

MGG-002

GEOMORPHOLOGY



Vol.**1****BLOCK 1****1-64****FUNDAMENTALS OF GEOMORPHOLOGY**

BLOCK 2**65-140****EVOLUTION OF LANDFORMS**

BLOCK 3**141-206****GEOMORPHIC PROCESSES: STATIC AND DYNAMIC I**

BLOCK**1****FUNDAMENTALS OF GEOMORPHOLOGY**

UNIT 1**DEVELOPMENT OF GEOMORPHOLOGY** **11**

UNIT 2**BASIC POSTULATES IN GEOMORPHOLOGY** **27**

UNIT 3**GEOMORPHIC SYSTEMS AND CONCEPTS** **45**

GLOSSARY **63**

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Acknowledgements: Mr. Anil Kumar for word processing. Should any infringement have occurred, the publishers and editors apologize and will be pleased to make the necessary corrections in future editions of this book. Photographs/diagrams/maps/drawings and other academic materials and text used in this course for academic purposes are gratefully acknowledged and credited.

Cover page designed by Dr. Koppiseti Nageswara Rao.

November, 2023

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ISBN- 978-93-5568-913-9

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Printed by : M/s Educational Stores, S-5 Bulandshahar Road Industrial Area, Site-1, Ghaziabad (UP)-201009

COURSE INTRODUCTION: GEOMORPHOLOGY

Geomorphology is a field of geography that develops scientific explanations for the evolution of landforms. Geoscientists, especially geographers and geologists, have been studying geomorphology for centuries in order to better comprehend the Earth's surface. Geomorphology mainly is a part of physical geography which deals with the study of landforms, their characteristics and various processes, i.e., physical, chemical, biological and extra-terrestrial responsible for their formation and changes.

Traditional geomorphology analyses landform descriptions, whereas quantitative geomorphology, which is process-based, explains forces working on Earth's surface that create landforms and landform change. The change to a more quantitative approach was greatly influenced by the work of Horton, Strahler, and Leopold, who argued for a physically-based assessment of landforms in the mid-twentieth century. Novel techniques for comprehending the forms and processes were introduced. Geomorphology has various sub-disciplines, including tectonic, fluvial, aeolian, floodplain, glacial, climatic, coastal and many others. The study of geomorphology encompasses how various agents like water, ice, and wind shape the topography of the Earth's surface. Anthropogenic geomorphology investigates the effects of humans on landform alteration all over the world. As a result, it is impossible to envisage a place or condition that has not been influenced by geomorphic processes.

This course-MGG 002, consists of five blocks, is intended to introduce learners to the concepts, theories, geomorphic processes, and major landforms that exist under various structural and climatic conditions. Geomorphology applications in environmental management are also introduced.

Geomorphology-MGG 002 course is printed in two volumes. Volume-1 consists of first three blocks namely: Block 1: Fundamentals of Geomorphology, Block 2: Evolution of Landforms and Block 3: Geomorphic Processes: Static and Dynamic I; and the other two blocks namely- Block 4: Geomorphic Processes: Static and Dynamic II and Block 5: Applied Geomorphology are arranged in Volume-2.

Geomorphology encompasses a wide range of geographical dimensions, from micro-landforms to gigantic landforms. Geomorphology's history may be traced back to the ancient and classical periods of Greek and Roman scientists and thinkers.

From the classical perspective of cyclic development to systems approaches, the core notions of geomorphology, nature and scope, and the genesis of landforms are discussed. You will also learn about "form and process geomorphology," a novel way to studying landform evolution and change. You will get a better understanding of the fundamentals of geomorphology by studying the development of the discipline, basic postulates, geomorphic systems, and fundamental concepts in Block 1, which is divided into three units.

Block 2 describes the evolution of landforms. A landform is a natural or human-made feature on the Earth's surface. The study of landform evolution is essential to grasp the attributes of landforms, such as their shape, material composition, and spatial distribution throughout the Earth's surface. The theories of major landform formation by describing Earth's core structure, theories of isostasy, eustasy, continental drift, and plate tectonics are explained. You have been introduced to tectonic processes and landforms in this block 2. Further, geomorphic processes

both dynamic and static dealing with weathering, mass wasting, and fluvial processes and landforms are explained in three units. You will study in details about these processes and landforms in Block 3 of Volume I of this course on Geomorphology.

Volume II consists of Block 4 and Block 5. We have explained the geomorphic processes and landforms related to wind, underground, ice and waves in Block 4 under geomorphic processes static and dynamic. The applications of geomorphology including slope processes, geomorphic mapping and techniques, landforms and environment management are described in details in the last Block of this course.

We hope after studying this course, you will better understand the geomorphology with reference to fundamental concepts and theories, geomorphic processes and resultant landforms, techniques and applications landform analysis. Our best wishes are with you in this endeavour.

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MGG-002 GEOMORPHOLOGY

VOLUME- 1

BLOCK 1 FUNDAMENTALS OF GEOMORPHOLOGY

- Unit 1 Development of Geomorphology
 - Unit 2 Basic Postulates in Geomorphology
 - Unit 3 Geomorphic Systems and Concepts
-

BLOCK 2 EVOLUTION OF LANDFORMS

- Unit 4 Theories of Development of Major Landforms
 - Unit 5 Tectonic Processes and Landforms I
 - Unit 6 Tectonic Processes and Landforms II
-

BLOCK 3 GEOMORPHIC PROCESSES: STATIC AND DYNAMIC I

- Unit 7 Weathering
 - Unit 8 Mass Movement
 - Unit 9 Fluvial Processes and Landforms
-

VOLUME- 2

BLOCK 4 GEOMORPHIC PROCESSES: STATIC AND DYNAMIC II

- Unit 10 Aeolian Processes and Landforms
 - Unit 11 Karst Processes and Landforms
 - Unit 12 Glacial Processes and Landforms
 - Unit 13 Coastal Processes and Landforms
-

BLOCK 5 APPLIED GEOMORPHOLOGY

- Unit 14 Slope Processes
 - Unit 15 Geomorphic Mapping
 - Unit 16 Geomorphic Techniques
 - Unit 17 Landforms and Environment Management
-

BLOCK 1: FUNDAMENTALS OF GEOMORPHOLOGY

Geomorphology is the scientific study of landforms. Humans have long been fascinated by the different landforms found across the world in a range of environments. Landforms raise concerns about how they develop, what mechanisms are involved in their formation, and how they change. The subject spans geographical dimensions ranging from micro-landforms for example alluvial fans or point bars to massive landforms such as continents and ocean basins.

Geomorphology is also concerned with changes in landforms caused by variables such as changing climate, sea level rise, tectonic activity, and human action. Geomorphological investigations are primarily concerned with recreating the past through understanding the present in order to anticipate the future. Though geomorphology began as a branch of geography and geology, it has gradually expanded into an inter- and multi-disciplinary study that deals with atmospheric, hydrological and oceanographic, soil, agricultural, and environmental sciences.

The history of development of geomorphology becomes a highly helpful instructional tool for making students aware of the subject's growth over time. Geomorphology may be traced back to the ancient and classical periods of Greek and Roman scientists and philosophers. During the ancient and classical periods, Greek and Roman scholars such as Aristotle, Ptolemy, Herodotus, Strabo, and others pondered and studied the origins of mountains, valleys, deltas, and so on. Thus, studying these geomorphic forms and processes has been crucial to understanding the Earth's surface.

Despite its origins in the Greek and Roman's periods, geomorphology is a relatively new study. Particularly, the nineteenth-century travels and findings gave rise to contemporary geomorphology. Its foundation was laid by a collection of scientists, including James Hutton, Charles Lyell, G.K. Gilbert, W.M. Davis, Penck, Jovan Cvijić, Strahler, Bagnold, Leopold, Andrew Goudie and Heather Viles. Many concepts and hypotheses put forth by geomorphologists in the early stages of development have experienced major shifts in their basic postulates in recent times. However, many of the principles and theories that have characterized and influenced the subject have remained relevant to this day.

This block introduces you to fundamentals of geomorphology dealing with development of geomorphology, basic postulates in geomorphology, and geomorphic systems and concepts in three units.

Unit 1: Development of Geomorphology

This unit explains the subject of geomorphology and its scope, and approaches, as well as how they have evolved over time. It also provides a brief overview of geomorphic theories and concepts, as well as application areas.

Unit 2: Basic Postulates in Geomorphology

This Unit describes basic postulates in geomorphology as well as their importance in evolving the discipline of geomorphology. We introduced the geological time scale and addressed the classical concepts of Neptunism vs Plutonism and Catastrophism vs Uniformitarianism, which set the foundation for the development of geomorphology. This unit ends with a study of the

fundamental concepts of geomorphology that have been determined to be most important for modern geomorphology in recent times.

Unit 3: Geomorphic Systems and Concepts

Geomorphic systems and concepts are introduced in this unit. We discussed general systems theory, which offered a unique concept and inquiry approach to the study of landform evolution. This unit will teach you how, as a result of scientific developments in other fields, the origin of landforms has evolved from the classical perspective of cyclic evolution to systems approaches. You will also learn about "form and process geomorphology," an innovative approach to examining the evolution and change of landforms. You'll also understand how the concepts of equilibrium and steady state, as well as geomorphic threshold, complex response system, and dynamic equilibrium, contribute to understanding the genesis and morphological disposition of landforms.

We hope after studying this block, you will better understand the fundamentals of geomorphology by studying development of subject of geomorphology, basic postulates, geomorphic systems and fundamental concepts. Our best wishes are with you in this endeavour.

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DEVELOPMENT OF GEOMORPHOLOGY

Structure

1.1	Introduction	1.3	History of Development of Geomorphology
	Expected Learning Outcomes		
1.2	Introduction to Geomorphology	1.4	How Geomorphology is Related to other Disciplines?
	What is Geomorphology?	1.5	Summary
	Significance of Geomorphology	1.6	Terminal Questions
	Nature and Scope of Geomorphology	1.7	Answers
	Approaches to Geomorphology	1.8	References and Suggested Further Reading

1.1 INTRODUCTION

Geomorphology is the scientific study of landforms, their origin, description, classification and application of this knowledge for the welfare of the mankind. The diverse landforms across the globe within a variety of landscapes have always been a matter of curiosity for the scientists as well as people. The questions connected with landforms are - how they originate, what processes are involved in their formation, how they change and how this knowledge can be useful in resolving the problems through the applications of this knowledge in human welfare. The scope of the study ranges from spatial scales of micro forms like alluvial fans, natural levees, point bars to the major landforms like continents and ocean basins as well as mountains and valleys. They can be studied through qualitative observations to quantitative measurements, theoretical conceptualizations to laboratory analysis and numerical simulations to geospatial modelling using real time data of remote sensing in GIS platforms. Geomorphological studies revolve around morphology and characterization of the landforms, quantitative analysis of their shapes, monitoring of their exogenetic and endogenetic processes that shape the landforms. Geomorphology also deals with changes in landforms in response to various factors like changing climate, sea level rise, tectonic activities and human interventions. Geomorphological investigations primarily focus on reconstructing the past by understanding the present to predict the future.

Though geomorphology has been a part of the disciplines of geography and geology and Earth Sciences, with the passage of time, it has become an interdisciplinary branch/subject sharing its objectives with other fields of sciences like marine sciences, pedology, agriculture and environmental sciences.

This unit highlights how the field of geomorphology has developed over time and explores its significance, scope, approaches, theories and principles as well as its application areas.

Expected Learning Outcome

After studying this unit, you will be able to:

- Describe the subject of geomorphology, its meaning and scope;
- Explain how geomorphology has evolved from ancient to present time; and
- Understand, how geomorphology is linked to other disciplines.

1.2 INTRODUCTION TO GEOMORPHOLOGY

1.2.1 What is Geomorphology?

Geomorphology is the scientific study of landforms, their origin, description, classification and application of its knowledge. The word geomorphology has been derived from the Greek word “**ge-** meaning the **Earth**, **morphe-** meaning **form**, and **logos-** meaning **discourse**”. Thus geomorphology means a discourse of the various forms of the Earth. It is a part of physical geography which deals with the study of landforms, their characteristics and various processes i.e., physical, chemical, biological and extraterrestrial responsible for their formation and changes. The study of geomorphology encompasses how various agents like water, air, ice, etc., shape the topography of the Earth's surface.

Landforms are generally produced by the processes of erosion and deposition influenced by several natural factors like relief, slope, climate and vegetation as well as human factors. Different climatic environments produce different types of landforms. While landforms of deserts like sand dunes and pediments are shaped by the action of the winds, landforms of the polar and sub polar areas are shaped by the glaciers. The knowledge of geomorphology has great many applications in the fields of river basin development and flood control, land use planning and city development, watershed management, mineral exploration and geological mapping, mineral prospecting and coastal zone management, etc.

Many geomorphologists have defined geomorphology to include the configuration of the Earth as a whole and their dynamic processes which shape its surface. Thornbury in 1969 suggested that the term geomorphology should be extended to include submarine forms, while Chorley and others in 1984 defined geomorphology as the scientific study of the geometric features of the Earth's surface. According to A.N. Strahler, geomorphology is the study of the origin and evolution of the Earth's surface features, in terms of physical,

biological and chemical processes that shape landforms, as well as the structure of the Earth's crust, geological processes, and climatic influences, because landforms are the product of the combined influence of all of these factors. Although the term is commonly restricted to the study of landforms at or above sea level, the study of geomorphology includes all the landforms existing and originating at the interface between the solid Earth, the hydrosphere and the atmosphere. Hence, geomorphology is not only the study of landforms of the continents, but also the morphology of the sea floor. Chorley, Schumm and Sugden (1984) in their book on "Geomorphology" mentioned that geomorphology is based on the two major interrelated concepts of historical and functional studies. They have mentioned that historical studies of landforms aim to deduce from the erosional and depositional features of the landscape, the sequence of events through which the Earth's surface has passed. Functional studies focus on reasonably contemporary processes and the behaviour of Earth materials.

1.2.2 Significance of Geomorphology

Geomorphology is a sub-branch of physical geography. Knowledge of geomorphology has found its relevance in other disciplines like geology, geophysics, agriculture and pedology, environmental studies, marine sciences, natural hazards and disaster management. Geomorphology can help in predicting risks associated with different geomorphological processes such as mass wasting and landslides, movement of the glaciers and dynamics of the waves, tides and river flows to manage and mitigate the natural hazards associated with these events. Geomorphological mapping has been widely used for groundwater exploration, terrain evaluation and land suitability mapping, watershed management and integrated coastal zone management.

