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A New Metal
from an
Old Mining Area
Contents

• Introduction to Cornish Lithium
• Current lithium exploration
  • Brines vs. hard rock
• Extraction technologies
  • Direct extraction of Li from brines
• Lithium potential in Cornwall
  • Historic occurrences of lithium brines
  • Historic data and mapping
  • 3D modelling
• Summary
Cornish Lithium

- Founded in 2016 by Jeremy Wrathall, a mining engineer turned investment banker
- Secured mineral rights to explore for lithium in brines for approx. 300km² Cornwall in January 2017
- Raised £1million to commence exploration in August 2017
- Company is private
- Technical office in Penryn
Lithium Supply

Find – Mine – Process
Lithium in Context

- We have been mining copper for at least 4000 years
- Lithium mining is an industry in its infancy
- The lithium-ion battery was first commercialised in 1991
- Lithium now becoming a critical metal
- Virtually all current production comes from “legacy” assets
- Supposedly a large mineral endowment – but not of economic deposits
- Mining industry has a huge task ahead
- New exploration, mining and processing methods needed
The electric car age has arrived
An unstoppable revolution

Electric Vehicle Revolution is Accelerating

“EVs will make up 54% of global sales by 2040.” Bloomberg New Energy Finance

Recent company announcements
- **Volvo** – all new models will be EVs from 2019
- **VW** – 25% EV mix by 2025, 1M EVs p.a.
- **Mercedes** – 10 EV models, 15-20% EV by 2025
- **BMW** – 0.4M EVs by 2020
- **Porsche** – 50% EVs by 2023
- **Ford** – 13 EV/PHEV models by 2020
- **Tesla** – 1M units by 2020

Recent country announcements
- **France** – 100% EV by 2040
- **UK** – 100% EV by 2040
- **Norway** – 100% EV by 2025
- **India** – 100% EVs by 2030
- **China** – 2M EV by 2030
- **Netherlands** – 100% EV by 2025
- **Germany** – 100% EV by 2030

“...around 2021 battery costs will reach $100/kWh, bringing EVs to cost parity.” Tesla CFO Deepak Ahuja
Dramatic increase in lithium demand

Lithium is the Commodity most-Impacted by Growth in EVs

Lithium supply must increase 30x in a 100% EV world

% Lift in Battery Material Demand from 100% EV Penetration

- Lithium: 2898%
- Cobalt: 1928%
- Rare earths: 655%
- Graphite: 524%
- Nickel: 105%
- Copper: 22%
- Manganese: 14%
- Aluminum: 13%
- Silicon: 0%
- Steel: -1%
- PGM: -53%

Source: UBS Securities
“In terms of new lithium supply the industry needs all the supply it can get. SQM, traditionally conservative of its lithium estimates, is expecting an 800,000tpa LCE market by 2027. These numbers are staggering considering the market was at 180,000tpa LCE in 2017.”

Source: Mining Journal – Interview with Simon Moores – MD Benchmark Mineral Intelligence - 5th September 2017
Mining projects take time

But it takes time to develop new assets and make them operational

- Brine: 7-10 years
- Rock: 4-6 years
- Conversion Plant: 1.5-2 years

- Most recent lithium projects have suffered delays
- A number of milestone to achieve:
  - Environmental study
  - Permitting approvals
  - Feasibility study
  - Project financing
  - Secure know-how

Source: IHS Markit
Where is lithium currently mined? And how?
Where is lithium mined?

