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CROWDSOURCING AND GEOPROCESSING AS A SUPPORT TO THE ELABORATION OF GEOTOURISTIC ROUTES

Crowdsourcing e Geoprocessamento como Suporte para a Elaboração de Roteiros Geoturísticos

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ABSTRACT

Geotourism presents itself as an important mechanism of valorization and conservation of the geological heritage. However, for the activity to be effective, it is necessary to analyze the context of the landscape in which it is intended to establish this kind of activity. For this, spatial analysis techniques have been implemented in the context of geodiversity and geological heritage studies, in order to provide an integrated understanding of the territory, highlighting those aspects related to tourism. Although, this research has used geoprocessing techniques attached with data from social media, through crowdsourcing, to raise the potential of the Serra da Calçada Natural Monument for geotourism. In addition, a guide was proposed for the area, highlighting the aspects of the behavior for tourists as the geological and the local heritage.
Keywords: Geodiversity, Multi-Criteria Analysis, Visualization, Crowdsourcing, Social Media.

RESUMO

O geoturismo se apresenta como um importante mecanismo de valorização e conservação do patrimônio geológico. Contudo, para que a atividade seja efetiva, se fazem necessárias análises acerca do contexto da paisagem na qual se pretende instituir tal atividade. Para isso, técnicas de análise espacial têm sido implementadas no contexto dos estudos da geodiversidade e do patrimônio geológico, a fim de propiciar uma compreensão integrada do território, ressaltando seus aspectos relacionados à atividade turística. Assim, esta pesquisa lançou mão de técnicas de geoprocessamento aliadas a dados provenientes de mídias sociais, por meio de crowdsourcing, a fim de levantar as potencialidades do Monumento Natural da Serra da Calçada para o geoturismo. Além disso, foi proposto um roteiro para a área, ressaltando aspectos do comportamento dos turistas e do patrimônio geológico e mineiro do local.
Palavras-chave:Geodiversidade, Análise Multicritério, Visualização, Crowdsourcing, Mídia Social.

1. INTRODUCTION

This paper discusses a recent and promising field of research in the context of geoinformation science called Volunteered Geographic Information (VGI) (GOODCHILD, 2007). In this context, it studied the concept of crowdsourcing, according to which the main source of data for the development of the research is the content generated by the masses, or groups of people, in web 2.0 environment (HOWE, 2008). Via social network, users contribute in the production of geographic data, in the specific case of this research, data regarding tourist visitation and sports practice in the Serra da Calçada. This group of people, althoughamateur cartographers, are a source of information with greater relevance than that of a single specialist. This point of view is observed in the context of the crowdsourcing concept (HOWE, 2008; GOODCHILD & GLENNON, 2010).

Tourism, in all its segments, is an important factor when it comes to increasing the perceived value of historical, environmental, cultural and geological heritages. Amongst these, we would like to draw attention to geological heritage, an object of direct interest within the field of geotourism. Geodiversity, according to Stantley (2001), is the product of a variety of environments that result from dynamic interactive geological processes and phenomena, which involve landscapes and human cultures providing the very basis for the development of life on Earth. Geodiversity can be understood as a fundamental part of terrestrial systems. Thus, it is necessary to think about the conservation of the elements that are associated with it and that have scientific, cultural, aesthetic and educational value, all of which areconsidered as geological heritage. These values are attributed to them because of their economic, environmental and cultural functions, given that geodiversity not only sustains and maintains social relations that take place within a space, but also life in general (SENA, 2015; RUCHKYS, 2007; BRILHA, 2005; SHARPLES, 2002).

Geological Heritage, according to Carvalho (1999), designates any occurrence of geological nature, such as a rocky outcrop, a quarry, an abandoned mine, a mineral deposit with fossils on it, amongst others, as long as they have a documentary and/or monumental value that justifies its conservation for generations to come. Nieto (2002) states that the protection of geological heritage must also promote sustainable development and possible social uses, from a scientific, educational and/or touristic perspective. The appreciation of geological heritage might show visitors a different way of viewing a particular landscape not only in connection to its biotic aspects, thus offering them a reason to further explore the territory and increase their time of stay.

