

Basic Principles of Geomorphology

Unit-1

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- ❖ **Geomorphology is the study of the morphology or form of the Earth's surface**
- ❖ **The study of landforms on or near the Earth's surface and the processes working on them**
- ❖ **Geomorphology is the sub-discipline of geology that describes the physical changes of the surface of the earth over time**
- ❖ **Geomorphology is the science of landforms – their origin, evolution, form and spatial distribution of Continental and Submarine landforms**

Geomorphology relates to all the other disciplines of geology in two directions:

Tectonics, petrology, geochemistry, stratigraphy, and climate determine the geomorphology of the earth and its regions by controlling the principal influences on landscape.

Therefore evidence from observations of the landscape in turn constrain the tectonic, petrologic, geochemical, stratigraphic, and climatic history of the earth and its regions

Landform Controls

Driving forces

- solar radiation
- gravity
- earth's internal heat

Resisting forces

- lithology
- geologic structure

Processes: interaction of driving and resisting forces

Keith – First person to use the term Geomorphology in 1894

Earlier, it was called as Physiography

But Physiography includes climatology, meteorology, Oceanography, mathematical geography and landforms

The term “Geomorphology has come as a result of dissatisfaction with the term of Physiography

Geomorphology is primarily geology.

Development of Geomorphology

In the 17th & early 18th century, surface features of the earth were commonly attributed to catastrophic, often biblical-like events; (Flood, Earthquake, Eruption, Tsunamis, Meteors)

- a school of thought referred to as "catastrophism"

During the late 18th & 19th century, the works of Hutton, Playfair, & Lyell introduced the concept of "uniformitarianism" (Mountain building, Erosion, deposition, glaciers)

"The present is the Key to the Past"

By the late 19th century, Gilbert postulated that landforms reflect an adjustment between geomorphic processes and geology

Uniformitarianism, in the philosophy of naturalism, assumes that the same natural laws and processes that operate in the universe now, have always operated in the universe in the past and apply everywhere in the universe.

It is frequently summarized as "the present is the key to the past," because it holds that all things continue as they were from the beginning of the world.

The concept of uniformity in geological processes can be traced back to the Persian geologist, Avicenna (Ibn Sina), in *The Book of Healing*, published in 1027.

Modern uniformitarianism was formulated by Scottish naturalists in the late 18th century, starting with the work of the geologist James Hutton, which was refined by John Playfair and popularised by Charles Lyell's *Principles of Geology* in 1830.

The term *uniformitarianism* was coined by William Whewell, who also coined the term catastrophism for the idea that the Earth was shaped by a series of sudden, short-lived, violent events.

C. Paradigms Of Landscape Formation And Change

Paradigm: dominant worldview; the way in which most scientists think about and understand the world

Catastrophism

- recurrent cataclysmic events occurring over a limited time (earth is young)

Uniformitarianism

- the present is the key to the past
- laws of physics, chemistry, and biology don't change over time
- change is slow and gradual (earth is old)

Davis' Geographical Cycle

- cycle of linear, unidirectional landscape change
- youth, mature, old age stages followed by rejuvenation

Process geomorphology

- driving and resisting forces
- thresholds and equilibrium

Early contributions to geomorphology

Herodotus (485-425 BC) – Father of history

He has made some geological observations

He observed the yearly increment of sand and silt in the Nile river and stated that **“Egypt as Gift of Nile”**

He noted shells in the hills of Egypt and concluded that the palaeo sea up to lower Egypt

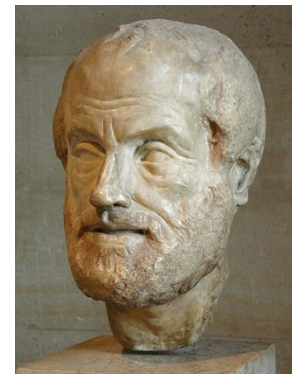
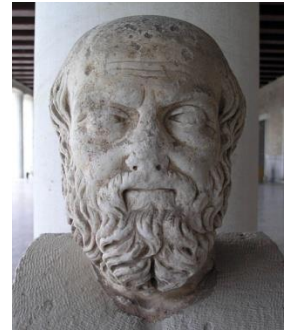
Aristotile (384-322 BC) – He made some observation on origin of Spring

He believe that the source of spring water is from the percolation of rainwater and water formed within the earth by condensation of air

Dry land can be submerged.

Land can be raised from beneath the ocean.

Described erosion by rivers, and deposition in deltas



Strabo (54BC – 25AD) – He traveled widely in Italy and observed sinking and rising lands

He inferred that the summit of mount Vesuvius was of volcanic origin

He also observed that the size of the delta of river varied from region to region

Seneca (...– 65AD) – He recognized that the valleys are developed due to stream erosion

THE DAWN OF MODERN GEOMORPHIC IDEAS

Avicenna (980-1037 AD) – He opined that the mountains are formed due to uplifting of ground or removing of soft rocks by erosion of stream

Leonardo da Vinci (1452-1519) studied the topography of the Arno River basin, drew the first contour map of a whole river basin, and believed that rivers carved their valleys and shaped topography.



Early contributions: Nicolas Steno

1638 -1686

Nicolas Steno wrote *Preliminary discourse to a dissertation on a solid body naturally contained within a solid* . He was the first person to hypothesize that the sea shells found at mountain tops were actually fossils and not spirits trapped within the rock, as was the current theory. He also introduced the ideas of original horizontality and superposition, and is recognized as one of the founding fathers of geology.



Italian and French hydraulic engineers developed the study of rivers in the late 17th century to address flooding problems along rivers draining the Alps.

Della Natura de' Fiumi
"The Nature of Rivers"

First Book on Rivers was published by Domenico Guglielmini in 1697.

The book discusses the nature of rivers and their parts, the motion of water, confluents and estuaries, banks, and materials and application.



Targioni-Tozzetti (1712 – 1786)

Italian who recognized differential stream erosion

He was the first person to say that age of the earth is not in terms of 1000's of years

Frenchman Guetthard (1715-1786) (Geologist)

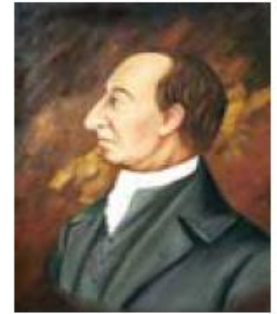
First to recognize the gradation of mountains

He say that the materials removed from hills not simply deposited in ocean, but develop the flood plains

He was the first to argue that sea is a powerful destroyer than the rivers (Massive destruction of chalk hills, N France)

