GOVERNMENT OF BRAZIL MINING SECTOR TECHNICAL SUPPORT AND COOPERATION

Task 2B: Developing a Framework for a Nickel-Cobalt Inventory

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Acronyms

BPA	Blanket Purchase Agreement
CACB	Brazilian Sediment Hosted Cu-Co
CAGR	Compound Annual Growth Rate
CAES	Compressed Air Energy Storage
CAPEX	Capital Expenditure
CIM	The Canadian Institute of Mining, Metallurgy and Petroleum
CMP	Carajás Mining Province
CPRM	Geological Survey of Brazil
CRIRSCO	Committee for Mineral Reserves International Reporting Standards
Cu-Co	Copper-Cobalt
DOS	Department of State
DRC	Democratic Republic of Congo
EMGP	Energy and Mineral Governance Program
ENR	Bureau of Energy Resources
ESG	Environment, Social, and Governance
EV	Electric Vehicles
HPAL	High-pressure-acid-leaching
IBGE	Instituto Brasileiro de Geografia e Estadística / The Brazilian Geographical and Statistical Institute
JORC	The Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves
MME	Ministry of Mines and Energy
Ni-Co	Nickel Cobalt
NMRR	U.S. National Mineral Resource Reports
PGE	Platinum Group Elements
PGM	Platinum Group Metals
PNM	National Plan for the Brazilian Mineral Sector
PV	Photovoltaic
REE	Rare Earth Elements
SGB	The Brazilian Geological Service
Ti	Titanium
UNFC	United Nations Framework Classification
USGS	United States Geological Survey
Zr	Zirconium

EXECUTIVE SUMMARY

Deloitte is implementing the *Government of Brazil Mining Sector Technical Support and Cooperation* Task Order (the Project) under Deloitte's Blanket Purchase Agreement (BPA) with the U.S. Department of State (DOS) in support of the Bureau of Energy Resources' (ENR), Energy and Minerals Governance Program (EMGP). The Deloitte team is providing technical assistance to support the Government of Brazil's Ministry of Mines and Energy (MME) and the Geological Survey of Brazil (CPRM) as they seek to improve their ability to:

- Develop safe, sustainable, and effective mine closure procedures and use of tailings, including methods of tailings sampling and characterization, based on international leading practices, to protect and improve the legacy of ongoing and future projects, thereby realizing sustainable benefits from the extractives industry;
- Manage a growing mineral sector and compete effectively in the global market, given a growing market and accelerated demand for critical minerals that are essential to the development of innovative technologies to advance the global clean energy transition [electric vehicles (EVs), batteries, and battery storage systems, etc.]; and
- Streamline the structure of Brazil's nickel-cobalt data inventory, so Brazil can improve its understanding and increase development of critical minerals.

Under *Task 2B: Developing a Structure of a Brazilian Nickel-Cobalt (Ni-Co) Inventory* (this Report) the Deloitte team provides: (i) a review and analysis of three mineral reports [graphite, rare earth elements (REEs), and manganese] developed by CPRM, which form the current approach and methodology for the Ni-Co inventory report; (ii) a detailed inventory structure for CPRM's consideration, plus leading practice examples of how other countries develop and organize mineral inventories (with a focus on Ni-Co inventories), and; (iii) recommendations on how CPRM could develop the inventory framework in a manner that would address both Brazil's strategic concerns, and the investment/commercial needs of potential private sector developers.

Key Findings

- A number of national, state, and provincial governments such as, the United States, the state of Alaska, Western Australia, and Brazil publish mineral inventory reports. The purpose of these reports is to: (i) document the country's/state's/province's geological and mineral resource occurrence information to support government's overall mineral policy; and (ii) make the information available to the public and industry to demonstrate a country's/state's/province's exploration potential, encourage mining development, and promote mineral-related economic growth. Leading practice mineral inventories generally include geological descriptions, locations, mineralogy, deposit types, work histories, resource and/or reserve statistics, analytical results on known mineral occurrences, and bibliographies. CPRM has produced several robust mineral inventory reports on the geological potential of various minerals in Brazil, including graphite, REE, and manganese. These reports generally align with leading practice requirements, such as those outlined in the McKelvey Framework[1] and the United Nations Framework Classification (UNFC)[2].

[1] McKelvey diagrams are used to describe a natural resource, such as in-situ mineralogy, based on the geologic certainty of its presence and its economic potential for recovery. The diagram is used to estimate the uncertainty and risk associated with the availability such a resource, illustrating that - as geological assurance and economic recoverability of a resource decreases - risk correspondingly increases.

[2] UNFC explicitly identifies three dimensions for assessing projects; (E) Economic and commercial viability; (F) Field project status and feasibility; and (G) Geological knowledge.

- Addressing environmental, social, and governance (ESG) challenges related to mining, smelting, refining, and tailings management in mineral production is becoming increasingly important to investors and original equipment manufacturers (OEMs). Leading practice inventory reports such as those produced by the United States Geological Survey (USGS)[3] include specific ESG requirements in an effort to enhance transparency and accountability of the governments and the mining industry. These reports now include information on the possible environmental effects of mining and mineral processing to give a more complete picture of both the positive and negative potential impacts of mineral production. To date, CPRM's inventory reports have primarily focused on providing investors with reliable geological information and resource and/or reserve statistics. Given the ESG global trends noted above CPRM should consider adapting its inventory format to also address ESG themes, thereby signaling to investors and OEMs that such requirements are now being integrated into long-term sector planning throughout the value chain.
- CPRM staff are well trained in mineral resource assessment, possessing the relevant advanced educational qualifications (e.g., Master of Science or Doctoral degrees in different aspects of the geosciences), technical skills, and expertise required to produce robust geological reports. As the Government of Brazil expands the production and development of critical minerals, CPRM should continue to expand its human and institutional capacity (with a focus on ESG) to support sector development and attract responsible sector investment for sustainable long-term industry growth.

Key Recommendations

To develop a Ni-Co inventory that addresses both Brazil's strategic concerns, and the investment/commercial needs of potential private sector developers, the Deloitte team recommends that the Government of Brazil considers the following:

- **Incorporate leading practices into the Government of Brazil's Ni-Co inventory framework, via:**
    - **Including ESG information in the Ni-Co inventory report generally, and promoting the ESG advantages of Brazilian nickel and cobalt projects in particular, to accelerate access to development finance and facilitate regional investment.** Nickel-cobalt projects in Brazil have systemic ESG advantages relative to (for example) DRC copper-cobalt and Indonesian nickel-cobalt producers. For example, Brazil's access to low-cost, low-emissions hydroelectricity would give local nickel-cobalt producers a competitive advantage in both operating costs and carbon footprint vs. other locations. This advantage could potentially lead to better mine offtake terms, improved access to ESG-focused sources of development finance, and similarly enabled downstream regional investment in cathode- or lithium-ion battery manufacturing facilities.

[3] https://www.usgs.gov/publications/cobalt

- **Including information on Brazil's use of "prior informed consent"** (the right of a community to be informed about mining operations on a full and timely basis, and to approve such operations prior to commencement). Brazil should aim for robust public participation as part of an open and informed impact assessment process. Engaging members of the public in matters that affect their community enables local citizens to better understand the costs and benefits of resource development, while simultaneously enabling them to participate in the planning process. When planning new projects, mining companies should look for opportunities that align with local communities' priorities. If there are opportunities for a community to benefit from mining infrastructure, such as a road, railway, or energy facility, discussions between industry and communities should happen as far in advance as possible to determine that the development of a mining project addresses the communities' needs and priorities.
- **Publishing Updates to Infrastructure Developments.** Natural resource development potential can often be closely tied to extant level of infrastructure near a prospective mine. This may include the existence of highway, power, and rail grids, all of which have the potential to enhance the attractiveness of a given project. An integrated approach to infrastructure planning may also enable national and regional governments to prioritize the scheduling and financing of new infrastructure projects, potentially via public/private partnerships.
- **Providing Education and Labor Information.** Mineral reports included in the Ni-Co inventory framework should also describe the availability and skills of the local workforce. Understanding the capacity of the local/regional population is a key factor in the successful development of the sector, and in negotiating appropriate local community hiring commitments.
- **Continuing to conduct basic scientific research, and outlining current and planned research, in future CPRM's mineral inventory reports.** Knowledge about regional geological factors, new research into potential Ni-Co sources (including seafloor sulfide nodules), and the potential for efficient mineral processing (bulk laterite leaching) will help to attract the attention of other innovative parties and investors.

Incorporating such information will depend on data availability, although much of this information is already available from the Brazilian Geographical and Statistical Institute (IBGE) online system and is therefore easily accessed.[4] Such information, coupled with the geological data already available on the CPRM website[5], provides a robust basis for attracting long-term responsible investment in the sector. Table 1 below outlines the information that is generally provided in leading practice mineral reports and compares this to the information currently provided in the inventory reports produced by the Government of Brazil. Of the reports noted below, the **Deloitte team recommends that the Government of Brazil use the USGS Cobalt report as a template** for Ni-Co inventory reports, and incorporate information on labor, education, and infrastructure developments to further enhance their mineral inventory framework to attract responsible investments in the country.

[4] https://www.ibge.gov.br/en/home-eng.html

[5] https://geosgb.cprm.gov.br/

Table 1: Leading Practice Mineral Report Comparison

	USGS Cobalt[6]	Alaska Platinum Group Elements [7](PGE)	Australia REE[8]	Australia Mineral Sands[9]	Brazil Graphite[10]	Brazil REE[11]	Brazil Manganese[12]
Introduction	**Y**	Y	Y	Y	Y	Y	Y
Objectives	**Y**	Y	Y	Y	Y	Y	Y
Commodity Uses and Demand	**Y**				Y	Y	Y
Mineral Economics	**Y**	Y			Y		Y
Ore Minerals	**Y**	Y	Y	Y	Y	Y	Y
Principal Deposit types	**Y**	Y	Y	Y	Y	Y	Y
Exploration Methods	**Y**				Y	Y	
Exploitation Methods	**Y**				Y		
Known Deposits	**Y**	Y	Y	Y	Y	Y	Y
Unknown/Potential Resources	**Y**				Y		
Environmental and Social Considerations	**Y**						
Updates to Infrastructure Developments							
Providing Education and Labor Information							
Ongoing/Future Research	**Y**				Y		

[6] Recommended format (with additional data on infrastructure) https://www.usgs.gov/publications/cobalt

[7] http://doi.org/10.14509/30468.

[8] https://www.ga.gov.au/scientific-topics/minerals/mineral-resources-and-advice/australian-resource-reviews/rare-earth-elements

[9] https://www.ga.gov.au/scientific-topics/minerals/mineral-resources-and-advice/australian-resource-reviews/minerals-sands

[10] https://rigeo.cprm.gov.br/handle/doc/21910

[11] https://rigeo.cprm.gov.br/handle/doc/16923

[12] https://rigeo.cprm.gov.br/handle/doc/20421

1. INTRODUCTION

1.1. Purpose of this Report

The purpose of this report is to help the Government of Brazil streamline the structure of Brazil's Ni-Co data inventory, so Brazil can improve its understanding and increase development of critical minerals, and the investment/commercial needs of potential private sector developers.

