Universidade do Minho
Escola de Ciências

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Geoheritage Use Value Assessment in the Azores UNESCO Global Geopark: Terceira Island Case Study

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Trabalho efetuado sob a orientação de
Paulo Jorge Silva Pereira
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julho de 2025

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Avaliação do valor de uso do património geológico no Açores Geoparque Mundial da UNESCO: estudo de caso da Ilha Terceira

RESUMO

Os geoparques são territórios que, para além de abrangerem áreas de significativa relevância geológica, visam fomentar o turismo, a educação e a investigação científica, potenciando o valor do seu património natural através de práticas sustentáveis. Esta missão multifacetada sublinha a necessidade de avaliar até que ponto o património geológico pode ser efetivamente utilizado para tais fins — comumente designado por valor de uso.

Este estudo propõe uma metodologia quantitativa para avaliar o valor de uso dos geossítios no Açores Geoparque Mundial da UNESCO, com especial atenção às características arquipelágicas únicas do território. O enquadramento de avaliação é composto por vinte e sete critérios, cada um associado a indicadores específicos, e avaliados numa escala até cinco pontos.

A aplicação desta metodologia a catorze pontos de visitação dos geossítios identificados na Ilha Terceira gerou pontuações individuais do valor de uso, permitindo a sua classificação como sítios *modelo*, *suficientes* e *inadequados*, com base no seu potencial para apoiar atividades educativas, recreativas e turísticas. Os resultados da avaliação permitem a seleção de geossítios-chave para investimento direcionado em envolvimento público e infraestruturas, fornecendo uma base para o planeamento estratégico para melhorar o seu acesso e promover um reconhecimento mais amplo.

A metodologia proposta representa uma ferramenta prática e baseada em evidências para a gestão informada, consciente e sustentável do património geológico. Os resultados oferecem uma estrutura básica para orientar a utilização responsável dos geossítios, contribuindo simultaneamente para a sua conservação e garantindo a sua viabilidade a longo prazo para as gerações futuras.

Palavras-chave: Avaliação do Valor de Uso, Geoconservação, Geoparques, Geopatrimónio, Geoturismo.

Geoheritage Use Value Assessment in the Azores UNESCO Global Geopark: Terceira Island Case Study

ABSTRACT

Geoparks are territories that, in addition to encompassing areas of significant geological relevance, aim to foster tourism, education, and scientific research by leveraging the value of their natural heritage through sustainable practices. This multifaceted mission underscores the need to assess the range to which geological heritage can be effectively used for such purposes—commonly referred to as its use value.

This study proposes a quantitative methodology for assessing the use value of geosites within the Azores UNESCO Global Geopark, with particular consideration given the unique archipelagic characteristics of the territory. The assessment framework comprises twenty-seven criteria, grouped in categories, each associated with specific indicators, and evaluated on a scale of up to five points.

Applying this methodology to fourteen visiting points of the geosites identified in Terceira Island, generated individual use value scores, allowing for their classification as *model, sufficient* and *unsuitable* sites based on their potential to support educational, recreational, and tourism-related activities. The results of the assessment enabled the proposal of ideas and tools to improve their access and promote wider recognition.

The proposed methodology represents a practical and evidence-based tool for the informed, conscious, and sustainable management of geological heritage. Acting as a suitable base framework that can be applied to the geosites located in the rest of the islands in Azores UNESCO Global Geopark.

Key words: Geoconservation, Geoheritage, Geoparks, Geotourism, Use Value Assessment.

CONTENTS

List of Figures

List of Tables

1. Introduction

Assessing the geological heritage is a step into the identification, inventory, selection, and categorization of sites of geological significance. In geoparks, assessing the value or relevance of geosites is a fundamental component of geoconservation strategies. At the same time, it enables the evaluation of both the potential uses of geosites and the necessary management actions to be considered.

In the recent past, several efforts have been made to assess geosites. Methodological proposals use a range of categories, and most of them have been focused on evaluating the scientific value, other values such as the ecological, cultural, aesthetic, economic and educational, have been assessed to a greater or lesser extent (Pasquaré Mariotto *et al.*, 2023).

Limited attention has been paid to methodologies that address the assessment of the use value of geosites. Use value refers to the ability of geosites to serve human activities related to recreation and education. It involves the use or enjoyment of these geosites and includes elements of science, education, and tourism (Esteves, 2023). Some works developed in geopark territories or protected areas (e.g., Pralong, 2005; Rybár, 2010; Pereira & Pereira, 2012; Doktor *et al.*, 2015; Brilha, 2016; Gonçalves, 2013; Viveiros, 2016; Afonso, 2019; Esteves, 2023) indicate certain generally accepted criteria for assessing use, with an inherently quantitative nature that is intended to facilitate comparisons between evaluated sites (Esteves, 2023).

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" (UNESCO, 2016). Having a notable geological heritage, geoparks are territories that are essentially associated with a sustainable development strategy, which has as fundamental pillars: geoconservation, education and geotourism (Zouros, 2004).

Geoeducation is a process that enables the transfer of geological knowledge, being developed in different settings, but with special focus and interest in the field trough the elements of outcrops, landscapes, and active processes. In geoparks, geoeducation is developed through the formulation of programs that teach about the value of the geodiversity of the territory, developing pedagogical tools for all educational levels, promoting knowledge about the scientific importance of geosites, and encouraging students to develop a stronger sense of identity with their territory. Within geoparks, geoeducational strategies are strongly supported by interpretive centres, field trips, interpretive itineraries, workshops, citizen science projects, and outreach campaigns. The educational tools developed by geoparks should support the effective

interpretation of geological features, providing high-quality pedagogical materials for both learners and educators (Brocx & Semeniuk, 2019).

Geotourism is a type of nature tourism or ecotourism, under the principles of sustainable development, in which visitors make use of geodiversity, primarily motivated by elements such as attractive landscapes, the presence of unique elements like fossils, minerals, or rocks, caves, hot springs, or emblematic natural sites, to name a few. It comprises important aspects like the responsible use of geoheritage to guarantee its conservation, communicating geological heritage, creating authentic geotourism products, cooperating with various stakeholders, and building community through engagement (Newsome & Dowling, 2008). To encourage geotourism, geoparks must implement measures to facilitate the use of these sites for tourists and locals alike, developing interpretive materials that allow lay people to easily understand the geological elements related to the place they are visiting.

The main objective of this work is to develop a methodology for the quantitative assessment of geoheritage use value in the Azores UNESCO Global Geopark. This methodology will be applied on geosites located in Terceira Island, which will work as a pilot study that will be the base for an assessment methodology expected to be developed in all the geopark. The specific objectives are the assessment of the geosites' use value and the proposal of ideas and tools for the valorisation, promotion, attractiveness, and use of the evaluated geosites, focusing on educational and tourism populations.

This study acts as a significant step that supports the knowledge and efforts in geoconservation to assess the geological heritage in geoparks, especially in archipelagic regions, where the territories have very particular and unique conditions.

Since enhancing the use value of geoparks' geosites serves as a basic framework for the development of strategies and initiatives for their conservation, visitor management and the development of tourist and educational resources, this work will be an important tool that the Azores UNESCO Global Geopark (UGGp) will apply for its management strategies, allowing the optimal use of the geosites in the archipelago, and improving the measures that lead to the valorisation of geosites to be exploited in a sustainable way.

2. Azores UNESCO Global Geopark

Located in the North Atlantic Ocean between 36°– 41° North latitudes and 24°– 33° West longitudes, the Azores archipelago, designated as the Autonomous Region of the Azores, is a Portuguese autonomous region that comprises nine inhabited islands and several non-inhabited islets geographically distributed in the Western Group (Flores and Corvo islands), the Central Group (Faial, Pico, São Jorge, Graciosa and Terceira islands) and the Eastern Group (São Miguel and Santa Maria islands). It is characterized by the small dimension of the islands (between 17 and 745 sq. km), by its dispersion along a strip of approximately 600 km and its distance from the European and American continents, 1815 km and 2625 km, respectively (Lima & Meneses, 2023) (Figure 1).

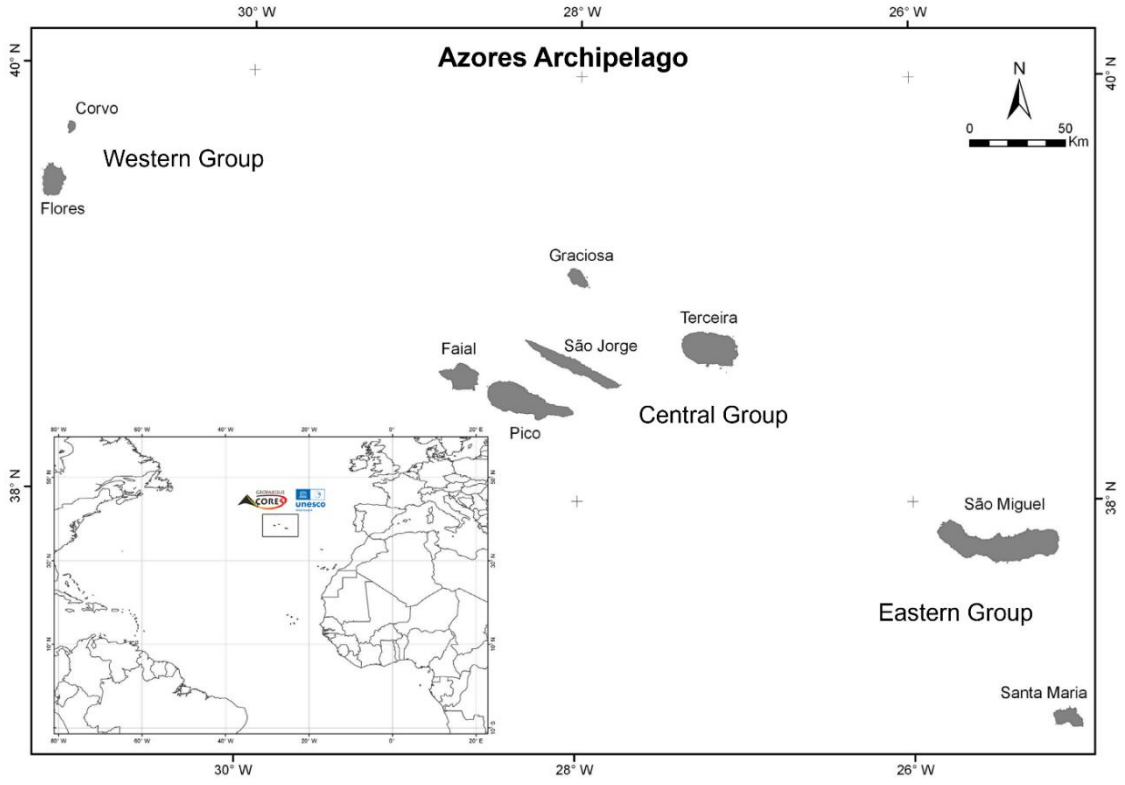


Figure 1. Geographic setting of the Azores UNESCO Global Geopark (Adapted from Lima & Meneses, 2023).

The growing awareness of the significance of the Azores' geological heritage prompted the development of systematic inventory and assessment efforts aimed at identifying and evaluating the region's geoheritage. These initiatives underscored the unique geological value of the territory and played a key role in fostering institutional recognition of its importance. As a result, the Regional Government of the Azores embraced the idea of establishing a geopark, incorporating it into its strategic planning as early as 2007. This commitment was further reinforced through the creation of a dedicated management

structure (RCG No. 36/2010, of March 4), GEOAÇORES – Azores Geopark Association. Internationally, these efforts culminated in the integration of the Azores Geopark into the European and Global Geoparks Networks in March 2013, followed by its inclusion in the UNESCO Global Geoparks Network in November 2015 (Lima, 2018), after the approval of the statutes of the International Geoscience and Geoparks Programme, by UNESCO.

The territory recognized as a UNESCO Global Geopark is limited by the bathymetric line of 2000 meters and includes all nine islands, their respective islets and four marine geosites, with a total area of 12,884 km². It contains a network of 122 geosites scattered throughout the archipelago, including the islands and surrounding marine area (Figure 2). These geosites are representative of the archipelago's geodiversity and its geological and eruptive history, being managed under a regional geoconservation strategy (Nunes *et al.*, 2011).

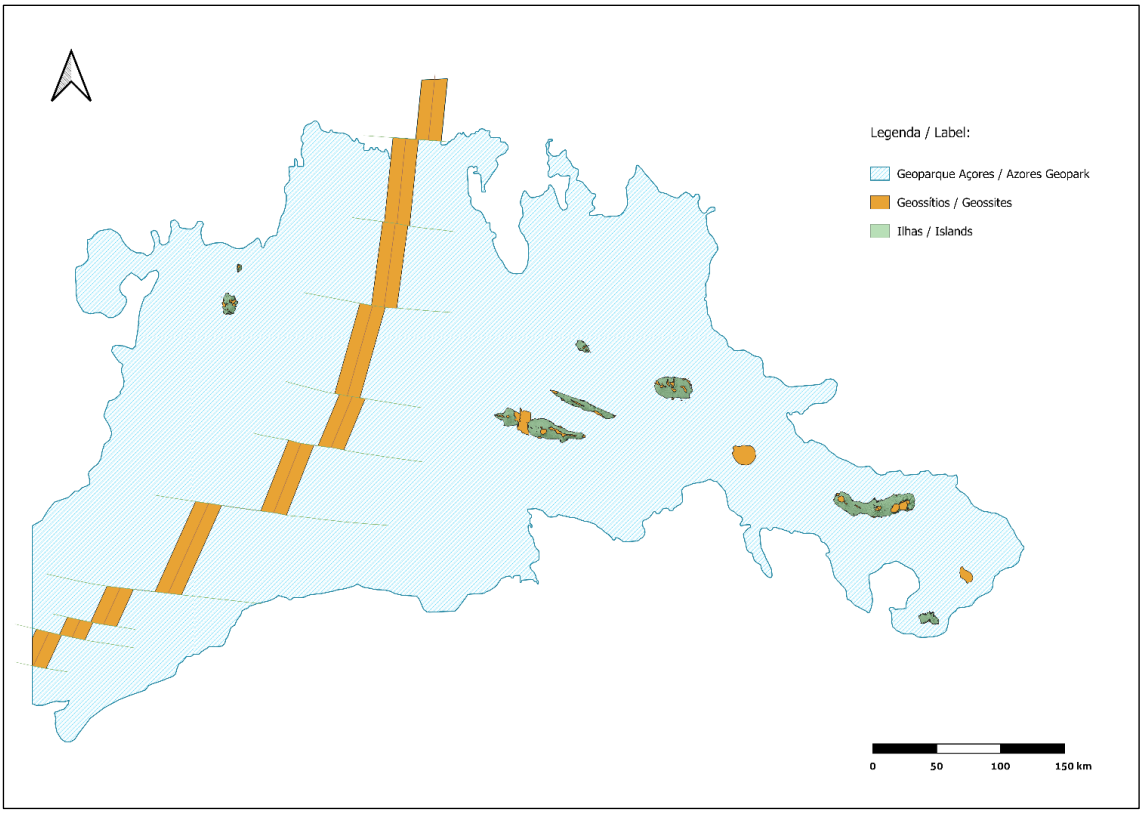


Figure 2. Azores UNESCO Global Geopark (UGGp) area and geosites (Pedagogical resources of Azores UGGp).

Four main criteria led to the selection of these geosites: the knowledge and scientific value of the region, the representativeness at the scale of the archipelago, its integrity, and whether they constitute a privileged or essential place for the observation of aspects and key elements in the regional geological and volcanological context, considering landscape and pedagogical values (Lima & Meneses, 2023). These geosites encompass different elements of geological interest, namely the next types of scientific

values: geomorphological, paleontological, mineralogical, petrological, stratigraphic, tectonic, hydrological, hydrothermal, volcanic, speleological, and sedimentary (Nunes *et al.*, 2011). They are also categorized considering their geological, geomorphological and volcanological characteristics into 23 different geomorphological and volcanological categories (Lima & Nunes, 2014).

The management of the Azores Geopark is based on a decentralized structure, with delegations on all the islands, and whose coordination is ensured by GEOAÇORES - Azores Geopark Association, a non-profit association, created in 2010 and headquartered in the city of Horta, Faial Island. The founding members are the Azores Regional Government, through the current Regional Secretariat for the Environment and Climate Action (SRAAC) and the Azorean associations of local development: ADELIAÇOR – Association for the Local Development of the Azores Islands, ARDE – Regional Association for Development, GRATER – Regional Development Association and ASDEPR – Association for Rural Development and Promotion (Lima, 2018), in representation of the 19 municipalities.

2.1. Geological setting of the Azores archipelago

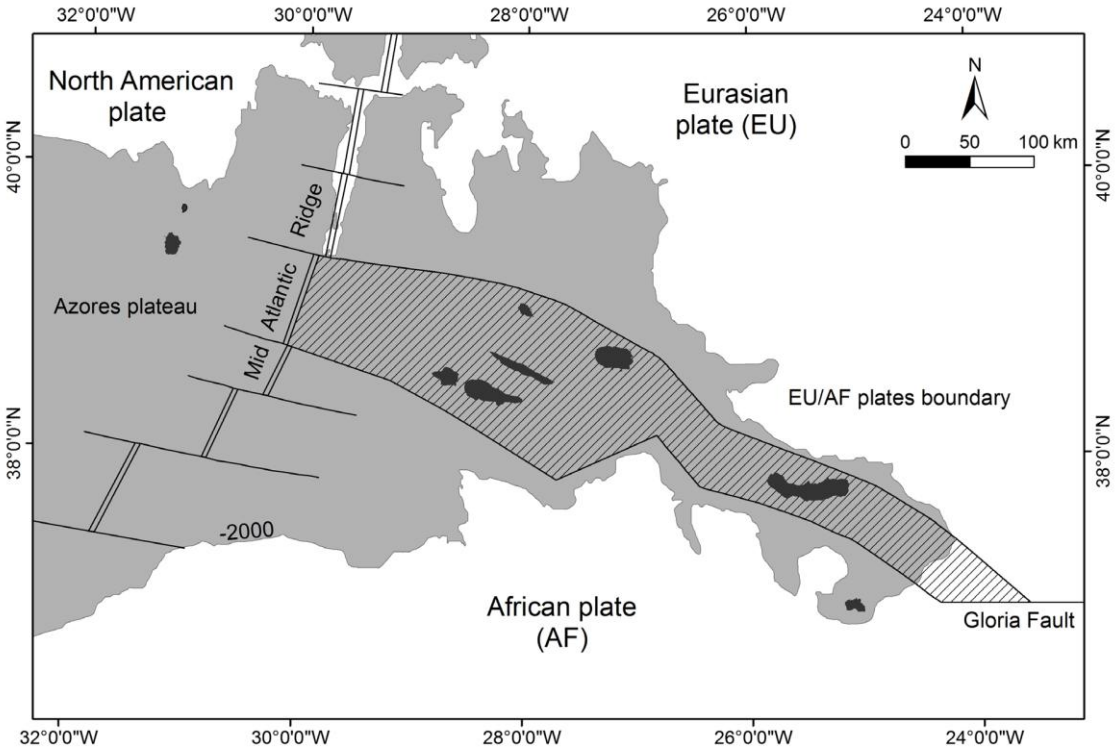


Figure 3. General geodynamic framework of the Azores archipelago (Lima & Meneses, 2023; adapted from Nunes *et al.*, 2011).

The Azores UNESCO Global Geopark is located in the triple junction of the lithospheric plates of Eurasia, Africa (or Nubia) and North America, crossed by the Mid-Atlantic Ridge and by the GLORIA Fault (Azores-

Gibraltar Fault). Composed of oceanic islands with volcanic origin that started to rise from the ocean floor around 36 million years ago, when different submarine volcanic phenomena caused a rising of the sea floor due to the stacking of volcanic material (Searle, 1980). Its area is limited by the 2,000 m depth bathymetric line from where this rising took place (Figure 3).

The oldest island of the archipelago is Santa Maria, having the oldest subaerial volcanism dated, around 6 million years ago (Ramalho *et al.*, 2017), and the youngest island is Pico, formed about 270.000 years ago (Chovelon, 1982). 26 historical eruptions are recorded in the Azores since the first settlements in the 15th century, one of the most recent being the famous Capelinhos eruption in 1957–1958, on Faial Island (Lima & Meneses, 2023).

There are 27 volcanic systems in the Azores: 16 polygenetic central volcanoes and 11 basaltic volcanic ridges. Nine of the polygenetic volcanoes and seven of the areas of fissural volcanism are considered active, but dormant. Manifestations of secondary volcanism have been identified at Banco D. João de Castro, a submarine polygenetic volcano located between the islands of São Miguel and Terceira, and on the islands of São Miguel, Terceira, Graciosa, São Jorge, Pico, and Faial. There are about 1,750 monogenetic volcanoes in the archipelago, represented by domes and coulees, tuff rings, tuff cones, maars, and scoria and spatter cones (Lima & Meneses, 2023).

