Mineral Exploration
Unit-2

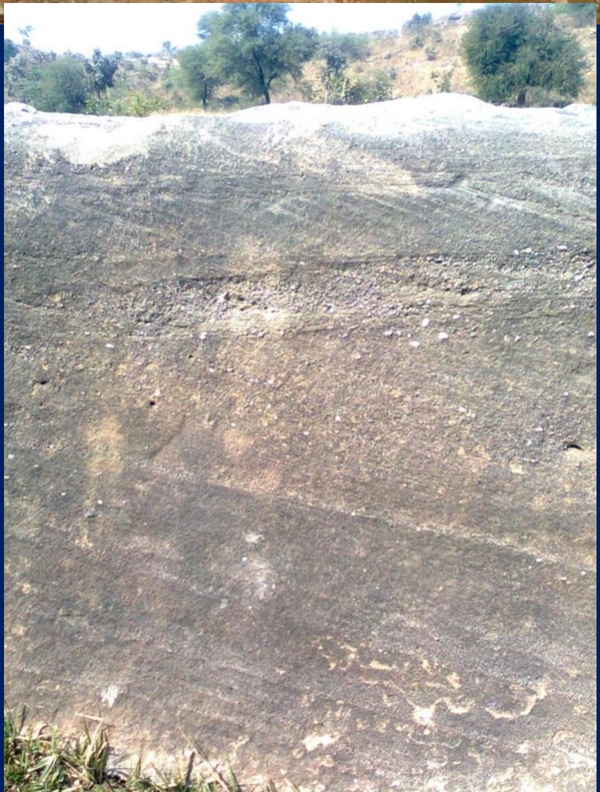
(Geological techniques and procedures of exploration)

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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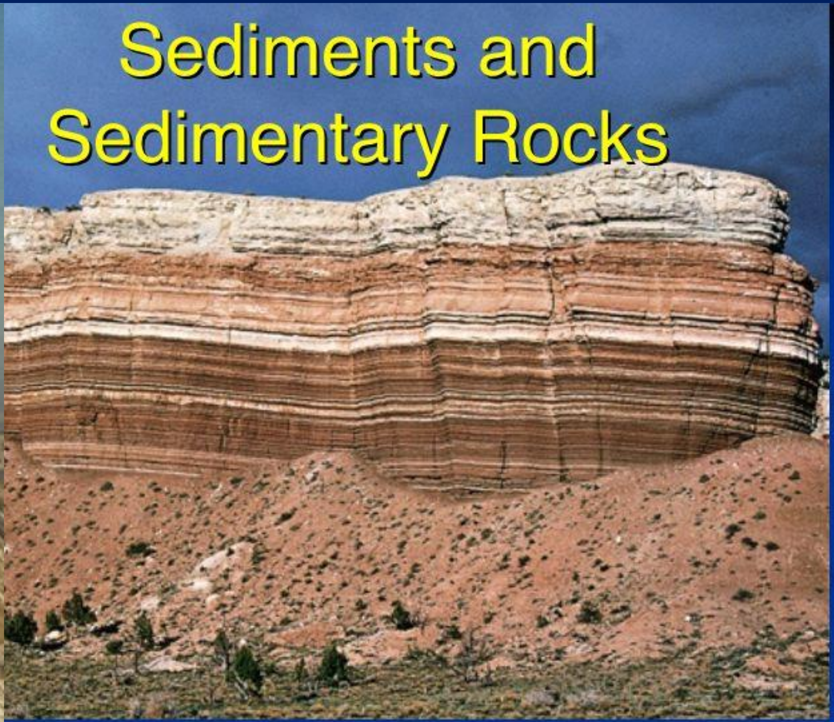
Sediments and
Sedimentary Rocks

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.

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)

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.

Channel or Groove or Trench Sampling

- It is the most accepted method of sampling which best suited to bedded, banded and vein type of deposits, this method consist of cutting channels across the face of exposed ore and collecting resulting chips, fragments and dust from each channels to make a sample. In some cases the channel may also be cut along a line making a small angle with thickness of deposit The process involves the following steps.


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.

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

Chemical Composition

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.

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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

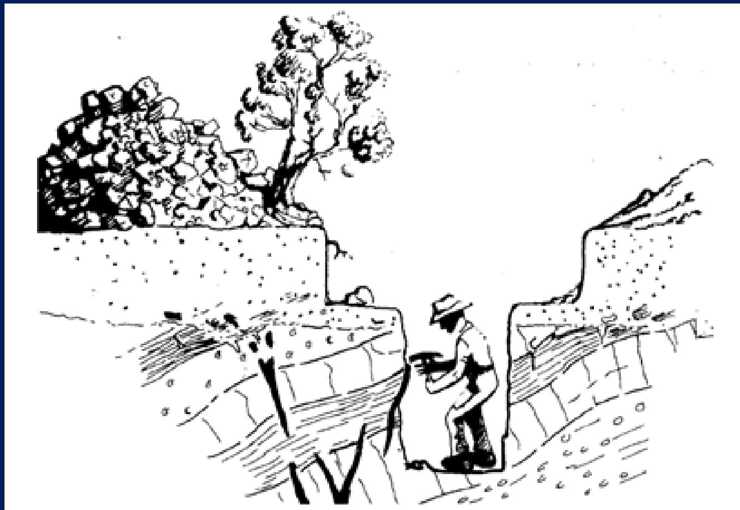
Water Sampling

- 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.

Pitting and Trenching

- Pitting and Trenching can be done where the soil thickness is high.
- Pits are shallow, square shaped holes while trenches are longer, linear and variable in depth.
- Simplest and least expensive method for deep sampling.
- Detailed geological logging can be carried out.
- Undisturbed and fresh sample can be collected.

Trenches and pits are excavated or blasted into the rock to expose mineralized zones for sampling and testing.



- 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 labour 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.

Pitting is usually employed to test shallow, extensive, flat-lying bodies of mineralization.

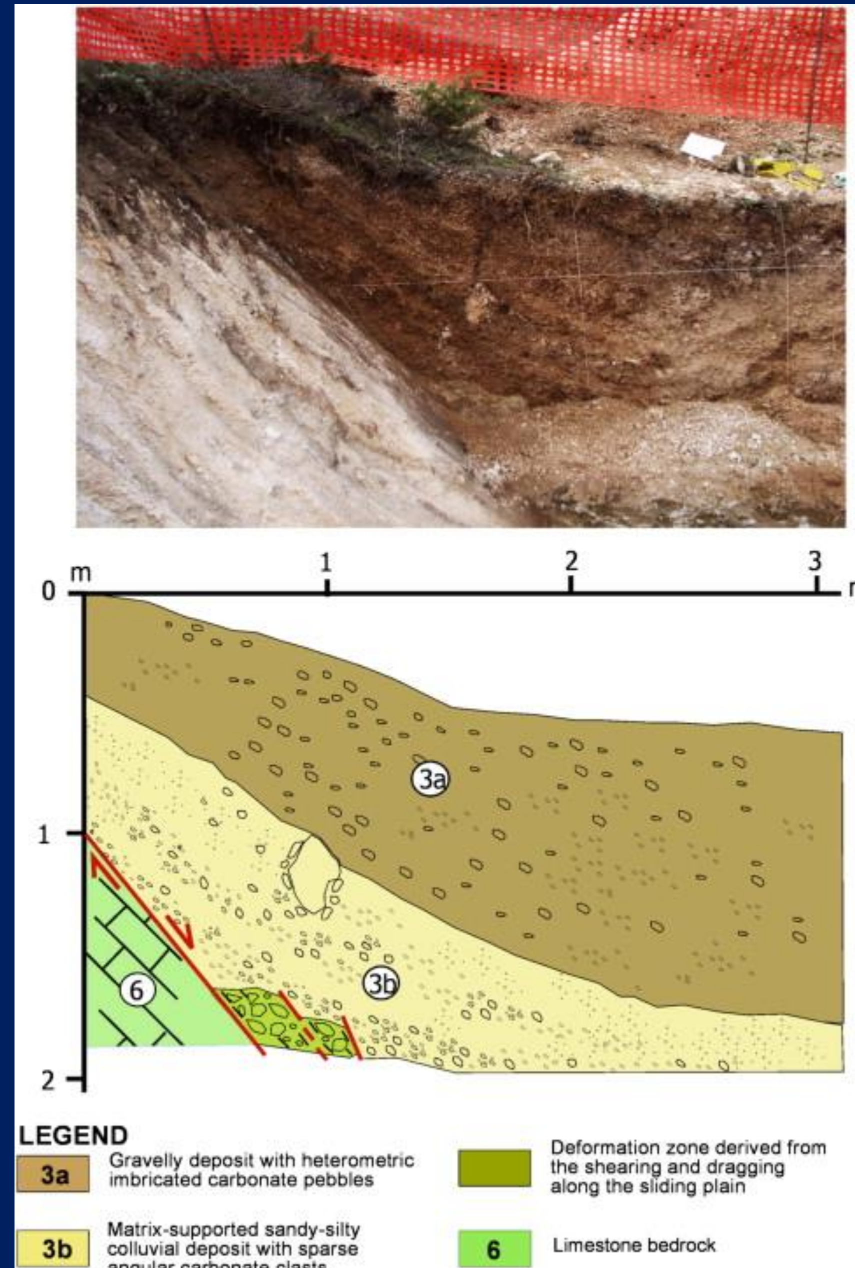
Pitting

- 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.


m
0
1
2
3
m
0
1
2
3a
3b
6
LEGEND
3a
Gravelly deposit with heterometric imbricated carbonate pebbles
3b
Matrix-supported sandy-silty colluvial deposit with sparse angular carbonate clasts
Deformation zone derived from the shearing and dragging along the sliding plain
6
Limestone bedrock

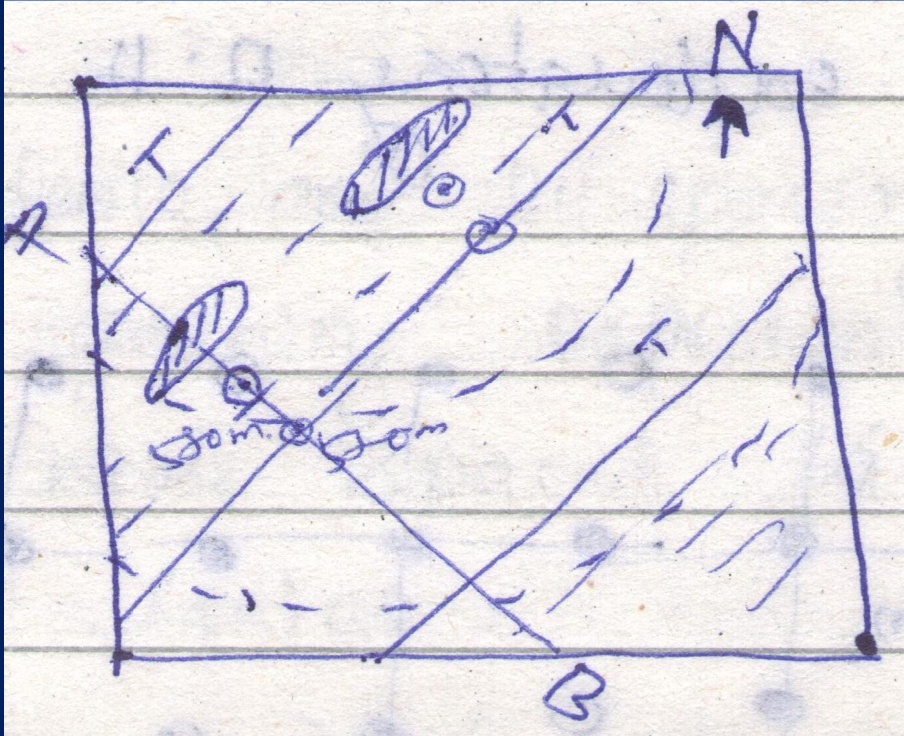
Exploratory Drilling

- 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.

