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# STRATIGRAPHY AND EVOLUTIONARY MODEL OF MADEIRA ISLAND

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With 1 Table

*ABSTRACT* A preliminary volcanostratigraphy for the island of Madeira Island is presented. Fieldwork has, so far, allowed the differentiation of seven main geological units, ranging from 5.2 My ago up to present times. The oldest unit, represented by subaereal lava flows, constitutes the nucleus of the island and is locally covered by marine sediments. During a period of volcanic rest the primitive island is partially dismantled, forming extensive and thick mudflow deposits. The reawakening of volcanic activity originates the main eruptive unit that forms the majority of the volume of the present island. The main fluvial valleys, incised on that unit, were partially occupied by lava flows of the following unit. The youngest volcanism occurred 120,000 to 25,000 years ago and may not be extinct. The last stratigraphic unit includes recent sedimentary deposits.

*RESUMO* Apresenta-se o estado do conhecimento, ainda preliminar, sobre a vulcanoestratigrafia da ilha da Madeira. Foram definidas, até agora, sete unidades geológicas principais, que se desenvolveram desde há pelo menos 5,2 Ma, até à actualidade. A unidade vulcânica mais antiga, representada por lavas subaéreas, constitui o núcleo da ilha, seguindo-se-lhe uma unidade sedimentar marinha, de pequena extensão. Durante

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um período de acalmia vulcânica ocorre o desmantelamento da ilha primitiva de que resultaram extensos e espessos depósitos de enxurrada. Segue-se nova fase de vulcanismo activo, formando-se o complexo eruptivo que constitui a maioria da parte emersa da ilha. Posteriormente deu-se o entalhe dos principais vales fluviais, com posicionamento semelhante ao actual, ao longo dos quais correram derrames lávicos agrupados noutra unidade estratigráfica. A actividade vulcânica mais recente ocorreu desde há 120 000 até há 25 000 anos, e poderá não ter terminado. Na sétima e última unidade incluem-se os depósitos sedimentares recentes.

## INTRODUCTION

The first publications on the geology of Madeira Island appeared during the 19th century with Bennet (1811), Drumond (1818), Vargas de Bedemar (1837), Mousinho de Albuquerque (1837), Macauly (1840), Lyell (1854), Hartung (1864), Ramos (1879) and Tierno (1897). During the 20th century many authors have studied varied aspects of the geology of the island. The first geological map was released in 1975 at a scale of 1/50000, by Zbysewski *et al*. (1975), and was published by Portuguese Geological Survey. Those of Mitchell-Thomé (1976), Mata *et al*. (1989) and Alves & Forjaz (1991) followed this work.

The volcanostratigraphy of Madeira Island here presented was developed for a doctoral thesis in the area of Geology, speciality of Hydrogeology. The extreme ruggedness of the island's relief, its abundant vegetation, which covers almost the whole island and the time available, have prevented a more detailed work. This is therefore just a preliminary volcanostratigraphic study of the island.

Fieldwork has so far allowed the differentiation of seven main geological units, here described according to their stratigraphic position, from the oldest to the youngest.

Basic volcanic rocks form the near totality of the emerged part of the island, both in surface and in volume, reaching values of more than 98% of the outcropping material (Mata, 1996), strongly conditioning its morphology.

Sedimentary formations, important for, in some cases, containing fossils, are scarce. Terrestrial sediments are represented by alluvium and stream terrace sediments, fossiliferous fossil sand dunes, sedimentary *fajãs* (Portuguese word for littoral platforms formed by the accumulation of slope deposits or by lava deltas), landslides, slope deposits, mud flows, while those of marine facies are represented by fossiliferous conglomerates, limestones and calcarenites, beach gravel and sand.

As to metamorphism it amounts to very mild contact actions, caused by lava flows and thick dikes, of no importance in the geological context.

## STRATIGRAPHY

The following seven main stratigraphic units were differentiated and are described from the more ancient to the more recent ones.

1. ANCIENT VOLCANIC COMPLEX (CA)
2. LAMEIROS - S. VICENTE MARINE LIMESTONES (CM)
3. CONGLOMERATE BRECCIA UNIT (CB)
4. MAIN VOLCANIC COMPLEX (CP)
5. S. ROQUE-PAUL VOLCANIC COMPLEX (SRP)
6. YOUNGER VOLCANICS (VR)
7. SLOPE DEPOSITS (dv), FAJÃS (fj), LANDSLIDE (q), RECENT MUDFLOW DEPOSITS (dr), BEACH SAND (ap), FOSSIL SAND DUNES (df), STREAM TERRACE SEDIMENTS (t), AND ALLUVIUM (a).

