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## Caves and Pits from the Azores With Some Comments on Their Geological Origin, Distribution, and Fauna

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### Abstract

In 1989 Ogawa published an account of the distribution of volcanic caves and pits from the Azores. Further work in the last few years justifies an updating of the information. Ogawa listed 33 caves and 7 pits; now these numbers are 88 and 24. In this paper the caves and pits are listed according to their occurrence in the islands of the archipelago: Corvo (1;0), Flores (0;0), Faial (3;1), Pico (28;8), Graciosa (16;1), São Jorge (7;5), Terceira (20;6), São Miguel (10;3) and Santa Maria (3;0). Some data on the location, length, elevation, and fauna of each cave and pit are also given. During recent speleological expeditions by Os Montanheiros to the islands of Faial, Pico, Graciosa, São Jorge, Terceira, São Miguel, and Santa Maria over 10,000 meters of lava tubes and 400 meters of pits were surveyed and a total of 17 new maps are presented in this work. The longest lava tube, Torres Cave (Pico), is 3,350 meters long, 15 meters high, and 22 meters wide. The biggest pit, Algar do Montoso (São Jorge), is 137.5 meters deep. Presently 75% of the known caves have less than 300 meters. Some caves really belong to a single longitudinal lava tube broken into different sections. We also present some comments on the more relevant characteristics of each of the main caves and the distribution of lava tubes, pits, and related lava flows in each island. A short narrative of Azorean geology and some information for the preservation of the caves as well as some comments on the relict hypogean fauna are also provided.

### Introduction

The Azorean archipelago is located in the North Atlantic, at the triple junction of the Eurasian, African, and North American plates. The distance between the Azores and the mainland is about 1,390 kilometers west of Cabo da Roca (the western most point of the European continent). It is formed by nine volcanic islands, aligned on a west-northwest to east-southeast trend, that are distributed in three groups: the western group with Corvo and Flores; the central group with Faial, Pico, Graciosa, São Jorge, and Ter-

ceira; the eastern group with São Miguel and Santa Maria (Figure 1).

The biggest island is São Miguel with 757 square kilometers and the smallest is Corvo with 17 square kilometers. Santa Maria is the most southern island (37°N, 25°W), and Flores is the most western one (31°W). The most northern one is Corvo (39.7°N) (see Table 1 and Figure 1).

The distance between Corvo and Santa Maria, the most widely separated islands, is about 615 kilometers. Corvo lies at approximately the same distance from the Iberian Peninsula and Newfoundland.

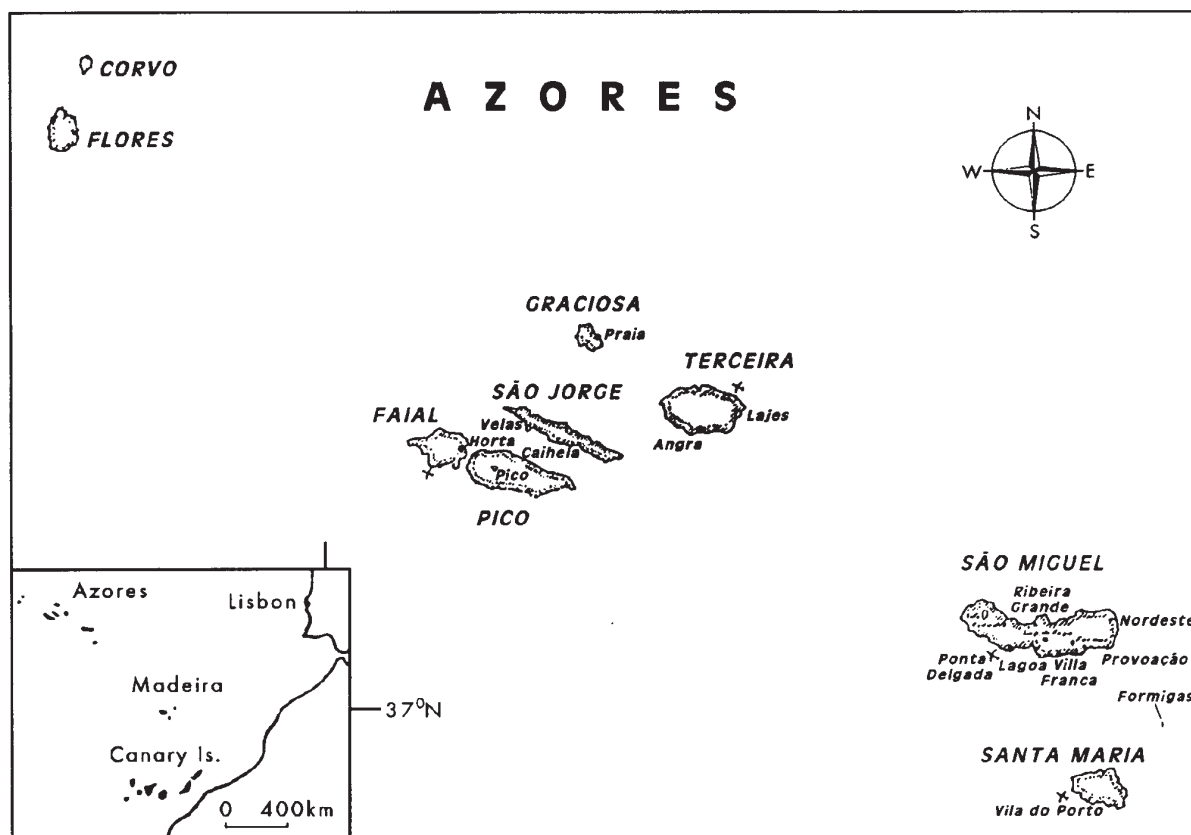


Figure 1—Map of the studied area, Azores.

All the information concerning the longitude, latitude, area, maximum altitude, and geological age of each island are given in Table I.

### Age and Origin of the Islands

All of the islands have a volcanic origin and there are many examples of historical volcanic eruptions

Island	Long.(W)	Lat.(N)	Area (km <sup>2</sup> )	Altitude (m)	Age (million years)		
					A	B	C
Corvo	30.8	39.7	17	718	?	?	?
Flores	30.9	39.4	142	915	0.010	0.62(2.9)	1.8
Faial	28.5	38.6	172	1,043	2.6	0.73	0.73
Pico	28.2	38.5	433	2,351	1.1	0.037	0.037
Graciosa	27.8	39.1	62	402	0.62	0.62	2.5
São Jorge	27.9	38.7	246	1,053	2	0.55	0.55
Terceira	27.2	38.7	402	1,023	2	0.30	2
São Miguel	25.5	37.7	757	1,103	4	4.01	4.01
Santa Maria	25.1	36.9	97	587	8	8.12	8.12

Table I—Comparison of the physical characteristics of the nine Azorian islands.

A = Forjaz (pers. comm.); B = Abdel-Monem et al. (1975), Feraud et al. (1980); C = Queiroz (1990)

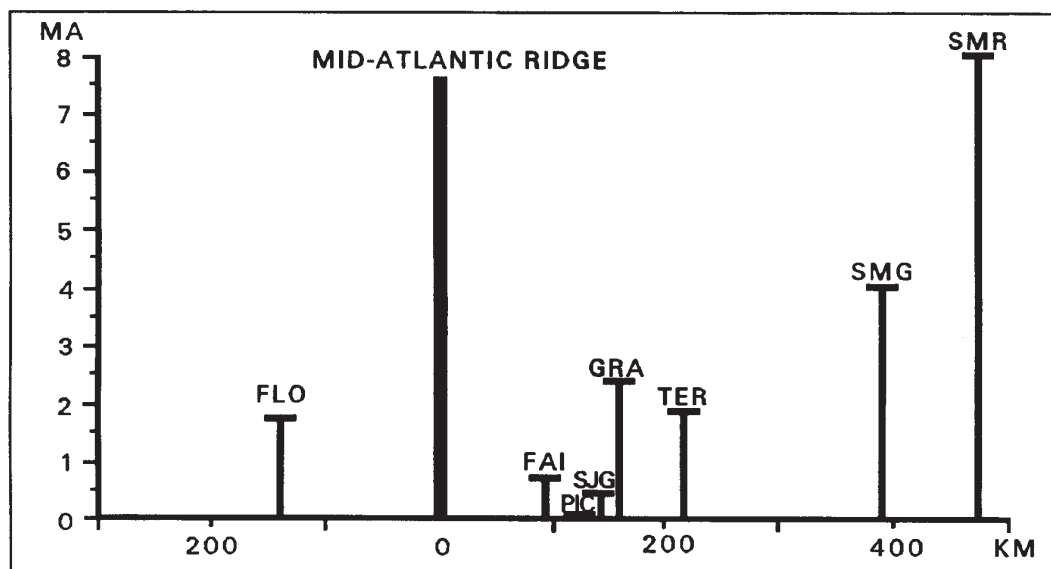


Figure 2 – Relation between the age of each of the Azorean islands and the Middle Dorsal Atlantic. The geological ages are those proposed by Queiroz (1990) (Modified from Borges, 1991).

(see Weston, 1964). The geological age of the nine islands is very dissimilar. Since their formation took a long period of time, these islands present a recent volcanic morphology (e.g., Pico) or a more eroded, ancient formations (e.g., Flores and Santa Maria). There are several studies concerning the geological dating of the Azorean islands, but unfortunately there is no agreement on the age of some islands.

Three alternatives are proposed: one following Forjaz (pers. comm.) (column A), another with the results obtained by Abdel-Monem *et al.* (1975) and Feraud *et al.* (1980) (column B) with the K/Ar method, and finally one following Queiroz (1990) (column C). This last author follows, in part, Abdel-Monem *et al.* (*op. cit.*) and Feraud *et al.* (*op. cit.*) but also other recent studies (e.g., Forjaz, 1986b; White *et al.*, 1976; Azevedo *et al.*, 1986, all in Queiroz, *op. cit.*).

In Figure 2 we present the data of Queiroz (1990) in a graphical way. The age of the different islands of the archipelago is not positively correlated with their distance to the Middle Dorsal Atlantic (Feraud *et al.*, 1980). The same could be inferred from the ages proposed by Forjaz (pers. comm.) or Abdel-Monem *et al.*, (1975)/Feraud *et al.*, (1980).

As we can see from Table 1, different ages have been proposed for some islands, but nevertheless the eastern group is the older one, with 8.12 million

years (Santa Maria) (Abdel-Monem *et al.*, 1975), coming from the middle of the Miocene. Serughetti and Roche (1968) (in Ryall *et al.*, 1983) propose about 2.9 million years of age for Flores (Column B, Table 1), but Azevedo *et al.* (1986) (in Queiroz, *op. cit.*) estimates the age of this island at 1.8 million years. The central group is the youngest one.

We would also like to point out that the geological datings of the Azorean islands are far from being considered totally correct, mainly because the geological samples dated were probably not taken from the older stratigraphic layers (Nunes, pers. comm.).

The western part of each Azorean island is, geologically, the most recent one. This is connected with the seismo-volcanic mechanisms of this archipelago (Forjaz, pers. comm.), which is important because the occurrence and distribution of the Azorean lava tubes are somewhat related to recent lava flows (see below).

### Speleological Studies in the Azores

The earliest reference concerning the occurrence of caves in the Azores is difficult to establish. Probably the work of Fouque (1873) – who briefly discussed lava tubes and pit caves on Terceira, Pico, and Graciosa – is one of the first. However, before his work, Webster (1821) mentioned caves

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in and near Ponta Delgada (São Miguel). Later, Pickering (1908) gave a follow-up on Fouque's exploration of the large pit Furna da Caldeira da Graciosa (Furna do Enxofre) on Graciosa Island.

The earliest speleological study recorded from the archipelago was made by Forjaz (1963) with a fine description and sketch of Furna de Henrique Maciel (Pico). Unfortunately the map of the cave is not presented. Recently (May 1990) two French speleologists (P. Brunet and C. Thomas) accompanied by one of us (A. Silva) made a map of this interesting cave (unpublished).

In 1966, a work of the Portuguese group Mocidade Portuguesa – Centro de Instrução Especial de Espeleologia – describes the cave of Pau Velho (Gruta dos Balcões) (Terceira) with an incomplete map. This map was reproduced later by Halliday (1980). In 1967 Os Montanheiros made a fine map of this cave, later completed by Montserrat and Romero (1983) (see below).

Mottet (1970, 1972, 1974) presented some data on the geomorphology of some caves from Terceira (e.g., Gruta das Agulhas, Gruta do Natal, Gruta dos Balcões), but no maps are available.

Arruda (1972) studied and described some caves and pits from Pico: Furna Abrigo, Furna de Henrique Maciel II, Furna de Manuel José Lima, and Algar do Alto do Morais. Although the maps of the Algar do Alto do Morais and Furna de Manuel José Lima are probably incomplete, this author presents a fine map of Furna Abrigo.

The American speleologist, W. R. Halliday, (see Halliday, 1980 and also Anonymous, 1978) visited the Azores in April 1980 and worked out the first checklist of the Azorean caves and pits (Halliday, 1981). He listed the following caves and pits: Corvo (0;0), Flores (0;0), Faial (0;0), Pico (2;2), Graciosa (1;1), São Jorge (1;2), Terceira (11;2), São Miguel (3;0) and Santa Maria (0;0) (see also Table II). In these works we can find some sketches of the caves and pits but no impressive maps were presented. Some of these sketches (e. g., Algar do Carvão, G. dos Montanheiros) were put at the disposal of W. Halliday by Os Montanheiros.

Authors	Caves	Pits	Total
Halliday (1981)	18	7	25
Ogawa (1989)	35	7	42
The Authors	88	24	112

Table II – Evolution of the knowledge of the number of caves and pits from the Azores.

The first complete maps of the Azorean caves were presented by Montserrat and Romero (1983). Three lava tubes (Balcões, Pau Velho, Natal) are described and mapped and one lava tube (Agulhas) and one pit (Algar do Carvão) from Terceira are described by these authors. More recently Chinchon *et al.* (in press) presents further studies on Gruta dos Balcões, now the best studied lava tube in the whole archipelago.

Recently, Hayes and Braga (unpublished) presented at the 5th International Symposium on Vulcanospeleology (Japan, 1988) the first checklist of caves and pits from São Miguel.

Two biospeleological expeditions were carried out in the Azores directed by N.P. Ashmole (Edinburgh University) and P. Oromí (La Laguna University). These expeditions were supported by the National Geographic Society, USA, in July through August 1987 and 1989 (the latter also with the participation of one of us P. Borges) (see Oromí *et al.*, in press; Oromí and Borges, in press; Borges and Oromí, in press). Oromí *et al.* (op. cit.) presented the description of the biologically studied caves during the first of these expeditions (July through August 1987).

The most recent catalogue of the Azorean caves and pits was made by Ogawa (1989) (Table II), listing 35 caves and 7 pits. Since then, several speleological expeditions have been made in the Azorean islands by the Terceira (Azores) Os Montanheiros speleological group.

For a long period of time (1963 to 1987) the activity of Os Montanheiros had a recreation and tourist orientation, but also some speleological studies were made during several expeditions in the Azores:

**1963 to 1976** – Several speleological visits were made to Graciosa, directed by A. Luís and R. Azevedo. The results of these visits are presented in Table III;

**1967** – A speleological expedition directed by A. Luís to Pico. Two caves were visited (Gruta do Henrique Maciel and Furna Frei Matias);

**1972** – A speleological expedition directed by A. Luís to São Jorge. As the main results of this visit, several sketches were made of the lava tubes Gruta da Beira and Gruta do Leão and the pit Bocas do Fogo. All of them were revisited and completely mapped (see Plates 5, 6, and 7) in recent expeditions of Os Montanheiros (see below, S. Jorge-88 and Montoso-90);

**1975** – A speleological expedition directed by A. Luís to Flores and Corvo. No caves were found on these islands;



**1976** – A speleological expedition directed by R. Azevedo to Pico. The lava tube, Gruta dos Montanheiros was explored for the first time and an access ladder was built;

**1978** – A speleological expedition directed by A. Silva to São Miguel. Several lava tubes and pits were explored (e.g., Gruta do Esqueleto, Gruta da Rua do Carvão, Algar da Batalha).

However, some of the works cited before (e.g., Mottet, 1974; Halliday, 1980, 1981; Montserrat and Romero, 1983; Chinchon *et al.*, in press; Ogawa, 1989; Oromí *et al.*, in press; Oromí and Borges, in press; Borges and Oromí, in press) were possible only thanks to the kind assistance of Os Montanheiros during part of the field work. Only recently a scientific goal was adopted by Os Montanheiros. The present work is done by three members of this group.

