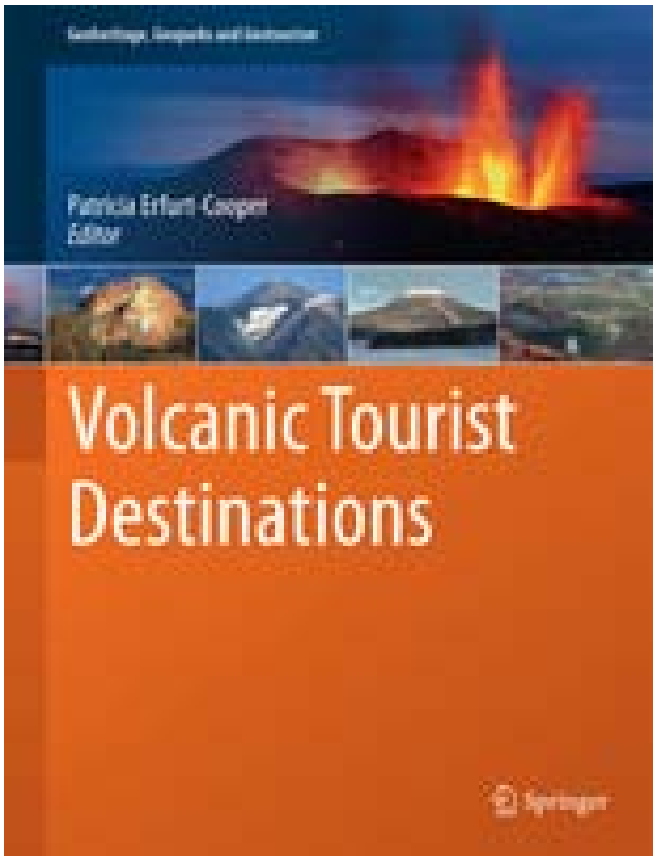

Book: *Volcanic Tourist Destinations*

Series: Geoheritage, Geoparks and Geotourism
Erfurt-Cooper, **Patricia (Ed.)**
2014, XVIII, 384 p. 373 illus.

THE AZORES ARCHIPELAGO: ISLANDS OF GEODIVERSITY

João Carlos Nunes, PhD
Geosciences Department, University of the Azores
Azores Geopark Scientific Coordinator
jcnunes@uac.pt

INTRODUCTION

The Azores Archipelago (a Portuguese Autonomous Region) is located in the North Atlantic at the distance of 1815 km from the Mainland Portugal, and is formed by nine islands and several islets, which are dispersed along a strip with 600 km length and with a WNW-ESE trend. The archipelago lies on the triple junction between the North American, Eurasian and African (or Nubian) plates (Laughton & Whitmarsh, 1974; Searle, 1980; Vogt & Jung, 2004) and, in general terms, the intervening plate boundaries are the Mid-Atlantic Rift (MAR), separating the American plate from the Eurasian and African plates, and the Azores-Gibraltar Fault Zone (AGFZ), bounding the latter two plates (Figure 4.1).

