Advance Geomorphology - III

Masterstroke: Course on Geography Paper I

Sachin Arora • Lesson 24 • Apr 5, 2022

L.C.KING:PEDIPLANATION

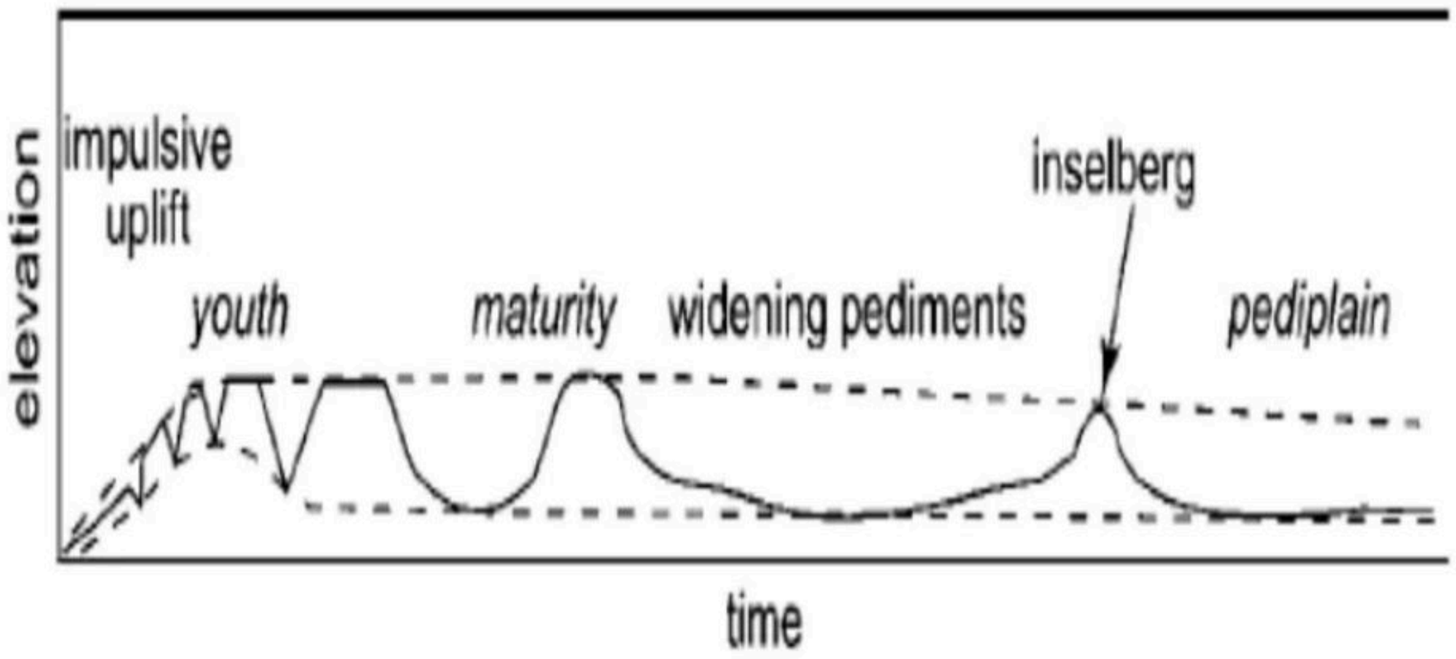
- Lester Charles King (1907 – 1989) was an English geologist and geomorphologist known for his theories on scarp retreat.
- Kings ideas are contained in his 2 books :-

1) Morphology of the earth (published in 1960)
2) Cannons of landscape evolution (1953)

- Kings received his training from C.A Cotton in Davisian morphology , T.J.D Fair for the ideas of slope and Alex L. Du Toit for ideas on tectonics.
- King’s ideas are influenced by his observations in southern Africa .
- His ideas included some components from the model of Davis and Penck . He rejected some of these and introduced some completely new ideas.

- He theorized that once pediment surfaces have been formed, they persist with little change until the next phase of surface uplift promotes a new cycle of river incision and escarpment retreat, which consumes existing pediplains and creates new ones.
- Like Davis, King envisioned impulsive uplift and long response times of landscape adjustment. He never accepted the Davisian concave-convex slope; he favored Penck’s view of concave hill slopes and slope replacement. On the basis of Penck's model he conclude that the landscape assumes the form of a series of nested, retreated escarpments.

- Lester King championed a model for long term landscape evolution very similar to the geographic cycle, but differing in the dominant mode of hillslope evolution (King, 1953, 1967).
- Like Davis, King envisioned impulsive uplift and long response times of landscape adjustment.
- King never accepted the Davisian concavo-convex slope; instead, he favored Penck's view of concave hillslopes and slope replacement.
- In fact, King took the Penckian model of slope replacement literally, to conclude that the landscape assumes the form of a series of nested, retreating escarpments.
- King called the low-gradient footslope extensions of the steep escarpments pediments and the flat beveled surface they leave in their retreating wake a pediplane.
- To King's credit he built upon the earlier work of Penck in making measurements in the field and incorporating the process work on pediment formation from other noted geomorphologists including Kirk Bryan (1922).
- King proposed that once pediments form, that they persist indefinitely until consumed by younger retreating escarpments following renewed base level fall. The base level fall in King's model is inherently episodic because it occurs on passive margins


elevation
impulsive
uplift
youth
maturity
widening pediments
inselberg
pediplain
time

- King used four slope elements which were initially proposed by ‘Wood'. For King, the profile of an ideal hillslope consists of all four elements of slope, viz., summit, scarp, debris slope and pediments and such hillslopes develop in all regions and in all climates where there is sufficient relief and fluvial process is the dominant agent of denudation.
- Each element is semi-independent. Any one of the elements can be completely absent on a given slope. This is particularly true for free face.

1) Waxing slope: It is a convex segment at he crest of the slope. It is covered by weathered material. Transportation on the surface is dominated by soil creep.

2) Free face: It is similar to cliff proposed by Penck.It is a bedrock out creep which retreats parallel to itself under the influence of weathering processes and uniform removal of material. However areas which do not have enough large relative relief ,free face may not develop.

3)Debris slope: Its development is dependent upon free face. If free face is there, debris slope will be there and vice-versa.

4)Waning slope: It has a gentle concave profile. There may be bedrock or transported material covering eroded bed rock surface, when the eroded transported debris cover such a surface it is known as pediment.

- Each of the upper parts of the slope retreats by the same amount and maintain the same angle . Therefore, the convexity, free face and debris slope all retain the same length. The concavity extends in length and becomes slightly gentler in angle. This is called pediment This type of evolution is called a parallel retreat.
- He envisaged the parallel retreat of a single free face slope unit, leaving a broad, concave pediments sloping at an angle of 6-7 degree or less at its base. Gradually over time, pediments coalesce to form pediplains and this mode of landscape development, is therefore called pediplanation.
- Pedimentation was proposed as a basic process in hill slope development by king . Parallel retreat of slope results in emergence and expansion of a pediment which have a concave form. At an advanced stage of development these pediment on both sides of land mass join together .On this type of surface there are isolated erosional remnants. These are the Inselbergs ,Bornhardt and are called Monadnocks .

L.C.KING – PEDIPLANATION CYCLE

- Pointing out that the Davisian model of arid cycle of erosion was inadequate to explain all types of landscapes, King, in the 1940s, propounded a new cyclic model of Pediplanation (or Pediplanation cycle) to explain the unique landscapes that he observed in the arid, semi-arid and savanna parts of southern Africa.
- He formulated a set of cyclic models (such as landscape cycle, epigene cycle, pediplanation cycle, hillslope cycle, etc.) and asserted that these are practicable in other parts of globe as well.
- Major landscapes in all the continents have been evolved by rhythmic global tectonic events. There is continuous migration (retreat) of hillslope and such retreat is always in the form of parallel retreat."