1.2. Organization of this Report

This Report is organized into five main sections and one annex:

- **Section 1: Introduction** – Presents the purpose of this Report, provides a background on developing a Ni-Co inventory framework, and summarizes leading practices for a mineral inventory structure.
- **Section 2: Comparative Review of Approaches of Selected Mineral Inventory Report** – Provides a summary of information on key aspects of inventory reports from Brazil, the United States, Western Australia, and Alaska.
- **Section 3: Competition for Brazilian Products** – Gives an overview of domestic and foreign markets for nickel and cobalt with key points to address in an inventory report framework.
- **Section 4: Leading Practices and Trends for Inventory Reports** – Provides information on a proposed Ni-Co inventory framework, highlighting recent key features related to ESG, infrastructure and labor information.
- **Section 5: Conclusions and Key Recommendations** – Summarizes the Deloitte team's analysis of a framework for Ni-Co inventory and provides next steps for Brazil.
- **Annex 1** – Provides an overview of a recommended Ni-Co inventory structure for Brazil.

1.3. Background and Context

1.3.1 The Importance of Nickel and Cobalt

Nickel and cobalt are important metals for a variety of industrial uses. Global nickel demand is driven by the stainless-steel industry currently, which accounted for 72 percent of total primary nickel consumption in 2020.[13] Other demand drivers for nickel include alloy steels and castings, plating, non-ferrous alloys, and batteries. In Brazil, nickel demand is driven by demand for stainless steel as well as for alloys,

Worldwide, cobalt demand and consumption is driven primarily by lithium-ion batteries. Global cobalt consumption in 2020 was approximately 135 kt, according to the Cobalt Institute, a trade association of producers, traders, and consumers of cobalt. Batteries accounted for 57 percent of the global consumption of cobalt in 2020. Other significant uses of cobalt include nickel-based alloys mainly used in turbine engine components (14 percent of global consumption), and hard materials used in carbides for cutting tools (8 percent).

[13] Nickel Institute.

1.3.2 History of Mineral Inventory Reports

Mineral inventory studies are designed as an application of science for the public good. As such, these studies are a resource for government policy decisions, university and post graduate education, and background information for potential domestic and international investors/developers. The reports communicate the availability of information as a key element in effective and efficient use of mineral resources to meet the future needs of economies and societies.

To accomplish this, a mineral inventory report:

- Informs the public of the existence of a specific mineral, the potential demand for that mineral, and the geological factors that would allow an interested party to explore and potentially discover similar resources;
- Supports national mineral policy and the development of policies to facilitate exploration, development, and production activities;
- Provides the information to industry to present development economic potential for raw materials development; and
- Allows commercial enterprises to focus their efforts on promising regions and technologies.

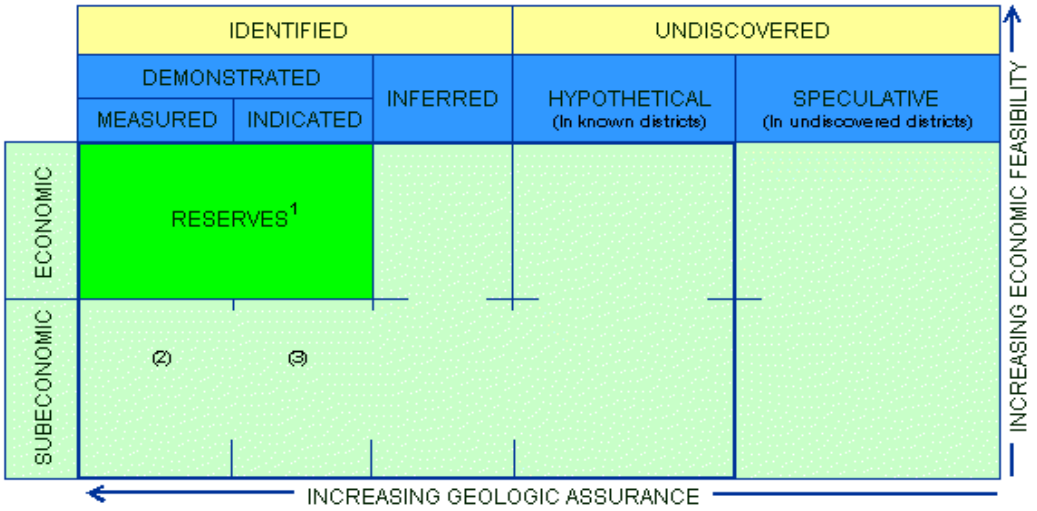
Although CPRM has produced several robust mineral inventory reports on the geological potential of various minerals in Brazil (e.g., graphite, REE, and manganese), these reports should also incorporate ESG information and impact concerning mineral production and strategies for future exploration, production, and reclamation/restoration.

1.3.3 Leading Mineral Inventory Frameworks

Since 1976, USGS has based its reports around a framework called the McKelvey Diagram shown in Figure 1.[14] The McKelvey Diagram has been the basis for several national inventories since its publication. It clearly defines a framework for mineral resource management by including key components, such as long-term public and commercial planning, geologic identification of resources, and technological development for deposits. The key elements in inventory reports normally include the mineral's uses, products, mineral economics, deposit types, exploration, and known and unknown deposits, which are directly referenced in the McKelvey classification schema.

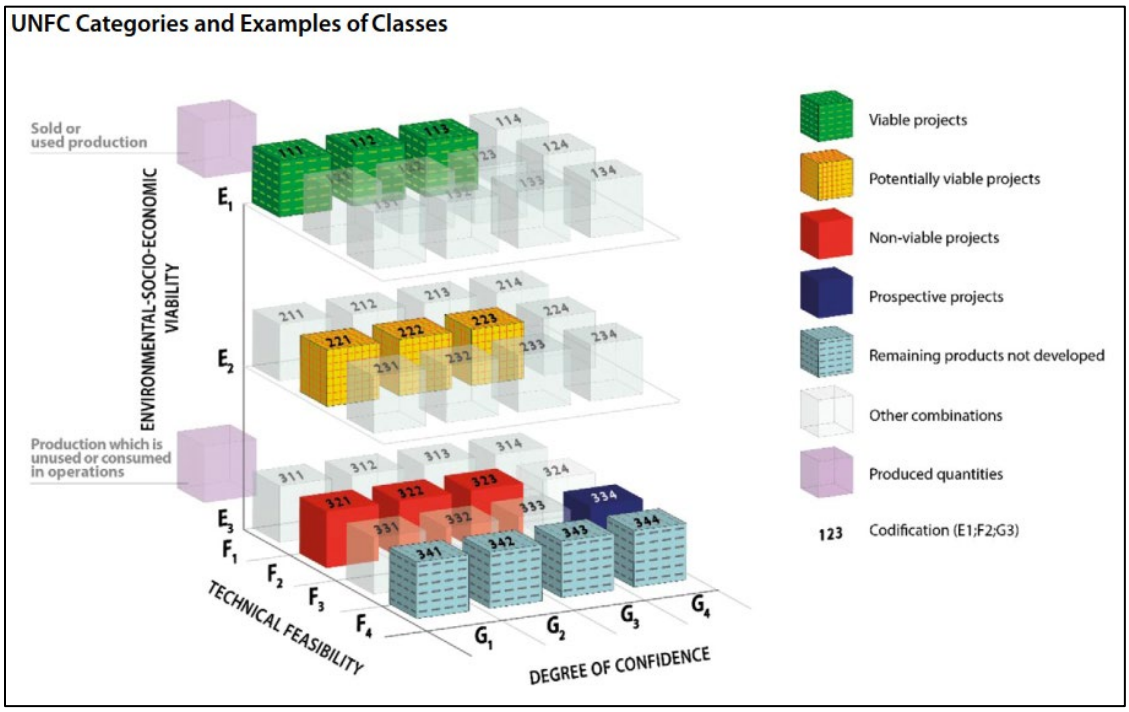
[14] Thomas S. Kleppe and V. E. McKelvey, 1976, "Principles of the mineral resource classification system of the U.S. Bureau of Mines and U.S. Geological Survey: Geological Survey Bulletin 1450-A" by U.S. Bureau of Mines and U.S. Geological Survey. Washington, D.C.: United States Government Printing Office, 1976, p. A2.

Figure 1: McKelvey Diagram[15]



In 2019, the United Nations published the UNFC for mineral resources shown in Figure 2. This classification contains the key elements of the McKelvey Diagram in a more generalized system. It is used as the basis of national resource classification in many countries including China, India, Mexico, Poland, and Ukraine, as well as in the European Union for raw material resources.

Figure 2: United Nations Framework Classification[16]



[15] Kleppe et al. p. A1.

[16] United Nations Framework Classification for Resources; Update 2019, p.2.

The UNFC defines a hierarchy where there are four significant levels of projects:

1. **Mineral Reserves**: Known projects that are technically and economically viable (Class 1);
2. **Mineral Resources**: Projects that are not viable but could become so through economic or technical advances (Class 2);
3. **Mineral Endowment**: Projects that are expected to exist but are not foreseen as viable (Class 3); and
4. **Prospective Projects**: Projects that are unknown but have similar geological characteristics as known projects (Class 4).

The national mineral resource reports commonly summarize information about Class 1 and 2 (mineral reserves and mineral resources) to inform the audience about potential in Class 3 and Class 4.

The overall scope of mineral inventory reports is described based on comparisons of reports currently available. The USGS has published many of these reports, and Brazil has also produced several well-developed mineral reports.

2. COMPARATIVE REVIEW OF APPROACHES OF SELECTED MINERAL INVENTORY REPORTS

This section provides a review and analysis of three mineral reports developed by CPRM, as well as other leading practice reports that serve as good examples of how other countries develop and organize mineral inventories. The Deloitte team utilized the McKelvey Framework and the UNFC hierarchy as benchmarks for these reports. The Deloitte team reviewed and analyzed the following CPRM and international reports:

- CPRM Graphite
- CPRM REE
- CPRM Manganese
- USGS Cobalt
- Alaska PGE
- Australia REE
- Australia Mineral Sands

2.1. Mineral Inventory Reports Developed by CPRM

The CPRM provided the Deloitte team with three mineral inventory reports as examples of previous work in the sector. These reports followed the guidelines provided in the McKelvey Framework and the UNFC hierarchy, which list mineral reserves, mineral resources, mineral endowments, and prospective projects as key items of a good inventory report. The following sections review and discuss the CPRM reports and include:

- Evaluation of Graphite Potential in Brazil, Sousa, M.
- Evaluation of the Potential of Rare Earths in Brazil, Takehara, L.
- Stratigraphy and Analysis of Manganese ore from Carajás, Araújo, R. et. al.

2.1.1 Graphite

Graphite is a versatile, carbon mineral that is used in many different metallurgical and manufacturing industries because of its unique properties such as its resistance to outstanding thermal and electric conductivity and its high resistance to oxidation, cyclic temperature stress, high pressure, and most chemical agents.

