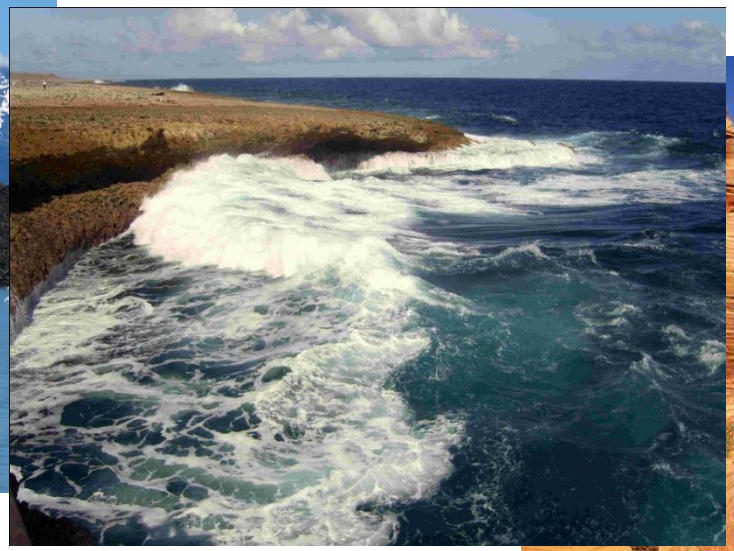
GEOL 23100: Principles of Geomorphology



Geomorphology

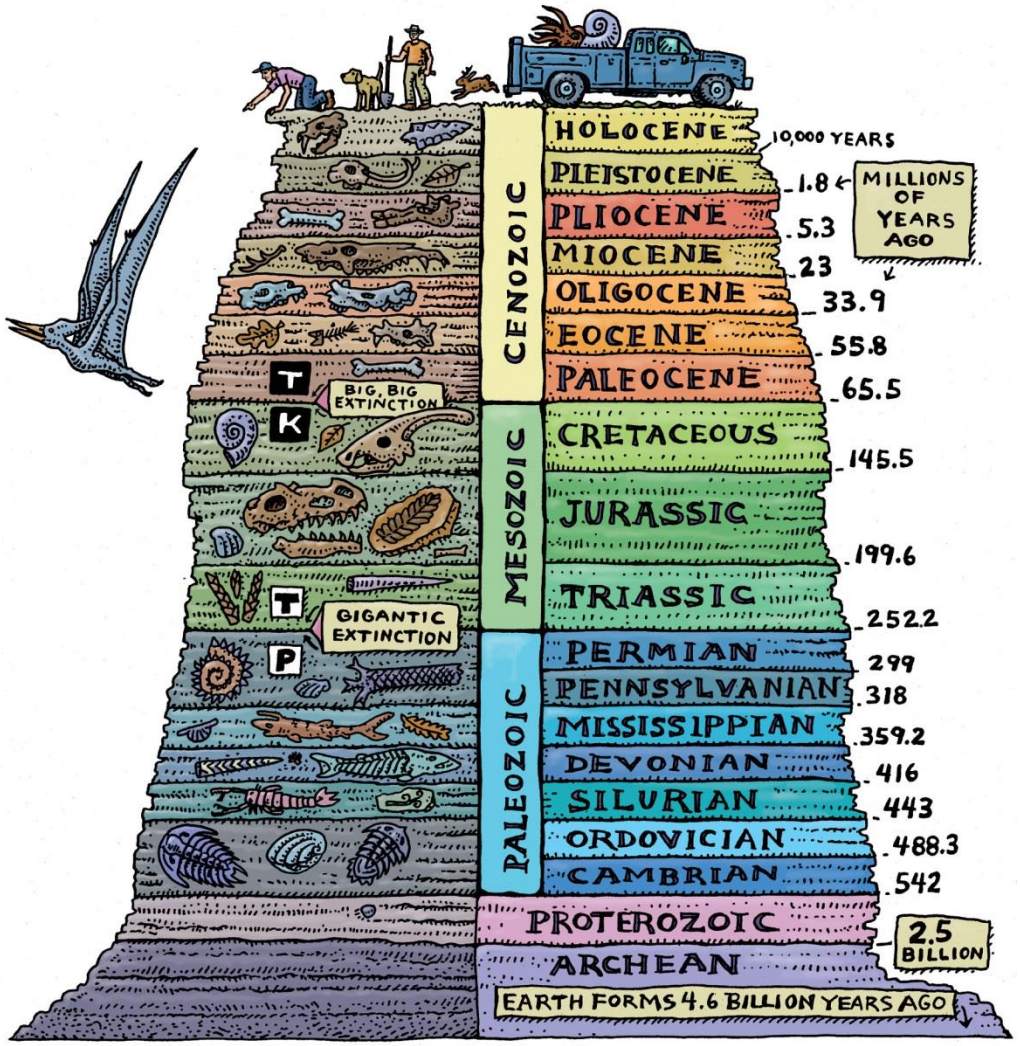
- The word “**geomorphology**" comes from the Greek roots "geo,“ “morph,” and “logos,” meaning “earth,” “form,” and “study,” respectively. Therefore, geomorphology is literally “the study of earth forms.”
- Geomorphologists are concerned primarily with earth’s surficial features, including their origin, 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 …

Geologic Timescale

EON	ERA	PERIOD		EPOCH		Ma
Phanerozoic	Cenozoic	Quaternary		Holocene		0.01
				Pleistocene	Late	0.8
					Early	1.8
		Tertiary	Neogene	Pliocene	Late	3.6
					Early	5.3
				Miocene	Late	11.2
					Middle	16.4
					Early	23.7
			Paleogene	Oligocene	Late	28.5
					Early	33.7
				Eocene	Late	41.3
					Middle	49.0
					Early	54.8
				Paleocene	Late	61.0
					Early	65.0
	Mesozoic	Cretaceous		Late		99.0
				Early		144
		Jurassic		Late		159
				Middle		180
				Early		206
		Triassic		Late		227
				Middle		242
				Early		248
	Paleozoic	Permian		Late		256
				Early		290
		Pennsylvanian				323
		Mississippian				354
		Devonian		Late		370
				Middle		391
				Early		417
		Silurian		Late		423
				Early		443
		Ordovician		Late		458
				Middle		470
				Early		490
		Cambrian		D		500
				C		512
				B		520
				A		543
Precambrian	Proterozoic	Late				900
		Middle				1600
		Early				2500
	Archean	Late				3000
		Middle				3400
		Early				3800?



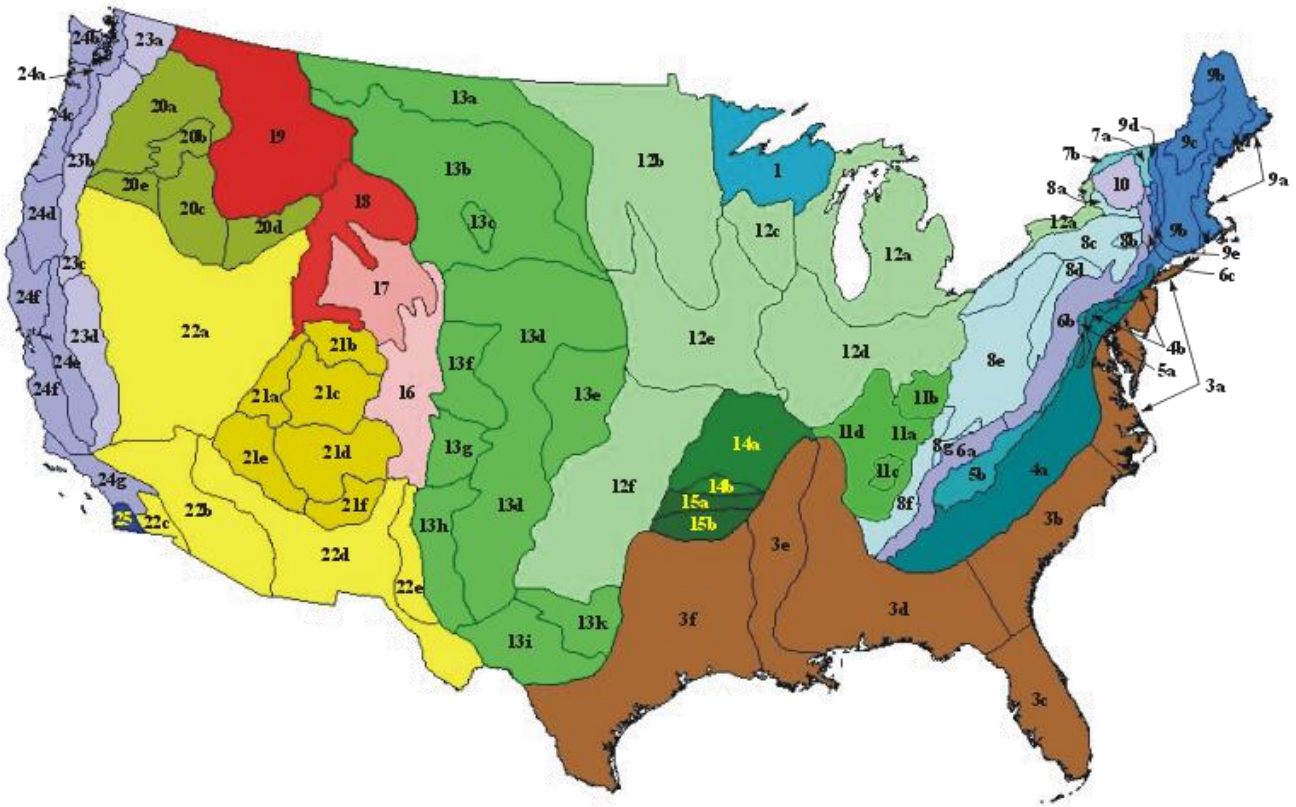
What past processes created this relict landscape?

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
Appalachian Highlands	4	Piedmont province
	5	Blue Ridge province
	6	Valley and Ridge province
	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	Wyoming 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)

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

- Scale of landforms varies over 15 (!) orders of magnitude.
  - continents (10^7 km^2) to microscale features like ripples, glacial striations (10^{-8} km^2).

