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The territorialization of the niobium global extractive network in Goiás, Brazil

A territorialização da rede global extrativa do nióbio em Goiás, Brasil

La territorialización de la red extractiva global de niobio en Goiás, Brasil

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Abstract
This research aims at interpreting the territorialization of the Niobium Global Extractive Network in Goiás state, Brazil. The methodology is based on secondary data and qualitative and quantitative information. The first part of the article describes the niobium extraction in Brazil, characterizing the metal's properties, its main applications in different economic sectors, location of the significant reserves, and operating mines. It also highlights the leading extractive corporations, their market strategies, and the evolution of iron-niobium production, market, and prices. In the second part, the text describes the participation of niobium mining corporations in the integration of Goiás state in the global extractive network. The final section summarizes the main results and underlines possible contributions for future critical research on the Brazilian mining model.
Keywords: Mining. Niobium. Global Production Network. Goiás.

Resumo
O objetivo da presente pesquisa é interpretar a territorialização da Rede Global Extrativa de nióbio em Goiás, Brasil. A metodologia conta com levantamento de dados secundários e informações qualitativas e quantitativas. A primeira parte da pesquisa apresenta resultados que abordam a mineração de nióbio no Brasil, com foco na caracterização desse metal, principais aplicações em diferentes setores produtivos, localização das maiores reservas e minas em operação. Destacam-se as principais empresas produtoras e suas estratégias corporativas, a evolução da produção de ferro-nióbio, mercado e preços. Na segunda parte, demonstra-se a participação da mineração,

com base nos empreendimentos de nióbio, no processo de integração do território goiano nas redes globais extrativas. As considerações finais sintetizam os resultados centrais expostos nas seções anteriores e sublinham as possíveis contribuições da pesquisa no campo das investigações críticas sobre o modelo de mineração no Brasil.
Palavras-Chave: Mineração. Nióbio. Rede Global de Produção. Goiás.

Resumen
El objetivo de la presente investigación es interpretar la territorialización de la Red Extractiva global de niobio en Goiás, Brasil. La metodología incluye la recolección de datos secundarios e información cualitativa y cuantitativa. La primera parte de la investigación presenta resultados que abordan la minería de niobio en Brasil, centrándose en la caracterización de este metal, las principales aplicaciones en diferentes sectores productivos, la ubicación de las mayores reservas y minas en operación. Destacamos las principales empresas productoras y sus estrategias corporativas, la evolución de la producción, el mercado y los precios del hierro de niobio. En la segunda parte, la participación de la minería, basada en proyectos de niobio, se demuestra en el proceso de integración del territorio goiano en las redes extractivas mundiales. Las consideraciones finales resumen los resultados centrales presentados en las secciones anteriores y subrayan las posibles contribuciones de la investigación en el campo de las investigaciones críticas sobre el modelo de minero en Brasil.
Palabras-Clave: Minería. Niobio. Red Mundial de Producción. Goiás.

Introduction

Since the beginning of the 21st century, it is possible to see the economic, political, and environmental implications of the "rentier-neo-extractive model" (CARVALHO et al., 2018) in Brazil, structured by extractive sectors such as mining. In 2017, Brazilian Mineral Production (BMP) value was US$ 32.0 billion, while the exports of mineral goods were US$ FOB 28.3 billion, being iron ore, gold, copper, and iron-niobium the four main ones. Indeed, Minas Gerais, Pará, Goiás, São Paulo, and Bahia were the leading mining states, according to the economic revenue (IBRAM, 2018).

The mineral extraction sector is present in almost all Brazilian states. In the national context, Goiás stands out as a territory for the extraction of nickel, phosphate, bauxite, copper, asbestos, gold, and niobium. With an emphasis on niobium, this study is based on the Global Production Networks model[1] (HENDERSON, 2002; HESS, 2004; SANTOS and MILANEZ, 2015) to describe the territorialization and positioning of the company CMOC International Brasil, a subsidiary of China Molybdenum Co., Ltd., in Goiás.

[1] Although the literature refers to Global Production Network (GPN), here we adopt Global Extractive Network to ensure greater precision in terms, and due to particular characteristics of mineral extractive sector that considerably differentiates it from manufacturing, for which GPN model was originally conceived. Despite this change in nomenclature, the categories and concepts used are essentially the same as in the GDP framework, as discussed in Milanez et al. (2018).

Thus, this research aims at describing the structure of the niobium Global Extractive Network and interpreting the territorialization of this network in Goiás. The methodology includes bibliographic review, data collection, and qualitative and quantitative information systematized in graphs and maps. The differences in the embeddedness of the network and the market strategies of CMOC are evaluated and compared with the Companhia Brasileira de Metalurgia e Mineração (CBMM). From this assessment, the network concentration is identified from both the point of view of supply and demand. Also, data suggest there are structural restrictions on the development of extraction and primary processing activities in Brazil. Besides, three particular elements of this network are highlighted: the growing material dependence on the technological transition to a low-carbon economy, the Chinese influence growth in the niobium network, and the risk of a sharp fall in metal price in case of an abrupt rise in supply.

In addition to this introduction, the text is divided into two main parts and the final remarks. The first describes Brazil's insertion in the niobium extractive network. For this purpose, the uses and general characteristics of this metal are specified, the positioning of Brazil within the network is analyzed, and CBMM's market strategy and network embeddedness is commented as a basis for comparison. The second section describes the participation of the mining sector in Goiás' economy and the process of territorialization of niobium mining corporations in the state. In the final part, not only research contributions are summarized, but also aspects that still need to be deepened in future research are highlighted.

