GOVERNMENT POLYTECHNIC JAJPUR

Lecture Note on

Mine Geology-2

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COURSE CONTENTS (Based on specific objectives)

1. Stratigraphy:-

- Describe the principles of stratigraphy
- Describe the geological time Scale.
- Describe the stratigraphic sequence, lithology, distribution & economic mineral deposits of Iron Ore series, Cuddpah Supergroup, Vindhyan super group & gondwana super group.

2. Fossil fuels:-

- **Coal**
- Describe the different ranks of coal.
- Describe different grades of coal like A,B,C,D.
- Describe the various theories accounting for the origin of coal.
- Describe various important lower gondwana Coalfields of India.
- **Petroleum**
- Describe the organic & inorganic theories accounting for the origin of petroleum.
- Define oil pool & oil trap.
- Describe process of accumulation of oil.
- Describe favorable conditions for accumulation of oil.
- Describe different important oil fields in India.

3. Prospecting & exploration:-

- Define prospecting.
- Differentiate between prospecting & exploration.
- Enumerate & describe various criteria for geological exploration.
- Describe various methods of Geophysical prospecting.
- Explain Geochemical prospecting.
- Differentiate between biogeochemical & geo botanical prospecting.

4. Economic Geology:-

- Define ore & gangue.
- Define tenor & grade.
- Describe the mineralogy, mode of occurrence, distribution & use of iron ore deposits in India.
- Describe the mineralogy, mode of occurrence, & description of Chromites deposits in India & its uses. Describe the mineralogy, mode of occurrence & distribution of copper deposits in India & uses of this Metal.
- UNFC (United Nation Framework of Classification) code of classification of reserves.

5. Sampling.:-

Define sampling, outline the method of preparation of samples for assay.

Explain sampling

Des�cribe the different methods of sampling as outlined by Bureau of

- **Indian Standards. (BIS)**

CHAPTER-1

STRATIGRAPHY

PRINCIPLES OF STRATIGRAF'HY:-

"Stratigraphy" **is the science of description, correlation and classification of strata in sedimentary rocks. It also includes the interpretation of the despositional environments of the strata,**

Faci es. A set of lithological and palaeontalogie,a1 eharaoterstics of a sedimentary rock which intlic.ate its pertivalar environment of depDsition. arc called *"dad es"*.

A lateral variation in lithology and fossil assemblage in a Rion which result from change in the environment of deposition, is called *'fades variation"*.

For example,, a .forrnation may l compced of shale in onc kg:alit), and limestone in another or frcsh water. fossils at one place wad marine fossils at another. For a metamorphic rock the tcrrn facies means the penicillin range of pressurc and temperature under which the rock crystallized.

Index Fossils. Those fossil forms which have short dme ranges of their existence and wide geographical .distribution, are a]led *"index fossils"*.

In Fig.13.1 the fossils 'A' have wid.e distribution and short duration, and thenpdpits.

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laX°1010,41."[1]

A ,

Fig.8..1. Showing Index Fossil.

fore they ape thc index fossils. The fossils 'Ware not index fossils because thry have long time ranges and limited distribution.

The index fossils are an excellent tool for correlating the fossilifcrous rock formations of the same age.

8,2. PRINCIPLES OF STRATIGRAF'HY

There are three major principles which arc used to detennine the relative _ These principles arc as follows.

Law of Superposition. In a series of undisturbed beds, a bed that overlies another bed is always the younger, The youngest bed will be at the top of the sequence.

Fossil Content. William Smith in 1799 noticed that each of the sedimentary beds contain a particular set of fossils by which it can- t.ic identified. Because the lower forms of life existed long before the higher organism appeared, it is possible to assign relative ages to the stralla cun• mining fossils.

Lithologieal Character. A sedimentary bed *may* be iniderilified by its distinct lithologicai character. But as similar rock beii are known to MOH in formations of widely different geological ages, the lithology is not of much use for determining relative ages.

8,3,PRINCIPLES OF CORRELATION

The rock formations of widely separated areas are correlated with the help of the following criteria..

Lithillogy, Correlation by means of lithology is not reliable because a rock bed when traced laterally may change its character. Further similar rock bed_q. are known to occur in form tions of widely different geological ages.

Fossil Content. Fossiliferous rocks are characierized by the presence of distinct and definite set of fossils in them, However, just as the beds show lateral variation in the lithology,they may also show lateral variation in *the* fossil assemblage. Hence only index fossils are used for correlation purposes..

thriconforrnities. The unconfonnities are of great significance in classifying and correlating rock formations. The unconformities represent breaks *in* depositional sequence hence they are significant in the interprc[allion of the geological history. For et ample, *an* angular unconforrnity is a surface of erosion that separates two sets of beds whose bedding planes are nol paratiejlt suggests that rilig the lower set of beds was formed in the horizontal disposition. This set was deformed and then eroded to a more or less even surface before the upper set was deposited horizontally upon ft.

Metamorphism. In a perticular area,the older rocks may show higher grade of metamorphism as compared to the younger rocks..

fenrouls Intrusion. The ip.e....}us history of a perticular region InaY be identical to another region. In such cases rocks can be correlated.

Radiometric Dating. The age of intrusive igneous bodies ti aY be deiennined by the radiometric methods and then the correlation may be &ice.

8.4. FOSSILS

"Pos.vits" an remains or impressions of ancient animals and plants which have &en preserved within the sedimeniary rocks.

8AJ. Conditions of Preservation

All the animals and plants are not preserved as fossils. The iwo most important conditions which favour the preservation of fossils are (i) SCSSion of hard pads., and *(ii)* immediate burial.

Possession or Hard Parts. After the death of the organisms, the soil parts are generally easily decomposed_ Therefore animals likc jcIly tisli and insects. which are totally composed of sort parts, *are not* ordinarily preserved as fossils. The animals which possess hard skeleton have a better *chance* of being convened inio fossils.

lintnecliate Burial. I t the animals and plants are not buried quickly tiftr their death, they are likely to tfre desiroyed by chemical decay and other agencies of erosion,

8.4.2. Forms of Fossils

The fossils are preserved in rocks in a number of different forms which are as follows_

Entire Organism 1PrEserved. The whole body of the organisdrri including its soft parts, may be preserved_ For example, the bodies c.)f mammoth elephants of pleistocenc age are found preserved in the ice in northern sibcria_ These type of fossils arc,. however, extremely rare,

Skeleton of Organism Preserved. ln rocks of Tertiary age, the bony skeletons of animals having original composition and structdre are found.

Petrifaction or Hard Parts. Mineral matter like silica+ calcium carbonate and iron sulfide may replace the remains of orpinisim particle by particle thereby preserving the structure faithfully. An example of this type of fossil is the silicified wood.

Molds. After burial the hard Parts of the °Mullis-ins Inalf he totailY dissolved and removed in solution. As a result hollows having the shape of the odtside of the body are left within the rock beds. Such hollows are called *"ntoids"*.

Casts. Molds may be filled with 'niacin' matter producing natural *"casts"*. A case shows all the external markings of the body of organism but not its internal strut Lure

Carbonization. When plants decompose slowly, their organic tissues ate transformed into carbon. Such carbonized remains commonly preserve thc structure of the original material. Seams of coal are the best examples of carbonized remains of plants.

