Mineral Exploration
Unit-2
(Geological techniques and procedures of exploration)

Study of Outcrops

Rock outcrop: It is the part of a rock formation that exposed on the surface of the earth.

- Information that can be obtained from outcrops are; Structural features orientations (e.g. bedding planes, fold axes, foliation).
- Depositional features orientations (e.g. paleo-current directions, grading, facies changes).
- Outcrops are also critically important for understanding fossil assemblages, paleo-environment, and evolution as they provide a record of relative changes within geologic strata.







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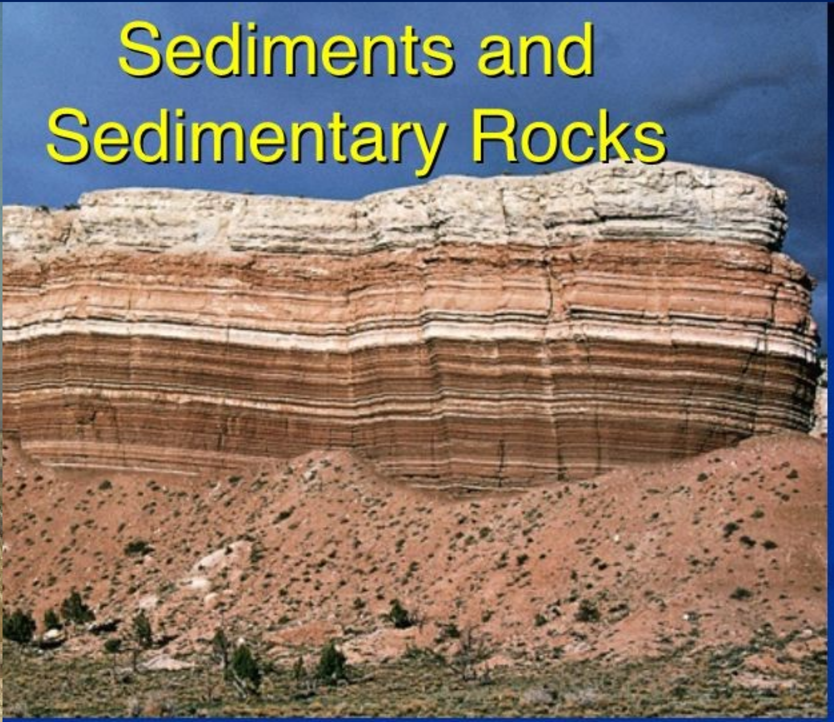
Sediments and Sedimentary Rocks



Sampling of on spot and lab analysis

- ✓ Sampling is a process of taking a small portion of a material such that the consistency of the portion shall be representative of the whole.
- ✓ A sample should be representative of the whole from which it is drawn
- ✓ Sampling of particulate materials and the subsequent preparation and analysis is the most important in the mining and metal industries in exploration.

Type of Sampling

1)Chip sampling

2)Grab sampling

3)Channel sampling

4)Bulk sampling and

5)Dump sampling

Chip sampling

In chip sampling first the outcrop or face to be sampled is cleaned properly and a regular rectangular or squares pattern is made by drawing lines along and across the outcrop at fixed intervals.

Then small pieces of ore are broken loose either from the center of the grid or rectangular or at the intersection points of the lines.

The ore pieces should have approximately the same chips size and weight and the rock pieces are mixed together to form the samples.

GRAB SAMPLING

In grab sampling, the quantity of material to be collected depends on the size of the largest pieces present in the materials to be sampled and the degree of heterogeneity of the material.

Channel sampling

In this sampling a channel is cut across the face of the exposed ore and the resultant cuttings and chips are collected as a sample. A thin layer of the exposed ore may be removed to avoid cutting the weathered ore.

Bulk sampling

Bulk sampling may be made by collecting a portion from every blast continuously, or from the shovels or cars in the case of mines, Bulk samples may be collected from a series of pits or number of trenches, adits or underground drives in the case of prospects.

Dump sampling:

Dump sampling can be carried by systematically driving the augur into the dumps and collecting the augured material. Benches may be prepared on the dumps and from the benches pits can be driven to collect samples

Criteria for the selection of a sampling procedure for a particular mineral type:

It depends on the shape and type of mineralization of the deposit.

1. When the ore body is thick and the values of mineralization are uniformly distributed, sampling can be done by chip or grab sampling.
2. When the ore-body is of medium size and mineralization is uniform, a combined chip and channel sampling will give the best results.

3. Where the ore-body is too thin but occurs in benches or layers sampling of various layers can be done by chip sampling

4. When a deposit is of very large dimensions, it becomes necessary to collect a large number of samples. In such cases, a large number of chip samples would give reliable results

5. With mineral like gold, rare metals etc. where values are too spotty and irregular, bulk sampling would give the best results.

6. Wherever the ore is banded, channel sampling would give the best results and

7. Very hard ore, particularly massive types of iron ore would require to be sampled by blast hole cuttings.

What is Sampling:

Systematic collection of representative fraction of any materials from its bulk is called sampling.

Types of Sampling

1. Point Sampling (Grab and Random)
2. Linear Sampling (Channel sampling, Chip, blast/drill hole sampling)
3. Volumetric Sampling (Bulk Sample)

Sampling during Reconnaissance survey:

1. Grab samples
2. 8cmx5cmx3cm size
3. 1 to 4 samples per sqkm
4. Point samples are mainly collected during the reconnaissance survey.
5. Fresh samples

Sampling during Exploration and Prospecting survey:

1. Linear samples
2. Trenching / Pitting
3. 10-1000 samples per sqkm
4. Drilling also essential type of samples

In Geochemical Analysis

Quantitative Analysis: It is simply represents the elements present in the sample.

Qualitative Analysis, which measures the concentration of the analyte in the sample.

