UNIT 1

INTRODUCTION TO GEOMORPHOLOGY

Structure

1.1 INTRODUCTION

We know that geology deals with the study of Earth including its origin, evolution, interior constitution, ancient life and various processes (internal and external) operating on it. You have already learned about its various branches viz. physical geology, structural geology, mineralogy, crystallography, petrology, stratigraphy, palaeontology, ore geology and economic geology in your previous semesters. In this unit, we will introduce you to another branch i.e. geomorphology.

Geomorphology is a part of Earth Science that studies changes on the Earth's surface and forces and processes that develop them. It is therefore 'a discourse on Earth forms'. Geomorphology deals with characteristics of the Earth's surface and all the geological processes that try to change it over a period of time. Earth's physical land surface features (i.e. landforms) are developed and sculptured by persistent action of agents like rivers, wind, glaciers, ocean, underground water and lake. You have already studied the geological work of rivers, wind, underground water, glaciers and oceans in the course BGYCT-131. Aim of geomorphology is to reconstruct evolution of landscapes through geologic time. The scope of geomorphology is very wide as it encompasses study of landforms and landscapes, geological processes, evolution, and dynamics of geomorphic changes.

In this unit you will be introduced to the basic concepts of geomorphology and the tools and techniques used. You will also learn about drainage and landscape analysis along with some applications of geomorphology.

Expected Learning Outcomes

After reading this unit, you should be able to:

- ❖ define geomorphology;
- ❖ describe the scope and applications of geomorphology;
- ❖ discuss developments of the geomorphic concepts; and
- ❖ explain tools and techniques used in geomorphic studies.

1.2 GEOMORPHOLOGY

Geomorphology deals with characteristics of the Earth's surface and all geological processes that try to change it over a period of time. Geomorphology is based on some fundamental concepts, which have developed over a long period of time. These concepts not only provide basic fundamental components of geomorphology but also provide a glimpse of the breadth and scope of the subject. These concepts deal with the underlying principles of landform and landscape characterisation, controlling factors, development and evolution, and constraints (both spatial and temporal) on geomorphic evolution. Due to its importance, geomorphological data has applications in various aspects of development, planning, and environmental management.

1.2.1 Definition

Geomorphology (*greek words*- *geo* meaning Earth, *morphē* meaning forms and *logus* meaning description) is considered as description of surface morphology of the Earth. Beginners in geomorphology often find commonly used terms like physiography and physical geography synonymous with geomorphology. However, this is not correct. *Physiography* embodies in its study the landform description. It covers only the basic notions of variations of the Earth's surface based on differences in relief. *Physical geography* deals with description of these surface variations and landforms primarily from the point of view of their applicability for use by humans. Both, physiography and physical geography are part of geography and do not include aspects of origin, processes and temporal development of surface features with time. Geomorphology is more comprehensive and has much wider scope. It includes the study of landforms, their development, responsible processes and their evolution with time.

Many geologists have defined the tem geomorphology in different ways. According to **Worcester** (1965), “Geomorphology is the interpretative description of the relief features of the Earth”. **Strahler** (1968) defined geomorphology as “analysis of the origin and evolution of Earth features”. According to **Thornbury** (1968) “ Geomorphology is the science of landforms including the submarine topography”. **Blooms** (1979) defined geomorphology as “ the systematic description, analysis of landscapes, and the processes that change”.

Geomorphologists like A.K. Lobeck, G.H. Dury, and W.D. Thornbury consider geomorphology as a branch of geology, whereas S.W. Wooldridge and Morgan consider it to be a part of geography. While describing evolution of a landscape, geologists emphasise on the influence of geological history and nature of rocks whereas geographers emphasise on relationship between the nature of landforms and impact of human activities on landforms.

Since the days of ancient civilisations and through scientific knowledge gained about surface of the Earth to extension of study of surface features to other planets in last few decades, the scope of geomorphology has expanded manifold. This has led to modifications in the definition of geomorphology from time to time. Looking at the contemporary work, the term **‘geomorphology’** can be defined as a branch of geology that **deals with the study of landforms and landscapes including identification, description, classification, origin, geological and anthropogenic processes of formation and modification of landforms and geological evolution of landscapes of planetary surfaces through time.**

As discussed in the previous paragraph, geomorphology revolves around two terms, i.e., **landform and landscape**. Landform is the fundamental geomorphic unit in the landscape of an area while the landscape is the sum total of all the landforms occurring in an area. For example, fluvial landforms like channel, floodplain and bars, etc. will form a fluvial landscape. Similarly, a coastal landscape consists of coastal landforms like beaches, mudflats, lagoons, etc. Likewise, glacial landscape is made up of glacial landforms, while aeolian or desert landscape comprise landforms formed by wind actions. You have already studied the works of different geological agents such as river, wind, underground water, glacier and oceans including the landforms developed by them in the course BGYCT-131.

Geomorphological studies can be carried out on various scales from local to regional to continental, and planetary scales. An important factor in the formation and development of landforms is geologic time. Landforms and landscapes evolve over variable time scales from tens of years to thousands or millions of years. Reconstructing the formation, modification and development of landscape over geological time is termed as landscape evolution or geomorphic evolution.

1.2.2 Scope

Scope of geomorphology is very wide as it encompasses study of landforms and landscapes, geological processes, evolution, and dynamics of geomorphic changes at spatial as well as temporal scales. The ultimate aim of geomorphology is to reconstruct landscape evolution through geologic time.

The wide scope of the subject of geomorphology is evident from the fact that parts of it overlap with several other branches of geology. These include sedimentology, stratigraphy, structural geology, petrology, hydrology, tectonics, marine sciences, geoarchaeology and many more. The diversity of data enhances the utility and application of the subject in variety of fields. Geomorphology, in fact, has widest scope amongst all other branches of geology which also means that it has application in a wide variety of fields.

1.3 DEVELOPMENT OF GEOMORPHOLOGICAL CONCEPTS

In the previous section you have been introduced to various definitions of geomorphology. In this section, we will learn about development of geomorphological concepts. The knowledge of the Earth's surface has grown through the period of existence of man on its surface. The progress in this branch of geology has been relatively more rapid during the last few hundred of years. The development of the concepts of geomorphology partially overlaps with the period of development of principles of stratigraphy especially the principle '*Present is the key to the past*' given by Charles Lyell. The principles of stratigraphy viz. order of superposition, uniformitarianism and the biostratigraphic zonation, significantly influenced our understanding of landscapes and the development of fundamental concepts of geomorphology.

You have been introduced to the concept of principles of stratigraphy in the course BGYCT-137. Further development occurred with the advent of the Davisian cycle of erosion and later through increasing knowledge of the geological processes including surface processes. A detailed sequence of development of the geomorphological concepts can be found in the book "Principles of Geomorphology" by W. D. Thronbury.

Let us study about some of the fundamental concepts in the next subsection.