Imprints. Plant.; and animals which do not .have hard parts nriay he preserved as irriprinbi. in soft _sediments such as shales. Distinct impressions of plant leaves are often found preserved in the shales above coal seams,.

13.4.3. Uses of Fossils

The fossils are commonly used for correlating the strata and determining !Choir relative ages_

2. Fossils; iridicaL whether the rock is a fresh water deposit or a rnarin.' e deposit.
3. Fosgils give information about the climate of the times in which they lived.

4, The fossils have trelped in understanding the evolution of plains . and animals.

83. GEOLOGICAL TIME SCALE

The. time span of earth's history is about 3000 million years.. It is roughly represented by the column of sedimentary rocks now present on the earth. In this record the time elasped during the fonnation of onconformities is missing, The unconformi Lies arc however,. 1111pYrtarlt be they subdivide the geological time into smaller On this ha, iF. a stanclivirl GepingJeal Time Scale (Ta.bie 8.1) has been prepared which is used universally for the. correlation of rociaomrations.

Ern& The major units of the. geological time 'are called *"era, "*_ in thc gculogicat time scalar thorc are four eras (i) P'recambriani (ii) Palaeozoic, (iii) Mesozoic, and (ii') Cenozoic.

Pgriod4i, Each era has been subdivided into srrollor time units calla' ti *"periods"* The strati graphic brealf...5 which subdivide eras are relatively of lesser significzricE. For example, in the Palaeozoic era, there are six puriods: (i) Cambrian, *(if)* Ordovician, (iii) Silorian. (iv) Devonian, (v) Carboniferous. Elffild (vi) Pcrrni.an.. .A succession of rocks deposited during a period constitutes a. *"system"*,

Epochs. The periods *are* further divided into smaller parts called *epoche'*. The rock Up LIS CarrCS111011diTIV. to Opochs aro called *"series.* For example. in th.f. Triassic period, there are three epochs : (i) Lower Triassic, *00* Middle Triassic, and *(iff)* Upptr Triassic,

Stage. A part of the series is called *"stage"*. It is characterized by typical assemblage of fossils.

Zone. The basic unit of a sta.ge is called. "zone-. It IA mognised main-1Y on 'the basis of the most charaeterstic form

On the basis of palaeo.ntologyi the 15recambrim era has becti divided into two groups *7 114)* Archaeozoic, and *(0* Noterozoic.

Table 8.11 Subdivisions of Geological Tillie Seale

The rockformations belonging to the *"Archaeozoic group" are generally* unfoissilikrous

Au Million rears	*Era*	*Period*	*Each*
		Quaternary	Recent
2·· i			P leis toccve.
l2-1		Teri iary	L Pliocene
			IN,1iacenz
26 -	C.FNOZOIC'		Oliguiceli e
3 7 -			Eocu c
5.3 -			Pakorctie
a -			
136 -	MESOZOIC	CreLace°us	
190 -		Julass[c	
DO -		Thassic	
2W -	PALAEULICPIC	1Przrniiin	
345 —		Carboniferous	
395 —		Down ian	
430 —		Sil'Arian	
500 —		Ordovicialio.	
570		Cambrian	
2500 —	PREC.AI.M3MAIN	Proictrozois	
		Archaic	

whereas those belonging to the *'Prolerozoic group"* show traces of the most primitive. life. The rocks of thc Palaeozoic, Mesozoic, and Cenozoic ems. contain abundant remains of past life (Table 8,2).

SA. LITHOSTRATIGRAPHIe CLASSIFICATION

In rc..gions having different kinds of geological hiss cry, ihe boundaries of the Geological Time Scale do not coincide with the actual stratieraphic boundarie..5. In rnan'y aril, though the major stratigraphic divisions are identified, the derniarcation. of smaller division_s, such as series kind stages become very difficult In case of unfossiliferous strata, it is not possible to identify the divisions corresponding to those of the aandard ihrIc scalier In order to avoid thcs.c difficulties the *"Liehostratigrapilie classfilCa0011"* has

been devised. In this classiticatiOn the rockformations are divided chiefly on the is of lithological criteria.

Table 8.2. Geological Time Scale

Ems	I	*Lift_*
Qu aternary	*Rece* lir Pleiscocen e .	Man, Modern plants, and animals._ .N.limy mammals die.
I .	Pliocene M.iouenu. I Oligocene I Eocene Paleocene	Mammals, Birc15,. Mollusc:a **and** Flowering plan.
l'Aesozoic .	Creraceous Jurassic I Triassic	Dinosaurs, Flowering plants. Ammonites, Dinosaurs. Aironinites, Reptiles, Amphibians.
1. alaeozoic	Permian 1 Carboniferous 1 Devonian Silurian Ordovician Cambrian	Rcplik.s., Nonflowering plants. Amphibians! Non-llowerir ig /dams. Corals, Brachiopods. Early land pleuras- Freshwater fishes. Graptoliles. Trilobites, Graptolites, Triblbitea..
c a Pre mbrian	{Prnierozoic Archaeozoic	Soft bodied animals au ... p.a1 31Ls_ id Lifeless.

Group. The major divisions of rockformations are called *"Grotops"r* Each Group includes a thick succession of rocks which extends ovCr a Large area, The bigger unconformities separate one Group from another. A *"Supergroup" is* formed whit two or more Groups join together,

Fonnation; It is the basic unit used for naming the rocks m stratigraphy, It may be defined as a set of rocks which have some distinctive feature of fithology and are large enough to be mapped.

Bed. A bed is the smallest Iithological unit. It may be defined as a single sedimentary rock unit which has a distinct set of mineralogical or fossil haraacrstics which help to distinguish it from beds above and below.

8.7. STHATIGILAPHIC UNITS OF ENDIA

The general outline of the broad stratigniphic units of India together with their relationship to the Geological Time Scale has been shown in Table 8,3. More than half of the Peninsular India is covered with the Archaean rocks, the rest is occupied by theCuddapahs, Vindhyans, Gondwanas, and Deccan Traps. In the Extra- Peninsular India, mainly the marine sedimelilarY rocks ranging in age from the Cambrian to Eocene are exposed.

Tabk 8.3+ Major Stratigraphic Units of India

Era		*Strafigraphic Urdu of India*
QuaCCEnaFT	Koceni.	Rent alluvium
	Pleis tocene	Karewas of Kashmir, OIdr
Tertiary		Siwalik Group
	Oligocene	Murre
	1	Boum... [.ski
	formations.	
Mesozoic	Junosio Triassic	1 Gondwana.Supergroup Spier shales., Lilting
	Permian Carboniferous	Group, Kioio litnesto KuilinggICIUpMissing in, Ilimal.o.yeri regiorl_
Pal decizOif	[3›evoniari Silurian Ordovician Cambrian	
Precambrian	Proterozziu	Cudidapah and Vindkiyari Supergroups.,
	Archaezzoic	Atmean, .1)hrwar and Aravali Groups_

PHYSIOGIAAPHIC DIVISIONS OF INDIA

India. can ham. divided into three Twin divisions which differ from one anothcr in physiography, siructure• and 5 traligraphy (Fig '8..2.), These divisions are as follows.

11. Pcninsular India,

Zr Indo-Gangetic Plain,

3. Extra-Penimular India, S.1.

Peninsular India

Penirmular India lies to Um south or hc plains of Indus and ariga river system.

