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A CASE STUDY OF THE EPANKO GRAPHITE PROJECT, TANZANIA

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Abstract

Several of the minerals featured on critical minerals lists published by Australia, the European Commission and the United States of America happen to be what the JORC Code regards as Industrial Minerals. Industrial Minerals are those whose variable physical specifications dictate their potential uses and thus their value. With graphite, much of the value lies with its flake size and carbon grade, which helps establish its suitability for different applications. For example, as a refractory (large flake) or battery anode (fine flake) material, with high purity carbon required for optimal performance and lifespan of the anode of lithium-ion batteries. The importance of physical specifications in Industrial Minerals can determine whether a deposit is economically viable or not, hence the requirement to consider these factors, along with other Modifying Factors whilst classifying an Ore Reserve.

Given the reliance on an Ore Reserve when determining the economics of a project, the authors of this paper consider that for Industrial Minerals a minimum portion of Ore Reserves must be Proved and as such, defined within the JORC Code. Thus, better informing companies and individuals involved in Industrial Mineral project evaluation. This becomes of greater significance when considering the elevated level of importance that Modifying Factors are anticipated to have in the forthcoming update to the JORC Code.

This paper takes the Epanko Graphite Project in Tanzania as a case study, where currently 82 % of its total Ore Reserve is classified as Proved, partially dictated by the strong understanding of the metallurgy, physical properties and marketability of the Ore and product, which has been established over the past 12 years.

Analysis was completed on 19 major, publicly listed graphite deposits, of which 15 had declared an Ore Reserve. Results of which demonstrate significant variation amongst peers. At 82 % Proved, Epanko is the only deposit globally with a Proved proportion of Ore Reserve greater than 75 %, and one of only two greater than 50 %. Of the 15 deposits with Ore Reserves, five contained 0 % Proved, and therefore all material classified as Probable, with one of these deposits already in production.

Introduction

The recent increased awareness of which minerals are critical for sovereign capability and continued economic advancement has resulted in attention being drawn to previously unloved minerals. Historically, it has been the classic metallic, non-industrial minerals to receive the majority of attention from explorers, miners and investors; gold, copper, nickel and iron, with fossil fuels at the centre of the energy mix. As the world evolves with regards to geopolitics as well as industrial and environmental ambitions, minerals that previously held a low priority, for

example lithium and natural flake graphite (graphite), have been thrust into the limelight. Several of the minerals featured on critical minerals lists published by Australia, the European Commission and the United States of America happen to be what the JORC Code regards as Industrial Minerals.

Industrial Minerals are those whose variable physical specification dictates its potential uses and thus its value. Taking graphite as an example, where the flake size impacts whether it is suitable as a refractory (large flake) or battery anode (fine flake) material, each of which carry a different valuation. Additionally, carbon purity, and the level and type of impurities dramatically effects the performance and lifespan of graphite battery anodes. Therefore, customers are willing to pay a premium for graphite with a higher carbon grade. The physical specifications of Industrial Minerals can define whether a deposit is economically viable, hence the requirement to consider these, along with other Modifying Factors whilst classifying an Ore Reserve.

Given the reliance on an Ore Reserve when determining the economics of a Project, the authors of this paper consider that, for Industrial Minerals, a minimum portion of Ore Reserves must be Proved and such as, defined within the JORC Code. Thus, better informing companies involved in Industrial Mineral project evaluation.

This paper takes the Epanko Graphite Project (Epanko or the Project) as a case study, where 82 % of the total contained graphite in the Ore Reserve is classified as Proved, partially dictated by the strong understanding of the metallurgical, physical properties and marketability of the Ore and its products.

Project Location and Accessibility

Epanko is located 6 km South-West of the town of Mahenge, in the Ulanga district of the Morogoro region of Tanzania. The country's commercial hub and largest city; Dar es Salaam, is approximately 350 km northeast of the Project area. The city of Dar es Salaam is strategically positioned on the Tanzanian coast of the Indian Ocean, and home to East Africa's second busiest port, a key link in the logistical chain for the Project. The city is connected to the Project area with a tarmac road running from Dar es Salaam, to within 65 km of the Project, after which, a well-maintained unsealed road takes over.