1.3.1 Fundamental Concepts

Some fundamental concepts, which come into use in the interpretation of landscapes are enumerated by W.D. Thornbury in his book "Principles of Geomorphology". These are:

1. ***"The same physical processes and laws that operate today operated throughout geological times, although not always with the same intensity".***

This concept is a slightly modified version of the Principle of Uniformitarianism given by Hutton in 1785 which states that the present is the key to the past. It is considered to be fundamental principle in the modern understanding of geology. Hutton's concept has been modified by Thornbury. While Hutton emphasised that same geological processes operated throughout geological time, Thornbury stated that although the processes remained same, they operated with different intensity in different time period of Earth's history e.g., glacial processes significantly influenced the landscape during the Pleistocene period. Similarly, aeolian processes were more significant during arid climatic time periods. The present concept underlies the uniformity of geomorphic processes through geological time that operated with different intensities at different times. The concept is applicable for understanding evolution of landscapes by processes varying in intensity through geological time.

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

This concept emphasises the dominant role of geological structures in the evolution of landscapes. We are now familiar with geological structures as we have studied structural geology and the theory of plate tectonics in the course BGYCT-131. The rocks of Earth's crust assume different structures like dipping rocks, fault zones, folds, joints, etc. in response to different type of stresses induced by movements of the tectonic plates. This introduces structural heterogeneities in rocks of the crust which in turn affect their variability and susceptibility to geomorphic processes. Over long periods of time, this leads to development of landforms and landscapes that correlate with structural elements of the crustal rocks. Landform attributes like location, relief, size, shape, linearity, etc. may be a consequence of structurally controlled erosion and deposition by various geomorphic agents. Since the advent of plate tectonics theory, the arrangement of shapes of landmasses and orogenic ranges together with volcanoes, earthquakes and others are attributed to varied nature of inter-plate interactions and tectonic stresses. These very well illustrate the dominating influence of structures and tectonics in formation and evolution of landscapes around the world.

3. "Geomorphic processes leave their distinctive imprints upon landforms, and each geomorphic process develops its own characteristic assemblage of landforms".

Different geomorphological agents like river, wind, glacier, seas and oceans and others have distinctive geomorphic processes that result in formation of their respective signature landforms. For example, fluvial processes carried out by rivers lead to formation of fluvial landforms like point bars, flood plains, river valley, etc. Similarly, each of the geomorphic agents produce their own distinctive set of landforms. Thus, the processes and agents responsible for formation of various landforms can be identified and characterised based on their distinctive characteristics. And these characteristics are suggestive of particular processes. This is possible because all the processes viz., fluvial, glacial, marine, aeolian and others are distinct from each other and therefore produce their specific set of landforms.

4. "As different erosional agents act upon the Earth's surface, they produce an orderly sequence of landforms having distinctive characteristics at different stages of their development".

This concept emphasises the role of erosion in development of landscapes over a period of time. As erosional agents start acting on the surface and continue their operation for long periods of time, the landscape undergoes changes depending on the extent of erosion and time elapsed. As a result, the landscape shows variable characteristics in different stages of erosion. The Davisian cycle of erosion exemplifies this concept. The landscape undergoes changes from initial to intermediate to advanced stage of erosion. In each stage, the nature of landscape and landforms assemblage is different from the other stages. This means that there is a sequential development of landforms. The order in which these landforms are produced, can be determined from geomorphological studies. It also means that it is possible to reconstruct the sequence of development of landforms in an area.

5. "Complexity in geomorphic evolution is more common than simplicity".

Geomorphic evolution occurs over geological time scale. During the course of geomorphic evolution, various processes may be triggered or controlled by factors like climate, tectonics and/or sea-level changes. It is expected that geomorphic evolution influenced by any one of the above factors will be straight forward and therefore easier to understand and explain. However, it is very common to see interplay of more than one factor during geomorphic evolution. This introduces complexity in the geomorphic evolution as more than one factors interact and one of those factors may dominate over the other factors. Understanding geomorphic evolution is at times difficult. For example, geomorphic evolution of Himalayas is complex because climate and tectonics both are significant factors influencing the geomorphic processes in the region.

6. "Little of the Earth's topography is older than Tertiary and most of it is no older than Pleistocene".

This concept has important implication in geomorphological studies while attempting to determine the age of landscapes in different parts of the planet Earth. As per the concept, most of the landscape of the Earth are of the Pleistocene age or younger. This is because various geomorphic agents have been continuously modifying the landscape through geological time. As a consequence, it is rare to find landscapes which are geologically ancient. You know that the Pleistocene is a division of Quaternary period which is the youngest time period in Earth's history that encompasses the geologic time from ~2.6 million years before present up to the present day. It is generally accepted that majority of the Earth's surface is sculpted or modified by geomorphic processes that operated during the Quaternary period. As a result, very little part of the surface is of Tertiary age or older.

7. "Proper interpretation of present day landscape is impossible without full appreciation of the manifold influences of geologic and climatic changes during the Pleistocene".

This concept underlines the importance of geomorphic processes which operated in the Pleistocene, in shaping the present landscape of the Earth. You are aware that Pleistocene is the largest epoch of the Quaternary period. During this time, the Earth experienced various geological changes, particularly extreme climatic changes. During the Pleistocene, the Earth's climate fluctuated several times from extremely cold glacial phases to warm inter-glacial phases. During glacial periods, major part of the Earth's surface was covered by glaciers while the glaciers retreated during the inter-glacial periods. This led to significant changes in the landscapes as the geomorphic processes changed repeatedly in response to climatic changes. The effects of the geomorphic processes attributed to Pleistocene extreme climatic changes are observed in large parts of different continents. It is therefore essential to have good knowledge of the geological and climatic changes to correctly interpret the landscape evolution during the Pleistocene.

8. "An appreciation of world climate is necessary to a proper understanding of varying importance of different geomorpoic process".

The wide variety of geomorphic processes operating on the surface of the Earth are responsible for the formation of different landforms and landscapes. The present day Earth shows latitudinally oriented climatic belts from the equator to poles in both hemispheres. The major climatic zones of the Earth comprise equatorial, subequatorial, tropical, subtropical, temperate and polar belts. Each of the climatic zones is characterised by landforms and landscapes that is distinctly different from the others. This is due to the fact that geomorphic processes operating in each of the climatic zones are different. This has led to formation of different landform assemblages and overall landscape characteristics in each of the climatic zones of the Earth. This suggests that geomorphic processes are dominantly controlled by climate. Therefore, a thorough knowledge of the world's climatic zones and related geomorphic processes is extremely important for understanding the landform and landscapes of the geological past.

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

The concept stresses on the need to extend the geomorphologic studies of landforms back in geological time to delineate geomorphic evolution. Geomorphic studies should not be limited or confined to identification and documentation of landforms. The full significance of geomorphic studies is realised only by interpreting the past geologic history of the landforms and landscapes. This is an important aspect of geomorphology as the landscapes continue to be modified and evolved over a period of time. By doing so, a full history of the development of landscapes can be delineated and understood.