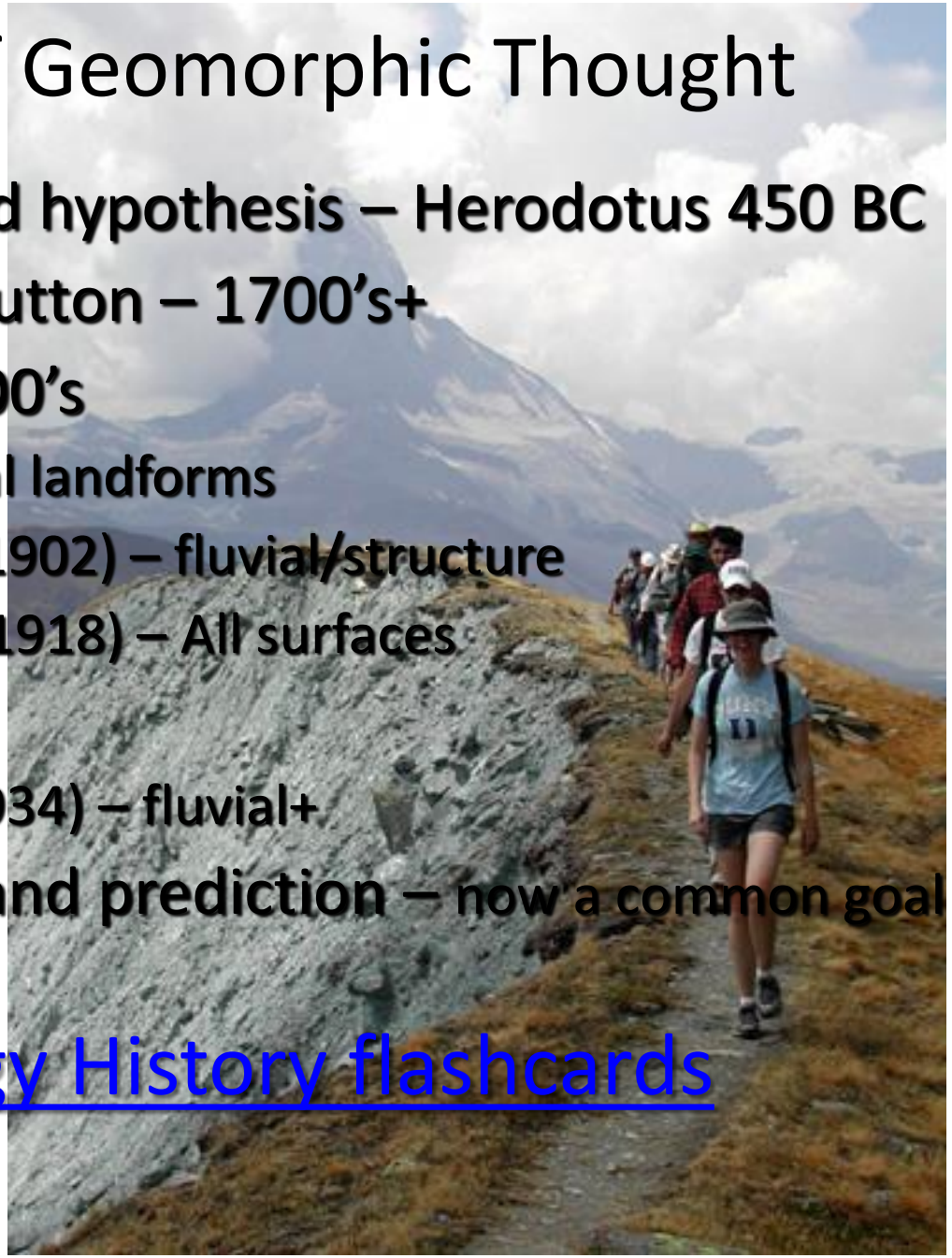
- Age of landforms varies over 7-8 orders of magnitude.
  - continents (10^9 years) to microscale features like pools and riffles (10^2 years).

- 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

Horn, cirque, col, rock slide

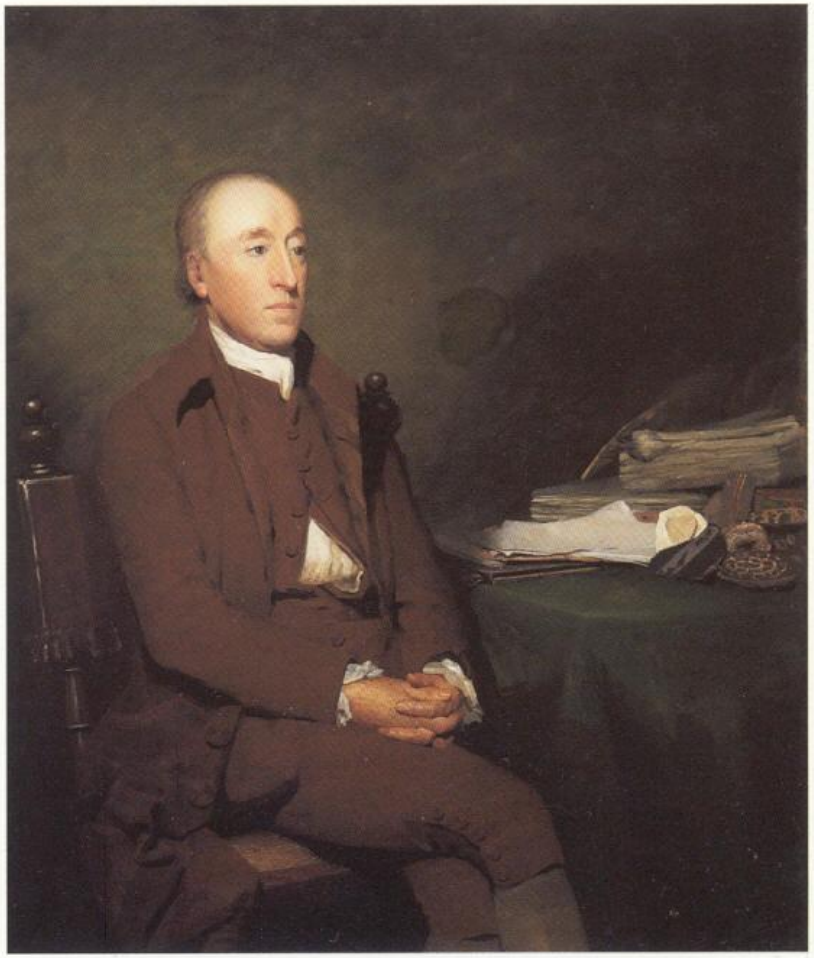
- **Herodotus** (484-425 BC): Rocks on land in Egypt contained marine fossils, assumed that the Nile *Delta* took thousands of years to form.
- **Arisotle** (384-322 BC): Dry land can be submerged, land can be raised from beneath the ocean, described erosion by rivers, and deposition in deltas.
- **Lucretius** (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.
- **Uniformatarianism**
- 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

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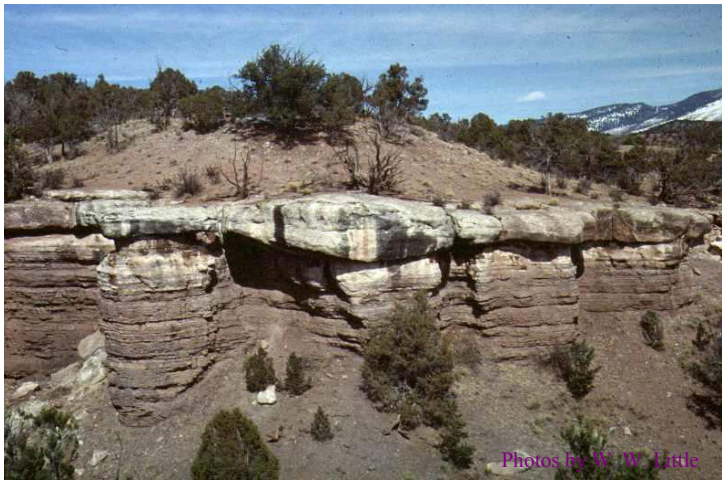


Ancient river channels

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)

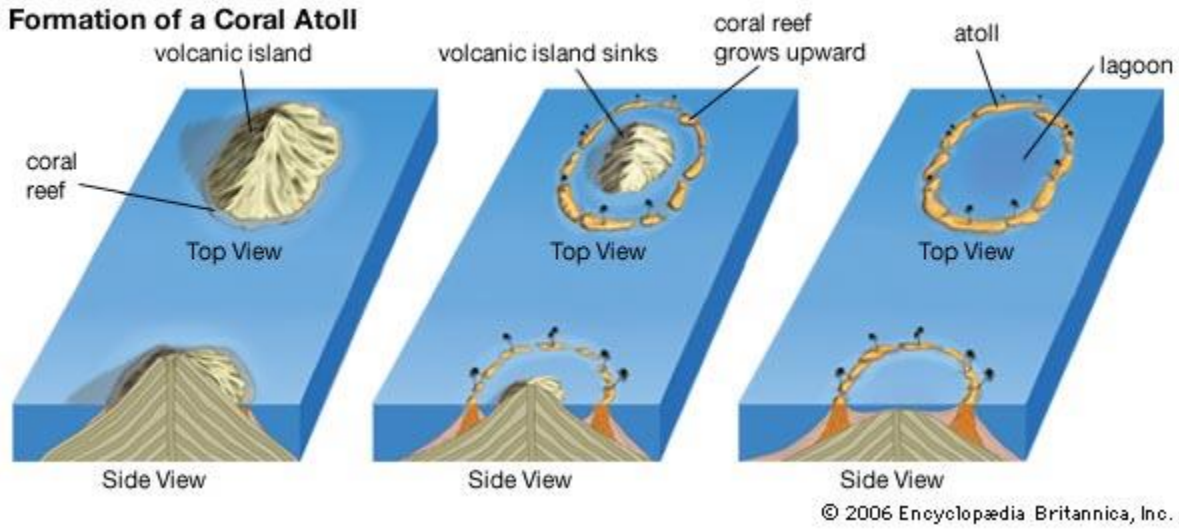
  The Principles of Geology (1833 - 1875)

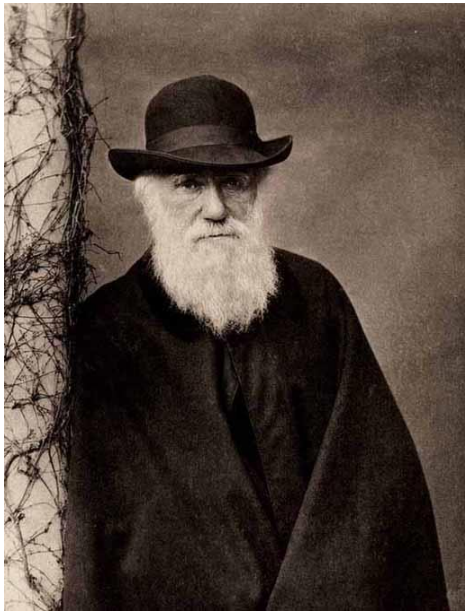
  A strong promoter of Uniformitarian theory

  A vehement opponent of Catastrophism

Other Nineteenth Century European Contributions

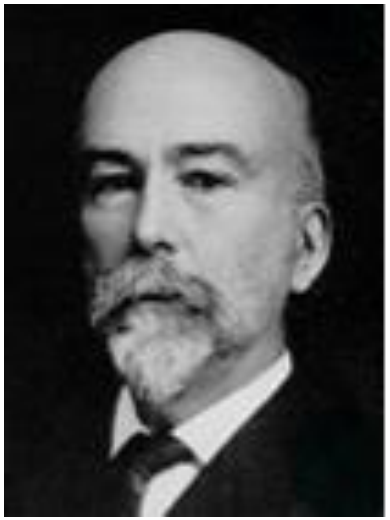
- Venetz, and Bernardhi: Moraines and erratics prove glaciations extended from polal regions(1832)
- Louis Agassiz : Recognized glacial landforms in Europe & N. Am.- introduced the concept of Ice Ages (1837)
- **Charles Darwin** (1809-1882): Recorded his observations during the voyage of "the Beagle.",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

