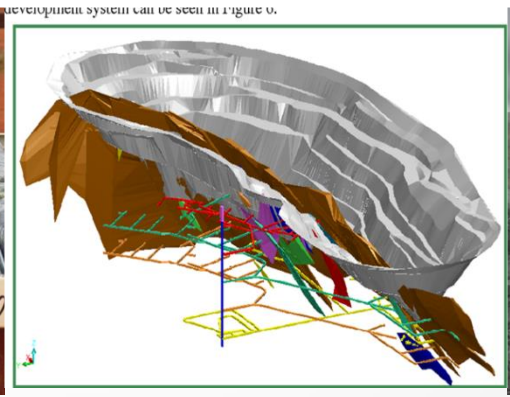
GGY 4119 – MINING GEOLOGY

GRADE CONTROL – DRILLING AND DILUTION IN MINING


GEOLOGIST AND GRADE CONTROL

Grade Control involves people who do …

- Drilling
- Geological face mapping
- Sampling: blast/RC holes, faces, lab submission
- QA/QC (checking, validation)
- Classifying (marking up) ore after considering geology….so Ore can be delineated and cut-off grades identified and block and size optimised and….
- …Dilution/ore loss is minimized
- Reconciliation & Reporting (feedback & improvement) Use all for continuous improvement

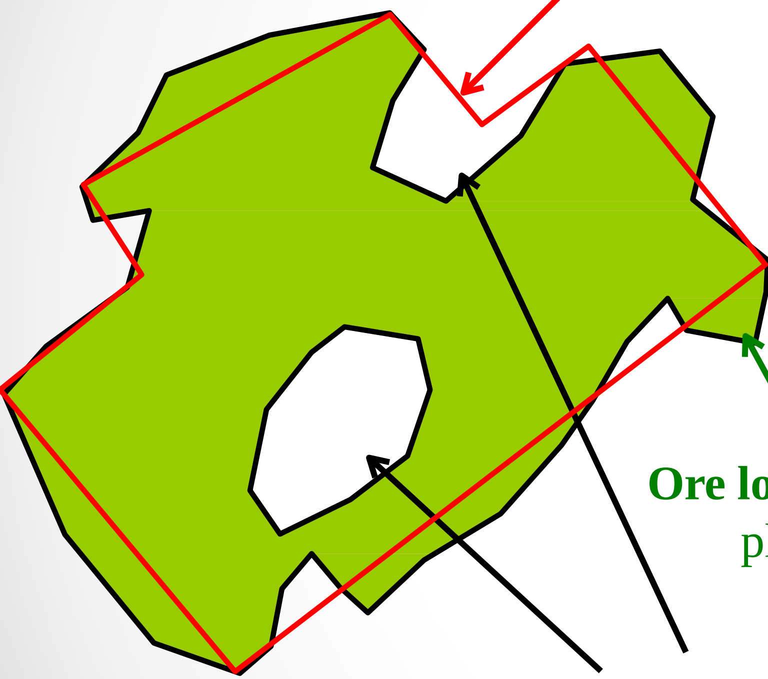
Must have a strong geological basis – type, geometry, structure and continuity of ore

WHY GRADE CONTROL?....

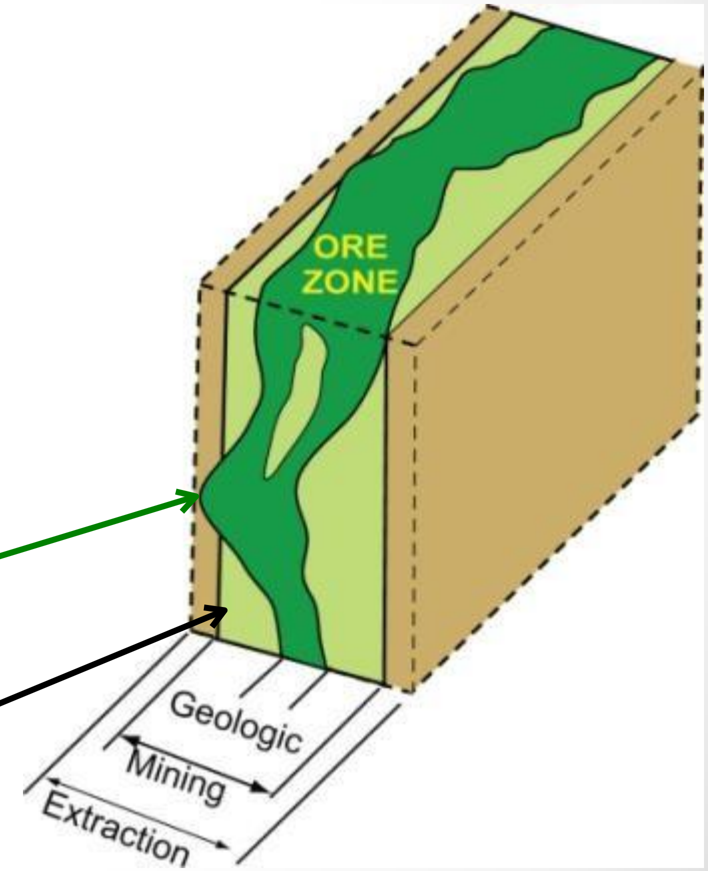
- Maximize the ore quality being fed to the mill – improve overall efficiency
- Improves selectivity of ore and reduce dilution
- Improves mine design and scheduling
- Allows correct measurement of individual mine operations
  - Drilling
  - Sampling
  - Assaying
  - Production
  - Milling

DILUTION or ORE LOSS – take your pick

Planned block boundary
(mining cut)



Ore loss – ore outside planned block



Dilution – waste inside planned block (cannot be avoided due to mining method)

GRADE CONTROL IN OPEN-PIT/SURFACE MINING

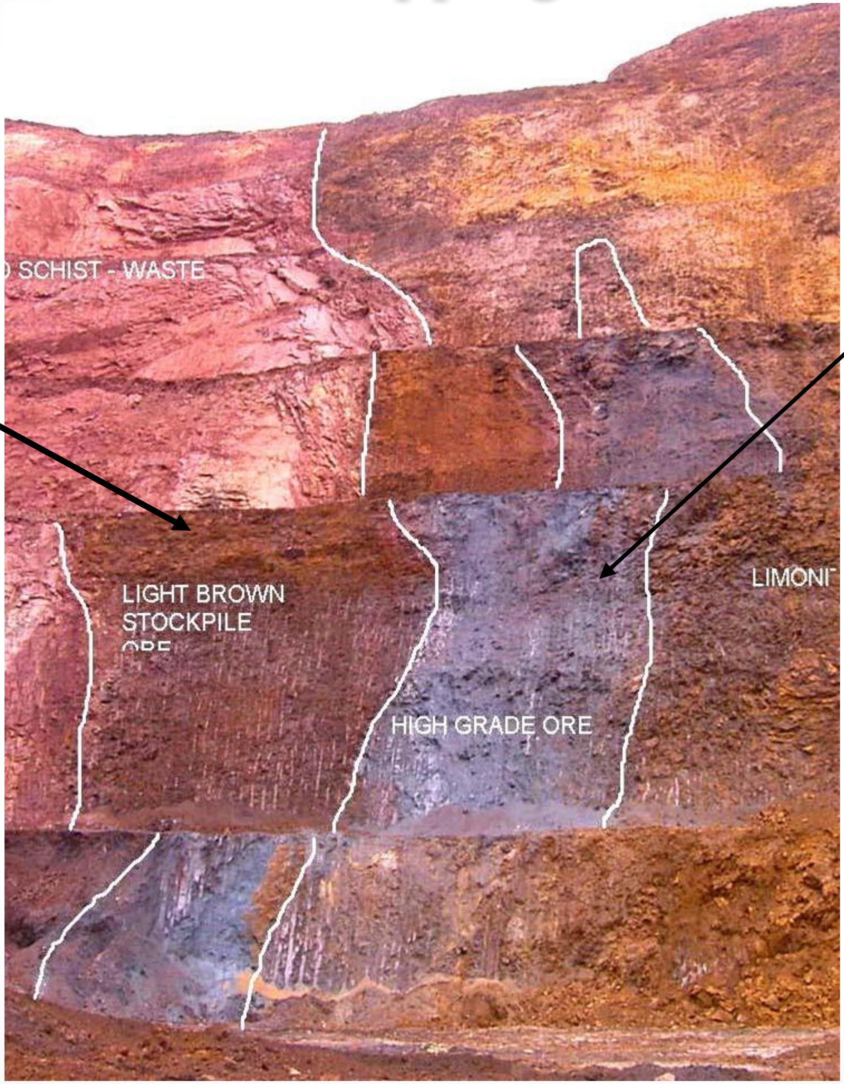
- Sampling and logging of Blasthole or RC cuttings: Proper application of sampling theory, strict QAQC, input into database, validation
- Classifying of bench reserves – compare different benches
- Designing mineable ore blocks – need to be based on geologically realistic boundaries
- Classification of mining blocks
- Ore
- Low grade
- Waste

Need to consider geology, mining method, blast movement

- Different metallurgical types; blending of ore types
- Continuous face mapping

Grade Control in Open-Pit Face Mapping

LOW GRADE
- 58 – 61% Fe
- Goethite
- Voids common
- Higher % of contaminants



HIGH GRADE
- >61% Fe
- Predominately hematite
- Minor contaminants
- High SG

LITHOLOGY TYPES EXAMPLE

ORE TYPES

Hematite –

- **Composition:** Fe_2O_3
- **Colour:** Black to Steel blue
- **Origin:** Mineral can precipitate out of water or can be a result of volcanic activity

Specular Hematite (Specularite) –

Composition: Fe_2O_3
Colour: metallic-silver
Description: Chemically inert ferric oxide mineral that cannot rust

Goethite –

Composition: Fe_2O_3.H2O
Colour: Brown, Reddish brown, Yellowish brown Brownish yellow, Ocher yellow
Origin: Hydrated iron oxide

LITHOLOGY TYPES EXAMPLE
WASTE TYPES

Limonite –

- **Composition:** $FeO.H_2O$
- **Colour:** Bright yellow
- **Origin:** Produced by the oxidation and hydration of primary iron containing materials

