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Basis for the geological heritage management in the Azores Archipelago (Portugal) *

Bases para a gestão do património geológico no arquipélago dos Açores (Portugal)

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ABSTRACT

The Azores archipelago, with a peculiar geodynamic setting, presents a huge geodiversity and important geological heritage, being considered a natural laboratory of volcanic geodiversity.

In the last decade, the geodiversity and geological heritage of the Azores archipelago is being inventoried, characterized, quantified, protected and promoted. Nowadays there are identified and characterized 121 geosites distributed through the nine islands and the surrounding seafloor. These geosites network ensure the representativeness of the Azorean geodiversity and reflects its geological and eruptive history with about 10 million years. Among the geosites, 57 were selected as priorities for the development of geoconservation strategies and implementation of promotion actions.

The analysis of the geosites included two main phases: a qualitative and a quantitative assessment, integrating the geological characterization, geomorphological and volcanological categorization, analysis of their relevance, identification of the potential type of use in each geosite, its scientific value and other associated values. The efforts resulted recognition of 6 geosites with international relevance [*e.g.* the Mid Atlantic Ridge, the Caldera of Furnas volcano (São Miguel island), the Pico Mountain (Pico island), the Caldera and Furna do Enxofre (Graciosa island), the Capelinhos volcano and Costado da Nau (Faial island) and Algar do Carvão volcanic pit (Terceira island)] and 52 geosites of national relevance. Besides its scientific value, most of the geosites have a relevant educational and geotouristic value. It is noteworthy that 93 geosites integrate the Regional Network of Protected Areas, lying under the management of the Island Natural Parks and the Marine Park.

The volcanic landscapes of the Azores have been promoted since the late twentieth century, especially for tourism campaigns, however since the begining of the work studies of the geological heritage of the archipelago in 2007, has also been promoted regionally, nationally and internationally.

The terrestrial geosites are monitored, focusing on the state of geosite, its geological conditions and the public characterization. Monitoring began in late 2013, pending the first results by the end of 2014.

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The recognition of the value of the Azorean geological heritage effectively occurs with its integration in the European and Global Geoparks Network, under the auspices of the UNESCO, in march 2013, being the first truly archipelagic geopark, with the motto "9 islands - 1 geopark" " where people can enjoy eruptions of flavours,smells and experiences".

With the mentioned background, there are established the basis for the definition of a methodology for the management of the geological heritage of the archipelago, in order to be compatible the usufruct and geoconservation, to be possible to maintain the quality of the geosites and pass this important legacy for future generations.

Keywords: geological heritage, geoconservation, management, Azores Geopark.

RESUMO

O arquipélago dos Açores, com um enquadramento geodinâmico singular, apresenta uma enorme geodiversidade e importante património geológico, sendo considerado um laboratório natural de geodiversidade vulcânica.

Nos últimos anos têm vindo a ser desenvolvidos estudos e ações de valorização do património geológico do arquipélago, estando, atualmente, identificados e caracterizados 121 geossítios distribuídos pelas nove ilhas e fundos marinhos envolventes, que garantem a representatividade da geodiversidade dos Açores e reflectem a sua história geológica e eruptiva de cerca de 10 milhões de anos. Destes, 57 geossítios foram selecionados como prioritários para o desenvolvimento de estratégias de geoconservação e para implementação de ações de valorização.

A análise dos geossítios incluiu duas fases principais: uma avaliação qualitativa e uma avaliação quantitativa, integrando a caracterização geológica, categorização geomorfológica e vulcanológica, análise da relevância, a identificação do potencial tipo de uso em cada geossítio, seu valor científico e outros valores associados. Dos trabalhos desenvolvidos resultaram o reconhecimento de 6 geossítios com relevância internacional [e.g. Dorsal Atlântica, a Caldeira do vulcãodas Furnas (ilha de São Miguel), a Montanha do Pico (ilha do Pico) a Caldeira e Furna do Enxofre (ilha Graciosa), o Vulcão dos Capelinhos e Costado da Nau (ilha do Faial) e o Algar do Carvão (ilha Terceira)] e 52 geossítios de relevância nacional. Para além do valor científico, a maior parte dos geossítios têm valor educacional e geoturístico. É de salientar que 93 geossítios integram a Rede Regional de Áreas Protegidas, encontrando-se sob gestão dos Parques Naturais de Ilha e do Parque Marinho dos Açores.

As paisagens vulcânicas dos Açores têm vindo a ser promovidas desde o final do século XX, principalmente por campanhas turísticas, contudo desde que se iniciaram os trabalhos de estudos do património geológico do arquipélago, em 2007, este também tem vindo a ser divulgado regional, nacional e internacionalmente.

Os geossítios terrestres estão a ser monitorizados, incidindo-se no estado do geossítio, suas condições geológicas de interesse e na caracterização do público que o visita. A monitorização iniciou-se no final de 2013 em todo o arquipélago, aguardando-se os primeiros resultados para o final do ano de 2014.

O reconhecimento do valor do património geológico açoriano concretiza-se com a integração do Geoparque Açores nas Redes Europeia e Global de Geoparques, em março de 2013, constituindo o primeiro geoparque verdadeiramente arquipelágico, com o mote "9 ilhas – 1 geoparque", onde se "Desfrutam de erupções de sabores, aromas e experiências!".

Estão, assim, estabelecidas as bases para se partir para a definição de uma metodologia de gestão do património geológico do arquipélago dos Açores, de forma a se compatibilizar, da melhor forma, o seu usufruto e geoconservação, para que se mantenha a qualidade dos geossítios e passe este importante legado para as gerações futuras.

Palavras- chave: *património geológico, geoconservação, gestão, Geoparque Açores.*

1. AZORES ARCHIPELAGO

The Azores archipelago is a Portuguese autonomous region located in the Atlantic Ocean (at a distance of 1815 km from Portugal mainland and 2625 km from Canada), composed by nine islands (with small dimension, between 17 and 745 sq. km), some islets and the surrounding seafloor. The islands are dispersed along approximately 600 km, between Santa Maria and Corvo islands, with an orientation WNW-ESE (Figure 1).

The Azores archipelago emerges from an extensive area of irregular bathymetry, defined by the 2000 meters bathymetric line, which makes the transitions to the surrounding abyssal seafloor.

In terms of the global geodynamics, the archipelago is located at the triple junction of the Eurasian, North American and African (or Nubian) lithospheric plates. The main structures that frame this junction are: i) the Mid-Atlantic Ridge (with an approximately N-S trend) - which corresponds to a pure distensive boundary between the North-American plate, on West, and the Eurasian and African plates, on East, and ii) the Gloria Fault (with a general W-E trend), that establishes the plate boundary Eurasia-Africa and integrates a major structure, the Azores-Gibraltar Fault.

The configuration of the islands of the central and eastern groups, with west-northwest - east-southeast, and Corvo and Flores islands through north-south direction, reflects the structural control by the main tectonic structures that interact at the Azores triple junction and influence the geomorphology of the islands (Nunes., 1991; França *et al.*, 2003;. Nunes *et al.*, 2009)(Figure 2).

All the Azorean islands are of volcanic origin, being identified 16 polygenetic volcanoes and 11 fissural volcanic systems, counting with a total of 1750 monogenetic volcanoes in the archipelago (Nunes & Lima, 2008). Given its complex geodynamic framework the Azores archipelago also presents an important seismicity on a global context, related either with the active tectonic activity in the Azores, either to the occurred volcanic activity.

The Azores archipelago has a rich and vast geodiversity and an important geological heritage, composed by several sites of scientific, educational and touristic interest. Volcanoes, calderas, lakes, lava fields, fumaroles, hot springs

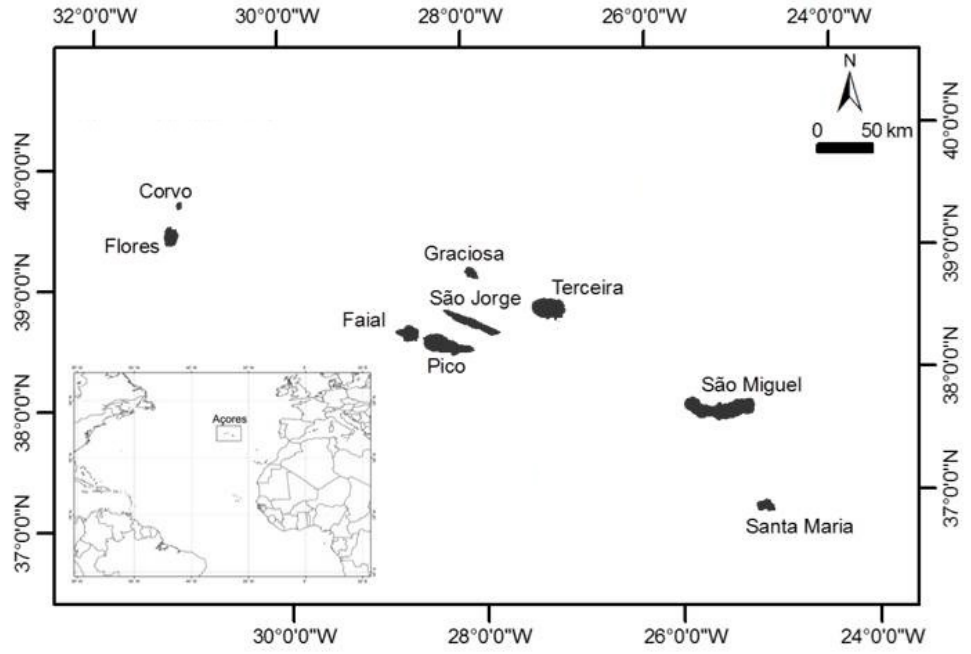

Figure 1. Geographic setting of the Azores archipelago, Portugal.
Figura 1. *Enquadramento geográfico do arquipélago dos Açores, Portugal.*

