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# Geoconservation: Research and extension in the context of the Iron Quadrangle, Brazil

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***Keywords*— Iron Quadrangle, research, extension, geoconservation, geoeducation**

***Abstract*—** *Brazil has a great geological potential, however there are only three geoparks recognized by UNESCO: Araripe, Seridó and Caminhos dos Cânions. Several studies show the potential of the Brazilian region, located at Minas Gerais state, named Iron Quadrangle to be incorporated in the Global Geopark Network,, where its conservation has importance in the geological, historical and social scene. The State University of Minas Gerais (UEMG), through its trajectory, has developed extension and research projects linked to the history of each region, with themes related to geodiversity, geoeducation, environmental preservation. This paper aims to demonstrate how the academy, especially the UEMG, can promote the conservation of the Iron Quadrangle. The city of João Monlevade has received special attention since this city integrates the Iron Quadrangle and it has important geological sites as Areão Park and Serra do Seara. João Monlevade city has an economy around the steel industry, metallurgy and mining, activities that interpose intensively in the landscape. . Research and extension works in these domains are essential, since they represent an important tool for its conservation. The institution can extend to the society the scientific knowledge about geological historical, economic heritage, space alteration and environment preservation as a whole creating an important way for local and regional sustainability.*

## I. INTRODUCTION

Geodiversity can be defined simply as the natural range (diversity) of geological (rocks, minerals, fossils rocks, fossils), geomorphological (land form, physical processes) and soil features. It includes their assemblages, relationships, properties, interpretations and systems (Gray, 2005).

Geopark is a geographical area where geological heritage sites are parts of a holistic concept involving conservation, education and sustainable development. It aims to protect the geodiversity, to promote geological heritage to the public, as well as to support sustainable economic development of geopark territories, primarily through the development of geological tourism, the geoturism. Geopark should take into account the whole geographical setting of the region, and shall not solely include sites of geological significance. The synergy between geodiversity, biodiversity and culture, in addition to both tangible and non-tangible heritage are such that nongeological themes must be highlighted as an integral part of each geopark, especially when their importance in relation to landscape and geology can be demonstrated to the visitors. For this reason, it is necessary to also include and highlight sites of ecological, archaeological, historical and cultural value within each geopark (UNESCO, 2014).

The Global Geoparks Network (GGN) is a non-profit International Association developed under the umbrella of UNESCO and serves to develop models of best practice and set quality-standards for territories that integrate the protection preservation of Earth heritage sites in a strategy for regional sustainable economic development.

Brazil has one of the greatest geological potential of the planet, with large geodiversity, however there are only three geoparks recognized by UNESCO: Araripe, Seridó and Caminhos dos Cânions do Sul, with the last two recognized in 2022. Several studies (Ruchkys 2006, 2007; Silva 2007; Mantesso-Neto et al. 2010; Castro et al. 2011; Ruchkys et al. 2012; Gomes et al. 2019; Carmo 2020; Castro et al. 2020; Santos et al. 2021) show the potential of the Iron Quadrangle, an important Brazilian heritage site, to be incorporated in the GGN.

The Iron Quadrangle geographically corresponds to an extension of the area, with about 7000 km², located in the southern region of Serra do Espinhaço, integrating 35 cities of Minas Gerais state. It is inserted as headwaters of important watersheds such as the São Francisco river, Rio Doce and Rio Grande ones (Ruchkys et al. 2012).

João Monlevade that integrates the northeast end of the Iron Quadrangle has important geological sites, such as Areão Park and Serra do Seara, that deserve to be considered from the point of view of geoconservation. The State University of Minas Gerais (UEMG -- acronyms for Universidade do Estado de Minas Gerais), located in João Monlevade city, offers the undergraduate courses in civil, metallurgical, environmental, mining and mechanical engineering. These courses are very important to the development of the country, but they interpose extensively in the landscape. For this reason, the academy takes over an important role, extending to the society the scientific knowledge about geographical, historical, economic heritage, space alteration and its natural environment as a whole, creating an important way for regional sustainability.

The aim of this paper is to demonstrate the role of the academy as a promoter of conservation activities of the Iron Quadrangle, especially in the João Monlevade city. The Iron Quadrangle has great importance in the history of mining in Brazil and relevance in the geological context and tectonic evolution for understanding the geological history of Earth.

