Lithium Brine Deposits: Challenges of Finding, Evaluating, and Reporting Mineral Resources

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Background
Lithium Supply Chain

### Upstream
- Lithium Producers
  - Albemarle
  - SQM
  - TPC
  - FMC
- Other Battery Raw Materials
  - Glencore
  - Norilsk Nickel
  - Vale

### Middle stream
- Battery Manufacturing Chain
  - LG Chem
  - Samsung
  - Panasonic
  - ATL
  - Umicore
  - BASF

### Downstream
- End-Users
  - EV
    - Volvo
    - Volkswagen
    - GM
    - BMW
    - Mercedes
    - BYD
- Consumer Electronics
  - Google
  - Apple
  - Huawei
Lithium Pricing

- Bubble?
- Speculation?

- Restart of two shuttered lithium mines
- Redevelopment of four current or formerly operating tantalum / phosphate operations to produce lithium
- Eight new operations developed or under construction
- Every existing producer is expanding
Finding Lithium Brine Deposits
Lithium Deposits Worldwide
Why brines?

- No mining engineers
- No "miners"
- Low environmental impact
- Low OPEX
- Low surface impact
- Byproduct potential
Global Lithium Brine Resources
Evaluating Lithium Brine Deposits
What makes/breaks a lithium brine project

- Process
  - Grade
  - Impurities
- Hydrogeology/Resources
- Logistics/Infrastructure
- Climate
- Land Tenure
Intro to Brine Extraction Process

Brine extraction from wellfield

Pre-concentration Ponds

Process Plant

Reagents

Power

Fresh Water

Final Product

- Li₂CO₃
- LiOH
- KCl

Byproducts

Spent Brine

Salts - Sludge

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Lithium Grade

- Capital Cost
  - Evaporation Pond Size
- Operating Cost
  - Impurities
  - Reagent Consumption
  - Energy Consumption
- Brine Volume to be pumped
Brine Chemistry

World Class

Tier 1

Tier 2

Mg/Li

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Brine vs Hard Rock Resource Estimation

Hard Rock

• Tonnes
• Grade

Brines

• Extractable brine volume = \( V_{\text{aquifer}} \times Sy \)
• Average brine chemistry
• Permeability which determines brine hydraulic conductivity and transmissivity, to factor how fast the brine can be extracted

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Hydrogeology

What are we looking for?

- **Brine Volume**
  - Lateral boundaries
  - Vertical distribution
  - Specific Yield (Sy) or specific storage (Ss) for confined zones
  - Effective porosity ($\eta_e$)

- **Transmissivity, Hydraulic Conductivity** (lateral and vertical)

- **Dispersivity** (longitudinal and transversal)

- **Assays** (Li, K, B, etc.)

- **Dilution** (e.g. presence of fresh water, brackish, low grade)
Brine Resource Estimate Model

\[ \text{Resource} = S_y \cdot \text{Concentration} \cdot \text{Volume} \]

- **Sy**: Specific yield (varies within and between lithologies)
  - RBRC, core sampling, long term pump tests
- **Concentration**: Li, K, Cl, Mg, etc. (varies within and between lithologies)
  - Brine samples
- **Volume of Lithologic Unit**
  - Lithology, thickness, transmissivity
Brine Resources to Reserves

In Situ (static) Resources

Drainable Resources

Extractable Resources

Mineral Reserves

Measured, Indicated, Inferred Classification
Effective Porosity
Transmissivity

Extractability

Sr
Sy
Transmissivity

In Situ Recovery Factors
Process Residuals
Adjacent Claims Interference
Measured + Indicated

Process Recovery
Land Tenure - Legal
Environmental - Permitting
Economics

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Infrastructure/Logistics

- Remote Location
- High Elevation
- Reagent Transport
- Fresh/Process water
- Power Availability
  - “New” Processes
Climate

ASX / TSX ANNOUNCEMENT

19 February 2019

Recent weather at Olaroz Lithium Facility

Orocobre Limited (ASX: ORE, TSX: ORL) ("Orocobre" or "the Company") provides the following update on recent weather at the Olaroz Lithium Facility in Jujuy Province, north west Argentina after completing an internal review of expected production for the remainder of the financial year.

Recent rainfall at the Olaroz Lithium Facility has exceeded that which occurred in 2017 and 2018. There have not been any material production stoppages, nor disruption to the import of supplies or the export of finished product. However, production has been lower due to dilution of the brine feedstock.

Orocobre now expects FY19 production to be approximately the same as that achieved in FY18.

Lithium Concentrations

Base Case 800 ppm

- Li Concentration (Pond 1)
- Li Concentration (Pond 2)
- Li Concentration (Pond 3)
- Li Concentration (Pond 4)
- Daily Precipitation

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Land Tenure

Brine not “owned” by Project

Production well

Adjacent Claim
Take Home Message

• Brine moves!
• Technically complex to explore and estimate resources
• Transition from Static Resource to Dynamic Resource using the continuum of geologic stratigraphy through the use of sequence stratigraphy and onto the final use of HSU’s
• Strong conceptual/dynamic GW models are key to project success
• Choice of process that fits the situation, brine chemistry, weather, etc.
• Be cautious about fractured ownership within a Salar
• Take good care of your hydrogeologist, you will thank them later