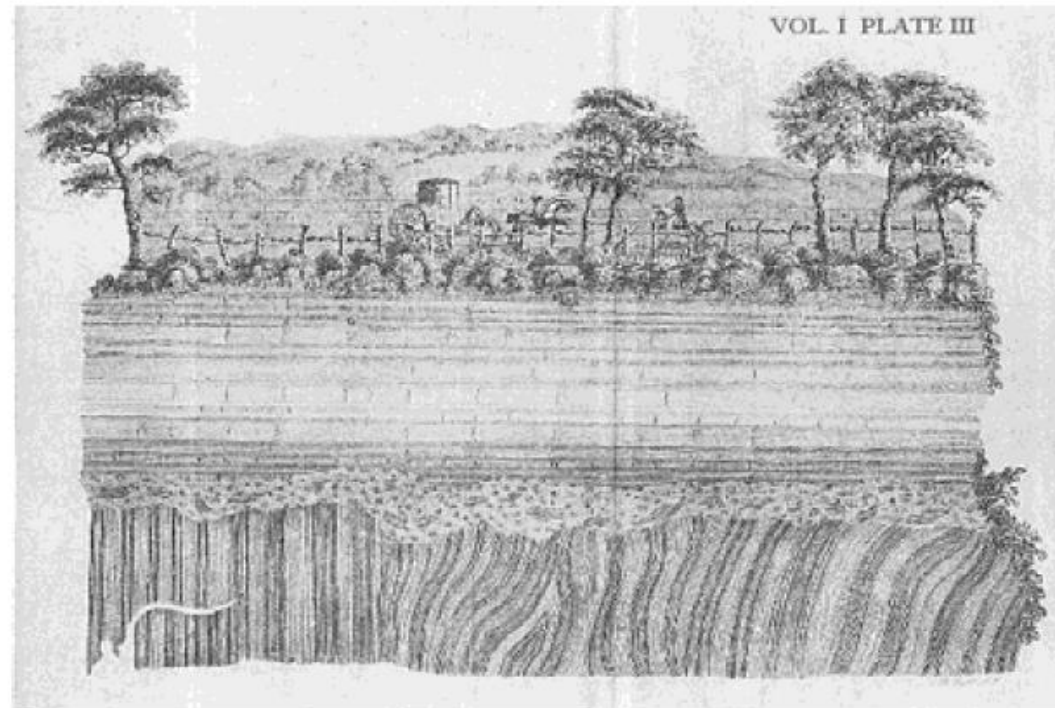
Evolve the fundamental principles of Denudation and first to recognize the volcanic landforms

Hutton's Era (1726 – 1797) Basically Physician interested in Geology from Edinburgh, Scot land



Wrote *Theory of the Earth* in 1795 where he laid the foundation of many of the fundamental principles of Geology. He included chapters on uplift, erosion, and consolidation of rock.

Unfortunately, he did not communicate his ideas very effectively, so they didn't catch on!



See for yourself:

Book 1 of 4 at <http://www.gutenberg.org/files/12861/12861-h/12861-h.htm>

Book 2 of 4 at <http://www.gutenberg.org/files/14179/14179-h/14179-h.htm>

Hutton's Era (1726 – 1797) Geologist from Scot land

Propounded the Granite was igneous origin

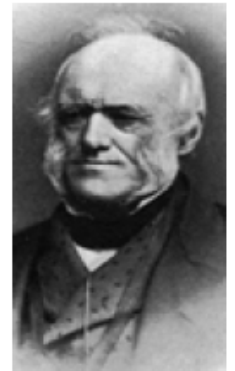
Evolve the concept of “Present is the Key to the Past”

Established the doctrine of “uniformitarianism” in opposition to that of catasotrophism

His first book “Theory of Earth” and 2nd one “Theory of Earth with proofs and illustrations”

Werner (1749-1817) theorized that all mountains formed under water, and were ultimately sculpted by rapidly receding oceans.

Early contributions: Sir Charles Lyell



Advocate of doctrine of **uniformitarianism**: theory that slow geological processes have occurred throughout the Earth's history and are still occurring today. 'The present is the key to the past.'

The idea contrasted **catastrophism**: theory that Earth's features formed in single, catastrophic events and remained unchanged thereafter.

The debate continues in some form today where geomorphologists are still piecing together the history of various landscapes across the earth.

Two geomorphic principles arise from Hutton and Lyell's works:

- 1) Landforms and the landscape evolve (*very Darwinian!*).
- 2) Frequency and magnitude in the landscape.

Contributions: *Principles of Geology*, first published in three volumes in 1830-33

Frequency and magnitude of geomorphic processes

The most frequent events do not do the greatest amount of work (not surprising)

The largest events do the most work, but they are infrequent.

Moderately sized transport events do the most geomorphic work in the landscape as a consequence of the frequency of moderate sized events

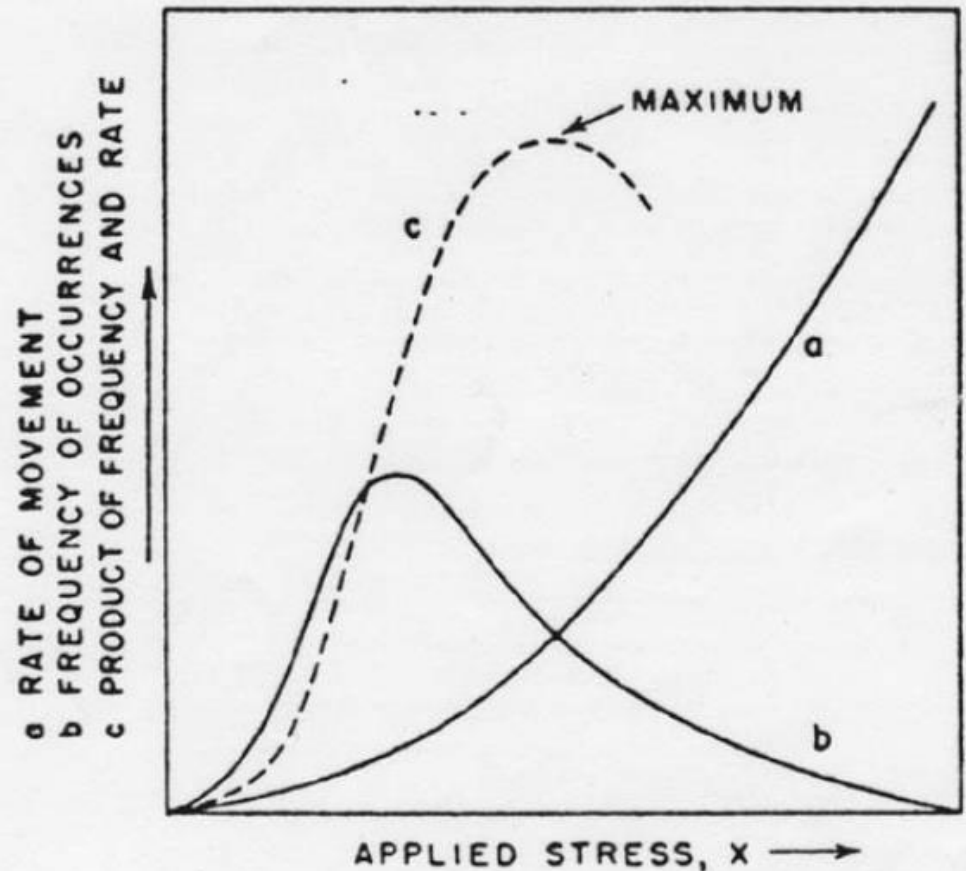
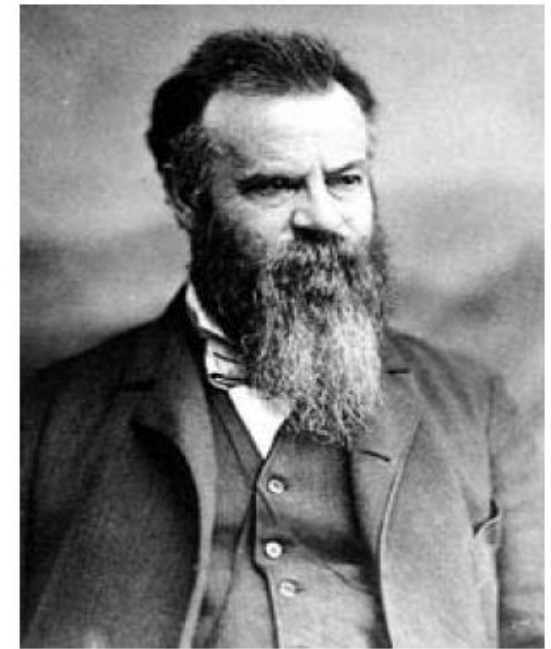


