

Underground Mining of Metalliferous Deposits
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Lecture – 2
Mine Life Cycle

In the first lecture we had some discussion about the metal and civilization, the importance of metal in human life. Here we will be talking about some preliminary information about the mine life.

The mining sequence right from the beginning to end can be divided into six stages. So, each stage represents a certain period in the life of a mineral deposit. The stages, now ordered chronologically from the earliest and following the order in which they occur, include: Prospecting, exploration, evaluation, mine development, production and closure.

The prospecting operation means any operations undertaken for the purpose of exploring, locating or proving mineral deposit. The prospecting gives mainly location specific data; and then broad idea what could it be. But it will not give you the details of grade and shape in details also; so, we go for a detailed exploration. Exploration gather data about potential mineral deposits and acquire the rights to harvest these mineral deposits.

The exploration also requires certain rights without which you cannot go for exploration. For this we have the license, lease for the mineral deposits. Before acquiring the rights, we go for the evaluation of mineral deposits. That means, whether this mineral deposit can be exploited with the maximum profit; or whether it is profitable or not, depending on the size of the reserve, quality of the reserve, geotechnical properties; the market value of that and the mechanization available, pre-investment available.

Once we have done that we can go for formal clearance from the government, for acquiring the rights for mining there. And also, some forest clearance, environmental clearance these are very much required. If land acquisition is there, then we have to go for that. If we have to participate in the auction; then you have to go for an auction bid in that auction, and get the right to mine.

Once you are you are confident that the economic aspects of mineral deposit that you are going to exploit is economical; and it is technically and the legally exploitable, you can go for the

exploitation of the deposit that is also known as mine development which is basically construction of minor mines, developing the mines. To access the deposit, you are now making the drives, raises cross cuts, shaft, incline etc. which are all part of mine development.

To do so we have to establish all the services for example, compressed air, the water line and electric power etc; all these things we have to send to underground mines. And then once we are ready with that; then we have to first determine the mining blocks; and then go for planning also. We must have a planned scheme or plan for exploiting the mineral.

The closure means the demolition of mine or mine structures. We have to take care of the people that we are sending off; these people what kind of compensation that we are giving. These things are very much connected to the socio-economic conditions of the area, where we are mining. The rule is very stringent; so right from the beginning you have to go on thinking and planning about the closure at different stages.

As the mining proceeds, then you have to take the closure actions in a progressive mine closure; also known as progressive mine closure plan. Also in the beginning we give a tentative mine closure plan.

“**Reconnaissance operations**” means any operations undertaken for preliminary prospecting of a mineral through regional, aerial, geophysical or geochemical surveys and geological mapping, but does not include pitting, trenching, drilling (except drilling of bore holes on a grid specified from time to time by the Central Government) or sub-surface excavation. Reconnaissance permit means a permit granted for the purpose of undertaking reconnaissance operation

So, **prospecting operations** means any operations undertaken for the purpose of exploring, locating or proving the mineral deposit. For that you need a prospecting license also; that means a license granted for the purpose of undertaking prospecting operations. This has to be taken from the government.

Mining lease means a lease granted for the purpose of undertaking the mining operations and includes a sub-lease granted for such purpose; it is not necessary that we have done the prospecting and exploration.

The **mining operation** means any operations undertaken for the purpose of winning any mineral; you are actually extracting the mineral from earth.

Regulatory authorities in India

For Conservation and Development of Minerals:

Indian Bureau of Mines

- Mines & Minerals (Development & Regulation) Act, 1957 (As amended up to 11th July, 2016)
- Mineral Conservation and Development Rules, 2017(As amended up to 27th March, 2018)

For Safety and Occupational Health:

Directorate General of Mines Safety

- Occupational Safety, Health and Working Conditions Code, 2020
(Replacement of the Mines Act 1952 and other Acts)
- (Draft) The Occupational Safety, Health and Working Conditions Code (Central) Rules, 2020

Prospecting and Exploration:

when the diamond drill bit cuts the rock inside the earth, the core is lifted by core barrels. These core barrels are then brought to the surface, and then kept in boxes known as core boxes; the information about the depth from which the core has been recovered from underground is also recorded. This is done by carefully examining the core and logging it. This may include, length of the core, the lithology of rocks, the condition of the rock, mineralization etc.