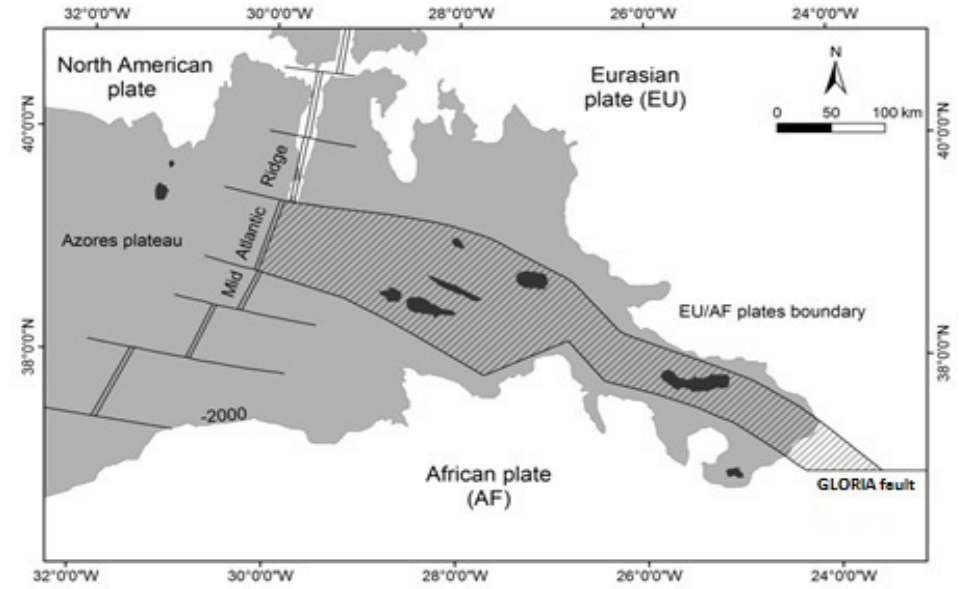

Figure 2. Geodynamic setting of the Azores archipelago, Portugal (adapted from Lourenço, 2007).
Figura 2. *Enquadramento geodinâmico do arquipélago dos Açores, Portugal. (adaptado de Lourenço, 2007).*

and thermal waters, volcanic caves, "fajás", fault scarps and marine fossil deposits, among many others, are characteristic elements of the Azorean geological heritage.

The volcanic features toghether with the tectonic, paleontological and others, were the starting point for the identification, characterization and quantification of the value of the geodiversity and geological heritage of the Azores (Lima, 2007;. Nunes *et al.*, 2011).

2. NATURE CONSERVATION IN THE AZORES ARCHIPELAGO

Since the settlement of the Azores, in the middle of the 15th century, the exceptional natural and landscape resources attract several visitors and distinguished naturalists and scientists. However nature conservation in the Azores becomes effective in 1972 with the creation of the first protected areas, the Integral Reserves of Faial Caldera and Pico Mountain (Decreto Legislativo n.º 78/72, de 7 de março, e Decreto Legislativo n.º 79/72, de 8 de março) (Lima, 2007).

After Goulart (1999), the main strategic actions in the archipelago in the conservation of nature are related to:

- the application of national law;
- the appropriateness of the legislation to the archipelagic specificities, from political-administrative status as an autonomous region;
- implementation of the regional ecological network;
- cataloging the natural heritage of the Azores;
- the implementation of measures for the development and management of classified areas;
- the allocation of a environmental monitoring staff (the nature guards);
- the promotion of information and dissemination campaigns about the natural heritage;
- encouraging the development of the scientific knowledge;
- the establishment of inter-regional, national and international projects of intersectoral cooperation.

Regarding the geological component of the Azorean natural heritage, the oldest descriptions of the geology of the islands were writen by Gaspar Fructuoso in the 16th century (Fructuoso, 1583; França *et al.*, 2003). However, only in the second half of the 20th century is introduced the concept of conservation of the geological heritage elements in the region with Victor Hugo Forjaz as a pioneer (Forjaz *et al.*, 2006; Forjaz, 2007; Lima, 2007).

The Environmental management in the archipelago, made in recent years, reflects the increased concerns safeguarding the rich geological heritage of the region, contributing also to their promotion and enhancement. Lima (2007) indicates several important steps to achieve this objective, presented in the following list:

- the opening to the public of some volcanic caves, such as *Furna do Enxofre* on the Graciosa island since 1939, the *Algar do Carvão* and *Gruta do Natal* at Terceira island since 1968 and 1969 respectively, and more recently, the *Gruta das Torres* in Pico island, *Gruta do Carvão* in São Miguel island, and showing part of the volcanospeleological heritage of archipelago;
- in 1998 the Azores Regional Government creates a multidisciplinary group to study the volcanic caves of the archipelago and their management, designated GESPEA;
- the Volcanological and Geothermal Observatory of the Azores, created in 1998, edited several publications for the dissemination and promotion of the geological heritage of the region; this institution has also promote public actions of geological education;
- some Azorean environmental non-governmental organizations (*e.g.* Amigos dos Açores - Ecological Association and Os Montanheiros - Speleological Society), also participate in the dissemination and promotion of the geological component of the natural heritage of the archipelago, through publications, proposed classification of geological interest sites, and recreational activities that promote the contact with the natural heritage;
- the volcanospeleological museum, opened to the public since the 1980's, property of Os Montanheiros – Speleological Society (Terceira island);
- the classification of some geosites as Natural Monuments in 2004 and 2005, such as *Pedreira do Campo* in Santa Maria island, *Gruta do Carvão*, *Pico das Camarinhas* and *Ponta da Ferraria* in São Miguel island and *Gruta das Torres* in Pico island, although there are other geological elements protected under others legal figures since 1972;
- in 2004 the project "GeoDIVA - Geodiversity of Protected Areas of the Azores" was implemented by the Azores University, providing scientific advice to the Environment Regional Directorate of the Azores Regional Government, regarding the promotion and enhancement of the geodiversity of these areas;
- several studies about the geodiversity and geological heritage of the Azores have been developed, such as publications about the "Azores islands of geodiversity" - Graciosa, Santa Maria and São Jorge islands (Nunes & Lima, 2005; Nunes *et al.*, 2007; Lima *et al.*, 2013a), "Geosites Maps" - Santa Maria, Graciosa, Corvo and São Jorge islands (Nunes *et al.*, 2008; Nunes *et al.*, 2009; Nunes *et al.*, 2010; Nunes *et al.*, 2013);
- there are also some academic studies and works on these topics, such as master's theses "Azorean Geologic Heritage: Valuing Geosites in Environmental Classified Protected Areas, Contribution to the Territorial Planning" (Lima, 2007), "Monitoring Strategies for the geosite ' Ponta da Ferraria e Pico das Camarinhas', S. Miguel Island: Contribution to the sustainable management of the geological heritage of the Azores Geopark "(Lima, 2012) and a degree thesis about "Geomonuments Map of Terceira Island (a contribution)" (Lopes, 2007);
- participation in dissemination sessions about the geodiversity and geological heritage of the Azores in regional, national and international events, providing

information about the work in progress and sharing experiences;

- in 2007 the Azores Regional Government announced its intention to create the Azores Geopark and submit its application to the European and Global Geopark Networks; in 2010 it was formally established the Azores Geopark Association, which manages the geopark; and in march 2013 occurred the inclusion in the networks, constituting the first archipelagic geopark, and thus being internationally recognized the value of their geological heritage and its importance in the social, cultural and economic dynamics of this region.

It is worth to note that the Regional Legislative Decree n. 15/2007/A, of 25 June, which reclassifies the protected areas of the region with uniform criteria, integrates, for the first time in regional and national environmental legislation, geological elements of the Azorean geodiversity (beyond those associated with biological aspect).

Therefore since the last decades of the 20th century there have been some initiatives that show concern for the protection of geological heritage of the archipelago, having stepped up the number of activities and studies for this purpose. As mentioned above, the geological heritage of the archipelago has its value, recently, recognized with the creation of the Azores Geopark.

3. GEOCONSERVATION IN THE AZORES ARCHIPELAGO

The set of strategies, policies and actions for an effective conservation of the geodiversity and geological heritage protection is called geoconservation (Sharples, 2002; Brilha, 2002, 2005; Gray, 2004).

The geoconservation is based on a working methodology that systematizes the tasks in the conservation of the geological heritage of given territory (Brilha, 2005). Some authors describe methods of work with that purpose, based generally on the same basic steps (Cendrero, 2000, Lago *et al.*, 2001; Brilha, 2005; Carcavilla *et al.*, 2007).

