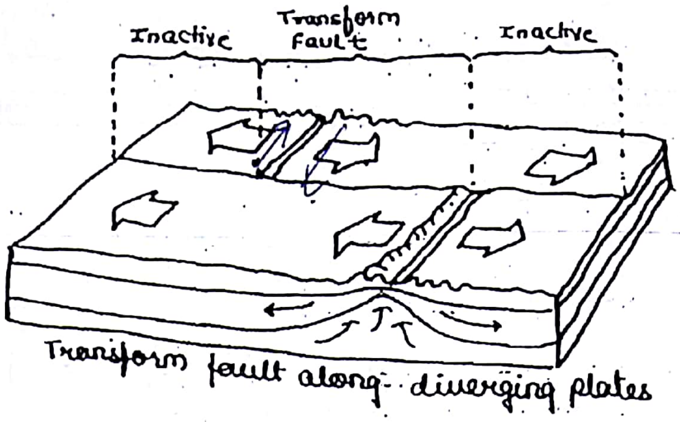
In fact, subduction of oceanic crust is nature's vast recycling program. As dense oceanic crust is destroyed by subduction, its destruction triggers melting and the ascent of more buoyant magma which cool to form new continental crust in islands arcs and volcanic mountain belts. Thus, the granitic crust of continents is produced above subduction zones as a consequence of the destruction of ocean floor. Volcanic island arcs are where continents first start to form, slowly growing from "microcontinents" to full-size continents as subduction proceeds with time. Because of the buoyancy and elevation of their crust, island arcs are generally not subducted, but tend instead to coalesce into larger bodies through "microcontinental" collisions, or become welded to the leading edge of larger continents when they are swept into ocean-continent collision zones. Because ocean-continent subducion zones where these processes take place can only form at continental margins, subduction-zone magmas and colliding volcanic island arcs are typically added to the edge of continents. As a result, continents tend to grow sideways with time such that they often have a nucleus of ancient rocks surrounded by progressively younger ones.

The previous sections serve to emphasize the wide range of processes associated with the subduction of oceanic lithosphere at convergent plate boundaries. Subduction may occur beneath oceanic crust, in which case the product is a volcanic island arc, or it may be consumed below continental crust in which case volcanic mountains are formed. Subduction may be of Marianas or Andean-type, or of a very intermediate between these two. Subduction causes magmatism which may be largely plutonic or largely volcanic, and volcanism may be basaltic and quiescent, or intermediate to felsic and highly explosive. Subducting also leads to collision and, this may involve "microcontinents" and affect quite small regions, or may be climatic and involve entire continents. No other type of plate boundary exhibits such diversity and, the complexity of convergent margins contrasts with the comparative simplicity of the third and last type of plate boundary, that of transform faults.

Transform Boundaries- Fracturing the Land

Where two plates struggle to slide past each other, the boundary between them is a fracture in the crust known as a **transform fault**. Plate motion here is one of horizontal translation and crust is neither created nor destroyed. The plate boundary is consequently a "conservative" one, the transform fault simply linking two other kinds of active plate boundaries. At either end of a transform fault, therefore, the movement on the fault abruptly ends and is taken up by (or is "transformed" into) movement of another kind, such as spreading, subduction, or transform motion on another fault. However, the fault itself is rarely smooth. If the rocks along a transform fault lock while the pressure or stress from plate motion continues, strain builds up in the rocks on either side of the fault so that they slowly bend or deform, storing up elastic energy like a spring ever drawn tighter.

Finally, when the spring snaps, rocks on either side of the fault jerk violently past each other and earthquake shock waves are sent out in all directions. Such stick-slip motion is typical of transform faults and accounts for the earthquakes with which they are often associated. As the fault movement occurs close to the surface, usually at depths of less than 20 km (12 mi), earthquakes associated with transform plate boundaries are often more damaging than deeper ones of similar magnitude.



Transform plate boundaries are of two principle types. The vast majority of transform faults link offset mid-oceanic ridges, or provides links between other plate boundaries in an entirely oceanic setting. Such transform faults occur on the sea floor and are termed **oceanic transforms.** Far less common are transform faults that separate two continental plates. These are termed **continental transforms** and have a far greater impact on society because they occur on land.

Oceanic Transforms

Transform faults are extremely common in oceanic settings where they most frequently offset mid-oceanic ridges perpendicular to their ridge crests, to produce the rectilinear pattern of ridges and transforms characteristic of spreading centers. The pattern is rectilinear because divergent plate boundaries are usually perpendicular to the spreading direction whereas conservative or transform plate boundaries are roughly parallel to plate movement. Because of this relationship, transform faults tend to intersect mid-oceanic ridges at high angles.