Banded Iron Formation (BIFs) –

Colour: Alternating banks of dark grey to metallic oxides and silica (chert)

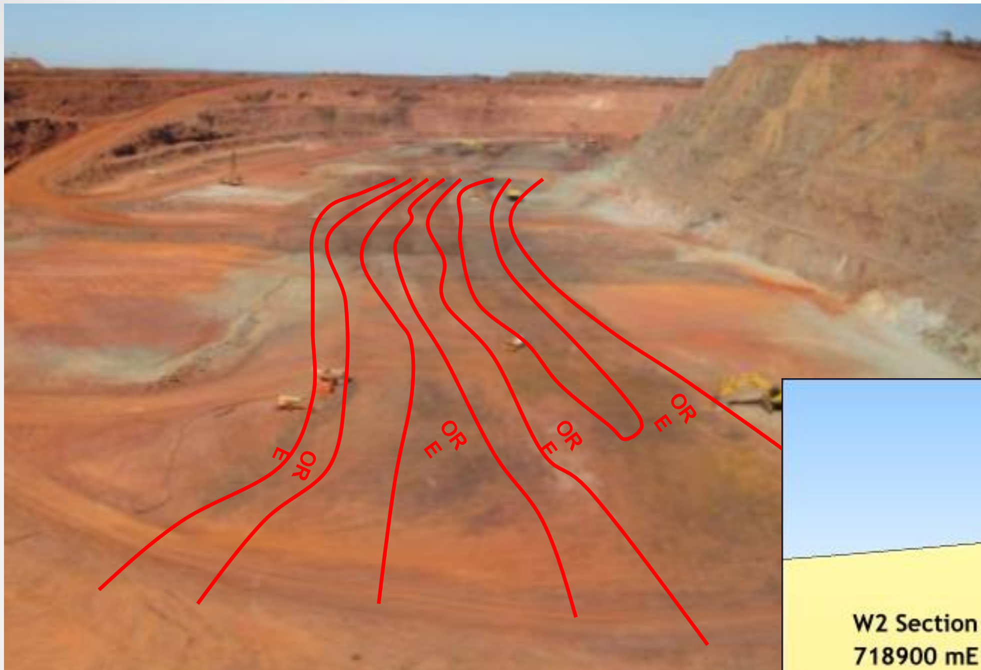
Origin: conventional concept that formed in sea water as a result of oxygen being released by cyanobacteria that combined with dissolved iron, which precipitated out

Schist –

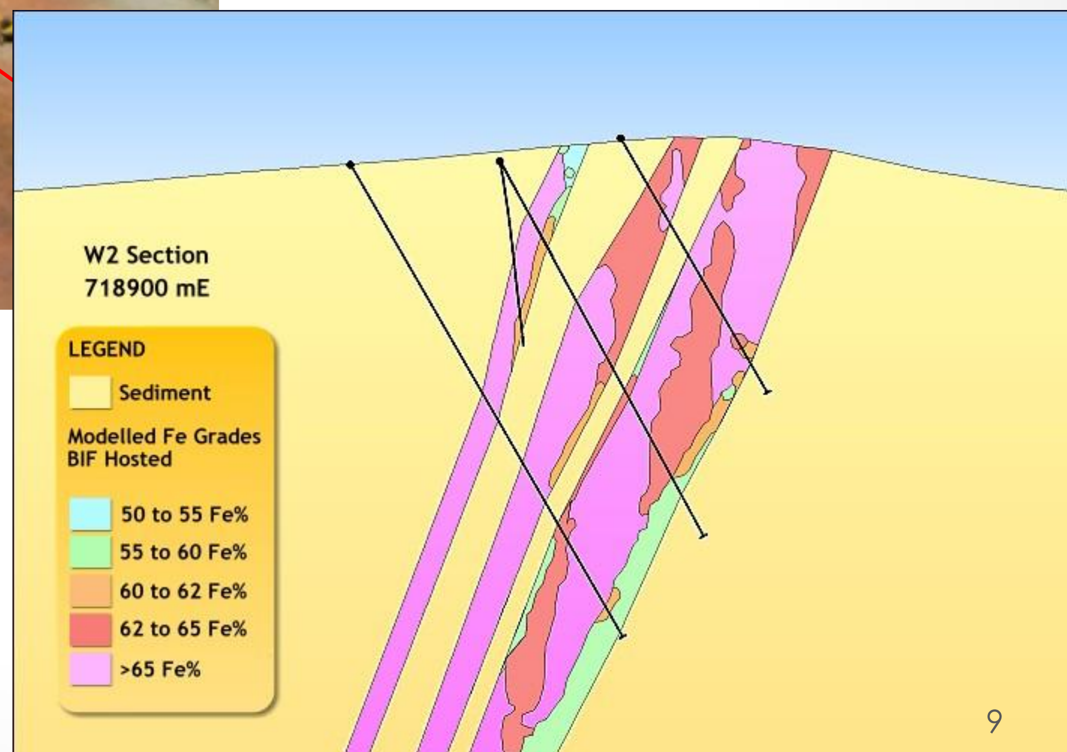
- **Colour:** Light green to light red
- **Description:** Term applied to several metamorphic rocks where the crystals of predominate minerals are aligned in parallel layers. The rock is easily broken along the lamination

GRADE CONTROL IN SURFACE MINING

PIT BENCH MAPPING



Section view showing the inclination and inter layered nature of the ore



GRADE CONTROL IN SURFACE MINING – DRILLING

Drilling type and spacing during grade control needs to consider:

- Cost benefits
- Geology of the mine
- Mining and metallurgical requirements

Selection of drilling method needs to ask..

- Are blastholes already present to sample?
  - Saves cost
- Will the blastholes adequately define the orebody?
  - Inclined ore body, faulted etc

DRILL SPACING

To determine optimum drill spacing for grade control..

- The drill spacing that will best define the ore body
- The Selective Mining Unit (SMU) that will best mine the ore body
- Whether closer spacing will define more metal
- Whether closer spaced drilling decrease dilution and ore loss by defining boundaries better
- Balance between cost of drilling against benefits
  - No point drilling on a 5 x 5 m pattern if mining is going to be on 20 x 20 m SMU

BLASTING BASICS

- **Why do we blast?**
- To minimise rock particle size so it can be economically and productively mined and processed
- **Blasting explosive:**

– Bulk Ammonium-Nitrate/Fuel Oil based explosive – both dry, prill form or emulsion which is used in wet holes

- **How it works**

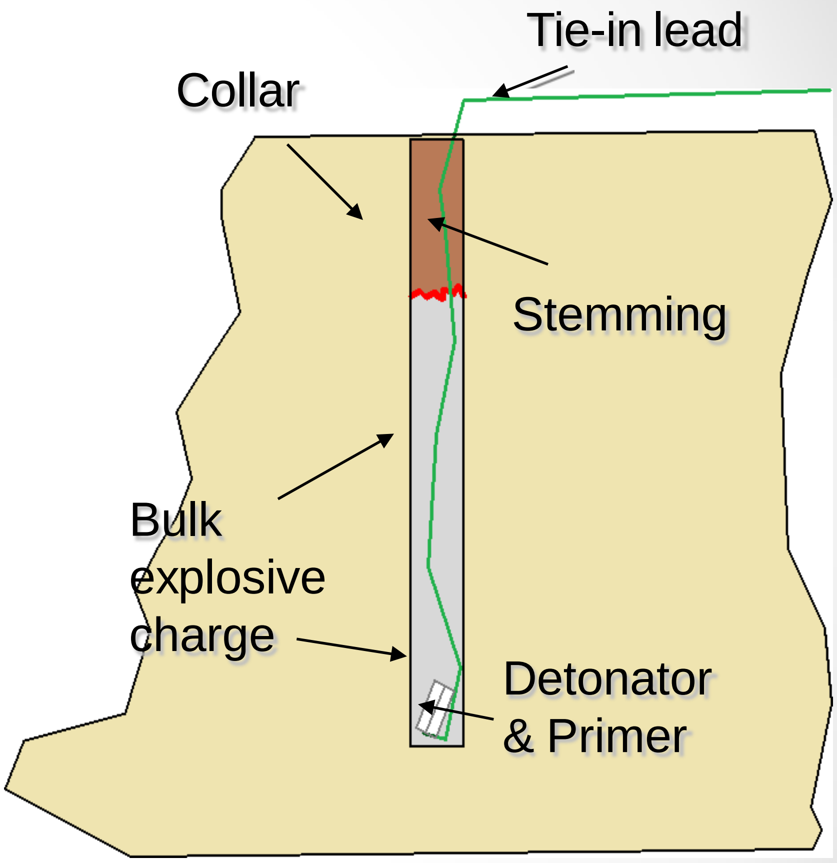
– The Bulk explosive charge is initiated by the primer and detonator assembly

– The Detonator and Primer are initiated by the tie-in lead.

– The Detonator has a pre-determined delay set-up before the blast to ensure that each hole detonates at the right time in the blast

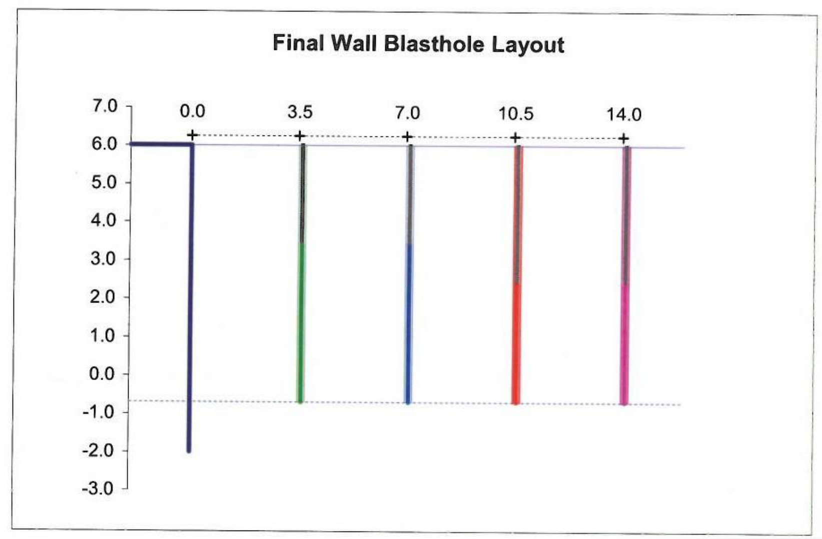
– When detonated the explosive product releases energy in the form of gas, which in turn breaks the rock ready for excavating.

