e-Terra
http://e-terra.geopor.pt
ISSN 1645-0388
Volume 5 – nº 1
2008

Revista Electrónica de Ciências da Terra
Geosciences On-line Journal

GEOTIC – Sociedade Geológica de Portugal

Geochemistry of Volcanic Rocks from Faial Island (Azores)

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ABSTRACT: Whole rock geochemistry of nine rocks from Faial Island (Azores) was used to characterize Faial Island volcanism. Studied rocks are lavas and were classified based on chemical data as basalts, hawaiites and trachyte. These rocks represent five stratigraphic units of island, from the base to the top: Ribeirinha Volcanic Complex, Cedros Volcanic Complex, Almoxarife and Capelo formations. The rocks belong to the sodic alkaline series, with the exception of the trachytic rock, that exhibits potassic affinity. Faial Island volcanism is characterized by low SiO2 contents (45 to 49 %), high TiO_2 (2 to 3 %) and P_2O_5 (0.29 to 0.74 %). MgO shows values varying from medium to high (2 to 15 %). The trachyte has 62 % of SiO_2, low MgO (0.42 %), TiO_2 (0.53 %) and P_2O_5 (0.13 %) contents. Al_2O_3 varies from low to high (11 to 18 %) and reflects the plagioclase abundance variation. Na_2O+K_2O values increase with fractionation and K_2O/Na_2O ratio is less than 0.54, with the exception of the trachyte (0.73). Ni content decreases with magmatic evolution, from 356 to 5 ppm. The presence of the cumulate phases in basalts of Almoxarife and Capelo formations explains the MgO and Ni high values. Almost all the samples show Rb, Ba, Ta, Nb, Zr enrichment and Th, Sm impoverishment. The trachyte shows Ba enrichment and K depletion. Zr positive anomaly and U, Sr, P, Ti negative anomalies are observed in the trachyte. The REE patterns are typical of oceanic island lavas, showing LREE enrichment relative to MREE and HREE. The REE patterns suggest a continuous fractionation from a common melt generated by low partial melting rates. The rocks of Faial Island are the result of fractional crystallization and derived from a magma, which has mixed characteristics, mainly reflecting PREMA and EM II reservoirs, with minor contribution of HIMU.

KEYWORDS: volcanism, alkaline rocks, sodic series, Faial, Azores.

1. INTRODUCTION

The Azores archipelago lies from 37º - 40ºN and 25º - 31ºW in the North Atlantic Ocean, close to the Mid-Atlantic Ridge (MAR) and to the triple junction between American, African and Eurasian lithospheric plates. The Azorean islands rise from Azores Platform, defined by bathymetric curve of 2000 m (Needham and Francheteau, 1974), which has WNW-ESE trend and occupies a area close to 400.000 km^2 (Lourenço et al., 1998). The Azorean Platform represents a geodynamic zone very complex and the main structures that affect the region are: Mid-Atlantic Ridge (MAR), East Azores Fracture Zone (EAFZ), Terceira Rift (TR) and Gloria Fault (GF) (fig. 1). The MAR is a pure extensional structure, active seismically, with N-S trend, which separates the American Plate from African and Eurasian plates. The EAFZ, from which the continuation to East from the archipelago is designed by GF, shows great fractures and can be considered as a limit between African and Eurasian plates (Lourenço et al., 1997). The GF corresponds to a well-defined E–W right lateral-slip fault and constitutes part of the border between African and Eurasian plates. The TR is an extensive structure, with WNW-ESE trend, composed by many basins separated by crests and blocks (Machado, 1959a,b; Searle, 1980). The dynamic of this region, concerning the border, between Eurasian and African plates, is still under debate and several models have been proposed since Krause and Watkins (1970), and more recently, Madeira (1998), passing by McKenzie (1972), Machado (1982, 1992), Machado et al. (1972), Ribeiro (1982), Forjaz (1983), Madeira and Ribeiro (1990, 1992), Luís et al. (1994) and Lourenço et al. (1997).

The Faial Island, one of the nine islands of the Azores archipelago, belongs to the Central Group and is the westernmost of its own group. The island lies from 38º30’56’’ - 38º38’40’’N and 28º35’55’’ - 28º50’06’’W, is 8.3 km away from Pico Island and 26 km from São Jorge Island. This island is located about 120 km east of the Mid-Atlantic Ridge, on the seismically active Faial-Pico Fracture Zone (fig.1).

This study used whole rock and isotope analyzes of the nine samples from Faial Island collected during a fieldwork made in September 2005. The data were used to classify geochemically the rock-types, to characterize the geochemical pattern of the volcanism, to identify the main magmatic process involved in the generation of the rocks and the magma source type.