Project History

Epanko is held under the Duma TanzGraphite joint venture, of which Australian publicly listed company; EcoGraf Limited (EcoGraf) owns 84 % and the Government of Tanzania 16 %, following the April 2023 signing of a framework agreement between the two parties.

Graphite was first recorded at Epanko by the German colonial government in 1914, with trenching completed by a Czech mineral exploration company in 1959. The Epanko mineral licenses were secured by EcoGraf (previously Kibaran Nickel) in 2011, via local subsidiary Tanzgraphite (TZ) Limited, with initial exploration commencing in 2012. Over the following 12 years, including a Project hiatus between 2017 and 2022, the deposit was taken to its current pre-development stage (total drilled 19,391.4 m), with a Mineral Resource of 290.8 Mt at 7.2 % Total Graphitic Carbon (TGC), the largest development ready graphite Mineral Resource in Africa (EcoGraf, 2024a) and Ore Reserve of 14.3 Mt at 8.8 % TGC (EcoGraf, 2024b).

Geology

The Project lies within the vast Neoproterozoic Mozambique belt, which forms part of a composite Proterozoic Mountain building period stretching from the Arabian-Nubian shield to the East Antarctica through East Africa and Southern Mozambique (Jacobs et al., 1998). The closure of the Mozambican Ocean during the Neoproterozoic and Cambrian periods resulted in the formation of this north-south trending orogenic belt (Shackleton, 1996). The belt in Tanzania is divided into two parallel sections, the Eastern Granulites and Western Granulites based on protoliths dating (Frietz et al., 2009, Leger et al., 2015). The two domains are separated by flat thrusts and sedimentary basins of young age.

Epanko is located within the Mahenge Mountains, in the western margin of the Eastern Granulite domain. The Eastern Granulite terrane contains anorthosites dating from 900 to 700 million years ago, as well as a metasedimentary sequence. This sequence includes the Epanko graphite deposit and several marble layers. However, part of the mountains have the same affinity of those of the Western domain where amphibolite orthogneisses, amphibolites and paragneisses dominate (Johnson et al., 2003). Both domains are bounded by major tectonic contacts and based on metamorphic ages, the peak metamorphism in the Eastern and Western domains occurred at 640 Ma and 560 Ma respectively (Moller et al., 2000, Leger et al., 2015, Apen et al., 2020).

The Epanko deposit is comprised of metasedimentary units, with the graphite Mineral Resource attributed to a graphite-quartz schist, where graphite concentration ranges between 3 to 30 %. The surrounding waste rock units include quartz-feldspar schist, quartz-garnet gneiss, dolomitic marble, amphibolite and metamorphosed granitoids.

Natural Graphite Occurrence

Graphite is a crystalline, grey to black, opaque, very soft allotrope of carbon. Considered as the most stable form of carbon under standard conditions (Puronaho, 2018), graphite occurs naturally exhibiting both metallic and non-metallic properties making it useful for diverse industrial applications.

Industrially, natural graphite is used in refractories, electrodes, batteries, brake linings, and steel making (Shaw, 2013). These vast applications are attributed to graphite's properties of being a good conductor of heat and electricity. Furthermore, graphite is valued industrially for its self-lubricating and dry lubricating properties. Many of these end uses, including refractory, expandable graphite and lubricants, require the large flake graphite in order to achieve the required physical properties of the products. Globally, fine flake graphite is more prevalent, with the scarcity of large flake being one factor that results in it carrying a higher price, as well as the high technicality and cost involved large flake production.

Geologically, natural graphite occurrences can be categorised into; flake graphite usually disseminated in gneiss or schist (in the case of Epanko), vein or lump graphite in magmatic rocks (Puronaho, 2018) and lastly, amorphous graphite formed by metamorphism of carbon rich sediments (Simandl et al., 2015).

Metamorphic rocks are the common host of graphite where organic materials in sedimentary rocks are heated and compressed to produce graphite. This process is believed to be responsible for the disseminated graphite mineralisation seen at Epanko. Alternatively, precipitation of carbon from hydrothermal fluids is thought to be the formation mechanism of vein hosted graphite, as seen in Sri Lanka (Simandl et al., 2015).