– The stemming ensures the maximum amount of energy is applied to the rock mass and not vented out the top of the blast hole



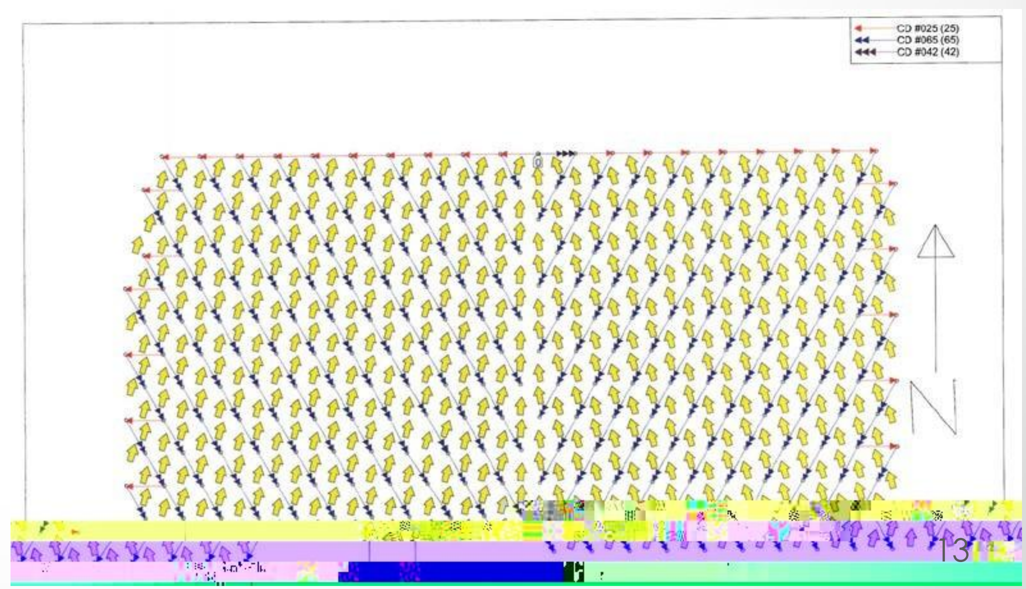
BLAST PROPOSAL

- Is signed of on by the
  - Shot firer
  - Drill and Blast Supervisor
  - Tech Support and
  - Mine Planning
  - Geology

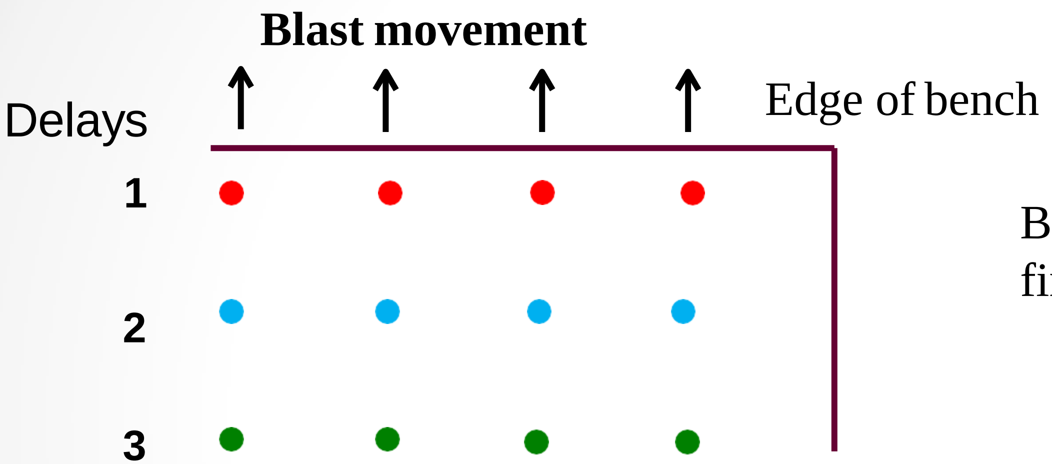


- Information included
  - Hole positions sizes etc
  - Explosives
  - Powder factor

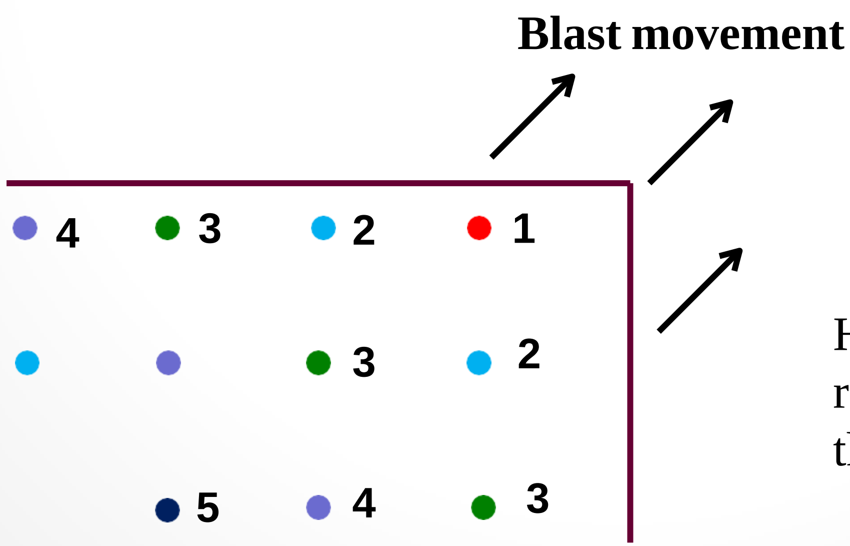
- Diagrams of the proposed movement of dirt during the blast



DELAY PATTERNS CONTROL BLAST MOVEMENT (THROW)



Bench cut with two free faces fired with one delay per row



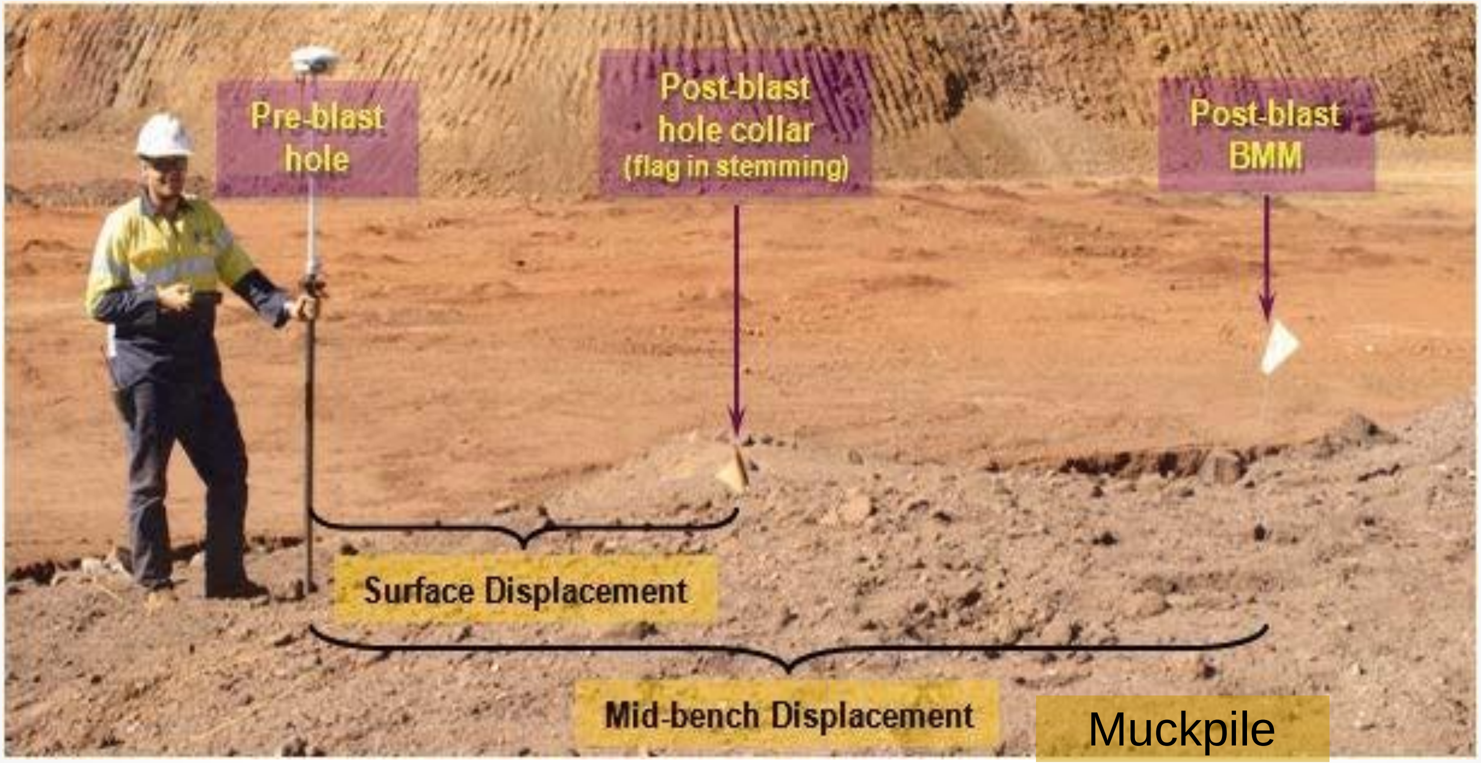
Holes fired in oblique rows results in rock mass thrown to the right

GOOD BLAST

Gets the best possible result by achieving:

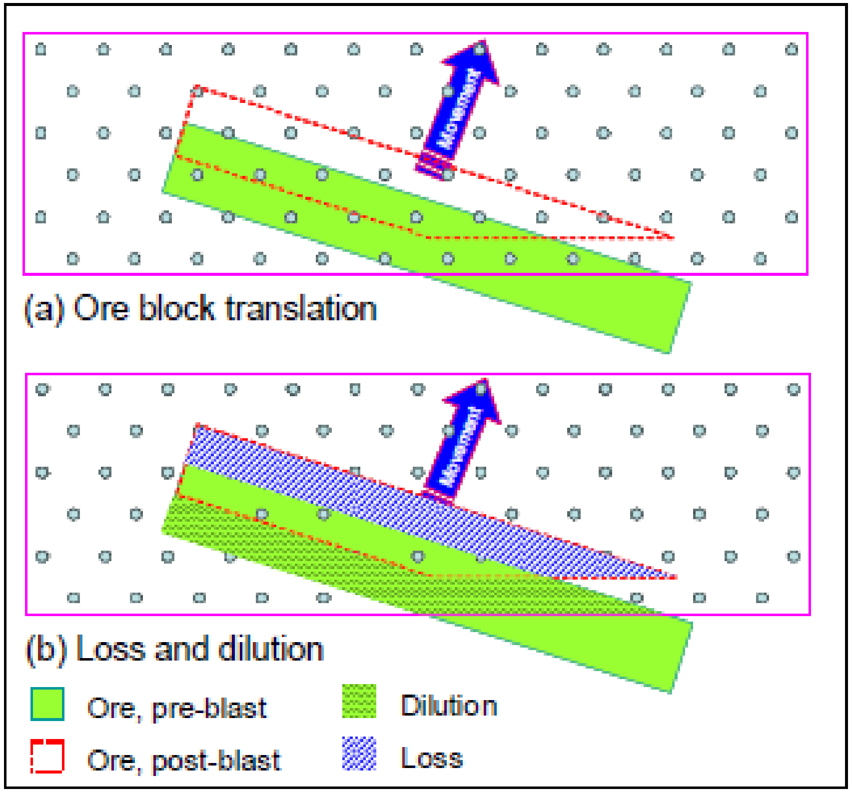
- Minimal Dilution: minimizes mixing of waste and ore
- Good Fragmentation: breaks rock up so it is easily mined. A well blasted shot will be easy for the digger to dig. This will allow for rapid mining and therefore cost savings
- Minimal Fly rock: rock thrown and scattered during blast
- Low Vibration: So minimal wall damage
- Geology considerations such as bedding planes and faults as well as rock mass hardness must be taken into account during the design process

BLAST MOVEMENT



From Thornton (2008)

Loss And Dilution Due To Blast Movement - Translation



If ore block was marked in its original location and shovelled, then area defined as dilution is sent to the mill and area marked as ore would be sent to the waste dump

From Thornton (2007)

Drilling Methods In Grade Control

- Should you use RC or Blastholes for sampling and assay?
- Is the lower cost of blastholes really saving money or is there a greater loss due to sampling constraints and ore body geometry issues?

Advantages of Blastholes
- Cheap
- Greater resolution
- Simple logistics

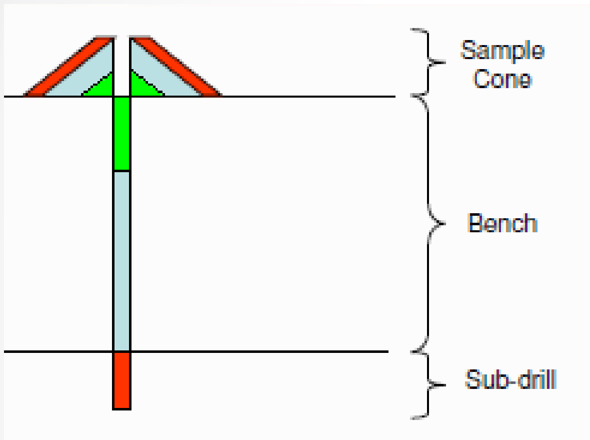
Disadvantages of Blastholes
- Sampling geometry depended on blasting requirements
- Receipt of grade data dependant on blast planning
- Sample error due to
  - Sub-drill
  - Spear
  - Slice

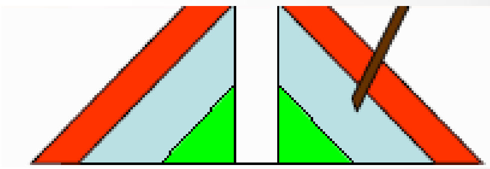
Drilling Methods In Grade Control - Blastholes

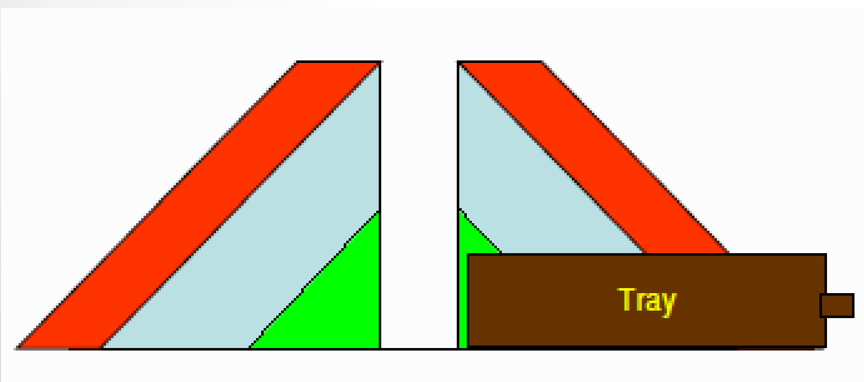
Blasthole rigs drilling on a square or rectangular grid

Grid spacing and type determined by ore type and mining issues (rock strength, free face etc)

Sampling issues with Blastholes





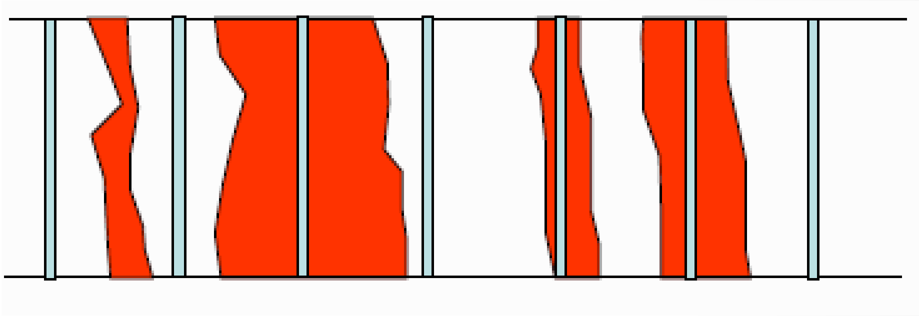


- Cone is only partially sampled
- Vacuum systems on blasthole rigs produce whole sample but
  - Segregate coarse and dust portions
  - Only sample coarse portion
  - Suffer from contamination
- Sample bias due to vertical blast hole
  - vertical orebody
  - inclined orebody

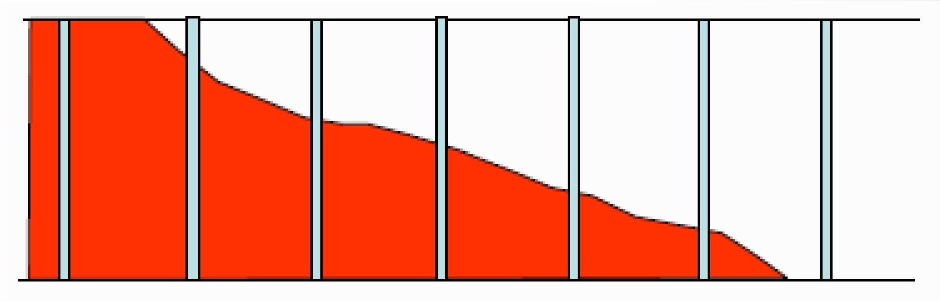
From Snowden Group

Blastholes And Ore Body Geometry

Vertical ore body
No correct representation of width



Inclined ore body
No correct representation of width or depth



From Snowden Group

RC DRILLING IN GRADE CONTROL

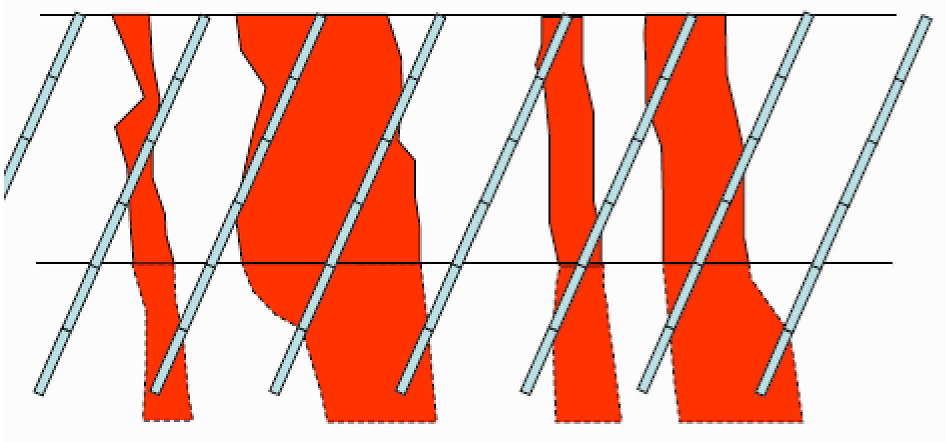
- **Advantages of RC**
- Drilling layout can be optimised for orebody geometry
  - Section line spacing
  - Drillhole spacing
  - Drillhole orientation
- Downhole sample length can be controlled
  - Improves sampling integrity
  - Improves definition of lateral orebody limits

Disadvantages of RC

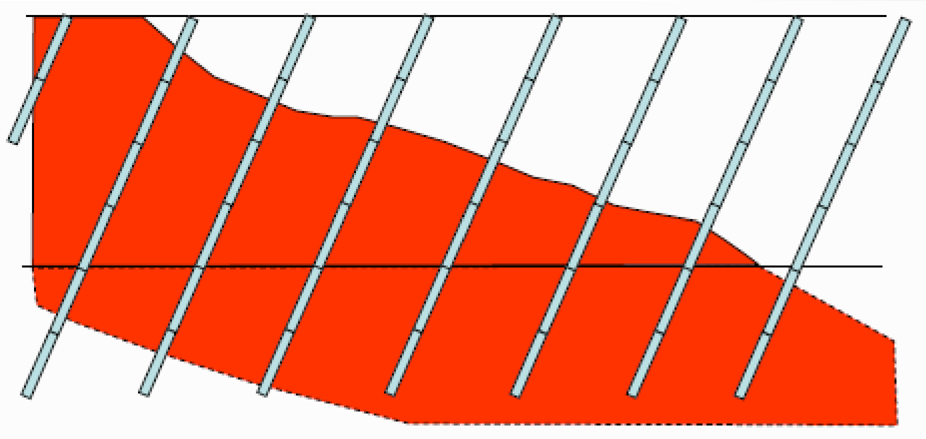
- Higher sampling and assay costs
- More complex logistics
- Poorer resolution – more costlier

