unit-1 .Introduction of geology

Scope Of Geology In Civil Engineering

It is defined as that of applied science which deal with the application of geology for a safe, stable and economic design and construction of a civil engineering project.

Engineering geology is almost universally considered as essential as that of soil mechanics, strength of material, or theory of structures.

The application of geological knowledge in planning, designing andconstruction of big civil engineering projects.

The basic objects of a course in engineering geology are two folds.

It enables a civil engineer to understand the engineering implications of certain condition should relate to the area of construction which is essentially geological in nature.

It enables a geologist to understand the nature of the geological information that is absolutely essentially for a safe design and construction of a civil engineering projects.

The scope of geology can be studied is best studied with reference to major activities of the profession of a civil engineer which are

Construction

Water resources development Town and regional planning

BRANCHES OF GEOLOGY

Geology is a relatively recent subject. In addition to its core branches, advances in geology in allied fields have lead to specialized sciences like geophysics, geochemistery, seismology, oceanography and remote sensing.

Main and Allied branches of geology:

The vast subject of geology has been subjected into the following branches:

Main Branches	**Allied Branches**
Physical geology	Engineering
geology Mineralogy	Mining
geology	Petrology
Geophysics Structural	geology
Geohydrology	Stratigraphy
Geochemistry Paleontology	
Economic geology	

Physical geology:

This is also variously described as dynamic geology, geomorphology etc. 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 surface like marine transgression, marine regression, formation or disappearance of rivers, springs and lakes.

iii) Geological work of wind, glaciers, rivers, oceans, and groundwater ands their role
in constantly moulding the earth surface features

iv) Natural phenomena like landslides, earthquakes and weathering.

Mineralogy:

This deals with the study of minerals. Minerals are basic units with different rocks and ores of the earth are made up of.

Details of mode of formation, composition, occurrence, types, association, properties uses etc. of minerals form the subject matter of mineralogy. For example: sometimes quartzite and marble resemble one another in shine, colour and appearance while marble disintegrates and decomposes in a shorter period because of its mineral composition and properties.

Petrology:

Petrology deals with the study of rocks. The earths crust also called lithosphere is made up of different types of rocks. Hence petrology deals with the mode of formation, structure, texture, composition, occurrence, and types of rocks. This is the most important branch of geology from the civil engineering point of view.

Structural geology:

The rocks, which from the earths crust, undergo various deformations, dislocations and disturbances under the influence of tectonic forces. The result is the occurrence of different geological structures like folds, fault, joints and unconformities in rocks. The details of mode of formation, causes, types, classification, importance etc of these geological structures from the subject matter of structural geology.

Stratigraphy:

The climatic and geological changes including tectonic events in the geological past can also be known from these investigations. This kind of study of the earth's history through the sedimentary rock is called historical geology. It is also called stratigraphy (Strata = a set of sedimementary rocks, graphy description).

Economic geology:

Minerals can be grouped as general rock forming minerals and economic minerals. Some of the economic minerals like talc, graphite, mica, asbestos, gypsum, magnesite, diamond and gems. The details of their mode of formation, occurrence, classification. Association, varieties, concenteration, properties, uses from the subject matter of economic geology. Further based on application of geological knowledge in other fields there is many other allied branches collectively called earth science.

Some of them described here are:

Engineering geology Mining geology

Geophysics Geohydrology Geochemistry

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.

Mining geology:

This deals with the application of geological knowledge in the field of mining. A mining engineer is interested in the mode and extent of occurrence of ores, their association, properties etc. It is also necessary to know other physical parameters like depth direction inclination thickness and reserve of the bodies for efficient utilization. Such details of mineral exploration, estimation and exploration are dealt within mining geology.

Geophysics:

The study of physical properties like density and magnetism of the earth or its parts. To know its interior form the subject matter of geophysics. There are different types of geophysical investigations based ion the physical property utilized gravity methods, seismic methods, magnetic methods. Engineering geophysics is a branch of exploration geophysics, which aims at solving civil engineering problems by interpreting subsurface geology of the area concerned. Electrical resitivity methods and seismic refraction methods are commonly used in solving civil engineering problems.

Geohydrology:

This may also be called hydrogeology. It deals with occurrence, movement and nature of groundwater in an area. It has applied importance because ground water has many advantages over surface water. In general geological and geophysical studies are together taken up for groundwater investigations.

Geochemistry:

This branch is relatively more recent and deals with the occurrence, distribution, abundance, mobility etc, of different elements in the earth crust. It is not important from the civil engineering point of view.

PHYSICAL GEOLOGY

WEATHERING

Weathering is defined as a process of decay, disintegration and decomposition of rocks under the influence of certain physical and chemical agencies.

Disintegration:

It may be defined as the process of breaking up of rocks into small pieces by the mechanical agencies of physical agents.

Decomposition:

It may be defined as the process of breaking up of mineral constituents to form new components by the chemical actions of the physical agents.

Denudation:

It is a general term used when the surface of the earth is worn away by the chemical as well as mechanical actions of physical agents and the lower layers are exposed.

The process of weathering depends upon the following three factors:

i) Nature of rocks
ii) Length of time
iii) Climate

Two Chief types of weathering are commonly distinguished on the basis of type of agency involved in the process and nature of the end product. They are:

i) Physical or mechanical weathering
ii) Chemical weathering

Physical weathering:

It is the physical breakdown of rock masses under the attack of certain atmospheric agents. A single rock block is broken gradually into smaller irregular fragments and then into particles of still smaller dimensions. It is the most active in cold, dry and higher areas of the earth surface Temperature variations are responsible to a great extent of physical weathering.

Thermal effects:

The effect of change of temperature on rocks is of considerable importance in arid and semi arid regions where difference between daytime and nighttime temperature is often very high. Such temperature fluctuations produce physical disintegration in a normally expected manner. Expansion on heating followed by contraction on cooling. When the rock mass is layered and good thickness additional disturbing stresses may be developed into by unequal expansion and contraction from surface to the lower regions. The rock sometimes is found to break off into concentric shells. This process is known as exfoliation.

When weathering occurs part of the disintegrated rock material is carried away by running water or any other transporting agent. Some of them are left on the surface of the bedrock as residual boulders. It is often seen that boulders have an onion like structure. This kind of weathering is called spheroidal weathering.

Chemical weathering:

The chemical decomposition of the rock is called chemical weathering which is nothing but chemical reaction between gases of the atmosphere and minerals of the rocks. The chemical changes invariably take place in the presence of water generally rainwater -in which are dissolved many active gases from the atmosphere like C02, nitrogen, Hydrogen etc.These conditions are defined primarily by chemical composition of the rocks humidity and the environmental surrounding the rock under attack.

Chemical weathering is essentially a process of chemical reactions between gases of the atmosphere and the surface rocks. For example:

1) 2CaCO3 + H2O + CO2 ------------------ 2 Ca (HCO3) 2

2) CaSO4 + 2H2O -------------------- CaSO42.H2O

Engineering importance of rock weathering:

As engineer is directly or indirectly interested in rock weathering specially when he has to select a suitable quarry for the extraction of stones for structural and decorative purposes. The process of weathering always causes a lose in the strength of the rocks or soil.

For the construction engineer it is always necessary to see that:

To what extent the area under consideration for a proposed project has been affected by weathering andWhat may be possible effects of weathering processes typical of the area on the construction material

Unit -2 Minerology &petrology

MINERALOGY

Inorganic substances which has more or less definite atomic structure and chemical composition

It has constant physical property which are used in the identification of mineral in the field It can be divided into 2 groups

Rock forming mineral: Which are found in abundance of earth crust Ore forming minerals: which are economic valuable minerals

MINERAL GROPUS:

MINERAL GROUP	EXAMPLES
Oxides:	Quartz, magnetite, haematite, etc
Silicates:	Feldspar, mica, hornblende, augite, olivine,et
Carbonates:	Calcite, dolomite, etc
Sulphides:	Pyrites, galena, sphalerite, etc
Sulphates:	Gypsum
Chlorite:	Rock salt, etc

Over 4000 mineral exist in earth crust

All are composed of oxygen, silicon, aluminium, iron, calcium, potassium, sodium and magnesium

PHYSICAL PROPERTIES OF MINERALS

The following are the important physical properties:

i) Color
ii) Streak
iii) Lustre
iv) Structure
v) Hardness
vi) Specific gravity
vii) Cleavage
viii) Fracture
ix) Tenacity
x) Form

Color:

Color is not constant in most of the minerals and commonly the color is due to stain or impurities in the minerals some minerals show peculiar phenomena connected with color.

Play of colors: It is the development of a series of prismatic colors shown by some minerals or turning about in light.

Change of colors: It is similar to play of colors that rate of change of colors on rotation is rather slow.

Iridescene: Some minerals show rainbow colors either in their interior on the surface. This is termed iridescence.

Streak:

The streak, which is the color of the mineral powder, is more nearly constant than the color. The streak is determined by marking unglazed porcelain or simply by scratching it with a knife and observing the color of the powder.

Lustre:

It is the appearance of a fresh surface of a mineral in ordinary reflected light. The following are the important terms used to denote the lustre of minerals. Classy or vitreous lustre - Lustre like a broken glass

Metallic lustre - When a mineral has lustre like

metal. Pearly lustre - Lustre like pearls

Structure:

This is a term used to denote the shape and form of minerals. The following are the important terms used to denote the structures of minerals.

Columnar Structure - The mineral has a thick or thin column like Structures

Bladed Structure - The mineral has blade like structure.

Radiated structure - For columnar of fibrous diverging from central Points

Lamellar structure - The mineral made of separable

plates. Botroidal structure - For an aggregate like bunch

of grapes. Reniform structure - For kindney shaped aggregate.

Hardness:

It is the resistance of mineral offers to abrasion or scratching and is measured relative to a standard scale of ten minerals known as Moh'scale sof hardness.

Hardness mineral : Name of the

01 Talc

02 Gypsum

03 Calcite

04 Fluorite

05 Apatite

06 Orthoclase

07 Quartz

The scale comprises ten minerals arranged to order of ascending hardness; the softest is assigned a value of 1 and the hardest value of 10. Hardness of any mineral will lie in between these two limits.

Specific gravity:

It may be defined as the density of the mineral compared to the density of water and as such represents a ratio.ie specific gravity of a mineral is the ratio of its weight of an equal

volume of water. Specific gravity of a mineral depends upon the weight and spacing of its atoms.

Cleavage:

It is defined as the tendency of a crystallized mineral to break along certain definite planes yielding more or less smooth surfaces. Cleavage is related to the internal structure of a mineral. The cleavage planes area always parallel to some faces of the crystal form typical of mineral. It is also described on the basis of perfection or the degree of easiness with which minerals can split along the cleavage planes.

Fracture:

The fractures of a mineral may be defined as the appearance of its broken surface. Common types of fractures are:

Conchodal fracture - The broken surfaces shows concentric rings Or curved surface.

Even fracture - When the broken surface is smooth and flat.

Uneven fracture - When the mineral breaks with an irregular Surface. It is a common fracture of many Minerals.

Splintery structure - When the mineral breaks with a rough.

Tenacity:

Important properties related to tenacity of the minerals are expressed by the terms like balances, flexibility, elasticity, sectility and mellability etc. when a mineral can be cut

with a knife it is termed 'sectile'and if the slice cut out from it can be flattened under a hammer. It is also said ella'mble''brittle'minerals. Term elastic is used if it regains its former shape as the pressure is released.

QUARTZ GROUP

It is an important rock forming mineral next to feldspar It is a non- metallic efractory mineral
It is a silicate group

PHYSICAL PROPERTIES OF QUARTZ:

CRYSTAL SYSTEM: Hexagonal **HABIT**: Crystalline or amorphous
FRACTURE: Conchoidal

HARDNESS: 7

SPECIFIC GRAVITY: 2.65-2.66(LOW)

STREAK: No

TRANSPARENCY: Transparent/semi-transparent/opaque

POLYMORPHISM TRANSFORMATION:

Quartz ,tridymite,crystotallite,melt

COLOURED VARIETIES:

Pure quartz is always colourless and transparent

Presence of impurities the mineral showing colour they

Amethyst: purple or violet

Smoky quartz: shades of grey

Milky quartz: light brown, pure white, opaque

Rose quartz: rose

FELSPAR GROUP

It is most abundant of all minerals

It is used for making more than 50% by weight crust of earth It is non-metallic and silicate minerals

CHEMICAL COMPOSITION:

Potash feldspar $KAlSi_3O_8$

Soda-lime feldspar $NaAlSi_3O_8$ (OR) $CaAl_2Si_2O_8$

VARITIES OF POTASH

FELSPAR: Orthoclase
Sanidine
Microcline
SODA LIME FELSPAR:
Albite
Oligoclase
Andecine
Amarthitie
Labrodorie

GENERAL PHYSICAL:

CRYSTAL SYSTEM: monoclinic,triclinic

HABIT: Tabular (crystalline)

CLEAVAGE: Perfect(2- directional)

PYROXENES GROUP

It is important group of rock forming minerals.

They are commonly occur in dark colours, igneous and metamorphic rocks They are rich in calcium, magnesium, iron, silicates
It show single chain structure of silicate

It is classified into orthopyroxene and clinopyroxene. It is based on internal atomic structure

<u>ORTHOPYROX ENE:</u> Enstatite

($MgSiO_3$)

Hyperthene [$(Mg,Fe)SiO_3$]

CLINOPYROXENE:

Augite [(Ca, Na) (Mg, Fe, Al) (Al, Si)2O6] **Diopside [**$CaMgSi_2O_6$]

Hedenbergite[$CaFeSi_2O_6$]

AUGITE:

CRYSTAL SYSTEM: Monoclinic

HABIT: Crystalline

CLEAVAGE: Good (primastic cleavage)

FRACTURE: Conchoidal

COLOUR: shades of greyish green and black

LUSTRE: vitreous

HARDNESS: 5-6

SPECIFIC GRAVITY: medium

STREAK: white

OCCURRENCE: ferro magnesium mineral of igneous rock (dolerite)

USES: rock forming mineral

COMPOSITON: [(Ca, Na) (Mg, Fe, Al) (Al, Si)2O6]

TRANSPARENCY: Translucent/opaque

AMIPHOBLE GROUP

These are closely related to pyroxene group It shows double chain silicate structure.

Rich in calcium, magnesium, iron oxide and Mn, Na, K and H.

