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Artículo

The Intertwined Architectural and Geological Heritage of Ouro Preto, Minas Gerais, Southeastern Brazil

El patrimonio arquitectónico y geológico entrelazado de Ouro Preto, Minas Gerais, Sureste de Brasil

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Abstract: Ouro Preto, located in the state of Minas Gerais, Brazil, is a city rich in historical, geological, and cultural significance. It was built during the gold rush of the 17th and 18th centuries in the colonial period, and its urban architecture has been remarkably preserved to this day. Ouro Preto is strategically located in the Iron Quadrangle, a globally important mineral province with a complex geological setting spanning from the Archean to the Proterozoic eon. The city is renowned for the exploration of conventional mineral resources such as gold, iron, manganese, uranium, gems, etc., as well as the extraction of ornamental rocks, particularly quartzite, soapstone, marble, and gneisses. These rocks, part of the Qfe stratigraphic framework, were used to construct the architectural heritage in the Baroque and Rococo styles, many of which were crafted by the hands of the artist Aleijadinho (Antônio Francisco Lisboa). Ancient quarries preserved around Ouro Preto, or even within the urban area, are remnants of rock extraction and are an integral part of the city's historical heritage. They have become a popular tourist attraction and a subject of scientific studies. Knowledge of the conection between the Qfe rocks and the historical monuments in the city of Ouro Preto emphasizes and enriches its legacy as a global geological and architectural heritage, affirming its status as a fundamental human heritage.

Keywords: Architectural heritage; Quarries; Ouro Preto; Brazil

Key points:

Ouro Preto, located in the state of Minas Gerais, Brazil, is a city rich in historical, geological and cultural significance.

The rocks that form part of the stratigraphic framework of Qfe, were used to build the architectural heritage of the baroque and rococo styles.

The old quarries that are preserved in the surroundings of Ouro Preto, or even within the city centre, are vestiges of rock extraction and are part of the historical heritage of the city.

Resumen: Ouro Preto, situada en el estado de Minas Gerais, Brasil, es una ciudad rica en significado histórico, geológico y cultural. Fue construida durante la fiebre del oro de los siglos XVII y XVIII, en la *época* colonial, y su arquitectura urbana se ha conservado notablemente hasta nuestros *días.* Ouro Preto está estratégicamente situada en el Cuadrángulo de Hierro, una provincia mineral de importancia mundial con un complejo entorno geológico que abarca desde el Arcaico hasta el Proterozoico. La ciudad es conocida por la exploración de recursos minerales convencionales, como oro, hierro, manganeso, uranio, gemas, etc., así como por la extracción de rocas ornamentales, en particular cuarcita, esteatita, mármol y gneises. Estas rocas, que forman parte del marco estratigráfico de Qfe, se utilizaron para construir el patrimonio arquitectónico de los estilos barroco y rococó, muchos de los cuales fueron elaborados por las manos del artista Aleijadinho (Antônio Francisco Lisboa). Las antiguas canteras que se conservan en los alrededores de Ouro Preto, o incluso dentro del casco urbano, son vestigios de la extracción de roca y forman parte del patrimonio histórico de la ciudad. Se han convertido en una popular atracción turística y son objeto de estudios científicos. El conocimiento de la conexión entre las rocas de Qfe y los monumentos históricos de la ciudad de Ouro Preto enfatiza y enriquece su legado como patrimonio geológico y arquitectónico global, afirmando su condición de patrimonio humano.

Palabras clave: Patrimonio arquitectónico; canteras; Ouro Preto; Brasil.

Puntos clave:

Ouro Preto, situada en el estado de Minas Gerais, Brasil, es una ciudad rica en significado histórico, geológico y cultural.

Las rocas que forman parte del marco estratigráfico de Qfe, se utilizaron para construir el patrimonio arquitectónico de los estilos barroco y rococó.

Las antiguas canteras que se conservan en los alrededores de Ouro Preto, o incluso dentro del casco urbano, son vestigios de la extracción de roca y forman parte del patrimonio histórico de la ciudad.

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Información complementaria ↓

1. INTRODUCTION

Old cities are vital cultural and historical repositories, encapsulating the development of human civilizations through their preserved architectures and urban layouts. These cities are often the birthplaces of significant political movements, urban engineering and architectural advancements, and technological innovations (e.g., Scully, 2013). Moreover, old cities often continue to influence contemporary culture, while fostering a sense of identity and continuity for their inhabitants. As living museums, these cities are crucial in educating current and future generations, preserving a rich heritage that might otherwise be lost (e.g., Lemos, 1996).

The intricate relationship between old architectures and the geological context of a region is a fascinating study of how natural environments influence human constructions. Throughout history, the geological features of a location have dictated the materials available for building and, by extension, the architecture styles that emerge. Moreover, the choice of building materials often reflects the economic and cultural elements of a time period, influenced by the abundance and ease of material transport and the technological capabilities of the era (e.g., Mason, 2009).

Ouro Preto, Minas Gerais state, is an example of a city steeped in rich historical and cultural significance. Founded during the colonial period, it is recognized for its historical and geological prominence. This is a consequence of this city's role during the gold rush of the 17th and 18th centuries, a period marked by intense European colonization and extensive mineral exploitation. Ouro Preto is located in the Quadrilátero Ferrífero, a globally significant mineral province, endowed with a complex geological scenario, which spans from the Archean to the Proterozoic era. The city is not only famous for its exploitation of conventional mineral resources (e.g., Au, Fe, Mn, U, gems, etc.) but also for its ornamental stones such as marbles, quartzites, and soapstones, which continue to be a key part of its social-economic development.

Thus, Ouro Preto serves as a natural laboratory for understanding how buildings and structures are designed and constructed, considering the materials used and their suitability based on the geological context of the region. This work aims to provide an overview of the old architecture of Ouro Preto within the geological framework of the Iron Quadrangle, emphasizing that this exploration extends beyond aesthetic and material choices to include a dialogue between the Earth's geological history and human creativity. This interplay has given rise to a diverse architectural heritage that reflects and responds to the environment from which it emerged.

2. ARCHITECTURAL AND GEOLOGICAL HERITAGE CONTEXT OF OURO PRETO

Ouro Preto, considered as a "gem" of colonial architecture nestled in the mountains of Minas Gerais, southeastern Brazil, stands as a spot of historical and cultural preservation (Figure 1). Once the thriving capital of a gold-rich state in the 17-18th centuries, the city's unique architectural landscape was shaped by the era's prosperity and subsequent decline. The dissemination of public, religious, and civil constructions paralleled the development of the urban nucleus of Vila Rica (Ouro Preto in colonial era), significantly bolstered by the Crown's administrative influence.

