area.

11.2. PROSPECTING METHODS

The object of prospecting of an area is : (*i*) to search ore deposits, (*ii*) to know the nature of overburden, (*iii*) to determine depth, shape, size, and grade of ore deposits, (*iv*) to determine the geologic structures, and (*v*) to discover the ground water conditions. The mineral exploration includes two activities. The first is "*prospecting*" which is mainly concerned with the outlining of mineral targets for exploration, and the second is "*exploration*" which consists of proving of targets outlined during prospecting.

The prospecting methods are broadly classified into two groups : (*i*) airborne prospecting methods, and (*ii*) ground prospecting methods.

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

Ground Prospecting Methods. The ground prospecting methods are broadly classified into two groups : (*i*) surface methods, and (*ii*) geophysical methods. In surface prospecting methods data are obtained by direct observation. Most of the information comes from natural exposures and artificial openings such as pitting, trenching, drilling, etc. In the geophysical methods, the information is obtained indirectly by studying the physical properties of rocks.

1. Surface prospecting methods
   (*i*) Geological mapping.
   (*ii*) Test pitting, trenching, and aditing.
   (*iii*) Augering and washboring.
   (*iv*) Drilling.
2. Geophysical methods
   (*i*) Gravity methods
   (*ii*) Magnetic methods
   (*iii*) Electrical methods
   (*iv*) Seismic methods.

11.3. SURFACE PROSPECTING METHODS

Geological Mapping. Before starting the prospecting work, a target area that can yield mineral deposits, is selected. Then its geological map is prepared on a suitable scale. Such a map shows topography, 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 programme.

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 to 1.5 meter wide, and 2 to 2.5 meter deep. They are commonly dug across the strike of the ore 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 information about the 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 process of digging rectangular openings to penetrate 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 narrow 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. Pitting is an important method of prospecting in many bauxite and iron ore deposits.

Aditting. The "*adits*" are horizontal openings which are dug in mountainous terrain to explore ore bodies. An adit many be driven across or along the strike of rocks. It should be dug in such a way so that at a later stage it could be used as an opening for exploiting the ore.

Augering and Washboring. Augering and washboring are commonly used for prospecting of flat and homogeneous deposits like clays which are concedaled under a thin cover of softandunconsolidated materials. "*Augering*" is a simple method of putting down holes of about 2.5 cm in diameter to depths upto 6 meters in soft soils. An auger consists of a screw blade mounted on a steel pipe. It is screwed into the ground by turning on a T-pipe attached to the upper end.

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

Drilling. Drilling is an important method of prospecting subsurface rocks and ore deposits. In drilling data are collected by direct penetration of subsurface rocks by drill holes. The samples of rocks are obtained in the form of cylindrical cores or rock fragments. The drill holes provide the following informations.

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

During prospecting, drill holes are located at certain intervals in certain directions depending upon the regularity of the ore body and its structure. In most cases, the test holes are drilled systematically in a grid pattern. In this pattern, the system of "*diminishing squares*" is adopted. First a gird of large squares is laid out and the holes are drilled at each corner of the squares. In case of simple deposits the grid lines may be kept 300—400 meters apart, while in complex and intricate deposits, this interval may be reduced to 200—300 meters and 100—200 meters respectively. Subsequently for closer examination, each grid is subdivided into four small squares and more holes are drilled at their corners. Thus systematic geological data are obtained for the entire deposit.

For every drill hole cores should be carefully logged and vertical sections of the geological formations penetrated should be prepared. The positions of drill holes are marked properly on the base map of the area, and a map showing variations of grade of the ore is prepared. Then the portions of it which have the proper tenor of ore are delineated and the area computed for estimating the reserve.

11.4. GEOPHYSICAL PROSPECTING

In geophysical prospecting certain 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 γ-ray (gamma-ray) radiations are measured. The measured data are then interpreted to give information about the presence of ore bodies, buried anticlines, faults, igneous intrusions, and other geological structures. The main geophysical prospecting methods are as follows.

1. Gravity methods.
2. Magnetic methods.
3. Electrical methods.
4. Seismic methods.
5. Radioactive methods.

11.5. GRAVITY METHODS

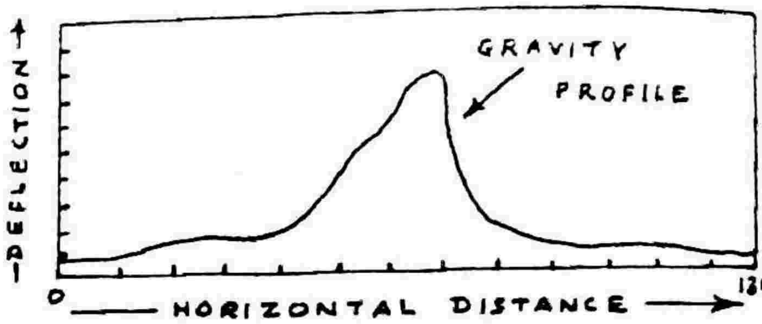
The gravimetric survey is based on the measurement of density contrast between the anomaly producing body and the surrounding rock.

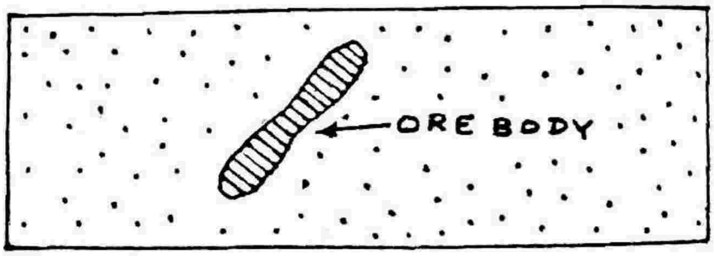
Use. (*i*) The gravity methods are used chiefly for the exploration of oil and gas. These have been used successfully for outlining anticlines, buried ridges, igneous intrusions, faults and other geological structures.

(*ii*) The gravity survey has also been utilized for the exploration of metallic ore bodies such as massive sulfide ore, iron ore, and chromite ore.

Method. The instruments which are commonly used to measure gravitational deflections are : (*i*) pendulum, (*ii*) torsion balance, and (*iii*) gravimeter. Of these the gravimeter is the most useful. For covering larger areas rapidly, airborne gravity survey is done.

In the area of search, traverses are laid at suitable intervals. Then the values of gravitational deflections are measured at predetermined points. The readings thus obtained are plotted on a graph with distances on x-axis and deflections on the y-axis. If a dense rock or a massive ore body is present in the area, the graph will show an anomaly in the form of a peak as shown in *Fig. 11.4*. The difference between the normal value and the observed value of deflection is called *"anomaly"*.





STRUCTURE SECTION

Fig. 11.4. Showing gravity profile of an 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 are drawn in the same way as contour lines.

11.6. 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.

(*ii*) At places faults may bring together rocks of different magnetic properties. Hence they may be delineated from magnetic data.

(*iii*) The magnetite and pyrrhotite are more abundant in basic igneous rocks than in acid rocks. Hence the former can be detected by the magnetic surveys.

(*iv*) Certain mineral deposits which contain magnetic minerals in subordinate amount, such as magnetite with asbestos and pyrrhotite with base metals, can be detected by magnetic surveys.

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

In the area of search, traverses are laid at suitable intervals. Then the values of magnetic intensities are measured at closely spaced stations. For each station, the observed value is compared with the normal value. The difference between them is the "*magnetic anomaly*".

The values of anomaly are plotted on 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 be interpreted by constructing magnetic profiles in the same way as done for gravity data (*Fig. 11.4*).

11.7. ELECTRICAL METHODS

The electrical methods are used mainly for the exploration of metallic mineral deposits. The electrical survey methods are of four types : (*i*) self potential method, (*ii*) equipotential method , (*iii*) electromagnetic method, and (*iv*) resistivity method.

