

LEARNING MATERIAL ON ENGINEERING GEOLOGY-II & MINE GEOLOGY-II



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CONCEPT OF STRATIGRAPHY

Stratigraphy

It is a branch of earth science, which deal with the sequential arrangement of layered rocks according to the time of their formation on the surface of the earth. That is the study of 3-D spatial and temporal relationship among rocks. *Stratigraphy* can be considered as the relationship between rocks and times, and the *stratigrapher* is concern with the observation, description and interpretation or direct and tangible evidence in rocks to determine the history of the Earth. The term ‘Stratigraphy is derived from the Latin word- **Stratum** and the Greek word- **Graphia**, which means “writing about the strata”

Stratigraphic studies involves the three basic phases namely,

- i. Description of local stratigraphy succession and their sub division in to units, from which studies chronologically, ordered geologic events of the locality, can be studied.
- ii. Correlation:- Correlation of the rock formations of different region from an important theme of stratigraphy. The correlation aims at matching of rock formation of the rock formation of the distant areas deposited at the same stage of the earth evolutionary history.
- iii. Interpretation:- Stratigraphy aims at interpretation of stratigraphic records of in terms of paleogeography, paleoenvironment, etc.

➤ History of the Stratigraphy

Stratigraphy had its origins in the Renaissance writings of Nicholas Steno (1638-1687) who was the first to write about sedimentary strata. He observed strata exposed in the Arno River Valley of Italy, and noted three axiomatic ideas, which became known as the first three “laws” of stratigraphy. These laws are known today as superposition lateral continuity and original horizontality.

Steno’s writings were full of common sense. In super-position, he noted the important criterion for relative age dating. In lateral continuity, he wrote about how correlation of sedimentary layers would be possible. In original horizontality, he noted the criterion necessary for any sort of analysis of later deformation, that, is the original state of a sedimentary layer can be assumed to be horizontal.

The first practical large scale application of stratigraphy was by *William Smith* in the 1790’s and early 19th century. Smith, known as the father of English Geology, created the first *geologic map* of England, and first

recognized the significance of *strata* or rock layering, and the importance of fossil markers importance of correlating strata.

➤ Principles of Stratigraphy

There are some guiding principles, upon which the knowledge of stratigraphy is based. They can be summarized as follows:

- Principle of Uniformitarianism
- Principle of Original horizontality
- Principle of Superposition
- Principle of Original Lateral Continuity
- Principle of Cross-Cutting Relationships
- Principle of Inclusion
- Principle of Faunal Succession

- i. Principle of Uniformitarianism: This principle was proposed by James Hutton, popularly known as *Father of Modern Geology* and was popularized by Charles Lyell. According to this principle, the same process and principles (e.g., erosion, transportation of materials, etc.) that cause change on the earth today have operated in the past to produce similar changes. Uniformitarianism, in the philosophy of science, assumes that same natural processes that operate in the universe now, have always operated in the universe in the past, and at the same rates; and that the same laws of nature apply everywhere in the universe. Its methodology is frequently summarized as “the present is the key to the past”, which means that all things continue as they were from the beginning of the world.



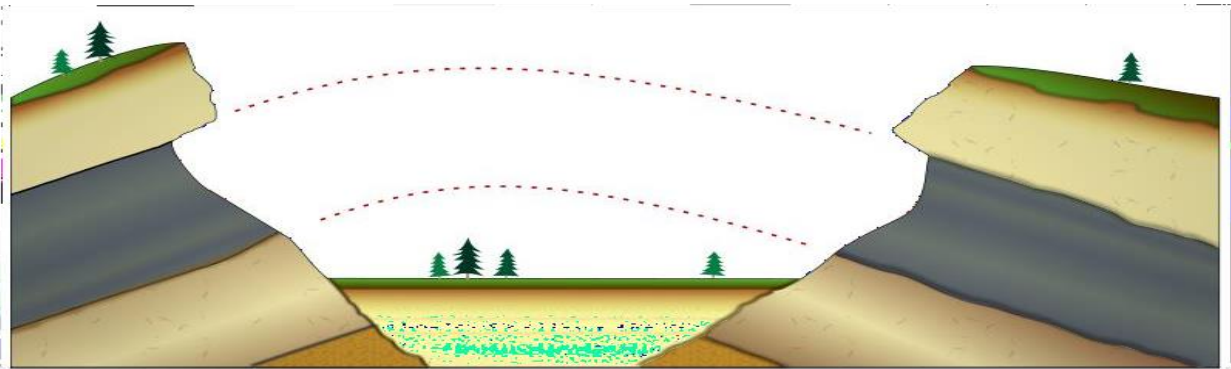
- ii. Principle of Original horizontality: Principle of Original Horizontality was proposed by the Danish geological pioneer Nicholas Steno (1638-1686). This principle states that layers of sediment are originally deposited horizontally. Sedimentary particles settle from fluids under the influence of gravity. Thus, sediments must have been deposited in layers that were nearly horizontal and parallel to the surface on which they were accumulating.



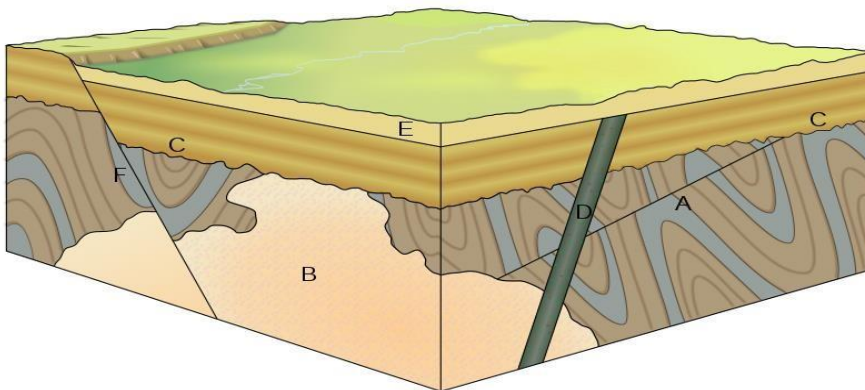
- iii. Principle of Order of Superposition: States that sedimentary layers are deposited in a time sequence, with the oldest on the bottom and the youngest on the top. i.e., for any sequence of undisturbed strata, the oldest layers are the bottom, and successively younger. The law was formulated more clearly in the 17th century by Nicholas Steno.



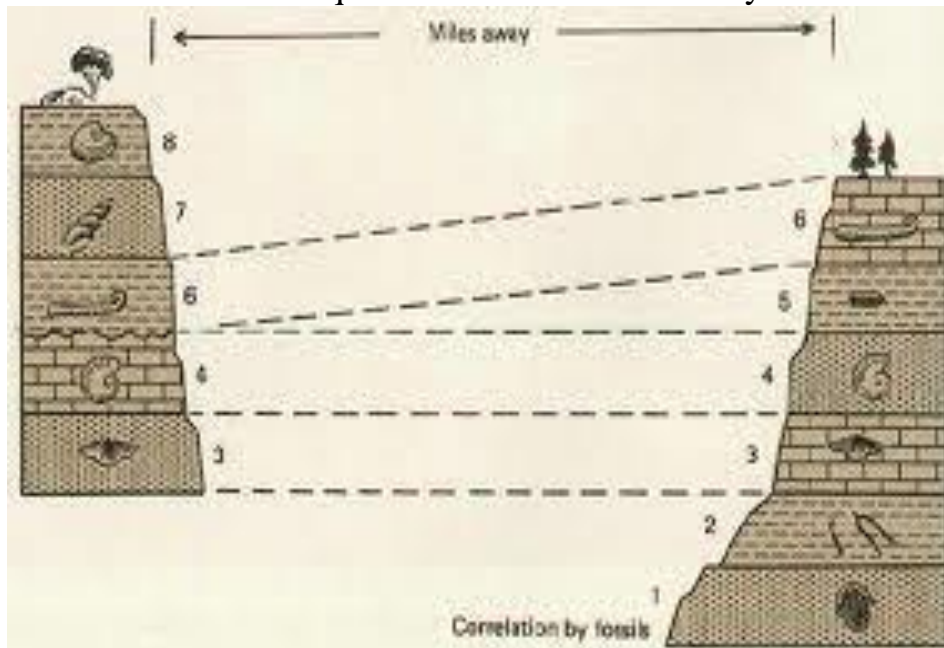
- iv. Principle of Original Lateral Continuity: The principle of Lateral continuity states that layers of sediment initially extend laterally in all directions; in other words, they are laterally continuous. As a result, rocks that are otherwise similar, but are now separated by a valley or other erosional feature, can be assumed to be originally continuous. The principle can also be stated as “At the time of deposition, soft sediments spread out laterally in all directions until they either thin out (due to lack of material) or run into a barrier, such as the edge of a geologic depression”. Layers of sediment do not extend indefinitely; rather, limits can be recognized and are controlled by the amount and type of sediment available and the size and shape of the sedimentary basin. As long as sediment is transported to an area, it will eventually be deposited. However, as the amount of material lessens away from the source, the layers of that material will become thinner.



- v. Principle of Cross-Cutting Relationships: states that- Any structure that cuts across another feature must be younger than that feature. A rock or fault is younger than any rock (or fault) through which it cuts. This principle was developed by James Hutton. For example, in a series of horizontal sedimentary beds, if there is an igneous dyke which cuts vertically through them, the dyke is younger than the sediment beds through which it crosses, as the beds would have been formed before the dyke could have intruded.



- vi. Role of inclusion: If the inclusions are found in a formation then the inclusions must be older than the formation that contains them.
- vii. Principle of faunal succession: is based on the observation that sedimentary rock strata contain fossilised flora and fauna, This principle, first identified in the early 1790s by the geologist William Smith, is of great importance in determining the relative age of rock and strata .The fossil contents of rocks together with the law of superposition helps to determine the time sequence in which sedimentary rocks were laid down.



Stratigraphy How to help us.?

- ❖ We all recognise that our planet is a dynamic one. where platetectonic creates mountains ocean and where changes in atmosphere affect the climate perheaven on a human time scale. To understand how those global system works, we need a record of their past behaviour to analysis (law of uniformitarianism) and this is provided by stratigraphy.
- ❖ Stratigraphic classification
- ❖ Correlation
- ❖ The stratigraphic record of sedimentary rocks is the fundamental data base for understanding the evolution of life, Plate Tectonics through time and global climatic change.
- ❖ Predict the climatic change in the future.

- ❖ If information about evolutionary changes.
- ❖ Gives a standard stratigraphic scale through correlation.
- ❖ History of earth.
- ❖ Finding new resources- 'Sequence stratigraphy' is a predictive technique widely used in the hydrocarbon industry, help to find new resources of oil and Gas.

➤ **Types of Stratigraphy**

Stratigraphy classified based on the different characters. Such as lithology, fossil content, time of origin, electrical characters seismic response, magnetic characters etc.

Stratigraphic Units

It is either a stratum or an assemblage of adjacent strata, that can be recognised as a unit in the stratigraphic classification on the basis of their specific properties.

i. Lithostratigraphy:

Lithostratigraphy is a study of formations, which are physically continuous packages of strata that have a consistent lithic character (grain size and mineralogical composition, bedding, biofacies) that differ in an objectively recognizable way from adjacent units.

Formal Lithostratigraphic Units

- **Formations:** It is the fundamental mappable units of rock stratigraphic classification, represent a series of strata that apparently originate through the same formative process are called as the formation. The name of formation includes two parts as lithologic area and typical lithology.
Eg: Quilon Limestone, Spiti Shale.
- **Group:** It is the assemblage of two or more formations, naming based on the geologic area. Eg: Nallamalai group, Kistna Group

- **Member:** It is the named lithological subdivision of formation. The features which cannot be identified in the map such as colour, hardness, composition, etc. Which are used for indicating member.
- **Bed:** It is the lithologic subdivision of member. It is the smallest division.
- **Flow:** It is the smallest distinctive layer in a volcanic sequence.
- **Complex:** It is the two or more group.

ii. **Biostratigraphy**

It is the element of stratigraphy that yields with the distribution of fossils in a stratigraphic record and organisations of strata into units on the basis of fossil content.

Biostratigraphic Unit

- These are the bodies of strata that can be defined as an unit on the basis of fossil content.
- Some times the Biostratigraphic units based on the single taxon and combination of taxa-morphological features content of fossils etc
- Lithostratigraphic unit may repeated in different, but biostratigraphic unit will not repeat, because the organism undergoing evolutionary changes.
- *Biozone* is the fundamental unit of Biostratigraphic classification.

Types of Biostratigraphic Units

Range zone (taxon range zone, concurrent range zone), Interval zone, Lineage zone, Assemblage zone, Abundant zone- These are the fundamental Biostratigraphic units.

iii. **Chronostratigraphy**

It is the element of stratigraphy that deals with the time of origin of rock or age of the rock. It is an attempt to organize the sequence of strata into units that relate to time, determine local time relations, correlate globally thus establish a standard global chronostratigraphic scale. The rank chronostratigraphic unit is based on time, not thickness.

Geochronologic unit	Chronostratigraphic unit
Eon	Eonanthem
Era	Eratham
period	System
Epoch	Series
Age	Stage

iv. Sequence Stratigraphy

Sequence stratigraphy is a sub discipline of stratigraphy, the later being defined as the historical geology of stratified rocks. The Exxon definition-Sequence stratigraphy is a genetically related sedimentary packages or sequences (units, beds, bed sets, etc.,) bounded above and below by unconformity or their correlative conformities. It provides the architecture of a depositional sequence like the rate of sediment supply, rate of subsidence/accommodation volume and sea level change. Sequence stratigraphy had developed into a powerful, predictive facies analysis tool for both the hydrocarbon industry and academic work.

Sequence stratigraphy is a an unparalleled exploration tool for oil, gas, coal as well as a production tool for reservoir development. It works for both clastic and carbonate systems. For Geophysicists it provides techniques for chronostratigraphic interpretation of seismic lines that provide; (1) the ability to age date to at least the period level seismic strata in previously un explored basins, (2) more accurate facies identification in unknown strata, (3) identification of probable source rock intervals and the location of probable reservoir facies, and (4) the development of both tectonic and sedimentation histories of new basin or basins where data are sparse or limited in aerial extend. For geologists, as stated by Van Wagoner et al., its application will result in “(1) more accurate surface for mapping and facies correlation and (2) higher-resolution chronostratigraphy for improved definition of plays, especially the stratigraphic traps”

v. Seismic Stratigraphy

Concept of seismic facies gave a new dimension in interpreting seismic data and eventually led to seismic stratigraphy. Seismic stratigraphy deals with identification of stratigraphic record from seismic data, i.e., facies tracts from seismic facies bound by strong reflectors considered time-parallel boundaries, and delineation of stratigraphic sequences by the succession of such facies tracts which could be validated with reference to well and surface out crop data. Over a period of more than a decade, 1960-1970, Vail and his coworkers in Exxon studied seismic reflection data and rationalized the concept and methods of seismic stratigraphy They work eventually led to the recognition of

sequence stratigraphy model for the interpretation of seismic records and building of regional/global stratigraphic synthesis. This in turn enabled them to work out the global sea-level chart. Seismic stratigraphy has the ability to trace unconformity-bounded into areas where the unconformable surfaces are not recognizable e.g., depocentral part of a basin.

The limitations in a seismic section is the resolution of minimum of 40-50 m, where as in out crops it is < 1 m and micro-sequence can be resolved.

vi. Magnetostratigraphy

Magnetostratigraphy is the study of the fossil (remnant) magnetism in rocks to identify the patterns of changes in earth's magnetic field for the stratigraphic purposes.

Scope of Magnetostratigraphy

Magnetostratigraphy can precisely identify the polarity of the rock at the time of its formation. For age dating purposes, this polarity sequences is correlated by comparing “finger prints” of the polarity pattern with dated sequence or the geomagnetic polarity time scale.

Give the clear evidence that, magnetic polarity of the earth reversals have occurred at irregular intervals during geologic time. These polarity of the earth's magnetic field have been successfully utilized in correlating the rock formations as well as assigning their periods of magnetisation of the formation and tectonics of the continental blocks containing them. This is the main basis of study of magnetostratigraphy during Cretaceous – Tertiary periods.

vii. Chemostratigraphy

The chemical stratigraphy is based on the chemical elements in sedimentary rocks to divide and correlate the strata, analyse the sedimentary environment and depositional processes. The chemical elements frequently used are Na, K, Ca, Mg, Rb, Sr, Ba, S, B, P, Fe, Co, Ni.

GEOLOGICAL TIME SCALE

EONS	ERAS	PERIODS	EPOCHS
PHANEROZOIC EON	CENOZOIC	Quaternary	Holocene 11,000
			Pleistocene 1.8
		Tertiary	Pliocene 5
			Miocene 23
			Oligocene 38
			Eocene 54
			Paleocene 65
	MESOZOIC	Cretaceous 146	Upper (Late)
			Lower (Early)
		Jurassic 208	Late
			Middle
			Early
		Triassic 245	Late
			Middle
			Early
	PALEOZOIC	Permian 286	
		Carboniferous	Pennsylvanian 325
			Mississippian 360
		Devonian 410	
		Silurian 440	
		Ordovician 505	
		Cambrian 544	
	PROTEROZOIC	Neoproterozoic 900	
		Mesoproterozoic 1600	
		Paleoproterozoic 2500	
PRECAMBRIAN EON	ARCHAean	Late Archaean 2900	
		Middle Archaean 3300	
		Early Archaean 3800	
	HADEAN		

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CUDDAPAH SUPERGROUP



CONTENTS

1. INTRODUCTION

2. LITHOSTRATIGRAPHY

3. ECONOMIC IMPORTANCE

4. CONCLUSION

5. REFERENCE

INTRODUCTION

- ❑ Cuddappah basin is an important proterozoic basin
- ❑ It covers an area of 44000 sq km
- ❑ Runs for a length of about 450 km along the arcuate eastern margin and with a width of 150 km
- ❑ Crescent shape- convex towards the west and concave towards the east
- ❑ The basin is divided into two halves
 1. The undeformed western half
 - RUDRAVARAM LINE**
 2. The Nallamalai thrust-fold belt
- ❑ The arcuate north, south and western boundary of the cuddappah basin marks the profound unconformity on basement granites enclosing greenstone belts of kadiri, Veligallu and Tsundupalle in the south and Raichur, Gadwal and Peddavuru in the north-
Eparchaeon Unconformity

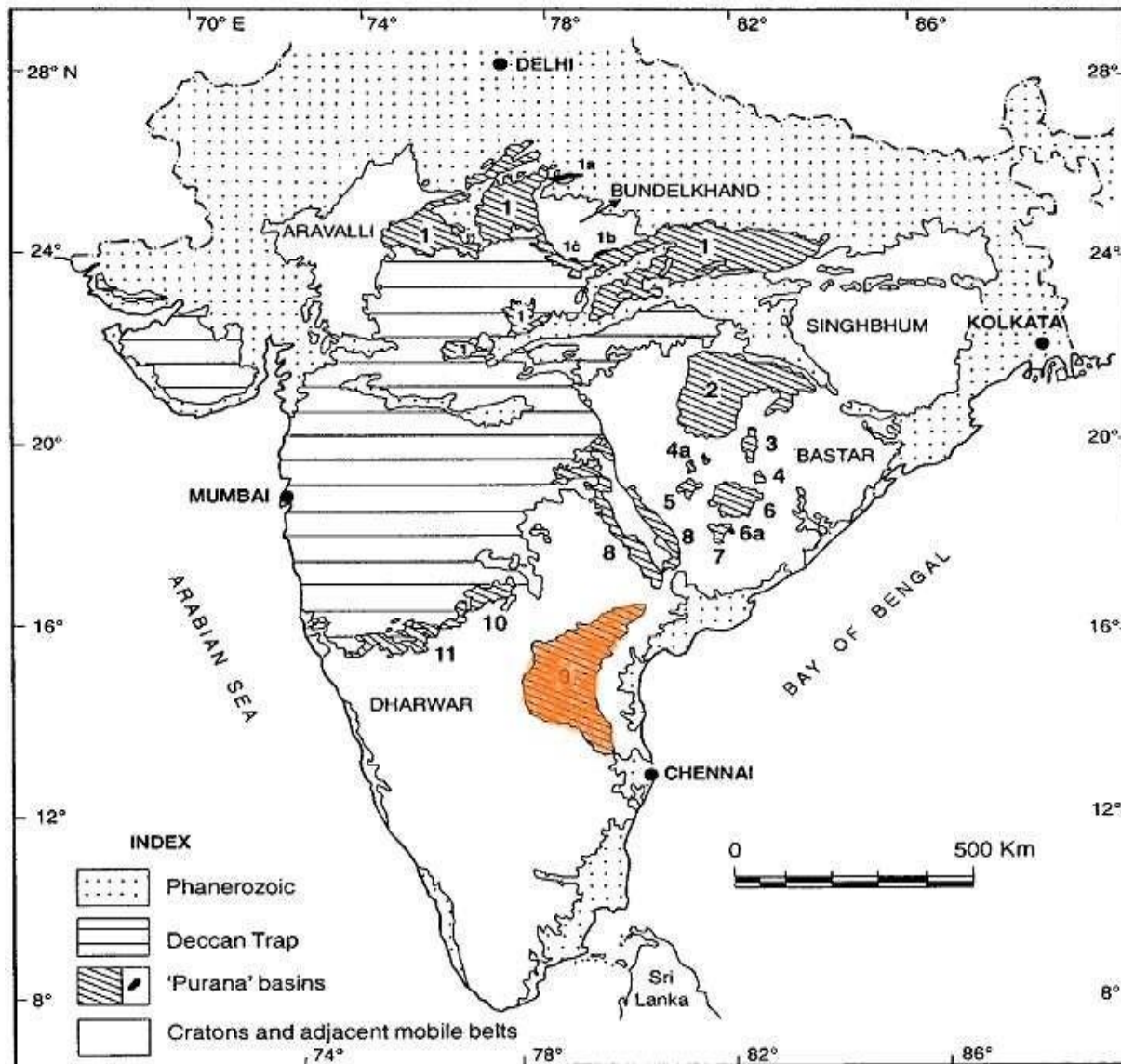


Fig.5.1. Purana basins of Peninsular India within different cratons (after Kale, 1991). 1 - Vindhyan, 1a - Gwalior, 1b - Bijawar & 1c - Sonrai basins, 2 - Chhattisgarh basin, 3 - Khariar basin, 4 - Ampani basin, 4a - Keskal and Singanpur outliers. 5- Abujhmar basin, 6 - Indravati basin, 6a - Chedrapal outlier, 7 - Sabari basin, 8 - Pranhita-Godavari basin, 9 - Cuddapah basin, 10 - Bhima basin, 11 - Kaladgi basin.

