**Karst Topography**

**Meaning of Karst Topography:**

Landforms produced by chemical weathering or chemical erosion of carbonate rocks mainly calcium carbonate (CaCO3, limestones) and magnesium car­bonate (dolomites) by surface and subsurface water (groundwater) are called karst topography which re­fers to characteristic landforms produced by chemical erosion on crystalline jointed limestones of Karst re­gion of earstwhile Yugoslavia situated along the east­ern margin of Adriatic Sea.

The Karst region of the earstwhile western Yugoslavia extends for 480 km in length and 80 km in width. The region having folded limestones rises to the height of 2,500m AMSL. The surface studded with numerous solution holes, ravines, gullies, clefts, lapies and narrow valleys has become so corrugated and rough that it becomes practically im­possible to walk with bare feet.

 Numerous caves and stalagmites and stalactites have been formed below the surface. Thus, the limestone topography all over the world having characteristic features similar to the karst region of earstwhile Yugoslavia is universally called karst topography.

**Distribution of Karst Topography:**

Karst topography generally develops in those areas where thick beds of massive limestones lie just below the layer of surficial materials. Besides, karst topography also develops on dolomite, dolomitic lime­stones and chalks. Besides typical karst region of earstwhile Yugoslavia, karst topography has well de­veloped in Causes Region of southern France; Spanish Andalusia; northern Puertorico; western Cuba; Ja­maica; southern Indiana, west-central Kerntucky, Vir­ginia, Tennessee and central Florida of the USA.

These areas are classified as major karst areas. Besides, there are a few minor karst areas e.g. Carlsbad area of the USA, chalk area of England (Peak District), chalk area of France, Parts of Jura mountains, some parts of Alps and Apennines. Limestone topography in India has not been properly identified and studied because of non­existence of extensive thick limestone formations near the surface.

Most of limestones of Vindhyan forma­tions are buried under thick covers of sandstones and shales. For example, Rohtas stage limestones having famous Guptadham cave in Rohtas plateau (south­western Bihar) are buried under 90-m thick cover of massive sandstones. A few areas of limestone topogra­phy have been identified in the Himalayas (mainly Jammu and Kashmir; Sahasradhara, Robert Cave and Tapkeshwar temple near Dehra Dun in Uttaranchal; Eastern Himalayas; Pachmarhi (Madhya Pradesh), Bastar district (Chhattisgarh); coastal area near Visakhapatnam etc.

**Development of Karst Topography:**

**Essential Conditions for the Development of Karst Topography:**

**The following conditions alone favour the de­velopment of true karstic topography:**

(1) The limestones must be massive, thickly bedded, hard and tenacious, well cemented and well jointed (high density of joints).

(2) Limestones should not be porous wherein permeability is largely controlled by joints and not by the mass of rocks because if limestones are porous, the water may pass through the rock mass and thus whole rock mass will become weak and will collapse. On the other-hand, if limestones are non-porous and thickly bedded, water will infiltrate through joints resulting into effective corrosion of limestones along the joints and solution holes would be formed.

(3) The position of limestones should be above the groundwater table so that surface drainage may disappear through sinks, blind valleys and sinking creeks to have subterranean (subsurface) drainage so that cave, passages and galleries and associated fea­tures may be formed.

(4) The limestones should be widely distributed in both areal and vertical dimensions.

(5) The carbonate rocks should be very close to the ground surface so that rainwater may easily and quickly infiltrate into the beds of limestones and may corrode the rocks to form solution landforms.

(6) The limestones should be highly folded, fractured or faulted.

(7) There should be enough rainfall so that required amount of water is available to dissolve car­bonate rocks.

**Erosional Landforms Lapies:**

The highly corrugated and rough surface of limestone lithology characterized by low ridges and pinnacles, narrow clefts and numerous solution holes is called lapies (a French term). In fact, lapies represent a fretted and fluted topography marked by small rills and gullies, minor ridges or pinnacles and deep clefts.

