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Exploration of different types of potash deposits – Case studies: Exploration of solid Potash deposits: Circum Minerals Danakil Potash Project Exploration of Brine deposits: Beyondie Lake Potash Project – Potash Exploration in Salt Lakes and Hidden Rivers

Salt Production

Keywords: potash; mining; exploration; brine deposits; CIM; JORC

Abstract

This paper describes the exploration programs and the Resources/Reserves Estimations of two different types of potash deposits as case examples: The Circum Minerals Limited's (CIRCUM) Danakil Potash Project is a solid potash deposit located in the Afar Region of north-eastern Ethiopia approximately 600 km north-north-east of the capital city of Addis Ababa. Kalium Lakes Limited's (KLL) Beyondie Potash Project is a liquid deposit (a saturated brine) located at the eastern margin of the East Pilbara region of Western Australia about 160 km south-southeast of Newman.

Main target of the CIRCUM exploration works in Ethopia between 2008 and 2015 was the potash sequence composed of a Marker bed (halite, anhydrite), Sylvite, Carnallite, Bischofite and Kainite within the so called Houston Formation. The field investigations included a drilling program with comprehensive logging, sampling and analytical investigations like chemical and physical laboratory assays and hydrogeological in-situ tests. Additionally environmental impact studies were realized.

The results of the field works and laboratory assays have been incorporated into a resource model. This model was used by K-UTEC's Competent Persons to estimate the mineral resource in the form of a NI 43-101 Technical Report concerning the CIM Definition Standard and facilitate preliminary mining and also processing studies. In collaboration with CIRCUM, K-UTEC developed a number of potential exploitation scenarios for the existing resource inclusive a preliminary estimation of capital and operating costs within the Detailed-Feasibility Study.

The Australian Beyondie potash deposit is a brine deposit, containing the target potassium and sulphate ions. This brine is hosted within saturated sediments in at least two separate horizons below the lake surface and in sediments adjacent to the lake. The lakes are located within the broader Ilgarari-Palaeochannel system that extends over hundreds of kilometres.

A field program with drilling, augering, sampling of brine and soil material, geophysical surveys, laboratory analysis and pumping tests has been realized in the Beyondie project area since 2015. Based on data from the fieldwork and laboratory analyses 2016 an assessment of the Mineral Resource has been undertaken using a combination of CIM and JORC to meet the requirements of a brine deposit. Currently an update of the resource estimate (Bankable Feasibility Study) including the building of hydrogeological flow models is worked out with respect also to the results of new drillings, auger holes and trenches as well as geophysical surveys. In-situ test ponds were constructed and evaporation and processing trials are running.

Introduction

K-UTEC AG Salt Technologies is a worldwide operating engineering company with the specialization of different types of salt deposits. We can cover with our knowledge the total life cycle of mining operation. This starts normally with the exploration and evaluation of the deposit, the mining plan and the product process development. Later the process and mining relevant task during the exploitation of the deposit will be accompanied by detailed mining exploration in the underground process engineering and safety monitoring like seismic monitoring. At the end of the life cycle of a mine/deposit we develop backfilling plans, reuse approaches as well as environmental monitoring.

In this presentation the section of exploration for two different types of projects will be presented. The first case is a solid potash deposit in the “hottest habituated area on earth” (Wikipedia) the Danakil depression. A specialty at this deposit evaluation is the planned mining type as solution mining, which works more or less only in cases of salt deposits.

The second case is a potash deposit as a brine deposit in Western Australia in salt lakes and hidden rivers.

Case examples

Case I: Exploration of solid Potash deposits: Circum Minerals Danakil Potash Project

Circum Minerals Limited (Circum), incorporated in 2011, has acquired the rights to explore within a potentially significant potash deposit in the Danakil Depression of Ethiopia. The area covered by the current exploration license (property) is comprised of two leases held before in the name of G&B Central African Resources Limited (G&B). These two leases are referred to as Danakil (324.7 km²) and Bada (40.4 km²) with a combined area of 365.1 km². The property (license area, Figure 1) is located in the Afar Region of north-eastern Ethiopia within the Afar National Regional State and approximately 600 km north-north-east of the capital city of Addis Ababa and nearly 85 km from the Red Sea on the coast of Eritrea.

