ENGINEERING GEOLOGY

UNIT – 1

INTRODUCTION

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Geology is the science of the earth (geo = earth, logos = study or science).

It deals with different aspects of the earth as a whole such as

(i) Origin, age, interior structure and history of the earth,

(ii) Evolution and modification of various surface features like rivers, mountains and lakes along with their causes, and

(iii) Materials making up the earth.

The vast subject of geology has been subdivided into the following branches for the sake of systematic study :

Main Branches :	Physical Geology	**Allied Branches :**
	Mineralogy	Engineering Geology
	Petrology	Mining Geology
	Structural geology	Geophysics
	Historical geology (Stratigraphy)	Geohydrology
	Palaeontology	Geochemistry
	Economic geology	

IMPORTANCE OF GEOLOGY IN CIVIL ENGINEERING

- The Civil Engineers aim at safety, stability, economy and life of the structures that they construct.
- Civil engineering constructions like dams and bridges will have their foundations on geological formations of the earth's surface. Therefore, their stability and safety depend on the competence of the in situ rocks of the sites concerned.

- Also, to be economical, such competent foundation rocks should be at a shallow depth.
- Further, for huge constructions like dams, building materials are required in very large quantities near the site. Otherwise, the cost of construction will increase.
- These critical details of civil engineering importance, i.e., durability and competence of foundation rocks, their depth of occurrence, availability of building material near project sites, can be reliably obtained from geological and geophysical studies.

CASE HISTORIES OF FAILURE OF SOME CIVIL ENGINEERING CONSTRUCTIONS DUE TO GEOLOGICAL DRAWBACKS

The significance of geology with reference to civil engineering will be better appreciated if the consequences of ignoring geological studies are also quotes. Few specific examples of failures of different kinds of important civil constructions due to geological cases are :

1. **St. Francis Dam (California, 1928)**

   This dam was a curved concrete gravity dam constructed between 1924 and 1926 in order to provide a storage reservoir for the Los Angeles Aqueduct system. The dam was failed in 1928, only twelve hours after its last inspection by **Mulholland**, who was a 'self – taught' engineer and orchestrated the design and construction of the Los Angeles – Owens River Aqueduct, the longest water conveyance system at that time.

The cause of dam failure is, When the plan for the dam construction is finalized and after construction began, the height of the dam was raised by ten feet on two separate occasions in order to provide additional reservoir storage needed to sustain the growing community surrounding the dam. Although these modifications increased the dam's height by twenty feet, no changes were made to its base width. As a result, the intended safety margin for this structural stability decreases significantly. At the time of failure, leaking cracks were observed within the main dam and at its abutments which were dismissed as conditions typical of the dam type. Finally, after the investigation of the failure, it was clearly proposed St. Francis Dam design was not reviewed by any independent party and the dam was designed to prevent small foundation stresses only and not accommodate full uplift. And the ultimate failure mode to weakening of the left abutment foundation rock due to the saturated condition created by the reservoir which essentially re-activated a large landslide that

combined with a destabilizing uplift force on the main dam caused failure to initiate at the dam's left end. At the left end, the maximum height section tilted and rotated which destabilized the right end of the main dam causing catastrophic failure at the right end as well.

View Looking Upstream of St. Francis Dam prior to failure

Aerial view of St. Francis Dam site after failure.

Geological Studies at the dam site will also suggest which design will be suitable for a given geological context. For example, gravity dams need very strong and competent foundation rocks; for Buttress dams, relatively less strong foundation rocks are enough; Arch dams need very strong and stable abutment rocks; for Earth dams, even weak foundation rocks met the requirements.

With Reference to Reservoirs:

The Jerome reservoir of Idaho and the Hondo reservoir of New Mexico are two examples of failures due to geological reasons.

As in the case of dam sites, selection of suitable sites for locating reservoirs needs geological studies to make them successful. Unfavourable geological conditions lead to quick silting of reservoirs, thereby decreasing its life, and profuse leakage of stored water.

