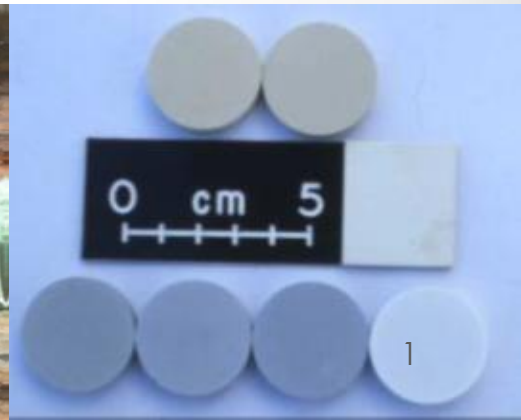


GGY 4119 – MINING GEOLOGY

DRILLING, LOGGING AND SAMPLING TECHNIQUES



Drilling and Sampling

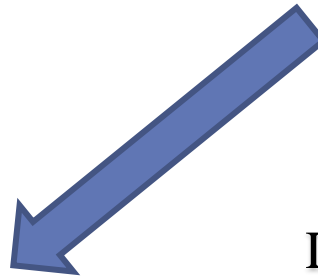
- Drilling and Sampling are critical for Exploration, Resource Estimation and eventually Mining/production purposes.
- It tests ideas and theories developed during prospecting/exploration, and should therefore be given careful consideration
- Drilling provides information to
 - Exploration to locate mineralisation
 - Define mineralisation
 - Estimation of mineral resource and reserve
 - Grade control and mining (To be looked at in detail)



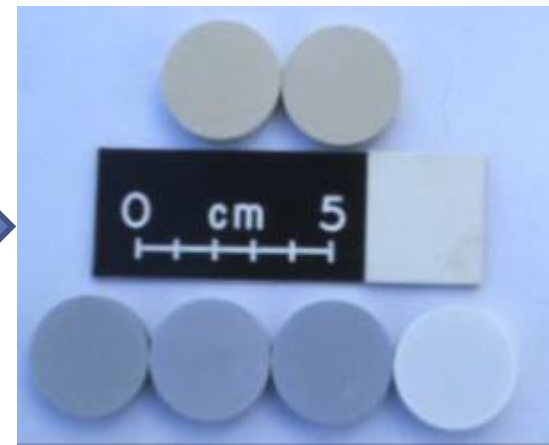
Deposit (millions of tonnes)



Drillhole (100's kg sample)



Sub Sample (100 Kg sample)



Assay (10 gram sample)

Setting Up A Drill Hole

- Identify and mark approximate position of hole with peg
- On peg
 - Hole ID
 - Bearing
 - Inclination
- Foresight and backsight pegs for orientation

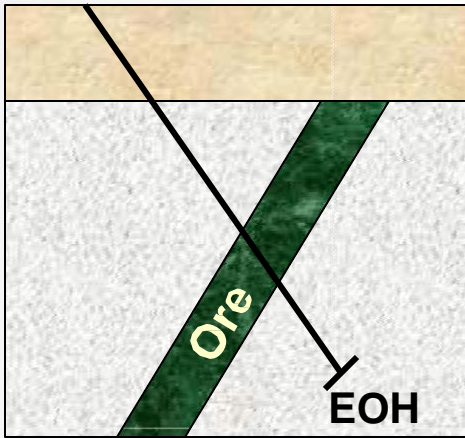


Drill Spacing

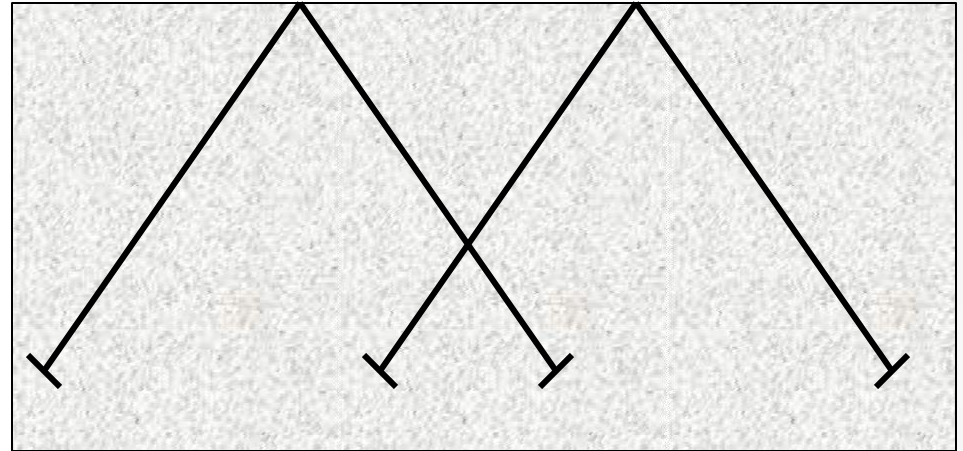
- What is optimum the drill spacing to define and resource a deposit?
IT DEPENDS!
- Optimum spacing depends on
 - Stage of exploration program
 - Style of mineralization
 - Simple homogeneous > wider spacing
 - Complex structure, erratic grade > closer spacing
 - Level of resource definition
 - Inferred resources (assume geological continuity) → wide spacing
 - Measured resources (strong geological evidence) → sufficiently close-spaced to confirm geological and/or grade continuity”