Physiography-The Peninsular Tndia has an extrcmelY vafithle P' &jugraPhy. There are phitea.uss repel:gained &ifeat fold rflounlaills, massifs, ehilicated graben like valleys, and coastal Plains› The Westers Ghats which 1-orrns. a prominent. physiographic feature exiMs at the western margin of the

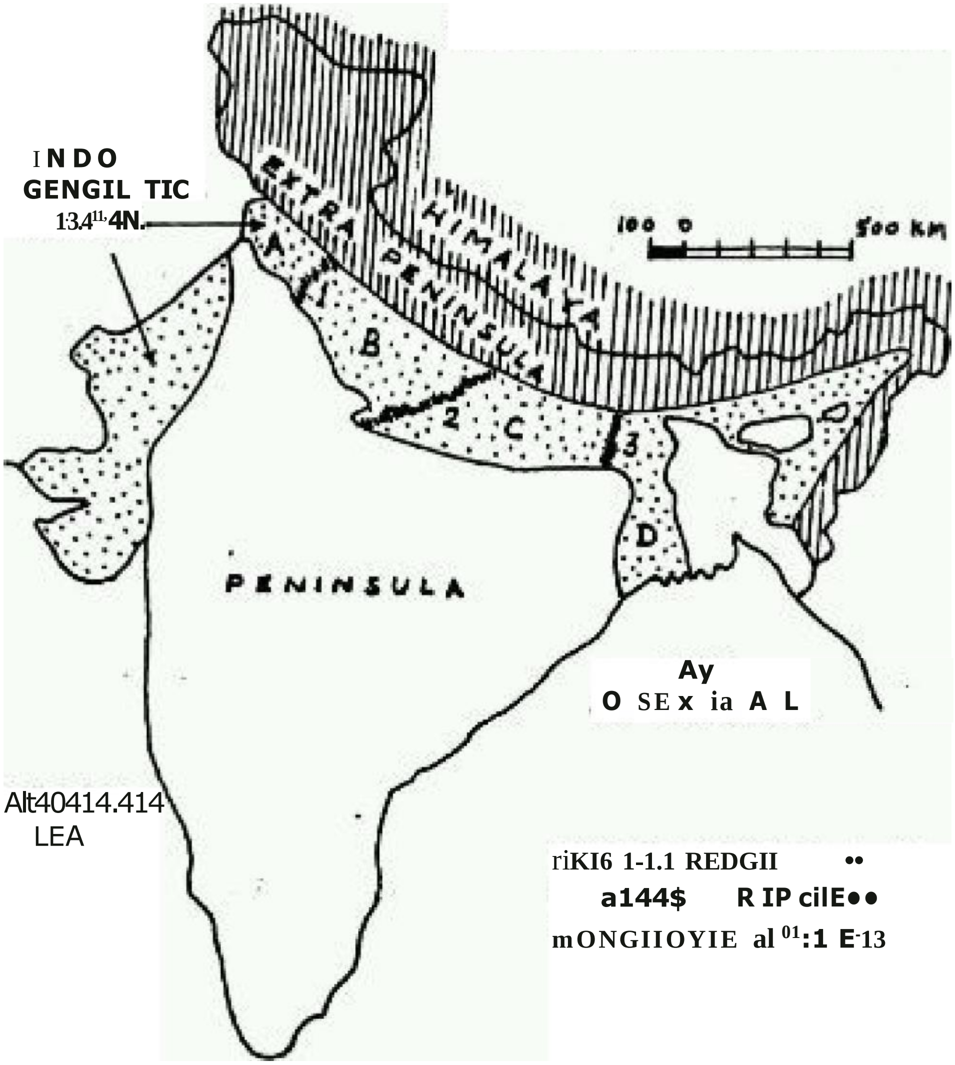


Fig_ 8.2. Physiographic Divisions. of

pcniEstilar India. Most of the. rivcrs have attained the base level of erosion and its mountains are of relict type.

Structure. The Peninsular India is nearly a stable plateau which has rerrmined unaffected by the orogenic movements of post Cambrian age. The nounal and block faulting is. however COM111011.

The Narmada. Son and Darnudar rivers flow in Ihe graben-like valleys which trend in the E-W direction. The trend of the Mahanadi and Godavari valitys is in the NW-SE clinic lion. The four distinct geomorphic and sinkcEural trends which have been recognised in the Peninsular India arc.

(i) NNW-SSE, trend oldie southern parts of Western (ihats, (i) ME-SW, trend of Eastern l.N., *WI)* E-W, lrend of Satpura in central India, and (iv) NE-SW, trend of AravaIlis in Raja.cthan.

Stratig.raphy. The Peninsular India is primarily made up of rocks Of the Archaean and Precambrian age. The Archaean rocks have been molar"' phosed to varying degrees. In addition there ox Isis the Deccan traps awl Rajmilikal traps of Jureomic to Eocene age. Post Canibrian_sedimentary racks occur in the Go.ndwana basin and occa.ssionally alorim the coasta] tracLS of the Peninsular India.

8.8.2. Indo.Gangetie Phan

The Iado-Gangetic Plain is a deep crustal trough fillcd with Quaiernarl. sedknenta. lts origin and structure is intimately related to the rise of Himalaya. This plain extends from Amain in the east, through Bengal. Bihar and upto Punjab in the west. Wig.

Physiography. The Indo Gangetic. Plain is the very extensive alluvial plink which is sloping with a very small gradient towards the sea_

Structure. The Indo Gangelic Plain is made up of the undisturbed layers of Quaternary sediments which have been deposited by the rivers of the Himalayan region.

The bottom of the Ind-0Gangetic in is asymmetrical. The northern margin of the Peninsular India dips gently northward_ Hence the thickness of the Quaternary sediments gradually increases towards north and the maximum thickness is found at the northern extremity near the Outer ilimalaya. The bottom of this trough is not stable and some changes fire sal] taking plaice which give rise to earthquakes..

In the Indo-Gangetic Plain three. transverse *"highs" have* been reoog.- rased. These highs arc

Delhi-Haridwar Ridge, (ii) Faizabad Ridge, and *OM* MoughyrSaharsa Ridge (Fig. 8,2). These highs divide the ludo Gangetic Plain into lour shelf areas *(i)* Puri...jab shelf, *(u)* west. U.P. shelf, *OW* east 11.1>.
and (iv) Bengal shelf,

Stratigraphy. The Ind-0-Gangetic Plain is chiefly made up of sands and clays of Pleistocene and Recent age. The basement of the Punjab shelf is made up of the Precambrian rocks. while that of the east and west U.P. shelves contain Precambrian and Vindhyan rocks. The Bengal shelf is believed to contain rocks of Gondwana age and Rajrnahal traps.

8.8.3. Extra Renin.sular India

The Extra-Peninsular India lies at the northern extremity of the country. It is made up of the Himalayan mountain ranges in the north and ArakanYoma ranges in the east The upper rraches tif Indus and IStrahrnputrd rivers mark its northern boundary.

Physiography. The Extra-Peninsular India is malde up of the tectonic mountains and the frontal fore folded belt or Tcrliary age, The frontal foredeep belt is also called the "Siwalik Range" or "Outer *Himalaya"*.

The Himalayan belt extends in the E—W direction and its total length is about 2400 Km. At its western end this belt takes a sharp arcuate tenet. This turn is calked the "syruazia bend". A bend of similar nature is also present at the eastern end of the Himalaya where the NE—SW trend chaligcs into the NNE—SSW trend.