1. ANCIENT VOLCANIC COMPLEX (AC)

This complex includes the oldest rock outcrops of the emerged part of the island at its present level of erosion. Although it is nowadays quite destroyed, the CA still forms an important patch uncovered by the deeper incised valleys or by marine abrasion; it ranges in altitude from 1600 m in the central zones of the proto-island to sea level. To the North it outcrops in the valleys of *Ribeira da Janela, Ribeira de S. Vicente*, in *Ponta Delgada, Ribeira do Porco, Arco de S. Jorge, Faial,* in the fluvial valleys of *Ribeira Seca, da Metade* and *Ribeiro Frio*, and from *Porto da Cruz*, along the coast to *Caniçal* and *Ponta de S. Lourenço*. To the South it outcrops in the valleys of *Machico, Socorridos, Ribeira Brava* and *Ribeira da Ponta do Sol*.

Resulting from both effusive and explosive subaereal activity and being frequently cut by dikes, the CA is formed by lava flows, cones and pyroclastic fields. In certain locations, as in the Central Massif, there is a clear predominance of explosive activity predominantly represented by coarse thick pyroclastic deposits.

The Ancient Complex is generally covered by the Main Complex (although stratigraphically it is not the following unit), by the Conglomerate Breccia Unit, less frequently by lava flows and pyroclastic cones of the S. Roque-Paul Volcanic Complex, and, at specific points, by reef limestone, namely in *Sítio dos Lameiros*.

Erosion revealed a granular rock intrusion, outcropping in *Sítio do Massapez* in the area of *Levada Nova,* at an altitude of 250 m, on a surface extension of more than 400 m. These outcrops represent the crystallisation of alkaline magma in pockets inside the volcanic building. Given the fact that they are intruded in the CA, it may be contemporary to the late Ancient Complex or to the early stages of the Main Complex.

2. LAMEIROS - S. VICENTE MARINE LIMESTONE (ML)

Presently the limestone forms an outcrop of very reduced dimension, located on the right bank of the *S.Vicente* stream at approximately 2,5 km of its mouth and at an altitude of 400 m. The outcrop is essentially made up of conglomerate, considered to be the base of the deposit. Above it, there are remains of the fossiliferous limestone described by ROMARIZ (1971a). Initially thought to be of Helvetian age (MAYER, 1864, quoted by CARVALHO &

BRANDÃO, 1991), these rocks were eventually included in the Vindobonian (11.2 My). More recent isotopic geochronology data, obtained in a lava flow which, according to FERREIRA *et al*. (1988), underlies the sedimentary formations, date it at 5,2 My. If the date is correct, the limestones were deposited during late Messinian or already in the Pliocene.

## 3. CONGLOMERATE BRECCIA UNIT (CB)

This sedimentary formation is composed of thick, compact mudflow deposits (NASCIMENTO, 1990). Formed under a climate different from the present one, characterised by abundant and concentrated rain-showers, the Conglomerate Breccia Unit (CB) is made up of approximately 95% of poorly calibrated clasts, ranging from just a few millimetres to about 2 metres. The elements vary from usually angular to sub-angular. Rounded pebbles are also to be found especially those of smaller dimensions. Sandy and/or conglomerate layers are frequent in the formation.

Nearer to the source, which is thought to be the Central Massif, the CB is generally coarser-grained with bigger and more angular elements. In distal areas, deposits still show high energy layers, presenting many angular, sub-angular and roughly rounded pebbles, which frequently alternate with low energy levels, formed by thin well-layered sediments.

As to the nature of clasts, it is scarcely varied (in hand sample). Basalt with pyroxene phenocrysts, olivine basalt, vesicular basalt, in which some of the vesicles are filled by crystallised secondary silica; trachyte, remains of volcanic bombs, gravel, scoria, etc. are also to be found. Many of the elements are remains of prismatic columns while others are onion-jointed weathering nucleus. The matrix, essentially derived from weathering of basalts, presents a greyish black colour, and varies from fine to coarse-grained sandy breccia. Cement is not abundant in the proximal outcrops. The amount of fine matrix and cement increases from the central areas to the periphery.

