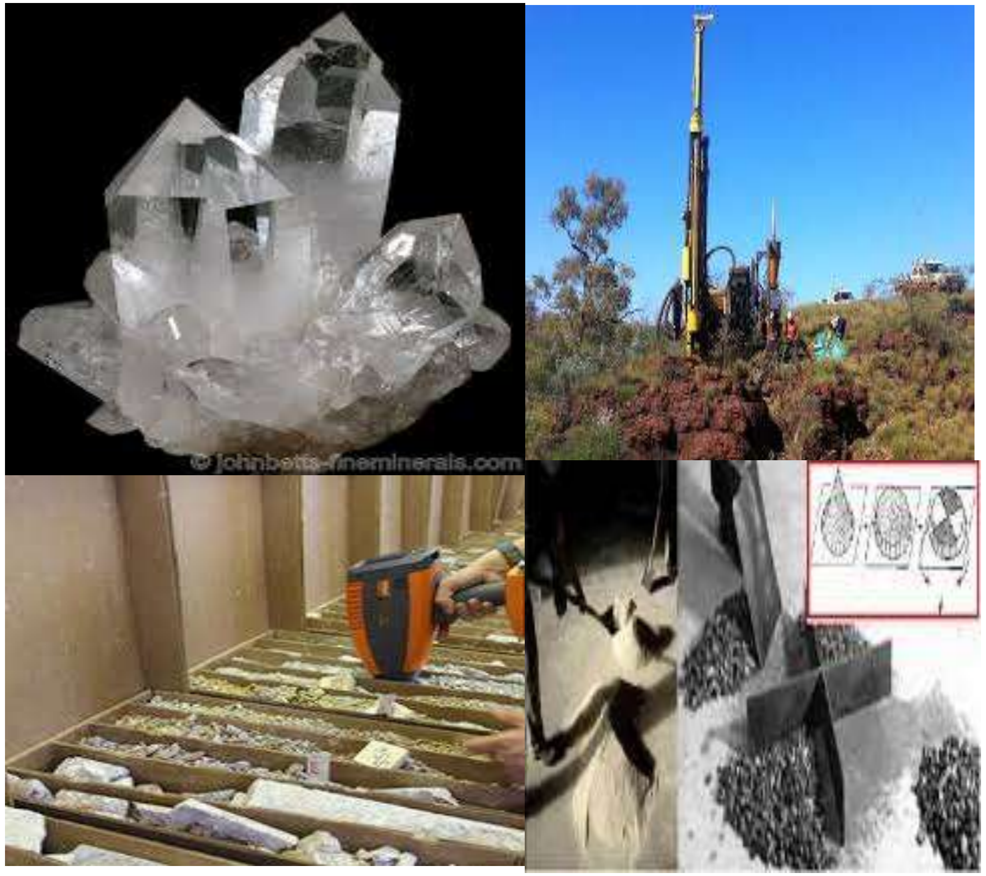

MECL

Welcome

BASICS OF MINERAL EXPLORATION TECHNIQUES

B.P. RATURI
ADVISOR, GENERAL MANAGER (Exploration)

MINERAL, ROCK, ORES & ORE DEPOSITS

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- **MINERALS-** Mineral is a homogeneous naturally occurring inorganic substance usually in crystalline form with a definite chemical composition. It is generally in solid form, the exception being mercury, natural water and fossil fuel.
- **ROCKS-** Rock is an assemblage of mineral(s) formed under natural process of igneous, sedimentary and metamorphic origin. The common rocks are basalt, granite, quartzite, sandstone, limestone, marble and mica schist.

ORES- Ore is a solid naturally occurring mineral aggregate of economic interest from which one or more valuable constituents may be recovered by treatment. All ores are minerals or its aggregate but the reverse is not true. The ores can be broadly classified as :-

1- Metallic : Native Pt, Au, Ag, Cu, chalcopyrite, sphalerite, galena, haematite, magnetite, etc.

2- Noble : Gold, Silver, Platinum, Palladium.

3- Industrial: Quartz, Phosphate, asbestos, barite.

4-Gemstones: Diamond, Amethyst, Emerald, Garnet, opal, ruby, sapphire, topaz, Zircon and aquamarine.

5- Rock: Granite, marble, Limestone, rock salt.

6- Bulk/ aggregate- Sand, gravel.

7- Mineral Fuel- Coal, Crude oil, Gas.

8- Rare Earth- Lanthanum (La), Cerium (Ce), neodymium (Nd), Promethium (Pm)

9- Life Essential – Natural Water.

Contd…

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- **ORE DEPOSITS-** An ore deposit is a natural concentration of one or more minerals within the host rock. It has a definite shape on economic criteria with finite quantity (tonnes) and average quality (grade). The shape varies according to the complex nature of the deposit such as layered, dessiminated, veins, folded and deformed. It may be exposed to the surface or hidden below rocky barren hills, agricultural soil, sand, river and forest.

  Some of the important ore /mineral deposits of Indian continent are Rampur Agucha Lead –Zinc, Singhbhum Copper, Bailadila Iron Ore, Sukinda Chromite, Kolar Gold Field, Nausahi Chromium-Platinum, Jhamarkotra Rock Phosphate, Jaisalmer Limestone and Salem Magnesite. In global context the Broken Hill, Lenard Shelf Zinc- Lead, Olympic Dam Copper-Uranium-Gold deposit, Australia; Sudbury nickel-copper- platinum, Sullivan Zinc-Lead deposit, Canada; Bushveld Chromite-Platinum deposit South Africa, Red Dog Zinc-Lead deposit, Alaska; Paguanta zinc-copper–silver deposit, South America, Stillwater platinum deposit, America; Noril S K and Kola platinum deposit Russia are some of the important ore deposits.

- **PRIME COMMODITY/ASSOCIATED COMMODITY & TRACE ELEMENTS:**

  1- Prime commodity is the principal ore mineral recovered from the mines/ deposits.

  2- Associated commodities are the associated minerals recovered as by products along with the main mineral.

  3- In general all ore deposits contain number of valuable Trace Elements that can be recovered during processing of Ore.

  The value of all prime commodity, associated commodity (by products) and trace elements are considered for valuation of the Ore deposit / Mine.

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- **GANGUE MINERALS:**

  In general the ore deposits are rarely comprised of 100% Ore bearing minerals, but usually associated with rock forming minerals (RFM) during mineralisation process. These associated minerals or rocks having no significant or least commercial value are called gangue minerals. Pure chalcopyrite having 34.5% copper metal in copper deposit and sphalerite with 67% Zinc metal in zinc deposit are hosted by quartzite/ mica schist and dolomite respectively. The constituent minerals of quartzite, mica schist are called gangue minerals. The common gangue minerals are Quartz-SiO_2, Calcite-$CaCO_3$, Barite-$BaSO_4$, Dolomite-Ca Mg $(CO_3)_2$, Pyrite –FeS, Felspar –all types, Mica –all types etc.

- **DELETERIOUS SUBSTANCES:**

  Metallic Ore Minerals are occasionally associated with undesired substances that pose extra processing cost and penalty on the finished product. Arsenic in nickel and copper concentrate, mercury in zinc concentrate, phosphorous in iron concentrate and calcite in uranium concentrate impose financial penalties to a custom smelter for damaging the plant.

CRUSTAL ABUNDANCES

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- An ore may be rock containing veinlets, dissemination or small amounts of useful mineral.
- Range of concentration factors that characterise the formation of ore deposits.
- Some of the strategically important metals such as Fe, Al, Mg, Ti, Mn are abundantly distributed in the crust (0.5- 10%) and needs only relatively small amount of enrichment in order to make a viable deposit.
- Fe and Al need concentration level of 9 and 4 respectively to make a viable deposit.
- In contrast Base metal (Cu Pb Zn, Ni) needs concentration by factors in 100s in order to form potentially viable deposits.
- For precious metals the level of enrichment goes upto 1000 times for making it a deposit.

Table 1 Average crustal abundances for selected metals and typical concentration factors that need to be achieved in order to produce a viable ore deposit

	Average crustal abundance	Typical exploitable grade	Approximate concentration factor
Al	8.2%	30%	×4
Fe	5.6%	50%	×9
Cu	55 ppm	1%	×180
Ni	75 ppm	1%	×130
Zn	70 ppm	5%	×700
Sn	2 ppm	0.5%	×2500
Au	4 ppb	$5\ g\ t^{-1}$	×1250
Pt	5 ppb	$5\ g\ t^{-1}$	×1000

Note: 1 ppm is the same as $1\ g\ t^{-1}$.

GRAPHICAL REPRESENTATION

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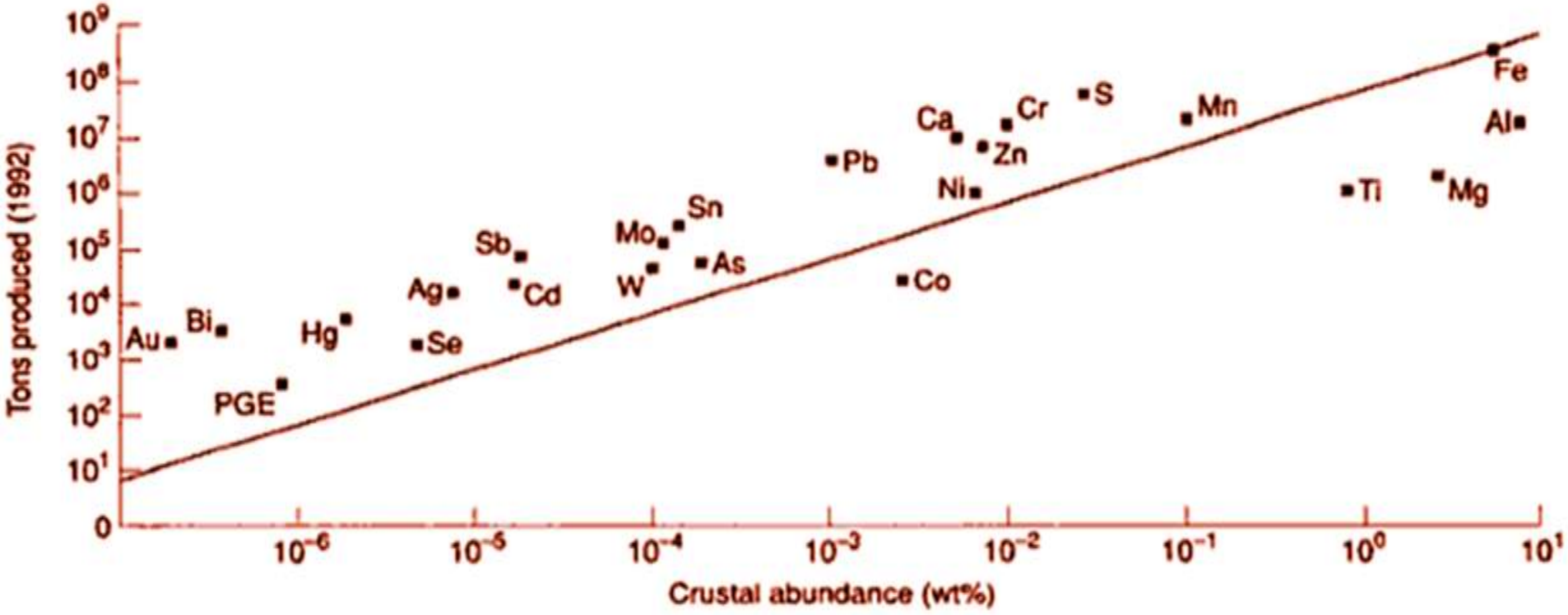

Figure 2 Plot of crustal abundances against global production for an number of metal commodities (after Einaudi, 2000). The line through Fe can be regarded as a datum against which the rates of production of the other metals can be compared in the context of crustal abundances.

GENERAL TERMINOLOGIES

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General Terminology Used in the Mineral Deposits are as :-

- **Syngenetic**: Refers to the ore deposits that form at the same time as their Host rocks. This include deposits that form during the early stages of sediment diagenesis.
- **Epigenetic:** refers to ore deposits that form after their host rocks.
- **Hypogene:** refers to mineralisation caused by ascending hydrothermal solutions.
- **Supergene:** refers to mineralisation caused by descending hydrothermal solutions. Generally refers to the enrichment processes accompanying the weathering and oxidation of sulphides and oxide ores at or near the surface.
- **Metallogeny:** the study of genesis of mineral deposits with emphasis on their relationships in space and time to geological features of the earth's crust.
- **Metallogenic Epoch**:- A unit of Geological Time favourable for the deposition of Ores or Characterised by a particular assemblage of deposit type.
- **Metallogenic Province**: A region characterised by a particular assemblage of mineral deposit type.
- **Epithermal:** hydrothermal Ore deposits formed at shallow depths (Less than 1500m) and fairly low temperatures (50-200*C)
- **Mesothermal:** hydrothermal ore deposits formed at intermediate depths (1500-4500mts) and temperatures 200-400*c).
- **Hypothermal:** hydrothermal ore deposits formed at substantial depths (greater than 4500mts) and elevated temperatures (400-600*c)

MINERAL DEPOSITS

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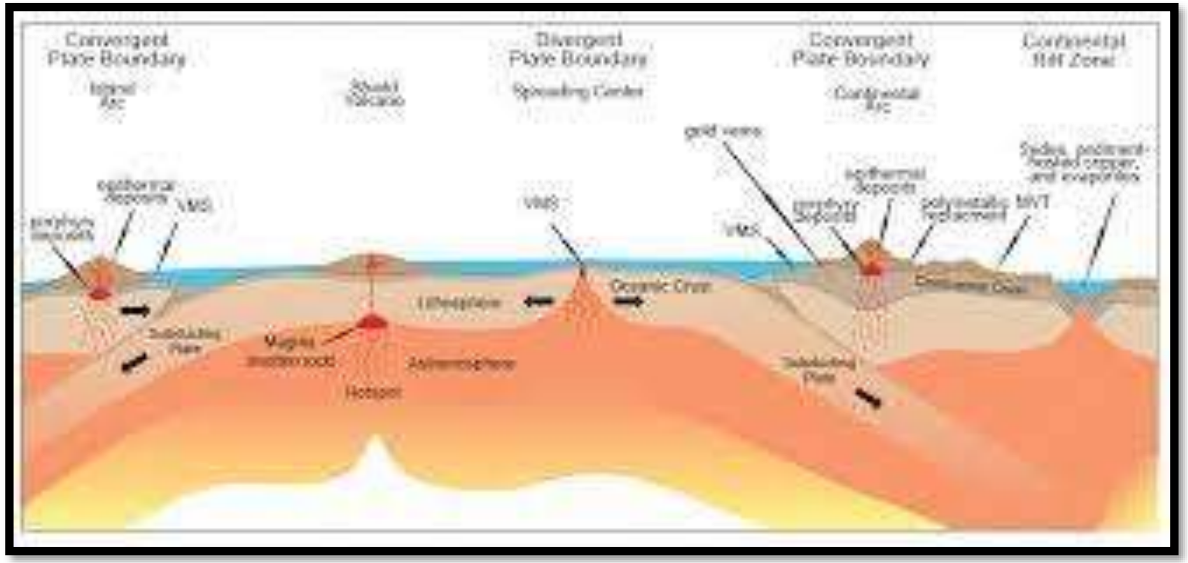
Mineral deposits are defined as natural accumulations of minerals in the earth crust, in form of one or several mineral bodies which can be extracted at the present time or in an immediate future. Mineral deposits (metallic, non-metallic and combustible materials) constitute major raw materials for industrial development.

CLASSIFICATION OF MINERAL DEPOSITS

The understanding of various types of mineral deposit can help to formulate appropriate and successful exploration programs from grassroots to detailed stages.

