



GOVERNMENT POLYTECHNIC , JAJPUR

LECTURE NOTE ON
“ MINE GEOLOGY – II ”

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Chapter-1:- Stratigraphy:-

* Stratigraphy:- branch of geology concerned with the study of rock layers (strata) & layering (stratification).

→ primarily used in study of sedimentary & layered volcanic rocks.

→ It is the relationship between rock & time.

* Father of stratigraphy → "William Smith"

"Stratigraphy is concerned with the observation, description & interpretation of direct and tangible evidence on rocks to determine the history of earth."

* Principle of Stratigraphy:-

1) Principle of uniformitarianism:- introduced by Charles Lyell

→ This was given by "James Hutton". He examines features like mud cracks, ripples mark, graded bedding etc.

→ He concluded that the processes are currently operating on the earth must be the same processes that operated in the past.

→ So he stated that "Present is the key to past".

* Uniformitarianism:- the same external & internal process that we recognize today have been operating consistently throughout most of earth's history.

2) Principle of original horizontality:-

→ It states that layers of sediment are originally deposited horizontally under the action of gravity, ||^o to earth's surface.

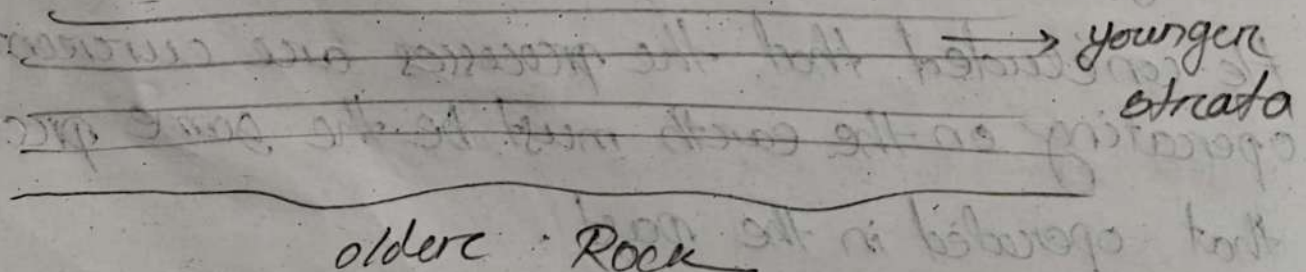
→ It is a relative dating technique (science of determining the relative order of past events)

ie. age of an object in comparison to another

→ Sediments deposited on steep slopes will be washed away, whereas if they are deposited in nearly horizontal layers can be buried and lithified.

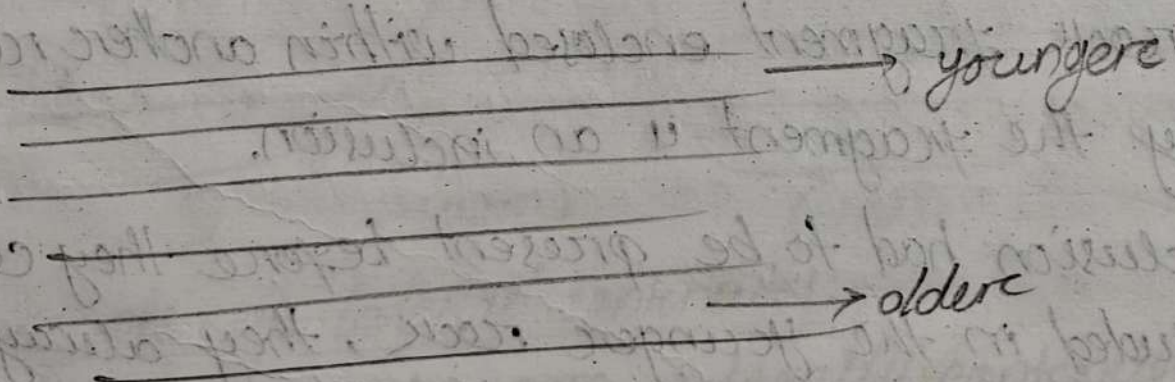
(this principle)

→ It is important for analysis of folded and tilted strata.



3) Principle of Super-position:-

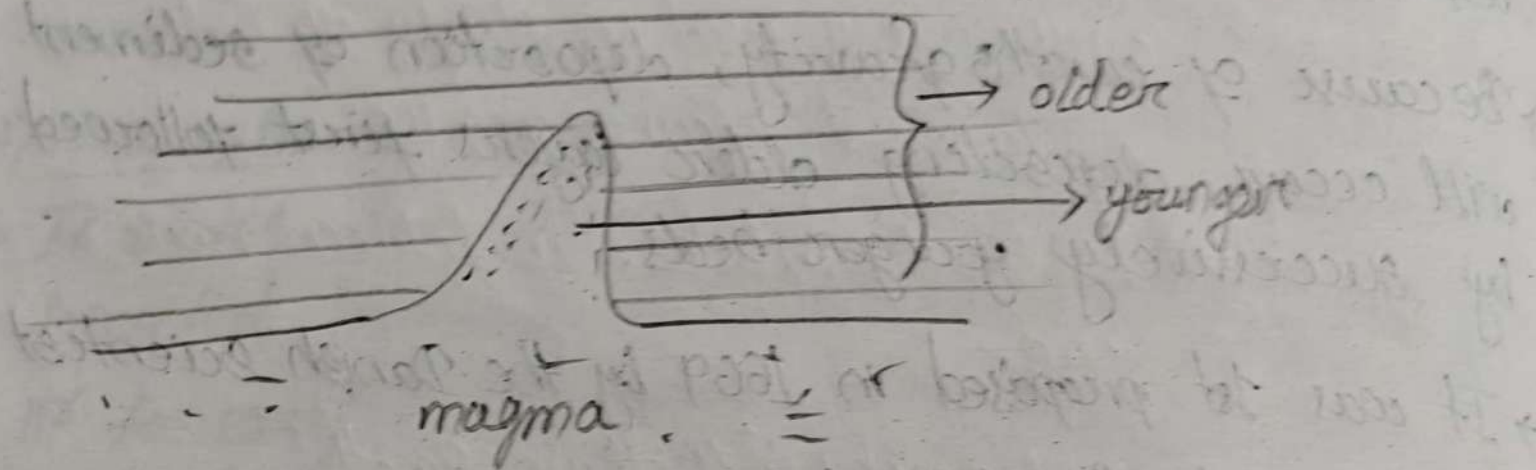
- It states that in a series of undisturbed beds, the youngest layer is on top & oldest on bottom.
- Each overlying bed is younger than the underlying bed under normal condition of stratification.
- Because of earth's gravity, deposition of sediment will occur depositing older layers first followed by successively younger beds.
- It was 1st proposed in 1669 by the Danish scientist "Nicolas Steno".



4) Principle of cross cutting relationship:-

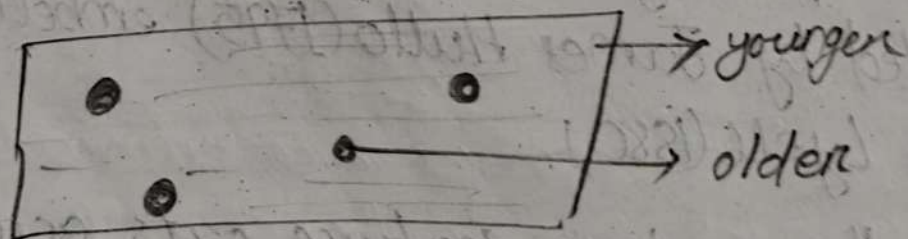
- It was 1st developed by "Nicholas Steno" in 1669. Later formulated by James Hutton (1795) embellished upon by Charles Lyell (1880).
- It states that the geologic feature cuts across another the feature that has been cut is older.

- Younger features are truncate (cut across) older feature.
- It can be used to determine the relative ages of rock strata and other geological structures.



⇒ Principle of inclusion:-

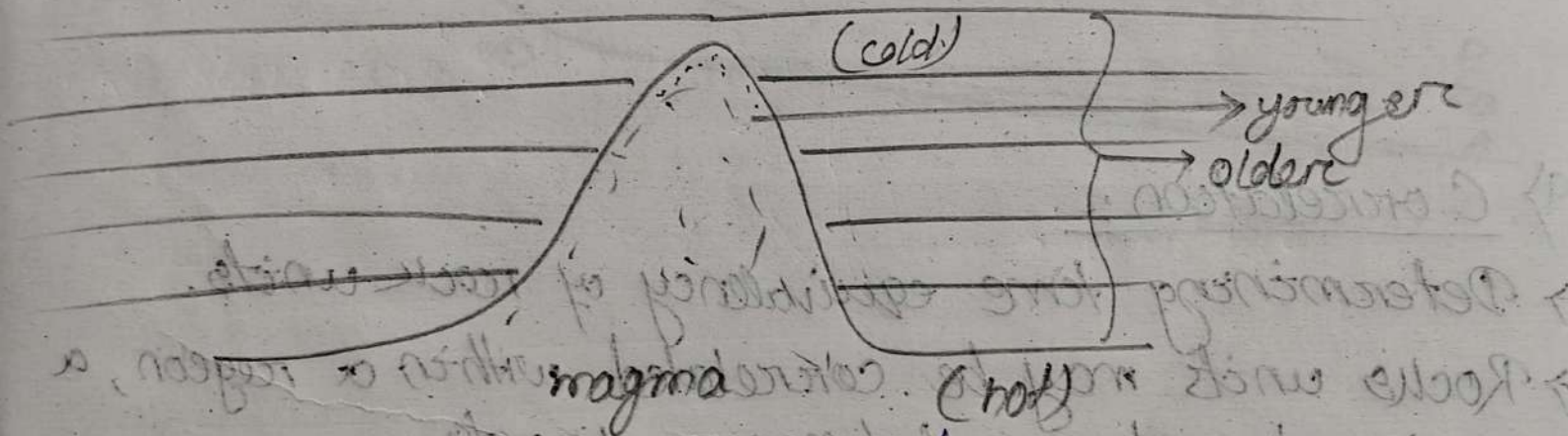
- If a rock fragment enclosed within another rock, we say the fragment is an inclusion.
- The inclusion had to be present before they could be included in the younger rock, they always represent fragments of an older rock.
- If the enclosing rock is an igneous rock, the inclusions are called "xenoliths".



- This principle often useful for distinguishing betⁿ a lava flow and a coal.

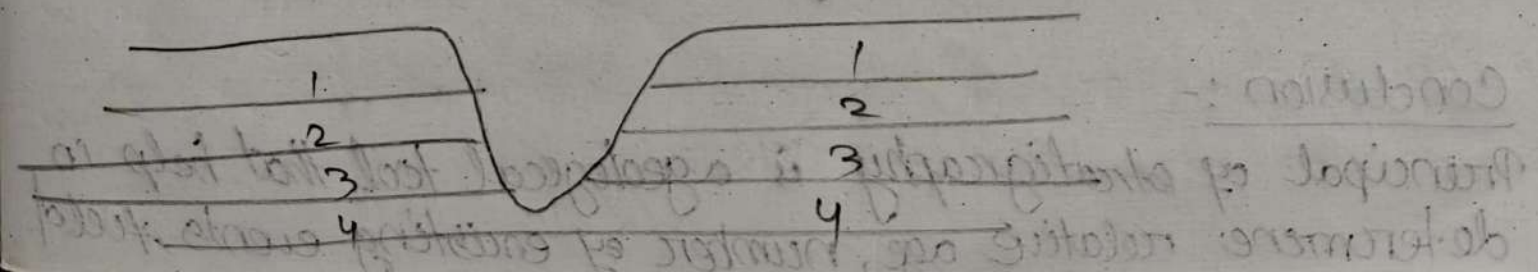
6) Principle of chilled margins:-

- when a hot magma intrudes into cold country rock the magma along the margins of the intrusion will cool more rapidly than the interior.
- Fine grained rock or glassy rock will be along the margin where as coarse grained will occur farther away from the margin.
- chilled margins are younger than surrounding rock.



7) Principle of lateral continuity:-

- Sedimentary rocks are laterally continuous over large area.
- As a result, rocks that are otherwise similar, but are now separated by a valley / other erosional feature, can be assumed to be originally continuous.



8) Principle of faunal Succession:-

- It is based on the observation that sedimentary rock strata contain fossilised flora & fauna.
- This allows for strata to be identified and dated by the fossils found within them..

9) Correlation:-

- Determining time equivalency of rock units.
- Rocks units may be correlated within a region, a continent and even between continents.
- Fossils represent living creatures that have evolved through time, so when we found a fossil of the same type in 2 different areas that are not laterally continuous, we are sure that the rocks are about the same age.

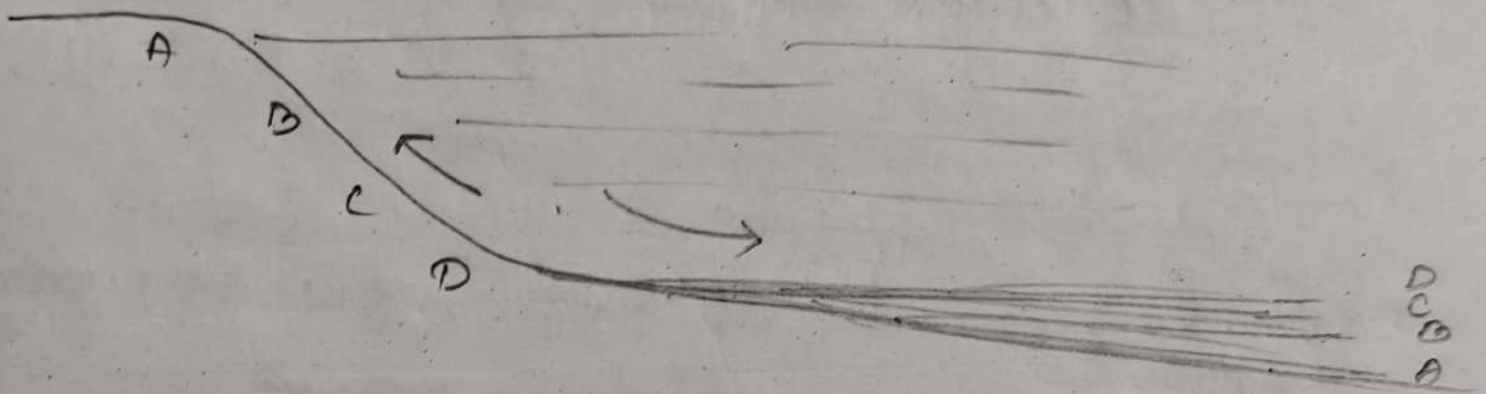
Conclusion:-

Principal of stratigraphy is a geological tool that help in determine relative age, number of existing events, field

relation etc.

10) Walther's law of facies :-

- it shows the vertical succession of deposit
- when the ocean level rises the sediments goes upward towards the beach and
- when the ocean level decreases the sediments goes downward towards the seaside



* Cuddapah Super group :-

- It is named after the cuddapah basin of andhra pradesh.
- The rocks of these supergroup lies over the schists & gneiss of archaean age & is overlain by vundhyans.

The cuddapah basin is more or less crescentic in shape, which is concave towards east and convex towards west.

In the main cuddapah basin the cuddapah rocks occupy an area about 35,000 km².

- The Nallamalai range along the middle of the crescent consist of high hills of folded cuddapah rocks.

✓ Distribution :-

In India, the ~~the~~ cuddapah rock formations occur mainly in 4 areas,

- a) cuddapah basin of A.P
- b) Bijapur district of Maharashtra (Kaladgi group)
- c) Chhattisgarh area
- d) Aravali mountain in Rajasthan (Delhi supergroup)

Lithology:-

- The cuddalah supergroup comprises over 6 km thick succession of essentially quartzites, quartzitic sandstone and slates or shales with subordinate limestone.
- The lower parts of the succession are intermixed with a great thickness of volcanic rocks rich iron deposits occur at various horizons of the succession.
- The rock show, in general a higher degree of metamorphism and deformation along the eastern flank of the crescent as compared to the rocks of the western flank.
- The cuddalah rocks are mostly unfossiliferous.
- * Age of cuddalah supergroup is approximately 1899 ± 20 ma

* Stratigraphic succession:-

- The cuddalah supergroup is divided into 4 groups which are separated from one another by marked unconformity.

group

formation

Kurcnool group

(Age lower Vindhyan)

Kistna group (600m)
thickness

U.C.