2.2. Geodiversity of Terceira Island

Terceira Island is conditioned by an important regional tectonic structure known as the Terceira Rift, defined by the alignment of basins, seamounts, and islands, which develops from the West Graciosa Basin to the Formigas Trough, reflecting roughly the border zone between the Eurasian and African plates (Searle, 1980). There is a clear influence of the Terceira Rift in the alignment of the volcanic manifestations and tectonic structures, important fault systems cross the island, with a dominant NW-SE orientation, being well represented by the Lajes Graben, structure that generated two important earthquakes in 1614 and 1841 (Pimentel, 2023b).

Terceira Island comprises four polygenetic volcanoes with caldera: Cinco Picos, Guilherme Moniz, Pico Alto, and Santa Bárbara; and a zone of fissural basaltic volcanism (Basaltic Fissural Zone) (Figure 4). The two oldest central volcanoes, Cinco Picos and Guilherme Moniz, are considered extinct and together, form the eastern and southern portions of the island, respectively. The northeastern flank of Cinco Picos is deeply dissected by the NW-SE-trending fault scarps of the Lajes Graben. The other two central volcanoes, Pico Alto and Santa Bárbara, form the northern and western parts of Terceira, respectively, while the

fissure zone crosses the entire island along a general WNW-ESE to NW-SE orientation (Pimentel *et al.*, 2021) (Figure 5).

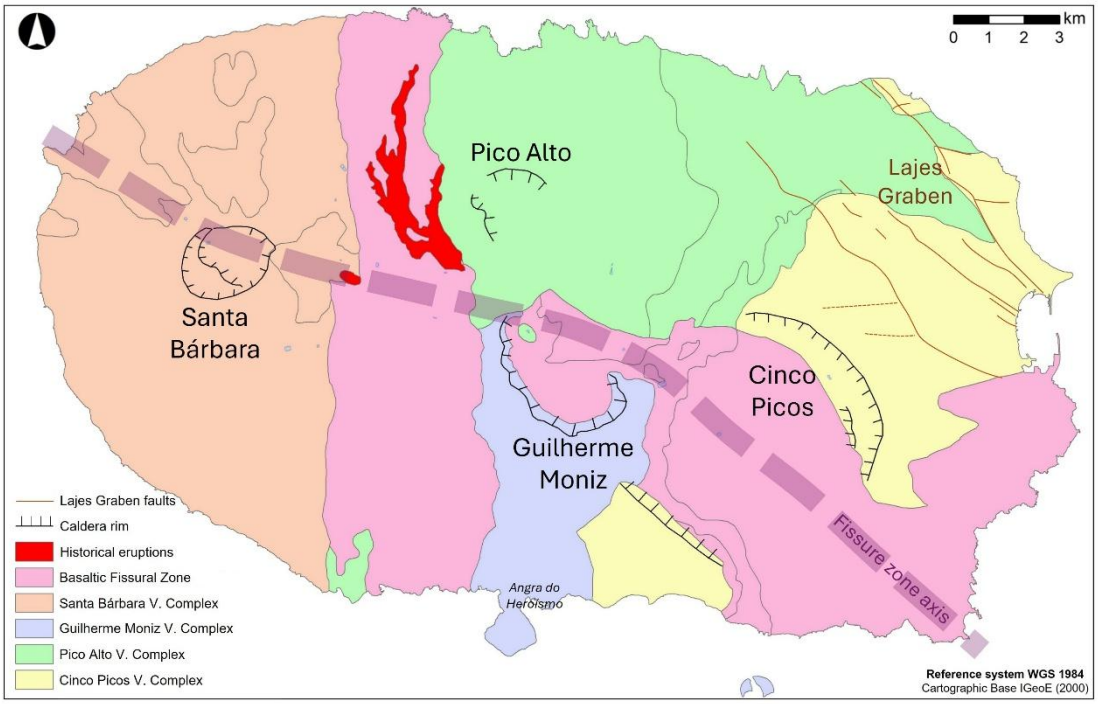


Figure 4. Geodiversity of Terceira Island (Adapted from pedagogical resources of Azores UGGp)

Terceira is one of the most geodiverse islands in the Atlantic Ocean, its bimodal geochemistry is recorded by the numerous basaltic eruptions scattered across the island and by the less frequent, but large-scale, trachytic (peralkaline) explosive eruptions of the central volcanoes. Historically, there have been three eruptions on the island: one paired eruption on land in 1761 and two eruptions at sea along the Serreta Oceanic Ridge (west of Terceira) in 1867 and 1998–2001 (Pimentel, 2023a). Under the denomination of "A Sea of Dense and Viscous Lava" the geopark promotes this island, where trachytic effusive materials are predominant, in domes and coulées, usually with obsidian levels. Other relevant elements of its geodiversity are the volcanic caves, represented mainly by the visitable Algar do Carvão (volcanic pit) and Gruta do Natal (lava tube cave), and manifestations of secondary volcanism as the Furnas do Enxofre, a diffuse fumarolic field.

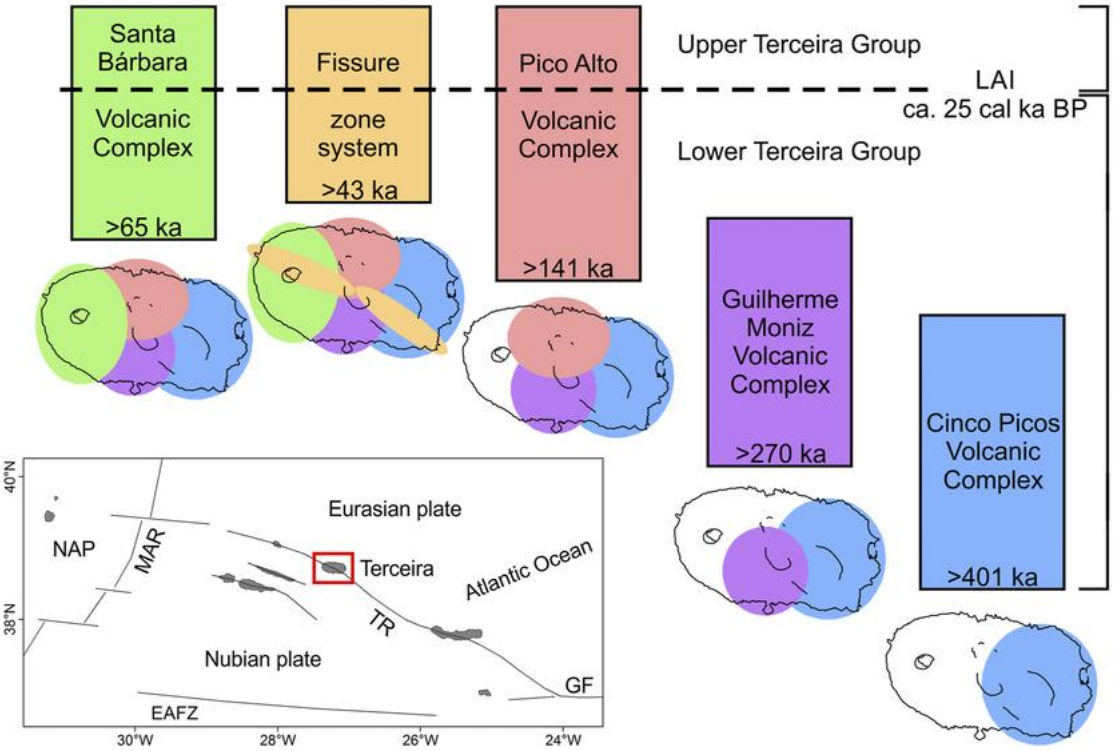


Figure 5. Stratigraphic scheme and reconstruction of the different phases of evolution of Terceira Island; LAI—Lajes-Angra Ignimbrite Formation, NAP—North American plate, MAR—Mid-Atlantic Ridge, TR—Terceira Rift, EAFZ—East Azores Fracture Zone, GF—Gloria Fault (Pimentel *et al.*, 2021).

2.3. Geoheritage and geosites of Terceira Island

Geosites in Azores UGGp are identified with a code composed of three letters, depending on the island, followed by an assigned number. For example, TER 1 would be the first geosite of Terceira Island. Codes for the four marine areas are different (marinhas 1, marinhas 2, marinhas 3, marinhas 4).

In Terceira Island there are 13 geosites: one of international relevance, five of national relevance and seven of regional relevance. All geosites have scientific use, and almost all of them (except for two) have both educational and touristic uses. Geosites of this island comprise 14 of the 23 geomorphological and volcanological categories defined for the archipelago (Table 1) (Figure 6).

Table 1. Geosites of the Terceira Island (Nunes *et al.*, 2011)

Geosite		Relevance	Use	Scientific Values	Geomorphological and Volcanological Categories
TER 1	Algar do Carvão	International	· Scientific · Educational · Touristic	· Speleological · Volcanic · Hydrological · Mineralogical	· Volcanic caves · Volcanic lakes
TER 2	Caldeira de Santa Bárbara e Mistérios Negros	National	· Scientific · Educational · Touristic	· Volcanic · Geomorphological · Tectonic	· Calderas · Domes and coulées · Historical eruptions

				· Mineralogical	· Tectonic structures · Polygenetic volcanoes
TER 3	Caldeira de Guilherme Moniz	Regional	· Scientific · Educational · Touristic	· Volcanic · Geomorphological · Speleological · Hydrological	· Calderas · Volcanic caves · Pahoehoe lava fields “lajidos” · Polygenetic volcanoes
TER 4	Furnas do Enxofre	Regional	· Scientific · Educational · Touristic	· Hydrothermal	· Weathering phenomena/mud deposits “barreiros” · Areas of hydrothermal activity
TER 5	Monte Brasil	National	· Scientific · Educational · Touristic	· Volcanic · Geomorphological · Petrological · Paleontological · Stratigraphic · Tectonic	· Sea cliffs · Surtseyan tuff cones · Tectonic structures · Fossiliferous deposits
TER 6	Pico Alto, Biscoito Rachado e Biscoito da Ferraria	National	· Scientific · Educational · Touristic	· Volcanic · Geomorphological · Tectonic · Mineralogical · Stratigraphic	· Calderas · Domes and coulées · Polygenetic volcanoes
TER 7	Ponta da Serreta e escoadas traquíticas	Regional	· Scientific · Educational · Touristic	· Volcanic · Petrological · Geomorphological	· Sea cliffs · Domes and coulées · Tectonic structures
TER 8	Fajã da Alagoa - Biscoito das Calmeiras	Regional	· Scientific · Educational · Touristic	· Sedimentary · Geomorphological · Volcanic · Stratigraphic	· Sea cliffs · Quaternary deposits · Domes and coulées
TER 9	Graben das Lajes	National	· Scientific · Educational · Touristic	· Tectonic · Geomorphological · Petrological	· Sea cliffs · Tectonic structures
TER 10	Ilhéus das Cabras	National	· Scientific · Touristic	· Volcanic · Tectonic · Petrological · Geomorphological	· Surtseyan tuff cones
TER 11	Mistério 1761 e sistema cavernícola da Malha Grande - Balcões	Regional	· Scientific · Educational	· Speleological · Volcanic · Mineralogical	· Volcanic caves · Historical eruptions
TER 12	Serra do Cume	Regional	· Scientific · Educational · Touristic	· Volcanic · Geomorphological	· Calderas · Polygenetic volcanoes
TER 13	Biscoitos - Matias Simão	Regional	· Scientific · Educational · Touristic	· Volcanic · Geomorphological	· Sea cliffs · Pahoehoe lava fields “lajidos”

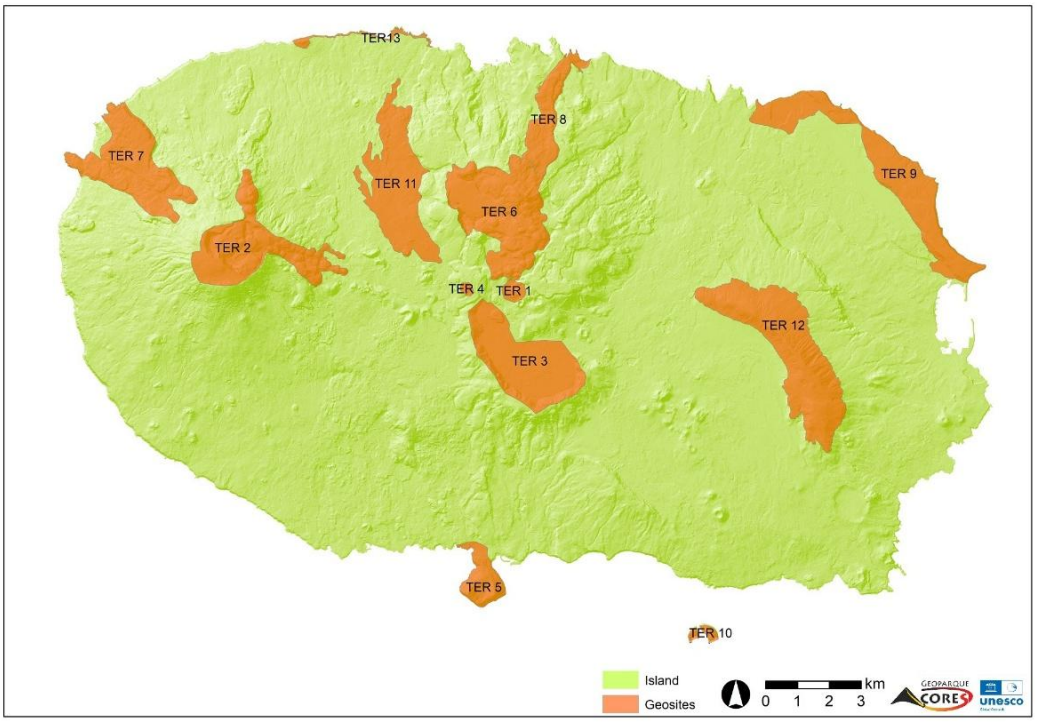


Figure 6. Location of the geosites in Terceira Island (Pedagogical resources of Azores UGGp)

Below is a description of each of the geosites of Terceira Island in their geological context and relationship to other values. These texts are derived from the geopark's own information.

TER 1 Algar do Carvão

The "Algar do Carvão" is located in the central part of Terceira Island and corresponds to a volcanic pit approximately 80 meters deep. The roof and walls have collapsed in some areas, while in others they are covered with volcanic glass (obsidian). Rainwater infiltration feeds a pool of clear water within the pit and contributes to the formation of amorphous silica stalactites and stalagmites, which can reach up to 1 meter in length and 40 to 50 cm in diameter—among the most beautiful and rare formations of this type found in volcanic caves worldwide. The vegetation covering the cone, crater, and upper section of the former volcanic vent includes several endemic plant species of the Azores. Invertebrate faunae are also present, including a noteworthy cave-dwelling spider that is endemic to the site. The first descent into the pit occurred in 1893, and it has been open to the public since December 1, 1968. It is a geosite of Azores UGGp with international relevance and significant scientific, educational, and geotouristic value.

TER 2 Caldeira de Santa Bárbara e Mistérios Negros

The Serra de Santa Bárbara is a polygenetic trachytic volcano, at the summit of which lies a caldera formed by two main collapse events. The first occurred approximately 25,000 years ago, and the more

recent caldera is partially filled by several lava domes. On the flanks of the volcano, around 100 monogenetic eruptive centres—including scoria cones, domes, and coulées—are identified, often aligned and reflecting local and regional tectonic structures.

The Mistérios Negros are associated with the initial phase of the 1761 historical eruption and correspond to trachytic domes and thick lava flows, frequently covered with black obsidian, which gives them their name. They are located on the eastern flank of the Santa Bárbara Volcano, where additional alignments of domes and coulées mark significant NW–SE-oriented fractures.

It is a geosite within the Azores UGGp, with national relevance and high scientific, educational, and geotouristic value.

TER 3 Caldeira de Guilherme Moniz

The Guilherme Moniz Caldera is located in the central part of the island and is an elongated volcanic depression that runs from NW to SE, with a maximum and minimum diameter of 4.3 and 2.3 km. Formed around 23,000 years ago, only the southern edge of the caldera is currently preserved, corresponding to the Serra do Morião, with steep escarpments and a height of around 170 m, where domes and coulées of this polygenetic volcano can be seen. The floor of this caldera was occupied by several basaltic lava flows, with special emphasis on those emitted around 2,000 years ago from the Algar do Carvão volcanic system and which overflowed from the eastern side of the caldera. Given the fluidity of these lavas of pahoehoe type, several lava tubes developed within them, such as Furna d'Água and Furna do Cabrito. On the flat surface of these flows, it is possible to observe several "relheiras" (in the form of grooves, some measuring more than 30 cm), caused by the wheels of the ox carts on the old "Passagem das Bestas" path. This is a geosite with regional relevance and scientific, educational and geotouristic value.

TER 4 Furnas do Enxofre

This is the most important fumarolic field on Terceira Island, consisting of multiple vents of the steaming ground type, with maximum temperatures ranging from approximately 95 to 98°C. Composed predominantly of steam (around 97%), this thermal area results from the ascent and release of steam and volcanic gases through a complex subsurface system of fissures, fractures, and pores.

The gaseous phase consists mainly of carbon dioxide (approximately 98%), with much lower concentrations of other gases such as hydrogen sulphide (H_2S), methane (CH_4), hydrogen (H_2), and nitrogen (N_2). The combination of hydrothermal activity, local climatic conditions, and vegetation

promotes the formation of thermal andosols and secondary mineral deposits, especially white clay minerals and yellowish sulphur deposits.

The elevated temperatures also affect the local trachytic structures (domes and coulées), which show intense alteration into clay minerals, often displaying a greyish coloration.

This geosite of the Azores Geopark is equipped with an interpretive trail and holds regional relevance, with significant scientific, educational, and geotouristic value.

TER 5 Monte Brasil

Monte Brasil is a surtseyan tuff cone formed by a submarine basaltic volcanic eruption in shallow waters. This tuff exhibits numerous, perfect, and well-preserved fossils of the vegetation that existed in the surrounding area at the time of the eruption, several millennia ago. Monte Brasil is the largest tuff cone in the Azores and forms a peninsula of approximately 1.4 km^2, flanked by two bays: Angra, to the east, and Fanal, to the west. Its crater is surrounded by four elevations: Cruzinhas, Facho, Vigia da Baleia and Zimbreiro peaks. It provides an excellent viewpoint over the city of Angra, the entire southern part of Terceira and the neighbouring islands. Various leisure activities are carried out at this location, such as hiking, cycling and visits to various points of tourist and historical-cultural interest, such as the Fortress and Castle of São João Baptista, the wall surrounding the cone, Pico das Cruzinhas and the Chapel of Santo António.

This geosite, next to the first Portuguese city to be declared a UNESCO World Heritage Site, is of national relevance and with scientific, educational and geotouristic value.

TER 6 Pico Alto, Biscoito Rachado e Biscoito da Ferraria

Pico Alto is the most recent polygenetic volcano the island, approximately 100,000 years old. The walls of its collapsed caldera are visible only in the Serra do Labaçal, Caldeira da Agualva and Rocha do Juncal, along an imposing trachytic escarpment, as this depression is filled by a significant number of domes and coulées. These volcanic forms, being more than fifty, are locally known as “biscoito” and define important tectonic alignments with a general NNW-SSE to ENE-WSW orientation, such as those found in the areas of Biscoito Rachado and da Ferraria. Pomitic deposits predominate throughout the geosite, with the presence of pumice bombs with a film of obsidian, which are very rare in the Azores, standing out for their uniqueness.

This is one of the most attractive geolandscapes on Terceira Island, a geosite with national relevance and scientific, educational and geotouristic value.

TER 7 Ponta da Serreta e escoadas traquíticas

At the western end of Terceira Island, several domes and coulées emerge, associated with radial fractures of the Santa Bárbara Volcano and the Terceira Rift. Some of these coulées are around 15-20 metres thick and the most recent forms the rocky peninsula of Ponta da Serreta, where the lighthouse of the same name is located. Submarine eruptions have occurred offshore Ponta da Serreta along fractures with a general NW-SE direction, such as the 1867 eruption. More recently, the 1998/2001 eruption, with emissions 8.5 km from the coast and at a depth of around 500 metres, had peculiar characteristics, namely the formation of "lava balloons", according to a volcanic activity that has since been referred to as "Serretian activity". This geosite is crossed by the PRC03 TER - Serreta hiking trail, along which thick deposits of pumice, obsidian, and endemic vegetation can be observed. This is a geosite with regional relevance and scientific, educational and geotouristic value.

