Mountain - Plain evolution : general model slope retreat hypothesis.

Introduction:

- Mountains - plains evolves over a period of time on Earth since it originated.
- Evolution of landforms can be inferred on the basis of remanance of the existing bedrock and the sediment load lying over it.
- Evolution of particular mountains existing on the Earth on the present day holds a long history since several million years.
- Generally Tectonics is the main cause of evolution – somewhere huge mountains and somewhere valleys, canyons and Gorges.
- Each and every landforms have unique history of evolution in their stratigraphical column.
- Evidences of evolution are fossil records, existing bedrock and number of radio active elements in it through which dating are possible.

Slope Form

- Slope form refers to the shape of the land surface what we see or infer at the landscape, a slope is steep or gentle, irregular or smoothly curved, high or low, are features of its form.

- ***Profile form*** is a shape when viewed in profile, as if a cross-section were taken at right angles to the hillside.

- ***Plan form*** is the shape when viewed from above; it is shown on a map by the curvature of contours.

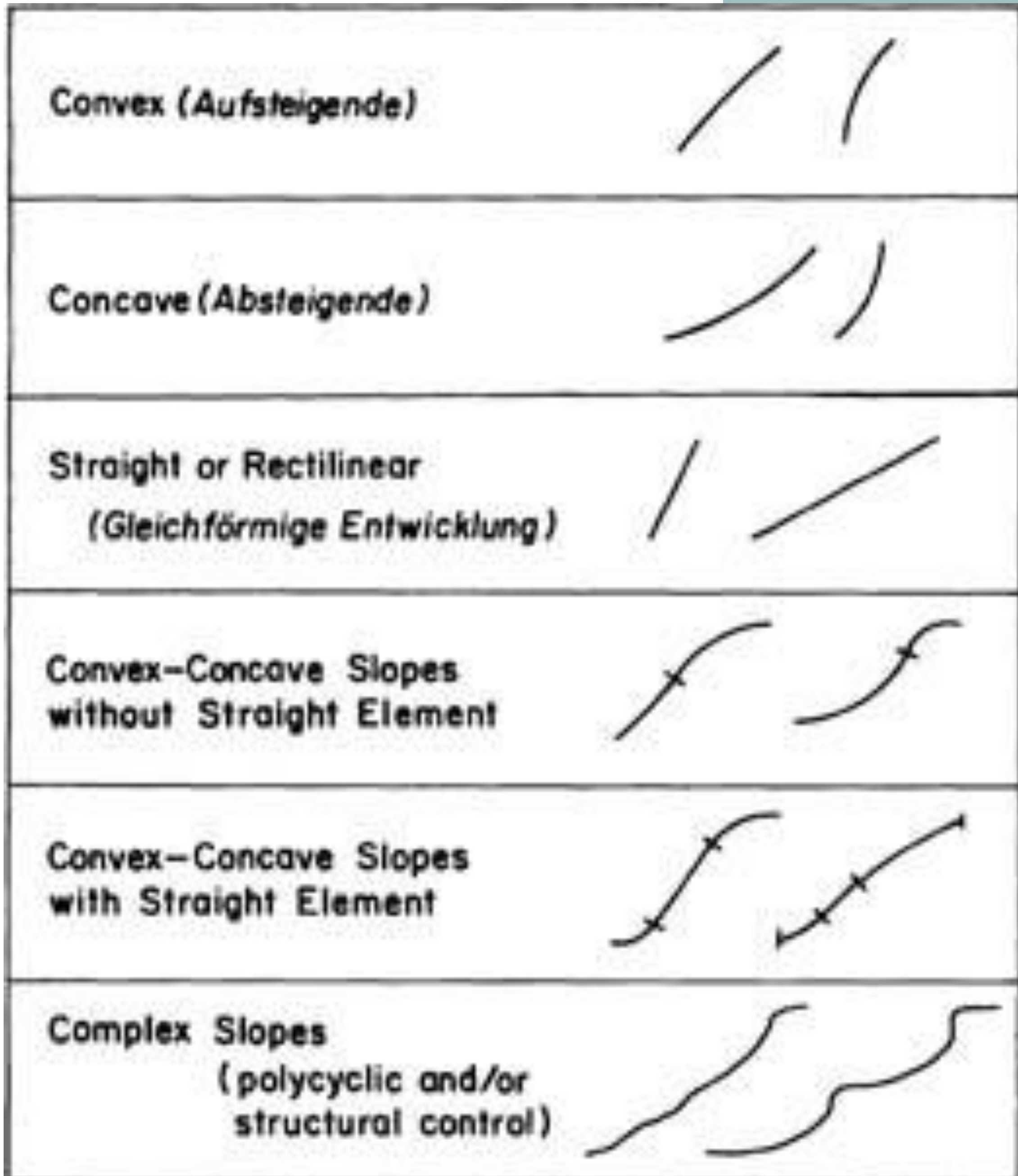
- Slopes that are **concave** in plan occur mainly at valley heads. The lines of water flow and regolith movement down such a slope converge, Slopes with **convex** plan form occur as spurs between two valleys.

- Within this general framework, several evolutionary sequences may be envisaged.
- First, the pediment or piedmont plain may be extended at the expense of the mountain mass within the erosional zone.
- Here the major explanatory hypotheses include the **slope retreat hypothesis**, and **drainage basin hypotheses** (including the **lateral planation hypothesis**).
- The lateral planation theory of pediment formation was proposed by Gilbert. His first hypothesis, lateral planation, was developed early in the 1930s and states flat land was caused by lateral stream erosion. floodplains (erosion surfaces carpeted with a veneer of alluvium) near sea level..
- Secondly, erosional processes may become ascendant over depositional processes in the piedmont zone, leading to the stripping of the alluvial cover to expose a pediment – the **exhumation hypothesis**.

- Thirdly, where the processes of debris supply equal or exceed those of removal, the piedmont surface may be subject to extensive weathering or etching beneath an alluvial cover – the ***mantle-controlled planation hypothesis.***

- Beyond this, there is evidence in some areas that present-day mountain pediment features are inherited from past conditions with or without substantial modification – the ***inheritance hypothesis***.

- Finally, ***sequences of piedmont*** surfaces may be formed, reflecting changes externally or internally to drainage systems.



Convex (Aufsteigende)
Concave (Absteigende)
Straight or Rectilinear
(Gleichförmige Entwicklung)
Convex–Concave Slopes
without Straight Element
Convex–Concave Slopes
with Straight Element
Complex Slopes
(polycyclic and/or
structural control)

Model classification of slope form

A. Four-unit model:

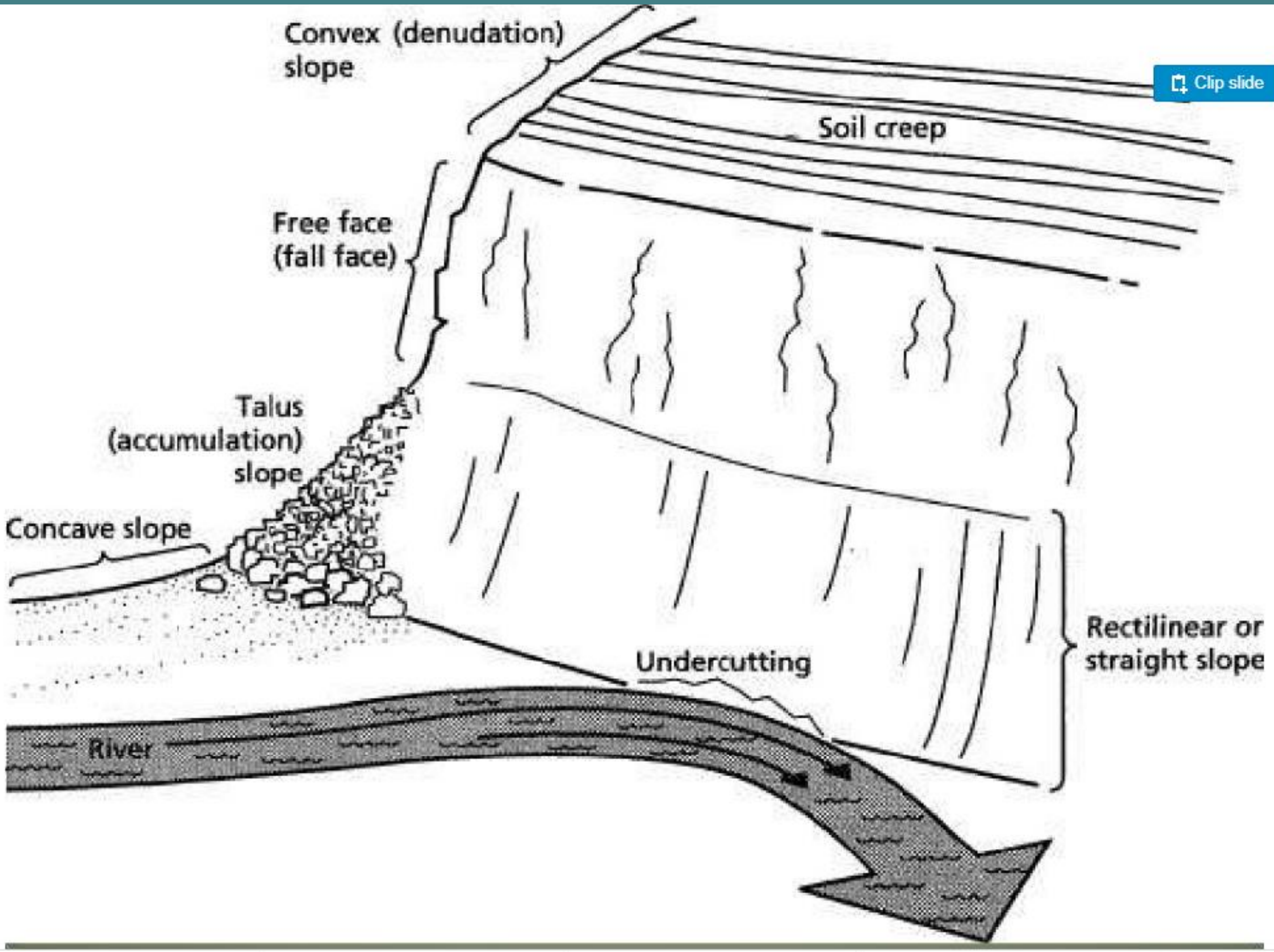
It was proposed by **A. Wood** in 1943.