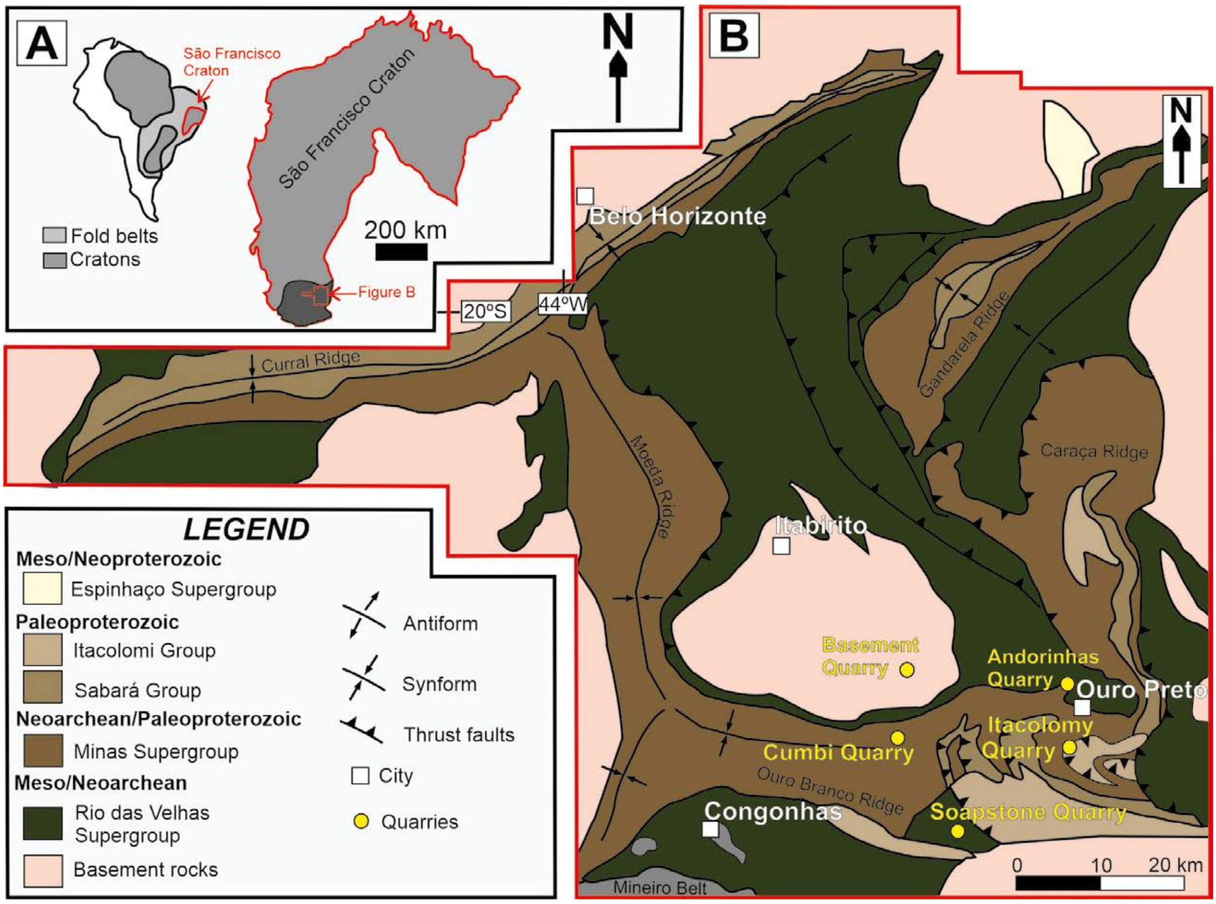

Figure 1. Geological map of the Quadrilátero Ferrífero showing the locations of the visited quarries.

Figura 1. Mapa geológico del Quadrilátero Ferrífero mostrando la ubicación de las canteras visitadas.

As gold reserves decreased, Ouro Preto's growth stalled, preserving its colonial structures almost intact (Andrade, 1975; Smith, 1969). This preservation has allowed the city to be recognized as a UNESCO World Heritage Site, acknowledging its architectural significance and the meticulous care that has gone into maintaining its historic character. In this sense, the city's preservation provides a window into Brazil's colonial past, offering invaluable insights into the architecture and society of the time (Castriota, 1999).

Currently, Ouro Preto has a complete architectural heritage that contrasts the past and the present through its colonial churches, museums, mansions, and decorative gateways (Figure 2). Beginning with the construction of the Empire palace in 1741, with the use of local rocks of old quarries as raw material. This rich architectural heritage exemplifies the Barroque and Rococo styles, with the prominently creations of the Aleijadinho (Antônio Francisco Lisboa) artist, who stands as a pivotal figure in Brazilian colonial art and architecture. His works are intricately crafted from locally sourced ornamental stones, obtained in historical quarries (Pereira & Liccardo, 2010).

Figure 2. Photo mosaic depicting the prominent historical monuments and artistic heritage of Ouro Preto.

Figura 2. Mosaico fotográfico que representa los principales monumentos históricos y el patrimonio artístico de Ouro Preto.

The Quadrilátero Ferrífero (QFe) province was designated in 2022 by the IUGS as part of the first 100 geological heritage sites in the world and the Ouro Preto city comprises one of the boundary references of QFe (Dorr, 1969). This large crustal segment is composed of Archean to Paleoproterozoic rocks. The stratigraphic framework of the QFe is composed by Archean rocks of the basement, the Rio das Velhas Supergroup and Paleoproterozoic metasedimentary sequences of the Minas and Estrada Real Supergroups (Endo et al., 2019b) (Fig. 1).

The basement rocks of QFe are Tonalite-Trondjhemite-Granodiorite (TTG) rocks metamorphosed in granitoid-gneiss complexes (e.g., Lana et al., 2013). The Rio das Velhas Supergroup is a typical greenstone belt Archean sequence, and is subdivided into Quebra Ossos, Nova Limas and Maquiné Groups (Endo et al., 2019a,b). The Quebra Ossos Group consists of an association of ultramafic, mafic, and felsic metavolcanic rocks. The Nova Lima Group is composed by chemical metavolcanosedimentary, metavolcaniclastic, and marine clastic metasedimentary rocks. The Maquiné Group comprises an association of non-marine metasedimentary rocks.

The Minas Supergroup is divided into the Tamanduá, Caraça, Itabira, and Piracicaba Groups (Endo et al., 2019a). It represents a continental-marine succession, depicting one of the stages in the evolution of a passive margin basin (Alkmim & Martins Neto, 2012). The Tamanduá and Caraça groups comprises quartzites, metaconglomerados, and phyllites (Dorr, 1969). The Itabira Group records one of the most important sequences of the QFe. This unit is composed by banded iron formation and stromatolite-rich carbonates (Dorr, 1969), and was responsible for giving to the QFe the title of geological heritage. The Piracicaba Group is composed of quartzites, phyllites, schist, and stromatolite-rich dolomites.

The Estrada Real Supergroup represents of the syn-orogenic flysch-type and molasse sedimentary succession (Dorr, 1969). It is formed by the Sabará and Itacolomi Groups. The Sabará Group consists of marine metasedimentary rocks, including quartzites, phyllites, schists, and banded iron formations. At least, the Itacolomi Group is the younger unit, is composed of quartzites, metaconglomerates and phyllites that represent a continental sequence (Alkmim & Marshak, 1998).

The Qfe hosts intrusive suites that are younger than the Minas Supergroup. These include the Santa Rita de Ouro Preto Suite, known for its ultramafic magmatism, and the Catas Altas da Noruega Suite, which is characterized by mafic magmatism.

This complex and diverse lithological composition has significantly influenced the architectural style of Ouro Preto. Specifically, the quartzites from the Caraça Group (Moeda Formation) and the Itacolomi Group (Pico do Itacolomi Formation), along with the metaultramafic rocks (soapstones) and the stromatolite-rich marbles were the most used raw materials. These materials, sourced from historical quarries in the region, provided the essential building blocks and decorative elements used by artists and builders to construct and adorn the city's iconic structures. The stonework technique, involved the carving of rocks into geometric shapes for both structural and ornamental purposes, showcases the extensive use and mastery of the craft in Ouro Preto, reflected in the intricately detailed stone carvings that characterize its monuments (Pereira & Liccardo, 2010; Vilela, 2003; Pereira, 2004, 2007).

3. METHODOLOGY

The research methodology involved conducting a review of geological literature on the Qfe, as well as studying architectural heritage, cultural preservation, Brazil's colonial history, and historical quarries of quartzite, soapstone, limestone, and gneiss.

During the field stage, we identified and described historic quarries, including their lithologies, structures, and variations. For some quarries, we were able to determine the period of activity and the methods used for rock extraction.

In the heritage recognition stage, we analyzed the rocks used in historical monuments in the city of Ouro Preto, particularly those dating back to Brazil's colonial period. This included studying street paving, sidewalks, porches, window frames, sculptures, and soapstone art.

