SEMESTER-1 (HONS.)
GEO-A-CC-1-TH
GEOTECHTONICS AND GEOMORPHOLOGY
TOPIC :12

SYSTEM APPROACH IN GEOMORPHOLOGY & MODELS ON LANDSCAPE EVOLUTION

(DAVIS, HACK, PENCK)

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- The interrelationship of the different parts of an organism when they are acting together ultimately guiding towards a result is called a system.
- Chorley and Kennedy wrote: *“A system is a structured set of objects and/or attributes. These objects and attributes consist of components or variables that exhibit discernible relationships with one another and operate together as a complex whole, according to some observed pattern*.”

CHARACTERISTICS OF SYSTEM:

- A system has structure, it contains parts that are directly or indirectly related to each other.
- A system has behavior, it exhibits processes that fulfils its functions or purpose.
- A system has inter connectivity, the parts and processes are connected by structural and/or behavioral relationship.
- A system structure and behavior may be decomposed via subsystem and sub-processes to elementary parts and process steps.
- A system has behavior that in relativity to its surroundings may be categorized as both fast and strong.

ELEMENTS OF SYSTEM:

- Inputs
- Outputs
- Process
- Feedback

• Inputs :

- Inputs involves capturing and assembling elements that enter the system to be the processed. The inputs are said to be feed to the system in order to get the out put .
- For example: Input of a computer system that includes- keyboard, mouse, joystick and sun, rain, etc.

- **Process**

- The processor is the element of a system that involves the actual transformation of input into output. It is the operational component of a system.

For example: CPU, Machineries, engines, fields, ecosystem etc.

- **Output:**

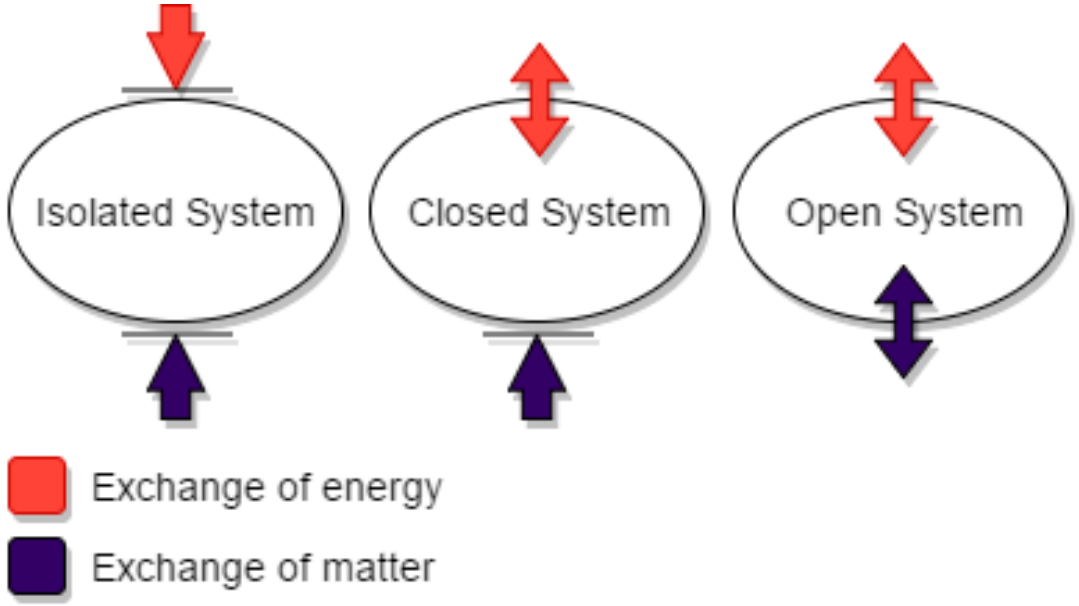
- Those elements that exist in the system due to the processing of the inputs is known as output. The output of a system may be in the form of cash, information, knowledge, reports, documents etc.
- For say: Output of a computer which includes printers and screens, monitor and erosion, grains, etc.

• OPEN SYSTEM:

- Open system have inputs and output flow representing exchange of matter, energy or information within the surrounding. In simple it is a system that transfers both energy and matter across its boundary to is surrounding environment.
- Example of an open system: Drainage basin, solar energy etc.

• CLOSED SYSTEM:

- It is a system that transfers energy but not matter, across its boundary to the surrounding environment.
- Our planet, carbon cycle, hydrological cycle are some examples of a closed system.



• Isolated System

- An **isolated system** is a thermodynamic **system** that cannot exchange either energy or matter outside the boundaries of the **system**.

FEEDBACK MECHANISM:

- **Positive:** A feedback is a change to a component of the system that causes a knock-on effect that further alters the original change. A positive feedback **amplifies the initial change**. If we look at a system in ***homeostasis***, a positive feedback loop moves a system further away from the target of equilibrium.

- **Negative:** Negative feedback is said to occur **when a change**. **in a system sets in motion a sequence of changes**. **that eventually neutralize the effects of the original change**, so stabilizing the system.