After permission of the exploration license for the property areas in 2008, an extensive exploration program started in February 2009. Up to and including 2015 a number of 51 explo-ration drillings as well as comprehensive logging, sampling and analytical investigations have been implemented. Main target of the exploration works was a potash sequence composed of a

- Marker bed (halite, anhydrite),
- Sylvite,
- Carnallite,
- Bischofite and
- Kainite

within the so called Houston Formation.

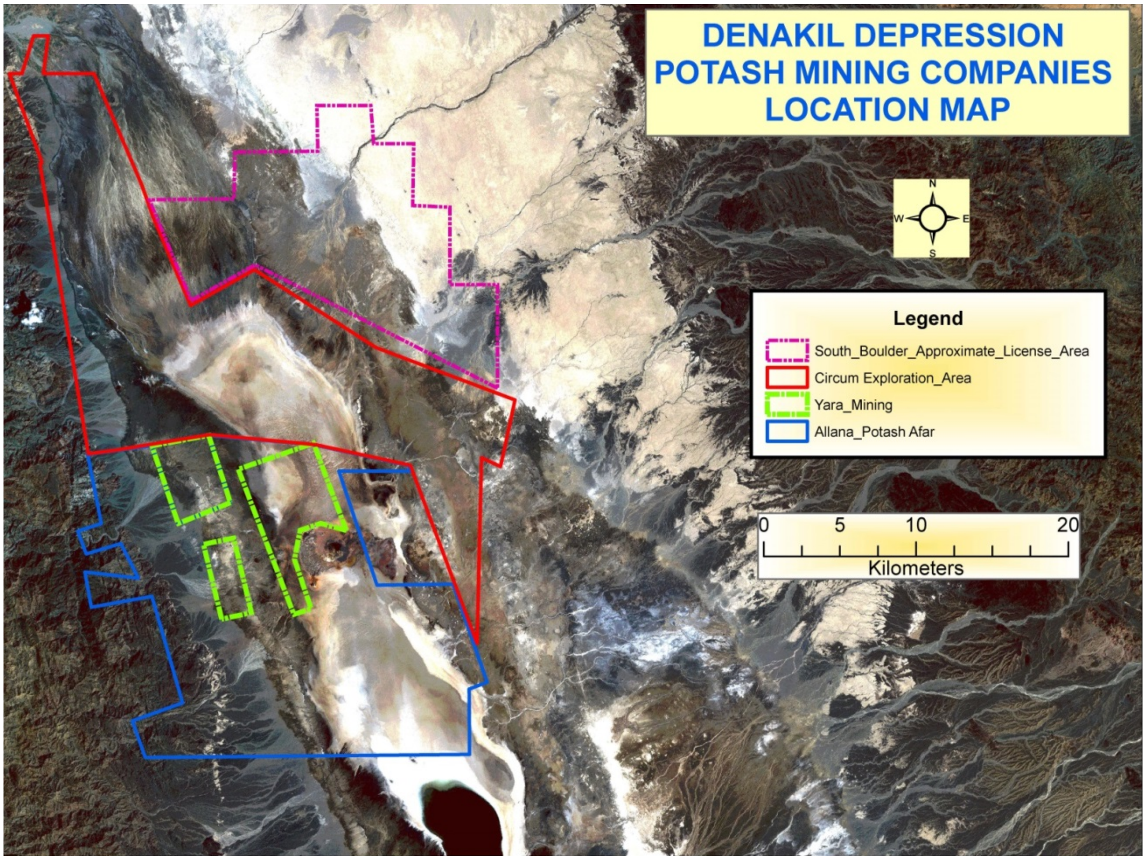

Figure 1: Satellite image showing the location of the lease and the adjacent properties.

Additionally, environmental impact studies, hydrogeological expertise and several hydrogeological field tests (pumping tests) have been realized. The results of the extensive exploration drilling program as well as of the chemical analysis, the downhole geophysical measurements and the reflection seismic program (Figure 2 and Figure 3) have been incorporated into a resource model. This model was used, among others, to estimate the mineral resource (Figure 4) for the explored license area as a NI 43-101 Technical Report concerning the CIM Definition Standard and facilitate preliminary mining and also processing studies.

The appearing potash salts in the deposit as nonmetallic resources belong to the CIM defined term of Mineral Resource (solid) of intrinsic economic interest which has been identified and estimated through exploration and sampling. The Technical Report, prepared by K-UTEC, has been compiled by Qualified Persons (QP) considering the regulations of form 43-101F of National Instrument 43-101 (NI 43-101) [1] accompanying the Detailed Feasibility Study (DFS). In collaboration with CIRCUM, K-UTEC developed a number of potential exploitation scenarios for the existing resource inclusive a preliminary estimation of capital and operating costs (PEA: Preliminary Economic Assessment) within the Detailed-Feasibility Study.