Major Elements

If the concentration of the elements exceeding 1% by mass, it is called major elements

Minor Elements

Concentration of the elements between 0.1 and 1%

Trace Elements

If the concentration of the elements less than 0.1% (1000ppm) is called trace elements

<u>Chemical Composition</u>

Average Chemical Composition
(Clark and Washington)

Element	Oxide (%)
SiO_2	59.14
$AlsO_3$	15.35
FeO	3.80
Fe_2O_3	3.08
CaO	5.08
MgO	3.49
Na_2O	3.84
K_2O	3.13
H_2O	1.15
Others	1.94

Laboratory Analysis

1. **Petrology Lab** (Petro-mineralogical study)
2. **X-ray Fluorescence (XRF)** is the emission of characteristic "secondary" (or fluorescent) X-rays from a material that has been excited by bombarding with high-energy X-rays or gamma rays.
3. **X-Ray Diffraction Analysis (XRD)** investigates crystalline material structure, including atomic arrangement, crystallite size, and imperfections.

4. **X-Ray Diffraction Analysis (XRD)** investigates crystalline material structure, including atomic arrangement, crystallite size, and imperfections.

5. **Electron Probe Micro Analyzer (EPMA)** is a non-destructive analytical tool to determine the chemical composition of small volumes of solid materials.

- Sample is bombarded with an electron beam, emitting x-rays at wavelengths characteristic to the elements being analyzed.
- This enables the abundances of elements present within small sample volumes to be determined

Water Sampling

- Collection of samples from turbid and stagnant water to be avoided.
- Filtration using 0.45µm filter.
- To stabilize the ion in solution, acidification using HNO3 to achieve pH <2.
- pH of water should be measured.
- Sample container should be virgin polythene and it should be cleaned with dilute nitric acid and rinsed by distilled water.

Panning

Pitting and Trenching

- Pitting and Trenching can be done where the soil thickness is high.
- Simplest and least expensive method for deep sampling.
- Detailed geological logging can be carried out.
- Undisturbed and fresh sample can be collected.

- In areas where soil cover is thin, the location and testing of bedrock mineralisation is made relatively straightforward by the examination and sampling of outcrops.
- However in locations of thick soil cover, deep sampling can be done by pitting, trenching, or drilling.
- Pitting to depths of 4 to 6m (up to 30 m in dry soil) is feasible and, trenching, forms the simplest and least expensive method of deep sampling but is much more costly below the water table.
- Despite their relatively shallow depth, pits and trenches have some distinct advantages over drilling in that detailed geological logging can be carried out, and large and, if necessary, undisturbed samples collected.

Pitting

- In areas where the ground is wet, or labor is expensive, pits are best dug with a mechanical excavator.
- Pits dug to depths of 3–4 m are common and with large equipment excavation to 6 m can be achieved.
- In wet, soft ground any pit deeper than 1 m is dangerous and boarding must be used.

- Diggers excavate rapidly and pits 3–4 m deep can be dug, logged, sampled, and re-filled within an hour.
- In tropical regions, thick lateritic soil forms ideal conditions for pitting and, provided the soil is dry, vertical pits upto 30 m depth can be safely excavated.

Trenching :-

- ✓ Trenching is usually completed at right angles to the general strike to test and sample over long lengths, as across a mineralized zone.
- ✓ Excavation can be either by hand, mechanical digger, or by bulldozer on sloping ground.
- ✓ Excavated depths of up to 4 m are common.

Exploratory Drilling

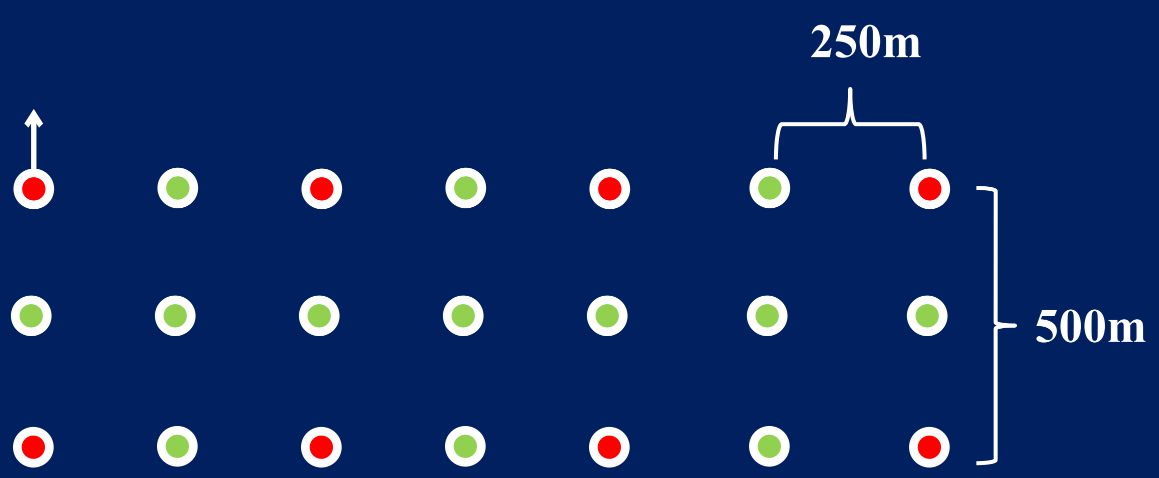
- In this stage the drilling is aimed primarily to understand the geological setup of the prospect area and a qualitative assessment of the potential ore.
- This is the most critical stage of prospect drilling.
- The geological logging process is often difficult due to unfamiliar rocks are being encountered.
- Nature of mineralisation should be understand on this stage otherwise ore body might be missed.