The main objective of geomorphology is to reconstruct the history of the surface of the Earth through the study of its landforms. To achieve this objective, an understanding of the genesis of landforms requires not only the present processes but also the processes which had operated in the past.

The basic objectives of studying geomorphology are:

- (a) To study the morphology of the surface of the Earth through its landforms and features, the materials of which they are composed of and the processes that shape the landforms.
- (b) To explore the conditions associated with their origin and their evolution over time.
- (c) To work out the agents and processes responsible for the formation and changes of landforms.
- (d) To understand how the geomorphological knowledge is linked to our everyday life and activities.
- (e) To make use of the knowledge of geomorphology in resource studies and to solve problems connected with our environment.

There are ten key points that are proposed for further knowledge of geomorphology; hence, the ten reasons why geomorphology is vital are

presented in Table 1.1. You will certainly have knowledge after going through the summarized table.

Table 1.1: Summary of the Ten Key Points.

1	Landscapes are shaped by processes of erosion, transportation and deposition	Landforms are shaped by geomorphological processes, which essentially involve the movement of Earth materials by different geomorphic agents and processes.
2	Landscape shaping processes are induced by many primary factors	Various tectonic, geological, climatic and weathering processes the rocks and sediments that constitute the surface of the Earth.
3	Landscape processes operate differentially	Spatially and temporally the geomorphic processes operate at various rates and scales.
4	Earth's landscapes are dynamic	Landforms and landscapes are not static but are dynamic and develop through time.
5	Landscapes are often complex	A ridge/hill can turn into a valley and a valley can turn into a hill through denudation and/or tectonics.
6	Landscapes are historical just like archives	Landscapes contain histories of their development that potentially can be deciphered and reconstructed from study of the associated landforms and sediments.
7	Global climate change is influencing landscape dynamics	Atmospheric warming and sea level rise, carry potential to influence landscape changes, including desertification, ice sheet and glacial retreat, and coastline erosion.
8	Human activities are influencing landscape dynamics	Human activities have a potential to induce changes in landscapes and landforms.
9	Earth's landscapes are turning more hazardous	Both global environmental change and human activities are increasing the magnitude and frequency of geomorphological hazards, which occur wherever and whenever land surface stability is affected and adverse socioeconomic impacts are experienced.
10	Successful environmental management needs geomorphological knowledge	Geomorphology can provide key inputs to environmental management.

(Source: Geomorphic Literacy, British Society for Geomorphologists)

1.2.3 Nature and Scope of Geomorphology

Geomorphology is the study of landforms, the materials of which they are composed of and the processes that shape the surface of the Earth. This helps to know the history of evolution of the landforms in particular and surface of the Earth in general. Geomorphologists also tend to predict and simulate future changes using a combination of methods involving field observation and numerical modelling. Denudation chronology aims at reconstructing the succession of relief at different times of the Earth's history. Scientific nature of study of the spatio-temporal variations in the origin, evolution, distribution and changing face of the landforms and their spatial relationship through a geological time scale are the core areas of investigation in the subject. Its inter-relationship with other disciplines of Earth and natural sciences like geology, geophysics, pedology, environmental science etc. exhibits its interdisciplinary nature (Fig. 1.1).

Geomorphology as a branch of academic discipline focuses on the study of landforms with emphasis on their forms, materials and processes. Traditionally the scope of geomorphology was limited to the "terrestrial environment" which has been the home of human. But along with the advancement of scientific tools and technology, the field and scope of geomorphology also started expanding its horizon to study landforms of the aquatic and planetary environments". Its tools of investigation have also started spanning from the ideographic methods to incorporate nomothetic methods, from conceptual modelling through qualitative observations towards theorisation based on quantitative techniques and computer based numerical simulations.

Use of geospatial technology and digital terrain modelling has also expanded the territory of geomorphology contributing significantly not only towards its core areas but also towards neighbouring disciplines who have been the users of this branch of knowledge promoting interdisciplinary investigations. On the basis of characteristics and scale of the relief features, the scope of geomorphology encompasses the study of landforms of the first order like continents and ocean basins and second order like mountains, valleys, plateaux and plains, etc. and third order landforms which are micro landform features and all other landforms which evolve with in the first and second orders. The scopes of geomorphic investigations have also expanded far and wide from simple observations to laboratory based analysis and studies based on digital technologies and geoinformatics.

1.2.4 Approaches to Geomorphology

Every scientific discipline stands on its own concepts which evolved over time and which play a key role in its progress. Geomorphology has also evolved its own concepts and approaches through its history which have characterized the discipline.

Fieldwork and data collection, application of geospatial technologies, geochemical analyses of sediments, and computer based modeling of the landform evolution have been an integral part of the field of geomorphology.

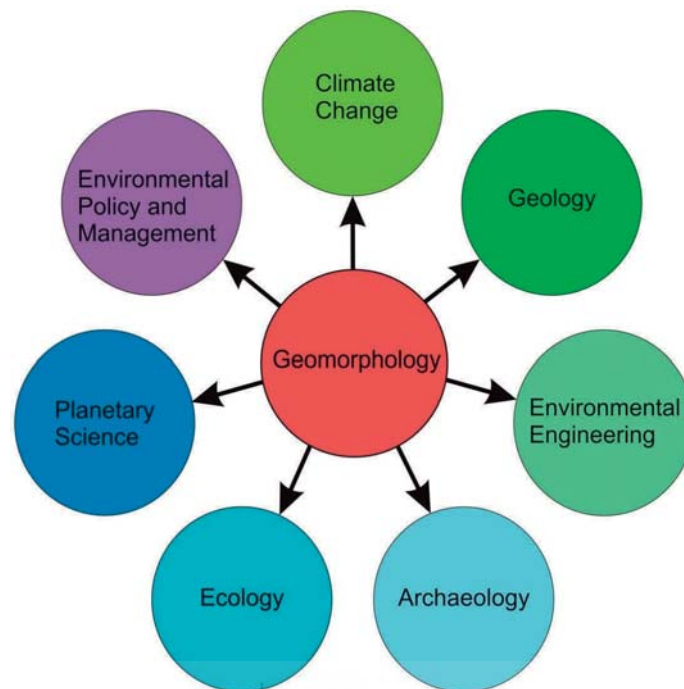


Fig. 1.1: Geomorphology interfaces with, and contributes to, many different aspects of the Earth, Environmental and Social Sciences.

Geomorphologists have also relied on geochronology to study the evolutionary process of landforms using methods of dating to measure the rate of changes in the landforms. Quantitative techniques and computer based digital simulations have also been used in terrain analysis on real time basis to describe the morphology of the Earth's surface. Use of Differential Global Positioning System (DGPS), real time digital terrain models, application of drone technology and machine learning are bringing revolution in inducing new approaches to the studies in geomorphology. Inductions of new advanced precision tools and techniques have made the subject applicable in hazard assessments for landslide investigation and mitigation, riverbank erosion and coastal protection works and so on.

A new branch of **planetary geomorphology** is also emerging to study the surface features of the extra-terrestrial bodies collected through space explorations. This new branch of planetary geomorphology explores the landforms of the other terrestrial planets and satellites like Mars, Venus and Moon through Earth analogies like effects of wind, water, glacier, mass wasting, volcanic processes and meteor impacts (on the Earth) to understand the surfaces of other celestial bodies. Bierman and Montgomery in their book on "Key Concepts in Geomorphology" mentioned that geomorphology relies on an integrative and applications oriented approach to the study the dynamic nature of the landforms of the surface of the Earth. Some of the important approaches used in the field of geomorphology are as follows:

(i) **Historical Approach**

Historical approach tends to derive and deduce sequential evidences from the landforms and its surroundings about the past processes such as tectonic, climatic and exogenetic, etc. Historical approach often relies on cyclic and denudational chronology of geomorphic processes and landforms.

(ii) Cyclic Approach

Cyclic approach started with W.M Davis (1850-1934), who promulgated the basic idea that landform evolution is a function of structure, process and stage. His conceptualisation of cyclic landform evolution in stages of youth, maturity and old age is synonymous with the evolution of human life in a similar cyclic process.

(iii) Denudation Chronology Approach

This approach attempts to reconstruct the history of geomorphological evolution of a region using erosion surfaces of different altitudes as a product of denudation through time. Study of the denudation chronology is based on the interpretation, identification and dating of planation surfaces exposed in the study region.

(iv) Climatic Geomorphology Approach

Different climates initiate and influence different processes and produce different types of landforms. This approach dates back to the period of Von Richthofen who developed these ideas of climatic geomorphology towards the end of 19th century. Subsequently this approach gained strength in Europe as well as North America since 1950 in studying the landform assemblages on regional basis across the globe.

(v) Qualitative and Quantitative Approaches

In the early phase of development of geomorphology, the subject was purely qualitative and descriptive. An inductive approach through observations of the landforms and their processes led to the establishment of a qualitative approach in the study of geomorphology. But subsequently with the advancement of technology which gave instruments and laboratory methods, scientific investigations started. The shift of geomorphology towards more quantitative methods has started with the work of Strahler, Horton and Leopold during 1940's and 50's advocating for multiple factor-based assessment of landforms. Nowadays quantitative approach is being widely used in study of landforms and specifically in the areas of 'process geomorphology'.

(vi) Modern Functional Approach

This is generally aiming at explaining the landforms through cause-effect relationships of multiple parameters. Such studies mostly involve contemporary processes and materials which are directly measurable. The systems approach helped in model building, simulation and future predictions. This has been further strengthened with the advent of geospatial technology, computerised simulations using machine learning and sophisticated dating and laboratory analysis of rock samples.

SAQ I

- a) Write any two key points to understand the geomorphology.
 - b) Explain the importance of climatic approach in geomorphology.
-

1.3 HISTORY OF DEVELOPMENT OF GEOMORPHOLOGY

Till now you have studied and understood about the geomorphology and its significance as well as various approaches to geomorphology. Let us now briefly discuss the history of development of the subject of geomorphology.

The history of geomorphology becomes a very valuable educational tool for making students aware about the development of the subject and its sub-fields over time. The history of geomorphology can be traced back to the period of ancient and classical times of Greek and Roman scholars and philosophers. Although it is rooted to the ancient and classical period of the Greek and Romans, the subject of geomorphology is a relatively younger science. Modern geomorphology has its origins in the nineteenth century through explorations and discoveries of many people. Its foundation was laid by a number of scientists like James Hutton, Charles Lyell, G.K. Gilbert and W.M. Davis. The history of development of geomorphology can be divided into the following four time periods.

1.3.1 Ancient Period (500 BC-1200 AD)

During the ancient period the geomorphological ideas which captured the imagination of the great philosophers like Aristotle, Herodotus, Strabo and Seneca are worth mentioning here. Chorley and others have also mentioned that the earliest recorded observations on relief and landforms, nature of fluvial erosion and hydrological cycle came from the ancient Greece. Aristotle, Herodotus, Strabo and Seneca had given their ideas on morphological evolution of fluvial landforms.

Aristotle (384-322 BC) had explained about the hydrological cycle and work of the rivers in creating alluvial deposits at the river mouths with examples from the Black Sea region. Herodotus (485?-425 BC) is known for his observations on evolution of the Nile delta by river deposits. Based on the fossil evidences, he could able to conclude that the sea level rise must have gone much inside Egypt.

Strabo (64 BC-25 AD) was able to observe that the Vale of Tempe was formed due to the volcanic activities and Earthquakes. Seneca's (65 AD) views on occurrence of Earthquakes and role of river abrasion on valley developments has inspired many subsequent philosophers to think about origin of landforms in a scientific manner. Avicenna's views on origin of the mountains and valleys (Ibn-Sina, 980-1037 AD) by upliftment due to Earthquakes and down cutting by river actions were classics of their times on geomorphological expositions.

1.3.2 Renaissance to Post-Renaissance Period (1200 AD-1800 AD)

Renaissance period is often referred to as the dark age of scientific learning when people were made to believe in the writings and preaching of the Bible in the western world. Scientists and philosophers were forced to believe in the

Bible and who ever tried to deviate from the dictums of the Bible had to face the wrath of the fundamentalists. Church played a dominant role in forcing the people and scientists as well to accept the facts of the Bible. This period brought a negative trend in the creation of new knowledge. This process took a considerable period of time to recover from the dogmatic believes of this Dark Age.

Scholars of the late 17th and early 18th century stressed that the concepts and ideas of geomorphology should be linked to the Bible and its catastrophic events. The people who believed in **catastrophism** were Thomas Burnet, Comte de Buffon and John Woodward. They believed that the Earth is shaped by big floods. Burnet was of the opinion that the Earth is hollow filled with water which came out during Noah's Flood. In his works (An Essay toward a Natural History of the Earth) John Woodward (1665-1728) revealed that the hard surface layers of the Earth can be divided into different strata, and its enclosed fossils were generated from the sea. Comte de Buffon believed the idea that the formation of the planet took place when there was a collision between a comet and the Sun leading to the formation of the planets. He also advocated that the early Earth began to cool from the poles to the present form.

In the western world, eighteenth century brought revival in the scientific learning, rapid industrialization and emergence of democratic values. Scientific and technological developments started replacing the dogmatic beliefs and superstitious perceptions. New research and educational institutions appeared and publications of scientific works have started.

Development of geomorphology took place through introduction of some of the basic principles in between 1780-1830 through the contribution of leading scholars like James Hutton of Scotland, Georges Curvier of France, William Smith of England, and Abraham Werner of Germany.

In the post-renaissance period, scientific explorations, voyages by the explorers and discoveries of new land and oceans piled up a lot of new information paving a stepping stone towards scientific thinking, experimentation and creation of new knowledge. Leonardo da Vinci (1425-1519) was the first person of this post renaissance period to study stream erosion, deposition and valley development.

Contribution of James Hutton (1726-1797) to the geomorphological studies gained significance with his revolutionary concept of “**uniformitarianism**” and “the present is the key to the past” opposing the prevailing idea of catastrophism. The belief that changes to Earth has always been consistent and that the present holds the answer to the past. Hutton's ideology of uniformitarianism was subsequently furthered by Charles Lyell (1797-1875) in studying the landforms. Thus, the modern geomorphology got a strong foothold in the eighteenth century with the contributions from the theory of universal ocean of Abraham Werner, glacial control theory of Luis Agassiz and James Hutton's theory of uniformitarianism opposing the views of neptunism, catastrophism and William Buckland's dilluvialism supported by Charles Lyell and John Playfair.