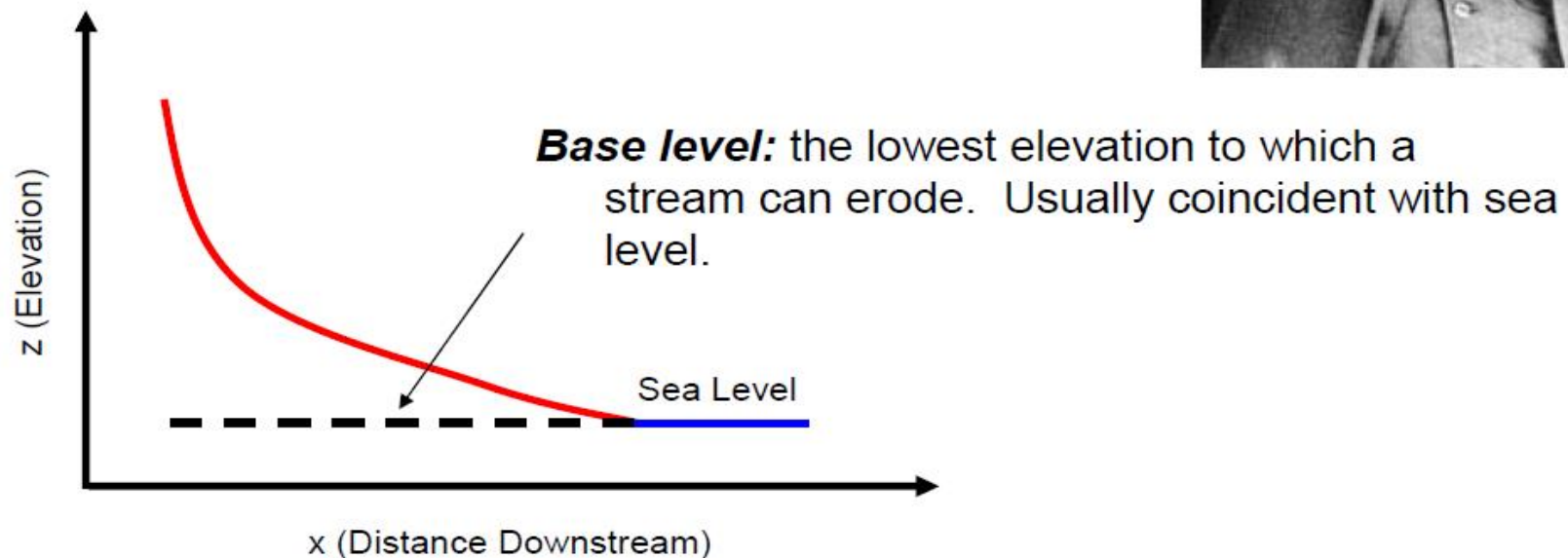
FIG. 1.—Relations between rate of transport, applied stress, and frequency of stress application.

From: Wolman, M. G. & Miller, J. P. (1960). Magnitude and frequency of forces in geomorphic processes. *Journal of Geology*, 68, 54-74.

John Wesley Powell



Early director of USGS who first explored the Grand Canyon and who introduced the idea of **base level**.



Contributions: *Exploration of Colorado River*, 1869. Wrote *Canyons of the Colorado*, 1895.

Grove Karl Gilbert

Powell's assistant in the Grand Canyon expeditions.

He is acknowledged as being the father of modern geomorphology.

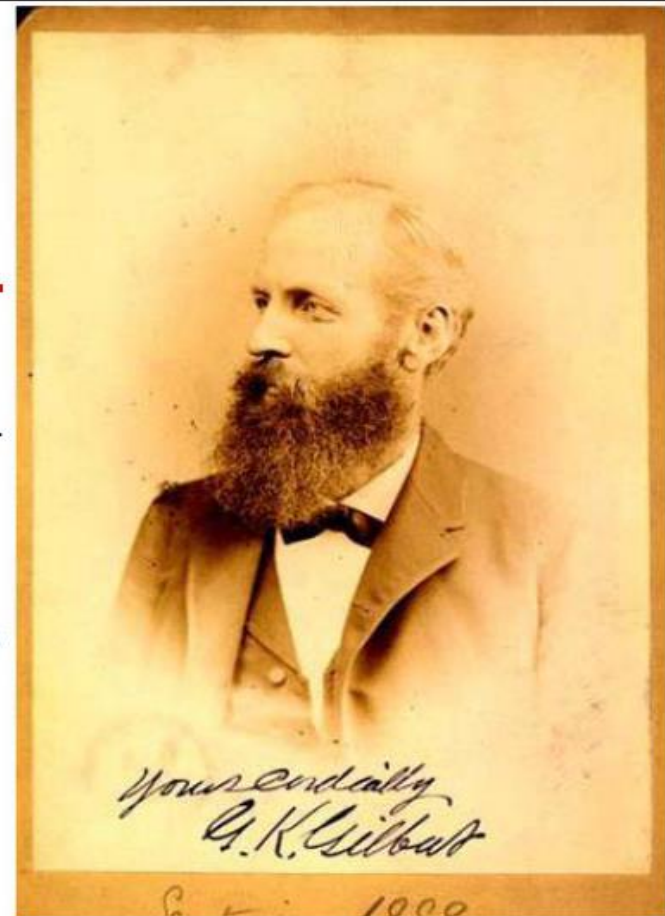
Gilbert's was the first work to systematically discuss weathering and bedrock erosion (debris production mechanisms) as well as erosion and transport of sediments in the landscape.

He also stated the fundamental relations between slope, energy available for erosion, and stream discharge.

Gilbert's View of *Dynamic Adjustment*

- Landforms reflect a unique accommodation between dominant processes and local geology.

Contributions: *Report on the Geology of the Henry Mountains* (1877), *The Transportation of Debris by Running Water* (1914), *Hydraulic-Mining Debris in the Sierra Nevada* (1917).



