ISSN: 2447-3359

REVISTA DE GEOCIÊNCIAS DO NORDESTE

Northeast Geosciences Journal

v. 9, nº 1 (2023)

https://doi.org/10.21680/2447-3359.2023v9n1ID28165

Chromitiferous Deposits of the Jacurici Valley: A Bibliographic Review

Depósitos Cromitíferos do Vale Jacurici: Uma Revisão Bibliográfica

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Abstract: Chromite was widely employed in the industry for many years as a component in manufacturing paint pigments. The world's most significant chromite ore resources are in South Africa, Kazakhstan, and India (90% of the reserves). Brazil is home to 0.13 percent of the world's chromium deposit reserves. The Jacurici Valley-BA national mafic-ultramafic complex possesses the most specimens in the territory. Although some works aimed at characterizing the geological existence of Jacurici Valley and the Ipueira-Medrado segment, a low scientific production is identified in other branches of geosciences. This work aims to develop the first systematic literature review of chromitic deposits in these regions. This work will promote an information base that will contribute to the direction of future research lines in the area. The bibliographic research was carried out systematically. We used the following works as a foundation: 24 articles relevant to the topic, 03 books, 03 reports, and an expanded abstract obtained from the Google Scholar digital platform. Expanding geoscience studies focusing on more specialized fields would aid the broader characterization of the region's chromium ore. As a result, fresh investigations are continually being conducted that will expand the scope of the mineral study.

Keywords: Chromitite Deposits; Mines of Ipueira-Medrado; Mafic-ultramafic Deposits.

Resumo: Por muitos anos, a cromita foi bastante utilizada na indústria como componente para produção de pigmentos para tintas. Os principais depósitos minerais de cromita são encontrados na África do Sul, Cazaquistão e Índia (90% das reservas). O Brasil detém 0,13% das reservas mundiais de depósito de cromo. Os maiores exemplares em território nacional são encontrados no complexo máfico-ultramáfico do Vale do Jacurici-BA. Embora exista alguns trabalhos com finalidade da caracterização geológica do Vale do Jacurici e do segmento Ipueira-Medrado, é identificado uma baixa produção científica em outros ramos das geociências. O objetivo do trabalho é o desenvolvimento da primeira revisão bibliográfica sistemática dos depósitos cromitíferos nestas regiões. Este trabalho promoverá uma base de informações que contribuirão com o direcionamento de futuras linhas pesquisas na área. As pesquisas bibliográficas foram desenvolvidas de modo sistemático, onde os trabalhos usados como base foram obtidas na plataforma digital Google Acadêmico: 24 artigos aplicáveis à temática em questão, 03 livros, 03 relatórios e um resumo expandido. O desenvolvimento de pesquisas focadas em ramos mais específicos em geociências, auxiliariam na caracterização mais ampla em torno do minério de cromo da região. Sendo assim existem estudos ainda não explorados que abrirão novos horizontes para a pesquisa mineral.

Palavras-chave: Depósitos de Cromita; Minas de Ipueira-Medrado; Máfico-Ultramáfico.

Received: 26/02/2022; Accepted: 17/04/2022; Published: 01/03/2023.

1. Introduction

Mineral mining, both metallic and nonmetallic, has long played an essential role in the national economy (DALLA COSTA *et al*., 2017). As the metallurgical sector evolved during the twentieth century, chromite and other minerals became essential commodities, primarily producing stainless steel (MALIOTIS, 1999). Metal alloys are the most common application for chromium, which is widely used in everyday products. In this context, the Jacurici Valley complex in Bahia has the world's largest chromite reserves. While there have been studies on chromium mineralization focusing on the deposit's properties, there have not been enough complementary studies to improve characterization and generate new research strands.

Chromite ($FeO.Cr_2O_3$) is a mineral that produces chromium ore, which is the fifth most commonly used metallic element in industry after iron, manganese, aluminum, and copper (SAMPAIO *et al*., 2005). It is one of the world's most important industrial minerals in metallic and nonmetallic applications. It is widely used in metallurgy (80% of global use), refractories (1%), and the chemical industry (8%) (ALMEIDA *et al*., 2017; SAMPAIO *et al*., 2005). Chromium (Cr) mineralizations are almost exclusively found in primary and ultrabasic plutonic igneous rocks. They are members of the orthomagmatic ores metal family.

South Africa, Kazakhstan, and India have the world's largest chromite reserves (more than 90% of total reserves) and are the metal's most essential production poles (DALLA COSTA *et al*., 2017). According to the most recent Brazilian Mineral Summary published by the Departamento Nacional de Pesquisa Mineral (National Department of Mineral Research) (DNPM) in 2014, Brazil is the only chromium producer on the American continent, with 0.13% of global reserves, equivalent to 1.9 million tons of mineable reserves and 570 thousand tons of Cr_2O_3 contained. When mineable and measured reserves are added together, 2.66 Mt of contained metal is accounted for, with the most significant resources in the states of Bahia (33,53%), Amapá (32%), and Minas Gerais (20%) (LIMA & NEVES, 2016). In 2014, the country produced 716,674.87 tons of compact, concentrated, granulated chromite and chromite sand, equaling 244,622.46 tons of contained Cr_2O_3. Geographically, 93.5% of Brazilian reserves are located in Bahia, within the territorial limits of Campo Formoso, Andorinha, Santa Luza, and Piritiba (LIMA, 2009). Bahia alone accounted for 70,80 % of national production or 507,423.87 t of Cr_2O_3 with a Cr_2O_3 content of 39% (LIMA & NEVES, 2016). In the state of Bahia, specifically in the deposits of the Campo Formoso district, there are four types of chromium mineralization. The first type is configured as metallurgical grade ore, called lump type.

