Geography Optional - 2024

NEETU SINGH

FUNDAMENTAL CONCEPTS OF GEOMORPHOLOGY

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.

This is the great underlying principle of modern geology and is known as the ***principle of uniformitarianism***. It was first enunciated by Hutton in 1785, beautifully restated by Playfair in 1802, and popularized by Lyell in the numerous editions of his *Principles of Geology*. Hutton taught that 'the present is the key to the past', but he applied this principle somewhat too rigidly and argued that geologic processes operated throughout geologic time with the same intensity as now. We know now that this is not true. Glaciers were much more significant during the Pleistocene and during other periods of geologic time than now; world climates have not always been distributed as they now are, and, thus, regions that are now humid have been desert and areas now desert have been humid; periods of crustal instability seem to have separated periods of relative crustal stability, although there are some who doubt this; and there were times when vulcanism was more important than now. Numerous other examples could be cited to show that the intensity of various geologic processes has varied through geologic time, but there is no reason to believe that streams did not cut valleys in the past as they do now; that the more numerous and more extensive valley glaciers of the Pleistocene behaved any differently from existing glaciers; that the winds which deposited the Navajo sandstone during Jurassic times obeyed any different laws from those which control wind movements today. Groundwater opened up solutional passageways in limestones and other soluble rocks and formed surface depressions which we now call sinkholes during the Permian and Pennsylvanian periods as it does today in many parts of the world. Without the principle of uniformitarianism, there could hardly be a science of geology that was more than pure description.

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

At one time it was common practice to indoctrinate students of geomorphology with the teaching of W.M. Davis that the major control factors in the development of landforms are structure, process, and stage. The term ***structure*** is not here applied in the narrow sense of such rock features as folds, faults, and unconformities but it includes all those ways in which the earth materials out of which landforms are carved differ from one another in their physical and chemical attributes. It includes such phenomena as rock attitudes; the presence or absence of joints, bedding planes, faults, and folds; rock massiveness; the physical hardness of the constituent minerals; the susceptibility of the mineral constituents to chemical alteration; the permeability or impermeability of rocks; and various other ways by which the rocks of the earth's crust differ from one another.

The term structure also has stratigraphic implications, and knowledge of the structure of a region implies an appreciation of rock sequence, both in outcrop and in the subsurface, as well as the regional relationships of the rock strata. Knowledge of geologic structure in the narrow sense thus becomes essential.

It is common practice to speak of rocks as being 'hard' or 'resistant' or 'weak' or 'nonresistant' to geomorphic processes. Such terms may be used so long as we recognize that we are using them in a relative sense and not always in a strictly physical sense, for rocks are attacked by both physical and chemical processes. A rock may be resistant to one process and non-resistant to another and under varying climatic conditions may exhibit different degrees of resistance.

In general, the structural features of rocks are much older than the geomorphic forms developed upon them. Such major structural features as folds and faults may go back to far distant periods of diastrophism. Even in areas of as recent diastrophism as that of the Pleistocene it is difficult to find uneroded folds. Hence as a general principle, we may assume that most rock structures were established long before the landforms which exist upon them.

Rock structure affects the characteristics of landforms. Commonly these relationships are obvious and result in striking topographic features.

Concept 3: To a large degree, the earth's surface possesses relief because the geomorphic processes operate at differential rates.

The main reason why gradation of the earth's surface proceeds differentially is that the rocks of the earth's crust vary in their litho logy and structure and hence offer varying degrees of resistance to the gradational processes. Some of these variations are very notable while others are very minute, but none is so slight but that it affects, to some degree, the rate at which rocks waste. Except for regions of very recent diastrophism, it is usually safe to assume that areas which are topographically high are underlain by 'hard' rocks and those which are low by 'weak' rocks, relatively speaking. Differences in rock composition and structure are reflected not only in regional geomorphic variability but in the local topography as well. Much of the minor topographic details, or what we may call the micro topography, is related to rock variations often too minute in nature to be readily detectable.

Although varying litho logy and structure are major factors contributing to differential wasting of the earth's surface, they are by no means the only reasons why geomorphic processes within narrow limits may operate at variable rates. The local intensity of particular processes may change notably in response to differences in such factors as temperature, moisture, altitude, exposure, topographic configuration, and the amount and type of vegetal cover. The microclimatic conditions may vary markedly between a valley floor and a hilltop, between a northern and a southern exposure, and between bare ground and that with a heavy vegetal cover. These differences may be reflected in the amount of precipitation as well as the type, the rate of evaporation, the amount of soil moisture, the intensity of insolation and the number of times annually that temperatures fluctuate above and below the freezing point. So complex are the many factors influencing the local rates of geomorphic processes that it is probably not much of an exaggeration to state that the rate of all weathering, all mass-wasting, all erosion, and all deposition varies appreciably within rather narrow limits in relation to the influence of local conditioning factors. Recognition of this fundamental principle of landscape evolution is particularly pertinent to an appreciation of the etching concept.