In general terms the steps to apply are:

- inventory and characterization - each geosite must be located and limited geographically, and characterized based on field work and bibliography;
- quantification of the value or relevance - calculated based on defined criteria;
- classification - the geosites that obtain greater importance should be proposed for classification in accordance with the existing legal framework;
- conservation - a geoconservation strategy should give concrete and practical answers to a preliminary assessment on the threats that may relate to the geosites;
- valorization and promotion - actions of information and interpretation that help the public to recognize the value of the geosites;
- monitoring - verification and analysis of the evolution of the geosites conservation, to ensure the maintenance of its value and relevance.

3.1. Inventory and characterization

The inventory and characterization of the geological heritage of the Azores was based on three studies: i) a Master thesis in Spatial and Environmental Planning at the Azores University, "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 Network and Global Geoparks (Nunes *et al.*, 2011); iii) and the scientific research project "Identification, characterization and conservation of geological heritage: a geoconservation strategy for Portugal" (2007-2010) (Brilha & Pereira, 2012).

3.1.1. Master thesis - Lima (2007)

The first systematic study of the geological heritage of the archipelago was carried out by Lima (2007). The analysis of the geological heritage of the 83 environmental areas classified in the Azores included two main steps: a qualitative and quantitative assessment.

The geological characterization of each environmental area and the selection of the sites that stand out for its geological features were based on the geological knowledge of the areas complemented with bibliography research, resulting in the identification of 59 geosites (56 terrestrial and 3 marine) (Figure 3).

Following the characterization of the geosites, these were categorized according to their geomorphological and volcanological characteristics, being based on the work performed by Nunes (2003).

According to the results obtained most of the geosites identified are coastal and marine areas (25), several altitude areas (19) and many integrate volcanic lakes or coastal lagoons (15), reflecting the morphological character of the islands, usually with a mountainous central zone and with great presence of water. In the remaining categories, we report the historical eruptions (13), areas of hydrothermal activity (10), calderas (9), surtseyan tuff cones (6), volcanic caves (4) and fields of scoria and spatter cones (3), portraying the diversity of morphologies and types of volcanic activity that gave rise to them.

About the quantitative assessment, Lima (2007) opted to adapt the methodology of Brilha (2005) to the territorial and geological reality of the archipelago. It is noted that the above method is based on the method described by Cendrero *et al.* (1996) and Cendrero (2000), but adjusted to the Portuguese reality. 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). Calculated the relevance or value of the geological heritage assigning numerical values to different criteria, allowed the comparison among the analyzed geosites, resulting the ranking and determining their international/ national or regional/local relevance.

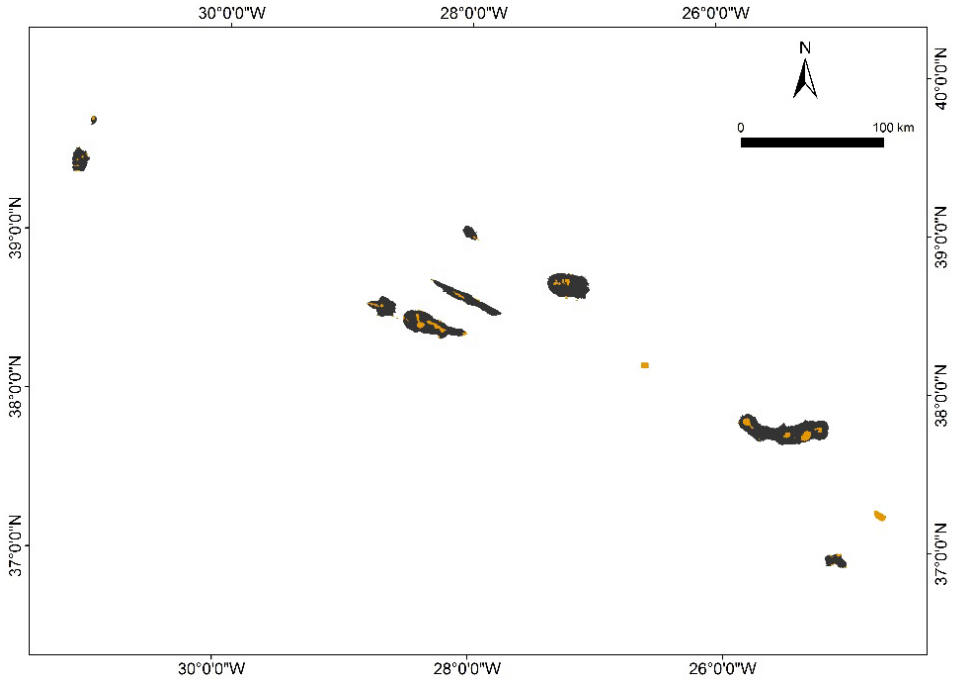

Figure 3. Geosites identified in the Azorean environmental areas, in 2007 (adapted from Lima, 2007).
Figura 3. *Geossítios (a laranja) das áreas ambientais dos Açores,em 2007 (adaptado de Lima, 2007).*

In the 59 geosites identified in the existing environmental areas of the Azores in 2007, 36 had international or national importance, and the other 23 had regional or local relevance. It was also found that the most valued sites are those that include a remarkable geodiversity. In the ranking the most importants sites are*Caldeira do vulcão das Furnas* (Furnas volcano caldera), on the island of São Miguel; *Montanha do Pico* (Pico Mountain); *Caldeira do Faial* (Caldera of the central volcano of Faial island); *Caldeira do vulcão das Sete Cidades* (Sete Cidades volcano caldera) and *Caldeira do vulcão do Fogo* (Fogo volcano caldera) both also in São Miguel.

3.1.2. Azores Geopark aplication to the European and Global Geoparks Networks

The inventory and characterization of geological heritage has been extended to the entire archipelago with the same methodology of Lima (2007), this analysis was crucial to the application of the archipelago internationally recognized as a geopark.

The developed works were based on the knowledge gathered about the geological characteristics of the territory, the eruptive history of each Azorean island and the elements of geological heritage identified in the islands and in the surrounding seafloor. Several researchers of the Region and national and foreigner scientists with assignments about the Azores in several areas have also contributed to this inventory, which have resulted in a sustained and wide approach (Nunes *et al.*, 2011).

The geopark is based on a network of 121 geosites spread over the nine islands and the surrounding seafloor (Figure 4) which ensures the representativeness of the geodiversity of the Azores and reflects its geological and eruptive history of about 10 million years. From these, 57 geosites were selected as priority for the development of geoconservation strategies and for the implementation of valorization actions at the aim of the project Azores Geopark, distributed by Santa Maria (5), São Miguel (10), Terceira (7), Graciosa (5), São Jorge (5), Pico (8), Faial (6), Flores (6) and Corvo (3) islands, and the Azores Plateau seafloor (2) (Lima *et al.*, 2009; Nunes *et al.*, 2011).

The choice of priority geosites relied on several parameters: i) the international or national relevance; ii) representativeness of the archipelago geodiversity; iii) its position in the geosites ranking; iv) category icons and v) characterization (vulnerability, usufruct, affluence, ...).

Qualitative and quantitative assesment were also performed, based on Lima (2007), incorporating not only the geological characterization, geomorphological and volcanological categorization and analysis of the relevance, as well as identifying the type of use in each geosite, its scientific value and others associated values. The geosites list and the most relevant results are presented in the Table 1 to 3.

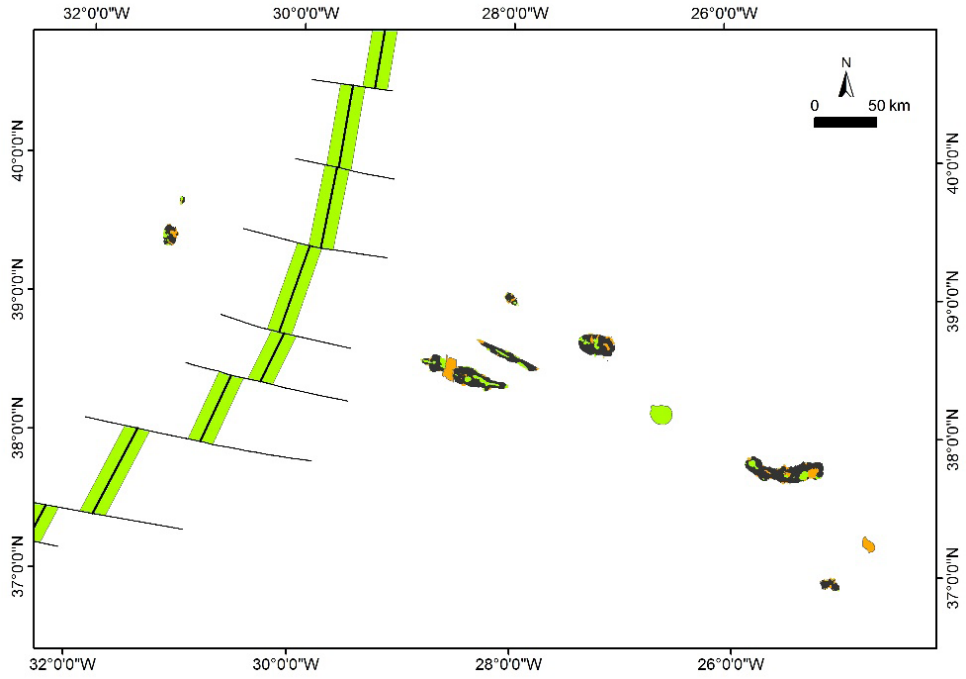

Figure 4. Location of the 121 Azorean geosites (main geosites – green, others geosites – orange) (in Nunes *et al.*, 2011).
Figura 4. *Localização dos 121 geossítios dos Açores (geossítios prioritários a verde e restantes geossítios a laranja) (in Nunes et al., 2011).*