- He rejected the relationship between uplift and slope formed by penck.
- He accepted the idea of structure- process and slope given by Davis but he changed the sequence in which process was placed first. Process for King meant the semi-arid enviornment. The semi-arid environment was suggested by king because in this type different types of river mass wasting and weathering process are important in addition to the work of river .
- His ideas represent a combination of Process, structure ,crustal movement and mass wasting.
- Kings idea can be understood in terms of 3 components: 1) Slope element 2)Development of Hill slope 3)Epigene cycle of erosion

- The reference system of King's model says "there is uniform development of landforms in varying environmental conditions and there is insignificant influence of climatic changes in the development of fluvially originated landforms.

- King accepted the concept of stages (i.e. at continental scale , there are massive erosional surfaces forming large staircase) and rejected the concept of crustal movements for creating of slope for cycle.
- The initiation of landscape depends upon the mode of development of hill sides . There are 2 different modes of development of hill sides:-

1 . (a) Valley formation through stream incision. (b)Formation of valley sides due to tectonic forces.

2 . Gentle lifting towards the sea. Acc. to him development of landscape depends upon mode of stream incision.

In this case valley sides are very steep because of uplift. The longitudinal profile of the river is broken by the development of knick points. The breaks in rivers beds form knick points. The river tries to remove or erode these knick points which recede in the upstream direction.

- His ideas on this aspect are based on his observation in coastal south Africa particularly Drakensberg mountains . The monoclinal warping resulting in continental scarps. These scarps are at right angle to the drainage lines. The drainage line are the major agent for the removal of material created through the progress of a particular cycle. The erosional processes results in the retreat of these continental scarp. The removal of the material results in the parallel retreat of the scarps. Between two scarps is a cyclic landscape surface.
- Different epigene cycle produce different cyclic surfaces. [The term epigene refers to the surface. Therefore the epigene cycle of erosion is related to water and wind. In addition to weathering, mass wasting. It doesn't include Glacial ,marine, volcanic and karst processes.

SIMILARITY BETWEEN DAVIS AND KING

- Lester C King's model of landscape evolution is similar to Davis' in that uplift is episodic and rapid in comparison with rates of denudation, and that the overall morphology of a landscape at any point in time is diagnostic of its evolutionary stages of development.
- It is worth noting that King's concept of upliftment and crustal stability is similar to the concept of Davis.
- The cycle of pediplanation is performed by twin processes of scarp retreat and pedimentation.
- Each cycle begins with rapid rate of upliftment followed by long period of crustal (tectonic) stability.
- The cycle of pediplanation begins with the uplift of previously formed pediplains and not of any structural unit.
- The pediplanation cycle passes through the stages of youth, mature and old as in the Davisian cycle of erosion.

DIFFERENCES BETWEEN DAVIS AND KING

- The difference: mode of slope development. King emphasized the role of erosion alone in the formation of pediment whereas Davis has emphasized both erosion and deposition in the formation of pediplains. His model is very comprehensive .
- Davis's peneplain is formed due to down wasting while King's pediplain is formed due to coalescence and integration of several pediments which are formed due to parallel scarp retreat.
- Once formed, Davis's peneplain does not experience further growth until it is reuplifted. When uplifted, new erosional cycle is initiated and the rivers are rejuvenated. On the other hand, King's pediplain once formed further grows headward.
- New scarp is initiated at the far end of the previously formed pediplain which is progressively consumed by the retreat of new scarp and thus second pediplain is formed while the former pediplain experiences decrease in its extent.
- The process continues and a series of intersecting pediplains are formed which extend headward. Hence, King's pediplains, so formed, are analogous to Penck's piedmont treppen.

Critique of King's Model

- King's model was subjected to many criticisms:

(a) King's model was limited to the southern African experience.

(b) It is doubtful to assert that there is uniform development of landscapes in different environmental conditions.

(c) King's concept of antique Pediplanation remains questionable.

DYNAMIC EQUILLIBRIUM THEORY

Theory of J.T. Hack

- American geomorphologist J.T. Hack made a serious attempt to fill the conceptual vacuum created by the criticism and rejection of Davisian evolutionary model of geographical cycle and Penck's morphological system.
- Hack pointed out that multi-level landscape (polycyclic relief) cannot be explained in terms of multiple erosion cycle (Davisian notion), rather these landscapes can be explained in terms of Dynamic Equilibrium Theory.
- According to Hack, geomorphic system is an open system and so long as energy remains constant in the geomorphic system, landscape remains in the steady state condition despite the lowering in the landscape by denudational processes.
- Hack's model envisages time-independent development of landscape.
- In other words, "the shape of the landforms reflects the balance between the resistance of the underlying materials to erosion and the erosive energy of the active processes".

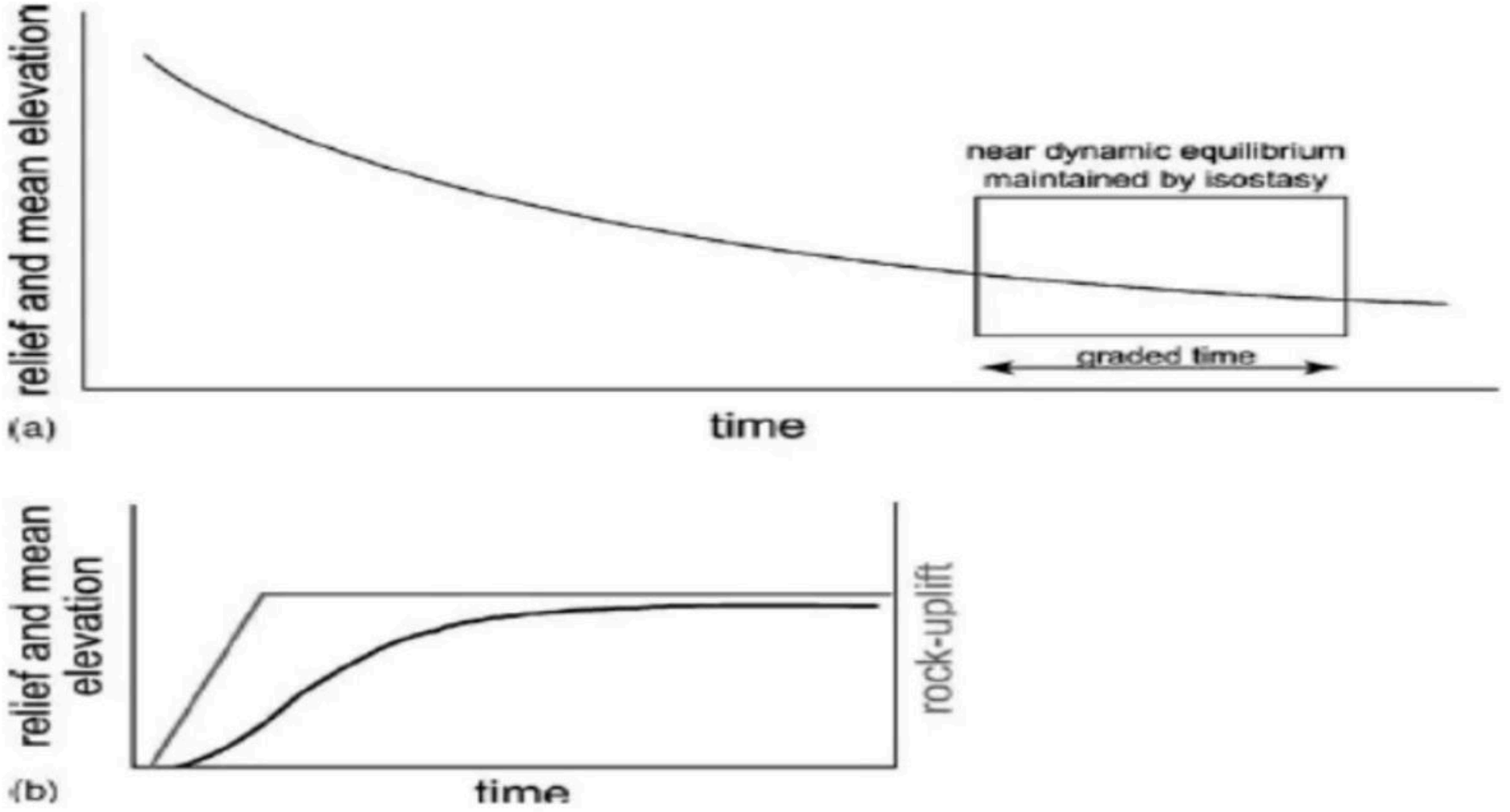


Fig. 6. Attainment of a near time-invariant relief and mean elevation of a dynamic equilibrium landscape (a) attained over graded time during a protracted period of decay (cyclic time) and (b) attained as a flux steady-state between the input of rocks by tectonic processes and output by erosion.