At first glance, it would appear as if the mid-oceanic ridges were once continuous and had been offset by horizontal movements along the transform faults. But the direction of offset along oceanic transforms is precisely the opposite to that which would need to produce the ridge offsets. For example, the ridge is offset to the right although the transform fault linking the two ridge segments moves the far side of the fault to the left. This is because the direction of movement on either side of the fault is determined by the relative plate motion produced by sea-floor spreading at the ridge crests. In fact, it is only between the offset ridge crests that the sea floor is moving in opposite directions, so it is only this segment of the transform fault that is active. Seismic activity on oceanic transforms, which is generally both frequent and shallow, is similarly restricted to the segment of the fault between two offset ridge crests. Beyond the offset ridge crests, the sea floor moves in the same direction on either side of the transform, so the fracture is merely a seismically inactive scar.

The origin of the transform offsets in mid-oceanic ridges is not fully understood, but it appears to be the result of physical constraints that inhibit divergence along a curved plate boundary. For example, if two oceanic plates begin to diverge along a curved boundary, the original curves are forced to readjust into a series of right-angle segments. The offsets may also be inherited from the initial continental rifting stage of ocean opening. Where pre-existing lines of weakness in the continent produced rifts at an angle to the direction of spreading, physical constraints will again cause the developing divergent plate boundary to readjust into a series of ridge segments offset by transform faults.

Other oceanic transform faults link mid-oceanic ridges to subduction zones or link one subduction zone to another. In so doing, transform faults provide the means by which oceanic crust is transported from the site of its creation to the site of its destruction. In the northeastern Pacific, for example, it is the Mendocino transform fault that permits oceanic crust of the Juan de Fuca plate to be transported to the Cascade subduction zone beneath the Pacific Northwest, whereas the Queen Charlotte transform fault off the coast of British Columbia transports ocean floor from the Juan de Fuca Ridge toward the Aleutian Trench beneath Alaska.

Continental Transforms

Only a few transform faults intersect continents. However, they tend to be longer and more continuous than their oceanic counterparts and do not display the simple rectilinear geometry of oceanic transforms. As they cut through the differing materials of the continental crust, continental transform faults continually exploit any weakness they encounter and so may bend and alter their path. These bends produce local areas of compression or extension that cause either uplift or small "pill-apart" basins to open along the fault zone.

The best known continental transform faults are the Dead Sea Transform of the Levant, where the two plates (African and Arabian) move in the same direction but at differing speeds, and the San Andreas Fault of California, where the adjacent plates (North American and Pacific) move in opposite directions. These transform faults serve as links between other plate boundaries. The Dead Sea Transform links the spreading ridge in the Red Sea to part of the convergent one of the Taurus-Zagros Mountains in Turkey, whereas the San Andreas Fault system links the spreading center in the Gulf of California to the subduction zone beneath the Cascade Mountains. Continental transform faults are said to display either **right-lateral motion** or **left-lateral motion** depending on whether the far side of the fault (as viewed by an observer on the ground) moves to the right or left. As we shall see, the Dead Sea Transform is left-lateral, whereas the San Andreas Fault is right-lateral. In either case, however, the resulting stick-slip motion threatens the surrounding region with earthquakes.

Erosional Surfaces

ES younger than Tertiary era are not found but partial ES myt hv developed.

[ES b4 tertiary] → changes → [not true ES].

[Nature & modificaⁿ of ES] depends on age (1) of surfaces, relative hardness (2) of rocks, stream (3) D & drainage density (4)

- Relatively younger surfaces & formed on resistant rocks are found in form of extensive plateaus having accordant heights & flat topped interfluves. Bcz these are ↓ dissected by streams.

- Pre-tertiary ES → dissected, segmented, obliterated by dynamic wheels of denudational processes.

- Peneplain by Davis. A surface of regional extent, low local relief, ↓ abs height, produced by long continued fluvial erosion. streams at base level of erosion, River braiding & meandering seen. → ∴ Featureless surface [not really flat but undulating & rolling]. Monadnocks or isolated convexo-concave hills are present.

- Penck gave end surface "endrumpf". hills: "inselbergs"

Types of Peneplains

on basis of compⁿ of landscape, mechanism of peneplainaⁿ, debris lying on them, sediments, minor relief etc.

(1) Local Peneplains :- Planaⁿ occurs slowly & gradually → some portion erodes to base level while other is in process. such locally produced plains are LPs or incipient peneplains.