Bore Hole Plan Contains

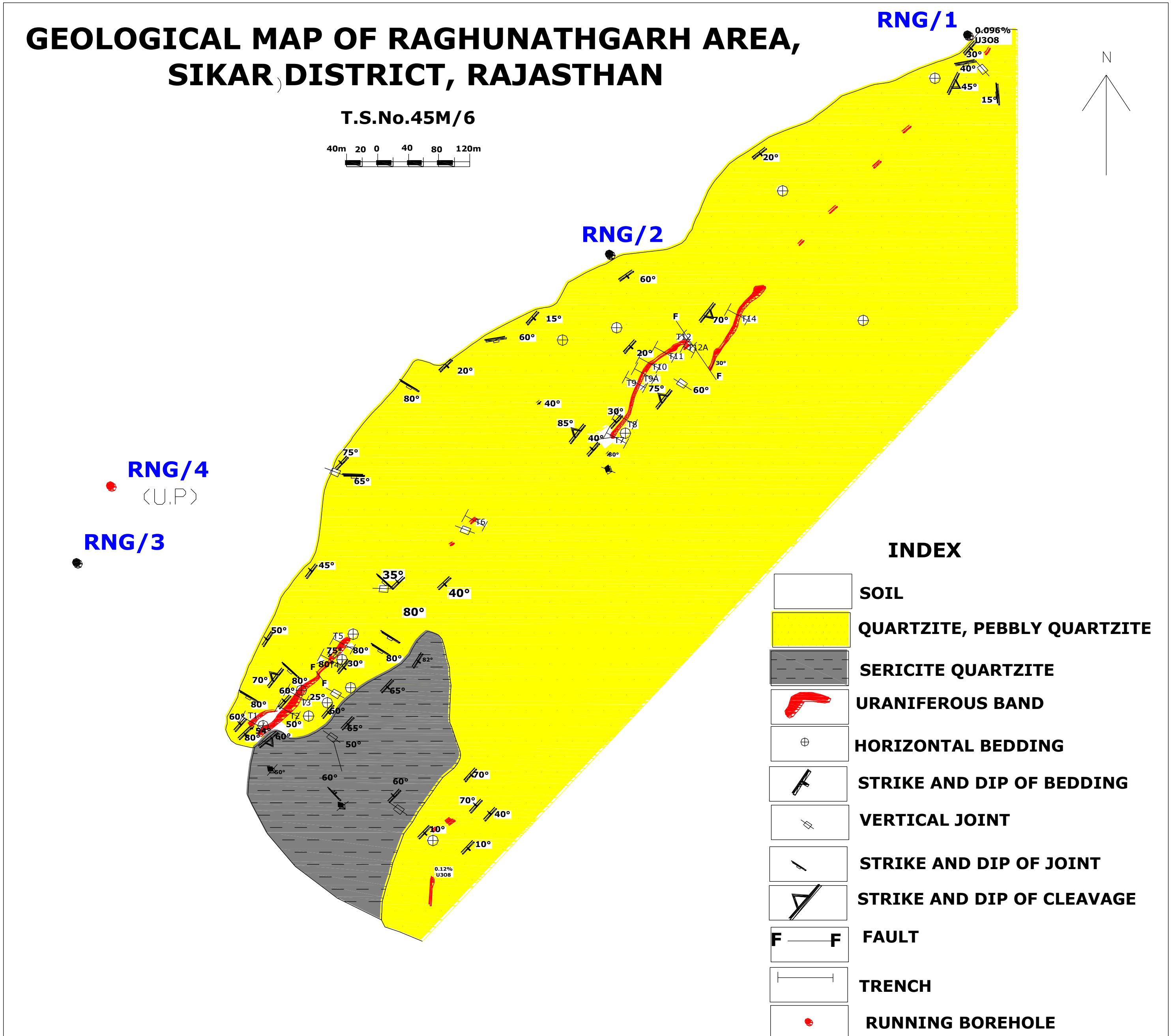
- Topographic features (surface contours, rivers, streams, road etc.,
- Geological map with ore body (If exposed)
- Bore hole numbers and their R.L

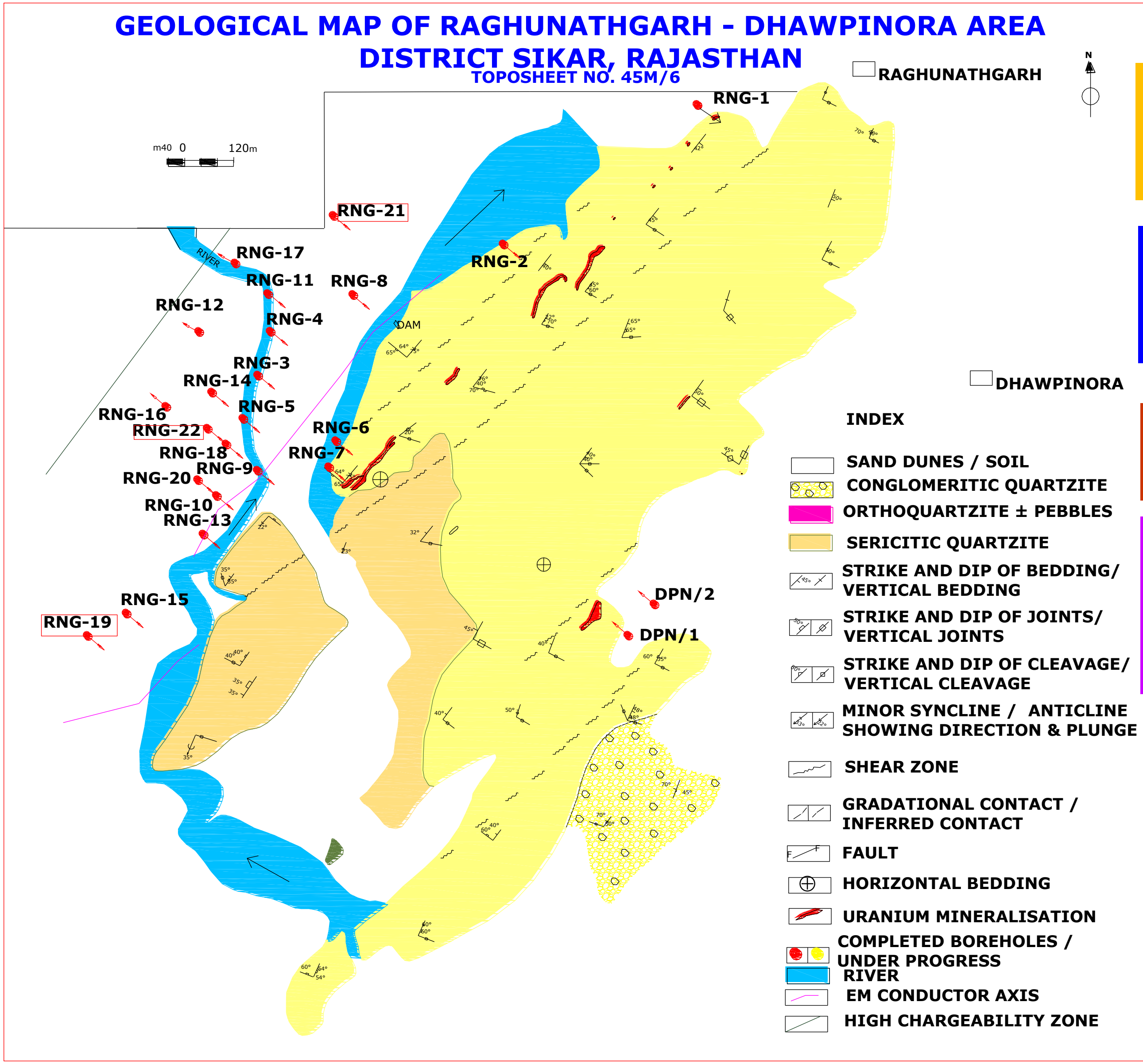
Bore Hole Plan



GEOLOGICAL MAP OF RAGHUNATHGARH AREA, SIKAR DISTRICT, RAJASTHAN

T.S.No.45M/6





OBJECTIVE

1. To explore the continuity of mineralisation intercepted in BH No. RNG/3 and 4

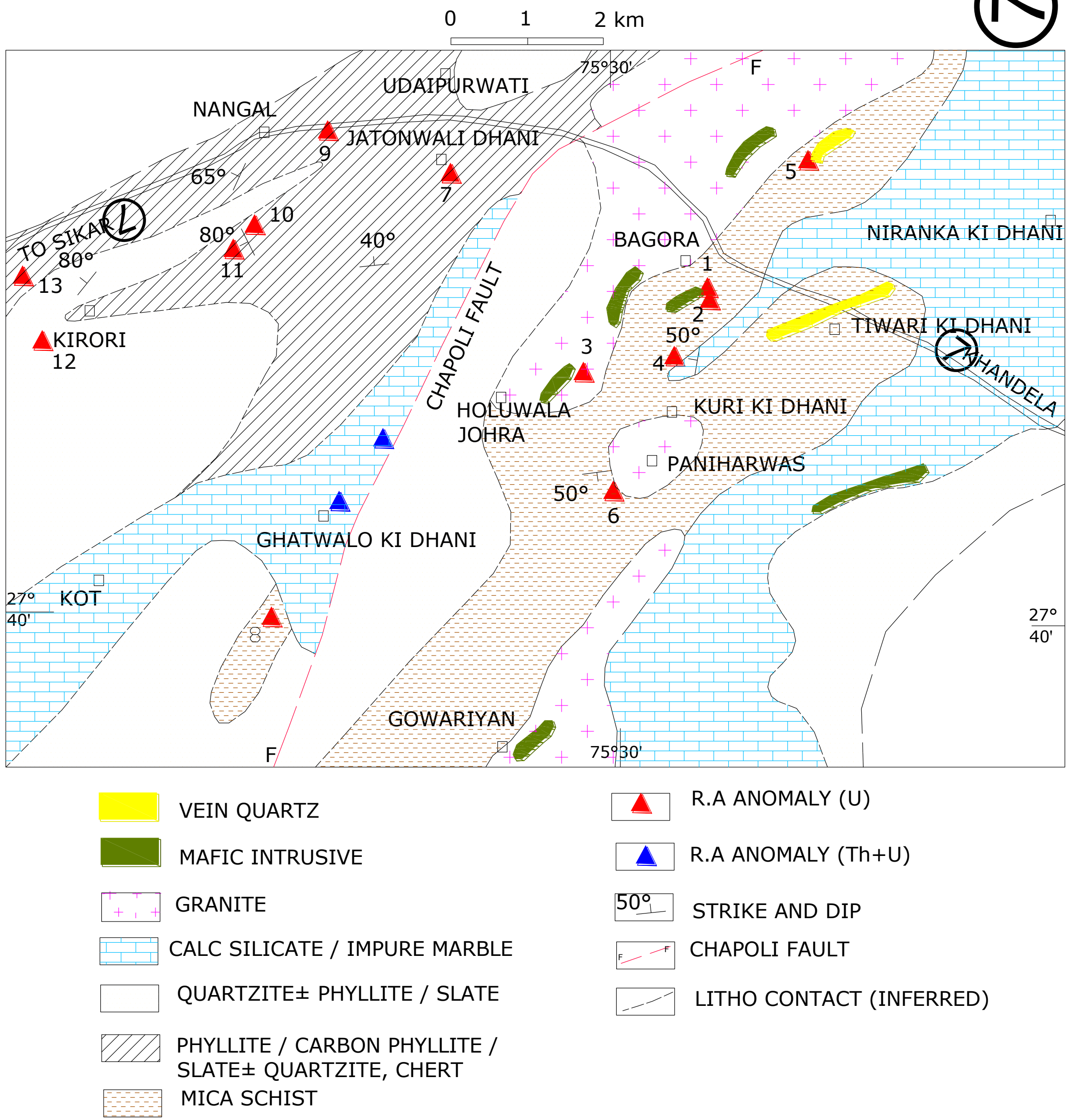
2. To exlore the sub surface continuity of surface mineralisation

3. To test the TEM conductors

4. To test the high chargeability and corresponding low resistivity zone

GEOLOGICAL MAP OF BAGORA-PANIHARWAS-KIRORI AREA DISTRICT JHUNJHUNU, RAJASTHAN

T.S. No. 45M/6 &10



Brannerite crystals associated with albitite vein in mica schist near Bagora and in granite near Kuri ki Dhani assayed 37.0-43.6% U_3O_8 and 3.4-6.9% ThO_2 (n=3).

Well dump samples of brecciated Feldspathic / silicified rock from two wells near Paniharwas assayed uraniferous values upto 0.150% U_3O_8) with negligible Th.

1km SW of Paniharwas, radioactivity in albitised mica schist, over an area of 200x90m (intermittent) (upto 0.188% U_3O_8 and 0.011% ThO_2.) Impure Marble with development of pyroxene crystals over 90x16m area has recorded 0.970% U_3O_8 and 0.073% ThO_2.

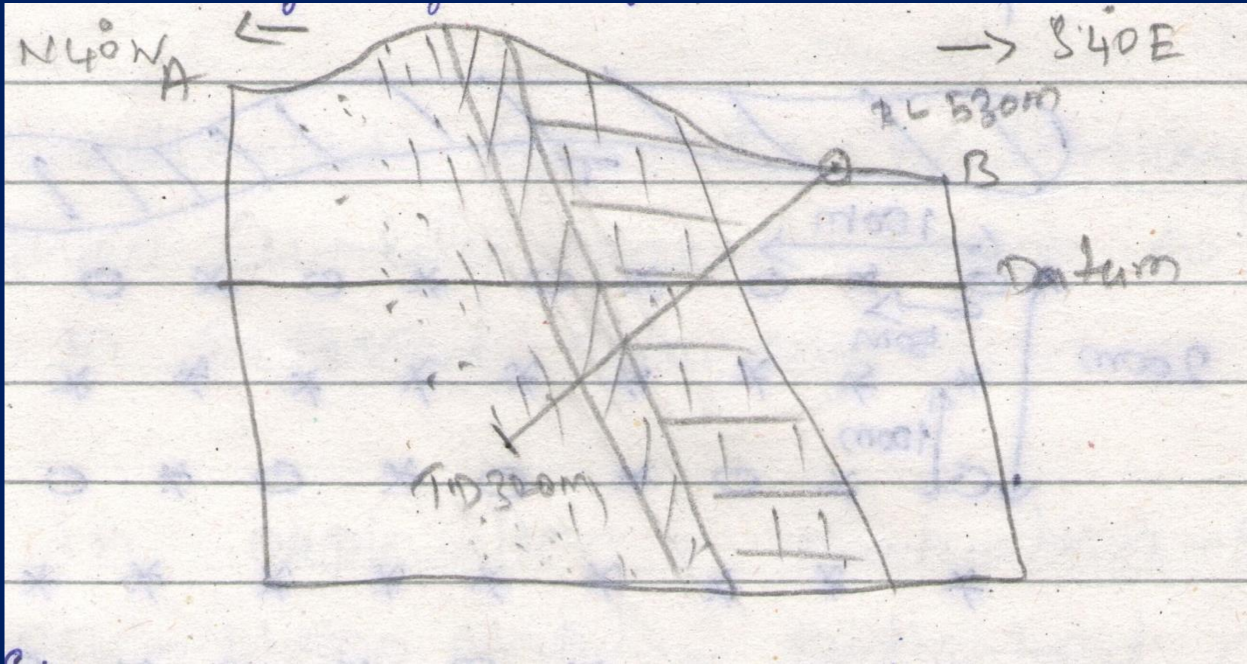
Uranium values (0.056% U_3O_8) near Jatonwali Dhani recorded in the Brecciated calc-silicate rock earlier. In the Kirori area radioactivity (upto0.139%U3O8) associated with Metasediments in contact with basic rocks.

