
Lava Caves of São Miguel Island, Azores

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Abstract

The Azores Archipelago is located in the north Atlantic at the triple junction of the Eurasian, African, and North American plates and is formed by nine volcanic islands aligned on a west-northwest to east-southeast trend.

At São Miguel, the largest island, nine lava caves and pits have already been identified, some of them being open volcanic conduits. Several smaller lava tubes are also known. The majority of these caves are found at the "Picos Volcanic Complex," a volcanic unit of about 50,000 years formed by several scoria cones and associated lava flows.

In the present paper some of the features of these lava caves are presented. Among these features we refer to their shape, size, local setting, small associated structures (levées, flow marks, benches, and stalactites), and their probable origin. The importance of a detailed study of the lava caves as well as their future use are also referred.

The Azores archipelago is particularly plentiful in lava tubes, above all owing to the abundance of lava flows of a basaltic nature (basalt and hawaiite) where plenty of structures of the pahoehoe type are to be found.

Considering the small area covered by the Azorean Islands, their speleological wealth is comparable to any other volcanic region in the world, due to the number of existing caves and to their particularities (Oromí *et al.*, 1988).

In spite of the fact that to date there is no detailed account of the existing caves in the island of São Miguel, the geological and geomorphological conditions of the island allow one to foresee an important speleological wealth. However, in the sixteenth century, the local historian, Gaspar Frutuoso, when describing the coast of Ponta Delgada, refers to volcanic caves to the west of the city: "Beyond, a short distance to the west of the Fortress, there is a point called Pits Point because there are two entrances to caves there and on entering these it is possible to walk a long distance under the ground, inside them. It seems that a

stream of volcanic stone flowed in former times, of which there is no record."

More recent historical references, above all of an informative character, refer mainly to the "Pit" (cave) of Rua Formosa, now Rua de Lisboa (Walker, 1886; Silva, (?); and Bryan, 1963) and a cave situated "about three or four miles northwest of Ponta Delgada" (Webster, 1821).

From 1988, on the initiative of the Amigos dos Açores ecological association, a bibliographic listing and an exploration of the caves and pits in the island of São Miguel was started. At the moment there are 22 known volcanic caves and four artificial cavities.

In 1989 the first scientific expedition of a biospeleological nature took place, a joint venture of the Universities of La Laguna (Canary Islands) and Edinburgh (Scotland) which explored about 20 caves. In 1990, with the participation of the Amigos dos Açores, Os Montanheiros, and the University of the Azores (Departments of Geosciences and Agrarian Sciences) the field work of the Biospel-São Miguel project took place, having as its main