TER 8 Fajã da Alagoa - Biscoito das Calmeiras

The "Fajã da Alagoa", also known as Alagoa da Fajãzinha, is located on the north coast of the island and is an ancient bay filled with sediments carried by the watercourse that flows into it (Grota da Alagoa), and which is delineated on the coast by a pebble beach. The fossil cliffs that border this coastal detrital platform (*fajã*) are of a trachytic nature, with particular emphasis on those to the west, which form the Biscoito das Calmeiras (or Colmeias), a thick trachytic flow (coulée) emitted from Pico Alto caldera and which, descending the slopes of this volcano, advanced into the sea to form a promontory. This geosite is equipped with viewpoints to the north coast of the island, particularly the columnar jointing displayed in the cliffs to the west of the geosite. This bay is part of the official PR02 TER - Baías da Agualva hiking trail. The geosite is of regional relevance, with scientific, educational and geotouristic value.

TER 9 Graben das Lajes

The Lajes Graben is one of the main tectonic structures on Terceira Island and Azores archipelago. It occupies the northeastern part of the island and is characterized by a stepped relief formed by an extensive system of active faults, generally oriented NW-SE. It is highlighted by fault scarps and flat low-lying platforms, with the airport, the village of Lajes and the city of Praia da Vitória occupying the central part of this tectonic depression. The Santiago fault scarp limits the graben to the northeast, while the Fontinhas Fault defines the southwest limit. The strong and destructive earthquakes of 1614 and 1841, which devastated the city of Praia da Vitória, are evidence of the seismic activity associated with this structure and its extensions into the sea. Several viewpoints offer good panoramic views of the central

valley and the fault scarps of the graben, such as Humberto Delgado, Serra do Facho and Serra do Cume viewpoints. This geosite of national importance has scientific, educational and geotouristic value.

TER 10 Ilhéus das Cabras

The "Ilhéus das Cabras", located in the sea about 1 km south of the coastline of Serretinha, in Feteira, correspond to a surtseyan tuff cone, resulting from a submarine volcanic eruption of basaltic nature. Currently, this cone is very eroded, presenting several coastal caves (such as the Gruta Brisa Azul) and is separated into two islets (the Pequeno and Grande islets) by the action of a tectonic structure with a general NW-SE orientation. The islets consist of pyroclastic rock with ash and lapilli sized particles. These rocks are yellowish to brownish in colour, show clear stratification and contain interbedded lithic fragments., These lithics come from surrounding rocks of the volcanic vent which were also projected during the eruption. This is a geosite of national importance and of scientific and geotouristic value.

TER 11 Mistério 1761 e sistema cavernícola da Malha Grande - Balcões

In 1761, two eruptions occurred on Terceira Island, one associated with the trachytic domes known as Mistérios Negros, on the eastern flanks of the Santa Bárbara volcano, and the other in the Basaltic Fissural Zone, namely in Pico do Fogo and Pico Vermelho. The latest is known as "Mistério Novo" and corresponds to a typical strombolian-type eruption, with the extrusion of basaltic scoria and associated lava flows, which flowed northwards. These aa-type lava flows did not reach the coast but covered areas of arable and cultivated land and affected the most upstream part of Biscoitos parish. The pahoehoe lava flows underlying the "Mistério Novo" (less than 7,130 years BP) hosts one of the largest cave systems in the Azores. This system comprises approximately a dozen lava tubes, including Malha, Branca Opala, Buracos and Gruta dos Balcões, the latter being the longest lava tube on the island, measuring approximately 4.4 km in length. This geosite is of regional importance and is of educational and scientific value.

TER 12 Serra do Cume

Serra do Cume, together with Serra da Ribeirinha, forms the rim of the collapse caldera of Cinco Picos Volcano, which represents the oldest volcanic complex on Terceira Island. With an average diameter of approximately 7 km, it is the largest volcanic caldera in the Azores. The interior of the caldera is filled with younger volcanic deposits emitted from neighbouring eruptive centres, which resulted in an extensive plain currently dominated by green pastures and the characteristic patchwork of enclosed fields bordered by dry-stone walls of volcanic rock. Scattered across this plain are around a dozen small volcanic cones, most of which are scoria cones. From the viewpoints along Serra do Cume, one can observe part of the

island and several other geosites of Terceira, including the Ilhéus das Cabras, the slopes of the Guilherme Moniz Volcano, Pico Alto, and the Lajes Graben. This is a geosite of the Azores Geopark with regional significance and scientific, educational, and geotouristic value.

TER 13 Biscoitos - Matias Simão

The coastal area of Biscoitos, on the north coast of the island, is formed by basaltic lava flows of aa-type, emitted about 4,500 years ago from Pico Gordo, a scoria cone located in the central part of the island. The main lava flows emitted from this cone moved about 7 km northwards reaching the sea and forming the several rocky points of Biscoitos and the typical littoral "mega-ropy lava" barriers, morphology that today is used as the natural pools of Biscoitos. Further inland are the traditional vineyards, with the typical "dry stone" walls (curraletas), which mark this geocultural landscape.

The Matias Simão cone, located to the west of Biscoitos in Altares parish, corresponds to the remains of a spatter cone, deeply eroded by the sea, whose adjacent cliff shows at its base important gravel beach deposits. This elevation, once used as a whale lookout, has a monumental Cross on its top and provides a unique viewpoint towards the northern flanks of Pico Alto and Santa Bárbara polygenetic volcanoes and their massive domes and coulées. This is a geosite of regional importance and scientific, educational and geotouristic value.

2.4. Assessment and management of geosites

Different analyses have been carried out in the Azores, integrating geological characterization, geomorphological and volcanological categorization, relevance analysis, identification of types of use, and associated scientific, educational and geotouristic values (Lima, 2007, 2018). The first systematic study of the geological heritage was carried out by Lima (2007), in an analysis of the geological heritage of the environmental areas classified in the Azores that included two main steps: a qualitative and quantitative assessment. In the quantitative assessment, the methodology proposed by Brilha (2005) was adapted to the territorial and geological reality of the archipelago. In this methodology three classes of criteria about the geosites are evaluated: A) intrinsic criteria (uniqueness, area, geodiversity, conservation status, association with other heritage elements, scientific knowledge), B) potential use (observation conditions, accessibility, potential audience, socio-economic conditions, different types of use) and C) need for protection (legal status, ownership, vulnerabilities and threats). The results gave a value to each geosite, allowing their comparison, ranking them, and determining their international/national or regional/local relevance (Lima *et al.*, 2014). This methodology worked as the framework that led to the inventory and characterization of the geological heritage in the entire archipelago, identifying the first 121 geosites of

Azores Geopark, and eventually allowing its application to the European and Global Geoparks Networks in 2011.

Currently, 77% of the Azores UGGp geosites (93 geosites) are under legal protection, integrating the Regional Network of Protected Areas, lying under the management of the Island Nature Parks and the Marine Park, with 49 geosites totally or partially overlapped with protected areas. Several geosites are also classified by international conventions and intergovernmental programmes like Natura 2000 Network, Man and Biosphere (MAB), Ramsar Sites, UNESCO World Heritage, Important Bird Areas (IBA's), and OSPAR Zones (Lima *et al.*, 2018).

The latest study regarding assessment of geosites and management of geological heritage was made by Lima (2018) in a PhD thesis "Definition of Geological Heritage Management Methodology. Application to the Azores Archipelago", comprising an analysis and proposals on i) nature conservation and geoconservation framework; ii) geoconservation in Azores archipelago; iii) monitoring of Azores geological heritage; iv) environmental function analysis of Pico Island geosites (pilot study); and v) management of geological heritage in insular geoparks, a management model proposal for Azores Geopark).

The function analysis, as a tool that promotes the proper development and management of geosites, compares the potential for conservation or for development of human activities, it is a quantitative assessment that finds the Environmental and Conservation Value and Use and Development Potential of a geosite. When implementing this methodology for geosites of Pico Island all results were plotted within the "Conflict Zone", which is expected since all geosites have moderate-high and similar environmental/conservation values and use/development potentials. Another finding and challenge when this assessment is applied is that there are geosites with very different areas and characteristics, and all are scored equally, there is a need to detail or carry out analysis by zones in the future, at least in large geosites or those located in areas of greater conflict (Lima, 2018).

Finally, the core of this thesis is the proposal of the methodology for the management of the geosites, and the author considers this management should be carried out at three levels: i) an archipelago level, in a formal way; ii) an island level, in a strategic way, with clear boundaries and a well-identified set of actors; and ii) a geosite level, in an operative perspective. At an island level the aim is to include the management of the geological heritage in the management already carried out by the Island Natural Parks, since most of the geosites are also previously classified and protected areas. At the geosite level, it is proposed to carry out a monitoring in collaboration with Nature Rangers (ideally monthly), which aim is to look after the evolutionary state of the geosite and its integrity, identify threats, quantify the eventual

loss of relevance over time, visitors' characteristics and activities developed in the area (Lima *et al.*, 2018).

Since August 2022, the Azores UGGp has been included in the Regional Council for the Environment and Sustainable Development, where important decisions are taken concerning the territory. This allows the geopark to be involved in the establishment of management measures to mitigate or prevent damage to geosites (Lima & Meneses, 2023).

2.5. Diagnosis of educational and touristic activities in the geopark

The volcanic landscape and the oceanic setting of the Azores are their main attractions, fascinating travellers, scientists, and distinguished naturalists (Lima, 2007). This archipelago is known mostly for being a nature destination. The establishment of Azores UGGp brought a refreshed approach to the touristic offer on the territory, implementing a strategy for geotourism and highlighting the link between natural and cultural values. Important achievements have enriched the geotouristic offer, providing a wider range of possibilities to explore and experience the islands, scattering visitors and lowering the pressure on hotspot sites (Lima & Meneses, 2023). The geopark has, in its Annual Action Plan, activities that contemplate its main objectives: geoconservation, environmental education and awareness, and sustainable regional development, combined with a communication strategy that is transversal to the various objectives (Lima, 2018).

Activities related to geoeducation

Educational programs have been defined with activities adjusted to school curricula for all different levels of education, from preschool to high school. These activities compose the PEGAz - Plano Educativo do Geoparque Açores (Azores Geopark Educational Plan), a compilation of indoor and outdoor activities that focus on the thematic of geohazards, Azorean geodiversity, its geological heritage and geoconservation, and are implemented on all islands in partnership with the Regional Secretariat for Environment and Climate Action. In the school year 2024/25 a new online offer dedicated to the geology of the Azores was introduced in PEGAz, enabling a wider access and enhancing the capacity to reach a more diverse audience, facilitating broader participation while overcoming geographical limitations.

The main actions carried out in educational programs are (Figure 7): i) the development and provision of online content on the Azores UGGp website and the "Educating for the Environment and Sustainability" webpage (Regional Secretariat for the Environment and Climate Action, 2025), with sessions, activities and respective scripts for teachers, and support for the delivering of the sessions if requested; ii) the development of support materials, such as children's guides and educational games; iii) the promotion

and support of study visits and fieldtrips, through each island "Route of... Geodiversity and Geosites" and "(Geo)Urban Routes"; iv) collaboration in educational events of partner entities and celebration of symbolic dates for the preservation of the environment (like annually the European Geoparks Week); v) the promotion of school competitions; vi) the promotion and coordination of the regional phase of the "Portuguese Geology Olympiads", an initiative of the Geological Society of Portugal; vii) the promotion of contact with geologists and academic field work; and viii) the provision of capacity building activities for teachers (Lima, 2018).

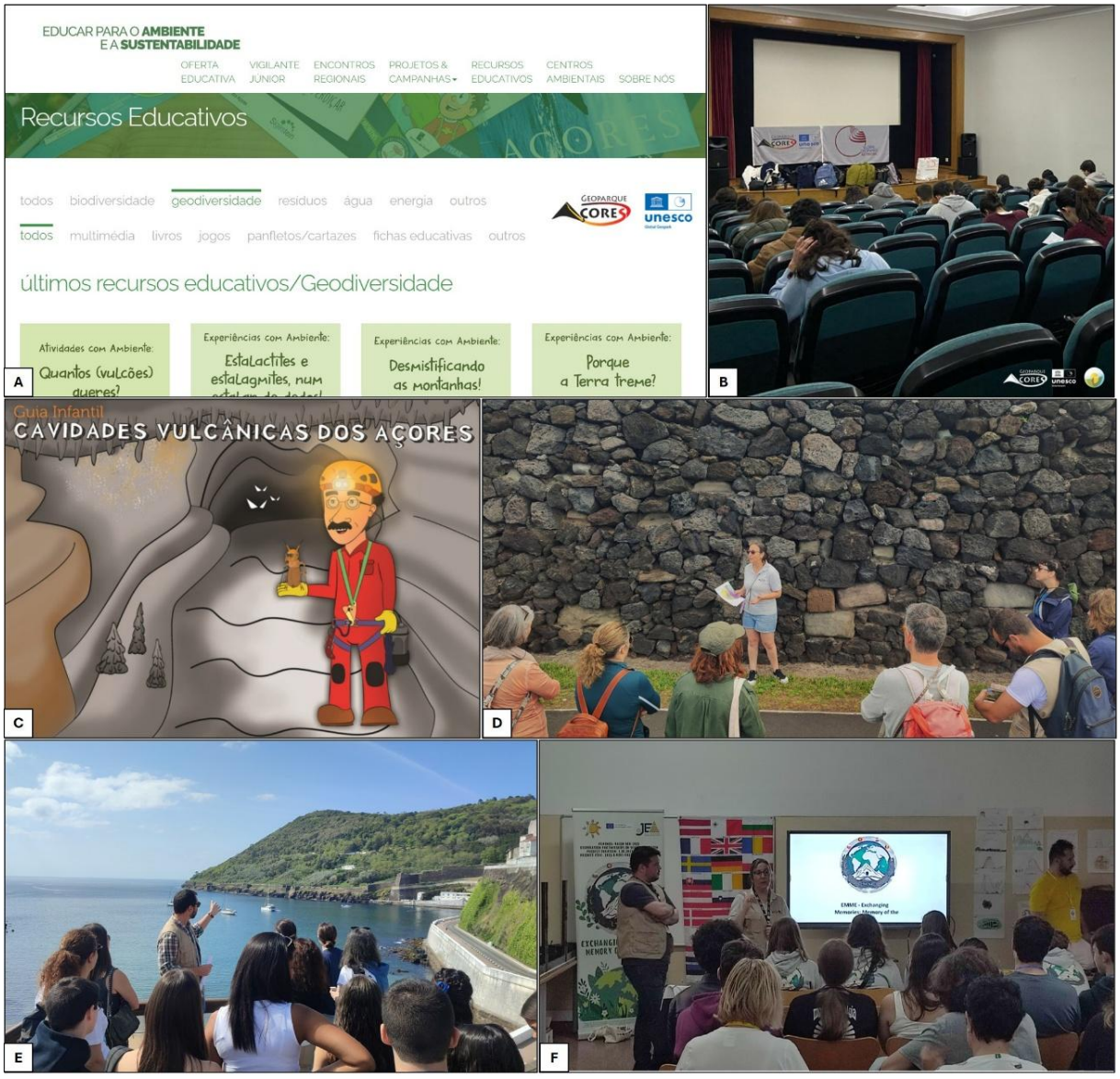


Figure 7. Examples of activities and educational programs developed in the Azores UNESCO Global Geopark: (A) Geodiversity educational resources in "Educating for the Environment and Sustainability" webpage; (B) Portuguese Geology Olympiads 2025; (C) "Cavidades vulcânicas dos Açores" one of the children's guides launched in 2023; (D) Interpretative tours "Rochas que Contam Histórias" within the scope of the 2025 European Geoparks Week; (E) Study visit through Angra de Heroísmo's (Geo)Urban Route; (F) Experimental activities and interpretative routes within "EMME" Exchanging Memories - Memory of the Earth, Erasmus program.

Figure 8. Broad community communication strategies. (A) Azores UGGp leaflet; (B) Routes of Geodiversity and Geosites leaflets; (C) Drawing contest "Geological Heritage in the Azores Geopark"; (D) "(Geo)Diversidades" page in Açoriano Oriental newspaper; (E) Stand in "Expo Atlantic Terroir" fair; (F) "Geoparque Açores em 5 minutos" radio segment on the Antena 1 Açores; (G) Engagement in social media (Geopark's Instagram account).

Communication for environmental awareness in the community is other element of action of the geopark through means like the production of information leaflets about the geosites and geopark, participation in social media, organizing activities at geosites for the public (such as interpretive walking trails and geosites routes), formal awareness-raising actions in the community, participation in fairs and seminars or conferences (in the archipelago and abroad), organization of thematic challenges and exhibitions (as photography and painting contests), "(Geo)Diversidades" page every two weeks in the "Açoriano Oriental" newspaper since 2012 (with articles about the importance of geological heritage and geoconservation, the geosites of the Azores, geoparks in the world, activities and themes developed by the geopark and its partners, and cultural curiosities related to geological heritage, among other topics), broadcast of the "Geoparque Açores em 5 minutos" weekly section on the radio station Antena 1 Açores broadcasting

since 2016 (with topics such as geodiversity, geosites, geoconservation, sustainable development, geoculture and activities of the geopark and its partners), production of a documentary ("9 islands – 1 geopark"), contribution for promotional videos of partners and a promotional video dedicated to the Geopark. These last actions in regional media, are those that have given the geopark the greatest visibility and impact, making people more aware of the value of the abiotic component of the natural heritage and the importance of its conservation and management (Figure 8).

Activities related to geotourism

The Azores UGGp adopts a comprehensive strategy for geotourism aimed at maximizing and enhancing existing services and tourism infrastructures, while empowering partners through a platform that fosters information sharing and promotes environmental awareness. This environmental awareness component is crucial, as it encourages responsible behaviour among stakeholders, strengthens the connection between tourism and nature conservation, and ensures that tourism development aligns with the principles of sustainability. By sensitizing both partners and visitors to the value and fragility of geological and natural heritage, the geopark fosters a more holistic and respectful engagement with the territory.

The Regional Network of Walking Trails has been expanded, with additional trails and improved informational resources available to visitors. Interpretive centres across the archipelago foster good environmental practices by providing accurate and engaging information on natural and geological heritage (Lima & Meneses, 2023).

Through geopark-led training courses and workshops (Figure 9), new tourism products and companies have emerged on several islands. These companies offer a broad range of geotourism experiences, including guided walking trails, geotours, speleological activities, and coasteering. Many rural accommodations embrace geological themes through naming or decoration and are often situated within geosites. Additionally, local partners have developed unique gastronomic, and handicraft geo-products based on autochthonous resources (Lima & Meneses, 2023).

In the early stages of geotourism development, the Azores Geopark proposed a series of thematic intra- and inter-island routes designed to highlight the archipelago's diverse geoheritage. These included:

a) The "Volcanic Caves Route", which invites discovery of the islands' subterranean volcanic world, featuring volcanic caves and interpretation centres.

b) The "Belvederes Route" designed for car travel to appreciate the islands' geolandscapes from numerous viewpoints.

c) The "Walking Trails Route", promoting on-foot exploration of geosites via the Regional Network of Walking Trails and other paths, supported by leaflets and itineraries.

d) The "Thermal Route", showcasing the health, leisure, and wellness benefits of the Azores' geothermal waters and muds.

e) The "Science and Interpretive Centres Route", which facilitates understanding of volcanic phenomena through various regional science and interpretation centres (Lima *et al.*, 2009).

Figure 9. Examples of the latest training courses and workshops led by Azores UGGp in its territory.

More recently, the geopark created the "Route of Geodiversity and Geosites" across all islands, supported by information poles and brochures. Cooperation with the Azores Tourism Board led to the creation of the "Volcanoes Route." The geopark has also developed (Geo) Urban Routes in major urban centres—including Angra do Heroísmo, Praia da Vitória, Horta, Ponta Delgada, Ribeira Grande, and Lagoa (more are in development)—which offer interpretative visits that highlight both geological features and the use of local rocks in the historical and architectural heritage. In parallel, the geopark continues to support new walking trails with local partners. These interpretive efforts are crucial for enriching visitor experiences at geoheritage sites through diverse materials such as panels, poles with QR codes, and digital content (Lima & Meneses, 2023).

A well-established network of partners spanning all nine islands supports geotourism services and products. The geopark maintains a close and collaborative relationship with the Regional Secretariat for Tourism, Mobility and Infrastructures, ensuring that geotourism is integrated into broader tourism policies

and strategic plans. Tourist information offices throughout the Azores function as official info points for the geopark, facilitating visitor access to geotourism resources.

The geopark regularly participates in national and international tourism events, notably through joint stands with the Portuguese Geoparks Network at the Lisbon Tourism Fair (BTL), increasing the visibility of Azorean geotourism on a broader stage (Figure 10).