Agassiz : Recognized glacial landforms in Europe - introduced the concept of Ice Ages (1837)

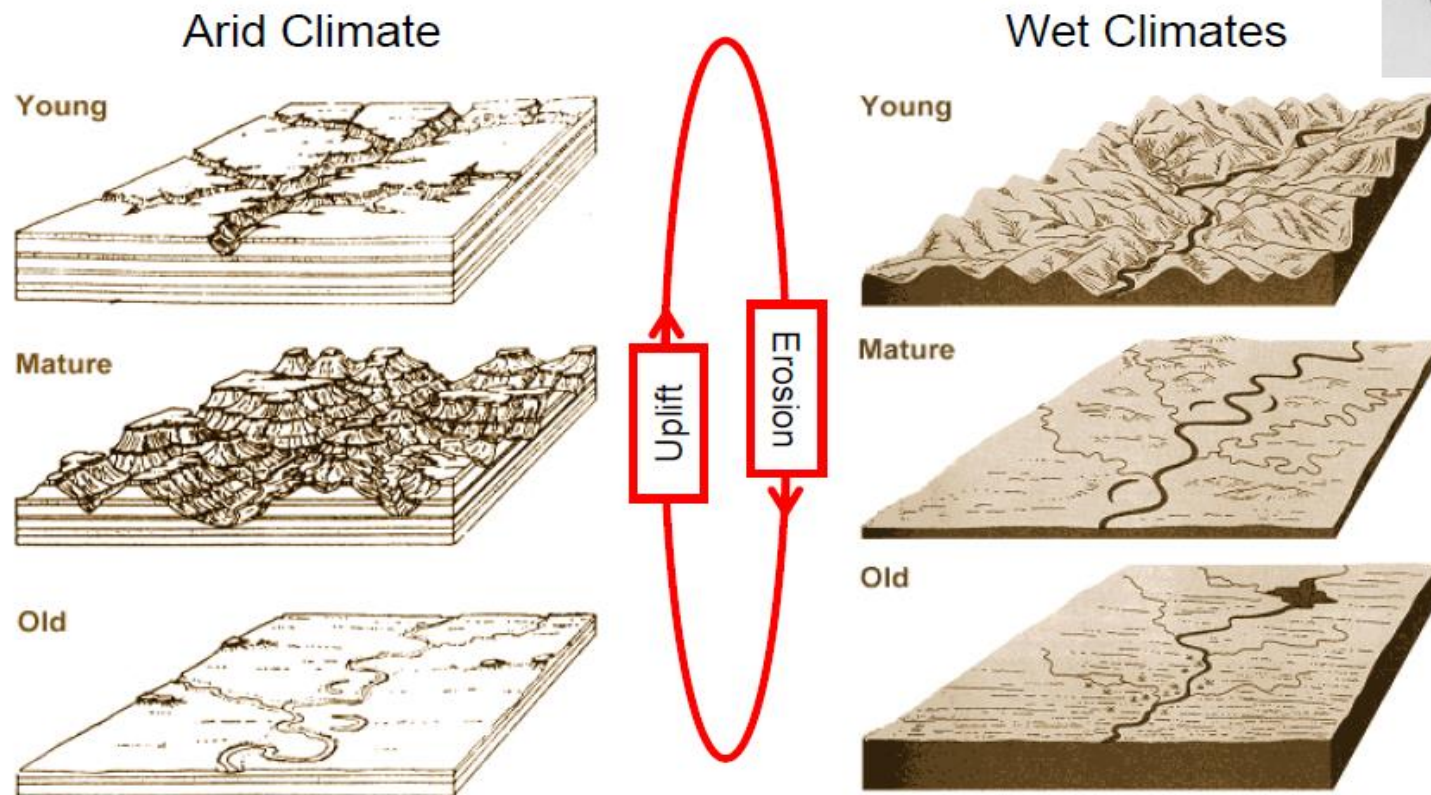
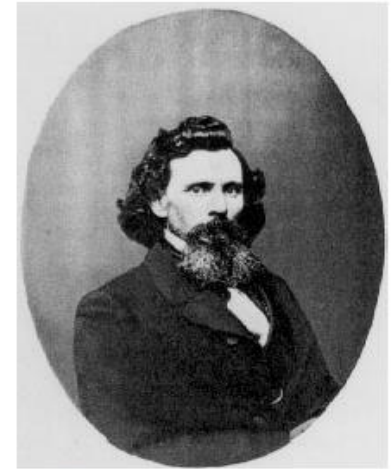
Davis (1850-1934) – “The great definer and analyst”

He gave a new life to geomorphology. He introduced the genetic methods of landform description

Propounded the concept of geomorphic cycle and there from evolution of landforms

He explained differences in landforms to differences in geological structures, geological processes and stages of development

William Morris Davis: Geographical Cycle (AKA: Cycle of Erosion)

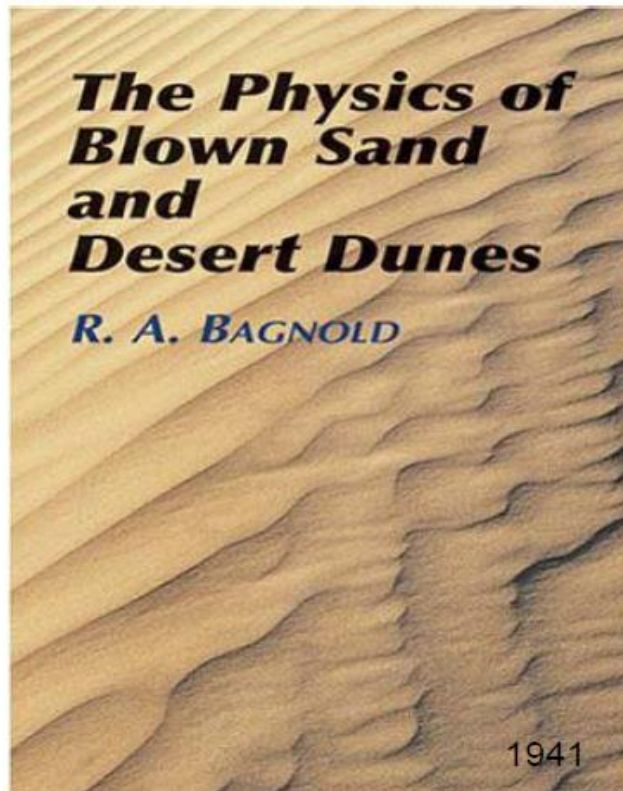


THE MODERN ERA

The modern era has refocused geomorphology as a predictive science, making G.K. Gilbert the most important early thinker in the discipline.

There were many leaders in the 20th century, but at least 2 stand out - Bagnold and Leopold.