4. QUARTZITE QUARRIES, ARCHITECTURE AND URBAN DESIGN

Quartzites are prevalent in the geological record (Condie, 2022). The Quadrilátero Ferrífero region contains significant occurences of these rocks. Among them, two types of quartzite have been particularly influential in shaping the architecture and urban design of Ouro Preto during the colonial era. The first is associated with the Moeda Formation, a component of the Caraça Group within the Minas Supergroup, dating to the Archean era. The second type of quartzite comes from the Pico do Itacolomy Formation (Itacolomi Group), which is from the Paleoproterozoic era. These two types of quartzite differ markedly from each other, leading to their distinct uses in the architectural and urban fabric of Ouro Preto. Each type was chosen for specific applications based on its unique properties, influencing the aesthetic and structural elements of the city's colonial architecture.

The porosity of rock types significantly influences their hardness and, by extension, the durability of the structures built with them. Rocks that contain a higher percentage of quartz typically exhibit lower porosity, making them more durable. In particular, quartzite that has finer and more uniform grain size tends to be more durable. The absence of cracks, fractures, and easily alterable minerals further enhances the rock's resistance to weathering processes. The durability of certain rocks used in construction also depends on the regional climatic conditions. For instance, in the climate prevalent in the Ouro Preto region, it is estimated that quartzite undergoes initial degradation within 200 to 500 years and reaches a state of significant degradation only after more than 1600 years. This estimation, as reported by Pereira et al. (2007), highlights the exceptionally durable nature of quartzite, making it a highly valued material for constructing enduring architectural works, such as those seen in historical buildings and monuments.

The quartzites associated with the Moeda Formation are primarily sericite quartzites characterized by fine granulometry and pronounced foliation (Dorr, 1969). These quartzites vary in color from white and reddish pink to yellow and gray. They are found within the urban area of Ouro Preto and contribute to the city's distinctive ridge topography, alongside the Itabira Group. The Moeda quartzites have been extensively utilized for wall cladding and paving in Ouro Preto (Figure 3).

Figure 3. (A) and (D): Quartzite from the Moeda Formation is used in sidewalks and window coverings in Ouro Preto. (B) and (C): Detail of the Moeda Quartzite on the floor and portal of the Science and Technique Museum of the Escola de Minas, ancient Governors Palace.

Figura 3. (A) y (D): La cuarcita de la Formación Moeda se utiliza en aceras y cortinas en Ouro Preto. (B) y (C): Detalle de la Cuarcita Moeda en el piso y portal del Museo de Ciencias y Técnicas de la Escola de Minas, antiguo Palacio de los Gobernadores.

Due to their proximity to the urban center, these quartzites are colloquially known as “Lages” quartzites. This term originates from a homonymous neighborhood in Ouro Preto, where old quarries once operated. Their use in this manner is attributed to their highly foliated nature, which makes them unsuitable for use as structural blocks in construction.

The historic quarries where Moeda quartzite was extracted can be found in the interior of the city. One example is the location where the Ouro Preto Fire Department is situated today. Another example is the old quarry near the Cachoeira das Andorinhas Park (figures 6A and 6B). The quarry is now situated in the Cachoeira das Andorinhas Environmental Protection Area (APA) and has three well-developed climbing sectors that are renowned worldwide among enthusiasts of this sport. The Quarry Sector is located in the highest part of the Serra das Camarinhas, very close to the source of the Rio das Velhas, where the extraction of ornamental stone is most prominent.

The quartzites of the Itacolomi Group are primarily composed of quartz, sericite, limonite, hematite, magnetite, with occasional clasts of phyllites and banded iron formations. Distinctly marked by cross-stratification patterns accentuated by iron oxide (figures 4A and 4B), these quartzites contribute a unique aesthetic to the landscape. They form a significant part of Ouro Preto’s topography, including the peak named after the group, situated south of the city in a natural park presumably near historical quarry sites. Unlike the quartzites from the Moeda Formation, the Itacolomi quartzites do not exhibit pronounced foliation. This characteristic renders them suitable for use as structural blocks in construction, providing essential strength and stability for the historical buildings of Ouro Preto (figures 4C and 4D). Their visual appeal also allows them to serve as decorative elements, enhancing the architectural charm of the city.

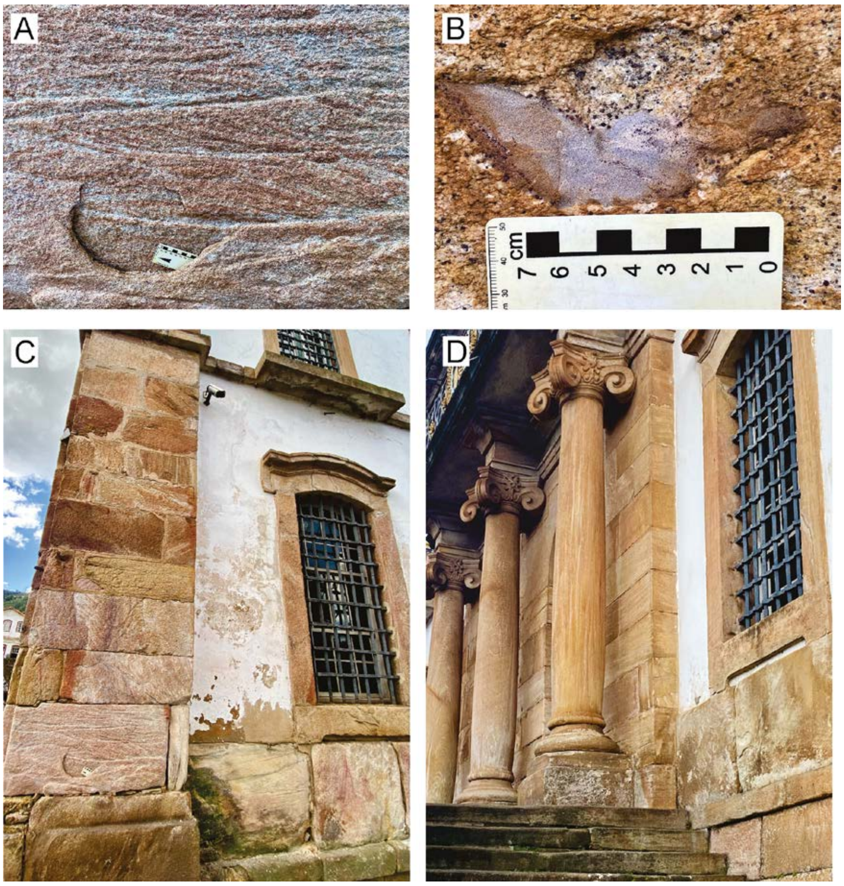

Figure 4. (A) Detail of the cross-stratified, (B) presence of clasts, and large quantities of magnetite crystals are characteristics of quartzite from the Itacolomi Group. (C) e (D) Quartzite from the Itacolomi Group can be seen at the walls of the Inconfidence Museum, ancient Town Hall, and Vila Rica Prison. The external stonework has a reddish color due to the presence of iron oxide minerals.

Figura 4. (A) Detalle de la estratificación cruzada, (B) presencia de clastos y grandes cantidades de cristales de magnetita son características de las cuarcitas del Grupo Itacolomi. (C) y (D) Se pueden observar cuarcitas del grupo Itacolomi en las paredes del Museo de la Inconfianza, del antiguo Ayuntamiento y de la prisión de Vila Rica. La mampostería exterior presenta un color rojizo debido a la presencia de minerales de óxido de hierro.