10. "To a large degree the Earth's surface possesses relief because the geomorphic processes operate at differential rates".

The earth's surface is not even. The extent of Earth's relief variations is reflected by high peaks of mountain ranges and depths of oceans. The concept attributes to large variations of relief of the Earth's surface to different rates at which the geomorphic processes operate. For example, rate of erosion is faster in some areas while slower in some areas. As a result, the area where rate is erosion is faster, will attain lower elevation in comparatively shorter period of time while area with slower erosion will attain the same relief over a longer period of time. Consequently, at a given point of time, both areas will be at different elevations. The different rates of erosion may be aided by other factors like lithological variations, geological structures and others.

After learning the fundamental concepts, let us get introduced to two more concepts in geomorphology in the next subsection.

1.3.2 Uniformitarianism and Catastrophism

We have studied about the concepts of uniformitarianism and catastrophism in the course BGYCT-137. The theory of uniformitarianism states that the processes operating on the Earth surface have been the same throughout the geologic time. James Hutton gave this theory that emphasised the uniformity of processes in the present and in the geologic past. Hutton also realised that these processes operate at slow rates and therefore would need a long period of time to bring about significant changes in the Earth's surface. Thornbury framed one of his fundamental concepts of geomorphology which has been described as Concept 1, earlier in this unit. The theory of uniformitarianism found application in estimating the enormity in geological time and antiquity of the processes observed today on the Earth surface. It also helped to dismiss the notion of previous theorists that the Earth was only a few thousands of years old.

The theory of catastrophism was put forward by Georges Cuvier. According to this theory, the Earth has been shaped mainly by abrupt, short lived and worldwide events. These events were of catastrophic nature that significantly affected the development of life and deposition of rocks. Cuvier developed this theory based on the abrupt disappearances of entire population of fossils found in rocks. He attributed these to the past catastrophic events of worldwide occurrence like floods. This led to the belief that all rocks on the Earth were deposited in a vast ocean.

We are now aware that the theories of uniformitarianism and catastrophism contradict each other. The theory of uniformitarianism emphasises the uniformity of processes and conditions throughout the geological history of the Earth. While the theory of catastrophism assumes that the conditions on Earth were completely different in the past and that no comparison is possible. The theory of catastrophism died out in the 19th century due to lack of scientific evidence. On the other hand, the theory of uniformitarianism gained acceptance with time as a consequence of evidence provided by modern geological developments.

1.3.3 Scale in Geomorphology

In this subsection, you will learn about the concept of scale in geomorphology. Geomorphological studies are carried out on a wide range of spatial and temporal scales. The spatial scales (i.e. the spatial extent or area covered) of investigations range from microscale (for example, site specific river channel characteristics) to planetary scales (for example, geomorphic studies of Mars, Moon and others). The temporal scale (i.e. the time/duration) refers to the geological time range under investigations in a geomorphic study. This also varies from short term landform forming events like floodplain deposition, formation of sand dunes, etc. The focus of these microscale studies is mostly on quantification of factors producing geomorphic change. In most of the cases, the factors are generally of local nature. Intermediate temporal scale of geomorphic studies document changes that occur on hundreds or thousands or few tens of thousands of years. The large temporal scales of geomorphic studies encompass millions of years and beyond.

1.3.4 Concept of Geomorphic Cycle

We have discussed the fundamental concepts, along with the concepts of uniformitarianism and catastrophism and also scales in geomorphology. Let us now learn about the concept of geomorphic cycle.

The theory of geomorphic cycle explains the evolution of landscapes through time. It is also known as the *cycle of erosion*, *peneplanation model* or *geographic cycle*. It was first proposed by William Morris Davis in the late nineteenth century and is also popularly known as the **Davisian theory** of landscape evolution. The geomorphic cycle explains the long-term landscape evolution through a series of stages. The theory is truly a complete cycle as it starts and ends with the same landscape i.e., a peneplain. A peneplain is defined as a low, almost flat, regionally extensive landscape with negligible relief. The geomorphic cycle introduced the terms - *youth*, *mature,* and *old* in geomorphological realm for the first time. The various stages of geomorphic cycle and consequent development of landscape is shown in Fig. 1.1.

The geomorphic cycle comprises six stages (Fig. 1.1) that encompasses the major stages of youth, maturity, and old stage. The theory assumes initiation and persistence of tectonic uplift of the Earth's surface through the cycle. The theory also assumes that the landscape consists of uniform lithology. Tectonic uplift causes erosion of the Earth surface, the cycle therefore, includes erosion as the main process of landscape evolution.

As you can visualise in the Fig. 1.1, the initial landscape is a low relief peneplain with poorly developed drainages. The peneplain is subjected to tectonic uplift that initiates erosion of the landscape. The rivers are also considered as one of the main agents of erosion; because the landscape modification normally starts from river valleys. In the initial stage, i.e., the early youth, the river tends to erode its valley downward. The process may be encouraged by simultaneous tectonic uplift. This results in broad and flat uplands with river valleys much deeper than broad. As uplift induced erosion proceeds further, the landscape enters late youth stage. During this stage, the vertical erosion continues to dominate but some lateral erosion of valleys also occurs. The number of drainages also increase significantly. Overall, the landscape in this stage shows dominantly the valley slopes with few inter-stream uplands. Continued tectonic uplift aided vertical and lateral stream erosion leads to the maturity stage of landscape development. The main characteristic of this stage is development of highly erosional landscape.

In late maturity, the landscape is characterised by subdued relief and broad valley floors. This occurs due to prolonged erosion that causes substantial lateral erosion by streams. The long erosional time period makes the landscape devoid of high elevations resulting in low relief and almost flat peneplain. Following the old stage, renewed tectonic uplift can initiate a new geomorphic cycle. A landscape can thus go through several such cycles producing a polycyclic landscape.