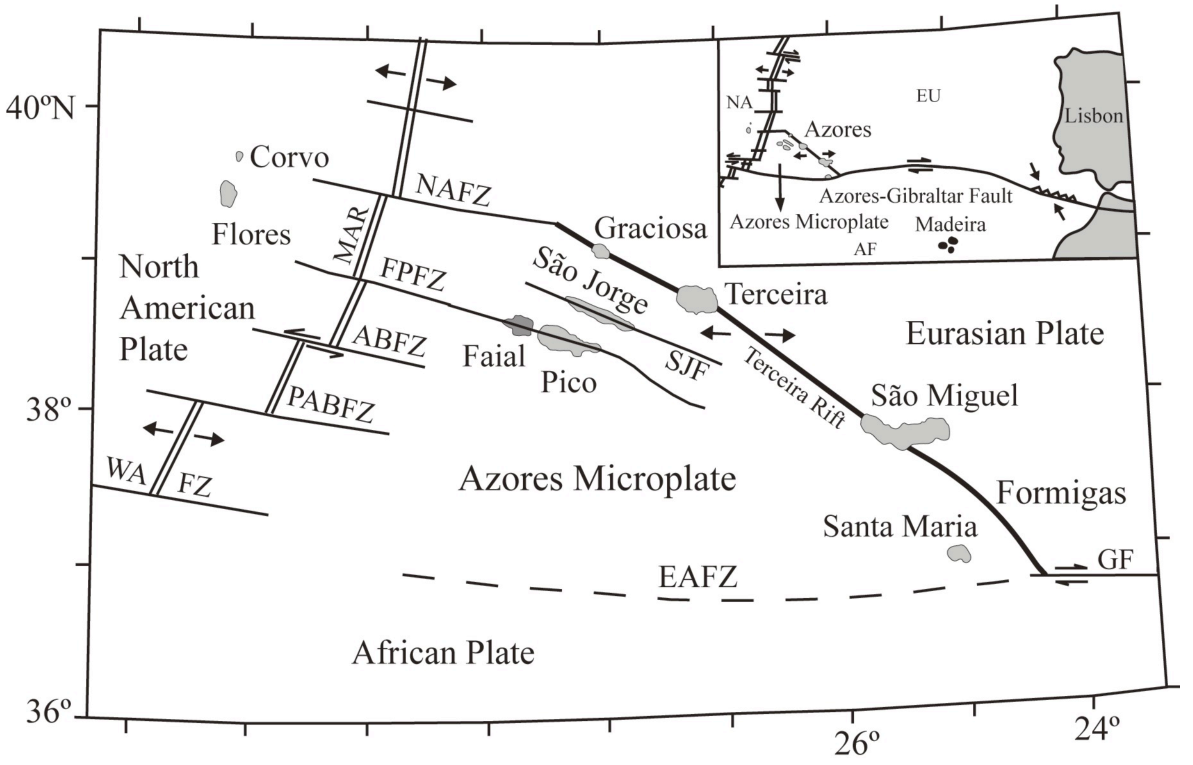

Figure 1 – General geotectonic framework of the Azores archipelago (adapted from Nunes et al., 2006). MAR = Mid-Atlantic Ridge; EAFZ = East Azores Fracture Zone; WAFZ = West Azores Fracture Zone; NAFZ = North Azores Fracture Zone; FPFZ = Faial–Pico Fracture Zone; ABFZ = Açor Bank Fracture Zone; PABFZ = Princess Alice Bank Fracture Zone; GF = Gloria Fault; SJF = São Jorge Fault; EU = Eurasian Plate; AF = African Plate; NA = North American Plate.

2. GEOLOGY OF FAIAL ISLAND

The island, which has maximum 21 km length, 14 km width, 173.1 km^2 area and a pentagonal shape, is affected by important tectonic features with a WNW-ESE general trend. These features combined with faults of the NNW-SSE to NW-SE and NE-SW trends may have conditioned the emplacement of the central volcano with caldera on the central part of the island (Caldera Volcano).

According to Madeira (1998) and Pacheco (2001), the island shows four geomorphological units, such as Caldera Volcano, the Pedro Miguel Graben, Horta Platform (Horta-Flamenos-Feteira areas) and Capelo Peninsula (fig. 2). These units result from the interaction between the tectonic and the volcanism.

The Caldera Volcano constitutes the main geomorphological unit and corresponds to formation of a polygenetic volcano with caldera of 2 km diameter at the top and 1 km diameter at the base. The deep of caldera is about 380 m and the walls are abrupt. The inner of the caldera shows a scoria cone with 50 m high, which is resulting of post caldera volcano activity (Madeira, 1998). The slopes of volcano walls increase with the altitude. The main superficial cover of Caldera Volcano is pyroclastic material such as pumitic rock projection, phreatic and phreatomagmatic deposits, pyroclastic flows and lahars, which allowed the formation of a dense radial hydrographic system (Madeira, 1998). The Caldera Volcano geomorphological unit is still constituted by Morro de Castelo Branco, a trachytic dome that forms a small peninsula and represents a resistant relief to the sea erosion.

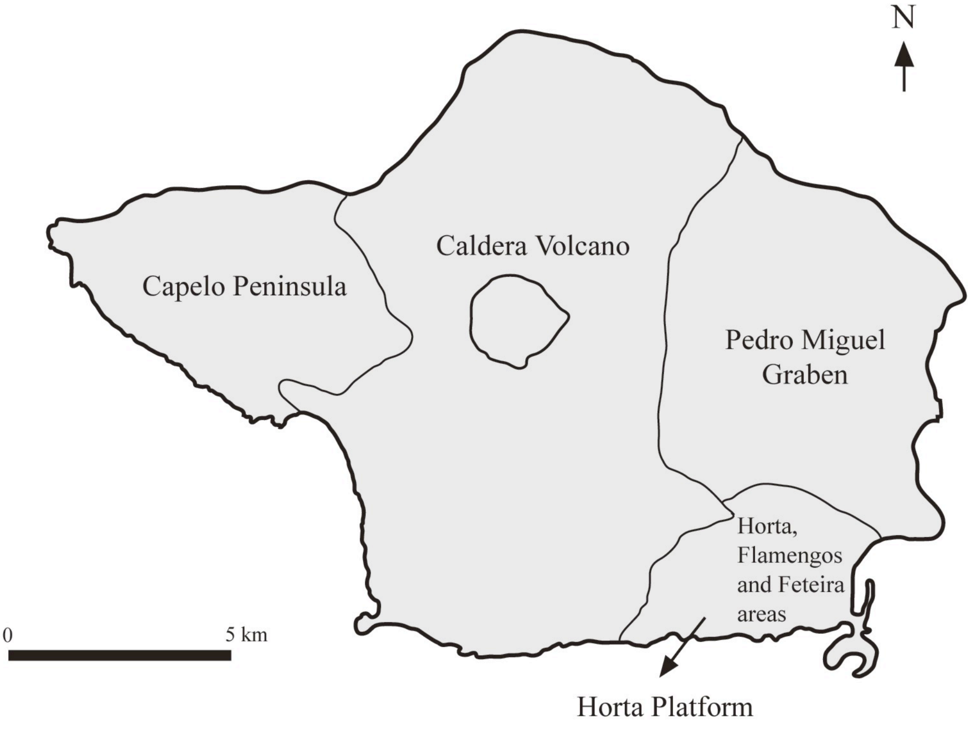

Figure 2 – Faial Island map showing the geomorphological units defined by Madeira, 1998 (modified from Cruz, 2006).