At present China dominates the mining and production of both natural flake graphite and Spherical Graphite (SpG). Global demand for natural graphite is expected to increase by 2030, driven by the rapid expansion of lithium-ion batteries used in electric vehicles and energy storage systems in North America, Europe and Asia. As electrification accelerates across the transport and energy sectors, lithium batteries are becoming central to this transition, placing increasing strategic importance on developing new technologies and supply channels. Forecasts show that approximately 2.5 Mt of natural graphite is required for battery demand which will represent 81 % of the market. Graphite will play a pivotal role in supporting global decarbonisation objectives and the scaling of clean energy technologies. (EcoGraf, 2024c)

Mineral Resource and Ore Reserve

The Epanko Graphite Project boasts the largest development-ready graphite Mineral Resource in Africa, totalling 290.8 million tonnes (Mt) at 7.2 % TGC, containing 21,010 thousand tonnes (kt) of graphite (EcoGraf, 2024a). The Resource is classified under the JORC Code 2012, with 88 Mt at 7.6 % TGC considered Measured and Indicated, providing a high degree of confidence. A significant Inferred Mineral Resource of 202.8 Mt at 7.2 % TGC also exists, demonstrating the potential for future upgrades and expansion of the Project's defined Resources.

TABLE 1 - March 2024 Mineral Resource Estimate for the Epanko Deposit >5.5% TGC (EcoGraf, 2024a)

JORC Classification	Tonnage (Mt)	Grade (%TGC)	Contained Graphite (kt)
Measured	32.3	7.8	2,500
Indicated	55.7	7.5	4,200
Measured + Indicated	88.0	7.6	6,710
Inferred	202.8	7.2	14,310
Total	290.8	7.2	21,010

Epanko has a total Ore Reserve of 14.3 Mt at 8.8 % TGC, of which 11.7 Mt in Proved and 2.6 Mt Probable. The Project's Ore Reserve supports Epanko's 18 year Life of Mine (LOM) Bankable Feasibility Study which included extensive metallurgical testing and flowsheet design, mining optimisation, environmental and social considerations, and detailed infrastructure and process plant engineering. This comprehensive approach supports reliable capital and operating cost estimates and enhances confidence in financial projections. Epanko's Ore Reserves are based solely on Measured and Indicated Mineral Resources, excluding Inferred Resources, which are treated as waste.

TABLE 2 - July 2024 Ore Reserve Statement for the Epanko Deposit (EcoGraf, 2024b)

JORC Classification	Proved			Probable			Total		
	Tonnes (Mt)	Grade (% TGC)	Cont. (kt)	Tonnes (Mt)	Grade (% TGC)	Cont. (kt)	Tonnes (Mt)	Grade (% TGC)	Cont. (kt)
Oxide	8.9	9.0	805	0.2	8.4	15	9.1	9.0	820
Transitional	1.0	8.0	79	0.8	8.3	65	1.8	8.1	144
Fresh	1.8	8.3	149	1.6	8.6	140	3.4	8.4	289
Total	11.7	8.8	1,033	2.6	8.5	220	14.3	8.8	1,253

