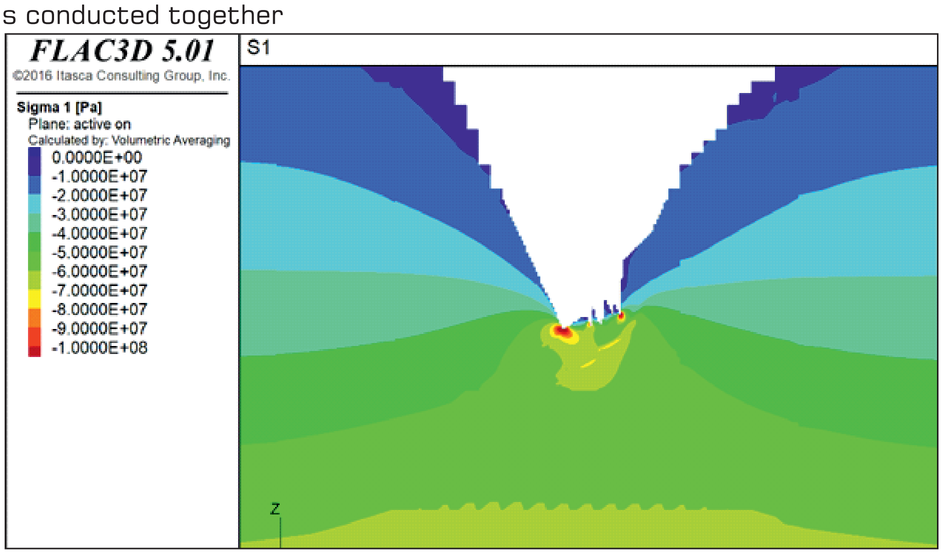
Developing of a new caving method for great depths

A novel caving method suitable for deep and high stress conditions is under development. A joint project with LKAB has been started.

Caving operations progress to depths below 1000 m and towards more competent rock masses. Stress magnitudes rise and result in increased rock mechanical issues, which cause amongst others damage to vital infrastructure, rock bursts, slow cave propagation or production delays. Thus, a safe, economic and complete extraction are endangered. The new caving method is based on de-stressing the rock mass so that vital mining infrastructure such as stope development, rock passes or footwall development can be protected from high stresses. Protective pillars are used to control stresses and seismicity. These pillars are removed in the course of subsequent stoping activities and hangingwall is allowed to cave.

In 2019, a pre-study was conducted together with LKAB with the objective to evaluate the application potential and to outline key issues of the proposed caving method. Therefore, well-established design criteria and design methodologies were used. It is found that the proposed caving method is applicable from a rock mechanics point of view to depths of 2000 m. Moreover, results indicate that in general the method would be applicable for even greater depths. The comparison to the currently applied caving methods shows that the proposed method offers significant improvements. These improvements comprise stability of drifts, ore passes and other infrastructure, encountered seismicity, expected surface subsidence as well as safety, productivity, automation potential and cost. Due to these promising results, the development of the new caving method continues. A comprehensive joint research and development project has been launched together with LKAB. Besides paper studies, a real test of the method and associated machinery is planned in one of LKAB's iron ore mines.



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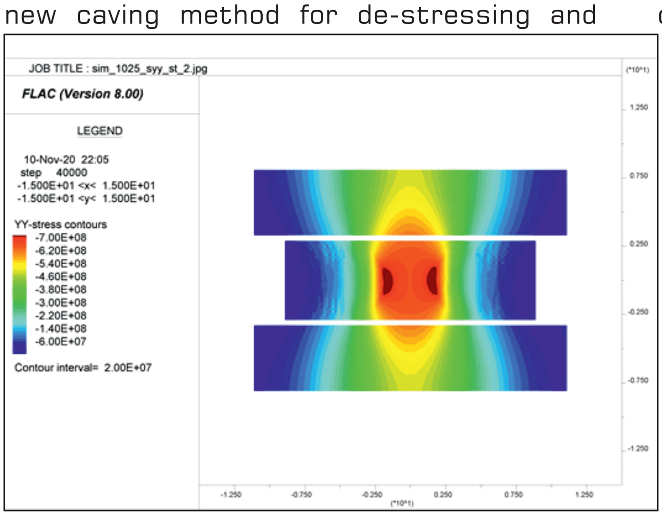
Rock mechanics aspects of a novel caving method

A cave mining method for great depths is under development. Diverse rock mechanics aspects related to high stress and seismicity have to be analyzed.