Hypothetical Transverse Section

Before a B.H starts, cross section drawn through proposed B.H that indicates

1. Anticipated depth and continuity of mineralisation
2. Other geological features like Lithology, Structures, etc

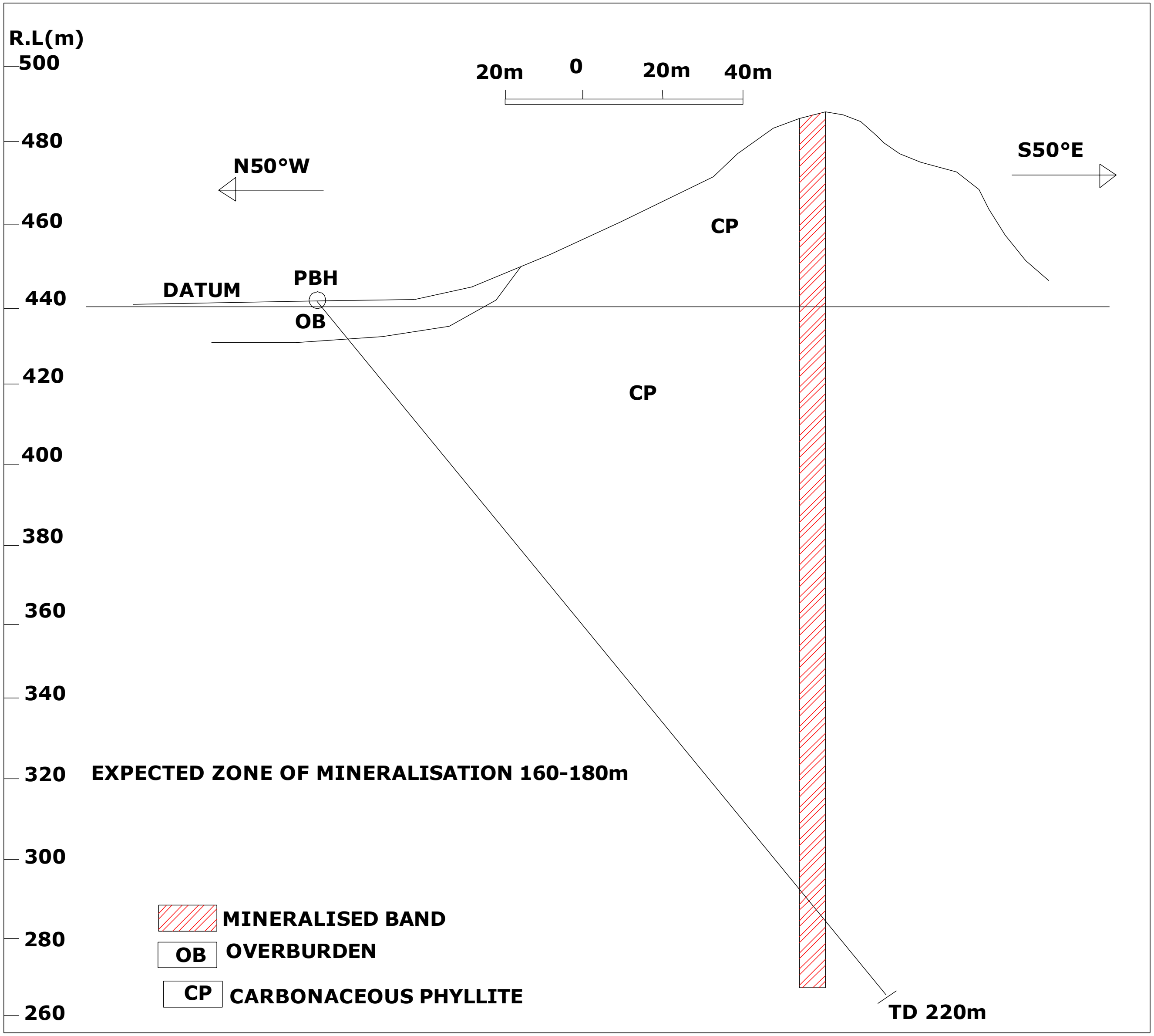
Hypothetical Transverse Section



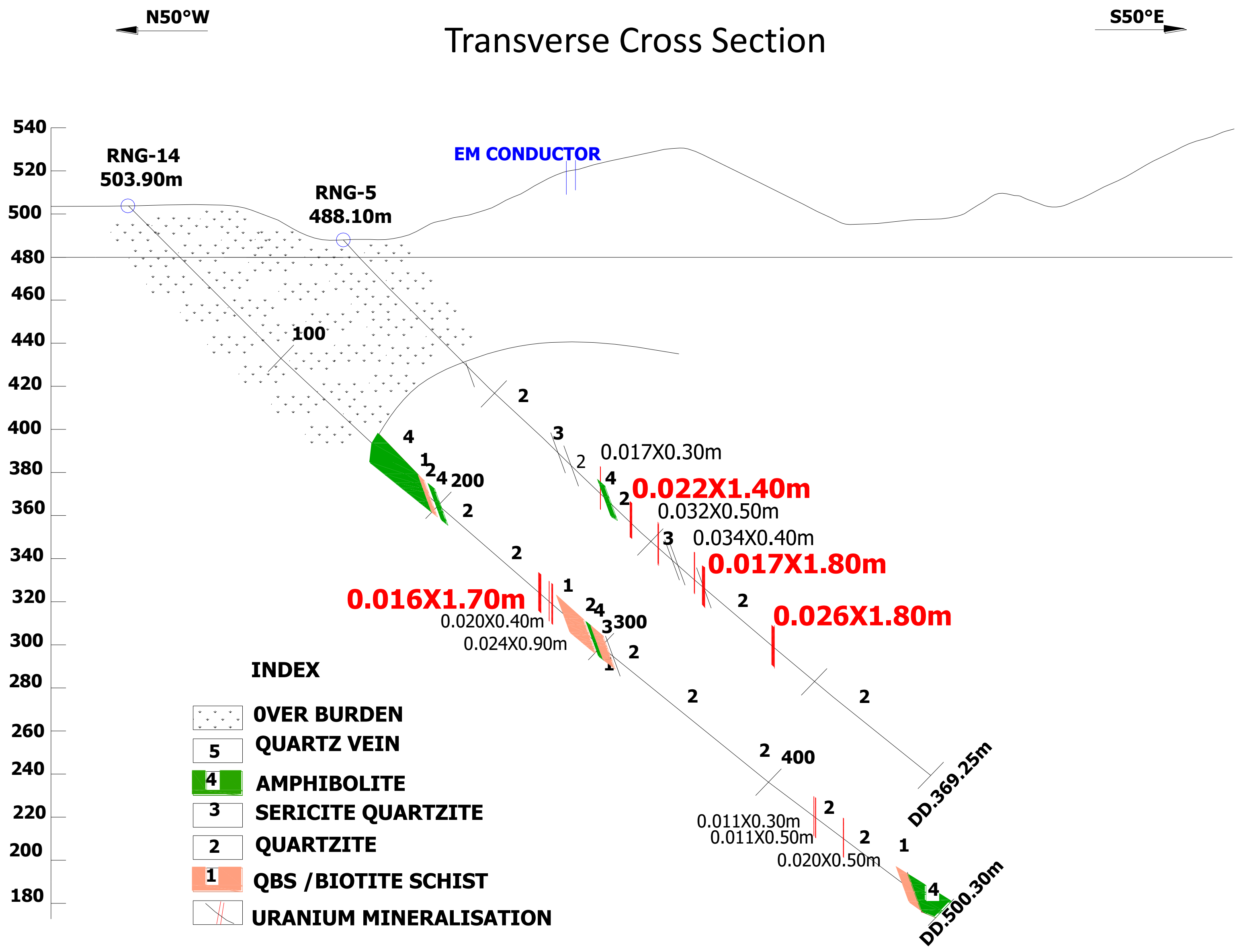
Steps to be followed

1. Draw Profile
2. Place the bore hole with R.L
3. Give appropriate angle and trace the B.H course up to the target depth.
4. Plot the anomaly/mineralisation and extend it along the dip till it crosses the B.H
5. Plot the litho contacts and extend it till it intercept the B.H

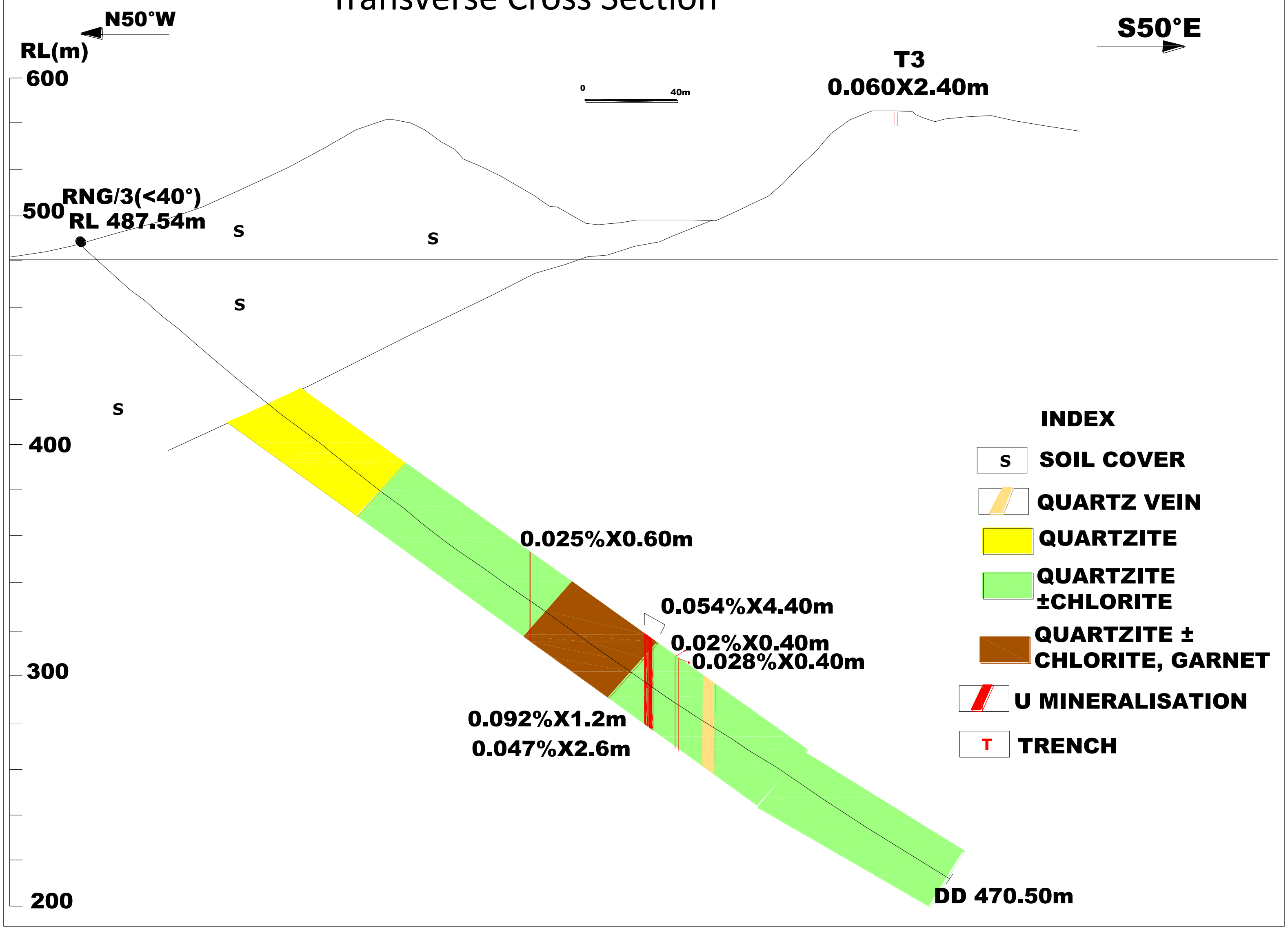
HYPOTHETICAL SECTION ACROSS MINERALISED ZONE,PAHADILA KI DHANI JHUNJHUNU DISTRICT,RAJASTHAN (T.S.No 45M/6)



Transverse Cross Section



Transverse Cross Section



From(m)	To(m)	Lithology
0.00	102.50	Sandy overburden
102.50	125.00	Quartzite
125.00	169.00	Phyllitic quartzite
169.00	256.00	Massive grey quartzite with presence of chlorite, sulphide, quartz and amphibolites veins.
256.00	302.00	Chlorite-biotite schist with garnet,minor phyllitic quartzite,sulphide along foliation plane
302.00	307.25	Grey quartzite with chloritic bands of 1-3 cm.disseminated sulphides
307.25	309.00	Dark grey massive quartzite
309.00	311.00	Grey quartzite with chloritic bands disseminated sulphides
311.00	320.00	Fine grained grey quartzite with sulphides(disseminated)
320.00	321.60	Grey-blackish quartzite with minor garnetiferous schist
321.60	323.00	Fine grained grey quartzite
323.00	332.90	Grey quartzite with minor chloritic bands disseminated sulphides
332.90	334.20	Fine grained grey quartzite
334.20	340.00	Phyllitic quartzite
340.00	344.60	Quartz vein
344.60	346.00	Grey quartzite with quartz vein
346.00	369.00	Chloritised quartzite
369.00	402.20	Garnetiferous chloritised quartzite
402.20	408.30	Chloritised quartzite
408.30	415.50	Hard grey quartzite with pyrite and chalcopyrite
415.50	416.90	Amphibolite schist with minor calcerious veins
416.90	422.75	Grey quartzite
422.75	424.00	Sericitic quartzite
424.00	426.00	Quartz vein
426.00	426.50	Chloritic quartzite
426.50	430.15	White fine grained quartzite
430.15	445.35	Grey to black quartzite with sulphides
445.35	447.00	White quartzite
447.00	447.50	Amphibolite
447.50	466.50	Grey quartzite with minor chlorites
466.50	[illegible]	Chloritised quartzite

What is the Objective of drilling?