② Regional : (2nd stage)
Most of LM is eroded to base level. several LPs coalesce together → RPs. LMs close to sea level may erode to base level while inland areas may have higher reliefs.

③ Uplifted : uplifted LPs & RPs. quite old. Marked by subsequent events of warping & downwarping. ex: Harrisburg, Ranchi, sommerville etc. Has structures like valley in valley / 2-storeyed valley, Nick points.

④ Resurrected : Some RPs get buried under sediments → buried peneplains. when sediments removed by erosion → BPs exposed are called Resurrected...

⑤ Partial : incomplete peneplain formed by incomplete cycle. [incipient, local, berms, straths, partial etc].

|Panplains| Crickmay-
Opposed peneplains. proposed panplanaⁿ in 1933 to a/c for dev of LFs in later stage of cycle of erosion.
opposed :- ① convexo-concave plan ② undulating surface
a/c for lateral planaⁿ (erosion) by meandering rivers in later stages of cycle → coalescence of flood plains.
lateral eroⁿ → backwasting of interfluves → "
Flat, almost even. x undulating.
-ve :- overemphasis on lateral eroⁿ → not accepted.

Channel morphology-
① geomorphic work performed by river = fn(vol, stage, Ve
② Flow < Laminar / calm : Thin & ‖ layers of water.
Turbulent : chaotic, eddies.

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③ **Discharge** m^3/sec . product of velocity & area.
= vol of water passing through a secⁿ in unit time.

④ **Roughness** fn(shape, size of bed, sediments, bends, depth, viscosity of water etc).

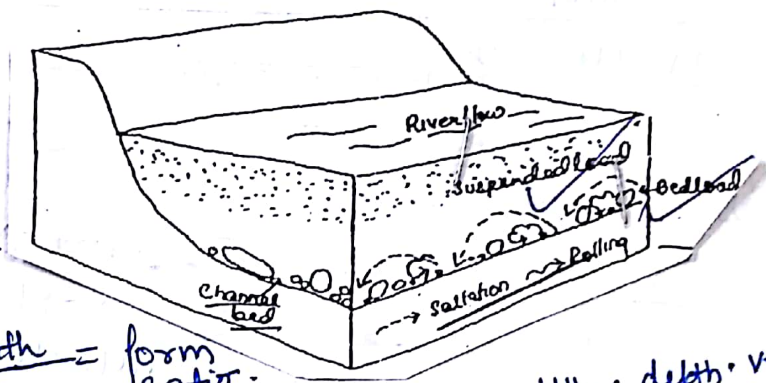
⑤ **Erosive processes** [coroⁿ/solⁿ, corassion, cavitation]
↑[chemical]   (mech)
[attrition, hydrolysis]

cavitaⁿ :- changes in velocity → vapour bubbles form → implode → shock waves → rocks → erode.

Hydraulic lift :- due to suction forces of eddies → pluck & detach fragments.

⑥ **River load** < solⁿ load
solid load < suspended load.
bed load.

bed load [rolling & sliding fashion]
= 10% of all load.



⑦ **Channel slope** & **long profile**

⑧ **Base level**, **knick point**

⑨ **Shape** : $\frac{\text{water surface width}}{\text{depth}}$ = form ratio.

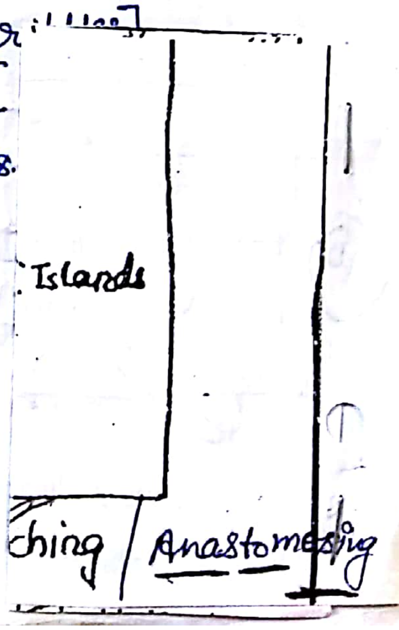
⑩ **Hydraulic geometry** [Leopold & Maddock] $Q \propto$ width · depth · vel.
[discharge]

⑪ **Channel pattern** or **planform** river as seen from sky.
— It is shape/config of a single river
= straight, braided, meandering, anabranching [anastomosing]

• deeper regions are pools [slow flow], shallower [riffles]
[

• Braided = several sub-channels sep by bars. within a main channel
→ shifting of bed materials, course.