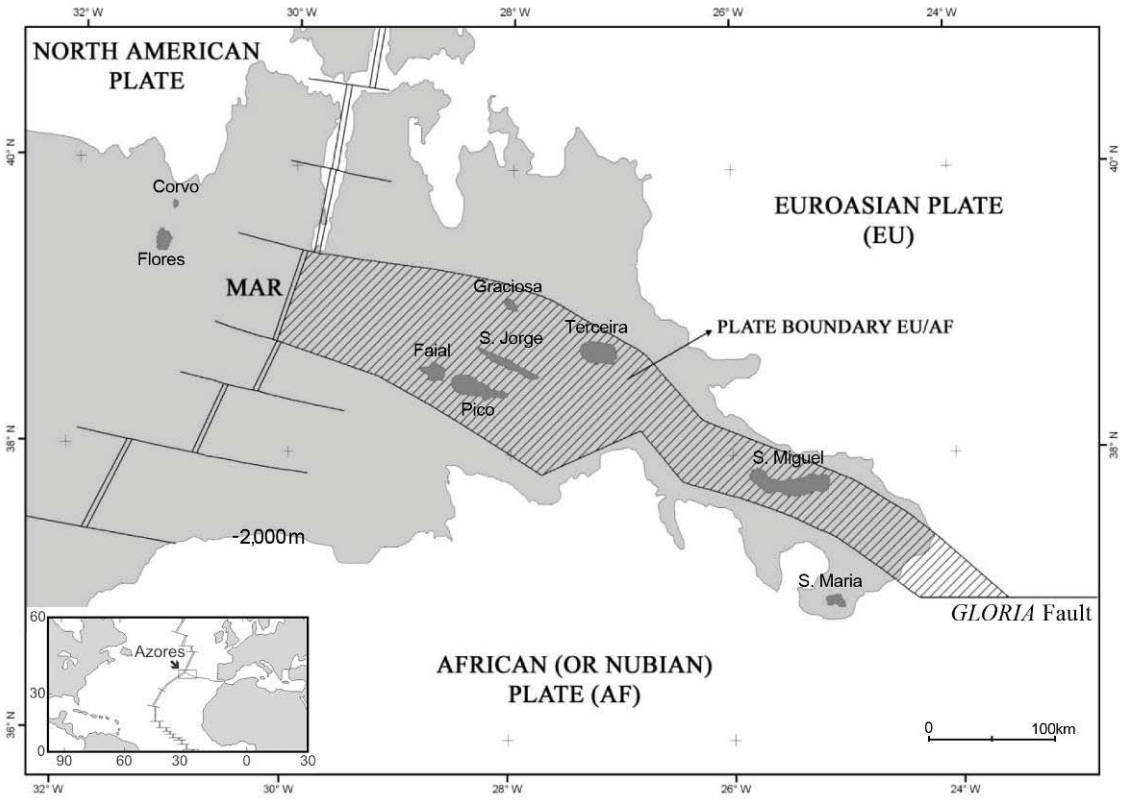

Figure 4.1 *General geotectonic framework of Azores Archipelago. MAR: Mid-Atlantic Rift. © JCNunes.*

In the Azores area, the MAR trends N-S to N20E and is divided by transform faults into seven short segments (Luis et al., 1994). The western AGFZ segment in the Azores region includes the east-west GLORIA Fault and a WNW-ESE general trend area (Figure 4.1) oblique to the spreading direction and allowing magmatic intrusion along faults, feeding the volcanism that built the islands (Lourenço et al., 1998). Volcanic and tectonic activities are well displayed in the geomorphology of the islands, the former includes 26 eruptions since the settlement of the islands in the early 15th century (Zbyszewski, 1963; Weston, 1963/64; Queiroz et al., 1995; Madeira & Brum da Silveira, 2003). Earthquakes reaching magnitude 7 that caused about 6,350 deaths, and successive pre-historic surface fault ruptures that produced well-developed fault scarps, represent recent seismotectonic and neotectonic activity (Madeira & Ribeiro, 1990; Nunes et al., 2001; Madeira & Brum da Silveira, 2003; Nunes, 2008).

All the Azores islands are of volcanic origin and are all oceanic islands that emerged from the surrounding seafloor due to the progressive build-up of submarine volcanic products, a deep-sea process that could have started about 36 million years ago. Thus, the Azores islands emerge from the Azores *Plateau* (or Azores Platform) defined by the 2,000 meter bathymetric line (Figure 4.1) and which makes the transition to the surrounding abyssal seafloor. The oldest terrestrial volcanism (8.12 million years) is evident in outcrops on Santa Maria Island while Pico is the youngest island of the archipelago that emerged about 300,000 years ago.

There are 27 main volcanic systems in the Azores Islands with 16 major central volcanoes (most of them silicic and with summit subsidence calderas) and 11 volcanic ridges associated with basaltic fissure volcanism. Among these, 9 major polygenetic volcanoes and 7 areas of basaltic fissure volcanism are classed as active (although currently dormant) and are located on the islands of São Miguel, Terceira, Graciosa, São Jorge, Pico and Faial and the Dom João de Castro Bank, a large submarine volcano. Located offshore near the islands are located important active submarine volcanic ridges including the Monaco Bank (south of São Miguel), the Princes Alice Bank (SW of Faial) and the Serreta Ridge (W of Terceira), where in 1998-2001 a 'Serretian' type eruption took place (Forjaz et al, 2001), the last one in the Azores region.

Moreover, there are about 1750 monogenetic volcanoes in the archipelago, either dispersed along the flanks and inside the summit depression of the polygenetic volcanoes, or belonging to the 11 basaltic fissure volcanic systems located in different islands (Nunes & Lima, 2008). These monogenetic eruptive centres include domes and *coulées*, tuff rings and tuff cones, *maars*, scoria and spatter cones, and eruptive fissures. Many of those features may be considered as geosites, together with other volcanic structures (such as historical eruptive centres and products, hydrothermal fields, pillow

lava and prismatic jointing outcrops, volcanic caves and primary pyroclastic deposit exposures), tectonic structures (fault scarps, sag ponds), sedimentary deposits (fossiliferous marine deposits of Miocene to Quaternary age, flood deposits, secondary lahars), and littoral features (e.g. littoral platforms of volcanic or landslide origin – locally called 'fajãs'). Additionally, some offshore sites are also worth mentioning, such as the Lucky Strike and Menez Gwen black smokers associated with this deep-sea hydrothermal fields and the Dom João de Castro Bank seamount volcano that erupted in 1720 A.D. and whose summit (at a depth of 12 m) presents an impressive field of fumaroles (Nunes et al. 2003).