The Pedro Miguel Graben unit has WNW-ESE trend, occupies NE area of the island and is characterized by an extensive fault system that compose the own graben. This unit still shows traces of old Ribeirinha Central Volcano, which is much eroded and cut by graben.

The Horta Platform, localized at SE of the island, is characterized by low altitude and a smooth relief resulting of lava flow covers. This unit shows many strombolian cones as well as the Monte da Guia tuff surtseyan cone. The volcanic cones make limit with smoothly planed areas constituted by lava flows with pumitic cover and in some cases, sedimentary materials.

The Capelo Peninsula is the more recent area and is composes by several scoria cones line, which are consistent to WNW-ESE fault system and are the result of basaltic volcanism of low explosivity. In case of Capelinhos and Costado do Nau, the volcanism was characterized by surtseyan phase in the beginning. The activity of the monogenetic volcanic cones allowed the emission of basaltic pyroclastic and lava flows, which flowed to south and north of the island, contributing to increase the primitive island area.

3. ERUPTIVE HISTORY AND VOLCANOSTRATIGRAPHY OF THE ISLAND

The Faial Island began its formation with submerse deposits, from which are not known any out crops. By successive accumulation of lava flows and pyroclastic materials, the island was built and the volcanism passed from submerse to subaerial.

The first phase of island building was the formation of Ribeirnha Central Volcano followed by Caldera Central Volcano, contemporaneous to Ribeirinha Central Volcano, which was extinguished and dismantled. The third and fourth phases are represented by Horta Platform and Capelo Peninsula, respectively. Both phases are contemporaneous to developing of Caldera Central Volcano.

Zbyszewski et al. (1959) made the first geological map of the island, which is based essentially in lithological criterions. Afterwards, several volcanostratigraphic maps were proposed (Machado and Forjaz, 1968; Forjaz, 1977; 1980; Chovelon, 1982; Serralheiro et al., 1989 and Madeira, 1998) as resulted of successive works of detail that many authors developed a long of time.

Pacheco (2001) reorganized the volcanostratigraphy from Serralheiro et al. (1989) and showed a volcanostratigraphy agree with Madeira (1998). Four geological main units were considered by Pacheco (2001): Ribeirinha Volcanic Complex, Cedros Volcanic Complex, Almoxarife and Capelo formations (fig. 3).

In this work, we choose to use the volcanostratigraphy established by Pacheco (2001) to correlate the studied samples since this volcanostratigraphy is in concordance with our fieldwork observations and data.

The birth of the island began some 730.000 years ago (Féraud, 1977) with the emplacement of a volcano on the NE of the island, the Ribeirinha Volcanic Complex, which consists of a series of lava flows of basaltic, hawaiitic, mugeritic and benmoreitic composition as well as pumitic deposit, welded scoria, ignimbrites and basaltic pyroclasts. The lava flows are frequently altered by vesicles and fractures filled by secondary minerals. According to Pacheco (2001), due to predominance of lava flows, this volcano would have been a shield central volcano, which centre would be in the Pedro Miguel Graben axis. At the Present, this volcano is eroded and the tectonic movements of Pedro Miguel Graben affected the area where there are traces of Ribeirinha Volcano. Subsequently, from West of Ribeirnha Volcano, it was formed the Caldera Central Volcano (Cedros Volcanic Complex), about 410.000 years old (Serralheiro et al., 1989), which would have emerged in confluence with several tectonic structures and corresponds to all products from Caldera Volcano. The initial phase is not preserved due to subsidence phenomenous resulting of dynamic from distensive system that affected the island. This complex was divided in Lower and Upper Groups (Pacheco, 2001) reflecting a chemical and volcanism type variation that occurred about 16.000 years old. The Lower Group is marked by predominance of hawaiian/strombolian eruptive style with emission of products formed until 16.000 years old and of basaltic to benmoreitic composition. The Upper Group shows ages from 16.000 to the Present, being the eruptions predominantly explosive and the volcano has been showed predominance of sub-plinian activity, emitting products more evolved. Pacheco (2001) separated 12 sub-plinian eruption deposits in Upper Group, which are characterized by pumice fall and surge deposits besides pyroclastic flows of trachytic to benmoreitic composition.