Intense weathering in the rocks upstream causes silting problems. Porosity and Permeability of rocks, occurrence of faults, joints and other weak planes cause leakage problems. Thus proper studies of geological conditions at any proposed reservoir site will forewarn an engineer of the problems, if any.

With Reference to Tunnels:

Ramganga diversion tunnel (Himalayas), Umiam – Barapani stage I tunnel (Meghalaya) are some examples where geological conditions posed serious problems.

Competence of the rocks, associated geological structures like bedding, faults, joints, porosity and permeability of rocks, and ground water conditions are the geological conditions which need to be thoroughly studied to solve such problems.

With Reference to Bridges:

The failure of a bridge near Cornwall(Canada) and difficulties faced in the construction of the Georges rives bridge illustrate the consequences of improper or incomplete study of geological condition of the sites concerned.

Strong and stable rocks are needed for foundations and abutments. Adverse geological structures should not occur at the site.

There are some failures of roads and railways also due to the geological failure.

IMPORTANCE OF SOME MAIN & ALLIED BRANCHES OF GEOLOGY

1. **PHYSICAL GEOLOGY/DYNAMIC GEOLOGY/GEOMORPHOLOGY**

   It is concerned with the work of natural processes which bring about changes upon the earth's surface.

As the name suggests it deals with :

(i) Different physical features of the earth, such as mountains, plateaus, valleys, rivers, lakes, glaciers, and volcanoes in terms of their origin and development,

(ii) The different changes occurring on the earth's surface, like marine transgression, marine regression, formation or disappearance of rivers, springs and lakes,

(iii) Geological work of wind, glaciers, rivers, oceans, ground water, and their role in constantly moulding the earth's surface features, and

(iv) Natural phenomena like landslides, earthquakes, and weathering.

- The main cause for surface changes is weathering. This is a natural phenomenon resulting directly or indirectly due to changes in the atmosphere. It disintegrates and decomposes rocks.
- This weathering is of special importance from the civil engineering point of view, because colour, appearance, strength and durability of rocks are adversely affected by weathering.
- Thus even granite which is considered ideal for most of the civil engineering works becomes weak and friable on thorough weathering, rendering it useless.

2. **PETROLOGY(Petro = rock, Logos = Study)**

   Petrology deals with the study of rocks. It deals with mode of formation, structure, texture, composition, occurrence, types of rocks.

(i) The earth's crust, also called lithosphere, is made up of different types of rocks.

(ii) The composition and textural characters of rocks primarily contribute to their inherent strength and durability.

(iii) Rocks based on their suitability can be used as foundation for dams, for tunnelling and as materials of construction.

Hence this is the most important branch of geology from the civil engineering point of view.

3. STRUCTURAL GEOLOGY

This branch of geology deals with the study of structures of rocks in the earth's crust.

(i) The rocks which form the earth's crust undergo various deformations, dislocations and disturbances under the influence of tectonic forces.

(ii) The result is occurrence of different geological structures like folds, faults, joints and unconformities in rocks.

(iii) The details of mode of formation, causes, types, classification, importance, etc., of these geological structures from structural geology.

From the Civil engineering point of view, it is as important as Petrology because these geological structures modify the inherent physical characters of rocks rendering them more suitable or unsuitable for civil engineering purposes.

4. MINERALOGY

This deals with the study of Minerals. This deals with the mode of formation, composition, occurrence, types, association, properties, uses, etc., of minerals form the subject Mineralogy.

- Minerals are basic units with which different rocks and ores of the earth are made up of.
- For example, sometimes quartzite and marble resembles one another in shine, colour and appearance. But quartzite by virtue of its mineral composition is very hard, tough, strong and durable, while marble disintegrates and decomposes in a shorter period because of its mineral composition and properties.

5. HISTORICAL GEOLOGY/ STRATIGRAPHY

It is the science of the description, correlation and classification of strata in sedimentary rocks including the interpretation of the depositional environments of those strata.

- The study of the earth's history through the sedimentary rocks is called historical geology. It is also called as Stratigraphy (Strata = a set of sedimentary rocks; Graphy = description) because this subject deals with details and description of sedimentary rock sequences.

6. **PALAEONTOLOGY**

   It is the science of fossils of ancient life forms and their evolution.

