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The volcanotectonic evolution of Flores Island, Azores (Portugal)

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Abstract

From the study and interpretation of the volcanic products and structures of Flores Island, we infer that its volcanic history was dominated by two major periods: (1) proto-insular volcanism, which includes all the submarine and emergent activities; and (2) insular volcanism, consisting exclusively of subaerial eruptions. The first period includes two phases: (1) the oldest (2.2 to 1.5 Ma) of shallow submarine volcanism; (2) the youngest (1.0 to 0.75 Ma) includes emergent volcanism. Throughout the second period, three volcanic stages are recognized: (1) the first one (0.7 to 0.5 Ma) includes the most voluminous volcanism, balanced between effusive and explosive events; (2) an intermediate stage (0.4 to 0.2 Ma) that involves a larger number of small-scale feeder centres, with effusive eruptions prevailing; (3) the third stage is the latest volcanic activity of the Island (≈0.003 Ma), with strombolian and subsequent phreatic and phreatomagmatic activity centred at four volcanic vents.

From 1.0 Ma to the present, the volcanotectonic development of Flores Island also reflects the operation of two major tectonic processes: (1) a marked volcanotectonic uplift during the first stage (1.0 to 0.55 Ma); and (2) subsidence, particularly intensive in the island's central area, which led to the subsequent formation of two and perhaps three large *calderas* during the period 0.55 to 0.4 Ma.

Keywords: volcanic island; volcanic complex and unit; volcanostratigraphy; subsidence and uplift

1. Introduction

Before the mid-1980s, no systematic and comprehensive geological study had been carried out on Flores Island. Our programme started in 1985 with the purpose of improving the 1:25,000 geological map of the island by Zbyszewsky et al. (1968). Initial studies focused on the older volcanic formations (Azevedo et al., 1986; Azevedo, 1988, 1990; Azevedo et al., 1991). Later mapping was extended to the entire island and island-wide volcanostratigraphy was defined. A new 1:15,000 volcanological map includes considerable new geochronologic, petrographic and geochemical data, as well as description of the tectonic and geomorphological histories (Azevedo, 1999, vol. 1; Azevedo and Ferreira, 1999). The volcanostratigraphy and related structural interpretation supported the further studies focused on hydrogeological modelling (Azevedo, 1999, vol. 2).

This paper provides a refined interpretation of the volcanic growth and the structural evolution of Flores, within the framework of the entire Azores region.

2. Geographic, geotectonic and geochronologic settings

Flores and Corvo islands constitute the western group of the Azores Archipelago (Fig. 1), which is near the middle of Atlantic Ocean and forms a 600 km-long

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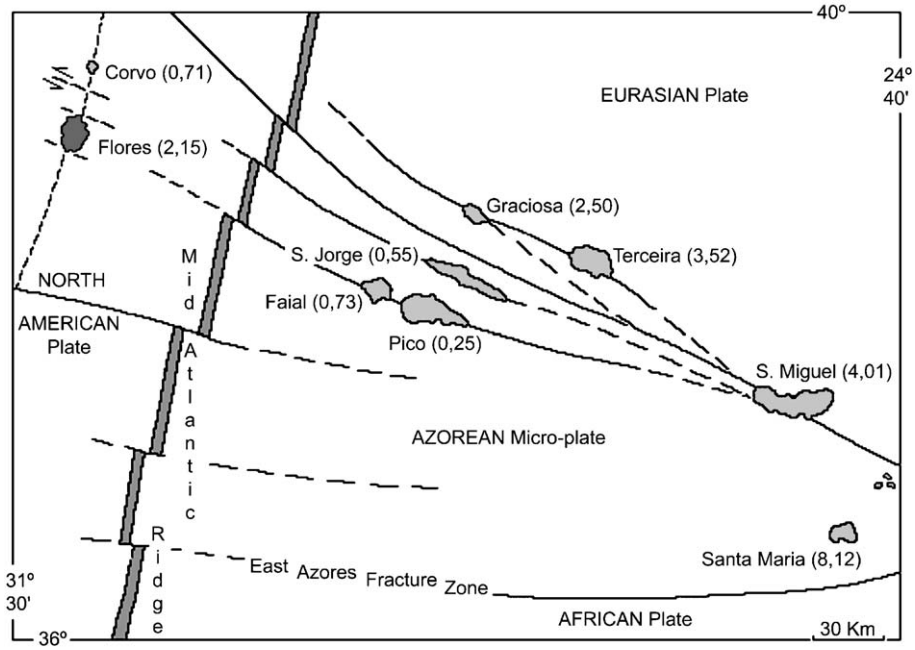

Fig. 1. Geographic and geotectonic setting of Azores Archipelago (adapted from Forjaz, 1988; Baptista et al., 1999) with the oldest radiometric ages (in parentheses; Ma) for each island (geochronological data from Abdel-Monem et al., 1968, 1975; White et al., 1976; Ferraud et al., 1980; Ferreira and Martins, 1983; Feraud et al., 1984; Forjaz, 1988; Azevedo et al., 1991; Azevedo, 1999; Nunes, 1999; Azevedo et al., 2003).

belt trending in a WNW direction. All nine islands (and related seamounts) of this archipelago are within a zone where three lithospheric plates (North American, Eurasian, and African) meet. Most of the islands are located along the fracture-zone extensions of transform faults of the Mid-Atlantic Ridge (MAR). Unlike the other seven islands, Flores and Corvo are on the North American Plate (Fig. 1). The islands of Central Group (Faial, Pico, S. Jorge, Terceira and Graciosa) and Eastern Group (S. Miguel and Santa Maria) are within a transition zone (called the Azorean micro-plate, after Forjaz, 1988) between the Eurasian and African Plates.

Several interpretations and models for the tectonic setting and geodynamic regime of the Azorean region have been proposed mainly on the basis of neotectonic, seismotectonic, GPS data and paleomagnetic interpretations (see for example: Krause and Watkins, 1970; McKenzie, 1972; Machado et al., 1972; Searle, 1980; Hirn et al., 1980; Machado et al., 1983; Buforn et al., 1987; Madeira and Ribeiro, 1990, 1992; Freire Luís et al., 1994; Madeira, 1998; Baptista et al., 1999).

Existing geodynamic models are mainly or exclusively focused on the islands of the Central Group (i.e., Azores microplate) and generally lack a detailed discussion of the tectonic regime for the Western Group islands of Flores and Corvo. This lack reflects the situation that these two islands: (1) are west of the MAR; (2) are aligned north–south, which is parallel to the MAR and nearly perpendicular to the alignment of the other Azorean islands; (3) have no record of significant historical seismicity; and (4) are subjects of few geophysical surveys.

Nonetheless, the results of several studies (Serughetti and Rocha, 1968; Krause and Watkins, 1970; Blakely, 1974; Azevedo, 1988, 1990; Azevedo et al., 1991; Bastos et al., 1993; Freire Luís et al., 1994; Azevedo and Ferreira, 1995; Baptista et al., 1999; Azevedo, 1999; Azevedo and Ferreira, 1999) support the following observation about Flores and Corvo volcanotectonic setting:

- Both islands are high subaerial parts of a single large mostly submarine edifice, built on a 9.0 to 10.0 Ma oceanic crust (Blakely, 1974; Needham and Francheteau, 1974; Freire Luís et al., 1994).
- The tectonic setting and volcanic construction of both islands are likely related to the geodynamics of the MAR and associated transform faults. However, this inferred that structural control is clearly less evident than those for the central and eastern Azorean islands.
- A westward displacement of Corvo from Flores at about 1 cm/year (Baptista et al., 1999), together with the near-linear E–W north and south coastlines of