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The Mineral Exploration Scenario in Brazil: Overview, Technological Advances, and Job Market for Geophysicists

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Abstract

This study analyzed the challenges of Brazil's mineral sector, highlighting the potential of geophysics for the sustainable exploration of critical minerals. The sector (2% of GDP) faces bureaucratic issues and low integration between research and industry, with 55% of mining processes stalled at the exploration stage. Production is concentrated in iron (67%) and dominated by foreign companies (69%) for substances such as bauxite, copper, and gold. Geophysics, underutilized due to a lack of professionals and technology (only 23% of companies invest in new techniques), could optimize/guide exploration. The study recommends: university-industry consortia, professional training, and regulatory streamlining to position Brazil in the global production of critical minerals, promoting a sustainable and inclusive model.

1. Introduction

In 2024, Brazil's national economy generated a GDP(Gross Domestic Product-PIB, in portuguese) of approximately BRL 11.7 trillion (IBGE), dominated by services (70%), followed by industry (20%) and agriculture (10%). The Brazilian mineral sector plays an essential role in the economy, accounting for 2.0% of total GDP, reinforcing its strategic and economic relevance. Brazil holds great mineral potential, with over 8,000 occurrences mapped (CPRM, 2022). The main mineral provinces are located in Minas Gerais (Iron Quadrangle and Jequitinhonha Valley), Bahia (Copper Belt and Uranium Province), and Pará (Carajás Mineral Province and Tapajós region), concentrating the production of iron, copper, gold, and other minerals. Despite this potential, the sector faces significant challenges. According to ANM, 55% of the 38,500 active mining processes in 2024 are halted at the exploration stage, due to regulatory hurdles, long analysis times by ANM, and high costs. The mining concession process takes, on average, four years to be reviewed, hindering new investments, in addition to interference by various stakeholders (MPF, communities, etc.) as seen in potash and gold projects in Amazonas. In this context, geophysics emerges as a strategic tool to expand mineral exploration with lower environmental impact by identifying more promising areas. However, its application is still hindered by resistance from companies and low priority given by research institutions. The lack of articulation between academia and the productive sector limits the advancement of geological knowledge through this methodology. Overcoming these barriers is crucial for the mineral sector to contribute sustainably and innovatively to the country's development by accelerating the discovery of new mineral deposits.

2. Methodology

This study adopted a comprehensive methodological approach to evaluate the integration of geophysics in the Brazilian mineral sector, combining analyses of official databases, surveys of mining companies, and academic curriculum reviews. Initially, databases from CPRM (Brazilian Geological Survey) and ANM (National Mining Agency) were consulted, with emphasis on Brazil's mineral production records, identifying figures, trends, and shortcomings. Concurrently, a direct survey was conducted with professionals working in mining companies of various sizes or companies providing geophysical services, through structured questionnaires aimed at mapping geophysicist employability in the job market. In this stage, 59% of surveyed companies were large, 27% medium-sized, and 14% small, operating in the extraction of iron, gold, copper, lithium, niobium, and other minerals. Additionally, an analysis was conducted on the Lattes Curricula of researchers affiliated with Brazilian institutions offering undergraduate/graduate programs in geophysics, specifically aiming to identify research/extension projects in mineral exploration over

the last 5 years. This stage focused on both publicly funded initiatives and partnerships with the mining industry. The data collected underwent statistical treatment, generating quantitative indicators on the employability of geophysicists in the sector, while qualitative information allowed for an assessment of the alignment between academic training and market needs.

3. Results

Current Brazilian Scenario: Brazil hosts a broad range of companies investing in mineral production. A survey categorized by substance/nationality revealed that 69% of the market is represented by foreign companies, and 31% by Brazilian firms. Notable company-substance associations (Figure 1): (i) Bauxite: MRN (PA), Norsk Hydro (Paragominas – PA), Alcoa (MG), CBA/Votorantim (MG and GO); (ii) Copper: Lundin (ex-Yamana) (GO), Vale (PA), Caraíba/Ero Copper (BA), BHP/OzMinerals (PA, ex-Avanco); (iii) Chromite: Ferbasa (BA) and Magnesita (BA); (iv) Iron: Vale (PA and MG), Samarco, CSN/Namisa, Usiminas, Anglo (Minas Rio), V&M, Arcelor Mittal, Herculano, Cedro, SFAM, Gerdau; (v) Gold: Anglogold, Kinross, Pan American (Yamana - Jacobina), Hochschild, Jaguar, Apoema (Aura Gold), Mineração Aurizona, Leagold (ex-BrioGold/Yamana), Nx Gold (Caraíba).