7. **ECONOMIC GEOLOGY**

   The economic geology deals with the study of minerals, ores and fossil fuels of economic importance.

8. **ENGINEERING GEOLOGY**

   This deals with the application of geological knowledge in the field of civil engineering, for execution of safe, stable and economic constructions like dams, bridges and tunnels.

9. **MINING GEOLOGY**

   This branch of geology is concerned with the study of application of geology to mining engineering.

10. **GEOPHYSICS**

    The study of physical properties like density and magnetism of the earth or its parts, to know its interior, forms the subject matter of geophysics.

Geophysical investigations are very useful in solving foundation problems, alignment of structures, leakage problems along canals, locating building materials like stones etc., Electrical resistivity methods and seismic refraction methods are commonly used in solving civil engineering problems.

11. **GEOHYDROLOGY**

    This is also called as Hydrogeology. It deals with occurrence, movement and nature (i.e., quality and quantity) of ground water in an area. This branch is closely related to geology because the very existence, movement of ground water, etc., are directly related to porosity, permeability, structure, texture and composition of the surface and underground rocks. Dykes may control the occurrence and movement of ground water.

12. **GEOCHEMISTRY**

    This branch is relatively more recent and deals with the occurrence, distribution, abundance, mobility etc., of different elements in the earth's crust.

WEATHERING OF ROCKS :

Weathering is a natural phenomenon resulting directly or indirectly due to changes in the atmosphere. It disintegrates and decomposes rocks. This aspect is of special importance from the civil engineering point of view, because colour, appearance, strength and durability of rocks are adversely affected by weathering. Thus even granite which is considered ideal for most of the civil engineering works becomes weak and friable on thorough weathering, rendering it useless.

- Any rock, however hard and strong it may be, when exposed to the atmosphere, decays and disintegrates, ultimately making the rock unfit to be at the site of the foundation or to be used as construction material.
- The earth's surface has been dynamic and therefore, subject to various kinds of changes like Transgressions and regressions of the sea, appearance of new mountains, rivers, glaciers, volcanoes, lakes, springs, waterfalls, etc., and disappearance of old or earlier features of similar kind are just a few such changes.
- The natural forces like rivers, glaciers, wind, volcanoes, earthquakes, tectonic forces, etc., which are part and parcel of earth's crust are responsible for all these changes.

GEOLOGICAL AGENTS : The natural forces which are responsible for the visible changes on the earth's surface are called geological agents.

Based on their origin these natural forces can be grouped into "**Exogenous or epigene**" geological agents and "**Endogenous or hypogene**" geological agents. These two groups differ not only in their origin but also in their nature of work and results produced, etc.

Exogenous Geological Agents	Endogenous Geological Agents
✓ These agents originate on the earth's surface, work slowly but steadily and erase topographic irregularities, i.e., ups and downs on the surface. ✓ Their geological work in a way is systematic, i.e., commences with erosion and is followed by transportation and deposition.	✓ The nature, origin and functions of endogenous geological agents are in principle opposite to those of exogenous geological agents. ✓ The latter originate below the earth's surface, work suddenly and create topographic irregularities. ✓ Volcanoes, Earthquakes, Ground

✓ The erosion process causes disappearance of protruding land masses like hills, while the deposition process causes the disappearance of depressed land masses like pits, lakes and seas. Thus plain land surface is made to evolve. ✓ Examples of Exogenous geological agents are Rivers, Wind, Glaciers, Tides and Waves of the sea, etc., ✓ The work of these forces appears to be too slow, because visible changes are not noticed even in decades or centuries. ✓ The distinctive characters of exogenous geological agents are : (i) Slow but methodical work involving erosion, transportation and deposition, (ii) Removal of irregularities such as elevations(like hills and highlands)) and depressions(like lakes and seas) leading to the development of plain ground on the earth's surface and (iii) Their origin on the surface.	water and tectonic forces are typical examples of the group of endogenous geological agents. Their action not only obliterates the results of exogenous geological agents but also creates great topographic heights and depths. ✓ Volcanoes are generally hill like structures with trenched tops. They undergo periodical eruptions and out of accumulations of resulting lava flows and ash, volcanic mountains develop. ✓ Earthquakes, which are often associated with geological faulting phenomena, result in steep fault scarps or ridges or highlands. Faults and folds of geological strata occur due to tectonic forces which are internal and inherent in the earth. They are combinedly responsible for all great mountain ranges of the world. ✓ Ground water is responsible for the occurrence of "Karst topography", Known for its rugged surface and irregularities.