2.1.1.1 Summary of the Report

The CPRM graphite report[17] is a leading example of a national geological report because it adheres to the McKelvey Framework of reporting, and it includes the following:

- The exploration and reconnaissance methods used for data acquisition;
- The physical and geological characteristics of graphite and a discussion of why the parameters are important to the future exploration-exploitation-industrial use of graphite; and
- The mineral economics of graphite with a description of the current use in the industry, including:

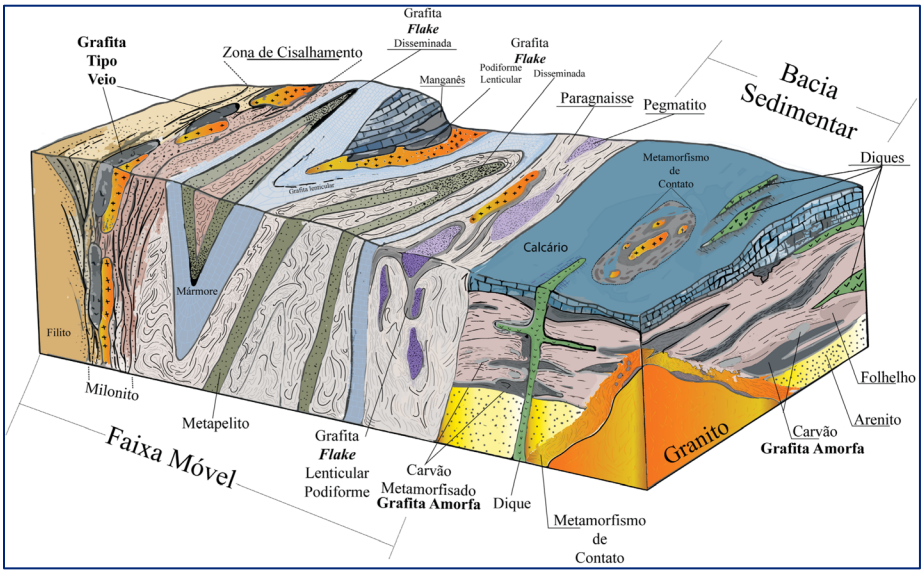
[17] Sousa, Marcelo Januário de Projeto Avaliação do Potencial da Grafita no Brasil: Fase 1 / Marcelo Januário de Sousa, Débora Rabelo Matos. (Org.) – São Paulo: CPRM, 2020. 141 p.

- The basis to declare graphite as a strategic and critical mineral;
- The international distribution of mineral resources; and
- The international distribution of production of graphite.

The metamorphic origins of most graphite are referenced in the discussion of individual deposits, as well as a graphical description of common depositional models, as depicted in Figure 3. Also, there is a discussion on the geological setting of the licensed deposits as a reference for explorers.

Although there is a thorough description of the regional situation within Brazil, the level of detail by tectonic province is not consistent. The Guiana Shield and the Goiás Massive, the areas with the most graphite development, are discussed in extensive detail, with maps, photos, and photomicrographs of mineral from individual projects. Similar detail should be provided for other regions, especially those with high graphite prospectivity.

Figure 3: Schematic Diagram of Classic Graphite Models[18]



2.1.1.2 Recommendations for the Report

The Graphite report ends with a theoretical discussion of graphite formation via metamorphism of coal deposits. This is described as a new metallogenic model previously not considered by the Brazilian mining industry. The report does not present any recommendations, and there is no discussion of what microgeological or geomorphological characteristics would be most useful in exploration or development of a generic graphite project. CPRM should consider providing recommendations on this topic.

In addition, adding descriptions of planned or proposed research work would be an important addition to the report, which may include suggestions for potential resource areas, exploration techniques that have proven successful in graphite discovery and development, combinations of remote sensing, geochemistry, geophysics, and on the ground field work such as geological mapping and sampling.

[18] Sousa, Marcelo Januário de Projeto Avaliação do Potencial da Grafita no Brasil: Fase 1 / Marcelo Januário de Sousa, Débora Rabelo Matos. (Org.) – São Paulo: CPRM, 2020. 141 p.

Finally, a plan for recommended government action would enhance the impact of the report. This could encompass strategic investment in infrastructure or refining facilities, research in industrial uses, and efficiencies for new products such as batteries.

2.1.2 Rare Earth Elements

The REE, which are composed of the lanthanide series in the periodic table, are relatively heavy elements, with some unusual properties that involve electricity and magnetism. This can make the minerals valuable for semiconductor chips and for high intensity permanent magnets.

In 2015, CPRM compiled an "Evaluation of Potential of Rare Earths in Brazil".[19] The report presents a good framework of the important deposits and the strategic context of the industry.

2.1.2.1 Summary of the Report

Brazil's REE inventory report offers a balanced summary with a general description of REE uses and deposit types. The report describes REE deposits with detailed maps, photos, and information of their principal geological characteristics. The report also has chapters with more detailed descriptions of each geologic deposit type such as alkaline complexes, carbonatites, granitic rocks, and terrestrial and marine placers. Moreover, there is a thorough discussion of granitic deposits weathering into ionic clays, which is a principal source of REE's in other mining jurisdictions, like China.

Finally, there is some discussion of REE's associated with other minerals as a bi-product or co-product, which include phosphate rock and niobium deposits as well as coal (principally coal ash). Through Brazil's extensive phosphate mining industry, with appropriate research, the phosphate mining in Brazil has potential to extract REEs.

2.1.2.2 Recommendations for the Report

The REE inventory report presents recommendations but focuses strictly on steps that CPRM could undertake on known, but underexplored deposits. The report does not include a discussion on the application of geological models for other discoveries and the geographies where those might exist. Thus, the detailed description of geology of the individual deposits could be synthesized into a depositional/exploration model of REE deposits in each terrane (alkaline, granitic, or placer), and what size or grade of targets could be expected based upon these models. Initial analysis could be done for Goiás or the Carajás area of Pará.

The definition of the regional potential would permit a discussion of the availability of infrastructure, talent, and industrial services. A discussion of environmental impacts or social risks and mitigations could focus attention for investors on the level of effort needed for exploration and development, as well as tools for government decision-making concerning medium and long-term development.

Several elements that are included in other national inventory reports are missing for the rare earth study. These include:

- Undiscovered resources and unconventional resources;
- The detailed fieldwork;
- Exploration for new deposits and principal target areas; and

[19] Takehara, Lucy. "Avaliação do potencial de Terras Raras no Brasil" Organizado por Lucy Takehara. – Brasília: CPRM, 2015. 218 p.: il. – (Informe de Recursos Minerais, Série Minerais Estratégicos, 02). ISBN 978-85-7499-278-5

- Non-geological considerations, which have the potential to expand the national graphite resources and reserves via creative geoscience and are important to include because of feasibility/permitting new mining operations.

2.1.3 Manganese in Carajás

2.1.3.1 Summary of the Report

Manganese is a metal that is commonly used in stainless steel to enhance metal alloys. It is common in hydrothermal deposits; however, profitable economic deposits are mined in less than 10 countries. In 2018, CPRM published a report about manganese in the Carajás area of Para.[20] The discussion on various districts within the Carajás area is detailed with extensive geological descriptions of each deposit and with photos and photomicrographs.

The Carajás Mineral Province (CMP) contains a large variety of geological terranes with varied characteristics. Many deposits are geologically older, including Archean and Proterozoic ages. Deposits are often sediment or metasediment (metamorphosed sediments) hosted.

Overall, the manganese report is thorough, detailed, and descriptive. It is a good example of a geological mineralogical summary of a specific area. It is very focused on known deposits, many of them currently or previously in production, which was the objective of the report. The report is, however, limited in terms of discussing mineral potential, or circumstances beyond the CMP.

2.1.3.2 Recommendations for the Report

The manganese report provides an excellent snapshot of the current situation in the country, however, it does not offer elements for policy planning, uses and markets of manganese, and a series of maps to show trends. First, a discussion of investment in research to enhance the industry and highlight some "next steps" would create a useful path for potential government investment or decision making. Second, a discussion of the uses and markets of manganese would be an important enhancement to the report.

Finally, a series of maps showing regional trends and the relationship between the geological terranes and the known deposits could be beneficial. The detail is exceptional although there is no synthesis of the information into a genetic model that could be used for exploration. The strategic aspect of the inventory, including unknown and undiscovered deposits, would require the interested reader to perform that analysis based on the data presented. Moreover, as with the other reports, a framework for exploration and development would greatly improve the usefulness of the report for industry readers.

2.1.3.3 Summary of the Three Reports Developed by CPRM

The three reports reviewed, graphite, REE, and manganese, could be improved with the use of the online CPRM database. The CPRM database contains a wealth of the survey's own data as well as other agencies online, which could be referenced to provide more background information on these and other mineral inventory reports. One example is the "Catalog of Prospectivity Maps," which give a GIS presentation of the current understanding of where each mineral in Brazil potentially resides. An example of such a presentation is included in Figure 4. The province Oceano Atlantico has been added by the Deloitte team to reflect the additional potential for sea floor cobalt enriched nodules off the coast of Brazil.

[20] Área de Relevante Interesse Mineral - Província Mineral de Carajás, PA: estratigrafia e análise do minério de Mn de Carajás - áreas Azul, Sereno, Buritirama e Antônio Vicente / Raphael Neto Araújo, Marcelo Januário de Sousa - Belém: CPRM – Serviço Geológico do Brasil, 2018.

Figure 4: Mineral Provinces of Brazil[21]

2.2. Comparable International Reports

The following paragraphs present a review and analysis of current international mineral inventory reports from other leading mining jurisdictions. As in the previous sections of this Report, the Deloitte team utilized the McKelvey Framework and the UNFC hierarchy as benchmarks for these reports.

2.2.1 USA – Cobalt

Cobalt is a lustrous, greyish-silver, brittle metal famous for its blue pigment, and has a broad range of uses based on certain key properties, including ferromagnetism, hardness, and wear-resistance. When alloyed with other metals, cobalt attains a low thermal electrical conductivity and a high melting point. Cobalt is mainly used in cathodes for rechargeable batteries and in superalloys for high temperature applications such as turbine engines in jet aircrafts.

2.2.1.1 Summary of the Report

The USGS Cobalt report was published in 2018[22] and provides the most complete and current national mineral resource report up to date. This report could provide a foundation for the Government of Brazil to begin the development of a Ni-Co report. The USGS report covers the major producing regions of the world and the recognized deposit types. According to the USGS Cobalt report, there are three principal sources of Cobalt. Table 2 shows the principal deposit types:

Table 2: Principal Deposit Types

Types of Principal Deposit	Description
Stratiform Sediment-Hosted Cu-Co Deposits	Majority of production from the DRC. Occurs as a byproduct of copper mining
Ni-Co Laterite Deposits	Weathered ultramafic rocks. Occur in tropics, including Brazil, Africa, and Australia
Magmatic Ni-Cu(-Co-PGE) Sulfide Deposits	Massive sulfides hosted in unweathered ultramafic rocks. Occur in Brazil, Canada, the northern USA, and Siberia

[21] CPRM

[22] Professional Paper 1802–F; U.S. Department of the Interior; U.S. Geological Survey) [Slack, J.F., Kimball, B.E., and Shedd, K.B., 2017, Cobalt, chap. F of Schulz, K.J., DeYoung, J.H., Jr., Seal, R.R., II, and Bradley, D.C., eds., Critical mineral resources of the United States—Economic and environmental geology and prospects for future supply: U.S. Geological Survey Professional Paper 1802, p. F1–F40, https://doi.org/10.3133/pp1802F. https://doi.org/https://doi.org/10.3133/pp1802F

Figure 5 illustrates the proportions of cobalt contained in mineral deposits worldwide including cumulative past production, plus reserves, plus other resources. Two pie diagrams show the cobalt resources for terrestrial deposits (A) and sea-floor deposits (B).

