Ore Geology Reviews 148 (2022) 105005

Contents lists available at ScienceDirect

Ore Geology Reviews

journal homepage: www.elsevier.com/locate/oregeorev

# The gold mining industry in Brazil: A historical overview

Marco Aurélio da Costa [a], Francisco Javier Rios [b,*]

[a] Jaguar Mining, Brazil
[b] CDTN/CNEN, Brazil

ARTICLE INFO

*Keywords:*
1. Gold mining
2. Brazil
3. Geohistory
4. Overview

ABSTRACT

For the past 300 years, Brazil has been one of the most important gold producers worldwide, including the first 'gold rush' of modern history. During the 18th century, an incredible amount of 1,200 tonnes was extracted with artisanal methods from the provinces of Minas Gerais, Goiás, Bahia and Mato Grosso. The country's first industrial mining companies were established thereafter; they stemmed mainly from English capital, located in the aforementioned provinces. During the last 120 years, industrial mining projects boomed and spread throughout Brazil, culminating in more than 80 mines with a production of around 2000 tonnes of gold. New gold-frontier areas were also consolidated in the Amazon region. The diversity of metallogenetic environments for gold deposits (e.g., orogenic, IOCG, Au-PGE, low-sulfidation epithermal, porphyry types, etc.) and the country's enormous geographic dimension hint at the possibility of great mining developments in the short and medium-term. This article presents the different phases of artisanal (*garimpo*) and industrial gold mining in Brazil by reviewing the country's geo-historical and production data, obtained and/or retrieved from several dispersed and restricted sources. Particular emphasis is placed upon the regional differences between gold-producing Brazilian provinces and on the roles of national and international corporations for the industry's development.

## 1. Introduction

Gold has been a part of human life since the dawn of civilization and, in most cultures, it has stood as a potent symbol of wealth and power. The mining of gold during ancient times can be traced to different kingdoms, often quite distant among each other: from Sumer and Egypt, to India and China. The Chinese Xia and Shang Dynasties (2100–1200 BCE) mined gold placers deposits, while the Egyptian Empire explored deposits in Nubia, Arabia, Armenia, and Sinai. As the papyri of Turin show us, in Egypt, at the time of Ramses II, there was already basic knowledge on the purification of gold and silver, and the elaboration of various alloys, including mercury. Later on, the Greeks extracted gold from mines in Macedonia, Thrace and the Cyclades; thereafter, the Romans did the same in Dacia, Tracia, and Dalmatia, as well in the Iberian Peninsula. The first gold rush of the world occurred in Las Medulas, a region in northwestern Spain, fueled precisely by the advances of the Roman Empire. Another two thousand years would pass, however, before the first modern "gold rushes" which involved much greater manpower began in countries and regions with notable exploration trajectories, and/or where gold rushes have occurred such as Europe, North and South America, China, South Africa and Australia (Del Mar 1901; Blainey, 1969; Maxwell-Hyslop, 1977; Richardson and Van Helten, 1984; Craig and Rimstidt, 1998; Monem, 1999; Klemm et al., 2001; Puche Riart, 2001; Lopes Velho, 2006; Rodrigues, 2006; Mudd, 2007; (Lima et al., 2011); Zhang et al. 2015).

Within (Table 1) such scope, recovering the history of gold mining in Brazil is paramount. As we will see, Brazil's case constitutes one of the most interesting chapters in the history of gold mining worldwide, especially given how the first gold rush of the Modern Age occurred on Brazilian soil, about 300 years ago. The largest gold deposits in Brazil are related to a diversity of metallogenetic environments. Those related to orogenic systems predominate, and to a lesser extent, those related to IOCG, Au-PGE, Low-sulfidation, Porphyry, and Witwatersrand type are already being explored. Currently, Brazil has four world-class mines: Cuiabá, Morro do Ouro, Crixás and Fazenda Brasileiro. Morro Velho mine, which closed in 2003, must also be considered world class.

The present paper provides an overview of the artisanal and industrial phases of gold mining in Brazil, starting from the 18th century. Its objective is to present a careful review of the country's historical and production data and to analyze it in terms of regional differences, highlighting the contribution of the relevant provinces, listing the mines and corporations responsible for that production over time, and briefly

* Corresponding author.
*E-mail addresses:* mac13@uol.com.br (M.A. Costa), javier@cdtn.br (F.J. Rios).

https://doi.org/10.1016/j.oregeorev.2022.105005
Received 6 December 2021; Received in revised form 14 June 2022; Accepted 28 June 2022
Available online 5 July 2022

**Table 1**
Super-large and large gold deposits in Brazil. MG: Minas Gerais State; GO: Goiás State; BA: Bahia State; PA: Pará State; AP: Amapá State.

| Type | Name | State | Accumulated Gold Production (tonnes) | Reference in maps |
|---|---|---|---|---|
| Super-large gold deposits (Au production greater than 100 tonnes) | Cuiabá | MG | 196.22 | (A) in Map 1, and detailed in Map 2 |
| | Morro Velho | MG | 370.14 | (B) in Map 1, and detailed in Map 2 |
| | Morro do Ouro | MG | 371.35 | (C) Map 1, and and detailed in Map 2 |
| | Crixás | GO | 138.37 | (D) Map 1, and and detailed in Map 3 |
| | Fazenda Brasileiro | BA | 101.38 | (E) Map 1 |
| | Igarapé Bahia | PA | ~100,00 | (F) Map 1, and and detailed in Map 5 |
| Large gold deposits (Au production between 40 and 100 tonnes) | São Bento | MG | 59.49 | Detailed in Map 2 |
| | Raposos | MG | 67.14 | Detailed in Map 2 |
| | Chapada | GO | 51.19 | Detailed in Map 3 |
| | Jacobina | BA | 72.59 | Map 1 |
| | Salobo (Cu-Au) | PA | 60.43 | Detailed in Map 5 |
| | Tucano | AP | 44.81 | Detailed in Map 5 |

assessing the geology of each area. Some broad considerations on the impact of mining on Brazilian society and the characteristics of its development are also given throughout the text. The data presented herein was obtained from several sources, most of which are dispersed or have limited access.

## 2. Artisanal mining in the 18th century Brazilian "gold rush"

Brazil's first 'gold rush' is usually dated back to 1693, for this was the year when gold was officially discovered on national soil. The discovery was claimed by the São Paulo born-*bandeirantes* (pioneers) and happened to the east of what would later become known as the gold region par excellence of Minas Gerais: the *Quadrilátero Ferrífero* ('Iron Quadrangle', or *QF* in current literature) (Figs. 1 and 2). The *QF* is an almost quadrangular geographic area, located between the present-day cities of Belo Horizonte, Ouro Preto, Congonhas and Santa Barbara, although its geological extension is known to carry on eastward to Itabira. Its denomination was sacramented in the early 1950 s by a United States Geological Survey (USGS) mission (Dorr II, 1957) and is owed to the numerous deposits of iron ore (in addition to gold) found on-site, many of them world-class deposits, making Minas Gerais one of the largest producers of iron and gold on the planet.

The histories of Brazil's first gold boom and that of the *QF* are closely intertwined. At the dawn of the 18th century, Brazil saw gold mines appearing one after the other throughout the whole *QF* region. Initial discoveries were made by the *bandeirante* Borba Gato within the Rio das Velhas basin, and subsequently, findings followed in Congonhas de Sabará (current Nova Lima), Caeté, Tripuí, Ribeirão do Carmo (Mariana), Vila Rica (Ouro Preto), Cata Preta (Santa Rita Durão), Antônio Dias, Catas Altas, Santa Bárbara and Itabira (Fig. 2). Meanwhile, around the Rio das Mortes river (which corresponds to the town of São João del Rei), alluvial gold was to be found in the vicinity of the town of Arraial Novo de Nossa Senhora do Pilar (São João del Rei).

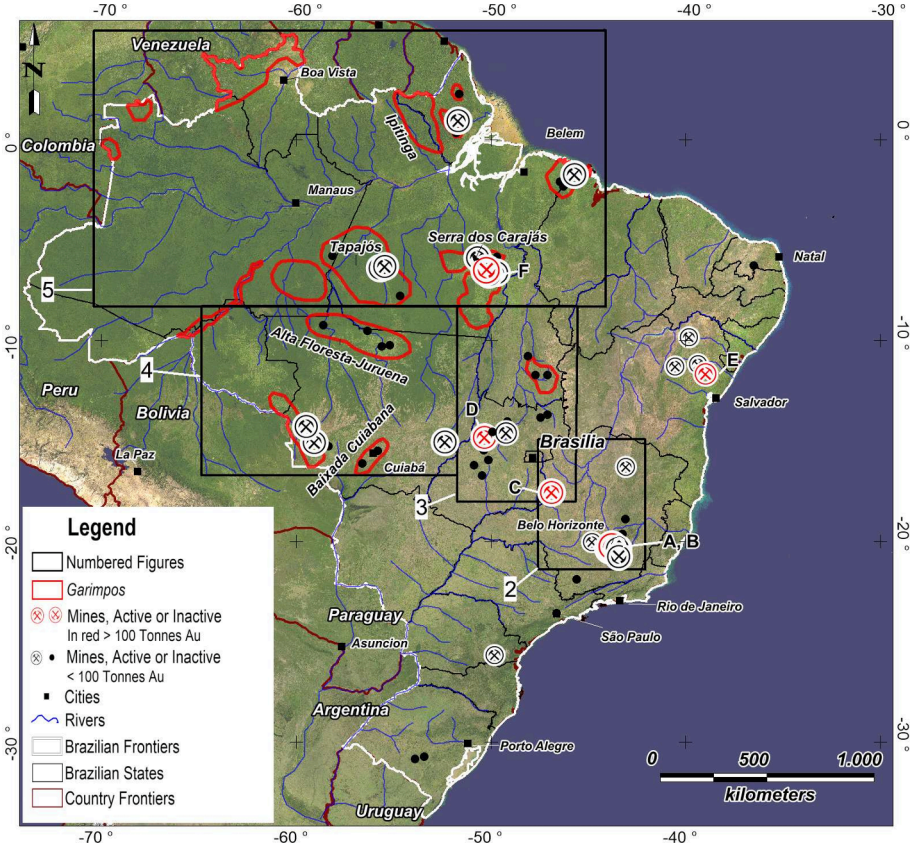


**Fig. 1.** Map of Brazil showing the main areas of industrial and artisanal (*garimpos*) mining developed in the last 300 years, as well as the distribution of gold deposits. The boxes correspond to the following detailed maps: (2) Quadrilátero Ferrífero and Minas Gerais State, see Fig. 2; (3) States of Goiás and Tocantins, see Fig. 3 (4) States of Mato Grosso and Rondônia, see Fig. 4); (5) Fig. 6 (States of Amazonas, Pará, Maranhão, Amapá and Roraima), see Fig. 5. (A to E): Major super-large Gold deposits greater than 100 tonnes. (A, B) Morro Velho and Cuiabá; (C) Morro do Ouro; (D) Crixás; (E) Fazenda Brasileiro; (F) Igarapé Bahia.

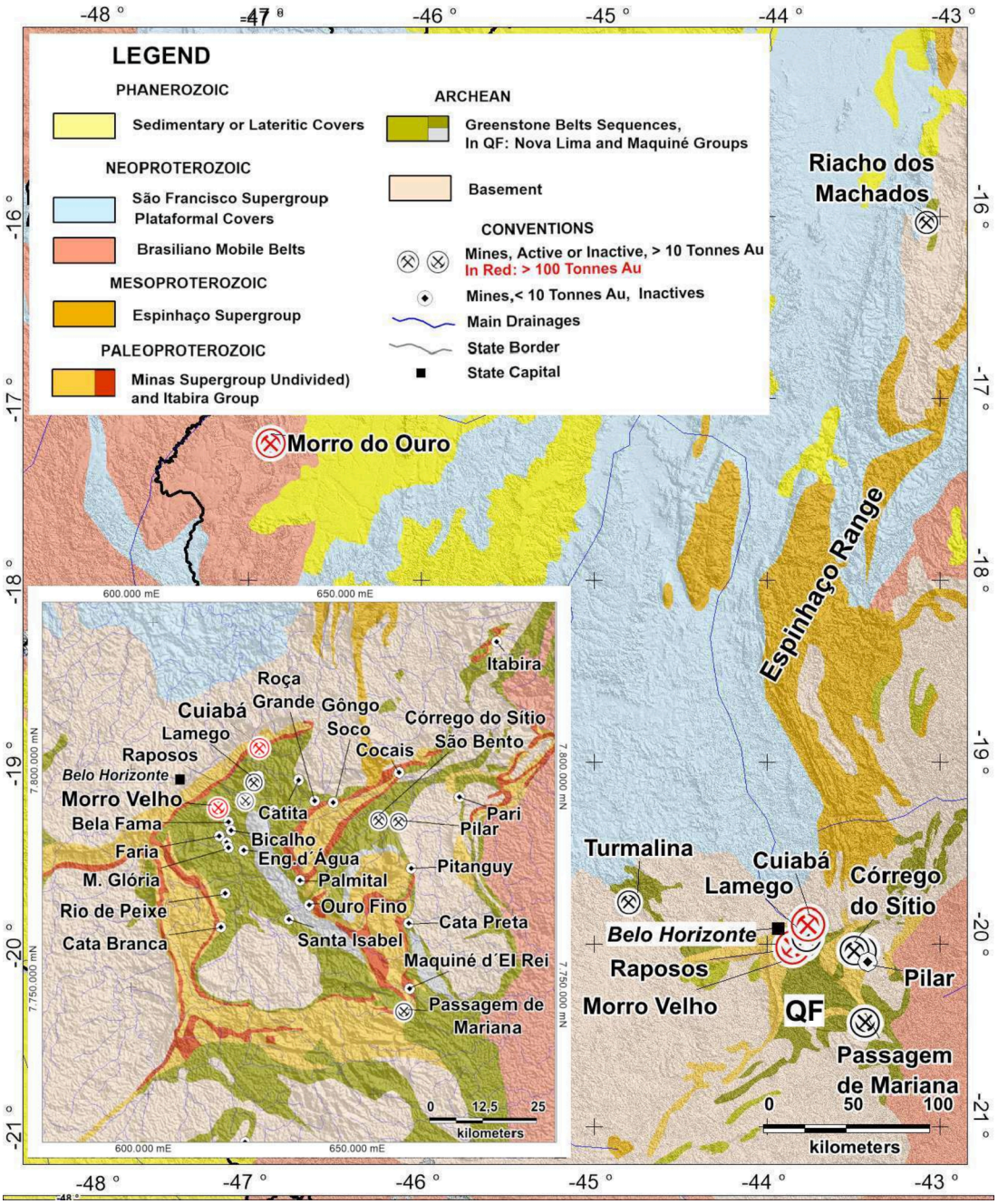


**Fig. 2.** Geological map of Minas Gerais (modified from Gómez et al., 2019). In detail, the *Quadrilátero Ferrífero*, modified by Dorr II (Dorr II, 1969).

Later, between 1700 and 1702, pioneers searched the quartzite-dominated Espinhaço Range. As a result, one after another, auriferous alluviums began appearing in the springs of the Jequitinhonha river, in the surroundings of several towns and villages: from Diamantina to Serro do Frio, extending to the Santo Antônio river to the south and, further east, reaching the Minas Novas de Fanado.

During the same period, but further to the north of the *QF* (in the hinterlands of the Bahia province), the first gold mines of the Itapicuru-Mirim river were discovered among the alluviums of the Proterozoic *meta*-conglomerates of the Serra de Jacobina (Farias, 2008) (Fig. 1). The extraction of gold in this sector was prohibited by the King of the time, D. Pedro II of Portugal, in 1703 - "due to the fact that the mines are close to the coast, and the consequences for the production of sugar and tobacco" (Noya Pinto, 1979). Nevertheless, the prohibition did not prevent the gold rush that was sweeping the *QF* from extending to the quartzites of Rio das Contas, in Chapada Diamantina, Bahia's second-most important mining region.

Then, around 1722, the gold rush took a western direction to the *sertões (*hinterlands) of the Goiás province, following the discovery of gold in the auriferous sands of Vila Boa de Goiás (Franco, 1989). The mines of Santa Ana (current Vila Boa de Goiás), Santa Cruz, Jaraguá, Guarinos, Tapir, Ouro Fino, Chapada, Meia Ponte (Pirenópolis), Formosa, Iporá, Água Quente, Santa Rita, among others, were found out (Fig. 3). The discoveries of new gold-bearing areas then proceeded towards the north to a geographically giant sector that reached up to the southern province of Tocantins. A second foray occurred between 1734 and 1740, and resulted in the gold centers of Traíras, Pilar, Santa Luzia, Anicuns, Arraias, Chapada da Natividade, Almas, São José do Duro and, notably, Cavalcante and Crixás (which currently concentrate important industrial gold mining projects).

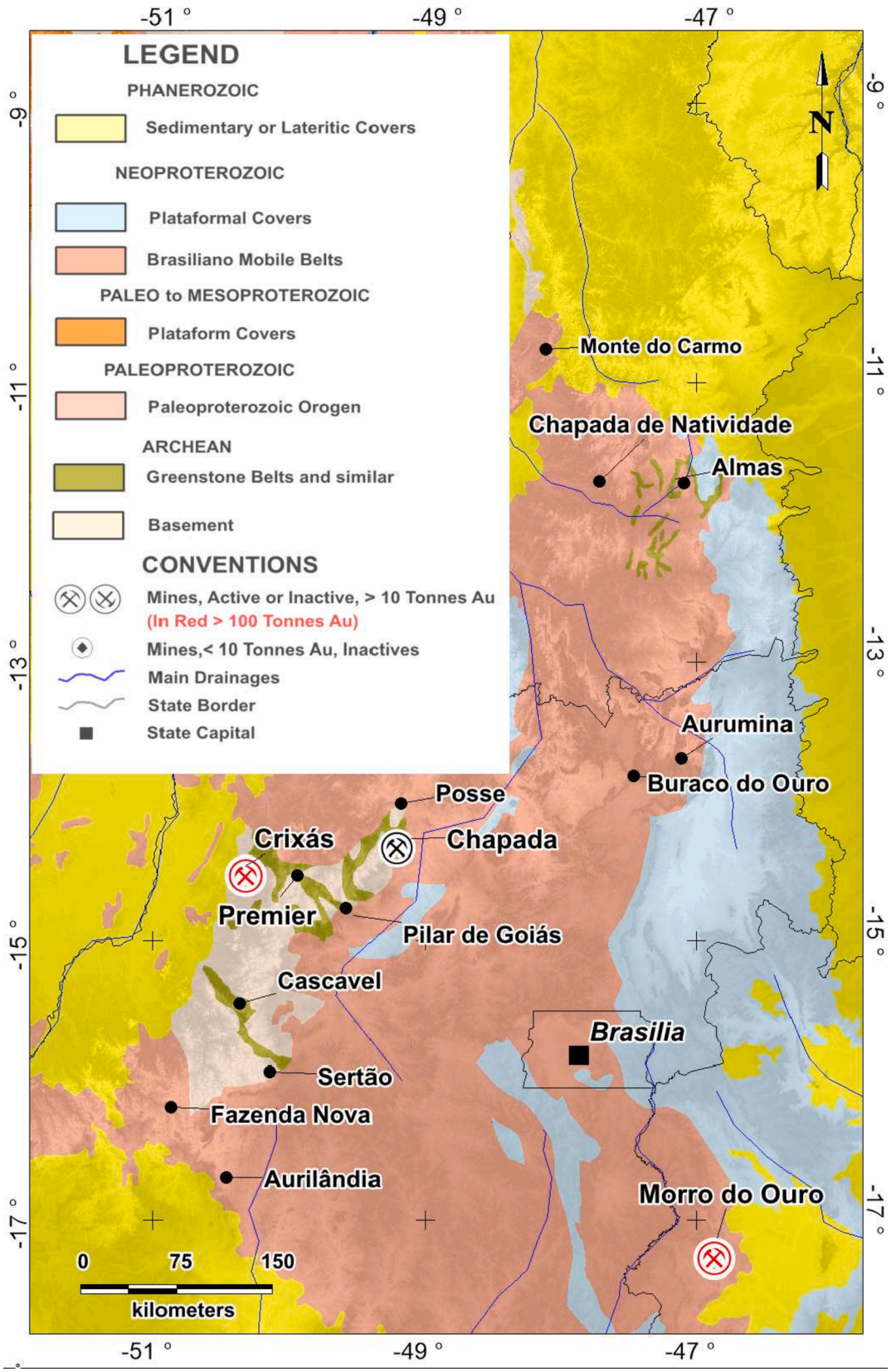


**Fig. 3.** Geological map of central Brazil (modified from Gómez et al., 2019), showing the position of mines in the Goiás region.

Gold was first discovered in Mato Grosso in 1718 by the *bandeirante* Pascoal Moreira Cabral Leme, on the margins of the Coxipó River, near Cuiabá, just to the north of an area that had already been prospected by the Spanish almost two hundred years before (Rios, 2018). Two years after Cabral Leme's arrival, the Coxipó-Mirim and Forquilha mines were already extracting gold at full steam. The later discovery of the Cuiabá gold-rich sands in 1722 was a key factor in setting off a gold fever in the province (Noya Pinto, 1979). Production in these mines declined quickly, however, given their rudimentary extraction methods; this lead to the flourishing of deposits located further to the northwest, in the direction of Rondônia province (part of the geological region of the Amazon). Thus emerged the towns of Vila Bela da Santíssima Trindade (1731), Arinos (1739), and Corumbiara (1745). Finally, discoveries in Poconé in 1777 ensured this gold boom's survival, while marking the end of a golden age for exploration in western Brazil.

### 2.1. Gold extraction methods during the 18th century

Different types of gold were found during the 18th century in Brazil through the use of disparate mining techniques. In the Espinhaço Range of Minas Gerais, around Jacobina and Rio de Contas (Bahia), and throughout the entire region of Cuiabá (Mato Grosso), alluvial gold had a characteristic metallic yellow appearance which made it easily recognizable. On the other hand, in other parts of Minas Gerais province, the presence of large quantities of platinum in the metal generated what the pioneers called 'white' gold. Then, in some sectors of central and northern Goiás and especially in the *QF* region, gold had a different, darkened, and shiny appearance, giving it the name of *ouro preto* (black gold). This last variety was rich in platinum, palladium, iron, and manganese, and contained Pd–O-bearing, dark-colored ferruginous coatings placed onto the gold itself, in which the associated seleniferous minerals of palladium and platinum could also appear (Jedwab and Cassedane, 1998; Cabral, 2003; Cabral et al, 2003; Cabral and Lehmann, 2007).

The techniques used during the alluvial artisanal extraction period focused on the exploration of *veios* (veins) and specific geographic formations called *tabuleiros* (Ferrand, 1913; Paiva, 2002). According to Paul Ferrand, the 'veins' were the gold-alluviums that formed the riverbeds themselves; the *tabuleiros* were deposits located on the riverbanks, at a slightly higher level than the veins; and the *grupiaras,* in turn, were the highest deposits, often embedded in mountain flanks. *Jacutingas* (see below) and *carvoeiras* (sulfide associations with hematite and tourmaline) were the two types generally richest in gold and thus more frequently sought out. Furthermore, the extracted gold already came in the form of powder or golden nuggets and did not require further separation.

In the case of the *grupiaras*, extraction was carried out through the *talho aberto* (open-cut) system, which consisted of dismantling the lands with water (Martins, 1984), generating almost vertical cuts into the soil. The method was extremely damaging to the environment and gave rise to a high level of waste of fine gold. Nevertheless, at that time, it was considered cheaper and more worthwhile to open such *talhos* (cuts) and use hydraulic devices to push out the extracted material than to develop a better thought-out mining strategy (Renger, 1999, 2006). Another method for gold extraction was the opening of galleries and small pits that followed a guiding layer (Eschwege, 1979). This technique prevailed mainly in the Ouro Preto region, crossing the syncline of Mariana.

Also a trademark of artisanal exploration was the presence of *catas*, small open-pit excavations shaped in the form of a funnel. In general, *catas* were developed in friable itabirites in which gold minerals, locally called *jacutingas,* would occur. These were vein-type mineralization without sulfide associations, and consisted predominantly of soft hematite with subordinate kaolinite, talc, manganese oxide and goethite, where gold is alloyed with palladium (Cabral, 2003; Hussak, 1904; Olivo et al., 2001; Kwitko-Ribeiro et al., 2002).