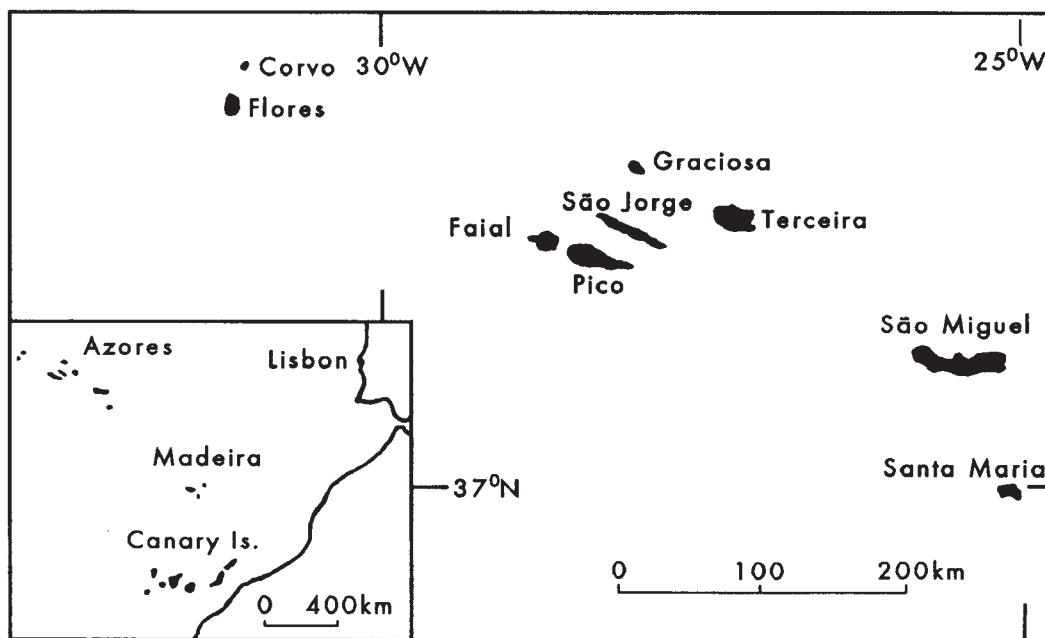


Figure 1 – Location of the Azores Archipelago.

objective the mapping, photographing, listing of geological characteristics, tourism possibilities, and possible stratagems for the preservation and protection of the caves and pits of São Miguel.



Figure 2 – Main tube of Agua de Pau Cave, covered with secondary deposits (white colored). (Photo by João Nunes)

With the present paper, as a follow up of that project and the field work which took place in 1991, we hope to fill in a gap existing in the vulcanospeleological bibliography of the island of São Miguel, present some of the results obtained, and give a general perspective of future activities.

The Azores Archipelago

The Azores Archipelago is made up of nine islands of volcanic origin situated in the middle of the North Atlantic, between latitude 37° to 40° north and longitude 25° to 31° west (Figure 1). Aligned in a general west-northwest to east-southeast trend, the Azores Islands evidence a very special geotectonic setting at the triple junction of the Eurasian, African, and North American lithospheric plates.

The Azores are a very active seismic region where volcanic phenomena are common. On the Islands of São Miguel, Terceira, São Jorge, Pico, and Faial, as well as in the surrounding ocean, several volcanic eruptions have occurred since they were settled in the first half of the fifteenth century. All the Azores Islands, with the exception of Santa Maria (the oldest), present one or more quaternary stratovolcanoes, often with a caldera (Booth *et al.*, 1978). On the other hand there are in the archipelago more than a thousand scoria cones, frequently aligned along faults and responsible for the emission of several flows of basaltic nature.