Global Lithium Production
~230Kt LCE in 2017

Source: IHS Markit
What does a lithium mine look like?
Deposit types

**Brine**
The most common form of lithium extraction is from salt brines
- ✔ Much cheaper
- ✗ Slower (18 months of evaporation time)
- ✗ High start-up costs

**Spodumene**
Crushing, roasting, and leaching lithium ore
- ✔ Faster, lower start-up costs
- ✗ More expensive
- ✗ Additional costs to upgrade to battery grades

**Mechanical Brine Extraction**
- ✔ Cheaper
- ✔ Over 90% lithium recovery rate
- ✔ Environmentally Responsible
- ✗ Not yet commercially proven

**Clay**
Similar process to spodumene
- ✔ Not proven yet to be viable on commercial basis

There are companies such as Tenova Bateman, who have created mechanical brine extraction processes with revolutionary technology to extract lithium from salar brines with over 90% recovery. (Traditional evaporation methods typically yield under 40%)

While this process is not yet widely available to producers, it has the potential to lower the cost of production.

Source: Visual Capitalist
Hard Rock - Greenbushes (Talison)

Source: The Australian Mining Review
Brine - Olaroz (Orocobre)

Source: Orocobre
Never easy

Orocobre Limited reported that lithium production at Olaroz in northern Argentina for the March quarter was 2,802 tonnes, down 29% from 3,937 tonnes in the December quarter. The company said that the lower production rate in the March quarter was due to evaporation rates that were 24% below those in 2017 with reduced solar radiation from cloudy conditions and above normal rainfall.

Source: IHS Markit
Lithium Extraction
Conventional brine processing

1. Pump lithium brine from the salar
2. Use solar evaporation to concentrate lithium brine in shallow ponds
3. Process concentrated lithium brine in a plant
4. Ship lithium carbonate

Source: Lithium Americas
New processes to extract lithium directly from brine have been developed by the following companies:
New tech – Pure Energy
Low environmental impact

Preliminary 3D Perspective
Drawing of Clayton Valley Pilot Plant

Source: Pure Energy Minerals
New tech – MGX

MGX’s Cleantech Design Process

Nano-Technology
Advanced nanomaterials utilized in conjunction with nanoflotation technologies.
New tech – Eramet

Extraction
The brine is pumped from a depth of >200m and is fed into the lithium extraction unit.

Rinse tank

Influent pond

1. Brine extraction

2. Brine returned to the brine field by influent

3. Brine returned to the brine field by influent

4. Industrial process

5. Tolerates water imbalance

Loading
The brine goes through columns filled with solid grains which contain lithium, allowing the majority of lithium ions to be absorbed while other elements such as boric and sulphate ions are not captured. These are then discharged with the brine.

Elution
After the brine has gone through the unit, a solution is sent to a lithium leach from the brine to which it is emulsified.

Applications
Extracted lithium salts are used in industrial applications for glass, ceramics, and greases. They are also used in the manufacture of rechargeable batteries for smart phones, tablets, laptops and electric vehicles.

Source: Eramet
New tech – Synexus

Proof of Concept Study - Synexus

**Lithium Recovery using Membrane Separation**

Selective Recovery of Lithium (and other cations) using Membrane Technology

- a possible alternative to the natural evaporation process
- could provide a process route to produce lithium hydroxide directly from the raw brine
- no need to remove contaminants like magnesium by liming, as would be required in the natural evaporation process.
- with further refining the technology could also permit the recovery of potassium and other cations if desired.

Block Flow Diagram of selective lithium recovery process (Synexus).

Source: International Lithium
Extraction technologies

Hard rock
Old tech - Spodumene

α-Spodumene

Crushing/Grinding

β-Spodumene

Heat Treatment (1100 °C)

Hot-digestion (250–300 °C)

Conc. H₂SO₄

Leaching

H₂O

Filtration

Residue

Filtrate

Ca(OH)₂

Precipitation-I (pH 5.5–6.5) → Precipitate (Fe, Al)

Ca(OH)₂

Precipitation-II (pH 11–13) → Precipitate (Mg, Ca)

Pure Li solution

Na₂CO₃

Precipitation (90 °C)

Filtration

Li₂CO₃

Source: Science Direct
New tech - Nemaska

Nemaska Lithium's Added Value: From the Mine to Lithium Salts

1. **Calcination and Roasting Process**
   - Lithium Sulfate Solution $\text{Li}_2\text{SO}_4$
   - Roast with Sulfuric Acid
   - Calcination