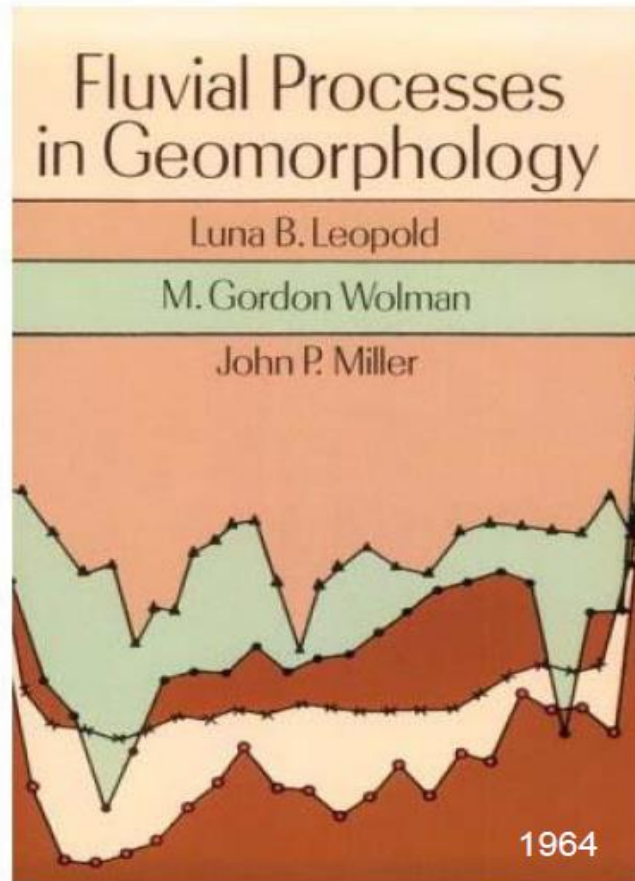
R.A. Bagnold



Bagnold was one of the first to use fundamental physics to explain landscape features. His book remains the standard reference in the field today.



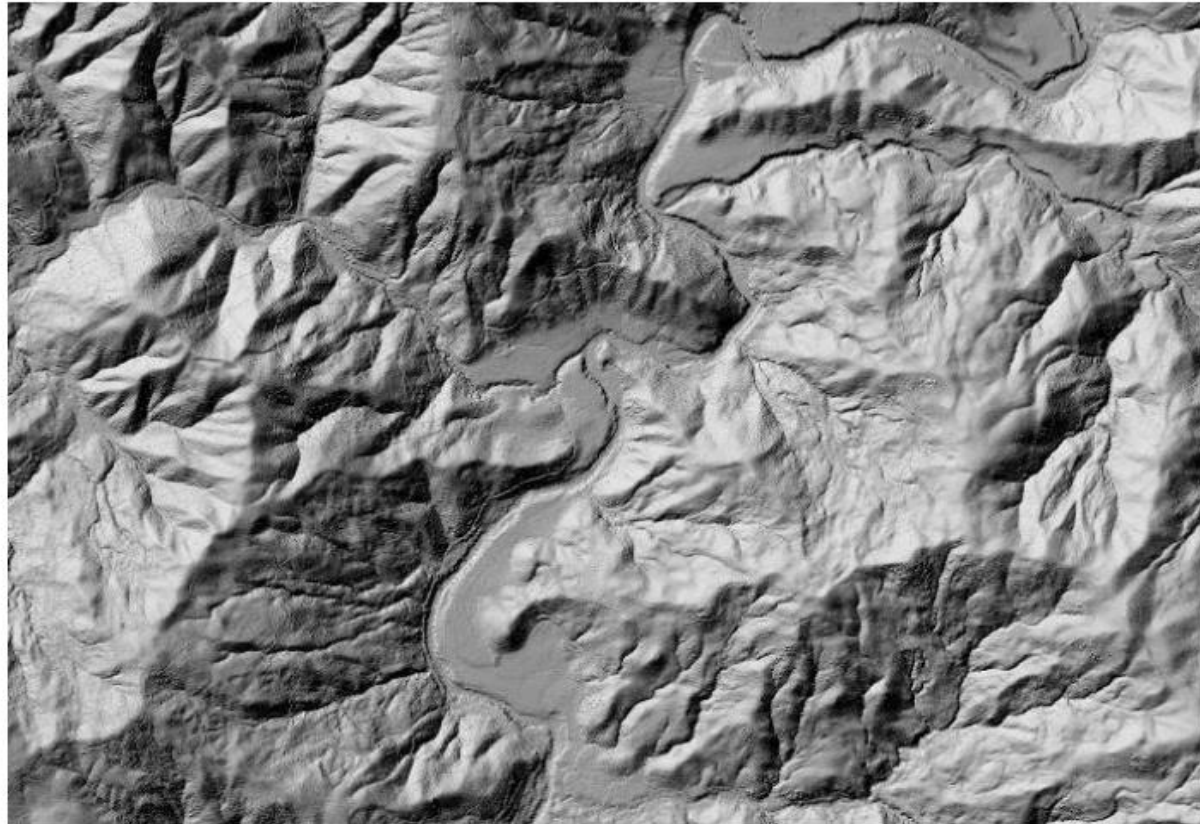
Luna Leopold



Leopold served as Chief of the Hydrology Section of the USGS in the late 1950s and 1960s where he and several colleagues revolutionized geomorphology by placing it on a firm quantitative and theoretical base.

Current trends

1. Quantitative analysis of topographic relief

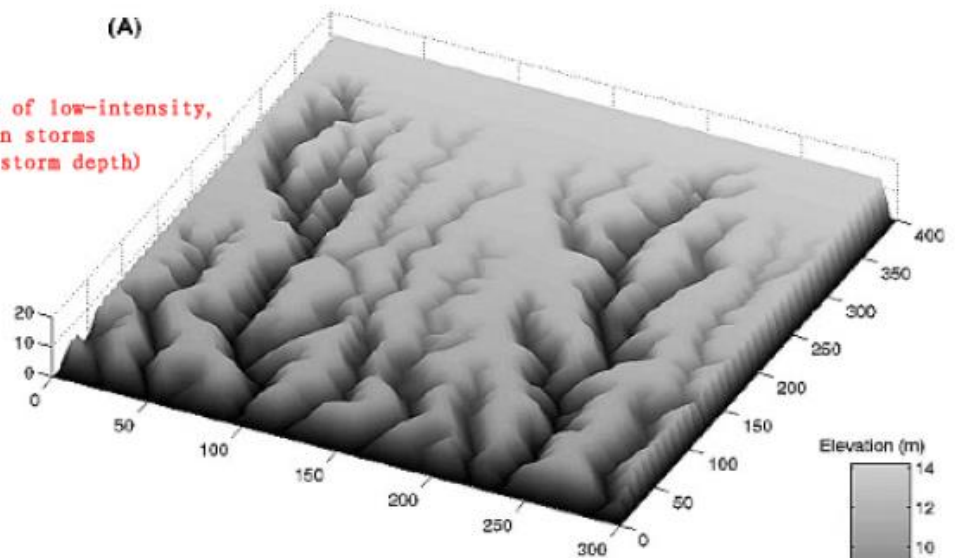


Eel River, California (Courtesy of Bill Dietrich)

