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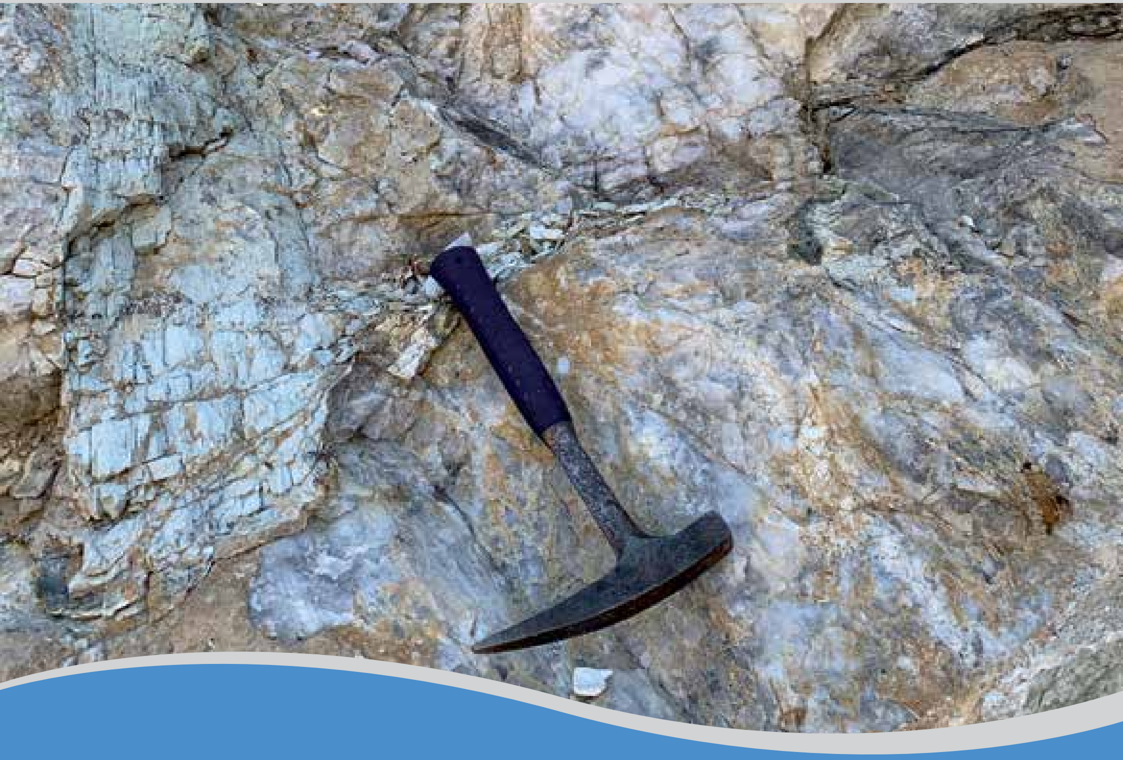

# Lithium Potential in Namibia
## – Evaluation of Economic Suitability

# Imprint

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Cover photo: © BGR-GSN-Project
Weathered spodumene outcrop at the De Rust pegmatite.

# Lithium Potential in Namibia

## – Evaluation of Economic Suitability

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# List of Abbreviations

| | |
|---|---|
| BGR | Bundesanstalt für Geowissenschaften und Rohstoffe<br>(Federal Institute for Geosciences and Natural Resources) |
| BGS | British Geological Survey |
| BMZ | Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung<br>(Federal Ministry of Economic Cooperation and Development) |
| EGD | Economic Geology Division |
| GSN | Geological Survey of Namibia |
| RTS | Reverse trade statistics |
| SADC | Southern African Development Community |
| USGS | United States Geological Survey |

# 1 Introduction

In 2019, mining contributed 9.3 % to the Namibian gross domestic product and more than 50 % to its export revenues. The mining industry also has a significant impact on Namibian society through its potential to enhance local value addition and job creation. However, as in other sectors of the Namibian industry, the mining sector faces a number of challenges and there remain untapped opportunities to bolster the Namibian economy, notably, concerning non-metallic commodities other than diamonds.

In order to push its growth potential, the Namibian Government launched the “Growth at Home” strategy for industrialisation in 2015. “Growth at Home” focusses on domestic value addition and mineral beneficiation figures prominently within this strategy. It is against this background that the Federal Institute for Geosciences and Natural Resources (BGR), on behalf of the Federal Ministry of Economic Cooperation and Development (BMZ) of Germany, cooperates with the Geological Survey of Namibia (GSN).

In 2017, BGR and GSN jointly implemented a project entitled “Sustainable Use of Namibia’s Mineral Potential” that contributes to the “Growth at Home” strategy by focussing on non-metallic commodities. The objective of this ongoing project is to support the Economic Geology Division (EGD) staff in taking custody and exploring potentials of local value addition of Namibia’s non-metallic minerals. These include industrial minerals, with lithium being one facet among this wide spectrum of commodities.

The GSN-BGR-Project investigated various pegmatites in central and southern Namibia regarding their mineral potential during several field campaigns. During a field campaign in 2019 lithium grab samples were taken from selected pegmatite occurrences for subsequent chemical analysis and interpretation regarding their suitability for different economic application. There is considerable economic potential for lithium as a precursor material in various applications.

This study aims to illustrate the potential of lithium occurrences in Namibia and thus promote local value addition. It shall be of value to the Namibian government, to potential investors, to mining and exploration companies, as well as to the general public.

# 2 What is lithium

Lithium (from Greek: Lithos) is a chemical element (i.e. alkali metal) with the atomic number three located in the second period and in the first main group of the periodic table of elements. Estimates for the Earth‘s crustal content are around $6 \cdot 10^{-3}$ % by weight.

In elemental form, lithium is a soft silvery-white alkali metal. Under standard conditions, it is the lightest of all solid elements. Among the alkali metals, lithium has the highest specific heat capacity in addition to the highest melting and boiling point (Table 1). In elemental state, it has the strongest enthalpy of hydration of all alkali metals and thus attracts water very strongly. Like all alkali metals, lithium is very reactive and reacts with many elements. Due to its reactivity, elemental lithium is stored in paraffin oil or petroleum. Upon contact with oxygen, lithium reacts violently to lithium oxide.

Scientific publications, company reports and presentations usually provide lithium content as LCE (Lithium Carbonate Equivalent) units, or $Li_2O$ content. 1,000 t of lithium metal equate to 5,323 t $LiCO_3$ (LCE) or 2,153 t $Li_2O$.

## 2.1 Lithium deposits

The economically most important sources of lithium are **hardrock deposits** and **brine deposits**. With the current market situation pegmatite deposits account for more than 55 % of global lithium supply in 2019.

Besides those two-deposit types lithium is also found in oilfield brines, geothermal brines, clays (i.e. hectorite) and lithium-containing minerals such as jadarite (i.e. type locality Serbia) or zinnwaldite (type locality Germany). There are about 200 minerals that contain lithium in concentrations > 0.002 % $Li_2O$. About 25 of them contain lithium in concentrations > 2 % $Li_2O$ (GARRETT 2004). However, only a few of them are economically viable (Table 1).

**Hard rock deposits:** Due to its chemical properties, lithium is considered an incompatible element and remains for a very long time in the fluidic phases of a magma. Therefore, primary lithium hard rock occurrences are located primarily in pegmatites as late stage magmatic events.

Pegmatites or aplites are very coarse or finer grained felsic dikes, respectively. They intrude into the country rock as highly differentiated magma, crystallizing either very slowly (pegmatites) or relatively fast (aplites). Pegmatites are usually of limited three-dimensional extent, ranging from a few meters to several hundred meters or even kilometers in length and depth. Besides quartz, feldspar and mica, lithium bearing pegmatites may also carry other valuable minerals that contain rare elements such as tantalum, niobium, tin, tungsten, cesium, rubidium, boron, fluorine and others. Those potential by-products may be of economic importance to some projects and mines. The most important minerals in these deposits are spodumene, petalite and lepidolite.

*Table 1: Important lithium bearing minerals (Source: BGS 2016, Roskill 2016a, Garret 2004).*

| Mineral | Formula | Li-Content (%) | Ø Li-Content Ores (%) |
|---|---|---|---|
| Spodumene | $LiAlSi_2O_6$ | 1.9 – 3.7 | 1.35 – 3.6 |
| Petalite | $LiAlSi_4O_{10}$ | 1.6 – 2.27 | 1.4 – 2.2 |
| Lepidolite | $K(Li,Al)_3(Si,Al)_4O_{10}(F,OH)_2$ | 1.39 – 3.6 | 1.4 – 1.9 |
| Amblygonite | $(Li,Na)AlPO_4(F,OH)$ | 3.4 – 4.7 | n. A. |
| Eucryptite | $LiAlSiO_4$ | 2.1 – 5.53 | 2.1 – 4.4 |
| Bikitaite | $LiAlSi_2O_6 \cdot H_2O$ | 3.4 | n. A. |
| Hektorite | $Na_{0,3}(Mg,Li)_3Si_4O_{10}(OH)_2$ | 0.24 – 0.54 | n. A. |
| Salitolite | $(Li,Na)Al_3(AlSi_3O_{10})(OH_5)$ | 0.77 | n. A. |
| Swinefordite | $Li(Al,Li,Mg)_4((Si,Al)_4O_{10})_2(OH;F)_4 \cdot nH_2O$ | 1.74 | n. A. |
| Zinnwaldite | $K(Li,Fe^{2+},Al)_3[(F,OH)_2 \vert AlSi_3O_{10}]$ | 0.92 – 1.85 | n. A. |
| Polylithionite | $KLi_2AlSi_4O_{10}(F,OH)_2$ | n. A. | n. A. |
| Jadarite | $LiNaSiB_3O_7(OH)$ | 7.3 | n. A. |

Important pegmatite occurrences are found in Western Australia, Canada and Sub-Sahara Africa (i.e. in Zimbabwe, Democratic Republic of Congo and Mozambique). There are also pegmatite occurrences in Namibia that are lithium-bearing.

**Other mineral occurrences:** Lithium-containing clays form during the weathering of lithium-containing volcanic intrusive rocks. Further enrichment can take place by hydrothermal processes. The most important of these clay minerals, hectorite, belongs to the group of smectites (Table 1). Hectorite contains between 0.24 % and 0.54 % lithium. Important occurrences are found in the USA (Roskill 2016).

Lithium may also occur in zinnwaldite, which is the name for the mixed series siderophyllite – polylithionite (end members). They belong to the phlogopite

group. Zinnwaldite has a relatively low lithium content of about 0.92 to 1.85 % but relatively high levels of iron (approx. 11 % FeO) as well as fluorine (approx. 6 % F), which limits the suitability for certain applications. In addition to the sources mentioned above, lithium also occurs in a mineral named jadarite (Table 1). It is a sodium-lithium-boron-silicate hydroxide, which can contain as much as 7.3 % lithium.