Prerequisite for braiding : ① fluctuating flow
② coarse material
③ ↑ channel gradient.



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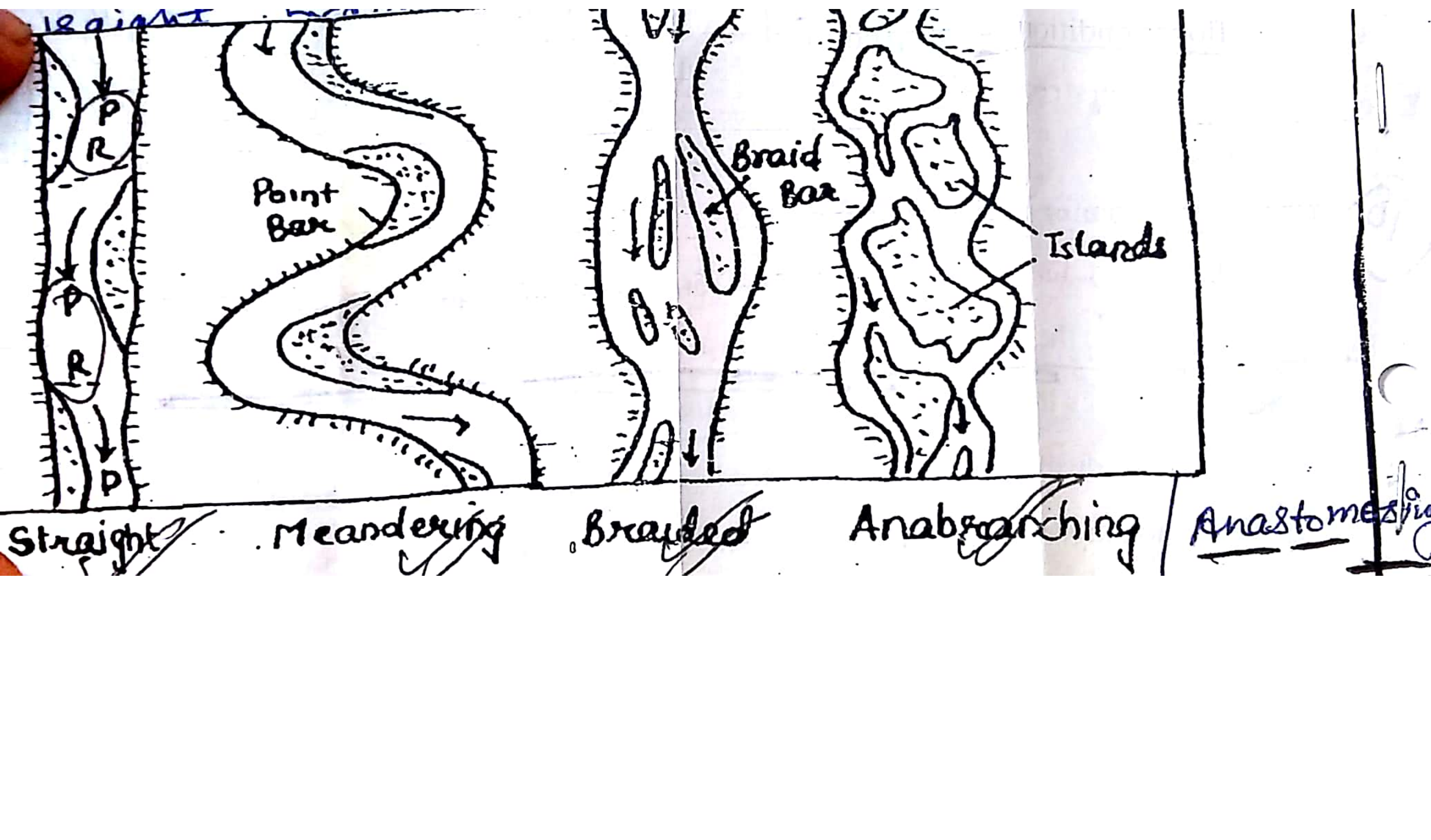
P
R
P
R
P
Point Bar
Braid Bar
Islands
Straight
Meandering
Braided
Anabranching

Anabranching / Anastomosing
multiple channels sep by vegetated stable alluvial islands. Indi channels can be of any type.

Drainage pattern

Arthur Howard compiled & classified.

