Applied Geomorphology

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Component-I (B) - Description of Module

Items	Description of Module
Subject Name	**Geography**
Paper Name	**Geomorphology**
Module Name/Title	**Applied Geomorphology**
Module Id	**GEO/35**
Pre-requisites	**Applied Geomorphology, systematic analysis and relation with geomorphological features**
Objectives	**To know about the application of geomorphology and its development in different geomorphological regions like karst, glacial, alluvial, fluvial and many more, and its contribution in regional planning, urban and coastal areas.**
Keywords	**Limestone terrain, Mineral exploration, Placer deposits, Gravel pits, Militray geology, Salt dome, Coastal zone.**

Applied Geomorphology

Introduction

There has been an increasing recognition of the practical application of geomorphic principles and the findings of geomorphological research to human beings who are influenced by and, in turn, influence the surface features of the earth. Continuous increase in population has led to pressure on land resources, extension of agriculture to hilly and marginal lands resulted in man induced catastrophies like soil erosion, landslides, sedimentation and floods. A proper interpretation of landforms throws light upon the geologic history, structure, and lithology of a region. As geology becomes more specialized there is growing possibility that the application of geomorphology to problems of applied geology will be overlooked. The role of applied geomorphology relates mainly to the problems of analyzing and monitoring landscape forming processes that may arise from human interference. Human beings have over time tried to tame and modify geomorphic/environmental processes to suit their economic needs. Geomorphology has diverse application over a large area of human activity while Geomorphologist may serve more effectively the need of society.

GEOMORPHOLOGY AND HYDROLOGY

Water either on the surface of the earth or groundwater used by human is available from different sources like streams, lakes and rivers. The lithological zones present different conditions of surface as well as groundwater.

Hydrology of limestone terrains

Comprehensive understanding of geomorphology is key to understand the hydrological problem of the limestone terrain. Limestone region yield more water than other due to its rock formation. Availability of water in limestone region depends on the type of rock. On the basis Permeability limestone rocks may be primary or secondary. Calcareous sediments decide the formation of rock and its primary permeability while earth movements in the form of tension and compression such as faulting, folding, warping, and due to solution or corrosion mechanism decide the secondary permeability.

Joints and fractures produced by diagenetic and diastrophic processes formed the secondary or acquired permeability which resulted into solution. The cavities of the solution in limestone region depends on whether it has been situated in the past or allow joints and bedding planes to be actively more enlarged. In Florida (USA), these solution cavities are common at considerable depth in the Tertiary limestones. The significance of solutional opening with increased permeability is important in present day topography but also in karst landscape too.

Geomorphology plays an important to obtained water in limestone region. It may be easy or difficult to obtain water from wells in a limestone terrain. There may not be difficulty in obtaining wells of large yields if the limestones have enough permeability and are capped with sandstone layer. In such case the yield of water may be low or inadequate, but subject to contamination. Karst plains lacks filtering cover, and any swallow holes, sinkholes, or karst valleys within an area of clastic rocks should cast doubt upon the purity of the water of springs.

Glaciated areas and groundwater

Preglacial and glacial time history, types of deposits and landforms determine the possibilities of large supplies of groundwater potentials in glaciated regions. Yield of large volume of water obtained from Outwash plains, valley trains, and intertill gravels or buried outwash. Due to clay content most of the aquifers are poor, but containing local strata of sand and gravel may hold and supply enough water for domestic needs. The study of preglacial topography and geomorphic history of the area could detect the presence and absence of underground water.

GEOMORPHOLOGY AND MINERAL EXPLORATION

There is a close association of geological structure and minerals deposits. Characteristic of landscapes of specific areas could indicate these geological structures. Economic geologist has not appreciated the exploration of some minerals in the name of understanding of the geomorphic features and history of a region. In search for mineral deposits, these three points may serve for Geomorphic features as:
(I) some mineral have direct topographic expression for its deposits;

(2) the geologic structure and topography of an area have correlation which clue the accumulation of minerals;
(3) geomorphic history clearly indicates the physical condition under which the minerals accumulated or were enriched of a particular area.