- The alternative favored by Hack is that landscapes are in a state of dynamic equilibrium.
- They are in equilibrium in the sense that given the same driving and resisting forces over a long period of time, a “timeindependent” characteristic landscape will emerge.
- This is a landscape where the rivers and hillslopes are all “graded” and the processes acting on the interfluves and channel bottoms, although different, are lowering their respective parts of the landscape at the same rate.
- The landscape is dynamic in the sense that climate, tectonics, and rock type change as subaerial erosion progresses so there is a constant adjustment between the principal driving and resisting forces such that true equilibrium is probably only asymptotically reached.
- Strictly speaking, a truely characteristic or steady-state landscape cannot exist, except in a tectonically active setting where the mass flux in and out of the orogen is conserved.

The main assumptions of the Hackian model of landscape development are:

(a) There is balance between denudational processes and rock resistance.

(b) There is uniform rate of downwasting in all components of landscapes.

(c) Differences and characteristics of form are explicable in terms of spatial relations in which geologic patterns are primary consideration.

(d) The denudational processes which operate at present have been carved out of the earth's surface landscapes.

(e) There is lithologic adjustment to landforms.

Gilbert's Theory

- On the basis of his investigation of landforms and the processes associated with their formation in different parts of the United States, Grove Karl Gilbert formulated a set of principles to explain geomorphic features.
- The concepts and principles propounded by Gilbert provided the base for the development of the dynamic equilibrium theory involving time- independent development of landforms and it subsequently became the pivot of drastic methodological shift in geomorphology.
- According to Gilbert, "the landscape is the result of two competing tendencies i.e. tendency towards variability (when driving force exceeds resisting force) and tendency towards uniformity (when driving force equals resisting force)".
- Gilbert says landscapes remain in equilibrium condition, their history is rhythmic punctuated by oscillatory changes and their forms are punctuated by frictional rhythms arising out of the mechanism of driving and resisting forces.

GIBERT'S PRINCIPLES

- The three major components of Gilbert's geomorphic principles are: the concept of quantification, the concept of time and the concept of equilibrium.
- Gilbert's concept of equilibrium, also known as the principle of least force, envisages that in the final form of any functional system "the sum of the forces acting on the final form equaled zero". There are two types of forces: driving force and resisting force. He tried to explain the formation of laccoliths resulting from vulcanicity during his field studies by applying the concept of equilibrium.
- According to him the formation of laccolith depends on the competence of driving force (rise of magma) and resisting force (overlying pressure of superincumbent load). The formation and growth of laccoliths continue so long as the driving force of rising magma is not countered by resisting force of equal magnitude acting downwards. When the driving force is balanced by the resisting force, the growth of laccolith becomes static.
- A state of equilibrium is achieved and thus the principle of least work becomes operative wherein the sum of driving and resisting forces becomes zero.

Geomorphic Ideas of Davis and Penck

Davis

W.M. Davis published his basic thesis on the cycle of erosion in 1899, considered some complications associated with the cycle in 1904 and brought out his main ideas together in a single work in 1909, and went on modifying and extending his views in a number of ways for the next 30 years.

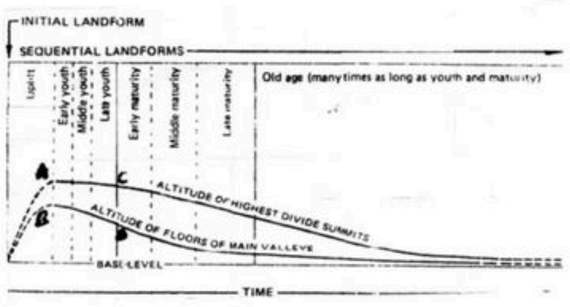
Davis coined the familiar phrase **"landforms are a function of structure, process and stage."**

There are probably none who doubt the importance of structure and process in landform development. But, today many doubt the validity of stage as a major factor. The following statement brings out Davis's idea of stage:

"As the differential erosional agents act upon the earth's surface there is produced an orderly sequence of landforms having distinctive characteristics at the successive stages of their development".

Based on this idea of stage Davis organised the orderly sequence of landforms into the concept of geomorphic cycle and its concomitant stages of YOUTH, MATURITY and OLD STAGE. Using a simple, descriptive, interpretive, deductive approach and using simplifying assumption (some of which he knew not to justifiable in nature) to make the exposition easier, he explained how the cycle operated. An Initially flat or nearly flat landscape is rapidly uplifted. Erosion then proceeds under prolonged tectonic stability and the landscape passes through the stages of youth maturity and old stage, each having a distinctive and recognisable characteristics. The end product is a surface of low relief-nearly a flat landscape-which Davis termed as PENEPLAIN. The peneplain is almost similar to the initial land surface, and thus a CYCLE of events has truly been run, since renewed uplift would trigger off the same sequence of events once again.

Graphical Representation of Davis's Cycle of Erosion

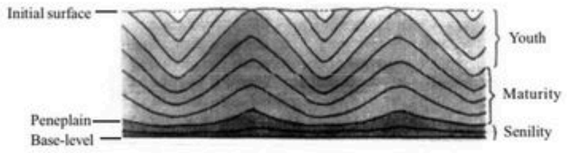


A — Represents the average initial height of the higher points of the uplifted landmass

B — Represents the average initial height of the lower points of the uplifted landmass

AB — Represents the average initial relief

CD — Represents the maximum relief



Stages in the cycle of erosion (according to Davis)

Introductory Episode: There is a short introductory episode of uplift (represented by dotted lines). The vertical distance AB is the measure of the average initial relief.

Initial Stage: In the initial stage of the cycle the floor of the valleys suffer down-cutting and are lowered but the summit of mountains remain relatively unaffected. This increases the relief, which is visible from the two lines of the graph getting away from each other. When the characteristics of the initial levels are eroded away the relief becomes maximum. This is the beginning of the mature stage represented by CD.

Mature Stage: As the land form enters the mature stage, vertical erosion slows down and horizontal erosion becomes important. During this stage mountain tops are eroded fast and their heights reduced actively. The floors of the valleys, however, are lowered slowly. As a result, the two lines AC and BD come closer to each other, representing reduction in relief.

Old Stage: In the later stages of the cycle the convergence of the curves continues but the process is immensely protracted in time. On account of the reduction in heights, and, the gentler slopes the process of erosion and slope reduction is slowed down. The continuance of the curves on the extreme right represents the old stage.

Davis's cycle of erosion has distinct stages along with special characteristics. Here an attempt has been made to outline some of the characteristic features of the fluvial cycle of erosion. (REFER TO THE TABLE)

The Term "Normal": The processes eroding the landscape were grouped together by Davis under one heading, 'NORMAL'. He did not explicitly define 'normal' but by implication he meant the assemblage of processes dominating the temperate landscapes of N. America and Europe (where he worked) and especially the action of running water. That is, by the term 'normal' he meant the fluvial cycle of erosion.

Base Level, Interruptions in Cycle: Partial Cycles

The concept of base level is crucial to Davis's thesis, and he examined the effect of minor uplift in detail. Later he acceded that due to intermittent and differential uplifts partial cycles instead of completed cycles may result. Many landforms are polycyclic with partial cycles.

He was also aware that the cycle might not be able to run its full course because of climatic changes. He viewed glaciation, aridity and indeed vulcanicity as interruptions of the cycle and called them accidents. Later he was even convinced of the need to formulate a separate cycle for arid regions.