The CB shows a range of weathering stages from scarcely to profoundly altered. When it is scarcely weathered it presents great compactness and consistency. When covered by thick lava flows it forms high vertical walls. These are the cases of *Paredão*, on the northern slope of *Paúl da Serra*, of *Pico das Furnas*, in *Vinháticos* area, and of the outcrops on the road-cuts of the road connecting *Arco de São Jorge* to *Arco Pequen*o, etc. When it isn’t covered by lava flows the vertical walls are rounded at the top as is to be seen in *Pico Redondo*, in *Vinháticos* area, and in *Pico da Cabra*, at *Ribeira Grande de São Vicente*.

## 4. MAIN VOLCANIC COMPLEX (CP)

This volcanic complex occupies, both in surface as in volume, the majority of the emerged part of the island and corresponds to a volcanic pile formed over a long period of time.

Two series, upper and lower CP, represent two different eruptive stages. However, in some areas it is not possible to differentiate them.

The rocks of this complex make up the present higher altitudes, as well as some structural platforms still preserved on the island.

Under the designation of lower Main Complex are included lavas from the first eruptive stage, characterised by alternate explosive and effusive events, represented by big scoria and lapili cones and thick and extensive lava flows, which are medium to highly weathered. The pyroclasts are in most cases transformed into tuffs.

Since the Conglomerate Breccia deposits were not enough to fill all the existing depressions in the topography of the Ancient Complex, the lava flows of the lower Main Complex occupied some of them, specially in the peripheral areas, which account for some strong inclinations observed.

The CP is cut by sub-vertical dikes, although less abundant than in the Ancient Complex.

The lower Main Complex outcrops at the head of *Ribeira de Santa Luzia*, in *Funchal*, in *Ponta do Pargo*, *Fajã da Ovelha*, *Paúl do Mar*, *Jardim do Mar*, *Calheta*, *Serra de Água*, *Curral das Freiras*, *Machico*, *Fajã da Nogueira*, etc.

The upper Main Complex is characterised by essentially effusive activity, predominantly along fissural vents, which originated the piling up of thick flows, with some alternating pyroclast levels of reduced thickness and extension. The lava flows of this series are sub-horizontal or slightly dipping towards the island's periphery.

Presently the separation between the lower and the upper series is done essentially by morphologic criteria. As a result of their horizontal geometry, the flows of the latter originate steeper slopes than those formed by the flows of the older series. Another difference is that there is an increase of effusive and a decrease of explosive volcanism in the upper Main Complex. Also from the upper series are the phreato-magmatic levels and pumice fall deposits found on the southern coast of the island, from *Calheta* to *Funchal*.

The Main Complex outcrops in the following locations: all of the southern coast, from *Ponta do Pargo* to *Caniçal*, in *Paúl da Serra* massif, where it forms its base and presents a thickness of about 500 m, at the top of *Penha de Águia*, with an average thickness of 300 m, in the slopes of *Ribeira do Seixal*, *Ribeira de João Delgado* and *Ribeira do Inferno* valleys, in the higher reaches of *São Vicente* and *Boaventura* valleys, in *São Jorge*, in *Santana*, in the higher zones of *Faial* and *São Roque do Faial*, and in *Porto da Cruz*, along the upper part of the sea-cliff to W of *Caniçal*. It also forms the upper part of the peaks of the Central massif (*Picos Ruivo, do Gato*, *Cidrão, Arieiro*, etc.).

## 5. S. ROQUE-PAUL VOLCANIC COMPLEX (SRP)

This complex was built up after the incision of today's main fluvial valleys. It is characterised by relatively reduced volcanic activity, contributing with a small percentage to the emerged volume of the island.

The eruptions were essentially of the Strombolian type. The majority of the lava flows filled, totally or partially, some of the existing valleys (*Seixal, São Vicente, São Roque do Faial*, *Machico*, etc.).

In terms of surface area its biggest expression is located on the top of the *Paul da*

*Serra* massif, where it spreads over a surface superior to 25 $km^2$, occupying all of the *Paul* surface, spreading north towards *Terra Chã* and *Montado dos Pessegueiros*, and NW to *Fanal*.

Contemporary to this volcanic complex are the lava flows, dated by MATA (1996), FERREIRA (1988), WATKINS & MONEM (1971), FERAUD *et al*., (1984) and ALVES & FORJAZ (1991), presented in Table 1.

Besides these, there is also an ash and lapili cone in *Santo da Serra*. Its crater, more than 300 m in diameter, is deep and well preserved; it is occupied by the lake known as *Lagoa do Santo da Serra*. A basalt lava flow issued from this cone flowed into a valley filling it; this may be observed in the area of *Maroços* and *Landeiros* (*Machico*). Due to the incision of the present Machico drainage system that lava flow originated a relief inversion. This lava flow has several lava tubes, known as *Grutas do Cavalum* caves.