Structure and Stratigraphy. The rockformations of the Extra- Pc.ni$_n$_ sular India have been disturbed *greatly* by the complex folding, faulting 4:111Ci overatrusting._ The Extra-Peninsular India has been subdivided into four longitudinal geomorphic zones Tethyan Himalayan zone, *(ii)* Central crystalline zone of the Higher Himalaya, *(iii)* Lesser Himalayan zone, and (h') Foredeep folded belt.

(1) Tehyan Hintotayari Zone. **This zone is at the northern extremity of the Extra-Peninsular India. Here the Himalayan. mountains rise 1.0 an average altitude of about 6000 meters. This zone consists of the marine rock beds of Palaeozoic and Mesozoic ages. This succession rests unconforratibly over the P'recambrian basement.**

it ***Central Zone of Higher iiimalaya.*** **In this zone the average height of the me lairs is also about 6000 meters but they are chiefly made up of the. Precambrian basement and the** *granitic* **plutons of Tertiary age,**

(iii) Lesser Himalayan Zone. **The average' height of M011irtaing in this zone is betWce41 20a0-3000 meters, Many antrcalent rivers flow through this zone. These rivers originate in the Tethyan Himalayan zone and flow across the Higher Himalayan and Lesser Himalayan ranges by cutting deep gorges, The rocklormations of this lone arc relatively less metamorphosed.. Thcy are unfossiliferous and therefore their correldtion can not be done. The structure of these rocks is very complex. They are affected by a series of thrust faults due to which the stratigraphic succession has been reversed in many places. The lower part of the unfossiliferotts rockfortnations is believed to be of Precambrian** ***age, Thos*** **are overlain by rock-formations of Gondwana age. Above these are the rocks of Tertiary age.**

(iv) ***Foredeep*** *Folded Bell.* **This zone lies at the southern margin of the Exult-Peninsular India, It is also called** ***the "Siwalik Range*****-The low lying hills of this belt are. mainly made up of the sedimews** of mio-pliocene ***age.*** **The southern boundary of this belt is marked by lhe "Main** *boundary faults",*

8.9. ARC HAEAN SYSTEM

The Archaean system is male up of very ***ancient*** **rocks such as** ***gn.eisses,*** **schists, and granites. These rocks form a basement on which all younge^r sedimentary rockformations rest. The general characters of the Archaean rocks are as follows.**

.1, They are unfossiliferous. it suggests that them was no life on the earth at the time of formation. of the Archaean rocks,

2. They are generally highly metamorphosed.

CHAPTER-2

FOSSIL FUELSS

COAL:-

Coal is the world's leading mineral fuel, It is burned to producc heat which is used to generate electric power, The coke which is. made by heating coal to a very high temperature in the abwrice or air. is used i n Lhe metallurgical industry.

The term. *"coal"* covers a wide variety of mats rials, ranging from lignite all one hand to anthracite on the other. It may he defined as a solid stratified roc k **composed mainly of c.arbonised piants.**

Ranks of Coal

The proccss of conversion of vegetable matter to coal involves loss of Ygen and hydrogen, and concentration of carbon. The. chief stages. of coal fonuation are pent. *(ii) lignite, WO* bituminous coal, and (iv) anthracite. Peat is not a coal th4.)ugh it is fuel. The "Rank" of a .c.o..9J is its position inthe lignite-anthracite series (From lignite to anthracite there is a progressive elimination of waterpxygen and hydrogen and an increase in carbon. In is carbon occurs in two Corms *:*

(i) **as fixed carboa$_r$and**

(ii) **as volatile matter, The. ratio of these two (fuel ratio) determines the rank of coal.**

CLASSIFICATION OF' COAL

an the basis of rank and quality, the coals are classified into toff Math grOUPC

(i) lignite,

(ii) bituminous coal,

(iii) anthracite, and 00 Calillt I coal. Peat lics above lignite and graphite below anthracite,

. BANDED CONSTITUENTS OF COAL

In banded coals four scparate kinds of coal constituents have ken recognised: (i) vitrain, clarain, *(1E)* durain and (1?) fusain,

Vitrain. Vitrain for thin bright glassy bands 01 coal which are up to half centimeter thick. 11 is very brittle and breaks with a conchoidal frauturc. The v.foody structure is not visible with !naked eye._ Vitrain is a coking
Tstituent of coal_

Clarnin. Clarain forms thin bands in coal, It is ch..aracterized by bright colour and silky lustre. It is composed Largely of attritus. Attritus is the finely
,• divided plant residue which is composed of the more resistant plant productsClarain is a coking constituent of mil,

Durnin. The dull earthy looking hands of coal are,called durain_ Derain is hard and compact, and has granuLar texture. Its colour is lead-gray. It COnnisi si of cuticles, spores, etc. Duraiiii is thc noncoking constituent of I.

Fusairi. Fusain is also called *"mineral charcoarr* It is a soft powderY. pitch black substance which soils the fingers. It is a minor constituent of coal which occurs in smell patches and in the body of durain and chrain. Fusain is high in ash and is a noncoking constituent.

CHEMICAL PROPERTIES OF COAL

The commercial value of a coal depends on its chemical characters. The main constituents which are determined in the *proximate* analysis of coal arc: (I) moisture content. (ii) volatile Tnalicr, (fit") fixed carbon. (iv) fuel ratio. (v) ash content,. (v0 sulfur content and *(ii)* calorific value.

Moictu re Content The raoistare content of a coat can be driven up at 'OTC. It is highest in peat and lignites, and lowest in anthracite.

Volatile ?Antler. The volatile matter is that which burns in the form of a gas. It consists of combustible gases such as hydrogen. carbon monoxide, methane and other hydrocarbons. These gaseous products are driven off from coal when it is heated in the absence of air to about 90CPC. The residue left after driving, out all the volatile matter is called *"coke"*. The coke coosi SIR of fixed carbon and ash.

The percentage of volatiles in coal varies within wide limits and directly affects the coking quality. Coals with volatile matter less than 18% or more than 40% are not good coking coals. Depending on the quality of coke produced from coal through carbonization, coking coals are subdivided into the following groups_

***(1)* Primary Coking Coal. Coal with volatile content between 22% and 33% on unit coal 1- is.**

***(0* Medium Coking Coal. Coal with volatile content helm...eel]. 22% and 25% on unit coal basis.**

orii) *semi* Coking Coal. Coal with volatile content between 18% and 22%, or 38% and 46% on unit coal basis,

Fixed Carhon, When the volatiles and ash art: removed from the coal fixed carbon is left. it burns with difficulty and gives intense heat. la anthracite, the fixed carbon is about 96% and in lignite it is about 38%.

Fuel Ratite. Coals contain carbon in two forms: (t) as fixed carbon. and (ii) as volatile matter. The ratio of these two is called *"fuel ratio"*,

$$\text{Fuel ratio} = \frac{\text{Fixed carbon}}{\text{Volatile matter}}$$

Naturally, the fuol ratio will be the lowest in ligi ite. and highest in anthracite, It is the main feature which determines the rank of coal. The rank of a coal produced is largely determined by the pressure to which it has been subjected and the time for which it had remained under such conditions.

Ash Content. Ash is the noncumbusLible mineral matter which is left after burning of coal. The main constituents of ash are silt, elaysilicajmn oxides and other mineral substances. Too much ash may put a high tank coal in a low grade. High percentage of iron in the ash produces clinkers.