Thus, the different natural forces of the earth can be grouped into two categories, i.e., Exogenous and Endogenous. Since they are inherent in the earth and permanent in existence, their effects too are always present and thus, make the earth's surface a scene of constant dynamic changes.

DEGRADATION : The continuous removal of topographic irregularities from hills, mountains or highlands reduces their height bit by bit and ultimately their topographic level

becomes equal to their surroundings. This phenomenon of lowering the elevation or altitude of high lands may be described as “Degradation”.

AGGRADATION : The exogenous geological agents dump their load in places favourable for deposition. Due to continuous deposition in the low lying tracts, basins, lakes, seas, etc., which are topographic depressions, these are gradually filled up, thereby decreasing their depths slowly bit by bit. Finally, their topographic level becomes equal to their surroundings. This phenomenon of the rising of the sea or lake bottom or their depth reducing may be described as “Aggradation”.

GRADATION: Due to degradation (i.e., lowering of highlands) and aggradation (i.e., concomitant elevation of lowlands) processes, the topographic elevations and depressions disappear, leading to the development of plain ground or land masses of a very gentle slope. This is called “Gradation”.

Note:

- The tough and hard rocks of giant size subjected to natural breakdown in the hills and rocks are reduced in size due to physical, chemical and biological factors of nature. They may act together or independently.
- When physical factors influence, the rocks are just mechanically broken down.
- When chemical factors influence, the rocks are decayed, decomposed and weakened.
- When biological factors influence, the rocks are disintegrated as well as decomposed.
- This disintegration and decomposition process which is instrumental in the breakdown or reduction of size of rocks is called “**Weathering**”.
- Thus, Weathering is the root cause for gradation.

WEATHERING OF ROCKS

- The deteriorating effect of weather, climate or atmosphere agencies on rocks may be described as weathering of rocks.
- The different kinds of rocks which are formed under different conditions undergo disintegration and decay when exposed to the earth’s surface.
- All kinds of rocks, when affected by weathering, lose their strength substantially and hence become unsuitable for use either for foundation purposes or as construction material.

- Thus, the weathering phenomenon is of special importance from the civil engineering point of view.
- Weathering of rocks is responsible for the formation of soils, laterites, some economic mineral deposits, ground water occurrence, etc.,

Role of Atmosphere in Weathering: Along with the gravity effect, the atmosphere is directly or indirectly responsible for the weathering phenomenon. Since the earth is enveloped by atmosphere(air) everywhere, all rocks exposed on the surface are invariably affected by weathering. The atmosphere is essentially a mixture of various gases like N_2, O_2 and CO_2 and water vapour.

Wind is nothing but the moving air. **Wind** is capable of forming considerable physical disintegration under favourable condition. The **water vapour** or moisture content of the atmosphere is responsible for rainfall and snowfall which cause formation of rivers, glaciers, seas, etc. these dynamic forces play a major role in causing disintegration and decomposition of rocks. The atmosphere also transmits heat and thereby influences effects of temperature changes.

The atmospheric carbon dioxide, oxygen, etc., cause carbonation, oxidation, reduction, etc., in the mineral constituents of rocks and thereby decompose the rocks. The inert nitrogen content of the atmosphere, at times under the influence of lightning and bacteria, changes into chemically potential nitric acid and aids in the decay of the rocks.

Further, water, carbon dioxide and oxygen which are largely determine in the animal and plant life, are interdependent and contribute together to the biological factors responsible for the weathering of rocks.

Thus, various physical, chemical and biological factors are responsible for the weathering of rocks are themselves related directly or indirectly to the atmosphere.