This ore occurs in tabular layers ranging from centimeters to two meters in thickness and containing 30 to 48% of Cr_2O_3. The stratified ore, also called phytate, presents an alternation of centimetric sheets of chromite and serpentinite, and presents contents ranging from 15 to 30% of Cr_2O_3. The disseminated type presents a variety of content between 10 to 20% of Cr_2O_3 and occurs associated with the stratabound type or isolated bodies. The last one is friable, which is usually found associated with clay and disseminated chromite, with variations of contents identical to the disseminated and stratified types. The latter originates from disseminated and stratified mining (LIMA, 2009).

The Jacurici Valley mafic-ultramafic complex is the primary chromium mineralization in the national area (FIGUEIREDO, 1977). It can be found in the São Francisco Craton, northeast of Bahia (ALKIMIM, 2004). The Serrinha Block borders the chromitic district. The block was consolidated at the end of the Transamazonian Cycle during the Archean. It was limited by the Sergipe Fold Belt and the Salvador-Curaçá Belt (BARBOSA, 1997). To the district's west are the Serra de Itiba syenite and rocks with a high metamorphic grade connected to the ductile shear zone of the northern part of the Itabuna Belt (ALMEIDA, 2017). The rocks of Jacurici Valley were subjected to solid deformations and metamorphism during the Paleoproterozoic due to the collision of the crustal Blocks of Serrinha, Gavião, and Jequié (KOSIN *et al*., 2003). The Jacurici Valley Complex contains 22 mafic-ultramafic intrusive rocks contained in granulites and gneisses in the geological environment of the Serrinha Block. The Ipueira and Medrado mines are two of the most important in terms of the financial requirements of the chromium deposits among these already recognized bodies (FRIEDERICH, 2019).

Notables' institutional information and online databases in the minas de Ipueira-Medrado region bring good works on local surface geology and conceptions of the mineral deposit's general characteristics. Aerogeophysics (DIAS, 2021), geological mapping (OLIVEIRA, 2016), structural geology (ALMEIDA, 2017), and petrological and lithogeochemical characterization are some geological research publications (MARQUES *et al*., 2003). However, several new research reports may study the mineral bodies, such as geostatistical data analysis from mineral source studies, geophysical studies of electroresistivity for dimensioning the mineral body, and applying Remote Sensing techniques to more recent data for potentially promising areas.

The primary goal of this research is to conduct the first systematic review of the literature on the various types and properties of chromitic deposits in Jacurici Valley. The research identified gaps that allowed for a state-of-the-art investigation of the chromium deposits in the Jacurici Valley. Furthermore, the study will create a database of information on the region, which will help guide future studies.

2. Material and Methods

2.1 Location of the study area

The research area is in the municipality of Andorinhas, in the geographic region of Piemonte Norte do Itapicuru, in the state of Bahia's central-north region. This municipality borders the municipalities of Senhor do Bonfim, Monte Santo, Jaguarari, Itiba, and Uauá and is located 450 kilometers from Salvador, BA. The mafic-ultramafic complex of Jacurici Valley, which is part of the São Francisco Craton, is prominent in the area (Figure 1).