During the last years Os Montanheiros organized or took part in several expeditions to the islands of Flores, Faial, Pico, Graciosa, São Jorge, São Miguel, and Santa Maria (also the local island, Terceira). They have explored and mapped over 10,000 meters of caves and 400 meters of pits. The expeditions were:

1988 – October 31 to November 11, **S. JORGE-88**, Speleological Expedition to the island of São Jorge;

1989 – May 21 to 26, **BIOSPEL-89**, Biospeleological Expedition to the island of Pico (Azores);

1989 – July 4 to 11, **FLORES-89**, Zoological Expedition of the University of Azores (Dept. of Biology);

1989 – October 10 to 14, **FAIAL-89**, Biospeleological Expedition to the island of Faial (Azores);

1990 – March 3 to 11 and 17 to 21, **BIOSPEL-90**, Biospeleological Expedition to the island of Pico (Azores);

1990 – June 8 to 16, **ST. MARIA-90**, Zoological Expedition of the University of Azores (Dept. of Biology);

1990 – August 9 to 29, **BIOSPEL-90-S. MIGUEL**, Speleological Expedition to the island of São Miguel (Azores);

1990 – September 11 to 15, **MONTOSO-90**, Speleological Expedition to the island of São Jorge;

1991 – March 28 to April 3, **TORRES-91**, Speleological Expedition to the island of Pico (Azores);

1991 – June 6 to 11, **ARCOSPEL-91**, Speleological Expedition to the island of Pico (Azores).

The aim of the present contribution is to present a commented checklist of all the known Azorean caves and pits (see Table III, below). A total of 19 new maps or sketches of lava tube caves, littoral caves, and pits are presented. Some remarks on the conservation of the caves and on their fauna are also made.

## Checklist of the Azorean Caves and Pits

Table III is a revised catalogue of the Azorean caves and pits (following four pages). Unfortunately in some cases the data presented is incomplete (e.g., caves from Graciosa). It includes the main name and other common names of each cave and pit, their location, the known length or depth in meters, and the minimum-maximum height and width also in meters. We also present data related to the altitude (elevation) of the main entrance of each cave and pit and the UTM coordinates. Finally, in each case we state whether there are maps and studies of the fauna available.

The data from Graciosa Island presented in Table III should be viewed with caution because it is based on incomplete notes taken by A. Luís, J.M. Fagundes, and R. Azevedo between 1963 and 1976 (speleological visits of Os Montanheiros to Graciosa).

The following abbreviations are used on the maps:

a = mapped by Arruda (1972)

b = mapped by Montserrat and Romero (1983)

c = mapped by the French speleologists, P. Brunet and C. Thomas accompanied by one of us (A. Silva) (unpublished)

d = mapped by Os Montanheiros speleological group and by the Amigos dos Açores ecologist group during the Biospel-90-S. Miguel, Speleological Expedition to the island of São Miguel (Azores)

Mont = mapped by Os Montanheiros speleological group

Ogawa = mapped by Ogawa (1989)

Sketch = only a sketch, made by Os Montanheiros, is available.

We also use in Table III the symbols: ? = information not available and ?? = not confirmed.

Seven maps are presented (Figures 3 to 7) with the location of the lava tubes, littoral caves, pits, and the main lava flows (information based on Anonymous, 1980 a, b, and c) in seven of the nine Azorean islands. The notation is the same as that used in the Checklist (Table III). For the caves we use the symbol "\*" and for the pits the symbol "0."

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Island and No.	Main Name	Other Names	Location	Length/ Depth (m)	Height (m)	Width (m)	Elev. (m)	UTM	Map	Fauna
1. Corvo Lava Tubes										
1	Gruta do Corvo		?	?	?	?	?	?		
2. Flores										
	No Caves Known									
3. Faial Lava Tubes										
1	Furna das Anelares	Lombega	Lombega	35.5	0.7-4.0	1.4-2.5	80	3482/42663	Mont	yes
2	Gruta do Cabeço do Canto	Concheiros	Cabeço do Canto	21.4	0.3-5.10	0.5-7.5	346	3420/42740	Mont	yes
3	G. do Parque do Capelo		Parque do Capelo	55.3	0.35-1.50	0.4-3.40	300	3452/42727		
Pits										
4	Furna Ruim		Cabeço Verde	-55		20.6-73.1	565	3467/42722	Mont	yes
4. Pico Lava Tubes										
1	Furna da Areia	F. do J. Maria	Caminho do cais Mourato	?	?	?	?	?		
2	F. da Laje	F. da Ti' Adelina;	Lajido	?	?	?	10	3755/42688		
3	F. da Miragaia	F. do Ranheta	Miragaia do Norte	50	?	?	140	3720/42661		
4	F. das Casas	F. do Chico	Lugar das Casas	?	?	?	20	3709/42685		
5	F. do Carregador	Algar do Barreia;	Algar	20	2	2-6.0	330	3716/42641		
6	F. do Frei Matias	F. dos Algar	Estrada Nova (Longit.)	666	2-7.2	2-14.2	680	3735/42609	Mont	
7	F. do Henrique Maciel	F. do Estácio	Santo António	812>??	2-4.5	2-4.0	140	3825/42649	c	yes
8	F. do Poço Novo	D. do Germano;	Poço Novo (Near the seaside)	?	?	?	?	?		
9	F. do Poço Velho	F. do Calote	Canada do Poço Velho	?	?	?	?	?		
10	F. do Tancaim	F. do Tanquinho;	Tambor (Mistério de St Luzia)	?	?	?	275	3731/42655		
11	F. dos Bodes	F. do Ranheta	Cabeço-Chão	?	?	?	?	?		
12	F. dos Caldeirões		Canada dos Caldeirões, Bandeiras	?	?	?	110	3721/42668		
13	F. dos Mendonças		Canada da Travessa	?	?	?	?	?		
14	F. dos Montanheiros		Curral Queimado, Brejos	741	0.45-6.79	0.40-8.59	785	3831/42610	Mont	yes
15	F. D'Água	Bandeiras I, Bandeiras II	Bandeiras (Mistério de St Luzia)	250+100	2-2.0	2-5.0	100	3738/42670		
16	F. Manuel José Lima	F. dos Faustinos	Santo António, Miragaia	52	0.5-5.0	2-6.0	140	3773/42670	a	
17	F. Nova I		Farrobo (Mistério de St Luzia)	270.1	0.75-4.0	1-2.50	230	3741/42658	Sketch	
18	F. Nova II		Farrobo (Mistério de St Luzia)	?	?	?	210	3741/42659		
19	Gruta da Barca		Estrada Marginal, Barca	?	?	?	0	3675/42670		

Island and No.	Main Name	Other Names	Location	Length/ Depth (m)	Height (m)	Width (m)	Elev. (m)	UTM	Map	Fauna
<b>4. Pico (cont)</b>										
Lava Tubes										
20	G. da Capucha	Agostinha; João Serafim	Canada da Capucha, Bandeiras	310.78	0.43-5.10	1.8-10.95	75	3730/42675	Mont	yes
21	G. das Torres		Cabeço Bravo, Creação Velha	3,350	0.50-15.0	1.1-22.0	300	3681/42618	Mont	yes
22	G. do Capitão-Mor		Cais do Pico	300	?	?	30	3850/42649	c	
23	G. do Galeão I		Panha do Galeão, S. Caetano	255.9/-7.0	3.0-16.0	2.0-10.0	100	3749/42545	Mont	
24	G. do Galeão II		P. do Galeão (Ringue) *	50	0.4-1.1	0.41-1.25	60	3748/42541	Sketch	
25	G. do Ruivo		Carregador	70	?	?	?	?		
26	G. do Soldão	Malha; Soldado; Moiro; Terra Tapada	Mistério da Silveira	1,150	0.40-5.96	0.43-5.39	10	3868/42526	Mont	yes
27	G. dos Arcos		Arcos (Mistério de St Luzia)	216.5	0.30-2.10	1.0-1.60	50	3778/42686	Sketch	yes
28	G. dos Esqueletos		Igreja de St Luzia	91	0.80-1.60	1.0-2.10	130	3780/42674	Sketch	yes
Pits										
29	Algar da Furna Abrigo		Pico do Pico	-39		10.0-13.0	1,200	3750/42598	a	
30	A. do Alto do Morais		Canada do Mato (Frei Matias)	65/-10		12.0-30.0	1,015	3755/42605	a	
31	A. do Cabeço Bravo		Cabeço Bravo (Creação Velha)	323/-28.5	4.5-9.0	1.8-15.0	400	3698/42611	Sketch	
32	A. do Cabeço da Negra		Campo Raso, Candelária	?/-15.0	?	?	75	3695/42562		
33	A. do Capitão	Tambor III	Tambor (Mistério de St Luzia)	?/-5.5	?	?	200	3731/42658	c	
34	A. do Lanchão	A. do Cadete; A. do Ti Alfredo	Banderias (Mistério de St Luzia)	40.5/-5.5	0.40-5.0	0.50-2.0	110	3721/42667	Sketch	
35	A. do Tambor	Cratera do Cabeço	Tambor (Mistério de St Luzia)	97.4/-31.5	1.0-3.5	1.20-7.40	244	3733/42657	Sketch	
36	A. do Vale da Nogueira		Vale da Nogueira	?	?	?	?	?		
<b>5. Graciosa</b>										
Lava Tubes										
1	Furna da Labarda		?	7.4	?	?-4.40	?	?		
2	F. da Maria Encantada	F. do Castelo	Cume da Caldeira	56.5	?-2.80	2.5-5.7	200	4151/43207		
3	F. do Anel		?	50.4	?	?-3.50	?	?		
4	F. do Canto		?	11.3	?	?-10.80	?	?		
5	F. do Cardo		?	15	?	?-2.20	?	?		
6	F. do Gato		?	11.0	?	?-6.60	?	?		
7	F. do Linheiro		?	8.2	?	?-10.0	?	?		
8	F. do Luís		?	12	?	?-9.0	?	?		
9	F. do Manuel de Ávila		?	14.7	?	?-8.10	?	?		
10	F. do Queimado		?	12.5	?	?	?	?		
11	F. dos Bolos		?	8	?	?-6.50	?	?		
12	F. D'Água		?	10.5	?	?	260	4148/43211		
13	F. Ferrada		?	3.4	?-6.20	?-8.10	?	?		

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Island and No.	Main Name	Other Names	Location	Length/ Depth (m)	Height (m)	Width (m)	Elev. (m)	UTM	Map	Fauna
5. Graciosa (cont) Lava Tubes										
14	Galeria do Forninho		Luz	96	0.80-3.5	?-7.30	?	?		
15	Gruta da Canada das Furnas	Furna do Roque	Canada das Furnas	83	1.9-6.5	3.4-6.10	125	4148/43208		
16	G. do Bom Jesus		Bom Jesus	16	0.55-2.10	2.25-3.0	50	4115/43255	Mont	
Pits										
17	Furna do Enxofre		Caldeira da Graciosa	42		100	137	4159/43199	Ogawa	
6. São Jorge Lava Tubes										
1	Furna das Pombas	G. do Cais da Urzelina	Urzelina	?	?	?	0	4029/42782		
2	F. do Poio	F. da Lagoa de St Cristo	Fajã de St Cristo	?	?	?	25	4189/42758		
3	F. do Pombal	Mina D'Água	Pombal, Fenos, Manadas	?	?	?	510	4048/42769		
4	Gruta da Beira		Beira	183	2.50-10.0	2.50-15.0	275	3952/42839	Mont	yes
5	G. da Granja		Velas	?	?	?	?	3958/42817		
6	G. da Lomba do Gato		Gueimada, Velas	?	?	?	250	3967/42816		
7	G. do Leão		Presa do Leão, Velas	177	0.5-6	0.8-3	250	3964/42818	Mont	
Pits										
8	Algar das Bocas do Fogo	Bocas de St Anaro	Lixeira de St Anaro	55.3/-12.0		30.0-50.0	521	3982/42817	Mont	yes
9	A. do Montoso		Pico do Carvão	269/-137.5	9.0-50.0	9.0-70.0	784	4048/42791	Mont	
10	A. do Pico da Maria Pires		Pico da Maria Pires	?	?	?	663	4000/42814		
11	A. do Pico dos Suspiros I		Pico dos Suspiros	?	?	?	920	4049/42792		
12	A. do Pico dos Suspiros II		Pico dos Suspiros	?	?	?	920	4049/42792		
7. Terceira Lava Tubes										
1	Forna de St Maria		Cabrito, Porto Judeu	320	?	?	450	4841/42852		
2	F. do Cabrito		Cabrito, Porto Judeu	200	?	?	400	4841/42849		
3	F. D'Água		Cabrito, Porto Judeu	250	?	?	450	4843/42845		
4	Galeria da Ribeira Seca		Ribeira Seca	60	?	?	175	4918/42813		
5	Galeria Queimada	Cafua Velha	Biscoitos, Pau Velho	639.9>??	0.3-2.5	0.26-10.9	473	4768/42895	Mont	
6	Gruta Branca Opala		Biscoitos, Pau Velho	87.3	0.9-3.1	1.1-2.8	280	4781/42923		
7	G. da Achada		Biscoito das Fontinhas	169	0.25-2.40	1.5-4.0	310	4868/42870		
8	G. da Madre de Deus		Porto Martins	244	0.5-10.8	0.5-21.0	210	4940/42816	Mont	yes
9	G. das Agulhas	G. da Salga	Porto Judeu	250.5	0.5-5.4	1.2-4.5	5	4909/42775	Mont	yes
10	G. das Feiticeiras		Outeiro do Bogango	?	?	?	600	4724/42854		
11	G. das Mercês		Canada dos Marcos, Feteira	69	0.60-2.70	1.2-1.7	135	4869/42784		
12	G. de Santo António		Porto Martins	302.1	0.35-9.40	0.6-18.0	220	4936/42818		
13	G. do Caldeira		Biscoitos, Pau Velho	148	0.40-2.60	1.1-5.6	260	4774/42911		yes
14	G. do Camelo		Cabrito, Porto Judeu	255.87	0.30-3.80	1.7-11.3	465	4841/42850	Mont	



Island and No.	Main Name	Other Names	Location	Length/ Depth (m)	Height (m)	Width (m)	Elev. (m)	UTM	Map	Fauna
7. Terceira (cont) Lava Tubes	G. do Chocolate		Biscoitos, Pau Velho	109.7	0.50-6.20	0.4-3.6	250	4781/42924	Mont	yes
	G. do Coelho		Lagoa do Negro	186.7 ??	1.0-2.1	1.2-3.5	540	4764/42879		
	G. do Natal	Galerias Negras; G. do Cavalo	Lagoda do Negro	389	0.50-7.0	0.8-12.0	540	4766/42878	b	
	G. do Pau Velho	G. dos Principiantes	Biscoitos, Pau Velho	245.5	1.0-4.0	0.4-12.0	350	4778/42908	b	
	G. do Zé Grande		Serretinha	31.61	0.40-2.10	1.9-3.8	125	4867/42781	Mont	
	G. dos Balcões		Biscoitos, Pau Velho	2,713	0.30-6.0	0.25-7.0	390	4778/42906	b	yes
	Pits									
	Algar do Carvão		Algar do Carvão, Porto Judeu	120/-90	1.6-40	2.10-20.0	629	4810/42865	Mont	yes
	A. do Fumil		Biscoitos	-22		11.0-20.0	500	4778/42879		
	A. do Mistério		Biscoitos	151/-12	0.50-2.10	0.5-2.4	545	4763/42877		
	A. do Negro		Lagoa do Negro, Biscoitos	16/-5.5		16	540	4762/42876		
	A. do Pico das Dez		Pico das Dez, St Barbara	60/-20	0.30-3.50	1.0-4.5	350	4698/42849		
	A. do Pico Gaspar		P. Gaspar, Lagoda do Negro, Bis	8.5/-18		2.35	540	4764/42873	Sketch	
8. São Miguel Lava Tubes	Gruta da Canada da Giesta		Pico da Pedra, Ribeira Grande	?	?	?	145	6228/41831		
	G. da Quinta-Irene		Ribeirinha, Ribeira Grande	30	?	?-20.0	105	6329/41879		
	G. da Rua do Carvão	Algar da Rua de Lisboa	Domingos Rebelo, P. Delgada	694.9	0.3-5.1	1.0-12.7	38	6159/41779	d	
	G. da Rua do Paim	Algar da Rua do Paim; G. da Fábrica de Tabaco	Rua do Paim, P. Delgada	285.4	0.5-5.1	1.2-10.5	71	6158/41785	d	
	G. das Arribanas		Arrifes, Serra Gorda	?	?	?	275	6153/41828		
	G. das Escadinhas		Ribeirinha, Ribeira Grande	31.2	0.44-1.6	0.75-5.1	140	6331/41868	d	
	Gruta de Água de Pau		Água de Pau	323.1	0.2-2.6	0.8-6.6	2	6295/41752	d	yes
	G. do Esqueleto		Lagoa do Fogo, R. Grande	188.2	0.3-9.5	1-12.5	250	6311/41843	d	yes
	G. do Pico da Cruz	Furno do Pico da Cruz	Pico da Cruz, Pico da Pedra	98.5	0.6-2.9	0.85-5.4	273	6217/41830	d	yes
	G. do Pico do Enforcado		Capelas, Ponta Delgada	184.8	0.45-3.20	0.7-6.0	245	6160/41868	d	yes
	Pits									
	Algar da Batalha	Gruta da Batalha	Fajã de Cima, Ponta Delgada	51.9/-9.5	0.4-3.3	0.5-5.7	240	6198/41837	d	
	A. da Merda	Gruta da Ribeirinha	Ribeirinha, Ribeira Grande	54.5/-5	0.9-2.5	?-3.7	150	6331/41870	d	
	A. do Pico Queimado		Pico Queimado/Pico do Sapateiro	10/-37.3	12	1.6	250	6283/41830	d	yes
9. Santa Maria Littoral Caves	Furna das Pombas	Furna Velha	Vila do Porto	337	0.5-14.5	0.4-12.5	0	6663/40900	Mont	yes
	Furna dos Anjos		Anjos	117.85	0.65-8.6	0.44-11.2	10	6639/40969	Mont	yes
	Gruta do Romeiro		Ilhéu do Romeiro de S Lourenço	?	?	?	40	6745/40947		

## New Maps and Sketches of Some Azorean Caves and Pits

Herewith we present 13 new maps and 4 sketches of 12 lava tube caves, 2 littoral caves and 3 pits. A short characterization of each is presented. The four sketches (Gruta das Torres, Algar da Bocas do Fogo, Galeria Queimada and Gruta das Agulhas) will soon be published as maps.