Pattern of Drilling:

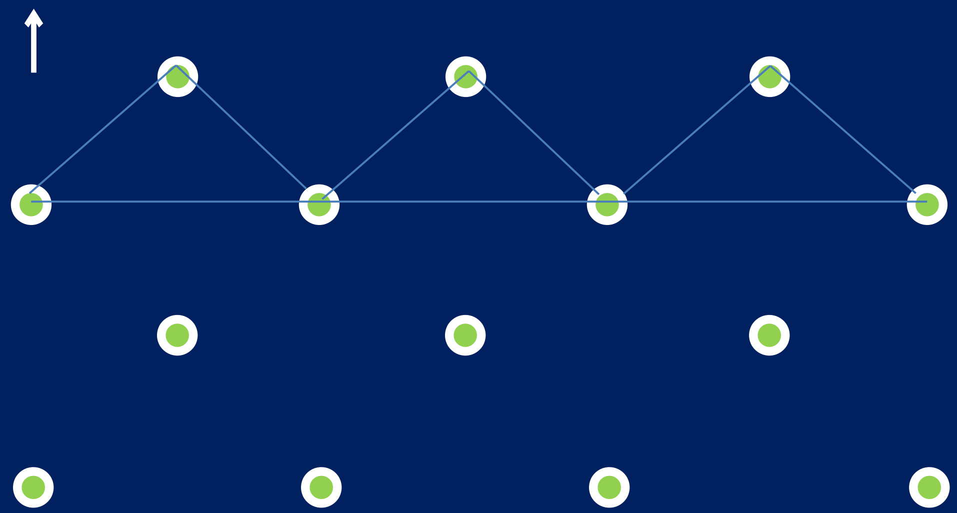
Triangular and square:

- Nearly horizontal or flat ore bodies
- In large systematic deposits like coal/lignite
- Spacing can be as long as 1km

Borehole Spacing for ore body (square grid)



Borehole Spacing for uniform ore body (Triangular)



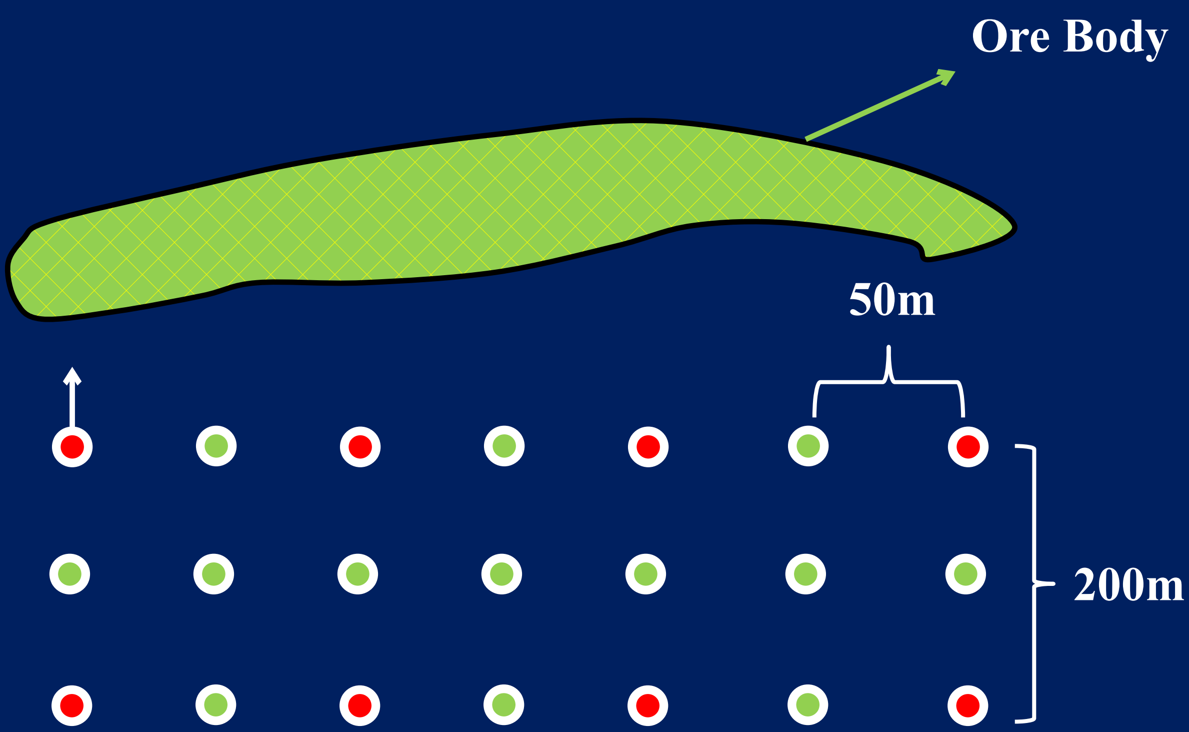
Rectangular Grid:

- It is for highly elongated ore body showing strong trend in one direction
- Example: Paleochannels and vein type
- Hole Spacing: 50-200m where mineralisation is uniform and continues. 10-50m where erratic and discontinuous