## II. GLOBAL GEOPARK NETWORK (GGN)

The Global Geoparks Network (GGN) is a legally constituted not-for-profit organization. It is a dynamic network where members are committed to work together, exchange ideas of best practise, and join in common projects to raise the quality standards of all products and practises of a UNESCO Global Geopark. UNESCO Global Geoparks are single, unified geographical areas where sites and landscapes of international geological significance are managed with a holistic concept of protection, education and sustainable development.

According to UNESCO the number of sites in the Global UNESCO Geoparks Network, at april 2021 was 169 distributed in 44 countries, as presented in Fig. 1, demonstrating the diversity of the planet's geology. Europe is the continent with the most geoparks, 87. Then; Asia has a total of 67 geoparks, where China has 42. There are thirteen geoparks on the American continent and only two geoparks on the African continent.

Brazil has one of the greatest geological potential of the planet, with large geodiversity, however there are a unique geopark recognized by UNESCO. The Araripe UNESCO Global Geopark was created in 2006, holds one of the largest and deposits of fossils from Lower Cretaceous in Brazil and in the world. The Araripe UNESCO Global Geopark is located in the Araripe Basin (Ceará state), which is considered the largest sedimentary basin in the brazilian northeast. The geological heritage of the geopark is characterized by important geological records from the lower cretaceous period between 90 and 150 million years ago, especially in its paleontological content. The preservation of this vast and rich heritage of fossils in the region was caused by unique conditions during the geological evolution of Araripe Basin, especially in the Cretaceous. Sedimentary deposits preserve a great diversity of rocks (limestones, claystones, sandstones, thick deposits of gypsum) that are a record of geological environments that existed in this region (UNESCO, 2020).

The geoparks project of the Geological Survey of Brazil, created in 2006, represents an important inductive role in the establishing of geoparks in Brazil. In 2012, this organization presented 35 proposal of creation of geoparks in the Brazil (CPRM, 2018; SCHOBBENHAUS and SILVA, 2012). Despite of the existence of these proposals, the most advanced projects are the Bodoquena-Pantanal, the Campos Gerais, the Alto Ribeira Valey, Iron Quadrangle (GUIMARÃES et al. 2009), Pathways of the Southern Canyons, and Seridó Geopark (UNESCO, 2022).

The potential of the Iron Quadrangle for understanding earth science and mining history is widely accepted (RUCHKYS 2006, 2007; SILVA 2007; MANTESSO-NETO et al. 2010; CASTRO et al. 2011; RUCHKYS et al. 2012; GOMES et al. 2019; CARMO 2020; CASTRO et al. 2020; SANTOS et al. 2021). Its mineral wealth, scenic

landscapes, geological features and human history reveal particularities that reinforce the need to include the Iron Quadrangle Geopark in the GGN.