The Proterozoic sedimentary basins are listed below (Fig.5.1) with reference to the associated cratons:

A. Palaeoproterozoic Basins

- | | | |
|--|---|--------------------|
| 1. Bijawar and Sonrai basins
and Harda Inlier | } | Bundelkhand craton |
| 2. Gwalior basin | | |
| 3. Abujhmar basin | } | Bastar craton |
| 4. Papaghni sub-basin
(Cuddapah basin) | | Dharwar craton |

B. Meso-Neoproterozoic Basins

- | | | |
|---|---|---------------------------------------|
| 1. Vindhyan basin | } | Bundelkhand craton |
| 2. Chhattisgarh basin | | |
| 3. Khariar basin | | |
| 4. a. Ampani basin,
b. Keskal, Singanpur
and Chedrapal outliers | | |
| 5. Indravati basin | | |
| 6. Sabari (Sukma) basin | | |
| 7. Pranhita-Godavari basin | | Between Bastar and
Dharwar cratons |
| 8. Cuddapah basin | } | Dharwar craton |
| 9. Kaladgi basin | | |
| 10. Bhima basin | | |

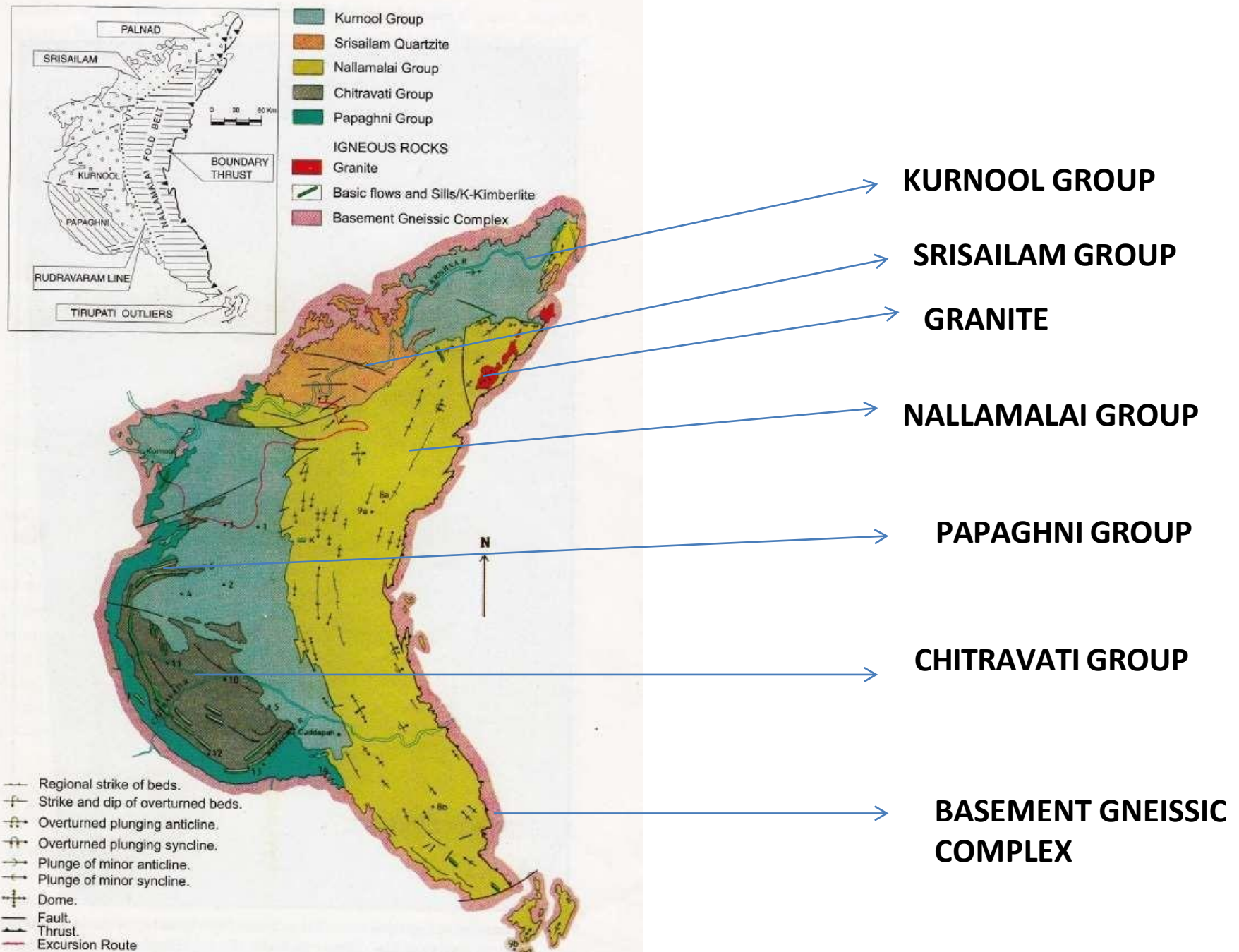


Fig.5.15a. Cuddapah basin in Eastern Dharwar craton. Inset depicts the different sub-basins (GSI, 1981b).

Table 5.6. Lithostratigraphy of Cuddapah basin

CUDDAPAH SUPERGROUP	Kundair Subgroup (75-150)	Nandyal Shale (50-100)	Shale, partly calcareous	
		Koilkuntla Limestone (15-50)	Siliceous, shaly limestone with quartzite interbeds	
		Paniam Quartzite (10-35)	Massive and pinnacled quartzite, siliceous shale, basal pebble bed	
	-----Paraconformity-----			
	Kurnool Group (200-450)	Jammalamadugu Subgroup (120-260)	Auk Shale (10-15)	Laminated shale, mostly ochreous with siltstone interbeds
			Narji Limestone (100-200)	Flaggy grey limestone, glauconitic sandstone interbeds
			Banganapalle Quartzite (10-50)	Oligomict conglomerate, 'grit', quartzite, shale
	-----Unconformity-----			
	(300)	Srisaillam Quartzite (300)	Glauconitic ferruginous quartzite with shale	
	-----Unconformity-----			
	Nallamalai Group (3500-6000)	Cumbum Formation	(2000)	Mainly slate and phyllite, chert, dolomite
		Pullampet Formation		Shale, felsic tuff, barytes, dolomite, quartzite
		Bairenkonda Quartzite (1500)/ Nagari Quartzite (4000)	Quartzite, quartz wacke, shale Quartzite, quartz wacke, shale, basal conglomerate	
	-----Angular unconformity-----			
Chitravati Group (4900-5000)	Gandikota Quartzite (300)	Shale-quartzite alternations, glauconitic quartzite interbeds		
	Tadpatri Formation (4600)	Shale, felsic tuff, basic sills and flows, chert, stromatolitic dolomite, quartzite		
	Pulivendla Quartzite (1-75)	Quartzite and conglomerate		
Papaghni Group (2100)	Vempalle Formation (1900) with Kuppalapalle Volcanics	Stromatolitic dolomite, chert, quartzite, basic sills and flows		
	Gulcheru Quartzite (30-210)	Basal conglomerate, arkose, quartzite with shale interbeds		
Crystalline basement of Dharwar craton				

*Number in parenthesis refer to thickness in metres

THE CUDAPPAH SUPERGROUP

□ The lithostratigraphy of Cudappah basin comprises of

Kurnool group

.....UNCONFORMITY.....

Srisailem quartzites

.....UNCONFORMITY.....

Nallaimalai Group

.....ANGULAR UNCONFORMITY.....

Chitravati Group

.....DISCONFORMITY.....

Papaghni group

.....UNCONFORMITY.....

Crystalline basement of Dharwar craton

□ The age of the Basin is bracketed between 1500 and 1800 Ma.

