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Review Article

Strategic Evaluation of Rare Earth Metals Resources in Africa: Geological Potential, Economic Viability, and Investment Risk Landscape

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Abstract

This study presents a strategic evaluation of rare earth metal (REM) resources across Africa, with a focus on their geological potential, economic viability, and investment risk landscape. As global demand for critical minerals intensifies due to the transition toward green technologies and digital infrastructure, Africa's REM endowment offers a timely and potentially transformative development opportunity. The study synthesizes geological data from major carbonatite and alkaline complexes in countries such as Malawi, Namibia, South Africa, Burundi, and Nigeria, highlighting their unique rare earth element (REE) mineralization profiles, ranging from light REE-rich monazite deposits to heavy REE-enriched xenotime systems. Economic analysis incorporates feasibility studies, market projections, and policy assessments, illustrating both the revenue generating potential of African REM projects and the structural limitations such as low downstream processing capacity and regulatory inconsistencies. The role of geopolitical factors is explored through case studies like Gakara (Burundi), where high-grade resources remain underexploited due to political instability and export restrictions. The study also assesses regional and continental policy frameworks, including the African Union's Africa Mining Vision and initiatives by institutions, which aim to harmonize mining regulations and promote value addition through beneficiation and local content. By integrating geological, economic, and governance dimensions, the study emphasizes that Africa's competitiveness in the global REM market will depend not only on its mineral wealth but also on strategic coordination, institutional reform, and sustainable development planning. The findings serve both technical experts and policy stakeholders seeking to understand how Africa can transition from a raw material supplier to an integrated player in the global REM value chain.

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Introduction

Rare earth metals (REMs), comprising the 15 lanthanide elements along with scandium and yttrium, have emerged as indispensable components in the global transition towards digitalization, clean energy, and advanced defense systems (Castor, 2008; Castor & Hedrick, 2006). Their unique magnetic, luminescent, and catalytic properties make them critical to the manufacture of permanent magnets in electric vehicles and wind turbines, phosphors in lighting and displays, catalysts in petrochemical refining, and guidance systems in modern military applications. Despite their ubiquity in modern technology, REMs are mined and processed in only a few regions of the world, with China currently controlling over 60% of global production and more than 85% of downstream processing capacity (Wall, 2014; USGS, 2022). This monopolization has raised significant geopolitical and economic concerns, prompting industrialized and emerging economies alike to diversify their supply chains.

Africa has recently gained attention as a potential frontier for REM exploration and production. The continent is endowed with a wide array of geodynamic provinces, including ancient cratons, mobile belts, and rift-related alkaline complexes, geological settings that are known globally to host rare earth mineralization. Countries such as South Africa, Malawi, Namibia, and Burundi already possess identified REM resources at varying stages of development, while others remain underexplored due to historical underinvestment, infrastructural limitations, and political uncertainty. However, as global demand surges and critical mineral strategies take shape worldwide, Africa's potential role in the rare earth sector has become increasingly relevant (Olasehinde et al., 2024)

The significance of rare earth development in Africa extends beyond mere resource extraction. Strategically, REMs present an opportunity for economic diversification, foreign exchange generation, industrial development, and geopolitical positioning (Castor & Hedrick, 2006). . Yet realizing this potential is not without challenges. High capital costs, volatile commodity prices, technological complexity, and regulatory ambiguity continue to hinder investment and project advancement. Moreover, most African countries lack comprehensive critical mineral policies that can integrate rare earth mining into broader industrialization agendas.

This study adopts a multidisciplinary approach to investigate the rare earth landscape in Africa, examining geological settings, exploration status, and economic viability while situating these within regional policy and strategic contexts. Specifically, it integrates geological mapping and mineral occurrence data with exploration economics and project risk analysis, using key case studies in Africa to illustrate varying developmental trajectories. Through this integrated lens, the study assesses Africa's readiness to participate meaningfully in the global rare earth supply chain and offers policy recommendations to strengthen the continent's competitive position.

Geological Context and Mineralization Styles

Africa's vast and diverse geological landscape provides a highly prospective environment for the occurrence of rare earth metal (REM) deposits. The continent's lithospheric structure encompasses ancient cratonic blocks, Pan-African mobile belts, and younger volcanic and sedimentary basins, all of which host a range of mineral deposit types (African Union Commission, 2009). Rare earth elements (REEs), a subset of critical minerals, are distributed across these varied geological settings in forms that significantly influence their extractive feasibility and economic value.

The geological evolution of Africa (Figure 1) includes major Precambrian cratons such as the Kaapvaal, Congo, and West African Craton; Neoproterozoic mobile belts such as the Pan-African orogenic systems; and Cenozoic rift-related volcanic provinces, particularly in East Africa (Gubanov & Mooney 2009). Each of these tectonic domains offers distinct mineralization potential for REMs.

Carbonatite intrusions, alkaline igneous complexes, and associated hydrothermal systems are particularly favorable environments for REE enrichment (Harmer & Nex, 2016). These geological settings are typically associated with tectonothermal events that promote magma differentiation and fluid enrichment, leading to the concentration of rare earth-bearing minerals like bastnäsite, monazite, and xenotime (Migdisov & Williams-Jones, 2014). Among the most economically significant REM-hosting geological units in Africa are carbonatites and alkaline igneous complexes. These occur predominantly in the East African Rift System, where tectonic extension facilitates deep mantle-derived magmatism.

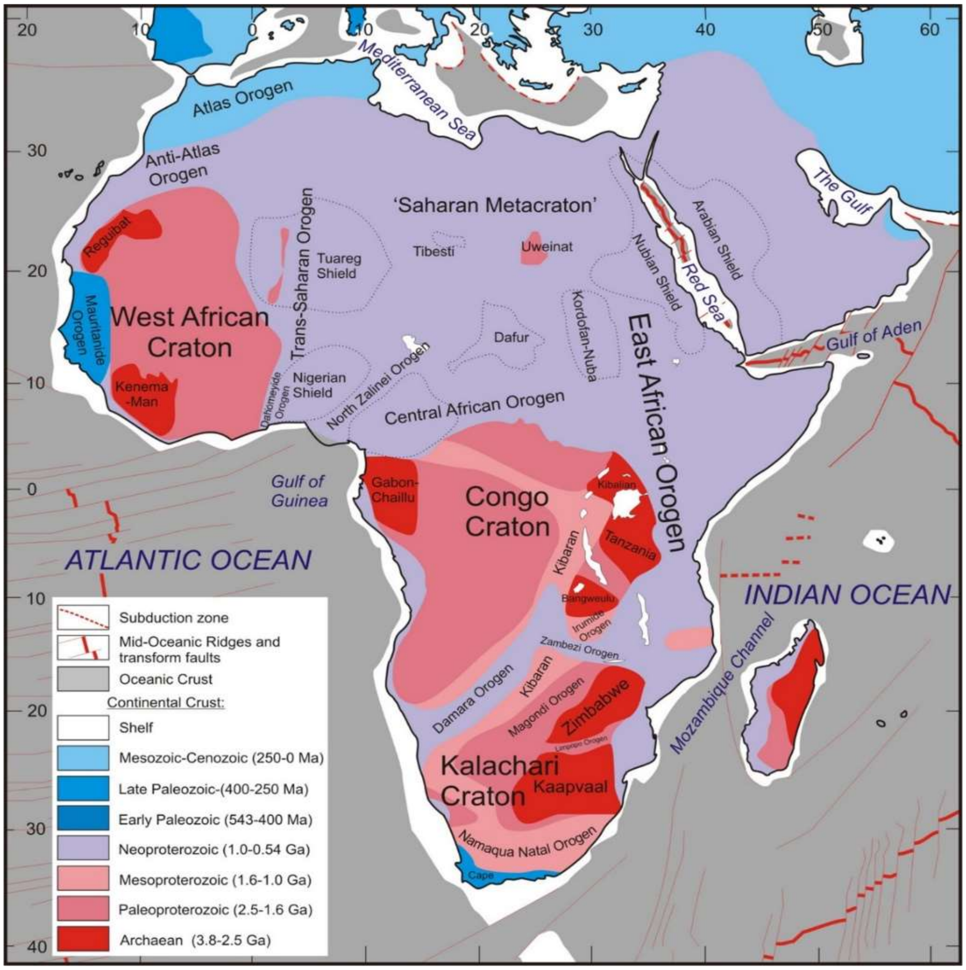

Figure 1 Age of African crustal basement (after Gubanov & Mooney 2009).

Carbonatite-Hosted Rare Earth Element Mineralization at Songwe Hill, Chilwa Alkaline Province, Malawi

Songwe Hill in Malawi is a prominent example, hosted within the Chilwa Alkaline Province. The deposit is enriched in light REEs (LREEs), particularly lanthanum, cerium, and neodymium, with mineralization occurring in bastnäsite and synchysite within carbonatite breccias and fenitized rocks (Broom-Fendley et al., 2014; Goodenough et al., 2017). The Songwe Hill carbonatite (Figure 2) is a prominent rare earth element (REE)-bearing intrusion situated along the western margin of the Mauze nepheline syenite complex in southern Malawi. Both Songwe and Mauze are constituents of the Chilwa Alkaline Province (CAP), a Mesozoic tectonomagmatic province characterized by widespread alkaline and carbonatitic magmatism. Geochronological data from zircon U-Pb dating (LA-ICP-MS) places the emplacement of both the nepheline syenite and the

Songwe carbonatite between 140 and 130 million years ago (Broom-Fendley et al., 2014), firmly anchoring them within a genetically related magmatic suite (Woolley, 2001).

Songwe Hill itself is a vent-like intrusion, approximately 800 meters in diameter, and is composed of a heterogeneous assemblage of feldspathic breccias, agglomerates, and arcuate carbonatite sheets. These carbonatites were emplaced in multiple intrusive phases, transitioning from early-stage calcite-carbonatites to more evolved ankerite-carbonatites, with late-stage ferroan-carbonatite dykes and veins representing the terminal magmatic activity (Croll et al., 2014). The structural geometry of the complex suggests polyphase magmatic activity with overlapping intrusive pulses, each distinguished by mineralogical and geochemical signatures.