Brazil integration in the niobium Global Extractive Network

According to information from the National Mining Agency (ANM, 2017), known niobium reserves in Brazil are approximately 842.4 million tonnes. Other countries contain metal deposits, such as Canada, Australia, the United States of America (USA), Angola, Russia, Saudi Arabia, Finland, Nigeria, and Ethiopia. About 527 carbonatites identified in the world can host niobium; from this total, 85 deposits already have studies and classification of mineral occurrence. Among them, nine produce niobium (CBMM, Brazil; Magris Resources, Canada; CMOC, Brazil [2 deposits]; Mineração Taboca, Brazil; AMG Mineração, Brazil; Lovozero, Russia [2 deposits]; Bayan Obo, Inner Mongolia, China) and four other projects are in the development stage (Dubbo, Australia; Panda Hill, Tanzania; Elk Creek, United States; and Kringlerne, Greenland) (CBMM, 2019; IBRAM, 2019).

Brazil is part of the niobium Global Extractive Network and responsible for around 84% of the metal production in the world, followed by Canada, which exploits niobium in the province of Quebec (CBMM, 2019; IBRAM, 2019). Since the early 1980s, Brazilian niobium has been transformed into semi-finished products before being exported. Approximately 90% of niobium extracted annually in Brazil is transformed into

ferroniobium (metallic alloy 65% composed of niobium and 35% of iron); only 10% is exported as goods of higher technological intensity, such as vacuum grade alloys, metallic niobium and niobium oxides (CBMM, 2019).

The main export product derived from Brazilian niobium is ferroniobium alloy. The production of high-strength microalloyed steel consumes most of this alloy. According to CBMM (2018), approximately 10% of world steel production uses niobium in ferroniobium form. Vacuum grade alloys, in turn, are useful in the production of nickel-based steel superalloys. Also, metallic niobium, which ingots have 99% niobium concentration, has superconducting properties and high resistance to corrosion and is applied in magnetic resonance devices, tomographers, and particle accelerators. Finally, niobium oxides are used in special applications of high technological value, such as telescope lenses, electric car batteries, and catalysts (VASCONCELOS, 2018; PEREIRA JÚNIOR, 2010; CBMM, 2019).

Despite the use of niobium for different purposes, the quantities demanded by the market tend to be small. Thus, considering the concentration of reserves in Brazil and low competition, companies in the sector have historically preferred to maintain a delicate balance between supply and demand to guarantee a price and profitability compatible with their expectations.

Brazilian ferroniobium production grew by 162.8% between 2005 and 2018 (ANM, 2009, 2018). The Brazilian consumption of ferroniobium is relatively low, on average, 4,000 tonnes, concentrated on the demands of national metallurgical companies located in Minas Gerais, Espírito Santo, Rio de Janeiro, São Paulo and Pará (ANM, 2017). This fact exposes mining companies´ dependence on global demand.

As shown in Figure 01, the Brazilian exports of ferroniobium grew by approximately 84.8% between 2005 and 2018. During these years, only 2009 showed a decrease in total exported quantity. That was probably connected to the 2008 financial crisis. Thus, the crisis that affected the global central economies also negatively affected Brazilian ferroniobium alloy exports.

During this period, Brazil sold ferroniobium to more than twenty-five different countries. However, only five stood out as the primary buyers: the Netherlands, China, the USA, Japan, and Singapore. For fourteen years, from 960,600 tonnes of ferroniobium exported, only these five countries purchased 840,500 tonnes, 87.4% from the total (MDIC, 2019).

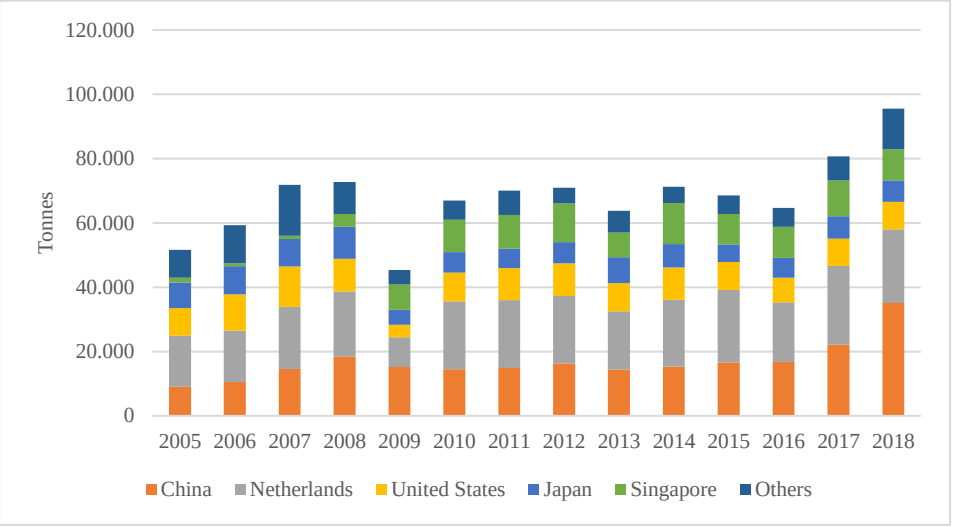

Figure 01: Evolution of ferroniobium exported and leading global importers - 2005 to 2018.
Source: MDIC, 2019. Prepared by: GONÇALVES, R. J. A. F .; MILANEZ, B., 2019.

This analysis broadens the understanding of the niobium Global Extractive Network, revealing the geopolitical backing of the participation of some countries and regions. First, the presence of the Netherlands, the USA, and Japan in this network stands out. These three countries represented stable average imports over the analyzed period - the Netherlands averaged 20,000 tonnes per year; the United States, 8,000 tonnes; and Japan 6,500 tonnes. The Netherlands is not directly related to the ferroniobium internal absorption, but to Rotterdam port, the largest seaport in Europe.

Another aspect revealed in Figure 01 is the growth of Asian market-share in the ferroniobium network. In addition to Japan, countries such as China, South Korea, India, and Singapore (which had significant growth since 2008) have increased the purchases of the alloy. Thus, among them, China stands out with an increase in its imports of 283.7% between 2005 and 2018. This country alone bought 24.3% of the total ferroniobium exported by Brazil for fourteen years.