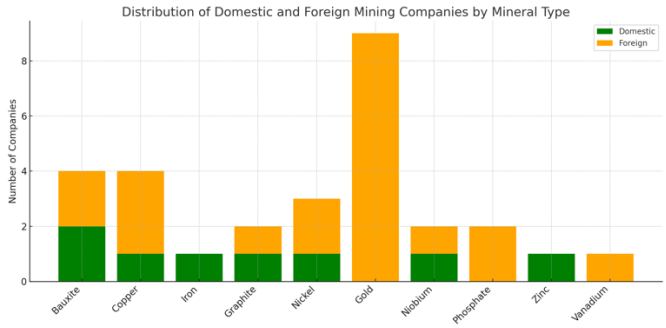

Figure 1 – Major companies categorized by substance and classified as domestic or foreign.

Regarding mineral production, iron remains dominant in Brazil, accounting for 67% of total mineral output in 2024, posing economic risks since 80% is destined for export markets, making it vulnerable to global price fluctuations.

The CFEM (Financial Compensation for the Exploitation of Mineral Resources) is a productivity indicator for mining companies, calculated based on net revenue and the type of mineral explored. ANM data indicate that the five regions/states with the highest CFEM revenue from 2022 to 2024 are: Minas Gerais, Pará, Goiás, Bahia, and Mato Grosso. Minas Gerais and Pará consistently dominate, jointly accounting for over 80% of total CFEM revenue in each year (Figure 2).

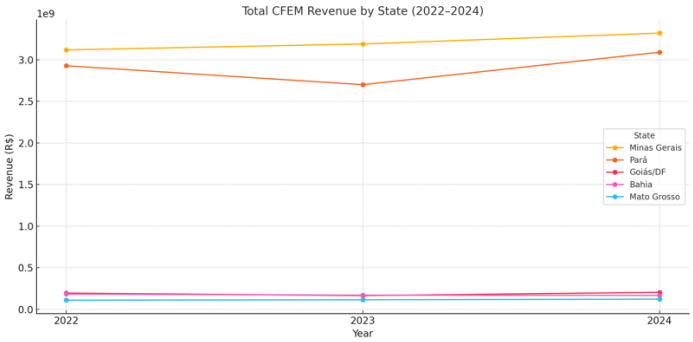

Figure 2 – CFEM trends for the five largest producers in Brazil.

In fact, Minas Gerais generated over BRL 570 billion, and Pará about BRL 450 billion in iron production during the same period (ANM, 2025b).

According to ANM's platform (2025a), there are currently 103,952 authorized mineral research processes. The development of mineral exploration projects follows a logic dependent on national incentive policies combined with international economic factors (prices, future demand, reserve replenishment, etc.). Reviewing the past 24 years, the number of exploration projects has shown irregular growth, with notable peaks in 2008, 2013, and 2023 (Figure 3). A decrease in exploration occurred in 2020, likely due to the COVID-19 pandemic, followed by a gradual recovery in 2021. The year 2023 saw the highest number of projects in recent years, due to strong interest in metals such as copper, gold, iron, and lithium — reflecting increased global demand for critical metals for the energy transition.

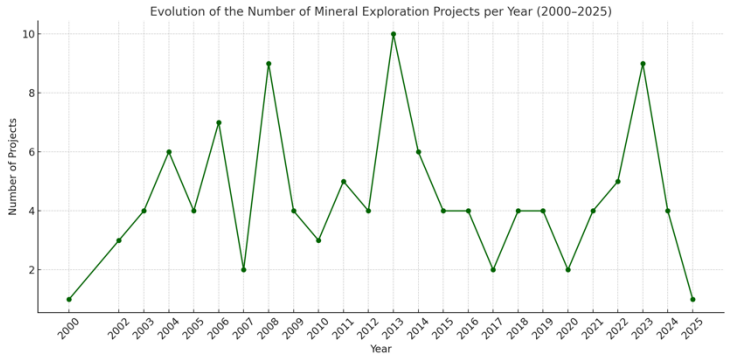

Figure 3 – Timeline of key exploration projects initiated in mineral exploration per year.