Criticism of Davis' Work

1. **In over-emphasising** stage Davis has given relatively lesser attention to structure as an important controlling factor and thereby has done injustice to his own statement that landforms are a function of structure, process and stage.
2. **Davis did not make a detailed study of** the mechanics and nature of the present day processes neither in theory nor in the field.
3. His use of the term 'normal' has been severely criticised. By implication his normal cycle mean the assemblage of processes dominating the temperate landscapes of N. America and Europe, where he worked, especially the action of running water i.e. The fluvial cycle of erosion. Since the humid temperate mid latitude landscapes cover proportionately very small area on the globe, application of the term normal is questionable. In the temporal sense also the term is inappropriate because the mid- latitude landscapes are just emerging from an orogenic period. They are also just emerging from the ice age (to be more precise they are almost certainly in an interglacial stage). In the context of conditions that have occurred in the geological past, present conditions are not normal but unique.
4. The **concept of grade** as defined by Davis has proved elusive.
5. The **assumption of initial rapid uplift and erosion proceeding only after complete upliftment and under prolonged Tectonic stability is unsatisfactory**.
6. Davis has **comparatively neglected** depositional processes as a factor in landform formation. This is faithfully reflected in the title- cycle of erosion'.
7. **Davis neglected biological processes completely.** This is quite surprising because he based his work on well vegetated mid latitudes.
8. Environmental changes may cause interrupted cycles giving rise to partial cycles and polycyclicity. Davis conceded this fact but this is not enough. The point is, the environmental changes mean periodic changes of processes also, so **landforms will be polygenetic not just polycyclic.**
9. Davis **never measured form**. Impressions of slope form are notoriously inaccurate and misleading.
10. The cycle of erosion has a **descriptive simplicity** and is a **gross generalisation** useful only at elementary level, but inadequate when a more sophisticated approach to landform evolution is attempted.
11. Davis's work is a deductive approach. This means basing an argument on certain assumptions, and proceeding or inferring from the general to the particular. This is unscientific. Scientific method is the inductive approach, which builds on experimental evidence from particular instances to general references.

Merits

The strength of Davis ideas cannot be substantiated any more firmly than by noting their pervasiveness and longevity. The fact that they still merit attention, above and beyond that assigned to a historical footnote, hundred years after their embryonic emergence is a truly remarkable measure of Davis's intellect. However, the geographical cycle no longer dominates geomorphological thinking as it once did. In short, it is possible to see both strength and weaknesses in the model.

1. The innate appeal of the geographical cycle is its theoretical tenor, reinforced by its simplicity (R. J. Chorley), applicability, elegance of presentation, seemingly careful field work, filling of an intellectual void, synthesis of prevailing thought, predictive and retrodictive, rational, embracement of evolution, confirmation of prevailing stratographic concepts and innate appeal of humid climate being normal of cyclicity.
2. It was a model that not only answered the questions being asked by geomorphologists at the time it was introduced, but did so by appealing to principles embraced by virtually the entire scientific community of the time.
3. Davis was a gifted artist and his field sketches did not merely illustrate his papers, but rather conveyed the entire message in an alternative medium to the written world.
4. Woodridge and Morgan are ardent supporters of Davis's geomorphic cycle and rightly so but, they too like Davis have unjustifiably assumed rapid uplift in the beginning so that there is no scope for "any significant amount of erosion during the process of elevation".
5. Except for the rapid uplift assumed for the beginning of the cycle, the cycle concept of Davis is probably still the most suitable and satisfactory framework for explaining landscape evolution.
6. Bretz from his field studies in the Ozarks mountains in the USA confirms the cyclic evolution of landscape.
7. L. Wilson believes in a gradual landscape evolution "perhaps similar to that postulated by Davis".

Critical analysis of Davis' Geomorphic ideas

Most geomorphologists do believe that landforms have an orderly and sequential development. However they are not convinced that stages of youth, maturity, and old age as postulated by Davis have reality. They consider Davis's concept as a gross generalisation useful only at the elementary level, but inadequate when a more sophisticated approach to landform evolution is attempted. Thus, whether there are distinctive and expectable characteristics at each stage of development is a point about which there has been increasing scepticism. Especially there has been increasing doubt on the reality of peneplain as the end product of an erosion cycle.

Most geomorphologists now believe that the term geomorphic cycle carries with it the implication only of orderly and sequential development, but carries no implication that designation of the topography of a certain area as youthful, mature and old means that the topography of another region in the same stage of development has fully comparable characteristics. Actually under varying conditions of geology, structure and climate, landform characteristics may vary greatly even though the geomorphic process may have been acting for comparable periods of time.

Moreover, although passage of time is implied in the concept of geomorphic cycle, it is in the relative rather than an absolute sense that it is accepted today. There is no implication that two areas that are in comparable stages of development have required the same length of time for their attainment.

Much confusion has arisen because of considering geomorphic cycle as the period of time required for reduction of an area to base level rather than as changes through which a landmass passes as it is reduced to the base level.

Partial cycles are a corollary to the concept of complete geomorphic cycle. In fact, partial cycles are more likely to occur than completed ones, for most of the earth's crust is restive and subject to intermittent and differential uplift. Only sometimes, the portions of earth's crust remain essentially stable for sufficient periods of time to permit the attainment of advanced stages of landscape evolution. Even in this case, partial cycles leave back some of their imprints. Polycyclic landforms, with partial cycles are much common than, with successive completed cycles.

Again, landforms are rarely carved out by a single geomorphic process. In most cases landforms are polygenetic.

Conclusion

Davisian geomorphology now stands in a peculiar position. On part it has been proven wrong, but it has been bypassed rather than replaced. Davis's failure to undertake process measurements undoubtly stimulated the modern emphasis on quantitative, process geomorphology. Finally we can conclude that Davisian approach is an "acceptable introductory teaching vehicle".

Penck

In the 1920's while he was still publishing frequently, Davis attracted criticism from a German geologist, Walter Penck. Penck worked for many years in S. America. In his "Die Morphologische Analyse" (1924) he offered a philosophy of geomorphology which some have considered a serious challenge to the teaching of Davis. His work is in difficult German prose. But its English version "Morphological Analysis of landforms" was brought out by Czech and Boswell (1953).

Davis and Penck saw geomorphology through different eyes

According to Davis the primary goal of geomorphic studies is the effective description of the features of the earth's surface.

Penck on the other hand held the view that the main purpose of geomorphological research is to obtain information that might contribute to the understanding of the earth's crustal movements i.e. of the endogenetic forces that had acted upon and are acting to influence the topographic features of any particular region.

Penck's Ideas on Slopes

He made the following assumptions:

i) Any slope, even if curved is in effect made up of a number of straight slope segments called slope units.
ii) All slope units undergo parallel retreat.
iii) The rate of slope retreat = f (gradient) i.e. steep slopes retreat quicker than gentle slopes. The above three assumptions were built into a theory of slope and landscape evolution that rested on one more vital assumption.
iv) The shape of slope (and thus shapes of landscapes in general) was determined by the relative importance of exogenetic and endogenetic processes.

He thought that the slopes of any region are essentially similar in gradient and that the "intensity of erosion" determined the characteristics of the slopes. Three situations were visualised:

a) *Convex Valley Side Slopes:* This results from an increasing intensity of erosion (which also implies an accelerating rate of uplift)-waxing development. Steilrelief (strong relief) is the result.
b) *Straight Valley Side Slopes:* This results from a constant intensity of erosion. The resultant landscape is Mitterelief (medium relief). Slope steepness would depend on the rate of incision.
c) *Concave Valley Side Slopes:* This result from a declining intensity of erosion (which also means a decelerating rate of uplift) - waning development.

Though factors other than crustal movements also influence the intensity of erosion, Penck considered the endogenetic processes to be the most important.

Criticism

Probably majority of geologists are unwilling to accept Penck's view that the shape of slopes depends on the intensity of erosion as conditioned by the nature of endogenetic processes. Valley side slopes are undoubtedly affected by numerous other factors such as lithology, structure, climate, nature of debris produced by weathering and its mode of transport. It is too much to assume that they reflect mainly the nature of crustal movements, which have affected a particular area.