To assess a deposit type more effectively, it is divided into groups. The classification can be based on single or multiple criteria,

1) Geographic localization,
2) Depth of occurrence,
3) Relation to host rocks
4) Structural control,
5) Nature of mineralization,
6) Morphology
7) Genetic features
8) Contained metal.



CLASSIFICATION OF MINERAL DEPOSITS ----- Contd.

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1- **Geographical Localisation:** Mineral deposits can broadly be described based on geographic location & dimension.

- The geographic locations are Province, Region, District, Belt, Deposit and Block.

2- **Depth of Occurrence:** Under this head the deposits are Deposits exposed to surface, shallow depth deposits and Deep seated Hidden deposits.

3- **Relation to Host Rocks:** The mineral deposits in relation to host rock are Host rock, Identical with Host rock, different from host rock, Metal Zoning and wall rock alteration.

4- **Structural Control:** The type of mineral deposits due to structural control are undeformed, joints and fractures, Folded, Fault, Shear Zone, Breccia, Subduction.

5- **Nature of Mineralisation:** Based on nature of mineralisation the deposits can be classified as Dissemination, Massive, Veins and Stringers, Ladder veins and Stock works.

6- **Morphology:** Based on morphological features the deposits are classified as Stratiform, Stratabound, Layered Rhythmic and Bedded, Porphyry, Lenticular and Pipe.

7- **Genetic Features:** Based on the genetic properties the deposits can be classified as Magmatic, Sedimentary, Metamorphic, Volcanogenic Massive Sulphide, Black smokers pipe type, Mississipi Valley Type, Sedex, skarn, Residual and Placer.

8- **Contained Minerals:** Based on the available concentration of mineral / metal grade the deposits can be classified as High Grade, Medium grade, Low grade and Very Low grade.

SURFACE GUIDE

MECL

There are many mineral deposit which display surface signature.
If these features are recorded properly during geological traverses in the field followed by exploration, a new deposit is likely to be discovered.

1). **Favorable Stratigraphy** & **Host Rocks**

- The existence and identification of favorable stratigraphy and complementary host rocks are the essential prerequisites to initiate any exploration program for a specific mineral or group of minerals.

- The layered ultramafic/mafic assemblage of the Archaean/Proterozoic age is the most suitable target for chromium-nickel-platinum-copper and gold association (e.g., Bushveld chromium-platinum in South Africa, Great Dyke platinum-chromium in Zimbabwe, and Sukinda-Nausahi chromium in India).

2). **Weathering**

- The weathering and leaching of near-surface metallic deposits is an indicator of the likely existence of mineral deposits at depth. significant surface signature for a base-metal exploration guide. Rajpura - Dariba Zinc –Lead deposit and Khetri Copper deposit are the good examples for base metal in India.

CONTINUED…..

MECL

3). **Ancient Mining and Smelting**

- These deposits offer much information regarding ancient mining, processing, smelting, and usages of metals and became a guiding force for present-day exploration.
- The remnants of ancient mines play a significant role in mineral exploration.
- The important surface signatures are the presence of fresh mineralized veins, gossans, and ancient open pits with wall supports as observed at East Lode of the Rajpura-Dariba mine, Rajasthan, India.

4). **Shear**

- The shear zone is the result of a huge volume of rock deformation due to intense regional stress, typically in the zones of subduction at depths down to a few kilometers.
- It may occur at the edges of tectonic blocks, forming discontinuities that mark a distinct structure.
- The shear zones often host orebodies as a result of syngenetic or epigenetic hydrothermal flow through orogenic belts. The rocks are commonly metasomatized and often display some retrograde metamorphism assemblage.
- Singhbhum shear zone, Jharkhand, India is an example of Shear controlled Copper and Uranium mineralisation.

5). **Lineament**

- In general, mineral deposits occur in groups and follow a linear pattern along the fold axis, shear zone, and basement fracture traps. The linear alignment can be traced in the regional map of Aravalli mountains, Rajasthan.

MINERAL EXPLORATION

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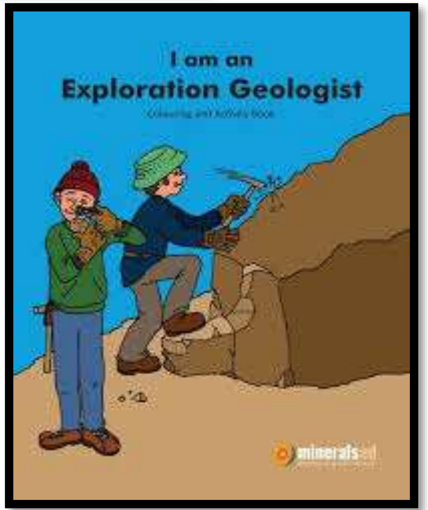


WHAT??

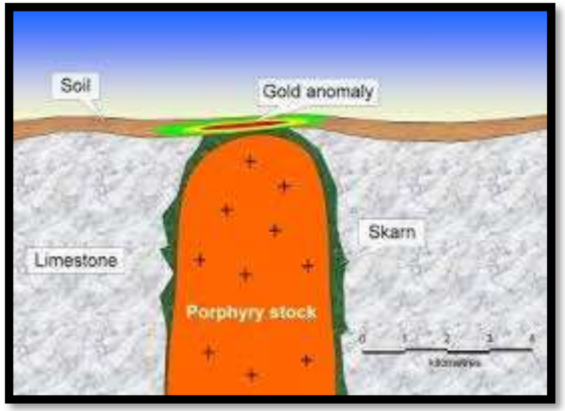
HOW??

EXPLORATION

WHY??

WHOM??

WHERE??



WHAT IS EXPLORATION ??

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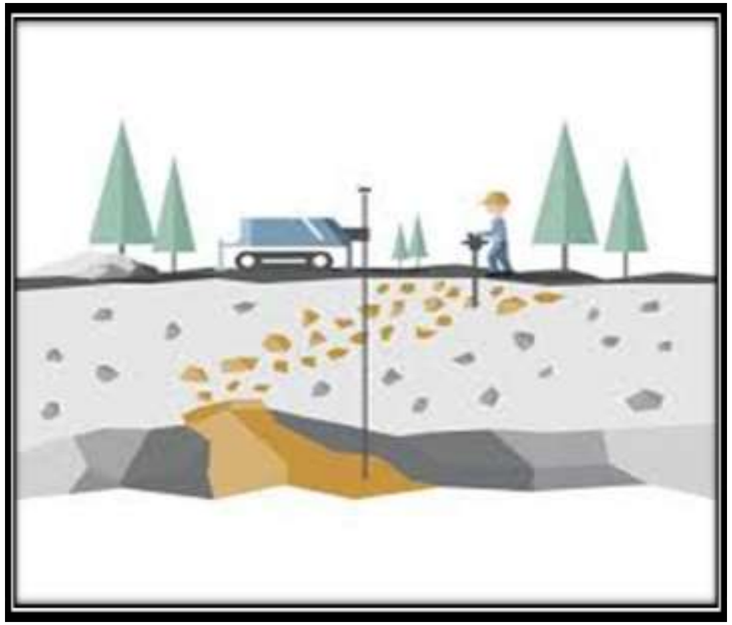
- Mineral exploration can be defined as the systematic and scientific search for the minerals from the earth with economic value and strategic importance for the country's Industrial and overall development.
- Exploration is the term used to describe a wide range of activities aimed at searching for minerals.
- Mineral exploration covers a wide range of objectives and activities that begin with the selection of a target area. The type of work carried out depends on the minerals being sought. Following promising clues that may lead to a discovery often requires substantial investment and years of work. Only a small number of such clues turn into discoveries, but it is not until drilling and rock excavation have more clearly defined the extent of the deposit and cost studies have concluded that profitable extraction is possible.



- There are various exploration techniques being followed over centuries.
- Exploration is conducted by one or a combination of many of the Techniques.
- The technique required is depends on availability of infrastructure, funds with the exploration agency, size and complexity of the deposit, Price of the mineral, Government Policy and good will.

WHY MINERAL EXPLORATION IS NEEDED ??

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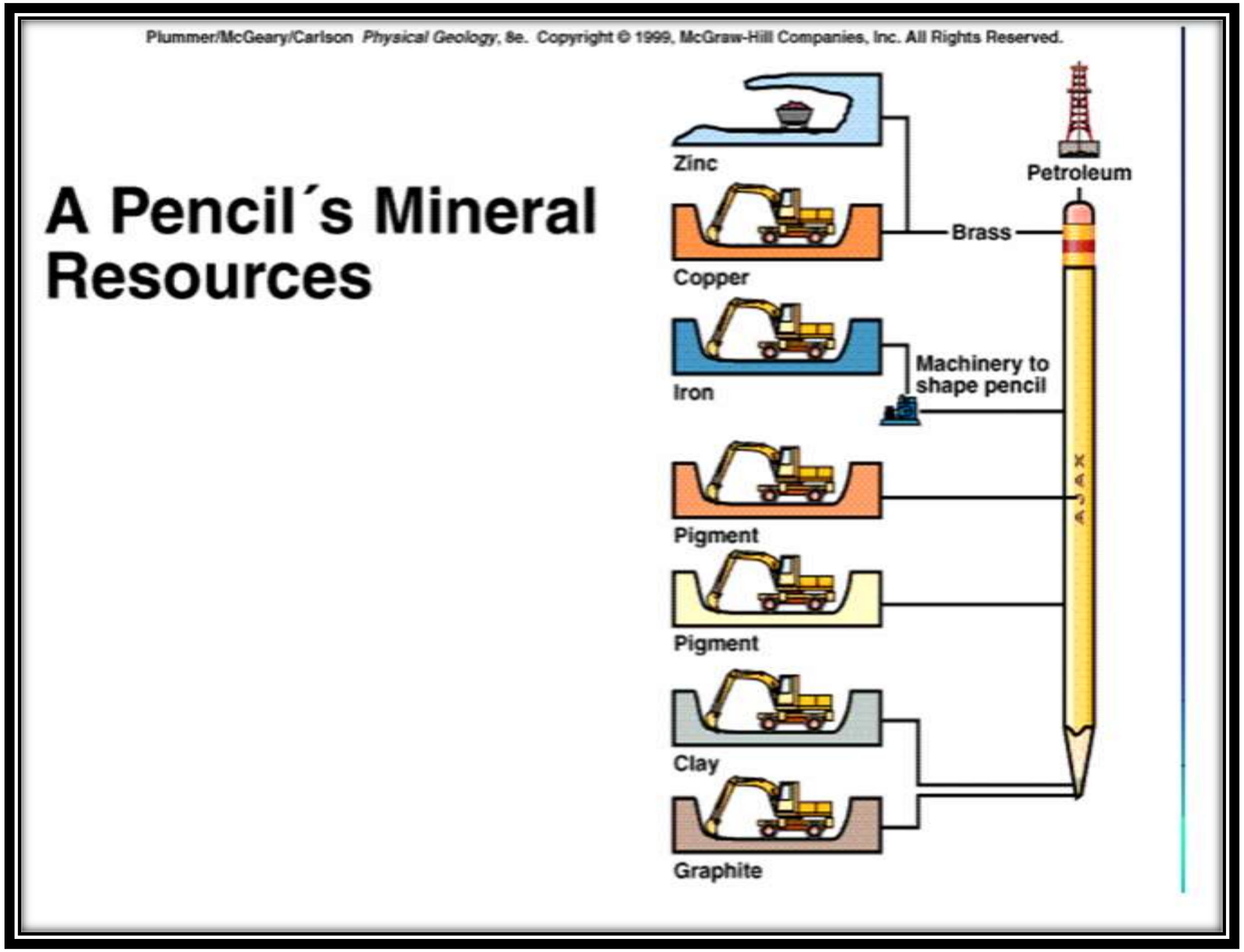

BY WHOM MINERAL EXPLORATION IS DONE ?

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- Generally, Exploration activity is conducted by a team who are experts in studying the earth sub-surface and delineate its history and the team generally consists of:-

1) Geologist / Geo-Scientist

2) Surveyor

3) Geophysicists

4) Drilling Engineers / Mining Engineers

5) Chemist

WHERE EXPLORATION IS DONE ??

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Mineral Exploration can be conducted where :

- Geological Settings
- The area is having high mineral potential / Metallogenic events had been taken place
- Obvious Geological Potential Area (OGP)

HOW EXPLORATION IS DONE

Mineral exploration is a complete sequence of activities. It ranges between

- ✓ searching for a new mineral prospect (reconnaissance)
- ✓ evaluation of the property for economic mining (feasibility study).
- ✓ It also includes augmentation of additional ore reserves and resources in the mine and total mining district.

To carry out systematic study there is standard procedures or stages which have been formulated to carry out Mineral exploration activities ‘ and these are divided into four stages-

GEOLOGICAL PARAMETERS FOR EXPLORATION

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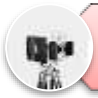
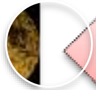
Aerial Reconnaissance


Topographic & Geological Survey (Mapping)


Ground Geophysical and Geochemical Survey

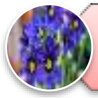

Sampling and Sub-sampling


Assay data & Laboratory tests


Petrographic & Mineragraphic Studies


Bulk density study


Bulk Sampling for Beneficiation studies


Environment Setting


Any other relevant data

MINERAL EVIDENCE AND MINERAL CONTENT RULE (MEMC RULE' 2015)

MECL

Part -III

Exploration Norms for different types of deposits

(The grid spacing given below are indicative. A closer spacing may be necessary depending upon the geological complexity of the deposit)

Type of deposit & principal minerals	G4 stage	G3 stage	G2 stage	G1 stage	Remarks
I. Bedded Stratiform and tabular deposits of regular and irregular habit: Iron ore, manganese ore, bauxite, limestone, chromite/potash and salt beds etc.	Scout drilling, if necessary (In line with grid specified by the Central Government from time to time)	For limestone, bauxite, potash and salt beds the grid spacing of bore holes may be 800m or closer for deposits of regular habit and 400m or closer for irregular habit; for others	For limestone, bauxite, potash and salt beds the grid spacing of bore holes may be 400m or closer for regular habit and 200m or	For limestone, bauxite, potash and salt beds the grid spacing of bore holes may be 200m or closer for regular habit and 100m or closer for irregular habit; for others the	For shallow surficial deposits continuing to a depth of up to 6m from surface pitting in a grid pattern as per the grid spacing for
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- Exploration for different mineral commodities are based on Mineral Evidence and Mineral Contents (MEMC) Rule prepared by Ministry of Mines, Government of India.

- For different kind of deposit there is set guidelines which has to be followed to carry out exploration at its different stages.

