On-Line Mine – Improving mining economy through on-line mineral analysis

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Background:

Mines of today are moving ever increasing tonnages of rock. The new ore bodies tend be of lower grade and located deeper in the earth's crust. The industry's focus to overcome this "deeper but poorer" ore problem has traditionally been to lower the costs by increasing the scale of mining. This has resulted in an ever increasing size of mining equipment like drills, loading shovels, dump trucks. The main focus has been in reducing the cost per ton of mining. This cost focus has often resulted in increased waste rock dilution and more ore losses.

From costs to value: Waste rock dilution means waste rock in the concentrator feed. It's value in open pit mining is equal to the value of ore it replaces. In underground mining, waste rock dilution's value is equal to the value of ore it replaces added to the costs of mining it. It is commonly accepted that waste rock dilution in open pit mining ranges between 5 and 20% and in underground mining between 5 and 40% .

In a typical large open pit mine ore value is from 20 to 60 USD per ton and mining costs are 1 to 3 USD per ton. One percentage point reduction in waste rock dilution represents savings corresponding to about 20% of total mining operation costs.

The difficulty of reducing waste rock dilution comes from the complicated nature of the ores. Accurate ore waste-border detection has not been possible due to excessive costs. Core drilling combined with geochemical lab analysis is the most accurate method for locating ore waste borders. However, it is also expensive and time consuming, which is why it is often combined with somewhat lower cost methods like sampling drill cuttings from blasting drill holes or from reverse circulation drills and analyzing them in a laboratory. The main drawback with these methods, in addition high costs, lies in the sampling accuracy and in the quality control of the whole process when a large number of samples have to be handled manually.

In every mine it is possible to halve waste rock dilution by using new on-line analysis technology.

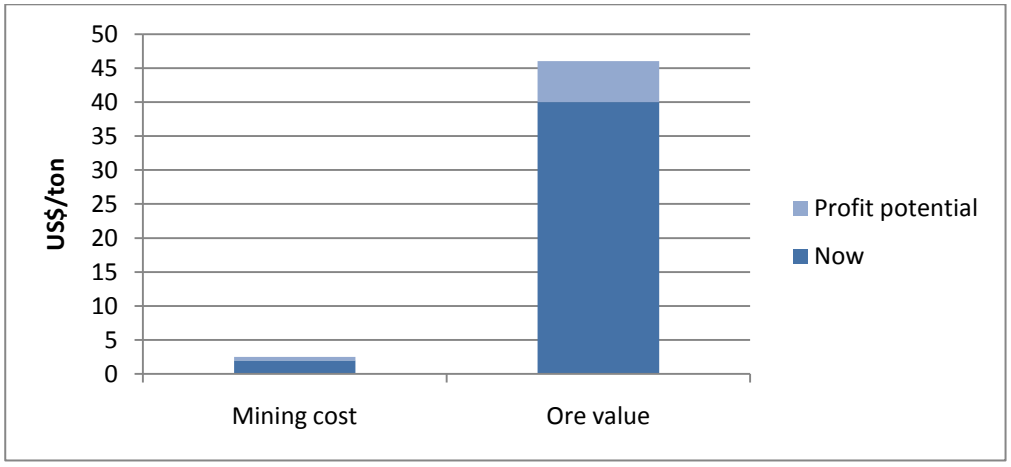

Fig. 1. Shift focus from cost to value

On-Line Mine

The On-Line Mine is a new concept which has been launched recently by a Finland based company Mine On-Line Service Oy. The concept is based on real time analysis information from drill cores, drill cuttings , blasted and crushed material. The On-Line Mine concept utilizes X-Ray Fluorescence (XRF) and Laser Induced Fluorescence (LIF) analyzers to identify and measure elements, minerals and rock types. Furthermore, the On-Line Mine concept places the information from analyses into xyz-coordinates on the mine maps for mine planning and production control.