Penck's Backwasting and Davis' Downwasting

One of the most recognised concepts of Penck is that of slope replacement from below. As a given straight slope unit retreats parallel to itself it is replaced from below by another straight slope unit of gentler gradient. Since the steeper slope units will retreat more rapidly than the gentler once, the gentler slope will eventually replace the steeper one above it.

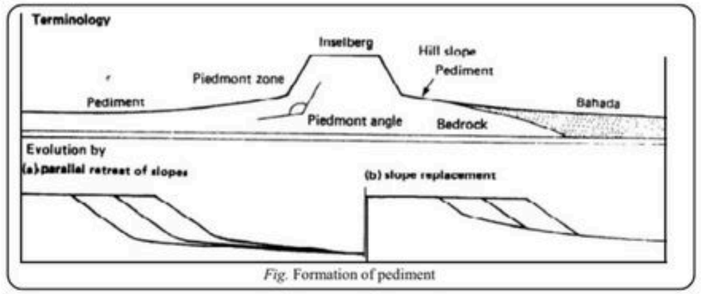


Fig. Formation of pediment

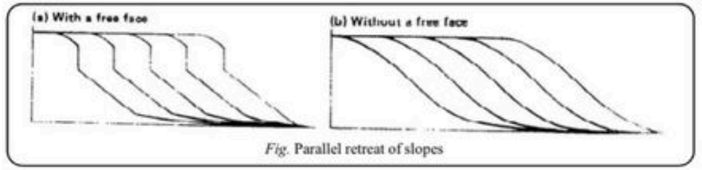


Fig. Parallel retreat of slopes

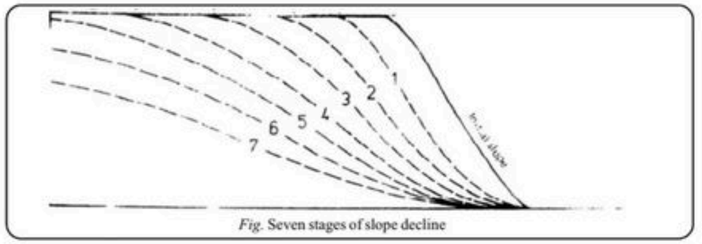


Fig. Seven stages of slope decline

As the process continues each slope is successively replaced by progressively gentler slopes from below.

To a degree both Penck and Davis believed, that flattening of slopes take place as land dissection goes on but they arrived at progressively flatter slopes in different ways. Penck believed that flattening of slopes took from below upwards through extension of the lower gradient slopes at the expense of the higher gradient slopes. Thus, according to him reduction of a landmass is largely a matter of back wasting of slopes. Davis, however, believed the slope flattening took place from above downwards. Thus, reduction of landmass according to him was a matter of down wasting.

Penck's Primarrumpf and Cycle of Erosion: Comparison with Davis' Cycle of Erosion and Peneplain Concept

Penck considered that the diastrophic conditions necessary for the progress of an erosion cycle, as envisaged by Davis, with its resultant peneplain represent a special and uncommon case and not a normal one. He was particularly dissatisfied with Davis' assumption of very rapid uplift followed by a prolonged period of structural stability. Penck built his whole body of the theory on the alternative assumption of uplift so protracted in time that the landscape would be eroded at the same time as it was being uplifted i.e. rates are such that the relief remains practically the same. Such a condition would give rise to a low, rather featureless plain which he called primarrumpf (called primary peneplain by Sauer).

As Penck pointed out, the primarrumpf looks like an end peneplain, but is actually at the beginning of a sequence of landforms. Primarrumpf forms the universal initial geomorphic unit for all the topographic sequences that follow. After its formation, the subsequent history of the primarrumpf depends upon whether it is under waxing, waning or constant development e.g. with waxing uplift may be elevated high above sea level, but It remains a primarrumpf even though it undergoes degradation.

Penck termed the terminal plain which resulted from the degradation of a landmass which has had high relief as endrumpf. Thus, primarrumpf is the initial stage in a period of diastrophism marked by accelerated uplift (waxing development) and the endrumpf is the end stage of a period of degradation marked by declining uplift (waning development).

Penck opposing Davis's rapid uplift concept said that the process of uplifting continues for a long time. It is not reasonable to think that erosion does not start till the upliftment is complete. Penck also emphasised that the rate of upliftment is not uniform.

Graphical Representation of Penck's Cycle

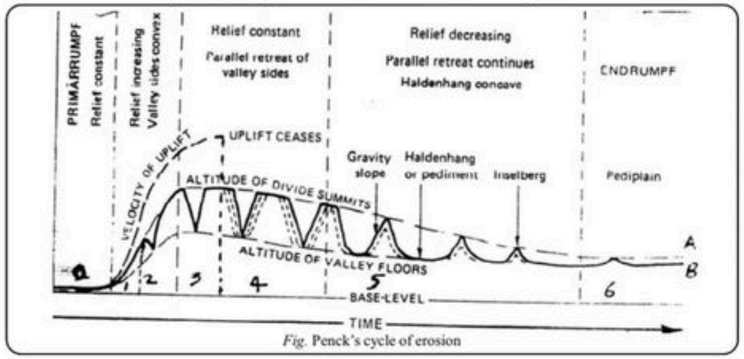


Fig. Penck's cycle of erosion

1. ***First Stage:*** It is evident from the figure that the height of the summits of interfluves (by A) increase with the rise of the land. As the downcutting by rivers is not brisk, the height of the lower part (by B) also rises, and does not keep pace with the upheaval, so that both absolute altitude and relief increases. The flat interfluves are little eroded and gain in altitude by the amount of upheaval.
2. ***Second Stage:*** Even in this stage the rate of downward cutting of valleys is less than that of upliftment. The land as a consequence rises slowly. Due to horizontal cutting by rivers the land becomes narrow and sharp. The irregularities of the surface remains almost the same (i.e. relief remains almost constant.)
3. ***Third Stage:*** The rate of downward cutting is the same as the rate of upliftment. Both, the height (altitude) of the interfluves and the relief remains constant.
4. ***Fourth Stage:*** In this stage upliftment has ceased. Valley deepening continues. The height of interfluves also decreases. Relief remains constant.
5. ***Fifth Stage:*** The deepening of the valleys is slowed down. The height of interfluves begin to decrease and ridges get rounded and their height decreases. Both altitude and relief decrease slowly.
6. Formation of Pedeplains.

The other Cycles of Penck

Penck in the first cycle supposed that the upliftment of land was long and continuous process. Some of the result derived by Penck in his studies of different parts of Europe are important. The stages of this cycle proved to be true in the middle parts of the Alps but Penck's cycle could not be successfully applied to the peripheral parts of the Alps. Hence Penck thought of other cycles.

Penck's Second Cycle

If land is uplifted in a short period of time, its stages of evolution will not be similar to those of Penck's first cycle. The interfluves are not angular but their ridges are directly converted into rounded shapes. In the initial stage when the slopes are steep, the valley deepening process is not much rapid.

Penck's Third Cycle

The cycle is applicable when the land rises slowly. Valley is deepened as fast as the land is raised and widened faster than they are deepened. The flat topped interfluves would be degraded as fast as they are raised and thus, sharp relief could never be attained.

The Second and Third cycles of Penck were found true in the peripheral regions of the Alps. Critics say that many similar cycles can be imagined to exist by supposing different rates of upliftment of land. Hence not much can be given to the cycles.

Merits of Penck's Cycles

1. Penck has done his **work on a large scale.** He has given a **lot of details**. The whole work was carried **in a systematic manner.**
2. Since he followed a deductive approach his results are not limited to any special condition of development.
3. The important contribution of Penck lies in the fact that the cyclic stages depend upon the **mutual relation between upliftment and the rate of degradation.**

The balance between uplift and degradation as envisaged in stage -3 is true in the middle parts of Alps.

Penck emphasizes the continuous rise of the land and does not believe that the land did not rise once it was uplifted. This is why Penck's hypothesis in known as forward looking.