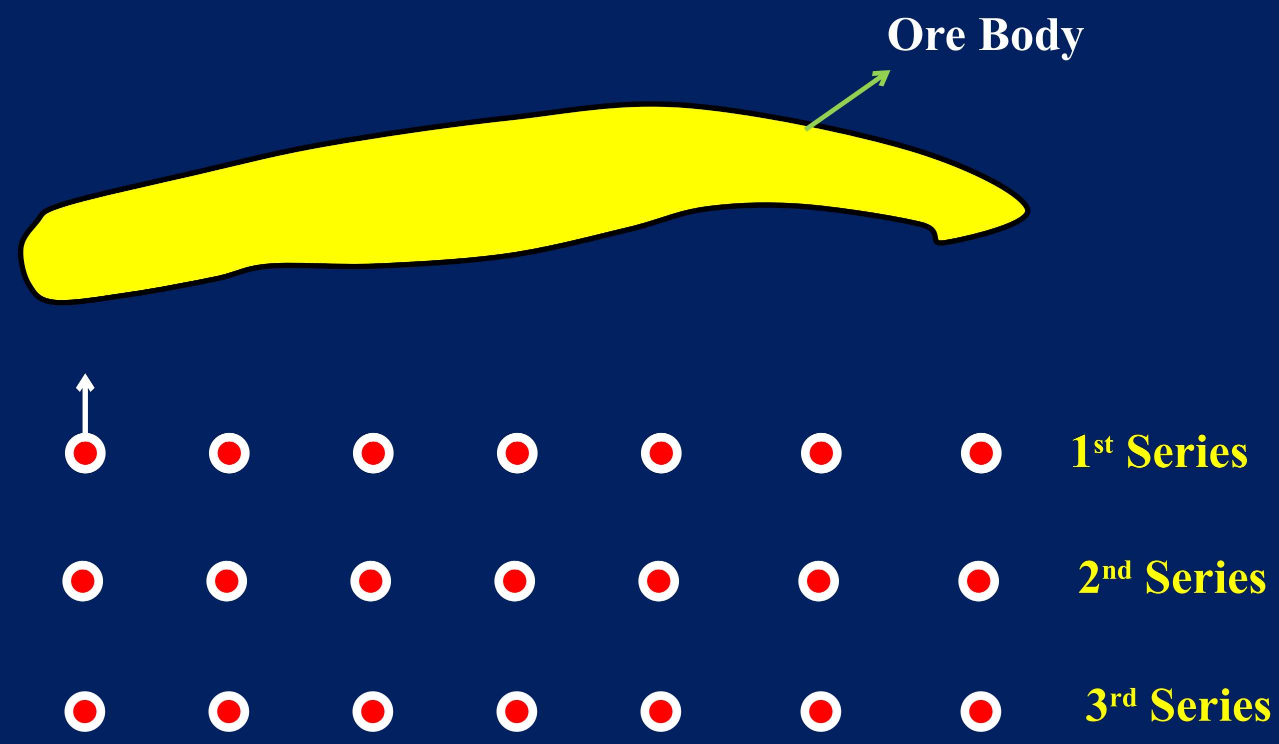
Random Pattern:

- It is adopted when regular pattern is not possible(topograpic &logistic) but it can be used in deposits with large aerial extent such as strata bound syngenetic deposits.

Borehole Spacing for Vein type/bedded tabular body



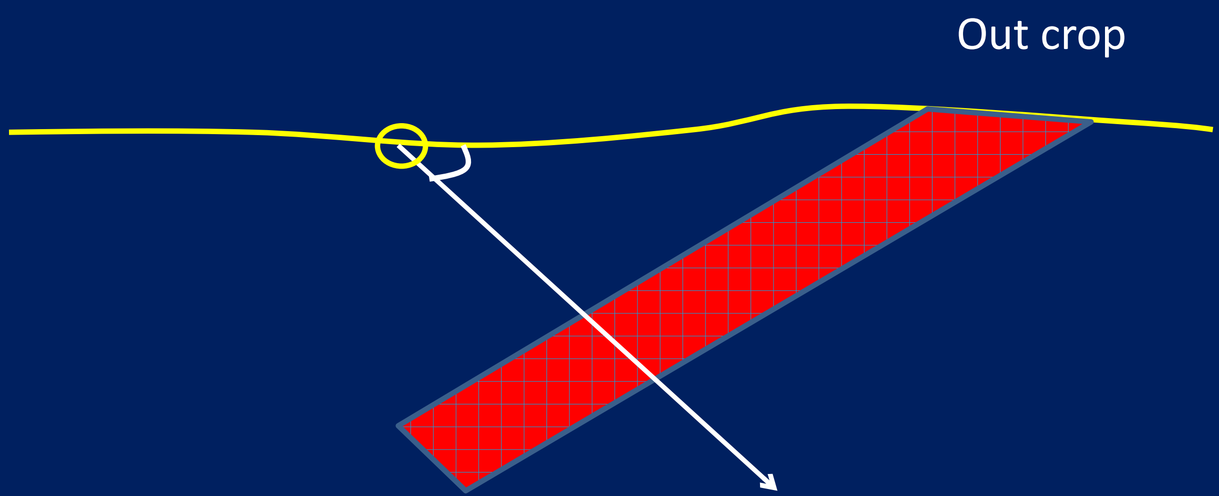
Borehole series



First Borehole

To intercept the mineralisation below the depth of weathering zone to know the mineralisation is present in depth or not.

To get the thickness (angled boreholes are given for dipping ore bodies)



Geological Logging - Logging of Core Samples

Logging – Depth wise

Core loss

Core Box

Stages of Drilling:

Stage 1:

- Exploratory drilling;
  - B.H Spacing 100m (upto 1000m)
  - B.H depth up to 250m (even 600m)

Objective:

1. To check subsurface anomalies
2. To study the control of mineralisation
3. Correlation study
4. To study the lithological and startigraphical variations

In this stage quantum of drilling is upto 25%. Inflow of data shows conformation of mineralogy and detailed geology

Stage 2:

- Evalutionary drilling (Intensive);
  - B.H Spacing 50 -180
  - B.H depth up to 600m

Objective:

1. To delineate ore
2. To estimate ore
3. To study by product
4. Hydro mineralogical study

Inflow of data shows Reserve, tons, cutoff grade and thickness. 2000 - 5000 Tons to establish for exploratory mining

Stage 3:

- Exploratory Mining Stage
    - Underground drilling from galleries and stops
    - B.H depth up to 15m
    - B.H Spacing 10m

Objective:

1. To establish reserves in stops

Inflow of data leads to detailed mining

- **Gold panning**, or simply *panning*, is a form of placer mining and traditional mining that extracts gold from a placer deposit using a pan.
-
- The process is one of the simplest ways to extract gold, and is popular with geology enthusiasts especially because of its cheap cost and the relatively simple and easy process.
- The productivity rate is comparatively smaller compared to other methods such as the rocker box or large extractors.
- Gold panning is a simple process.
-
- Once a suitable placer deposit is located, some alluvial deposit are scooped into a pan, where it is then gently agitated in water and the gold sinks to the bottom of the pan.