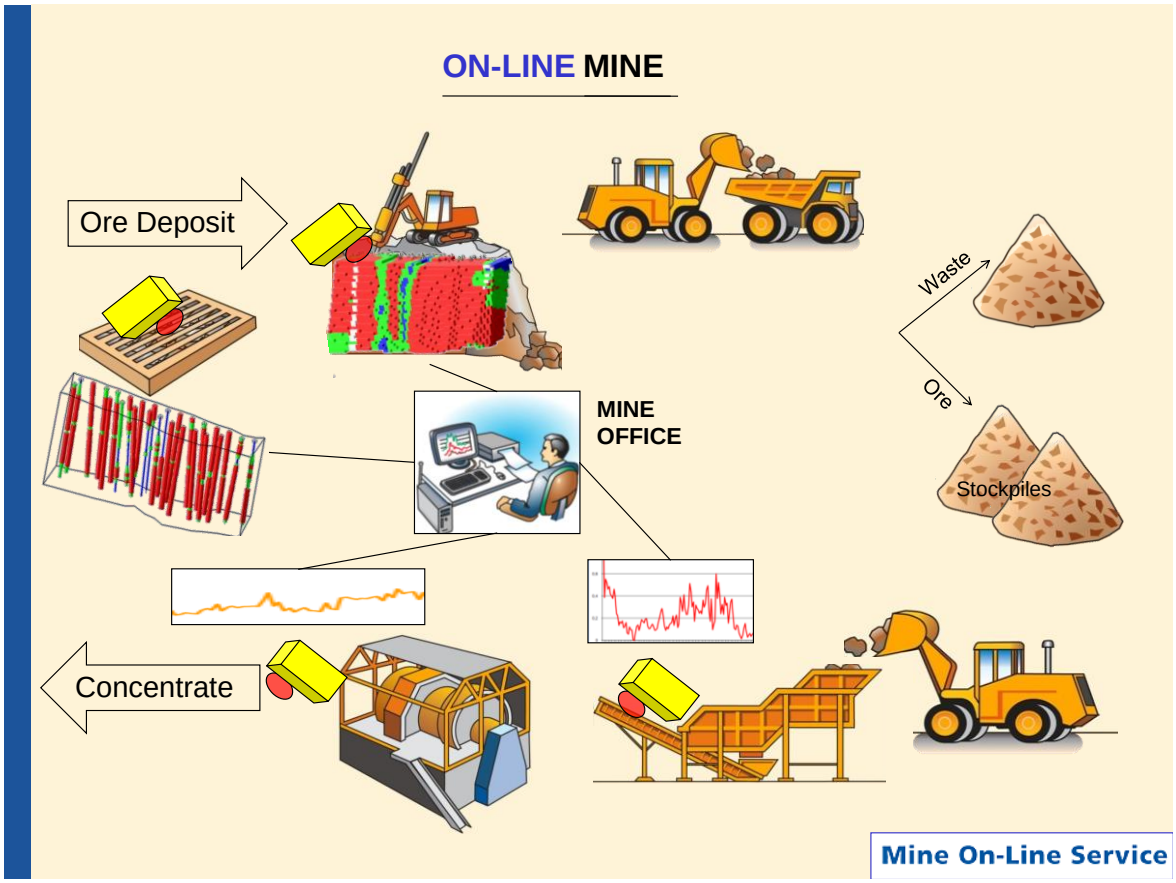

Fig. 2. The On-Line Mine analysis points (yellow boxes)

Exploration and mine grade control.

Rapid analysis of drill cores and drill cuttings are done at the mine site by the ***Scanmobile*** mobile laboratory combined with a remote logging browser ***(Remolog™)*** for instant analysis results which can be viewed using the internet. The *Scanmobile* lab is built in a large utility truck that can access mine and exploration sites. Upon arrival at the site it is operational within two hours. The *Scanmobile* provides digital photographs and non destructive geochemical XRF analyses on the drill cores in a box. The XRF analyzer scans the cores one by one by analyzing the exposed surface. Typically the analysis length is between 10 and 30 cm. The results are summed up to the desired lengths of the customer.

Fig. 3 The Scanmobile operating in drill core storage

Geologists can access the *Scanmobile's* core images and the scanned XRF analysis results on-line with the *Remolog™* browser via internet. The analysis results are shown as a function of borehole length and also in a spreadsheet format.