Thus, the Azores may be considered a natural laboratory of international relevance with regard to active volcanism, volcanic and tectonic landforms, global plate tectonics, and neotectonics (Figures 4.2 and 4.3). The archipelago displays varied and abundant geological features of scientific, educational, scenic, socio-cultural and economic (touristic) interest, both on the islands and at sea, whose intrinsic value was evaluated during the preparation of the Azores Geopark project (Lima, 2007; Nunes et al., 2011; Nunes & Lima, 2013).


a


b


c


d


e


f


g


h


i

Figure 4.2 *Examples of volcanic features and landforms from the Azores Islands; a) Lava delta and tuff cone (Velas, São Jorge Island); b) Prismatic jointining (Ribeira do Maloás, Santa Maria Island); c) Maar (Caldeira Negra, Flores Island); d- Subsidence caldera (Caldeirão, Corvo Island); e) Stratovolcano (Pico Mountain, Pico Island); f) Boiling water-type fumarole (Furnas, São Miguel Island); g) Silica stalactites (Algar do Carvão volcanic pit, Terceira Island); h) Slumping marks (Monte da Guia, Faial Island); i) Volcanic neck (Ilhéu da Baleia, Graciosa Island). © Photos: J.C. Nunes.*

a b c

Figure 4.3 *Examples of tectonic features of the Azores Islands: a) Normal faulting in a plinian pumice type sequence (Fogo Volcano, São Miguel Island); b) Fault scarps of Pedro Miguel graben (Faial Island); c) Lagoa do Capitão fault scarp and sag pond (Pico Island). © Photos: J.C. Nunes.*

THE AZORES ISLANDS GEOLOGY: A BRIEF SUMMARY

Santa Maria Island

Santa Maria Island has an area of 97 km^2 and is part of the Eastern Group of the archipelago, together with São Miguel Island and the Formigas Islets, the latter located about 37 km northeast from Santa Maria Island.

Santa Maria is the southern and easternmost island of the archipelago, was the first one to be discovered and settled and was also the first to be formed. Therefore the island can be considered the geological birth place of the archipelago which emerged about 10 million years ago at the Baia dos Cabrestantes area, where the older rocks of the Azores are still visible as outcrops (Figure 4.4).

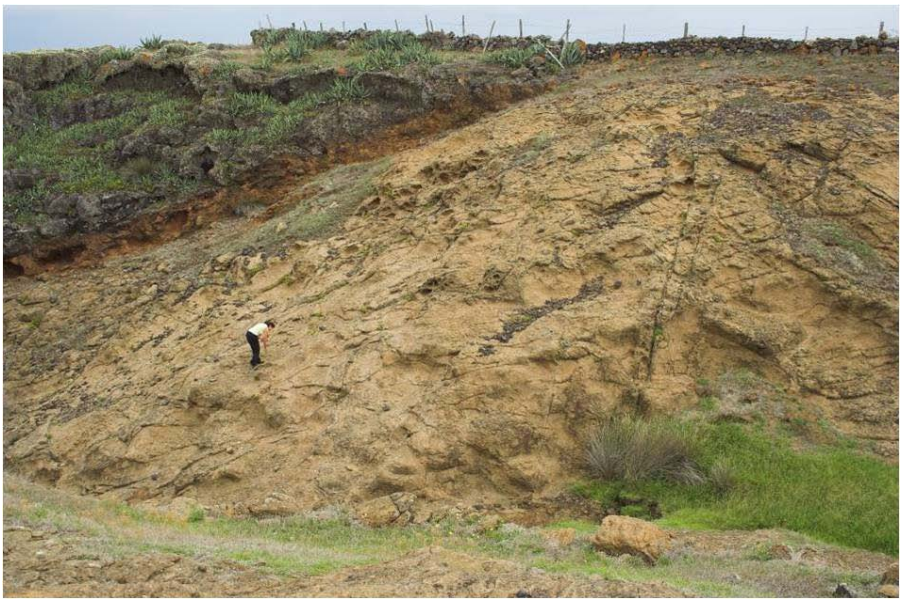

Figure 4.4 *The Surtseyan tuffs at the Baia dos Cabestantes on Santa Maria Island are the oldest rocks of the Azores archipelago and are covered by basaltic lava flows (top left). © JCNunes.*

Showing a volcanic origin like the other Azorean islands, in spite of not presenting active volcanism, Santa Maria includes several volcanic complexes, almost all of basaltic rocks, either associated with submarine or terrestrial volcanism. Besides the oldest geological formations of the archipelago, Santa Maria island exhibits unique and distinctive characteristics, such as i) major outcrops of pillow lavas, ii) important areas with consolidated sedimentary rocks, including limestone, sandstone, claystone and conglomerates, and iii) a remarkable fossil content in many of the sedimentary rocks.