Surface expression of ore bodies

Some of ore bodies have surface expression, but many do as topographic forms, as outcrops of ore, gossan, or residual minerals, or as such structural features as faults, fractures, and breccia zones. It is not necessary that all ore outcrops are reflected in positive topographic forms. The lead-zinc lode could be marked by a conspicuous ridge in the case of Broken Hill, Australia. Quartz veins could stand out prominently as they are much more resistant to erosion than the unsilicified rocks, as in Chihuahua, Mexico. Some veins and mineralized areas may lack conspicuous topographic expression or it may be reflected by subsidence features or depressions. Though no generalization can be made about the exact type of topography necessary for the iron ore accumulation, distinct topographic expression is needed for a particular deposit. Residual iron deposits are the results of concentration of iron due to long periods of weathering, and thus for their accumulation, old erosion and weathering surfaces are favorable sites.

Weathering residues

Geomorphology can play an important role for several important economic minerals which are essentially weathering residues of present or ancient geomorphic cycles. Apart from iron deposits, materials like clay minerals, caliche, bauxite and some manganese and nickel ores are of this nature. Recent weathering surfaces may exhibit residual weathering products or it may lie upon ancient weathering surfaces which are now buried.

Peneplain or near peneplain surfaces are most commonly surfaces upon which they form. In general such minerals are to be found upon remnants of tertiary erosional surfaces above present base levels of erosion. It is not yet clear why the weathering of igneous rocks produces both clay minerals or hydrous aluminum silicates and hydrous oxides of aluminum, such as bauxite. The difference in the final product is determined by the climatic conditions under which weathering takes could be one of the explanation.

The residual products from the weathering of igneous rocks are clay minerals found in temperate climates known as kaolinization. It should be recognized that numerous minerals other than kaolin may form in same climate. On the contrary, under tropical climates final weathering products are hydrous oxides of such metals as aluminum, manganese and iron. This type of weathering is known as laterization. The phase of geology which concerns with the recognition and the study of ancient weathering surfaces and soil has come to be known as paleopedology. Though it offers many possibilities but still in its infancy in the search for the type of mineral deposits designated as weathering residues of geological phase.

Epigenetic minerals and unconformities

Ancient erosion surfaces are associated with numerous deposits of Epigenetic minerals. Mills and Eyrich (1966) emphasized the role played by unconformities in the localization of mineral deposits. The mineral deposits found from the ranging age of Precambrian to Tertiary, shown evidences of close association with unconformities in districts of US and Canada, such minerals are uranium, vanadium, copper, barite, fluorite, lead, nickel, and manganese. There is constant work of weathering and erosion on the rocks of earth's surface and this weathering work has economical value of rock product.

Placer deposits

Placer deposits are mixtures of heavy metals with specific location, geomorphic principles have been applied other than any other phase of economic geology. Geomorphic processes are the main cause of placer concentration of minerals, found in specific positions with distinctive topographic expression. the deposition of placers affected by the type of rock forming the bedrock floor. There are as many as nine types of placer deposits. They are residual or 'seam diggings', colluvial, eolian, bajada, beach, glacial including those in end moraines and valley trains, and buried and ancient placers. The most important among them is alluvial placers.

The other name of Residual placers is 'seam diggings' which are residues from the weathering of quartz stringers or veins, are usually of partial amount, and grade down into lodes. Creep down slope is the main reason for the production of colluvial placers and are thus transitional between residual placers and alluvial placers.

Most of the gold placers of this form have been found in California, Australia, New Zealand, and elsewhere. Colluvial placers (the koelits) and alluvial placers (the kaksas) are parts of the tin placers of Malaya. . The most important minerals like gold, tin and diamonds are obtained from alluvial placers. South Africa's diamonds from Vaal and Orange River districts, the Lichtenburg area, the Belgian Congo, and Brazil's Minas Geraes, are obtained from alluvial placers. Placer deposits have total share of around 20 per cent of world's diamonds. Australia, lower California, and Mexico have yielded gold in aeolian placers. Gold in California and Alaska, diamonds in the Namaqualand district of South Africa, zircon in India, Brazil, and Australia, and ilmenite and monazite from Travancore, India have yielded from beach placers.