Cuddapah Supergroup	Kurnool Group (500+ m)	Nandyal Shale
		Koilkuntala Limestone
		Paniam Quartzite
		Owk Shale
		Narji Limestone
		Banganapalle Quartzite
	~~~~~ unconformity	
	<b>Chitravati Group</b> (4975 m)	Gandikota Quartzite
		Tadpatri Formation
		Pulivendla Quartzite
~~~~~ unconformity		
Papaghni Group (2110 m)	Vempalle Formation	
	Gulcheru Quartzite	
	~~~~~ unconformity	
<b>Peninsular Gneiss</b> (Dharwar batholith)		

# **THE PAPAGHNI GROUP**

- ❖ Rest with nonconformity on granitic basement and with profound angular unconformity over the greenstone belts of EDC.
- ❖ It consists of lower arenaceous sequence, an upper carbonate sequence topped by basic volcanic and sills
- ❖ The Group consists of-

<b>Vempalle Formation with Kuppalapalle Volcanics</b>	<b>Stromatolitic limestone, chert, quartzite, basic sills and flows</b>
<b>Gulcheru quartzites</b>	<b>Basal conglomerate, arkose, quartzite with shale interbeds</b>



# **THE CHITRAVATI GROUP**

❖ The Group disconformably overlies the Papaghni Group with a basal conglomerate marking the hiatus and consists of lower Pulivendla quartzite and upper Tadpatri Formation

❖ The Group consists of-

<b>Gandikota quartzite</b>	<b>Shale quartzite alterations, glauconitic quartzite interbeds</b>
<b>Tadpatri Formation</b>	<b>shale, felsic tuffs, basic sills and flows, chert, stromatolitic dolomite, quartzite</b>
<b>Pulivendla quartzite</b>	<b>Quartzite and conglomerate</b>

## **THE NALLAMALAI GROUP**

- ❖ **The Group overlies the Chitravati Group**
- ❖ **It is the deformed and feebly metamorphosed shale-siltstone-quartzite-dolomite sequence of the Nallamalai fold belt**
- ❖ **The group consists of-**

<b>Cumbum Formation</b>	<b>Slate, phyllite, chert, dolomite</b>
<b>Pullampet Formation</b>	<b>shale, felsic tuffs, barytes dolomite, quartzite</b>
<b>Bairenkonda quartzite</b>	<b>Quartzite, quartz wacke, shale</b>
<b>Nagari quartzite</b>	<b>Quartzite, quartz wacke, shale, basal conglomerate</b>

# **SRISAILAM QUARTZITE**

- ☐ The Srisailam quartzite overlies the Papaghni and Nallamalai Groups with a profound unconformity marked by local conglomerate
- ☐ The quartzite is horizontally bedded
- ☐ It comprises of glauconite bearing Ferruginous quartzite
- ☐ Minor shale intercalations are found in the quartzites
- ☐ The quartzite is believed to indicate shallow marine to tidal flat environment

# **GEOLOGICAL AGE**

- ❑ Pre-cuddapah basement dykes are of two prominent ages at 2100 and 2400 Ma
- ❑ Rb-Sr dating of dolerite and picrite sills of Pulivendla Formation gives an age of ~1800 Ma
- ❑ K-Ar ages of some dolerite dykes underlying the basin are also similar at 1800 Ma
- ❑ The age of galena and micas in Cumbum shales is 1350-1450 Ma
- ❑ Rb-Sr age for Dolerite dyke intruding Kurnool basin is 980 Ma that suggests Mesoproterozoic age for Kurnool group



# ECONOMIC IMPORTANCE

- ❖ Uranium- Found in Vempalle Formation of Papaghni Group, host rock is phosphatic dolostone , promising mineralisation at Tummalapalle, Rachak-untapalli and Gadankipalli
- ❖ Barytes- Found in Pullampet Formation of Nallamalai Group at Mangameta, forms the single largest deposit of bedded barytes in the world, has been declared as a National Geological Monument
- ❖ Diamond- Found as placer deposit in Banganapalle quartzite of Kurnool Group
- ❖ Limestones and Dolomites
- ❖ Chrysotile- asbestos and steatite- Vempalle Formation of Papaghni Group
- ❖ Ornamental stones like jasper, chert, etc
- ❖ Pb- Zn deposit- Hosted by dolomite, found in Pullampet Formation of Nallamalai Group at Agnikundala, Zangamrajupalle-Varikunda



# **CONCLUSION**

- ❑ Cuddapah is a very important Palaeo-Meso Proterozoic sedimentary basin and is typically arcuate shape.**
- ❑ It is the second largest Purana Basin next to the Vindhyan**
- ❑ Cuddapah Supergroup comprises of the Papaghni, Chitravati, Nallamalai and Srisailam quartzites**
- ❑ Cuddapah Basin is a storehouse for many rich mineral resources like barytes, Chrysotile, asbestos, steatite and base metal like diamond, phosphorie, uranium and abudent building and ornamental stone.**
- ❑ It is one of the Indian site, where the great Eparchaeon Unconformity exposed.**

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- ❖ Geology of India and Burma, M.S.Krishnan 1982, (163-181)
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## **Vindhyan Supergroup**

- ❑ Vindhyan basin is named after the Vindhyan Mountains
- ❑ Covers an exposed area of 60,000sq.km and a concealed area of 1,62,000km.sq under the Indo-Gangetic Alluvium and Deccan Trap
- ❑ The strata are exposed in Son valley, Bundelkhand and Rajasthan
- ❑ The Son –Narmada fault bound the basin in the south and the Great Boundary Fault in the northwest
- ❑ Geographically, it starts from Sasaram in the east to Dholpur in the north.
- ❑ Vindhyan basin belongs to mesoproterozoic
- ❑ It is sickle shape, ENE trending situated on the Bundelkhand craton.
- ❑ Vindhyan supergroup can be divided into two viz... upper Vindhyan and lower Vindhyan, composed of sandstone, shale and carbonate, few conglomerate and volcanoclastic bed
- ❑ Lower vindhyan is 1,300-1,100M.y, marine in origin consisting of calcareous and argillaceous sediments
- ❑ Upper vindhyan is 1,000-600my, fluvial in origin and exclusively arenaceous
- ❑ Upper Vindhyan enclose two diamond bearing horizon, from which Panna and Golconda diamonds have been mined

- ❑ The upper and lower Vindhyan supergroup are separated by unconformity, prominent in the North but almost disappears in the Southern areas.

**Table 5.1.** Lithostratigraphy of Vindhyan Supergroup

Group	Formation	Alternative Names
Bhander Group (1300-1500 m)	Maihar Sandstone	(Upper Bhander Sst.: Divided into Bhavpura Sh., Balwan Lst. Shikaoda Sst.)
	Sirbu Shale	
	Bundi Hill Sandstone	(Lower Bhander Sst.)
	Lakheri Limestone	(Bhander Lst., Nagod Lst.)
	Ganurgarh Shale	(Simrawal Sh.)
----- Disconformity/ Gradational Contact -----		
Rewa Group (100-300 m)	Govindgarh Sandstone	(Upper Rewa Sst., Gahadra Sst.)
	Drummondganj Sandstone	
	Jhiri Shale	(Variegated Sh.)
	Asan Sandstone	(Lower Rewa Sst., Itwa Sst., Kanar Sst.)
	Panna Shale	
----- Normal Contact / Facies Change -----		
Kaimur Group (400 m)	Dhandraul Quartzite	(Upper Kaimur Sst., Scarp Sst.)
	Mangesar Formation	
	Bijaigarh Shale	
	Markundi Sandstone	(Ghaghar Sst.)
	Ghurma Shale	(Susnai Breccia)
	Sasaram Sandstone	(Lower Kaimur Sst.)
----- Unconformity / Normal Contact -----		
Semri Group (3000-4000 m)	Suket Shale	(Baghwar Sh.)
	Rohtas Limestone	(Nimbahera Lst.: Divided into Bari Sh., Jiran Sst. and Khori Malan Cong.)
	Chorhat Sandstone	(Glaucinite Bed, Rampur Sst., Basuhari Sst., Tirohan Breccia)
	Bargawan Limestone	(Salkhan Lst., Fawn Lst., Chorhat Lst., Tirohan Lst.)
	Kheinjua Shale	(Olive Sh., Koldaha Sh., Binota Sh.)
	Chopan Porcellanite	(Deonar Porc.)
	Kajrahat Limestone	(Kuteshwar Lst., Bhagwanpura Lst., Tirohan Lst., Lohar Dol.)
	Arangi Shale	
	Deoland Sandstone	(Khardeola Sst., Pandwafall Sst.)
----- Angular Unconformity / Non-conformity -----		

Granites and Supracrustals

Sst. - Sandstone; Sh. - Shale, Lst. - Limestone, Dol. - Dolomite, Porc. - Porcellanite, Cong. - Conglomerate



## **Lithology**

### **Lower Vindhyan**

#### **Semri group-**

- ☐ 3000 to 4000m thickness
- ☐ Derived its name from Semri river well developed in the eastern Son valley
- ☐ It rests with non-conformity on Bundelkhand
- ☐ Irregular thickness indicates irregular basin floor
- ☐ It is made up of five alternating formations of shale and carbonates with areas of sandstones and volcanic clastic units
- ☐ Basal succession consist of conglomerate, cross bed ferruginous sandstone and shale
- ☐ Pb-Pb isochron age is 1750-1500Ma.

### **Upper vindhyan**

#### **Kaimur group-**

- ☐ Seperated from the lower Vindhyan by unconformity
- ☐ 400m thickness
- ☐ Named after kaimur scarp
- ☐ It is essentially made up of sandstone-shale
- ☐ Ripple marks and sun cracks are found on the shales

- ☐ In Bundelkhand it shows a basal conglomerate containing pebbles of jasper

Using Rb-Sr isochron the age is 1100-1150Ma

### **Rewa group**

- ☐ Named after the Rewa state
- ☐ Thickness 100-300m
- ☐ Sediments thicken to the north indicating deepening of the basin
- ☐ Separated from Kaimur by a zone of diamond bearing conglomerate
- ☐ Consist of a series of shales and sandstone formations that, in areas contain kimberlite derived diamondiferous conglomerates
- ☐ The presence of mud cracks suggest periodical exposures and the presence of rain prints in the shale indicates sub aerial conditions
- ☐ The basal Panna shale without any basal conglomerate indicates continuity of deposition from Kaimur group.

### **Bhander group**

- ☐ Named after Bhander upland, extensively developed along the axis of the basin and in the Bhopal inlier within the Deccan trap
- ☐ Thickness is 1300-1500m
- ☐ Separated from the Rewa group by a horizon diamond bearing conglomerate
- ☐ Bhander sandstone are fine grained and soft.

- ❑ The Ganurgarh shale with stromatolitic limestone indicates shoreline lagoon-tidal flat complex
- ❑ The top unit of Maihar sandstone unit is a blanket deposit with ripple marks, cross bedding and load-cast indicating tidal flat to near shore littoral environment.

#### Economic deposits;

- ❑ Diamond,pyrite,coal,limestone,building and decorative stones are reported from Vindhyan basin
- ❑ Diamond have been reported in the conglomerate in Panna
- ❑ The limestone of Vindhyan are among the most important sources of raw materials for the lime and cement industry in India
- ❑ Vindhyan sandstone near U.P on disintegrating by weathering yield good sands which are being used for the manufacture of glass.
- ❑ Pyrite is reported from the Bijaigarh shales of lower Kaimur.The material is of good quality, containing around 45% sulphur, without any arsenic.

# Gondwana Supergroup

# Contents

- Introduction
- Distribution
- Lithology
- Topography
- Stratigraphic Classification
- Economic Significance
- Conclusion
- Reference



# Introduction

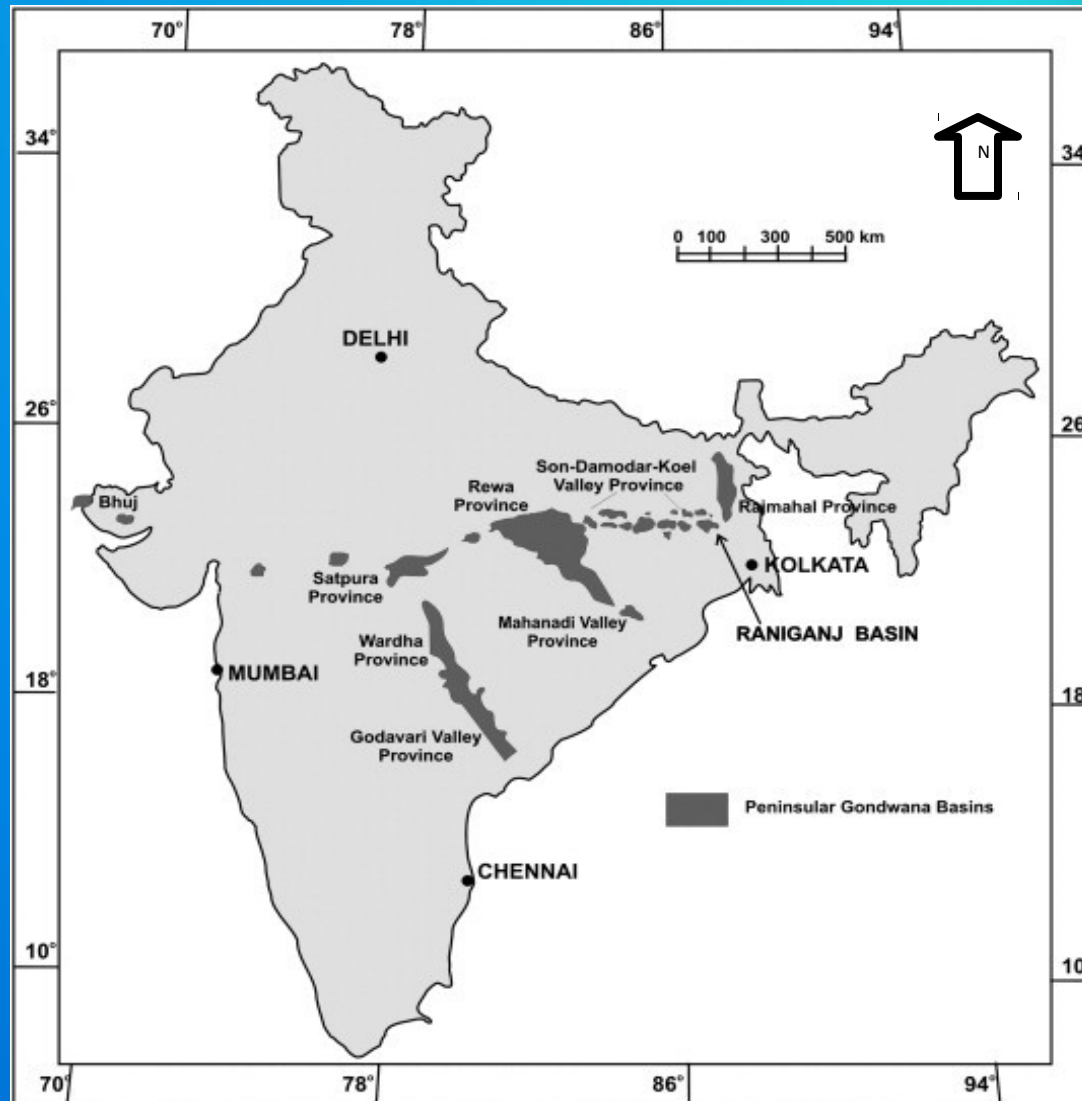
## Gondwana

- The term “Gondwana” was coined by H.B. Medlicott in 1872.
- It was derived from the kingdom of the Gonds, a great and ancient tribe who still inhabit in the Central Provinces (Madhya Pradesh).

## Supergroup

- The term supergroup may be use for several associated groups or for associated groups and formations with significant lithological properties in common.

# A map of Gondwana basin of Peninsular India



# LITHOLOGY

- The Gondwana superGroup is made up of 6 to 7 km thick succession of mainly fluviatile and lacustrine deposits.
- However, a glacial deposit occurs at the base and the intercalations of the fossiliferous marine beds occur both in the lower and upper parts of the succession.
- The chief rock types are sandstones ,shales, clays, conglomerates and coal seams.
- In addition to these rocks the upper Gondwana succession contain about 600 meter thick lavaflows of basalt.

# TOPOGRAPHY

- The rocks of Gondwana are found occupying basin shaped depressions in the older formation and such depressions sometimes, though not always, nor even generally correspond to the existing river valleys. The Gondwana beds were originally deposited on an uneven surface.

# Stratigraphic Classification

- A major part of the Gondwana sediments are confined to the three tracts, which include Koel- Damodar, Son-Mahanadi and Pranhita - Godavari basins.
- The Gondwana Supergroup is divided into two major divisions based on their lithological and palaeontological evidences.
  - (i) Two-fold classification by W.T. Blanford, divided into lower and upper Gondwanas, characterised by the *Glossopteris* and *Ptilophyllum*.
  - (ii) Three-fold classification by Hughes, who identified a mixed flora called *Dicroidium* in between the *Glossopteris* and *Ptilophyllum* floras.



# Two fold classification

**Table 7.2.** General stratigraphic succession of Son-Mahanadi Graben (after Pande and Dave, 1998)

Age	Supergroup/ Group	Formation Rock unit	Lithology	Thickness
Paleocene to Upper Cretaceous	Deccan Trap	Deccan Trap Basalt/intrusives and extrusives	Fine grained basalts and dolerites	
Unconformity				
Upper Cretaceous (Turonian)		Lametas	Hard cherty limestone and calcareous conglomerates	40 m
Unconformity				
Lower Cretaceous		Bansa-Chandiya	White clays, silty sandstone, clayey silt and quartzzone sandstone towards the top	125 m
Unconformity				
Rhaetic to Norian	UPPER GONDWANA	Parsora Formation	Purplish white, kaolinitic sandstone Pebble beds. Maroon to crimson clays	400 m to 600 m
Lower Norian to Carnian		Tikki Formation	Laminations of white fine grained sandstone, occasional siltstone	200 m approx.
Upper Permian to Lower Triassic		Pali Fm / Kamthi Upper Member	Brownish to buff sandstone and some pebble beds, dark brown to brick red clays and carbonaceous clays and hard ferruginous sandstone in Kamthi Formation	200 m to 300 m
