

Applied Geomorphology

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 catastrophes like soil erosion, landslides, sedimentation and floods. A proper interpretation of landforms throws light upon the geologic history, structure, and lithology of a region.

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 needs of society.

According to D.K.C. Jones, applied geomorphology could be defined as “the application of geomorphic understanding to the analysis and solution of problems concerning land occupancy, resource exploitation, and environmental management and planning”.

Geomorphic knowledge and techniques may be applied in the following areas:

- Studying the impact of geomorphic/ environmental processes on human society and activities and dealing with problems arising out of such impact;
- Investigating the changes brought about in the geomorphic/environmental processes by human activities and dealing with the problems arising out of such interaction;
- Managing resources and monitoring changes in the geomorphic system to suggest suitable remedial measures for maintaining development at a sustainable level.

The application of geomorphology, according to Charley, Schumn and Sugden, may be considered along two lines:

1. Geomorphology can be an aid to resource evaluation, engineering construction and planning. In this category we may put resource inventories, environmental management, soil and land evaluation, production of maps for hydrological, erosional and stability control, geomorphic mapping, mapping for land systems and evaluating terrain, classification and retrieval of information on terrain and other matters of use to earth scientists, engineers and planners. Applied geomorphology in this aspect can be of use in urban planning in different geomorphic environments and in preparation of natural hazard maps, morpho-agricultural regionalisation, land use planning, construction and management of roads.
2. Applied geomorphology is also concerned with human beings as geomorphic agents, in terms of their planned or inadvertent effects on geomorphic processes and forms. Human beings have over time tried to tame and modify geomorphic/environmental processes to suit their economic needs. Embankments have been built to check

flooding of rivers; meandering courses of rivers have been straightened and channels diverted; coastal areas have been sought to be protected against wave erosion by building walls; there have been attempts to stabilise sandy areas through plantation, and check soil erosion through afforestation. These are some examples of planned activities by human beings that have an impact on geomorphic forms and processes. The inadvertent effects of human activities on geomorphic forms and processes are many: forests are cleared and grasslands burnt for cultivating crops or for building settlements; mining activities and water extraction cause subsidence of land; building and mining activities result in modification of terrain; excessive, unplanned deforestation causes accelerated soil erosion and increase in sediment load leading, in turn, to recurrent floods and riparian decay. Pollution has been a major inadvertent effect of human economic activity. Dams cause changes in river load and accelerated erosion. High altitude construction has modified permafrost.

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.

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.

The ease with which water may be obtained in a limestone region depends on the geomorphology of the area. If the limestones have enough permeability and are capped by sandstone layer, there may be no difficulty in obtaining wells of large yields. Moreover, the water would get naturally filtered as it passes through the sandstone beds. If, however, the limestone is dense and compact, with little mass permeability, movement of groundwater will be largely through secondary openings. In such circumstances, the yield of water may be low or, even if adequate, subject to contamination. Karst plains lack a filtering cover and sinkholes, swallow holes or karst valleys within an area of clastic rocks should cast doubt on the purity of the water from springs nearby.

Groundwater potential in glaciated regions can be determined on the basis of understanding the geomorphic history of the area, characteristics of glacial deposits and landform. Outwash plains, valley trains and intertill gravels are likely to yield large volumes of water. Most tills are poor sources of water because of the clay in them, but they contain local strata of sand and gravel which may hold and supply enough water for domestic needs.

Buried preglacial and interglacial valleys could be good sources of groundwater. Their presence (or absence) may be detected by studying the preglacial

topography and geomorphic history of the area. Buried valleys are located by constructing bedrock topography maps of glaciated areas.

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. In search for mineral deposits, these three points may serve for Geomorphic features as:

1. 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 ore bodies have obvious surface expressions as topographic forms, as outcrops of ore, gossan, or residual minerals, or structural features such as faults, fractures and zones of breccia. Lead-zinc lodes could be marked by a conspicuous ridge as in the case of Broken Hill, Australia. Quartz veins could stand out prominently as they are much more resistant to erosion than the unsilicified surroundings, as in Chihuahua, Mexico. Some veins (calcite, for instance) and mineralised areas may be indicated by depressions or subsidence features.