STAGES OF EXPLORATION

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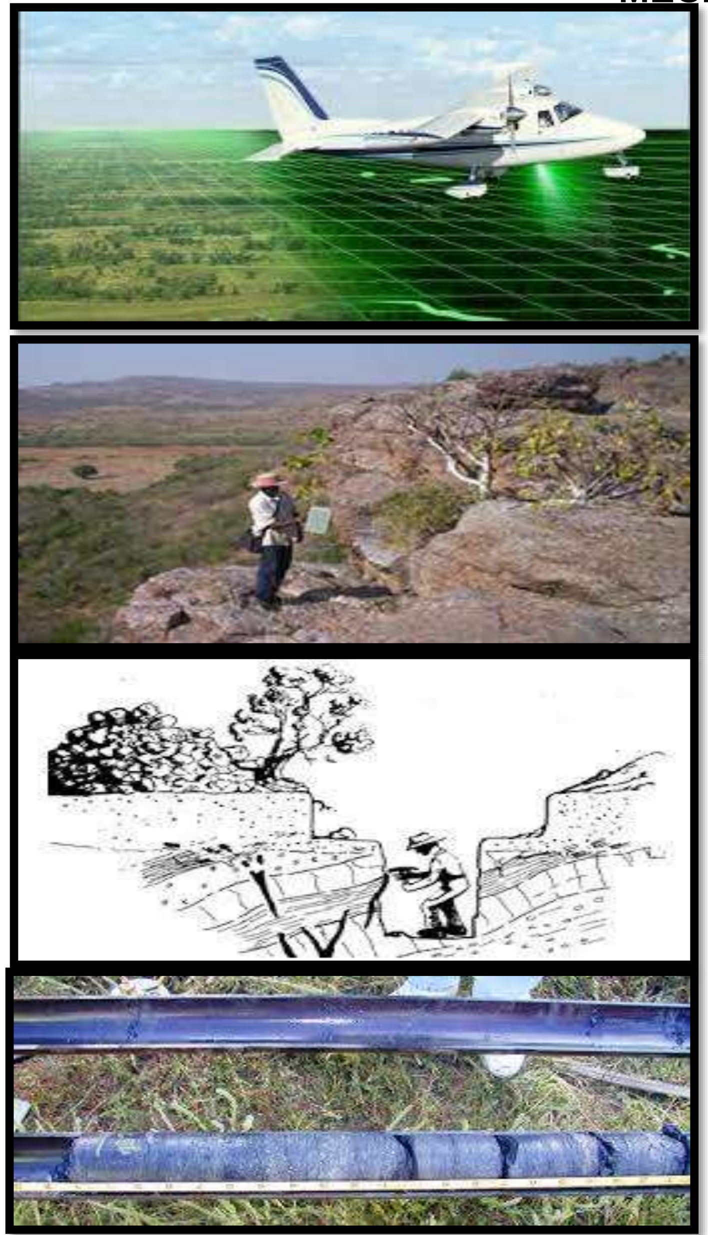
- G4 Reconnaissance Survey
- G3 Preliminary Survey
- G2 General Exploration
- G1 Detailed Exploration



STAGES OF EXPLORATION

MECL

- Any exploration program can be classified by successive stages: each stage is designed to achieve a combined specific objective within the time schedule and allocated fund. The outputs of each stage provide inputs to the next successive stage.

❑ Reconnaissance Survey (G4)

- ➢ Reconnaissance is grassroots exploration for identifying the existence of mineral potential or initial targets on a regional scale.
- It includes:-
- ➢ Background preparation like literature survey
- ➢ Outcrop Identification
- ➢ Regional Geological Mapping
- ➢ Acquisition of geophysical data
- ➢ Mineral Targeting through Remote Sensing
- ➢ Collation of previous data on geological, geophysical, geochemical, airborne geophysics.
- ➢ Scout Drilling of Interesting Targets

CONTINUED..

MECL

❑ Preliminary Survey (G3)

- Prospecting is the systematic process of searching promising mineral targets by narrowing down area of promising mineral potential identified during Reconnaissance.
- It includes:

➢ Geological Mapping on 1: 25000 – 1: 10000 scale or as per requirement mineralwise.

➢ Geochemical orientation Studies through Bed Rock, Soil Sampling and Stream Sediment Sampling

➢ Collection of sample by trenching & pitting method.

➢ Indirect Methods such as Geophysical and Geochemical studies.

➢ RC or Diamond drilling at 200x200m to 400x400m strike interval at one level intersection of Mineralised zones depending on mineral type.

➢ Petrographic & Mineragraphic studies.

➢ Borehole Geophysical Logging.

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❑ General Exploration (G2)

- It involves the initial delineation of an identified deposit.
- Methods used include geological mapping, pitting/ trenching/ drilling (at an strike interval of 100-400m) and depth upto 100mts (Two level), followed by sampling for evaluation of mineral quantity and quality.
- Borehole Geophysical survey.
- Bulk sampling for Laboratory and Bench scale beneficiation Test.
- Limited interpolation based on indirect methods of investigation.
- The objective is to establish the main geological features of a deposit giving a reasonable indication of continuity and providing estimate of size with high precision, shape, structure and grade. Resources estimates are in Indicated and Inferred category.

CONTINUED..

MECL

❑ Detailed Exploration (G1)

- Detailed Exploration is conducted before the start of Mining Phase or mine development.
- It involves the 3 dimensional delineation of an known deposit.
- Geological Mapping at 1:5000 to 1:1000 scale
- Close Space Diamond drilling (100x100m, 50x50m) along with borehole Geophysics.
- Sampling such as from outcrop, pits, trenches etc.
- Sampling grid are closely spaced such that size, shape, structure, garde and other characteristics of the deposits are established with a high degree of accuracy.
- The sample data are to be adequate for conducting 3D Geostatistical Ore body modeling
- The resources / reserves are categorized as Developed, Measured, Indicated and Inferred with high degree of accuracy.

EXPLORATION TECHNIQUES / PROSPECTING

MECL

This includes:-

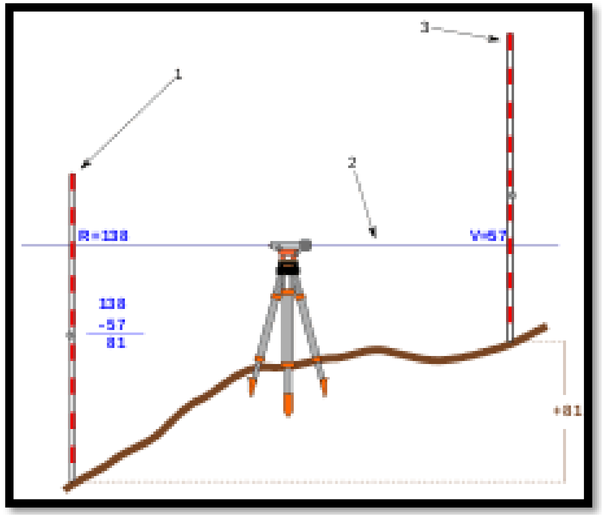
- Topographical Survey
- Geological mapping
- Detailed geochemical surveys
- Integrated approach
- Geophysical prospecting / Geophysical Methods
- Drilling
- Sampling
- Sample Analysis
- Geostatistical Evaluation & Orebody Modeling
- Preparation of Geological Report

Topographic SURVEY

MECL

An accurate topographic map is essential for long term and short term purposes of any type of projects. Topographic surveying is more relevant during all stages of mineral exploration, mine development and mining related activities.

- Topographic surveys
- Levelling
- Triangulation
- Contouring.



Survey Instruments

- Compass
- Plane table survey with alidade
- Levelling survey
- Theodolite
- Electronic Total Station Survey (Electronic Theodolite with Distomat and GRE 4 a- data recorder.

GEOLOGICAL MAPPING

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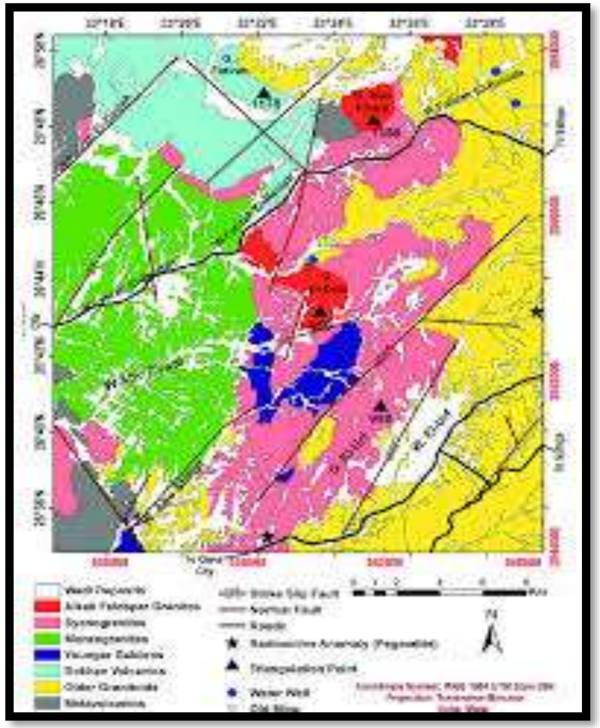
- The first work in mineral exploration is the preparation of a high quality Geological Map. A Geological Map is a record of geological facts such as occurrence of rocks in space and their contacts, weathering effects such as leaching or gossan and structure i.e. strike, dip, plunge, joints and lineation’s.

REGIONAL GEOLOGICAL MAPPING

- The National Surveys and State organizations publish Regional maps of 1:250,000 or on 1:1million scales.
- These maps may not contain specific data required by an exploration agency.
- 50000 and 25000 scale maps of GSI are helpful in this regard.



- The large scale mapping of an area is done with specific objective and are supposed to generate additional details on lithology, structure, metallogenic aspects etc. There may be some geochemical inputs also here.

DETAILED GEOLOGICAL MAPPING (DM)

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- Detailed Mapping (DM) is a prerequisite for taking up subsurface exploration.
- The DM is done on 1:2000 or 1:1000 scale depending on the intricacies of the prospect/ mineral deposit.
- The objective is to map the lithounits and all structural features that are important from the exploration point of view.
- Detailed structural features of local scale are also given importance while mapping the prospect.
- DM is generally accompanied by detailed geochemical sampling on grid pattern, sampling along proposed profile of boreholes, pitting trenching for exposing concealed litho contacts and oxidized zones.
- Important cultural features are also plotted in a DM.
- DM done by triangulation surveys are very accurate.

APPICATION OF REMOTE SENSING IN MINERAL EXPLORATION

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- The Remote Sensing Principle involves that each type of object reflects or emits a certain intensity of light when in contact with different range of wavelength of Electro Magnetic Spectrum (EMS) depending on the physicochemical attributes of the objects.
- Remote sensing includes various mapping techniques that are carried out from airborne systems.
- Such techniques have received great deal of attention especially in connection with space exploration projects. The sensors are fitted either to a aircraft or to a space craft.
- However it is mainly the aerial photography and imaging systems that are useful in Reconnaissance Exploration.
- Aerial photo interpretation with limited field checks are popular techniques used advantageously even today.
- Satellite photos and imageries taken from space-crafts are useful in broadly defining favourable areas of mineralisation.

HYPERSPECTRAL DATA

Hyper spectral data are currently in great demand by various mineral exploration agencies and has a prime role in RE Stage.
Very helpful in inferring chemical variations in zones of hydrothermal alteration.
Hyperspectral data are not readily available to exploration agencies and their interpretation needs refinement

GEOCHEMICAL SURVEY

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- Exploration Geochemistry fundamentally deals with the enrichment or depletion of certain chemical elements in the vicinity of mineral deposits other than barren regions. Geochemical prospecting is performed by systematic measurements of one or more chemical parameters, usually in traces of naturally occurring material in the earth crust.
- Geochemical surveys are used to target areas for further exploration. The surveys usually involve the collection of bed rock, soil and Stream sediment samples. These samples are sent for laboratory analysis to identify areas of potential mineralisation.
- For base metal exploration group of elements are viz. Cu, Pb, Zn, Ni, Co, Au, Ag. For gold -Au, Ag, As, Cu, Hg, W and Zn. Scale of geochemical work is very important which decides on methodology (i.e. grid spacing)
- Geochemical prospecting can be broadly classified into the following types depending on stages of the survey, nature of the terrain, surface weathering, climate, and signals associated with mineralization:-

1) Bed Rock Sampling
2) Soil Survey/ Sampling
3) Stream Sediment / Water survey Sampling
4) Vegetation
5) Hydro-geochemical survey

GEOCHEMICAL ANOMALY

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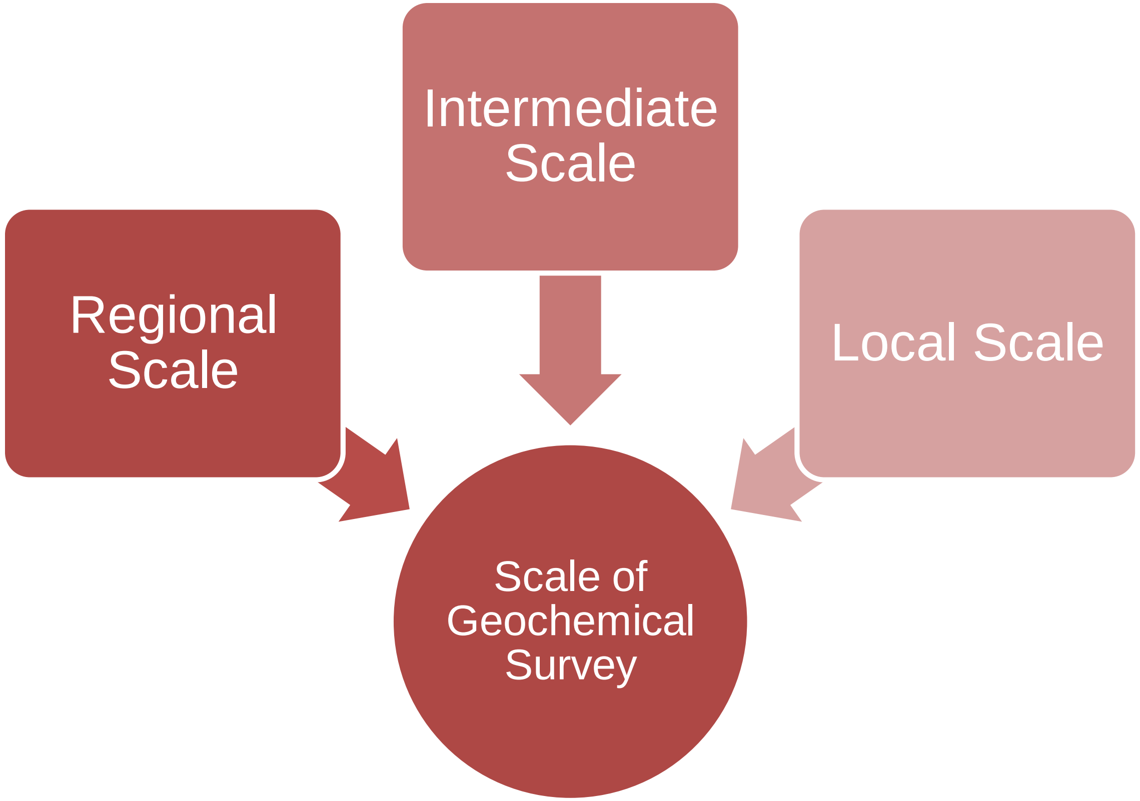
- The Geochemical samples are collected from rocks, debris, soil, gossan, streams or lake sediments, groundwater, vegetation etc. The results of samples at times shows abnormal chemical pattern over the regional properties. This abnormality is defined as geochemical anomaly.

- Regional scale and Local scale. However some times a third intermediate scale is introduced in special cases. Depending on the scale the “geochemical anomaly”, which is the final output of the geochemical exploration is graded.

- Thus you may call an anomaly ‘local’ or ‘regional’, based on whether the survey was done regional or local scale.



GEOPHYSICAL PROSPECTING / GEOPHYSICAL SURVEY METHODS

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INTRODUCTION

- The science of Geophysics is based on the principles of Physics to the study of whole earth from the deepest to the surface. The Geophysical tools operate much above the ground from aircraft or helicopter platform fitted with multisensors or on the Ground in general.
- The Geophysical Studies are always quantitative and involve real measurements based on the variation of response pattern or contrast of propagating waves passing through the nonhomogeneous medium. The propagation parameters are seismicity, density, magnetic susceptibility, electrical conductivity, resistivity, electromagnetic (EM) and radiometric radiance.
- The propagating waves reflects and refracts at the interface of rock types, structure, stratigraphic formations and presence of mineralisation, water, oil and gas.
- The execution of Geophysical data collection is both from airborne and ground base.
- The various key Geophysical methods are listed below:-

AIRBORNE GEOPHYSICAL SURVEYS

- Airborne geophysical surveys may include magnetic, radiometric, gravity, or electromagnetic surveys.
- These surveys are typically conducted from low-flying helicopters or light aircraft, which fly in a grid pattern, with measurement instruments either mounted on the aircraft or towed underneath or behind.