### Faial

**1. Gruta Das Anelares** (Gruta da Lombega) (Plate 1; Figure 3, lava tube 1)

Location: Lombega (Faial); Elev: 80 m; UTM: 3482/42663; Length: 35.5 m; Height: 0.70-4.00 m; Width: 1.40-2.50 m.

During the Torres 91 Expedition to the island of Pico Os Montanheiros had the opportunity to study and map a small lava tube at Lombega, Faial. Later named by us Furna das Anelares, because of the ring-like (*anel* in Portuguese) stalactites commonly dispersed all over the ceiling. This is a small lava tube with only one entrance, a skylight situated 3.40 meters above the ground.

The floor is of aa lava and the ceiling is completely covered with thin brown stalactites (blade like) and ring stalactites.

**Fauna:** During the visit to this cave we had the opportunity to collect some specimens of one interesting hypogean species. The species is probably the troglotic *Cixius cavazoricus* Hoch (Homoptera, Fulgoroidea) described from Gruta do Cabeço do Canto (see below). They were collected on roots situated at the north part of the cave (see points 3 and 3' of the map, plate 1).

**2. Gruta do Cabeço do Canto** (Gruta dos Concheiros) (Plate 2; Figure 3, lava tube 2)

Location: Cabeço do Canto, Capelinhos (Faial); Elev: 346 m; UTM: 3425/42740. Length: 21.4 m; Height: 0.30-5.10 m; Width: 0.50-7.50 m.

During the Faial-89 Biospeleological Expedition to the island of Faial we had the opportunity to visit the Capelinhos area. On information from a local person we went to the Cabeço do Canto and found a small lava tube there. The entrance is covered with ashes of the Capelinhos eruption (1957-58) and the floor of the cave is covered with many collapsed rocks.

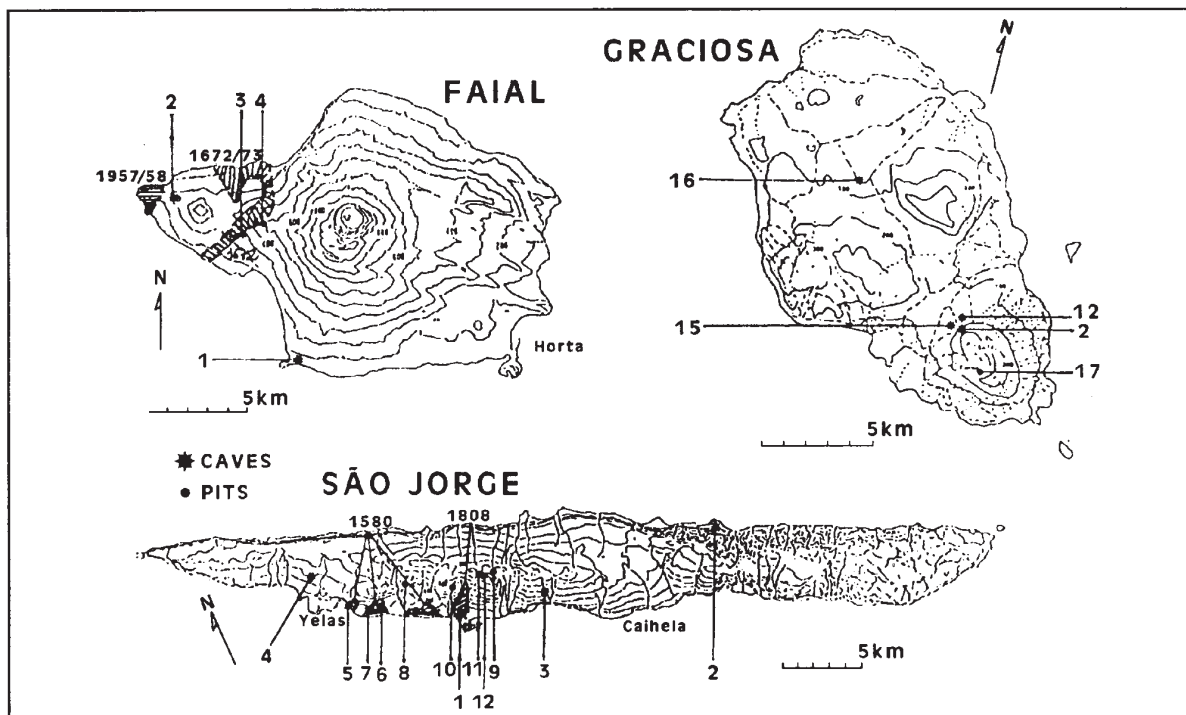


Figure 3—Maps of three central Azorean islands, Faial, Graciosa, and São Jorge, showing the location of the lava tubes and pits (see also Table 3).

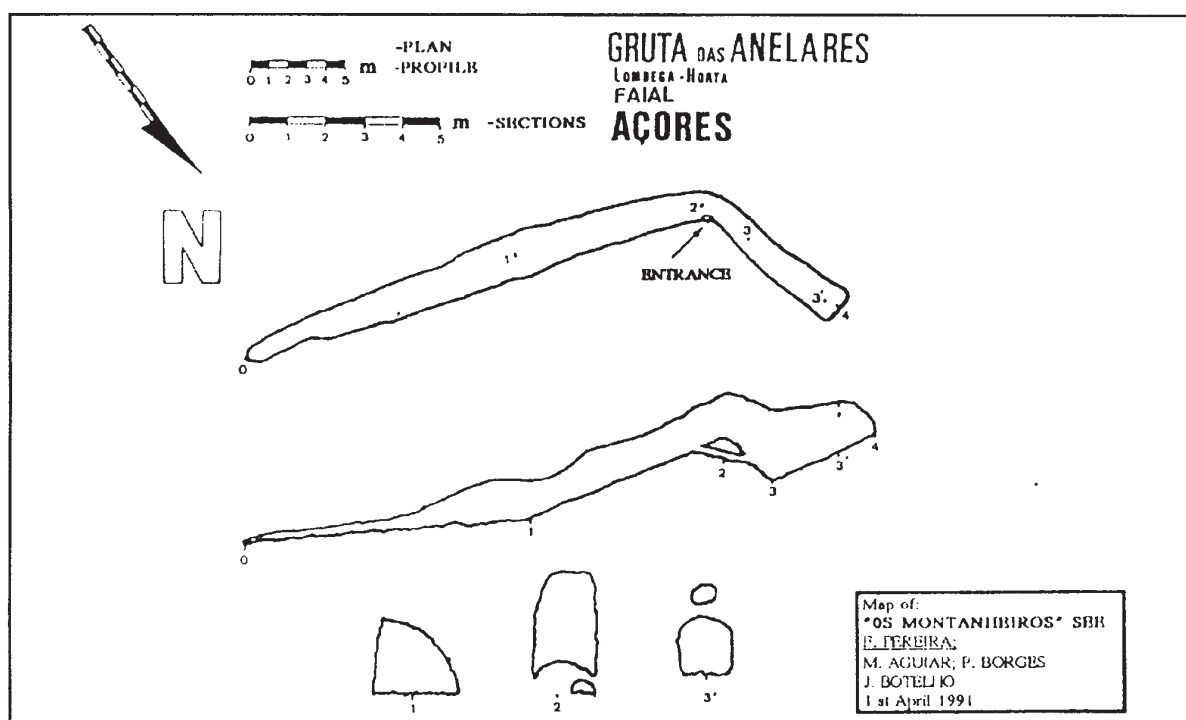
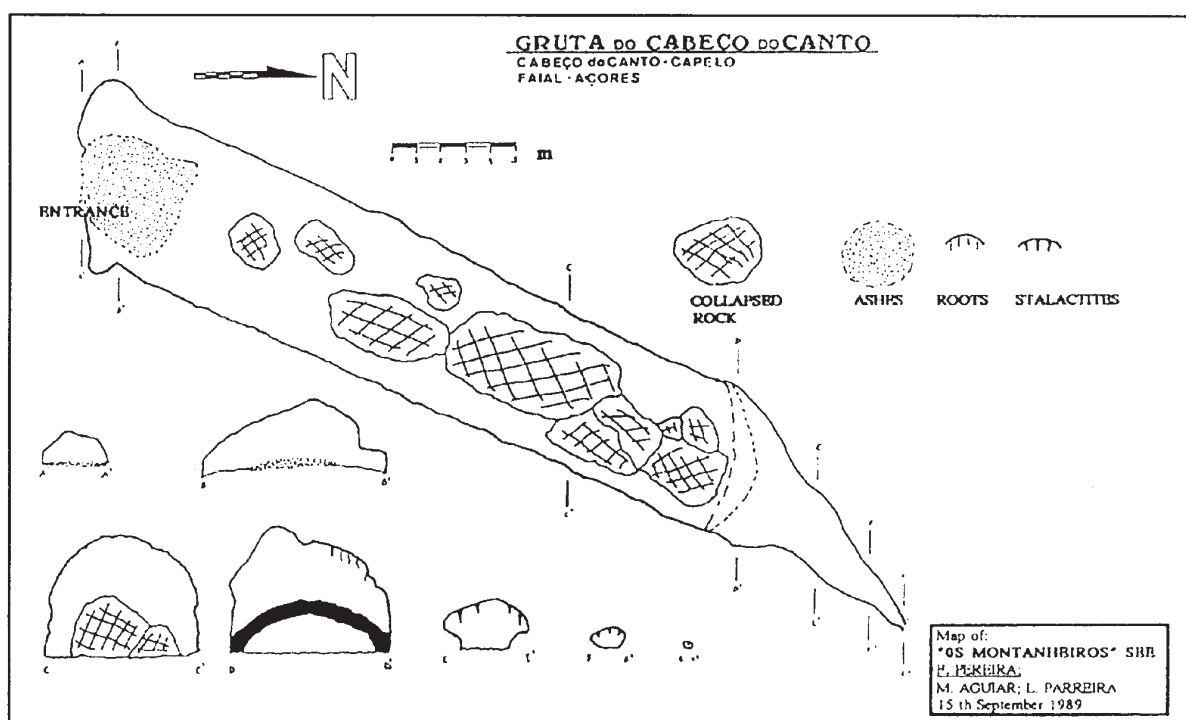


Plate 1 – Gruta das Anelares.



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There are two obvious levels of drainage shown on the double gallery at the end of the cave. In this part the upper level forms an arch (double ceiling) and the walls are reddish. Some small lava stalactites are present.

The Cabeço do Canto volcano is part of a recent complex of volcanoes aligned over a fracture line that connects the Caldeira do Faial and the Capelinhos Volcano.

**Fauna:** Recently Hoch (manuscript) described the troglotitic species *Cixius cavazoricus* Hoch (Homoptera, Fulgoroidea) with type specimens collected by us in this cave. The specimens were collected in roots situated in the north part of the cave (see sections D-D' and E-E' of the map). *Cixius cavazoricus* Hoch is a relict species, i.e., a cavernicolous species which has no close epigeal relatives on the same, or neighboring islands (Hoch, *op. cit.*). Mainly to ensure survival of this organism, this cave should be protected.

### Pico

**3. Furna dos Montanheiros** (Plate 3; Figure 4, lava tube 14)

**Location:** Curral Queimado, Brejos, Regional Road nº 3, km 17 (Pico); Elev: 785 m; UTM: 3831/42610; Length: 741 m; Height: 0.45-6.79 m; Width: 0.40-8.59 m.

The cave is a typical lava tube and was mapped during the Biospel-90 Biospeleological Expedition of Os Montanheiros.

The main entrance is a skylight situated 400 meters from the west part of the tube where another skylight (hornito) occurs. The access is a wooden staircase constructed by Os Montanheiros.

It is a unitary "throughway" system, with remarkable formations that make it one of the most interesting lava tubes in the Azores.

The floor of this volcanic tunnel is of aa or pahoehoe type. There are several levels of drainage registered on the walls by lateral benches (*bancadas*). The same occurs in the impressive lava tubes Gruta dos Balcões (Terceira) and Gruta das Torres (Pico) (see below).

The west part of the cave is the most interesting one with some notable formations on the floor, like a model lava tube at reduced scale that shows how a large lava tube can be formed. In this part of the cave the lava flow was oxidized by the entrance of air (due to the compression of gases), and as a

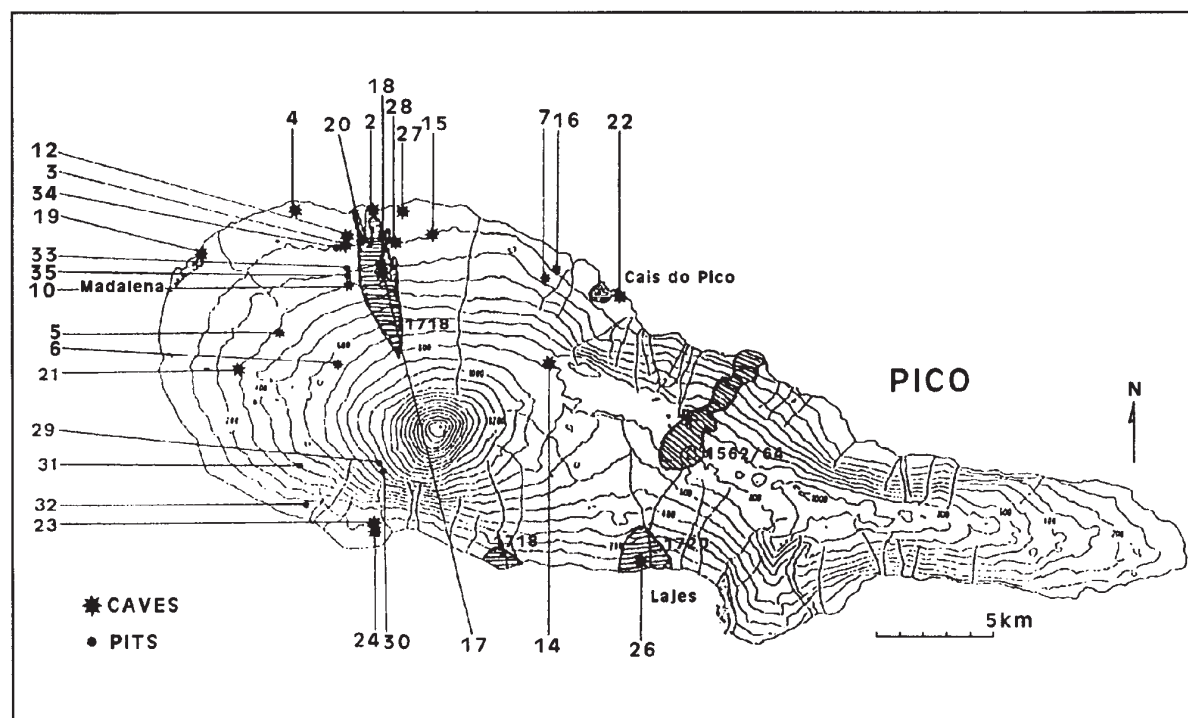


Figure 4—Map of Pico Island showing the location of the lava tubes and pits (see also Table 3).

