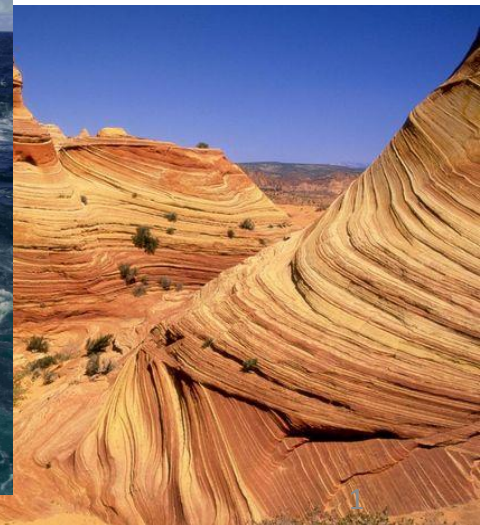
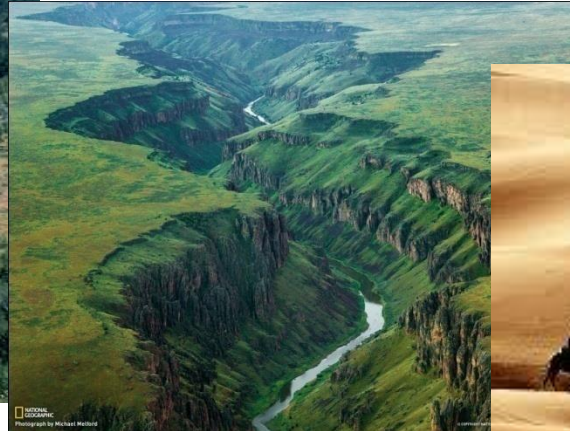


# CE 2203: Geology and Geomorphology



# Geomorphology

- The word “**geomorphology**” comes from the Greek roots “geo,” “morph,” and “logos,” meaning “earth,” “form,” and “study,” respectively. Therefore, geomorphology is literally “the study of earth forms.”
- Geomorphologists are concerned primarily with earth’s surficial features, including their origin, history, composition, and impact on human activity.
- Geomorphology concentrates primarily on Quaternary (**Pleistocene** and **Holocene**) features.
- Earth’s landforms reflect the local and regional balance between hydrologic, tectonic, aeolian, glacial, atmospheric, and marine processes.



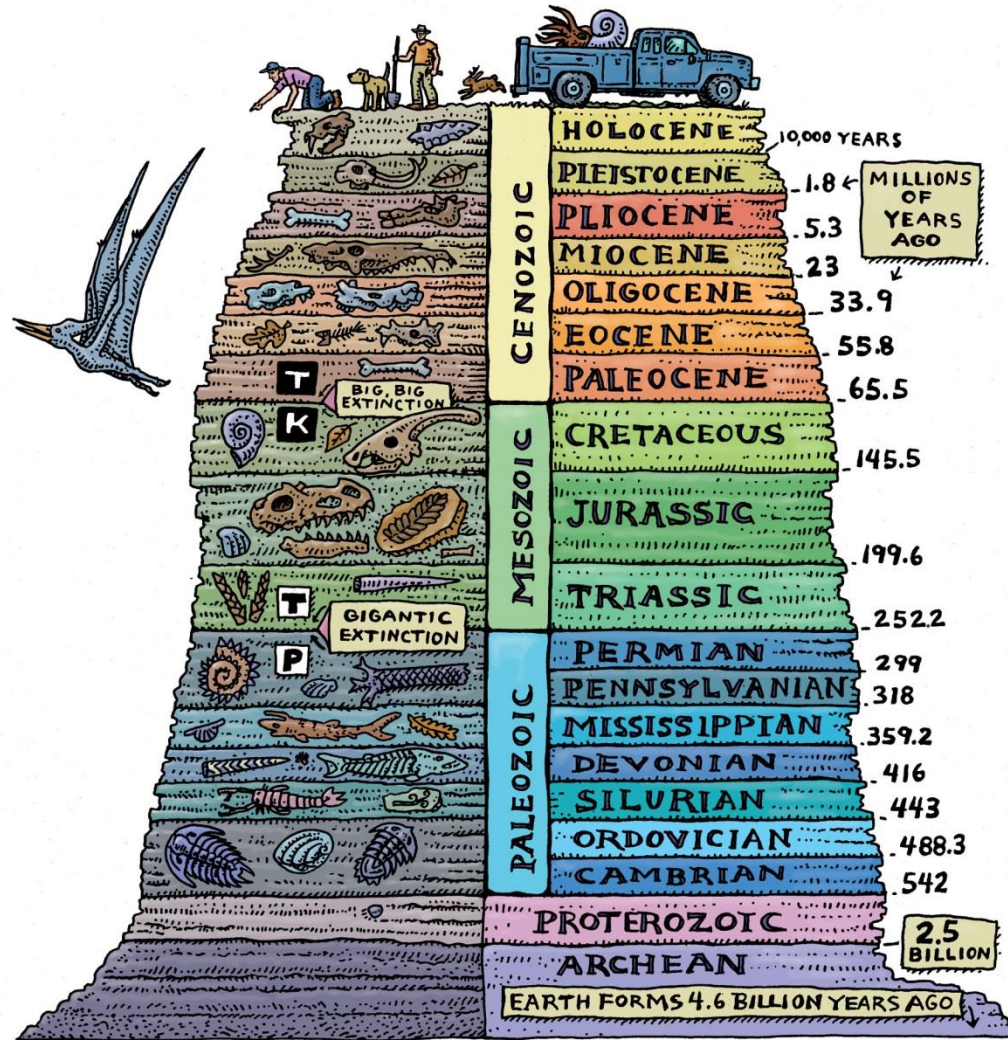
# Importance of Geomorphology

- To understand **geomorphological processes** of various environment.
- To detect **natural and environmental hazards** efficiently, e.g. earthquake, flooding, landslide, tsunami, volcanism etc.
- To identify **various landform features and landscapes**
- To identify various landform features **from satellite images**
- Coastal and river research
- Vulnerability studies
- Geology, Geography, Archeology, Engineering, Planning, Mining, Construction, Urbanization ...



EON	ERA	PERIOD	EPOCH	Ma		
Phanerozoic	Cenozoic	Quaternary	Holocene	0.01		
			Pleistocene	Late	0.8	
		Early		1.8		
		Tertiary	Neogene	Pliocene	Early	3.6
					Late	5.3
				Miocene	Early	11.2
					Middle	16.4
					Late	23.7
			Paleogene	Oligocene	Early	28.5
					Late	33.7
					Early	39.0
				Eocene	Middle	41.3
					Early	49.0
		Paleocene	Late	54.8		
	Early		61.0			
	Mesozoic	Cretaceous	Late	65.0		
			Early	99.0		
		Jurassic	Late	144		
			Middle	159		
		Triassic	Early	180		
			Late	206		
		Paleozoic	Permian	Middle	227	
				Early	242	
			Pennsylvanian	Late	248	
				Early	256	
	Mississippian		Late	290		
			Early	323		
	Devonian		Late	354		
			Middle	370		
			Early	391		
Late			417			
Silurian	Early	423				
	Late	443				
Ordovician	Early	443				
	Middle	458				
	Late	470				
Cambrian	Early	490				
	D	500				
	C	512				
	B	520				
	A	543				
Precambrian	Proterozoic	Late	900			
		Middle	1600			
		Early	2500			
	Archean	Late	3000			
		Early	3800?			

# Geologic Timescale



What past processes created this relict landscape?

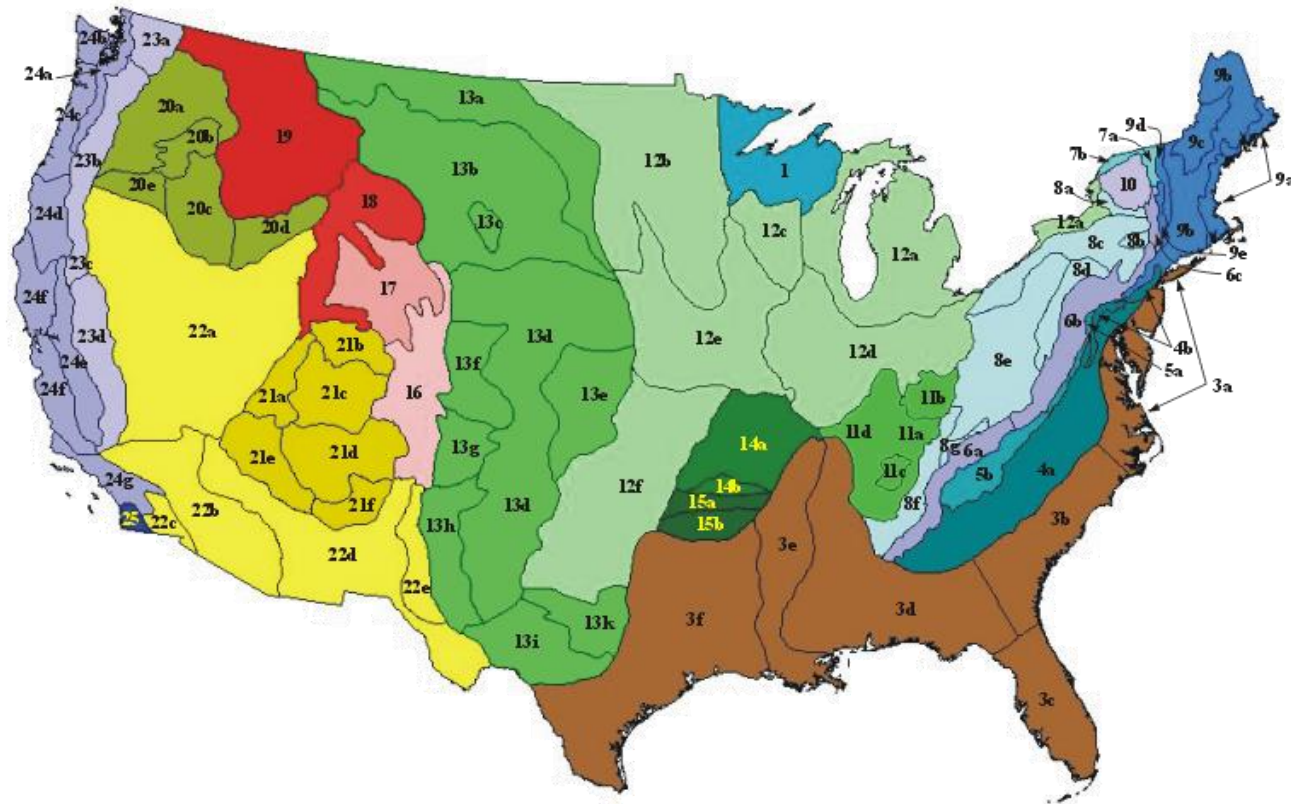
What modern processes are modifying it?