Ideally the geologist logs the drill cores after they have been analyzed by the *Scanmobile.* The logging is more accurate and it takes less time when elemental analysis results are available while logging. It reduces the number of drill core samples to be sent for lab analysis for bankable feasibility studies- if they are needed. Geologists may also log the cores by the detailed high resolution digital photographs from a remote location. In doing so, time and travelling expenses are saved. Moreover the analysis data can be used for training geologists for the subject ore type by having a supervisor geologist and trainee view the same cores from different locations via internet.

The instant access to drill core analysis data makes it possible for geologists to react quickly to core analysis data. They may decide to finish or continue the hole being drilled, or may place the next borehole in a

different location than planned based on the previous holes analysis results. This reduces the number of empty boreholes and prevents ending the hole in middle of the ore anomaly intersection.

The *Scanmobile* concept is also being used also for drill cuttings analysis by using a *Softcore™* (pat.pend.) sampling method. The drill cuttings are stored in a elongated "sample sock" for quick and location accurate analysis by the Scanmobile.

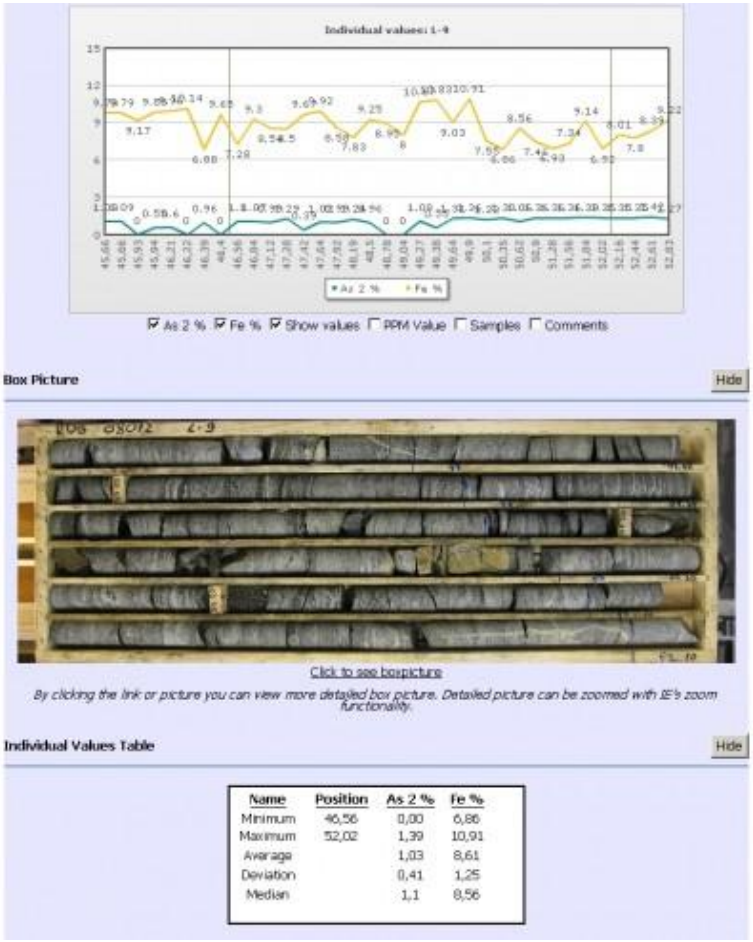

Fig 4. Remolog™ internet browser report on drill cores

Blast Hole Sampler-Analyzer (BSA) is a new product and tool for analyzing blast hole drill cuttings for mine grade control. The BSA takes a continuous sample from drill cuttings when they come out of the blast hole. The cuttings sample volume is 15 to 95% of the total drill cuttings volume. The sample is analyzed by on-line XRF analyzer which provides detailed elemental analysis information of the blast holes as a function of hole depth. Location coordinates in XYZ format are given to each individual analysis based on drill bit location and hole location information. Typically the ore grade information is summed up by 10 cm intervals. The BSA can analyze several elements simultaneously. The BSA solves both the problems of accurate sampling and low cost accurate analysis.

Ore grindability is an important factor that has a big influence on mill throughput and mine economy. The BSA has a capability to analyze and measure the ratio of those elements in the ore that correlate with minerals having different grindability characteristics.

