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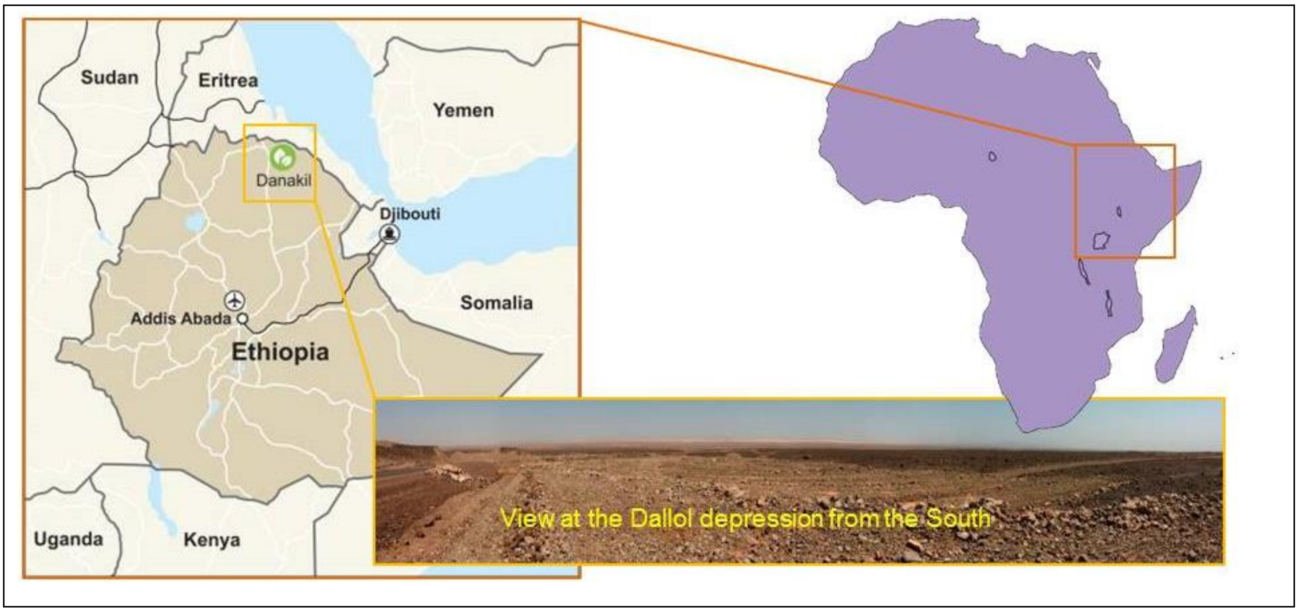
Selective solution mining within complex deposit structures at Dallol Region in Ethiopia

Abstract

K-UTEC AG Salt Technologies, a German research and engineering company with more than 60 years of experience within the sector of potash and rock salt mining, develops actually one of the world's first solution mining operation for selective leaching of potash layers in different levels within the Circum's Danakil Potash Project. The successful running test work is based on a special well layout and adjusted leaching schedule applying a modified blanket operation. K-UTEC designed the test well and delivered key components of the test facility, like safety equipment and a full laboratory for brine monitoring. To ensure a well targeted test operation K-UTEC commissioned the well and provides a comprehensive support on site. K-UTEC will produce the final products in pilot plant scale after finishing the on site test work.

Keywords

Solution mining, Potash processing, Drilling, Test well, Pilot plant, Evaporation pond



Picture 1: CIRCUM's Danakil Project license within the Afar Region of north-eastern Ethiopia.

Location & Geological Settings

CIRCUM's Danakil Project license is located in the Afar Region of north-eastern Ethiopia, approximately 600 km north-north-east of the capital city of Addis Ababa and nearly 85 km from the Red Sea coast of Eritrea (Picture 1). It is situated in an area north of the Crescent and the Musley potash deposits, which were explored in the 1950’s and 1960’s by the Ralph Parsons Company.

Potash mineralization occurs in depths as shallow as 85 meters up to depths of about 600 m below surface. The seam structure comprises a mineable lower Kainite unit with overlying Carnallite and an upper Sylvinite unit, partly connected with an underlying smaller Carnallite layer. Between these two mineable horizons, a Bischofite layer occurs with a thickness up to more than 60 m /3/.