From this data, it can be said that, throughout the 18th century in Brazil, mining technology remained rudimentary. The techniques employed usually not the most appropriate to obtain high yields of gold (Renger, 2006; Eschwege, 1979; Russel-Wood, 1990).

### 2.2. Gold production in Brazil during the 18th century

Calculations of the amount of gold produced during the 18th century in Minas Gerais indicate a value of approximately 550 tonnes of gold (the gross amount for the entire century). The available data on the captaincies (the first jurisdictional division of Brazil) of Goiás, Mato Grosso and Bahia are sparser, suggesting values from 1 to 10 tonnes of gold (Noya Pinto, 1979; Calógeras, 1957; Simonsen, 1977; Costa and Rocha, 2007). The production values of the four main mining captaincies, however, including more reliable data for Minas Gerais, were likely hampered by smuggling, a process that also generated a significant loss of foreign exchange for the Kingdom of Portugal. Furthermore, several areas of alluvial production operated clandestinely for years, even decades - such as Jacobina, Rio de Contas, Minas Novas, etc (Rios, 2018).

By taking these factors, including the geology of the area, into account, more precise values can be reached. According to the literature, they range around 1,200 tonnes of gold in terms of Brazilian production between 1700 and 1810 (Rios, 2018). For its part, Portugal, by way of the taxation concept of the *quinto real* (the royal one-fifth part), collected some 130 tonnes of gold (Rios, 2018). Much of that colonial gold, in turn, went directly to England to pay for imports linked to the Methuen Treaty or for the metal trade that had not been filtered by the Portuguese tax (Del Mar 1885, 1901).

In terms of controlling the mining activity that went on in Brazil, the first formal instrument implemented by the Portuguese Crown was the First Mines Regiment. Enforced during the 17th century, the law stipulated the payment of a fifth of the total extracted volume of each gold mine (the *quinto real)*, which was calculated after the metals were melted, without considering any operational costs (Ferrand, 1913; Renger, 2006). The strict observance of this determination soon saw the need to enact "foundry houses" or *casas de fundição*, places where all the extracted gold could be collected, purified, melted, and turned into bars to facilitate the tax collection. Nevertheless, the Portuguese Crown would eventually begin to doubt the system's effectiveness, and in 1734, it decided to implement the so-called "capitation" (*capitação*) system.

Unlike the "royal fifth" policy, the *capitação* was a fixed payment of 17 g of gold made by all Brazilian inhabitants, including mining slaves and traders in general. The system was quite disruptive to the mining industry, seen as it "encouraged ambitious mining in detriment of a rational exploration of deposits, even inhibiting the development of new mines, because that type of exploitative work does not produce gold; despite this, the labor force was taxed the same amount as productive mines" (Renger, 2006). *Capitação* did not produce the expected returns and generated the opposite effect, causing a significant decrease in revenue − 22% during the 15 years it was in use. It also had important social consequences, giving rise to large migrations to escape the abusive taxation, and thus creating marginal pockets (Renger, 2006; Martins, 2018). Within this scenario, the new system's expiry was inevitable, and in 1751, the *casas de fundição* were reopened in order to reinstate the collection of the *quinto real*.

The extraction and production of gold during the 18th century in Brazil, both at the sites of mining activities and at the *casas de fundição*, was far from ideal or efficient. Much gold was lost in the extraction and foundry processes that manufactured ingots. In addition, the amalgamation process with mercury bichloride used at the *casas de fundição* was, once implemented, much more expensive than in Europe. As a result, some smelters inexplicably worked without the use of mercury, which was often in short supply (Barcelos, 2013) (to this day, however, it is not well ascertained how they purified it under such conditions). In these old processes of extraction and separation, fortunes of platinum and palladium were regularly discarded as well. Naturally, these

elements had not been yet identified in the 18th century; today, their commercial value oftentimes exceeds that of gold. Nonetheless, the presence of palladium in concentrations of up to 2% was a distinguishing and somewhat remarkable feature of the ingots manufactured in the Brazilian gold-producing captaincies. On the other hand, the virtual absence of palladium as well as the high concentrations of platinum (amongst other lesser metallic elements) in ascribed Brazilian ingots produced and sold during the 17th century, therefore immediately before the seventies' rush, proves that these were processed with significant admixtures of gold derived from Mexico, Peru, Colombia, Chile, and Bolivia (Guerra, 2004), countries whose gold chemical signatures are compatible with such traces.

The dawn of the 19th century would see the complete exhaustion of artisanal production-type mines (De Ferreira and Rios, 2021); in 1827, the *quinto real* was reduced to the *vintena* (a 5% tax) and the last *casas de fundição* were closed five years later (Renger, 2006). Concurrently, the era of industrial production of primary gold in Brazil was taking its first steps. All the while, gold was ceasing to be the circulating currency in the country, replaced by paper money.

## 3. Industrial gold mining in primary deposits: From the 19th century to the present

In terms of the industrialization process of gold mining, the Brazilian panorama changed radically during the first few decades of the 19th century. Central to this transformation was the presence of foreign investment. It was only after 1808, with the transfer of the Portuguese Court to Brazil and due to increasing external pressure, that the national market finally opened up to organizations from overseas. In order to attract British investors, after 1822, the newly proclaimed Empire of Brazil offered the British exceptional conditions, such as preferential rates for loans, military assistance, and even judicial prerogatives. This scenario culminated with the publication, in 1824, of a decree that officially authorized mining companies to operate in the country - and, more specifically, in Minas Gerais. Today, that decree is considered the landmark for the beginning of Brazilian industrial mining as a whole.

Between 1824 and 1836, and 1861 and 1901, twenty companies went into production in Brazil. Most of them were British and were established in Minas Gerais. More ephemeral enterprises also took place, their short duration usually owing to the speculative capital involved. Among those with a longer lifespan, the case of the Morro Velho Mine (formerly owned by **St. John d'El Rey Min. Corp.**, now **AngloGold Ashanti**) is of particular note, given its continuous operation between the years 1834 and 2003.

The 19th century also marked the stage in which primary (hypogene) deposits were found through their secondary accumulations (the alluviums). Foreign companies innovated by implementing new ore processing and ore dressing methods, and their greatest initial challenge was the lack of available energy. This was eventually remedied through a rational use of hydraulic power, thus enabling the use of arrastres and wood stamp mills, the hoisters of heavy structures, as well as more modern types of ore transportation. In addition to the energy availability enabled by small steam engines - and, later on, by way of small hydroelectric plants (e.g., at Morro Velho and São Bento, both in the *QF*) – some other technological advances were quite significant for the operation of the mines. This included the acquisition of modern industrial equipment, such as stamp-mills, associated with shaking tables and amalgamation tables, and amalgamation barrels. New techniques for gold recovery and refining were thus developed. Also of particular note at that time was the introduction of underground drilling rigs, as well as the use of gunpowder and dynamite for dismantling rock massifs.

At the end of the 19th century, another major technological leap was comprehensively implemented by means of cyanide leaching in the metallurgical extraction stage. The innovation had been used in South Africa during the gold rush of the Witwatersrand Basin and rendered positive results, encouraging its realization in Brazil. Thereby, the volume of extracted metal in some Brazilian mines underwent remarkable growth – even if only three mines initially made use of this technology in the country (*viz.* Morro Velho, Passagem de Mariana, and São Bento, all located in the *QF)*. "Industrial" gold production has since then definitely become predominant in detriment to "artisanal" (also called *garimpo*) mining; that remains that the case until the present day, despite many gold *garimpos* having selectively adopted aspects of modern industrial technologies.

In the 20th and 21st centuries, industrial extraction and Au activity have followed global trends and allowed for the installation of modern projects of national and multinational capitals, guaranteeing a leading role for Brazil in the gold production scenario worldwide. This phenomenon is reflected in the elevated numbers of contemporary industrial activity in the country: currently, in Brazil, 14 business groups operate in 20 mines, and there are another 6 projects (5 groups) with advanced projects. On the other hand, artisanal gold mining (the *garimpo*-type activity) has also remained active for the past two hundred years. Despite undergoing a sharp decline during the 19th century, the numbers of *garimpo* mining increased significantly in the 20th and 21st centuries, especially since having adopted new technological resources and, more recently, being regulated as a lawful business activity, subject to a significantly less regulatory regime than that controlling industrial mining. A discussion of the consequences of this type of exploitation activity will be presented in item 4.

### 3.1. Details about the industrialization of gold in the historically gold-producing provinces

Below, the histories of each gold-producing province are detailed. Highlight is given to characterizing the main deposits and their geological signatures, as well as tracing the mines' trajectories and the corporations responsible for their technological development.

#### 3.1.1. Minas Gerais State

According to our preliminary survey, at least thirty-five companies of both English and mixed capital were established during the 19th century in Minas Gerais. In terms of production data, only ten could be accessed or found; the remainder probably did not support implementation costs or were speculative capital ventures only.

In a first wave, between 1824 and 1834 (Table 2), four companies were noteworthy for their impact on gold production, namely: the **Imperial Brazilian Mining Association** (Gongo Sôco Mine), the **St. John Del Rey Mining Co. Ltd.** (Morro Velho Mine, in Nova Lima, currently owned by **AngloGold Ashanti**), the **National Brazilian Mining Association** (which extracted gold from the Cocais Mines) and the **Brazilian Co.,** responsible for the disastrous Cata Branca Mine project (Rios, 2018).

Of the companies that were established during the second wave of investors – that is, after 1857 - the following are highlighted: the **Anglo Brazilian Gold Min. Co. Ltd.** (1863) and the **Ouro Preto Gold Mines Co. Ltd.** (1884), who alternated exploring the Passagem de Mariana or Passagem Mine; the **Dom Pedro North del Rey Min. Co. Ltd.** (Maquiné Mine, in 1863); and the **São Bento Gold Estates Ltd.** (São Bento Mine, in 1898).

During the 20th century and up until 2020, the participation of private and/or foreign investment in the country's mining had increased dramatically. At least 27 companies have since been established in Minas Gerais, but of this total, only eight- notably of English, South African, Australian, Canadian and Brazilian capital - have available data (Table 2). They are: **Saint John dEl Rey Min. Co. Ltd.** - later **Mineração Morro Velho** and presently **AngloGold Ashanti -** (Raposos, Bicalho, Faria, Bela Fama, Esperança, Morro da Glória, Cuiabá, Córrego do Sítio, Lamego and Morro Velho Mines), **São Bento Mineração** (São Bento Mine), **Serras do Oeste/Jaguar Mining** (Turmalina, Roça Grande, Pilar, Catita, Santa Isabel, Serra do Paraíso, Palmital, Rio de Peixe and Ouro Fino Mines), **Mundo Mineração/Mundo Minerals**

**Table 2**
List of gold-producing companies operating in Minas Gerais between 1825 and 2021. MG: Minas Gerais State.

| Operation Period | Mine | Group | Ore Type | Place | State | Tonnes Au |
|---|---|---|---|---|---|---|
| 1825–1856 | Gongo Soco | Imperial Brazilian Mining Assoc. | 4 | Caeté | MG | 13.26 |
| 1832–1844 | Cata Branca | Brazilian Company Ltd | 2 | Itabirito | MG | 1.18 |
| 1834–2006 | Morro Velho | Saint John d'El Rey Mining Co. Ltd. | 1 | Nova Lima | MG | 370.14 |
| 1834–1853 | Cocais | National Brazilian Mining Assoc. | 4 | Barão de Cocais | MG | 0.25 |
| 1847–1853 | Água Quente | Imperial Brazilian Mining Assoc. | 4 | Barão de Cocais | MG | 0.35 |
| 1862–1896 | Maquiné ́dEl Rei | Dom Pedro North ́dEl Rei Gold Min Co. | 4 | Mariana | MG | 5.28 |
| 1862–1898 | Pary | Santa Bárbara Gold Mining Co. Ltd. | 1 | Santa Bárbara | MG | 1.83 |
| 1863–1883 | Passagem de Mariana | Anglo Brazilian Gold Mining Co. Ltd. | 2 | Mariana | MG | 0.83 |
| 1870–1872 | Cuiabá | Cuyabá Gold Mining Co.Ltd | 1 | Caeté | MG | 0.55 |
| 1876–1887 | Pitanguy | Pitanguy Gold Mines Ltd. | 4 | Santa Bárbara | MG | 0.28 |
| 1880–1900 (?) | Borges | Ouro Preto Gold Mines Co. Ltd. | 1 | Caeté | MG | 0.01 |
| 1883–1927 | Passagem de Mariana | Ouro Preto Gold Mines Co. Ltd. | 2 | Mariana | MG | 26.47 |
| 1892–1900 (?) | Bicalho | Companhia Aurífera Brasileira | 1 | Nova Lima | MG | 2.00 |
| 1895–1912 (?) | Descoberto de Cuiabá | Rótulo Limited | 1 | Caeté | MG | 0.05 |
| 1898–1905 | São Bento | São Bento Gold Estates Ltd. | 1 | Santa Bárbara | MG | 2.01 |
| 1920–1955; 1961–2002 | Raposos | Anglogold Ashanti | 1 | Raposos | MG | 67.14 |
| 1927–1932; 1938–1943; 1946; 1964–1996 | Bicalho | Anglogold Ashanti | 1 | Nova Lima | MG | 8.79 |
| 1927–1971 | Passagem de Mariana | Companhia Minas da Passagem | 2 | Mariana | MG | 10.83 |
| 1934–1995 | Faria | Anglogold Ashanti | 1 | Raposos | MG | 10.18 |
| 1935 | Juca Vieira | Companhia Brasileira de Mineração | 1 | Caeté | MG | 0.49 |
| 1967–1996 | Rio Jequitinhonha | Mineração Tejucana | 5 | Diamantina | MG | 1.50 |
| 1970–1994 | Bela Fama | Anglogold Ashanti | 1 | Nova Lima | MG | 2.00 |
| 1971–1982 | Esperança | Anglogold Ashanti | 1 | Nova Lima | MG | 0.55 |
| 1983–2011 | Itabira | (Vale) | 4 | Itabira | MG | 7.86 |
| 1987–2022* | Morro do Ouro | Kinross | 2 | Morro do Ouro | MG | 371.35 |
| 1988–1996 | Morro da Glória | Anglogold Ashanti | 1 | Nova Lima | MG | 0.71 |
| (1878–1887); 1899–1910; 1985–2022* | Cuiabá | Anglogold Ashanti | 1 | Caeté | MG | 196.22 |
| 1987–2007; 2014–2022* | São Bento | Anglogold Ashanti | 1 | Santa Bárbara | MG | 59.49 |
| 1989–1987; 2014–2022* | Riacho dos Machados | Equinox Gold | 2 | Porteirinha | MG | 14.65 |
| 1990–1998; 2002–2022* | Córrego do Sítio | Anglogold Ashanti | 1 | Santa Bárbara | MG | 34.07 |
| 1992–1997; 2007–2022* | Turmalina | Jaguar Mining | 1 | Conceição do Pará | MG | 22.46 |
| 1995; 2001–2004; 2007–2011 | Engenho ́dÁgua | Mundo Mineração | 1 | Rio Acima | MG | 3.42 |
| 1996–2001; 2010–2018 | Roça Grande | Jaguar Mining | 1 | Caeté | MG | 4.64 |
| 2004 –2022* | Lamego | Anglogold Ashanti | 1 | Sabará | MG | 15.88 |
| 2005–2022* | Pilar | Jaguar Mining | 1 | Santa Bárbara | MG | 11.23 |
| 2005–2006 | Catita | Jaguar Mining | 1 | Caeté | MG | 0.11 |
| 2005–2009 | Lamego OP | Jaguar Mining | 2 | Caeté | MG | 2.19 |
| 2006–2012 | Santa Isabel | Jaguar Mining | 1 | Itabirito | MG | 4.21 |
| 2008–2009 | Serra do Paraíso | Jaguar Mining | 1 | Caeté | MG | 0.18 |
| 2008–2012 | Mazagão | Jaguar Mining | 1 | Itabirito | MG | 0.58 |
| 2009–2011 | Palmital | Jaguar Mining | 3 | Itabirito | MG | 0.61 |
| 2011–2013 | Rio de Peixe | Jaguar Mining | 1 | Rio Acima | MG | 0.10 |
| 2012–2014 | Ouro Fino | Jaguar Mining | 3 | Itabirito | MG | 0.35 |
| | | | | Total (tonnes Au) | | 1,276.28 |

1 = Orogenic Archean; 2 - Orogenic Proterozoic.; 3 - Paleoplacer; 4 - Jacutinga Type e 5 - Alluvial

(Engenho ́dÁgua Mine), **Vale** (Conceição and Cauê, both iron mines, also mining gold from *jacutinga* ore), **Tejucana Mining** (operating on the Jequitinhonha River bed, in Diamantina), **Mineração Riacho dos Machados**, currently **Equinox Gold** (Riacho dos Machados Mine), and **Mineração Morro do Ouro / Kinross** (Morro do Ouro Mine).

Given the scope of our survey as a comprehensive overview on gold mining in Brazil, the series of companies that held producing mines in Minas Gerais during this period but for whom records are not available should also be mentioned. These are: the **East ́dEl Rey Mining Co. Ltd.** (Morro das Almas, São Vicente, and Papa Farinha/Capão da Emília Mines, the latter two constituting the current Lamego Mine), the **Rossa Grande Brazilian Gold. Min. Co. Ltd.** (Roça Grande Mine and vicinity), **The São Vicente Mining Co. Ltd.** (present day Santa Isabel Mine); the **Companhia Aurífera de Minas Geraes** (Bicalho Mine), **Brazilian Consols** (Taquara Queimada and São Romão Mines, developed in *jacutinga* ore) and **Rótulo Ltd.** (Descoberto de Cuiabá Mine). All of these are located in the Quadrilátero Ferrífero. Furthermore, the **Société Anonyme des Mines d'Or de Ouro Falla** (Andaimes Mine, amongst others, in the São Gonçalo do Sapucaí region in southern Minas Gerais), the **Serra da Candonga Gold** (Candonga Mine, also in *jacutinga* ore, in Guanhães, to the east of the Serra do Espinhaço Range), as well as numerous other smaller companies, are also of note.

*3.1.1.1. Geological context of the gold deposits in Minas Gerais.* The development of industrial mines in primary gold deposits, mostly located in areas where alluvial mining had been extensively developed, allowed for the identification of varied geological and metallogenic characteristics, especially for the *QF* region.

In the Archean section of the *QF*, most of the deposits are hosted in packages of metapelites, metapsamites and mafic-metavolcanics from the Nova Lima Group, which are part of the Rio das Velhas Supergroup (Archaean). The latter is carbonaceous and micaceous phyllite, metamorphosed to the greenschist facies, and considered to be a sequence of metavolcanossedimentary, Greenstone Belt-type rocks. The package hosts numerous gold deposits, classified as orogenic gold (Groves et al., 1998), where the predominant gold mineralization typology may be associated with the Algoma BIF or metassediments, and be related to altered Archaean hydrothermal alteration zones with a strong structural control element, affected by a compressional tectonic regime. The most representative examples of this variety are the deposits of Cuiabá, Morro Velho, Raposos and São Bento, amongst others (Fig. 2). The mineralization of the Archean deposits are predominantly sulfide-type with Au-Ag-As, with a strong association with pyrrhotite-pyrite-arsenopyrite and chalcopyrite, stibnite, sphalerite, galena, and tetrahedrite. Gold occurs as free grains ("free gold"), as refractory inclusions in both pyrite and arsenopyrite, and intergrown in pyrrhotite.

In the Proterozoic section of the *QF*, three varieties of gold mineralization originated. The first involves gold-productive occurrences (ex. Passagem de Mariana) located within a shear zone, that has itabirites (Lower Proterozoic, Itabira Group, Minas Supergroup) over other units of the Minas Supergroup (filites and quartzites) as well as Archean schists of the Nova Lima Group (Rio da Velhas Supergroup) - composed of intercalations of metapelite-psamites, tourmalinites and calc-silicate rocks. The second variety is associated with *jacutinga* gold ore, in turn hosted within Superior Lake-type BIFs (itabirites). The best example of this typology is the Gongo Sôco Mine, considered to be a notable case of a high-grade manganiferous soft hematite deposit, with the occurrence of *jacutinga*-type ores (Cabral et al, 2001; Cabral and Lehmann, 2007; Cabral et al, 2009; Cabral, 2006). A third Proterozoic variety are the paleoplacers/quartz metaconglomerates, with ore consisting of Au-pyrite associated with anomalous uranium (i.e., Ouro Fino and Palmital mines), both of Proterozoic age.

In Neoproterozoic deposits - outside the *QF* - the highlight is the Paracatú sector. It is inserted in the Brasília Belt, a north–south trending Neoproterozoic belt that extends along the western side of the São Francisco Craton, where Morro do Ouro deposit is located (Fig. 2). It is considered by the literature as an orogenic-type gold deposit, and is contained within a series of regional thrust faults that mark this belt towards the east-northeast.

*3.1.1.2. Current situation of industrial gold mines in Minas Gerais.* Among the Archaean Gold deposits in the *QF*, the mines of Morro Velho, Raposos, Cuiabá, São Bento and Passagem de Mariana should be highlighted in terms of historical importance for the region.

The history of the Morro Velho Mine started in 1834, with a British company called **Saint John d'El Rey Min. Co. Ltd.** The company began mining in the auriferous primary deposits of the Congonhas de Sabará sector, current Nova Lima (MG) (Camargo, 1957; Graton and Bjorge, 1929; Graton and Bjorge, 1931; Calaghan, 1958; Matheson, 1956; Peale, 1958) (Fig. 2, Table 2). This stage of activities extended until 1960, when the site's mining rights were acquired by **Mineração Morro Velho.** The new owner became largely responsible for the discovery of several targets and reopened small mines in the region near Nova Lima (Oliveira, 1975; Siqueira, 1973; Siqueira and Oliveira, 1974; Wieller, 1977). For operational reasons, mining at Morro Velho was from then on carried out from two underground mines, Mina Velha and Mina Grande, developed above the same orebody, with a total depth of 2,454 m at level 27.

Between 1975 and 1999, **Mineração Morro Velho S.A.** had a strong participation from the **Anglo-American Group**[1], at the time a South African mining group undergoing intensive restructuring. These two decades saw the re-equipment of the mine and the construction of a new ore treatment plant (Queiroz Metallurgical Plant). In 1995, however, activities stopped at Mina Grande; eight years later, they were also halted at Mina Velha. Currently, both mines are in the process of final decommissioning and are being partially flooded. For historical records, in terms of accumulated gold production, there is consensus on the number of 370 extracted tonnes between 1834 and 2003 for the combined productions of the Grande and Velha Mines.

In the case of Raposos Mine (Fig. 2, Table 2)**,** the first venture in the area started in 1883, when a small company, **Ouro Preto Gold Mines** acquired practically all the smaller mines located within the Raposos sector. At first, recovery via amalgamation was considered to be low, and the high costs of cyanide at the time did not justify mining efforts (Hussak, 1900). In 1899, the mines were acquired by **Saint John del Rey Mining Co. Ltd.,** but only after 1910 did systematic mining of the different bodies begin[2] (Gair, 1958). The underground Raposos Mine activities stretched between 1920 and 1955 and 1961 to 1998, this last period when it was modernized. The Raposos mine and its equipments are still kept under maintenance and frequent feasibility studies are carried out (Junqueira et al., 2007). In terms of documented production, this mine has produced at least 67 tonnes of gold over its lifetime.

Activities at the Cuiabá Mine (Fig. 2, Table 2) started in 1870, when a set of mining rights of old excavations and gold mining galleries was acquired by the **Cuyabá Gold Mining Company** in London (Silva, 1997). The property was passed on to **Saint John d'El Rey Rey Mining Company Ltd.** in 1877, who explored the location from 1878 to 1887. Operations were restarted in 1899, but were halted again in 1910. During the 1980 s, the **Anglo American Group** invested in the site's restructuring and re-equipment, culminating in the opening of the Cuiabá underground mine in 1985, after 75 years of inactivity. Since 1980, great effort was also invested into studying the geometry of the mine's structure, its at depth behavior, and the deposit's hydrothermal characteristics (Araújo, 2019; Costa, 2010; Ferraz et al., 2020; Kresse, 2018, Kresse et al, 2018, Kresse et al., 2020; Lobato et al., 2001; Martins, 2000; Ribeiro-Rodrigues et al., 1994, Ribeiro-Rodrigues, 2007, Ribeiro-Rodrigues et al., 2007; Roncato., 2016; Schrank and Machado, 1996; Toledo et al., 1988; Vial, 1980, 1988, Vieira, 1988a, b; 2000; Vitorino, 2017; Xavier et al., 2017; Vieira et al., 1986). Due to the refractory characteristics of the Cuiabá ore, the Queiroz plant produces, in addition to gold ore, a large volume of sulfuric acid as a by-product.