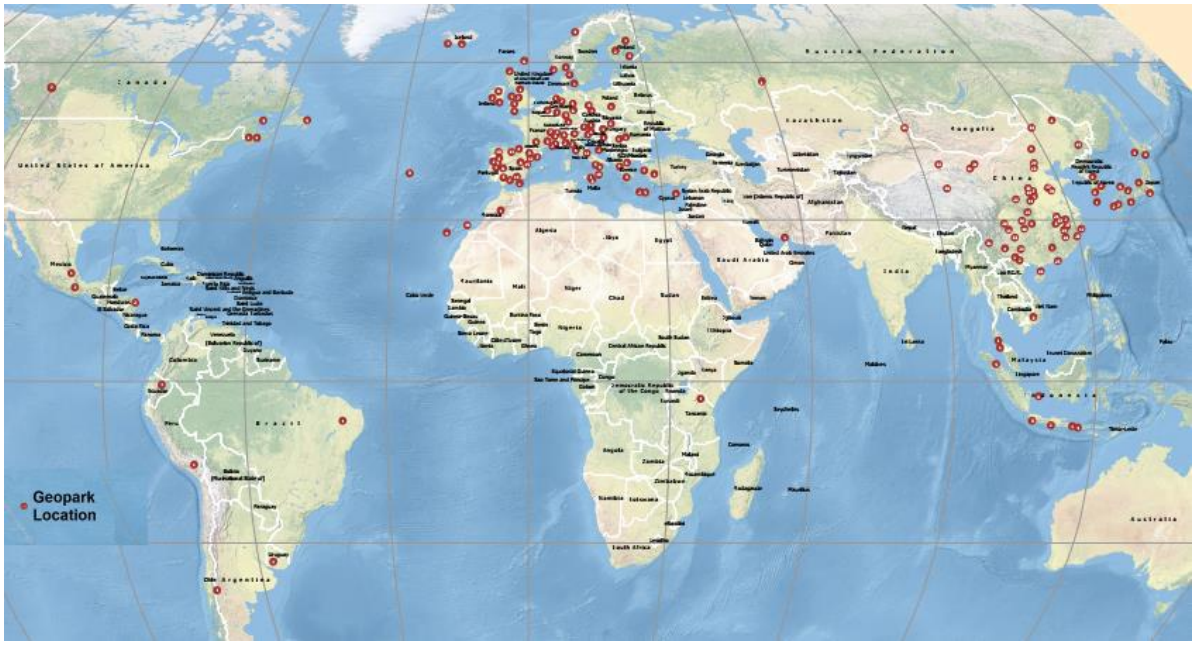


*Fig. 1: Distribution of GGN Members* (UNESCO, 2021).

## III. IRON QUADRANGLE GEOPARK

The central region of Brazil is so rich in minerals that it was named, General Mines, in portuguese Minas Gerais. Gold was found in this region in the end of the 17th century and its extraction declined progressively in the end of the 18th century (MACHADO 2009, CASTRO et al. 2011). However, gold is still mined, and since early the 19th century, iron ore is heavily extracted. A high percentage of Brazil's mineral production, (approximately 60%) comes from an area called Iron Quadrangle, located in the central-southeastern part of the Minas Gerais State (MANTESSO-NETO et al. 2010).

The Iron Quadrangle played an essential role in the development of the portuguese empire and in the evolution of the brazilian nation. The history and occupation of Iron Quadrangle were determined by the conditions of the exploration of the gold and other minerals. During the colonial period, several hundred tons of gold produced from the rich placer deposits of the region formed a large part of the financial foundation for rapid expansion of the portuguese empire and the influence of that nation in world affairs (DORR, 1969).

Over time, the Iron Quadrangle diversified its mineral production, being one of the most important mining districts in Brazil, standing out for the production of iron ore, manganese, gold, steatite (soapstone), gemological minerals, among others (SILVA 2007).

The Iron Quadrangle is the subject matter of a project for the creation of a geopark. According to [8], the proposed area for the limits of the geopark, covers: i) to the north, the Serra do Curral (from the Serra do Rola Moça to the Serra da Piedade); ii) to the west, the Serra da Moeda; iii) to the south, the Serra do Ouro Branco, the Serra da Itatiaia and the Itacolomi peak; iv) to the east, the Frazão peak, the Serra do Caraça, the Serra do Tamanduá, the Serra do Brucutú, the Serra das Cambotas and the Serra da Piedade, as presented in Fig. 2.

Rock formations in Iron Quadrangle date from the Archean to the Paleo-proterozoic, and represent meaningful processes in the Earth evolution. Briefly, its geodiversity includes some intrusives and three extensive complexes: i) Archean metamorphics; ii) Archean greenstone belt-type rocks, some gold-bearing; iii) Paleo- and meso-proterozoic metasedimentary sequences, with bodies of banded-iron formation (alternating layers of hematite and silicates); this world-known itabirite is the main local iron ore, and, along with the quartzites, forms the mountain ranges that surround and characterize the Iron Quadrangle (FARINA et al., 2016). Fig. 3 presented the simplified geological map of the Iron Quadrangle with the location of main geological formations.