The analysis of Chinese participation in the ferroniobium market highlights two significant growth moments, from 2005 to 2008 and from 2016 to 2018. In the first period, imports were 9,100 tonnes in 2005 and 18,400 tonnes in 2008, an increase of 101.9%. After 2009, a balance in Chinese consumption was maintained until 2016, when imports increased 109.5%, from 16,700 tonnes to 35,000 tonnes in 2018. The increase in Chinese demand can be associated with the change in the shareholding structure of companies operating in Brazil, as will be discussed in the following sections.

Thus, it is noted that global ferroniobium market behavior, with a recent increase in the presence of China, influenced the price of niobium between 2005 and 2018, as shown in Figure 02.

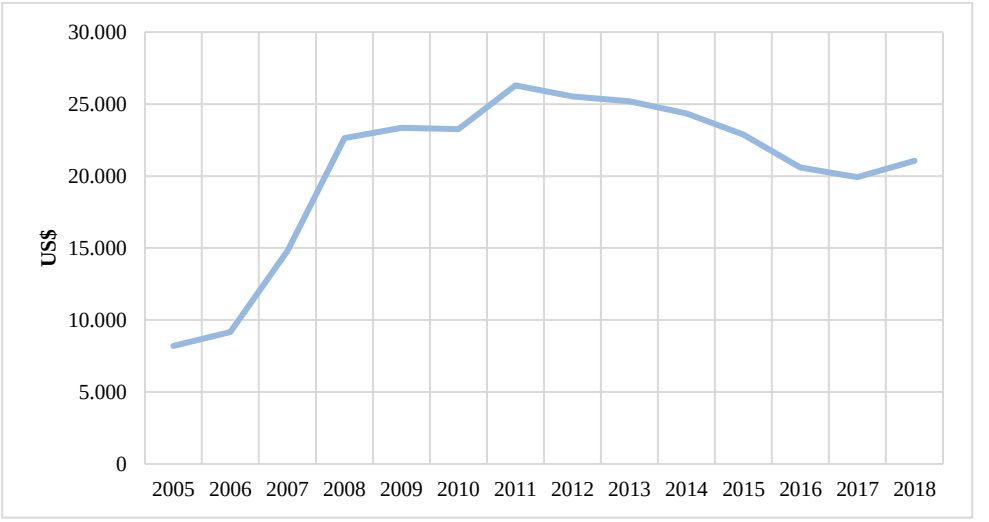

Figure 02: Evolution of ferroniobium nominal price (in US$ per tonne) - 2005 to 2018.
Source: MDIC, 2019. Prepared by: GONÇALVES, R. J. A. F.; MILANEZ, B., 2019.

Pereira Junior (2010) explains that ferroniobium prices are related to niobium product commercialization, which is carried out directly by the producing companies in the consumer markets and not through commodity exchanges such as the London Metal Exchange and the New York Commodity Exchange. The prices stipulation is related to the content of niobium in the alloys and the values practiced by CBMM, which, historically, have been adopted as a reference for other companies (CBMM, 2019).

Also, the price of ferroniobium depends on the performance of the steel industry and investments in infrastructure, which require reinforced, such as gas pipelines, refineries, oil platforms, and bridges (Pereira Junior, 2010). Consequently, the international geopolitical configuration represented by new arrangements such as the economic growth of Asian countries in the last years, with the leading role of China, stands out.

Thus, comparing Figures 01 and 02, a period of consumption and rising prices in the period 2005 - 2008 can be identified. With the financial market crisis, the exported quantity fell significantly, despite some price stability (probably associated with previously defined sales contracts, as is common in some strategic metals segments). In the 2009 - 2013 period, there was a slight variation in quantity and price, possibly related to demand adjustments in post-crisis. From 2014 to 2016, demand decreased, a trend that

reversed in 2017, with the growth of Chinese consumption. The price, on the other hand, showed some recovery a year later, which suggests, in turn, the balance instability between price and quantity exported (MDIC, 2019).