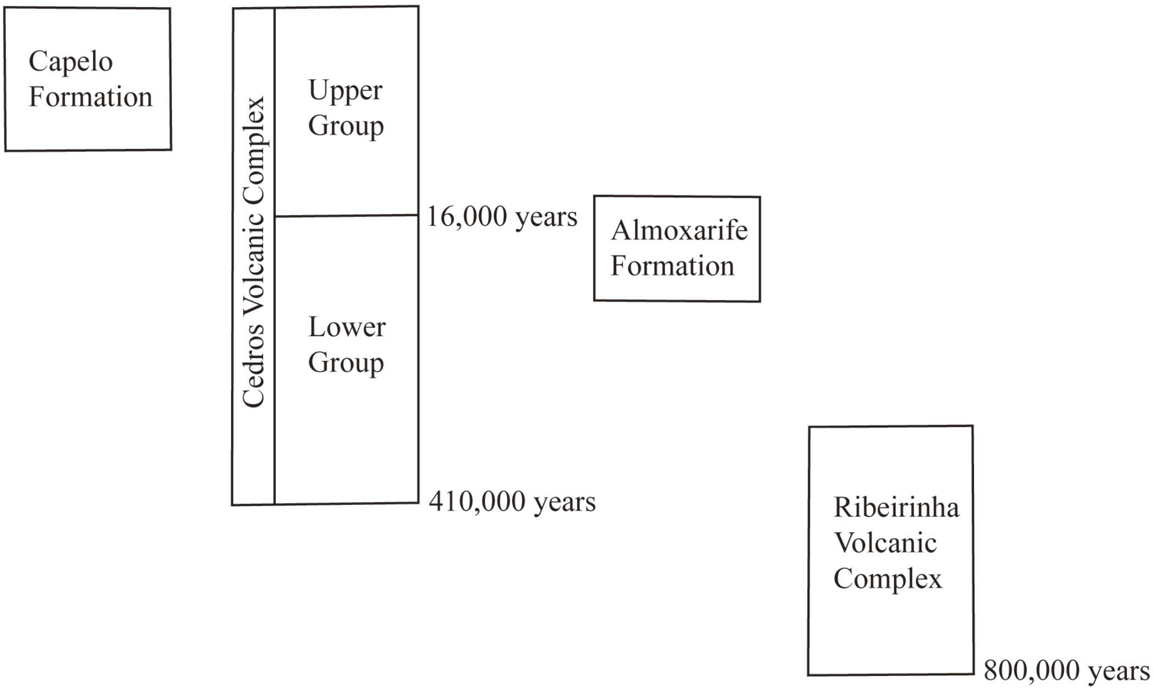

Figure 3 – Volcanostratigraphic column elaborated by Pacheco (2001).

After the formation of Lower and Upper Groups, the island rise to SE, resulting of fissural volcanism with a trend identical to the Pedro Miguel Graben, building the Horta Platform (Almoxarife Formation), whit deposits showing ages around 11.000 years (Serralheiro et al. 1989). Thus, a hydromagmatic volcanism of surtseyan type begin its activity, that along time gave source to an eruptive activity from low to media explosivity. The physical conditions allowed the isolation of ducts and consequently, the formation of subaerial volcanism of hawaiian or strombolian type. The Almoxarife Formation consists of lava flows that vary from alkaline-olivine basalts to hawaiites-mugerites and mugerites-benmoreites. The lava flows interbedded with pumice levels and subaerial-submarine basaltic pyroclasts, which build some scoria and tuff cones. The volcanic activity of this unit began as hydromagmatic passing to emergent until became subaerial, according to volcanic products accumulated.

The Capelo Peninsula (Capelo Formation), which is the unit most recent of the island, comprises the western fissural volcanism and the historical eruptions of Cabeço do Fogo and Capelinhos. Just as Horta Platform, this peninsula shows volcanic shapes and products resulting of surtseyan, hawaiian and strombolian volcanism types. Capelo Formation is composed predominantly by basaltic types, although hawaiitic rocks are also observed with less frequency.

4. ANALYTICAL PROCEDURES

Whole rock analyses of nine samples were carried out in the ACME Labs (Canada) using a Groups 4A, 4B and 1DX routines. Major elements were analyzed by ICP - emission spectrometry. Rare Earth and refractory elements are determined by ICP mass spectrometry. All results are presented in wt%.

Isotope determinations were carried out at the Isotope Geochemistry Laboratory of Federal University of Rio Grande do Sul, Brazil. Rock powders for Sr and Sm-Nd analyses were dissolved in PFTE vials on hot plate using HF, HNO_3 and 6 N HCl. Sr and REE were extracted using a standard AG-50W cation resin. Sm and Nd were extracted using HDEHP-coated Teflon powder. Pb was extracted with ion-exchange techniques with AG-1 x8; 200-400 mesh anion resin. Isotopic compositions were measured with a VG sector 54 mass spectrometer using the static mode.

5. PETROGRAPHY

The studied samples are representative to the volcanostratigraphic units defined by Pacheco (2001): Ribeirinha Volcanic Complex (one hawaiite), Cedros Volcanic Complex (two hawaiites and one trachyte), Almoxarife Formation (two hawaiites and one basalt) and Capelo Formation (one basalt and one hawaiite).

The rock classification is based on chemical data (fig. 4). $Na_2O > K_2O$ prevails in all the samples, so that the trachybasalts are classified as hawaiites, according to the IUGS Subcomission on the Systematics of Igneous Rocks (Le Maitre, 1989).

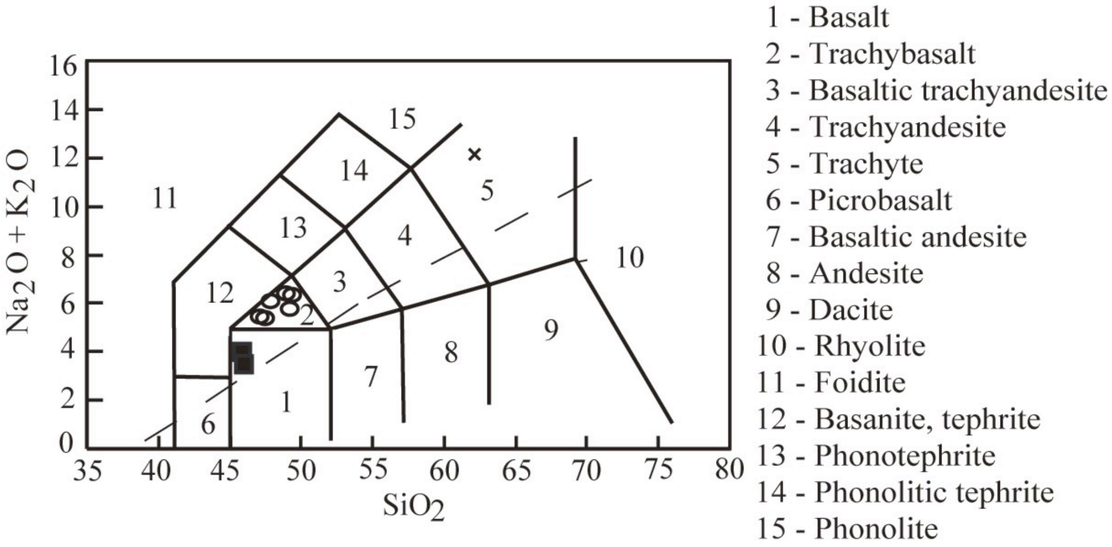

Figure 4 – Total Alkali-Silica diagram (TAS) in weight percentages. Compositional fields defined by Les Bas et al. (1986). The dashed line separates the alkaline rocks of sub-alkaline one, according to Rickwood (1989). Symbols: ■ = basalts; ○ = hawaiites and x = trachyte.