1.3.3 Modern Geomorphology and Exploration of American West (1800 AD-1900 AD)

The word geomorphology was first introduced by Lauman in a publication written in German language in the year 1858. Subsequently this word was used by J.W. Powell and W.J. McGee in an International Geological Conference. Keith Tinkler has suggested that the word came into general use in English, German and French after Powell and McGee used it during an International Geological Conference of 1891. Later on geomorphology was used in a book titled "The Scientific Study of Scenery" by John Edward Marr. Foundation of modern geomorphology was laid by the pioneering work of William Morris Davis conceptual model of geomorphic cycle (1884 to 1899) and sequential development of landforms. Charles Darwin's (1809-1882) voyage of the Beagle and his observations on the evolutionary history of fringing reefs, barrier reefs and atolls greatly influenced the work of Davis. Wide acceptance and application of this cyclic evolutionary model of Davis in to fluvial, aeolian, glacial and coastal landforms laid the foundation of geomorphology as an established discipline in the field of Earth Sciences.

The time 1875–1900 was a golden period of geomorphology in North America. During this period, the Geological Survey of Western North America was headed by some pioneers of geomorphology i.e. J.W. Powell (1834-1902), G.K. Gilbert (1843-1918), and C.E. Dutton (1841-1912). Their contributions to geomorphology together with the life and work W.M. Davis laid a scientific basis to carry over to the 20th century. Powell's work on "Base Level of Erosion", Gilberts work on "Slope Development and Graded Profile of Rivers", Dutton's work on "Development of Canyons" and Thornbury's work on "Fundamental Concepts in Geomorphology" became the foundation for modern geomorphology of the twentieth century.



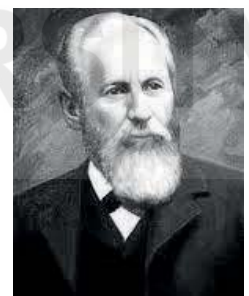
William Morris Davis
(1850-1934)



Walther Penck
(1888-1923)



John Wesley Powell
(1834-1902)



Grove Karl Gilbert
(1843-1918)

(Source: https://en.wikipedia.org/wiki/William_Morris_Davis; https://en.wikipedia.org/wiki/Walther_Penck; <https://www.usgs.gov/media/images/grove-karl-gilbert>; <https://www.usgs.gov/media/images/john-wesley-powell-1>)

1.3.4 Geomorphology of the 20th Century and Beyond

In the early part of the twentieth century, Walther Penck, a German geomorphologist suggested a new and alternative model non-cyclic evolution of landforms opposed to Davis. His model of landform evolution was a manifestation of landform as function of process and time with the premises that landform evolution can take place simultaneously with upliftment and denudation, as opposed to the ergodic and cascading system of energy reduction through a cyclic progression from youth to old age. In the beginning

of the 20th century, the study of climate, glaciations and L.C. Peltier's publication on periglacial cycle of erosion in 1950 gave rise to climatic geomorphology in Europe. L.C. King's study of the South African desert landforms and pedimentation process was more akin to the ideas of Penck in the evolution of landforms.

In the middle of the twentieth century quantitative revolution in geomorphology started opening a new dimension in the study of landforms. Quantitative analysis of erosional landforms by A.N. Strahler, R.E. Horton and Ronald Shreve opened a new dimension in morphological analysis and numerical predictions following a systems approach and modeling of forms and processes. In this direction the contributions of the following exponents like W.W. Rubey, R.A. Bagnold, John Hack, L. Leopold, Thomas Maddock and Stanley Schumm are worth mentioning in adopting quantitative techniques in geomorphological studies and research. The newly inducted quantitative methods helped in understanding the past and simulating the future behavior of geomorphic processes and landforms. Quantitative geomorphology has started involving fluid dynamics, solid mechanics, morphometric analysis of landform features, laboratory investigations and field observations, theoretical work, and full landscape evolution modeling. These approaches are used to understand the interactions between forms and processes involving a wide range of elements and factors of landforms through the middle of 20th century. Introduction of quantitative analysis through the works of the distinguished scholars like Strahler, Bagnold, Leopold, Miller and Wolman, Gregory and Goudie provided impetus to the emergence of "Process Geomorphology" in shaping the landforms.

Progress of geomorphology in the 20th century was accelerated by the establishment of a number of geomorphological societies and publication of journals. Advances in the dating technology, analysis and collection of ocean cores, advent of geospatial technology and use of real time aerial photography and satellite data, use of Light Detection and Ranging (LiDAR) in geomorphic data collection process, use of digital surveying system and advanced computer based modeling tools has brought many technical developments in the subject during the later years of 20th century. Towards the later part of the twentieth century, the theory of dynamic equilibrium and geomorphology as an open system in opposition to the closed systems inducted a new approach to geomorphology.



Arthur Newell Strahler
(1918-2002)



Richard John Chorley
(1927-2002)



Kenneth John Gregory
(1938-2020)



Andrew Shaw Goudie
(1945)

(Source: Schumm (2004) doi: 10.1111/j.1467-8306.2004.00420.x; <https://www.geog.cam.ac.uk/people/chorley/>; <https://rgs-ibg.onlinelibrary.wiley.com/doi/10.1111/geoj.12375>; <https://www.geog.ox.ac.uk/staff/agoudie.html>)

SAQ 2

What are the observations of Herodotus on geomorphic perspective?

1.4 HOW GEOMORPHOLOGY IS RELATED TO OTHER DISCIPLINES?

Traditionally, geomorphology as a distinct branch of knowledge has been a part of the academic disciplines of geography and geology. In many universities it has been a part of the departments of either Geography or Physical Geography. But geology departments across the globe have also incorporated geomorphology as a part of their syllabus in teaching and research. Because of the links between geomorphology and some allied disciplines like pedology, hydrology, marine science and geophysics, it has been included in their syllabus.

Civil engineering makes use of geomorphological knowledge when it comes to construction of dams and water harvesting structures. Civil, hydrological, irrigation and environmental engineers apply geomorphological knowledge like erosion and sediment transportation while working for irrigation canals, slope stability in landslide areas, river training works in the deltaic areas and management of coastal hazards. Glacial movements, glacial lake outburst and snow avalanches often cause extensive erosion and deposition in a short time. These phenomena become extremely important hazards in the high latitudes. Thus geomorphology becomes an important part of glaciology.

Geomorphology has also played a significant role in the disciplines of environmental management. Earth scientists have applied geomorphological knowledge in natural hazard studies and management of landslides, coastal erosion and in the field of glaciology. While geomorphology is related to many other disciplines beyond its domain, there are also many branches and sub-branches within this discipline. The sub-disciplines within geomorphology are historical, tectonic, fluvial, aeolian, glacial, coastal, karst, applied, regional, quantitative, geomorphic hazards so on and so forth. These sub-disciplines are classified by certain distinctions like processes/agents and approaches. Some new branches like hydro-geomorphology, eco-geomorphology, bio-geomorphology or socio-geomorphology are expanding the frontiers of geomorphology making it relevant to the contemporary times.

Soil science or pedology is very much linked to geomorphology because the terrain, landforms and geomorphic processes to a great extent help in understanding soil genesis, distribution and classification. Environmental management is a multi-disciplinary activity where geomorphology plays a very significant role. A few specific roles of geomorphology in environmental management can be seen in the applications to natural hazards like landslides, avalanches, coastal and river bank erosion and its protection, environmental restoration and conservation as well as sustainable development of natural resources. In the process of environmental management, attention is generally given towards understanding

geomorphological processes like weathering, soil erosion by water wind and glacier, flooding and river action, land subsidence and coastal processes.

Marine science and oceanography makes use of the geomorphological methods, approaches and principles in the study of coastal landforms, topography of the ocean bottoms, coral reefs, offshore islands and island arcs. Many geomorphic processes like action of waves, currents and seepage of fluids through the seafloor are associated with the marine environment. Mass wasting along the shore and submarine land sliding in the deep sea are also important processes of marine geomorphology. Ocean basins are the ultimate sinks for a large fraction of terrestrial sediments, thus, erosional and depositional processes and their related forms (e.g., sediment fans, deltas) are the key features of marine geomorphology. In the field of agricultural science, scientists and researchers very often use geomorphology in the evaluation of terrain for land suitability and land capabilities for various agricultural activities.

Geomorphology contributes significantly to the assessment of seismic hazards and its vulnerability and risk. The geomorphological studies applicable to seismic risk assessment are of two types; (a) morpho-neotectonic study and investigations for identifying active tectonic zones and structures; (b) geomorphological and morphometric analyses for identifying the vulnerable situations which amplify or reduce seismic susceptibility. The morpho-neotectonic studies help in identification, detection and characterisation of the lineaments which are very often linked with active tectonic structures. Other important geomorphologic factors that can lead to seismic susceptibility are: slope angle, nature of debris, failure of slopes, paleo-landslides, land slumping and underground cavities. All these geomorphic attributes signifies its link with seismology and management of seismic hazards.

Geomorphological mapping is undergoing radical changes due to technological advancements and availability of high resolution satellite data. As a result, classic paper based geomorphological maps which were used during last 50 years are rapidly getting replaced by digital geomorphic information layers applying GIS. Maps are also being replaced and updated with a very high degree of precision about the location of features and thematic contents by adding more geomorphological details, taken from high resolution elevation data and images. Automatic extraction and classification of geomorphological features from digital elevation models (DEM), new digital visualization and computer assisted GIS techniques have enhanced the field and scope of geomorphology. DEMs are often used as the basis to derive Land Surface Parameters, geomorphic and other ancillary information using pixel based classification alternative to traditional map based superimpositions. Automated classification processes are increasingly useful to extract morphometric, hydrological and geomorphic information. All the above observations signify the interrelationship of geomorphology with remote sensing, GIS, geo-informatics and geospatial technology.

Geomorphology also plays a critical role in two areas of forensic science. Geomorphological knowledge is used in searching objects over the land surface as well as the buried objects and establishing of crime and control

installations. Geo-science and geomorphologic disciplines have substantial work dedicated to the forensic investigations. It is needless to emphasise that the location of a crime in a terrain is important and significance of geomorphology has featured in many works and study of criminalistics and geoforensics of crime. Application of geomorphology has been widely used in military science in studying the terrain, in garrison engineering and troop movements. Recently application of the methods and principles of geomorphology has been widely used in the study and mapping of surface features of extra terrestrial bodies like Moon and Mars. In this way geomorphology has been linked with space science and astronomy.

SAQ 3

How geomorphology important in glaciology?

1.5 SUMMARY

In this unit, you have studied so far:

- What is geomorphology?
- Significance, scope of geomorphology and approaches in geomorphology.
- History of development of geomorphology from ancient time to 1200 AD.
- Nature of Geomorphology during renaissance and post-renaissance period from 1200 to 1800 AD.
- Development of modern geomorphology during the 19th century i.e. from 1800 AD. to 1900 AD.
- Recent developments of Geomorphology in the 20th Century and beyond.
- How geomorphology is related to other disciplines?

1.6 TERMINAL QUESTIONS

1. What is geomorphology? and describe the scope of geomorphology.
2. Explain approaches in geomorphology.
3. Describe the history of development of geomorphology in detail.
4. How geomorphology is related to other Earth Science disciplines?

1.7 ANSWERS

Self-Assessment Questions (SAQ)

1. a) (1) Landscape processes operate differentially and (2) the landscapes are often complex.
b) Different climates initiate and influence different processes and produce different types of landforms.

2. Herodotus is known for his observations on evolution of the Nile delta by river deposits. Based on the fossil evidences he could able to conclude that the sea level rise must have gone much inside Egypt.
3. Glacial movements, glacial lake outburst and snow avalanches often cause extensive erosion and deposition in a short time. So, landform study can help in understanding glaciology.

Terminal Questions

1. Geomorphology is the scientific study of landforms. Refer to Section 1.2.
2. Refer to Sub-Section 1.2.4.
3. Refer to Section 1.3.
4. Refer to Section 1.4.

1.8 REFERENCES AND SUGGESTED FURTHER READING

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BASIC POSTULATES IN GEOMORPHOLOGY

Structure

2.1	Introduction	2.6	Summary
	Expected Learning Outcomes	2.7	Terminal Questions
2.2	Geologic Time Scale	2.8	Answers
2.3	Catastrophism	2.9	References and Suggested
2.4	Uniformitarianism		Further Reading
2.5	Fundamental Concepts		

2.1 INTRODUCTION

Geomorphology is the study of landforms, their origin, description, classification and its application in human welfare. The word “geomorphology” was first coined and used between the 1870s and 1880s to describe the morphology of the surface of the Earth. The contributions of Hutton, Davis, Gilbert, Strahler and many more played a key role in setting a conceptual base to the modern geomorphology.

Over billions of years, the Earth has gone through many changes in its morphology and structure through its internal and external forces. The meteoritic impact, earthquake and volcanic activities, and erosional processes of rivers, winds, glaciers, oceans, etc. along with the sea floor spreading and plate tectonics have been constantly operating to shape the Earth. While many of these activities occurred during a short time span, some of the processes had taken millions of years to create various morphological systems. All of these processes are still going on and shaping our Earth. In the ancient and classical times, Greek and Roman scholars like Aristotle, Ptolemy, Herodotus, Strabo and many others speculated and discussed about the origin of the mountains, valleys, deltas, etc. Thus, the study of these geomorphic forms and processes has been critical to understand surface of the Earth. In the early stage of development of geomorphology, many concepts and theories put forth by the geomorphologists have undergone sea changes in the latter times, in their basic postulates. But however, many of the concepts and theories mark the surges that have characterized and shaped the discipline and have yet remained significant still.

This unit makes an attempt to present before you some of the classical concepts of the past and present and their relevance in shaping and evolving the field and scope of geomorphology. This unit tends to bring before you a basic understanding of the geological time scale to relate the major events of landform evolution, stratigraphic succession of rocks and their fossil characteristics. This unit is also going to discuss the classical concepts of neptunism verses plutonism, and catastrophism verses uniformitarianism which laid a foundation to the development of geomorphology. At the end of this unit, you will find a discussion on the fundamental concepts of geomorphology which are mostly found relevant for the modern geomorphology of the recent times.

Expected Learning Outcomes

After studying this unit, you will be able to:

- Understand about the geological time scale, formation of major landforms and evolution as well as disappearance of life forms;
- Describe the basic concepts of catastrophism and uniformitarianism in explaining the origin of landforms; and
- Describe the significance of fundamental concepts governing the origin and evolution of landforms over the Earth's surface.

