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Opinion

Review of Critical Battery Metals Resources in Botswana

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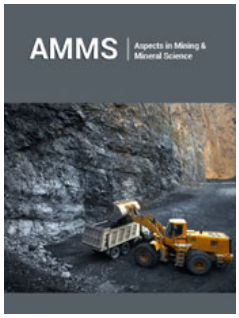
ISSN: 2578-0255



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Submission: February 01, 2023

Published: February 03, 2023

Volume 10 - Issue 5

How to cite this article: Mmilili M Mapolelo*, Biki T Kalake, James Darkwa*, Charles Siwawa. Review of Critical Battery Metals Resources in Botswana. Aspects Min Miner Sci. 10(5). AMMS. 000747. 2023.
DOI: 10.31031/AMMS.2023.10.000747

Opinion

This review covers the mineralization and development status of some of the mineral deposits for Critical Battery Metals (CMBs) resources and reserves found in Botswana. The rapid development of Electric Vehicles (EVs) has led to unprecedent demand for CBMs and other significant battery metals. Currently, lithium-ion batteries are the dominant rechargeable batteries for EVs, with the most common cathodes for EVs batteries being Lithium Cobalt Oxide (LCO), Lithium Manganese Oxide (LMO), Lithium Iron Phosphate (LFP), lithium Nickel Cobalt Aluminum Oxide (NCA) and lithium Nickel Manganese Cobalt Oxide (NMC) [1]. Graphite is widely used as the anode in lithium-ion batteries [1]. It is therefore clear that EV battery chemistries depend on the following five critical minerals: lithium, cobalt, manganese, nickel and graphite, whereas copper is critical for wiring in EVs. In this review we focus on the status available EV relevant mineral resources found in Botswana, the economic viability of proven reserves and development stage of mining reserves and highlight the potential or opportunities to mine and beneficiate the minerals to high purity battery grade materials for EVs.

Nickel-Copper-Cobalt-Platinum group metals (PGM) resources

More than half of global nickel output and 96% of PGM production is linked to sulfide deposits [2]. The north-east of Botswana holds several plutonic magmatic sulfide deposits that have these nickel output and PGM characteristics, including the already exploited Phoenix, Selebi-Phikwe and Selkirk ore bodies [3,4]. For example, the Bamangwato Concession Limited (BCL) Ltd [3,4] at Selebi-Phikwe, the largest of Botswana's magmatic sulfide deposits (circa 31 million tonnes) contains 1.36% Ni, 1.12% Cu, whereas Tekwane the smallest (circa 0.6 million tonnes) contains 1.2% Ni, 0.6% Cu [3]. Some of the deposits, notably at Phoenix, contain concentrations of PGM (circa 5-10ppm) [3]. Mining of the Selebi-Phikwe and Tati deposits to recover nickel and copper has been going on since the 1970s [3,4] and until 2016. BCL operated a smelter that processed copper-nickel concentrate from the company's Selebi-Phikwe mine and also toll-smelted concentrate from the Phoenix mine that was operated by Tati Nickel Mining Company [5]. The matte from the smelter had general composition of nickel- 39%, copper- 35%, cobalt-<1%, iron- 2.5%, sulfur-22% and PGMs- trace [6]. However, both BCL and Tati Nickel mines are currently inactive since 2016 when the parent company, BCL Ltd was placed under liquidation; but efforts by the government of Botswana to reopen the mines are under way. Interestingly, the nickel-copper sulfide deposits have good levels of PGMs, especially at Phoenix mine. For instance, Phoenix mine produced 278,746 tonnes of

concentrate in 2003 from its operation containing 11,509 tonnes of Cu, 8,141 tonnes of Ni, 71 tonnes of Co, 0.102 tonnes of Pd, 0.167 tonnes of Pt, 203 kg of Ag and 29.5 kg of Au. In fact a recent scale up extraction project by Botswana Institute for Technology Research and Innovation (BITRI) and Process Research ORTECH (PRO) in Canada has been able to establish that high purity battery grade nickel and cobalt salts, and copper salt can be extracted from Tati-(Phoenix mine) copper-nickel concentrates; leading to the general conclusion that the magmatic sulfide deposits are rich sources of critical battery materials that position Botswana as a key player in search of critical battery materials. Other notable developments in search of battery metals and PGMs in Botswana is the partnership of Japan Oil Gas and Metals National Corporation and the Australian firm Discovery Metals to jointly explore for platinum and nickel in Dikoloti, North-Eastern Botswana [7]; and a technical report by Kavango Resources that shows that the company's Kalahari Suture Zone (KSZ) has copper, nickel and PGM deposits [8].