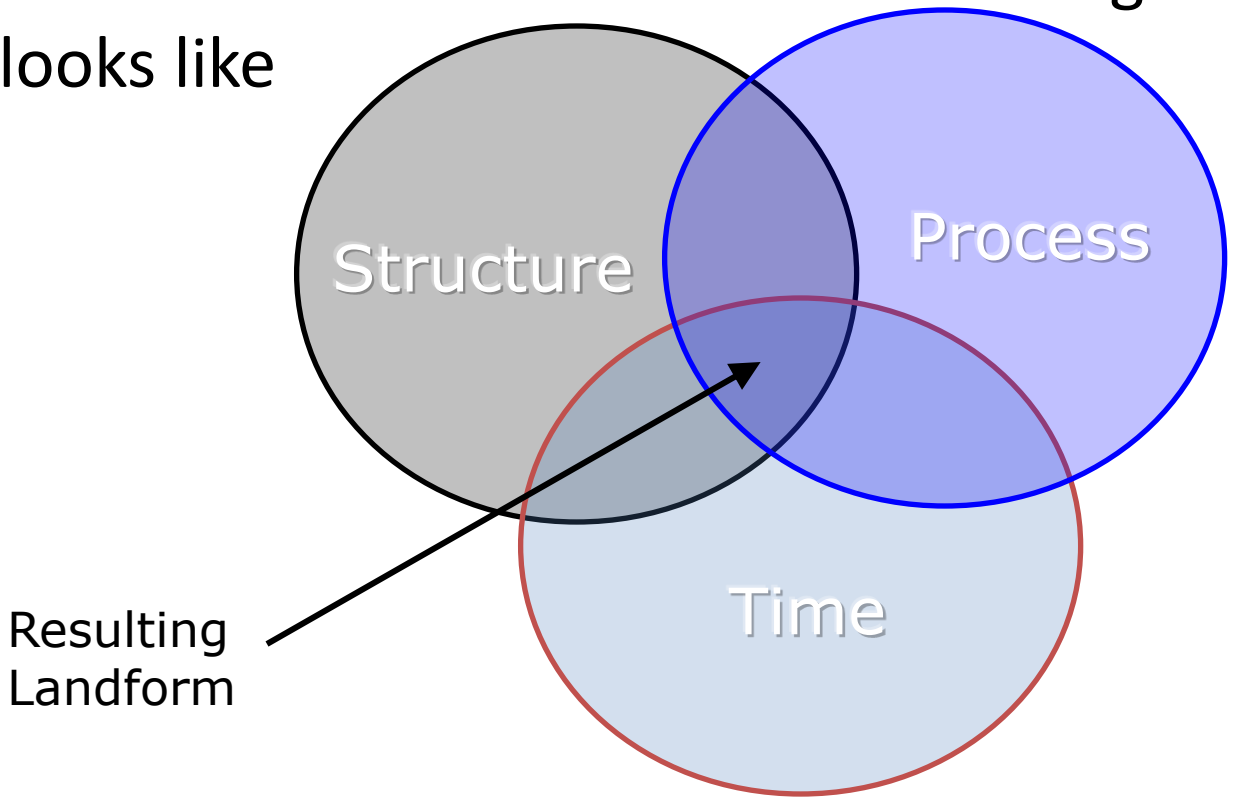




Evolutionary Geomorphology

- 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





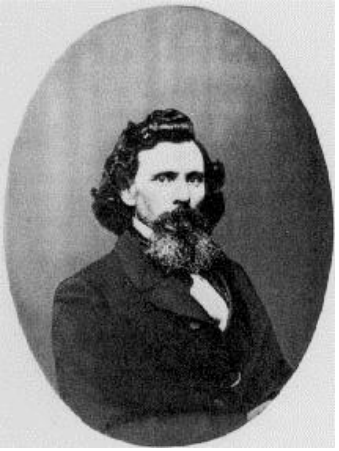
Structure: rock mass (or unconsolidated material mass).

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

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

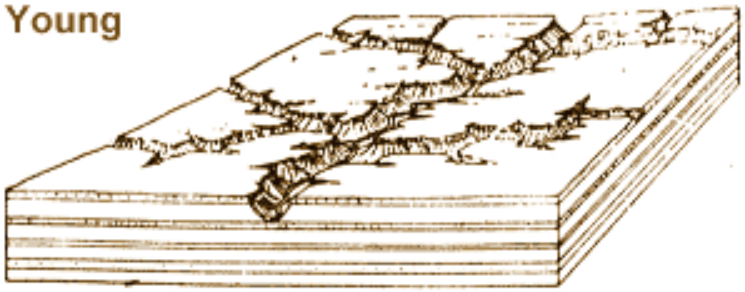
Structure: **limestone bedrock**
Process: **weathering (dissolution)**
Time: **10^3 to 10^6 years?**

Structure: **delta sediments**
Process: **deposition / erosion**
Time: **10^3 to 10^4 years?**



William Morris Davis

- **Davis' Cycle of erosion**



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

- **Davisian 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,…)

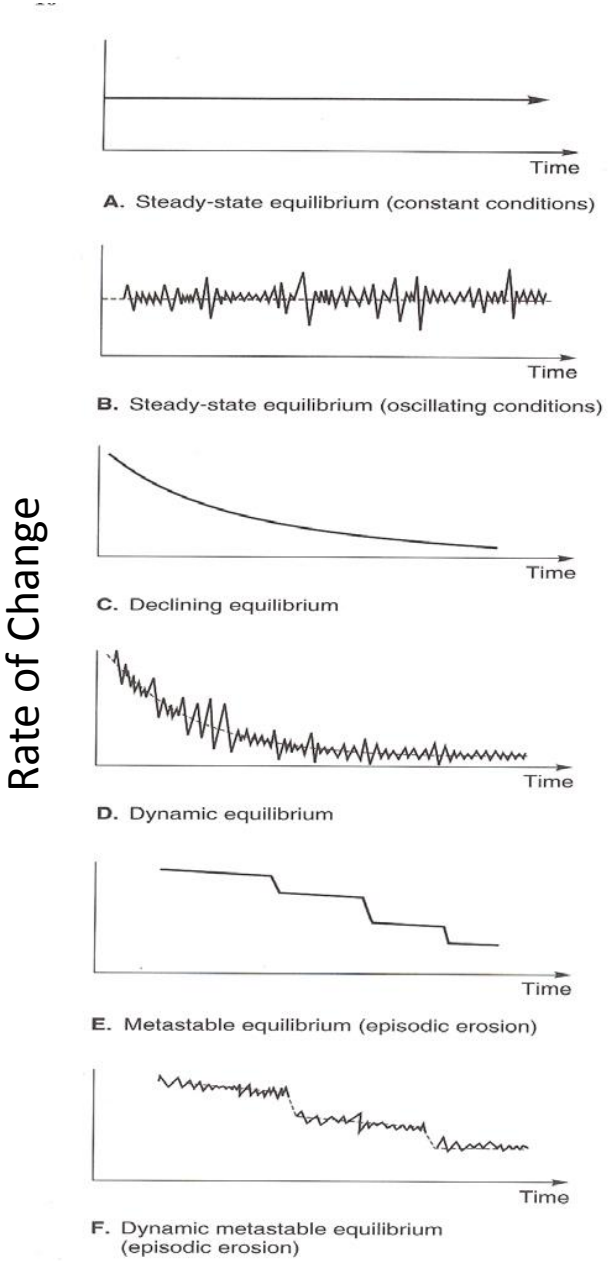


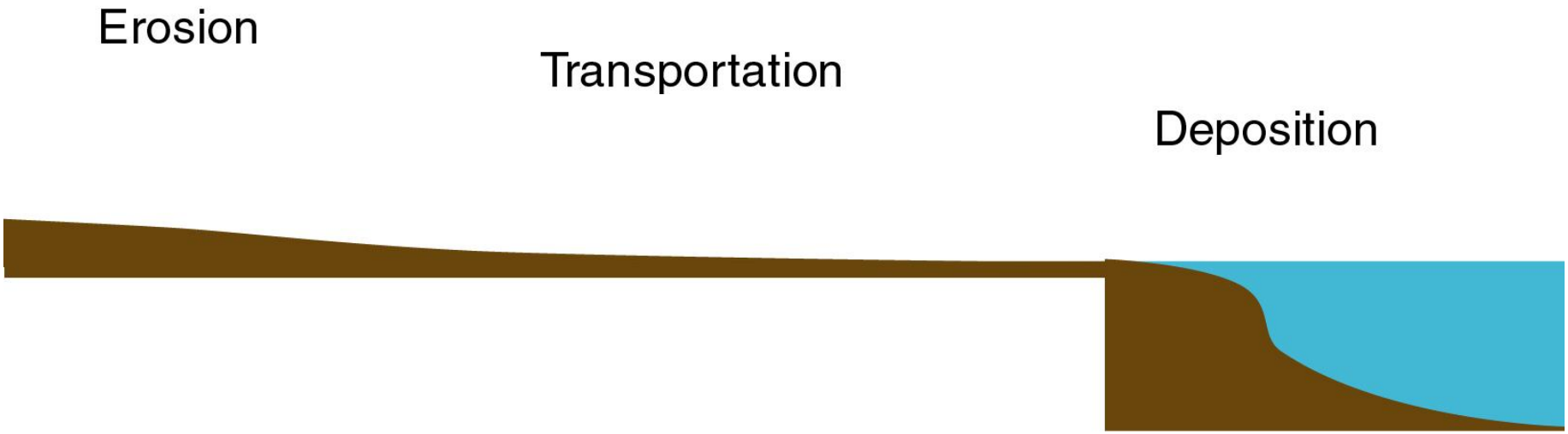
FIGURE 2–1
Types of equilibria.

Types of Geomorphic Equilibria

- 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

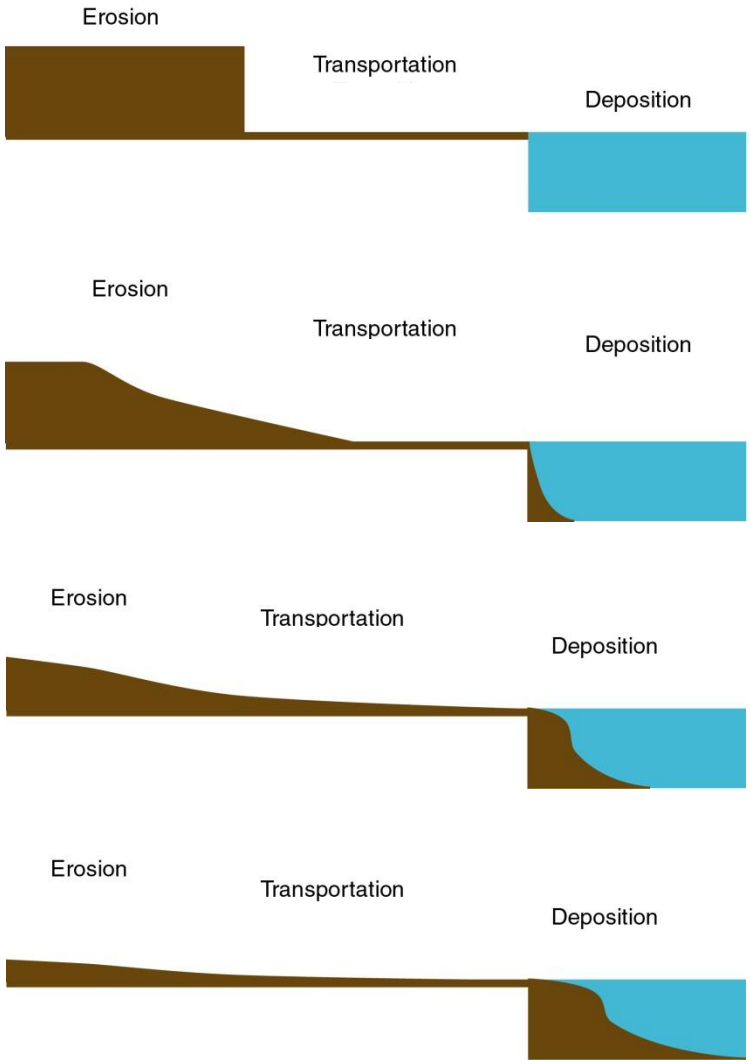
Concepts of Equilibrium

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.