Aim: maximum benefit at minimum cost

Layout Surface Drilling



Exploratory drillholes for known orientation of mineralization



Exploratory drillholes for unknown orientation of mineralization

Directional Control

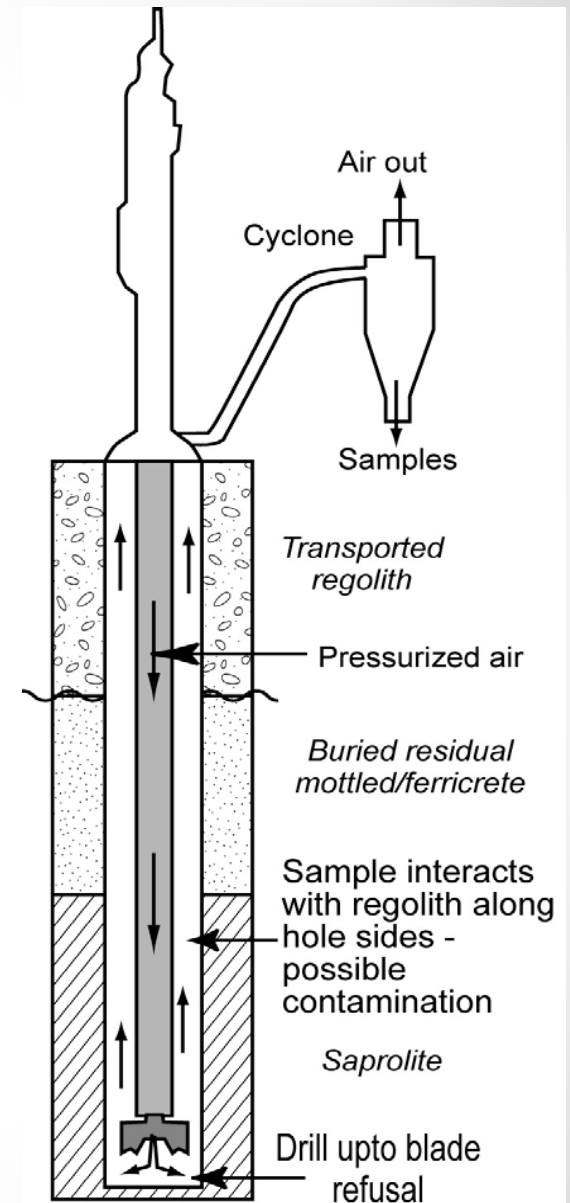
- Drilling rods have tendency to deviate from straight line because of lithology, flexibility of steel rods
- Need to be surveyed downhole so position of subsurface geological features can be precisely determined - DhSurvey
- Downhole surveys are conducted by
 - Accelerometers for inclinations
 - Magnetometers or gyros for azimuth at specific depths
 - Gyros better – unaffected by magnetic rocks
- Remedial action taken by driller if drillhole is significantly deviated

Drilling Methods

Drilling Technique	Use
Rotary Percussion	
Rotary Air Blast (RAB)	Initial Stage of Exploration
Air Core (AC)	Initial Stage of Exploration
Reverse Circulation (RC)	Exploration, Resource Definition, Evaluation
Diamond Drill Core (DD)	Exploration, Resource Definition, Evaluation, Geotech

Rotary Air Blast (RAB)

- In this method, high pressure air is blown down inside a drill pipe while rotating bit grinds regolith.
- The air moves cuttings up along walls to surface; geochemical contamination and no water is required
- This method is only good to drill through “soft rock” (regolith ~ 100m), cannot penetrate fresh rock.
- Cheapest form of exploratory drilling ~ \$10 – 20



Advantages of RAB

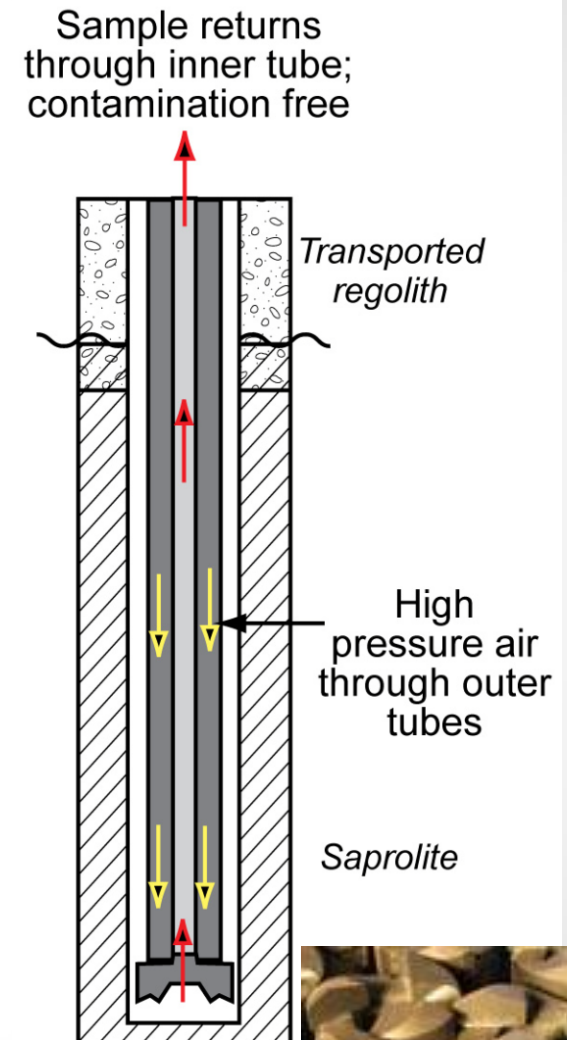
- Cheap
- Fast
- Large sample volume

Disadvantages of RAB

- No fresh rock sample
- Limited depth
- No structural data
- Geochemical contamination