Table 1. Geomorphological and volcanological categories of the geosites (adapted from Nunes, 2003; Lima, 2007; Wood, 2009).
Tabela 1. *Categorias geomorfológicas e vulcanológicas dos geossítios dos Açores (adaptado de Nunes, 2003; Lima, 2007; Wood, 2009).*

Geomorphological and volcanological categories			
1	Sea cliffs	13	Lava deltas (or lava "fajãs")
2	Calderas	14	Weathering phenomena/mud deposits-"barreiros"
3	Volcanic caves	15	Fossiliferous deposits
4	Fields of scoria and spatter cones	16	Volcanic lakes
5	Surtseyan tuff cones	17	Coastal lagoons
6	Volcanic ridges	18	*Pahoehoe* lava fields-"lajidos"
7	Quaternary deposits (*e.g.* beaches and slope deposits-"fajãs")	19	Maars
8	Prismatic and spheroidal jointing	20	Fluvial valleys
9	Domes and *coulées*	21	Polygenetic volcanoes
10	Historical eruptions	22	Areas of hydrothermal activity
11	Sub-volcanic structures (*e.g.* necks and dykes)	23	Others
12	Tectonic structures (*e.g.* faults and *grabens*)		

Table 2. Elements used in the evaluation of the Azorean geosites (in Nunes *et al.*, 2011).
Tabela 2. *Elementos utilizados na avaliação dos geossítios dos Açores (in Nunes et al., 2011).*

Relevance		Scientific Value		Others Values	
Int	International	**Geom**	Geomorphological	**Arq**	Archeological or similar
Nac	National	**Paleo**	Paleontological	**Cult**	Cultural
Reg	Regional	**Min**	Mineralogical	**Ecol**	Ecological
		Pet	Petrological	**Hist**	Historical
Use		**Estr**	Stratigraphic	**Pvist**	Scenic (Landscape)
Cie	Scientific	**Tect**	Tectonic		
Ec	Economic	**Hidro**	Hydrological		
Ed	Educational	**Hidrot**	Hydrothermal		
Geot	Geotourism	**Vulc**	Volcanic		
		Espeleo	Speleological		
		Sed	Sedimentary		

Table 3. List of Azores archipelago geosites, its geomorphological and volcanological categories, relevance, use and values. The 57 prioritary geosites are distinguished at gray (in Nunes *et al.*, 2011).
Tabela 3. *Lista de geossítios do arquipélago dos Açores, suas categorias geomorfológicas e vulcanológicas, relevância, uso e valores. Destacam-se, a cinzento, os 57 geossítios prioritários (in Nunes et al., 2011).*

Island	Geosite		Geomor phological and Volcanological Categories	Relevance	Use	Scientific Values	Other Values
Corvo	Caldeirão	(COR 1)	2 | 16 | 21	Nac	Cie | Ed | Geot	Geom | Hidro | Vulc	Cult | Ecol | Pvist
	Fajã lávica de Vila do Corvo	(COR 2)	13	Reg	Cie | Ed	Geom | Estr | Vulc	Cult | Pvist
	Ponta do Marco	(COR 3)	1 | 11	Reg	Cie | Geot	Estr | Vulc	Ecol | Pvist
	Coroínha e arriba de Pingas	(COR 4)	1 | 11	Reg	Cie | Ec | Ed	Geom | Estr | Vulc	
Flores	Caldeiras Negra, Comprida, Seca e Branca	(FLO 1)	16 | 19	Nac	Cie | Ed | Geot	Geom Hidro | Vulc	Ecol | Pvist
	Caldeiras Rasa e Funda das Lajes	(FLO 2)	16 | 19	Nac	Cie | Ed | Geot	Geom | Estr | Hidro | Vulc	Ecol | Pvist
	Fajã Grande e Fajãzinha	(FLO 3)	1 | 7 | 13 | 20	Nac	Cie | Ed | Geot	Geom | Estr | Tect | Hidro | Vulc | Sed	Cult | Pvist
	Pico da Sé	(FLO 4)	9	Reg	Cie | Ed | Geot	Geom | Vulc	Pvist
	Ponta da Rocha Alta e Fajã de Lopo Vaz	(FLO 5)	1 | 7	Reg	Cie | Geot	Geom | Estr | Sed	Ecol | Hist | Pvist
	Rocha dos Bordões	(FLO 6)	8	Nac	Cie | Ed | Geot	Geom | Vulc	Ecol | Pvist
	Costa Nordeste	(FLO 7)	1 | 8 | 11	Nac	Cie | Geot	Estr | Vulc	Pvist
	Filão dos Frades	(FLO 8)	11	Reg	Cie | Ed | Geot	Geom	Pvist
	Litoral de Santa Cruz	(FLO 9)	13	Reg	Cie | Ed | Geot	Geom | Pet | Vulc	Cult
	Ponta do Albarnaz - Ponta Delgada	(FLO 10)	1 | 8 | 11 | 14	Reg	Cie | Ed | Geot	Pet | Estr | Tect | Vulc	Cult
	Vale da Ribeira da Cruz e Ponta da Caveira	(FLO 11)	1 | 3 | 11 | 20	Nac	Cie | Ec | Ed | Geot	Geom | Hidro | Hidrot | Vulc	Pvist
	Vale das Ribeiras da Badanela e Além Fazenda	(FLO 12)	11 | 20	Nac	Cie | Ed | Geot	Geom | Hidro | Vulc	Pvist
	Vale e fajã lávica das Lajes	(FLO 13)	12 | 13	Reg	Cie | Ec	Geom | Min | Estr | Vulc	Pvist
	Ilhéu de Monchique	(FLO 14)	23	Reg		Geom	Pvist