Deposit & Mining Method

The total Mineral Resource Estimate includes the Sylvinite, Upper Carnallitite, Lower Carnallitite and the Kainite potash bearing beds, comprises a Measured and Indicated Mineral Resource totaling 2.8 Bt at an average grade of 18.6% KCl, which gives a total of 525.8 Mt of KCl and an Inferred Mineral Resource of 2.1 Bt at an average grade of 17.5% KCl, which gives a total of 366.5 Mt KCl /1/.

Through a comparison of the advantages and disadvantages of various applicable mining technologies, solution mining could be identified as preferred technology. Solution mining is the most appropriate method for this resource owing to factors such as ease of integration with the processing concept, low-risk, established technology, low cost and manpower requirement and low management complexity /2/. Depending on Bischofite thickness, ore qualities and the desired product choice (certain SOP to MOP ratio necessary) different solution mining procedures were developed.

Although $MgCl_2$ from Bischofite can be accommodated within the processing concept, its exploitation by solution mining would be extremely disadvantageous in terms of water consumption and energy. It was therefore decided to develop solution mining concepts which avoided the extraction of excessive amounts of Bischofite. The extraction of zero Bischofite is obviously not a practicable expectation since it is situated between the Upper and Lower Carnallitite units and effects of the solution mining procedures on the sensitive Bischofite cannot be avoided.

The so called SolMin1 procedure considers the creation and exploitation of solution mining caverns extracting the whole potash sequence leading to the generation of high caverns (possibly up to 30m). In this case Sylvinite, Carnallitite and Kainite layers will be extracted simultaneously.

The second option SolMin2 is characterized by the selective solution mining of units in areas where Bischofite exceeds a certain thickness. In this case, solution mining takes place initially in the lower horizons, finally followed by the upper horizons after piping is drawn to the upper Carnallite and Sylvinite layers /4/.

The brine emanating from the solution mining caverns is pumped to the processing plant for further treatment. Clearly, the purpose of the plant is to concentrate the solution and extract the potassium in the desired compounds. Due to the ratio of anions and cations within the brine (which can also be varied according to the selection of SolMin1 or SolMin2) several production opportunities exist. However, owing to its unselective nature, all scenarios associated with SolMin1 will yield SOP as the main product. MOP may still be produced during the last evaporation step this will be in minor quantities though.

The aim of SolMin2 is to fully utilize the entire resource. Because of the incorporation of Kainite, it is implicated that SOP will be the predominant product as well. As with SolMin1, minor quantities of MOP can be produced within the process.

Exploration Work & Test Well Facilities

The Mineral Resource Estimate is based on the assessment of 74 core drill holes totaling 20,284 meters conducted between 2010 and 2014. The MRE also took more than 74.78 kilometers of 2D seismic survey conducted in December 2014 into consideration. To calculate the polygon areas of each drill hole location a radius of 500 meters was defined for the Measured category, 1,000 meters for the Indicated category and 2,000 meters for the Inferred category.

To evaluate and verify the solution mining procedures as well as the processing routes, a test well program was designed and started in 2015. The program comprised comprehensive weather monitoring; drilling, completion and operation of a solution mining test well and the erection of various evaporation ponds and pools. Furthermore some water wells were drilled and investigated.

Test Well Erection & Operation

The drill hole of the test well Solmin01 had the same dimensions that would be applied for a regular production well. It was situated within a typically structured potash sequence. Within the overburden and the cap rock two technical casings 18-5/8” and 13-3/8” of size were used. The last cemented casing reaching the top of the Sylvinite unit was 9-5/8”. The selection of the final location was based on the updated geological model and the results of the seismic survey.

Picture 2: Drill pad during well cementation of the final 9-5/8” casing, drill rig Nordmayer DSB 3-14 of the Company Nord Bohr- und Brunnenbau.

For the drilling process a reverse drilling method (air lifting based on RC-drilling) was chosen to minimize energy consumption and to avoid negative effects on the rocks of the overburden. Picture 2 shows the drill pad with the drill rig during cementation. Within the potash sequence core drilling was applied to get sample material for further test works (leaching tests and investigations in laboratory scale). For cementation of the 13-3/8" and 9-5/8" the German company BLZ Gommern provided a special support to ensure a safe and tight cementation. The equipment for testing and the preparation of the cement suspension was provided by K-UTEC.