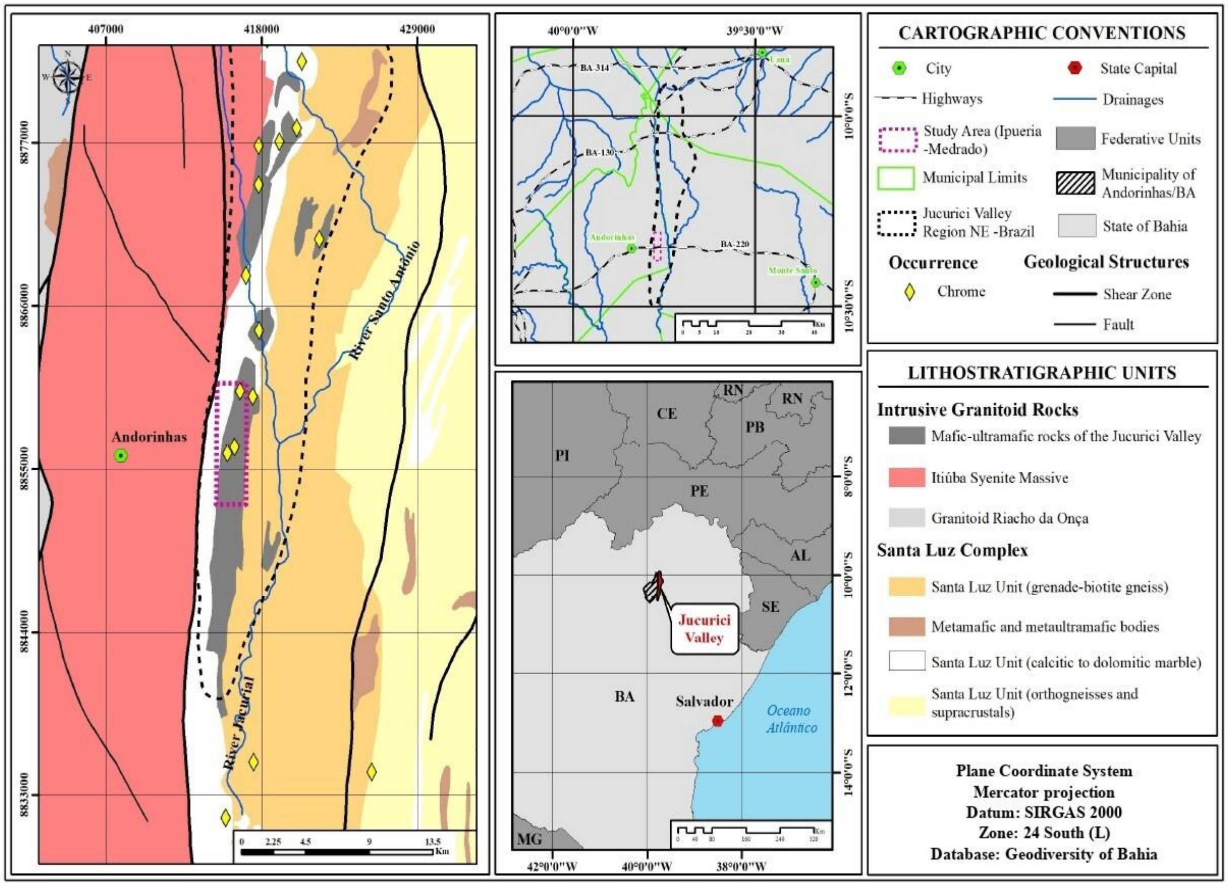

Figure 1 – Study area location map and lithostratigraphic of a portion of the Jacurici Valley, with emphasis on the Ipueira-Medrado study area region.
Source: CARVALHO (2010).

2.2 Regional Geology and Chrome Deposits Metallogeny

In regional geological evolution, the cratons of the South American and African continents are considered more stable inner portions of the plates. They merged these parts after more minor cratonic segment collisions (BRITO NEVES *et al*., 1999; CAMPOS NETO, 2000). Plate margins and aggregated portions became part of the Brasiliano-Pan-African orogenic belts (ALKMIM, 2004).

The Brasília belts delimit the São Francisco Craton to the south and west, the Rio Preto belt to the northwest, the Riacho do Pontal and Sergipana belts to the north, and the Araçuaí belt to the southeast (ALMEIDA, 1977). According to Alkmim (2004), the center of the craton contains Neoproterozoic covers of the Rio Pardo and Sergipe Belt. Precambrian and Phanerozoic units cover its interior, comprising three critical morphotectonic units: the São Francisco Basin, the Parnamirim Aulacogen, and much of the Recôncavo-Tucano-Jatobá Rift (ALKMIM, 2004).

The Mineiro Belt is a basement section exposed south of the craton during the Transamazonian Event. It was subjected to deformation and heat activity (NOCE *et al*. 1998; MACHADO *et al*. 1992). These terrains comprise a base metamorphic complex and supracrustal rocks from the Rio das Velhas, Minas, and Itacolomi Supergroups. Granites from the Archean and Paleoproterozoic periods are also present (ALKMIM, 2004).

North of the Craton, a piece of the Paleoproterozoic Orogen Fragment can be found (BARBOSA & DOMINGUEZ, 1996; TEIXEIRA *et al*., 2000; BARBOSA & SABATÉ, 2004; ALKMIN, 2004). This section is divided into four major lithotectonic components, each with its genetic composition and habitat (BARBOSA & DOMINGUEZ, 1996; TEIXEIRA *et al*., 2000; BARBOSA & SABATÉ, 2004). We summarize the four Archean lands in Table 1.

Table 1 – The Lithotectonic Components of the São Francisco Craton's Northern Portion.

Lithotectonic Components	
Lands	**Features**
Gavião Block	It comprises an Archean core that has been reworked on the edges. There are older rocks from the São Francisco Craton in this setting. Greenstone belt sequences, TTG plots with a 3.4 Ga age, two generations of granitoid with 3.2–3.1 Ga and another with 2.7 Ga, and TTG plots with a 3.4 Ga age. The amphibolite facies have metamorphosed all the rocks in this group.
Jequié Block	Most of the structure comprises 2.9 Ga migmatites and 2.7 Ga granitoid. It exhibits extreme deformation and Transbrasilian metamorphism under granulite facies settings. Metasediments and rudimentary metavolcanic can fill the block's rifts in this part.
Serrinha Block	In retro-arc basins, significant metamorphism marks it and contains Paleoproterozoic greenstone belt sequences covering part of the basement. The basement of the block comprises 2.9 Ga granites and tonalites.
Itabuna-Salvador-Curaça Belt	The terrain is made up of tonalites, trondhjemites, and metasediments. Its distinguishing characteristic is the Neoarchean/Paleoproterozoic magmatic arc setting. Because of the Paleoproterozoic convergence condition, metamorphism and deformation in the granulite facies can be seen. Shoshonitic rocks have been found.

Source: Adapted from BARBOSA & DOMINGUEZ (1996), TEIXEIRA *et al*. (2000); BARBOSA & SABATÉ, (2004), ALKMIN (2004).

2.2.1 Mineralogy and Metallogeny of chromium deposits

We can find chromium in nature as chromite and magnesium-chromite, both members of the spinel group, which includes minerals that contain magnesium, chromium, iron, and aluminum in their structure (SAMPAIO *et al*., 2005). Chromite is the only economically viable ore mineral among the chromium minerals. Thus, this element is distinguished in essential minerals: chromite ($FeCr_2O_4$), the aluminochromite [$Fe(CrAl)_2O_4$], magnesiochromite ($Mg,FeCr_2O_4$), and chromopyrite [$(Mg,Fe)(Cr,Al)_2O_4$)] (LIMA, 2009).