Some recent research techniques are currently being used to create analyses that focus on the administration of Geological Heritage in association with tourism or, in other words, geotourism. Amongst these, GIS (Geographical Information System) tools are worth noting, due the possibility of manipulating and representing large volumes of data in forms that are multi-thematic and have multiple scales. Such characteristic has presented itself as a viable way of documenting, visualizing and elaborating analyses regarding a particular site, thus making the investigation of spatial relations easier through the representation of maps and graphs. Another advantage presented by this technique is it makes it viable to simulate possible spatial scenarios to evaluate the impact of interventions. It also allows us to predict the possible consequences of a specific project, thus helping administrators make more precise and systematic decisions.

Once aware of the possible applications of GIS, some researchers employed the concepts related to geodiversity, geotourism and geoconservation to techniques of spatial analysis, accessible through geoprocessing tools. Amongst the works that develop such perspective we can point out the ones that propose the use of geodiversity indexes, as developed by SENA & RUCHKYS, 2015; PEREIRA, 2014; HJORT & LOUTO, 2010; SERRANO & RUIZ-FLAÑO, 2007; cartographic representation of methods for evaluating and quantifying geosites, by SENA *et al*., 2015; LIMA, 2015; PEÑALVER, 2013 and the analysis of geotouristic potential (SENA, 2015).

The process of working in a GIS environment that is associated with information that is referenced to a system of coordinatesis called geoinformation. The production of geoinformation has been through major changes in the last years thanks to the diffusion of computing technology, such as the web2.0, social media and the "culture of sharing". According to Bravo and Sluter (2015) the systems that allow for the production of geoinformation by ordinary users, who have no previous contact with the technical production or manipulation of spatial data, arecalled VGI (Volunteered Geographic Information). These systems are based on the creation and distribution of geographical information by volunteers or, in other words, on the crowdsourcing of maps.

As emphasized by Borges *et al*. (2016), the increasing popularity of social media and the culture of sharing, associated with the technological development of mobile phones, contributed to the production of large amounts of information provided by users. This process had an important role on the emergence of new approaches for gathering and interpreting data, especially for spatial planning, where they have a considerably relevant use in terms of decision-making processes. Therefore, crowdsourcing can be understood as a set of techniques that help the acquirement of data that was generated by the general population.

The acquirement of spatial data through crowdsourcing has been strengthened mainly due to the increasing popularity of devices that have GPS capabilities.Smartphone GPS tracking (SGT), which consists of a system for gathering spatial data from smartphone applications, is currently being used for studies on urban planning, especially ones that focus on transportation and urban mobility (KORPILO *et al*., 2017).

Regarding geotourism, the products derived from the usage of these collaborative systems, as well as GIS, can help foster a greater interaction with end-users, who can enrich available information by inputting their own personal experiences and cooperate to promote a touristic area, thus increasing their affective bond with the heritage site they visited. Aldighieri *et al*. (2013) described the work done by the Italian Association of Geology and Tourism, which collaboratively created a 3D route called "Goethe in Italy", focused on the appreciation of geological heritage. To do so, they used 3DRTE technology, which allows the user to navigate a 3D representation composed of high-definition images, thus making it possible to overlap several information layers. The tool has a great potential for helping visitors explore a certain territory and includes the possibility of tagging the points of most interest.

Argondizza *et al*. (2012) describe another example of the use of collaborative tools: a project that seeks to list and promote the geological heritage of the Italian province of Consenza. The data was collected through crowdsourcing,with the collaboration of many specialists that shared their knowledge on the subject. The data is available on a GIS platform and can be continuously improved as more knowledge is produced, thus considering specific environmental dynamics or changes induced by human activity. The authors point out the importance of participatory process on the construction of a network that favors the protection and diffusion of information about geological heritage.

Yet another example is a tool called Wikiloc, launched in 2006. It uses crowdsourcing to foster awareness on geodiversity and the conservation of geological heritage for geotouristic purposes. Wikiloc is a website that invites its users to exchange experiences, photos and videos related to different kinds of trails (for hiking, biking, mountaineering, etc.). Currently, the website has a large community of people interested in outdoor activities, amounting to over 2.3 million users. In 2009, Wikiloc was one of the winners of the Geotourism Challenge: Power of Place, promoted by Ashoka's Changemakers and National Geographic. According to information available on the Change maker's website, Wikiloc's founder, Jordi Ramot, expects the platform to be used for promoting geotourism on a global scale. He says he believes the profile of the website's users fits perfectly within the principles of geotourism.