Information on ore blastability can be collected with the BSA via rock elemental analysis combined to drill bit penetration rates that is measured automatically. It can also be connected to the drills measure while drilling systems (MWD) to get further information on drilling parameters.

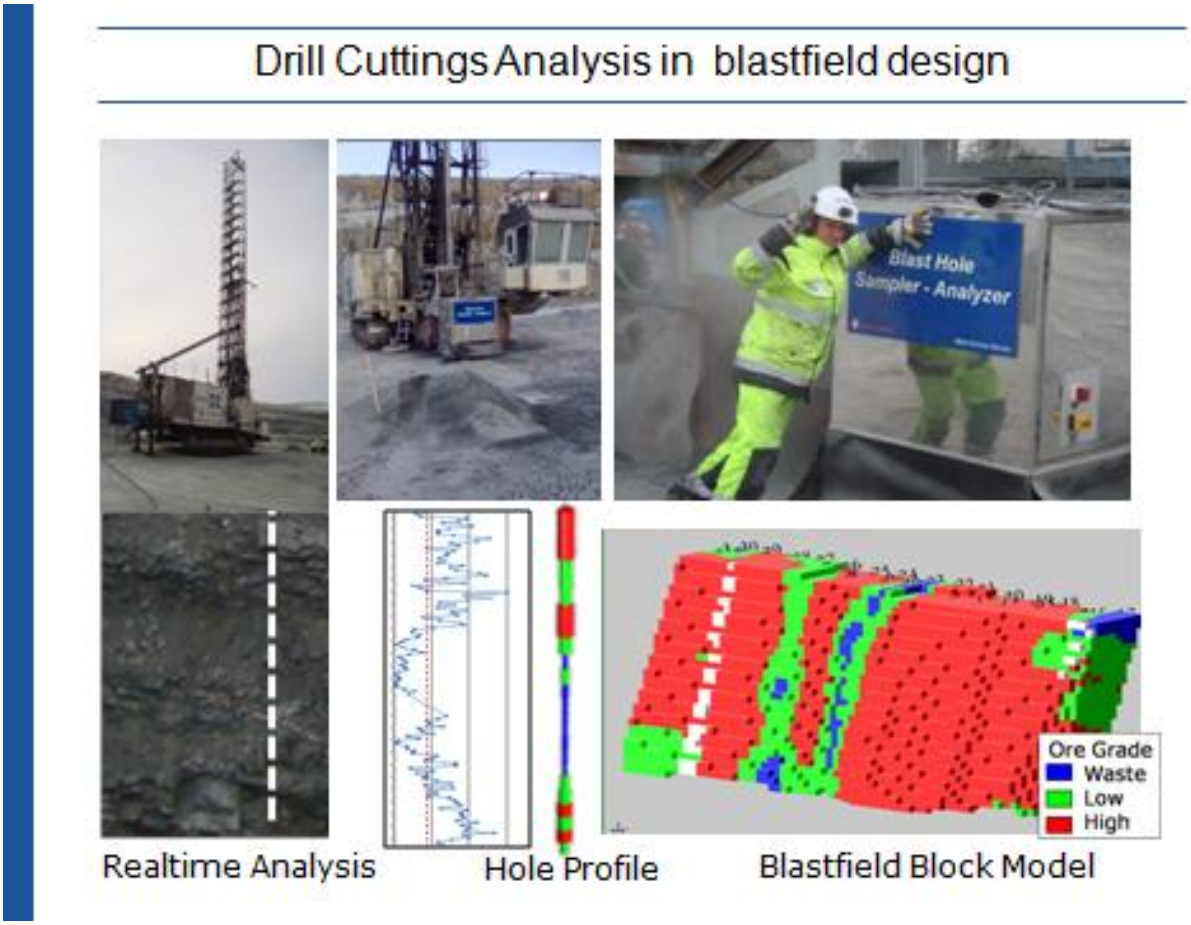

Figure 5. Blast Hole Sampler-Analyzer (BSA) in blast field design

Small scale block models on blasting benches are provided by using Kriging method and BSA analysis information. Block sizes are recommended to be equal to the loading machine's bucket size, i.e. from 1 cubic meters to to 70 meter cubes depending on the loading machines bucket size. The BSA block model provides accurate information on ore waste borders on the blasting bench and also new information for the geologists on the ore characteristics. The block models can be done based on the ore grade (ore value), or based on grade and grindability (ore value x mill throughput). Also skarn minerals that may have a negative effect on metal recovery can be identified and valued on the block model when defining the cut off by value.