Grisailam quartzite
Kolamngla shales
irilakonda quartzite

Nallamalai group (1000m)

UC

Cumbum shales
bairenkonda quartzite

cheyair group / (3300m)
chitravati group

UC

tadpatre (Pullampset) sh
Pulverda (Nagri) quartzite

Papaghani group (1400m)

U.C.

Vempalle shales &
cimestone
gulcheru quartzite

UC

PreCambrian basement

Archean schists & gneisses

* Papaghanic group :-

- The rocks of this group are exposed in the papaghani river valley.
- This group has been divided into 2 formations.
- The lower gulcheru formation comprises quartzite & it is overlain by the 'vempalle shales & limestone'.
- The upper formation is 3 times greater than the lower formation.
- In 'vempalle shales & limestone' deposits of asbestos and barytes takes place.
- The quartzites are rise along the southwestern margin of the crescent in the form of the steep cliffs.

* Cheyair group :-

- The rocks of this group in the cheyair river comprises of quartzites and shales.
- The lower arenaceous part is called 'Pulivendla quartzite' and upper argillaceous part is called 'Tadpatri shales'.
- The south eastern extension of pulivendla quartzite is known as 'nagri quartzite'.

* Nallamalai group :-

- The succession of this group is exposed in the

"Nallamalai hills".

- It is divided into 2 functions
i.e. - the lower formation is known as "Bairankonda quartzite" & upper formation known as "cumbum shales". occupies the synclinal troughs of the folded cuddapah rocks.
- The shales are often intercalated with beds of limestones and quartzites.
- Here rocks are known to contain ores of lead & copper.

* Krishna group :-

- The rocks of this group are exposed along the "Krishna river" cutting a deep gorge in the Krishna Nallamalai plateau in the northwestern parts of the crescent.
- The succession is divided into 3 formations.
- The lower part is "iralakonda quartzite" consist of about 400m thick massive bedded quartzite.
- The middle part is "kolamnala shales", the shales contain thick beds of ferruginous quartzites & upper is "erelailam quartzite".

Structure :-

- 1) The different groups are separated by unconformities.
- 2) The western side of the basin shows an undisturbed sequence. In the eastern side the rocks have been folded and metamorphosed.
- 3) The ripple marks are found frequently in the sandstone of the cheyair group.

Economic importance :-

The cuddapah rock contains important economic minerals and good building stones such as

- (i) Talc → vempalle limestone
- (ii) Asbestos → pulivendla
- (iii) barcyle → vempalle limestone
- (iv) Cobalt & copper → cumbum
- (v) diamond → stream sediment of A.P.
- (vi) building stone → quartzite & limestone

→ 2nd largest purana basin of India

* Vindhyan Supergroup:-

- The vindhyan supergroup named after the scarped plateau mountains on the north side of the Narmada Valley is exposed in an area of about 104,000 km².
- An area of about 78,000 km² of the vindhyan rocks are concealed under the "Deccan Traps" of the Malwa plateau and the Alluvium of the Indo-gangetic plain.
- The term vindhyan was first used for a thick succession of sandstone formation of Bundelkhand and Malwa regions.
- The vindhyan succession rests unconformably over the older formations such as -

Bijawars and Archaeans and are overlain by the Deccan Traps. The vindhyan supergroup is considered to be of "upper purana" age.

Distribution:-

The Indian vindhyan rock formations occur in 4 areas

- (a) Main vindhyans basin in central India.
- (b) Cuddapah super district (A.P.)
- (c) Bhima & Godavari river valley
- (d) NW sides of Aravali ranges in Rajasthan.

- The succession of Vindhyan super group has best developed in the "main Vindhyan basin" on central India.
- This basin is very large and is situated to the north of the Narmada and Gon rivers.
- It extends E.W. for about 650 km from Gwalior in Bihar to Chittorgarh in Rajasthan, and N-S about 160 km from Bhopal in M.P. to Agra in U.P.

Lithology :-

The chief rock types of the Vindhyan supergroup are sandstone, shales and limestones. The total thickness of the succession is about 4500 m.

The Vindhyan rocks contain ripple marks, current bedding and other sedimentary structures which suggest that they are of shallow water origin.

Fossils :-

Vindhyan rocks are generally un-fossiliferous. Presence of some very primitive type of life has been indicated by some traces or fossil impressions found in the fawn limestone (L.V) and Suket shales (U.V).

Structure :-

- The rocks of the Vindhyan super group are un-metamorphosed.
- At the NW margin of the Vindhyan basin a great boundary fault is present.
- Betⁿ the Bundelkhand granite and Son valley the Vindhyan rocks occur in a large syncline.
- Lower Vindhyan rocks are best developed along the south side of the Son valley.

Classification :-

On the basis of difference in lithology Vindhyan super group divided into 2 divisions.

(a) Lower Vindhyan

(b) Upper Vindhyan

- Lower Vindhyan are made up of calcareous rocks and upper Vindhyan are made up of Arenaceous rocks.
- The upper Vindhyan is 3 times thicker than the lower.
- The lower Vindhyan succession is called the semigroup and upper Vindhyan succession divided into 3 groups.
 - (i) Kaimur group
 - (ii) Rewa group
 - (iii) Bhandara group

group

formation

Bhandar group
(1000 m)

upper bhandar sandstone
Sircu shales
Lower Bhandar sandstone
Bhandar limestone
Ganurgarch shales

Diamond bearing conglomerate

Rewah group
(2000 m)

upper rewash sandstone
Jheri shales
Lower rewash sandstone
Panna shales

Diamond bearing conglomerate

Kaimure group
(400 m)

upper kaimur sandstone
Bijagarch shales
Lower kaimur sandstone

Gemre group
(1300 m)

Rohats formation
Rheinjua formation
Porcellinite formation
Basal formation

Bijawar group & Bundelkhand granite

* Lower Vindhyan:-

Gemri group:-

- The rocks of the Gemri group occur on the son valley and NW side of Aravali ranges.
- Succession of the Gemri group is about 1300m thick and is composed of shale and limestones.
- This group is divided into 4 formation.

* Upper Vindhyan:-

- The upper vindhyan succession rests over the Gemri group with a well marked unconformity in the son valley and Dhar forest areas.
- The succession of upper vindhyan's consist mainly of the sandstones and shales with some limestone.
- These succession is divided into 3 groups.
i.e. Kaimur, Rewa & Bhandar, which are separated from one another by a horizon of diamond bearing conglomerate.

(a) Kaimur group:-

- The thickness of Kaimur group is 400m.
- It is further divided into 4 formations i.e. Suket shales, Lower Kaimur sandstone, Bijagarch shales and upper Kaimur sandstone.

→ The upper and lower Kaimur sandstone formation comprise flagstone, siltstone & quartzite.

(b) Reva group :-

- The thickness of the Reva group is 2000m.
- It is separated from the Kaimur group by a diamond bearing conglomerate horizon.
- The conglomerate bed is about 70cm in thickness.
- The famous Panna diamond field of India is situated in the country of Reva rocks.

(c) Bhandar group :-

- The most widely distributed group of the upper Vindhyan consist of about a 1000m thick succession of shales, sandstone & limestone.
- It is separated from the Reva group by a diamond bearing conglomerate horizon.
- The sandstone formation extending from Jodhpur to Pokharan in Rajasthan has been informally grouped as Jodhpur sandstones.

* Economic minerals:-

1) Diamond:-

→ 3 groups of upper vendhyan are separated from one another by a horizon of diamond bearing conglomerate.

2) Limestones:-

→ The imp. deposits of limestone occur in the son valley region of bihar & up. Rewa etc.

→ These limestones are used in cement & metallurgical industries.

* The Kaimur & Rewa groups are mostly consisting of siliciclastic rocks.

→ Rewa - Diamond

* Gondwana Super group :-

The gondwana super group includes rocks ranging in age from upper carboniferous to lower cretaceous. This super group has been named after the Gond kingdom of Madhya Pradesh where these rocks were first studied in 1872. The Gondwana rocks rest unconformably over the Archeans and are overlain by Deccan traps.

Distribution :-

- The gondwana rocks are exposed in
- (i) along the son-Damodar valley
 - (ii) along the Mahanadi valley
 - (iii) along the Godavari warooha valley

The gondwana rocks are also found in the sub himalayan regions of Kashmir, Sikkim & Assam.

Lithology :-

- The term gondwana was coined by Medlicott (1872) for a 6 to 7 km thick succession of fluvial and lacustrine deposit with a glacial deposit at the base.
- The chief rock types are sandstones, shales, clays, conglomerate and coal seams. The upper Gondwana succession contains about 600m thick lava flow of basalt.

Structure:-

The Gondwana rocks aren't folded, only faulted. Faults are common. The Gondwana basin are mostly bounded by faults and the rocks have been preserved only in the down-faulted grabens.

Igneous intrusion:-

There was a period of volcanic activity during the Rajmahal times (upper Gondwana period) which lead to the formation of "Rajmahal traps". The lower Gondwana rocks have been intruded by the dykes of dolerite and basalt and sills of micropegmatite & lamprophyre. In the Damodar valley area they are said to be genetically related to the Rajmahal traps.

Classification:-

Two types of classification have been proposed

(i) Two fold classification

(ii) Three " "

* Two fold classification:-

→ It was adopted by Oldham (1893), Collett (1917), C.B. Fox (1931).

→ It is based on the basis of assemblage of plant fossil.

- The Gondwana succession has been classified into 2 divisions
- (a) Lower Gondwana
 - (b) Upper Gondwana
- The lower Gondwana division is characterized by the presence of "Glossopteris Flora" in which equisetals, pteridosperms and sphenophyllates predominate. (The line of division has been placed above the "panched termination" and it is marked by a slight unconformity).
- The upper Gondwana rocks contain "Ptilophyllum Flora" in which cycads and conifers predominate.

* Three fold classification :-

- It is advocated by O. Feistmantel (1880) and later followed by Vrederberg (1910) and D.N. Wadia (1926) is based on the lithological similarity.
- The Gondwana succession has been divided into 3 parts.
- (a) Lower Gondwana
 - (b) Middle Gondwana
 - (c) Upper Gondwana
- In this case these 3 divisions correspond roughly to the Permian, Triassic and Jurassic periods, respectively.
- The lower part is mainly made up of rocks deposited in humid subtropical climate and contains a number of coal seams.

- The middle part include rocks formed in dry climatic conditions and contain fossils of amphibians and reptiles.
- The upper part appear to have formed under milder temperature and humid conditions.

	<u>Group</u>	<u>Formation</u>	<u>Lithology</u>
upper Gondwana	Jabalpur	- unna	- sandstone, shale
		- Jabalpur	- clays, sandstone
		- chaugon	- clays, sandstone
	Rajmahal	- Kota	- sandstone, grits, coal bands
		- Rajmahal	- Basaltic lava flows
	Mahadeva	- maleri	- Red clays, sandstone
		- pachmarhi	- Red sandstone, clays
		V.C	
lower Gondwana	Panchet	- Panchet	- Brown sandstone, shales
	Damuda	- Raniganj	- S.S. shales, coal seam
		- barren measures	- S.S. ironstone shale
		- Barakar	- S.S. shale, coal seam
		- Karahankarci	- S.S. grits, coal seam
	Talchir	- Rikba	- Sandstone
		- Talchir	- Greenish shale
		- Boulder bed	- Boulder bed

Sedimentation & palaeoclimate :-

- Beginning of the Gondwana sedimentation is characterised by the deposition of glacial sediments.
- The basin of the Godavari valley region show a longitudinal dispersal pattern of sediments.
- A thick sequence of crinoid shales were deposited in the eastern and the southern Gondwana basins.
- In the Satpura basin of central India took place in an oxidising environment giving rise to the deposition of variegated clays and ferruginous (iron oxides) sandstones.
- The Triassic Gondwana is characterised by cyclic alternation of arkosic sandstones and red shales where as the Jurassic and lower Cretaceous Gondwana formations consist of quartz-arenite pebble, sandstone and red siltstone.

Palaeoclimate :-

- The lower part of the Gondwana sequence is dominated by arkosic sediments, representing a cold palaeo-climate.
- Coal bearing sediments were deposited in humid sub-tropical palaeo climate.
- The dry climates were responsible for the disappearance of the *Glossopteris flora*.

Lower Gondwana Formations:-

* Talchir group:-

- The Talchir formation having a ~~fairly~~ wide distribution were first described from Talchir in Odisha.
- The rock of this group rest unconformably over either the Archean or the precambrian rocks.
- The formation comprises a 20-30m thick talchir boulder beds overlain by a succession of green silty shales, mudstones, fine soft sandstone with a few calcareous bands.
- The boulder beds also known as Talchir Tillites and they were laid by the continental glacier.
- The southern continents were joined together during the palaeozoic era.
- The super continent known as Gondwana land was located nearer to the south pole of the permian period.
- The talchir formation contains a few plant fossils of seed ferns *Gangamopteris cyclopteroides* & *Orthis-pteris India* and its characteristic stem *vertebraria India*.
- The thickness of the succession varies from 170-350m.

Damuda group :-

- This group is named after the Damodar river and composed of 2000m thick succession of sandstone, shale, grit and coal seam.
- It is divided into 4 formations

(i) Karcharkari

(ii) Barakar

(iii) Barren measures

(iv) Raniganj

(i) Karcharkari formation (lower permian) :-

- It is the basal unit of the Damuda group and rests over the rocks of talchir group.
- It is composed of 60-120m thick succession and sandstone, grits and coal seam.
- It is well developed in the Giridih coal field.

(ii) Barakar formation (lower permian) :-

- This formation is named after the barakar river and composed of sandstone, shale and coal seam.
- The total thickness of the succession is about 800m
- Barakar formation is the most important coal bearing formation of the lower gondwana succession
- In the Jharia coal field, this formation contains about 25 coal seams.

(iii) Barron measures formation (middle permian)

→ This formation is composed of sandstone and ironstone shale.

→ The total thickness of the succession is about 500m.
(Cyclodendron, Glossopteris)

→ It don't contain any coal seam.

(iv) Raniganj formation (upper permian) :-

→ This formation is composed of about 1000m thick succession of sandstone, shales and coal seams.

→ It is the top most formation of the Damuda group.

* Panchet Group :-

- This group has been named after the panchet hills in the Raniganj coal field.
- It is composed of about 700m thick succession of coarse sandstone and shales.

Upper Gondwana formation :-

* Mahadeva group :-

- It is subdivided into 2 formations.

(i) Pachmarhi

(ii) Maleri

(i) Pachmarhi formation :-

- It consist of about 800m thick coarse white sandstone (Red clays).

→ The beds of "Denua clay" rest over the pachmarhi sandstones.

→ The pachmarhi formation is lower to middle triassic age.

(ii) Maleri formation (upper triassic) :-

- It consist of red clays with minor sandstones.

→ The "Tiki beds" of Rewa, M.P. are equivalent to the maleri formation.

* Rajmahal group :- (Lower Permian)

- This formation is well developed in the Rajmahal hills of Bihar and West Bengal.
- It is made up of extensive lavafloes of basic composition called the "Rajmahal traps".
- The thickness is about 650m.
- Richest flora assemblages of the world.

Kota formation :-

- It attains a thickness of about 650m in the Gonda valley (Kotagouras - Dinosaur fossil).
- Here it rests over the Maleri beds.
- It is composed mainly of sandstones and grits.

Jabalpur group :-

- This group forms the upper part of Gondwana succession.
- The rocks of the Jabalpur group rest unconformably over the Mahadeva group.
- On the basis of floral assemblage, the succession of the Jabalpur group has been divided into 2 formations.

(i) Chaugon beds

(ii) Jabalpur formation

- The Chaugon beds which form the lower part of the succession contain "Taeniopteris", "Nilssonia".

→ The main fossils of the Jabalpur formations are *Ptilophyllum*.

→ The top most formation of the Gondwana succession is called the unia formation consist of sandstones and shales.

Economic minerals :-

(a) Coal :-

→ The barakar and raniganj formations of the damuda group constitute the most imp. coal bearing rock formation.

(b) Iron ore :-

→ About 760m thick ferruginous shales, known as the "Ironstone shales" occur in the barren measures formation of the Damuda group in the Raniganj coal field.

(c) clay :-

→ The clays of various types are found in the Gondwana rock which are used for making bricks.