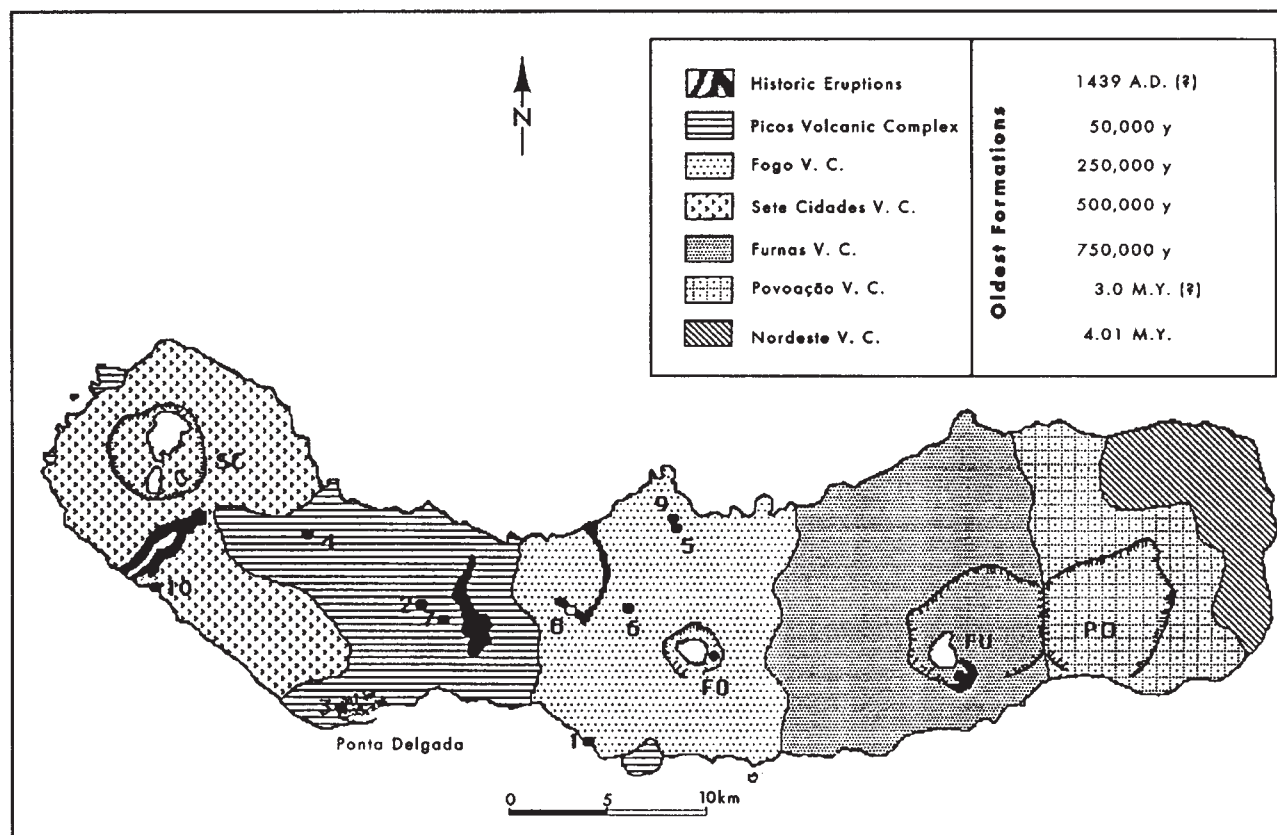


Figure 3—Location and geological setting of São Miguel volcanic caves. Volcanostratigraphic sketch by Forjaz, 1984 and 1985; in: Queiroz, 1990. SC = Sets Cidades, FO = Fogo, FU = Furnas, PO = Povoação.