GEOPHYSICAL SURVEYING METHODS

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Geophysical Surveying Methods, with Parameters and Properties suitable for type of Deposits

Method	Measured Parameters	Operative Physical Property	Suitable Deposit Type
Seismic	**Travel time of reflected & refracted Seismic Waves**	**Density & Elastic mode velocity**	**Oil & Gas, Layered sedimentary basins**
Gravity	**Spatial variation in the strength of Earth's gravitational Field.**	**Density contrast between the surrounding host rocks.**	**Massive sulphides, Chromite, Salt dome, barite, Kimberlite, concealed basins**
Magnetic	**Spatial variation in the strength of Geomagnetic field**	**Magnetic Susceptibility**	**Magnetite, Ilmenite, pyrrhotite rich sulphides.**
Electrical			
1-Resistivity	**Earth Resistance**	**Electric Conductivity**	**Ground water , Sulphide ores.**
2-Induced Potential (IP)	**Polarisation Voltage/ frequency development of Ground resistance**	**Electrical capacitance**	**Large Sulphide dissemination, graphite**
3-Self Potential (SP)	**Electrical potential**	**Electrical conductivity and Inductance**	**Sulphide veins, Graphite, Ground water.**
EM	**Response to EM radiation.**	**Electrical Conductivity and inductance**	**Sulphide Ore Graphite deposits**
Radiometric	**Gamma radiation**	**Gamma ray**	**Thorium, uranium & radium.**
Borehole Geophysics and Mise-a-la-Masse	**Downhole probe**	**All types**	**Continuity of mineralisation in strike and dip.**

DIFFERENT TYPES OF GEOPHYSICAL SURVEYS

MECL

➢ ELECTROMAGNETIC (EM) SURVEYS

- Electromagnetic (EM) surveys create an electromagnetic field and measure the three-dimensional changes in conductivity within the near-surface soil and rock.
- The variations in conductivity can be studied to locate metallic minerals and to understand groundwater and salinity.

➢ SEISMIC SURVEYS

- Seismic surveys measure vibration as it passes through the Earth.
- Ground-based seismic surveys use the principles of seismology (earthquakes) to create a picture of the geology beneath the surface.
- Seismic surveys can provide information about rocks down to many kilometres in depth and are particularly suited to flat-lying sedimentary basins

➢ INDUCED POLARISATION (IP) SURVEYS (IP)

- Induced Polarisation (IP) surveys create an electric field in the ground and measure the chargeability and resistivity of the area below the Earth's surface.
- The technique can identify differences in resistivity arising from aquifers, metallic minerals and different rock types.

CONTINUED…

MECL

➢ MAGNETIC GEOPHYSICAL SURVEYS

- Magnetic surveys measure the variations of the Earth's magnetic field due to the presence of magnetic minerals.
- They are used to interpret rock types and geological structures and can assist in identifying resources.
- They are most often used in metallic mineral exploration.

➢ RADIOMETRIC GEOPHYSICAL SURVEYS

- Radiometric surveys measure gamma rays, which are continuously being emitted from the Earth by the decomposition of some common naturally occurring radiogenic minerals.
- The surveys focus on recording the amounts of isotopes of potassium, thorium, and uranium.
- These surveys are most often used in metallic and industrial mineral exploration.

INTEGRATED REGIONAL DATA AND DELINEATION OF PROSPECT

MECL

- This part is truly a Desk study. All the Available databases on Regional geology, Aero geophysical signatures, RS data and mapping are integrated for delineating a prospect.
- It is not merely a prospecting target but possible grade tonnage models are kept in sight before initiating exploration activities on the selected prospect

SAMPLING / TYPE OF SAMPLING

MECL

A sample is the representative part of any homogenous material. Sampling is the process of taking a small portion of a homogenous material such that consistency of the part shall represent the entire population of the material.

➢ BED ROCK SAMPLING

- Bed rock sampling is defined as a process of taking representative rock sample from a fresh surface of the insitu outcrop.

➢ SOIL SAMPLING

- Hand-held tools such as shovels, picks, and hand augers are used to collect samples of soil and subsoil. Samples are typically collected on a regular grid pattern and involve collection of small samples of soil. Sieve analysis of samples indicates that minus 80mesh fraction of soil represents sufficient material for further processing.

DIFFERENT TYPE OF SAMPLING

MECL

➢ ROCK CHIP SAMPLING

- In case the mineralisation is irregularly distributed or disseminated and not easily recognized by necked eye chipping of fragments of 1-2 by 1-2cm covering the entire surface exposures, underground mine face , wall roof in regular grid interval of 25x25cm is done. Rock chip samples will usually be collected during geological mapping programs.

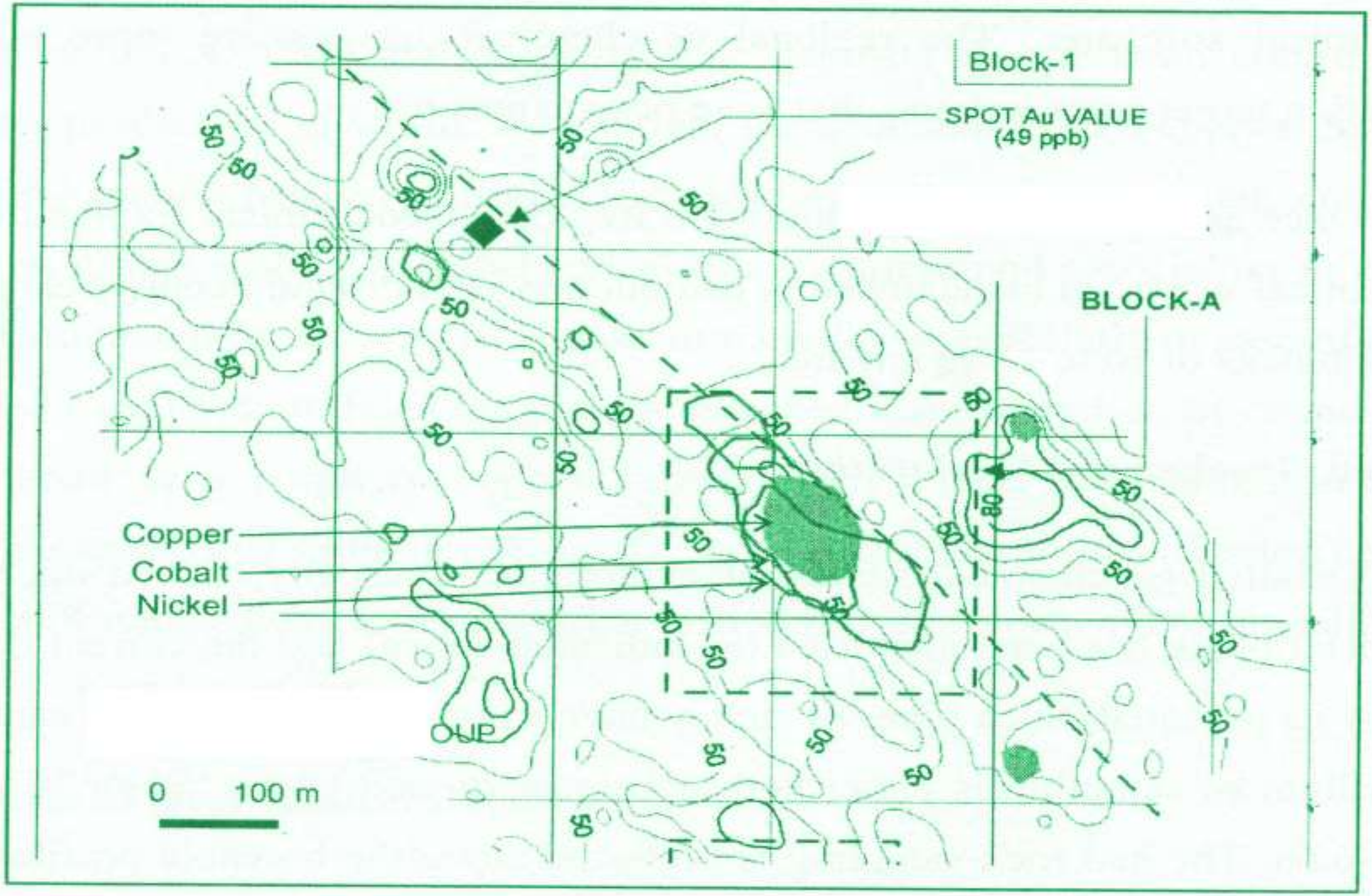
➢ TRENCH SAMPLING

- ➢ Trenching is done across the mineralization zone
- ➢ It is a form of geochemical sampling where a shallow trench is dug and the exposed rock mapped, analysed, and sampled.
- ➢ It involves digging a trench, using a backhoe or similar equipment.
- ➢ The length of the trench depends on the thickness of mineralised zone and generally trenches are excavated around 1m to 1.50m wide and the depth of around 2.00m depending on the availability of fresh surface.
- ➢ The edges of the trench are typically geologically mapped and channel samples collected for laboratory analysis.

➢ STREAM SEDIMENT SAMPLING

Approximately two-kilogram samples of sediment are collected within drainage lines. Three samples are usually taken where two creeks join: one downstream of where they join and two upstream of where they join (in each of the merging drainage lines). Samples are typically taken using hand tools and may be sieved during collection.

GRID PATTERN SAMPLING



DETAILED GRID PATTERN SAMPLING OF ABOVE AREA

CONTINUED….

MECL

➢ CHANNEL SAMPLING

- The sample is a series of samples of soil or rock are collected along the face of the excavation. This may be a road cutting, the face of an existing open cut or underground mine, a pit or trench or similar.

➢ PLACER SAMPLING

- Alluvial placer deposits are formed by weathering, transportation and deposition of valuable minerals.
- In general these deposits are less consolidated loose and soft material.
- Scooping by hand spade or by auger drills is employed to collect the loose sandy samples at certain grid interval upto certain depth.

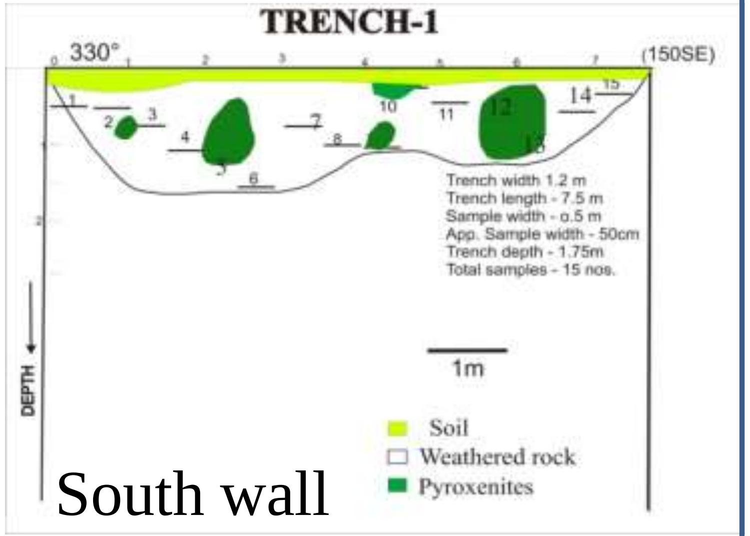
➢ BULK SAMPLING

➢ The bulk sampling method is used in very advanced exploration programs.

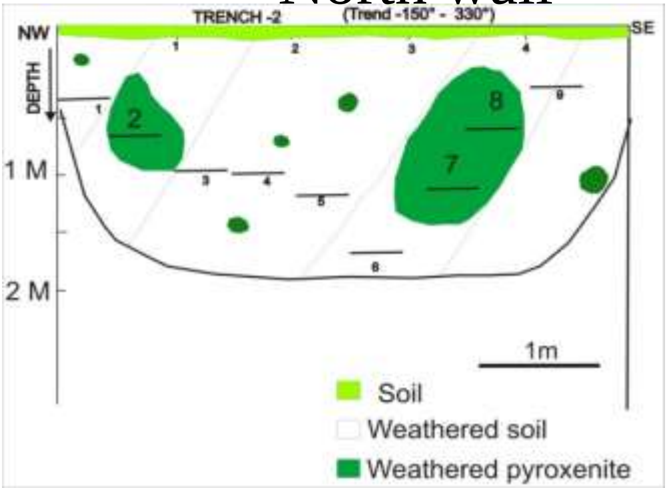
➢ Before deciding to apply to develop a mine, an explorer may extract a bulk sample of the material to be mined to allow further metallurgical or chemical testing and refinement of the proposed mining procedures.

➢ Extraction of a bulk sample typically involves excavation of a small open cut type of mine or development of a small underground operation.

TRENCHING



North wall

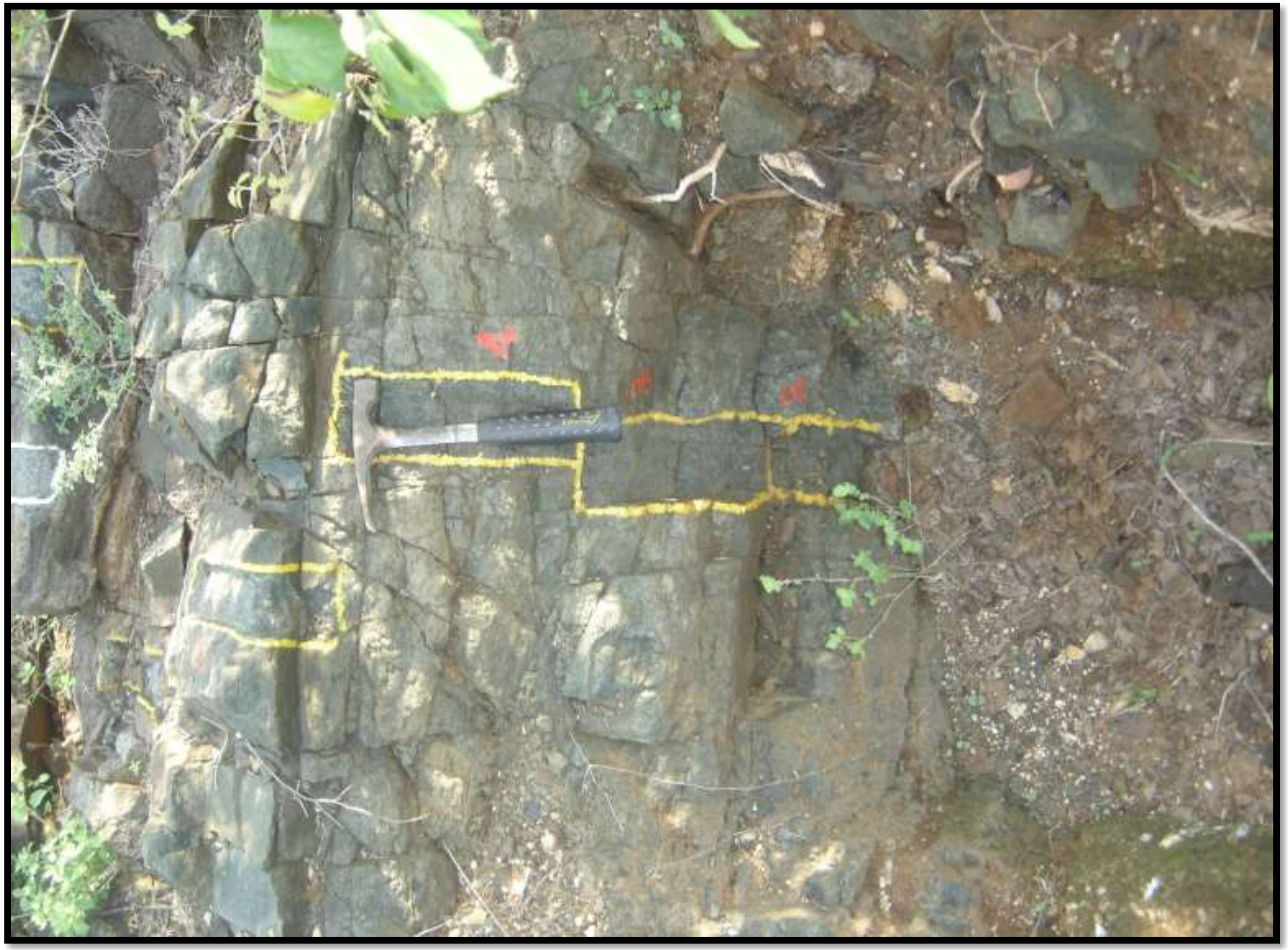


Trench sections depict the nature of disposition of the pyroxenite

Reflection of soil characters in trench section.