The surrounding country rocks, primarily Proterozoic gneisses have undergone extensive metasomatic alteration to form fenites. These fenites, resulting from alkali-rich fluid interaction during carbonatite emplacement, are dominated by K-feldspar and exhibit distinctive pale-red coloration. More sodic fenites, rich in albite and nepheline, are observed to the north at Chenga Hill, indicating a compositional gradient in metasomatic alteration products (Swinden & Hall, 2012).

The calcite-carbonatites**,** which dominate the intrusion, occur as massive to irregular bodies and are emplaced in multiple intrusive phases. Early calcite-carbonatites are typically coarse-grained and consist of calcite with accessory apatite, zircon, and minor REE-bearing phases. Later generations are enriched in Fe and Mn, and contain ankeritic carbonate, Fe-oxides, Mn-oxides, fluorite, pyrite, and K-feldspar (Croll et al., 2014; Broom-Fendley et al., 2014; Broom-Fendley, 2015). These mineralogical assemblages indicate progressive magmatic differentiation and evolving fluid composition, potentially enhancing REE enrichment during later stages of emplacement. The ankerite-carbonatites manifest predominantly as thin, sheet-like dykes, veins, and breccias that cross-cut earlier lithologies. These are mineralogically distinct, composed mainly of ankerite with subordinate calcite, fluorite, pyrite, quartz, and REE-fluorocarbonates such as bastnäsite and synchysite. These later intrusions are of particular economic interest due to their higher concentrations of critical REEs, including neodymium and praseodymium.

Breccia zones within Songwe are lithologically complex and can be subdivided into two main types:
(i) *Feldspar-rich breccias*, composed of angular fragments of fenite, nepheline syenite, and minor calcite-carbonatite set within a matrix rich in Fe- and Mn-bearing carbonates.

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(ii) *Carbonate-rich breccias*, consisting of clasts of fine-grained calcite-carbonatite and minor fenite, hosted in a carbonate-dominated matrix, often exhibiting hydrothermal overprinting (Swinden & Hall, 2014).

Late-stage phonolitic dykes have also been observed in drill cores, representing evolved magmatic phases likely associated with residual melt or fluid activity toward the waning stages of intrusion (Swinden & Hall, 2012). It is hypothesized that the fenitised zone at the crest of Songwe Hill marks a magmatic roof zone, reflecting the uppermost expression of metasomatic alteration caused by degassing magmas and associated volatile-rich fluids. This interpretation is supported by the zonal distribution of fenites and the presence of late-stage, REE-enriched hydrothermal veins, indicating post-magmatic fluid circulation and mineralization.

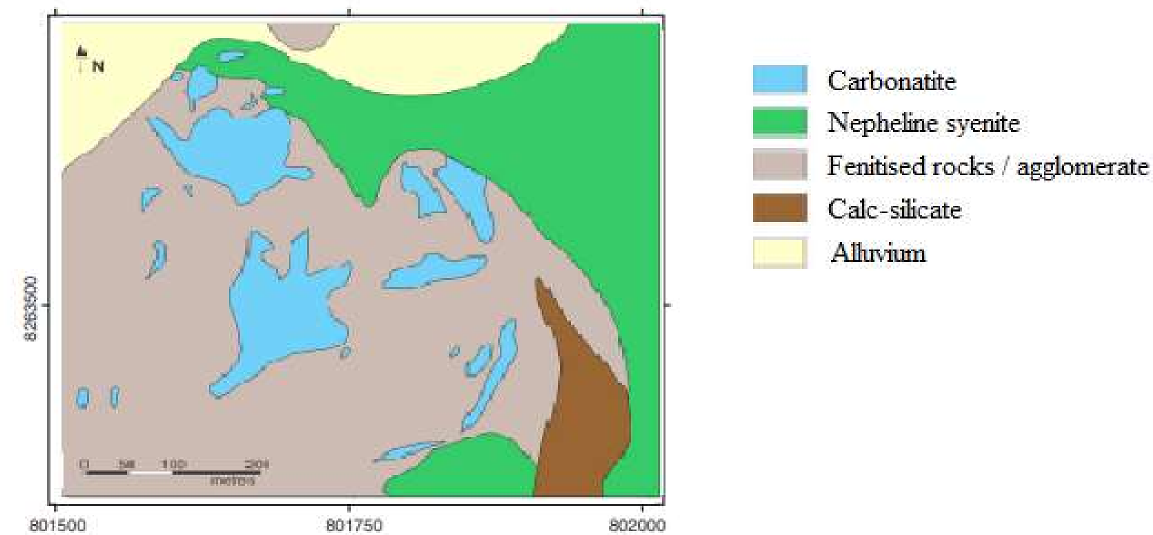

Figure 2. Simplified geological map of the Songwe Carbonatite (modified after Swindon & Hall, 2012; Croll, et al., 2014).

The Ngualla Weathered Carbonatite: A Major Neodymium-Praseodymium Rare Earth Deposit in Tanzania

Ngualla in Tanzania, one of the largest undeveloped REE projects globally, is hosted in a weathered carbonatite ring complex, with high LREE grades and low radioactive elements, making it attractive for open-pit mining (Peak Rare Earths, 2022).

The Ngualla Rare Earths Project, situated near Ngwala Village approximately 147 kilometers north of Mbeya in southern Tanzania, is one of the world's largest undeveloped rare earth deposits, particularly rich in neodymium (Nd) and praseodymium (Pr), two critical components for permanent magnet production in

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electric vehicles, wind turbines, and other clean energy technologies. The deposit is hosted within the Ngualla carbonatite complex, a late Mesoproterozoic, sub-circular, pipe-like intrusion emplaced along the margin of the East African Rift System. The complex is part of a broader suite of alkaline and carbonatitic intrusions associated with mantle-derived magmatism and crustal extension during the breakup of the supercontinent Rodinia (Witt,et al., 2019).

The Ngualla carbonatite comprises a central magnesiocarbonatite plug, surrounded concentrically by annular calcite-carbonatite and an outer ring of fenitized felsic country rocks, indicative of intense metasomatic alteration during and after emplacement (Figure 3). The complex includes three major carbonatite phases, calcite carbonatite, ferroan dolomite carbonatite, and magnesiocarbonatite as well as three principal silicate-rich igneous phases, notably ultramafic intrusions and two varieties of glimmerite (phlogopite-rich rocks), interpreted to be either residual magmatic phases or metasomatically altered xenoliths derived from surrounding rocks (Lukowski et al., 2013). Mineralization at Ngualla is interpreted to have originated from igneous differentiation processes that concentrated rare earth elements (REEs), fluorine, barium, and silica in residual melts and late-stage cavities. The primary REE-bearing minerals are bastnäsite and synchysite-group minerals, with bastnäsite being the dominant economic phase in both fresh and weathered zones. These minerals occur in association with barite, fluorite, apatite, quartz, and magnetite, especially within miarolitic cavities of the magnesiocarbonatite and along brecciated zones (Lukowski et al., 2013).

Post-magmatic weathering played a key role in enhancing REE grades. Extensive tropical weathering and partial erosion leached calcium and magnesium carbonates ($CaCO_3$ and $MgCO_3$), particularly from ferroan dolomite phases, resulting in a residual goethite-rich saprolite enriched in REEs. This supergene enrichment has led to Total Rare Earth Oxide (TREO) concentrations ranging from 3% to 6% in weathered zones, compared to 1–2% TREO in unaltered primary carbonatite (Lukowski et al., 2013; Hoatson et al., 2011). The bastnäsite in the weathered zone is interpreted to have replaced primary synchesite during alteration, while barite remained stable, contributing to the bulk of the mineral residue.

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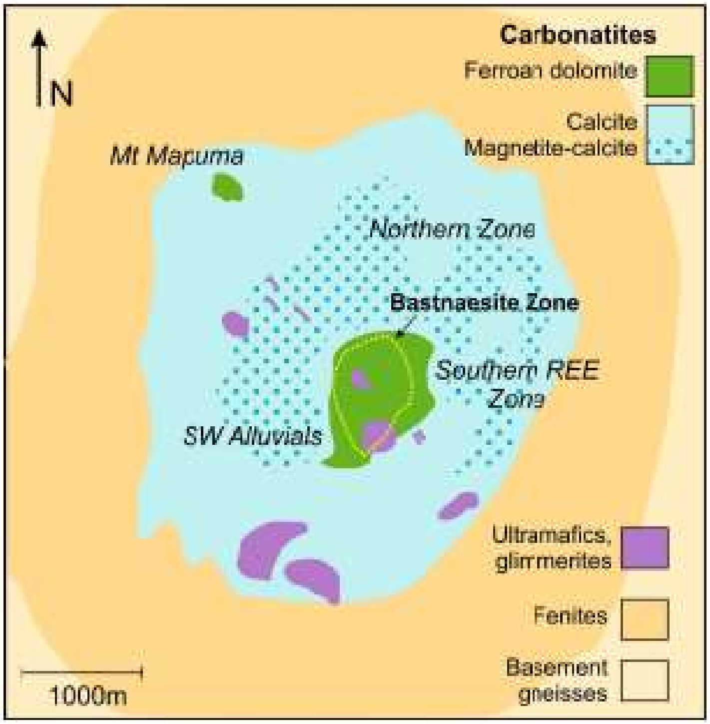

Figure 3. Geological map of the Ngualla Hill Carbonatite (modified from Peak Resources, 2014)

Three primary mineralized zones have been delineated at Ngualla:

(a) Southern Rare Earth Zone (SREZ): Hosting the highest-grade mineralization, including the Bastnäsite Zone (within both fresh and weathered carbonatite) and a subordinate Monazite Zone.
(b) Southwest Alluvials (SWA): A zone of colluvial and eluvial concentration of REE-bearing material from the erosion of upslope carbonatite bodies.
(c) Northern Zone (NZ): Characterized by more variable mineralization, partly associated with primary lithologies and structural controls.