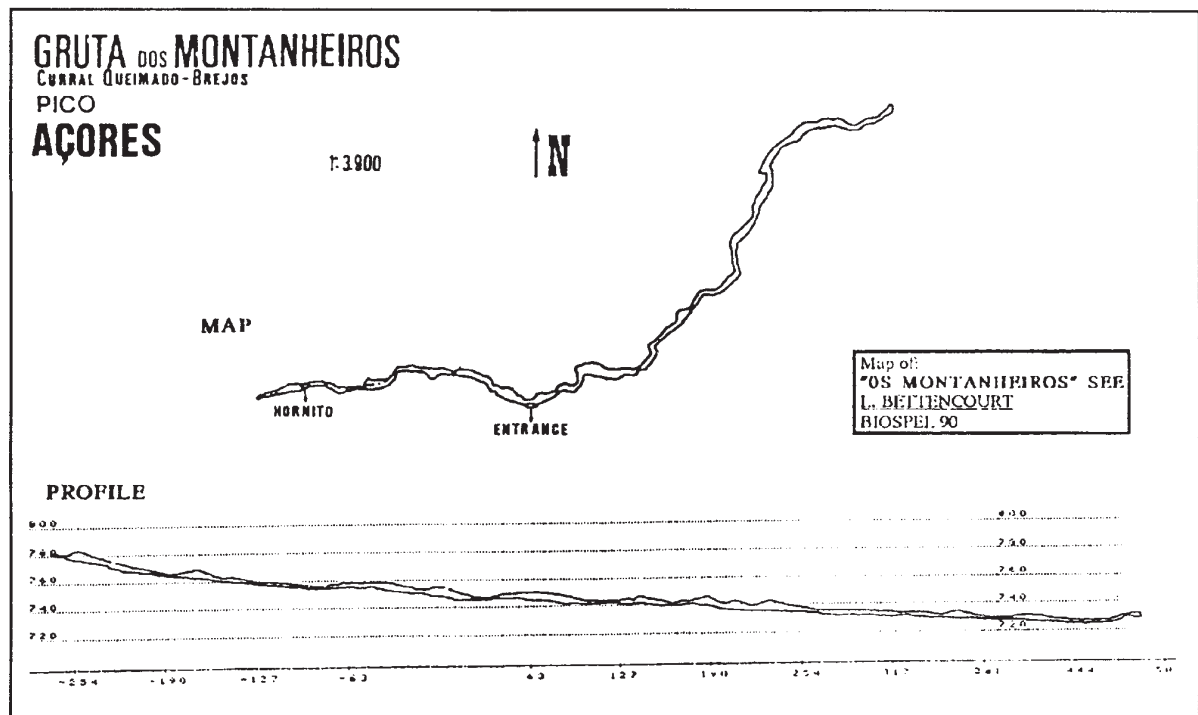


Plate 3—Gruta dos Montanheiros.

consequence the rock is reddish. There are multiple levels. Fortunately the tube is well preserved with almost no collapsed rocks from the ceiling or walls.

In the north part of the tube there are some areas with collapsed rocks and in other parts we can find a collapsed rock covered by the lava flow. Several types of stalactites (lava-drops) cover the ceiling of all the cave.

**Fauna:** Biospeleologically this is one of the best studied caves in the Azores. As a consequence of the biospeleological expedition directed by N.P. Ashmole and P. Oromí (1987), a hypogean ground beetle was described, *Trechus picoensis* Machado (see Oromí *et al.*, 1990).

Later, another carabid species (present only in the skylight area of the cave) was described, *Trechus montanheiorum* Oromí and Borges (see Oromí and Borges, in press). The type specimens were collected during the former expedition and during the Biospel-89 and Biospel-90 Biospeleological Expeditions of Os Montanheiros. The origin and speciation of these two interesting *Trechus* species are discussed in Borges and Oromí (in press).

In this cave we also found two new species of Collembola, *Onychiurus* sp. and *Pseudosinella azorica* Gama, both with obvious adaptations to cave life (Oromí *et al.*, 1990).

Other species, common to other Pico caves (e.g., Soldão, Capucha, Arcos), could also be found in Gruta dos Montanheiros, like the undescribed *Cixus* sp. (see Hoch, in press) and the spider *The ridion pico* Merrett and Ashmole.

Speleologically and biologically Gruta dos Montanheiros is one of the most important caves of the Azores and should be protected.

#### 4. Gruta das Torres (Plate 4; Figure 4, lava tube 21)

Location: Cabeço Bravo, Creação Velha (Pico); Elev: 200 m; UTM: 3681/42618; Length: 3,350 m; Height: 0.50-15.00 m; Width: 1.10-22.00 m.

This is now the most impressive volcanic lava tube in the Azores, with 3,350 meters mapped and more than 600 to 800 meters only visited for a total length of about 4,000 meters. In the list of the world's longest lava tubes revised (second revision) by Crawford (1979) the Gruta das Torres would occupy the seventh place. Gruta dos Balcões (Terceira) is now the second longest one in the Azores.



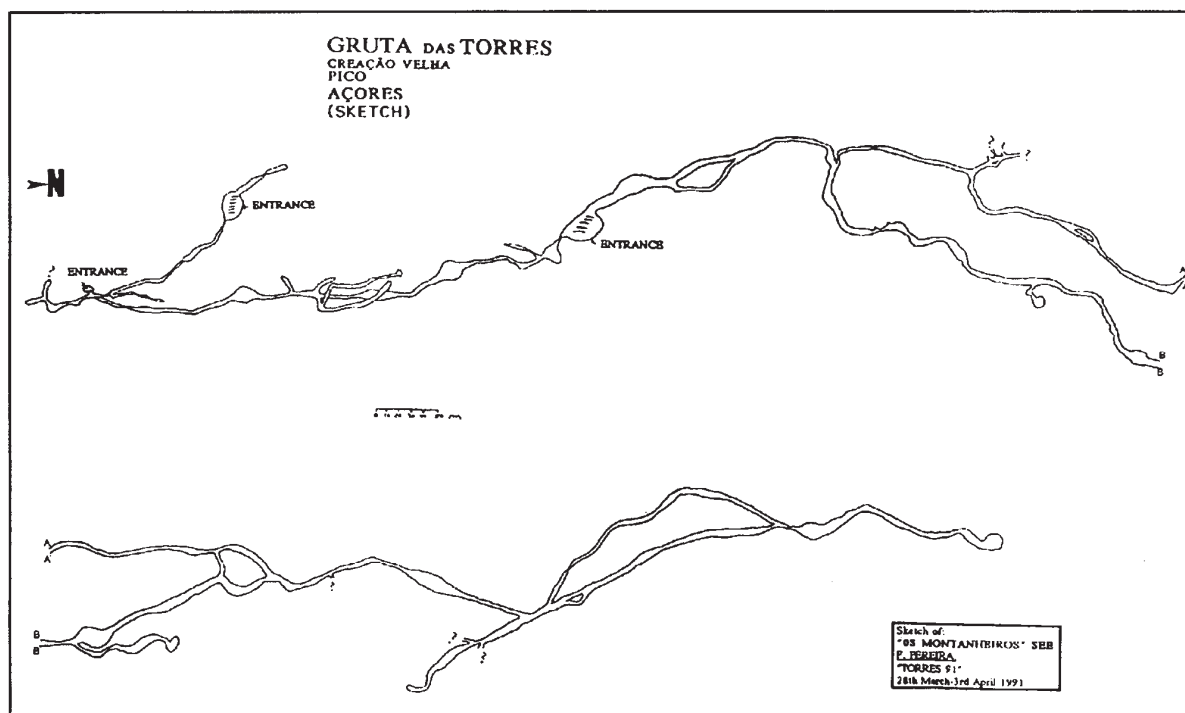


Plate 4—Gruta das Torres.

Between March 28 and April 3, 1991, a team of seven members of Os Montanheiros undertook a speleological expedition, Torres-91, to this magnificent cave, mapping and filming it.

The cave lies in lava fields of the northeast volcanic sector of Pico Mountain, southeast of Creação Velha.

It is a three-dimensional braided system with some remarkable formations. The floor is aa or pahoe-hoe type. There are at least 11 levels of drainage registered on the walls by lateral benches and three cornice levels. The height of 15 meters and the 11 drainage levels give an idea of the majesty of this lava tube cave.

This lava tube has two entrances, one, a skylight near one extremity, the other, 600 meters down, a large cone formed by the slumping of the roof. All over the main tube (about 2,500 meters in length) there are great blocks of lava collapsed from the roof making progress very difficult, but in some areas the floor is clean and of a beautiful pahoe-hoe lava or aa lava. In the main tunnel we can find some impressive lava gutters. The most interesting formations are in the secondary tunnels, some of them are unique. Sometimes there are very low crawl-way passages.

**Fauna:** The undescribed *Cixius* sp. (see Hoch, *op. cit.*) was collected by us during the Torres-91 Speleological Expedition of Os Montanheiros to this cave. We have also put a set of pitfalls in the cave but the arthropods collected by these traps are still undetermined.

## São Jorge

**5. Gruta da Beira** (Plates 5 and 6; Figure 3, lava tube 4)

**Location:** Beira (São Jorge); Elev: 275 m; UTM: 3952/42839; Length: 183 m; Height: 2.50-10.0 m; Width: 2.50-15.0 m.

This cave was mapped during the Speleological expedition of Os Montanheiros directed by A. Luís to São Jorge in 1972 and later revisited by the recent S. Jorge-88 Expedition of Os Montanheiros.

The cave is located in the Rosais Volcanic Complex, mainly with porphyric basalts. The lava tube has a north-northwest orientation, flowing to south-southwest at the sea direction.

The entrance, measuring ten by six meters, is a hollow in the collapsed roof of the cave. In the southern part of the tunnel there is a large room filled with earth. Several collapsed rocks from the

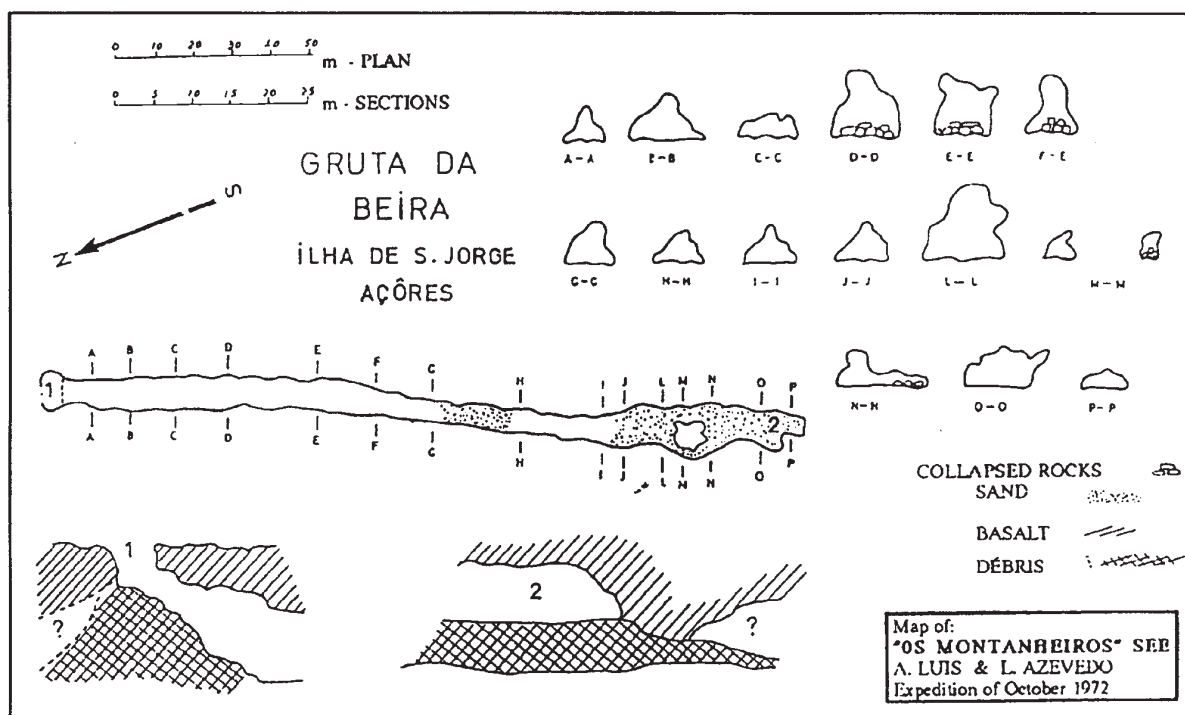


Plate 5—Gruta da Beira (plan).

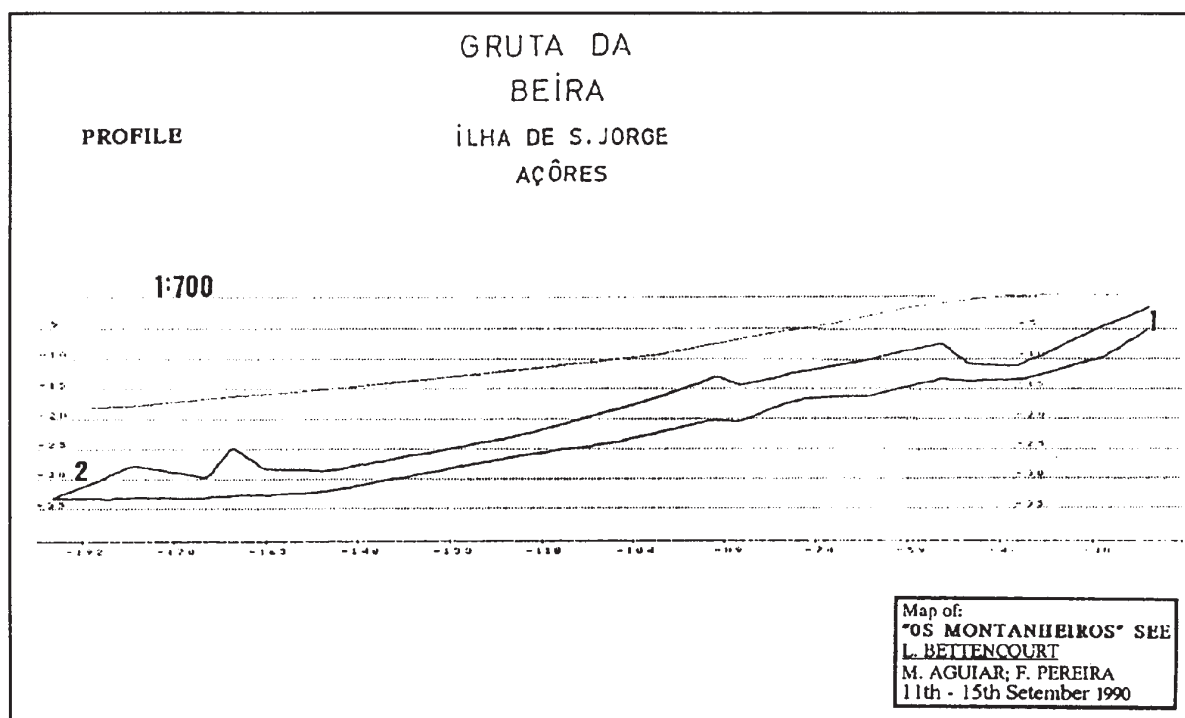


Plate 6—Gruta da Beira (profile).

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ceiling can be found all over the cave. The floor, and to some extent the lateral walls, are covered by earth, because of water infiltration from the roof and the entrance.

There are no lateral benches, but many stalactites can be found covered with a white substance similar to that found in Gruta das Agulhas (Terceira) (see below). Because of its dimensions and beauty, this lava tube should be protected.

**Fauna:** As a result of the biospeleological expedition directed by N.P. Ashmole and P. Oromí (1987), two troglobitic species were described from this lava tube, the pseudoscorpion *Pseudoblothrus oromii* Mahnert and an isopod (*Trichonoscidæ*) Gen. sp. indet. that probably represents a new genus (see Oromí et al., 1990).

### 6. Gruta do Leão (Plate 7; Figure 3, lava tube 7)

**Location:** Presa do Leão (Queimada), Velas (São Jorge); Elev: 250 m; UTM: 3964/42818; Length: 177 m; Height: 0.50-6.00 m; Width: 0.80-3.00 m.

As with the previous cave, this lava tube was mapped during the speleological expedition to São Jorge of Os Montanheiros directed by A. Luís in

1972 and later revisited by the recent S. Jorge-88 Expedition of Os Montanheiros.

We think that this cave was formed by the lava flows of the eruption of 1808 (Bocas de St. Amaro). The entrance is a hollow, 0.6 by 0.4 meters, with a six-meter vertical drop. The gallery is narrow and high with a considerable slope. There are yellowish formations near the entrance, probably with the same composition as those present in the Algar das Bocas do Fogo (see below). Some collapsed rocks from the ceiling and walls are present.

**Fauna:** Unknown.

### 7. Algar das Bocas do Fogo (Bocas de St. Amaro) (Plate 8; Figure 3, pit 8)

**Location:** Lixeira de St. Amaro (São Jorge); Elev: 521 m; UTM: 3982/42817; Length: 55.3 m; Depth: 12.0 m; Width: 30.00-50.00 m.

This pit was mapped during the recent S. Jorge-88 Expedition of Os Montanheiros.