RC Holes – Ore Body Geometry – Less Bias

Vertical ore body
Angled RC holes
define extents
accurately

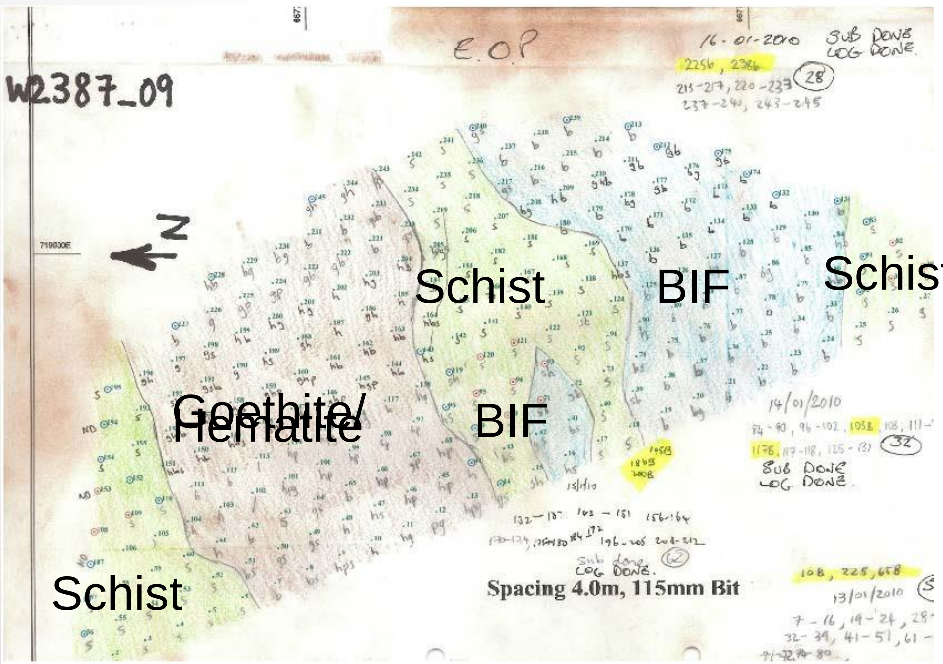


Inclined ore body
Angled RC holes
define extents

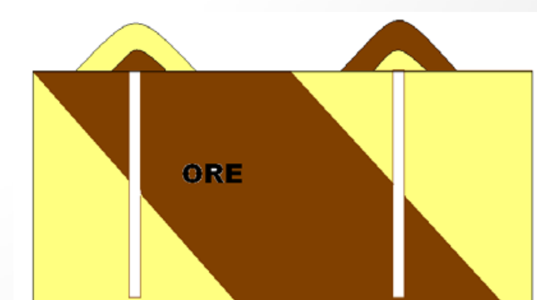


Logging And Sampling of Drill Piles

Geologists draw contacts on maps based on blast hole logging – minimizes ore loss & dilution

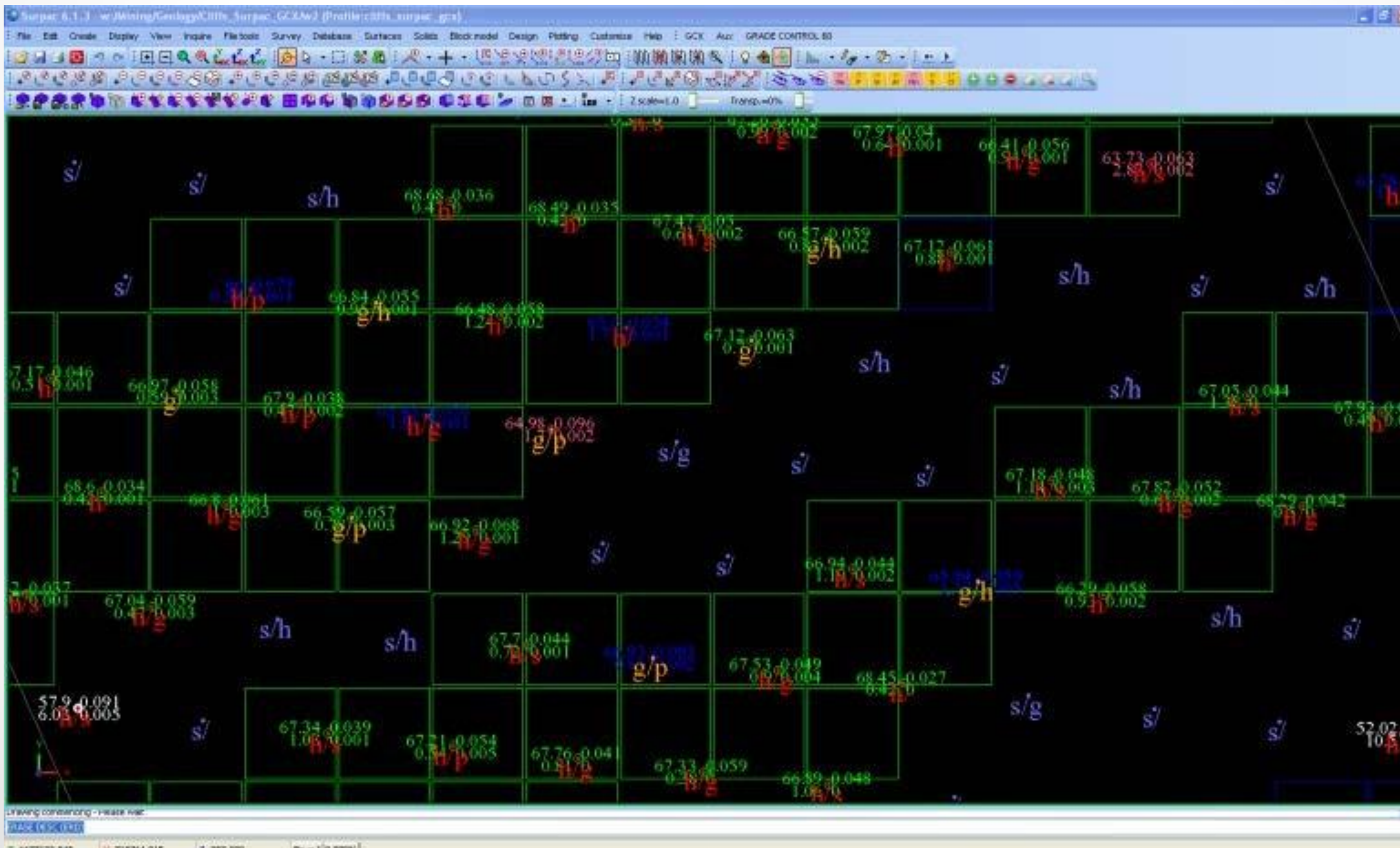


Geologists identify rock types and sample piles



GRADE CONTROL - BLOCKING OUT ORE

- Logging, assays and hole coordinates loaded into a database
- Data is then exported into mining package to define ore blocks



Grade Control – Ore Mark up

Ore is marked up on ground to show the excavator operator where ore and waste are

All blasted ore (muckpile) needs to be checked for movement in order to minimize ore loss

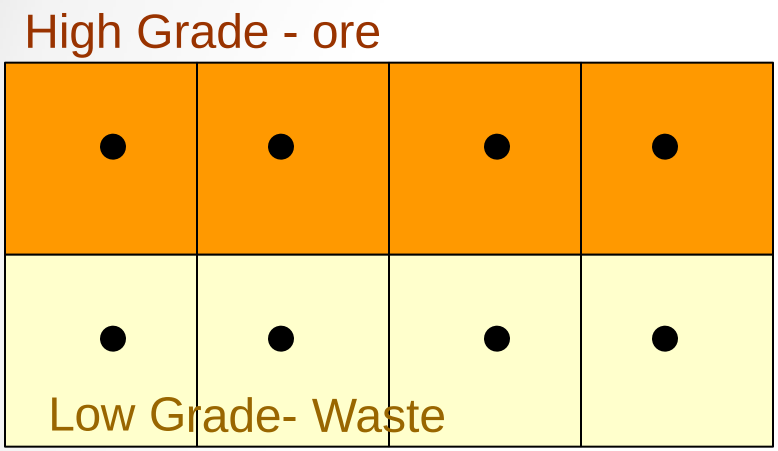
Based on the assay values from blasthole/RC samples, eahc selective mining unit (SMU) or block is marked up as Ore or Waste

Grade Control – Ore Mark up

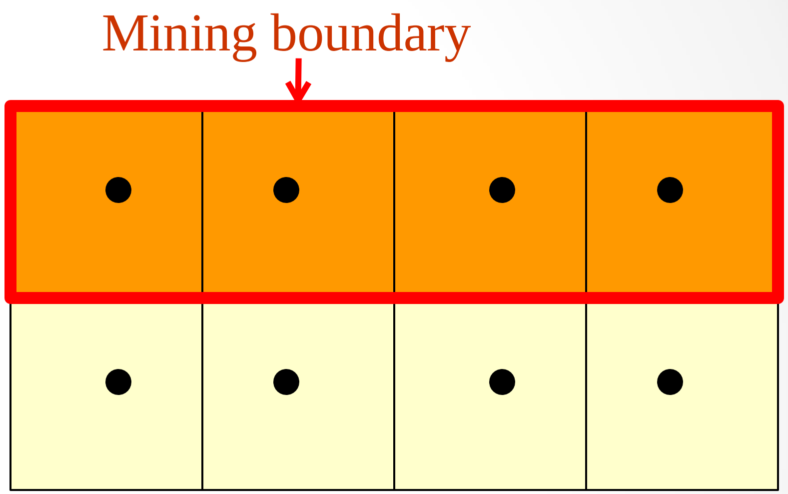
- Coordinates of ore blocks given to survey

- Survey
  - Mark out points of ore blocks
  - Edge of Blast
- Geology
  - Geologists use the survey points and lithology to mark up ore blocks.
  - Ore blocks marked with tape and spray paint.
  - Ore types are colour coded.