Figure 5: Proportion of Worldwide Cobalt Resources by Geologic Terrain[23]

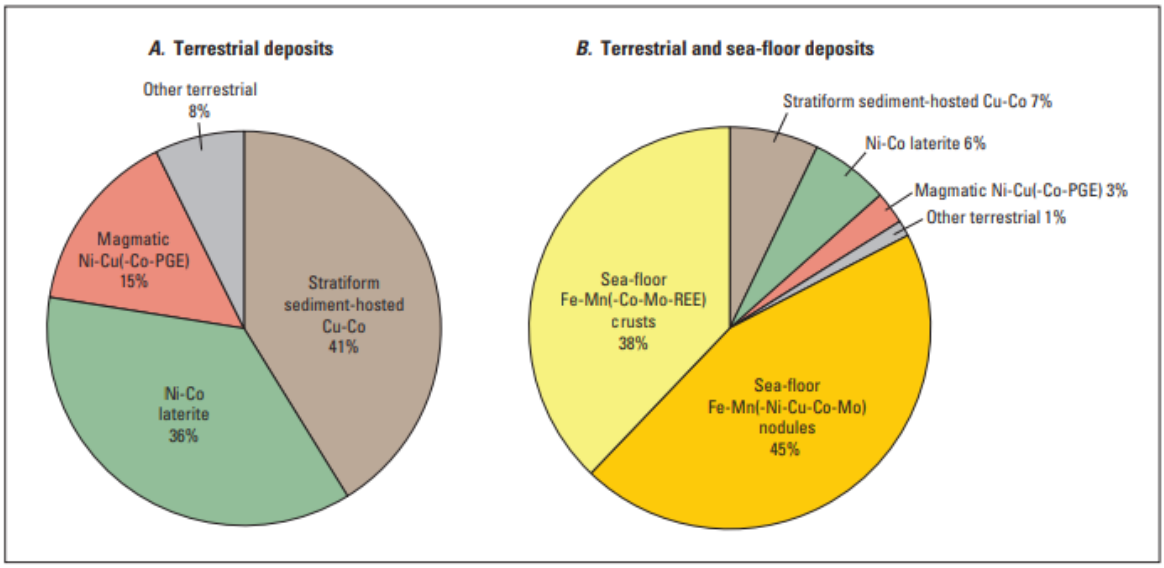
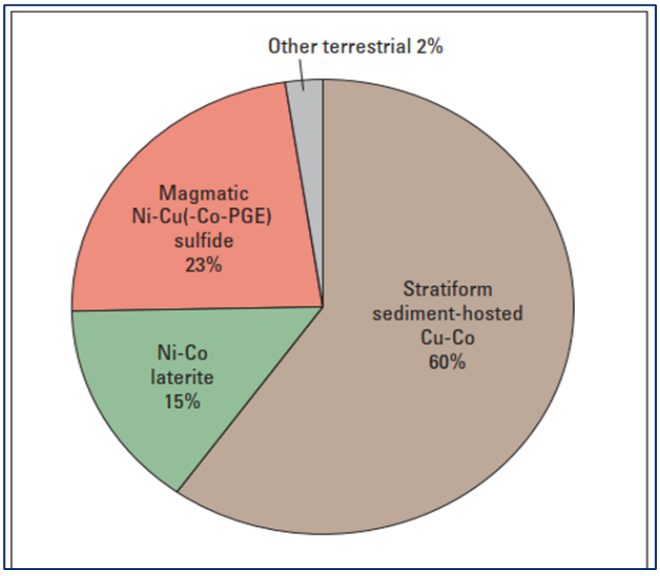


Figure 6 shows the breakdown of world cobalt production in 2011 by primary deposit type. Not included in the figure are other secondary terrestrial deposits including black-shale-hosted Ni-Cu-Zn-Co deposits, polymetallic (Ag-Ni-Co-As-Bi) cobalt-rich veins, and volcanogenic Cu(-Zn-Co-Ag-Au) massive sulfide deposits.

Figure 6: Percentage of World Cobalt Mine Production in 2011, by Deposit Type[24]



[23] Slack et al. 2017.

[24] Slack, et al 2017.

In addition to these deposits, the USGS Cobalt report highlights an increasingly important area of interest for cobalt, which is found in sea floor crusts and sea floor nodules. This is a relatively new area of research with exploration of the Atlantic seafloor off of the South Africa and Namibia coasts. Results of the exploration of the Rainbow vent field on the Mid-Atlantic Ridge has shown volcanogenic massive sulfide (VMS) deposits that contain significant amounts of cobalt.[25]

The geological processes that form VMS deposits occur at the depths of the ocean and are associated with volcanic and/or sedimentary rocks.[26] Other deposits of this type that are found on the Mid-Atlantic Ridge occur in the Logatchev[27] and the Nibelungen fields.[28] Research on this topic is referenced in Section 3.1.

An innovative aspect of the Cobalt report is the introduction of ESG impacts and solutions. The USGS Cobalt report is the first report that describes the environmental aspects of the metal's mineral production. It states, "*Cobalt is an essential nutrient for most life, but it can cause toxic effects when present in solids or waters at concentrations that are significantly enriched relative to normal background levels.*" The report identifies concerns with waste rock, process tailings, human health, environmental health, and mine closure that may be affected by cobalt.[29]

An environmental focus combined with the current mining industry focus on ESG impacts of mining projects has become an essential part of National Mineral Resource Reports (NMRR). Data is currently available in the Government of Brazil databases, which should be included and discussed in the Ni-Co inventory report.

2.2.1.2 Recommendations for the Report

The USGS report concludes with recommendations on further research focused on four distinct topics:

- Better geologic models for cobalt-rich ores;
- Improved methods for increased recovery of cobalt from Ni-Co laterites;
- Development of processes for the efficient and economic recovery of cobalt from silicate minerals and other ultramafic minerals; and
- Technological advances to help make the mining and extraction of cobalt from deep-sea ferromanganese nodules and crusts economically profitable.

These might form a basis for a Brazilian Ni-Co report, and through connections with the USGS, might offer opportunities for original research on these themes.

2.2.2 Alaska – Platinum Group Metals (PGM) Elements in Wrangell Area

The most common PGM are platinum, palladium, and rhodium. While platinum is used in jewelry, most of the demand for these three metals is the manufacture of catalytic converters for the automotive market.[30]

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[25] Bogdanov and others, 2002.

[26] Lepan, Nicholas, , 2022

[27] Mozgova and others, 1999.

[28] Melchert and others, 2008.

[29] op.cit. USGS pF16-F18.

[30] https://www.thermofisher.com/blog/metals/what-are-the-platinum-group-metals-and-why-do-they-matter/

2.2.2.1 Summary of the Report

The Department of Natural Resources of the State of Alaska has produced a focused report on platinum group elements (PGE) near the Wrangellia deposit.[31] This report is focused on "…*the geologic context of mineralization hosted by the Wrangellia terrane in the eastern Alaska Range and Talkeetna Mountains, with particular emphasis on evaluating the area's potential for hosting the strategic and critical platinum-group elements (PGEs) and cobalt (Co)".* The goal for this report is to understand the ore-forming processes to assess mineralization potential.

The report describes in some detail the geological model and the interrelationships of the minerals to the geological factors. As an example, an explorationist may find it useful to use the report's finding an association of higher grade PGE with higher measures of Mg # (100*[molar MgO/(MgO+FeO)]) within high titanium rocks of picrite, basalt, and gabbro.

2.2.2.2 Recommendations for the Report

The host rock, deposit, and mineral genesis of the deposits is thorough in this report. This thoroughness is founded in the inclusion and compilation of information from specialists within the Alaskan Geological Survey, the U.S. Geological Survey, and private contributors. Although no specific conclusions are presented concerning further work or recommendations, this collaborative method has enhanced the value of the report and the report is a good model for the Government of Brazil/CPRM to follow in future studies.

2.2.3 Australia REEs

In 2019, Australia published a mineral inventory report on REEs.[32] The scope included REE resources in Australia, as of the publication date.

2.2.3.1 Summary of the Report

The Geoscience Australia report is entirely focused on REEs and summarizes mineral resources and reserves that have been reported under the JORC (Australian Joint Ore Reserves Committee) code (a Committee for Mineral Reserves International Reporting Standards [CRIRSCO] code). The report covers only the "reserves" portion of the McKelvey Framework.

There is discussion of Australia's place in world production and on the markets and expected demand for REEs. There is also a territory-by-territory list of Australian projects with a summary of each project and its key points.

2.2.3.2 Recommendations for the Report

Resources of REE worldwide are associated with four geological environments: alkaline igneous rocks, carbonatites, placers (alluvial or fluvial deposits) with monazite xenotime minerals, and ion adsorption clays. In Australia, REE discoveries to date have been found principally in carbonatites and placers.

The report does not provide a discussion of deposit types, exploration methods, or geology other than the JORC provided information. In general, this report is a catalog of existing projects without presenting strategic recommendations. Presentation of future steps for both the government and industry would enhance the value of the report.

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[31] Twelker, Evan, Lande, L.L., Newberry, R.J., Wypych, Alicja, Sicard, K.R., and Freeman, L.K., 2020, Magmatic and structural framework of PGE and other mineralization in northwestern Wrangellia, Central Alaska: Alaska Division of Geological & Geophysical Surveys Report of Investigation 2020-6, 72 p. http://doi.org/10.14509/30468.

[32] Huleatt, M.B., 2019. Australian Resource Reviews: Rare Earth Elements 2019. Geoscience Australia, Canberra.

2.2.4 Australia Mineral Sands (Ti and Zr)

Mineral sands are often found in river and beach deposits where lighter silica sands have been removed by flowing water. The titanium oxide (TiO) minerals, ilmenite, and rutile are commonly utilized to produce titanium dioxide ($TiO_{2)}$, which is very white and is used in paints and pigments. Zirconium (Zr) is a silicate mineral which is very hard and resistant to erosion. It is used in decorative ceramics and in abrasives.

2.2.4.1 Summary of the Report

In 2018, Geoscience Australia published an inventory report on mineral sands[33] focused on ilmenite, rutile, and zircon. The mineral sands report is comparable to the REE inventory and to the Brazilian manganese report. It includes a detailed discussion of known resources and projects, but no additional information about the potential for the industry or for exploring unknown areas.

The Titanium and Zirconium report is a bit more thorough than the Australia REE report on past production and on expected market demand. This may be based on the relative maturity of the two industries. Mineral sands have been commercial in Australia at least since 1975, whereas REE reserves were first reported in 2012. Currently only one mine, owned by Lynas, is in production at Mt. Weld.

2.2.4.2 Recommendations for the Report

The report does not contain information about deposit types, exploration methods, or geology other than the JORC provided information. Comments are limited about the prospects for exploration or production in the industry. The Ti and Zr report is a catalog of existing projects without presenting strategic recommendations. Presentation of future steps for both the government and industry would be a beneficial addition.

2.3. Comparison of Reports

The reports are compared below in tabular form for ease of comparison. A detailed description of leading practices based on the comparison is presented in Section 4. The United States and Brazil are clearly the leaders in the content of the reports. The depth of detail varies among the reports; however, world class reports present the basic science, as well as plans or suggestions to move forward, strategically, operationally, economically, or in terms of social, environmental, and management of both projects and industries.

[33] Hitchman, A. P., 2018. Australian Resource Reviews: Mineral Sands 2017. Geoscience Australia, Canberra.

3. COMPETITION FOR BRAZILIAN NI-CO PROJECTS

A Ni-Co mineral inventory report should focus on the ability of Brazil to increase its production of raw materials for domestic and international consumption. The report should also outline the existence of a specific mineral, the potential demand for that mineral, and the geological factors that would allow a mining company to explore and potentially discover similar resources. It is also important that the report provides an overview of the domestic and international market for the mineral, its projected regional potential, the deposit types, and potential production methods, as well as projected global demand for the mineral to support investment decisions. Global pool of investment dollars for Ni-Co projects is limited, so it is important to highlight Brazil's strengths, such as its extensive laterite deposits.