Fig. 1: Gold placer, Source: http://scienceblogs.com/startswithabang/2014/04/23/striking-cosmic-gold-synopsis/

__Oil exploration__

Several oil fields have been discovered because of their striking topographic expression. These oil fields are characterized by anticlinal structures which strikingly reflected in the topography. When viewed from aerial photographs, many of the Gulf Coast salt dome structures are evident in the topography. For the student of geomorphology, it is fairly good working principle to suspect that areas that are topographically high may also be structurally high, where possibilities of topographical inversion at the crest of a structural high may result with weak beds.

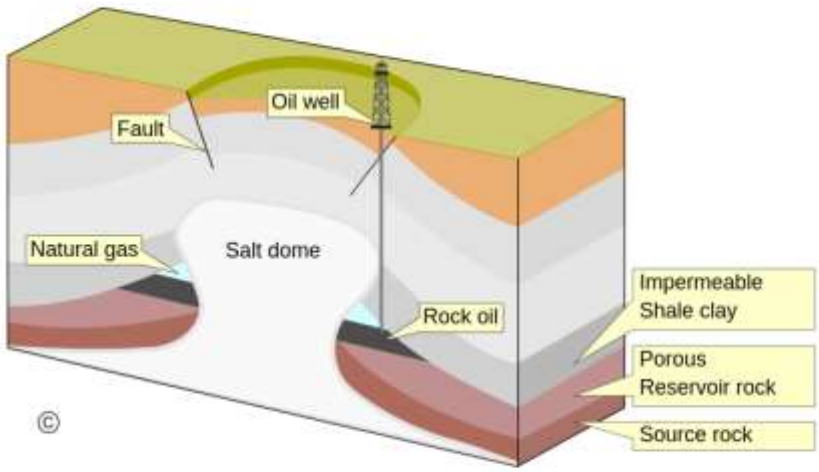

Fig. 2- Salt dome, Source: Source: https://commons.wikimedia.org/wiki/File:Salt_dome_trap.svg

In regions of heavy tropical forest, topography cannot be seen through the intense forest cover, an anticlinal or domal structure may outline due to the tonal differences in the vegetation. In search for oil, more subtle evidence of geologic structures favourable to oil accumulation is being made. Aerial photography is one such technique through which drainage analysis of a terrain can be shown. Drainage analysis is useful particularly in regions where rocks have low dips and the topographic relief is slight. Permeability may be either primary or secondary in carbonate rocks. Number of large oil yields from limestone has been obtained from rocks which have a high degree of permeability produced by solution.

Elongate buried sand bodies are basically shoestring sands. Probably there is no phase of petroleum exploration which can use to better advantage a knowledge of the in depth characteristics of specific topographic features than that which deals with the misuse of shoestring sands. Most of the oil and gas sources are associated with unconformities - ancient erosion surfaces; hence a petroleum geologist must deal with buried landscapes.

GEOMORPHOLOGY AND ENGINEERING WORKS:

Evaluation of geologic factors of one type or another often involve in most of the engineering projects, among all the factors terrain characteristics is most common. A detailed study of the geomorphic history of an area may support the proper evaluation of surficial materials and the bedrock profile configuration.

Road Construction

Topographic features of an area determined the most feasible highway route. Road engineering faces a number of problems by different types of terrain that includes geologic structure, geomorphic history of the area, lithological and stratigraphic characteristics and strength of the surficial deposits. Area like karst plain required repeated cut and fill, if not done then the road will be flooded after heavy rains with surface runoff from the sinkholes.