Weathering Residues:

Many economically important minerals are the weathering residues of present or ancient geomorphic cycles and geomorphology can be of use in searching for such minerals. Iron ore, clay minerals, caliche, bauxite and some ores of manganese and nickel may be such weathering residues. Weathering and erosion are constantly at work on the rocks of earth's surface, and the products of rock weathering may be of economic value.

The surfaces on which residual weathering products commonly form are peneplain or near-peneplain surfaces. Such minerals are more commonly to be found upon remnants of Tertiary erosional surfaces above present base levels of erosion. Bauxite, for instance, is either the residue of a small amount of insoluble aluminous material in dolomites and limestones or it is the direct product of the weathering of aluminous minerals.

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 which are aggregates of materials derived through chemical weathering or erosion of metallic formation. Placer concentration of minerals results from definite geomorphic processes and, found in specific topographical positions, may have a distinctive topographic expression. The type of rock forming, the bedrock floor may influence the deposition of placers.

Residual placers or 'seam diggings' are residues from the weathering of quartz stringers or veins, are usually of limited amount, and grade down into lodes. Colluvial placers are produced by creep downslope of residual materials and are thus transitional between residual placers and alluvial placers. Gold placers of this type have been found in California, Australia, New Zealand, and elsewhere.

Part of the tin placers of Malaya is colluvial placers (the koelits) and parts are alluvial placers (the kaksas). About one-third of the world's platinum is obtained from alluvial placers in Russia, Colombia, and elsewhere. Gold, tin and diamonds are among the more important minerals obtained from alluvial placers. Diamonds in the Vaal and Orange River districts of South Africa, the Lichtenburg area of South Africa, the Belgian Congo, and Minas Geraes, Brazil, are obtained from alluvial placers. About 20 per cent of the world's diamonds comes from placer deposits.

Aeolian placers have yielded gold in Australia and Lower California, Mexico. Bajada placers form in the gravel mantle of a pediment and in the confluent alluvial fans of a bajada. They are more likely to be found near a mountain base than out on the more gentle slopes of a basin fill.

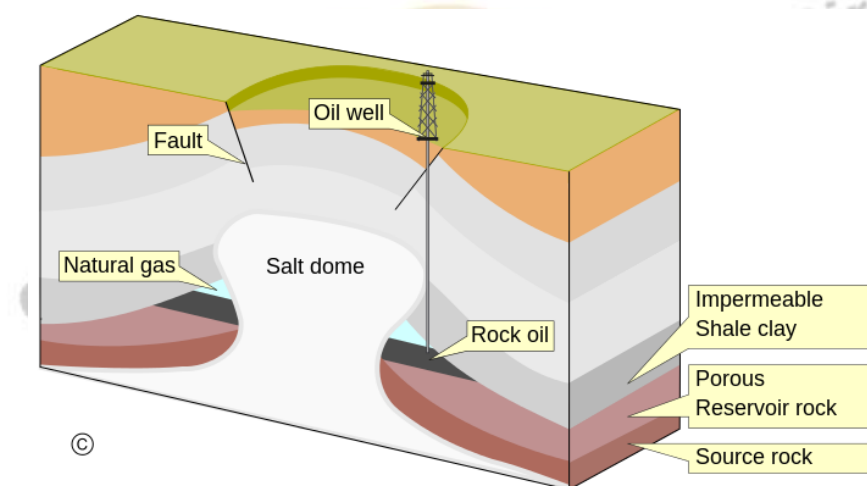
Beach placers have yielded gold in California and Alaska, diamonds in the Namaqualand district of South Africa, zircon in India, Brazil, and Australia, and ilmenite and monazite in Travancore, India.