Algar das Bocas do Fogo is a volcanic crater in which the chimney has three openings that lead to a chamber of 30 by 50 meters. The best access is the larger opening with a drop of 40 meters. The 1808 eruption of St. Amaro originated at two openings with two lava flows.

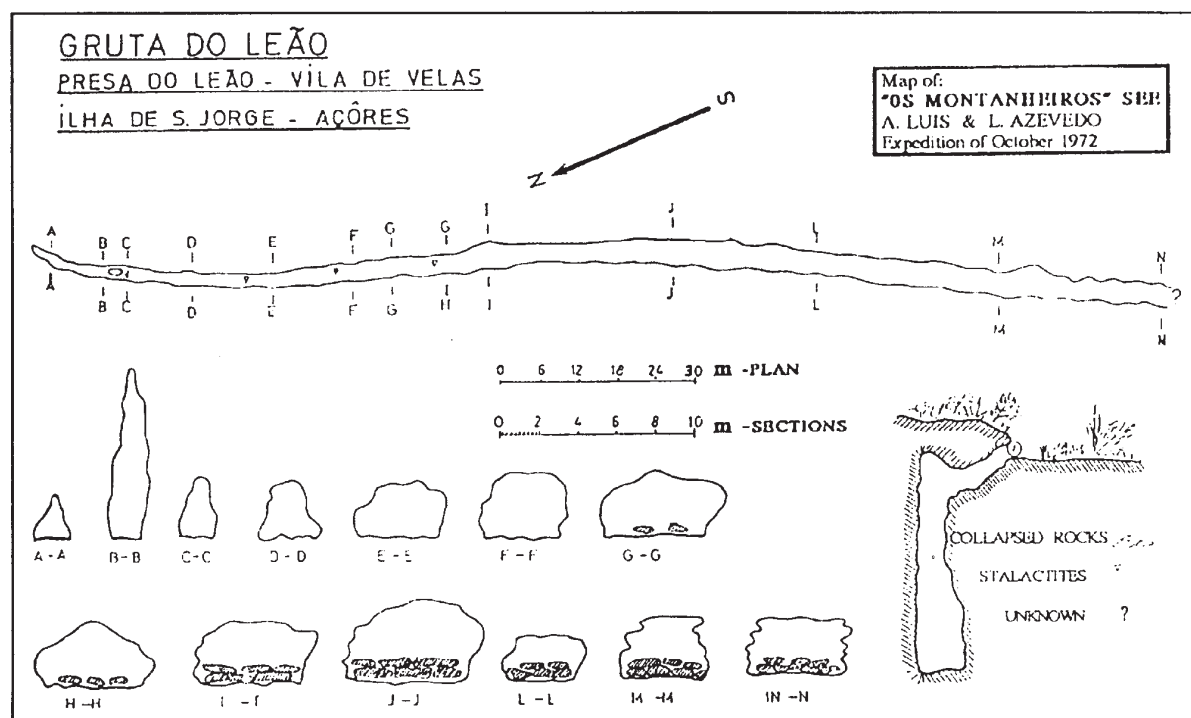


Plate 7—Gruta do Leão.

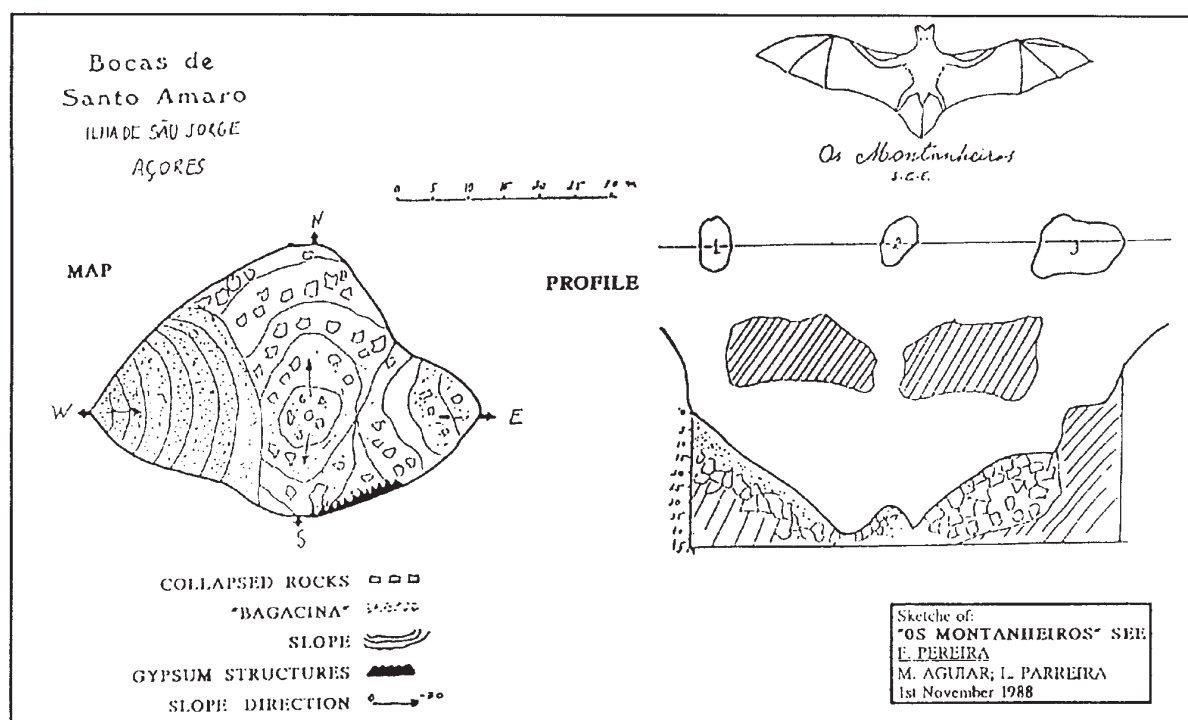


Plate 8 – Algar das Bocas do Fogo.

Due to the materials accumulated under the lateral openings, the floor has a “V” cross section. A small cone of volcanic materials is present under the central opening. The two lateral ramps are 30 and 20 meters long with a drop of 15 and 10 meters. On the walls of the south part of the crater there are some deposits of white gypsum.

**Fauna:** During the biospeleological expedition directed by N.P. Ashmole and P. Oromí (1989), a new species of a troglobitic ground beetle was found and described later, *Trechus jorgensis* Oromí and Borges. Unfortunately only a female is known.

#### 8. Algar do Montoso (Plate 9; Figure 3, pit 9)

Location: Pico do Carvão (São Jorge); Elev: 1,019 m; UTM: 4048/42791; Length: 269 m; Depth: 137.5 m; Height: 9.00-50.00 m.; Width: 9.00-70.00 m.

This pit was mapped during the recent Montoso-90 Expedition of Os Montanheiros.

The Pico do Carvão is an extinct volcano with one crater and three openings – two of them closed and the third one open. This last volcanic chimney has three orifices (1, 2, and 3 from plate 8), the Algar do Montoso (named incorrectly by an error of toponymy, the correct name should be Algar do Carvão).

Of the three vertical pits, only the second and third (see plate 8) are used for vertical caving. Number 2 is more suitable, being formed by several terraces with a drop of 60 meters, ending in a large chamber of 150 by 70 meters (height 40 to 50 meters).

After reaching the bottom of pit number 2 the floor has a steep slope; a small lake covered by plant debris carried in by the rain water lies at one extremity. The ceiling and walls lost part of their cover because of the collapse of large basalt stones.

As in the Algar do Carvão (Terceira) (one of the most beautiful volcanic chimneys of the Azores), there are dripstone and flowstone formations on the walls, which are composed of obsidian or pitchstone, as well as locally profuse silicious ( $\text{SiO}_2$ ) speleothems.

Pit Number 1 has a vertical drop of 80 meters ending in a circular chamber measuring 50 by 30 meters. The assemblage resembles very well an inverted funnel.

Pit Number 3 is a small well, 20 meters deep, all covered by a reddish stone, typical of the hornitos, that ends in a “throat” without any passage.

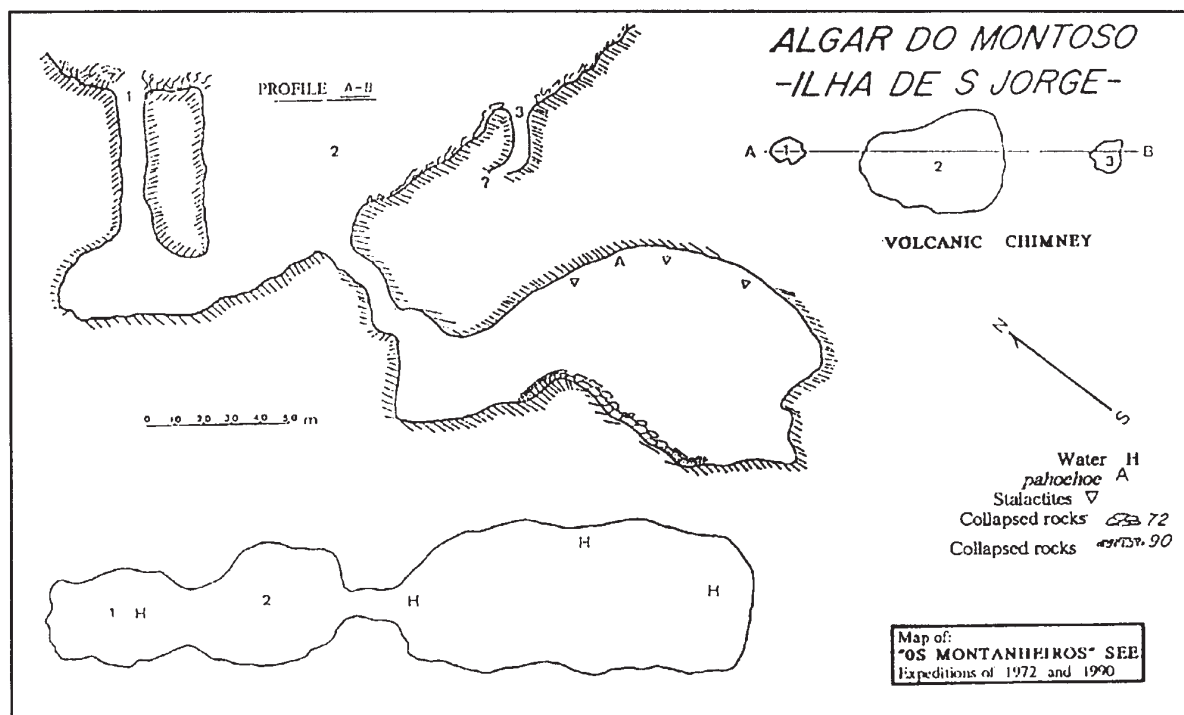


Plate 9—Algar do Montoso.

The Algar do Montoso is the Azores' deepest pit and could be developed as a show cave like Algar do Carvão (Terceira).

Fauna: Unknown.

## Terceira

**9. Galeria Queimada** (Cafua Velha) (Plate 10; Figure 5, lava tube 5)

Location: Pau Velho, Biscoitos (Terceira); Elev: 473 m; UTM: 4768/42895; Length: 639.9 m; Height: 0.30-2.50 m; Width: 0.26-10.9 m.

The Galeria Queimada is located in the historical lava flow of Pau Velho (1761). Like the larger Gruta dos Balcões (situated in the same lava flow) it is a three-dimensionally braided system. It is a cave with some planimetric complexity and is not completely mapped (see ? in plate 10). It is the second biggest lava tube on Terceira and one of the most beautiful.

After the entrance, the broader part of the ceiling has a particular design, forming two large "teats" (*mamelones* from the Spanish). There are some unusually colorful limonite speleothems forming columns. Near the end of the main tube there is a beautiful structure of limonite forming a

"waterfall." In the main tube the floor is mostly of aa lava, but in the narrow, low secondary tubes the floor is pahoehoe type. In several parts of the lava tube the floor is covered with mud and water. Polymorphic stalactites (lava-drops) occur on the ceiling, some of them being very interesting.

Fauna: Unknown.

**10. Gruta das Agulhas** (Gruta da Salga) (Plate 11; Figure 5, lava tube 8)

Location: Porto Judeu (Terceira); Elev: 5 m; UTM: 4909/42775; Length: 250.5 m; Height: 0.50-5.40 m; Width: 1.20-4.50 m.

This is a mildly braided lava tube cavern (Halliday, 1981) formed by lavas from the eruption of Pico do Refugo. It was studied especially by Mottet (1974) because of its outstanding sequence of flow features. The cave was named "Agulhas" (needle) because of its needle-like lava formations of vitrified silica (opal) about 0.2 to 0.5 centimeters long.

The main entrance is at sea level. The floor is aa or pahoehoe. There are at least four levels of drainage registered on the walls by lateral benches.

In the middle of the cave there is evidence of a false floor which shows where the lava has drained away leaving a small tube (30 meters long and 0.5



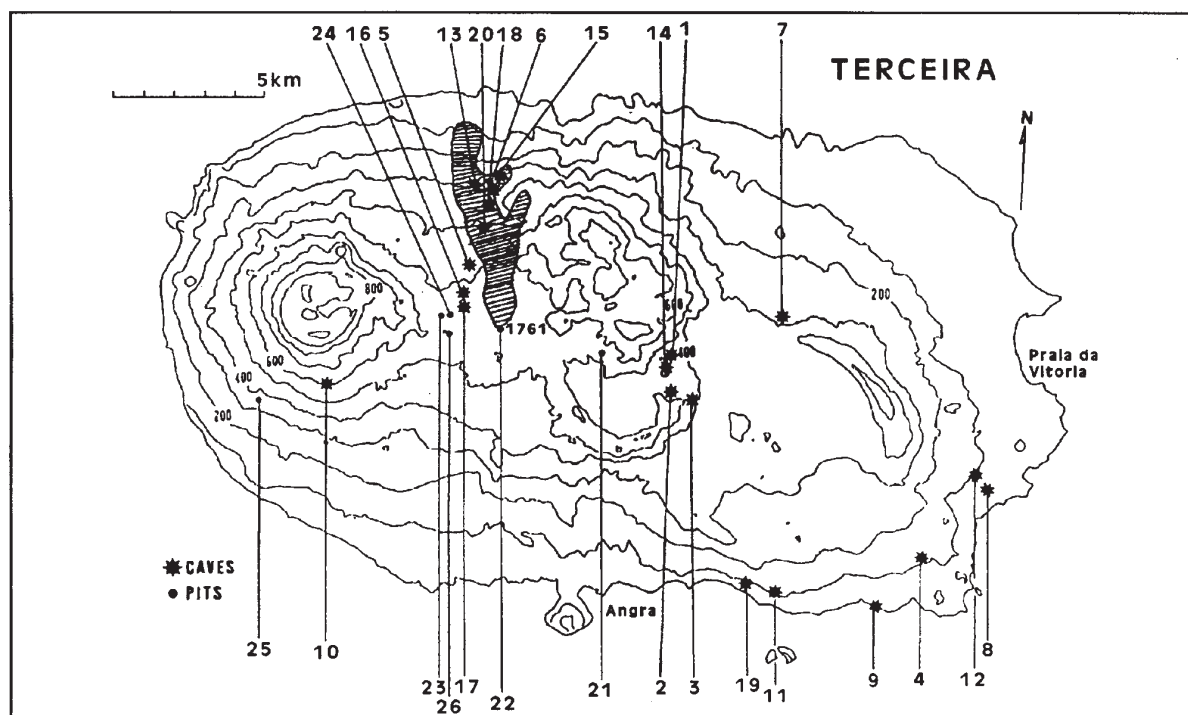


Figure 5—Map of Terceira Island showing the location of the lava tubes and pits (see also Table 3).