For the initial test well operation a diesel blanket was applied. A suitable blanket system facility comprising of two pumps and tanks was erected. After an unwanted cavern development towards the Bischofite layer the blanket medium was changed to use compressed air. K-UTEC designed and delivered the blanket system and the test work could be continued after securing the Bischofite bed with compressed air. After a Kainite cut the Bischofite bed was bridged with brine and finally the Sylvinite was leached. Subsequently a performance test of the well was carried out applying a higher volume flow. Picture 3 shows the well head of the test well together with the control devices on the brine line.

Picture 3: Well head of the test well SolMin01, in the foreground the monitoring devices on the brine line.

Evaporation Test Work

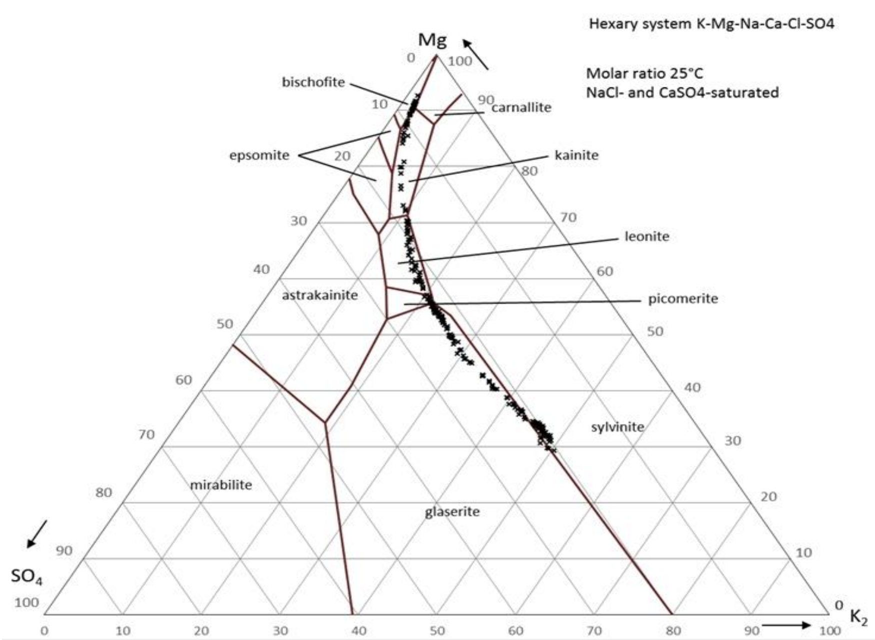
To verify the designed process routes comprehensive evaporation test work was planned and realized. In a first step of pre-tests synthetical brines similar to the expected production brines were prepared and evaporated. These test works could verify the principal theory and a more detailed scheduling of the follow up evaporation tests was possible.

To monitor the brine quality a laboratory was installed on site. K-UTEC designed the lab and instructed the lab personal. Lab liability and the quality of analyses were on a good level and according to normal standards.

Picture 4: Evaporation pond with a mobile brine pump. The pond in the background is harvested and the pond in the fore ground is ready for filling.

After the pre-test phase the produced brines from the test well operation were stored temporarily inside a buffer tank to be able to control the target composition. After storing of an adequate volume of high quality brines, the real evaporation test started by filling the big evaporation pond. Picture 4 shows the evaporation ponds and the used brine pump.

During test work daily sampling and analyses were carried out for exact brine composition monitoring. After reaching the target point the whole brine volume was transferred to the next pond. The resulting crystallizate was harvested by hand and representative samples were analyzed. For Kainite evaporation a total of 6 brine transfers were realized.



Picture 4: Crystallization pathway of the Kainite brine test in the Jänecke diagram of hexa-system K-Mg-Na-Ca-Cl-SO4.

The total amount of crystallizate after 5 brine transfers was around 90 tons, with approximately 11 tons of Sylvite and 20 tons of Kainite. The Kainite content in the 5th harvest stage was 75 %. Picture 5 shows the crystallization pathway in the Jänecke diagram of the hexa-system K-Mg-Na-Ca-Cl-SO4.

To test the final processing steps a representative sample volume will be send to the K-UTEC facilities in Sondershausen when the on site evaporation test work is finished. K-UTEC will produce the final products in pilot plant scale.

References

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