Concept 4: Geomorphic processes leave their distinctive imprint upon landforms, and each geomorphic process develops its own characteristic assemblage of landforms.

The term process applies to the many physical and chemical ways by which the earth's surface undergoes modification. Some processes, such as diastrophism and volcanism, originate from forces within the earth's crust and have been designated by Penck as ***endogenetic***, whereas others, such as weathering, mass-wasting, and erosion, result from external forces and have been called ***exogenetic*** in nature. In general, the endogenetic processes tend to build up or restore areas which have been worn down by the exogenetic processes; otherwise, the earth's surface would eventually become largely featureless. The concept of geomorphic processes operating upon the earth's crust is not a new one. Even the ancients recognized it to some degree, but the idea that the individual processes leave their distinctive stamps upon the earth's surface is rather recent.

Just as species of plants and animals have their diagnostic characteristics, so land forms have their individual distinguishing features depending upon the geomorphic process responsible for their development. Floodplains, alluvial fans, and deltas are products of stream action; sinkholes and caverns are produced by groundwater; and end moraines and drumlins in a region attest to the former existence of glaciers in that area.

The simple fact that individual geomorphic processes do produce distinctive land features makes possible a ***genetic classification*** of landforms. The recognition of this fact and his insistence upon its superiority to other types of landscape description was one of Davis's important contributions to geomorphology: for it changed the subject from one in which landforms were classified upon a purely morphological basis without regard to interpretations which could be made from them as to their geomorphic history.

A proper appreciation of the significance of process in landform evolution not only gives a better picture of how individual landforms develop but also emphasizes the genetic relationships of land form assemblages. Land forms are not haphazardly developed with respect to one another but certain forms may be expected to be associated with each other. Thus, the concept of certain types of terrain becomes basic in the thinking of a geomorphologist. Knowing that certain forms are present, he should be able to anticipate to a considerable degree the other forms that may be expected to be present because of their genetic relationships to one another.

Although it is convenient in discussing the origin of landforms to consider each geomorphic process separately, we soon come to realize that most landscapes are the products of a group of processes. The complex of geomorphic processes and agents, which operates under a particular set of climatic conditions, has been termed a ***morphogenetic system***. Many landscapes give evidence of having developed under changing morphogenetic systems associated with the changing climates of Pleistocene time.

Concept 5: As the different erosion agents act upon the earth's surface, there is produced an orderly sequence of landforms.

At one time, we would have added with considerable assurance to the above statement the phrase 'having distinctive characteristics at the successive stages of their development'. Today, we are not quite so sure whether this would be a correct statement. That landforms possess distinctive characteristics depending upon the stage of their development is an idea that W.M. Davis stressed most and out of it grew his concept of the geomorphic cycle and its concomitant stages of youth, maturity, and old age culminating in a topographic surface of low relief to which Davis assigned the name peneplain.

It is probably true that most geomorphologists believe that landforms have an orderly and sequential development. However, not all are convinced that the stages of youth, maturity, and old age as postulated by Davis have reality. As a gross generalization, the concept may be useful at the elementary level but it has some inadequacies when a more sophisticated approach to landform evolution is attempted. Whether there are distinctive and expectable characteristics at each stage of development is a point about which there has been increasing skepticism.

Especially has there been increasing doubt as to the reality of the peneplain as an end product of an erosion cycle.

Despite the possibility that the term geomorphic cycle is not an entirely appropriate term to designate the changes through which landscapes go as the gradational processes operate upon them, it is difficult to find a substitute term, or for that matter a substitute concept of landscape evolution, that does not have its shortcomings. We shall therefore continue to use the terms cycle and geomorphic cycle but in using them, we are not necessarily implying that why they designate are truly cyclic in nature or that the so-called stages of a cycle categorically represent progressive and readily recognizable stages of land form evolution. Use of the term will carry with it the implication of orderly and sequential development but there will be no implication that designation of the topography of a certain area as youthful, mature, or old means that the topography of another region in the same stage of development has fully comparable characteristics. Under varying conditions of geology, structure, and climate, landform characteristics may vary greatly even though the geomorphic processes may have been acting for comparable periods of time. Similarity in the topographic details of two regions would be expectable only if the initial surface, lithology, structure, climate, and diastrophic conditions were comparable. Although passage of time is implied in the concept of the geomorphic cycle, it is in a relative rather than absolute sense. There is no implication that two areas that are in comparable stages of development have required the same length of time for their attainment. Much confusion has arisen from the fact that numerous geologists have defined a geomorphic cycle as the period of time required for reduction of an area to base level rather than as the changes through which a landmass passes as it is reduced toward base level.