3.1. Domestic Projects

Brazil has only one Ni-Co exploration project at a relatively advanced stage, Piauí, and two projects at pre-feasibility stage, Vermelho and Jacaré. There are currently five significant nickel mines operating in Brazil that produced over 85 kt of nickel in 2021 (*see* Table 3). Barro Alto and Onça Puma are mid-sized operations, while Santa Rita, Codemin, and American do Brasil are small operations. Santa Rita and Americano do Brasil are sulfide projects while the other three are laterite operations.

Table 3: Brazilian Nickel Producers (Nickel Production tonnes)

Mine	State	Owner	Production		
			2019	2020	2021
Barro Alto	Goiás	Anglo	33,900	34,900	33,900
Onça	Pará	Vale	11,600	16,000	21,429
Santa Rita	Bahia	Appian	0	9,159	16,087
Codemin	Goiás	Anglo	8,700	8,600	7,800
Americano	Goiás	Prometálica	6,000	6,000	6,000
		Total	**60,200**	**74,659**	**85,216**

Source: S&P Global Intelligence.

To meet the future sources of nickel and cobalt, new geological models and exploration technologies are needed.[34] From Brazil's perspective, it is paramount to implement geological, geophysical, and geochemical surveys. In addition, fundamental geoscience research should be promoted in both private and public sectors.

Some collaborative research projects have been initiated, such as the 'Cobalt Project', which is a "BioProLat - Reductive Bioprocessing for Cobalt and Nickel recovery from Laterites in Brazil"[35] project. For the Cobalt Project, the CPRM, together with the Federal Institute of Geosciences and Natural Resources of Germany (BGR), and Brazil's Mineral Technology Center (CTEM) researched the development of technology for mineral processing of cobalt based on bioleaching. The objectives as described include "… increase the recovery of metals for existing mines, transform unexploited ores and limonite stockpiles into valuable resources, thereby unlocking new reserves of raw materials[36].

[34] Slack, J.F., et. al. https://doi.org/https://doi.org/10.3133/pp1802F.

[35] https://www.bgr.bund.de/EN/Themen/Min_rohstoffe/Projekte/Lagerstaettenforschung_laufend_en/BioProLat/BioProLat_en.html

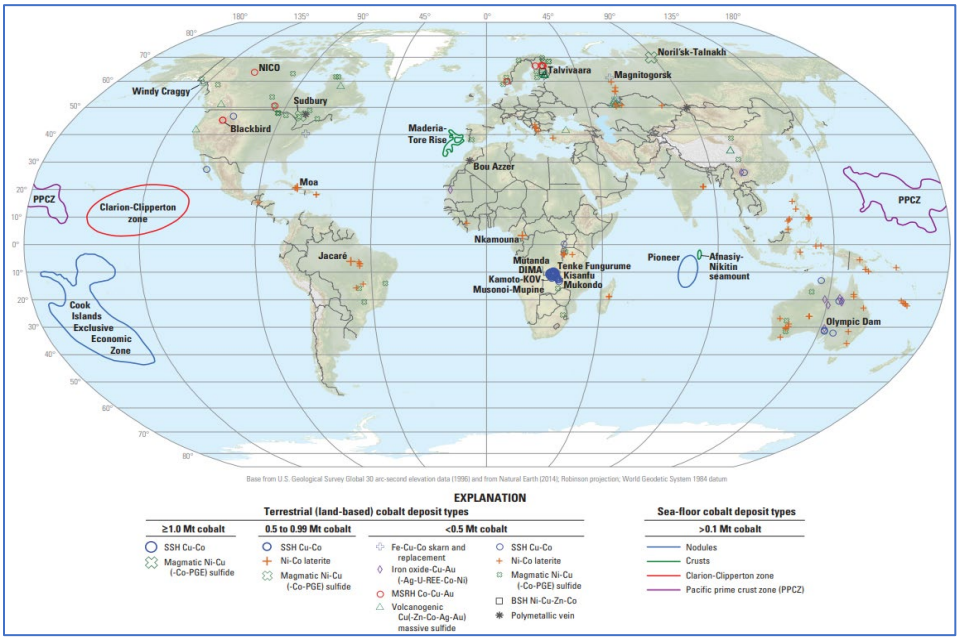
[36] ibid

In 2014, Brazil was awarded a 15-year grant of mineral exploitation rights by the International Seabed Authority (ISA) in an area known as the Rio Grande Rise approximately 1,500 km off the coast of Rio Grande do Sul. The ISA is an intergovernmental body set up under the UN Convention on the Law of the Sea (UNCLOS) to encourage and manage seabed mining.[37] Some work was completed on the Rio Grande Rise, and the project was presented on December 8, 2015, at FAPESP's headquarters in the city of São Paulo, but cobalt was not included in those results. Potential cobalt from sea floor nodules is an important area of continued research. The Brazilian Continental Shelf Project is an example of the CPRM collaborating with academia to map polymetallic sulfides in the Mid-oceanic Cordillera of the South Atlantic and Equatorial.[38]

3.2. International Projects

The current hub of international cobalt production is Africa. Mutanda (Glencore) and Tenke Fungarume (China Molybdenum) are leading seven mine expansions and restarts in the DRC. There are a total of 12 projects that are under construction, recently commissioned, or finalizing feasibility studies, two in the DRC, five in Indonesia, one in Canada, and two each in the United States and Australia. The five largest projects are in either Indonesia or the DRC. There is a total of 110k tonnes of cobalt production in these 19 projects. Figure 7 provides an overview of cobalt resources worldwide.

Figure 7: Cobalt Resources Worldwide[39]



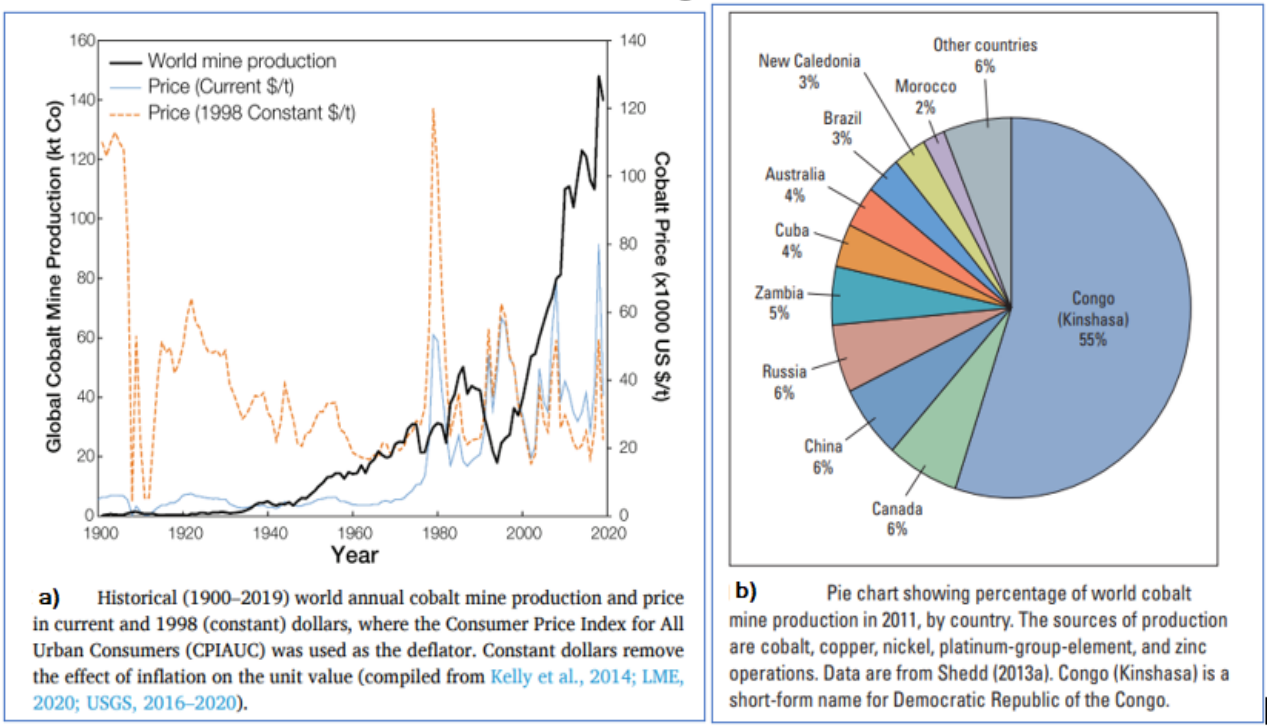
[37] https://www.lexology.com/library/detail.aspx?g=8968afa7-72ee-4af4-9b62-8d67674f208d

[38] Pro-Strategic Minerals: Decree 10,657, of March 24th, 2021 - Institutes the Policy to support the Environmental Licensing of Investment Projects to produce Strategic Minerals - Pro-Strategic Minerals, provides for its qualification under the Investment Partnership Program and creates the Inter-ministerial Committee for the analysis of strategic minerals projects. Integrate the National Mining Agency's database with that of the CPRM Geological Survey of Brazil. To meet this objective and other a mining development plan was published as the (Plano Nacional de Mineração 2030).

[39] Slack et al.

A key feature of inventory reports, in addition to the location of domestic and international resources, is the percentage of production around the globe and the overall production estimates, shown in Figure 8. Figure 8 shows that in 2013, Brazil at 3 percent and Cuba at 4 percent, respectively, of production are the only two Latin American countries with a significant percentage of world cobalt production.

Figure 8: World Annual Cobalt Mine Production



a) Historical (1900–2019) world annual cobalt mine production and price in current and 1998 (constant) dollars, where the Consumer Price Index for All Urban Consumers (CPIAUC) was used as the deflator. Constant dollars remove the effect of inflation on the unit value (compiled from Kelly et al., 2014; LME, 2020; USGS, 2016–2020).

b) Pie chart showing percentage of world cobalt mine production in 2011, by country. The sources of production are cobalt, copper, nickel, platinum-group-element, and zinc operations. Data are from Shedd (2013a). Congo (Kinshasa) is a short-form name for Democratic Republic of the Congo.

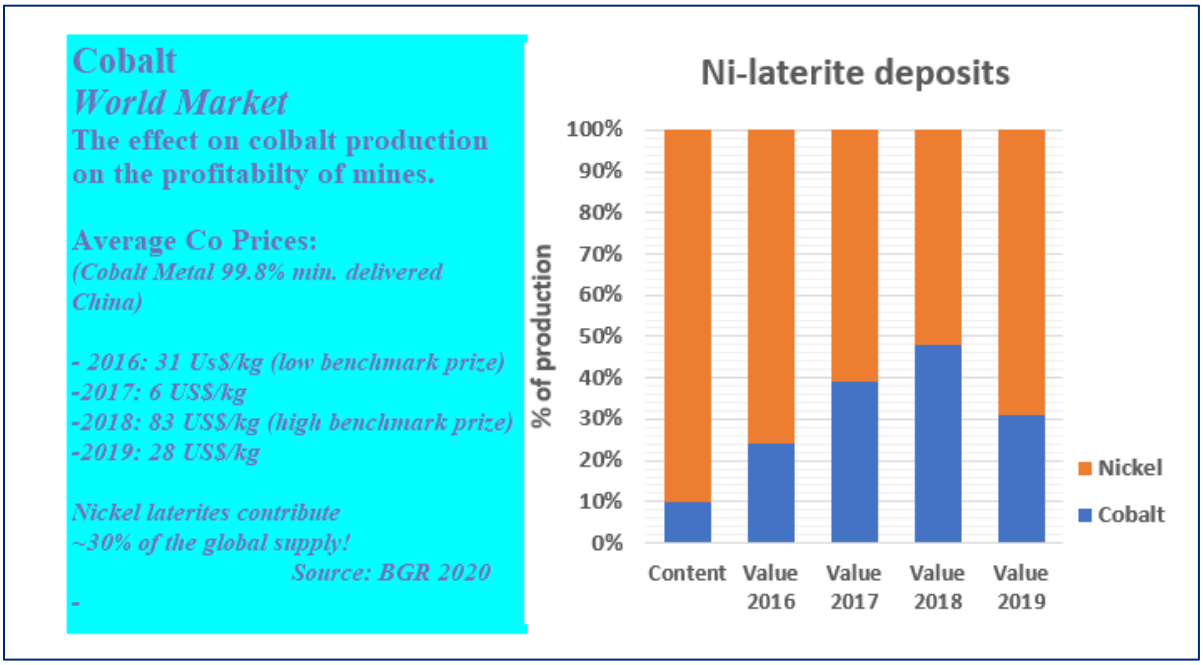
3.3. Projected Regional Potential (per CPRM)

Cobalt is predominantly mined as a by-product of copper (55 percent in 2020) and nickel (29 percent in 2020). Cobalt supply is dependent on demand and production of copper and nickel. In Brazil, until 2016, all cobalt produced came as a byproduct production of sulfide nickel mining. (1.5 MT Ni at 1 percent, 75 KT Co at 0.05 percent).