- Materials with a low specific gravity are allowed to spill out of the pan, whereas materials with a higher specific gravity sink to the bottom of the sediment during agitation and remain within the pan for examination and collection by the prospector.

- These dense materials usually consist primarily of a black, magnetite sand with whatever stones or metal dust that may be found in the deposit that is used for source material.

- Pans remain in use in places where there is limited capital or infrastructure, as well as in recreational gold mining.

- In many situations, gold panning usually turns up only minor gold dust that is usually collected as a souvenir in small clear tubes by hobbyists.

- Nuggets and considerable amounts of dust are occasionally found, but panning mining is not generally lucrative.

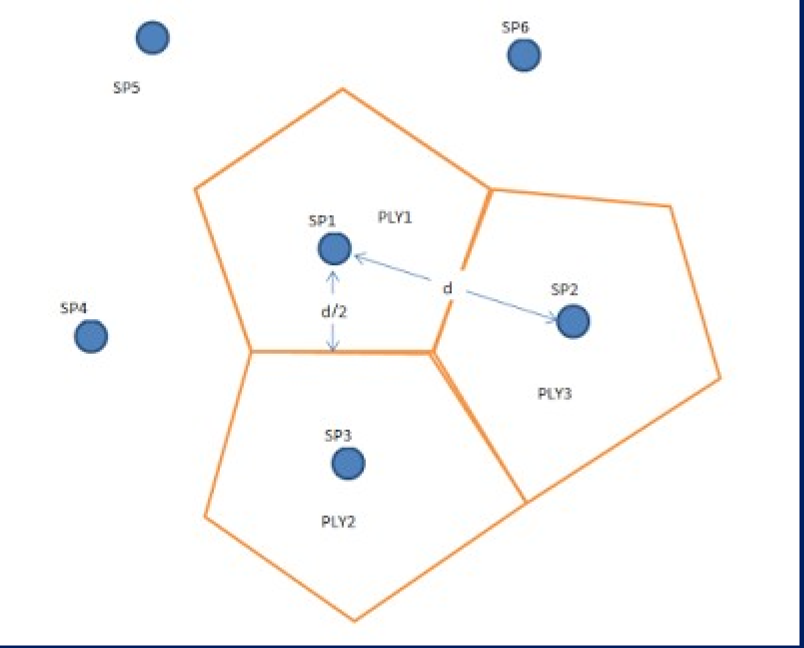
- Panning for gold can be used to locate the parent gold veins which are the source of most placer deposits.

- Gold pans of various designs have been developed over the years, the common features being a means for trapping the heavy materials during agitation, or for easily removing them at the end of the process.
- Pans are measured by their diameter in inches or centimeters. Common sizes of gold pans today range between 10–17 inches (25–43 cm), with 14 inches (36 cm) being the most used size.
- The sides are generally angled between 30° to 45°.
- Pans are manufactured in both metal and high-impact plastic.
- Russia iron or heavy gauge steel pans are traditional. Steel pans are heavier and stronger than plastic pans.
- Some are made of lightweight alloys for structural stability.

- Plastic gold pans resist rust, acid and corrosion, and most are designed with moulded riffles along one side of the pan.
- Of the plastic gold pans, green and red ones are usually preferred among prospectors, as both the gold and the black sand stands out in the bottom of the pan, although many also opt for black pans instead to easily identify gold deposits.
- The batea (Spanish for "gold pan") is a particular variant of gold pan. Traditionally made of a solid piece of wood, it may also be made of metal.
- Bateas are used in areas where there is less water available for use than with traditional gold pans, such as Mexico and South America, where it was introduced by the Spanish.
- Bateas are larger than other gold pans, being closer to half a meter (20 inches) in diameter.

Classical Technique

- Classical methods use simple geometric principles like (area, volume) to estimate the grade and tonnage of ore deposit.
- Different classical procedures are used in calculating reserve mainly differ in the ways in which they combine the sample data. These are;
- **Polygon method**
  - *areas of influence polygons are assigned to drillholes either on plan or cross section and reserve calculations are done thereon.*
- **Triangle method**
  - *a modification of the polygon method, differs from it by constructing triangles with the drill holes forming the apices of the triangle. The advantage is the the data in three point holes enter into the calculations and then proceed the same manner as in polygon method*
- **Section method**
  - *blocks of ore are outlined on regularly or evenly spaced cross sections of the ore body. Areas of influence are calculated from the same way and all calculations are tabulated.*
  - By selecting/employing one of these methods, the calculation of tonnage and grade for an ore body could be done with simple geometric and arithmetic functions.