❖To intercept the mineralisation in subsurface

❖To evaluate the size, shape, thickness and grade

❖ Collecting subsurface sampling.

❖Drilling helps in establishing ore reserve estimation

Types of drilling?

Coring: Core samples obtained from entire drill depth

Non-Coring: No core is recovered, only sludge (crushed rock cuttings) only produced.

Classification of drilling input

Startigraphic Drilling

Exploratory Drilling

Evaluation Drilling

Startigraphic Drilling:

✓It is conducted in reconnaissance phase

✓Large area covered by widely spaced B.H (1km)

✓Delineating certain startigraphic horizon of specific interest by drilling.

Exploratory Drilling

✓It is conducted in well defined target area

✓ B.H spacing between 60 and 100m

✓Purpose of drilling iss to know the subsurface continuity of ore body, its geometry, grade, thickness and tonnage.

Evaluation Drilling

➢Intensive drilling

➢B.H spacing between 30m or less

➢Prerequisite for mine development

➢Increasing the reliability by intensive drilling.

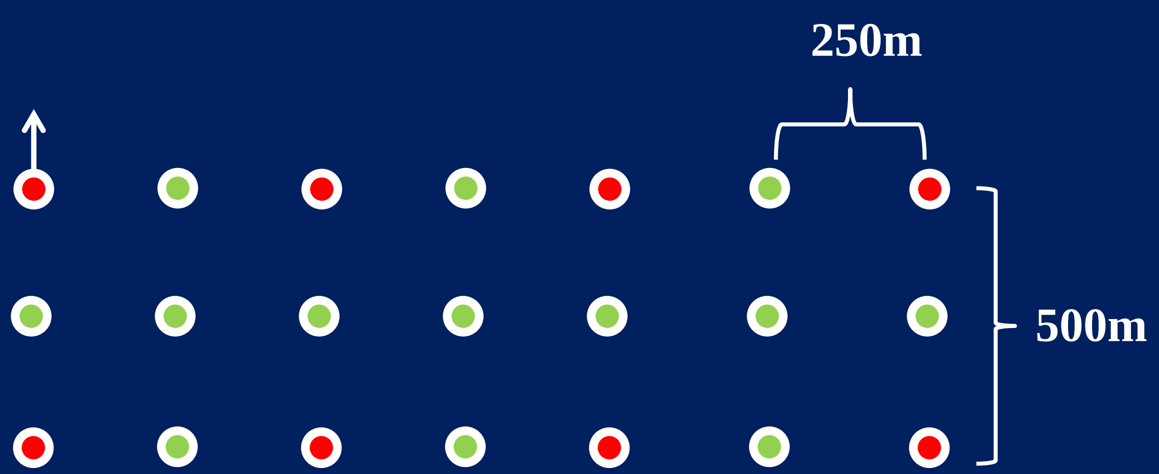
➢It is to define its shape and size precisely for the benefit of exploiting agency.

Pattern of Drilling:

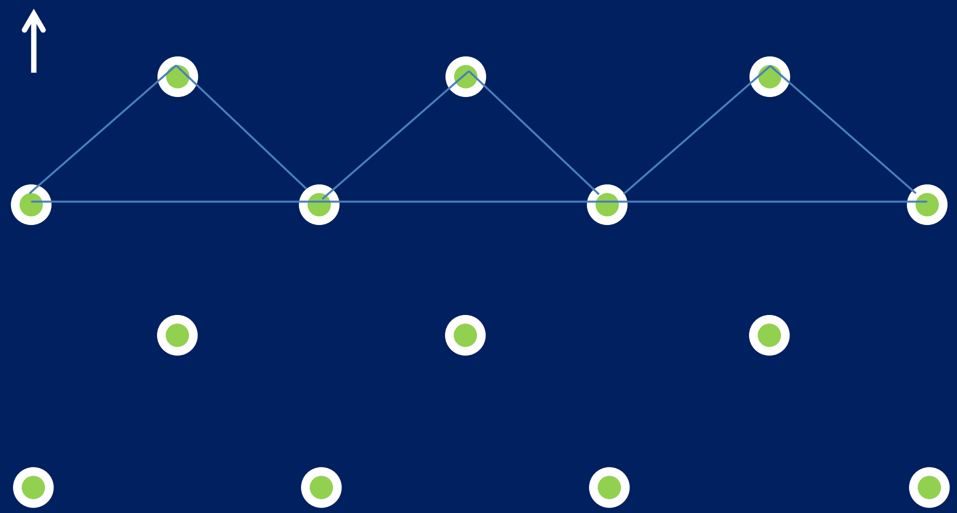
Triangular and square:

- 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)



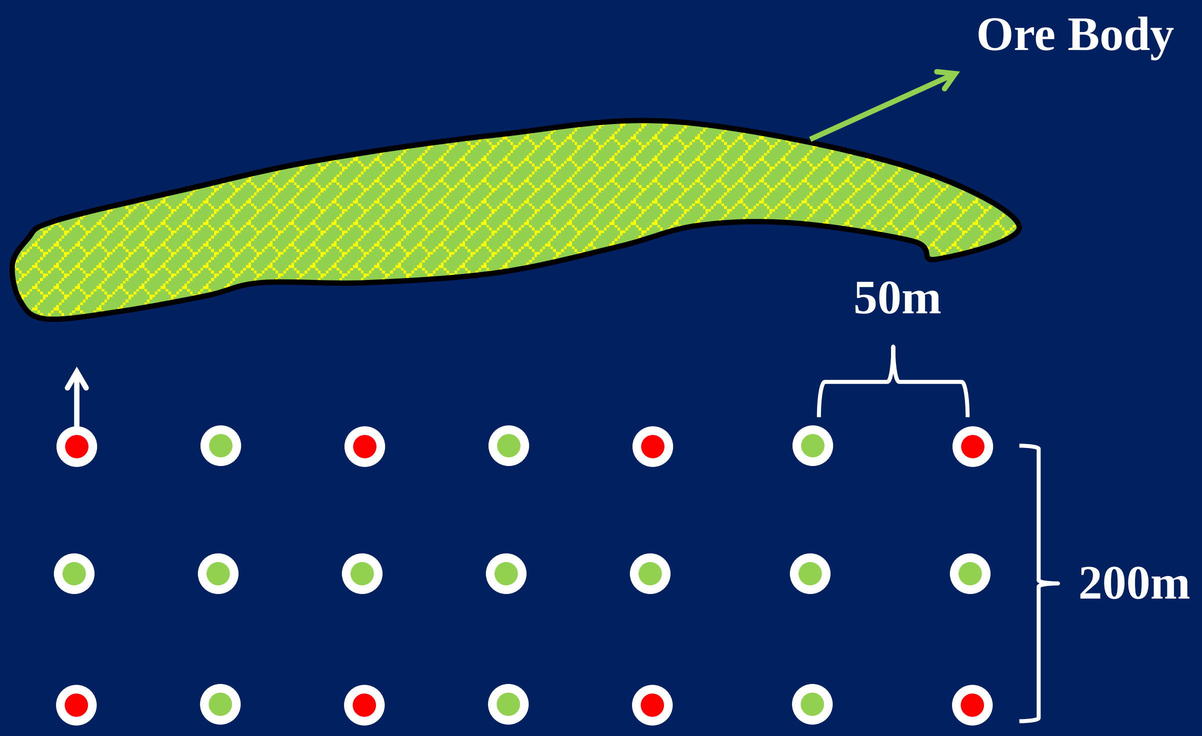
Rectangular Grid:

- 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

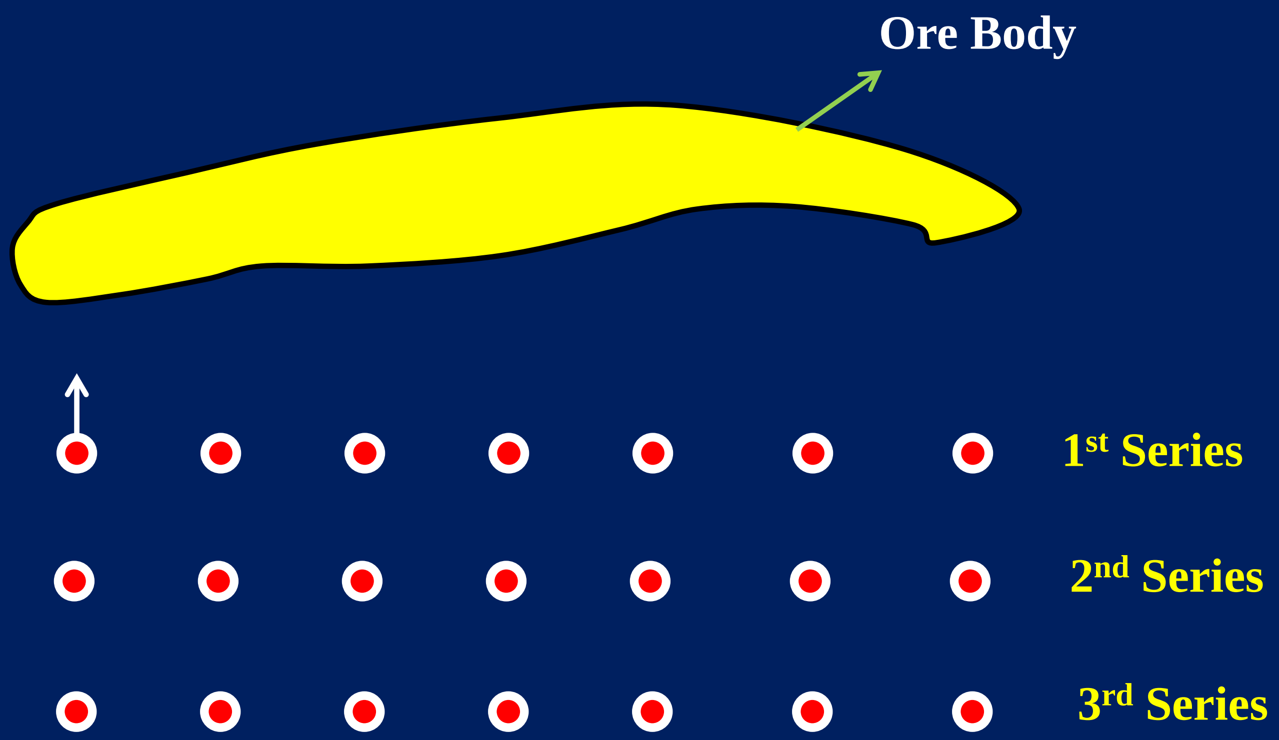
Random Pattern:

- 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



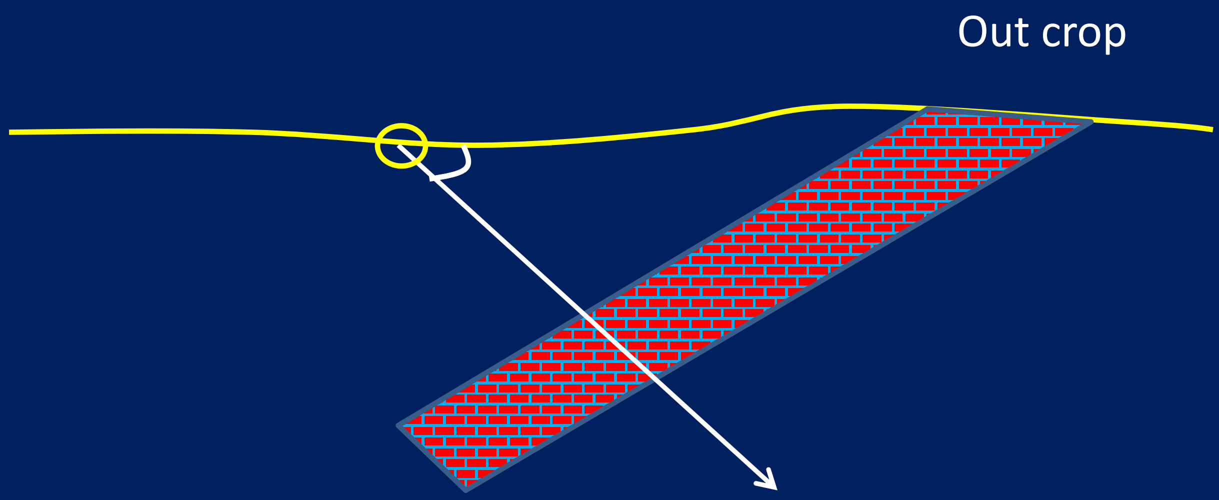
Borehole series



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

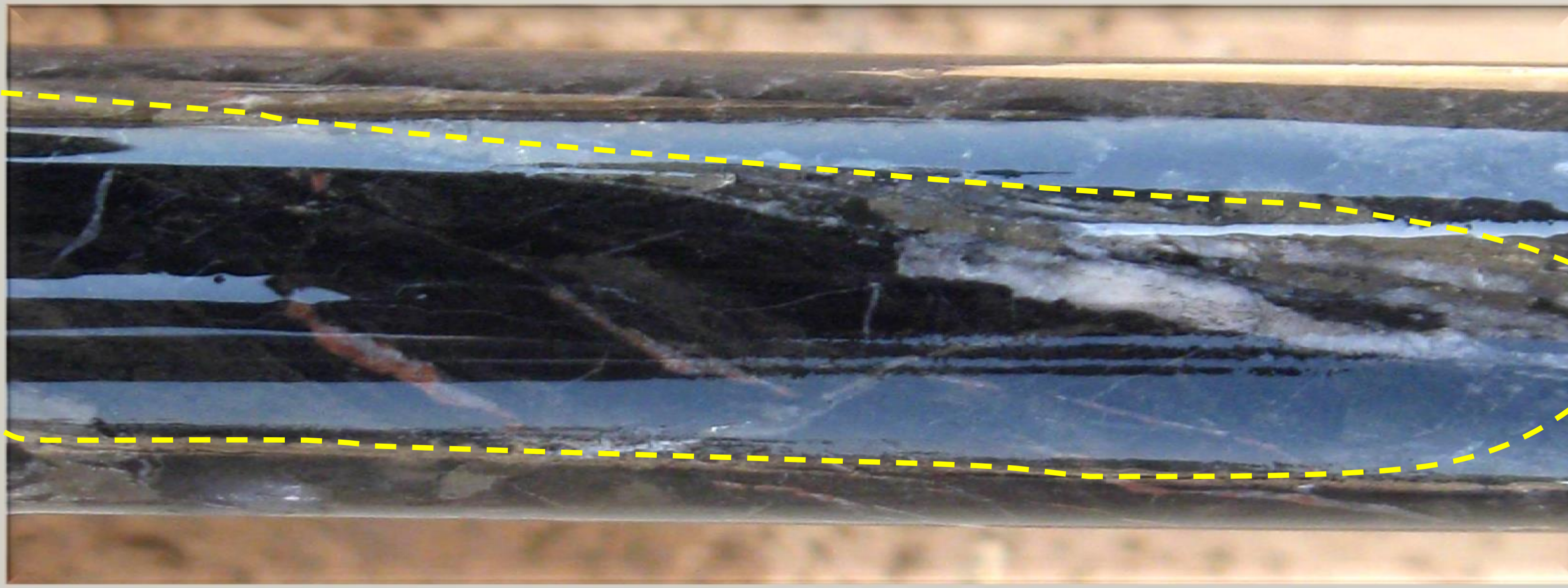
Logging – Depth wise

Core loss

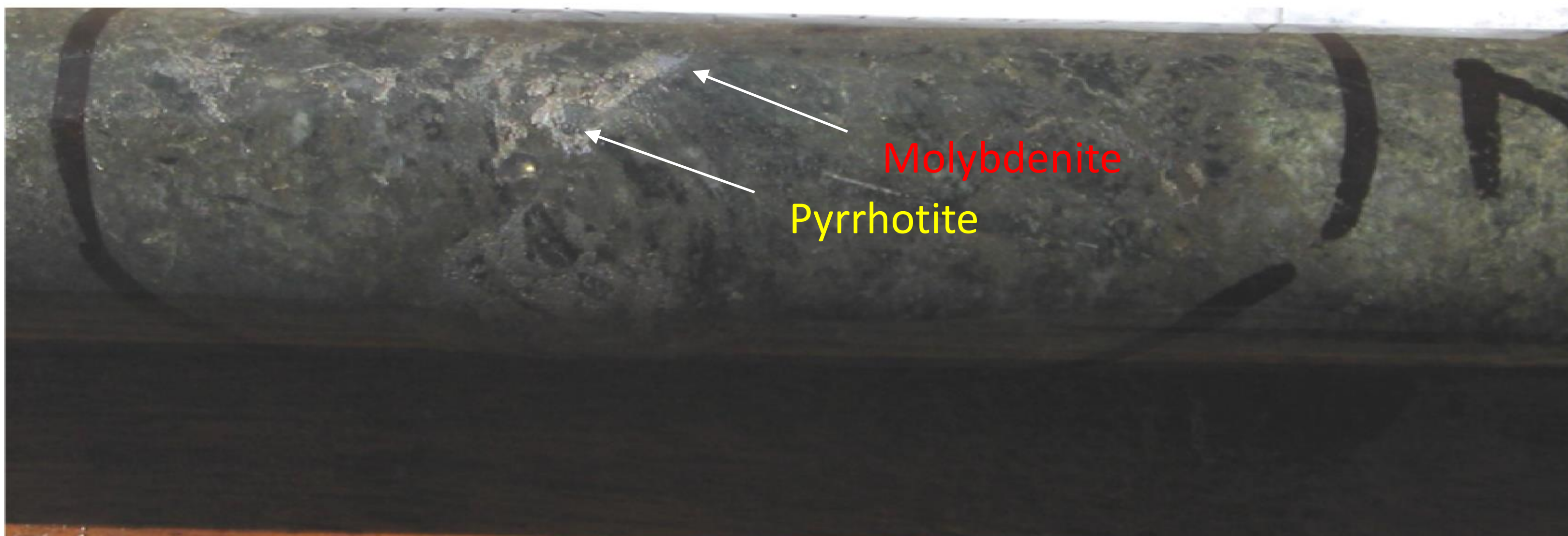
Core Box

Radioactive Core of Quartzite of RNG-18 at 288.50m (Part of the mineralised band of 0.119x5.70m)

Sulphides and brecciation at 202.30m in RNG/9 (Part of the mineralised band of 0.110x1.70m)



Borehole HKD/2 Pyrrhotite vein along fracture N5^{0}W / 75^0 E (COD) at 136.40m.Part of mineralised band 0.144 % eU3O8 x 13.10m (136.25-149.35m)



Borehole HKD/2Radioactive Core containing Molybdenite and Pyrrhotite at 141.05m. Part of mineralised band 0.144 % eU3O8 x 13.10m (136.25-149.35m)

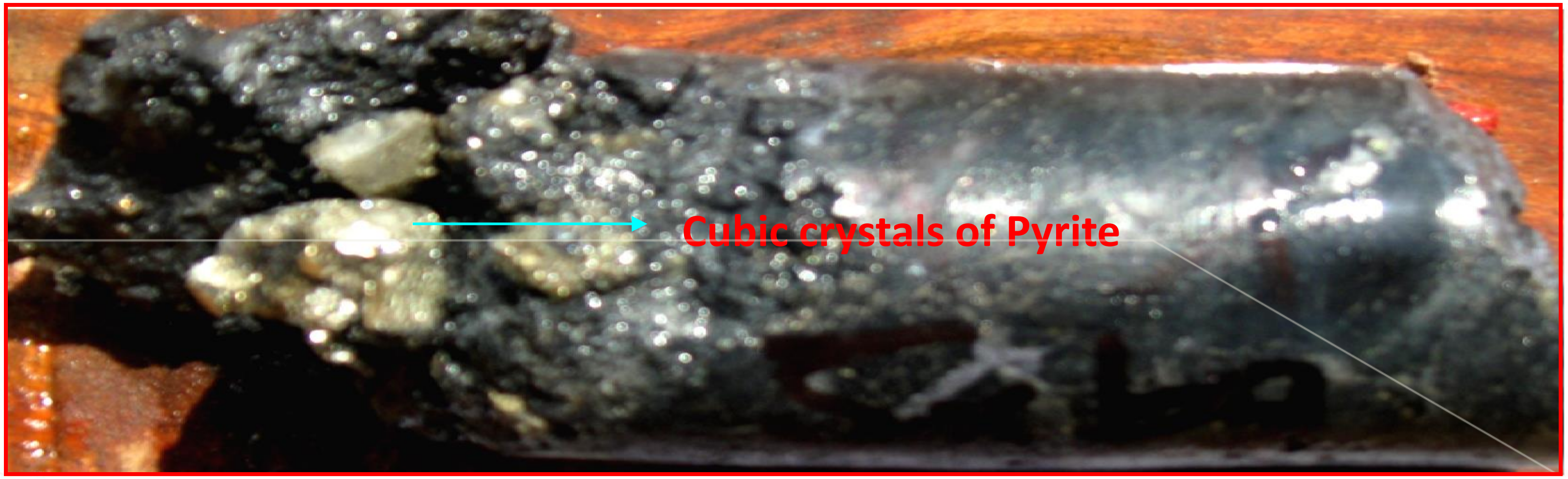
Borehole HKD/2 : Radioactive Core showing Albitised Schistose rock containing Pyrrhotite at 145.60m. Part of mineralised band 0.144 % eU3O8 x 13.10m (136.25-149.35m)

Borehole HKD/2 : Radioactive Core containing chunk of Pyrrhotite at 146.60m. Part of mineralised band 0.144 % eU3O8 x 13.10m (136.25-149.35m)

Borehole HKD/3 Radioactive Core showing Albitised Quartz Biotite Schist at 274.50m. Part of mineralised band 0.023 % eU3O8 x 1.90m (274.35-276.25m)

Borehole HKD/3 Radioactive Core containing Molybdenite and Pyrrhotite at 293.10m. Part of mineralised band 0.042 % eU3O8 x 18.10m (291.55-309.65m)

Borehole HKD/3 Radioactive Core containing Sulphides at 293.10m. Part of mineralised band 0.042 % eU3O8 x 18.10m (291.55-309.65m)



Borehole HKD/3 Radioactive Core containing chunk of cubic crystals of Pyrite in altered chloritised core at 297.70m. Part of mineralised band 0.042 % eU3O8 x 18.10m (291.55-309.65m)

Orientation marks – what the….?
Confusion due to methods used

- A Reflex tool indication mark for a good quality orientation looks like a bad Spear mark (bottom).
- It is imperative that the method of orientation is captured in the database.

OREFIND

Core logging

- Core logging is a highly specialized skill requiring careful observation and accurate recording of lithological, structural, mineralogical and stratigraphical information from the core samples obtained from drilling.
- Logging techniques are extremely useful, dependable, and accurate for identification of mineralisation extent, formation evaluation, and depositional environment analysis etc.

Core sampling

A core sample is a cylindrical section of naturally occurring substance. Most core samples are obtained by drilling with special drills into the substance, for example sediment or rock, with a hollow steel tube called a core drill.

Stratigraphic and Sedimentological Logging

A separate core logging sheet is used for each core run which included a brief description about lithology, stratigraphic and sedimentological observations such as:

- Rock type
- Rock colour
- Rock structure/texture
- Sedimentological features
- Alterations
- Fold/fault/fracture/shear
- Intrusive

weathering/alteration grade

- The *weathering/alteration grade* is a measure of how the core properties (i.e. strength, mineralogy, etc.) have been changed from their original form.
- Although these two characteristics are often paired together, it is important to make a distinction between weathering and alteration.

Colour and rock description

Colour and rock descriptions should be logged as part of the core logging procedure to identify the lithologies and alteration sequences encountered.

Such attributes include:

- Pattern
- Colour
- Grain size
- Texture
- Fabric
- Lithology
- Alteration

Discontinuity Logging

- Identification of individual *natural fractures* and *artificial breaks* (during drilling or handling).
- The natural fractures were identified as having a generally smooth or somewhat weathered surface with soft coating or infilling materials such as clay, gypsum, calcite, anhydrite, iron oxide.
- Rough brittle surfaces with fresh cleavage planes in individual rock minerals were considered artificial breaks.
- To be conservative, questionable breaks along weakness planes such as bedding planes were logged as natural fractures as long as there was no evidence of rough drilling conditions.

Number of discontinuities

- The number of geological discontinuities (fractures, joints, shears, bedding, etc.) within each interval is counted and recorded.
- Breaks in the core from the process of drilling or boxing the drill core (mechanical breaks) are not included in this count.

Cont……

Mechanical breaks are identified by sharp core edges at the break and will often have clean breakage surfaces with no infilling and no discolouration. If the cause of the break in the core is in doubt, treat the break as a natural feature and include it in the discontinuity count.

Strength grade

- The *strength grade*, sometimes referred to as *hardness grade*, is a field estimate of the strength of the intact material.
- It is important to use your hands, knife and rock hammer when estimating the strength of a sample.

- A single value should be used for the strength grade.
- If the grade within the interval ranges from one hardness grade to another, use half values.
- If the hardness is extremely variable, consider splitting the run into two or more intervals to accurately capture the variability.

Discontinuity description

Engineering in rock provides different challenges than those faced when using soil or concrete as engineering materials because rock is a discontinuous material: the rock mass is made of blocks defined by joints, bedding, faults, etc. (discontinuities).

Discontinuity depth

The discontinuity location should recorded as the total downhole distance along the core from the collar or other zero reference point used for the program (drill deck, top of *stick-up*, ground surface) to the intersection of the structure with the core axis to the nearest centimeter.

Discontinuity orientation

The orientation of discontinuities encountered in a drillhole can be determined a variety of ways. The general concept is to mark the core with reference to a known direction or location (generally the top or bottom of the core or magnetic north), depending on the method used to survey the core hole, then measure the relative orientation of the discontinuities to the reference line.

Fracture Orientation Logging

- An apparent dip angle and apparent dip direction were measured for all natural fractures.
- The apparent dip angle, alpha, represents the angle between the core axis and the maximum dip of the core discontinuity and is therefore expressed as an angle between 0 and 90 degrees.
- The apparent dip direction, beta, is the angle measured clockwise from the black reference line to the bottom of the core discontinuity ellipse while looking down the core axis and is therefore expressed as an angle between 0 and 360 degrees.