CHANNEL SAMPLING

MECL



- Channel Sampling across the Mineralized Zones.

CORE SAMPLING PROCEDURE

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- The core is split in to half so that one half is the mirror image of the other.
- After logging the mineralised zones are demarcated and sampling zones are fixed.
- Sample lengths may vary from 50 cm to 100cm depending on the nature of mineralisation.
- Samples are crushed to –120 to 200 mesh.
- Size of the samples may be reduced by coning and quartering process.
- The process of coning and quartering is repeated until the quantity of powder is reduced to half.
- Half is sent for analysis and the other half is preserved for future reference.

Core Box with Bore drill core of Nagaur Sandstone Rajasthan

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Core Box with Core of Potash bearing Halite Cycle

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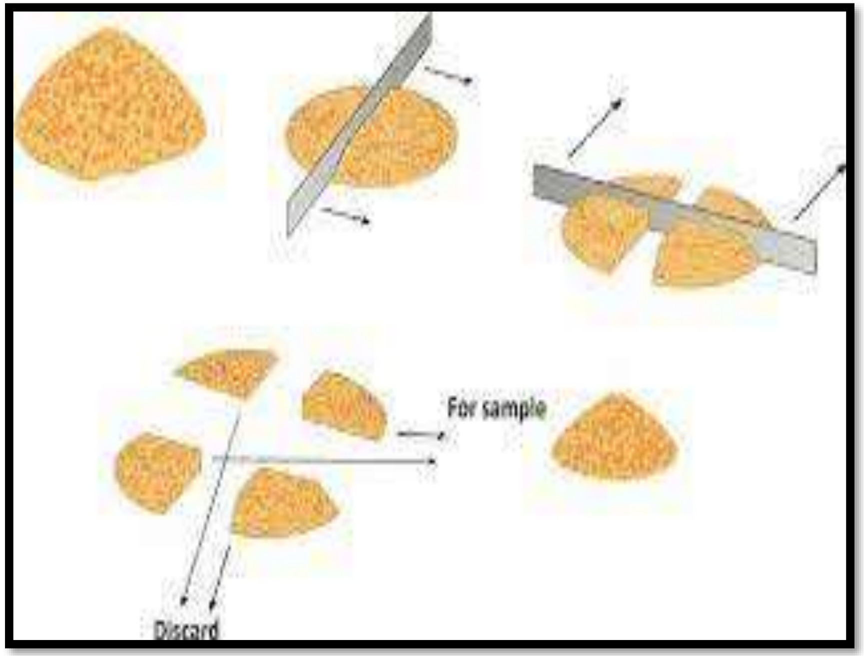
CORE SAMPLING - Contd



SAMPLING PROCEDURE

MECL

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DRILLING

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The purpose of drilling is;

- To define ore body at depth.
- To access ground stability (geotechnical).
- To estimate the tonnage and grade of a discovered mineral deposit.
- To determine absence or presence of ore bodies, veins or other type of mineral deposit.

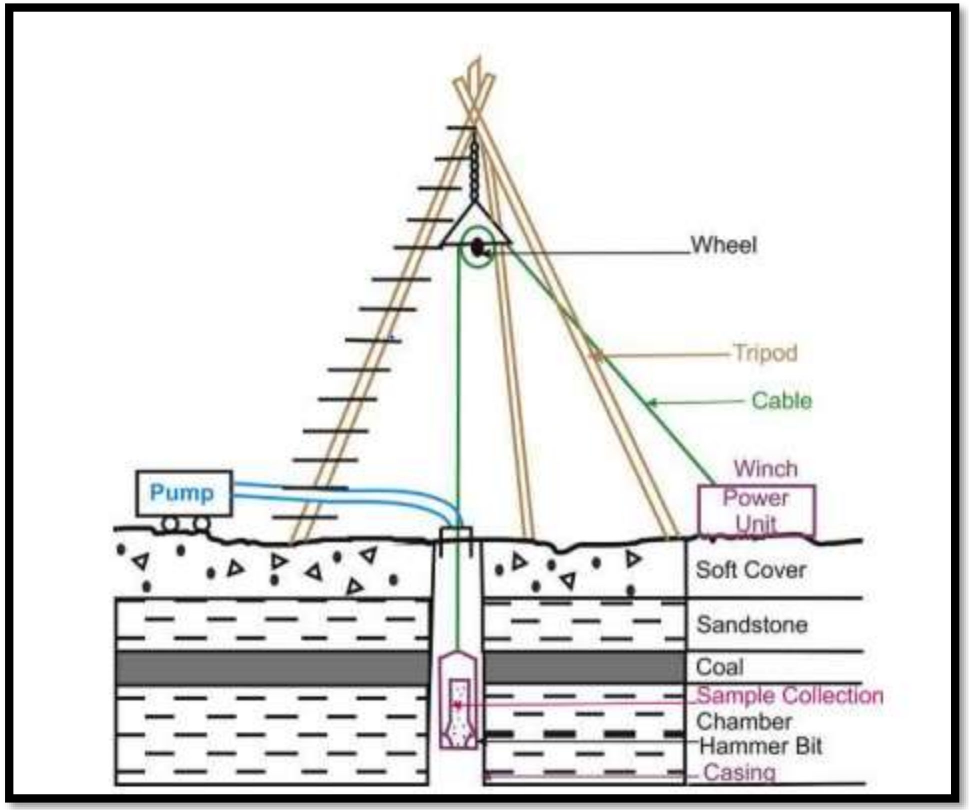
DRILL MACHINES (AUGER AND DIAMOND DRILL)

MECL

Drilling is generally categorized into different types:

1. Percussion drilling.
2. Percussive cum rotary drilling.
3. Auger drilling.
4. Diamond drilling.
5. Wire-line drilling.
6. Reverse circulation drilling.
7. Air-core drilling.
8. Directional drilling.

Standard Drilling type, Hole Diameter & Core Diameter		
Drilling Type (Casings)	Hole Diameter (mm)	Core Diameter (mm)
HX	99.20	76.20
NX	75.60	54.70
BX	59.90	42.00
AX	48.00	30.00
EX	37.70	21.40



ADVANCED DRILL MACHINE KDR-1000 KORES (MEC-335)

CORE LOGGING

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- The core should be cleaned and wetted.
- Variation in lithology in a run has to be recorded taking into consideration of the core recovery.
- Attitudes of structural features like foliation, bedding, fracture, cleavage etc should be recorded and intersection of these planar structures with core Axis has to be determined.
- If core recovery is less then it should be extrapolated.
- Nature of the core broken, fractured, powdery etc should be recorded and RQD has to be recorded
  - Mineralised portion of the core should be studied in detail such as nature of mineralisation- stringers, specks, dissemination- and grain size should be mentioned.
  - Ore minerals identified should be documented. Those difficult may be described in terms of their physical properties.
  - Visual estimate of ore has to be given. (sulfides, WO_3, Pb, Zn etc.)
  - Sampling zone have to be demarcated.
  - Size of bit and core to be mentioned.
  - Water loss cavities to be mentioned;

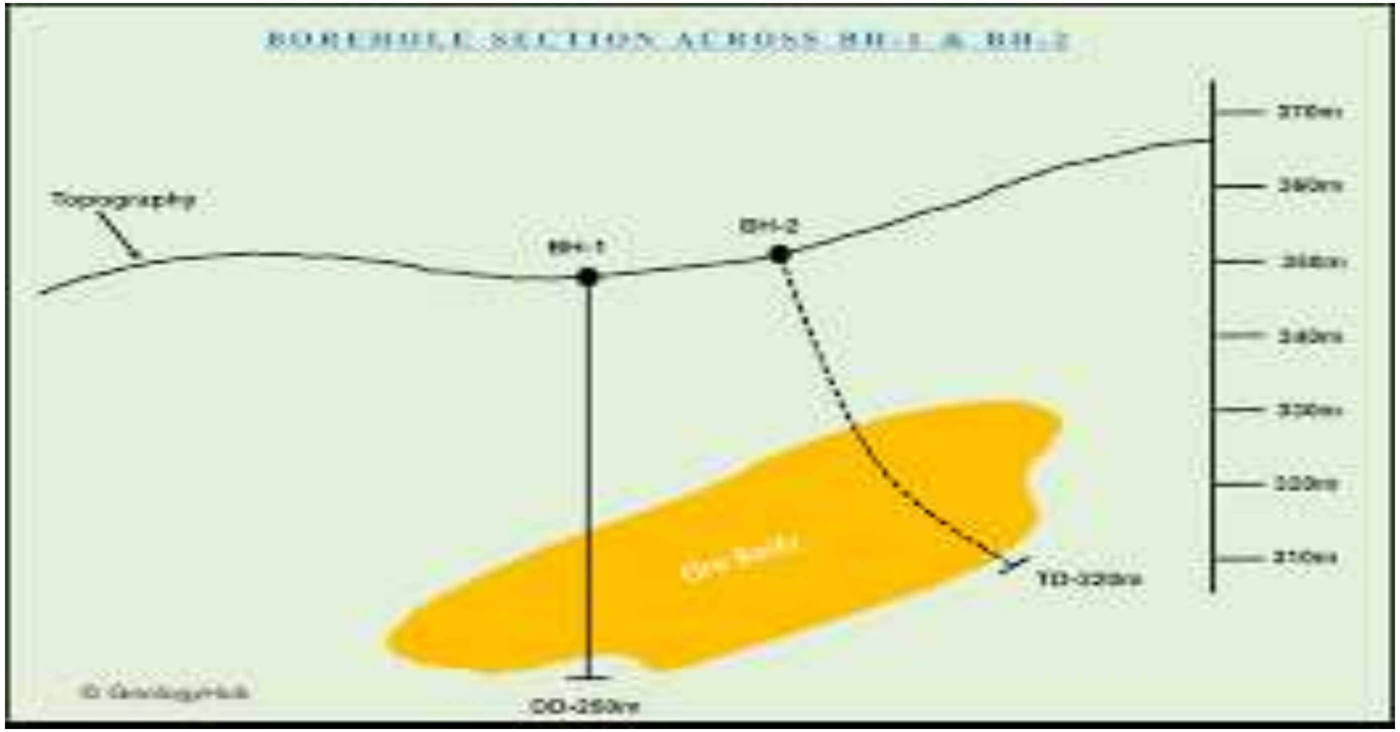
BOREHOLE GEOPHYSICS

- Very important when core recovery is poor.
- Electrical logging down hole indicates the depth and thickness of ore zones.
- Helps in correlation of ore zones from borehole to borehole.
- Delineation of lithology and interpretation of surface geophysical data.
- EM logging is increasingly used in BGP
- IP logging also advantageous when the ore is of massive sulfide type and is good conductor.

BOREHOLE PLANNING

MECL

- Drilling is an important stage of mineral exploration in view to get the data of the 3rd dimension of the prospect.
- As it is a costly venture this is undertaken only in the advanced stage of exploration.
- This provides complete record of geological structure and rock texture ore quality.
- Provides reliable samples for chemical testing.