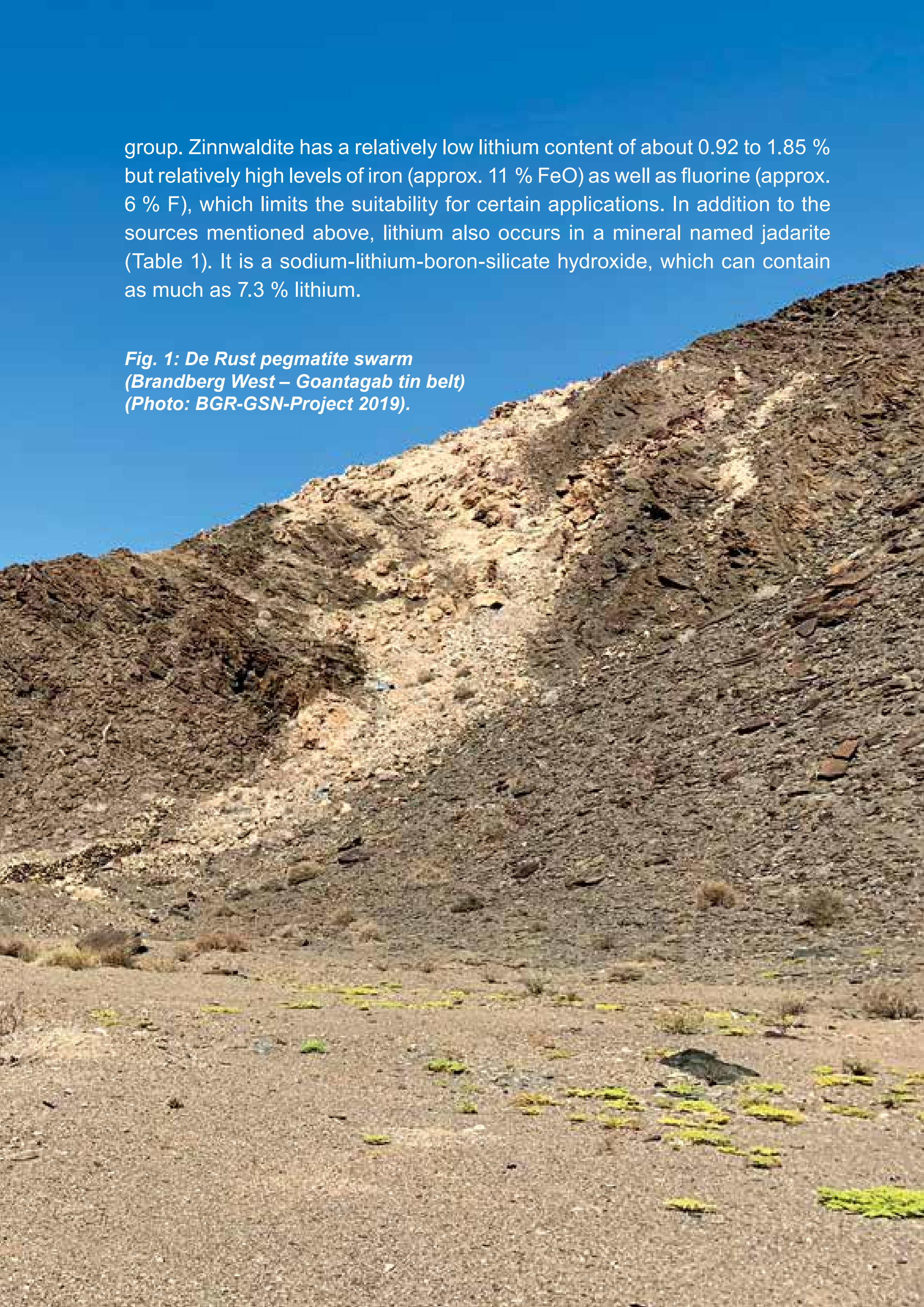

***Fig. 1: De Rust pegmatite swarm (Brandberg West – Goantagab tin belt) (Photo: BGR-GSN-Project 2019).***

# 3 Application

Many products contain lithium due to its very specific properties. By far the most important use of lithium is in the field of rechargeable batteries.

In 2019, this area accounted already for 65 % of total demand compared to 37 % in 2015 (Fig. 2). Lithium is an essential component in modern lithium-ion-batteries since it has the highest electrochemical potential of all metals and the highest specific capacity. Compared to other battery types, lithium-ion battery technology has currently the highest energy density, the longest cycle life, the widest temperature range tolerance and the lowest self-discharge rates (Bauer 2017).

Classical 3C applications such as laptops, tablets, smartphones and smart watches use lithium-ion-batteries (Fig. 3). E-mobility as well as off-grid energy storage (ESS) for renewable energies are the major applications of such batteries with the highest projected annual growth rates. Power tools play a minor role. However, products such as e-bikes, e-trikes and especially e-scooters are gaining momentum.

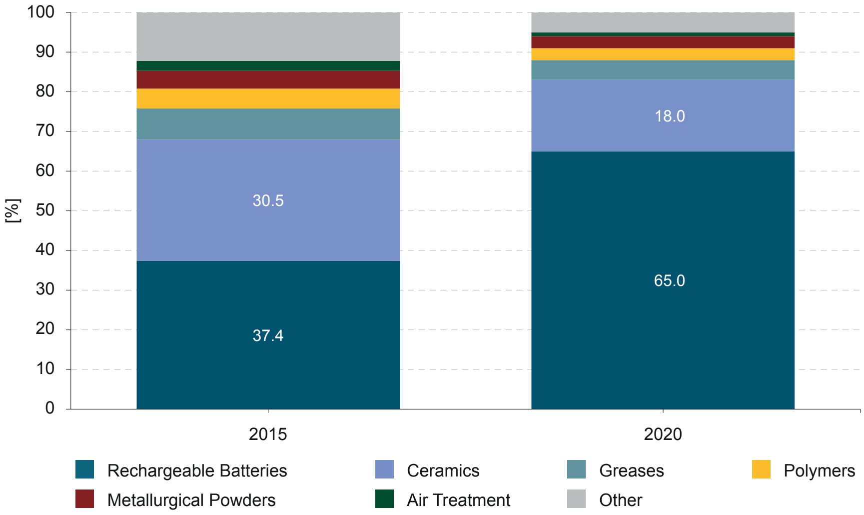

*Fig. 2: Lithium demand 2015 (left) vs lithium demand 2019 (right) (Source: Roskill 2016, Statista 2020).*

The second important application of lithium is in the field of **glass** and **ceramics**. Cumulatively, this area accounts for 18 % of demand in 2019 (Fig. 2). In the ceramic industry, for the production of glazes and ceramic products (tiles, sanitary items, dishes, etc.), pure chemical grade lithium carbonate, spodumene-concentrate or petalite/lepidolite-concentrate is used as lithium source. Positive effects of lithium are increase in gloss, increase in luminosity, increase of chemical and abrasion resistance and reduction of glaze viscosity. In ceramic bodies, the use of lithium lowers the firing temperature, shortens the firing time, and thus reduces overall $CO_2$ emissions. In addition, the use of lithium has a positive effect on the expansion behavior and the mechanical resistance of products.

In **lubricants**, lithium is used as lithium-stearate or lithium-12-hydroxy-stearate primarily produced from lithium carbonate or lithium hydroxide and stearin-acid. Di-Lithium-Azelate, Lithium-Docosanoate and Lithium-Stearate are also used in lubricants (Roskill 2016). Overall lithium content is usually below 0.4 %.

In the **steel casting industry**, fluxes are used to optimize the casting process or to minimize the risk of faulty goods. Lithium is used in the form of spodumene or petalite, which reduces the viscosity of the melt. As a result, the flow rate and thus the productivity can be increased. The flux also acts as a temperature barrier between the mold and the molten steel. In addition, the surface of the continuous cast body is protected from oxidation and impurities such as $Al_2O_3$ are removed (Roskill 2016). In traditional casting, lithium oxide prevents the formation of defects in the finished casting. Typically, these fluxes contain up to 5 % $Li_2O$. Lithium is added to the flux as either lithium oxide or lithium carbonate. The addition of spodumene or petalite is also possible.

In **polymers**, Butyllithium (n-butyllithium = n-BuLi) is used as reagent or catalyst for the production of natural rubber compounds. Depending on the rubber compound, different amounts of n-BuLi are required (3 – 14 kg per ton rubber compound).

Different **air treatment** applications also use lithium. Lithium bromide solutions are used in combination with water in „water-lithium-bromide absorption chillers“ (AKM) (Roskill 2016). Absorption based air de-humidifiers use lithium chloride (LiCl). This compound has the ability to absorb ten times its own weight in water. Lithium is also used in air purification. By means of lithium hydroxide, $CO_2$ can be removed from the air.

**Primary batteries** also use lithium due to its electrochemical properties. These cells are used in watches, calculators, pacemakers, etc. They are characterized by small size, high energy density, low weight, long storage capacity, low self-discharge and high cell voltage.

*Fig. 3a: Pouch-Lithium-Ion Cell (Source: BGR).*

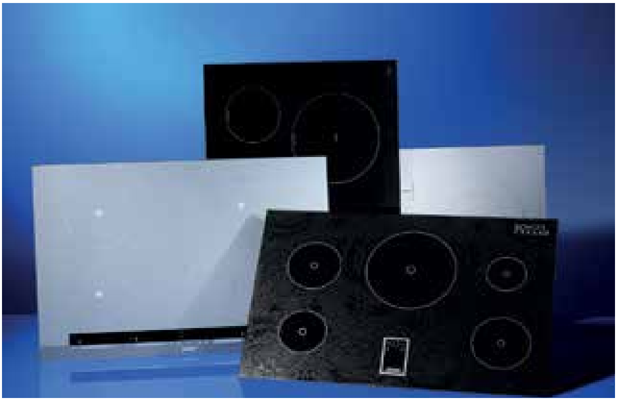

*Fig. 3b: Ceramic stove top (Source: SCHOTT AG 2017).*

# 4 Chemical requirements

Lithium is not a typically mined metal and the quality requirements are very specific and stringent depending on the field of application and thus vary from end-user to end-user.

The first products that enter the value chains are usually the intermediates lithium carbonate and/or lithium hydroxide produced from either brine sources or hard rock deposits, i.e. currently mostly pegmatite sources (Fig. 4).

Lithium from pegmatite sources is primarily sold as concentrates of either spodumene, petalite or lepidolite with minor quantities of amblygonite in the market. Each industry has unique requirements in terms of desired chemical composition, particle size and tolerable values of impurities. Concentrates are usually graded and priced according to their $Li_2O$ content, impurity levels and aimed mainly at the growing battery industry as well as glass/ceramics industry.

Concentrates for the battery industry are rated "chemical grade" and concentrates for the glass industry are rated "technical grade". In general, the glass industry has tighter limits on certain impurities as the battery industry due to the direct usage of the concentrates in the respective product flow sheets.

The current industry standard for lithium concentrates in the battery industry is called SC-6, a chemical grade spodumene-concentrate that contains approx. 6 % $Li_2O$. Higher values of lithium are uncommon as concentrating them beyond 6 % $Li_2O$ increases the cost of production exponentially.

Petalite, lepidolite, zinnwaldite, amblygonite and other lithium bearing minerals are not used in this industry yet. However, there are processes in development for the extraction of lithium from these sources.

Some companies, especially in Australia, sell spodumene-concentrates with lower $Li_2O$ contents (2.2 – 5 %) at lower prices per ton. A special case are so-called DSO-concentrates ("direct shipping ore"), with $Li_2O$ contents of only 1.2 – 1.4 %. DSO shipping's out of Australia decreased significantly as the monetary value is quite low with < 150 US$/t and higher qualities are available.

Mica (muscovite) is an unwanted impurity in these concentrates as it disturbs the converting steps. Heavy minerals are usually also extracted from the sources as they may represent by-product value (e.g. tantalum). Wall-rock impurities may cause problems in the further processing steps (basalt etc.). $Fe_2O_3$ content is also an issue as it may also pose problems in the converters (clogging).

Technical grade lithium concentrates for the glass industry may have the same values of lithium in terms of $Li_2O$ but more stringent requirements in terms of iron content and some other elements such as fluorine.