Air Core (AC)

- Drilling rods have inner tube inside outer core barrel
- Pressurised air blown down outer tubes, cuttings carried back up through inner tubes.
- More expensive than RAB < \$ 20 – 30/m.
- Slower and may still not be able to penetrate fresh rock, and has less sample contamination than RAB.



Advantages of AC

- Relatively cheap
- Fast
- Minimal contamination
- Some core recovery

Disadvantages of AC

- Small sample size
- Limited depth

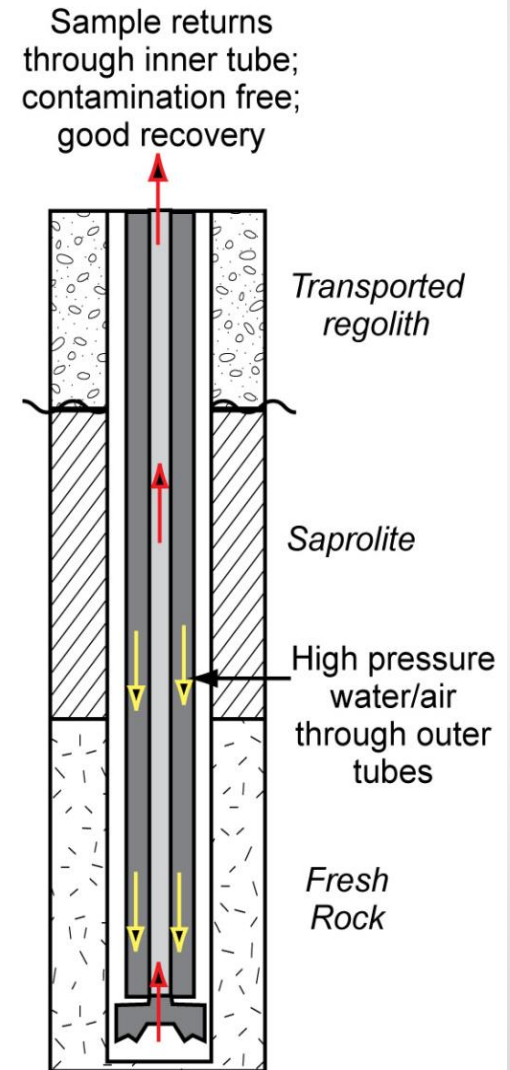
RAB/AC Sampling

- Drilling cuttings (powder to small chips) are collected from the cyclone and laid on the ground in heaps; each heap = 1 or 2m interval
- Grab samples are taken with a trowel from cutting heaps.
- Composite sample