According to Sampaio *et al*. (2005), chromite has a theoretical composition of 68% Cr_2O_3 and 32% FeO. However, these quantities are never encountered in nature because of impurity implications. Chromite can be metallurgical, chemical, or refractory depending on the Cr2O3 content and the Cr/Fe ratio (LIMA, 2009). In crystallographic terms, Sampaio *et al*. (2005) characterize chromite as an oxide with the structure of spinels, with the crystallographic formula XY_2O_4.

The genesis of chromite deposits is because of mineral crystallization during the cooling of magma, with chromite as the only cumulus phase (FERREIRA FILHO, 2002; SAMPAIO *et al*., 2005). The chromite deposits are formed by partially melting the peridotitic upper mantle. For the system to enter the chromite stability field, according to Ferreira Filho (2002), specific phase relationships must exist for chromite deposition in the magma chamber.

Based on their development, we can divide deposits into podiform chromite and compact (stratiform) chromite (STOWE, 1994). Kropschot and Doebrich (2010) proposed a third group of chromitites associated with zoned Alaskan-Uralian mafic-ultramafic complexes (FRIEDERICH, 2018).

The first type of chromitic deposit is the podiforms. These deposits originated around the edges of tectonic accretion plates of the oceanic lithosphere. Obduction mechanisms that absorb them at the continental margins keep them on the continent (MOORES, 2003). We can find them in the same mafic-ultramafic rocks as the stratiform rocks. However, the formation genesis is different, having the Wilson cycle as the theoretical basis of formation. Compared to stratiform deposits, these deposits are smaller but have higher chromium contents and Cr/Fe ratios. The ores of this type of deposit are generally compact (lump: 30 to 48% of Cr2O4) (LIMA, 2009). Seafloor sedimentary association at the top, basalts with tholeiitic pillow characteristics, and basic dyke swarms in most regions are typical core elements of this mineralization pattern. The gabbro mafic complex is just below the most superficial section, and the ultramafic complex (harzburgite, lherzolite, and dunite) is close to the base (MOORES, 2003).

Stratiforms are tabular chromitic deposits in beds of igneous intrusions. They account for a significant portion of known chromium reserves, corresponding to 90% of the total (SAMPAIO *et al.*, 2005). These shield-shaped intrusions connect with mafic-ultramafic intrusions in championships and are more than 1.9 billion years old (THAYER & JACKSON, 1972; SAMPAIO *et al*., 2005). Mafic-ultramafic magma intrusions are linked to cratonic terrains and even rifting episodes. Dunites, peridotites, pyroxenites, and gabbros are among the rocks that make up this group. In the mafic zone, widespread and massive mineralization can include up to 90% or more chromite and is associated with lower sections of intrusions (THAYER & JACKSON, 1972). Generally, the ore found is more friable (LIMA, 2009). The Mafic-Ultramafic Complex in Vale do Jacurici, in Bahia (Brazil), is an excellent example of this type of deposit. The Witwatersrand and Bushveld Complexes in South Africa are the most notable examples of these genetic models.

In its mechanism of formation of tabular deposits, new magmatic inflows from the same intrusive processes fracture the mineralizations in subsequent magmatic events or pulses known as automatic, which occur between the mafic and ultramafic zones. Chromite crystallizes at the base of the magma chamber. Through the remobilization of crystals, there is a subdivision into two groups: on-stage and off-stage (Jackson, 1961; 1963; Eales, 2000; Friedrich, 2018). Jackson (1961; 1963) suggested the first concept, On-Stage, based on observations of the chromititic strata of the Stillwater Complex in the United States. In this scenario, Jackson (1963) determined that chromite crystals form at the magma chamber's base. As a result, magma settles relatively still and without lateral transit, resulting in a cotectic displacement caused by mixing the most advanced resident magma with a primitive one contaminated by crust (IRVINE, 1977).

Jackson produced essential papers in 1963 on lateral variations in the oxidation ratio ($Fe^{3+}/Fe^{2++}Fe^{3+}$) and fluctuations in the sum of total iron ($Fe^{2+ +} Fe^{3++}$) between layers (FRIEDERICH, 2018). He linked the differences to a lateral gradient in the magma's fO_2 during the Ultramafic Zone's development. The change is thus tied to the cell's convection pattern, the placements of the feeder ducts, or even the extraction of water from the sediments that intruded along the intrusion's edges (JACKSON, 1963).

According to Cameron (1980), chromites in chambers crystallize as a function of overall pressure variations. Chromite can only crystallize before pyroxene if the initial Cr_2O_3 concentration is over 0.2% by mass (Friederich, 2018). In this situation, the magma would be close to the chromite precipitation limit, causing the system to be moved to the chromite stability field due to pressure fluctuations. Other authors have postulated changes in total pressure caused by CO_2 bubbles, an increase in the magma chamber, and a subsequent reduction or magmatic escape as a displacement agent toward the olivine-chromite border (LIPIN, 1993).

