

The Power of 3

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Driving the future further

Overview

Although lithium¹ does not occur free in nature, it's found in small amounts in almost every igneous rock² and in the waters of salt lakes and mineral springs worldwide. Minerals that contain lithium include lepidolite, petalite, amblygonite and spodumene.

As noted in the *Power of 3, issue 1*, lithium was first produced commercially in 1923. Since then it's become intrinsic to myriad commercial applications – not least as a result of its electrochemical potential, which makes it a vital component of lithium-ion batteries. In the 21st century demand for, and the price of, lithium are being impelled upwards by the electric vehicle³ and electronics industries, as well as the energy sector.

Until the early 1980s, lithium production was dominated by 'hard-rock' mining, primarily from pegmatites⁴. However, the advent of lithium production from brines, primarily in Latin America, created a paradigm downward shift in operating costs.

By the 1990s, brine producers dominated the market⁵ and most hard-rock operations shut down. Of the latter, only those producing high-purity spodumene concentrates for specialist applications maintained viability, since they were not competing in the same market as companies creating low-cost lithium chemicals from brines.

Currently, the global supply of lithium from brine and hard-rock deposits is around 50% for each method⁶. Brine processing results in the direct production of lithium chemicals⁷ whereas the output from hard-rock production is mineral concentrate that requires downstream processing to deliver the refined chemicals.

Everyman's guide to lithium production

*"In a drop of brine live all the secrets of the ocean,
in a lump of rock all the secrets of the land."*

~ with apologies to Kahlil Gibran

Lithium from brines

Lithium brine deposits can be classified as continental, geothermal or oilfield.

In general, the operating cost of producing lithium chemicals from brine is less than that for hard-rock deposits. Brine deposits are easier to explore too, but generally require high capital input to develop. Much depends on their proximity to infrastructure and the ease of transporting equipment and personnel to the site – the remoteness of many brine deposits is a major constraining factor, although environmental impacts may be less of an issue.

Continental brine deposits, the most common form of lithium-containing brine, are underground reservoirs containing high concentrations of dissolved salts, including salts of lithium, potassium and sodium. Igneous in origin, most lie within the 'Lithium Triangle' of the Andes, an otherworldly landscape of high-altitude lakes and bright white salt flats that straddles Chile, Argentina and Bolivia. Continental brine deposits are also found in China and the United States.

The Salar de Uyuni in Bolivia in the Altiplano of the high Andes, the world's second-largest plateau. The biggest salt flat on Earth, its surface mirrors the sky during the rainy season.

Generally, continental brine deposits are located below the surface of dried lake beds or 'salars' (Spanish for 'salt lakes'), at high altitudes and in areas of low rainfall where solar evaporation can cost-effectively precipitate the salts.

To extract lithium, the salt-rich waters are first pumped into a series of ponds to evaporate (potassium is often harvested early on).

Once the lithium chloride in the ponds reaches an optimum concentration, the solution is pumped to a recovery plant to produce lithium carbonate. The residual brines are then pumped back into the salar.

Lithium from brines

Although lithium production from continental brines is now a mature business, few new operations have been commissioned in the past two decades, Orocobre's Olaroz operation in Argentina being an exception. Political factors have proved the main impediment, but so too is the requirement to evaporate huge volumes of water if a project is to be commercially viable – as noted, solar evaporation is the cheapest method. Few locations can match Chile's Atacama Desert, where optimal geology coincides with a climate perfect for the natural concentration of brines.



The Atacama Desert stretches from southern Peru into northern Chile. One of the driest places on Earth, it's occasionally hydrated by flash floods.

Geothermal brine deposits make up about 3 per cent of known global lithium resources. Hot, concentrated saline solutions, they have circulated through crustal rocks in areas of very high heat flow, in the process becoming enriched with elements

such as lithium, boron and potassium. The Salton Sea in southern California is the best-known example of a lithium-bearing geothermal brine, but small quantities of the element can also be found in geothermal brines at Wairakei in New Zealand, the Reykanes Field in Iceland and El Tatio in Chile.