SP6
SP5
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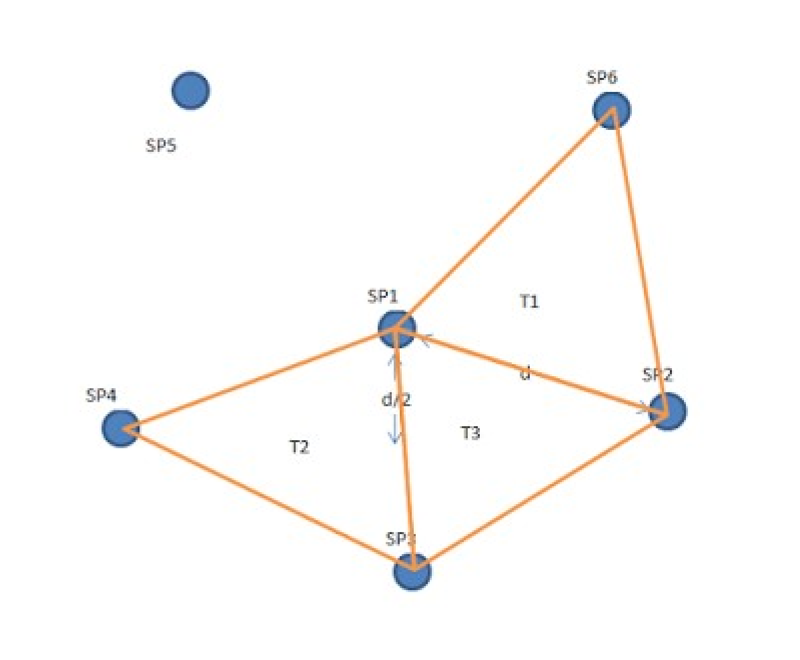
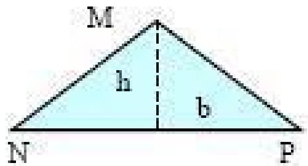
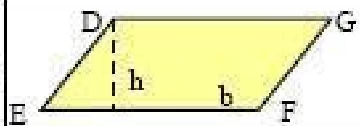
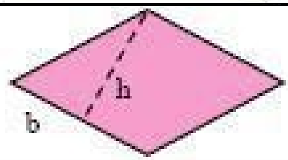
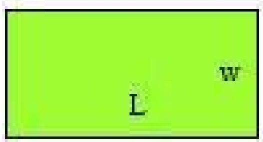
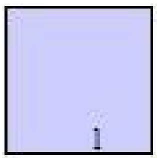
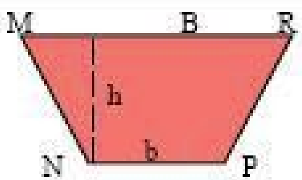
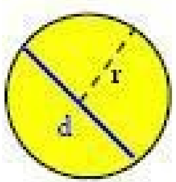
PLY3
SP3
PLY2

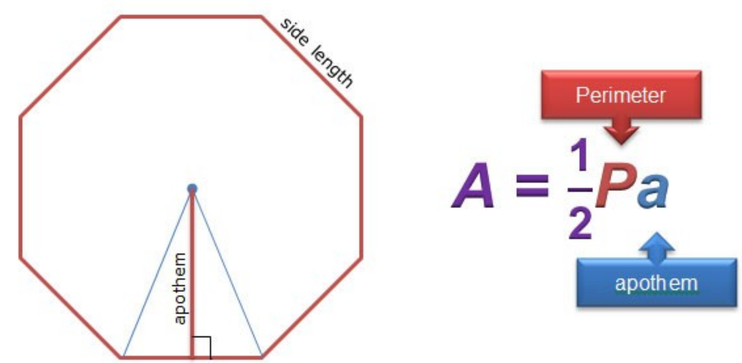

SP6
SP5
SP1
T1
d
SP2
SP4
d/2
T3
T2

Geo-statistical

- This technique involves the application of mathematics of random functions to the reconnaissance of mineral deposits. Usually this procedure entails these steps;

- Study of geologic controls on mineralization and any zones of the deposit
- Computation of variograms (graphical correlation of mineral characteristic) for each geologic zone
- Division of ore body into matrices of blocks for kriging (calculation of block grade related to adjacent samples); blocks are then classed as measured, indicated and inferred
- Estimate of tonnage and grade of each block at given cut-off-grade
- Printing of recoverable grade distribution plans by level or bench in the proposed mine.
- While there will always be doubts as to whether the added sophistication and cost are justified, geostatistics does provide a comprehensive suite of tools-not only to find the total ore reserve parameters but also, the distribution of recoverable grade throughout the deposit.

NAME	FIGURE	AREA	PERIMETER CIRCUMFERENCE
TRIANGLE		$A = \frac{b \times h}{2}$	$P=MN+NP+PM$
PARALLELOGRAM		$A = b \times h$	$P=DE+EF+FG+GD$
RHOMBUS		$A = b \times h$	$P = b+b+b+b$ $P = 4b$
RECTANGLE		$A = L \times w$	$P = L+w+L+w$ $P = 2L+2w$
SQUARE		$A = l^2$	$P = l+l+l+l$ $P = 4l$
TRAPEZOID		$A = \frac{(B+b) \times h}{2}$	$P=MN+NP+PR+RM$
CIRCLE		$A = \pi r^2$	$C = 2\pi r = \pi d$



RESERVE ESTIMATION METHODS

For moderately to steeply dipping tabular ore body

- Cross section method
- Longitudinal section method
- Level plan method

For bedded/ horizontal or low dipping deposits

- Included area method
- Extended area method
- Triangle method
- Polygon method
- Method of isoline
- Isopach maps method

CLASSIFICATION & CATEGORISATION OF RESERVES

In India, GSI standardized the terminology of ores & Mineral resource Classification.

- In practice in India since 1981.
- Later standardized by Bureau of Indian standards (BIS) in 1989.
- **This system was followed in the (National Mineral Inventory) NMI database created by IBM.**

Type of Reserve

- **Developed**
- **Proved**
- **Probable**
- **Possible**

PROBABLE RESERVE

A. Estimates made on the basis of measurements from widely spaced sampling points and exploratory openings(borehole/ pit/ trenches) with reasonable extrapolation on geological grounds.

B. The shape, thickness variation, likely persistence, geological structure are broadly known. Some information on mineralogy, petrography of the host rock and wall rocks, ore dressing characteristics.

C. The error of estimation of tonnage should be in the range of 20-30 %.

D. This category implies a clearly lower status to the ore reserve in terms of degree of assurance, in spite of being still within the direction of economic considerations.