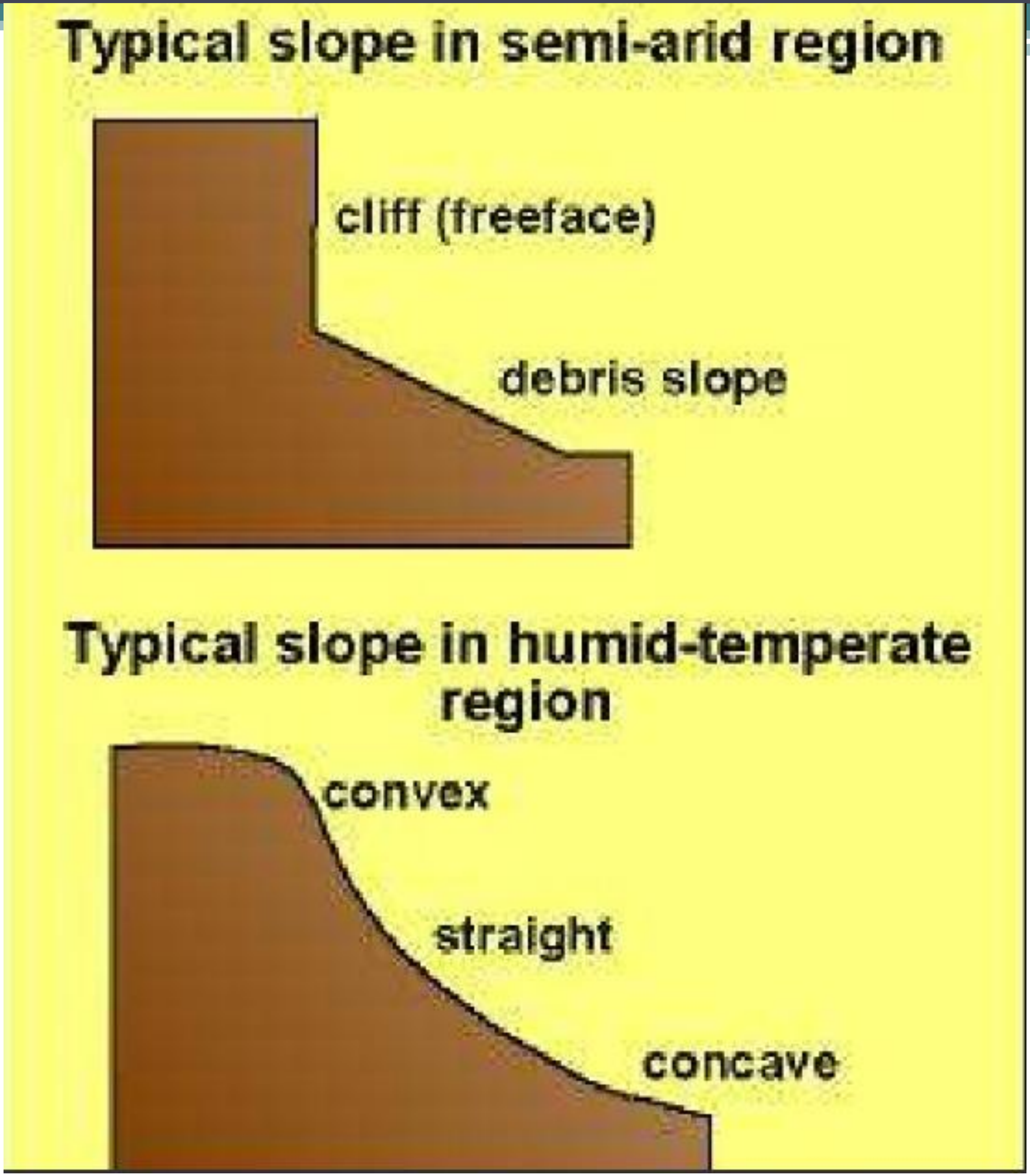
a) ***The waxing*** (Plateau)
b) ***The free face***(Barren moderate to steep sloop)
c) ***The constant slope*** (uniform angle with debris cover)
d) ***Waning slope*** (Part of hill and plain interaction)

B. Nine-unit model:

This was proposed by **Dalrymple** in 1968 and is a more complex model which relates slope form to the processes of slope formation. The main processes in operation are weathering, throughtflow and mass movements (landslides, slumping, rockfall.)

- 1 is Interfluve, 2 is Seepage slope, 3 is Convex creep slope (**waxing slope**.)
- 4 is fall face - it is equivalent to the **free face**.
- 5 is Constant slope, (**constant slope**)
- 6 is Colluvial foot-slope, 7 is alluvial toe-slope (**waning slope)**
- 8 is Channel wall and 9 is Channel bed.


Convex (denudation) slope
Clip slide
Soil creep
Free face (fall face)
Talus (accumulation) slope
Concave slope
Rectilinear or straight slope
Undercutting
River


Typical slope in semi-arid region
cliff (freeface)
debris slope
Typical slope in humid-temperate region
convex
straight
concave

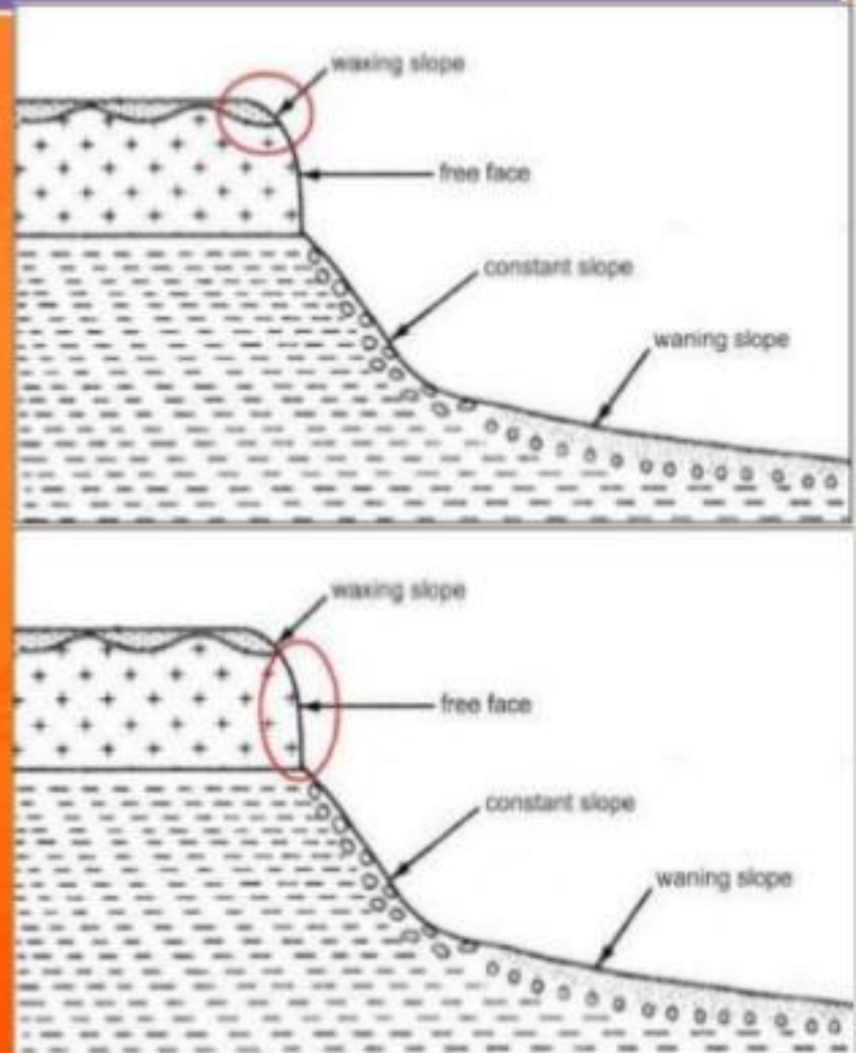
Four units model

- A. Wood divided a slope into 4 elements
  - Waxing slope:
    - It is the convex curve of the hill crest.
  - Free Face / Cliff
    - It is a vertical or very steep rock-face.
  - Constant slope:
    - It maintains a constant angle of rest.
    - It is formed by the debris fall from free face and gradually accumulates to building up a heap of scree (talus).
  - Waning slope:
    - It is below the constant slope, which is formed by fine materials.
    - It is also the washing slope because it is derived from the material washed down from constant slope.
    - The low- angle wash slopes will gradually coalesce to form a depositional pediment.

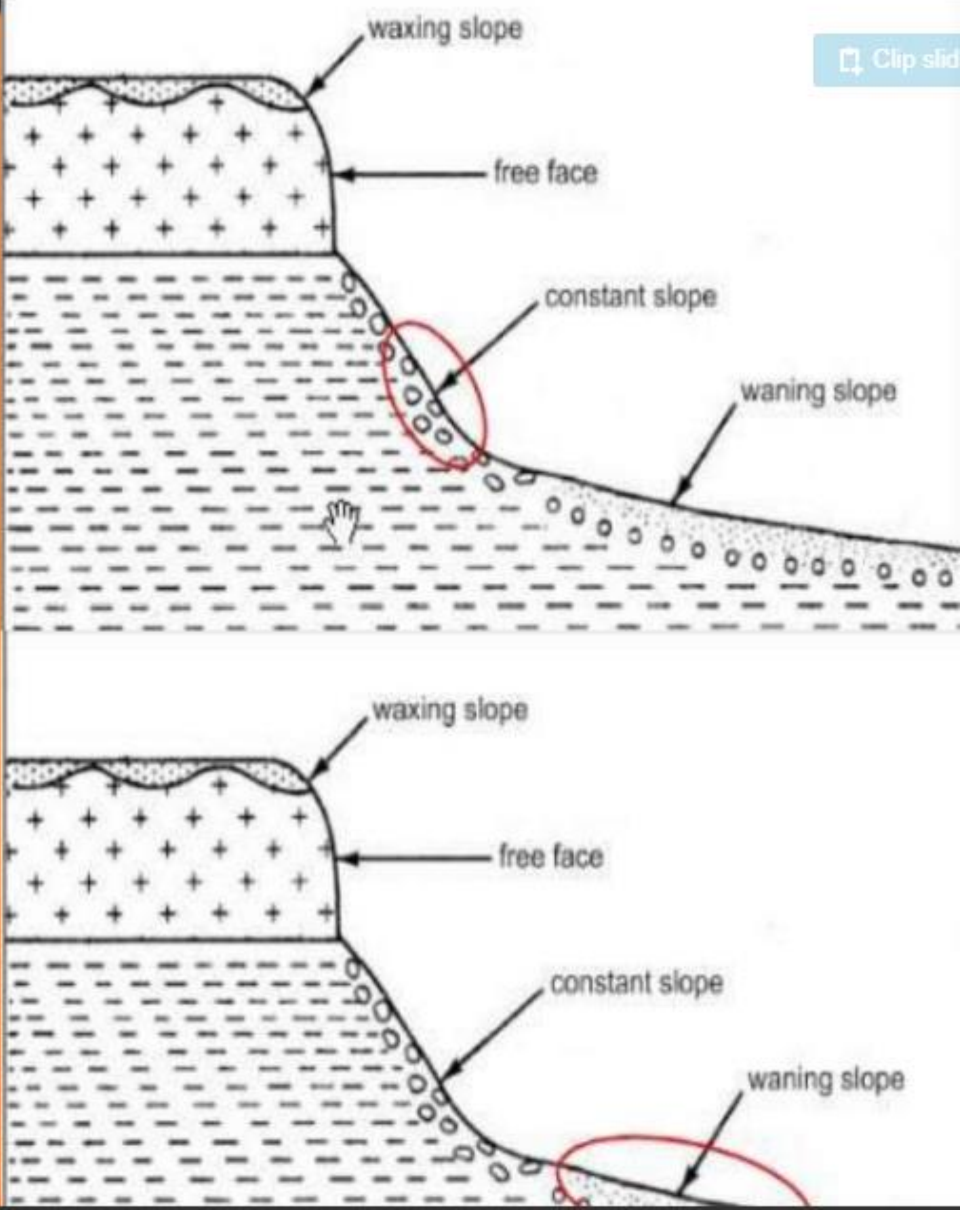
SLOPE ELEMENTS

King used four slope elements which were initially proposed by 'wood'. 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.