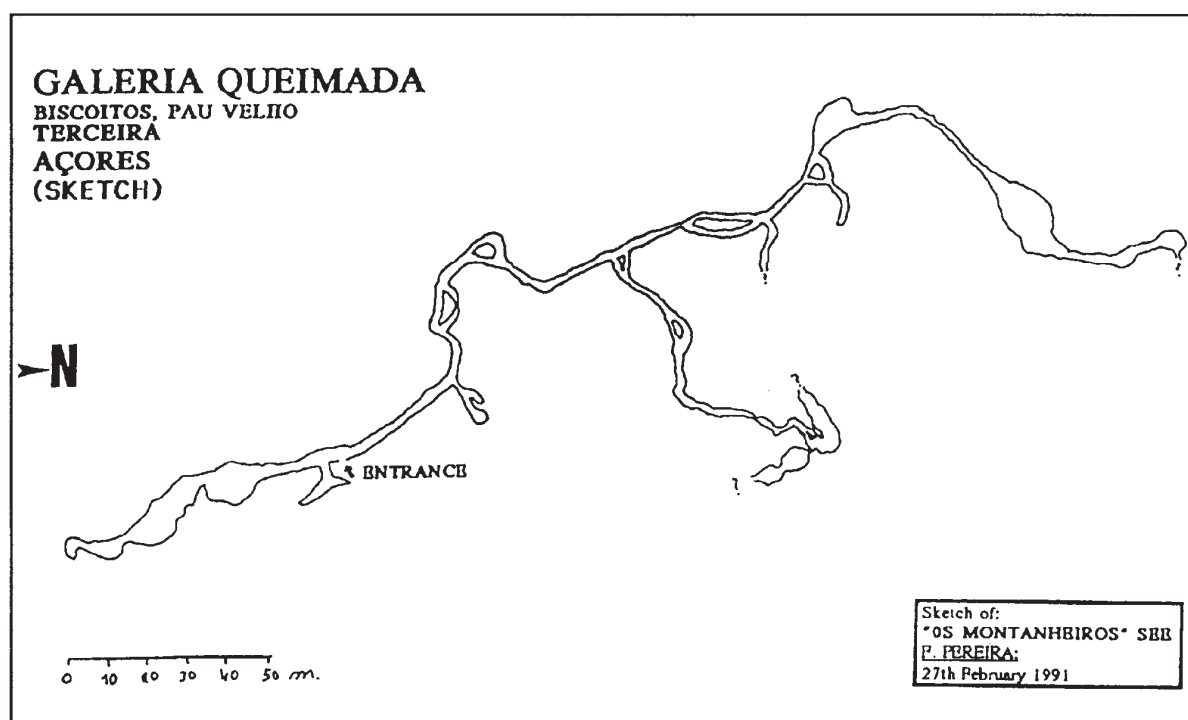


Plate 10—Galeria Queimada.

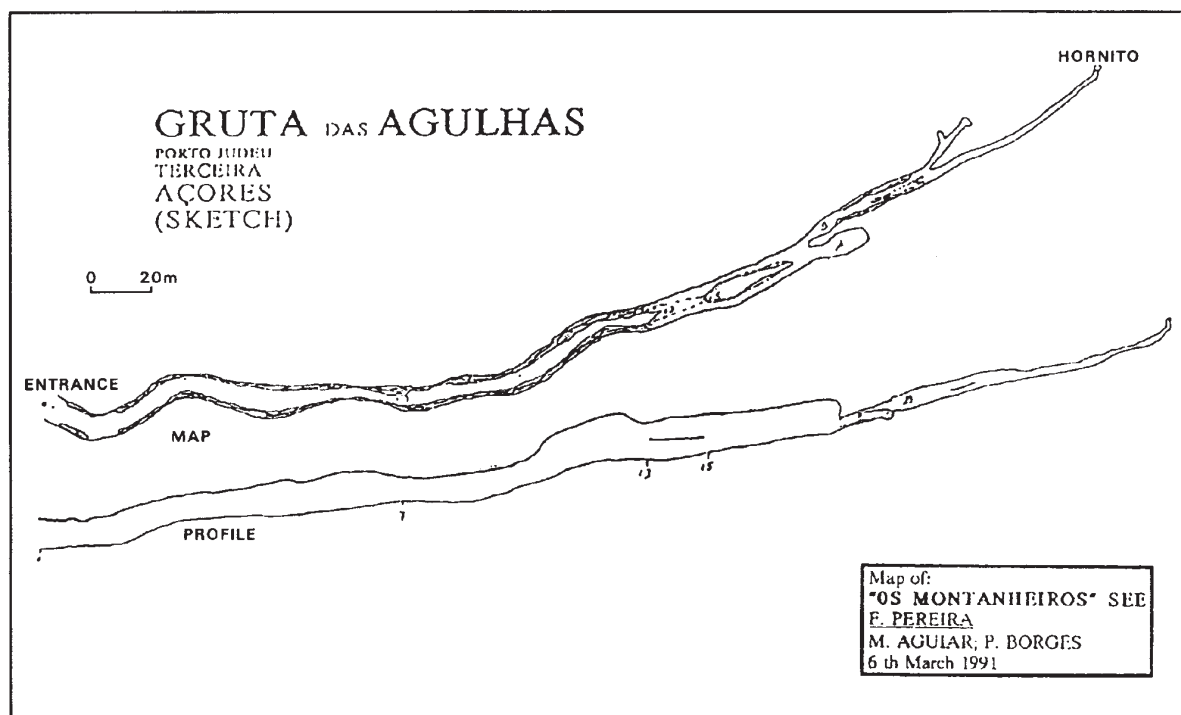


Plate 11 – Gruta das Agulhas.

to 1.2 meters high) inside the main lava tube. On the lateral walls there are oblique striated marks as a consequence of the accelerated escape of gases.

**Fauna:** As a consequence of the biospeleological expedition directed by N.P. Ashmole and P. Oromí (1987), several new interesting species were found and described from this cave: the hypogean Pseudoscorpion, *Pseudoblothrus vulcanus* Mahnert and the Amphipod (*Talitridae*), *Macarorchestia martini* Stock (*Macarorchestia* being a new genus) – its only cave adaptation is the small eyes (Stock, manuscript).

Three other hypogean species, not restricted to this cave, were also found: the collembola (*Entomobryidae*) *Pseudosinella ashmoleorum* Gama and *P. azorica* Gama (see Oromí *et al.*, 1990) and the centipede *Lithobius melanops orotavae* Latzel (see Eason and Ashmole, manuscript).

#### 11. Gruta do Chocolate (Plate 12; Figure 5, lava tube 14)

**Location:** Pau Velho, Biscoitos (Terceira) Elev: 250 m; UTM: 4781/42924; Length: 109.7 m; Height: 0.50-6.20 m; Width: 0.40-3.60 m.

Gruta do Chocolate is a small but beautiful lava tube located in the Pau Velho lava flow (1761).

The entrance, a small aperture of 40 by 40 centimeters, is made through a secondary gallery which is partially obstructed by earth and roots. The first part of the cave has a reddish coloration up to one third of its height, probably as a consequence of oxidation.

We think that the occurrence of three superimposed tubes is a consequence of the bent tendency of the ground where the cave was formed. Therefore, the main gallery was subjected to several strangulations caused by materials that obstructed the flow of the lava. A new superimposed tube formed once the lava flowed again.

The first of the galleries is formed by a drainage tube through a hollow in the main “sink” type tube. It is a narrow, low tube with an aa type floor. The walls and ceiling are rich in remelt structures. There is also a formation (miniature of a lava tube) that shows how a lava tube can arise. Over the first gallery there is another, extending the main tube. A third gallery occurs over the second and reaches the cave entrance.

Forty meters upstream there is a large lava rock recovered by the lava flow. The passage at this site is difficult and has to be traversed by crawling over pahoehoe lava. Higher upstream there are yellow-

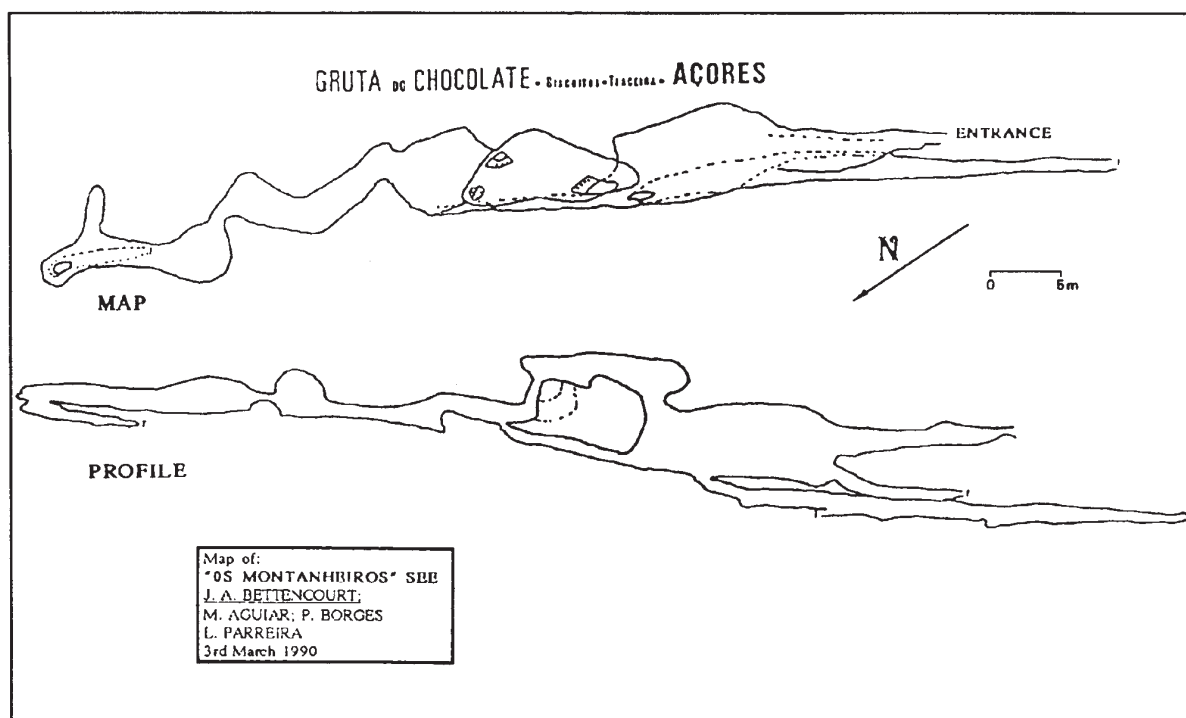


Plate 12 – Gruta do Chocolate.

ish formations, probably silica, covering the lava structures.

Fauna: Unknown.

## São Miguel

**12. Gruta de Água de Pau** (Plate 13; Figure 6, lava tube 4)

Location: Água de Pau (São Miguel); Elev: 2 m; UTM: 6295/41752. Length: 323.1 m; Height: 0.20-2.60 m; Width: 0.80-6.60 m.

This lava tube was mapped during the recent Biospel-90-S. Miguel Expedition of Os Montanheiros.

This is a small, somewhat braided lava tube cave located only two meters above sea level and covered by some 70 meters of overburden (Oromí and Borges, in press). There are also two levels of galleries – a lateral entrance near the ceiling, 40 meters from the main entrance, being the access to the second gallery.

There are two main galleries that intercept each other. The main galleries have lateral benches in some parts, covered with rocks collapsed from the ceiling and walls. On the floor there are large blocks

of lava. On the walls there are rod stalactites and blisters (remelting stalactites). The secondary gallery has very low passages and some crawlways. The floor is pahoe-hoe and the ceiling is covered by stalactites (lava-drops).

The tube is interrupted by a collapse of the roof. Before reaching this point another large amount of collapsed rocks makes progress very difficult.

**Fauna:** The fauna of this cave was studied during the biospeleological expedition directed by N.P. Ashmole and P. Oromí (1989). The general results of this study are still unpublished, but one troglotic species of ground beetle collected in this cave was recently described, *Thalassophilus azoricus* Oromí and Borges (see Oromí and Borges, in press). The type material consisted of 14 specimens (10 of them collected by Borges in 1990), but two more individuals were collected by one of us (F. Pereira) during the Biospel-90-S. Miguel Speleological Expedition of Os Montanheiros to the island of São Miguel.

So far it is the only eyeless ground beetle known from the Azores; it is a relict and paleoendemic species (Borges and Oromí, in press).

This cave should be protected.

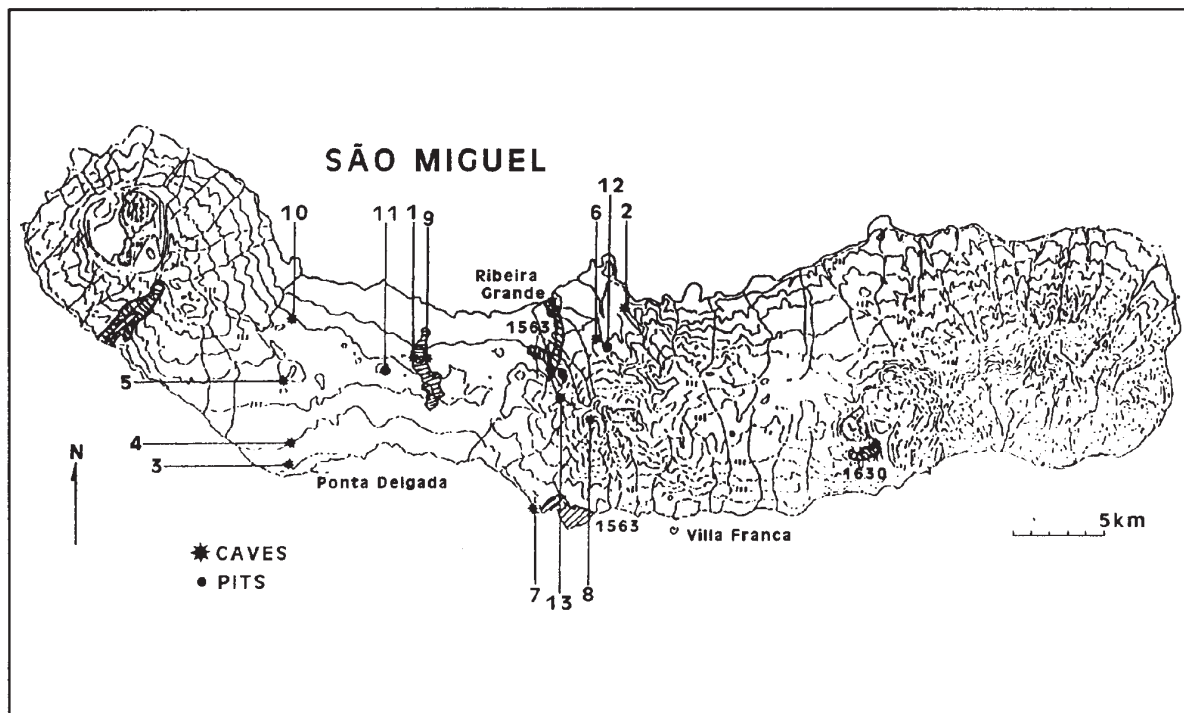


Figure 6—Map of São Miguel Island showing the location of the lava tubes and pits (see also Table 3)

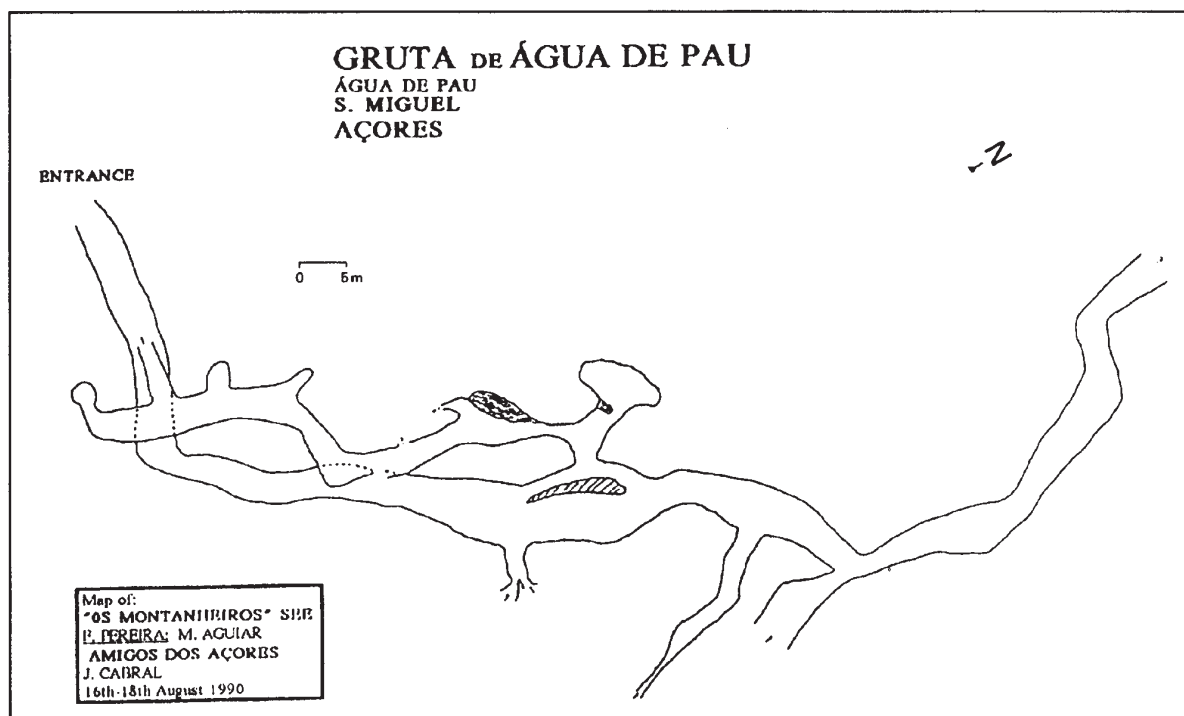


Plate 13—Gruta de Água de Pau.