Figure 10. Participation of Azores UGGp together with the Portuguese Geoparks Network at BTL Fair 2025.

The "Geodiversity and Geotourism" capacity building activities, targeted specifically at geopark partners, provide updated scientific information and training sessions. This initiative fosters a more holistic approach to territorial management and supports the sustainable development of tourism by enhancing partners' knowledge of the region's geodiversity.

Collaborative work with regional authorities, scientific institutions, and tourism organizations has resulted in the development of extensive interpretive infrastructure. This includes clear signage and panels for geosites, walking trails, educational panels, and panoramic viewpoints. These panels and other interpretive materials serve dual educational and geotourism purposes by delivering accessible scientific

content, improving visitor orientation, and increasing appreciation of the Azores' volcanic landscapes. Furthermore, interpretive content is integrated into science and visitor centres, enhancing overall visitor engagement. This consistent set of communication equipment significantly enriches the geotourism experience and fosters greater awareness of the archipelago's geological heritage.

The Azores are internationally distinguished as the first archipelago certified as a sustainable tourist destination. The Azores Tourism Board's Strategic and Marketing Plan for Tourism in the Azores (PEMTA 2030) highlights geotourism as a key experience category, with many other tourism sectors also heavily dependent on geodiversity. The PEMTA 2030 further positions the archipelago based on nine unique characteristics— (volcanic origin; authenticity; biodiversity; preserved natural landscapes; warm and hospitable local communities; safety and tranquillity; commitment to sustainability; proximity to nature; and unique active-tourism opportunities)—which collectively differentiate the destination on the global stage. The plan recognizes geosites as essential elements that contribute to the attractiveness of each island, and geotourism is now a consolidated activity across the archipelago. Visitor flow analyses through the Azores UGGp demonstrate that geotourism functions as an integrated circuit spanning all nine islands, thus promoting regional cohesion and shared economic benefits (Regional Government of the Azores & Regional Secretariat for Tourism Mobility and Infrastructure, 2023).

The Azores have been internationally acknowledged with awards related to sustainable tourism and environmental stewardship, reinforcing the global reputation of the archipelago as a model for responsible tourism development.

3. Methodology

Lately, quantitative assessment methodologies have been created and implemented to evaluate the geological heritage in geoparks or protected areas, highlighting the ones developed by Pralong (2005), Rybár (2010), Pereira & Pereira (2012), Kubalíková (2013), Doktor *et al.* (2015), Brilha (2016), Gonçalves (2013), Viveiros (2016), Afonso (2019) and Esteves (2023), their works indicate generally accepted criteria for assessing use, in these studies usually referred as tourist potential or (geo)tourism value, with a fundamentally quantitative nature that is intended to facilitate comparisons between evaluated sites. All these works were reviewed, with special interest to the studies made by Esteves (2023), Kubalíková (2013), Pereira & Pereira (2012) and Doktor *et al.* (2015) that acted as the main basis for the developed methodology in the present study.

Four studies of characterization of the geological heritage in the Azores UGGp that included quantitative assessments have been developed: i) the Master thesis "Azorean Geologic Heritage: Valuing Geosites in Environmental Classified Protected Areas, Contribution to the Territorial Planning" by Lima (2007); ii) the works and studies leading the Azores Geopark application to the European and Global Geoparks Network (Nunes *et al.*, 2011); iii) the scientific research project "Identification, characterization and conservation of geological heritage: a geoconservation strategy for Portugal" (2007-2010) (Brilha & Pereira, 2012); iv) and the PhD thesis "Definition of Geological Heritage Management Methodology. Application to the Azores Archipelago" by Lima (2018). Since these studies assess mainly the scientific value and the degree of vulnerability, they were not used completely as base for the proposed methodology, but they included valuable information in their results that was source material for the assessment of several criteria. It is worth of mentioning that Lima (2018) carried out a function analysis methodology that included the assessment of "use and development potential", but some limitations were found in this methodology.

Once a methodology for the Azores UGGp was established, with indicators appropriate for the reality of a small islands' archipelago, considering aspects such as dimensions of the islands, distances, and available infrastructure, a form and spreadsheets were created to record the assessment data.

During the fieldwork on Terceira Island, two main activities were carried out: i) visiting and evaluating the main visiting points of each geosite, which are the specific places where the geosites are used, in order to calculate their use value; ii) and participating in activities organized by the geopark and carrying out alternative activities independently, in order to obtain a diagnosis of, and in turn, support the mechanisms of geoeducation, geotourism, partnerships, monitoring, management, and organizational structure of the Geopark.

After obtaining the quantitative results of the assessment, the geosites were ranked based on their scores. The performance of the criteria was evaluated to identify overall strengths and weaknesses for the island's geosites as a whole. The geosites are then analysed independently, and qualitative assessments of their use value are given, ultimately generating valuation proposals for the geosites.

Furthermore, in addition to the valorisation proposals for each geosite, recommendations are provided for the development of the geopark's geosites in general. As a result of the diagnostic analysis of its activities and strategies for developing geoeducation and geotourism in the area, ideas and tools are proposed for the promotion, attractiveness, and use of the geosites for educational and tourist populations.

Finally, the results of the study are analysed, the effectiveness of the methodology developed is assessed, and its determinate if the stated objectives were achieved. In addition to these conclusions, some complementary studies and actions are suggested for further investigation.

3.1. Selection of assessment criteria and indicators

Esteves (2023) proposed and developed a methodology for the quantitative assessment of the geosites' use value, specifically to be used in geoparks. It is an exhaustive compilation work that had already reviewed the methodologies implemented previously, which is why this work was the primary basis used to develop a methodology for the Azores UGGp; only some criteria were refined, and specific indicators were established for the reality of the archipelago.

In the methodologies developed by Pereira & Pereira (2012) and Doktor *et al.* (2015), the assessment criteria are grouped into major categories as *main criteria* and *values*, respectively. This was used as inspiration to create an own way of grouping the assessment criteria and facilitating the management of the evaluation results in order to develop geosite valorisation tools based on the values obtained for the criteria.

As mentioned previously in Chapter 2 (Section 2.4 – Assessment and management of geosites), the work of Lima (2018) involved the development of a functional analysis of geosites on Pico Island. This assessment aimed to determine both the Environmental and Conservation Value, as well as the Use and Development Potential of each geosite. However, some weaknesses were identified in the methodology: (i) the criteria were assessed at different spatial scales—some at the local (geosite) scale and others at the municipal or island level; and (ii) because the assessment was designed to evaluate geosites as unified entities, it did not account for internal variability—areas with very different characteristics within a single geosite were assessed as if they had the same values and potentials. This was not practical given the

characteristics of Azores UGGp, where most of its geosites are large areas, and frequently various locations inside the same geosite are not suitable for the same activities. That is why the present study sought to assess the visiting points or places of interest that act as a focus for geosites usufruct.

Selected criteria

Given that Esteves (2023) compilated a refined list of criteria from several methodologies developed by the time, that list was the one used as a framework for this study. Most of those criteria were kept with very few modifications, mostly the order of analysis, trying to group them by related topics, and the names of some criteria. A new criterion was added, "Related local products and creations", adapted from a proposed criterion in the methodology developed by Kubalíková (2013).

Broadly speaking, the selected criteria include those associated to the availability or ease of use of the place (access and safety related criteria), to sensorial properties (like the interpretative potential, or criteria linked with aesthetic attractiveness), to the different uses and other values provided by the site, and to closeness to facilities that ease logistics. All of them are designed to be assessed at a local level (visiting point or geosite scale), criteria at larger scales should be avoided to not create discrepancies in the model (Lima, 2018).

Each criterion is listed below with its definition and an explanation of how it influences the use value.

1. Accessibility

Conditions of access to the visiting point. The possibility of reaching the visiting point by motorized vehicle increases the site's visibility and attracts more visitors due to easier access. Conversely, more difficult access reduces visitation, implying that the site is either distant from roads or accessible only with special equipment, such as ropes and ladders, or by boat.

2. Trail

The existence of a path or route already being used for hiking, biking, or walking near or crossing the visiting point can significantly increase the touristic and educational value of a geosite, especially in a region like the Azores where there is an important use of this type of infrastructure by tourists and locals. This criterion will be evaluated based mostly on the Official Azorean Walking Trails Network, including other paths administrated locally if necessary (Azores Trails - https://trails.visitazores.com/en).

3. Visiting time limitation

Availability for the site to be used in time. If the site is available all day every day or only during some specific hours and/or days. Restrictions given by seasonality or specific schedules would decrease the value.

4. Access and natural hazards

Safety in access and potential natural dangers that can occur. Regarding the access, the site should have designated pathways and fences to limit the site and the way to the site. The safer the place the higher the use value. If the natural danger is relatively high, measures like proper infrastructure and warnings about it can valorise the site. Optimal access conditions would guarantee the use of the site by all users, including people with reduced mobility.

5. Phone coverage

Existence of telephone network coverage, to call emergency services in case of facing physical troubles or an emergency. Adequate phone coverage would facilitate safety and increase the value.

6. Health services

Distance to the nearest emergency facility like hospital, health centre or firefighter station. The existence of emergency services close to the site makes visiting safer for users.

7. Degradation risk

Potential deterioration or decline in value of a geosite over time, which can result from several factors such as the presence of a geosite in a legally protected area, proximity to urban zones, anthropogenic vulnerability, and intensity of use. If the risks are low the local is suitable for being used. With high risk of degradation of the elements, activities should be avoided at the place.

8. Visibility

Refers to the degree to which the geological elements can be seen or observed by the visitors from the main visiting point, often influenced by the weather, distance, the need of artificial light and obstructions like vegetation, buildings, fences and so on. The better the observation conditions, the higher the use value.

9. Number of viewpoints

Possibility of seeing the geosite from multiple different perspectives from known and official viewpoints. To assess this criterion, consider public and formal information regarding viewpoints, especially in the

means given by tourism authorities: maps, leaflets, panels, road and trails signage, tourism guides, and official web pages. If the site can be seen from multiple perspectives it would be more accessible and have a higher value.

10. Prominence in the landscape

Refers to a distinctive and easily noticeable geological feature within the natural environment, often standing out due to its size, elevation or unique characteristics. If the site distinguishes from its surroundings, it will be more accessible visually, and usually also more attractive to visit. Sites with low contrast or hidden, would have a lower value.

11. Naturalness of landscape

Refers to the degree to which a geosite reflects the original and untouched state of its elements. If it is free from significant human intervention or modification it would be more attractive to visit, sometimes certain human interventions in the landscape in rural areas can also be attractive (vineyards, "cerrados", crops), but in general the more urbanized an area is, the less valuable it will be to visit.

12. Uniqueness

Consider the uniqueness and scarcity of geodiversity features that could evoke a feeling of fulfilment among visitors. The existence of rare elements makes a place more appealing for all types of users.

13. Geological diversity

Diversity of geological features of interest observable in the geosite at the same time. In the context of Azores UGGp, the number of geomorphological and volcanological categories assigned to the geosite should be assessed (Lima, 2018).

14. Representativeness

The geosite represents the best example of its kind, to illustrate geological elements or processes for pedagogical or geotourism use. For Azores UGGp, this criterion is based on how a geosite represents its geomorphological and volcanological categories. A geological feature displaying all its typical elements should be an optimal didactic example of its kind, and its representativeness decreases when some elements are lost or degraded. A representative geosite has a high use value, especially for geoeducational purposes.

15. Interpretative potential

Regarding the geodiversity element's ability to be comprehensible to individuals without a geological background or knowledge. This criterion is related with other criteria like visibility and representativeness, and other aspects like the complexity of the geological processes. When the geological features are understandable for the lay people, a geosite has a high use value.

16. Access to geological information

Refers to the ability for every person interested to obtain and utilize data, maps or knowledge related to the geosite for various purposes, such as research, education, or resource management. If there are easy access to information and numerous publications about the geosite, it will have a high value, especially for geoeducation.

17. Use of other values

The presence of other natural and cultural values, and their promotion and current utilization should be highlighted. The occurrence of these other elements associated with the geosite attracts more visitors and may justify interdisciplinary fieldtrips increasing the value of the site.

18. Related local products and creations

Existence of local products or contents that support or promote the site. The occurrence of culinary products, souvenirs, crafts, songs, cultural traditions and costumes, multimedia content as series, stories and myths, etc, related with the geosite will increase its value.

19. Touristic promotion of the site

If the site is being used in any kind of publicity around the world, in the country or locally as a tourist destination. Well known and promoted sites will be more attractive and used by tourists. The higher the reach level, the higher the value.

20. Signage

Set of signage along roads, streets and trails. Clear indications and specific signs or signals that provide instructions or guidance about or to the site. Existence of signs along the way and at the site is the best way to make the site more accessible and easier to find for visitors and therefore increase visibility.

21. Current use of geological values

Refers to the use being given to the geosite at this moment, whether it is only used by scientific experts or by general public. Locations already being used for recreational purposes and tourist visits have the highest value.

22. Dissemination of geoheritage value

Involves the communication and promotion of the geosite to the public, scientists, educators and policymakers through various means such as interpretative centres and panels, exhibitions and publications. A wide, frequent and on-site communication about geoheritage values increases the use value, an ideal situation would be to have an interpretation centre dedicated to the geosite.

23. Use limitations

Refers to the specific restrictions or constraints placed on the utilization of the site often due to legal, such as private or state land, environmental related to a protected area, or practical considerations, like fences or obstacles. A place without any possibility for visiting would simply have the lowest value, while when there are few or no restrictions the site will be suitable for use.

24. Cleaning and recreation

Assess the site's hygiene conditions considering potential picnic or bathing activities. The cleaner the site the better the experience for the visitor, the more tourists it will attract, especially if the site offers picnic conditions.

25. Toilets

Determine the proximity of public restroom facilities or the feasibility of using toilets at nearby restaurants or cafes, considering their distance from the visiting point. The existence of restrooms will ease the use of the site.

26. Gastronomic facilities

Distance from the nearest restaurant, café, bar or food truck ("tasca"). Having an easy access to food will make the site more attractive and included in itineraries.

27. Proximity to recreational areas

Distance to near places, landmarks, events, or activities that draw the interest and visitation of tourists and travellers due to their unique, cultural, historical, natural, or recreational significance and appeal. For Azores UGGp, consider the typical recreational areas like parks and gardens, "lazer" zones, camping

parks, beaches and bathing areas; and touristic attractions as viewpoints, lighthouses, fortresses, museums, and even other geosites. If the geosite is near some of these places, it will be more likely to be visited and used.

Criteria classification

Some authors classify and group the criteria used in their assessment methodologies for various reasons, such as to organize them thematically, facilitate analysis, perform weighting, or for other reasons. Pereira & Pereira (2012) group thirteen (sub)criteria into four "main criteria": availability, use, logistics and perceptiveness. All criteria have the same value, so they are not differentiated for the purpose of making a weighted evaluation; rather, they are done with the aim of reading partial results through these criteria. The order given to the criteria selected in the present study almost corresponds to the main criteria just mentioned.

Doktor *et al.* (2015) propose a methodology for geotourism assessment aimed at different types of recipients: tourists (casual, witting, hobbyist), educators (schoolteachers, academic staff, guides, organizers) and investors (owners, managers). Using four principal categories of criteria or values: visual, cognitive, functional and investing. Criteria are grouped into these categories because "various recipients have different preferences", depending on the type of user certain categories will have more relevance (Table 2).

Table 2. Importance of geotourism valorisation criteria for various recipients (Adapted from Doktor *et al.*, 2015)

RECIPIENT		Valorisation criteria	
group	type	primary values	secondary values
Tourist	casual	visual values functional values	cognitive values
	witting	cognitive values functional values	visual values
	hobbyist	cognitive values	visual values functional values
Educator	school/academic teacher	cognitive values functional values	visual values
	guide	functional values cognitive values	visual values
	organizer	visual values functional values	cognitive values
Investor	owner	investment values visual values	cognitive values functional values
	manager	investment values cognitive values	visual values functional values

For this study, three categories were created to classify the criteria, based on the degree of difficulty in changing their conditions and making improvements. The aim of this is to facilitate the planning of measures to be implemented to enhance the value of geosites and focus the efforts of the geopark in this case. The proposed categories are: i) improvable, when the conditions represented by the criterion are easy to change and strategies to improve its value can be developed with feasible measures; ii) hardly changeable, when there is a possibility of changing the conditions but it would require big efforts, usually in criteria related with infrastructure and facilities availability; and iii) static, when the conditions cannot be changed because they are intrinsic characteristics of the site.

Table 3. Classification of criteria in categories.

CATEGORIES			CRITERIA
Pereira & Pereira 2012	Doktor 2015	Villamil 2023	
(A) Availability - (U) Use - (L) Logistics - (P) Perceptiveness	(V) Visual - (C) Cognitive - (F) Functional	(I) Improvable - (H) Hardly changeable - (S) Static	
A	F	H	1 Accessibility
A	F	H	2 Trail
A	F	I	3 Visiting time limitation
A	F	H	4 Access and natural hazards
A	F	H	5 Phone coverage
A	F	H	6 Health services
A	F	H	7 Degradation risk
(P)-A	F-(C)	H	8 Visibility
(P)-A	(F)-V	H	9 Number of viewpoints
P-(A)	V	S	10 Prominence in the landscape
P	V	H	11 Naturalness of landscape
P	C	S	12 Uniqueness
P	C	S	13 Geological diversity
P	C	S	14 Representativeness
P	C	S	15 Interpretative potential
U	C	I	16 Access to geological information
U	(F)-C	S	17 Use of other values
U	F-(C)	I	18 Related local products and creations
U	F	I	19 Touristic promotion of the site
U	F	I	20 Signage
U	F	I	21 Current use of geological values
U	F	I	22 Dissemination of geoheritage value
U	F	H	23 Use limitations
L	F	I	24 Cleaning and recreation
L	F	H	25 Toilets
L	F	H	26 Gastronomic facilities
L	F	H	27 Proximity to recreational areas

To a certain extent, all conditions represented by the criteria can change, but in the case of static criteria, extraordinary conditions would have to occur for this to happen. It is also worth mentioning that the degree of difficulty in changing the criteria varies depending on the location, and if this classification is adopted, the categories must be adapted according to the conditions of each territory. In this case, the assignment of each criterion with a category was done for the reality of Azores UGGp.

In Table 3 are shown the criteria and their assign category(s) according to the previous described methodologies. When trying to relate some specific criteria with the categories proposed by Pereira & Pereira (2012) and Doktor *et al.* (2015), it was noticed that they might correspond to more than one category at the same time, or sometimes they would not even correspond exactly to any of them, in practical terms it was adopted the most suitable alternative.

Selection of indicators

The selection of indicators by Esteves (2023) was based on their ability to remain as objective as possible, ensuring that they can be universally applicable in geoparks. For the case of this work the indicators were adapted to the conditions of the archipelago, especially those related to distance, to facilities and infrastructure. The indicators used in the quantitative assessment of Lima (2007) were conceived for the reality of the Azores, that is why they were used to calibrate some of the indicators in this work, and some were even incorporated exactly the same (Table 4).

Another important change was the one related to the scoring indicators give to the criteria. Each criterion can have a maximum score of 5 points, but while for Esteves (2023) all indicators rate from 1 to 5, in this work it was considered that some criteria can have a score of 0 points. For instance, in the case of the criterion "Use of other values" if there are no other values related to the geosite it would be rated as 0, here is considered that there is no point in assigning any score if no value exists.

Table 4. Criteria, indicators, and scores system proposed and implemented for the quantitative assessment of the use value of Azores Geopark geoheritage.