Cobalt in Brazil today is generally associated with nickel laterite deposits (cobalt has approximately one-tenth of the grade of nickel). The higher value of cobalt compensates for a laterite deposit that has less cobalt than nickel.

Figure 9 charts cobalt's contribution of value to a nickel laterite mine as the price differential of cobalt to nickel varies.

Figure 9: Impact of Co on Probability of Ni Mines[40]



3.4. Presentation of Opportunities

The Deloitte team researched and reviewed existing mineral inventory reports and current research into nickel and cobalt exploration, production, and recovery; and identified several opportunities. These opportunities are described below.

3.4.1. Exploration

Brazil has the potential to become a major producer of nickel and cobalt from laterite deposits. Currently, the principal identified source of nickel and cobalt in Brazil involves the weathering and supergene/hypogene enrichment of nickel and cobalt in laterites (weathered ultramafic rocks) and sea floor sulfide nodules (Copper-Cobalt [Cu-Co] or Ni-Co).

As Ni-Co laterites are derived from weathering of ultramafic host rocks, they occur commonly in the tropics, where the high rainfall and weathering by meteoric water are prevalent. Brazil also hosts Magmatic Nickel Copper (Ni-Cu) Sulfide deposits which are related to mafic/ultramafic magmatic intrusions. A promising area of research is whether nickel and cobalt enriched nodules can be mined from the Atlantic Ocean floor.[41] This technology is in its infancy and neither the economics nor the environmental impacts are fully understood. [42]

A more speculative future source of cobalt may include Brazilian Sediment Hosted Cu-Co (CACB) deposits like those found in the DRC. Brazil is separated by thousands of kilometers from the DRC cobalt mines, however, Figure 10 speculates that plate tectonics may have split the CACB mineralized terrane and show that a portion may also exist in Brazil.

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[40] Stropper, J., et. al., (2021), Economic Viability and Global Market Competitiveness of Specific Minerals Cobalt Geoeconomic Profile, Serviço Geológico do Brasil – CPRM PowerPoint Presentation.

[41] Hitzman, M.W., et al, 2017, Slack, et al.

[42] "Deep-Sea Mining Could Help Meet Demand for Critical Minerals, But Also Comes with Serious Obstacles", U.S. Government Accountability Office, December 16, 2021

Figure 10: CACB Resource Model that Utilizes Hypothetical Reconstruction of Paleo-Geology and Plate Tectonics

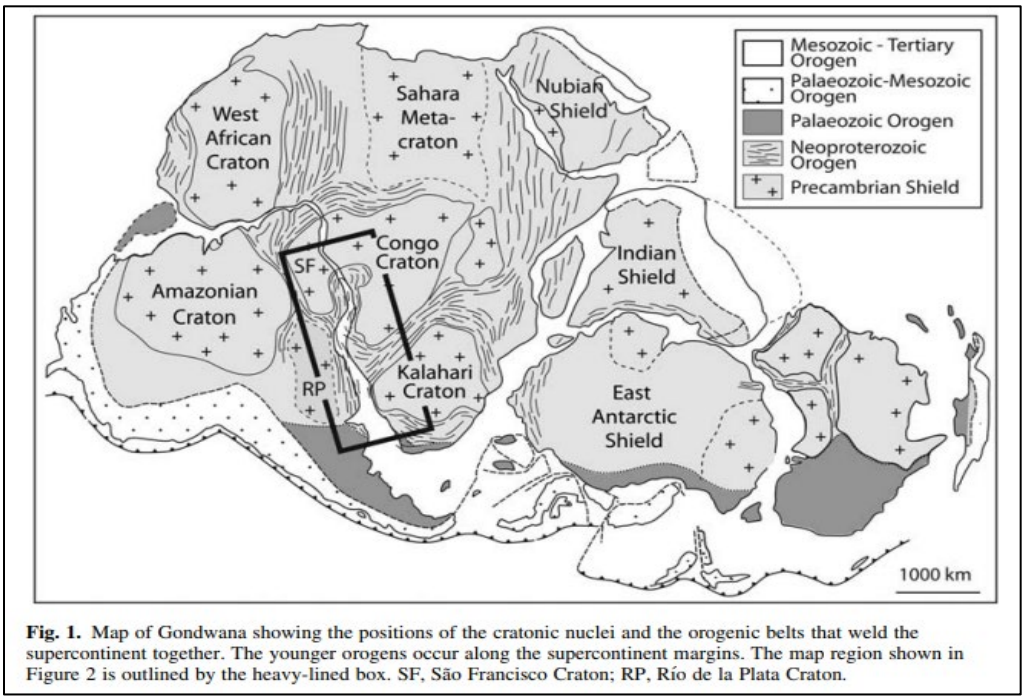

Fig. 1. Map of Gondwana showing the positions of the cratonic nuclei and the orogenic belts that weld the supercontinent together. The younger orogens occur along the supercontinent margins. The map region shown in Figure 2 is outlined by the heavy-lined box. SF, São Francisco Craton; RP, Río de la Plata Craton.

3.4.2. Production

The type of ore mined also has a large impact on the value of a deposit. The sediment hosted Cu-Co deposits are unique to the copper belt of the DRC. These commonly have better cobalt ore grades and metallurgical extraction efficiencies than Brazil's nickel laterite ores and require significantly less energy to extract cobalt then the current methods for nickel laterites.

While most Ni-Co production in Brazil is expected to be in laterites, predominantly with surface mining methods, the physical extraction of Ni and Co is well understood. There are four common mineral processing methods, two of which are appropriate for nickel and cobalt in laterites: high pressure acid leaching (HPAL) and roasting followed by ammonia leaching, both of which are high temperature and thus energy intensive.

The predominance of laterites in Brazil puts the country at a disadvantage as compared to the sulfide deposits in other locations. The Cobalt Project underway between Brazil and Germany (Section 2) could offer important advantages.

Brazilian Nickel PLC has proposed bulk leaching of Ni and Co laterites[43], potentially in situ. In September 2022, Brazilian Nickel PLC has declared commercial success in surface heap leaching (mining the material to leach in lined pads on the surface)of laterites[44], which can offer opportunities to Brazil. In situ leaching would create another quantum advance in the economics and environmental impacts. Any advances in these fields should be presented in an inventory report.

[43] Minerals Engineering, Vol.54, Dec. 2013, pp2-13 "Hydro-Pyro Integration in the processing of Nickel Laterites"]

[44] "Brazilian Nickel launches the world's first stand-alone nickel laterite heap leaching operation", Kitco, July 2022.

Variations of the nickel laterite metallurgical processes are discussed in NI43-101 technical reports on possible mining operations worldwide. For example, a report on the Vermelho Nickel and Cobalt Project in the Para State, Brazil discusses the proposed hydrometallurgical and HPAL processing.[45]

A partial list of reports that exist on the extensive number of other Ni-Co projects worldwide proposing variations of laterite metallurgical processing are:

- NI 43-101 Technical Report, Nkamouna and Mada Deposits, East Provinces of Cameroon, Africa, SRK Consulting for Geovic Mining Co., 2020;
- NI 43-101 Technical Report, Ravensthorpe Nickel Operations, FQM, 2022;
- NI 43-101 Technical Report, Amatovy Nickel Project, Madagascar, CSA Global Consultants, June 30, 2018;
- NI 43-101 Technical Report, Ramu Nickel Cobalt Project, Behre Dolbear Australia Ltd. For Cobalt 27 Capital Corp, July 19, 2019; and
- NI 43-101 Technical Report, Moa Nickel Project, Cuba, CSA Global Consulting, June 6, 2019.

3.4.3. Market Forecast (Demand) for Ni-Co

Market competitiveness reports for both nickel and cobalt were developed for this Project. The Deloitte team recommends that the Government of Brazil provide market information in the Ni-Co inventory report.

Nickel

In 2021, primary nickel consumption was 2.85 Mt, a 17 percent increase over 2020 levels.[46] This demand exceeded supply and there was a significant drawdown of the exchange inventories during the year. Currently, the stainless-steel industry is the predominant driver of global nickel demand, accounting for 72 percent of total primary nickel consumption in 2020.[47] Other demand drivers for nickel include alloy steels and castings, plating, and non-ferrous alloys, which each accounted for only 6 to 7 percent of primary nickel consumption in 2020. Although the battery sector accounted for only 7 percent of primary nickel consumption in 2020, it has the strongest growth potential of all the first uses of nickel. It is expected to account for 26 percent of demand by 2030.[48]

Cobalt

Global cobalt consumption in 2020 was approximately 135 kt, according to the Cobalt Institute. Demand for cobalt is expected to increase from 135 kt/y in 2020 to 258 kt/y by 2030, as indicated by Roskill in Figure 14, equivalent to a Compound Annual Growth Rate (CAGR) of 6.7 percent per annum from 2020 levels. This compares with a CAGR of 6.1 percent from 2014 to 2020. Jinchuan Group, a Chinese minerals producer, in a company presentation, forecasts cobalt demand to increase at a CAGR of 9.4 percent out to 2025.

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[45] NI 43-101 Technical Report – Vermelho Project, Pará State, Brazil, Snowden Consulting for Horizonte Minerals Plc, Oct. 31, 2019.

[46] Norilsk Nickel Nov 2021.