Demerits of Penck's Cycle

1. It is imaginary to think that all stages of the Penck cycle took place in the same **order.**
2. Penck's **too much emphasis on mutual relation** between rise of land and deepening of valley has been severely criticised.
3. Our **knowledge of the initial condition of land is inadequate**. Hence the facts and estimation of Penck appear to be imaginary.
4. **Aspects other than geological are** also important but have been **given less importance** by Penck.

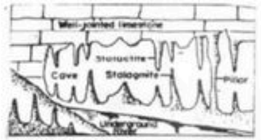
Fluvial Cycle

YOUTH	MATURITY	OLD STAGE
Drainage A few consequent streams present. Numerous Short tributaries and gullies present which will be extending themselves by headward erosion and developing a valley system.	Valleys have extended themselves so that the region has now a well integrated drainage system. Subsequent streams are dominant as tributaries.	Tributaries to trunk streams usually fewer in number than in mature but more numerous than in youth.
Valley profile Valleys have V shaped cross profiles.	Valleys have open V shaped cross profiles. Interlocking spurs are common.	Valleys are extremely broad and sloping both laterally and longitudinally.
Interstream Tracts Interstream tracts are extensive and poorly drained. Lakes and swamps may exist in the interstream areas if these are not well above the local base levels. Stream divides are broad and poorly defined.	Stream divides are sharp and ridge like resulting in a minimum of interstream uplands.	Interstream areas have been reduced in height and stream divides are not seen as in maturity. Lakes, swamps and marshes may be present but they are in floodplains and not on interstream tracts as in youth
Waterfalls etc Waterfalls, rapids may be present. Potholes may present.	Waterfalls, rapids not present.	
Floodplains There is a general lack of floodplain development.	A slight development of floodplain may occur.	There is a marked development of floodplain.
Meanders Stream meandering may exist, but the meanders are those on a flat and undissected initial surface or as closely confined meanders in valleys incised below the upland surface.	Meanders may be conspicuous but as contrasted to those of youth they are free to shift their positions over the floodplain. The widths of the valley floors do not greatly exceed the widths of the meander belt.	The river meanders are very broad in the floodplain. The valley widths are considerably more than the widths of meander belt.
	Maximum possible relief exists at the beginning of the mature stage.	Mass wasting and chemical denudation are dominant over fluvial processes. Extensive areas are at or near the base level of erosion.

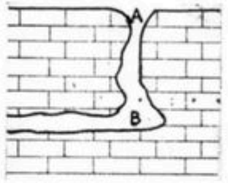
Karst Landforms and Cycle

- The word karst is a comprehensive term applied to limestone or dolomite areas that passes a topography peculiar to and dependent upon underground solution and diversion of surface waters to underground routes. The term comes form a province of Yugoslavia on the Adriatic sea coast where such formations are most noticeable. Karst topography is the only geomorphic landscape, which is named after rock formation.
- The conditions contributing to maximum development of karst include
  a) location of soluble, highly jointed and thinly bedded, dense rocks near or at the earth's surface
  b) presence of deeply entrenched valley of a master stream and
  c) a moderate amount of rainfall.
- The groundwater moves vertically downwards, rises in capillaries, percolates and flows turbulently through large openings. Basic processes involved in the development of topography are solution, corrosion, corrasion and deposition.
- Features of the karst topography develop on the surface as well as below it. LAPIES are highly rugged surface with marked relief. SINK HOLE is a funnel shaped depression underneath which cylindrical SWALLOW HOLE lies at some depth. These holes virtually forming a BLIND VALLEY. DOLINE is formed by unification of many sink holes. As a result of subsidence several doline may merge to form an UVALA- a very large elongated depression occurring on steep slopes. Block movement of limestone due to faulting forms a large and deep depression called POLJE. The KARST LAKE is formed by lateral colescence of sink holes. NATURAL BRIDGE represents the remnant of the roof of a natural tunnel or subterranean cut off.
- CAVES and CAVERNS are formed by solution and contain some characteristic underground features formed mainly due to deposition of Calcium by evaporating and drying water drops which trickle down from the cave roof. Sharp, slender, downward growing pinnacles hanging from the roof are known as STALACTITES. The STALAGMITES rise upwards from the cave floor and are shorts, fatter and more rounded. Eventually they join to form a pillar known as COLUMN.
- Relatively uniform solubility of limestone makes karst landscape simples and more amenable to cyclic evolution.

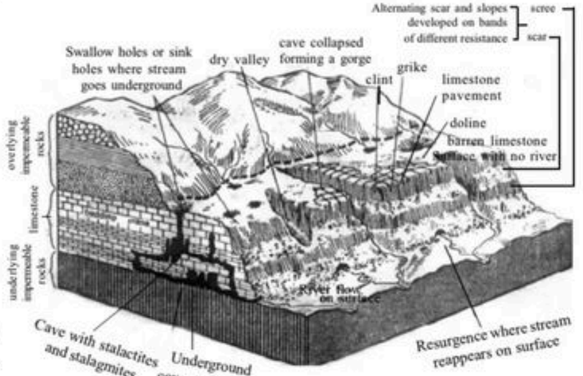
LAPIES



INTERIOR VIEW OF A LIMESTONE CAVE



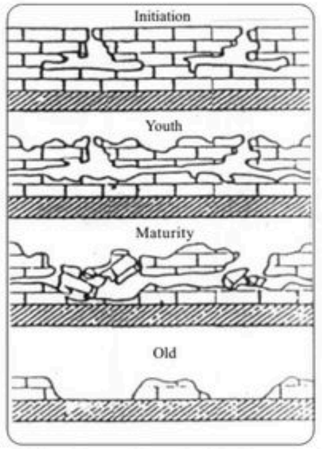
A - Sinks on the surface of limestone rock
B - Swallow holes at the bottom of a funnel shaped sink



LIMESTONE SCENERY

Karst Cycle

- While certain karstic features are common to limestone areas, the individual peculiarities of the major karst regions can be better explained in terms of an orderly sequential development by the introduction of a cycle and stage concept. This was attempted by CVIJIC for the Dinaric Karst.
- Whether there exists a distinct cycle of landform evolution in karst region or is it better to consider it as karst phase of a fluvial cycle, is a disputed question. However in most, if not all, karst areas we start with surface drainage and end with it. Relative uniform solubility of limestone and dominance of one geomorphic process that of solution, makes karst landscape more amenable to cyclic evolution and applicability of such terms as Youth Maturity and old age to the stages of karst development seems permissible.
- Conditions contributing to maximum development of karst include
  a) location of soluble highly jointed and thinly bedded, dense rocks near or at the earth's surface
  b) presence of deeply entrenched valley of a master stream and
  c) a moderate amount of rainfall.
- Karst cycle operates, through the movement of groundwater and an intricate combination of basic processes of solution, corrosion, corrasion and deposition.
- INITIATION of karst cycle may be
  a) through uplift above base level of a limestone terrain on which fluvial erosion had been in progress or
  b) through uplift of an area of elastic rocks beneath with are limestone's lying above the new base level.
- The **Stage of Youth** is marked by the presence of lapies, increasing in number and enlarging sink holes and gradually merging doline. There is progressive increase of underground drainage at the expense of surface streams leading to more solution, abrasion and thus enlargement of caves and caverns. Blind valleys are formed by eventual disappearance of surface streams, which also marks the end of youth and beginning of maturity.
- In **The Stage of Maturity** vigorous underground action by solution and abrasion and enlargement of passageways, caves and caverns continues. Such action tends to lower the water table towards the underlying impervious bed, which is the effective base



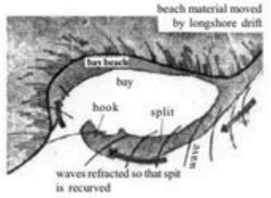
level of underground erosion. Solution action from above and below leads to the thinning of the roof of caverns and their eventual collapse forming uvalas and polies. Karst windows may be seen which are the parts of subsurface stream revealed by the collapse of a section of cavern roof. Arches, bridges and polie lakes are some other characteristic features of this stage.