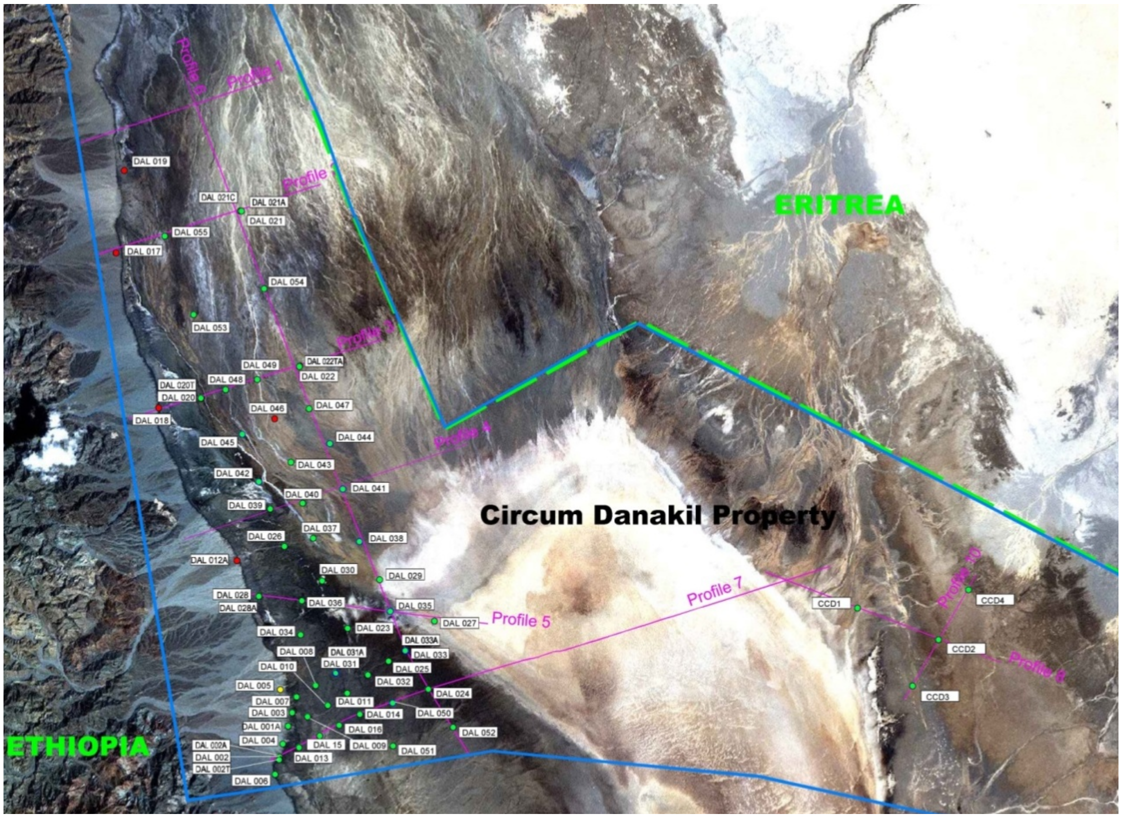

Figure 2: Map of the drilling location as well as the seismic profiles

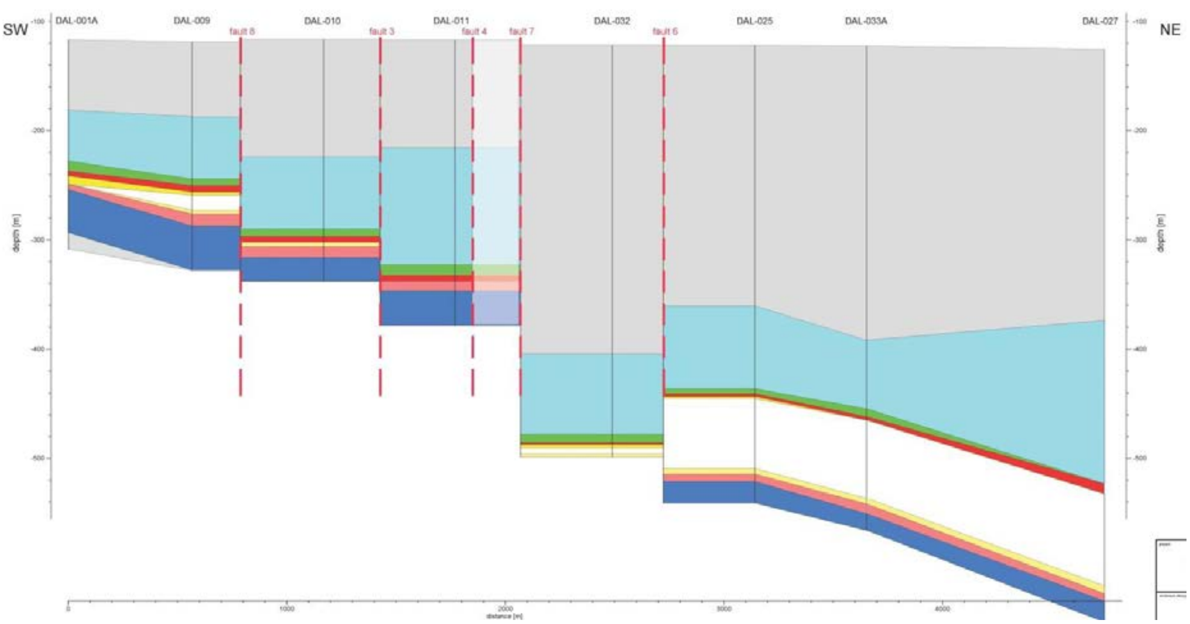

Figure 3: Schematic Cross Section of