CLASSIFICATION:

1. Orthorhombic
2. Monoclinica. Hornblenb. Tremolitec. Actinolite

MICA GROUP

Form sheet like structure

Can be spilt into very thin sheets along one direction Aluminium and magnesium are rich Occupy 4% of earth crust

HORNBLENDE:(COMPOUND-COMPLEX SILICATE) CRYSTAL SYSTEM: Monoc;inic

HABIT: crystalline

CLEAVAGE: good(prismatic) **FRACTURE**: conchoidal

COLOUR: dark green, dark brown black

LUSTRE: vitreous

HARDNESS: 5 to 6

SPECIFIC GRRAVITY: 3 to 3.5 (medium)

STREAK: colourless or white

COMPOSITION: hydrous silicates of Ca, Na, Mg, Al **TRANSPARENCY**: translucent/opaque

OCCURRENCE: found in igneous rocks

USES: road material

IGNEOUS ROCKS

Rocks that have formed from an originally hot molten material through the process of cooling and crystallization may be defined as igneous rocks.

Important Conditions For The Original Material

very high temperature and

a molten state

COMPOSITION

Magma

1 The hot molten material occurring naturally below the surface of the Earth is called magma.

2 It is called lava when erupted through volcanoes.

3 Igneous rocks are formed both from magma and lava.

4 It maybe mentioned here that magma is actually a hypothetical melt.

5 Lava is a thoroughly studied material that has poured out occasionally from volcanoes in many regions of the world again and again.

6 Magma or lava from which igneous rocks are formed may not be entirely a pure melt: it may have a crystalline or solid fraction and also a gaseous fraction thoroughly mixed with
it.

7 The solid and gaseous fractions, however, form only a small part of the magma or lava, which are predominantly made up of liquid material igneous rock.

Igneous rocks are divided into following three sub-groups

Volcanic rocks

These are the igneous rocks formed on the surface of the Earth by cooling and crystallisation of lava erupted from volcanoes.

Since the lava cools down at very fast rate (compared to magma), the grain size of the crystals formed in these rocks is very fine, often microscopic.

Further, cooling of lava may take place on the surface or even under waters of seas and oceans, the latter process being more common.

Plutonic Rocks

These are igneous rocks formed at considerable depths-generally between 7-10 km below the surface of the earth.

Because of a very slow rate of cooling at these depths, the rocks resulting from magma are coarse grained.

These rocks get exposed on the surface of the earth as a consequence of erosion of the overlying strata.
Granites, Syenites, and Gabbros are a few **examples** of Plutonic rocks.

Hypabyssal Rocks

These igneous rocks are formed at intermediate depths, generally up to 2 kms below the surface of the earth and exhibit mixed characteristics of volcanic and plutonic rocks.

Porphyries of various compositions are **examples** of hypabyssal rocks.

COMPOSITION

Mineralogical composition

Igneous rocks like other rock groups are characterised by the abundance of only a few, minerals.

S.No	**Mineral**	**(%)**	**S.No**	**Mineral**	**(%)**
(i)	Felspars	59.5			
(ii)	Pyroxenes & Amphiboles	16.8			
(iii	Quartz	12.0			
(iv)	Biotite	3.8			
(v)	Titanium	1.5			
(vi)	Apatite	0.6			
(vii	Accessory Minerals	5.8			

1. TEXTURES OF IGNEOUS ROCKS

The term texture is defined as the mutual relationship of different mineralogical constituents in a rock. It is determined by the size, shape and arrangement of these constituents within the body of the rock.

Factors Explaining Texture

The following three factors will primarily define the type of texture in a given igneous

rock:
Degree of Crystallization

In an igneous rock, all the constituent minerals may be present in distinctly crystallized forms and easily recognized by unaided eye, or, they may be poorly crystallized or be even glassy or non- crystallized form.
The resulting rock textures are then described as:

(i) Holocrystalline: When all the constituent minerals are distinctly crystallized;

(ii) Holohyaline: When all the constituents are very fine in size and glassy or non crystalline in nature.

The term **merocrystalline** is commonly used to express the intermediate type, *i.e.* when some minerals are crystallized and others are of glassy character in the same rock.
Rocks with **holocrystalline** texture are also termed as phaneric and the holohyaline rocks

are referred as aphinitic. The term microcrystalline is used for the textures in which the minerals are perceivably crystallized but in extremely fine grain.

Granularity

The grain size of the various components of a rock are the average dimensions of different constituent minerals which are taken into account to describe the grain size of the rock as a whole. Thus the rock texture is described as :

(i) **Coarse-grained**. When the average grain size is above 5 mm; the constituent minerals

are then easily identified with naked eye.

(ii) **Medium-grained**. When the average grain size lies between 5 mm and 1 mm. Use of magnifying lens often becomes necessary for identifying ail the constituent mineral components.

(iii) **Fine-grained**. When the average grain size is less than 1 mm. In such rocks, identification of the constituent mineral grains is possible only with the help of microscope for which very thin rock sections have to be prepared for microscopic studies

Fabric

This is a composite term expressing the relative grain size of different mineral constituents in a rock as well as the degree of perfection in the form of the crystals of the individual minerals.

The texture is termed as equigranular when all the component minerals are of approximately equal dimensions and as inequigranular when some minerals in the rock are exceptionally larger or smaller than the other.

Similarly, the shape or form of the crystals, which is best seen only in thin sections under microscope, may be described as perfect, semi perfect or totally irregular. The textural terms to describe these shapes are, respectively, euhedral, subhedral and anhedral.

An igneous rock may contain crystals of anyone type in a predominating proportion;

hence its fabric will be defined by one of the following three terms related to fabric:

(i) **Panidiomrphi**: when majority of the components are in fully developed shapes;

(ii) **Hypidiomorphic**: the rock contains crystals of all the categories: euhedral, subhedral or anhedral;

(iii) **Allotriomorphic**: when most of the crystals are of anhedral or irregular shapes

Types of Textures

These can be broadly divided into five categories:

. Equigranular textures
. Inequigranular textures

. Directive textures
. Intergrowth textures and

. Intergranular textures.

(1) Equigranular Textures

All those textures in which majority of constituent crystals of a rock are broadly equal in size are described as equigranular textures.

In igneous rocks, these textures are shown by granites and felsites and hence are also often named as granitic and felsitic textures
In the granitic texture, the constituents are either all coarse grained or all

medium grained and the crystals show euhedral to subhedral outlines.

In the felsitic texture, the rock is micro granular, the grains being mostly microscopic crystals but these invariably show perfect outlines.
Thus felsitic textures may be described as equigranular and panidiomrphic.

Orthophyric texture is another type of equigranular texture, which is in between
the granitic and felsitic textures. The individual grains are fine in size but not micregranular.

(2) Inequigranular Texture

Igneous textures in which the majority of constituent minerals show marked difference in their relative grain size are grouped as inequigranular texture.

Porphyritic and Poiklitic textures are important examples of such textures.

Porphyritic Texture is characterised by the presence of a few conspicuously large sized crystals

(the phenocrysts) which are embedded in a fine-grained ground mass or matrix.

The texture is sometimes further distinguished into mega-porphyritic and microporphyritic depending upon the size of the phenocrysts.

Difference in. molecular concentration

When the magma is rich in molecules of particular mineral, the latter has better chance to grow into big crystals which may get embedded in the fine-grained mass resulting from the deficient components.

Change in physico-chemical conditions.

Every magma is surrounded by a set of physico-chemical conditions like temperature, pressure and chemical composition, which influence the trend of crystallisation greatly.

Abrupt and discontinuous changes in these textures may result in the formation of the crystals of unequal dimensions.

Thus, magma crystallizing at great depths may produce well-defined, large sized crystals.

When the same magma (carrying with it these large crystals) moves upward, the pressure and temperature acting on it are greatly reduced.

Crystallisation in the upper levels of magma becomes very rapid resulting in a fine-grained matrix that contains the big sized crystals formed earlier.

Relative insolubility

During the process of crystallisation, their crystal grains get enlarged whereas crystals of other soluble constituents get mixed up again with the magma; thus, the relatively insoluble constituents form the phenocrysts

And the soluble constituents make up the ground mass crystallizing towards the end.

(3) Directive Textures

The textures that indicate the result of flow of magma during the formation of rocks
are known as directive textures.

These exhibit perfect or semi perfect parallelism of crystals or crystallites in the direction of the flow of magma.
Trachytic and Trachytoid textures are common examples.

The former is characteristic of certain felspathic lavas and is recognised by a parallel arrangement of felspar crystals; the latter is found in some syenites.

(4) Intergrowth Textures

During the formation of the igneous rocks, sometimes two or more minerals may crystallize out simultaneously in a limited space so that the resulting crystals are mixed up or intergrown.
This type of mutual arrangement is expressed by the term intergrowth texture.
Graphic and granophyric textures are examples of the intergrowth textures.

In graphic texture, the intergrowth is most conspicuous and regular between quartz and felspar crystals. In granophyric textures the intergrowth is rather irregular.

(5) Intergranular Textures

In certain igneous rocks crystals formed at earlier stages may get so arranged that polygonal or trigonal spaces are left in between them.
These spaces get filled subsequently during the process of rock formation by crystalline or glassy

masses of other minerals.

The texture so produced is called an intergranular texture. Sometimes the texture is specifically termed intersertal if the material filling the spaces is glassy in nature.

2.FORMS OF IGNEOUS ROCKS

An igneous mass will acquire on cooling depends on a number of factors such as

(a) the structural disposition of the host rock (also called the country rock)

(b) the viscosity of the magma or lava

(c) the composition of the magma or lava

(d) the environment in which injection of magma or eruption of lava takes place.

It is possible to divide the various forms of igneous intrusions into two broad classes:

All those intrusions in which the magma has been injected and cooled along or parallel to the structural planes of the host rocks are grouped as concordant bodies.

Forms of concordant bodies Sills

The igneous intrusions that have been injected along or between the bedding planes or sedimentary sequence are known as sills.

It is typical of sills that their thickness is much small than their width and length. Moreover, this body commonly thins out or tapers along its outer margins.

The upper and lower margins of sills commo11ly show a comparatively finer grain size than their interior portions. This is explained by relatively faster cooling of magmatic injection at

these positions

In length, sills may vary from a few centimeters to hundreds of meters

Sills are commonly subdivided into following types:

(a) **Simple Sills**: formed of a single intrusion of magma;

(b) **Multiple Sills**: which consist of two or more injections, which are essentially of the same kind of magma;

(c) **Composite Sills**: which result from two or more injections of different types of magma;

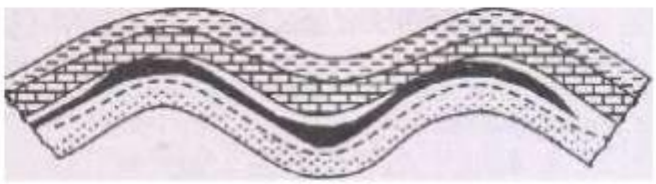
(d) **Differentiated Sills**: these are exceptionally large, sheet-like injections of magma in which there has been segregation of minerals formed at various stages of crystallisation into separate layers or zones.

*(e)***Interformational Sheets:** the sheet of magma injected along or in between the planes of unconformity in a sequence are specially termed as interformational sheets. These resemble the sills in all other general details.

These arecordant, small sized intrusive that occupy positions in the troughs and crests of bends called folds. In outline, these bodies are doubly convex and appear crescents or half-moon shaped in cross-section.

As regards their origin, it is thought that when magma is injected into a folded sequence of rocks, it passes to the crests and troughs almost passively *i.e.* without exerting much pressure.

Phacoliths



Lacocothis

These are concordant intrusions due to which the invaded strata have been arched up or deformed into a dome.

The igneous mass itself has a flat or concave base and a dome shaped top.

Laccoliths are formed when the magma being injected is considerably viscous so that it is unable to flow and spread for greater distances.

Instead, it gets collected in the form of a heap about the orifice of eruption. As the magma is injected with sufficient pressure, it makes room for itself by arching up the overlying strata.

Extreme types of laccoliths are called bysmaliths and in these the overlying strata get ultimately fractured at the top of the dome because of continuous injections from below.

Lopoliths

Those igneous intrusions, which are associated with structural basins, that are sedimentary beds inclined towards a common centre, are termed as lopoliths.

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It is believed that in the origin of the lopoliths, the formation of structural basin and the injection of magma are "contemporaneous", that is, broadly simultaneous.

DISCORDANT BODIES

All those intrusive bodies that have been injected into the strata without being influenced by their structural disposition (dip and strike) and thus traverse across or oblique to the bedding planes etc. are grouped as discordant bodies.

Important types of discordant intrusions are dykes, volcanic necks and batholithsThese may be defined as columnar bodies of igneous rocks that cut across the bedding plane or unconformities or cleavage planes and similar structures.

Dykes are formed by the intrusion of magma into pre-existing fractures.

It depends on the nature of magma and the character of the invaded rock whether the walls of the fracture are pushed apart, that is, it is widened or not Dykes show great variations in their thickness, length, texture and composition.

They may be only few centimeters or many hundreds of metes thick.

In composition, dykes are generally made up of hypabyssal rocks like dolerites, porphyries and lamprophyres, showing all textures between glassy and phaneritic types.

Cone sheets and Ring Dykes may be considered as the special types of dyke The cone sheets are defined as assemblages of dyke-like injections, which are generally inclined towards common centres.
Their outcrops are arcuate in outline and their inclination is generally between 30 o - 40 o .

The outer sheets tend to dip more gently as compared to the inner ones

Ring Dykes are characterised by typically arcuate, closed and ring shaped outcrops. These may be arranged in concentric series, each separated from the other by a screen of country rock.

They show a great variation in their diameter; their average diameter is around 7 kilometers. Few ring dykes with diameters ranging up to 25 kms are also known.

Origin of dykes It has been already mentioned that dykes are intrusions of magma into pre- existing fractures present in the rocks of the crust.

These original fractures are generally caused due to tension.

Their original width might have been much less than the present thickness of the dykes.

This indicates widening of the cracks under the hydrostatic pressure of magmatic injection.

Volcanic Necks

In some cases vents of quiet volcanoes have become sealed with the intrusions. Such congealed intrusions are termed volcanic necks or volcanic plugs.

In outline these masses may be circular, semicircular, or irregular and show considerable variation in their diameter. The country rock generally shows an inwardly dipping contact.

Batholiths

These are huge bodies of igneous masses that show both concordant and discordant relations with the country rock.

Their dimensions vary considerably but it is generally agreed that to qualify as a batholith the igneous mass should be greater than 100 square kilometers in area and its depth should not be

traceable. This is typical of batholiths: they show extensive downward enlargement

In composition, batholiths may be made of any type of igneous rock They also exhibit many types of textures and structures. But as, a matter of observation, majority of batholiths shows predominantly granitic composition, texture and structure.

BRIEFLY EXPLAIN ABOUT SEDIMENTARY ROCKS

Sedimentary rocks are also called secondary rocks.

This group includes a wide variety of rocks formed by accumulation, compaction and consolidation of sediments.

The sediments may be defined as particles produced from the decay and weathering of pre- existing rocks or may be derived from remains of dead sea or land animals in suitable environments.

The accumulation and compaction of these sediments commonly takes place under water or at least in the presence of water.

FORMATION

The process of formation of sedimentary rocks is ever prevailing.

sea floors where they are deposited, get compacted and consolidated and finally transformed into a cohesive solid mass.

