Underground Mining of Metalliferous Deposits
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Lecture: 10

Dilution is the waste material not separated from the ore in the stages of mining, and is sent to the processing plant.

It is defined at the ratio of tonnage waste mined and sent for processing over the combined ore and waste tonnage milled.

The following equation is the expression used for dilution:

$$Dilution(\%) = \frac{Tonnes\_waste\_milled}{Tonnes\_ore\_milled + Tonnes\_waste\_milled}$$

$$\frac{Tonnes\_waste\_milled}{Tonnes\_ore\_milled + Tonnes\_waste\_milled} \times 100$$

Geological Reserves (T_g): The tonnage of ore above the cutoff grade

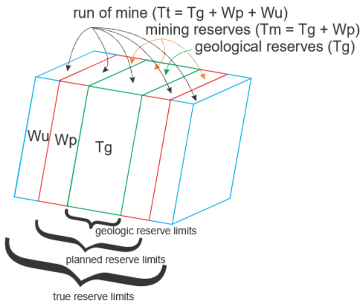
Planned Waste (W_p): Rock with a lower mineralization content than the cutoff grade *within stope limits*

Mining Reserves (T_m): The ore tonnage within the planned stope limits

Unplanned Waste (W_u): Rock with a lower mineralization content than the cutoff grade, coming from *beyond the planned stope limits*

Total Waste: Rock which includes mineralization below the cutoff grade

Run of Mine Ore (T_t): The tonnage generally sent to the mill, sum of geological reserves, planned waste, and unplanned waste



Dilution

$$UnplannedPercentDilution(\%) = \frac{UnplannedWaste, Wu}{RunofMineOre, Tt} * 100\%$$

$$PlannedPercentDilution(\%) = \frac{PlannedWaste, Wp}{MiningReserves, Tm} * 100\% = \frac{Wp}{Tg + Wp} * 100\%$$

$$FinalPercentDilution(\%) = \frac{TotalWaste}{RunofMineOre, Tt} * 100\% = \frac{Wp + Wu}{Tt} * 100\% = \frac{Wp + Wu}{Tg + Wp + Wu} * 100\%$$

INTERNAL DILUTION

Internal dilution occurs within a mining block in which pockets of waste are unable to be separated and are mined with the block.

Degrees of internal dilution can vary within various types of deposits; specifically, lithological and grade distributions significantly influence the degree of dilution.

The following four main components govern internal dilution:

- Geology and Mineralogy: Typically fine-grained mineralization with local but relatively small occurrences of mineralization.
- Data Density: Becomes a significant factor once the geology is understood.
- Estimation Method: Manual and automatic estimation methods tend to overestimate grade and underestimate tons.
- Cutoff grade and grade control: When cutoff grade is applied to a deposit, the engineer assumes that the grade contacts are definable at any given grade.

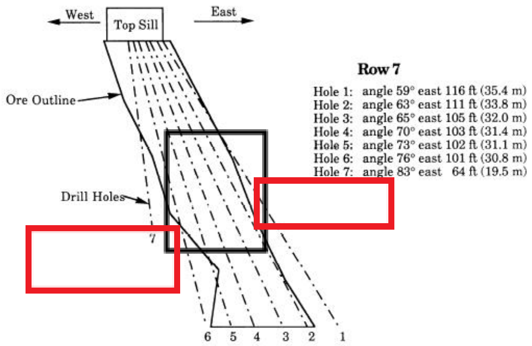
EXTERNAL DILUTION

External dilution is the waste outside of the orebody that is mined within the block. It varies based on an assortment of parameters and can be controlled using effective equipment and mining practices.

The following initiatives can be used to minimize external dilution:

- Defining the contact surfaces of ore and waste
- Selection of the proper equipment to attain desired selectivity
- Mining along the contact surfaces

- Modelling the effects of unavoidable dilution



VCR/Long-hole blasting: Ore Sorting is not possible

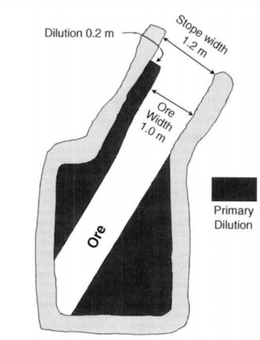
ESTIMATING DILUTION

Estimating dilution prior to mining is a challenging task, demanding the use of an engineer's best judgement to assess the feasibility and economic value of mining a block, stope, or deposit.

An important parameter to consider while doing so is total dilution, a value which can be expressed in the following equation:

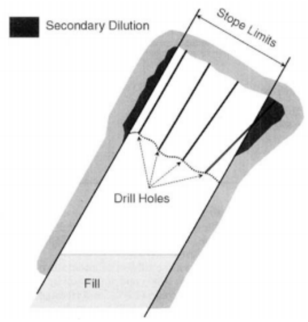
$$TotalDilution(\%) = PrimaryDilution(\%) + SecondaryDilution(\%)\cdot$$

In general, **primary dilution** is found in narrow deposits, as the thickness of the ore zone becomes the main source for dilution.



Conversely, **secondary dilution** is the dilution that occurs beyond the planned stope dimensions.

Secondary dilution is caused by a number of factors which include *sloughing, drilling and blasting, ground conditions, planar discontinuities, mining method, equipment, and work practices*.


Secondary Dilution
Stope Limits
Drill Holes
Fill

MINING METHODS AND DILUTION

Mine dilution occurs due to the mining method selected and from over-break during the mining process.

Mining methods such as block caving, sublevel stoping and room-and-pillar are more predictable, where dilution can be modeled using empirical equations.

Major factors which have a direct effect on dilution:

- **Mine Depth** – Methods with greater selectivity exhibit lower dilution
- **Rock Competency** – More competent rock will be less susceptible to sloughing and over-breaking
- **Ore Type** – Defines the selective and effective dilution parameters
- **Ground Support** – Support can be used to maintain ore and waste surfaces, limiting the amount of dilution

Self-supported openings are more selective and have lower dilutions than block caving with typical dilution ranging from 5% to 15%.

Additional factors which influence dilution to a lesser extent are as follows:

- Rock Mechanics – Mechanical parameters and technical ability lead to increased dilution Ore
- Geometry – Layout of the ore in skewed orientation leads to increases in unplanned dilution
- Hanging-wall Dip – The likelihood of wall slabbing and release of wedges will depend on wall dip relative to the orientation of lamination and joints
- Geotechnical – Parameters are increased lead to an increase in dilution values
- Stope Span – Larger stope spans are less stable, increasing the risk of wall failure and unplanned dilution

Problem:

Calculate the *mill-head grade* and *total tonnage (ore + waste) mined* for the following Shrinkage Stope assuming 12% dilution:

In situ tons : 100758

In situ grade : 7.86 oz Ag per ton

Avg. grade of waste : 1.2 oz Ag per ton

Solution: Total ROM from the stope = Ore+ Waste = 100758 × 1.12 = 112849 t

(Waste = 100758 × 0.12 = 12091 t

Mill head grade = $\frac{(100758 \times 7.86) + (12091 \times 1.2)}{112849}$ $\frac{(100758 \times 7.86) + (12091 \times 1.2)}{112849}$ = 7.146 oz /t

Ans.