Were the processes that created the relict landforms  
*destructional or constructional?*

Are the modern processes modifying this landscape  
*destructional or constructional?*

# Physiographic Province: Issues of Scale



## Laurentian Upland

1 Superior Upland

## Atlantic Plain

3 Coastal Plain

4 Piedmont province

5 Blue Ridge province

6 Valley and Ridge province

## Appalachian Highlands

7 St. Lawrence Valley

8 Appalachian Plateaus

9 New England province

10 Adirondack province

## Interior Plains

11 Interior Low Plateaus

12 Central Lowland

13 Great Plains province

## Interior Highlands

14 Ozark Plateaus

15 Ouachita province

## Rocky Mountain System

16 Southern Rocky Mountains

17 Woming Basin

18 Middle Rocky Mountains

19 Northern Rocky Mountains

## Intermontane Plateaus

20 Columbia Plateaus

21 Colorado Plateaus

22 Basin and Range province

## Pacific Mountain System

23 Cascade-Sierra Mountains

24 Pacific Border province

25 Lower California province

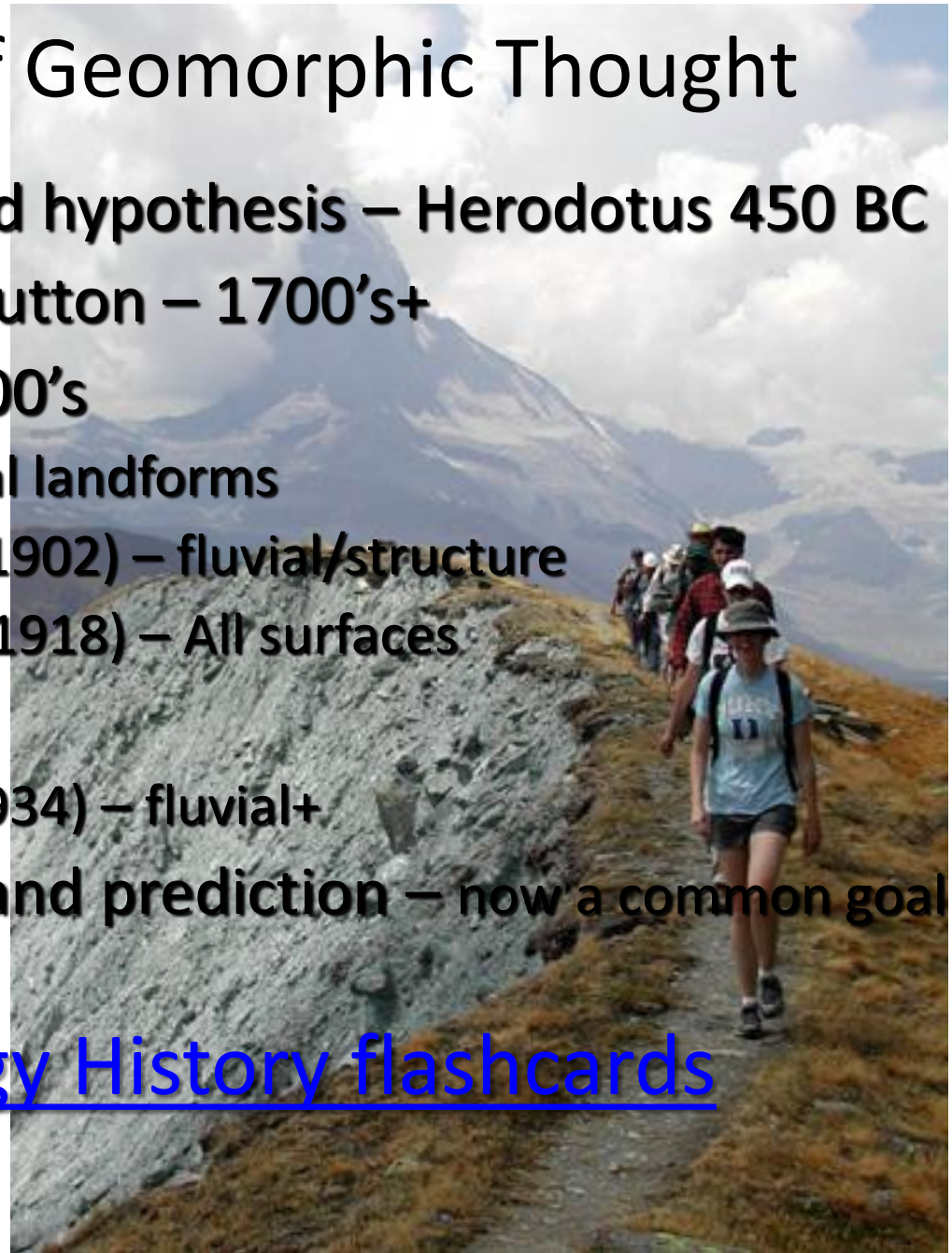
**Table 1-1****A Classification of Terrestrial Geomorphological Features by Scale (Baker, 1986, Table 1-1)**

<b>Order</b>	<b>Approximate Spatial Scale (km<sup>2</sup>)</b>	<b>Characteristic Units (with examples)</b>	<b>Approximate Time Scale of Persistence (years)</b>
1	10 <sup>7</sup>	Continents, ocean basins	10 <sup>8</sup> -10 <sup>9</sup>
2	10 <sup>6</sup>	Physiographic provinces, shields, depositional plains	10 <sup>8</sup>
3	10 <sup>4</sup>	Medium-scale tectonic units (sedimentary basins, mountain massifs, domal uplifts)	10 <sup>7</sup> -10 <sup>8</sup>
4	10 <sup>2</sup>	Smaller tectonic units (fault blocks, volcanoes, troughs, sedimentary subbasins, individual mountain zones)	10 <sup>7</sup>
5	10-10 <sup>2</sup>	Large-scale erosional/depositional units (deltas, major valleys, piedmonts)	10 <sup>6</sup>
6	10 <sup>-1</sup> -10	Medium-scale erosional/depositional units or landforms (floodplains, alluvial fans, moraines, smaller valleys and canyons)	10 <sup>5</sup> -10 <sup>6</sup>
7	10 <sup>-2</sup>	Small-scale erosional/depositional units or landforms (ridges, terraces, sand dunes)	10 <sup>4</sup> -10 <sup>5</sup>
8	10 <sup>-4</sup>	Larger geomorphic process units (hillslopes, sections of stream channels)	10 <sup>3</sup>
9	10 <sup>-6</sup>	Medium-scale geomorphic process units (pools and riffles, river bars, solution pits)	10 <sup>2</sup>
10	10 <sup>-8</sup>	Microscale geomorphic process units (fluvial and eolian ripples, glacial striations)	

- Scale of landforms varies over 15 (!) orders of magnitude.
  - continents ( $10^7$  km<sup>2</sup>) to microscale features like ripples, glacial striations ( $10^{-8}$  km<sup>2</sup>).
- Age of landforms varies over 7-8 orders of magnitude.
  - continents ( $10^9$  years) to microscale features like pools and riffles ( $10^2$  years).
- Larger landforms most durable (longer-lasting).
  - Smaller landforms created/destroyed faster than larger ones.
- Rates of geomorphic / geologic change slow for larger areas, faster when measured over small areas.
  - example: earthquakes compared to glaciers
  - rate of erosion in small watershed compared to larger one

# Rise of Geomorphic Thought

- Observation and hypothesis – Herodotus 450 BC
- Description – Hutton – 1700's+
- Explanation 1800's
  - Agassiz – glacial landforms
  - Powell (1834 -1902) – fluvial/structure
  - Gilbert (1843 -1918) – All surfaces
- Correlation
  - Davis (1850 -1934) – fluvial+
- Quantification and prediction – now a common goal



[Geomorphology History flashcards](#)

- **Herodotus** (484-425 BC): Rocks on land in Egypt contained marine fossils, assumed that the Nile *Delta* took thousands of years to form.
- **Arisotle** (384-322 BC): Dry land can be submerged, land can be raised from beneath the ocean, described erosion by rivers, and deposition in deltas.
- **Lucretius** (99-55 BC): Recognized weathering processes on rocks.
- **Seneca** (3-65 AD): Observed erosion of valleys by running water.
- **Ibn-Sina** (980-1037 AD): Concluded that mountains could be uplifted, and later eroded.
- **Leonardo DaVinci** (1452-1519 AD): found marine fossils on land
- **G. Bauer** (1494-1555 AD): hypothesized that mountains were sculpted by weathering and mass movements
- **Steno** (1638-1687AD) regarded water as the most significant agent of erosion

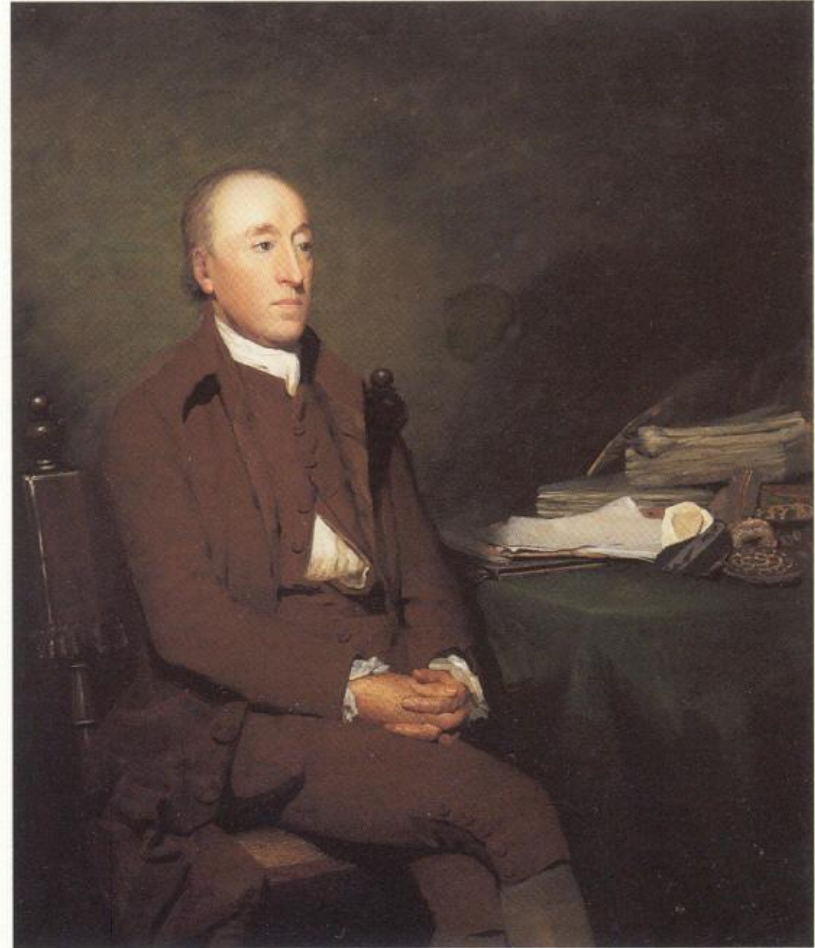
# Landscape Creation vs. Landscape Development

- Biblical interpretations hindered the proliferation of non-catastrophic landform evolution theories.
- **Werner** (1749-1817 AD): theorized that all mountains formed under water as layers of sediment, , and were ultimately sculpted by rapidly receding oceans.
- **Georges Cuvier**: Great catastrophic floods produced unconformities, and carved Earth's landscape.



## James Hutton (1726-97)

- Granites form through heat & fusion deep underground, and are later uplifted and exhumed.
- Landforms are produced by slow, continuous processes.
- **Uniformitarianism**
- Sediments are eroded from landforms, only to be deposited and later lithified into new rocks.
- There is neither an apparent beginning nor end to landform development.



# *Uniformitarianism*



Modern river channels



Ancient river channels

Scientists make observations of an event or an object and then try to explain those observations by organizing them into a logical system. As rock bodies can cover extensive areas and represent vast periods of time, much of geological research cannot be done as controlled experiments in a formal laboratory setting. In these situations, we rely on the assumption that physical, chemical and biological laws are constant. That is, the processes operating today are the same as those that operated in the past. For instance, since water flows down hill today, it must have done so in the past. Therefore, if we identify a body of rocks that exhibits characteristics similar to those found in a modern geological environment, we assume that it must have formed in a similar manner.