The presence of enlarged solutional cavities in karst region emphasis on the designed of roads in such a way that road should not be weakened. Region like glacial terrain presents a number of engineering problems. Road construction in flat till plain is topographically ideal but other areas where moraines, eksers, kames or drumlins like features exist there is need for cut and fill to avoid circuitous routes. Areas which are characterized by late, youth and maturaity of relief will require more bridge construction and many cuts and fills. These types of areas are consistently facing problems like landslides, earth flows, and slumping.

Landslides and different types of mass-wasting present problems not only in different phases of engineering but in highway construction also. Subgrade or the soil beneath a road surface has become more significant because of its control over the drainage beneath a highway, therefore construction design of highway should be in such a way to carry heavy traffic. Two factors largely determine the lifetime of a highway under moderate loads is the quality of the aggregate used in the highway and the soil texture and subgrade drainage. The type of parent material and the relationships of soils to its varying topographic conditions are more essential in modern road construction.

The most serious problems encountered by highway engineers is Pumping which means expulsion of water from beneath road slabs through joints and cracks. It is evident that pumping is particularly greater over glacial till than over permeable materials such as wind-blown sand and outwash gravel. Poor drainage in a subgrade is mainly responsible for pumping. Poor and best performance of the highway is characterized by silty-clay subgrades with a high water table and granular materials with a low water table respectively.

Dam site selection

A synthesis of knowledge concerning the geomorphology, lithology, and geologic structure of terrains has greatly helped while selecting sites for dam construction. According to Bryan, five main requirements of good reservoir sites depend on geologic conditions**:**

(1) adequate size water-tight basin;
(2) a narrow outlet of the basin with a foundation that will permit economical construction of a dam;
(3) to build an adequate and safe spillway to carry excess waters;
(4) availability of resources needed for dam construction (earthen dams); and
(5) Assurance that excessive deposition of mud and silt will not short the life of reservoir.

Constructing a dam in a Limestone terrain may prove a difficult one, for instance, the Hondo reservoir was built over limestone in southeastern New Mexico with a water table some 20 feet below the surface. Rapid Leakage was the cause to abandonment of the reservoir. Building a dam in a valley may not be a good dam site from the standpoint of the size of the dam. Buried bedrock valleys containing sand and gravel fills are common in glaciated areas, which may not depict adequate picture of surface condition. Making dam on those sites where subsurface topography is not supportive with buried preglacial valley with sand and gravel in it would have a chance of leakage.

Fig. 3- Hondo reservoir in New Mexico Source: https://commons.wikimedia.org/wiki/File:Navajo_Lake.jpeg

Location of sand and gravel pits

Sand and gravel have more commercial and industrial uses than many engineering. Evaluation of geologic factors such as variation in grade sizes, lithologic composition, degree of weathering, amount of overburden, and continuity of the deposits are important while selecting suitable sites for sand and gravel pits. Floodplain, river terrace, alluvial fan and cone, talus, wind-blown, residual, and glacial deposits of various types are areas where sand and gravel may be found in abundance. In recent years, there is a great demand of gravel than sand due to decreased use of plaster in home construction therefore knowledge of various grade sizes is more important.

Fig. 4- Sand and gravel pits, Source: http://www.geograph.org.uk/photo/3321976

There are high proportions of silt and sand in floodplain deposits which show many variable and vertical gradations and heterogeneous lateral. With their angular shape as well as variable in size alluvial fan and cone gravels are found near their apices. Being angular like talus materials are too large to be useful and are limited in extent. There is only sand in wind-blown sands but have no gravel. Residual deposits are likely to contain pebbles that are suitable for cement work. These residuals are also limited in extent. Favorable sites for pits are terraced valley trains and outwash plains, which are usually extensive and do not have a thick overburden. Due to its large amount of the material, kame deposits show a poor degree of assortment because it discarded on the ground of too large or too fine.

GEOMORPHOLOGY AND MILITARY GEOLOGY

Allied powers during world war were slow to make the maximum use of geology in warfare. Geologist were utilized but to a limited extent in World War I. Before military authorities saw the needs for and possibilities of the use of geologic experts, the war was well-advanced. During wars the information that was useful was more geologic than geomorphic in nature. The information regarding digging trenches, mining, countermining, and water supply or other material was not utilized. Topography became more important during World War II with the development of the blitzkrieg type of warfare, because effectiveness of a blitz depends to a large extent upon the trafficability of the terrain. In recent years terrain appreciation or terrain analysis have become more important with military.

