



Mining Evaluation of a Low Grade Uranium Mineral Resource



Bingham Canyon (2005)

- ❑ Presentation attempts to shed some light on how the mining of a low grade uranium mineral resource might be evaluated
- ❑ A generic approach rather than a specific uranium has been adopted
- ❑ Radiation risk does not have to be all pervasive
- ❑ Deals only with the mining - not resource estimation or processing
- ❑ Surface mining has been restricted to hard rock open pit activities- not include solution or sand mining

Paper to consider➤ Part 1 **Selection of a Mining Method for a Uranium Mineral Resource**

❖ Stages in a normal evaluation

❖ Mining Method Selection

➤ Part 2 **Mine Design for a Uranium Mineral Resource**

❖ Mine design

❖ Remediation

❖ Risk

 Both parts are quite long but will be published on the IAEA web site



Part 1

Selection of a Mining Method for a Uranium Mineral Resource

2.

Stages of Evaluation

Evaluation of a mineral resource is the process of determining if the resource will support economic exploitation

☐ Cost Estimation Handbook (Noakes and Lanz, 1993)

2.1 When should evaluation start?

- ☐ Exploitation of a mineral resource is a risky undertaking – non homogeneous rock masses
- ☐ No two resources are identical – need to sort out idiosyncrasies as soon as possible
- ☐ Exploration team should have some development concepts
- ☐ Inferred resource for formal studies

2.2 Stages of evaluation

☐ Formal resource project evaluation is an iterative process usually accomplished via a series of progressively more detailed studies that punctuate and drive ongoing data collection programs

☐ Stages are

- Scoping (Conceptual)
- Prefeasibility
- Feasibility

2.2 Stages of evaluation Cont...

Scoping to identify:

- Technical issues requiring further investigation or testwork*
- Features and order of magnitude parameters of project*
- Costs and time required to undertake further development.*

Scoping studies are conceptual studies and

- ***are not sufficiently accurate to carry out a meaningful assessment of the economic viability of any project,***
- ***only whether and how much, further predevelopment is warranted***

Issues

- May not be once-off**

2.2 Stages of evaluation Cont...

Prefeasibility

- Assess probable reserve & approaches to recovery*
- Identify techniques & rates of extraction*
- Outline possible features of the facilities*
- Develop capital & operating costs estimates*
- Test marketability of the commodity*
- Assess economic viability*
- Determine what further efforts are required to progress predevelopment activities*

Prefeasibility studies should be sufficiently accurate to allow a comparative analysis of economic viability to be developed for alternative capacity and project configurations (ie options study).

Issues

- Less common**
- Not used as options studies enough**

2.2 Stages of evaluation Cont...

Feasibility undertaken at two levels

➤ for internal final assessment purposes

Or

➤ for obtaining external funding (bankable feasibility study).

With the objective of:

- Establishing proved & probable reserves within overall measured indicated & inferred resources
- Proving the technical viability of the mine & extraction methods
- Defining the features & capacity of the facilities
- Estimating development, capital & operating costs of mine over economic life of resource
- Establishing the market for the commodity
- Completing economic assessments of the selected project configurations
- Assessing the economic sensitivity of the proposed development to various factors
- Setting a framework for the implementation of the capital investment in the development.

Issues

- Does not always produce a positive outcome

**Table 1
Comparative
Quality Levels for
Predevelopment
Cost Estimates**

Activity	Scoping	Pre-feasibility	Feasibility
Accuracy	30-35%	20-25%	10-15%
Contingency	20-25%	15-20%	10-15%
Resource Status	*Inferred/Indicated	* Indicated	* Indicated/Measured
Reserve Status	n/a	Probable	Proven/Probable
Resource analysis	Limited data	* Preliminary Block Model / Cross section	Detailed block model
Reserve Analysis	Limited data	* Preliminary Block Model / Cross section	Detailed block model
Geology	Preliminary	Preliminary	Detailed
Geotechnical	Preliminary	Preliminary	Detailed
Mine Plan	Sketch Only	Preliminary	Firm detail
Mine Schedules	Assumed	Approximate	Calculated
Mine Equipment	Assumed	In house data	Optimised
Mine Services	Assumed	Sketch design	Full outline
* Mining Cost	* Factorised / Similar operations	* Calculations / indicative tenders	* Detailed estimate / tender
Staffing Levels	Factorised	Preliminary	Detailed estimate
* Capital Cost	* Factorised /	* Single check price / preliminary estimate	* Multi quotes / detailed estimates

After Noakes and Lanz, 1993 (* Edited/changed by writer)

2.3 Time Required

Table 2
Typical Durations for
Average Predevelopment
Studies (Months)

Issues:

- Data acquisition, specifically geological and geotechnical is time consuming
- Studies flounder when data acquisition results are not as anticipated.
- Time (and cost) is projected related.
- No provision for political or environmental delays or delays for approvals

Activity	Scoping	Prefeasibility	Feasibility
Establish data and basis of study	2	2-3	3-4
Study core period	3-4	4-6	6-9
Review and Evaluation	2-3	3-4	3-4
Total	7-9	9-13	12-17

2.4 By Whom?

- ❑ Largely dependent on size of company and available resources

- ❑ **Scoping** - by owners using inhouse resources & staff, assisted by specialists or consultants assigned specific tasks

- ❑ **Prefeasibility** - be led by owner's inhouse staff with areas assigned to consultants

- ❑ **Feasibilities** - be managed by owners staff, assisted by project orientated staff, with defined areas or disciplines to consultants or contractors.



Rössing Uranium (Copyright, Rio Tinto. 2009)

3.1 Surface Vs Underground

First Big Question – Surface, Underground or Both

Is there a preference?

Advantages of Surface over Underground Methods:

- Generally less risky both operationally and financially
- Usually would provide earlier cashflow
- Development is more forgiving with respect to incomplete resource assessment
- More suitable for near surface geotechnical conditions
- More suitable for “weathered/disseminated” surface mineralisation
- Can be assessed relatively simply via optimisation software
- Less complicated mining methods & scheduling
- Higher productivity & production capacity
- Better working conditions
- Easier planning and supervision
- Preferred working conditions for uranium

Disadvantages

- Greater environmental impact
- Potential weather delays
- Limited to near surface deposits
- Higher rehabilitation costs

First Question

- Will resource support open pit ?

3.2 Mining Selection Sequence

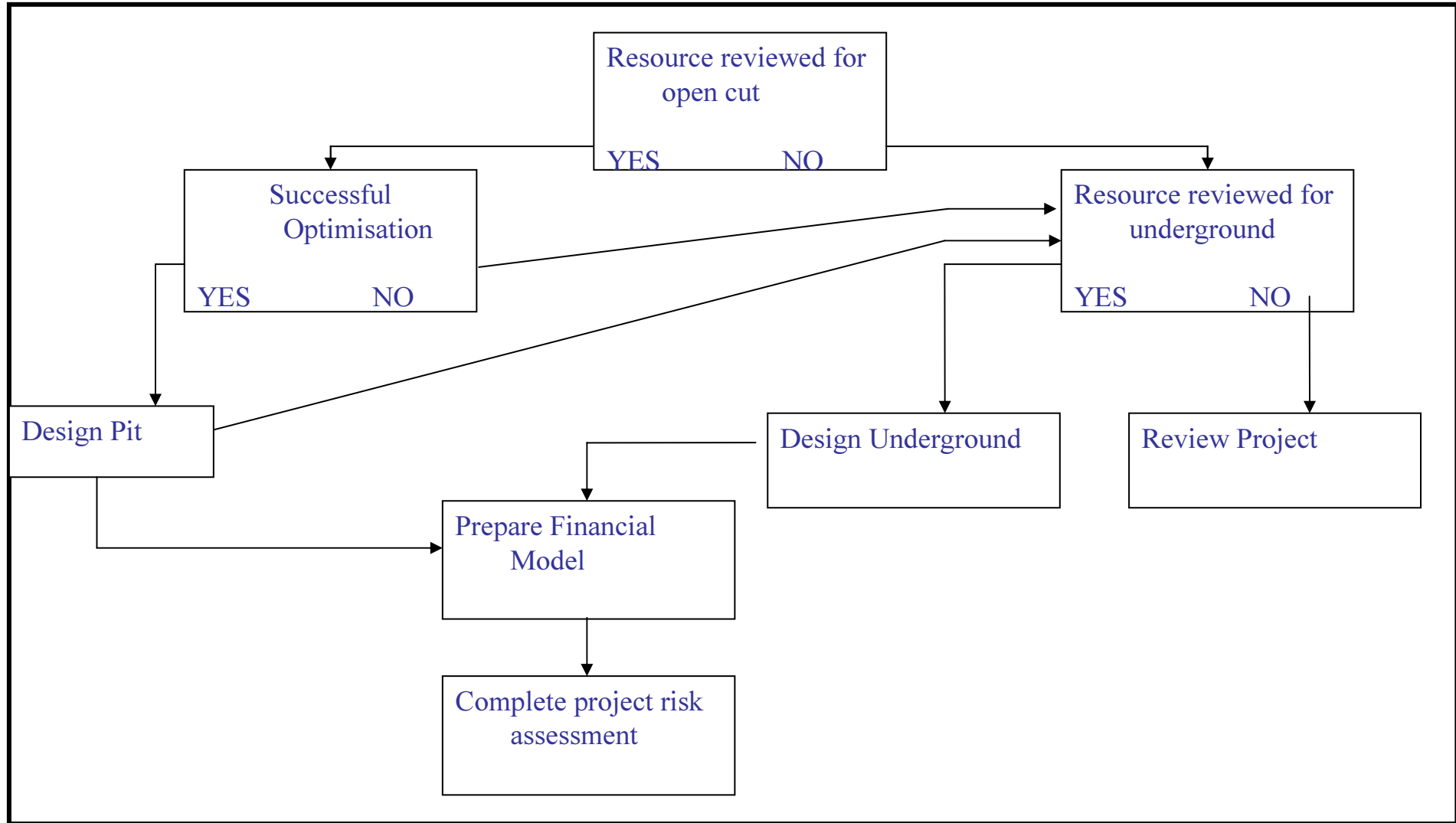


Figure 1 Flow Chart for Mining Selection

3.3 Preliminary Open Pit Considerations

How is a resource assessed to be suitable for open pit mining? Need to review four basic preliminary parameters:

1. Resource Geometry
2. Geotechnical
3. Hydrology and Hydrogeology
4. Environmental

1. Resource geometry

- Open cuts are suitable for almost any ore body geometry
- The closer to the surface the better.
- The pit shape is simply designed to fit the geometry of the deposit

However

- Resource geometry impacts greatly on grade control procedures and productivities – cost structure may be different for similar size resources if geometry differs substantially



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3.3 Preliminary Open Pit Considerations Cont....

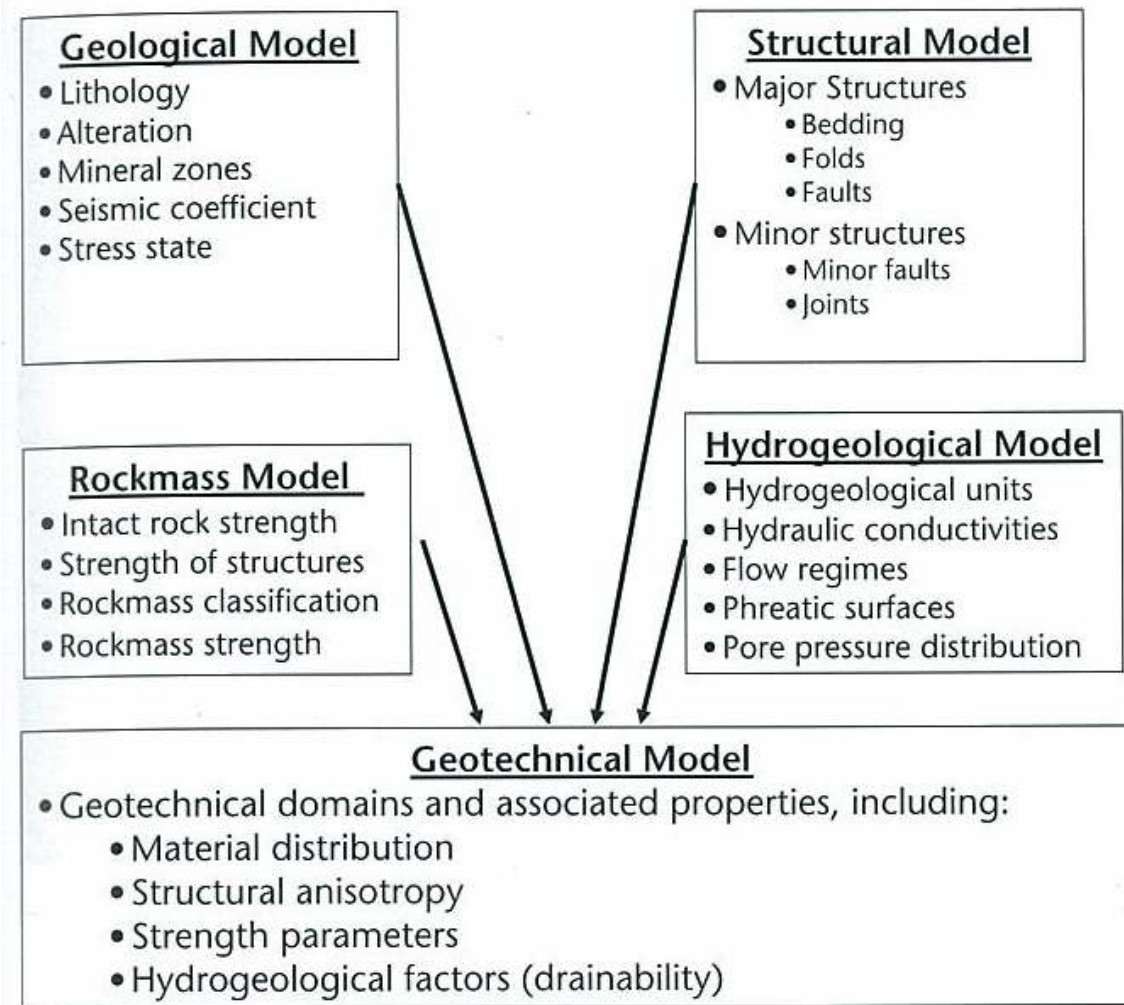
2. Geotechnical

- Geotechnical conditions:
 - Type of surface mining (here only open pit)
 - Determine wall angles – Drives economics
- Studies for small pits normally not as detailed as for large pits or underground.
- Issues investigated in studies also include;
 - Wall support requirements
 - Breaking techniques (drill and blast, ripping etc)
 - Equipment type (articulated or rigid trucks)
- Understanding the seismic regime is part of geotechnical review and fundamental.
- Geotechnical would not usually produce fatal flaw but possible
- Geotechnical Model is now the cornerstone of slope design for large pits.

Geotechnical Cont...

3.3 Preliminary Open Pit Considerations Cont....

2. Geotechnical Cont



Component information and output from the geotechnical model (Read and Stacey, 2009)

3.3 Preliminary Open Pit Considerations Cont...

3. Hydrology/Hydrogeological

- ❑ Hydrology refers to surface water studies and Hydrogeology to groundwater issues.
- ❑ Hydrology issues concern the likely impact on an open pit from
 - Major watercourses
 - Natural or artificial water impoundments (including tailings facilities)
 - General surface drainage
 - Might provide early fatal flaw
- ❑ Hydrogeology issues concern:
 - Potential groundwater issues
 - Pre-development and on-going dewatering
 - Input for geotechnical model
 - Early fatal flaw unlikely
- ❑ Storage or disposal for pumping (for both)
 - No storage / disposal – no mining

3.3 Preliminary Open Pit Considerations Cont

4. Environmental/Social

- Environmental can be a fatal flaw area for open pit mining
 - Residential areas
 - National parks
 - ❖ Why explore?

3.4 Preliminary Underground Mining Considerations

- ❑ Underground much less constrained, more complex
 - Not just top down – accessed from any direction
 - Unlike open pit, - methods are quite different
 - ❖ some rely on stability, some on instability
- ❑ Decisions on U/G methods, especially for small operations, are frequently influenced by
 - the maturity of the project,
 - systems at neighbouring projects
 - people's experience
 - do not necessarily always do full technical analysis
- ❑ More complex with massive orebodies
 - Full technical analysis
 - Select methods that will work
 - Decide on optimal method(s)

3.4 Preliminary Underground Mining Considerations Cont...

The same four basic parameters

1. **Resource geometry**
2. **Geotechnical issues**
3. **Hydrogeological/hydrology**
4. **Environmental**

1. **Resource geometry**

- Affects every aspect of an underground mining system
 - Mining method selection
 - Production capabilities
 - Equipment size and personnel requirements
 - Access options

Resource Geometry Cont...

3

Mining Method Selection Cont...

3.4 Preliminary Underground Mining Considerations Cont...

1. Resource geometry Cont...

Mining Method	Ideal Geometry	Production Capability	Selectivity	Cost	Suitable for Low Grade U ₃ O ₈	Comment
Block Caving	Very massive	Very High	Very Poor	Very Low	Maybe	Rock Factory
Sub Level Caving	Massive to large	High	Poor	Low	Maybe	Forced Ventilation
Longhole Open Stoping	Massive to large	High	Medium	Low	Yes	Olympic Dam
Retreat Benching	Steep vein /selective/ large/	Medium	Good - medium	Medium	Yes	Rabbit Lake
Cut and Fill	Steep vein /selective	Low	Good	High	Maybe	
Room and Pillar	Flat lying	Low	Good	High	Maybe	
Shrink Stoping	Steep vein /selective	Low	Good	Very High	No	Out of favour Hand held Mining

Note - Cost structure of high grade Canadian methods would be inappropriate for low grade resources therefore they are not included above

Resource Geometry Cont...