# Hutton's Proponents

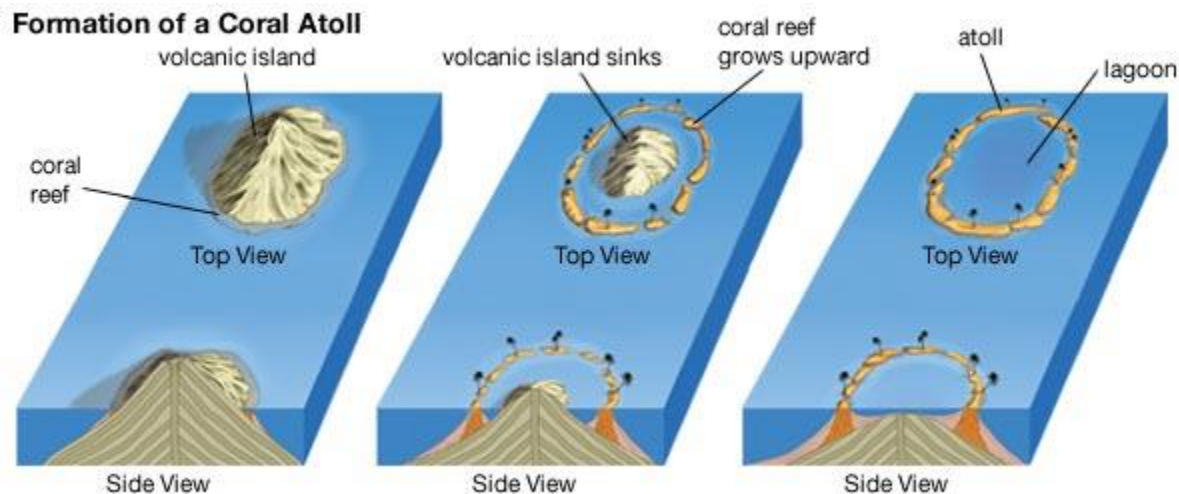


- **John Playfair** (1748-1819)
  - *Illustrations of the Huttonian Theory of the Earth* (1802).
    - Streams carve their own drainage systems.
    - Stream reaches and maintains equilibrium, adjusted to local gradient. CONCEPT OF “GRADED STREAM”
    - The Earth is very ancient; ongoing processes continue to change it.
- **Charles Lyell** (1797 - 1875)
  - The Principles of Geology* (1833 - 1875)
  - A strong promoter of Uniformitarian theory
  - A vehement opponent of Catastrophism

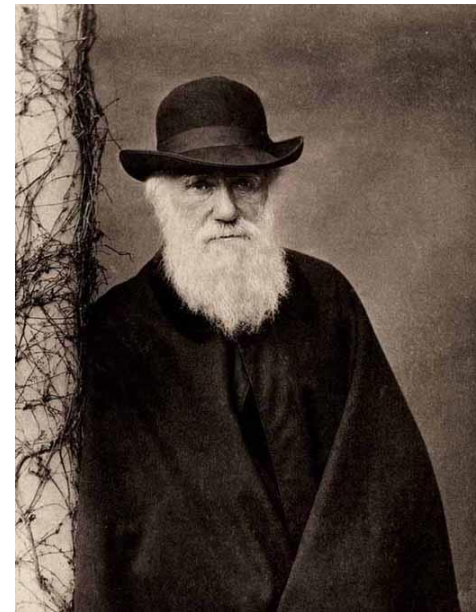


# Other Nineteenth Century European Contributions

- Venetz, and Bernardhi: Moraines and erratics prove glaciations extended from polar regions(1832)
- Louis Agassiz : Recognized glacial landforms in Europe & N. Am.- introduced the concept of Ice Ages (1837)
- **Charles Darwin** (1809-1882): Recorded his observations during the voyage of “the Beagle.”, suggested an origin for atolls.

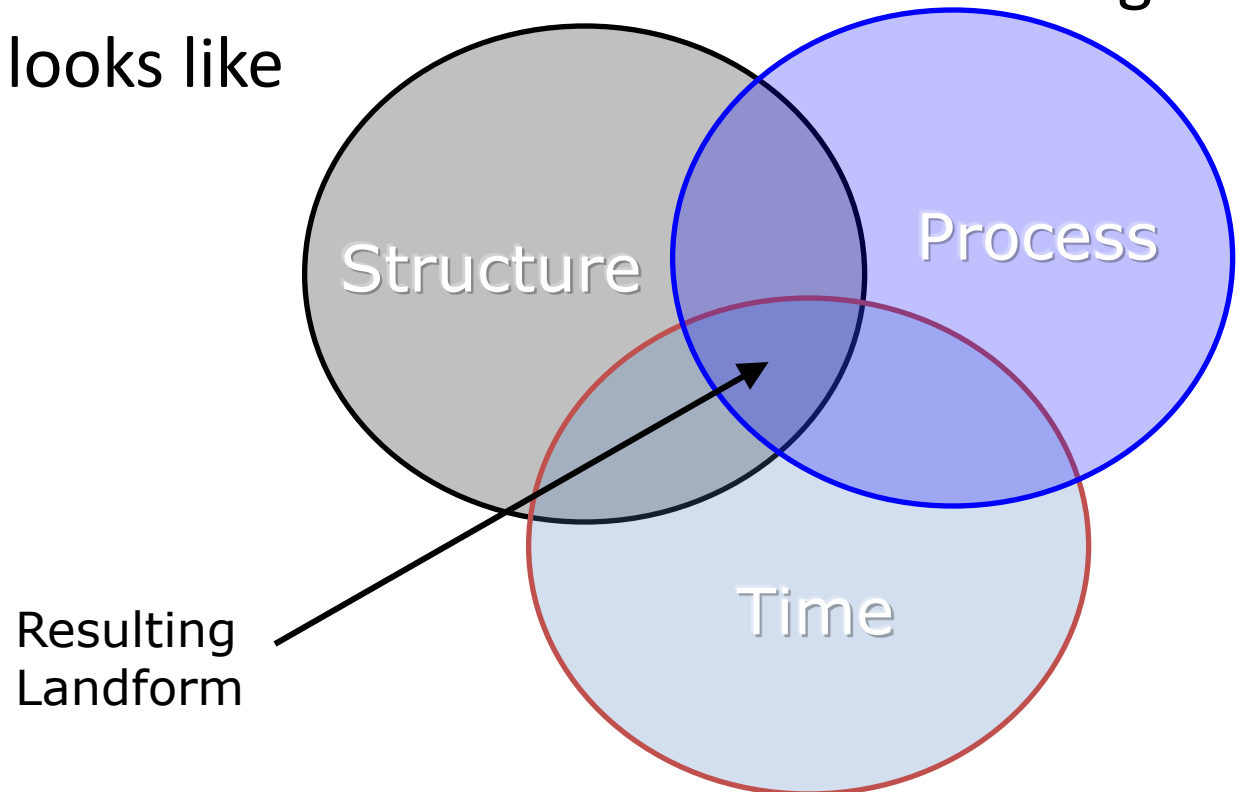
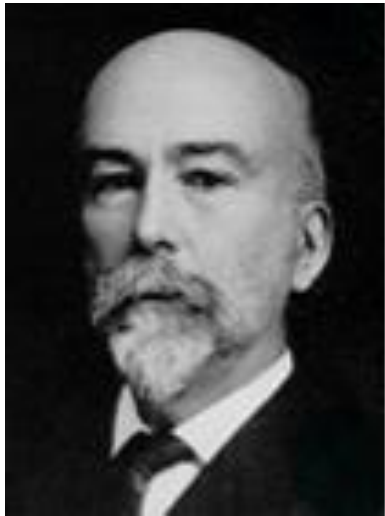


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# Evolutionary Geomorphology

- William Morris Davis (1850-1934)
- Based on Darwinian Evolutionary Theory
- Landscapes evolve throughout time
- Stage of evolution can be determined by examining the characteristics of the landscape
- Implies that TIME is the critical factor in determining what the landscape looks like



**Structure:** rock mass (or unconsolidated material mass).

**Process:** constructive or destructive process(es) modern/relict

**Time (stage):** landforms evolve through stages from continued actions of geomorphic process(es).

**Structure:** limestone bedrock

**Process:** weathering (dissolution)

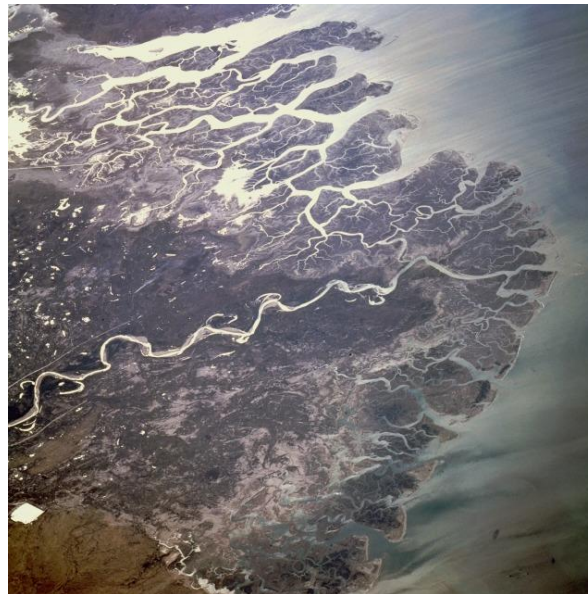
**Time:**  $10^3$  to  $10^6$  years?

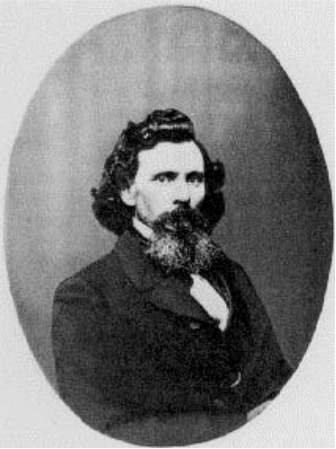


**Structure:** delta sediments

**Process:** deposition / erosion

**Time:**  $10^3$  to  $10^4$  years?

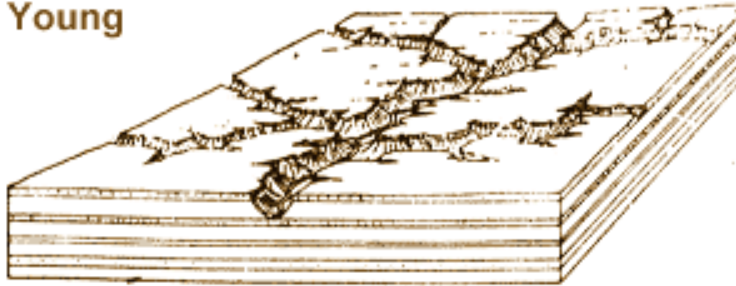




# William Morris Davis

- **Davis' Cycle of erosion**

Young



Mature



Old



An example from an arid climate.

Davis' idea of a peneplain:

**peneplain**: an area of low relief form through a long period of continual erosion



# Grove Karl Gilbert

## Process Geomorphology

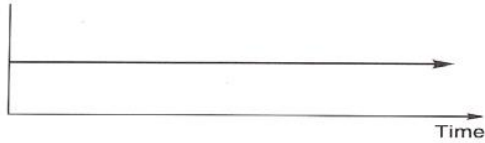


- (1890) Recognized some Utah landscapes were formed by Pleistocene Lake Bonneville. Great Salt Lake and Bonneville salt flats are remnants, contributed to the understanding of river incision, Identified lunar craters as caused by impacts, and carried out early impact - cratering experiments
- Landforms are a balance between resisting framework and the forces acting to alter the landscape
- Implies that **time** is one component of many that affect the appearance of the Earth
- Inferred that the landscape was in **equilibrium** between driving forces and resisting forces

- **Davision Geomorphology & TIME** as the dominant factor dominated the scientific literature until the 1960's
- John Hack proposed landscape development occurred similarly to the way Gilbert had espoused, recognizing considerable variability in most geomorphic systems
- Most were in **Dynamic Equilibrium**
- 1930-1965 Rise of Quantitative Approaches to Geomorphology
- Quantitative trends continue (computers, satellite, other remotely sensed data, numerical methods, improved dating techniques,...)