Petrogenetic interpretations indicate that ultramafic intrusions were emplaced syn-magmatically into the magnesiocarbonatite before its complete solidification, facilitating magma mingling and complex textural relationships. Rounded hematite-barite enclaves within the magnesiocarbonatite are interpreted to be products of magma immiscibility. After the crystallization of the main intrusive phases, late-stage magnesiocarbonatite and ultramafic dykes, some exhibiting diatreme textures, intruded the complex, signaling continued volatile-driven magmatic activity.

Notably, the Ngualla genetic model departs from many other African REE carbonatite systems such as those in the Chilwa Alkaline Province (Malawi) which are often dominated by late-stage hydrothermal REE enrichment. In contrast, Ngualla's mineralization is primarily magmatic in origin, with subsequent residual weathering enhancing grades to economic levels. This fundamental difference is likely attributable to both the greater age and deeper erosional exposure of the Ngualla complex (Hoatson et al., 2011; Rankin, 2001). In addition to REEs, phosphate and niobium have been identified as potential by-products. These are concentrated particularly within weathered zones over the calcite-carbonatite, where karstic weathering has led to the residual accumulation of apatite and pyrochlore-group minerals.

Hydrothermal Albitite-Hosted Heavy Rare Earth Element (HREE) Mineralization at Lofdal, Damara Belt, Namibia

The Lofdal REE deposit is located within the Damara Orogenic Belt in northwestern Namibia and is part of a broader suite of alkaline intrusive complexes (Figure 4) spatially associated with the Neoproterozoic continental rifting that preceded the Damara Orogeny (Williams-Jones, et al., 2015). This geologic setting, along the southern margin of the Congo Craton, hosts a unique type of REE mineralization notable for its exceptional enrichment in heavy rare earth elements (HREEs), particularly xenotime (Y) (Castor, 2008; Moore et al., 2014). The Lofdal area lies within the Welwitschia Inlier of the Damara Belt, which comprises Paleoproterozoic metamorphic basement rocks, including gneisses, schists, and amphibolites. These are intruded by Neoproterozoic alkaline igneous rocks of the Lofdal Intrusive Suite, emplaced around ~750 Ma during continental rifting (de Kock et al., 2000). The regional structure is defined by a NW–SE foliation along which magmatic intrusions and faults are aligned. The Lofdal Intrusive Suite consists of several small plutons and dykes of alkaline silicate and carbonatite compositions. The Main Intrusion, approximately 2 km in diameter, is the largest body and comprises two main phases: Early nepheline syenite, and later calcio-carbonatite, which intrudes the syenite (Williams-Jones, et al., 2015).

The contact between these two lithologies is marked by intense, particularly sodic fenite zones, developed through metasomatic alteration driven by alkaline fluids from the carbonatite magma. Surrounding the Main Intrusion is a 5 km wide swarm of NW–SE trending dykes composed of phonotephrite, phonolite, and carbonatite, although the carbonatite dykes are mainly confined to areas within 1 km of the intrusion. The REE mineralization at Lofdal is not hosted in carbonatites themselves, contrary to earlier interpretations. Instead, it occurs in albitites hydrothermally altered feldspathic gneisses and schists along regional faults (Williams-Jones, et al., 2015).These rocks have been intensely albitized and subsequently altered by carbonate fluids (calcite and dolomite), producing distinct brown, grey, and red weathered ridges up to 2 m wide and

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1 m high. The host albitites were previously misidentified as ferrocarbonatite dykes due to their carbonate content and appearance. However, petrographic, geochemical, and mineralogical evidence indicates a hydrothermal rather than primary igneous origin (Williams-Jones, et al., 2015).

The Lofdal Rare Earth Element (REE) deposit in northern Namibia is among the most geologically and economically significant REE-bearing systems globally, primarily due to its unusual enrichment in heavy rare earth elements (HREEs). Unlike most REE deposits worldwide, which are dominated by light REEs (LREEs), Lofdal stands out for its dominance in HREEs, making it a critical target in the global search for strategic and critical minerals. The REE mineralization at Lofdal is characterized by the co-occurrence of both LREE and HREE phases, although the deposit is distinctly HREE-enriched. The heavy REEs are primarily hosted in the mineral xenotime-(Y), which occurs in millimetre-scale veinlets cutting through hydrothermally altered albitite (Wall, et al., 2008). These xenotime-bearing veinlets commonly contain associated minerals such as biotite, calcite, pyrite, and zircon. In some instances, xenotime is also found within fluorapatite veinlets, where it occurs at triple junctions of apatite crystals, suggesting late-stage crystallization during hydrothermal activity ((Wall, et al., 2008; Migdisov, et al., 2009).

In contrast, the light REE mineralization is mainly present as monazite (Ce), typically found in biotite-calcite±pyrite veinlets. These veinlets cut across mafic dykes and amphibolites, or occur in altered carbonatite dikelets situated around the margins of the main fault-bound albitized zones. The distinct spatial separation of xenotime (Y) and monazite (Ce) mineralization reflects not only differing mineral stability fields but also strong fluid-rock interaction and chemical fractionation processes during hydrothermal fluid evolution. This mineralogical zonation is a key indicator of a hydrothermal origin, with the distribution of REEs strongly influenced by the pH buffering capacities of the host rocks, as well as by the temperature gradients along fluid pathways (Williams-Jones et al., 2012; and Migdisov & Williams-Jones 2014).

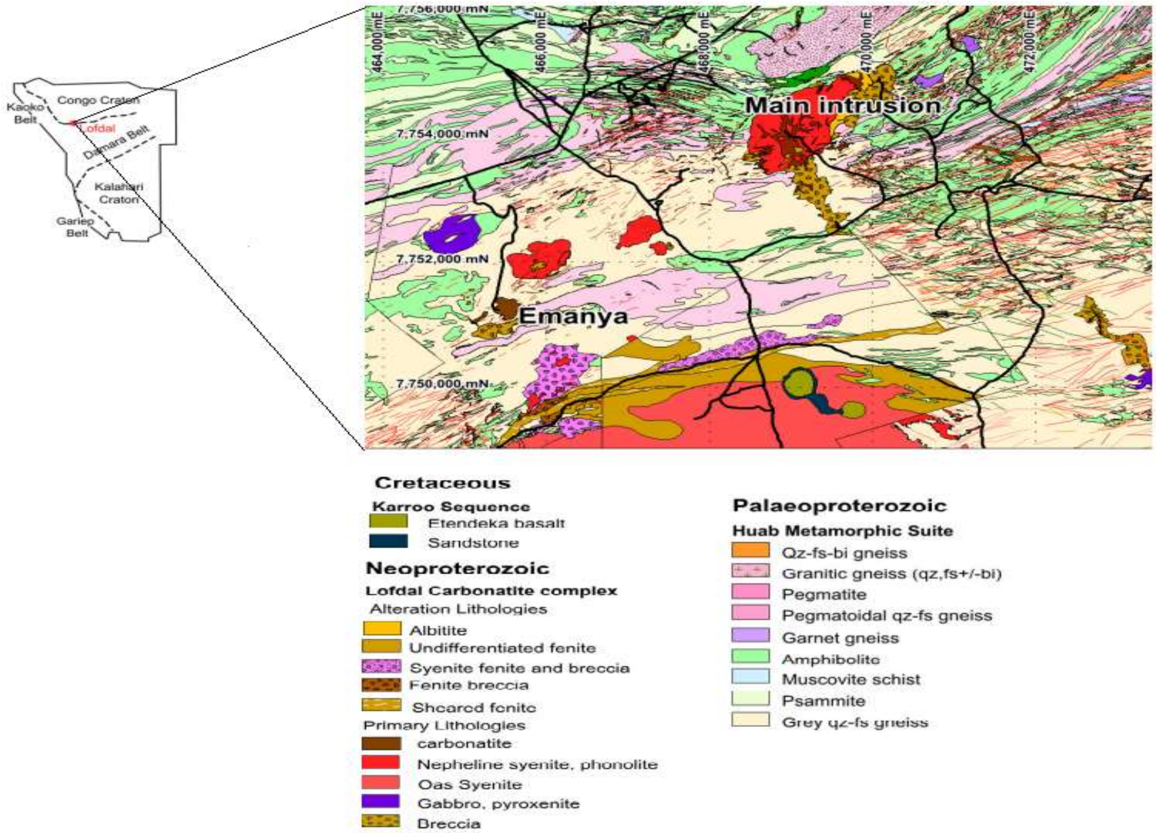

Figure 4 Location of the Lofdal intrusive suite in an outlier of the Congo Craton and Geological map of the Lofdal field area showing the distribution of alkaline rocks and carbonatites (after Williams-Jones et al., 2015)

Geology and Mineralization of the Steenkampskraal Monazite Deposit, South Africa: A High-Grade Hydrothermal Rare Earth Element System

The Steenkampskraal monazite deposit, located in the Western Cape Province of South Africa, is one of the most significant rare earth element (REE) deposits on the African continent. It is hosted within the Namaqualand Metamorphic Complex (Figure 5), a Mesoproterozoic high-grade metamorphic terrane forming part of the Namaqua-Natal Belt (Moore, 1983, 1989; Albat, 1984) which extends along the western and southern margins of the Kaapvaal Craton. Geologically, the Steenkampskraal deposit is characterized as a hydrothermal, vein-type monazite deposit. The mineralization is structurally controlled and hosted within a steeply dipping quartz vein that ranges from 0.2 to over 2 meters in width and extends for over 400 meters along strike. The quartz vein intrudes high-grade metamorphic rocks, predominantly garnet-biotite gneisses, and is associated with retrograde alteration and metasomatic overprints. Monazite (Ce), the principal REE-bearing mineral at Steenkampskraal, occurs as coarse-grained, often

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massive aggregates within the quartz vein and is accompanied by accessory minerals such as apatite, allanite, thorite, zircon, and fluorite (Moore and Reid, 1989). The monazite is rich in light REEs (LREEs), particularly cerium, lanthanum, neodymium, and praseodymium, with total rare earth oxide (TREO) grades commonly exceeding 14% making it one of the highest-grade REE deposits globally. The mineral also contains thorium (up to 10% ThO_2), making it both a valuable and radiologically sensitive material. The origin of the Steenkampskraal deposit is attributed to late- to post-metamorphic hydrothermal activity, likely related to regional tectonothermal events associated with the Namaqua Orogeny (~1.0 Ga) (Andreoli, et al., 1994; Bassoon, et al., 2016). The mobilization and transport of REEs and phosphate occurred through structurally controlled fluid flow, with monazite precipitating from phosphate-rich, high-temperature hydrothermal fluids in extensional fractures or shears.