Contact gradational to unconformable				
Upper Permian	LOWER GONDWANA	Raniganj/ Kamthi (Lower Member)	Flaggy sandstone with thin laminated alternations of carbonaceous shale, siltstone carbonaceous shale, siltstone in Raniganj Fm. Medium grained, brown, ferruginous sandstone and micaceous carbonaceous shales in Kamthi Formation	200 m to 400 m
Middle Permian		Barren Measures	Moderately hard, ferruginous, greyish sandstone, occasional grey shales laminated siltstone and red mottled clays. Some haematitic bands	125 m to 300 m
		Barakar Formation	Sandstones with alternations of shale/ siltstone and thick coal seams and carbonaceous shale	200 m to 1150 m
Lower Permian		Karharbari Formation	Mottled ferruginous, hard sandstone, carbonaceous shales with occasional coal seams	100 m
		Talchir Formation	Basal boulder bed in clay/silty matrix followed by alternations of shales, siltstones and sandstone. Shales are olive green to buff splintery	50 m to 450 m
Unconformity				
Precambrian to Archaean		Unclassified/ Dharwars/ Bijawars/Cuddapah	Gneisses, schists, quartzites, phyllites pegmatites Phyllites, pegmatites, granites, cherty limestone	

# Three fold classification

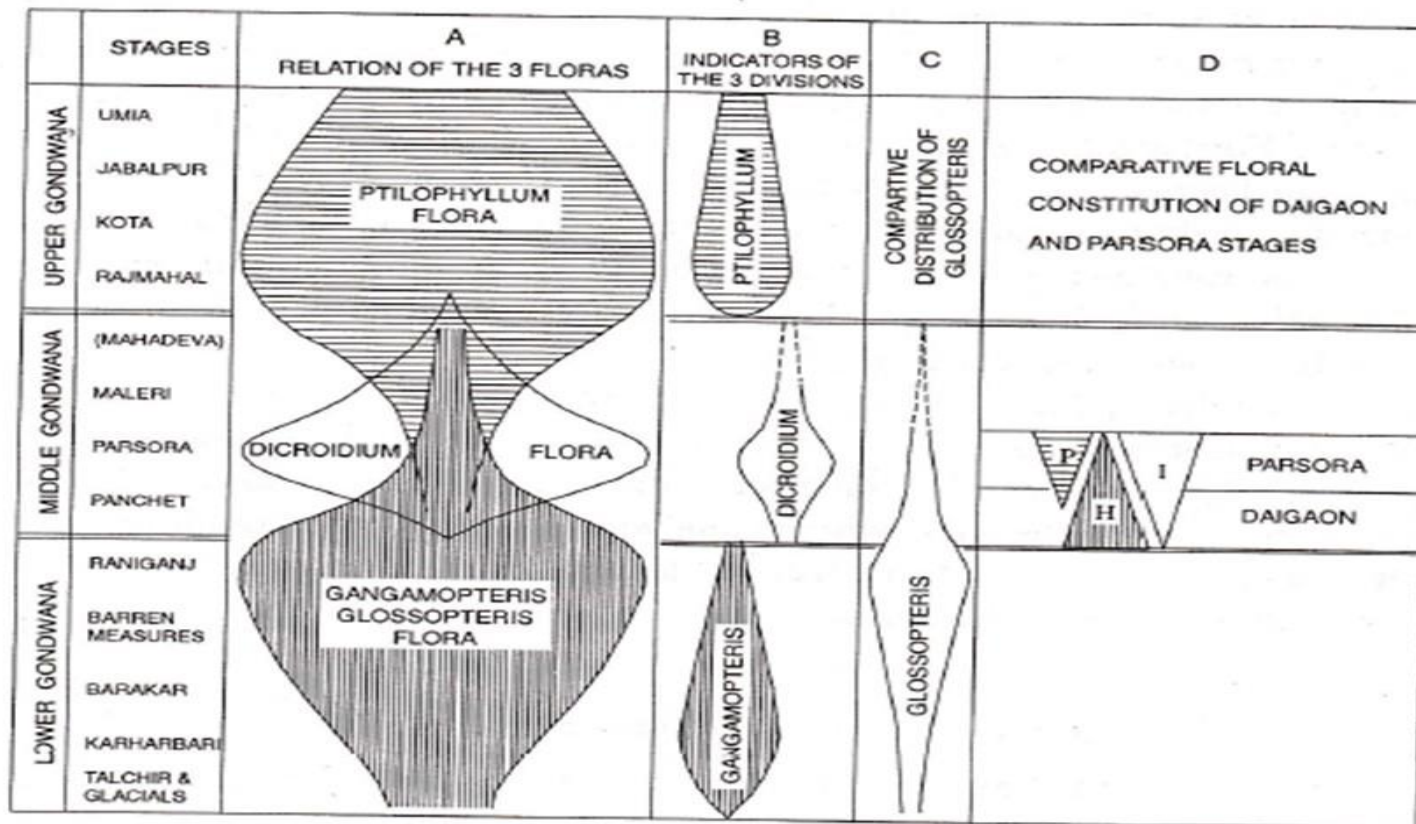


Fig.7.12. A. Semidiagrammatic representation of the relation between the floras of the Lower, Middle and the Upper Gondwana showing the overlap of the Permian 'Hold-overs' and the Jurassic 'Precursors' with *Dicroidium* in the Middle Gondwana times. B. Index plant genera of the three floras which serve to delimit the Lower, Middle and Upper Gondwana divisions. C. Vertical distribution pattern of *Glossopteris* (as contrasted with *Gangamopteris*) showing its transgressive tendency and unreliability for delimiting the Lower Gondwana. D. Diagrammatic representation of the floral constitution of the Daigaon and Parsora Stages in terms of the so-called 'Hold-overs' (H), the so-called 'Precursors' (P) and the Index plant (I). (after Lele, 1964).

# Talchir Formation:

- This formation rests unconformably over the basement of either Archaean gneisses and schists or Proterozoic age.
- Boulder bed/ tillite, rhythmite, khaki green needle shale and light green sandstone are constitute in this formation.
- Presence of a few plant fossils of seed ferns *Gangamopteris cyclopteroides* and *Glossopteris indica*.

# Karharbari Formation:

- Conglomerates, pebble beds, coarse to very coarse grained pebbly sandstone, siltstone, shale and thin streaks and bands of coal are present.
- Contains of coal seams in a few basins and the plant fossil *Gondwanidium burriada* biozone is considered as characteristic of this formation.

## Barakar Formation

- A 250m thick Barakar Formation
- The china-clay deposits of the formation are often of economic significant.

## Barren Measures Formation

- It is represented by alternating units of cross-bedded ferruginous sandstone, micaceous siltstone and ferruginous shale.
- The latter rock unit is called Ironstone Shale in the Raniganj coalfield.



# Raniganj Formation:

- Consists of sandstones, shale and coal seams, the sandstones being fine-grained than those in the Barakar Formation.
- Valuable coal-seams occur in these strata only in the Raniganj coalfield.

# Panchet formation:

- The formation comprises of greenish, buff and brownish sandstones and shales in the lower part, and greyish micaceous and feldspathic sandstones and shales in the upper part.
- The lower sandstones are often false-bedded and contain no coal seams or carbonaceous matter.

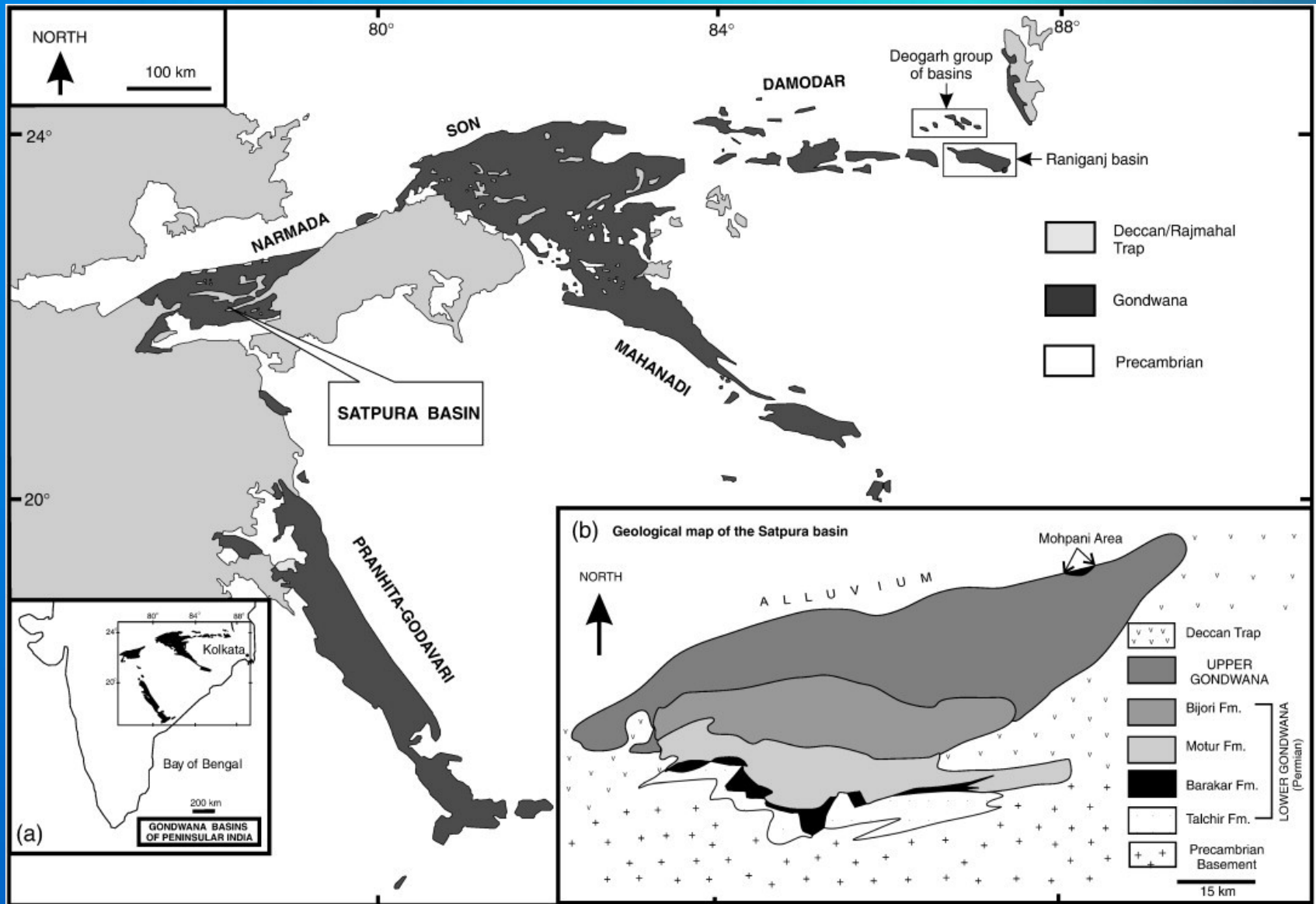
## Supra -Panchet (Mahadeva):

- Maximum development of Supra -Panchet is found in the Bokaro basin, where it attains a thickness of 600m in the Luga Hill section.
- Ferruginous sandstone, conglomerate, pebble beds and red clay are prominent rock units of this formation.

## Satpura Basin:

- The Satpura basin is spindle-shaped with a length to breadth ratio of 4:1.
- The entire area is about 1200 sq. km.
- It constitutes of sandstone, coal, carbonaceous clay, shale etc.

# Satpura basin



# Son- Mahanadi valley

- About 575 km long funnel-shaped Gondwana tract of Son Valley basin in the northwest and NW-SE trending Mahanadi Valley basin in the SE.
- Most of the coalfields are located in Rewa-Chattishgarh areas.
- The coalfields of Son Valley part include Singrauli, Sohagpur, Sonhat, Ramkola, Tatapani etc.
- The coalfields of Mahanadi Valley are Korba, Hasdo-Arand and Mand-Raigarh.



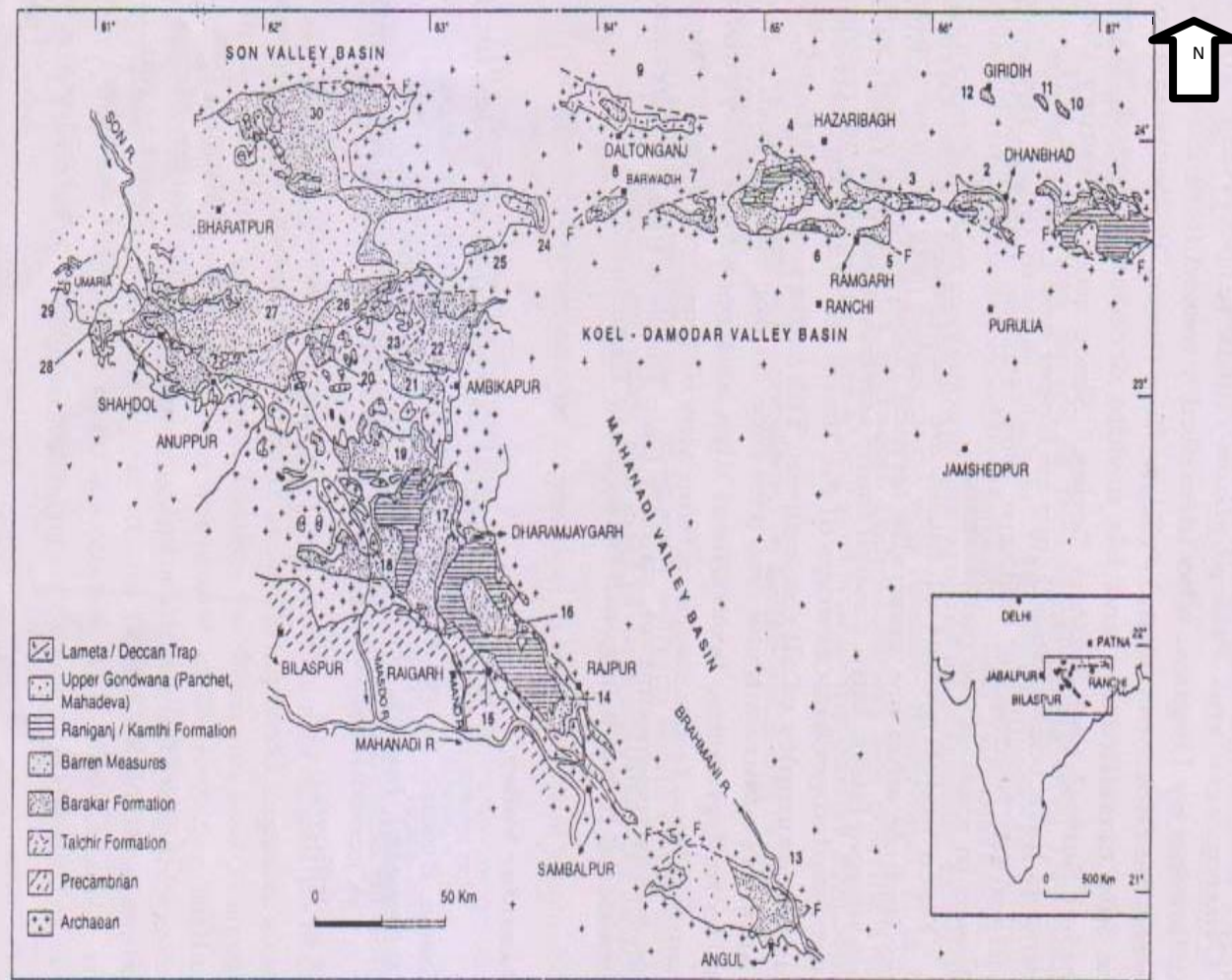


Fig.7.2. Geological map showing the distribution of Gondwana rocks in the Son-Mahanadi and Koel Damodar Valley basins. Inset shows the location of the Gondwana basins. Numbers (1)-(30) refer to coalfields. (1) Raniganj, (2) Jharia, (3) Bokaro, (4) North Karanpura, (5) Rungarh, (6) South Karanpura, (7) Hutar, (8) Auranga, (9) Daltonganj, (10) Jainty, (11) Saharjuri, (12) Giridih, (13) Talchir, (14) Ib-river, (15) South Raigarh, (16) North Raigarh, (17) Mand River, (18) Korba, (19) Hasdo Arand, (20) Chirimiri, (21) Lakhanpur, (22) Bistrampur, (23) Jhillimili, (24) Ramkola, (25) Tatapani, (26) Sonhat, (27) Sohagpur, (28) Johilla, (29) Umari, (30) Singrauli (after Casshyap and Tewari, 1984). (Reprinted with permission from Blackwell Publishers).



# Pranhita-Godavari Valley

- The NW-SE trending Pranhita- Godavari Valley is unique as it preserves about 3000 m thick sediments deposited in a time span of 200 Ma from late Carboniferous/ early Permian to Cretaceous.
- Most of the coalfields are located along the western margin at Sirpur, Chelpur, Pasara, Lingala, Bellampalli, etc. whereas Cherla and Manuguru are located in the east.
- Three prominent faults pattern are identified in the Pranhita-Godavari Gondwana basin -
  - (i) NNW-SSE trending syndepositional faults that controlled sedimentation and grabens/ half-grabens development.
  - (ii) NW-SE faults that imparted echelon fabric to south western margin, and
  - (iii) the NE-SW transverse faults, oriented parallel to the grain of the eastern Ghat Mobile belt transecting the Godavari valley basin into different sub-blocks.

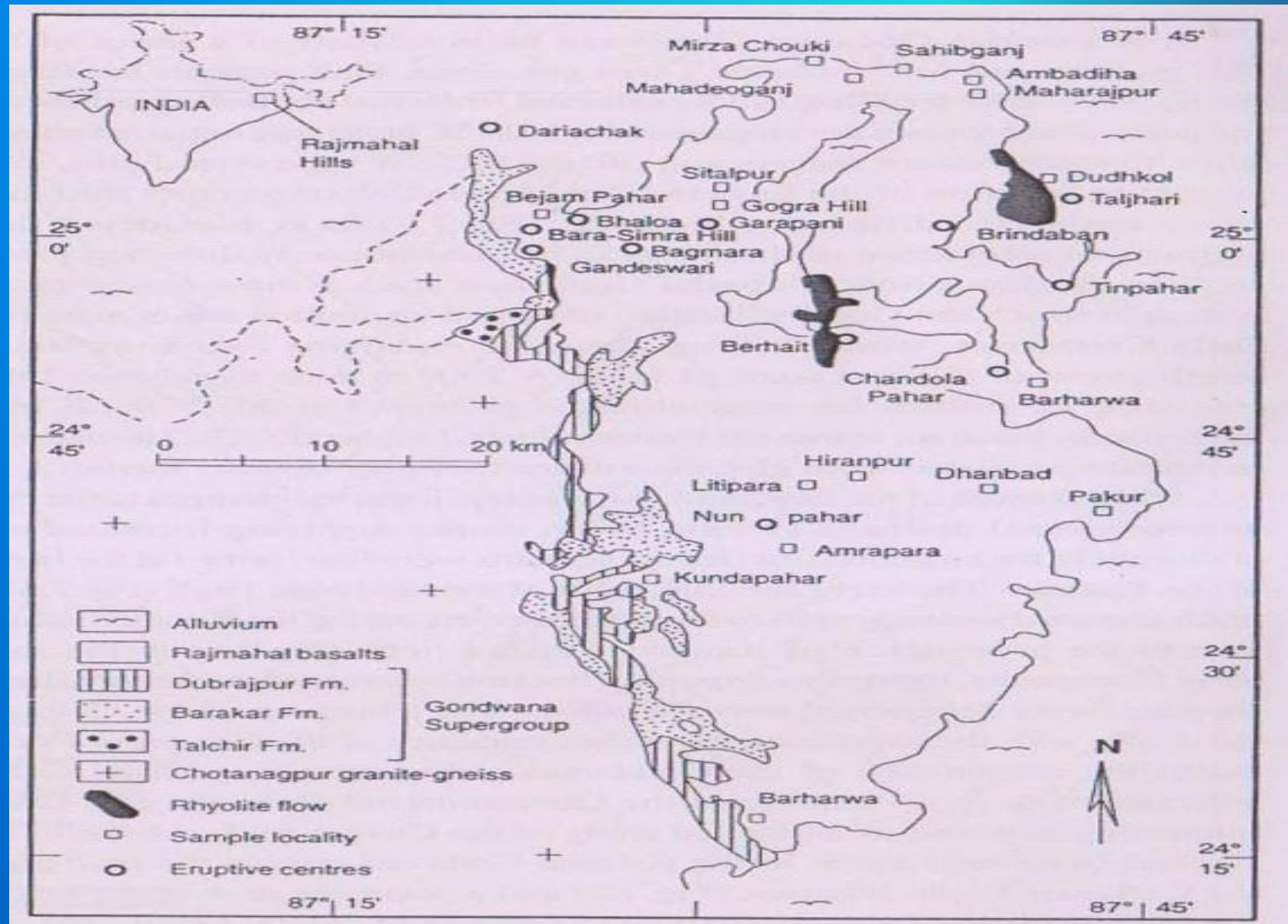
# Wardha Valley

- The Gondwana rocks of the Godavari Valley extend northwest ward into the Wardha valley of Maharashtra.
- Important coalfields are located in an area of about 4150 sq. km. having similar geological succession to that of the Godavari Valley.
- The Wardha coal field is a broad anticline plunging NNW.

# Rajmahal Hills

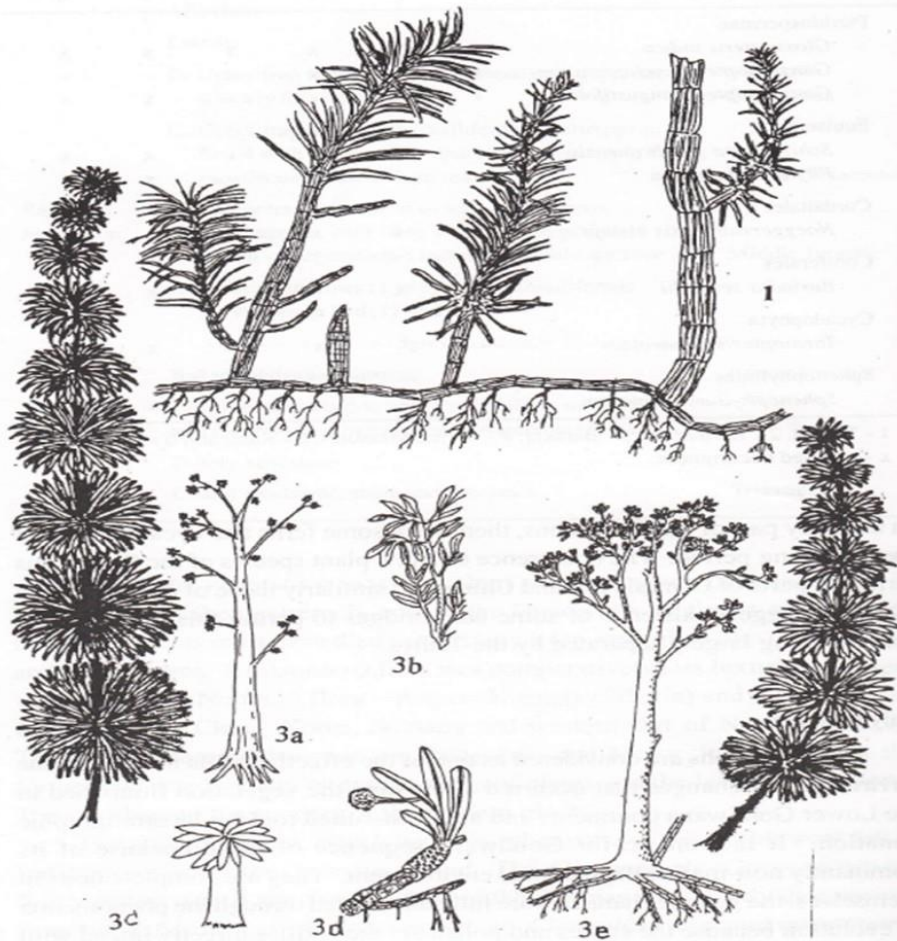
- It is situated in the north eastern part of the Jharkhand State, preserve Gondwana Formation comprising Talchir, Barakar and Dubrajpur Formations.
- These are overlain by the Rajmahal Formation made up of a series of basaltic lava flows and associated inter- trapping beds.
- The Rajmahal Traps are predominantly composed of fine grained to coarsely crystalline dolerite.
- These Traps are plateau basalts characterised by the absence or rare occurrence of olivine.

# Distribution of basalts and Gondwana sediments as exposed in the Rajmahal Hills, Jharkhand State

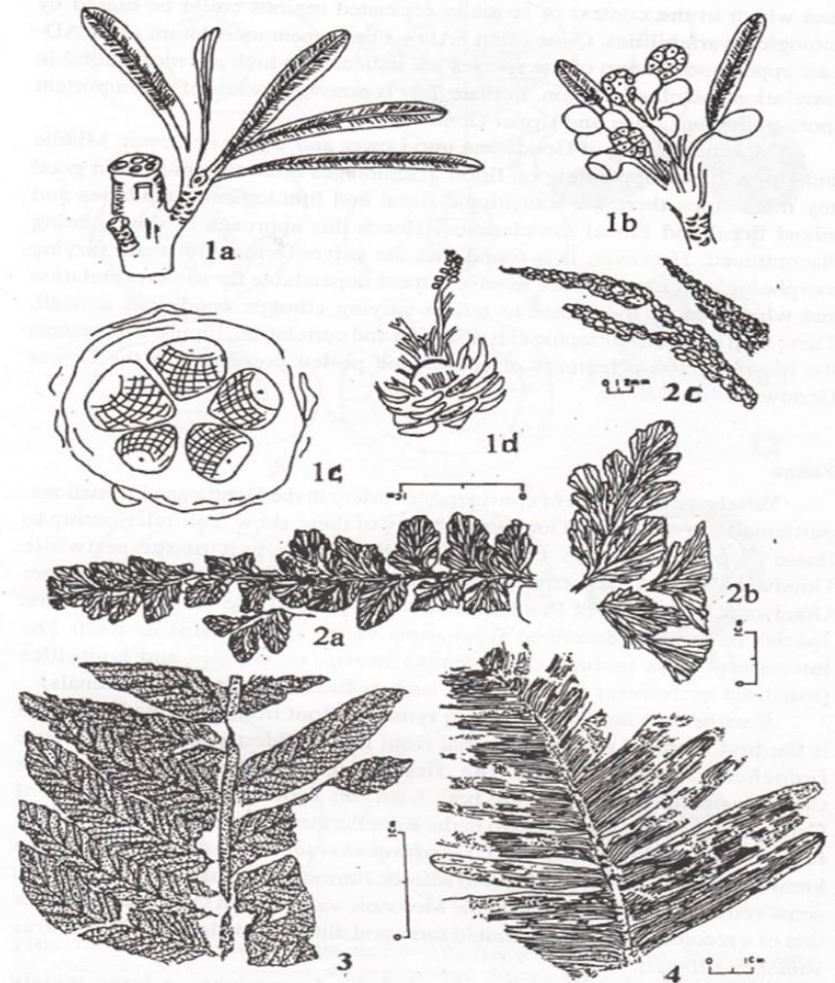




# Flora



**Plate 7.1.** 1 - Reconstruction of the plant *Phyllothea indica* (Lower Gondwana). 2a-b. Reconstruction of the plant *Raniganjia bengalensis* (Lower Gondwana). 3a-e. Reconstruction of the plant *Glossopteris* (Lower Gondwana). (Courtesy: B.S. Venkatachala and N.C. Mehrotra). (reproduced with permission from the Editor of the Palaeobotanist).

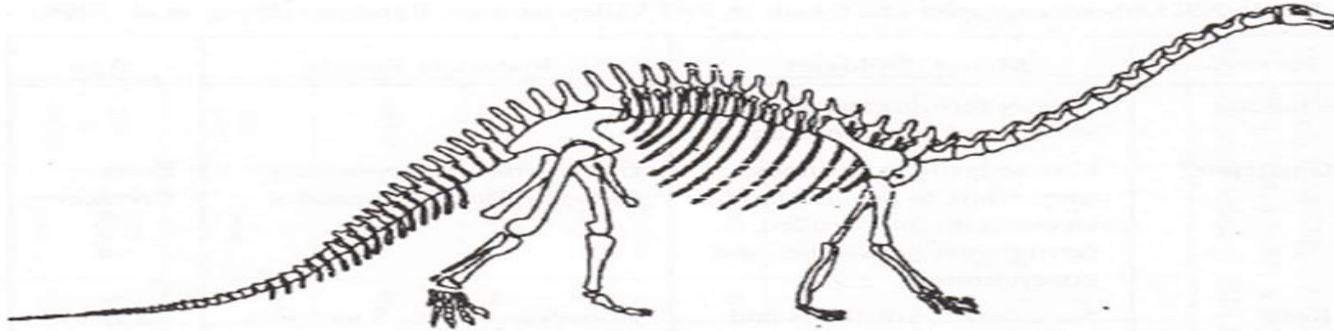


**Plate 7.2.** 1a-d - Reconstruction of *Pentoxylon sahnii* (Upper Gondwana). 2a. *Thinnfeldia khatangiensis* (Upper Gondwana). 2b. *Sphenopteris hislopi* (Upper Gondwana). 2c. *Brachyphyllum mantillare* (Upper Gondwana). 3. *Cladophlebis indica* (Upper Gondwana). 4. *Pterophyllum morrisianum* (Upper Gondwana). (Courtesy: B.S. Venkatachala and N.C. Mehrotra). (reproduced with permission from the Editor of the Palaeobotanist).

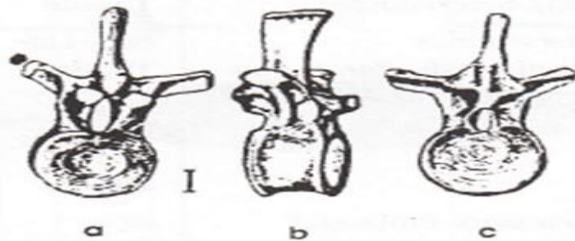


# Fauna

-reported from Kota Formation of Krishna-Godavari tract



*Kotasaurus Yamanapalliensis*, a sauropod dinosaur skeleton reconstructed and mounted by the Geological Survey of India at Birla Museum, Birla Science Centre, Hyderabad.



Dorsal vertebra in (a) anterior (b) anterior-lateral (c) posterior views. The bar is 5 cm



A molar tooth of a micromammal from lower Jurassic Kota Formation



Teeth of dinosaurs, lower Jurassic Kota Formation



A complete humerus (fore limb element) of Sauropod dinosaur

# Economic significance in the Gondwanas

- **Coal.** The Barakar and Raniganj Formation of the Damuda Group constitute the most important coal bearing rock formations. All of the Gondwana coal is of bituminous variety.
- **Iron Ore.** About 760m thick ferruginous shales, known as the "Iron stones shales". These shales form a deposit of sideritic iron ore which contains about 40-50% iron.
- **Clay.** The clays of various types are found in abundance in the Gondwana rocks. These clays are used for making refractory bricks, pottery and china ware.
- **Stone Buildings.** The Gondwana sandstones is generally of inferior quality. However, some of it is being used as building stone.

Cont.....

- Most of the gondwana coal is found in the Damuda series.
- Gondwana land comprises India, Australia, Africa, S. America and Antarctica
- Reserves of grade- A in Gondwana coalfields on India. Non- cooking coal production in almost all the states other than Assam, Arunachal Pradesh, Meghalaya, Nagaland are graded on the bases of useful heat value in kcal/ kg. coal from Assam, Arunachal Pradesh, Meghalaya, Nagaland are not graded.

# Coal Mines

- Ganga valley
- Damodar valley
- Kaveri delta
- Narmada valley

# Conclusion

- Talchir and Karharbari formations (Permian-Carboniferous) records an abrupt change over from glacio marine to terrestrial fluviolacustrine depositional environment
- The lower Gondwana is characterised by *Glossopteris* flora whereas the upper Gondwana is characterised by *Ptilophyllum* flora.
- The lower Gondwana consists of predominantly Upper Palaeozoic rocks whereas the lower Gondwana basin comprises essentially of the Mesozoic rocks.

# Reference

- Geology of India, Volume 2 by R. Vaidyanadhan and M. Ramakrishna, Pages-615-661.
- Geology of India and Burma by M.S. Krishnan, 6th Edition, Pages 239-298.
- Fundamentals of Historical Geology and Stratigraphy of India by Ravindra Kumar, Pages 176-193.





# COAL

- 
1. Definition of coal
  2. Varieties of coal
  3. Rank of coal
  4. Formation/Origin of coal

# HISTORY OF COAL

- Coal was first mined in the Raniganj Coal field field in the year 1774 by the East Indian Company.
- We needed to fuel steam engines, and coal was a readily available fuel.
- Fuel was burned to create steam to turn a turbine in power plants.
- Today 72% of Indian electricity comes from coal. We have 300 years' worth of coal!

## **Definitions 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 solid or brittle 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.

## **Definitions of coal:**

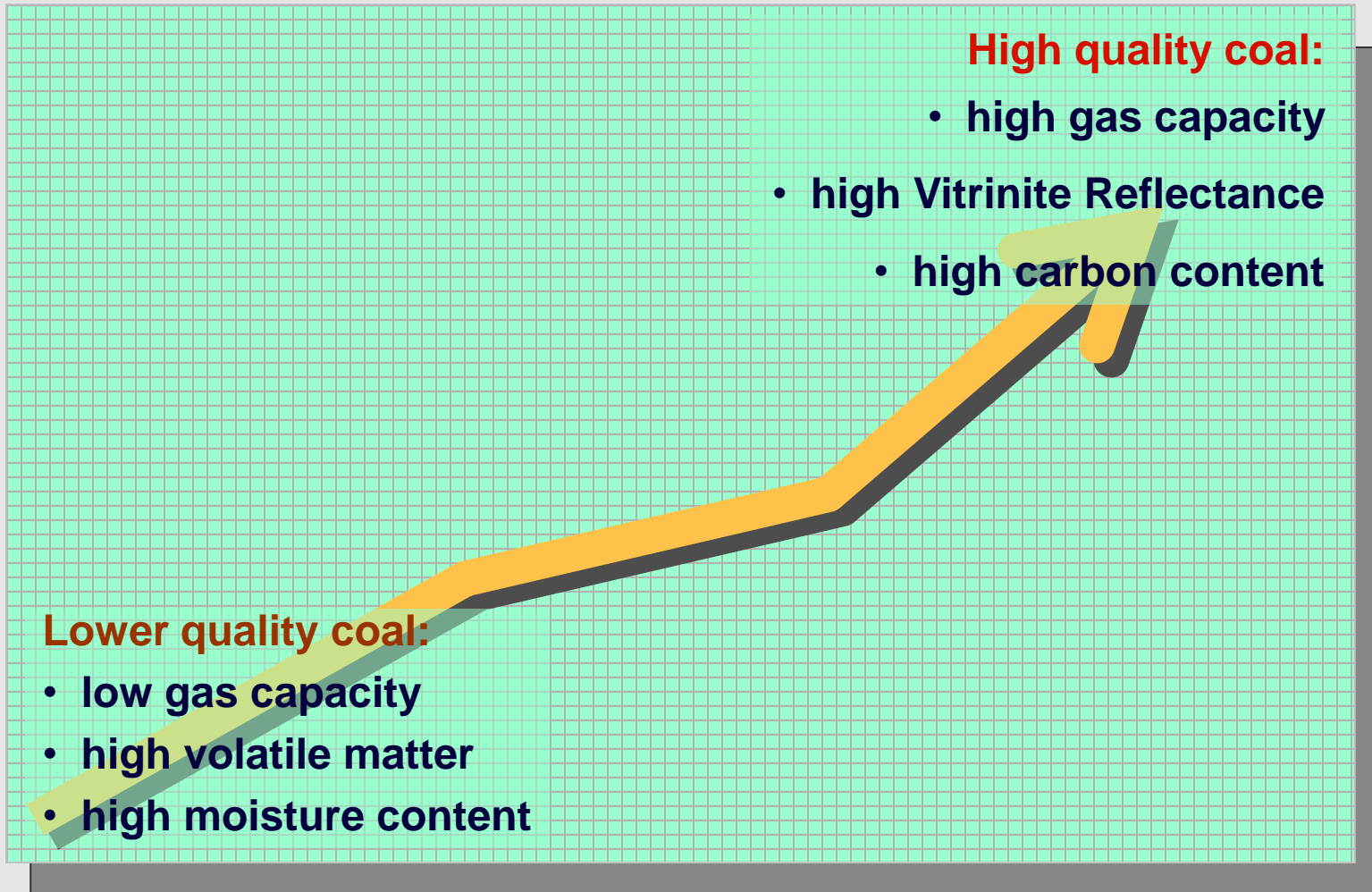
- Coal is formed from accumulated vegetable matter that has been altered by decay and by various amounts of heat and pressure.
- A black or brownish-black solid, combustible substance formed by the partial decomposition of vegetable matter without access to air.



# Coal Ranking & Quality

- The rank of coal, which includes anthracite, bituminous coal, sub-bituminous coal, and lignite are based on fixed carbon, volatile matter, and heating value.
- Coal rank indicates the progressive alteration, or coalification, from lignite to anthracite.
- The heat contents of Lignite contains approximately 9 to 17 million British Thermal Unit (BTU) per ton.
- The heat contents of subbituminous and bituminous coal range from 16 to 24 million BTU per ton.

# Coal Ranking & Quality



# Carbon Content in Coal

❑ Peat	Less than 50% C
❑ Lignite	71% C
❑ Sub-Bituminous	80% C
❑ Bituminous	90% C
❑ Anthracite	More than 93% C

Coal is a dirty fuel and contains abundant pyrite, which when burned creates  $\text{SO}_2$ . In the atmosphere the  $\text{SO}_2$  combines with water to form sulfuric acid (acid rain) that acidifies our lakes and streams.

# Coal Ranking & Quality

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

# 1. Peat

- Not really a coal
- It is undeveloped
- Soft & Spongy
- Carbon content : 20-25%
- Deposited during last 100 years by decomposed plant remains.



# 1. Peat



## 2. Lignite

- The first real coal
- Low heating value
- Often found near the earth surface
- Loses moisture when exposed to air



## 2. Lignite



### 3. Sub-bituminous

- Lower carbon content than bituminous
- It also loses moisture when exposed to air

