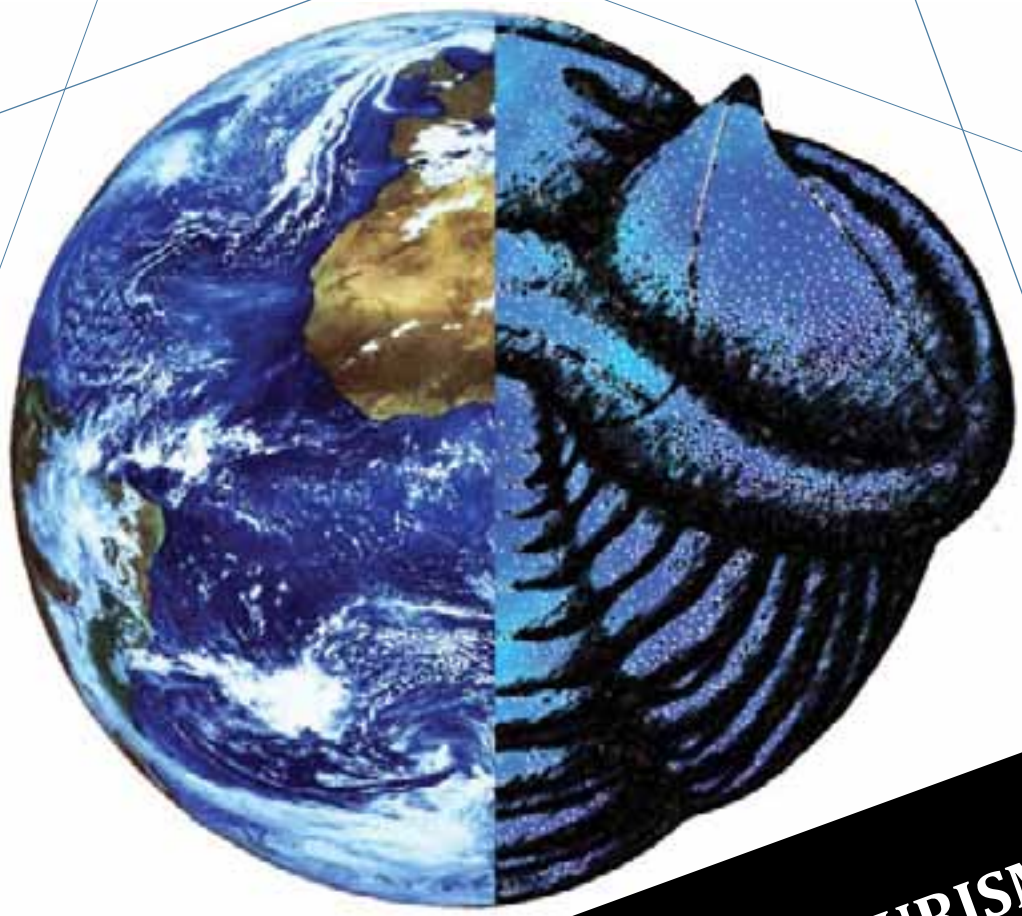

NEW CHALLENGES WITH GEOTOURISM

PROCEEDINGS OF THE VIII EUROPEAN GEOPARKS CONFERENCE

Idanha-a-Nova, 14-16 September 2009 (Portugal)

C. Neto de Carvalho & Joana Rodrigues (Eds.)

TITLE
New Challenges with Geotourism

EDITORS
Carlos Neto de Carvalho & Joana Rodrigues

EDITION
Idanha-a-Nova Municipality/ Geopark Naturtejo da Meseta Meridional

8th European Geoparks Conference Logo by
Andrea Baucon

DESIGN AND GRAPHIC COMPOSITION
ESCALA VERTICAL, Lda.
cristinafatela@gmail.com

PRINTED AND BOUNDING BY
PRINTMOR IMPRESSORES, Lda.

COPIES
500 ex.