3.4 Preliminary Underground Mining Considerations Cont...

1. Resource geometry Cont...
 - Technology and remote control



Remote Control Dozer

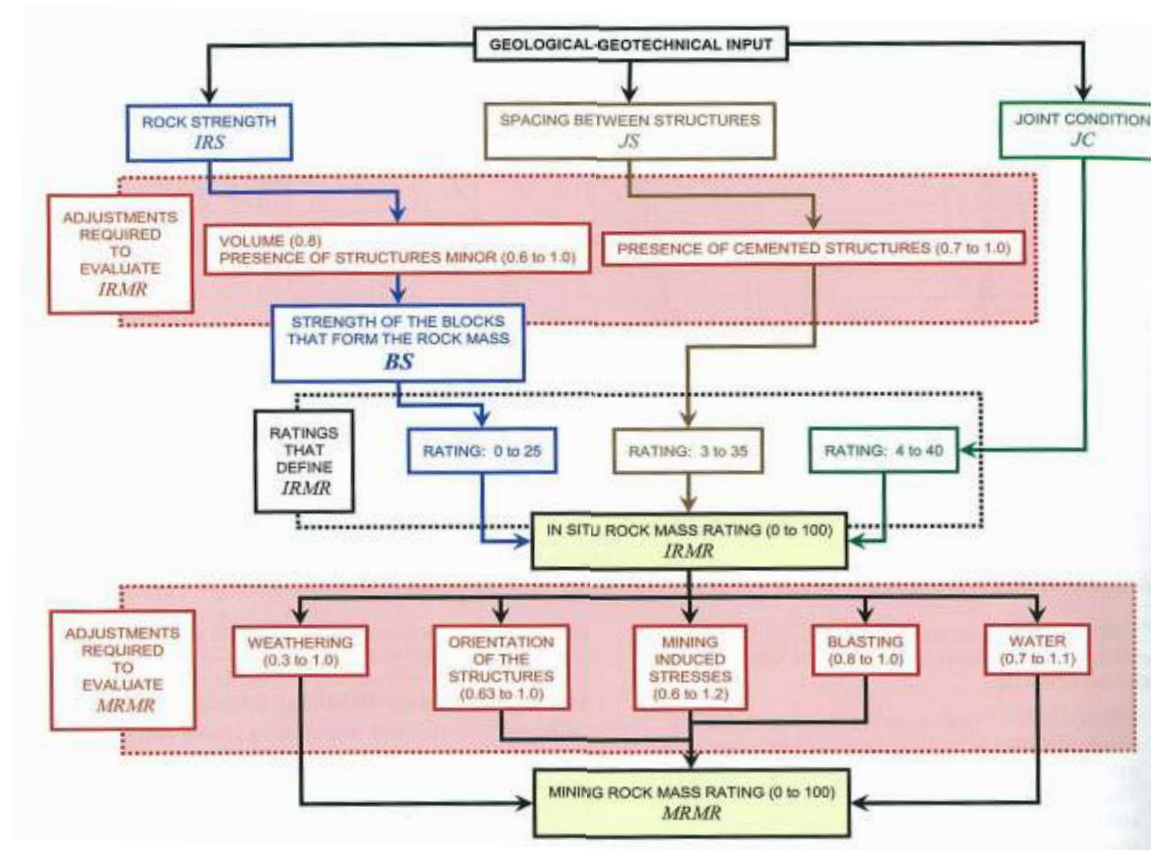


Picture of Rabbit Lake Remote Control LHD

3.4 Preliminary Underground Mining Considerations Cont...

2. Geotechnical

- ❑ Considers both the regional and operational levels and drives method selection
 - The regional is concerned with the stability of the rock mass globally – level at which broad method decisions are made
 - Operational defines the more specific operational detail eg individual stope dimensions
- ❑ Geotechnical models prepared in similar way to open pit models using the same inputs
- ❑ Underground investigations especially interested in
 - insitu stress levels
 - rock mass classification
- ❑ *Rock mass classification systems are used to provide a basis for the extrapolation of experience in one rock mass to another and utilise all the individual aspects of geotechnical investigation to do so. (Brown and Rosengren, 2000)*
 - Overall numerical rating is developed for the rock mass (relative rating)
 - Examples include
 - ❖ NGI tunnelling quality or Q index by Barton Lien and Lunde,
 - ❖ Rock Mass Rating (RMR) by Bieniawski
 - ❖ Mining Rock Mass Rating (MRMR) by Laubscher.



Procedures involved in evaluating IRMR and MRMR (Read and Stacey, 2009. page 120)

Fig 24
Laubscher's Caving Chart
(Nickson, Coulson,
Hussey, 2000)

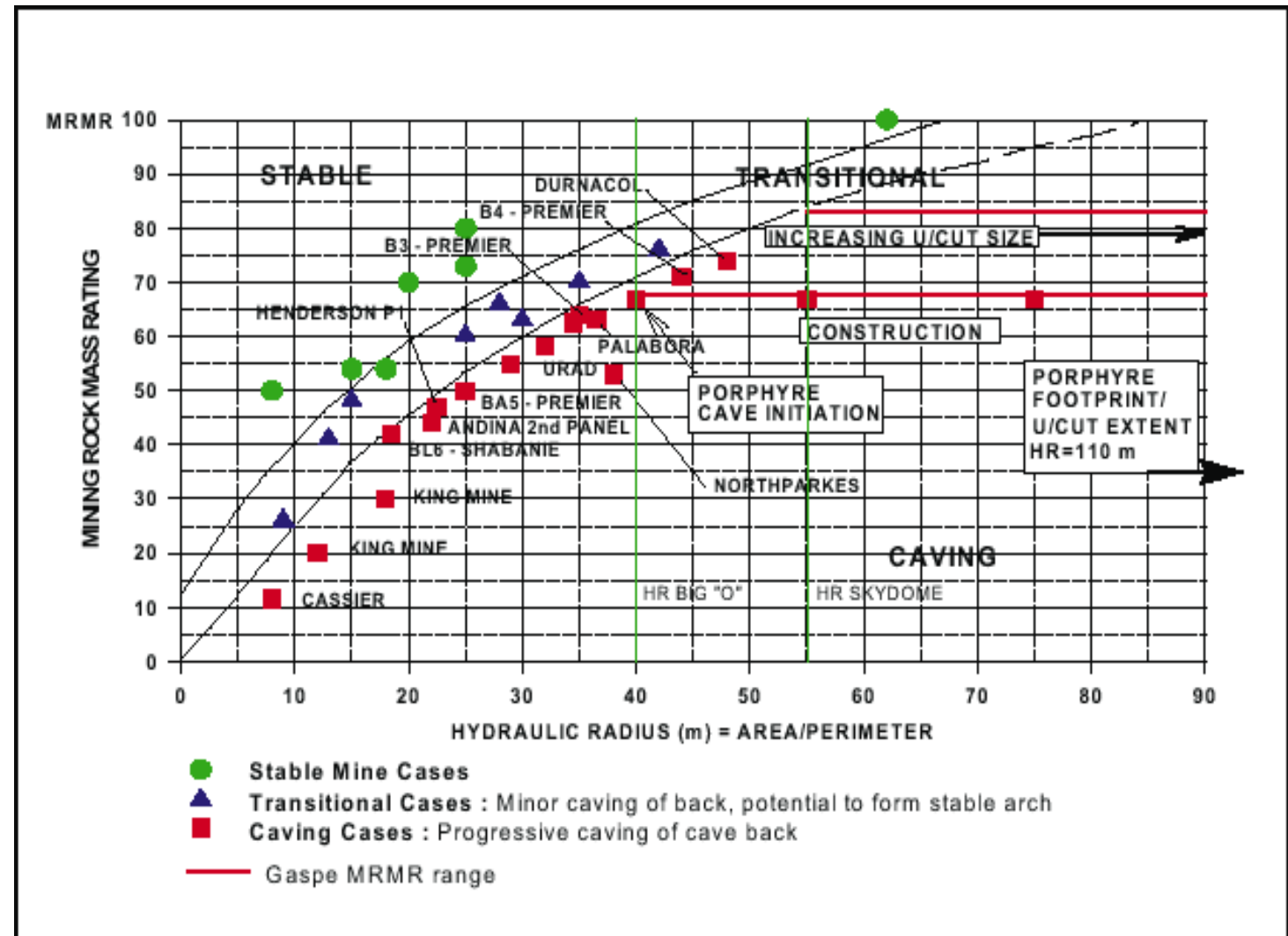


FIG 4 - Laubscher Caving Stability Graph (after Laubscher, 1990), indicating the relative location and points of potential cave initiation for the Mont Porphyre orebody, compared to other operations around the world.

3.4 Preliminary Underground Mining Considerations Cont...

3. Hydrology/ Hydrogeological:

Similar to surface mining,

- Particular concerns
 - Inrushes from surface
 - Impact on location of surface infrastructure
 - Likelihood of sudden intersection of underground water
 - Other mining voids
 - As with open pit – looking for fatal flaws
- Are essential inputs for development of geotechnical model
- Indication of pumping requirements

4. Environmental

- Underground would normally be favoured
- Caving operations?