That is a sedimentary rock.

Some chemical processes especially evaporation and precipitation regularly operate on surface of water bodies containing dissolved salts and produce solids that settle down in those bodies. Sedimentary rocks are broadly grouped into three classes on the basis of their mode of formation: Mechanically formed or Clastic Rocks; Organically formed Rocks and Chemically formed Rocks

The last two groups are considered as a single class and named as Non-Clastic Rocks.

Clastic (Mechanically Formed) Rocks

A series of well-defined steps are involved in the formation of clastic rocks.

Decay and Disintegration

Rocks existing on the surface of the earth are exposed to decay and disintegration by the action of natural agencies like atmosphere, water and ice on them

The original hard and coherent rock bodies are gradually broken down into smaller and still smaller fragments, grains and particles.

The disintegrated, loosened material so formed and accumulated near the source is called detritus.

Hence, clastic rocks are often also called as detrital rocks

.

Transport of Sediments

The detritus produced from the decay and disintegration of the pre-existing rocks forms the source of the sedimentary rocks but it has to be transported to a suitable place for transformation again into a rock mass.

The wind, running water and ice in the form of glaciers are the very strong and

common agents of transport for carrying millions of tonnes of sediments and particles from one place to another including seas and oceans.

The winds transport the sediments from ploughed fields, the deserts and dry lands in series of jumps (saltation) and in suspension modes.

These loads of sediments are dropped down wherever intercepted by rains.

The mightiest agents of transport of sediments are, of course, streams and rivers, all terminating into lakes or seas.

The running water bodies transport the sediment load as bed-load, suspended-load and. dissolved load, all dumped at the settling basins.

Ice in the form of huge moving bodies called glaciers also breaks the rocks along their bases and sides (in valley glaciers) and dumps the same at snow lines thereby making large volumes of the

clastic load available for further transport by other agencies. It is easy to imagine that millions of tonnes of land mass as scratched by these surface agencies is transported to seas and oceans every year and deposited there.

Dradual deposition

The sediments as produced through weathering and erosion are transported to settling basins.

These basins may be located in different environments such as on the continents, along the seashores or in deep-sea environments.

As such sedimentary rocks formed in different environments will show different inherent characters.

In the continental environments may be included the glacial deposits, the fluvial deposits, the glacio-fluvial deposits and the eolian deposits, each type giving rise to a definite type of

sediment accumulation.

In the marine deposits, some sediments may be dropped just along the sea-shore, or at some shallow depth within the sea or miles away in the deep-sea environment.

Diagenesis

The process of transformation of loose sediments deposited in the settlement basins to solid cohesive rock masses either under pressure or because of cementation is collectively known as diagenesis.

It may be achieved by either of the two methods: **welding or cementation**.

Welding is the process of compaction of the sediments accumulated in lower layers of a basin due to the pressure exerted by the load of the overlying sediments.

This results in squeezing out all or most of the water .from in between the sediments, thus bringing them closer and closer and consolidating them virtually in a solid rock mass.

In fact the degree of packing of sediments in a sedimentary rock is broadly directly proportional to the load of the overlying sediments.

Cementation is the process by which loose grains or sediments in a settlement basin get held together by a binding material.

The binding material may be derived from within the accumulated particles or the fluids that percolate through them and also evaporate or precipitate around those particles thus binding

them in a rock like mass.

. **Chemically Formed (Non-clastic) Rocks**

Water from rains, springs, streams, rivers, lakes and underground water bodies dissolves many compounds from the rocks with which it comes into contact.

In most cases all these dissolved salts are carried by the running water to its ultimate destination the sea.
Hence the brackish or saltish taste of the sea water.

In many other cases also, the local water-bodies may get saturated with one or other dissolved salt.

In all cases, a stage maybe reached when the dissolved salts get crystallized out either through evaporation or through precipitation.
Thus, limestone may be formed by precipitation from carbonated water due to loss of carbon dioxide.
Rock salt may be formed from sodium-chloride rich seawater merely by the process of continued evaporation in bays and lagoons.
Chemically formed rocks may be thus of two types: precipitates and evaporites. Examples are lime stones, rock salt, gypsum, and anhydite.

Organically Formed (Non-clastic} Rocks

These extensive water bodies sustain a great variety of animal and plant life.

The hard parts of many sea organisms are constituted chiefly of calcium and/or magnesium, carbonates.
Death and decay of these organisms within the water bodies gradually results into huge accumulations of carbonate materials, which get compacted and consolidated in the same manner as the normal sediments.
Lime stones are the best examples of organically formed sedimentary rocks

TEXTURES

***(i)* Origin of Grains**

A sedimentary rock may be partially or wholly composed of clastic (or allogenic) grains, or of chemically formed or organically contributed parts.
Thus the rock may show a clastic texture or a non-clastic texture.

(ii) Size of Grains

The grain size in the sedimentary rocks varies within wide limits.

Individual grains of less than 0.002 mm and more than 250 mm may

form a part or whole of these rocks.
Three textures recognized on the basis of grain size are:
Coarse -grained rocks; average grain size> 5 mm
Medium grained rocks; average grain size between 5 and 1 mm.

Fine-grained rocks; average grain size < 1 mm

(iii)Shape of Grains

The sediments making the rocks may be of various shapes: rounded, sub rounded, angular and sub angular.
They may show spherecity to various degrees.
Roundness and spherecity are the indications of varying degree of transport and abrasion suffered during that process.
indicating least transport and abrasion.
Conglomerates are full of rounded and smooth-surfaced pebbles and gravels indicating lot of transport and rubbing action during their transport before getting deposited and consolidated into a
rock mass.

LIMESTONES

Definition

These are the most common sedimentary rocks from the non-clastic-group and are composed chiefly of carbonate of calcium with subordinate proportions of carbonate of magnesium.

They are formed both bio-chemically and mechanically.

Composition

In terms of chemical composition, limestone' s are chiefly made up of CaO and CO2, Magnesium Oxide is a common impurity in most limestone' s; in some its percentage may exceed 2 percent, the rock is then called magnesian limestone.

Other oxides that may be present in limestone are: silicon dioxide, ferrous and ferric oxides (or carbonates); and aluminium oxide. Strontium oxide is also present in some. limestone' s as a trace element.

Texture.

The most important textural feature of limestone' s is their fossiliferous nature. Fossils in all stages of preservation may be found occurring in limestone' s. Other varieties of limestone' s show dense and compact texture; some may be loosely packed and highly porous; others may be compact and homogeneous. Concretionary texture is also common in limestone' s. .

Types. Many varieties of limestone' s are known.

Broadly speaking these can be divided into two groups: autochthonous and allochthonous.

Autochthonous includes those varieties which have been formed by biogenic precipitation from seawaters.

Allochthonous types are formed from the precipitated calcareous sediments that have been transported from one place to another where they were finally deposited.

Following are common types of limestones.

DOLOMITE

Definition.

It is a carbonate rock of sedimentary origin and is made up chiefly more than 50 percent - of the mineral dolomite which is a double carbonate of calcium and magnesium with a formula of CaMg(C03h.

Ferrous iron is present in small proportions in some varieties.

Gypsum also makes appearance in some dolomites.

But the chief associated carbonate is that of calcium, in the form of calcite.

Texture

Dolomite shows textures mostly similar to limestones to which it is very often genetically related.

In other varieties, dolomites may be coarsely crystalline, finely crystalline or showing interlocking crystals.

Formation.

Dolomites are formed in most cases from limestones by a simple process of replacement of Ca^{++}

ions by Mg^{++} ions through the action of Mg^{++} ion rich waters.

This ionic replacement process is often termed dolomitization

The replacement may have started shortly after the deposition of limestone or quite subsequent to their compaction.

Direct precipitation of dolomites from magnesium rich waters is also possible.

Such directly precipitated deposits of magnesium carbonate occur in association with gypsum, anhydrite and calcite.

It is believed that in such cases, it is the calcite, which is precipitated first, depleting the seawater of CaC03 and enriching it with MgC03.

The CaMg(C03h precipitates at a later stage.

Dolomitization by replacement method, however, is believed to be the most common method of formation of dolomites.

7. Coals

Definition.

These may broadly be defined as metamorphosed sedimentary rocks of carbonaceous character in which the raw material has mostly been supplied by plants of various groups.

The original raw material passes through many biomechanical and biochemical processes before it becomes a coal in technical terms;

Formation.

In most cases coals represent carbonized wood.

The process of coal formation involves a series of stages similar to formation of sedimentary rocks such as wastage of forests and transport of the wood material through different natural

agencies to places of deposition, accumulation of the material in hugeformations.

Its burial under clays and other matter and its compaction and consolidation under superimposed load.

Biochemical transformation of the organic matter so accumulated starts and is completed under the influence of aerobic and anaerobic bacteria available at the place of deposition.The degree of carbonification depends to a great extent on the time and type of environment in which the above processes have operated on the source material giving rise to different varieties of coal.

METAMORPHIC ROCKS

METAMORHISM

METAMORHISM is the term used to express the process responsible for all the changes that take place in an original rock under the influence of changes in the surrounding conditions of temperature, pressure and chemically active fluids.

METAMORPHIC ROCKS

Definition

Metamorphic rocks are defined as those rocks which have formed through the operation of

Stress Minerals

various types of metamorphic processes on the pre-existing igneous and sedimentary rocks involving changes in textures, structures and mineralogical compositions.

The direction of change depends upon the type of the original rock and the type of metamorphic process that operates on the rock.

Heat, pressure and chemically active fluids are the main agents involved inmetamorphic processes.

Plastic deformation, recrystallisation of mineral constituents and development of parallel orientation are typical characters of metamorphic rocks.

MINERALOGICAL COMPOSITION

Metamorphic rocks exhibit a great variation in their mineralogical composition that depends in most cases on

(i) the composition of the parent rock;

(ii) the type and degree of metamorphism undergone by the rock.

Two broad groups of minerals formed during metamorphism are:

- v Stress minerals and
- v Anti-stress minerals

Stress minerals

The minerals, which are produced in the metamorphic rocks chiefly under the stress factor, are known as stress minerals.

They are characterised by flaky, platy, lamellar, flattened and elongated forms.

kyanite, *staurolite*, *muscovite, chlorite* and some amphiboles.

Anti-Stress Minerals

These are metamorphic minerals produced primarily under the influence of temperature factor.

Such minerals are generally of a regular equidimensional outline. **Examples:** sillimanite, olivine, cordierite and many pyroxenes

Textures of Metamorphic Rocks

These can be broadly grouped under two headings:

(a) **Crystalloblastic**

Textures which include all those textures that have been newly imposed upon therock during the process of metamorphism and are, therefore, essentially the product of metamorphism.

(b) **Palimpsest (Relict)**

Textures that include textures which were present in the parent rock and have been retained by the rock despite metamorphic changes in other aspects.

Among the crystalloblastic textures, Porphyroblastic and Granoblastic types are most common. outlines) of stronger minerals.

In the granoblastic texture, the rock is made of equidimensional recrystallised minerals without there being any fine grained ground mass. Palimpsest textures are similar in essential details as in the parent rock with little or no modifications taking place during metamorphism. These are described by using the term blasto as a prefix to the name of the original texture retained by the rock.

1. CLASSIFICATION OF METAMORPHIC ROCKS

(a) **Foliated Rocks** All metamorphic rocks showing development of conspicuous parallelism in their mineralogical and structural constitution falling under the general term foliation are grouped together as foliated rocks.

The parallelism indicating features include slaty cleavage, schistosity and gneissose structures

Typical rocks included in this group are slates, phyllites, schists and gneisses of great variety.

*(b)***Non-Foliated Rocks**

Included in this group are all those metamorphic rocks characterised with total or nearly total absence of foliation or parallelism of mineralogicaJ constituents.

Typical examples of non-foliated rocks are quartzites, hornfels, marbles, amphibolites and soapstone etc.

QUARTZITE

Definition

Quartzites are granular metamorphic rocks composed chiefly of inter sutured grains of quartz.

The name Orthoquartzite is used for a sedimentary rock of similar composition but having a different (sedimentary) origin, in which quartz grains are cemented together by siliceous cement.

Composition

Besides quartz, the rock generally contains subordinate amounts of micas, felspars, garnets and some amphiboles which result from the recrystallisation of some impurities of the original sandstone during the process of metamorphism.

Origin

Metamorphic quartzites result from the recrystallisation of rather pure sandstones under the influence of contact and dynamic metamorphism.**Uses**

The rock is generally very hard, strong, dense and uniformly grained.

It finds extensive use in building and road construction.

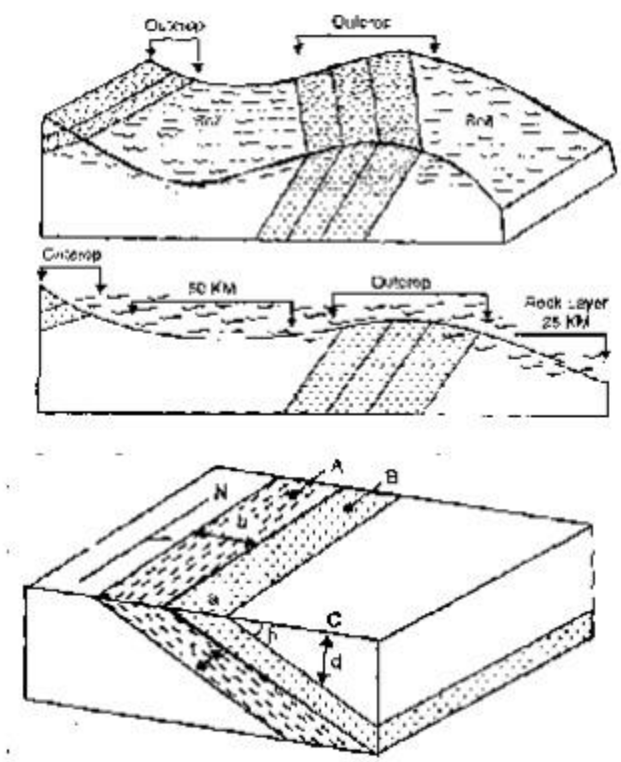
UNIT-3 .STRUCTURAL GEOLOGY

Geology: OUTCROP

In the mountainous and sub-mountainous tracts and also in shallow plains, exposures of rocks may be easily seen forming sides of valleys or caps of hills or even uplands and slopes in level fields.

An **outcrop** is simply defined as an exposure of a solid rock on the surface of the earth.

Outcrop Dimensions



The **width or breadth** of the outcrop of a particular bed is given by the distance between the top and bottom edges of the bed as measured on the surface of the ground in a direction perpendicular to the strike of that particular bed

Many variations are induced in the breadth of an outcrop of a rock by the topography of the area.