Appropriate strategies include:

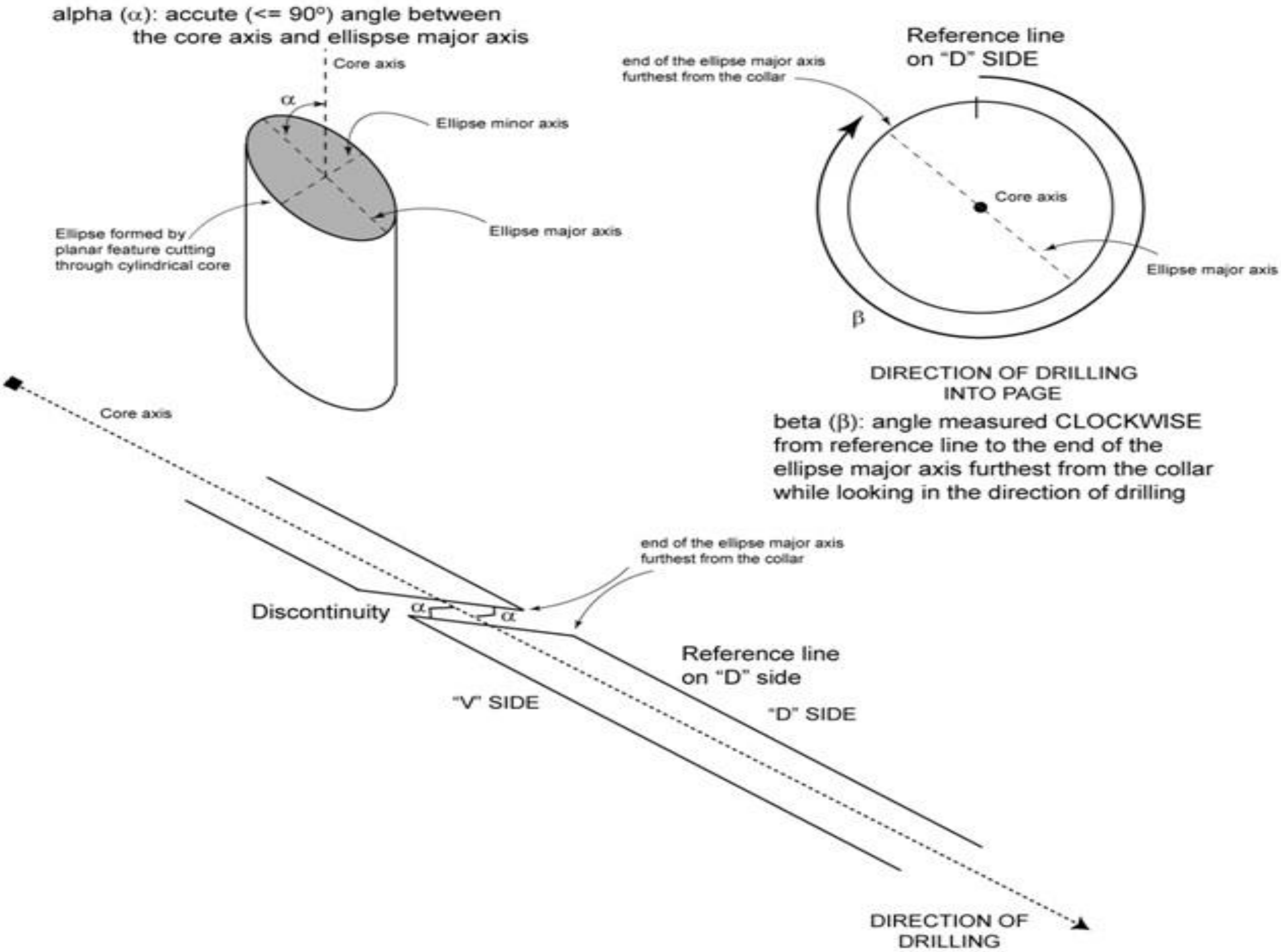
- Distribute core loss (or gain) over all intervals between the core blocks .
- Record the interval nearest the first core block as having the difference .
- Select the interval that contains the most fractured rock as having the difference .

Alpha and beta angles

For drilling programs where more traditional methods of core orientation are undertaken, the orientation of individual discontinuities and geological structures can be calculated by measuring the alpha (α) and beta (β) angles .

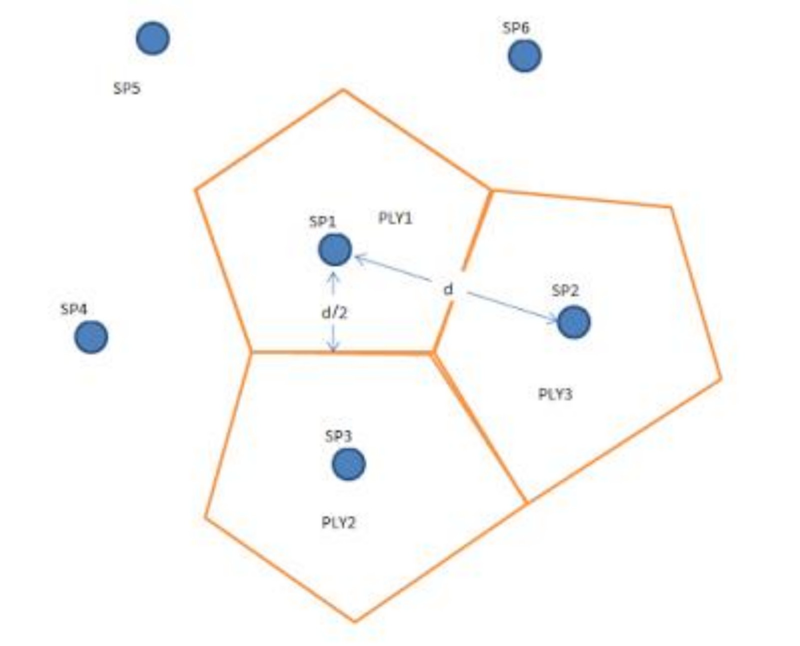
The *alpha angle* (α) is the angle of intersection of between the discontinuity surface and the core axis. This can be measured with protractor. The alpha angle is always a positive angle between 0^o to 90^o.

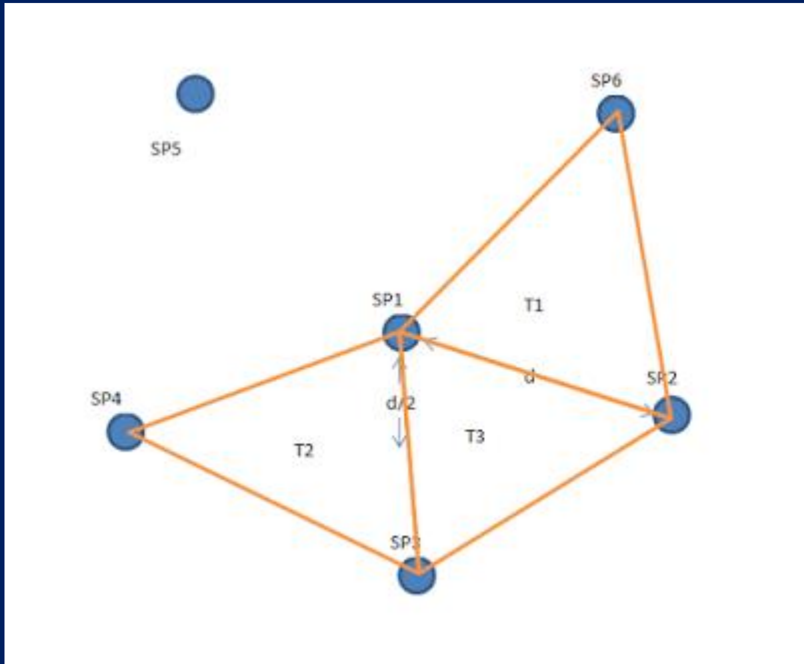
The *beta angle* (β) is measured around the circumference of the core, clock-wise from the reference line provided from the core orientation method.


alpha (α): accute (<= 90º) angle between the core axis and ellispse major axis
Core axis
α
Ellipse minor axis
Ellipse formed by planar feature cutting through cylindrical core
Ellipse major axis
Reference line on "D" SIDE
end of the ellipse major axis furthest from the collar
Core axis
Ellipse major axis
β
DIRECTION OF DRILLING INTO PAGE
beta (β): angle measured CLOCKWISE from reference line to the end of the ellipse major axis furthest from the collar while looking in the direction of drilling
Core axis
end of the ellipse major axis furthest from the collar
Discontinuity
α
α
Reference line on "D" side
"V" SIDE
"D" SIDE
DIRECTION OF DRILLING

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 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.

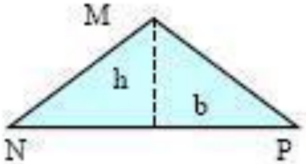
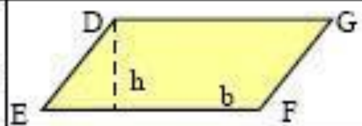
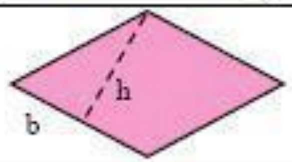
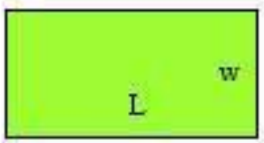
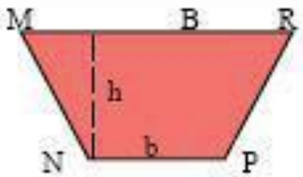
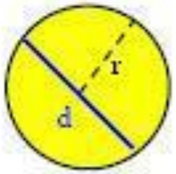

SP5
SP6
SP1
PLY1
d
SP2
SP4
d/2
SP3
PLY3
PLY2

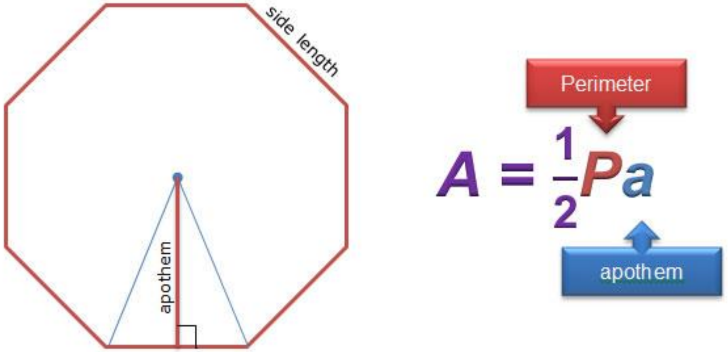

SP5
SP6
SP1
T1
SP4
d/2
d
SP2
T2
T3

Geo-statistical

- This technique involves the application of mathematics of random functions to reconnaissance the 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**

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 %

Inferred Category

✓Reserves estimated from the preliminary stage of exploration is falls under this category (widely spacing and 1:5000 to 1: 10000 map scale)

Indicated Category

✓Reserves estimated in exploration and evaluation stage (1:2000 to 1: 500 map scale)

Proved Category

✓Reserves estimated from exploratory stage (1:100 to 1: 500 map scale)

Ore Reserve Classification

Proved/ Measured

- ✓Reserves are identified resources in which
  - ✓Tonnage is calculated from dimension revealed in outcrop trenches, workings, drill holes. Grade is calculated from detailed sampling
  - ✓Sampling done very closely, geological characters are well defined, sizem shape and mineral content well established.
  - ✓Permissible error up to 20%
  - ✓Mining plan done on this basis.

Probable/ Indicated

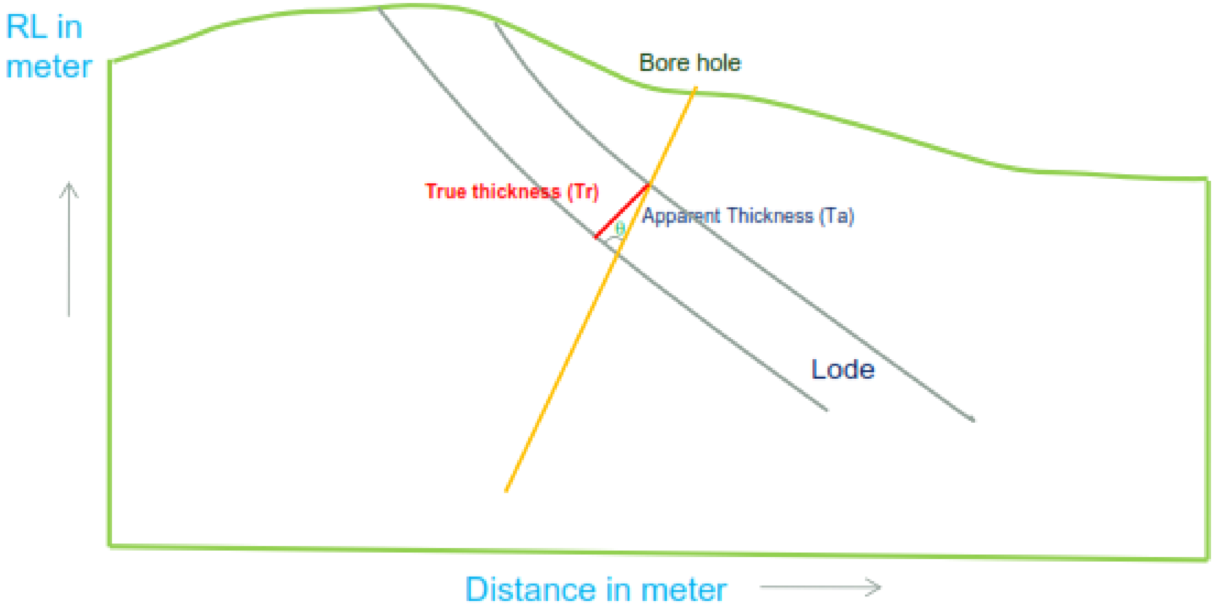
- ✓Reserves are identified resources in which
  - ✓Boreholes are widely spaced
  - ✓Tonnage calculated partly from specific measurement and partly from projections on the basis of sound geological knowledge
  - ✓Permissible error up to 50%

Possible/ Inferred

- ✓Reserves are identified resources in which
  - ✓Quantitative measurement based on knowledge of geological characters.
  - ✓Very few samples points, past mining records
  - ✓Integration studies of geology, geochemistry, geophysics, geography and remote sensing
  - ✓Planning few further prospecting
  - ✓Error up to 90%