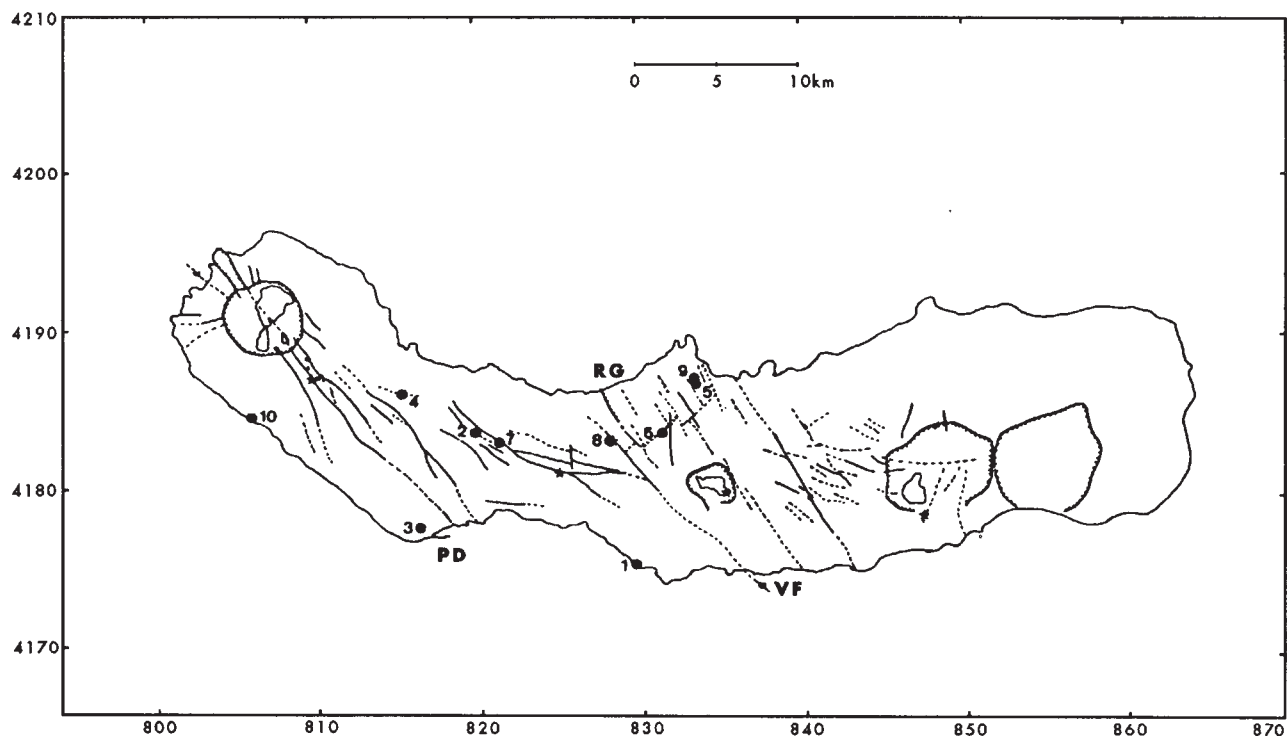


Figure 4—Tectonic map of São Miguel island (Forjaz, 1986) and lava cave locations. PD = Ponta Delgada,

Summary Table of São Miguel Caves Main Features						
Name	C = Cave P = Pit	Geographic Coordinates	Altitude (m)	Total Length (m)	Geological Setting	Age (years)
1-Água de Pau	C	37°42'55" 25°31'48"	15	323	F.V.C	>>6,500?
2-Batalha	C/P	37°47'27" 25°38'25"	245	52/9.5	P.V.C.	4,000-4,600
3-Carvão	C	37°44'14" 25°40'51"	20	>980	P.V.C.	>4,600?
4-Enforcado	C	37°48'49" 25°41'36"	235	185	P.V.C.	<4,000
5-Escadinhas	C	37°49'03" 25°29'00"	135	31	F.V.C	4,990
6-Esqueleto	C	37°47'23" 25°30'29"	210	188	F.V.C	4,790
7-Pico da Cruz	C	37°47'06" 25°37'22"	260	98.5	P.V.C	<4,000
8-Pico Queimado	P	37°47'08" 25°32'45"	285	37	Hist.	1563 A.D.
9-Ribeirinha	C/P	37°49'14" 25°29'04"	150	54.5/5	F.V.C	4,990
10-Feteiras	C	37°48'06" 25°47'51"	35	22	SC.V.C.	≈20,800

F.V.C. = Fogo Volcanic Complex; P.V.C. = Picos Volcanic Complex; SC.V.C. = Sete Cidades Volcanic Complex; Hist. = Historic Eruptions.

The Island of São Miguel

The island of São Miguel, the largest (747 square kilometers) and the most densely populated in the Azores, has three active stratovolcanoes with calderas (Furnas, Sete Cidades, and Fogo) and a long record of explosive eruptions (Figure 3). The eastern part of the island, of extinct volcanism, includes the Volcanic Complex of Nordeste, where the oldest rocks in the island exist and are about four million years old. The Volcanic Complex of Povoação is composed of a stratovolcano with a caldera (the biggest in the island), very much affected by erosion.

During the last thousand years, several basaltic eruptions have taken place in the region known as "Picos Volcanic Complex," an area extending between the volcanic massifs of Sete Cidades and Fogo (Booth *et al.*, 1978 and Forjaz, 1986). It is composed of about 200 scoria cones (built during

strombolian eruptions), aligned mostly along faults in generally northwest to southeast and east to west directions, and associated lava flows (Figure 4). The basaltic nature of the lava flows (mostly the aa and pahoehoe type) and the relative youthfulness of the formations (2,000 years) make this region particularly plentiful in lava tubes. In fact, more than 60% of all the known caves and pits in the island of São Miguel are situated in this area.

Volcanic Caves in São Miguel Island

In the present paper there are some notes concerning about ten of the caves and pits in São Miguel Island according to their size, geomorphological situation, and existing structures. In Figures 2 and 3 the location of these caves is shown while in Table I their main features are summarized.