* *Systema Naturae* - Carl Linnaeus (biospecies)

* Coal :-

- The term originated from the Sanskrit term "kala" which means black. It is one of the "fossil fuel" and is the principle source of heat and energy. Coal is popularly known as "black diamond" since it is more valuable than diamond in terms of monetary value and its usefulness.
- In ancient India, during Indus valley civilization coal was used for extraction of metal.
- Coal beds are underlain and overlain by shale and sandstone usually constitute the roof.
- Coal was first mined in the Raniganj coal field in the year 1774 by the East India Company in India.
- They needed to fuel steam engine and coal was a readily available fuel.
- Coal was burned to create steam to rotate a turbine in power plant.
- Today 72% of Indian electricity comes from coal, we have 300 yr worth of coal.

Definition of coal :-

- Sedimentary rock composed of combustible matter derived from the partial decomposition of plant material.
- A generic term applied to carbonaceous rocks that were formed by the partial or complete decomposition of vegetation. These stratified carbonaceous rocks are either banded or banded and are highly combustible.

- A combustible rock of organic origin composed mainly of carbon, hydrogen and oxygen with lesser amounts of nitrogen, sulphur and other elements.
- A black or brownish black solid combustible substance formed by the partial decomposition of vegetable matter without access of air.

Composition of coal :-

- Chemically coal is composed of organic & mineral matter.
- The principal chemical constituent of coal are carbon, hydrogen, oxygen & slight amount of nitrogen & phosphorus.
- In the process of coalification there is a gradual increase of carbon and decrease of oxygen and hydrogen.
- The chemical composition of coal is determined either by proximate analysis or by ultimate analysis.
- Proximate analysis is done for general purpose. It includes moisture, volatile matter and ash content.
- Ultimate analysis is the elemental analysis of coal which contain carbon, hydrogen, nitrogen, sulphur etc. in varying amounts.

Coal ranking & quality :-

- The rank of coal which includes anthracite, bituminous, sub bituminous & lignite are based on fixed carbon, volatile matter & heating value.
- Coal rank indicates the progressive alternation or

coalification from lignite to anthracite.

→ The heat contents of lignite contains approximately 9-17 million British Thermal Unit (BTU) per tonne.

→ The heat contents of sub-bituminous & bituminous coal range from 16-24 million BTU per tonne.

Low quality coal:-

- Low gas capacity
- High volatile matter.
- High moisture content
- ~~low~~ low economic value
- produce less heat

High quality coal:-

- High gas capacity
- High vitrinite reflectance.
- High carbon content
- high economic value
- produce more heat

Carbon content in coal:-

Peat → Less than 50% Carbon

Lignite → 71% C

Sub-bituminous → 80% C

Bituminous → 90% C

Anthracite → >93% C

→ Coal is a dirty fuel and contains abundant pyrite, which when burned creates SO_2 . In the atmosphere the SO_2 combines with water to form sulphuric acid (acid rain) that acidifies our lakes and streams.

* Coal Ranking & quality:-

1. Peat
2. Lignite
3. Sub bituminous
4. Bituminous
5. Semi-anthracite
6. Anthracite

Peat

- not really a coal
- it is undeveloped
- soft & spongy
- carbon content $\approx 20-25\%$
- deposited during last 100 yrs by decomposed plant remain
- it is used in preparation of whisky

Lignite :-

- The first real coal
- low heating value
- often found near the earth surface
- loses moisture when exposed to air

Sub-bituminous :-

- High carbon content ($65-85\%$)
- Low carbon content ($5-12\%$)
- It is usually burns with a yellow flame.

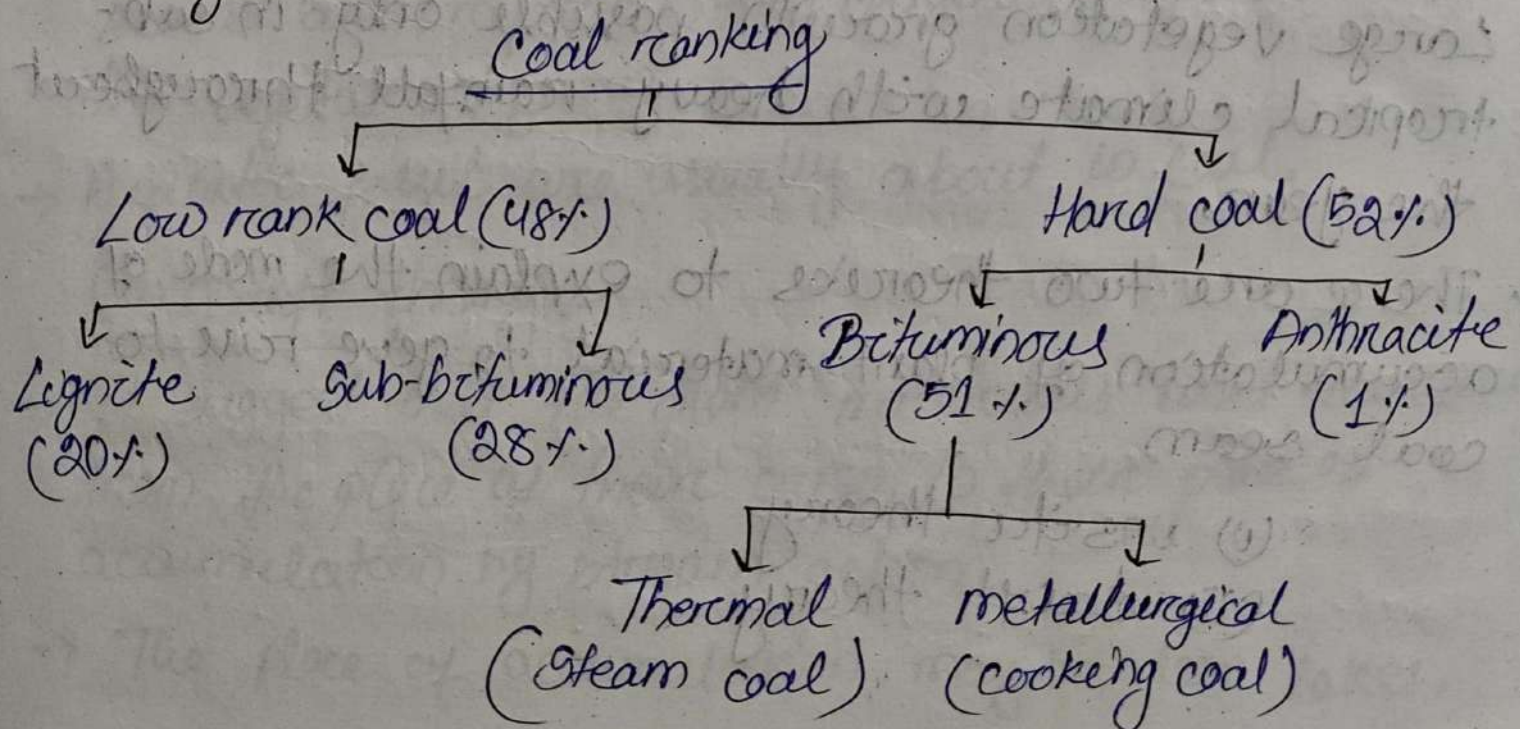
Gemi-anthracite :-

- Hard coal but softer than anthracite
- fixed carbon % (80-85%)
- contains more volatile matter than anthracite
- Burns freely

Anthracite :-

- Hard
- Durable
- high density
- low volatile matter
- fixed carbon % (85-98%)
- Burns slowly with little smoke

<u>Coal rank</u>	<u>Carbon %</u>	<u>specific energy (MJ/kg)</u>
Anthracite	95	35.2
Gemi - "	92	36
Bituminous	90	36
Sub - "	80	33.5
Legnite	71	23



* Chemical properties of coal :-

- (i) moisture content
- (ii) volatile matter = hydrogen, CO, methane +, other hydrocarbons
- (iii) fixed carbon = $100 - (\text{volatile} + \text{moisture} + \text{Ash})$
- (iv) fuel ratio = $\frac{\text{Fixed carbon}}{\text{volatile content}}$
(F.R. = $\frac{C}{V}$)
- (v) Ash content = non combustible material
- (vi) sulfur content = pyrite and marc
- (vii) Calorific value = amount of heat/unit weight

* Origin of coal :-

- Coals are sedimentary rocks formed by accumulation of plant materials on swamps brackish / fresh water basin
- The formation of coal deposits requires a large accumulation of vegetation of matter
- Large vegetation growth possible only in sub-tropical climate with heavy rainfall throughout the year
- There are two theories to explain the mode of accumulation of plant material to give rise to coal seam

(i) insitu theory

(ii) drift theory

(i) in situ theory :-

- This theory suggest that coal vegetation was fossilized on the site of growth, either due to tectonic movement or due to some other reasons.
- This means that the forests grew at the same place where we now find coal seams.
- Due to disturbances on the surface of earth and due to pressure of overlying sediments and temp., the vegetal matter was transformed into coal.

Evidences :-

- A vast amount of plant material is accumulating in situ in the swamps that exists today.
- In coal seams the stems of fossil trees are found standing straight with their roots extend onto the underlays.
- The underlays which are found beneath the coal seams are represent the original soils on which the vegetation grow.
- Aquatic fossil are usually about in coal.

(ii) Drift theory :-

- It suggest that the plant materials was transported from the place of their origin to their place of accumulation by stream action.
- The place of accumulation may be deep lakes.

lakes, river valley etc. which are covered by sediments like sand and clay after accumulation of the plant materials.

→ Coal seams of India are of Drift origin.

Evidences :-

→ The coal seams show wider variation in composition.

→ In some cases the underlays which represent the soil at the root are not found below the coal seams.

→ Large amount of detrital/clastic materials like sand and clay are found in the coal seams.

mode of occurrence :-

→ Coal is found in sedimentary rock as layers and beds. Coal is associated with sandstone & shale. In some cases coals are associated with terraclay and limestone.

→ Tertiary coal in certain cases found to occur as in-situ deposits but Gondwana coal occurs as drifted deposited.

→ About 98% of the coal produced in India comes from the rock formations of lower Gondwana system, while the rest is obtained from the tertiary rocks are lignites.

→ Igneous intrusions in the form of dykes and sills are present in the coal seams.

* Formation of coal:-

→ Two conditions mainly control the formation of coal

(i) environmental condⁿ, which favoured the growth of vegetation

(ii) swampy/marshy condⁿ which favoured bacterial decay and decomposition of plant material.

There are 2 process in the formation of coal

(i) Bio-chemical process / Humification (peat forming stage)

(ii) Geo-chemical " / Coalification (conversion of peat into higher ranks of coal)

(i) Humification (Bio-chemical process):-

→ In the initial stage the plant material are decomposed due to process of oxidation by fungi and bacteria.

→ The p^{++} (hydrogen ion potential) and Eh (redox potential) controlled the changes.

→ In this process the less resistance parts of the plants such as cellulose, proteins are decomposed by plants ~~and~~ bacterial action and the resistance part such as wax, resin sink to the bottom of the swamp.

→ Thus the partly decomposed plant debris accumulated and it gradually turn into peat.

(ii) Coalification (Geo-chemical process) :-

→ With the passage of time, peat changes slowly into different types of coal when peat is buried & compacted chemical changes takes place by increase in pressure and temp.

→ From peat to anthracite the amount of oxygen goes on decreasing and the amount of carbon goes on increasing.

Indian distribution:-

→ Coal occurs in geological periods from carboniferous i.e. lower Gond (mostly permian) and tertiary (mostly cenozoic)

Gondwana coal field of india :-

(a) Damodar valley region:-

→ Coal fields of west Bengal and Bihar.

(a) WB → Raniganj coal field, Durgam, Barjore

(b) Bihar → Jharia, Bokaro, Ramgarh coal field, Giridih, Ramgarh, Auranga, Deoghar

(a) Semi-maharadi valley region:-

Coal fields of madhya pradesh & orissa.

(a) M.P. = Korba, Singrauli, perch-Kanhan valley, Jabalpur, Mandla, Sohagpur

(b) Orissa $\rightarrow$ Pakheri coal field, Ib-reiver coal field
(Sambalpur, Jharsuguda, Himigiri coal field,
Sundargarh)

(iii) wardha-Godavari valley region:-

coal fields of Andhra pradesh and maharashtra.

(a) A.P. - singareni coal field (Godavari valley)

maharashtra - wardha coal field, Bhandar, Chanda

Tertiary coal field:-

1. meghalaya $\rightarrow$ Garohills, Khao & Jaintia hills

2. Assam $\rightarrow$ Jaipur coal field, wiker hill, makeum

3. Jammu & Kashmir $\rightarrow$ Kalakot, Jigani-mitka, Jangalge

4. Tamilnadu $\rightarrow$ Neyveli

5. Nagaland $\rightarrow$ Borjan

* Uses of coal:-

- (i) Generation of electricity in thermal power plants
- (ii) used as fuel for the production of iron steel
- (iii) Coal is converted to hard coke and used in metallurgical industry
- (iv) in high temp. carbonization, coal produces tars which is used for construction of roads.

$\rightarrow$ Gondwana coals are largely confined to the river valley like Damodar, Mahanadi and Godavari

$\rightarrow$ workable coal are confined, ~~mahanadi and Godavari~~ to Damoda group (lower Gondwana).

$\rightarrow$ Here it occurs in 2 horizons

(a) Barakare measures (Lower peruvian)

(b) Raniganj measures (upper peruvian)