In 2004, under the control of **AngloGold Ashanti**, the Cuiabá mine was fully structured in a consolidation of operations at both the Cuiabá and Lamego mines (active since 2007, located 6 km to SSW), as part of a unified management structure called the Cuiabá-Lamego Complex. Since 2004, the mine concentrate produced in Cuiabá/Lamego is transported over 15 km by aerial ropeway to the Queiroz Plant (AngloGold Ashanti, 2011). The owner also implemented a daring project to deepen the mine. Since 2014, due to the smoothing of ore bodies at deeper levels, the Cuiabá complex is changing its mining methods from cut-and-fill to sublevel stoping, so as to increase the contribution of narrow vein ore bodies to the production (from 15% to 40%) and to improve rock-engineering controls (AngloGold Ashanti, 2011, 2019a, b). It has recently reached the goal of 170 tonnes in terms of the gold extracted since beginning operations.

The São Bento Mine (Fig. 2, Table 2)**,** currently grouped by the literature within the Córrego do Sítio deposits (CDS I, II and III), started its activities around 1894, when incipient, independent mining operations began in the region (Ferrand, 1913). Between 1897 and 1898, its deposits were acquired by "**The São Bento Gold Estates, Ltd.**", which belonged to the English group John Taylor & Sons. A treatment plant was then implemented and thereby a cyanidation process was introduced, which was hitherto unprecedented in Brazil (Calógeras, 1904; Santos Pires, 1905; Scott, 1902). The plant's low recovery, however, led to that company's liquidation at the end of 1905 (Pereira, 1995). In 1906, the mine was acquired by the "**São Bento Syndicate**"; it remained deactivated until 1923, when its ownership changed once again, going to the Canadian-owned **South America Gold Areas Ltd.** (Calvert, 1915). The mine was reactivated for a few months in 1925, after which it began a long period of inactivity that only ended in 1984. In 1977, the project was transferred to **CONVAP** Mineração (reformulated as **São Bento Mineração Ltda**), and in 1984 to **UNAMGEM** (Gencor Group, from South Africa), who started the mine operations and the building of a new plant. The mine started production in 1986, with the construction of a new beneficiation plant using pressure oxidation/bio-leaching methods, due to the existence of refractory ore. In 1996, **Mineração Eldorado** (**Eldorado Gold Mining Group**, of Canadian capital) acquired the São Bento Mine. Activities continued until 2007, when it was

[1] In 1993, all of Anglo American's assets outside of Africa were consolidated into **Minorco S.A;** in 1999, all of the group's gold assets went to AngloGold, which merged with the English company **Ashanti Goldfields Corporation** in 2004 and changed its name to **AngloGold Ashanti**, used to this day.

[2] The company had its controlling interest acquired by the **Anglo American Group** in 1975.

decided to close the mine (AngloGold Ashanti, 2019a, b). During its 19 years of operation, production at the mine was reportedly 58.8 tonnes of gold. In 2008, the São Bento Mine and its treatment plant were sold to **AngloGold Ashanti Mineração** (AngloGold Ashanti Group). The change brought about good synergy and the potential for expansion to the Córrego do Sítio Mine, located nearby. Since 2015, a modest production (less than 1 tonne) has been obtained in some of the mine's sectors.

The Passagem de Mariana Mine (Fig. 2, Table 2), located 7 km east of Ouro Preto (MG), in the *QF*, started its activities around 1819. By then, a series of small underground mines had already been developed (Hussak, 1900; Ferrand, 1913). Later, Passagem was acquired by Baron Eschwege, who organized the newly created **Mineralogical Society of Passagem**. This was the first mining company with exclusively Brazilian capital; it operated until 1824, during which time the mine remained in full operation. Between 1863 and 1865, Passagem's small mines were gradually acquired and began being operated by the English-owned company "**Anglo-Brazilian Gold Mining Company Limited**" (Burton, 1869; Ferrand, 1913; Hussak, 1900). In 1873, Passagem de Mariana was closed and then sold, in 1883, to a representative of a French Union, properly organized in 1884 as "**Ouro Preto Gold Mines of Brasil Limited**"(Ferrand, 1913; Hussak, 1900). In 1893, cyanidation was pioneeringly tested at Mariana, and had completely replaced chlorination by 1902 (thus the second mine in Brazil to do so, after São Bento). In 1927, the mine was sold to **Companhia Minas da Passagem** or **CMP** (belonging to the Ferreira Guimarães Group, bankers from Minas Gerais state). In 1954, due to numerous problems, the mine paralyzed its underground work, leaving the galleries to be gradually flooded. Between 1973 and 1976, the control of **CMP** changed hands, passing on to the **Companhia Anglo Brasileira de Construções**; however, neither corporation was successful in reopening it (Fleischer, 1971; Fleischer and Routhier, 1973; Fleischer and Vial, 1983; Vial, 1991). Since 1990, several mining companies operating in Brazil have analyzed the viability of this deposit, all of them without success.

Among the Proterozoic Gold Deposits, two historical deposits should be highlighted: Gongo Sôco and Morro do Ouro.

The Gongo Sôco mine (Fig. 2, Table 2) is located on the northern flank of the Gandarela Anticline in the *QF*. From a historical point of view, this was where the first industrial mining company of the country was formed, under the name "**Imperial Brazilian Mining Association**", during the first quarter of the 19th century (Hussak, 1900; Ferrand, 1913). Production began in 1824, after the discovery of fantastic gold nuggets in the mine's surroundings - the size of potatoes or even larger. Initially, it operated through open-pits (*talhos)*; later on, this evolved into underground mining, when Gongo Sôco was equipped with shafts and galleries, as well as more precise layouts. After 1840, a series of other technological innovations were implemented, such as the use of a steam engine to drain galleries, the use of rails and minecarts to transport ore, and amalgamation barrels (Alves, 2014, 2015). In 1856, Gongo Sôco was closed.

During the 20th century, Gongo Sôco had several owners: they was, respectively, **São Carlos Minérios** (American Capital), **Mineração Socoimex S.A**. (part of the Santa Inês Group) and the **Companhia Vale do Rio Doce (**current **VALE),** invested in exploring only its iron ore. The mine is currently closed and in the process of decommissioning; in addition, some of its pit walls are unstable and, therefore, need to be permanently monitored in order to avoid landslides that may affect the tailings dam and, consequently, the villages located downstream. The historical gold production in Gongo Sôco during the 19th century - between the years 1824 and 1856 - was of 13.26 tonnes of gold (Ferrand, 1913).

The Morro do Ouro Mine (Fig. 2, Table 2)**,** located in the municipality of Paracatú, in the northwest of Minas Gerais, is one of the largest gold deposits in Brazil in terms of reserves, while having the lowest minable gold grades of Brazilian mines. Unimportant exploration efforts occurred during the 19th century (Pearson, 1906), but the beginning of industrial mining only started after a regional exploration campaign was developed in 1977 by both **Enjex Mineração Ltda** (New Jersey Zinc Group) and **Mineração Rio Xingu Ltda** (**Billiton Metais**, then still a subsidiary of Royal Dutch Shell) (Zini et al, 1988). The obtained results encouraged the establishment, by 1980, of a Joint Venture between **Billiton** and **Riofinex do Brasil** (Rio Tinto Zinc Group-RTZ). Later, in 1984, **Riofinex** acquired all of operations and, in 1987, its successor company **(RTZ Mineração)** established a Joint Venture with **Autram Mineracão e Participações** (TVX Participações), thus forming the **Rio Paracatú Mineracão (RPM)**. Subsequently, Morro do Ouro was acquired by TVX Participações, which later became the Canadian-owned **TVX Gold.** Finally, in early 2003, the Canadian Company **Kinross Group** procured participation in the Morro do Ouro property by fusing with TVX and Echo Bay and acquiring, in 2004, Rio Tinto Mineração's entire holding in RPM. In 2010, the name of the operational entity was changed to **Kinross Brasil Mineração (KBM)**. After that, the project went through several expansion phases, reaching the position of the largest gold producing mine in 2009, in Brazil. Since 2015, **KBM** has been reprocessing the tailings in tailings dams. Currently, it operates two process plants, extracting gold through gravity/flotation/CIL recovery processes (Sims, 2020). Notably, current prospects for regional exploration in Paracatú are very positive. **Kinross**' technical report NI43-101 in 2020 mentions that between 1987 and 2020, the company treated about 840 million tonnes at an average content of 0.45 g/t, for a total of 277 tonnes of gold.

Other industrial gold mines of Minas Gerais that are worthy of mention are:

(1) the Córrego do Sítio Mine, located in the northeastern part of the *QF*. It was discovered with tradicional geochemistry and run in two intervals - from 1990 until 1998 and from 2002 onwards. Today, it is operated in conjunction with the São Bento Mine (the property of **AngloGold Ashanti**);
(2) Engenho DÁgua Mine in Rio Acima (owned by **Mundo Mineração,** closed**)**;
(3) the Lamego open-pit Mine, the Turmalina, Santa Isabel, Pilar and Roça Grande Mines, and the Palmital and Ouro Fino Mines (the latter acquired from Minas Novas Minérios): all of these projects are presently owned by **Mineração Serras do Oeste/Jaguar Group** and restarted operations between 2005 and 2012, but at present, only the Turmalina and Pilar Mines remain in operation;
(4) the Lamego Mines (underground), owned by **AngloGold Ashanti**. Its ore is treated together with that of Cuiabá, as part of the Lamego-Cuiabá complex;
(5) Riacho dos Machados was discovered by **Docegeo** (a subsidiary of VALE at the time) with traditional geochemistry, worked from 1989 to 1987 and from 2014 onwards; operations have been run by **Carpathian Gold** and, more recently, by **Equinox Gold**;
(6) São Gonçalo do Sapucaí Mines (**Conquista Xicão Gold Mines Ltd.),** a group of small mines in the southwestern portion of Minas Gerais;
(7) The diamondiferous alluvial mines operations of the Jequitinhonha River, with gold as a by-product. They have operated the with great success for almost 30 years at the western margin of the Serra do Espinhaço, run by **Mineração Tejucana** (**Societé Générale de Belgique, Sobradiam**) and **Rio Novo Mineração (Andrade Gutierrez).**

Minas Gerais state remains the province with the highest production of gold in Brazil. Between 2010 and 2019, statewide production ranged between 28 and 34 tonnes per annum.

### *3.1.2. Goiás and Tocantins provinces (former Goiás Captaincy)*

Despite the efforts and incentives from the Portuguese Crown in the installation of mining companies in Brazil, the Goiás Captaincy persisted as a late developer throughout the 19th century. Only two companies

were established in that period - between 1821 and 1825, in the town of Anicuns. However, neither venture was successful. Mining activities only resumed over a century later (Table 3), that is, after the 1960 s, when geological and geophysical surveys enabled the discovery of several deposits of precious and base metals.

*3.1.2.1. Geological context of gold deposits in Goiás and Tocantins.* Gold deposits in Goiás and Tocantins are associated with different deposit types. Firstly, there are the orogenic-type gold deposits, originating within metamorphosed Archean-Paleoproterozoic greenstone belts and structurally modified during the Neoproterozoic. In terms of gold mineralization, the most important among these belts deposits are the Crixás, Guarinos, Pilar, and Faina Belts, which form part of the Archean-Proterozoic Goiás Massif (Borges, 2016; Jost et al, 2014). Such belts are composed by a sequence of schists and felsic metavolcanic rocks, metabasic rocks, mostly metabasalt and amphibolite, metasedimentary layers, with a thick basal sequence of *meta*-ultramafic and metamafic flows. The most relevant mineralization styles associated with such greenstone belts are, in general, massive sulfide, quartz veins and disseminated styles. All of these occur at the Crixás Mine (Jost et al, 2014; Jost et al., 2019).

Another type of gold deposit is associated with the Goiás Magmatic Arc, formed by Neoproterozoic plutonic and calc-alkaline metavolcano-sedimentary rocks, which host Au-Cu porphyry systems. Locally, they may be superimposed by orogenic auriferous systems and metamorphosed deposits of volcanic-hosted massive sulfide mineralization (e.g., the Zacharias deposit near Mara Rosa) (Kuyumjian et al, 2010; Oliveira et al., 2016a; Oliveira et al., 2016b). The Au and Cu-Au deposits may be temporally and spatially related to the magmatic evolution model of a collisional belt, in the intraoceanic subduction stage (900–800 Ma), of which the Cu-Au Chapada Mine is an example.

On the other hand, several small gold deposits considered to be of Au-EGP type, including small mines near Cavalcante, are located along the outer tract of the Brasilia Fold Belt (the NE portion of the what was the Captaincy of Goiás). They are apparently associated with shear zones at the contact zone between Paleoproterozoic peraluminous granites, schists, and paragneiss (Dardenne and Botelho, 2014).

Finally, it should be mentioned the Archaean Almas Greenstone Belt (Costa, 1984; Cruz and Kuyumjian, 1998, 1999; Kuyumjian et al, 2012), one of several greenstone belts located in the southern part of the Tocantins Province. It is inserted within a tectonically complex tract (the Goiás Median Massif) that lies between the Brasilia-Uruaçu fold belt to the east, and the Paraguai-Araguaia fold belt to the West. In Almas Greenstone Belt is located the Almas gold mine, and a lot of small-to-medium garimpos, around Chapada da Natividade, Natividade, Almas, Príncipe, Dianópolis (formely São José do Duro), and Conceição do Tocantins.

*3.1.2.2. Current situation of industrial gold mines in Goiás and Tocantins.*

**Table 3**
Gold Production current + historical (tonnes), distribution in different provinces and regions of Brazil as estimated between 1800 and 2020 (in centuries).

| Province | Gold Production (Tonnes) | | |
|---|---|---|---|
| | **Sec XIX** | **Sec XX** | **Sec XXI*** |
| MG/QF | 117.86 | 515.92 | 253.14 |
| MG, out QF | | 94.87 | 292.63 |
| Goiás | | 55.84 | 167.77 |
| Bahia | 0.08 | 86.22 | 101.28 |
| Mato Grosso | | 12.35 | 47.15 |
| Pará | | 97.01 | 110.84 |
| Amapá | | 23.27 | 44.31 |
| Maranhão | | | 12.58 |
| South Region | | 3.81 | 8.58 |
| Northeast (NE) Region | | 8.09 | 0.24 |
| **Total** | **117.94** | **897.38** | **1,038.85** |

Among the orogenic gold deposits, Crixás and Pilar should be highlighted. They are both located to the south of the province and are associated with Archean-Proterozoic greenstone belts.

Crixás (Fig. 3) is the only world-class deposit of Goiás. In the beginning of the 20th century, small underground mines were in operation in the region – more specifically, between 1918 and 1944 (Berbert and Mello, 1973; Fortes et al, 2001). It was only in the 1970 s that actual regional and geochemical exploration would be carried out, by teams from **METAGO** (Goiás State Mineral Exploration Company) and the Canadian **INCO Corporation,** respectively. The development of semi-mechanized mining, with superficial excavations and rare galleries, was also resumed at the time by small-scale businesses In 1976, an auriferous mineralization zone was discovered under a series of old excavations, which currently correspond to Mine III (Fortes et al, 2001; SRK, 2003). In 1983, **Kennecott Corporation**, an American group, signed an option contract to obtain a 50% stake in the project. After 1985, the opening of the underground mine (Mine III) began. One year later, **Kennecott** sold its stake in the project to the **Anglo American** Group, thereby originating **Serra Grande Mineração (MSG)**. In 1989, mining and operations at beneficiation and metallurgy plant started, and in 1991, **TVX Gold**, acquired its stake in the property through a negotiation with **INCO** (SRK, 2003). In 2003, **TVX Gold** was acquired by **Kinross Gold Corp.** (of Canadian capital). Between 2003 and 2012, many other orebodies were discovered; they have since been run with a strong synergy-type strategy, divided into three underground mines and one small open-pit (SRK, 2003). In 2012, the **AngloGold Ashanti** group acquired full control of the Joint Venture, with the acquisition by **MSG** of the participation of the Canadian **Kinross Gold Corp.** (Costa, 2016). By the end of 2019, around 139 tonnes of gold had been produced in this mine.

The Pilar Mine (Fig. 3) was discovered by the Brazilian company **Mineração Montita** in 1972. Subsequently, exploratory campaigns were carried out by different corporations - **Mineração Colorado** (**Utah Mines Group**), **Mineração Marex** (**BHP**) and **INCO,** respectively **-** until 1990. Such campaigns culminated in the opening of exploratory galleries and, in 2006, **Yamana** acquired the deposit. From 2013 to 2018, the mine produced a total of 12.86 tonnes of gold. Yamana was the owner of Pilar until 2020, when the mine was purchased by Equinox Gold, together with the Maria Lázara and Caiamar Mines, located nearby. Thus was born the "Pilar complex" (RPA, 2020). In the first quarter of 2021, the entire complex was sold to **Pilar Gold Mining,** of Canadian capital, who are reopening these mines.

Also located in the Crixás sector is the Premier Mine (former Meia Pataca Deposit). It was discovered by **METAGO** in the 1970 s and mined as a small operation, and was then reopened and operated by **Cleveland Mineração** between 2014 and 2016, producing 0.25 tonnes of gold.

Among the orogenic gold deposits, the Sertão and Cascavel mines should be mentioned. Both are associated with the Archean Faina greenstone belt. The Sertão Mine was discovered by way of a geochemical follow-up by **WMC** in 1995; was sold in 2001 to Sertão Mineração Ltda (70% Troy Resources and 30% Amazônia Mineração Ltda) who developed and operated an open-pit mine between 2003 and 2006, producing 6.9 tonnes of gold. The Cascavel Mine was studied and opened by **Orinoco Gold** in 2018, and presented problems in its metallurgical recovery, which caused a halt to activities. Mineralization in that region occurs in the form of quartz veins and silicified zones with high grades of free gold, hosted in metavolcanosedimentary and metasedimentary shales. Both mines are currently undergoing reassessment and regional exploration by **Pilar Gold Mining.**

Among the Neoproterozoic deposits, three are of note. Firstly, the Mara Rosa Deposit encompasses both the Au-Cu **Posse Mine** and the Au-Ag-Ba **Zacarias** Mine (in central-northern Goiás). These mines were discovered in 1980 by **Mineração Colorado (BHP-Utah Mining**), and later acquired and mined by **WMC (Western Mining Corp.)** between 1992 and 1995 - during which they produced 4.82 tonnes of gold, initially operating with Heap Leach process until 1992, migrating to

Carbon in Leach process - CIL until 1995. In 2003, they were acquired by **Amarillo Gold**, and have been undergoing pre-mining operations ever since (Palermo et al., 2000; Poll, 1994; SRK, 2020). In 2021 Hochschild Mining acquired Amarillo Gold and advanced studies continues.

Secondly, the deposit of Fazenda Nova or Bacilândia is also metallogenetically associated with the genetic line of the Mara Rosa deposits as part of the evolution of the Goiás Magmatic Arc, and is thus classified as a Neoproterozoic-age orogenic gold deposit (Oliveira et al., 2016). Fazenda Nova was discovered in the 1970 s, by **WMC.** It was later passed on to **Santa Elina Mining** in the 90′s, and in 2003 was sold to **Yamana Gold**, which was operated an open-pit, developed between 2003 and 2008, by Mineração Bacilândia. More recently ceded it to its current owner, **Pilar Gold Mining**.

With respect to the Cu-Au deposits of the Neoproterozoic age, there is the Chapada Mine. It was discovered by **INCO** in 1973 and became the property of **Santa Elina** and **Echo Bay** under a Joint Venture agreement in 1995. Later, in 2003, it was acquired by **Yamana**, starting production in 2007. Recently, in 2019, it was acquired by the **Lundin Group**. There are currently three open-pits at the mine, to be unified into a single operation in the near future. Recent exploration efforts have highlighted a number of mineral orebodies, presently under investigation (RPA, 2019).

Among the Au-PGE-type mineralization, the Aurimina deposit is worthy of note. It was discovered in 1980 s and mined by **Mineração Jenipapo** (75% by **WMC** and 25% by Banco Garantia S.A.) as two small open-pits, operated between 1988 and 1993, during which it produced 0.12 tonnes of gold. Other smaller deposits include the Buraco do Ouro Mine (Penery Group) in Cavalcante and the Bonfim Mine (Silvânia). The potential for small deposits in the region of Cavalcante, Niquelândia, Uruaçu, and Campinorte has continually increased, and good opportunities lie ahead; in the near future, we believe that a series of small mines will be proven viable.

Finally, among the smallest productive mines, Aurilândia should also be mentioned. As with Aurumina, it was also discovered by **WMC** and mined by **Mineração Jenipapo**. Located in the region of São Luiz de Montes Belos, it is embedded in the orthogneisses of the Goiás Magmatic Arc. Aurilândia was operated as a small open cut operation between 1989 and 1991, when was sold to MIBASA (Mineradora Barro Alto S.A, from Toniolo Busnello Group), which was produced 2.98 tonnes of gold in a small underground mine (Toniolo Busnello, 1994). The Almas Gold Mine, in Tocantins Province, should also be mentioned. Is situated near Almas town, and was discovered in 1980 through a traditional geochemical campaign by **Docegeo**. It currently constitutes the largest known gold deposit within the south Tocantins region. Although records are fragmentary, it has been worked intermittently since 1996 and was active until 2001 (Ferrari and Choudhuri, 2000) and produced 2.7 tonnes of gold. Between 2008 and 2016 was explored by Rio Novo Gold, and in 2018 was acquired by Aura Minerals; the project is actually in the installation phase.

Presently, the State of Goiás is responsible for 9% of the Brazilian gold production, with emphasis on the Crixás (**AngloGold Ashanti**), Chapada (**Lundin**) and Pilar (**Pilar Gold Mining**) mines. They produced approximately 2.84, 1.67 and 1.18 tonnes of gold in 2019, respectively (ANM Statistics, 2020).

### 3.1.3. *Bahia province*

Much has changed in the province of Bahia since the 18th century, when the boom of artisanal gold mining was taking place around the mountains of Jacobina and Rio das Contas. Throughout the 19th century, the district suffered a notable decrease in gold production, as was also the case in Goiás. During that entire period, only two producing companies were established within it. One was the **Companhia Metallurgica do Assuruá**, which operated between 1858 and 1861 at the Gentio do Ouro Mine - though no production data is available. The other was the **Companhia Minas do Jacobina** (see item 3.1.3.2). Nevertheless, artisanal mines (*garimpos*) remained active in Bahia up until the mid-20th century, albeit with little significant development. They operated in Gentio do Ouro, Itapicuru, Jacobina, Rio de Contas, and Assuruá, in addition to several others in the Chapada Diamantina, to the south of the state, generally procuring diamonds and gems (Hussak, 1900; Carneiro, 1908). Industrial mining resumed in the 1960 s, when regional work of basic geological mapping began, based on broad airborne geophysical surveys initiated by the **CGBA** (Brazil-Germany Geophysical Agreement) and continued by the **DNPM**. A decade later, **Docegeo** (current **Vale**), **Billiton, Unigeo, Unamgem**, and **CBPM** (Companhia Baiana de Pesquisa Mineral), among others, executed several exploration campaigns in the region, which led to the discovery of the gold mineralization of the Rio Itapicuru Greenstone Belt - the main gold-bearing district of Bahia, where a large portion of the main deposits of the district are located, such as the Fazenda Brasileiro and C1-Santa Luz Mines. (Table 4).

#### 3.1.3.1. *Geological context of gold deposits in Bahia.*

The primary gold mineralization of Bahia occur in association with Meso to Neoarchean, and Paleoproterozoic through Neoproterozoic units. They are located in four well-defined regions, *viz.* the Rio Itapicuru Greenstone Belt, the Serra de Jacobina, the Western Chapada Diamantina, and the Curaçá River Valley. In the former three, the gold deposits are typically hydrothermal in nature, normally associated with quartz and sulfides. In the Curaçá River Valley, gold is extracted only as a by-product in the refining of copper-sulfide ore.