- 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.

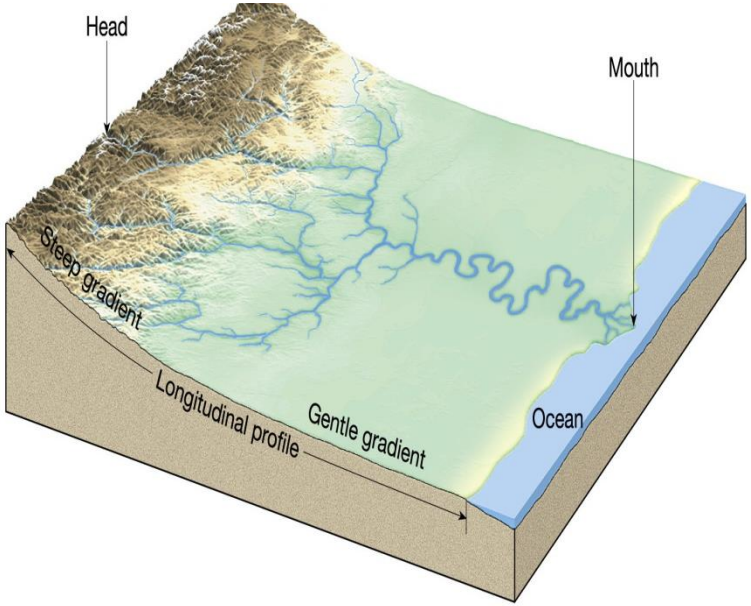
Weathering and erosion dominate headland areas with removed material being transported to a depositional basin.

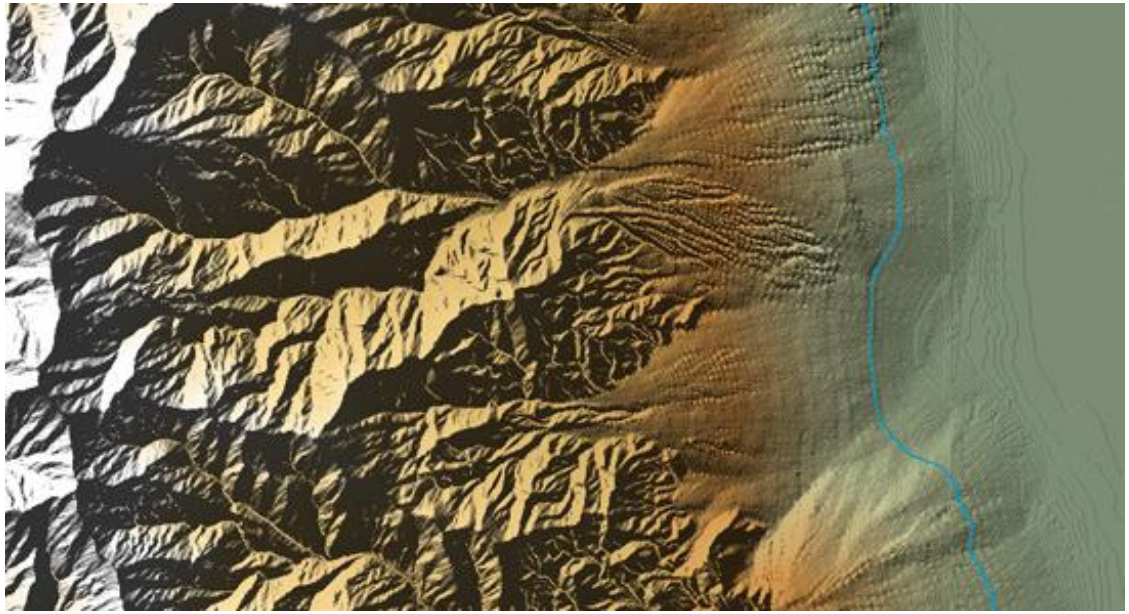
As headlands recede, both erosional and depositional rates decrease.

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

Base Level

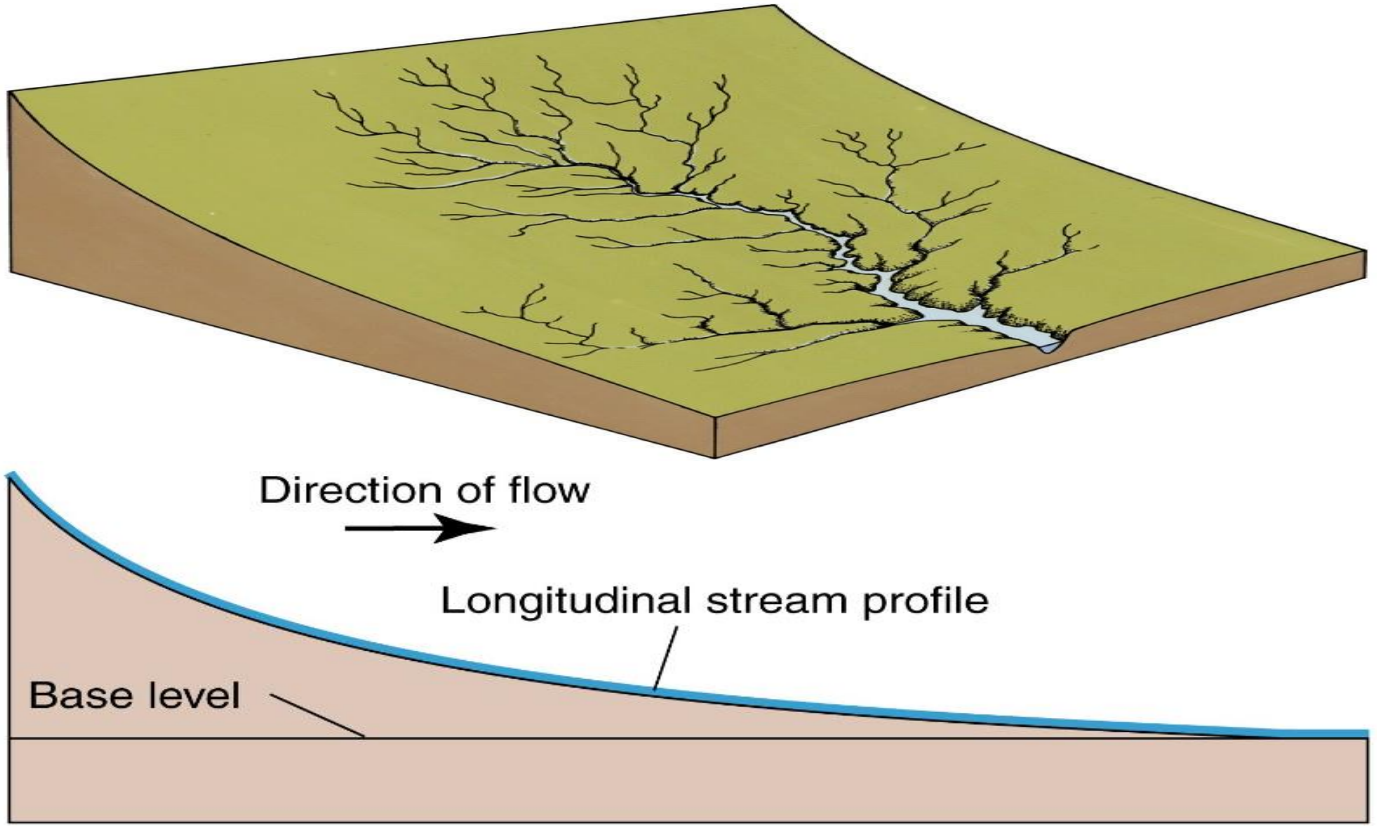
Base level is the level below which erosion cannot occur and above which deposition does not take place.



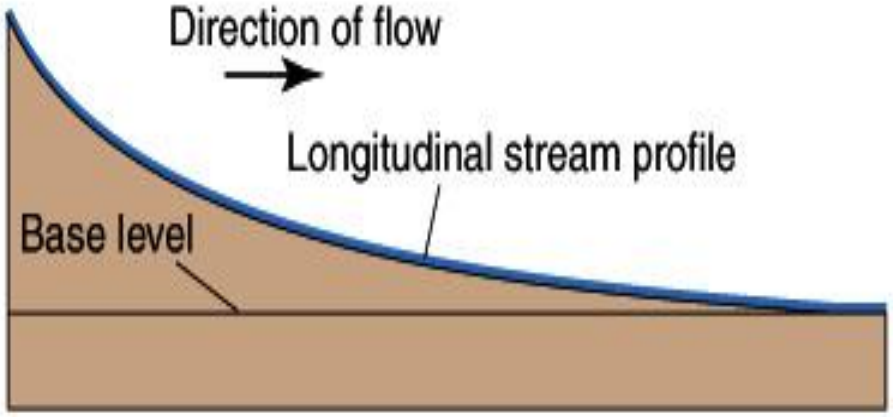


- Sea level is the ultimate base level
- Lakes and reservoirs provide temporary base levels
- Changes in sea level can be eustatic or relative
- Changes in base level create and destroy accommodation space

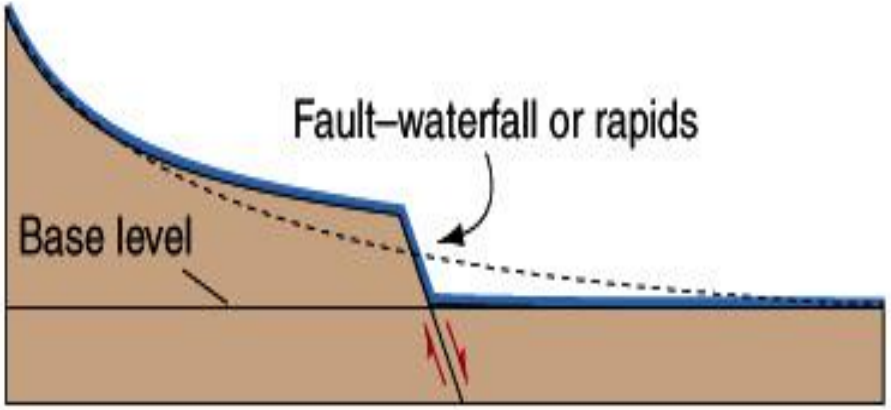
Graded (Longitudinal) Profile



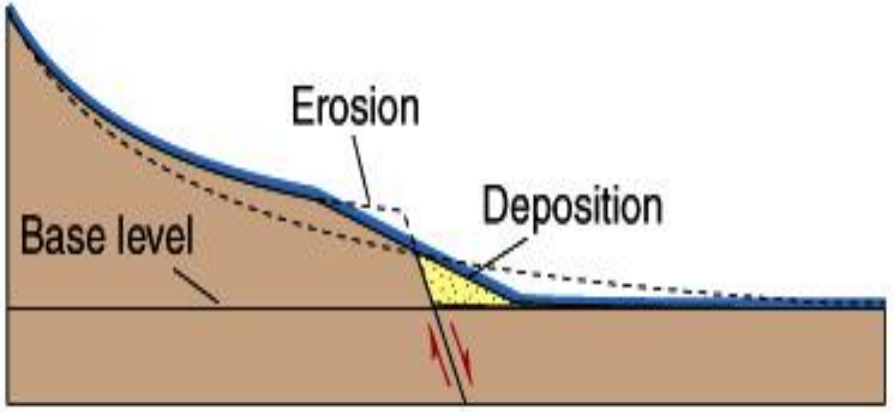
Stream gradient is related to water velocity and the load it can transport. A change in any of these affects the other two. Each can be influenced by factors outside of the stream system, such as base level fluctuations (gradient), precipitation changes (discharge), and sediment character.