11.7.1. Self Potential Method

In this method the electrical energy produced by the ore body itself is directly measured and no outside energizing force is required. Certain ore bodies, perticularly those containing sulfide minerals when subjected to

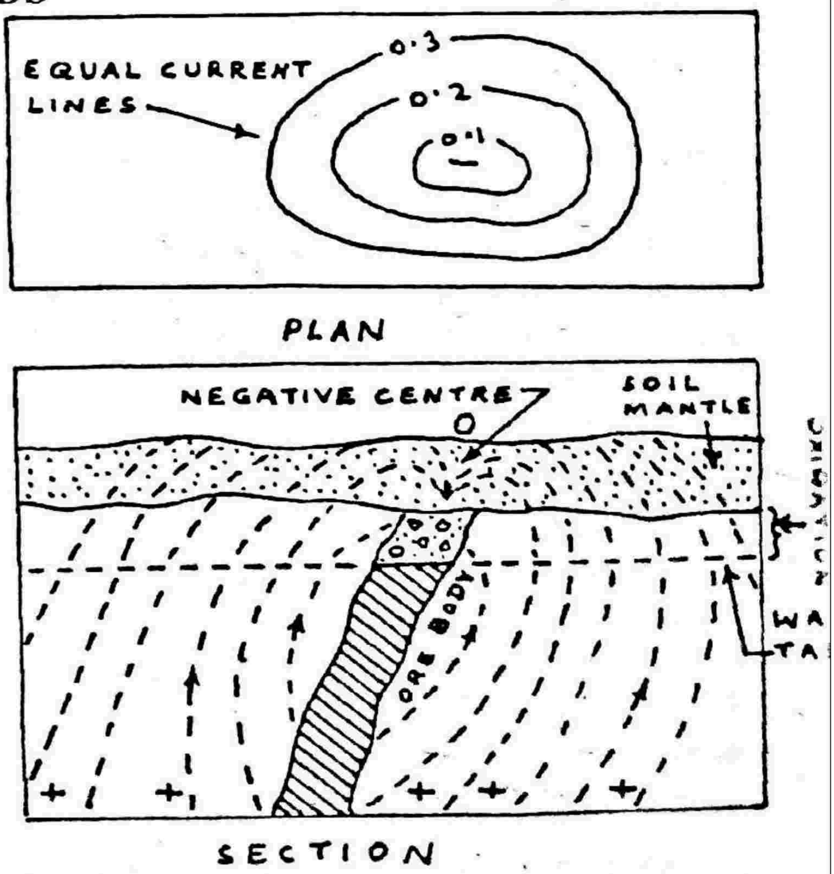


Fig. 11.5. Showing self potential currents of an ore body.

3. The resistivity methods have been used widely for the exploration of groundwater. In regions of gentle dips the presence of aquifers can be determined.

4. Fault zones may be determined as they contain electrolyte in solution.

5. Resistivity surveys can be used for discovering the subsurface structure and lithology. The buried anticlines can be traced by determining depths to strata of greater or lesser resistivity. Hence they are also used in the exploration of petrolium.

11.8.1 Wenner Method. In resistivity surveying various electrode arrangements are employed but the arrangements shown by Wenner is widely used.

In the Wenner method the spacing between the electrodes are kept equal. In *Fig. 11.8* this spacing is designated as 'd'. The current is introduced into the ground by two current electrodes C_1 and C_2, and the potential difference

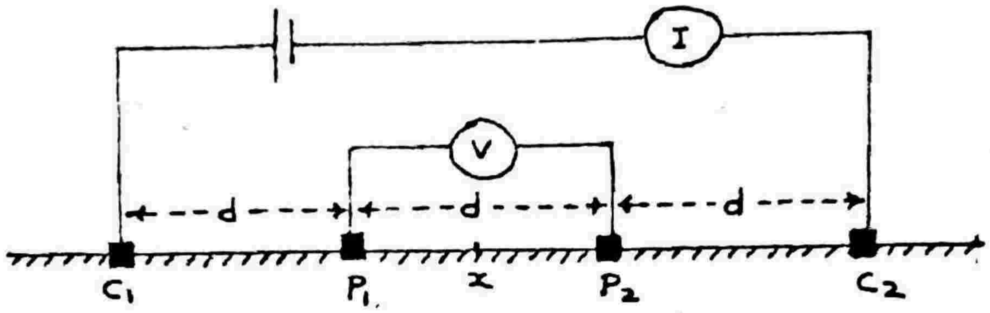


Fig. 11.8. Showing electrode arrangement in Wenner method.

between the inner electrodes P_1 and P_2 is measured. All the four electrodes are placed in a line as shown in *Fig. 11.8.* The resistivity of the ground is determined by the following equation.

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

Where ρ is resistivity, d is the distance between electrodes, V is the difference in potential between inner electrodes, and I is the current flowing between the end electrodes. In this case, the depth of exploration is approximately equal to the electrode separation. By Wenner method two types of resistivity surveys are carried out : (*i*) resistivity traversing, and (*ii*) resistivity sounding.

11.8.2. Resistivity Traversing

This method is also called *"resistivity trenching"*. It is used to investigate variations of rock beds in the horizontal direction at constant depth.

The spacing of the electrodes are kept constant while they are moved along a traverse line. The resistivity measurements are made at various stations. From the data thus obtained, the resistivity curves are drawn by plotting the distance of stations on X-axis and resistivity values on the Y-axis. An abrupt change in the curvature of a resistivity profile indicates a change in the nature of the underlying material (*Fig. 11.9*).

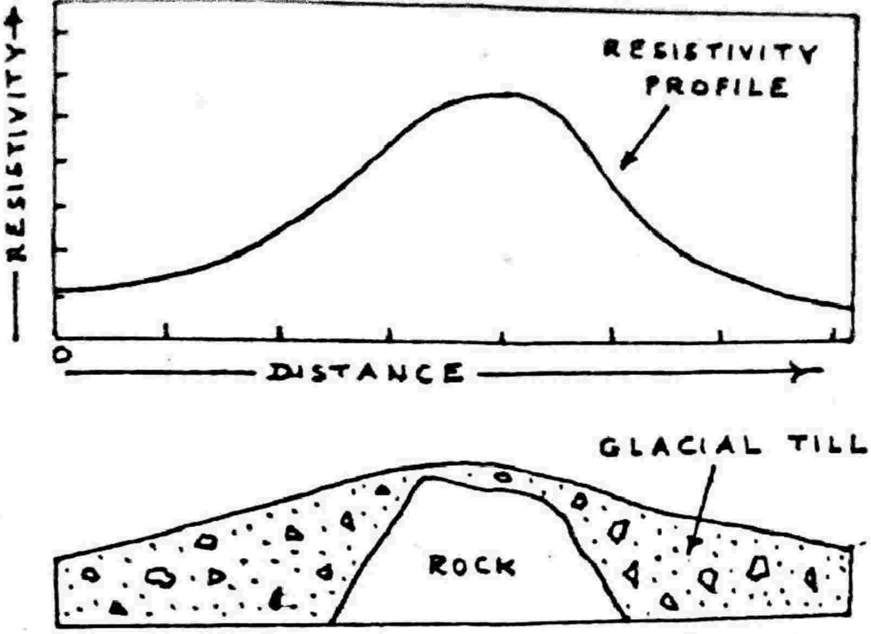


Fig. 11.9. Resistivity profile showing change in the nature of the underlying material horizontally.

11.8.3. Resistivity Sounding

This method is used to investigate the nature of subsurface strata at depth. In resistivity sounding, the resistivity is measured by increasing the electrode separation progressively about a central fixed point '*x*' (*Fig. 11.8*).

As the distance between the electrodes is increased, the depth of penetration of the current is also increased. In this way the data on variation of resistivity with depth are obtained. Then the resistivity-depth curves are drawn by plotting the resistivity values on *X*-axis and electrode spacing on *Y*-axis (*Fig. 11.10*).

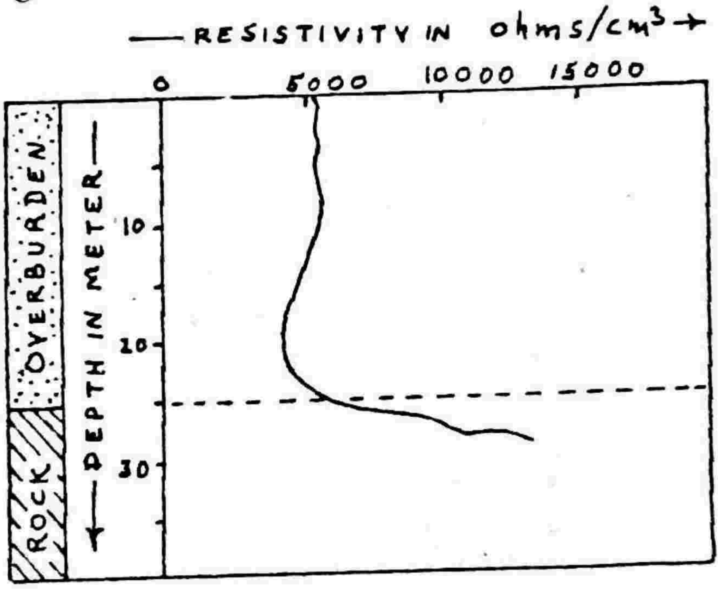


Fig. 11.10. Resistivity curve showing depth of overburden.