2.2 GEOLOGIC TIME SCALE

Geologists have classified the Earth's history into a number of time intervals of different length of time depending on the major events in the life history of the Earth depending on the evidences of the fossils. The geological time scale presents the history of the Earth divided in a hierarchical set of divisions of geologic time based on geochronology and dating of the sequential events throughout the Earth's history. The historical idea of geological time scale came from the miners of UK who were trying to know the rock sequences of different times. In 1669, its first idea came from Nicolaus Steno. Subsequently it came from a surveyor and amateur geologist named William Smith, who produced a geologic map of England through faunal succession. The accepted divisions of the scale of geological time are age, epoch, period, era and eon. It has been established by the geologists adopting the principles of relative dating of landform features and their stratigraphic successions. The principles followed in making the geological time scale is as follows.

- **Principle of Superposition:** In sedimentary strata, each layer of rock is younger than the one below it and older than the one above it.
- **Nature of Horizontality:** Sediment layers are normally deposited horizontal to the surface.
- **Relationship of Cross-Cutting:** An intrusion or a fault in the layer of rocks is younger than the rocks affected by it.
- **Inclusions:** The included materials in a mass of rock are younger than the mass of rocks containing the intrusions.
- **Unconformities:** Interruptions in the process of sedimentation in the rock strata indicates a gap of material and time.

- **Basis of Fossil Succession:** Fossils of different organisms are found in succession with respect to one another in an orderly manner from older to younger rocks and help to establish the living period of the organisms as well as period of deposition of Earth materials.

The boundaries of the geologic time scale indicate the origin or extinction of a particular type of species of fauna or flora. For example, if you find a dinosaur fossil from a rock, it will indicate that the rock is of Mesozoic era and Jurassic epoch during which dinosaurs lived. Different periods in the geologic time scale have been classified based on different types of fossils found during different time periods of the Earth's history.

It is important to note that the world stratigraphical community has tried for a single, universal time divisions and terms for the same. While most of the geologists have agreed on the divisions of **eon**, **era** and **periods**, at the lower hierarchical levels, local terms have been used to represent different environments of deposition. Fossils are used to correlate formation/deposition of Earth materials in different parts of the globe. You may refer to Fig. 2.1 for understanding the Geologic time scale.

A) EON

Geological time scale has been divided into four major time divisions called eons. These are 1) Hadean (4570 to 3850 Ma), 2) Archean (3850 to 2500 Ma), 3) Proterozoic (2500 to 541 Ma), and 4) Phanerozoic (540 Ma to present). The initial three eons such as Proterozoic, Archean and Hadean represent nearly ninety percent of the history of the Earth.

(1) Hadean Eon (4500 - 4000 Ma)

Dating (Radiometric) of the meteorites and oldest rocks had indicated that the Earth is nearly 4500 Ma (Million years) old. During this time, there were a lot of meteorite bombardments on the surface of the Earth. The rocks of this eon have no evidence of any life forms.

(2) Archean Eon (4000 - 2500 Ma)

Archean eon represents the Earth between 4000 to 2500 Ma. The prokaryotic life forms like blue-green algae and bacteria are the evidences found from the rocks of this Eon. During the Archean Eon, evidences in the form of stromatolites of 3500 Ma old were also noticed from different parts of the Earth.

(3) Proterozoic Eon (2500 - 541 Ma)

This eon has carried the evidences of multi-cellular organisms in the form of trace fossils like worm trails and worm holes. Geologists are of the opinion that the life forms of this eon have lacked shells and these rocks were devoid of coal, oil or natural gas. But rocks formed during this Eon contained iron ore formations in the form of hematite (Fe_2O_3) in different parts of the Earth. The most common fossils found in the rocks of this eon are stromatolites formed by the blue green algae and bacteria.

Eon	Era	Period	Epoch	MYA	Life Forms	North American Events			
Phanerozoic	Cenozoic (CZ)	Quaternary (Q)	Holocene (H)	0.01	Age of Mammals	Extinction of large mammals and birds Modern humans	Ice age glaciations; glacial outburst floods		
			Pleistocene (PE)				Cascade volcanoes (W) Linking of North and South America (Isthmus of Panama)		
		Neogene (N)	Pliocene (PL)	2.6		Spread of grassy ecosystems	Columbia River Basalt eruptions (NW)		
			Miocene (MI)	5.3			Basin and Range extension (W)		
			Oligocene (OL)	23.0					
		Paleogene (PG)	Eocene (E)	33.9		Early primates	Laramide Orogeny ends (W)		
			Paleocene (EP)	56.0					
							66.0	Mass extinction	
			Mesozoic (MZ)	Cretaceous (K)				Age of Reptiles	Placental mammals
						145.0	Early flowering plants		Sevier Orogeny (W)
	Jurassic (J)			Dinosaurs diverse and abundant	Nevadan Orogeny (W) Elko Orogeny (W)				
					201.3	Mass extinction First dinosaurs; first mammals Flying reptiles	Breakup of Pangaea begins		
	Triassic (TR)								
	Paleozoic (PZ)			251.9	Mass extinction	Sonoma Orogeny (W)			
		Permian (P)		Age of Amphibians	Supercontinent Pangaea intact				
					298.9	Ouachita Orogeny (S) Alleghany (Appalachian) Orogeny (E) Ancestral Rocky Mountains (W)			
		Pennsylvanian (PN)			Coal-forming swamps Sharks abundant First reptiles	Antler Orogeny (W) Acadian Orogeny (E-NE)			
						323.2			
		Mississippian (M)			Mass extinction First amphibians First forests (evergreens)				
						358.9			
		Devonian (D)			Fishes				
						419.2			
		Silurian (S)			Marine Invertebrates	First land plants Mass extinction Primitive fish Trilobite maximum Rise of corals Early shelled organisms	Taconic Orogeny (E-NE) Extensive oceans cover most of proto-North America (Laurentia)		
			443.8						
		Ordovician (O)		485.4					
		Cambrian (C)							
					541.0				
	Proterozoic					Complex multicelled organisms	Supercontinent rifted apart Formation of early supercontinent Grenville Orogeny (E)		
						Simple multicelled organisms	First iron deposits Abundant carbonate rocks		
	Archean		Precambrian (PC, W, X, Y, Z)		2500				
						Early bacteria and algae (stromatolites)	Oldest known Earth rocks		
	Hadean				4000	Origin of life	Formation of Earth's crust		
					Formation of the Earth				

(4) Phanerozoic Eon (541 Ma to Present)

The Phanerozoic Eon refers to a geologic time when there was "visible life". Phanerozoic rocks are the most common rocks bearing evidences of various life forms. During this Eon majority of the macroscopic organisms like plants, animals, algae and fungi had flourished on the Earth. The animals evolved during this time appeared with external skeletons, outer shells and also vertebrates in its later phase.

B) ERA

The Phanerozoic Eon has been divided into Paleozoic, Mesozoic and Cenozoic era. The three eras come with a "zoic" suffix which means with a zoological basis. The Pre-Phanerozoic time is usually referred as the Precambrian which has been divided into three eons as Hadean, Archean and Proterozoic. During the three eras of Phanerozoic, major changes have taken place in the composition of faunas. Each of the three eras are characterized by the dominance of a particular group of animals. These three eras Cenozoic, Mesozoic and Paleozoic are generally referred to as the "Age of Mammals", "Age of Dinosaurs" and the "Age of Fishes", respectively although other groups of animals and plants lived during these three eras.

1) Paleozoic Era (541 - 252 Ma)

Palaeozoic era is referred as the primary era in the geological history of the Earth. It comprises six different periods known as Cambrian followed by Ordovician, Silurian, Devonian, Carboniferous and Permian. Characteristics of each of these periods are described below.

- 1.1 Cambrian Period (541 - 485 Ma):** Cambrian Period is the beginning of the Paleozoic era. The beginning of the Cambrian period was marked with the evolution of the first organisms with shells. Trilobites, the mud-burrowing scavengers are considered as the index species of this Period. The Cambrian Period was dominated by the emergence of a large number of multi-cellular animals which is referred to as the "Cambrian Explosion" of invertebrates. The fossils of these multi-cellular animals are found in the rocks of this period.
- 1.2 Ordovician Period (485 - 444 Ma):** This period is known as the "Years of Invertebrates". Trilobites were one of the abundant species of this period. In this period, brachiopods and large cephalopods thrived in great abundance than those of the trilobites. For the first time fishes started appearing during this Ordovician period.
- 1.3 Silurian Period (444 - 419 Ma):** The first land plants started appearing during this Silurian Period. The presence of fossils of corals, brachiopods, trilobites and graptolites reveal the dominance of these animals during this period. It is also known as the "Age of Fishes" due to their abundance.
- 1.4 Devonian Period (419 - 359 Ma):** This Period is also referred as the "Age of Fishes" due to its dominance. Primitive sharks, insects and land plants evolved during this period. By the end of the Devonian, fossil evidence suggests the growth of forests. This period also saw

the evolution of the lung fishes, lobe-finned fishes and true air-breathing amphibians.

1.5 Carboniferous Period (359 - 299 Ma): The Period was marked by the appearance of the first reptiles on the surface of the Earth. This Carboniferous period saw the evolution of large tropical swamps across the globe and specifically these swamps of North America, Europe and Siberia have become the source of large coal deposits of the world. During the Carboniferous Period, Britain was close to the equator. Limestone deposits carrying fossils of corals, brachiopods and trilobites thrived in shallow seas during this period. Some geologists have also attempted to divide the carboniferous period into Pennsylvanian and Mississippian periods.

1.6 Permian Period (299 - 252 Ma): The first fossils of this period were discovered from the Perm region of Russia by geologist Roderick Murchison in 1841. The name Permian has been adopted after the discovery of the fossils from the region of Perm. This Permian and Carboniferous periods are popularly known as the "Age of the Amphibians". Towards the end of the Permian Period the dominant trilobites and many more marine species started becoming extinct. This "Great Paleozoic Extinction" was one of the greatest of five major extinctions on the Earth's surface during the past 600 million years. Theory of plate tectonics suggested that by the end of this Permian Period, all the continents were together as one super continent called Pangea which subsequently started breaking and spreading into the present configuration.

2) Mesozoic Era (252 - 66 Ma)

This era consists of three distinct periods i.e. Triassic, Jurassic and Cretaceous. This era is popularly known as the "Age of Reptiles" as well as evolution and extinction of the Dinosaurs family of the Earth.

2.1 Triassic Period (252 - 201 Ma): This period was characterized by the predominance of Dinosaurs species across the globe. The geologic formations of this period are characterized by mudstones and red sandstone. Lack of fossils in these rocks is suggestive of a land environment during this period. Geologists have inferred that the formations of mudstones, salt and sandstones in the river valleys, lakes and deserts during this period would have been due to a prevailing hot climate and dry environment.

2.2 Jurassic Period (201 - 145 Ma): The fossil evidences of this period established the fact that the dominant species of this time were Dinosaurs, reptiles and birds. During early Jurassic period, the super continent "Pangea" started breaking and the Atlantic Ocean started opening with the west ward shifting of both the Americas. The westward moving Atlantic plate started overriding the Pacific plate. The subducting Pacific plates led to the formation of the western Rocky and Andes mountains.

2.3 Cretaceous Period (145 - 66 Ma): The Cretaceous period has been well known because of the major extinction event towards the end of

this period and has marked the end of the dinosaurs' family from the Earth's surface. During this period in fall of a large meteorite led to the formation of huge impact crater named Chicxulub in Yucatan Peninsula of Mexico. The Cretaceous period also experienced the evolution of first flowering plants on the surface of the Earth.

3) Cenozoic Era (0 - 66 Ma)

This era consists of two distinct periods i.e. Tertiary and Quaternary. The Tertiary period again is divided into two periods of Paleogene and Neogene.

3.1 Paleogene Period (66 - 23 Ma): It is the early part of the Tertiary. Before the Paleogene major extinction of species of plant and animal life has taken place on the Earth which includes more than half of the plant and animal species of the world and the entire dinosaur families. This period has been further subdivided into the Paleocene Epoch (66-56 Ma), the Eocene Epoch (56-33.9 Ma), and the Oligocene Epoch (33.9-23 Ma). During this Palaeogene Period, Britain was in a lower latitudinal zone having a warm climate. Gradually Britain turned cool when it drifted to the present location.

3.2 Neogene Period (23 - 2.6 Ma): The Neogene period is further subdivided into the Miocene and Pliocene epochs with time span ranging from 23 to 5.3 Ma and 5.3 to 2.6 Ma, respectively.

3.3 Quaternary Period (2.6 Ma - 0): The Quaternary Period is further divided into the Pleistocene Epoch from 2.6 to 0.01 Ma and the most recent Holocene Epoch from 0.01 Ma to the Present. By the beginning of the Quaternary Period, major plate tectonic movements and there were many modifications in the distribution and spread of continents. Glaciation and erosion processes were dominant in this period. Human beings emerged during this Period. By the end of Quaternary, glaciers covered the middle and north of Britain, shaping the landscape we see today.

SAQ I

Till now we have discussed about the geological time scale. Can you explain?

- a) What is the basis on which the geologic time scale has been framed?
 - b) What are four Eons?
-

2.3 CATASTROPHISM

Catastrophism states that the origin of the Earth's surface features are mostly due to sudden, short duration violent events and related processes like cataclysmic earthquakes, volcanic eruptions and severe floods. The theory of catastrophism postulates that Earth, since its origin has gone through long periods of stability followed by sudden events which can explain the origin of major landforms as well as extinction of flora and fauna.

Historical Background to the Theory: This theory was a pre 19th century postulation of the geologists who believed that catastrophes like Biblical

floods were responsible for most the Earth's fossiliferous rocks. The French zoologist Baron Georges Cuvier popularised this theory of catastrophism in early 19th century based on the palaeontological evidences from Paris Basin. He used this theory to explain the major biological and geological changes in the history of the Earth. While observing the stratigraphic records of the Paris Basin, Cuvier observed several gaps in the succession of fossil records of the rock layers. Cuvier found several gaps where all evidences of life would disappear and then abruptly reappear again after a period of time. Cuvier believed that these gaps in the fossil succession in the rock layers were due to sudden events of mass extinction which led him to propose the theory of catastrophism.