The Rio Itapicuru Greenstone Belt, located in the northeast of the state of Bahia, is a Paleoproterozoic vulcano-sedimentary association constituted by metavolcanic and metasedimentary rocks. The belt hosts two operating mines, Fazenda Brasileiro and C1-Santa Luz, as well as several *garimpos*. The Serra da Jacobina, on the other hand, consists of a N-S-aligned sedimentary basin of Neoarchean age. It contains the Jacobina Group, composed of a series of quartzites, metaconglomerates, and shales of Paleoproterozoic age, aligned along a N-S oriented mountain range that hosts the historic mines of Serra de Jacobina.

#### 3.1.3.2. *Historical and current situation of industrial gold mines in Bahia.*

In the Jacobina region, after the historic stage of the artisanal gold rush, the initial phase of industrial gold production occurred between 1884 and 1887. That was the period in which the mines of Morro do Vento, in the Serra de Jacobina, obtained their concessions to private individuals. In 1890, the **Minas de Jacobina Company** was established; it came to a halt in 1897 (Hussak, 1900;Ponte Neto, 1998). Industrial mining activities only resumed in 1930 and, at the beginning of the 1940 s, they were once again halted. A resumption took place in 1947, when the **Mineração de Ouro de Jacobina Ltda.** was founded to explore the Canavieiras Mine. In 1950, the company entered a period of financial difficulties, resulting in its sale to a Canadian company, **Mineração Northfield Ltda**. This organization would operate the mines until 1966, when operations stopped once more (Molinari, 1981; Ponte Neto, 1998). In 1973, exploration and economic studies in Jacobina were initiated by the South African mining group **Anglo American** (Minter, 1975; Strydom and Minter, 1975). These studies were completed in 1979, and the areas were set for exploration by **Mineração Morro Velho**. A year later, in 1980, **Jacobina Mineração e Comércio SA (JMC)** was created, initiated mine development, and commissioned a processing plant in 1982. In 1996, the Canadian-owned Junior Company **William Resources Inc**. purchased and operated this mine for two years, suspending its activities in 1998. In 2003, **Desert Sun Mining (DSM)** of Canadian capital (Forbes & Manhattan Group) acquired the company and focused on expanding its brownfield and greenfield operation. The mine was reactivated in 2004, and went into production in 2005. Finally, in 2006, the **Yamana Group** acquired the Jacobina Mine through the purchase of **DSM** (Heider and Costa, 2020). According to Yamana, cumulative production between 1983 and 2019 was 72.59 tonnes Au (Souza Soares et al., 2020).

With respect to the deposits located in the Rio Itapicuru Greenstone Belt, the first discoveries of **Docegeo** in 1972 unveiled the Gold District of the Weber Belt, where the Fazenda Brasileiro Mine is hosted. The mine went into operation in the open-pit in 1984, and in 1988 underground work began. Note that this was the first gold producing unit in Brazil to operate a heap leaching plant with oxidized surface ore (Teixeira, 2019). In 2003, **Yamana Gold** acquired Fazenda Brasileiro and other nearby areas; it was then transferred, in 2014, to **Brio Gold**. A year later, the venture was sold to the **Leagold Mining Corporation**, and finally, to **Equinox Gold** in 2019. This deposit has been operating uninterruptedly since 1984. Initially, it operated with a Heap Leach process; after 1988 and until today, with a mixed Heap Leach and Carbon-in-leach (CIL); thereafter, with CIL only (RPA, 2018). The total production up to 2020 was 101.38 gold tonnes (RPA, 2018).

The Rio Itapicuru Greenstone Belt also hosts the Santa Luz Mines region. In the 70 s, **CBPM** (Companhia Baiana de Pesquisa Mineral) and **Docegeo** started mineral exploration there, in search of base metals and gold. As a result of these studies, in 1987 a small open-pit mine entered into operation under **Rio Salitre Mineração Ltda** (RIOSAM, a CBPM subsidiary) (Teixeira, 2019). It had produced 1.72 tonnes of gold from the C1 body of Santa Luz by 1995. Shortly before that, in 1990, a new deposit had also started operating in the region: the Maria Preta Mine, managed by **CVRD** (currently **Vale**), with small-scale, open-pit mining. In 1996, this mine was stopped, and reported a production of 3.56 tonnes of gold (Lott et al, 2004). In the period between 2005 and 2007, the areas of **CBPM** and **Vale**, respectively, were leased by **Yamana Gold**. This group immediately performed an integration of data detailing. Later, between 2013 and 2014, **Yamana** reactivated the C1-Santa Luz Mine, but halted operations soon thereafter. Presently, the new proprietor, **Equinox Gold,** has developed a re-opening project in which the opening of six small open-pit mines is envisioned, it expects to restart production in the second quarter of 2022, starting mining works by former C1 Mine (Andrade Filho et al, 2020).

With regard to the western flank of the Chapada Diamantina, in 1977, **Billiton**, while prospecting for base metals, proved the feasibility of the copper–gold deposit of Ibiajara (Rio do Pires). In 1988, this deposit was transferred to **Unamgem**, and in 1983, a reevaluation of gold and silver reserves was developed. Ibiajara was operated by **Mineração Pajeú** between 1994 and 1996, with a production of approximately 0.91 tonnes of gold, but stopped due to low metallurgical recovery (Campos, 2013). At the western edge of Chapada Diamantina, the current potential of the Lavra Velha IOCG deposit (**Yamana**) holds promising expectations (Campos, 2013; Carlin, 2016).

Finally, in the northeast of Bahia, gold is recovered at the Caraíba Mine as a by-product of copper ore. Activities were kicked off in 1979 by **Mineração Caraíba**, and they currently continue with the **Grupo Ero-Copper Corp**, of Canadian capital. The volume of gold recovered as a by-product of the metallurgical process has been at least 6.55 tonnes (incomplete data, from 2008 to 2019).

Presently, the State of Bahia is responsible for 10% of the gold production in Brazil. Mina Jacobina (**Yamana Gold**) and Mina Fazenda Brasileiro (**Equinox Gold**) alone produced approximately 4.96 and 2.29 tonnes of gold in 2019, respectively (ANM -Agência Nacional de Mineração, statistics, 2020).

### 3.1.4. *Mato Grosso province (former Mato Grosso Captaincy)*

Gold occurrences and deposits in Mato Grosso are concentrated in four regions: Baixada Cuiabana, Águapeí Belt, Alta Floresta-Juruena Province, and Nova Xavantina (Fig. 4). With the exception of the Alta Floresta-Juruena, all other regions were discovered during the 18th century, but were gradually abandoned due to several factors – such as the decrease in the gold grades of the worked alluviums, endemic diseases, and recurrent attacks by native indigenous peoples. During the 19th century, despite the efforts and encouragement of the Portuguese Crown in the installation of industrial mining companies in Brazil, no great gold mining endeavors were established in Mato Grosso. Only one company had been registered to work in the region, that is, the **Companhia de Mineração de Cuyabá** - in fact, the first Brazilian mining company lawfully regularized by the Empire (1817) - but it was not successful in its venture. Mining activities would only restart between 1905 and 1906, when five mining companies of English-Argentine capital were created. They developed alluvial dredging in several rivers near Cuiabá, but were eventually also unsuccessful. After 1960, artisanal *garimpo* rushes started in four Mato Grosso regions: close to

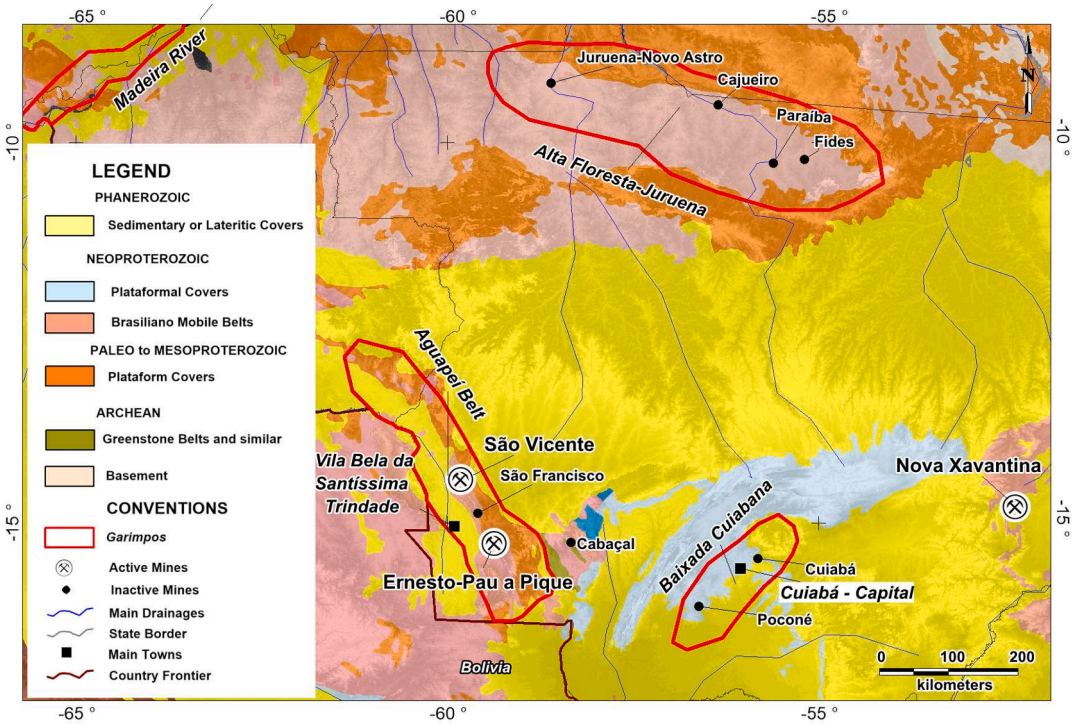


**Fig. 4.** Geological map of the region of Mato Grosso and Rondônia (modified from Gómez et al., 2019), showing mines and *garimpos* areas.

Cuiabá (Baixada Cuiabana); towards Rondônia (along the Guaporé valley, in the Aguapeí Belt and Jauru Belt); in the north of Mato Grosso (Alta Floresta, Aripuanã and Peixoto de Azevedo regions); and in Nova Xavantina and its surroundings.

*3.1.4.1. Geological context of gold deposits in Mato Grosso.* Mato Grosso's gold deposits are associated with different deposit types in different geological provinces; Baixada Cuiabana, Sunsás, and Alta Floresta-Juruena are presently highlighted (Fig. 4).

Between Cuiabá and Poconé, gold is found in phyllitic rocks in quartz veins, along an extensive NE-SW zone, and in lateritic soils (Bettencourt et al, 2014). Conversely, in Nova Xavantina, further to the east, gold mineralization is characterized as shear-zone-hosted and sulfide-rich, hosted in quartz veins and in a NE shear-zone that crosscuts a sequence of phyllites and metamorphosed volcano-sedimentary schists of the Proterozoic Cuiabá Group (GE21, 2020) (Fig. 4).

The Sunsás Province, in the southwest of the state, is an orogen of the Mesoproterozoic, represented by the Aguapeí Belt and by Paleoproterozoic terrains of Jauru, Rio Alegre, and Paraguá (all reworked). This belt extends to the region of Nova Brasilândia and Colorado in Rondônia. In the São Francisco, São Vicente, and Ernesto-Pau a Pique mines, gold mineralization are associated with shear zones/quartz veins with rare sulfides, shear-zone hosted sulfide-rich Au mineralization, and dissemination in the country rocks (Ruiz et al, 2014) (Fig. 4). In Alto Jauru (Cabaçal Mine), gold mineralization with Cu-Fe-sulfides, selenides, bismuth, and Au-Ag alloys are related to breccia, and massive and banded bodies were associated with a series of alterations that, genetically, are characteristic of deformed volcanogenic massive sulfides (VMS) deposits (Pinho et al, 2010; Ribeiro and Mantovani, 2016; Santos, 2014; Toledo, 1998).

The Alta Floresta-Juruena Province, in the northern part of Mato Grosso and southern part of the Amazonian Craton, is a Paleoproterozoic orogen formed by magmatic arches and associated volcano-sedimentary basins (Assis et al, 2014). Most mineralization are related to plutono-volcanic suites of Paleo-Mesoproterozoic age, arranged for more than 500 km in an NW-SE direction, and occur in the form of quartz veins or disseminations, presenting hydrothermal alteration with a strong zoning around mineralized zones. They were tentatively characterized as belonging to Au-porphyry types, sometimes as Intrusion-Related Gold Systems, and sometimes as Intermediate Sulfidation Epithermal, thus grouped into at least two distinct hydrothermal systems: Au-Cu and Au + Base metals (Assis et al, 2014).

*3.1.4.2. Historical and current situation of artisanal and industrial gold mines in Mato Grosso.* Artisanal and industrial mining has developed in the regions of Cuiabá-Poconé-Nova Xavantina, in Aguapeí Belt, and Alto Jaurú. Between Cuiabá and Poconé, a 120 km long strip of land concentrates more than 80 gold *garimpos* with significant production values - in 1994 and 1995, for example, they went up to 0.40 and 0.50 tonnes per month respectively. There were also small industrial gold mines/companies in the region, with little or no data available, including the Mineração Casa de Pedra and Salinas Gold/Morrinhos. To the northeast of Cuiabá, one finds the Nova Xavantina Mine, previously named Garimpo dos Araés. Between 1990 and 2003, the mine was explored by a consortium of Brazilian companies; in 2012, **MCSA (Mineração Caraíba S.A.)** started the mine's development and gold production. In 2018, **MCSA** was acquired by **Erocopper**. The production between 2012 and 2020 was of 6.88 tonnes of gold (GE21, 2020).

In the Aguapeí Belt, the mines of São Francisco and São Vicente were found by the *bandeirante* pioneers near Vila Bela da Santíssima Trindade and Nova Lacerda (Serra da Mesa) during the 1700 s, but were soon abandoned; they were rediscovered only in 1970 by *garimpeiros* and then reacquired by **Mineração Santa Elina** (a Brazilian company). The São Francisco mine operated as an open-pit from 2005 to 2017, producing 28.17 tonnes of gold. In turn, the São Vicente Mine started as an alluvial mine (1985–1995); after 1990, more effective exploration was developed, which culminated in 1996 with the formation of a Joint Venture with the Canadian company **Echo Bay**, thus guaranteeing continuity for the exploration efforts. In 2003, **Echo Bay** was acquired by **Yamana Gold**, which decided to operate an open-pit at São Vicente. Between 2009 and 2013, the mine's total production was of 9.87 tonnes of gold. In 2020, both São Francisco and São Vicente mines were acquired by **Aura Minerals**.

Further to the south, in the Pontes e Lacerda region, is the mine of Ernesto-Pau a Pique. It has been run by several companies (**Unigeo/Anglo American, Mineração Santa Elina, TVX Gold**, and others). **Madison do Brasil** acquired its rights in 1993, and, a year later, they were transferred to **TVX Gold**, then (1995) to **Mineração Santa Elina.** In 2003, they were acquired by **Yamana Gold**, who recommenced exploration in this area, and finally, in 2020, they were transferred to **Aura Minerals**. After 2017, production commenced, and continues, having reached a sum of 6.21 tonnes of gold between 2012 and 2020. Also noteworthy was a gold rush in 2015 in the vicinity of the sites, when large gold nuggets were found, each weighing several kilograms.

In the Alto Jaurú region, the Cu-Au Cabaçal Mine is located (Fig. 4). The deposit was discovered by **BP Mineração**'s regional exploration survey (**Mineração Manati**) around 1979 in breccia bodies, and mine development commenced in 1985. Two years later, the company started its operations as an underground mine, eventually reaching 200 m in depth. In 1988, Cabaçal was acquired by **RTZ (Rio Tinto)**. Operations ended in 1991 with a total production of about 5.15 tonnes of gold. According to (RTZ - Rio Tinto Zinc, 2008), the mine was subsequently decommissioned, receiving a decommissioning certificate from FEMA (the MT District Environmental Foundation) in 1992. Recently, it was acquired by **Meridian Mining** (Canadian capital), and exploration and reassessment efforts are currently underway.

In the Alta Floresta and Juruena Provinces, despite the previous successful phase of gold mining - thanks to the *garimpos* developed therein - only small mining companies prevail at present, without any production data as of yet. There are records of several organizations currently active in the location, mainly *garimpo*-type cooperatives and PLGs (small-*garimpos*). In terms of major corporations, **Anglo American, Codelco** and **Votorantim/Nexa** all have exploration permits. Junior companies with deposits in the area are **Meteoric Resources** (Juruena and Novo Astro), **Altamira Gold** (Cajueiro), **PA Gold** (Paraíba), **Fides Mining** (União do Norte and Jaca), and **Aura Minerals** (X1/Serrinha). Recently, **Anglo American** discovered and characterized a Cu-porphyry body called "Jaca" in the southeastern part of this province.

*3.1.5. Maranhão province (former Captaincy of Maranhão)*

In the Captaincy of Maranhão there are indications of prospecting for gold since 1615, near Vila Aurizona (municipality of Godofredo Viana). The Jesuits searched this region, preparing reports since 1655, presumably in an area between Turiaçú and Serra do Pirocaua, as far as current location of Vila Aurizona. Between 1719 and 1720 there was news of new discoveries, followed by the ban on gold mining in this sector. However, it was not until 1818 that gold was officially confirmed in the Pirocaua region, further to east.

In 1853, there was news of discoveries between the villages of Maracassumé, Montes Áureos and Gurupy (Paiva et al, 1937). Other findings followed in 1884, in Piriá, and in 1887, in the Caramuji River. Between 1879 and 1886, sporadic mines, built by speculators and foreign adventurers, were developed without success (Hussak, 1900). Thirty years later, some alluvial and primary ore mining projects are mentioned. Shortly thereafter, in 1931, a stage of strong *garimpo* mining started in Aurizona and its surroundings. Meanwhile, between 1930 and 1940, a series of **DNPM** expeditions were carried out in the Gurupy region (Moura, 1936; Paiva et al, 1937); the first scientific publication on the sector was issued in 1935 (Shaw et al, 1925). However, gold mining in Maranhão would only truly start around 1950, when many

small artisanal works began cropping up in the region – in particular, near Aurizona village.

*3.1.5.1. Geological context of Maranhão's gold deposits.* The aforementioned area, located between the states of Maranhão and northeasten Pará, is part of the Gurupi Belt and the São Luiz Craton (Fig. 5). The auriferous mineralization, considered within a large Paleoproterozoic orogen, are all located in the Gurupi Group (Klein, et al, 2017a, b). This Group is composed of a series of NNW-SSE structured, metasedimentary and metavolcanic rocks in the SSW part of the Craton. Mineralization occur on the coast of Maranhão (albeit in a more isolated way) in the Aurizona Group, which is composed of metavolcanosedimentary rocks and several intrusives with abundant mineralization, characterized, in turn, by the abundance of veins of quartz ± carbonate-sulfide, which are structurally controlled and related to regional shear zones. Several prospects (i.e., Caxias, Areal, Pedra de Fogo, and Cavala) of Au-orogenic type and an important mine – Piaba - are currently under investigation in the region of the São Luís cratonic fragment (Klein et al, 2005; 2017a). Piaba Mine (Fig. 5) is an orogenic gold deposit, epizonal–mesozonal, with gold mineralization associated with quartz ± sulfide veinlets and subordinate narrow breccia veins with gold dissemination and, subordinately, low-sulfide Au-quartz veins with free gold (Klein et al, 2015; 2017b). A large part of the *garimpos* on the coast of Maranhão occur in the recent extensive clastic sedimentary coverings over a thick mottled zone and laterites in the mangrove zone, thus subject to notable strong tidal variation.

*3.1.5.2. Historical and current situation of industrial gold mines in Maranhão.* The Piaba Mine (Fig. 5) is located near the Aurizona Village, where several mining companies have been operating since the 1960 s. In 1978, **Cesbra (Brascan Recursos Naturais S.A.)** developed an exploration program in the region which lasted until 1985. In 1991, a Joint Venture was created between **Cesbra** and **Unamgen (Gencor)**, including the development of new detailed analyses. Five years later, **Unamgen** sold its gold assets in Brazil to the **Eldorado Gold Corp. (Eldorado)**, which intensified work in the Aurizona region and on smaller targets. In 2007, **Lunagold Corp**. acquired the project and, in 2010, Mina Piaba was inaugurated, operating as an open-pit mine with a nearby treatment plant. It was then acquired by a new financial group (**Trek Mining Corp**), which shortly afterward changed its name to the current **Equinox Gold Corp** (merger between Trek, Newcastle Gold and Anfield Gold). The mine initially operated between 2010 and 2015 only in oxidized ore, and since 2019, has been running in primary ore as well, with a total volume of 12.58 tonnes of gold produced (Black et al, 2020). Of note is the fact that, in the records of the Caixa Econômica Federal Bank (CEF), between 1985 and 1987, there are related acquisitions of old nuggets coming from this region.

Finally, in the northeast of Pará and Maranhão, there are three other projects under evaluation. These are the Centro Novo (by **Oz Minerals**), Montes Áureos and Cachoeira do Piriá (by third parties) projects.

### 3.2. The Amazon region: Brazil's new frontiers of gold industrial mining

#### 3.2.1. Pará province (former capitancy of Grão Pará)

In the old Captaincy of Grão Pará, evidence of artisanal extraction before the 20th century is sparse and poorly documented, focusing mainly on the northeast of Pará State. However, the gold mining industry has taken a fantastic leap in the last fifty years, to the point that the region has become one of the main players in the Brazilian gold market. The most prominent areas are: the Carajás Mineral Province, the Tapajós Province (western Pará state), and the Serra do Ipitinga (northeast of the province) (Fig. 5).

In terms of Pará's mining history, the discovery of Carajás in 1967 resulted from a series of both efforts and coincidences led by the team of the **Companhia Meridional de Mineração (United States Steel's)** investigation of manganese ore in that region. Ten years after the discovery, the project was fully acquired by **Vale** (then **Companhia Vale do Rio Doce**). In the Serra dos Carajás, **Docegeo (Vale)** had already started an aggressive exploration campaign in previous years, identifying a series of iron and manganese deposits, targets of gold, and copper–gold (Salobo, Pojuca, Igarapé Bahia, Serra Leste, and others). Concomitant to this, Serra Pelada, an Au-PGE rich deposit, was discovered in the northeastern Carajás sector and developed into a massive garimpo, attracting thousands of garimpeiros to the region. In the south of Pará, the Diadema, Tucumã, Rio Branco, Rio Maria, São Félix do Xingu, Cumarú, Inajá, among other gold deposits, were also discovered by *garimpeiros*. Further west, in the Tapajós region, an explosion of gold garimpo operations took place throughout the 1970 s in tributaries of the Tapajós River and along the Rio das Tropas, Creporizinho, Cuiú-Cuiú, and Jamanxim, among others. Initially, these were mostly alluvial or dredging mines, guided by divers with specialized suits; eventually, they evolved to primary ore mining. The beginning of industrial mining projects in Tapajós only took place in the 1970 s, when several companies developed geological exploration campaigns in the region, even if in permanent conflict with the *garimpeiros*.

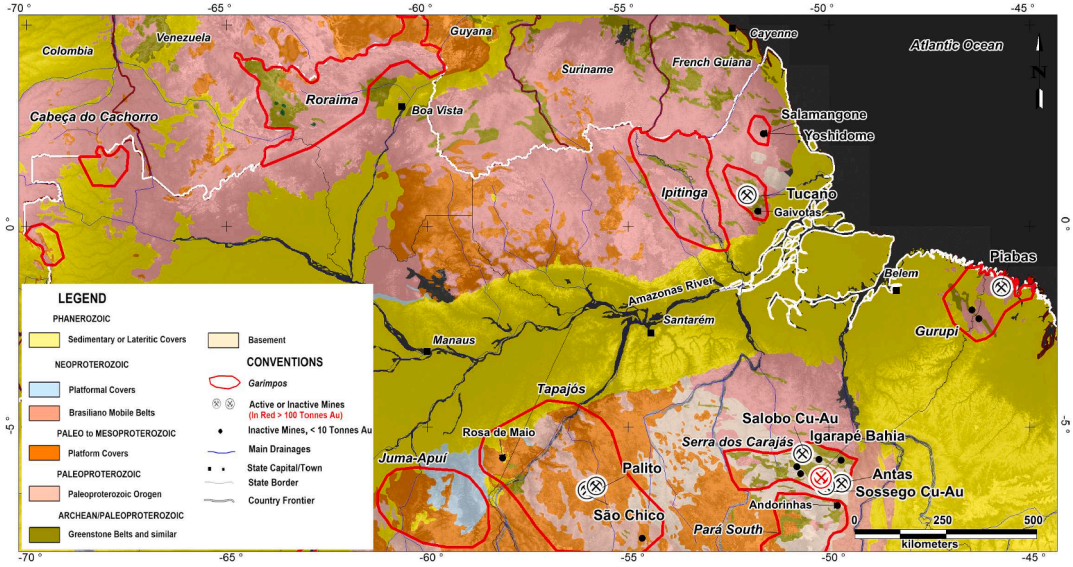


**Fig. 5.** Simplified geological map of the Amazon region and Maranhão (modified from Gómez et al., 2019), showing gold mines and *garimpo* areas.