USE VALUE	
Criteria/Indicators	Points
1. Accessibility	
Direct access from main roads (paved, travelled by any motor vehicle)	5
Access from secondary paths (not paved, transitable by any type of motor vehicle or bicycle)	4
Access by secondary paths, only transitable by all-terrain vehicles	3
Access by pedestrian trail less than 1 km from path usable by motor vehicles	2
Hidden place of difficult access, by pedestrian trail to more than 1 km of a path usable by motor vehicles, or by the sea, or only by using special equipment	1
Impossible access	0

2. Trail	
Visiting point along a trail	5
Visiting point less than 250 m from tourist trail	4
Visiting point more than 250 m from tourist trail	3
Visiting point less than 500 m from tourist trail	2
Visiting point more than 500 m away from tourist trail	1
Visiting point is isolated from the island (the case of the islets)	0
3. Visiting time limitation	
Available any time at any day	5
Available all year round but in a specific time schedule	4
Available less than six months a year	3
Available a couple of weeks each year	2
Available just a couple of days each year	1
Not available at all for visiting	0
4. Access and natural hazards	
Safe for all visitors, there are no natural dangers, and it has proper visiting infrastructure	5
Very safe, there are no natural dangers, but there is not adequate infrastructure for users with limited mobility	4
Relatively safe (only with little precaution), even if it has considerable natural danger there is a proper infrastructure and signage warning about it	3
Safe regarding natural hazards, but adjustments must be made regarding the access	2
Not safe regarding access, attention related with conditions of the site is required (steep slopes, water courses, waves, thermal activity, etc)	1
Not safe at all regarding access and natural hazards (landslides, watercourses, steep slopes, highly active volcanic activity, etc.)	0
5. Phone coverage	
Phone coverage on the visiting points	5
Phone coverage more than 1 km away	4
Phone coverage more than 2 km away	3
Phone coverage less than 3 km away	2
Phone coverage more than 3 km away	1
6. Health services	
Hospital or health centre less than 5 km away	5
Hospital or health centre more than 5 km away	4
Hospital or health centre more than 20 km away	3
Hospital or health centre less than 30 km away	2
Hospital or health centre more than 30 km away	1
7. Degradation risk	
No risk of permanent deterioration of all geological elements	5
Minor possibility of deterioration of secondary geological elements	4
Possibility of deterioration of secondary geological elements	3
Possibility of deterioration of the main geological elements	2
Possibility of deterioration of all geological elements	1

High degradation risk of all geological elements, there are already important deterioration effects	0
8. Visibility	
Well exposed and excellent observation conditions	5
Weakly covered and good observation conditions	4
Partially covered and normal observation conditions, some displacement needed	3
Considerably covered, visibility limited by vegetation, buildings, etc.	2
Mostly covered and difficult observation conditions (only with the help of special equipment, artificial light, ropes, etc.)	1
Completely covered and unsuitable observation conditions	0
9. Number of viewpoints	
More than 5 viewpoints	5
4 to 5 viewpoints	4
3 viewpoints	3
2 viewpoints	2
1 viewpoint	1
0 viewpoint	0
10. Prominence in the landscape	
Site is in itself a landmark; its distinguished characteristics turn the site as a landscape unit	5
Site very prominent in the surrounding landscape	4
Can be clearly distinguished from the surrounding landscape	3
Slightly different from the surrounding landscape, difficulty in differentiating due to low contrast	2
Similar to the surrounding landscape, there is no contrast	1
The site is not distinguishable; it is hidden in the middle of the landscape	0
11. Naturalness of landscape	
Natural area with practically no traces of civilization	5
Near an urban zone but located in a natural area with low impacts, or it is an attractive rural area	4
Natural or rural area with considerable interventions (forestry projects, stabilization works, etc)	3
In a not densely populated zone, like a village	2
In an urban zone	1
In an industrial zone	0
12. Uniqueness	
Shows unique and uncommon features in the country and the rest of the world	5
Shows unique and uncommon features in the country and the region	4
Shows common features in this region but they are uncommon in other regions of the country	3
Shows features rather common in the whole country	2
Shows features rather common in the whole country and in other countries	1
13. Geological diversity	
High diversity (5 or more visible types of geodiversity elements)	5
4 types of geodiversity elements in the site	4
Medium diversity (3 types of geodiversity elements in the site)	3

2 types of geodiversity elements in the site	2
Low diversity (only 1 type of geodiversity elements in the site)	1
14. Representativeness	
High representativeness and high potential for pedagogical use, geodidactics and geotourism	5
High existing representativeness and pedagogical use with restrictions (some elements are not clear, and it needs additional tools to be clearer)	4
Existing representativeness, but with limited pedagogical use	3
Low representativeness and pedagogical use of the site	2
Very low representativeness and pedagogical use of the site	1
15. Interpretative potential	
The geological features are easily understandable for the general public, grown-ups and kids	5
The geological features are easily understandable for the general grown up public	4
The geological features on the site are only understandable to public who has some geological background	3
The geological features on the site are only understandable to geological experts	2
The geological features on the site are very difficult to understand even for specialists	1
16. Access to geological information	
Easy access, special geotouristic publications	5
Access to general information (internet, tourist guidebooks)	4
There is information but very technical (scientific papers or thesis)	3
Only scientists have access to geological information	2
Very difficult access	1
17. Use of other values	
With both, natural and cultural values, with promotion and use	5
With other type of interest, with promotion and use	4
With other types of interest, with promotion but no use	3
Integrated in walking trails by chance, without promotion	2
With other types of interest without promotion or use	1
Site without other type of interest	0
18. Related local products and creations	
Emblematic local products or creations completely dependent on the site	5
Emblematic local products developed in the site but not exclusively	4
Highly referenced site with specific products that promote or are dedicated to the site	3
Some local products promote the geosite or refer to it	2
There are local products that allude to the site	1
No local products related to the site	0
19. Touristic promotion of the site	
Frequently used as a tourism destination in national campaigns, even international campaigns	5
Occasionally used as a tourism destination in national campaigns	4
Constantly used as a tourism destination in the region	3
Constantly used as a tourism destination in local publicity	2

Occasionally used as a tourism destination in local campaigns	1
Not used in campaigns as a tourist destination at any level	0
20. Signage	
With signs along the way to the site and at the site showing it as a "geosite"	5
With signs along the way to the site and on site as a place of interest	4
With signs along the way to the site or just at the site	3
With signs but very far from the site	2
Only 1 or few signs but wrongly signed or placed, or without easing the access	1
No signs at all	0
21. Current use of geological values	
Guided tours for all kinds of public, kids and grown-ups. Used by tourists without a guide	5
Site used by educational programs (primary schools, secondary schools, universities, etc.) and average tourist	4
Site as a part of specialized tourist excursions or used by self-guided geotourists	3
Site used for educational purposes as part of excursions at university level	2
Site only used by experts, like geologists and professionals	1
The geological values of the geosite do not have any use	0
22. Dissemination of geoheritage value	
Interpretative centre specifically dedicated to the geosite	5
With dissemination onsite (interpretative and informative panels)	4
There is dissemination dedicated to the geoheritage value of the geosite, but not located at the site	3
There is a tourism office, museum or interpretative centre with references to the geosite, but not located at the site	2
With dissemination but only on internet, booklets, or leaflets	1
Without any kind of geoheritage dissemination	0
23. Use limitations	
Site without any restrictions to visit	5
Site with physical constraints (fences, obstacles, etc.) but not preventing visitation	4
Site located in a protected area, with limited number of visitors	3
Site located in a protected area or managed by private entities, with paid entrance, opening hours and/or limited number of visitors	2
Site with strong restrictions (e.g. private property, integral protection) but possible to visit with proper authorization	1
Without any possibility to visit the site	0
24. Cleaning and recreation	
Clean place, with picnic conditions and running water nearby	5
Clean place with picnic conditions	4
Clean place, but without picnic conditions	3
Punctual waste, there are not bins or code of conduct	2
Unpleasant place, but with garbage collection containers	1
Not clean. Full of rubbish spread all over the place.	0
25. Toilets	
Toilets on the visiting point	5

Less than 250 m away	4
Less than 500 m away	3
Less than 1 km away	2
More than 1 km away	1
26. Gastronomic facilities	
On the site or very nearby	5
Less than 1 km away	4
Less than 5 km away	3
Less than 10 km away	2
More than 10 km away	1
27. Proximity to recreational areas	
Recreational area or tourist attraction less than 1 km away from the site	5
Recreational area or tourist attraction less than 5 km away from the site	4
Recreational area or tourist attraction less than 10 km away from the site	3
Recreational area or tourist attraction less than 15 km away from the site	2
Recreational area or tourist attraction more than 15 km away	1

3.2. Methodology proposal for geoheritage use value assessment in Azores UGGp

The proposed methodology consists of evaluating 27 criteria, each of which can obtain a maximum score of 5 points. All criteria are intended to be evaluated at a local scale, specifically at the level of the visiting point, or otherwise at geosite level.

The analysis of results can be made for the overall results by geosite and for the individual results by criterion, in addition the categories assigned to group the criteria will allow different types of analysis. The Pereira & Pereira (2012) categories allow to make a broad analysis of the criteria's behaviour according to their typology; the Doktor *et al.* (2015) values allow for evaluations and weightings depending on the type of users who wish to benefit from the information; and the categories formulated in this report are intended to be used to prioritize strategies for improving the value of geosites.

Scoring and classification

No weighting was considered in calculating the use value of the geosites, so all criteria have the same weight in this assessment. The total scores are represented as absolute values resulting from the sum of the scores assigned to each criterion, from 0 to 135 points, and relative values presented as percentage, from 0 to 100%.

The relative value will be used to categorize each geosite, considering the same intervales defined by Esteves (2023), the categories defined for this assessment are:

- Model: geosites with a value over 80% that achieve optimal conditions and behave as exemplars.
- Sufficient: geosites with scores between 70% and 80%, having potential for improvement, deserving attention and promotion.
- Unsuitable: geosites rated below 70%, indicating they are not adequately prepared for receiving promotion or utilization.

Information record

Two tools were developed for the information record of the assessment: a form (Google Forms) and a spreadsheet (Google Sheets). Both are versatile, with user-friendly interfaces for all types of users, and offer advantages for use on different types of devices (cell phones, tablets, computers). Both can record the same type of essential information; in addition to assigning a numerical value to each criterion based on its indicators, there are fields for comments and qualitative assessments.

The form (Figure 11) also contains complementary visual tools that help answer some of the criteria, and at the end, it offers the option to upload files that complement the observations made. At the end, another advantage of this tool is the ease of managing the data entered, allowing for the creation of tables and graphs from the collected information.

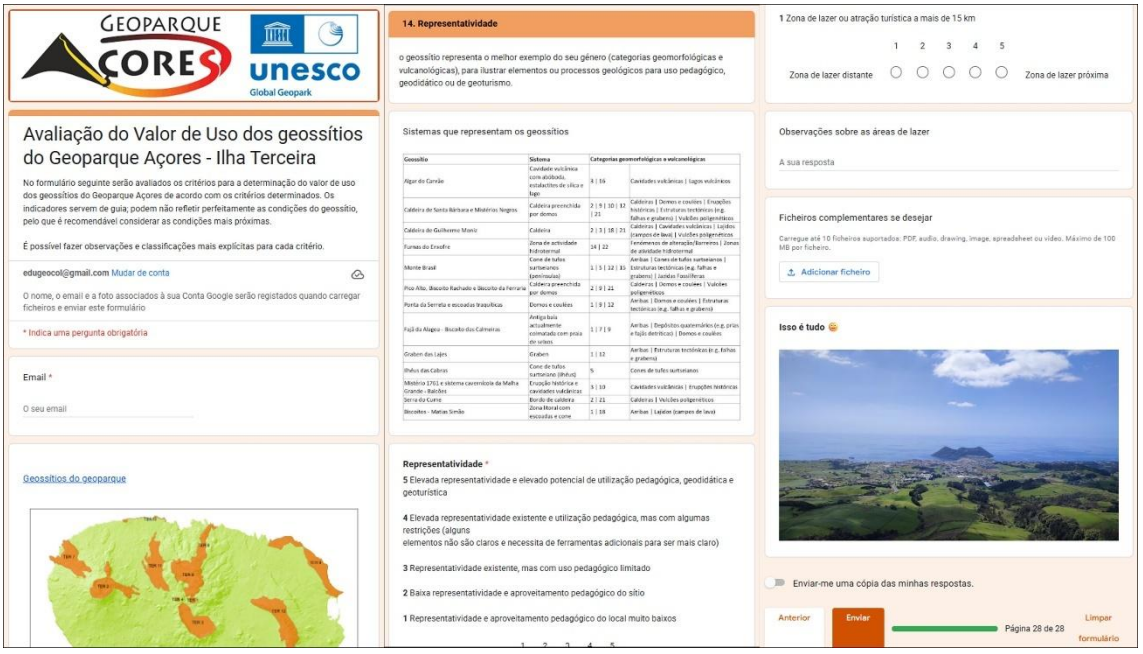
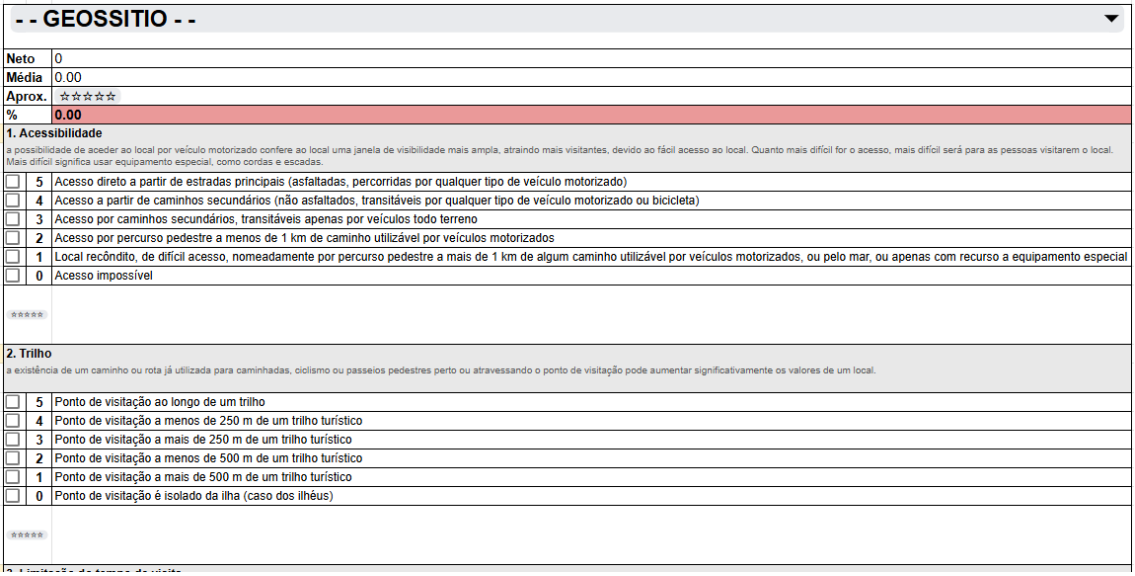


Figure 11. Preview of the form used to quantify the geoheritage use value in the present study.

Additional advantages offered by the spreadsheets (Figure 12) include the disposal of the document offline, pre-defined formulas that allow for the calculation of total values as the information is being

entered, the ability to be used by multiple evaluators simultaneously, and the disposal of a summary sheet that is pre-designed to display the final scores for all geosites.



- - GEOSSITIO - -

Neto	0
Média	0.00
Aprox.	☆☆☆☆☆
%	**0.00**

1. Acessibilidade

a possibilidade de aceder ao local por veículo motorizado confere ao local uma janela de visibilidade mais ampla, atraindo mais visitantes, devido ao fácil acesso ao local. Quanto mais difícil for o acesso, mais difícil será para as pessoas visitarem o local. Mais difícil significa usar equipamento especial, como cordas e escadas.

☐	**5**	Acesso direto a partir de estradas principais (asfaltadas, percorridas por qualquer tipo de veículo motorizado)
☐	**4**	Acesso a partir de caminhos secundários (não asfaltados, transitáveis por qualquer tipo de veículo motorizado ou bicicleta)
☐	**3**	Acesso por caminhos secundários, transitáveis apenas por veículos todo terreno
☐	**2**	Acesso por percurso pedestre a menos de 1 km de caminho utilizável por veículos motorizados
☐	**1**	Local recôndito, de difícil acesso, nomeadamente por percurso pedestre a mais de 1 km de algum caminho utilizável por veículos motorizados, ou pelo mar, ou apenas com recurso a equipamento especial
☐	**0**	Acesso impossível

☆☆☆☆☆

2. Trilho

a existência de um caminho ou rota já utilizada para caminhadas, ciclismo ou passeios pedestres perto ou atravessando o ponto de visitação pode aumentar significativamente os valores de um local.

☐	**5**	Ponto de visitação ao longo de um trilho
☐	**4**	Ponto de visitação a menos de 250 m de um trilho turístico
☐	**3**	Ponto de visitação a mais de 250 m de um trilho turístico
☐	**2**	Ponto de visitação a menos de 500 m de um trilho turístico
☐	**1**	Ponto de visitação a mais de 500 m de um trilho turístico
☐	**0**	Ponto de visitação é isolado da ilha (caso dos ilhéus)

☆☆☆☆☆

Figure 12. Preview of the spreadsheet used to quantify the geoheritage use value in the present study. It includes fields that calculate scores as the assessment is filled.

4. Activities

4.1. Quantitative assessment of the use value of Terceira Island geosites

The main activity conducted in the fieldwork stage was the quantitative assessment of the use value of the geosites located in Terceira Island. The major aim was to apply the methodology developed for Azores UGGp, and the work conducted in this island as a pilot study expected to be extended to the rest of the geopark's territory in the future.

To achieve this objective, the main visiting points of each geosite, which are the specific places where activities and uses are developed in geosites, were visited and analysed to calculate their use value. The Azores UGGp's geosites are areas and are not defined or managed as points unlike other geoparks, and within these usually large areas there are different zones with particular characteristics and aptitudes. In this report, references to the use value of a geosite concern the value of the specific location where it is used or intended for use. For the geosite TER 13 Biscoitos – Matias Simão, an especial assessment was made, given that it is a geosite composed by two areas (Biscoitos and Pico Matias Simão) with very distinctive features, both originated in different geological contexts and used independently. These two visiting points, although part of the same geosite, were assessed individually.

At the time of this study, the visitor centre of the geosite TER 1 Algar do Carvão was not in its regular condition and was not available for visits due to ongoing improvement works and the construction of a new interpretative centre. Therefore, the assessment for this geosite was done based on the conditions it will have once the new centre is operational.

Table 5. Final scores for Terceira Island geosites' use value

Geosite	Total	Average	Rating	Percentage
TER 1 Algar do Carvão	106	3,93	★★★★☆	78,52%
TER 2 Caldeira de Santa Bárbara e Mistérios Negros	101	3,74	★★★★☆	74,81%
TER 3 Caldeira de Guilherme Moniz	99	3,67	★★★★☆	73,33%
TER 4 Furnas do Enxofre	104	3,85	★★★★☆	77,04%
TER 5 Monte Brasil	119	4,41	★★★★☆	88,15%
TER 6 Pico Alto, Biscoito Rachado e Biscoito da Ferraria	93	3,44	★★★☆☆	68,89%
TER 7 Ponta da Serreta e escoadas traquíticas	108	4,00	★★★★☆	80,00%
TER 8 Fajã da Alagoa - Biscoito das Calmeiras	107	3,96	★★★★☆	79,26%
TER 9 Graben das Lajes	104	3,85	★★★★☆	77,04%
TER 10 Ilhéus das Cabras	79	2,93	★★★☆☆	58,52%
TER 11 Mistério 1761 e sistema cavernícola da Malha Grande - Balcões	89	3,30	★★★☆☆	65,93%
TER 12 Serra do Cume	98	3,63	★★★★☆	72,59%
TER 13 Biscoitos	118	4,37	★★★★☆	87,41%
TER 13 Matias Simão	101	3,74	★★★★☆	74,81%

Table 5 shows the final scores of the quantitative assessment of the use value for the geosites' visiting points. As defined in the methodology proposed in this work, the relative value was used to create categories that were assigned to classify the geosites, according to this, two geosites are *model* (>80%), acting as exemplars; nine are *sufficient* (70-80%), being appropriate for use and with improvement potential; and three are *unsuitable* (<70%) for promotion and use.

Of outstanding use vale are the geosite TER 5 Monte Brasil and the geosite TER 13 at its visiting point Biscoitos. Worth of mention are the geosites TER 7 Ponta da Serreta, TER 8 Fajã da Alagoa, and TER 1 Algar do Carvão, even if they did not get the scores required to reach the maximum level of classification, they were very close to get inside this category.

In Table 6 all the individual scores obtained for the geosites in each criterion are displayed, including the categories mentioned in the methodology (*Criteria classification*) to ease the analysis thematically.

Among all geosites the criteria *Visiting time limitation*, *Phone coverage*, *Interpretative potential*, and *Access to geological information* obtained excellent scores: All geosites are available any time at any day, only three of them have a schedule restriction, but still available all year round. There is full phone coverage on twelve visiting points, for two there is coverage more than 1 km away. The geological features are easily understandable for the general public in all geosites, only in five geosites there is a limitation of interpretative potential for kids (TER 6, TER 7, TER 10, TER 11 and TER 12). There is easy access to geological information for all geosites, including the availability in special geotouristic publications.

In general terms the accessibility is easy, in almost all cases directly by roads, but more difficult for those visiting points along pedestrian trails and for the islets by sea. Most of the points are integrated in walking trails, prove of the importance of the development of the Regional Network of Walking Trails and the impact it has in the accessibility to geosites, not only the physical access and safety but also to geological information, since this network does dissemination of the geodiversity value of the trails with information provided by the geopark, thanks to the partnership and articulated work .