- **All models of landscape change are of two types:**

1. **Time-dependent Model**
    1. Landforms change in response to an initial disturbance or change in input (climatic change, tectonism), and then gradual progressive sequential change is characterized by the association of morphology with stage of development
    2. *e.g.* The **Davisian** cycle of erosion that dominated geomorphological thinking for decades
    3. It was a time-decay model because no further inputs were envisioned after the initial uplift of the landscape
    4. Just gradual, inevitable landscape evolution at an increasingly slower rate as the initial energy is dissipated

1. Time-independent Model

1. The alternative and subsequent view of landscape evolution
2. Rather than subject to ever-decreasing energy, landscapes are open systems, constantly adjusting to changing inputs and levels of internal energy
3. Geomorphic systems adjust to approach an equilibrium with the inputs acting on them
4. Because the inputs constantly vary, equilibrium can probably never be attained and thus characteristic is preferred to equilibrium to describe forms which reflect the landscape after a period of adjustment (relaxation) to a disturbance or major change in inputs

- **Geomorphic Time Scale**
- **cyclic**
  - longest timespans of landscape evolution
  - time is an independent variable and the most important one, because there are no specific or constant temporal relationships between independent and dependent variables (cause and effect)
  - climate, initial relief and geology are the other independent variables, all others are dependent
- **graded**
  - a short segment of cyclic time during which a graded condition or dynamic equilibrium exists, that is, fluctuations about (approaches to) a steady state and tendency for negative feedback
  - applies to some but not all components of a geomorphic system because relief is still being reduced throughout the entire system
  - time and initial relief are irrelevant because parts of a geomorphic system are adjusted to prevailing inputs
  - the only dependent variables are responses (*i.e.* morphology and output from the system)
- **steady**
  - a brief period during which some part of a system is unchanging and thus truly time-independent
  - once again time and initial relief are irrelevant
  - the only dependent variable is outputs of energy and mass since morphology is constant
  - more recently referred to as engineering time

- Cycle of erosion: (DAVIS)

- Development of geology as a separate branch of science -1775 to 1830.
- Hutton (1726-1797) -**uniformitarinism**. John Playfair (1748-1819) published Hutton's theories and added further ideas.
- Lyell published the classic textbook, 'Principles of Geology', in 1830-1833.
- William Smith (1769-1839)-stratigraphical successions based on fossils
- By the middle of the Nineteenth Century, the general geological time scale based on fossils and stratigraphic mapping was established.
- Geomorphological studies were advanced by the work of Agassiz, who in the 1840s recognised the effects of Pleistocene glaciation in Europe and the USA.
- Later Gilbert and Powell made classical studies on arid erosion in the western USA.
- The strongest influence up to 1900 was the work of W.H. Davis, an American who worked both in USA and Europe and who first defined the cycle of erosion.

Why is it designated as NORMAL cycle of erosion?

- **NORMAL CYCLE OF EROSION = FLUVIAL CYCLE OF EROSION**

- STRUCTURE = Denotes LITHOLOGY, ATTITUDES COMPOSITION, TEXTURE OF EARTH MATERIALS

- PROCESS = Denotes Exogenetic and endogenetic processes

- STAGE = Denotes THE SUCCESSIVE PHASESOF LANDFORM EVOLUTION

- **The basic premises of Davisian model of 'geographical cycle' included the following assumptions made by Davis:**
- (1) Landforms are the evolved products of the interactions of endogenetic (diastrophic) forces originating from within the earth and the external orexogenetic forces originating from the atmosphere (denudational processes, agents of weathering and erosion-rivers, wind, groundwater, sea waves, glaciers and periglacial processes).
- (2) The evolution of landforms takes place in an orerly manner in such a way that a systematic sequence of landforms is developed through time in response to an environmental change.
- (3) Streams erode their valleys rapidly downward until the graded condition is achieved.
- (4) There is a short-period rapid rate of upliftment in land mass. It may be pointed out that Davis also described slower rates of upliftment if so desired.
- (5) Erosion does not start until the upliftment is complete. In other words, upliftment and erosion do not go hand in hand. This assumption of Davis became the focal point of severe attacks by the critics of the cyclic concept.

Davis has described his model of geographical cycle through a graph below:

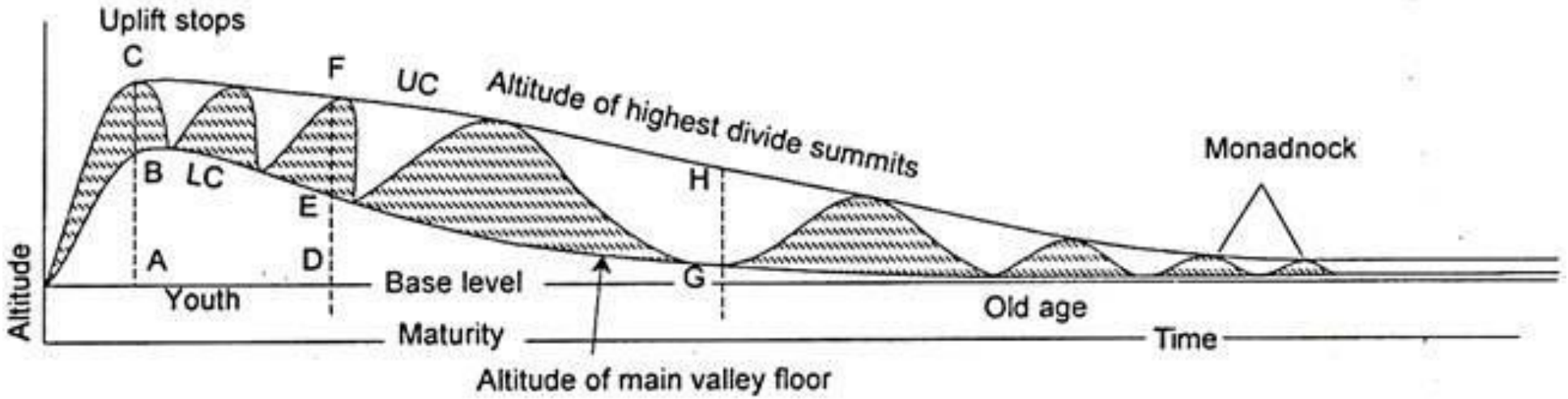
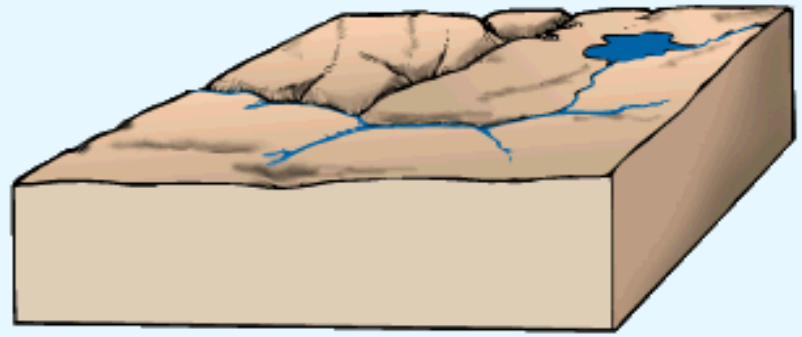


Fig. 16.1 : Graphical presentation of geographical cycle presented by W.M. Davis.



A Youth

V-shaped valleys, few or no floodplains, extensive interfluves, many falls and rapids plus some lakes and swamps; incising watercourses

B Maturity

well-drained terrain, all in slopes except floodplains; trunk and some tributary streams meander; maximum relief

C Old Age

broad, open valleys with widely meandering streams, indistinct divides, erosion remnants of resistant lithologies, surface near erosional base level

Youthful stage:

- (i) Absolute height remains constant (CF is parallel to the horizontal axis) because of insignificant lateral erosion.
- (ii) Upper curve (UC) representing summits of water divides is not affected by erosion.
- (iii) Lower curve (LC) falls rapidly because of rapid rate of valley-deepening through vertical erosion.
- (iv) Relief (relative) continues to increase.
- (v) Valleys are of V shape characterized by convex valley side slopes.
- (vi) Overall valley form is gorge or canyon.
- (vii) Long profiles of the rivers are characterized by rapids and water falls which gradually diminish with march of time and these practically disappear by the end of late youth. The main river is graded.

Mature stage:

- Lateral erosion of the valley is greater than vertical erosion at this stage.
- Elimination of lakes and waterfalls
- The Summit of the valley erodes more as compare to the bottom erosion of the Valleys.
- Gentler slope emerged.
- In this stage, the " V" shaped valley gets converted to a "U" shaped valley.
- U-shaped valleys are found in southern Indian.
- Maximum possible Relief
- Topography consists much of Slopes of Hillsides and Valley sides

Old stage:

- Tributaries – less numerous than in Maturity but more than in Youth
- Valleys – extremely broad & gently sloping laterally and longitudinally
- Extensive Floodplains with broadly Meandering Streams
- Valley widths – greater than those of the Meander belts
- Stream divides reduce in heights, gently sloping→Residualhills—MONADNOCKS (after Mt. Monadnockin New Hampshire)
- Lakes, Swamps, Marshes on floodplains, not on interstream areas
- Extensive areas are or at near BASE LEVEL OF EROSION

- **Positive Aspects of Davis' Model:**
- (1) Davis' model of geographical cycle was highly simple and applicable.
- (2) He presented his model in a very lucid, compelling and disarming style using very simple but expressive language. Commenting on the language of Davis used in his model Bryan remarked, "Davis rhetorical style is just admired and several generations of readers be-came, slightly bemused by long though mild intoxication of the limpid prose of Davis remarkable essay."
- (3) Davis based his model on detailed and careful field observations.
- (4) Davis' model came as a general theory of landform development after a long gap after Hutton's cyclic nature of the earth history.
- (5) This model synthesized the current geological thoughts. In other words, Davis incorporated the concept of 'base level' and genetic classification of river valleys, the concept of 'graded streams' of G.K. Gilbert and French engineers' concept of 'profile of equilibrium' in his model.
- (6) His model is capable of both predictions and historical interpretation of landform evolution.