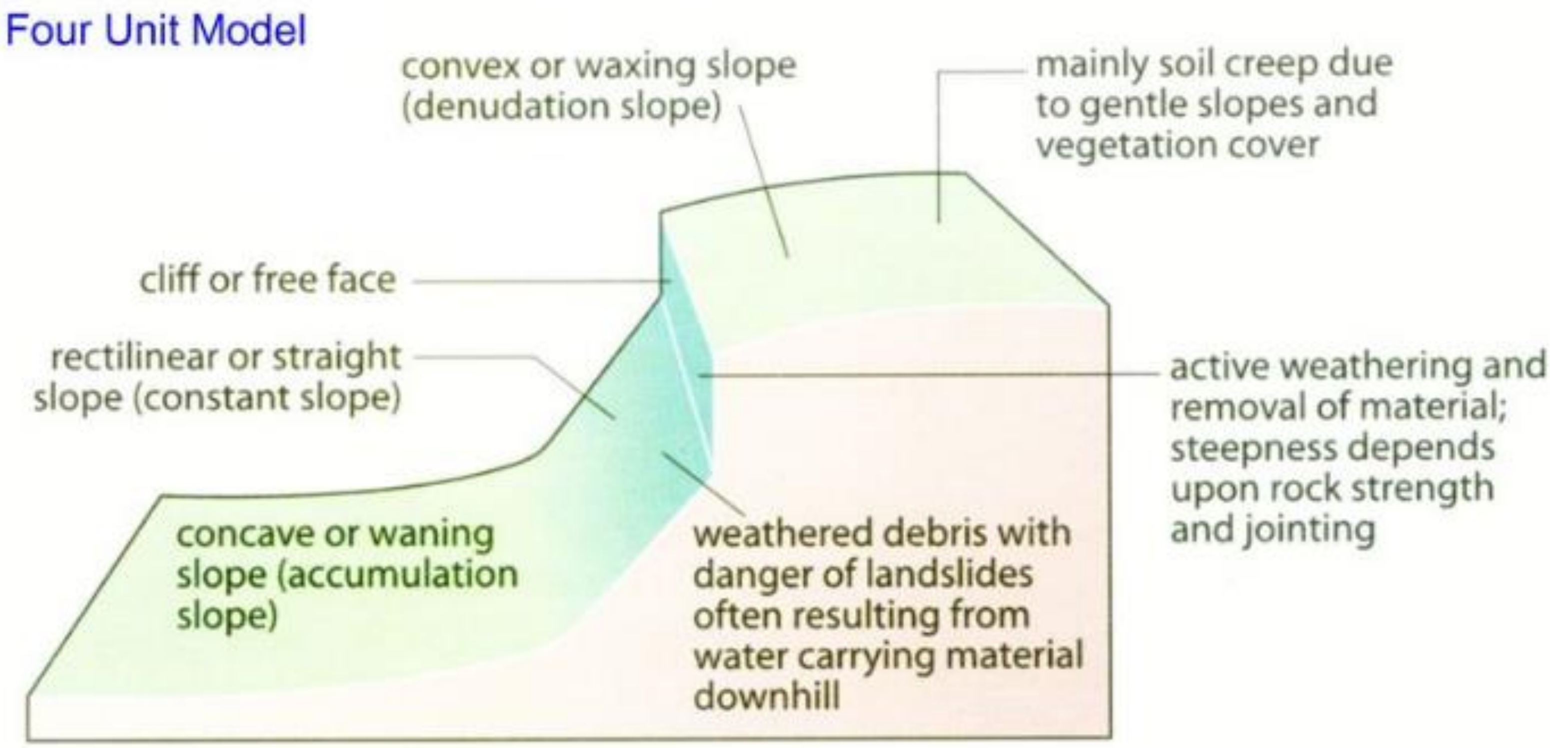


- **3)Debris slope:** Its development is dependent upon free face. If free face is there, debris slope will be there and vice-versa.
- **4)Waning slope:** It has a gentle concave profile. There may be bedrock or transported material covering eroded bed rock surface, when the eroded transported debris cover such a surface it is known as