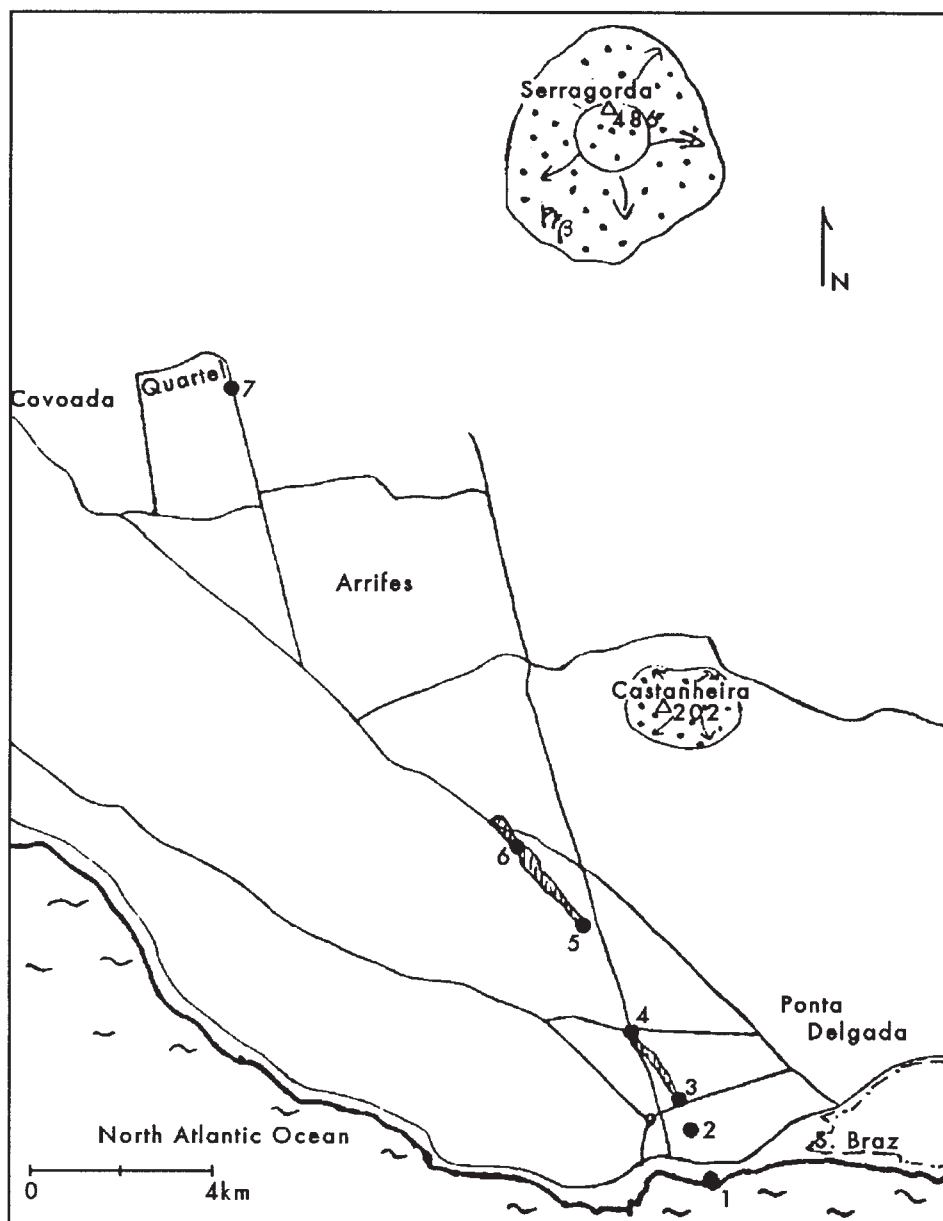


Figure 5—Simplified sketch of Carvão Cave. 1 = Point indicated by Frutuoso, 2 = Alcohol/sugar factory, 3 = Tobacco factory, 4 = Carvão Street, 5 = residence of Mr Belchior, 6 = Residence of Mr Madeira, 7 = Military barracks. Indicated also are the location of two scoria cones and the explored sections of the cave (hatched line).