A new cave mining method is under joint development with LKAB. The method enables extraction of deposits under high stress conditions at great depths. Stress management is essential in deep mining environments in order to avoid rock pressure problems, such as unacceptably large fracture zones or rock bursts. For this reason, the rock mass is first de-stressed with minimum amount of infrastructure. Afterwards production commences in de-stressed ground and shielded from seismically active areas. Thereby, vital mining infrastructure such as stope development or rock passes can be protected. Moreover, stress magnitudes and seismicity are controlled during de-stressing as well in order to enable safe and efficient de-stressing. Large, protective pillars are an integral part of the new caving method for de-stressing and production. These pillars are finally extracted, as mining progresses. A proper rock mechanics design of the mine layout and mining sequence during de-stressing and subsequent production is crucial for success.



Overall, the rock mechanics design of the new caving method must consider various aspects, which comprise amongst others the stability of excavations, the strength and behavior of pillars, the time and method of pillar extraction and the subsequent caving of hangingwall. The large, protective pillars were identified as a key issue. Principally, pillars influence the stress situation and mining-induced seismicity significantly. Moreover, pillars affect the initiation and propagation of hangingwall caving. However, pillar strength and behavior, especially of pillars with planned size and dimensions used in the novel caving method, is not sufficiently understood currently. For this reason, a comprehensive research program was set up. Investigations focus on the one hand on improving the understanding of pillar strength and behavior and on the other hand on outlining and evaluating different types of pillar strength and behavior on the stress situation and seismicity. Theoretical concepts and numerical simulations are mainly used for latter analyses. Besides paper studies, pillar strength and behavior will be studied in full-scale under high stress conditions in a designated test site in Kiruna mine.

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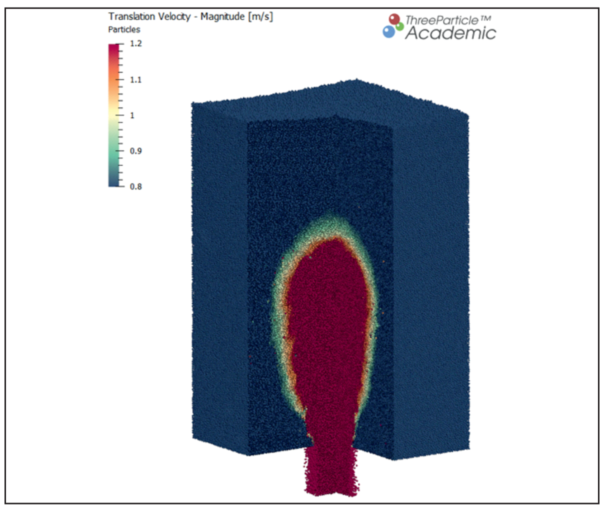
INVESTIGATIONS ON THE ORE FLOW IN DEEP CAVE MINING

THEORETICAL AND NUMERICAL APPROACH TOWARDS ORE FLOW MECHANISMS IN DEEP CAVE MINING IN ORDER TO EVOLVE MINE LAYOUTS FOR A NOVEL CAVING METHOD