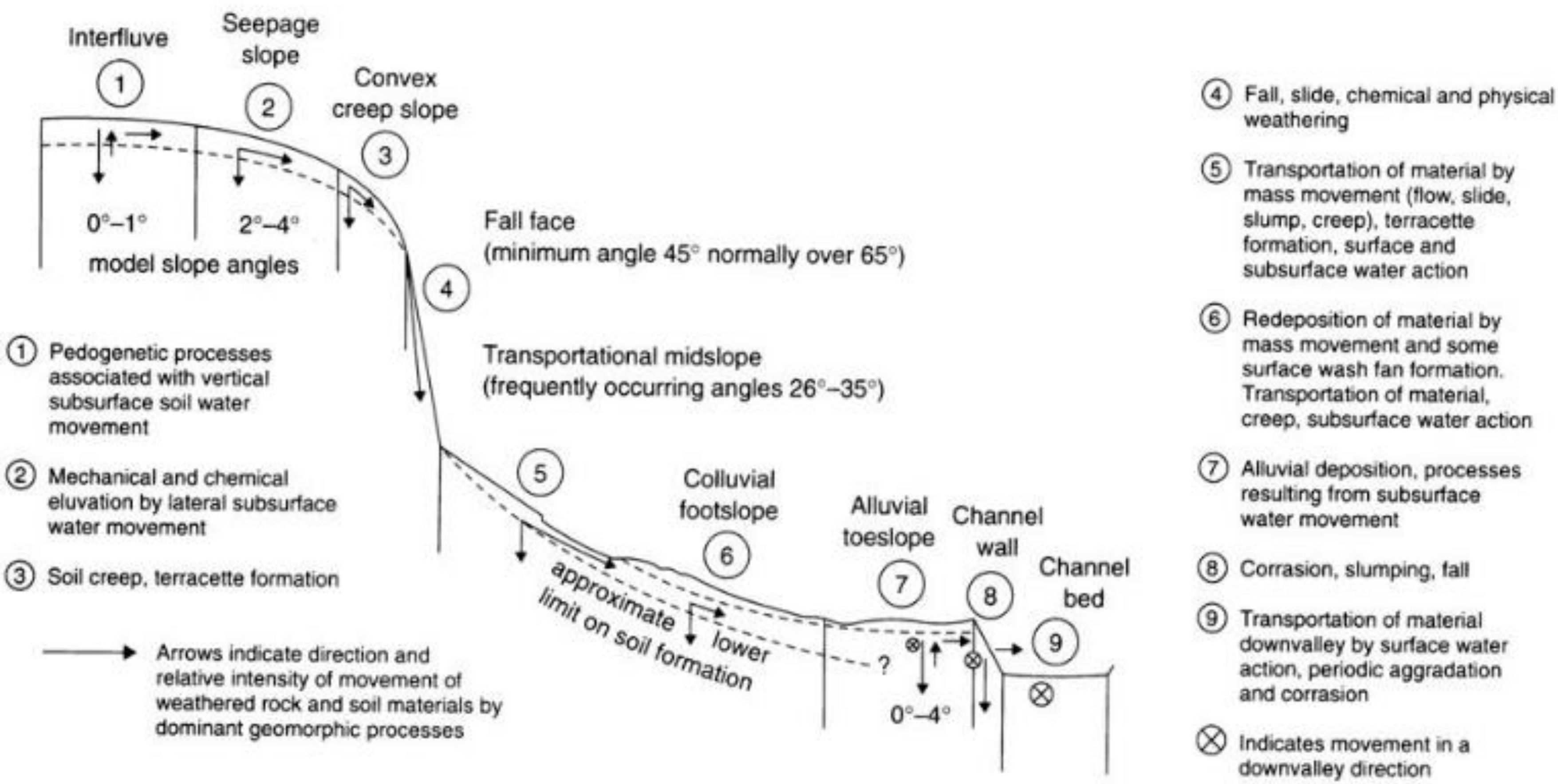


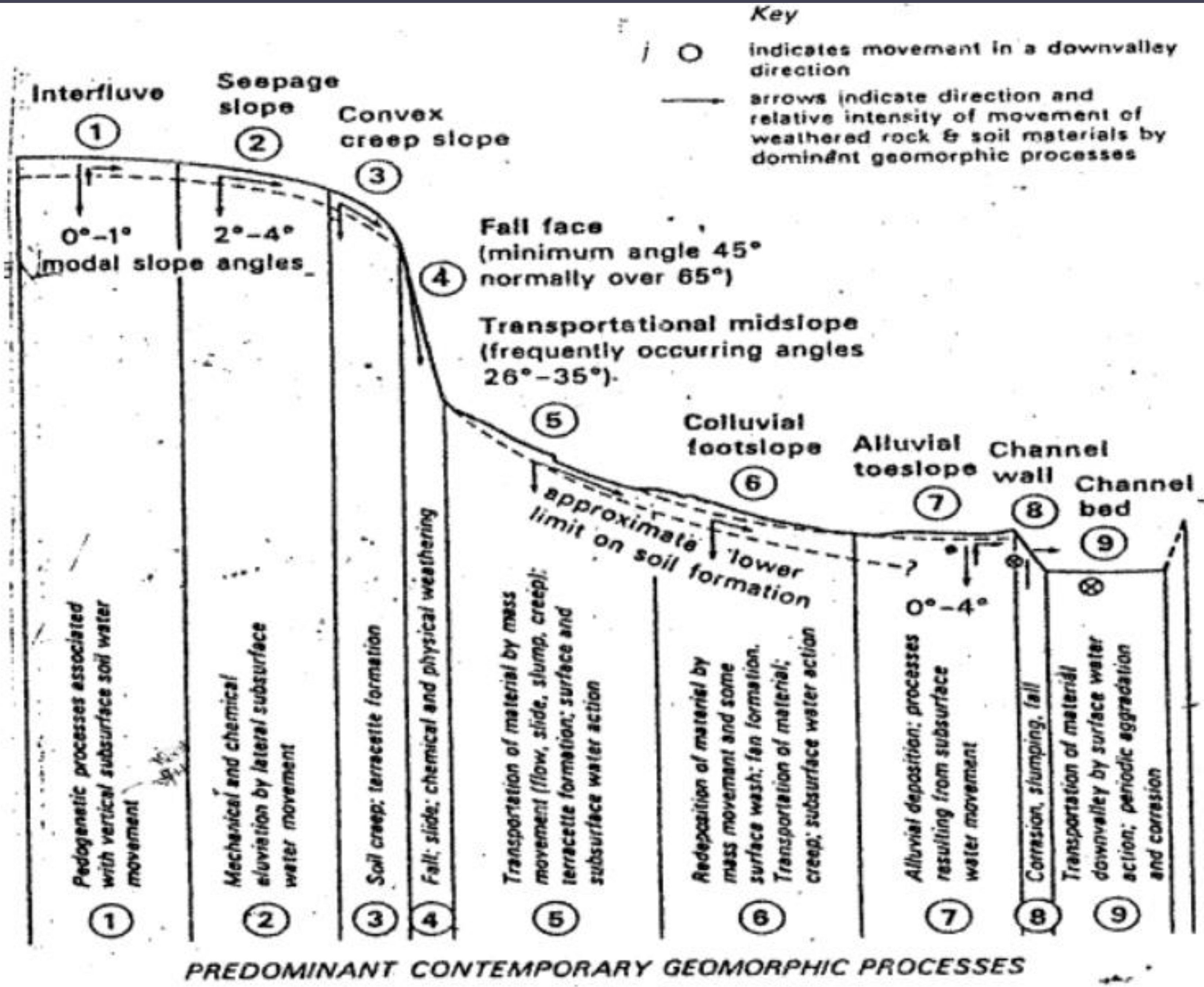
Slope elements

- Slope profiles may be divided into a series of slope units for analysis

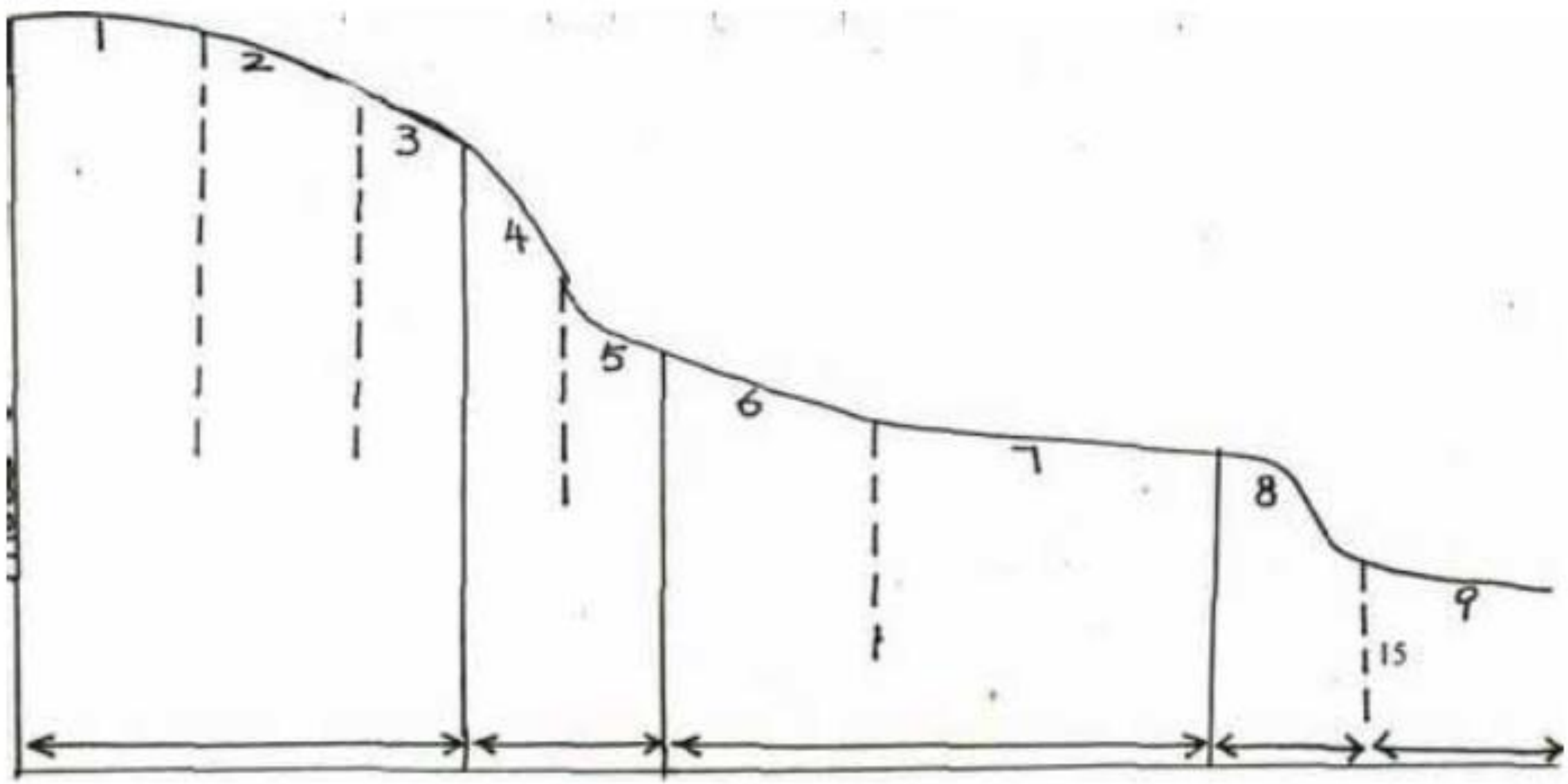


Nine units model





Hypothetical nine-unit landsurface model slopes.



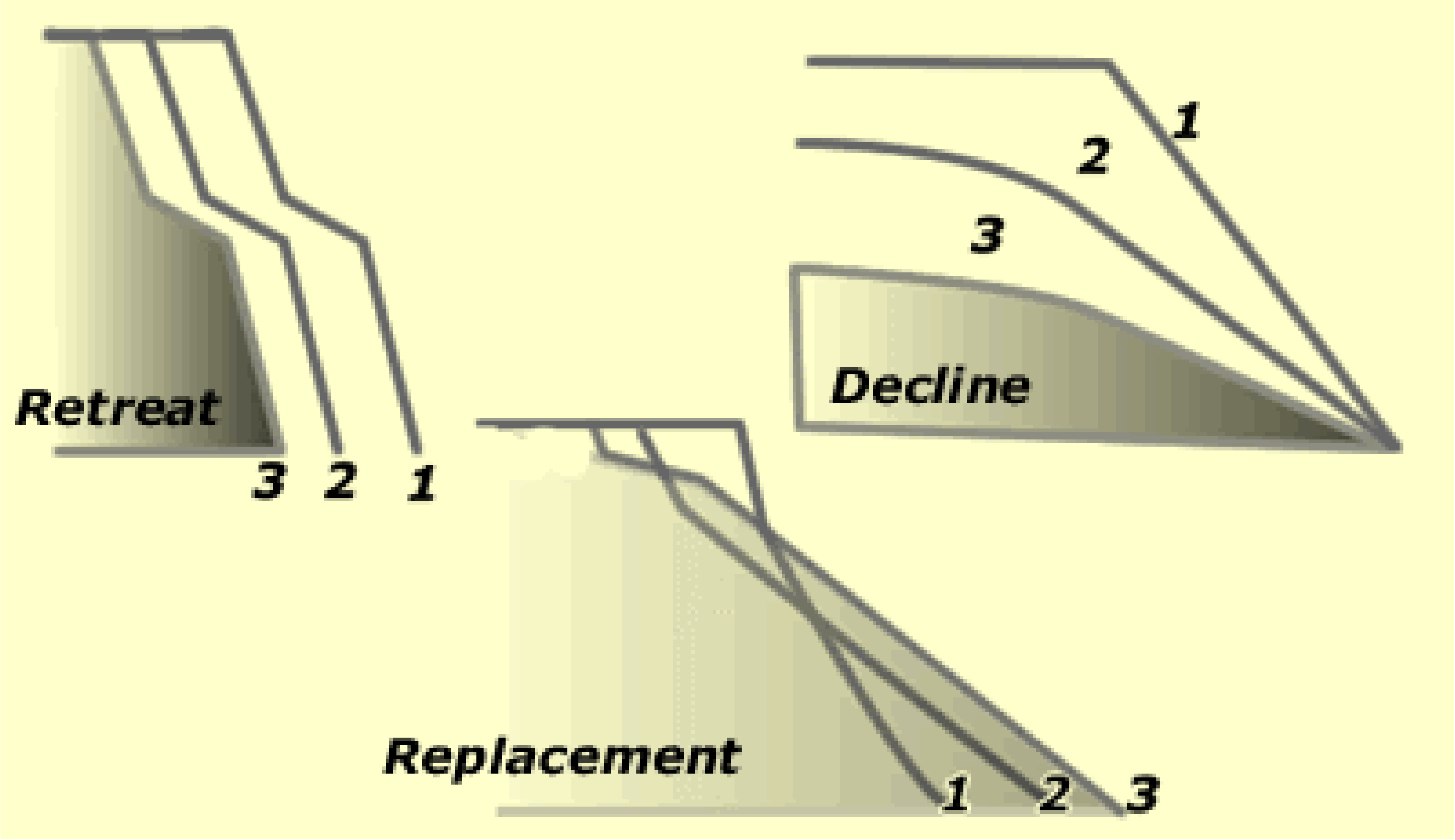
Slope development / evolution

- The forms of slopes develop through time and the factors (rock structure, lithology, soil, climate, vegetation and human activities).
- There are few models of slope development or slope evolution.
  - Slope Decline
  - Slope replacement
  - Slope parallel retreat

Slope Evolution

Evolution is the change in slope form with time, as brought about by the action of processes. ***Three models*** of slope evolution have been proposed.