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* Petroleum :-
~~~~~

→ Latin language :- Petra + oleum = Petroleum  
(Rock) (oil) (Rock oil)

Def<sup>n</sup> :- "A naturally occurring liquid, gas, semi-solid mixture of hydrocarbon and non-hydrocarbon molecules."

→ Other names of petroleum are

1. liquid gold
2. mineral oil
3. Crude oil
4. Crude petroleum
5. Crude
6. Simply oil.

→ It is a naturally occurring and flammable liquid.

→ Complex mixture of hydrocarbons and organic compounds.

→ Found in geologic formations beneath the earth's surface.

→ The term petroleum first used in the written book "De Nature Fossilium" published in 1546.

Georg Bauer (German mineralogist)

→ Oil and gas provided about 60% of the energy.



## \* History of petroleum:

### (i) Ancient :-

- Egypt :- oil to preserve mummies
- China :- natural gas for fuel
- Babylonia :- oil to seal walls and pave streets
- America :- tar to seal canoes

### (ii) First drilling

America: using cable tool: to 70' in 1859.

### (iii) First product :-

- Kerosene for lamps (Gasoline an unwanted by product)

### (iv) Demand :-

- Industrial Revolution
- Internal Combustion engine (1885)
- Global economic growth

## \* Composition of petroleum :-

Carbon : 84 - 87 %

Hydrogen : 11 - 15 %

Sulphur : 0.1 - 3 %

Nitrogen : 0.1 - 1.5 %

Oxygen : 0.3 - 1.8 %



## \* Detection of petroleum:-

### (i) Geophysical method:-

→ Includes the measurement of density, elasticity, magnetic and electric property of rocks in the crust of earth.

### (ii) Geological method:-

→ Includes the measurement of age and nature of rocks inside the earth crust which gives an idea of oil deposit.

### \* Drilling:-

→ Drilling on the earth crust in the final test when petroleum deposits have been proved either by above two method or both.

### production of petroleum:-

- Petroleum always occurs along with natural gas.
- After drilling on the crust of earth both natural gas and oil flow up through pipes initially.
- when the oil pressure decreases then the residual either sucked by creating vacuum or pressure is created by injecting compressed gas.
- when the oil well contain oil and gas it is called "wet well" and if it contain only gas then it is called "dry well".
- for digging an oil well rotary drilling system is used.



- The main boring is of 20-30 cm in diameter and its depth may vary from 1.5 to 4.5 km.
- The entire well is provided with a steel casing to prevent boring wall to collapse.

### \* Varieties of petroleum:-

- No two petroleum are exactly alike.
- varies in appearance and nature.
- Organic in origin.
- Occurs in solid, liquid and gaseous forms.
- Petroleum can occur as
  - liquid (crude oil)
  - gas (natural gas)
  - solid & semi-solid (Asphalt, Bitumen, Tar)

### \* Origin of petroleum:-

- The origin of petroleum still has uncertainties despite the tremendous researches and studies devoted to it rather than any other natural substances.

There are 2 different theories for the origin of petroleum

1. Organic theory
2. Inorganic "



## (1) Organic theory:-

(a) According to Engler, Petroleum is formed by the process of putrefaction of animal remains. Nitrogen gets eliminated and residual fats get converted into petroleum by earth's heat and pressure.

→ This has been put forward by Engler. His theory is based on the fact that by destructive distillation of fish-blubber, a product similar to natural petroleum could be obtained.

## (b) Vegetable origin theory:-

→ On the basis of certain facts it is believed that petroleum is of vegetable origin.

(i) Oil and coal appear to have close relationship indicating a vegetable origin.

(ii) Oils similar to petroleum can be generated from coal, lignite etc.

## (c) Animal origin theory:-

→ Since 95% of the oil fields occur on marine sediments it is assumed that oil was formed from marine organisms i.e. foraminifera, diatoms, algae etc. buried in sediments.

→ Bacterial action, pressure, moderate temperature and great length of time play an important role in the conversion of organic matter into oil.



## (2) Inorganic Theory:-

### (a) Brothelot's alkaline-carbide theory:-

According to him  $\text{CO}_2$  might react with alkaline metals contained in the interior of alkaline carbides. These on contact with water liberate acetylene which through subsequent process by polymerisation and condensation forms petroleum.

### (b) Mendeleev's carbide theory:-

It is believed that iron carbides within the earth on contact with percolating water form acetylene which escape through fissures to the overlying porous rocks and there condenses. This theory based on laboratory experiments but presence of iron-carbide within the earth has not been established definitely.

### (c) Moissan's volcanic theory:-

He suggest that volcanic explosions may be caused by the action of water on subterranean carbides and may lead to the formation of petroleum.

### (d) Cosmic theory:-

Taking into account the presence of small quantities of hydrocarbons occasionally on meteorites Sokolov considers petroleum to be an original product resulting from the combination of carbon and hydrogen on the cosmic mass during



the consolidation of the earth.

### \* Oil pools :-

oil field / oil pool

- A substance oil accumulation. An "oil field" can consist of one or more oil pools or distinct reservoirs within a single large trap.
- The term "pool" can create the erroneous impression that oil fields are immense caverns filled with oil, instead of rock filled with small oil-filled pores.
- The essential elements required for the presence of oil pools are
  - (i) Source rock
  - (ii) Reservoir rock
  - (iii) Cap rock / seal
  - (iv) Trap

### (i) Source rock :-

- These are the rocks from which hydrocarbons have been generated or are capable of being generated.
- They form one of the necessary elements of a working petroleum system.

### Characteristics :-

- Organically rich
- Fine grained
- mature
- Capable of generating and expelling commercial and enough quantities



- Deposited in variety of environments including deep water marine lacustrine and deltaic.

### (ii) Reservoir rock:-

- It is a rock where hydrocarbons are stored and from which they can be produced.
- The natural sub surface reservoir is a container of oil, gas and water where they can move, and its shape is determined by the relationship between the reservoir rock and surrounding poorly permeable rocks.
- This element is a kind of porous or permeable lithological units which retains the immigrating oil and gas from source rock.
- Petroleum accumulation occupy by the pore spaces of sandstone or porous carbonates.
- Oil and gas usually accumulate on the top of water.
- The petroleum migrates from the source rock into adjacent porous and permeable rocks and accumulates there to form a pool. Such permeable rocks are called "Reservoir rocks".

### Characteristics:-

- must have sufficient porosity to contain fluids and permeability ( $k$ ) to permit their movement
- must contain hydrocarbons in commercial quantities



- must contain hydrocarbons in commercial quantities
- must have some natural driving force, usually gas or water to allow the fluids to move
- most reservoir rocks are limestone, dolomites, sandstones or a combination

iii

### (iii) Seal or cap rocks :-

- For the trap to have integrity, it must be overlain by an effective seal.
- Any rock that is impermeable can act as seal or cap rock but commonly mudstone



#### (iv) Oil traps:-

- The oil migrates outward and upward from the source rock and passes into the porous reservoir rock.
- The migration of oil continues until it meets a suitable structure where its lateral as well as upward movement is checked.
- At such a place the oil accumulates to form an oil pool. Such places are called "oil traps".
- The conditions necessary for the formation of an oil trap are as follows.

(i) The porous reservoir rock must have a favourable structure such as an anticlinal fold or dome to hold oil.

(ii) There must be an impermeable cap rock to check the upward migration of oil. The common cap rocks are shale, clays, salt, gypsum and dense limestone.

(iii) The structural deformation of rocks must not be very severe. Intensely fractured rocks may render traps ineffective by causing leakage.



## Types of oil traps:-

(a) structural traps

(b) stratigraphic traps

(c) combination of stratigraphic and structural trap

### a. Structural traps:-

→ These are formed as a result of folding, faulting and igneous intrusions. The description of some of the important.

(i) anticlines and domes

(ii) Faults

(iii) Salt domes

(iv) Igneous intrusion

### anticline & domes:-

→ The anticline and domes are the most important because they form oil traps in practically all the large oil fields of the world.

→ Here the oil and gas migrate up the limbs and collect at the crest below a cap.



## Faults:-

→ when a fault affects inclined strata, a reservoir rock may be blocked off by an impervious shale thereby creating an oil trap.

## Salt domes:-

→ where salt domes intrude into the sedimentary rocks good oil traps are formed. Here the oil accumulates near the upturned edges of the reservoir rock which are sealed by the salt.

## Igneous intrusion:-

→ The volcanic rocks and dykes may seal the upturned edges of the reservoir rock to form oil traps.



## b. Stratigraphic traps:-

→ The stratigraphic oil traps are formed as a result of lateral and vertical changes in the permeability of the reservoir rocks.

→ The changes are caused by variations in the conditions during the deposition of rocks.

Some of the important stratigraphic oil traps are as follows

(i) Unconformities in the rock sequence often give rise to oil traps

(ii) A porous sandstone may wedge out thereby creating an oil trap

(iii)

Shales which are the source rock of petroleum may contain lenses of sandstone. The oil may accumulate in these sandstone lenses.

## c. Combination of stratigraphic & structural trap:-

→ Combination traps that combine more than one type of trap. These are common in petroleum reservoirs.

→ Here are included these reservoirs where structural stratigraphic and lithological features are significant in controlling the accumulation, migration



and retention of oil and gas. They include both deformational as well as erosional features for example bald headed structure traps with buried hill etc.

### \* Migration of oil :-

- The fine grained muddy sediments in which petroleum originates are called "source rocks"
- migration is the process of the oil & gas moving away from the source rock.
- This is a slow process (few km over a million of years).
- There must be space "porosity" within the rocks to allow for movement.
- In addition there should be "permeability" within the rocks to allow for flow.
- Such permeable rocks are called reservoir rocks.
- The common reservoir rocks are sandstone, conglomerates, porous limestone fractured shales and jointed igneous and metamorphic rocks.

The causes for the migration of petroleum are

- (i) Bouyancy effect
- (ii) Compaction of source rock
- (iii) Capillary effect
- (iv) water flushing



→ In an oil pool, the oil floats on the top of water and above the oil there is usually a lens of natural gas.

Types of migration :- (4 types)

- (i) Primary migration
- (ii) Secondary "
- (iii) Tertiary " (dis migration)
- (iv) Re-migration

a. Primary migration:-

→ It involves the expulsion of the petroleum from source rocks to the reservoir rocks.

b. Secondary migration:-

→ It involves the movement of petroleum through permeable layers (carried beds) to the trap.



### c. Tertiary migration:-

→ migration to the surface, either from the reservoir or source rock (desmigration)

### d. Re-migration:-

→ migration from one reservoir system position through an intervening section into another reservoir position (trap) on the same or different reservoir.

### \* Distribution of petroleum:-

In India deposits of petroleum and natural gas are associated with tertiary rocks of assam, Gujarat, off shore region of bombay and in converci and godavari deltaic areas.



## Oil field of Assam :-

- (i) Digboi oil field
- (ii) Nahankatiya " "
- (iii) Moran " "
- (iv) Rudrasagan " "
- (v) Lakwa " "

### (i) Digboi oil field :-

- This oil field is situated on the Lakhimpur district of Assam.
- It is 13 km long and about 01 km wide.
- It lies on a tightly folded anticline.
- The steeper flank of this anticline has been cut by the Nagatrust in the North-west.
- The oil bearing formation is the Tapam sandstone of miocene age. The source rocks in this case are probably Baraills.
- In the Digboi oil field there are several oil sands and about 400 producing wells of which only 30 are good produce.

### (ii) Nahankatiya oil field :-

- This oil field is situated on the Brahmaputra valley of upper assam.
- It lies about 40 km southwest of Digboi.
- The oil deposits occurs in an anteclineal structure.
- There are about 5 oil bearing sands all lying within the upper part of the Baraill sandstone of



oligocene age.

- In the overlying Tipams only gas is found.
- This oil field is cut into a number of blocks by faults.

### (iii) Moran oil field:-

- This oil field lies about 41 km WSW of Naborkakla.
- Here the oil bearing formation are the Baraills of oligocene age.
- A major fault divides this field into 2 halves.

### (iv) Rudragarc oil field:-

- This oil field lies about 40 km southwest of moran.
- Here deposits of oil are found in a gentle dome which is cut by several faults.
- The oil bearing formations are the Baraills of oligocene age.

### (v) Laksa oil field:-

The oil field is situated about 20 km south-south-west (SSW) of moran.

- Here the oil pools are found in the anticlinal structure which is cut by a number of faults.
- The oil bearing horizons occur both in the tipams of miocene age and Baraills of oligocene age.



## Oil fields of Gujarat:-

- (i) Anklesh oil field
- (ii) Combay gas "
- (iii) Kalol oil "
- (iv) Nawagam " "

### (i) Anklesh oil field:-

- This is the most important oil field in Gujarat.
- It is situated to the south of Narmada river near Broach. (mouth of the Narmada river)
- The oil pools occurs on the anticlinal structure.
- The oil bearing formations are sands of eocene age. The oil field is about 20 km long and its max width is about 4 km.

### (ii) Combay gas field:-

- The combay gas field is situated about 9 km. NNW of combay town.
- Huge gas deposits are found in a North-South trending anticline which is faulted on both flanks.
- The oil and gas bearing sands which are about 150 meters thick, occur in the formations of oligocene age.

### (iii) Kalol oil field:-

- The Kalol oil field is situated about 25 km North of Ahmedabad.
- The deposits of oil are found in an elongated dome trending on the NNW-SSE direction.



→ This dome is cut by a longitudinal fault.  
Here the oil pools occur in the rock formation of eocene age.

#### (iv) Nawagam oil field:-

→ This oil field is situated about 24km south of Ahmedabad.

→ The oil pools occur in an anticlinal structure on the eocene formation.

#### \* Oil fields in Bombay:-

##### Bombay High:-

→ A huge deposits of oil has been found on the west coast of India in the offshore structure called "Bombay High".

→ The Bombay high lies in the Arabian seas, about 160 km. NW of Bombay.

→ This has proved to be the richest deposit in the country.

→ The Bombay High structure covers an area of about 2500 km<sup>2</sup>.

→ Here the oil bearing rocks are the limestones of miocene age.

→ The estimated reserves of petroleum in this structure are of the order of 4 Billion tonnes.



### Other areas :-

- In addition to the above mentioned oil deposits there are possibilities of getting oil and gas on the deltas and alluvial troughs of Indus, Ganges, Brahmaputra, Cauvery and Godavari.
- Besides these other promising areas are offshore region of Tamilnadu and Andhra Pradesh and states of Tripura and West Bengal.

### Uses of petroleum :-

- generate electricity
- fuel (petrol, diesel)
- Asphalt for Road
- Natural gas (LPG)
- lubricants manufacturing
- chemical " (fertilizer, pesticide)
- synthetic fibres (nylon, polyester, acrylic fibres)



\* Field work :-

- The geological fieldwork carried out to search mineral deposits and to explore ground for many civil engineering works.
- During the geological survey sufficient data are gathered to prepare geologist maps and reports about a particular area of interest.

\* Field equipments :-

- The equipments which are required for doing a geological field work are

(i) Topographic map

(ii) Compass

(iii) Hammer

(iv) Mallet

(v) Altimeter

(vi) measuring tape

(vii) field note book

(i) Topographic map :-

- First the topographic map of the area to be investigated is procured.
- It is the most imp. tool of the geological fieldwork.
- The map should show topographic details on a sufficiently large scale that is  $1\text{cm} = 2.5\text{ km}$  or  $1:5000$ .



→ It serves as a base map for systematic field work and geological mapping.

### (ii) Compass :-

- A magnetic compass is used for finding direction.
- The magnetic needle of the compass always points towards the magnetic north.
- The chief compasses used by geologists for the field work are.

(i) Clinometer compass

(ii) Brunton compass

### (iii) Hammer :-

- A hammer is essential for chipping rocks and collecting rock samples.
- Geological hammer are generally one chisel end and another flat end. The flat end used for breaking rocks while the chisel end is used for trimming and sizing the specimens.

### (iv) Haversack :-

- It is used for carrying compass, notebooks and rock samples collecting in the field.

### (v) Altimeter :-

- It is a barometer which is used for determining ground elevations. Along with compass, altimeter greatly helps in locating outcrops in mountainous area.



### (vi) Measuring Tape :-

→ A steel or metallic tape of 30m length and a pocket steel tape of 2m length is required for the fieldwork.

### (vii) Field note book :-

→ A field notebook is used for keeping a record of observations made in the field. Field notes should be brief but clear.

### \* Prospecting method :-

→ Objectives

- (i) To search ore deposits
- (ii) To know the nature of overburden
- (iii) To determine depth, size, shape and grade of ore deposits
- (iv) To determine geologic structures
- (v) To discover the ground & water conditions

→ The mineral exploration includes 2 activities  
→ The first is "prospecting" which mainly concerned with the outlining of mineral targets for exploration and the second is "exploration" which consists of providing of targets outline during prospecting  
→ The prospecting methods are broadly classified into 2 groups (i) Airborne prospecting method  
(ii) Ground " "