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Island	Geosite		Geomorphological and Volcanological Categories	Relevance	Use	Scientific Values	Other Values
Faial	Caldeira	(FAI 1)	2 | 10 | 21	Nac	Cie | Ed | Geot	Geom | Tect | Hidro | Vulc	Ecol | Hist | Pvist
	Graben de Pedro Miguel	(FAI 2)	1 | 12	Nac	Cie | Ec | Ed | Geot	Geom | Tect	Cult | Hist | Pvist
	Monte da Guia e Porto Pim	(FAI 3)	5 | 7	Nac	Cie | Ed | Geot	Geom | Pet | Vulc | Sed	Cult | Pvist
	Morro do Castelo Branco	(FAI 4)	1 | 9 | 14	Nac	Cie | Ed | Geot	Geom | Min | Vulc	Ecol | Pvist
	Península do Capelo	(FAI 5)	3 | 4 | 6 | 10 | 12	Reg	Cie | Ec | Ed | Geot	Geom | Tect | Vulc	Hist | Pvist
	Vulcão dos Capelinhos e Costado da Nau	(FAI 6)	1 | 5 | 10 | 11	Int	Cie | Ed | Geot	Geom | Pet | Estr | Tect | Vulc	Ecol | Hist | Pvist
	Arriba fóssil da Praia do Norte	(FAI 7)	1 | 7 | 18	Reg	Cie | Ec | Ed | Geot	Geom | Estr | Sed	Pvist
	Arriba fóssil do Varadouro	(FAI 8)	1 | 22	Reg	Cie | Ed | Geot	Geom | Estr | Hidrot	Cult | Pvist
	Ponta Furada	(FAI 9)	1 | 8 | 18	Nac	Cie	Geom | Vulc	
Pico	Arriba fóssil Sto António - São Roque	(PIC 1)	1 | 13	Reg	Cie | Ec	Geom | Pet | Estr | Vulc	
	Fajã lávica das Lajes do Pico	(PIC 2)	1 | 11 | 13 | 17	Reg	Cie | Ed | Geot	Geom | Vulc	Cult | Ecol | Pvist
	Gruta das Torres	(PIC 3)	3	Reg	Cie | Ec | Ed | Geot	Min | Vulc | Espeleo	Ecol
	Ilhéus da Madalena	(PIC 4)	5	Nac	Cie | Geot	Geom | Pet | Vulc	Pvist
	Lajido de Santa Luzia	(PIC 5)	1 | 10 | 18	Nac	Cie | Ed | Geot	Geom | Vulc	Cult
	Montanha	(PIC 6)	7 | 12 | 18 | 21 | 22	Int	Cie | Ed | Geot	Geom | Estr | Tect | Hidrot | Vulc | Sed	Ecol | Hist | Pvist
	Planalto da Achada	(PIC 7)	4 | 6 | 10 | 12 | 16	Reg	Cie | Ec | Ed | Geot	Geom | Estr | Tect | Hidro | Vulc | Espeleo	Ecol | Hist | Pvist
	Ponta da Ilha	(PIC 8)	1 | 8 | 18	Nac	Cie | Ec | Ed | Geot	Geom | Vulc	Cult | Ecol
	Algar/Gruta do Canto da Serra	(PIC 9)	3	Reg	Cie	Vulc | Espeleo	
	Fajã lávica de São Mateus	(PIC 10)	1 | 13	Reg	Cie | Ed	Geom | Vulc	
	Fajã lávica das Ribeiras	(PIC 11)	1 | 13	Reg	Cie | Ed	Geom | Min | Vulc	Pvist
	Furna Vermelha	(PIC 12)	3	Reg	Cie	Vulc | Espeleo	
	Gruta dos Montanheiros	(PIC 13)	3	Reg	Cie	Vulc | Espeleo	
	Hornitos e Furna do Frei Matias	(PIC 14)	3	Reg	Cie | Geot	Vulc | Espeleo	
	Lajidos da Criação Velha	(PIC 15)	1 | 18	Nac	Cie | Ed | Geot	Geom | Vulc	Cult | Pvist
	Lomba do Fogo	(PIC 16)	10 | 12	Reg	Cie	Geom | Tect | Vulc | Espeleo	Ecol | Hist | Pvist
	Ponta do Mistério	(PIC 17)	1 | 10 | 13	Reg	Cie | Ed | Geot	Geom | Pet | Vulc	Ecol | Hist | Pvist
	Cabeço Debaixo da Rocha	(PIC 18)	5	Nac	Cie | Ed	Pet | Estr | Vulc	Pvist
São Jorge	Arribas das Fajã dos Vimes – Fajã de São João	(SJO 1)	1 | 7 | 12 | 20	Nac	Cie | Ed | Geot	Geom | Tect | Sed	Cult | Ecol | Pvist
	Cordilheira vulcânica central	(SJO 2)	3 | 4 | 6 | 10 | 12 | 16	Reg	Cie | Ec | Ed | Geot	Geom | Tect | Hidro | Vulc | Espeleo	Hist | Pvist
	Fajãs do Ouvidor e da Ribeira da Areia	(SJO 3)	1 | 13	Reg	Cie | Ed | Geot	Geom | Estr | Vulc	Pvist
	Fajãs dos Cubres e da Caldeira de Sto Cristo	(SJO 4)	1 | 7 | 17	Nac	Cie | Ed | Geot	Geom | Hidro | Sed	Cult | Ecol | Pvist
	Morro de Velas e Morro de Lemos	(SJO 5)	1 | 5 | 15	Nac	Cie | Ed | Geot	Geom | Paleo | Pet | Vulc	Ecol | Pvist
	Ponta dos Rosais	(SJO 6)	1 | 11	Reg	Cie | Geot	Geom | Estr | Vulc	Cult | Pvist
	Mistério da Urzelina	(SJO 7)	1 | 10	Nac	Cie | Ed | Geot	Vulc	Hist
	Ponta e ilhéu do Topo	(SJO 8)	1 | 8	Reg	Cie | Ed | Geot	Geom | Pet | Estr | Vulc	Cult | Pvist

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Island	Geosite		Geomorphological and Volcanological Categories	Relevance	Use	Scientific Values	Other Values
Graciosa	Caldeira e Furna do Enxofre	(GRA 1)	2 | 3 | 9 | 16 | 21 | 22	Int	Cie | Ec | Ed | Geot	Geom | Min | Tect | Hidro | Hidrot | Vulc | Espeleo	Cult | Hist | Pvist
	Caldeirinha de Pêro Botelho	(GRA 2)	3	Reg	Cie | Ed | Geot	Vulc | Espeleo	Pvist
	Ponta da Barca e Ilhéu da Baleia	(GRA 3)	1 | 11 | 22	Nac	Cie | Ed | Geot	Geom | Estr | Hidrot | Vulc	Cult | Pvist
	Porto Afonso e Redondo	(GRA 4)	1 | 4 | 11	Nac	Cie | Ed | Geot	Geom | Estr | Vulc	Pvist
	Ponta do Carapacho, Ponta da Restinga e Ilhéu de Baixo	(GRA 5)	1 | 5 | 11 | 22	Nac	Cie | Ec | Ed | Geot	Geom | Estr | Hidrot | Vulc	Cult | Ecol | Pvist
	Arribas da Serra Branca e Baía do Filipe	(GRA 6)	1 | 9 | 11	Nac	Cie | Ed | Geot	Geom | Estr | Vulc	Pvist
	Baía da Vitória	(GRA 7)	18 | 22	Reg	Cie	Hidro | Hidrot | Vulc	
	Erupção do Pico Timão	(GRA 8)	1 | 4	Reg	Cie | Ec	Geom | Vulc	
	Santa Cruz da Graciosa	(GRA 9)	4 | 13	Reg	Cie | Ed | Geot	Geom | Hidro | Vulc	Cult | Pvist
Terceira	Algar do Carvão	(TER 1)	3 | 16	Int	Cie | Ec | Ed | Geot	Min | Hidro | Vulc | Espeleo	Ecol
	Caldeira de Santa Bárbara e Mistérios Negros	(TER 2)	2 | 9 | 10 | 12 | 21	Nac	Cie | Ed | Geot	Geom | Min | Tect | Vulc	Ecol | Hist | Pvist
	Caldeira de Guilherme Moniz	(TER 3)	2 | 3 | 18 | 21	Reg	Cie | Ed	Geom | Tect | Vulc | Espeleo	
	Furnas do Enxofre	(TER 4)	14 | 22	Reg	Cie | Ed | Geot	Hidrot	Pvist
	Monte Brasil	(TER 5)	1 | 5 | 12 | 15	Nac	Cie | Ed | Geot	Geom | Paleo | Pet | Estr | Tect | Vulc	Cult | Hist | Pvist
	Pico Alto, Biscoito Rachado e Biscoito da Ferraria	(TER 6)	2 | 9 | 21	Nac	Cie | Ec | Ed | Geot	Geom | Min | Estr | Tect | Vulc	Ecol | Pvist
	Ponta da Serreta e escoadas traquíticas	(TER 7)	1 | 9 | 12	Reg	Cie | Ed | Geot	Geom | Pet | Vulc	Ecol
	Fajã da Alagoa - Biscoito das Calmeiras	(TER 8)	1 | 7 | 9	Reg	Cie | Ed | Geot	Geom | Estr | Vulc | Sed	Pvist
	Graben das Lajes	(TER 9)	1 | 12	Nac	Cie | Ed | Geot	Geom | Pet | Tect	Pvist
	Ilhéus das Cabras	(TER 10)	5	Nac	Cie | Geot	Geom | Pet | Tect | Vulc	Pvist
	Mistério 1761 e sistema cavernícola da Malha Grande – Balcões	(TER 11)	3 | 10	Reg	Cie | Ec	Min | Vulc | Espeleo	Ecol | Hist
	Serra do Cume	(TER 12)	2 | 21	Reg	Cie | Ed | Geot	Geom | Vulc	Pvist
	Biscoitos - Matias Simão	(TER 13)	1 | 18	Reg	Cie	Geom | Vulc	Cult