Note : There are three natural processes closely interrelated, though they differ from each other. They are

WEATHERING : When the rocks undergo decay due to various reasons, they are said to have weathered. In other words, the process of mere chemical decay and mechanical disintegration of rocks is called Weathering.

EROSION: It is a process of breakdown of rocks into smaller and smaller pieces and their subsequent removal from their places of original occurrence. i.e., Erosion reduces the sizes of rocks to such an extent that they are easily transported by the exogenous geological agents.

DENUDATION : When erosion takes place, fresh underlying surfaces of country rocks are exposed for weathering attack. This process of exposing fresh rocks to the surface due to the removal of their overlying weathered material is called Denudation.

- In any area denudation leads to weathering, weathering leads to erosion and erosion leads to denudation. Thus these processes are interrelated and go on.

The Weathering Process

Weathering of rocks due to the processes of mechanical disintegration and chemical decomposition. This happens due to different physical, chemical and biological factors of nature. Due to weathering, rocks become smaller. They are reduced in size either when they are physically broken down or chemically dissolved or leached.

Natural Disintegration Process in Rocks

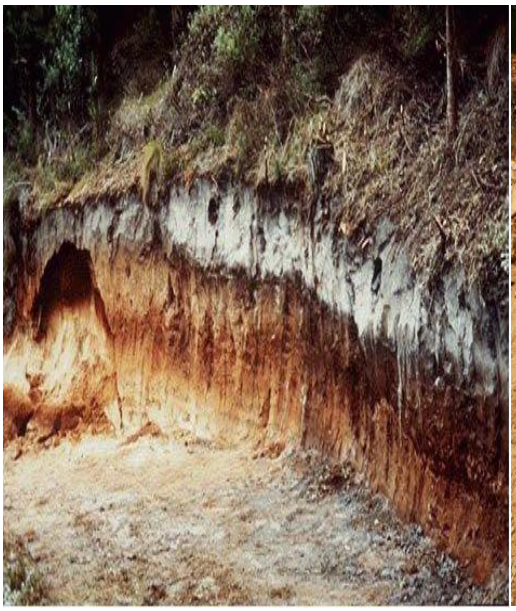
- ✓ During disintegration, the rocks are broken down without chemical changes by temperature, frost, water or air.
- ✓ Disintegration occurs mainly in the drier, higher and colder regions of the earth's surface.
- ✓ In desert and mountainous regions the great variations in temperature cause strains to be set up in the surface layers of rocks by which fragments are scaled off. The rocks may be split into numerous thin pieces by this action.
- ✓ The freezing of water in cracks may break rocks into angular fragments, and much of the weathering in high mountainous takes place in this way.
- ✓ Glaciers may pluck and tear boulders from their beds and by their slow movement grind the material they carry against the sides and floors of the valleys, with the formation of sand and mud. Many streams which are formed from glaciers are heavily loaded with material derived from this action.
- ✓ The disintegration process usually occurs under conditions which preclude chemical activity upon the rocks. The products of disintegration are frequently quite fresh or comparatively unaltered rock fragments.

Decomposition of Rocks : This process is more active in moist, warm and low lying areas.

- ✓ The main factors of decomposition are water and air.
- ✓ When rain falls through the atmosphere it dissolves a certain proportion of the carbon dioxide, oxygen and other gases. This oxygenated and carbonated water is particularly active in attacking the minerals.
- ✓ It is strengthened by ground water, which has already attacked the rocks, and is therefore poorer in oxygen and carbon dioxide, but richer in dissolved substances which may exert a very active influence in further attack upon the rock constituents.
- ✓ Important processes of decomposition are solution, oxidation, hydration and carbonation.
- ✓ Oxidation involves the alteration of minerals with the products of oxides. It is particularly more active with iron – bearing minerals forming the iron oxides hematite and limonite, which are the chief colouring matter in rocks and produce the red, brown and yellow colours that are so common on weathered surfaces.
- ✓ The process of hydration alters minerals into substances rich in combined water.
- ✓ In carbonation the minerals are altered with the formation of carbonates.
- ✓ In this way, the effect of decomposition is to produce certain soluble substances such as carbonates, sulphates and chlorides and to leave behind an insoluble residue consisting of hydrated oxides and silicates, mixed with minerals such as quartz and muscovite which have suffered negligible attack by the agents of weathering.