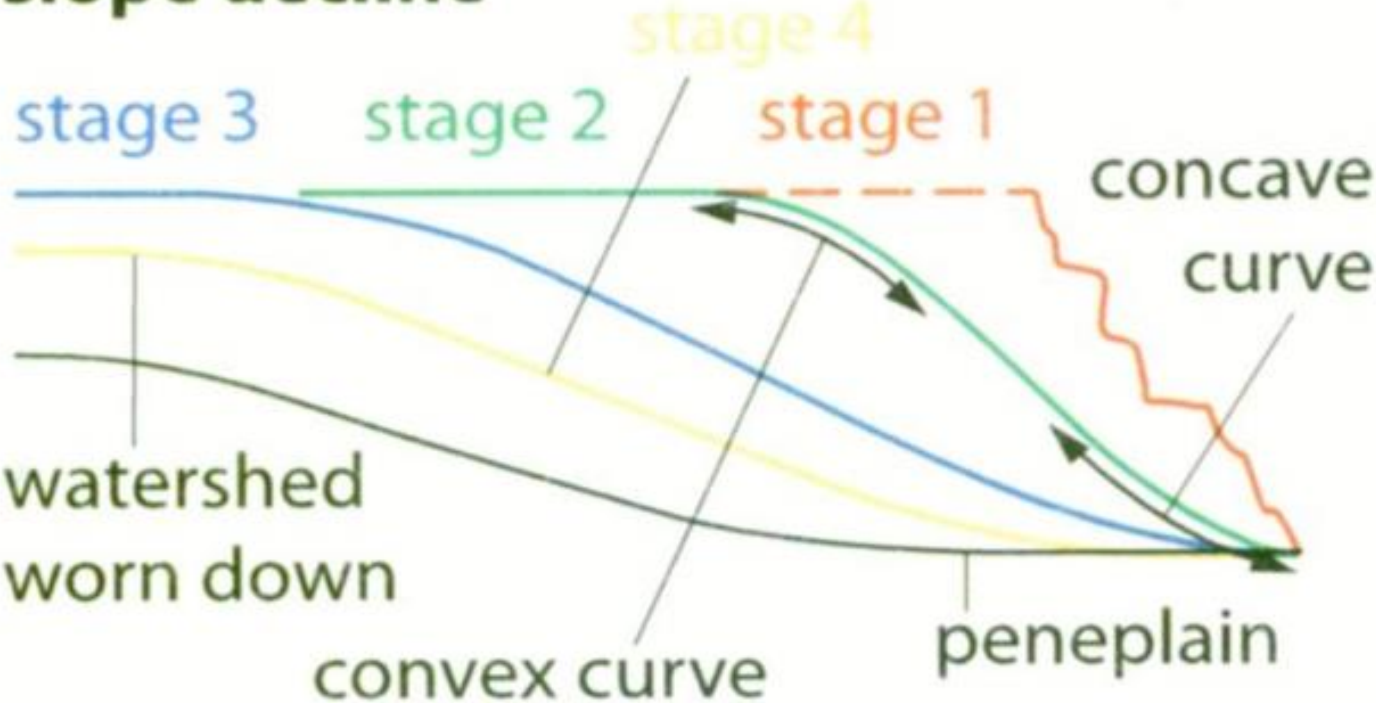
- ***Slope decline***
- ***Slope replacement***
- ***Parallel retreat***



Retreat
3
2
1
1
2
3
Decline
Replacement
1
2
3

Slope decline

slope decline



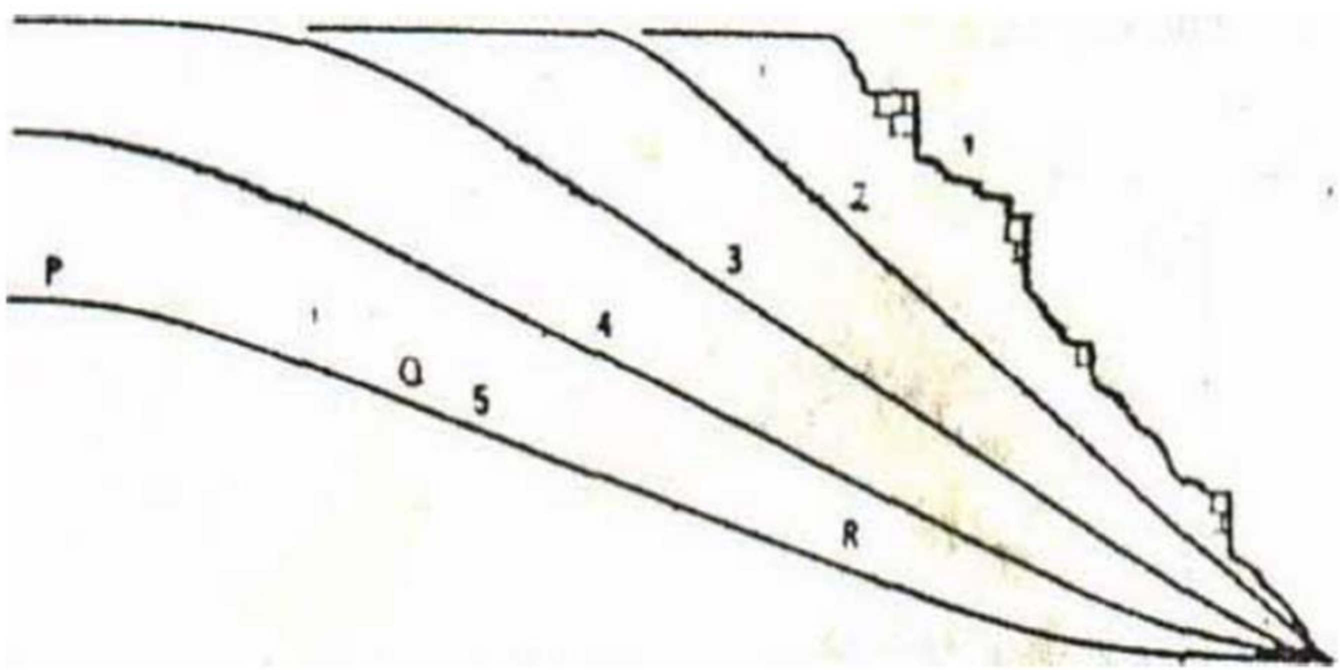
By stage 4 land has been worn down into a convex-concave slope

Slope decline(W.M. Davis, 1899)

- Slope decline is common in many humid temperate regions.
- Steepest slopes at beginning of process with a progressively decreasing angle in time to give a convex upper slope and a concave lower slope.
- The movement of rock waste is seen as one stage between *weathering* on the one hand and t*ransportation by rivers* on the other.
- The forms of slopes change as the *cycle of erosion* advances.
- When slopes are first developed they are *steep* and covered with coarse material. Later in the cycle the graded slopes are *gentler* and are covered with a thicker layer of finer material.
- The slope decline is caused by the fact that the downwash of soil from *convex* upper slopes is faster than its removal from the slope base.

Slope Decline (By W.M. Davis, 1899)

- The slope becomes progressively decrease in the angle of slope in each phase of their development.
- It becomes less steep and a concavity develops at the base, the convexity extends in length and becomes more gently curved,
- Cause: it is equilibrium between the rates of weathering and transport

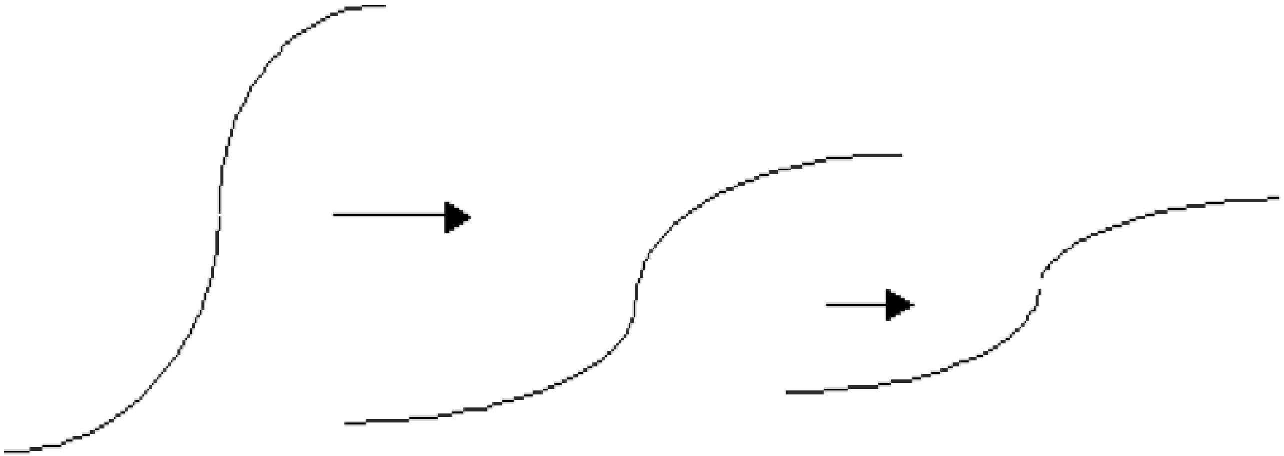


- Stage 1, the elimination of the free faces is done by the processes of fall and slump of the bedrock until the slope is gentle enough to develop a cover of regolith.
- Stage 2 shows this phase which is called the graded slope. The regolith maintains a constant thickness over the slope and all the weathered materials is transported by mass movements and wash. The form of the slope is concave-convex.
- Stage 3 & 4, the length of the straight segment increased. The curvature of the elements decreases as the slope continues to decline, and the length of straight segment diminishes. The upper convexity experiences more and more output than input, whereas the lower concavity receives more input than what it can output.
- Lower part of the slope - with the accumulation of the transported regolith, lowering is less.
- Davis, the original proponent of this theory, based his arguments on visual assessment of slopes in humid temperate areas.

Slope decline(W.M. Davis, 1899)

Humid-Temperate Climates

The pattern of slope evolution in these climates is one of faster erosion on steeper upper slopes and slower erosion + possibly deposition on lower slope -> overall slope "flattening out" or SLOPE DECLINE:

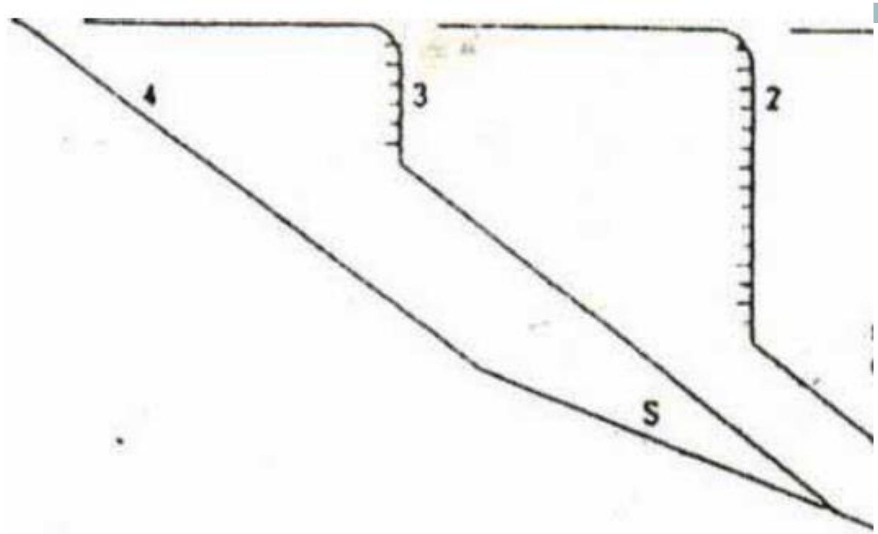


Slope decline

- American geographer, W.M. Davis (1899)
- From NW Europe and NE USA
- Normal (Humid) climates
- Concept of the "cycle of erosion".
- Steepest slopes at beginning of process with a progressively decreasing angle in time to give a convex upper slope and a concave lower slope.
- Slopes will continuous to decline and develop or evolve from youthful stage, maturity stage, old age stage and finally to become a low relief peneplain (almost a plain).