With such a context in mind, this paper's goal is to elaborate a map of geotouristic potential for the Serra da Calçada (Quadrilátero Ferrífero) using, as one of its variables, trails that were shared by Wikiloc users. Furthermore, it elaborates a touristic route based on a set of selected geosites. Finally, it seeks to promote the visualization of geographic information provided by social media, further promoting general interest in territories and help allowing more people to "see the unseen" (MCCORMICK *et al*., 1987). Through that, we hope to lead to a change in the way people see geographical information and contribute to the construction of new spatial knowledge based on these new forms of viewing information.

2. CASE STUDY

The Quadrilátero Ferrífero (QF), located in the central southeast portion of the Minas Gerais state, occupies an area of approximately 7.000 km² and has a considerable geotouristic potential. This is due not only to its geological and geomorphological peculiarities, but also because of how its geodiversity was historically exploited. The QF is a set of structures from the Precambrian, with four sides that are elevated due to differential erosion, causing the formation of quartzite and itabirite ridges, on altitudes that range from 1300 to 1600 meters. These formations correspond to the alignment of the Serra do Curral, to the north; the Serra de Ouro Preto, to the south; the Serra da Moeda, to the west; the Serra do Caraça and Serra do Gandarela, to the east, both of which form the southern edge of the Serra do Espinhaço (BARBOSA & RODRIGUES, 1967).

This region has tremendous reserves of iron ore and other mineral riches, such as gold, manganese, imperial topaz and bauxite, to name but a few. It also bears significant geological heritage, composed of numerous rocky outcrops of outstanding scientific and pedagogical value, which can help us understand the processes related to Earth's geological evolution. Furthermore, its value as a geological heritage site increases in face of the economic use of its geodiversity through mineral-related activities. The area also has a great potential in terms of geotouristic activities, as pointed out by Liccardo (2007); Ruchkys (2007); Silva (2007); Ruchkys (2009); Castro *et al*. (2011); Ostanello (2012); Ruchkys, Machado (2013) and Sena *et al*. (2015).

QF's mineral heritage is associated with the history of human occupation in this region and the development of colonial and imperial Brazil, a period in which gold mining played a predominant role in the emergence of the first urban nuclei in Brazil's countryside. The pinnacle of this process happened throughout the second