3.5 Combination Surface/Underground

Its not always a case of either/or.

- Often even very preliminary investigations will indicate a resource will likely support both underground and surface mining.
- ❑ Decisions must be made on;
 - Concurrent or sequential mining
 - Transition point
 - Underground mining only
- ❑ Large resources especially might require detailed option studies.
- ❑ Issues that might need consideration include
 - Geotechnical interaction between concurrent operations
 - Hydrological/Hydrogeological interactions
 - Operational interaction between the two operations (eg blasting interaction)
 - Multiple or variable ore types
 - Start up and long term production rates
 - Underground access arrangements and interaction with operational pit(s)

3.5 Combination Surface/Underground Cont...

A variation is to intentionally delay detailed evaluation of the underground resource until open pit mining has established a positive cashflow.

Issues

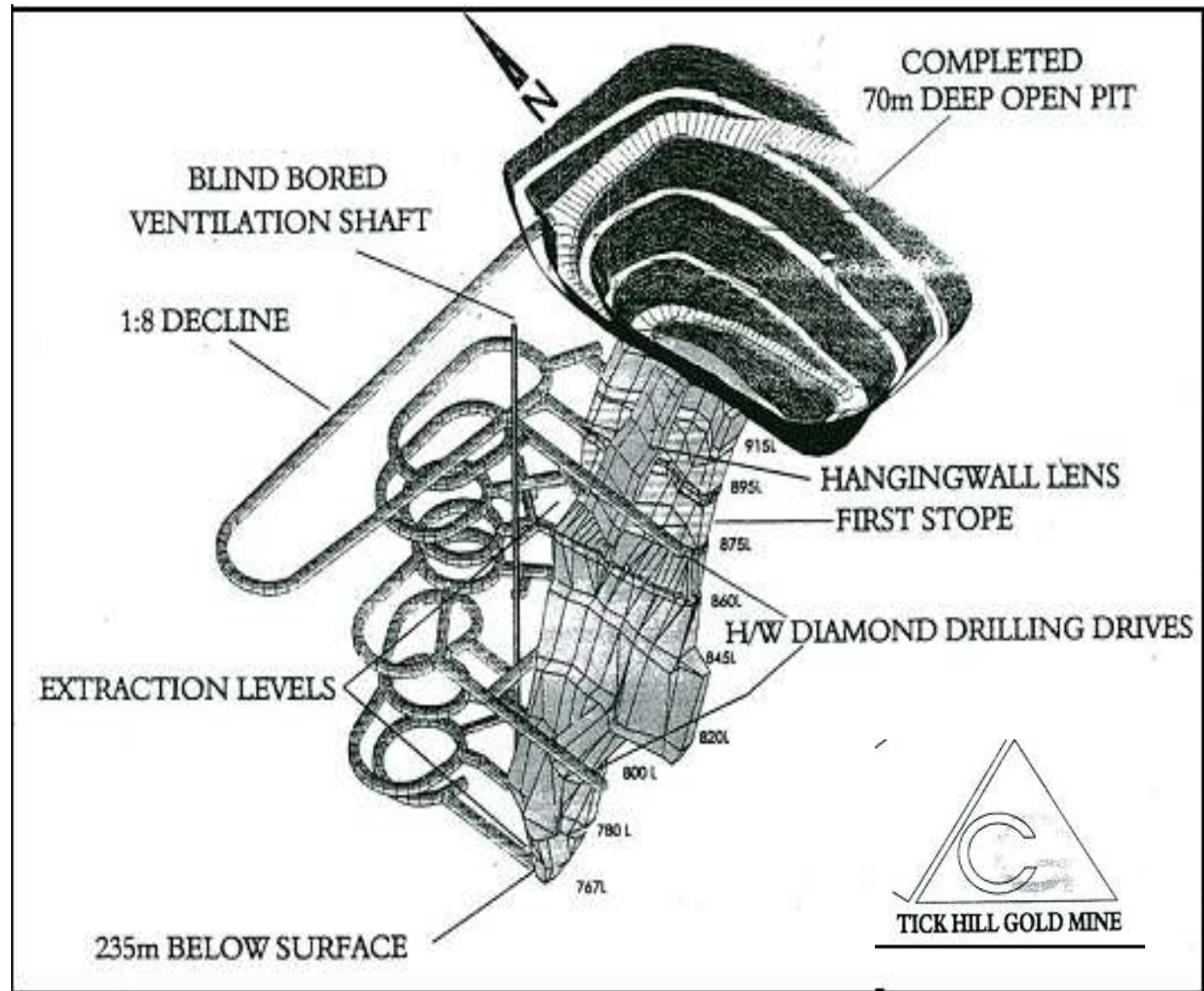
- As pit *matures*, a renewed effort is made to understand the potential for future underground
- Progressive development promotes risk minimisation
- Improved confidence in the underground resource results from the open pit operation.
- Underground and open pit will still potentially be operating together
- Some risk that open pit might compromise underground

Reverse occurs - open pit after underground

- Porgera
- Olympic Dam

3.5 Combination Surface/Underground Cont...

Figure 11
Tick Hill Gold Mine
(After Schubert & Crookes)





End of Part 1

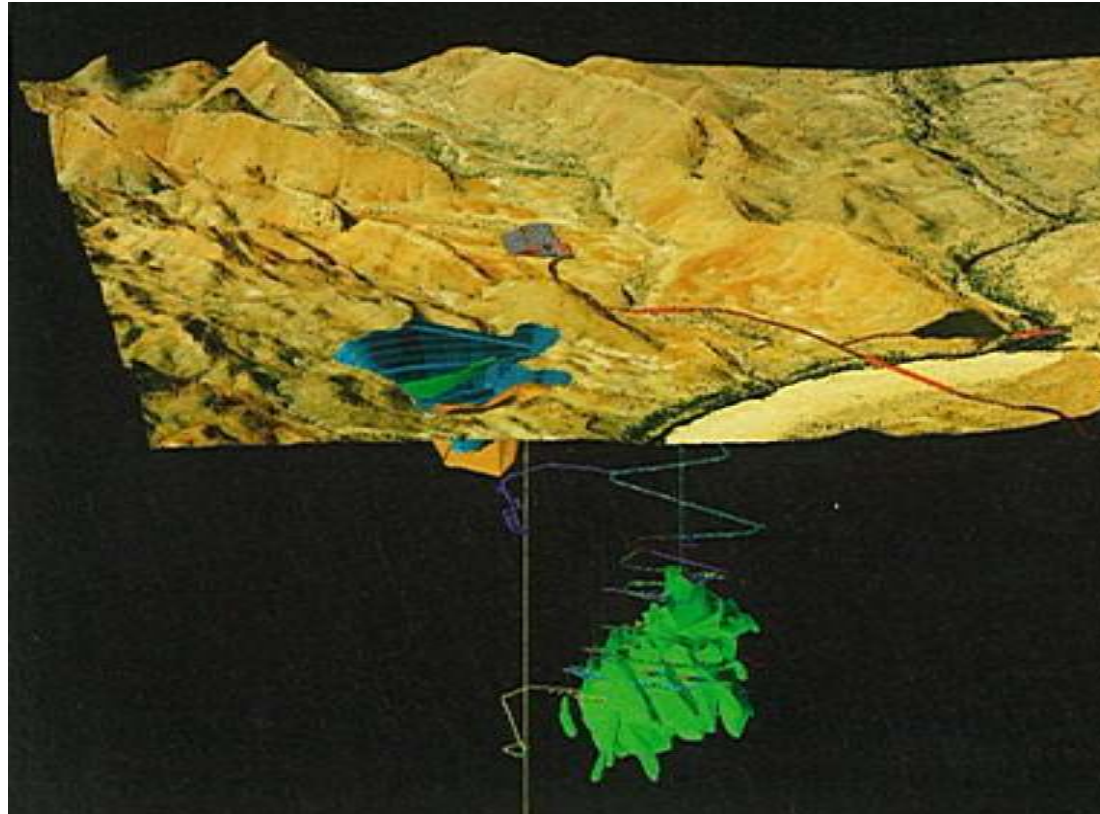
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Part 2

Mine Design for a Uranium Resource

- **Mine design**
- **Remediation**
- **Risk**



Mine design is a sequential and frequently circuitous process.

- ❑ Broad brush assumptions are made followed by preparation of preliminary layout
- ❑ After the “Preliminary Layout”, complementary studies are commenced that complement, support and enhance that layout to produce a basic mine plan

Mine Design – General Cont...

Firstly, two key decisions:

- ❑ Production rate
 - Why?
 - ❖ All cost parameters relate to production rates
 - Resource should determine production rate, not other external factors
 - Taylors rule is a starting point
 - ❖ Taylor's Rule **Annual Production Rate = (Resource)^{0.75} x 5**
 - ❖ Example - Resource of 5.0 million tonnes equates to production rate of 500,000 tonnes per annum

- ❑ Cut-Off Grades
 - Purpose
 - ❖ Defines economic material, ie ore
 - ❖ Potentially impacts on available resource size
 - The Economic Definition of Ore, Lane, F L, (1991)
 - Break Even
 - Marginal
 - Cut-off strategy - different cut-off for different processing – milling and heap leach
 - Cut-off grades relate to costs/production levels and need constant review as parameters change or are refined

5.