Agua de Pau Cave

This cave, the second longest, has a general east to west direction and most of it can be walked through standing upright. The two branches into which it is divided upslope are obstructed by big falls which prevent going beyond them. In the secondary tubes, with a very low roof about 60 centimeters high and a level floor, there are beau-

tiful formations of cone-shaped fusion lava stalactites. Also to be seen are various long extensions of benches, witnesses of ancient lava flow surfaces.

The entrance to the cave is almost at sea level through a nearly circular opening about two meters in diameter. The flow shows layered lava and in the area around the cave it is possible to observe some buckling in the lava flow and lesser tubes, sometimes totally filled in. Owing to its difficult access, the cave is little visited and so is relatively unspoiled.

Batalha Pit

Having an oval opening situated in a pasture, the Batalha pit has a lava tube about three meters from the surface. This pit is situated east of the Picos de Lima scoria cone, which is placed on an active geological fault with a northwest to southeast direction (Figure 4). A couple of lateral ridges can be observed on the surface at a bearing of N155°E, as a result of the collapse of the central part of the lava flow.

The geomorphology of this area, local information, and a note written by Luis Ataíde (1951) lead to the conclusion that other caves and/or pits exist in this locality. This writer refers to a visit to one of them in 1909 and to "underground chambers full of animal bones and live owls."

Recently it was not possible to carry out a more detailed study of it due to the nauseating smell caused by dead animals inside, probably thrown down there

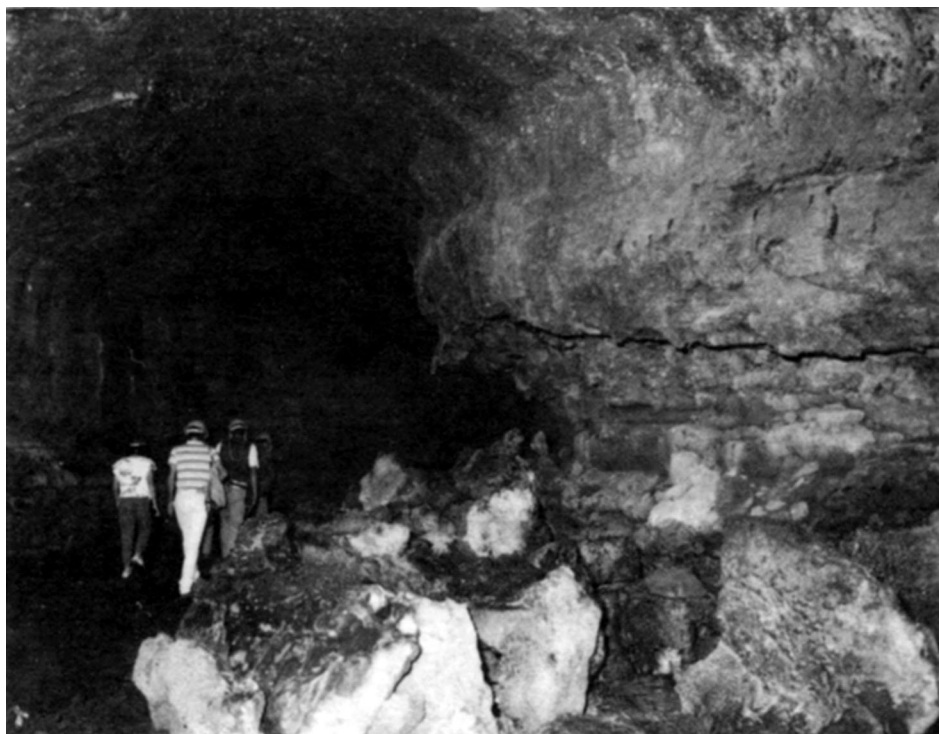


Figure 6—Carvão Cave, the most important known tunnel on São Miguel Island and a potential tourist site. In this section the cave is almost five meters high and two levels of benches can be observed. (Photo by João Nunes)

by the farmers. The entrance of this pit is in urgent need of protection to avoid its total destruction.