LEGAL DEPOSIT
298910/09

ISBN
978-972-8285-52-4

THE AZORES ARCHIPELAGO IN THE AMERICA-EURASIA-AFRICA TRIPLE JUNCTION: A GEOLOGICAL FRAMEWORK AS THE SCIENTIFIC BACKGROUND FOR THE CREATION OF THE AZORES GEOPARK

João Carlos Nunes[1], José Madeira[2] & José Brilha[3]

[1]Departamento de Geociências, Univ. Açores; jcnunes@uac.pt. [2]LATTEX-IDL (L.A.) e Departamento de Geologia, Fac. Ciências Univ. Lisboa; jmadeira@fc.ul.pt. [3]Departamento de Ciências da Terra, Univ. Minho: jbrilha@dct.uminho.pt

The Azores Archipelago (a Portuguese Autonomous Region) is located on the triple junction between the North American, Eurasian and African (or Nubian) plates (Laughton & Whitmarsh, 1974; Searle, 1980; Vogt & Jung, 2004). 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 (Fig. 1).

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, with a WNW-ESE general trend, is oblique to the spreading direction 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 seismotectonic and neotectonic activity (Madeira & Ribeiro, 1990; Nunes *et al*., 2001; Madeira & Brum da Silveira, 2003; Nunes, 2008).

Figure 1: Azores Plateau bathymetry, after Miranda et al. (1998), left and location of the Azores Islands in the Atlantic Ocean and its general tectonic setting, modified from Madeira & Brum da Silveira (2003), right. MAR- Mid Atlantic Ridge; EAFZ- East Azores Fracture Zone; GF- GLORIA Fault. Shaded area is the shear zone that constitutes the Azorean segment of the Eurasia - Africa plate boundary.

The Azores Islands are formed by 16 major polygenetic volcanoes, most of them silicic and with summit subsidence calderas. Nine of these polygenetic volcanoes are active and are located on the islands of S. Miguel, Terceira, Graciosa, Pico, Faial and D. João de Castro Bank. Moreover, there are about 1750 monogenetic volcanoes in the archipelago, either dispersed along the flanks and inside the summit depression of the polygenetic volcanoes, either belonging to the 11 basaltic fissural 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 submarine hydrothermal fields and the D. João de Castro Bank submarine volcano that erupted in 1720 A.D., whose summit, at a depth of 12 m, presents an impressive fumaroles field (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 (Figs 2-3). 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 is under evaluation.

Figure 2: Examples of volcanic features and landforms from the Azores Islands: **a-** Lava delta and tuff cone (Velas, S. Jorge Island); **b-** Prismatic jointining (Ribeira do Maloás, S. 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, S. 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 by J.C. Nunes, except (a), by J. Madeira and (g), by "Os Montanheiros" SEE.

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), together with the rich biological and cultural heritage, all supported on a major effort of the Azores Government to implement Geoconservation and Environmental Education policies, strongly justifies the creation of the Azores Geopark and its application to the UNESCO's Global Geopark Network. The future Azores Geopark will also be supported on the strategic decision of the regional and local authorities to develop Nature Tourism policies based on the most effective touristic icon of Azores: its volcanic landscape.

Figure 3: Examples of tectonic features of the Azores Islands. **a-** Oblique slip (dextral/normal) faulting in a scoria cone (Cabeço Vermelho, Pico Island); **b-** Fault scarps of Pedro Miguel *graben* – north sector (Faial Island); **c-** Lagoa do Capitão fault scarp and sag pond (Pico Island). Photos by J. Madeira (a, b) and J.C. Nunes (c).

Acknowledgements

The present paper is a contribution to the Project "Identificação, Caracterização e Conservação do Património Geológico: uma Estratégia de Geoconservação para Portugal", Projecto PTDC/CTE-GEX/64966/2006 financed by the FCT- Fundação para a Ciência e Tecnologia.

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.

Laughton, A.S. & Whitmarsh, R.B. 1974. The Azores-Gibraltar plate boundary. *In:* Kristjansson, L. (Ed.), *Geodynamics of Iceland and the North Atlantic Area*. D. Reidel Publ. Co., Dordrecht, 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, 106 p.

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 the Azores 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 (Eds.), *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, p. 31.

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 S. 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**, 227 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.