Surface Mine Design

5.1 Surface Mine Design - Overview

The basic planning tools/requirements for a simple, initial evaluation of an open cut mine.

- Geological resource (including surface topography)
- General Mine Planning Software (GMP)
- Optimisation software
- Planning and optimisation input parameters
- Skilled practitioner(s)

Open pit Mine Plan is achieved via:

- Preparation of a Mining Resource**
- The completion of an Optimisation exercise**
- Design of the Open Pit Design and Scheduling**
- Completion of Complementary Studies**



Langer Heinrich

5.

Surface Mine Design Cont...

5.2 Mining Resource:

- ❑ Not a Joint Ore Reserve Committee (JORC) term -
 - part way between resource and reserve
- ❑ Is a *massaging* of the geological resource to better represent what might be mined. For example
 - Removes blocks too small to be mined
 - Dilutes other areas to better reflect reality
- ❑ Completed in the GMP or manually on plans/sections

5.

Surface Mine Design Cont...

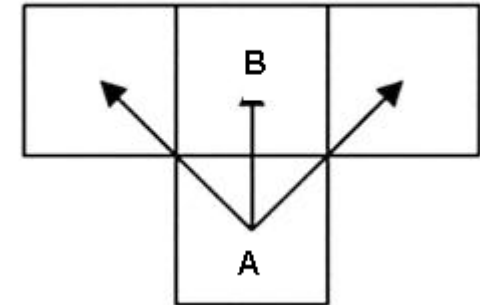
5.3 Optimisation

□ Optimisation Software

- Lerchs Grossman algorithm (1964)
- Has revolutionised open pit design.
- Produces a pit shell, **not a designed pit**.
- Shell can be output as a set of wall contours (strings)
- Based on concept of structured arcs (to mine block A must mine block B but not necessarily the reverse)

□ Input Parameters

- Revenue estimates (inc statutory charges and royalties)
- Metallurgical/processing recoveries
- Site Operating cost estimates
- Wall slope parameters (geotech model)
- Assumptions on production rates
- Mining operational parameters for NPV estimates (optional)

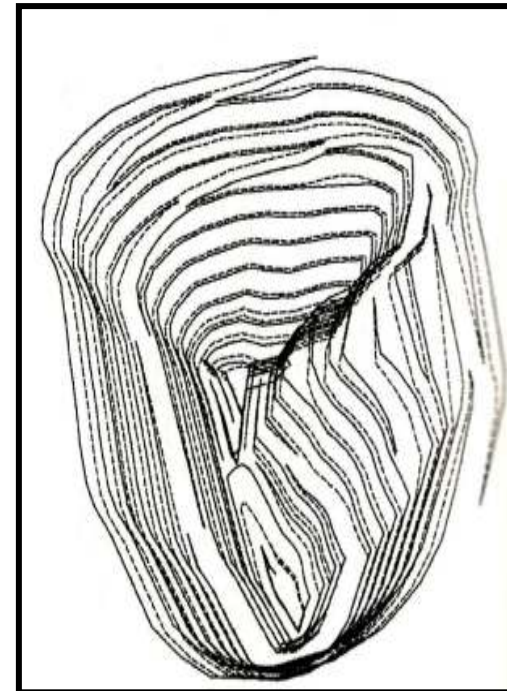
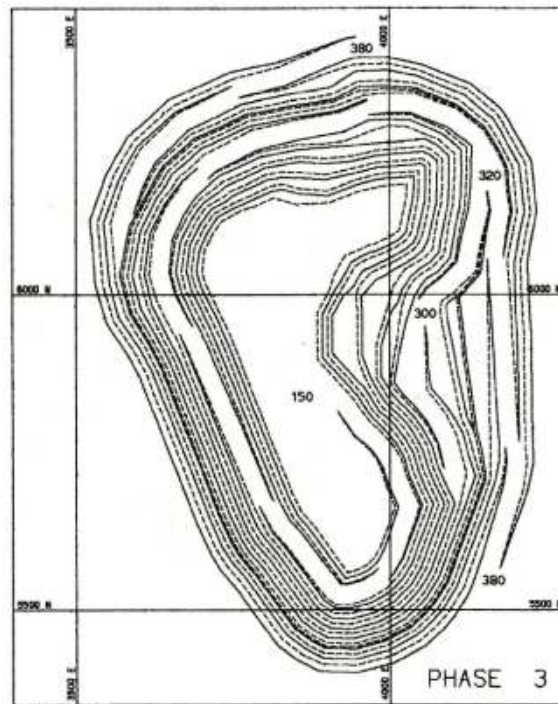
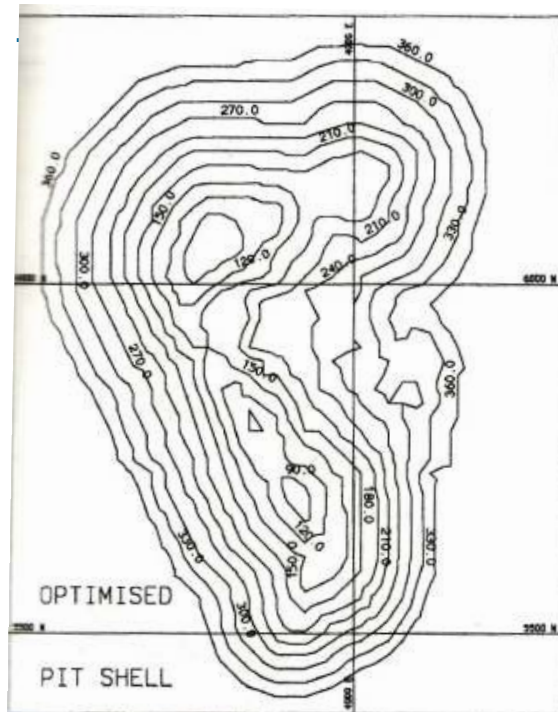


Structured Arc

5.

Surface Mine Design Cont...

5.3 Optimisation Cont...



Optimisation Vs Designed Pit (Moddejongen, 1994)

5.

Surface Mine Design Cont....

5.4 Pit design and scheduling

- ❑ Completed within General Mining Package (GMP)
- ❑ Designed pit must produce similar results to optimisation
- ❑ Start with simple pit and improve as necessary
 - Optimisation strings used as template
 - From top down or bottom up
 - Pit design functions are driven by haul road segments and pit base/top
- ❑ Scheduling
 - Continuity of ore to processing
 - Smooth out material movements
 - Test scheduling from optimisation

5.5 Complementary Studies

The following mining studies either complement, contribute to or are dependant on the pit design.

- Further Geotechnical/Hydrogeological
- Ore and Waste Dump Design
- Environmental
- Grade Control Requirements/Procedures
- Contractor vs Owner Operator
- Equipment Size and Selection
- Drill and Blast Procedures
- Radiation Management Plan
- Mining Ore Reserves
- Infrastructure
- Costing
- Manning
- Logistics

6. Underground Mine Design

6.1 Overview

Underground “Mine Plan” is produced from:

1. The preparation of a Mining resource
2. The development of a Mine production layout and sequence
3. The development of a Primary access and development layout
4. The development of Primary ventilation network
5. The completion of Complementary Studies

6.2 Mining resource and mining sequence

- Preparation of an underground mining resource is a two part process
 - *Massaging* of geological resource for minimum width etc as per open pit
 - ❖ Related to mining method
 - Identifying attractive mining areas from within a global resource
 - ❖ Identification is driven primarily by cut-off grades
 - ❖ Completed manually within GMP and/or via underground optimiser

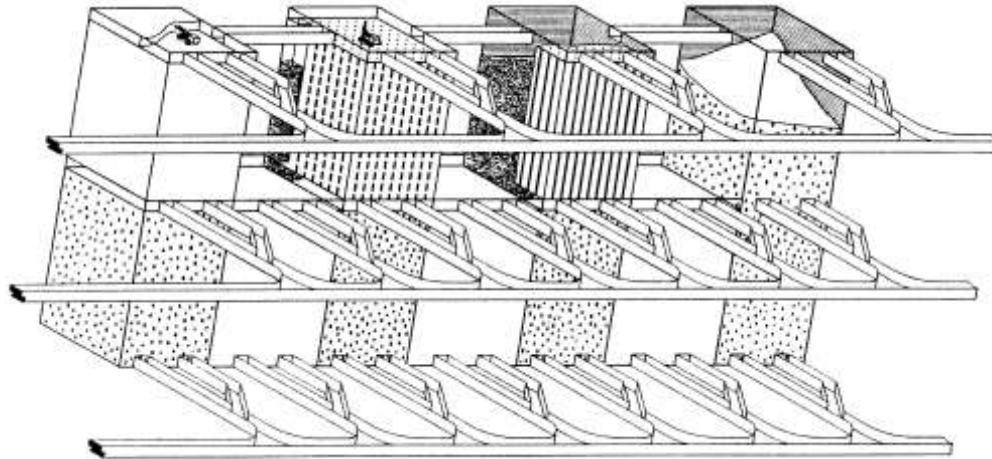
6. Underground Mine Design Cont...