Blocks And Ore/Waste Boundaries



Easy grade control boundaries



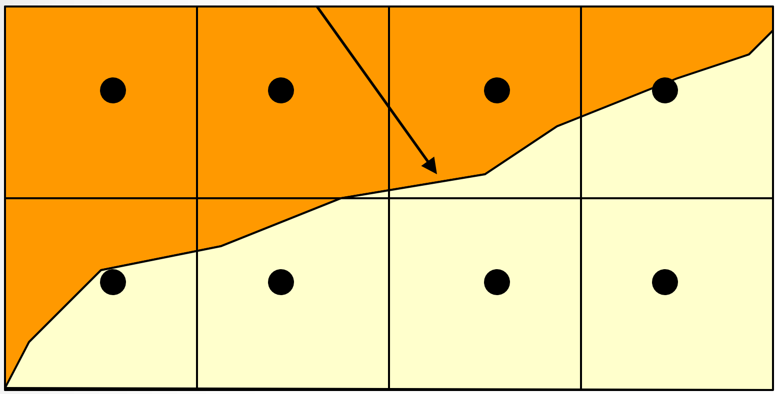
Minimal dilution and ore loss

Blocks adjoining ore-waste boundaries are composed of waste including ore. Their classification as ore leads to dilution, their classification as waste leads to ore loss

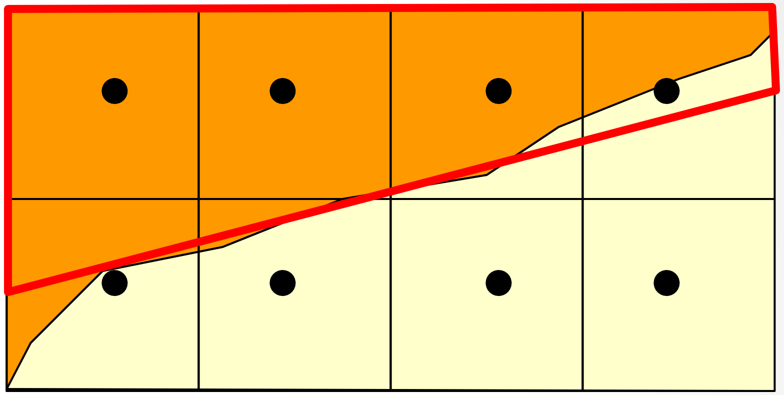
Modified after Sinclair & Blackwell (2001)

Blocks And Ore/Waste Boundaries

High Grade –Waste contact



Geologically more realistic Ore zone boundary!

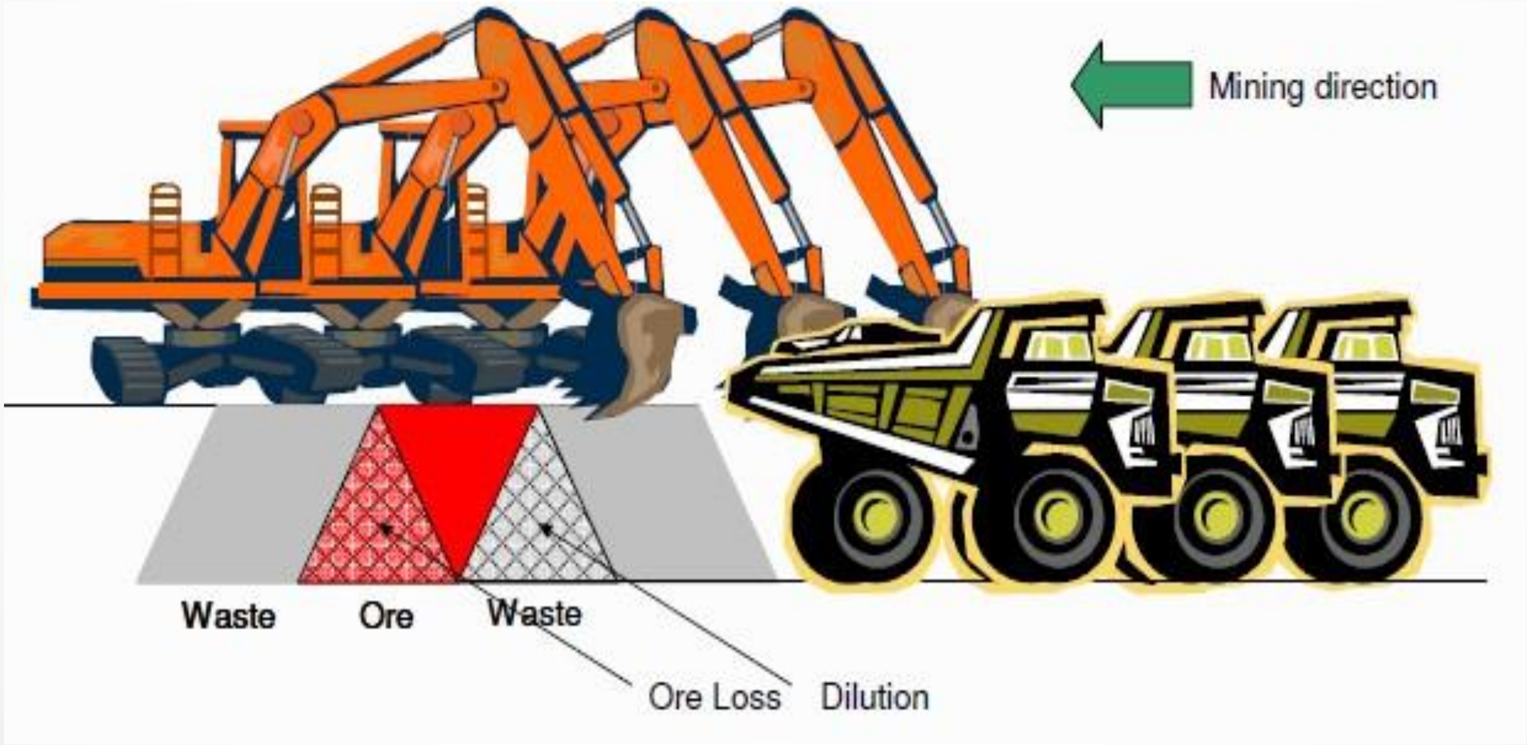


Mining block shape changed to minimize ore loss = improve in resolution

Need to consider block classification and mining block shape to minimize dilution and ore loss

Mining Direction And Dilution

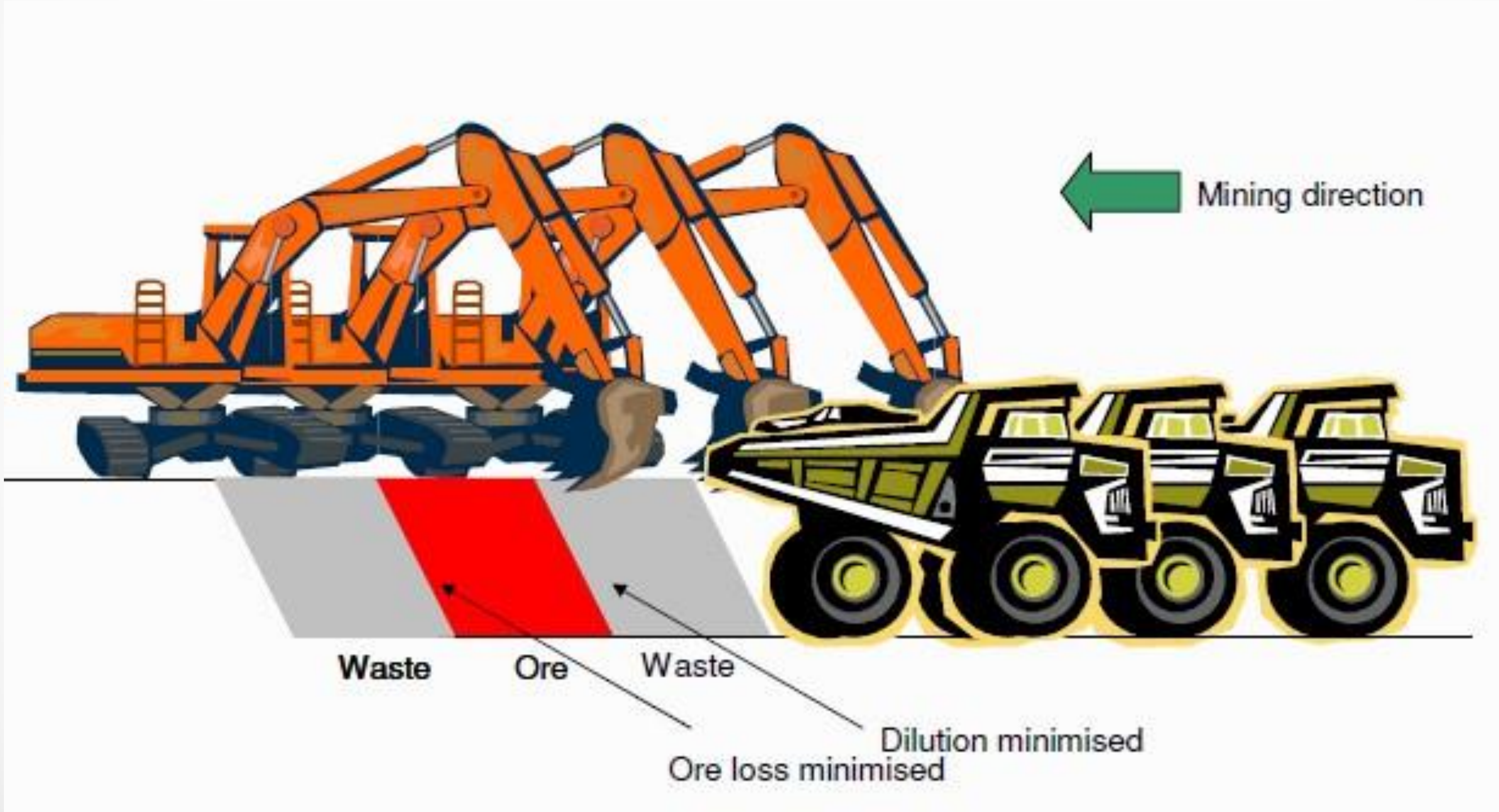
- Mining direction affects dilution, especially for inclined ore bodies
- Mining against dip slope increases dilution