This industry usually uses petalite concentrates, which can be used directly in the production process. The advantage of petalite over spodumene-concentrates is the generally lower iron content, which is a crucial impurity even though these concentrates have lower lithium contents. $Fe_2O_3$ content above a certain threshold (> 0.15 %) will lead to unwanted discoloration in the final glass or ceramic products, thus low values are needed.

Fluorine-bearing lithium concentrates of lepidolite, amblygonite and zinnwaldite are not used in the glass and ceramics industry as this impurity is highly unwanted. Besides fluorine, the high $Fe_2O_3$ content of zinnwaldite is an issue as mentioned above.

Particle size of the concentrates is also an issue, as very fine material may lower the melt temperature due to a higher specific surface. Therefore, concentrates for this industry are either tailor-made or mixtures of different sources.

The glass and ceramics industry also uses pure lithium carbonate to a certain extent based on pricing.

Lithium carbonate and lithium hydroxide are the first semi-finished products, apart from lithium-concentrates, used in the various industries for direct use or further downstream precursors. There is a distinction between battery grade and technical (other) grade for lithium-carbonate and lithium-hydroxide. The main differences lie within the lithium content, level of impurities and particle sizes.

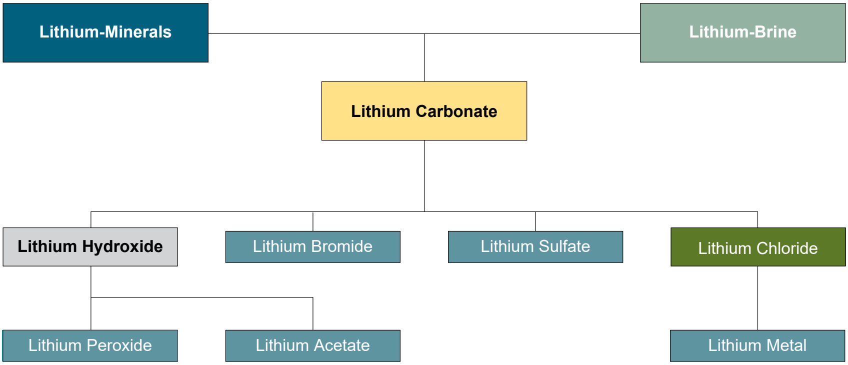

*Fig. 4: Simplified production scheme of lithium and important lithium compounds (modified after ROSKILL 2016).*

Commercial extraction of lithium takes place from lithium-containing brines and from hard rock (i.e. pegmatitic) deposits. A simplified schematic representation of conventional production steps and key intermediates is shown in Figure 4.

For the extraction of lithium from hard rock deposits, the raw ores (e.g. pegmatites) mined in open-pit or underground mines are processed into lithium-containing concentrates by sorting, crushing, grinding, gravity separation, magnetic separation, flotation, washing, filtering and drying. The exact production steps vary depending on occurrence (i.e. locality), mineralogy, company and the intended use of the produced concentrates.

As of 2020, more than 95 % of the conversion from spodumene-concentrates into lithium carbonate and/or lithium hydroxide takes place in China. The most widely used process in the industry is the acid-roast process (Fig. 5).

In this process, spodumene-concentrate is ground and heated to 1,075 – 1,150°C in a rotary kiln (Fig. 5). This converts α-spodumene into β-spodumene, which is soluble in hot acids. After mixing with hot sulfuric acid, lithium sulfate solution is mixed with water. As a result, lithium sulfate dissolves. The solution is mixed with calcium carbonate to remove impurities such as iron, manganese and aluminum. In addition, the pH is raised. After a first filtering process, $Na_2CO_3$ and CaO are added to obtain an alkaline solution. Impurities such as calcium and manganese are removed. The solution is then neutralized with sulfuric acid and heated to increase the concentration of $Li_2SO_4$ to about 200 – 250 g/l. The addition of $Na_2CO_3$ and heating the solution to about 100°C triggers the precipitation of lithium carbonate. The carbonate produced in this way has purities of up to 99.3 %. The battery industry, however, requires purities of min. 99.5 %, obtained through ion exchange and extraction of impurities. The produced lithium carbonate can then also be used for the production of lithium hydroxide.

Common understanding was that the production of lithium carbonate was much cheaper from brines compared to hard rock sources. Due to many developments in the brine industry, mostly related to a recently introduced royalty system in Chile, this is no longer the case. On the contrary, the cost advantage of brines is lost.

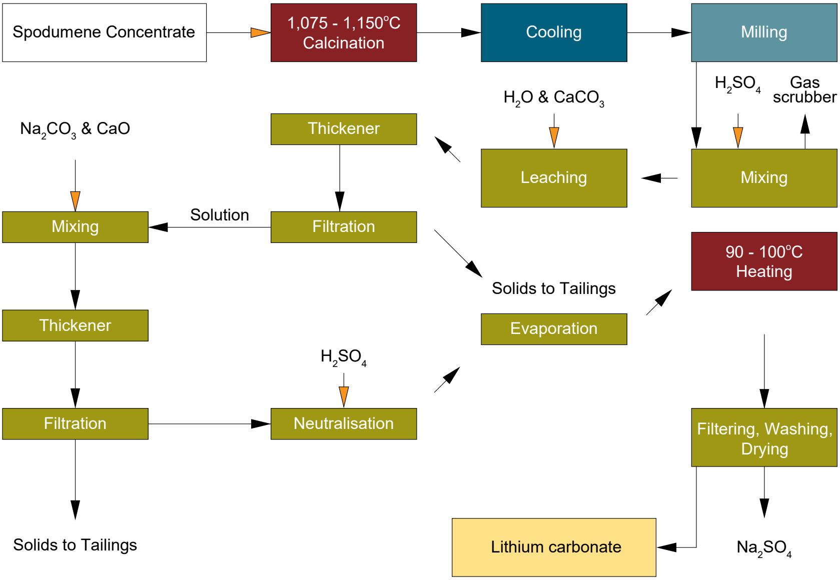

*Fig. 5: Simplified production scheme of lithium carbonate derived from spodumene-concentrates via acid-roast-process (modified after GARRET 2004).*

The production of lithium hydroxide, which is a fast growing market and a higher priced intermediate product, appears to become cheaper when sourced directly from high quality hard rock conversion relative to sourcing from brines via an intermediate step (lithium carbonate). As the cost advantage of brine deposits compared to hard rock deposits is fading, the industry has shifted its focus towards hard rock deposits all over the world.

In addition to the acid-roast process, there are new technological approaches to recover lithium carbonate and lithium hydroxide directly from high quality spodumene-concentrates as well as other mineralogies.

# 5 Mining and trade of lithium in the SADC

## 5.1 Lithium production

Each year, every mining country of the world is urged to share production statistics regarding their mining activity. These statistics are compiled and published by different entities such as the British Geological Survey (BGS) and the United States Geological Survey (USGS) among others.

If a country does not appear in these statistics, there was either no mining activity for this specific commodity, the country did not publish any statistics or the production data is unknown.

*Table 2: Mine production of lithium (Source: BGR 2020, Roskill 2016, USGS 2020, Geoscience Australia 2020).*

| Mine production [t Li-Content] | | | | | | | |
|---|---|---|---|---|---|---|---|
| Years | 2014 | 2015 | 2016 | 2017 | 2018 | 2019$^e$ | Share 2018 [%] |
| Australia[1)] | 12,333 | 13,160 | 15,590 | 21,000 | 57,000 | 42,000 | 64.7 |
| Chile[2)] | 11,640 | 11,787 | 14,526 | 16,584 | 15,886 | 18,000 | 17.5 |
| Argentina[2)] | 3,388 | 3,515 | 5,767 | 5,75 | 6,241 | 6,400 | 6.9 |
| China[3)] | 1,895 | 2,002 | 2,293 | 3 | 7,376 | 7,500 | 8.1 |
| Zimbabwe[1)] | 1,024 | 1,025 | 974 | 994 | 700 | 1,600 | 0.8 |
| USA[2)] | 846 | 846 | 900 | 900 | 567 | n.A. | 0.6 |
| Portugal[1)] | 470 | 470 | 299 | 763 | 700 | 1,200 | 0.8 |
| Brazil[1)] | 186 | 186 | 195 | 154 | 153 | 300 | 0.2 |
| Namibia[1)] | n.d. | n.d. | n.d. | n.d. | 500 | n.d. | 0.5 |
| Other [3)] | 19 | 19 | 18 | 18 | 18 | 500 | <0.1 |
| Global[4)] | 31,801 | 33,011 | 40,562 | 49,012 | 90,941 | 77,000 | 100 |

[1)] Hardrock, [2)] Brine, [3)] Hardrock/Brine, [4)] Deviation due to rounding, $^e$ estimated

In 2018, global mine output of lithium was around 91.000 t Li-content of which only 1,200 t originated from the Southern African Development Community (SADC), namely Zimbabwe and Namibia.

## 5.2 Trade data

Trade data is retrieved from the commercially available Global Trade Atlas® (IHS Global SA). The database provides both import and export data for more than 90 countries based on customs data of individual countries. Data is primarily classified through Harmonised System (HS) product codes by the WCO (World Customs Organization). The HS nomenclature consists of approximately 5,000 product groups, identified by a 6-digit code.

There are limitations to trade data. The most prominent issue arises with data availability since many countries do not publish trade data. Especially export data is an issue among many countries.

There may also be issues with mislabeled products (wrong HS), product baskets, data entry errors or missing data in general. Were export data is not available so-called reverse trade data (RTS) is an option.

If a country does not state any exports, cumulative global imports from that particular country may be used as a rough, yet incomplete estimate of exports. It should be noted that these statistics do not represent absolute, but rather minimum values as trade between two non-reporting countries will not be reflected. The majority of the SADC countries do not report their import and export statistics.

The most important lithium products that are globally traded in significant amounts are lithium-carbonate, lithium-oxide (hydroxide), lithium-chloride and lithium-mineral-concentrates.

## 5.3 Export

The most important intermediate product in the lithium market is **lithium carbonate**. In 2019, global exports amounted to approx. 117,743 t with Chile being the largest exporter (82,344 t, 70 %). There are no listed exports from the SADC region except minor quantities from South Africa to the Democratic Republic of Congo (9 t) and Zambia (2 t).

**Lithium oxides and lithium hydroxides** are grouped together under one HS code, hence an individual consideration of both products on a country basis is not possible due to the lack of country-specific commodity codes.

In 2019, global exports of HS 2825.20 stood at approx. 97,550 t with China being the largest exporting country (49,800 t, 51 %).There are no exports published for the SADC region except South Africa with small quantities (28 t), which are considered to be trade through only.

Assessment of lithium chloride global trade flows is also difficult as this product is listed together with many other chemical products under HS 2827.39. Global trade can only be investigated using country-specific commodity codes (8-digits and above) if available. Only three countries list this product under specific trade codes, namely China (2827.39.10), Chile (2827.39.30) and Argentina (2827.39.60). SADC countries including Namibia do not publish any data under HS 2827.39. Based on the available data, global exports in 2019 stood at 2,254 t with Chile being the largest exporter (2,101 t, 89 %).

**Lithium-containing mineral concentrates** are, among other non-lithium related products, listed in a product basket under HS 2530.90. Only two countries provide information on this product, namely Australia as the largest and hence most important producing and exporting country by far and Brazil as a minor exporter (2530.90.10).

