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Geoeological profile of the Serra do Gandarela National Park, Minas Gerais, Brazil

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Serra do Gandarela National Park.
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Abstract

This paper presents a geosystemic study of the Serra do Gandarela National Park. This conservation unit is inserted in the context of the Quadrilátero Ferrífero, in Minas Gerais, where outcrops of Precambrian lithostratigraphic units of the Rio das Velhas and Minas Supergroups can be found. Thus, a geoeological profile was elaborated using a methodology of cartographic representation of a transect on the area of interest. This favours the elaboration of horizontal readings along with each represented element, as well as vertical readings, where correlations can be interpreted between the various elements present. The compartments of the morphostructural domains elaborated for the Belo Horizonte Southern Metropolitan Region Environmental Protection Area Project (Projeto APA Sul da Região Metropolitana de Belo Horizonte) were used as units of analysis for interpretation of the geoeological profile. The constructed geoeological profile enabled a more holistic understanding of the study area, which may contribute to the management of this conservation unit.

INTRODUCTION

The geosystemic approach seeks to articulate “anthropic” and “natural” variables to construct a holistic analysis of the environment (MONTEIRO, 2001). Based on the work of Bertalanffy (1950), which understood Geosystems as a specific category of hierarchically structured dynamic systems, Sotchava (1977) proposes their use in the understanding of geographical phenomena. The construction hierarchy with the main characteristic of geosystems stands out, whereby all the subdivisions of the natural environment, from the minimal units of the terrestrial surface to the planetary geosystem, are characterized as dynamic units with specific geographic organizations. Thus, for this author,

the systemic framework is not limited to morphology or landscape subdivisions, but seeks, above all, to understand its dynamic and structure (SOTCHAVA, 1977).

For Bertrand (1972), the landscape results from the dialectic interaction between physical, biological and anthropic elements, in constant evolution, constituting a unique, spatially localized set. This author develops a hierarchical classification system composed of six levels: Zone, Dominion, Natural Region, Geosystem, Geofacies and Geotope. In this taxonomy, the geosystem includes a unit that dynamically integrates geomorphological, climate and hydrological factors; presents the same type of evolution, solid biological and ecological unit; and, often, homogenous physiognomy. From the same perspective, Ramos et al. (2019) defend that the terrestrial

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surface can be understood as a spatial unit that possesses a dynamic of interactions between natural and anthropic processes, thus composing a systemic relationship.

Based on the concepts presented above, Marés Mikosik et al. (2009) consider that the construction of geoecological profiles is a form of systematic approach to the landscape. In the same vein, Levighin and Viadana (2003) indicate that this method explains the environmental aspects of the area under analysis, since it enables the representation of sections of space and establishes correlations between their elements.

These premises have been the basis of different studies using geoecological profiles to carry out integrated analyses of the landscape, especially those aimed at understanding and management in conservation units (JANSEN, 2014; MARENT; PORTILHO, 2017; LOPEZ; LEÃO, 2018; SANTOS et al., 2018; RAMOS et al., 2019).

STUDY AREA

The Serra do Gandarela National Park (PNSG), a full protection conservation unit, was created in October 2014, with an area of 31,270 hectares. It occupies part of the municipalities of Nova Lima, Raposos, Caeté, Santa Bárbara, Mariana, Ouro Preto, Itabirito and Rio Acima. Located around 50 km from Belo Horizonte, in the state of Minas Gerais, it aims:

To guarantee the preservation of samples of biological, geological, speleological and hydrological heritage associated with the canga formations of the Quadrilátero Ferrífero, including the campo rupestre montane savannas and the remaining pockets of semi-deciduous forest, the aquifer recharge areas, and the scenic group consisting of mountains, plateaus, natural vegetation, rivers and waterfalls (BRASIL, 2014).