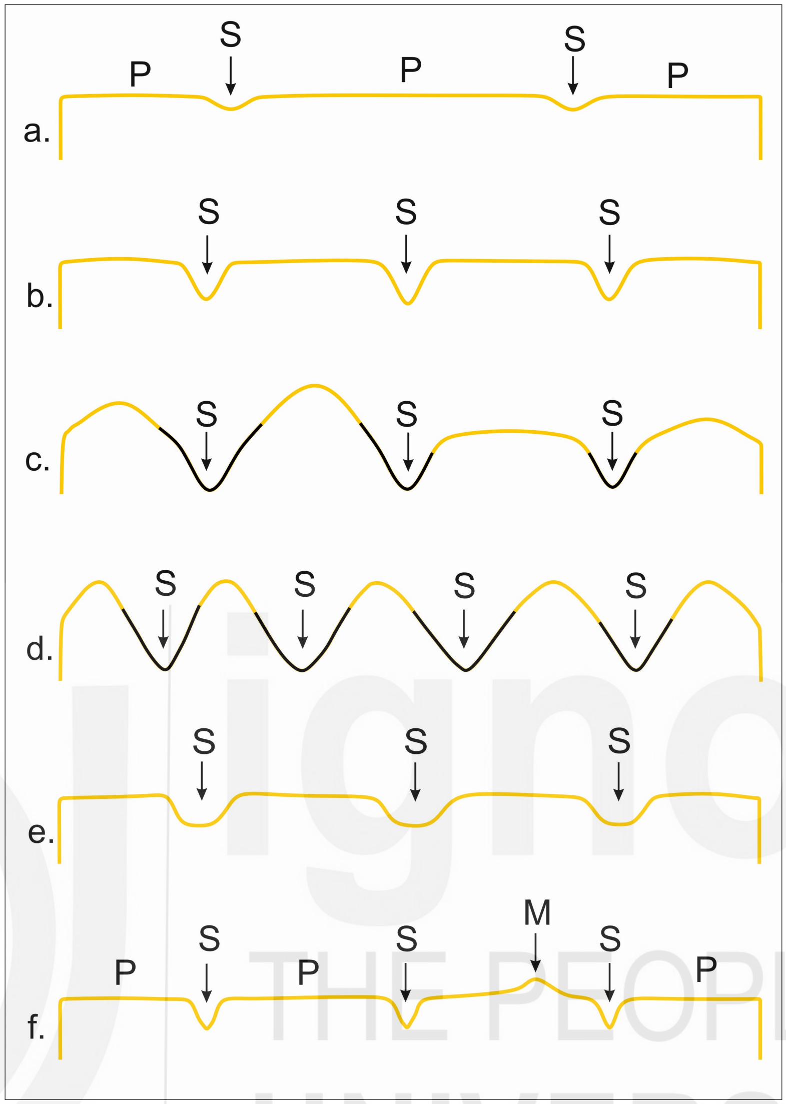


Fig.1.1: Schematic cross sections depicting the stages in geomorphic cycle (S- Stream, P- Peneplain, M- Monadnock); (a) Initial stage- relief slight, drainage poor; (b) Early youth- stream valleys narrow, uplands broad and flat; (c) Late youth- valley slopes (shown in black colour) predominate, some interstream uplands remain; (d) Maturity- complete dominance of valley slopes and narrow divides; (e) Late Maturity- subdued relief and broad valley floors and (f) Old stage- peneplain with monadnocks.

The main advantage of the concept of geomorphic cycle is that it recognises the importance of geologic time in the evolution of landscapes. Though no time limits are set, the cycle if uninterrupted, can last up to tens of millions of years. It also provides a sequential framework with well-defined stages - youth, mature and old, to reconstruct the progressive changes in landscape. The cycle also recognises the significance of tectonics as a causative factor for large scale erosion of landscapes. This has important application in understanding long-term landscape evolution of regions located in active parts of various tectonic plates.

You have learnt the definition and scope of geomorphology and development of geomorphological concepts. Now, spend few minutes to check your progress.

SAQ 1

a) Define the term geomorphology.

b) Which concept for interpreting landscapes given by Thornbury exemplifies the Davisian cycle of erosion?

c) What is uniformitarianism?

d) What is catastrophism?

1.4 TOOLS AND TECHNIQUES IN GEOMORPHOLOGY

Man uses the Earth surface for his survival by utilising the natural resources for his benefit and also for various developmental works. For this reason, geomorphological data is of prime importance in sustainable and environment-friendly utilisation of Earth's natural resources. Geomorphological study of landforms and landscapes utilise a variety of tools and techniques. Primary data for all geomorphological maps are provided by topographic maps, aerial photographs, satellite data, Digital Elevation Models (DEM), and field surveys. The resulting geomorphologic data are used extensively for wide variety of purposes. Technological developments have enabled high resolution digital maps and digital data analysis. In the following subsections, we will discuss about various tools and techniques used in geomorphology.

1.4.1 Topographic Maps

You have read about topographic maps in Unit-14 of the course BGYET-141. Let us recall, that topographic maps are an indispensable tool for carrying out field based geomorphological mapping of landforms and landscapes. A topographic map is a detailed and accurate map that shows all physiographic including relief, hydrographic, cultural and vegetation features of an area (Fig. 1.2). Geographic location of the maps can be known with the coordinates and index number given in the maps. All topographic maps contain detailed standard legend that shows all the notations, symbols, colors, etc. marked on the maps. These maps are available on the scale (representative fractions) of 1:250,000, 1:50,000 and 1:25,000.

In India, the topographic maps are prepared and made available to users by the Survey of India. Topographic maps form the base map for preparation of geomorphological maps. All mappable geomorphic landforms are marked on the map are extracted, which can then be converted to digital form for generating digital geomorphological maps.

1.4.2 Stereoscopic Aerial Photographs

Stereoscopic aerial photographs are overlapping photographs of an area taken by flying aircraft over predetermined paths. Normally, several photographs are taken along parallel transects. Viewing the overlapped part in the aerial photograph (Fig. 1.3a) through a stereoscope (Fig. 1.3b), provides 3-dimensional view of the area. Now digital aerial photographs have gradually replaced the earlier obtained analog photographs by film cameras. The stereo images obtained by the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) onboard the US/Japan *Terra* satellite, have proved useful for identification of landforms and geomorphological mapping of the landscapes. Study and interpretation of stereoscopic aerial photographs is based on attributes like tone, texture, pattern, shape, context and scale. These attributes in the photograph are controlled by illumination, which depends on time of the day, season and vegetation cover. Stereoscopic aerial photographs are found extremely useful for geomorphological studies as they capture several geomorphic features like landforms and also subtle changes in slope.