It is possible that an area of *Funchal* is covered by lava flows from the S. Roque/ Paul complex, but this is still being investigated.

## 6. YOUNGER VOLCANICS (VR)

This designation corresponds to the volcanism that occurred 120 000 to 25 000 years ago. These are very well located volcanic episodes, essentially of the explosive type, with reduced eruption rates and located mainly in *Funchal* and surrounding areas but also in *Porto Moniz*.

According to ALVES & FORJAZ (1991), the first eruptions of this stage occurred E-SE of *Curral das Freiras*, near *Funchal*, represented by a basalt flow 120 000 years old. Contemporary to this period were the strombolian eruptions that formed the following scoria cones, still well preserved in present day morphology:

- In *Porto Moniz*, the lake of *Pico Redondo*, or *Alagoa*, at an 640 m altitude, is the crater of a bomb and lapili cone with the capacity to store 90000 $m^3$ of water. Still in this zone there are two other scoria cones which are though to be contemporary to this stage, the *Pico da Lagoa* and *Pico da Fajã do Barro*. They are located in *Lamaceiros*, west of the mouth of *Ribeira da Janela* valley. From one of them lava flowed into the valley till the sea where it originated pillow morphology and probably the small islets opposite. It has good outcrops under the bridge of *Ribeira da Janela* (on the left margin), and in the block of the right margin.
- *Pico das Covas* and *Pico do Caldeirão*, the latter responsible for the emission of the lava flow which formed the lava delta of *Porto Moniz*. According to ALVES & FORJAZ (1991) this lava flow is about 25 000 years old.
- *Pico do Areeiro* (near *Câmara de Lobos*), *Pico de S. Martinho, Pico do - Funcho, Pico do Buxo*, *Pico dos Barcelos*, *Pico de Sto António da Romeiras*, and - *Pico da Ponta da Cruz* where the last eruption occurred (ALVES & FORJAZ, 1991).
- *Cabeço das Eiras*, in *Figueirinhas,* and *Pico de Água*, in *Assomada*: although they present a relative degree of degradation, ALVES & FORJAZ (1991) considered them to be younger than 120 000 years.
- *Pico do Balancal*, or *da Bica de Pau*, in *S. Gonçalo*.

- *Pico da Torre*, in *Câmara de Lobos*, whose low degree of alteration suggests it is contemporary to this phase.

We admit the possibility that some volcanic cones, which were included in Younger Volcanics, may in fact belong to the S. Roque/Paul complex and vice versa. In the absence of absolute geochronology data, the used criteria were field stratigraphic relations and the degree of alteration, which are not always conclusive.

7. SLOPE DEPOSITS (dv), FAJÃS (fj), LANDSLIDE (q), RECENT MUD FLOW DEPOSITS (dr), BEACH SAND (ap), FOSSIL SAND DUNES (df), STREAM TERRACE SEDIMENTS (t), AND ALLUVIUM (a)

## EVOLUTIONARY MODEL

With the present knowledge about the volcanostratigraphy of Madeira and the available absolute geochronology data (Table 1), it is possible to define the following evolutionary steps for the island:

Formation of a submarine volcano, of which the Ancient Complex is the upper subaereal part and which emerged 5.2 My ago or more, since that is the age of the oldest rock (FERREIRA *et al*., 1988).

The island so formed reached considerable dimensions, both in area and in altitude, as can be inferred from the location and thickness of the mudflow deposits of the Conglomerate Breccia unit of whose dismantlement they resulted.

Sea level rise and/or island subsidence. According to MATA (1996), the island subsidence may have been originated by isostatic adjustment as a consequence of the transference to the crust of an important volcanic mass (MOORE, 1987, quoted by MATA, 1996). The weight of the lava pile over the oceanic plate, together with the withdrawal of magma in depth, may cause subsidence movements, which can exceed a kilometre.

Formation of calcareous reefs, apparently over a platform cut on submerged subaereal volcanic formations. The fossiliferous conglomerates of the base of the deposit, indicating deposition in rough shallow sea, and the limestones at the top, deposited in calmer deeper waters, prove the referred sea level rise or island subsidence (the present day existence of limestones at an altitude of 400 m cannot be explained solely by eustatic sea-level changes, it also needs by isostatic compensation).