Determined Faults in the Southern Part of the Property Area

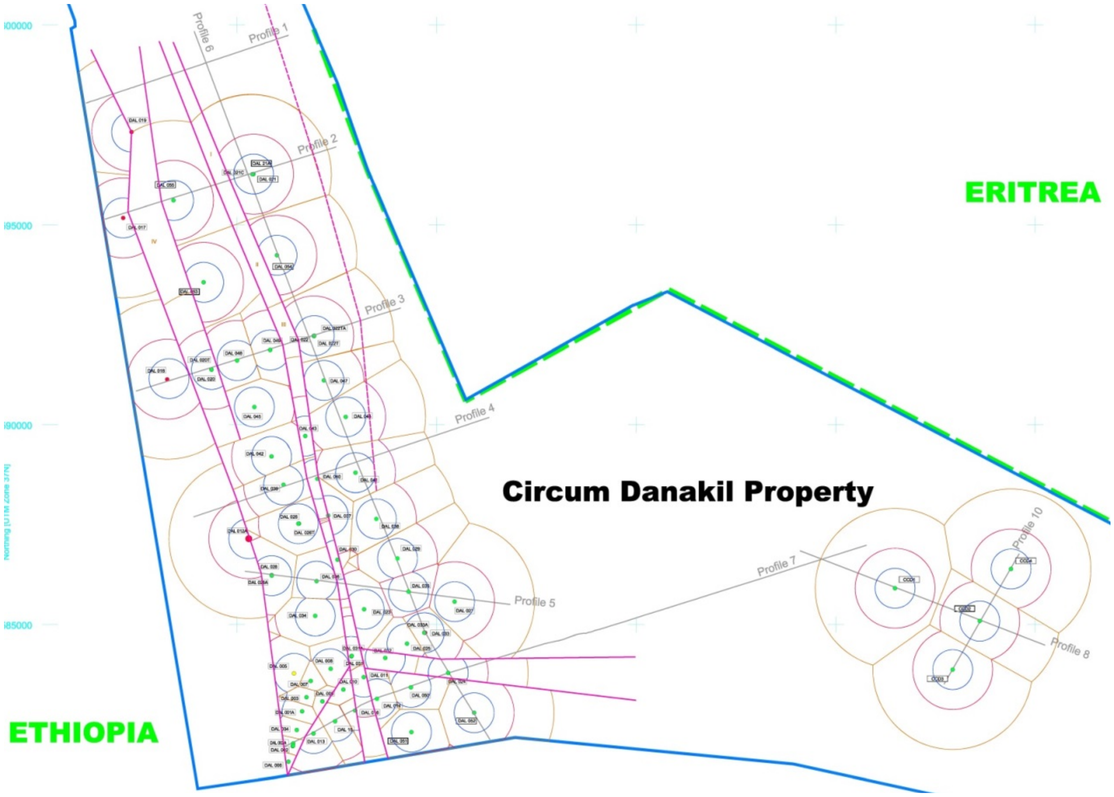

Figure 4: Map of the mineral resource confidence areas the Circum Minerals Danakil Potash Project