This conservation unit is inserted within the Quadrilátero Ferrífero (QF), where outcrops of Precambrian lithostratigraphic units of the Rio das Velhas and Minas supergroups can be

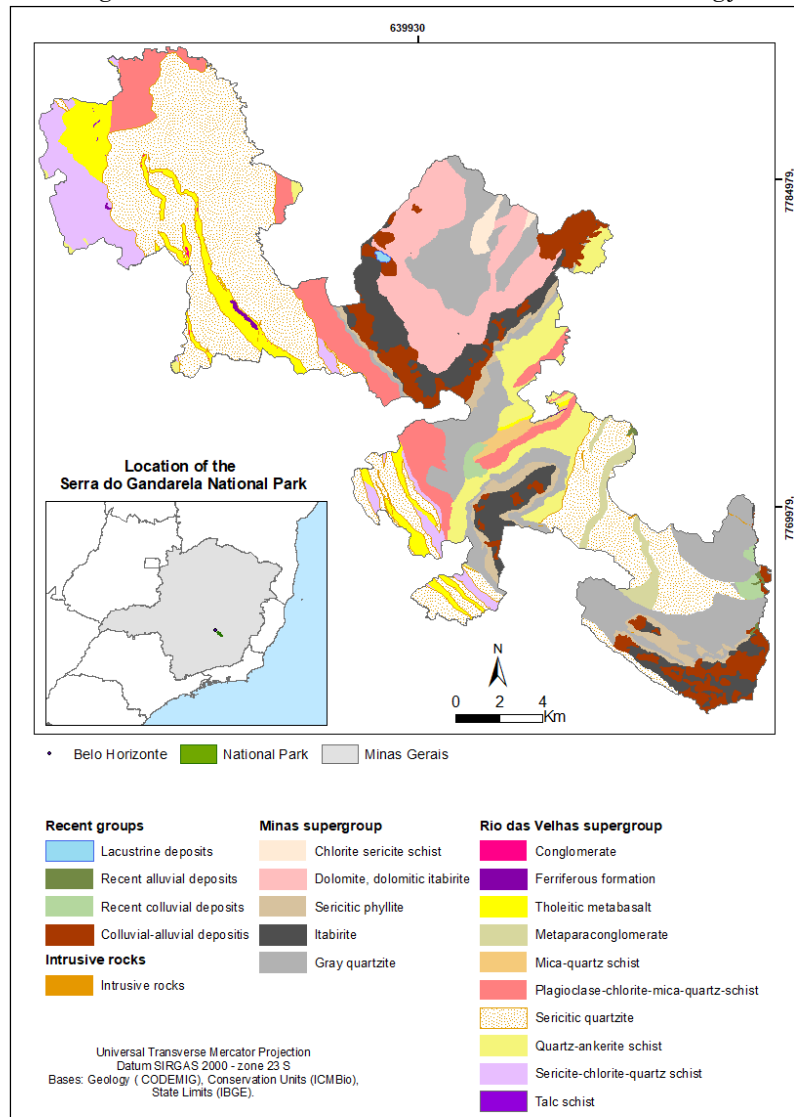
found. At a lesser scale, there are also lacustrine deposits, lateritic-detrital coverings, colluvial deposits, and colluvial-eluvial deposits, of Cenozoic age, as well as alluvial deposits composed of Phanerozoic rocks (Figure 1).

Different lithological types, with multiple degrees of resistance to chemical weathering and erosion, combined with complex structural conditioning, marked by folding and thrust faults, as well as Cenozoic tectonic uplift and bioclimatic factors, conditioned the modelling of the morphostructural compartments found in the QF, at their origin and during their evolution (MEDINA; DANTAS; SAADI, 2005). Among the morphostructural units proposed by these authors for the QF, six were identified in the study area: the Rio das Velhas Anticlinal Valley, Staggered Levels of the Serra do Jaguará, the Depressão Suspensa of Gandarela Syncline, the Conceição River Anticlinal Valley, the Serra do Ouro Fino Syncline Crest, and the Caraça Massive

The diversity of outcropping lithotypes in the PNSG favours the occurrence of a large quantity of natural subterranean cavities. In December 2019, the National Register of Speleological Information (CANIE) indicated the occurrence of 275 caves in the park area, developed in carbonate, ferriferous rocks and siliciclastic rocks. The park is situated in an area where medium, high and very high potential for the occurrence of caves predominates (JANSEN; CAVALCANTI; LAMBLÉM, 2012). As such, new caves may come to be located in the region as speleological prospection studies are carried out.

The pedological coverage, determined by the parent material, is composed mainly of Haplic Cambisols and Neosols, which occupy around 75% of the area. Shinzato and Filho (2005) point out that these soil types are underdeveloped and are shallow or not very deep, presenting a high concentration of minerals and low resistance to weathering, being associated with dynamic relief. These characteristics, combined with periods of heavy rainfall, with greater surface runoff speeds, favour morphogenetic processes. Approximately 20% of the area has low-thickness or non-existent soil coverage, being composed of rocky outcrops, canga exposures or degraded areas. Argisols, Latosols and Gleisols can be found in the rest of the area.