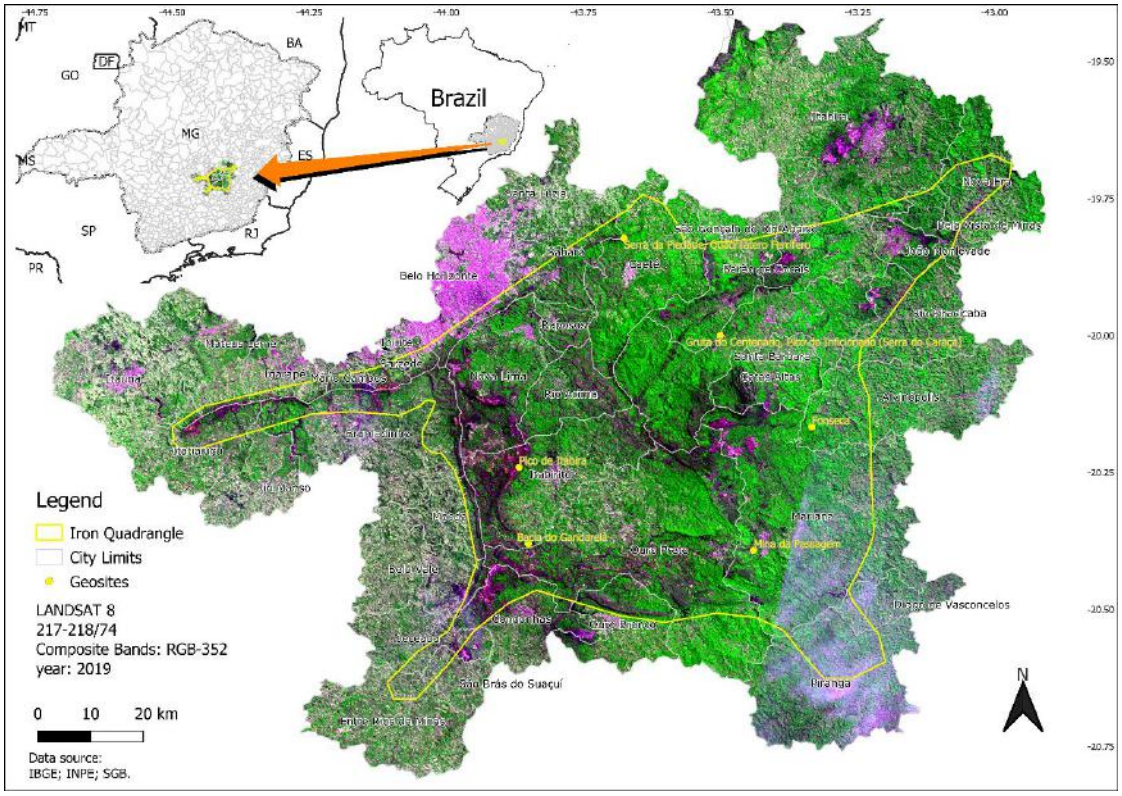


*Fig. 2: Location and limits of the proposed Iron Quadrangle Geopark (Adapted from Ruchkys et al. 2012).*