A corollary to the concept of a completed geomorphic cycle is that of a partial cycle. In fact, partial cycles are far more likely to occur than completed ones, for much of the earth's crust is restive and subject to intermittent and differential uplift. Despite this fact, it does appear that portions of the earth's crust do at times remain essentially stable for sufficient periods of time to permit the attainment of advanced stages of landscape development. However, even a partial cycle may leave its imprint upon a landscape and the geomorphologist needs to be able to recognize the evidence of one.

It should be noted that to explain landforms in terms of the three control factors of structure, process, and stage, as these terms were used by Davis, the diastrophic history of a region must be encompassed either under structure or process. Usually it is considered under process, but much might be said for considering this factor equally as important as the other three. Particularly in such tectonically active areas as California and New Zealand, this factor may be critical one and actually seem to obscure any tendency to sequential landform development. Under conditions of continuing uplift or rapidly repeated intermittent uplift, a landscape may be kept perpetually youthful or mature without running the course of a normal cycle.

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

It is probably a fundamental human trait to prefer a simple explanation to a more involved one, but a simple explanation is probably rarely the correct one. Many of the great controversies in science have arisen from this preference for a simple explanation. The serious student of landforms does not progress far in his study of them before he comes to realize that little of the earth's topography can be explained as the result of the operation of a single geomorphic process or a single geomorphic cycle of development. Usually, most of the topographic details have been produced during the current cycle of erosion, but there may exist within an area remnants of features produced during prior cycles, and, although there are many individual landforms which can be said to be product of some single geomorphic process, it is a rare thing to find landscape assemblages which can be attributed solely to one geomorphic process, even though commonly we are able to recognize the dominance of one. It may facilitate our interpretation of landscapes to group them, as **Horberg did, in five major categories: (1) simple, (2) compound, (3) monocyclic, (4) multicyclic, and (5) exhumed or resurrected landscapes.**

Simple landscapes are those, which are the product of a single dominant geomorphic process, and ***compound landscapes*** are those in which two or more geomorphic processes have played major roles in the development of the existing topography. It might, of course, be argued that nearly all landscapes are compound in nature, and in a strict sense this is true, for rarely do we find any extensive area in which the landforms can be attributed solely to the action of one process. But to press for this narrow usage of the world would to a large degree leave us in the hopeless dilemma of having to discuss all types of landscapes together without recognizing the dominance of certain processes in their development. It is a perfectly logical to designate a certain landscape as being primarily the work of running water even though we may realize full well that weathering, movement of material under the direct influence of gravity, and removal of loose materials by the wind may have contributed to its development. It is equally logical to designate another type of landscape as being largely the product of solution by groundwater even though erosion by surface waters, weathering, and other processes may have contributed to its development. The type of landscape which we may logically designate as compound in nature is well illustrated in areas that were subjected to Pleistocene glaciations or felt the indirect effects of it. This is particularly true of the areas glaciated before the Wisconsinan age. In such areas, there may be found upland tracts which still retain mainly their original glacial characteristics, yet along stream courses, running water has formed the topography. Locally features may also exist resulting from wind deposition of materials derived from the streams which carried glacial melt waters. Even beyond the limits of actual glaciations, the topography may be compound in nature. The main topographic features may be the result of stream action, but along some stream courses there may be found features resulting from glacial outwash into the area and from wind action upon this outwash. In portions of such states as Arizona, New Mexico, Nevada, and Utah, we find examples of compound landscapes in which stream-cut topography has within it volcanic cones and lava flows and locally prominent scarps produced by faulting of blocks of the earth's crust.