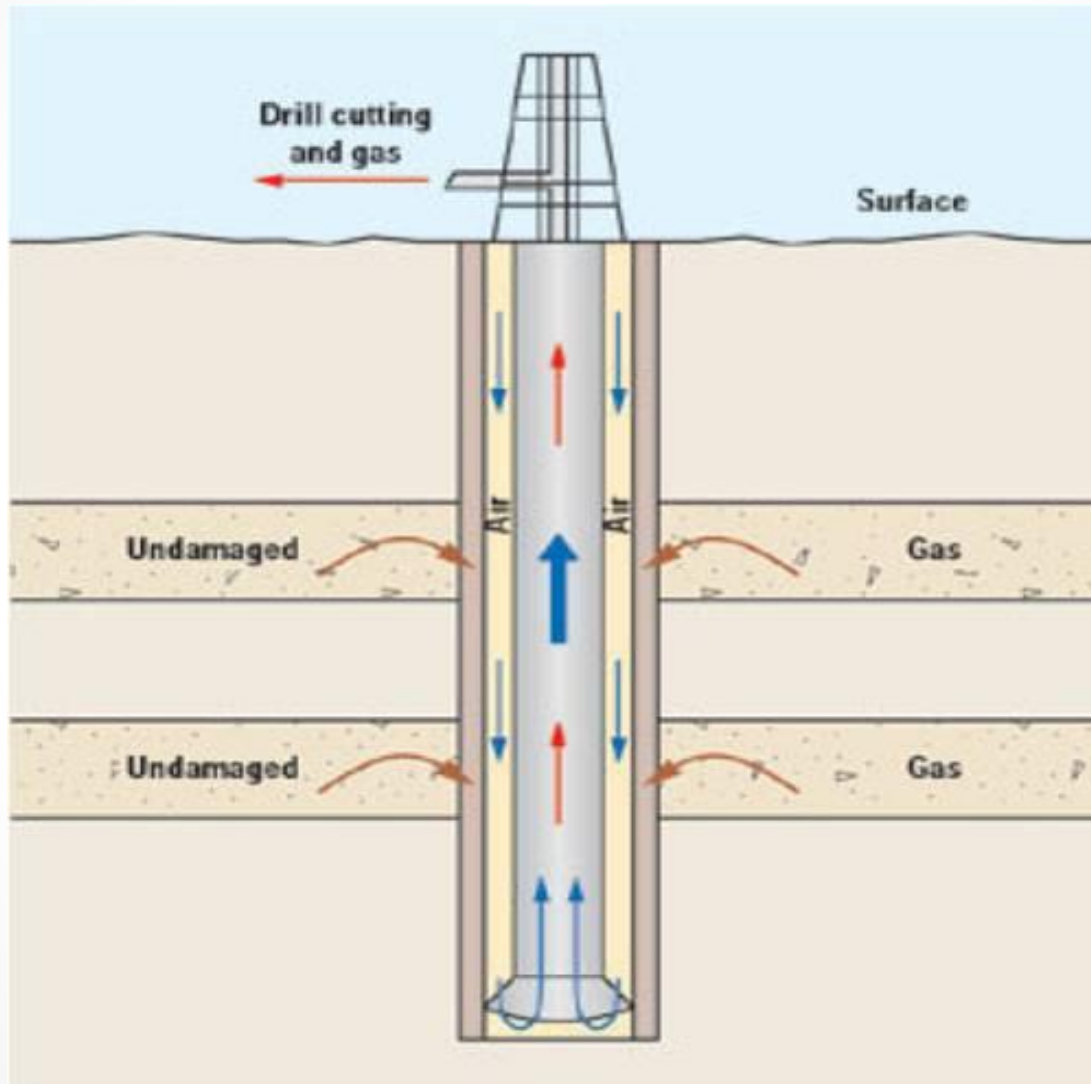


Reverse Circulation (RC) drilling

- In RC drilling, dual barrel/tubes are used consisting of outer and inner tube.
- Compressed air/water is driven down outer or annular space to the tungsten drill bit – cuts through fresh hard rock
- The drill cuttings return to surface through inner rods/tubes for collection through cyclone.
- Over RAB/AC, RC has an advantage of good penetration ~ 400m drilling through regolith and fresh rock , and a costly disadvantage ~ \$ 40 – 70/m



Schematic presentation of RC drill rig



Advantages of RC drilling

- Relatively Cheap ($< DD$ but $> RAB/AC$)
- Fast/quick
- Uncontaminated sample
- Large sample

Disadvantages of RC drilling

- Limited access
- No structural data
- Geochemical contamination below water table

RC Sampling

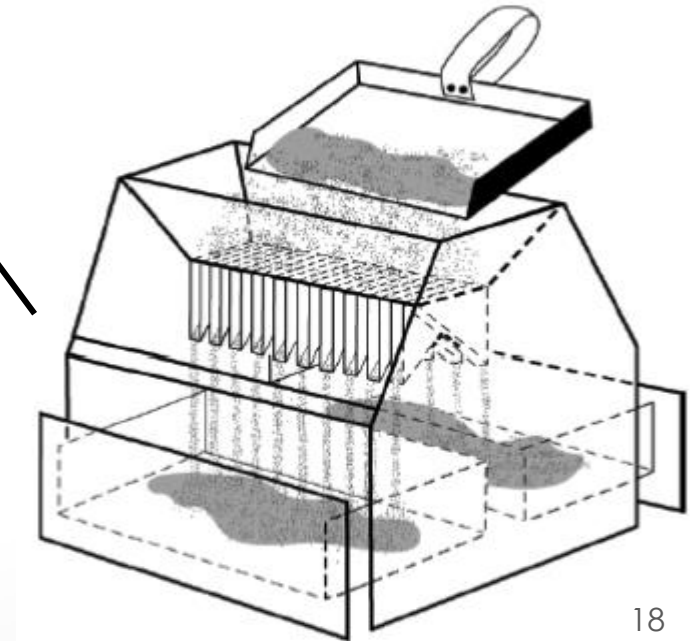
- Large sample volumes representative of 1m Intervals (25-50kg) and samples are collected into polyethylene bags through;
- Cone splitter attached to the rig or
- Riffle splitter
- Errors arise due to contamination from collapsed walls and mixing of hard and soft materials, and poor sample collection
- The samples are logged by a geologist and a small sample from each meter is stored in “chip trays”.



Cone Splitter



Riffle Splitter



Diamond Drill (DD) Core

- Series of connected long hollow tubes or rods with the end connected to a cylindrical diamond impregnated bit that rotates and moves down around a solid column of rock enclosed within the drill rods
- A solid cylinder of rock collects inside the “core barrel” as the drill bit advances. Core is then recovered from core barrel.
- Used in advanced stage of exploration and resource development.
- Has the advantage of providing the precise and best geological information to analyse ore body for detailed geological, metallurgical, geotechnical tests. Disadvantage is - most expensive ~\$150/m, has slow penetration rate and requires extensive water supply



Advantages of diamond drilling

- Maximum geological information
- Uncontaminated sample
- High quality sample

Disadvantages of diamond drilling

- Expensive
- Slow
- Small sample size
- Extensive site preparation and water supply required