São Miguel Island

São Miguel Island is part of the Eastern Group and is the biggest island of the archipelago with a 747 km^2 surface area and about 56% of the Azores population.
In general terms São Miguel Island's volcanism is associated with four main silicic polygenetic volcanoes, each with a summit caldera (Povoação, Furnas, Sete Cidades and Fogo central volcanoes) and two areas of exclusively basaltic volcanism (Figure 4.5). The latter display different ages: the Nordeste volcano complex is the oldest on the island, and the Picos complex is the most recent, occupying the area between Relva-Lagoa (on the South coast) and Capelas-Ribeira Grande (on the North coast).

Figure 4.5 *Furnas volcano caldera (São Miguel Island) is the most relevant terrestrial geosite of the Azores archipelago. © JCNunes.*

About 500 monogenetic volcanoes, 35 lakes of different size and a wide variety of mineral and thermal waters and hydrothermal fields are some testimonies of the geodiversity of São Miguel Island. Since the beginning of human settlement several eruptions have occurred, like the 1563 eruption (Fogo Volcano), the 1630 eruption (Furnas Volcano), and the Pico do Fogo, 1652 eruption, at the Picos Volcanic Complex. Besides these, submarine eruptions have occurred offshore São Miguel Island, the most famous being the Sabrina Island eruption, which took place offshore Ponta da Ferraria in 1811.

Terceira Island

Terceira Island is part of the islands of the Central Group, and with a 400 km^2 area is the second most populated of the archipelago. Terceira is composed of four polygenetic volcanoes with caldera (Cinco Picos, Guilherme Moniz, Santa Bárbara and Pico Alto central volcanoes) and by a basaltic fissure volcanism area, split in two main sectors of the island. The geology of the island is marked by impressive silicic effusive volcanism products, occurring as numerous domes and thick *coulées*, often with obsidian (Figure 4.6).

Figure 4.6 *Santa Barbara volcano at Terceira Island with its summit nested caldera and flank domes and coulées. © MPCosta.*

The historical volcanism dates back to the 18th century, with terrestrial eruptions in 1761 in the Mistérios Negros and in the Basaltic Fissural Zone, and submarine eruptions in 1867 and 1998-2001, the latter on the Serreta submarine ridge, northwest of Terceira Island. The submarine volcano of Serreta, which was active from 1998 to 2001, was the last volcanic episode of the archipelago and an important milestone for the international volcanology community, as it allowed the first observations and interpretation of Serretian-type eruptions.

The Dom João de Castro Bank is an important active seamount volcano, located about 63 km southeast of Terceira Island, with an impressive submarine fumarolic field, and was an ephemeral island following the 1720 A.D. eruption.

Graciosa Island

Graciosa is the northernmost island of the Central Group and the second smallest island of the archipelago (with an area of 61 km^2). It is also the one with the lowest altitude of the archipelago, displaying only 405 m at its highest point.

Graciosa Island includes the smallest polygenetic volcano of the Azores (the Caldeira Volcano) which takes up most of its southeast side. In contrast, the northwest sector of the island is dominated by a field of 32 basaltic scoria cones and their associated lava flows.

After discovery and settlement of the island no volcanic eruptions were reported, and the last volcanic eruption was associated with the Pico Timão scoria cone, less than 2,000 years ago. Besides this Holocene eruption, the active volcanism of the island is well expressed in its fumarolic fields, the most important one being located inside the Furna do Enxofre volcanic cave (Figure 4.7).

Figure 4.7 *Furna do Enxofre volcanic cave at Graciosa Island. © GESPEA & J.Góis.*

São Jorge Island

São Jorge is the most central island of the archipelago with an area of 244 km^2 and is characterized by its elongated shape, being the second biggest island in length after São Miguel.

The distinctive geological features of the island are: i) its exclusive basaltic volcanism, ii) the absence of a central volcano, and iii) being an island with a long volcanic ridge, composed of about 350 cones (mostly scoria cones) and associated basaltic lava flows

(Figure 4.8). The smooth and flatten morphology east of the Ribeira Seca stream shows the older age of this sector of the island, where 1.3 million years old lava flows outcrop.