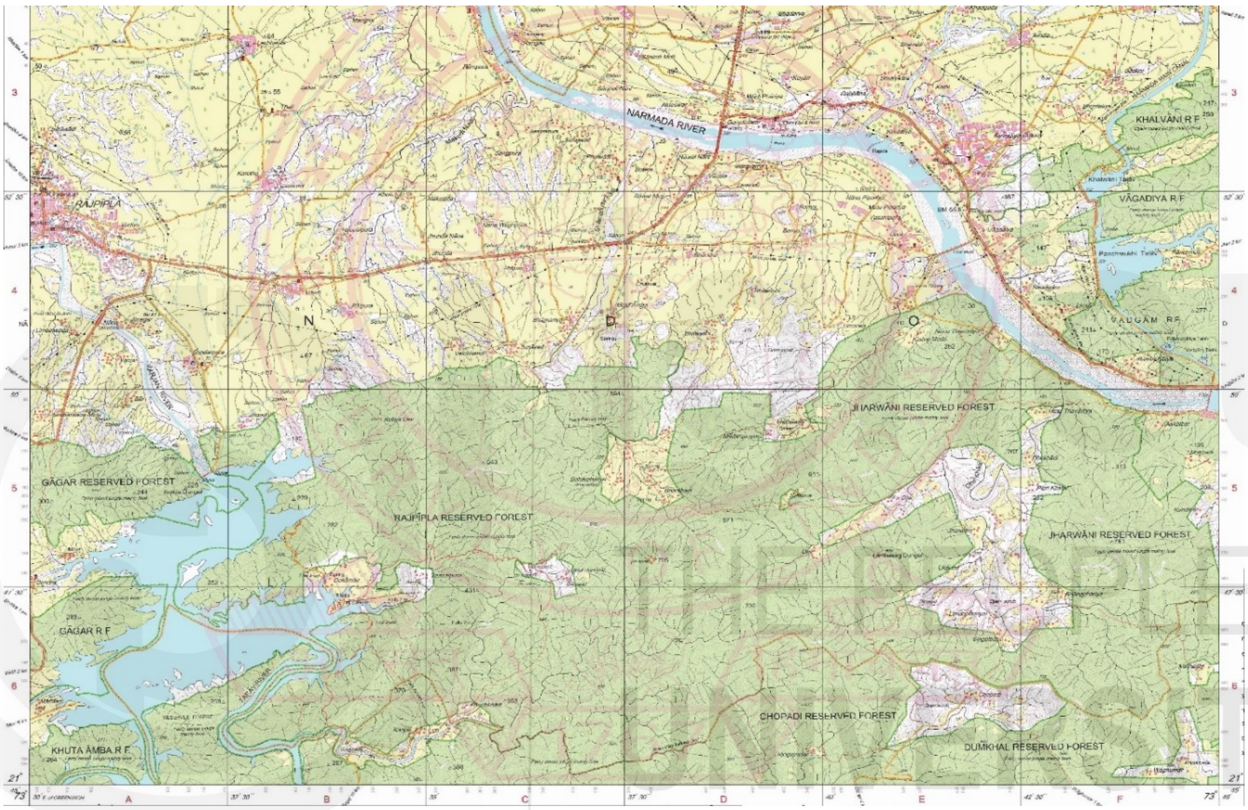


Fig. 1.2: Part of a topographic map of the area around Narmada River in Gujarat.
(Source: https://onlinemaps.surveyofindia.gov.in/)

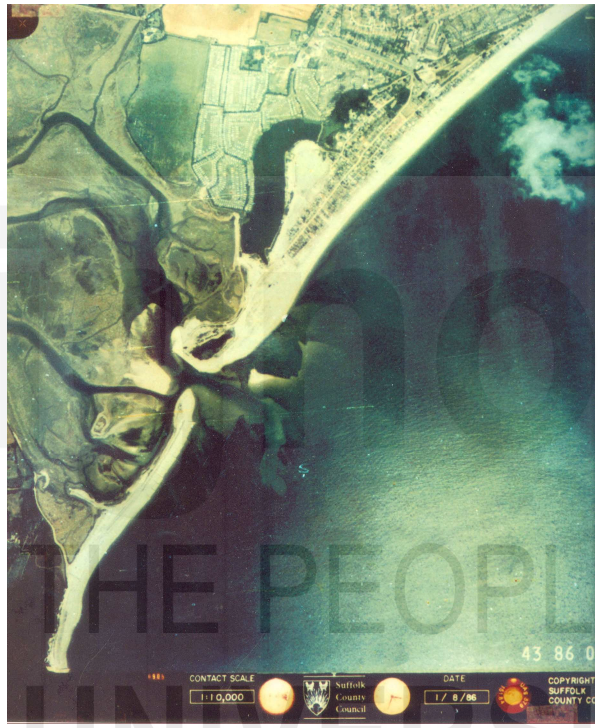
1.4.3 Satellite Data

Remote sensing satellite data of planetary bodies including Earth are obtained from cameras mounted on orbiting satellites. Such data are now available in large volumes for free, and is used extensively in various fields like geomorphology, geology, exploration of natural resources and natural hazard studies.

Interpretation of satellite data comprises identification of features of interest with the help of several elements such as shape, size, tone, texture, pattern, shadows, location and association. For correctly interpreting a satellite data as shown in the Fig. 1.4, it is essential to have knowledge of scale and how light interacts with different objects.

There are some platforms such as ISRO's Bhuvan (Fig. 1.5a), Google Earth (Fig. 1.5b) and many others through which we can visualise places of our interests in satellite images. Many of us are familiar with Google Earth, which is a web-based data platform comprising virtual globe showing digital satellite images, of the Earth's surface and also of other planets and satellites. The data can be seamlessly used with changing location, scale and view directions. It is useful for students and researchers in geomorphology as we can visualise landform of different terrain types and also associated cultural features. We can also understand changes in landscape with time through the images of different periods.

(a)



(b)

(c)

Fig.1.3: (a-b) Colour stereo-pair aerial photographs showing coastal landforms © 1986 Suffolk County Council, USA; (b) Students using pocket stereoscope to study aerial photographs.