The formation of these limestones, that took some thousand years, seems to have been accompanied by a period of relatively weak volcanic activity, since the volcanic activity favours the creation of anoxic water conditions, which often prevents the growing of coral (VOGT, 1989, quoted by MATA, 1996), besides the fact that there are no known submarine volcanics contemporary to this stage. This period of limestone formation was also accompanied by intense erosion of the island.

4. Continuation of volcanic quiescence (no volcanic intercalations are known in the Conglomerate Breccia Unit) and intensification of the erosion of the volcanic building.

Relative sea level descent and/or island uplift in such a way that the sea level was near or slightly below that of the present day.

In a tropical climate, with abundant and concentrated rain, thick beds of mudflows were deposited, from an altitude of 1 100 m to present-day sea level. The latter seems not to differ greatly from when the CB was deposited for nowadays there are no outcrops of rocks with marine characteristics. The deposition of the CB must have occurred between 4,5 and 4,07 My.

5. The restart of volcanism, with very high eruption rates, led to the formation of the Main Volcanic Complex, which constitutes the majority of the volume of the island above sea level.

In this unit, two different series, corresponding to different eruptive stages, were separated. The older one, named Lower Main Volcanic Complex, was emplaced from 4,07 My to 2,55 My. The younger one, designated Upper Main Volcanic Complex, formed 2,19 to 1,62 My ago. The volcanism of the Upper series is characterised by the existence of pumice fall and phreatomagmatic deposits that outcrop on the southern side of the island. Gabbro intrusion in the CA must be contemporary to the formation of the Lower Main Volcanic Complex or to the late stages of the CA.

During the long period of time in which the Main Volcanic Complex was formed, epochs of no volcanism occurred. These are represented by alluvial deposits, mud flows, and slope deposits, which are presently fossilised by lava flows from the latest eruptions of the Main Volcanic Complex.

6. Period of volcanic rest, during which present day valleys or valleys with similar locations were cut. Available absolute geochronology dates suggest that the first valleys were formed on the northern slopes; the 1,5 My old mugearite lava flow of *Porto da Cruz* ran into a valley cut on the Main Volcanic Complex; the valleys on the southern slope formed later, as indicated by 0,89 to 0,74 My old lava flows that outcrop in the interfluvial ridges of *Ribeira do Porto Novo*.

According to MATA (1996), this diachronism may be due to an earlier decline of the volcanic activity on the northern regions of the island.

7. After a pause of some hundred thousand years, volcanism resumed in centres scattered all over the island, from *Ponta de S. Lourenço*, passing by *Paul da Serra*, to *Porto Moniz*, producing relatively reduced volumes.

The oldest known lava flows of the S. Roque/Paul Volcanic Complex is the 1,5 My old mugearite of *Porto da Cruz*; younger lava flows also occupy pre-existing valleys, as shown by those in *S. Roque* (1,26 and 1,09 My), the ones in *S. Vicente* (0,89 My), *Seixal* (0,39 My) and *Boaventura* (0,38 My) valleys. Although the lava, which flowed into the Ribeira de Machico valley, has not been, to this moment, dated by absolute geochronology, it seems to be contemporary to this volcanic unit.

8. Finally, the last volcanic stage occurred 1,2 to 0.025 My ago in *Funchal* and surrounding areas, and in *Porto Moniz* (Table 1).

9. After the interruption of latest eruptive activity, erosion favoured by weathering, progressively lowered the relief, deepened the valleys and receded the sea cliffs, forming slope deposits, sedimentary *fajãs*, alluvium and present-day beaches.