Smarm Content. Suffer is an objectionable. impurity of coal. It is commonly present in most coals in the form of pyrite and marcasite, It helps to produce clinkers in the furnace and yields corrosive sulfurous fumes on burning. More. than 1.5% sulfur excludes coal for making gas. or coke..

Calorific Value. The calorific value of a coal is the amount. 01 heat that the unit weight of coal would produce on burning. It may be. stated either in British. Thermal Units (B.T.U.),, or in calories per kilogram. The calorific va.iiie of lignite is about 7500 B.T.U. and that of Bituminous coal is over 15000 B.T.U.

. ORIGIN OF COAL

Coals are sedimentary rocks formed by accumulation of plant materials in swamps. Hence the source matenial of coal is the vegetation matter. The formation of a ectal de sit requires a large accumulation of vegetation matter. This implies large vegetation growth which is possible only in subtropical climate with heavy rainfall well distrihuted throughout the year,

There. are two theories to explain the mode of accumulation of plant materials to Five rise to coal seams ; (I) the in-situ them. and *(0* the drift theory.

%I LL In-situ Theory

The in-situ theory suggests that the vegetation matter had accumulated at the place **of growth itself in the swamps. This means that the forests grew at the same place where we now rmd coal seams_ The in-situ theory may briefly be summarized as follows.**

The vegeLable matter wa-s accumulated in the coal forest itself. (0 As the land wan sinking skowl.Y. tlic accumulated pleint Material

was kept saturated with water and therefore. it Was not decomposed and destroyed,.

01) In the course of time, the rate of sinking of land was increased and the coal forest was submerged under water. This resulted in The. geological burial of the vegetable matter below sand and mud layers,

(iv) Then uplifting took place and the land emerged out or water The coal forests came into existence again and the above said cycle of c°4[111] formation was repeated. In this way atternation of st,t-ata and coal seams were formed,

Evidences. The evidences in support of in-situ theory arc as follows,

IL. A huge smolt of plant rWerial is accumullitiv in-situ in the swamps that exist today.

2. In coal seams, the stems of fossil trees arc found standing erect with their roots protruding into the underciays.

3, The underc lays which are found beneath the c.val scams are supposed to represent the original soils on which the vegetation grew.

4. The coal seams contain coal which is relativey pure and frte from shale bands. This suggests that the plant material was not transported along with sedim.ents,

5. The uniformity in thickness and composition of coal seams over wide areas suggests that the deposition of the plant material took place in still waters.

9,21.1. Drift Theory

This tlur..ory suggests that the plant arterial was transported by stream action from their place of growth and deposited to suitable places in lakes or sea just like other sediments.

The coal seams of India are of drift origin. The drift thcory may briefly be sumtnarized follows,.

(i) The plant material from the coal forest was transported by water and deposited in lakes or sea just like other sediments,

(ii) During transportation the various materials were sorted out as usual, in accordance with their specific gravities..

(iii) The pure coal scam was formed in places to which only the lightest material (plant material) had access,

(iv) A stream with shale bands was formed in places where a temporary change in the *water* currents anAl hence the nature of sediment oceured_

are of bituminous type whereas those found in the teriiary rrpcks are livites,,

Most of the Gondwana coals are noncoking bituminous coals. The coking coals are found only in ihari9,, Girdih and Bokaro coal fields. The reserves of all types of coal occurring within a depth of 600 meters arc estimated at 120,000 million tonnes. The reserves of coking coals are about 20,000 million tonnes. The reserves of lignite deposits arc cgtinoted in be about 3500 million tonnes. The deposits of lignite occur main[Y ire (he tertiary rocks of Kashmir valley, Assam, Madras(Nerreli) and Rajasthan(Palana).

9.23.1. Lower Gondwana Coal Fields

The Lower Gondwana. coal fields of India are situated chiefly in river valkys.

I. Damodar Valley Region. Coal fields of West Bengal and Bihar. (i.) West Bengal. Ranigoni coal fields.

(ii) Bihar. Jharia, Girdih, Bokaror Kaninpura, and Daltongani coal fields,

2. Son-Iiiiialianadi Valley Region. Coal fields of Madhya Pradesh and Orissa.

***(A)* Madhya Pradesh. timaria, Singrauli, Korha, Chirmiri, Sohagpur, Bisrarnpur, Mohpani and PeachKL1.Itheln valley coal fields,**

Ott) Orissa. Tapir coal fields.

3. Wan:lha-Godavari Valley Region. Coal fields of Andhra Pradesh and Maharashra-

CO Andhra Pradesh. ,,Singareni coal fields. *(ii)* Maharashtra, Wardha valley coal fields.

PETROLIUM;-

***"Petmlium"* is the general term used for 911 the natural hydrocarbons found in rocks. It not only includes the liquid hydrocarbons but gaseous and solid hydrocarbons also However in conuipon usage,. Lhe leTTELS *"peimliang"* refers only to the liquid oil, Gaseous varieties are called *"natural gas"* and highly viscous to solid varieties are called *"bihrmeri"*.**

The retroliurn is a complex mixture of hundreds of dilferent hydrocarbons. The hydrocarbons fall into several natural series of 'which parafm• series is the most familiar.

Origin or Petrolium

It is now universally believed that petroliurn and natural gas are of organic origin, They originate from slow decomposition. of lower forgo of

marine organisms such as foraminifers, diatoms, algae, ostracods Thc process of formwiori or petrolium may be summarized .t)!q

In coastal ·waters, large numbor of marine organisms thrive_

Hon in offshurc Sedimentary basins huge amount o organic matter iderosilect along with muddy sediments. .Because in thc bullorn of stagnant water, there is deficiency or oxygen, r_he ()re:Link Matter is prore..;tecl from oxidation, Linder such conditions anaerobic bacteria extract ox.ygen from the organic matter and transform it into fatry .Faid waxy substances.

00 During the millions or yeArs of deep burial thi organic molter is converted into oil and gas by the slow chemical n.:actions. The exact pri3ccss by which this transtormalicui cakes pace, is not known, but it is believed that becteria, pressure, moderate temperatures, and great length s. or time play an important pan-

9.24.2. Migration of re.t.rollurn

The fine grained muddy sedirrients in which petrohuni originates are called *"source rocks"*, The source rocks of petrofium are generally Shalai, &HIS, and limestones_ The petrolium mi8rates from the source rock into adjacent rX)rOUS and permeable rocks. and ·accumulales there to forma pool_ Such permeable rocks are called "reservoio' was", The c·orarrion reservoir rocks are sandstones,. congIonnerates, porous limestones, fractured shales, and jointed igneous arid metamorphic rocks. The causes for· the migration of pciroburn are (1) compaction of thy source rock, Of? 134Juyancy effe4..:z.,, au) capillary effect, and waler flushing. In an oil pout. the oil flan.; on the top of water and above the oil there is usually a lens of natural gas (Fig. 9.171

OIL TRAP

The oil migrates outward and upward from the source rock and paws into the porous. res...,rvo.ir rock. The migration of oil cominues until it meets a suitable structure where its lateral as well EIS upward movomeni is checked_ At such a place the oil accum1Ulate4 to from an oil pool. Such places arc !rapt% The conditioms necessary for the formation of an oil trap arc as follows,

(i) The porous reservoir rocks must have a favourable structure such as an anyfuld or dome, to hold oil..