Catastrophism explains that mountain ranges are formed due to the sudden and massive upliftment over the Earth's surface by earthquakes or volcanic eruptions. This theory was advocated when the European culture was revolving around Christianity and the scientific community were made to believe in the writings of the Bible and its stories of catastrophic floods. During this time the astronomic community was also made to believe in the static universe adhering to the religious sentiments of the prevailing time.



Baron Georges Cuvier (1769-1832)

He postulated in his Essay on the "Theory of the Earth" (1813) that now-extinct species were wiped out by periodic catastrophic flooding events. Cuvier therefore became the most important proponent of catastrophism.

(Source: https://en.wikipedia.org/wiki/Georges_Cuvier)

During those times, geologists felt that they had to go with the Bible. They also believed that the surface of the Earth is sculptured by rapidly on-setting catastrophic events. This theory was supported by Abraham Werner, a leading geologist of the 18th century who had proposed the theory of **Neptunism**. In his theory of Neptunism he advocated that most of the rocks formed over the Earth's surface must have precipitated out of a vast ocean. Before the theory of Neptunism, Abbé Anton Moro, proposed a theory called **Plutonism** which was propagated by the famous geologist James Hutton. This theory was named after the Roman god of the underworld Pluto. The theory stated that igneous rocks of the Earth were formed due to intrusive magmatic activity. Subsequently weathering and erosion of these rocks led to the formation of sedimentary rocks by deposition of these weathered

materials on the sea floor with compaction under heat and pressure. But both these theories got discarded in the 19th century in the light of many evidences on the contrary.

2.4 UNIFORMITARIANISM

In opposition to the views of catastrophism, non-catastrophic view of the Earth's geology began to evolve which believed that gradual processes and uniform intensities were responsible for the origin and evolution of varied landforms over the Earth's surface. James Hutton (1726-1797) was born in Edinburgh and studied medicine and chemistry at the Universities of Edinburgh, Paris, and Leiden, in the Netherlands. Hutton's key concept was the Theory of Uniformitarianism published in 1788.

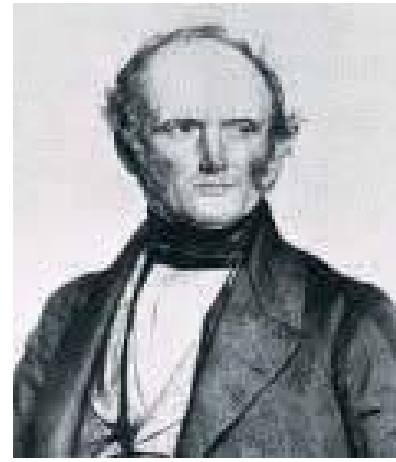
Uniformitarianism is one of the fundamental principles of Earth Science. According to this hypothesis, the forces and processes observable at surface of the Earth-barely noticeable to the human eye, yet immense in their impact-are the same that have sculpted the planet's landscape throughout natural history. The gradualistic idea that "the present is the key to the past" has been a part of uniformitarianism. This means that current rates of processes like erosion and sedimentation are comparable to past rates, making it easy to calculate how long it would have taken to deposit a specific thickness of sandstone, for example. Such study made it clear that extremely long epochs were needed to explain the thicknesses of exposed rock layers.

Scientist John Playfair (1748-1819) later improved Hutton's work and geologist Charles Lyell (1797-1875) popularized it. John Playfair's book "Illustrations of the Huttonian Theory of the Earth", which summarized James Hutton's work, is what made him most famous.

The seminal book "Principles of Geology" published in 1830 by Charles Lyell, who was born the same year Hutton passed away and whose work helped popularize the *Theory of Uniformitarianism* later. Hutton's theories, which were also, gave a framework for biological evolution based on the fossil record used by Charles Darwin. Darwin used uniformitarianism as evidence for his idea of how new species appear. The evolution of life or extinction required a long period of time as like mountains to build up and erode away. The cornerstone of contemporary geography and Earth Science was laid by Lyell and Hutton's combined efforts.

In his book "Theory of the Earth", James Hutton states, "We find no vestige of a beginning - no prospect of an end". The idea that the Earth must be so immensely old that the mind cannot even begin to fathom its length was initially put out by Hutton. Today, it is believed that Earth's history has been a lengthy, steady process, occasionally interrupted by catastrophic natural occurrences.

Lyell was fundamentally responsible in establishing the popularity and credibility of geology as a science in the nineteenth century. He challenged the idea of catastrophism and propagating the idea of uniformitarianism, which is still a dominant theory in Earth Science.

**James Hutton (1726-1797)****Charles Lyell (1797-1875)**

(Source: <https://commons.wikimedia.org/w/index.php?curid=21865717>;
<https://www.sciencephoto.com/media/717890/view/sir-charles-lyell-british-geologist>)

The theory of Uniformitarianism states that the processes by which current geological features were created were slow, steady, and constant. These forces, processes, and patterns have always been and will always be present on the Earth. Uniformitarianism is also known as the **Doctrine of Uniformity** or the **Uniformitarian Principle**. This theory assumes that the same natural laws and processes that operate in our present-day scientific observations have always operated in the universe in the past and apply everywhere in the universe. In his theory he advocated for three principles in explaining the origin and evolution of landforms over the Earth's surface.

- a) The uniformity of law: the uniformity of process (actualism),
- b) The uniformity of rate (gradualism), and
- c) The uniformity of state (steady state).

Although it got the acceptance of many Earth scientists as the first principle of scientific research, many scientists disagreed considering that nature is not absolutely uniform, even though it does exhibit certain regularities.

Theory of Uniformitarianism

Charles Lyell's theory of uniformitarianism is distinctly different from the theory of uniformitarianism as it exists today. Lyell's theory was on the basis of the work of several previous geoscientists like James Hutton, who was the first scientist to suggest that the Earth had been created through slow, constant processes. Lyell was one of the ardent supporters of this theory.

Lyell's theory was based on four basic principles given below.

- **Uniformity in Processes:** The same processes that have created this physical world will continue steadily as long as the Earth exists.
- **Uniformity of Rate:** The processes have operated at the same rate throughout the geologic history of the Earth.
- **Uniformity of State:** The surface features will continue to be in a uniform state as it is now because geologic processes have been extremely slow.

- Uniformity of Law: The nature's laws normally remain constant across space and time.

Today the gradualistic concept has been accepted as a part of uniformitarianism. But, now many geologists no longer accept a strict gradualism. It has been accepted that "the present is the key to the past". Although the processes must have been same, their intensities must have differed. Today, it is accepted that the processes operated over the Earth have been a slow and gradual with occasional catastrophic events.

Uniformitarianism vs Catastrophism

The theory of uniformitarianism is in contrast with the theory of catastrophism. Catastrophism regards Earth's geological history as being relatively stable with intermittent and abrupt events of cataclysms. On the contrary, uniformitarianism explains that actions that change Earth's crust are continuous and uniform processes such as weathering, sedimentation, erosion, continuous and periodic volcanism, earthquakes, and other events associated with the theory of plate tectonics. When uniformitarianism was popularized, scientists essentially wanted to distance themselves from religion and theories concerning cataclysms.

Features	Uniformitarianism	Catastrophism
Small and Large Processes	Earth's features are due to small scale processes	Earth's features are due to large scale processes
Geological Time period	Earth's features are accounted over a large period of time	Earth's features are accounted over a relatively short period of time
Geological Processes	Due to slow and steady geological processes of erosion, deposition, compaction and upliftment.	Due to geological processes like great floods and rapid formation of greater mountain chain
Theological Influence	Not influenced by theology	Influenced by theology

Uniformitarianism explains that processes that happen today (erosion, weathering) happened in the same way and at the same rate since the beginning of the Earth. That means geologic time is extremely slow. Catastrophism explains that all geologic processes happened all at once (volcanic eruptions). Thus, this is the key difference between uniformitarianism and catastrophism. However, modern scientists have a more integrated view of geological events, reflecting acceptance of some catastrophic events along with gradual changes.

In the above section we have discussed about the concepts of Catastrophism and Uniformitarianism. Let us answer the given question below.

SAQ 2

How catastrophism different from uniformitarianism?

2.5 FUNDAMENTAL CONCEPTS

Geomorphology is the science of landforms. The wide variety of landforms of different shape, size, composition, structure in different locations and different environments had intrigued the human mind regarding their genesis and distribution. Scientific speculations on their origin and evolution have been a subject matter of inquisitiveness for the Earth scientists since the ancient and classical times of Greek and Romans. Gradually, with the contributions from the scientists based on their field observations and laboratory experiments, geomorphology has evolved as an independent field of knowledge. Simultaneously the subject as a branch of natural sciences built up its foundation enriching itself with contributions from different scientists through their ideas, concepts and theories.

With the advancement of scientific observations, real time data bases, computer simulated models and piling of evidences, many of the ideas, principles, concepts and theories had changed over time. Some of those had become obsolete and many of those have also been improved strengthening the foundation of geomorphology. In this entire process of evolution of subject knowledge of geomorphology some of the fundamental concepts and theories well known and accepted by the majority of the geomorphologists are described below. The book "Principles of Geomorphology" by W.D. Thornbury (1900-1986) does indeed have a comprehensive sequence of development of the geomorphological concepts.

Concept 1: 'The same physical processes and laws that operate today operated throughout geologic time although not necessarily always with the same intensity as now'.

Concept of uniformitarianism has given rise to this fundamental principle. Origin of this principle dates back to the period of James Hutton who propagated the idea that "the present is the key to the past" and geologic processes must have operated on the Earth throughout with an intensity as it is now. But when we look at the process over the Earth's surface, it is distinctly visible that glaciers were more active during the Pleistocene than now. Climatic processes have been different from the present time in different parts of the globe throughout the geologic history of the Earth. Regions which are humid have been deserts and present deserts have been humid in the past. There are numerous examples which reveal that the geologic processes had varied throughout the geologic time.

In the initial phase of the Earth, vulcanism and earthquakes were more intense than now. This concept connotes that the streams must have cut their valleys in the past as it is going on now. The glacial valleys formed during the Pleistocene are no different from the present glacial valleys. It is needless to point out that the coastal winds which developed sand dunes in the past obeyed the same laws of wind movements as of now. That means, the laws of dynamics of various processes and agents being universal, there are evidences of changing intensities.

Concept 2: 'Geologic structure is a major controlling factor in the evolution of landforms and the significance of structure is reflected in them'.

This fundamental principle has its origin in the Davis's theory of Cycle of Erosion. He postulated that the structure, process and stage are the major controlling factors in the evolution of the landforms. But now a day's geomorphologists doubt about the validity of stages of youth, maturity and old age but there is no contradiction for the control of structure and process. Penck argued and explained in his theory of pan planation that landforms are the product of structure, process and time. Geomorphologists like L.C. King, Walther Penck, A. N. Strahler, William Hack and many others have opposed the idea of stage as a controlling factor of landform evolution. Rather there was a general agreement that process and materials together under varying conditions control and modify the morphology of the landforms.

Concept 3: 'To a large extent, the Earth's surface possesses relief because the geomorphological processes operate at differential rates'.

This fundamental concept tends to believe that the Earth's surface exhibits varied relief because geomorphic processes operate at differential rates in different parts of the globe. There are ample evidences that the rivers cut their valleys at differential rates producing varied relief over the Earth's surface depending up on terrain, slopes, rocks and structural controls in different climates. The main reason of differential gradation on the surface of the Earth is due to different lithology and structure offering differential resistance to the aggradational and degradational processes. Very often topographic relief variations are reflect differential composition and structures of the rocks even though the gradational processes are same over different regions. It has been assumed that areas with topographically higher altitude are underlain by 'hard' rocks and those which are low by 'soft' rocks. Although lithology and structure are major controlling factors for differential wasting of rocks, these are not the only reasons for variation of relief on the Earth's surface. There are other local factors like altitude, temperature, rainfall, exposure and vegetation cover which can affect intensity of processes leading to differential relief.

Concept 4: 'Geomorphological processes leave their distinctive imprints upon landforms and each geomorphic process produces its own unique assemblage of landforms depicting the evidences of the processes'.

The term geomorphic processes refer to the physical and chemical actions by which morphology of the Earth's surface undergoes changes. Just like plants and animals have their distinctive morphological traits so also, landforms carry their distinguishing features depending on processes of involved in their formation. That means, if a landform is identified, process or agent responsible for its formation can be identified. Alluvial fans and deltas carry the imprints of the action of streams. Sinkholes and caverns reveal the evidences of action of groundwater. The shape of the valleys from the glacial and riverine environment reveals the evidences of their respective agents and their characteristic processes.

Concept 5: 'As the different erosional agents act upon the Earth's surface, there is produced an orderly sequence of landforms having distinctive characteristics at the successive stages of their development'.

The idea of distinctive characteristics of landforms in different stages of their development was stressed by W. M. Davis in his theory of geomorphic cycle. In his theory he put forth the idea that different erosional agents produce an orderly sequence of landforms through three different stages i.e. youth, maturity, and old age. Many critics like Walther Penck and C.A.M King had pointed out that it is hard to believe that the topographic features evolve through sequential stages. It has also been further stressed that landforms can evolve based on the processes and time rather than the stage. It has also been observed that in tectonically active areas like California and New Zealand, it is difficult to see sequential landform development. In areas of continuing uplift or repeated intermittent uplift, landforms may not find time to complete the normal cycle of erosion. If there is stability, sequential development of landforms passing through youth, mature and old stages, is possible. But, Earth's surface had never been stable for long periods of time facilitating sequential development of landforms.

Concept 6: 'Complexity of geomorphic evolution is more common than simplicity'.

This fundamental principle conveys an idea that most of the landforms produced over the Earth's surface are more complex due to the simultaneous actions of many agents and their processes with varied structure and lithology. Although there are many landforms which can be attributed to the action of some single agent and process but most of the landforms are attributed to multiple geomorphic processes. So it is more normal to believe and even be argued that by and large landforms are compound and complex in nature.

It is needless to mention that we designate some landforms as a product of running water although we realize fully well that weathering, mass wasting, erosion and other processes may have contributed to its development simultaneously. It has also been noticed that over glaciated areas there are upland tracts carrying original glacial characteristics, yet there are river cut valleys and terraces formed due to the action of running water as examples of compound landscapes evolving under different set of climatic situations. Thus, most of the topographic features carry the evidence of the action of multiple agents and processes in its evolution.