11.9. SEISMIC METHODS

In seismic methods, the variations in the seismic wave velocity are measured in different rock layers. 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 the differences in the velocities, the structure of the subsurface rocks can be worked out.

Method. In seismic surveys, truck mounted drilling rigs and recording systems are used. Small charges of explosives are detonated in shallow boreholes drilled in the surface rocks. The seismic waves thus generated are transmitted through the rocks and are picked up by a series of geophones carefully spaced along a line of traverse [*Fig. 11.11 (a)*].

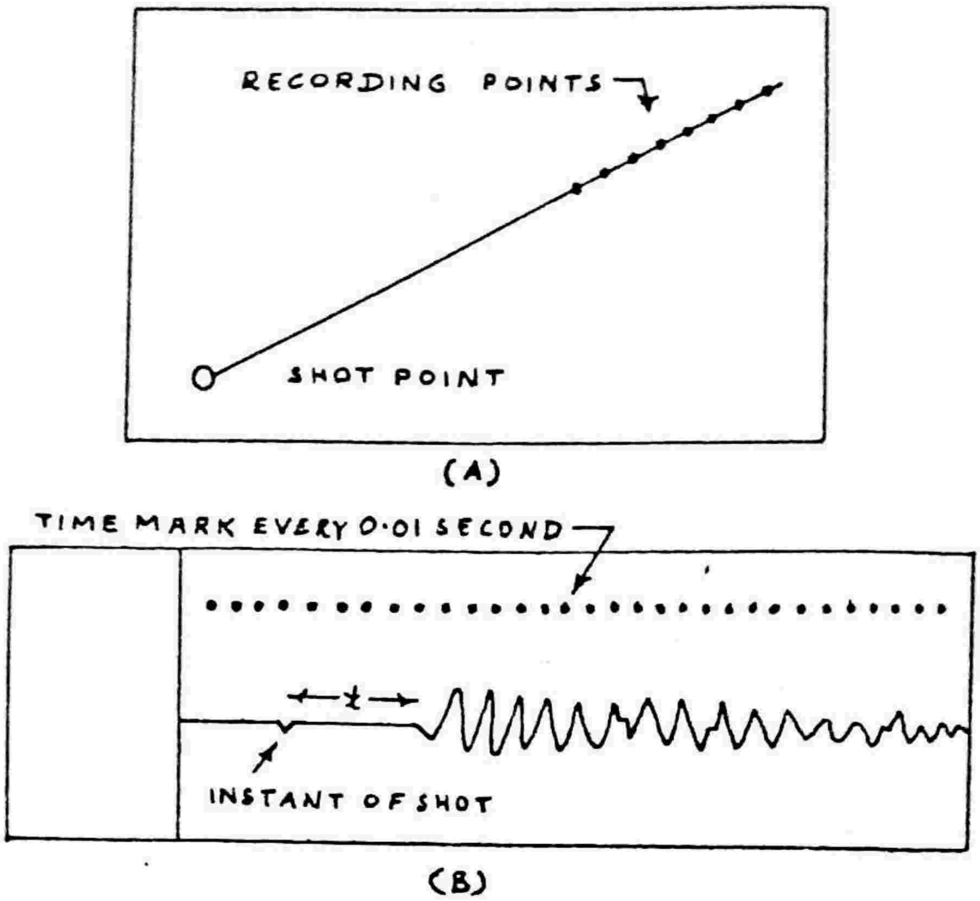


Fig. 11.11. Seismic method. (*a*) Showing shot points and geophones along a line of traverse. (*b*) Seismogram showing interval of time t between instant of shot and arrival of first wave at a geophone.

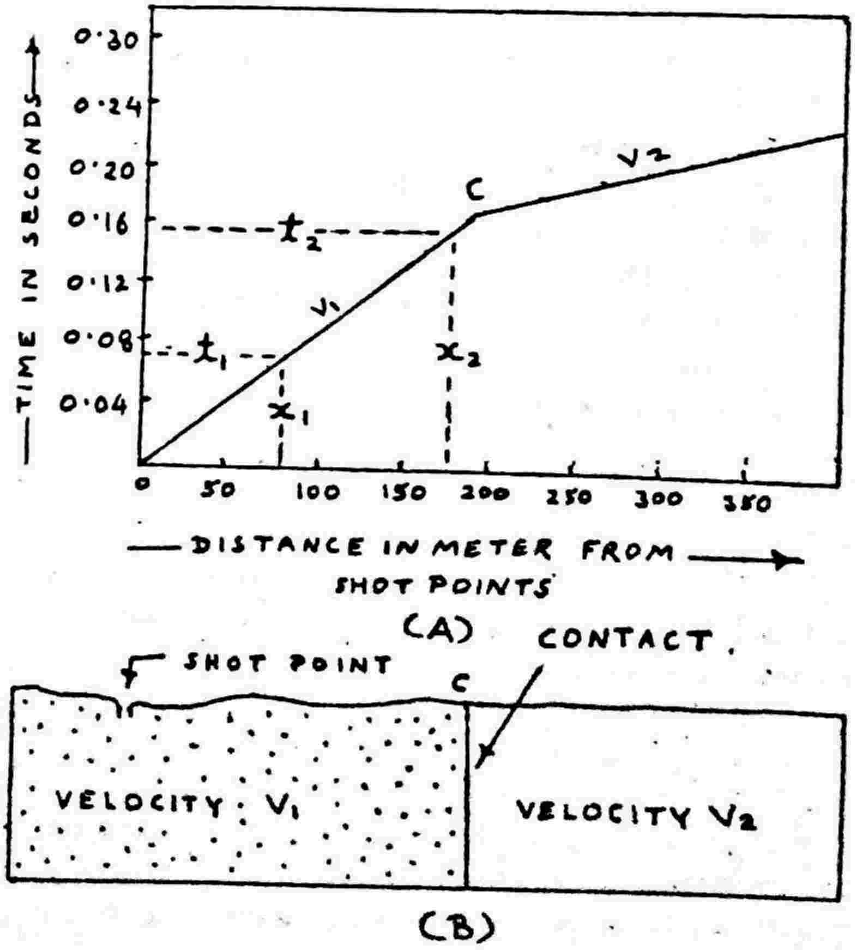


Fig. 11.12. Travel time curve. (*a*) Obtained from the seismic survey of the ground shown in (*b*).

The geophones record the vibrations on a rapidly moving photographic paper. The instant of explosion is also marked on this paper [*Fig. 11.11 (b)*]. From this photographic record (seismogram) the time-distance curves are prepared (*Fig. 11.12*). Then the velocity of seismic waves is determined by the following equation.

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

Where V is the velocity of seismic waves, x_1 and x_2 are the distances of any two recording stations from the shot point, and t_1 and t_2 are the times of arriaval of the seismic wave at the same stations.

The velocity of seismic waves differ in different kinds of rocks. Hence from the velocity data, the structure of subsurface rocks can be worked out. The seismic methods are of two types : (*i*) refraction survey, and (*ii*) reflection survey.

11.9.1. Refraction Survey

The seismic waves undergo reflections and refractions at the rock boundaries. In the refraction method only the refracted waves are recorded and used for determining the structure of rocks. The refraction survey is commonly used for the following.

(*i*) For determining the structure of rocks lying at relatively shallow depth. It is widely used for civil engineering explorations.

(*ii*) For the location of shallow salt domes and the oil pools associated with them.

11.9.2. Reflection Survey

In this method the reflection waves from a reflecting surface are recorded and used for determining the rock structures. The reflection survey is generally used for deep explorations (600 meters ore more). Hence it is widely used for oil exploration. This method accurately delineates the subsurface structural traps and salt domes.