The off-stage model proposed by Eales (2000) states that, besides the magma chamber that formed the Bushveld Complex, a second chamber containing a magma richer in magnesian composition and richer in Cr would be present where fractional crystallization processes and gravitational settlement would take place (FRIEDERICH, 2018). According to Friederich (2018), a magmatic injection containing up to 3% chromite microphenocrysts was introduced to the previously crystallized Bushveld chamber, enriching in Cr via intercumulus liquid escapes from this second chamber. In addition, Voordouw (2009) presented a similar concept in which it would generate chromite along the chamber's feeder ducts because of a mixture of magma flowing through the space and accumulating in structural traps (VOORDOUW, 2009). According to Friederich (2018), chromite crystals gathered in conduits would be remobilized and injected into the magma chamber as sills via chromite mud containing roughly 53 to 62% chromite (Figure 2). Processing a 2.5 km thick magma column and perfect gravitational separation between chromite and olivine would be required to create a one m-thick chromitite layer.

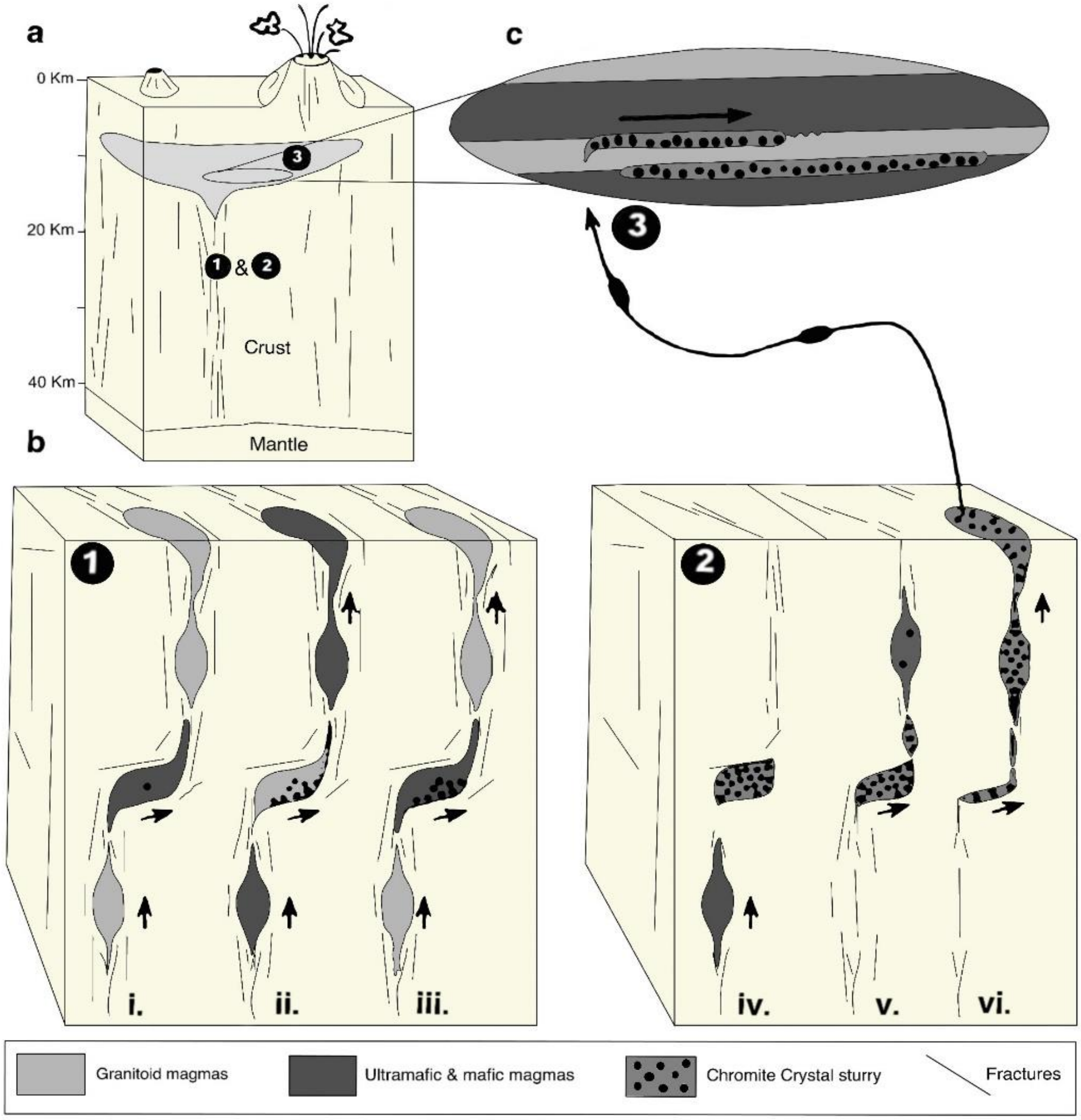

Figure 2 – Model illustrating an intrusive origin for chromitite layers. (a) Sketch of the Earth's crust, showing the approximate locations of the three stages. (b) Steps 1–3: (1) protected from chromitiferous mud in a structural trap; (2) remobilization of the mud rich in chromite crystals and rise through the conduit; (3) placement of chromitiferous mudalongof lithological contacts in the Layered Suite of Rustenburg.
Source: Modified from Voordouw (2009).

2.2 Methods

The systematic review was based on studies on public and private agency websites such as books, articles, theses, dissertations, and publications. These platforms provide data on the characterization of chromite deposits in the national and local contexts of the Jacurici Valley/BA chromitic complex. We found the sources by searching Google Scholar for the terms "Chromitite Deposit" and "Jacurici," which yielded 42 results. Because of the approach to the themes covered in the evaluation, we reduced it to 24 appropriate pieces after the screening: three volumes, three reports, and an expanded abstract round up the integrated works.