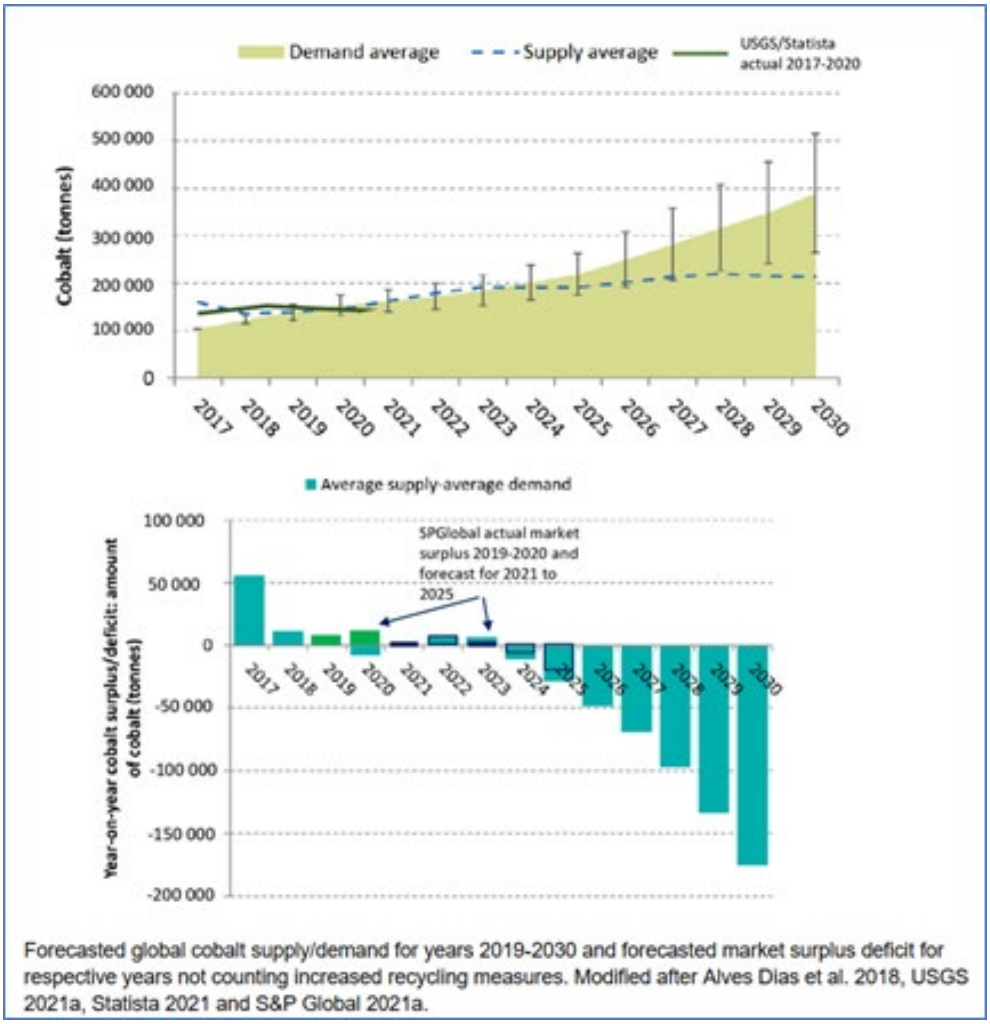
[47] Nickel Institute.

[48] Wood Mackenzie (June 2021).

Figure 14 shows that this growth is expected to be largely driven by increased demand from lithium-ion batteries, principally from increased demand for EVs. This is expected to result in cobalt use in lithium-ion batteries increasing at a CAGR of 8.4 percent through to 2030 despite ongoing advances in battery composition expecting to lead to lower cobalt requirements per unit. Nickel-based alloys are also expected to grow strongly, with a CAGR of 6.1 percent over the period

In addition to the industry forecasts, it will be important to note that a consensus forecast by multiple organizations around the world is showing a deficit by 2030 that is approximately equal to the total world supply in 2023, Figure 13.

Figure 13: Estimated Cobalt Market Deficit



Forecasted global cobalt supply/demand for years 2019-2030 and forecasted market surplus deficit for respective years not counting increased recycling measures. Modified after Alves Dias et al. 2018, USGS 2021a, Statista 2021 and S&P Global 2021a.

3.5. Outlook for Ni-Co

To meet future demand, the mining industry worldwide will have to address a series of challenges, which can be grouped into three main themes:

- Sufficient cobalt resources;
- Cobalt resource efficiency and processing technology; and
- Socio-environmental aspects of cobalt extraction.

When assessing investment potential, it will be important to understand the challenges and market dynamics that can either enhance or detract from investment potential into the Ni-Co sector globally. The market will face challenges and opportunities from resource constraints, technology cost and efficiency, and increasing focus on the ESG impacts of mining. Exploration will be important for the availability of these resources. Efficient beneficiation of the ores will be key to the success of Ni-Co laterites in meeting growing demand, especially for electric vehicles and battery metals. Eventually, the economics of mineral production will create the leaders of the market.

Brazil has an opportunity to be at the forefront of cobalt production. As the market evolves globally, Brazil should focus on relying on their scientific knowledge and strong mineral resources to position as a major player in the Ni-Co market globally. In addition, the Government of Brazil should promote the ESG advantages of Brazilian nickel and cobalt projects in the Ni-Co inventory report to accelerate access to development finance and facilitate regional investment. Nickel-cobalt projects in Brazil have systemic ESG advantages relative to DRC copper-cobalt and Indonesian nickel-cobalt producers. Access to low-cost, low-emissions hydroelectricity in Brazil gives nickel-cobalt producers a competitive advantage in both operating costs and carbon footprint. This advantage could potentially lead to better mine offtake terms, improved access to ESG-focused sources of development finance, and similarly enabled downstream regional investment in cathode-manufacturing facilities and lithium-ion battery manufacturing.

4. LEADING PRACTICES AND TRENDS FOR INVENTORY REPORTS

4.1. Assessment of Current Practices

Historically, mineral inventories have generally included geological descriptions, locations, mineralogy, deposit types, work histories, resource and/or reserve statistics, analytical results on known mineral occurrences, and bibliographies. Addressing ESG challenges related to mining, smelting, refining, and tailings management in mineral production is becoming increasingly important to investors and OEMs. Leading practice inventory reports, such as USGS Cobalt report, now include specific ESG requirements in an effort to enhance transparency and accountability of the governments and the mining industry. These reports now include information on the possible environmental effects of mining and mineral processing to give a more complete picture of both the positive and negative potential impacts of mineral production.

Table 4 below provides a summary of the information that is generally provided in leading practice mineral reports and compares this information to that provided in the inventory reports produced by the Government of Brazil. CPRM's inventory reports have primarily focused on providing investors with reliable geological information and resource and/or reserve statistics. Given the ESG global trends, CPRM should consider adapting its inventory format to also address ESG themes, thereby signaling to investors and OEMs that such requirements are now being integrated into long-term sector planning throughout the value chain. Of the reports noted below, the Deloitte team recommends that the Government of Brazil use the USGS Cobalt report as a template for their Ni-Co inventory reports, and incorporate information on labor, education, and infrastructure developments to further enhance their mineral inventory framework to attract responsible investments in the country.

Table 4: Leading Practice Mineral Report Comparison

	USGS Cobalt[49]	Alaska Platinum Group Elements	Australia REE[51]	Australia Mineral Sands[52]	Brazil Graphite[53]	Brazil REE[54]	Brazil Manganese[55]
Introduction	**Y**	Y	Y	Y	Y	Y	Y
Objectives	**Y**	Y	Y	Y	Y	Y	Y
Commodity Uses and Demand	**Y**				Y	Y	Y
Mineral Economics	**Y**	Y			Y		Y
Ore Minerals	**Y**	Y	Y	Y	Y	Y	Y
Principal Deposit types	**Y**	Y	Y	Y	Y	Y	Y

[49] Recommended format (with additional data on infrastructure) https://www.usgs.gov/publications/cobalt

[50] http://doi.org/10.14509/30468.

[51] https://www.ga.gov.au/scientific-topics/minerals/mineral-resources-and-advice/australian-resource-reviews/rare-earth-elements

[52] https://www.ga.gov.au/scientific-topics/minerals/mineral-resources-and-advice/australian-resource-reviews/minerals-sands

[53] https://rigeo.cprm.gov.br/handle/doc/21910

[54] https://rigeo.cprm.gov.br/handle/doc/16923

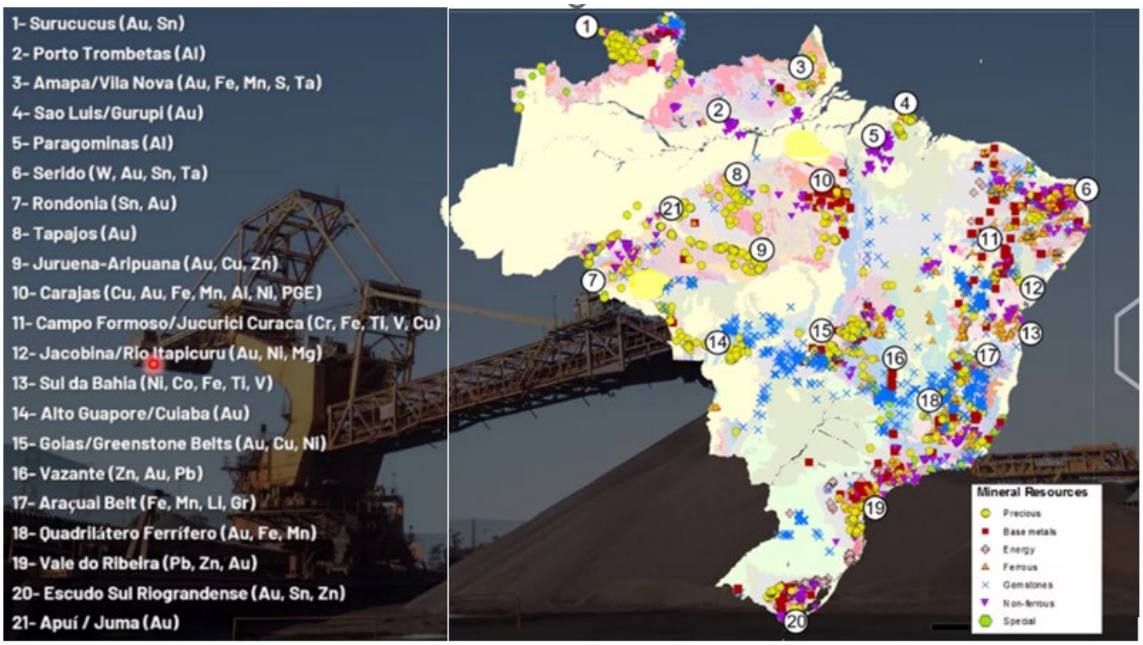
[55] https://rigeo.cprm.gov.br/handle/doc/20421

	USGS Cobalt[49]	Alaska Platinum Group Elements	Australia REE[51]	Australia Mineral Sands[52]	Brazil Graphite[53]	Brazil REE[54]	Brazil Manganese[55]
Exploration Methods	**Y**				Y	Y	
Exploitation Methods	**Y**				Y		
Known Deposits	**Y**	Y	Y	Y	Y	Y	Y
Unknown/Potential Resources	**Y**				Y		
Environmental and Social Considerations	**Y**						
Updates to Infrastructure Developments							
Providing Education and Labor Information							
Ongoing/Future Research	**Y**				Y		

4.2. Current State of Reporting

The CPRM reports reviewed by the Deloitte team clearly identified deposits, especially those that are licensed and reflected in public records. The USGS, CPRM, and Geoscience Australia[56] produce written reports on individual minerals. Several countries have online mineral databases, including the United States, Brazil, and the European Union, amongst others. The mineral databases from those countries commonly contain information on licensed mineral concessions. Many also show known mineral districts within a country, as Brazil has presented in Figure 12.