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

Earth scientists of present time believe that the present topography of the Earth's surface is probably a product of the Pleistocene and subsequent period. They also believed that little of it is older than tertiary. Geological history reveals that origin of the Himalayan mountain system started during Cretaceous and subsequent folding took place during Eocene and Miocene period. But its present form and topography can be related to all those endogenetic and exogenetic forces and processes of the Pleistocene or later

in age superimposing and obliterating the pre-Pleistocene-Tertiary landscape. The climatic fluctuations and tectonic disturbances during Pleistocene have far reaching implication in shaping the present landscapes.

Most of the Earth scientists believe that the present day landforms such as mountain cliffs and valleys, lakes and shores, canyons and coasts are of post-Miocene time. It has been estimated that at least 90 percent of the present landscapes are products of post-Tertiary time and 99 percent is of post-middle Miocene in age. Around the margins of the Pacific ring of fire, diastrophism during Pleistocene time has played a significant role in shaping the landscape around it.

Concept 8: 'Proper interpretation of present-day landscape is impossible without a full appreciation of the manifold influences of the geologic and climatic changes during the Pleistocene'.

In the geological history of the Earth, there is a far-reaching effect of Pleistocene epoch on the present-day landscapes. Glaciation of this time has affected many parts of the globe but the effects of glaciations are also felt far away from the glaciers. Outwash plains of the glaciers and glacial till deposits had covered many parts of the non-glaciated areas of the Earth's surface.

Effects of the glacial climate were profound across the mid-latitudes of the globe. There are evidences that many areas of humid climate have changed over to semiarid or arid climates during the Pleistocene time. Besides glaciations of the Pleistocene, we are aware of the diastrophism of the Pliocene which continued into the Pleistocene and present time. Diastrophic activities around the plate boundaries have brought many changes in the present day landscapes. Hence it has become fundamental to the geomorphologists that understanding present day landscape is not possible without understanding the influence of the climatic and geological changes in Pleistocene.

Concept 9: 'An appreciation of world climates is necessary for a proper understanding of the varying importance of the different geomorphic processes'.

Elements of climate like temperature, precipitation and wind etc. have been considered as the drivers of many geomorphic processes. Hence, climatic variations are some of the important factors which affect the functioning of geomorphic processes. The amount of rainfall, snowfall, temperature and wind speed directly affect the magnitude of erosion and intensity of weathering and mass wasting. The amount of rainfall which controls the type and distribution of natural vegetation indirectly influences the intensity of erosion. Climate has changed over the Earth throughout its geological history and has been responsible for initiation of different agents and geomorphic processes. Right from its origin, geomorphology has remained as an interface between geology and geography. Geologists focus more on rocks and minerals and geographers focus more on human and environment. This fundamental principle brings in to focus that appreciation of world climate and its changes seems necessary for proper interpretation of the landscape evolutionary process.

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

Geomorphology is basically the study of landforms, their origin, evolution, description and classification. It is primarily concerned with the study of the landforms of the present time which are actually a result of long time action of processes and agents. So, the present day landscapes are basically products of long history. As a result, geomorphologist adopt to a historical approach to unravel their geological past. Although geomorphology deals with the present day landscape, historical extension of the geomorphic investigations often leads to a meaningful conclusion. For example if you want to study the landforms of the Himalayas or of the Aravalli Hills, understanding its geological past is likely to bring greater relevance to the understanding of the present day landforms.

SAQ 3

Discuss “Geomorphic processes leave their distinctive imprints over the landforms”.

2.6 SUMMARY

In this unit, you have studied so far:

- The significance of the geologic time scale and its utility in geomorphology.
- The classical concepts of catastrophism and uniformitarianism and its acceptance in the present context.
- You must have also understood the most fundamental principles of geomorphology which governs the origin and evolutionary processes of landforms.

2.7 TERMINAL QUESTIONS

1. Give a brief account of the Geologic Time scale of the Earth explaining the fossil characteristics of different periods.
2. Discuss the significance of uniformitarianism in modern geomorphology.
3. Elucidate the stanza given in the quote with suitable examples
“Geologic structure is a dominant controlling factor in the evolution of landforms?”

2.8 ANSWERS

Self-Assessment Questions (SAQ)

1. a) The principles of relative dating of landform features and their stratigraphic successions studied in making the geological time scale.

- b) 1) Hadean (4570 to 3850 Ma), 2) Archean (3850 to 2500 Ma), 3) Proterozoic (2500 to 540 Ma), and 4) Phanerozoic (540 Ma to Present).
2. Catastrophism regards Earth's geological history as being relatively stable with intermittent and abrupt events of cataclysms. On the contrary, uniformitarianism explains that actions that change Earth's crust are continuous and uniform processes such as weathering, sedimentation, erosion, continuous and periodic volcanism, earthquakes, and other events associated with the theory of plate tectonics.
 3. Geomorphic processes are the physical and chemical actions that affect the shape of the Earth's surface. Alluvial fans and deltas, for example, bear the marks of stream activity. The valleys' shapes offer evidence of their respective agents and their distinctive processes.

Terminal Questions

1. Refer to Section 2.1.
2. Refer to Section 2.2.
3. Refer to Section 2.3.

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GEOMORPHIC SYSTEMS AND CONCEPTS

Structure

3.1	Introduction	3.5	Summary
	Expected Learning Outcomes	3.6	Terminal Questions
3.2	General Systems Theory	3.7	Answers
3.3	Form and Process in Geomorphology	3.8	References and Suggested Further Reading
3.4	Concept of Equilibrium in Landform Evolutionary Process		

3.1 INTRODUCTION

The concept of 'System' or 'General Systems Theory' has been used for a long time in physical sciences, particularly in thermodynamics. Von Bertalanffy is one of the pioneers who worked on this concept and also is one of its greatest exponents. Later this concept has also been applied in natural sciences, particularly life sciences. During 1950s and '60s, several attempts have been made by several geomorphologists including Strahler (1950 & 1952), Culling (1957), Hack (1960), Chorley (1962) and Howard (1965) to apply general systems theory to the study of geomorphology.

Geomorphology is the scientific study of the Earth's landforms. By the mid-twentieth century, general systems theory had become an element of geomorphological research. This hypothesis introduced a novel concept and method of inquiry to the study of landform evolution. It perceived the geomorphic evolution as the result of an assemblage of landforms linked in a system, with several components organised in a structural hierarchy, interacting between their units and subunits, exchanging mass and energy with the surrounding environment, and changing towards a steady state or equilibrium.

In this unit, you will understand how the genesis of landforms has shifted from the classical approach of cyclic evolution to systems approaches as a result of scientific advances in parlance with the other areas of science. You will

also learn about "form and process geomorphology," a novel way to studying landform evolution and change. You will also learn more about how the concepts of equilibrium and steady state, as well as geomorphic threshold, complex response system, and dynamic equilibrium, play a role in understanding the origin and morphological disposition of landforms.

Expected Learning Outcomes

After studying this unit, you should be able to:

- Understand General Systems Theory, its characteristics and significance;
- Describe what is systems approach in geomorphology?
- Explain the emergence of form and process studies in geomorphology; and
- Elaborate the concept of equilibrium in the evolution of landforms.

3.2 GENERAL SYSTEMS THEORY

General Systems Theory was put forward by Austrian biologist Karl Ludwig von Bertalanffy in early 1930s. He formulated this theory to explain a behaviourism model of stimulus-response to establish a causal reductionism. The theory states how to see a whole thing in different parts and to see how the parts are interlinked and function together in a system. This theory is often referred to as the theory of open systems or System Theory. It is based on the concept that the system is an interlinked complex of different elements. The theory is to provide a basis of studying the principles and interrelationships of interrelated components within a system. After the emergence of this theory, many scientists from many disciplines of science and social science began to see its applicability to their own fields. Systems are often viewed as open or closed, natural or human-made, static or dynamic and conceptual or physical depending upon the characteristics, structure, interrelationship and functioning.

Let us now understand what system is? A **system** can be defined as a set of objects together with relationships between objects and between their attributes. The objects consisting of components or parts or variables or sections with inter-relationships, act together as a complex whole according to a pattern or method. Interrelationship or interdependence of parts or variables is a diagnostic property of systems. Systems can be identified at all scales of magnitude and with all degrees of complexity. So a type of hierarchy can be brought into systems, viz. supersystem, system, subsystem, etc.

Systems can be classified into three types: 1) Isolated System, 2) Closed System, and 3) Open System.

1. Isolated Systems

These systems will have their boundaries closed to the import and export of both mass and energy. For example, most of the chemical reactions in the laboratory belong to this category.

2. Closed Systems

These systems possess clearly defined boundaries which prevent import and export of mass but not of energy. For example, the Earth which exchanges energy but not mass with outer space. Another characteristic of closed systems is that, with a given amount of free, or potential, energy within the system, they develop toward states with maximum entropy. That means, the initial fixed quantity of energy is gradually used up during the life of the system. **Entropy** is an expression for the degree to which energy has become unable to perform work. The maximum entropy means minimum or no energy. Hence, in a closed system, there is a tendency for levelling down of existing differentiation within the system; in other words, progressive decrease of energy into its lowest form and also a uniform result. In closed systems, therefore, the change of entropy is always positive, associated with a decrease in the amount of free energy, or, to state this another way, with a tendency towards progressive destruction of existing order or differentiation.

Davis's views of landscape development contain certain elements of closed system. It can be argued that Davis's was not a closed system. But since one factor (potential energy-land elevation above sea level) was initially added and ultimately consumed, it can be treated as such. But if one puts the clock back by uplift 'the so-called complications of Davis's geographical cycle' there will be an increment of free energy or release of energy which will be progressively dissipated through degradation. This is again nothing but a closed system. So in closed systems the initial energy conditions will determine its ultimate equilibrium conditions and this is inevitable. The condition of a closed system at any particular time can be considered as a function of the initial system conditions and the amount of time which has subsequently elapsed. Thus closed systems can be studied on a time basis. Again, the fact that closed systems can be studied on a time basis, enables one to draw a striking analogy between closed system thinking and the historical approach to landform study proposed by Davis. Stage in Davis's famous trilogy, structure, process and stage, implies nothing but time. The sequential development in a system to attain equilibrium with maximum entropy again speaks of an analogy with sequential development of Davis's landforms.

3. Open Systems

These are characterized by an exchange of both mass and energy with their surroundings. It involves the flow of matter and energy not only out of the total system but also through interrelated parts of the system. A best example for this is a drainage basin. A drainage basin receives energy in the form of temperature, precipitation and relief, and mass in the form of water and products of underlying bedrock which provide the basis for the outputs of heat, water, organic and inorganic debris into the atmosphere or the sea.

Open systems will have no boundaries and need energy supply for its maintenance and preservation. It needs not only supply but also some removal of energy as well as material or mass or the result. Changes in the supply of mass and energy from outside lead to an adjustment, called self-adjustment or self-regulation to accommodate the changes. Thus it may attain a steady state or equilibrium. This is the most diagnostic characteristic of an open system. A geomorphic example explains all this like this. Take a (facet

of) slope. The slope receives water and waste of the slope above it which discharges its own water and waste upon the slope below. Suppose if the rate of erosion is increased on this stretch of slope above, the lower stretch, being clogged by the debris brought from above will have its rate of erosion diminished. So the overall acceleration of erosion above and declivity is reduced the rate of erosion likewise will be reduced. So each member or part is influenced by every other and like this there is an interdependence throughout. This is what is called form-adjustment or landform adjustment.

Steady state doesn't mean that the form is static and unchanging. The form is maintained in the flow of matter and energy traversing the system. It may be therefore be said that a stream or reach may be adjusted in the sense of being graded or in a steady state without necessarily presenting the smooth longitudinal profile. The landscape may get adjusted, may attain a steady state but still the mass will constantly be removed (unless and until the landscape becomes featureless). So, force (geomorphic processes) may exceed the (geologic) resistance and cause mass to be removed. If the landscape attains equilibrium i.e., once a steady state has been established, the influence of initial system conditions vanished and with it the evidence for a previous history of the system.

3.2.1 Systems Approach in Development of Geomorphology

A **geomorphic system** is an integrated complex of landforms which operate together according to some discernible pattern. Any subject of investigation showing unity and a strong interdependence of constituent parts can be treated by the systems approach. Systems analysis is employed to organize the relevant information from physical systems into operational units, so as to allow them to be treated in a rational manner and evolve a basis for computer analysis.

The introduction of the systems approach into geomorphology provides a means whereby morphology can be related to processes in a useful framework of quantitative inter-relationships. It provides a sound basis to study and understand the three elements, process, material, and morphology, which make up the science of geomorphology.

Four **geomorphic systems** are identified in terms of their internal complexity or structures: (1) Morphological systems, (2) Cascading systems, (3) Process-Response systems, and (4) Control systems.

1) Morphological Systems

Morphological systems consist of a network of structured relationships between the constituent parts. These are consisting of the relationships among physical properties of natural features or materials. So, for example, the morphological properties of a beach system might include such parameters as beach slope, mean grain size, range of grain sizes, beach firmness and the like. The relationships between these variables can be expressed by a web of correlations and it is usual to interpret the operational efficiency of such a system in terms of the degree to which these morphological variables are related. Thus, although these variables can be identified individually, their relationships are often indicative of the degree to

which their dynamic properties are related. An important feature of such systems is the role played by feed back loops, particularly negative ones, in governing the general morphological changes that follow changes in individual variables.

How do you interpret feed back? The mutual interaction of many variables or a two-way relationship among many variables is known as **feed back**. It can be exemplified by the relationship between beach slope and wave steepness. The wave steepness affects the beach slope, but is in turn affected by the beach slope. So that a feed back relationship exists between the two variables. Feed back is positive when the change in one variable is intensified by a change in the second. It is negative when the change in the second variable results in the first being modified in such a way that it tends to return to its original state. The positive feedback loop results in self-generation of processes, while the negative leads to self regulation. Most of the geomorphic systems operate dominantly as negative feedback open systems of the self-regulatory type. That is to say, negative feedback loops are more important and lead to the concepts of grade and equilibrium. This self-regulation involves internal reorganization of the system and is accomplished in a time period referred to as '**relaxation time**'. Relaxation time depends on: (i) the resistance to input changes of the individual system components and (ii) the complexity of the system (i.e., the number and linkages of variables involved). The relaxation time of some geomorphic systems is short, for example, the channel adjustments to changing discharge, but that of the others is long (changes of erosion induced on different terrains by climatic changes).

You may refer to Figure 3.1, which explains negative and positive feedback in a geomorphic system.