The **thickness** of a particular layer or bed is the perpendicular distance between the top and bottom surface of the same layer as seen in a vertical section at right angles to the strike of the layer

The **depth** to a particular layer or bed at any place from the surface, if believed to be present on the basis of general geology and dip of the formation, is given by the perpendicular distance between the ground surface and the top surface of that particular layer.
When the ground surface is horizontal, depth d to the bedrock of known dip may be obtained by the relationship
D = aC x tan b

where is the angle of true dip of the bed exposed at a place, say at B and C is the distance from that exposure to the place C where it is desired to find out depth to that bedrock.

Structural Geology: Folds

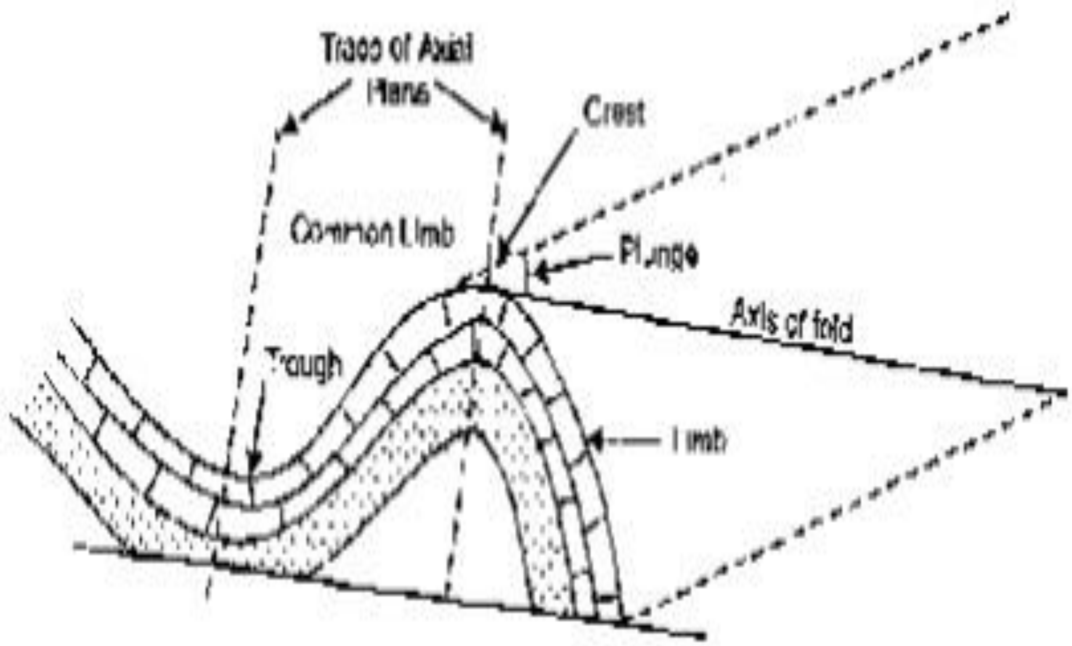
Definition
FOLDS may be defined as undulations or bends or curvatures developed in the rocks of the crust as a result of stresses to which these rocks have been subjected from time to time in the past history of the Earth.

d indicates an effort of the rocks in a particular environment to adjust themselves to the changing force fields operating on, within or around them.
Folding is a ductile type of deformation experienced by the rocks compared to the brittle deformation where the rocks actually get broken and displaced when stressed.

1 PARTS OF A FOLD

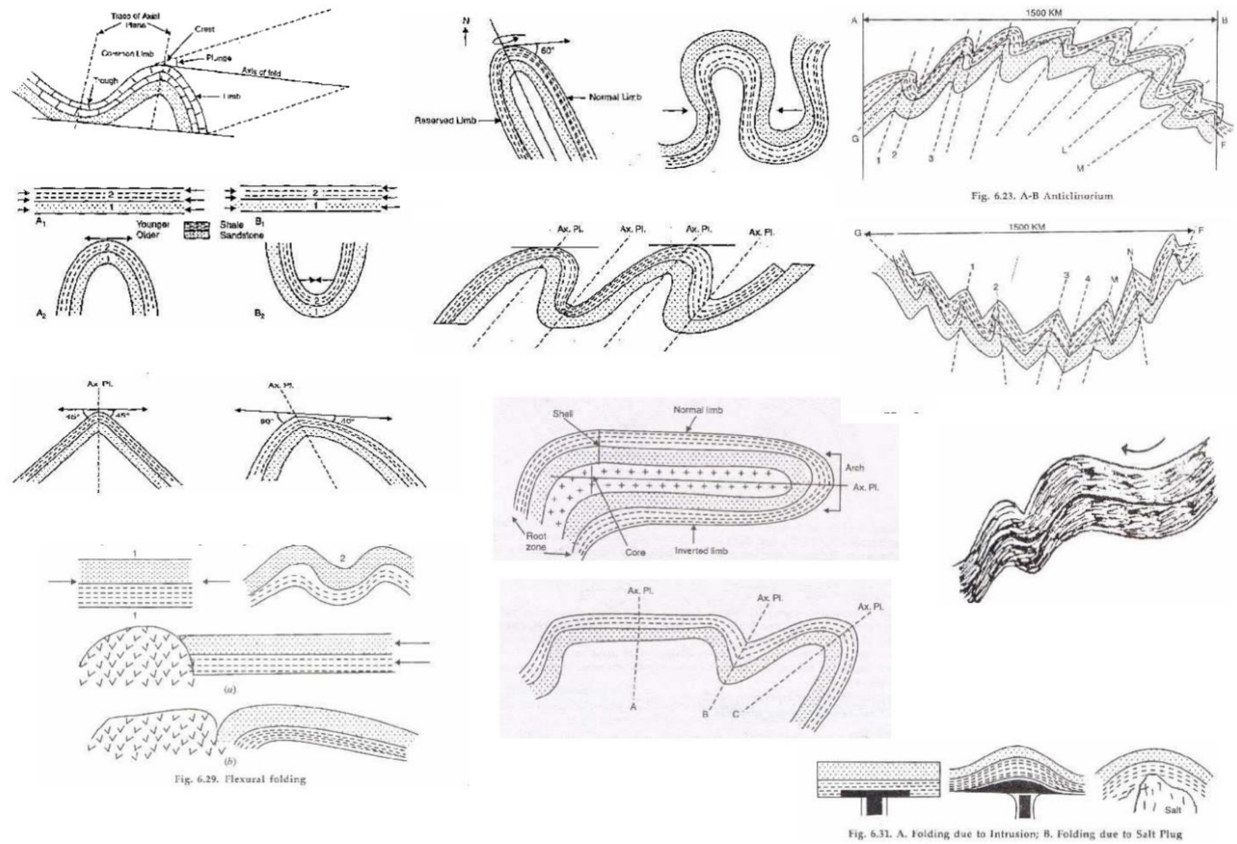
Limbs

These are the sides or flanks of a fold. An individual fold will have a minimum of two limbs but when the folds occur in groups, as they very often do, a middle



Trace of Axial Plane
Crest
Common Limb
Plunge
Axis of fold
Trough
Limb

limb will be common



to two adjacent

Hinge

In a folded layer, a p oint can be found where curvature is maximum and one limb ends and the other li mb starts from that point. This is the **hinge poin t**.

When rocks occur in a sequence and their all hinge points are joined together, they make a line, called the **hinge line**.

Axial surface

When the hinge line is traced throughout the depth of a folded sequence a surface is obtained which may be planar or non-planar. It is referred to as axial surface

Axial plane

Axial plane is the im aginary plane that passes through all the points of maximum curvature inclined or horizontal in nature.

A fold surface is plan ar in nature; otherwise it in a folded sequence.

It may be vertical, is sometimes called a planar fold if the axial is a n on-planar fold.

Axis of a fold

It is simply defined a s a line drawn parallel to the hinge line of a fold .

A more precise defin ition of an axis of a fold would be the line repr esenting the intersection of the ax ial plane of a fold with any bed of the fold.

Plunge of a fold

The angle of inclination of the fold axis with the horizontal as meas ured in a vertical plane is term ed the plunge of the fold.

Crest and Trough.

Most folds are variations of two general forms; uparched and downarched bends. The line running thr ough the highest points in an uparched fold defi nes its crest.

A corresponding lin e running through the lowest point in a down arched fold makes its trough. The crest and trough may or may not coincide wit h the axis of the fold.

2.CLASSIFICATION OF FOLDS Anticlines are defined as tho se folds in which

the strata are uparch ed, that is, these become CONVEX UPWARDS ;

the geologically olde r rocks occupy a position in the interior of the fold, oldest being positioned at th e core of the fold and the youngest forming the outermost flank,

the limbs dip away from each other at the crest in the simplest cases.

Synclines

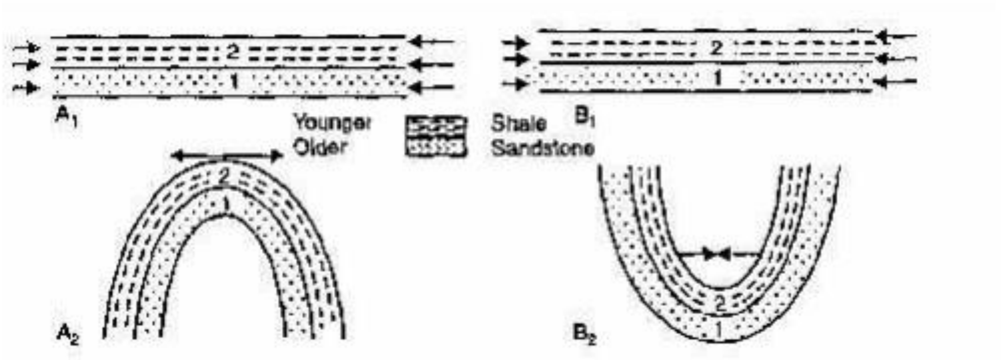
the strata are downar ched, that is, these become CONVEX DOWNWARDS;

the geologically younger rocks occupy a position in the core of th e fold and the older rocks form the outer flanks, provided the normal order of superposition is not d isturbed,

in the simplest cases in synclines, the limbs dip towards a common c enter.

Position of Axial Plane

Depending upon the nature a nd direction of the stresses the axial plane in a r esulting fold may acquire any position in space, that is, it may be vertical, inclined or eve n horizontal. Following main types are re cognized on the basis of position of the axial plane in the resulting fold:



Symmetrical Folds

These are also called normal or upright folds. In such a fold, the axia l plane is essentially vertical.

The limbs are equal i n length and dip equally in opposite directions.

it may be an anticline or syncline and when classified, may be described as symmetrical anticline / syncline as the case may be.

Asymmetrical Folds

All those folds, anticlines or synclines, in which the limbs are unequ al in length and these dip uneq ually on ether side from the hinge line are termed as asymmetrical folds.

Overturned folds

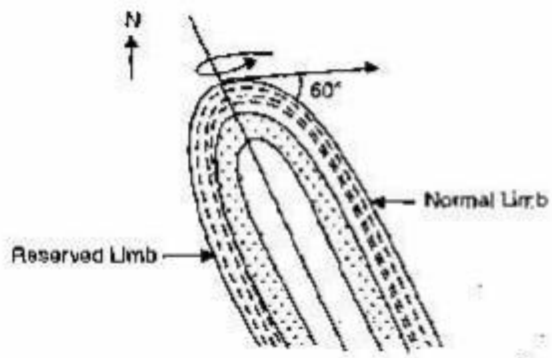
These are folds with inclined axial planes in which both the limbs are dipping essentially in the same general direction.

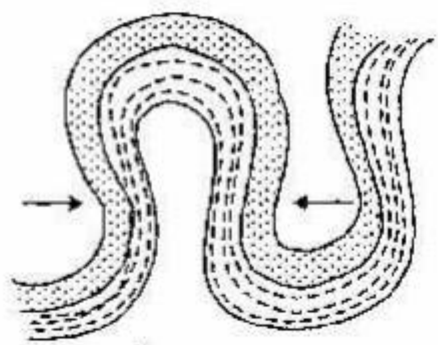
The amount of dip of the two limbs may or may not be the same.

Overfolding indicates very severe degree of folding.

One of the two limbs (the reversed limb) comes to occupy the present position after having suffered a rotation through more than 90 degrees.

The other limb is known as the normal limb.





In certain cases, both the limbs of a fold may get overturned because of very high lateral compression.

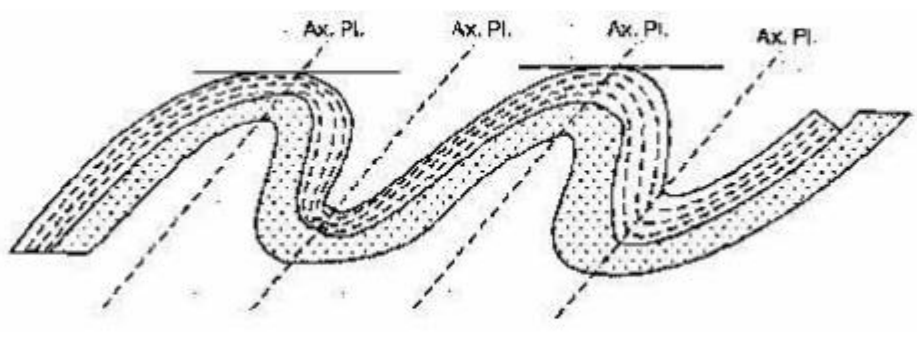
It may be originally either an anticline or a syncline but the extreme compression from opposite sides results in bringing the limbs so close to each other that the usual dip conditions may get reversed -anticlinal limbs dip towards each other and the synclinal limbs dip away from each other.

Such a type of fold is commonly referred to as a fan fold

In such folds, the anticlinal tops are said to have opened up into a broad, fan-shaped outline due to intense compression in the lower region.

Isoclinal Folds

These are group of folds in which all the axial planes are essentially parallel, meaning. that all the component limbs are dipping at equal amounts. They may be made up of series of anticlines and synclines



Recumbent Folds

These may be described as extreme types of overturned folds in which the axial plane acquires an almost horizontal attitude.

In such folds, one limb comes to lie exactly under the other limb so that a drill hole dug at the surface in the upper limb passes through the lower limb also.

The lower limb is often called the inverted limb or the reversed limb.