11.10. RADIOMETRIC SURVEYING

The radioactive elements, such as uranium-238 and thorium-232, constantly undergo a process of disintegration. During disintegration they emit radiations of three types : (*i*) α rays, (*ii*) β rays, and (*iii*) γ rays.

(*i*) **α-Rays.** These are the beams of positively charged particles. These particles are the nuclei of helium atoms (2 protons + 2 neutrons). They travel with velocities of thousands of kilometers per second.

(*ii*) **β-Rays.** These are the beams of negatively charged particles. They travel faster than α rays.

(*iii*) **γ-Rays.** These are the rays of very short wave length like *x*-rays. They travel with velocity of light and have a very high penetrating power.

Of the three above said radiations, only the γ-rays are useful from the point of view of radiometric surveys. The instruments commonly used for radiometric surveys are : (*i*) Geiger Mueller counters, and (*ii*) scintillation counters.

Geiger Mueller Counter. This instruments is fitted with an ionization chamber, meters and count registers. These make it possible to measures the intensity of γ-rays.

The γ-rays are detected by the ionization chamber. This chamber consists of a closed tube containing an ionisable gas under pressure. An electrical potential is applied to produce an electrical field inside the tube. As a result the positive ions move towards the negative electrode and the negative ions towards the positive electrode. A beam of incoming γ-rays librates a large number of ions inside the tube and produces an impulse of electric current.

Scintillation Counter. This is a very sensitive instrument which measures the intensity of γ-ryas (gamma rays) in terms of electrical signals.

11.10.1. Types of Radiometric Surveys

Depending on whether the measurements are made from air, at the ground, or along drill holes, the radioactive surveys are classified into three groups : (*i*) airborne radiometric surveys, (*ii*) ground radiometric surveys, and (*iii*) radioactive logging of bore holes.

Airborne Radiometric Surveys. In airborne surveys, scintillation counters are used for recording the γ-rays from the air. These surveys are usually carried out along with the aeromagnetic and aeroelectromagnetic surveys. By airborne radiometric surveys the deposits of radioactive substances and boundaries between various rocktypes may be outlined.

Ground Radiometric Surveys. The ground radiometric surveys are used mainly : (*i*) to search deposits of radioactive substances, and (*ii*) to outline geological structures such as faults.

(*i*) **To Search Deposits of Radio-active Ores.** In ground surveys, the G.M. counter is commonly used to detect the intensity of γ-rays. A radioactive deposit which is hidden beneath a thick cover of soil, may not be detected because most of the radioactive emanations are absorbed by the soil cover. In such a case the detection of the hidden deposit depends on the migration of the radioactive elements from the source. This migration is caused in two ways : (*a*) the radioactive substances may migrate in solution after the deposition of the ore, and (*b*) the radon which is the gaseous member of the radioactive series, may diffuse through the overlying cover.

The process of migration of radioactive elements may result in the formation of an "*aureole*", or in the localization of radioactivity along faults or fissures. By detecting these clues, the hidden ore body may be outlined.

(*ii*) **To Outline Faults.** Certain groundwaters contain radon and soluble radioactive materials in appreciable amounts. Faults containing such radioactive fluid may be outlined by measuring variations in the radioactivity of rocks.

Radioactive Logging. The "*radioactive logging*" is an operation in which γ-ray counts of various rockformations met in a borehole are recorded continuously along the depth. This depthwise record is called "*radioactive log*". The radioactive logging is used for (*i*) correlating rockbeds, and (*ii*) determining porosity and permeability of rocks.

(*i*) **For Correlating Rocks.** Every rockformation contains some natural radioactivity in measurable degrees. As a rule, acid rocks are more radioactive then basic rocks. Because different rocks have different amount of radioactivity, they may be correlated by using this criteria.

(*ii*) **For Determining Porosity.** The radioactivity counts of different rocks vary with their densities. The more dense rocks have higher values of radioactivity than those of less dense rocks. Hence from the density, the porosity of rocks may be determined.

11.11. GEOCHEMICAL PROSPECTING

The geochemical prospecting is very effective is locating deposits of base metals, such as Cu, Pb, Zn, etc. In India this method is used commonly for this purpose. The essential principle of geochemical prospecting is as follows.

1. Samples of the surface soil or sediment of the target area are taken systematically from grid points.
2. The metal content of the samples are determined precisely by rapid geochemical analyses.
3. The distribution of the metal content in the surface soil or sediment is determined by plotting the values on a base map of the target area.
4. Then the comparision of these values is made with the known "*background*" values.
5. This comparision will give the idea about the presence of the mineral deposit hidden below the ground.

Method. The main steps involved in the geochemical prospecting are : (*i*) sampling, (*ii*) geochemical analyses, and (*iii*) interpretation of data.

(*i*) **Sampling.** The geochemical prospecting of a target area is started with the collection of samples. The samples of surface soil, stream sediment, water or rock chips are collected at regular intervals. Generally a large number of samples are collected from grid points at fixed intervals. The grid lines are drawn transverse to the strike of the suspected zones of mineralization.

(*a*) **Soil Sampling.** The soils always contain mineral particles present in the parent rock. The soils caped over the ore body commonly shows anomalously high values of metal concentration. In soil sampling, the samples weighing about 100 gm. are collected from each grid point.

(*b*) **Stream Sediment Sampling.** In geochemical surveys, the stream sediment sampling is commonly done. In this case, samples of fine stream sediments are colleceted from stream channels. These sediments usually carry mineral particles derived from their original source rock. The samples of stream sediment are normally collected at intervals of 0.15 km.

(*c*) **Water Sampling.** Water sampling is done mainly for uranium deposits and rarely for zinc and copper deposits. The water samples are collected from lakes, rivers, and underground sources.

(*d*) **Rock Sampling.** In case of rock sampling, chips of rocks are collected from visible outcrops at regular intervals. These chips are then crushed to –100 mesh size and analysed for the metal content.

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

(*iii*) **Interpretation of Data.** The data obtained from the geochemical analyses are interpreted with the help of graphical statistical procedures or by computer methods. The method of interpretation may briefly be summarized as follows.

1. The area under investigation shows three types of values : (*a*) background values, (*b*) threshold values, and (*c*) anomalous values. The average values of the metal content of the area are called "*background values*". The "*threshold values*" are those which demarcate the zone separating the average values and the anomalous values. The values which are above the threshold values are called "*anomalous values*".

2. The area of anomalous values outlines the mineral deposit hidden below the ground.

12.12. GEOCHEMICAL SURVEY FOR OIL AND GAS

The gases associated with petrolium are mainly methane, ethane and propane with minor amounts of N_2, CO_2 and SO_2. Since the gases are highly mobile, they move upward through the rocks and reach the ground surface. As a result the soils get enriched in the methane. The petrolium may also be searched by determining the presence of oil bitumens in the rocks, soils and waters.

In the geochemical survey, the samples of soil, rock and water are collected systematically from grid points. These samples are then analysed chemically to determine the presence of hydrocarbon gases and bitumens. The data thus obtained give clues to the presence of petrolium deposit hidden underneath.

The geochemical methods of prospecting for oil has been divided into two groups : (*i*) direct methods, and (*ii*) indirect methods. In the "*direct methods*" mainly gas and bitumen are used as indicators, while in the "*indirect methods*" hydrochemical, soil salts, physico-chemical, and microbiological indicators are used.

Gas Survey. Of the direct methods, the gas survey is the most important. It has helped in discovering many oil formations independently. In this method, the migrating hydrocarbon gases which are directly associated with the oil or gas deposit, are detected. The most difficult part of gas survey is sampling. The samples of subsoil gas are taken from shallow wells dug at grid points. The samples are taken in such a manner that the atmospheric air does not dilute them.

Each sample of the subsoil gas is analysed chemically to determine the amount of hydrocarbon gases present in it. The results thus obtained are recorded on a map. Then the area of oil and gas deposit may be outlined.

Economic Geology

Ore Mineral. A mineral from which one or more metals can be extracted at a profit is known as "*ore mineral.*" Examples of ore minerals are hematite,bauxite,galena, etc. The ores may be high grade or low grade depending on the percentage of the metal present in it.