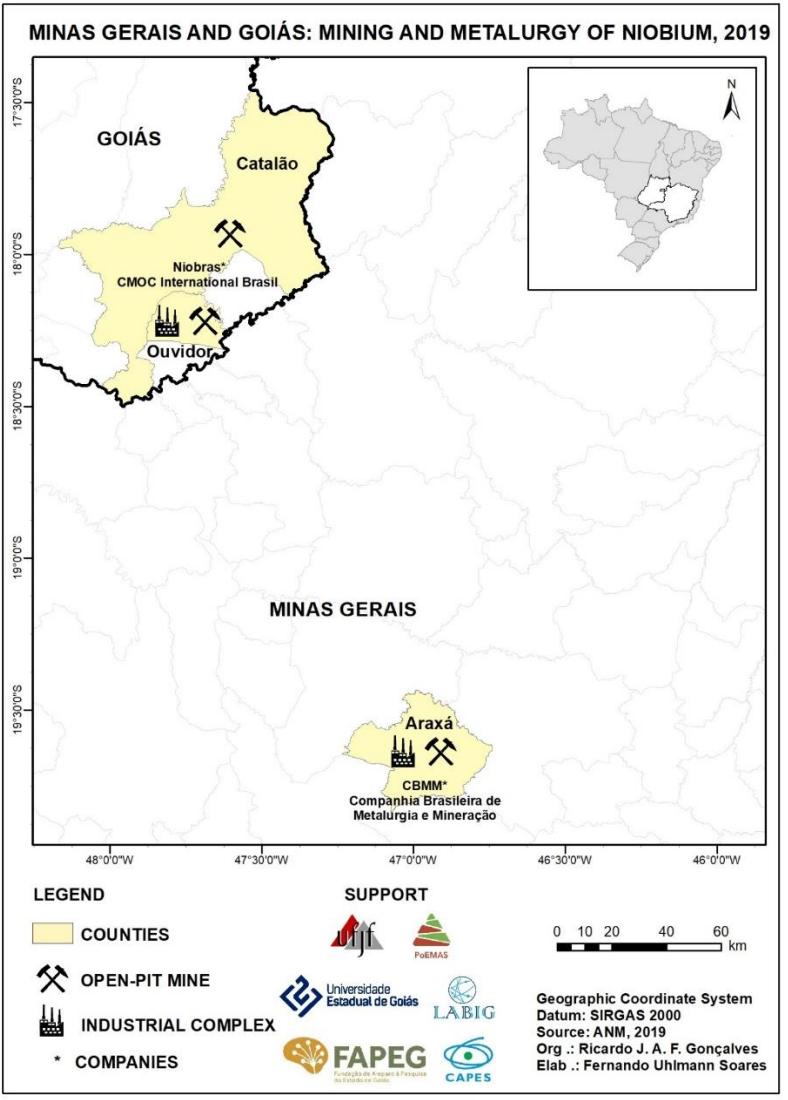

Figure 03: Location of two primary niobium mining and refining plants in Brazil.

The extraction and the refining of niobium in Brazil are concentrated in two large projects located in Goiás and Minas Gerais (Figure 03), operated respectively by CMOC / Niobras and CBMM. These mega-enterprises are responsible for almost the totality of ferroniobium produced in Brazil (about 90%). The rest of production is concentrated in smaller projects, such as Mineração Taboca S. A., and Metalmig Ltda., in Amazonas and Rondônia, respectively (ANM, 2018).

In Goiás, China's CMOC International Brasil controls Niobras. The Mina Boa Vista, an open-pit mine located in Catalão, is the primary source of pyrochlore, one of the main niobium minerals (SILVA et. Al., 2017). The ore is transported by trucks to the refining plant in Ouvidor, 23 km from the mine, where ferroniobium alloys are produced for commercialization in the global market (CMOC, 2019).

Located in Araxá (Minas Gerais state), the Barreiro Complex is composed of open-pit mines and the CBMM industrial unit. Niobium is extracted from the CBMM mine and a pit owned by the Companhia de Desenvolvimento Econômico de Minas Gerais (CODEMIG), a state-owned company. To manage the niobium deposits, in 1972, CBMM and CODEMIG created a joint venture called Companhia Mineradora do Pirochloro de Araxá (COMIPA). The contract between the companies defines the shared control of COMIPA and the equal extraction of ore in mines. CBMM stands out in the market for its investment in the development of processing and application technologies for industrialized products (ALMG, 2019; CBMM, 2019; G1, 2019).

With a much smaller market share, Mineração Taboca, controlled by the Peruvian Minsur, which has a mining unit and a refinery in Presidente Figueiredo (AM), might also be mentioned. Unlike other companies, it extracts niobium from columbite-tantalite reserves. Finally, Metalmig operates in Itapuão do Oeste (RO), where it also extracts columbite-tantalite (ANM, 2019).

The international demand for niobium had an impact on the dynamics of the extractive network in Brazil. From the territorial point of view, the producing companies expanded the existing mines, or opened new mines, when necessary. They also invested in projects to develop industrial units, tailings dams, and waste-rock piles. Still, there was the emergence of new investment projects to increase production. In the producing states, the growth in niobium mineral operations value was considerable. In Goiás, these values increased from R$ 24.7 million in 2005 to 369.3 million in 2018, an increase of 1,391%. In Minas Gerais, this amount rose from R$ 50.8 million in 2005 to R$ 336.9 million in 2018, an increase of 563% (ANM, 2019).

Due to this dynamic, it is imperative to analyze the process of territorialization of CMOC / Niobrás in Goiás. Before this assessment, however, a brief analysis of the CBMM structure is necessary as a basis for comparison.

Brazilian Metallurgy and Mining Company positioning (CBMM)

CBMM was founded in 1955 and, in the following years, consolidated itself as the largest global supplier of niobium products. It has been controlled since 1965 by the Moreira Salles family (CBMM, 2019). In 2011 a consortium formed by the Chinese state-owned investment company Citic Group Corporation Ltd., and stainless steel producers Taiyuan Iron & Steel Corporation (TISCO) and Baosteel, bought 15% of CBMM, for US$ 1.9 billion (STELZER JR., 2016; CMOC, 2019). In the same year, a group of Japanese and South Korean companies bought another 15% of CBMM (CBMM, 2018).

In 2019, in addition to the headquarters, mine, production units, and technology center in Araxá, and an office in São Paulo (SP), CBMM had subsidiaries in different countries, such as CBMM Europe BV, in Amsterdam, the Netherlands; CBMM Asia Pte. Ltda., in Singapore; CBMM North America Inc., in the USA; and the subsidiary CBMM Technology Suisse, in Switzerland, dedicated to the development of new niobium applications and products. The company also owns two suppliers: CITIC Metal Co. Ltd. in Beijing, China, and Sojitz Corporation, in Tokyo, Japan. It has product warehouses in Sweden, Russia, the Netherlands, Italy, Spain, Canada, the USA, China, South Korea, and Japan (CBMM, 2018; 2019).

In this way, CBMM's repertoire of actions in Brazil and several other countries exposes its corporate practices aiming at creating, increasing, and capturing value (MILANEZ et al., 2018). Among CBMM's strategies, initiatives towards the market stand out, acting through its subsidiaries, it develops programs for marketing, maintenance of product warehouses and corporate offices in central regions in terms of market access, such as Europe, South America North, and Asia.