(i/) There must be an iumpervious cap rock to check the upward Ill igration of of The common cap narks are shale, clays, sal!, gypsum. and dense limestone_

(ii) The structusftl deformation of rocks must TWA be very severe. Intensely fractured rocks may render traps inefil.....ctive IEY causing leakage_

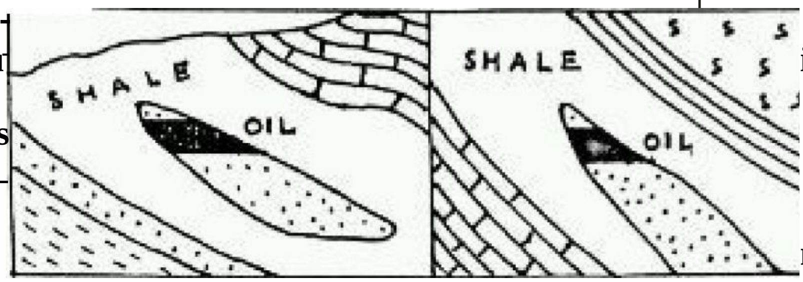
Unconfonnities in the rock sequence often give rise to nil traps [Fig_ 9.18. (Mt

The shales ____

which are the source rock of petrolium may contain lenses of sandstone, The oil ro.a.y ac- cumulate in thew;.....u ikistone lenses [Fig.

(b• oil trap, in a sand SI Ong which is wedging out_

OW A porous saildtaono may wedge out thereby creating an oil trap



A)

FiFo 9.19. 02) Oil trap in a y.ancistone leas.

PETROLIUM DEPOSITS

hi India, resrvoirs of petrolium and natural gas are found in the bells of Tertiary rocks of Assam, Gujrat, Offshore region of Bombay and in the Cauiveri a.rid Godavari deltati(areas.

9.26.1. Oil Fields of Assam

The chief oil fields 011 Assam are : (i) Digloolb Nlahork.atiya, *(ii)* Moran, (IV) Rudrasagar, and (v) Lakwa.

Digboi Oil Field. This oil field is siLuate.41 in the Lakhirapur district of Assiut'. It is 13 km. long arid about one kilometer wide, lt lies on a tightly folded anticline. The steeper flank or this anticline has been cut by the Naga tit in the northwest. The Oil bearing formation is the TIpain sandstones

Mily.:enc age. The source rocks in this case are probably &nails. In the Digboi oil nem, there are several oil sands and .ahout 400 producing, wells of which only 30 are good tic r,

Nahork.atiye Oil Field. This oil field is situated in ihe Braiu-nputra valley of upper Assam_ it lies about 4.0 km. southwest of Dig i. The oil deposits occur in an anticlinal struaure. Thcre are about 5 oil bearing sands all lying within the upper part of the Barai I sandstones of Oligocene age. In the overlying 'I pans only gas is found, This oil field is cut into a number of blocks by faults_

M.orari Oil Field. This it field lies about 41· km. WSW of Naht-yrkatia. Here the oil bearing formation are the Banns of Oligocene age. A major fault dividcs ihtis field into two halves.

Rtdrasagar Oil Field.. This oil field lies about 40 km., southwest of Moran, Here deposits of oil are found in a gentle dome which is cut by several. faults. The oil bearing fonwtions arc the Barails of Oligocene age.

CHAPTER-3

PROSPECTING AND EXPLORATION

SURFACE PROSPECTING METHODS:-

Geological Mapping. Before starting the prospecting work, a target arca that can yield mineral deposits, is selected. Then its geological map is prcpared on a suitable scale, Such a snap shows topo,graphy, rock outcrops, and structural features such as dip, strike, folds, faults. etc,. This sort of map gives an idea of the length and width of the deposit. It also serves as a base map for planning out a trenching, pitting or drilling progrmme.

Trenching. A *"trench" is* a narrow linear excavation which is made to expose ore bodies concealed under soil cover.. The trenches may be 6 to 9 meter long, 1 Lo 1.5 meter wide, and 2 to 2.5 meter deep. They arc commonly dug across the strike of the orc body at intervals of 15 to 150 meters. The spacing of trenches depends upon the consistency of data, Prospecting by trenching is generally done when the ore outcrops are narrow and the soil cover is thin (about one meter). The trenching gives reliable- inforniation about ithr geology, structure. extension and grade variation of the ore body, This method has been adopted as a major prospecting method in may iron ore and bauxite deposits.

Pitting. The prime...7...s or digging rectangular openings to pen.etrate soil cover to reach ore bodies concealed underneath is called *"Pitting"*- The common dimension of pits is 1.2m x 1.2m x 6m. However pits may be sunk to a depth of about 10 meters beyond which they become very expensive. Pitting is a. very useful method of prospecting those ore bodies which are flat or gently dipping and lying near the ground surface. For steeply dipping ore bodies and those having linear and rrarrow outcrops, pitting would not be favourable, The pattern of the layout of the pits may be regular or irregular, In a regular system pits are sunk in rows in grid or triangular pattern, pilling is an important method of prospecting in many bauxite and iron ore deposiis4

Aditting. The *"adits"* are horizontal openings which are dug in mountainous terrain to explore ore bodies, An edit many he driven across or along the strike of rocks. It should be dug in such a way so that at a 1aier stage it could be used as in opening (cc exploiting Ow ore.

Au ring And Mrashboring. Augering and washboring are conurionly used for prospecting of flat and homogeneous depositS like clays which are concedaled under a thin cover of sofland unconsolidated materials.. *"Auger-*

is a simple method of puffing down holes of about 2.5 cm in diameter to depths upio 6 meters in soft soils, An auger consists of a screw blade mounted on a steel pipe. It is scre*ed into the ground bytimi.ng on a T-pipe attached to the upper end.

In "wa..E10.wriing" a hole is dug in the soft *ground* by forcing a jet of water thrnugh the washpipe. ThE soil !bus eroded comes to the surfa.oe a :A's:pension in water where it is exalilinoti and identified.

Drilling. Drilling is .fin important rnetbod of prospecting subsurface rocks oind ore d.epoisils. In drilling data are. collected by direct penetration of subsurface rocks by drill Flo l . The samples of rocks arc obtained in the form of cYlindrical cores or rack iragments. The drill holes provide the
f o l l o w i n g i n

I_ Size, shape and morphology of the ore body.

2- Geological structures and number or lodes present.

3. Nature of the host rocks_

4. Composition. and grade of the ore body.

During prospecting, drill holes are located at crtain intervals in certain dirt .Lions depending upon laic regularity of the ore body and its structure-in most C.3.5e2k, the Li.:51. holes are drilled systemaiically in. a grid pattern.. In this pattern, the system of *"dimitrisirimg solares"* in adopted. First a gird of large squares is laid out and the bolts *are* drilled at each comer of scpares_ ht ease of simple deposits the grid. lines may he kept 3043 .400 muffs apart, while lit complcx and intricate dcpositi, this interval may he reduced to 200-300 meters and WO-1.1.0 me4ers respectively. Sub, sequently for closer examination, each grid is subdivided iiii0 Cedar small square-.s and more hales are drilled at their come- Thus systematic geological data are olmlined for Le cntire deposit_

For every drill hole cores should be carefully logged arid verlica.I sections of the geological formations penetrated should be prepared. The posi. 'IOW of drill holes are marked properly en the base map of the area, and a rnap showing variations of grade *of* the 'ore is prepared.. Then the porlions of it have the proper ttnor of ore are delineated and the area computed for aitirnatiny the reserve.