Alteration assemblages in and around the quartz vein include sericitization, chloritization, and hematitization, reflecting fluid-rock interaction at lower temperatures during late-stage hydrothermal activity (Moore, 1989; Andreoli, et al., 1994). Fenitization, common in many carbonatite-hosted REE deposits, is absent at Steenkampskraal, reinforcing its classification as a hydrothermal monazite vein-type system. The Steenkampskraal monazite deposit represents a high-grade, vein-hosted REE occurrence within Proterozoic metamorphic rocks. Its unique geological setting, high REE content particularly LREEs and structural controls make it an important source of strategic metals and a reference point in the global rare earth industry.

Nigeria's Emerging Rare Earth Metal Potential: Geological Prospectivity and Underexplored Opportunities

Nigeria holds considerable potential for rare earth metal (REM) resources, though these remain largely underexplored and undeveloped. With increasing global demand and a strategic push for supply chain diversification away from dominant producers like China, Nigeria's REM potential is gaining growing attention. Geologically, Nigeria is endowed with a variety of lithological units that are favorable for REM mineralization. These include:

(a) Younger Granite Complexes of the Jos Plateau e,g Riruwai area (Figure 6), which are known to host REE-bearing minerals such as monazite, bastnäsite, and xenotime in pegmatites, granites, and associated hydrothermal veins. These are often associated with other strategic minerals like niobium, tantalum, and tin. (Kinnaid, 1984; Ogunleye, et al 2006; Olasehinde & Ashano, 2021)

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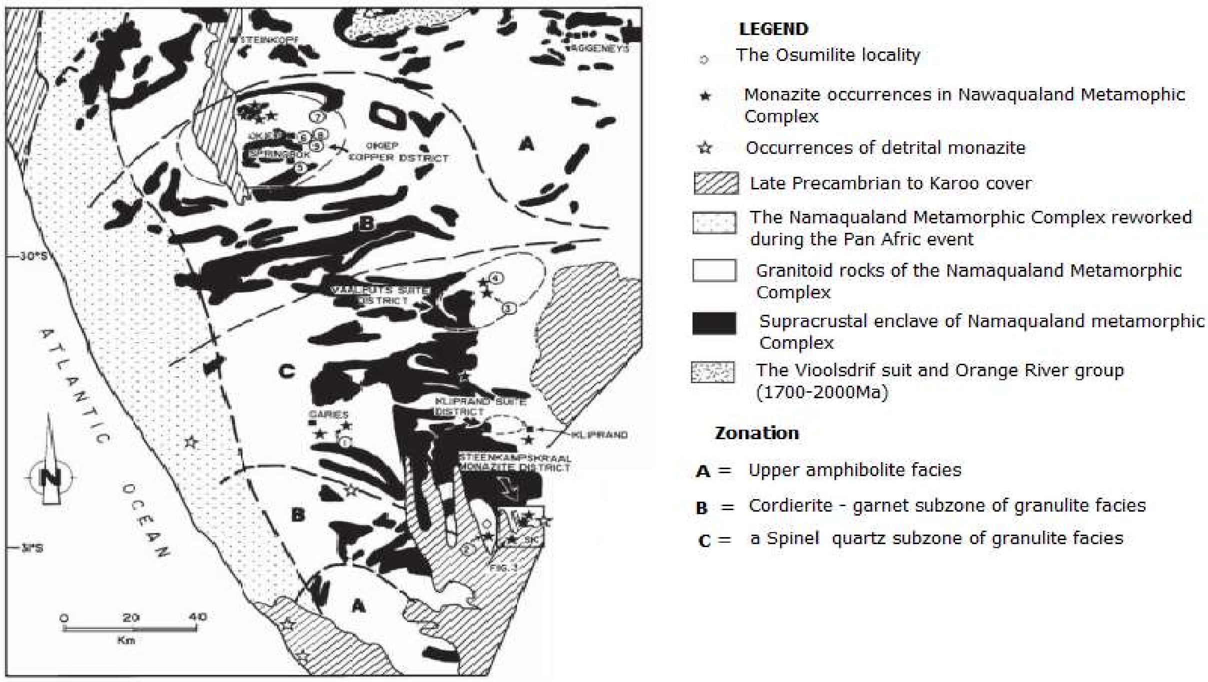

Figure 5 The Geology of Western Namaqualand modified after Albat 1984; Moore and Reid, 1989 and Andreoli and Hart, 1987

(b) Pegmatite belts in southwestern Nigeria, especially within the Pan-African Basement Complex (e.g., in states like Ekiti, Ondo, and Kwara), which have shown occurrences of REE-bearing accessory minerals (Akoh and Ogunleye, 2014; Kolawole, et al 2021).
(c) Carbonatite and alkaline complexes**,** notably in central and northern Nigeria (e.g., the Kogi, Nasarawa, and Kaduna regions), are also promising environments for both light and heavy REE mineralization, often associated with niobium, tantalum, and thorium (Elueze and Bolarinwa, 2004; Elatikpo, et al, 2013; Akoh and Ogunleye, 2014; Ukaegbu, 2013; Omotunde, et al 2020)

Preliminary geochemical and mineralogical studies from the Nigerian Geological Survey Agency (NGSA) and academic research institutions have confirmed anomalous concentrations of REEs in several localities. For instance, stream sediment and rock chip analyses from Nasarawa State reveal significant enrichment in lanthanum, cerium, and neodymium key light REEs used in magnets and batteries. Similarly, the alkaline ring complexes of central Nigeria are believed to be genetically similar to known REE-bearing carbonatite systems elsewhere in Africa (Ogunleye, et al., 2005; Woolley, 2001).

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Despite these favorable geological conditions, REM exploration in Nigeria is still at a nascent stage. Most known occurrences are at the reconnaissance or early exploration phase, with limited drilling and resource estimation. Challenges include inadequate funding, lack of modern exploration infrastructure, regulatory uncertainties, and insufficient baseline geoscientific data.

However, recent policy shifts, including the creation of the Nigerian Mining and Minerals Development Act (2007) and the establishment of the Nigerian Mining Cadastre Office (NMCO, 2023), aim to attract investment and improve the regulatory framework. The government has also identified REMs as strategic minerals in its national mineral policy roadmap, prioritizing their development to support local industrialization and participate in global value chains According to *The Guardian* (2025), Nigeria aims to dominate Africa's rare-earth market with a $400 million plant in Nasarawa.

While Nigeria’s rare earth metal sector remains underdeveloped, its geological settings offer considerable potential for future discovery and exploitation. With enhanced exploration efforts, improved governance, and international partnerships, Nigeria could emerge as a significant player in the global REM market. These types of deposits typically offer higher grades but smaller tonnage and more complex mineralogy, requiring precise beneficiation strategies. Their economic exploitation often depends on co-products (e.g., tin, tantalum), and they are more amenable to small-scale or artisanal mining operations.

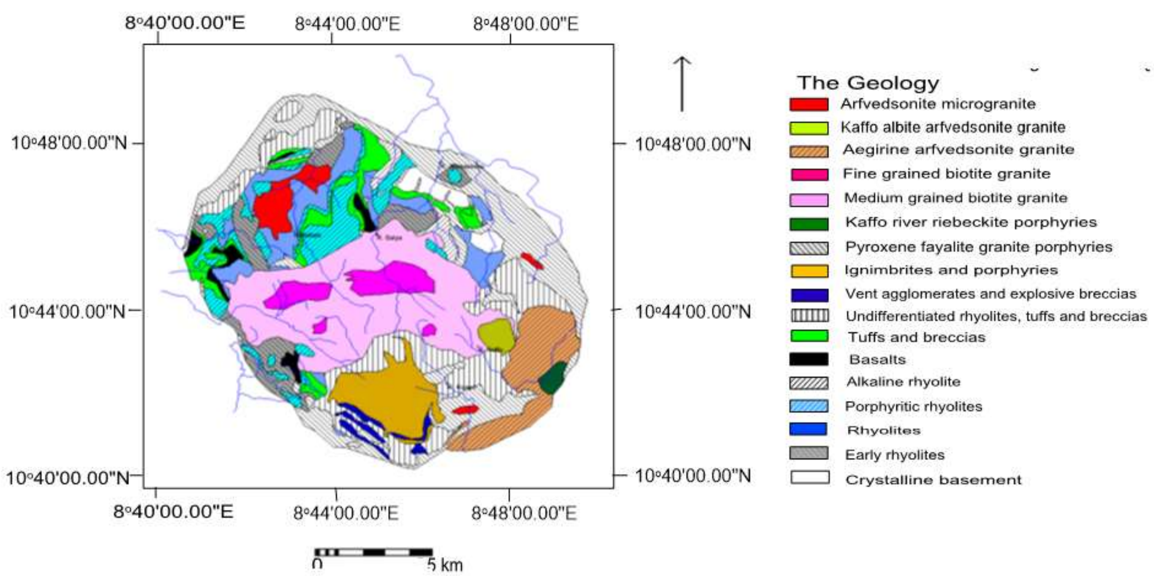

Figure 6 Geology Map of the Riruwai Complex. Modified after Ogunleye, et al. (2006); Olasehinde and Ashano, (2021)

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Lateritic and Ionic Adsorption Clay Deposits

Lateritic and ionic clay deposits are the dominant sources of HREEs in southern China, where REEs occur in loosely bound, easily leachable forms within weathered granites. These deposits have low environmental footprints due to simple extraction methods, typically involving in-situ leaching.