Thickness

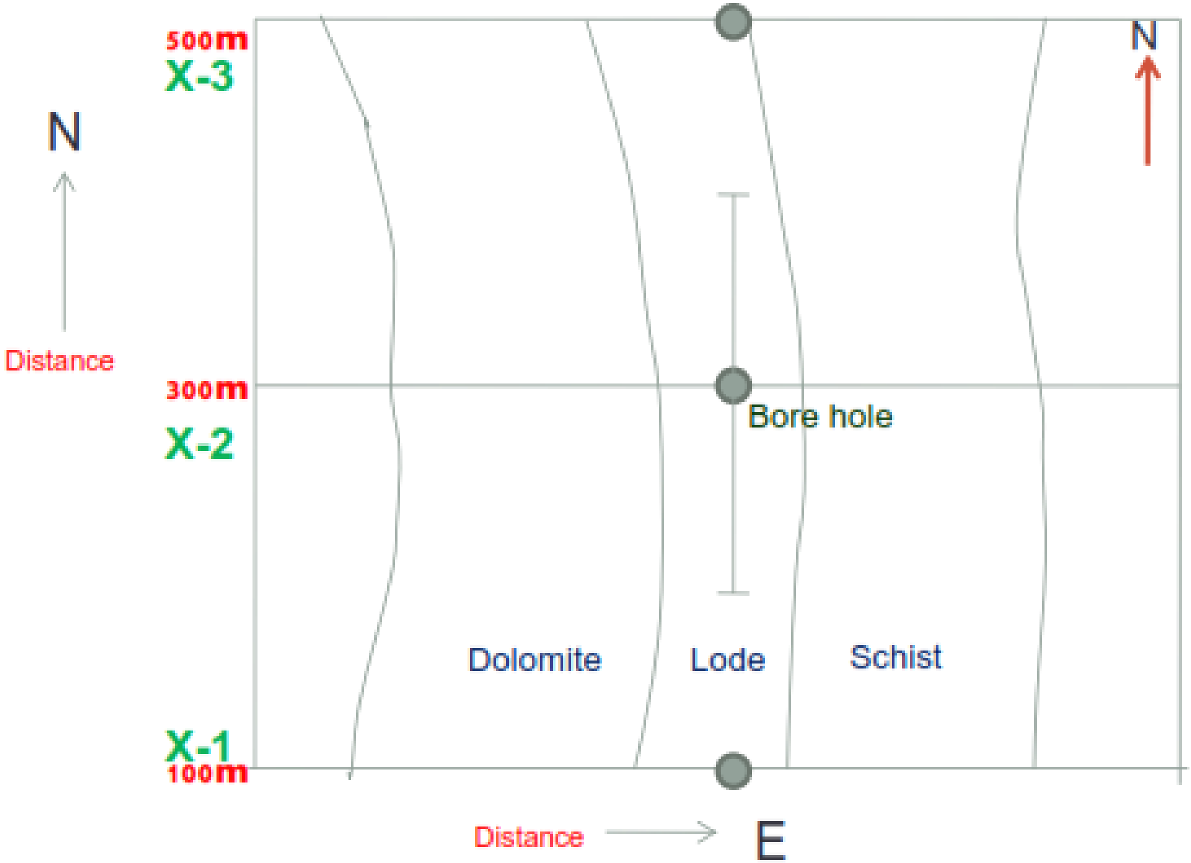
Thickness of the body is determined by computing the thickness of the lode in individual borehole.



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

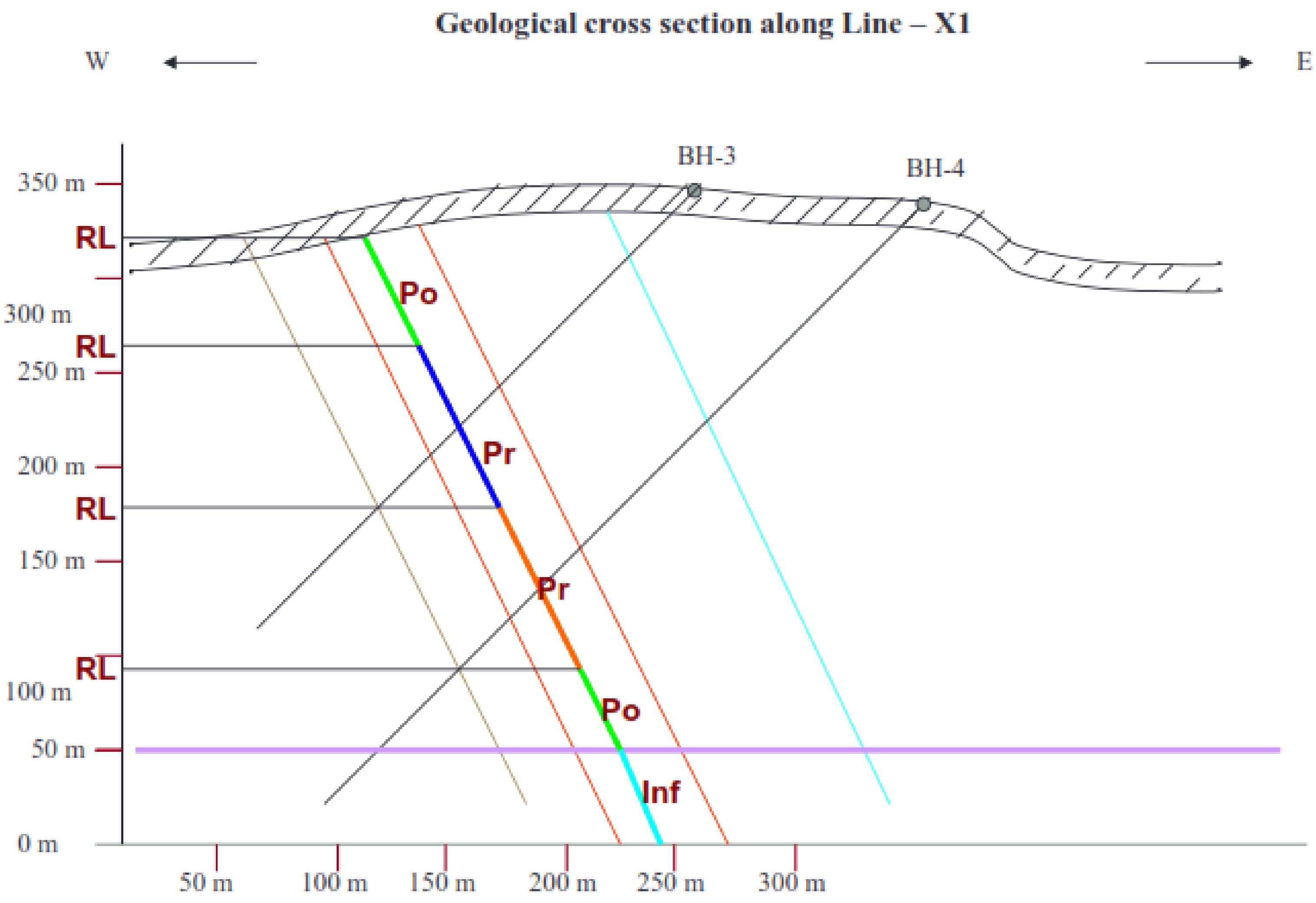
Tr = True thickness
Ta = Apparent thickness
θ = Angle between core axis and bedding plane

Strike length

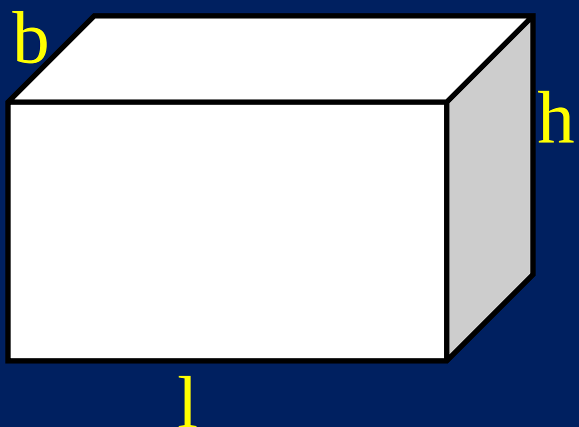


Geological map

Dip length

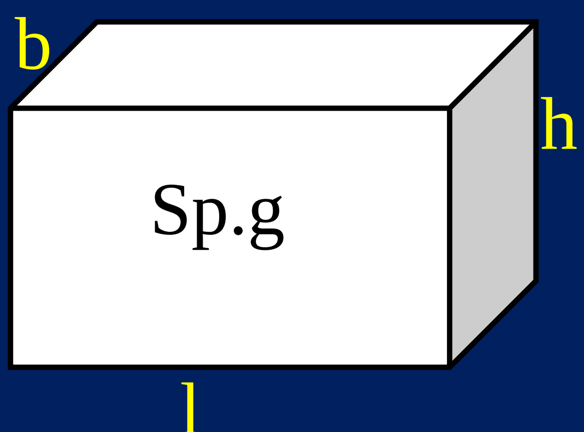

Geological cross section along Line – X1
W
E
BH-3
BH-4
350 m
RL
300 m
RL
250 m
200 m
RL
150 m
RL
100 m
50 m
0 m
Po
Pr
Pr
Po
Inf
50 m
100 m
150 m
200 m
250 m
300 m

Area = l x b



Volume = l x b x h

(Volume = Area x h)

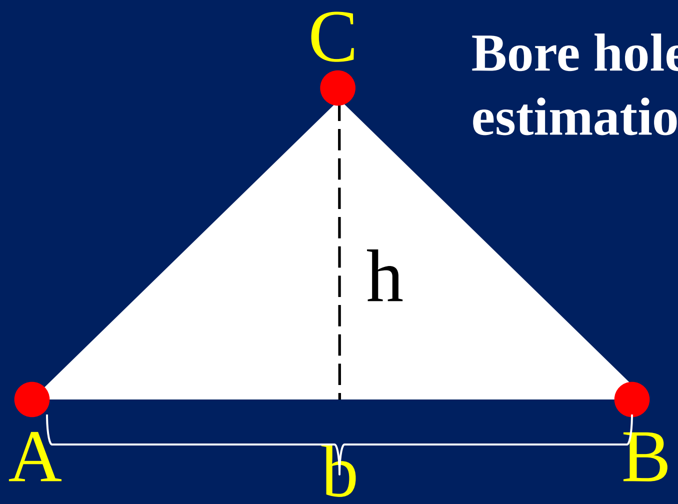


Tonnage = l x b x h x specific gravity

(Tonnage = Volume x Sp.g)

Ore Tonnage = l x b x h x specific gravity x Grade

(Ore Tonnage = Tonnage x Grade)



Bore holes A, B, C are shown in figure used for ore reserve estimation using Triangular method

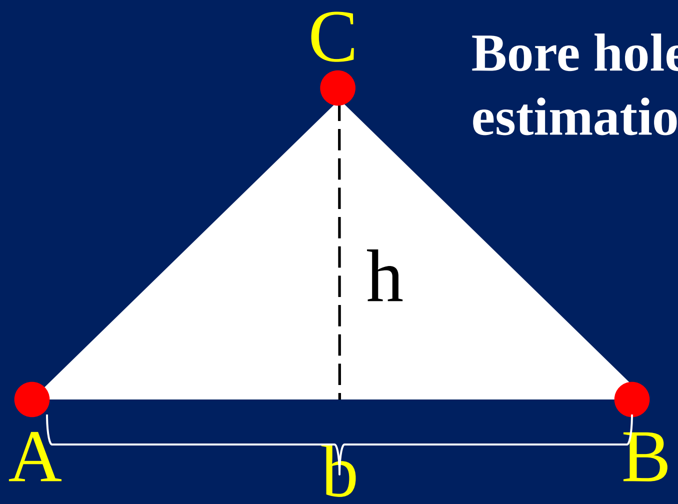
Area of Triangle = ½ bh

Ore Grade at A_G, B_G and C_G

$$\text{Average Grade} = \frac{A_G + B_G + C_G}{3}$$

Ore Thickness at A_T, B_T and C_T

$$\text{Average Thickness} = \frac{A_G + B_G + C_G}{3}$$



Bore holes A, B, C are shown in figure used for ore reserve estimation using Triangular method

Area of Triangle = ½ bh

Area x Avg. Thickness = Volume

Volume x Sp. Gravity = Tonnage

Tonnage x Avg. Grade = Ore Tonnage

To calculate the grade of copper for the sample, geologists use the equation: (amount of copper metal/amount of copper ore rock)*100 2.

If a deposit area has 200lbs of copper in 10,000lbs of ore rock, what is the grade? 200/10000*100=2%

If a deposit area has 6 tons of copper in 1,000 tons of ore rock, what is the grade? 6/1000*100=0.6%

The theoretical basis of geostatistics was developed by Georges Matheron in the late 1950's and early 1960's in order to study data that exhibit spatial correlation to some degree

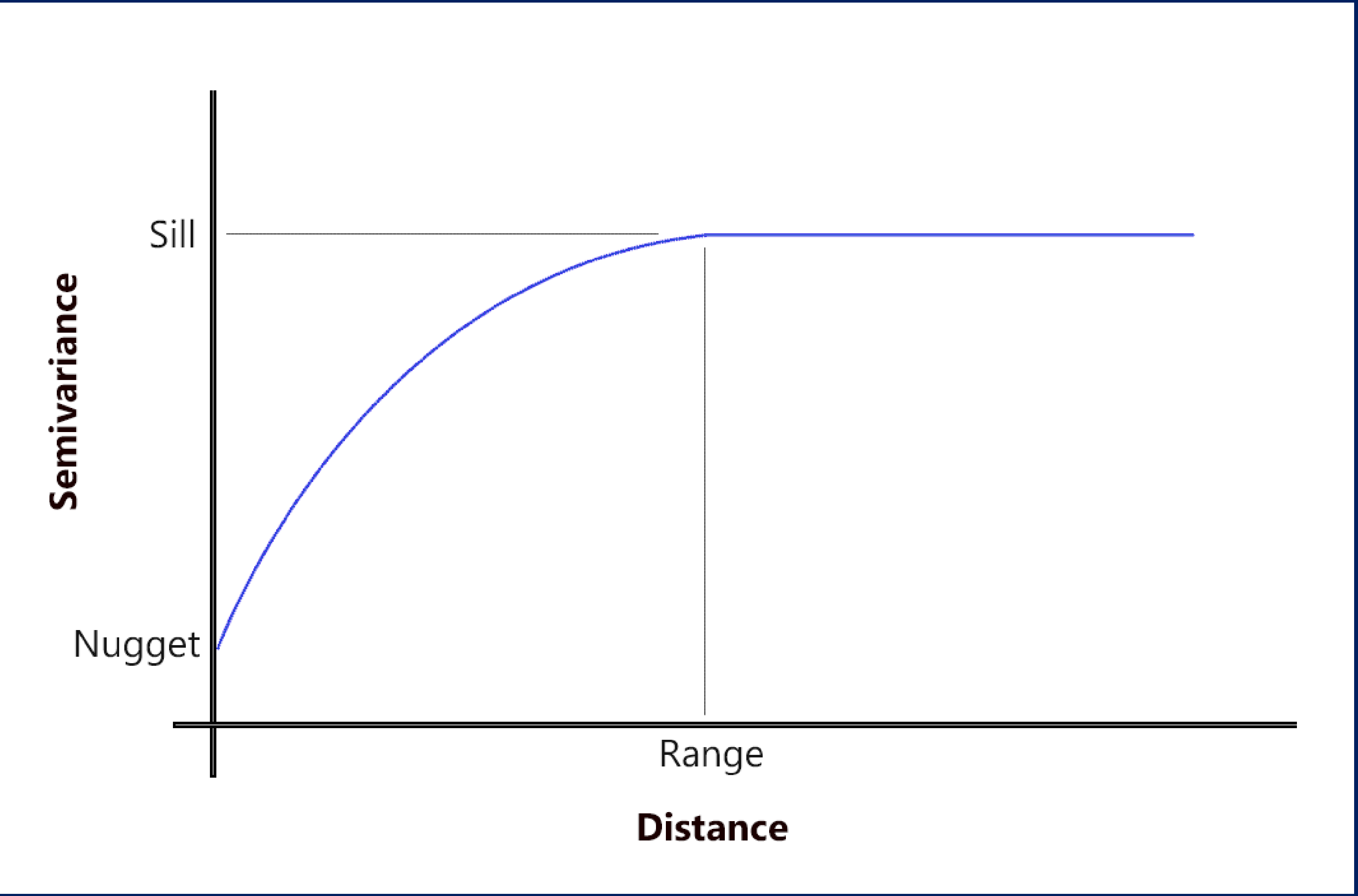
The theory developed by Matheron is known as the theory of regionalized variables.