**TABLE I -** Stratigraphic setting of published absolute geochronologic determinations (K/Ar).

| Volcano-stratigraphy | Age (My) | Location | Author |
|---|---|---|---|
| **Younger Volcanics (VR)** | 0.025 | Pico da Cruz and Pto Moniz | Alves & Forjaz, 1991 |
| | 0.035 | S. Gonçalo | Alves & Forjaz, 1991 |
| | 0.049 | Savoy and Carlton seacliffs | Alves & Forjaz, 1991 |
| | 0.050 | | |
| | 0.12 | Funchal | Alves & Forjaz, 1991 |
| **S. Roque/Paul volcanic complex (SRP)** | 0.38 | Escoada da Boaventura | Mata, 1996 |
| | 0.39 | Escoada do Seixal | Ferreira, 1988 |
| | 0.50 | Ilhéu Mole | Alves & Forjaz, 1991 |
| | 0.88 | Montado do Barreiro | Mata, 1996 |
| | 0.89 | Escoada de S.Vicente | Ferreira, 1988 |
| | 0.42 | Paul da Serra | Mata, 1996 |
| | 1.04 | Fonte da Pedra - Paúl | Mata, 1996 |
| | 0.74 | Rib. do Porto Novo | Watkins & Monem, 1971 |
| | 0.89 | Rib. do Porto Novo | Watkins & Monem, 1971 |
| | 1.03 | Rib. do Porto Novo | Watkins & Monem, 1971 |
| | 1.03 | Rib. do Porto Novo | Watkins & Monem, 1971 |
| | 1.05 | Rib. do Porto Novo | Watkins & Monem, 1971 |
| | 1.15 | Head of Rib. S.Luzia | Watkins & Monem, 1971 |
| | 1.09 | Escoada de S. Roque | Mata, 1996 |
| | 1.26 | Escoada de S. Roque | Ferreira, 1988 |
| | 1.29 | Ponta do Buraco | Mata, 1996 |
| | 0.96 | Pico Arieiro /Pico Ruivo | Féraud *et al*., 1984 |
| | 1.23 | Pico Arieiro /Pico Ruivo | Féraud *et al*., 1984 |
| | 1.40 | Pico Arieiro /Pico Ruivo | Féraud *et al*., 1984 |
| | 1.50 | Mugearite – Pto da Cruz | Mata, 1996 |

(cont. **TABLE I**)

| | | | |
|---|---|---|---|
| **Main Complex (CVP)** **upper** | 1.71 | Calheta/ Jardim do Mar | Mata, 1996 |
| | 1.62 | Caniçal - Marconi | Mata *et al.*, 1995 |
| | 1.72 | Caniçal - Marconi | Mata *et al.*, 1995 |
| | 1.64 | Rib. do Porto Novo | Watkins & Monem, 1971 |
| | 1.76 | Rib. do Porto Novo | Watkins & Monem, 1971 |
| | 1.81 | Pico Arieiro /Pico Ruivo | Féraud *et al.*, 1984 |
| **lower** | 2.19 | Montado do Pereiro | Mata, 1996 |
| | 2.55 | Matur | Mata, 1996 |
| | 2.55 | Pico do Arieiro | Mata *et al.*, 1995 |
| | 2.63 | Curral das Freiras | Mata, 1996 |
| | 2.97 | Curral das Freiras | Mata *et al.*, 1995 |
| | 3.05 | Rib. Frio / Rib. da Lenha | Watkins & Monem, 1971 |
| | 4.07 | Curral das Freiras | Mata *et al.*, 1995 |
| **Conglomerate Breccia Unit (CB)** | 4.07 a ≅ 4.5 | | |
| **Lameiros-S. Vicente marine Limestones (CM)** | ≅ 4.5 a 5.2 | | |
| **Ancient Complex (CA)** | ≥5.2 | Under the limestones | Ferreira, 1988 |

In 1998, however, during the opening of the *Rosário/Serra de Água* tunnel, faults were crossed which discharged gas and water for more than 6 months. An analysis of the gas content of the water revealed large amounts of $CO_2$; the persistence of the gas emissions from the fault indicates it is not related to some rock degassing process, but that it is probably associated to very incipient secondary hydrothermal activity.

10. Thus, in the course of millions of years, the island has been modified, by both to the constructive processes of volcanic activity and by erosion phenomena, until it reached the actual shape: an huge east-west oriented volcanic mass, cut by deep valleys, with a total surface area of 737 $km^2$, and a maximum altitude of 1861 m, which corresponds to the emerged portion of an over 5000 m high volcanic building. The fact that the 100 m isobath almost connects the *Desertas* islands to the *Ponta de S. Lourenço* suggests that those small islands are part of the same volcanic building of which this island is the most important emerged portion.

## CONCLUSION

If the 25 000 year old volcanism remains dormant, weathering and marine erosion will accomplish their mission and recede the sea cliffs, lower the relief, widen and deepen the valleys, towards a smaller more levelled island, similar to *Porto Santo* island, where volcanic activity ceased approximately 8 My ago (FERREIRA, 1993). However, during the course of the history of volcanic islands prolonged hiatus in volcanic activity may occur. This has happened in *Cabo Verde* (islands of *Santiago, Sal, Maio, Boa Vista*, etc) and in the Canary islands, namely on the island of *Fuerteventura*, where, according to MATA (1996), after the main eruptive stage, there has been, between 12 and 4 My, a period of volcanic rest which lasted about 8 My. Thus, given the fact that there are still manifestations of secondary volcanic activity, it can be admitted that the island of Madeira is merely going through a period of eruptive inactivity similar to those registered in so many oceanic islands.

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