6.3 Mining Production Layout and Sequence

- ❑ Production layout follows mining resource preparation
- ❑ Layout needs to consider geotechnical requirements for
 - stope dimensions
 - local pillar dimensions
 - Sublevels intervals
 - Extraction sequences
- ❑ Layout also needs to consider
 - Broad concepts on pillar recovery
 - General understanding of extraction sequence including likely effect on stress levels
 - General understanding of scheduling requirements
- ❑ Easier to match development to ore body than ore body to development
 - Existing development can make extraction layout more difficult

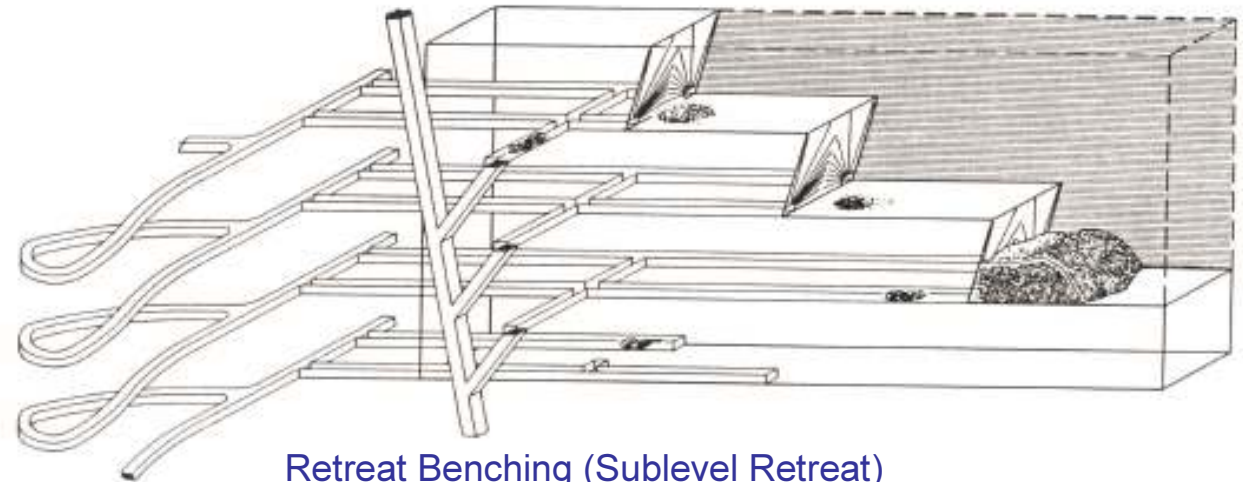
6. Underground Mine Design Cont....

6.3 Mining Production Layout and Sequence Cont...



Transverse Blasthole Open Stopping

Schematics of Open Stopping
Methods (Potvin and Hudyma
2000)



Retreat Benching (Sublevel Retreat)

Issues

- Stope dimensions ?
 - Open Stope (20x20x40 = 50,000 tonnes)
 - Benching (10x150x15 = 67,000 tonnes)
- Sublevel intervals ?
- Pillar dimensions ?
- Extraction sequence ?

Underground Optimiser

- ❑ Underground optimiser is a computer routine often contained within GMP software that is used to optimise the blocking out of underground mining resource
 - Open pit optimiser deals with individual blocks from a block model – each block is a stand alone economic entity

BUT

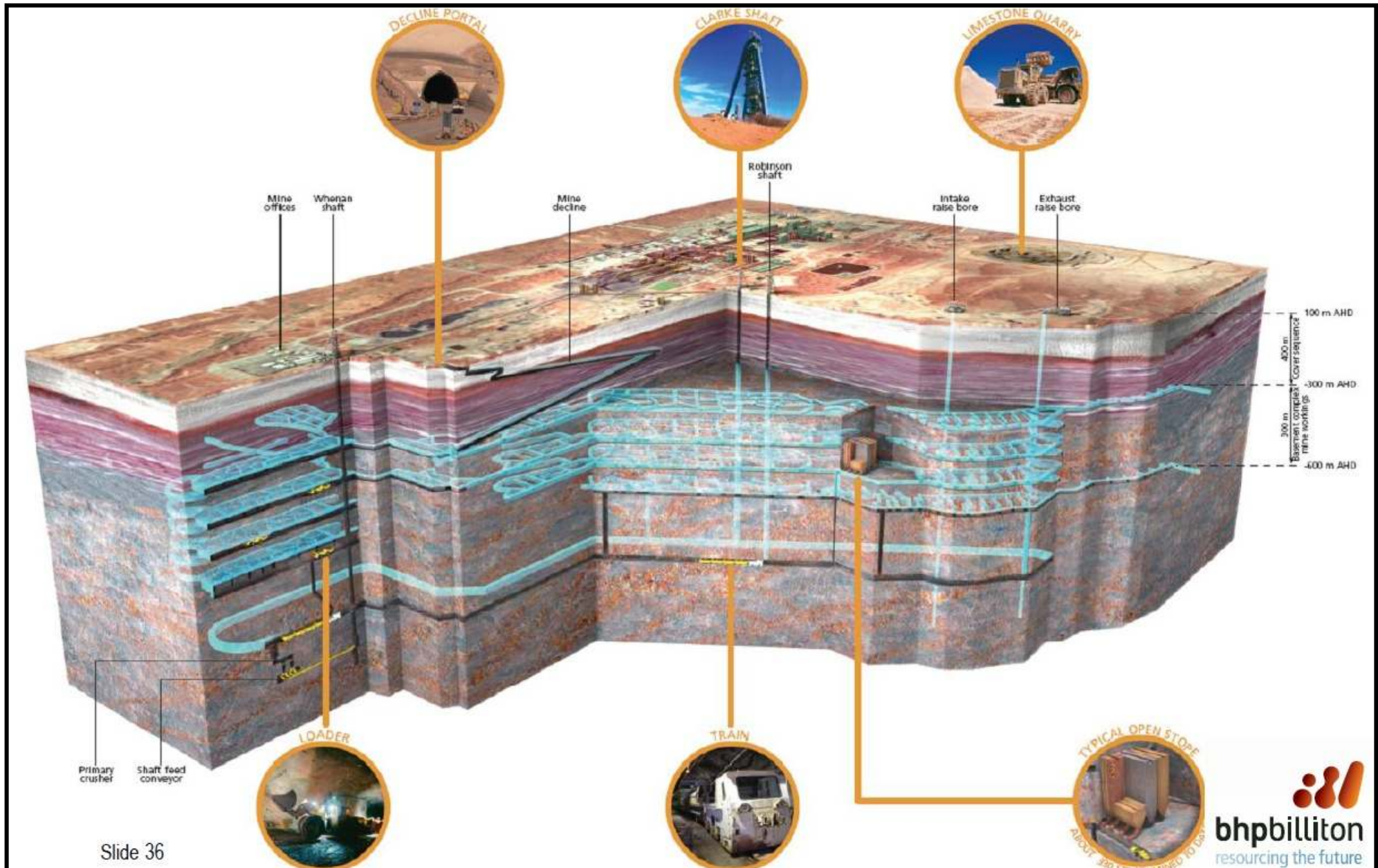
- U/G must consider composite production areas not individual blocks
- ❑ U/G optimiser started with “Floating Stope” routine (1990s) – Passed a “floating stope” envelope over a resource trying to identify and optimise above cut-off material
- ❑ Current generation include Datamine’s Mineable Shape Optimiser and Snowden’s Stopesizer
- ❑ Do not have the “Gravitas as open pit optimisation but “they are working on it” (Alford, and Hall, 2009)