*3.2.1.1. Geological context and gold deposits in Pará.* From a geological point of view, the Amazonian Craton hosts important world-class metallogenic provinces. These have a wide range of styles of primary precious, rare, base metal, and placer deposits, including gold. They are divided into different mineral provinces, the most prominent of which is the Archean Carajás Mineral Province, located in the southern portion of the Amazon Craton. The Carajás Mineral Province is divided into two Archean tectonic blocks (Santos et al., 2000): the Rio Maria Block (tracts of greenstone belts *strictu sensu*, with abundant Meso-Archean magmatism of granitic and TTG composition (Almeida et al., 2010; Oliveira et al., 2016a; Oliveira et al., 2016b), and the Carajás block. In the latter, thick metavolcano-sedimentary sequences are common; Meso-Archean magmatism occurs, predominantly A-Type alkaline to metaluminous high-K granitoids, with extensive crustal reworking during the Neo-Archean (Barros et al, 2001; Grainger et al, 2008; Silva et al, 2014).

In the Paleoproterozoic, an extensive Orosirian, metaluminous-to-peraluminous, anorogenic felsic, type-A granitogenesis (1.88 Ga, Serra dos Carajás Suite) was recorded, characterized by the Serra dos Carajás, Pojuca, and Cigano granites (Rios et al., 1995; Teixeira et al, 2019). The Carajás Block has an unique diversity and metallogenetic potential, with several world-class iron and copper–gold deposits and mines. Since 1997, many copper–gold deposits in and around Carajás have been framed in the IOCG model (Assis et al, 2014; Craveiro et al, 2020; Huhn and Nascimento, 1997), some with considerable volumes, such as the Igarapé Bahia Mine (**Vale**, currently inactive, with 97 tonnes of gold produced), and the deposits of Alemão, Serra Verde, 118, Cristalino, Jatobá, Bacaba, Visconde, Bacuri, GT-46 and Pedra Branca, among many others. Some have also been framed in a granite-related Cu-Au model, as is the case with Águas Claras, Pojuca, Breves, Estrela, and Gameleira (Grainger et al, 2008; Pollard et al, 2019; Tallarico et al., 2005). These deposits characterize a high potential region for IOCG deposits. Two deposits in IOCG, Sossego and Salobo, are already being mined; their accumulated production is of 32.43 and 60.43 tonnes of gold, respectively. In both of them, gold is a by-product of the copper ore treatment (Monteiro et al, 2016).

Two mines south of Carajás should also be mentioned (Fig. 5). The first is the newly implanted Antas North (**Oz Minerals**), with a production of 1.08 tonnes of gold, and the second is the Mina de Andorinhas-Reinarda (**Troy**), which produced about 7.93 tonnes of gold between 2007 and 2016. Still in the Carajas block, Serra Pelada is considered to be a unique Au-PGE deposit and hosts Au-Pd-Pt mineralization (Berni et al., 2016; Cabral, 2003, 2006; Cabral et al, 2009; Cabral et al., 2017). Gold nuggets of dozens of kilograms were common in the region – the most famous of which is the Canaã nugget (60.8 kg), currently on display at the Central Bank of Brazil in Brasília. It is thus logical that the region would be a haven for artisanal mining: in fact, between 1980 and 1990, more than 42 tonnes of gold were extracted by artisanal *garimpeiros* in Serra Pelada (Mathis, 1995). The Canadian company **Colossus Minerals Inc.**, in 2000 s tried to make an underground mine viable in Serra Pelada, but the attempt was unsuccessful.

Pará's other gold producing region that showed exponential growth was the Tapajós Province, located in the southern part of the Amazon Craton and part of the Tapajós-Parima Domain, in the form of a Paleoproterozoic orogenic belt adjacent to the reworked Archean crust (Semblano et al, 2016). In it, orogenic and epizonal filonian type deposits predominate in shear zones that cut granitoids and various schist/amphibolite packages. More recently, auriferous mineralization and hydrothermal magmatic base metals have been described, as well as high- and low-sulfidation epithermal deposits, hosted in the acidic volcanic rocks of the Iriri Group (Uatumã Event), and porphyry-type deposits located in sub-volcanic granites (Guimarães et al, 2015; Guimarães et al., 2020; Jacobi, 2017; Juliani, 2002, Juliani et al, 2004; Klein et al 2001; Santiago et al, 2013, Veloso et al, 2013). In the 1980 s, several companies developed geological exploration campaigns in the region, and disagreements with *garimpeiros* were frequent. The discovery of the low-sulfidation V6 (Chapéu de Sol) deposits by **Rio Tinto Group** dates from this time, as well as that of smaller deposits - respectively, high-sulfidation epithermal deposits and Cu-Mo porphyry-type mineralization. Meanwhile, the mining of small alluvial deposits began in mines throughout the Parauari River basin (**CMP-Companhia de Mineração e Participações**, a Brazilian company) and other sectors.

In the 1980 s, the CPRM (Geological Survey of Brazil at present) carried out a regional survey, including the risky registration of *garimpo* mines, in order to characterize the mineral potential of Tapajós province. As expected, the alluvial-type ore, being easier to extract, has been decreasing over the decades. In this context, the ineffable *garimpeiros* are adapting, and have started to open dozens to hundreds of mines in primary rock, most of them on a small scale. In the current situation, many junior companies have taken the gamble and have started to invest in the Tapajós. Examples of this are the Castelo dos Sonhos **(Tristar Company**), located in Proterozoic paleoplacers; Tocantinzinho (**G Mining Ventures Corp.)**, in the intrusion-related gold deposit hosted in Paleoproterozoic granites; and Cuiú-Cuiú (**Cabral Gold**) and Coringa (**Serabi Gold**), in different shear-hosted veins projects. Nevertheless, the only mining company in operation in the region today is **Serabi Mineração (Serabi Gold,** UK capital, AIM listed), it administrates the Palito and São Chico mines. Notably, even though Tapajós large gold nuggets have reportedly all been since long discovered, in 2020 a beautiful piece of 18 kg was found in the Cuiú-Cuiú area.

In addition to the Carajás and Tapajós Provinces, the region around the **Serra de Ipitinga**, in the northeast of Pará, and the **Bacajá Domain**, just north of Carajás, are the next frontiers as new gold targets.

The **Serra do Ipitinga region** is located in the northeastern part of the so-called Guianas Shield, pressed between the Amapá and Carecuru tectonic domains, within the Paleoproterozoic Maroni-Itacaiunas orogenic belt. The gold district in the Serra do Ipitinga is associated with the rocks of the Ipitinga Group (mafic and ultramafic metavolcanic rocks), which presents sulfidized mineralization of the syndepositional, hydrothermal, volcanogenic type, with occurring pyrrhotite, pyrite, chalcopyrite, sphalerite, and associated gold and silver (Faraco et al, 2006; Klein et al, 2010). The whole metavolcanosedimentary Ipitinga Group was deformed by brittle-ductile shearing and generated quartz veins that crosscut the sequence. Pyrite, chalcopyrite, and covellite with associated gold can be hosted; the latter is also interpreted as being orogenic gold, spatially associated with a precursor volcanogenic Cu-Au sulfide mineralization (Faraco et al, 2006; Klein et al, 2010). Hundreds of *garimpos* crop up in the region; currently, mineral exploration in the area is restricted.

The **Bacajá Domain** is made up of reworked Archean and Paleoproterozoic tectonic associations related to the Transamazonas Province, of Transamazonic ages, and composed by granitoids and granulites, as well as metavolcano-sedimentary sequences such as Archean-Paleoproterozoic greenstone belts (Bettencourt et al, 2016; Santos, 2003). Gold mineralization develops preferentially in shear zones that cut granitoids (Vasquez and Rosa-Costa, 2008) close to the contact zone between these and the schists (Cristo, 2018). In this geological context, dozens of artisanal mines were developed in microfractures associated with sulfides, veins, and quartz veins or in brecciated areas, and through disseminations in metavolcanic rocks (Macambira and Klein, 2018; Souza and Kotschoubey, 2005). **Belo Sun** (Canadian capital) is currently negotiating environmental licenses for the area in order to make the Volta Grande Mine, located at the margins of the Rio Xingu, viable.

*3.2.2. Amapá Province (former Contestado Franco-Brasileiro)*

The Amapá region only began being worked for gold at the end of the 19th century by *garimpeiros* from present-day French Guiana. These men focused their efforts in the regions of the Oiapoque River (1853), the Flexal River (1882), and around Lourenço (already in 1890), thus starting a small, localized gold rush (Ackerman, 1972). A series of gold *garimpos* emerged at the time (Levat, 1898; Hussak, 1900), some of which remain active to the present day. *Garimpo* activity gained

increased in force some fifty years later, initially centering around the region of Gaivotas, Vila Nova and Santa Maria and Coambas range. It was particularly strong around 1940 and in the 1970 s (Ackerman, 1972), by which time three well-defined focuses had been mapped out. One of them was in the Lourenço region, in the center north of Amapá, where the Salamangone Mine was later opened. Another focal area was that between Serra do Navio and Rio Vila Nova and along the Rio Jari, to the west of the province - crossing the border with Pará, in continuity of the Ipitinga, Molocopote, and Tumucumaque ranges. Finally, the region between the Amapari and Araguari Rivers also hosted a series of small cassiterite mines and gold *garimpos* during the 1940 s, which were reactivated as of 1970. Industrial mining started when the Salamangone Mine, in Lourenço, was implemented by the **Companhia de Mineração do Amapá-CMA (**Brazilian Company) in the 1980 s.

*3.2.2.1. Geological context and gold deposits in Amapá.* The Amapá district is underlain by the Amazon Craton, located within the Transamazonian Province - consolidated as the Lourenço, Amapá and Carecuru orogenic domains (Bettencourt et al, 2016; Santos, 2003; and Vasquez and Rosa-Costa, 2008).

The Lourenço Domain, continuous to French Guiana, is an expressive Paleoproterozoic tract with terrains constituted by a granite-greenstone association, comprising Rhyacian suites of *meta*-granitoids, gneisses, and discontinuous strips of metavolcano-sedimentary rocks (Bettencourt et al, 2016; Sousa and Coelho Neto, 2014; Viana, 2019). Gold mineralization is hosted in ductile–brittle shear zones, which control epigenetic quartz vein systems associated with saussuritization, chloritization, and sulfidation in the host tonalites (Klein et al, 2014). The Lourenço Domain's main mine is the Salamagone deposit, where gold appears either associated with quartz or related to sulfide association assemblies (Nogueira et al, 2017). The deposit is classified as composed of magmatic-hosted (Biondi, 2003), orogenic gold deposits (Nogueira et al, 2017), even if, more recently Klein et al (2014) have expressed uncertainty about the deposit type. The Yoshidome Mine is also hosted in this association (Klein et al, 2014). Gold was discovered by *orpailleurs* in the Lourenço Domain in the late 19th century, and about 3 tonnes of alluvial gold were recovered. Almost a century later, between 1970 and 1989, a large sector was worked by *garimpos*. In 1983, the first industrial exploration works were developed - including geological mapping, alluvial and soil geochemical prospecting, excavations, drilling, and experimental mining (Ferran, 1988; Klein et al, 2014). These studies made it possible to open the mines at Yoshidome, and Salamangone (Klein et al, 2014). The Salamagnone mine, operated by the national company **CMA**, was active between 1984 and 1995. It was initially operated as an open-pit and later developed as an underground mine, extracting a total 19.96 tonnes of gold.

The Amapá Domain comprises an Archean basement that associates metagranite-gneiss-migmatites-granulites, high-grade metasedimentary sequences, and charnockites. This array was intruded by pre-orogenic mafic–ultramafic rocks and orogenic granitoids at 1.99 to 2.22 Ga, and by anorogenic granites between 1.84 and 1.75 Ga (Bettencourt et al, 2016). The gold deposits at the Tucano and Gaivotas mines occur associated with the Vila Nova Group (Klein et al, 2014).

The Tucano Mine (Fig. 5), located within the Amapá Domain, is the largest industrial gold mine of Amapá. It occurs as a series of deposits aligned along an N-S shear zone close to the contact between metasediments and amphibolites, hosted in the Paleoproterozoic Vila Nova Greenstone Belt (GPM - Great Panther Mining Ltd, 2021). Mineralized bodies are composed of concentrations, veins, and disseminations of silica, in addition to carbonates and sulfides (pyrrhotite, pyrite, arsenopyrite, chalcopyrite and galena), which fill up the spaces or partially replace host rocks. Gold occurs both as free gold grains or included within sulfides (Scarpelli and Horikava, 2017). Gold mineralization were first detected by **Unigeo** (subsidiary of **Anglo American do Brasil**) and explored by **Minorco** as part of the Amapari Project, leading to the definition of a gold deposit (Scarpelli and Horikava, 2018). The project was then taken over by **AngloGold Ashanti**, at the time of its decoupling from the **Anglo American Group**. Shortly thereafter, Tucano was sold to **Mineração Pedra Branca do Amapari Ltda**, of the **EBX Group** and in 2004, to **Wheaton River/Goldcorp** (Canadian capital), which started production in 2005. In 2010, **Beadell Resources Ltd.** (Australian capital) acquired the mine, installing a CIL (carbon-in-leaching) plant in order to minimize the problems of the leaching process in tailings dams, generated by the continuous rains (Scarpelli and Horikava, 2017). During this period, the deposit was renamed Tucano Mine, and in 2019, it passed onto the hands of the **Great Panther Mining. Ltd**. (Canadian capital). In the period between 2005 and 2010, and from 2013 to the present day, Tucano Mine has produced a total amount of 44.81 tonnes of gold (GPM, 2021).

The Gaivotas Mine (Fig. 5) is located in the Santa Maria region, in the southernmost portion of the Amapari Greenstone Belt. It is also conditioned to an extensive north–south shear zone, with mineralization in quartz veins and, locally, gold mines in the Proterozoic metaconglomerates and BIFs of the Vila Nova Group, in addition to extensive pits developed by *garimpeiros* (Scarpelli and Horikava, 2018). It was identified by **ICOMI** (Brazilian Company) and exploited by **Mineração Água Boa (**Brazilian Company) between 1991 and 1997. Operations were carried out as an open-pit with an associated CIL process, and more than 2.5 tonnes of gold were produced - at a grade of 2.7 g / t Au (Scarpelli and Horikava, 2018; Spier and Ferreira Filho, 2017). Noteworthy is the fact that the *garimpeiros* swiftly entered the northern sector of this deposit (Spier and Ferreira Filho, 2017). As expected, there is no record of the amount of gold that was mined at the time. This highlights the critical situations under which some industrial gold companies operating in the Amazon region.

*3.2.3. Rondôniaa, Amazonas, and Roraima provinces*

In the province of Rondônia, from the year 1730 onwards, a series of small gold artisanal mines along the Guaporé River and its tributaries was discovered by the *bandeirantes* from São Paulo. This period of intense artisanal mining extended until 1765; it had started in the present-day Mato Grosso, but soon extrapolated that district's borders, reaching as far as the town of Corumbiara (Rondônia). Almost two hundred years later, in 1952, with the discovery of extensive deposits of cassiterite in Rondônia, a new influx of gold miners began, and was only interrupted by an extraction ban in 1970. From then onwards, the *garimpeiro* migration took the path downstream the Madeira River, where gold had been discovered in sedimentary coverings on the border with Bolivia. Their activity was quickly modernized, with the extensive use of mechanized dredges in alluvial works. Presently, such equipment operates in large sections of the river, and can even be observed in the vicinity of Porto Velho, the capital of Rondônia, as well as around the municipalities of Manicoré and Humaitá - both already in the district of Amazonas. Between 1979 and 1991, these dredges had an official production of 38.47 tonnes of gold (Adamy and Pereira, 1991). A large part of this gold arrives in Rondônia thanks to the tributaries of the Madeira River that are born on the eastern slopes of the Peruvian Andes, where the incredible mega-*garimpo* of *Madre de Dios* is located.

Another noteworthy region in Rondônia is the area between Corumbiara and Colorado d'Oeste. It had already been prospected for gold by the pioneers of the 18th century; a series of gold garimpos were developed between 1985 and 1995. The region is included in the southeast of the Amazonian Craton and the *garimpos* are hosted in supergenic Au deposits, linked to the Metavulcano-Sedimentary Sequence Nova Brasilândia, of Meso-Proterozoic age, with gold mineralization in localized, shear-hosted, structures with strong associated alteration (Quadros, 2020;.Romanini, 2000),

In the district of Amazonas, gold *garimpos* also occur, most of which emerged in the 1970 s. The regions of Jacareacanga (corresponding to the rivers Abacaxis and Parauari, near the border with Pará), Juma-Apuí (in the south), Uaupés-Traíra and *Cabeça de Cachorro* (on the border

with Colombia), as well as the Madeira River should be highlighted. The Jacareacanga mining region, including the Abacaxis and Parauari rivers, is the northwestern extension of the Tapajós Province, and is dominated by *meta*-vulcanosedimentary rocks of the Jacareacanga Group and granitoids of the Paleoproterozoic Parauari suite. There has been news of *garimpo* development in this sector since the early 1960 s; they gained the foreground in the 1980 s, when the the *garimpos* extended towards the tributaries Anta, Grande, Bandeirantes, Rosa de Maio, Comandante Peres, Cachoeirinha, Serra Morena, Pinzon, and Abacaxis (Schmaltz and Guimarães, 1983). Rosa de Maio was operated by the **CMP-Companhia de Mineração e Participações** (Brazilian Company) during the 1980 s.

Presently, gold mining in the district of Amazonas is active in the Juma-Apuí region, located in the western portion of the Amazonian Craton, within the northwestern extension of the Alta Floresta-Juruena Province (Simões et al., 2020). Here, there is evidence of structures indicative of the presence of volcanic calderas and epithermal deposits, associated with the Proterozoic volcanic sequence of the Colider Group (CPRM, 2010). The region had little development of *garimpo* activity in the 1990 s, and only gained greater importance after 2003, when a small invasion took place. Today, most of these alluvial garimpos are deactivated.

Finally, between the Tunuí and Caparro regions (Fig. 5), in the northwest of the state (a region known as "dog's head" or Cabeça de Cachorro), some gold *garimpos* were developed along clastic metasediments of the Tunuí Formation, of Mesoproterozoic age (Andretta, 2020).

Finally, in the state of Roraima (Fig. 5), diamond and subordinate gold *garimpos* have carried on for decades. The development of mineral exploration by mining companies in the best potential areas of Roraima (i.e., mountains of Mucajaí, Parima, Pacaraima, etc.), however, is impossible, as the targets are mostly located in indigenous reserves, in addition to parks and national forests. Nonetheless, *garimpeiros* are not usually concerned with such "technicalities". Historically, the first *garimpo* operations in the region occurred around 1912, between the current Cotingo and Maú *garimpo* areas, in the northeast of the province, which led to the discovery of diamonds. Later, in 1937, the *garimpeiros* entered the Serra Tepequém, developing gold-diamond mines that, in some cases, last until today. Generally, the mines are developed in drainages associated with metasedimentary rocks of the Roraima Group and similar, of Paleoproterozoic age (Oliveira, 1937). In the 1970 s, a gold *garimpo* mining explosion took place throughout the virtual entirety of Roraima, originating several instances of conflict, mainly with local indigenous peoples. This foray gave rise to the implantation of diamond-gold garimpos in the mountains of Surucucus, Mucajaí, Parima, Uraricauá, and Anauá. Recently, the implantation of illegal gold *garimpo* has generated violent conflicts with the indigenous people from the Yanomami Lands and the Raposa Serra do Sol, the latter in the vicinity of the National Park that hosts the mythological world-heritage site Mount Roraima. Sadly, these conflicts tend to increase, evermore resulting in numerous deaths for the already vulnerable native peoples of Brazil.

### 3.3. Gold, garimpos, and industrial mines in other regions of Brazil

In northeastern Brazil (except for Bahia and Maranhão) citations of gold have been reported since the beginning of the 18th century; some regions are more abundant than others, especially Ceará. It was there that, between the years of 1756 and 1758, that the **Companhia das Minas de São José dos Cariris Novos** developed mining efforts - in practice, a failure of an undertaking that yielded Portugal only 36 marks, 5 octaves, and 36 grains of gold (Ferreira, 2013; Rios, 2018). In terms of industrial gold mining, only the current district of Rio Grande do Norte (within the Seridó geological region) has had producing mines - two small ones, Bonfim and São Francisco. Both were discovered in the post-World War II era and began operations for gold mining after the 1980 s. The São Francisco Mine was mined by **Mineração Xapetuba** in 1988 as an open-pit, and processed by Heap Leaching. It was paralyzed between 2001 and 2005, and had its tailings reworked by a small company; by then, it had produced a total of 8.08 tonnes of gold. In 2010, its rights were acquired by **Crusader Resources** (the current **Big River Gold**, of Australian capital), which, in 2020, completed a definitive feasibility study - including the guaranteeing of licenses required for the resumption of operations at São Francisco - Borborema (Big River Gold, 2019). This resumption is likely to occur by 2023. On the other hand, Mina Bonfim was worked between 2011 and 2018 by the **Mineradora Santo Expedito (Grupo Edem**, a Brazilian group) and produced about 0.24 tonnes of gold. Interestingly, this mine has a strong Au-Bi-Cu association.

Another northeastern region that holds a series of gold *garimpos* is the border between Rio Grande do Norte and Paraíba. Here, the garimpos of Itapetim (worked by the experimental mining of **CPRM** during the 1980 s), Santo Aleixo, and Pimenteiras are located. Nearby, in the state of Paraíba, a series of small gold garimpos occur, cropping up in well-defined sectors, such as Piancó. This is a historic region from the point of view of gold mining, since, in 1860, **Tasso Brazilian Gold Mining Co. Ltd** developed some projects there (of which we unfortunately have no records; mining was resumed by prospectors only eighty years later) (Cornejo and Bartorelli, 2010). Still in Paraiba, the garimpos of Catingueira, Itujatatiba, Mãe dÁgua, Cachoeira de Minas, Santa Isabel, all of them small, should be cited. For its part, in Pernambuco, gold *garimpo* mining took place around Serrita and Salgueiro towns. Finally, in Alagoas, the copper–gold deposit of Serrote da Laje was recently characterized (Canedo, 2016). The deposit, previously owned by **Aura Minerals,** was recently acquired by **Mineração Vale Verde (**Appian Group).

The south of Brazil has also hosted a few industrial gold ventures**.** In **São Paulo**, small artisanal mines had been opened along the Ribeira River Valley (such as Iporanga, Apiaí, Ribeira and others) during the early stages of colonial history, but were all overshadowed by the discovery of the rich mines of the Quadrilátero Ferrífero at the end of the 17th century. Later, during the twentieth century, the only two mines that operated in São Paulo were the **Saint George Mine** (Araçiguama), between 1936 and 1940 (0.05 tonnes of gold produced) (Oliveira and Barbosa, 1940), and the **Morro do Ouro Mine**, in Apiaí, mainly in the 1920 s, with no data available as to production (Faleiros, 2012; Krug, 1902; Leonardos, 1970; Shimada, 2013). Both mines worked in the form of rudimentary underground mines in quartz veins, with free and scattered gold and sulfides. Further to the south, in Paraná, and more specifically in the region between Curitiba and Campo Largo, two mines (**Leão Jr**. and **Timbutuva)** were explored between the years of 1930 and 1950, of which we only have partial data. Subsequently, in 1984, **Mineração Tabiporã** (Brazilian capital) was implemented in the Campo Largo region. and has been in production ever since, yielding 10.84 tonnes of gold by 2021.