No other country, including member states of the SADC, specifies lithium-containing concentrates as such. The currently only producing and exporting country in the SADC is Zimbabwe, which does not specify exports at all. Thus, exports are derived from RTS (global imports).

A general problem with HS 2530.90 is that only information on quantity is available but no information on lithium content, which can vary between 1.2 % and 6 % $Li_2O$, thus, the margin of possible errors in terms of total contained lithium is large.

In 2019, Australia exported about 1.6 million tons of spodumene-concentrate, down from 3.5 million tons in 2018. More than 95 % destined to China.

Inferred exports (RTS) of Zimbabwe were approx. 93,300 t for HS 2530.90. About 62,000 t of that quantity are listed as imports by South Africa and are unrelated to lithium. The remaining quantity is much more in line with production figures of Zimbabwe as well as the known downstream industries of the destination countries within Europe.

There are no export records published by Namibia. In general and across all traded lithium products South Africa appears to act as an import/export hub within the SADC. Also some of the traded products may be used in the glass and ceramic industry of South Africa.

## 5.4. Import

For most of the SADC countries, the statistics retrieved though the Global Trade Atlas do not necessarily represent reliable trade data due to above-mentioned reasons. This is especially true when only small import numbers (usually in tons) are listed as these are supposedly artefacts or errors in declaration.

Global imports of **lithium-carbonate** amounted to approx. 142,965 t with South Korea being the largest importer (38,578 t, 27 %). There are no listed imports for the SADC region except South Africa (72 t).

Global imports of **lithium-oxides (hydroxides)** amounted to approx. 84,900 t with Japan being the largest importer (37,300 t, 44 %). In analogy to lithium carbonate, there are no published imports into the SADC except for South Africa (428 t).

There is no information for imports of **lithium-choride** or **lithium-mineral-concentrates** into the SADC. The largest importer of lithium-choride is China with approx. 253 t. The largest importer of lithium-mineral-concentrates is also China (> 95 %).

# 6 Lithium occurrences in Namibia

In Namibia significant lithium occurrences are found only within pegmatites. These Precambrian and early Namibian pegmatites are restricted to two different areas respectively, the Damara Orogen in north-central Namibia and the Namaqua Metamorphic Complex in southern Namibia (Fig. 6).

*Fig. 6: Simplified geology of Namibia with major towns as well as railway and tar roads. Blue polygons indicate pegmatite belts and districts in central and southern Namibia. (Data source: GEOLOGICAL SURVEY OF NAMIBIA 2020).*

Within the Damara Orogen, four linear pegmatite belts are found, all of which strike northeast – southwest (Fig. 7): Brandberg West – Goantagab, Cape Cross – Uis, Nainais – Kohero and Sandamap – Erongo, with the latter connected to the Karibib Pegmatite District (Schneider 1992).

Each of these pegmatite belts exhibit numerous individual pegmatite swarms that occur zoned or unzoned and may carry significant amounts of rare metals or semi-precious stones. In the south, Lithium-Caesium-Tantalum (LCT) pegmatites occur in two areas: Tantalite-Valley, south of Warmbad in close proximity to the northwest-trending Tantalite Valley Shear Belt and the Sandfontein-Ramansdrift area close to the Orange River.

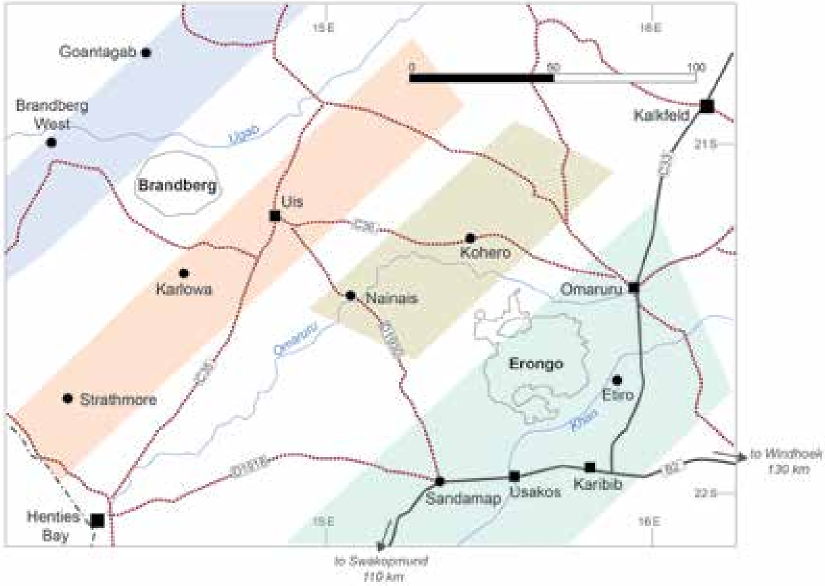

*Fig. 7: Pegmatite belts in north-central Namibia from west to east: Brandberg West – Goantagab, Cape Cross – Uis, Nainais – Kohero and Sandamap – Erongo as well as the Karibib Pegmatite District (after Geological Suvey of Namibia 2002).*

# 7 Lithium mining in Namibia

Data for historic lithium mine production is available for the period 1939 – 1998 (Fig. 8). After 1998, all mining activities ceased due to product quality issues and overall market environment.

Until the mid-1950s, lepidolite was the most important mined lithium mineral of the country (Fig. 8). As mine output of lepidolite decreased output of petalite increased. However, quantity on a year-to-year basis was quite variable and fluctuated between 1,000 – 10,000 t. Since the early 1980s, production of petalite was quite stable and ranged between 1,000 – 2,500 t. Production fell sharply in 1997 and 1998 after which it ceased. Mining of amblygonite has always been small compared to lepidolite and petalite and never exceeded 1,000 t per annum.

According to the USGS (2020) 500 t of lithium were mined in Namibia in 2018. This is most likely stockpiled lepidolite material from the Rubicon mine.

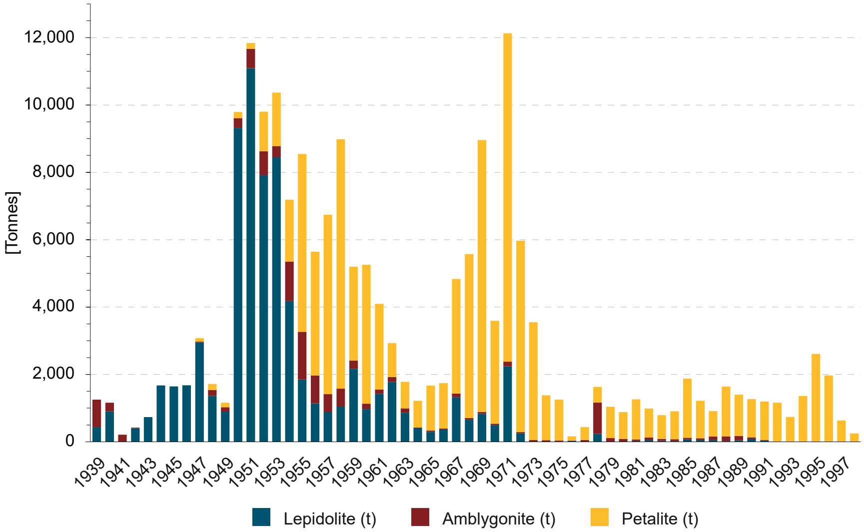

*Fig. 8: Lithium production in Namibia in [t] per year (after SCHNEIDER 1992, BGR 2020).*

Currently, there is no active consecutive mining for lithium in substantial quantities in Namibia although there are prospects and projects under development.

## 7.1 Current mining activities and projects

### Soris

The Soris project is located in the De Rust pegmatite swarm, which is part of the “Brandberg West – Goantagab tin belt” (Fig. 7). This belt stretches to the northeast of the Brandberg massif over a length of 60 km and a width of 25 km. This belt was previously mined for cassiterite on a larger scale. Some of the pegmatites in this belt may carry substantial amounts of lithium, such as pegmatites in the De Rust pegmatite swarm.

The De Rust pegmatite itself is a Li-rich rare metal pegmatite that was mined for cassiterite and tantalite but also for minor quantities of spodumene between 1960 and 1990 (Diehl 1990). It intruded into metasediments of the Amis River Formation, Lower Ugab Group of the Southern Kaoko Zone.

It is the largest pegmatite of the De Rust pegmatite swarm within the Brandberg West – Goantagab pegmatite belt (Diehl 1992c). Outcrops are 100 – 470 m long, up to 30 m wide and can be followed over a length of roughly 2.4 km.

The pegmatite shows well-developed zonation with a border zone (quartz, alkali feldspar, muscovite), outer (quartz, microcline-perthite, muscovite, altered petalite) and inner (quartzo-feldspathic rock with spodumene crystals with accessory apatite, lepidolite, eucryptite, zircon and monazite) intermediate zone as well as a core zone (quartz, subordinate microcline, muscovite, sporadic tantalite). Spodumene crystals may reach up to 80 cm in length (Fig. 12). Towards the core zone spodumene carries rounded nodules of lithium phosphates (amblygonite – montebrasite series).

It is located northwest of the nearest town of Uis in the Kunene region of Namibia about 6km to the east of farm De Rust 532 and about 2.5 km north of the Ugab River. The nearest railhead is located in the town of Karibib and the deep-water port of Walvis Bay is 120 km to the southwest. Windhoek is about 180 km to the southeast.

The project can be reached via paved but mostly unpaved roads from the town of Uis. From White Lady Lodge, which is about 38 km northwest from Uis, a 35 km gravel road leads towards the project, 15 km of which are in the riverbed of the Ugab River. There is currently no electricity and water supply at the project location site.

According to S&P Global (02/2020) current owner of the Soris project is Montero Mining & Exploration Ltd. (TSX.V: MON) which holds 80 % interest of the property. Another 20 % are allocated to an unnamed private owner. Based on data from the Namibia Mining Cadastre Portal (09/2020) multiple entries for mining licence applications exist for the area where the main De Rust pegmatite is located (Fig. 9).

### Resource estimate

Due to the early stage of the Soris project, no resource estimate is available. However, Montero Mining claims the project to be drill ready targeting a resource of 10 Mt @ 1 % $Li_2O$ with tantalum and tin by-product credits. This would equate to 46,400 t of lithium or 247,000 t LCE.

Grab samples of the deposit showed lithium contents of 0.07 % to 5.32 % averaging 1.37 %. Channel samples showed average lithium contents of 0.76 % and values up to 3.66 % (Montero 03/2019). The company also re-assessed 1097 previously tested RC drill samples. The main lithium-bearing mineral is spodumene.

Remnants of historic intermittent mining activities like old foundations and quartzo-feldspathic tailings are still visible east to the main pegmatite (Fig. 10 – 11).