- DD has several core sizes. The drill core size depends on: size of drill rig , the hole depth required, the rock type being drilled and also the purpose of drilling. The common drill core sizes for deep holes (+500m): PQ/HQ > NQ > BQ

Core size	Core diameter (mm)	Hole diameter (mm)
AQ	27.0	48.0
BQ	36.5	60.0
NQ	47.6	75.7
HQ	63.5	96.0
PQ	84.0	122.6

Diamond Drill Core Sampling

- Core is sampled either along standard lengths (< 1.0m) or on geological intervals
- Geological intervals are recommended so as not obscure any geological controls on mineralisation
- Core is generally cut or split longitudinally in half for sampling
- Errors arise where core is split unevenly and not divided properly



Logging of drill samples

- The logging of the drill samples and assay will need to follow a proper procedure that complies with the JORC (Joint Ore Reserve Committee) reporting and must include quality control procedures such as blanks, duplicates and standard samples.
- Eventually, all the data generated must be stored systematically and safely in a resource database for future use and reporting.

RC Logging

- For RC logging, broken fragments (silt to sand sized) – chips or cuttings are sieved and washed. Representative drill samples are stored in chip trays. Samples are logged at 1m down-hole intervals (or 2-4m composite). When logging RC holes, the geologist needs to note;
 1. Lithology (rock/regolith type)
 2. Colour
 3. Mineralogy
 4. Oxidation (degree of weathering)
 5. Alteration



DD Logging

- For DD logging the core is placed in orientation on core trays washed and logged in intervals determined by the logging geologist.
- More detail is logged/recorded compared to RC
- The interval used maybe influenced by colour changes, lithological changes, alteration etc. Here is an example of a logging sheet;

DRILL CORE LOGGING

Documentation of geological logging of drill core

- Geologist(s) logging core
- Core number, location, azimuth and inclination
- Purpose (lithology, structure, geotechnical)
- Mark-up of core (orientation)
- Geology codes used for rock types
- Explanation of rock nomenclature (e.g. granite v basalt)
- Core recovery (core loss)
- Adverse drilling problems (e.g excessive water loss)
- Structural measurement
- Physical property measurement (e.g. magnetic)
- Core storage and record (photos)

LOGGING CORE

- Preferably, observe in natural light
- Arranged on racks
- Cleaned: hose or brush
- Start with summary of the entire core
 - Lithological contacts
 - Major structures
 - Mineralization
- Detailed log
 - Lithology
 - Mineralogy
 - Grain size
 - Alteration
 - Regolith
 - Geotechnical
 - Magnetic

ALTERATION & ORE

Look for signs of

- Silica (quartz)
- Chlorite
- Epidote
- Sericite
- Talc & serpentine
- Carbonates
- Kaolinite & illite
- Biotite + K-spar



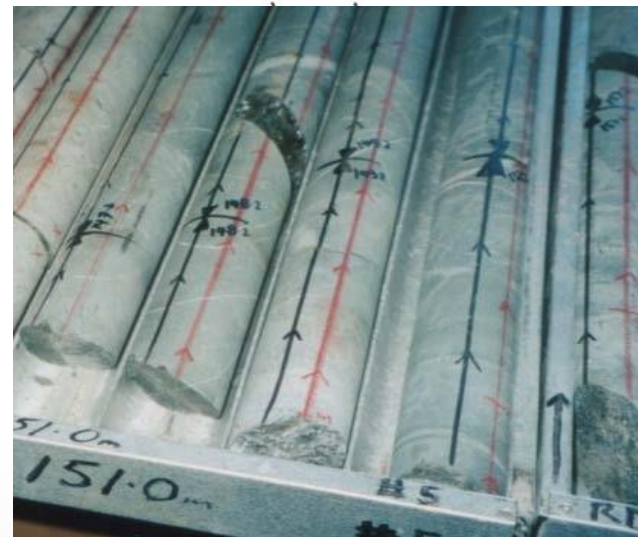
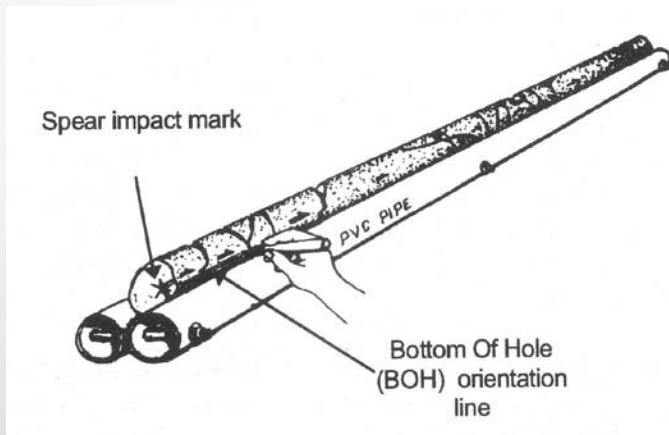
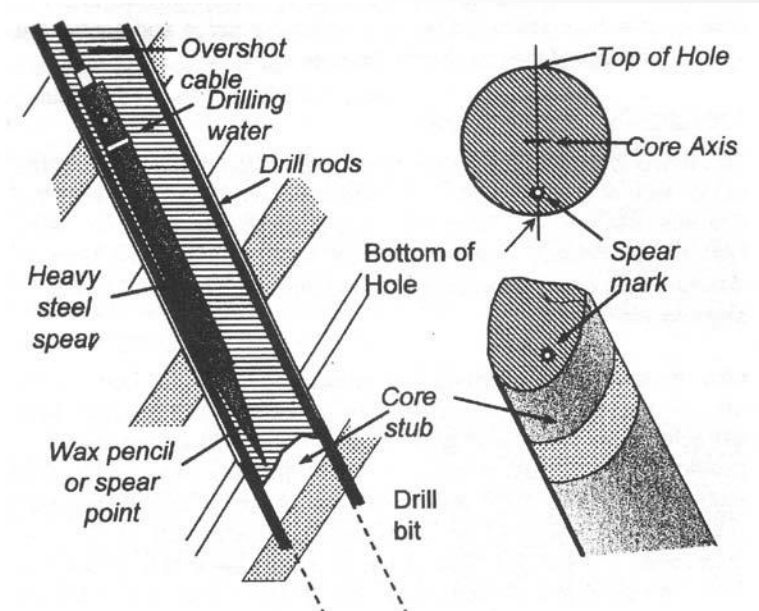
Sulphides