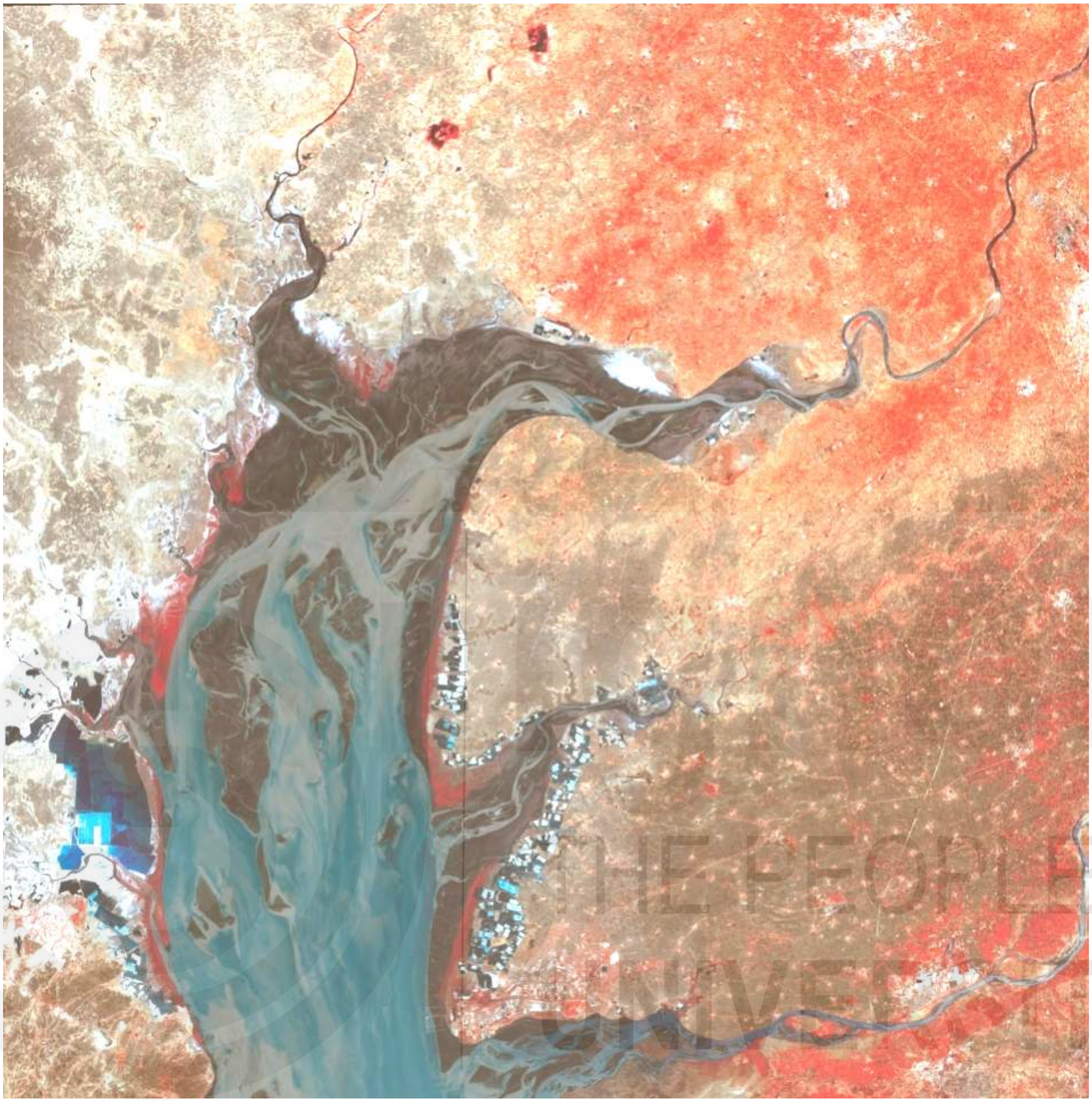
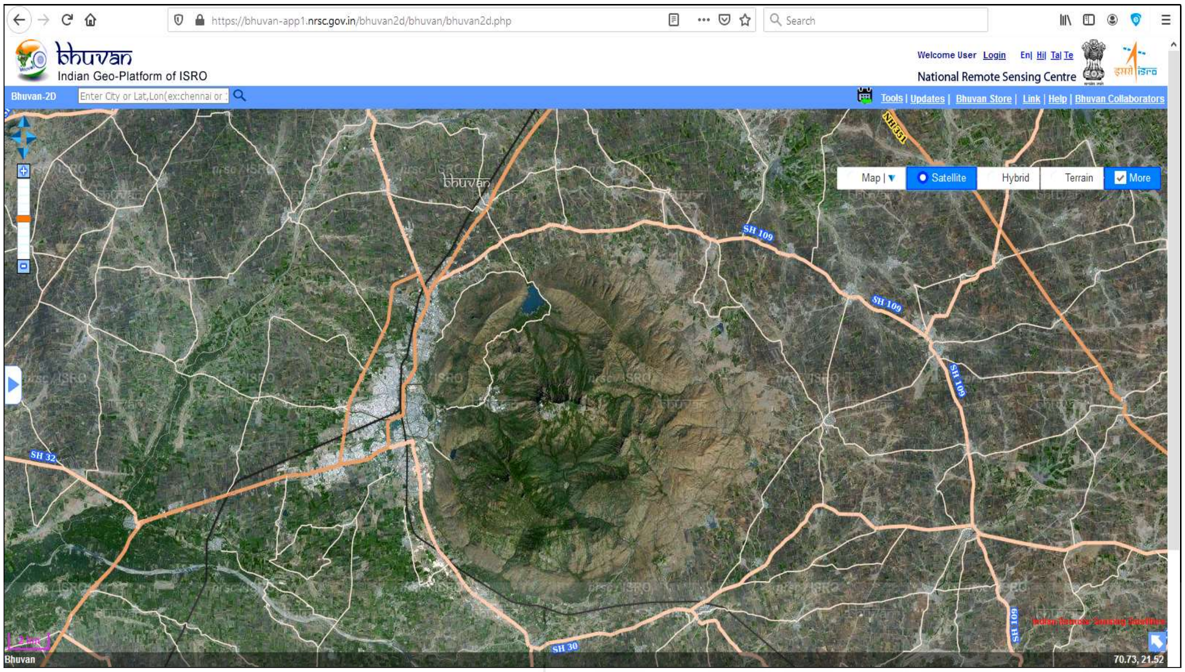


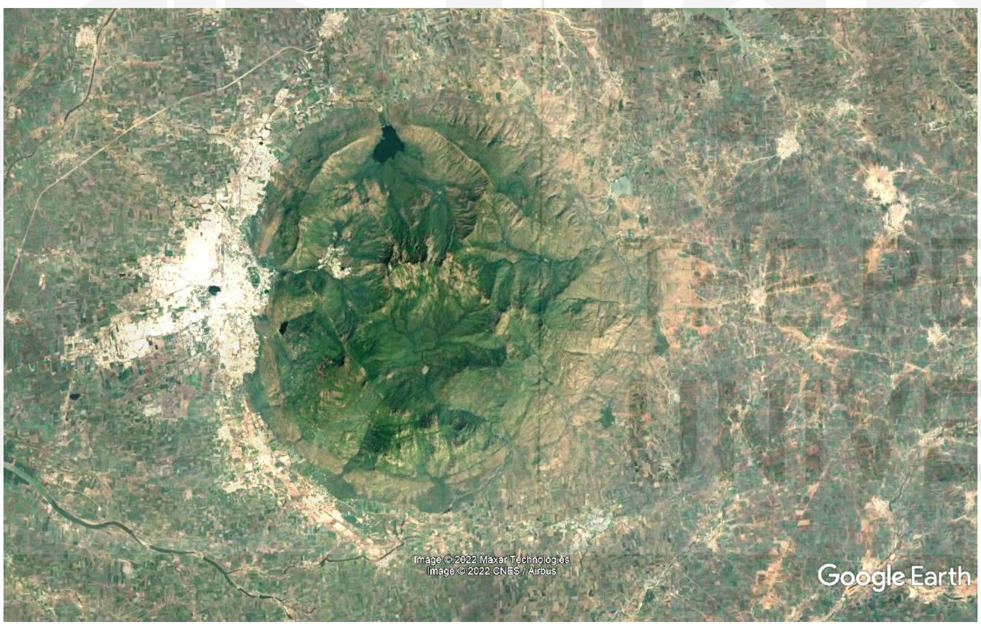
Fig.1.4: Sentinel-2 L1C satellite image of Gulf of Khambhat. (Source: https://eos.com)

1.4.4 Digital Elevation Models

The term digital elevation model (DEM) refers to relief models of Earth's surface. In simple words, it is a digital model or 3D representation of the surface of a terrain generated from elevation data (Fig. 1.6). The elevation data incorporated in DEMs can be sourced from remote sensing data collected by satellites, airplanes and drones or from measurements in the field. Modern elevation databases used for generating DEMs include images taken from satellites and aerial platforms such as airplanes, besides elevation information generated from contour lines, Digital Global Positioning System (DGPS) and ground based surveys using instruments such as digital theodolite.