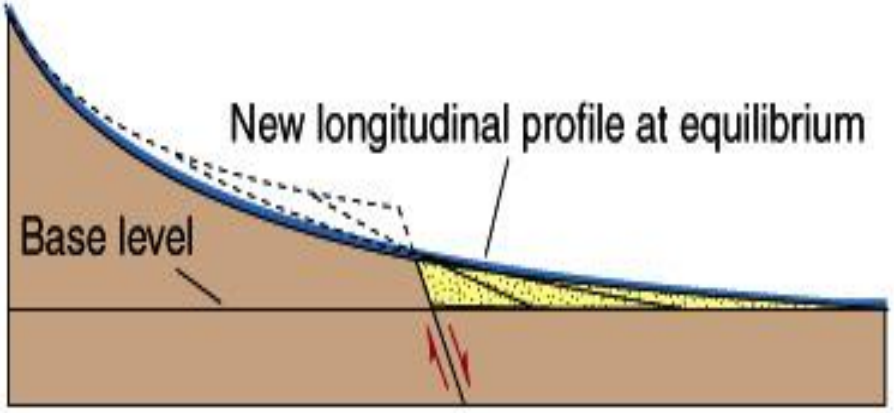
(A) Initially, when the stream profile is at equilibrium, the velocity, load, gradient, and volume of water are in balance. Neither erosion nor deposition occurs.



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

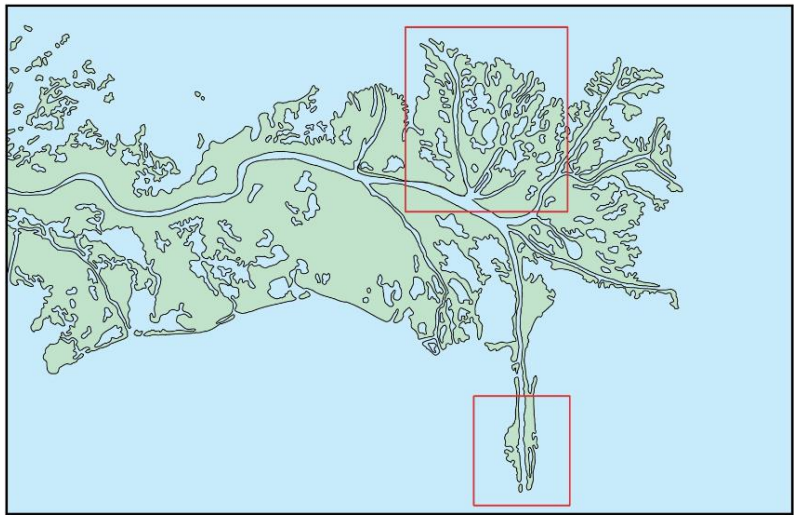


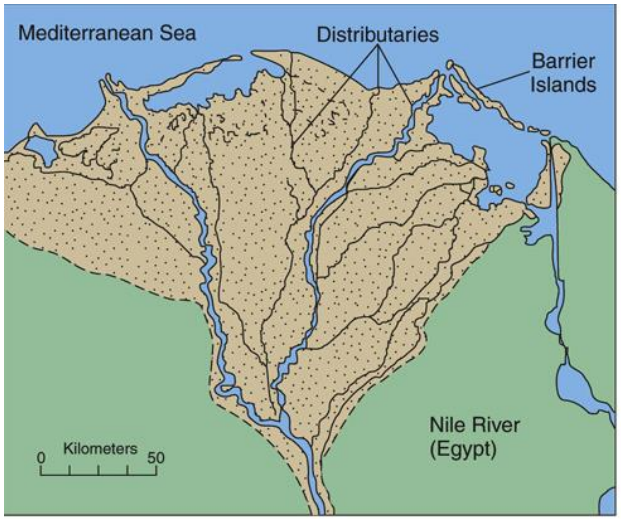
(C) Erosion proceeds upstream from the fault, and deposition occurs downstream and a new stream profile starts to develop.

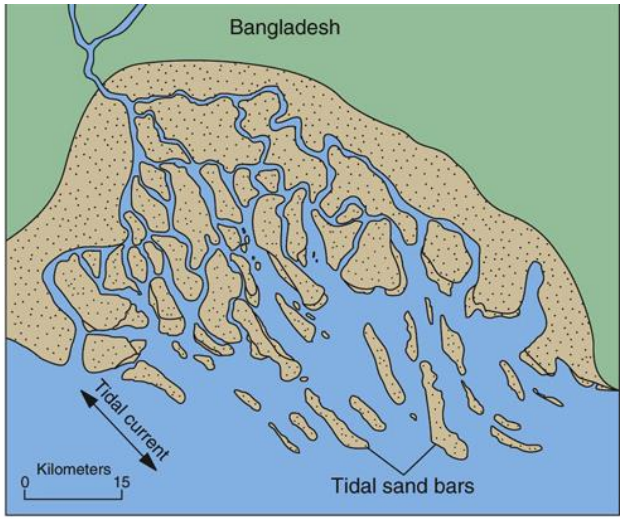


(D) Erosion and deposition eventually develop a new stream profile at which the velocity, load, gradient, and volume of water will be in balance so that neither erosion nor deposition occurs.

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…)

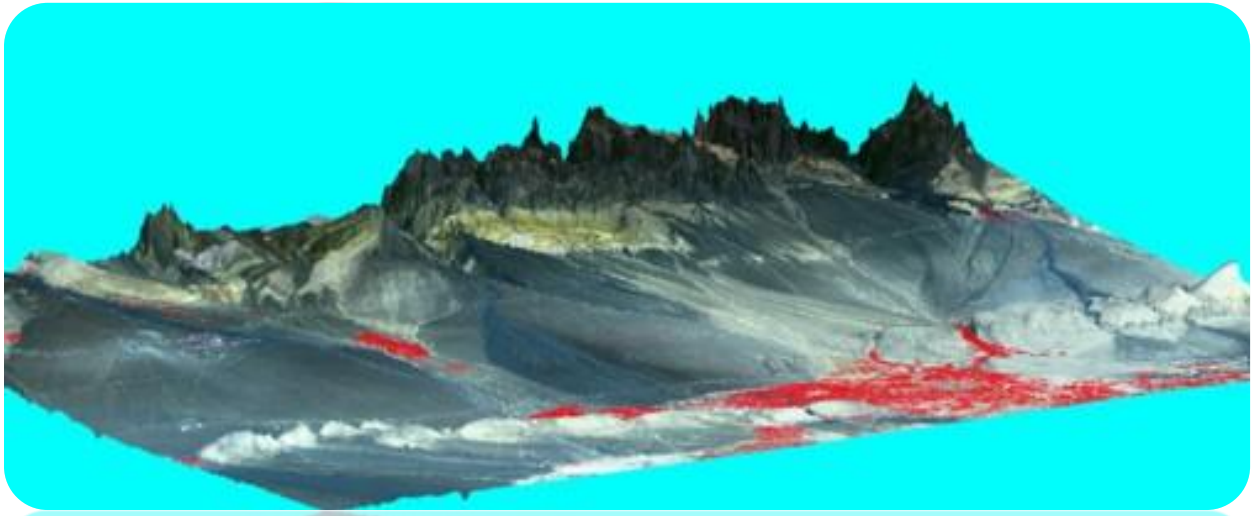
Definition:

- 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

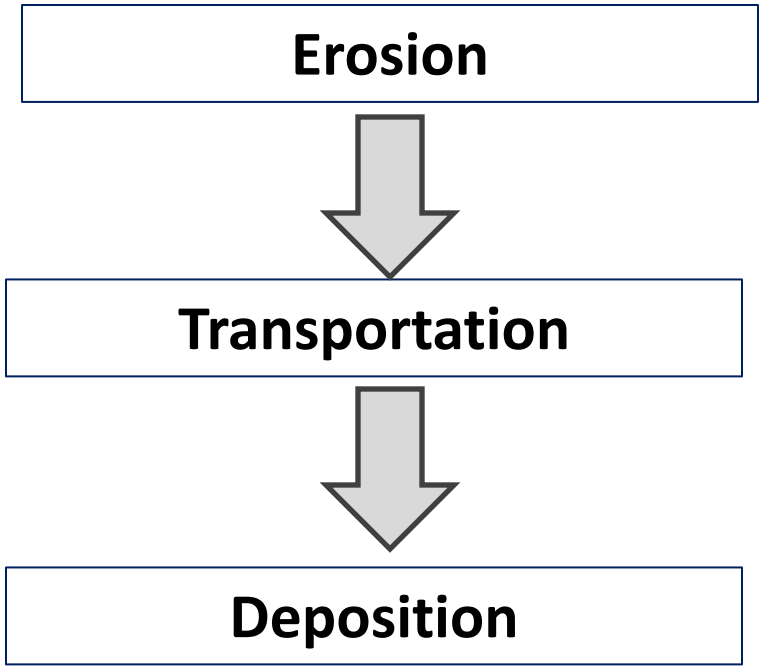
- River -**Humid Geomorphic Environment**
- Wind - **Arid Environment**
- Glacier/ice - **Polar Environments**
- Wave - **Coastal Environment**



