Underground Mining of Metalliferous Deposits

Professor Bibhuti Bhusan Mandal
Professor Kaushik Dey
Department of Mining Engineering
Indian Institute of Technology, Kharagpur

Lecture 28
Selection of Mining Methods-III

Mining Methods- Quantitative Ranking Systems

D E Nicholas (1981)*

The parameters that must be examined when choosing a mining method include: (Nicholas 1981)

1. Geometry and grade distribution of the deposit
2. Rock mass strength for the ore zone, the hanging wall, and the footwall
3. Mining costs and capitalization requirements
4. Mining rate
5. Type and availability of labor
6. Environmental concerns
7. Other site-specific considerations

STAGE-1

- This Quantitative classification system relies on a series of steps:
    a. The ore geometry and grade distribution
    b. The rock mechanics characteristics of the ore zone, H/W and F/W
    c. Numerical ranking based on addition of scores
    d. Using a weighting factor of the categories based on experience

Nicholas (1981)

- Numerical method selection system is intended to indicate those methods that will be most effective given the geometry/grade distribution and rock mechanics characteristics.
- The first step is to classify the ore geometry and grade distribution using following table.
- A value of 3 or 4 indicates that the characteristic is preferred for the mining method.
- A value of 1 or 2 indicates that a characteristic is probably suited to that mining method

- While a value of 0 indicates that a characteristic will unlikely promote the use of that mining method, although it does not rule it out entirely.
- A value of (– 49) would indicate that a characteristic will completely eliminate consideration of that method.

Ranking process for grade and geometry (values)

	General Shape*			Ore Thickness†				Ore Plunge‡			Grade Distribution§		
Mining Method	**M**	**T/P**	**I**	**N**	**I**	**T**	**VT**	**F**	**I**	**S**	**U**	**G**	**E**
Open-pit mining	3	2	3	2	3	4	4	3	3	4	3	3	3
Block caving	4	2	0	–49	0	2	4	3	2	4	4	2	0
Sublevel stoping	2	2	1	1	2	4	3	2	1	4	3	3	1
Sublevel caving	3	4	1	–49	0	4	4	1	1	4	4	2	0
Longwall mining	–49	4	–49	4	0	–49	–49	4	0	–49	4	2	0
Room-and-pillar mining	0	4	2	4	2	–49	–49	4	1	0	3	3	3
Shrinkage stoping	2	2	1	1	2	4	3	2	1	4	3	2	1
Cut-and-fill stoping	0	4	2	4	4	0	0	0	3	4	3	3	3
Top slicing	3	3	0	–49	0	3	4	4	1	2	4	2	0
Square-set stoping	0	2	4	4	4	1	1	2	3	3	3	3	3

Source: Nicholas 1992.
*M = massive, T/P = tabular or platy, I = irregular.
†N = narrow, I = intermediate, T = thick, VT = very thick.
‡F = flat, I = intermediate, S = steep.
§U = uniform, G = gradational, E = erratic.

Definition of deposit geometry and grade distribution

General shape/width	
Equi-dimensional	All dimensions are on same order of magnitude.
Platy–tabular	Two dimensions are many times the thickness, which does not usually exceed 100 m.
Irregular	Dimensions vary over short distances.
Ore thickness	
Narrow	<10 m
Intermediate	10–30 m
Thick	30–100 m
Very thick	>100 m
Plunge	
Flat	<20°
Intermediate	20°–55°
Steep	>55°
Depth below surface	Provide actual depth.
Grade distribution	
Uniform	Grade at any point in deposit does not vary significantly from mean grade for that deposit.
Gradational	Grade values have zonal characteristics, and the grades change gradually from one to another.
Erratic	Grade values change radically over short distances and do not exhibit any discernible pattern in their changes.

Figure 1. Classification by Nicholas 1981

- The rock mechanics characteristics of the ore zone, hanging wall, and footwall are similarly classified using the following table.

Rock mechanics characteristics

Rock Substance Strength (uniaxial strength/overburden pressure)		
Weak	<8	
Moderate	8–15	
Strong	>15	
Fracture Frequency	**No. of Fractures/m**	**% RQD**
Very close	>16	0–20
Close	10–16	20–40
Wide	3–10	40–70
Very wide	<3	70–100
Fracture Shear Strength		
Weak	Clean joint with smooth surface or fill with material with strength less than rock substance strength	
Moderate	Clean joint with rough surface	
Strong	Joint filled with material that is equal to or stronger than rock substance strength	

Figure 2. Rock mechanics characteristics by Nicholas

- The values of the tables represent the suitability of a given characteristic for a particular mining method.
- A numerical ranking is then performed by adding up the values of each mining method, using Tables 2 & 4.

Ranking process for rock mechanics

Mining Method	Rock Substance Strength*			Fracture Spacing†				Fracture Strength*		
	W	M	S	VC	C	W	VW	W	M	S
Ore Zone										
Open-pit mining	3	4	4	2	3	4	4	2	3	4
Block caving	4	1	1	4	4	3	0	4	3	0
Sublevel stoping	–49	3	4	0	0	1	4	0	2	4
Sublevel caving	0	3	3	0	2	4	4	0	2	2
Longwall mining	4	1	0	4	4	0	0	4	3	0
Room-and-pillar mining	0	3	4	0	1	2	4	0	2	4
Shrinkage stoping	1	3	4	0	1	3	4	0	2	4
Cut-and-fill stoping	3	2	2v	3	3	2	2	3	3	2
Top slicing	2	3	3	1	1	2	4	1	2	4
Square-set stoping	4	1	1	4	4	2	1	4	3	2
Hanging Wall										
Open-pit mining	3	4	4	2	3	4	4	2	3	4
Block caving	4	2	1	3	4	3	0	4	2	0
Sublevel stoping	–49	3	4	–49	0	1	4	0	2	4
Sublevel caving	3	2	1	3	4	3	1	4	2	0
Longwall mining	4	2	0	4	4	3	0	4	2	0
Room-and-pillar mining	0	3	4	0	1	2	4	0	2	4
Shrinkage stoping	4	2	1	4	4	3	0	4	2	0
Cut-and-fill stoping	3	2	2	3	3	2	2	4	3	2
Top slicing	4	2	1	3	3	3	0	4	2	0
Square-set stoping	3	2	2	3	3	2	2	4	3	2
Footwall										
Open-pit mining	3	4	4	2	3	4	4	2	3	4
Block caving	2	3	3	1	3	3	3	1	3	3
Sublevel stoping	0	2	4	0	0	2	4	0	1	4
Sublevel caving	0	2	4	0	1	3	4	0	2	4
Longwall mining	2	3	3	1	2	4	3	1	3	3
Room-and-pillar mining	0	2	4	0	1	3	3	0	3	3
Shrinkage stoping	2	3	3	2	3	3	2	2	2	3
Cut-and-fill stoping	4	2	2	4	4	2	2	4	4	2
Top slicing	2	3	3	1	3	3	3	1	2	3
Square-set stoping	4	2	2	4	4	2	2	4	4	2

Source: Nicholas 1992.
*W = weak, M = moderate, S = strong.
†VC = very close, C = close, W = wide, VW = very wide.

Figure 3. Ranking process by Nicholas

STAGE- 2

The numerical assessment is followed by

- Laying out general mining plans
- Determining cut-off grades
- Calculating mineable reserves
- Economic analyses to determine which mining method will provide the greatest return on investment.
- The rock mechanics data is further used to provide realistic estimate of underground Opening size:

1) Amount of support
2) Orientation of openings
3) Caving characteristics
4) Open pit slope angles.