Southern California's Salton Sea was created in 1905, when spring flooding broke down the canal gates leading to the Imperial Valley, causing waters from the Colorado River to rush into a depression in the Colorado Desert.



Small geothermal fumarole at El Tatio, Chile.

Oilfield brines, which account for a further 3 per cent of known global lithium resources, are found in some deep oil reservoirs in several areas of the United States.

Lithium from hard-rock mining

With limited new capacity in the production of lithium from brines at present, hard-rock sources are a logical alternative ... in the short term at least.

In Australia, Canada, Zimbabwe and Portugal, hard-rock mining and conventional processing techniques are used to produce high-grade lithium from pegmatites containing spodumene and petalite.

Spodumene, the principal ore mineral of lithium, is a lithium-alumino silicate containing 6 to 7% lithium oxide. Once recovered, the spodumene concentrates are sent to refiners, or 'converters' (presently all are located in China), and roasted⁸ and leached to generate lithium chemicals. Those chemicals are then on-sold to third-parties.

Citi Research has estimated that some 16 lithium projects – most of them hard-rock deposits – will commence production between 2016 and 2020⁹.

Take Western Australia's Pilgangoora region (purportedly one of the world's largest deposits of shallow, hard-rock spodumene), where a number of miners are targeting near-term concentrate production to sell into the Chinese conversion facilities.

Also in Western Australia, the hard-rock mine at Greenbushes produces various different lithium concentrates to meet specific customer requirements, and is the dominant supplier of high-purity spodumene concentrates for the ceramics industry globally.

Conclusion

Whatever the source, it seems that timing will be key for those hoping to supply lithium raw materials. With moves afoot to develop an 'innovative and sustainable lithium extraction process from medium lithium grade brines'¹⁰, and with Deutsche predicting a 'substantial response [to market conditions] from incumbent major brine producers' over the next decade'¹¹, hard-rock miners need to get a move on.

Which **Perth-based company** aims to simplify lithium production from hard-rock sources?

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The Power of 3 is sponsored by Lithium Australia.

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Notes

- ¹ The term 'lithium' is used loosely here to describe lithium carbonate, lithium hydroxide and other forms of the element.
- ² Igneous rock is formed through the cooling and solidification of volcanic magma or lava.
- ³ Tesla, for example, uses 50 kilograms of lithium in its EV batteries.
- ⁴ A pegmatite is an intrusive igneous body of highly variable grain size that often includes coarse crystal growth. Pegmatites occur most commonly in granites and their mineralogy can be simple or exotic: a simple granite pegmatite may contain only quartz, feldspar and mica, while more complex pegmatites can contain minerals like tourmaline, garnet, beryl, fluorite, lepidolite, spodumene, apatite and topaz.
- ⁵ USGS (US Geological Survey) Mineral Commodity Summaries, January 2016.
- ⁶ While lithium can also be extracted from hectorite (a rare clay from volcanic sources) and mines for this type of production are currently in development, the lithium feed grades will be low and the economics of the recovery methods are yet to be vindicated. (<http://lithium-au.com/about-lithium/>)
- ⁷ Lithium carbonate, a stable white powder, is a key intermediary in the lithium market, as it can be converted into specific industrial salts and chemicals or processed into lithium metal.
- ⁸ The energy input for roasting is the main cost component of the process. Production of lithium carbonate, the most commonly traded lithium chemical, from spodumene costs around US\$4,000/tonne, whereas lithium carbonate from brines (no roasting required) costs around US\$2000/tonne. [Griffin, A. Sources and availability of materials for lithium batteries. *Proceedings of IDC's Lithium Battery Conference, North Sydney, Australia 2016.*]
- ⁹ Citi Research 2015. *Lithium: The Future is Electric.*
- ¹⁰ <https://ec.europa.eu/growth/tools-databases/eip-raw-materials/en/content/development-innovative-and-sustainable-lithium-extraction-process-medium-lithium-grade>
- ¹¹ Ingram, T. Financial Review, 31 May 2016. *Investors get in on the lithium rush.*