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Island	Geosite		Geomorphological and Volcanological Categories	Relevance	Use	Scientific Values	Other Values
São Miguel	Caldeira do vulcão das Furnas	(SMG 1)	2 | 9 | 10 | 14 | 16 | 20 | 21 | 22	Int	Cie | Ec | Ed | Geot	Geom | Min | Estr | Tect | Hidro | Hidrot | Vulc	Cult | Hist | Pvist
	Caldeira do vulcão das Sete Cidades	(SMG 2)	2 | 7 | 10 | 16 | 21	Nac	Cie | Ed | Geot	Geom | Estr | Hidro | Vulc | Sed	Cult | Pvist
	Caldeira do vulcão do Fogo	(SMG 3)	2 | 7 | 10 | 16 | 21	Nac	Cie | Ed | Geot	Geom | Min | Hidro | Vulc	Hist | Pvist
	Caldeira Velha	(SMG 4)	20 | 22	Reg	Cie | Ed | Geot	Tect | Hidro	
	Gruta do Carvão	(SMG 5)	3	Reg	Cie | Ec | Ed | Geot	Vulc | Espeleo	Cult
	Ilhéu de Vila Franca	(SMG 6)	5	Nac	Cie | Ed | Geot	Geom | Pet | Vulc	Ecol | Pvist
	Lagoas do Congro e dos Nenúfares	(SMG 7)	16 | 19	Reg	Cie | Ed | Geot	Geom | Hidro | Vulc	Pvist
	Ponta da Ferraria e Pico das Camarinhas	(SMG 8)	4 | 13 | 22	Nac	Cie | Ec | Ed | Geot	Geom | Min | Estr | Tect | Hidrot | Vulc	Cult | Pvist
	Serra Devassa	(SMG 9)	4 | 6 | 12 | 16	Reg	Cie | Ec | Ed | Geot	Geom | Tect | Hidro | Vulc	Cult
	Vale da Ribeira do Faial da Terra e Fajã do Calhau	(SMG 10)	1 | 7 | 9 | 11 | 20	Reg	Cie | Ed | Geot	Geom | Estr | Hidro | Vulc | Sed	Cult
	Caldeira da Povoação	(SMG 11)	2 | 20 | 21	Reg	Cie | Ec | Ed | Geot	Geom | Pet | Hidro | Vulc	Cult | Pvist
	Coroa da Furna – Arrenquinha	(SMG 12)	3 | 4 | 6	Reg	Cie | Ec | Ed	Geom | Tect | Vulc | Espeleo	
	Fajã lávica e arriba fóssil da Caloura	(SMG 13)	1 | 8 | 11 | 13	Reg	Cie | Ec | Ed | Geot	Geom | Estr | Vulc	Cult | Ecol | Pvist
	Fajã lávica e ilhéus dos Mosteiros	(SMG 14)	1 | 5 | 7 | 12 | 13	Nac	Cie | Ec | Ed | Geot	Geom | Pet | Tect | Hidrot | Vulc	Cult | Pvist
	Morro das Capelas	(SMG 15)	1 | 5 | 15	Nac	Cie	Geom | Paleo | Pet | Vulc	Cult
	Morro de Sta Bárbara, praias e Bandejo	(SMG 16)	1 | 7 | 9 | 10	Reg	Cie | Ed | Geot	Geom | Vulc | Sed	Cult
	Pico da Vara e Planalto dos Graminhais	(SMG 17)	20 | 23	Reg	Cie | Geot	Geom | Hidro	Ecol | Pvist
	Pisão - Praia (Água d'Alto)	(SMG 18)	1 | 7	Nac	Cie | Ed | Geot	Pet | Estr | Sed	Pvist
	Ponta do Cintrão - Ladeira da Velha	(SMG 19)	1 | 9 | 22	Nac	Cie | Ed | Geot	Geom | Estr | Hidrot | Vulc	Cult | Pvist
	Praias do Pópulo, Milicias e São Roque	(SMG 20)	7	Reg	Cie | Ed | Geot	Vulc | Sed	Cult | Pvist
	Rocha da Relva	(SMG 21)	1 | 7	Reg	Cie | Ed	Geom | Estr | Sed	Pvist
	Salto da Farinha	(SMG 22)	8 | 14 | 20	Nac	Cie | Ed | Geot	Geom | Hidro | Vulc	Pvist
	Salto do Cabrito	(SMG 23)	20	Nac	Cie | Ec | Ed | Geot	Tect | Hidro	
	Vale da Ribeira Quente	(SMG 24)	1 | 7 | 20 | 22	Reg	Cie | Ed | Geot	Geom | Estr | Hidro | Hidrot | Vulc | Sed	Hist | Cult
	Vale das Lombadas	(SMG 25)	9 | 20 | 22	Reg	Cie | Ec | Ed | Geot	Geom | Min | Hidro | Hidrot	Cult | Pvist
	Fontanário da Ribeira Seca	(SMG 26)	10	Nac	Cie | Ed | Geot	Vulc	Hist | Pvist
	Campo Geotérmico do Vulcão do Fogo	(SMG 27)	22	Nac	Cie | Ec | Ed | Geot	Hidrot	

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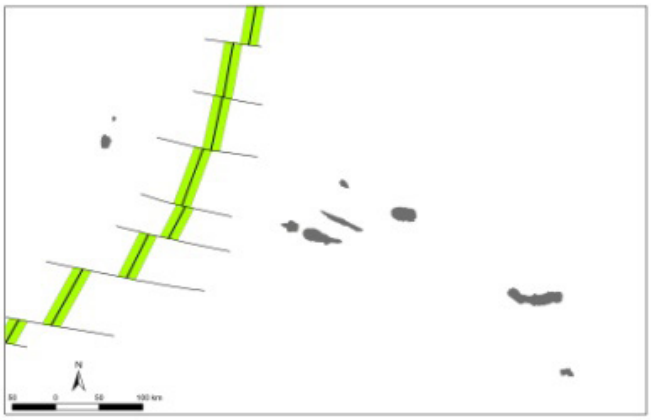
Island	Geosite		Geomor phological and Volcanological Categories	Relevance	Use	Scientific Values	Other Values
Santa Maria	Barreiro da Faneca	(SMA 1)	14	Nac	Cie | Ed | Geot	Geom | Pet | Vulc	Pvist
	Pedreira do Campo	(SMA 2)	8 | 15	Nac	Cie | Ed | Geot	Paleo | Min | Pet | Estr | Vulc	Arq
	Poço da Pedreira	(SMA 3)	11 | 14	Nac	Cie | Ed | Geot	Geom | Vulc	Arq
	Ponta do Castelo	(SMA 4)	1 | 8 | 11 | 15	Nac	Cie | Ed | Geot	Geom | Paleo | Min | Pet | Estr | Vulc	Cult | Pvist
	Ribeira do Maloás	(SMA 5)	8 | 20	Nac	Cie | Ed | Geot	Geom | Vulc	Pvist
	Baía da Cré	(SMA 6	1 | 15	Reg	Cie | Ed | Geot	Geom | Paleo | Pet | Estr	Cult
	Baía de São Lourenço	(SMA 7)	1 | 7 | 15	Reg	Cie | Ed | Geot	Geom | Paleo | Sed	Pvist
	Baía do Raposo	(SMA 8)	1 | 8 | 20	Reg	Cie	Geom | Hidro	
	Baía do Tagarete e Ponta do Norte	(SMA 9)	1 | 14 | 15 | 20	Nac	Cie	Geom | Paleo | Hidro | Vulc	
	Baía dos Cabrestantes	(SMA 10)	1 | 5	Reg	Cie	Pet | Estr | Vulc	
	Barreiro da Malbusca	(SMA 11)	8 | 14	Nac	Cie | Ed	Min | Estr | Vulc	
	Cascata do Aveiro	(SMA 12)	8 | 20	Reg	Cie | Ed | Geot	Geom | Estr | Hidro	Pvist
	Figueiral	(SMA 13)	1 | 3 | 8 | 11 | 15	Reg	Cie | Ed | Geot	Paleo | Pet | Estr | Espeleo	Arq
	Porto de Vila do Porto	(SMA 14)	1 | 8 | 11	Nac	Cie | Ed	Estr | Vulc	Pvist
	Praia Formosa e Prainha	(SMA 15)	1 | 7 | 8 | 15 | 20	Nac	Cie | Ed | Geot	Geom | Paleo | Pet | Hidro | Sed	Cult | Pvist
Marine Areas	Banco D. João de Castro	(Marinha 1)	10 | 21 | 22	Reg	Cie | Geot	Geom | Tect | Hidrot | Vulc	Hist
	Dorsal Atlântica e Campos hidrotermais	(Marinha 2)	6 | 12 |22	Int	Cie	Geom | Min | Tect | Hidrot | Vulc	Ecol
	Canal Faial-Pico	(Marinha 3)	5 | 22	Reg	Cie	Geom | Tect | Hidrot | Vulc	
	Ilhéus das Formigas e Recife Dollabarat	(Marinha 4)	11 | 15	Reg	Cie | Geot	Geom | Paleo | Pet | Tect | Vulc	Ecol

The geosites were grouped in categories according to their geomorphological, geological and volcanological characteristics, having adopted the previous categorization performed by Lima (2007) and detailing aspects of volcanic morphology according the classification of Wood (2009). So 23 geomorphological and volcanological categories were established, highlighting sea cliffs, polygenetic volcanoes with caldera, volcanic caves, prismatic and spheroidal jointing, historical eruptions, sub-volcanic structures (*e.g.* necks and dykes), fluvial valleys and areas of hydrothermal activity, confirming the archipelagic and volcanic nature of the territory.

In the analysis of the geosites relevance it was applied the same quantitative methodology of Lima (2007), but distinguished themselves in geosites with international relevance (6 geosites), national relevance (52 geosites) and regional relevance (63 geosites). The geosites of international relevance are: the *Dorsal Atlântica e Campos hidrotermais* (Mid-Atlantic Ridge and deep-sea hydrothermal fields), as it is a global tectonic boundary; the *Caldeira do vulcão das Furnas* (Furnas volcano caldera) (São Miguel island), which besides being a volcano-lab, has an important hydrothermal and hydrological system (mineral, thermal and CO_2-spring gas waters) richness; *Montanha do Pico* (Pico Mountain polygenetic volcano), because is the 3rd highest central volcano on North Atlantic; the *Caldeira e Furna do Enxofre* (Graciosa volcano caldera and "Furna do Enxofre" volcanic cave) (Graciosa island), by its size, shape and genesis of the volcanic cave; *Vulcão dos Capelinhos e Costado da Nau* (Capelinhos volcano and Costado da Nau volcano) (Faial island), due to the relevance of the Capelinhos eruption for volcanology science; and *Algar do Carvão* volcanic pit (Terceira island), because it includes the top ten worldwide volcanic cave in terms of mineral deposits (silica speleothemes) (Nunes *et al.*, 2011) (Figure 5).

Most geosites are used for scientific studies, also being realized in most of them geotouristic and education activities. In about one third of the geosites occur economic activities directly related to the geology of the site, either through paid visits to the geosites (*e.g.* volcanic caves), either by quarries or geothermal energy production (Figure 6).