Monocyclic landscapes are those that bear the imprint of only one cycle of erosion; ***multicycle landscapes*** have been produced during more than one cycle of erosion. Monocyclic landscapes are less common than multicyclic and are in general restricted to such newly created land surfaces as a recently uplifted portion of the ocean floor, the surface of a volcanic cone, lava plain or plateau, or areas buried beneath a cover of Pleistocene glacial deposits. Much, if not most, of the world's topography bears the imprint of more than one period of erosion. The older erosion topography may be represented only by limited upland remnants or by benches along valley sides above present valley floors. Features of multicyclic origin have been described from all the continents except Antarctica. It should be recognized that both a monocyclic landscape and a multicyclic landscape may be either simple or compound in nature.

To the idea of complex evolution of landforms should be added the concept of ***polyclimatic landscapes***. It has become evident in recent years that many landscapes have evolved under more than one set of climatic conditions with accompanying variation in the dominant geomorphic processes. Many of these varying climatic conditions were associated with the fluctuating climates of Pleistocene time, but in some areas certain aspects of the topography reflect climatic conditions that existed in Tertiary time.

Exhumed or ***resurrected landscapes*** are those which are formed during some past period of geologic time, then buried beneath a cover mass of igneous or sedimentary origin, then still later exposed through removal of the cover. Topographic features now being exhumed may date back as far as the Precambrian or they may be as recent as the Pleistocene. Throughout the areas covered by Pleistocene deposits there are hundreds of streams in the process of exhuming buried pre glacial topography. Most resurrected features are of local extent and constitute a small portion of our present-day landscape, but they may be striking features. For example, along one stretch of the Wabash River, in northern Indiana, where it flows across a buried pre glacial topography, its valley is less than one-half mile wide where the stream cuts into the bedrock of a buried ridge, but the valley suddenly widens to three miles where it is being cut in the more readily erodible glacial materials filling a pre glacial valley.

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

It is common in reading older discussions on the age of topographic features to find references to erosion surfaces dating back to the Cretaceous or even as far back as the Precambrian. We have gradually come to a realization that topographic features so ancient are rare, and, if they do exist, are more likely exhumed forms than those which have been exposed to degradation through vast periods of geologic time. Most of the details of our present topography probably do not date back of the Pleistocene, and certainly little of it existed as surface topography back of the Tertiary. Ashley has made a strong case for the youthfulness of our topography. He believed that 'most of the world's scenery, its mountains, valleys, shores, lakes, rivers, waterfalls, cliffs, and canyons are post-Miocene, that nearly all details have been carved since the emergence of man, and that few if any land surfaces today have any close relation to pre-Miocene surfaces'. He estimated that at least 90 percent of our present land surface has been developed in post-Tertiary time and perhaps as much as 99 percent is post-middle Miocene in age. Whether these figures are correct is unimportant, but they certainly point the way to a conclusion which geomorphologists should accept, despite the fact that it is still possible to find geologists who believe otherwise.

It is, of course, true that many geologic structures are very old. It has been previously stated that geologic structures are in general much older than the topographic features developed upon them. The only notable exceptions are to be found in areas of late Pleistocene and recent diastrophism. The Himalayas were probably first folded in the Cretaceous and later in the Eocene and Miocene but their present elevation was not attained until the Pliocene and most of the topographic detail is Pleistocene or later in age; the structural features which characterize the Rocky Mountains were produced largely close of the Cretaceous, but little of the topography in this area dates back of the Pliocene and the present canyons and details of relief are of Pleistocene or Recent age.

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

Correlative with the realization of the geologic recency of most of the world's topography is the recognition that the geologic and climatic changes during the Pleistocene have had far-reaching effects upon present-day topography. Glaciation directly affected many million square miles, perhaps as much as 10,000,000 square miles, but its effects extended far beyond the areas actually glaciated. Glacial outwash and windblown materials of glacial origin extended into areas not glaciated, and the climatic effects were probably worldwide in extent. Certainly in the middle latitudes the climatic effects were profound. There is indisputable evidence that many regions that are today arid or semiarid had humid climates during the glacial ages. Freshwater lakes existed in many areas which today have interior drainage. At least 100 of the closed basins in western United States had Pleistocene lakes in them. Similar evidence of pluvial conditions in regions now arid or semiarid has been found in Asia, Africa, South America, and Australia, so that there can be no doubt about the worldwide influence of glacial conditions upon climates.