# Types of Geomorphic Equilibria

Rate of Change



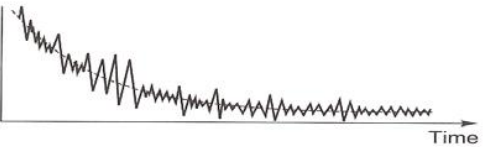
A. Steady-state equilibrium (constant conditions)



B. Steady-state equilibrium (oscillating conditions)



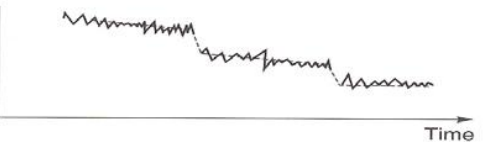
C. Declining equilibrium



D. Dynamic equilibrium



E. Metastable equilibrium (episodic erosion)



F. Dynamic metastable equilibrium (episodic erosion)

- Positive Feedbacks
- Negative Feedbacks
- Changes in the balance between forces may destabilize the system
- The system may cross a threshold, and may initiate a new pattern of equilibrium

FIGURE 2-1  
Types of equilibria.

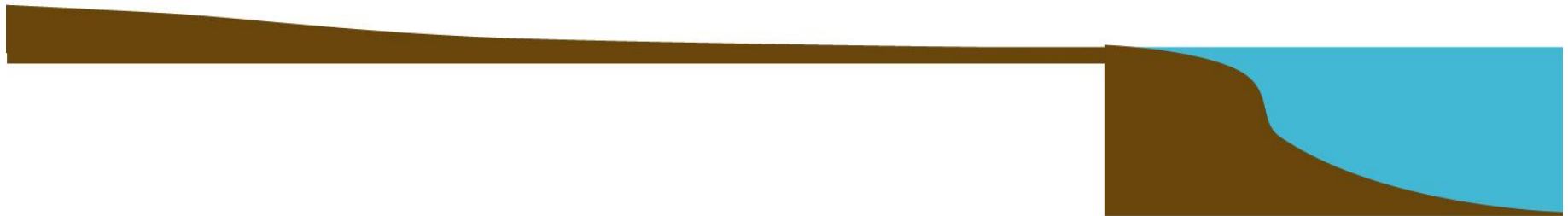
# *Concepts of Equilibrium*

Equilibrium means balance. In geomorphology, it refers to no net change, usually in terms of a balance between deposition and erosion, uplift and downcutting, or soil production and removal.

Erosion

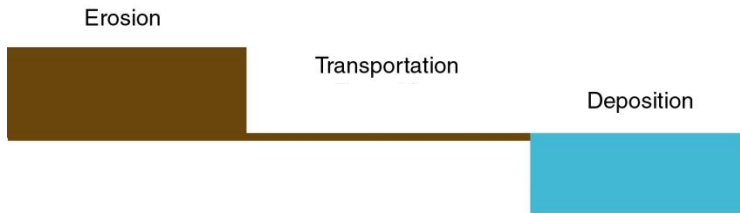
Transportation

Deposition

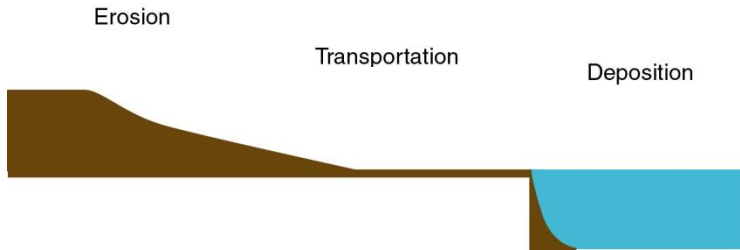


- Equilibrium is strived for but seldom achieved.
- A change in one part of a system affects all others.

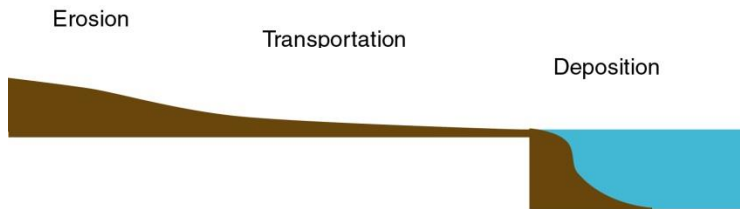
# *Fluvial Equilibrium*



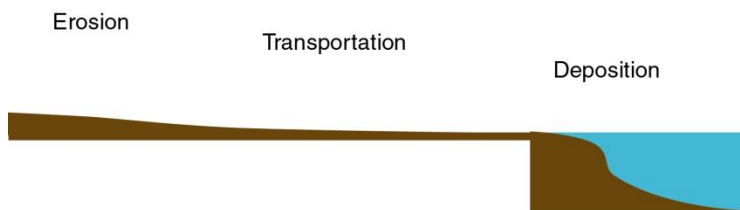
Recent uplift in excess of erosional rates results in a system that is out of equilibrium.



Weathering and erosion dominate headland areas with removed material being transported to a depositional basin.



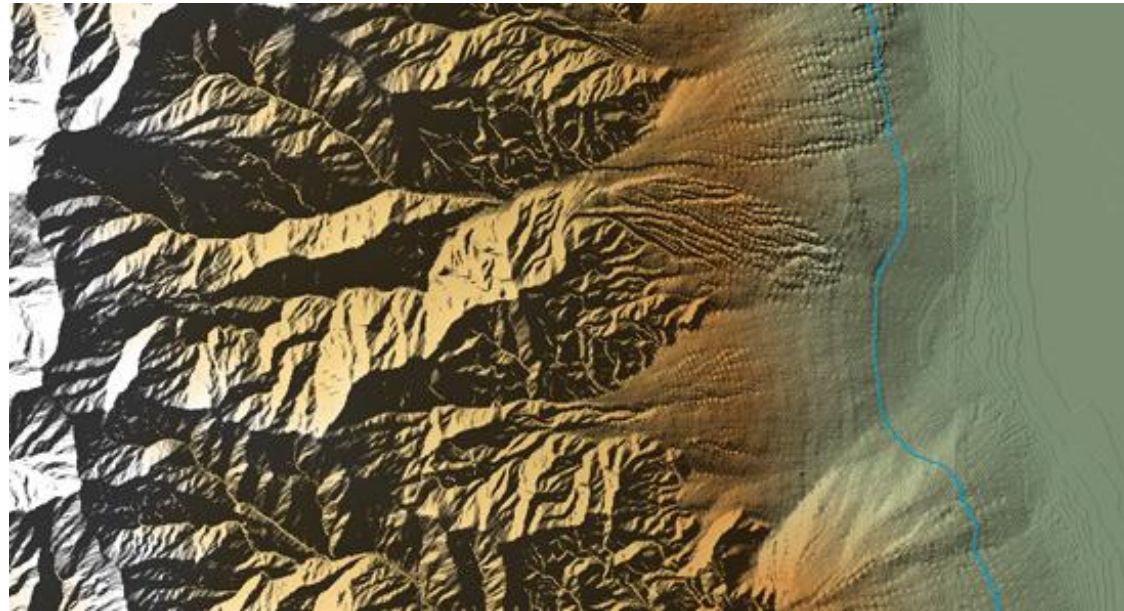
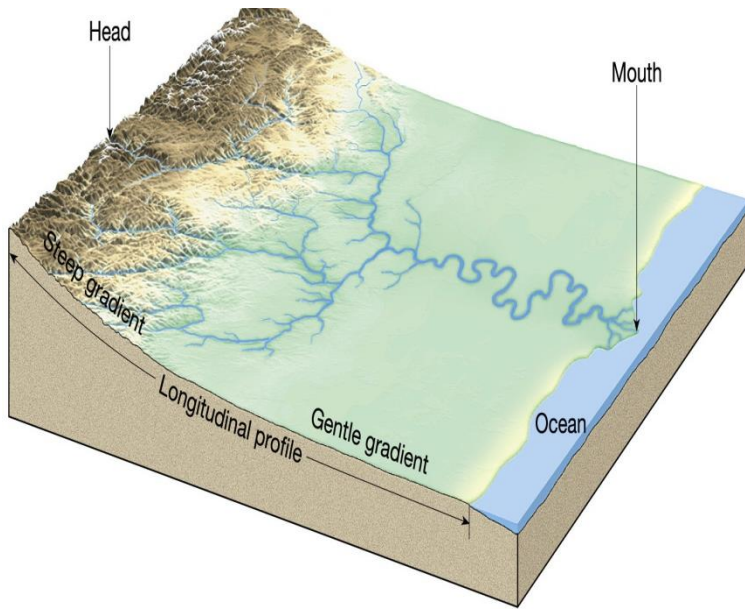
As headlands recede, both erosional and depositional rates decrease.



If the region remains stable for an extended period, equilibrium, where erosional and depositional rates are equal, might be achieved.

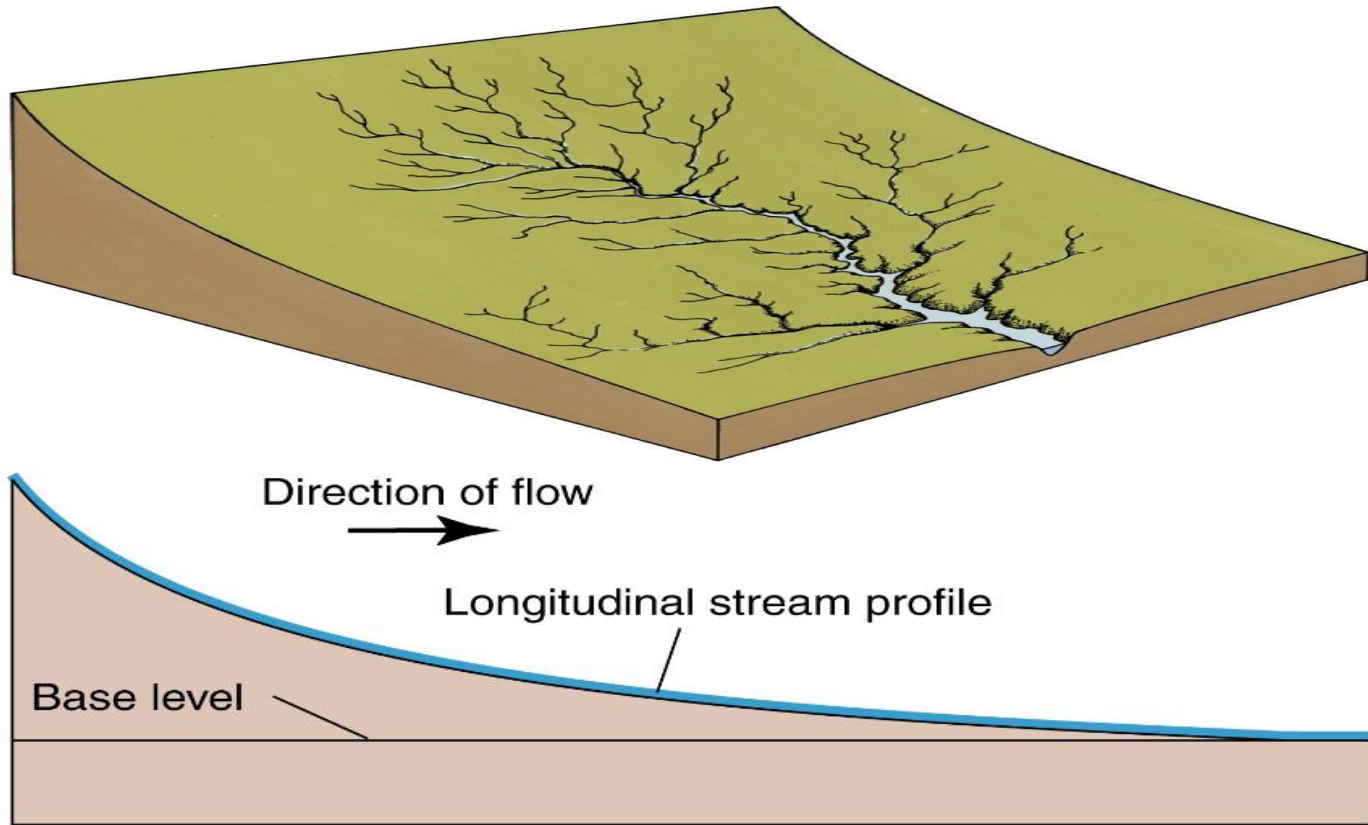
# *Base Level*

**Base level** is the level below which erosion cannot occur and above which deposition does not take place.

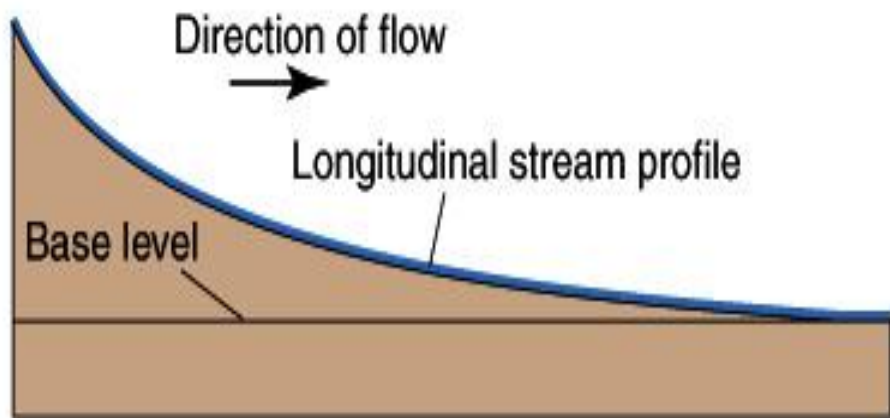


- Sea level is the ultimate base level
- Lakes and reservoirs provide temporary base levels
- Changes in sea level can be eustatic or relative
- Changes in base level create and destroy accommodation space