As a result of the emergency services network of the island focused on three spots, Angra do Heroísmo, Praia da Vitória and Altares, the access to these services is guaranteed less than 20 km away for most of the visiting points.

Table 6. Individual scores by criteria compiled from the use value assessment for each geosite.

	Availability									Perceptiveness						Use									Logistics					
	Functional								Visual	Cognitive						Functional														
	H	H	I	H	H	H	H	H	H	S	H	S	S	S	S	I	S	I	I	I	I	I	H	I	H	H	H		
Geosites	Accessibility	Trail	Visiting time limitation	Access and natural hazards	Phone coverage	Health services	Degradation risk	Visibility	Number of viewpoints	Prominence in the landscape	Naturalness of landscape	Uniqueness	Geological diversity	Representativeness	Interpretative potential	Access to geological information	Use of other values	Local products and creations	Touristic promotion of the site	Signage	Current use of geological values	Dissemination of geoheritage value	Use limitations	Cleaning and recreation	Toilets	Gastronomic facilities	Proximity to recreational areas	Total	%
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27		
TER 1 Algar do Carvão	5	4	4	3	5	3	3	5	0	0	3	5	2	5	5	5	4	4	5	5	5	5	2	5	5	5	4	106	78.52%
TER 2 Mistérios Negros	1	5	5	2	4	4	5	5	1	4	5	4	5	5	5	5	4	1	4	4	5	3	5	3	1	2	4	101	74.81%
TER 3 Guilherme Moniz	1	5	5	3	5	4	5	5	4	5	3	3	4	5	5	4	4	1	3	3	5	3	4	3	1	2	4	99	73.33%
TER 4 Furnas do Enxofre	4	5	5	3	5	4	5	5	1	3	5	3	2	5	5	4	4	3	4	5	5	4	5	3	1	2	4	104	77.04%
TER 5 Monte Brasil	5	5	4	5	5	5	5	4	5	5	4	3	4	4	5	5	5	3	4	4	5	4	3	5	5	3	5	119	88.15%
TER 6 Biscoito Rachado	4	1	5	5	4	4	5	5	2	2	4	4	3	4	4	5	4	2	3	3	2	3	5	3	1	2	4	93	68.89%
TER 7 Ponta da Serreta	5	5	5	4	5	3	3	4	4	3	3	3	3	5	4	5	5	4	4	4	5	4	5	2	3	3	5	108	80.00%
TER 8 Fajã da Alagoa	4	5	5	4	5	4	5	5	4	3	4	3	3	5	5	4	4	2	4	5	5	4	5	3	1	2	4	107	79.26%
TER 9 Graben das Lajes	5	1	5	5	5	5	5	4	4	4	1	3	2	5	5	5	4	1	3	3	5	4	5	3	3	4	5	104	77.04%
TER 10 Ilhéus das Cabras	1	0	4	1	5	4	3	5	5	5	5	3	1	3	4	4	4	3	2	1	3	3	1	3	1	2	3	79	58.52%
TER 11 Mistério 1761	5	5	5	4	5	4	4	3	0	2	5	3	2	4	4	5	4	0	0	3	4	2	5	3	2	2	4	89	65.93%
TER 12 Serra do Cume	5	1	5	5	5	4	5	4	4	4	4	3	2	3	4	4	3	1	4	5	5	4	5	3	1	2	3	98	72.59%
TER 13 Biscoitos	5	5	5	5	5	4	5	5	3	3	3	3	2	5	5	5	4	4	4	5	5	3	5	5	5	5	5	118	87.41%
TER 13 Matias Simão	3	1	5	4	5	5	4	4	4	4	4	4	2	5	5	5	5	2	1	4	5	4	5	3	1	3	4	101	74.81%

The degradation risk is low in general terms, and the observation conditions are excellent or good. The criteria related to perceptiveness and visual values have varied behaviour, but have especially low results for the geosite TER1, which is a volcanic cave.

Overall, the criteria related to cognitive values obtained good scores, reinforcing the potential geosites have for pedagogical purposes. The geosites act as good examples of the geological systems they represent and have high interpretative potential, there is an easy access to geological information, and all (but TER 12) have at least another type of value with use and promotion, in general they have medium geodiversity, with around two or three types of geodiversity elements (scores 2, 3). As for uniqueness, ten of them show common features in this region but uncommon in other regions of the country, three outstand for having uncommon features in the whole country (including the archipelago), and one has unique features in the country and the rest of the world, which is TER 1, the island's geosite with international relevance.

Use related conditions such as the existence of local products and/or creations, the touristic promotion of the sites, the signage and the dissemination of the geoheritage value can be improved for several geosites. There is a good performance of the *Current use of geological values*, which could be considered the most important criteria in this assessment since it reflects the actual uses developed on the sites; most of the geosites are used by all types of public (guided tours, autonomous tourists and schools), geosites TER 11 (Mistério 1761 or "Mistério Novo") and TER 13 (at Pico Matias Simão) can be used by average tourists but they are specially used for educational purposes, the use of geosite TER 10 is considered as part of specialized tourist excursions since the visits to this place are carried out only by boat experiences offered by some tourist entertainment companies, and the visiting point of TER 6 is only used by the geopark for educational itineraries occasionally.

For the logistics related criteria, it was found that most of the geosites are close to other recreational areas, all of them have excellent cleaning conditions but only three of them have picnic and running water facilities, this also applies to the availability of toilets. The food services for most of the geosites is located more than five kilometres away. These are important criteria to consider when planning excursions and itineraries.

4.2. Proposals for the valorisation of geosites

The use value quantitative assessment gives numerical values for the usability of geosites, allowing to categorize and compare them with one another, but this data needs to be analysed in context. A qualitative

analysis of each geosite is then conducted based on the data collected during the assessment, and suggestions are made for improving their value, if necessary.

It is crucial to identify and choose visiting points for the geosites when planning future use value assessments, these locations will be the evaluated ones, not the geosites as a whole (not in all criteria at least). This selection of visiting points can be applied also after performing the assessments since its results can show that a previous location is not suitable for use, which is the case of geosite TER 6, and a proposal from the present work is to change the main visiting point for this geosite.

TER 1 Algar do Carvão

With a use value of 78.52% (sufficient). The Algar do Carvão is the geosite of international relevance of Terceira Island. When this assessment was performed, the new interpretative centre CAVE – "Centro Açoriano de Vulcano-Espeleologia do Algar do Carvão" (Azorean Volcano-Speleology Centre of Algar do Carvão) was under construction, but thanks to ''Os Montanheiros'' Association, partner and delegate of the Azores UGGp in Terceira island, and organization in charge of this geosite's management, a visit could be arranged with access not only to the volcanic pit but also to the blueprints of the new centre. This geosite was assessed under the conditions it will have once the works are completed.

Figure 13. Parking lot and construction works of the new CAVE interpretative centre (Photography by Salomé Meneses).

For availability criteria, the centre is of direct access by the José Ataíde da Câmara road or Algar do Carvão road until the parking lot (Figure 13), and less than 250 m away from the walking trail PRC10 TER Algar do Carvão - Furnas do Enxofre. The site is available the entire year in a specific schedule. In practical terms the access is very safe and although there are some dangers, there is proper infrastructure and signage. It is considered that there is a possibility of degradation of the secondary geological elements of the geosite given the high number of visitors the place receives, but there are geoconservation efforts to avoid that (Figure 14).

Figure 14. Acrylic structure intended to protect the lava structures from direct contact, but allowing to see them at the same time.

For perceptiveness values, it receives the lowest scores, since it is a cave, it does not have prominence in the landscape, and it cannot be seen from viewpoints. That contrasts with its uniqueness, and the fact that it is one of, if not the most iconic place of the island. It also has great representativeness and interpretative potential.

Figure 15. Windbreaker coat part of the Algar do Carvão visitor centre's merchandising.

In the use related criteria, it has natural values with promotion and use, with several related products from the centre's gift shop (Figure 15), and a signature product which is a wine "cooled" inside the lake at the bottom of the pit. It is frequently used in tourism campaigns, with high dissemination of its geoheritage values, used by every kind of public. There are signs all over the island indicating the way there, and it has a sign identifying it as a geosite (Figure 16). The schedule and entry payment are the only restrictions for its use.

Figure 16. Different signs indicating the way to Algar do Carvão, giving information about its values, and identifying it as a geosite.

For logistics, it acts as exemplar, having restrooms, a bar, and a terrace on site. It is by itself a tourist attraction remarkably close to Furnas do Enxofre, another geosite and attraction.

Clearly the construction of the new interpretative centre is a big effort that will be effective in the valorisation of the geosite. All the improvable criteria already have high scores, being the only one with opportunity of enhancement the time limitation in visits, but it is unrealistic to allow visits without control every day. It would require big efforts to increase the value of the site; the suggestion is to attempt to improve hard changeable criteria, a prolongation of the trail until the visiting centre and a reduction in the degradation risk. Theoretically the use value could increase with the reduction of use limitations, but this would go against conservation strategies.

TER 2 Caldeira de Santa Bárbara e Mistérios Negros

With a use value of 74.81% (sufficient). This geosite is integrated within a Nature Reserve, with high limitations of use, having only two possible visiting points, the Serra de Santa Bárbara viewpoint, and the Mistérios Negros historical eruption domes. The viewpoint is located at the highest point of the island, with a geopark's interpretative panel and even an interpretative centre of the Natural Park in the area, with an exceptional panoramic of the south of the island but with a big limitation: it lacks a perspective inwards the caldera, meaning there is actually no visual access to the geosite from this point. On the other hand, the Mistérios Negros, a set of domes product of the 1761 historical eruption, are integrated in a walking trail of the same name, in fact the first trail of Terceira to be classified into the regional network, which is why this was selected as the area to be assessed.

Figure 17. One of the perspectives to the Mistérios Negros domes along the walking trail PRC01 TER.

For availability criteria, the domes are accessible only by the walking trails PRC01 TER Mistérios Negros and GR01 TER Grande rota do Oeste on a route of 1.5 km from the beginning of the trail until the first outcrops, this trail has some risks in terms of access, the conditions of the terrain make it to be classified as a route with high difficulty. Other limitations are the phone coverage, which is not constant along the trail, and the lack of viewpoints, although there are several points along the trail with excellent perspectives of the domes, there are not official viewpoints (Figure 17). There is no deterioration risk of the geological elements, and they have great exposure with excellent observation conditions.

Every perceptiveness criterion obtained good scores, the lack of vegetation and black colour of the domes grant them prominence in the landscape and a special appealing, with pristine natural conditions, the uniqueness of the features at national level, the high geodiversity, representativeness and interpretative potential, make of this site an excellent example of the features it represents (Figure 18).

Figure 18. The outcrops of the Mistérios Negros along the trail show ideal examples of *crumble breccia* structures, typical in domes.

The strengths found in the criteria related with use are the easy access to geological information, the use and promotion of natural values, its touristic promotion, good signage, the use by all type of public and the lack of use limitations, mainly because it is one of the most relevant trails on the island (Figure 19). Less favourable scores were obtained because of the absence of geoheritage dissemination on site and the lack of products that promote the place.

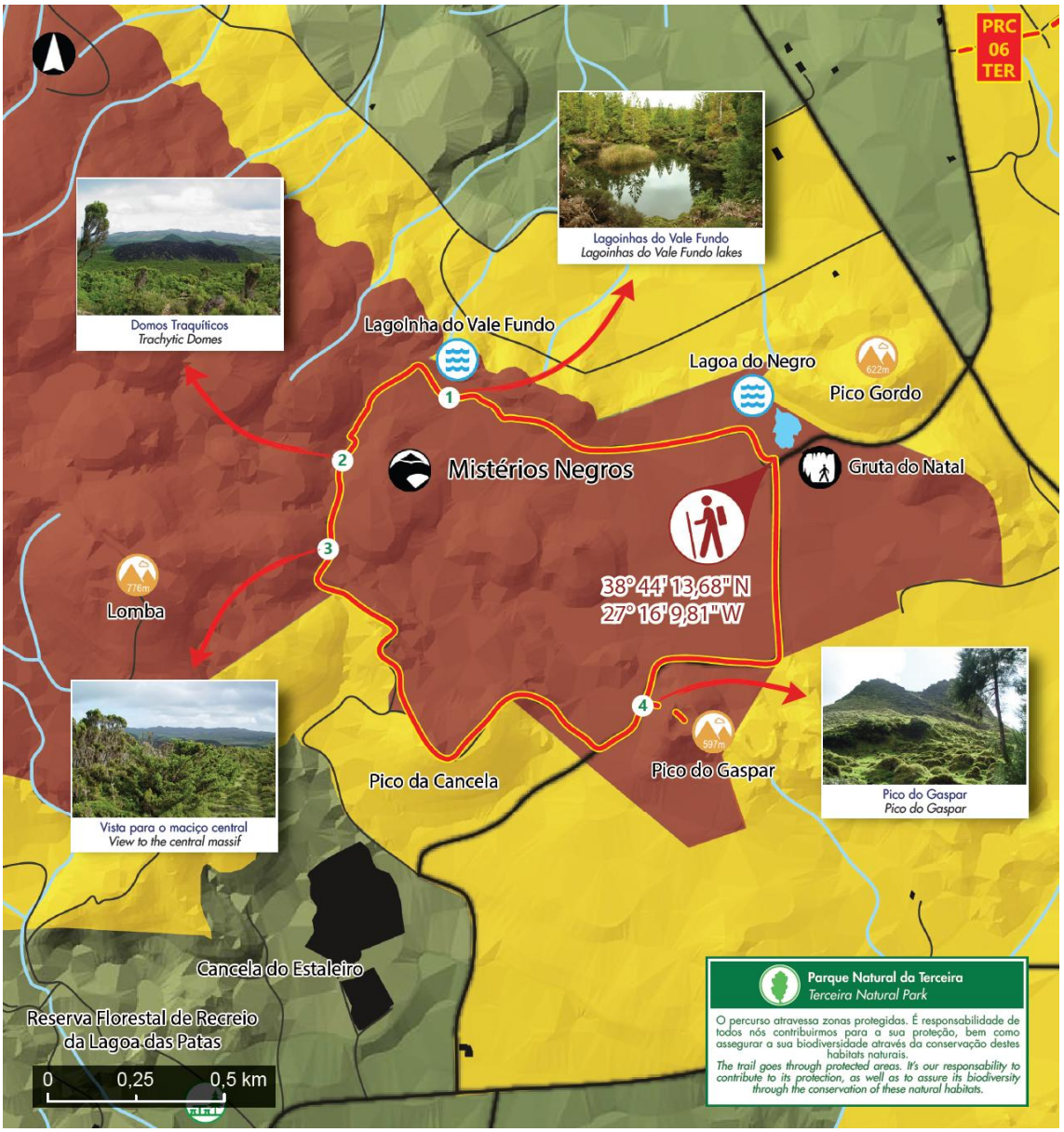


Figure 19. Map found in the leaflet and panel of the trail PRC01 TER Mistérios Negros, showing the Mistérios Negros as a geosite and highlighting them as a site of interest (Azores Trails website https://trails.visitazores.com/en/trails-azores/terceira/misterios-negros)

For logistics, the site is very clean, and recreational areas are found less than 5 km away, the Gruta do Natal a lava tube and very visited place is located at the beginning of the trail. Some difficulties are found for the access to toilets and gastronomy facilities.

Some suggestions for the valorisation of this site can be given at different levels. For improvable criteria, like related products and creations, some campaigns can be launched for the development of creations related to art, photography and souvenirs, or to gastronomy with the creation of biscuits or cakes inspired by the domes shape and structure, and the dissemination of geological values including interpretative material on site if possible. For hardly changeable criteria that might require bigger efforts, the

establishment of official viewpoints would give higher visibility to the geological features, along the trail at least one viewpoint can be set and duly signed.

Another proposal, on the long term and for the entire geosite, is the creation of a "virtual tour" to the caldera of Serra de Santa Bárbara volcano; this site is of exceptional beauty and high representativeness of a caldera filled with domes, and since there are strong use limitations for the Nature Reserve, a virtual tool of high quality can be a successful strategy for the dissemination of the geological values of the geosite.

TER 3 Caldeira de Guilherme Moniz

With a use value of 73.33% (sufficient). To assess the use value of this geosite the official walking trail PRC07 TER Passagem das Bestas was chosen as main visiting point, since it has two viewpoints with privilege perspectives into the caldera of Guilherme Moniz volcano.

For availability criteria, the viewpoints are accessible along the walking trail after a walk of 2.1 km from the parking lot (Figure 20), without any temporal restriction and full phone coverage. There is no risk of degradation of the geological elements. Apart from the two viewpoints located on the trail there is visual access from other two viewpoints, on the road EN5-2A and the walking trail PRC10 TER.

Figure 20. Trail sign indicating the way to one of the viewpoints to the caldera of Guilherme Moniz volcano.

In perceptiveness criteria, it is a prominent site with top representativeness and interpretative potential, but it presents features common in this region and the landscape inside the caldera is dominated by "cerrados" for raising cattle, and these factors might lower the attractiveness of the site (Figure 21). In

terms of these criteria the place is more suitable to be used for pedagogical purposes although it has high scenic value.

Figure 21. Perspective of the bottom of Guilherme Moniz's caldera with *cerrados*.

Figure 22. Panel located in the parking lot at the beginning of the trail PRC 07, with descriptions of the geological values of the site and highlighting it as a geosite on the map.

In terms of use criteria the value of the site has several opportunities for improvement; the broader access to geological information is restricted to the geopark's site and the site Angrosfera, some related products and creations can be developed, the touristic promotion of the site could be included frequently in national campaigns, more signs about the geosite could be placed in other parts of the island since they are restricted to the area around the caldera, and although there is dissemination of the geoheritage values in the panel at the beginning of the trail (Figure 22) some interpretive equipment could be developed to be placed locally at one of the viewpoints.

In logistics criteria the site does not perform well, considering the access and distance to restaurants and toilets. These criteria are hardly changeable, so the valorisation efforts should focus on the improvable use criteria mentioned above. This location already has great values and potential to be used; it is only essential to increase its promotion.

TER 4 Furnas do Enxofre

With a use value of 77.04% (sufficient). The fumarolic field is surrounded by an interpretative circuit that is in turn integrated into the PRC10 TER Algar do Carvão - Furnas do Enxofre walking trail (Figure 23). This circuit is a model to follow in terms of access and dissemination of geological knowledge.

Overall, the availability criteria obtained good scores. The circuit is equipped with fences that limit the path, and wooden platforms ease the transit, but some segments of the trail are susceptible to puddles (Figure 24). The lowest score was obtained by the number of viewpoints, although the steaming grounds are observable along the circuit, apart from it they are only visible from a point in the surrounding walking trail PRC10 TER, but it is not an official viewpoint.

For perceptiveness values, it obtained perfect scores for the naturalness of the landscape, its representativeness and interpretative potential. But the site has low geodiversity and prominence in the landscape and possesses commonly found characteristics in the region. These are *static* criteria, so there is not an improvement opportunity for them.

Figure 23. Parking lot at the beginning of the Furnas do Enxofre Interpretative Circuit.

Figure 24. Wooden infrastructure of the Interpretative Circuit. (Left) Fences and walking platforms. (Right) Paths with puddles.

In general, the use related criteria performed well but they are capable of being improved. The place is usually used in touristic national campaigns; it could be promoted more frequently even with an international reach. The access to geological information for large and non-specialized audiences through especial geotouristic guides is an opportunity. The greatest strength of this visiting point is the dissemination of geoheritage value and other related values (Figure 25), the interpretative circuit developed here is an exemplar compatible with geoconservation strategies.

Figure 25. Specific panel about geodiversity at the spot with greater exposure of the elements of Furnas do Enxofre.

For logistics, this place faces difficulties with the distance to gastronomic facilities and toiles. The closest recreational areas are the Tentadero da Administração Florestal and Algar do Carvão more than 2 km away.

Other improvement measures can be done in hardly changeable criteria, requiring infrastructure interventions; for the lack of viewpoints at least one viewpoint can be recognized and classified on the trail PRC10, and for the access safety in the segments of the circuit that are susceptible to puddles, some works can be developed. Weeks after this assessment was applied, the circuit was partially closed due maintenance works on the path, hopefully to adjust the safety conditions, leading to the valorisation of the place.

TER 5 Monte Brasil

With a use value of 88.15% (model). The Monte Brasil, the emblematic peninsular volcano next to the city and UNESCO World Heritage Site of Angra do Heroísmo, is a popular recreational spot for locals and visitors alike. It has four peaks and six viewpoints in total, the Pico das Cruzinhas viewpoint was selected to make this assessment since it already has an interpretative panel of the geopark (Figure 26), and it is the most visited viewpoint.