Further south, in the province of Santa Catarina, gold mineralization and mining are both mentioned in the regional reports of CPRM (Kaul and Rheinheimer, 1974; Lins and Silva, 1985). The region's mines are located in the northeastern center of the district, between the municipalities of Gaspar, Blumenau, Brusque, Canelinha, and Itajaí. The only registered mine is the Au-Cu-Pb-Zn, Schramm Mine (Brazilian capital, located in Blumenau), of which no data is available (Biondi, 2003) (Biondi et al., 2002)(Biondi et al., 2004)(Biondi and Xavier, 2002) Finally, in Rio Grande do Sul, between 1870 and 1910, at least seven companies with English, Belgian, or Brazilian capital settled and mined around Lavras do Sul. Some probably operated alluvial mines, but most were small open-pit excavations and galleries, of which no recorded production data remained (Carvalho, 2013; Ronchi and Lobato, 2000), Between 1936 and 1949, a nationally-owned company (**Companhia de Mineração do Bloco Butiá**) operated the Bloco Butiá mine in the open and underground, with data records of its partial production indicating just 0.034 tonnes of gold in 2 years, (Oliveira and Barbosa, 1943; Teixeira and Leinz, 1942). From 1980 onwards, the companies **CBC (Companhia Brasileira do Cobre**) and **RTZ** performed a series of mining efforts in Lavras do Sul. In 2006, **Amarillo Gold. Corp.** acquired

this portfolio, and the project has been undergoing an evaluation phase ever since, but in 2021 was sold to **Hochschild Mining.** In 2011, the **Mining Ventures Group** also carried out a series of exploration works in the region of São Sepé/Bossoroca (Bossoroca Mine), while other smaller companies explored around Palma, Seival, and Cerrito do Pires. Both Bossoroca and Cerrito do Ouro operated between 1980 and 1990, but no production data is available for either case. These deposits have variable typologies, ranging from veinlets and quartz veins (associated with shear zones with hydrothermal alteration), to stockworks and disseminated distribution in various types of Neoproterozoic casters (Custódio et al, 2019; Gastal et al, 2015; Rocha et al., 2013).

In summary, the Brazilian states of São Paulo, Santa Catarina, Paraná, and Rio Grande do Sul hold reasonable potential for new discoveries of gold and other metals. New techniques should be applied in order to develop geological models for their case, given that they are still scarcely used for these regions.

## 4. Discussion

### 4.1. The Brazilian gold production considered in a global context

According to data from the WGC-World Gold Council, in 2020, Brazil occupied the tenth position in the global production of gold, with 106.9 tonnes produced annually. The list is headed by China (383.2 tonnes), Russia (329 tonnes), Australia (325 tonnes), and the USA (200.2 tonnes); Brazilian production has also been surpassed by Canada, Peru, Ghana, South Africa, and Mexico. Nevertheless, the numbers over the past twenty years have been very positive and show a strong recovery in Au yields. This growth is made clear when we consider previous production values, such as those for 2018, in which the country officially produced 72.20 tonnes of gold through companies and around 13.4 tonnes in *garimpos* (data retrieved from the ANM - Brazilian Mineral Yearbook 2019). Also worth noting is the fact that Brazil currently has four world-class mines: Cuiabá (located in the QF), Morro do Ouro (in Paracatú, Minas Gerais), Crixás (in Goiás), and Fazenda Brasileiro (in Bahia) (Table 3, Fig. 6). Considering the Morro Velho mine (in QF), closed in 2003, from a historical and current point of view, there are five world-class mines in Brazil.

In historical terms, between 1700 and the first quarter of the 19th century, artisanal mining in Brazil was responsible for the production of approximately 1,200 tonnes of gold. This was by far the largest production of that century on the planet, amounting to at least 90% more than the entire volume from the combined Spanish Colonies (Rios, 2018). Such figures are rendered even more impressive when the following is taken into account: (i) the extraction methods of the time were rudimentary, often precarious; (ii) mining and taxation regulation systems hindered gold productivity over time; and mainly, (iii) no mercury was used in the fundamental artisanal extractive processes. To put this into perspective, it may be interesting to compare these historic values with that of another, more recent Brazilian artisanal gold production cycle, initiated during the gold rush at Serra Pelada during the 1980 s. There, some 40,000 gold prospectors (*garimpeiros*) and diggers participated in one of the greatest gold sagas of modern history, with a total gold production that probably exceeded 50 tonnes. However large, such values are still incomparably smaller than those of the early history of Brazil.

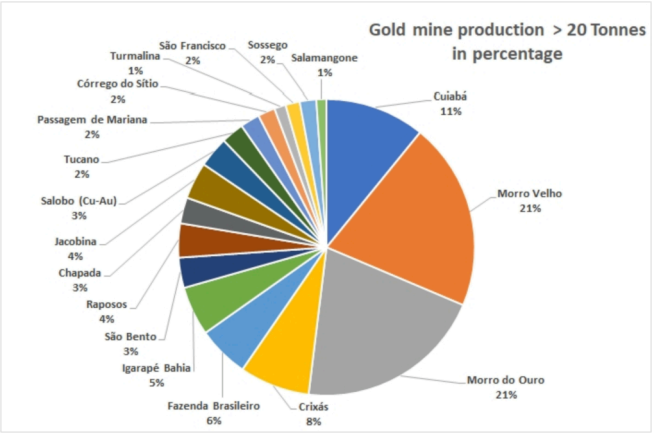


**Fig. 6.** Production graph, current + historical, of the main gold deposits in Brazil.

### 4.2. Industrial mining vs. Artisanal mining (garimpos): Societal impact and development

It is fair to point out that the development of gold mining in Brazil during the last three hundred years has effectively contributed to define frontiers of population expansion and jurisdictional units (captaincies and provinces) and to create a strong mining-oriented culture in certain sectors of the country. The most notable case is Minas Gerais, where the *QF*, a tiny area (about 10,000 km$^2$, Fig. 2) when compared to the continental extent of Brazil, has historically been responsible for more than 70% of the gold (and iron) ore mined in the country. Thereby, a local society that is strongly linked to the development of industrial mining – culturally, simbolically, economically, etc. – has been generated. It is interesting that this development (which includes the presence of some Au-and-Fe world-class mines) has taken place despite the mines' countless changes in ownership from the 19th century until today, with the participation of companies of very different capitals. The fertility of this geological sector as a host to gold mineralization is remarkable, and its standing as a host to at least two large world-class deposits (*viz.* Morro Velho and Cuiabá), where there are still possibilities for new discoveries, sets it as a special place for gold mining indeed.

The artisanal extraction of gold, for its part, has remained active in the country for the past 300 years. After the 18th century boom, it suffered a strong decline, especially during the 19th century - the time that industrial mining began to develop. Then, it was mostly restricted to residual works. There are almost no records of *garimpo* production for that period; however, it probably must not have exceeded 40 tonnes. As has been previously pointed out, the main reason for this documental scarcity was that the fiscal control of the Empire of Brazil (thus from 1822 onwards) upon the extraction of national gold did not adopt the same rigor implemented by Portugal in the previous century. *Garimpo* activity underwent a notable reactivation in the 20th and 21st centuries, and currently continues its expansion, seen as it is being constitutionally regulated as a compliant or mainstream business activity. However, as in the 18th century, its recorded production values are not consistent with the actual extracted volumes.

Official figures from the National Mining Agency of Brazil (ANM) indicates that a total of 151 tonnes of Au was produced by *garimpos* in the entire country between 1995 and 2007. Even though tax records - due to the frequent smuggling and/or evasion - do not reveal the true amount of gold extracted, it must have approached 700 tonnes of Au. For this estimation, the gold boom occurred from 1977 to the present in the states of Pará, Rondônia, Amapá, Amazonas, Roraima, Tocantins, Goiás, and Mato Grosso must be considered. Nevertheless, by all accounts, this production still falls far short of that achieved during the 18th century.

It should be noted that, in modern-day *garimpos*, unlike the previous three hundred years, tractors, excavators, suction and jet pumps, river dredges, divers, mercury, cyanidation and many other non-rudimentary methods and technologies are regularly used. As has been shown earlier in the article, this activity is subject to a significantly less regulatory regime than that controlling industrial mining, and is currently developed over extensive areas, mainly in the Amazon Basin region. It generates a critical environmental and human impact on account of the persistent, precarious extraction methods, which cause extensive degradation across large swaths of land and river channels. The impact

is also accentuated by the localized use of cyanide leaching and by the extensive use of amalgamation of gold with mercury. During the application of the latter technique, mercury is routinely dumped into the environment, polluting water courses and affecting all associated ecosystems, including human settlements and the food supply chain. In the Tapajós area (Fig. 5), mercury contamination from *garimpo* activity has already reached the Santarem region, located 300 km downstream from the mines area (Meneses et al., 2022). One is dumbfounded to hear how it is still argued by some that gold *garimpos* should be considered a type of environmentally low-impact activity.

On the other hand, industrial gold mining, whether in the form of small or large enterprises, must always follow strict environmental licensing provisions, in addition to being subject to frequent supervision by Brazilian governmental agencies in order to avoid problems of contamination to the environment and local populations. In this sense, companies should develop permanent planning schemes and monitoring systems that prevent the release of cyanide and heavy metals into soils and water courses. In addition, mining operations need to effectively control acid mine drainage (AMD) and to ensure the stability of dams, thus protecting communities located nearby.

However, it appears that there is still a great deal of lack of communication between the mining industry and Brazilian society in geral. Two major accidents with iron ore dams in the *QF* region in the last five years (at Mariana and Brumadinho) resulted in human deaths and great environmental and economic impact for the regions; as a result, the mood of environmental and public entities was exacerbated in the sense of tightening rules for the implementation of dams, with many gold companies already adapting. A factor that must be considered by corporations regarding this delicate balance is how the expansion of industrial mining has taken over certain sectors where populations have been established for centuries; this can result in the loss of local identity and ways of living and even in the acculturation and death of indigenous peoples - who were almost extinct in the *QF* during the gold boom in the 18th century, for example. In the other hand, it is important that the public be made aware of the benefits brought about by industrial mining (from the jobs it creates to the materials it enables) and the essential role it plays on modern-day life, as well as the compliances mining companies are obliged to adhere to, such as strict environmental licensing regulations to avoid contaminating both the environment and local populations.

## 5. Conclusions

1) The mining developed in Brazil throughout the 18th century was artisanal, and the gold production values, of about 1,200 tonnes, were considered exorbitant for the time, at least 90% higher than all of the production of the Spanish colonies put together.
2) It was only after 1808, with the transfer of the Portuguese Court to Brazil, that the Brazilian market opened to foreign companies. The first industrial mining companies that were then established produced, throughout the whole of the 19th century, around 144 tonnes of gold, distributed in 17 mines. The most productive mines of that period were Gongo Sôco, Morro Velho, and Passagem de Mariana, all located within the *QF*, which accounted for 85% of the total gold value.
3) The extractive methods used in the industrial gold production showed an evident technological increase from the end of the 19th century onwards. Certainly, the employment of amalgamation was decisive, but the turning point in industrial mining was the use of cyanidation. Initially implemented in the Morro Velho, Passagem de Mariana, and São Bento mines, it gradually allowed for industrial mining to surpass the extraction of gold *garimpos* in productive terms.
4) During the twentieth century, industrial mining spread throughout the country, producing 897 tonnes of gold in 39 mines operated by 27 different business groups. Six of such mines accounted for 86% of the entire Brazilian production: Raposos, Morro Velho, Cuiabá, Crixás (**AngloGold Ashanti**), São Bento (**Eldorado**), Morro do Ouro (**Kinross**), Fazenda Brasileiro (**Equinox**), and Igarapé Bahia (**Vale**).
5) In the first two decades of the 21st century, industrial mining in Brazil produced around 1,023 tonnes of gold in 42 mines. Of this total, seven large enterprises concentrated 80% of production. These are the mines of Cuiabá (**AngloGold Ashanti**) and Morro do Ouro (**Kinross**) in Minas Gerais, Salobo and Sossego (**Vale**) in Pará, Chapada (**Lundim**) and Crixás (**AngloGold Ashanti**) in Goiás, Fazenda Brasileiro (**Equinox**) and Jacobina (**Yamana**) in Bahia, and Tucano (**Great Panther**) in Amapá.
6) The artisanal gold extraction (*garimpo)* activity underwent a notable reactivation in the 20th and 21st centuries, when it was regulated as a lawful business activity and began employing modern machinery. Even though tax records, due to frequent tax evasion, do not reveal the true amount of gold extracted from *garimpo* mining, it is estimated that production for this period must have approached 600 tonnes of Au. *Garimpos* were and still are mainly concentrated in the Amazon region, especially around Tapajós, Alta Floresta-Peixoto de Azevedo and Juruena, Cuiabá-Poconé as well as the south of Carajás, Amapá, Gurupí, Roraima, Amazonas, Goiás, Tocantins, and Bahia.
7) The gold mining companies of the 19th century were mainly built up from foreign capital. English companies predominated (some 85%) over Brazilians, who had no experience in industrial mining. In the twentieth century, until 1950, English capital still prevailed, weakening only in the post-World War II period. After 1960, South African investments began; during the 1990 s, with the strengthening of mining in both Canada and Australia (and of their stock exchanges), an inflow of capital from companies based in such countries also started.
8) Since then, a series of Junior exploration companies have entered Brazil, some operating speculatively, a few of which evolved into direct mining operations. These companies operated through the acquisition of either small and medium-sized operations or advanced projects, while the major mining operations were mainly in the hands of major mining companies.
9) The QF is the most representative historical region in Brazil in terms of gold mining and currently hosts an important number of mines. For their part, the Amazonian Craton (notably Serra dos Carajás, Tapajós, Alta Floresta-Peixoto de Azevedo and Amapá), the Gurupí Belt, and the Goiás magmatic Arc undoubtedly constitute the current frontier in terms of new discoveries, with great potential for the future development of industrial gold mining. In particular, we consider that the Tapajós, Aguapeí Belt and Alta Floresta-Peixoto de Azevedo regions may bring pleasant surprises in terms of new deposits in the following years. This trend shows that, although Minas Gerais continues to be the country's most important gold producer (hosting the two largest gold mines in Brazil), the Amazon region is beginning to consolidate itself irreversibly as a key player in this field.
10) The potential for discovering new deposits via traditional geochemistry cannot be underestimated, given the relatively recent discovery of deposits at Mina Tucano (Amapá), Córrego do Sítio, Riacho dos Machados (Minas Gerais), Almas (Tocantins) and Igarapé Bahia (Pará).
11) In comparative terms, during the 20th century, the national production of gold (industrial + *garimpos*) was practically the same as that obtained during the 18th century boom. It is somewhat impressive that such values were reached in a time when mining was completely rudimentary, motorized machinery was non-existent, and mercury was not available, much less cyanide. As such, this period could be deemed the "golden age" of gold production in the country.

12) Finally, it can be said that, after the 18th century gold boom, the older gold captaincies promoted the development of industrial extraction in different ways, eventually evolving to open-pit and underground mines. Four of those historic mines (Morro Velho, Cuiabá, Crixás and Morro do Ouro) are today considered to be world-class gold mines and most of them related to orogenic systems. This is proof that the saga of Brazilian gold mining, despite finding renewed breath in different and previously unexplored parts of Brazil, still continues to be written in the same place where it began: in the fascinating Quadrilátero Ferrífero of Minas Gerais.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

*Acknowledgments*

Acknowledgments are due to Co Editor-in-Chief of OGR Huayong Chen, and to two anonymous reviewers for constructive criticism that greatly contributed to the improvement of the manuscript. Special thanks are due to Lydia M. Lobato and Steffen Hagemann, for the remarkable and careful review of the paper, and to Laura Lobato-Baars for reviewing the English and her valuable suggestions. The authors would also like to thank Rosaline Figueiredo e Silva, Mathias Heider, Armando José Massucatto, and the support of CNPq and CDTN/CNEN.

**Funding:** The conduct of the research was supported by CNPq (grant 304270/2018-0).

## Appendix A. Supplementary data

General table of active mines in Brazil from 1817 to 2020, including information on mine name, corporate group, ore type, capital, location, and tonnage. Supplementary data to this article can be found online at https://doi.org/10.1016/j.oregeorev.2022.105005.

## References

Ackerman, F.L., 1972. O Ouro na Amazônia. CPRM-Companhia de Pesquisas de Recuros Minerais, Belém, p. 57.
Adamy, A., Pereira, L.A.C., 1991. Projeto Ouro Gemas - Frente Rondônia. CPRM-Companhia de Pesquisa de Recursos Minerais, Relatório Anual. Porto Velho, p. 72.
Almeida, J.A.C., Dall'Agnol, R., Dias, S.B., Althoff, F.J., 2010. Origin of the Archean leucogranodiorite–granite suites: evidence from the Rio Maria terrane and implications for granite magmatism in the Archean. Lithos 120, 235–257.
Alves, D.B., 2014. Ernst Hasenclever em Gongo-Soco: exploração inglesa nas minas de ouro em Minas Gerais no século XIX. História, Ciências, Saúde-Manguinhos 21, 281–298.
Alves, D.B., 2015. Ernst Hasenclever, e suas viagens às Províncias do Rio de Janeiro e Minas Gerais (1839) Belo Horizonte: Fundação João Pinheiro, pp. 290.
Andrade Filho, H.R., La Brooy, S., Raponi, T.R., Michaud, R.L., Mathisen, M.B., 2020. NI 43–101 Technical Report on the Santa Luz Project. Equinox Gold Corp, Bahia State, Brazil, p. 131.
Andretta, E.R., 2020. Terras indígenas do noroeste do Amazonas: Geologia, geoquímica e cadastramento mineral na região do Tunuí-Caparro. CPRM-Serviço Geológico do Brasil, Manaus, p. 229.
Araújo, J.C.S. 2019. Modelo deposicional das formações ferríferas bandadas hospedeiras de ouro no greenstone belt arqueano Rio das Velhas, Quadrilátero Ferrífero, com base em geoquímica e análises in situ de magnetita por ablação a laser via ICP-MS. MSc., UFMG-Universidade Federal de Minas Gerais, Belo Horizonte, pp.183.
AngloGold Ashanti, 2011. Mineral Resource and Ore Reserve Report 2011. Technical Report: AngloGold Ashanti, pp. 240.
AngloGold Ashanti, 2019. Mineral Resource and Ore Reserve Report 2019. Technical Report: AngloGold Ashanti, pp. 240.
AngloGold Ashanti, 2019. Operacional Profile. AngloGold Ashanti, pp. 3.
Assis, R.R., Xavier, R.P., Barros, A.J.P., Barbueana, D., Trevisan, V.G., Ramos, G.S., Teixeira, R.V., Miguel Jr., E., Rodrigues, R.M., Stabile Jr., A., Santos, T.J.S., Miranda, G.M.T., Barros, M.A.S., Pinho, F.E.C., 2014. Metalogênese do Setor Leste da Província de Alta Floresta (MT), Cráton Amazônico. In: Silva, M.G., Rocha Neto, M. B., Jost, H., Kuyumjian, R.M. (Eds.), Metalogênese das Províncias Tectônicas Brasileiras. Belo Horizonte, CPRM-Companhia de Pesquisa de Recursos Minerais, pp. 305–340.
Barcelos, R., 2013. Casas de fundição e da moeda no Brasil e em Portugal: purificar o ouro, apurar as técnicas. População e Sociedade 143–163.
Barros, C.E.M., Sardinha, A.S., Barbosa, J.P.O., Krimski, R., Macambira, M.J.B., 2001. Pb-Pb and U-Pb zircon ages of archean syntectonic granites of the Carajas metallogenic province, northern Brazil. In: Proceedings of the South American Symposium on Isotopic Geology, pp. 94–97.
Berbert, C.O., Mello, J.C.R., 1973. Relatório de viagem à mina Chapéu do Sol, Crixás, Goiás. Companhia de Pesquisa de Recursos Minerais-CPRM, Diretoria de Operações, Goiânia, p. 73.
Berni, G.V., Heinrich, C.A., Lobato, L.M., Wall, V., 2016. Ore mineralogy of the Serra Pelada Au-Pd-Pt deposit, Carajás, Brazil and implications for ore-forming processes. Miner. Deposita 51, 781–795.
Bettencourt, J.S., Pinho, F.E.C., Barbosa, E.S., Boggiani, P., Geraldes, M.S., 2014. Metalogênese da Faixa Paraguai. In: Silva, M.G., Rocha Neto, M.B., Jost, H., Kuyumjian, R.M. (Eds.), Metalogênese das Províncias Tectônicas Brasileiras. Belo Horizonte, CPRM-Companhia de Pesquisa de Recursos Minerais, pp. 489–500.
Bettencourt, J.S., Juliani, C., Xavier, R.P., Monteiro, L.V.S., Neto, A.C.B., Klein, E.L., Assis, R.R., Leite Jr, W.B., Moreto, C.P., Fernandes, C.M.D., 2016. Metallogenetic systems associated with granitoid magmatism in the Amazonian Craton: An overview of the present level of understanding and exploration significance. J. S. Am. Earth Sci. 68, 22–49.
Big River Gold, 2019. Definitive Feasibility Gold Project - Borborema Gold Project. Belo Horizonte: Big River Gold-Cascar 2 volumes.
Biondi, J.C., 2003. Processos metalogenéticos e os depósitos minerais brasileiros. Oficina de Textos, São Paulo, p. 528.
Biondi, J.C., Franke, N.D., Carvalho, P.R.S., Villanova, S., 2002. Processo mineralizador e modelo genético da Mina de Ouro Schramm (SC-Brasil). Revista Brasileira de Geociências 32, 461–470.
Biondi, J.C., Franke, N.D., Carvalho, P.R.S., Villanova, S., 2004. Zonalidade vertical no corpo mineralizado da Mina de ouro Schramm (SC) - Detalamento do modelo genético. Revista Brasileira de Geociências 34, 147–156.
Biondi, J.C., Xavier, R.P., 2002. Fluidos associados à mineralização da mina de ouro Schramm, Complexo Granulítico Luis Alves (SC). Revista Brasileira de Geociências 32, 235–244.
Black, E., Lincoln, N., Rabb, T., Zurowski, G., 2020. Technical Report on the Aurizona Gold Mine. Equinox Gold Corp, Maranhão, Brazil, p. 375.
Blainey, G., 1969. The Rush That Never Ended: a history of Australian mining, 2nd edn,. Melbourne University Press, p. 464.
Borges, C.C.A., 2016. Petrografia, geoquímica e geocronologia das rochas metavulcânicas e metaplutônicas dos Greenstone Belts Faina e Serra de Santa Rita: implicações para o ambiente tectônico. MSc., UNB-Universidade de Brasília, pp. 121.
Burton, R.F., 1869. Explorations of the Highlands of the Brazil. A Full Account of Gold and Diamond Mines, canoeing down 1600 miles of the Great River São Francisco, from Sabará to the sea. Tinsley Brothers, London, p. 291.
Cabral, A.R., 2003. Palladiferous Gold Mineralisation (ouro preto) in Brazil: Gongo Soco, Itabira and Serra Pelada. Technical University of Clausthal, Clausthal, p. 101. PhD. Thesis.
Cabral, A.R., 2006. Palladiferous gold mineralisation (ouro preto) in Brazil: Gongo Soco, Itabira and Serra Pelada. Sonderhefte Reihe D - Geol Jahrbuch. Heft 8, 115.
Cabral, A.R., Lehmann, B., 2007. Seleniferous minerals of palladium and platinum from ouro preto-bearing mineralisation in Brazil. Ore Geol. Rev. 32, 681–688.
Cabral, A.R., Lehmann, B., Kwitko-Ribeiro, R., Jones, R., Pires, F.R.M., Rocha Filho, O.G., Innocentini, M.D., 2001. Palladium-oxygenated compounds of the Gongo Soco mine, Quadrilátero Ferrífero, central Minas Gerais, Brazil. Mineral. Mag. 65, 169–179.
Cabral, A.R., Lehmann, B., Kwitko-Ribeiro, R., Jones, R.D., Rocha Filho, O.G., 2003. On the association of palladium-bearing gold, hematite and gypsum in an ouro preto nugget. Canad. Mineral. 41, 473–478.
Cabral, A.R., Lehmann, B., Tupinambá, M., Schlosser, S., Kwitko-Ribeiro, R., Abreu, F.R., 2009. The platiniferous Au–Pd belt of Minas Gerais, Brazil, and genesis of its botryoidal Pt–Pd–Hg aggregates. Econ. Geol. 104, 1265–1276.
Cabral, A.R., Tupinambá, M., Zeh, A., Lehmann, B., Wiedenbeck, M., Brauns, M., Kwitko-Ribeiro, R., 2017. Platiniferous gold–tourmaline aggregates in the gold–palladium belt of Minas Gerais, Brazil: implications for regional boron metasomatism. Mineral. Petrol. 11, 807–819.
Calaghan E., 1958. Outside Gold Exploration Program. Technical Report. Nova Lima: Saint John dEl Rey Mining Company Limited/Morro Velho, pp. 14.
Calógeras, J.P., 1904. As Minas do Brasil e sua Legislação. Rio de Janeiro: Imprensa Nacional, Tomo I, 479.
Calógeras, J.P., 1957. Formação Histórica do Brasil, 4th ed. Companhia Editora Nacional, São Paulo, p. 511.
Calvert, A.F., 1915. Mineral Resources of Minas Geraes (Brazil). E. & F. N. Spon Limited, London, p. 100.
Camargo, W.G.R., 1957. A jazida de ouro de Morro velho, MG (contribuição ao conhecimento da gênese). Ph.D Thesis, USP-Universidade de São Paulo, pp.108.
Campos, L.D., 2013. O depósito de Au-Cu Lavra Velha, Chapada Diamantina Ocidental: Um exemplo de depósito da classe IOCG associado aos terrenos paleoproterozoicos do Bloco Gavião. MSc., UNB-Universidade de Brasília, pp117.
Canedo, G.F., 2016. Os depósitos Serrote da Laje e Caboclo (Cu-Au), Nordeste do Brasil: sulfetos magmáticos hospedados em rochas ricas em magnetita e ilmenita associadas a intrusões máficas-ultramáficas. MSc. UNB-Universidade de Brasília, p. 75.
Carlin, A.C., 2016. Características petrográficas e químicas das rochas encaixantes das mineralizações auríferas do depósito Lavra Velha (Região de Ibitiara, borda oeste da Chapada Diamantina. MSc., UNESP-Universidade Estadual Paulista, Bahia, p. 114.
Carneiro, A.J.S., 1908. Riquezas Mineraes do estado da Bahia. Reis & Company, Salvador, p. 152.