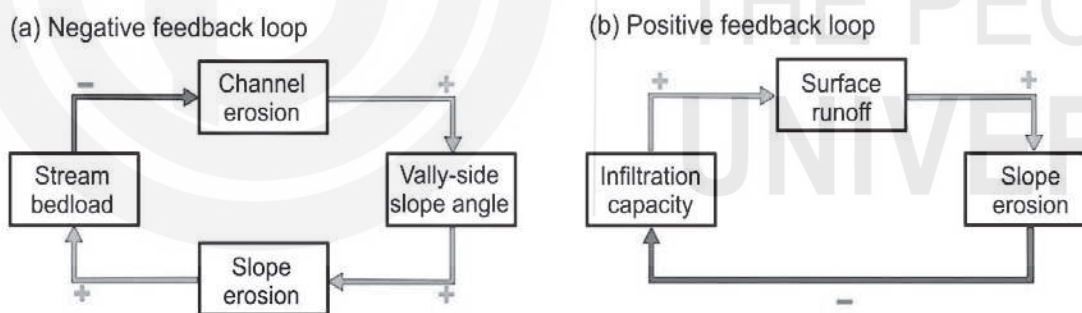


Fig. 3.1: Positive and Negative Feedbacks in a Geomorphic System
(a) Negative Feedback in a Valley-Side Slope–Stream System (b) Positive Feedback in an eroding Hillslope System.

(Source: Fundamentals of Geomorphology by R.J. Huggett)

2) Cascading Systems

These comprise a series of sub-systems having spatial magnitude and are dynamic in character. They are dynamically linked by a cascade of mass or energy. It can also be defined as a structure or system within which the output from one sub-system forms the input into the next one and so on. For example, the output of debris and surface runoff from the slope (subsystem) becomes part of the input (of water and debris) into the stream channel sub-system, partly governing its operation. So other characteristic of a cascading system include a regulator or governor within the sub-system. The regulator may direct part of the mass or energy into a store within the system or create

a throughput, which becomes the sub-system output which in turn becomes the input to adjacent sub-systems. The regulators in the system are important from the geomorphology point of view and may be represented by morphological variables for example, the debris in transit across a slope or the sediment in a beach or in a river. However, it is at this point that human can often intervene to make the system into a control system.

The regulators are of three types: (1) threshold regulators, which include surface infiltration capacity, (2) dispositional regulators, which control the distribution of energy or mass, for example, the route taken by water entering a sub-system and (3) presence or absence regulators, such as whether a stream is present or absent at the foot of a slope.

Each major process produces its own dynamic cascade, as potential energy is expended on the water and material involved in the system. All these sub-systems are parts of larger ones. In analyzing a system, inputs, outputs, storage or energy, and mass must all be measured and understanding of the regulators is also necessary. Many different measuring methods are required to obtain the data, partly because the inputs and outputs are continuous, but variable, and observations are often made at points in both space and time. Regulators can sometimes be expressed in the form of mathematical equations when their operation is fully understood in numerical terms. Detailed field work or laboratory analysis is often necessary to obtain the value of essential constants.

3) Process-Response Systems

These are formed by the uniting of the morphological and cascading systems. This union is brought about either by a sharing of certain variables by the two types of systems (as when, for example, infiltration capacity is both a morphological property of slope system and a decision regulator in the basin hydrological cycle cascading systems), or when a high level of correlation exists between a variable in the cascading sub-system and one or more in the associated morphological system. The process of cascading system changes the morphological variables. An important element of the interchange is the negative feedback loop (process), so that the morphological responses to changes in the energy cascade of such a system are dominated by self-regulatory processes. It is thus possible to view process-response systems as consisting of cascading and morphometric components that mutually adjust themselves to changing input-output relationships. The time requirement for such adjustments to a new equilibrium (i.e., the relaxation time) is dependent on such considerations as the amount and direction of change in the energy cascade and the richness of connectivity of the variables.

4) Control Systems

In physical-process-response systems, there may exist certain key variables or 'valves' (commonly in the form of regulators), which can intervene to produce operational changes in the distribution of energy and mass within the cascading systems, and consequently bring about changes in the morphological variables linked with these key variables in the process-response systems. Thus, for example, man-induced changes in sand movement on a beach can produce considerable changes in beach geometry.

Hence this type of systems may be useful in the management of natural environment.

We have understood the four types of geomorphic systems. Let us now understand about the 'time' as it controls various parameters in system and subsystems.

Time plays a complex and very important role in systems. Time and scale effects are intimately linked when a geometrical form is controlled by a number of factors, any change of form with the passage of time is entirely dependent upon the net result of the effect of time upon those factors. Some factors are profoundly affected by the passage of time, others are not. The character of reality alters according to the time scale on which it is viewed. The large extensive landscape viewed over a long period of time becomes modified; slopes, for example, decreased in gradient, but not all aspects need necessarily change, such as drainage density. There is also the problem of exogenetic and endogenetic processes, which also change their mutual relationships through time.

SAQ I

- a) Define the system. What are the different kinds?
 - b) Drainage basin is a best example for?
 - i) Open System ii) Closed System iii) Isolated System
 - c) What is a morphological system? Give an example.
-

3.3 FORM AND PROCESS IN GEOMORPHOLOGY

The inter-relationship of landforms and their processes are the basic component of geomorphologic investigations in the study of evolution of landforms. There are a number of concepts and models, which has evolved over the last century with the advent of scientific tools and quantitative methods has attempted to establish that processes can be the most significant factor of all other factors in predicting the forms.

Landforms on the surface of the Earth are continuously in the process of formation and deformation due to the continuous effect of internal and external factors. Geomorphic processes are the internal and external activities that stress Earth surface materials, react chemically and act physically with them, and modify the geometry of the Earth's surface materials.

Various agents are responsible for geomorphic processes to happen. But geomorphic agents are the mobile medium that extracts, transports, and deposits earth materials. Running water, ice, wind, waves, ocean currents, groundwater, etc. are a few examples of geomorphic agents. Gradients, whether from higher levels to lower levels or from high-pressure zones to low-pressure areas, are the cause of all motions. Different agents are responsible for the various geomorphic processes to function over the Earth's surface. Exogenetic and endogenetic forces are responsible for the physical and chemical changes to occur, agents to be driven and processes to operate. Various geomorphic processes and their agents are given in Figure 3.2.

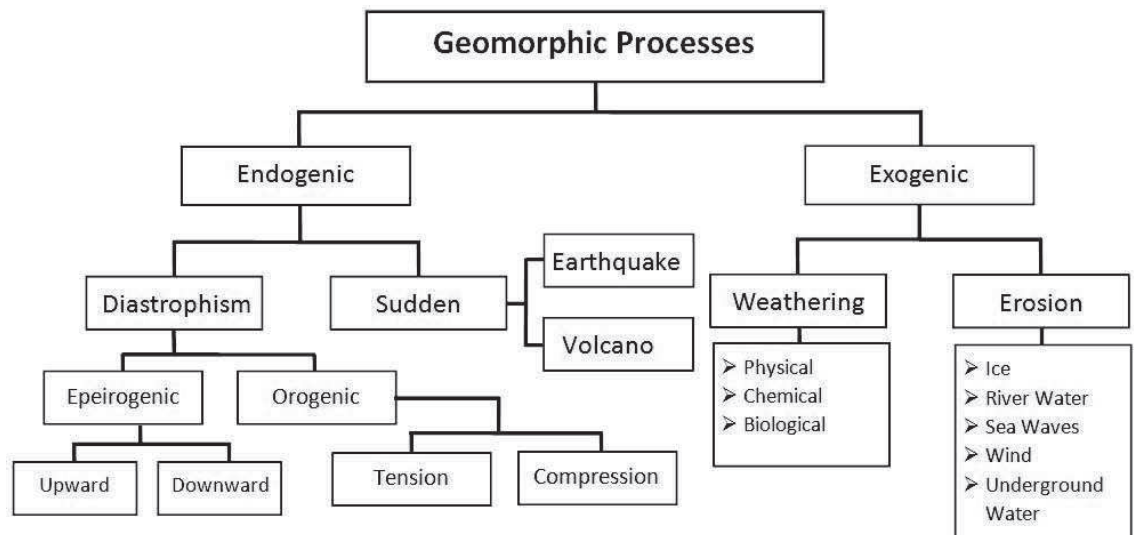


Fig. 3.2: Classification of Geomorphic Processes.

Geomorphological studies are under taken based on a wide range of concepts and approaches varying from historical to functional based on the form–process relationships. There are several approaches to the study of geomorphology based on the concepts of uniformity, evolution and complexity. With the advent of modern geomorphology, significance of form and process marks a turning point in geomorphological study and research. The classical ideas of landform evolution was challenged by the new insights with the believe that landform is neither a function of structure, process and stage or time (Fig. 3.3). Influenced by the new developments of systems approaches in different branches of science and more so in geography, the study of form and processes presented a new framework to the study of landforms taking geomorphology to the new millennium offering a fresh insight.

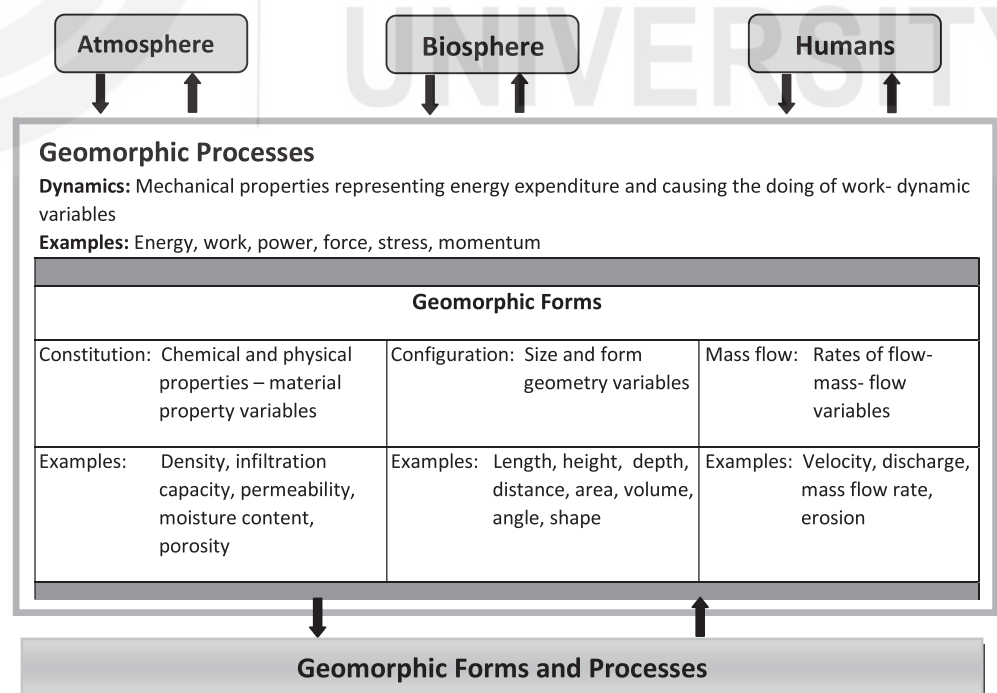


Fig. 3.3: Process-Form Interactions: The Core of Geomorphology.

(Source: Fundamentals of Geomorphology by R.J. Huggett)

The term '**form**' implies the morphology of a given landform unit or region, small or big at a given time. It refers to different shape attained by the landforms while 'process' indicates the actual operation of different agents which bring morphological changes in the physical environment. In a hill slope evolution, process includes various activities of geomorphic agents such as weathering, soil creep, and surface flow etc.

Process–response or process–form systems are considered as an energy flow system which is linked to a morphological system in a way that the system processes often alter the system forms. This in turn again changes the system processes. Process-response system in geomorphology normally comprises of a natural system formed by the combination of morphological and cascading systems. This explains how form and geomorphological processes are inter-related. Coastal process-response system which consists of a cascading system of wave energy advancing from deep water to the edge of the beach and the swash zone is linked to different morphological features of the coastal zone. For example, different morphological forms of the beach or their physical dimensions such as angle of beach slope, different grain sizes of beach sediments or their porosity may be related to each other in some orderly manners which constitute a morphological system. Similarly the geometric properties of a valley-side slope are found correlated with certain characteristics of soil and amount of flow of water.

Process Geomorphology was originally proposed by G.K. Gilbert who conceptualised that landforms are a balance between resisting framework and the forces acting to alter the landscape. This implies that time is one component of many that affect the appearance of the Earth. He had also inferred that the landscape remains in equilibrium between driving forces and resisting forces. Later on John Hack proposed that landscape development occurs in the way as Gilbert had postulated adding a view point that most of the systems remain in dynamic equilibrium. This means that there is a balance between the opposing forces. If the equilibrium is lost, balance is re-established under the new conditions.

An evolutionary hill slope system can be considered in the light of dynamic equilibrium where variables of slope forms and slope process interact with each other. In this system, rocks coming out of the hill slope and cliff develop the talus deposits along the foot hills. However, when the extent of the talus deposits grows, it buries the cliff face, diminishing the area that supplies debris. As a consequence, the growth of talus deposit diminishes and the system changes in a decreasing rate. This is an example of a negative feedback in process–form systems. Systems also display a positive feedback where an original change is multiplied and magnified. In an eroding hill slope, erosion brings reduction in infiltration of water, increases the amount of surface runoff furthering more slope erosion.

Dynamic meta-stable equilibrium was introduced by Schumm (1973), stating that thresholds within a fluvial system can bring a shift in its mean state of equilibrium. Meta-stable equilibrium was referred to the episodic shifting of the mean state of equilibrium when there is a crossing of the thresholds in a system. Meta-stable equilibrium is achieved when a stable equilibrium is affected by some trigger mechanism or changes which can drive a system

over a threshold into a new state of equilibrium. A stream, for example, when forced away from a steady state due to some thresholds, gradually adjusts to the change to attain a new state of equilibrium, although the nature and type of the adjustment may vary in space and times within the system. Thus, the concept of geomorphic threshold introduced the concept of non-equilibrium or disequilibrium into geomorphological systems thinking (Chappell, 1983).

SAQ 2

Explain the form and process in geomorphology.