Lapies are variously named in different parts of the world e.g., clints or grykes in North England, karren in Germany, bogaz in earstwhile Yugoslavia etc. Lapies are generally formed due to corrosion of limestones along their joints when limestones are well exposed at the ground surface. The weathering residues left at the surface are called terra rosa which means red residual soils or red earth.

**Solution Holes and Associated Features:**

Chemically active rainwater (charged with at­mospheric carbon dioxide) dissolves limestones and other carbonate rocks along their joints and thus nu­merous types of solution holes (e.g. sink holes, dolines etcr) are developed at the ground surface when lime­stones are directly exposed to the atmospheric proc­esses.

**Smaller holes are called sink holes which are generally of two types viz.:**

(i) Funnel shaped sink holes, and

(ii) Cylindrical sink holes.

The depth of sink holes ranges from a few centimetres to 10 metres but gener­ally average depth remains between 3 to 10 m. Area varies from a few square metres to few acres. Gradual enlargement of sink holes due to continuous dissolu­tion of limestones results in the coalescence of closely spaced sink holes into one large hole which is called swallow hole

Some swallow holes are fur­ther enlarged due to continuous solution into larger depressions which are called dolines in the Karst Region and dolinas in Serbia. The solution holes enlarged due to collapse of some portion of upper surface because of formation of cavities below the ground surface are called collapse sinks. The diameter of doline ranges from a few metres to 1000 metres while the depth varies from a few metres to 300 metres.

A feature almost similar to doline in appearance but with shallow depth and larger area! extent is called solution pan. The solution pan of the Lost River of Indiana (USA) is 30 acres in area. Sometimes, the floor of dolines is plugged due to deposition of clay, with the result water cannot percolate downward and thus doline is filled with water. Such dolines full of water are called karst lakes. Rock-walled steep depres­sions caused by the collapse of ground surface are called cockpits.

Karst window is formed due to collapse of upper surface of sink holes or dolines. These windows enable the investigators to observe sub-surface drainage and other features formed below the ground surface.

Extensive depressions are called uvalas which are upto one kilometre across.

**They are formed in a number of ways e.g.:**

(1) Due to coalescence of several dolines due to continuous solution and enlargement of dolines,

(2) Due to collapse of upper roof of large cavities formed underground, and

(3) Due to coalescence of various sink holes etc.

**Elongated uvalas are formed either due to:**

(i) The elongated pattern of joints, or

(ii) Due to coalescence of numerous sink holes aligned in a line. Smaller uvalas are called jamas.

Uvalas are so extensive that surface drainage is lost in them and takes subterranean course. C.A. Malott has termed such uvalas as karst windows. Uvalas are called as com­pound sinks because of coalescence of several sink holes . The sides of uvalas are very steep. They are generally dry depressions. The floors are generally characterized by the deposition of clay but they are usually of even surface.

**Poljes:**

Most extensive, larger than dolines, depressions are called ‘poljes’. They are characterized by vertical side walls, flat alluvial floors, independent surface drainage systems on their floors, irregular borders and central lake. Poljes are, in fact, closed basins of ellip­tical shape having an area up to 258 km2. They are frequently found in Karst Region of earstwhile Yugoslavia and in Jamaica.

The Livno Polje of the Balkan Region of Europe is 64 km long and 5 to 11 km wide. There is difference of opinions about the forma­tion of polje. They are believed to be formed due to downfolding and downfaulting of limestone areas due to earth movements. The resultant grabens are then modified by solution work of water. According to B.W. Sparks (1972) ‘the poljes are probably not solu­tion forms at all but tectonic depressions modified by solution of limestone preserved in them.’

**Valleys of Karst Region:**

The upper surface having several sink holes in the region of limestones having horizontal beds or slightly inclined beds is called karst plain on which surface drainage systems develop various types of valleys and typical landforms. Almost all of the valleys are related to sink holes or swallow holes in one way or the other.

**The following types of valleys are more important :**

**(1) Sinking Creek:**

The surface of the karst plain looks like a sieve because of development of closely spaced numerous sink holes. These sink holes act as funnels because surface water disappears to go under­ground through these holes.