The quarry of the Itacolomi Group was historically noted for their high-quality quartzite (figures 6C and 6D), which has been used extensively in various buildings throughout the region, including churches, colonial houses, and historical monuments (Figure 5). The strategic location and the superior quality of the material extracted have made it a favored choice among contractors and architects since the colonial period and this preference continues to the present day. Quartzites from this group vary in color from white and light gray to yellowish, brown, and reddish hues. The reddish tones are often due to thin films of iron hydroxides/oxides that coat the quartz grains and are also visible in microfractures within the rock. For instance, the Museum of Inconfidence exhibits external stonework with a distinct reddish color, a feature attributed to the presence of iron oxide minerals (figures 4A and 4B; Silva, 2007).

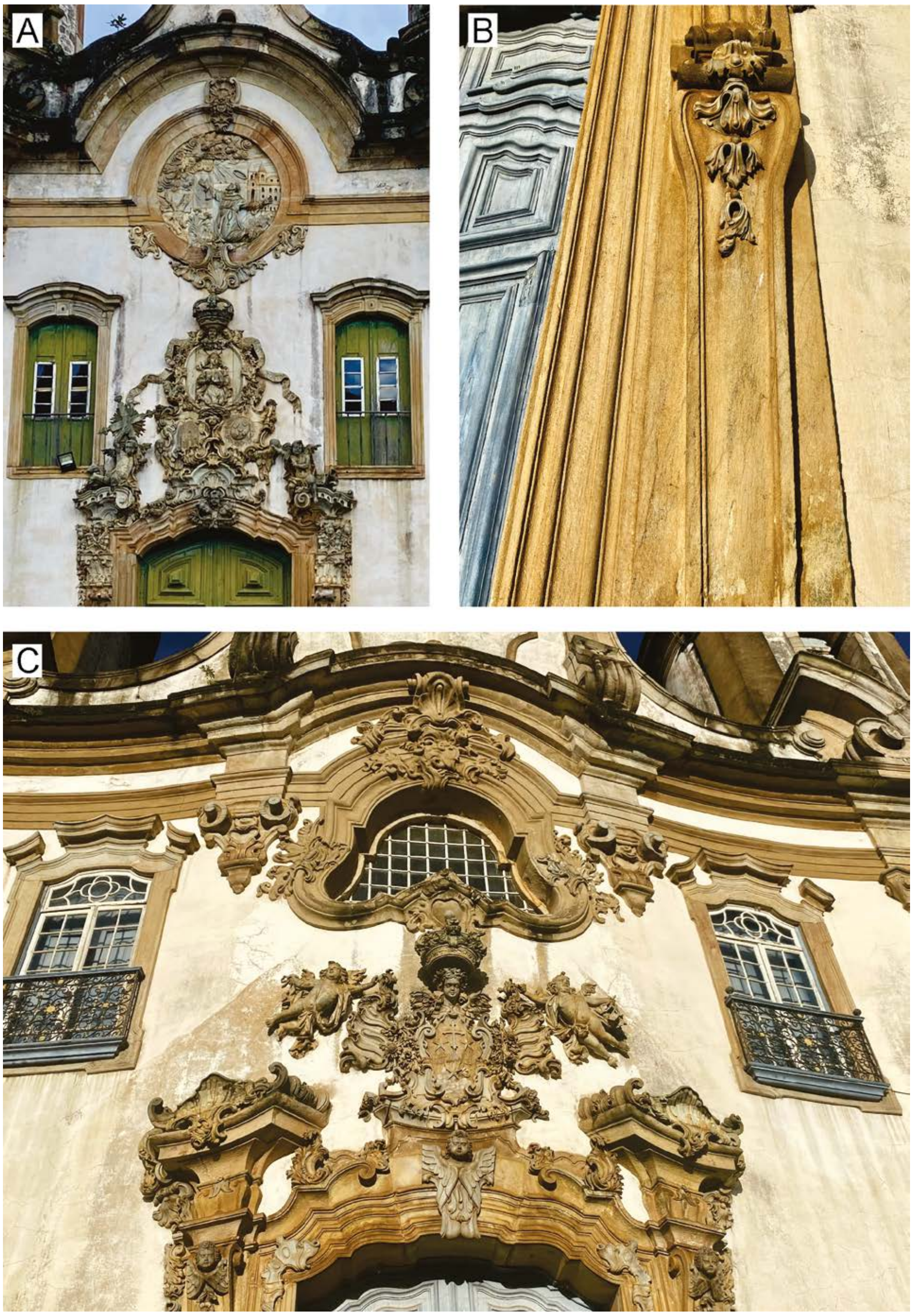

Figure 5. (A) Frontispiece of the São Francisco de Assis Church carved in soapstone and quartzite from the Itacolomi Group, a work by Aleijadinho. (B) and (C) The façade and frontispiece of the Nossa Senhora do Carmo Church features carvings in quartzite from the Itacolomi Group and soapstone, created by Aleijadinho.

Figura 5. (A) Frontispicio de la Iglesia de São Francisco de Assis tallado en esteatita y cuarcita del Grupo Itacolomi, obra de Aleijadinho. (B) y (C) La fachada y el frontispicio de la Iglesia Nossa Senhora do Carmo presentan tallas en cuarcita del Grupo Itacolomi y esteatita, creadas por Aleijadinho.