Slope replacement

- By W. Penck (1924)
- Evidence from the Alps and Andes (tectonic areas)
- The slope of maximum angle decreases as the gentler lower slopes.
- Waxing slope will be replaced by free face
- Free face will be replaced by constant slope
- Constant slope will be replaced by waning slope.



Slope Replacement (By Walter Penck, 1924)

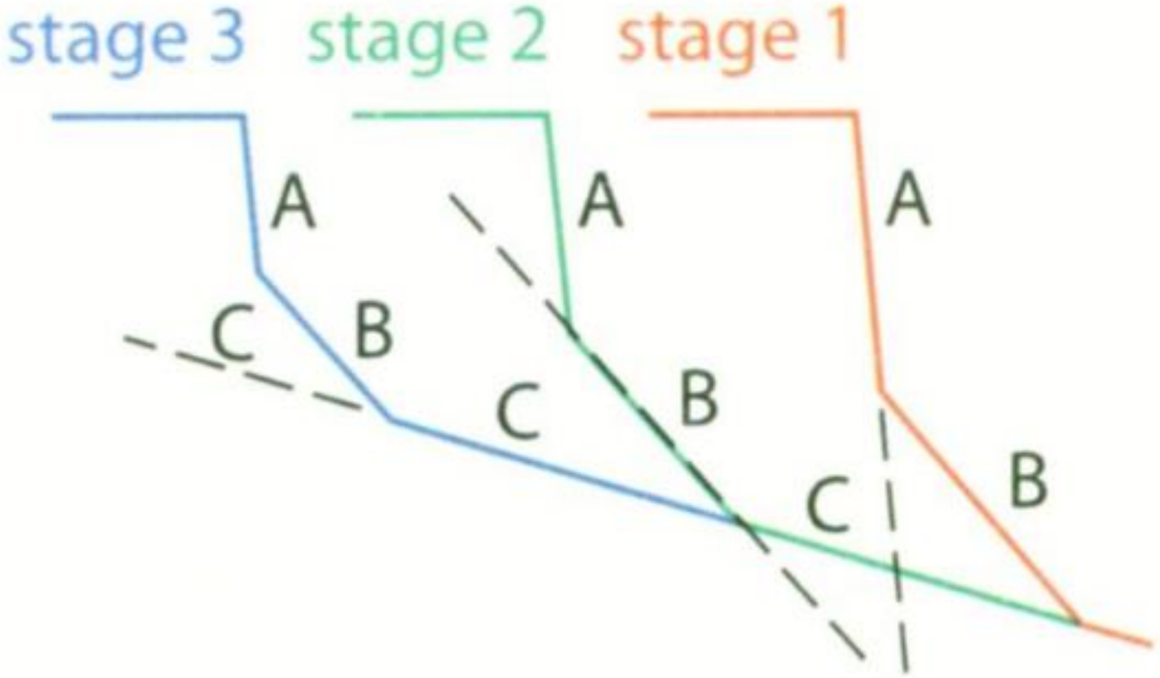
Slope replacement means **original steep slopes being replaced by lower angle slopes which extends upwards from the base at a constant angle.**

A free face slope is slowly buried by a scree which accumulates at the base of cliff. (It means the replacement of a **cliff by a scree).**

All parts of the cliffs face are exposed to weathering. The scree accumulating at the base increase in height and if it is not removed, it will eventually replace the entire cliff by a slope of about 35 , the angle of rest.

- The theory of slope replacement is particularly applicable to explaining the slope development of *cliff* in subtropical semi-humid climatic areas.
- The *maximum angle* decreases as the gentler lower slopes erode back to replace the steeper ones giving a concave central portion to the slope.
- This theory assumes that the surface of the slope is weathered evenly and crumbles - the fragments (**scree**) falling to the base. Thus maximum angle of the slope decrease and is replaced by a gentler slope.

Slope replacement



talus-scree slope B will replace slope A;
slope C will eventually replace slope B

Slope retreat (or Parallel retreat) (L.C. King, 1948, 1957)

- The theory of slope retreat is particularly applicable to explaining the slope development in arid to semi-arid areas, Sea cliffs with wave-cut platforms.
- The *maximum angle* remains constant as do all slope facets apart from the lower one which increases in concavity.
- Each of the upper parts of the slope retreats by the same amount and maintains the same angle.
- Thus the *convexity*, *free face* and *debris slope* all retain the *same length*, both absolute and relative to each other during retreat.
- The *pediment* extends in length and becomes slightly gentler in angle.

America.

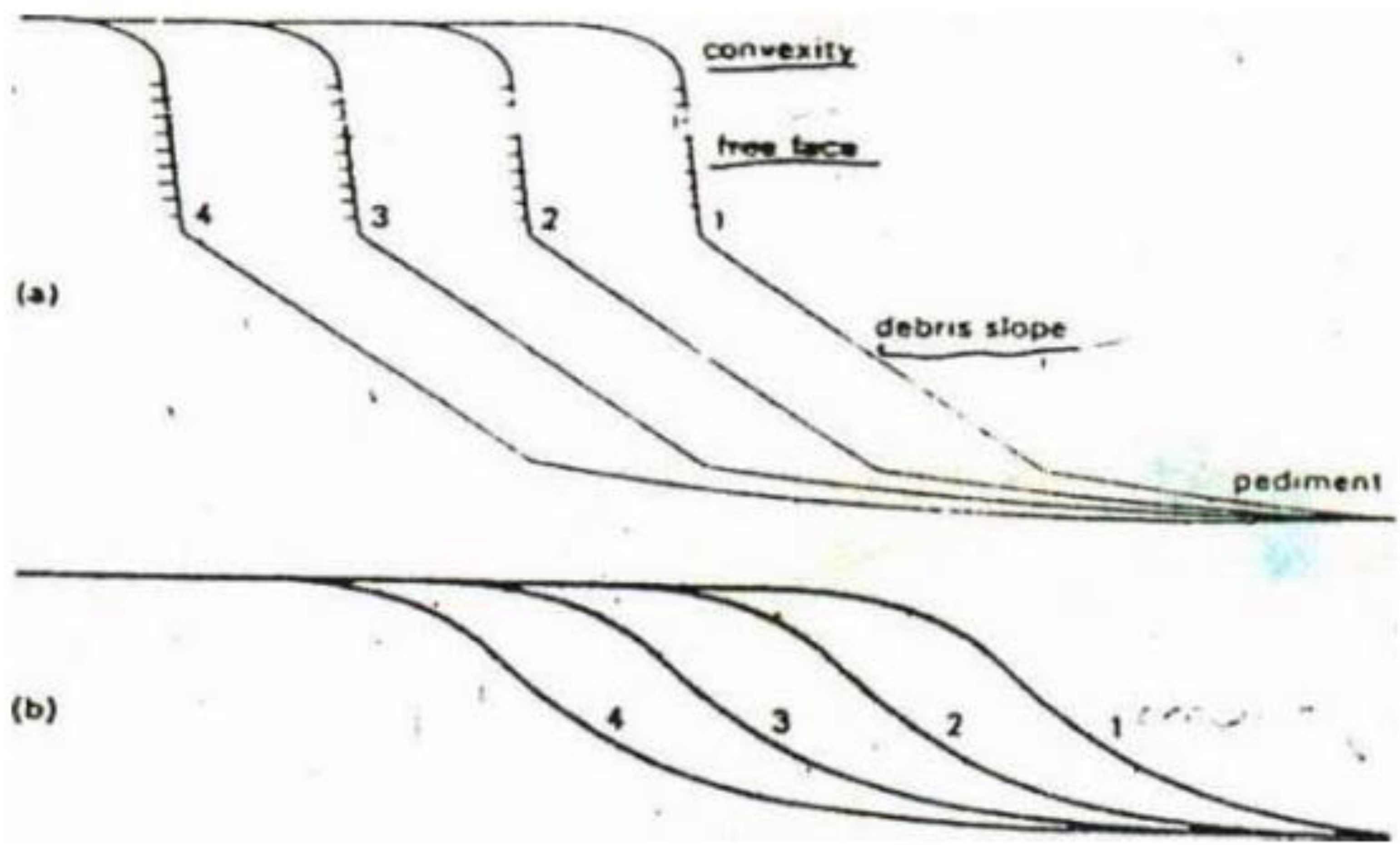


Figure 20 Parallel retreat

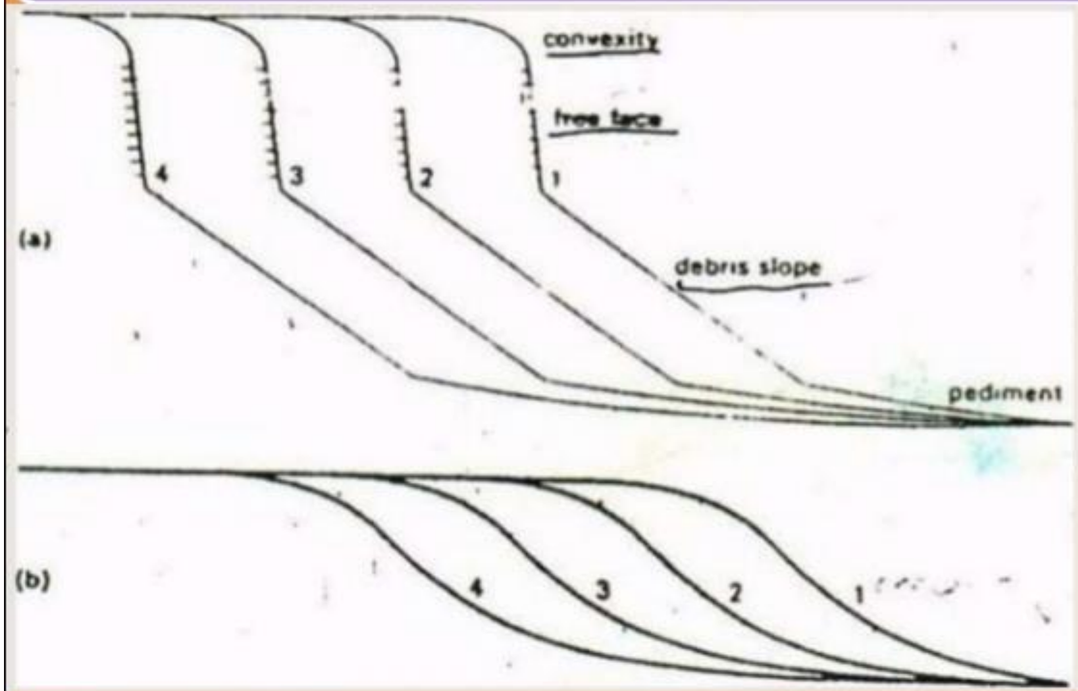
(a) Of a slope containing a free face and debris slope,