In Africa, this deposit style is relatively rare, but occurrences have been reported in Madagascar, particularly in lateritized terrains overlying alkaline and granitic rocks. Exploratory work has identified REEs in clay-rich saprolites, though grades and leachability remain under investigation (British Geological Survey, 2020). If developed, such deposits could provide a low-cost, low-radioactivity alternative to hard-rock mining, but would require robust environmental controls due to potential soil and water contamination from leaching agents.

The Gakara Rare Earth Project in Burundi: A Case Study in Political Risk and investment Fragility in Africa's REM Sector

The Gakara rare earth project in Burundi exemplifies the inherent risks and complexities associated with REM exploration in politically sensitive and institutionally fragile environments. Operated by Rainbow Rare Earths, the Gakara deposit is widely recognized for its exceptionally high-grade mineralization, with total rare earth oxide (TREO) concentrations averaging between 47% and 67% in bastnäsite and monazite minerals, among the highest in the world (Rainbow Rare Earths, 2020). However, the project has been repeatedly affected by non-technical risks that have undermined its operational viability. In June 2021, the Burundian government abruptly suspended all exports of rare earth concentrates from Gakara, citing concerns over revenue transparency and alleged undervaluation of mineral resources (Reuters, 2021). This action effectively halted production and led to a significant financial setback for Rainbow Rare Earths, despite the company's ongoing investment in beneficiation and exploration infrastructure.

The Gakara case emphasizes the broader issue of regulatory unpredictability in some African jurisdictions. While many countries possess significant REM potential, weak institutional frameworks, opaque decision-making processes, and sudden shifts in policy can deter foreign direct investment (FDI) and disrupt long-term project planning. These risks are particularly acute in countries undergoing political transition or facing governance challenges, where mining policy can be influenced by internal political considerations rather than stable legal frameworks (Fraser Institute, 2022). In addition, the lack of clear legal and fiscal regimes specific to REMs, especially regarding radioactive mineral by-products like thorium, further complicates investment. This regulatory ambiguity, often coupled with insufficient capacity for geological oversight and revenue tracking, can fuel mistrust between host governments and investors, as seen in the Gakara conflict.

From a strategic standpoint, the Gakara experience illustrates that high-grade geology alone is insufficient to guarantee successful REM development. Political risk, regulatory opacity, and the absence of strong governance mechanisms are equally decisive. As noted by the United Nations Economic Commission for Africa (UNECA, 2013), attracting sustainable investment in Africa's mineral sector requires more than geological endowment; it demands predictable institutions, transparent legal frameworks, and effective state capacity. While Gakara remains a geologically exceptional deposit, its operational history reveals the fragility of REM investments in high-risk jurisdictions. Unless structural governance and regulatory reforms are prioritized, such volatility may continue to undermine Africa's potential as a stable and competitive player in the global REM supply chain.

Status of Exploration in Africa

Africa's contribution to global REE production remains limited in volume but is strategically significant. In 2021, Burundi and Madagascar together produced just 2,400 tons (less than 1%) of global output (USGS 2022). However, the continent's reserve base is underexplored and potentially extensive. South Africa and Tanzania report confirmed reserves of 790,000 and 890,000 tons, respectively (Table 1). Other countries like Malawi and Namibia, though not included in the USGS table, host advanced exploration projects such as Songwe Hill and Lofdal, which are globally significant for their heavy rare earth element (HREE) content.

The exploration of rare earth metals (REMs) across Africa remains nascent when compared to more mature mineral sectors such as gold, copper, and diamonds. While the continent possesses significant geological potential for rare earth element (REE) mineralization, systematic and sustained exploration efforts are still limited in scope and depth. Most current projects are situated in early to mid-exploration phases, with only a handful progressing to advanced feasibility studies or pre-development stages. The disparity between geological endowment and exploration maturity underscores both the opportunity and challenge of developing a globally competitive REM industry in Africa (Harmer & Nex, 2016).

Several noteworthy projects exemplify the continent's emerging presence in the rare earth landscape. In South Africa, the Steenkampskraal deposit stands out as one of the few brownfield projects with a historical mining legacy. Originally exploited for thorium, the site is now being redeveloped with a focus on extracting high-grade monazite ores rich in light rare earth elements (LREEs). Its existing infrastructure and proven ore body provide a unique advantage, although the regulatory and operational environment remains complex.

In Malawi, Songwe Hill represents one of the most geologically advanced rare earth prospects in Africa. Operated by Mkango Resources, the project has completed a pre-feasibility study and delineated confirmed mineral reserves (Swinden & Hall, 2012). The deposit is associated with carbonatite-hosted mineralization, a common and economically significant source of LREEs. Songwe Hill's development has been buoyed by strong partnerships and targeted exploration campaigns, positioning Malawi as a potential early mover in the African REM value chain.

Namibia's Lofdal project is particularly significant for its focus on heavy rare earth elements (HREEs), including dysprosium and terbium elements that are crucial for high-performance magnets and defense technologies (Williams-Jones, et al., 2015). The project, managed by Namibia Critical Metals Inc., has advanced through exploration drilling and preliminary resource assessments, indicating promising long-term potential. This deposit contains measured and indicated reserves of approximately 1.65 million tonnes of ore with an average grade of 0.60 wt.% total rare earth oxides (TREO), of which a remarkable 85.4% comprises heavy rare earth elements (HREEs) (Namibia Rare Earth, 2014; Williams-Jones, et al., 2015). Globally, Lofdal ranks second only to the Browns Range deposit in Australia in terms of HREE proportion among over 50 advanced-stage REE exploration projects. Namibia's relatively favorable investment climate and mining governance structures further strengthen the project's prospects.

Conversely, Gakara in Burundi illustrates the volatility and complexity of REM exploration in politically sensitive regions. Despite boasting some of the highest-grade REM ore in Africa, the project has suffered repeated operational disruptions due to regulatory uncertainties, export bans, and shifting government policies (Rainbow Rare Earth, 2020) These challenges highlight the broader risks that can hinder even the most promising geological prospects on the continent (Fraser Institute, 2022). Africa's REM exploration efforts face several systemic constraints. One of the most pressing issues is the lack of up-to-date and high-resolution geological data. Many national geological surveys are underfunded, and historical exploration records are often incomplete or inaccessible. This data gap discourages private investment and leads to underestimation of mineral potential.

Moreover, access to exploration financing is a recurring barrier. REM exploration and development are capital-intensive, requiring specialized knowledge, long lead times, and

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often uncertain returns. African projects compete globally for funding, often against jurisdictions with more predictable regulatory regimes and established infrastructure (African Union, 2009). As a result, junior exploration firms operating in Africa frequently struggle to advance projects beyond the discovery phase. Geopolitical risk further complicates the investment climate. Political instability, inconsistent policy frameworks, and a lack of transparent permitting processes deter long-term commitments from both domestic and international investors. In some countries, abrupt policy changes and resource nationalism have disrupted operations and undermined investor confidence.

Despite these challenges, the underlying geology of Africa remains compelling. As global demand for REMs intensifies, driven by the clean energy transition and digital technologies, Africa's role as a prospective supplier is expected to grow (African Union, 2009; Fraser Institute, 2022). The key to unlocking this potential lies in addressing the structural barriers to exploration and creating an enabling environment for investment and sustainable development.

Table 1 Global Rare Earth Element (REE) Production and Reserves: Contextualizing Africa's Position

Country	Mine Production (tons)		Reserves (tons)
	2020	2021	
China	140,000	168,000	44,000,000
United States	39,000	43,000	1,800,000
Australia	21,000	22,000	4,000,000
Burma (Myanmar)	31,000	26,000	Not Available (NA)
India	2,900	2,900	6,900,000
Russia	2,700	2,700	21,000,000
Brazil	600	500	21,000,000
Vietnam	700	400	22,000,000
Burundi	300	100	NA
South Africa	—	—	790,000
Madagascar	2,800	2,300	NA
Tanzania	—	—	890,000
Other Countries	100	300	280,000
World Total	240,000	280,000	120,000,000

Source: USGS 2022

Burundi's sharp drop in production from 300 tons in 2020 to 100 tons in 2021 (Table 1) highlights the volatility of small-scale operations, often influenced by regulatory and infrastructural challenges. Meanwhile, Madagascar's decline also reflects the operational

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and geopolitical risks that frequently affect African mining sectors. Despite low production figures, Africa's geological potential combined with growing global demand for diversified REE supply chains positions the continent as a critical frontier for future REE development. This justifies increasing foreign investment and exploration activity across the continent.

Exploration Economics and Project Feasibility

The economics of rare earth metal (REM) exploration and development in Africa are shaped by a unique blend of high geological potential, infrastructural challenges, and global market uncertainties (Christianson, 2025). Unlike more conventional mineral commodities, REMs require a highly specialized approach to valuation due to their complex metallurgy, fragmented markets, and dependency on geopolitical factors. For African nations seeking to participate in the global REM value chain, understanding the economic parameters that govern project feasibility is essential.

Capital and Operational Expenditures (CAPEX and OPEX)

Mining REMs typically entails substantial capital expenditure (CAPEX) in the early stages, particularly in Africa where infrastructure such as roads, power, and water are often underdeveloped. Projects situated in remote areas, such as Lofdal in Namibia or Songwe Hill in Malawi, require extensive investment in logistics and processing infrastructure (Goodenough et al., 2017), thereby raising the initial capital requirements. According to Wall (2014), the processing of rare earth-bearing minerals like bastnäsite or monazite involves complex and energy-intensive separation techniques, further inflating operational costs (OPEX).

Nevertheless, some African contexts benefit from comparatively lower labor costs and potential tax incentives offered by governments keen to attract foreign direct investment (FDI). These cost-saving advantages may partially offset higher infrastructure and technical expenses, although they rarely compensate fully for the lack of advanced processing infrastructure. As highlighted by the British Geological Survey (2020), a lack of local capacity to process REMs remains one of the most significant economic bottlenecks in African REM projects.