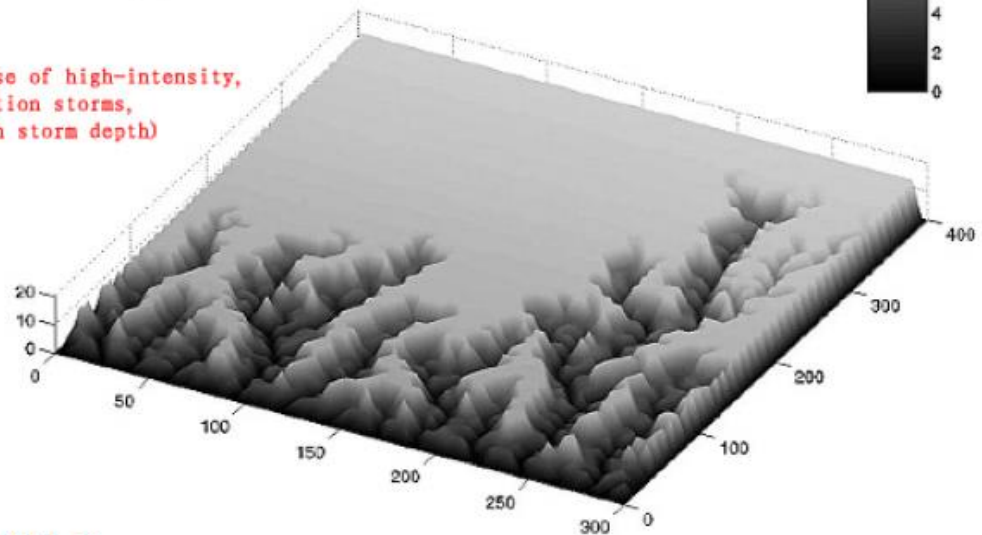
2. Computer-generated models of landscape evolution

Output from CHILDS
(**C**hannel-**H**illslope
Integrated **L**andscape
Development)

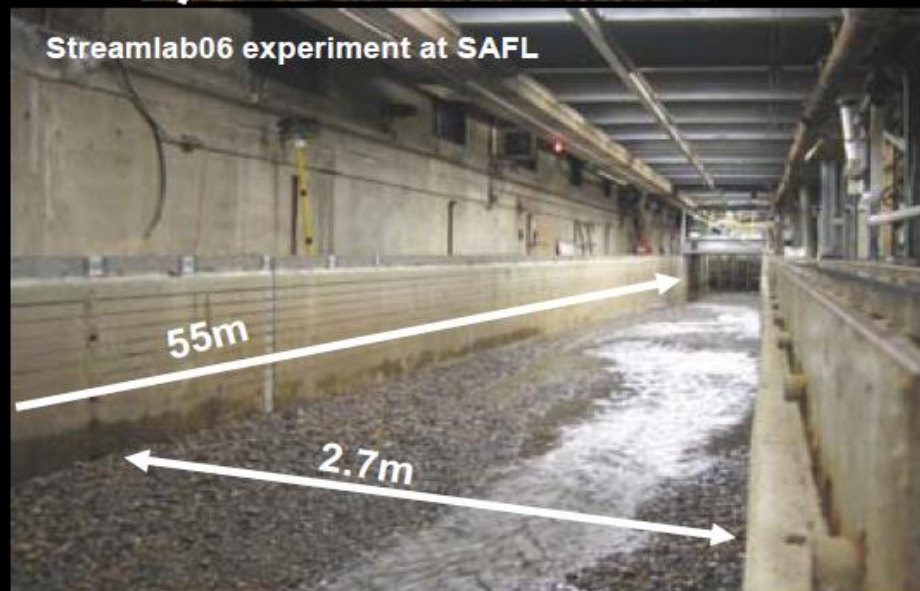
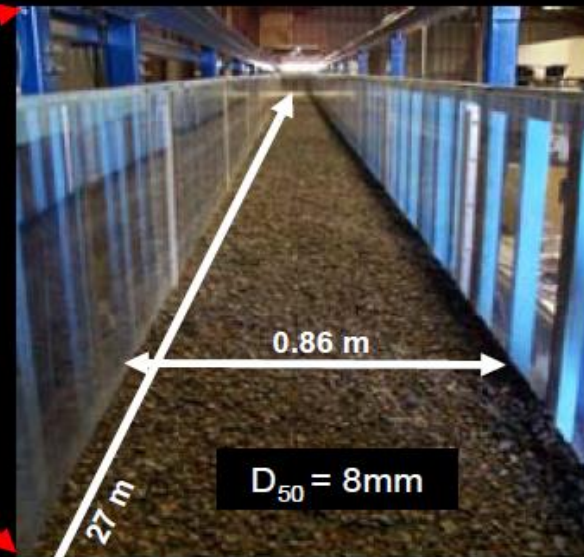
(A)
Random pulse of low-intensity,
long-duration storms
(fixed mean storm depth)



(B)
Random pulse of high-intensity,
short-duration storms,
(fixed mean storm depth)