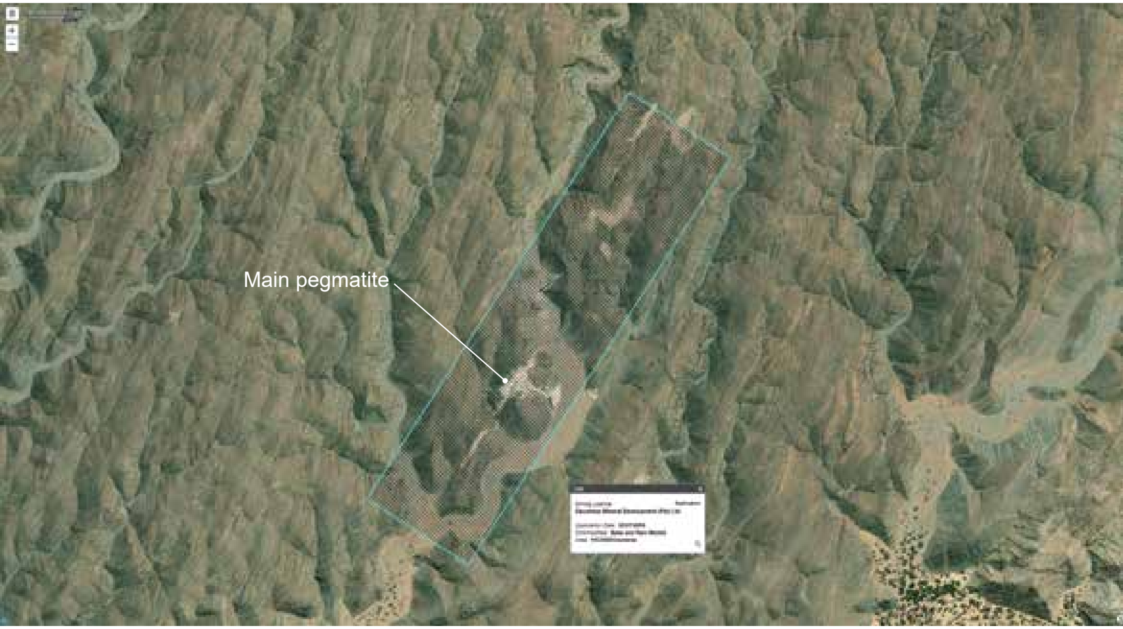

*Fig. 9: Satellite image of the De Rust project including the outlined mining license. Main pegmatite coordinates 20°57'48''S – 14°30'12''E (Source: http://portals.flexicadastre.com/namibia/ 09/2020).*

*Fig. 10: Remnants of historic open pit mining (upper) and tailings of De Rust pegmatite (lower) northwest of the Brandberg massif (Photo: BGR-GSN 2019).*

*Fig. 11: Historic open pit of the De Rust pegmatite (Photo: BGR-GSN 2019).*

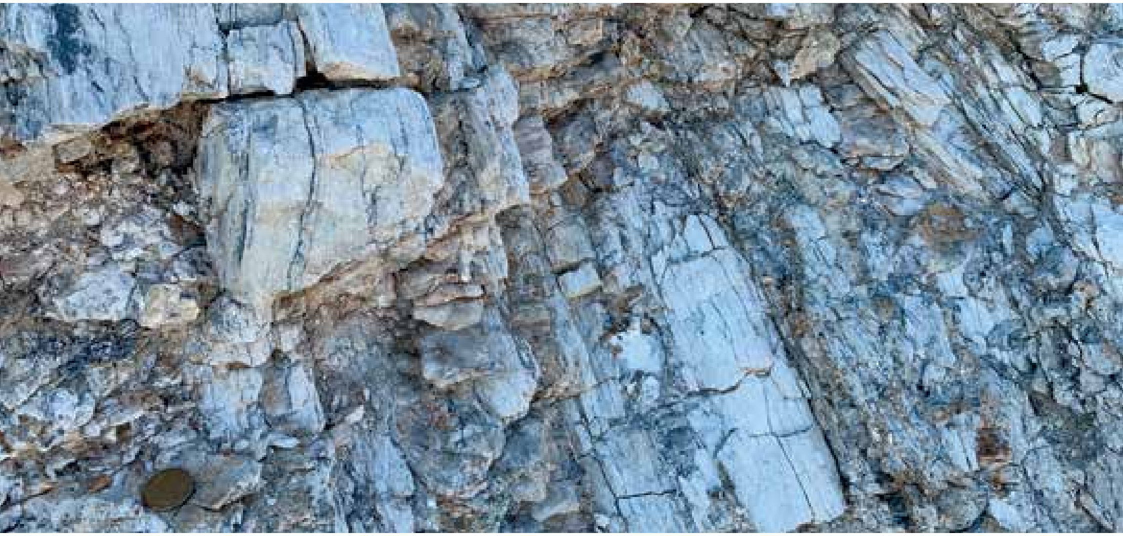

*Fig. 12: Weathered spodumene chrystals at the historic open pit mine. (Photo: BGR-GSN 2019).*

## Uis

The Uis projects (former mine and tailings) are located in the northern part of the "Cape Cross Uis pegmatite belt" east of the town of Uis on the farm Uis Townlands No. 215 in the Erongo region of Namibia.

The Cape Cross-Uis belt is approx. 120 km long and up to 40 km wide and extends in a NE direction (Fig. 7). It comprises three distinct pegmatite swarms; the Strathmore swarm, Karlowa swarm and Uis pegmatite swarm. In general lithium-bearing pegmatites (Li-Nb-Ta-Sn-Be and Li-Nb-Ta-Sn) are the least common in this belt (Fuchsloch et al. 2018).

The Uis swarm field consists of more than 120 individual pegmatites, each with a northeasterly to easterly strike direction and northwesterly down dip (30° – 70°). This field is accompanied by a peripheral pegmatite field of approx. 25 individual pegmatites.

Some of the main pegmatites, especially around the formerly world's largest tin mine at Uis, are exceedingly large. Some of them are up to 1 km long and some 50 m wide.

In terms of lithium, petalite, amblygonite and minor spodumene mineralization occurs in the various pegmatites but no lepidolite. Most common lithium bearing minerals in the eight pegmatites that were mined at Uis are amblygonite, petalite and spodumene.

Currently, the Uis tailings project and the Uis tin mine are owned by two different companies. As of 2020, the tin mine is operating a pilot processing plant and aims to ramp up the production of lithium in the near future. The current ownership of the tailings project as of September 2020 is unclear.

The nearest commercial deep-water port to the projects is Walvis Bay 220 km to the southeast. The town of Omaruru is 130 km to the east and Henties Bay lies about 120 km to the southwest. The nearest railhead is located in Omaruru. The area is accessible year-round by paved and un-paved roads. NamPower provides electricity and the town of Uis is connected to the NamWater pipeline.

The tin deposit was discovered in 1911 and mined between the 1950s and 1989 for cassiterite by Uis Tin Mining Company (SWA) Ltd and IMCOR.

Coarse tailings are located in the northern part of the former mine just south to the main road C36 (Fig. 13). The fine material is located south to the coarse waste dumps (Fig. 13).

After 1990, multiple companies owned the property until AfriTin Mining Ltd. bought all the rights (license ML134). The current lithium tailings project of Montero Mining & Exploration Ltd. (TSX.V: MON) is based on the historic mine tailings of the former tin mine on mining license ML134 that is currently owned by AfriTin Mining Ltd. The acquired tailings material does not fall under the ML134 license of AfriTin since historical tailings material (Fig. 14) is not regulated by Minerals (Prospecting and Mining) Act 33 of 1992 of Namibia.

### Resource estimate

**Uis tin mine:**

According to AfriTin the former Uis mine holds a JORC compliant, resource (inferred) of 71.5 Mt of ore @ 0.134 % Sn with a cut-off grade of 0.05 % Sn (AfriTin 2020). Grades of ancillary elements are given at 0.63 % $Li_2O$ and 85 ppm Ta for the total resource of 71 Mt of ore.

This equals to approx. 95,000 t of tin, 209,000 t of lithium (1.1 Mt LCE) and 6,090 t of tantalum. 85 % of the total resource are attributable to the company. The remaining 15 % are allocated to SMU (Small Miners of Uis).

**Uis tailings:**

Montero Mining filed an inferred resource estimate of 14.4 Mt of ore 0.37 % $Li_2O$ and 0.05 % $SnO_2$ with a 0.35 % $Li_2O$ cut-off grade for lithium and assumed processing recoveries of 70 % for their tailings project (Montero 2019). This equals to approx. 24,700 t of lithium content (131,500 t LCE) and 7,200 t $SnO_2$.

This resource estimate only includes coarse tailings material. There is currently no information on the lithium content of the fine tailings material that totals 2.71 Mt t due to insufficient or no test work (Montero 2018). The company also states that the average $Li_2O$ grade of the fines material does not hurdle the cut-off for the fines of 0.82 % $Li_2O$.

In 2016, Australian based Tawana Resources carried out a drilling program at Uis for a private company called Lithium Africa 1 on the fine and coarse tailings (Table 3, Hole 1 & Hole 2). Below some of the obtained data on lithium content is given. Additionally, $Li_2O$ content of two obtained grab samples by BGR (Table 3, Sample 2019a & 2019b) is given.

*Table 3: Sample data Uis (Tawana 2016, Montero 2018, BGR 2019).*

| **Sample** | **Sample 0 to 1m $Li_2O$ (%)** | **Sample 1 to 2m $Li_2O$ (%)** | **Sample 2 to 3m $Li_2O$ (%)** |
|---|---|---|---|
| Fines Hole 1 | 0.71 | 0.85 | 0.92 |
| Fines Hole 2 | 0.80 | 0.89 | 0.95 |
| Coarse Hole 1 | 0.50 | 0.43 | 0.43 |
| Coarse Hole 2 | 0.54 | 0.62 | 0.62 |
| BGR Sample 2019a (Coarse tailings) | 0.28 | | |
| BGR Sample 2019b (Coarse tailings) | 0.28 | | |
| Montero NI 43-101 | 0.37 | | |

*Fig. 13: Former Uis tin mine, Uis tailings project with coarse tailings. Tailings coordinates (center): 21°13'31"S – 14°52'44"E (Source: http://portals.flexicadastre.com/namibia/ 09/2020).*

*Fig. 14: Tailings of the historic Uis Tin Mine (Photo: BGR-GSN 2019 with kind permission of AfriTin Mining Limited).*

## Karibib Lepidolite Project

The Karibib Lepidolite brownfield project is located in the *“Karibib – Usakos Pegmatite District*” southeast of the town of Karibib on the farm Okongava Ost No. 72 in central Namibia (Fig. 15 – 16).

This pegmatite district, which is of Damaran age, hosts the most important pegmatite occurrence (Rubicon swarm) in terms of lithium in Namibia. In addition, numerous other different pegmatite swarms, some of which have previously been relevant in terms of lithium are know from this district. These are: Dernburg, Karlsbrunn, Albrechtshöhe, Berger, Kaliombo, Gamikaubmund, Okatjimukuju, Etusis, Daheim, Friedrichsfelde and Etiro (Diehl 1992a).

The Rubicon pegmatite itself is the largest of the individual pegmatites that occur in this field and has been the prime source of lithium until mining seized in the early 1990s. The Helikon pegmatites are part of the Rubicon pegmatite swarm and are located northeast to the Rubicon pegmatite. They have previously been mined for lepidolite, amblygonite, petalite, and muscovite, beryll, pollucite, quartz and columbite-tantalite as valuable by-products (Fig. 18 – 19).

The pegmatite itself consist of two, ellipsoidal, well zoned, Li-mineralized orebodies. The larger one is about 320 m long and 25 – 35 m wide. It dips at 46° to the northeast and has a northwesterly strike. The second orebody is about 230 m long and about 10 m wide. It is dipping with 30° to the northeast and has a northwesterly strike. In total the outcrop of the Rubicon pegmatite is about 600 m long with a maximum width of 65 m (Fig. 17).

A very prominent feature is the presence of a very well developed, concentric shell and zones from the footwall to the inner core of the pegmatite. Both orebodies exhibit a border-, wall-, intermediate- and core-zone.