Besides the regional tectonic control that influences its shape, the volcanic landscape of the island is dominated by the several 'fajãs' that are emplaced at the foothills of the high sea cliffs of the island (either as detritic slope deposits or as lava deltas), which are the main touristic exhibits of the island.

Figure 4.8 *Volcano-tectonic alignment of scoria cones (foreground) and Morro Grande de Velas Surtseyan tuff cone peninsula (top left) at São Jorge Island. Pico Island is in the background. © JCNunes.*

The volcanism of the island includes also some submarine episodes, such as those responsible for the genesis of the Morro Grande de Velas and Morro de Lemos Surtseyan tuff cones. Historical eruptions took place on this island in 1580 (at three different eruptive centres) and in 1808. More recently in 1964 a submarine eruption took place off the coast of Velas.

Pico Island

Pico is the biggest island of the Central Group, the second largest of the archipelago (445 km^2) and exhibits the highest point of Portugal (2350m), the Pico Mountain volcano, which is the 3rd highest volcano of the North Atlantic Ocean. In relation to the

surrounding sea-floor Pico Mountain is a 3500m high stratovolcano, characterized by dominant effusive basaltic volcanism episodes of Hawaiian type eruptions and extensive pahoehoe lava fields (Figure 4.9).

Figure 4.9 *Basaltic pahoehoe lava field at the UNESCO's site 'Landscape of the Pico Island Vineyard Culture'. Note the 'rilheiras' excavated by the wheels of vehicles pulled by animals. © JCNunes.*

The main geological features of the island are related to the fact that Pico is the youngest island of the archipelago (about 300,000 years old) and its volcanism is essentially basaltic, evident either in the Pico Mountain volcano, the Topo shield volcano or in the volcanic ridge of the Planalto da Achada. This latter area has a length of 30 km and is composed of about 190 scoria and spatter cones and eruptive fissures.

Since the island's settlement there have been historical eruptions in 1562/64, in 1718 and in1720. It is important to mention that the 1718 eruption had two subaerial eruptive centres and a third submarine vent offshore the southern coast of the island. The last eruption took place in 1963 off the northern coast of the island, north of Cachorro, being a serretian-type submarine eruption.

Faial Island

Faial, with an area of 173 km^2, is the westernmost island of the Central Group and the one closest to the Mid-Atlantic Ridge, located about 120 km east of the MAR (Figure 4.10).

Figure 4.10 *Costado da Nau fossil sea cliff, the westernmost Faial Island shoreline prior to the Capelinhos eruption (1957-58 A.D.). © JCNunes.*

Generally speaking, the islands' volcanism is associated with the presence of two main central volcanoes (the Caldeira and Ribeirinha volcanoes) and two areas of markedly fissural basaltic volcanism (the Horta Basaltic Zone and the Peninsula of Capelo).

The polygenetic volcano of Caldeira dominates all of the central part of the island and in recent times is characterized by explosive eruptions of trachytic nature, with the extrusion of large volumes of pumice. The summit of the volcano is occupied by a 2 km diameter, 470 m deep and 10,000 years old caldera.

Besides the Ribeirinha shield volcano, the eastern part of the island of Faial is dominated by an important tectonic structure (the *Graben* of Pedro Miguel), with WNW-ESE trending active faults that deeply shape the volcanic landscape of the island.

Faial Island has seen two historical eruptions, in 1672/73 and in 1957/58, the latter at Capelinhos and inside the Caldeira. The Capelinhos eruption increased the size of the

island by 2.4 km^2 (nowadays only 0.6 km^2), and represents a historical mark in the World volcanology and for Faial's population and society.

Flores Island

Flores Island, with 141 km^2, is part of the Western Group of the archipelago and is the westernmost territory of Europe **(**Figure 4.11**)**.While it does not exhibit a major central volcano of large dimensions (like on the neighbouring island of Corvo), the most significant characteristic of this island is the presence of several explosion craters associated with hydromagmatic eruptions, which caused the formation of maars (e.g. Lagoa Funda and Lagoa Seca) and tuff rings (e.g. Caldeira Branca).

Figure 4.11 *The western coastline of Flores Island, which is the westernmost European territory. © JCNunes*

Also, the important drainage basins existing on this island (e.g. Badanela and Santa Cruz creeks basins) and the presence of several ancient volcanic cones, have shaped a landscape marked by several volcanic necks and outcropping dikes, the latter as walls that intersect the nearby landscape.
Along the shoreline are several sea erosion caves and well preserved prismatic and spheroidal jointing of lava flows. The Rocha dos Bordões is an excellent example of prismatic jointing in the 570,000 years old mugearitic lava flows.