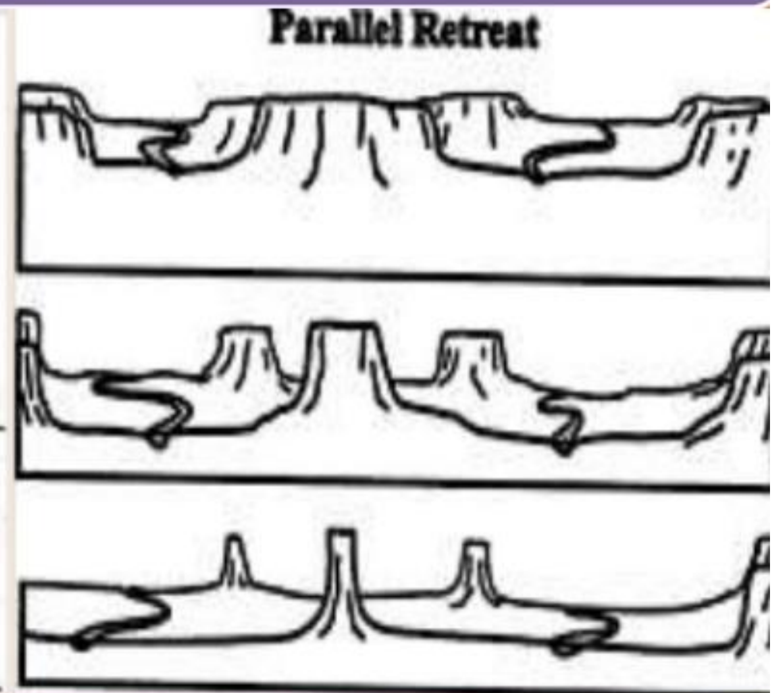
~ the angle of the free face is determined by the strength of the rock. A strong will often form a vertical free face.

(b) Of a slope without a free face

~ In less resistant rocks, the free face may not be present. Weathering reduces the slope to a continuous debris-covered slope.

WHAT IS PARALEL RETREAT ?





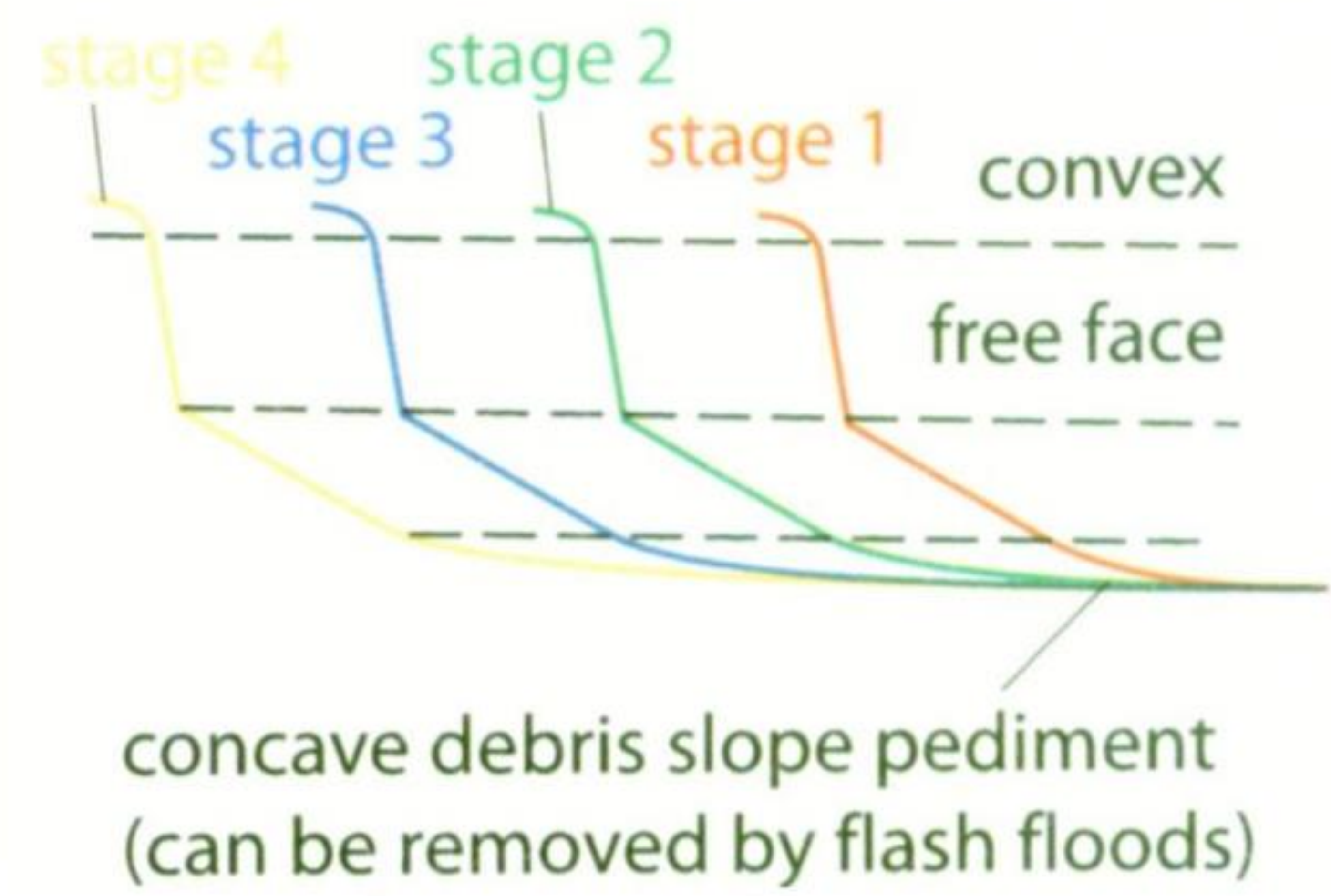
Each of the upper parts of the slope retreats by the same amount and maintain the same angle .
Therefore, the convexity, free face and debris slope all retain the same length.
The concavity extends in length and becomes slightly gentler in angle. This is called pediment
This type of evolution is called a parallel retreat.

Slope Parallel Retreat

Slope Parallel Retreat

- By L.C. King (1948, 1957)
- From South Africa
- Semi-arid regions and sea cliffs with wave-cut platforms
- Sedimentary rocks structure
- The slope units retreat by the same amount (proportion) so that the whole profile retains but leaves an extending concave unit (pediment) at its foot.
- This sequence is controlled by the rate of retreat of free face which is controlled by geology and climate (weathering and transport processes)

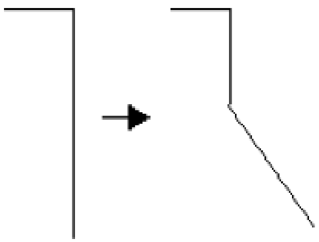
Slope Parallel Retreat



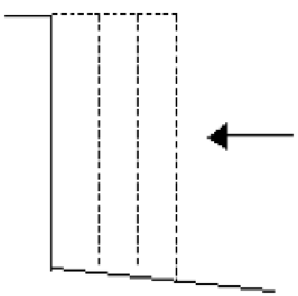
Slope replacement and Parallel Retreat

<u>Arid Climates</u> The lack of soil and dry conditions means that mass movements dominate. In the absence of "smoothing" by creep; slope erosion tends to be fairly uniform, producing straight (erosional) and concave (depositional) slope segments.

The pattern of slope evolution in these climates reflects the balance between mass wasting and removal of sediment by erosion - if material accumulates at the slope base faster than it can be removed -> SLOPE REPLACEMENT:



If material is removed by erosion as fast as it is moved down slope by mass wasting -> PARALLEL RETREAT and PEDIMENT formation:



WHAT IS PEDIPLANATION ?