### 3. Sub-bituminous



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## 4. Bituminous

- High carbon content (65-85%)
- Low oxygen content (5-12%)
- It usually burns with a yellow flame

## 4. Bituminous



## 5. Semi-anthracite

- Hard coal but softer than Anthracite
- Fixed Carbon Percentage (80-85%)
- Contains more volatile matter than anthracite
- Burns freely

## 5. Semi-anthracite



## 6. Anthracite

- Hard
- Durable
- High Density
- Low Volatile matter
- Fixed Carbon Percentage (85-98%)
- Burns slowly with little smoke



## 6. Anthracite

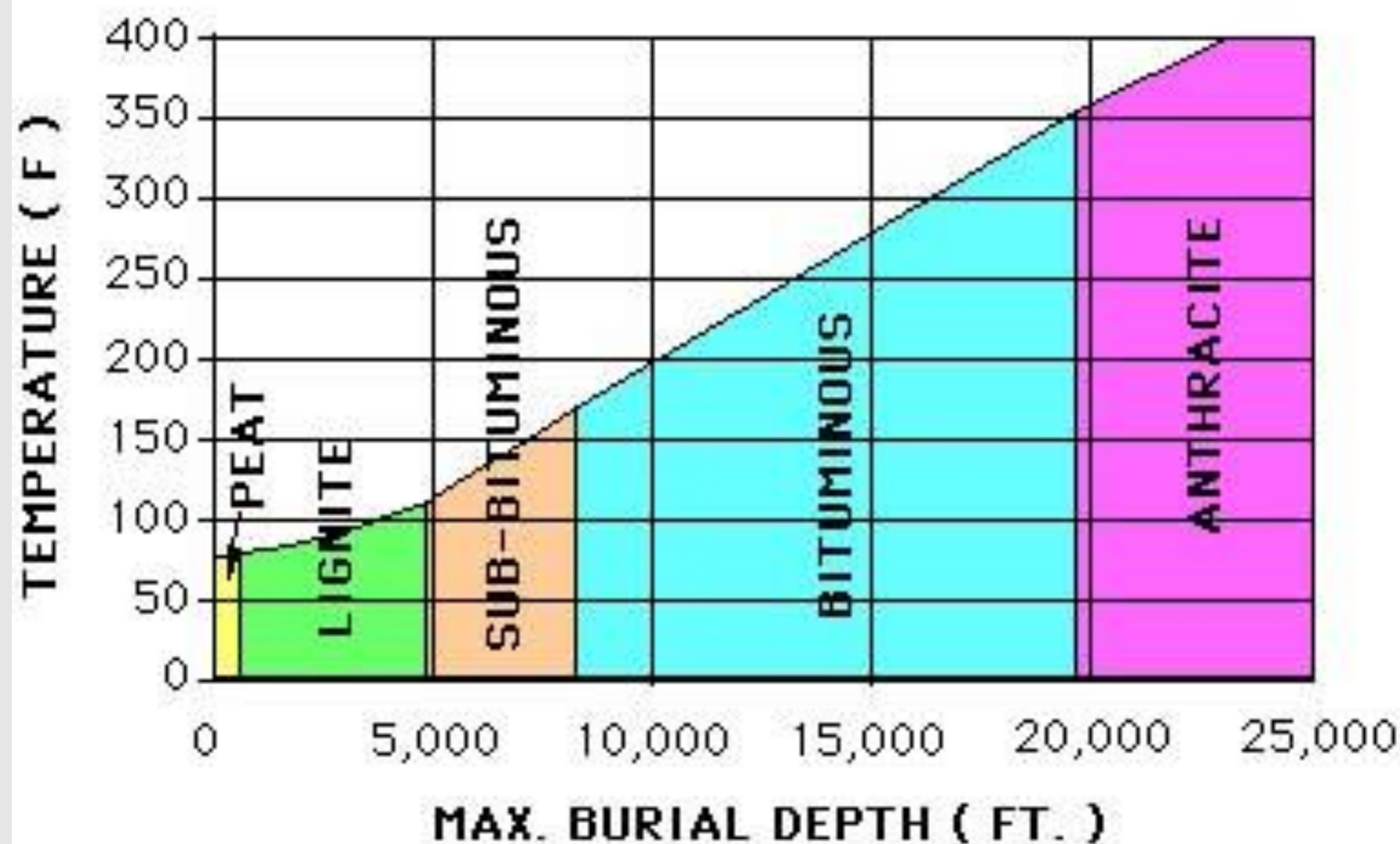




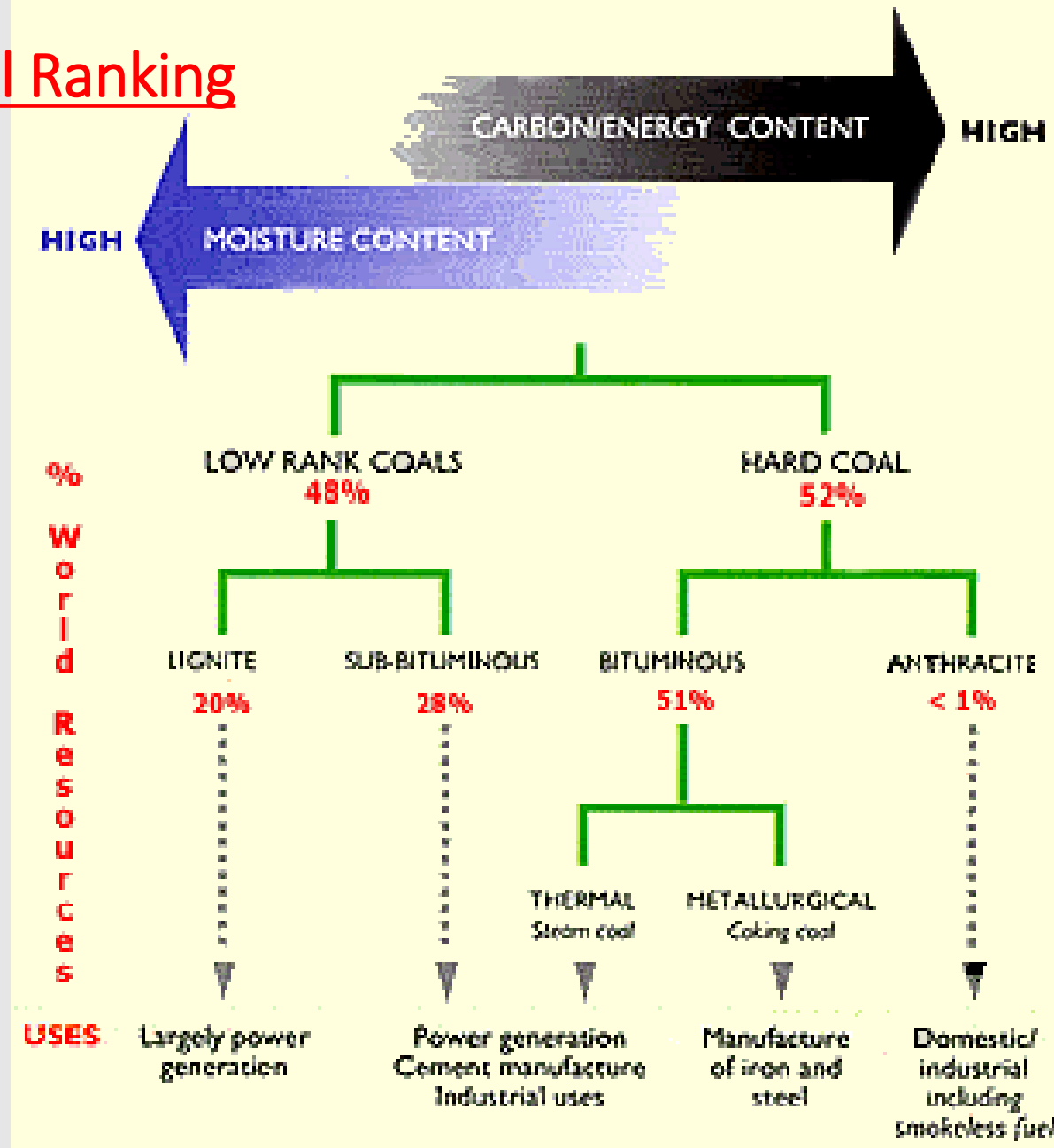
# Coal Ranking & Quality

Coal Rank	% Carbon	Specific Energy (MJ/Kg)
Anthracite	95	35.2
Semi-Anthracite	92	36
Bituminous	90	36
Sub-bituminous	80	33.5
Lignite	71	23

## COAL RANK INCREASES WITH BURIAL DEPTH



# Coal Ranking



# THE FORMATION OF COAL

The origin of coal involves

1. Burial
2. Compaction
3. Induration (baking) of plant material

# Coalification Sequence

**Living Plants**



**Dead Organic Matter**

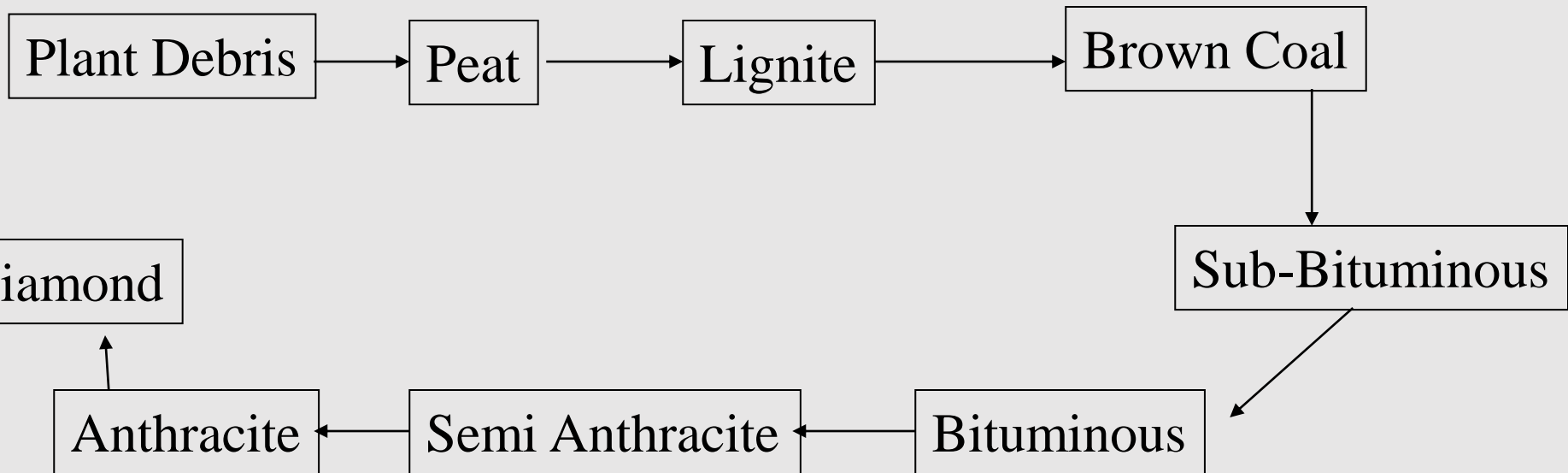


**Biological and Chemical Degradation of  
Organic Material to Peat**



**Thermal Conversion of Peat to Coal**

# Formation of Coal





# FORMATION OF COAL

- The formation of coal begins in a waterlogged environment (Swamps) where plant debris accumulated
- In such an environment, the accumulation of plant debris exceeds the rate of bacterial decay of the debris.
- The bacterial decay rate is reduced because the available oxygen in organic-rich water is completely used up by the decaying process.
- Anaerobic (without oxygen) decay is much slower than aerobic decay.

# FORMATION OF COAL

- Peat is an accumulation of partially decayed vegetation matter.
- For the peat to become coal, it must be buried by sediment.
- 10 vertical feet of original peat material is required to produce 1 vertical foot of coal.



# Formation of Coal

## Phase 1. Aerobic decay

- In the first few inches of peat, aerobic (oxygen needing) bacterial decay reduces the volume by as much as 50%.
- Because the water is stagnant and the peat is almost impermeable, the bacteria soon use up all the available oxygen and die, ending the first stage of decay.

# Formation of Coal

## Phase 2. Anerobic decay

- A second type of bacteria exists in the swamp that requires no oxygen. These anerobic bacteria continue the decay process reducing the volume still further.
- Anerobic decay produces more acids and when the acidity gets too high, it kills off the remaining bacteria ending all decay.

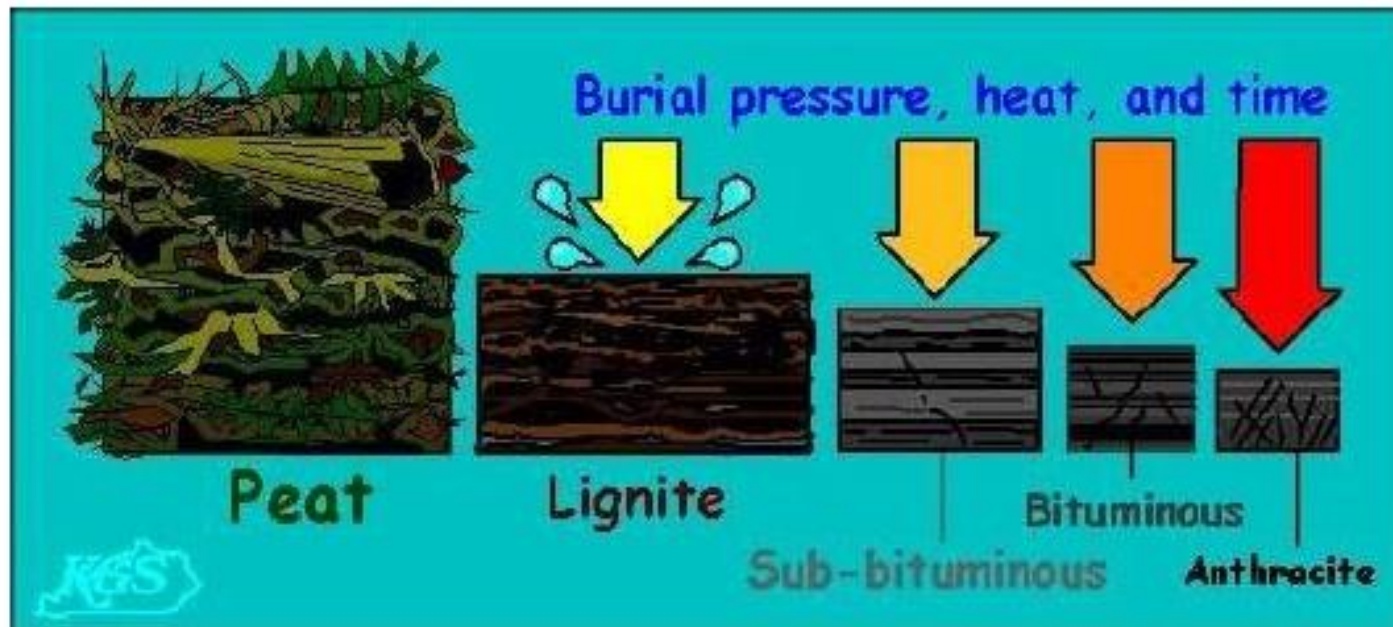
# Formation of Coal

## Phase 3. Bituminization

- After the bacterial decay stages, the peat must be buried under thousands of feet of sediment that provides an insulating blanket trapping the natural heat rising to the surface.
- Once the temperature reaches 100°C, (212°F) the bituminization process begins.
- Chemical reactions drive off water, oxygen and hydrogen which raises the percentage of carbon.

# Formation of Coal

- The stages of this trend proceed from plant debris through peat, lignite, sub-bituminous coal, bituminous coal, to anthracite coal.
- Takes millions of years to convert peat to anthracite coal.

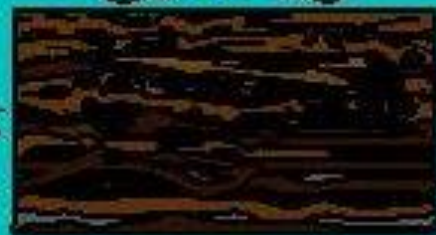






Peat

Burial pressure, heat, and time



Lignite



Sub-bituminous



Bituminous

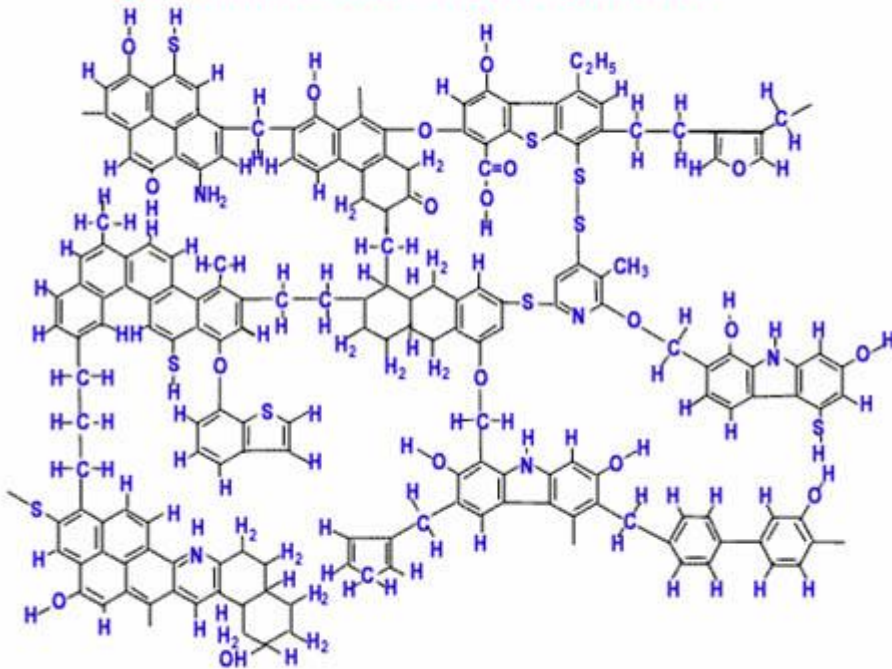


Anthracite

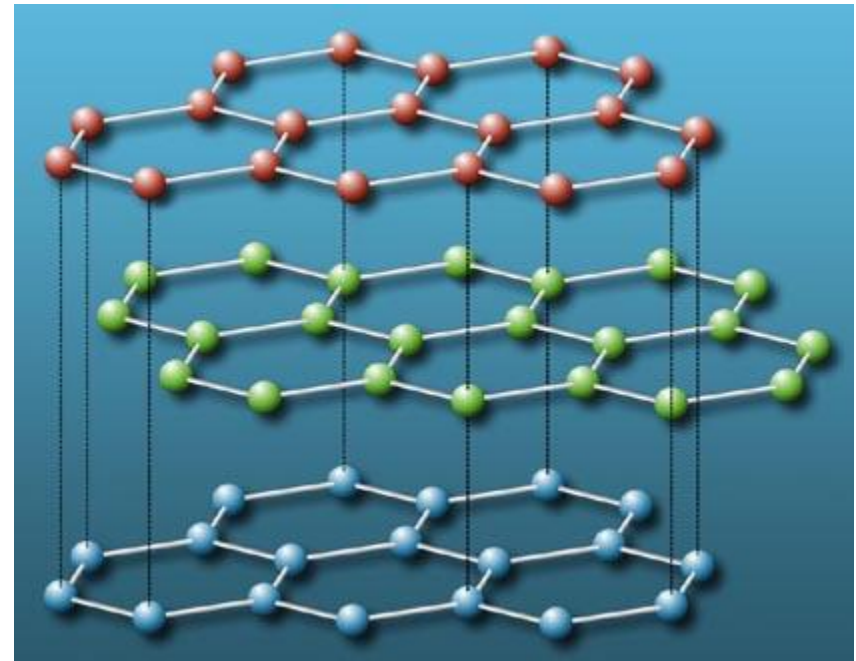
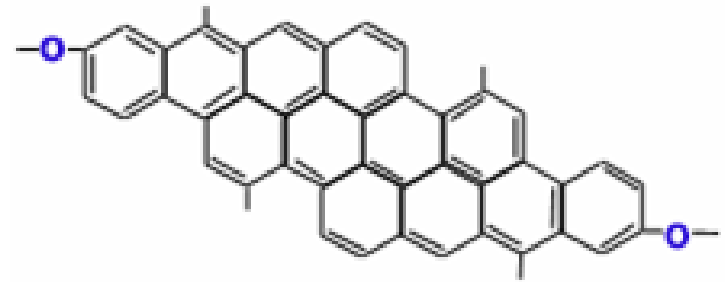


# Chemical Structure of Coal

Bituminous Coal Representation



Representation of anthracite



# **The factors determining the composition of coal.**

- Mode of accumulation and burial of the plant debris forming the deposits.
- Age of the deposits and the geographical distribution.
- Structure of the coal forming plants, particularly details of structure that affect chemical composition or resistance to decay.
- Chemical composition of the coal forming debris and its resistance to decay.
- Nature and intensity of the peat decaying agencies.
- Subsequent geological history of the residual products of decay of the plant debris forming the deposits.



# COKE

- Coke is produced by partially burning coal in a reduced oxygen atmosphere.
- This removes most of the gasses leaving a solid that burns with a higher temperature than coal.





# Gondwana Coal

- Gondwana coal makes up to **98 per cent of the total reserves and 99 per cent of the production of coal in India**. Satpuras, denudation [weathering + erosion] has exposed coal bearing Gondwana strata.
- The carbon content in Gondwana coal [**250 million years old**] is less compared to the Carboniferous coal [**350 million years old**][**Almost Absent in India**] because of its much younger age.
- Gondwana coal forms India's metallurgical grade as well as superior quality coal.
- The **Damuda series (i.e. Lower Gondwana)** possesses the best worked coalfields accounting for 80 per cent of the total coal production in India. 80 out of 113 Indian coalfields are located in the rock systems of the **Damuda series** [lower Gondwana Age].
- Coking as well as non-coking and bituminous as well as sub-bituminous coal are obtained from Gondwana coal fields.
- **Anthracite** is generally not found in the Gondwana coal fields.
- The volatile compounds and ash (usually 13 – 30 per cent) and doesn't allow Carbon percentage to rise above **55 to 60 per cent**. [It requires few million years more if the quality has to get better. Remember Gondwana coal is 100 million years younger than Carboniferous coal].
- Gondwana coal is free from moisture, but it contains **Sulphur** and **Phosphorous**.
- These basins occur in the valleys of certain rivers viz., the Damodar (Jharkhand-West Bengal); the Mahanadi (Chhattisgarh-Odisha); the Son (Madhya Pradesh Jharkhand); the Godavari and the Wardha (Maharashtra-Andhra Pradesh); the Indravati, the Narmada, the Koel, the Panch, the Kanhan and many more.

## Distribution of Gondwana Coal in India

- First coal mine was opened in 1774 at **Raniganj in West Bengal**.
- Coal industry was nationalized in 1973-74. [The present government made some serious changes during the last year [2015] by allowing private sector to play a bigger role in coal production].
- India is now the **third largest coal producer** in the world after **China and the USA**.
- Coal industry provides employment to nearly seven lakh persons.
- Gondwana Coalfields == exclusively found in the Peninsular plateau of India.

## Gondwana Coalfields in Chhattisgarh





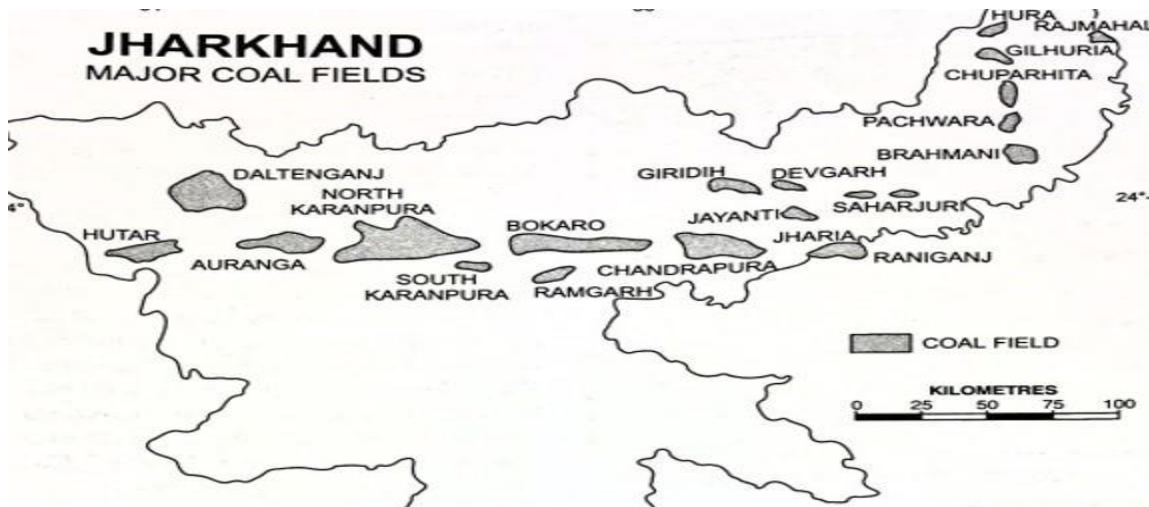
### Coalfield

Korba coalfield  
Birampur coalfield  
Hasdo-Arand coalfield  
Chirmiri coalfield  
Lakhanpur coalfield  
Jhilmili coalfield  
Johilla coalfield  
Sonhat coalfield  
Tatapani-Ramkota coalfields

### Extent

Korba district.  
  
Surguja district.  
  
Shandol district & Koriya district  
Johilla valley  
Surguja district  
Surguja district

## Gondwana Coalfields in Jharkhand



- 1st in reserves [28%].
- 2nd in production [20%].
- Most of the coal fields are located in a narrow belt running in east-west direction.
- Major coalfields are present in Dumka (Santhal Parganas), Hazaribagh, Dhanbad and Palamu.
- **Jharia, Bokaro, Girdih and Karanpura** are the major coal fields

## Gondwana Coalfields in Odisha

Talcher field	Talcher town to Raikhol in Dhenkanal and Sambalpur districts	Ranks <b>second in reserves</b> (24,374 million tonnes) after <b>Raniganj</b> ;
		Coal from this field is most suitable for steam and gas production. Most of the coal is utilised in <b>thermal power and fertilizer plants at Talcher.</b>
Rampur-Himgir coalfields	Sambalpur and Sundargarh	Coal occurs here in middle and lower Barakar seams. inferior quality
Ib river coalfield	Sambalpur and Jharsuguda district	Much of the coal is of inferior quality.

## Gondwana Coalfields in Madhya Pradesh

		largest coalfield of Madhya Pradesh Jhingurda, Panipahari, Khadia, Purewa and Turra are important coal seams
Singrauli (Waidhian) coalfield	Sidhi and Shandol districts	Jhingurda with a total thickness of 131 m is the richest coal seam of the country.
Pench-Kanhan-Tawa	Chhindwara district	thermal power plants at Singrauli and Obra Ghoravari seam in Kanhan field is 4.6 m thick and contains coking coal
Sohagpur coalfield	Shandol district	
Umaria coalfield	Umaria district	inferior quality with high percentage of moisture and ash.

## Gondwana Coalfields in Andhra Pradesh

- 6th in reserves [7.07 %].
- 5th in production [9.69 %].
- Most of the coal reserves are in the **Godavari valley**.
- Adilabad, Karimnagar, Warangal, Khammam, East Godavari, and West Godavari.
- The actual workable collieries are situated at **Singareni and Kothagudam**.
- Almost the entire coal is of **non-coking variety**.
- These are the southern most coalfields of India and a **source of coal supply to most of south India**.

## Gondwana Coalfields in Maharashtra

- 3 per cent reserves.
- 7 per cent of the production.

## Gondwana Coalfields in West Bengal

- 4 % of India's coal.
- 11 % of the coal reserves.
- **Darjeeling** and **Jalpaiguri** are the chief producing districts.
- **RANIGANJ** is the largest coalfield of West Bengal.
- Raniganj == Bardhaman, Bankura and Purulia districts; Small part of this field is in Jharkhand state.
- The coal here is non-coking steam coal.
- Dalingkot coalfield == Darjeeling district.

## Gondwana Coalfields in Uttar Pradesh

- Do not possess coal reserves.
- A small portion of the Singrauli field of Madhya Pradesh falls within Mirzapur district.
- A high grade coal seam, about 1 to 1.5 m thick occurs near Kotah.

In **petroleum geology**, a trap is a geological structure affecting the **reservoir rock** and **caprock** of a petroleum system allowing the accumulation of hydrocarbons in a **reservoir**.

Traps can be of two types: stratigraphic or structural. Structural traps are the most important type of trap as they represent the majority of the world's discovered petroleum resources

Oil or petroleum pools are local accumulations of natural oils filling the fine capillary tubes, fractures, and other openings of certain relatively porous rocks at various depths beneath the ground water level.

## **Oilfields: Major Oilfields found in India**

On-shore Oil Production. One-shore oil fields are located in the Brahmaputra valley of north-east India, Gujarat coast in western India and Cauvery on-shore basin in Tamil Nadu. Besides Andhra Pradesh has both on-shore and off-shore oil reserves.

### **Oilfields in North-East India:**

The major oilfields in north-east India are those of the Brahmaputra valley in Assam and its neighbouring areas including Arunachal Pradesh, Nagaland, Meghalaya, Tripura, Manipur and Mizoram.

#### **Assam:**

Assam is the oldest oil producing state in India. The main oil bearing strata extend for a distance of 320 km in upper Assam along the Brahmaputra valley. Following are some of the important oilfields of Assam:

##### **1. The Digboi field:**

Located in the north-east of Tipam hills in Dibrugarh district of Upper Assam, Digboi is the oldest oil field of India. The oil bearing strata cover an area of about 13 sq km where oil is available at 400 to 2,000 metre depth.

Over 800 oil wells have been drilled so far. Before the opening of the oil fields of west India, Digboi used to account for three-fourths of the total oil production of India. The most important centres are Digboi, Bappapang, Hassapang and Paintola. Most oil is sent to oil refinery at Digboi.

## **2. The Naharkatiya field:**

It is located at a distance of 32 km southwest of Digboi at the left bank of Burhi Dibing river. Here oil was discovered in 1953 and production started in 1954. Oil is available at depths varying from 4,000 to 5,000 metres. Out of the 60 successful wells drilled so far, 56 are producing oil while the remaining 4 are producing natural gas.

The annual production is 2.5 million tonnes of oil and one million cubic metre natural gas. Oil from this area is sent to oil refineries at Noonamati in Assam (443 km) and Barauni in Bihar (724 km) through pipeline.

## **3. The Moran-Hugrijan field:**

It is located about 40 km south-west of Naharkatiya. Oil at Moran- Hugrijan field was discovered in 1953 and production started in 1956. Drilling has proved an oil bearing Barail horizon at a depth of 3,355 metre. Moran s potential may be estimated at one million tonnes per annum. As many as 20 wells have been drilled which yield oil as well as gas.

Other fields have been discovered at Rudrasagar, Sibsagar, Lakwa, Galeki, Badarpur, Barholla and Anguri.

Oilfields of Assam are relatively inaccessible and are distantly located from the main consuming areas. Oil from Assam is, therefore, refined mostly in the refineries located at Digboi, Guwahati, Bongaigaon, Barauni and Nomaligarh.