3. Results and Discussions

3.1 Chromitic districts of the Jacurici Valley

Three Neoproterozoic mobile belts (Riacho do Pontal, Rio Preto, Sergipana, Araçua, and Brazilian Belt) restrict the mafic-ultramafic complex of Jacurici Valley, which is located northeast of the state of Bahia and is an integral part of the São Francisco Craton. The ages of such a complex range from 2,085 to 5 Ma, equivalent to the region's metamorphic peak (BARBOSA *et al*., 1996; FRIEDERICH, 2019).

Several intrusive masses are interbedded in this complex win this complex Granodiorite to tonalitic leucocratic gneisses with amphibolite intercalations, banded iron formations, olivine-marbles, diopside-rich calc-silicates, quartzites, grenadier gneisses, and metacherts are the most common lithotypes (MARINHO, 1986). Silveira *et al*. (2015) hypothesized meta-gabbro-norite as the origin of the amphibolic bodies formerly thought to be sedimentary. In contrast, Almeida *et al*. (2017) suggested cogenetic intrusions to the Jacurici Complex.

The chromitic bodies in this complex are found in the Archean contexts at the Serrinha block. The mafic-ultramafic intrusions that occur in the Jacurici Valley complex, according to Dias *et al*. (2021), cover a region of around 70 km in length and 20 km in width, with most of them orientated N-S.

According to Alves (2005), 14 chromitic bodies were discovered in the valley in 2005, with names ranging from north to south: Logradouro do Juvenal, Várzea do Macaco I, Várzea do Macaco II, and Várzea/Teiú (municipality of Uauá); Monte Alegre, Cemetério, Riacho I, Riacho II, Barra, Algodões, and Lajedo (municipality of Queimadas). Medrados, Pindoba, Ipueira/Socó and Pedra of Dórea (municipality of Andorinha); Laje Nova (municipality of Cansanção); and finally, Barreiro and Pau Ferro (municipality of Queimadas). Friedrich (2019) claims that 22 mafic-ultramafic entities have been cataloged in a more recent investigation.

During the Paleoproterozoic, the Jacurici Valley complex rocks suffered an intense deformation and metamorphism events associated with the Serrinha, Gavião, and Jequié block collisions (BARBOSA &SABATÉ, 2004). The chromitic deposits of the Jacurici complex are elongated and oriented parallel to the regional foliation, with an interruption in continuity because of tectonic activity (MARQUES & FILHO, 2003).

According to Marinho (1986), three deformational events ruled over the terrains of the region during the formation of the deposits forming the isocline and transposed folds, closed folds, and lineation of foliations in the NNE and NNW directions. High metamorphic grades (amphibolites) affected these rocks, according to Del Lama (2001). Post-peak metamorphic metasomatic took place, producing serpentinization and phlogopitization processes.

In Brazil, there are other chromitic deposits with different evolution models but of great importance for the genetic knowledge of these deposits, namely the Bacuri Complex (Amapá) and Niquelândia Complex (Goias). In addition, the two complexes, together with the Ipueira-Medrado complex, have a distinct igneous stratigraphy, further strengthening their uniqueness because of the internal formation environment (FERREIRA FILHO, 2002).

3.1.1 Ipueira-Medrado Chromite Complex

The Medrado and Ipueira mine is in the chromitic district of Jacurici Valley, on the western edge of the Serrinha Block, bordering the Salvador-Curaçá Belt. There are many economic deposits and occurrences of chromite hosted in mafic-ultramafic rocks (ALMEIDA *et al*., 2017; BARBOSA *et al*., 1996).

The chromium mines are structurally found in a mafic-ultramafic sill, which hosts the largest chromite deposit in Brazil. The geological body is described as an elongated form, 7 km long and 300 m thick, with a continuous layer of chromitite 5 to 8 meters thick, mineralized within the ultramafic zone (MARQUES & FERREIRA FILHO, 2003). Some authors also mention that the body presents a strong differentiation and stratification, originating from primitive magmatism and crustal contamination (DEUS & VIANA 1982).

In the geological bodies of the Medrado and Ipueira mines, the rocks are interspersed with gneiss rocks and metasedimentary rocks of high metamorphic grade. The lithotypes in the mine area are migmatized banded gneisses, granulites, metacherts, quartzites, diopsites, and olivine-marbles (ALMEIDA *et al*., 2017). The sill in the Ipueira mine, which corresponds to the extension of the Medrado sill (east flank), presents lithotypes with chemical metasedimentary sequences that include serpentine, marble, diopside, and strictly metacherts (ALVES, 2005).

The chromite deposit is divided into three zones (Figure 3) using the following sill stratigraphic stacking: marginal (5 to 20 m thick), ultramafic (up to 250 m thick; the layer is subdivided into upper and lower), and mafic (approximately 30 m thick) (MARQUES & FERREIRA FILHO, 2003). The layered chromitite in the sills is represented by a granulometry that varies between 0.4 to 0.6mm, is little disseminated, and presents sudden contact with the host rock.

According to Deus & Viana (1982), the olivines and pyroxenes in these deposits show shifts in composition, with more Mg-rich minerals towards the top of the deposit and more Fe-rich minerals at the bottom. This situation shows possible recent magmatic mixtures injected with the resident magma through convective flow during magma cooling.

The Ipueira-Medrado sill divides into seven strata units, according to Marques & Ferreira Filho (2003), since it is formed of dunites, pyroxenites, and harzburgites.