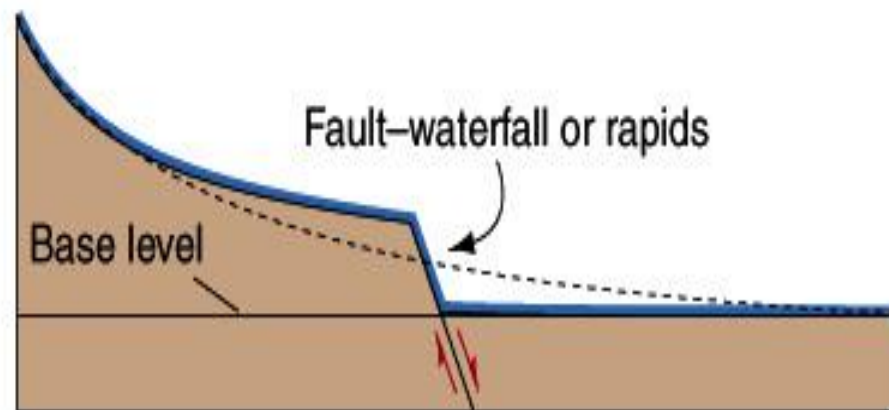
# *Graded (Longitudinal) Profile*



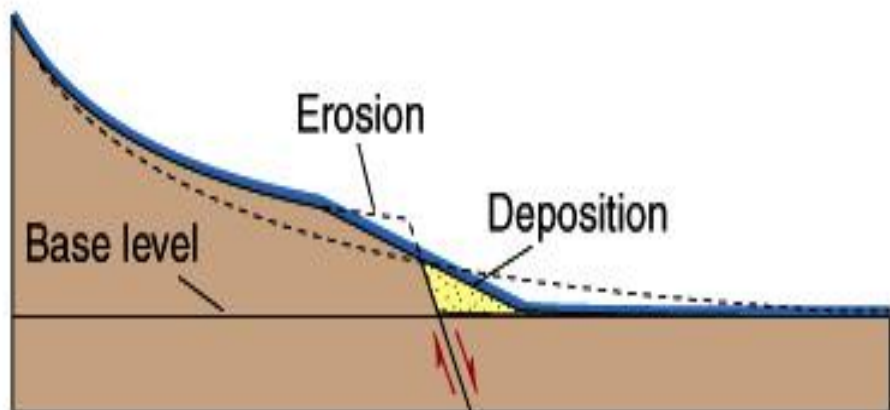
Stream gradient is related to water velocity and the load it can transport. A change in any of these affects the other two. Each can be influenced by factors outside of the stream system, such as base level fluctuations (gradient), precipitation changes (discharge), and sediment character.



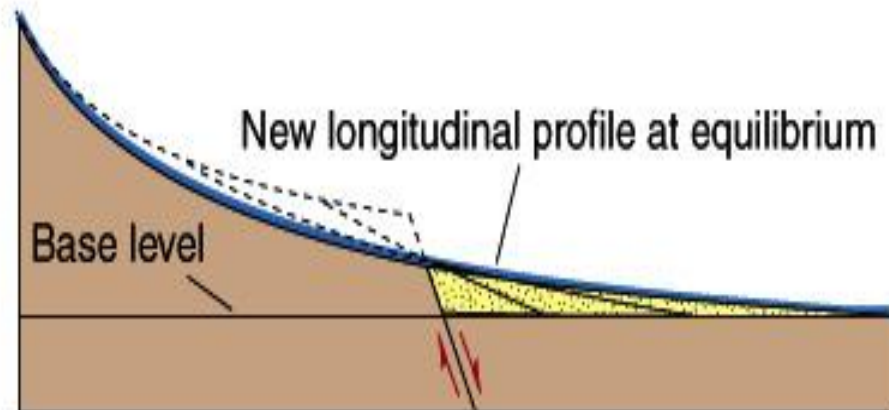
(A) Initially, when the stream profile is at equilibrium, the velocity, load, gradient, and volume of water are in balance. Neither erosion nor deposition occurs.



(B) Faulting disrupts equilibrium by decreasing the gradient downstream and increasing the gradient at the fault line.

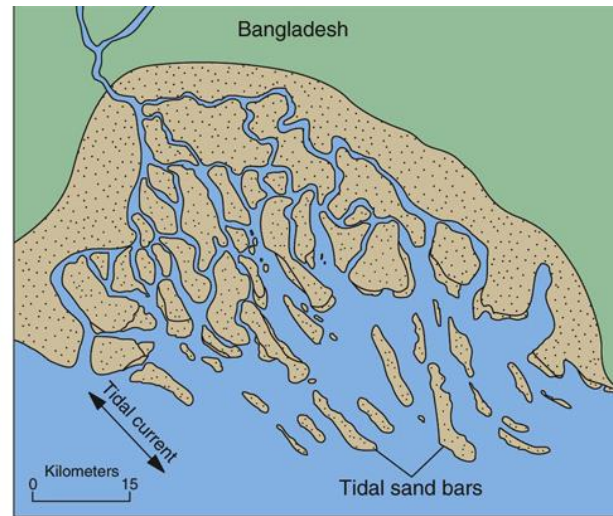
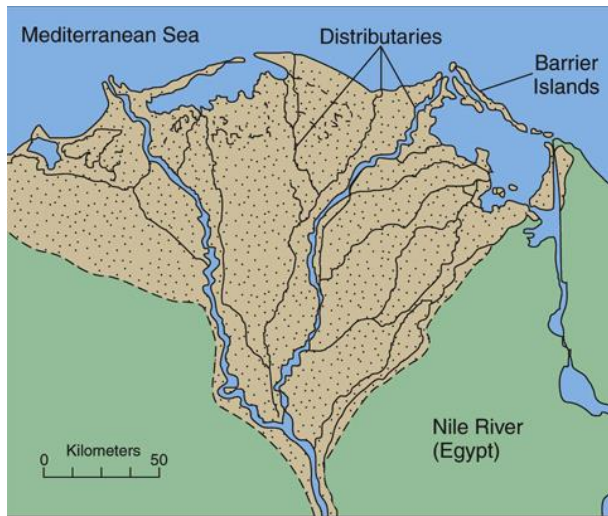
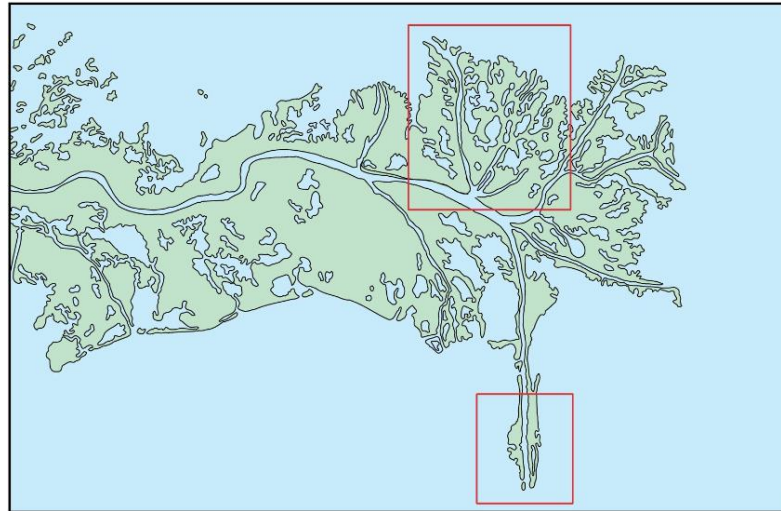


(C) Erosion proceeds upstream from the fault, and deposition occurs downstream and a new stream profile starts to develop.



(D) Erosion and deposition eventually develop a new stream profile at which the velocity, load, gradient, and volume of water will be in balance so that neither erosion nor deposition occurs.

# *Coastal Equilibrium (Channel Mouths)*



Deltas represent a “battle” between fluvial and marine (wave & tidal) processes. Delta morphologies are highly influenced by which of these processes dominates.

# Geomorphic Process

- The process responsible for the **formation** and **alteration** of the earth's surface.
- The physical and chemical **interactions** between the **earth's surface and the natural forces** acting upon it to produce landforms.
- The processes are determined by such natural environmental variables as **geology, climate, vegetation** and **base level**, to say nothing of human interference.

# Geomorphic Process (Cont...)

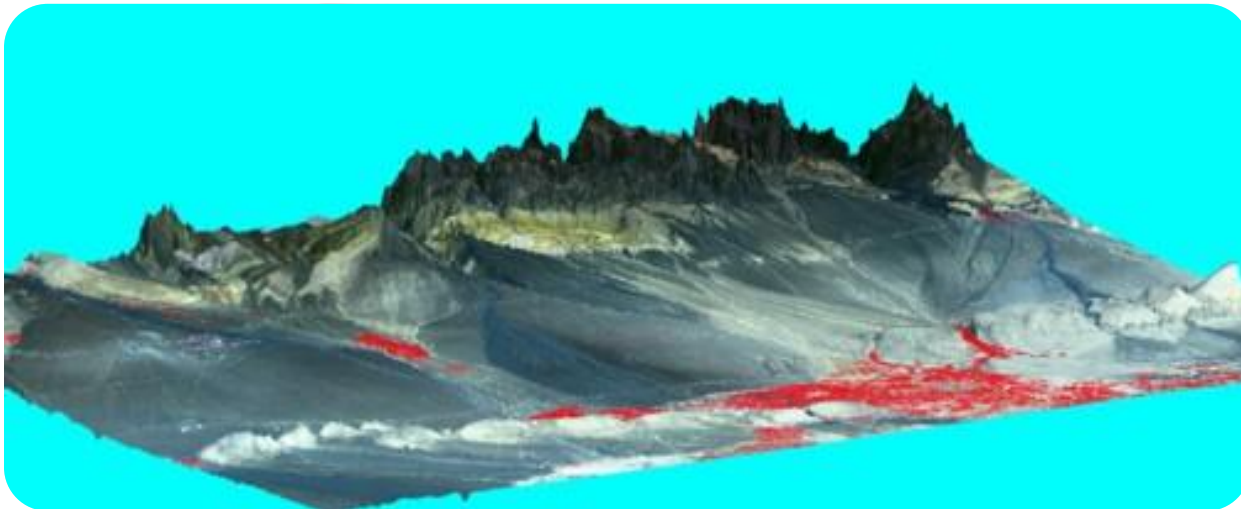
## Definition:

- The geomorphic processes are all those **physical and chemical changes** which effect a modification of the earth's surgical form [W. D. **Thornbury** (1968): Principles of Geomorphology, pp. 34].
- A process by which the earth's land forms are **changed or maintained** [Jim **Gardner** (1979): Physical Geology].