Agent, Process & products

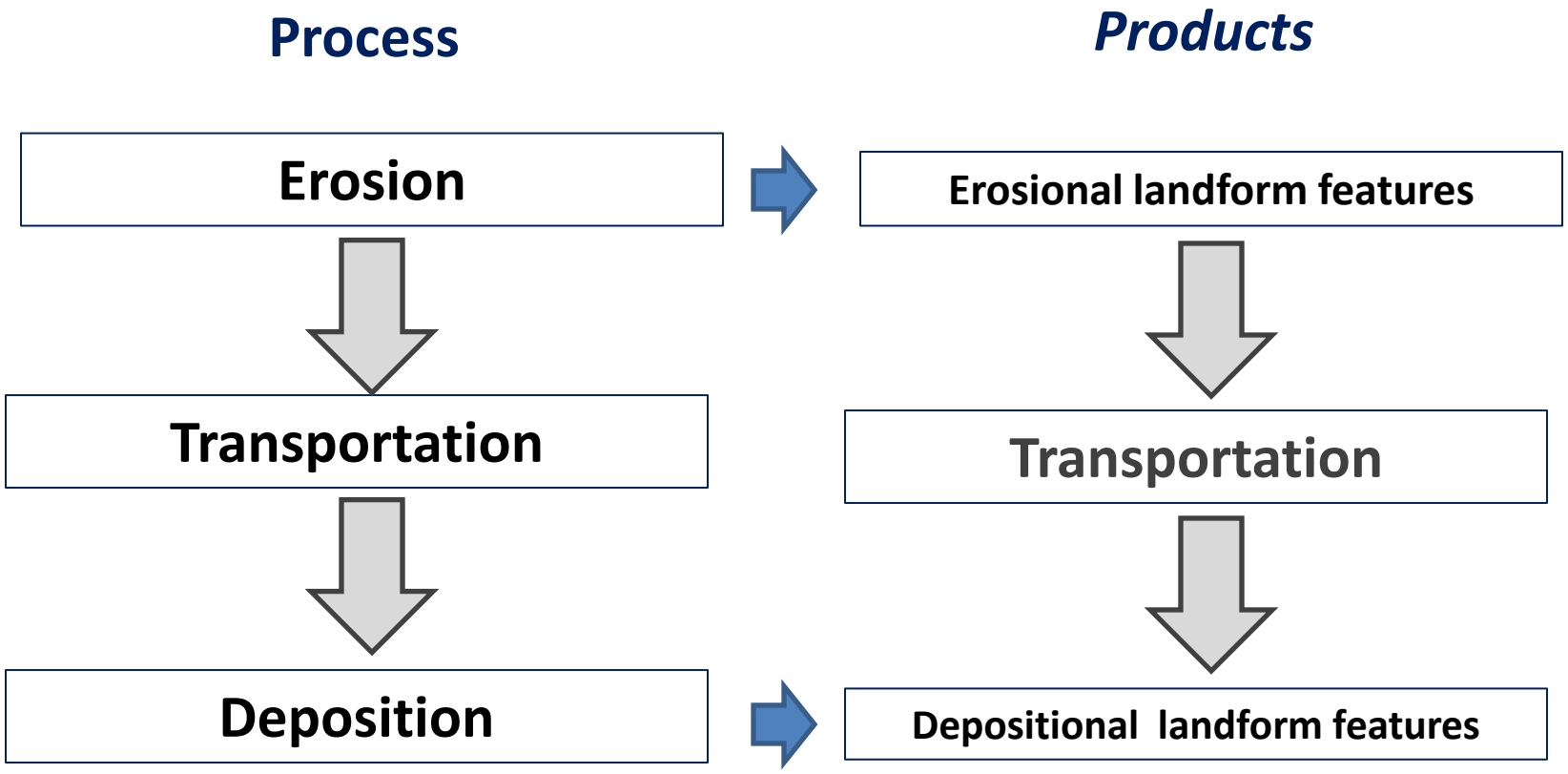
Process

Process includes three types of activities

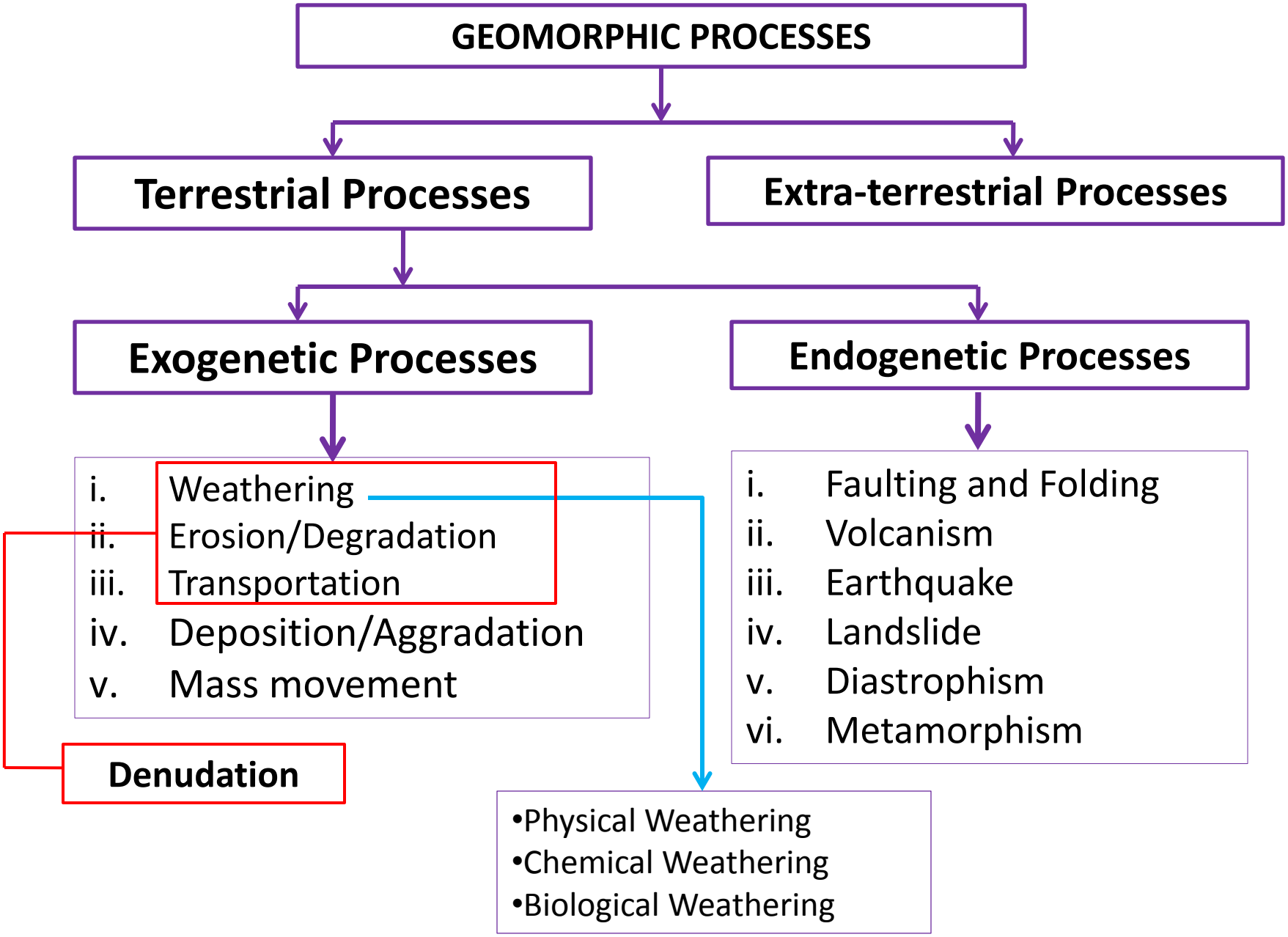


Agent, Process & products

Products **of Geomorphic Processes**



Agents of Change...


GEOMORPHIC PROCESSES
Terrestrial Processes
Extra-terrestrial Processes
Exogenetic Processes
Endogenetic Processes
i. Weathering
ii. Erosion/Degradation
iii. Transportation
iv. Deposition/Aggradation
v. Mass movement
i. Faulting and Folding
ii. Volcanism
iii. Earthquake
iv. Landslide
v. Diastrophism
vi. Metamorphism
Denudation
•Physical Weathering
•Chemical Weathering
•Biological Weathering

Types of Geomorphic Processes

❑ Geomorphic Processes

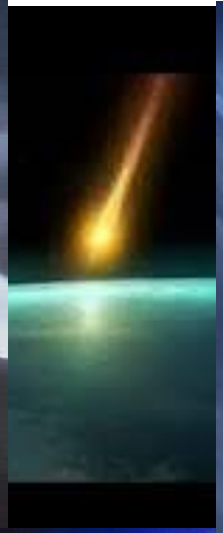
A. Terrestrial processes

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

Terrestrial processes

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

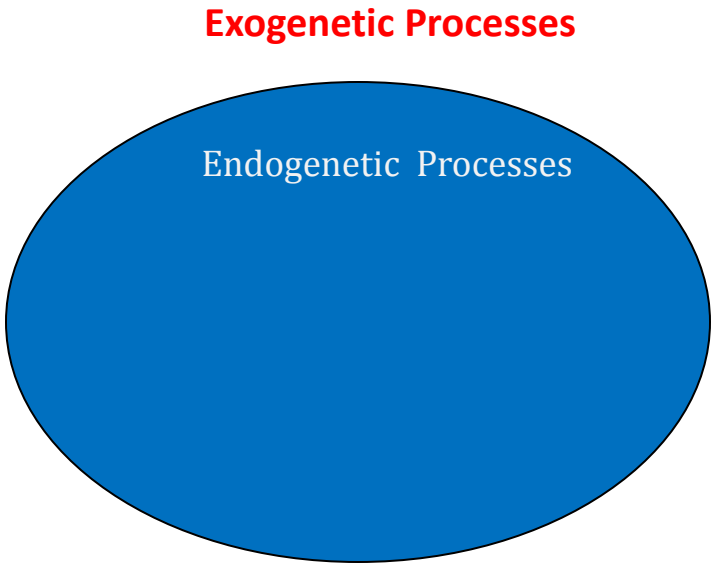
Extra-terrestrial processes, e.g. fall of meteorite



Types of Geomorphic Processes (Cont…)

Exogenetic/Exogenous Processes

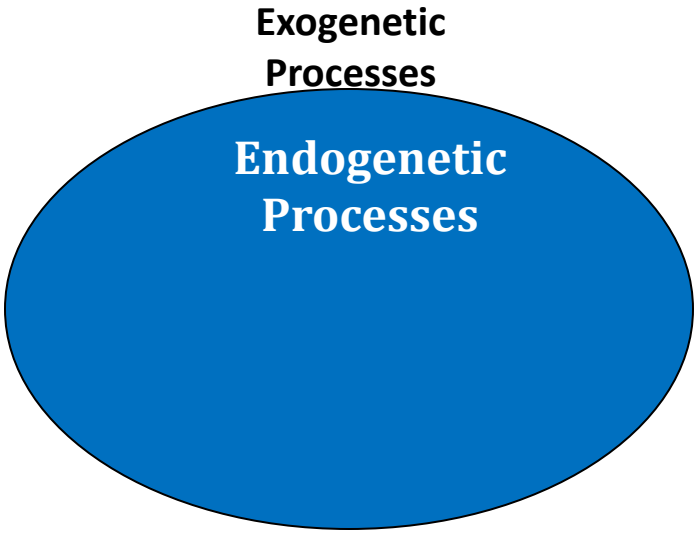
Outer geomorphological processes = exogenetic processes (solar radiation, wind, temperature changes, water) create relief sculptures, surface features.