Marques & Ferreira Filho (2017) published stratigraphic correlations between the chromitic layers of Ipueira and Medrado among themselves and between Monte Alegre Sul and Várzea do Macaco through the divisions suggested for the Jacurici complex (Figure 3).

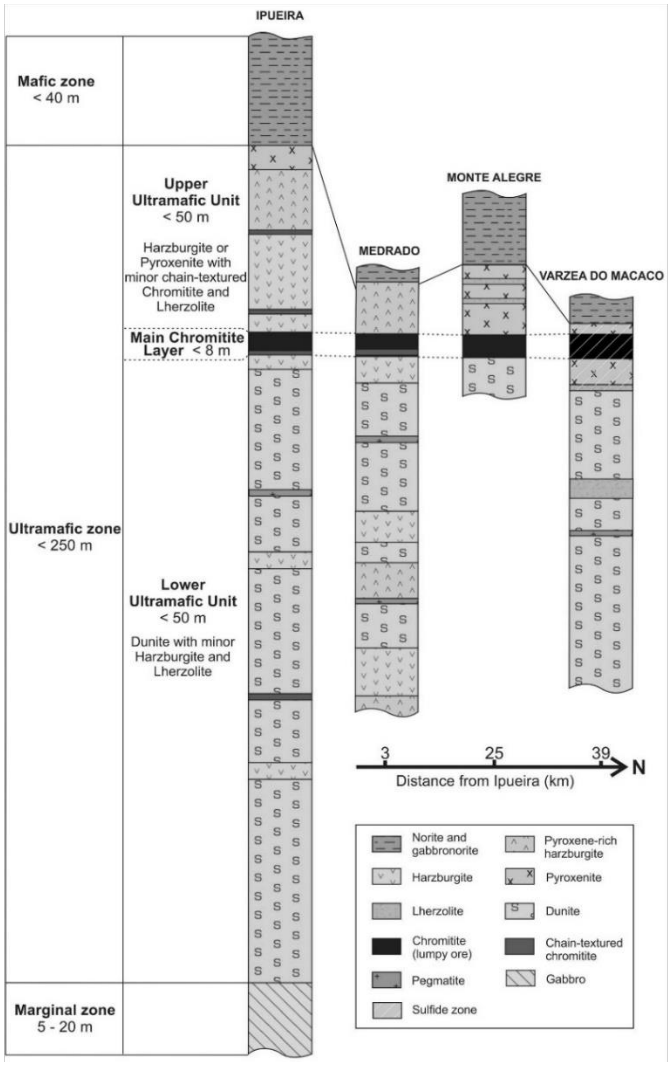

Figure 3 – Representative sections of the Ipueira, Medrado, Monte Alegre Sul, and Várzea do Macaco segments, seeking to illustrate the stratigraphic correlation and divisions for the Jacurici complex.
Source: Partially adapted from Marques & Ferreira Filho (2003).

Marques and Ferreira Filho (2003) describe that the Ipueira-Medrado deposits were formed in oneness; however, through shearing processes, the original body was divided into two groups that conserved similar lithological and structural characteristics.

Regionally, the rocks underwent intense metamorphism events (high metamorphic grade) and deformation, with minimum temperatures of the amphibolite facies (ALMEIDA *et al*., 2017). Alves (2005) states that the elongation and discontinuity result mainly from a robust east-west compression caused by bending and transpositions in the north-south direction.

Almeida *et al*. (2017) explain that the evolution of the mafic-ultramafic chromitic bodies occurred similarly to the gneissic host rock. According to Almeida *et al*. (2017), these configurations of structural controls allowed the development of mine-scale bodies (thickness between 7 and 8 m) on both sides of the fold. The chromite layers' repetition may be related to thrust shear zones identified both regionally and at a local scale.

Because of the constraints in the structure's formation, the chromititic levels also occur in the forms of bodies. They are parallelized with the hinge line of the synformal folds. The Medrado synform Fold is normal, with an axial surface dipping from 75° to 90°, with a weak slope on its axis to the southwest (ALMEIDA *et al*., 2017). The Ipueira fold configures as a reverse synform, in which both flanks dip to the east with a southwesterly slope of 10 to 15° (ALMEIDA *et al*., 2017).

In general terms, the Ipueira-Medrado chromitic deposits correlate with the Bushveld Complex's models (BIONDE, 2015). This correlation is motivated by its genetic origin, magma chamber structure, and formation environment. A strong argument that supports the traits that approximate the two models (Ipueira-Medrado with Busheveld) is the presence of the formation of nickel deposits associated with mafic-ultramafic bodies. Nickel deposits, similar to chromium, are generated during magmatic segregation processes and lodged in the chamber's lower portion. In geotectonic terms, another substantial similarity between both complexes is their origin of formation, where both are correlated to Precambrian cratonic areas.

When approached from the perspective of extraction through mining activities, the Ipueira-Medrado deposits are subdivided into three segments: Medrado, Ipueira II, and Ipueira Sul (Figure 4) (MARQUES & FERREIRA FILHO, 2003). The ore in these mines is hosted in serpentinites, which can vary in disseminated or massive occurrences. According to Figueiredo (1977), content can reach up to 70%.