# *Agent, Process & products*

## Agents of Geomorphic Processes

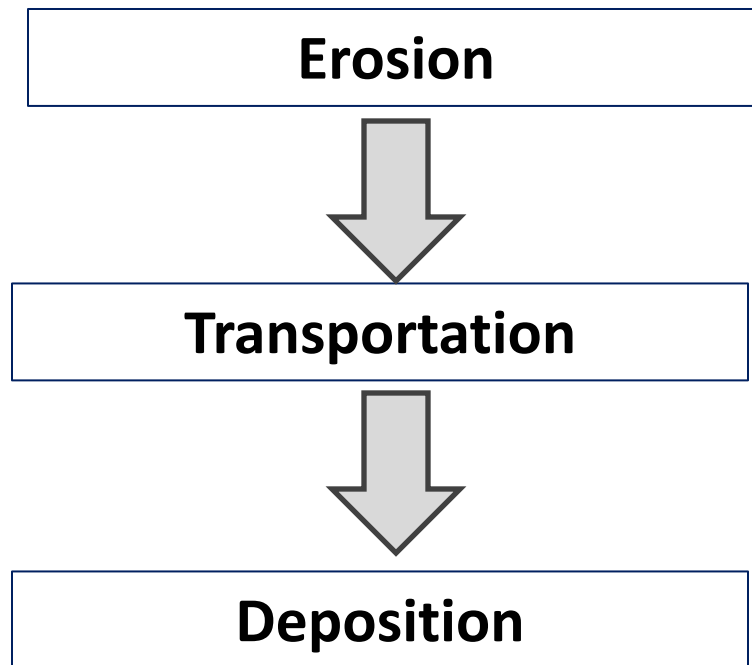
- River - **Humid Geomorphic Environment**
- Wind - **Arid Environment**
- Glacier/ice - **Polar Environments**
- Wave - **Coastal Environment**



# *Agent, Process & products*

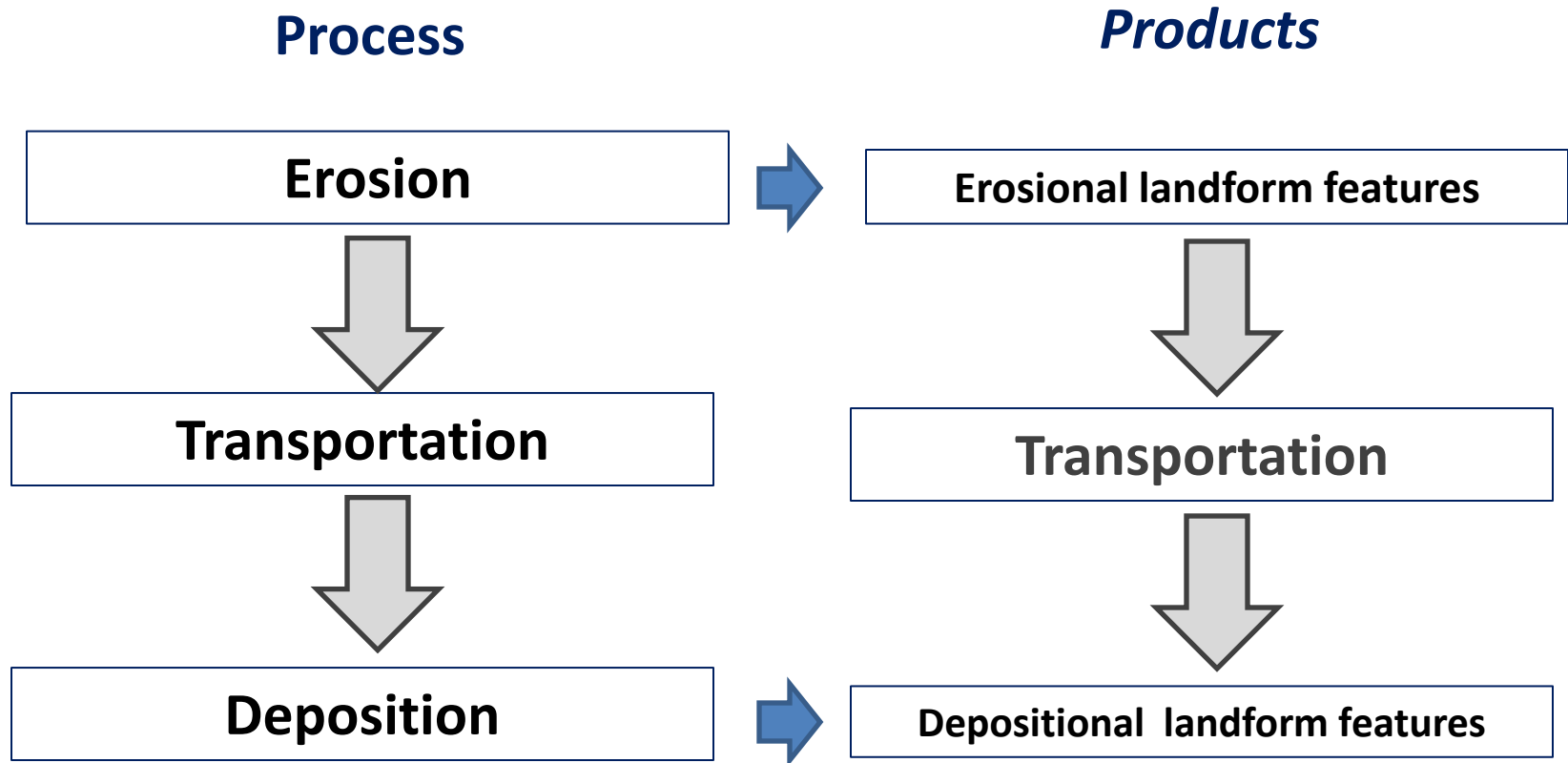
## **Process**

Process includes three types of activities



# *Agent, Process & products*

## Products of Geomorphic Processes



# Agents of Change...

**River activities**



**Wind activities**

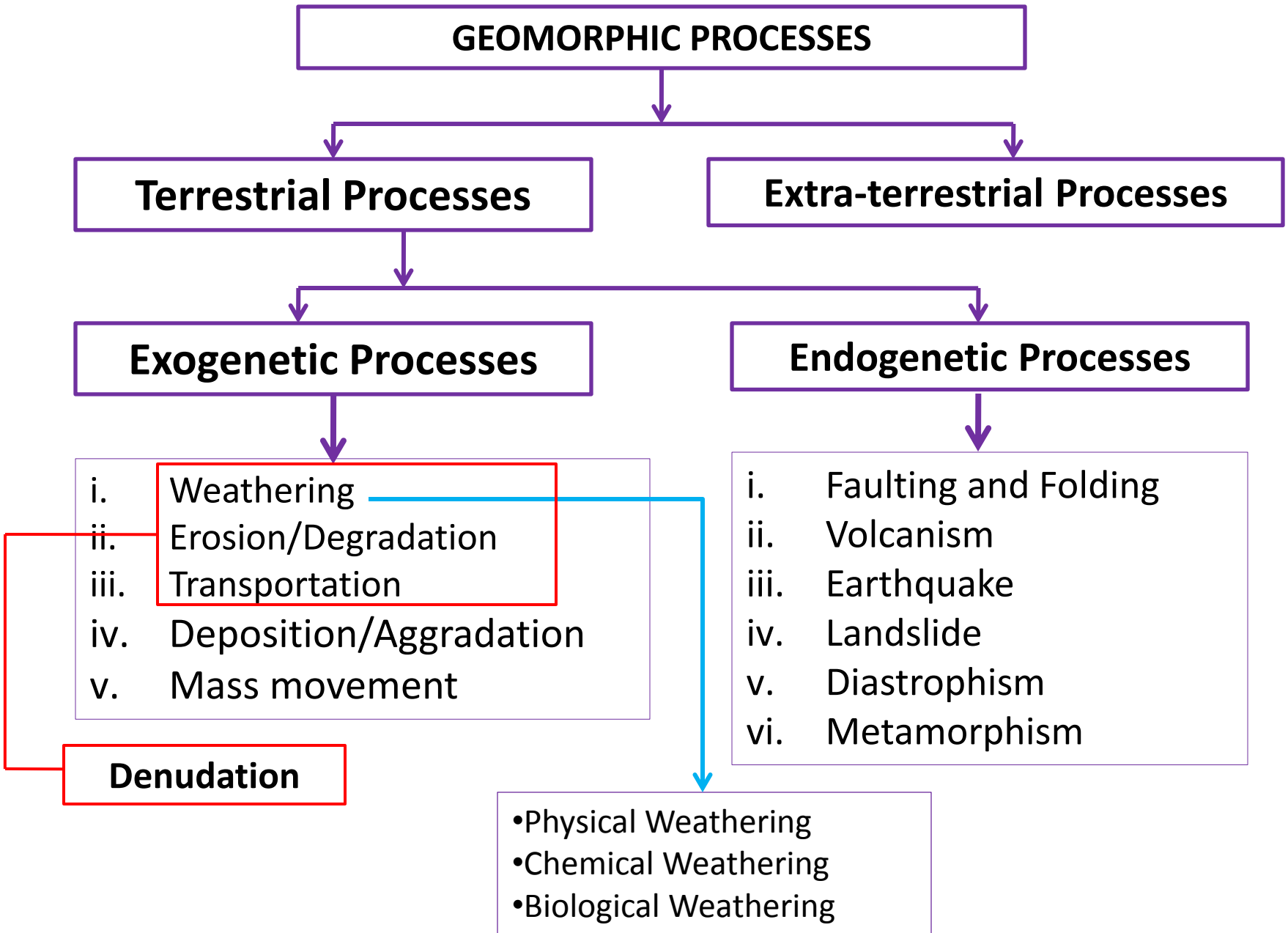


**Glaciers activities**



**Wave activities**





# Types of Geomorphic Processes

## □ Geomorphic Processes

- A. Terrestrial processes
- B. Extra-terrestrial processes, e.g. **fall of meteorite** (mass/rock from outer space).

### Terrestrial processes

1. Exogenetic / Exogenous Processes
2. Endogenetic / Endogenous Processes

## Extra-terrestrial processes, e.g. fall of meteorite

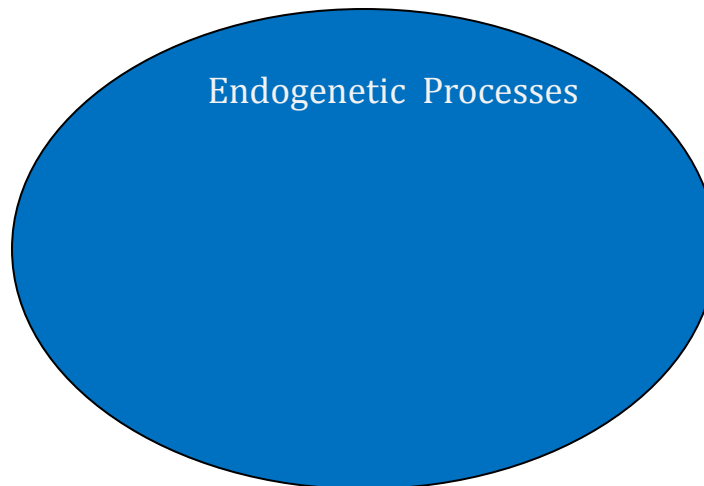


# Types of Geomorphic Processes (Cont...)

## Exogenetic/Exogenous Processes

Outer geomorphological processes = exogenetic processes (solar radiation, wind, temperature changes, water) create relief sculptures, surface features.