Gangue Mineral. The useless minerals which occur in association with the ore, are called "*gangue minerals*". They are commonly discarded in the treatment of the ore. The common gangue minerals are quartz, calcite, barytes, fluorspar, felspar, and tourmaline.

Ore Deposit. The mixture of ore minerals and gangue forms an "*ore deposit*". The ore deposits are generally found enclosed within the country rocks.

Tenor. The term "*tenor*" describes the metal content of an ore. In order to declare the ore economically workable, a deposit must contains a certain percentage of metal in it and the lowest admissible limit of metallic content of an ore is called its "*tenor*". The tenor of an ore depends on the price of the metal obtained from it. For costly metals the tenor is very low, such as for gold it is 0.01% whereas in case of cheap metals like iron, the tenor is much higher, that is 50% or more.

Syngenetic Ore Deposit. The ore deposits that are formed at the same time as the enclosing rock, are called "*syngenetic ore deposits*". Sedimentary ore deposits are the examples of syngenetic deposits.

Epigenetic Ore Deposits. The ore deposits that are formed later than the enclosing rock, are called "*epigenetic ore deposits*". Hydrothermal ore deposits are the examples of epigenetic deposits.

Being one of the most widely distributed elements in the earth's crust iron rarely occurs in the free state as it enters into the composition of many rocks and minerals. It consists of about 4·6 percent of the earth's crust. In nature, iron occurs in four principal forms, viz., oxides (hydroxides also), carbonates, sulphides and silicates. The chief economic iron ore minerals are

Magnetite	Fe_3O_4	(Containing 72·4% of iron)
Hematite	Fe_2O_3	(Fe=70%)
Limonite	$2Fe_2O_3, 3H_2O$	(Fe=59·8%)
Goethite	Fe_2O_3, H_2O	(Fe=62·9%)
(Spathic-ore)- Siderite	$FeCO_3$	(Fe=48·2%)
Pyrite	FeS_2	(Fe=46·2%)

Chamosite and thuringite are examples of iron-silicate minerals.

Origin. Iron ore deposits are generally formed by the following processes :

(*i*) **Magmatic.** Magnetite, titaniferous magnetite, *e.g.*,—Kiruna (Sweden), Keonjhar and Mayurbhanj (Orissa), Salem (Tamilnadu), Hassan (Karnataka) etc.

(*ii*) **Sedimentary.** Hematite deposits of Bihar, Orissa, Madhya Pradesh, Maharashtra and Karnataka. Siderite deposits of economic importance are usually sedimentary deposits.

(*iii*) **Replacement.** Magnetite, hematite, deposits, *e.g.*, Lyon Mountain, Newyork.

(*iv*) *Residual concentration.* Laterite formations in the Eastern ghats of India.

(*v*) *Oxidation.* Limonites, *e.g.*, Rio Tinto, Spain.

Besides the above, contact metasomatism also plays some role in the formation of magnetites and specularite.

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 :

(*i*) 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 Orissa. The *massive-ores* where the iron content ranges from 66 to 70% occur on top of hill ranges. The *shaly* ore may be as rich as hematite and as low as 50% or less in iron. The *biscuit* or *laminated* ore contain about 55 to 66% of iron. *Blue dust* ore, which is an extremely friable and micaceous hematite powder contain about 68% of iron, is formed by leaching process from BHQ. There also occurs lateritic ore.

The important mining centres of Orissa and Bihar are Barbil, Gua, Bonai, Joda, Kiriburu, Suleipat, Gorumahisani, Noamundi, Barajamda etc.

(*ii*) **Madhya Pradesh.** In the Bailadila hill ranges.

(*iii*) **Maharashtra.** Ratnagiri district.

(*iv*) **Goa.** Bicholim—Pale in Goa.

(*v*) **Karnataka.** Bababudan hills in Chikmagalur district, and in Sandur, Bellary, Hospet districts as well as Shimoga and Chitaldrug districts. Important one is that of 'Kudermukh'.

(*vi*) **Andhra Pradesh.** Cuddapah, Kurnool, Chitoor, Nellore, Anantapur, Warangal and Adilabad districts.

(*vi*) **Tamilnadu.** Salem district, and Tiruchirapalli district.

(*viii*) **West Bengal.** Deposit of lateritic ores mostly occur in West Bengal.

(*ix*) **Assam.** Iron stone-clay are found as nodules and thin beds in the coal measures of Eocene age and in the Tipam saries of Miocene age.

CHROMIUM

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

Chromite—FeO, Cr_2O_3, Cr_2O_3=68·0% and Cr=46·66%.

Origin. Chromite deposits are magmatic segregations in ultrabasic igneous rocks of Archaean age. Chromite is associated only with highly basic or ultrabasic rocks like peridotite, saxonite, dunite and pyroxenites or their alteration product, serpentine rock.

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 districts of Orissa, and also in the Keonjhar district of the state. The belt extends over a distance of about 20 km. the width of the belt is about 2 km. The ore bodies are lenticular in shape, and occur as lenses and patches within the lateritised ultra-basic rocks. The following type of ores are found to occur *viz.*

(*i*) massive ore
(*ii*) banded ore
(*iii*) disseminated ore
(*iv*) ferruginous lateritic ore
(*v*) powdery or friable ore
(*vi*) conglomeratic ore
(*vii*) placer ore etc.

The reserve is estimated to be about 8 million tonnes.

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).

Economic uses :

(*i*) 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.

(*ii*) In refractory industries, due to its high resistance against corrosion, high temperature and sudden temperature changes and its chemically neutral character.

(*iii*) In chemical industries, for the manufacture of chromium compounds like chromates and bi-chromates and chromic acid etc.

COPPER

It is the most important non-ferrous metal and was the earliest metal used by man.

Ore-minerals. In nature copper occurs in four principal formes, *viz*, sulphides, carbonates, oxides and as native copper. Of these the bulk of copper is obtained from the sulphide ores. The chief economic ore-minerals however, are

		Composition	% of copper
1.	*Native copper*	Cu	100
2.	*Sulphides* :		
	(*i*) Chalcopyrite	$CuFeS_2$	35·5
	(*ii*) Bornite or erubescite	Cu_5FeS_4	63·3
	(*iii*) Covellite	CuS	66·4
	(*iv*) Chalcocite	Cu_1S	79·8
	(*v*) Enargite	Cu_3AsS_4	48·3
	(*vi*) Tetrahedrite	$Cu_8Sb_2S_7$	52·1
3.	*Carbonates* :		
	(*i*) Azurite	$2CuCO_3Cu(OH)_3$	55·1
	(*ii*) Malachite	$CuCO_3Cu(OH)_2$	57·3
4.	*Oxides* :		
	(*i*) Cuprite	Cu_2O	88·8
	(*ii*) Tenorite	CuO	79·8
	(*iii*) Chrysocolla	$CuSiO_3H_2O$	36

To be economically exploited a copper ore should contain at least 2·5% of copper. In modern times ores with 1% of copper are also used.

Origin. All large copper ore bodies are closely connected with igneous rocks mostly of an acidic nature. It is mostly believed that

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 bearing solutions percolating along shear-zones and rock-fractures deposit copper minerals with changes of temperature and pressure forming fissure-veins, *e g*.,—Copper deposits of Singhbhum.

(*d*) Deposits following stratigraphic beds, as is the case with the deposits of Khetri (Rajasthan).

Distribution :

(*i*) In Andhra Pradesh, the most important copper deposits are the Agnigundla-deposits.

(*ii*) 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-schists, quartz-schists, chlorite-schists, biotite-schists, granite and granite-gneisses. The veins are best developed along a zone of over thrust, where they form well defined lodes, as seen at Rakha mines, Mosabani and Dhobani. Individual lodes normally consist of one or more veins one inch to two feet thick, the average being 5 to 7 inches.

(*iii*) In Madhya Pradesh, the important deposit is the Malan Jhakhand copper deposit, where copper ores occurs in the form of veins within dolomitic limestone.

(*iv*) The Khetri copper deposit of Rajasthan is one of the important copper deposit in the country. This belt has 3-richly mineralised sections—Madhian, Kolihan and Akhwali. The copper ore bodies occur in phyllites, slates and schists of the Ajabgarh series (Delhi system) as irregular stringers, fillings of schistose planes and fractures and disseminations in the host rock. The mineralisation in Rajasthan copper belt is epigenetic and seems to have occurred under mesothermal conditions from post-Delhi (Erinpura) granite magma.