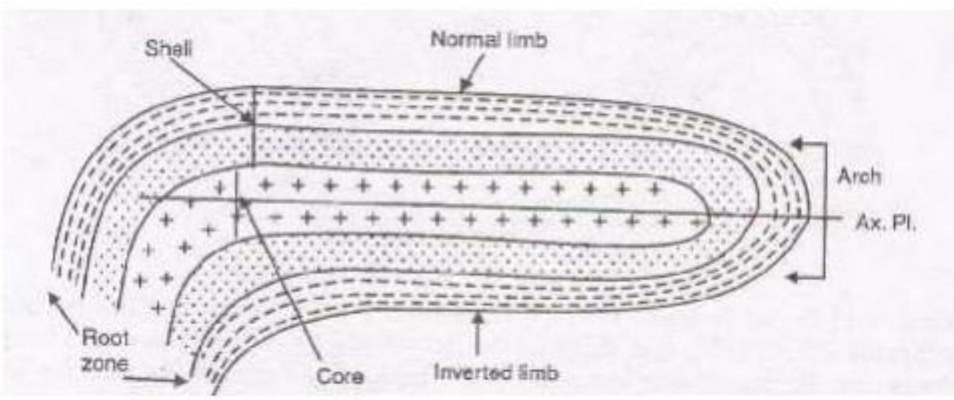
Other parts of a recumbent fold are sometimes named as follows:

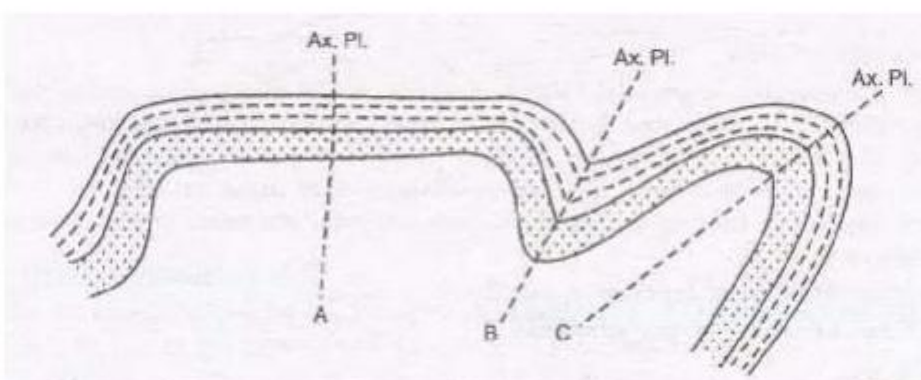
the arch, which is zone of curvature corresponding to crest and trough in the upright folds;

the shell, which is the outer zone made up mostly of sedimentary formations;

the core, which is the innermost part of the fold and maybe made mostly of crystalline igneous or metamorphic rocks;

the root or the root zone, which is the basal part of the fold and may or may not be easily traceable; once traced it can throw light whether the fold was originally an anticline or syncline that has suffered further inversion.





Conjugate Folds

In certain cases a pair of folds that are apparently related to each other may have mutually inclined axial planes.

Such folds are described as conjugate folds.

The individual folds themselves may be anticlinal or synchnal or their modifications.

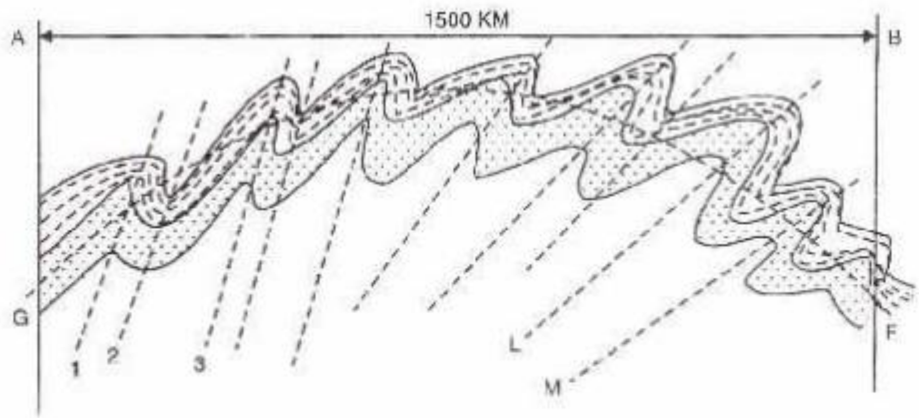


Fig. 6.23. A-B Anticlinorium

Box Fold

It may be described as a special type of fold with exceptionally flattened top and steeply inclined limbs almost forming three sides of a rect In both the anticlinorium and synclinorium, presence of large number of secondary folds, faults and fracture systems is a characteristic feature.

Similar folding but signifying still larger bending and uplifting of strata on sub-continental scales is expressed by the terms GEANTICLINES AND GEOSYNCLINES respectively.

Great importance is attached to the major depressions, the geosynclines, in the process of mountain building discussed elsewhere.

The geosynclines are believed to serve as depositional fields or basins of sedimentation to which sediments derived by the erosion of the adjoining gentilities get accumulated and compacted.

This material is then compressed and uplifted in the second stage of orogeny, to gradually take the shape of mountain systems.

3 CAUSES OF FOLDING

The Tectonic Folding may be due to any one or more of the following mechanisms:

Folding Due to Tangential Compression

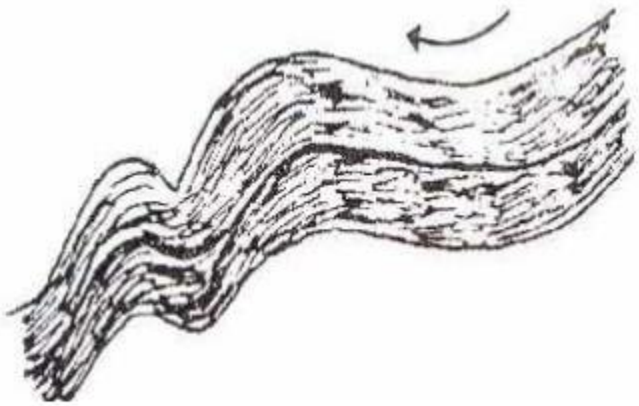
Lateral Compression is believed to be the main cause for throwing the rocks of the crust into different types of folds depending upon the types of rocks involved in the process and also the direction and magnitude of the compression effecting those rocks.

In general, this primary force is believed to act at right angles to the trend of folds. under the influence of the tangential stresses, folding may develop in either of the three ways: flexural folding, flowage folding and shear foldin
Flexural Folding.

It is that process of folding in which the competent or stronger rocks are thrown into folds due to their sliding against each other under the influence of lateral compression.This is also distinguished as flexural-slip-folding in which the slip o r movement of the strata involved takes place parallel to the bedding planes of the layers.

It has been establis hed that in flexural folding, the amount of slip (and hence the ultimate type of fold) depends on a number of factors such as:
thickness o f the layers and nature of the contact; thick er the layers, greater is the slip; further, cohesionless contacts favour easy and greater slips;
distance fr om the hinge point; greater the distance from the hinge points, larger is the
displacement, so much so that it may be negligible at the hin ge point;
type of the rocks involved; siltstones, sandstones and li mestones are more prone t o flexure slip folding compared to soft clays and shales.

Flowage Folding
It is t he principal process of folding in incompetent or weaker, plasti c type of rocks such as clays, shales, gypsum an d rock salt etc.
behaves almost as a viscous or plastic mass and gets buckled up and d eformed at varying rates suffering unequal disto rtion.
In such cases the thickness of the resulting fold does not remain unifor m.



Shear Folding.

In many cases, folding is attributed to shearing stresses rather than simple compression.

It is assumed that in such a process, numerous closely spaced fractures develop in the rock at the first stage of the process.

This is followed by displacement of the blocks so developed by different amounts so that ultimately the rocks take up folded or bent configuration.

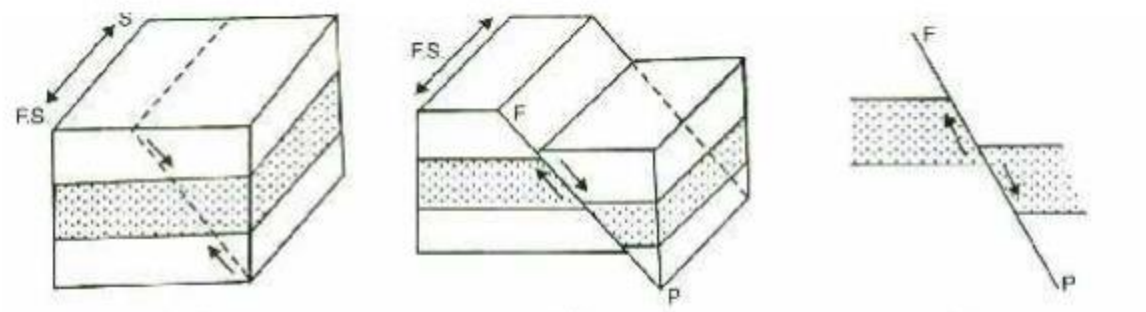
The folded outline becomes more conspicuous when the minor fractures get sealed up due to subsequent recrystallisation.

Fig. 6.31. A. Folding due to Intrusion; B. Folding due to Salt Plug

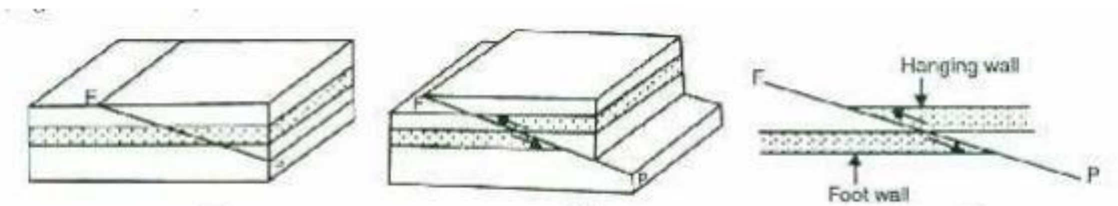
FAULT And FAULTING

Those fractures along which there has been relative movement of the blocks past each are termed as **FAULTS**.

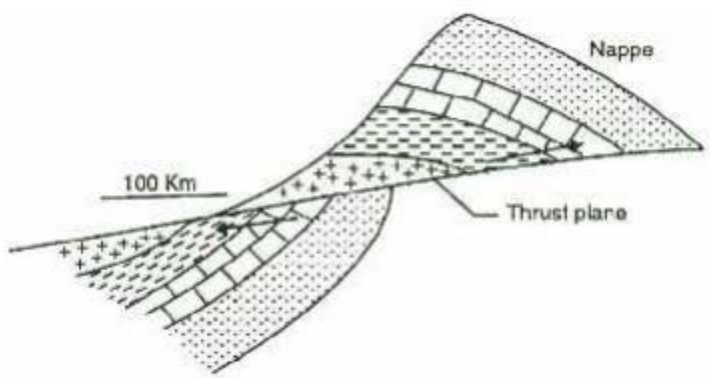
The entire process of development of fractures and displacement the blocks against each other is termed as

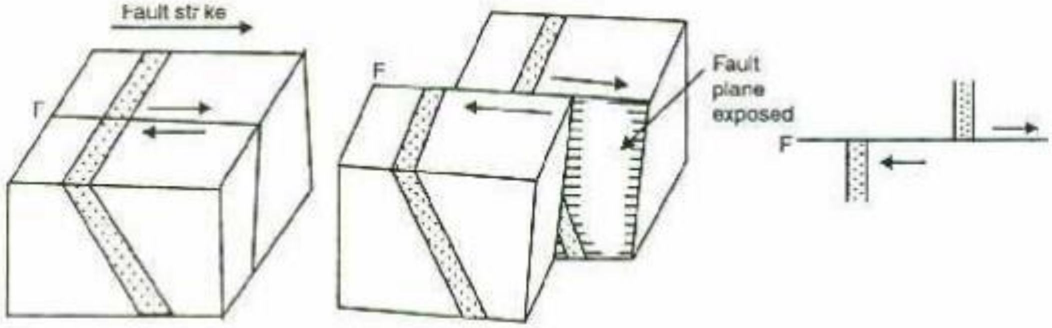


(a) (b) (c)



(a) (b) (c)





(a) Before faulting (b) After faulting. (c) Plan.

FAULTING CLASSIFICATION OF FAULTS

Following factors are more commonly considered important in classification of faults: The apparent movement of the disrupted blocks along the fault plane;

The direction of slip;

The relation of fault attitude with the attitude of the displaced beds; The amount of dip of the fault;

Mode of Occurrence.

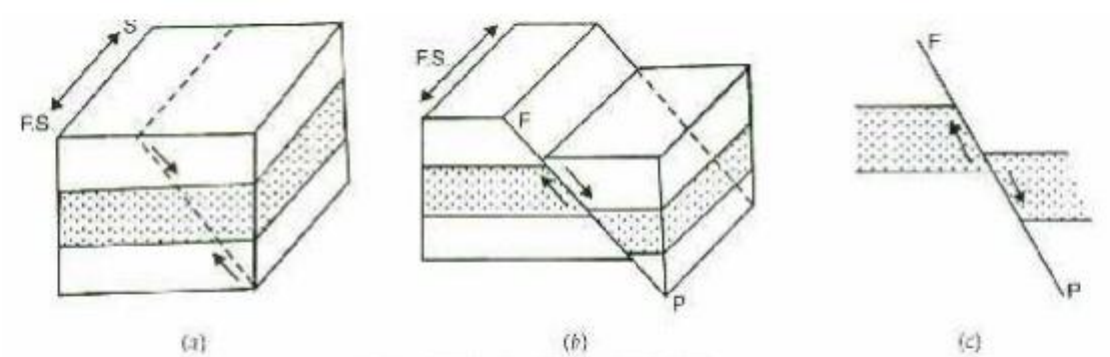
Three fundamental types of faults are commonly distinguished on the basis of apparent movement: normal faults, reverse faults and strike slip faults.

Normal Faults

Such a fault in which hanging wall has apparently moved down with respect to footwall is classified as a Normal Fault.

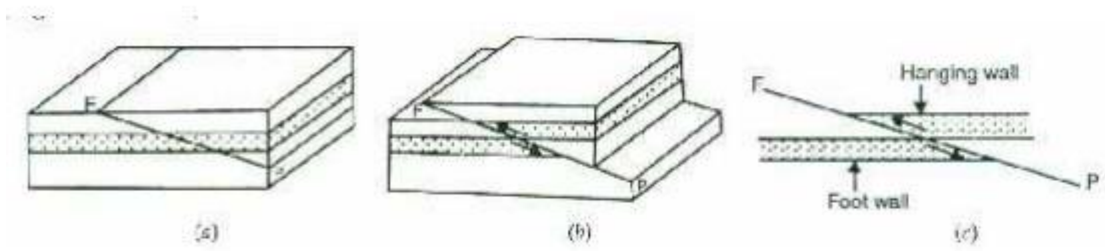
In this definition it is clearly implied that nothing can be said with certainty whether it was the hanging wall which moved down or the foot wall which moved up or both the walls moved down, the hanging wall moving more than the foot wall and hence the appearance.

when the fault satisfies the definition of hanging wall standing at a lower position with respect to the footwall it may be classed as a normal fault.



Reverse Faults

It is such a type of fault in which the hanging wall appears to have moved up with respect to the footwall. In reverse faults, the fault plane is generallyinclined between horizontal and 45 degrees although reverse faults with steeply inclined fault surface have been also encountered.