- **Negative Aspects of Davis Model:**
- Davis concept of upliftment is not acceptable. He has described rapid rate of upliftment of short duration but as evidenced by plate tectonics upliftment is exceedingly a show and long continued process.
- Davis' concept of relationship between upliftment and erosion is erroneous. According to him no erosion can start unless upliftment is complete. Can erosion wait for the completion of upliftment? It is a natural process that as the land rises, erosion begins.
- Slow period of Erosion can be disrupted by dynamic endogenesis & Climate changes (Rejuvenation of land form).
- Long stability of landmass is not possible .
- Rock structure may not be homogeneous .

GEOMORPHIC MODEL OF J.T. HACK

- **(DYNAMIC EQUILLIBRIUM THEORY)**

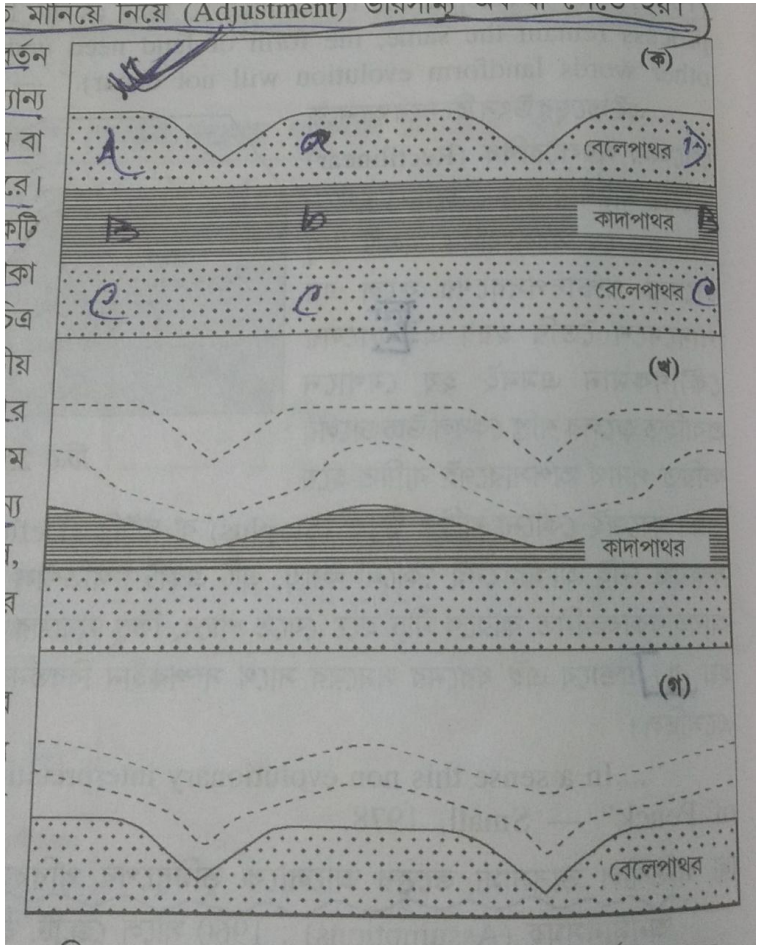
- The basic premises of Hackian model of landscape development is-

"the landscape and the processes that form it are part of an open system which is in **steady state of balance"**.