Still, in the field of strategic market action, CBMM maintains investments and partnerships with niobium end-users. As highlighted by Vasconcelos (2018), one of the examples is the collaboration signed in 2017 with Japanese company Toshiba. The intention would be to increase the demand for niobium oxides used in electric cars. This way, CBMM planned to invest US$ 7.2 million in a pilot battery unit next to a Toshiba plant in Kashiwazaki, Japan. In this plant, it would develop a new generation of batteries with mixed niobium oxide anodes and titanium. (VASCONCELOS, 2018; CBMM, 2018).

Besides, the investment policy in research and development of new niobium products and applications stands out, which contributes to its market and social strategy. It maintains a Technology Center in Araxá, which has 130 researchers and technicians involved in 30 technological innovation projects linked to niobium applications. In 2017, CBMM invested approximately R$ 150 million in the development of new technological

processes and applications of niobium (CBMM, 2018)[2]. That year, it added 179 technical cooperation projects around the world, with 137 partnerships with clients, 27 with universities, and 15 with research institutes (CBMM, 2019). It also opened a new technology center, the International Welding Technology Center, in Xian, China (CBMM, 2019; VASCONCELOS, 2018).

The option for technological development of niobium uses might be considered a strategy of market creation, and it has been historically linked to CBMM. Since the 1970s, the company has promoted and participated in symposia, lectures, seminars, and publications of technical and scientific works to disseminate niobium technologies in promising markets. In 1979, the Charles Hatchett Award was created, sponsored by CBMM and awarded by the Institute of Materials, Minerals, and Mining (IOM3), in London. It focused on researchers who published papers on niobium science and technology and its alloys. Also organized by IOM3, CBMM participates, since 2011, in the sponsorship of Young Persons 'World Lecture Competition (YPWLC), a competition created in 2005 that covers the participation of young scientists from different countries (CBMM, 2018; 2019). Thus, according to CBMM's strategic priorities, the rent generated by mineral extraction in Brazil is used, considerably, to subsidize and stimulate technological development in other countries.

Thus, CBMM seems to have a clear policy for the development of the demand for ore mined in Brazil. Despite focusing its activities on the extraction and intermediate processing of niobium, the company demonstrates a concern in guaranteeing the expansion of demand and the development of new uses. This stance is realized in product diversification since it is the only company in the country that refines niobium in different varieties; ferroniobium alloy, vacuum-grade alloy, metallic niobium and niobium oxide (VASCONCELOS, 2018; PEREIRA JÚNIOR, 2010; CBMM, 2019).

This positioning defines a strategy quite different from the one adopted by CMOC. The Chinese company positioning in Goiás shows another policy, as will be seen in the next section.

Goiás and the Niobium Global Extractive Network

Large-scale mining in Goiás

Goiás ranks third – below Pará and Minas Gerais - among the leading mining states in Brazil. The value of mining operations in the state increased from R$ 1.1 billion in 2005 to R$ 4.9 billion in 2018, an increase of 372.6%. Likewise, the payment of mining

[2] "Due to the technology projects developed, CBMM has been enjoying since 2007 a federal tax benefit, granted based on the Innovation Incentive Law (11,196 / 2005): the accumulated benefit until 2017 was around R$ 57 million" (CBMM, 2018, p. 28).

royalties jumped from R$ 15.2 million in 2005 to R$ 98.7 million in 2018, an increase of 547.3 % (ANM, 2006; 2018).

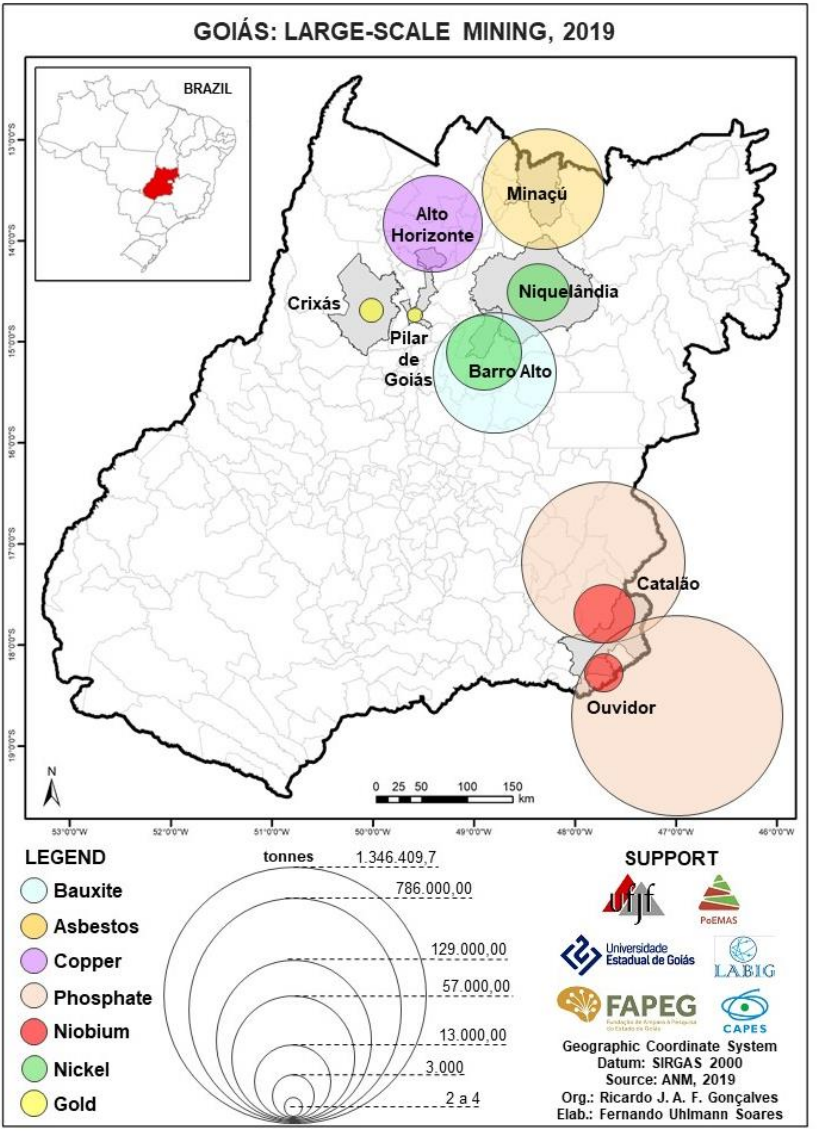

Figure 04: Main municipalities mined in Goiás.