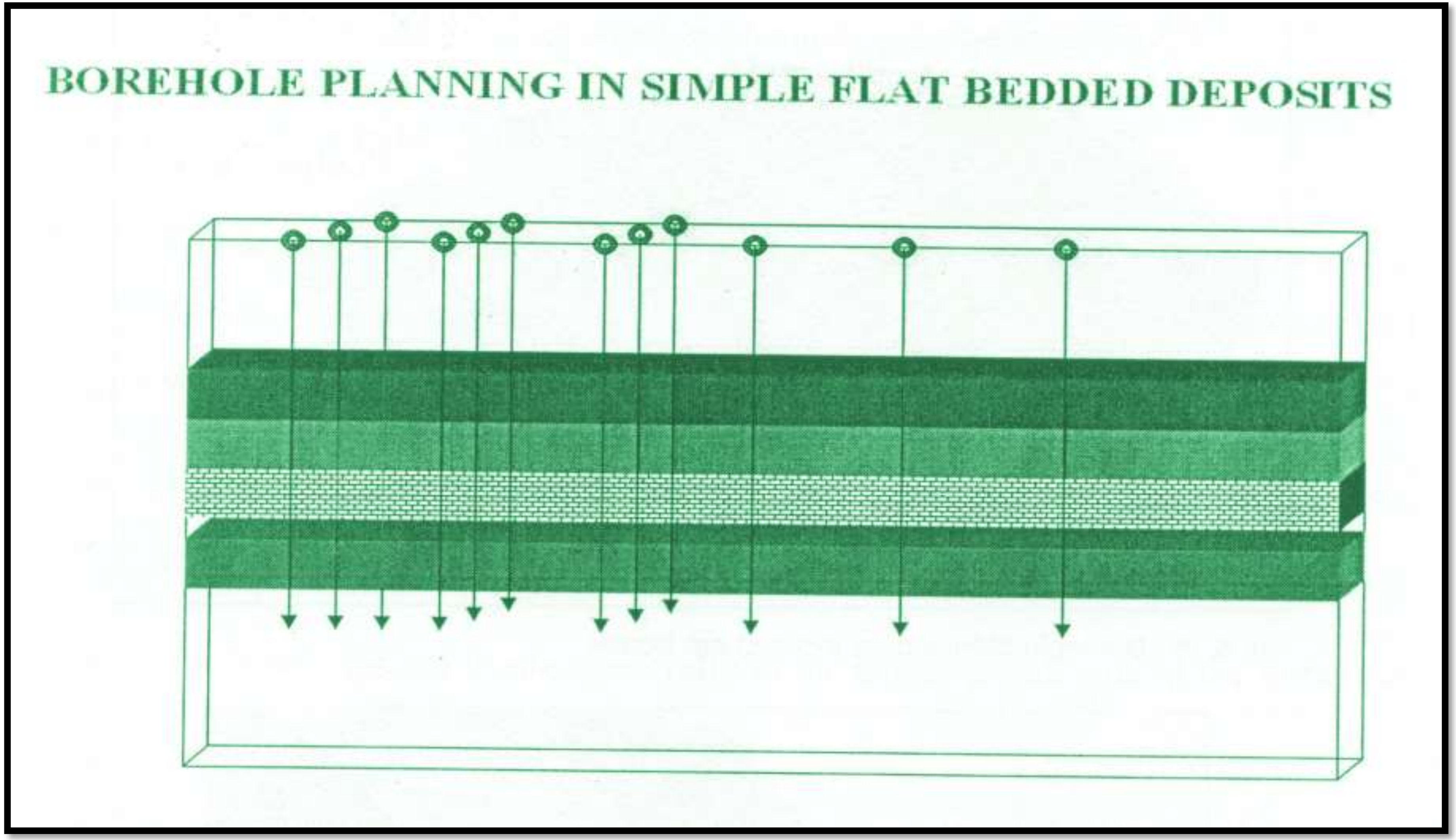
HOW TO PLAN BOREHOLES

MECL

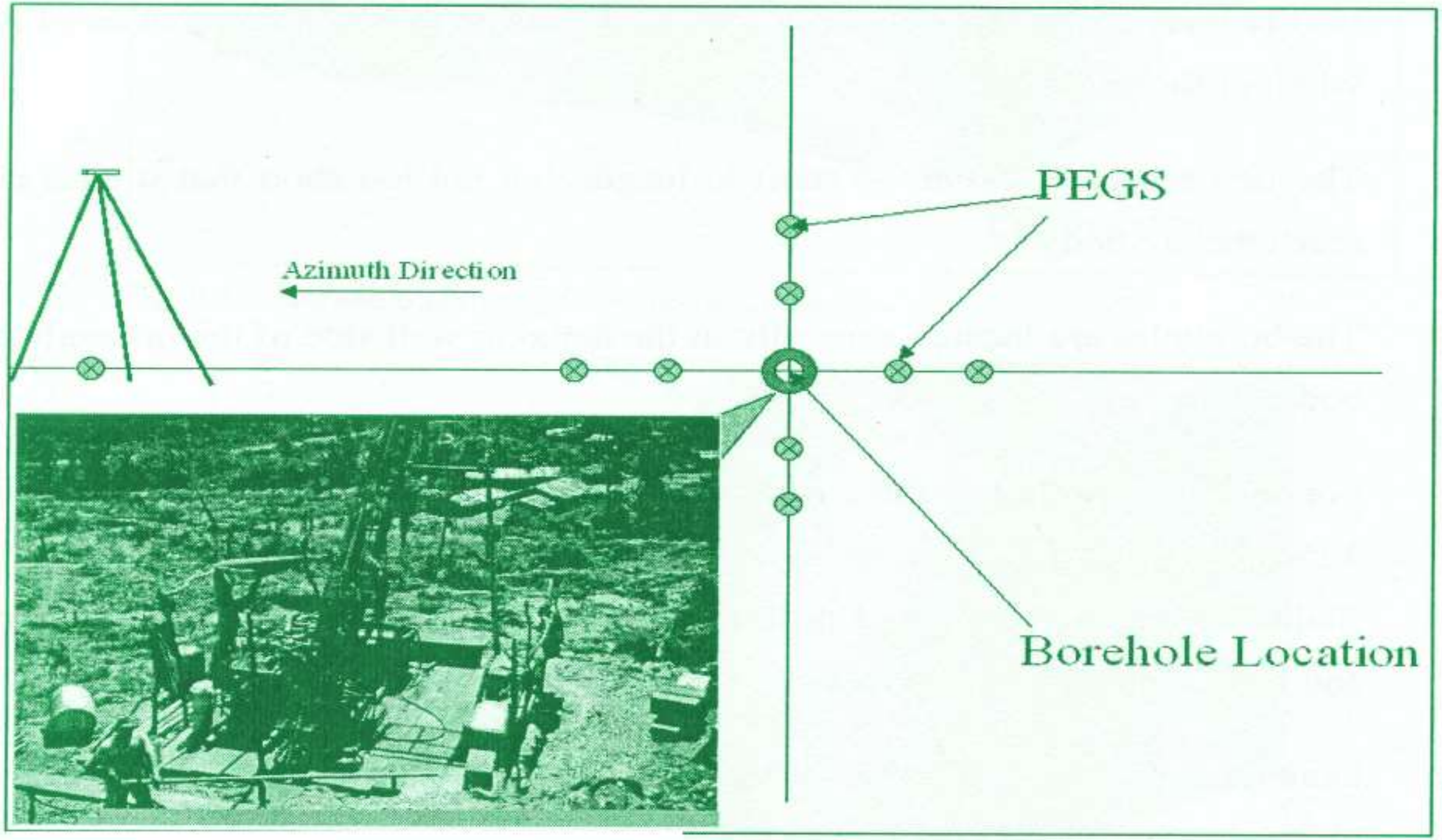
- **Simple ore Deposits**: Homogenous in extent with horizontal to sub-horizontal disposition covering large areas; vertical boreholes in grid pattern of 100X 100 or 200x 200m or 400m by 400m.
- The grid pattern can be modified as per situation and type of data required, nature of the deposit.
- **Deformed Ore Deposits:** Planning of initial boreholes are important as the fate of exploration depends on initial drillholes.
- The first few boreholes are planned at the most promising locales of mineralisation.
- The point of intersection of the mineralized zone should be planned to intersect the primary zone below the oxidized zone. Say generally 20-30m from oxidized zone.

- Incase any old mine exist in the area intersection should be located 20-30m below the deepest level of old workings.

- Information of pits and trenches sampling, mapping and Geophysical Survey are important for planning boreholes.

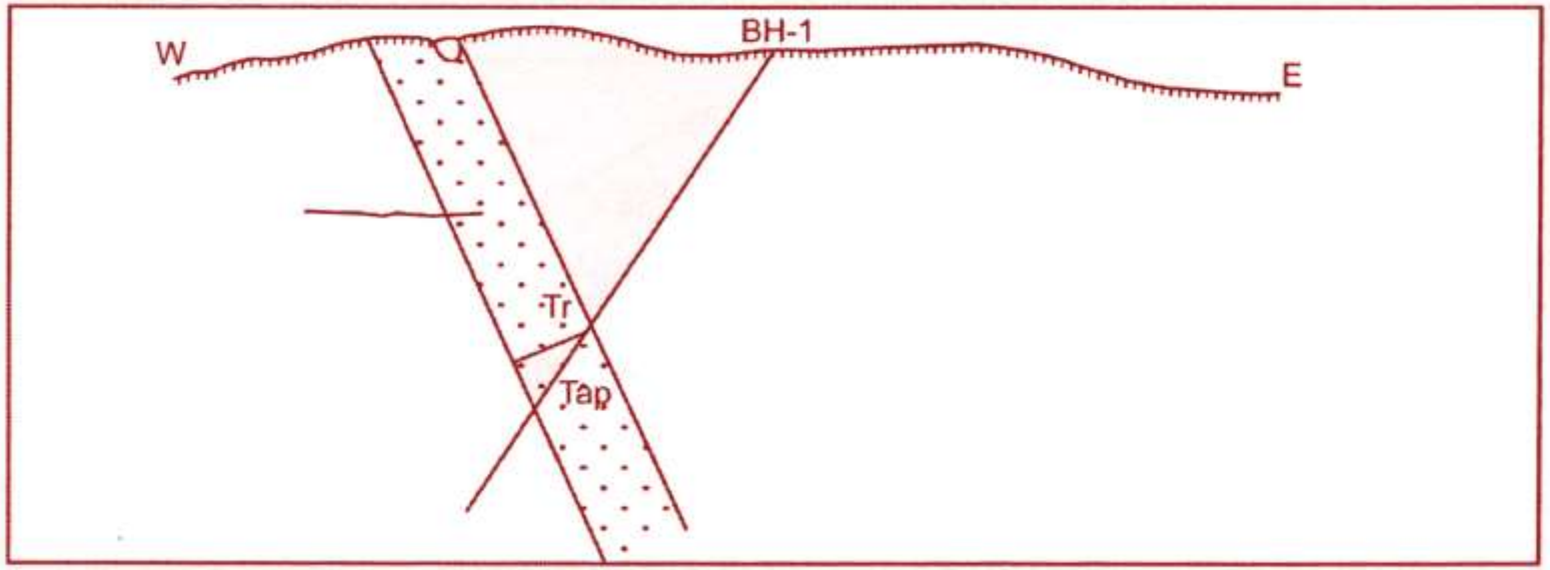

BOREHOLE PLANNING IN SIMPLE FLAT BEDDED DEPOSITS

MECL

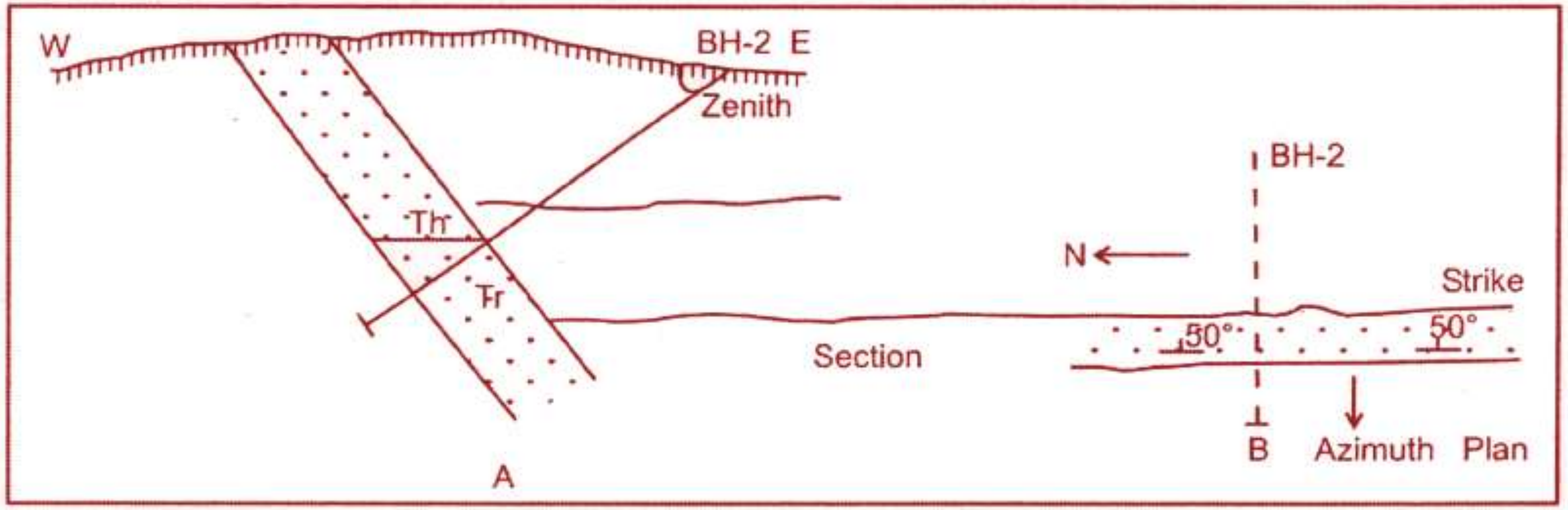


FIXING BOREHOLES ON THE GROUND

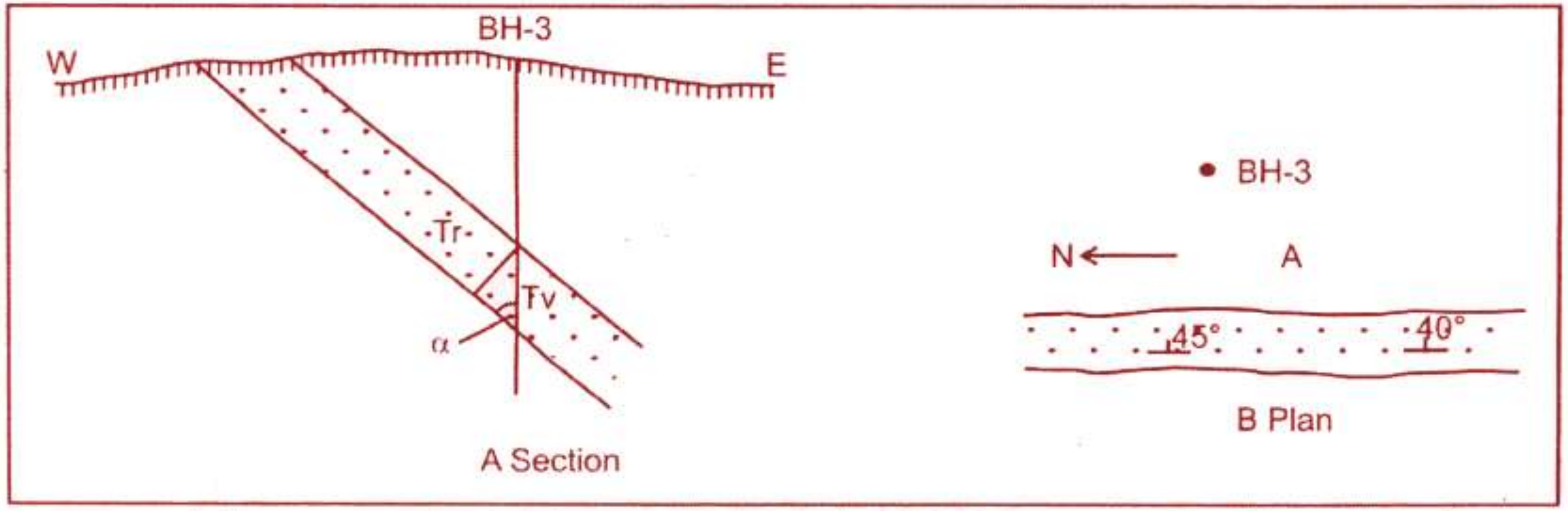
MECL



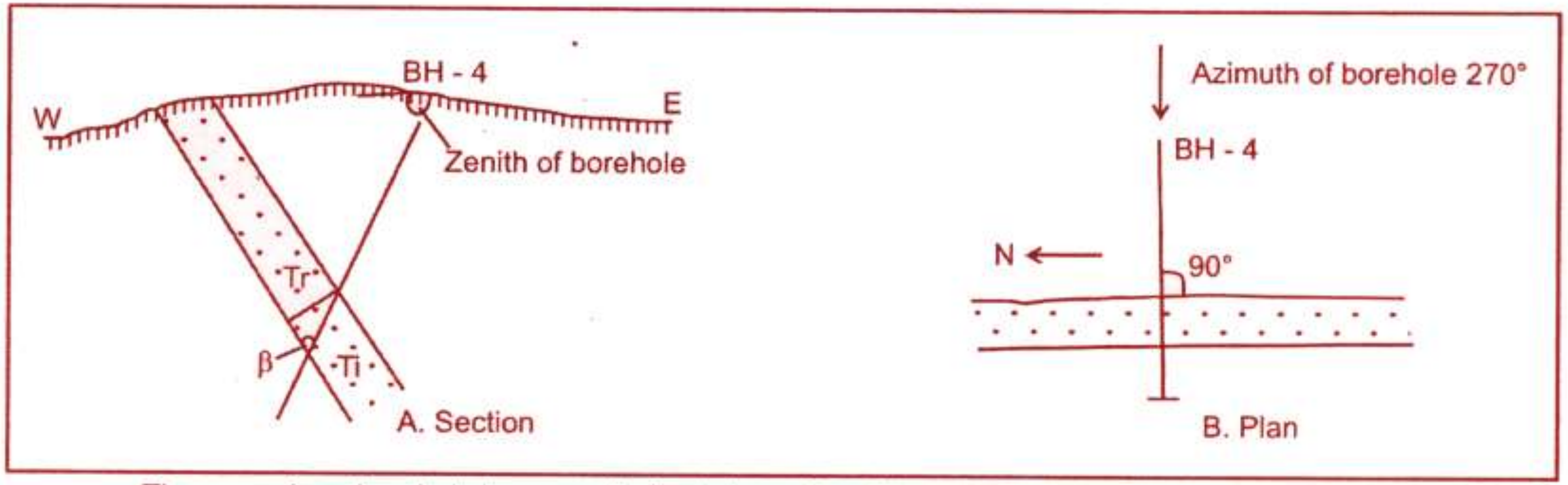
Borehole BH-1 has intersected the apparent thickness of the ore body as BH-1 is not perpendicular to the dip plane Tap =apparent thickness. Tr true thickness