Border-zone, wall-zone and outer intermediate zone of the larger orebody do not contain Li-bearing minerals of economic importance. The inner intermediate zone does contain lepidolite. The outer core zone may be sub-divided into a petalite zone, low-grade lepidolite zone and a high-grade lepidolite zone. The inner core zone also contains a petalite zone. Mining occurred previously in the later named zones. The zonation of the smaller orebody to the northwest is less pronounced but Li-mineralization and style are equal to the larger orebody. There is no spodumene mineralization within the orebodies and respectively zones of the Rubicon pegmatite.

The Helikon I pegmatite is also a lens-shaped pegmatite with a length of roughly 400 m and a width of approx. 66 m. It dips to the north with about 60° – 70°. Helikon I also consists of well-defined zones. The main Li-bearing minerals are lepidolite and petalite. According to Roering (1963) the lepidolite is difficult to separate from the intergrown albite and hence of low grade and quality.

The Helikon II pegmatite is approx. 1.7 km long and only 9 – 15 m wide. It lies a bit north of Helikon I and dips steeply to the north with 55° – 80° striking east west. The main Li-bearing minerals are lepidolite and petalite. According to Diehl (1990) the westernmost portion of the pegmatite has historically been the economically most important. A massive, up to 6 m wide, petalite zone was mined here according to Diehl (1990).

The nearest railhead to the project is 17 km away in Karibib and the deep-water port of Walvis Bay is 220 km to the southwest. Windhoek is about 180 km to the southeast. NamPower connects the town of Karibib to electricity and the project currently utilizes generators. There is a 7 km long 22 kV power line spur to grid connection pending (Lepidico 2020). Water is available via on-site boreholes.

The project was previously owned by Desert Lion Energy Inc (TSVX: DLI). Lepidico Ltd. (ASX: LPD) bought into the project and currently holds 80 % interest, which comprises Mining License 204 (69 km$^2$) as well as three Exclusive Prospecting Licenses (EPLs), namely 5,439, 5,555 and 5,781 (Lepidico 2020).

Lepidico will cover mining from multiple sources as well as chemical conversion by utilizing their proprietary lithium processing technologies L-Max®, LOH-Max® and S-Max® (Lepidico 05/2019). The company aims to produce high purity lithium chemicals such as lithium carbonate and lithium hydroxide.

The takeover also included a nonbinding offtake agreement between the former owner Desert Lion Energy Inc. and German chemical company BASF. On April 2nd 2019 Desert Lion Energy Inc. announced this offtake agreement which at the time was valid through to December 31, 2019. On December 20th 2019 Lepidico announced that the LOI with BASF was extended to December 31st 2020 (Lepidico /12/2019).

The feasibility study criteria of Lepidico are as follows:

- Throughput of the concentrator on-site of 0.35 Mtpa.
- Expansion of throughput after year five to 0.5 Mtpa.
- Chemical plant in the industrial city of Abu Dabi (ICAD).
- Plant design for 58,000 tpa of concentrate (4 % $LiO_2$) for the production of up to 5,500 tpa LiOH.
- Utilization of L-Max® and LOH-MaxTM
- Non-binding off-take MOU with BASF for LiOH only.
- Targeting for project commissioning to commence late 2021 for commercial production in 2022.

The preliminary mine plan indicates a strip ratio of 0.3 – 1 for the first two years. The ratio will then go up to 1 – 1.4. In the first four years elevated grades of 0.6 %$LiO_2$ will be mined.

### Resource estimate

A JORC 2012 compliant resource estimate for the deposit is given in Table 4 (Lepidico 2020). The deposit currently holds 23,200 t of lithium (Indicated & Inferred) based on a cut-off grade of 0.15 % $Li_2O$. This resource estimate is based solely on the lepidolite occurrences at the mine site.

*Table 4: Resource estimate Karibib Lepidolite Project (Source: Lepidico 2020).*

| Deposit | Resource Category | Cut-off ($Li_2O$) | Ore (Mt) | $Li_2O$ (%) | Li (t) | Li (LCE) |
|---|---|---|---|---|---|---|
| Rubicon | Measured | 0.15 | 2.2 | 0.57 | 5,819 | 30,974 |
| Rubicon | Indicated | | 6.66 | 0.38 | 11,637 | 61,943 |
| Rubicon | Inferred | | 2.37 | 0.43 | 4,728 | 25,167 |
| Helikon | | | | | | |
| | Total | 0,15 | 11.24 | 0.43 | 22,184 | 118,086 |

*Fig. 15: Satellite image of the Karibib Lepidolite project. Rubicon coordinates (center): 22°6'11''S – 15°59'44''E. (Source: http://portals.flexicadastre.com/namibia/ 09/2020).*

*Fig. 16: Satellite image of the Karibib Lepidolite project. Helikon 1 coordinates (center): 22°2'49''S – 16°1'13''E. Helikon 4 coordinates (center): 22°2'24''S – 16°1'41''E. (Source: http://portals.flexicadastre.com/namibia/ 09/2020).*

*Fig. 17: Rubicon pegmatite (Photo: BGR-GSN 2019 with kind permission of Lepidico Chemicals Namibia (Pty) Ltd 2020).*

*Fig. 18: Lepidolite sample from Rubicon pegmatite (Photo: BGR-GSN 2019 with kind permission of Lepidico Chemicals Namibia (Pty) Ltd 2020).*

*Fig. 19: Petalite sample from Rubicon pegmatite (Photo: BGR-GSN 2019 with kind permission of Lepidico Chemicals Namibia (Pty) Ltd 2020).*

*Fig. 20: Helikon 1 pegmatite (Photo: BGR-GSN 2019 with kind permission of Lepidico Chemicals Namibia (Pty) Ltd 2020).*

*Fig. 21: Helikon 4 pegmatite (Photo: BGR-GSN 2019 with kind permission of Lepidico Chemicals Namibia (Pty) Ltd 2020).*

## Tantalite Valley

The Tantalite Valley Project lies within the “Namaqua Metamorphic Complex” in Southern Namibia. Within this complex Lithium-Caesium-Tantalum (LCT) pegmatites occur in two main areas: Tantalite-Valley, south of Warmbad in close proximity to the northwest-trending Tantalite Valley Shear Belt and the Sandfontein-Ramansdrift area close to the Orange River.

The area were the pegmatites of the Tantalite Valley occur is primarily composed of a large ovoid gabbro intrusion (7.1 km by 3.3 km in extent) within paragneiss units of the Namaqua Complex. The gabbro outcrop forms a large dome shaped mountain that rises about 500 m above the surrounding topography.

The pegmatites belong to the Kenhardt and Gordonia pegmatite districts in Namaqualand but only the younger group of them carry accessory ore minerals such as tantalite, beryl, REE minerals and lithium.

The Tantalite Valley pegmatites include several individual subhorizonal dikes that are up to 1000 m long and 0.2 to 40 m wide, plunging towards southeast (Diehl 1992b). Four of those are of economic interest: Homestead, Whitkop, White City and the Lepidolite pegmatites (i.e. Purple Haze) (Fig. 22).

They are all well zoned (quartz core, inner and outer intermediate zones, wall zone) and were predominantly targeted for beryl, columbite-tantalite, as well as lithium and bismuth minerals.

The project is located on the farms Umeis 110 and Kinderzitt 132 between the Farms 109, 131, 129, 308 and 473 in the magisterial district of Karas. It currently comprises Mining License (ML-77) fully owned by Tameka Shelf Co. Four (Pty) Ltd. which is a 100 % subsidiary of African Tantalite Pty Ltd (AFTAN). Above all, Kazera Global Investments PLC holds a 75 % stake in AFTAN (Kazera 2019) with the other 25 % of local farmer ownership.

The project is accessible via gravel road from Karasburg, which is about 80 km to the north. The nearest railhead is also located in Karasburg. Electricity is currently supplied by generators and water is recovered from multiple drill holes. The Orange River is about 15 km to the south of the project. Mining infrastructure as well as equipment are on site as well as a plant for the production of tantalite concentrate.

NTI is working on an extensive exploration program with a clear focus on reviving tantalite mining in Namibia with a possible by-product stream of lithium bearing minerals. The company will focus primarily on the pegmatites Homestead, Purple Haze, Signaalberg and White City (Fig. 23).

The area is known for its tantalum occurrences and since the late 1940s tantalite and other minerals have been recovered at Tantalite Valley until 1981 when mining ceased. Initially, alluvial deposits were mined followed by the pegmatites themselves. Grades of the concentrates produced prior to the closure of the mine were quite high with 65 – 70 % $Ta_2O_5$ with very low $U_3O_8$ and $ThO_2$ values of 0.25 % max.

**Resource estimate**

According to S&P Global (09/2020) Measured and & Indicated resources at Tantalite Valley are 104,800 t of ore @ 0.042 $Ta_2O_5$ and 0.653 % $Li_2O$ as of 11/2019. This would equate to 315 t of lithium or 1,690 t LCE. Total inferred resources are 517,400 t of ore @ 0.018 % $Ta_2O_5$ and 0.144 % $Li_2O$. This equals to approx. 91 t of tantalum and 750 t of lithium (3,535 t LCE).

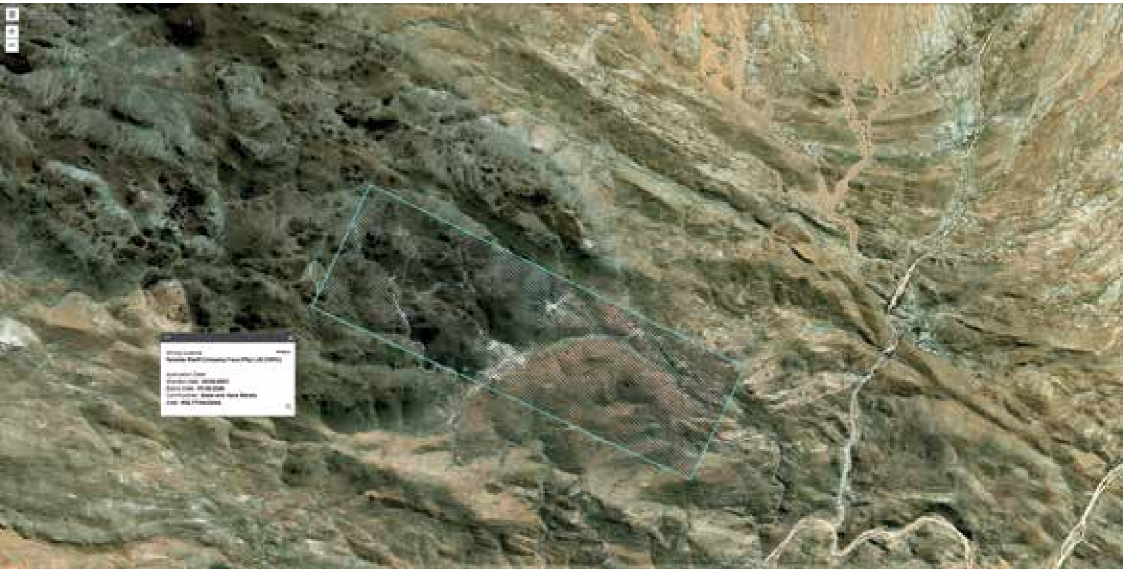

*Fig. 22: Satellite image of the Tantalite Valley project. White City pegmatite coordinates (center): 28°43'07''S – 18°44'45''E. Homestead pegmatite coordinates (center): 28°43'19''S - 18°44'24''E. Purple Haze pegmatite coordinates (center): 28°43'09''S – 18°43'55''E. (Source: http://portals.flexicadastre.com/namibia/ 09/2020).*

*Fig. 23: White City pegmatite (Source: Kazera global Investments PLC 2020).*

# 8 Analysed lithium samples

During the course of the cooperation project between the Economic Geology Division (EGD) of the Geological Survey of Namibia (GSN) and the German Federal Institute of Geosciences and Natural Resources (BGR) several sampling campaigns to southern and central pegmatites took place.