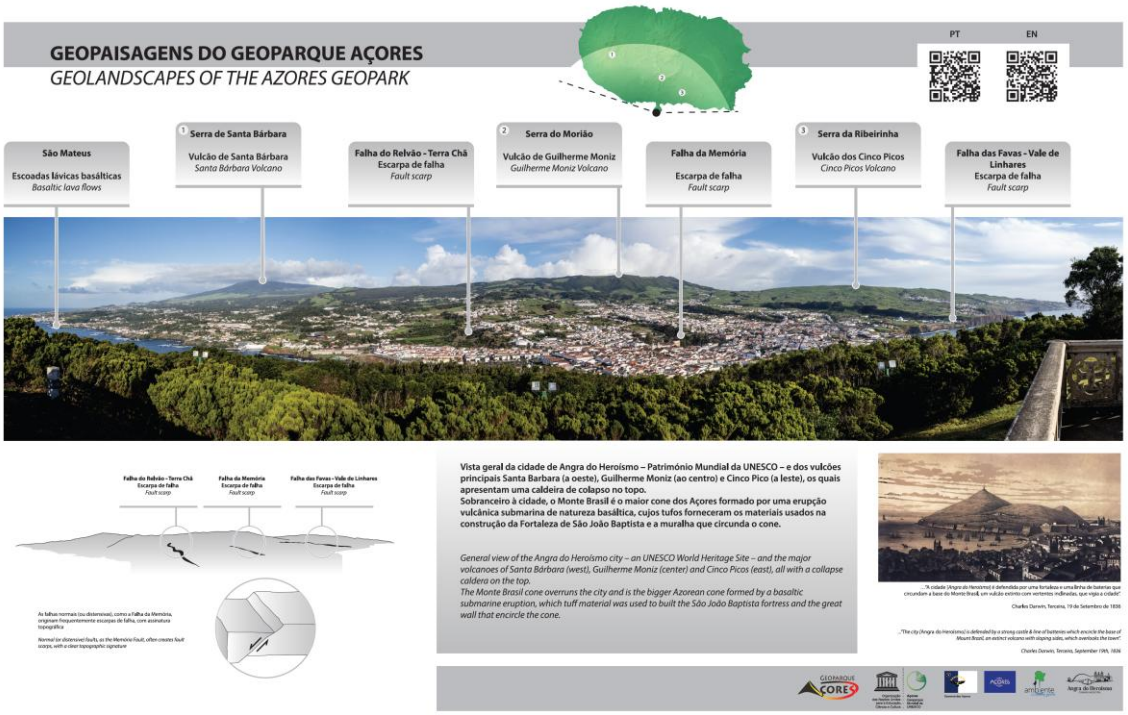


Figure 26. Interpretative panel of the geolandscapes of the south of Terceira Island, located at Pico das Cruzinhas viewpoint.

Being a model geosite for its use value, this geosite obtained good scores overall and no criterion was scored under 3. The best values of this site are the availability criteria; the viewpoint can be accessed directly by the main road and the walking trail PRC 04 TER, with a parking lot, the access is safe for all types of visitors, having infrastructure for users with limited mobility (Figure 27), total phone coverage, and the two emergency services of Angra do Heroísmo closer than 5 km away. There are no degradation risks for the geological features. With several viewpoints on the geosite itself, it can be seen also from several others in the south of the island. The only limitation is the visiting time restrictions; the site is available only in a specific time schedule. The visibility can be an issue, the geological elements of this volcano are well exposed and can be seen from different points, but it is precisely at Pico das Cruzinhas viewpoint where they cannot be seen entirely, some displacement is needed to be able to see the interior of the cone.

Since it is an elevated peninsula, it stands out greatly in the landscape. The interpretative potential of the geosite is high, its characteristics as a surtseyan tuff cone are easily understandable in locations like Alto da Caldeira and Pico do Facho, but not so much from Pico das Cruzinhas. There is access to geological information from diverse sources. It is one of the few geosites on the island with use and promotion of both natural and cultural values. This volcano is visited and used by all types of users.

Figure 27. Ramp for users with reduced mobility at Pico das Cruzinhas viewpoint in Monte Brasil.

The criteria related to logistics are highlighted. There are recreational areas in several parts of the geosite; very clean, with picnic conditions, running water and toilets (Figure 28). Its privileged location next to Angra do Heroísmo, makes the access to other recreational areas and restaurants very easy.

Figure 28. Picnic facilities in Monte Brasil with perfect cleaning conditions, running water and proper bins for garbage.

An issue with the dissemination of the geoheritage value of this geosite was identified; the Pico das Cruzinhas viewpoint has visual access to the southern part of the island, but to see the interior of the cone some displacement is needed, in the same way the interpretative panel, although with mention to

Monte Brasil, is dedicated mostly to this landscape (Figure 26). Having another formal visiting point with interpretative material at the Alto da Caldeira viewpoint would be ideal, it has a great perspective of the crater and even an obsolete panel (not from the geopark) is placed there (Figure 29), but actually implementing this measure would require immense efforts, not only investment in interpretive infrastructure but also adding another point to the monitoring carried out by Nature Rangers. An alternative proposal is to use the existing panel at Pico das Cruzinhas and adding some new information, perhaps just a phrase inviting users to "go see the crater in the central part of the mount!".

Figure 29. Alto da Caldeira viewpoint at Monte Brasil with view to the volcano's crater.

Another proposal is the creation of an interpretative material with diagrams about the origin process and evolution of this surtseyan volcano, showing its eruptive stages "step by step", mentioning the value of its paleontological sites and heritage, and the effect of this volcano on the very existence of the city of Angra do Heroísmo. This material could be placed in one of the viewpoints within the city like the Corpo Santo viewpoint or Jardim dos Corte-Reais (Figure 30), or at the Volcanospeleologic Museum, island delegation of the geopark in Terceira, or the Science Centre of Angra do Heroísmo, partner of the geopark. Having a material of this type in the city, apart from accomplishing a dissemination objective, can increase the sense of belonging and appropriation with this landscape by Angra and Terceira people.

Figure 30. Viewpoint to Monte Brasil at Jardim dos Corte-Reais, site already used by the geopark on its (Geo)Urban Routes.

TER 6 Pico Alto, Biscoito Rachado e Biscoito da Ferraria

With a use value of 68.89% (unsuitable). This geosite is included in a Nature Reserve and has big limitations of use. The location assessed was the Biscoito Rachado; this place was chosen because the geopark has a wooden pole with QR code in this location (Figure 31), as part of the Geodiversity and Geosites Route of the island.

Figure 31. General view of Biscoito Rachado site and detail of the wooden pole with QR code.

For the availability criteria it is in general well qualified, it only had low scores in the criteria related with trails and viewpoints, there are no walking trails including this point, the closest one (PRC10 TER) is 1.9 km away, and the geosite in general can be seen only from two viewpoints at the trail PRC06 TER Rocha do Chambre.

For perceptiveness values, the representativeness and interpretative potential of the site are high for volcanic domes, but there are limitations when trying to explain a caldera filled with domes. Also, the prominence is low, it is slightly different and difficult to differentiate from the surroundings.

Overall, the use related criteria had a bad performance, with special mention to the *Current use of geological values*, the site is part of the Geodiversity and Geosites Route of Terceira Island, but it is rarely used by the geopark in its educational itineraries, only occasionally when there is a possibility of doing a two-day route, the point is relatively distant from other geosites. In logistics, it is a clean site, but the access to toilets and food offer is limited.

In this study two alternatives are proposed for the proper use of this geosite: i) since the lower scores were obtained by improvable criteria (*Local products and creations, Touristic promotion of the site, Signage, Current use of geological values, Dissemination of geoheritage value*) some efforts can be made for the valorisation of this site as the main visiting point, mostly by increasing its promotion, it has not been an attractive place to visit but there is potential for use and the availability is guaranteed already; ii) to change the visiting point to the walking trail PRC06 TER Rocha do Chambre, given it is one of the most popular and recommended trails and it includes two viewpoints with a privileged view of the caldera walls.

Since this geosite faces similar conditions to Santa Bárbara volcano and as part of a Nature Reserve has high use restrictions, the same suggestion of the development of a virtual tool is made for this site. A "virtual tour" would do a good dissemination of the geoheritage value.

TER 7 Ponta da Serreta e escoadas traquíticas

With a use value of 80.00% (sufficient). The Ponta da Serreta or Ponta do Queimado is a popular spot, frequently visited and promoted by the local authorities as a fishing and leisure area, it has one of the wooden poles of the geopark and interpretative material about the geoheritage value of the site (Figure 32).

Figure 32. Visiting point of Ponta da Serreta with wooden pole with QR code.

For availability criteria, the access is direct by a main street and by the walking trail GR01TER Grande Rota do Oeste, with a route that goes through the entire geosite passing by this and other visiting points. There are two additional trails included in the geosite: Rocha do Peneireiro trail and PRC03 TER Serreta. It is worth drawing attention to the risk of degradation, there is a possibility of deterioration of secondary geological elements (Figure 33), it was found deposition of waste by visitors, presence of perforation holes in the outcrops, and the cement interventions can affect some elements.

Figure 33. Punctual waste and perforation holes in the rock at Ponta da Serreta.

For perceptiveness criteria the scores were low in general, but the site has high representativeness and good interpretative potential, it is a perfect example of a trachytic lava flow (coulée), showing the typical morphologies and structures of this type of volcanism (acid and effusive).

This geosite stands for its good scores in the use related criteria, especially for the access of geological information, having both natural and cultural values, the use of the geological values by all kinds of users, and not having use limitations.

For logistics, it had a bad performance, except for the easy access to other recreational areas. The bad cleaning conditions had a big impact on this assessment.

Overall, this geosite was very close to be a model for its use value, only one additional point would be necessary to accomplish that. So, there is no need of big efforts to improve the value of the site; the priority should be to assure the good cleaning conditions of the place, since the current state is negatively affecting two criteria. Apart from that, an additional measure could be to include the site more frequently in touristic campaigns of broader reach.

A proposal for this site, given its high representativeness and interpretative potential, is the development of didactic tools to explain processes of higher complexity in these coulées, like the presence of obsidian in the external parts and how it is "included" in the middle of the main rock body.

TER 8 Fajã da Alagoa - Biscoito das Calmeiras

Figure 34. Biscoito das Calmeiras/Colmeias, coulée showing a crumble breccia and columnar jointing.

With a use value of 79.26% (sufficient). The Fajã da Alagoa or Alagoa da Fajãzinha is a popular area known for its outstanding views and used mainly by the walking trail PR02 TER Baías da Agualva. There are two important features here, the Biscoito das Calmeiras (Biscoito das Colmeias), a coulée, and the Alagoa da Fajãzinha, a detritic *fajã*.

All availability criteria obtained good scores, the access can be direct by car or by the walking trail, there are some restrictions for people with limited mobility. The elements have great exposure and are visible, the viewpoints offer great observation conditions.

For perceptive values, the outstanding criteria were the representativeness and the interpretative potential, the coulée shows the typical crumble breccia structure and displays columnar jointing (Figure 34), and the fajã, an ancient sea cliff and bay filled with sediments.

In the use related criteria, the *Signage*, *Current use of geological values* and *Use limitations* obtained perfect scores; the place is signed as geosite, it is used by every type of users, and it has no restrictions in use. Improvements can be made for the creation of local products, and the replacement of the interpretative panel (Figure 35).

Figure 35. Deteriorated panel about the values of the Fajã da Alagoa.

For logistics, most of the facilities are located far from the visiting area. The newly adapted recreational area of Mata dos Outeiros offers picnic conditions with running water and toilets, 1,3 km away.

This is an exceptional place with special appeal and clarity of its geological features, and these characteristics should be taken advantage of. At the viewpoint of the Alagoa (Figure 36) an interpretative

panel or infrastructure about the evolution of the landscape and the process that led to the creation of the fajã could be placed, but since applying this type of measure could affect the aesthetic values of this viewpoint, an effort to develop a virtual interpretative tool can be done, perhaps an augmented reality tool that can be used on the site.

Figure 36. Access to the Alagoa viewpoint.

The fact that the coulée of Biscoito das Calmeiras has columnar jointing can be used also to develop didactic materials explaining the formation of this type of features, and their connection with other hexagonal structures in nature.

TER 9 Graben das Lajes

With a use value of 77.04% (sufficient). This geosite along the Serra do Facho or Serra de Santiago and the Caldeira das Lajes, has three points of interest and use by the geopark. The viewpoint located at the Serra do Facho right next to the city of Praia da Vitória, known as Miradouro da Serra do Facho, was selected to be assessed as it is a well visited place and the geopark has an interpretative panel in there (Figure 37). It is worth of mention the placement of poles with QR codes by the geopark at the other two visiting points, Humberto Delgado viewpoint and Caldeira das Lajes.

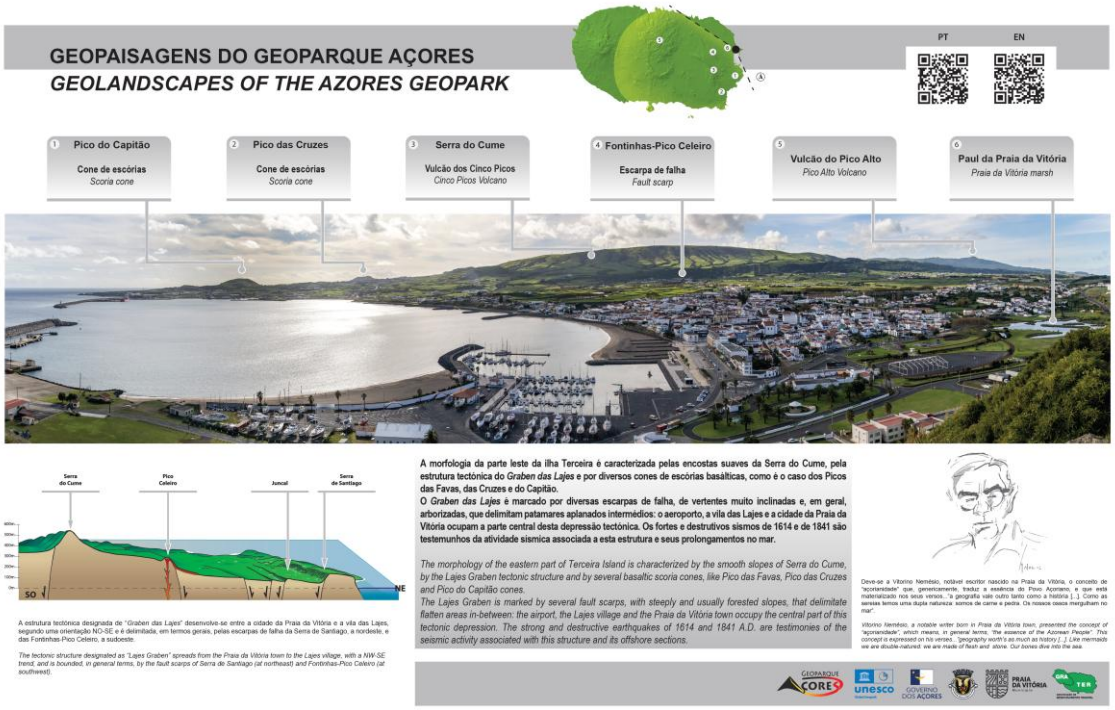


Figure 37. Interpretative panel located at Miradouro da Serra do Facho with information about the landscape and the graben.

This location obtained perfect scores in almost all the availability criteria, the access is assured by a road that gets until a parking lot at the viewpoint, safe for all types of users and very close to the emergency services of Praia da Vitória. There is not a walking trail related to this geosite, the closest one is the trail of the Beiras located 5 km away.

Figure 38. Perspective from Miradouro da Serra do Facho over the city of Praia da Vitória and the Lajes graben.

For perceptiveness values, the lowest score was obtained by the naturalness of the landscape since the viewpoint is above the city and most of its perspective is of the urban area (Figure 38). But highlighting the representativeness and interpretative potential of this place, the integrity and magnitude of the elements make this to be an excellent representation for a graben structure.

In the use criteria, it is possible to make improvements about the products and creations related to the geosite, the touristic promotion should not be limited to the regional campaigns, and there could be more signs about this geosite or the specific viewpoint.

Considering the logistics criteria it is a proper site to be used given its proximity to Praia da Vitória, with easy access to restaurants, toilets and recreational areas like the beaches and the Paul.

This geosite serves as an excellent didactic model of a graben, with great accessibility, all of which should be taken advantage of. It is not far from being a model geosite, and the efforts of valorisation should focus on the improvable criteria mentioned above. If more relevance is given to the city of Praia da Vitória it will have a direct impact on the use of this geosite.

TER 10 Ilhéus das Cabras

Figure 39. Perspective of the islets from the recreational and bathing zone of Fajã do Ficher (Serretinha).

With a use value of 58.52% (unsuitable). This surtseyan cone, today two islets, has clear issues with its availability, the closest access is possible only by boat and it is a protected area with no possibility for development of uses on the islets land. There were three alternatives for the assessment of this geosite;

to attempt to do it properly on the islets (as closest as possible), to assess the Cruz do Canario viewpoint which is the place used by the geopark for the monitoring of this geosite, or to assess the bathing zone of Fajã do Ficher (Figure 39) at Serretinha and its viewpoint with an interpretative panel (Figure 40).

Figure 40. Interpretative panel of the Ilhéus das Cabras including information about the geoheritage value.

Since boat trips to the islets are promoted as an experience promoted by tourist entertainment companies, some use is given to the geosite. That is why, with the support of OceanEmotion, partner of the geopark, a visit to the islets could be carried out guaranteeing the assessment directly on the geosite (Figure 41).

Figure 41. Visit by boat to the Ilhéus das Cabras, on an "eight-shape" route passing through the cone and by its slopes.

All the criteria based on the *in-situ* characteristics were evaluated based on the usual experience offered to tourists by OceanEmotion and other companies, special experiences can be offered as part of educational and partnership programs of the geopark. The islets are close to 1 km away from the coast of Terceira, but the access is by boat from Angra marina, located more than 6 km away. The time limitation is given by the schedules each company has for the visits.

In terms of safety, some conditions must be guaranteed for the development of activities, like the use of life jackets and good weather conditions. There is total phone coverage the whole way there. To use the emergency services of Angra it is necessary to get to the marina.

There is a possibility of degradation of secondary geological elements due the high marine erosion, but at the same time this erosion gives great exposure and excellent observation conditions of the elements of the cone and is responsible for the construction of features like marine caves (Figure 42). There are important natural values with use and promotion, the naturalness of the landscape is almost pristine.

Figure 42. Cliff of the interior of Ilhéus das Cabras cone displaying clearly stratified surtseyan tuffs, interbedded lithics and marine caves.

Of course, it is not possible to develop interpretative materials on site, but the dissemination of the geoheritage and other values of the geosite is made by the guides, they are qualified marine biologists with knowledge about the geological processes that led to the creation of the islets, and they show several features of the cone during the experience.

Currently this geosite is unsuitable for use given its especial conditions of access and land ownership, but improvements can be made in few aspects. A bigger and responsible touristic promotion of the site can be developed, through campaigns of broader reach and the dissemination of its geoheritage value.

It is proposed the creation of a didactic material to be available for the companies that offer the boat experience, prioritizing the geopark's partner. OceanEmotion already uses graphic cards and posters of the islets' biodiversity (Figure 43), providing them with visual materials about the origin, processes and features of the geosite is a great opportunity.

Figure 43. Visual material used by OceanEmotion for the Ilhéus das Cabras experience (OceanEmotion https://www.oceanemotion.pt/ilheus-das-cabras)

The partnership with this company should be strengthened and communication should be frequent. It would be beneficial to have statistical data on the frequency of visits and the number of users who use this experience. Another idea to promote the use of the geological values is the officialization of an inter-partners agreement between OceanEmotion and Os Montanheiros to promote a joint tour package "Algar do Carvão + Ilhéus das Cabras"; Os Montanheiros already offer a *combo ticket* to visit the two caves Algar do Carvão and Gruta do Natal at a lower price, something similar could be developed to visit "the only visitable interior of a volcano in the world" and "the volcano cut in half".

TER 11 Mistério 1761 e sistema cavernícola da Malha Grande - Balcões

With a use value of 65.93% (unsuitable). This geosite is composed of two main features: the "Mistério de 1761" or "Mistério Novo", names given to the lavas product of the 1761 historical eruptive event; and the volcanic cave system of Malha Grande – Balcões. For the management strategies of this geosite, the geopark considers it is not beneficial to make a touristic promotion of the caves, since they are fragile systems and there are already two volcanic caves on the island destined and adapted for use; the priority should be the conservation of these elements. And for the features related to the historical eruption, the geopark proposes the creation of the Mistério Novo educational route, so this is the feature that was assessed.