By virtue of their inclination and direction of movement, reverse faulting involves shortening of the crust of the Earth (compare with normal faults).

Thrust Faults

These are, broadly speaking, such varieties of reverse faults in which the hanging wall has moved up relative to the footwall and the faults diat angles below 45 degrees.

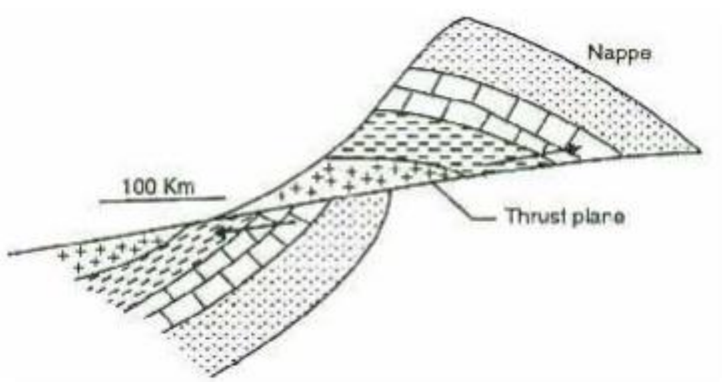
The thrust faults or simply thrusts are of very common occurrence in folded mountains and seem to have originated as a further step in the process of adjustment of rocks to the imposed stresses.

Thrusts are sometimes further distinguished into two sub-types: the over thrusts and the under thrusts.

Nappes

This term is used for extensive blocks of rocks that have been translated to great distances, often ranging to several hundred kilometers, along a thrust plane.

The large-scale movement maybe attributed to a major over thrusting or a recumbent folding followed by thrust faulting.



When a series of thrust faults occur in close proximity, thrust blocks are piled up one above another and all fault surfaces dip in the same direction, the resulting interesting structure is known as an imbricate Structure.

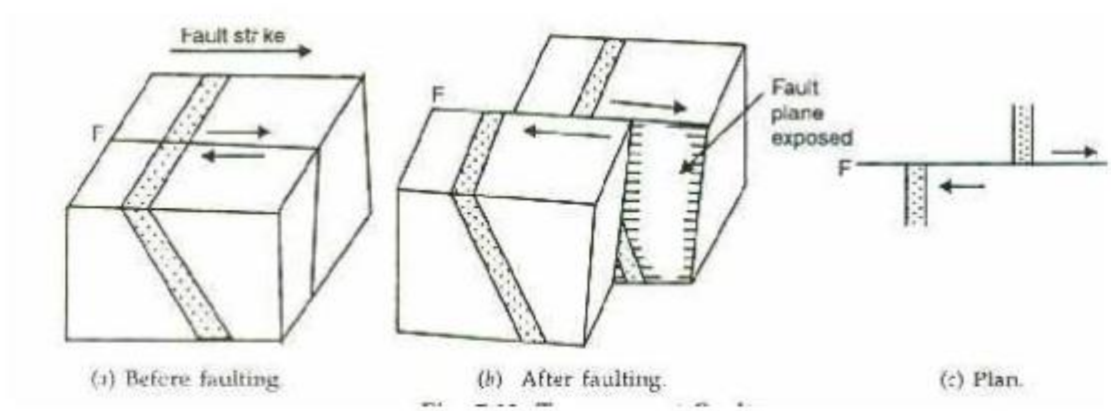
Strike-Slip Faults

These may be defined as faults in which faulted blocks have been moved against each other in an essentially horizontal direction.

The fault plane is almost vertical and the net slip may be measured in great distances.

There are some other terms used for strike slip faults such as lateral faultstransverse faults, wrench faults and transform faults.

Of these, the transform faults are very common and denote strike slip faults specially developed in oceanic ridges.



JOINTS AND JOINTING

Terminology

Joints are defined as divisional planes or fractures along which there has been no relative displacement.

These fractures divide the rocks into parts or blocks and unlike the faults, the parts have not suffered any movement along the fracture plane.

There may be or may not be an opening up of blocks perpendicular to the joint planes.

Nature. Joints may be **open or closed** in nature.

Open joints are those in which the blocks have been separated or opened up for small distances in a direction at right angles to the fracture surface.

1 These may be gradually enlarged by weathering processes and develop into fissure in the rocks.

2 In **closed joints**, there is no such separation.

3 Even then, these joints may be capable of allowing fluids (gases and water) to pass through the rock

Similarly, the joints may be smooth or rough on the surface and the surface may be straight or curved in outline the joints may be small in their extension

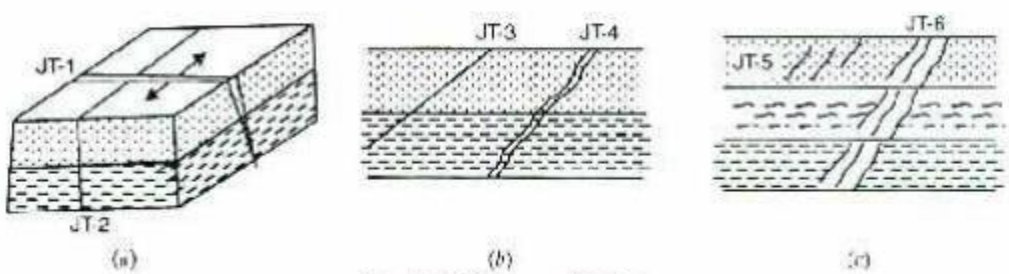


Fig. 7.26 Nature of Joints
JT-1, Open joint JT-2, Closed joint,
JT-3, Smooth joint JT-4, Rough joint,
JT-5, Small joint JT-6, Master joints

Attitude

1 Joints are fracture planes or surfaces and their occurrence often takes place in such a way that their position in space or attitude (dip and strike) may be described conveniently either independently or with respect to the attitudof the rocks in which they occur.

CLASSIFICATION

Joints have been classified on the basis of spatial relationships, geometry and genesis.

A. Spatial Relationship

All joints are divided into two main groups on the basis of presence or otherwise of some regularity in their occurrence:

1. Systematic joints (regular joints).

1 These show a distinct regularity in their occurrence which can be measured and mapped easily.

2 Such joints occur in parallel or sub-parallel joint sets that are repeated in the rocks at regular intervals.

3 The columnar joints and the mural joints described below are examples of regular or systematic jointing.

2. Nonsystematic (or irregular) joints.

1 As the name implies, these joints do not possess any regularity in their occurrence and distribution.

They appear at random in the rocks and may have incompletely defined surfaces. In many cases these are related to the systematic joints in that these occur between them.

2 At other times, the non- systematic joints may show no relationship with the systematic joints and their curved and rough surfaces may even cut across the former.

B. Geometry

In stratified rocks, joints are generally classified on the basis of relationship of their attitude with that of the rocks in which they occur.

Three types recognized on this basis are :
Strike joints in which the joint sets strike parallel to the strike of the rocks.

Dip joints in which the joint sets strike parallel to the dip direction of the rocks; **Oblique joints** are those joints where the strike of the joints is at any angle between the dip and the strike of the layers. These are also called diagonal joints when they occur midway between the dip and strike of the layers.

C. Genesis (Origin)
In such cases, joints are classified into one of the following genetic types:

Tension joints are those, which have developed due to the tensile forces acting on the rocks. The most common location of such joints in folded sequence is on the outer margins of crests and troughs. They are also produced in igneous rocks during their cooling. Joints produced in many rocks during the weathering of overlying strata and subsequent release of stresses by expansion are also thought to be due to the tensile forces (Fig. 7.31).

Shear joints. These are commonly observed in the vicinity of fault planes and shear zones where the relationship with shearing forces is clearly established (Fig. 7.32). In folded rocks, these are located in axial regions.

Compression joints. Rocks may be compressed to crushing and numerous joints may result due to the compressive forces in this case. In the core regions of folds where compressive forces are dominant, joints may be related to the compressive forces.

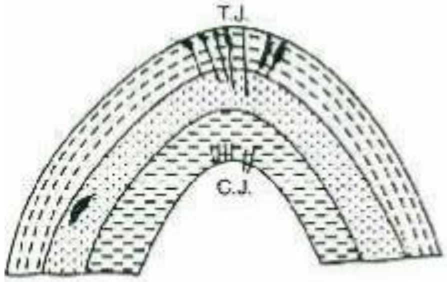


Fig. 7.31 Tension Joints (T.J).

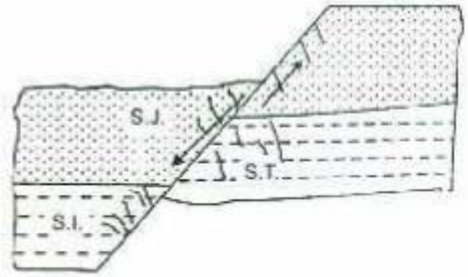


Fig. 7.32 Shear joints (SJ) and Compression Joints (C.J).

UNIT-4 GROUND WATER

GROUND WATER

Groundwater hydrology may be defined as the science of the occurrence, distribution and movement of water below the surface of the earth. Ground water is the underground water that occurs in the saturated one of variable thickness and depth below the earth's surface. Groundwater is an important source of water supply throughout the world. Its use in irrigation, industries, urban and rural home continues to increase.

Origin of ground water:

Almost all groundwater can be thought of as a part of hydrologic cycle, including surface and atmospheric waters. Connate water is water entrapped in the interstices of sedimentary rock at the time it was deposited. It may have been derived from the ocean or fresh water sources and typically is highly minimized.New water of magmatic, almost all ground water can be thought

of as a part of the hydrologic cycle, including surface volcanic or cosmic origin added to the terrestrial water supply is juvenile water.

Ground water constitutes one portion of the earth water circulatory system known as the hydrologic cycle. Water bearing formations, of the earth crust act as conduits for transmission and as reservoirs for storage of water. Water enters these formations from the ground surface or form bodies of surface water

After which it travels slowly for varying distances until it returns to the surface by action of natural flow, plants or man. Ground water emerging into surface stream channels aids in sustaining stream flow when surface runoff is low or non-existent. Similarly water pumped from wells represents the sole water source in many regions during much of every year.

All ground water originates as surface water. Principal sources of natural recharge include precipitation, stream flow, lakes and reservoirs. Other contributions known as artificial recharge occur from excess irrigation, seepage from canals and water purposely applied to augment groundwater supplies. Discharge of ground water occurs when emerges from underground. Most natural discharge occurs as flow into surface water bodies such as streams, lakes and oceans. Flow to the surface appears as spring. Groundwater near the surface may return directly to the atmosphere by evaporation from the soil and by transpiration from vegetation.

Occurrence of ground water:

Ground water occurs in permeable geologic formations known as aquifers. ie, formations having structures that permit appreciable water to move through them under ordinary field conditions. Ground water reservoir and water bearing formation are commonly used synonyms.

An aquitard is a formation, which only seepage is possible and thus the yield is insignificant compared to an aquifer. It is partly permeable. An acquiclude is an impermeable formation which may contain water but incapable of transmitting significant water quantities. An aquifuge is an impermeable formation neither containing not transmitting water.

Porosity:

The portion of a rock or soil not occupied by solid mineral matter may be occupied by groundwater. These spaces are known as voids, interstices, pores or pore space. Because interstices can act as groundwater conduits they are of fundamental importance to the study of groundwater. Typically they are characterized by their size, shape, irregularity and distribution. Original interstices were created by geologic process governing the origin of he geologic formation and are found in sedimentary and igneous rocks. Secondary interstices developed after the rock was formed. Capilary interstices are sufficiently small so that surface tension fo4ces will hold water within them. Depending upon the connection of interstices with others, they may be classed as communicating or isolated. The amount of pore space per unit volume of the aquifer material is called porosity. It is expressed as the percentage of void space to the total volume of the mass**Permeability:**

As stated above the ground water is stored in the pores of rock and will hence be available in the ground rocks, only if they are sufficiently porous. The porosity of the rock, thus defining the maximum amount of water that can be stored in the rock. In fact the water can enter into a rock only if the rock permits the flow of water through it, it depends on whether the rock is permeable or not.

The size of the pores is thus quite an important factor and it should be sufficiently large to make the rock permeable.

Vertical distribution of groundwater:

The subsurface occurrence of groundwater may be divided into:

i) Zones of saturation
ii) ii) Zones of aeration

In the Zones of Saturation water exists within the interstices and is known as the groundwater. This is the most important zone for a groundwater hydraulic engineer, because he has to tap out this water. Water in this zone is under hydrostatic pressure. The space above the water and below the surface is known as the zone of aeration. Water exists in this zone by molecular attraction.

This zone is also divided into three classes depending upon the number of interstices present. The capillary fringe is the belt overlying the zone of saturation and it does contain some interstitial water and is thus a continuation to the zone of saturation while the depth from the surface, which is penetrated by the rocks of vegetation, is known as the soil zone.

Explain The Causes, Classification Of Earthquake

The physical forces the surfaces are rearranging rock materials by shifting magmas about altering the structures of solid rocks. The adjustment beneath the surface however involve various crystal movements, some of which because of suddenness and intensity produce tremors in the rocks and they are known as earthquake. The science dealing with the study of earthquakes in all their aspects is called seismology.

Focus and epicenter:

The exact spot underneath the earth surface at which an earthquake originates is known as its focus. These waves first reach the point at the surface, which is immediately above the focus or origin of the earthquake. This point is called epicenter. The point which is diametrically opposite to the epicenter is called anticenter.

Intensity and magnitude:

Intensity of an earthquake may be defined as the ratio of an earthquake based on actual effects produced by the quakes on the earth.

Magnitude of a tectonic earthquake may be defined as the rating of an earthquake based on the total amount of energy released when the over strained rocks suddenly rebound, causing the earthquake.

Causes of earthquake:

The earthquake may be caused due to various reasons, depending upon it intensity. Following causes of earthquake are important:

1. Earthquakes due to superficial movements:

The feeble earthquakes are caused due to superficial movements.i.e, dynamic agencies, and operation upon surface of the earth.

The dashing waves cause vibrations along the seashore.

Water descending along high water falls, impinges the valley floor and causes vibrations along the neighbouring areas.

At high altitudes the snow falling down is an avalance.also causes vibrations along the neighbouring areas.

2. Earthquake due to volcanic eruptions:

Most of the volcanoes erupt quietly and as consequence, initiate no vibration on the adjoining area. But a few of them when erupt, cause feeble tremors in the surface of the earth. But there may be still a volcanic eruption may cause a severe vibration on the adjoining area and have really disastrous effects.

3. Earthquake due to folding or faulting:

The earthquakes are also caused due to folding of the layers of the earth's crust. if the earthquakes are caused due to folding or faulting then such earthquakes are more disastrous and are known as tectonic earthquakes and directly or indirectly change the structural features of the earth crust.