Carvão Cave

This is the best known cave in São Miguel. Already in the sixteenth century the historian Gaspar Frutuoso, in his “Saudades da Terra” refers to the existence of lava caves west of Ponta Delgada. Emigdyo da Silva, in his work, “São Miguel in 1893” considers it “the most remarkable of the volcanic caves in the Azores” and refers to it in the following terms: “the cave of Ponta Delgada is over one kilometer in length, so far as is known. It comes out by the sea after passing under the alcohol factory in Santa Clara, coming in a north to south direction.”

Halliday (1981) explored the southern section and estimated its length to be about 400 meters. During the Bioespele expedition, Os Montanheiros explored about 980 meters of this cave, most of it more than five meters wide.

Besides the extensions, historical writings, and the existence of other sections—fallen in, blocked up, or simply of impossible access—there are indications that Carvão Cave must be much longer

(Figure 5). As can be seen in Figure 5, the cave, following a north-northwest to south-southeast direction, extends for more than 20 kilometers from the coastline to the village of Arrifes. Halliday (1981) refers to the existence of a cave the entrance of which was near the military barracks in the village of Arrifes. It appears to be an up-slope portion of a system including Carvão. According to the author this cave might be the one described by Webster (1821).

An important feature of the Carvão cave is the fact that the visited up-slope portion ends in a chamber over ten meters wide (Cabral, 1990), completely blocked, possibly as a re-

sult of filling in (see Figure 5). So it is possible to suggest the continuation of the Carvão Cave further to the northwest, as suggested by Halliday (1981) and also to the cave mentioned by Webster (1821). If this were the case, the Carvão Cave would be the most important underground structure in the archipelago, being over five kilometers in length.

Owing to its size, a great variety of structures can be observed such as flow marks, burst bubbles of lava, branching galleries, superimposed channels, long extensions with benches of rare beauty, and at several steps. On the roof there are many fusion lava stalactites and other irregular deposition-type stalactites, sometimes over the former.

Drainage work has greatly affected this cave, where garbage is thrown in as well as the overflow of water. These latter affect mostly the flatter extensions depositing sand and clay which silt them up. The Carvão Cave, commonly known as the “Algar do Carvão,” is therefore an important lava tube in the island of São Miguel and the Azores. A detailed study of it should be urgently carried out including a variety of specialities.

Enforcado Cave

This is a cave composed of three extensions separated by falls caused by the clearance of land when it was turned into pasture. With a total length of about 185 meters and an average height of two meters, it shows a roof generally in the shape of an inverted funnel and the floor, seemingly aa, shows levées.

The Enforcado Cave, with an alignment N138°E, is situated in a geological structure defined by the scoria cones and spatter cones of the Pico do Cedro and Pico do Enforcado, responsible for extensive lava flows. The fault so defined is considered as one of the best examples of fissure eruption in the island of São Miguel (Booth *et al.*, 1978).

Escadinhas Cave

Escadinhas Cave is a small lava tube near the surface following a N40°E direction. It is situated in the graben of Ribeira Grande (Forjaz, 1986) and to the west of Pico da Multa, a very altered scoria cone.

The very irregular and scoriaceous roof shows a plastic collapse in its central part, while the floor shows characteristics of aa lava, over which it is extremely difficult to walk.

Esqueleto Cave

This is a volcanic tube, the exploration of which involves some risk, owing to enormous piles of rocks fallen from the roof—falls which have reached the surface, leaving four openings.

In spite of these difficulties, Esqueleto Cave, owing to its size, easy access, and existing structures (such as levées and flow marks) is a place worth visiting.

Pico Da Cruz Cave

This cave is situated on the Picos Volcanic Complex and along the northwest to southeast