For the availability criteria the site obtained outstanding results, the access is direct by a main road and the beginning of the walking trails PRC06 TER Rocha do Chambre and PR09 TER Malha Grande – Biscoitos. It is very safe, but it is not entirely proper to be accessed by people with reduced mobility. The biggest issue on this matter is the lack of viewpoints, there are not recognized viewpoints from where this site can be seen.

For the perceptiveness values, the naturalness of the landscape, its representativeness and interpretative potential perform well, the elements of the historical eruption are preserved enough to be used for pedagogical use (Figure 44).

Figure 44. Scoria deposits formed during the 1761 eruptive event being presented during a capacity building activity for local teachers.

In the use related criteria, there is easy access to geological information and the site has no restrictions for its use, it is use frequently used as part of the geopark's educational programs (Figure 45) and partially by tourists through the trails PRC06 TER and PR09 TER. It has use and promotion of ecological values, having the possibility of observing the starting sequence of plant population in lava flows.

Figure 45. Educational itinerary developed on the site (EMME program visit).

Figure 46. Starting point of PRC06 TER and PR09 TER walking trails, wooden pole with QR code is placed here.

The place is signed only by a wooden pole of the geopark located at the beginning of the trails (Figure 46). The physical dissemination of geoheritage is restricted to the presence of a model at the

Volcanoespeleologic Museum, and references at interpretative centres located in other islands. The lowest scores were obtained for the nonexistence of related products and creations and the lack of touristic promotion.

The suggestion is to focus the valorisation strategies into the educational use of the geosite by the proposed route. The initial step is to formalize an agreement with the Forest Service in charge of the area for adapting the rout infrastructure. This route is partially integrated in the PRC06 TER and PR09 TER walking trails, the part that is not included can be used as an extension of these trails once it is established and fitting for use, if this happens, some dissemination of the geoheritage values can be included in the leaflets and panels of these trails.

Another proposal is to implement an annual commemorative visit and itinerary for the 1761 eruption. This measure could greatly increase the use value through an original local creation completely dependent on the site.

TER 12 Serra do Cume

With a use value of 72.59% (sufficient). Serra do Cume is part of what remains from the Cinco Picos caldera rim, the widest caldera in the Azores, and it is an emblematic place of Terceira Island, its viewpoint is a "mandatory" stop for visitors. The most frequent images in postcards of the island, apart from Angra do Heroísmo, are from the views of this mountain.

Figure 47. Serra do Cume viewpoint platform, access directly by car and safe for users with reduce mobility.

For availability criteria, it is of direct and safe access for all visitors (Figure 47), without restrictions or risks of degradation, the visibility is good, but it is highly dependent on weather conditions. The weakest attribute is the lack of a walking trail that integrates this geosite.

For perceptiveness values, the Serra do Cume outstands for its prominence, and although the landscape is not of a natural area, the rural landscape offered by the "cerrados" is very appealing for visitors. There is representativeness for a caldera system, but it has some limitations for pedagogical use, given the dimensions and eroded state of the rim it can be difficult for some users to identify it as a caldera, because it does not show the typical expected "complete" geometry of one.

The strengths in the use related criteria are the use of the geological values by all types of users in guided tours or as autonomous tourists, and the signage of the place as a geosite and presence of an interpretative panel of the geopark at the main viewpoint (Figure 48). Some constraints for its use are the use of other values and the low existence of related products. For logistics, given the location of the viewpoint the access to other facilities is not easy.

Figure 48. Interpretative panel at Serra do Cume about the geolandscapes of the island.

Most of the improvable criteria already have good scores, so the valorisation of the site would require big efforts if desired. Some suggestions for this site include to encourage the creation of local products inspired by this place, since it is already known for its "patchwork" landscape and the island has a large tradition on patchwork confectionery and creations, some arts and crafts event, exposition or contest can be developed, linking the traditions of this island with the geoheritage values of this geosite. For a long-

term effort, the development of a walking trail passing through the geosite would increase its value immensely.

TER 13 Biscoitos

With a use value of 87.41% (model). The parish of Biscoitos is an emblematic spot on the island, famous for its natural pools and landscape of vineyard "curraletas" (Figure 49), both strongly related to the basaltic lava flow that reached this area coming from the centre of the island.

Figure 49. Vineyard *curraletas* with walls made of basalt, iconic elements of the geocultural landscape of Biscoitos (Protected Landscape Area of Vinhas dos Biscoitos).

The scores obtained for the availability criteria were almost perfect, the Biscoitos natural pools are accessible directly by car until a big parking lot, available every day, without risks and safe for all visitors providing proper access infrastructure (Figure 50). The geological elements are well exposed. The site is integrated in the walking trails PR09 TER Malha Grande - Biscoitos and Vinhas dos Biscoitos Route.

The perceptiveness criteria were the lowest scored overall, the geological diversity is especially low, having only two geomorphological and volcanological categories. It can be clearly distinguished from the surroundings, but since it is a basaltic lava flow it is not prominent in the landscape. In terms of the naturalness of the landscape, the natural pools have significant interventions in infrastructure. It stands out for its representativeness, being a great and ideal example of "mega-ropy lavas", giving it a high interpretative potential.

Figure 50. Access to the natural pools right after restaurants and stores in the parking lot, with proper infrastructure and signage, including bins, showers and water fountains.

In the use related criteria, the access to geological information is broad, it has use and promotion of cultural values, the vineyards make up the Protected Landscape Area of Vinhas dos Biscoitos (Figure 49), it is signed as geosite, it is used frequently in guided tours and by autonomous tourists without restrictions. The geosite has a signature geoproduct, the Magma wine produced by the Adega Cooperativa dos Biscoitos, a partner of the geopark (Figure 51).

Figure 51. Verdelho grape wine Magma, a geoproduct developed at Biscoitos geosite.

This geosite is the only one with a perfect score in all logistics criteria, it is clean and has picnic conditions, toilets, restaurants, running water in fountains and showers (Figure 50), and many other recreational and touristic activities are found nearby.

There is a deficiency in the dissemination of geoheritage values on the site, since it is a highly touristic spot, this could be used to promote the geological heritage. The natural pools provide an opportunity to develop interesting interpretative material or scripts, and it is precisely there that the shape of the arched lava ridges helps to understand how the lava flow movement occurred.

TER 13 Matias Simão

With a use value of 73.33% (sufficient). Pico Matias Simão is a spatter cone that stands out in the coastal relief of the parish of Altares. Although part of the same geosite as Biscoitos, it was assessed separately for having different geological contexts and uses.

There is access by car to a parking lot at the base of the volcano where a wooden pole with QR code is placed, from there the access to the top is by a walking route along 205 metres, at the beginning of this route there is an interpretative panel about the geoheritage values of the place (Figure 52). There are no time limitation, restrictions in use or hazards along the way. The observation conditions are good; the elements are barely covered but it is necessary to control the vegetation growth. One deficiency found is the absence of an official walking trail.

Figure 52. Beginning of the walking route that gives access to the top of Pico Matias Simão, and the panel placed by Angra do Heroísmo City Council.

For perceptiveness criteria, the site has good visual values in general; it is prominent, located in a natural zone with low impacts and having an attractive rural landscape, and presents unique features in the country. It is worth highlighting its great representativeness and potential to be used as pedagogical model, the high presence of welded lava spatters with striking shape, allow to understand the mechanisms that originated and agglutinated these pyroclasts (Figure 53).

Figure 53. Detail of an outcrop of the Matias Simão spatter deposits.

Figure 54. Matias Simão included in the geoeducational activities of the geopark, making use of the spatter outcrops.

In the use related criteria, there is easy access to geological information, proper signage and dissemination of the geological heritage, apart from the panel at the beginning of the route there is another one at the viewpoint in the top, concerning the geolandscapes that compose the north of the island. It is one of the few assessed sites with use and promotion of both cultural and ecological values. The place is used by the general public, usually locals and occasionally visited by tourists, and it is frequently used for educational itineraries (Figure 54). It obtained a low score in the touristic promotion, although this place is known, it is not well promoted in campaigns, this can be improved.

For logistics, the place is completely clean, and the closest toilets and restaurants are located at the parish of Altares. Recreational areas are found more than 3 km away.

The artisanal work traditionally carried out in the tile factories that existed in Altares was completely dependent on Pico Matias Simão and its geological history. The eruptive activity of the cone is responsible for the formation of a paleosol whose clayey material was historically used for the manufacture of roof tiles (telha de canudo) and bricks. Unfortunately, these artisanal works have ceased to be carried out in the parish. One way to enhance this geosite is to strengthen alliances with pottery artisans on the parish or the island who can revive this tradition and create products related to this geosite.

Another suggestion for the valorisation of this visiting area, and one for which the first steps have already been taken, is to establish an Interpretive Itinerary of Pico Matias Simão, inspired by that of TER 4 Furnas do Enxofre. Interpretive materials are already available at the beginning and end of the route, and the site is frequently used on pedagogical itineraries, this could be also consolidated as an official walking trail or part of one. A concrete proposal is to place frames highlighting the spatter on the outcrops (Figure 53, Figure 54); this would give them prominence along the trail, as they often go unnoticed by users. It is useful to take advantage of the interest and initiatives driven by the local authorities in enhancing the site.

4.3. Participation in other activities of the geopark

Some activities that were not contemplated in the initial working plan were carried out. The participation in activities organized by the geopark, besides supporting the efforts of the geopark, together with other alternative activities developed autonomously (Table 7), allowed to make a complete diagnosis on the field of the mechanisms of geoeducation, geotourism, partnerships, monitoring, management, and organizational structure of Azores UGGp. This was fundamental in the analysis and understanding of the strategies the geopark adopts, allowing to make further proposals.

Table 7. Additional activities developed during the internship.

Date	Activity	Objective/Description
19-Mar	Volcanospeleologic Museum visit	To find out how the geopark delegation works, check interpretative materials and information about the geopark and geosites.
21-Mar	TER 6 and TER 11 monitoring	Visit to Rocha do Chambre and Malha Grande caves with Salomé Meneses and park rangers (Ivan and Valter) for geosites monitoring as part of the management of geological heritage.
22-Mar	Water World Day - "Rota da água"	Walking through PRC12 TER - Rota da água hiking trail in Serra do Morião (Guilherme Moniz caldera), citizen education activity in partnership with Os Montanheiros.
23-Mar	TER 5 monitoring	Autonomous visit to Monte Brasil to develop a monitoring of the geosite at Pico do Facho viewpoint.
24-Mar	TER 9 monitoring	Autonomous monitoring of Graben das Lajes from Serra do Facho viewpoint.
27-Mar	Walking in PRC10 TER hiking trail	Environmental education activity organized by the "Associação de Dadores de sangue da Ilha Terceira" and supported by the Natural Park.
5-Apr	Azores Trails Fest	Visit to Mistérios Negros by PRC01 TER hiking trail, Biscoitos vineyards and Ribeira da Agualva trail with Regional Directorate for Tourism, the geopark offered an interpretative walking.
6-Apr	Expo Atlantic Terroir	Supporting as an information giver for users assisting the event in the geopark stand.
9-Apr	Monte Brasil with ERASMUS+ students	Participation in an interpretative walking in Monte Brasil requested for students of Terceira and Poland being part of an Erasmus+ program.
2-May	Formação executiva Geoturismo by Geoparques	Field trip part of the conclusion for the Executive Training in Geotourism in Geoparks.
19-May	"EMME" Exchanging Memories - Memory of the Earth (Terceira)	Activities in Terceira Island: Discovering Geodiversity (experimental activities) and Mistério Novo interpretative walking, within the EMME Erasmus program.
22-May	"EMME" Exchanging Memories - Memory of the Earth (Pico)	Geosites route in Pico Island, within the EMME Erasmus program activities.
23-May	"EMME" Exchanging Memories - Memory of the Earth (Faial)	Geosites route in Faial Island, within the EMME Erasmus program activities.
27-May	"...Entre Mar e Vulcões"	Talk by Salomé Meneses about Azores and Terceira geodiversity. Collaboration with Lar Doce Livro and Gê-Questa.
2-Jun	(Geo)Urban Route	Activities requested by Filipa de Vilhena secondary school (Porto).
3-Jun	Route of Geodiversity and Geosites	Activities requested by Filipa de Vilhena secondary school (Porto).
6-Jun	Geosites monitoring	Geosites route with André Borralho and park rangers to support the PhD student Laura Balaguer.
7-Jun	"Rochas que contam histórias"	Interpretative walking with Salomé Meneses, within the framework of the European Geoparks Week - "Pedaços de Mar e Ambiente" Campaign.
8-Jun	"O mar aos nossos pés"	Walking trail with Os Montanheiros, within the framework of the European Geoparks Week - "Pedaços de Mar e Ambiente" Campaign.
18-Jun	São Sebastião fieldtrip	Preliminary visit to evaluate São Sebastião (Ponta das Contendas) as a potential geosite.
17-Jul	Route of Geodiversity and Geosites	Part of Formação de professores - Introdução à geodiversidade como ferramenta pedagógica
18-Jul	(Geo)Urban Route	Part of Formação de professores - Introdução à geodiversidade como ferramenta pedagógica

4.4. Supplementary proposals

Based on the assessment of each geosite and the participation in other activities, it was possible to make a broad analysis of the management and specific strategies of Azores UGGp for its geoeducational and geotourism programs. Leading to the development of proposals for the valorisation of geosites, but this time not for each geosite, but by the enhancement of the geopark in general. The main aim of the proposed ideas and tools is to increase the promotion, attractiveness, and use of the geosites for educational and tourist populations.

Improvement of existing tools and measures

- Website: It is extremely important to update the website. This is the very first contact many people have with the geopark's content. An aesthetically pleasing platform must be created, providing organized and comprehensive access to information for users. All geosites should include their own photographs. A direct link to the episodes of " Geoparque Açores em 5 minutos " program should be included.
- Wooden poles with QR codes: As part of the Route of Geodiversity and Geosites of each island, the geopark placed poles with QR codes in each of the sites of the routes, these codes direct to the "To Visit" section of Azores Geopark website. In this section there is access to the leaflets of the routes for each island (Route of Geodiversity and Geosites and (Geo)Urban Route, if one exists), along with links to some of the island's geosites. It is suggested that this code redirects to content of the specific site, preferably didactic or interactive content, and also provide the opportunity to explore the rest of the locations on the route and other geosites.
- Geotouristic Brochure “9 ilhas, 1 geoparque”: The geopark made a great effort to create an interactive brochure with geotourism content, this brochure was available on the website of the entity responsible for promoting tourism in the region, with a very high reach. However, due to technical problems, this tool was removed from the website and is no longer available. It is suggested that efforts are made to make this valuable tool available to the public again.
- Partnerships: The contact and engagement with all partners should be constant, applying some sort of periodic “monitoring” of the state of the partners can be a good measure. Geopark partners are very diverse, and it is understandable that some are sought out and integrated more into the geopark's activities. However, it may happen that some, especially those that are startups, end their activities or change their corporate name, and the geopark should be aware of this. Maintaining constant contact, even when nothing is "required" of them, can make them feel valued and truly part of an alliance. It is also proposed to create or redesign an inter-partner network to streamline the development of joint activities and programs such as exhibitions or fairs or creating joint promotional packages.
- Geoproducts: It is suggested that the geopark consolidates its own brand of geoproducts, an exclusive strategy for the territory that can maintain autonomy and not be dependent on external brands like GEOfood. Hopefully in conjunction with a local brand like AZORES Certified by Nature (Marca Açores), to create an especial sub-label; creating additional labels can also generate conflicts.

New strategies

- Reviewing platforms: Nowadays, many people use websites and mobile applications to plan their daily lives, discover new places and do activities. The proposal is to actively add general and geoheritage information about geosites in platforms usually used to check comments and reviews about places like Google Maps or TripAdvisor. It would grant a broad visibility to those geosites with use value.
- Feedback from users: Geoparks usually make great efforts to adapt the geosites and create interpretive materials, but normally there is no practical way to know if these strategies are effective and appropriate for the target audience; there is no certainty as to whether the content is understandable and whether a good job of dissemination is actually being done. Granting users the possibility to give feedback about the infrastructure they benefit from, their contents and state, and even provide ideas, would be very beneficial for the geopark. The proposal is to include in the materials already placed and future ones (interpretative panels and poles with QR codes) a feature that allows visitors to leave comments and suggestions; it can be in the form of an additional QR code, a phrase motivating them to do it directly to the geopark providing contact details, or a link within the content they are referred to through the existing QR codes.
- Development of virtual tools: The creation of virtual materials and multimedia content may seem like a very ambitious goal. These measures have a high impact if well positioned. However, a major limitation is the costs associated with their implementation. A long-term measure to achieve this is to apply for specific calls and grants to fund these types of projects.

  In the short term, the geopark can leverage tools like Geocaching, a global platform used by amateur explorers. It involves placing items or challenges in specific locations; app users must physically travel to the locations to complete certain goals. Many "geocaches" are grouped by theme, and this has been used to disseminate diverse values. This encourages visiting the sites and would allow for communication about the geoheritage values of geosites.
- Transportation: Specifically in the case of Terceira Island, it is extremely difficult to reach the central part of the island without a car. Long-term efforts could be made to implement routes that allow access to the geosites located there, at least seasonally.
- Azores Geopark App and alternative: Having a mobile app seems to be a requirement for any organization lately. Indeed, these are platforms equipped with numerous tools and materials in a user-friendly environment. Making content available through this type of tool seems to offer advantages; various types of materials and information can be included here. However, developing a measure of

this magnitude requires significant investments, and there is no certainty that the objectives of dissemination and usefulness will be achieved.

A low-cost, risk-free, and easily scalable alternative is the tool generated in this work, which serves as a concrete valorisation proposal. The initial development of an interactive map for Terceira Island includes the visitor points evaluated in this report, the geopark island delegation, official trails, poles of the Geodiversity and Geosites Route, interpretive panels, and points within the (Geo)Urban Route. This tool is available via a link, for use on the Google Maps platform, with the option of offline use. This idea emerges as a practical resource, as it can be used autonomously by tourists, helping them to explore the island and educating them about geoheritage values. It can also be distributed and promoted by the geopark's partners. Future versions may include more features, such as the main viewpoints of the geosites, geopark partners, museums and interpretive centres, and other services (https://goo.gl/maps/LnzrxeoxbE91avDe6?g_st=aw).

5. Conclusions

The use value of fourteen visiting points of geosites of Azores UNESCO Global Geopark in Terceira Island was assessed. From the results of the quantitative assessment, it was possible to classify these visiting points according to their final scores: two as models, nine as sufficient, and three as unsuitable for use. The individual scores by criterion show how they perform across the geosites and give more specific analysis from the criteria categories created in this work. A qualitative analysis, together with the quantitative assessment, allowed to evaluate the geosites' strengths and weaknesses for use, and give proposals for the valorisation of each one of them.

From the activities developed, apart from the assessment, it was possible to make a diagnosis of the geopark's strategies and management. This led to the proposals for the improvement of the existing tools and measures, and the creation of new strategies, highlighting the creation of an interactive map as part of an accessible tool that can be used for the valorisation of geosites and help the geopark's strategies.

The methodology developed in this work turned out to be effective for the quantitative assessment of Azores UGGp geosites' use value. The criteria and indicators adapted to the reality of the archipelago proved to be appropriate in the assessment of the geosites of Terceira Island. The proposed criteria categories allowed to make an easier and systematic analysis of the performance of the geosites' value. The proposed categories of classification of geosites based on their final scores proved useful for ranking them according to their use value. And from the two tools developed for the information record of the assessment, the most suitable was the spreadsheet, as it allowed to know in real time the scores as the information was filled thanks to the pre-defined formulas in cells, and the fact it could be used offline on the field.

The objectives set at the beginning were achieved, a methodology for the quantitative assessment of geoheritage use value in Azores UGGp was developed. This proposed methodology could be applied successfully to assess the geosites located in Terceira Island, and it is suitable to be used in the rest of the geopark. After this assessment, ideas and tools for the valorisation, promotion, attractiveness, and use of the evaluated geosites were proposed.

This methodology proved that different places within the same geosite can have different use values and be used in different ways and for other purposes, which is the case of geosite TER 13 Biscoitos – Matias Simão. In addition, it is expected to be useful also to the assessment of geoheritage in other archipelagic

regions in the world. And for the case of Azores UGGp, might be even used to assess the use value of other geodiversity sites, not only geosites, as those included in the Geodiversity and Geosites Routes.

For future efforts it is suggested the development of some of the proposed ideas and tools of valorisation in this work and replicate the assessment to evaluate if these strategies were effective. A next phase for this assessment could be to apply an evaluation with the same criteria but weighted, hopefully using the criteria categories proposed for different types of recipients.

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