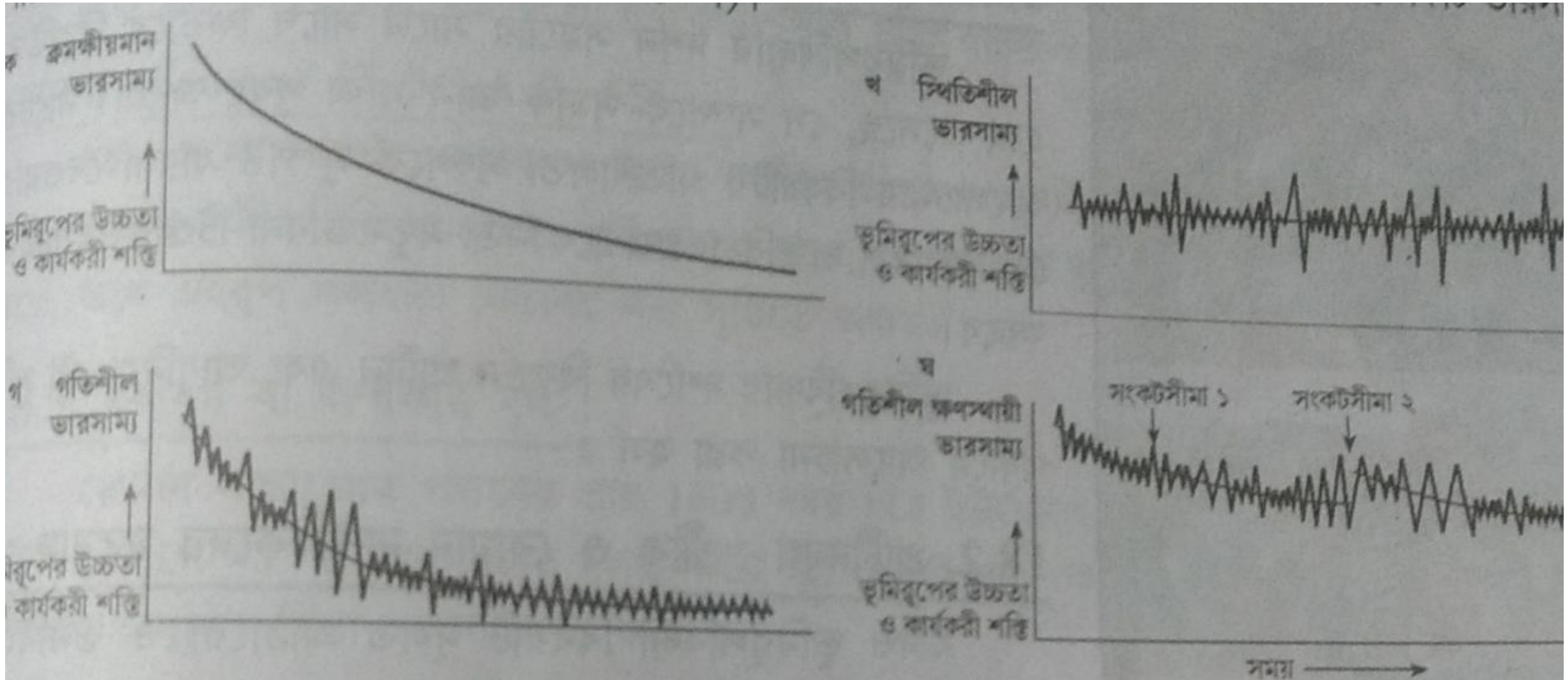
- **His other assumptions are:**
- There is a balance between denudational process and rock resistance.
- There is a uniform rate of downwasting in all components of landscapes.
- The processes which operate today have carved out the landscapes of the earth's surface.
- Differences and characteristics of form are explicable in terms of spatial relations in which geologic patterns are primary consideration
- There is lithologic adjustment to landforms.

- Hack opined that the landforms do experience changes with changing equilibrium conditions but these changes are not like Davisian evolutionary changes. He postulated the concept of variation of landscape in relation to varying conditions of balance between rates of upliftment and erosion viz.-
- He further opined that evolutionary models can be conceived on the basis of base level of erosion. In this context he considered three conditions of base level viz. **(i) stable base level (ii) positive changes in base level (iii) negative changes in the base level**

- Hack also propounded the concept of **lithological adjustment to landforms**



- **Hack also proposed that ‘ridge and ravine topography’ is the normal expression of a condition of dynamic equilibrium.**



চিত্র 17.9 : বিভিন্নপ্রকার ভারসাম্যের ধারণা (Chorley and Beckinsale, 1980)

Model on landform evolution: Penck

(Die Morphologische Analyse)

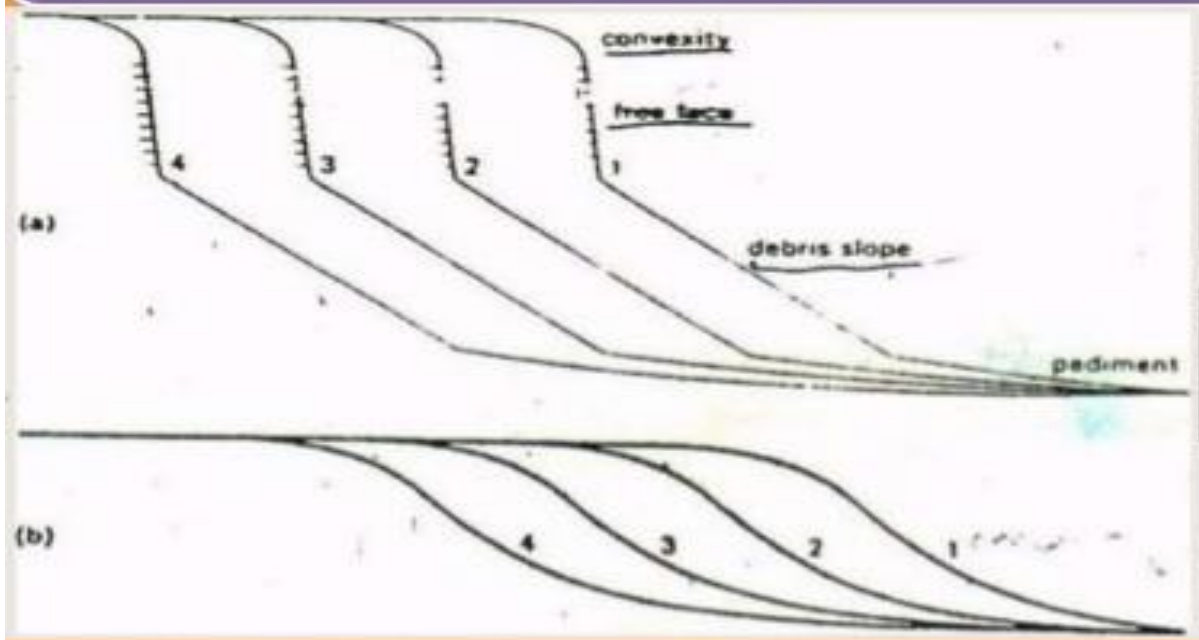
- It may be pointed out that German scientist **Walther Penck** pleaded for the rejection of Davisian model of geographical cycle based on time-dependent series of landform development and **presented his own model of 'morphological system' or 'morphological analysis' for the explanation of landscape development.**
- Contrary to the concept of W.M. Davis, '**that landscape is a function of structure, process and time (stage)',** Walther **Penck postulated that, 'geomorphic forms are an expression of the phase and rate of uplift in relation to the rate of degradation**.
- It is assumed that interaction between the two factors, uplift and degradation, is continuous.

