Dewatering challenges in an large scale production hard rock open pit in northern Sweden

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Abstract

During the last years BOLIDEN increased production of Aitik mine up to 36 million tons of ore per year. The fast development of the pit in area and depth also leads to an increase of the hydraulic head and by that to stronger water inflows. Wet mining conditions influence the production efficiency negatively, especially during mining of the pit floor they can reduced the production efficiency dramatically.

To gain dryer mining conditions BOLIDEN implements a large scale dewatering system in Aitik. This includes the implementation of in-pit wells and cutting of recharge sources. To gain effective results from these measures, decisions of where and how to apply them need to be based on further research of the local hydrogeology.

The approach for this research described in this paper is the deep analysis of available information at BOLIDEN and results of an extensive sampling trip. Strategy of the sampling trip was to sample water inflows and surface waters in the vicinity of the pit, which might function as potential water sources.

Based on onsite measured parameters, the samples were grouped according to their behavior.

Water flow path hypotheses of how potential sources and inflows could be related were developed. Full analysis with a wide range of elements have been carried out for all samples. The results of these analyses were used to validate the flow path hypotheses. Especially higher Al-, Cu- and REE- contents, which were generated in weathered zones or tailings, were used as tracers to evaluate possible relations between surface waters and inflows.

By interpreting all information certain flow path suppositions were discarded and others became more likely. This new knowledge was used to avoid investments on probably ineffective measures. The new understanding of where certain inflowing waters are generated lead to further decisions for dewatering measures.

Key words: Dewatering, Hardrock open pit, local hydrogeology, flow path interpretation

Introduction to the topic

During the last years BOLIDEN increased the production of its Aitik mine up to 36 million tons of ore per year and further increases are planned. The fast development of the pit in area and depth also leads to an increase of the hydraulic head and by that to a higher amount of water that enters the pit.

Wet mining conditions influence the production efficiency negatively. Especially during mining of the pit floor the water inflows reduced the production efficiency dramatically.

To reduce or even fully avoid these effects BOLIDEN plans to implement a large scale dewatering system in Aitik. This includes an optimization of the current shotgun pattern according to which the horizontal drains are drilled, the implementation of in-pit wells and cutting of recharge sources.

To gain effective results from these measures, decisions of where and how to apply them need to be based on further research of the local hydrogeology.

Short Introduction to the Aitik mine

Aitik is located 60 km north of the Arctic circle, close to the city of Gällivare in Sweden. Aitik is the city´s largest private employer with about 650 employees. With a length of 3 km, a width of 1 km and a depth of 450 m Aitik is one of the biggest hard rock open pits in Europe. Furthermore Aitik is also one of the most efficient copper open pits in the world. In 2015 Aitik produced 36.361.000 t of ore, 67.000 t of copper, 61.452 kg of silver and 2.042 kg of Gold. Furthermore there is the mining of about 32.000.000 t of waste rock at the current production rate.
According to the current mine plan, Aitik will reach a final depth of 645 m in 2039, during that time the surface area will increase by roughly 30 %.
The bedrocks in Aitik are primarily gneiss and shale. Chalcopyrite and pyrite are the main valuable minerals. A 10 – 20 m thick layer of alluvium, typically moraine and peat, covers the hard rock of the deposit. Feature of the hard rock body is a strong fracturing, that can be seen on the majority of the exposed rocks in the pit slopes. Most of the joints seem to be open and show a very low infilling. It is believed that almost every ground water flow in the pit area occurs under fracture flow conditions. As the rock is very well jointed, it is easy to drain the rock mass itself, but the rock itself shows a low permeability about 5×10^{-7} to 10^{-8} m/s. In 2014 Aitik had a water output of roughly 4.400.000 m³. Figure 1 gives a good impression on how water inflows spread through the slopes. On the left side of the image the slope seems to be quite dry, while the very well jointed shear- and orebody zone in the middle and the right side of the image is obviously wet due to the strong inflows.
The leading climate in Aitik is a humid subarctic continental climate with cool summers and no dry season. Based on weather records between 1996 and 2014, the mean annual precipitation in the area of Gallivare is about 668 mm and with average temperatures clearly below 0°C between November and March and 13 °C between June and August.

Figure 1 Wet and dry zones in Aitik north pit, Photo by Lars de wall

Sampling inflows – Basis of a new understanding

Our approach for the further research on the local hydrogeology is the deep analysis of available information at BOLIDEN and the analysis results of an extensive sampling trip. Strategy of the sampling trip was to sample water inflows in the mine and surface waters in the vicinity of the pit, which might function as potential water sources. Figure 2 gives an overview of the collected samples in and around the Aitik open pit.