## (i) Airborne prospecting method:-

- The airborne prospecting methods include "remote sensing method" in which photogeological study is undertaken and aerial geophysical prospecting methods.
- By these methods large areas are covered quickly and target areas are outlined for ground prospecting.

## (ii) Ground prospecting methods:-

- The ground prospecting methods are broadly classified into 2 groups

(a) Surface method

(b) Geophysical method

- In surface prospecting methods data are obtained by direct observation

- Most of the information comes from natural exposure and artificial openings such as pitting, trenching, drilling etc.

- In the geophysical methods the information is obtained indirectly by studying the physical properties of rocks.

### a. Surface prospecting method:-

(i) Geological mapping

(ii) Test pitting, trenching & adeting

(iii) Augering & wash boring

(iv) Drilling



## b. Geophysical methods:-

(i) Gravity method

(ii) Magnetoe "

(iii) Electrical "

(iv) Seismic "

(v) Radio active "

## (a) Surface prospecting methods:-

### (i) Geological mapping:-

- Before starting the prospecting work, a target area that can yield mineral deposits is selected.
- Then its geological map is prepared on a suitable scale.
- Such a map show topography, rock outcrops and structural features such as dip, strike, fold, faults etc.
- This sort of map gives an idea of the length and width of the deposit.
- It also serves as a base map for planning out a trenching, pitting or drilling programme.

### (ii) Trenching:-

- It is a narrow linear excavation which is made to expose ore bodies concealed under soil cover.
- The trenches may be 6 to 9 meter long, 1 to 1.5 meter wide and 2 to 2.5 m. deep.
- They are commonly dug across the strike of the ore body at intervals of 15 to 150 m.
- Prospecting by trenching is generally done when



the ore crops are narrow and the soil cover is thin (about 1m.).

- The trenching gives reliable information about the geology, structure, extensions and grade variation of the ore body.
- This method has been adopted as a major prospecting method on many iron ore and bauxite deposits.

### (\*) Pitting :-

- The process of digging rectangular openings to penetrate soil cover to reach orebodies concealed underneath is called "pitting".
- The common dimensions of pit is  $1.2\text{m} \times 1.2\text{m} \times 6\text{m}$ .
- However pits may be sunk to a depth of about 10m beyond which they become very expensive.
- Pitting is a very useful method of prospecting those ore bodies which are flat or gently dipping and lying near the ground surface.
- The pattern of the layout of the pits may be regular or irregular.

### (\*) Aditting :-

- The adits are horizontal openings which are dug on mountainous terrain to explore ore bodies.
- An adit may be driven across or along the strike of the rocks.
- It should be dug in such a way so that



at a later stage it could be used as an opening for exploiting the ore.

### (iii) Augering and wash boring:-

→ These are commonly used for prospecting of flat and homogenous deposits like clays which are concealed under a thin cover of soft and unconsolidated materials.

→ "Augering" is a simple method of putting down holes of about 2.5 cm in diameter to depths upto 6 m. in soft soils.

→ An auger consists of a screw mounted on a steel pipe. It is screwed into the ground by turning on a T-pipe attached to the upper end.

→ In "wash boring" a hole is dug on the soft ground by forcing a jet of water through the wash pipe. The soil thus eroded comes to the surface as a suspension in water where it is examined and identified.

### (iv) Drilling :-

→ It is an important method of prospecting subsurface rock and ore deposits.

→ In drilling data are collected by direct penetration of subsurface rocks by drill holes.

→ The sample of rocks are obtained in the form of cylindrical cores or rock fragments.

→ The drill holes provide the following informations



1. Size, shape & morphology of the ore body
2. Geological structures and number of lodes present
3. Nature of host rocks
4. Composition and grade of the ore body

→ During prospecting drill holes are located at certain intervals in certain directions depending upon the regularity of the ore body and its structure.

### (b) Geo physical Prospecting :-

→ In geophysical prospecting certain physical properties of the wtg rocks are measured from the surface.

→ The properties of rocks measured commonly are density, magnetism, electrical conductivity & elasticity.

→ In the radiometric surveys mainly the γ-ray radiations are measured.

→ The measured data are then interpreted to give information about the presence of ore bodies, buried anticlines, faults, igneous intrusions and other geological structures.

→ The main geophysical prospecting method areas follows

- (i) Gravity method
- (ii) magnetic "
- (iii) electrical "



- (iv) Seismic method
- (v) Radioactive "

### (vi) Gravity method:-

The gravimetric survey is based on the measurement of density contrast bet<sup>n</sup> the anomaly producing body and the surrounding rocks.

#### use:-

- (i) The gravity methods are used chiefly for the exploration of oil and gas. These have been used successfully for outlining anticlines, buried, ridges, igneous intrusions, faults & other geological structure.
- (ii) The gravity survey has also been utilized for the exploration of metallic ore bodies such as massive sulfide ore, iron ore and chromite ore.

#### method:-

→ The instruments which are commonly used to measure gravitational deflections are

- (i) pendulum
- (ii) torsion balance
- (iii) gravimeter

→ Of these the gravimeter is the most useful, for covering larger areas rapidly, airborne gravity survey is done.

→ In the area of search traverses are laid at suitable intervals.



- Then the values of gravitational deflections are measured at predetermined points.
- The readings thus obtained are plotted on a graph with distances on x-axis and deflections on the y-axis.
- If a dense rock or massive ore body present on the area, the graph will show an anomaly in the form of a peak as shown in fig.
- The difference bet<sup>n</sup> the normal value and the observed value of deflection is called 'anomaly'.
- The gravity data can be also ~~be~~ interpreted by contouring the anomaly. In this case the gravity anomaly for each station is plotted on a base map and then line of equal gravity anomaly are drawn in the same way as contour lines.



## (a) magnetic method :-

- The magnetic survey is based on the measurement of value of magnetic anomalies.
- In these surveys the vertical component of the earth's magnetic field is measured.

### Use :-

- (i) The magnetic surveys have been used widely for the exploration of oil and magnetic ore bodies such as deposits of magnetite, pyrrhotite & ilmenite.
- (ii) At places faults may bring together rocks of different magnetic properties. Hence they may be delineated from magnetic data.
- (iii) The magnetite and pyrrhotite are more abundant in basic igneous rocks than in acid rocks. Hence the former can be detected by the magnetic surveys.
- (iv) Certain mineral deposits which contain magnetic minerals in subordinate amount, such as magnetite with asbestos and pyrrhotite with base metal can be detected by magnetic surveys.

### method :-

- The magneto meters are used to measure the magnetic intensity of the ground at various stations. For covering large areas rapidly, airborne magnetic surveys are conducted,



- In the area of search, traverse are laid at suitable intervals.
- Then the values of magnetic intensities are measured at closely spaced stations.
- For each station the observed value is compared with the normal value.
- The difference bet<sup>n</sup> them is "magnetic anomaly".
- The values of anomaly are plotted on a base map. Then the lines of equal magnetic anomaly are drawn on the same way as contour lines.
- From such a map, the area of the magnetic body can be readily delineated.
- The anomaly data may also be interpreted by constructing magnetic profiles in the same way as done for gravity data.

### (iii) Electrical method :-

The electrical methods are used mainly for the exploration of metallic mineral deposits.

The electrical survey method are of 4 types

- (i) self potential method
- (ii) equipotential "
- (iii) electromagnetic "
- (iv) resistivity "



## Self potential method:-

- In this method the electrical energy produced by the orebody itself is directly measured and no outside energizing force is required. Certain ore bodies, particularly those containing sulfide minerals when subjected to oxidation produce electrical currents.
- These currents are called "telluric currents".
- By measuring these currents the presence of the hidden orebody can be detected.



- The figure shows a selfed ore body which is undergoing oxidation.
- Its upper end which is in contact with the soil mantle is chemically more active than the lower part.
- Hence a potential difference is created and electric current flows down through the ore body and return upward through the surrounding rock.
- Because the country rocks have high resistivity the current spreads out to great distance.
- On the ground lying immediately above the ore body the current flows towards the negative centre 'O' as shown in fig. The centre 'O' of the ore body can be located by constructing an equipotential diagram.

### Equipotential method:-

- It is the best suited to shallow deposits in the regions not too wet.
- It can be used to locate ore bodies in the glacial drift for determining structure beneath the soil.
- This method is also used to study the geological formations with steep or vertical contacts such as igneous intrusion.

### method:-

- The current is introduced into the ground by



- means of 2 line electrodes.
- A "line electrode" is a bare copper wire which is pegged into the ground at intervals.
  - The current flows between them through the ground because of the difference in potential.
  - If the intervening ground is of uniform conductivity the lines of equal potential will be  $\perp$  to the electrode's line.
  - This is shown in fig by dotted lines a, b, c etc.
  - On the other hand, if an orebody which is a better conductor than the surrounding rock is present on the ground the lines of equal potential will be distorted.
  - This is shown in the fig by solid lines 1, 2, 3 etc. Hence by noting the distortions on the equipotential lines, the hidden body can be demarcated.



## Electromagnetic method:-

- Out of the electrical methods, the electromagnetic method is the most favoured method for search of ore bodies.
- It is more precise and yields greater information regarding shape, size & position of the hidden ore body.
- The electromagnetic method can be used for rocky ground, barren mountain region, dry sands and ice covered ground.
- When an alternating current is passed through a conductor induced currents are produced around it.
- If a conductor such as an ore body, lies within the induced field it sets up secondary induced currents around it which can be measured.

### method:-

- A rectangular loop of insulated cable is placed on or above the ground.
- Then an alternating current is supplied to the loop.
- The loop sets up a "primary magnetic field" within the surrounding ground which diminishes with distance from the loop.
- If a conductor (ore body) is present within the ground, a "secondary field" is induced about the conductor.



- Because both the primary and secondary fields are present at the same place, the primary fields get distorted.
- The orebody is outlined by measuring the distortion by sensitive receivers.
- In order to detect the distortion, ~~transverse~~ lines are laid normal to the longer axis of the loop and normal to the hidden ore body.
- These transverse lines are then surveyed by the receiver.
- If the ground is uniform the readings of the field will decrease with distance.
- On the other hand if an ore body is hidden in the ground, the readings will rise at the boundary of the ore body as shown in fig.



## Resistivity method:-

- In resistivity surveys the amount of resistance met by an electric current which is passed through a portion of the earth is measured.
- The measure of resistivity is presumed to be a measure of the fluid content and porosity of rocks.
- Therefore the resistivity measurements help on making distinction betn saturated and unsaturated rocks and also rocks of differing porosity.

### Uses:-

The resistivity surveys are very effective in the investigation of horizontal or gently dipping rocks. These are used in detecting the following.

1. Thickness of overburden or depth ~~of~~ to bedrock is determined very accurately.
2. It is used in exploration of the placer deposits and bedded deposits.
3. It is used widely for the exploration of ground water. In region of gentle dips the presence of aquifers can be determined.
4. Fault zones may be determined as they contain electrolyte & solution.
5. It is used for discovering the subsurface structure and lithology. The buried anticlines ~~are~~ <sup>have</sup> lesser resistivity. Hence they can be traced by



determining depths to strata of greater or lesser resistivity. Hence they are also used in the exploration of petroleum.

### Wenner method:-

- In resistivity surveying various electrode arrangements are employed but the arrangement shown by Wenner is widely used.
- In the Wenner method, the spacing between the electrodes are kept equal. In fig this spacing is designated as "d".
- The current is introduced into the ground by 2 current electrodes  $C_1$  &  $C_2$  and the potential difference between the inner electrodes  $P_1$  &  $P_2$  is measured.
- All the 4 electrodes are placed in a line as shown in fig.
- The resistivity of the ground is determined by the following equation

$$\rho = 2\pi d \frac{V}{I}$$



where,  $\rho$  = resistivity

$d$  = distance bet<sup>n</sup> electrodes

$V$  = difference in potential bet<sup>n</sup> inner electrodes

$I$  = current flowing bet<sup>n</sup> the end electrodes

→ In this case, the depth of exploration is approximately equal to the electrode separation.

→ By Wenner method 2 types of resistivity surveys are carried out

(i) Resistivity traversing

(ii) Resistivity sounding

### Resistivity traversing

→ also known as "resistivity trenching"

→ used to investigate variations of rock beds in the horizontal direction at constant depth.

→ The spacing of the electrodes are kept constant while they are moved along a traverse line.

→ The resistivity measurements are made at various stations.

→ From the data thus obtained, the resistivity curves are drawn by plotting the distance of stations on X-axis and resistivity values on the Y-axis.

→ An abrupt change in curvature of resistivity profile indicates a change in the nature of the underlying material.



### Resistivity sounding :-

This method is used to investigate the nature of subsurface strata at depth.

- In resistivity sounding, the resistivity is measured by increasing the electrode separation progressively about a central fixed point 'x'.
- As the distance bet<sup>n</sup> the electrodes is increased the depth of penetration of the current is also increased.
- In this way the data on variation of resistivity with depth are obtained.
- Then the resistivity - depth curves are drawn by plotting the resistivity values on  $x$ -axis and electrode spacing on  $y$ -axis.



#### (iv) Seismic methods:-

- In this method, the variations in the seismic wave velocity are measured on different rock layers.
- The values of the seismic velocity are obtained from the time-distance curves.
- Since the velocity & density of rocks; by noticing the difference in the velocities the structure of the ~~substance~~ surface rocks can be worked out.

#### method:-

- Truck mounted drilling rigs and recording system are used.
- Small charges of explosives are detonated in shallow boreholes drilled in the surface rocks.
- The seismic wave thus generated are transmitted through the rocks and are picked



up by a series of geophones carefully spaced along a line of traverse.

Seismic method.

(A) showing shot points and geophones along a line of traverse

(B) seismogram showing interval of time  $t$  bet<sup>n</sup> instant of shot and arrival of first wave at a geophone.

- The geophones record the vibrations on a rapidly moving photographic paper.
- The instant of explosion is also marked on this paper
- From this photographic record (seismogram) the time-distance curves are prepared.
- Then the velocity of seismic wave is determined



by the following eq<sup>n</sup>.

$$V = \frac{x_2 - x_1}{t_2 - t_1}$$

where,  $V$  is the velocity of seismic waves,  $x_1$  &  $x_2$  are the distances of any 2 recording stations from the shot point and  $t_1$  &  $t_2$  are the times of arrival of the seismic wave at the same stations.



→ The velocity of seismic wave differ in different kinds of rocks. Hence from the velocity data, the structure of subsurface rocks can be worked out.

The seismic methods are of 2 types

- (i) refraction survey
- (ii) reflection survey

### Refraction survey:-

- The seismic waves undergo reflections and refractions at the rock boundaries.
- In the refraction method only the refracted waves are recorded and used for determining the structure of rocks.
- It is used for the followings
  - (i) for determining the structure of rocks lying at relatively shallow depth. It is widely used for civil engineering explorations.
  - (ii) For the location of shallow salt domes and the oil pools associated with them.

### Reflection survey:-

- The reflection waves from a reflecting surface are recorded and used for determining the rock structures.
- The reflection survey is generally used for deep explorations (600m or more)
- Hence it is widely used for oil exploration.
- This method accurately delineates the sub-surface



## Structural traps and salt domes.

### (V) Radiometric surveying:-

→ The radioactive elements, such as uranium-238, and thorium 232, constantly undergo a process of disintegration.

During disintegration they emit radiations of three types

(i)  $\alpha$  rays

(ii)  $\beta$  "

(iii)  $\gamma$  "

#### a) $\alpha$ rays

→ These are the beams of +vely charged particles.

→ These particles are the nuclei of He atoms  
(2 protons + 2 neutrons)

→ They travel with velocity of thousands of km/sec.

#### b) $\beta$ rays:-

→ These are the beams of -vely charged particles.  
They travel faster than  $\alpha$ -rays.

#### c) $\gamma$ -rays:-

→ These are the rays of very short wave length like x-rays

→ They travel with velocity of light and have a very high penetrating power.

→ Of the 3 above said radiations, only  $\gamma$ -rays are useful from the point of view radiometric surveys.



→ The instruments commonly used for radiometric surveys are

- (i) Geiger mueller counters
- (ii) Scintillation counters