Arunachal Pradesh has oil reserves at Manabhum, Kharsang and Charali. In Tripura, promising oilfields have been discovered at Mamunbhanga, Baramura-Deotamura Subhang, Manu, Ampu Bazar, Amarapur-Dambura areas. Nagaland also has some oil bearing rock strata.

## **On-Shore Oil Fields of Western India:**

### **Gujarat:**

Explorations by Oil and Natural Gas Commission (ONGC) have yielded valuable findings of oil bearing rock strata over an area of about 15,360 sq km around the Gulf of Khambhat. The main oil belt extends from Surat to Amreli. Kachchh, Vadodara, Bharuch, Surat, Ahmedabad, Kheda, Mehsana, etc. are the main producing districts.

In 2002-03, Gujarat produced over 60 lakh tonnes of crude oil which accounted for over 18 per cent of the total oil production of India. Ankleshwar, Lunej, Kalol, Nawgam, Kosamba, Kathana, Barkol, Mehsana and Sanand are the important oilfields of these regions.

### **1. Ankleshwar:**

The first major oil-find came in 1958 with the discovery of Ankleshwar field located about 80 km south of Vadodara and nearly 160 km south of Khambhat. Ankleshwar anticline is about 20 km long and 4 km wide. Oil is available at depths varying from 1,000 to 1,200 metres. It has a capacity of 2.8 million tonnes per annum.

It is such a prolific oilfield that Pt. Jawahar Lai Nehru called it the fountain of prosperity. As many as 170 oil wells have been bored so far. It is estimated that 25 lakh tonnes per year of oil can be obtained from this field. Oil from this field is sent to refineries at Trombay and Koyali.

### **2. Khambhat or Lunej field:**

The oil and Natural Gas Commission drilled test wells in 1958 at Lunej near Ahmadabad and confirmed the occurrence of a commercially exploitable oil field. Oil was obtained on 4th Sept. 1959. Till 1969, a total of 62 wells were drilled out of which 19 yielded gas while 3 yielded oil. The annual production is 15 lakh tonnes of oil and 8-10 lakh cubic metres of gas. The total reserves are estimated at 3 crore tonnes.

### **3. Ahmedabad and Kalol field:**

It lies about 25 km north-west of Ahmedabad. This field and a part of Khambhat basin contain 'pools' of heavy crude trapped in chunks of coal. Nawgam, Kosamba, Mehsana, Sanand, Kathana, etc. are important producers.

Oil has also been struck in Olkad, Dholka, Kadi, Asjol, Sandkhurd, Siswas, Nandesan, Bandrat, Sobhasan and Vadesar areas.

### **Rajasthan:**

One of the largest onland oil discoveries was made in Banner district of Rajasthan in 2004. The oil block covers an area of approximately 5,000 sq km. State-of-the-art technology with innovative geological modeling was used in discovering this oil field. Initial estimates of the oil in place of this discovery range from 63 to 153 million tonnes.

Two important discoveries, viz., Sarswati and Rajeshwari, with a total 35 million tonnes of inplace oil reserves were made earlier in 2002. The Sarswati discovery had found 14 million tonnes of in place oil reserves for which drilling upto 3,476 m was done. The commercial production is expected to commence in 2007.

## **Western Coast Off-Shore Oilfields:**

Extensive surveys have been conducted by ONGC in the offshore areas of Kuchchh, Khambhat, Konkan, Malabar and Coromandal coasts, Krishna-Godavari delta and Sunderbans. Success on commercial scale has been achieved at Mumbai High, Bassein and Aliabet.

### **1. Mumbai High:**

The greatest success achieved by the ONGC with respect to offshore surveys for oil was that of Mumbai High in 1974. It is located on the continental shelf off the coast of Maharashtra about 176 km north-west of Mumbai.

Here the rock strata of Miocene age covers an area of 2,500 sq km with estimated reserves of about 330 million tonnes of oil and 37,000 million cubic metres of natural gas. Production on commercial scale began in 1976. Oil is taken from a depth of over 1,400 metre with the help of a specially designed platform known as Sagar Samrat.

The discovery of Mumbai High has revolutionised the oil production in India. The share of Mumbai High in the total oil production of India has shot up considerably. This area produced 85 lakh tonnes of oil in 1982 which rose to over 189 lakh tonnes or over 62 per cent of all India in 1991-92.

Production from this field declined between 1989-90 and 1993-94 due to over exploitation. Remedial measures have been taken to enhance the production and the declining trend has been reversed since 1994-95. In 2002-03 this area produced 215.73 lakh tonnes of oil which was about two-thirds of total production of India.

### **2. Bassein:**

Located to the south of Mumbai High, this is a recent discovery endowed with reserves which may prove to be higher than those of the Mumbai High. Huge reserves have been found at a depth of 1,900 metre. Production has started and is expected to pick up fast.

### **3. Aliabet:**

It is located at Aliabet Island in the Gulf of Khambhat about 45 km off Bhavnagar. Huge reserves have been found in this field. A sum of Rs. 400 crore has already been spent on this field. Commercial production is expected to start soon.

## **East Coast:**

The basin and delta regions of the Godawari, the Krishna and the Cauvery rivers hold great potential for oil and gas production. As such these are both on-shore and off-shore areas where extensive exploration has been conducted during the last few years. The Rawa field in Krishna- Godawari off-shore basin is expected to produce 1 to 3 million tonnes of crude oil annually.



In 2002-03, Tamil Nadu produced 3.95 lakh tonnes of oil which was slightly more than the one per cent of the total oil production of India. The Narimanam and Kovilappal oilfields in the Cauvery on-shore basin are expected to produce about 4 lakh tonnes of crude oil annually. A 5 lakh tonne refinery is being set up at Panaigudi near Chennai to refine crude oil from this area.

Andhra Pradesh produces less than one per cent of the total crude oil of India. Oilfields have recently been discovered in the Krishna-Godavari basin. The oilfield near Amolpur is expected to yield 3,600 barrels of crude oil per day

## **MINING GEOLOGY**

### **( THEORY 3 )**

#### **Chapter -3:: Prospecting And Exploration**

##### **Prospecting.**

Prospecting means looking for ores minerals of value of importance. Prospecting is a sum total of systemic process under taken in a sequential manner to discover new ore deposit.

##### **Differentiate between prospecting & exploration.**

Prospecting	Exploration
Prospecting is a sum total of systemic process under taken in a sequential manner to discover new ore deposit.	Exploration is a incorporates set of operation take drilling, trenching keeping sampling assaying, core, ranger, estimated of determining the availability of the ore deposit.

##### **Various criteria for geological exploration.**

##### **Geochemical prospecting :**

This method aims of plotting on suitable map such dispersion pattern of farce metal in sample of soil ground water or vegetation (usually leaves) collected of suitable interval from the area to be prospected aromatizes are indicated by a marked in the concentration of farce metal from the back ground valve. It deals with examination with the earth crush consist of not only rock but also water & gases.

It is divided into two primary and secondary processes. Primary process are connected with magnetism. Metamorphism. Secondary process are associated with superegos agent of rock degradation of water.

On primary geochemical prospecting important to dated difference in the distributor of element in the earth crust. Dispersion is influenced both mechanical as well as chemical process, primary cone of mineral is due to pressure and temperature condition.

Element under normal differentiation separate group oxy phallic, chalo phyllic (sulpher) phylllic side rophyllic (iron) and phylllic.

## **Methods of Geophysical prospecting.**

### **Geophysical exploration :**

It takes the help of natural physical parameters of earth side like gravity magnetism or natural electric field. Artificial physical field is created by electrical radioactivity.

There are major type of geophysical exploration method such as

- (a) Gravity Method, (b) Magnetic Method, (c) Seismic Method,  
(d) Geothermal Method, (e) Radiometric Method (f) Electrical Method.

### **Gravity Method :**

1. It represented a set of geophysical method which makes use of the natural gravity field of the earth. Density is the physical property which helps in gravity method.
2. In gravity method the nature of distribution of gravity on the surface is analyzed. The gravity influenced positively by heavier longer & shallow depth ore bodies.
3. If the gravity field deviates from the normal value then bodies can be present below the surface.
4. The geophysical unit of gravity is milligals & cots.
5. The different kinds of gravity methods are gravity prospecting gravity logging air born gravity & sea born gravimetric.
6. It finds application for exploration of ore deposit oil & natural gas regional geological structure sub surface geology solving engineering problems etc.

### **Magnetic Method :**

1. It makes use of the natural magnetic field of the earth.
2. The physical properties with operates upon this method is based on the fact.
3. The magnetic method is based on the fact that magnetic bodies present in the earth sub surface continue to the magnetic field of the earth.
4. When the magnetic field of the earth is measured on the surface bodies possessing magnetic moment different from those of surrounding rock contribute.

5. Magnetic instrument use are magnetic meter tension magnetometer & fluxgate magnetometer.
6. Unit Gamma & Orestar.
7. It is used for locating iron nickel, tin chromites.

### **Seismic Method :**

1. The elastic property, difference in rocks the controlling properties.
2. It is based on the principle that sub surface rock formation bear different elastic properties.
3. The velocity of propagation of seismic waves through them changes with change in lithology.
4. In seismic method artificial explosion are made in ground.
5. The waves this practice travel through the sub surface layer critical refraction.
6. With the help of geophones fixed suitable intervals on the ground, the different seismic waves reaching the surface are recorded & from the time of the arrival time distance curve are constructed.
7. These graphs known as hodographs seismic waves are of 4 types, (a) Primary wave, (b) Secondary wave, (c) Long wave, (d) Reflected wave.

### **Radiometric Method :**

1. The controlling parameter is the natural radioactivity of rock & ore.
2. The normal radioactivity is different types of rocks.
3. If rock contains radioactive bodies such area will show very high radioactivity given rise to anomalies.
4. Igneous body have relatively more radioactivity than basic & ultra basic rocks.
5. There are two types of natural radiometric method employed in the field. These are (a) Gamma method and (b) An Emanation method.

**Gamma method :** In which the intensity of gamma rays from rocks or ores in an area is measured.

**An Emanation method :**

1. In this method the concentration of radioactive emanation of solid & air are measured.

2. The instrument used as Geiger miller counter or scintillation counter or Gamma ray spectrometer.
3. Unit : Millicurie or Microcurie
4. It is used in exploration of uranium thorium rare earth metal like Beryllium, Lithium, Tantalum, Neobium.
5. In the exploration of oil & natural gas the radioactive tracer techniques is utilized to measure velocity of ground water direction of flow & salt water intrusion.

### **Geothermal Method :**

1. Here the controlling factors thermal conductivity.
2. The temperature distribution on the surface of the earth is occurred in three sources.
  - (a) Insulation : in coming solar radiation.
  - (b) Heat conveyed from the interior of earth by conduction & convection.
  - (c) Due to radioactive mineral.
3. The residual value of temperature distribution on the earth surface can be interrupted in forms of sub surface geology.
4. The instrument used as thermistor thermometer, platinum thermometer, radiometer and crystal deflector.
5. It used in deep structural ore deposits and ground water.

### **Electrical Method :**

It is based on the fact that the sub surface formation & ore deposits contain different electrical properties. The different methods are as follows :

- (a) Electrical resistivity method : Electrical resistivity of sub surface formation varies from one another.
- (b) Wenner : Unit – ohm x meter, Instrument used is electrical resistivity meter.

### **(c) Electromagnetic Method :**

- The alternative emf is established ground using an artificial source.
- The electromagnetic field induces eddy current in the conducting ore body.