Figure 1- Serra do Gandarela National Park - Geology



Source: Elaborated by the authors.

The PNSG is situated in an area of transition between the Cerrado and Atlantic Forest biomes. The Coverage and Land Use map developed by Oliveira, Jacques and Shinzato (2005) for the APA Sul RMBH project, indicates the prevalence of *Campo Cerrado/Campo Graminoso* (Savanna Field/Grassy Field) and *Mata* (Forest) phytophysionomies. On a lesser scale, they also indicate the occurrence of other coverage, including Campo Rupestre montane savanna, as well as the “Exposed Soil” class of use. The authors point out that, in this area, the Campo Rupestre class is associated with coverage of canga and quartzite outcrops. Lamounier et al. (2010); Filho, Curi and Shinzato (2010) advanced the analysis of the relationship between lithology and coverage. For these authors, the lithological variation determines the establishment and development of the phytophysionomies found in the region.

This region is historically marked by mineral

They describe that the greater resistance to weathering of the rocks of the Itabira, Caraça and Maquiné groups conditions the higher altitudes and is associated with the occurrence of quartzite and ferruginous campo rupestre montane savannas. Meadows and shrubby grassland, phytophysionomies of the Cerrado, are related to the occurrence of rocks from the Nova Lima Group. The areas where Semi-Deciduous Seasonal Forest can be established have deeper soil layers, developed from the rocks of the Gandarela formation and phyllites of the Piracicaba Group, which are more susceptible to epigenetic processes. The Company Vale S.A. and Amplo Engenharia e Gestão de Projetos Ltda., in 2019, through analyses of the nature of the substrate, identified a Quartzitic Geosystem and a Metapelitic Geosystem on the borders of this national park. exploration, especially iron mining. It can be

highlighted that, as shown by Piló, Coelho and Reino (2015), the QF and the Serra dos Carajás, in Pará, account for more than 90% of national iron production. Thus, the locational rigidity of the iron reserves has been used as an argument for the installation and amplification of mining ventures, putting significant pressure on areas which, as shown by Carmo (2010), are invaluable for presenting high rates of endemism, the occurrence of rare species, and a unique geodiversity with various categories of associated heritage.

Souza and Carmo (2015) classified these areas as ferruginous ecosystems, defined as spatial units whose lithology is composed of ferruginous rocks originating mainly in the Archean (2.7 – 2.6 Ga) and in the Paleoproterozoic (2.5 Ga to 540 Ma). These geosystems include the physical components and the inter-relationships between them, housing important natural elements such as hydric resources, flora and fauna endemism, and speleological heritage. Salgado (2015) argues that these geosystems are classified among the most expressive on the Earth's surface, due to the richness of their geodiversity and biodiversity. However, this author emphasizes that where mineral exploration occurs more intensely in these geosystems, its geodiversity, which is yet to be fully studied and remains little known, has suffered degradation and, in many cases, destruction of its elements. In addition to protecting the well-preserved part of the ferruginous geosystems, this conservation unit

METHODOLOGY

A geoecological profile was elaborated for a better understanding of both spatial distribution and the relationships between the abiotic elements and vegetal coverage in the study area. This method consists of cartographic representation of a transect over the area of interest, which favours horizontal readings along with each represented element, as well as vertical readings, where correlations between the various elements at a determined location can be interpreted (MONTEIRO, 2001; LEVIGHIN; VIADANA, 2003).

The compartments of the morphostructural domains elaborated for the Belo Horizonte Southern Metropolitan Region Environmental Protection Area Project (Projeto APA Sul da Região Metropolitana de Belo Horizonte) (MEDINA; DANTAS; SAADI, 2005) were used as analysis units for the interpretation of the

geoecological profile. As such, a transect of around thirty kilometres was created in a north-west to south-east direction, to intercept all the morphostructural compartments existing in the park area (Figure 2). This transect begins at point A, located in the north-west of the area, at UTM coordinates 624223 and 7786758, and extends to point B, in the south-east, located at coordinates 647906 and 7771076.