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 interior of the earth.	Originate on the surface of the earth.
Causes sudden or rapid movements	Causes slow movements.
Eg: Earthquake, faulting, diastrophism	Eg: Erosional and Depositional

Types of Exogenetic / Exogenous Processes

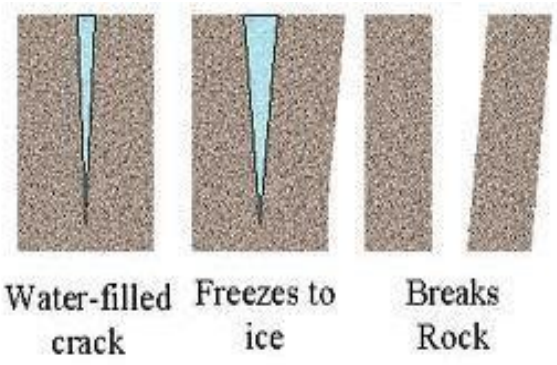
i. Weathering
ii. Erosion/ Degradation
iii. Transportation
iv. Deposition/Aggradation
v. Mass movement

Denudation

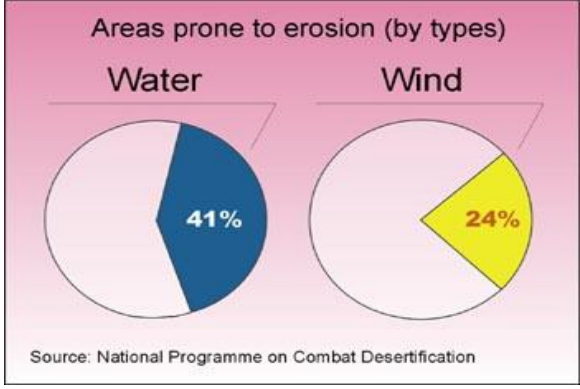
- It means to make the things exposed.
- The processes by which the rocks on the earth's surface are broken into pieces through the application of external physical forces and the debris are transported elsewhere is known as denudation.
- This denudation work is performed through three processes such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

Weathering

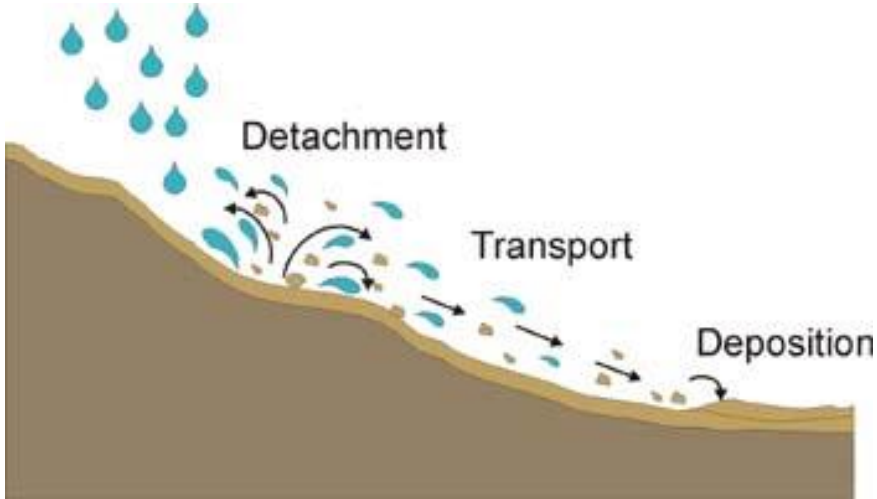
- The weathering is a process by which the rocks on the surface of the earth is broken mechanically into pieces due to snow or frost, the variation of temperature and pressure or due to chemical (dissolution) action on the materials.
- Even the rocks are dislodged by the animals. But the rocks weathered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

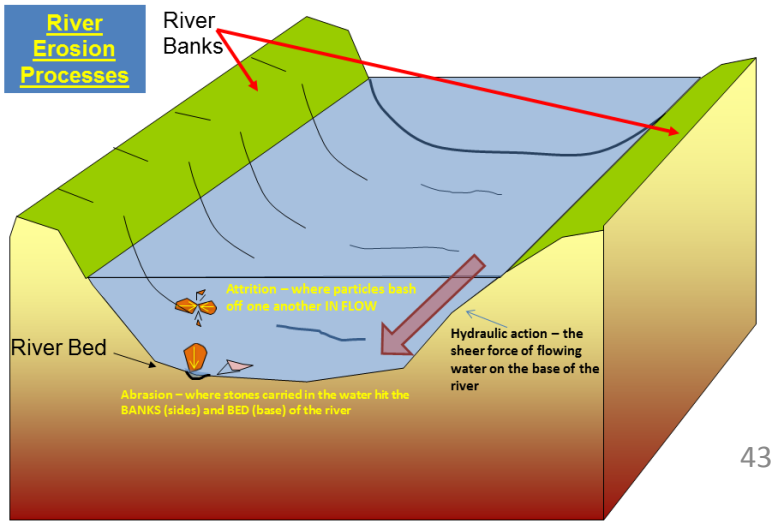


Erosion



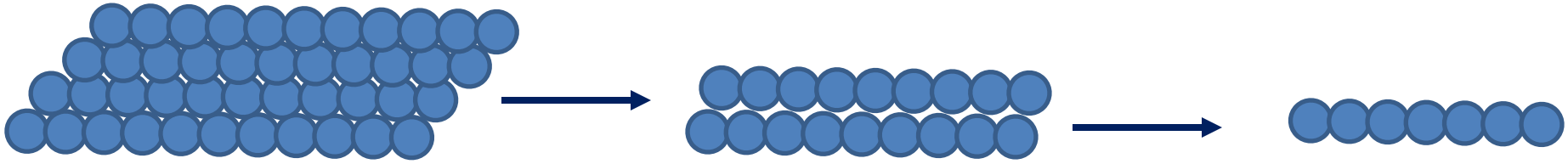
- Erosion and transportation are accomplished together.
- The process by which the rocks of the earth's crust are eroded by the river, wind, glacier, ocean currents etc. are transported elsewhere is known as erosion.





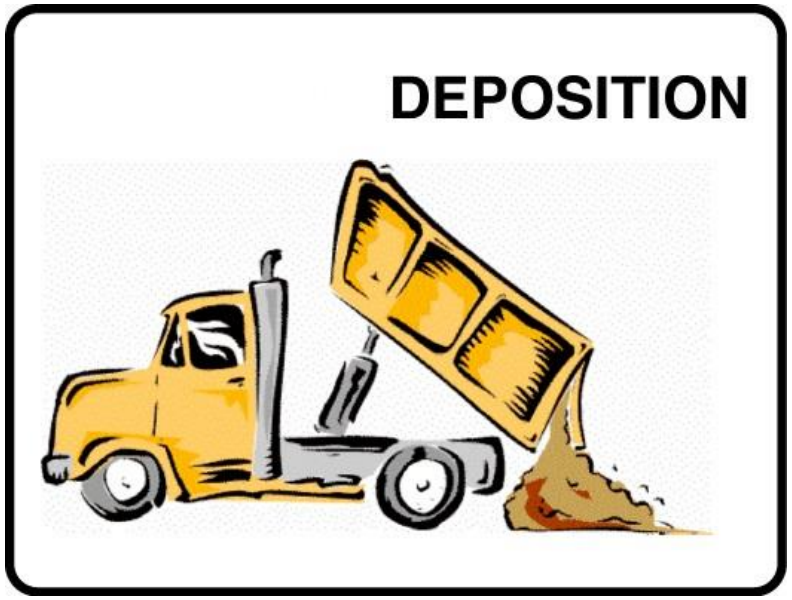
Degradation

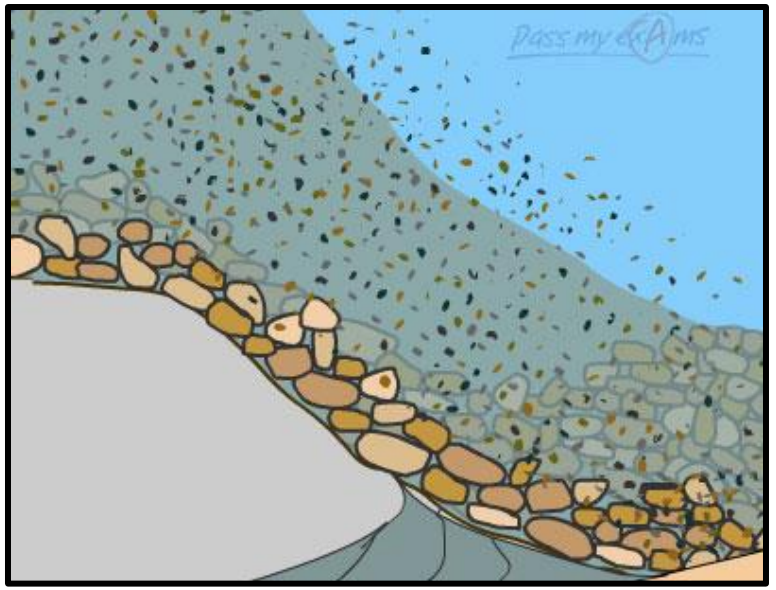
- Degradation is the lowering of a bottomland surface through the process of erosion;
- Conceptually it is the opposite of the vertical component of aggradation and is most frequently applied to sediment removed from a channel bed or other low-lying parts of a stream channel.



Deposition

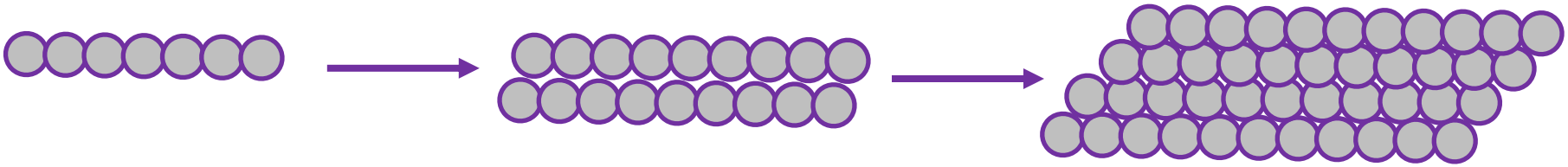
Deposition is the constructive process of accumulation into beds or irregular masses of loose sediment or other rock material by any natural agent;





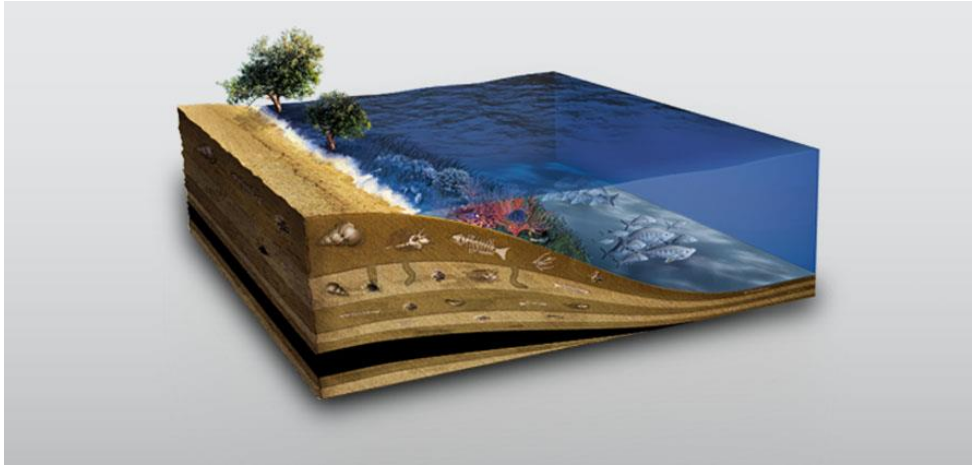
Aggradation

- 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.