Classification of earthquakes:

Earthquakes are classified on a no. Of basis. Of these the depth of focus, the cause of origin and intensity are important.

a) Depth of focus:

Three classes of earthquakes are recognized on this basis, shallow, intermediate and deep seated. In the shallow earthquakes the depth of focus lies anywhere up to 50 km below the surface. The intermediate earthquakes originate between 50 and 300 km depth below the surface.

b) Cause of origin:

i) Tectonic earthquakes are originated due to relative movements of crystal block on faulting, commonly, earthquakes are of this type.

ii) Non tectonic earthquakes: that owes their origin to causes distinctly different from faulting, such as earthquakes arising due to volcanic eruptions or landslides.

C) Intensity as basis:

Initially a scale of earthquakes intensity with ten divisions was given by Rossi and ferel. Which was based on the sensation of the people and the damage caused. However it was modified by Mercalli and later by wood and Neumann.

Engineering considerations:

The time and intensity of the earthquake can never be predicted. The only remedy that can be done at the best, it is provide additional factors in the design of structure to minimize the losses due to shocks of an earthquake. This can be done in the following way:

To collect sufficient data, regarding the previous seismic activity in the area.

To assess the losses, which are likely to take place in furniture due to earthquake shocks To provide factors of safety, to stop or minimize the loss due to sever earth shocks.

Following are the few precautions which make the building sufficiently earthquake proof.

The foundation of a building should rest on a firm rock bed. Grillage foundations should preferably be provided.

Excavation of the foundation should be done up to the same level, throughout the building.

The concrete should be laid in rich mortar and continuously

Masonry should be done with cement mortar of not les than 1:4 max. Flat R.CC slab should be provided.

All the parts of building should be tied firmly with each other. Building should be uniform height.

Cantilivers, projections, parapets, domes etc, should be provided. Best materials should be used.

UNIT-5 GEOPHYSICS

GEOPHYSICAL INVESTIGATIONS

A. Electrical Methods

Principle.

1 All electrical method are based on the fundamental fact that different materials of earth' s crust possess widely different electrical properties.

2 Resistivity, electrochemical activity and dielectrical constant are some of these properties that are generally studied through these methods

3 potential-drop methods: the natural potential may be due to electrochemical reactions between the solutions and the surrounding - subsurface rocks.

These reactions are not always of the same order throughout the dimensions of the rock masses thereby creating a potential difference and conditions for flow of current from one end to the other end.

4 Elongated ore bodies of magnetite and pyrite etc. are easily delineated by this method.

5 Natural electrical potential is measured with the help of nonpolarising electrodes along definite directions and results are plotted in terms of potential gradient along horizontal distances which are then interpreted.

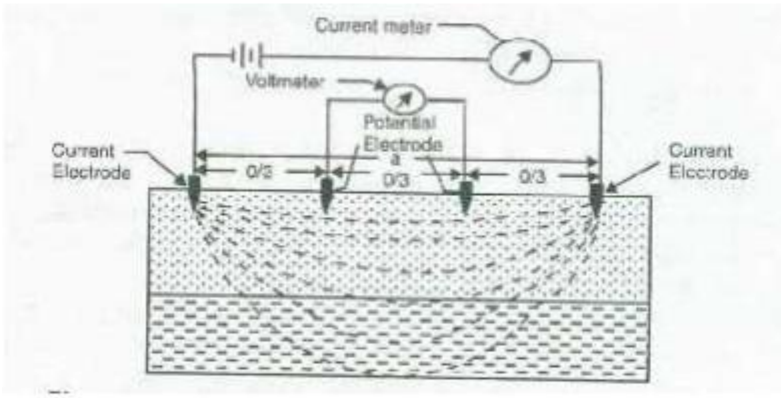
Potential Drop Methods.

1 These include a variety of methods in which electrical current is artificially introduced from an external source at certain points and then its flow through subsurface materials recorded at different distances.

2 In the Equipotential Method two primary electrodes are inserted into the ground, 6-7 meters apart from each other, across which current is introduced.

3 The position of these primary electrodes remains fixed in the subsequent investigations.

Potential between these primary electrodes is determined with the help of two search electrodes and points of equal potential found out along the entire region under investigations, which are jointed to get equipotential lines.



4 Under normal conditions, that is, when the material below is of uniform nature, electrically c the ec lines would be regular in character.

5 But in cases when the material w is not of uniform character (that is, it contains patches of high or low conductivity), equipotential lines would show clear distortions or irregularities which would include probable location of rock masses of different characteritics.

6 The Resistivity Method is similar to equipotential method but in this case it is the resistivity of the material of the subsurface which is determined and from which important interpretations are made

Here also, a known current is introduced through two electrodes- current electrodes, which are inserted at some distances apart from each other.,

Investigation.

1 The depth of penetration of electrical current in these investigations is broadly equal to although there are many conditions attached to this generalization.

2 The resistivity method envisages interpretation of the qualitative as well as quantitative characters of the subsurface materials which are governed by two basic principles

(i) If material below is of uniform nature, the resistivity values would be of regular character.

(ii) If the material is non-uniform, that is, it consists of layers or masses of different character, then these would be indicated by irregularities or anomalies in the resistivity values.

(iii) The depths at which these anomalies occur can be calculated and also the nature of the subsurface material broadly understood.

Applications:
(a) In Prospecting: The electrical methods have been successfully employed in delineation of ore bodies occurring at shallower depths. For such surveys at great depths, these are not of much help.

In table 1, some typical value-ranges of resistivity are given. As may be seen, rocks exhibit a great variation ranging from as high resistivity as > io ohms-meters in igneous rocks to as low as less than I ohm-rn for clayey mans.
In Civil Engineering: Resistivity methods have been widely used in engineering investigation for determination of
Depth to the bed rock -as for instance, in important projects like dams, buildings and bridge foundations, where it would be desirable that the structure should rest on sound hard rocks rather than on overburden or soil

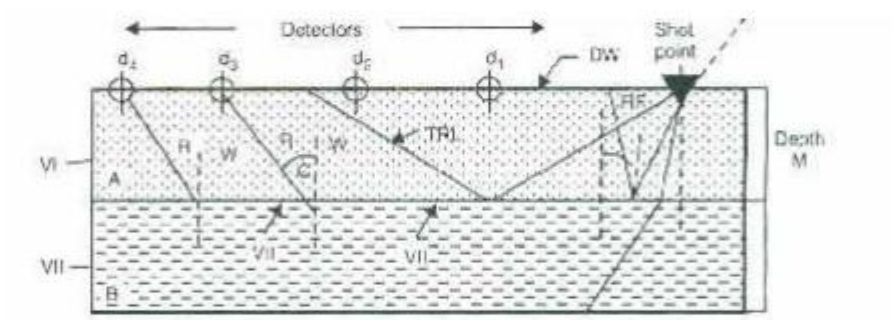
Location of geological structures -like folds, buried valleys, crushed and fractured zones due to shearing and faulting.
Location of Aquifers -and other water bearing zones which could be easily interpreted on the basis of known resistivity values of moisture rich rocks and dry rocks.

SEISMIC METHODS

Principle.

Shocks or explosions within the earth' s crust are always accompanied by generation of elastic waves, which travel in all directions from the point or place of shock, the focus.
Velocity of these shock waves is related to the nature of the medium through which they travel. In nature these waves are produced during earthquakes. The seismic waves reveal a great deal of information about the internal constitution of the earth.

Although different types of waves are generated when a shock occurs, these are the P waves (longitudinal waves), which are the fastest and strongest. Their velocity, Vp, is related broadly to the medium (rocks) through the following equation:



where E is Modulus of elasticity, e is density and v is the Poisson' s Ratio of the medium.

The controlling factor is, obviously, the modulus of elasticity which itself is dependent upon nature of rock, its chemical and mineralogical composition, degree of freedom from structural discontinuities and degree of saturation with water and other fluids.

From experimental investigations, characteristic velocity values for P waves have been broadly established for different rock types.

As such, if the velocity of seismic waves travelling through a section of the ground is known, nature of the ground can be fairly assessed.

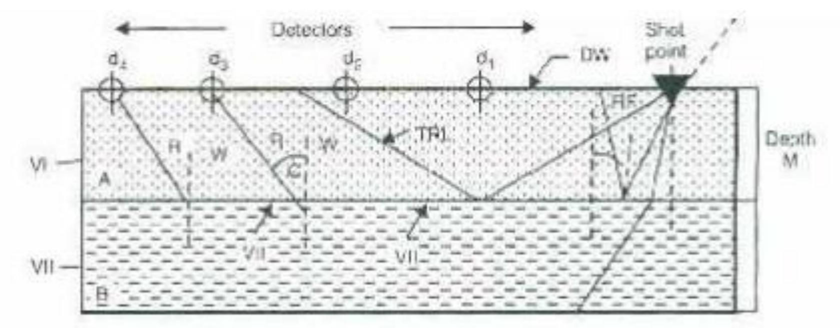
This is the underlying principle of all the seismic methods.

Method.

1 The fundamental procedure in all seismic investigations for subsurface explorations is the same: a shock is created at a chosen point or location either by exploding a charge, of dynamite;

the waves so produced are recorded at different distances from the shot point with the help of geophones or special detectors.

2 The instant of shot, that is the shot time and the first arrival are recorded very carefully from which time -d istance plots are prepared in a selected manner.



1 A proper interpretation of these time-distance plots may reveal presence of unusually high or low velocity media at certain depths.

Reflection methods have been found especially useful for subsurface studies under! bodies of water (e.g. lakes, rivers, and estuaries) because in such surveys signals from surface and shear waves are obliterated by water and arrival times of only longitudinal waves are recorded clearly and easily.

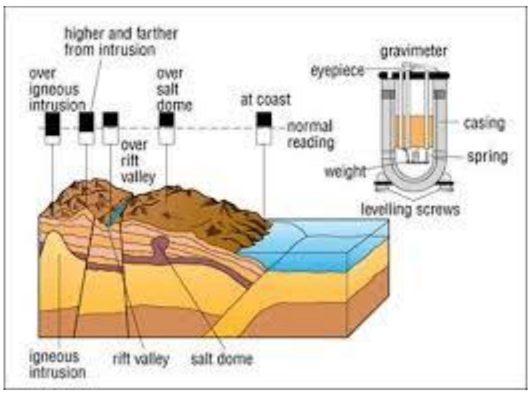
2 It may be pointed out that for correct inferences, it is imperative that reflection and refraction records are properly distinguished from each other as well as from records of other associated events.

These demand considerable skill and expertise.

GRAVITATIONAL METHODS

Principle

Gravity or the force by which the earth attracts other objects towards itself is a well-known principle in Physics. It can be theoretically calculated for any part of the earth I from the relationship:



where g is the normal gravity value at sea level and 0 is the latitude of the place under consideration.

1 In these calculations it is assumed that the earth is ideally homogenous in nature. Actually, however, the earth is far from homogenous.

2 Thus, we have another means to locate the materials which are ' less' or ' more' dense than the ideal material of the earth.

3 Procedure is simple: for any given area, we would know its latitude and thus calculate the value of normal gravity (the theoretical value).

4 Then observations are made with sensitive instruments to determine the actual value of gravity at that place.

5 This is called observed value. Under ideal conditions the two values should be identical but when there is considerable difference, a

gravity anomaly is believed to exist and that would be a pointer towards existence of some unusual rock mass below the place of gravity anomaly.

6 The unit for gravity is gal, which is acceleration of 1 cm/sec/ sec and that of gravity anomaly a milligal (which is a thousandth part of a gal).

Methods.

7 A number of methods and instruments are available to determine the value of gravity.

8 The earlier used pendulum method and the torsion balance method are almost obsolete now.

9 The gravimetric method is most commonly used at present. In this method, the value of gravity is measured directly by instruments known as gravimeters.

10 Two important versions of these instruments are: the stable gravimeter and

the unstable gravimeter.

In the stable gravimeter,

- v the spring in the gravimeter remains unchanged in its position if the gravity pull is same.

- v when there is a change in the value of gravity at a place, there is a change in the length of the spring: it increases or decreases compared to original length.

With the help of an external element, the spring can be made to acquire the original position and thereby indicate the amount of change.

In the unstable type

v the spring once disturbed due to change in gravity at the place of measurement is not brought back to the balanced state there and then.

v instead its deflections are recorded directly on a suitable magnified scale, which give a measure of gravity anomaly.

vi Isogams or lines passing through points of same gravity anomaly are drawn as a result of gravimetric observations which could be then interpreted to reveal important conclusions.

MAGNETIC METHODS

Principle.

These include some of the oldest geophysical methods of exploration and take into account the fact the earth is a gigantic magnet with definite magnetic field, the intensity of which can be calculated for any part of the earth.

But, as the earth is not ideally homogenous, the theoretical values of magnetic intensity may be quite different (higher or lower) than the values observed at given locations.

The difference between these two values is a magnetic anomaly (compare gravity anomaly) and forms the basis for interpreting bodies of magnetic ores and also such structures that can cause magnetic 'highs' or 'lows'.

Method.

1 The magnetic intensity of rocks of earth at a given location is measured directly by very sensitive instruments called magnetometers.

2 specially designed magnetometers are used for measuring horizontal intensity or vertical intensity.

3 These observations are repeated in different directions over the selected area, and from the values so obtained, the magnetic anomalies are calculated.

4 Lines are then drawn through the points of similar anomalies.

5 This gives the isoanomalies map.

6 From such maps the location and extension of materials of highly magnetic or less magnetic bodies can be determined.

7 Another instrument for measuring the magnetic intensity over wider areas in the shortest possible time is Airborne Magnetometer.

8 It consists of a highly sensitive detector element that is made to hang down from a plane or helicopter.

9 This helps in recording total magnetic intensity along the line of flight

10 The lines of flight, the height of flight and speed of the plane are controlling parameters which require very careful planning and execution of the aerial magnetic surveys.

Interpretation

In the simplest cases, an unusually high magnetic intensity as shown by the isoanomaly map can be taken as indicative of a magnetic ore body in that area.

In actual practice, however, a number of factors have to be considered and corrections applied for arriving at reliable results. Of these, corrections due to magnetic storms are quite important.

Applications. The magnetic methods have been successfully used in prospecting for magnetic ore bodies and for oil exploration.

ACOUSTIC METHODS

1 This method has been specially useful in locating weathered zones, caves and major and minor cavities in rocks of susceptible compositions in the foundations.

2 In this method these are the sound waves which are transmitted in a controlled manner from the boreholes through the bodies of rocks and

their transmission velocities recorded.

3 The acoustic wave velocity sketches are prepared for the site from which the size and position of caves can be interpreted.

4 The acoustic surveys are reliable when the site is made up of broadly homogenous rocks and the wave transmission velocities are recorded very carefully.

