XXIII Conference of PhD Students and Young Scientists

Interdisciplinary topics in Mining, Geology and Geomatics

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Underground mining dilution: management, trends and the role of machine learning

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Dilution in underground mining

Dilution is a phenomenon found in underground mining that has deep implications for resource recovery, operational efficiency, and the economic viability of projects. Dilution is the unintentional mixing of valuable ore with the surrounding waste material during the extraction process (Figure 1), this leads to a decrease in the grade and recovery of ore. Dilution can manifest in various forms, such as physical blending, interlocking, or dispersion of ore material within adjacent waste zones.

Accurate tracking and control of dilution play a pivotal role in underground mining as it influences the following parts of the process:

- Grade control of extracted material.
- Ore sorting and processing.
- Resource recuperation.
- Stope stability.
- Mine planning and design.
- Waste management and disposal.
- Environmental impacts.

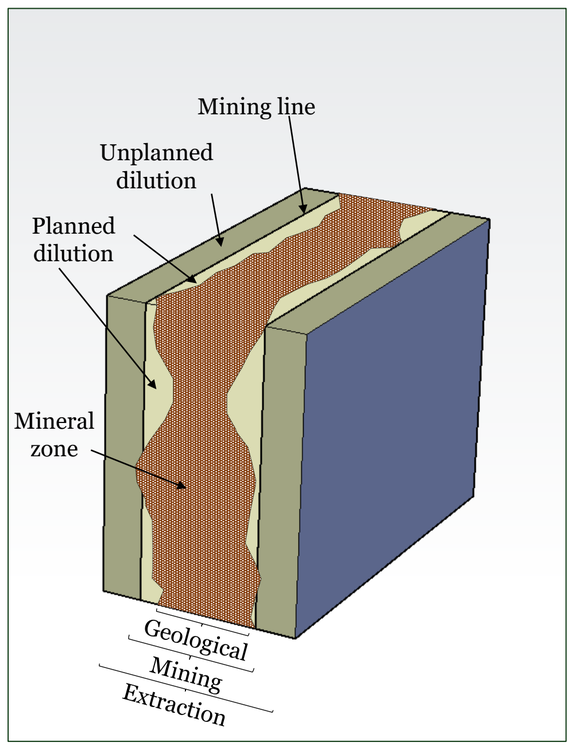

Figure 1. Representation of ore body, planned and unplanned dilution.

Main factors of dilution

An important aspect of dilution management consists in establishing the factors that influence its occurrence, plenty of studies have focused on this area of research concluding the following main factors [1] (Figure 2):

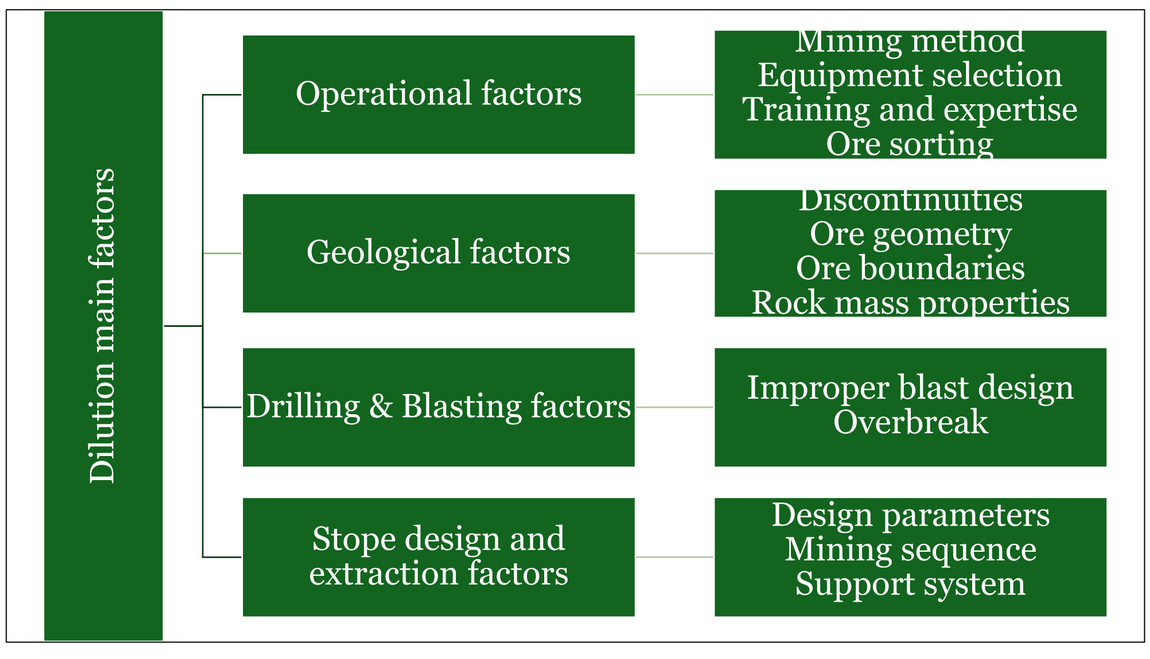

Figure 2. Dilution main factors.

Dilution: management and estimation

The minimization of dilution is a critical aspect of mining, needed to ensure adequate ore recuperation and increase productivity, but to achieve this is needed to estimate and keep good management of the dilution. Strategies most widely used for dilution control and estimation are (Table 1):

Table 1. Dilution control and estimates strategies

Geological understanding	Detailed mapping, core logging and geotechnical assessments to identify the ore body and geological structures.
Stope design optimization	Increase efficiency of extraction with proper design parameters (stope geometry, dimension and orientation)
Drilling and Blasting techniques	Accurate and controlled blasting is crucial to control dilution (presplitting, smooth blasting and perimeter blasting).
Empirical methods	The established relationships between geological factors, mining practices, stope stability and dilution, with the help of statistical analysis permit the estimation of dilution.
Support system	Ground support can ensure stope stability and help to control dilution (rock bolts, shotcrete, mesh).
Monitoring instrumentation	Regular monitoring of the mining operation and making use of the data helps identify potential dilution areas (microseismic sensor, TDR and Convergence).
Simulation and Modeling	Computer-based simulation and modeling techniques simulate parts of the mining process, allowing the estimation of dilution. Common tools (Map3D, FLAC 3D, Rocscience, machine learning).
Stope surveying	Accurate mapping of the stope area (ore and waste volume, spatial distribution, overbreak) provides essential data for dilution management. Common tools are laser scanning and photogrammetry.

Machine learning: dilution control

The use of machine learning and advanced data analytics have enabled the extraction of major insights from large datasets (geological, production, monitoring, drilling, and blasting data), gaining notoriety for analysing and predicting dilution in main areas previously mentioned. Examples of machine learning algorithms used in mining and their application are:

- ANN: has been applied for the analysis of stability of underground mine pillar at Laisvall mine , as well as prediction of mechanical properties rock such as UCS, Young modulus and brittleness [2].
- Random Forest: a random forest algorithm for the prediction of HW stability was developed, taking into account 13 variables [3]. Later, an algorithm based on random forest was designed to predict the maximum failure depth of open stope hanginwalls [4], analyzing different factors affecting HW.
- SVM: A study performed in underground coal and stone mines using index and mechanical properties achieved a valid method for the determination of pillar stability in underground mines [5]

Acknowledgments

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