Corvo Island

Corvo, with only 17 km^2 in area, is the smallest island of the Azores and together with Flores forms the Western Group of the archipelago. In spite of its small area, the island displays an interesting geodiversity, expressed namely by a wide diversity of rocks that includes basalts, trachytes, pumice, scoria, ignimbrites, etc.

The entire island is consistent with a polygenetic volcano with a summit caldera (named Caldeirão) and can therefore be considered an island-volcano. This volcanic depression has a 2.1 km average diameter and is occupied by a lake with a maximum depth of about 2 metres. This central volcano has several secondary cones, either on its flanks like the Cova Vermelha scoria cone, or inside the caldera, like the Montinho do Queijo spatter cone.

Due to the marine erosion the island undergoes, the nature of its volcanic products and the fact that this island does neither show historic volcanism nor any recent volcanic activity (e.g. during the last thousands of years), the shoreline of the island of Corvo is high and steep. A single exception is the Vila do Corvo lava delta, where the only community of the island is emplaced and where took place the last eruption that occurred in the island, at the Pão do Açucar-Moinhos area (Figure 4.12).

Figure 4.12 *Vila do Corvo lava delta at Corvo Island. Flores Island is in the background (top left). © EA Lima.*

THE AZORES GEOPARK AND GEOTOURISM

The international relevance of the Azorean geodiversity, the high number and quality of its geosites and the undoubted importance of its geological heritage (Brilha et al., 2005; Lima, 2007, Nunes et al., 2011; Nunes & Lima, 2013), together with a rich biological and cultural heritage, supported a major effort of the Azores Government to implement Geoconservation and Environmental Education policies. This resulted in the creation of the Azores Geopark and its application to the UNESCO's Global Geopark Network.

The Azores Geopark, the 53rd geopark of the European Geoparks Network after March 2013, is also supported on strategic decisions of the regional and local authorities to develop Nature Tourism policies based on the most effective tourism icon of the Azores: its volcanoes and volcanic landscape.

Despite its small land surface (2324 km^2), the archipelago offers a wide diversity of landforms, together with different types of rocks, structures and features, which derive namely from the type of eruption they originated from, its dynamics, the nature of the magmas, and the subsequent actions of weathering and erosion processes, and thus constitutes a natural laboratory of volcanic geodiversity.

The Azores archipelago includes 121 geosites, dispersed over the nine islands and the surrounding seafloor, with relevant scientific, educational and touristic value. Thus, volcanoes, calderas, lakes, lava fields, fumaroles, hot springs and thermal waters, volcanic caves, 'fajãs', fault scarps and marine fossil deposits, among many others, belong to this network of geosites.

Among those, 57 are considered as priority geosites for the Azores Geopark, and include 6 geosites of international relevance: the Mid-Atlantic Rift and associated deep-sea hydrothermal fields, the Furnas Volcano caldera, the Pico Mountain Volcano, the Graciosa Caldeira and Furna do Enxofre volcanic cave, the Capelinhos Volcano and the Algar do Carvão volcanic pit.

Given the insular nature of the region, the Azores Geopark is supported on a geosites network dispersed over the nine islands and the surrounding seafloor, i) that ensures the representativeness of the geodiversity that characterizes the Azorean territory, ii) that reflects its geological and eruptive histories, iii) with common conservation and promotion strategies, and iv) is based on a decentralized management structure with support of all the islands.

Besides the geological heritage of the Azores Islands, there are other values of reference in the archipelago, such as its rich biodiversity and the architectural, cultural, ethnographic and immaterial heritage of undeniable value. The Azorean geo-landscapes

are thus the main *ex-libris* of the archipelago, with huge potential for tourism due to its attributes of great attractiveness and good opportunities for sustainable use.

Following the "Strategic Plan of Marketing for Tourism in the Azores - 2008/2010" coordinated by the Azores Tourism Association (ATA) and the Azores Government, a geotouristic strategy was implemented based on two main principles: i) the development of intra and inter-islands routes, and ii) the implementation of dissemination actions accompanied by monitoring actions (Nunes et al 2010a; Nunes et al 2010b). The main routes proposed for the development of the Azores Islands geotourism include:

a) The Volcanic Caves Route – to discover the subterranean world of the islands, valuing the volcanic caves and associated visitor centers, such as 'Gruta das Torres' (Pico island), 'Gruta do Carvão' (São Miguel island), 'Furna do Enxofre' (Graciosa island) and 'Algar do Carvão' and 'Gruta do Natal' (Terceira island);
b) The Belvederes Route – to discover, by car, the Azores volcanic landscapes, valuing the numerous belvederes ('Miradouros' in Portuguese), and viewpoints that exist on all islands of the archipelago, often superbly located, with supporting infrastructure (e.g. benches, fences, parking areas, restrooms) and in general impeccably maintained;
c) The Walking Trails Route – to discover, by foot, the Azores geosites, enhancing the Regional Network of Walks and other trails in Azores, with more than 100 different options;
d) The Thermal Route – to discover and enjoy the power of Azores volcanism, taking advantage of the benefits in terms of health, leisure and well-being of the Azorean thermal waters and mud, as in Ferraria, Furnas, Caldeiras da Ribeira Grande, Caldeira Velha and Poça da D. Beija (São Miguel island), Carapacho (Graciosa island), Varadouro (Faial island), and Furnas do Enxofre (Terceira island);
e) The Science and Interpretation Centers Route – to learn and interpret the Azorean volcanic phenomena, valuing the 25 science, interpretation and visitors centers existing on all the islands, such as the Capelinhos Volcano Interpretation Center (Faial island), the Mountain House (Pico island) or the Astronomical Observatory and the ExpoLAB (São Miguel island);
f) The Urban Georoutes – to discover the geology of my village/town, that allow local population and visitors to see and learn about the rocks in buildings and monuments and to understand about the geology of urban areas.

The promotion and development of this geoturistic strategy and all these routes is a key issue and a priority goal for the Azores Geopark, taking into account the rich Azorean geodiversity, the high number and quality of its geosites and the undoubted importance of its geological heritage.

Thus, visitors and tourists are welcomed to use the walking trails, visit viewing points, belvederes and tea plantations, go whale-watching, dive in the blue ocean, go bird-

watching, enjoy the regional handicraft, taste the geothermal Furnas stew (cooked in the ground at a fumarolic field), taste the regional sweets and wines or take a bath in warm waters ... while visiting and being part of a fascinating tour in an active volcanic landscape.

The slogan: *"*Come to meet the Azorean volcanoes *and enjoy an eruption... of Flavours, Smells and Experiences",* says it all.

REFERENCES

Brilha, J.; Andrade, C.; Azerêdo, A.; Barriga, F. J. A. S.; Cachão, M.; Couto, H.; Cunha, P. P.; Crispim, J. A.; Dantas, P.; Duarte L. V.; Freitas, M. C.; Granja, M. H.; Henriques, M. H.; Henriques, P.; Lopes L.; Madeira, J.; Matos, J. M. X.; Noronha, F.; Pais, J.; Piçarra, J.; Ramalho, M. M.; Relvas, J. M. R. S.; Ribeiro, A.; Santos, A.; Santos, V. & Terrinha, P. (2005) Definition of the Portuguese frameworks with international relevance as an input for the European geological heritage characterisation, *Episodes* 28 (3): 177-186.

Forjaz, V. H.; França, Z. & Nunes, J. C. (2001) "Serretian, a new type of submarine eruptions". *Poster – "Cities on Volcanoes 2 – Abstracts Book"*. February. Auckland. New Zealand: 39.

França, Z.; Cruz, J. V.; Nunes, J. C. & Forjaz, V. H. (2003) Geologia dos Açores: uma perspectiva actual, *Açoreana* 10 (1): 11-140.

Laughton, A.S. & Whitmarsh, R.B. (1974) The Azores-Gibraltar plate boundary. *In:* Kristjansson, L. (Ed.), *Geodynamics of Iceland and the North Atlantic Area*. Dordrecht: D. Reidel: 63-81.

Lima, E. A. (2007) *Património geológico dos Açores: Valorização de Locais com Interesse Geológico das Áreas Ambientais, Contributo para o Ordenamento do Território*. Tese de Mestrado em Ordenamento do Território e Planeamento Ambiental. Departamento de Biologia. Universidade dos Açores.

Luis, J. F.; Miranda, J. M.; Galdeano, A.; Patriat, P.; Rossignol, J. C. & Mendes-Victor, L. A. (1994) The Azores triple junction evolution since 10 Ma from an aeromagnetic survey of the Mid-Atlantic Ridge, *Earth and Planetary Science Letters* 125: 439-459.

Lourenço, N.; Miranda, J. M.; Luis, J. F.; Ribeiro, A.; Mendes-Victor, L. A.; Madeira, J. & Needham, H. D. (1998) Morpho-tectonic analysis of theAzores Volcanic Plateau from a new bathymetric compilation of the area, *Marine Geophysical Researches* 20: 141-156.

Madeira, J. & Ribeiro, A. (1990) Geodynamic models for the Azores triple junction: a contribution from tectonics, *Tectonophysics* 184 (3/4): 405-415.