(v) Other important copper deposits of the country are as follows :

(a) *Himachal Pradesh.* Kangra, Kulu valley.

(b) *Mysore.* Chittaldrug, Hassan, Bellary districts.

(c) *West Bengal.* Darjeeling, Jalpaiguri districts.

(d) *Sikkim.* Rangpo and Dickchu 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.

LEAD AND ZINC

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 followings are the important minerals of lead and zinc :

Lead	*Zinc*	
Galena-PbS-Pb 86·6%	Sphalerite *Or* Zinc blende	ZnS, Zn-67%
Cerussite-$PbCO_3$-Pb 77·5%	Smithsonite *Or* Eng. Calamine	$ZnCO_3$, Zn-52%
Anglesite-$PbSO_4$, Pb 68·3%	Hemimorphite *Or* Americanname-Calamine Zincite-ZnO	$2ZnO_2SiO_22H_2O$, Zn-54·2%

Origin. Lead and zinc ore minerals, particularly the sulphide-ones are formed due to contact metasomatism, replacement by hydrothermal solutions.

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 meagre compared to her needs.

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

The Zawar mine is located in the Mochia Magra hills. The principal rock types of zawar area consists of phyllites, slates, mica-schists, dolomites and quartzites of the Aravalli system. But mineralisation of lead and zinc sulphides is solely confined to the dolomites, whereas adjoining phyllites are almost barren. The lead and zinc deposits are confined to the upper series of the Aravalli-rocks in the zawar area. The localisation of the ores are structurally controlled by the shear zones. The ores occur in shear zones and follow shear planes which are the youngest tectonic feature in the area.

Most of the ore-shoots are found to occur as irregular steeply dipping and thin parallel tabular masses. Galena is generally concentrated in some particular portions of the deposits but the sphalerite is more or less evenly distributed. The gangue is dolomite and quartz.

Evidences obtained so far suggest the formation of the *Zawar* lead-zinc deposits from hydrothermal solutions at about 250°C.

The ore minerals consist of argentiferous galena associated with sphalerite containing a small percentage of cadmium, pyrite, arsenopyrite 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 (Orissa).

The estimated reserve in the country is about 9 million tonnes.

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, galvanising iron and steel products, in the manufacture of pigments and alloys with other metals (like brass, bronze, german silver), in the manufacture of batteries and electric appliances. Besides, they are widely used in textile industry, timber preservation etc.

UNFC code of classification of reserves

I Introduction

The United Nations Framework Classification (UNFC) for Energy[1] and Mineral Resources[2] is a universally applicable scheme for classifying/evaluating energy and mineral reserves[3] resources. Most importantly, it allows a common and necessary international understanding of these classifications/evaluations. The Classification is designed to allow the incorporation of currently existing terms and definitions into this framework and thus to make them comparable and compatible. This approach has been simplified through the use of a three-digit code clearly indicating the essential characteristics of extractable energy and mineral commodities in market economies, notably (i) degree of economic/commercial viability; (ii) field project status and feasibility; and (iii) level of geological knowledge.

1.2. Classification

Total remaining resources are categorized using the three essential criteria affecting their recoverability:

- Economic and commercial viability (E).
- Field project status and feasibility (F).
- Geological knowledge (G).

Most of the existing resource classifications recognize these explicitly or implicitly. By making them explicit, the UNFC becomes a framework that allows for harmonization of existing classifications.

The three criteria are easily visualized in three dimensions as shown in Figure 2

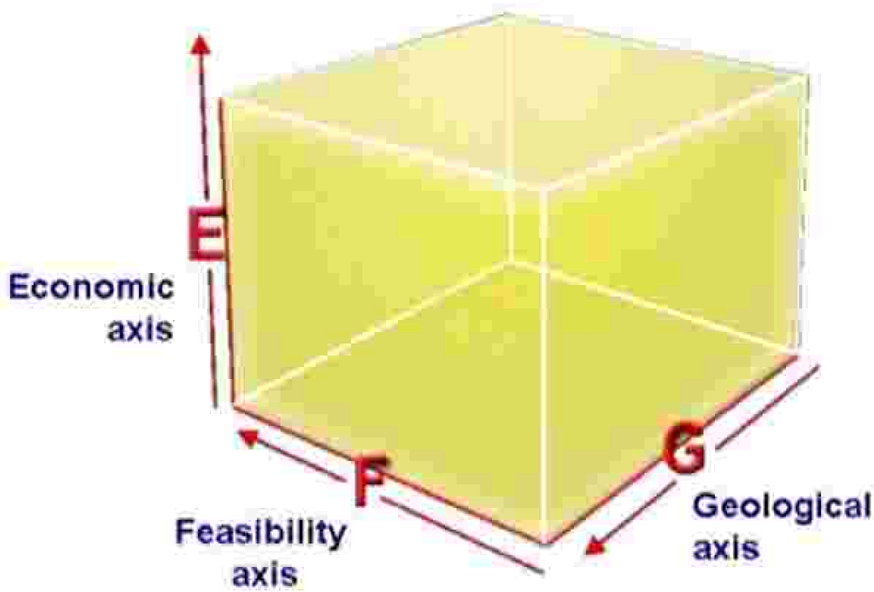


Figure 2. Principal elements of the UNFC

Three main categories are used to describe economic and commercial viability, three to describe field project status and feasibility and four to describe the level of geological knowledge. Further subdivision of the main categories is useful for special applications. Resource quantities are then grouped into classes that are defined by an E a F and a G category represented by the sub-cubes in Figure 3

Figure 3 A class of quantities may be a single sub-cube, i.e. 111, or a collection of sub-cubes. Total resources are an example of such a class where all sub-cubes are included in the class.

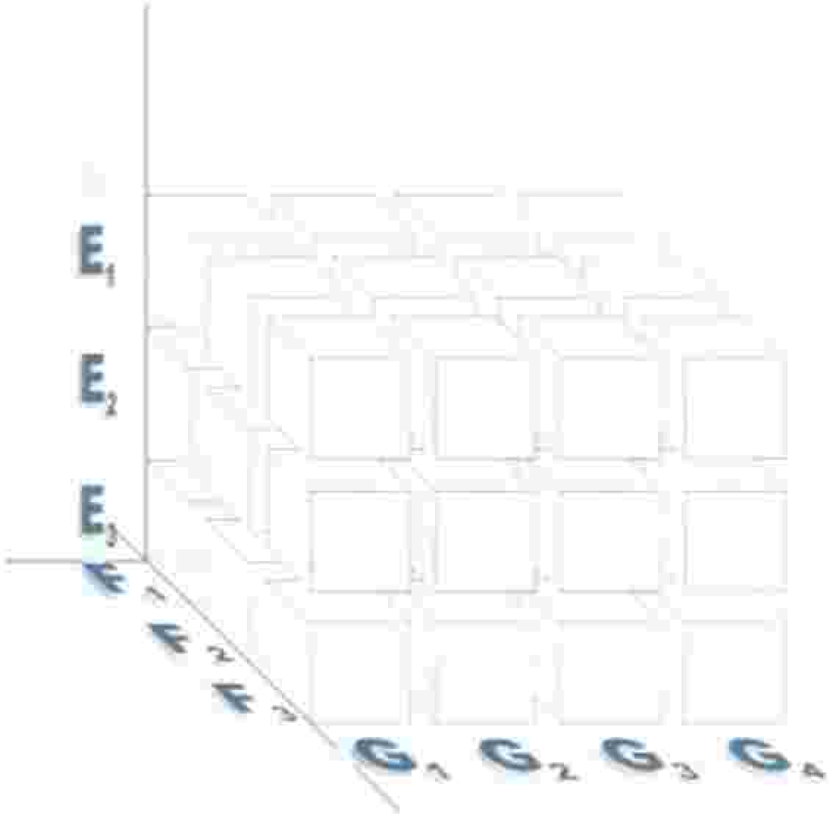


Figure 3. Classification

The three dimensions of categorization are represented by the edges of a cube. The digits are quoted in the order EFG firstly because the alphabetical order is easy to memorize, and secondly because the first digit refers to the economic viability, which is of decisive interest to producers, investors and host countries.