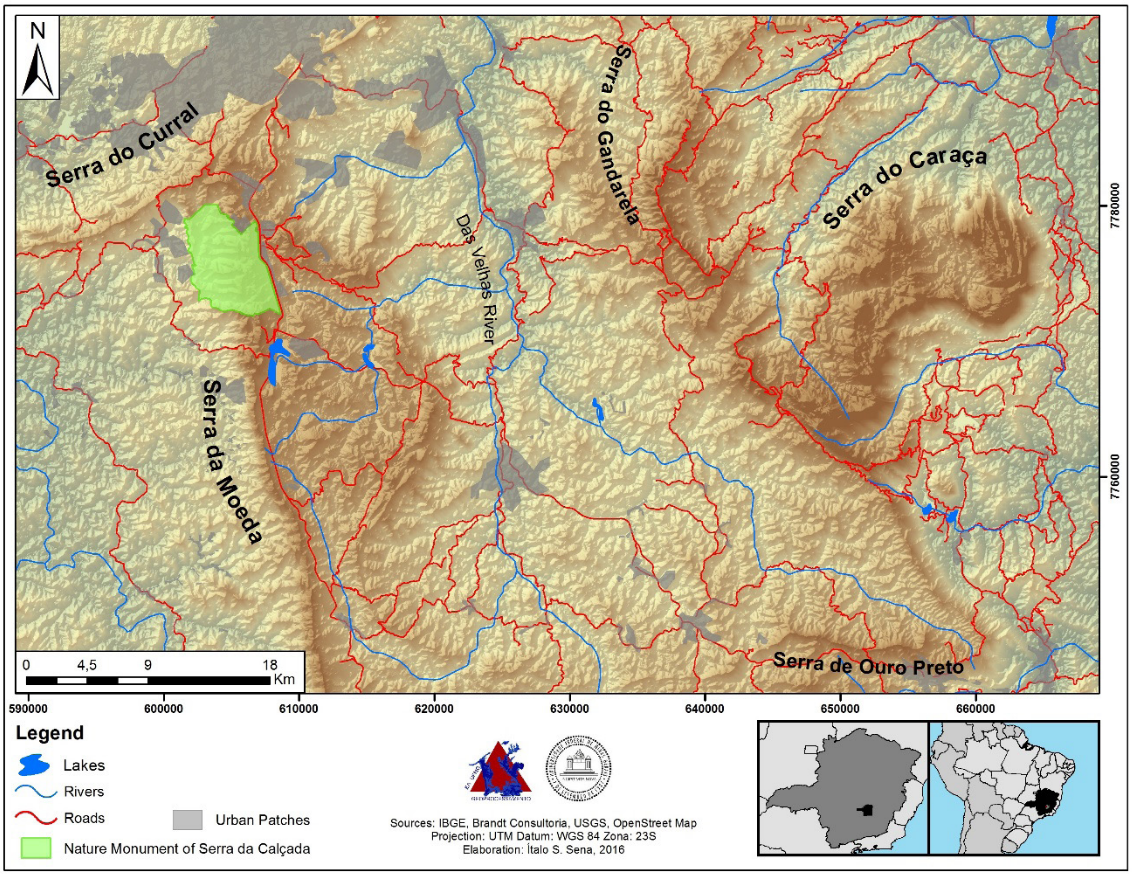

Fig.1 - Location of the studied area.

half of the XVIII century. During this period, known as Ciclo do Ouro (the Gold Cycle), the exploitation of gold spread through various areas of Brazil and came to its strongest form in the mid-southern portion of the Minas Gerais state. The end of this cycle can be traced back to the later part of the XIX century, as a consequence of the technical difficulties of exploiting gold and its gradual substitution towards the exploitation of iron(RUCHKYS, MACHADO, 2013).

The Serra da Calçada is one the places that still bears signs of these periods. Located in the northern portion of the Serra da Moeda (Figure 1), it has approximately 3.700 hectare and shows traces of activities related to colonial mining, all of which make it an important area for studies of geoscience and other natural sciences. The reason why we chose to study this region is that it is a highly visited area, with a large diversity of potential attractions (RUCHKYS, 2007; BORGES, 2008; SENA *et al*., 2015).

3. METHODOLOGY

This research's methodological approach is based on two stages: creating a map of the area's geotouristic potential and proposing a geotouristic route (Figure 2).

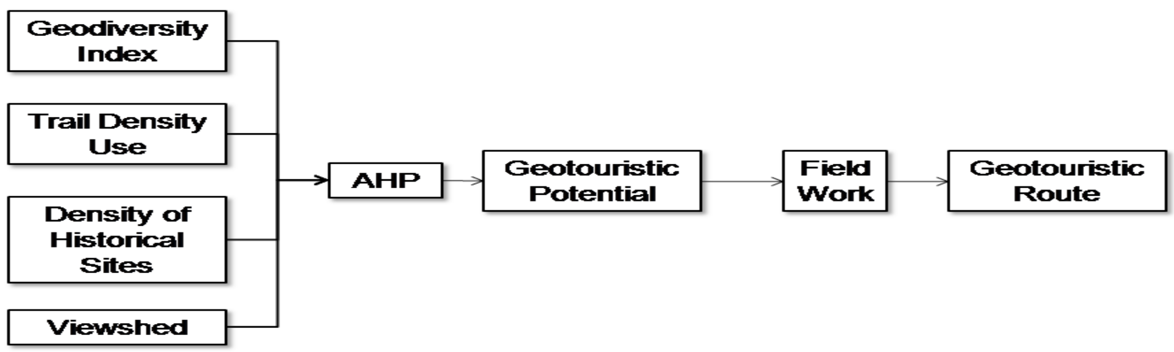

Fig. 2 - Methodological flowchart.

3.1 Geotouristic Potential

Based on Sena's (2015) proposal for the analysis of geotouristic potential, we built four variables that, we believe, summarize the Serra da Calçada's geotouristic potential: the intensity of trail use, the geodiversity index, the density of historical sites and landscape visibility.