The field trips were preceded by literature and data research regarding information on lithium occurrences and/or previous lithium mining activity to identify specific target areas.

During a campaign in 2019, 16 lithium-bearing, mixed mineral samples were taken from five different locations and subsequently analyzed. Two of the samples originate from the Uis Tin Mine Tailings of the former tin mine. All remaining samples were taken either from stripped outcrops for future mine activities or from previous mine sites (i.e. pits).

All 16 samples were analyzed at BGR labs in Hanover, Germany through qualitative XRD, XRF and ICP-MS. Given data shall be understood as a first indicator for the sampled lithium occurrences.

Most if not all sampled occurrences have previously been analyzed or are currently being assessed by the property owners or current licensees. Detailed information of these sampling and analytical campaigns remain confidential and are thus not available for comparison.

Appendix A lists the identified qualitative mineralogy of the samples as well as the major element analysis. Additional samples from previous campaigns are also given.

Interpretation of the results are based on their applicability in the various lithium-consuming industries for which information is available.

Most of the current lithium applications require a chemical intermediate product such as lithium carbonate or lithium-hydroxide. The glass and ceramic industry does use lithium-bearing mineral concentrates depending on the prices of these materials when compared to $LiCO_3$.

Since the main applications require an intermediate or downstream chemical product, lithium content as well as impurity values are the main criteria for the suitability of the sampled occurrences. Other quality criteria are particle size and surface area/structure.

# 9 Interpretation

As previously stated, all obtained grab samples are mixtures of lithium-bearing minerals (i.e. spodumene, petalite, lepidolite), feldspars, quartz, micas as well as secondary minerals. Therefore, all given analytical data has to be taken with caution and will not be representative for the individual outcrops or deposits.

The evaluation of the economic suitability for various economic applications of the analysed lithium samples is based on the chemical specifications in Chapter 4.

Lithium content > 1 % $Li_2O$, $Fe_2O_3$ content < 0.15 % as well as F content < 0.1 % are individually highlighted (Appendix A) as these three values are the most important.

Based on the chemical analysis nine of the 16 samples showed $Li_2O$ contents of more than 1 % (range: 1.17 – 3.27 %). Seven of those nine samples also exhibited low $Fe_2O_3$ content (range: 0.04 – 0.08 %) (Appendix A). Three of those seven samples also had fluorine values below 0.05 %.

Of the ten additionally included samples from previous campaigns four showed $Li_2O$ contents of more than 1 % (range: 1.26 – 1.99 %). Three of those samples also exhibited low $Fe_2O_3$ content (range: 0.04 – 0.07 %) (Appendix A). One of the three samples had fluorine values below 0.05 %.

The mentioned samples (sources) could be of potential use but for further interpretation statistical sampling will be required.

# 10 Conclusions

There is currently no lithium industry established in Namibia. This accounts to both mining and processing of ores into commercial lithium-bearing concentrates as well as the production of downstream products such as lithium carbonate and/or lithium hydroxide. In order to evaluate the potential for a lithium industry in Namibia the current global market and price developments need to be addressed.

Currently, the main application for lithium is in the chemical industry as lithium carbonate and/or hydroxide for the manufacturing of lithium-ion batteries. There is currently no domestic market (supply) or demand for this industry in Southern Africa or Namibia in specific. Processing of lithium-bearing ores into these highly specific downstream products is economically more viable in close proximity to the demanding industries. It also requires large investments (double-digit million dollars per 10.000t of capacity). Additionally, there is already huge capacity and strong capacity build up in Asia at rather low cost.

The second most important application lies in the glass and ceramics industry. This industry uses lithium either as lithium-bearing concentrates or lithium carbonate depending on current market price and process/product requirements. There is currently no such industry established in Namibia but potential plans. There is glass and ceramics manufacturing in South Africa and thus a potential market for lithium bearing products (concentrates) should this industry require it depending on product.

The 2018/2019 primary lithium supply, based on spodumene-bearing mineral concentrates, was dominated by Australia with a market share of well over 95 %. On an annual basis, the country exports more than three million tons of lithium-bearing concentrates to China. To put this into perspective, Lepidico plans to export just 58 ktpa of concentrate to Abu Dhabi for refinement from their project annually. Therefore, potential production in Namibia will always be rather small scale when compared to peer producing countries/companies.

As of late 2020, the concentrate market is in strong oversupply with strong competition. Thus, prices have eroded quite substantially for a standard SC.6 concentrate (Fig. 24). In general, prices vary significantly based on lithium content and impurities of the concentrates. Lithium bearing mineral concentrates are a relatively low-value mineral commodity when compared to lithium-carbonate or other lithium downstream products, thus, product quality, cost reduction and cost control are key components in this industry. Since prices are depressed currently, many of the Australian producers have drastically reduced output or even went into care and maintenance. This situation may change towards 2025 or beyond as demand picks up.

Prices for the higher valued product, lithium-carbonate, spiked at the end of 2017 towards 2018 to more than 20.000 $US/t on a contract basis with prices being very volatile. Since then, prices have also eroded to below 9.000 $US/t due to oversupply and slow demand pickup (Fig. 25). With this product, stable quality and chemical composition are crucial for the downstream industry.

Based on available grade/tonnage data the Namibian projects/prospects are relatively small in overall size and low in grade when compared to global peers for the resource category “Measured/Indicated” (Appendix B). Total contained lithium quantity is thus relatively small in comparison. On a global scale the most promising hard rock projects that are currently being mined and developed have $Li_2O$ grades of 1.0 % or above.

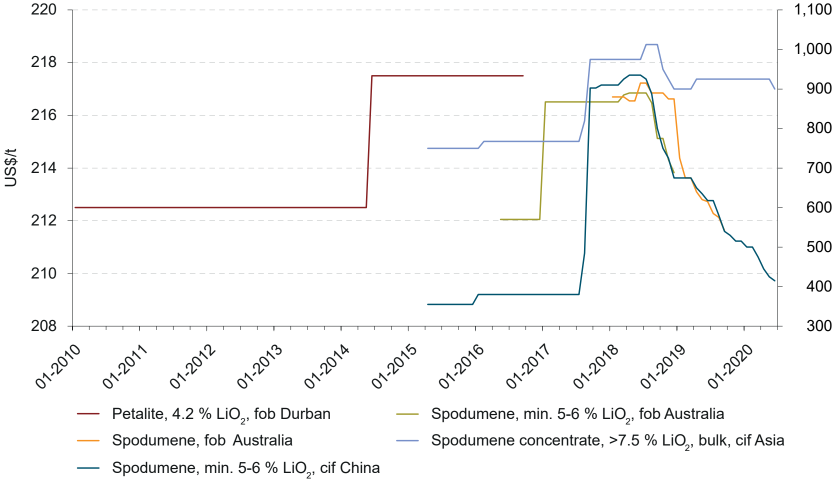

*Fig. 24: Lithium-mineral-concentrate prices 01/2010 – 06/2020 (Source: BGR 2020).*

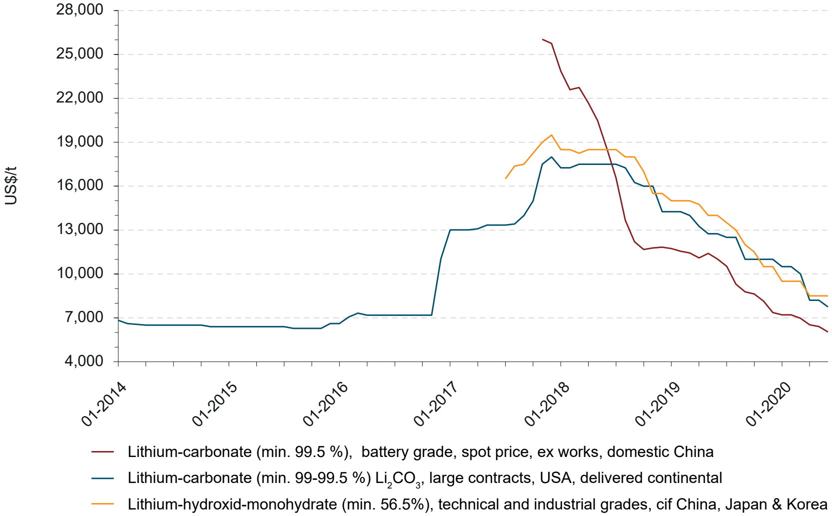

*Fig. 25: Lithium chemical prices 01/2014 – 06/2020 (Source: BGR 2020).*

For the resource category “Indicated”, which generally represents the lowest level of confidence, only the Uis mine project of AfriTin represents a sizeable resource even though grades are relatively low (Appendix C). The Uis tailings project as well as the Rubicon project are again relatively small when compared to their global peers. Tantalite Valley is the smallest of all included projects (Appendix C).The given data for the De Rust project reflects only an exploration target of the company rather than actual data and may thus be not representative.

Based on size and contained lithium-content none of the visited early stage projects/prospects would justify the financial investment into the construction of a chemical conversion plant for the production of lithium carbonate and/or hydroxide on site as it requires very large monetary investments. Due to their size, payback of the required investments may be unfavorable when compared to global peers. In addition, the current market environment is very harsh with strong competition from Asia that has a huge cost advantage due to capacity build up. This industry is also very energy and water intensive.

In addition, location within Namibia as well as distance to possible downstream markets may become an issue as it increases the transportation cost immensely. This is especially true for the Soris/De Rust pegmatite, which is in a remote location without any allocated infrastructure. The projects Karibib, Uis and Tantalite Valley are much easier to access.

The approach of Lepidico to produce a lithium bearing concentrate on site seems plausible approach. Since this will already require a skilled workforce, mining and beneficiation equipment in order to produce a high quality lithium-bearing concentrate it may already be considered “added value” for the industry of the country. This approach may also be suitable for the other mentioned and visited projects.