### 13. Gruta do Esqueleto (Plate 14; Figure 6, lava tube 5)

Location: Lagoa do Fogo road, Ribeira Grande (São Miguel); Elev: 250 m; UTM: 6311/41843; Length: 188.2 m; Height: 0.30-9.50 m; Width: 1.00-12.50 m.

As with the previous one, this lava tube of large dimensions was mapped during the Biospel-90 S. Miguel Speleological Expedition of Os Montanheiros to the island of São Miguel.

It is located in the lava fields of the Serra de Água de Pau volcano. The entrance is a consequence of the collapse of a lateral part of the wall and roof at about 40 meters from the beginning of the lava tube.

The initial part of the cave, the largest one, is well preserved. There is a lid-type wall, probably the stopping point of a lava flow posterior to the tube formation. The walls have marks of several lava levels. In the ceiling there are many melt-stalactites.

Unfortunately the major part of the cave is very much spoiled. This is due to the collapse of great blocks of basalt from the ceiling and walls. Some vestiges of small stalactites and preliminary lava can still be seen. The tube ends with a collapse of

the roof. Probably this cave was destroyed by earthquakes and the land movements they caused.

Fauna: A biospeleological expedition directed by N.P. Ashmole and P. Oromí (1989) visited this cave. The general results of this study are still unpublished.

### 14. Gruta do Pico da Cruz (Plate 15; Figure 6, lava tube 6)

Location: Pico da Cruz, Ponta Delgada (São Miguel); Elev: 273 m; UTM: 6217/41830; Length: 98.5 m; Height: 0.60-2.90 m; Width: 0.85-5.40 m.

This is a simple unitary or throughway lava tube (see Halliday and Larson, 1983) and was mapped during the Biospel-90 S. Miguel Speleological Expedition of Os Montanheiros to the island of São Miguel.

It is a narrow, low lava tube with an ovoid configuration in all its length. The entrance consists of two holes, quite near each other, that are a result of a collapsed vault. We think that the lava flow of the Pico da Cruz volcano is the origin of this lava tube.

Five meters before the end of the tube it becomes narrower and lower with a great slope. Fifteen meters after the main entrance there is a "sink"

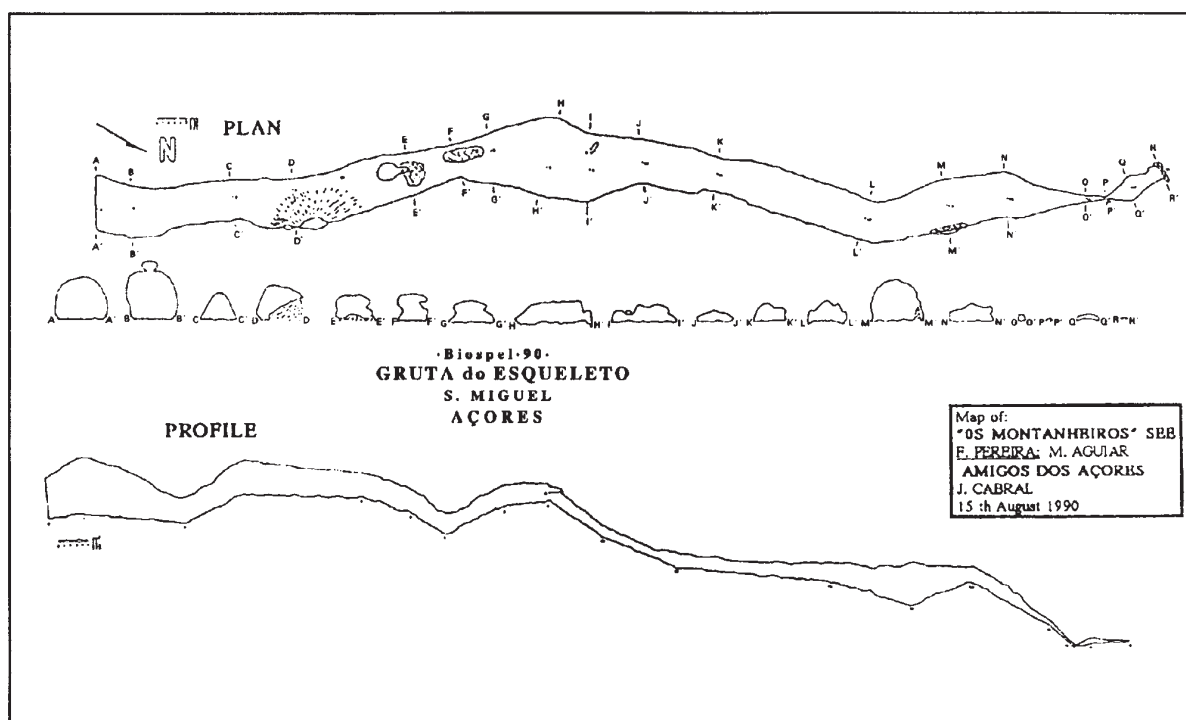


Plate 14—Gruta do Esqueleto.



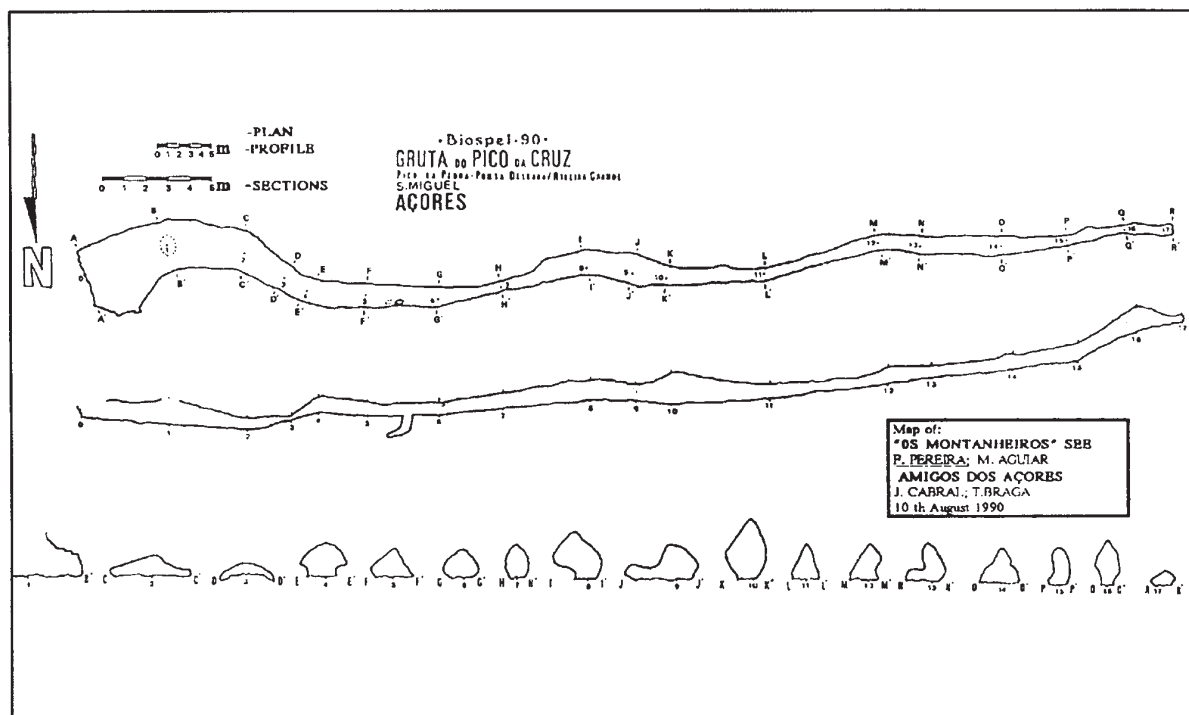


Plate 15— Gruta do Pico da Cruz.

that begins a secondary small tube under the main gallery. The levels of drainage are evident in the walls where we can also see signs of draining.

Due to its proximity to the high ground and the speleometric data, this cave must be a secondary lava tube originated by a small lava flow. This situation contrasts with other bigger lava flows originating from that volcano. Nearby there are several sinks showing the occurrence of other cavities that were destroyed by land movements.

Fauna: A biospeleological expedition directed by N.P. Ashmole and P. Oromí (1989) visited this cave. The general results of this study are still unpublished.

**15. Algar da Batalha** (Plate 16 and 17; Figure 6, pit 8)

Location: Fajã de Cima, Ponta Delgada (São Miguel); Elev: 240 m; UTM: 6198/41837. Length: 51.9 m; Depth: 9.5 m; Height: 0.40-3.30 m; Width: 0.50-5.70 m.

Mapped during the recent Biospel-90-S. Miguel Expedition of Os Montanheiros, this pit is associated with a lava tube. The lava that flowed in the tube rose through the roof forming a pit and a

secondary tube that ended in a low, crawling gallery.

The upper level is 33.7 meters long, 0.50 to 3.20 meters wide, and 0.40 to 2.30 meters high. The lower level is 18.2 meters long, 2.90 to 5.70 meters wide, and 0.90-3.30 meters high. The entrance is a hole 1.40 by 0.90 meters and 9.5 meters deep.

Fauna : Unknown.

## Santa Maria

**16. Furna das Pombas** (Furna Velha) (Plate 18; Figure 7, littoral cave 1)

Location: Vila do Porto (Santa Maria); Elev: 0 m; UTM: 6663/40900; Length: 337 m; Height: 0.50-14.50 m; Width: 0.40-12.50 m.

This cave was mapped during the recent St. Maria-90 Expedition, being a littoral cave of marine erosion located on the south cliff of Santa Maria near the aeolic park of Vila do Porto.

Inside the cave there are layers of fossiliferous sandstone and two basalt veins, with horizontal prismatic disjunction. Fifty meters after the main entrance, buried in the sand that covers the floor, we found a calcite speleothem. The wall in this

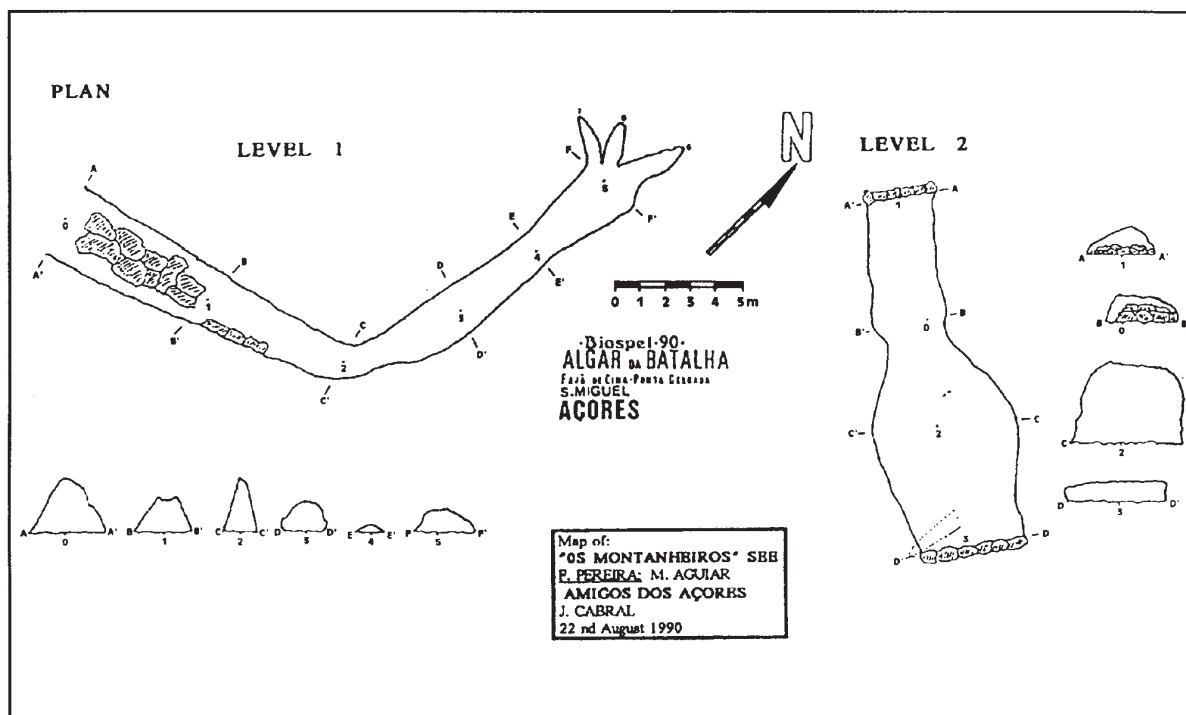


Plate 16—Algar da Batalha (Plan).

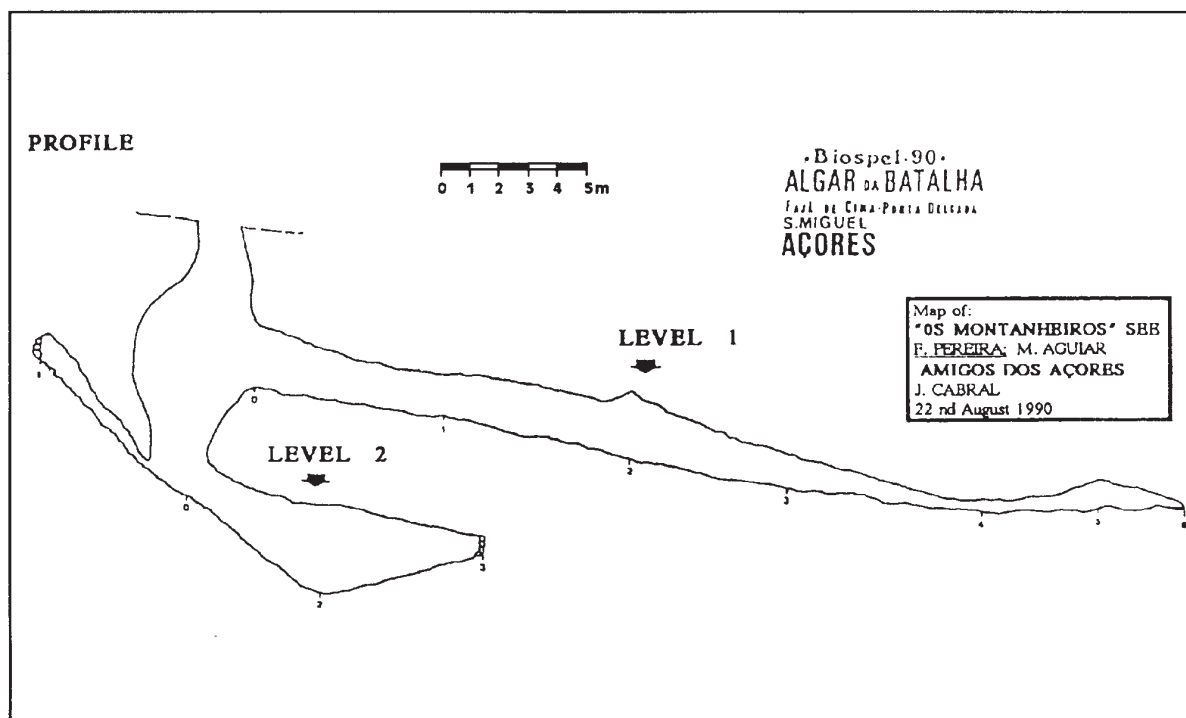


Plate 17—Algar da Batalha (Profile).

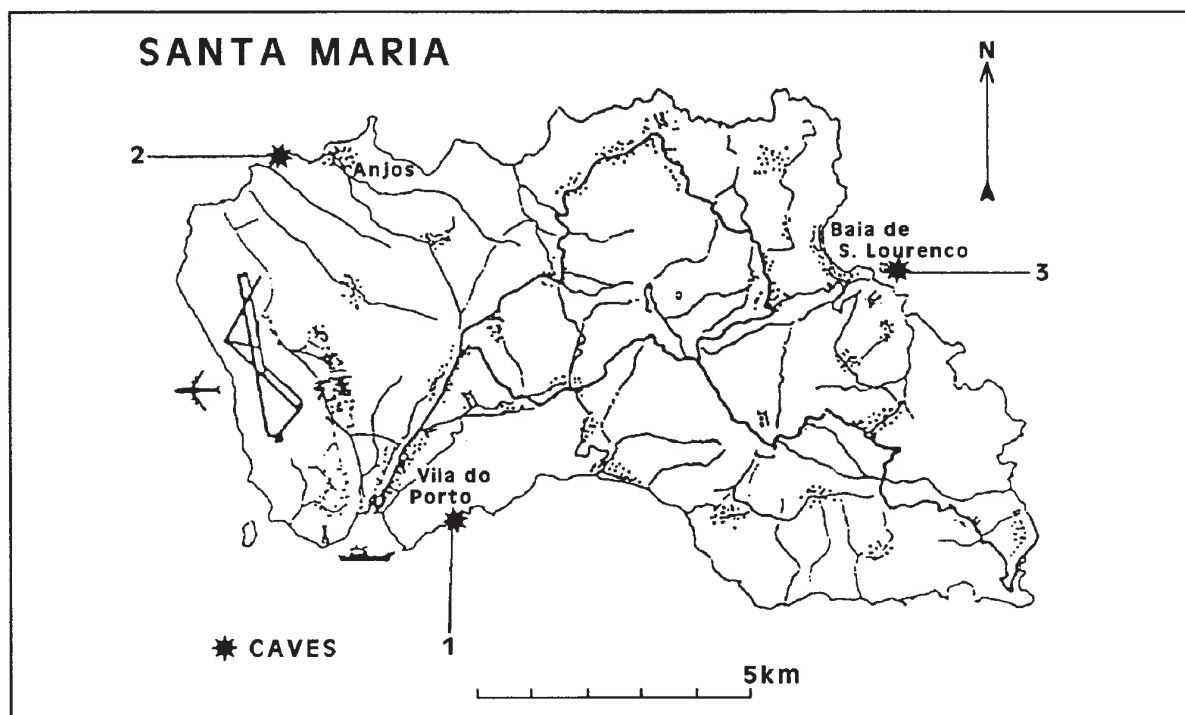


Figure 7—Map of Santa Maria Island showing the location of the littoral caves (see also Table 3).