2. **Impurity Removal**
   - Remove Fe, Al, Si, Cu, Ca, Mg

3. **Ion Exchange**
   - Remove Impurities to PPB Levels

4. **Membrane Electrolysis**
   - Lithium Hydroxide Solution $\text{LiOH}$

5. **Crystallization**
   - Lithium Hydroxide Monohydrate $\text{LiOH.H}_2\text{O}$
   - Lithium Carbonate $\text{Li}_2\text{CO}_3$

6. **Production of Concentrate**
   - Mining
   - Crushing and Ore Sorting
   - DMS and Floatation
   - Concentrate $\text{Li}_2\text{O}$

Nemaska Lithium's patented process produces directly $\text{LiOH.H}_2\text{O}$.
Lithium in Cornwall
• Cornish Lithium aims to establish a lithium production industry in the UK
• Numerous historic records indicate the presence of lithium in underground hot spring brines over a large area in Cornwall
• We believe that advances in extraction and process technology make the extraction of lithium from such sources possible
• Cornish Lithium has secured rights to explore and commercially develop lithium contained in brine over approximately 300km²
• The company is currently private
Miller, W.A., 1864, Chemical examination of a hot spring containing caesium and lithium in Wheal Clifford, Cornwall. Chem. News, v. 10, p. 181-182; Mining and Smelting Mag., v. 6, p. 197-198
Cornwall – A giant pressure cooker

Water

Heat

Lithium Enriched Granite

300 Million Years

Lithium Brine
Faults appear to be the geological key
Applying modern GIS to historic data
Applying modern GIS to historic data
Applying modern GIS to historic data
Incorporating Tellus data

Incorrect annotation, should be North Buzzas Lode

Approximate shape of elvan taken from 1870 United Mines transverse section

Potential positioning of elvan from Wheal Maid Decline section and borehole C47 (48mE of section 1800E)

Incorrect sketch of Hot lode

-200 m = (1800mEl – mine grid)

-100 m = (1900mEl – mine grid)

0 m = (2000mEl – mine grid)

On Section 1900E

Correlation of Leapfrog3D model to section 1900E

Topography

0 m = (2000mEl – mine grid)

-100 m = (1900mEl – mine grid)

-200 m = (1800mEl – mine grid)

Complex vein relationships of Hosking, Gellards and Scobles lodes, not included within 3D model

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Incorrect annotation, should be North Buzzas Lode

Approximate shape of elvan taken from 1870 United Mines transverse section
BH4 elvan has potential correlation to elvan positioning in Wheal Maid Decline section and C47 borehole (see previous slide).

BH4 and BH5 confirmed intersection with North Buzzas Lode.
Leapfrog3D model looking east south east

Borehole Legend:
- Hot Lode
- Tiddys (Buzzas New Tin) Lode
- Great South Lode

0 m = (2000mEl – mine grid)
-150 m = (1900mEl – mine grid)
Why was the potential not recognised before?

- Cornwall has had no real exploration for at least 30 years
- There was no large scale market for lithium
- Processing options were not available
- All metal mining in Cornwall ceased with closure of South Crofty mine in 1998
- The mineral rights system in Cornwall makes exploration difficult
Exploration Sequence

- Desktop research
- Geophysics
- Test boreholes
- Feasibility work
- Drilling of initial production wells
- Pilot Li extraction plant
- Production

Summary

- Newly developed techniques make a new lithium industry in Cornwall possible.
- Underground mining in Cornwall was plagued by upwelling hot water which made working conditions very challenging. It is this same water that contains lithium.
- The mineral rights secured by Cornish Lithium (~300 km²) make this the largest unified exploration effort in the history of Cornwall.
- Agreements have been secured over the most prospective areas for lithium and other minerals contained in brine.
- Demand for lithium is set to increase rapidly in the near future.
- The UK Government have highlighted lithium as a metal of strategic importance to UK industry.