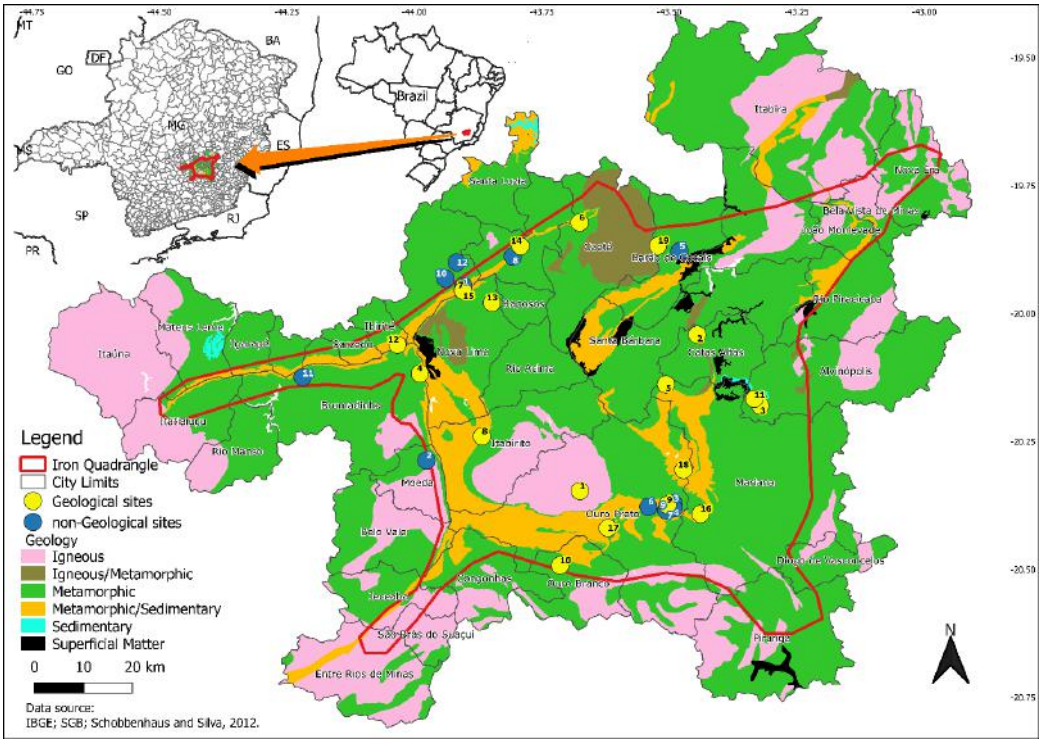


*Fig. 3: Simplified geological map of the Iron Quadrangle (Adapted from Ruchkys et al. 2012).*

Table 1 presents the identification of the geological sites and non-geological sites of the Iron Quadrangle.

*Table.1: Geological and non-geological sites of the Iron Quadrangle (Ruchkys et al. 2012)*

| GEOLOGICAL SITES | |
|---|---|
| 1 | Cachoeira do Campo (Cachoeira do Campo) |
| 2 | Rio das Velhas supergroup metavolcanics and Bicame de Pedra Aqueduct (Catas Altas) |
| 3 | Metarenites of Andaime peak (Itabirito) |
| 4 | Quartzite and basal conglomerate of the Moeda formation (Moeda) |
| 5 | Natural Park of Caraça (Catas Altas and Santa Bárbara) |
| 6 | Itabirites from Serra da Piedade (Caeté and Sabará) |
| 7 | Curral moutain range (Belo Horizonte and Nova Lima) |
| 8 | Itabira peak (Itabirito) |
| 9 | Itacolomi peak (Ouro Preto and Mariana) |
| 10 | Ouro Branco mountain range (Ouro Branco) |
| 11 | Fonseca (Alvinópolis) |
| 12 | Rola-Moça moutain range (Belo Horizonte, Nova Lima, Ibirité and Brumadinho) |
| 13 | Morro Velho mine (Nova Lima) |
| 14 | Córrego do Meio mine (Sabará) |
| 15 | Águas Claras mine (Nova Lima) |
| 16 | Passagem village (Mariana) |
| 17 | Capão do Lana (Ouro Preto) |
| 18 | Nossa Senhora da Lapa grotto (Ouro Preto) |
| 19 | Cambotas mountain range (Barão de Cocais) |
| NON GEOLOGICAL SITES | |
| 1 | Mangabeiras park (Belo Horizonte) |
| 2 | ruins of clandestine gold smelting house (Moeda) |
| 3 | ruins of Patriótica iron factory (Congonhas and Ouro Preto) |
| 4 | Queimada hill (Ouro Preto) |
| 5 | Pedra Pintada archaeological site (Barão de Cocais) |
| 6 | Tripuí ecological station (Ouro Preto) |
| 7 | Science and technology museum of mines school – Federal University of Ouro Preto (Ouro Preto) |
| 8 | gold museum (Sabará) |
| 9 | House of Contos (Ouro Preto) |
| 10 | Mines and metal museum (Belo Horizonte) |
| 11 | Inhotim (Brumadinho) |
| 12 | Geological heritage reference center – Federal University of Minas Gerais (Belo Horizonte) |

The geological context of the Iron Quadrangle is characterized by a basal metamorphic complex, the supracrustals of the Rio das Velhas Supergroup and metasedimentary sequences paleo and mesoproterozoic represented by the Minas Supergroup and Espinhaço Supergroup and their respective petrographic formations as presented in the Fig. 3.