We know also that many regions now temperate, experienced during the glacial ages temperatures such as are found now in the subarctic portions of North America and Eurasia, where there exists permanently frozen ground or what has come to be called permafrost conditions. Stream regiments were affected by the climatic changes, and we find evidence of alternation of periods of aggradation and downcutting of valleys. Such streams as the Ohio and Missouri Rivers, and to a considerable except the Mississippi, have the courses which they do today largely as a result of glacial modifications of their pre glacial courses. World sea levels are also affected. Withdrawal of large quantities of water from the oceans to form great ice sheets produced a lowering of sea level of at least 300 feet and perhaps as much as 500 feet. Return of this water to the oceans during interglacial ages caused a return of high sea levels such as characterize present geologic time. The discharge of cold glacial melt waters to the oceans may have had significant effects upon certain marine organisms such as the reef-building corals. Winds blowing across glacial outwash or fresh glacial deposits in many areas built up dual accumulations of sand or deposited over areas a mantle of silt and clay called loess. Glaciation has been responsible for the formation of more lakes than all other causes combined. The Great Lakes, the world's greatest internal waterway system, are the result of glacial modifications of pre glacial lowlands and valleys.

Although glaciation was probably the most significant event of the Pleistocene, we should not lose sight of the fact that in many areas the diastrophism which started during the Pliocene continued into the Pleistocene and even into the Recent. Around the margins of the Pacific Ocean, Pleistocene diastrophism has played a most significant role in the production of present-day landscapes. It is further evidenced in the Rocky Mountains by deep canyon cutting, in many places over 1000 feet, which took place between the earlier glacial ages and the later Wisconsin glaciations.

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

That climatic factors, particularly those of temperature and precipitation, should influence the operation of the geomorphic processes seems self-evident, yet there have been surprisingly few detailed studies made which attempted to show to just what degree climatic variations influence topographic details. The reason for this somewhat paradoxical situation is not apparent. It may possibly be in part a result of the fact that geologists in general are not climate-minded and that geographers, who are better acquainted with the details of climate in recent years have been more concerned with the adjustments of man's activities to varying landscapes than with the origin of the landscapes themselves.

Climate variations may affect the operation of geomorphic processes either indirectly or directly. The indirect influences are largely related to how climate affects the amount, kind, and distribution of the vegetal cover. The direct controls are such obvious ones as the amount and kind of precipitation, its intensity, the relation between precipitation and evaporation, daily range of temperature, whether and how frequently the temperature falls below freezing, depth of frost penetration, and wind velocities and directions. There, are however, other climatic factors whose effects are less obvious, such as how long the ground is frozen, exceptionally heavy rain falls and their frequency, seasons of maximum rainfall, frequency of freeze and thaw days, differences in climatic conditions as related to slopes facing the sun and those not so exposed, the differences between conditions on the windward and leeward sides of topographic features transverse to the moisture-bearing winds, and the rapid changes in climatic conditions with increase in altitude.

Most of what we consider the basic concepts in geomorphology have evolved in humid temperate regions. We have to a large degree considered such regions as representing the 'normal' conditions. Although we have come to realize to some degree the differences between processes in arid and in humid regions, whereas there really are several types of arid climates, and thus we oversimplify when we speak of the arid cycle. As yet we have hardly begun formulation of basic geomorphic concepts with respect to the humid tropical, arctic, and subarctic regions. Of this much we may feel certain, that the processes which are dominant in the humid middle latitudes are not necessarily important to the same degree in the lower and higher latitudes and that their significant differences will not be fully comprehended until we take into full account climatic variations. High altitudes within any climatic realm impose modifications which should also be recognized.

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

Geomorphology concerns itself primarily with the origins of the present landscape but in most landscapes there are present forms that date back to previous geologic epochs or periods. A geomorphologist is thus forced to adopt an historical approach if he is to interpret properly the geomorphic history of a region. Application of the principle of uniformitarianism makes this approach possible.

At first thought it might seem that the recognition of ancient erosion surfaces and the study of ancient topographies does not belong in the field of geomorphology, but the approach of the geomorphologist may well be the most logical one. This aspect of landform study is called ***paleogeomorphology***.

The historical nature of geomorphology was recognized by Bryan when he stated:

'If landforms were solely the result of processes now current, there would be no excuse for the separation of the study of landforms as a field of effort distinct from Dynamic Geology. The essential and critical difference is the recognition of landforms on the remnants of landforms produced by processes no longer in action. Thus in its essence and in its methodology, physiographic (geomorphology) is historical. Thereby, it is a part of Historical Geology, although the approach is by a method quite different from that commonly used.'

When geomorphologists themselves fully realize and in turn convince other geologists of this use which can be made of geomorphic principles and knowledge, the subject will become a true working tool in many of the practical applications of geology.

****