### Geiger Mueller Counters:-

- This instrument is fitted with an ionization chamber, meters and count registers.
- These make it possible to measure the intensity of  $\gamma$ -rays.
- The  $\gamma$ -rays are detected by the ionization chamber.
- This chamber consists of a closed tube containing an ionisable gas under pressure.
- An electrical potential is applied to produce an electrical field inside the tube.
- As a result the +ve ions move towards the -ve electrode and the -ve ions towards the +ve electrode.
- A beam of incoming  $\gamma$ -rays liberates a large no. of ions inside the tube and produces an impulse of electric current.

### Scintillation counter:-

- This is a very sensitive instrument which measures the intensity of  $\gamma$ -rays (gamma rays) in terms of electrical signals.

### Types of radiometric surveys:-

Depending on whether the measurements are made from air, at the ground or along drill holes, the radioactive surveys are classified into 3 groups.



- (i) Airborne radiometric surveys
- (ii) ground "
- (iii) radiobactive logging of boreholes

### Airborne radiometric surveys:-

- Scintillation counters are used to recording the  $\gamma$ -rays from the air.
- These surveys are usually carried out along the aeromagnetic and aero-electromagnetic surveys.
- By airborne radiometric surveys the deposits of radioactive substances and boundaries bet<sup>n</sup> various rock types may be outlined.

### Ground radiometric surveys:-

- This method is used for
  - (a) to search deposits of radio active substances
  - (b) to outline geological structures such as faults

#### a. To search deposits of Radio-active ores:-

- In ground surveys the G.M. counter is commonly used to detect the intensity of  $\gamma$ -rays.
- A radioactive deposit which is hidden beneath a thick cover of soil, may not be detected because most of the radioactive emanations are absorbed by the soil cover.
- In such a case the detection of hidden deposit depends on the migration of the radioactive element



- from the source.
- The migration is caused in 2 ways
    - (a) the radioactive substances may be in solution after the deposition of the ore
    - (b) the radon which is the gaseous member of the radioactive series may diffuse through the overlying cover
  - The process of migration of radioactive elements may result in the formation of an "aureole" or in the localization of radioactivity along faults or fissures
  - By detecting these clues, the hidden ore body may be outlined.

#### b. To outline faults:

- Certain ground waters contain radon and soluble radioactive materials in appreciable amounts.
- Faults containing such radioactive fluid may be outlined by measuring variations in the radioactivity of rocks.

#### Radioactive Logging :-

- The "radio active Logging" is an operation in which  $\gamma$ -ray counts of various rock formations met in a borehole are recorded continuously along the depth.
  - This depth wise record is called "radioactive Log".
- The radioactive logging is used for
- (a) Correlating rock beds
  - (b) Determining porosity & permeability of rocks



### a. For correlating rocks:-

- Every rock formation contains some natural radio-activity in measurable degrees.
- As a rule, acid rocks are more radioactive than basic rocks.
- Because different rocks have different amount of radioactivity they may be correlated by using this criteria.

### b. For determining porosity:-

- The radioactivity counts of different rocks vary with their densities.
- The more dense rocks have higher values of radioactivity than those of dense rocks.
- Hence from the density, the porosity of rocks may be determined.

### \* Geo-chemical Prospecting:-

- The geochemical prospecting is very effective in locating deposits of base metals such as Cu, Pb, Zn etc.
- In India this method is used commonly for this purpose.
- The essential principle of geochemical prospecting is as follows:
  1. Samples of the surface soil or sediment of the target area are taken systematically from grid points.



2. The metal content of the samples are determined precisely by rapid geochemical analysis
3. The distribution of the metal content in the surface soil or sediment is determined by plotting the values on a base map of the target area.
4. Then the comparison of these values is made with the known "background" values
5. The comparison will give the idea about the presence of the mineral deposit hidden below the ground.

#### method :-

The main steps involved in geochemical prospecting are

- (i) Sampling
- (ii) Geochemical analysis
- (iii) Interpretation of data

#### Sampling :-

- The geochemical prospecting of a target area is started with the collection of samples.
- The samples of surface soil, streams, sediment, water or rock chips are collected from grid points at fixed intervals.
- The grid lines are drawn transverse to the strike of the suspected zones of mineralization.

#### (a) Soil Sampling :-

- The soils always contain mineral particles present in the parent rock.
- The soils caped over the orebody commonly shows



anomalously high values of metal concentration.

→ In soil sampling, the samples weighing about 100g are collected from each grid point.

#### (b) Stream sediment sampling :-

→ In geochemical surveys the stream sediment sampling is commonly done.

→ In this case, samples of fine stream sediments are collected from stream channels.

→ These sediments usually carry mineral particles derived from their original source rock.

→ The samples of stream sediment are normally collected intervals of 0.15 km.

#### c. Water sampling :-

→ Water sampling is done mainly for uranium deposits are rarely for zinc and copper deposits.

→ The water samples are collected from lakes, rivers and v/g sources.

#### d. Rock sampling :-

→ In case of rock sampling, chips of rocks are collected from visible outcrops at regular intervals.

→ These chips are then crushed to 100 mesh size and analysed for the metal content.



### (ii) Geochemical analysis :-

- Each sample is analysed precisely by rapid geochemical methods to determine its metal content.
- Thus for a single geochemical survey, individual readings of the order of 50,000 to 60,000 are obtained.

### (iii) Interpretation of data :-

- The data obtained from the geochemical analyses are interpreted with the help of graphical statistical procedures or by computer methods.
- The method of interpretation may briefly be summarized as follows
  1. The area under investigation shows 3 types of values
    - a) background values
    - b) threshold values
    - c) anomalous values
  - The average values of the metal content of the area are called "background values"
  - The "threshold values" are those which demarcate the zone separating the average values and the anomalous values.
  - The values which are above the threshold values are called "anomalous values"
- 2. The area of anomalous values outlines the mineral deposit hidden below the ground.



## Ch:-4 :-

## Economic Geology :-

It deals with the study of mineral deposit their mode of formation, mode of occurrence and distribution etc.

- \* Elements are building blocks of mineral
- \* minerals are " " " " rocks
- \* rocks " " aggregate of minerals

Mineral:- Naturally, solid, homogeneous, inorganic, <sup>physical,</sup> <sup>chemical</sup>

→ It is a naturally occurring homogeneous solid element or compound of definite chemical composition, having an ordered atomic str<sup>n</sup> and thus in a crystalline cond<sup>n</sup>.

Rock:-

The solid materials of the earth, are aggregate of one or more minerals are called rock.

Ore:-

a natural rock or sediment that contains valuable minerals (typically metals) that can be extracted from it through mining with profit. It is the assemblage of ore mineral and gangue minerals.

e.g. copper ore, Iron ore, chromite ore etc

Ore mineral:-

→ The economic minerals of an ore is called ore mineral.

→ A mineral from which one or more metal can be extracted at profit is called ore "ore mineral".



eg. hematite, bauxite, pyrite etc.

### Ore deposits:

- A mineral deposit that is sufficiently rich to be worked at a profit is called an "ore deposit" is an economic term.
- The diff<sup>n</sup> factors of it are like shape, size, depth, geographic remoteness, access to transportation, the political stability of the region and market price.

### Mineral deposit:

- These are naturally occurring accumulations or concentration of metals or minerals on rocks of different size.

### Gangue:-

- The useless minerals associated with the ore minerals are called as gangue minerals.
- The common gangue minerals are quartz, feldspar, tourmaline, beryl etc.

### Tenor:

- metal content of an ore is called "Tenor".
- It is generally expressed in % of the metal.
- It depends on the price of the metal obtained from it.
- For costly metals, the tenor is very low such as for gold it is 0.01% where as in case of cheap metals like iron, the tenor is much high i.e. 50% or more.



## Tonnage:-

- It is a quantitative term that means the total metal content of an ore deposit.
- It has units such as tonnes, pounds.

## Metals:-

- These are elements that are malleable, ductile & conductive in case of heat & electricity.

## Metalloids:-

Elements with both metallic and non-metallic properties & have a low ability to conduct heat & electricity.

ex: Arsenic, antimony

## Heavy metals:-

Density  $76 \text{ g/cm}^3$  ex: Fe, Cu, Pb, Zn

\* Gold  $\approx 18 \text{ g/cm}^3$

## Native metals:-

Pure metals / metal alloy

## Grade:- (synonyms of tonnage)

- It is a qualitative term.
- It is the % of metal ~~content~~ content in an ore.
- There is a certain grade below which it is not profitable to mine a mineral even though it is still present in the ore.



→ High grade iron ore ranges from 80-100% hematite, copper ore ranges from few % upto 75%. The lower grade are being concentrated and those with higher % being smelted directly.

### Lode :-

→ It is a deposit of metallic ferrous ore that fills in a fissure in a rock formation.

### \* Cut off grade :-

→ The lowest permissible grade of the deposit above which ore can be deposited above which ore can be extracted with profit is called as "cut-off grade".

→ materials found to be above the grade is considered to be ore while materials below the grade is considered as waste.

### \* Classification of ore bodies :-

Based on relation with host rock :-

- (i) Synergetic ore deposit
- (ii) Epi genetic " "

→ Ore deposits which are formed at the same time as the enclosing rock called "synergetic ore deposit".  
e.g. Sedimentary ore deposit

→ Ore deposits which are formed later than enclosing rock called "epigenetic ore deposits".  
e.g. hydrothermal ore deposits



### (a) Strategic (total inadequacy) :-

→ A strategic mineral is one in which a country has more or less negligible resource available and depend upon outside sources.

### (b) Critical (deficiency) :-

→ Critical minerals are the minerals which are available in a country but they are not feasible to extract today, they may be extract in the crucial cond<sup>n</sup> like wars.

### (c) Essential :-

The minerals which are plenty, available in a country and produce in sufficient quantities.

The classification varies from country to country depending upon the resource pos<sup>n</sup> of individual countries.

### \* Strategic minerals of India :-

- (i) Antimony (Sb)
- (ii) borates
- (iii) Cobalt (Co)
- (iv) Fluorite ( $\text{CaF}_2$ )
- (v) Molybdenum (Mo)
- (vi) Nickel
- (vii) ~~Co~~ Tungsten (W)
- (viii) Selenium (Se)

Arsenic, sulphur, Fe, mercury  
asbestos, industrial diamond.



## \* Critical mineral of India:-

- (i) beryllium (Be)
- (ii) Germanium
- (iii) rare earths (heavy & light)
- (iv) rhenium (Re)
- (v) Tantalum

(vi) graphite

Copper, lead & zinc,  
uranium, lithium,  
phosphate, apatite

## \* Essential minerals of India:-

- (i) Coal (4th largest reserves)
- (ii) Fe
- (iii) Mn (7th largest reserves)
- (iv) mica
- (v) bauxite (5th)
- (vi) Chromite



## Iron :-

- It is the most vital metal in human use.
- It constitutes 5.05% of crust materials and holds 3rd position in abundance after "silicon" and "Al".
- The mineral containing iron must be minerable at profit in order to be called an "iron ore".
- The total world production of iron ore in 1990 was about 1.008 million tonnes to which indians contribution was about 55.5 million tonnes with 6th position on the world production.
- The discovery of the iron was the beginning of great industrial age of the iron ore minerals.
- It is widely available as oxides.

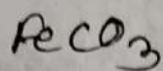
## Mineralogy :-

The chief ores of Iron are its oxides & carbonates the comp of them are

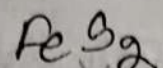
| <u>minerals</u>                             | <u>chemcomp.</u>                                  | <u>Fe%</u> | <u>remark</u>                                            |
|---------------------------------------------|---------------------------------------------------|------------|----------------------------------------------------------|
| <u>oxides</u>                               |                                                   |            |                                                          |
| Hematite                                    | $\text{Fe}_2\text{O}_3$                           | 69.9%      | steel grey to red colour, streak - cherry red, s.g - 5.6 |
| Magnetite                                   | $\text{Fe}_3\text{O}_4$                           | 72.4%      | Blue, black or brown-black colour & streak s.g - 5.17    |
| Turgite                                     | $2\text{Fe}_2\text{O}_3 \cdot \text{H}_2\text{O}$ | 66.1%      | Brown to red colour s.g $\rightarrow$ 4.2 - 4.7          |
| Goethite<br>(limonite)<br>Hydrated iron ore | $\text{Fe}_2\text{O}_3 \cdot \text{H}_2\text{O}$  | 62%        | Brown to yellow, s.g. $\rightarrow$ 3.3 - 4.3            |



Carbonate  
siderite  
Sulphide  
pyrite



48.2%



41.1% →

Ash grey to brown streak  
S.G. → 3.96

yellow colour

### Origin :-

- All most all the major Indian ore deposits are of sedimentary and residual origin.
- They occur in the rocks of the iron ore series (Archean) and their equivalents. They are closely associated with the banded - hematite - quartzite and are derived from them.
- The banded hematite quartzites are of sedimentary origin. This rock contains about 28-30% iron.
- Subsequently the silica of this rock is removed by leaching and the concentrated iron ore is left behind to form residual iron ore deposits. These deposits occur on beds which are upto 90m thick.
- The iron ore consists of massive, laminated and powdery hematite containing 60-69% iron.

### \* Classification of Iron ore deposit :-

#### 1. Metamorphic banded deposits :-

- The major iron ore deposits of India fall within this group. They are typically sedimentary or volcanosedimentary and metamorphosed rocks, consisting of rich iron ore and siliceous bands.
- They have been differently named in different countries, like Itabacites, Taconites, Jaspilites,



Banded hematite quartzites, metamorphosed iron ore.

→ Indian iron-ore deposits of Bihar-orissa belt, Bailadila (M.P) and those of Karnataka are typical examples.

→ The metamorphosed equivalent of this rock is banded magnetite quartzite.

## 2. Continental sedimentary deposits :-

→ These are assumed to have formed in fresh water (fluvial or lagoonal) or under brackish swamp (lacustrine) conditions.

→ Iron stones of Raniganj and Auranga coalfields are typical example of this type of deposits.

## 3. Marine sedimentary deposit such as oolites, detrital, placer and mixed type :-

→ The type ore is in Lorraine, France. The Indian example is magnetite deposits of coastal regions such as at Travancore associated with ilmenite and heavy mineral sand.

## 4. Volcano-sedimentary deposits :-

→ These deposits are related to the volcanic rocks of diabase group of initial geosynclinal magmatism.



- The ore-bearing horizons are sub marine and are bedded.
- Insignificant minor pockets of iron ore in Dera-Thasgam area Ladakh are the Indian example.

### 5. Liquid-magmatic deposits:-

- They are formed due to early crystallization of basic plutonic rocks, mainly by - gravitational differentiation.
- The typical Indian occurrence is that of titanovanadium bearing, iron-ore deposits of Mayurbhanj district Orissa.

### 6. Intrusive magmatic deposits:-

- They are related to alkaline rocks of the Precambrian shields. Apakke-magnetite rocks of Singhbhum represents this type.

### 7. Contact metasomatic deposits:-

- These are found at the contact aureoles of granitic intrusions within the limestone and are widely distributed. Main ore mineral is magnetite.
- Magnetite deposits of Kotwala, Vishakhapatnam, district, Andhra Pradesh and of Gorce and Besiba-bathan, Palamau district, Bihar are examples.



# Distribution :-

| <u>State.</u> | <u>Dist.</u>                                                | <u>locality</u>                                                  | <u>Remarks</u>                                                          |
|---------------|-------------------------------------------------------------|------------------------------------------------------------------|-------------------------------------------------------------------------|
| A.P.          | Guntur                                                      |                                                                  | magnetite ore is found                                                  |
| Bihar         | Singhbhum -                                                 | Namundi<br>Notaburki<br>Jamda, Gua<br>Jhilingbura<br>Pangirabuda | Titaniferous &<br>vanadiferous<br>magnetite is found                    |
|               | Palamau                                                     | Pathargora, Kumaria<br>Kharua, Singri                            | apatite-magnetite<br>ore is found                                       |
| Goa           | —                                                           | —                                                                | Banded iron ore<br>formation with good<br>hematite ore                  |
| Karnataka     | Ballariy<br>Hospet<br>Shimoga<br>Chitradurga<br>Chikmagalur | —                                                                | Banded iron ore<br>formation with good<br>hematite iron-ore<br>deposits |
|               | Tumkur                                                      | Kudramukh<br>Bababudanhills                                      | Magnetite iron ore<br>deposits are found                                |
| M.P.          | Bastar                                                      | Bailadila, Raughat<br>Parurekora near<br>Kanker                  | Banded iron ore<br>formation with good<br>hematite ore<br>deposits      |