The Minas Supergroup, which in terms of stratigraphy, it can be divided into two main megasequences: (i) a sequence between delta fluvial and platform marine that includes the Caraça, Itabira and Piracicaba Groups and (ii) immature marine deposits of the Sabará Group. Grupo Itabira, where the itabirites are, the name given to Banded Iron Formations, a predominantly marine sequence from shallow to deep (DORR, 1969).

## IV. RESEARCH, EXTENSION AND TEACHING IN THE CONTEXT OF IRON QUADRANGLE

### 4.1 Importance of Geoconservation

The conservation of the geological heritage for future generations depends of an adequate use of the land, where everyone is responsible. This conservation imposes new challenges for all sectors of society: politicians, businessmen, educators, media, etc. In this way, it is urgent to improve the methods of exploration of geological resources enabling and promoting their sustainable use. Changes in citizen's unsustainable consumption rates are required in order to mitigate current problems affecting society, namely those emerging from the fragility of the physical environment (HENRIQUES et al. 2011).

The deep transformation of the land surface is one of the major environmental impacts associated with the industrialization. The intense transformation of the earth's surface has a negative impact on the conservation of the geological heritage.

In Brazil, native forests -- that includes areas of native vegetation in rural properties, integral conservation units, indigenous lands and native vegetation in vacant and unregistered lands -- occupy 66.3% of the land surface. Agriculture and cattle raising correspond to 30.2%, distributed in native and planted pasture; agriculture; and planted forest. Other purposes, including settlements and infrastructure totalize 3.5% (EMBRAPA, 2018). In this way, these activities result in significant modifications of the surface and consequently, inevitable destruction of geological heritage of the country. Figure 4 shows the occupation of the land surface of the Brazilian territory with more details.

Furthermore, Brazil is one of the richest countries in minerals on the planet, being the second largest producer of iron ore in the world, according to IBRAM 2021. This abundance of raw material makes Brazilian mining, as well as the steel industry, stand out in the international market in the production and export of iron ore and steel, where Minas Gerais and Iron Quadrangle are the biggest representatives of these activities. Relative to the steel industry, João monlevade was one of the pioneers cities in the implementation of this segment in Minas Gerais.

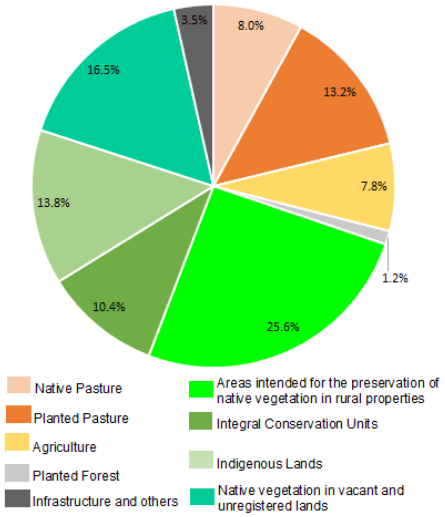


*Fig. 4: Occupation of the land surface of the brazilian territory (Adapted from EMBRAPA, 2018).*

### 4.2 The context of João Monlevade

João Monlevade city is located at the northeast end of the Iron Quadrangle, in the region named Steel Valey. Its economy turns around to the steel industry, metallurgy and mining. Thus, the city and the region have concentration of companies related to these sectors and educational institutional that offers courses in these areas. Important geological sites of the city that must to be considered from the point of view of geoconservation are Areão Park and Serra do Seara. Figure 5 displays the limits of João Monlevade with the location of the important places of the region from the point of view of geoconservation i. e. Arcelor Mittal, Andrade Mine, Areão Park, Serra do Seara and UEMG.

Arcellor Mittal, the largest steel conglomerate in the world, has an integrated production unit in the city of João Monlevade that includes production processes from the use of iron ore -- extracted at the Arcelor Mittal Andrade Mine (MG) that produces sinter feed -- through sintering, reduction in blast furnace, steel refining, up to rolling (ARCELLOR MITTAL 2020).