Madeira, J. & Brum Da Silveira, A. (2003) Active tectonics and first paleoseismological results in Faial, Pico and S. Jorge islands (Azores, Portugal). *In:* Pantosti, D., Berryman, K., Yeats, R.S. & Kinugasa, Y. (Eds.), Ten Years of Paleoseismology in the ILP: Progress and Prospects, *Annals of Geophysics* 46 (5): 733-761.

Miranda, J. M.; Mendes-Victor, L. A.; Simões, J. Z.; Luis, J. F.; Matias, L.; Shimamura, H.; Shiobara, H.; Nemoto, H.; Mochizuki, H.; Hirn, A. & Lépine, J. C. (1998) Tectonic setting of the Azores Plateau deduced from a OBS survey, *Marine Geophysical Researches* 20: 171-182.

Nunes, J.C. (2008) *Caracterização sumária da sismicidade da Região dos Açores*. In: C. S. Oliveira, A. Costa, J. C. Nunes – *Sismo 1998 - Açores. Uma Década Depois*. Governo dos Açores/SPRHI, S.A.: 59-72.

Nunes, J. C.; Forjaz, V. H. & França, Z. (2001) Principais sismos destrutivos no arquipélago dos Açores – uma revisão. *In:* M. R. Fragoso (Ed.), *5º Encontro Nacional de Sismologia e Engenharia Sísmica.* Ponta Delgada (Açores). Laboratório Regional de Engenharia Civil: 119-131.

Nunes, J. C.; Forjaz, V. H.; Alves, J. L. & Bernardes, A. C. (2003) Caracterização vulcanológica do Banco D. João de Castro (Açores): novos dados. *Ciências da Terra (UNL), nº esp.* V, CD-ROM: D55-D58.

Nunes, J. C. & Lima, E. A. (2008) Paisagens Vulcânicas dos Açores: Valor Intrínseco Enquanto Recurso Natural e Património Geológico. *Livro de Resumos – IV Congresso Nacional de Geomorfologia*, Braga, Outubro: 31.

Nunes, J. C. & Lima, E. A. (2013) Ranking and classifying the Azores Islands geosites. *Rendiconti Online della Società Geologica Italiana, Special Issue for the 12th European Geoparks Conference,* Ascea, Italy; Vol. XX: 4 p. *In Press*.

Nunes, J. C.; Lima, E. A.; Costa, M. & Porteiro, A. (2010a) Azores Islands geodversity and geological heritage: contribution to tourism development in the Autonomous Region of The Azores. In: M. L. Rodrigues & M. E. Freire (Eds.), *Proceedings of the International Conference on Geoheritage and Geotourism*. APGeotur & CEG-Univ. Lisbon: 63-64.

Nunes, J. C.; Lima, E. A.; Costa, M. P & Porteiro, A. (2010b) Azores Islands volcanism and volcanic landscapes: its contribution to the geotourism and the Azores Geopark Project. *Geociences On-line Journal* 18 (16):4 p.

Nunes, J. C.; Lima, E. A.; Ponte, D.; Costa, M. P. & Castro, R. (2011) Azores Geopark Application. Available at www.azoresgeopark.com, 50 p.

Nunes, J. C.; Madeira, J. & Brilha, J. (2009) The Azores archipelago in the America-Eurasia-Africa triple junction: a geological framework as the scientific background for the creation of the Azores Geopark. In: *C. N. Carvalho & J. Rodrigues (Eds)*,

Proceedings "8th European Geoparks Conference", *Idanha-a-Nova, Geopark Naturtejo, 14-16.Setembro*: 176-179.

Queiroz, G.; Gaspar, J. L.; Cole, P. D.; Guest, J. E.; Wallenstein, N.; Duncan, A. M. & Pacheco, J. (1995) Erupções vulcânicas no vale das Furnas (ilha de São Miguel, Açores) na primeira metade do século XV, *Açoreana* 8 (1): 159-165.

Searle, R. (1980) Tectonic pattern of the Azores spreading centre and triple junction, *Earth and Planetary Science Letters* 51: 415- 434.

Vogt, P. R. & Jung, W. Y. (2004) The Terceira Rift as hyper-slow, hotspot-dominated oblique spreading axis: a comparison with other slow spreading plate boundaries. *Earth and Planetary Science Letters* 218: 77-90.

Zbyszewski, G. (1963) Les phénomènes volcaniques modernes dans l'archipel des Açores. *Comunicações dos Serviços Geológicos de Portugal* 47: 231 p.

Weston, F. S. (1963/64) List of recorded volcanic eruptions in the Azores with brief reports. *Boletim do Museu e Laboratório Mineralógico e Geológico da Faculdade de Ciências de Lisboa* 10 (1): 3-18.