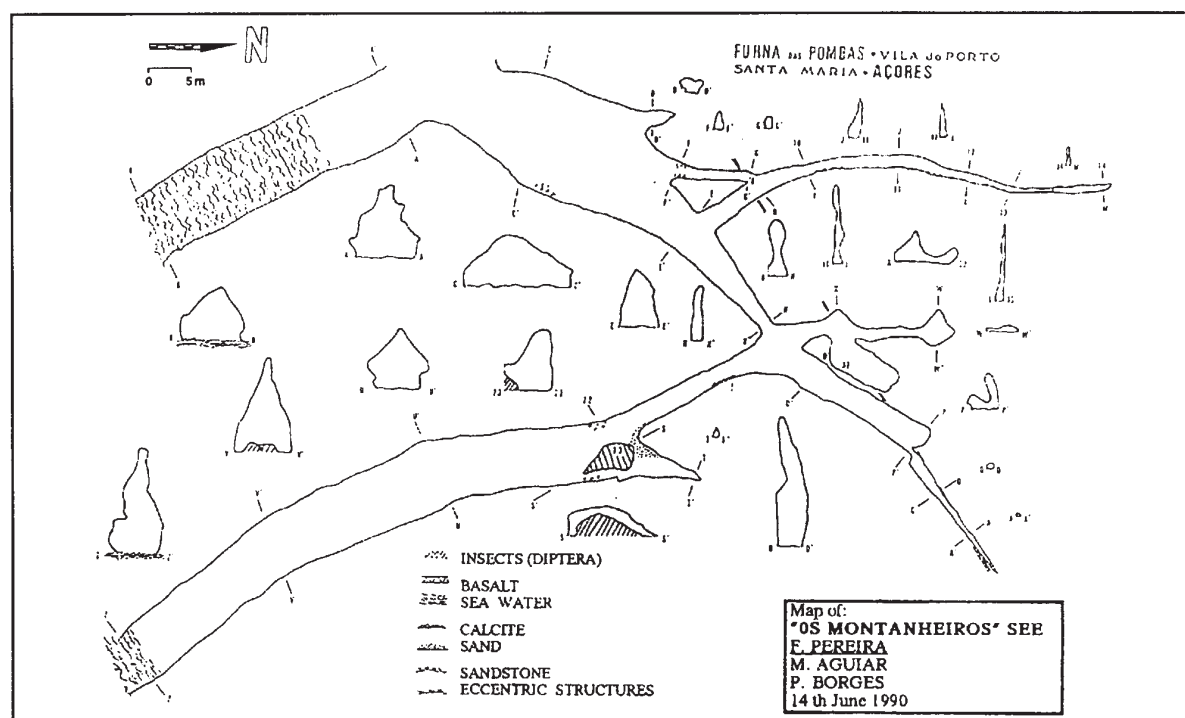


Plate 18—Furna das Pombas.

locality is covered by a layer of calcite from the ceiling to the floor.

Fauna: A biospeleological expedition directed by N.P. Ashmole and P. Oromí (1989) visited this cave. The general results of this study are still unpublished.

**17. Furna dos Anjos** (Plate 19; Figure 7, littoral cave 2)

Location: Anjos (Santa Maria); Elev: 10 m; UTM: 6639/40969; Length: 117.85 m; Height: 0.65-8.60 m; Width: 0.44-11.20 m.

As with the previous one, this cave was mapped during the recent St. Maria-90 Expedition, being also a littoral cave of marine erosion located in a cliff to the west of Anjos. The cave is located in a basalt vein and we had the information that a rock exploration occurred on it. It has a relatively large chamber at the entrance that elongates itself into a tunnel which bifurcates just before the end.

Fauna: A biospeleological expedition directed by N.P. Ashmole and P. Oromí (1989) visited this cave. The general results of this study are still unpublished.

## Conclusions

The most interesting Azorean island from the vulcanospeleological point of view is Pico. This island is dominated by the Pico volcano, a tall basaltic cone (2,351 meters high). The western two thirds of the island form a conspicuous lava field of recent age (Anonymous, 1980c).

All the main volcanic lava tubes on Pico are situated in pahoehoe basaltic lava flows (Forjaz, 1963). They are built by very fluid lavas under special conditions. Such a type of cave is very common, appearing in other Azorean islands also (e.g. Terceira).

On Pico there are several historical lava flows (see Figure 4), areas with a great concentration of lava tube caves and pits. The Mistério of S. Luzia (1718) is the Pico lava flow with a larger number of lava tubes (see Figure 4 and also Table III). Probably some of them are remains of a single longitudinal tube. In the Mistério of Silveira (1720) there is a remarkable lava tube, Gruta do Soldão (1,150 meters long), a simple unitary or throughway type lava tube (see Halliday and Larson, 1983) that is very well preserved.

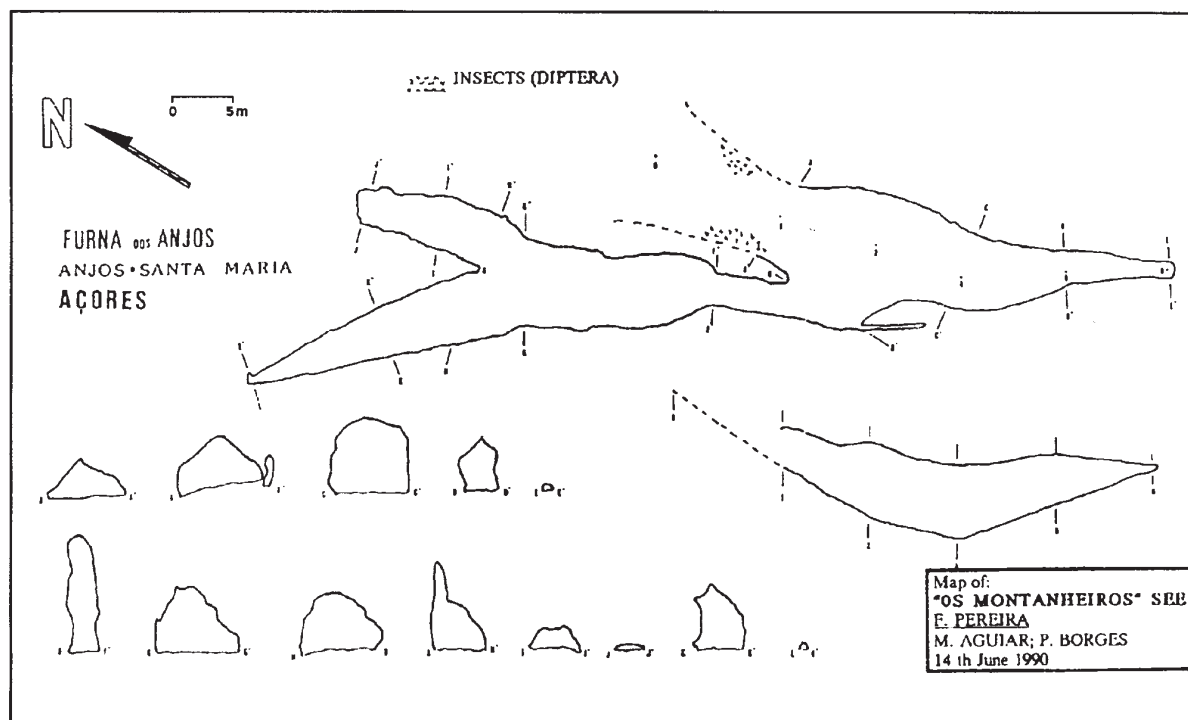


Plate 19—Furna dos Anjos.

Several levels of drainage registered on the walls by lateral benches (*bancadas*) are commonly found in many caves from Pico and also Terceira and São Miguel. However the best example of this is in Gruta das Torres (Pico), with approximately 11 different levels of drainage.

Up to now 28 lava tubes and eight pits are known from Pico, but as a consequence of the laborious work of the amateur speleologist A. Garcia (Pico, Madalena) more will probably be discovered soon.

The cavernicolous fauna of Pico is very rich and diversified. Much work on ecology and evolutionary ecology can be done here in the future.

With respect to the caves and pits that occur on it, Terceira is without any doubt the second most interesting Azorean Island, after Pico. On this island there are several areas with caves of great interest (see Figure 5). The Pau Velho lava flow (1761) is probably the area with the most interesting caves from this island (see lava tubes 5, 6, 13, 15, 18, and 20).

Until now, three speleological sites have been identified in the Pau Velho lava flow (1761) on Terceira Island: Balcões (20), Galeria Queimada (5), and Caldeira (13). One of them, Balcões, is made up of more than one cave (Balcões, Pau Velho, Branco Opala, Chocolate), located between altitudes of 240 and 400 meters. It is quite probable that other caves, still unknown, will be found in the area.

Montserrat and Romero (1983) mapped Balcões and Pau Velho. During the field surveys (helped by Os Montanheiros) most of the other lava tubes situated in the lava flow mentioned above were visited and mapped in the last few years.

Balcões is the second longest lava tube in the Azores, 2,713 meters long. The caves cited before vary from 87 to 640 meters, with several galleries, rooms, and halls as beautiful as in Balcões.

Two of the caves already explored and mapped, the Galeria Queimada and Gruta do Chocolate (see Plates 10 and 12 respectively) have very diversified formations and may illustrate the importance of the speleological sites of the Pau Velho lava flow.

These caves have a moderate importance from the entomological point of view, because most of them are covered by pastures and there is some mud infiltration. Nevertheless, the relict cave carabid *Trechus terceiranus* Machado could be found in Balcões and Caldeira lava tubes (Borges and Oromí, in press).

On Terceira there is also Algar do Carvão, a remarkable volcanic chimney developed as a show cave since 1988.

As a consequence of the constant effort of Os Montanheiros, most of the main lava tube caves and pits from Terceira are already listed, however this speleological group has not yet been able to find the "magnific" pit described by Fouque (1873) (300 meters deep).

The hypogean fauna of Terceira is not so diversified as that of Pico, even though some remarkable troglobitic species occur in Terceira's lava tubes and pits.

On São Jorge there are two lava tubes (Beira and Leão) and two pits (Bocas do Fogo and Montoso) of great interest, not only because of their speleological structures but also because of their unique fauna. Algar do Montoso is a remarkable volcanic chimney (see plate 9) still poorly studied.

Faial has small and unimpressive lava tubes but with striking endemic hypogean arthropods on it. Furna Ruim is an exception with the third biggest vertical drop of the Azorean pits (55 meters).

On São Miguel all of the main caves are located in the recent part of the island, the center plateau. Most of them are small and very much destroyed. In spite of that, their fauna is worth noticing, probably because of the ancient age of the island (four million years) (Abdel-Monem *et al.*, 1975).

Santa Maria is the oldest island of the archipelago (eight million years) (Abdel-Monem *et al.*, *op. cit.*) without recent lava flows. It has only littoral caves of sea erosion (e.g., Anjos and Pombas).

Graciosa is still poorly studied, but on this island the beautiful Furna do Enxofre occurs, with a large lake at the bottom and *sofataras*.

On the smallest of the two eastern islands, Corvo, there is the record of one cave, presently closed.

Beautiful stalactites (lava-drops) and some stalagmites of many types and forms cover the ceiling and floor of the Azorean caves making them excellent objects of admiration and study.

After this work the number of known caves and pits from the Azorean Islands are: Corvo (1;0), Flores (0;0), Faial (3;1), Pico (28;8), Graciosa (16;1), São Jorge (7;5), Terceira (20;6), São Miguel (10;3) and Santa Maria (3;0).

Islands like Faial, Graciosa, and Santa Maria need a lot of field work for a better inventory. Others like Pico, Terceira, and São Miguel are in an advanced stage of knowledge but in spite of that there is still much speleological work to be done.



Pico is doubtless the Azorean island where more speleological surprises may show up. The Gruta das Torres is a good example of it. Presently the biggest lava tube known from this archipelago, it was only discovered very recently (1990).

## Conservation Aspects

Cave ecosystems provide a unique habitat for evolutionary and ecological research. Because of that, all the caves where there is fauna adapted to the subterranean environment should be protected from all types of injuries (see Table III; and also Oromí *et al.*, 1990, Oromí *et al.*, in press, Borges and Oromí in press). These Azorean caves with biological interest are: Anelares, Cabeço do Canto, and Furna Ruim from Faial; Montanheiros, Soldão, Henrique Maciel, Capucha, Arcos, Gruta dos Esqueletos from Pico; Beira and Algar das Bocas do Fogo from São Jorge; Balcões, Coelho, Caldeira, Agulhas, Madre de Deus, Algar do Carvão from Terceira; Água de Pau and Esqueleto from São Miguel.

But the Azorean caves have other values, and we should preserve them for their geological or educational interest. In protecting them we are protecting much scientific and recreational patrimony.

Unfortunately some Azorean caves (e.g., Furna do Cabrito, Furna D'Água-Terceira) were closed and modified by construction by the government for protection of water resources. Others, like the once beautiful Gruta do Camelo (Terceira) is now completely destroyed, for the same purpose.

On the other hand, many of the Terceira lava tubes are visited by tourists and the population in general which is good. However a great amount of trash can be found on the floors of these caves (e.g., Natal, Balcões, Agulhas). Os Montanheiros has recently cleaned up Grutas do Natal and Agulhas. On Pico and São Miguel the entrances of some lava tubes and pits are currently used to dispose of domestic animals (e.g., Gruta do Galeão) or as garbage and offal dumps (e.g., Gruta do Galeão, Gruta da Rua do Carvão, Gruta da Merda, and so on).

Some lava tubes (e.g., Natal and Agulhas) and pits (Algar do Carvão) from Terceira are under the management of Os Montanheiros speleological group from Terceira (Azores). The peculiar features and dimensions of these caves and the remarkable scenic aspects of the Algar do Carvão make Terceira Island unique in the Azores. Some support for carefully supervised tourism is being

implanted by Os Montanheiros with the help of Secretaria Regional de Turismo e Ambiente (Environmental and Tourism Regional Secretary).

We recently found the hypogean relict beetle from Terceira, *Trechus terceiranus* Machado in the Algar do Carvão, showing that a rational tourist exploration won't harm the fauna of caves (pit in this case).

Nevertheless we should like to point out that, in some cases, if the habitat of a peculiar species is changed, the species is doomed to disappear. For example, the *Trechus montanheirorum* Oromí and Borges lives only at the entrance of the Gruta dos Montanheiros (Pico) (see Borges and Oromí, in press). In this case we think that its habitat must not be changed, and in consequence, no cement or other related products should be used for the construction of a better access than the existing wooden staircase.

As already noted by Halliday (1981) the Azores are islands of unusual speleological interest. They have some remarkable volcanic chimney caves (e.g., Algar do Carvão, Algar do Cabeço Bravo, Algar do Tambor, Furna Ruim, and Algar do Montoso) and lava tube caves (e.g., Balcões, Chocolate, Queimada, Agulhas, Torres, Montanheiros, Frei Matias, Soldão, and perhaps still others). Therefore all the lava tubes and pits of these islands should be protected.

There are several solutions for this. The top priority for the conservation of the caves and their fauna is to conduct accurate speleological and biological inventories on all islands in order to establish conservation priorities. Simultaneously it is also urgent to learn more about the ecology of the Azorean cave species so the protection measures will be effective.

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## 6th International Symposium on Vulcanospeleology

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Our vertical caving instruction was done by one of us (F. Pereira) who made a course of one month (February 1988) in La Laguna (Canaries) with the orientation of L. Esquivel, J. Hernandez, A. Medina and I. Zamora, and with the support of the National Geographic Society, Câmara Municipal de Angra do Heroísmo and Serviço Regional de Protecção Civil dos Açores.

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