Source Snowden

Mining Direction And Dilution

Mining along dip direction of ore body decreases dilution



Shoveling And Hauling

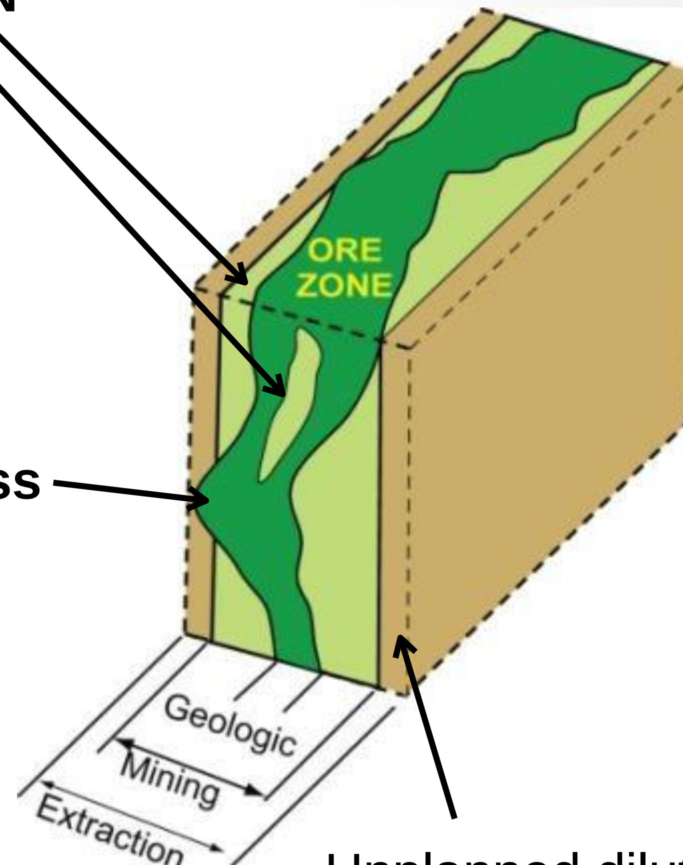
Excavators used to load blasted material (muckpile) from pit to truck

Ore to ROM pad or mill; waste to waste pile

GRADE CONTROL IN UNDERGROUND MINING

DILUTION

Ore Loss



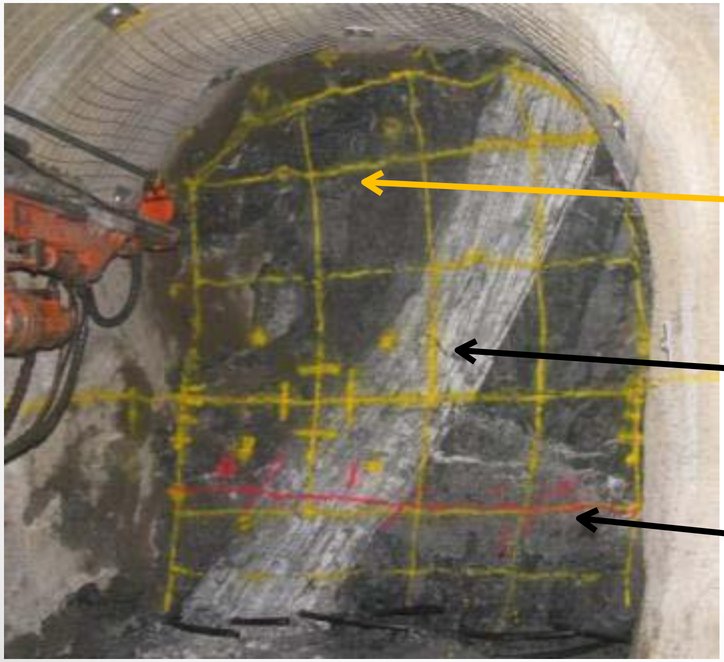
Unplanned dilution due to overbreak

Mining exposed ore body and makes data collection easy, but only between sublevels

Modified after Scobble & Moss (1994)

UNDERGROUND GRADE CONTROL

- Face mapping to differentiate ore from waste (dilution) – strict boundaries and areas
- Diamond drilling – fan drilling from levels
- Faults/shears

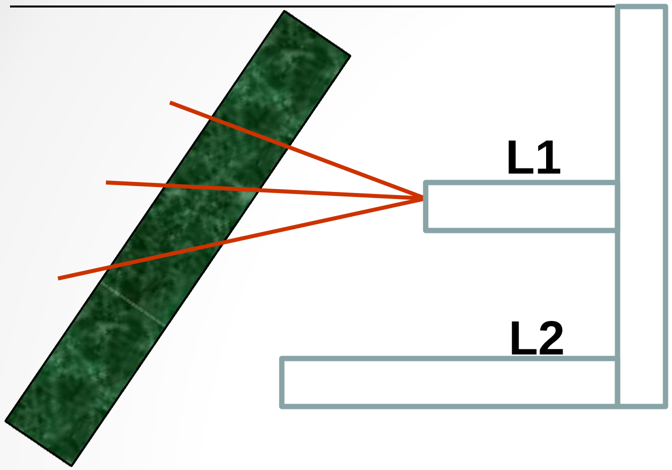


Metasediments (< 1 g/t)

High grade quartz vein (> 50 g/t)

Altered andesite (~ 2 g/t)

UNDERGROUND DRILLING



Fan drilling – several holes drilled from one location to minimize rid movement

Mine planning & development drilling (drives, access)

Grade control (with face sampling)

Production drilling blast holes (jumbo)

UNDERGROUND SAMPLING and GRADE CONTROL

- Grade control in UG Mines is strongly linked to mining methods and development/production chain

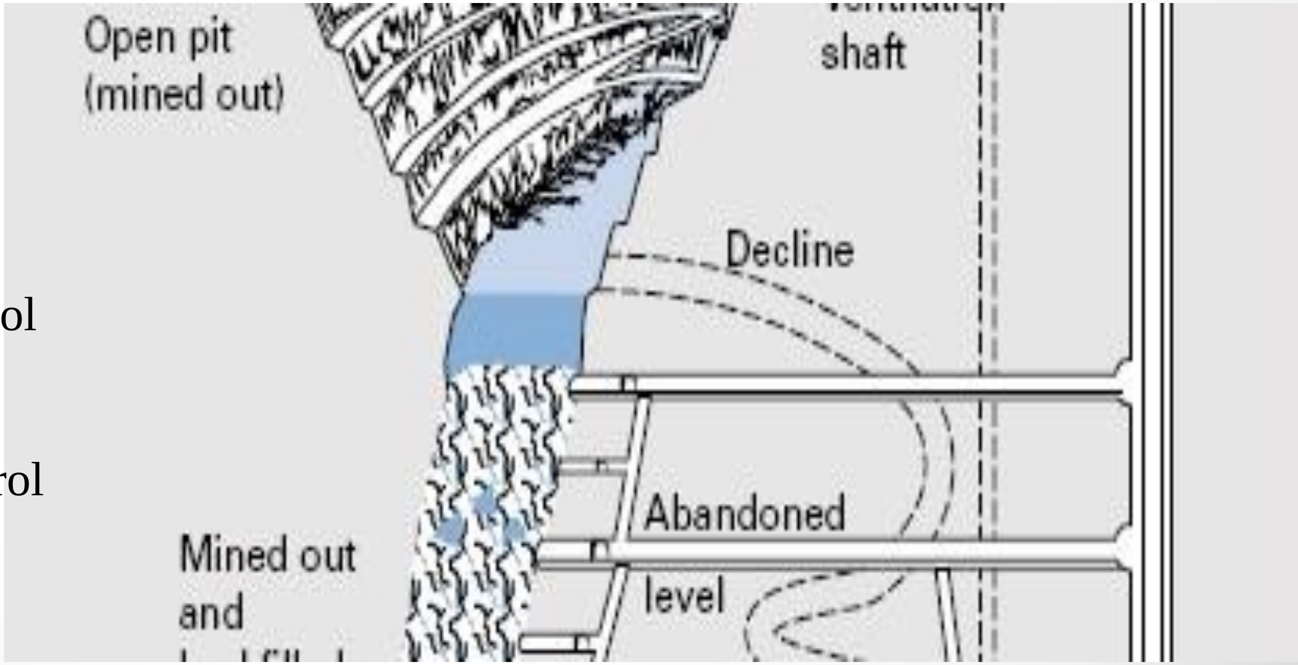
Activity in mining chain	Sampling method
Development	Linear Grab Diamond core
In-stope	Linear Grab Blast holes/sludge
Post-stoping	Grab

Underground Grade Control - Geometry Of Ore

- Dependent on Ore geometry and geotechnical issues
- Good control on sublevels
- Variation in Ore shape between sublevels to affect dilution