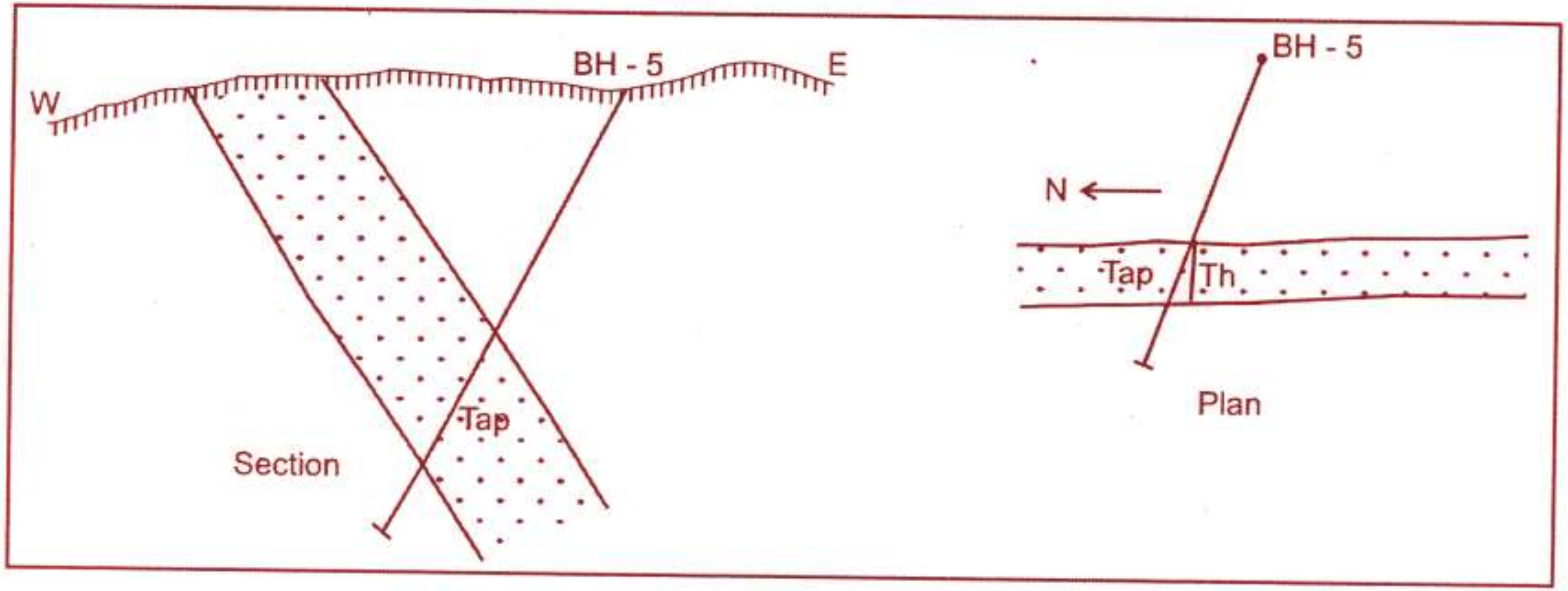
: A. BH-2 intersecting the ore body perpendicularly i.e. borehole is perpendicular to the dip plane of ore body B. Shows that borehole is perpendicular to the strike of the ore body. Tr = True thickness



A. The apparent length intersected in borehole BH-3. Tv is apparent length α angle between core axis and bedding plane. Tr true thickness. B. surface plan, position of bore hole and inclined ore body



The case where borehole is perpendicular to the strike of the ore body (B) but incline to dip plane (A). Ti incline thickness True thickness Tr = Ti Sin β



A. Borehole is inclined to strike (plan) and to dip plane (section)

MECL

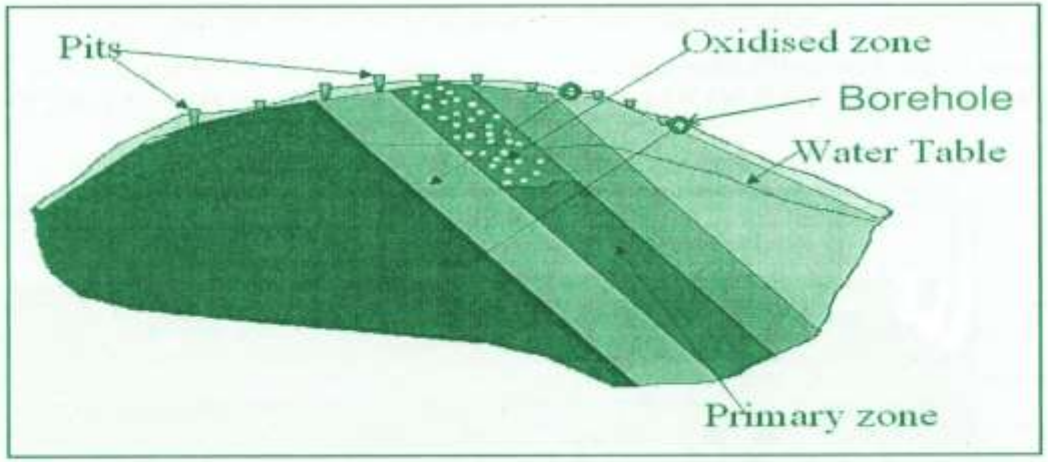


Fig. : Borehole planning for inclined ore bodies

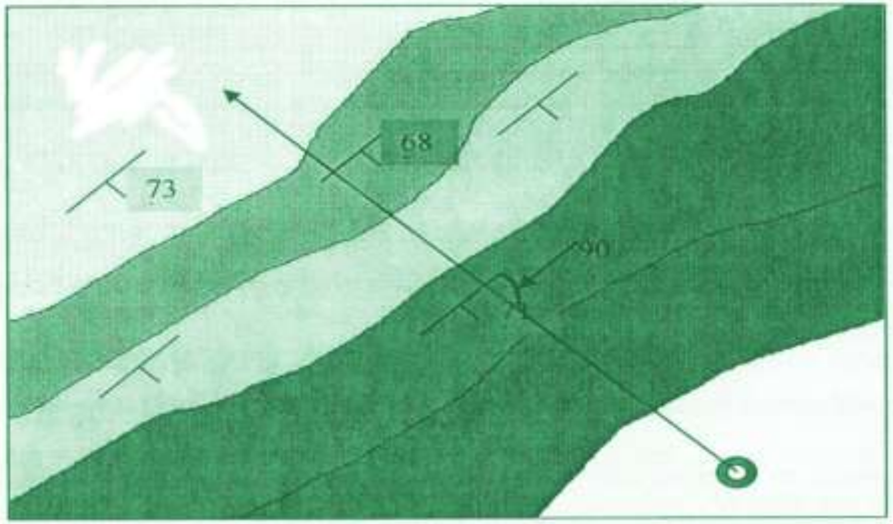
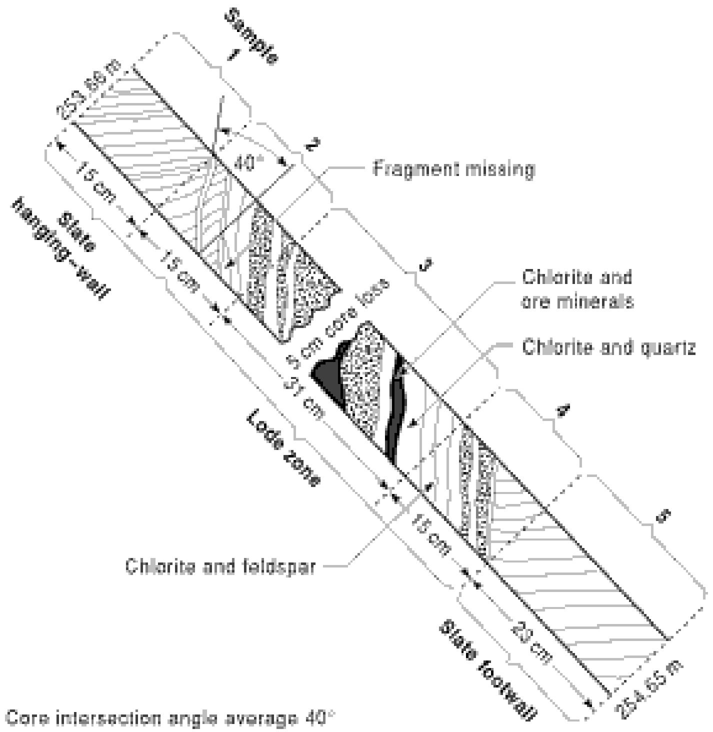


Fig. 6.16 Borehole on a geological map

Map showing Mineralised zone Dipping with Borehole planned to intersect at 90 *.



Core intersection angle average 40°

Sample number	Depth from(m)	Depth to(m)	Recovery (m)	Recovery (%)	True width (cm)	%Sn	cm%
1	253.66	253.81	0.15	100	12	0.03	0.36
2	253.81	253.96	0.15	100	12	0.56	6.72
3	253.96	254.27	0.25	81	20	4.75	95.00
4	254.27	254.42	0.15	100	12	1.27	15.24
5	254.42	254.65	0.23	100	18	NIL	–

$$\text{Weighted average lode value} = \frac{116.96\ \text{cm\%}}{44\ \text{cm (true thickness)}} = 2.66\%\ \text{Sn}$$

at a weighted average core recovery of 91%

Typical intersection of a tin-bearing vein showing sampling intervals and the uncertainty introduced by incomplete core recovery.

Fig: -Typical Intersection of a tin bearing vein showing sampling intervals and the uncertainty introduced by incomplete core recovery.

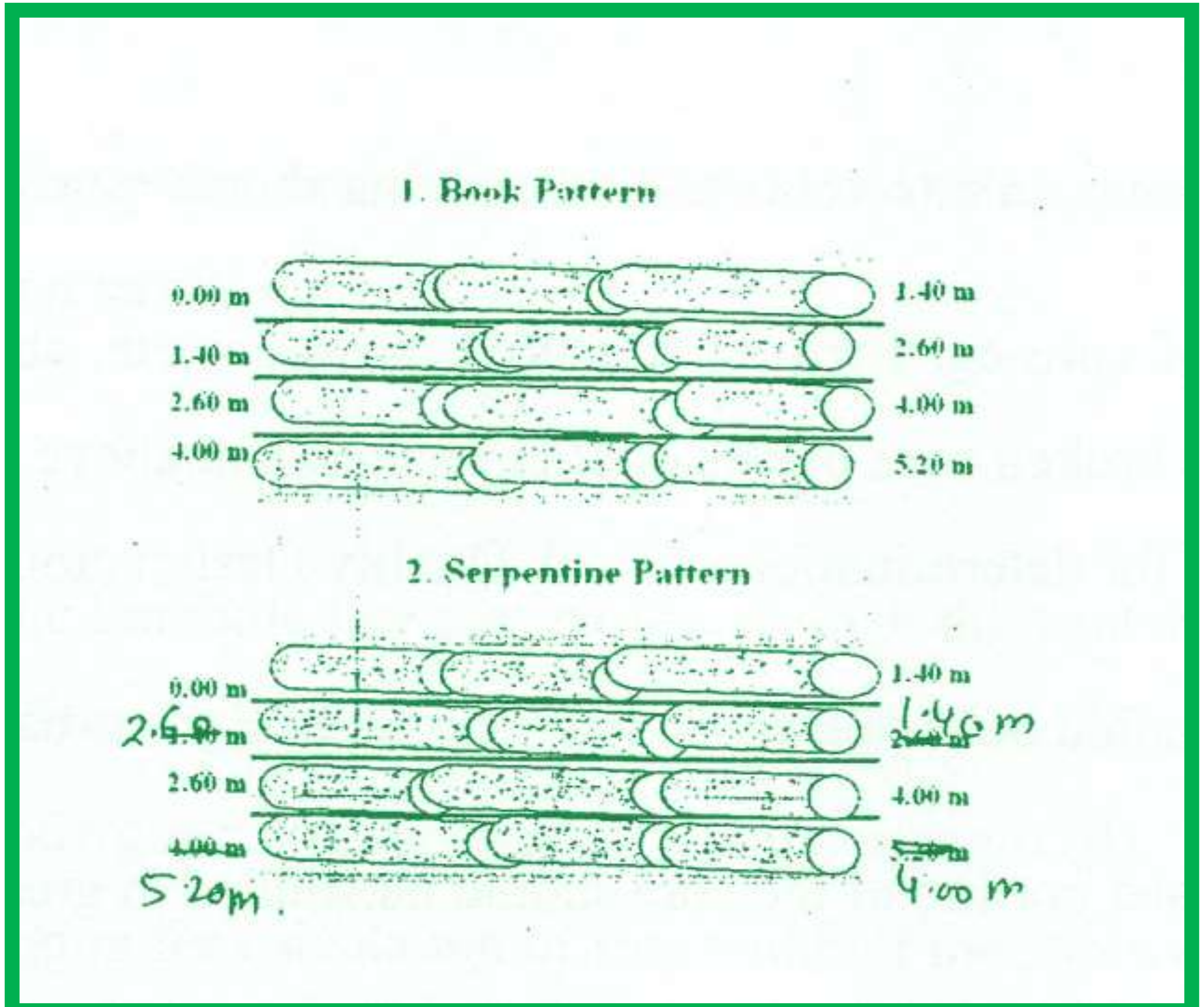


Fig: Assemblage of cores in core box in two different pattern.

CORE ANGLE

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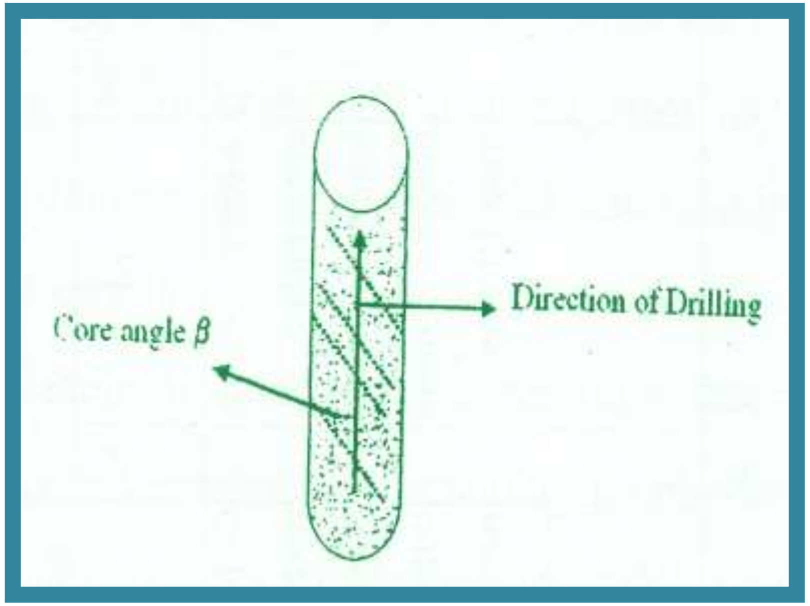
Core Axis: The line passing through the center of the core in the direction of drilling.
The angle between core axis and bedding/ foliation is the core angle (ß).This angle is important in for calculation of true width of the unit/ zone.