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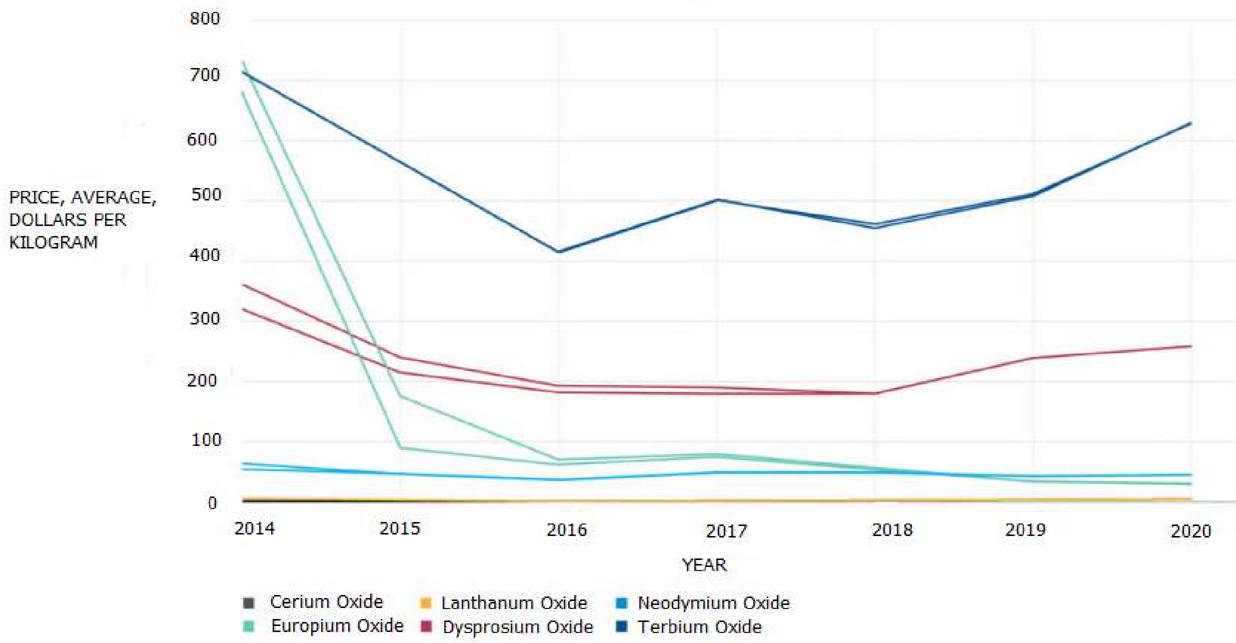

Figure 7 Trends in Average Global Prices of Selected Rare Earth Oxides (2014–2020) (after Hyong-Min and Deep, 2021)

Market Volatility and Pricing Risks

The rare earth market is notoriously volatile, largely due to its concentrated supply chains. China accounts for over 60% of global REM production and controls the majority of the world's processing capacity (USGS, 2022). As a result, price fluctuations are frequently triggered by Chinese production quotas, export policies, or international trade disputes (Figure 7). For instance, during the 2010–2011 supply crisis, prices for key elements like neodymium and dysprosium spiked dramatically, only to decline again once market panic subsided.

This pricing instability complicates financial forecasting for African projects. Discounted Cash Flow (DCF) models employing Net Present Value (NPV) and Internal Rate of Return (IRR) calculations, are highly sensitive to assumptions about long-term rare earth prices. Many African projects, particularly those at pre-feasibility stages, require rare earth oxide (REO) prices to remain above global average thresholds for prolonged periods to justify investment (MMR, 2025). According to Goodenough et al. (2017), only a handful of African projects show robust economic returns under conservative pricing scenarios.

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Project Risk and Investment Confidence

The rare earth metals (REE) market is poised for substantial growth over the next decade, underpinned by accelerating demand in strategic technologies and the global transition toward renewable energy and digital infrastructure. As of 2024, (Figure 8) the global REE market is valued at approximately US$6.69 billion and is projected to reach US$17.06 billion by 2032, growing at a compound annual growth rate (CAGR) of 12.4% (MMR, 2025). This upward trajectory highlights increasing investment confidence across the sector while raising essential considerations about project risks, especially in emerging exploration regions such as Africa.

The market is diversified across several industrial applications, with magnets, catalysts, metallurgy, and polishing compounds representing the most significant demand drivers in 2024. Among these, permanent magnets (used in electric vehicles, wind turbines, and electronics) are projected to dominate, given the surge in clean energy initiatives and electric mobility (Goodenough et al., 2017). This application diversity helps disperse market risks, ensuring that demand fluctuations in one sector (e.g., phosphors or lighting) can be mitigated by consistent growth in others. The wide industrial base, therefore, strengthens investor confidence by providing multiple revenue streams for REE producers.

From a geographical standpoint, the Asia-Pacific region continues to lead the REE market, reflecting China's long-standing dominance in both supply and consumption. This geographic concentration, however, introduces significant geopolitical risks. Events such as export restrictions, trade wars, or strategic resource nationalism may create supply chain vulnerabilities (Wall, 2014). In this context, Africa's emerging role as an REE producer is gaining strategic relevance. Countries like Malawi, Tanzania, Namibia, and South Africa host world-class deposits, including Songwe Hill, Ngualla, Lofdal, and Steenkampskraal many of which are advancing to development or early production stages (Broom-Fendley, 2015; Williams-Jones et al., 2015).

However, investment in African REE projects is not without risks. While the continent offers geological potential and competitive production costs, it also presents challenges such as regulatory uncertainty, underdeveloped infrastructure, and governance-related risks. Data from the Fraser Institute's Annual Survey of Mining Companies (2022) accentuates investor concerns in several African jurisdictions related to land access, political stability, and taxation frameworks. These concerns must be weighed against the long-term strategic benefits of supply chain diversification and access to critical REE inputs. Mitigating these risks requires a multi-faceted approach. First, investors can prioritize jurisdictions aligned with the Africa Mining Vision (African Union

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Commission, 2009), which aims to harmonize policies and improve resource governance. Second, projects that demonstrate clear environmental, social, and governance (ESG) strategies are more likely to attract global capital and off-take agreements, especially from OECD nations seeking ethical sourcing.

The rare earth metals market is entering a period of robust expansion, with compelling investment opportunities across various regions and applications. The growing value of REEs in strategic technologies makes them a key asset in the global energy transition (MMR, 2025). While Asia-Pacific continues to dominate, the push for supply chain resilience is opening new frontiers in Africa, albeit with heightened project risks. Prudent investors will need to balance these risks with proactive due diligence, policy engagement, and ESG alignment to ensure sustainable and profitable operations.

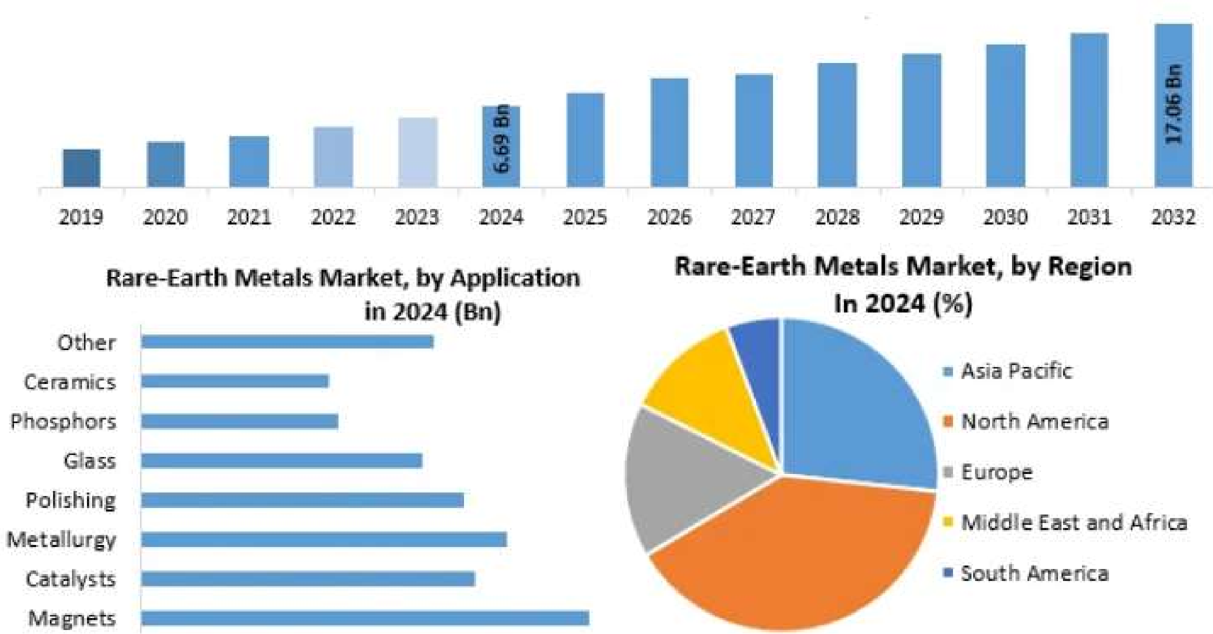

Figure 8 Rare earth metals market size in USD billions (2019-2032). *The global rare earth metals market was valued at approximately USD 6.69 billion in 2024 and is projected to grow at a compound annual growth rate (CAGR) of 12.4% from 2025 to 2032, reaching an estimated USD 17.06 billion by the end of the forecast period. (MMR, 2025)*

The Role of Beneficiation and Value Addition

The economic case for local beneficiation (the processing of ore into higher-value products within the country of origin) is strong but not without challenges. On-site beneficiation could drastically improve project economics by capturing more of the value chain, reducing reliance on export markets, and generating skilled employment.

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However, beneficiation plants are capital- and technology-intensive, often costing hundreds of millions of dollars to establish.

Countries like South Africa have explored the integration of rare earth processing facilities into their industrial strategies, but progress has been slow due to technological gaps and inconsistent policy implementation (African Union, 2009). Regional cooperation through economic blocs such as the Southern African Development Community (SADC) could facilitate shared beneficiation hubs, spreading both cost and risk across multiple countries.