Therefore, Goiás also saw an increase in mineral production values, which rose from R$ 2.7 billion in 2005 to R$ 9.3 billion in 2017, an increase of 234.2% (ANM, 2006; 2018). However, these figures are concentrated in a few mined municipalities and a limited number of minerals. In 2017, from 32 mineral substances that made up the mineral production, only nine accounted for R$ 9.1 billion, equivalent to 97.7%, namely: copper, nickel, gold, phosphate, niobium, asbestos, agricultural limestone, gravel, and mineral water. Still in the same year, from a list of 141 municipalities that contributed to the mineral production value in the state, only Alto Horizonte, Niquelândia, Catalão, Ouvidor, Minaçu, Crixás, Barro Alto and Pilar de Goiás, accounted for R$ 8.7 billion, equivalent to approximately 92% of the total value (ANM, 2018). Thus, the concentration of mineral income becomes one of the main characteristics of the activity in the state. This information is summarized in Figure 04.

The mapping of large-scale mining in Goiás, and the concentration of projects in the North and Southeast, reflect its integration in the global extractive network. For example, in 2018, gold extracted from municipalities such as Crixás was exported to the United Kingdom, Italy, Belgium, India, and the United Arab Emirates. The copper exploited in Alto Horizonte was sold to Spain, India, Bulgaria, and Singapore. Nickel (iron-nickel alloy) from Barro Alto and Niquelândia was traded with sixteen countries, and the leading importers were China, the Netherlands, South Africa, Sweden, Finland, and the USA. The asbestos mined in Minaçu was sold to sixteen countries, including India, Indonesia, Malaysia, Vietnam, and Bangladesh. Finally, niobium (transformed into ferroniobium) from Catalão and Ouvidor, was exported to 12 countries, including China, the Netherlands, the USA, India, Singapore, South Korea and Turkey (ANM, 2018).

Thus, the perspective put forward, at least for mining corporations, is to deepen the dependence of the Goiás economy on the export of mineral resources.

Extractive niobium megaprojects

The territorialization of niobium projects in Catalão and Ouvidor links Goiás and the Global Extractive Network. It is part of the internationalization process of Goiás, which started in 1970s with agro-mineral projects. Thus, Carvalho (1988) and Ferreira Neto (1998) explain that the pyrochlore deposits identified by Metais de Goiás S.A. (METAGO) in Catalão and Ouvidor resulted in the creation of Mineração Catalão de Goiás SA, owned by South African corporation Anglo American.

After identifying the economic viability of the project, the company developed an open-pit mine in Chapadão (between Catalão and Ouvidor) and built a pyrochlore concentration plant in Ouvidor (the Boa Vista Concentration Plant). In the same period, Mineração Catalão de Goiás S.A started extracting and refining niobium into ferroniobium alloy. Besides, the firm was the first private company to explore alkaline-carbonatite mineral deposits in Catalão (CARVALHO, 1988; FERREIRA NETO, 1998).

Figure 05: Boa Vista Mine, Catalão, Goiás.
Source: ANM, 2017.

Thus, in 1976, 773 tonnes of ferroniobium were produced in Goiás; in 1980, it reached 3,517 tonnes, and since then, until the early 2000s, it has been relatively stable. At the beginning of the 21st century, Anglo American made new investments in the expansion of niobium extraction and refining projects. Among them, a new open-pit mine, the Mina Boa Vista, in Catalão. The beginning of the ore extraction at the Boa Vista Mine in 2000 (Figure 05), occurred to supply the Boa Vista Concentration Plant.

Still in the years 2000, in the context of increasing global demand for niobium, Mineração Catalão developed the Tailings Project, approved in 2006 and finished in 2008. The company invested US$ 30 million to recover the niobium, which was present in the tailings from the phosphate processing plant run by Copebrás, then, also linked to Anglo American (SILVA et al., 2017).

Four years after the conclusion of Tailings Project, in 2012, Anglo American invested in a new project named Boa Vista Fresh Rock (BVFR), focused on a new process of ore extraction, due to the expected exhaustion of the oxidized ore in 2016 (SILVA et al., 2017). The BVFR Project was completed in 2014 and involved investments of approximately US$ 350 million. Silva et al. (2017) emphasize that BVFR increased in 20

years the lifespan of the mine and the niobium business in Catalão and Ouvidor. Also, it allowed the company to triple the production of ferroniobium alloy.