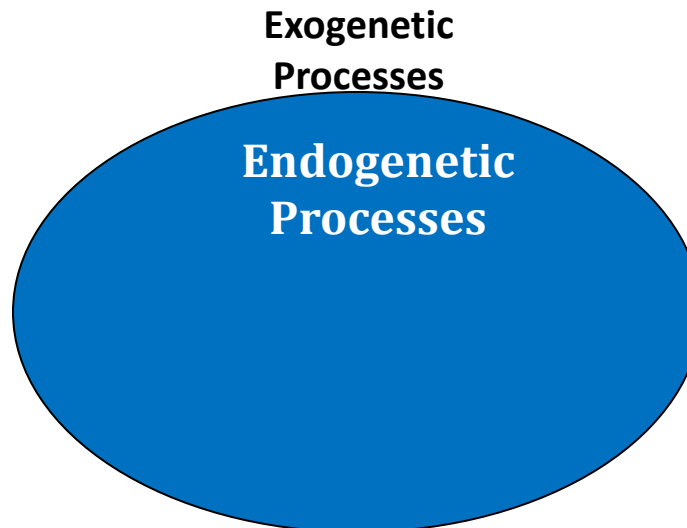
**Exogenetic Processes**



# Types of Geomorphic Processes (Cont...)

## Endogenetic Processes

*Inner geomorphological processes* = endogenetic processes (earthquakes, volcanoes, folding and faulting) create rough features of the Earth's relief. e.g. oceanic basins, mountain ranges, oceanic ridges and trenches, rift valleys, folds, faults and volcanoes, etc.



# Basic difference between the two process

- Processes that are caused by forces from **within** the Earth are **endogenous** processes.
- By contrast, **exogenous** processes come from forces **on or above** the Earth's surface.

Endogenic Processes	Exogenic Processes
Originate in the <b>interior</b> of the earth.	Originate on the <b>surface</b> of the earth.
Causes <b>sudden</b> or rapid movements	Causes <b>slow</b> movements.
Eg: Earthquake, faulting, diastrophism	Eg: Erosional and Depositional

# Types of Exogenetic / Exogenous Processes

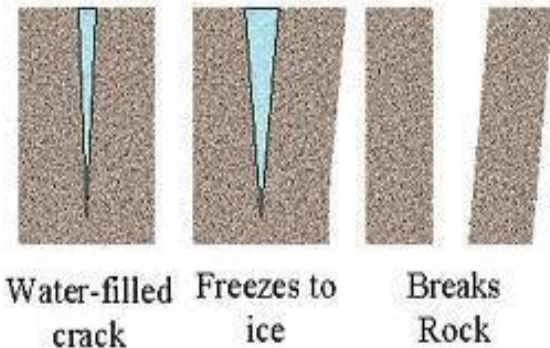
- i. Weathering
- ii. Erosion/ Degradation
- iii. Transportation
- iv. Deposition/Aggradation
- v. Mass movement

# Denudation

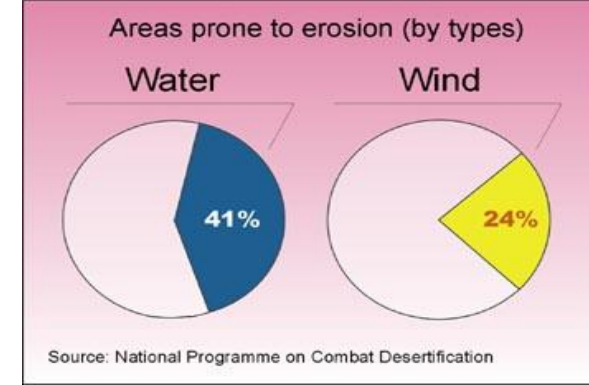
- It means to make the things **exposed**.
- The processes by which the rocks on the earth's surface are **broken into pieces** through the application of **external physical forces** and the **debris are transported elsewhere** is known as denudation.
- This denudation work is performed through three processes such as weathering, erosion and transportation.
- **Denudation= Weathering + Erosion + Transportation**

# Weathering

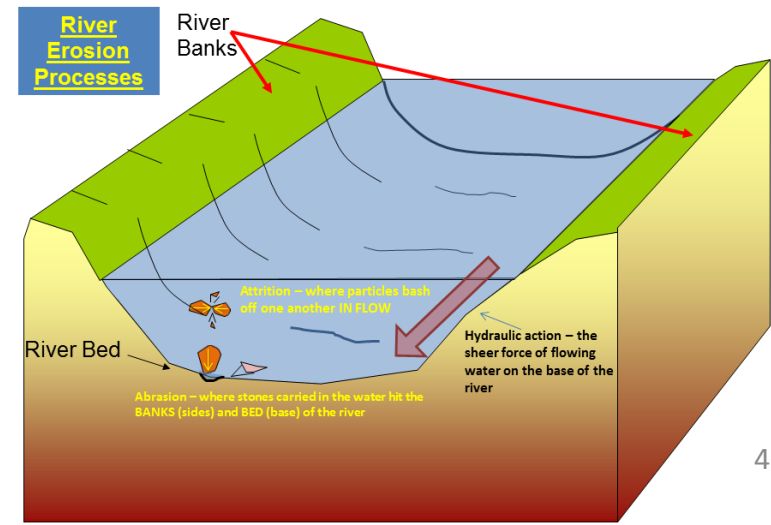
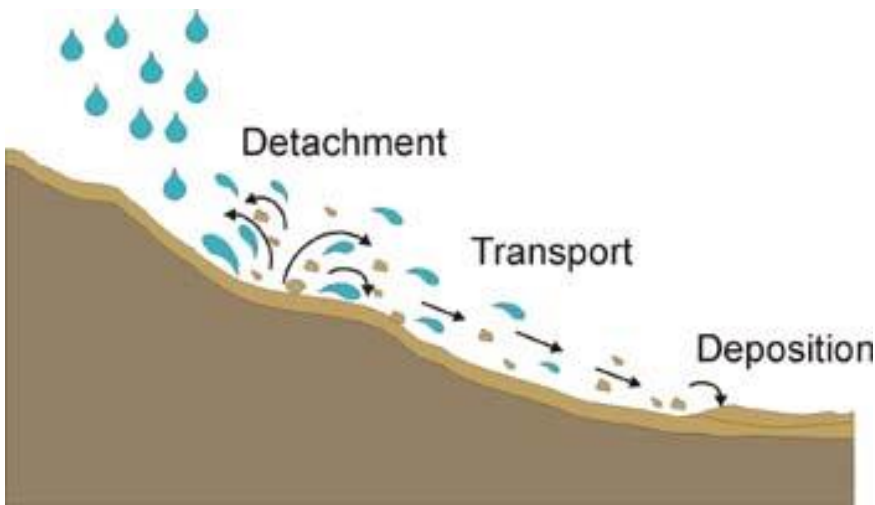
- The weathering is a process by which the rocks on the surface of the earth is **broken mechanically into pieces** due to **snow or frost**, the **variation of temperature** and **pressure** or due to **chemical (dissolution) action** on the materials.
- Even the rocks are dislodged by the animals. But the rocks weathered this way, **are not transported elsewhere**.



# Erosion

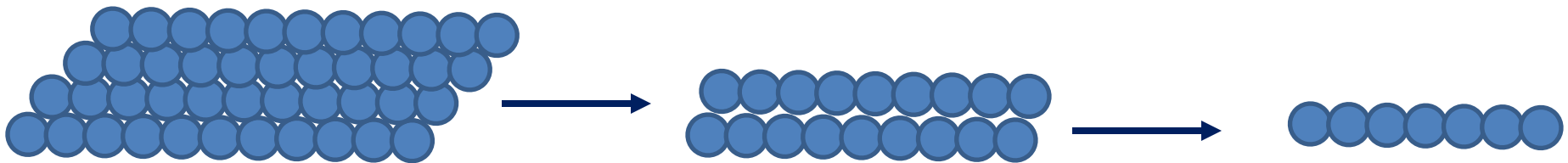


- Erosion and transportation are **accomplished** together.
- The process by which the rocks of the earth's crust are **eroded** by the river, wind, glacier, ocean currents etc. are **transported** elsewhere is known as erosion.



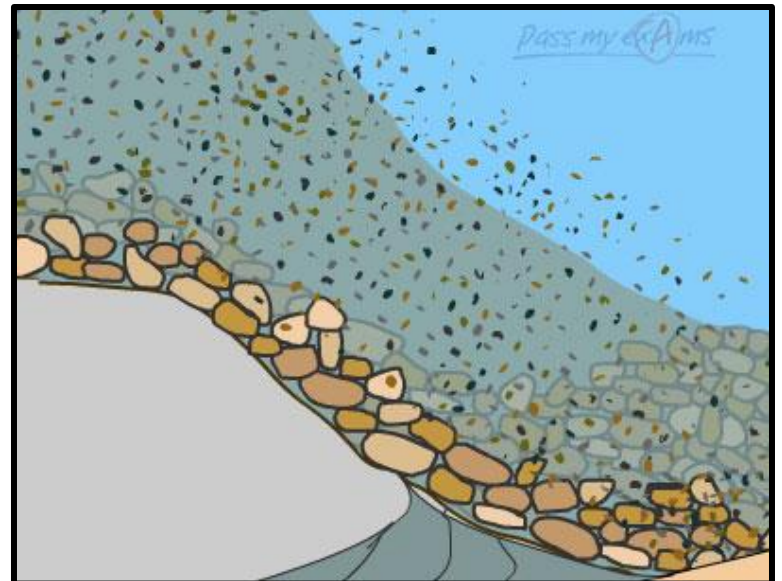
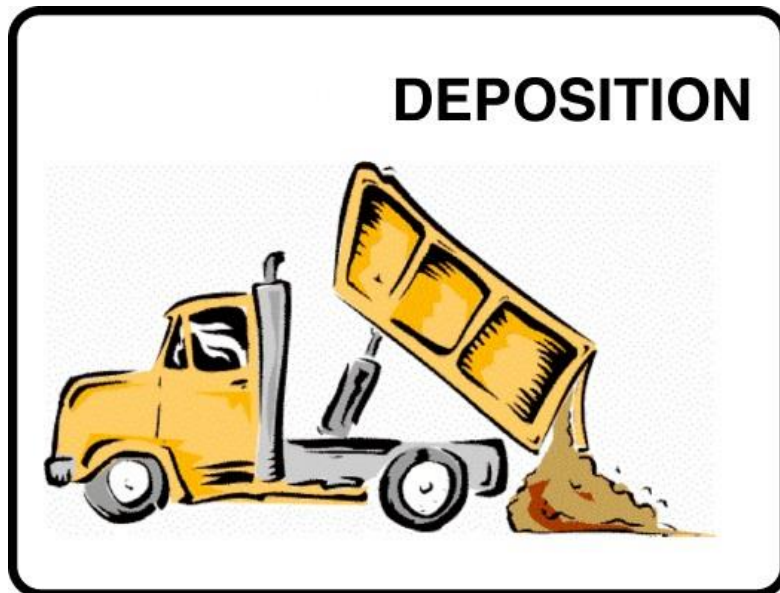
# Degradation

- Degradation is the **lowering** of a bottomland **surface** through the process of erosion;
- Conceptually it is the opposite of the vertical component of aggradation and is most frequently applied to sediment removed from a channel bed or other low-lying parts of a stream channel.