Numbers are used to designate the different classes. Number 1, in accordance with the usual perception that the first is the best, refers to the highest degree of economic viability on the E axis, the most advanced project status on the F axis and the highest quality assessment on the G axis. The use of categories is different for fluids and for solids. This is primarily due to the fact that fluids may flow in a reservoir, irrespective of the level of geological knowledge. In the case of solids, recovery will normally be restricted to rock bodies that have been reliably assessed.

1.3. Codification

Due to variation between terminologies in different systems and languages, it is recommended to use only three-digit numeric codes for individual categories, so that they will be universally understood. For this to be possible, the sequence is always fixed, so that the quantity characterized as E1;F1;G1 may be written in number form as 111, independent of languages. In practice, only a limited number of combinations (classes) are valid.

To illustrate, the UNFC for coal, uranium and other solid minerals, shown in Figure 5 may be expanded in Figure 4.

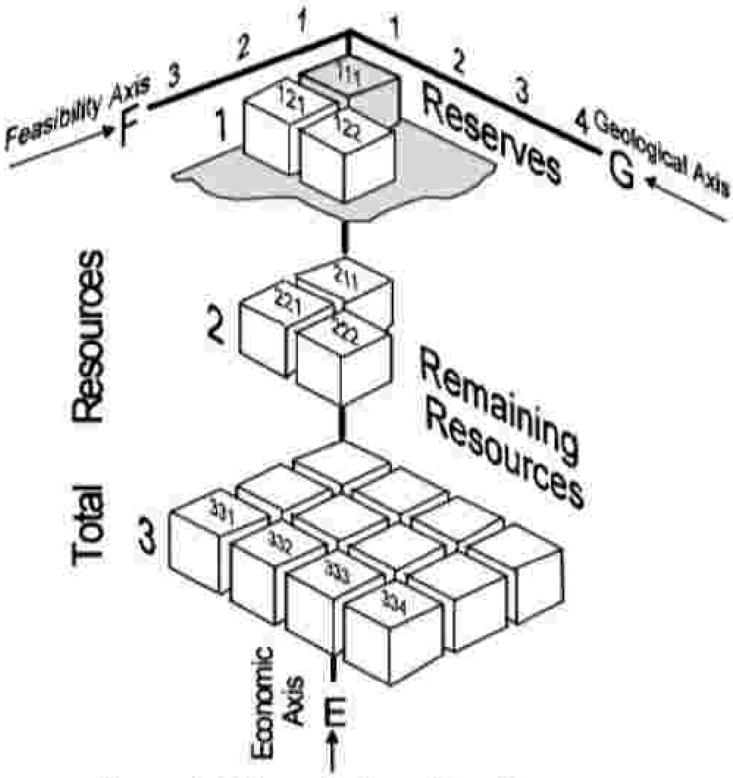


Figure 4. Three-digit codification

Class 111 is of prime interest to an investor. It refers to quantities that are: economically and commercially recoverable (number 1 as the first digit); have been justified by means of a feasibility study or actual production to be technically recoverable (number 1 as the second digit); and are based on reasonably assured geology (detailed exploration for solids) (number 1 as the third digit).

Subcategories may be added under the main categories when required. Categories and sub-categories shall be numbered. A sub-category shall be separated from the main category number by a decimal point, e.g. E1.1. In such cases the categories have to be separated by a semicolon to distinguish the different categories that are included in the codified unit, e.g. 1.1;1;1 for the subcategory defined by E1.1, F1and G1.

A single geological deposit or accumulation of a recoverable quantity may be subject to production by several separate and distinct projects that are at different stages of exploration or development. The estimated remaining recoverable quantities obtained through each such project may be categorized separately.

12sec
100%

Paper-IX

Unit-IV Mining and Surveying

:- Sampling :-

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

→ It is evident that one small fractions can not be representative of the whole mass. A large no. of samples are required to be obtained for providing satisfactory approximation to the grade and physical characteristic of the deposit.

→ How much and how the sample should be drawn will depend upon various geological factors.

- Nature of the deposit.
- Shape and size of deposit.
- Purpose and shape for which it is required.

→ In case of alluvial or placer deposits vein which are exposed to the surface or lie under a thin mantle of soil or residual product of weathering the samples draw from digging shallow pits and trenches would sufficient.

→ In case of copper and sulphide ores deposits which are reached near the surface and exposed in the form of Gossan the samples drawn from the zone of weathering will not be helpful.

→ In such case the samples are drawn by deep pits & bore hole going below the W.T.

→ For water supplying due care should be taken the selection of sample position.

→ The technique of sampling from the out cropping trench mine etc may be grouped into following:
(a) Grab samples or chip sample.
(b) Channel or groove sample.
(c) Bore hole sample.
(d) Bulk sample.
(e) Car and wagon sample.

(a) Grab samples or Chip Sample :—

Grab sample is a random collection of known chips from the exposed surface of an out crop, from the mine working from stacked materials the grade of the deposits can be relied upon from the assey value of such sample likely to be. this kind of samping is done for dissemnated ore bodies.

(b) Channel / Groove Samples :—

→ Channel or groove sample is collected from grooves cut symmetrically across the exposure of the ore body. This method is usually applied in sampling of trenches, pots, underground mines.

→ The purpose of cutting a groove and drawing a samples to ensure that uniform quantity of material is drawn over the entire width of the ore body. The channel is cut with a width of about 10cm & 25cm deep.

→ The amount of sample drawn is generally of the order of 1 kg for 30 cm of groove length.

→ Through it is always descrable to cut the channel across the ore body parallel to the true width it is not always convinient to do.

→ When the ore body consist of alternate bands of richer & leaner ore, the groove is subdivided so that each type is separately sample channel. Sampling is generally done for vein deposits.

(c) Bore holes Sample :—

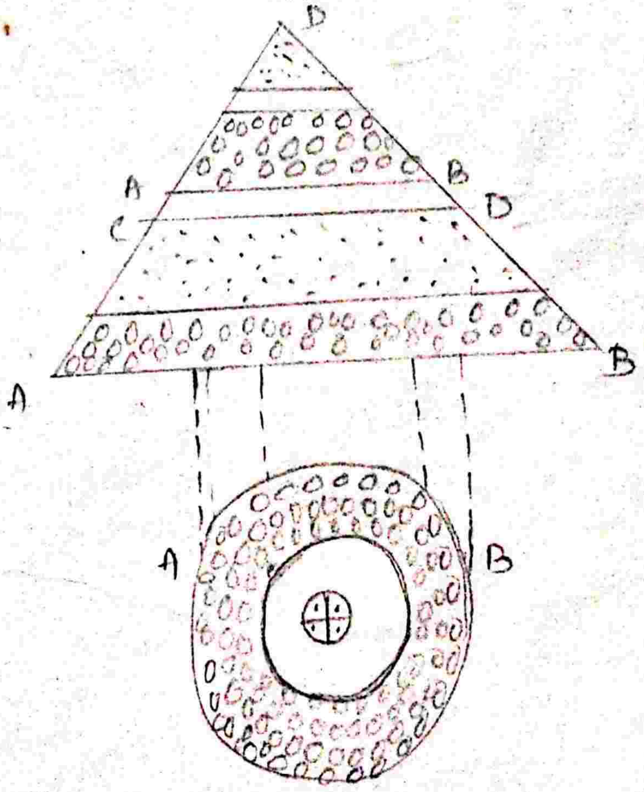
The Bore hole samples are taken out by drilling.

→ It is the most modern method of visual examinal of the mineralisation underground.

→ It helps both in delimiting the lateral as well as the vertical extension of ore body. Drill holes are suitable spaced to cover the area. This kind of sampling is done for under ground or concealed deposits.