No geological control between sublevels

Good geological control on sublevels

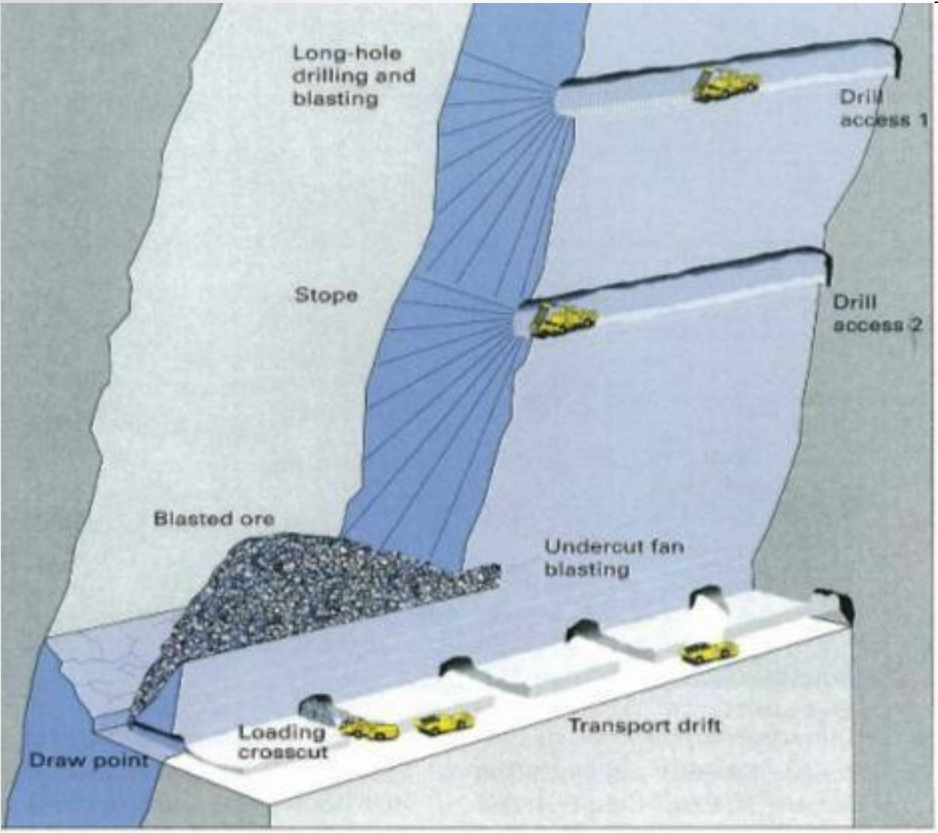


UNDERGROUND GRADE CONTROL
MINING METHOD

Detailed ore face data provides ability to mine selectively

Selectivity depends on mining method

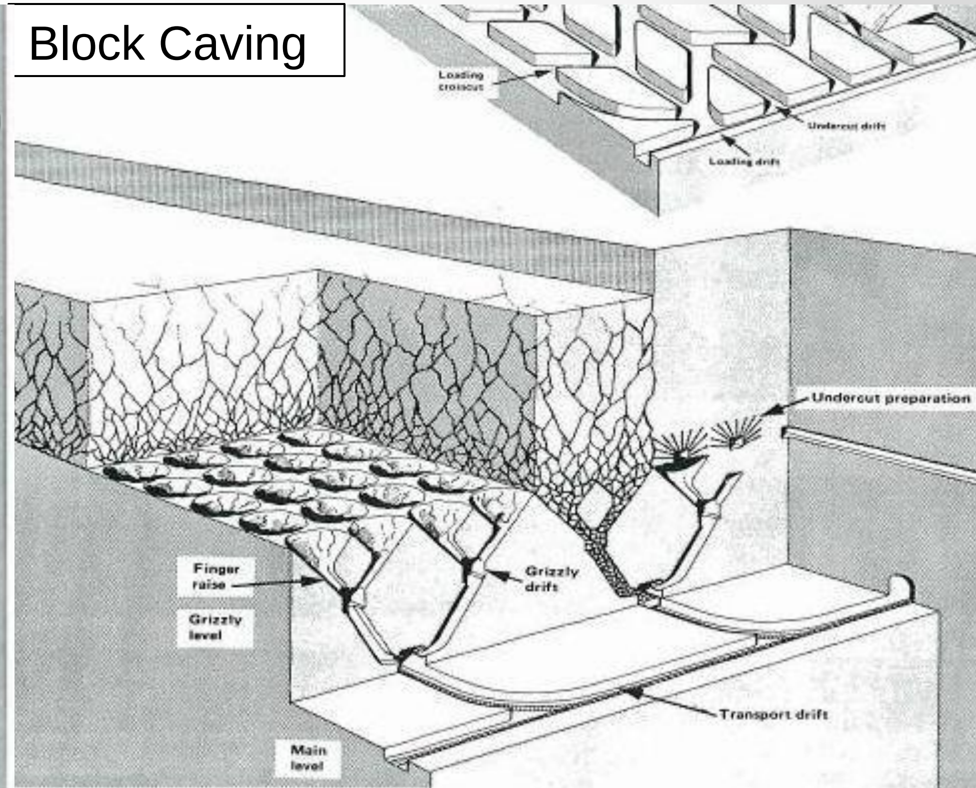
Mining Method	Mining Selectivity	Data Collection
Room & Pillar	High	High
Long-hole open stoping		
Sub-level stoping		
Block caving	Low	Low



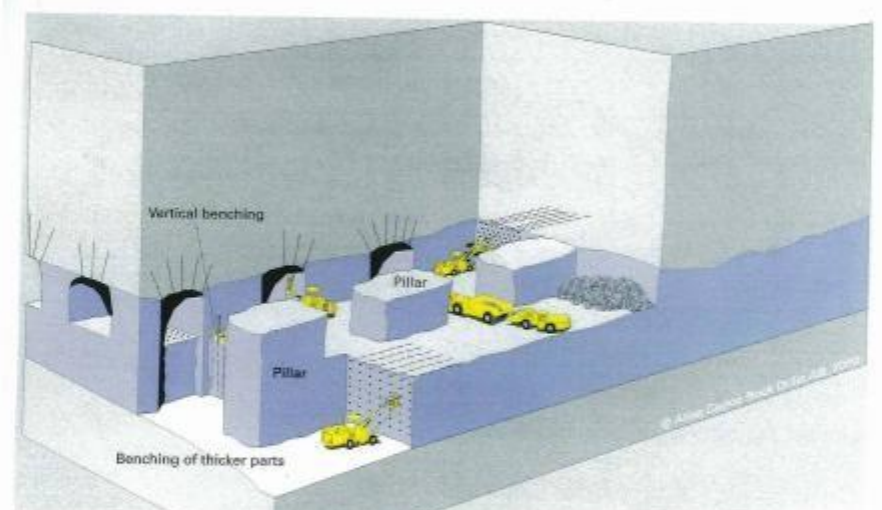
el open stoping layout

Sub-level Stoping

Block Caving



36. Block

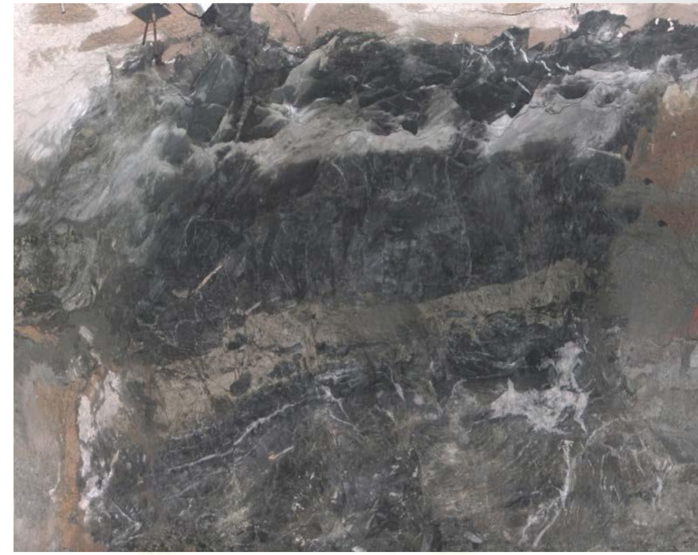


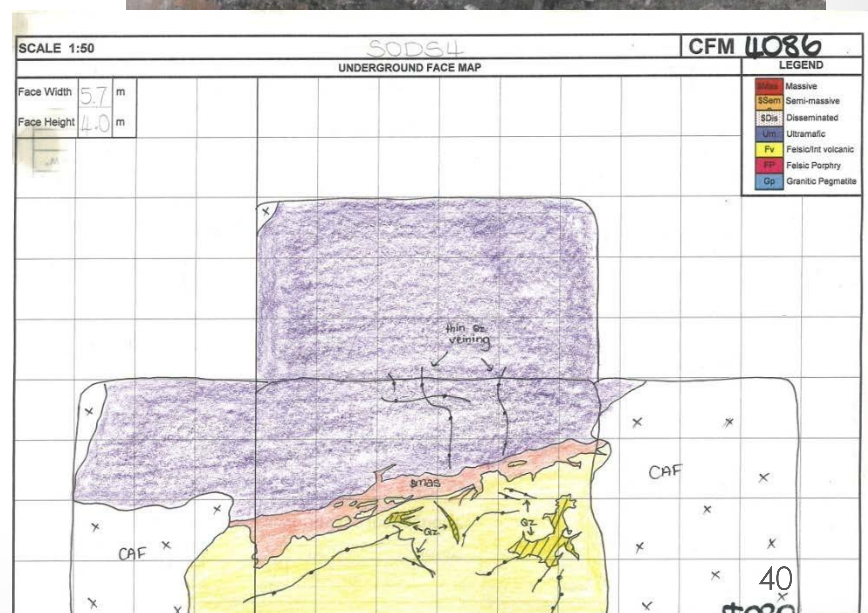
Classic room and pillar layout.

How Do You Estimate Dilution?

Several methods of estimating dilution

- From reconciliation
- Calculate grade from face geology and assay
  - Relatively easy for stope faces
- Comparing similar deposits, but this is found to be not reliable
- Difficulty in estimating tonnage of dilution





Estimating dilution from Face Geology

Quartz vein tonnage for 4 m = 72 t

Andesite and metasediment (waste) tonnage for 4 m = 116 t

Total tonnes for face = 188 t

$$\text{Dilution \%} = \frac{\text{Waste tonnes}}{\text{Grade control tonnes}}$$

Dilution % = 116/188 * 100 = 62%

Which One Is Better?
Ore Loss Or Dilution

Is it better to lose ore at 2.5 g/t or accept dilution at 0.75 g/t?

Calculate ore loss @2.5 g/t

Cost	= Milling + Transport = $14
Revenue (lost)	=Price x Recovery x Grade
	= $25 x .92 x 2.5 = $57.5
Net Revenue	= 57.5 – 14 = **$43.5**

Calculate loss due to dilution @.75 g/t

Cost savings	= Milling + Transport = $14
Revenue (lost)	=Price x Recovery x Grade
	= $25 x .92 x .75 = $17.25
Net Revenue	= 17.25 – 14 = **$3.25**