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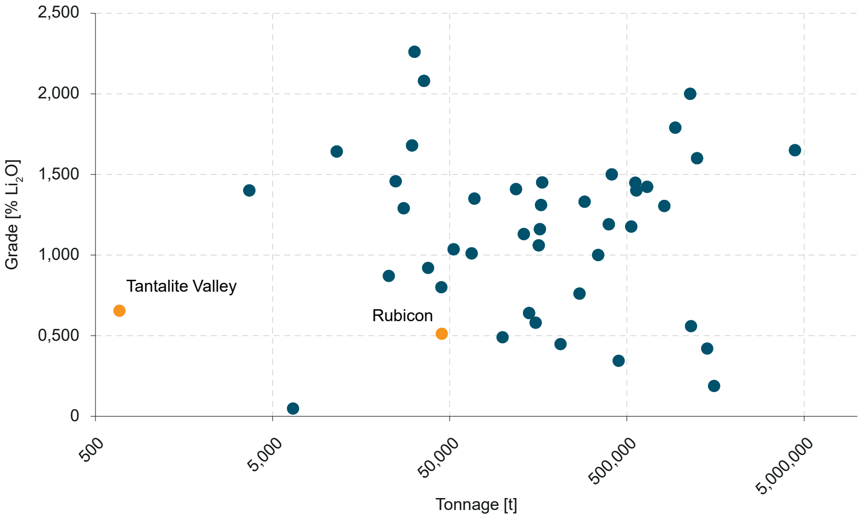
# Appendix

## *Appendix A: Analytical data of lithium samples collected in Namibia. Threshold values highlighted in green.*

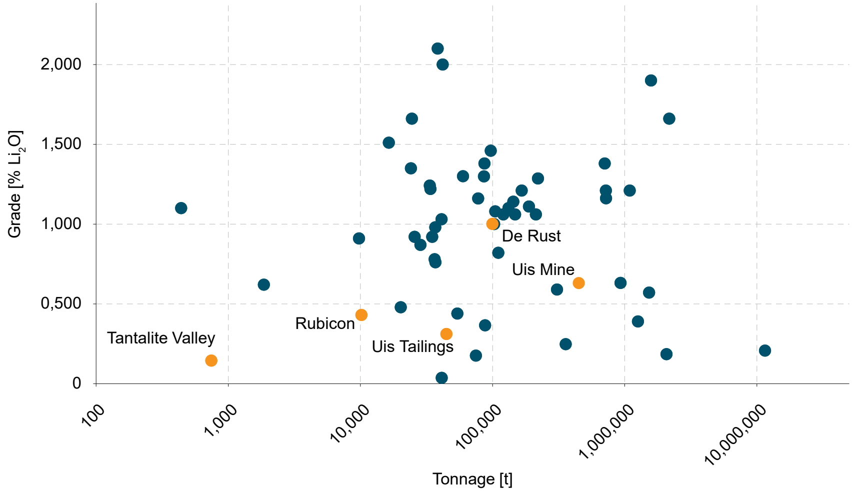
| Sample ID | | Farm | Latitude | Longitude | Sample description (XRD qual.) | $LiO_2$ (%) | $SiO_2$ % | $TiO_2$ % | $Al_2O_3$ % | $Fe_2O_3$ % | MnO % | MgO % | CaO % | $Na_2O$ % | $K_2O$ % | $P_2O_5$ % | $SO_3$ % | Cl % | F % | LOI % | Sum % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2015-03 | previous sample campaigns | Helikon | n. A | | Feldspar/Quartz/Lepidolite | 0,25 | 68,71 | <0.001 | 19,05 | 0,02 | 0,029 | 0,05 | 0,532 | 9,28 | 0,679 | 0,559 | <0.01 | <0.002 | <0.05 | 0,93 | 99,85 |
| 2016-12 | | Rubicon | | | weathered Petalite | 1,26 | 64,73 | <0.001 | 18,06 | 0,07 | 0,327 | 1,86 | 0,795 | 0,78 | 0,525 | 0,062 | <0.01 | <0.002 | <0.05 | 11,46 | 98,71 |
| 2016-17 | | Rubicon | | | Lepidolite + Quartz | 1,30 | 63,67 | 0,02 | 19,93 | 1,6 | 0,929 | 0,03 | 0,054 | 0,29 | 6,218 | 0,052 | <0.01 | <0.002 | 2,62 | 3,27 | 98,67 |
| 2016-20 | | Helikon | | | Lepidolite + Albite | 1,76 | 55,14 | <0.001 | 26,87 | 0,04 | 0,121 | 0,07 | 0,021 | 2,39 | 7,039 | 0,045 | <0.01 | <0.002 | 1,56 | 3,69 | 96,98 |
| 2016-21 | | Helikon | | | Lepidolite | 1,99 | 54,32 | <0.001 | 26,27 | 0,04 | 0,224 | 0,06 | 0,038 | 2,66 | 7,14 | 0,069 | <0.01 | <0.002 | 4,06 | 2,89 | 97,77 |
| FN2019_04 | | De Rust | | | Feldspar/Amblygonite/Petalite (non XRD) | 0,03 | 65,13 | <0.001 | 18,82 | <0.01 | 0,002 | 0,01 | 0,109 | 2,43 | 11,41 | 0,575 | <0.01 | 0,004 | <0.05 | 0,38 | 98,84 |
| 2015-09 | | Molopo | | | Petalite (non XRD) | 0,09 | 52,85 | <0.001 | 16,72 | <0.01 | 0,002 | 4,87 | 0,323 | 3,42 | 0,352 | <0.001 | 0,04 | 0,034 | 0,36 | 21,13 | 100,12 |
| 2016-14 | | Molopo | | | Petalite weathered (non XRD) | 0,07 | 52,16 | 0,003 | 16,51 | 0,02 | 0,051 | 4,78 | 0,589 | 2,34 | 0,645 | 0,069 | 0,02 | 0,086 | 0,22 | 22,63 | 100,13 |
| 2016-15 | | Molopo | | | Feldspar (non XRD) | 0,06 | 64,02 | <0.001 | 19,37 | 0,03 | 0,004 | 0,03 | 0,151 | 2,16 | 12,49 | 0,796 | <0.01 | <0.002 | <0.05 | 0,53 | 99,55 |
| 2016-23 | | Molopo | | | Zinnwaldite (non XRD) | 0,06 | 50,44 | 0,068 | 33,07 | 0,48 | 0,011 | 0,12 | 0,426 | 2,61 | 7,674 | 0,181 | <0.01 | <0.002 | <0.05 | 4,2 | 99,25 |
| 1909249 | 2019 | Uis Tailings | | | Quartz/Feldspar/Petalite/ Muscovite | 0,28 | 72,93 | 0,045 | 14,79 | 0,51 | 0,062 | 0,2 | 1,298 | 3,09 | 2,766 | 1,362 | 0,02 | <0.002 | <0.05 | 2,33 | 99,38 |
| 1909250 | | Uis Tailings | | | Quartz/Feldspar/Petalite/ Muscovite | 0,28 | 72,69 | 0,043 | 14,82 | 0,5 | 0,059 | 0,19 | 1,306 | 3,13 | 2,794 | 1,347 | 0,02 | <0.002 | <0.05 | 2,51 | 99,37 |
| 1909251 | | Helikon 4 | 22°02'48"S | 16°01'30"E | Quartz/Feldspar/Petalite/ Lepidolite | 1,64 | 64,44 | 0,003 | 19,42 | 0,03 | 0,121 | 0,04 | 0,883 | 2,53 | 4,568 | 0,68 | 0,04 | 0,007 | 2,72 | 2,89 | 98,38 |
| 1909252 | | Helikon 1 | 22°02'20"S | 16°01'19"E | Petalite/Lepidolite/Quartz | 2,95 | 76,92 | 0,001 | 16,68 | 0,03 | 0,003 | 0,41 | 0,173 | 0,11 | 0,681 | 0,001 | <0.01 | <0.002 | <0.05 | 2,05 | 97 |

(Continued) Appendix A: Analytical data of lithium samples collected in Namibia. Threshold values highlighted in green.

| Sample ID | | Farm | Latitude | Longitude | Sample description (XRD qual.) | $LiO_2$ (%) | $SiO_2$ % | $TiO_2$ % | $Al_2O_3$ % | $Fe_2O_3$ % | MnO % | MgO % | CaO % | $Na_2O$ % | $K_2O$ % | $P_2O_5$ % | $SO_3$ % | Cl % | F % | LOI % | Sum % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1909253 | 2019 | Rubicon | 22°06'13"S | 15°59'45"E | Petalite/Lepidolite/Quartz | 3,27 | 78,73 | <0.001 | 16,87 | 0,02 | 0,006 | 0,02 | 0,157 | 0,11 | 0,03 | 0,002 | 0,03 | 0,003 | <0.05 | 0,75 | 96,63 |
| 1909254 | | Rubicon | 22°06'10"S | 15°59'41"E | Feldspar/Quartz/Muscovite | 0,04 | 68,2 | <0.001 | 19,35 | 0,03 | 0,024 | 0,02 | 0,506 | 10,08 | 0,868 | 0,43 | <0.01 | <0.002 | <0.05 | 0,41 | 99,85 |
| 1909255 | | Rubicon | 22°06'10"S | 15°59'41"E | Feldspar/Lepidolite/Muscovite/Kaolin | 0,26 | 61,04 | 0,004 | 23,18 | 0,22 | 0,136 | 0,06 | 0,119 | 3,67 | 8,411 | 0,159 | <0.01 | <0.002 | <0.05 | 2,22 | 99,15 |
| 1909256 | | Rubicon | 22°06'10"S | 15°59'41"E | Lepidolite | 2,72 | 49,87 | 0,01 | 29,34 | 0,04 | 0,805 | 0,04 | 0,07 | 0,46 | 9,731 | 0,031 | <0.01 | <0.002 | 0,87 | 4,41 | 95,69 |
| 1909257 | | Rubicon | 22°06'13"S | 15°59'45"E | Petalite/Lepidolite/Quartz | 3,06 | 70,09 | 0,003 | 20,26 | 0,08 | 0,109 | 0,15 | 0,299 | 0,19 | 2,68 | 0,015 | <0.01 | 0,004 | <0.05 | 2,65 | 96,48 |
| 1909258 | | Rubicon | 22°06'10"S | 15°59'41"E | Lepidolite/Feldspar/Quartz | 2,06 | 59,78 | 0,002 | 24,1 | 0,05 | 0,524 | 0,03 | 0,05 | 1,3 | 7,247 | 0,051 | <0.01 | 0,002 | 2,65 | 3,88 | 99,66 |
| 1909259 | | Tantalite Valley | 28°43'09"S | 18°43'55"E | Feldspar/Lepidolite/Muscovite | 1,17 | 62,64 | <0.001 | 21,39 | 0,04 | 0,161 | <0.01 | 0,399 | 7,7 | 3,124 | 0,109 | 0,02 | 0,01 | 1,99 | 1,26 | 98,85 |
| 1909260 | | Tantalite Valley | 28°43'09"S | 18°43'55"E | Feldspar/Lepidolite/Muscovite | 0,30 | 59,86 | 0,014 | 25,13 | 0,16 | 0,422 | 0,03 | 0,228 | 6,05 | 4,722 | 0,139 | 0,02 | 0,009 | 0,41 | 2,37 | 99,56 |
| 1909261 | | Tantalite Valley | 28°43'09"S | 18°43'55"E | Feldspar/Quartz/Muscovite | 0,03 | 63,6 | 0,005 | 22,18 | 0,22 | 0,122 | 0,02 | 0,381 | 7,27 | 3,809 | 0,272 | <0.01 | <0.002 | <0.05 | 1,31 | 99,17 |
| 1909262 | | Tantalite Valley | 28°43'20"S | 18°44'23"E | Quartz/Spodumene/Muscovite | 1,31 | 80,51 | 0,004 | 15,89 | 0,34 | 0,124 | 0,13 | 0,195 | 0,26 | 0,404 | 0,005 | 0,02 | 0,003 | <0.05 | 0,73 | 98,56 |
| 1909263 | | De Rust | 20°57'48"S | 14°30'13"E | Felsdpar/Spodumene/Quartz | 0,74 | 73,13 | 0,006 | 20,48 | 0,07 | 0,15 | 0,05 | 0,154 | 3,98 | 0,831 | 0,073 | 0,01 | 0,003 | <0.05 | 0,82 | 99,74 |
| 1909264 | | De Rust | 20°57'48"S | 14°30'13"E | Spodumene/Feldspar/Quartz | 2,30 | 69,24 | 0,006 | 26 | 0,28 | 0,102 | 0,03 | 0,105 | 1,01 | 0,214 | 0,068 | <0.01 | 0,003 | <0.05 | 0,48 | 97,53 |



*Appendix B: Grade/Tonnage data (Measured & Indicated) for selected lithium projects in comparison to Namibian projects (Source: S&P 09/2020).*



*Appendix B: Grade/Tonnage data (Inferred) for selected lithium projects in comparison to Namibian projects (Source: S&P 09/2020).*

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