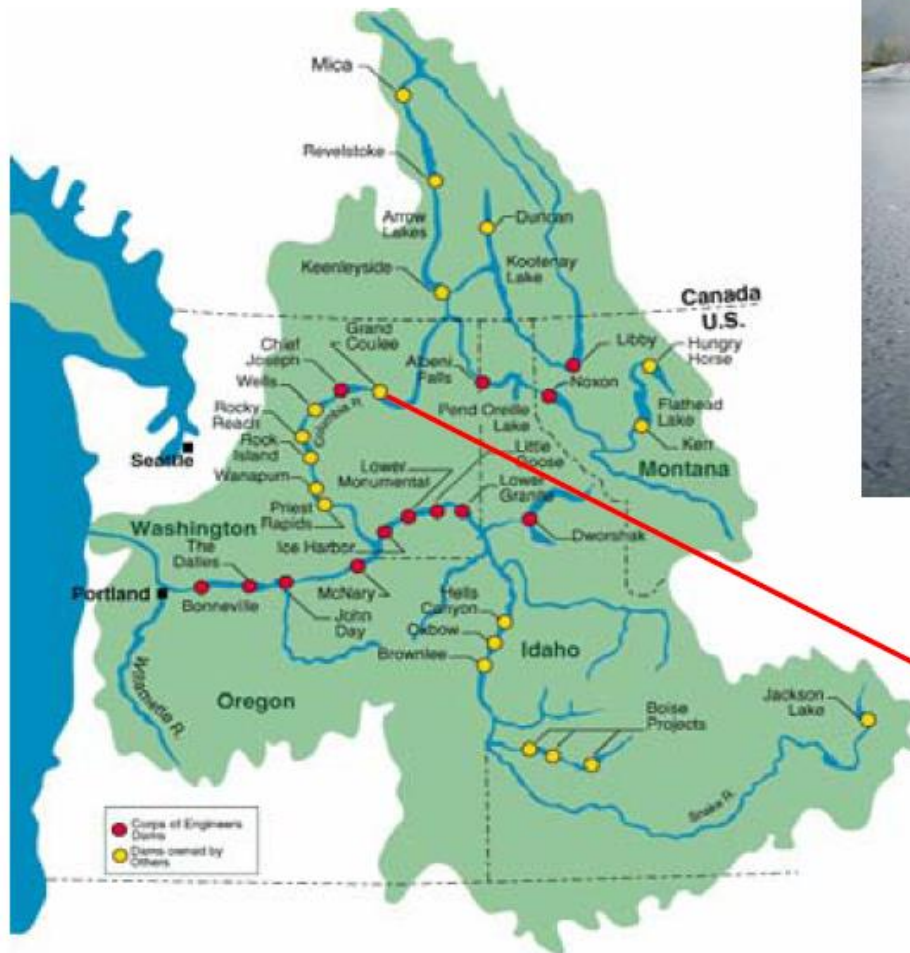


3. Application and testing of models of landscape processes





4. Using geomorphology as a tool to understanding ecologic processes and landuse impacts





Trinity River, CA: Pre-dam

Effects of Dam Construction on River Channels



Trinity River: Post-dam

- Incision
- Bed Coarsening
- Vegetation Encroachment

TRINITY DAM
BUILT BY AND FOR THE PEOPLE
OF THE UNITED STATES
TO CONSERVE AND WISELY USE
THE WATERS OF
THESE MOUNTAINS

DAVID C. BROWN, DIRECTOR OF THE UNITED STATES
BUREAU OF RECLAMATION

RECENT TRENDS IN GEOMORPHOLOGY

A tendency for geomorphology to become more strictly geological than geographical as a result of an increasing application to geomorphic studies of other phases of geology

- ❖ Mineralogy in the study of weathering**
- ❖ Stratigraphic and paleontology methods in palaeogeomorphology**

The development of regional geomorphology, which attempt to divide the continents into areas of similar geomorphic features and history

Application of geomorphic principles in groundwater, soil science, engineering geology,

FUNDAMENTAL CONCEPT OF GEOMORPHOLOGY

1. The same physical processes and laws that operate today operated through out geologic time, although not necessarily always with same intensity as now.

This is based on the important principle of modern geology and is known as the principles of **uniformitarianism**

It was first by Hutton in 1785, beautifully restated by Playfair in 1802 and popularized by Lyell with lot of editions

Hutton taught that the “The present is key to the past”, but he applied this principles very rigidly and argue that the geological processes operated through out the geological time with same intensity. We know now this not true

Glaciers were more significant during Pleistocene and during the other periods than now

Climates have not always distributed as now

Some regions that are now humid have been desert. The areas now deserts have been humid

2. Geologic structure is a dominant control factor in the evolution of landforms and is reflected in them.

W.M. Davis stated earlier that the major control factor in the development of landforms are structures, process and stage

Today there are some geologists who doubt the validity of stage as a major control factor. But no geologists doubts the important of process and structures

In general, structural features such as fold, fault, joint, etc. of rocks are much older than the geomorphic forms developed upon them

3. To a large degree the earth's surface possess relief because the geomorphic processes operates at different rates.

Different gradation of the earth surface due to the variation in lithology and structure from place to place of earth crust

Hence they behave with varying degrees of resistance to the gradational processes

Differences in rock composition and structures are not only reflected in regional geomorphic variability but in the local topography as well

The local intensity of particular processes may change notably in response to differences in such factors such as temperature, moisture, altitude, topographic configuration and the vegetal cover

4. Geomorphic processes leave their distinct imprint upon landforms and each geomorphic process develops its own characteristics assemblage of landforms.

Just as species of plants and animals have their diagnostic characteristics, same way landforms have their distinguishing features depending upon the geomorphic process responsible for their development
Floodplains, alluvial plains and deltas are by the stream action

Sinkholes and caverns are by groundwater

Morains and drumblins by glaciers

Sand dunes by aeolian actions

5. As the different erosional agents act upon the earth surface there is produced an orderly sequence of landforms.

The landforms possess distinctive characteristics depending upon the stage of their developments

It is probably true that most geomorphologists believe that landforms have an orderly and sequential development in youthful, mature and old stage as postulated by Davis

6. Complexity of geomorphic evolution is more common than simplicity.

Usually, most of the topographic features have been developed in current cycle of erosion, but there may exist within an area remnants of features produced prior cycles

It is a rare thing to find landscape assemblages which can be attributed solely to one geomorphic processes, even though we can recognize the dominant one

Horberg (1952) classify the landforms into 1) simple, 2) compound, 3) monocyclic, 4) multicyclic, 5) exhumed or resurrected landscapes

Simple landscapes – by a single dominant processes

Compound landscapes – by two or more geomorphic processes

Monocyclic landscapes –the imprint of only one cyclic of erosion

Multicyclic landscapes – by the more than one cyclic of erosion

Exhumed or resurrected landscapes – formed during the geological past, then buried and now exposed for erosion

7. Little of the earth's topography is older than Tertiary and most of it no older than Pleistocene

The age of the topographic features with erosion surfaces dating back to Cretaceous or even as far as the Precambrian.

These are very rare, they are exhumed forms (buried and exposed)

Most of the present topographic features are Pleistocene and only some of the topographic features are date back to Tertiary

Ashley (1931) believed that the most of the world scenery like mountains, valleys, shores, lakes, etc. are Post-Miocene

He estimated that the 90% of the present topography belonging to Post-Tertiary age

But geological structures very old compare to topographic features developed upon them

Himalayas were probably first folded in Cretaceous and latter in Eocene and Miocene, but its present elevation was attained only in Pleistocene

8. Proper interpretation of present day landscape is impossible without a full appreciation of the many fold influences of the geological and climatic changes during Pleistocene.

Climatic changes during the Pleistocene have had far-reaching effects upon present day topography

Glaciations directly affected many million sq km

Many stream courses were altered as a result of ice invasions for example: Ohio, Missouri, Mississippi

World sea level were affected. Withdrawal of sea water and from the huge ice sheets lead to lowering of sea level to 300 – 500 ft

During the interglacial ages, sea level again raised

9. An appreciation of world climate is necessary to a proper understanding of the varying importance of the different geomorphic process

The climatic factors such as temperature and precipitation influence the operation of geomorphic features

Some detailed studies indicate that the climatic factors influence the topographic details

Climatic factors controls the vegetal covers, precipitation, evaporation

Differences in climatic conditions as related to slopes facing the sun and those are not exposed

10. Geomorphology, although concerned primarily with present day landscapes, attains its maximum usefulness by historical extension.