The basalts show glomeroporphyritic, porphiritic textures and consist of phenocrysts of plagioclase, olivine and clinopyroxene. The basalt of Capelo Formation shows cumulates of clinopyroxene and olivine. The groundmass shows intergranular, pilotaxitic and intersertal textures, and is composed of microcrysts of plagioclase, clinopyroxene, olivine, opaque minerals, rarely, apatite and altered volcanic glass. The phenocrysts of plagioclase often contour some vesicles. Phenocrysts of olivine and clinopyroxene predominate in relation to plagioclase. The calcite, epidote, chlorite, iron oxide minerals are common as minerals of alteration. The olivine is colorless, subedric to euedric, in general, is fractured and altered to bowlingite, iddingsite and serpentine. Some crystals show inclusion of apatite and opaque minerals. The clinopyroxene is light-green, subedric to anedric. Rarely, some crystals show twinning and zonation. The plagioclase shows Carlsbad-Albite twinning, oscillatory zonation and in general, the crystals show corroded rims.

The hawaiites show similar textures and mineralogy than those showed by basalts, although some samples show the presence of phenocrysts or microphenocrysts of amphibole, which shows dark-brown color and subedric shape.

The trachyte shows trachytic texture composed of microphenocrysts of plagioclase and K-feldspar. These minerals sometimes appear as phenocrysts as well. Amphibole, biotite, opaque minerals, apatite can be observed too. The K-feldspar is colorless, euedric to subedric, sometimes shows undulatory extinction and corroded rims. The phenocrysts of biotite occur as palettes disseminated in the matrix or associated to transformation of other minerals.

6. GEOCHEMISTRY

Faial volcanism is characterized by low SiO_2 contents (45 to 49 %) (table 1). The MgO contents are variable, from 2 to 15 %. High MgO values (> 7 %) are observed in two basalts (Almoxarife and Capelo formations), which reflect the accumulation of mafic phases such as olivine and clinopyroxene. Fe_2O_3 varies from 9 to 13 % and exhibits a positive correlation with MgO. The trachyte has 62 % of SiO_2, low MgO and Fe_2O_3 values (0.42 and 4.43 %, respectively). TiO_2 contents are high (> 2 %). In the all samples with MgO < 6.5 %, the TiO_2 content increases with decreasing MgO. This trend reflects significant Ti-magnetite fractionation.

The samples show low to high Al_2O_3 (11-18 %), as a result of variations in the plagioclase abundance. CaO decreases with decreasing MgO, reflecting the strong clinopyroxene and plagioclase fractionation. The trachyte of Cedros Volcanic Complex shows low CaO content (1 %). This is related to the fact that clinopyroxene and plagioclase were not an important phase in this rock. Na_2O and K_2O exhibit negative correlations with MgO, common in a magmatic system that involves fractionation of calcic plagioclase and clinopyroxene. The Na_2O and K_2O values (7 and 5 %, respectively) are high in the trachyte, which is consistent the crystallization of K-feldspar. P_2O_5 decreases with increasing MgO, which is compatible with the presence of apatite.

The figure 5 shows that the studied rocks belong to sodic series. The trachyte shows a different classification, plotting in the potassic field.

The samples are subsaturated in silica, with nepheline varying from 5 to 28% and only the trachyte is oversaturated, with 27% of normative quartz.

Rb, Ba and Sr show negative correlations with MgO, illustrating that these elements behave incompatibly until advanced stages of differentiation. Ni contents vary from 356 to 5 ppm. The Ni values of basalts (138 and 356 ppm) of Almoxarife and Capelo formations are related to presence of cumulatic phases in these rocks.

The patterns obtained on the spider diagram (fig. 6) show that almost all the samples are characterized by enrichment in Rb, Ba, Ta, Nb, Zr and impoverishment in Th, Sm. The Cedros Volcanic Complex, Almoxarife and Capelo formations rocks exhibit enrichment in Ti. Almoxarife Formation samples show enrichment in P and the hawaiites of Cedros Volcanic Complex exhibit depletion in this element. The hawaiites of Almoxarife Formation exhibit enrichment in K and the basalt shows impoverishment. The basalt of Almoxarife Formation and the hawaiite of Ribeirinha Complex show Sr negative anomaly. The trachyte of Cedros Complex is characterized by enrichment in Ba and depletion in K. Zr positive anomalies and U, Sr, P, Ti negative anomalies are observed in trachytic rock.

The REE patterns (fig. 7) show enrichment in LREE relative to MREE and HREE, which is typical of oceanic island lavas (Flower, 1971). According to Wilson (1989) is also characteristic of lavas resulting from low degree of partial melting, originated from mantle sources enriched in those REE or from a source with garnet.