Economic and Strategic Mineral Potential of Rare Earth Metals in Africa

Africa's rare earth metal (REM) endowment presents not only a compelling economic opportunity but also a growing strategic advantage in a rapidly evolving global resource environment. As the global economy pivots toward decarbonization and digitalization, rare earth elements (REEs) have become indispensable to a range of high-tech and clean energy applications including electric vehicles (EVs), wind turbines, advanced electronics, telecommunications, and defense systems (Goodenough et al., 2017; National Research Council, 2008). In this context, Africa's REM resources are emerging as vital not only for meeting global supply gaps but also for repositioning the continent within critical mineral value chains.

Beyond economic value, the strategic importance of African REM resources is heightened by the current geopolitical landscape. China dominates the global REM supply chain, accounting for over 60% of mine production and more than 85% of processing capacity (USGS, 2022). This concentration has raised concerns among Western governments and industries about supply vulnerability and the need for diversification. As such, African countries with stable governance and favorable geological profiles are increasingly viewed as alternative sources, particularly by the EU and U.S. (Wall, 2014; United Nations Economic Commission for Africa, 2011). This strategic repositioning can enhance Africa's geopolitical leverage while encouraging bilateral and multilateral investment in its mineral sector (Table 2).

Economically, REM exploitation offers African nations the prospect of foreign direct investment (FDI), job creation, and infrastructure development. However, realizing this potential requires overcoming several barriers, including poor downstream processing capacity, underdeveloped transport infrastructure, regulatory uncertainty, and environmental risks. Initiatives such as the Africa Mining Vision (AMV) provide policy frameworks aimed at enhancing transparency, beneficiation, and sustainable development in the mineral sector (African Union, 2009). In addition, a shift toward local

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Table 2. Economic and Strategic Potential of Rare Earth Metals in Africa: Critical Perspective and Policy Considerations

Dimension	Critical Perspective	References
Economic Opportunity	Africa's REMs are vital for clean energy and high-tech sectors (e.g., EVs, wind turbines, electronics, defense).	Goodenough et al., 2017; National Research Council, 2008
Strategic Positioning	African REMs can reduce global reliance on China, which dominates >60% of production and >85% of processing.	USGS, 2022; Wall, 2014
Geopolitical Relevance	Stable African countries with favorable geology are attracting EU and U.S. interest as alternative sources.	UNECA, 2011
Investment Potential	REM mining could drive FDI, job creation, and infrastructure development across African nations.	African Union, 2009
Key Barriers	- Poor downstream processing capacity - Underdeveloped transport and energy infrastructure - Regulatory uncertainty and environmental risks	Wall, 2014; UNECA, 2011
Policy Frameworks	Africa Mining Vision (AMV) promotes resource governance, transparency, beneficiation, and local development.	African Union, 2009
Local Value Addition	Developing refining/separation plants could improve economic returns and reduce export dependency.	Wall, 2014
Global Demand Outlook	Sustained demand for REEs due to global transition to low-carbon and digital economies ensures long-term relevance of African REMs.	Goodenough et al., 2017; National Research Council, 2008
Development Imperatives	Africa must invest in infrastructure, governance reform, and sustainability integration to convert REM wealth into long-term socio-economic transformation.	UNECA, 2011; African Union, 2009

value addition (such as establishing REE separation and refining plants) can significantly improve economic returns and reduce dependency on foreign processing hubs. Africa's rare earth mineral potential positions the continent as both an economic frontier and a

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strategic player in the 21st-century resource economy (African Union, 2009). The global push toward green technologies and digital systems ensures sustained demand for REEs, creating opportunities for African nations to harness their geological wealth for transformative development. However, capitalizing on this window requires proactive governance, infrastructure investment, and the integration of sustainability and local content into mining operations (Fraser Institute, 2022).

Foreign Exchange and Economic Development

The most immediate economic advantage of REM development lies in the generation of foreign exchange through exports. Global demand for rare earth oxides and concentrates is expected to rise sharply, driven by green energy policies in the European Union, United States, and parts of Asia (Goodenough et al., 2017). African countries with proven REM deposits, such as Malawi, South Africa, and Namibia, stand to benefit from tapping into this market.

However, current trade models remain skewed toward the export of raw or semi-processed materials. As observed by the British Geological Survey (2020), the sale of REM concentrates generates significantly less revenue than processed products like individual rare earth oxides or alloys. Without beneficiation infrastructure, much of the economic value derived from REMs is captured outside the continent, limiting Africa's potential to generate long-term wealth from its natural resources.

Industrial Diversification and Technological Development in Africa's Rare Earth Sector

Africa's rare earth metal (REM) endowment offers not only opportunities for export revenue but also a strategic avenue for industrial diversification and technological upgrading. In contrast to traditional bulk commodities like iron ore or bauxite, REEs are central to a wide range of advanced and high-value manufacturing sectors, including electronics, electric vehicles, clean energy systems, medical imaging technologies, and defense applications (Goodenough et al., 2017; Castor & Hedrick, 2006). Harnessing this potential could enable African economies to move beyond the export of unprocessed raw materials and catalyze the development of knowledge-based and innovation-driven industries.

The establishment of downstream processing industries (such as those producing permanent magnets, battery alloys, phosphors, or catalysts) can provide greater value addition and employment opportunities. Such industrial linkages are critical to ensuring that REM mining contributes to broader economic transformation. However, the realization of these linkages requires robust industrial policy frameworks, investment in infrastructure, and coordinated innovation ecosystems (United Nations Economic Commission for Africa, 2011; Wall, 2014). South Africa remains one of the few African nations to formally integrate REMs into its industrial strategy. The country's Beneficiation Strategy for the Minerals Industry of South Africa, implemented under the

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Department of Mineral Resources and Energy, identifies rare earths as key inputs for the green and digital economy. Nonetheless, practical progress has been slow, largely due to systemic barriers such as limited technical expertise, insufficient investment in research and development, and underdeveloped value chain infrastructure (Wall, 2014; Harmer & Nex, 2016). In particular, the absence of rare earth separation facilities and advanced material fabrication units continues to restrict industrial upgrading.

Moreover, very few African countries have articulated comprehensive national strategies that link REM development with technological innovation, university-industry collaboration, or special economic zones focused on clean-tech or materials science. The failure to integrate mineral policy with innovation policy risks marginalizing REMs as yet another enclave industry, generating revenue without driving structural economic change (U.S. National Research Council, 2008).

Table 3: Industrial Diversification and Technological Development Potential of Rare Earth Metals in Africa

Thematic Area	Critical Perspective	Challenges	References
Strategic Value of REMs	REMs are essential for advanced manufacturing in electronics, clean energy, defense, and medical technologies.	Africa's reliance on raw material exports limits economic transformation.	Goodenough et al., 2017; Castor & Hedrick, 2006
Value Addition through Downstream Industries	Establishing industries to produce magnets, battery alloys, phosphors, etc., enhances employment and revenue.	Lack of infrastructure, industrial policy gaps, and limited financing.	UNECA, 2011; Wall, 2014
National Industrial Policy Efforts	South Africa's beneficiation strategy identifies REMs as critical for green/digital economy development.	Implementation remains slow due to R&D gaps and technical skill shortages.	Wall, 2014; Harmer & Nex, 2016
Innovation Linkages and Ecosystem Development	Few countries link REMs with R&D, university collaboration, or special economic zones for tech growth.	Risk of REMs becoming another enclave industry with limited broader impact.	National Research Council, 2008
Human Capital and Technology Transfer	Investing in skills (geology, metallurgy, materials science) and tech partnerships is crucial for transformation.	Without deliberate planning, REM development remains disconnected from structural change.	Hoatson et al., 2011; UNECA, 2011

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To avoid this pitfall, investment in human capital (particularly in geology, metallurgy, chemistry, and material engineering) (Table 3) is essential. Equally important is the facilitation of technology transfer through strategic partnerships with countries and firms that already possess REE processing capabilities. Without such deliberate efforts, the REM sector is unlikely to yield transformative outcomes and may remain vulnerable to the volatility of global commodity markets (Hoatson et al., 2011; UNECA, 2011). Africa's REM wealth holds immense promise as a springboard for industrial diversification and technological advancement. However, this promise will only be fulfilled through coordinated strategies that embed REM development within broader innovation, education, and industrial policy agendas.

Geopolitical Leverage and Strategic Alliances

Africa's REM resources also possess significant geopolitical value. With over 90% of REMs currently processed in China, the rest of the world is increasingly seeking to diversify its supply chains. African nations especially those with viable deposits and favorable investment climates, are well-positioned to become alternative suppliers of critical raw materials. This could provide leverage in forming strategic trade partnerships, attracting foreign direct investment, and negotiating technology-sharing agreements (Wall, 2014; Harmer & Nex, 2016).

Recent developments, such as the European Union's "Critical Raw Materials Act" and the U.S. Department of Defense's funding of non-Chinese REM supply chains, suggest that strategic alliances with African producers may become more frequent (USGS, 2022). These geopolitical trends offer African governments an opportunity to position their rare earth sectors not just as commodities, but as instruments of diplomatic and economic negotiation.

However, capitalizing on this potential requires institutional coherence, transparency, and long-term planning. Most African countries currently lack the regulatory frameworks and policy coherence needed to convert strategic resources into strategic power. According to the Fraser Institute (2022), investor perception of governance quality, policy stability, and infrastructure capacity remains low for many African jurisdictions.

Policy Gaps and the Challenge of Value Retention

Despite the immense potential, REM development across Africa suffers from significant policy and institutional deficiencies. Export of unprocessed ore remains the dominant mode of operation, due in part to weak regulatory enforcement and the absence of beneficiation mandates (UNECA, 2011). As a result, African countries often lose out on the value-added components of the rare earth value chain. Moreover, few countries have

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articulated national strategies that integrate REM development with industrial policy, education, or energy transition goals. The Africa Union (2009) Africa Mining Vision acknowledges the need for such integration but implementation remains slow and inconsistent. In the absence of coordinated policies, Africa risks repeating historical patterns of resource extraction with limited development dividends.