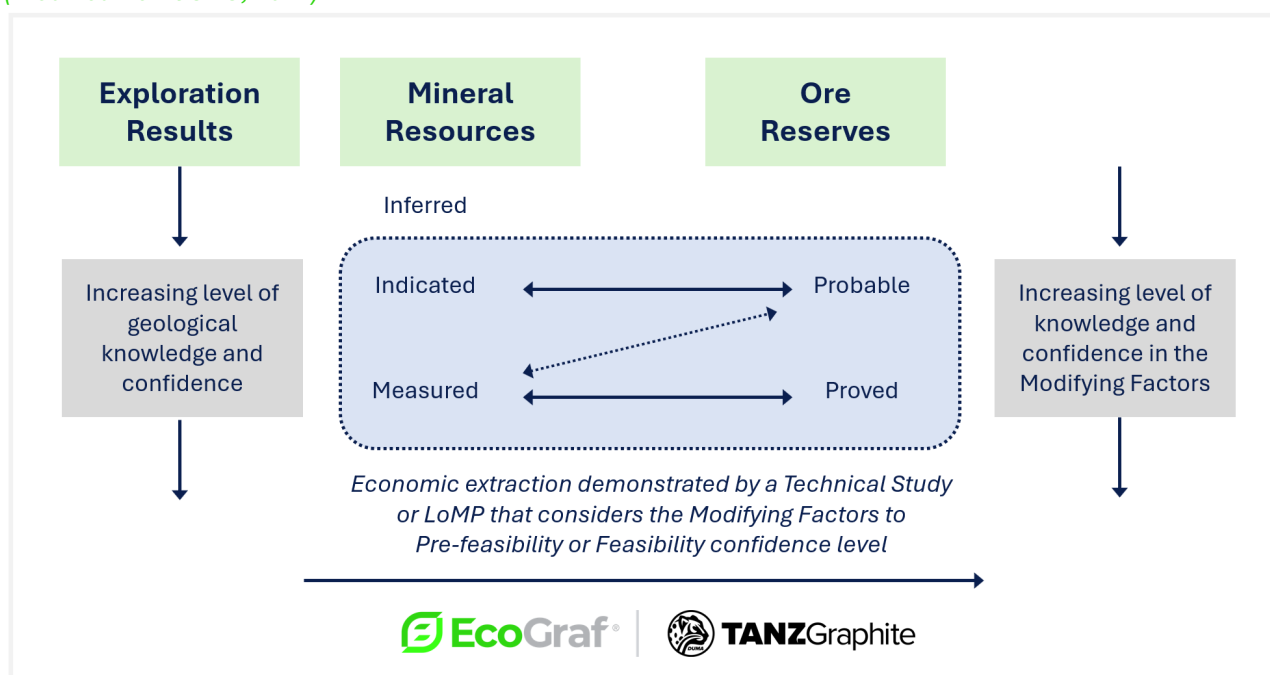
The combination of the extensive multi-disciplinary studies for Epanko, along with the confidence provided by the Project's European and Asian offtake partners, helps support the classification of the Epanko Ore Reserve, with a market leading 82 % of contained graphite as Proved.

The Importance of Proved Ore Reserves for Industrial Minerals

The conversion of Mineral Resource to Ore Reserve and subsequent classification takes into account both the geological knowledge and confidence, as well as consideration of various Modifying Factors. Modifying Factors are defined by the JORC Code as considerations used to convert Mineral Resources to Ore Reserves. These include, but are not restricted to, mining, processing, metallurgical, infrastructure, economic, marketing, legal, environmental, social and governmental factors.

Due to Industrial Mineral deposits economic viability being as much related to the products physical specification as it is the deposit's size and grade, the importance of several of the Modifying Factors is further elevated when compared to non-Industrial Minerals.

FIG 1 - General relationship between Exploration Results, Modifying Factors, Mineral Resources and Ore Reserves (modified from JORC, 2024).



It is this point surrounding the extra importance of Modifying Factors, when it comes to Industrial Minerals that is the support for the argument that all Industrial Mineral Ore Reserves should have a minimum portion classified as Proved, in order for an Ore Reserve to be declared. This becomes of greater significance when considering the elevated level of importance that Modifying Factors are anticipated to have in the forthcoming update to the JORC Code.

Without in-depth consideration of Modifying Factors for Industrial Minerals, with particular focus on metallurgy and marketing, an Industrial Mineral deposit's economic viability can vary greatly.

Ore Reserves are a fundamental input in evaluating the economic viability of a mining project. Consequently, defining a minimum portion of Proved Ore Reserves, rather than predominantly Probable Ore Reserves, strengthens the reliability of project economics and reduces risk.

Unlike precious metals, base metals and bulk commodities, the value of Industrial Minerals is highly sensitive to:

- Physical and chemical characteristics
- End-user requirements
- Market-specific specifications
- Downstream processing capabilities

Projects can show apparently favourable resource quantities but fail commercially if their product does not meet market needs.