“Location of placers may be aided by drilling and geophysical testing. A magnetic survey will usually be helpful because magnetite is likely to be associated with gold. If the bedrock is a basic type with a higher magnetic intensity than the placer gravels, areas of magnetic “lows” may reflect the positions of the filled channels. “Knowledge of the bedrock geology, application of geophysical surveying, test drilling and aerial- photograph interpretation all contribute their parts to exploration for these buried placers, but most fundamental to this search is a thorough understanding of the geomorphic history of the region,” observes W.D. Thornbury.

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.



Mineral oil is considered to have been formed by the decay and decomposition of organic matter. After formation, this oil gets trapped in rocks under structural traps or stratigraphic traps. Sedimentary strata are folded into anticlines and synclines allowing the permeable and impermeable strata to get closer, and the mineral oil are well-preserved within the upper permeable and the lower impermeable beds.

Generally mineral oil is found in the porous and permeable rock structures with lower layers of impermeable rocks. Sandstone and limestone provide ideal locations of mineral oil as they are porous and permeable. The shale below acts as the impermeable bed. In regions of heavy tropical forests, where topography cannot be seen through the forest, tonal differences may indicate an anticlinal or domal structure.

More subtle evidence of geologic structures favourable to oil accumulation is being made use of today in the search for oil. Drainage analysis of a terrain shown on aerial

photography is one such technique. A sophisticated perception of drainage anomalies of an area is required, and a geomorphologist would most likely possess the requisite knowledge. Drainage analysis is particularly useful in regions where rocks have low dips and the topographic relief is slight.

According to Levenson, many oil and gas sources are associated with unconformities—ancient erosion surfaces; hence a petroleum geologist must deal with buried landscapes. Where ancient erosion surfaces shorten permeable beds and are later sealed over by deposits, the erosion surfaces become stratigraphic traps, most of which are along unconformities.

Geomorphology and Engineering Works:

Engineering works most often involve evaluation of geologic factors of one type or another; terrain characteristics are among the most common factors.

Road Construction:

The most feasible highway routes would be best determined by the topographic features of the area. Knowledge of the geologic structure, lithological and stratigraphic characteristics, strength of the surficial deposits, geomorphic history of the area, among other things are of importance in road engineering.

A route over a karst plain necessitates repeated cut and fill otherwise the road will be flooded after heavy rains as sinkholes fill with surface runoff. Bridge abutments in a karst region should be so designed that they will not be weakened by enlarged solutional cavities which are likely to be present.

Glacial terrains present many types of engineering problems. A flat till plain is topographically ideal for road construction, but in areas where end-moraines, eskers, kames or drumlins exist there is need for cut and fill to avoid circuitous routes. Muck areas, which mark sites of former lakes, are unsuited for roads which are to carry heavy traffic. If a road is built across them as they are, heavy traffic will cause the plastic materials beneath the lake floor to flow, and 'sinks' in the road bed will result. To avoid this, the lacustrine fill may have to be excavated and replaced with materials that will not flow under heavy load.

Areas with the considerable relief which characterises late youth and early maturity will necessitate much bridge construction and many cuts and fills. In such areas landslides, earth flows and slumping become serious problems.

In highway construction designed to carry heavy traffic, the nature of the soil beneath a road surface, or what is called the subgrade, has become increasingly significant because of its control over the drainage beneath a highway. The lifetime of a highway, under moderate loads, is determined largely by two factors: the quality of the aggregate used in the highway and the soil texture and drainage of its subgrade.

Thus an appreciation of the relationships of soils to varying topographic conditions and type of parent material becomes essential in modern highway construction. A knowledge of soil profiles, which to a large degree reflect the influence of geomorphic conditions and history, is basic. Poor highway performance characterises silty-clay subgrades with a high water table, and best performance is found on granular materials with a low water table.

Dam Site Selection:

Selecting sites for the construction of dams would be greatly helped by a synthesis of knowledge concerning geomorphology, lithology, and geologic structure of terrains.