Matrix

Massive

ORIENTING CORE – STRUCTURAL LOGGING

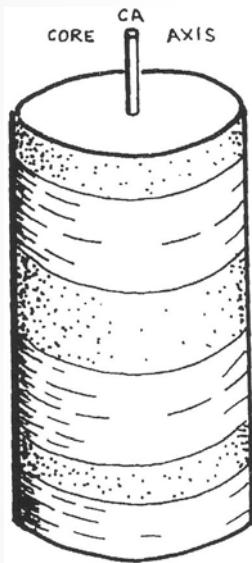
- Use well-developed structures – cleavage/bedding of known orientation OR
- Mechanical methods
 - Downhole Spear
 - Core-Stub Template



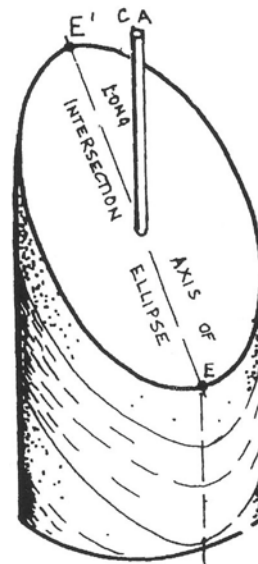
From Marjoribanks (2002)

RECOGNIZING AND INTERPRETING STRUCTURES IN CORE - PLANAR

Bedding, faults, veins

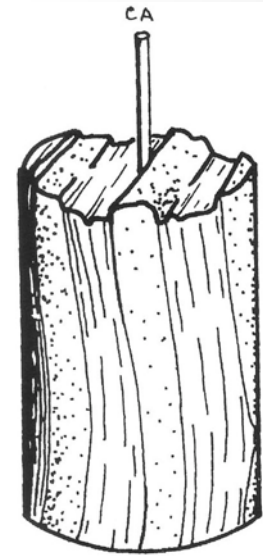


Hole normal to
surface



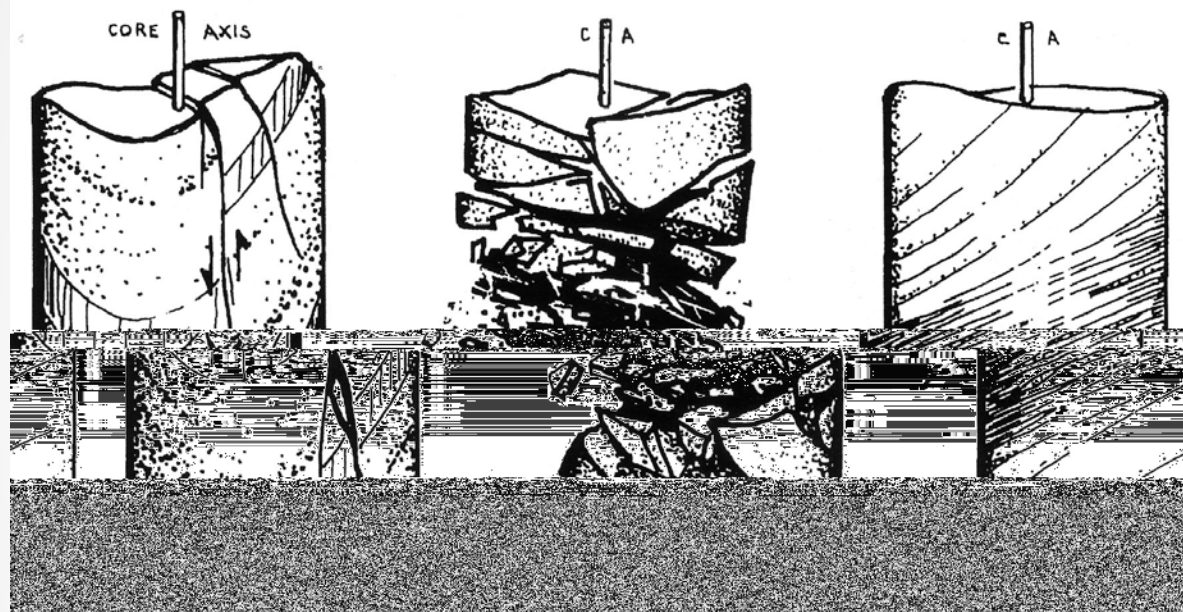
Hole at angle $>0^{\circ} <90^{\circ}$
to surface