UNIT-VI : Geology Of Dams, Reservoirs And Tunnels

GEOLOGICAL CHARACTERS FOR INVESTIGATION

Geology of the Area

Preliminary geological surveys of the entire catchments area followed by detailed geological mapping of the reservoir area have to be conducted. These should reveal

main topographic features, natural drainage patterns,

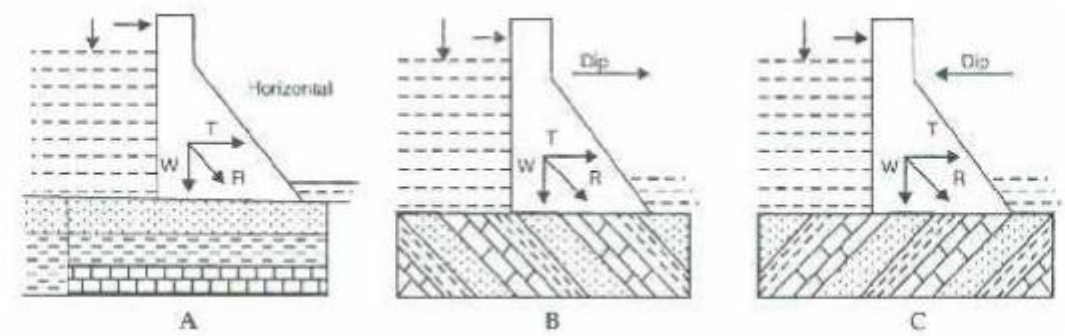
general characters and structures of rock formations such as their stratification, folding and faulting and igneous intrusions, and

the trend and rate of weathering and erosion in the area.

Geology of the site Lithology.

1 The single most important feature that must be known thoroughly at the site and all around and below the valley up to a reasonable depth is the Lithology, i.e. types of the rocks that make the area.

2 Surface and subsurface studies using the conventional and latest techniques of geological and geophysical investigations are carried out.



3 Such studies would reveal the type, the composition and textures of the rocks exposed along the valley floor, in the walls and up to the required depth at the base.

4 Rocks are inherently anisotropic materials, showing variation in properties in different directions.

5 Complex litho logy definitely poses challenging design problems.

Structures

1 This involves detailed mapping of planes of weakness like bedding planes, schistosity, foliation, cleavage, joints, shear zones, faults and fault zones, folding and the associated features.
2 While mapping these features, special attention is given to recording their attitude, spacing and nature.
3 Shear zones have to be searched, mapped and treated with great caution.

4 In some cases, these may be developed to such an extent that the rock may necessitate extensive and intensive rock treatment (e.g. excavation, backfilling and grouting etc.).

Following is a brief account of the influence of more important structural features of rocks on dam foundations

Dip and Strike

1 The strength of sound, un fractured stratified rock is always greater when the stresses are acting normal to the bedding planes than if applied in other directions.

2 This being so, horizontal beds should offer best support for the weight of the dam.

3 But as is shown in a latter section, the resultant force is always inclined downstream.

4 the most UNFAVOURABLE strike direction is the one in which the beds strike parallel to the axis of the dam and the dip is downstream

5 It must be avoided as far as possible.

6 Therefore, other conditions being same, beds with upstream dips are quite favorable sites for dam foundations.

Faults

These structures can be source of danger to the dam in a number of ways. Thus,

v The faulted rocks are generally shattered along the rupture surfaces;

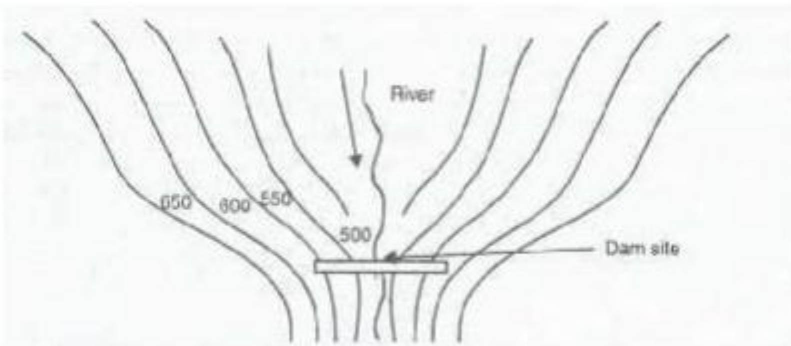
v Different types of rocks may be present on either side of a fault plane. Hence, sites with fault planes require great caution in calculating the design strength in

various sections of the dam.

v Dams founded on beds traversed by fault zones and on major fault planes are more liable to shocks during an earthquake compared to dams on non-faulted rocks.

GEOLOGICAL CONDITIONS NECESSRY FOR CONSTRUCTION OF DAMS

DEFINITION



A DAM may be defined as a solid barrier constructed at a suitable location across a river valley with a view of impounding water flowing through that river. (1) generation of hydropower energy;

SELECTION OF SITES

Topographically

It would be a narrow gorge or a small valley with enough catchments area available behind so that when a dam is placed there it would easily store a calculated volume of water in the reservoir created upstream.

This should be possible without involving significant uprooting of population, loss of cultivable land due to submergence or loss of existing construction.

Technically

1 The site should be as sound as possible: strong, impermeable and stable.

2 Strong rocks at the site make the job of the designer much easy: he can evolve best deigns.

3 Impermeable sites ensure better storage inventories.

4 Stability with reference to seismic shocks and slope failures around the dam, especially upstream, are a great relief to the public in general and the engineer in particular.

5 The slips, slides, and slope failures around and under the dam and susceptibility to shocks during an earthquake could prove highly hazardous.

Constructionally

1 The site should not be far off from deposits of materials which would be required for its construction.

All types of major dams require millions of cubic meters of natural materials - earth, sand, gravel and rock -for their construction.

Economically

1 The benefits arising out of a dam placed at a particular site should be realistic and justified in terms of land irrigated or power generated or floods averted or water stored.

2 Dams are invariably costly structures and cannot be placed anywhere and everywhere without proper analysis of cost-benefit aspects.

Environmentally

1 The site where a dam is proposed to be placed and a reservoir created, should not involve ecological disorder, especially in the life cycles of animals and vegetation and man.

2 The fish culture in the stream is the first sector to suffer a major shock due to construction of a dam. Its destruction may cause indirect effects on the population.

3 These effects require as thorough analysis as for other objects. The dam and the associated reservoir should become an acceptable element of the ecological set up

GEOLOGICAL CONSIDERATIONS IN TUNNELLING

Rocks may be broadly divided into two categories in relation to tunnelling: 1.consolidated and 2. unconsolidated or soft ground. Only a brief accounts is given below.

(A) Consolidated Rocks

Tunnel design, method of its excavation and stability are greatly influenced by following geological conditions: lithology, geological structures and ground water conditions.

Lithology

It has already been mentioned that information regarding mineralogical composition, textures and structures of the rocks through which the proposed tunnel is to pass is of great importance in deciding

the method of tunneling

the strength and extent of lining and, thus the cost of the project.

Hard and Crystalline Rocks

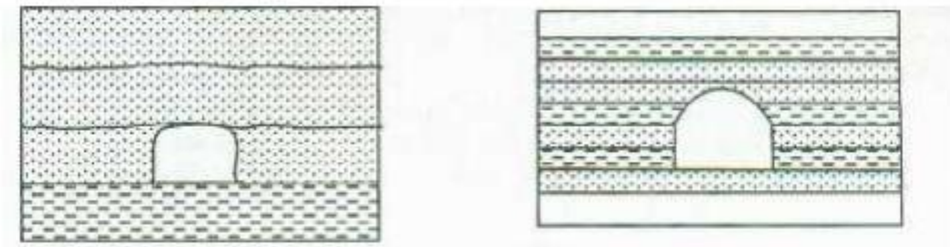
1 These are excavated by using conventional rock blasting methods and also by tunnel boring method

2 In the blasting method, full face or a convenient section of the face is selected for blasting up to a pre-selected depth

3 These are loaded with predetermined quantities of carefully selected explosives of known strength.

4 The loaded or charged holes are ignited or triggered and the pre-estimated rocks get loosened as a result of the blast.

5 The blasting round is followed by a mucking period during which the broken rock is hauled out of the excavation so created.



A. Safe situation B. Unsafe at top

6 The excavations in hard and crystalline rocks are very often self

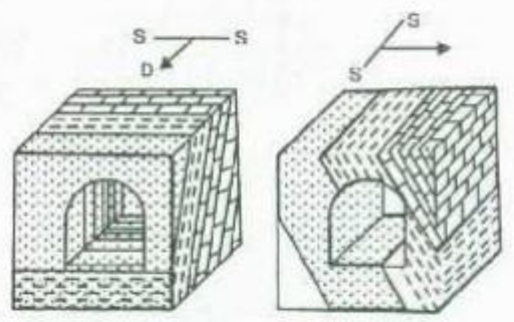
supporting so that these could be left unlined and next round of blasting in the new face created is undertaken, ensuring better advance rate.

7 Rocks falling in this group include granites, diorites, syenites, gabbros, basalts and all the related igneous rocks, sandstones, limestones, dolomites, quartzites, arkose, greywackes and the like from sedimentary group and marbles, gneisses, quartzites, phyllites and slates from the metamorphic groups.

8 When any one of these rocks is stressed, such as during folding or fractured as during faulting, tunnelling in these rocks proves greatly hazardous.

9 Rock bursts which occur due to falling of big rock blocks from roofs or sides due to release of stresses or falling of rock block along fractures already existing in these rocks often cause many accidents.

10 **Soft Rocks** This group includes shales, friable and poorly compacted sandstones, chalk and porous varieties of limestones and dolomities, slates



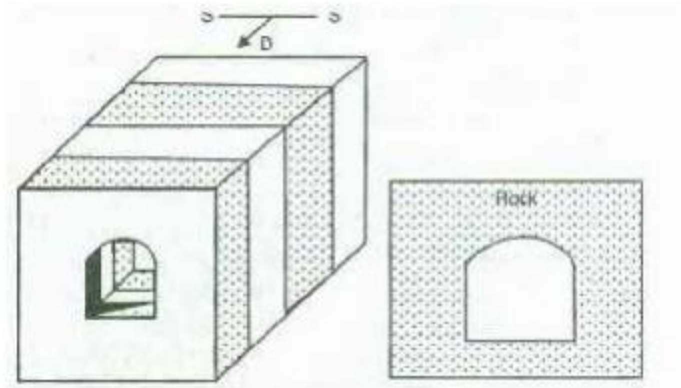
A. Dip of layers B-Strike of layers

and phyllites with high degree of cleavage and also decomposed varieties of igneous rocks.

11 Their excavation cost, volume for volume, might be lower than those in hard rocks.

12 Hence, temporary and permanent lining becomes necessary that would involve extra cost and additional time.

Rocks like clays, shales, argillaceous and ferruginous sandstones, gypsum bands and cavernous limestones have to be viewed specially with great caution during tunnelling



Geological Structures Dip and Strike

These two quantitative properties of rocks determine the attitude (disposition in space) of the rocks and hence influence the design of excavation (tunnel) to a great extent.Three general cases may be considered.

Horizontal Strata

When encountered for small tunnels or for short lengths of long tunnels, horizontally layered rocks might be considered quite favourable.

In massive rocks, that is, when individual layers are very thick, and the tunnel diameter not very large, the situation is especially favourable because the layers would then over bridge flat excavations by acting as natural beams

But when The layers are thin or fractured, they cannot be depended upon as beams; in such cases, either the roof has to be modified to an arch type or has to be protected by giving a lining.

Sides of tunnels, however, could be left unsupported except when the rocks are precariously sheared and jointed.

TUNNELS

Definition

Tunnels may be defined as underground routes or passages driven through the ground without disturbing the overlying soil or rock cover.

Tunnels are driven for a variety of purposes and are classified accordingly.

Chief classes of tunnels are:

Traffic Tunnels hydro-power tunnels and public utility tunnels.

Geological Investigations

These determine to a large extent solutions to following engineering problems connected with tunnelling:

Selection of Tunnel Route (Alignment).

There might be available many alternate alignments that could connect two points through a tunnel.

the final choice would be greatly dependent on the geological constitution along and around different alternatives

Selection of Excavation Method.

Tunnelling is a complicated process in any situation and involves huge costs which would multiply manifolds if proper planning is not exercised before starting the actual excavation.

And the excavation methods are intimately linked with the type of rocks to be excavated.

Choice of the right method will, therefore, be possible only when the nature of the rocks and the ground all along the alignment is fully known.

This is one of the most important aim and object of geological investigations.

Selection of Design for the Tunnel.

The ultimate dimensions and design parameters of a proposed tunnel are controlled, besides other factors, by geological constitution of the area along the alignment. Whether the tunnel is to be circular, D-Shaped, horse-shoe shaped or rectangular or combination of one or more of these outlines, is more often dictated by the geology of the alignment than by any other single factor.

Thus, in self-supporting and strong rocks, either, D-shape or horse-shoe shape may be conveniently adopted but these shapes would be practically unsuitable in soft ground or even in weak rocks with unequal lateral pressure.

Assessment of Cost and Stability.

These aspects of the tunnelling projects are also closely interlinked with the first three considerations.

Since geological investigations will determine the line of actual excavation, the method of excavation and the dimensions of excavation as also the supporting system (lining) of the excavation, all estimates about the cost of the project would depend on the geological details.

Similarly tunnels passing through hard and massive rocks even when left unsupported may be regarded as stable.

Moderately Inclined Strata.

Such layers that are dipping at angles up to 45 o may be said as moderately inclined.

The tunnel axis may be running parallel to the dip direction, at right angles to the dip direction or inclined to both dip and strike directions.

In the first situation, that is, when the tunnel axis is parallel to the dip direction the layers offer a uniformly distributed load on the excavation.

The arch action where the rocks at the roof act as natural arch transferring the load on to sides comes into maximum play.

Even relatively weaker rocks might act as self-supporting in such cases. It is a favourable condition from this aspect.

it also implies that the axis of the tunnel has to pass through a number of rocks of the inclined sequence while going through parallel to dip

- In the second case, that is, when the tunnel is driven parallel to strike of the beds (which amounts to same thing as at right angles to the dip),

- the pressure distributed to the exposed layers is unsymmetrical along the periphery of the tunnel opening; one half would have bedding planes opening into the tunnel and hence offer potential planes and conditions for sliding into the opening.

- The bridge action, though present in part, is weakened due to discontinuities at the bedding planes running along the arch

- Such a situation obviously requires assessment of forces liable to act on both the
sides and along the roof and might necessitate remedial measures.

- In the third case, when the tunnel axis is inclined to both the dip direction and the strike direction, weak points of both the above situations would be encountered.

Steeply Inclined Strata

- In rock formations dipping at angles above 45 o , quite complicated situations would arise when the tunnel axis is parallel to dip or parallel to strike or inclined to both dip and strike directions.

- In almost vertical rocks for example, when the tunnel axis is parallel to dip direction, the formations stand along the sides and on the roof of the tunnel as massive girders.

- An apparently favourable condition, of coarse, provided all the formations are inherently sound and strong

ALL THE BEST