GEOPHYSICAL PROSPECTING

In 80E:physical prospceting ceriain physical properties of the underground rocks are measured from. the surface.. The properties of rocks measured commonly are density, magnetism, electrical conductivity and elasticity, In the radiometric surveys mainly the y-ray (gamma-ray) radiations. are measured, The measured data arc then interpreted to give information about the presence of *ore* bodies, buried anticlines, faults, igIICOUS intrusions, and other *geological* stria' 'es. The main geophysical prospeoing inethAls. are as follows.

'I_ Gravity methods,

2. Magnetic methods.

3. Electrical methods..

4. Seismic methods.

5. Radioactive Methods,

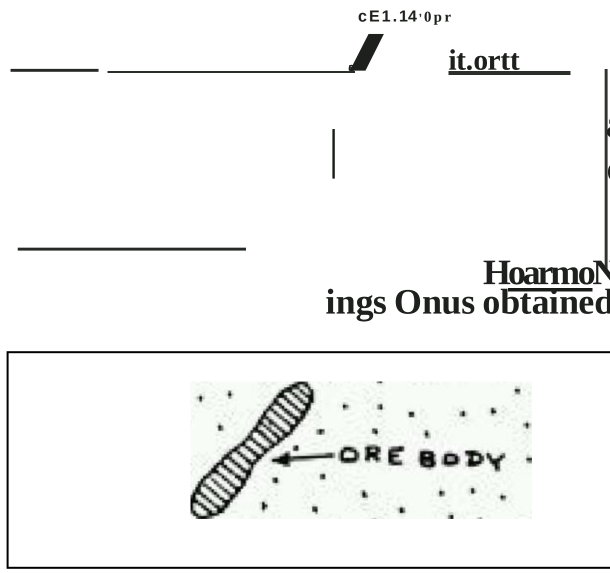
GRAVITY METHODS

The gr.avimetric survey is 'lased on the cricasurement of density contrast between the anomaly producing body and the surrounding rock_

Use. (i) The gravity methods are usial chiefly for the exploration of oil and gas. These have heen used successfully for outlining anticlines,. buried riqes, ignctw intrusioas, faults and other geological structures.

Oil The gravity survey l also been utilized for the cx.ploration of metallic ore bodiui such as massive sulfide ore., iron ore, and cliroraite

MethodThe instrumenis, which are commonly used to measure gra v i La-liana] deflections are : pendulum, (4) torsion balance_r and ail) gravimeter. Of these the gravimeter is Lhc most useful. For covering larger areas rapidly, airborne gravity survey is done.



In the area of search, tTaverses are laid at suitable intervals. Then the values of gravitation il lurt defiections are measured at predetermined points. The read_ 1 ings Onus obtained arc plotted on a graph with distances on xaxis and deflections on the yaxis, If a dense rock or a massive ore body is present in the area, thc graph will show an anomaly in the form of a peak as shown in 'ig. *11.4.* The difference between the nor-

K U C T L I K E 5 E t L Ck

mal value and the observed value of deflection is called "Gnomic? *ty*"

Fig. 1 I.4, Showing gravity profile of au ore body.

The gravity data can also be interpreted by contouring the anomaly.. In this case the gravity anomaly for each station is plotted on a base map and then lines of equal gravity anomaly arc drawn in the same way as contour Lincs.

MAGNETIC METHODS

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

Use. (i) The magnetic surveys have been used widely for the exploration of oil and magnetic ore bodies such as deposits of magnetite, pyrrhotite and ilmenite.

(U) At places fa.ults may bring together rocks of different 'nag°clic properties, *Hence they* may be delineated from magnetic data

Off) The magnetite and pyrrhotite are more abundant in hay is igneous rocks than in acid rocks. Hence the former cam he dctccled by the magnetic surveys.

(iv) Certain mineral depoiRits which contain magnetic minerals in subordinate amount, such as magnetite with asbestm and pyrrhoiite with baie metals.. can be (Tel *eeted* by magnetic surveys..

Method, The magnetorno ter& are used to measure the magnetic intensity of the ground at various stations. For covering Large was rapidly, airborne magnetic unity s are conducted.

In the area of se h, traverses are Laid at suitable intervals, 'Then the values.. of magnetic intensities are measured at c1 1y spaced stations. Pm-each station., the observed value 1..4 compared with the normal valut. The difference between them is the *"magnelic an'ma1V* "_

The values of anomaly are plotted rrn a base map. Then the lines of equal magnetic, anomaly are drawn in the same -way as contour lines. From *such* a map, the area of the magnetic body can be readily delineated. The anomaly data may also he. interpreted by constructing magnetic profiles in the mime way as clone for gravity data *(Fig. H.4).*

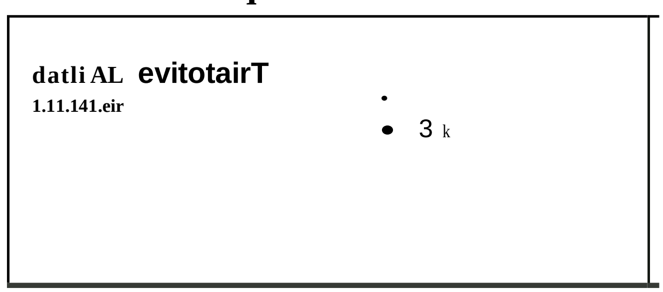
ELECTRWAL METHODS

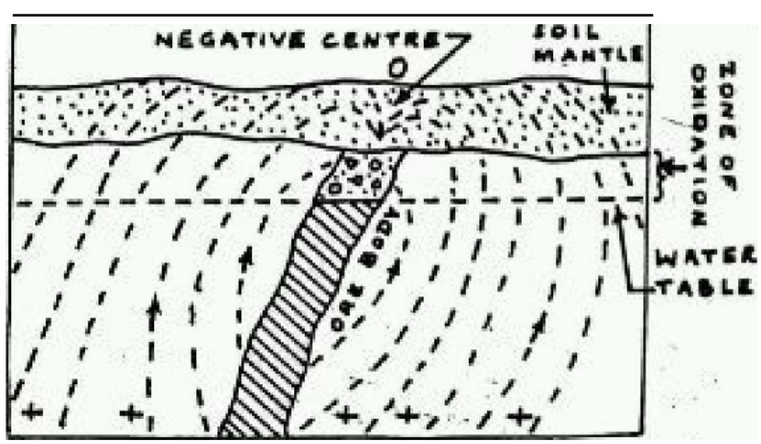
The electrical methods are used mainly for the exploration of metallic mineral deposits. The electrical stimy methods are of four types : (i) self potential method, (a) equipoteiltia! method , *(iii)* electromagnetic method, and (iv) resistiv4 method.

11..7,1., Self Potential Method

In this method the electrical energy produced by the ore body itself is direaly measured and no outside energizing force i9 required. Certain ore bodies,. penicularly those containing sulfide minerals. when subjectffl. io

.2EcTrofq .





Fig, [1_5. showing self potential currents of an ore bviiiy_ oxidation, pr du electrica] currents.. These currents are called *"telluric currents"*. By measuring these currents the presence of the hidden ore body can be detected.