(a)



(b)

Fig. 1.5: a) A view of the Girnar hill, Gujarat as seen in a satellite image (with some road network) in ISRO Bhuvan portal; and b) A view of the same hill in Google Earth.

1.5 DRAINAGE ANALYSIS

In the previous section, you have read about various tools and techniques used in geomorphological studies. Let us now discuss about drainage analysis.

You have already studied about drainage systems and patterns in Unit 6 of the course BGYCT-131. One important aspect of landscape analysis is the drainage analysis since drainage pattern reflect the nature of the terrain. Drainage analysis involves the study of individual stream pattern, overall drainage pattern, basin characteristics and drainage parameters, or indices. Individual stream pattern can be identified as straight, sinuous, or anastomosing in nature. We are aware that the drainage pattern is a design formed by drainage network as a result of various contolling factors such as lithology, structure, tectonics and climate. The dominance of one of the above controlling factors can lead to formation of distinct drainage patterns viz., dendritic, trellis, rectangular, radial, parallel, barbed, centripetal, etc.

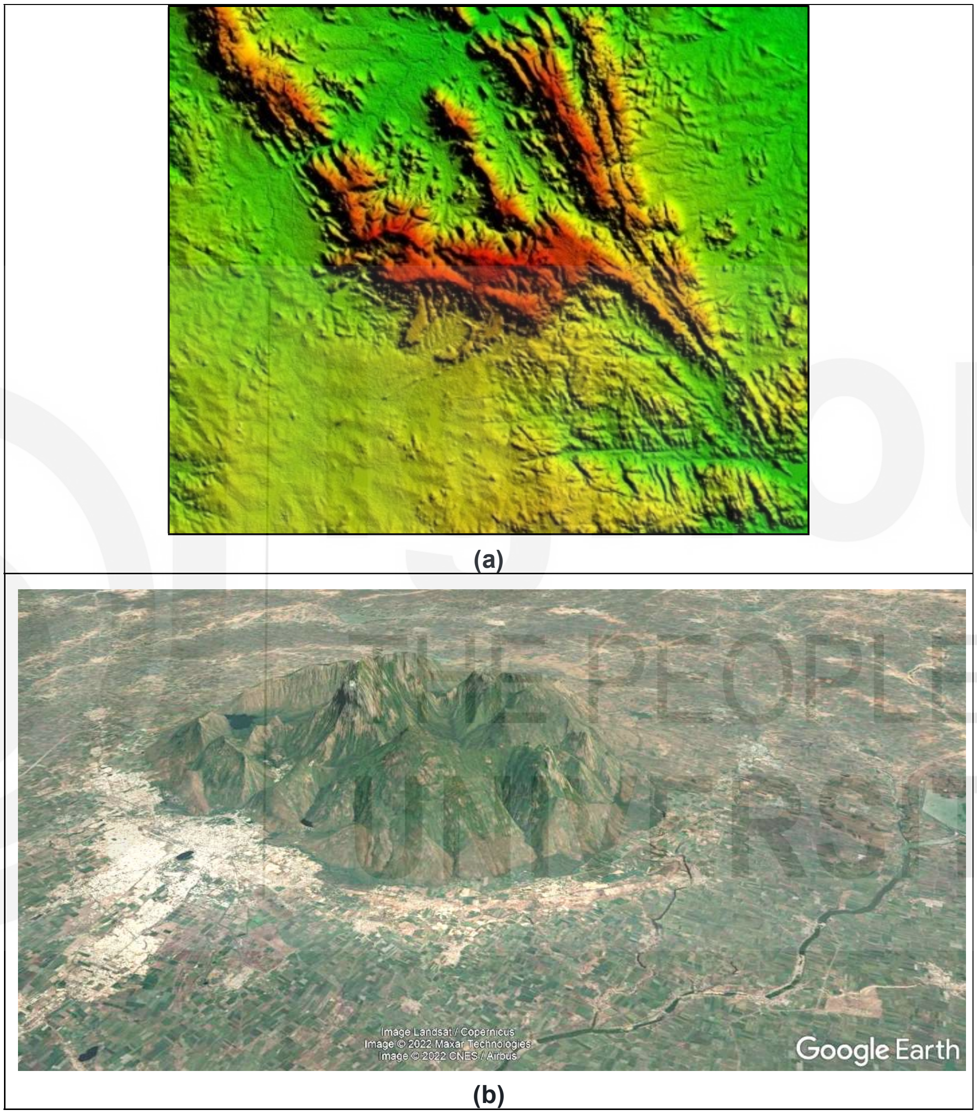


Fig. 1.6: a) Relief map generated from a Digital Elevation Model (DEM) of a part of the Sandur Schist Belt region in Karnataka. Note that low to high elevations are represented in the range of green to red colours, respectively. (Source: a- CartoSat DEM obtained from ISRO Bhuvan portal); and b- 3D view of Girnar hill, Gujarat in Google Earth).

Drainage basin is defined as the area where all the precipitation is collected and drained into a single outlet or stream. The shape and elongation of the drainage basin can indicate the controls of the structure, tectonic and climate in the given area.

To assess the morphotectonic evolution of drainage network in an area, drainage parameters or morphometric parameters are calculated. Drainage morphometry (also known as morphometric analysis and Horton analysis) is a quantitative analysis performed to understand the dimension and aspect of a geomorphic unit of the landscape. It provides information about surface form of a drainage basin and organisation of drainage networks and their relationships in that basin.

The drainage morphometric parameters are broadly classified as linear, areal and relief aspects or parameters based on their characteristics. Linear morphometric parameters include Stream order, Stream Length, Basin length, etc. Areal aspects of the drainage basin include Basin Perimeter, Basin Area, Drainage Density, etc. The relief aspects include basin relief, etc. These will be discussed in brief in Unit 6 of this course.

The drainage basin analysis is considered important for various assessments for planners and environmentalists to evaluate groundwater potential, management and exploration, geomorphic evolution of the terrain, controlling of floods, understanding river runoff patterns, etc.

1.6 LANDSCAPE ANALYSIS

Landscapes evolve over a period of time in response to surface and subsurface geological processes. The main controlling factors responsible for landscape evolution are tectonics, climate and eustatic sea level changes. Landscape analysis helps to characterise and unravel the history of landscape evolution. It also helps us to identify relative roles of various controlling factors and geomorphic processes. Landscape analysis can be carried out with two different approaches: qualitative and quantitative. Qualitative landscape analysis is mainly concerned with characterisation of landscapes in terms of stage of evolution, identifying major processes and geological controls. Quantitative approach of landscape analysis includes quantification of landscape parameters, rates of processes and estimating magnitude of influencing factors.

Several methods of landscape analysis are available that use topographical data, remote sensing data and DEMs. However, no single method encompasses entire range of landscape analysis. Selection of method or methods depends on objective, type of input data available and approach adopted. Landscape analysis is successfully applied in assessment of landscape characteristics, evolution, exploitation of natural resources, socio-cultural linkages, developmental planning and policy making.