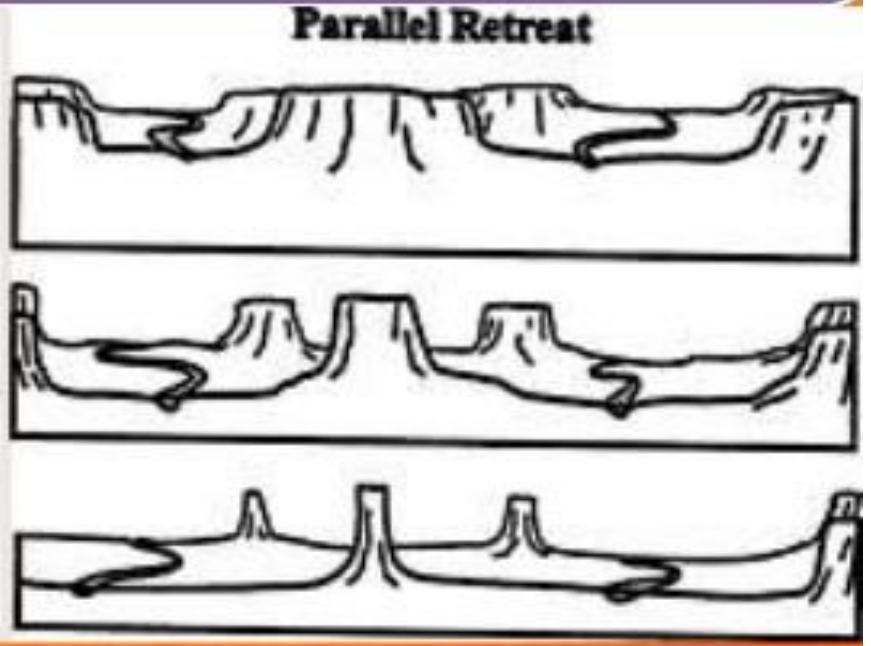
- **Penck’s views could not be known in true sense and could not be interpreted in right perspective because of:**
- (i) His incomplete work due to his untimely death,
- (ii) His obscure composition in difficult German language,
- (iii) Ill-defined terminology,

Basic concept of landform development:

- Landform development is **time-independent**.
- The landforms, reflect the ratio between the intensity of **endogenetic** processes (i.e., rate of upliftment) and the magnitude of displacement of materials by **exogenetic** processes (the rate of erosion and removal of matrials).
- Rate of erosion is proportionally related to slope.
- Upliftment and erosion are always co-existent.
- The land slope has a **parallel retreat**; so same slope angle over time.

WHAT IS PARALEL RETREAT ?





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.