Fig. 5- Trenches during World War, Source: https://en.wikipedia.org/wiki/Trench_warfare

For a terrain if geological maps fail somewhere, geological principal can be applied with advantage to interpreting the terrain from aerial photographs. Little training required to recognize features like mountains, hills, lakes, rivers, woods, plains or some kinds of swamps. It is important to know the kind of hill, plain, river or lake, and so on, because by knowing this it is quite possible to reconstruct the geology of that region. Aerial photographs are useful for the preparation of terrain intelligence as they provide information on the geology of the area. Terrain has been an important factor in the Korean War and in the fighting in Vietnam region. With the development of atomic bomb and ballistic missiles, topography would no longer play an important role in wars but its confine to the local areas for war purpose.

GEOMORPHOLOGY AND REGIONAL PLANNING

Geomorphologic information can be utilized at various levels of planning. Combination of topographic information, soils, hydrology, lithology, terrain characteristics and engineering included on terrain maps make suitable for regional planning. Applied geomorphology has distinct place in regional planning. At broadest scale it can be used as delineate areas for forest, mountain, plateau, recreational, rural and urban areas. A balanced growth of a country's economy requires a careful understanding of its natural resources and human resources. Rural or underdeveloped terrain fulfills a variety of recreational needs. There is a transformation from a terrain maps into land-use suitability maps to develop rural and urban areas. Detailed information on topography enlightened regional planners who may then advise development projects best suited for separate region.

GEOMORPHOLOGY AND URBANISATION

There is a separate branch known as urban geomorphology applied to urban development. According to R.U. Cooke, this branch of geomorphology is concerned with "the study of landforms and their related processes, materials and hazards, ways that are beneficial to planning, development and management of urbanized areas where urban growth is expected".

Geomorphic features decide the stability, safety, basic needs and even its expansion. That means city or towns entirely depends on lithological and topographical features, hydrological conditions and geomorphic features. Urban geomorphologist commence even before urban development through field survey, terrain classification, identification and selection of alternative sites for settlements irrespective of plain or hilly areas. These urban geomorphologists would be concerned with impact of natural events on the urban community and that of urban development on the environment.

Fig. 6- Urban morphology, Source: https://commons.wikimedia.org/wiki/File:Zamalek_Arial.jpg

When geomorphological problems not understood by the planners and engineers then it leads to destruction and damage to urban settlements in different environmental regions. Settling of foundation material in dry or glacial region, weathering process, damages of roads and buildings through floods in many parts of the world are not a recent phenomenon. These problems arise due to misunderstanding of the geomorphological conditions. In developing countries attention has not been given to the geomorphological conditions before the development of existing urban centres. This leads to haphazard growth of city with squatter settlement and shanty towns with urban morphology.

GEOMORPHOLOGY AND COASTAL ZONE MANAGEMENT

Coastal zones are not in linear as a boundary between land and water rather viewed as dynamic region of interface of land and water. The major threat to the fragile coastal zone is its deteriorating coastal environment through shoreline erosion, loss of natural beauty, pollution and extinction of species coastal zone management requires an integrated approach. The most widespread material is beach sand, found mainly in low latitudes. Beach sand and gravel is widely used for construction industry.

Geomorphologists have made some significant contribution towards an understanding of shoreline equilibrium in Eastern Australia where it considerable development of sand mining for heavy minerals has been done. Some measures have been designed or coast protection includes sea-defence structures such as seawalls, breakwaters, jetties and groynes. To protect the sea backshore zone from direct erosion cut, sea walls are designed since these walls are impermeable they increase the backwash and produce a destructive wave effect. Breakwaters can be built either normal or parallel to the coast. It is necessary to monitor and quantify wave conditions, tidal currents and sediment movement in the nearshore zone to evaluate how sea defenses and other man-made structures affect shoreline equilibrium.