REGOLITH: The resulting product of Disintegration is the mantle of broken and Decomposed material of varying compositions and thickness, called the Regolith, which covers the whole surface of the earth except in areas in which it is removed as fast as it is formed. The regolith may remain in the same place for a long period or may be quickly transported by natural forces to find its ultimate resting place in the sea.

Below diagrams shows the Regolith Geography




The total effect of Decomposition and Disintegration is known as the Weathering process.

Factors Responsible for Weathering Process are

Physical Factors	Chemical Factors	Biological Factors
❖ Disintegration process of weathering is accomplished in nature by a great variety of natural agencies. ❖ Natural agencies are wind, rivers, Glaciers, Dashing waves and Tides, Gravity(Waterfalls, landslides, avalanches, meteorites), Exfoliation, Frost wedging, Frost	❖ These factors refer to the decay or decomposition effect in rocks due to various natural causes. This is a relatively slow process but very effective in the weathering of rocks. ❖ These factors may not cause any physical breakdown. ❖ Water(By Dissolution, Leaching, Hydration	❖ Plants, animals, Man and even bacteria help in disintegration and decomposition of rocks.

heaving and miscellaneous. ❖ These are the physical factors which are responsible for disintegration process of weathering.	and hydrolysis) Atmospheric gases(CO_2, N_2 and O_2) some minerals of rocks(Pyrite), volatiles of volcanoes, etc., contribute to the chemical decomposition of rocks.	

Importance of Weathering :

Some useful effects of weathering are :

1. Weathering produces soil which is vital for agriculture and for the production of different crops.
2. Weathering makes rocks porous and permeable. This is very important from ground water occurrence point of view in the case of hard rocks like granites and gneisses. These acquire aquifer characteristics because of weathering. Of course, the presence of joints, faults, shear zones in them also contributes to this phenomenon.
3. Cheap building stones like laterites develop due to weathering.
4. Economic mineral deposits like bauxites are formed due to weathering.
5. Oxidation and supergene enrichment are important phenomena in the formation of some ore deposits, particularly sulphides.
6. Occurrence of a few economically important placer deposits too is indirectly related to weathering.

However, from the civil engineering point of view, weathering is not a welcome process, because it reduces the strength, durability and good appearance of rocks.

1. Therefore, all thoroughly weathered rocks, irrespective of their original competence, become unfit to be at the site of foundation of important civil structures like dams and

bridges. To make such sites fit, either intensive grouting or digging the weathered zone and refilling with concrete are resorted to. These increase the cost.

2. Since weathered rocks lose characters of strength, durability and good appearance, they also become unfit to be used as construction material, either in the form of building stones, or railway ballast or road metal or concrete aggregate.
3. Weathering due to sea waves results in coastal erosion, which poses a difficult problem for civil engineers.
4. Weathered rocks being weak are unsuitable for tunnelling.
5. Enormous loose soils (formed our of weathering) along steep slopes may turn out to be landslides, a civil engineering hazard.
6. Occurrence of a thoroughly weathered zone in the upstream side creates silting problems in case of reservoirs. Rapid silting reduces the capacity of the reservoir, in other words, the life of the reservoir. Thus, weathering poses many problems for civil engineers.

WEATHERING OF "GRANITE" ROCK

- Among different rocks which occur on the earth's surface granite is one of the most abundant. Therefore, it will be appropriate to critically analyse the process of weathering in granite.
- Mineralogically, ordinary granite contains Feldspar(Orthoclase and Plagioclase) and Quartz as essential minerals and Muscovite, Biotite and Hornblende as common accessory minerals.
- Hornblende responds to weathering in a manner similar to biotite, as it is also a ferromagnesium mineral.
- Thus, due to decomposition, granite produces different kinds of material. Which may be grouped as follows :
  (a) **Unaltered minerals**: Quartz forms sand grains, and muscovite produces mica flakes.
  (b) **Insoluble Residue**: The resulting hydrous aluminium silicates are the fundamental constituents of clays, iron oxides are the colouring matter of rocks.
  (c) **Soluble Substances**: These are the salts formed from substances such as Potassium, Sodium, Calcium, Magnesium, Iron and Silica.