1. Dendritic on uniformly resistant rocks.
2. ‖ on moderate to steep slopes.
3. Trellis small tribs are of same size on opposite sides of long ‖ streams. 7F
4. Rectangular Joints / faults at ⊥ ∠.
5. Radial volcanoes, domes, erosional residuals.
6. Annular
7. Multi-basinal multidepressⁿ pattern ex limestone

genetic classificaⁿ

1. consequent : as result of slope.
2. subsequent : Erode the valley & cross mountain.
3. Obsequent : opp to consequent, low order tribs.
4. Antecedent : those which maintain their valley post fresh tectonic activity.
5. Superimposed :
6. captured.

Thornbury

Applied geomorpho [Thornbury]

1. hydrology 2. eco-geology 3. Engg practices.

urban floods, EIA, dams & their effects, coastal erosion due to global warming.

urbanisaⁿ → flooding.

- Urban geomorphology

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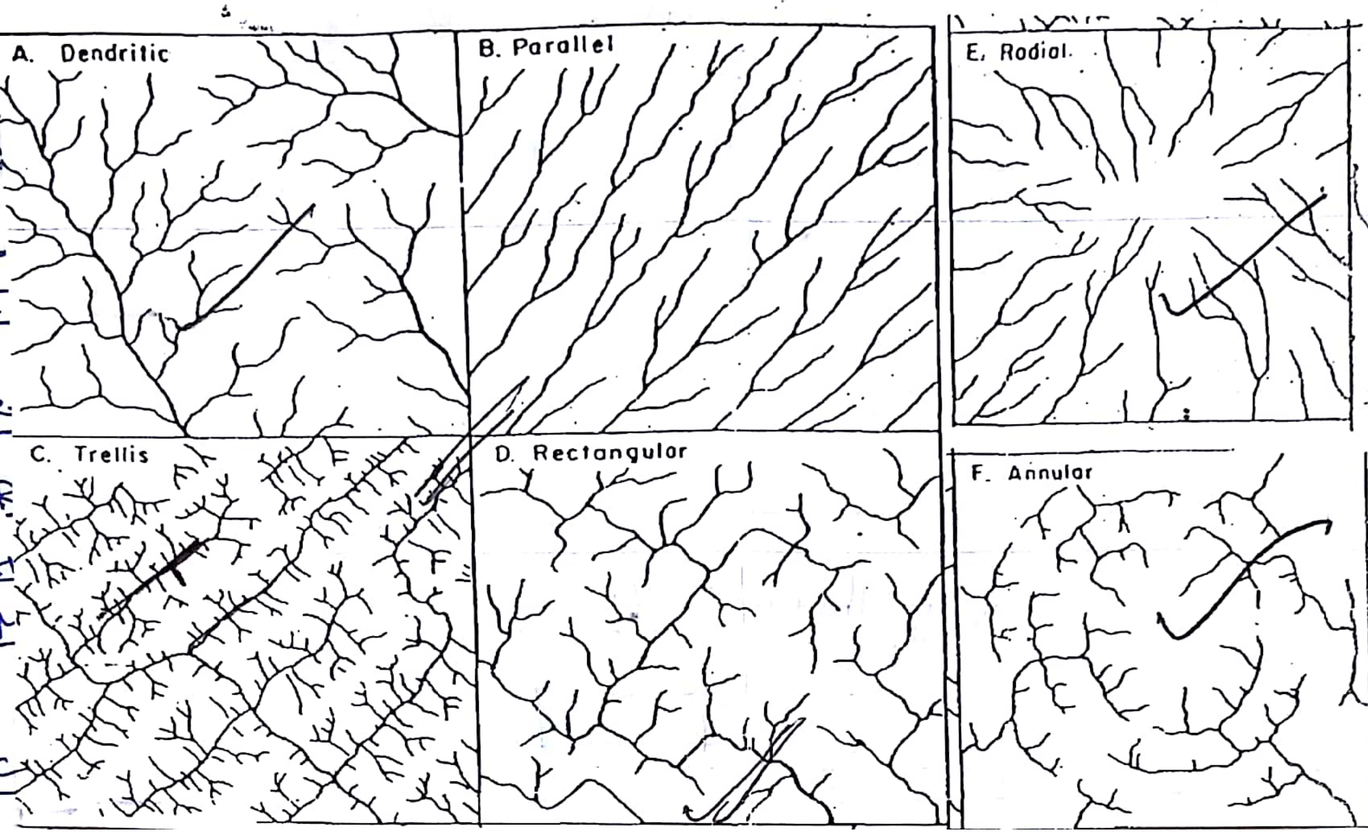
A. Dendritic
B. Parallel
C. Trellis
D. Rectangular
E. Radial
F. Annular