Table 1: Summarized results for the measured and indicated resource category for the potash units for in the western Western exploration area and the Colluli exploration area

Measured + Indicated Category				
Area West and Colluli	Sylvinite	Upper Carnallite	Lower Carnall-ite	Kainite
Resource Tonnage [Mio t]	**754,838**	**174,098**	**677,316**	**1.227,265**
Resource Tonnage [Mio t]	928,936		1.904,781	
Resource Tonnage [Mio t]	**2.833,717**			
Geological Resource KCl [Mio t]	190,791	31,405	84,358	219,251
Geological Resource KCl [Mio t]	222,196		303,609	
Geological Resource KCl [Mio t]	**525,805**			
Geological Resource K_2O [Mio t]	120,523	19,838	53,289	138,501
Geological Resource K_2O [Mio t]	140,361		191,790	
Geological Resource K_2O [Mio t]	**332,151**			

Solution mining is applicable only for the extraction of soluble minerals. Drill holes which are driven from the surface into the deposit are used for the exploitation of potash and other soluble salts. The exploitation of the raw material is carried out by dissolution of the potash and the creation of so-called brine caverns. By constructing wells which comprise various leaching strings of different diameter, both the injection and the removal of the production brine can occur within a single drill hole.

The solution mining method presents the lowest hydrological risk and the lowest required initial investment costs. Since the safety of personnel for Kainite mining cannot be guaranteed with conventional mining due to the weakness of the overlying horizons, the conditions for effective resource utilisation of the lower Kainite horizon are improved with solution mining.

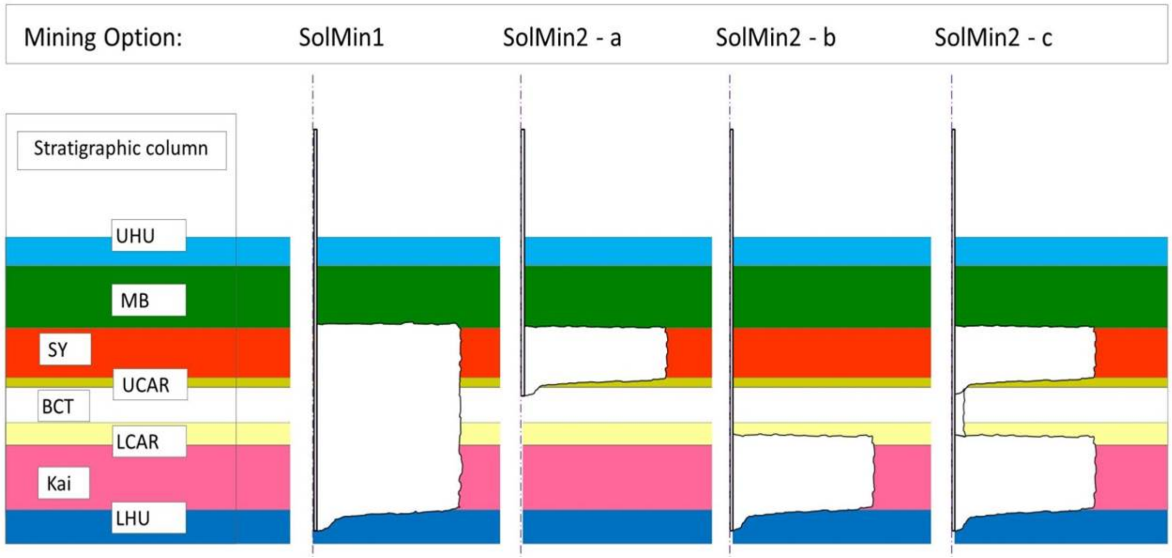

Figure 5: Options for the mining design.

The current NI 43-101 compliant Mineral Resource Estimate, which has tested about 35% of the license area to a depth of 400 meters, consists of 2.8 billion tonnes of Measured and Indicated material grading, on average, 18.5% potassium chloride (the average of the Sylvinite layer, Upper and Lower Carnallite layers and the lower Kainitite layer) and 2.2 billion tonnes of Inferred material grading on average 17.4% potassium chloride. The geologic estimate of the endowment of the remaining 65% of the project area is an additional 7-9 billion tonnes to a depth of approximately 800 metres.