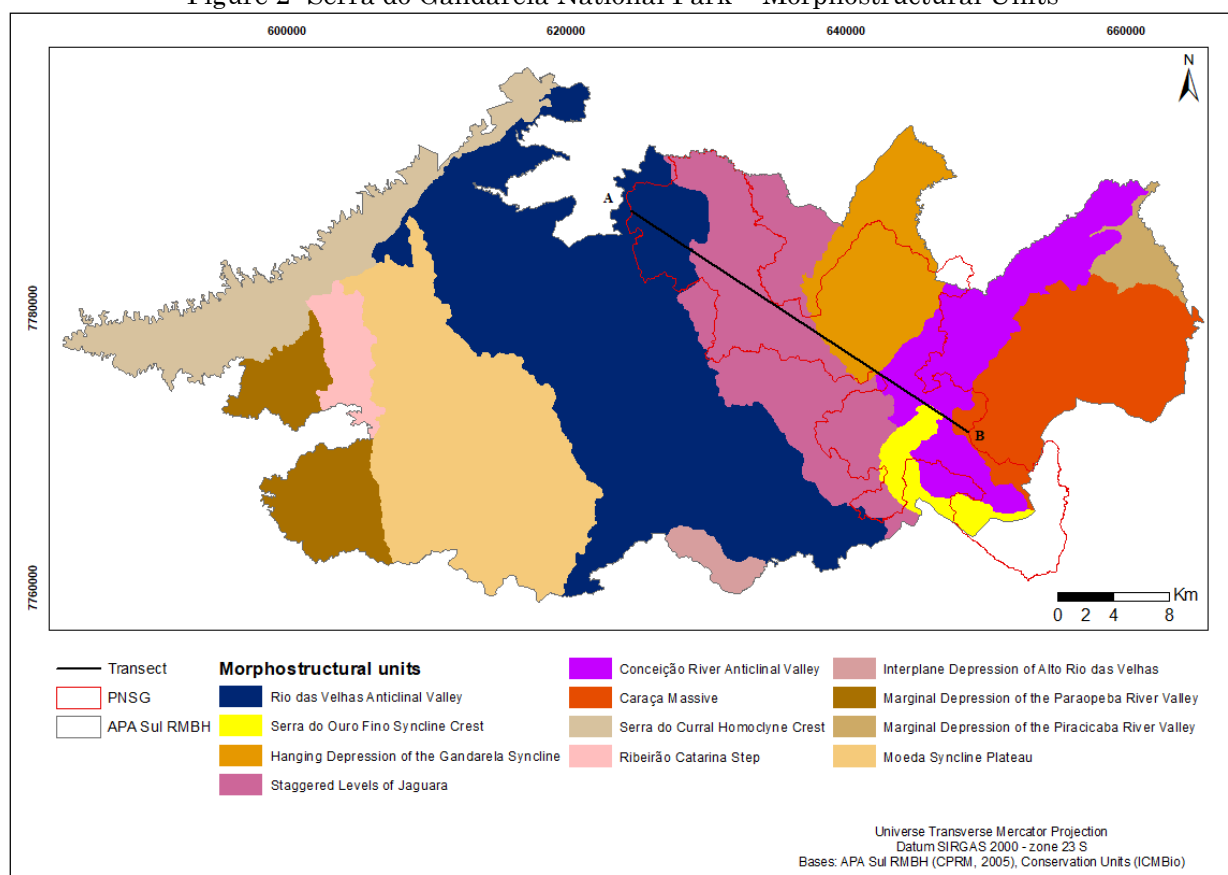
The proposed analyses were carried out using the Geographic Information System. After defining the transect, a topographic profile was developed, using SRTM images (s20w044 and s21w044) with a resolution of 30 metres, with the help of TrackMaker software. This topographic profile was then laid over the information (shapes) referring to the geology, geomorphology, pedology and coverage, and land use (Projeto APA Sul da RMBH – CPRM, 2005), as well as the municipal limits (IBGE), and a map of Cave Occurrence Potential (JANSEN; CAVALCANTI; LAMBLÉM, 2012). This stage was carried out using ArcGIS software. The office analyses were accompanied by field trips for better interpretation of the profile.

RESULTS

The geoecological profile (Figure 3) enabled vertical and horizontal readings, with the aim of a holistic understanding of the study area.