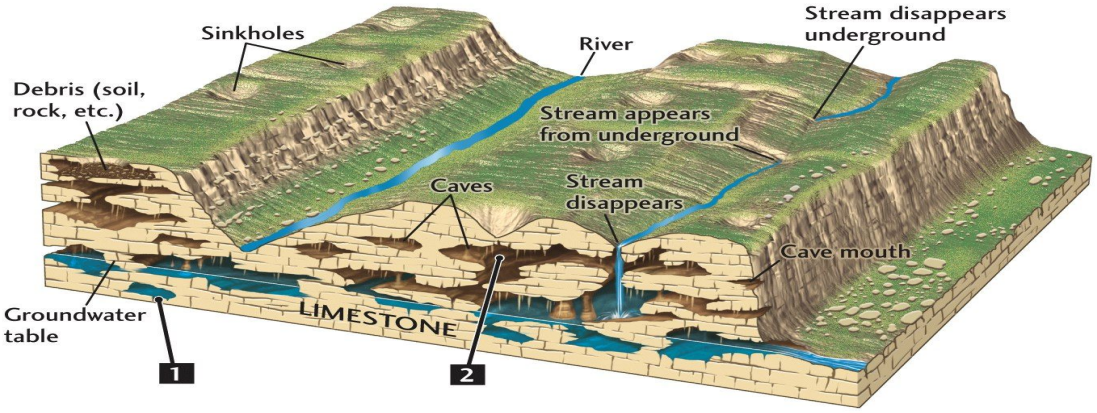
Decomposition in Granite

S.No	Mineral	Chemical Composition	Weathering Effect	Product of Weathering
1	**Feldspars**			
	A. Orthoclase (or Microcline)	K_2O	Goes into solution as Carbonate, chloride, etc.,	Soluble Material
		Al_2O_3 $6SiO_2$	Hydrated to form hydrous aluminium silicate, with the liberation of soluble silica	Clay, Soluble material
	B. Oligoclase (Plagioclase)	$3Na_2O$	Goes into solution as carbonate, chloride, etc.,	Soluble material
		CaO	Forms carbonate, which is soluble in water containing carbon dioxide	Soluble material
		$4Al_2O_3$ 2O SiO_2	Decompose as in othoclase	Clay
2	Quartz	SiO_2	Remains undecomposed	Sand grains
3	Muscovite(White mica)	$2H_2O$ K_2O $3Al_2O_3$ $6SiO_2$	Remains undecomposed	Mica flakes
4	Biotite(Black Mica)	H_2O K_2O	Goes into solution as carbonate,	Water – soluble material

			chloride	
		2(Mg, Fe)O	Goes into solution as carbonate, chloride; iron carbonate oxidizes to hematite or Limonite	Soluble material and colouring material
		Al_2O_3 $3SiO_2$	Forms hydrous aluminium silicate and soluble silica	Clay, Soluble material
Hornblende responds to weathering in a manner similar to biotite, as it is alo a ferromagnesium material.				

- ✓ The soluble material enters the rivers and is carried to the sea, contributing to the dissolved salts of the ocean.
- ✓ Soluble silica is usually quickly redeposited as veins in fissures and as cementing material in rocks.
- ✓ The insoluble products and the unaltered minerals may remain for some time in the same place, forming part of the regolith, but ultimately they are carried to the rivers and then to the sea.
- ✓ Disintegration may also produce rough angular rubble consisting of any kind of rock, which may form a mantle on a mountain top, or accumulate by the action of gravity at the foothill regions. These loose accumulations are called *Talus or Scree*.
- ✓ When these angular fragments get lithified due to cementation, sedimentary rocks known as *breccias* are formed.
- ✓ An extremely rugged topography known as "*Karst topography*" is the result of the weathering process in limestone terrain.

Karst Topography



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