In total 43 samples were collected, the samples were grouped according to their type into potential water sources and water inflows. Samples of potential water sources were collected from “artificial” (12 samples) and natural surface waters (3 samples). Water inflow samples were collected from the pit sumps (3 samples), conveying tunnels (6 samples), horizontal drains (12 samples) and uncontrolled inflows (8 samples).

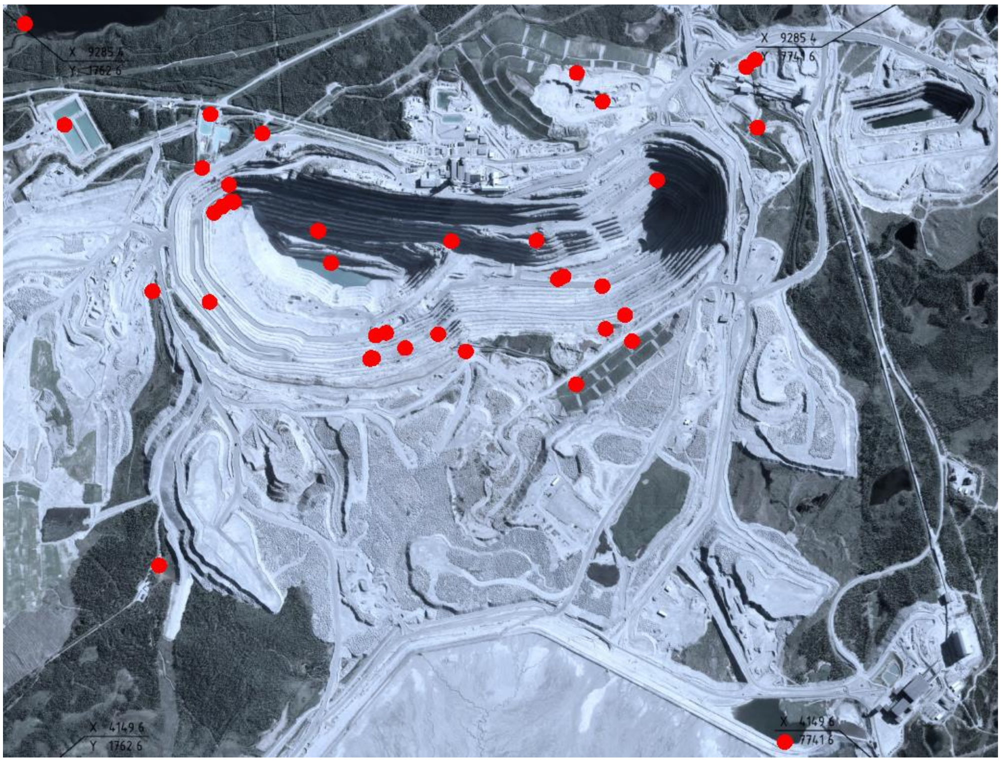

Figure 2 Overview of collected samples in and around Aitik

Analysis and Interpretation – Way to a new Understanding

Based on the onsite measured parameters, pH-Value, electric conductivity, redox potential, alkalinity and acidity, the samples have been grouped according to their behavior.

Water flow path hypotheses of how potential sources and inflows could likely be related have been developed. Basis for these hypotheses were the grouping and locations of the samples.

Figure 3 shows an example for such a hypothesis. The green dots represent inflows to the pit that were believed to be likely related to the nearby surface waters, represented by the red dots.