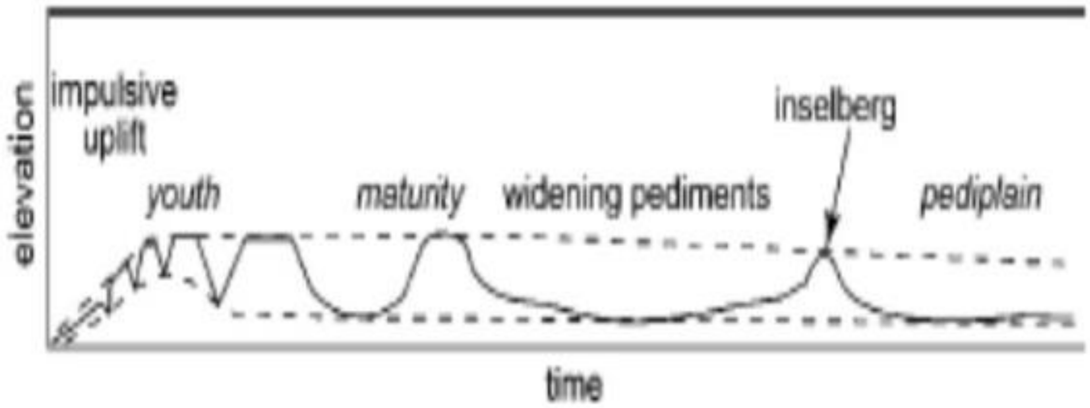
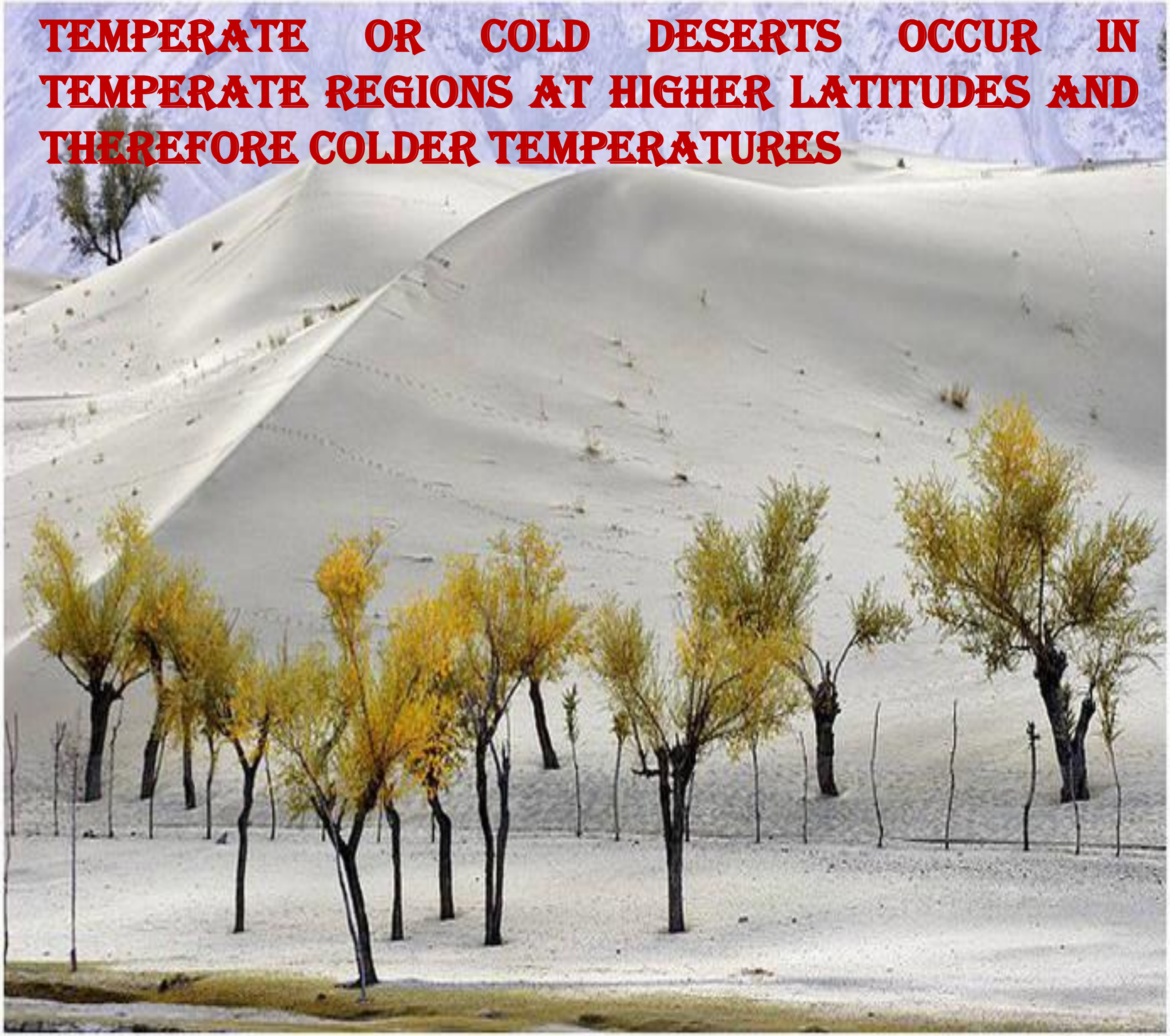


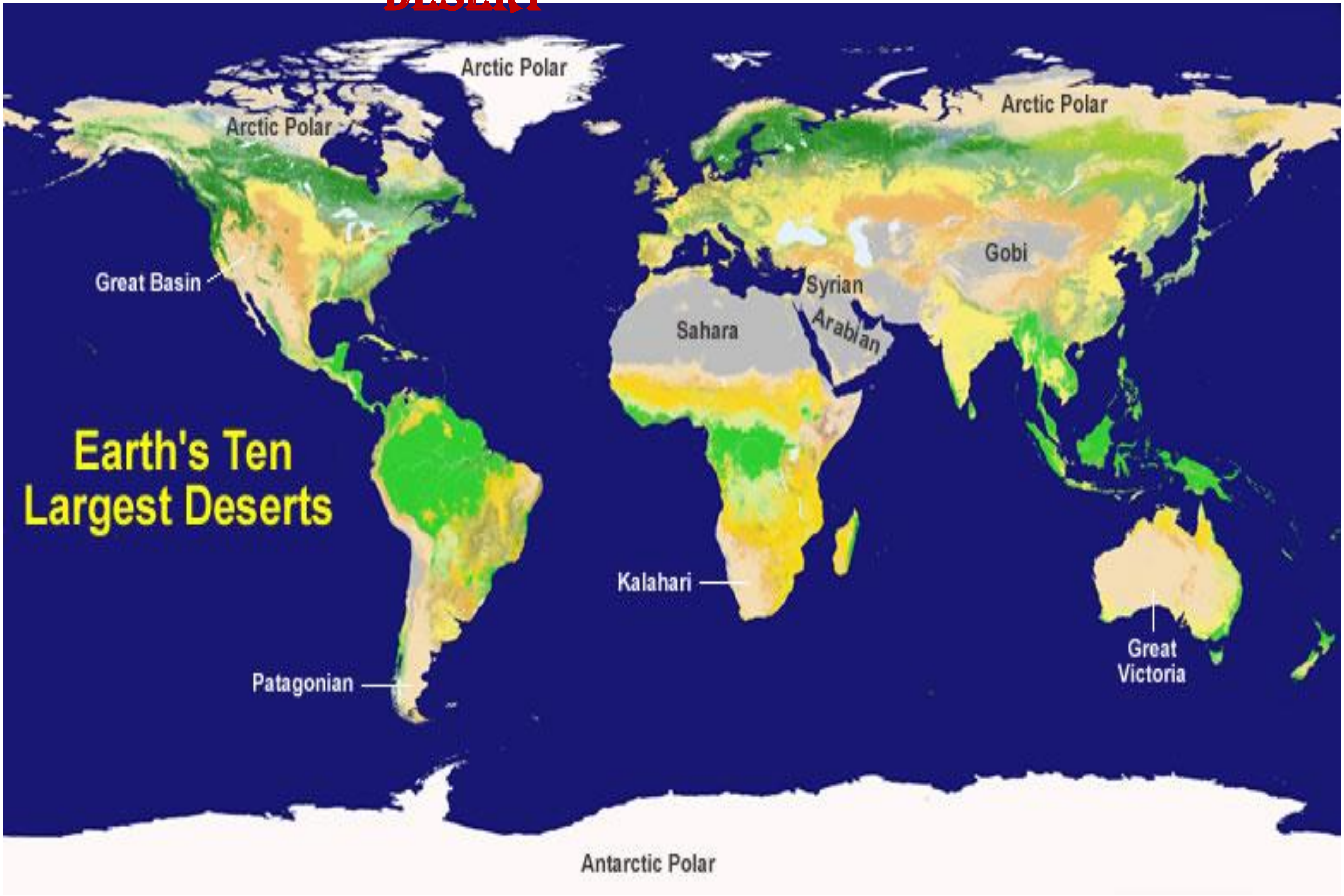
Fig. 5. The pediplanation model of King (1953) (modified from Summerfield, 1991). Penck's model stresses the development of concave-up slopes that retreat faster than interfluves lower, resulting in widespread pediments that coalesce into a pediplain. Note that mean elevation decreases in this model, but relief persists along escarpments or inselbergs.

- 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.

TEMPERATE OR COLD DESERTS OCCUR IN TEMPERATE REGIONS AT HIGHER LATITUDES AND THEREFORE COLDER TEMPERATURES



DISTRIBUTION OF COLD DESERT



Climate

Winters: cold, high levels of snow and rainfall; usually fairly long winters. Average temp. is -50°F

Summers: Short and moist, with most rain during April and May. The average summer temp. is 40°F

Geography

Most Cold Deserts are made of thick ice and rock. Average elevations are between 2,000 and 4,000 meters. Mountain ranges can reach up to 5,000 meters. Cold Deserts also include floating ice shelves and in Antarctica make up about 11% of the continent.

Natural Resources

Mineral Resources: Oil, Gold, Copper and coal

Soils

The soil in the Cold Dessert is heavy, silty, and salty and mostly sand, ice, or rock.

The Largest Desert

The two largest deserts on Earth are in the polar areas.

The Antarctic Polar Desert covers the continent of Antarctica and has a size of about 5.5 million square miles.

The second-largest desert is the Arctic Polar Desert. It extends over parts of Alaska, Canada, Greenland, Iceland, Norway, Sweden, Finland and Russia.

It has a surface area of about 5.4 million square miles.

Non-Polar Deserts

The rest of Earth's deserts are outside of the polar areas. The largest is the Sahara Desert , a subtropical desert in northern Africa. It covers a surface area of about 3.5 million square miles.

Major Deserts of the World			
Name	Type of Desert	Surface Area	Location
Antarctic	Polar	5.5 million mi^2	Antarctica
Arctic	Polar	5.4 million mi^2	Alaska, Canada, Greenland, Iceland, Norway, Sweden, Finland, Russia
Sahara	Subtropical	3.5 million mi^2	Northern Africa
Arabian	Subtropical	1 million mi^2	Arabian Peninsula
Gobi	Cold Winter	500,000 mi^2	China and Mongolia
Patagonian	Cold Winter	260,000 mi^2	Argentina
Great Victoria	Subtropical	250,000 mi^2	Australia
Kalahari	Subtropical	220,000 mi^2	South Africa, Botswana, Namibia
Great Basin	Cold Winter	190,000 mi^2	United States
Syrian	Subtropical	190,000 mi^2	Syria, Iraq, Jordan, Saudi Arabia
Chihuahuan	Subtropical	175,000 mi^2	Mexico
Great Sandy	Subtropical	150,000 mi^2	Australia
Kara-Kum	Cold Winter	135,000 mi^2	Uzbekistan, Turkmenistan
Colorado Plateau	Cold Winter	130,000 mi^2	United States
Gibson	Subtropical	120,000 mi^2	Australia
Sonoran	Subtropical	120,000 mi^2	United States, Mexico
Kyzyl-Kum	Cold Winter	115,000 mi^2	Uzbekistan, Turkmenistan, Kazakhstan
Taklamakan	Cold Winter	105,000 mi^2	China
Iranian	Cold Winter	100,000 mi^2	Iran
Thar	Subtropical	75,000 mi^2	India, Pakistan
Simpson	Subtropical	56,000 mi^2	Australia
Mojave	Subtropical	54,000 mi^2	United States
Atacama	Cool Coastal	54,000 mi^2	Chile
Namib	Cool Coastal	13,000 mi^2	Angola, Namibia, South Africa