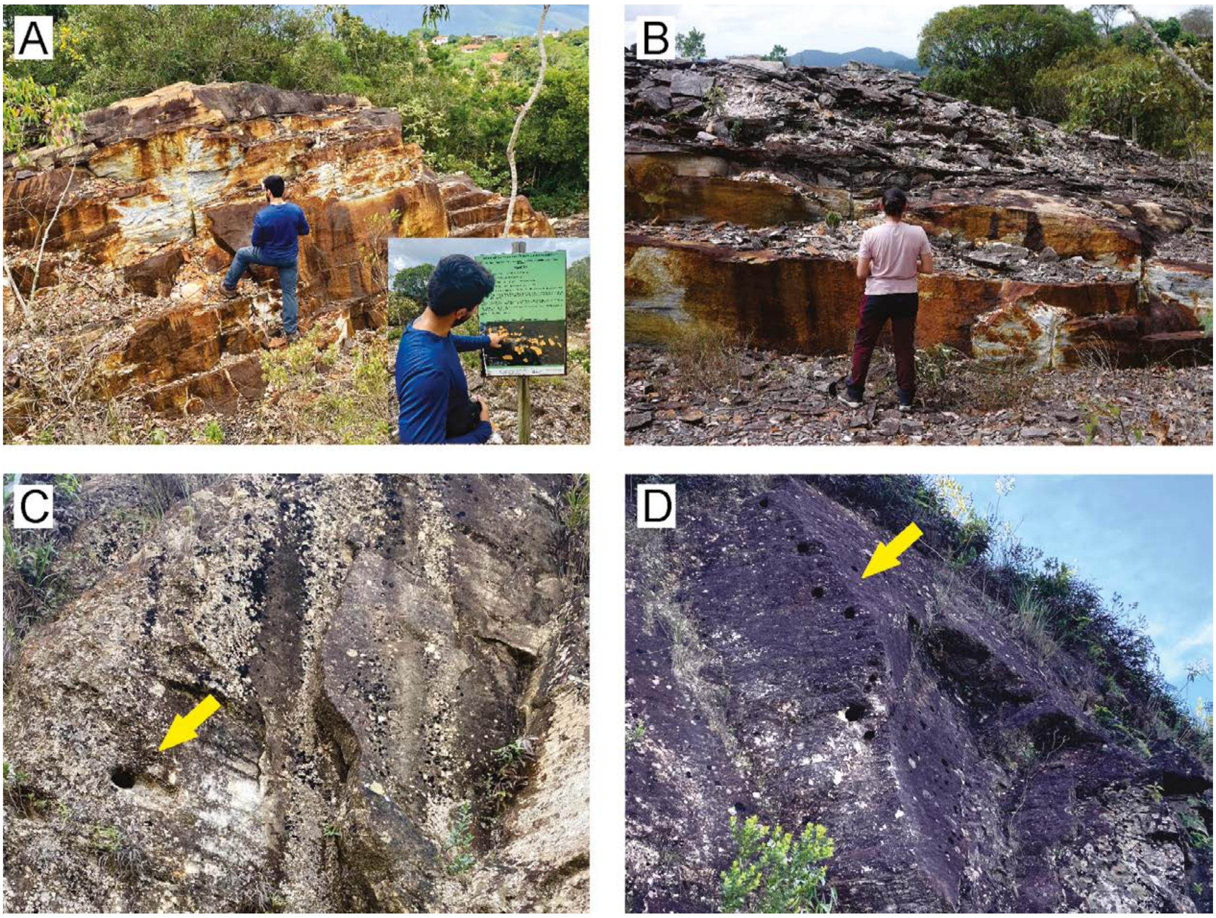

Figure 6. (A) and (B) Ancient quartzite quarry of the Moeda Formation, now located in the Environmental Protection Area of the Cachoeira das Andorinhas Park, features three well-developed climbing sectors that are recognized worldwide among sports enthusiasts. (C) and (D) Remnants of holes used for explosives in an old quartzite quarry in the Itacolomi Group. The quarry is currently located in Itacolomi Park, an environmental preservation area.

Figura 6. (A) y (B) Antigua cantera de cuarcita de la Formación Moeda, hoy ubicada en el Área de Protección Ambiental del Parque Cachoeira das Andorinhas, presenta tres sectores de escalada bien desarrollados y reconocidos mundialmente entre los amantes del deporte. (C) y (D) Restos de orificios utilizados para explosivos en una antigua cantera de cuarcita del Grupo Itacolomi. La cantera está actualmente ubicada en el Parque Itacolomi, un área de preservación ambiental.

Aleijadinho, one of Brazil's most renowned sculptors and architects from the colonial period, extensively utilized quartzites in his works, which are pivotal in defining the Baroque architecture of Ouro Preto. His choice of materials, notably the quartzites from the Itacolomi and Moeda units, not only highlighted the natural beauty and durability of the stone but also allowed for detailed and expressive craftsmanship in his sculptures and architectural designs. Among the famed works of Aleijadinho using quartzites are the portals of the Nossa Senhora do Carmo and São Francisco de Assis churches (figures 5A, 5B and 5C), and the architectural elements of Casa dos Contos Museum, as well as the iconic Alto da Cruz fountain (Figure 7A). These structures showcase the fine-grained quality of the quartzite, enabling intricate carvings that have withstood the test of time. Aleijadinho's skill in manipulating this hard stone into delicate artistic expressions significantly contributed to the aesthetic and cultural landscape of Ouro Preto, embedding a sense of historical and artistic richness in the city's architectural heritage.

Figure 7. (A) Alto da Cruz fountain was constructed using quartzite from the Itacolomi Group, and the upper bust was adorned with soapstone by the hands of Aleijadinho, dated 1761. (B) Detail of the ornate soapstone staircase at the Inconfidence Museum. (C), (D) and (E) Objects sold at the Largo de Coimbra Crafts Fair often reflect the local religion and culture.

Figura 7. (A) La fuente del Alto da Cruz fue construida con cuarcita del Grupo Itacolomi y el busto superior fue adornado con esteatita por manos de Aleijadinho, fechada en 1761. (B) Detalle de la ornamentada escalera de esteatita del Museo de la Inconfianza. (C), (D) y (E) Los objetos vendidos en la Feria de Artesanía de Largo de Coimbra suelen reflejar la religión y la cultura local.

5. SOAPSTONE: THE STONE OF MINAS GERAIS

5.1. The rock and the geological context

Steatite, also known as “soapstone”, is a metamorphic rock formed when ultramafic igneous protoliths are hydrated under low temperature and pressure conditions. The primary mineral in steatite is talc, but it may also contain chlorite, dolomite, amphiboles, serpentine, oxides (such as hematite and magnetite) and sulfides (such as pyrite and chalcopyrite). This rock is usually light brown or greenish-gray in color and it is easily recognizable due to its unctuous texture and low hardness (it can be scratched with a fingernail).

In the stratigraphic context of the Iron Quadrangle, the steatites are part of the ultramafic magmatism of the Santa Rita de Ouro Preto suite intrusive in the Archean and Paleoproterozoic units (Endo et al., 2019a, b). These rocks are metamorphosed in greenschist facies, with mineral paragenesis formed by chlorite, serpentine, talc, tremolite, and carbonate (Gonçalves et al., 2011). The steatites have nematoblastic, and granolepidoblastic to decussate texture variations, depending on their dominant mineralogical composition. Some outcrops preserve igneous minerals and texture relics of the protolith. (Jordt-Evangelista & Silva, 2005).

5.2. Quarries and Historical Monuments

In the 18th century, soapstone was a rock widely used for building facades and numerous structural details of historical monuments in Ouro Preto and Mariana. Due to its low hardness, it was a popular material for creating beautiful Baroque and Rococo sculptures, many of which were designed by Aleijadinho.

The main quarries for extracting steatite are located in the Santa Rita de Ouro Preto (Figure 8) and municipalities of Mariana, including Cachoeira do Brumado, Padre Viegas, Furquim, and Acaiaca. According to Costa (2021), the historical ornaments in Ouro Preto were extracted from quarries in the Santa Rita region, while those in Mariana were extracted from quarries in their own municipalities. In mid-1755, the oldest quarries were opened in order to construct monuments in Ouro Preto, previously known as Vila Rica. According to Bazin (1981), one of the earliest known soapstone pieces is the upper bust of the Alto da Crus fountain (Figure 7A), which dates back to 1761. This artwork is attributed to Aleijadinho (Pereira et al., 2007). Soapstone was utilized for significant constructions in Brazil during the 20th century, mainly in Rio de Janeiro city. Such as the covering of the Cristo Redentor statue.

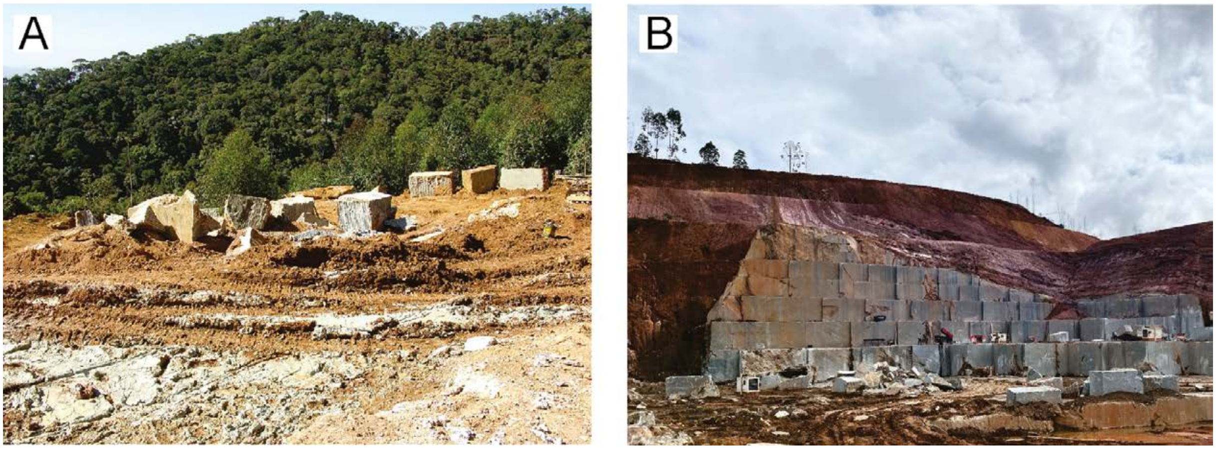

Figure 8. (A) and (B) Old soapstone quarry located in the Santa Rita de Ouro Preto region.
Figura 8. (A) y (B) Antigua cantera de esteatita ubicada en la región de Santa Rita de Ouro Preto.