Africa's rare earth metals represent far more than a geological curiosity; they are economic assets and strategic tools in a rapidly transforming global economy. Their value lies not only in direct export revenue but in the broader opportunities they offer for industrial development, geopolitical influence, and sustainable growth (Wall, 2014; Harmer & Nex, 2016). However, without coherent policies, investment in infrastructure and human capital, and integration into global value chains, this potential may remain unrealized. To truly benefit from its REM wealth, Africa must move from being a passive supplier to an active player in the strategic minerals economy.

Policy and Institutional Recommendations

The effective development of Africa's rare earth metals (REMs) sector depends not only on favorable geology and investor interest but also on robust policy frameworks and institutional support. While geological evidence points to significant REM potential across the continent, the lack of regulatory clarity, weak governance structures, and infrastructural deficits continue to limit progress (UNECA, 2011; Harmer & Nex, 2016). To overcome these barriers and translate mineral wealth into sustainable development, coordinated policy and institutional reforms are imperative.

Modernization of Geological Surveys

One of the foundational steps toward attracting investment and ensuring sustainable exploration is the modernization of geological data systems. Many African countries rely on outdated or incomplete geological maps, which hampers investor confidence and increases exploration risk (African Union, 2009; Harmer & Nex, 2016). Utilizing modern technologies such as remote sensing, airborne geophysics, and geochemical mapping can improve the precision of resource estimations and reduce exploration costs.

For example, countries like Namibia and Botswana have made strides in developing comprehensive digital cadastres, which have improved transparency and investor engagement. The United Nations Economic Commission for Africa (UNECA) has consistently emphasized that reliable geological information is a public good necessary for sustainable resource management (UNECA, 2011).

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Fiscal Incentives to Attract Investment

To incentivize early-stage exploration, African governments should adopt targeted fiscal policies such as tax holidays, royalty reductions, and duty exemptions on exploration equipment. These measures can help offset the high risks and long payback periods associated with REM projects, particularly in frontier jurisdictions.

South Africa's Mineral and Petroleum Resources Development Act (MPRDA) allows for certain fiscal incentives but has faced criticism for regulatory uncertainty. In contrast, Malawi's Mines and Minerals Act of 2019 introduced clearer provisions for investor-friendly taxation while retaining state oversight, offering a more balanced model for resource governance (Mkango Resources, 2015).

Regional Value Chains and Beneficiation Centers

Africa's REM strategy must move beyond extraction toward regional integration and beneficiation. Developing regional value chains, such as shared processing facilities, transportation corridors, and research hubs, can help landlocked and resource-poor countries benefit from proximity to mineral-rich neighbors. For instance, the African Union (2009) Africa *Mining Vision* explicitly calls for collaborative frameworks to enhance value addition within the continent.

Establishing regional beneficiation centers could also help address the high capital and technological costs associated with REM processing (Harmer & Nex, 2016). These centers would require multi-country partnerships, pooled investment, and public-private collaboration but could dramatically improve Africa's position in the global value chain.

Environmental and Community Engagement Frameworks

Given the complex and often hazardous nature of REM extraction (particularly the management of radioactive by-products like thorium) environmental governance must be a top priority. Clear environmental regulations, enforced through independent monitoring agencies, can reduce the ecological risks of REM mining (Fraser Institute, 2022). Equally important is the integration of community development plans into mining licenses. Many mining conflicts in Africa arise from poor stakeholder engagement and unmet expectations. Models such as Free, Prior, and Informed Consent (FPIC), adopted in countries like the Democratic Republic of Congo and Ghana, offer frameworks for building trust between communities and mining companies (World Bank, 2020).

Governance and Transparency as Investment Catalysts

Transparent and consistent governance is critical to reducing investor risk and curbing corruption. Africa's performance on global mining governance indices remains uneven. The Fraser Institute's Annual Survey (2022) shows that many African countries score poorly on regulatory stability and corruption perception. Strengthening governance requires institutional capacity-building, anti-corruption enforcement, and transparent licensing procedures. Digital platforms like mining cadastres, beneficial ownership registries, and contract disclosure portals have proven effective in countries such as Zambia and Liberia. Additionally, participation in global initiatives such as the Extractive Industries Transparency Initiative (EITI) enhances credibility and investor confidence.

The Role of Regional Institutions in Advancing Rare Earth Metal Development in Africa

The successful development of Africa's rare earth metal (REM) sector hinges not only on the continent's geological wealth but also on the strength and coordination of its policy and institutional frameworks (Table 4). Regional and continental bodies such as the African Union (AU), the Economic Community of West African States (ECOWAS), and the Southern African Development Community (SADC) are strategically positioned to drive structural reforms, harmonize policies, and support regional integration efforts necessary for unlocking the full value of REM resources (UNECA, 2011).

One of the most pressing challenges facing investors and policymakers in the African mining sector is regulatory fragmentation. Differing mining codes, fiscal regimes, and permitting procedures across borders create uncertainties that deter long-term investment. Regional institutions can play a vital role by harmonizing mining regulations and environmental standards, thereby reducing investment barriers and fostering a more predictable business environment (African Union, 2009; UNECA, 2011).

Additionally, cross-border infrastructure development, including transport corridors, energy networks, and data-sharing platforms, is essential to connect landlocked mineral-rich areas to global markets. Regional economic communities (RECs) such as ECOWAS and SADC are already involved in corridor development projects, and greater emphasis on REM-focused infrastructure could significantly lower operational costs and enhance market access (World Bank, 2020; UNECA, 2011). Capacity constraints at the national level, especially in areas of geological surveying, environmental regulation, and mineral processing, underscore the need for technical assistance and regulatory capacity building. Regional bodies can coordinate training programs, provide technical advisory services, and promote knowledge sharing through platforms like the African Minerals Development Centre (AMDC) and the Pan-African Mining Agenda (African Union, 2009; UNECA, 2011). These institutions aim to align national mineral policies with the broader goals of industrialization, environmental sustainability, and equitable growth.

Moreover, regional organizations are well-placed to support joint ventures and cross-country research initiatives in REE geology, metallurgy, and beneficiation. Given the

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Table 4: Institutional, Environmental, and Governance Frameworks for Africa's REM Sector

Thematic Area	Critical Perspective	Challenges/Needs	Examples/References
Environmental and Community Engagement	REM mining involves hazardous by-products (e.g., thorium), requiring strong environmental governance. Community development must be embedded in mining operations.	Inadequate enforcement and weak community engagement often lead to social conflict.	FPIC model in DRC and Ghana; World Bank, 2020
Governance and Transparency	Transparent governance enhances investor confidence. Consistency in regulations is essential.	Many African countries perform poorly on mining governance indices. Corruption and unstable licensing are barriers.	Fraser Institute, 2022; EITI; mining cadastres in Zambia and Liberia
Role of Regional Institutions	AU, ECOWAS, and SADC are crucial for policy harmonization and institutional support. They can reduce cross-border investment risks and build capacity.	Fragmented regulations, lack of infrastructure, and weak institutional coordination.	UNECA, 2011; African Union, 2009; World Bank, 2020
Cross-border Infrastructure	Transport corridors, energy access, and data-sharing platforms reduce operational costs.	Connectivity to global markets remains limited for landlocked countries.	ECOWAS and SADC corridor initiatives
Technical Capacity & Training	Training in geology, regulation, and processing can be coordinated regionally.	National technical institutions are under-resourced.	AMDC, Pan-African Mining Agenda; African Union, 2011
Research & Innovation	Joint research in REE geology and beneficiation supports technological entry into global markets.	High cost and complexity of REM value chains limit individual country efforts.	Harmer & Nex, 2016; Goodenough et al., 2017
Strategic Imperative	REM development success depends on bold, coordinated policy reforms beyond geology.	Failure to act may reduce Africa to a marginal role in global supply chains.	

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capital-intensive and technologically demanding nature of REM value chains, pooled resources and collaborative research across borders can help African countries overcome barriers to entry and compete in global supply chains (Harmer & Nex, 2016; Goodenough et al., 2017). Modernizing geological information systems, offering regionally-coordinated fiscal incentives, and strengthening governance institutions are equally important. Africa's REM competitiveness will depend on more than geological endowment, it will require bold, coordinated policy reforms, underpinned by effective regional collaboration and institutional innovation. As the global demand for rare earths intensifies, the ability of African regional institutions to shape a coherent and investor-friendly environment will determine whether the continent becomes a marginal supplier or a central player in the global REM economy (World Bank, 2020; Fraser Institute, 2022).

Conclusion

Africa stands at the threshold of becoming a globally relevant supplier of rare earth metals, a position that holds transformative implications for both the continent and the wider international community. The geological diversity of the continent (including carbonatites, pegmatites, and alkaline complexes) offers a promising foundation for rare earth mineralization. As demonstrated in key case studies such as Steenkampskraal, Songwe Hill, Lofdal, and Gakara, Africa hosts a range of light and heavy rare earth deposits, many of which remain underexplored or are in the early stages of development. While the resource base is encouraging, realizing its full potential requires addressing significant economic, technical, and institutional hurdles. Exploration and development of REM projects in Africa face substantial capital and operational costs, compounded by volatile market dynamics and elevated geopolitical risks. These factors often deter investment and hinder long-term project viability. Financial modeling give emphasis to the need for stable rare earth prices and infrastructure support to achieve commercial success. Moreover, the strategic significance of REMs demands that African governments view these resources not merely as commodities, but as instruments for industrial diversification, technological advancement, and geopolitical leverage. Yet, current national policies in most countries remain fragmented and reactive, often lacking integration with broader economic development plans. The continued export of unprocessed ores also limits value addition and job creation.

To bridge this gap, the study lay emphasis on the need for coordinated policy action, regional collaboration, and investment in downstream industries. Modernizing geological surveys, offering targeted fiscal incentives, ensuring regulatory transparency, and establishing regional beneficiation hubs are essential steps. Institutions like the African Union and ECOWAS must play a central role in harmonizing strategies and

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securing Africa's place in the critical mineral value chain. Africa's rare earth future is not guaranteed but must be actively constructed. With informed planning, technological investment, and good governance, the continent can transform its geological endowment into a cornerstone of economic resilience, energy transition, and global competitiveness in the 21st century.

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