Mid-Atlantic Ridge and deep-sea hydrothermal fields

Furnas volcano caldera (São Miguel island)

Pico Mountain
(Pico island)

Graciosa volcano caldera and Furna do Enxofre volcanic cave
(Graciosa island)

Capelinhos volcano and Costado da Nau volcano (Faial Island)

Algar do Carvão volcanic pit (Terceira Island)

Figure 5. Geosites with international relevance.
Figura 5. *Geossítios de relevância internacional.*

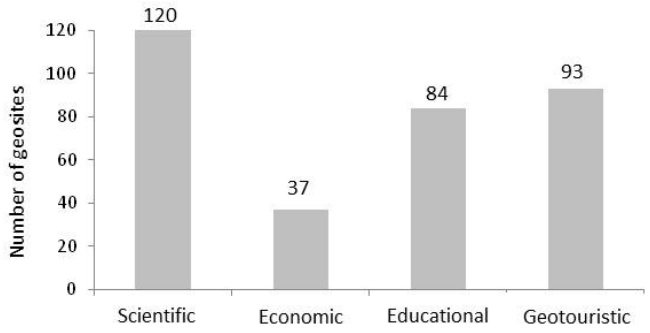


Figure 6. Types of use of the Azores geosites.
Figura 6. *Tipos de uso dos geossítios dos Açores.*

The scientific value of each geosite was decomposed in different geological areas, verifying that the main types of scientific values expressed by the Azorean geosites are in terms of geomorphology and volcanology, as it is expected in a volcanic archipelago (Figure 7).

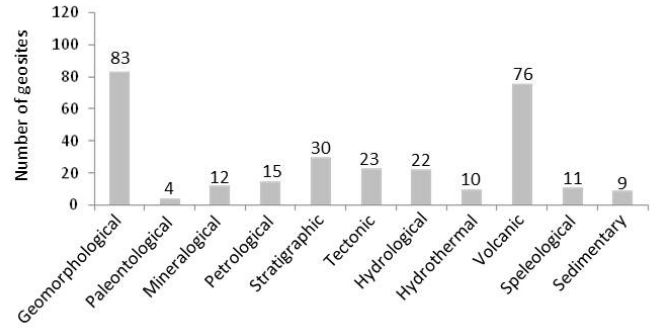


Figure 7. Scientific value of the Azores geosites.
Figure 7. *Valor científico dos geossítios dos Açores.*

The geological heritage is sometimes associated to other types of heritage, valuing them, and in some cases, complementing them. Most of the Azorean geosites have associated other value types, being the most common the scenic, cultural (highlighting the close relationship between the Azorean people and their volcanoes), and ecological (several geosites are the substrate and create conditions for the existence of important habitats and ecosystems) (Figure 8).

An analysis made to the 117 geosites of the insular territory, having in account the related urban and industrial pressure, has shown that 54% of the geosites present a reduced actual or potential pressure and only 10% (12 geosites) are subject to a high urban pressure. Concerning the vulnerability to human interventions, in 10 geosites (*e.g.* volcanic caves, Fountain of Ribeira Seca, in São Miguel

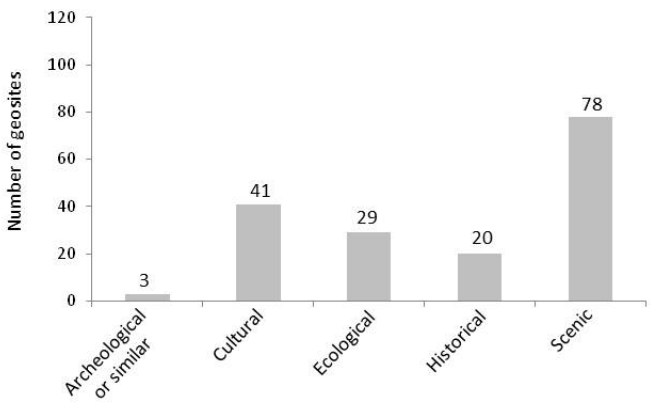


Figure 8. Other values of the Azores geosites.
Figura 8. *Outros valores associados aos geossítios dos Açores.*

island, and the coastal lagoons associated to the Lajes do Pico lava delta, in Pico island) several elements of geodiversity may be destroyed even by little anthropic interventions or by small structures of easy depreciation. In an opposite way, 86 geosites present geomorphological aspects or large geological structures that, by its dimensions, relief, etc., are hardly affected, in a significant way, by the anthropic activities, or its destruction is not likely to happen (Nunes *et al.*, 2011).

Considering the vulnerability to the natural evolutionary processes of the geosites (*e.g.* erosive actions, cliff retreats, fauna activity, vegetation growth), only two geosites are under high pressure, due to the marine erosive processes (Pisão – Praia, at Água d'Alto, São Miguel island) and the vegetation growth (Capelinhos and Costado da Nau, Faial island) (Nunes *et al.*, 2011).

3.1.3. Scientific research project "Identification, characterization and conservation of geological heritage: a geoconservation strategy for Portugal" (2007-2010)

Additionally, there was an evaluation of the scientific value of the 121 geosites in the Azores archipelago and of its degree of vulnerability, taking into account the criteria commonly used in several European countries. This evaluation took place in the context of the research project "Identification, characterization and conservation of geological heritage: a geoconservation strategy for Portugal", funded by the FCT - Foundation for Science and Technology (2007-2010), which sought to implement, in whole Portuguese territory, a methodology for the inventory and the classification of geological heritage, from the perspective of its geoconservation, valorization and dissemination (Brilha *et al.*, 2006; Brilha & Pereira, 2012). This analysis assigned numerical values to various criteria such as uniqueness, recognition as a local standard, scientific knowledge, integrity, diversity and rarity. The obtained results confirmed the relevance of the main geosites already mentioned from the previous methodologies: the Mid-Atlantic Ridge and deep-sea hydrothermal fields, followed

by the Caldera of Furnas silicic polygenetic volcano (São Miguel island), Pico Mountain polygenetic volcano (Pico island), Graciosa volcano caldera and "Furna do Enxofre" volcanic cave (Graciosa island), and the Capelinhos volcano and "Costado da Nau" volcano (Faial island).

The vulnerability of the 121 geosites was evaluated under the same project - using criteria such as the possibility of deterioration of the geological content, the proximity to potentially degrading areas, accessibility and population density - resulting in 10 geosites with high vulnerability (*e.g.*quarries - *Pico Timão*, Graciosa island, or urban pressure - *Fajã lávica e arriba fóssil da Caloura*, São Miguel island), while the remaining geosites present a moderate vulnerability (63%) or low (29%) (Nunes *et al.*, 2011).

3.2. Classification

Currently a significant number of the Azores geosites (93 geosites) are under legal protection of the Island Natural Parks and the Azores Marine Park. Additionally several geosites are covered by other classifications and protection and enhancement measures such as Natura 2000 Network, Ramsar, OSPAR, Important Bird Areas, and some also integrate classified areas as UNESCO World Heritage sites (*e.g.* the Historical Centre of Angra do Heroísmo, Terceira island, and Landscape of the Pico Island Vineyard Culture), or Biosphere Reserves of Graciosa, Flores and Corvo islands. Although there are 19 geosites without any legal classification or protection (Nunes *et al.*, 2011).

But it was not always like this, though in 1972 the first sites of geological interest were classified (as mentioned above: Pico Mountain and *Caldeira* from Faial island), they were not protected for its geological features, happening the same with others 50 now recognized as geosites, that were classified essentially by their biological and/or ecological factors, and others few (22) were classified by geological and biological or ecological factors abreast (Lima, 2007).

This change happened with the contribution and cooperation of the technical staff of the Azores Geopark in the reviewing of the protected areas performed, in recent years, under the 15/2007/A Regional Legislative Decree, of 25 June.

3.3. Valorization and promotion

The Azores geological heritage has been promoted and disseminated since the beginning of its studies in 2007 (Lima *et al.*, 2012), although the Azorean geolandscapes are promoted since the late 20th century, mainly through tourism campaigns at national and international levels. However, it has been a lack of information and promotion in the archipelago itself, so that the Azorean people can be aware of the value and importance of their geosites often used in the daily and leisure activities.

As it use to say "people only value what they know" and with this purpose several promotional and informational products of the Azores geological heritage have been developed, directed to: i) the general public (a newspaper page published every two weeks "Geodiversidades" in the newspaper with largest circulation in the archipelago - "Açoriano Oriental", leaflets and brochures about the geosites and the Azores Geopark, the web page and the participation in social networks and newsletters), ii) to the student audience (through the educational programs of the Azores Geopark, the Children's Guide "Volcanoes of the Azores", some games and activities development in the school context or at study visits), and iii) the specialized geological heritage public (through the participation in national and international events on geological heritage, geoparks and geotourism or projects with other specialists) (Lima *et al.*, 2012).

Several partners of the Azores Geopark also contribute to the dissemination of the value and importance of the Azorean geosites, either through his explanation at the Environmental Interpretation Centres or the Science Centres or through the geological heritage usufruct with tourism companies.

A community informed will value its geological heritage and ensure a greater commitment to its conservation (Lima *et al.*, 2012).

3.4. Monitoring

Monitoring ensures a better conservation of geological heritage and improves the management practiced in a given geosite (Lima, 2012).