Possible Reserve

The Possible Reserve have the following characteristics:-

A. The grade estimate of a possible reserve is a broad indication of the likely quality.

B. The possible reserve contains only very general information on the mode of occurrence of geological structure and ore behavior.

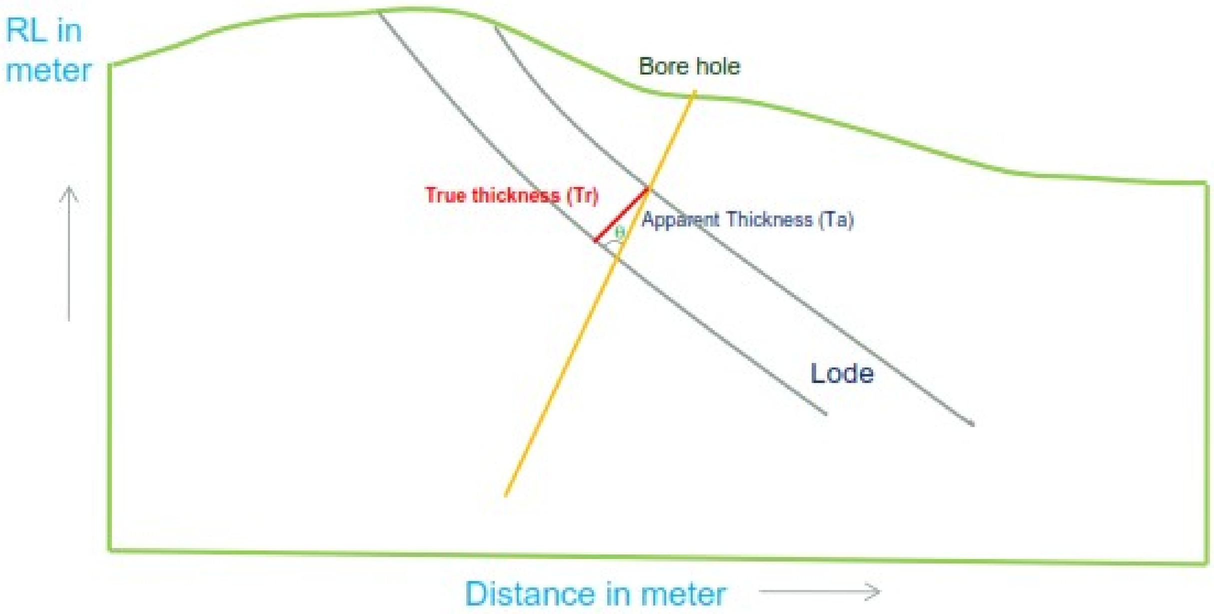
C. The 'Possible Reserve' may have an error level of 30 to 50 %.

COMPARISON OF CONVENTIONAL INTERNATIONAL AND NATIONAL CLASSIFICATION SYSTEM (1980)

U.S.G.S/ U.S.B.M CLASSIFICATION			U.S.S.R CLASSIFICATION			NATIONAL CLASSIFICATION		
Category	Purpose	Permissi. Error	Category	Pourpose	Permissi. Error	Category	Purpose	Permissible Error
			A	Production planning Mine protection	15-20 %	Developed	Production planning and ready for mining	0-10 %
Measured		0-20 %	B	Estimating mining investment and planning of development of the deposit.	20-30 %	Proved	Investment decision mine planning	10-20 %
Indicated		20-40%	C_1	Long term development plans for projecting exploration needs.	30-60 %	Probable	Backup tonnage to proved reserves for investment decision for mine development/ likely geological reserve to decide on detailed exploration	20-30 %
Inferred	Planning for further explorati on		C_2	Planning further prospecting	60-90 %	Possible	First quantitative approximation for planning for national resources survey	30-50 %

Thickness

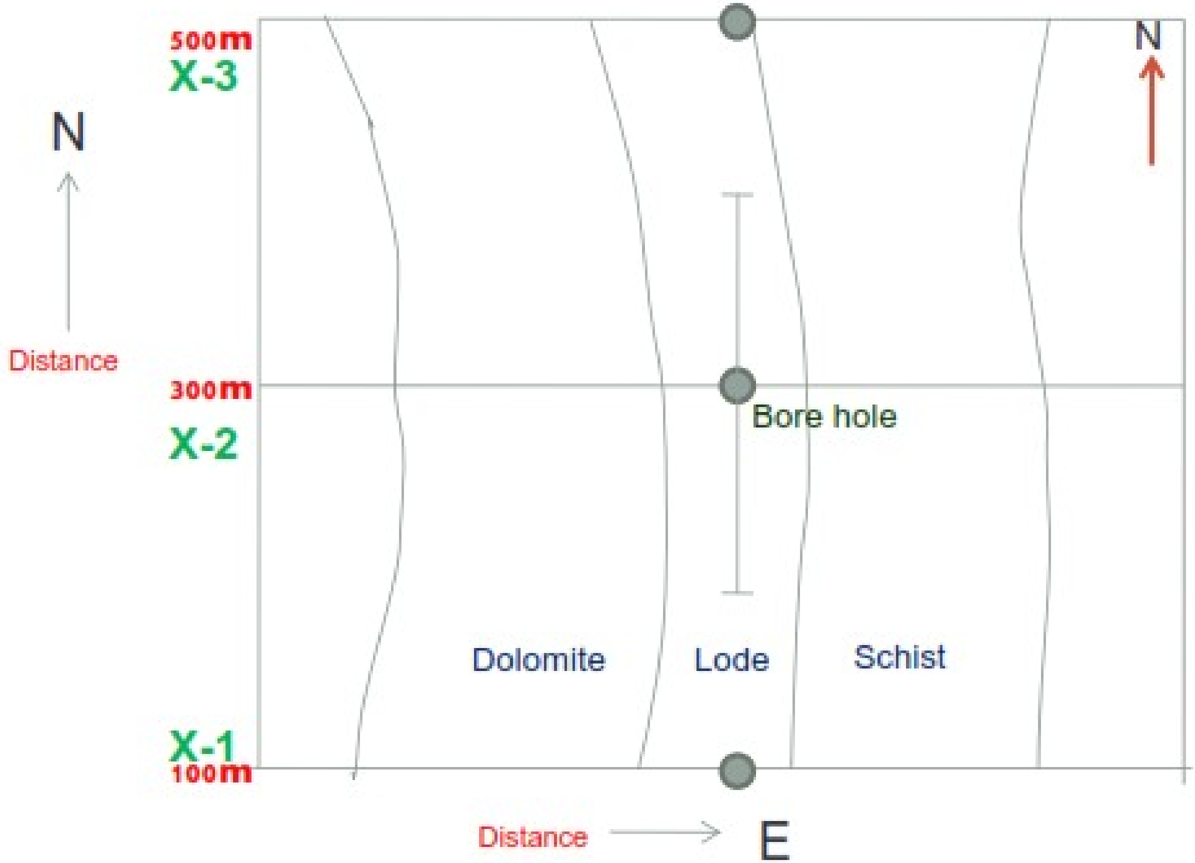
Thickness of the body is determined by computing the thickness of the lode in individual borehole,