Sample	FA-1	FA-2	FA-3	FA-4	FA-5	FA-6	FA-7	FA-8	FA-9
SiO_2	48.96	45.14	49.13	62.43	47.29	46.75	45.68	48.69	47.24
TiO_2	3.35	3.37	2.95	0.53	3.24	3.28	2.34	2.95	3.47
Al_2O_3	16.76	14.44	18.50	17.21	17.64	17.00	11.96	17.59	16.68
Fe_2O_3	11.44	13.35	9.52	4.43	10.60	10.91	10.92	10.36	12.17
MnO	0.19	0.18	0.16	0.17	0.15	0.16	0.15	0.17	0.17
MgO	3.78	9.15	2.93	0.42	5.31	5.52	14.23	4.36	6.03
CaO	8.26	10.74	8.35	1.15	9.15	10.26	11.23	7.41	8.43
Na_2O	3.83	2.67	4.35	7.12	4.47	3.86	2.46	4.09	3.92
K_2O	1.84	1.15	1.93	5.18	1.69	1.50	0.83	2.22	1.38
P_2O_5	0.61	0.5	0.67	0.13	0.56	0.58	0.29	0.74	0.6
LOI	0.9	0.2	1.4	1.2	- 0.2	0.1	- 0.3	1.3	- 0.2
Total	99.92	100.89	99.89	99.97	99.90	99.92	99.79	99.88	99.89
Rb	32.8	21	36.3	80.1	31.8	28.7	16.5	42.3	27.3
Ba	445.2	305.3	506.9	1064.1	418.3	392.9	214.8	619	402.6
Sr	593.6	556.2	785.3	27.2	775.9	745.7	428.4	741.2	789.9
Ni	< 5	138	< 5	< 5	33	42	356	24	59
Co	29.6	60.8	30.2	11.8	50.4	44.9	71.7	38.1	43.6
Nb	50.1	41.8	63.3	86.4	50.3	48.7	26.3	66.9	57.4
Zr	268.10	195.90	318.80	466.70	225.80	231.60	141.00	354.60	271
Y	36.5	27.9	38.3	33	26.7	30	20.2	35.1	31.6
Hf	6.5	5.4	7.9	11.3	5.7	5.9	3.9	8.9	6.6
U	0.8	1	1.5	2	1.1	1.1	0.6	1.7	1.4
Th	3.7	3	5.1	9.4	3.8	3.4	2.1	5.8	4.1
Pb	1.9	1.2	0.9	3.6	0.8	1.8	1	0.8	1.3
Ga	22.7	19.4	24.6	24.5	21.7	21.4	14.7	23.6	22.4
Sc	18	28	15	4	19	22	35	14	17
V	256	297	179	< 5	267	281	234	195	237
Cs	0.2	0.2	0.3	0.5	0.3	0.3	0.1	0.2	0.2
Ta	3.3	2.9	3.9	5.3	3.4	3.2	2.0	4.2	3.8
Sn	2.0	2.0	2.0	3.0	2.0	2.0	1.0	2.0	2.0
La	33.2	26.2	44.6	58.4	33.3	32.1	18	55.8	37.8
Ce	71.2	57.2	92	113.4	71.2	71	40.8	109.1	81
Pr	9.6	7.96	12.17	13.55	9.26	9.48	5.52	14.09	10.44
Nd	39.3	34.5	48.8	48.1	37.8	39.8	23.4	55	42.9
Sm	8.1	7.1	9.5	8	7	7.6	4.8	9.7	8.2
Eu	2.55	2.15	2.88	2.28	2.16	2.42	1.56	3.03	2.59
Gd	7.66	6.56	8.7	6.45	6.27	7.12	4.71	8.48	7.66
Tb	1.33	1.1	1.47	1.16	1.05	1.18	0.82	1.37	1.29
Dy	6.77	5.29	6.89	5.67	4.9	5.5	3.88	6.6	6.04
Ho	1.23	0.97	1.23	1.08	0.9	0.98	0.69	1.18	1.08
Er	3.62	2.56	3.45	3.32	2.46	2.89	1.88	3.16	2.97
Tm	0.45	0.36	0.46	0.46	0.33	0.37	0.25	0.4	0.37
Yb	2.87	2.12	2.76	3.08	2	2.23	1.45	2.58	2.33
Lu	0.43	0.29	0.39	0.46	0.28	0.31	0.21	0.35	0.35

Table 1 – Geochemical compositions of volcanic rocks from Faial Island.

The hawaiite of Ribeirinha Complex and the trachyte of Cedros Volcanic Complex are the more enriched samples in LREE relative to HREE. The trachyte is characterized to be more enriched in HREE than the other samples. The basalt of Capelo Formation is the less fractionated sample in REE compared to the other ones, but follows the same fractionation patterns. There is not Eu negative anomaly in any sample. The (La/Yb)n ratio varies from 11.57 to 21.63. The REE patterns suggest a continuous fractionation from a common melt generated by low partial melting rates.

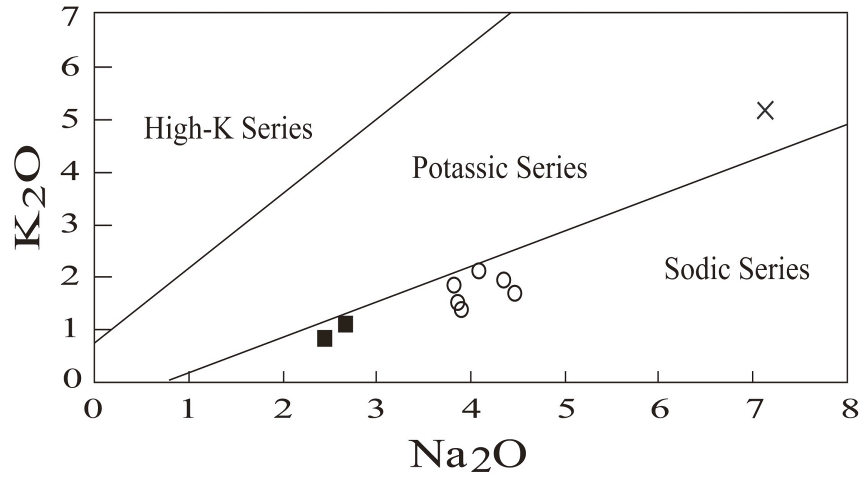

Figure 5 – Na_2O-K_2O diagram proposed by Middlemost (1975) showing the sodic character of differentiation series of studied rocks. Symbols as in figure 4.