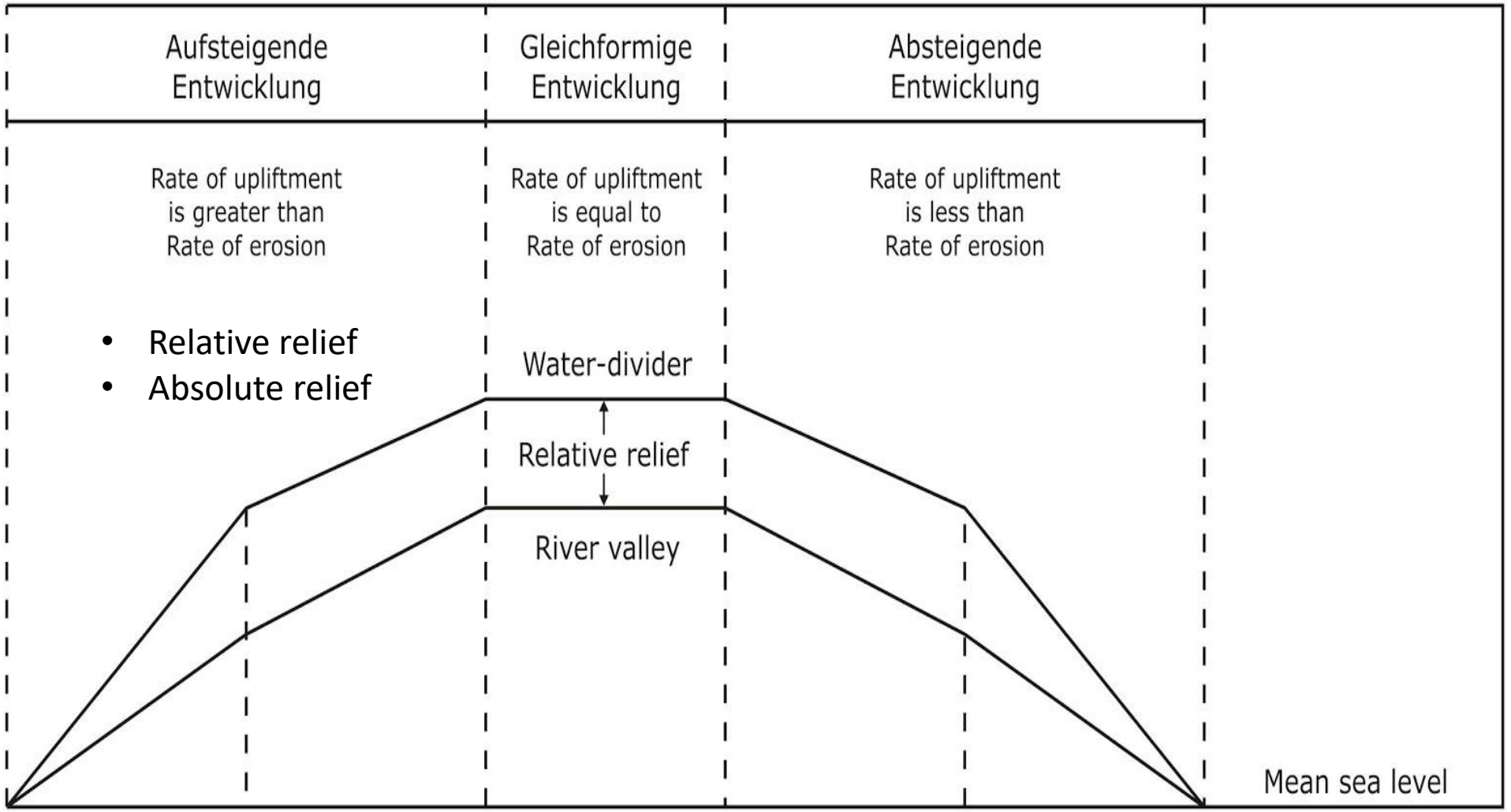
Primarumpf:

- Primarumpf is primary peneplain that represents either newly emerged surface from below sea level or a ‘fastenbene’ or ‘peneplain’
- *primarumpf is the initial landscape* with evidences of erosion but with low altitude.

- According to O.D. Von Engeln (1960) **“Penck found escape from the concept of cyclic change marked by the stages youth, maturity and old age.”** In the place of **‘stage**’ he used the term **entwickelung** meaning thereby development.
- Thus, in the place of youth, maturity and old stages he used the terms **aufsteigende entwickelung** (waxing or accelerated rate of development), **gleichformige entwickelung** (uniform rate of development) and **absteigende entwickelung** (wanning or decelerating rate of development).

LATER STAGES OF DEVELOPMENT

In the place of stage he used the term 'entwickelung' meaning 'development'



- Relative relief
- Absolute relief

- # Aufsteigende Entwickelung:
- ***Aufsteigende entwickelung means the phase of waxing (accelerating) rate of landform development.*** Initially, the land surface rises slowly but after some time the rate of upliftment is accelerated.
- Because of upliftment and consequent increase in channel gradient, flow velocity and kinetic energy and of course increase in discharge (not due to uplift) the rivers continue to degrade their valleys with accelerated rate of down-cutting (valley deepening or incision) but the rate of upliftment far exceeds the rate of valley deepening (say degradation of uplifted landmass).
- Continuous active downcutting and valley deepening results in the formation of deep and narrow V shaped valleys. As the rate of uplift (aufsteigende entwickelung) continues to increase the V shaped valleys are further deepened and sharpened. Since valley deepening does not keep pace with the upliftment of landmass the absolute height continues to increase.
- The valley side slopes are continuously steepened due to continued valley deepening. The radius of convexity of slopes is reduced with passage of time due to parallel retreat of the steeper slope segments. With the passage of time and more accelerated uplift and degradation the primary peneplain or say primarumpf is surrounded by a series of benches called as piedmont treppen.