Geomorphology concerns itself primarily with the origin of the present landscapes, but in most landscape, there are present form that date back to previous geologic epochs or period

So geomorphologist must adopt historical approach to identify the geomorphic history

Palaeogeomorphology deals with the ancient topography and paleolandforms

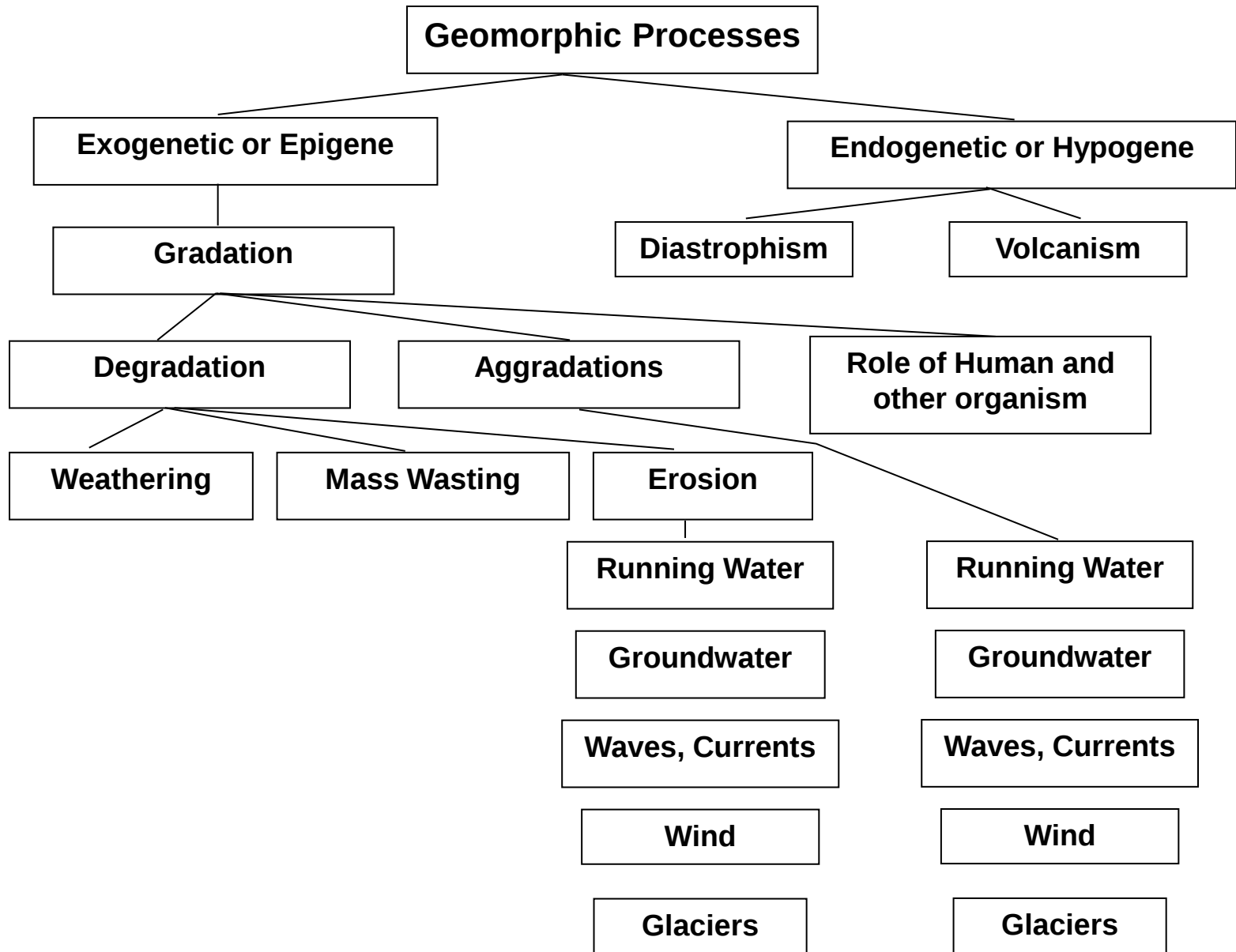
GEOMORPHIC PROCESSES

→ Depending upon their individual nature and mode of operation, the natural agencies may be classified broadly into two categories

→ Earthmovements, earthquakes and volcanic necessarily have their origin underneath the surface of the earth. Therefore, they may be classified as endogenous or hypogene processes

→ That is the geological processes originating and operating within the earth are called endogenous or hypogene processes

→ The blowing wind, running and underground water, waves and currents of water bodies (Lakes, sea, oceans), glaciers, blowing sand, etc. are originating and operating on the surface of the earth are called as the exogenous or epigene processes.



→ Endogenous or hypogene processes are generally develop the irregularities upon the earth surface. For example:- accumulation of lava due to volcanic eruption causes the formation of volcanic mountain or plateau in vast plain surface and the severe earthquakes create the lot of irregularities in the surface of the earth

→ Endogenic processes expansion of oceanic crust and continual drifting of continental crust

→ Diastrophism: *is a general term for all crustal movements produced by endogenic Earth forces that produce ocean basins, continents, plateaus and mountains*

→ Diastrophism: involves orogenic processes marked by the deformation of the Earth's crust and epiorogenic processes which result in regional uplift and subsidence of the crust without large scale deformation

→ Orogenesis, or mountain building, tends to be a localized process that distorts pre-existing strata

→Volcanism: There are nearly 60,000 volcanoes on the earth and about 50,000 occur as seamounts in the Pacific Ocean floor. Accordingly, it is obvious that the volcanoes have an important role in modifying the Earth's surface

→Upwelling of magma through the vent and fissure type volcanoes naturally modifies the topography

→Extensive flow of magma creates the vast plateaus like Deccan plateau in western India

→The crustal rocks may also be deformed by the intrusion of magma producing domal structures

- The exogenous or epigene processes always tend to reduce the surface of the earth to a continuous and gradual slope with out any irregularities
- The process of development of a continuous and gradual slope of the land-mass may be defined as the gradation
- The mechanism of reducing the altitude of a highlands due to its wear and tear processes may be described as the degradation
- The materials or sediments result from the degradation are deposited in the low lying lands like river, lake basins, surface depression are called aggradation
- The aggradations and degradation occur simultaneously upon the earth surface to reduce the same to continuous and gradual slope

The natural processes which are play in grading the surface of the globe in four different stages as follows

- 1.Mechanical breaking down of the rock masses**
- 2.Decomposition of the rock due to chemical reactions**
- 3.Transportation of broken rock debris, sand, silt, etc.**
- 4.Deposition of the transported materials under favourable condition**

Weathering: Weathering which is responsible for disintegration and decomposition of rocks. Through various processes reduce the great mountains into fine particles (sand, clay)

The factors which are influence the weathering are structure of the rock, the topography, vegetation of the terrain, climate, etc.

Weathering may be classified into Physical and Chemical weathering

Physical weathering: also called mechanical weathering due to

- Rocks expand due to unloading of rock masses
- Repeated heating and cooling arising out of fluctuations in temperature
- Activities of organisms

Chemical Weathering: Due to chemical processes, disintegration of rock will take place. The following are the some of important chemical weathering processes such as

- Hydration
- Hydrolysis
- Oxidation
- Carbonation
- Solution

Erosion and Transportation of Materials: Erosion encompasses acquisition of loose materials, grinding and wearing down of the bedrock by the material, mutual attrition of particles and transportation of the debris and also taken the materials by solution

The following are the important agents of erosion

- ❖ Running water
- ❖ Groundwater
- ❖ Waves & currents
- ❖ Wind and
- ❖ Glaciers

Human Activity: is also recognized to modify the Earth's surface, large quarries, rock cut and fills and other excavations are some examples

Geomorphic Equilibrium

- **A balance exists between landforms and processes;**
- **This balance is dependent on the interaction of energy, force and resistance;**
- **When thresholds are exceeded, a temporary disequilibrium will trigger a response to meet a new equilibrium condition;**
- **One process may affect others;**
- **Equilibrium conditions are more obvious over extended timeframes.**

MAP OF THANKSGIVING DINNER