In the Ouro Preto historic buildings, soapstone was used mainly in pieces with finer and more delicate carvings, such as portals, frontispieces, washrooms of chapels, staircases, fountains and saints' images. As an example, in Figure 7B, we can see the external staircase details of the Museu da Inconfidência, formerly known as Palácio dos Governadores. In figures 5A and 5C, we can observe the intricate details of the frontispiece of the São Francisco de Assis and Nossa Senhora do Carmo Churches, which are sculptures attributed to Aleijadinho. Additionally, in Figure 5B, we can see an ornament on the portal of the Nossa Senhora do Carmo Church, which serves as an example of the countless ornaments that are used to adorn the facades of churches.

In present times, numerous soapstone quarries are still functioning, exporting rock blocks to Europe and the United States, as well as providing the local artisan community with raw material. The crafts made out of soapstone are an integral part of Ouro Preto's artistic heritage, and are of significant economic and tourist value for the region. One such example is the Largo do Coimbra Crafts Fair, situated in front of the São Francisco de Assis church, a site of cultural heritage in Ouro Preto. Figure 7C displays various examples of items that are sold at the Largo do Coimbra Crafts Fair. The handicrafts available include several household utensils like pans, jugs, plates, mugs, etc. The fair also showcases sculptures that reflect the catholic Christian religiosity, such as images of saints and rosaries (as seen in Figure 7D). Additionally, sculptures that represent the Brazilian culture and its people are also common, like dolls with Afro-descendant features that carry elements from the slavery period (Figure 7E).

6. BASEMENT QUARRY

Basement rocks are widely found along the QFe and it is overlain by the later supracrustal rocks from the Rio das Velhas and Minas supergroups. These rocks represent the oldest units of the regions and are comprised by gneisses, migmatites and granitoids, commonly with a TTG (tonalite–trondhjemite–granodiorite) composition (Farina et al., 2016). Geochronological data individualized them into three main periods of magmatism, which span from 3,220 to 2,770 Ma: the Santa Barbara (SB), Rio das Velhas I (RVI) and Rio das Velhas II (RVII) events (Lana et al., 2013, Farina et al., 2016).

One good example of these variety of basement rocks is the Bação Complex, in which the cities of Itabirito and part of Ouro Preto lies in. The Bação Complex comprises a large dome with alternation of TTG and potassic granitoids (Lana et al., 2013). This complexity is also observed in other basements complexes in the QF (i.e., Bonfim, Belo Horizonte and Santa Bárbara complexes).

The Bação Complex can be nicely seen at the Fazenda Retiro das Rosas Quarry, in the Cachoeira do Campo district, Ouro Preto. The quarry is currently inactive with preserved mining fronts and flagstones (Figure 9A). The quarry is close to a famous basement outcrop in the Cachoeira do Campo district (Ruchkys et al., 2013). Similar basement quarries are widespread in the region, particularly in the Itabirito.

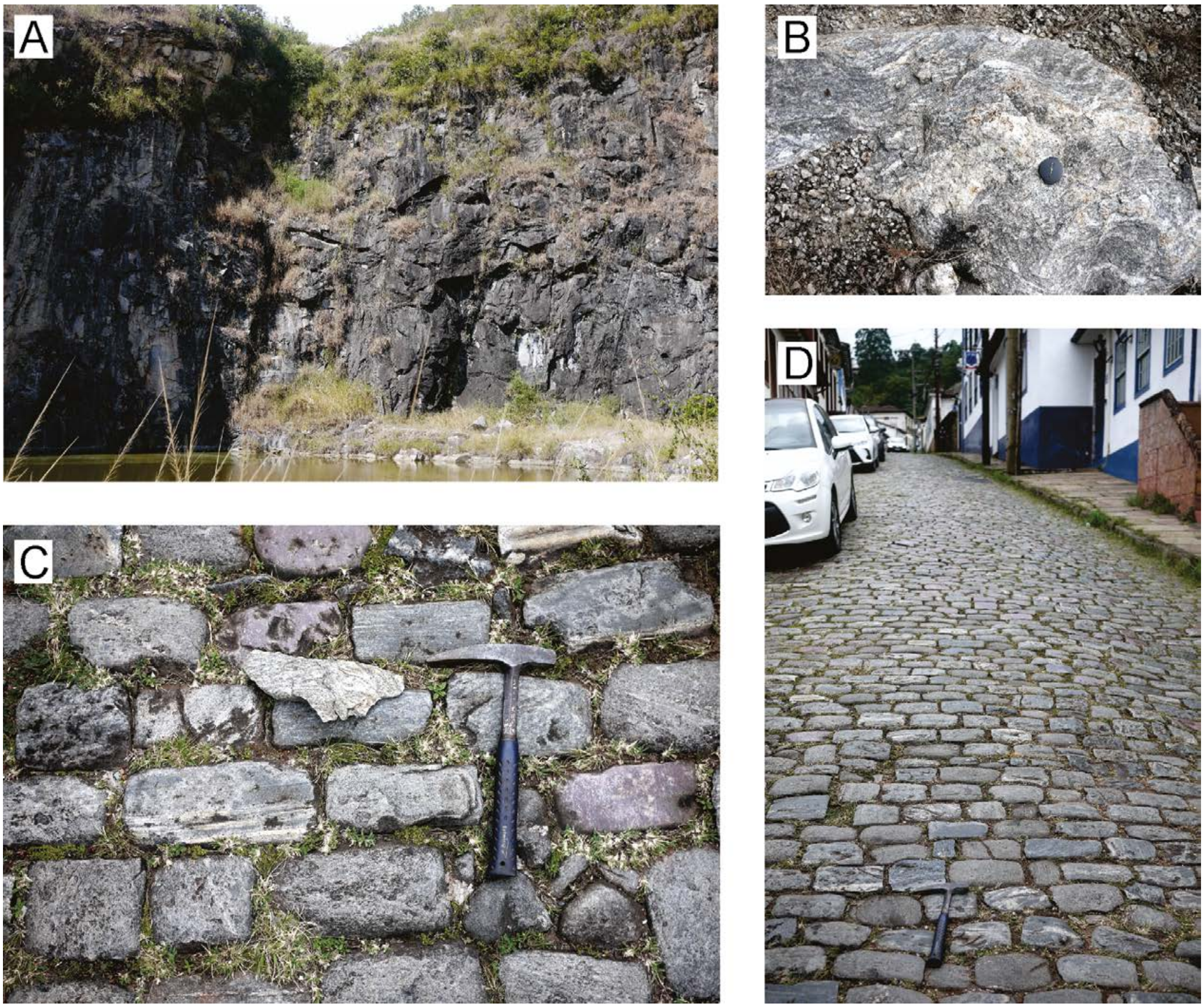

Figure 9. (A) General view of the Fazenda Retiro das Rosas Quarry. (B) Banded gneisses with alternation of quartz-felspathic and mafic minerals-rich bands. (D) Detailed view of the pavement in the Ouro Preto downtown with some blocks of the gneissic rocks. (E) General view of the pavements in the Ouro Preto downtown.

Figura 9. (A) Vista general de la Cantera Fazenda Retiro das Rosas. (B) Gneises bandeados con alternancia de bandas ricas en cuarzo-felspático y minerales máficos. (D) Vista detallada del pavimento en el centro de Ouro Preto con algunos bloques de rocas gneísicas. (E) Vista general de las aceras del centro de Ouro Preto.