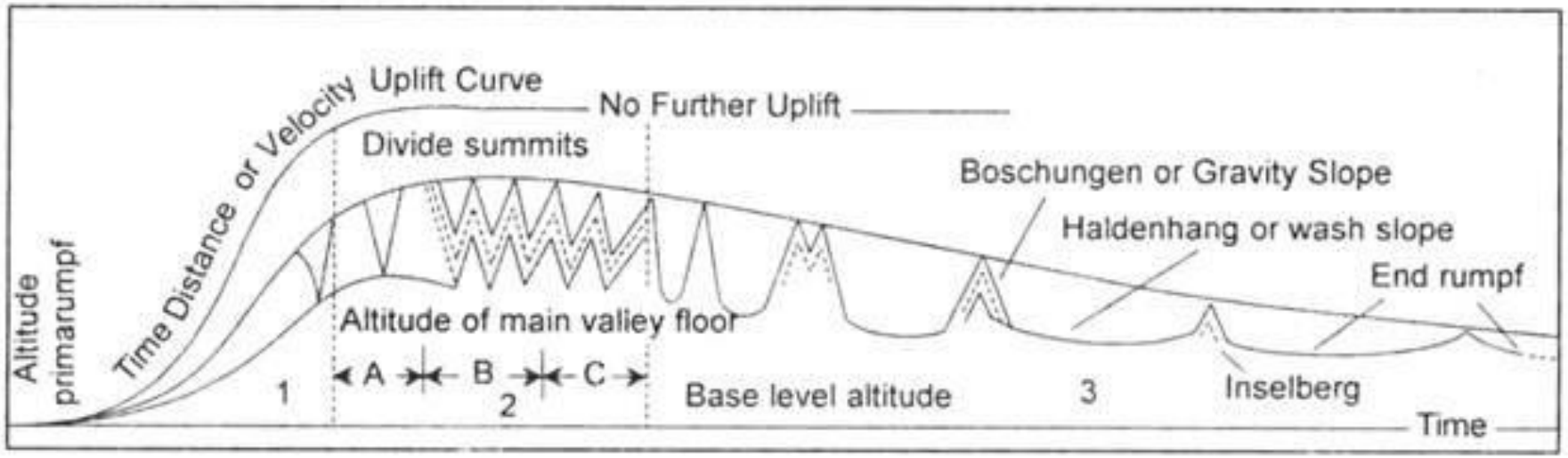


Fig. 16.2 : Graphic presentation of Penck's model of landform development.

- **Gleichformige Entwickelung:**
- Gleichformige entwickelung means uniform development of landforms. This phase may be divided into 3 subphases on the basis of rate of uplift and degradation.
- **Phase (a):**
- Is characterized by still accelerated rate of uplift. Absolute height still increases because the rate of erosion is still less than the rate of upliftment.
- **Phase (b):**
- Altitude (absolute relief) neither increases nor decreases i.e. remains constant due to matching of upliftment by the lowering of divide summit due to denudation. It means that upliftment still continues.
- **Phase (c):**
- Upliftment of the land stops completely. Absolute reliefs or altitudes of summit divides start decreasing because of absence of upliftment but continued erosion of summits of divides.

- **Absteigende Entwickelung:**
- Absteigende entwickelung means wanning development of landscape during which the landscape is progressively dominated by the erosional process of lateral erosion and consequent valley widening and marked decrease in the rate of valley deepening through vertical downcutting.
- This phase is marked by progressive decline of landforms. Absolute relief (altitude from sea level) decreases remarkably because of total absence of upliftment but continued downwasting of divide summits. Relative relief also decreases because the divide summits are continuously eroded down and lowered in height while downcutting of valley floor decreases remarkably due to decrease in channel gradient and kinetic energy.
- Now the valley side slope consists of two segments. *The uppermost segment maintains its steep angle inspite of continuous lowering of ridge crests. This slope is called gravity slope or* ***boschungen****.* The lower segment of the valley sides is called wash slope or **haldenhang**. Haldenhang, composed of talus materials of lower inclination, is formed at the base of the valley sides due to rapid parallel retreat of gravity slope or boschungen and consequent elimination of much of the convex waxing slopes.
- Thus, the intersection of boschungen and haldenhang produces sharp knick **(break in slope**).

- Eventually**, inselbergs** are also consumed and the whole landscape is dominated by a series of concave wash slopes or haldenhang. Such extensive surface produced at the end of absteigende entwickelung is called '**endrumpf',** which may be considered equivalent to Davis' peneplain.

The following are the difference between Davis and Penck Cycle:

- Davis Erosion cycle starts after upliftment of landform stoped whereas upliftment and erosional act simultaneously in the Penck cycle.

•The end product of the Davis Cycle is Peneplain whereas the end product of the Penck cycle is Pedeplain.

•Davis Geographical Cycle of Erosion is a monocycle that means cycle complete after the old stage of landforms whereas the Penck erosion cycle is polycyclic that means a never-ending process, the cycle starts again by the rejuvenation of landforms.

•In Davis cycle, landforms are the result of Davis trios that are the structure, process, and Time. Whereas Penck's landforms are the result of the ratio between the intensity of endogenic and exogenic forces.

•Davis's cycle of landform development is time-dependent whereas the Penck cycle of erosion is not time-dependent.

•Landform development is a form of "slope decline"; for example "V" shaped valley get converted to "U" shaped valley and than featureless peneplain in Davisian cycle of erosion whereas Landform development in the Penck cycle of erosion is in form of "slope replacement" where a free face slope and concave slopes get replaced to rectilinear slopes.

- FURTHER READING:
- McCULLAGH, P. 1978.MODERN CONCEPT IN GEOMORPHOLOGY
- KALE & GUPTA 2001 INTRODUCTION TO GEOMORPHOLOGY
- SINGH, S. GEOMORPHOLOGY