Recently, the Kalahari Copper Belt in North-Western Botswana is emerging as a "hotbed" of copper, copper-silver and PGMs mining jurisdiction. The Kalahari Copper Belt, especially Zone 5 deposit being developed by Cupric Canyon Capital (Khoemacau Copper Mining) has found significant high-grade copper deposit with a total mineral resource of 92.4 million tonnes at 2.1% Cu and 22g/tonne Ag (i.e. in-situ and stockpile ore) [9]. The mineralization is predominately bornite, chalcocite, and chalcopyrite [9]. Overall, Khoemacau's total sulfide resource (i.e., from Zone 5, Zeta NE, Zone 5 North, Mango NE2 and Banana & Other Resources) measured, indicated and inferred is estimated to be 451 million tonnes at 1.5% Cu and 18g/tonne Ag, with total contained metal in the ore at 6.6 million tonnes of Cu and 271 million ounces of Ag [9]. Cupric Canyon projections are that the mine will produce more than 155,000 to 165,000 tonnes of high-grade copper concentrate at 38-42% copper content (more than 60,000 to 65,000 tonnes of payable copper metal and 1.8 to 2 million ounces of silver annually) [9]. In June 2021, Khoemacau Copper Mining reported production of the first copper silver concentrate from its Boseto process plant [9]. The overall target of the mine is to produce approximately 100,000 tonnes of copper per annum and 3 million ounces of silver from the high-grade copper silver concentrate by 2025, which will place it amongst the top 10 copper mines in the world [9].

The other pertinent development from Kalahari Copper Belt is from Tshukudu Metals Botswana (Pty) Ltd (a subsidiary of Sandfire Mod Resources) T3 Motheo Copper Mine project that envisages planned output of a 60 million tonnes T3 copper mine and processing plant [10]. The T3 deposit has economically viable quantities/amounts of copper and silver; with projections that it will produce more than 100,000 tonnes of copper concentrate at 30% copper content and 1.1 million ounces of silver annually [10]. Tshukudu Metals Botswana (Pty) Ltd is actively preparing for the development and subsequent operation of the Motheo Copper Mine with construction to commence in 2021 and first production scheduled for 2023 [10]. The above two copper deposits clearly demonstrate the Kalahari Copper Belt, with its high-grade copper discoveries, will soon be the "hotbed" of copper mining in Botswana. Nevertheless, there are new and old copper potentials in other parts of Botswana. One is the Kalahari Key Mineral Exploration Company (Pty) Ltd's promising exploration results for nickel, copper and PGMs in Southern Botswana [11]. On the South-Eastern side of the Kalahari Copper belt, we have African Copper (Mowana Copper mine), currently known as Kopano copper mine. The total measured and indicated reserves for the Kopano deposit is 87.67 million tonnes of copper grading at 0.71%, including total proven and probable reserves for the open-pit standing at 14.8 million tonnes at grading 1.11% copper [12]. In addition, inferred mineral resources total 46.27 million tonnes of 0.63% copper. Since most of the Kopano resources are not within the open-pit zone, the company has commissioned a pre-feasibility study to investigate the viability of an underground mine [12]. Interestingly, cobalt is most often a by-product of either nickel or copper mining production, with just a small percentage coming from primary cobalt sources. As such, all these new copper mines could hold promise for low levels of cobalt, that could be significant and can be extracted with the BITRI-PRO process that was recently used for the scale up extraction of the Tati copper-nickel concentrate mentioned above.

Manganese resources

Manganese ore in 2020 the global manganese market was about 20 million tonnes per annum, but the battery grade market represented only 0.5% of the total manganese consumption [13]. However, with the increase in demand for EV batteries the low demand for battery grade manganese will increase. Giyani Metals Corp's discovery 3 battery-amenable manganese prospects in Kgwakgwe Hill (K.Hill), Otse and Lobatse in Botswana places the country in a position to benefit from the expected increased demand for manganese. Recent exploration results highlight growth from 1.7 million tonnes inferred to 2.1 million tonnes indicated and 3.1 million tonnes inferred resources [13]. It is not stated how much of these tonnages would be from open-pit or underground mining. Nonetheless, the mineral resource estimate for K. Hill, classified according to the Canadian Institute of Mining Best Practice Guidelines [14], shows that material falling within an optimized pit shell representing a long-term price for high purity manganese sulfate monohydrate (HPMSM) of USD 1,588 per tonne, based on 2020 market data. This estimate counters a report by Baldock et al. [15] that K.Hill cannot operate economically; especially if one considers the price of HPMSM, which Giyani metals has already demonstrated can be produced from K.Hill ore and is currently building a 600 kg per day HPMSM demonstration plant as part of its soon to start mining operations at K.Hill [13].

Graphite

The last battery mineral that has recently been discovered in Botswana is graphite. The first natural flake graphite in Botswana was discovered by Tonota Resources Graphite [16]. "With a confirmed 20 km of graphite mineralization out of a potential 100 km, Tonota is shaping up to be amongst the largest deposits amongst global players" reported by Tonota Resources in 2019

[16]. The report further states that "over 75% of Tonota's graphite is in the high-value large, jumbo and super jumbo flake size, along with excellent purity [16]. It is anticipated that the project will be able to supply the booming electric vehicle and expandable graphite markets for a significant length of time" [16]. The resource is estimated or inferred to be 69.9 million tonnes that has 8.82% Total Graphite Content (TGC), which is 5.9 million tonnes contained graphite [16]. However, Tonota Resources has an exploration target of 400-500 million tonnes with 8.0% TGC on the inferred resource. Interestingly, independent quality testing on Tonota's graphite has proven the majority of deposit is battery-grade high flake size and with excellent purity.

Conclusion

This review highlights some of the excellent opportunities that Botswana has for battery material resources, for both mining and beneficiation. Some of these battery materials like nickel and cobalt are amongst those classified as critical battery materials. Botswana should therefore be seen by the EV battery industry as a country that has tremendous potential to the supply chain of battery materials and be seen as a place that could be a hub for EV battery manufacturing and near regional lithium resources.

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