Fig. 7- Breakwater, Source:http://maxpixel.freegreatpicture.com/Southbourne-Beach-Panorama-Breakwaters-1267734

In context of coastal zone management Hails emphasizes that applied geomorphology must be concerned with quantitative and not descriptive research in order to obtain relevant and accurate data on (i) natural erosion and deposition rate (ii) at what rates and amount the sediment transport from river catchments to the near shore zone; (iii) variations in sediment composition and offshore distribution; (iv) sand supply sources and shoreline equilibrium; (v) interchange rate of sand between beaches and dune systems; (vi) the effects of constructing sea defences; (vii) offshore sediment dispersal and the dredging effects of seabed morphology, sediment transport and wave refraction; and (viii) analysis of landform including topography of the near-shore zone, form of the continental shelf and of relict coast lines, particularly in terms of rock outcrops. Above investigation provides relevant baseline data needed for systematic planning process and monitoring programmes but also for land use scheme.

Fig. 8- Coastal erosion, Source: http://www.thezooom.com/2013/04/12570/

GEOMORPHOLOGY AND HAZARD MANAGEMENT

Hazards can be put in natural or man-induced where tolerable level or unexpected nature exceeds. According to Chorley, geomorphic hazard may be defined as "any change, natural or man- made, that may affect the geomorphic stability of a landform to the adversity of living things". These hazards may arise from immediate and sudden movements like volcanic eruptions, earthquakes, landslides, avalanches, floods, etc. Faulting, folding, warping, uplifting, subsidence, or vegetation changes and hydrologic regime due to climatic change arise from the long term factors. Areas having past case histories of volcanism and seismic events help in making predictions of possible eruptions and earthquakes respectively. Regular monitoring of seismic waves, measurement of temperature of craters lake, hot springs, geysers and changes in the configuration of volcanoes whether dormant or extinct can reduce the hazard to some extent. A detailed knowledge of topography can predict the path of lava flow and its eruptions points in advance.

Fig. 9- Path of lava flow
Source:https://upload.wikimedia.org/wikipedia/commons/4/45/Lava_flow_at_Krafla%2C_1984.jpg

The behavior of a river system can be well understood by its geomorphic knowledge through its channel, morphology, flow pattern, river metamorphosis and so on. It may help controlling excess water in river and control measures during flood season. Prior knowledge of erosion in the upper catchment area and carrying sediments to its proportion may help in understand the gradual rise in river bed, which may lead to levee breached and cause sudden floods. Earthquakes may be man induced or natural geomorphic hazards. Detailed study of seismic waves region would help in identifying and mapping the zones of high to low intensity to reduce the risk of human life.

OTHER APPLICATIONS OF GEOMORPHOLOGY

Some of the applications of geomorphic principles have been used in applied geomorphology but there are other fields where geomorphic knowledge of terrain is more important. Soils maps to some extent are topographic maps and difference in soil series fundamentally rest upon topographic conditions under which each portion of soil series developed. Soil erosion related problem is essentially a problem involving recognition and proper control of such geomorphic processes like sheet wash erosion, gulleying, mass-wasting, and stream erosion. The angle of slope is not a single factor determined the severity of erosion.

With the introduction of air photographs and satellite imageries preparation of specialized maps and interpreting them has become easier and more accurate. Now a days, aerial photographs are being used for evaluating landforms and land use for city developmental plans, construction projects, highway etc. Another tool i.e. Remote sensing is necessary for sustainable management of natural resources like soil, forest, crops, oceans, urban and town planning etc. At present Geographical Information Systems (GIS) technology has been used along with Remote Sensing techniques in geomorphic features interpretation.

All fields discussed in this chapter should be sufficient to show an understanding of geomorphic principal, besides the geomorphic history of a particular region, geomorphic features may contribute in applied geology to the solutions of problems. To control the adverse effects of human activities on geomorphic forms and processes, application of geomorphology can be of immense use.