In order to express the current public use of the Serra da Calçada, we used crowdsourced data available on Wikiloc. To research and gather said data, we used the following keywords on the website's search engine: 'Retiro das Pedras', 'Casa Branca', 'Serra da Calçada' and 'Forte de Brumadinho', all of which refer to nearby locations, access points to protected sites and the area's most characteristic historical site.

Thanks to this Wikiloc search, we could to identify 54 trails, categorized as walking, trekking, cycling and mountain biking trails. To generate the intensity of use, all 54 trails were put together and, with the help of the ArcGIS software, a Kernel density estimation was done.A radius of 120 meters (60 on each side) was employed, considering that the tourist tends to cross a reduced perimeter in the surroundings of the trail and respecting the cartographic scale of the data that was available on the database (30m)(Figure 3a).

The geodiversity index was generated based on the methodology proposed by Pereira (2014) and adapted by Sena (2015) for this purpose. We used an available spatial database and considered the following features of local geodiversity: lithology (10), soils (9), geomorphology (3), structural geology (7), hidrogeology (7), caves (1), mineral occurrences (1), adding up to 39 features (Figure 3b).

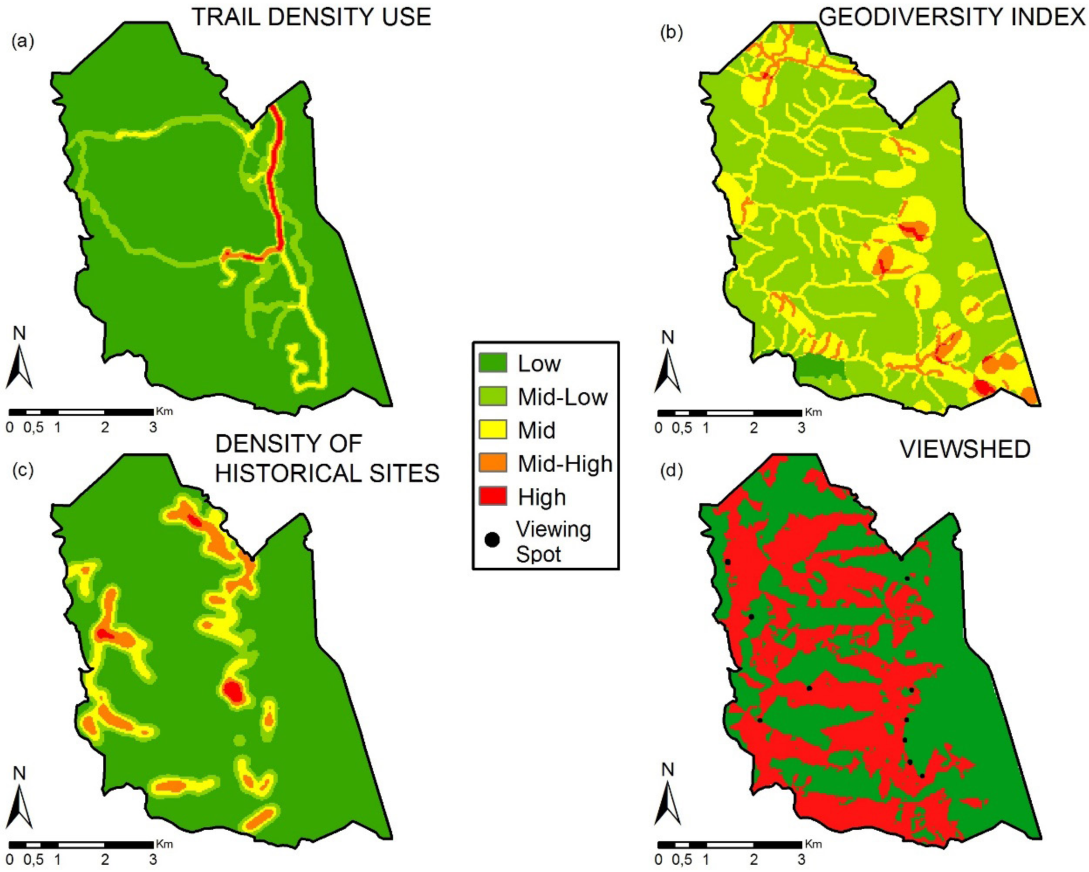

Fig. 3 - Variables comprised in the Geotouristic Potential.