Carvalho, F.R.T., 2013. Rota do ouro: resgate da memória da mineração em Lavras do Sul através de seu patrimônio arquitetônico urbano. MSc., UFSM-Universidade Federal de Santa. Maria 88.
Cornejo, C., Bartorelli, A., 2010. Minerais e Pedras Preciosas do Brasil. Solaris Edições Culturais, São Paulo, p. 704.
Costa, M.N.S., 2010. Estudo dos Isótopos de Carbono e Oxigênio, e caracterização petrográfica dos corpos de minério da Mina de Cuiabá, Quadrilátero Ferrífero/MG. MSc., UFMG-Universidade Federal de Minas Gerais, Belo Horizonte, p. 127.
Costa, D.A., 2016. Rejuvenescimento do Potencial Exploratório de uma Área Madura Crixás Greenstone Belt: Rejuvenation of the Exploration Potential on a Mature Area (AngloGold Ashanti). VII SIMEXMIN-Simpósio Brasileiro de Exploração Mineral. Adimb-Agência de Desenvolvimento da Indústria Mineral Brasileira, pp. 39.
Costa, L.F., Rocha, M.M., 2007. Remessas do ouro brasileiro: organização mercantil e problemas de agência em meados do século XVIII. Análise Social 182, 77–98.
Costa, J.B.S., 1984. Aspectos litoestruturais e evolução crustal da região centro-norte de Goiás. Centro de Geociências da Universidade Federal do Pará, Belém, Ph.D. thesis, 210 pp.
CPRM, Serviço Geológico do Brasil, 2010. Metalogenia do distrito aurífero do Rio Juma-Nova Aripuanã. SGM-Serviço Geológico do Brasil, Manaus, AM, p. 46.
Craig, J., Rimstidt, D., 1998. Gold production history of the United States. Ore Geol. Rev. 13, 407–464.
Craveiro, G.S., Villas, R.N.N., Xavier, R.P., 2020. A Fluid Inclusion and Stable Isotope (O, H, S and C) study of the Archean IOCG Cristalino deposit, Carajás Mineral Province, Brazil: Implications to ore genesis. Ore Geol. Rev. 103822, 23.
Cristo, L.C.F., 2018. Estudo petrográfico e isotópico (Pb-Pb, U-Pb e Sm-Nd) de rochas encaixantes e mineralizações auríferas associadas ao greenstone belt Três Palmeiras, Volta Grande do Xingu, domínio Bacajá, Pará. MSc., UFPA-Universidade Federal do Pará, Belem, p. 65.
Cruz, E.L.C.C., Kuyumjiam, R.M., 1998. The geology andtectonic evolution of the Tocantins granite-greenstone terrane: Almass Dianópolis region, Tocantins State, Central Brasil. Rev. Bras. Geoc. 28 (2), 173–182.
Cruz, E.L.C.C., Kuyumjiam, R.M., 1999. Mineralizações auríferas filoneanas do terreno granito-greenstone do Tocantins. Rev. Bras. Geoc. 29 (3), 291–298.
Custódio, C.M., Laux, H., Sander, A., 2019. Seria a Mina Barcelos um exemplo de mineralização associadas a Suíte Vauthier (RS)? IV Simpósio Brasileiro de Metalogenia, Gramado, p. 2.
Dardenne, M.A., Botelho, N.F.M., 2014. Metalogênese da zona externa da Faixa Brasília. In: Silva, M.G., Rocha Neto, M.B., Jost, H., Kuyumjian, R.M., editors. Metalogênese das Províncias Tectônicas Brasileiras. Belo Horizonte: CPRM-Companhia de Pesquisa de Recursos Minerais, p. 431-454.
De Ferreira, T.H., Rios, F.J., 2021. The Miguel Burnier district: An encapsulation of Brazil's mining history. Extract. Indust. Soc. 8 (4), 19.
Del Mar, A., 1901. A History of the Precious Metals: From Earliest Times to the Present, 2nd ed. Cambridge Encyclopedia Company, New York, p. 467.
Del Mar, A., 1885. A History of money in ancient countries from the earliest times to the present: G. Bell, pp. 385.
Dorr II, J.V.N.,1957. Revisão da Estratigrafia Pré-Cambriana do Quadrilátero Ferrífero. Rio de Janeiro: DNPM-Departamento Nacional de Produção Mineral, Avulso 81, p. 31.
Dorr II, J.V.N., 1969. Physiographic, stratigraphic, and structural development of the Quadrilatero Ferrifero, Minas Gerais, Brazil. US Government Printing Office; Geological Survey Professional paper 641-A, pp.115.
Eschwege, W.L., 1979. Pluto Brasiliensis. Belo Horizonte/São Paulo: Livraria Itatiaia/ Edusp, 2 volumes.
Faleiros, A.M., 2012. Regimes de fluidos hidrotermais e formação de veios quartzo auríferos da Mina Morro do Ouro, Apiaí, SP. São Paulo, PhD Thesis, Universidade de São Paulo, pp.73.
Faraco, M.T.L., Fuzikawa, K., Ramboz, C., McReath, I., 2006. A fluid inclusion study in the hydrothermal volcanogenic sulfide and orogenic gold mineralization at the Serra do Ipitinga, Amazon, Brazil. Revista Brasileira de Geociências 36, 51–58.
Farias, S.O., 2008. Enredos e tramas nas Minas de Ouro de Jacobina. Recife: PhD Thesis, UFPe-Universidade Federal de Pernambuco, pp. 246.
Ferran, A., 1988. Depósito de ouro de Salamangone e Mutum, Calçoene, Amapá. In: DNPM/CVRD/CPRM, editors. Principais Depositos Minerais do Brasil, Volume III, Metais básicos não-ferrosos, ouro e alumínio. Brasília, p. 581-588.
Ferrand, P., 1913. L'Or à Minas Geraes (Brésil). Étude publiée par les soins da la Commission de l'exposition préparatoire de l'État de Minas Geraes, à Ouro Preto à l'occasion de l'Exposition minière et métallurgique de Santiago (Chili) en 1894. Belo Horizonte: Imprensa Official do Estado de Minas Geraes, vol. I, pp.165.
Ferrari, M.A.D. & Choudhuri, A. 2000. Chemical and structural constraints on the Paiol gold deposit, Almas greenstone belt, Brazil. *Rev. Bras. Geoc.*, **33**:297-301.
Ferraz, M., Kyle, J.R., Lobato, L.M., Ketcham, R.A., Figueiredo e Silva, R.C., Fernandes, R.C., 2020. Orogenic Gold in three-dimensions: case study of distinct mineralization styles at the world-class Cuiabá deposit, Brazil, using high-resolution X-ray computed tomography. In: SEG Chapters, 100 Student Showcase 2020, pp. 11.
Ferreira, J.V., 2013. Conflitos jurisdicionais no sertão do Ceará (1650–1750). MSc., UFPe-Universidade Federal de Pernambuco, Recife, p. 139.
Fleischer, R. Vial, D. S., 1983. Surface and Underground geological excursion around and in the Passagem de Mariana gold mine, Minas Gerais, Brazil. In: Thorman CH, Ladeira, E. A., Schnabel, D.C., editors. Gold Deposits Related to Greenstone Belts in Brazil - Deposit Modeling Workshop. Washington: US Geological Survey Bulletin, 1980-A, p. 49-62.
Fleischer, R., Routhier, P., 1973. The" Consanguineous" Origin of a Tourmaline-Bearing Gold Deposit, Passagem de Mariana (Brazil). Econ. Geol. 68, 11–22.
Fleischer, R., 1971. Le gisement aurifère à tourmaline de Passagem de Mariana (Minas Gerais-Brésil) et son cadre: influence de l'évolution structurale et métamorphisme sur une minéralisation syngénétique familière. Paris: PhD Thesis, Fac. des Sciences,: Université de Paris, pp.149.
Fortes, P.T.F.O., Gaspar, J.C., Coelho, R.F., Giuliani, G., Jost, H., Costa Jr., C.N., Moraes, R., Kuyumjian, R.M., Santos, R.V., Pimentel, M.M., 2001. Geologia das jazidas auríferas Mina III e Mina Nova, greenstone belt de Crixás (GO). In: Caracterização de depósitos auríferos em distritos mineiros brasileiros. Brasília: DNPM/ADIMB, p. 243-300.
Franco, F.A.C., 1989. Dicionário de Bandeirantes e Sertanistas do Brasil. Livraria Itatiaia/ Edusp, Belo Horizonte, p. 444.
Gair, J.E., 1958. Age of Gold Mineralization at the Morro Velho and Raposos Mines, Minas Gerais. São Paulo: Boletim da Sociedade Brasileira de Geologia, 7, p. 39-45.
Gastal, M.C., Ferreira, F.J.F., Cunha, J.U., Esmeris, C., Koester, E., Raposo, M.I.B., Rossetti, M.M.M., 2015. Alojamento do granito Lavras e a mineralização aurífera durante evolução de centro vulcano-plutônico pós-colisional, oeste do Escudo sul-riograndense: dados geofísicos e estruturais. Braz. J. Geol. 45, 217–241.
GE21, Consultoria Mineral, 2020. Mineral Resource and Mineral Reserve Estimate of the NX Gold Mine. ERO Copper Corp, Nova Xavantina Belo Horizonte, p. 179.
Gómez, J., Schobbenhaus, C., Monte Ramírez, N.E., compilers, 2019. Geological Map of South America 2018. Scale 1:5.000.000. Comission for the Geological Map of the World (CGMW), Colombian Geological Survey and Geological Survey of Brazil. Paris.
GPM - Great Panther Mining Ltd, 2021. Amended and Restated Technical Report on the 2020 Mineral Reserves and Mineral Resources of the Tucano Gold Mine, Amapá State. Brazil. Report for NI 43-101. Great Panther Mining Ltd, p. 378.
Grainger, C.J., Groves, D.I., Tallarico, F.H.B., Fletcher, I.R., 2008. Metallogenesis of the Carajás mineral province, southern Amazon craton, Brazil: Varying styles of Archean through Paleoproterozoic to Neoproterozoic base-and precious-metal mineralisation. Ore Geol. Rev. 33, 451–489.
Graton, L.C., Bjorge, G.N., 1929. Geology of Morro Velho Mine. Mineração Morro Velho, Saint John D'El Rey Mining Corp. Nova Lima, p. 251.
Graton, L.C., Bjorge, G.N., 1931. Second Report on the Morro Velho Mine, Nova Lima, Saint John D'El Rey Mining Corp. Mineração Morro Velho, Nova Lima, p. 83.
Groves, D.I., Goldfarb, R.J., Gebre-Mariam, M., Hagemann, S.G., Robert, F., 1998. Orogenic gold deposits: a proposed classification in the context of their crustal distribution and relationship to other gold deposit types. Ore Geol. Rev. 13, 7–27.
Guerra, M.F., 2004. The circulation of South American precious metals in Brazil at the end of the 17th century. J. Archaeol. Sci. 31, 1225–1236.
Guimarães, S.B., Klein, E.L., Lisboa, C.L., Souza, S.M., Castro, J.M.R., Queiroz, J.D., Feio, J.V.B., Lima, R.G.C., 2015. Metalogenia das Províncias Minerais do Brasil: Área sudeste do Tapajós, Estado do Pará. Stella Bijos Guimarães et al. Brasília, DF: CPRM – Serviço Geológico do Brasil, pp. 61.
Guimarães, S.B., Klein, E.L., Harris, C., Costa, I.S.L., 2020. Metallogenesis of the Orosirian epithermal Coringa gold-silver (Cu-Pb-Zn) deposit, Southeastern Tapajós Mineral Province, Amazonian craton, Brazil. Ore Geol. Rev. 103908, 61.
Heider, M., Costa, M.A., 2020. Nova Configuração da Cadeia Produtiva do Ouro no Brasil (2005–2020). Inthemine, XIV, pp. 9–11.
Huhn, S.R.B., Nascimento, J.A.S., 1997. São os depósitos cupríferos de Carajás do tipo Cu-Au-U-ETR.? Contribuições à Geologia da Amazônia. Belém: FINEP/SBG-PA, Volume 1, pp. 143-160.
Hussak, E, 1900. Riquezas Auríferas do Brazil. Tradução de Souza, H.C.A., Rio de Janeiro: 1933 (Relatório Técnico do DNPM, 1900, não publicado), pp.227.
Hussak, E., 1904. Über das Vorkommen von Palladium und Platin in Brasilien. Sitzungsber Kaiserl Akad Wiss, Wien, Math-Naturwiss Cl, Abt 1., CXIII, p. 379-468.
Jacobi, P., 2017. The discovery of epithermal Au-Cu-Mo proterozoic deposits in the Tapajós Province, Brazil. Revista Brasileira de Geociências 7, 277–279.
Jedwab, J., Cassedane, J., 1998. Historical observations on oxygen-bearing compounds of platinum and palladium in Minas Gerais, Brazil. Canad. Mineral. 36, 887–893.
Jost, H., Carvalho, M.J., Rodrigues, V.G., Martins, R., 2014. Metalogênese dos greenstone belts de Goiás. In: Silva, M.G., Rocha Neto, M.B., Jost, H., Kuyumjian, R.M. (Eds.), Metalogênese das Províncias Tectônicas Brasileiras. CPRM-Companhia de Pesquisa de Recursos Minerais, Belo Horizonte, pp. 141–168.
Jost, H., Apollo, J.F.H., Weber, W., Reis Salles, R., Marques, J.C., Massucatto, A.J., Costa, D.A., Santos, B.A., 2019. Stratigraphic update, paleotectonic, paleogeographic, and depositional environments of the Crixás Greenstone Belt, Central Brazil. J. S. Am. Earth Sci. 96, 22.
Juliani, C., 2002. Alteração hidrotermal e metalogênese em sistemas vulcano-plutônicos paleoproterozóicos na província aurífera do Tapajós, Cráton Sul Amazônico, Pará. Post-Doc, USP-Universidade de São Paulo, São Paulo, p. 183.
Juliani, C., Bettencourt, J.S., Monteiro, L.V.S., 2004. Modelos conceituais de depósitos paleoproterozóicos high-e low-sulfidation (Au, Cu-Mo±Au) e do tipo pórfiro (Au-Cu, Cu-Mo). In: na Província Aurífera do Tapajós (PA). Araxá: 42°Congresso Brasileiro de Geologia, p. 2.
Junqueira, P.A., Lobato, L.M., Ladeira, E.A., Simões, E.J.M., 2007. Structural control and hydrothermal alteration at the BIF-hosted Raposos lode-gold deposit, Quadrilátero Ferrífero, Brazil. Ore Geol. Rev. 32, 629–650.
Kaul, P.F.T., Rheinheimer, D., 1974. Projeto Ouro do Rio Grande do Sul e Santa Catarina 4 vol., 372.
Klein, E.L., Santos, R.A., Fuzikawa, K., Angélica, R.S.A., 2001. Hydrothermal fluid evolution and structural control of the Guarim gold mineralisation, Tapajós Province, Amazonian Craton, Brazil. Miner. Deposita 36, 149–164.
Klein, E.L., Moura, C.A.V., Harris, C., Giret, A., 2005. Reconnaissance stable isotope (C, O, H, S) study of Paleoproterozoic gold deposits of the São Luis Craton and country rocks, Northern Brazil: implications for gold metallogeny. Int. Geol. Rev. 47, 1131–1143.
Klein, E.L., Lafon, J.M., Brito, R.S.C., Vasconcelos, P., 2010. Fluid inclusion and isotopic constraints on the genesis of vein-quartz gold deposits of the Ipitinga Auriferous