- The different method includes (a) Sargram, (b) Enslin, (c) Turam, (d) Sundberg.

(d) **Self potential** : It uses the natural method electric field of the earth sulphide one like pyrite, pyrrhite, chalcophrite. The instrument used a pair of non polarisable electrodes & potentiometer. Unit is Millivolt.

(e) **Induced polarisation** : Based on the study of secondary electro chemical process that takes place on the sub surface due to flow of electric current. When direct electric current is passed in the ground the current is ionic electrolyte & electric solid minerals. Thus at the electrolyte conducting particle boundary the change is transformed from ion to the particle. Thus (+ve) ion change pole of at the particle boundary when the current is stopped the accumulated charge is the material give rise to residual voltage which decrease with time. Unit is Millivolt. It is used in exploration of sulphide & ground water.

### **Geochemical prospecting.**

It deals with the examination of the earth crust consisting not only of rocks but also water gases. Geochemical processes are divided into primary & secondary processes. Primary processes are connected with magnetism and metamorphism. Secondary processes are associated with super gane agent rock degradation as well as magnetic water. In primary geochemical prospecting it is important to detect difference in the distribution of elements in the crust. Dispersion in influence by both mechanical as well as chemical. Primary concentration of ore minerals is due pressure & temperature condition. Element under normal condition magnetic differentiation separate out as group like oxy phyllic, chalcophyllic, lethophyllic, sidenophyllic, atmophyllic, which plug a significant path lock for emplacement and concentration of economic mineral deposit.

### **Biogeochemical & Geobotanical prospecting.**

Biogeochemical Prospecting: Roots, barks, leafs, concentrate, elements from the ground uniform of nutrient elements like as CO, Zn, Ca, K, P, Fe, Mg, Mn, etc are important for the growth of plants to be surveyed to be assayed using various chemical and weight chemical method. First this plant parts are dry in the sun burnt under errabic condition. Then the ash is finally powdered & leached with hydrochloric & hydrogen sulphide. The organic part are washed a ray leaving behind elements residue. Then this residue are analysed or assayed using weight chemical & instrumental techniques. The concentration of a particular element in the plant parts we give the picture about the concentration the element below.



Geobotanical Prospecting : Plants depend for their growth on geological CO₂ moisture and mineral nutrients. Certain elements are essential & important for its growth & development where as some elements are toxic to plant growth the different morphological modification are visible.

For Cu, osmium humble is a indicator of Cu mineralization in below. A crocephylus Roberto, polycarpea, spira styles, poly, carpea, corymboso are indicator of Cu.

For CO, Critotora cobalticola & silence cobalticola.

For Pb & Zn, Plantgo lanceolate, lobilla inflate, sorghustram Neutrons (grass)

For Mo, Molitus alba, trifolium repens, lotus carniculates.

## **Chapter 4:: Economic Geology**

### **Tenor :**

The metal content of an ore is called the tenor of the ore. It is generally expressed in percentage of the metal. It say pays for the extraction cost of the ore.

### **Grade :**

Signifies the commercial classification of an ore where by the physical and chemical parameters are taken into account beside its qualitative aspect.

## **Mineralogy, mode of occurrence, distribution & use of iron ore deposits in India.**

### **Mineralogy :**

The chief economic iron ore minerals are :

Magnetite	Fe ₃ O ₄	(containing 72.4% of iron)
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Hematite	Fe ₂ O ₃	(Fe=70%)
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Limonite	2Fe ₂ O ₃ , 3H ₂ O	(Fe=59.8%)
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Goethite	Fe ₂ O ₃ , H ₂ O	(Fe=62.9%)
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(Spathic ore)

Siderite	FeCO ₃	(Fe=48.2%)
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Pyrite	FeS ₂	(Fe=46.2%)
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Chamosite and thuringite are examples of iron silicate minerals.

### **Mode of occurrence :**

Iron ore deposits occur as magmatic deposits, as bedded deposits, as residual concentration deposits or sometimes as nodules and concretions in shales associated with coal-seams.

### **Distribution in India :**

1. The biggest iron ore field of India is situated in the Singhbhum district of Bihar and the adjoining districts of Keonjhar, Sundergarh and Mayurbhanj of Odisha. The important mining centres of Odisha and Bihar are Barbil, Gua, Bonai, Joda, Kiriburu, Suleipat, Gorumahisani, Noamundi, Barajamda etc.
2. Madhya Pradesh: In the Bailadila hill ranges.
3. Maharashtra: Ratnagiri district.
4. Goa: Bicholim- Pale in Goa.
5. Karnataka: Bananudan hills in Chikmagalur district, and in Sandur, Bellary, Hospet districts as well as Shimoga and Chitaldrug districts. Important one is that of Kudermukh.
6. Andhra Pradesh: Cuddapah, Kurnool, Chitnoor, Nellore, Anantapur, Warangal and Adilabad districts.
7. Tamilnadu: Salem district, and Tiruchirapalli district.
8. West Bengal: Deposit of lateritic ores mostly occur in West Bengal.
9. Assam: Iron stone clay are found as nodules and thin beds in the coal measures of Eocene age and in the Tipam series of Miocene age.

### **Use of Iron :**

1. Smelting for steel.
2. Spongy iron.
3. Rail, coaches, wagons, ships.
4. Heavy machineries.
5. Coal breeze & building dums.
6. Weapons and rebar.
7. High speed steel.
8. Utensils & forming equipments.

9. Coal iron, Pig iron, wrought iron.

**Mineralogy, mode of occurrence & description of Chromites deposits in India & its uses.**

**Mineralogy:**

It is an important alloying element in the manufacture of steel Chromite is the only ore-mineral of chromium.

Chromite –  $\text{FeO}$ ,  $\text{Cr}_2\text{O}_3$ ,  $\text{Cr}_2\text{O}_3 = 68.0\%$  and  $\text{Cr} = 46.66\%$ .

**Mode of occurrence:**

Chromite deposits occur as lenses, masses, veins and disseminated grains in host rocks. The deposits are regarded as the early or late magmatic segregation or injection product.

**Distribution in India:**

The largest chromite deposit in the country is located in the Sukinda ultrabasic belt of Cuttack and Dhenkanal district of Odisha, and also in the Keonjhar district of the state. The belt extends over a distance of about 20km, the width of the belt is about 2km. the ore bodies are lenticular in shape and occur as lenses and patches within the lateritised ultrabasic rocks.

The other important deposits occur in:

- (i) Andhra Pradesh: Kistna district (Kondapalle)
- (ii) Bihar: Singhbhum district.
- (iii) Karnataka: Chitaldrug, Hassan and Shimoga districts.
- (iv) Tamil Nadu: Salem districts (Sittampundi).
- (v)

**Economic uses:**

1. In the metallurgical industries in the production of various non ferrous alloys of chromium and also in the form of ferro chrome for manufacturing chrome steel.
2. In refractory industries, due to its high resistance against corrosion, high temperature and sudden temperature changes and its chemically neutral character.
3. In chemical industries, for the manufacture of chromium compounds like chromates and bi-chromates and chrome acid etc.

## **Mineralogy, mode of occurrence & distribution of copper deposits in India & uses of this metal.**

### **Mineralogy:**

It is the most important non-ferrous metal and was the earliest metal used by man. In nature copper occurs in four principle formes, sulphides, carbonates, oxides and as native copper. Of these the bulk of cooper is obtained from the sulphide ores. To be economically exploited a cooper ore should contain at least 2.5% of copper. In modern times ores with 1% of copper are also used.

### **Mode of occurrence:**

Copper deposits may occur as.

- (a) Disseminated ore bodies: Where the copper minerals are generally dispersed in a large volume of rock. They are generally of low grade. The porphyry copper deposits of USA are of this type.
- (b) Massive, irregular or lenticular ore bodies, which are formed by the process of replacement.
- (c) Vein deposits or lodes: In which the copper hearing solutions percolating along shear zones and rock fractures deposit copper mineral with changes of temperature and pressure forming fissure veins, copper deposits of Singhbhum.
- (d) Deposits following stratigraphic beds, as is the case with the deposits of Khetri (Rajasthan).

### **Distribution in India :**

1. In Andhra Pradesh, the most important copper deposits are the Agnigundla deposits.
2. In Bihar, in the Singhbhum district, a copper bearing belt of about 80 miles long occurs. Here the copper ores occur as veins in the country rock consisting of mica achists, quartz-schists, chlorite-schists, biotite-schists, granite and granite-gneisses.
3. In Madhya Pradesh, the important deposit is the Malan Jhakhand copper deposit, where copper ores occurs in the form of veins within dolomitic limestone.
4. The Khetri copper deposit of Rajasthan is one of the important copper deposit in the country. This belt has 3 richly mineralized sections - Madhian, Kolihan and Akhwali.

5. Other important copper deposits of the country are as follows

(a) Himachal Pradesh: Kangra, Kulu valley.

(b) Mysore: Chittaldurg, Hassan, Bellary districts.

(c) West Bengal: Darjeeling, Jalpaiguri districts.

(d) Sikkim: Rangpo and Dikchu deposits which are found to occur in association with the metamorphic rocks belonging to the Daling series.

### **Economic Uses:**

The metal is of great industrial importance, because of its high electric conductivity, high ductility and malleability. Thus it is mostly used in electrical manufactures. Besides, the copper alloys are used in buildings, automobiles, air planes, naval ships, house hold utensils as well as in metallurgy and paints.

### **Mineralogy, mode of occurrence, distribution of lead & zinc deposits in India & the uses of these metals.**

#### **Mineralogy:**

The two metals lead and zinc rarely occurs in native state, they generally occur in combination with other elements. The ore minerals of lead and zinc are usually found to occur in association with each other. The following are the important minerals of lead and zinc:

<b>Lead</b>	<b>Zinc</b>
Galena-PbS-Pb 86.6%	Sphalerite or zinc blende – $\text{ZnS}$ , Zn – 67%.
Cerussite- $\text{PbCO}_3$ -Pb 77.5%	Smithsonite or Eng. Calamine – $\text{ZnCO}_3$ , Zn-52%.
Anglesite- $\text{PbSO}_4$ , Pb 68.3%	Hemimorphite or Americanname Calamine      Zincite- $\text{ZnO}$ – $2\text{ZnO}_2\text{SiO}_2\cdot 2\text{H}_2\text{O}$ , Zn– 54.2%

#### **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. Both lead and zinc ore bodies usually occur as veins and massive or tabular lodes, and as disseminations, mostly in limestone or dolomites. Majority of these ores occur as cavity fillings and replacements formed by low temperature hydrothermal solutions.

### **Distribution in India:**

The most important lead zinc deposits of economic value in India is the Zawar deposit of Udaipur district of Rajasthan. India's reserve of these ores is meager compared to her needs.

In the Zawar area, the Mochia Marga, Barai Magra and Zawar Mala hills contain most extensive deposits.

The ore minerals consist of argentiferous galena associated with sphalerite and chalcopyrite. The ore contains 1.5 to 2% of lead and 4.5 to 5% zinc.

Other important occurrences in the country are as follows:

- (a) Lead copper ore deposits in Agnigundla area of Guntur district of Andhra Pradesh.
- (b) Lead zinc copper belt of 3 km long in Ambamata Devi area of Gujarat and Rajasthan.
- (c) Sargipalli area in the district of Sundergarh (Odisha).

### **Economic uses:**

- (i) Lead is used in the construction of accumulators, for lead piping and sheeting cable covers, as pigments in glass making, in medicine etc.
- (ii) Zinc is used for coating, galvanizing iron and steel products, in the manufacture of pigments and alloys with other metals, in the manufacture of batteries and electric appliances. Besides they are widely used in textile industry, timber preservation etc.

### **Methods of sampling as outlined by Bureau of Indian Standards. (BIS).**

The different methods of sampling are as follows:

#### **1. Grab sampling:**

- It is the random collection of broken chips from the exposed surface of an outcrop from the mine working or from stock material.
- The material from the stock can be obtained by a small hand shovel.
- Grab sample is generally obtained during the preliminary survey.
- The grade of the deposit can't be relied upon from the assay value of such sample.