A regionalized phenomenon spreads in space and exhibits a certain spatial structure. The value of this phenomenon at a point x is called a regionalized variable (Matheron, 1971, p. 5). The grade of ore in a channel sample is an example of a regionalized variable.

Regionalized variables occur in a given field and have a geometric support. For instance, the field of a channel sample is the ore deposit and its support is the size and shape of the sample.

The variogram is a function that expresses the degree of continuity of a regionalized variable. Thus, it is the basic tool of geostatistics.

The variogram can express the following structural characteristics of the phenomenon under study (Matheron, 1971, p. 58). 1. Continuity. The continuity of the phenomenon under study is reflected by the rate of growth of the variogram near the origin. Figure 2 illustrates different degrees of continuity expressed by the variogram. A high degree of continuity is reflected by a parabolic growth near the origin. Average continuity is expressed by a regular growth from the origin. A discontinuity at the origin is called a ''nugget effect" and can have real physical meaning or be due to errors of measurement, recording, or sampling. A completely discontinuous variogram indicates a pure random phenomenon. 2. Zone of influence. The variogram gives a concise definition of the notion of zone of influence. Often, beyond a certain distance called the range, the variogram becomes nearly flat indicating that the samples are independent (see Figure 2). A sample has no influence beyond the range of the variogram. A variogram with a range is called a transitive variogram. In some cases the variogram never reaches a limiting value but Assay data used in the calculation of this variogram was taken from Hazen (1958, p. 36).



SILL: The value at which the model first flattens out. **RANGE**: The distance at which the model first flattens out. NUGGET: The value at which the semi-**variogram** (almost) intercepts the y-value.

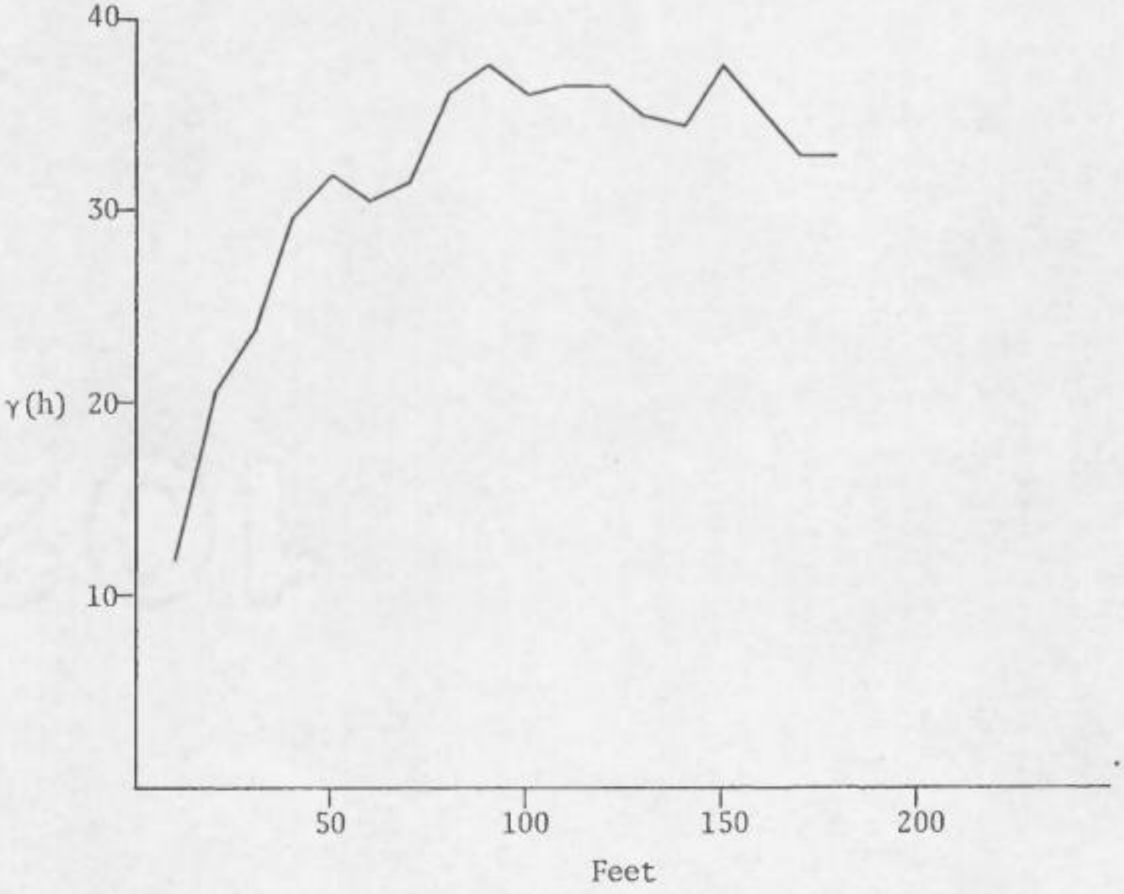
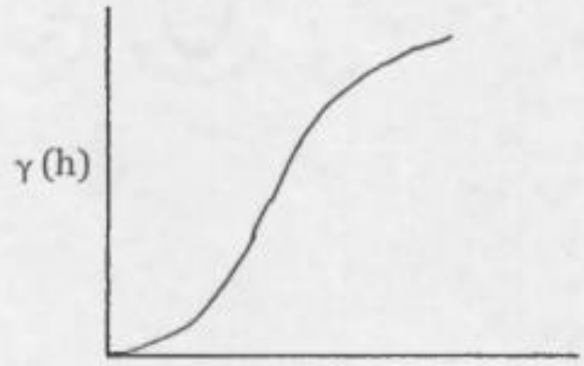
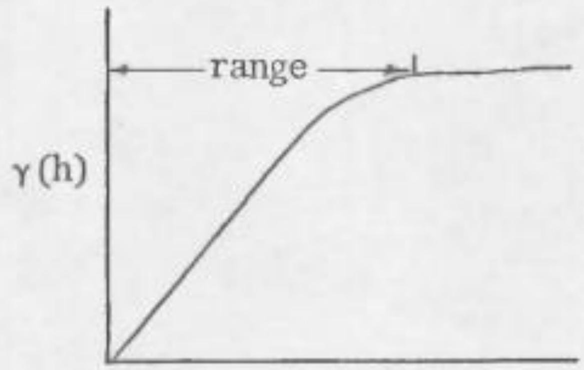


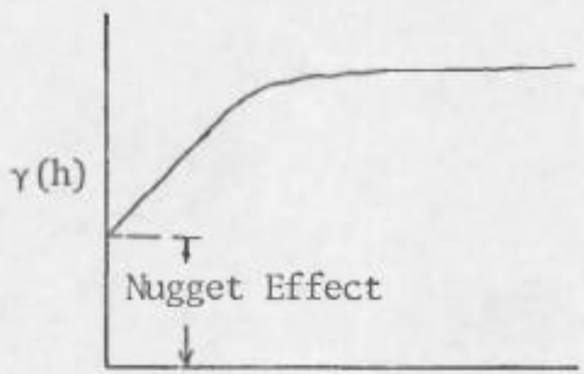
Figure 1. Variogram of Maggie Canyon manganese deposit.



High degree of continuity. Can be approximated by parabola near the origin. Bed thickness is an example.



Average continuity. Almost linear near origin. Typical of many metal deposits.



Nugget effect. Discontinuity at the origin and thereafter much like above variogram.

Figure 2. Degrees of continuity expressed by variogram.

Anisotropy. Variograms computed in different directions are often different, indicating anisotropy. Figure 3 shows an hypothetical example of anisotropy. The range of the horizontal variogram is 60 feet and the range of vertical variogram is 30 feet. The anisotropy factor is 60/30 or 2. This means that one foot in the vertical direction is equivalent to two feet in the horizontal plane as far as grade variation is concerned.

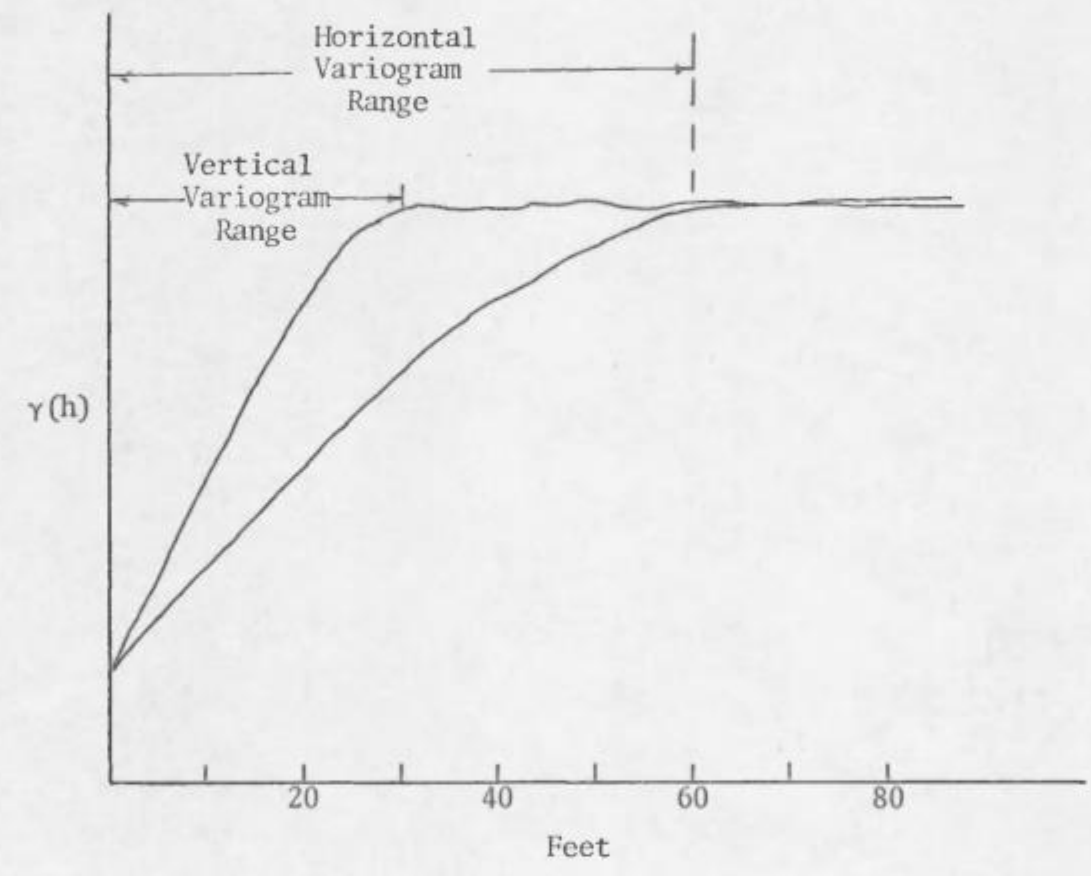


Figure 3. Hypothetical example of geometric anisotropy.

Variogram Models Variograms calculated for mineral deposits have been found to be adequately described by a few theoretical models (David, 1974, p. 59). The most often used models arc the spherical model and the DeWijsian model.

The spherical model is a transitive variogram and is expressed by the equation 2.7:

$$\gamma(h) = C_o + C\left[\frac{3}{2}\frac{h}{a} - \frac{1}{2}\frac{h^3}{a^3}\right] \text{ for } h \leq a \tag{2.7}$$

and $\gamma(h) = C_o + C$ for $h > a$

where C_o = nugget value

C = sill value minus C_o

h = distance

a = range.

Kriging The previous section discussed how to calculate the probable error of an estimate. This section will discuss how to make the estimate in such a way that it is unbiased and has minimum estimation variance. The procedure used is called kriging and was developed by Matheron (1971, p. 115). 2 The object of kriging is to find the best linear estimator of the grade of a block by taking into account all available samples. Kriging is a weighting procedure. The weights are calculated for each sample in such a manner to minimize the estimation variance subject to the geometrical constraints of the problem.

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

Panning

- **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.