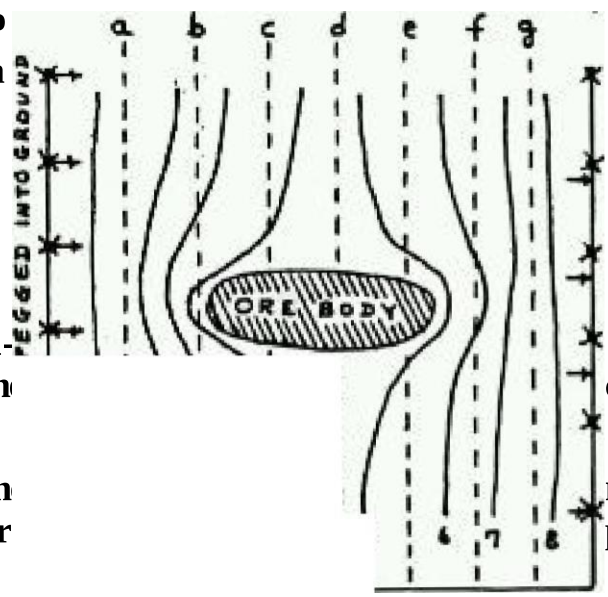
Fig. 11.5 shows a sulfide ore body which is undergoing oxidation, lts upper end which is in contact with the soil mantle, is chemically more active then the lower part. Hence a potential difference is created and electric currents flow down through the ore body and return upward through the Surrounding rock. Because the ci.-Juntry rocks have. high resistivity, the currents spread out to great distances, On the ground lying immediately above the ore body, the currents. now towards the negative centre '0' as shown in *Fig. 11.5*. The centre Q of the ore body can be located by conscructing an equipotendal diagram *(Fig. 11,5)*.

11.72. EquiPotentiat Method

The equipotential method is best suited to shallow deposits in the regions not too wet. It can be used to locate ore bodies in the gthicial drift and for determining structure beneath the „son, This method is also used to study the geological formations with steep or vortical coriLacis such as igneous intrusions,

Method, The current is intro ________ toc duced into the ground by means of two line electrodes. A *"line electrode"* is a bare copper wire which is pegged into the ground at intervals *(Fig.* 11,6). The =- rent flows between them through the ground because of the difference in poteritial.

If the intoning ground is of uniform conductivity, the lines of equal potuntial will be. parallel to the line electrodes. This is shown in *Fig. 11,6* by dotted lines *a, b, c* etc, On the ocher hand, if an ore body which is a better conductor than the surrounding rock, is present in the ground, the lines of equal potential will he distorted. This is shown in the Fig= by solid lines 1, 2, 3, etc. 1- len.ce by noting the distortion in the equipotential lin can be demarcated.



11.73. Electromagnetic Method

Oat of the electrical methods, th method is the most favoured method for search of or precise tend yields greater information regarding shape.. *size* and position of the hidden ore b$_o$dy: The elcetrorrognetic method can be used for rocky ground, barren motintain region, dry sands and ice covered ground.

When an alternating current is passed through a conductor, induced $_{cu}$rrems are produced around it.. If a conductor, such as an are bodY, within the. induced held, it set up a secondary induced cuffents around it which can lx measured.

fvfethodl. A rectangular loop of insulated Qtble is placed on or above the. ground. Then an alternating current is supplied to the loop *(hg. 11,7)*. The loop sets up *a "prima ty inagnesic fleid* within *the* surrounding ground which cam diminishes with distance c from the loop.

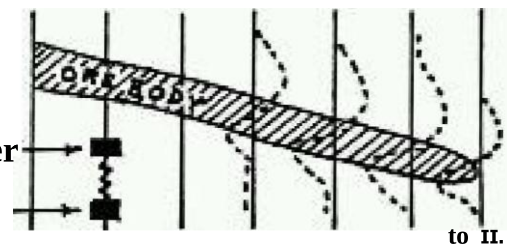


Fig. 11.7, Electromagnetic method.

If a conductot (ore body) is present wit hir L the ground$_s$ a *"secondary field"* is induced about the conductor. Because both the primal). and secondary fields are present at the same place the primary field gets distorted, 'The are body is outlined by measuring the distortion by sensitive receivers, In order to detect the distortion, traverse lines are laid normal to the longer axis of the loop and normal to the hidden ore body *(Fis, 11.7),* These traverse lines are then surveyed by the receiver. If the ground is uniform, the readings of the field will decrease with distance, On the other hand if an ore body is hidden in the ground, the readings will rise at the boundary of the ore body as shown in *Fig* 11. 7.

RESISTIVITY METHODS

En resistivity E irveys the amount of resistance met by an electric current which is passed through a portion of the earth, is measured. The measure of resistivity is presumed to he a measure of the fluid content and porosity of rocks, Therefore the resistivity measurements help in making distinction between saturated and =saturated rocks, and also between rocks of differing porosity,

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

I - The thickness of overburden or depth to bed rock is. determined very accurately.

2. The resistivity surreys have been used in the exploration of the placer deposits and bedded deposits,

3- Tic resisiiv.iiy methods. have been used widely for the exploration of groundwater. In regions of gentle dips the presence of aqui firs caI be lictermined.

4 Fault zones may be d.eiermined. .as they contain electrolyte in solution_

5- Resistivity surveys can be used for disc.overing the subsurtaim structure and Ethology_ The buried anticlines can ice. traced by acturrnining dopths to strata of greater or lesser resistivity. Hence thcy are also used in Ihe exploration 1 perroliilm.

11.8.1 rruler Method. Tri re,sistivity surveying vDri.ous elearcKle tangenicras are employed hut the arrangements shown by Wenner is widely used.

In the Wenner method the spacing betuiecn the cleoln-Jdes are kept equal. Trt Fig. *11.8* this spacing. is designated as 'if. The current is iotraduced into the g mania by two currcnt electrodes C_1 and C2, and the potential difference

All the four electrodes arc placed in a line as shown in *Fig. 11.8.*. The resistivity of the ground is determined by the following egloAtioill-

Where p is resistivity. d is the distance between electrode,s, V is the difference in potential bet.ween inner electrodes, and I is the current flowing between the end a ie ctrodes In this COSC, the depth of exploration is alpprox imaley equal to the electrode separation. By Wenner method two types of resistivity 5unmys are carried:1 out ; (i) resistivity traversing, and (U) resistivity sounding.

11.8.2 , Resistivity Traversing.

This method is also called "resi.5.filitY IrEnching "- It is used to in

The spacing of the electrodes are kept constant while they are moved along a traverse line, The resistivity rneasurernents are Ina& at various sta.tirrorm_ From the data thus °Wined, the resimivity ourves are drawn by plotting Ole dig t] of stations on X-.axis and resistivity values on the Y-fLX15- An abrupt change in thc curvature of a resistivity profile indicates .

SEISMIC METHOD.'

In seismic methods, ihe. variations in the seismic wave velocity are measured in ditTere.nt rock iayers. The 'values of the seismic velocities are obtained from thE time-distance curves. Since this velocity is directly proportional to the density of rocks, by noting tho differences in the veiocifics, the stmeture of the subsurface rocks can he worked out Method. In seismic surveys, tnick mounted drilling rigs and recording systems are used.