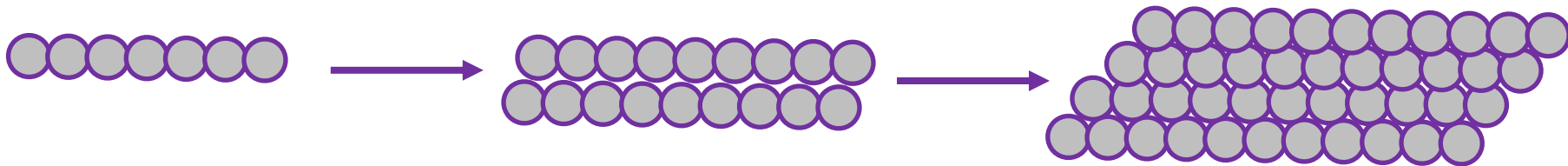
# Deposition

Deposition is the constructive process of **accumulation** into beds or irregular masses of loose sediment or other rock material by any natural agent;



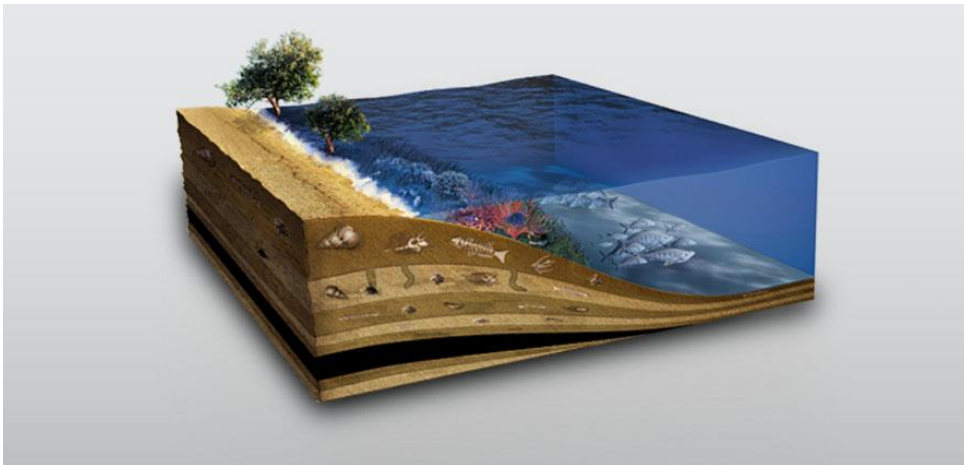
# Aggradation

- Aggradation is the **raising** or **elevating** of a bottomland **surface** through the process of alluvial deposition;
- Conceptually it is the vertical component of accretion and is most frequently applied to sediment deposition on a channel bed, bar or other near-channel surfaces, flood plain, or, less often, low-lying alluvial terrace.



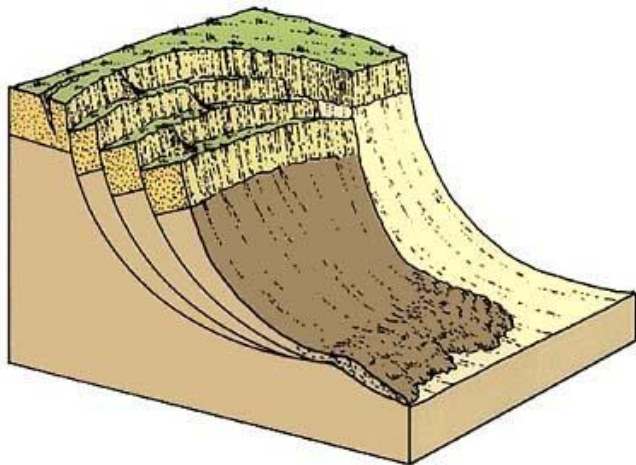
# Sedimentation

- Sedimentation is the process by which sediment is mechanically **deposited** from suspension within a fluid, generally water, or ice, thereby accumulating as **layers of sediment** that are segregated owing to differences in size, shape, and composition of the sediment particles.



# Mass movement/Mass Wasting

- **Mass movement** is any **downslope transfer**, through **gravitational** and generally water-facilitated (viscous) processes, of near-surface **soil and rock material**;
- Rates of mass movement range from very slow **creep** to nearly instantaneous **slope failure**.



# GEOMORPHOLOGICAL PROCESSES

## Terrestrial Processes

## Extra-terrestrial Processes

## Exogenetic Processes

## Endogenetic Processes

- i. Weathering
- ii. Erosion/Degradation
- iii. Transportation
- iv. Deposition/Aggradation
- v. Mass movement

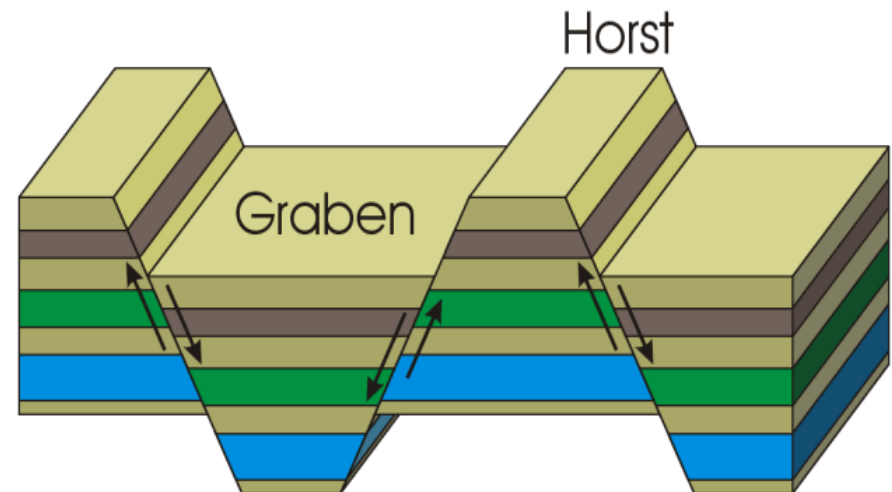
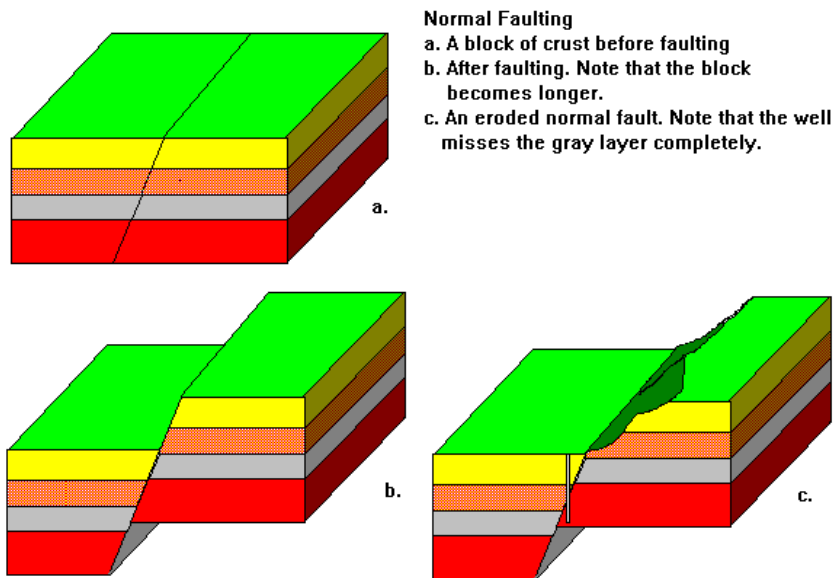
## Denudation

- i. Faulting and Folding
- ii. Volcanism
- iii. Earthquake
- iv. Landslide
- v. Diastrophism
- vi. Metamorphism

- Physical Weathering
- Chemical Weathering
- Biological Weathering

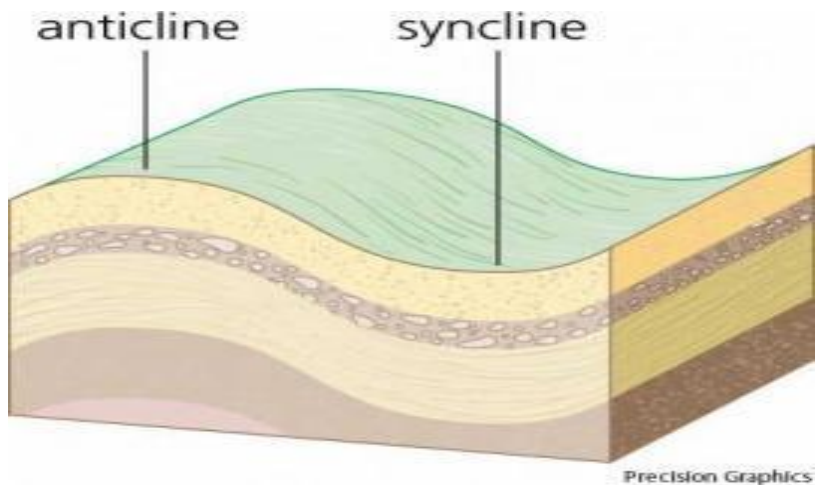
# Faulting

- Fault is a planar or gently **curved fracture** in the rocks of the earth's crust, where compressional or tensional forces cause relative displacement of the rocks on the opposite sides of the fracture.



# Folding

- Fold is an **undulation** or **waves** in the stratified rocks of the earth's crust.
- A fold occurs when one or a mass of originally flat and planar **surfaces**, such as sedimentary strata, are **bent or curved** as a result of permanent **deformation**.



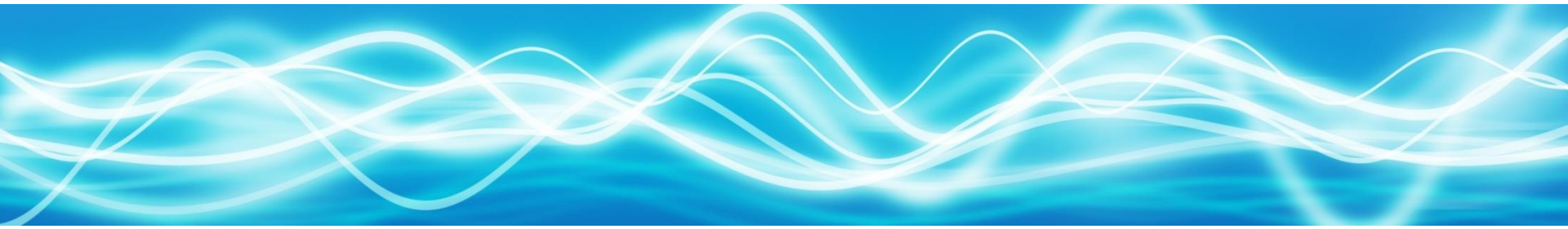
# Volcanism

- Volcanism is the phenomenon of **eruption of molten rock** (magma) onto the surface of the earth, where lava and volcanic gases erupt through a break in the surface called a vent.
- Eruption of the volcanoes or the magma is the main **sources of igneous rocks** on the surface of the earth.



# Earthquake

- An earthquake is a **vibration or oscillation** of the surface of the earth caused by sudden release of enormous pressure.



# Landslide

- A landslide, also known as a landslip, which includes a wide range of ground movements, such as rock fall, deep failure of slopes and shallow debris flows, which can occur in offshore, coastal and onshore environments.

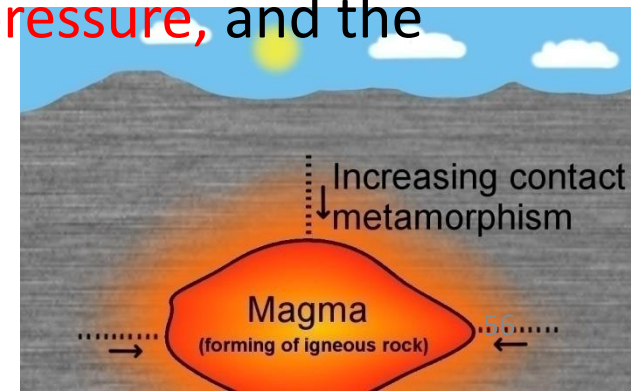


# Diastrophism

- Diastrophism is also called tectonism, **large-scale deformation** of earth's crust by **natural processes**, which leads to the formation of **continents and ocean basins, mountain systems, plateaus, rift valleys**, and other features by mechanisms such as plate movement, volcanic loading, or folding.
- Internal forces active here

# Metamorphism

- Metamorphism is the **change in rock structure, minerals or geologic structure.**
- It is a process of change in the physical structure of rock as a result of long-term heat, pressure and introduction of chemically active fluids, especially a change that increases the rock's hardness and crystalline structure.
- The change occurs primarily due to **heat, pressure,** and the introduction of **chemically active fluids.**



# Geomorphological Processes at a glance