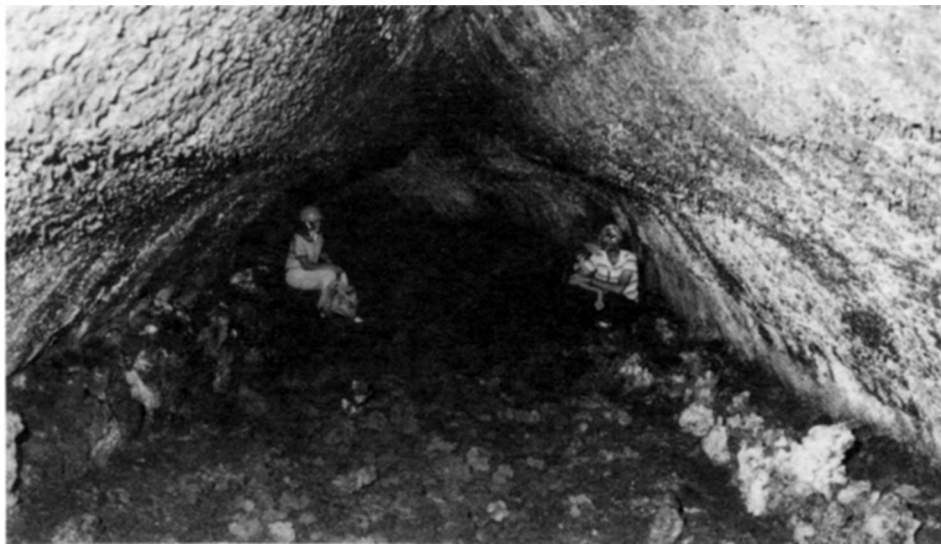


Figure 7— Enforcado Cave with a general shape of an inverted funnel. The floor shows levée structures. (Photo by João Nunes)

tectonic alignment defined by a group of scoria cones (Figure 4). In this area there is a reference to two pits over 20 meters deep which could be the result of the withdrawal of lava from a fissure (Booth *et al.*, 1978).

The main features of this cave are its funnel shaped roof and very narrow walls. Seemingly very solid and resistant, this is one of the most interesting of the speleological heritage in the island of São Miguel and is still in a good state of preservation.

Pico Queimado Pit

Pico Queimado Pit is a pit about 30 meters deep to be found in a parasitic spatter cone of Pico Queimado, situated on its northwest slope. It is an open volcanic conduit that had formed a vent in the historic basaltic eruption of 1563, which gave rise to a very fluid lava flow. This lava flowed along two distinct branches, one to the northwest and another to the northeast (Figure 3).

To southeast of the pit there is a tension fracture about one meter wide, more than five meters long and six meters deep. Developing in a N140°E trend, it is to be found in the continuation of the multiple craters of Pico Queimado and in the orientation of the active faults mapped in the area (Forjaz, 1986).

Ribeirinha Pit

Situated very close to the Escadinhas Cave, this pit has an opening about eight meters in diameter.

At the bottom of the pit, about ten meters deep, there is a small cave. There is historical and geological evidence of other volcanic caves in this area, where the pits may result from the withdrawal of lava from existing faults.

Unfortunately it has been used as a dump for waste and garbage so that its state of preservation leaves much to be desired.

Feteiras Cave

This is probably the oldest of the known caves in the island of São Miguel and one of the few situated in the Sete Cidades Massif in the western part of the island. In spite of its small size, 22 meters long, and average height of one meter more or less, it has an interesting particularity: about half of its length consists of two superimposed galleries as a result of the joining of two levées. Its up-slope termination was filled by a lava flow after its formation.

Some hundred meters to the west there is a lava flow which came from Picos das Ferrarias (Queiroz, 1990) and which, according to some authors, is considered to have taken place during the first half of the fifteenth century (Figure 3). However, the lava flow where Feteiras Cave is to be found is a much older flow and corresponds to the last effusive local phenomena. In fact, the superior formations are composed of explosive materials, specially trachytic pumice and basaltic pyroclasts (*lapilli* and ash). Below the cave are other lava flows sometimes with very small lava tubes.

Conclusions

On account of their scientific importance and potential tourist interest, the natural caves justify the passing of regional legislation to protect them and energetic measures for their recovery. It is also necessary to promote campaigns for the preservation of the caves and pits in the island of São Miguel, an integral part of the regional landscape heritage.

After legally protecting Carvão Cave and carrying out the necessary and urgent work of cleaning up, it will be possible and desirable to include the cave in the tourist attractions of the island of São Miguel, following an order of controlled and duly guided visits. It is equally urgent to protect the openings of the remaining caves to avoid their deterioration.

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