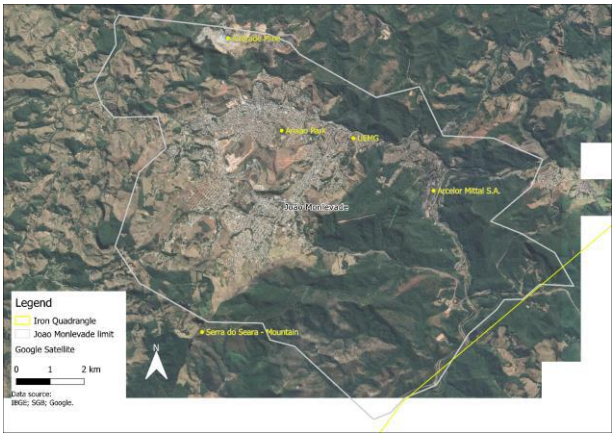


*Fig 5. Limits of João Monlevade city (Google Earth).*

Areão Park corresponds to an important conservation unit representative of the Iron Quadrangle, specifically in the extreme northeast in contact with other geological environments. The name Areão refers to the intensive extraction of sand, (areia in portuguese) which began in the mid-60s and ended in the 90s of the 20th century. Figure 6 shows the rocky blocks (boulders) and quartzite outcrops that represent the characteristic rocky landscapes of Areão Park.

*Fig. 6. Coarse quartzite outcrops in the central area of Areão Park (Silva and Ferreira Neto 2020).*

Serra do Seara is the highest point in the region reaching 1330 meters of absolute altitude. It is part of a group of topographic highs of the Iron Quadrangle that served as a geographical reference for the displacement of people heading to the central region of Minas Gerais after the discovery of gold in the surroundings of Sabará and Ouro Preto (Castro et al. 2020). Figure 7 presents the cliff and the outcrops features of the relief of Serra do Seara.Important geological sites of the city that must to be considered from the point of view of geoconservation are Areão Park and Serra do Seara.

*Fig. 7. Outcrops of the Serra do Seara.*

Silva and Ferreira Neto (2020) analyzed outcrops in Areão Park, identified metamorphic lithologies such as gneisses, amphibolites, metagranitoids and supracrustal metasedimentary rocks. The predominant lithology in the outcrops of the walls of the park is sericitic quartzite, a metamorphic rock.

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Fig. 5 presents the limits of João Monlevade with the location of the important places of the region from the point of view of geoconservation i. e. Arcelor Mittal, Andrade Mine, Serra do Seara, Areão Park and State University of Minas Gerais (UEMG).

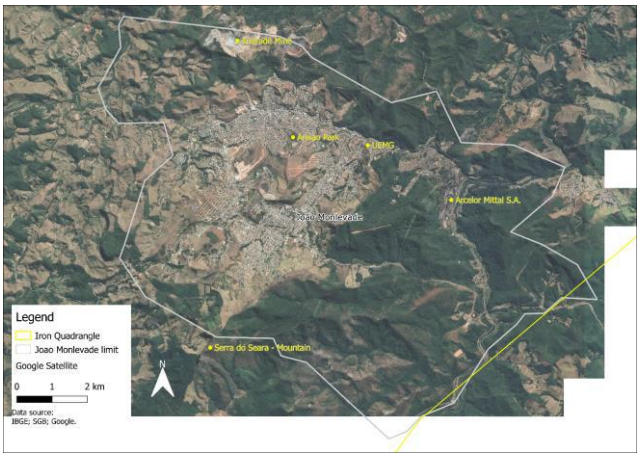


*Fig. 5: Limits of João Monlevade city.*

### 4.2 The State University of Minas Gerais

The UEMG is a university located in João Monlevade city and it offers the undergraduate courses in civil, metallurgical, environmental, mining and mechanical engineering. These courses are very important to the development of the country, but they interpose extensively in the landscape.

The UEMG, through its trajectory, has developed extension activities linked to the history of each unity. Therefore, since the great areas of origin of UEMG as arts, education and technology until the expansion for the engineering, public politics, physical, exact and social sciences, the emphasis in teacher formation and the search of solutions to the problems of the reality of Minas Gerais and Brazil always were present in the extension practices.

Therefore, the institution can stimulate the development of scientific research at the undergraduate and postgraduate level with important themes in the scientific, technological and social fields related to the conservation of the geological patrimony. Creation of extension and research specific projects turned over geodiversity, geoeducation, environmental preservation are necessary. These projects can be directed to the local reality, emphasizing characteristics of the region, such as the natural sites of the Areão Park and Serra do Seara.