The Rio das Velhas Anticlinal Valley compartment, situated in the north-west of the study area, covers part of the Nova Lima and Raposos municipalities. Cerrado vegetation (field savanna and grassy fields) predominates in this compartment, with ciliary forest occurring alongside the bodies of water. The soils are composed of Haplic Cambisols (dystrophic typic and dystrophic leptic or lithic) and Neosols (dystrophic typic) of very gravelly texture and Argisols (red-yellow dystrophic cambic or typic). Hills dominate the relief with sharp tops or crests, supported by rocks of the Rio das Velhas Supergroup, dated from the Mesoarchean-Neoproterozoic, locally represented by Metagraywacke lithotypes, metatuft, siltstone, carbonaceous schist, and metadensite, and Metabasalt, metatuft, metavolcanic acid, metachert, and carbonaceous schist, both from the Nova Lima Group and Schists with quartzite intercalations from the Maquiné Group. This region has medium potential for the occurrence of natural subterranean cavities.

Figure 2- Serra do Gandarela National Park – Morphostructural Units



Source: Elaborated by the authors.

The Staggered Levels of Jaguará compartment, in the section of the park situated in the Rio Acima and Caeté municipalities, has varied altimetry, between, approximately, 1,000 metres in the north-west and 1,500 metres towards the south-east. Field savanna and grassy fields, typical of the Cerrado, predominate among the vegetation types. Forest coverage also occurs in association with the bodies of water. The existence of unpaved roads exposes the pedological coverage, which essentially consists of Cambisols and Neosols. In various sections, the non-existence or low depth of pedological profiles enables outcropping of the rocky substrate. The relief is dominated by mountains/levels, quartzite plateaus, spurs and scarps. Siliciclastic rocks of the Rio das Velhas Supergroup predominate in this section, represented by Quartzite and conglomerate lithotypes, Quartzites with metaconglomerate intercalations, and Schists with quartzite intercalations, all from the Maquiné Group, as well as Quartz-mica schist, carbonaceous schist, ferriferous formation and Mica-quartz schist and graphite schist, both from the Nova Lima Group. Where the transect approximates to the

next compartment (Hanging Depression of the Gandarela Syncline) rocks from the Minas Supergroup begin outcropping, associated with scarp relief. In this section, there are conglomerate Quartzite and phyllite lithotypes, phyllite with metachert intercalations and Itabirite, dolomitic itabirite and bodies of hematite of Paleoproterozoic age, as well as canga coverage of Cenozoic age in the transition between the compartments. This compartment has potential for the occurrence of caves, varying from medium in the western portion, to high further to the east, to the extent that they are at higher altitudes and reach the canga coverage.

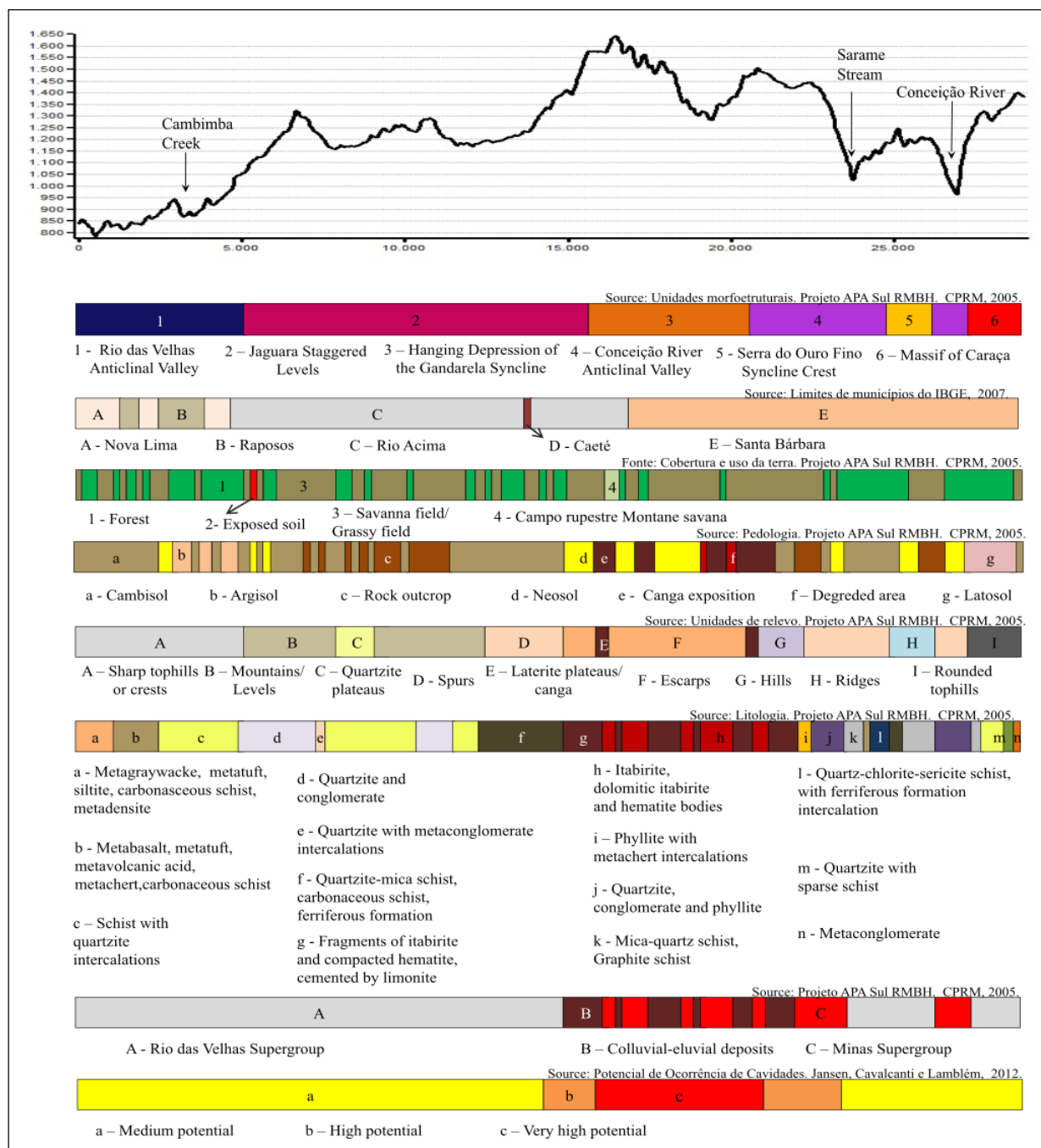
The Hanging Depression of the Gandarela Syncline compartment has the highest altitudes of the profile, varying between 1,300 and 1,600 metres, occupying areas of the municipalities of Rio Acima and, mainly, Santa Bárbara. Savanna field / grassy field vegetation predominates, with stretches of forest associated with the drainage. In the highest parts, there are campo rupestre montane savannas. When present, the pedological coverage consists of Neosols. In the other sections, where it is absent, colluvial-eluvial