Case II: Exploration of Brine deposits: Beyondie Lake Potash Project – Potash Exploration in Salt Lakes and Hidden Rivers

Kalium Lakes Limited (KLL or Kalium Lakes) is a public owned company with about 2,400 km^2 of granted tenements (see Figure 6) at the eastern margin of the East Pilbara region of Western Australia. KLL is looking to develop a sub-surface brine deposit to produce 75-150 ktpa of Sulphate of Potash (K_2SO_4 or SOP) product via evaporation and processing within the Beyondie/10 Mile tenement holding – the Beyondie Potash Project.

Figure 6: Tenement area of KLL at the Beyondie Potash Project

The Beyondie potash deposit is a liquid deposit (a brine), containing the target potassium and sulphate ions required to form a potassium sulphate salt. The brine is contained within saturated sediments in at least two separate horizons below the lake surface and in sediments adjacent to the lakes – the alluvial sediments and the basal sands. The lakes are located within the broader Ilgararipalaeochannel system that extends over hundreds of kilometres. A conceptual cross section through a lake is shown in Figure 7.

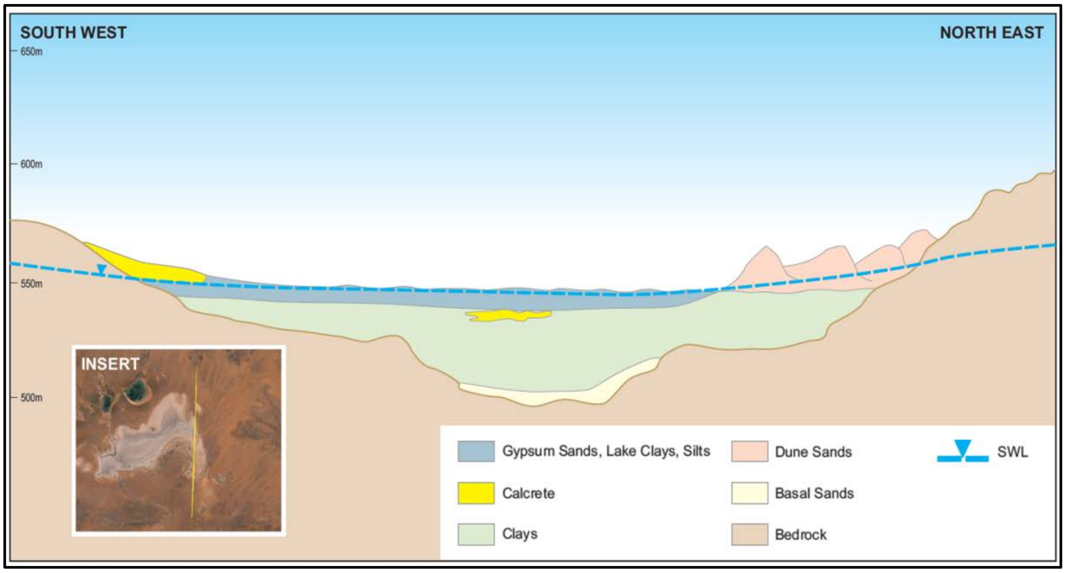

Figure 7: Geological cross section through the Beyondie Lake

A drilling and augering program with sampling of brine and lithological material, geophysical fieldwork (gravity traverses across the lakes from bedrock to bedrock), laboratory analysis and pumping tests has been realized in the project area. Based on data from the fieldwork and laboratory analyses from 2014 to 2017 an assessment of the Mineral Resource and Reserve has been undertaken using a combination of CIM and JORC to meet the requirements of a brine deposit. Only the CIM guidelines for Lithium Brines [2] are currently adapted to liquid deposits but attempts at implementing it to the JORC Code [3] are made.

Currently an update of the resource estimation including the refining of hydrogeological FEFLOW models for Ten Mile Lake and Lake Sunshine is worked out with respect geophysical surveys. In-situ evaporation ponds were constructed and first evaporation trials are running since 2017.

The exploration campaign comprises about 400 shallow auger holes (see Figure 8) across the lakes surface, more than 120 drill holes with up to 140 m depth as well as six trenches (summary length: 980 m) with 2 m to 5 m depth. Figure 9 shows a trench construction.