## 2. **Chip Samples:**

- Chip samples closely resemble grab sampling except that the sample is collected from a fresh rock surface.
- The surface of an ore body is first clean by a wire brush and then a chip or fragment is broken by a hammer.
- This is also used in preliminary survey.

## 3. **Channel or Groove Sampling:**

- It is collected from groove cut systematically across the exposure of the ore body.
- It is used in sampling of frenches, pits, drifts, winzes, raises, shafts.
- The purpose of cutting a groove or channel is to ensure that uniform quantity of material is drawn the entire ore body.
- A channel of 10cm with and 2.5cm depth is cut.
- After cutting a groove across the ore body parallel to the true with samplers drawn by further deepening the groove by means of a chisel to a uniform depth.
- When the ore body consists of a alternate bend if reached and liner and each type is separately sample.

## 4. **Bore Hole Sampling:**

- It is carried out by drilling bore & hole in the leased hole area.
- It is the most modern method of examination of mineralization under neat the surface of the earth.
- The horizontal extension and the vertical persistency of ore body is easily de-marketed by bore hole sampling.
- Drill holes are place at suitable intervals preferably on a grid pattern to determined on easy valve of the ore.
- Bore hole cores are taken out and preserved in core box.

## 5. **Bulk Sampling:**

- A few tones of the ore either from the French pit channel or from run of mine ore taken out all are collected to determined ore for its physical properties and its accumulative to beneficiation techniques by pilot plant foot.

- For iron ores the bulk sample is taken to examine the ratio of fines to total mass of core mines.

6. **Car and Wagon Sampling:**

- It is obtained by taking a predetermined quantity of run off mine from each car load or wagon load.
- It is done to determine the quality of ore dispatched to the mill of beneficiation.

# SAMPLING

# What is a sample?

- **A sample** is a finite part of a statistical population whose properties are studied to gain information about the whole (Webster, 1985).

# What is sampling?

Sampling is the act, process, or technique of selecting a suitable sample, or a representative part of a population for the purpose of determining parameters or characteristics of the whole population.

**This is achieved by taking samples from natural exposures, bore holes and mine openings.**

# Introduction

- Sampling methods vary from simple grab samples on existing exposures to sophisticated drilling methods.
- As a rule, the surface of the mineralization is obscured by various types of overburden, or it is weathered and leached to some depth, thereby obscuring the nature of the mineralization."

# Objective Based Sampling

- Sampling may be chemical, mineralogical, technical and technological.
- **1. Chemical:** Samples are taken for determining the **content of useful and secondary components**.
- **2. Mineralogical:** It is done to ascertain the **mineral and petrographical composition of the mineral**. It helps to establish the origin of the deposit, the dependences governing grade variations and also to plan the ore dressing and beneficiation.
- **3. Technical:** Samples are taken to study the **technical properties of the raw material**, which does not require metallurgical or chemical treatment. The factors are strength and flexibility of fibres; mica – the size; sand and gravel – grain size distribution.
- **4. Technological:** Samples are collected for the study of the technological properties of the raw material in the course of its **beneficiation and processing**.



- The process of sampling falls into several stages
  1. Collecting samples,
  2. Their processing,
  3. Laboratory studies of the sample (assaying),
  4. Analysis/Interpretation of the laboratory findings.

## **Sampling During Large-scale and Detailed Mapping**

- i) to identify and pigeon-hole the rock type;
- ii) to gain an understanding of geological events;
- iii) in laying plans for more thorough sampling;
- iv) to delineate and narrow down mineralized zone; and
- v) to elucidate the type and nature of mineralization and for possible extension along strike and at depth

# Types of Sampling

- (i) spot samples;
- (ii) serial samples to test hypotheses;
- (iii) sampling to find variations;
- (iv) sampling for bulk composition; and
- (v) sampling for distribution of compositions.

# SAMPLING OF ORE MINERALS

- Grade of a mineral and metal values vary in proportion from one place to another.
- One single sample taken from one part of the ore body generally does not provide a representative picture of the grade of the entire ore body
- Some degree of error between the actual value and the value computed from the samples.
- The aim of sampling is only to reduce the error to the minimum possible level.

# SAMPLING OF ORE MINERALS

- Sampling also reveals the pattern of mineralisation within the ore richer and leaner ore portions.
- The limits of mineralisation towards both the hanging and footwall contacts can also be precisely defined by careful sampling.
- Determine the processing the extractability characteristics of the ore

# PRINCIPLES OF SAMPLING

- True representative of the entire ore body.
- It is necessary to choose proper places for sampling.
- Different samples collected from various parts of the ore body can be combined into a single composite sample to give the most representative picture of the whole ore body.
- This is never done because it is also necessary to know the average grade of the rich and lean portions or the ore body separately. Samples are spaced at regular intervals
- The actual intervals cannot be determined arbitrarily, but have to be arrived at based on the experience gained in similar deposits in the past
- Any interval which minimizes the error is justified in sampling.
- Fixed minimum width or their multiples for each sample, depending upon the complexity of value distribution visualized



# TYPES OF SAMPLING

- **Grab Sampling**
- **Chip Sampling**
- **Channel Sampling**
- **Bulk Sampling**
- **Dump Sampling**
- **Trench Sampling**
- **Pit Sampling**

## GRAB SAMPLING

Grab sampling is done at random over the mineralized zone on account of certain distinct features such colour, texture, weight or any other striking feature.

Analysis of grab sample gives a preliminary idea about the nature and grade of the ore mineral.

However it is not representative of any large volume or bulk of the deposit.

# GRAB SAMPLING

- Richards – Chechette formula

$$Q = KD^2$$

- Where Q = the reliable weight of the worked down (also initial ) sample in Kg.
- D = the diameter of the largest particle in the sample in mm, and
- K =a factor depending on the homogeneity of the mineral.
- The values of k which may be used in most cases

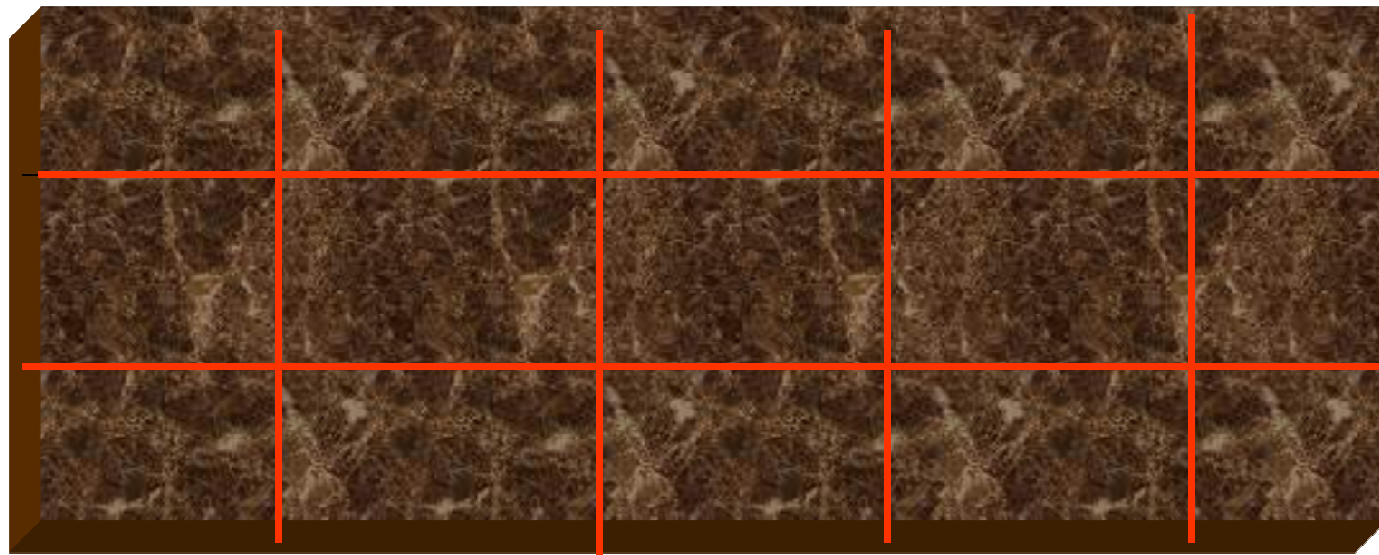
Ore type	Value of k
Homogenous	0.05
Non-homogenous	0.10
Very non-homogenous	0.20 to 0.30
Extremely nonhomogeneous	0.40 to 0.50

# CHIP SAMPLING

Chip sampling is done for rapid assessment to determine general grade of deposit.

Chip samples are collected at suitable intervals, in equal size and weight, along a line covering the width of the mineralized zone.

The sample chipped along a line should be suitably sub-divided based on nature of ore and grade variation of the deposit.



# CHANNEL SAMPLING

- It consists of cutting across the mineralized zone, collecting resultant material like chips, dust, etc and combining them together to form one sample.
- Channel cutting is to be along the direction of maximum variability and is normal to the planar surface of the mineral zone disposition, which usually coincides with the thickness of the ore body.
- Normally, channels are 3 to 6 cm wide and 1 cm thick.

# BULK SAMPLING

- Bulk sampling is done in two specific cases. One situation is when a pilot plant test is to be done on an ore determined accurately
- Bulk samples may be made by collecting a portion from every blast continuously, or from shovels or cars in the case of mines. Bulk samples may be collected from a series of pits or number of trenches, adits or underground drives in the case of prospects
- For technological studies covering laboratory scale benefaction tests, the bulk sample may be 100 to 250 kg. In weight .In some complex ores, upto 1000 kg. May be necessary whereas for pilot plant tests 50 tons of material would be usually required

# DUMP SAMPLING

- Dump sampling can be done by systematically driving auger into the dumps and collecting the augured material.
- Benches may be prepared on the dumps and, from the benches, pits can be driven to collect samples.
- If a shovel is available,. Shovels can be deployed to take out representative bulk samples



# SELECTION OF SAMPLING METHOD

When the ore body is thick and the values of mineralisation are uniformly distributed, sampling can be done by chip or grab sampling.

- When the ore body is of medium size and mineralisation is uniform, a combine chip and channel sampling will give the best results.
- Where the ore body is too thin but occurs in benches or layers, sampling of various layers can be done by chip sampling.

# SELECTION OF SAMPLING METHOD

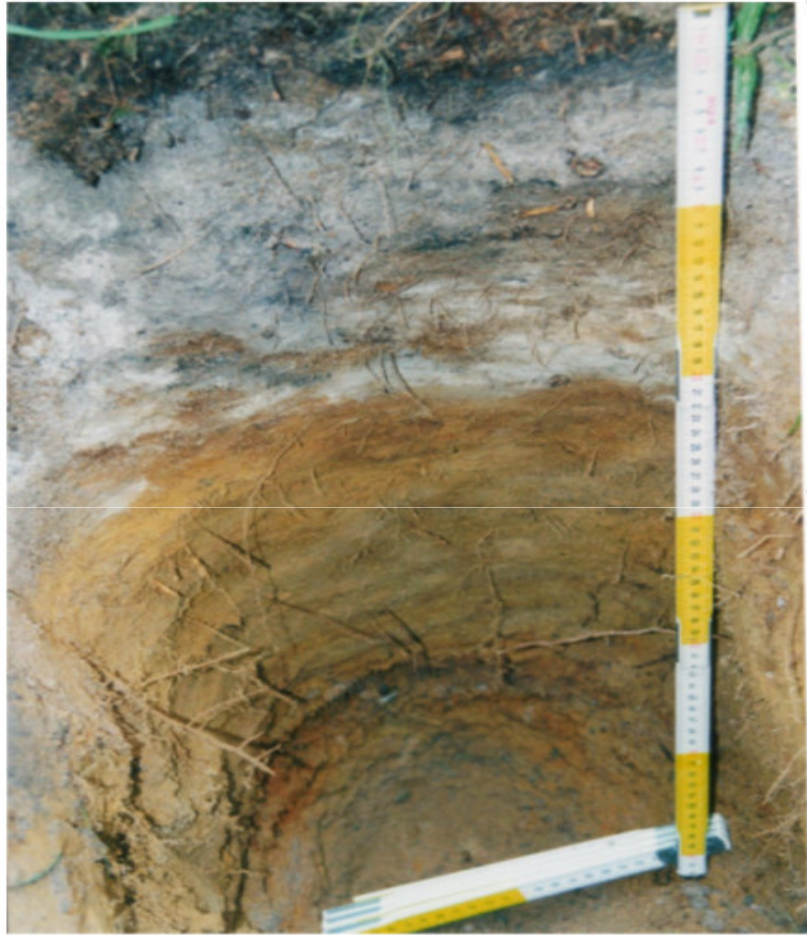
**When a deposit is of very large dimension, it becomes necessary to collect a large number of samples. In such cases, a large number of chip samples would give reliable results. Here, the quicker and not necessarily the most accurate method should be preferred.**

- With minerals like gold, rare metals, etc . Where values are too spotty and irregular, bulk sampling would give the best results.**
- Wherever the ore is banded, channel sampling would give the best results, and very hard ore, particularly massive types of iron ore, would require to be sampled by blast hole cuttings**

# Surface Sampling Methods

- Near-surface samples can be collected with a spade, scoop
- Sampling at greater depths or below a water column may require a hand auger, coring device, or dredge.
- As the sampling depth increases, the use of a powered device may be necessary to push the sampler into the soil or sediment layers.

# Surface Sampling



The soil sample pit



The alluvial horizons at the floodplain sediment sampling

**Recommended Cross-Section of Channel Sampling, cm²**

Distribution of components	Thickness of ore bodies, m	
	> 2.5	0.5-2.5
		< 0.5
Strong Mineral Deposits		
Highly homogenous and homogenous (regular)	2x5	2x6
Inhomogenous	2.15x8	2.5x9
Extremely inhomogenous (non-uniform)	3x8	3x10
		2x10
		2.5x10
		3x12
Soft Mineral Deposits (without consideration of thickness of ore bodies)		
Highly homogenous and homogenous	(2-5)x(5-10)	
Inhomogenous and highly inhomogenous	(5-10) x (10-20)	



Group	Metal Distribution	Coefficient of variation in metal content, %	Type of deposit	Sample spacing
I	Very regular	Up to 20	Marine sedimentary deposit of Fe and Mn	50-15
II	Regular Irregular	20-40	Sedimentary deposits of Fe, Mn, bauxites; some metamorphic occurrences of Fe	15-4
III	Very Irregular	40-100	Most occurrences of non-ferrous metal deposits, some deposits of rare metals	4-2.5
IV	Extremely	100-150	Predominantly non-ferrous metal deposits and also occurrence of Au	2.5-1
V	Irregular	>150	Some Au and rare metal deposits	1.5-1

# Sampling of Exploratory Bore Holes

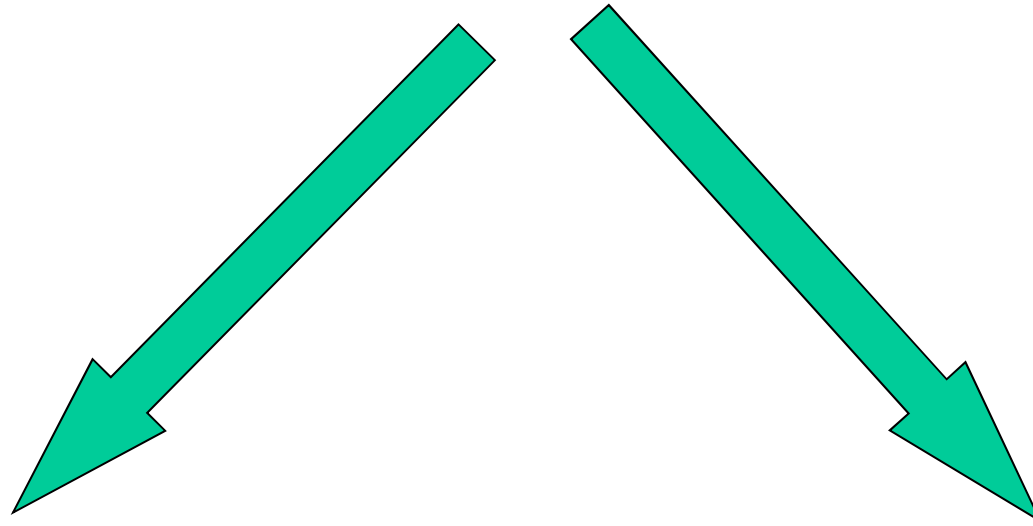
sampling material comes from the core, core and sludge, and sludge

$$\text{Core Recovery (C.R.)} = l/L * 100\%$$

Where  $l$  = length of the core, and  $L$   
= bore hole length



# SAMPLING ERRORS



**RANDOM**

**SYSTEMATIC**

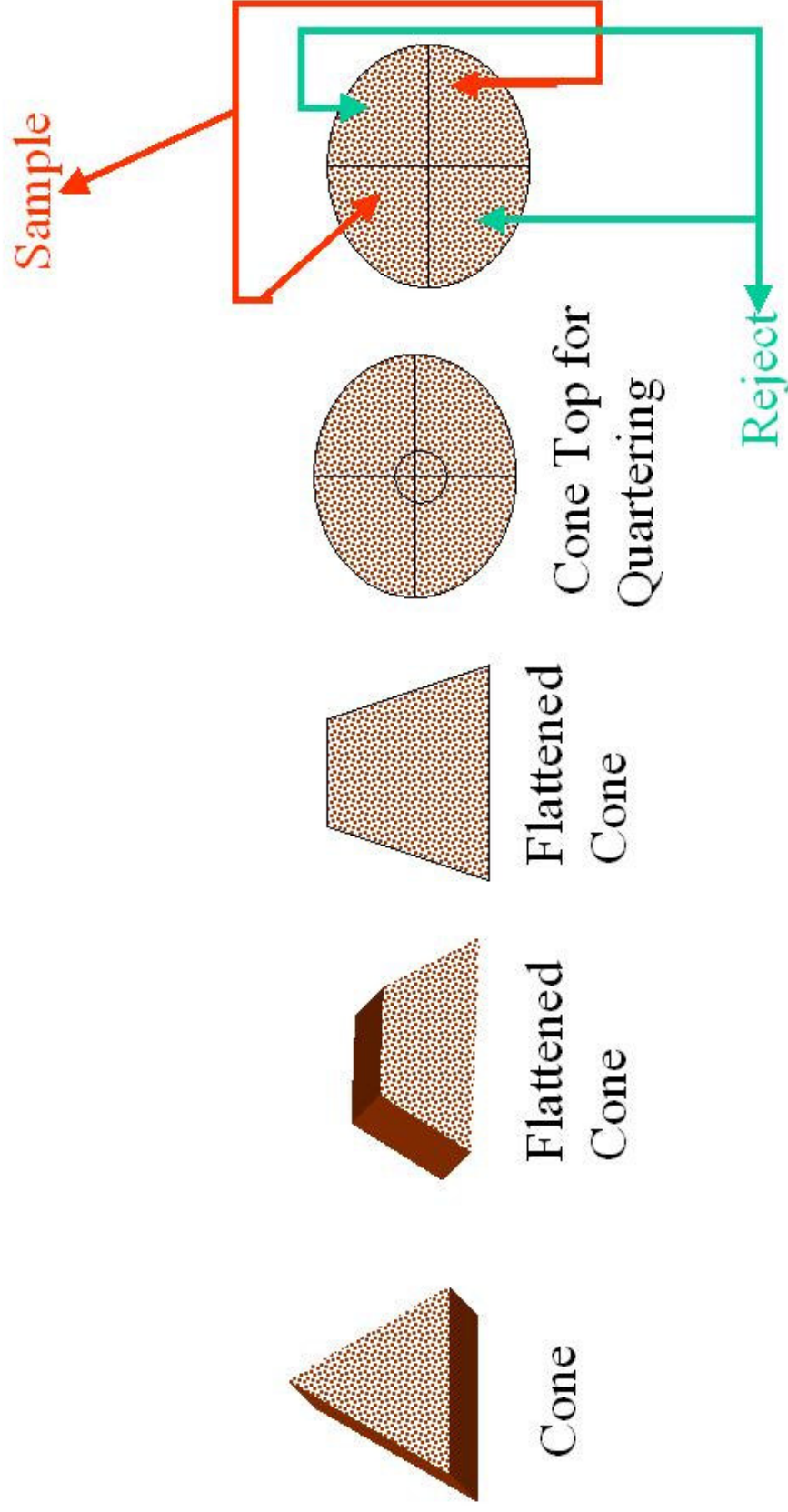
# RANDOM ERRORS

- When check samples are taken from the same spot, there will be natural divergence between the value of the principal sample and the control sample. This cannot be overcome.
- 
- Errors accumulated due to measurement errors, poor facilities and equipment, and poor eye judgment of the sampler

# SYSTEMATICAL ERRORS

- Errors due to mistaken of calculations, misprints and poor numbering
- Limitations of the assay technique itself

# CONING AND QUARTERING



# TESTING OF SAMPLES

- Assay of useful constituents and harmful ingredients.
- Mineralogical investigations to ascertain mineral composition, grain size, texture and structure.
- Semi-quantitative spectral analysis to determine all the elements present in the ore.
- Technological tests to establish the most efficient method for treating the mineral.
- Tests to determine certain physical properties of the mineral to establish the grade and mining methods and to estimate the reserves

# LABORATORY-SCALE EXAMINATION

- Testing physical characteristics
- Petrological tests
- Chemical analysis
- X-ray and spectroscopic and other method