E'-E is long ellipse axis



Hole parallel to
surface

RECOGNIZING AND INTERPRETING STRUCTURES IN CORE - FAULTS



Brittle micro-faults

Displacements

Brittle faults

Disoriented
broken
fragments

Ductile faults

Intense planar
foliation and
high strain



From Marjoribanks (1997)

GEOCTECHNICAL CORE LOGGING

- Geotechnical information critical for mine planning & design
 - Kinematic analysis – prediction of slope/wall stability & wall failures
 - Fractures, joints, fault, bedding planes dictate open-cut mine stability
- Surface mining - removal of overburden causes expansion increasing failure risks
- Underground mines – structures can open on blasting
- Need to assess fracture/joint parameters and rock quality during core logging

GEOTECHNICAL DATA -CORE

- Lithological units
 - Adverse mineralogy (e.g. talc)
 - Adverse structural features (e.g. schistose rock)
- Qualitative Rock Strength
 - Percentage of core recovery - RQD
- Geological Structures
 - Location of faults & fractures
 - Intersection angles of discontinuities (e.g. joints, bedding, cleavage)
 - Frequency of occurrence of discontinuities
 - Fracture infilling or veins

RQD - GEOTECHNICAL

RQD – Rock Quality Designation

It is % of recovered core, counting of intact core 10 cm or larger

Total length drilled = 200 cm

Total core recovered = 164 cm

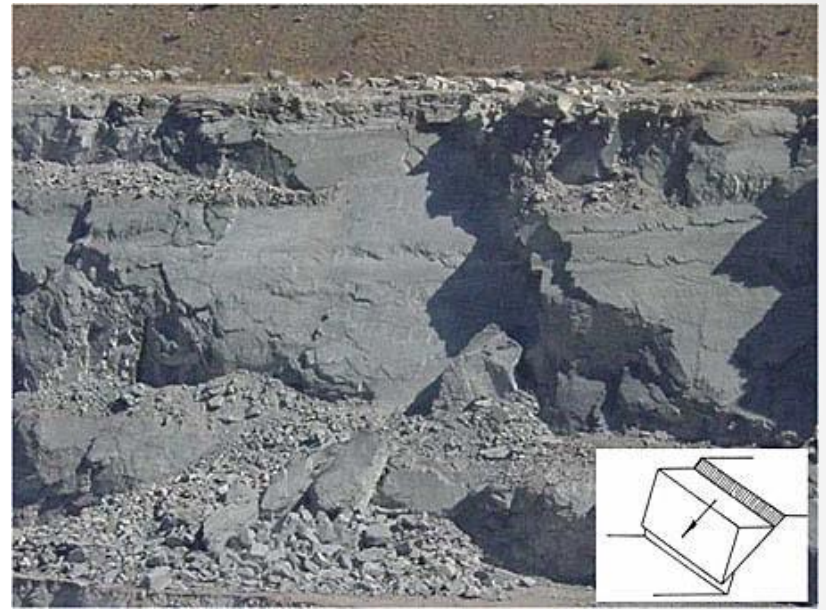
Core recovery = $164/200 = 82\%$

Summed core lengths > 10 cm = 85 cm

RQD = $85/200 = 42\%$

RQD %	Quality
0 – 25	Very Poor
25 – 50	Poor
50 – 75	Fair
75 – 90	Good
90 - 100	Excellent