1.7 APPPLICATIONS OF GEOMORPHOLOGY

In the previous sections you have read about drainage and landscape analysis. Now, let us discuss some applications of geomorphology.

Application of geomorphological knowledge for the benefit and well-being of human race forms the subject matter of applied geomorphology. An intelligent use of characteristics of the Earth’s surface has helped the humans to survive, evolve and adapt to variety of conditions since the pre-historic times. This indicates that applied geomorphology existed in one form or the other since the pre-historic to the modern times. However, the modern applied geomorphology has started since the last 40-50 years.

Geomorphological knowledge is required for variety of purposes by several professional organisations like administrative bodies, engineers, land developers, resource managers, planners, and environmentalists.

Advantages: Geomorphological data provides important datasets for use in various applications. Some of the distinct advantages of using geomorphological data are:

- It provides accurate spatial data viz., precise location, area of influence, relief variations, etc.
- It imparts visualisation and detection of spatial characteristics of landform units and their correlation.
- It helps in better appreciation of nature and scale (regional and local) of the problem.
- It provides an opportunity to incorporate the time dimension for evaluating the problem.
- It provides documentary evidence in form of theme specific maps, plans, photography, satellite data, DEMs, and others.
- It helps in evaluating the relative roles of natural and anthropogenic causes.
- It furnishes critical scientific information about the processes and their controlling factors.

Some of the application examples are given here:

- **Natural hazard studies and management:** Various types of natural hazards like floods, volcanoes, earthquakes, tsunamis and mass movements like, soil creep, landslides, debris flows and avalanches, occur frequently on the surface of the Earth. Other hazards also cause substantial damage by soil erosion, subsidence, desertification, etc. The effects of each hazard are multi-dimensional, e.g., earthquakes may cause tsunamis, uplift, subsidence, liquefaction, landslides, etc. besides extensive damage to manmade structures. Floods also show multiple effects like, high river discharge, high sediment inflow, inundation of flood plain, farmlands, soil erosion, slope collapse, devastation in human habitats, etc.. Geomorphological studies provides critical data for flood hazard estimation and predictions like, peak discharge, total runoff, area of inundation, lag time, duration of inundation, sediment load, flood frequency and expected timing of floods. Similarly, geomorphological data forms the base line for planning preventive measures for all natural hazards which are useful in minimising damage and also for predicting future occurrences.
- **Environmental management:** Environmental management estimates the causes and response to all geomorphic processes which are intentionally or unintentionally affected by anthropogenic activities. Some of these activities accentuate the effects of natural hazards and geomorphic processes. For

example, enhanced development activities like, constructing roads, mining, construction of large engineering structures like dams can alter the landscape to such an extent that hazards like, slope instability, erosion, floods, inundation and land use patterns change drastically. A strong geomorphic database and in-depth understanding of the processes is vital at the planning and implementation stage for minimizing the adverse environmental impact of various anthropogenic activities.

- **Natural resources studies:** Resource evaluation comprises consideration of landscape as an economic, strategic and esthetic resource. Land system mapping and landuse mapping along with geomorphological mapping and terrain analysis are important components of resource evaluation. Major resources of the landscape are soil, minerals, groundwater and sand and gravel.

  Geomorphological mapping provides important clues for locating, evaluating and exploiting natural resources like gold, diamond, deposits of bauxite, clay, copper, manganese, iron, etc. It also helps in monitoring environmental impacts during the mining process. Land system mapping provides fundamental data required for environmental and resource management. The area is divided into land systems through analysis of topographical maps, aerial photographs and satellite images. This forms the basis for resource evaluation and environmental impact assessment.

  Besides these applications, geomorphology is useful in military science, engineering projects, etc.

Now spend few minutes to check your progress.

SAQ 2

a) What is a topographical map?

b) What is qualitative landscape analysis?

c) List the drainage patterns.

1.8 SUMMARY

Let us sum up what we have studied in this unit. We have learnt that:

- Geomorphology can be defined as a branch of geology that deals with the study of landforms and landscapes.
- Some fundamental concepts were enumerated by W.D. Thornbury. These concepts help in interpretation of landscapes.
- Theory of uniformitarianism states that the processes operating presently on Earth's surface have been the same throughout the geologic time.
- According to the theory of catastrophism, the Earth has been shaped mainly by abrupt, short lived and worldwide events.
- Geomorphological studies are carried out on a wide range of spatial and temporal scales.

- Davisian theory of landscape evolution or the geomorphic cycle explains the long-term landscape evolution through a series of stages, which are truly a complete cycle as it starts and ends with the same landscape i.e., a peneplain.
- Topographic maps, stereoscopic aerial photographs, satellite data, digital elevation models, Google Earth data, etc. are various important tools and techniques for carrying out geomorphological mapping of landforms and landscapes.
- One of the important aspects of landscape analysis is the drainage analysis which involves the study of individual stream pattern, overall drainage pattern, basin characteristics and drainage parameters or indices.
- Qualitative landscape analysis is mainly concerned with characterisation of landscapes in terms of stage of evolution, identifying major processes and geological controls. Quantitative approach of landscape analysis includes quantification of landscape

1.9 ACTIVITY

Redraw the schematic cross sections depicting the stages in geomorphic cycle as shown in Figure 1.1.

1.10 TERMINAL QUESTIONS

1. List all the fundamental concepts enumerated by W.D. Thornbury. Explain any two of them.
2. Explain the geomorphic cycle with neat diagrams.
3. Discuss in detail any two tools used in geomorphological studies.
4. Write a note on applications of geomorphology.

1.11 REFERENCES

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1.12 FURTHER/SUGGESTED READINGS

- Holmes, A. (1965) Principles of Physical Geology, London and Edinburgh: Thomas Nelson & Sons, p. 628.
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1.13 ANSWERS

SAQ 1

a) Geomorphology can be defined as a branch of geology that deals with the study of landforms and landscapes including identification, description, classification, origin, geological and anthropogenic processes of formation and modification of landforms and geological evolution of landscapes of planetary surfaces through time.

b) *Concept: As the different erosional agents act upon the Earth's surface, they produce a sequence of landforms having distinctive characteristics at different stages of their evolution.*

c) The theory of uniformitarianism states that the processes operating presently on the Earth's surface have been the same throughout the geologic time.

d) The theory of catastrophism states that the Earth has been shaped mainly by abrupt, short lived and worldwide events.

SAQ 2

a) A topographical map is an detailed and accurate map which reveals all physiographic details including relief, hydrographic, cultural and vegetation features of an area.

b) Qualitative landscape analysis is mainly concerned with characterisation of landscapes in terms of stage of evolution, identifying major processes and geological controls.

c) Drainage patterns viz., dendritic, trellis, rectangular, radial, parallel, barbed, centripetal, etc.

Terminal Questions

1. Please refer to section 1.3.
2. Please refer to sub-section 1.3.4.
3. Please refer to section 1.4.
4. Please refer to section 1.7.