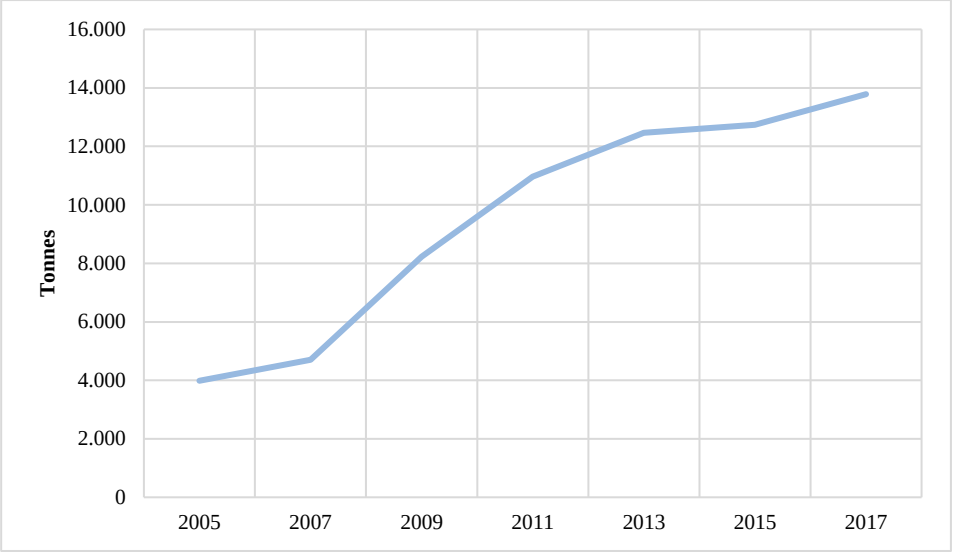

Figure 06: Evolution of ferroniobium production in Goiás from 2005 to 2017.
Source: ANM, 2018. Prepared by: GONÇALVES, R. J. A. F .; MILANEZ, B., 2019.

Consequently, since the mid-2000s, with Boa Vista Mine in Catalão, Boa Vista refinery, Tailings project, and the BVFR project in Ouvidor, the production of ferroniobium has grown significantly, as shown in Figure 06.

The production of ferroniobium in Goiás grew from 3,900 tonnes in 2005 to 13,700 tonnes in 2017, an increase of 245.8%. Figure 06 indicates the relationship between the amount of ferroniobium produced in Goiás and the main projects developed in that period. Thus, the growth from 2005 to 2009 is distinguished first, from 3,900 tonnes to 8,200 tonnes respectively, an increase of 106.3%. This moment coincides with Boa Vista Mine's expansion and the Tailings Project conclusion. Second, it is observed that as of 2010, the growth trend was significant, reaching the highest level in 2016, when production reached 15,000 tonnes, 141.2% more in comparison to 2010. The growth in this second interval, 2010 to 2016, was simultaneous with two main aspects: the implementation of the BVFR Project and the entry of Chinese capital in the niobium business in Goiás with the purchase of Anglo American business by CMOC International Brasil, in 2016. Thus, there is a relationship between the increase of ferroniobium exports and the strengthening of its participation in the global network (Figure 07).

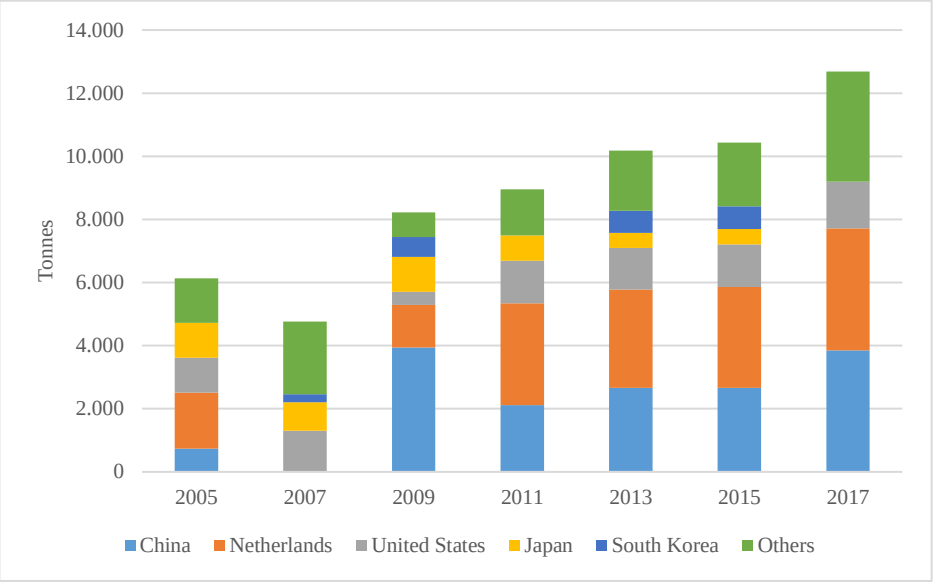

Figure 07: Evolution of Goiás ferroniobium exports - 2005 to 2017.
Source: ANM, 2018. Prepared by: GONÇALVES, R. J. A. F.; MILANEZ, B., 2019.

Figure 07 highlights ferroniobium exports from Goiás to the leading importing countries between 2005 and 2017. Over thirteen years, the state exported 108,900 tonnes of ferroniobium. Of this total, only the five highlighted countries purchased 86,300 tonnes, equivalent to 79.2%. Two of them, China and the Netherlands, increased the scale of their purchases and imported about half of the total extracted 54,000 tonnes. The rest, except Japan, which decreased its share of imports since 2010, maintained relatively stable purchasing rates. Still, in 2005, 2006, and 2007, in addition to these five countries, Goiás had Germany as its main international route, which imported, on average, 2,000 tonnes (ANM, 2018).

When considering changes of the property structure, an episode of high relevance was the purchase of the phosphate (Copebrás, in Goiás and São Paulo) and niobium (Mineração Catalão, in Goiás) businesses by China Molybdenum (CMOC), through its subsidiary CMOC International Brasil, in 2016. Consequently, CMOC created Niobras, which started to operate the niobium mine and refinery projects in Catalão and Ouvidor. (CMOC, 2019).

CMOC is a company with global operations in the mining, refining, product technology, trade, research, and mineral development sectors. Its shares are traded on the Hong Kong Stock Exchange and the Shanghai Stock Exchange. In China, it extracts molybdenum and tungsten in the Sandaozhuang mine in Henan Province. In addition to

CMOC International Brasil, China Molybdenum controls 80% of Northparkes Mines, one of the largest copper producers in Australia. It also owns nearly 60% of Tenke Fungurume, which operates copper and cobalt developments in the Democratic Republic of Congo. Besides, it has corporate offices in Phoenix, in the USA, and Sydney in Australia (STELZER JR., 2016; CMOC, 2019).