- **The Stage Of Old Age** marks the reappearance of streams and deep entrenched valleys on the surface. All remaining underground caverns will be revealed by continued surface wasting. Over time remaining masses of limestone will be removed and the 'karst peneplain' is left dotted with bay stock like isolated residual hills called hums which are last surviving remnant of cavern walls.
- In a karst region the various stages of karst cycle may be present. The areas remote from the lines of maximum entrenchment by streams will be younger in cycle.

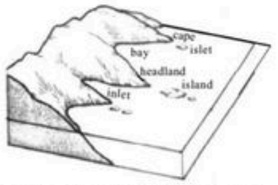
Karst cycle is unique in the sense that term 'cycle' has been applied to the evolution of landforms fashioned from a certain type of rock, instead of under particular climatic condition or by a particular process. Thus disruption in homogenity of limestone may obstruct wide application and utility of the concept of Karst cycle. Inadequate knowledge about the behaviour of underground water and contraversial origin of caverns are other limitations.

Coastal Landforms

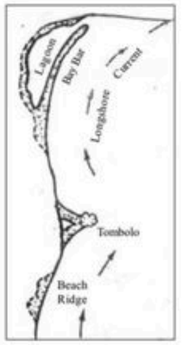
- Water in ocean is in constant motion. As it moves, it constantly modifies the shore producing a distinctive assemblage of landforms called coastal landforms.
- Waves particularly stern waves and tsunamis, armed with rock fragments are the most powerful agents of marine erosion. Tides extend the line of erosion and currents mainly help in transportation of debris.
- Besides wave strength, other factors influencing rate of marine erosion include (a) structure, composition and durability of rocks along the shore, (b) depth of water offshore, stability of sea level and tidal range, (c) configuration of coastline and openness of shore to wave attack, (d) abundance and size of abrasive tools and (e) human interference.
- Processes contributing significantly to marine erosion are corrasion, corrosion or abrasion, attrition, hydraulic action and the shock pressure of breaking waves.
- Confined to narrow coastal zone, many topographic features result from marine erosion and deposition. The softer rocks on the coast are worn back into INLETS, COVES or BAYS and harder one persist as HEADLAND, PROMONTORIES or CAPES. When the coast facing the sea has a scarp face resulting from wave erosion, it is known as CLIFF. As a cliff recedes landwards due to undercutting, an eroded base called WAVE CUT PLATFORM is left behind, long shore drift may deposit the sediments in deeper waters to form a WAVE BUILT TERRACE. Stream valleys are shortened and left as HANGING VALLEYS when cliff recedes.
- Wave action may hollow out a SEA CAVE in zones of weaknesses, which are loci of accelerated erosion. Two caves unite to form as ARCH. Eventually the arch collapses and seaward portion of headland remains standing as an isolated pinnacle called STACK which is further worn down to form a STUMP.



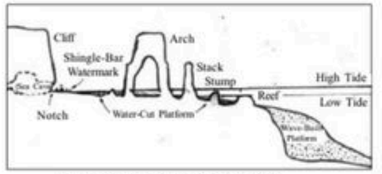
Beach, Spit, Hook



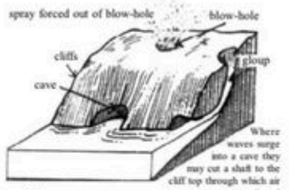
Coastal features of differential erosion



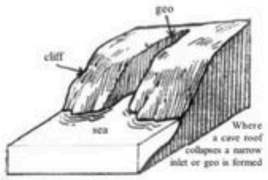
Bay bar, Beach Ridge and Tombolo



Composite section of cliff coast



Gloup



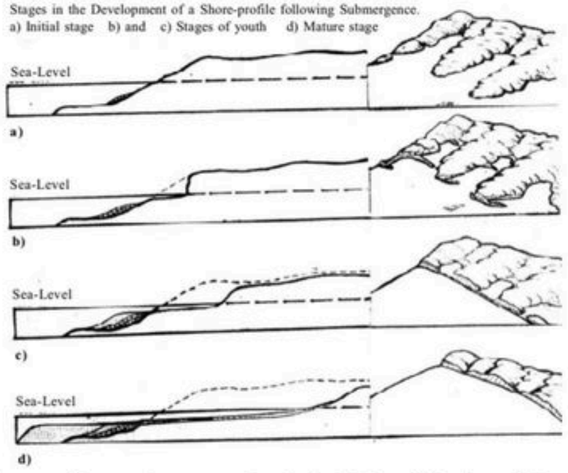
Geo

- Wave action on the zone of weakness in cave roof forms a natural shaft called GLOUP or BLOW HOLE. When roof collapses a long narrow inlet or GEO is formed.
- TIDAL POOLS are deeper depressions on the wavecut platforms. ROCK REEFS are isolated hard resistant parts of platform, which have withstood erosion.
- Sediments transported by waves and longshore drift is deposited to produce a variety of landforms. Sands and gravels loosened from the land are moved by waves to be deposited along the shore as BEACHES. Deposition tangential to the headland, resulting in a ridge or embankment attached to land at one end and projecting in the open sea at the other is called SPIT. Oblique waves may curve the spit into HOOK. BAR is the ridge formed across the mouth of a river or the entrance to a bay. Connecting bar that joins two landmasses is better known as TOMBOLO.
- BARRIER BEACHES are elongated sand ridges running parallel to the shore and rising slightly above high tide. A series of these features extending for a considerable distance is known as BARRIER CHAIN.
- Scholars like D W JOHNSON have presented a theoretical scheme to explain the sequential development of shorelines passing through the stages of YOUTH, MATURITY and OLD AGE.
- Shorelines and spectacular landforms are especially important to us because of the concentration of population on or near the coast. To live in harmony with this rapidly changing environment, we must understand the coastal dynamics and resultant landforms.

Coastal Cycle of Erosion

Process of erosion and depositions along a shoreline tend to develop a long and straight or gently curving coastline. The configuration of the shoreline evolves until energy is distributed equally along the coast, and neither large-scale erosion nor deposition occurs. In the process of attaining such equilibrium, a shore may be regarded as resulting from an initial form, erosion and deposition giving rise to succession of sequential forms passing through the stage of YOUTH, MATURITY and OLDAGE.

Stages in the Development of a Shore-profile following Submergence.
a) Initial stage b) and c) Stages of youth d) Mature stage



D W JOHNSON (1919) prevented a theoretical scheme to explain the sequential development of shorelines based on Davisian concept of cycle. He accepted that the cycle may be interrupted by crystal movements, and the coastal topography will vary according to the nature of rocks, the configuration of coastline and the strength of waves and currents. He proposed different cycles for submergent and emergent coastlines.

Shoreline development along submerged coastlines:

INITIAL STAGE is marked with an irregular coastline and numerous islands if there was moderate relief.

YOUTHFUL STAGE starts with wave attack concentrated on the headland sea cliffs arches and blow holes may abound as a wavecut platform is developed. Spits, hooks and bars extend out from the cliff and islands often connecting them.

MATURE STAGE the headlands cut back to the level of intervening bays and the coastline is straightened. Connecting bars are removed.

OLD AGE is achieved when waves and currents have reduced the shore to a gently sloping plain while land agents have reduced the relief almost to the sea level.

Shoreline development along emergent coastlines:

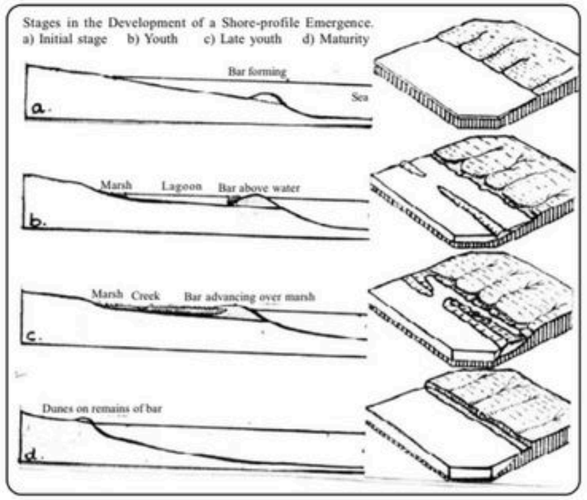
INITIAL STAGE is an uplifted marine plain into which the waves cut a notch. Offshore bars are common.