deposits formed by fragments of hematite and itabirite cemented by limonite (canga), create planation surfaces supporting the highest altitudes of the compartment, at around 1,600 metres. Mining activities have degraded part of this coverage. The relief is composed primarily of scarps, intercalated with laterite plateaus. These relief forms are sustained by rocks constituted by Itabirite lithotypes, dolomitic itabirite and bodies of hematite, of the Minas Supergroup and by Fragments of itabirite and compacted hematite, cemented by limonite (Canga). This compartment has the highest potential for the occurrence of caves, due to the presence of itabirite in the elevated parts of the relief and of dolomites in the Gandarela formation, in the interior of the hanging depression.

The Conceição River Anticlinal Valley compartment had two sections intercepted by the profile, both in the Santa Bárbara municipality. It has altitudes varying between 1,500 metres, close to the hanging Gandarela Syncline compartment, and 950 meters, on the bed of the Conceição River. The vegetation is composed of smaller phytophysionomies, savanna field / grassy field, in the higher parts, and forest in the lower sections. The pedological coverage consists of Cambisols and Neosols. However, there are large extensions of rocky outcrops, through the exposition of canga or

other rocks. The relief has a laterite plateau and hills in the higher section of the compartment profile. These are supported by canga and by Itabirite lithotype, dolomitic itabirite and hematite bodies of the Minas Supergroup. In the sections with greater altitude variation, between 1,450 and 950 meters, spurs predominate. These, in turn, present great lithological diversity. In the lower sections, coinciding with the beds of the Conceição River and the Sarame stream, there is Mica-quartz schist lithotype from the Rio das Velhas Supergroup. In the other areas of this profile compartment, there are rocks of the Minas Supergroup, represented by Quartzite lithotypes, conglomerate and phyllite, and phyllite with metachert intercalations, and, Quartz-chlorite sericite schist lithotypes, with intercalations of ferriferous formations and Metabasalt, metatuft, metavolcanic acid, metachert, and carbonaceous schist from the Rio das Velhas Supergroup. In the more western portion, this compartment presents a high potential for the occurrence of caves, due to the presence of itabirites. In the more easterly section, where quartzites predominate, there is medium potential for the occurrence of caves.

Figure 3- Geological Profile of the Serra do Gandarela National Park.