Silva and Ferreira Neto (2020) analyzed outcrops in Areão Park, identifying metamorphic lithologies such as gneisses, amphibolites, metagranitoids and supracrustal metasedimentary rocks. The predominant lithology in the outcrops of the walls of the park is sericitic quartzite, a metamorphic rock.

Serra do Seara mountain has a predominance of metamorphic rocks of the quartzite type. Rocks from the Minas supergroup, typical of the Iron Quadrangle, such as sericitic quartzites and quartz-muscovite-schist from the Caraça group represent the geology of the mountain range (Reeves 1966). Figure 8 presents the geological contact of the gneiss-granitic sequence of the basement (outcrop in the center of the image) with quartzite and quartzite-sericite schist from Serra do Seara.

It is important to study these places from the point of view of geoethics and geological heritage, making a parallel with the local economic scenario that has mining and steel industries (e.g. Arcellor Mital) generating a demand for professionals of in this areas (presence of higher and technical institutions that offer courses focused on engineering and related areas).

*Fig. 8: Gneiss-granitic sequence in contact with quartzite and quartzite-sericite schist, in the Serra do Seara.*

Relative to the extension projects, events to the students and society in general, such as seminars, technical visits and excursions for the connecting geo-education with the local context, highlighting the importance of their geological heritage inter-related to the biodiversity and local cultural heritage. Relative to research projects to the geological mapping of the area, characterization of the soil and environmental preservation are of some importance.

Alterations in the Course Pedagogical Projects creating mandatory and optional disciplines with subject related to Iron Quadrangle according to the features of each region and each course. For example, disciplines linked to the geoconservation and geoethics; principles of interpretation of geodiversity; geological heritage, can contribute to the geological preservation of the natural sites Serra do Seara and Areão Park.

In this way, universities could be contributing in the social and cultural transformation of the state, especially in Minas Gerais, emphazing important cenarios of the substantiality of the region.

## V. CONCLUSION

This paper presented the importance of the geopark Iron Quadrangle to the Brazil due to its mineral wealth, scenic landscapes, and geological and human history. João Monlevade city – that integrates the northeast end of Iron Quadrangle -- has received special attention, since it has an economy around the steel industry, metallurgy and mining, activities that interpose intensively in the landscape. These activities generate a demand for educational institutions that offer training related to these areas, for example engineering courses.

In this context, the UEMG is involved, since the academy has the function to the preserve the region, especially institutions that offer courses that modified severely the natural landscape. In this way, important geological sites of the João Monlevade city such as Areão Park and Serra do Seara must to be considered from the point of view of geoconservation. Creation of extension and research specific projects turned over geodiversity, geoeducation, environmental preservation can be contribute for the geoconservation of these areas.

Relative to extension, events to the students and society in general, such as seminars, technical visits and excursions for the connecting geo-education with the local context, highlighting the importance of their geological heritage to the biodiversity and local cultural heritage. Relative to research projects, the geological mapping of the area, characterization of the soil and environmental preservation are of some importance.

Alterations in the Course Pedagogical Projects creating disciplines with subject applied to local reality related to the geoconservation and geoethics, principles of interpretation of geodiversity, and geological heritage can contribute to the preservation of region.

Then, the academy can extend to a society the scientific knowledge about geographical, historical, economic heritage, space alteration and its natural environment as a whole, creating an important way for regional sustainability. highlighting the importance that Iron Quadrangle represents for the history of mining in Brazil, especially in Minas Gerais state, and the relevance of its geological context and tectonic evolution for understanding the geological history of Earth.. Thus, projects and programs with groups and sectors of civil society and the state can possibility transformations in the pedagogical process, in which students, teachers, managers and technicians-administrative are participants, knowledge producers, expressing a position of the university towards the society in which it operates, intervening in the concrete reality.

The theme addressed in this article also contributes to geological sites such as Areão park and Serra do Seara being contemplated by research and extension projects of UEMG, João Monlevade unit, and by other segments of education, especially due to the proximity of these sites and their riches, when considered from the point of view of geoconservation.

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