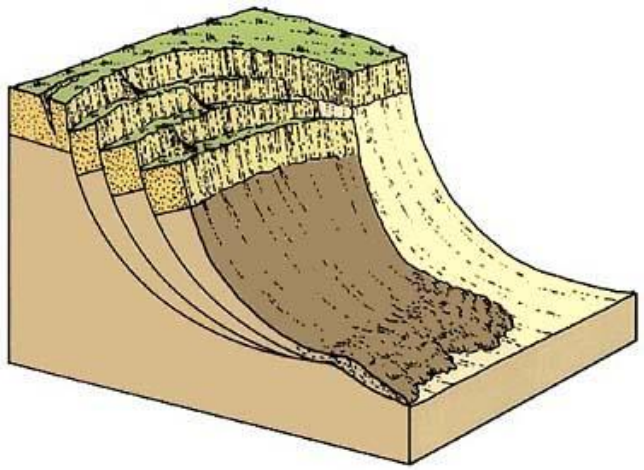
Sedimentation

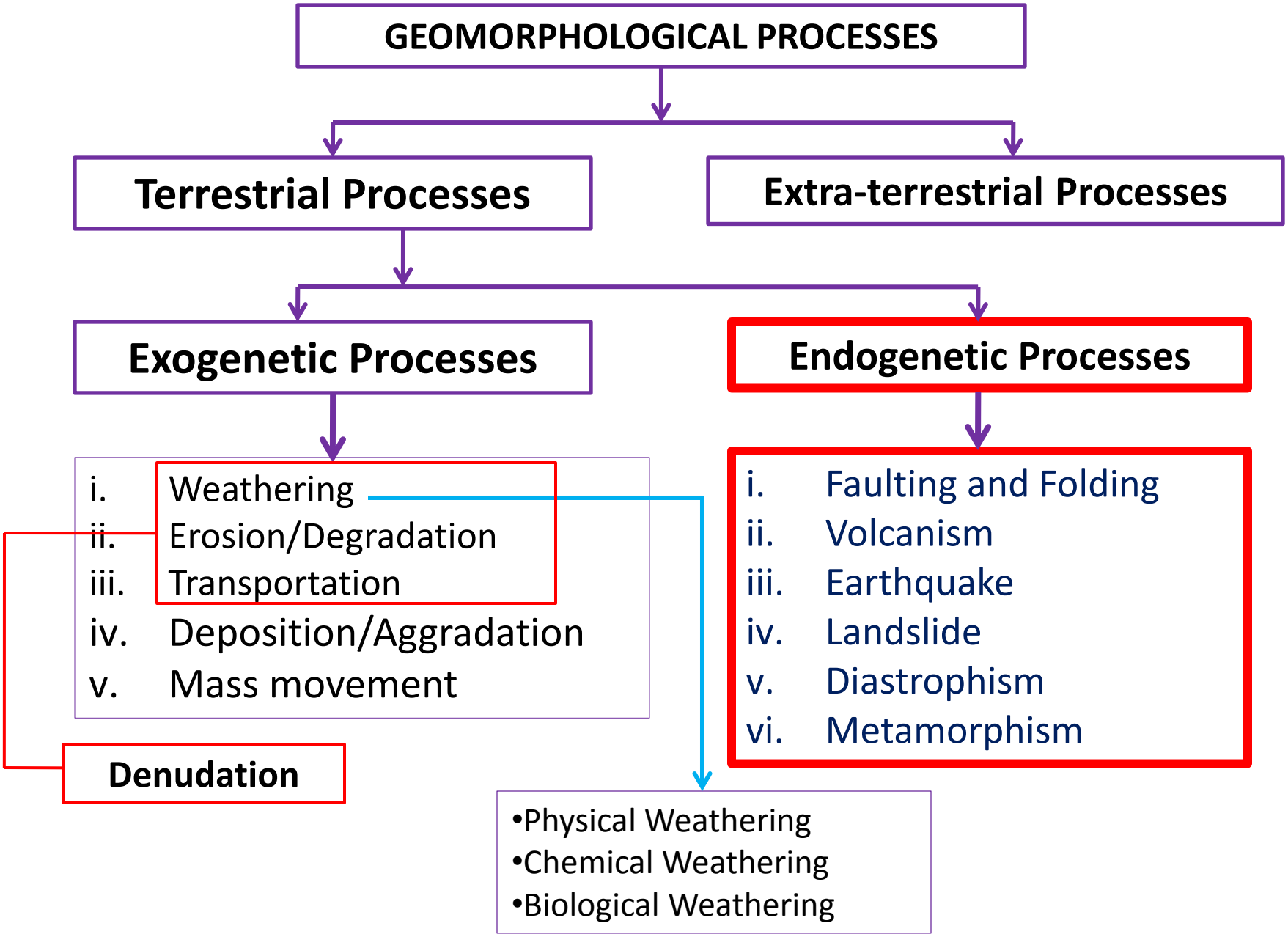
- Sedimentation is the process by which sediment is mechanically deposited from suspension within a fluid, generally water, or ice, thereby accumulating as layers of sediment that are segregated owing to differences in size, shape, and composition of the sediment particles.



Mass movement/Mass Wasting

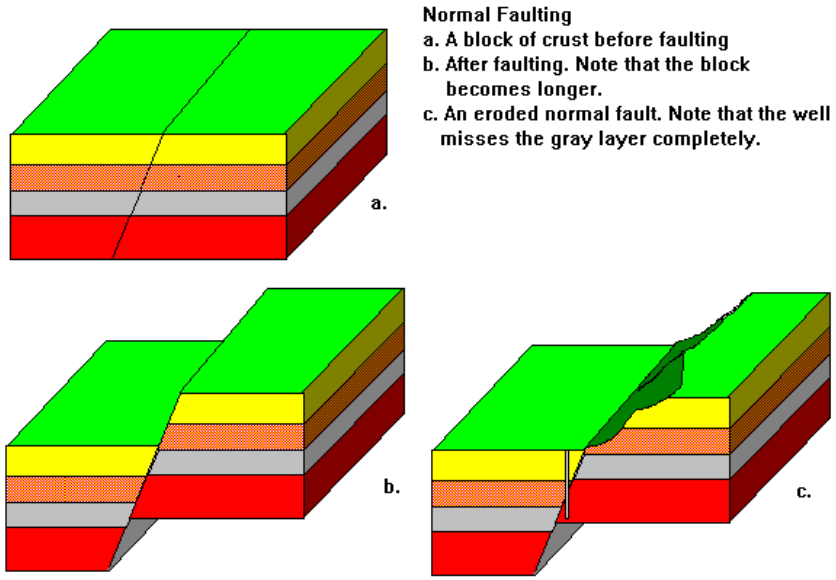
- **Mass movement** is any downslope transfer, through gravitational and generally water-facilitated (viscous) processes, of near-surface soil and rock material;
- Rates of mass movement range from very slow creep to nearly instantaneous slope failure.

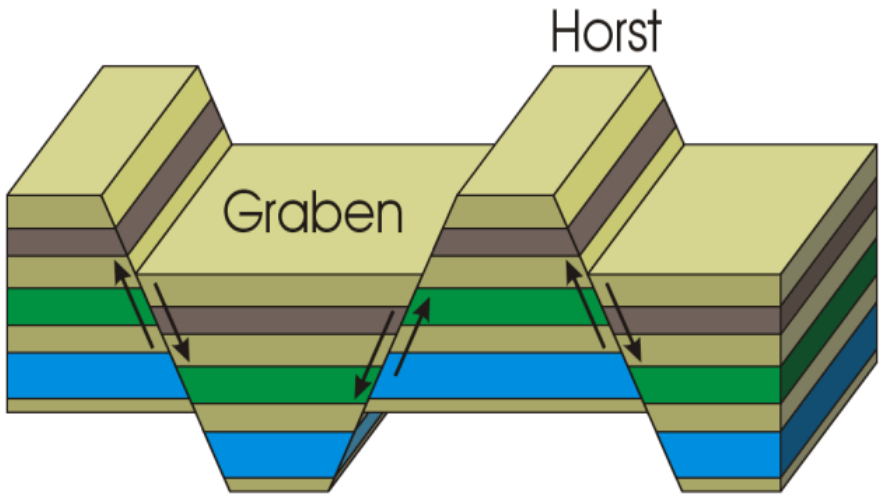



GEOMORPHOLOGICAL PROCESSES
Terrestrial Processes
Extra-terrestrial Processes
Exogenetic Processes
Endogenetic Processes
i. Weathering
ii. Erosion/Degradation
iii. Transportation
iv. Deposition/Aggradation
v. Mass movement
Denudation
i. Faulting and Folding
ii. Volcanism
iii. Earthquake
iv. Landslide
v. Diastrophism
vi. Metamorphism
•Physical Weathering
•Chemical Weathering
•Biological Weathering

Faulting

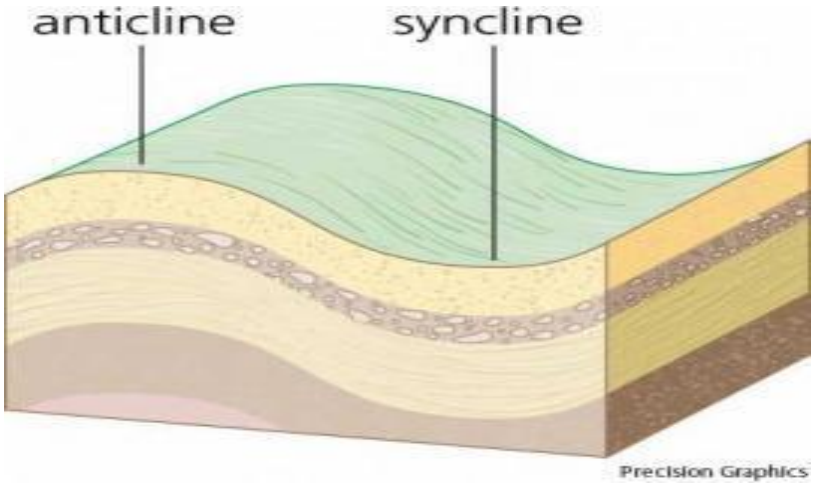
- Fault is a planar or gently curved fracture in the rocks of the earth's crust, where compressional or tensional forces cause relative displacement of the rocks on the opposite sides of the fracture.





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

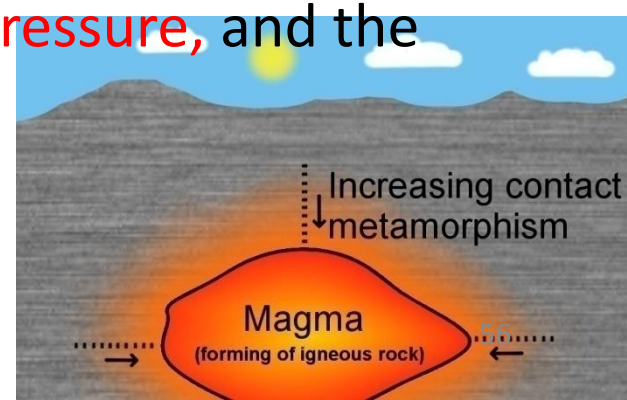
- A landslide, also known as a landslip, which includes a wide range of ground movements, such as rock fall, deep failure of slopes and shallow debris flows, which can occur in offshore, coastal and onshore environments.

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