Figure 8: Hand held auger drilling

Figure 9: Trench SST02 construction at Lake Sunshine

During 2015 and 2017 about 1,130 line km of gravity traverses were completed. Additionally H/V seismic profiles were measured. Resistivity/conductivity surveys have also been completed using the NanoTEM system to resolve some ambiguity in the gravity data at a number of key locations. The calibrated integrated geophysical methods used have enabled a more robust geophysical model to be constructed which has used two independent methods to locate and map the palaeochannel aquifer. Figure 10 shows the geophysical survey lines of the western part of the Beyondie Potash Project as an example.

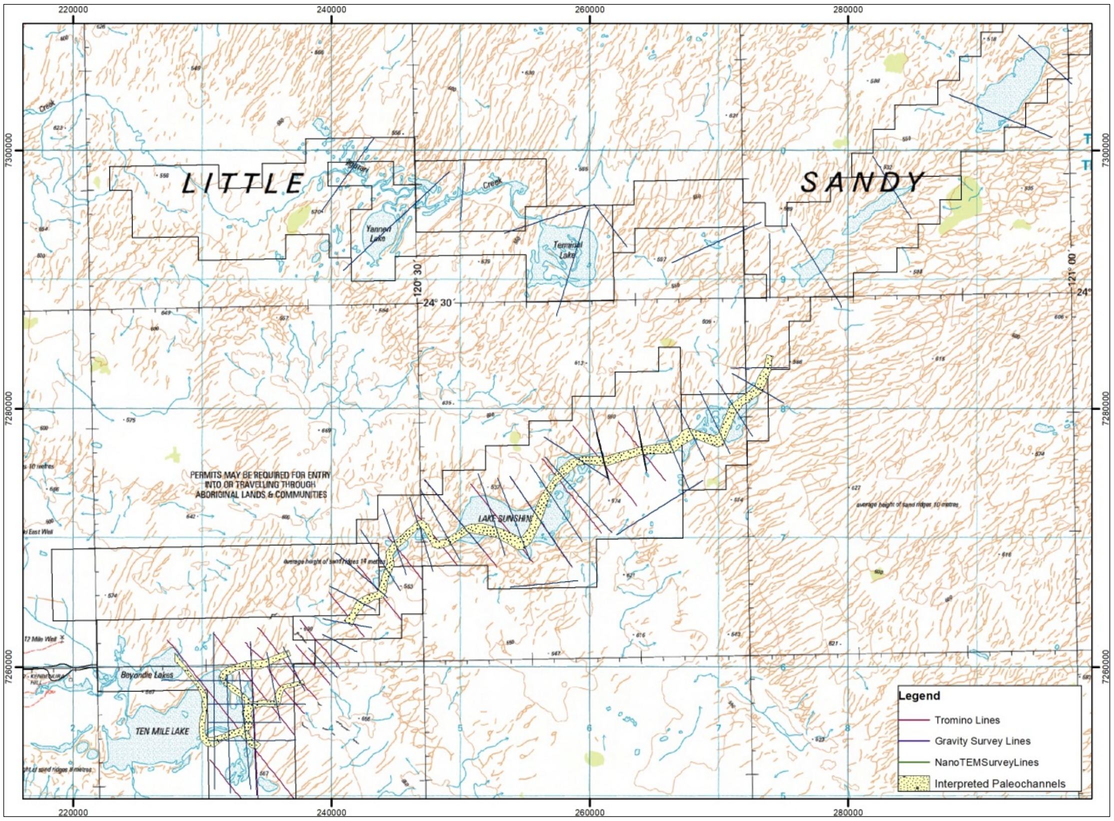

Figure 10: Gravity, Passive Seismic (Tromino) and NanoTEM traverses, Western Area

The geophysical surveys and auger-hole exploration covers the complete tenement of the Beyondie Potash Project. With this information Resources Estimation for the upper aquifer on all lakes within the tenement could be done. Reserves Estimation was only possible for Ten Mile Lake and Lake Sunshine area. Here trenches were constructed, lithological samples were laboratory analysed and short term/long term pumping tests occurred. All of this data could be implemented into a numerical FEFLOW model for each of the two lakes to calculate Probable Reserves.

Because of accessibility and other factors the exploration work for the deeper aquifer mostly concentrated on the Ten Mile Lake/Lake Sunshine area. Results from geophysics as well as drill-hole data and laboratory assays were put into a numerical FEFLOW model for each of the two lakes to calculate Resources as well as Probable Reserves.

The following Table 2 and

Table 3 show the summary results of the Mineral Resources/Reserves for the complete Beyondie Project tenement.