The density of historical sites from the Ciclo do Ouro period was based on the work developed by Sena *et al*. (2015), which used the Kernel density method along with an evaluation and quantification of geosites to identify the areas with the highest geotouristic potential. In this paper, we chose to review available data and generate a new approximation regarding the density of historical sites, applying a search parameter of 240m (Figure 3c).

Landscape visibility was obtained in accordance to what was proposed by Casagrande *et al*. (2016), meaning we evaluated the possibility to observe other formations from the Quadrilátero Ferrífero while standing on the trails that exist within the Serra da Calçada. Given that this research's focus was to understand visibility on a larger scale, we took ten places of scenic overlook into consideration. These were located throughout existing local routes and trails. The data regarding altitude was then related to these viewing spots, thus generating a binary surface where visible (green) and non-visible (red) areas are presented.

The area's geotouristic potential was obtained through a multi-criterial analysis (JANKOWSKI, 1995). The weight of each variable was defined using Analytic Hierarchy Process (AHP) (SAATY, 1980)with help from the extAHP 2.0 tool, which can be obtained free at the ArcGIS software repository. Each of this paper's authors helped ponder the variables' weights, arriving at the percentages that follow: TrailDensity Use (43,242%), Geodiversity Index (21,174%), DensityofHistorical Sites (27,319%) and Viewshed (8,264%), by the use of theoretical and practical experience of each author.

3.2 Geotouristic Route Proposal

The map of geotouristic potential was validated through fieldwork. Regarding the path with the highest geotouristic potential, we cataloged sites that are interesting for observing geodiversity and geological and mineral heritage. These sites were documented through photographs, described with the aid of a fieldwork chart and categorized under 'on site observation' or 'landscape observation'. The proposed route was marked upon the map of geotouristic potential, which presents sites of interest and their particularities (Figure 4).

4. RESULTS AND FURTHER DISCUSSIONS

Bearing in mind that the most important touristic attractions of geotourism are elements of geodiversity (geological heritage), including those that have an economic use (mineral heritage), we believe that the chosen variables (intensity of trail use; geodiversity indexes; density of historical sites; landscape visibility) reflect the area's geotouristic potential. Obtaining the intensity of trail use through crowdsourcing was quite useful in terms of understanding how the public use of this area works. Namely, it showed us that the Forte de Brumadinho (Brumadinho Fort), one of the most well-known areas in the Serra da Calçada, tends to attract the most visitors. The geodiversity index showed that the areas with the highest indexes are located mainly in the northeastern, central and southeastern portions. It is also possible to see that the drainage network presented medium indexes.

The analysis of historical site density showed that the hot spots of historical interest match the places with a high geodiversity index, except for the western region of the Serra da Calçada, which presented points of high and medium-to-high density. The visibility map shows that most of the area is visible from two places of scenic overlook, which is very important in terms of geotourism.

4.1 Serra da Calçada's Geotouristic Potential

The highest geotouristic potential is distributed alongside the two axes of entrance and the area's hot spots of historical sites. Locations with high and medium-to-high geotouristic potential add up to approximately 8.5% of the area, and areas of low and low-to-medium potential comprise 75% of the area. These results may vary according to the weight attributed to each variable:

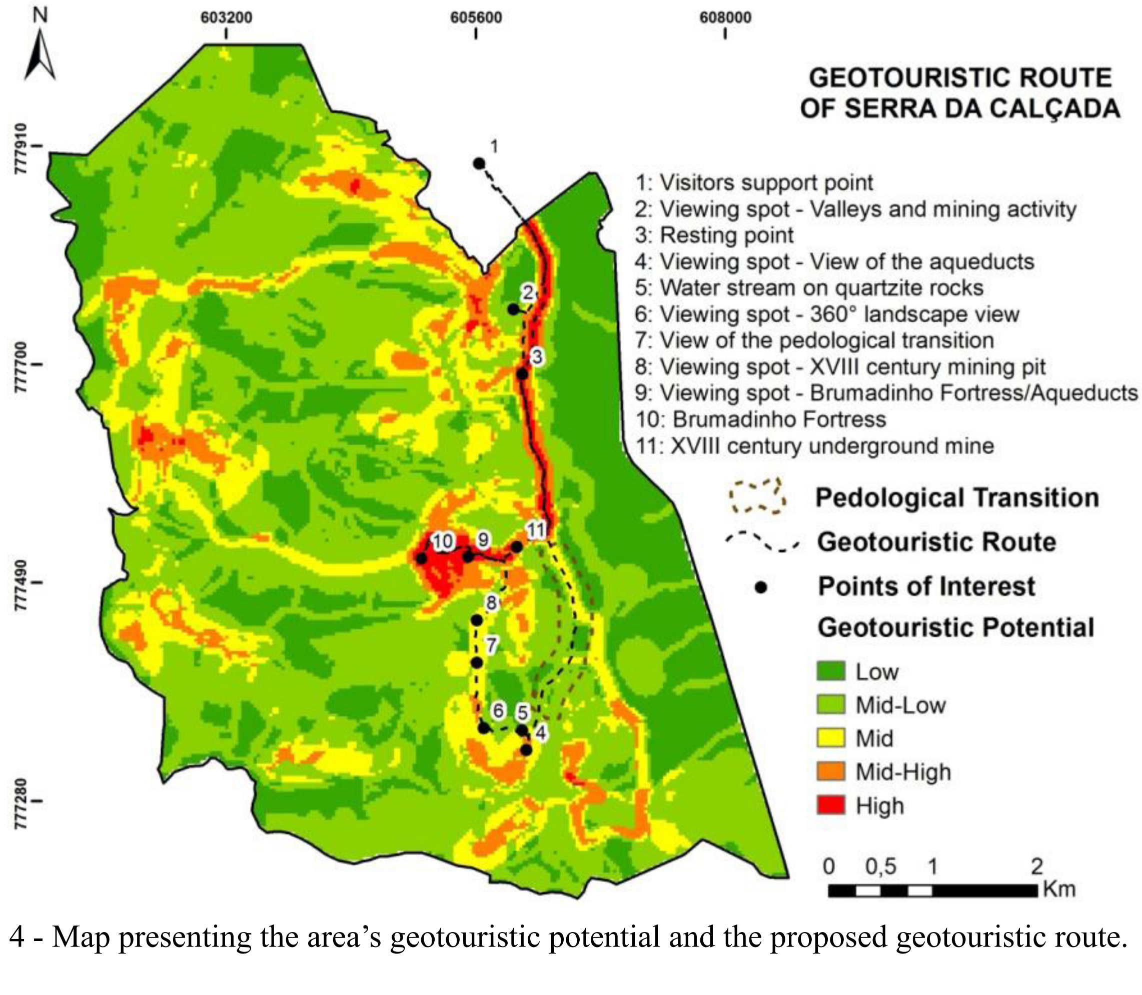

Fig. 4 - Map presenting the area's geotouristic potential and the proposed geotouristic route.

4.2 Geotouristic Route

The route gathered 11 sites of interest, two of which are spots for resting and/or getting support, six are for landscape interpretation and three are points of localized interest.

Point 1 is a supporting structure, built by ARCA AMASERRA, a non-profit organization aimed at environmental conservation and restoration. This area has an eco-container that provides information and support for visitors (Figure 5a).

Point 2 is a scenic overlook that allows visitors to observe the northern portion of the Serra da Calçada and serves as a reference point. It is worth noting that this area has a water reservoir that, from time to time, receives some form of artistic intervention. The landscape, as seen from this scenic overlook, allows for a discussion regarding the structures and past or current geological and geomorphological processes, which are responsible for the formation of vales like the ones that are part of the Ribeirão Catarina micro-basin (Figure 5b).

Point 3 is a resting space that is widely used by visitors, since several trails end up there. This location also has some wooden trunks that make do as benches and large-size trees that provide a shaded environment.

Point 4, located the furthest south, allows visitors to appreciate the economic value of geodiversity, which is mostly related to mineral extraction. This landscape bears easily identifiable marks of ancient structures used for the extraction of gold. The aqueducts, once used for water transportation, are especially interesting (Figure 5c). This location also has a large mining facility that extracts itabirite, a mineral ore with a large percentage of Iron.

Point 5 marks the beginning of the point of return from the route. It is characterized by a crossing between the trail and a perennial drainage. While on this site, it is possible to see the fluvial dynamics that are specific of rivers located upon quartzites, where drainage occurs over exposed rock (Figure 5d).