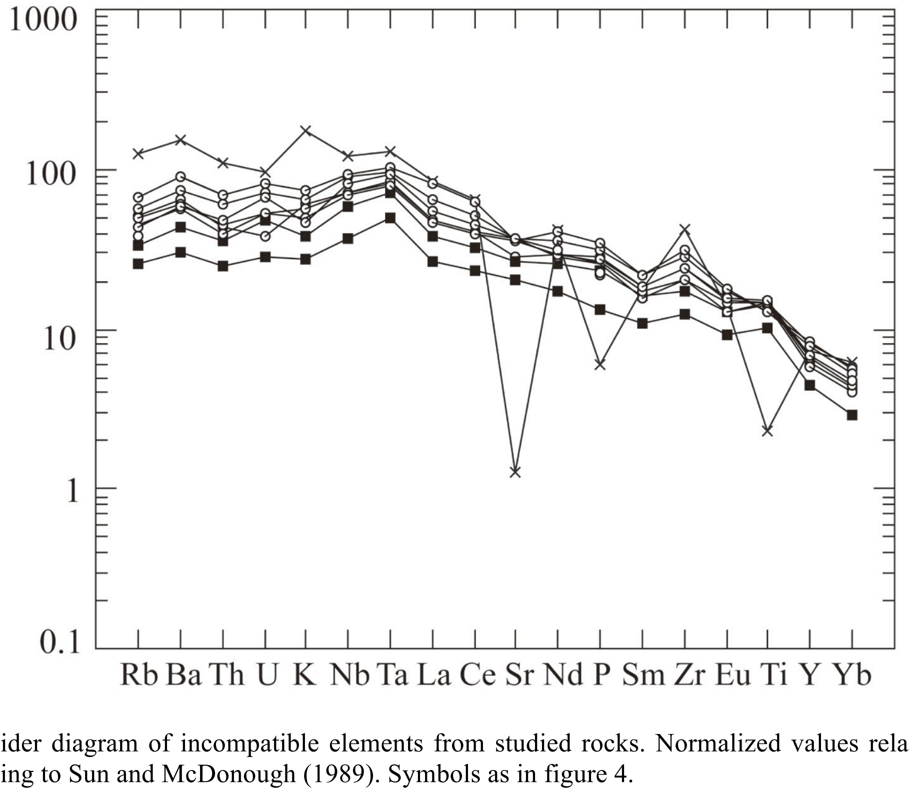

Figure 6 – Spider diagram of incompatible elements from studied rocks. Normalized values relative to Primitive Mantle according to Sun and McDonough (1989). Symbols as in figure 4.

The Azores rocks plot on the alkaline basalts of intra-plate environment (fig. 8), which agree with classification made by many authors (Torres de Assunção and Canilho, 1970; Ridley et al., 1974; White et al., 1975; Flower et al., 1976; Self and Gunn, 1976; White et al., 1976; White et al., 1979; Rodrigues et al., 1989; Gaspar et al., 1990; Cruz, 2006).

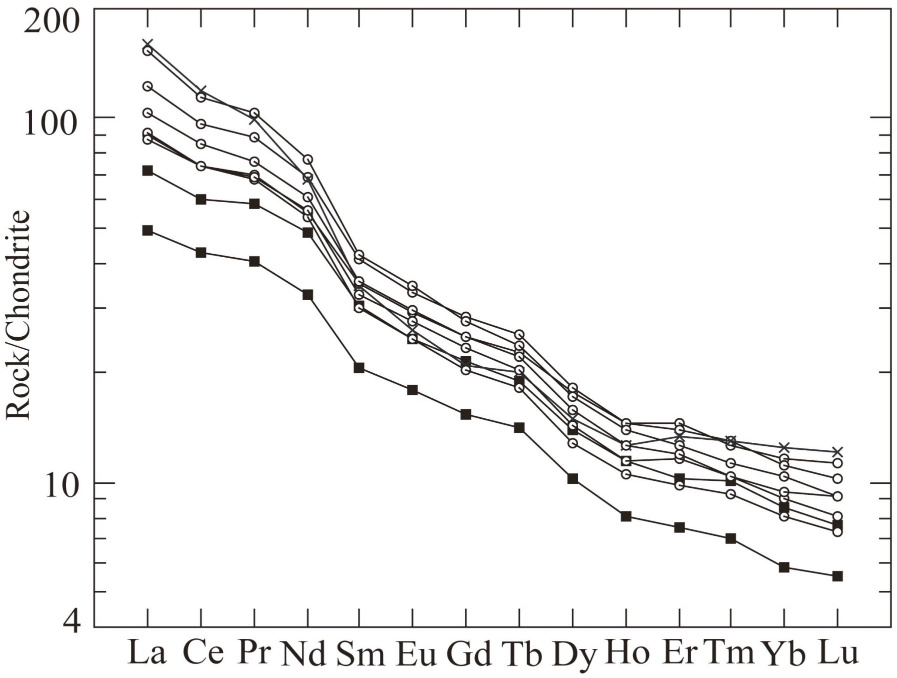

Figure 7 – Rare Earth Elements patterns to the studied rocks. Normalized values relative to Chondrite according to Taylor and McLennan (1985). Symbols as in figure 4.

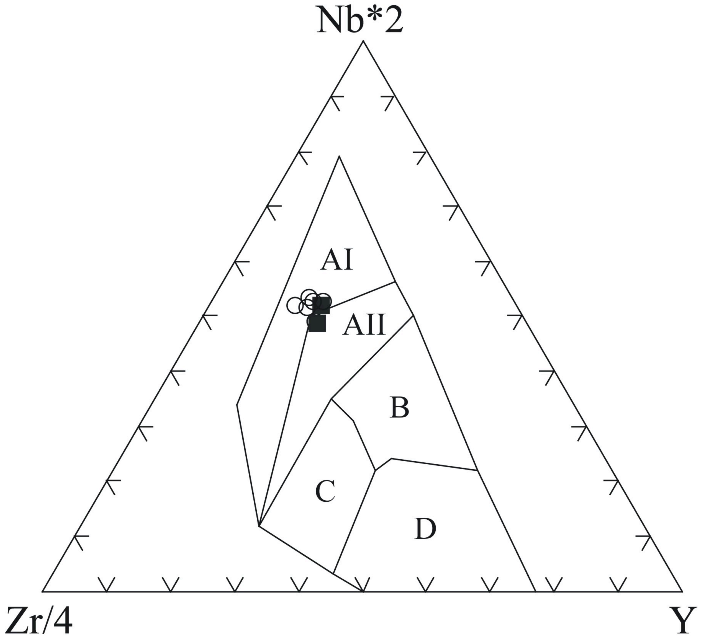

Figure 8 – Nb-Zr-Y discrimination diagram of tectonic environment (Meschede, 1986). AI = intra-plate alkaline basalts; AII = intra-plate alkaline and tholeiitic basalts; B = E-MORB; C = intra-plate tholeiites and oceanic arc basalts; D = N-MORB and volcanic arc basalts. Symbols as in figure 4.