The first monitoring plan applied to a geosite in the archipelago was carried out by Lima (2012) at the *Ponta da Ferraria e Pico das Camarinhas* geosite (São Miguel island), from October 2011 to October 2012, with the goal to identify the threats that endanger the integrity of the geosite and to quantify the gains or loss of relevance that it has suffered over time due such threats. It was made a direct count of the number of visitors, observation of their behavior and questionnaires were administered.

By observing the behavior adopted it was found that most visitors follow the rules, and only a minority goes out the marked trails or ride motorized vehicles outside the proper areas; it appears however that the accumulation of waste is a problem, also due to ineffective collection performed. By the questionnaires analisys it is know that most of the public want to spend 1-2 hours on this place and are interested in knowing it better, so it is justified to bet on additional measures and specific interpretation [being indicated by Lima (2012): a geodiversity interpretation trail, production of interpretive brochures and creating a visitants centre]. With the count of visitors it was concluded that about 72,000 people visit this geosite per year, being 850 the highest number of visitors recorded in a day, but not reaching the load capacity calculated for geosite, which is 2050 visitors a day (Lima, 2012).

At the end of the year 2013 began the experimental monitoring of the Azores geological heritage with several tests in Faial, Pico, Terceira and Santa Maria islands, reaching at a final monitoring checklist to be applied systematically in all terrestrial geosites of the archipelago. It includes parameters such as: the geosite status (cleanliness, accessibility, signage), its geological conditions of interest (conservation, threats, natural evolution) and the characterization of the public.

Given the geosites number and their dispersion in the archipelago, this monitoring counts with the cooperation of the Nature Vigilants of the 9 Island Natural Parks

(Azores Geopark partners), with a periodic verification by the technical staff of the geopark. The first results and conclusions are expected at the end of 2014, after monitoring throughout the calendar year, covering different seasons and inherent changes in natural conditions, and high and low visitation seasons.

In the work plan is also set for 2015 start the monitoring of the submarine part of the coastal geosites and even the submarine geosites, also relying on the stablished partnerships for this purpose (*e.g.* regional diving companies and the Oceanography and Fisheries Department of the Azores University.

4. ANALISYS OF THE INTEGRATION OF GEOHERITAGE HERITAGE IN THE ENVIRONMENTAL AND LAND-USE POLICIES

The analysis of the integration of the geological heritage in environmental and use policies of the archipelago was made by Lima (2007), checking the inclusion of this issue in key strategic and operational instruments and documents.

All documents considered (32) integrate a nature conservation component, but only 9 explicit the geological component in their policies for the conservation and valorization of nature, and of these, only 6 used the appropriate nomenclature of the subject. There is also the note that the instruments surveyed are more indicative than operating, regarding the topic of geological heritage.

In 2013, Lima *et al.* (2013b) returned to do this analisys, and this time from the 49 planning instruments analyzed (with 21 new documents for environmental and land use planning implemented), 16 included a geological component of the natural heritage. Then it appears that although the main strategic and operational tools integrate existing nature conservation, only about a third (the same proportion as in 2007) of these refer their geological component, verifying that there is still much to do to raise awareness of the work teams of spatial planning concerning this subject.

5. GEOLOGICAL HERITAGE USUFRUCT

The Azorean people learned to live with its volcanoes and earthquakes, taking advantage of the fertile soils, the geological resources and beautiful landscapes to promote their socioeconomic development.

The relationship human/geodiversity marks the daily life of the Azorean society, namely: the regional architecture (popular, religious and military) with the use of local ornamental rocks; religious events (pilgrimages, processions and the Holy Spirit festivities) closely related to the occurrence of natural events (volcanic eruptions and earthquakes); the traditional enjoyment of secondary manifestations of volcanism through baths in thermal pools, the use of mineral and CO_2-sparkling waters, the use of mud as peloids and the degustation of food that is steamed in the fumarolic field of the Furnas Volcano; toponomy like "Lajedo", "Lajidos", "Biscoitos" and " Mistérios", among other geological names used on the islands as well as in geoproducts as in the case of wines such as "Terras de Lava", "Basalto", "Magma" or "Pedras Brancas", and even on Azorean stories and legends (Nunes *et al.*, 2011).

The Azoreans geolandscapes also assume the main motto of interest and development of nature tourism in the archipelago and feature a wide range of possibilities for sustainable use , where it can be practice different activities and develop associated tourism products, such as the geotourism through walking trails and trekking, volcanic speleology, geotours, and hydrotherapy among others. The Azores geotourism is also supported on different thematic routes that promotes the region based on the volcanism and the geolandscapes: i) the volcanic caves route; ii) the belvederes route; iii) the walking trails route; iv) the thermal route; v) the science and interpretation centres route, vi) urban routes and vii) litoral routes (Machado *et al.*, 2013). It is noteworthy that besides the contribute to the socio-economic development mainly in rural areas, these products have highlighted the importance of the geotourism as a tool to promote and preserve the geological heritage of the Azores, turning, also, as an important instrument of environmental awareness through the local and foreign people (Lima *et al.*, 2013).

6. GEOLOGICAL HERITAGE MANAGEMENT

The Azores geological heritages constitutes an ex-libris of the archipelago and is an important resource that must be promoted and used in a sustainable way. To reach this goal a good management of the recreational, educational and tourism uses should coexist with a geoconservation policy (Lima *et al.*, 2013b).

There are several papers about inventory methodologies for geological heritage and its scientific, educational and tourism uses, however, management methodologies for geological heritage are still poorly developed. They should be included in environmental and land-use planning and nature conservation policies, in order to support a holistic approach to natural heritage. This gap is explained by the fact that geoconservation is a new geoscience and still need of more basic scientific research, like any other geoscience (Henriques *et al.*, 2011).

Also in the Azores, despite the developed works on the inventory, characterization and monitoring of the geological heritage, there isn't an integrated planning for their management. Also lacking studies to identify threats and to propose guidelines for their sustainable management that constitute basic tools to an adequate geoconservation (Caetano & Lima, 2005).

Lima (2007) refers some existing management measures and informal management plans for some geosites:

- as verified in the previous analysis, most of the Azorean geosites are integrated in the Island Natural Parks and other legal figures, being subjected to its management measures;
- some geosites have load capacities defined, such as the *Vila Franca do Campo* islet, São Miguel island (400 visitors per day), and Pico Mountain (160 visitors simultaneously and 40 people in *Piquinho* per 30 minutes);
- some geosites have restricted access and their visitation is controlled, as in *Caldeira* from Faial Island and the

volcanic caves with guided tours (*Gruta do Carvão* in São Miguel island, *Gruta das Torres* in Pico Island, *Furna do Enxofre* in the Graciosa island, *Algar do Carvão* and *Gruta do Natal* in Terceira island) with load capacities also defined.

Then becomes necessary to establish mechanisms and protocols targeted for conservation and management of geological heritage. This management is complex because it serves not only the natural features and aspects, seen from a scientific perspective, but also legal, economic, cultural, educational and recreational aspects, also taking into account the variety of natural and anthropogenic (Lima *et al.*, 2013b).

With the integration of the archipelago in the European and Global Geopark Networks increases the challenge and reinforces the commitment of the management of its geological heritage.

A PhD in Environmental Geology about the "Definition of a methodology for the management of geological heritage. An application to the Azores archipelago" is being developed in the Azores University, under which it is intended to investigate, evaluate and define a methodology for the management of the geological heritage, with a view to mainstreaming of spatial and environmental planning. The application to the Azores is expected to set management measures to the proper functioning of the geosites and better enjoyment by those who visit or use them daily.

7. CONCLUSIONS

The Azores archipelago, despite its small territorial dimension, presents a wide range of morphologies, rocks and structures, arising, among other factors, from the nature of the magmas, the type of eruption that originated, its dynamics and the subsequent action of external agents, such as the hydrosphere, atmosphere and biosphere. The expression of this geodiversity is reflected in volcanic calderas, lava fields, volcanic ridges, volcanic lakes, prismatic jointings, etc.

The geodiversity of the Azores islands, along with other determinants factors as their size, dispersion, geographic location and climate, are responsible for distinctive ecological conditions, which translate, in a unique way, the close relationship between the geodiversity and biodiversity of the archipelago.

There have been developed, in recent years, studies and actions of inventory, characterization, classification, valuation and monitoring of geological heritage and there are currently identified and characterized 121 geosites (117 terrestrial geosites and 4 marine geosites), with high relevance (6 of international relevance, 52 of national relevance and the others with regional relevance), some protected (93), some vulnerable (22), and almost all with usufruct by the Azoreans and visitors.

Interpretation and dissemination resources about the geological heritage were produced, and developed awareness and promotion activities with the general public and the school population.

It is also noteworthy that the identified geosites have been taken into account in the recent environmental and land use planning policies and in the review of the protected areas of the archipelago.

It is missing to manage systematically the geological heritage, defining measures for a proper management of each geosite.

So, now that the inventory, characterization and evaluation of the Azorean geological heritage are done, are created the bases to work on a management methodology of geological heritage of the archipelago, which given their characteristics (size, dispersion of the islands and its genesis), may also be adapted later to other Macaronesian archipelagos (Madeira, Canary and Cape Verde).

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