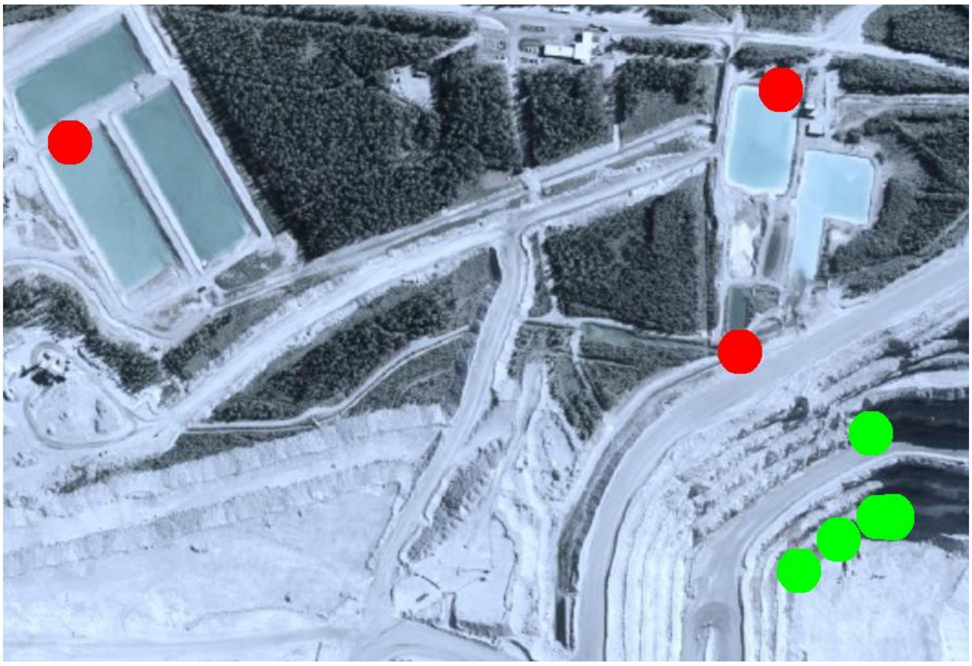

Figure 3 Example for sample relation hypothesis

Full analysis with a wide range of elements, a TC/TN-analysis and an analysis of the stable isotopes (^{2}H/ ^{18}O) have been carried out for all samples. The results of these analyses were used to validate the developed flow path hypotheses. Especially higher Al-, Cu- and REE- contents, which have been generated in weathered zones or tailings, were used as tracers to evaluate possible relations between surface waters and inflows.

Figure 4 shows the Al-, Cu- and REE- contents of the samples shown in figure 3, which were believed to be related. On the one hand the left group (red box), which represent the surface waters and by that the suspected inflow source, show noticeable Al-, Cu- and REE- contents. On the other hand the inflow samples (green box) do not show noteworthy contents of these elements. In order to this the suspected relation of both groups is very unlikely or the surface waters only have a very marginal influence on the inflows.

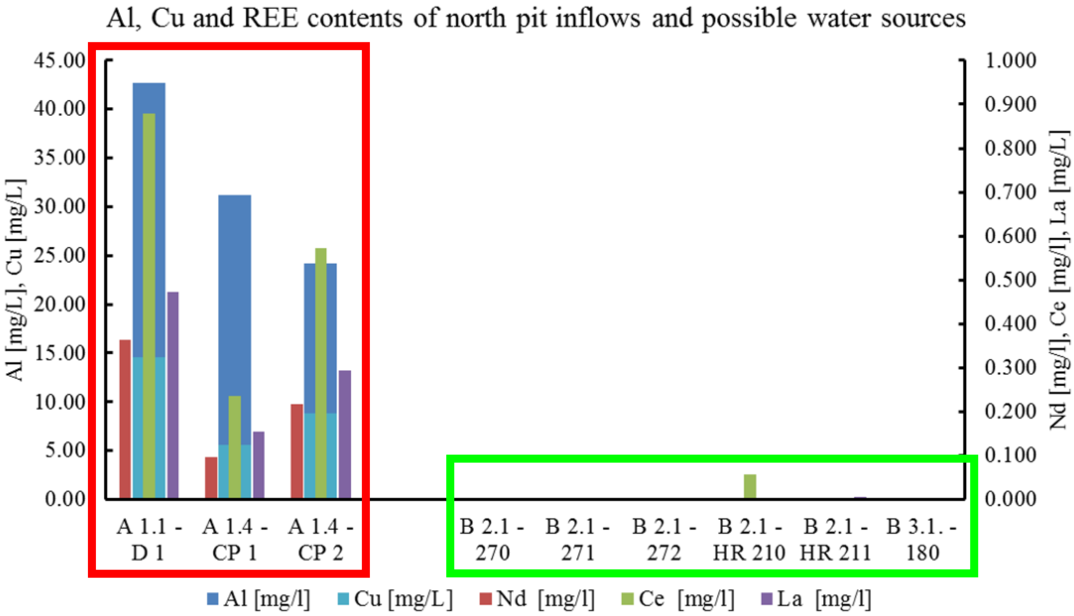

Figure 4 Example for sample relation hypothesis

Conclusions – A new understanding as basis for decision making

By interpreting the new collected data and the available information certain flow path suppositions or water relations could be discarded and other became more likely. These new knowledge was used to avoid investments on probably ineffective measures. The new understanding of where certain inflowing waters are generated lead to further decisions for dewatering measures.

Further research goal is to increase the understanding of the local hydrogeology and actual flow paths to provide information for the decision making with the higher aim of reducing the overall water inflows and increase the production efficiency and safety by gaining dryer mining conditions.