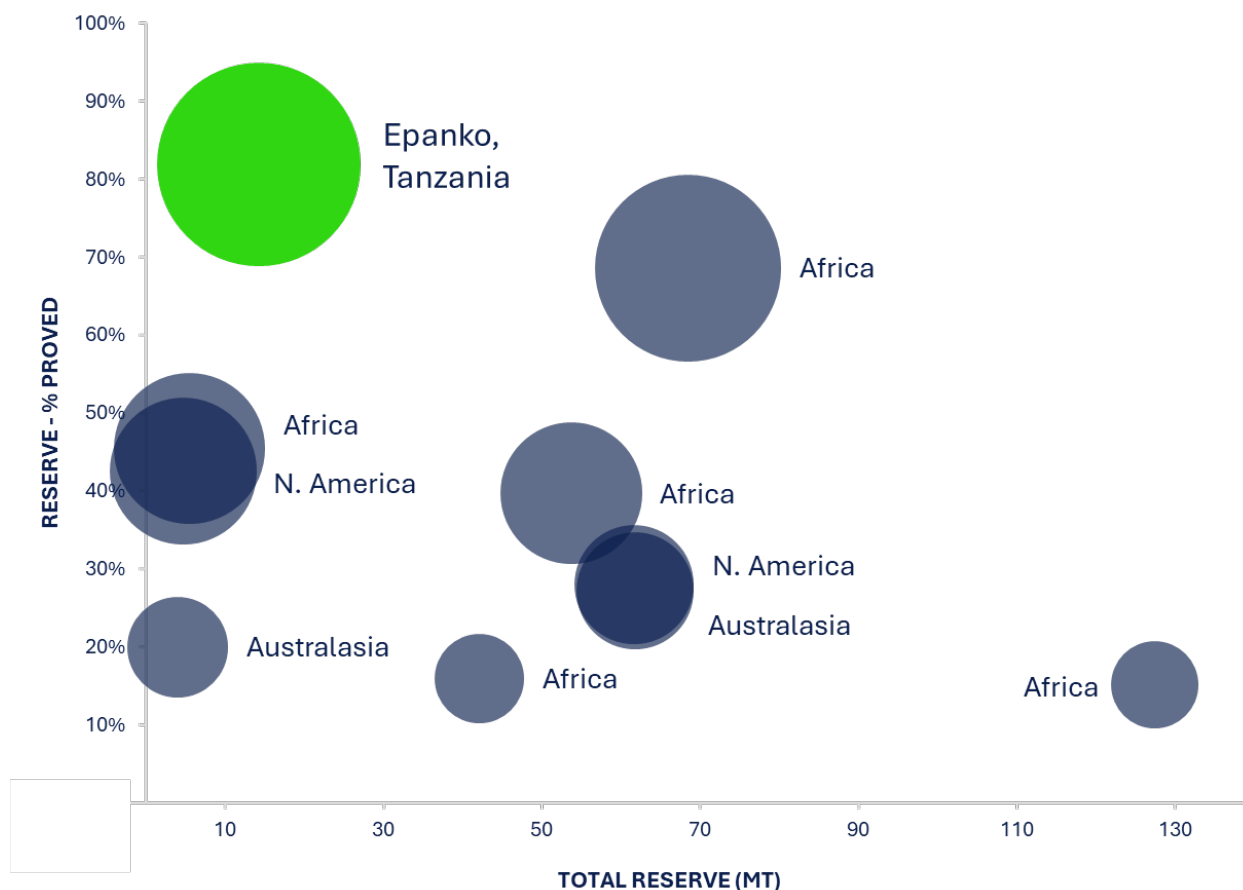
The JORC Code requires that Modifying Factors, such as metallurgical recoveries, product specifications, marketing, and pricing, are reasonably well-defined and justifiable when converting a Resource to an Ore Reserve. In Industrial Minerals, these factors carry elevated importance because they directly affect saleability and pricing.