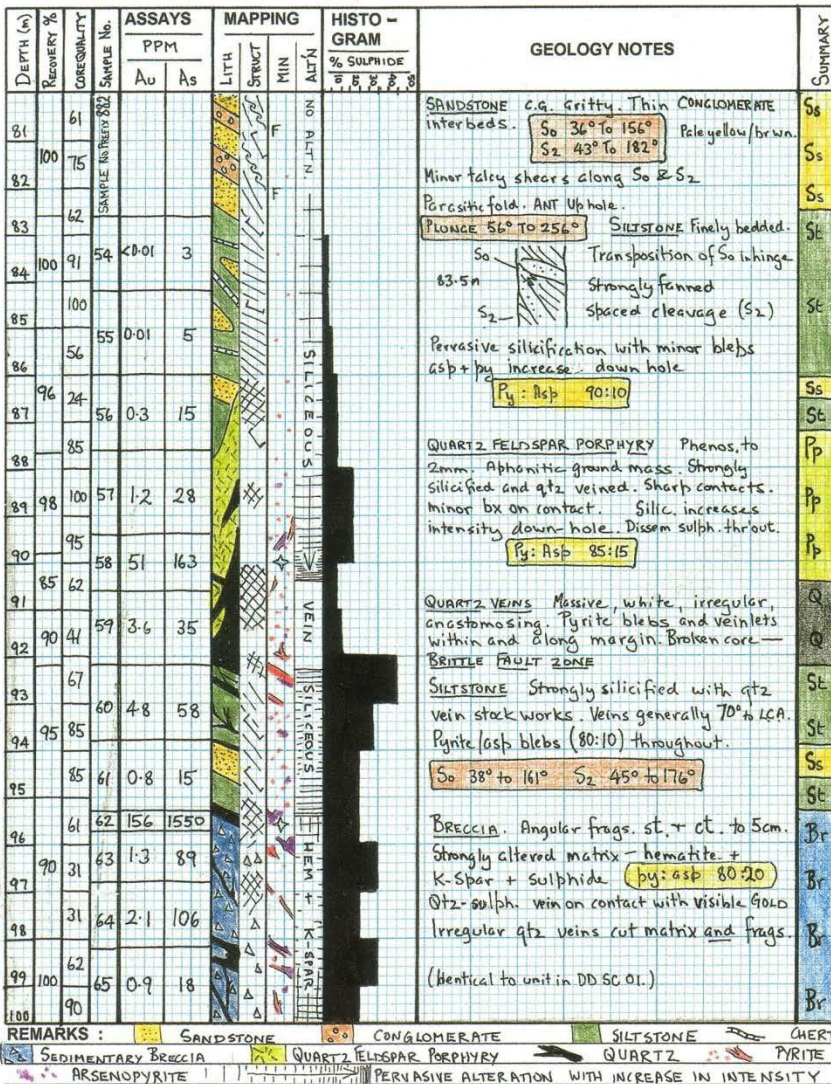
GEOTECHNICAL – SLOPE FAILURES



CORE LOGGING

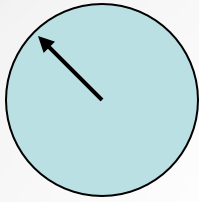
- BEDDING
- CLEAVAGE
- FAULT
- ... PERVASIVE
- MASSIVE
- VEIN
- △ BRECCIA
- ⋄ VISIBLE GOLD
- ⊘ BROKEN CORE

Project:	Cloncurry Volcanics
Prospect:	Serendibity Creek
Date:	10 th JAN, 1993
Logged by:	Tony McGregor.

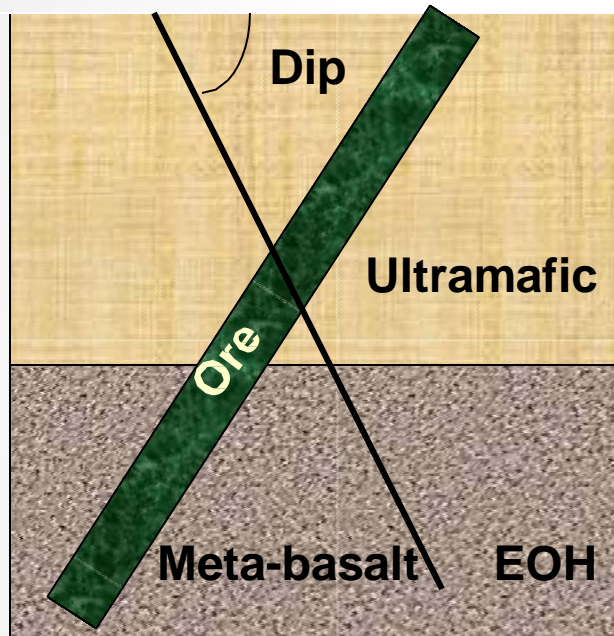


Hole ID	Fr	To	Lith_ID	Col	Alt	Lith
1	0	8	TQ	Y	N	TReg
1	8	15	BSI	G	N	Bsap
1	15	30	Mb	Gr	Ch	Bas

Azimuth

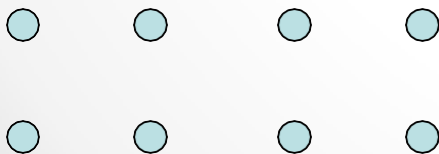


Drillhole Data(base)



Plan view of holes

N



East

- Collar table
 - ID, E, N, RL, EOH
- DhSurvey table
 - ID, Azimuth, Dip
- Lithology table
 - ID, From (depth), To (depth), Lithology
- Assay table
 - ID, Depth, SiO₂, Au etc

Drilling Database - Example

Collar Table

HoleID is primary key

Hole ID	East	North	RL	EOH	Collar_Dip
MA001		8854000	0	145	15
MA002	596400	8850000	0	110	15

Downhole Lithology Table

HoleID	Depth	Lithology	Colour	Sulphides
MA001	5	Granite	Grey	No
MA001	6	Basalt	Dark green	No

Downhole Assay Table

HoleID	Depth	FeO ₃	Au	As	Sb
MA001	8	4.5	12	25	2
MA002	8	4.8	35	37	4
MA002	9	5	43	44	6

Drilling methods & use

Drilling Technique	Exploration/Development/Mining
RAB & AC	Early stages of exploration (first pass) Infill drilling during early stages
RC	Intermediate to advanced stage of exploration Delineation of ore body Resource definition Grade control (surface mining)
Diamond Core	Intermediate to advanced stages Resource definition Geological & structural control Mining development Metallurgical testing
Blasthole	Grade control and blasting (surface mining)

Conclusions

- Drilling and geological logging is central to the entire mining geology process from resource development to mining
- Each drilling method has its pros and cons
- Logging geology is an essential part of resource estimation
- The drillhole database is very important to resource estimation, mining and reconciliation process

END OF MODULE I