|               | Durg                                                        | Dhali, Rayhara                                                   | - do -                                                                  |



Chanda Loharga, Pipalgaon,  
Asola, Deuralgaon

of these only Loharga  
deposit is large

Jabalpur Majgaon, Agarwa  
Barkoli, Cora, Jauli  
Kanhara hills

These ores are poorer  
and contain iron  
varying from 45 to  
60 percentage

Orissa Keonjhar Joda, Bhadrasahi  
Bolaria, Banspani

Sundargarh Khandabar, Barua  
Ballupahar

Mayurbhanj Gorumahisani pahar  
Similipal hills

Cuttack Daitari, Tamaka  
Kansa

Koraput Hircapur, Umar Kot

Banded iron ore  
formation with  
very good hematite  
iron deposits

Mayurbhanj BISOI - Raikarpur  
BISOI - Joshipur &

Baripada - Udala

Rajasthan Jaipur Udaipur, Alwar &  
Bundi

- lateritic magnetite  
is found

Banded iron ore  
formation with  
hematite ore

Tamilnadu Salem,  
Tiruchirappalli

magnetite ore is  
found



Uses :-

- Iron found its industrial use first time in 800 BC which marks the commencement of Iron age.
- The iron ore is basically used for the extraction of metal in the form of cast iron, wrought iron, steel & iron alloy.
- The iron metal finds its use both in home & outside. It has a major role in buildings construction, ~~iron~~ tools, machines, rails, railway wagons, automobiles, ships etc. besides domestic utensils.
- The other use of iron ore in coal washery as a medium for floatation.
- Iron ore is mainly utilised for making pig-iron, sponge iron and steel.
- Lumpy iron-ore is utilised after preliminary washing and screening for sizing.



## CHROMIUM :-

- Chromite is the only source of chromium metal required by the alloy steel industry.
- India has been one of the imp producers & exporters of this mineral.
- With the industrial advancement the demand of chromite has increased & so its production.
- The world chromite production has been increased & the contribution of India is self sufficient in the production of chromium metal.
- The chromite deposits of Odisha mainly belongs to the Sukinda as well as Nausahi belt of Jajpur dist & theoretically it contains 68%  $\text{Cr}_2\text{O}_3$  & 32%  $\text{FeO}$ .
- Chromite is iron-black brownish black in colour, streak brown, faint submetallic lustre, Fracture - Brittle, Hardness - 5 to 6, sp. gr. - 4 to 5.

\* Based on chemical composition, chromite types:-

- (i) High grade ore with very low iron oxide  
e.g. Sukinda - Nausahi (Orissa) with high  $\text{Cr}_2\text{O}_3$
- (ii) Ferriferous chromite with  $\text{Fe}_2\text{O}_3$  more than 30%.  
e.g. Jajpatti (Bihar) ore, Pauri (Maharashtra) ore & some ores from Sukinda - Nausahi (Orissa)
- (iii) ~~Ferriferous~~ Aluminous chromite with  $\text{Fe}_2\text{O}_3$  more than 20% & less than 30%.



e.g. Kondapali (A.P.) &  
Sitampudi (Tamilnadu)

(iv) Siliceous chromite with high  $SiO_2$  i.e.

e.g. Pauri (Maharashtra)

some of the chromites of Sukinda (Orissa)

→ The chromium:Iron (Cr:Fe) is 3:1 for Sukinda ore,  
2:1 for Chaibasa (Jharkhand) & Kondapali ores  
1.5:1 for Sitampudi ore  
1:6:1 for Pauri ores.

### Mode of occurrence :-

1. Banded, massive
2. Banded, crystalline
3. massive
4. crystalline
5. Disseminated forms

→ The Kondapali (A.P.) & Chaibasa (Jharkhand) ores are banded, massive, while Sukinda & Nausahi belt of Orissa ores are banded crystalline.

→ The disseminated ores are found in Kondapali (A.P.) & Nausahi belt.

→ Structurally there are mainly of 2 types.

1. Stratiform type deposit
2. Podiform " "



## 1. Stratiform type deposits :-

- In India the deposits of Sukenda - Nausahi, Chaibasa, Sittampudi, Kondapalle, Pauri, Byrapur, areas are associated with pyroxenite, peridotite & dunite of Precambrian age are represent stratiform type of deposit.
- All the deposits occur in long bands or lenticular bands & some of these are associated with Anorthositic gabbro, vanadiferous, magnetite bodies & nickeliferous ultramafic layers.
- Pyroxenite & peridotite are more common rock type though dunite is also found.
- The Cr:Fe is around 2:1 except on the case of Sukenda - Nausahi one where the Cr:Fe is 3:1.

## 2. Podiform type deposit :-

- They occur mostly in nodular forms & are associated with dunite & serpentinite.
- In India the deposits of this type are in Ladakh (J&K) & Manipur.
- They are associated with dunite & serpentinite and are emplaced into the Mesozoic, Tertiary geosynclines along core of the folds where the Cr:Fe is exceeding 2:1.



### Oreogen:-

- All most all primary chromite deposits that occurs within ultrabasic rocks & originated from concentration of early magmatic crystallization.
- However some workers site evidences of late magmatic or even hydrothermal chromite & in some cases disseminated grains have undergone residual concentration.

### Indian Distribution:-

The indian chromite deposits are distributed in the following 3 types of formation

1. The eastern Ghats group of rocks
2. The iron ore groups - Dharwar group of rocks
3. The tertiary formation

#### 1. The Eastern Ghat group of rocks:-

- The chromite is emplaced during the eastern orogeny.
- The chromite is associated with hypersthene, bronzite & diopside.

#### (v) Andhra Pradesh:-

- chromite deposits are found near Kondapalle in Krishna district. Here chromite occurs in serpentinized ultrabasic charnockites.



### (i) Tamilnadu :-

→ Chromite deposits are found near Sattampudi in Salem district. Here the chromite occurs in anorthosites and pyroxenites which are intruded as sheets in the biotite-gneiss.

### 2. The iron ore group - Dharwar group of rocks :-

→ Basically Bihar, Odisha, Karnataka, Maharashtra deposits belongs to this group

### (a) Bihar :-

→ Chromite deposits are found near Jajohatu & Rorobhera areas of Singhbhum district. These deposits occurs in dunite and saponite which intrude into the rocks of Iron-ore series. On the average the ore of this area contains about 53%  $\text{Cr}_2\text{O}_3$ .

### (ii) Orissa :-

→ It is the major chromite producing area in India.  
→ The chromite deposits occur in Keonjhar, Cutback & Shenkaral district in talc serpentine rock among the Iron-ore series. The ore is of high grade with 40-50%  $\text{Cr}_2\text{O}_3$ .

### (iii) Karnataka :-

→ Imp. chromite deposits are found in Hassan & Mysore districts. Chromite occurs in serpentinites peridotites & amphibolites among Dharwars.



Nagihalli - Sindhuvally - Talur belt.

(or) Maharashtra :-

→ The chromite deposits are found in Ratnagiri & Bhandara districts. Here chromite occurs as thin layers in serpentinites of Sakoli series. The ore is variable composition with  $\text{Cr}_2\text{O}_3$  betn 35-50%.

3. The tertiary formations :-

(i) In Jammu & Kashmir chromite deposits are found near Deras in Kargil district. Here chromite is associated with serpentinite & dunite.

(ii) In Manipur chromite deposits are found near Burobi peak, 'Nepali Basti' in Ukhrul Manipur district. Here sporadic occurrences on peridotite and serpentinite.

Uses :-

→ chromite is mainly used on metallurgical refractory & chemical purposes.

→ The metallurgical uses consist of a variety of alloys - mainly with Iron, Nickel & Cobalt.

→ The stainless steel contains 18% chromium & 8% Nickel.

→ chromite is an imp. raw material for refractories that withstand temp. about  $2000^\circ\text{C}$ .

→ It is also used in pigment manufacture, leather & textile treatment dyeing bleaching & oxidising agents.



## Copper :-

- Copper is called one of the base metal in industrial & commercial geology.
- The world refinery production of primary copper metal was about 10. million tonnes in 1990, to which contribution of India was about 40,000 tonnes i.e. - 0.4% with 30th position.
- The principal producers were Chile, USA, U & Canada, Zambia, Zaire, Poland and Peru which together accounted for more than 70% of world mine production.
- The world reserve of copper metal have been placed at 566 million tonnes
- The imp. ores of copper are chalcopryrite ( $\text{CuFeS}_2$ ) & Native Copper (Cu).

## Mineralogy :-

| <u>minerals</u>          | <u>Composition</u>        | <u>%</u> | <u>Physical properties</u>                                                |
|--------------------------|---------------------------|----------|---------------------------------------------------------------------------|
| <u>Sulphides</u>         |                           |          |                                                                           |
| 1. Chalcopryrite         | $\text{CuFeS}_2$          | 34.5%    | → Brass yellow with greenish black streak, $H = 3.5-4$ , $S.G. = 4.1-4.3$ |
| 2. Bornite<br>(Peak ore) | $\text{Cu}_5\text{FeS}_4$ | 0.3.3%   | → greyish black streak metallic lusture, $H = 3$ , $S.G. = 4.9-5.4$       |
| 3. Chalcocite            | $\text{Cu}_2\text{S}$     | 79.8     | → Blackish lead grey, metallic $H = 2.5-3$ , $S.G. = 5.5-5.8$             |
| 4. Covellite             | $\text{CuS}$              | 66.4     | → Indigo blue, $H = 1.5-2$ , $S.G. = 4.6$                                 |
| 5. Enargite              | $\text{Cu}_3\text{AsS}_4$ | 48.3     | → Greyish black to iron black, metallic, $H = 3$ , $S.G. = 4.4$           |



6. Tetrahedrite  $\text{Cu}_8\text{Sb}_2\text{S}_7$  52.1  $\Rightarrow$  steel grey to iron black  
metallic,  $H=3-4.5$   
 $S.g. = 4.5-5.1$

### Oxides:-

7. Cuprite  $\text{Cu}_2\text{O}$  88.8  $\Rightarrow$  brownish red streak,  
adamantine or submetallic to  
earthy lusture,  $H=3.5-4$   
 $S.g. = 5.8-6.15$

8. Tenorite  $\text{CuO}$  79.8  $\Rightarrow$  mostly in black powder  
 $H=3-4$ ,  $S.g. \Rightarrow 6.25$

### Carbonate:-

9. Malachite  $\text{CuCO}_3\text{Cu(OH)}_2$  57.3  $\Rightarrow$  Bright green encrustation  
 $H=3.5-4$ ,  $S.g. = 3.9-4$

10. Azurite  $2\text{CuCO}_3\text{Cu(OH)}_2$  55.1  $\Rightarrow$  Azure blue,  $H=3.5-4$   
 $S.g. = 3.7-3.8$

### Silicate

11. Chrysocolla  $\text{CuSiO}_3 \cdot 4\text{H}_2\text{O}$  36  $\Rightarrow$  Bluish green or sky  
blue, white streak,  
 $H=2-4$ ,  $S.g. = 2-2.2$

### Element:-

12. Native Copper  $\text{Cu}$  100.1  $\Rightarrow$  Copper red colour with  
metallic shining streak  
 $H=2.5-3$ ,  $S.g. = 8.8$



### \* Origin :-

- Copper deposits have largely originated from hydrothermal sol<sup>n</sup>.
- All copper ore bodies are closely connected with igneous rock mostly of an acidic nature.
- In these deposits the replacement dominates over cavity filling.
- Most copper deposits have undergone oxidation, and some supergene enrichment.
- Copper deposits generally show complex geometrical shapes.
- The mineralization is commonly in form of stringers, disseminated veins and massive lenses.

### Mode of occurrences :-

- Copper occurs in a variety of ways as magnetite segregation or disseminated forms in veins and lodes in contact metamorphic deposits or bedded deposits etc.

### (a) Disseminated ore bodies :-

- Here the copper bearing minerals are generally dispersed on a large volume of rock.
- This type yields the bulk of world's production.
- They are generally of low grade.
- The porphyry-copper deposits of USA are of this type.



(b) massive, irregular & lenticular bodies :-  
→ It is formed by the process of replacement

→

of vein deposits or lodes :-

→ In which the copper bearing solutions percolating along shear-zones and rock-features deposits copper minerals with changes of temp. & pressure forming fissure veins.

ex:- Copper deposits of Singhbhum

(d) deposits following stratigraphic beds :-

→ Some copper deposits of Khetri in Rajasthan.

Indian distribution :-

| <u>State</u> | <u>Locality/area</u> | <u>Remarks</u> |
|--------------|----------------------|----------------|
|--------------|----------------------|----------------|

|       |                                                                                                                   |
|-------|-------------------------------------------------------------------------------------------------------------------|
| Bihar | (i) <u>Singhbhum copper belt</u><br>Pathargora, Rakha, Turandih,<br>Roamadheshwar, Tamapahar,<br>Ramchandra pahar |
|-------|-------------------------------------------------------------------------------------------------------------------|

→ The belt extends from Duarpuram in the west to Barahagora in the south east.

(ii) Hesatu-belbathan belt :-

There are 4 dozen occurrences covering the whole belt, the imp. of them are at, Chandian, Jbalakdih, Granganpur Dange, Toolaitan, Pirurah and Baghorari.

→ The belt extends in NW-SE direction for about 250 km having a width of about 50 km from Hesatu in west to Belbathan in the east.



Rajasthan (i) Khetri copper belt  
Jhunjhunu dist.

The potential areas are  
madhan Kudan, Kalihans  
Chammarci

→ The Khetri belt runs  
for about 80 km in the  
north east part of the  
state.

(ii) Pun-Banera-Ghipder belt

The potential deposit is at  
Dirciba in Alwar district.

→ It runs for about  
135 km in south  
eastern part of the  
state and include 4  
smaller belts. Pun-  
Banera, Jasra-Recura  
-Karo, Rajpura-  
Dariba, Bethani &  
waree Bhopal sager.

(iii) Detached occurrences, namely  
at pali, Sirohi, Udaipur, Churu  
& Nagpur

Madhya Pradesh Malanj Khand, Balaghat  
district

→ It extends for 26 km  
in arcuate form.

Karnataka Ingaldah in chetradurga  
district & Kalypadi in Hassan  
dist.

A.P. mailakam, Khammam dist.,  
Gare Kurnool dist., Bandalmotu  
Nallakonda & Dhokonda,  
Agnigundela belt, Guntur dist

Himachal Pradesh Kangra, Kulu valley



West Bengal Darjelling,  
Jalpaiguri

Girkeim Rangpo & Dikchu  
Bhotang, Chakong,  
Rangit valley area

Uses :-

- It is a soft metal and can be easily shaped so it is used in ornaments and vessels.
- The metal is of great industrial importance because of its high electrical conductivity, high ductility & malleability.
- Thus it is mostly used in electrical industry as conductors, windings, stream engine automobiles tractors & other machine.
- The copper alloys are used in building, air planes, naval ships, household utensils as well as metallurgy and paints.
- It is also used for making bronze, gun metal & brass.



## Lead & Zinc :-

- Lead and zinc ore occur, generally together in close association.
- India's present need for lead & zinc is met mostly about 80% by imports from foreign countries.
- With the growth of civilisation the demand of these metals is also increasing.
- The total world production of lead and zinc metals in 1990 were about 5.7 & 7.4 million tonnes, respectively to which India's contributions were about 0.7% (0.040 m. tonnes) lead & about 1% (0.070 m. tonnes) zinc.
- U.S.A, Russia, Japan, Germany, U.K., Canada, France, Australia, Belgium & China together produce about 70% of the world production of refined lead & zinc metals.

## Mineralogy :-

### Lead :- (Pb)

- It occurs in native state, but it is quite rare.
- The metal is bluish grey in colour & shows on its fresh surface a bright metallic lustre which quickly oxidises on exposure to air.
- It is so soft that it can be scratched with finger-nail & shows a black streak on powder.
- It is however quite heavy, the s.g. 11.34
- The chief ore of lead are found



| ore       | chem comp <sup>n</sup> | %     | Physical properties                                                                             |
|-----------|------------------------|-------|-------------------------------------------------------------------------------------------------|
| Galena    | PbS                    | 86.6% | → Perfect cubic cleavage, lead grey colour, metallic lusture, H = 2.5<br>S.G. = 7.4-7.6         |
| Cerussite | PbCO <sub>3</sub>      | 77.5% | → white or greyish colour, with colourless streak, adamantine lusture, H = 3-3.5<br>S.G. = 6.55 |
| Anglesite | PbSO <sub>4</sub>      | 68.3% | → white, blue, grey, green or yellow tint, adamantine lusture, H = 2.5-3, S.G. = 6.3-6.4        |

### Zinc :-

- It is a bluish white brittle metal with a S.G. of 7.15 & m.p.  $\Rightarrow 419^{\circ}\text{C}$ .
- It may be rolled into sheets or drawn into wire bet<sup>n</sup>  $100^{\circ}\text{C}$  &  $150^{\circ}\text{C}$  but reverts into a brittle cond<sup>n</sup> at  $300^{\circ}\text{C}$  & may be readily powdered under hammer.
- It is soluble in ductile acids.
- It is the 24th most abundant element on earth's crust & has few stable isotopes.
- It is refined by froth floatation of the ore, roasting and final extraction using electricity.
- Sulphuric acid is produced as a by product.



Ores    chem comp?    %    Physical properties:-

Sphalerite  $ZnS$     67%  $\rightarrow$  black or brown colour, white, reddish brown streak, resinous to adamantine-lusture,  $H=3.5-4$   
 (Zn blende)    s.g. = 3.9-4.2

Smithsonite  $ZnCO_3$     52%  $\rightarrow$  white, greyish, greenish or brownish white colour, with white streak, vitreous lusture on cleaving to pearly,  $H=5.5$   
 s.g. = 4-4.5

Zincite  $ZnO$     80.1%  $\rightarrow$  Red, orange, yellow, white colour with orange yellow streak & conchoidal fracture.

Hemimorphite  $2ZnO \cdot 3SiO_2 \cdot 2H_2O$     54.2%  $\rightarrow$  green colour, blue-green, white, brown, yellow & vitreous lusture

Gahnite  $ZnAl_2O_4$      $\rightarrow$  yellow & vitreous lusture

$\rightarrow$  Galena & zinc blende are commonly found together & form mixed lead & zinc ore deposits

$\rightarrow$  The galena frequently contains some silver & such ores are called argentiferous galena.

$\rightarrow$  Pyrite & chalcopyrite are commonly found in association with galena & zinc blende.



### Oreogen:-

→ Most of the deposits of lead & zinc ores are of hydrothermal origin.

The galena & zinc blende are commonly deposited by low temp hydrothermal sol<sup>n</sup>.

The deposits of lead & zinc are mostly occurs as cavity fillings and replacement on limestones & dolomites.



many deposits may show signs of oxidation.  
→ The sulphide ores are also formed due to contact metasomatism.

### Mode of occurrence:-

- most of the lead ore mines of the world are also zinc ore producers and nearly all zinc ore deposits carry lead ore.
- The chief mode of occurrence are as lodes or veins, as metasomatic replacement & contact metamorphic deposits as cavity or joint fillings or as dissemination.
- Most deposits of lead & zinc are confined to limestone, dolomite & other calc-magnesium rich rocks.
- The ores of lead & zinc (galena & sphalerite) are found in close association and are oxidised on their upper parts into only salts of which the most imp economically are cerussite, anglesite, smithsonite, zincite, willemite ( $ZnSO_4$ ) etc.
- In Zawar Rajasthan, they occur on fine grained dolomite & gritty conglomeratic dolomite with subordinate inter bedded phyllite & quartzite as sheeted zones, veins, stringers & dissemination, forming lenticular bodies arranged in enechelon pattern.