The inclined bore holes give a false length; so, we have to project it in a vertical form. This will give the depth description of the minerals and rocks at various depths. By geochemical analysis and observation, you can find out the condition of the rock inside the mine, inside the earth; and also, the chemical composition of the overall mineral. We feed this data into computer programs and with geostatistical inferences, we can now model and visualize with minimum error.

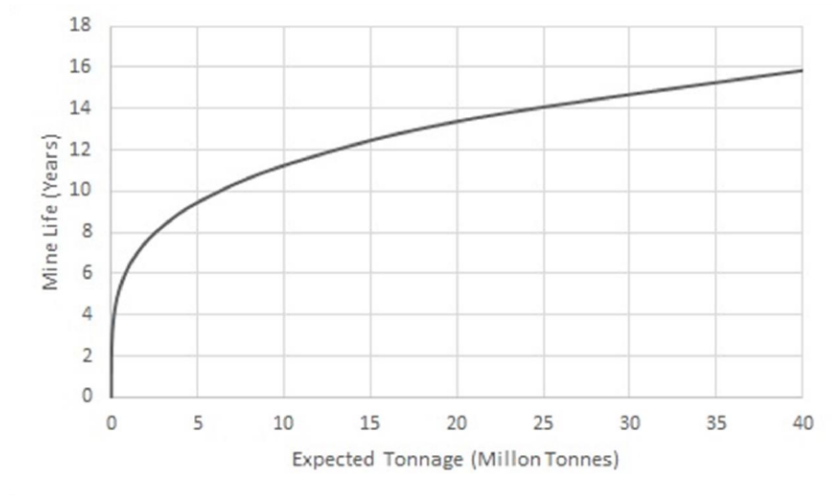


Figure 1. Mine life and production rate (Taylor, 1977)

So, in 1977, Taylor took up an empirical analysis to determine the Mine life in years from the expected tonnage to be mined in million tonnes. He found that the expected tonnage in millions tonnes, if you plot in the x axis; then it's behavior can be seen as depicted in figure 1.

The empirical equation for mine life that Taylor developed is:

$$Life = 0.2\sqrt[4]{Tonnage}$$

The equation can be used to find production rate by

$$Production \left(\frac{mt}{day} \right) = \frac{Tonnage}{Mine\ life \times Operating\ days}$$

Assuming a mine operating 350 days a year, Taylor's rule gives the equation

$$Production \left(\frac{mt}{day} \right) = 0.0143 \times Tonnage^{0.75}$$

Here (mt/day) refers to metric tonne per day

Long (2009) found that there was significant difference between the production rate of underground vs open pit and block caving. Long's study is the most extensive of all studies looking at the relationship between production rate capacity and reserves. The study looked at 342 open pit and 197 underground mines located in the Americas and Australia.

Equation for mine life and production rate (long 2009):

$$Production \left(\frac{mt}{day} \right) = a \times Tonnage^b$$

- 1) For underground deposits:

$$Production \left(\frac{mt}{day} \right) = 0.297 \times Tonnage^{0.562}$$

- 2) For opencast mines and block caving:

$$Production \left(\frac{mt}{day} \right) = 0.123 \times Tonnage^{0.649}$$

Problem: Estimate life (in years) of an underground mine with a mineable reserve of 70 Million tonnes using Long's revised empirical equation. It is decided to exploit the mineral with Room and pillar. Assume 350 working days per year. (use a = 0.297 and b = 0.562 in the empirical equation) (round off to 2 decimal places)

Solution:

$$Life\ of\ mine = \frac{Reserve}{Production(T/day) \times Operating\ days}$$

According to Long (2009), for *underground deposit (Room and pillar)*,

$$\begin{aligned}
 \text{Production(T/day)} &= 0.297 \times \text{Reserve}^{0.562} \\
 &= 0.297 \times 70,000,000^{0.562} \times 88,000,000^{0.562} \\
 &= 7615.554 \text{ tonnes/day}
 \end{aligned}$$

$$\begin{aligned}
 \text{Therefore, Life of mine} &= \frac{\text{Reserve}}{\text{Production(T/day)} \times \text{Operating days}} \\
 &= \frac{70,000,000}{7615.554 \times 350} \\
 &= 26.26 \text{ years}
 \end{aligned}$$