Table 2: Mineral Resources Summary for Beyondie Potash Project (assessment 2017)

Level	Drainable Brine Volume (10^6 m^3)	K Grade (mg/l)	K (10^6 tonnes)	SO_4 (10^6 tonnes)	SOP (10^6 tonnes)
Indicated Resource	311,88	6,278	1.96	5.56	4.37
Inferred Resource	1,074.48	5,735	6.16	18.37	13.74

Table 3: Ore Reserves Summary(assessment 2017)

Level	Drainable Brine Volume (10^6 m^3)	K Grade (mg/l)	K (10^6 tonnes)	SO_4 (10^6 tonnes)	SOP (10^6 tonnes)
Probable Ore Reserve	187.06	6,373	1.19	3.34	2.66

There are two principal methods applicable to extract the brine:

- Pumping from production bores in the basal sands (lower aquifer) plus leakage from brine bearing segments within the palaeovalley clay and fractured/weathered bedrock;
- Pumping from trenches inside the alluvial sediments (upper aquifer) in trenches up to 8 m depth.

It is likely that both methods will be used because of the properties of the different aquifers. The design of the bore field and trenches will be based on the brine demand and aquifer conditions. The deposit life at each lake area has been based on the modelled out puts from Ten Mile Lake and Lake Sunshine and the percent of reserves and resources determined on an annual basis, along with annual production rate and grade. For instance the scenario with a production rate of 75,000 ktpa SOP comes out with a mine life of ~70 years.

The general mineral processing concept is comprised of the following areas:

- Brine winning;
- Brine concentration and crystallization of solid raw materials for the processing plant;
- Processing plant; and
- Utilities.

According to the composition of the deposit brine the present unique process design, developed by K-UTEC AG, considers the recovery of SOP as the principle product, with the potential for producing the following by-products: Epsomite, Magnesium Hydroxide, Bischofite, and Hydrated Magnesium Carbonate (HMC).

Conclusions

Both presented case studies have the target Potash; but the different types of these deposits – solid or liquid – require different approaches for assessment of Resources and Reserves. International reporting standards like CIM NI 43-101 [1] or JORC Code [3] refer mostly to solid deposits. For brine deposits currently only the CIM Best Practice Guidelines for Lithium Brines [2] are applicable. The main difference is: brine moves and cannot be treated as steady state like a solid deposit.

The following fieldwork is to be considered:

Solid deposits require (main points):

- reasonably dense grid of drill-holes for definition of vertical and lateral extension of the deposit;
- information regarding the drilled material: lithology, petrophysical properties, chemical composition (grade of target minerals);
- verification of lithology and petrophysical properties by suitable downhole geophysics;
- verification of lateral extension and tectonic elements by suitable surface geophysical survey.

Liquid deposits require (main points):

- reasonably dense grid of drill-holes and/or shallow auger-holes
- information regarding the drilled material: lithology (brine hosting material), petrophysical and hydraulic properties (aquifer or aquitard), chemical composition (source of target minerals, which are leached by groundwater/brine flow);
- groundwater/brine level;
- assessment of catchment and drainage areas;
- possible dilution or saturation factors (rainfall, inflow by rivers, evaporation rates etc.)
- pumping tests: aquifer properties, chemical composition of brine (grade of target minerals)
- verification of lithology, petrophysical and hydraulic properties by suitable downhole geophysics;
- verification of lateral extension of the deposit and tectonic elements by suitable surface geophysical survey.

K-UTEC AG has experience in exploration and assessment of salt deposits of all types. The company can deliver expertise by it's various Competent/Qualified Persons from the very beginning of a greenfield project from exploration up to mining plans and process design for production. The K-UTEC AGphysico-chemical analytics laboratory is accredited according toDIN EN ISO/IEC 17025.

References

[1] Canadian Institute of Mining, Metallurgy and Petroleum (2014): CIM Definition Standards – For Mineral Resources and Mineral Reserves.

[2] Canadian Institute of Mining, Metallurgy and Petroleum (2012): CIM Best Practice Guidelines for Resource and Reserve Estimation for Lithium Brines.

[3] JORC, 2012: Australasian Code for Reporting of Mineral Resources and Ore Reserves – The JORC Code 2012 Edition.- The Joint Ore Reserves Committee of the Australasian Institute of Mining and Metallurgy and the Australian Institute of Geoscientists and the Minerals Council of Australia. 20 December 2012.