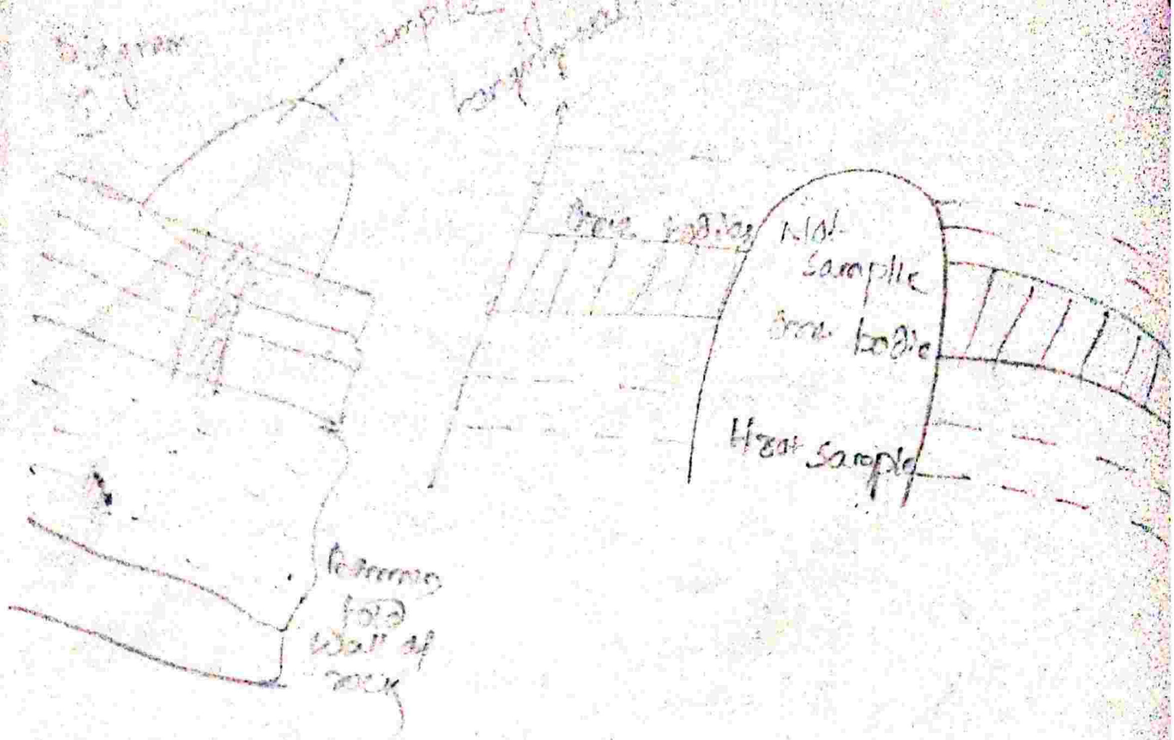
(d) Bulk samples :—

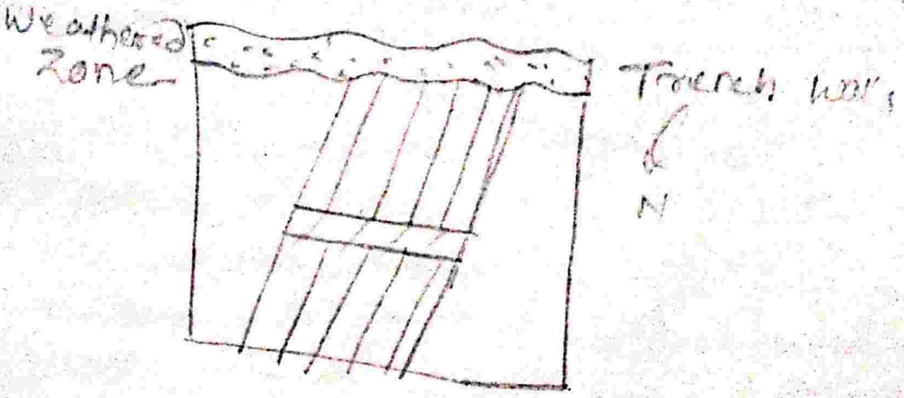
Bulk sample is obtained which may be order of few tons either from the trench, pit channel or from the run off mine. Done for massive deposits.



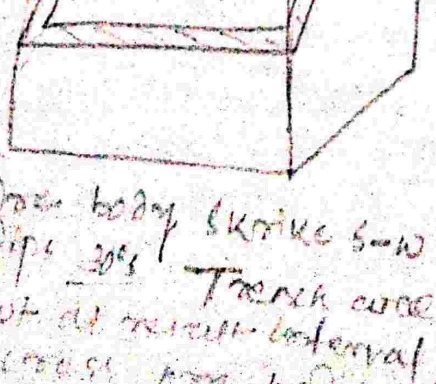
(e) Care and wagon sample :—

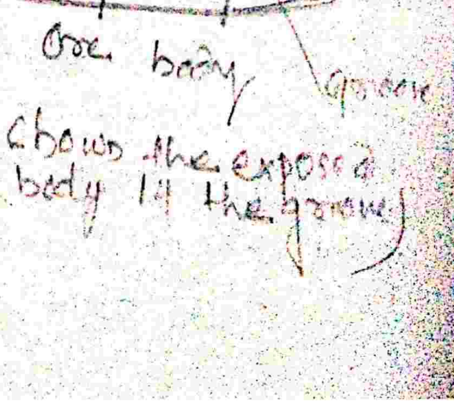
It is obtained by taking a pre-determined quantity of run-off mined from each car load (under ground) or from each wagon load (surface siding) order such samples are mainly taken for ascertaining the physical properties & a man ability to benification by pilot plant text.





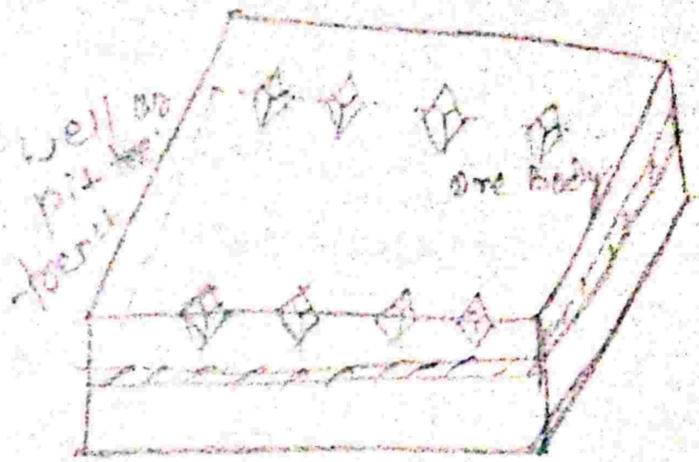
True width require a deeper-trench [to locate of all the trench or horizontal groove in adventuwary]



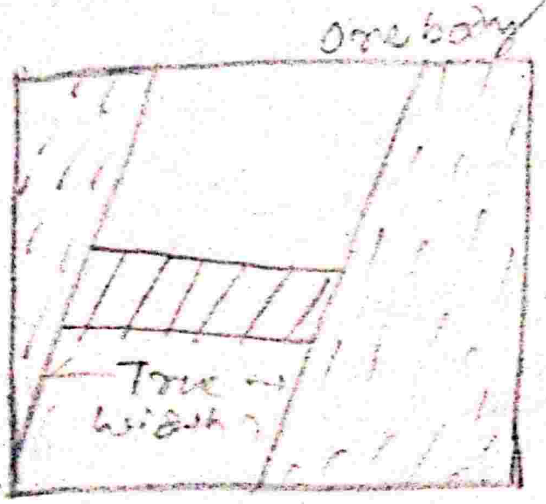


[Ore body strike S-W dip 30° Trench are put at regular interval across ore bodies]

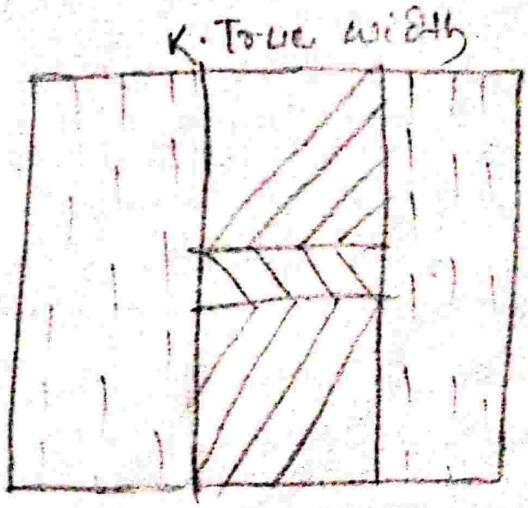
(Shows the exposed body in the groove)



(Pits are put in case of horizontal beds to expose the ore body)



[Inclined groove in a dipping ore body]



(Horizontal groove in vertical ore body)