In this quarry banded orthogneisses predominates primarily composed by quartz, plagioclase, potassium feldspar, biotite and amphibole. The banding is comprised by the alternation of quartz-fedsphatic with mafic minerals-rich bands (Figure 9B). These rocks are crosscut by coarse-grained quartz-felspathic injections. The later can be interpreted as partial melting, though this assumption remains uncertain.

6.1. Uses of the basement rocks at Ouro Preto

Quarries of the basement rocks were mainly dedicated to provide (i) gravel for civil construction in the region, (ii) gravel and blocks for small dirt roads around Ouro Preto and (iii) blocks for the pavements in the Ouro Preto downtown. The later represents the main use of these basements rocks as historical monuments.

In the Ouro Preto downtown, most of the pavement are consisted by blocks of the basement rocks, though other rocks can also be seen. The metamorphic structures observed in the quarries and regional outcrops can be easily recognized in the pavements (figures 9C and 9D). It is difficult to affirm if these blocks came from a specific quarry form the region, once these rocks are quite common in the QFe.

7. THE CUMBI QUARRY: A PALEPROTEROZOIC STROMATOLITES

The Cumbi Quarry is located in the district of Cachoeira do Campo, in the city of Ouro Preto (Minas Gerais). It’s an important occurrence of Paleproterozoic stromalites, in which one of the oldest occurrences of biosedimentary structures (cyanobacteria) in Brazil.

According to information obtained from the GEOSSIT website of the “Serviço Geológico do Brasil” (Geological Survey of Brazil), the location is included in a proposed geopark (Quadrilátero Ferrífero - MG). The quarry is currently inactive and corresponds to a huge area with several abandoned mining fronts, with stacked blocks measuring up to 3 meters in height (figures 10A and 10B).

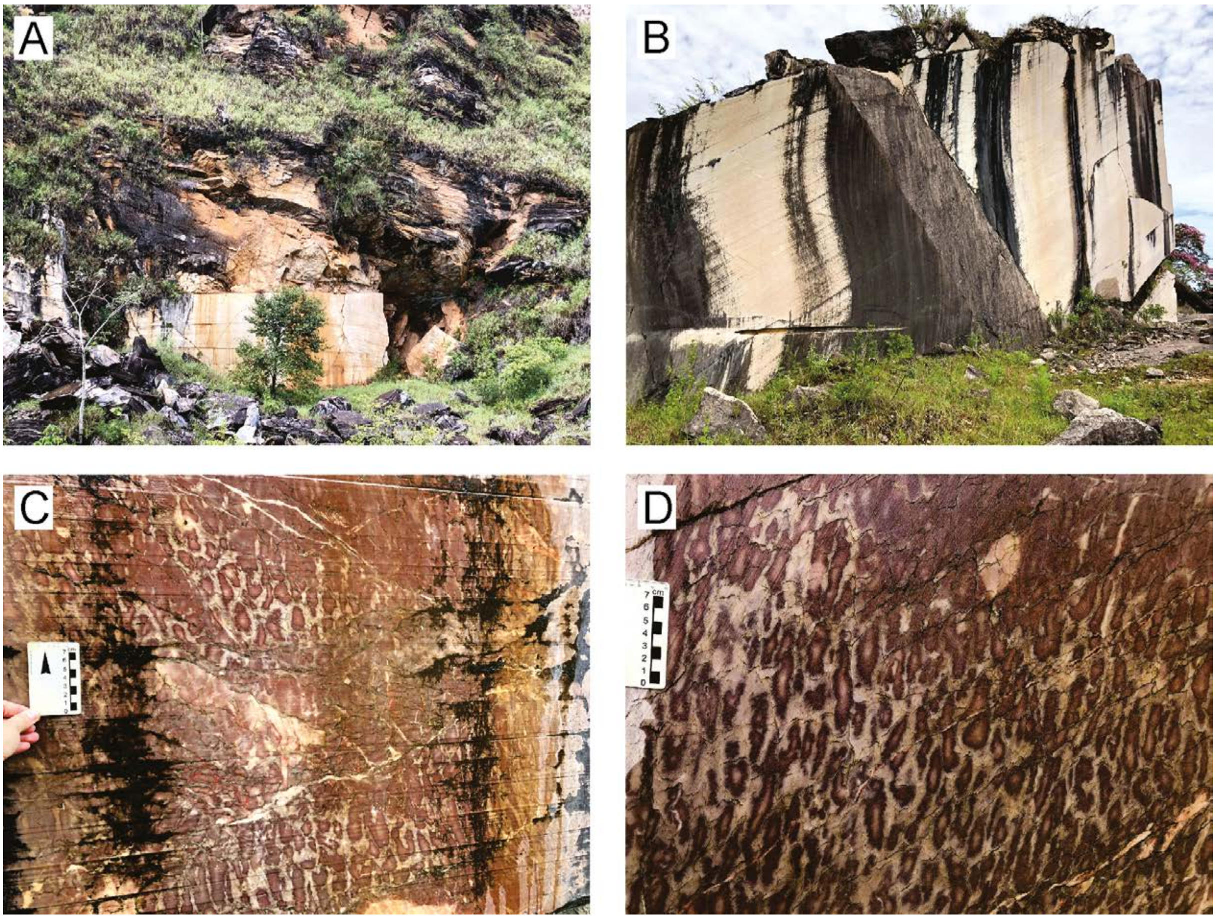

Figure 10. (A) and (B) Cumbi quarry overview. (C) and (D) Detail of the cuts in the rock reveals stromatolites with a “pele de onça” texture, typical of this quarry’s rocks.

Figura 10. (A) y (B) Descripción general de la cantera de Cumbi. (C) y (D) El detalle de los cortes en la roca revela estromatolitos con textura de “cáscara de onça”, típica de las rocas de esta cantera.

7.1. Geological Context

The stromatolites from the Cumbi quarry are in the context of the Minas Supergroup (São Francisco Craton of the Fecho do Funil Formation, belonging to the Piracicaba Group (Dardenne & Campos Neto, 1975). Nogueira et al. (2016), shows different variations of the Cumbi quarry such as: crystalline dolomite with convex lamination, crystalline calcitic dolomite with stromatolites domics; crystalline dolomitic metabreccia; and crystalline dolomite with stromatolites dendriforms.

Commercial operation took place for seventy years (between 1935 and 2005). According to Kuchenbecker et al. (2015), the main lithotype that was sold is classified as stromatolitic metadolomite, being recognized in the ornamental stone market, mainly in Brazil, as “mármore pele de onça” (figures 10C and 10D).

Other commercial types being exploited in the Cumbi quarry are the dolomites “Aurora Pérola” (beige color), “Aurora Prata” (gray), “Jacarandá” (red), “Light and dark pink (pink color)” (Bezerra, 1999).

7.2. Exploration and extraction

The use of explosives was one of the techniques used in mining for several years. This activity culminated in the fracturing and relaxation of the quarry structure, including along discontinuities (zones of structural weaknesses) (Bezerra, 1999).

In the heyday of the quarry's activity, voluminous mining fronts were exploited synchronously (Bezerra, 1999) and it is still possible to observe the blocks in the yard today.

Explosives were no longer used in the last decades of quarry exploration and were only used to "clean" certain mining fronts. Little by little, the diamond wire cutting technique was used more efficiently (Bezerra, 1999).

Currently, the quarry can be used for scientific and educational interest associated with stratigraphy, paleontology, sedimentology and paleoenvironmental content (GEOSSIT – Serviço Geológico do Brasil - Geological Survey of Brazil). In this way, the importance of registering the Cumbi quarry as a geological site and its historical importance is highlighted.

7.3. Historical monuments

The rocks from the Cumbi quarry are of historical importance, forming part of several "old" buildings in the city of Belo Horizonte in the state of Minas Gerais. (Bezerra, 1999).