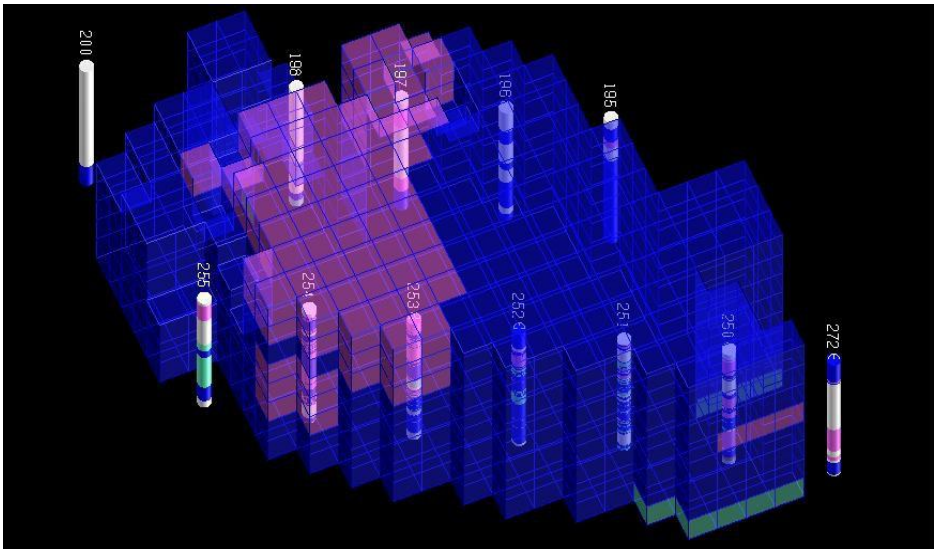

Fig.6 BSA block model, 3X3X3 meter blocks

While analyzing the BSA continuously registers drill penetration rates which gives further information on rock characteristics. The BSA can be connected to the drills existing measure while drilling (MWD) systems to combine the MWD data with BSA's elemental analysis and mineralogy data. This way the BSA system can be used for blasting fragmentation optimization by detecting weak minerals, cracks and crevices in the bench.

The blast hole profile and block model analysis data can be used also for directional blasting planning in selective mining. By adjusting timing on ignition caps in blast holes waste and ore can be directed to have a different trajectory in blasting to improve selective loading.

In buffer blasting the rock movement is limited. The rock swell and rock movement in the blast can be simulated to the BSA block model on blasted bench giving a new volume and location for each block. Modern mines have loading machines operating on GPS coordinates achieve centimeter level location accuracy. The loading machines can selectively load the right blocks based on the BSA blasted bench block models to dump trucks going to the mill or to the waste rock dump. When the ore block is loaded on a truck its information follows the dump truck. The mill operators will know beforehand the grade of the ore that is coming in shortly.

The grade information can be used to homogenize the mill at homogenization stocks or by loading from two or several benches simultaneously. Waste rock, being inert or non inert based on the BSA analysis, will be directed to the right dump site.

Mining quality control is performed by **Cross Belt XRF or LIF analyzers**. They give immediate feedback to the loader operators on the quality of the selective loading. They also provide accurate information in advance for concentrator operators to tune recovery or homogenization processes for the incoming ore. The XRF and LIF cross belt analyzers have no radioactive sources and they can be installed on top of almost any conveyor belt operating with steady or fluctuating loads and with varying material bed heights. A typical application for detecting waste rock dilution is after primary crushing when ore and waste are mixed to relatively small degree.(fig. 7). The best mining quality improvement is reached when on-line analysis is done from several points in the mining process (fig.8).