The acquisition of Mineração Catalão and the creation of Niobras was accompanied by substantial investments, seeking to expand niobium extraction in Goiás. Thus, considering the total niobium mineral operations in the country, the average share of Niobras rose from 27% (2011 - 2014) to 51% (2015 - 2018)of the operations (ANM, 2019).

At the same time, as shown in Figure 07, there was significant growth in China's share of imports at the end of that period. Between 2007 and 2017, Chinese purchases jumped from 736 tonnes to 3,800 tonnes, an increase of 423%. Over the years, it bought 28,700 tonnes and became one of the primary consumers of ferroniobium alloy produced in Goiás.

Also, Chinese participation growth in imports has gained strength in recent years, coinciding with its entry into the niobium business in Catalão and Ouvidor. From 2016 to 2017, China increased imports of ferroniobium from Goiás by about 63%, from 2,300 tonnes to 3,800 tonnes. Internally, the economic effects of this process are also evident, considering that the value of CMOC's niobium mineral operations in Brazil rose from R$ 306.2 million in 2016 to 369.3 million in 2018, an increase of 20.6% (ANM, 2019).

As a result, the total value of Goiás' ferroniobium exports rose from US$ 48.6 million in 2005 to US$ 270 million in 2018, which meant an increase of 445.5%. Because of this increase, in 2018, among the products of the exportation list in Goiás, ferroniobium was the sixth most important good. Among ores and minerals, it was the third, after copper and iron-nickel.

Based on the assessment of Anglo American's initiatives (until the beginning of 2016) and, especially, of CMOC, a very different strategy can be seen when compared to CBMM. While the latter invested in the development of higher value-added and niobium technology-intensive use in other countries, the Chinese company, has as a priority only the expansion of niobium extraction and commercialization of ferroniobium alloy, which has less noble purposes. Depending on China's interests in this metal use, there is a risk that a very rapid expansion of extraction and export may take place. That can lead to imbalances between supply and demand, resulting in a significant reduction in prices, which, in a first analysis, could mainly benefit the Chinese metallurgical sector.

Final remarks

This article had as main objective to present the general structure of the niobium Global Extractive Network and to analyze, in more detail, its node in Goiás. Thus, we sought to emphasize the differences in network embeddedness and the market strategies of the leading mining companies of this network.

On the supply side, the network structure is considerably concentrated, so that 84% of the extraction takes place in Brazil, where only two companies, in Minas Gerais and Goiás, account for almost all sales, especially ferroniobium. Demand also has a high degree of concentration; 90% of exports are concentrated in five countries, which dominate advanced technologies in the steel industry and other knowledge-intensive sectors, such as medical equipment, optics, and electronics.

Although the reserves concentration in Brazil has the potential, in theory, to provide higher power to companies that operate in the country, such power is not necessarily transformed into value capture. Thus, most of the national export is limited to semi-finished products (ferroniobium alloy, metallic niobium, or niobium oxide) that are transformed into products with higher added value in importing countries. Therefore, the network is structured in such a way that Brazil remains on the periphery of the International Division of Labor.

In this sense, CBMM's positioning is particularly contradictory or, at least, divergent from a perspective of national interest. The company has developed different initiatives to multiply the uses of niobium, particularly in industrialized countries, as a way to expand the metal consumer market. However, such innovations, subsidized by mineral income generated in the country, are not necessarily incorporated by the Brazilian industrial sector. If, on the one hand, such an initiative does not add value to products exported by Brazil; on the other hand, it demonstrates success in terms of value capture by the company; for example, between 2017 and 2018, CBMM increased its profit by 54.7%, from R$ 1.7 billion to R$ 2.8 billion (CBMM, 2019).

Goiás' position shows an even more regressive insertion in the Global Extractive Network. During Anglo American's operation period, no specific efforts to increase vertical integration were identified. This subordinate insertion in the global market, as a mere supplier of intermediate goods with low added value, apparently consolidated itself after CMOC entry. The main investments of this company were restricted to expanding extractive activities, and the respective territorial impacts, competition for the subsoil, and conflicts with communities (GONÇALVES, 2016; PAES, 2019).

These findings of the network structure may be associated with three particular remarks, presented preliminarily, but which should be developed in future studies.

First, there are indications of the need to deepen the debate about the material bases of the transition to a "low carbon" economy. Within the context of the climate crisis,

a series of "solutions" aimed at modernizing the global energy matrix. However, electric cars, photovoltaic panels, and wind generators depend fundamentally on materials such as niobium, lithium, tantalum, indium, and other "strategic minerals." The expansion of this solution maintains the dependence on non-renewable resources and leads to the expansion of the mineral frontier.

Second, the niobium network analysis highlights the crucial role that China plays. In the Brazilian niobium case, it is manifested both by the acquisition of mines in Goiás and shares of CBMM. China's "race" for mineral control around the world is already being debated in specialized literature both from a global perspective (KLARE, 2013) and in Latin America (IRWIN and GALLAGHER, 2013). However, the theme does not yet seem to have been studied in depth in the Brazilian context.

Finally, CBMM's effort to develop new uses for niobium suggests a limited capacity of the market to generate specific demand for this metal. Thus, there seems to be a fine between supply and demand that guarantee relative price stability. Data indicate that the current extraction scale is more than enough to supply industrial demand. According to CBMM (2019) and Ibram (2019), the extraction capacity of producing companies in the world is more than twice larger the market demand. In this context, there are still several new projects being implemented in different countries. Therefore, a significant increase in niobium extraction will mainly cause a substantial drop in prices, harming exporting countries, and benefiting exclusively metal consumers.

Finally, based on such analyzes, it is argued that studies about the GPN concept show a promising path for a better understanding of this chain and opens up relevant questions for further research.

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