YOUTHFUL STAGE sees the growth of the offshore bar and the formation of lagoons linked to the open sea by tidal inlets. The offshore bar is now driven landwards obliterating the lagoon.

MATURE STAGE is the point at which the waves have destroyed the protecting bar and are actively attaching the former raised shoreline.

OLD STAGE is a theoretical concept. The evolution in profile, hereafter, will not differ materially from those of shorelines of submergence.

Naturally, the development of a shoreline is also affected by special conditions of structure and topography and by fluctuations of sea level or tectonics. However, the process of erosion of headlands by wave action and the straightening of the shoreline by both erosion and deposition follow the general sequence of these idealised models, although actual shorelines rarely proceed through all of these stages, because fluctuations of sea level upset the previously established balance. Despite the persuasiveness of arguments in favour, it is still not wholly clear whether the cycle of marine erosion has any, but theoretical value.



Arid Cycle of Erosion

Based on Davis's idea, the arid cycle of erosion is an idealised cycle, which applies only to mountain deserts where block faulting has produced many enclosed basins. As to open low-level deserts the concept of cycle largely fails. Besides wind, water also plays a very important role in this cycle. Davis regards this as modification imposed upon the humid cycle by a change to aridity, one of his so called climatic accidents.

Davis envisaged some differences between the humid (normal) cycle and arid cycle as

1. Contrast in run off,
2. Maximum relief in the youthful stage of arid cycle (not in maturity) and progressive decrease thereafter,
3. A prevalence of consequent drainage into enclosed basins,
4. Considerable aggradation of basins in the youthful stage when streams are actively dissecting the mountains,
5. Predominance of local base levels of erosion with few streams showing exorheic tendencies and
6. A 'desert peneplain' in the old age largely by wind removal.

In recent years, the tendency has been to emphasise the formation and extension of pediments as the major geomorphic process in the development of the desert landscape. L. C. King who outlined the 'Pediplanation cycle' was perhaps the most ardent supporter of this line of thought.

King stated that with the passage of time the low angled slopes gradually extended themselves at the expense of adjacent upland thereby leading to pedimentation. This process of parallel retreat of slope is referred to as 'scarp retreat' or back wearing by King. The twin processes of pedimentation and scarp retreat are considered to combine in the cycle of Pediplanation with its distinct stages of youth, maturity and old.

The Stage of Youth

The stage of youth is marked by river incision and valley development, increasing relief and the beginning of lateral pediments along the valley side. Pediments become more extended with scarp retreat. However, the remnants of the original pediplain will exist on all summits. By late youth many interfluves will have already been converted into inselbergs, many of which would take the form of remarkably rounded domes i. e. bonhardts and castle koppies. There is an independent centripetal drainage in each basin. If rain water survives strong evaporation a Playa may be formed. The centres of these basins would be the base level of erosion. Ravines and canyons develop in the slopes of highlands which undergo dissection and recession. The divides between the basin would be thus lowered and narrowed. On lower parts of the slope, fans and cones are formed and further down Bajadas may grow. The floodwater emerging from the Canyon mouths after storm rains may tear the fans, into wide channels called wadis.

The Stage of Maturity

The Stage of maturity is characterised by shrinking of inter stream hills tracts through extension of pediments by scarp retreat and near destruction of the initial topography. There will be a progressive reduction in the number of inselbergs as these are weathered into Koppies and finally destroyed. The widening pediments of adjacent valleys will begin to coalesce. In this stage, the relief would be further decreased and divides breached by recession of slopes and lowering of ridge summits the higher basins will become tributaries to lower larger ones thus forming a somewhat integrated drainage. By middle maturity continuous uninterrupted gradient may be established from the highest point to the lowest local base level.

In the old stage, the residual uplands of the original topography disappear through intersection of pediment scraps from opposing sides of the uplands. There is an ever-increasing coalescence of pediments culminating in the formation of a multi-concave topographic surface to which the name pediplain is commonly applied. It is marked with minimum relief, achieved not by rivers but by gradual lowering of the area by wind action which now dominates though active from the beginning of the cycle.

The eroded surfaces of the end stage may be even below the sea level because of inland drainage and dominance of wind action. The lower limit of deflation, however, may be set by the water table.

The earlier stages of the arid cycle of erosion can be matched in many places. However, considerable dubiety has existed concerning the old stage and the true character and origin of the ultimate plain feature, if any.

Formation of inselbergs and bonhardts especially in the Savana region (inselbergland schaft has evoked diverse explanations. Some schools like Budel, Cotton, Twidale, Ollier and Thomas have suggested that in the savanna landform, 'down wearing' rather than 'back wearing' is the dominant process. They believed that Bonhardts represent residual rock masses that were resistant to chemical weathering, which have been exhumed when the cirume-adjacent deeply weathered rock was eroded away. Amidst such controversies, now, the concept of arid cycle with limited applicability has few adherents.

Glacial Cycle of Erosion

Based on Davis's idea, W. Hobbs (1992) out lined a scheme to explain the sequential destruction of uplands by back wearing of cirque walls. In this cycle 3 landforms – cirques, aretes and pyramidal peaks are fundamental. The concept is based in the erosive power of moving ice.

In the youthful stage the pre-glacial surface will be dissected by cirques forming 'grooved uplands'. The cirques will be relatively widely sperced and much of the pre-glacial surface remains intact.

In the adolescent stage smooth topped ridges are broken by well proportioned and enlarging cirques to form 'early fretted uplands'.

In the mature stage the pre-glacial surface is eaten up by the further enlargement of cirques. Residual summits are now pyramidal peaks and the intervening ridges arretes. This is an 'advanced stage of fretted uplands'.

The old stage is the 'mommental upland' when aretes are broken through by cols. The pyramidal peaks are reduced to coomb ridges. This stage completes the desturction of the original surface.

Some geo-morphologists have pointed out that the lowering of mountains by 'glacial peneplanation' is merely a theoretical abstraction, not matched in the modern landscape, but others suggest that a surface of glacially induced low relief probably exists beneath thick ice-sheets in Antarctica and Greenland.

The attempt to establish a glacial cycle is attractive and useful, but it is as yet not based on sufficient numerous carefully studied examples. It would by premature to accept the theory in its entirely.

• ***COL*** is the lowest point on a mountain ridge between 2 peaks.

Polycyclic Landforms

- The concept of Polyclicity is a by-product of the idealistic "Davisian Geomorphic Cycle" and its inadequacies to explain the complete process of landscape evolution through time.

Partial cycles are far more likely to occur for much of the earth's crust is restive and subject to intermittent and differential uplift causing – **Interruptions** in the cycle. Mature or old age topography is likely to have superposed upon it, youthful features as a result of – **Rejuvination** which are DYNAMIC, EUSTATIC or STATIC in nature.

- In nature as is the Complexity of Landscape evolution more common than Simplicity so is the Polycyclic evolution more common than Monocyclic Development.
- HORBERG presented a five fold classification of Landforms:
  1. SIMPLE (one dominant process)
  2. COMPOUND (Tow or more process)
  3. MONOCYCLIC
  4. POLYCYCLIC or MULTICYCLIC
  5. EXHUMED or RESURRECTED

- MONOCYCLIC Landscapes bear the imprint of only one cycle of erosion and are restricted to newly created Land Surfaces such as a volcanic cone or a Lava Plateau.
- POLYCYCLIC Landscapes have been fashioned by tow or more partial cycles. Much, of not most, of the world's topography is Polycyclic and are found on all continents except Antarctica.
- Polycyclic landscapes can be simple or compound.
- Polycyclicity can also result from changes in the climatic conditions with accompanying variation in the dominant geomorphic processes and are alternatively referred to as –

  * POLYCLIMATIC landscapes e. g. the Great Lakes of North America, Fjord coasts of Norway etc.

  * Other Examples: The Rejuvenated Landforms e. g. paired river terraces – older Alluvial plains, two cycle valleys, incised meanders are all Polycyclic in Origin.