Fig. 7. LIF Cross Belt analyser

Conclusions:

To be able to define the ore location and grade accurately is a fundamental factor of success for all mining operations. The On-Line Mine concept provides tools for this to optimize the mine production based on ore value. The concept collects and processes a large amount of timely analysis data into a format from which it is easily accessible for the mine personnel. Selective mining, small or large scale, can be designed around the ore grade, quality and location information provided.

The On-Line Mine concept provides following **economical benefits:**

- Lower waste rock dilution
- Less ore losses
- Higher mill throughput
- Increased mill head grade
- Better overall recovery at the concentrator

- Better reconciliation of ore reserves and production
- Improved mine economy

Being able to utilize the ore reserves more efficiently by the On-Line Mine concept results in several **environmental benefits:**

- Less waste rock in rock dumps
- Better separation of inert and non inert waste
- Less ore in waste dumps
- Less acid rock drainage
- Better waste rock quality and location control
- Less emissions
- Lower energy consumption
- Less waste for settling dams

The technology and the related services to reach these benefits by the On-Line Mine concept are available today.

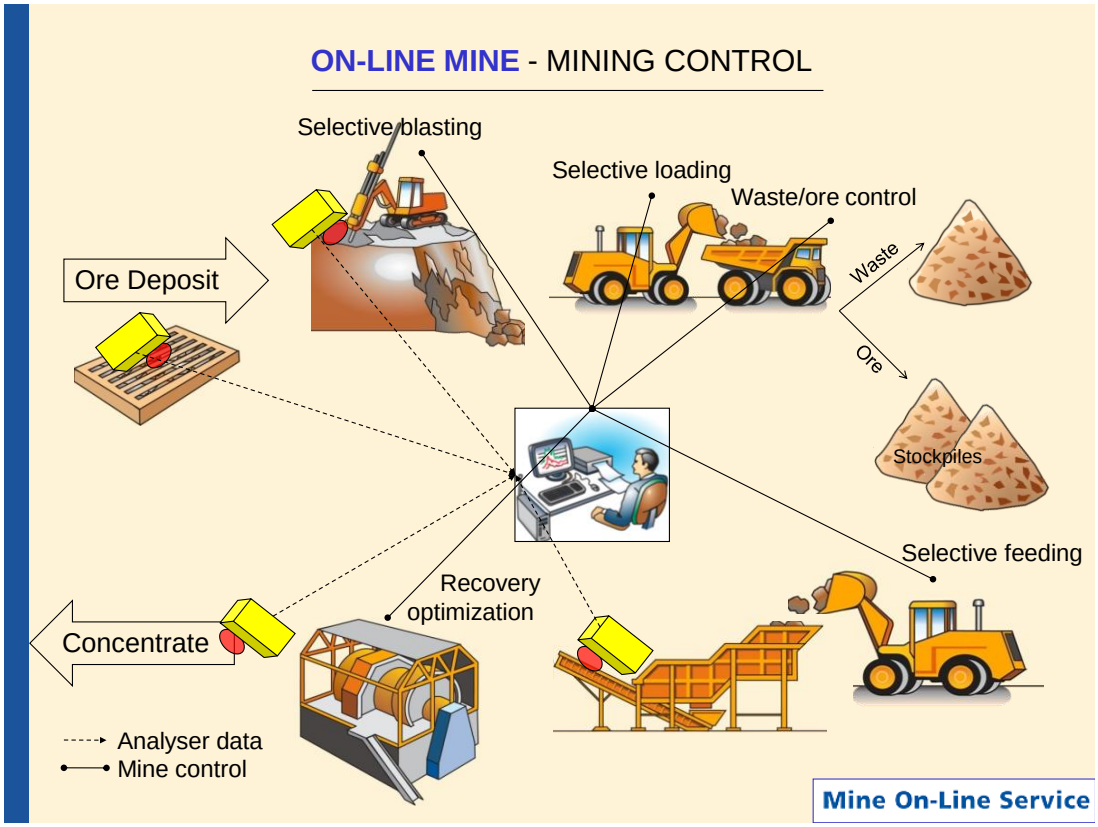

Fig. 8. On-Line Mine information network