District, SE-Guyana Shield. Brazil. Belém: Contribuições à Geologia da Amazônia 6, 19–38.
Klein, E.L., Rosa-Costa, L.T., Vasquez, M.L., 2014. Metalogênese da borda oriental do Cráton Amazônico. In: Silva, M.G., Rocha Neto, M.B., Jost, H., Kuyumjian, R.M., editors. Metalogênese das Províncias Tectônicas Brasileiras. Belo Horizonte: CPRM-Companhia de Pesquisa de Recursos Minerais, pp. 171-194.
Klein, E.L., Lucas, F.R.A., Queiroz, J.D.S., Freitas, S.C.F., Renac, C., Galarza, M.A., Jourdan, F., Armstrong, R., 2015. Metallogenesis of the Paleoproterozoic Piaba orogenic gold deposit, São Luís cratonic fragment, Brazil. Ore Geol. Rev. 65, 1–25.
Klein, E.L., Fuzikawa, K., Koppe, J.C., Dantas, M.S.S., 2017a. Fluids associated with the Caxias mesothermal gold mineralization, São Luís Craton, northern Brazil: a fluid inclusion study. Revista Brasileira de Geociências 30, 322–326.
Klein, E.L., Lopes, E.C.S., Tavares, F.M., Campos, L.D., Souza-Gaia, S.M., Neves, M.F., Perrotta, M.M., 2017. Áreas de relevante interesse mineral Cinturão Gurupi: estados do Pará e Maranhão. Brasília: Informe de Recursos Minerais, Série Províncias Minerais do Brasil, n° 11, CPRM-Serviço Geológico do Brasil, pp. 206.
Klemm, D., Klemm, R., Murr, A., 2001. Gold of the Pharaohs–6000 years of gold mining in Egypt and Nubia. J. Afr. Earth Sc. 33 (3–4), 643–659.
Kresse C., 2018. Isotopic, fluid inclusion and LA-ICP-MS studies on the worldclass Cuiabá gold deposit, Rio das Velhas greenstone belt, Quadrilátero Ferrífero, MG: implications for the mineralizing fluid reservoirs. Belo Horizonte: PhD. Thesis, UFMG-Universidade de Minas Gerais, pp. 109.
Kresse, C., Lobato, L.M., Hagemann, S.G., Silva, R.C.F., 2018. Sulfur isotope and metal variations in sulfides in the BIF-hosted orogenic Cuiabá gold deposit, Brazil: implications for the hydrothermal fluid evolution. Ore Geology Reviews, p. 98, p. 1-27.
Kresse, C., Lobato, L.M., Silva, R.C.F., Hagemann, S.G., Banks, D., Vitorino, A.L.A., 2020. Fluid signature of the shear zone–controlled Veio de Quartzo ore body in the world-class BIF-hosted Cuiabá gold deposit, Archaean Rio das Velhas greenstone belt, Brazil: a fluid inclusion study. Miner. Deposita 55, 1441–1466.
Krug, E., 1902. The Apiahy gold deposits. Brazilian Mining Review, Vol I 6, 174–175.
Kuyumjian, R.M., Oliveira, C.G., Oliveira, F.B., Borges, C.E.P., 2010. Depósito cobre-ouro porfirítico Chapada, Goiás. In: Modelos de depósitos de cobre do Brasil e sua resposta ao intemperismo, Programa Geologia do Brasil, Recursos Minerais. Série Metalogenia. Rio de Janeiro, CPRM-Serviço Geológico do Brasil, pp. 49–70.
Kuyumjian, R.M., Cruz, E.L.C.C., de Araujo Filho, J.O., Moura, M.A., Guimarães, E.M., da Silva Pereira, K.M., 2012. Geologia e ocorrências de ouro do Terreno Granito-Greenstone do Tocantins, TO: síntese do conhecimento e parâmetros para exploração mineral. Braz. J. Geol. 42 (1), 213–228.
Kwitko-Ribeiro, R., Cabral, A.R., Lehmann, B., Laflamme, J.H.G., Cabri, L.J., Criddle, A. J., Galbiatti, H., 2002. Hongshiite, PtCu, from itabirite-hosted Au–Pd–Pt mineralization (jacutinga), Itabira district, Minas Gerais, Brazil. Canad. Mineral. 40, 711–723.
Leonardos, O.H., 1970. Geociências no Brasil: a contribuição britânica. Editora Forum, Rio de Janeiro, p. 344.
Levat, M.E.D., 1898. Guide pratique pour la recherche et l'exploitation de l'or en Guyane Française. Vve C. Dunod, Paris, p. 268.
Lima, A., Rodrigues, R.M., Félix, N., Silva, M.A., 2011. Contribuição para o estudo da mineração romana de O Ouro na Serra de Banjas, Norte de Portugal. In: BETTENCOURT, A.., MARINS, C. (Ed.). Povoamento e exploração dos recursos mineiros na Europa Atlântica ocidental. CITCEM, Portugal, pp. 237–250.
Lins, F.A.F., Silva, L.A., 1985. Processamento de Minérios de Ouro. CETEM-Centro de Tecnologia Mineral, Rio de Janeiro, p. 112.
Lobato, L.M., Ribeiro-Rodrigues, L.C., Costa, M.N.S., Martins, R., Lehne, E., Alves, J.V., Tassinari, C.C.G., Vieira, F.W.R., Biasi, E.E., Silva, R.C.F., 2001. Depósito de ouro Cuiabá, Quadrilátero Ferrífero, Minas Gerais. Brasília: DNPM-Departamento Nacional da Produção Mineral/Adimb-Agência para o Desenvolvimento Tecnológico da Indústria Mineral Brasileira, p. 3-77.
Lopes Velho, J., 2006. Os Recursos Minerais. Uma visão geo-histórica; Palimage Editores: Viseu, Portugal, pp. 478.
Lott, C.P.M., Bessa, G.D., Vilela, O., 2004. Reabilitação de áreas e fechamento de minas. Brasil Mineral 228, 26–31.
Macambira, E.M.B., Klein, E.L., 2018. Potencial Aurífero do Domínio Tectonico Bacajá-Estado do Pará. In: SBG, editor. 49°Congresso Brasileiro de Geologia. Rio de Janeiro, pp.1.
Martins, R., 2000. Caracterização petrográfica e geoquímica mineral do minério da Mina de Ouro de Cuiabá, Quadrilátero Ferrífero, Minas Gerais. MSc., UFMG-Universidade Federal de Minas Gerais, Belo Horizonte, p. 112.
Martins, A.L, 1984. Breve História dos Garimpos de Ouro no Brasil. In: Em busca do ouro: Garimpos e Garimpeiros no Brasil. Rio de Janeiro: Editora Marco Zero., CONAGE, p. 177-215.
Martins, T.J., 2018. Quilombo do Campo Grande: história de Minas que se devolve ao povo. Belo Horizonte, Santa Clara Ed., pp. 1032.
Matheson, A.F., 1956. The Saint John del Rey Mining Company, Limited, Minas Gerais. Brazil. Bull Can Min Met. 49, 37–43.
Mathis, A., 1995. Serra Pelada. Paper do NAEA 50, 1–15.
Maxwell-Hyslop, K.R., 1977. Sources of Sumerjan Gold the Ur Goldwork from the Brotherton Library, University of Leeds. A Preliminary Report. Iraq 39 (1), 83–86.
Meneses, H.D.N.D.M., Oliveira-da-Costa, M., Basta, P.C., Morais, C.G., Pereira, R.J.B., de Souza, S.M.S., Hacon, S.D.S., 2022. Mercury Contamination: A Growing Threat to Riverine and Urban Communities in the Brazilian Amazon. Int. J. Environ. Res. Public Health 19 (5), 2816.
Minter, W., 1975. Sedimentological Aspects of the Serra do Córrego Formation with Particular Reference to the Main Reef unit at Cus-Cuz and Morro do Vnto near Jacobina. Occasional Report to Anglo American Corporation of South Africa Limited, Bahia, Brazil, p. 11.
Molinari, L., 1981. Mineralizações auríferas em Jacobina-BA. Simpósio sobre Mineralizações Auríferas no Estado da Bahia. Salvador, Sociedade Brasileira de Geologia, Núcleo Bahia, Secretaria das Minas e Energia, pp. 26–31.
Monem, R.M., 1999. Economic prosperity of the gold-mining industry in Australia and the consequent gold tax. Account., Busin. Financial History 9 (3), 307–323.
Monteiro L.V.S., Juliani, C., Fernandes, C.M.D., 2016. Cobre no Brasil: Cenário Atual e Potencial Metalogenético. VII SIMEXMIN- Simposio Brasileiro de Exploração Mineral. Ouro Preto: Adimb-Agência de Desenvolvimento da Indústria Mineral Brasileira, pp. 49.
Moura, P., 1936. Rio Gurupy. SGM-Serviço Geológico e Mineralógico. Boletim 78, 82.
Mudd, G.M., 2007. Gold mining in Australia: linking historical trends and environmental and resource sustainability. Environ. Sci. Policy 10 (7–8), 629–644.
Nogueira, S.A.A., Bettencourt, J.S., Tassinari, C.C.G., 2017. Geochronology of the granitoid hosted Salamangone Gold Deposit, Lourenço District, Amapá, Brazil. Revista Brasileira de Geociências 30, 261–264.
Noya Pinto, V., 1979. O ouro brasileiro e o comércio anglo-português: (Uma contribuição aos estudos de economia atlântica no século XVIII). Rio de Janeiro. Companhia Editora Nacional 369.
Oliveira, A.I., 1937. Recursos Mineraes do Rio Branco. Mineração e Metalurgia, Volume I 6, 243–249.
Oliveira, A.I., Barbosa, O., 1940. Relatório da Diretoria - 1938. Rio de Janeiro: DNPM-Departamento Nacional de Produção Mineral, SFPM-Serviço de Fomento da Produção Mineral, Boletim 41, pp. 187.
Oliveira, A.I., Barbosa, O., 1943. Relatório da Diretoria - 1940. Rio de Janeiro: DNPM-Departamento Nacional de Produção Mineral, SFPM-Serviço de Fomento da Produção Mineral, Boletim 57, pp. 95.
Oliveira, M.A., Dall'Agnol, R., Althoff, F.J., 2016b. A Petrografia e geoquímica do Granodiorito Rio Maria da região de Bannach e comparações com as demais ocorrências no terreno Granito-Greenstone de Rio Maria-Pará. Revista Brasileira de Geociências 36, 313–326.
Oliveira, C.G., Oliveira, F.B., Della Giustina, M.E.S., Marques, G.C., Dantas, E.L., Pimentel, M.M., Buhn, B.M., 2016a. The Chapada Cu–Au deposit, Mara Rosa magmatic arc, Central Brazil: constraints on the metallogenesis of a Neoproterozoic large porphyry-type deposit. Ore Geol. Rev. 72, 1–21.
Oliveira, G.A.I., 1975. Projeto Lapa Seca, texto e mapas, escala 1:10.000. Nova Lima, Internal report, Mineração Morro Velho, pp. 200.
Olivo, G.R., Gauthier, M., Williams-Jones, A., Levesque, M., 2001. The Au-Pd mineralization at the Conceição iron mine, Itabira district, southern Sao Francisco craton, Brazil: an example of a jacutinga-type deposit. Econ. Geol. 96, 61–74.
Paiva, G., Souza, H.C.A., Abreu, S.F., 1937. Ouro e Bauxita na Região do Rio Gurupi (Pará-Maranhão). Rio de Janeiro: DNPM-Departamento Nacional de Produção Mineral, Avulso 13, 207.
Paiva, E.F., 2002. Bateias, Carumbés, Tabuleiros: mineração africana e mestiçagem no mundo novo. In: Anastasia, C.M.J., Paiva, E.F., O trabalho mestiço: maneiras de pensar e formas de viver, séculos XVI a XIX. São Paulo: Annablume, p. 3-16.
Palermo, N., Porto, C.G., Costa Jr, C.N., 2000. The Mara Rosa gold district, central Brazil. Revista Brasileira de Geociências 30, 256–260.
Peale, R., 1958. Preliminary Report: Geology of the Gold Properties, Saint John ́El Rey Min. Co., Ltd. Internal report. Saint John ́El Rey Mining Company, Limited, Nova Lima, p. 19.
Pearson, H., 1906. The Goldfield Of Paracatu, Minas Geres. Brasil. Transactions Intitute Mining Engineering, XXXI, pp. 257–263.
Pereira, S.L.M., 1995. Controles litoestruturais da mineralização aurífera no distrito de Santa Bárbara, Quadrilátero Ferrífero, MG: Mina São Bento. MSc., UFMG-Universidade Federal de Minas Gerais, Belo Horizonte, p. 158.
Pinho, F.E.C., Barboza, E.S., Fernandes, C.J., 2010. Depósito de Cobre de Cabaçal, Mato Grosso. In: Modelos de Depósitos de Cobre do Brasil e sua resposta ao intemperismo. Brasíla, CPRM, Companhia de Pesquisa de Recursos Minerais, pp. 127–146.
Poll, N.J., 1994. Geology of the Zacarias gold-silver-barite deposit. MSc., Colorado School of Mines, Goiás State, Brazil, p. 124.
Pollard, P.J., Taylor, R.G., Peters, L., Matos, F., Freitas, C., Saboia, L., Huhn, S., 2019. $^{40}Ar$-$^{39}Ar$ dating of Archean iron oxide Cu-Au and Paleoproterozoic granite-related Cu-Au deposits in the Carajás Mineral Province, Brazil: implications for genetic models. Miner. Deposita 54, 329–346.
Ponte Neto, O., 1998. A evolução da produção de ouro no Estado da Bahia. MSc., Unicamp-Universidade Estadual de Campinas, Campinas, p. 134.
Puche Riart, O., 2001. La mineria del oro durante el periodo colonial en la cultura española. In *El libro de la minería del oro en Iberoamérica.* Coedita, Ed. ESPI, J. A.. Madrid, pp. 41-49.
Quadros, M.L.E.S., 2020. Geologia, geoquímica e geocronologia das rochas da Suíte Rio Branco, Cinturão Nova Brasilândia e implicações na evolução do orógeno Sunsás no sudoeste do Cráton Amazônico. Brasília: PhD. Thesis, UNB-Universidade de Brasília 132.
Renger, F.E., 1999. Direito mineral e mineração no Códice Costa Matoso (1752). Varia História 156–170.
Renger, F.E., 2006. O quinto do ouro no regime tributário nas Minas Gerais. Revista do Arquivo Público Mineiro 42, 90–105.
Ribeiro, V.B., Mantovani, M.S.M., 2016. Gamma spectrometric and magnetic interpretation of Cabaçal copper deposit in Mato Grosso (Brazil): Implications for hydrothermal fluids remobilization. ournal of. Appl. Geophys. 35, 223–231.
Ribeiro-Rodrigues, L.C., Friederich, G., Oliveira, C.G., Vieira, F.W.R., Callegari, L.A., Biasi, E.E., 1994. Ore textures and structures of the Archean banded iron formation Cuiabá gold deposit, Iron Quadrangle, Minas Gerais, Brazil. Zbl Geol und Palaont, Teil. 1, 627–642.

Ribeiro-Rodrigues, L.C., Oliveira, C.G., Friedrich, G., 2007. The Archean BIF-hosted Cuiabá Gold deposit, Quadrilátero Ferrífero, Minas Gerais, Brazil. Ore Geol. Rev. 32, 543–570.
Ribeiro-Rodrigues, L.C., 2007. Gold mineralization in Archean banded iron-formation of the Quadrilátero Ferrífero: The Cuiabá Mine. Minas Gerais, Brazil. Belo Horizonte: PhD. Thesis, UFMG-Universidade Federal de Minas Gerais, pp.264.
Richardson, P., Van Helten, J.-J., 1984. The development of the South African gold-mining industry, 1895–1918. Economic History Review 319–340.
Rios, F.J., 2018. Ouro no Brasil, História dos Caminhos Esqueçidos. Belo Horizonte: CDTN-Centro de Desenvolvimento da Tecnologia Nuclear, 1st Ed,, p. 271.
Rios, F.J., Villas, R.N., DalÍAgnol, R., 1995. O granito Serra dos Carajás: l, fácies petrográficas e avaliação do potencial metalogenético para estanho no setor norte. Revista Brasileira de Geociências. 25, 20–31.
Rocha. A.M.R., Dorneles, N.T., Gindri, M.D., Rizzardo, R., Rosenstengel, L.M., 2013. Projeto Cerro Dourado: Descoberta de um sistema epitermal Hot Spring no escudo sul-riograndense, Lavras do Sul, Brasil. (Grupo Mining Ventures, Brasil). III et alletSimpósio Brasileiro de Metalogenia. Gramado, pp. 51.
Rodrigues, J. P.M., 2006. Bartolomé de las Casas: a pena contra a espada. MSc thesis, UFPe-Universidade Federal de Pernambuco, Recife, 127 pp.
Romanini, S.J., 2000. Geologia e Resultados Prospectivos da área Nova Brasilândia-Rondônia. CPRM-Companhia de Pesquisa e Recursos Minerais, Projeto Platina e Associados. Porto Alegre, p. 45.
Roncato Jr., J.G., 2016. Evolução de turbiditos e sua mineralização aurífera no lineamento Córrego do Sítio e área Cuiabá-Lamego: geoquímica, geocronologia e in situ LA-ICP-MS em sulfetos. MSc., UFMG-Universidade Federal de Minas Gerais, Belo Horizonte, p. 191.
Ronchi, L.H., Lobato, A.O.C., 2000. Minas do Camaquã: um estudo multidisciplinar. Unisinos-Universidade do Vale do Rio dos Sinos, São Leopoldo, p. 366.
RPA, 2018. Technical Report on the Fazenda Brasileiro Mine, Goiás State, Brazil. RPA - Roscoe Postle Associates Inc. to Lundin Mining Corporation, Toronto, p. 197.
RPA, 2019. Technical Report on the Chapada Mine, Goiás State, Brazil. RPA - Roscoe Postle Associates Inc. to Lundin Mining Corporation, Toronto, p. 252.
RTZ - Rio Tinto Zinc, 2008. Encerramento da Mina Cabaçal - Mineração Manati. In: RTZ, Seminário “Encerramento de Mina: Aspectos Ambientais e Sócioeconômicos”, pp. 17.
RPA, 2020. Technical Report on the Pilar Operations, Goiás State, Brazil. RPA - Roscoe Postle Associates Inc. to Equinox Gold Corporation, Toronto, p. 281.
Ruiz, A.S., Quadros, M.L.E.S., Fernandes, C.J., Palmeira, L.C.M., Pinho, F.E.C., 2014. Metalogênese da Província Sunsás. In: Silva, M.G., Rocha Neto, M.B., Jost, H., Kuyumjian, R.M. (Eds.), Metalogênese das Províncias Tectônicas Brasileiras. Belo Horizonte, CPRM-Companhia de Pesquisa de Recursos Minerais, pp. 295–304.
Russel-Wood, A.J.R., 1990. O Brasil Colonial: O Ciclo do Ouro, c. 1690-1750. In: América Latina Colonial. São Paulo: Edusp/FUNAG, editor., Bethel, L. (Org), p. 471-525.
Santiago, E.S.B., Villas, R.N.N., Ocampo, R.C., 2013. The Tocantinzinho gold deposit, Tapajós Province, Pará state: host granite, hydrothermal alteration and mineral chemistry. Revista Brasileira de Geociências 43, 183–208.
Santos, F.R.P., 2014. Geologia e petrografia do Grupo Alto Jauru, na região da Fazenda Retiro, SW do Cráton Amazônico: evidências de um prisma acrescionário estateriano. MSc., UFMT-Universidade Federal de Mato Grosso, Cuiabá, p. 68.
Santos, J.O.S., Hartmann, L.A., Gaudette, H.E., Groves, D.I., McNaughton, N.J., Fletcher, I.R., 2000. A new understanding of the provinces of the Amazon Craton based on integration of field mapping and U-Pb and Sm-Nd geochronology. Gondwana Res. 3, 453–488.
Santos Pires, A.O., 1905. The History of Brazilian Mining. Brazilian Engineering Mining Review 10, 166–167.
Santos, J.O.S., 2003. Geotectônica dos Escudos das Guianas e Brasil-Central, Geotectonics of the Guyana and Central Brazilian Shields. In: Bizzi, LA., Schobbenhaus, C., Vidotti, R.M, Gonçalves, J.H., Geologia, Tectônica e Recursos Minerais do Brasil: texto, mapas e SIG. Brasília: CPRM-Companhia de Pesquisa de Recursos Minerais, p. 169-226.
Scarpelli, W., Horikava, E.H., 2017. Gold, iron and manganese in central Amapá. Brazil. Brazilian Journal of Geology. 47, 703–721.
Scarpelli, W., Horikava, E.H., 2018. Chromium, iron, gold and manganese in Amapá and northern Pará, Brazil. Braz. J. Geol. 48, 415–433.
Schmaltz, W.H., Guimarães, G., 1983. Garimpos do Brasil. Brasília: DNPM-Divisão de Fomento da Produção Mineral. Av. 5, 313.
Schrank, A., Machado, N., 1996. Idades U-Pb em monazitas e zircões do distrito aurífero de Caeté, da mina de Cuiabá e do depósito de Carrapato-Quadrilátero Ferrífero (MG). 39th Congresso Brasileiro de Geologia. SBG-Sociedade Brasileira de Geologia/BA, Salvador, pp. 473–475.
Scott, H.K., 1902. The gold field of the state of Minas Geraes, Brazil. Transactions of the American Institute of Mining Engineers. 33, 406–444.
Semblano, F.R.D., Macambira, M.J.M., Vasquez, M.L., 2016. Petrography, geochemistr y and Sm-Nd isotopes of the granites from eastern of the Tapajós Domain, Pará state. Braz. J. Geol. 46, 509–529.
Shaw, E.W., Wright, W.H., Darnell, J., 1925. Mineral resources of Maranhão, Brazil. Econ. Geol. 20, 723–728.
Shimada, H., 2013. Mina do Morro do Ouro, Apiaí, SP–A transformação em parque. Boletim Paranaense de Geociências 70, 180–189.
Silva, M.S., Rocha Neto, M.B., Jost, H., Kuyumjian, R.M., 2014. Metalogênese das províncias tectônicas brasileiras. Rio de Janeiro: Programa Geologia do Brasil, Recursos Minerais, Série Metalogenia. CPRM-Serviço Geológico do Brasil, pp. 590.
Silva, F.C., 1997. Barões do ouro e aventureiros britânicos no Brasil: a Companhia Inglesa de Macaúbas e Cocais, 1828-1912. São Paulo: PhD. Thesis, FAFICH-Faculdade de Filosofia, Letras e Ciências Humanas, USP-Universidade de São Paulo, pp. 151.
Simões, M.S., Meloni, R.E., Santos, J.O.S., 2020. Stratigraphy, depositional environments and zircon U-Pb (LA-ICP-MS) ages of the Statherian volcano-sedimentary Beneficente Group: Implications for tectonics and gold mineralization in SW of the Amazon Craton. Precambr. Res. 345 (105756), 23.
Simonsen, R.C., 1977. História Econômica do Brasil, 1st ed. Companhia Editora Nacional, São Paulo, p. 587.
Sims, J., 2020. Paracatu Mine Brazil National Instrument NI 43-101. Technical Report for Kinross Gold Corporation, pp. 158.
Siqueira, L.T., 1973. Geologia de Raposos (II Simpósio de Mineração). Capítulo VII. Geologia e Metalurgia (CMR-Centro Moraes Rego) 33, 30.
Siqueira, L.T., Oliveira, G.A.I., 1974. Projetos de Pesquisas da Morro Velho (IV Simpósio de Mineração). Geologia e Metalurgia CMR-Centro Moraes Rego) 35, 59–73.
Sousa, C.S., Coelho Neto, M.C., 2014. Programa Geologia do Brasil-PGB., Lourenço. Folha NA.22-V-D, Estado do Amapá. In: CPRM-Companhia de Pesquisa de Recursos Minerais Minerais, Série Carta Geológica. Belém, escala 1:250.000.
Souza, V.S., Kotschoubey, B., 2005. Geologia e mineralizações auríferas do garimpo do Manelão, região do médio rio Bacajá (PA). Contribuições à geologia da Amazônia 4, 151–163.
Souza, E.L.R.G., Soares, H., Marsden, L., Vasquez, Iturralde, C., 2020. NI 43–101 Technical Report-Jacobina Gold Mine. Technical Report to Yamana Gold Inc., Bahia State, Brazil, p. 205.
Spier, C.A., Ferreira Filho, C.F., 2017. Geologia, estratigrafia e depósitos minerais do Projeto Vila Nova, escudo das guianas, Amapá, Brasil. Revista Brasileira de Geociências 29, 173–178.
Strydom, P.M., Minter, W., 1975. A Stratigraphic and Sedimentological Report of the Main Reef in the Itapicurú Prospect near Jacobina, Bahia, Brazil. Geology Department, Welkom Office, OFS Gold uranium Division, Anglo American Corporation of South Africa Limited, pp. 20.
SRK, 2003. Independent Technical Report On The Crixas Mine, Brazil. SRK - Steffen, Robertson and Kirsten Inc., Technical Report, Toronto, p. 80.
SRK, 2020. NI 43–101 Technical Report, Definitive Feasibility Study, Posse Gold Project, Brazil. SRK - Stefen, Robertson and Kirsten Inc, Technical Report, Belo Horizonte, p. 858.
Tallarico, F.H.B., Figueiredo, B.R., Groves, D.I., Kositcin, N., McNaughton, N.J., Fletcher, I.R., Rego, J., 2005. Geology and SHRIMP U-Pb geochronology of the Igarapé Bahia deposit, Carajás copper-gold belt, Brazil: An Archean (2.57 Ga) example of iron-oxide Cu-Au-(U-REE) mineralization. Econ. Geol. 100, 7–28.
Teixeira, M.F.B., Dall’Agnol, R., Santos, J.O.S., Kemp, A., Evans, N., 2019. Petrogenesis of the Paleoproterozoic (Orosirian) A-type granites of Carajás Province, Amazon Craton, Brazil: Combined in situ HfO isotopes of zircon. Lithos 332, 1–22.
Teixeira, E.A., Leinz, V., 1942. Ouro no Bloco do Butiá. Rio de Janeiro: DNPM-Departamento Nacional de Produção Mineral, DFPM-Serviço de Fomento da Produção, Boletim 50, 83.
Teixeira, J.B.G., 2019. Ouro na Bahia – Metalogênese e Potencial Exploratório. Salvador: CBPM-Companhia Baiana de Pesquisa Mineral, Publicação Especial, Volume 23, pp. 383.
Toledo, C.L.B., Xavier, R.P., Schrank, A., Vieira, F.W., La Rosa, M.T., Silva, D., 1988. The fluid-carbonaceous matter interaction and the deposition of gold at the Cuiabá Mine. SBG-Sociedade Brasileira de Geologia/MG, SE Brazil. XLI Congresso Brasileiro de Geologia. Belo Horizonte, p. 177.
Toledo, F.H., 1998. O deposito de ouro do Cabaçal, Mato Grosso: estudos isotopicos aplicados a mineralização. Brasília: MSc., Unicamp-Universidade Estadual de Campinas, pp. 104.
Vasquez, M.L., Rosa-Costa, L.T., 2008. Geologia e Recursos Minerais do Estado do Pará. Programa Geologia do Brasil, mapas geológicos estaduais, scala 1:1.000.000. Belém: CPRM-Companhia de Pesquisa de Recursos Minerais, pp. 329.
Toniolo Busnello, S.A., 1994. Mineradora Barro Alto, Projetos Aurilândia e Aurumina. Toniolo Busnello p. 26.
Veloso, A.S.R., Santos, M.D., Rios, F.J., 2013. Evolução dos fluidos mineralizantes e modelo genético dos veios de quartzo auríferos em zona de cisalhamento do depósito Ouro Roxo, Província Tapajós, Jacareacanga (PA), Brasil. Braz. J. Geol. 43, 725–744.
Vial, D.S., 1980. Mapeamento Geológico do nível 3 da Mina de Cuiabá. Gerência de Geologia/Mineração Morro Velho S.A, Nova Lima, p. 25.
Vial, D.S., 1988. Mina de ouro de Cuiabá, Quadrilátero Ferrífero, Minas Gerais. In: Schobbenhaus, C., Coelho, C.E.S. (Eds.), Principais Depósitos Minerais do Brasil. Brasília, DNPM-Departamento Nacional de Produção Mineral, pp. 413–419.
Vial, D.S., 1991. Introduction to the geology of the Quadrilátero Ferrífero - field and mine trip to Quadrilátero Ferrífero of Minas Gerais, Brazil. In: Fleischer, R., Grossi Sad, J.H., Fuzikawa, K. and Ladeira, E.A., editors. Brazil Gold’91, Rio de Janeiro: Balkema, Rotterdam, p. 4-22.
Viana, S.Q., 2019. Geocronologia U-Pb e Geoquímica Isotópica Nd-Hf dos Granitóides Transamazônicos do Domínio Paleoproteroizo Lourenço, Sudeste do Escudo das Guianas. MSc., UFPA-Universidade Federal do Pará, Belém, p. 121.
Vieira, F.W.R., 1988a. Caracterização petrográfica e Mineralógica do Minério do Corpo Galinheiro extensão open-pit - Cuiabá. Gerência de Geologia/Mineração Morro Velho S.A, Nova Lima, p. 5.
Vieira, F.W.R., 2000. Geologia da Mina de Ouro de Cuiabá, Quadrilátero Ferrífero. In: Quadrilátero Ferrífero Workshop AngloGold 2000. Nova Lima, Gerência de Geologia/Mineração Morro Velho S.A, pp. 1–13.
Vieira, F.W.R., Corbani Filho, M., Fonseca, J.T F., Pereira, A., Oliveira, G.A.I., Clemente, P.L.C., 1986. Excursion to the Cuiabá Gold Mine, Minas Gerais. In: Thorman, C.H., Ladeira, E.A., and Schnabel, D.C, editors. Gold Deposits Related to Greenstone Belts in Brazil-Deposit Modeling Workshop. Washington: Government Printing Office-US Geological Survey Bulletin, pp. 30.
Vieira, J.A.N., 1988. Mina de Cuiabá-Passado, Presente e Futuro. 12º Simpósio Internacional de Mineração. Belo Horizonte: Revista Minerais e Minérios, pp. 33.

Vitorino, A.L.A., 2017. Mineralização aurífera associada aos veios quartzo-carbonáticos hospedados na unidade máfica basal da jazida Cuiabá, *greenstone belt* Rio das Velhas, Quadrilátero Ferrífero, Minas Gerais, Brasil. MSc., UFMG-Universidade Federal de Minas Gerais, Belo Horizonte, p. 250.

Wieller, A.L., 1977. Projeto Formação de Ferro. Texto e Mapas 1:10.000. Mineração Morro Velho, Nova Lima, p. 20.

Xavier, R.P., Toledo, C.L.B., Taylor, B., Schrank, A., 2017. Fluid evolution and gold deposition at the Cuiabá mine, SE Brazil: fluid inclusions and stable isotope geochemistry of carbonates. Revista Brasileira de Geociências 30, 337–341.

Zhang, R., Pian, H., Santosh, M., Zhang, S., 2015. The history and economics of gold mining in China. Ore Geol. Rev. 65, 718–727.

Zini, A.F., Forlim, R., Andreazza, P., Souza, A., 1988. Depósito de ouro do Morro do Ouro, Paracatu, Minas Gerais. In: Schobbenhaus, C., Coelho, C.E.S. (Eds.), Principais Depósitos Minerais do Brasil. Brasília, DNPM-Departamento Nacional de Produção Mineral, pp. 479–489.