6. Underground Mine Design Cont....

6.4 Mine access and primary orebody access

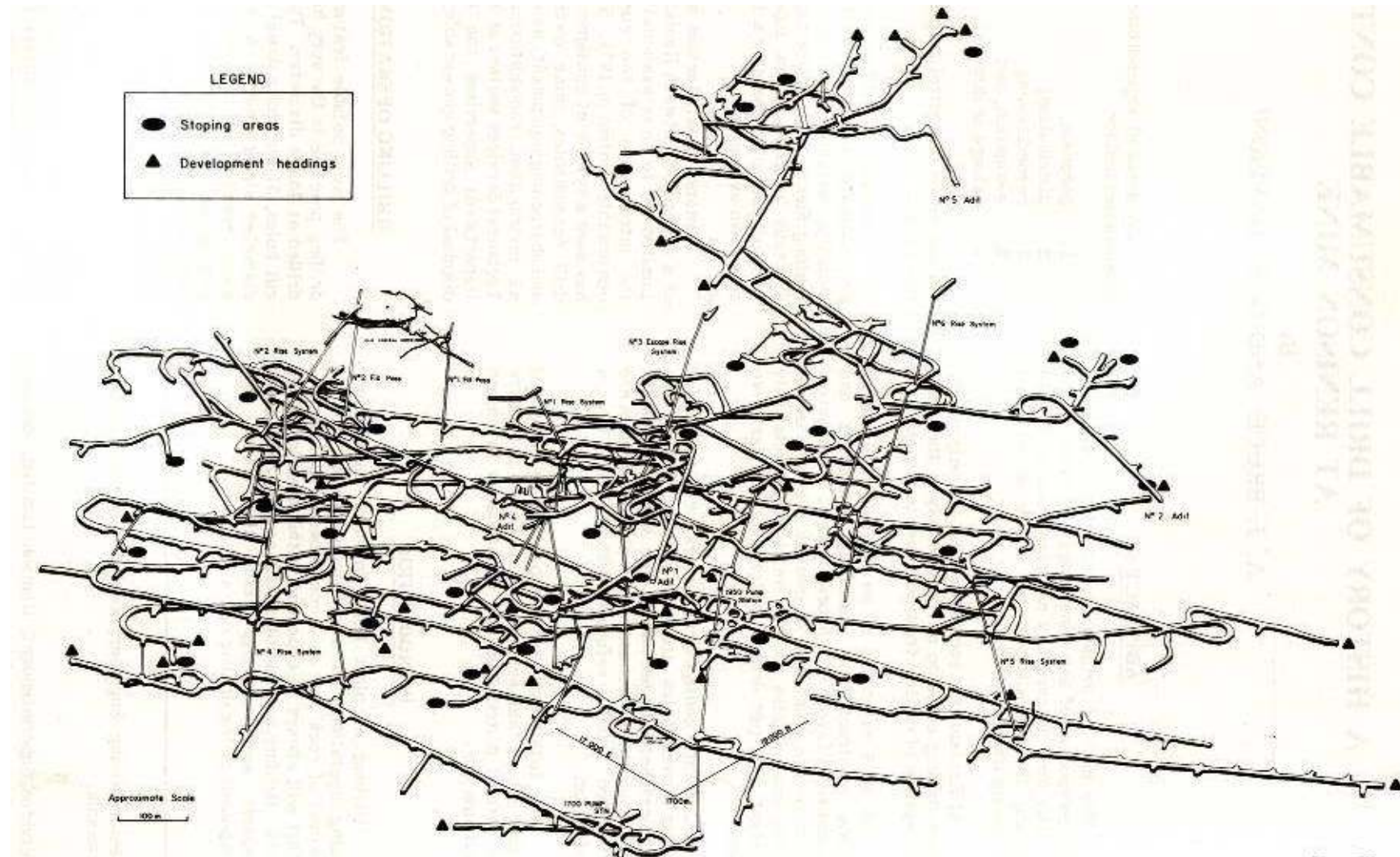
- Mine access is access from surface
- Orebody access is the link between the mine access and the orebody
- ❑ Need to consider material haulage **and** man and supply logistics
- ❑ Mine access and haulage options include
 - Shaft
 - Decline
 - Conveyor
 - Pumping
 - Combination of above
- ❑ Decision on main mine access must include decision on orebody access.
 - Used to be 100 foot spaced levels with rail haulage. Diesel trackless equipment revolutionised options
 - Decline access and internal ramps with trackless haulage
 - Shaft and conventional level with trackless or rail haulage
 - Shaft and internal decline/ramp access with trackless haulage
 - Decline access and conventional level with trackless haulage
 - Decline access and internal ramp for man and supply with one or more main trackless haulage levels to a haulage shaft
 - As above but utilising rail haulage on main haulage levels
 - As above for shafts but with conveyors
- ❑ Considerations include; Production rate, Mine life, Flexibility, Mining method.
- ❑ For economical, mass movement ore passes/rail is still very much an option (Olympic Dam)

6. Underground Mine Design Cont....



6. Underground Mine Design Cont....

6.4 Mine access and primary orebody access



Renison Mine-Isometric View of Underground development 1985 (Bruce and Davidson, 1985)

6. Underground Mine Design Cont....

6.5 Primary ventilation network

- ❑ Primary network consists of the major exhaust and intake airways that control the total airflow
 - consists of the major exhaust and intake airways that determine the total airflow
 - involve longterm infrastructure and mine development
 - must exist harmoniously with the longterm mine plan and extraction sequence.
 - inadvertent damage from nearby mining can result in major mining interruptions

- ❑ Secondary Network involves the ventilation of individual stopes/production areas
 - Needs adequate, robust and flexible primary system

- ❑ Design starts
 - after primary production layout
 - with estimate of overall ventilation requirements based on
 - ❖ Production rates
 - ❖ Equipment levels
 - ❖ Radiation issues
 - ❖ Working areas

Primary ventilation network cont...

6. Underground Mine Design Cont....

6.5 Primary ventilation network Cont...

Ventilation General

- ❑ Stope ventilation is usually flow through ventilation
- ❑ Sub level cave ventilation is forced
- ❑ Development ventilation is forced
- ❑ Ventilation requirements in non uranium mines based ultimately on air quality
- ❑ Uranium ventilation based on air quality and time
 - not as flexible
 - higher volumes required
- ❑ High grade uranium requires remote or un-manned techniques
- ❑ Low grade uranium requires
 - adequate ventilation
 - provision for dealing with random high radiation situation
 - Ventilation needs to consider radiation issues associated with mine drainage
 - Ventilation needs to be supplemented by hygiene regime

6. Underground Mine Design Cont....

6.6 Complementary Studies

The following mining studies complement, contribute to or are dependant on the preliminary mine layout

- Scheduling
- Further Geotechnical/Hydrogeological investigation
- Major Infrastructure Design
- Fill Requirements
- Development Procedures
- Operating Geology and Grade Control Procedures
- Drill and Blast Procedures
- Radiation Management Plan
- Contractor Vs Owner Operator
- Equipment selection
- Ventilation
- Mining Reserves
- Services (utilities) : power, pumping, service water, compressed air, communications
- Costing
- Manning
- Logistics

7.1 General

- ❑ Addressing environmental issues, including remediation issues from day one is in a company's own self interest. It is not in a company's interest to exhaust a resource but be unable to leave site because of unresolved remediation issues.
- ❑ An immediate commitment to environmental issues
 - Establishes a company's credentials with both the community and authorities
 - ❖ **For the current project and for other projects**
 - Establishes an effective permitting process
 - Provides the opportunity to credibly obtain required baseline and sampling data including that required for remediation such as waste rock characterisation data
 - Provides the opportunity to embed an environmental culture within the company
 - Enables the most efficient and cost effective methods of remediation to be implemented.
 - Enables design to encompass agreed final landform and other remediation commitments without resource consuming *retro fitting*

For mining, primary (although not only) remediation considerations are:

- ❑ Waste Dumps
- ❑ Mine Drainage
- ❑ Mining Voids

7.2 Waste Dumps

- ❑ Mostly an open pit issue but not exclusively.
 - ❑ Waste dump remediation is now relative standard practice
 - ❑ Stockpiling of topsoil from pit and waste dump footprint stripping, for later use.
 - ❑ Face angles to be cut back from 37 degrees to 7-20 degrees
 - ❑ All exposed surfaces to be contoured for drainage control, top soiled and vegetated.
 - ❑ Material with undesirable characteristics to be encapsulated within the dump
 - ❑ Stability to be designed and constructed to accepted geotechnical standards .
 - ❑ Topsoil and/or seeding requirements dependent on the final landform/use
- ❑ Early remediation is:
 - Cost effective and efficient.
 - More importantly, failure to plan and start early is not cost effective resulting in
 - ❖ Poor top soil
 - ❖ Difficult dump faces
 - ❖ Failure to encapsulate problematical material



7.2 Waste Dumps Cont...



Concurrent reclamation of waste dump (Read and Stacey, 2009)

7.3 Drainage

Evaluation and planning needs to consider drainage during and after operations

1. Drainage during operation

- Can't avoid dirty/ contaminated drainage
therefore
 - ❖ Need segregation of clean and dirty
 - ❖ Forward planning to minimise dirty reticulation
- Would normally have a restriction of zero discharge for contaminated water
therefore
 - ❖ Cleanup procedures/facilities required to permit discharge
 - ❖ Plan required to minimise requirement for discharge

2. Drainage after operation

- Eliminate source of contamination by burying and/or sheeting and vegetating.
- Cleanup and integrate old contaminated with old clean
- Establishment of sustainable cleaning if required (eg wetlands)
- Designing drainage networks that are suitable for purpose (flows, volumes, velocities)



Erosion due to poorly designed water-control structures

7.4 Mining Voids

- Dependent on required landform/ land use **and** community safety.
- Unlike dumps and drainage no generic remediation procedures
- ❑ Open Pit Considerations
 - Long term stability and wall angles
 - Requirement for full or partial backfilling
 - Management of water inflows and flooding in tropical/wet conditions
 - Management of fluctuating water table levels in arid conditions
 - Management of adverse water chemistry including radiation issues
 - Security to restrict accidental access of personnel and/or stock
- ❑ Underground Considerations
 - Not easily visible
 - ❖ Sudden collapse of inadequately supported workings
 - ❖ Obscured surface breakthroughs
 - Long term stability
 - ❖ Stopes
 - ❖ Cave
 - ❖ Workings open to surface
 - Water discharge and/or quality (as per open pit)
- ❑ Options available to small operations may not be available to large operations.
 - eg 100 metre pit Vs 500 metre pit with significant wall failure