ANALYSIS OF SAMPLE

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- **Primary Samples :-** Samples are analyzed for Quantitative assay of principal constituent
- **Check Samples** :- 5-10% samples drawn from the same zone with different number for assay check.
- **Duplicate Half Core Samples**:- One set of duplicate samples are sent to different laboratory for checking lab.
- The other half sample powder is subjected to check analysis.
- **Composite samples** : Combining a number of samples composing is done. Care is taken to collect proportionate weight from each sample.
- Now a days due to technology advancement, various instruments are used for element analysis. Such as Hand-held XRF are used which directly provide the element concentration of the sample.

ESTIMATION OF RESOURCE

MECL

- Mineral Resources and Reserves are defined by the quantity (Tonnage) and Quality (grade of Elements) of in situ concentration of material in or on the Earth Crust.
- The resources & reserves exist within well defined 3D mineralised envelopes.
- The boundaries are drawn between Ore and waste or between several grades of Ore of all possible bodies within overall framework of mineralised horizon.
- The firm knowledge of resources & reserves are required for investment decision of any property.

PARAMETERS OF RESOURCE / RESERVE ESTIMATION

- **Cutoff Grade-** Cutoff grade is an artificial boundary demarcating between low grade mineralisation and techno economically viable ore that can be exploited at a profit. The cutoff boundary change with the complexity of mineral distribution, method of mining, rate of production, metallurgical recovery, cost of production, royalty, taxes and finally the commodity price in international market. Cutoff grade are normally expressed in percentages (%) of metals, for base, ferrous and non ferrous metals (Cu, Pb, Zn, Fe, Al, Cr etc) and in gram per metric tonne (g/t) or parts per million (ppm) for precious metals (Au, Ag, Pt, Pd etc).
- **Minimum width-** Mining of ore, by open –pit and underground methods requires minimum width of ore body restricts the vertical limit of open pit mining due to increase of ore to waste ratio with depth. A minimum of 3metre is suitable for semi mechanized ore extraction in underground mining.
- **Specific Gravity / Bulk density-** Specific gravity / Bulk density is an important parameter which is required for estimation of resources / reserves. The specific gravity is determined during exploration stage by sending the mineralised core / samples to petrological lab. The average specific gravity is calculated for the number of samples collected during exploration and the same is utilized for estimation of resources.

Mineral reserve estimation has attained its crucial importance owing to large investments in mining industries either due to mechanization or extreme need of the world for feedstock.

Methods of Resource Estimation

MECL

Ore resource can be estimated by a number of methods. It depends upon the commodity and nature of deposit explored

In general the following methods are used for estimation of resource.

1. Triangular Method
2. Square or Rectangle Method
3. Polygonal Method
4. Isograde / Isopach Method
5. Geological cross section method.
6. Longitudinal Vertical Section (LVS) method.
7. Level Plan Method.
8. Inverse Power of distance or principle of gradual change method.

Borehole geological data is used in preparation of cross section and longitudinal vertical section and in the conventional form, the areas were measured, volume and tonnage were calculated, and the average grade were determined

Geological Cross Section of Purheibahal Iron Ore Block, Distt-Sundargarh, Odisha

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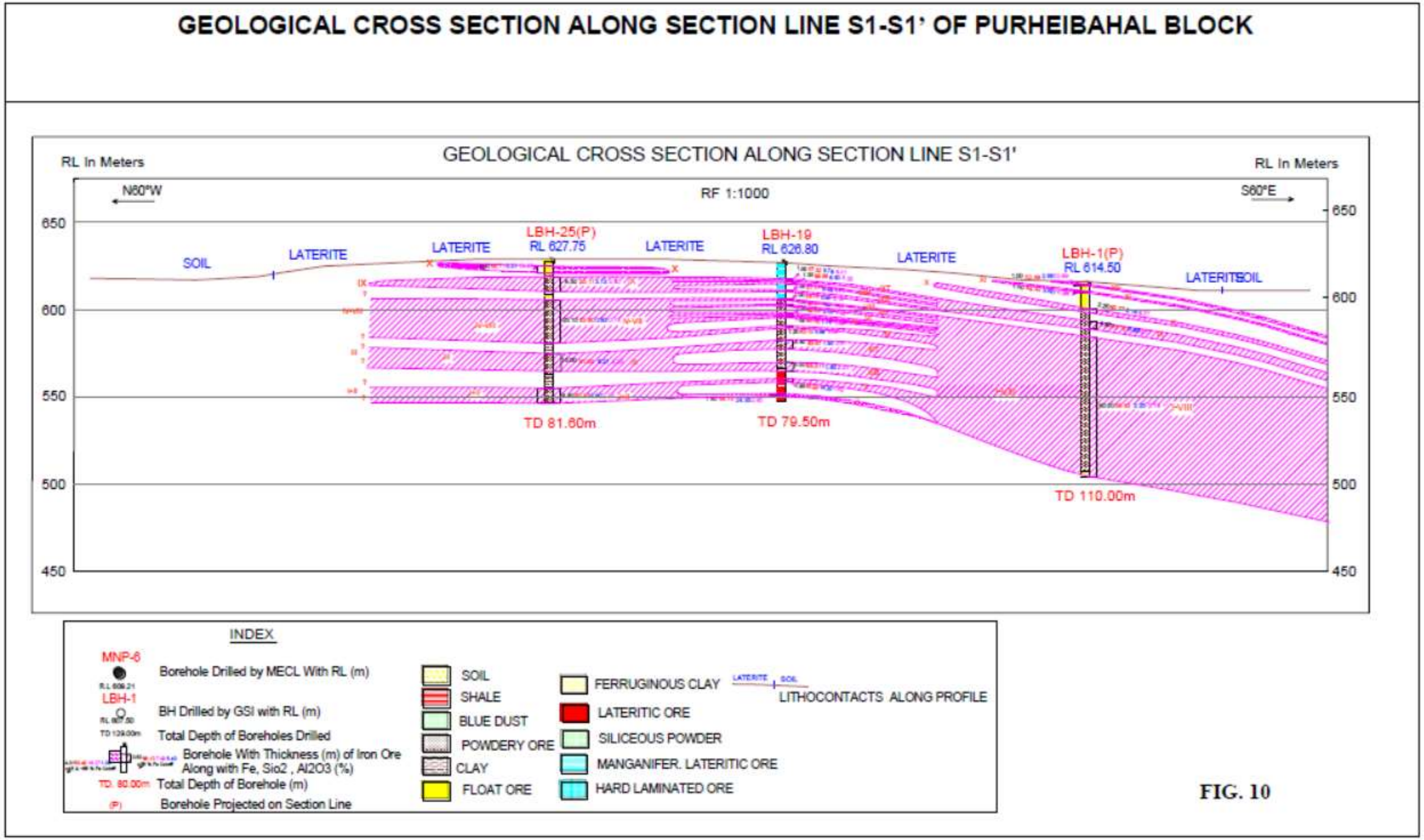

FIG. 10

Slice Planat 600mRL of Purheibahal Iron Ore Block, Distt- Sundargarh, Odisha

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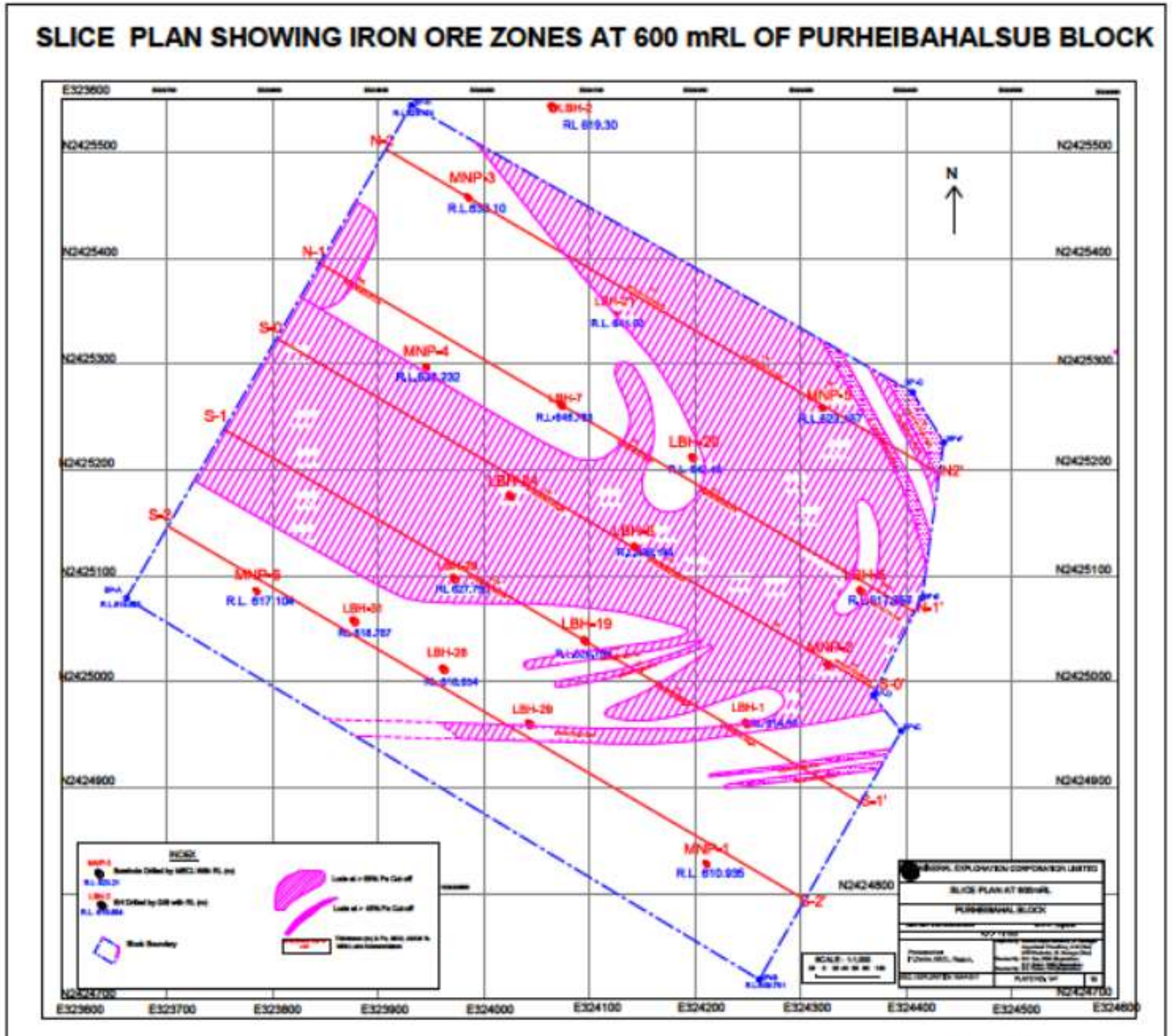

FIG 11

FINAL GEOLOGICAL REPORT PREPARATION

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The data generated during the different stages of Exploration and by different techniques / methods (Topographic Survey, Geological Mapping, Geochemical sampling, Remote Sensing, Geophysical Survey, Drilling, Sampling and Analytical Studies) are compiled, interpreted and Final Geological Report is prepared along with Orebody modeling & Geostatistical studies (As per requirement of Client) by the Exploration Agencies and handed over to the Clients / State Government for taking up feasibility Study and decision for going for exploitation.

MINERAL EXPLORATION LIFE CYCLE

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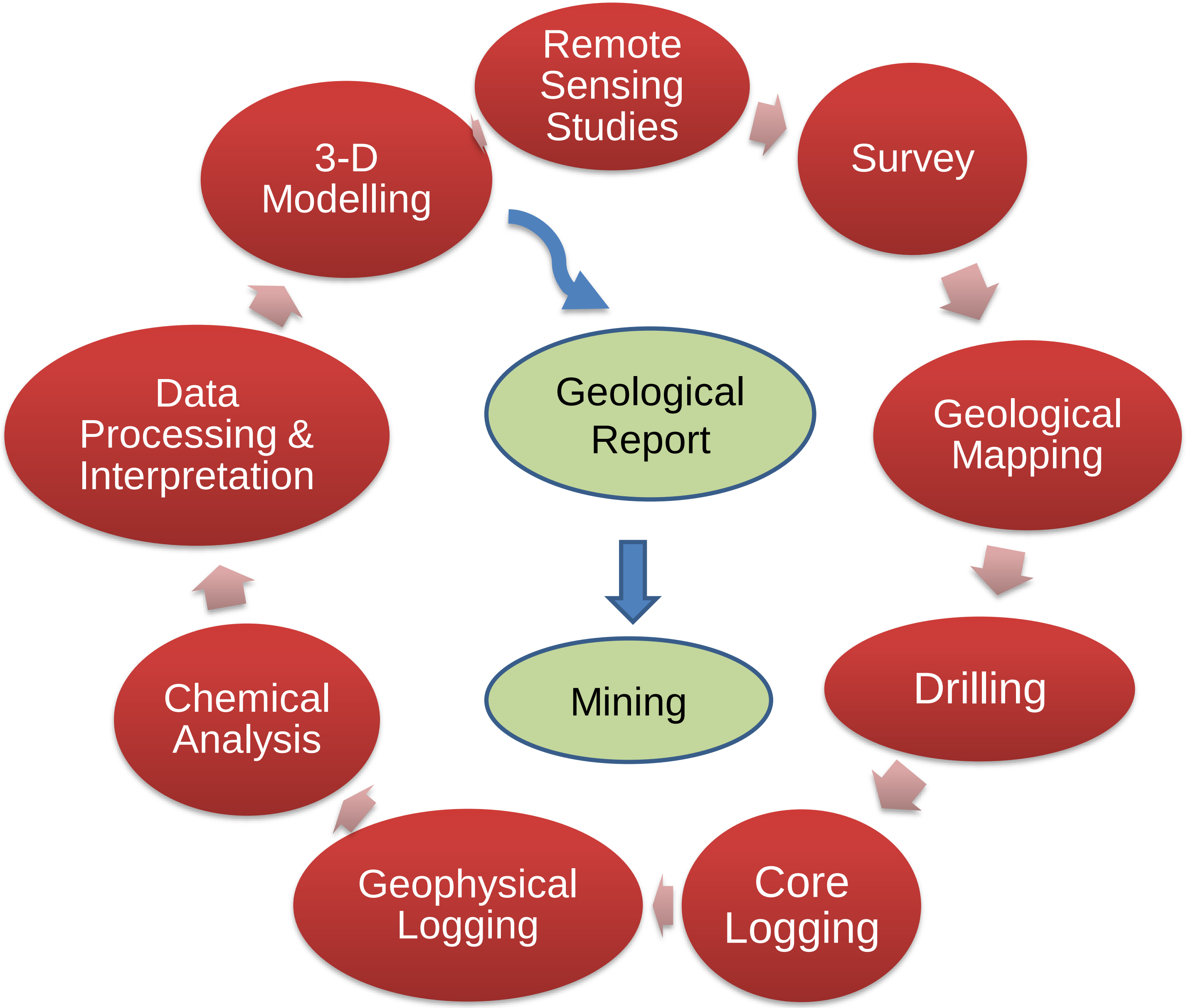

CONCLUSION…

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- The start of the process comes from the generation of ideas, which are based on the geology of a region, company exploration models and the broad scoping of potential resources that might suit a current commodity market.

- Geologists will look at other known deposits to determine how and what geological process formed them.

- They will then use these models to find conditions that are similar in different regions of the state and other countries. These models and concepts continually change as more is known about the area they are exploring.

- The market defines the resources that are of interest and may be profitable and hence drives much of the exploration being undertaken.

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Thank You

GROOVE SAMPLING

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