When surface water disap­pears through numerous sink holes located in a line, the resultant feature is called sinking creek and the point through which water goes downward, is called sink . The water of short rivers disappears through a single ‘sink’ while that of large streams disappears through many ‘sinks’.

**(2) Blind Valley:**

Blind valley refers to the valley of that surface stream which disappears in limestone formation through a swallow hole or sink hole. In other words, that valley is called blind valley the flow of which terminates at a swallow hole and the valley looks dry valley. Accord­ing to O.D. Von Engeln blind valleys are developed on uvala floors.

**(3) Karst Valley:**

Surface streams develop their U-shaped valleys on limestone formation. Such wide U-shaped valleys developed on limestones are called solution valleys or karst valleys. Such valleys are always temporary because generally water disappears through swallow or sink holes and the valleys become dry.

**Caves or Caverns:**

Caves or caverns are voids of large dimension below the ground surface. In fact, caves are the most significant landforms produced by erosional work (mainly corrosion or solution and abrasion) of groundwater in limestone lithology. Caves vary in sizes and shape ranging from smaller size to larger caves. Large caves are formed in the regions of pure, massive and thickly bedded limestones.

Carlsbad and Mam­moth caves of the USA are the examples of very extensive caves. Carlsbad cave of New Mexico State of the USA, having a dimension of 1219 m length, 190.5m width and 300m depth, consists of several chambers. The ceiling is about 83.3 m high from the floor. The largest chamber is known as Big Room.

Limestone caves are found in India near Dehra Dun in Uttar Pradesh (Robert Cave, Sahasradhara), in south-western Bihar (Guptadham Cave, 1.5 km long), in Bastar district of Chhattisgarh (Kutumbsar Cave), in Pachmarhi hill, in Chitrakut area of Satna district of Madhya Pradesh (Gupta Godavari Cave), near Visakhapatnam coast etc.

The Guptadham cave of the Rohtas plateau (located in the south-western corner of Bihar) is an example of galleried cave and has been formed due to dissolution of Rohtas stage limestones of Vindhyan formations lying below 90m thick capping of quartzitic sandstones. The cavern is characterized by horizontal passages and amphitheatre-like extensive areas at the junctions of tunnels (cave crossings

he formation and development of limestone caverns is most debatable of all the karstic landforms.

**Various contrasting theories have been put forward by different geomorphologists to account for the origin and development of limestone caves viz.:**

(1) Corrasion theory of Lapparent, Martonne, Martel, Weller and C. A. Malott,

(2) Two-cycle theory of W.M. Davis and supported by J.H. Bretz,

(3) Water table theory of A.C.. Swinnerton,

(4) Static water zone theory of J.H. Gardner,

(5) Invasion theory of C.A. Malott etc.

It may be pointed out that difference of opinions about the formation of caverns and galleries is related to solution process, water table of groundwater and corrasion process.

According to ‘corrasion theory’ caves are formed due to corrasion (abrasion) of limestones by groundwater in the vadose zone above the water table of groundwater. W.M. Davis contradicted the corrasion theory in 1930 and postulated his two-cycle theory for the develop­ment of limestone caverns.

According to him caves are formed by phreatic water i.e. water under hydrostatic pressure below water table. In the first cycle or stage caves are formed due to solution of limestones in the phreatic zone below water table.

In the second cycle or stage the area is uplifted and thus the cave comes under vadose zone because of lowering of water table and the cavern becomes dry resulting into the formation of depositional landforms (speleothems). ‘Water table theory’ of A.C. Swinnerton states that caves are not formed by phreatic water under hydrostatic pressure but are formed by lateral flow of water in the vadose zone or by freely moving water at the level of water table.

According to ‘static water zone theory’ of J.H. Gardner caves are formed due to solution of limestone above the water table. The ‘invasion theory’ of C.A. Malott states that most of the present caverns and galleries in limestone regions have been formed by the subterranean streams.

According to Malott surface streams disappear at sink holes and take underground courses where they dissolve and abrade limestones to form their passages. These passages are gradually enlarged due to corrosion and abrasion of limestones and thus caverns and galleries are formed.