- While in the Hazrat - Belbathan belt, Bihar, they are



limited to calc-silicate

# Indian distribution:-

| <u>State</u> | <u>dist</u>                                                   | <u>Area</u>                                                  | <u>total reserves<br/>ores in million<br/>tonnes</u> | <u>grade</u>                              |
|--------------|---------------------------------------------------------------|--------------------------------------------------------------|------------------------------------------------------|-------------------------------------------|
| AP           | Cuddapah                                                      | Verikunta<br>Zangamarajupat<br>Gollapalle                    | 8.319                                                | 0.64- 8.88% Pb<br>1.08- 4.21% Zn          |
|              | Cuntur                                                        | Bandalamottu<br>Dhukonda<br>Karempudi<br>(Agni gundala belt) |                                                      | -                                         |
|              | Prakasam                                                      | Nallakonda                                                   |                                                      |                                           |
| Bihar        | Godda<br>Banka,<br>Deoghar<br>Jamui<br>Hazari Bagh<br>Giridih | Hesatu -<br>Belbathan<br>belt                                | 0.55                                                 | Av. 2-5.5% <del>Pb &amp; Zn</del> Pb & Zn |
| Gujarat      | Banaskantha<br>Vadodara                                       | Ambamata<br>Chitrasani<br>Khandva                            | 7.775                                                | Av. 4.5% Pb & Zn                          |
| Maharashtra  | Nagpur                                                        | Kolaru &<br>Tambekhani                                       | 1                                                    | Av 3% Zn                                  |
|              | Bhandara                                                      | Mlendki                                                      | 0.118                                                | Av 0.04% Pb<br>2.83% Zn                   |
| Meghalaya    | Khasi &<br>Jharkia hills                                      | Umpyetha                                                     |                                                      | 1.35% Cu                                  |



Odisha Sundargarh Sargipalli 2.630 Av 6.69% Pb  
0.32% Cu

Mayurbhanj Kesarpur —  
Sambalpur Katmali —

Rajasthan Ajmer Ghuagra 8.32.716 0.51-5.49% Pb  
Lokakan + 17.16 0.40-7.30% Zn  
Sawar  
Tikhi

Bhilwara Rampur Agucha —  
Pur Banera

Sirohi Deri —  
(Basantgarh-Delri belt)

Udaipur Zaurar area —  
(Mochia, Balarua Barot)  
Rajpur - Dariba

Sikkim East sikkim Bhotang & 0.950 av 1.09% Pb  
(Rangpo) Dikhu 2.59% Zn  
1.08% Cu

Tamil Nadu South Arcot Mamandar 0.679 Av. 1.13+1.17% Pb  
5.20-5.40% Zn  
0.53-0.67% Cu

Uttar Pradesh Pithoragarh Askat 1.030 av. 2.64% Pb  
3.95% Zn  
2.32% Cu

West Bengal Dargjeeling Gorubathan 3.250 Av 4.01% Pb  
4.23% Zn



### Uses:-

- Lead and zinc are the most essential nonferrous metals that are used in modern industry.
- Lead is used in construction of accumulators, for lead piping and sheeting, cable covers, as pigments in glass making, in medicine, insecticide, plum and rubber industry, electrical storage batteries.
- Zinc is used for coating, galvanising iron and steel products, in dry battery in pigments, soldering, preventing decay in wood, dying, glue making, making of alloys like brass, bronze, german silver, making of toothpaste tubes, in textile industry etc.

### Maharashtra:-

- Chromite deposits are found in Rantogere & Bhandra districts. Here chromite occurs as thin layer in serpentinites of Sakoli series. The ore is variable composition with  $\text{Cr}_2\text{O}_3$  bet<sup>n</sup> 35% to 50%.

- 3. The tertiary formation:-  
In gamma & Kashmir chro



## UNFC :- (United Nations Framework Classification)

- \* UNFC for energy & mineral resource is a universally applicable scheme for classifying/evaluating energy & mineral reserves & resources.
- \* It uses a numerical codeification system of the 3 diff<sup>n</sup> geological and technical stages.
- \* most imp. it allows a common and necessary international understanding of these classifications/evaluations. The classification is designed to allow the incorporation of currently existing terms and definitions into the frame work and thus to make them comparable and compatible.
- \* It has the further advantages of providing a short, unambiguous identification of the reserve/resource classes, which facilitates computer processing of data as well as exchange of information.

→ The numerical codeification of UNFC comprises 3 digit representing

1. economic viability
2. Feasibility assessment
3. Geological.

→ The economic viability categories (E) refer to quantities extractable at present, quantities possibly extractable in future and quantities with prospects of being economically extractable not yet defined.



→ The feasibility assessment (F) refers to engineering, economic, legal, environmental and other relevant appraisal.

→ Geological assessment refers to geological, geophysical, geochemical, chemical, mineralogical and other relevant investigations.

→ These 3 degrees are quoted on the order EFC<sub>1</sub>.

Because firstly alphabetical order is easy to memorise and secondly, first degree refers to economic viability, which is of decisive interest to both industry and investors).

→ Numbers are used to designate the degree of economic viability and the different stages of feasibility assessment and geological assessment.

→ The first and the lowest number refers to the highest degree of economic viability, feasibility assessment and geological assessment.

→ Economic viability again divided into 3 categories viz Economic (E<sub>1</sub>), Potentially Economic (E<sub>2</sub>), Intrinsically economic (E<sub>3</sub>).

→ Feasibility assessment divided into 3 categories viz, Feasibility and mining report (F<sub>1</sub>), Prefeasibility study (F<sub>2</sub>) and Geological study (F<sub>3</sub>).

→ Geological assessment divided into 4 categories, viz Detailed exploration (G<sub>1</sub>), General Exploration (G<sub>2</sub>), Prospecting (G<sub>3</sub>) and Reconnaissance (G<sub>4</sub>).



→ The highest category of resources under UNFC system will have the code (111) and the lowest category the code (334).

### 'E' axis category definitions:-

E<sub>1</sub> → extraction and sale has been confirmed to be economically viable

E<sub>2</sub> → Extraction & sale is expected to become economically viable in the foreseeable future

E<sub>3</sub> → Extraction & sale is not expected to become economically viable in the foreseeable future or evaluation is at too early a stage to determine economic viability

### "F" axis category definitions

F<sub>1</sub> → Feasibility of extraction by a defined development project or mining operation has been confirmed

F<sub>2</sub> → Feasibility of extraction by a defined development project or mining operation is subject to further evaluation.

F<sub>3</sub> → Feasibility of extraction by a defined development project or mining operation can't be evaluated due to limited technical data

F<sub>4</sub> → No development project or mining operation has been identified



## "G'arus' category definition :-

- G<sub>1</sub> → Quantities associated with a known deposit that can be estimated with a high level of confidence
- G<sub>2</sub> → Quantities associated with a known deposit that can be estimated with a moderate level of confidence
- G<sub>3</sub> → Quantities associated with a known deposit that can be estimated with a low level of confidence
- G<sub>4</sub> → Estimated quantities associated with a potential deposit, based primarily on indirect evidence

→ The various terms used in this classification and their definitions are as follows.

### \* Total mineral Resources :-

- a concentration (or occurrence) of material of intrinsic economic interest
- Reasonable prospects for eventual economic extraction.
- Location, grade, quantity, geological characteristics known, estimated or interpreted from specific geological evidence and knowledge

### (i) measured mineral Resource (331)

→ That part of a mineral resource for which tonnage, densities, shape, physical characteristics, grade & mineral content can be estimated with a high level of confidence i.e. based on detailed exploration.



(i) Indicated mineral Resource (332) :-

Tonnage, densities, shape, physical characteristic, grade and mineral content can be estimated with reasonable level of confidence based on exploration, sampling and testing information, location of borehole, pits etc too widely spaced.

(ii) Inferred mineral Resource (333) :-

Tonnage, grade and mineral content can be estimated with low level of confidence. Inferred from geological evidence.

\* Mineral Reserve :-

→ Economically mineable part of measured and/or indicated mineral resource.

(i) Proved mineral reserves (111) :-

→ Economically mineable part of measured mineral resource.

(ii) Probable mineral Reserves (121 & 122) :-

→ Economically mineable part of indicated or in some cases a measured mineral resource

\* Reconnaissance Mineral Resource (334) :-

→ Estimate based on regional geological studies and mapping, airborne and indirect methods, preliminary field inspections as well as geological inference and exploration.



## \* Pre-feasibility Mineral Resource (221 & 222) :-

- The part of an indicated, and in some circumstances measured mineral resource that has been shown by pre-feasibility study to be not economically mineable.
- Possibly economically viable subject to changes in technological, economic, environmental and/or other relevant conditions.

## \* Feasibility Mineral Resource (21) :-

- The part of measured mineral resource, which after feasibility study has been found to be economically not mineable.
- Possibly economically viable subject to changes in technological, economic, environmental and/or other relevant conditions.



## Definition of terms of Indian system:-

### (a) Reserve:-

→ specific bodies of natural concentration of minerals whose location, quality, broad shape and quality are known from geological evidence, supported by actual measurements. These resources can be in situ or recoverable depending on whether losses on mining, beneficiation etc. have been estimated and taken into account or not.

### (i) Assure reserve:-

→ This term is used only for coal. It means estimation of reserve and grades of very high confidence level and which are economically mineable - gradewise and depthwise.

### (ii) Proved reserve:-

→ Tonnage in ore bodies and average characteristics sufficiently known.  
→ Exploration by closely spaced boreholes, pits, trenches, large scale maps.  
→ Reliable measurement of thickness, quality, mineralogical composition etc.  
→ Reliable evaluation of shapes, physical continuity, structure, tenor, amenability to beneficiation etc.



### (iii) Probable Reserve:-

Estimation based on wide spread sampling points such as outcrops and boreholes/pits/trenches with reasonable extrapolation.

### (iv) Possible reserve:-

- First approximation of quantitative commercial evaluation of ore body.
- estimates on the basis of assured continuity of ore on the strength of geological inference.
- very widely spaced or scattered sampling points.
- past mining records
- analogy with similar deposits
- Geological interpretation of geophysical and geochemical anomalies

### (b) Prospective resource:-

- Part of undiscovered resource comprising estimates not based on measurements of basic parameters but are made in known mineral districts/belts on several considerations such as (i) exploration on strength of geological condition (ii) projection based on geophysical and geochemical studies / anomalies



### (c) Prognostic resource:-

Resource guessed intuitively or by modelling approach for unspecified areas.

### (d) Conditional resource:-

→ Resource which are presently not economically but are likely to become so subject to favorable changes in factors like price, infrastructure, legislative constraints, technology etc.



Sampling :-

→ It is an art of collecting small fraction of material so as to represent the whole mass.

OR

→ Sampling requires collection of ore (samples) from a small portion of the ore body that will represent the physical, chemical and mineralogical characteristics of the whole body.

\* Physical character :-

- (i) Hard & soft determines the amenability to beneficiation.
- (ii) Cohes & strength affects the industrial use and hence the grade of the ore.

Chemical character :-

Important constituents of ore, metal content & impurities present affect the grade and specification of the ore.

Mineralogical character :-

Minerals present in what combination, determine the extractability characteristics.



## Principle of sampling:

- A large no. of samples are required to be obtained for providing satisfactory approximation to the grade and the physical characteristics of the deposits.
- How much and how the sample should be drawn depend upon various geological factors like nature, shape and size of a deposit and the purpose and scope for which it is required.
- The samples may be drawn from outcrops, trenches, pits, boreholes or from different sections of the quarry and underground mine.

## Purpose of sampling:

- To find out a new mineral/ore deposit
  - To determine the average grade for a particular tonnage
  - To study the variation or distribution of economic mineral on the deposit showing rich portion and lean portion.
  - To study the physical character, metal content, important constituents, impurity present which determine the processing (treating/beneficiation/characteristics of ore dressing/ and extractability/ smelting) characteristics of the deposit.
- The main purpose of sampling is to determine the average mineral value in the deposit.



## Procedure of sampling:-

- A sample should be true representative of the entire ore body. In order to achieve this samples are collected from exposed portions over the entire ore body place at regular intervals.
- The sampling pattern as to place, number and volumes of samples depends upon the nature, shape size and regularity of mineralisation in the deposits.
- Samples collected carefully are to be properly kept indicating the place of collection and number of samples as such properly labeled.
- It should be kept under safe custody to avoid salting and loss.
- Samples collected from the places are to be shown on plans with separately indicating the very rich and very lean portions.

## Types of sampling:-

### (i) Chemical sampling:-

Here the samples are taken for assaying and determining the content valuable and deleterious components in the body of useful minerals.



## (i) Technological sampling :-

Here samples are collected for the study of technological properties of raw material made in course of its beneficiation and processing.

## (ii) Technical sampling :-

→ Samples are taken to study a technical properties of raw materials which doesn't require a metallurgical or chemical treatment.

## \* Different methods / Techniques of sampling :-

→ 5 methods

(i) chip or point sampling

(ii) Bulk sampling

(iii) Grab sampling

(iv) Channel or groove or Trench sampling

(v) Borehole sampling

Occasionally special sampling like ear or wagon sampling, Run of mine sampling, stock sampling and muck or face or lump sampling are done.

→ The suitability or selection of the method depends on the nature of deposit / type of mineralization and is indicated below.



(i) when an ore body is thick with uniform mineralisation - chip or grab sampling is adopted.

~~(ii) when ore body is of medium size with uniform mineralisation -~~

(ii) when ore body is of medium size with uniform mineralisation - combine channel and chip sampling

(iii) when ore body is very thin but occurs in benches or layers - chip sampling

(iv) when ore body is very large requiring large number of samples - chip sampling

(v) Ore body shows sporadic, patchy and irregular mineralisation as in case gold and rare mineral - bulk sampling

(vi) when the ore body is banded - channel sampling

(vii) very hard ore particularly in massive iron ore blast hole eatings



## Channel sampling :-

- This is the conventional method of sampling and is best suited to bedded, banded and vein deposits.
- In this sampling a channel is cut across the face of the exposed ore running along its entire width and the resultant cuttings as chips, fragments and dust from each channel are collected to make a sample.
- In order to draw uniform quantity of material from the surface a channel of 5 to 10 cm width and 2.5 cm in depth and extending across the width of the ore body from the footwall to hanging wall is cut.
- If the surface is highly irregular then the channel may be cut to a greater depth.
- After the channel is made, sample is drawn by further deepening the groove by means of moil or chisel and hammer to a depth equal to the width of the channel.
- It is always desirable to cut channel across the ore body i.e. to the true width.
- But in trenches, a gently dipping ore body, it is convenient to have a horizontal groove instead of the usual inclined groove.



## Bore hole sampling :-

- Drill holes are used to collect samples, samples are collected for every 5 ft, run to drilling.
- It is a sub-surface sampling method.
- It determines the deposits boundaries.
- The samples are usually collected beyond the walls of underground working with a constant cross-section.
- Depending upon the type of deposit and degree of mineralisation, the whole mineralised portion of core may be taken as one sample or subdivided into 2 or more samples and assayed separately.
- The sludge and core analysis are studied together to determine the grade of the ore.

## Muck Sampling :-

- It is a grab sampling by picking up pieces of ore of convenient size from the muck pile (broken ore) after blasting.
- It also referred to group of point sampling.
- This is done when the values are uniformly distributed.



- The purpose of this sampling is to find out the mineral and also the chemical composition.
- It is very simple, quick and cheap but ~~not~~ accuracy is low.

### Car Sampling :-

- It is obtained by taking pre-determined quantity of run of mine from each car load or wagon loader coming from the face.

- \* It determines the physical properties and flexibility.

### CONCLUSION:-

- A sample should represent as closely as possible the value contained in material from which it is taken.
- Sampling is useful in almost all stages of exploration.