The rocks of Faial Island show features similar to the HIMU ocean islands (Hoernle et al., 1995), which include great enrichment in Nb, Ta and low La/Nb (0.63-0.83) ratios. The 87Sr/86Sr ratios range from 0.7031 to 0.7034 and 143Nd/144Nd ratios from 0.512941 to 0.513048 (table 2). The Sr and Nd isotopic ratios show data relative to the mantle array of

DePaolo and Wasserburg (1976a, b) and inferred end-member mantle components of Zindler and Hart (1986). The data plot on PREMA (Prevalent Mantle) reservoirs towards HIMU on 143Nd/144Nd vs. 87Sr/86Sr diagram (fig. 9A). The Pb rations range among 18.90-19.45 (206Pb/204Pb), 15.61-15.69 (207Pb/204Pb) and 38.53-39.01 (208Pb/204Pb). In the 207Pb/204Pb vs. 206Pb/204Pb diagram, the samples plot on EM II field (fig. 9B). The available Sr, Nd and Pb isotopic data suggest that the magma source, which Faial rocks derived, is mixture of multiple magma reservoirs involving great amounts of PREMA and EM II, with probable participation of HIMU component.

Sample	**$^{87}Sr/^{86}Sr$**	**$^{143}Nd/^{144}Nd$ (Error in ppm)**	**$^{206}Pb/^{204}Pb$**	**$^{207}Pb/^{204}Pb$**	**$^{208}Pb/^{204}Pb$**
FA-1	0.703060 ± 0.00001	0.513016 ± 14	19.202143	15.6092	38.532221
FA-2	0.703392 ± 0.00001	0.513019 ± 15	19.371734	15.68336	38.690452
FA-3	0.703131 ± 0.00002	0.512997 ± 7	19.445229	15.694481	38.818177
FA-5	0.703248 ± 0.00001	0.512991 ± 9	19.277545	15.660093	38.744453
FA-6	0.703307 ± 0.00001	0.512988 ± 11	19.181079	15.668019	38.706134
FA-7	0.703274 ± 0.00001	0.512996 ± 25	19.04136	15.649961	38.707436
FA-8	0.703222 ± 0.00001	0.512941 ± 8	18.900696	15.631945	38.75207
FA-9	0.703292 ± 0.00001	0.513048 ± 5	19.23631	15.628817	38.684881

Table 2 – Sr, Nd and Pb isotopic data of Faial Island samples.

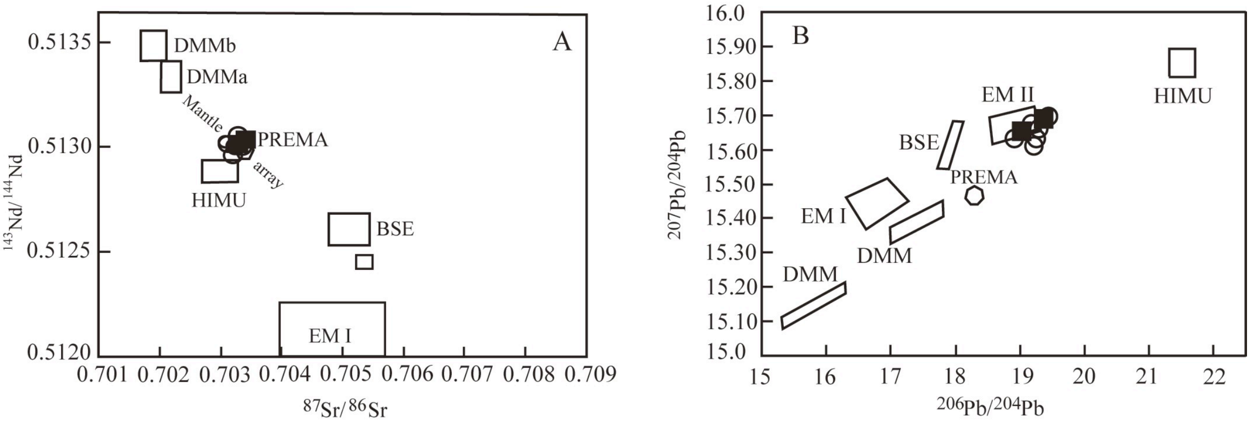

Figure 9 – Correlations of Sr vs. Nd and Pb vs. Pb to volcanic rocks from Faial Island. The magma reservoirs were identified by Zindler and Hart (1986). Symbols as in figure 4.

7. CONCLUSIONS

The evolutionary trend of the Faial rocks is the result of fractional crystallization involving clinopyroxene, magnesium-rich olivine and calcium-rich plagioclase. The trace and REE patterns observed to the Faial rocks are identical, suggesting a fractionation from a common melt generated by low partial melting rates. The geochemical variations in the rocks also partly result from the differences in degree of partial melting of the mantle source. In the case of Cedros Volcanic Complex rocks, the magmatic liquid would have developed in the magmatic chamber before reaching the surface. Otherwise, to the Almoxarife and Capelo formations, the same liquid did not have time to undergo through significant differentiation in magmatic chamber or during ascent to the surface. The mantle source of Faial rocks has mixed characteristics, mostly reflecting PREMA and EM II reservoirs, with minor contribution of HIMU.

Acknowledgements

This work was made possible by a Fellowship (SFRH/BPD/20807/2004) granted by Fundação para a Ciência e Tecnologia-FCT (Portugal).

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Presented during the VI Congresso Ibérico de Geoquímica / XV Semana de Geoquímica, Universidade de Trás-os-Montes e Alto Douro, Vila Real, Portugal, 16-21 July 2007.

Received 15 January 2008
Revised 15 January 2008
Published 6 May 2008