The historical importance also dates back to its participation in the History of Brazil, as an example of the city of Rio de Janeiro, with the presence of rocks with stromatolites from the Cumbi quarry at the time when the city was the country's capital.

In the city of Rio de Janeiro it is possible to observe carbonate rocks and marble in historic buildings, linking a relationship in the context of the History of Basil: 1) The buildings that were built during the Brazilian Empire were made up of lithologies from Portugal; 2) The rocks that were used in construction at the end of the Brazilian Empire and at the beginning of the Old Republic were brought from Italy; and 3) During the government of President Getúlio Vargas (1930 to 1945), the buildings contained rocks from Brazil, such as stromatolites from the Cumbi quarry (Medeiros & Polck, 2017). This characteristic makes explicit an exacerbated nationalism characteristic of Vargas (1930 to 1945), especially in the "dictatorial" period known as Estado Novo (1937 to 1945). The era was also marked by the creation of the Ministry of Labor and the granting of rights.

Metalimestones with stromatolites from the Cumbi quarry can be found in historic buildings in the center of the city of Rio de Janeiro, built during the Old Republic, such as: Court of Justice, Regional Superintendence of Federal Revenue, Regional Labor Court. In the city center there is also the Banco do Brasil Cultural Center (CCBB) with its interior lined with sheets of ornamental metalimestone rocks with stromatolites from the Cumbi Quarry - variety "pele de onça" (figures 11A and 11B).

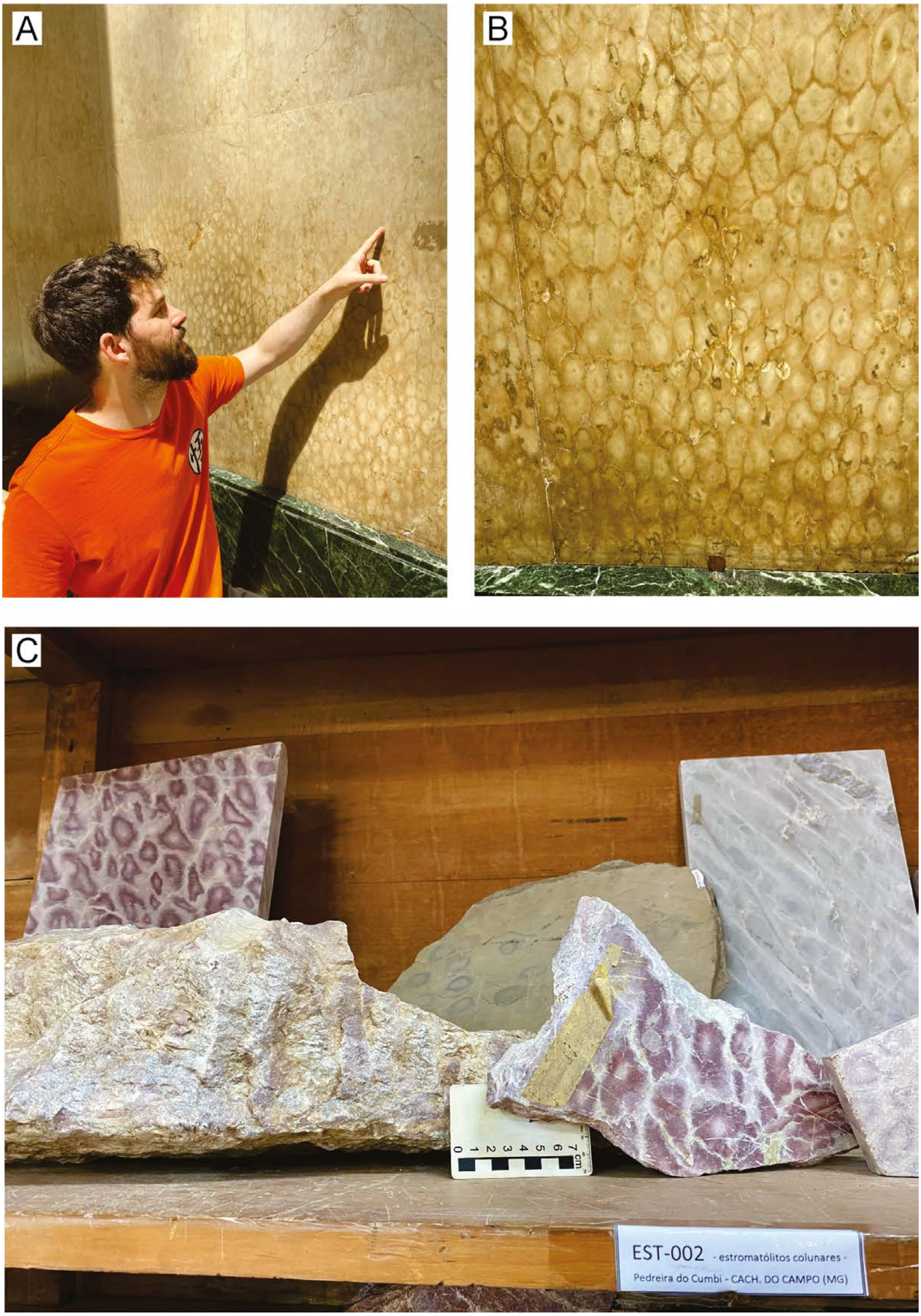

Figure 11. (A) and (B) Ornamental rock – meta limestone with stromatolites from the Cumbi quarry at Centro Cultural Banco do Brasil, in the city of Rio de Janeiro, Brazil. (C) Samples of meta limestone from the Cumbi quarry are included in the technical collection of the Paleontology Laboratory at the Geology Department of the Federal University of Ouro Preto.

Figura 11. (A) y (B) Roca ornamental – metacaliza con estromatolitos de la cantera Cumbi en el Centro Cultural Banco do Brasil, en la ciudad de Río de Janeiro, Brasil. (C) Muestras de metacaliza de la cantera de Cumbi están incluidas en la colección técnica del Laboratorio de Paleontología del Departamento de Geología de la Universidad Federal de Ouro Preto.

8. CONCLUSIONS

The rocks around Ouro Preto have not only contributed to the region's architectural splendor but also formed a significant part of the city's economic and social history. Aleijadinho's beautiful works shaped the city of Ouro Preto, making it a living painting of the Baroque of Minas Gerais. The architecture of this city and its historical significance make Ouro Preto one of the main destinations for cultural tourism in Brazil, attracting visitors from all over the world. Soapstone, a strong candidate to be considered national heritage, is important not only in local historical monuments but is also widely used to make handicrafts, which drives the region's economy and culture.

The preserved ancient quarries are remnants of rock extraction used for building historical monuments, mainly during the colonial period. Some, like the Santa Rita´s soapstone quarry, are still in operation. Their significance in literature is substantial, as they are an integral part of the city's historical heritage. Today, some quarries have become tourist attractions, such as the Lages quartzite quarries, while others serve as sites for scientific studies, like the Cumbi quarry.

Ouro Preto is strategically located in the Quadrilátero Ferrífero, which is an internationally recognized geological heritage. Its rocks, ranging from the Archean to Proterozoic ages, and its mineral resources, serve as the backdrop for research conducted by scientists from around the world. Consequently, Ouro Preto is home to the Federal University of Ouro Preto (UFOP), which offers one of the country's most traditional Geological and Mining Engineering courses.

The connection between the stratigraphic framework rocks of the Quadrilátero Ferrífero and the construction of the city of Ouro Preto emphasizes its enduring legacy as a geological and architectural heritage, reaffirming its status as an essential human heritage.

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Competing interests

The authors of this article declare that they have no financial, professional, or personal conflicts of interest that could have inappropriately influenced this work.

Statement on the use of Artificial Intelligence

Not applicable.

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