**Ponores:**

The vertical pipe-like chasms or passages that connect the caves and the swallow holes are called ‘ponores’ in Serbia and ‘avens’ in France. Ponores are formed due to downward extension of sink holes through continuous solution of carbonate rocks. Ponores may also be inclined .

**Natural bridges in limestone areas are formed in two ways viz.:**

(1) Due to collapse of the roofs of caves, and

(2) Due to disappearance of surface streams as subterranean streams, formation of valleys below the ground surface and reappearance of disappeared (subter­ranean) stream on the ground surface.

**Like caves various theories have been put forth to account for the origin of natural bridges and natural tunnels in lime­stone regions e.g.:**

(1) Solution theory of F.W. Gilmer,

(2) Theory of C.D. Walcott,

(3) Subterranean stream piracy theory of H.P. Woodward, and

(4) Subterranean stream cut off theory of C.A. Malott and R.R. Shrock etc.

**Depositional Landforms:**

All types of deposits in the caverns are collec­tively called speleothems of which calcite is the com­mon constituent. Banded calcareous deposits are called travertines whereas the calcareous deposits, softer than travertine, at the mouth of the caves are called tufa or calc-tufa. The calcareous deposits from dripping of water in dry caves are called dripstones.

The columns of dripstones hanging from the cave ceiling are called stalactites while the calcareous columns of dripstones growing upward from the cave floor are known as stalagmites. Cave pillars are formed when stalactites and stalagmites meet together (fig. 19.9). Numerous needle-shaped dripstones hanging from the cave ceil­ing are called drapes or curtains. The dripstones grow­ing sideward from stalactites and stalagmites are called helictites and heligmites respectively.

The helictites of globular structure are called globulites. Floor deposits caused by seepage water and water flowing out of stalagmites are called flowstones.

Stalactites are formed due to deposition of cal­careous solutes which are carried by water dripping through the cave ceilings in dry environment. The water is evaporated and solutes are deposited in incicle-like or needle-like forms. These structures have broad bases stuck to the cave ceiling and tapering ends hanging downward from the cave ceiling.

There is gradual increase in the length and thickness of stalac­tites. The shapes of stalactites are controlled by the shape of cave ceiling. The stalactites become uniform and their tapering lower ends are directly pointed towards the cave floor when the cave ceiling is flat or is uniformly arched.

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There is gradual increase in the length and thickness of stalac­tites. The shapes of stalactites are controlled by the shape of cave ceiling. The stalactites become uniform and their tapering lower ends are directly pointed towards the cave floor when the cave ceiling is flat or is uniformly arched (fig. 19.10, C and F respectively).

The stalactites hanging downward are almost perpen­dicular to the cave ceiling. When the cave ceiling is steeply inclined, inclined and elongated stalactites are formed (fig. 19.10, D). When the cave ceiling is flat but is gently inclined towards one side, slightly inclined and elongated stalactites are formed (fig. 19.10 E).

The solution that drops on the cave floor is also precipitated and crystallized and forms a column-like structure of stalagmites at various centres. When a group of stalagmites is formed together from closely spaced centres the resultant stalagmites are called compound stalagmites.

**Landforms of Karst Regions:**

Cockpits, cone karst, polygonal karst and tower karst are important typical landforms of karst regions. Carbonate rocks are quickly dissolved in tropical hu­mid regions. If the dolines, which are cone-shaped solution depressions, are closely spaced, they expand in size due to fast rate of solution and change into star- shaped depressions. Such star-shaped solution fea­tures are called cockpits which have developed in Jamaica, Vietnam, China, Java, New Zealand etc.

The polygon-shaped depressions are called polygonal karsts which are formed due to coalescence of several dolines and development of numerous arms in their perimeter which give the shape of polygon. Polygonal karsts have developed in New Zealand, southern China, New Guinea etc. When a few closely spaced cockpits coa­lesce, the ridges between them become conical in shape.