The Project's chosen route for development financing has been through Germany's KfW IPEX-Bank, with a German Government loan guarantee. This high-quality financing approach has necessitated the highest level of technical, environmental, social and financial due diligence to meet the strict requirement of a bank of KfW IPEX-Bank's stature. A positive result of this has been the elevated quality and quantity of work put into the various disciplines for the Project, which are also those considered to be Modifying Factors by the JORC Code. This, when coupled with the geological confidence that the Measured Mineral Resource provides, has allowed for the market leading classification of 82 % of the Ore Reserve as Proved, ensuring the Project financier has the highest level of confidence prior to execution.

Analysis was completed on 19 major, publicly listed graphite deposits, of which 15 had declared an Ore Reserve. At 82 %, Epanko is the only deposit globally with a Proved proportion of Ore Reserve greater than 75 %, and one of only two greater than 50 %. Of the 15 deposits with Ore Reserves, five contained 0 % Proved, hence not visible on Figure 2 (including projects in Australia, Sweden, Mozambique and Tanzania), with all material classified as Probable. One of these deposits with 0 % Proved Ore Reserves is already in production. The graphite industry

has experienced multiple mine closures in recent years which has elevated the importance of sufficient due diligence in the sector to ensure that necessary supply is established to facilitate the desired commodity independence from China.

FIG 2 - Proportion of Proved Material in the Ore Reserves for Major Global Graphite Deposits (host region labelled)



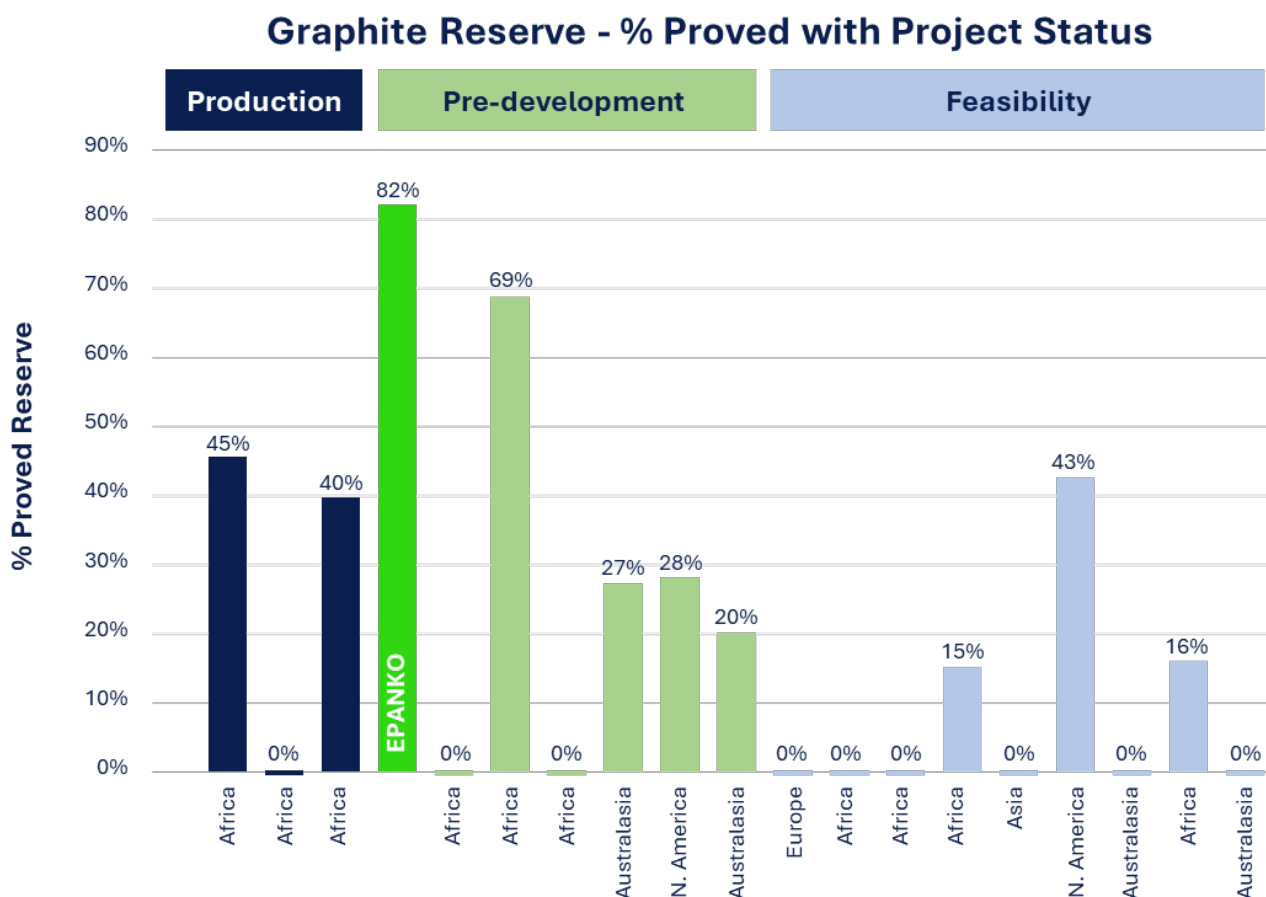
The risks of the lack of sufficient Proved material in an Ore Reserve have been recently realised at operating graphite mines in North America, Africa, Europe and Asia Pacific regions, where insufficient understanding of a project’s deposit, processes and end users resulted in product which did not meet the customers stringent requirements for flake size and carbon grade.