3.4 CONCEPT OF EQUILIBRIUM IN LANDFORM EVOLUTIONARY PROCESS

In geomorphological investigations, the concept of equilibrium and steady state has been used by many authors like Gilbert, Schumm and others while explaining evolution of landforms. Different types of equilibrium have been identified where landforms or their processes maintain a steady or stationary state. Static or stable equilibrium occurs when the processes or forces acting upon a landform are in a balanced state. A boulder that remains in balance over a mountain slope or a valley that has reached to the base level of its erosion can be the examples of static equilibrium. Static equilibrium is achieved in a system when the system bounces back to its original state after experiencing a small perturbation due to negative feedback in the process of restoration.

Unstable equilibrium is associated with forces which move a system away from its original state of equilibrium towards a new state. Sometimes this state of unstable equilibrium move towards a disequilibrium or in-equilibrium with the forces leading towards a change through a process of positive feedback. A boulder running down a hill slope from its state of rest due to a force sufficient to dislodge the boulder is an example of disequilibrium. This occurs through a positive feedback process leading towards disequilibrium.

Steady state equilibrium is another type where a geomorphic system continues to remain in a state of equilibrium by its self-maintenances and internal adjustments within the system. An example of steady state equilibrium can be the evolution of a concave-convex hill slope in humid climatic regions where a concave lower slope and a convex upper slope continue to exist in a steady state equilibrium along a mountain slope through the operation of varying intensities of erosion, deposition, and mass movement. Such type of steady-state equilibrium results from many small-scale fluctuations occurring with respect to a mean stable state (Chorley and Kennedy, 1971).

In the steady-state equilibrium, there is a basic presumption that an open system may attain a time independent state of equilibrium i.e., a steady state in which the system and its components remain unchanging with respect to maximum entropy and minimum free energy and the system continues to remain constant passing through a number of transient states with material or

energy passing through it. But during the later part of 20th century, some geomorphologists were critical about the concept of equilibrium and steady state when the idea of geomorphic threshold was considered important within the functioning of the systems (Alan D. Howard, 1965).

3.4.1 Geomorphic Threshold and Complex Response of Geomorphic Systems

(a) Geomorphic Threshold

In a systems approach, threshold is a key concept of significance in geomorphology. It indicates a boundary line situation during the changing forms and processes. Geomorphic thresholds indicate changing distinguishable situations in a system. This concept of threshold demarcates a situation when a process functions to initiate a new balance in the progress of a geomorphic system. The geomorphic threshold is of two categories: 1) Internal which originates from inside the system and 2) External, which is caused by the influence of external variables like climate, tectonic movements or human induced interventions.

Most of the geomorphic processes function in different magnitudes or frequencies only when the threshold limit is crossed. For example, landslides require a critical slope angle besides all other factors remaining constant. Rivers start depositing their sediments when the surface gradient changes its threshold limit of carrying the sediments. In geomorphology, the concept of thresholds is important because it indicates some significant events that bring a sudden change from one type of landscape to another. These are often caused by the intrinsic (Internal) and extrinsic (External) forces and processes affecting the landscape. Thus, a geomorphic threshold is a threshold of landform stability that is exceeded either by intrinsic change of the landform itself, or by a progressive change of an external variable.

This powerful distinction between external and internal system, thresholds were introduced by a leading geomorphologist named Stanley A. Schumm (1973). He believed that a geomorphic system will cross an external threshold by a change in an external variable. Climate Change can be a prime example of an external variable in the functioning of a geomorphic system. Change of climate as an external variable may initiate a change in runoff of a river system beyond a critical level which often leads to a changing geomorphic system by sudden response in reorganizing itself into a new physical state and regime. No change in an external variable is required for a geomorphic system to cross an internal threshold. Rather fluctuations in the internal variables of a geomorphic system may take the system towards an internal threshold leading towards its reorganization.

When some river channels encounter a changing lithology after a long period of erosion and deposition in the river catchment, a complex response is triggered in the system of river channel developing a complicated pattern of denudation with phases of concurrent accretion and erosion taking place in the channel system. Thus, a geomorphic threshold is an inherent component in a system which plays a significant role in changing the landforms. Under normal situation a threshold develops within the geomorphic system by

changes in the system itself through time. The threshold refers to a critical situation when a new adjustment or failure will occur. It also becomes difficult to identify within a system how much is the response to a geomorphic threshold or to an external influence.

(b) Complex Response of Geomorphic Systems

In a geomorphic system, a complex response relates to a reaction to change that occurs at multiple levels inducing a cascading effect to a single initial change within the system. It is often referred to as the “butterfly effect” where one small change can cascade through a given system creating new agents, processes and forms of change operating at several levels. The term is frequently used in hill slope evolution, fluvial geomorphology or the study of river basins, networks, their water and sediment discharges and changing landforms within those systems.

The concept of “Complex Response and Geomorphic Thresholds” plays a significant role in understanding the nature of evolution of landforms. It is needless to emphasise that the intricate relationship between the different components and variables within a geomorphic system implies that any change imposed by some external or internal forces may induce changes in the system in a complex manner. These complex responses may bring a change over a time span in any part of the system leading to a new equilibrium. The complex response in the behaviour of a geomorphic system resulting from an intervention or a given stimulus renders the system indeterminate to predict the change. This can be very well understood with respect to a small river basin. When a river basin is uplifted and undergoes rejuvenation in some region, the response is not simply an entrenched valley rather there develops a new equilibrium with a range of complex responses like accretion, erosion, sedimentation, down cutting and many more morphological changes. Their complexity is further accentuated and multiplied by the development of threshold conditions due to intrinsic and or extrinsic causes.

3.4.2 Dynamic Equilibrium Theory of Hack

American geomorphologist J.T. Hack made an attempt to address the drawback and criticisms of the classical models of Davis and Penck through his idea of **dynamic equilibrium** in the evolution of landforms. He tried to establish that polycyclic evolution of landforms cannot be explained through multiple cycles of erosion, rather can be explained applying the theory of dynamic equilibrium. He postulated that geomorphic systems are open systems. In such a geomorphic system, when the energy remains constant, landforms continue to remain in the steady state although the denudational processes continue in reducing the landscape. This model demonstrates a time-independent process of landform development. This model envisages that “the morphology of the landforms manifests a balance between the resistive force of the parent materials to erosion and the erosive force and energy of the operating processes”. This theory of Hack was greatly influenced by the concept of dynamic equilibrium developed by G. K. Gilbert (1877) in his theory of erosion, evolution of slope profile and landscape

development. Hack proposed his theory of dynamic equilibrium in landscape evolution in the year 1960.

Hack believed that the principle of dynamic equilibrium is not an evolutionary model like the geographic cycle of Davis. However, the concept of dynamic equilibrium can be used as a universal principle to explain specific landscape features and its associated problems, when a landscape development takes place during a long period of continuous down wasting. Hack was of the opinion that this concept is distinctly different from the approaches of multiple erosion cycle concepts by examining a variety of specific features in a landscape. He mentioned that the Appalachian Mountain system has developed by continuous down wasting from the period of latest orogeny and that the diverse forms developed due to equilibrium of action in the erosional system can be viewed as a model. Simultaneously it can be viewed that evolution is also an obvious truth of nature and the inheritance of form is a natural possibility. Such a diverse landscape with widely varying forms cannot be fully explained through the theory of the geographic cycle involving the process of peneplanation, it is also difficult to deny that the evolutionary changes during a cycle of erosion might look like that of Davis, but this is distinctly different from the approach of multiple cycles and the inheritance of peneplain forms. The basic assumptions of the Hack's theory of dynamic equilibrium are given below:

- There exists a balance between the gradational processes of denudation and resistance of the rock bodies.
- The landscape exhibits a uniform rate of down wasting in all its components during the evolutionary process.
- The nature of variation in the characteristics of landforms can be explained in terms of the spatial pattern of geological structure and lithology.

Davis' and Penck's concepts are 'cyclical and non-cyclical' and postulate that landforms are essentially 'historical' such that every erosional process leaves a largely indelible imprint upon surface forms and deposits. Hence, the 'cyclical' concepts interpret the landscape in terms of an assemblage of largely independent form elements of different ages.

In contrast to the 'cycle concepts,' Hack proposes the concept of 'equilibrium' landforms, which is non-cyclical in nature. Hack argues for a 'dynamic equilibrium' in present landforms where all topographic elements are eroding vertically at an equal rate with no change through time of slopes or areal arrangement of the topography. Such equilibrium landforms would be completely adjusted to the processes presently acting upon them. It implies that the landforms adapted to the present day conditions rather than inherited from the past. This is not to deny the existence of a prolonged period of landform evolution, but to contend that its details are now lost beyond reconstruction.

Penck viewed landscape as a result of competition between uplift and erosion. But Hack views the landscape as the product of competition between the resistance of crustal materials and the forces of denudation. For example, evenness of ridge crests as explained by Davis is due to rejuvenation of an

old peneplain. But Hack sees it as the manifestation of equal resistance to the forces of erosion. Within a single climatic region where stream and slope profiles are controlled by the nature of bedrock, similar geological conditions should produce similar topography. If there is orderliness of stream organization, it will naturally lead to a regularity in the overall pattern of relief.

As the land surface is lowered the available energy diminishes and the new forms are merely a response to the changing conditions, and no inferences can be drawn about landform history. So, it is intrinsic to Hack's argument that landforms adapt rapidly to changing environmental controls.

SAQ 3

Describe the geomorphic threshold.

3.5 SUMMARY

In this unit you have studied so far:

- Conceptual developments in the approaches towards geomorphic investigations in tracing the origin and evolution of landforms.
- Systems modeling had swept through the geomorphological studies since 1960's quantifying input and output variables and their form and processes associated with the landforms.
- Simple mechanics and classical thermodynamics gave rise to the concept of equilibrium whereas, open system thermodynamics brought in the concept of steady state and dynamic equilibrium. The concept of non-equilibrium thinking led to the emergence of complex response of geomorphic systems.
- In a systems approach geomorphologists started assuming that landforms constitute a geomorphic system comprising of several units and subunits organised in a structure and hierarchy, interacting with each other through exchange of mass and energy within the system and with its surrounding environment, and leading toward a steady state or equilibrium.
- Gradually the idea of geomorphic system got established as a general framework of research but however, criticisms to this idea was brought in through the introduction of the concepts of equilibrium and steady state, relevance of form and process in geomorphology, nature of complex response of geomorphic systems and dynamic equilibrium.

3.6 TERMINAL QUESTIONS

1. How systems approach is different from classical approaches in the study of landform evolution? Discuss with examples.
2. What is form-process approach in study of origin of landforms? Why it gained importance in geomorphic studies?
3. Explain what do you understand by "Complex Response of Geomorphic Systems"?

4. Give a brief account of the "Theory of Dynamic Equilibrium" of Hack.

3.7 ANSWERS

Self-Assessment Questions (SAQ)

1. a) A system is defined as a group of objects having relationships between them and their attributes. There are three kinds of systems: 1) isolated systems, 2) closed systems, and 3) open systems.
b) (i) Open Systems
c) Morphological systems are composed of a series of organized interactions between their constituent components, which are mainly the physical attributes of natural features or materials. For example, the morphological characteristics of a beach system could include elements like beach.
2. Form implies the morphology of a given landform unit, small or big at a given time, while process indicates the actual operation of different agents which bring morphological changes in the physical environment.
3. Threshold is a critical idea of relevance in geomorphology when using a systems approach. It denotes a position at a boundary during the development of forms and processes. Geomorphic thresholds show shifting, observable conditions in a system.

Terminal Questions

1. Refer to Section 3.2
2. Refer to Section 3.3
3. Refer to Section 3.4.1
4. Refer to Section 3.4.2

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GLOSSARY

Cascading System	: A series of subsystems dynamically linked by cascade of mass or energy. In this system, the output of one subsystem forms the input of another subsystem and so on. For example, debris and runoff within slope and channel subsystem.
Catastrophism	: This concept was believed by Cuvier, Burnet, Buffon and Woodward. They believed that the Earth is shaped by big floods. It states that the origin of the Earth's surface features are mostly due to sudden, short duration violent events and related processes like cataclysmic earthquakes, volcanic eruptions and severe floods.
Closed Systems	: The systems can prevent import and export of mass but not of energy. Example, the Earth exchanges energy but not mass with outer space.
Entropy	: It is an expression for the degree to which energy has become unable to perform work. The maximum entropy means minimum or no energy.
Eon	: Geological time scale has been divided into four major time divisions called eons. These are Hadean (4570 to 3850 Ma), Archean (3850 to 2500 Ma), Proterozoic (2500 to 541 Ma), and Phanerozoic (541 Ma to Present).
Era	: The Phanerozoic Eon is divided into Paleozoic, Mesozoic and Cenozoic era. The three eras come with a "zoic" suffix which means with a zoological basis.
General Systems Theory	: Bertalanffy formulated this theory states that how to see a whole thing in different parts and to see how the parts are interlinked and function together in a system. This theory is often referred to as the theory of open systems or System Theory.
Geological Time Scale	: The geological time scale presents the history of the Earth divided in a hierarchical set of divisions of geologic time based on geochronology and dating of the sequential events throughout the Earth's history.
Geomorphology	: Geomorphology is a part of physical geography which deals with the study of landforms, their characteristics and various processes responsible for their formation and changes.
Geomorphic Threshold	: It is a threshold of landform stability that is exceeded either by intrinsic change of the landform itself, or by a progressive change of an external variable.
Isolated Systems	: The boundaries closed to the import and export of both

	mass and energy are called isolated systems. E.g., chemical experiments in the laboratory.
Morphological System	: These systems consist of a network of structured relationships between the continent parts. E.g., a beach system.
Neptunism	: It explains that most of the rocks formed over the Earth's surface must have precipitated out of a vast ocean.
Open Systems	: These are characterized by an exchange of both mass and energy with their surroundings. It involves the flow of matter and energy not only out of the total system but also through interrelated parts of the system. E.g., a drainage basin.
Planetary Geomorphology	: It studies the surface features of the extra-terrestrial bodies collected through space explorations. Planetary geomorphology explores the landforms of the other terrestrial planets and satellites like Mars, Venus and Moon through Earth analogies.
Plutonism	: The igneous rocks of the Earth were formed due to magmatic activity. Because of weathering and erosion this led to the formation of sedimentary rocks.
System	: A set of objects together with relationship between objects and their attributes.
Uniformitarianism	: This concept was proposed by James Hutton. He proposed that "the present is the key to the past" opposing the prevailing idea of catastrophism. The belief that changes to Earth have always been consistent and that the present holds the answer to the past. The theory of Uniformitarianism was supported by Charles Lyell.