Five main requirements of good reservoir sites depend on geologic conditions, according to Kirk Bryan:

- (1) a water-tight basin of adequate size;
- (2) a narrow outlet of the basin with a foundation that will permit economical construction of a dam;
- (3) opportunity to build an adequate and safe spillway to carry surplus waters;
- (4) availability of materials needed for dam construction (this is particularly true of earthen dams); and
- (5) Assurance that the life of the reservoir will not be too short as a result of excessive deposition of mud and silt.

Limestone terrain, for instance, may prove a difficult one for constructing a dam. The bedrock surface may be irregular because of differential solution and, unless a true picture of the subsurface is understood, it could lead to avoidable expenditure.

A construction in a valley is desirable from the standpoint of the size of the dam that will have to be built, but it may not always be a good dam site. In glaciated areas, where buried bedrock valleys containing sand and gravel fills are common, surficial topography may not give an adequate picture of sub-surface conditions.

On a superficial level, a dam could be situated at a constriction in a valley between a valley wall on one side and a spur end on the other. However, it is possible that the subsurface topography is not suitable; there may be a buried preglacial valley with sand and gravel in it. The dam, if built on such a site, would leak.

Construction of Air Strips

While selecting sites for air strips, where aeroplanes may land and take off from requires engineering skill, the engineer could well benefit from a geomorphologist's knowledge of landscape characteristics. The best sites for air strips would show an extensive flat surface with resistant geomaterials available: here a safe and suitable runway can be constructed. Furthermore, the ground surface should show an almost level slope, the area should be free of floods and marked by good visibility (may be free of frequent and intense

fog). These characteristics could be gathered from a morphological map of the region where the air strip is to be built.

Locating Sand and Gravel Pits:

Sand and gravel have many engineering as well as commercial and industrial uses. Selection of suitable sites for sand and gravel pits will entail evaluation of such geologic factors as variation in grade sizes, lithologic composition, and degree of weathering, amount of overburden and continuity of the deposits. Sand and gravel may be found as floodplain, river terrace, alluvial fan and cone, talus, wind-blown, residual and glacial deposits of various types.

All have distinctive topographic relationships and expressions and varying inherent qualities and possibilities of development. Recognition of the type of deposit is essential to proper evaluation of its potentialities. Demand for gravel is generally greater than for sand, particularly in recent years with the decreased use of plaster in home construction, and thus knowledge of the percentages of various grade sizes is important.

Floodplain deposits are likely to contain high proportions of silt and sand and show many variable and heterogeneous lateral and vertical gradations. Alluvial fan and cone gravels are angular in shape as well as variable in size, especially near their apices. Talus materials, in addition to being angular, are too large to be suitable for most uses and are limited in extent.

Wind-blown sands may be satisfactory sources of sand but have no gravel in them. Residual deposits lack assortment and are likely to contain pebbles that are too deeply weathered to be suitable for use as aggregate in cement work. A high percentage of iron-coated chert when used as aggregate usually has deleterious effects. Residual deposits are furthermore likely to be limited in extent.

Terraced valley trains and outwash plains are usually favourable sites for pits, for they do not have a thick overburden and are usually extensive.

Geomorphology and Military Geology:

Thornbury points out the importance of geomorphology in the context of war. "World War I was largely stabilised trench warfare, and the information that was most useful was more geologic than geomorphic in nature (Brooks, 1921). Information about the kind of rock that would be encountered in digging trenches, in mining and countermining and the possibilities of water supply and supplies of other geologic materials was most utilised. Topography did play a role in manoeuvring and planning routes of attack, but it can hardly be said that the Allies utilised basic geomorphic knowledge to any great extent.

"With development of the blitzkrieg type of warfare during World War II, topography became more important, because the effectiveness of a blitz depends to a large degree upon the traffic ability of the terrain. As a consequence, in more recent year's terrain appreciation or terrain analysis have become semi-magic words with the military.



Trenches during World War

As Erdmann (1943) put it, the geomorphologist has ‘an eye for the ground or an instinctive eye for configuration, the judgement of how distant ground, seen or unseen is likely to lie when you come to it... Terrain is the common denominator of geology and war.’ Whether it is in connection with the interpretation of topographic maps or aerial photographs, this basic appreciation of different types of terrain is fundamental to a proper planning of military campaigns.”