Investments in critical minerals: Countries' strategies and policies regarding critical minerals aim to meet current and future demands, reflecting their economic, technological, defense, and even health interests. These represent a response to the growing international competition to supply technological innovation and green economy demands, and to reduce geopolitical vulnerabilities — especially given China's current dominance in these supply chains. Notably, energy transition critical minerals alone could reach a demand of USD 400 billion by 2050, showcasing their potential for mining companies. Brazil's list of critical minerals was established by Resolution No. 2, dated 06/18/2021, from the SGM/MME (Secretariat of Geology, Mining and Mineral Transformation, under the Ministry of Mines and Energy). In R&D, lithium, rare earths, graphite/graphene, and uranium (which recently underwent important regulatory changes in Brazil) are prominent. Their development should be properly evaluated to attract companies aiming to build productive chains in Brazil (Heider and Fonseca, 2022). In this context, Brazil holds a strategic global position in niobium production, accounting for 88% of the market. However, it has yet to diversify its mineral matrix. Essential minerals for the energy transition, such as lithium and rare earths, still account for less than 1% of total output, revealing an underexploited opportunity. Countries like Australia and Canada are advancing with critical mineral policies, while Brazil lacks a national strategy. Niobium and rare earths, for example, are exported as raw commodities, losing added value. Moreover, Brazil's potential in Ionic Clays presents a vast opportunity for advancement in the value chain and for attracting significant investments.

Royalty Distribution: CFEM reached BRL 7.1 billion in 2024, and its distribution is highly concentrated. Pará (42%) and Minas Gerais (31%) account for 73% of the total, while emerging states like Rio Grande do Norte (tungsten) reach lower thresholds. Notably, only 65% of the funds

go directly to mining municipalities, and 20% of them lack clear plans for using these resources, according to the Mining Observatory (2024).

Corporate and academic geophysical investment in mining: The survey of mining companies reveals that 54% are large firms employing in-house geophysicists, while 33% are medium-sized and also employ such professionals. However, 32% of companies — including some large ones — do not have geophysicists on staff, relying on external consultants in 83% of cases for specific demands.
Regarding areas of operation, half of the companies with geophysicists work in iron exploration, 20% in gold, and 75% in critical minerals and other commodities. However, only 23% invest in new prospecting technologies, indicating a possible technological lag. The challenges are significant, as noted by Heider (2022). The identification of competitive mineral assets and deepening of mines with declining grades requires greater use of geophysics, but companies face obstacles such as high costs — 68% of small and medium enterprises consider it unfeasible to retain full-time geophysicists. There is also a shortage of skilled professionals, especially in the North, and underutilization of geophysics, as 45% of companies without specialists underestimate its use beyond the exploratory phase. In research institutions, the situation somewhat mirrors the labor market. Although the average number of geophysics faculty across eight institutions is 19.25 per institution, two have no faculty engaged in mineral exploration projects. In four institutions, fewer than 30% of professors work in the field, dropping to less than 15% in one case. UNIPAMPA stands out, with over 30% of its faculty involved in this area, while UnB leads in productivity, with an average of four projects per professor. This scenario highlights the need for policies that encourage geophysicist training and stronger integration between academia and industry.

4. Conclusions

Brazil's mineral sector faces a critical choice: maintain its traditional model or become a global leader in strategic minerals by overcoming bureaucratic, technological, and environmental challenges. Investment in rare earth research and support for small and medium-sized enterprises is essential, given the technical disparity between large corporations and other players. Creating regional consortia, centers of excellence in geophysics, and internship programs with universities can democratize knowledge. The regulation of the geophysics profession was an essential step toward greater job market inclusion. However, its appreciation and greater investment in mineral research are fundamental steps to strengthen the field, still overshadowed by petroleum.
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