7.4 Mining Voids Cont...



Backfilled pit showing reclaimed area (Read and Stacey, 2009)

Conclusion

- ❑ Collectively, these issues can be expected to have an impact on project economics
- ❑ Intent should be to minimise impact which must include inclusion in early planning and evaluation

8.1 General

Risk ...the chance of something happening that will have an impact on objectives and is measured in terms of a combination of the consequences of an event and their likelihood (Standards Australia 2004)

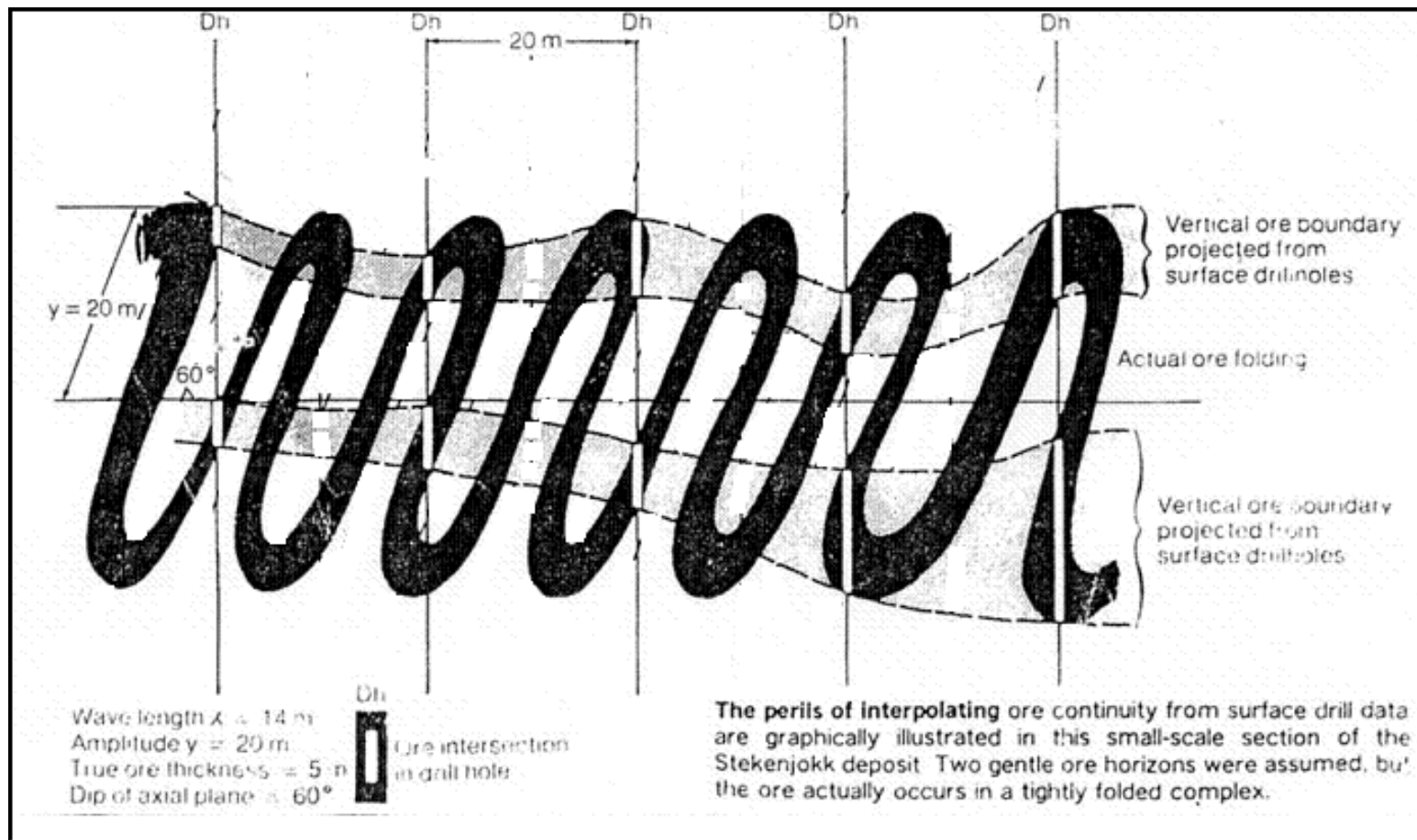
- ❑ Evaluation, design and operation is driven by
 - Risk identification and qualification
followed by
 - Development and implementation of risk management systems
(at least it should be)
- ❑ Positive as well as negative risk
- ❑ Two categories of risk in project evaluation
 1. Risks to completing the evaluation process on time and budget
 2. Risks of the evaluation achieving the correct outcomes - primary concern here
- ❑ Four main generic areas of mining evaluation technical risk
 1. Geological resource model
 2. Geotechnical/hydrogeological model
 3. Mining method selection
 4. Revenue assumptions

8.2 Geological Resource Models

- ❑ Failure of resource to provide “the goods” can result in financial impact - up to closure
- ❑ Incorrect structural interpretation can result in incorrect mining method or development location
 - Geology inputs are interpretations – not facts (*Berry, 2009*)
- ❑ Resources are non homogeneous rock masses, structurally and mineralogically
- ❑ Estimation is a balance between data density, data quality, cost and time.
- ❑ Need to consider the unknown unknowns (logging consistency) as well as the known unknowns (drilling density)
- ❑ Risks are recognised by industry
 - Purpose of JORC code categories of resources is to identify levels of confidence
 - Development of sophisticated geostatistics - improve estimation confidence
 - Range of Quality Assurance measures have evolved for exploration and resource preparation activities
- ❑ Resource evaluation *learning* usually continues well into the life of an operation. It is unlikely a resource will ever be completely understood before mining commenced

8.2 Geological Resource Models Cont...

“Not Getting It Right” (Stekenjokk)



8.3 Geotechnical and Hydrogeological Models

- ❑ Failure of models can result in anything from pillar failure to mine flooding to multiple fatalities
- ❑ Economic consequences range from financial impost to mine closure
- ❑ Geology model is a major component of geotechnical model – same issues
- ❑ Structural and hydrogeological model also based on drilling and interpretation and data sets are also limited
- ❑ Models developed need to be adequate for global decisions during evaluation
 - Underground block caving
 - Open pit developed as series of cutbacks
 - Open pit with final wall development from start
- ❑ Lower confidence level during evaluation results in higher probability of changes during operation?
 - Trade-off for project management?
- ❑ No equivalent of JORC confidence categories – working on it (*Read and Stacey, 2009*)
- ❑ *Learning* also continues well into life of an operation

Geotechnical and Hydrogeological Models Cont...



Hydrogeological - Not getting it right

8.4 Mining Method

- ❑ Incorrect mining method can result in
 - Significant disruption whilst method is changed
 - Loss of reserve/resource
- ❑ Economic consequences range from financial impost to mine closure
- ❑ Open Cut instead of underground?
 - Unlikely from a technical consideration
 - Possible from a resource consideration
- ❑ Underground
 - Stability charts – transitional zone
- ❑ Conversion from one method to another?
- ❑ At operational level method might be correct but parameters incorrect
 - Equipment size
 - Bench heights
 - Sub level intervals
 - Not just negative, design parameters may be too conservative

8.5 Revenue Assumptions

- ❑ Revenue assumptions, especially commodity prices, are primary evaluation risk

- ❑ Revenue assumptions have potentially positive as well as negative risk

- ❑ Incorrect revenue assumptions
 - Go straight to the bottom line
 - Can result in mine closure
 - May require adjustment to cut-off grades and head grades resulting in
 - ❖ changes to reserves
 - ❖ compromised mining sequence

8.6 Evaluation Risk Management

- ❑ Evaluation sequence is one of risk minimisation and progressive risk assessment is now a standard requirement of the process
- ❑ At a high level, the sequence of scoping, prefeasibility and feasibility is risk adverse. Expenditure and commitment advance with increasing confidence
- ❑ At a low level, mine planning departments usually have formal protocols
 - Checklists to manage activities
 - Approvals by different departments (ie, geotechnical, survey)
 - Formal risk assessment exercises
- ❑ At a project level (dependent on project manager and company philosophy)
 - Large companies
 - ❖ Formulate project standards
 - ❖ Conduct formalised review by “experts”
 - ❖ Implement peer reviews
 - Smaller companies
 - ❖ Similar process but often less formalised and routine
 - ❖ Outside consultants especially for major areas of risk ie resources

END

End of Part 2

Thank you for your Attention

Acknowledgements

Acknowledgements



This presentation borrows substantially from a training document prepared by the author in 2004 for Global Resource Solutions, a company that provides global client project management consulting services. The author gratefully acknowledges Global Resource Solutions for permission to use this material.

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