$$Tr = Ta * \sin\theta$$

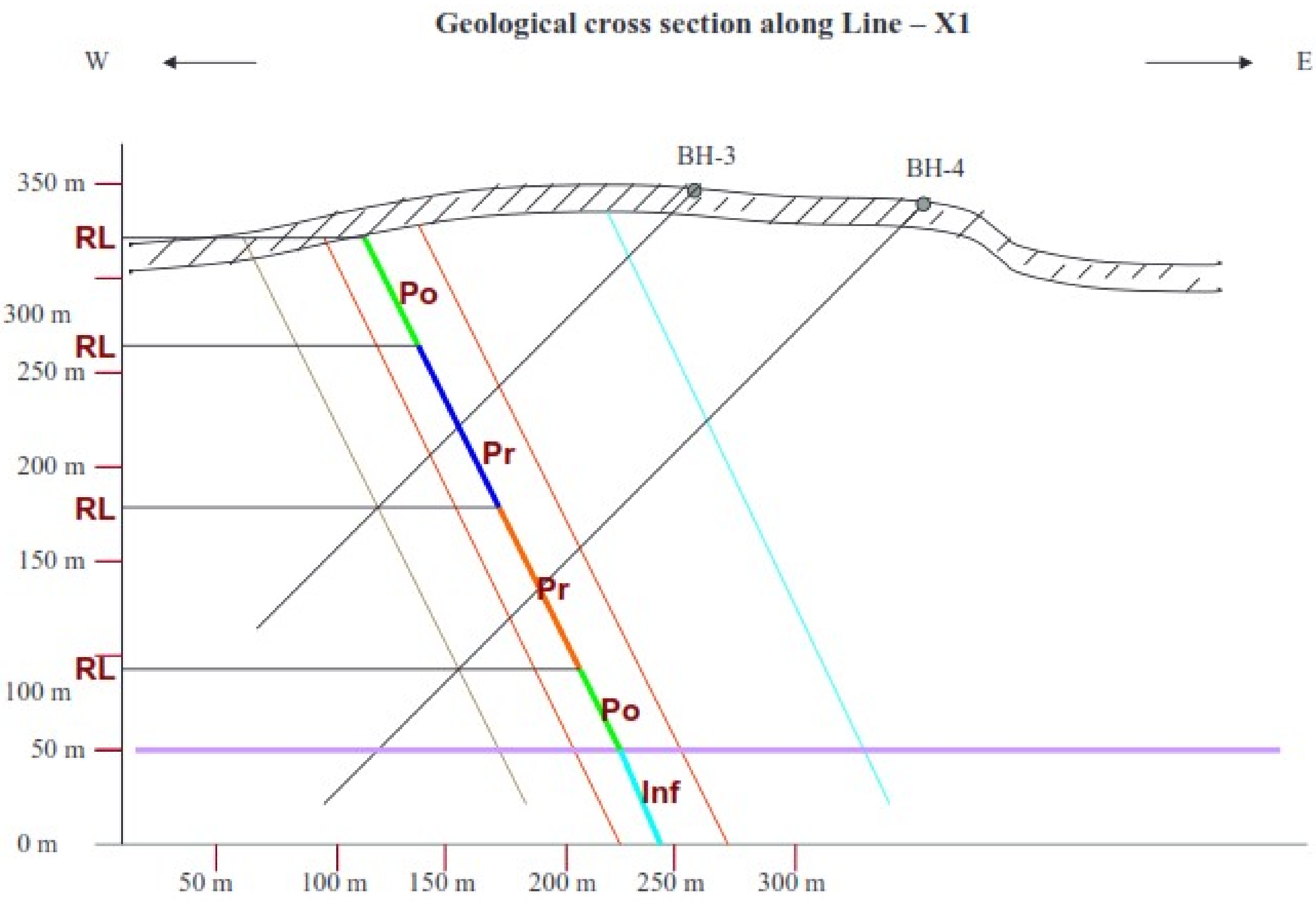
Tr = True thickness
Ta = Apparent thickness
θ = Angle between core axis and bedding plane

Strike length



Geological map

Dip length


Geological cross section along Line – X1
W
E
BH-3
BH-4
350 m
RL
300 m
RL
250 m
200 m
RL
150 m
RL
100 m
50 m
0 m
Po
Pr
Pr
Po
Inf
50 m
100 m
150 m
200 m
250 m
300 m