The graphite sector has seen mine closures across multiple jurisdictions where variations in aspects relating to Modifying Factors have resulted in unviable operations. Examples include greater than expected impurities in the Ore and resultant graphite product, carbon grades of the product being below standard, insufficient high-value large flake material, poor segregation of the varying flake sizes and challenges with meeting production capacity.

Prior to development, a greater understanding of these project’s Modifying Factors, including the metallurgical process that delivers the final flake distribution and carbon grade, and its sale and marketing, would have provided the opportunity to better factor these considerations into the operations design and capacity. The lack of sufficient Proved material, can result in an

operationally flawed project, highlighting the criticality and real-world importance of this discussion, elevating the need for changes in regulations.

FIG 3 - Graphite Ore Reserves - % Proved with Project Status and Project Location



Conclusion

As the recognition of the importance of Modifying Factors grows, so too does the importance of the percentage of Proved within Ore Reserves, no matter what the mineral. At this stage, the focus is on Industrial Minerals, given the added importance that Modifying Factors hold in their economic viability, when compared to non-Industrial Minerals. The authors of this paper consider that, for Industrial Minerals, a minimum portion of Ore Reserves must be Proved and as such, defined within the JORC Code.

A minimum of 40 to 50 % Proved in Ore Reserves would be good starting point for regulations, whilst also stating that a higher percentage is encouraged due to its ability to lower the risk to commercial success of a new operation. By enforcing a mandatory minimum Proved Ore Reserve component for Industrial Mineral projects:

- Investors are better informed,
- Projects will be more likely to progress based on credible technical and commercial evidence,
- The industry will benefit from greater consistency and rigour in how Industrial Mineral assets are evaluated and communicated to the market.

EcoGraf's Epanko Graphite Project in Tanzania, demonstrates that by following a thorough path of technical studies and due diligence, a project can establish itself where the majority of its Ore Reserve is classified as Proved, greatly reducing the risk carried by investors and financiers. In turn, these changes will have the effect of improving the attractiveness of investment into the mining sector, at a time when development financing for junior and medium scale mining companies is becoming increasingly difficult to secure.

Without change, the industry faces a situation where technically flawed projects continue to gain access to financing, and risk resulting in failed operations. Further failed operations have the potential to drive investors away from the industry, opting to focus on sectors where returns carry lower risk and quicker turnaround. A situation like this, at a time when the global requirement for minerals is continuing to increase, carries profound risks that will impact all in society, and not just mining professionals.

Given the critical role of Ore Reserves in supporting the economics of a project and the nuanced characteristics of Industrial Minerals, a requirement for a minimum proportion of Proven Ore Reserves is a reasonable safeguard. It would enhance the transparency and integrity of reporting, particularly in light of the expected emphasis on Modifying Factors in the forthcoming JORC Code update. This shift aligns with broader efforts to improve investor confidence and the quality of technical disclosures in the industrial minerals sector.

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