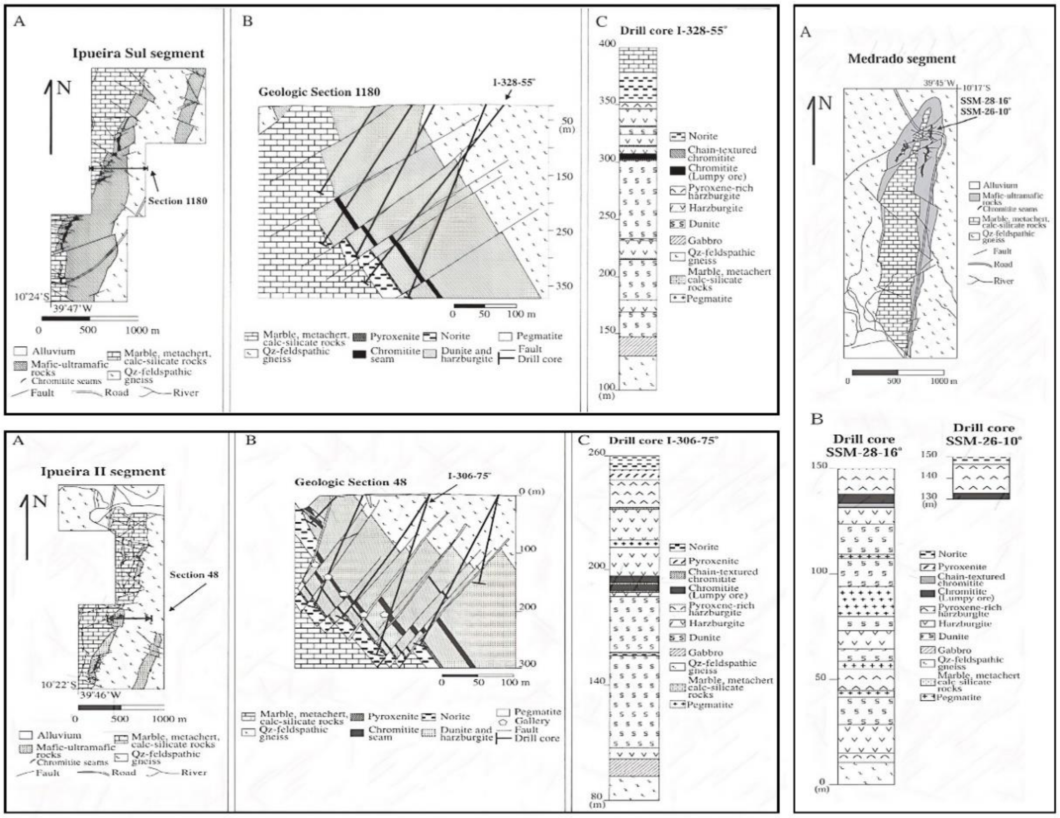

Figure 4 – Detail map and stratigraphic section of the underground mine of the Medrado, Ipueira Sul, and Ipueira II sill segment. Internal mining report of Jacurici Valley S.A.

Source: Partially adapted from Marques & Ferreira Filho (2003).

4. Conclusions

The work sought to bring in a bibliographic review of some concepts and theories about chromite mineralization models. Therefore, in its scope, it was structured in information and classification of chromitic deposits according to the shape of the geological body (stratiform or podiform) and chromium remobilization (On-stage or Off-stage).

The focus was on the mafic-ultramafic deposits of the Jacurici Valley complex in Bahia (Ipueira-Medrado segment). Studies carried out in other deposits of the same genus, such as mineralizations of the segment mentioned above, were formed in a stratiform deposit model with a closed remobilization system (Off-stage).

Deposits of metallurgical-type chromium grades mostly form the deposits of the Vale Jacurici Complex, and their grades are high for an ore-type class (lump). In the municipality of Andorinhas, where they are located as the mines of Ipueira-Medrado, medium ores (lump type) are found, with contents in the order of 38% of Cr_2O_3. As a significant characteristic of the local ore, it is aluminous, with grades ranging from 17.2% to 20.5%. Based on estimates provided by the Companhia de Ferro-Ligas da Bahia (FERBASA), the mineral deposits in this region have toral reserves exceeding 20 million tons, which are sufficient to sustain a useful life of 30 years.

As for the structural form, it still reverberates discussions about its structuring. Two discussions are raised regarding the formation model: a) synform fold or b) inverse faults generated through thrust zones. Both theories are still in force and are being discussed.

Although there are works focused on the geological characterization of the area, mainly on the surface and structural geology, there is low production of works in other branches of geosciences. This condition ends up generating gaps that have not yet been filled. The idealization of specialized study fronts would open new horizons for mineral research.

Within the economic sphere, geostatistical studies applied to drillhole geochemistry would help determine the continuities and directions of mineralizations. Implementing new geoprocessing techniques in Remote Sensing products and terrestrial geophysics by resistivity method, for example, would be excellent support in the delimitation of the physical body of the mineral or even in obtaining new study targets.

Regarding environmental studies, research in fields such as environmental geology, medical geology, and hydrogeology would allow the analysis of the condition of the environment and possible health risks to residents. Thus, with the detention of this knowledge, studies could be directed to identify if the mining activity causes problems.

Acknowledgments

The authors are grateful to the Department of Geology, the Graduate Program, Laboratory of Geoprocessing of Ceará (GEOCE), and the Science Center of the Federal University of Ceará for the structure made available to carry out the research. Funding: Fundação Cearense de Apoio ao Desenvolvimento Científico (FUNCAP) supported this work (Process: BMD-0008-01397.01.08/21), which provided a postgraduate scholarship at the master's level that guaranteed ideal conditions for scientific research and the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES).

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