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 to 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:

Geomorphological knowledge applied to urban development has become important enough to grow into a separate branch, namely, urban geomorphology. 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 urbanised areas where urban growth is expected,” according to R.U. Cooke.

A city or town depends for its stability, safety, basic needs and, later, its expansion on geomorphological features: lithological and topographical features, hydrological conditions and geomorphic features. An urban geomorphologist begins work even before urban development through field survey, terrain classification, identification and selection of alternative sites for settlements. During and after urban development, an urban geomorphologist would be concerned with studying the impact of natural events on the urban community and that of urban development on the environment.

It has been pointed out by R.U. Cooke that “various geomorphological problems hitherto not understood by the planners and engineers lead to destruction and damage to urban settlements in varying environmental realms viz., settling of foundation materials in the dry lands of oil-rich states and in the periglacial regions; destruction of foundations by weathering processes; damage of highways; damage to buildings through inundation during floods in the subtropical humid regions etc.

All these and many other problems arise in part from mismanagement or misunderstanding of geomorphological conditions.” Very little attention is paid to understanding the geomorphological conditions before the development of existing urban centres mainly in the developing countries. This results in uncontrolled growth, giving rise to squatter settlements or shanty towns. It commonly creates serious social and environmental problems.

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.

Some measures have been designed for 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.

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 nearshore 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 in Coastal Areas in a sustainable manner.

Geomorphology and Hazard Management:

Events, natural or man-induced, exceeding a tolerable level or of an unexpected nature may be called hazards. A geomorphic hazard, says Chorley, 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 long-term factors such as faulting, folding, warping, uplifting, subsidence caused by earth movements, or changes in vegetation cover and hydrologic regime caused by climatic change. More immediate and sudden hazards are volcanic eruptions, earthquakes, landslides, avalanches, floods, etc.

Geomorphic knowledge can be of use in identifying and predicting such hazards and in assessing their effects and proper management. Regular measurement of seismic events and earth tremors by seismic methods; regular measurement of ground surface, mainly tilt measurement by tilt metres; constant measurement of temperature of crater lakes, hot springs, geysers, fumaroles; monitoring of gases coming out of craters, hot springs, geysers; monitoring of changes in the configuration of dormant or extinct volcanoes by lasers; measurement of local gravity and magnetic fields and their trends etc., help in making predictions of possible eruptions in the areas having past case histories of vulcanism. The path of lava flow can be better predicted on the basis of detailed analysis of topography and identification of possible eruption points.

The geomorphic knowledge of the behaviour of a river system and its morphological characteristics viz. channel geometry, channel morphology and channel pattern, river metamorphosis, bank morphology etc., may help in controlling river floods through flood control measures.

These include steps: (i) To delay the return of runoff resulting from torrential rainfall to the rivers; (ii) To hasten the discharge of water (by straightening the meandering channels); (iii) To divert the flow of water (through, diversion channels); (iv) To reduce the impact of floods

(through construction of protective embankments); and (v) To forewarn the occurrence of floods.

Without the knowledge of the nature of erosion in the upper catchment area and sediment load characteristics of the river, the construction of levees to confine the flood water within the valley may prove disastrous: if the rate of erosion is very high in the upper catchment area, resulting in high sediment load, there would be more sedimentation in the valley causing a gradual rise in the river bed; this may lead to sudden flash floods whenever the levee is breached.

Earthquakes may be natural or man-induced geomorphic hazards. The geomorphic knowledge of the stability of terrain and probable impacts of man-made structures (such as dams and reservoirs) on crustal stability is of paramount importance in identifying weaker zones which are likely to be affected by seismic events. Similarly, the geomorphic study of the nature of hill slopes and their associated lithologies enable us to know the stability or instability of the hill slopes. This knowledge would help in identifying and mapping unstable hill slopes unsuitable for human settlements and road construction.



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