Fig.5 - Visitor support center (a); Landscape view of the vales that are part of the Ribeirão Catarina micro-basin (b); Aqueducts from the gold mining period (c); Perennial drainage over quartzite (d). Source: The authors.

Point 6 is located a few hundred meters after the previous point, and is a scenic overlook that allows for a wide view of the landscape, with a 360 degrees sight radius. Within this area it is possible to observe several aspects of Serra da Calçada's geodiversity, ranging from aspects related to structural geology (quartzite stratification), pedology (the conformation of soil variations), and historical archeology (Forte de Brumadinho) (Figure 6).

Fig. 6 - Landscape view, as observed from point 6.Source: The authors.

Point 7 is representative in the sense that it allows for a better understanding of the conditioning of pedology to its lithological context. The reason for this is that this location allows us to observe the transition from the lithological domain of itabirite and canga (with the presence of clayey and reddish soils) to the lithological domain of quartzite (with a predominant presence of white and sandy soils) (Figure 7).

Fig. 7 - Portion of pedological transition.Source: The authors.

Points 8, 9 and 10 are directly related to the main historical site of the Serra da Calçada. While on point 8, it is possible to see the ancient front of a mine where gold was extracted during the XVIII century, also allowing us to see the left side of the Forte de Brumadinho, characterizing this as a point aimed at landscape interpretation (Figure 8a). Point 9, although characterized as point for landscape observation, allows for a frontal view of the site and emphasizes the strategic positioning of the fort in relation to its access area (Figure 8b). Point 10 allows for a closer relationship to be established between the visitors and the site, since it is possible to walk through the ancient ruins of the fort, where minerals were once extracted from centuries-old mines (Figure 8c).

It is characterized as a location of on-site interpretation, since it is an open underground structure that was possibly established with the purpose of prospecting new areas for mining, as outlined by Borges (2008). On this location, the visitor can get to know how the techniques used for mining gold during that period worked, namely, focusing on the search for quartz veins that contained the precious metal (figure 8d e 8e).

Aside from the interest points listed throughout the route, we also proposed a trail, located between points 3 and 4, which allows the observation of on-site pedological transition. Within this portion of the trail, approximately 2 kilometers long, it is possible to observe the variation of soils from itabirites to quartzites, but also transitional lithological domains, such as the ones featured by phyllite and shale (figures 9a, 9b, 9c, 9d).

Fig.8 - View from the ancient gold mine and the left side of the Forte de Brumadinho (a); frontal view of the passage into Forte de Brumadinho (b); internal view of the fort’s ruins (c); entrance point into the underground structure; internal view of the underground structure (e). Source: The authors.

Fig.9 - Itabirites (a); shales and phyllites (b); quartzite outcrop (c); quartzarenitic soil (d). Source: The authors.

5. CLOSING REMARKS

The Quadrilátero Ferrífero has an intrinsic geotouristic potential due to the fact it is such a representative geological heritage site. However, localized studies can underline the particularities of its territory.

Applying statistical modeling to calculate geotouristic potential contributes to making geotouristic analyses more flexible, given that the usage of geoprocessing tools allows for the construction of scenarios based on multiple variables. This makes it even more usable, since it may be applied to any location with georeferenced data available, as is the case with the Serra da Calçada.

Crowdsourcing, in the form of data regarding the usage of trails, helped understand how the public use of this location works and responded to a demand for tourism-related data. This data also presents, in broader terms, how tourists behave in this territory, favoring a deeper analysis of their preferences.

In this sense, by integrating geoprocessing techniques and spatial analysis with crowdsourced data and social media, it is possible to see the rise of a field specialized in cartographic visualization, focused on the transformation of available information into knowledge regarding territory. New forms of landscape perception allow the emergence of interests based on criteria that can be applied in other locations, as is the case with this paper.

It's worth noting that the proposed route is not aimed at conditioning the visitor to the route, but to take note on locations of interest, expanding the reach of the visitor's experience and contributing to the promotion of the site's intrinsic geotouristic potential. Such potential shows how valuable is the location's geodiversity, making it a geological heritage not only because of its natural particularities, such as mineral occurrences, but also because of human use of the landscape, which adds historical value to the region's geodiversity.

We hope this work may help subsidize other routes within the Serra da Calçada, as well as foster other initiatives related to geotourism.

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