Source: Elaborated by the authors.

The section of the Serra do Ouro Fino Syncline Crest compartment represented in the profile is inserted into the Santa Bárbara municipality and has altitudes of around 1,250 metres. Herbaceous-shrubby vegetation, consisting of savanna field / grassy field, predominates on a pedological layer composed of Cambisols and Neosols, in addition to a section where the rock is outcropping. The relief is characterized by the presence of mountains on rocks of the Rio das Velhas Supergroup, locally represented by Quartz mica-schist lithotypes,

graphite schist, carbonaceous schist and ferrous formation. This compartment has medium potential for the occurrence of natural cavities.

The Caraça Massive compartment is represented in a small stretch, in the extreme south-east of the profile, in the Santa Bárbara municipality, presenting altitudes between 1,200 and 1,400 metres. The vegetal coverage is formed almost entirely of a forest, developed on the deepest soils of the profile, which consist of Latosols. Countryside phytophysionomies occur in a lower proportion, sustained by Cambisols.

The relief is marked by hills with rounded tops, sculpted on rocks of the Minas Supergroup, where the following lithotypes are identified: Mica-quartz schist, graphite schist, Schists with quartzite intercalations, Quartzites with sparse scree and Metaconglomerates. In this compartment, the predominance of siliciclastic rocks promotes a prevalence of medium potential for the occurrence of caves.

The profile highlighted some challenges for the management of this conservation unit. In general, it can be stated that the predominance of Neosols, underdeveloped Cambisols, and rocky outcrops associated with dynamic relief and vegetal coverage composed of herbaceous and shrubby phytophysionomies conditions, elevate the degrees of environmental vulnerability in the Serra do Gandarela National Park (Santos, 2017). This factor can be verified in sections of the Rio das Velhas Anticlinal Valley and Staggered Levels of Jaguará compartments. These are places where the vegetal coverage has been eliminated, mainly through the practice of motocross or for the construction of access to the waterfalls, suffering an intense erosive process, even reaching a point of exposing the underlying rock. The large and, at times, abrupt altitude variation favours the occurrence of look-out points and waterfalls, operating as tourist attractions for the practice of adventure sports and outdoor activities. On the other hand, this same dynamic to the relief, associated with underdeveloped soils, favours the prevalence of morphogenetic processes, reinforcing the importance of careful planning both for the installation of infrastructure for the use of park attractions and for the urgency in recovering areas degraded by previous uses prior to the creation of the park.

Another highlighted challenge, also related to environmental vulnerability, is in respect to the ferruginous campo rupestre montane savannas, intrinsically associated with ferruginous geosystems, especially in the transition between the Staggered Levels of Jaguará and the Hanging Depression of Gandarela compartments. This vegetation is sustained by a slim layer of organic material laid directly over the rock, consisting mainly of canga. At points where this incipient soil has been removed, for mineral research or bauxite exploration, there has been no spontaneous repopulation of the vegetation, even after the passing of some decades.

CONCLUSIONS

The geoecological profile represents the landscape characteristics in the form of a transect. Abiotic elements (soils, relief units, morphostructural units, lithology, and the potential for the occurrence of caves) and biotic elements (use of soil and vegetal coverage) were used to elaborate the geoecological profile of the Serra do Gandarela National Park.

Structural representation of the landscape in the form of a transect demonstrated variable behaviour in the potential for the occurrence of caves, the compartment with the highest potential being the Hanging Depression of the Gandarela Syncline.

The use of this technique enabled the highlighting of challenges to the management of the Conservation Unit, especially concerning erosive processes caused by the practice of motocross or for access to waterfalls, which indicate high environmental vulnerability; areas with a prevalence of morphogenetic processes associated with underdeveloped soils; and the suppression of ferruginous campo rupestre montane savanna vegetation as a result of past uses for mineral research or exploration without spontaneous re-composition of the vegetation.

The results indicate that the geoecological profile can serve as support for the minimization of adverse environmental impacts as well as for the planning and management of the conservation unit, reflected in the management plan still in development.

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AUTHORS' CONTRIBUTION

Darcy José dos Santos, Úrsula Ruchkys and Luiz Eduardo Panisset Travassos designed the study. Darcy José dos Santos collected, analyzed the data and wrote the text. Ursula Ruchkys analyzed the data, supervised the study and wrote the text. Luiz Eduardo Panisset analyzed the data, supervised the study, wrote and revised the text.



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