Figure 11: Mineral Districts and Provinces of Brazil[57]



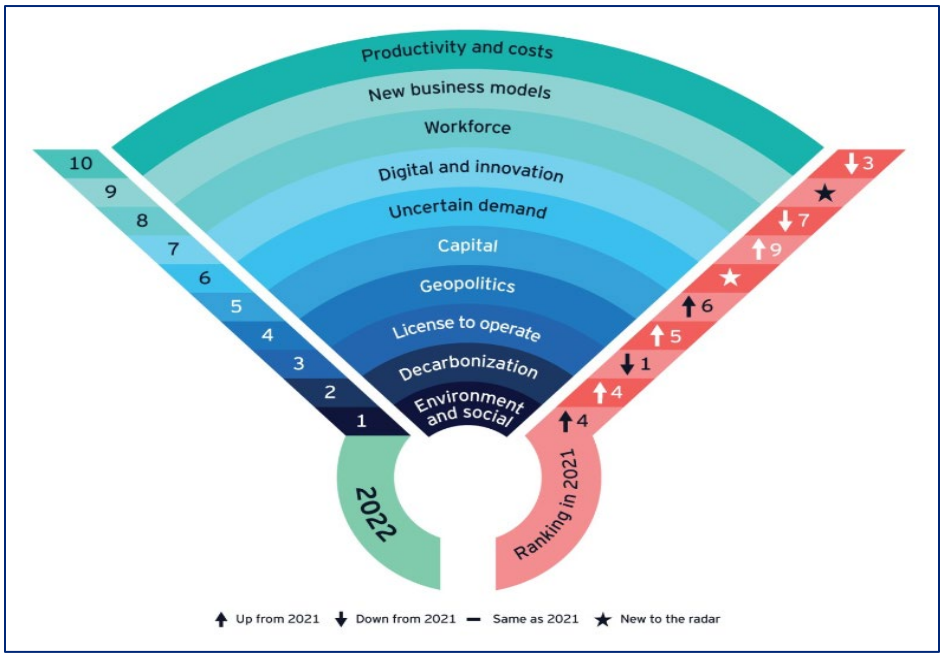
[56] Geoscience Australia prepares the annual assessment of Australia's mineral reserves and resources for all major, and some minor, commodities

[57] CPRM

4.3. Recent Trends: Addition of Non-geological Topics in Mineral Inventory Reports

Coalescing information needed to make decisions on development priorities is the next step to minimizing the spread of disinformation and promoting well-informed research. In 2020, Ernst and Young's survey of mining executives classified environmental and social factors as the highest risk to mining projects (Figure 13).[58] The top three risks to investing are related to the social and environmental aspects of projects. Capital cost is ranked fifth, labor availability eighth, and operating costs and productivity, historically considered a key factor, is now ranked tenth. Figure 13 lists the perceived risks for mining and how those risks have shifted in priority for investors from 2021 to 2022.

Figure 12: Mining Perceived Risks for 2022[59]



In the subsequent sections of this report, the Deloitte team recommends other factors that the Government of Brazil should consider including in mineral inventory reports. Incorporating such information will depend on data availability, although much of this information is already available from the IBGE online system and is therefore easily accessed. Such information, coupled with the geological data already available on the CPRM website, provides a basis for attracting long-term responsible investors

4.3.1. Regional Environmental Impacts

In mineral reports, it is important to describe the potential environmental impacts such as acid mine drainage, contamination by process chemicals, contamination by toxic products, air, soil, and water impacts. This can include natural toxicity of soils (as may occur with arsenic bearing minerals in some environments), mineral processing methods and reagents, fugitive dust emissions, etc.

[58] https://www.ey.com/en_gl/mining-metals/top-10-business-risks-and-opportunities-for-mining-and-metals-in-2022

[59] Ernst and Young

These topics should highlight the aspects of the metals and mineralogy that should be considered during exploration, feasibility, and environmental development, closure planning, and the overall economics of nickel and cobalt production. The reports should also require references to other public reports from government sources or research institutions, such as the Agency for Toxic Substances and Disease Registry,[60] a federal public health agency of the U.S. Department of Health and Human Services.

As in the USGS Cobalt report, the CPRM Ni-Co inventory report should include whether the metallurgical processing or mine waste/tailings may be detrimental to the environment. Potential research topics should be discussed as well as their future role in economic development.

4.3.2. Regional Infrastructure Development

Natural resource development potential can often be closely tied to extant level of infrastructure near a prospective mine. This may include the existence of highway, power, and rail grids, all of which have the potential to enhance the attractiveness of a given project. Regional needs for such features will help the government in prioritizing infrastructure projects. An integrated approach to infrastructure planning may also enable national and regional governments to prioritize the scheduling and financing of new infrastructure projects, potentially via public/private partnerships.

4.3.3. Regional Demographics & Economics

4.3.3.1 Education, Labor, and Socio-Economic Impacts

Understanding the capacity of the local/regional population is a key factor in the successful development of the sector, and in negotiating appropriate local community hiring commitments. The Ni-Co inventory report should describe whether there is a local work force available. Categories of labor include professionals as well as skilled and unskilled labor.

A presentation of socio-economic impacts of a development project is a valuable consideration for all parties. Minerals extraction, even in remote areas, includes both positive and negative socio-economic impacts. Table 5 provides examples of positive and negative impacts from minerals extraction.

Table 5: Examples of Impacts of Minerals Extraction

Positive Impacts	Negative Impacts
Expanded labor and training opportunities.	Loss of access to previous grazing or hunting areas.
Influx of cash including funding for education and/or medical care	Influx of persons from other regions/countries.
Construction of critical infrastructure which can offer further development opportunities.	Shifts from a barter economy to a cash economy

Transparent presentation of impacts and opportunities or the region/population may lead to improved decision-making and transparent governance. It also offers a sound basis for both policymakers and developers to clarify their decision process.

[60] https://www.atsdr.cdc.gov/

4.3.3.2 Indigenous Peoples Issues

Brazil should aim for robust public participation as part of an open and informed impact assessment process. Consultation protocols and community education should begin early in an exploration process. Free, prior, informed consent (FPIC), originally published by the Food and Agriculture Organization of the United Nations,[61] is mandated in international finance agreements and some aspects are included in Brazilian law, but transparency is key to a successful project life cycle. Engaging members of the public in matters that affect their community enables local citizens to better understand the costs and benefits of resource development, while simultaneously enabling them to participate in the planning process.

[61] https://www.fao.org/3/i3496e/i3496e.pdf

5. CONCLUSIONS AND RECOMMENDATIONS

CPRM has produced several robust mineral inventory reports on the geological potential of various minerals in Brazil, including graphite, REE, and manganese. These reports generally align with leading practice requirements, such as those outlined in the McKelvey Framework and the UNFC. In an effort to expand its mineral development and attract responsible investment in the country, the Deloitte team recommends that the Government of Brazil develop a Ni-Co inventory framework that addresses both, Brazil's strategic concerns, and the investment/commercial needs of potential private sector developers. The Deloitte team recommends that the Government of Brazil considers the following:

5.1. Key Recommendations

- **Incorporate leading practices into the Government of Brazil's Ni-Co inventory framework, via:**
    - **Including ESG information in the Ni-Co inventory report generally, and promoting the ESG advantages of Brazilian nickel and cobalt projects in particular, to accelerate access to development finance and facilitate regional investment.** Nickel-cobalt projects in Brazil have systemic ESG advantages relative to (for example) DRC copper-cobalt and Indonesian nickel-cobalt producers. For example, Brazil's access to low-cost, low-emissions hydroelectricity would give local nickel-cobalt producers a competitive advantage in both operating costs and carbon footprint vs. other locations. This advantage could potentially lead to better mine offtake terms, improved access to ESG-focused sources of development finance, and similarly enabled downstream regional investment in cathode- or lithium-ion battery manufacturing facilities.
    - **Including information on Brazil's use of "prior informed consent"** (the right of a community to be informed about mining operations on a full and timely basis, and to approve such operations prior to commencement). Brazil should aim for robust public participation as part of an open and informed impact assessment process. Engaging members of the public in matters that affect their community enables local citizens to better understand the costs and benefits of resource development, while simultaneously enabling them to participate in the planning process. When planning new projects, mining companies should look for opportunities that align with local communities' priorities. If there are opportunities for a community to benefit from mining infrastructure, such as a road, railway, or energy facility, discussions between industry and communities should happen as far in advance as possible to determine that the development of a mining project addresses the communities' needs and priorities.
    - **Publishing Updates to Infrastructure Developments:** Natural resource development potential can often be closely tied to extant level of infrastructure near a prospective mine. This may include the existence of highway, power, and rail grids, all of which have the potential to enhance the attractiveness of a given project. An integrated approach to infrastructure planning may also enable national and regional governments to prioritize the scheduling and financing of new infrastructure projects, potentially via public/private partnerships.
    - **Providing Education and Labor Information:** Mineral reports should also describe the availability and skills of the local workforce. Understanding the capacity of the local/regional population is a key factor in the successful development of the sector, and in negotiating appropriate local community hiring commitments.

- **Continuing to conduct basic scientific research, and outlining current and planned research, in future CPRM's mineral inventory reports.** Knowledge about regional geological factors, new research into potential Ni-Co sources (including seafloor sulfide nodules), and the potential for efficient mineral processing (bulk laterite leaching) will help to attract the attention of other innovative parties and investors.

Incorporating such information will depend on data availability, although much of this information is already available from the IBGE online system and is therefore easily accessed.[62] Such information, coupled with the geological data already available on the CPRM website[63], provides a robust basis for attracting long-term responsible investment in the sector. Of the reports reviewed and analyzed in this Report, the Deloitte team recommends that the Government of Brazil use the USGS Cobalt report as a template for their Ni-Co inventory reports, and incorporate information on labor, education, and infrastructure developments to further enhance their mineral inventory framework to attract responsible investments in the country.

[62] https://www.ibge.gov.br/en/home-eng.html

[63] https://geosgb.cprm.gov.br/

ANNEX A – RECOMMENDED NICKEL-COBALT INVENTORY REPORT STRUCTURE FOR BRAZIL

A brief description of the recommended structure for Ni-Co Inventory reports will include:

1) Introduction
    a) A description of the report as well as terms of reference.
2) Objectives
    a) The general goal(s) of the inventory report.
3) Uses and Demand
    a) Industrial consumption of the commodity of interest
    b) Current market perspective and future projections for consumption and prices
4) Mineral Economics
    a) The economic factors that can benefit an economy and the macroeconomic impacts of development on the host country and on world markets
5) Ore Minerals
    a) The specific ore minerals, their geochemistry, and geographic distribution
6) Principal Deposit types
    a) The genetic processes that form ores for the target mineral, how they fit within the nation's geological/tectonic framework
7) Exploration Methods
    a) Highlight efficient techniques for exploration, discovery, sampling, and modeling for the ores.
8) Exploitation Methods
    a) Describe the methods for extraction (mining), and beneficiation (processing/refining) for these ores to demonstrate their place in the industrial/ecological framework
9) Known Deposits
    a) Discuss known occurrences of these ores, domestically and internationally. Compare the conditions to conditions in the target areas
10) Unknown/Potential Resources
    a) Highlight areas where these minerals have not been discovered but where there may be comparable geologic conditions to areas with known deposits.
11) Environmental Considerations
    a) Discuss effects of exploration/exploitation on the environment, including potential for acid mine drainage, management of fugitive dust, water, and tailings.
12) Regional Socio-Economic Framework
    a) Present a high-level panorama of the educational baseline of the regions where minerals are known or likely to be discovered. This can be utilized for targeting underdevelopment or to advise investors of the manpower base. This information should be based on cross agency information such as that provided through the Brazilian institute of Geography and Statistics (IBGE).

13) Regional Infrastructure Development Framework

a) Present the industrial level of the regions where minerals are known or likely to be discovered. Present links to sources of information concerning roads, highway, rail networks, power grids, etc.

14) Ongoing/Future Research

a) Highlight information about current (especially government) initiatives related to deposit types, exploration, mineral processing efficiencies, and downstream manufacturing plans. Focus on domesticating the value chain for these minerals.

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