Such conical ridges developed in carbonate rocks are called cone karsts which, when attain greater height, are called tower karsts, which have developed in Cuba, Puertorico, Vietnam, south China etc. It may be pointed out that cone and tower karsts are formed in humid tropical regions. If they are presently found in extra-tropical areas (e.g. Poland, Canada and New Zea­land), it means, they are not the result of present climate but are palaeo landforms indicating climatic change.

**Karst Cycle of Erosion:**

The concept of cycle of erosion m also applied in limestone area by J.W. Beede in 1911 and by Jovan Cvijic in 1018. W.M. Davis (1930) regarded karst cycle of erosion as a special phase of the normal fluvial cycle of erosion characterized by the development of surface drainage, disappearance of surface drainage underground and reappearance of substerranean drain­age as surface drainage.

The karst cycle of erosion is simpler than other geomorphic cycles because of uni­formity of structure (generally limestones) and domi­nance of mono-process (solution process). The diffi­culties are related to the nature of movement of groundwater and base level of erosion which are not precisely known.

Most of the geomorphologists be­lieve that the water table of groundwater should be taken as the base level of erosion. According to some geomorphologists the rainwater infiltrates through the joints of the rocks in vertical manner until it reaches the surface of the water table and thereafter it moves horizontally below the surface of water table.

**Two types of conditions have teen recommended for the initiation of karst cycle of erosion e.g.:**

(1) Exposure of thick limestone cover at the ground sur­facem, and

(2) Limestone cover overlain by non-soluble rocks (e.g., sandstones, shales etc.).

**Karst cycle of erosion becomes more operative over two types of structures viz.:**

(1) Folded limestones, and

(2) Faulted beds of limestones.

It may be pointed out that karst cycle of erosion becomes more effective where thick beds of limestones, whether folded or faulted, are exposed on the ground surface because rainwater im­mediately comes in contact with the rocks and starts dissociating them. Beede postulated 3-stage karst cy­cle (e.g., youth, mature and old stages) whereas Cvijic presented 4-stage karst cycle (e.g., youth, maturity, late maturity and old stage).

**The characteristic features of different stages of karst cycle of erosion are summa­rized below:**

**1. Youth:**

The karst cycle starts with the initiation of surface drainage in the regions of thickly bedded limestones of folded or faulted structure or even of horizontal structure [fig. 19.11(1)]. The limestones are directly exposed at the ground surface. If the lime­stones are overlain by thin deposits of insoluble or non- calcareous formations, the surface runoff first removes these formations.

The rainwater mixed with atmos­pheric carbon dioxide now reacts with limestones along the interfaces of their joints and thus form sink holes and swallow holes through the mechanism of solution process. These sink holes gradually increase in number and are enlarged due to continuous solution of limestones.

The ground surface is characterized by rough terrain due to development of lapies because of dissolution of limestones along their joints. With the enlargement of sink holes and swallow holes into dolines surface drainage starts disappearing under­ground through different sinks or blind valleys. The underground drainage initiates the formation of caves and caverns through underground solution and abra­sion.

The characteristic geomorphic features of this stage are sink holes; swallow holes, dolines, lapies, blind valleys, sinking creeks, caves and caverns of smaller dimension. The termination of youth stage is marked by total disappearance of surface drainage.

**(2) Maturity:**

The initiation of early maturity is heralded by total disappearance of surface drainage underground. Thus, the ground surface is characterized by dry water­less condition. The surface drainage disappears under­ground through dolines and blind valleys. Thus, nu­merous sinking creeks are formed. The processes of underground solution and abrasion are augmented because of increased volume of water due to maxi­mum development of subterranean drainage.

Increased solution of carbonate rocks results in gradual enlarge­ment of caves, galleries and passages. The covering roofs of caves and caverns undergo the process of thinning because of alround enlargement of caves. The thinning of cave roofs causes their colapse giving birth to uvalas, poljes and karst windows [fig. 19.11 (3)]. The residual uplands with highly pitted surface be­tween uvalas become ridges. The late maturity is characterized by the destruction of most of solutional landforms.