To extract most of the ore in cave mines, it is important to create an ambience of uniform draw over the whole mining area. Otherwise risks like early dilution arise, that have a major impact on the operation in the sense of production and reserves. Handling the ore flow therefore defines the success of the cave mining operation. The circumstances in deep cave mining are more complex than at lower depths. The high rock pressure leads to a higher probability of rock pressure problems, rock bursts and seismicity. As a consequence, draw points may require a larger spacing, so that pillars between draw points can be larger. A further critical issue is the Hangingwall caving and its accompanying waste dilution. Other problems arising in great depths can be the convergence of surrounding walls, clamping the ore and clogging draw-points. Hang-ups can form by large boulders arching above a draw-point, causing a blockage. Consequently, the ore cannot be mucked from these draw-points until the blockages are released, which mostly implicates difficulties.
In order to address these rock mechanics issues, a novel caving method is under joint development with LKAB. Ore flow was identified as a key issue for the successful implementation of the novel method. Therefore, one of the targets is to find a way of analyzing the ore flow in deep cave mining and associated potential problems. The result should enable the evaluation and comparison of draw layouts and find weak points. Using this knowledge, it is aimed to enable a uniform, controlled flow, such that a high recovery and late dilution with hangingwall waste rock can be realized with an appropriate draw strategy. An important part of research will be represented by Discrete Element Method simulations to get on the track of the ore flow. A crucial point are the unknown properties of the broken ore and broken hangingwall. Input data from the active Kiruna mine is used to decrease latter uncertainties and thereby to define input parameters for the ore flow simulations. Moreover, it is planned to conduct full-scale tests in Kiruna mine. Overall, the work shall contribute to a deeper knowledge of flow mechanisms in a deep cave mining and how to address them.

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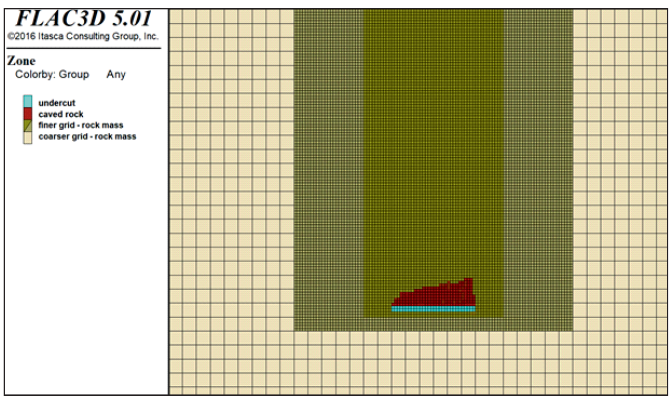
Research on hangingwall caving in deep mining

A methodology to describe and forecast initiation and progression of hanging-wall caving in a novel mining method applied at great depths is developed

Underground cave mining projects have been successfully implemented over the last decades, since they are defined as productive, efficient, low-cost and safe extraction techniques. In this particular type of underground extraction, the rock mass is allowed to cave during or after the mineral is extracted. Among others, block and sublevel caving are included in this kind of methods. Moreover, a novel caving method is developed, which is especially suited for deep and high stress conditions. The development of the novel caving method is carried out in close collaboration with LKAB.

For caving methods, it is crucial to understand and measure the caveability of the material, as well as predict the caving behavior of the deposit and the host rock masses. Thus, describe how the cave propagates once the mining activity begins. Cave propagation has a significant impact on dilution as well. High stressed situations are related to deep mining and affect caving considerably. Finally, subsidence is a direct consequence of cave mining.

These issues have to be avoided or forecasted and controlled, in order to maintain a high performance and safety during the mining activity. However, this is not a straight forward task, since a large list of factors, situations and parameters must be taken into consideration. Studies, researches and methodologies on this topic have been developed, which used sophisticated tools and software and required a large list of parameters and measures to carry them out. Although, regularly those required measures and tools are not available. Therefore, the target is the development of a simplified methodology to describe cave initiation and propagation by means of numerical simulations. The methodology is to be implemented for studying the characteristics of caving in the novel cave mining method. Besides paper studies, the application of the novel method in Kiruna mine is going investigated. Therefore, Kiruna specific geotechnical parameters, stress situation and deposit geometry are used. Moreover, the developed methodology is applied to study and back analyze cave initiation and propagation in the current sublevel caving in Kiruna as well as in the planned test site of the novel caving method.



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