THE PROTECTION OF THE VIENTO-SOBRADO CAVE - A VERY LONG VOLCANIC CAVE IN THE CANARY ISLANDS

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Abstract

The Viento Cave is a very long lava tube (> 20 Km) localised in Icod de los Vinos, at the north slope of Tenerife (Canary islands, Spain). The cave is formed inside a lava flow coming from Teide mountain, probably in the last thousand years. It has important morphologic and biologic feature for conservation, and because of this the regional government is promoting its protection.
Under biologic point of view, the cave is significant. It has the mayor concentration of species troglobites of the Canary Islands. Right now it has been found thirty six cave-dweller, many of them have remarkable adaptations to underground life. This fauna includes species belonging to several rare groups as blataria or homoptera, although the more abundant group are the coleoptera.
The Canary Government has elaborated a Management Plan to guarantee the conservation of this unique ecosystem. One of the goals of it is the declaration of the cave as Special Natural Reserve, a category of protection equivalent to the level IV of UICN. Similarly, at the surface it has been established a control system to be based in the impact assessment of any action that may transform it natural conditions. New building on the surface is forbidden and, at the same time, a sewage plan for the existence shelter is being implemented. Near the entrances it has been projected a Visitor Centre with slipping rooms for visiting scientist. Now, the European Union is developing a conservation program of several caves of Canary Islands, were the Viento cave is the main objective.

Introduction

Site

The Viento cave comprises a series of underground caverns that stretch for over 20km in the north of Tenerife in Icod de los Vinos. The cave is actually situated inside a solidified lava flow that ran down from the peaks of the island to the coast many years ago, although there are different opinions as to exactly when: according to Montoriol-Pous & De Mier (1974) and Wood & Mills (1977) the lava flows are only a few thousand years old, however according to Coello (1989) they may date back as much as 150,000 years.
Ever since the cave was first explored in 1891 by a group of English tourists who made the first map of part of its galleries (Sobrado) (Oromí and Martín, 1995) the length of the cave known to mankind has gradually increased and on occasions has been considered the longest volcanic cave in the world (Halliday, 1972: Wood, 1973). The "longest-cave" record is now held by other lava tunnels in Hawaii and Australia, but the Viento-Sobrado cave may yet be considered as the longest, since it has still not been fully explored.

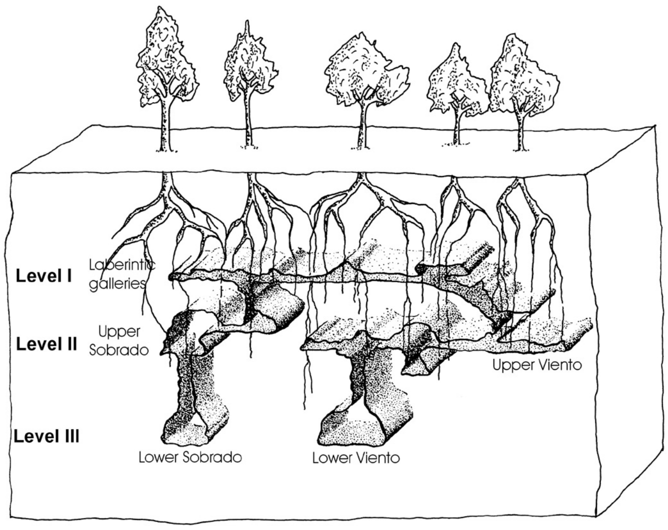

Fig. 1. Depth levels and their drops connection in Viento cave

Table I. Longitude of the different branches in Viento-Sobrado cave
(including the inconnected Felipe Reventón cave)

BRANCH	DEPTH LEVEL	AUTHOR	LONGITUDE
Piquetes	II	Woods & Mills (1977)	2.080 m
Breveritas	I-II	Woods & Mills (1977)	5.582 m
Ingleses	III	Oromí (1995)	3.144 m
Belén	II	G.M. Teide	158 m
Sobrado superior	I-II	J.L. Martín, H.G. Court & A. Vera (Published in Hernández *et al*. 1995).	3.570 m
Sobrado inferior	III	Laínez (1996)	2.346 m
Petrólea	II	Zurita *et al*. (1996)	152 m
Felipe Reventón	I-II	Hernández *et al*. (1985)	3.000 m
TOTAL	I-II-III		20.032 m

The history of its different stages of discovery

A long gap followed the visit of the above-mentioned English tourists, in spite of the fact that the cave’s existence was already known even before their appearance, as is clear by references dating from the eighteenth century (Castro, 1776). It was at the end of the 1960’s that a group of speleologists from the Tenerife Mountain Group started exploring and charting the cave in detail (Chávez, 1970). In 1974, Montoriol-Pous and De Mier published the first topography of the cave, ascribing it a length of 6,200 metres. A few years later, a group of English geologists discovered a new network of galleries even deeper than the previous ones and increased the cave’s length to ten kilometres (Wood & Mills, 1977). In 1988, local cavers managed to connect the nearby cave of Sobrado to the Viento cave, increasing the total length to 13,750 metres and shortly afterwards, in 1994 the biospeleologist Juan José Hernández Pacheco discovered a new 2,346 metre branch that increased the cave's total underground length to over 17 kilometres. If we add to this the approximately 3 kilometres of the Felipe Reventón cave located not fifty metres away from one of the Viento-Sobrado galleries and in the same lava flow, the total underground system is over 20 kilometres long (table I)

The same speleologists who in the sixties made the first topography were also those who discovered the first animal-life, more specifically a small troglobite cockroach, which many years later was to be described as *Loboptera subterranea* (Martín and Oromí, 1987). But it was in the eighties that there was a tremendous boost to biological studies of the cave, with the discovery by researchers from the Laguna University's Speleology Research Group of a serie of new species, mainly arthropods, that made the cave one of the most important sites of cave-dwelling fauna in the whole of the palearctic region.

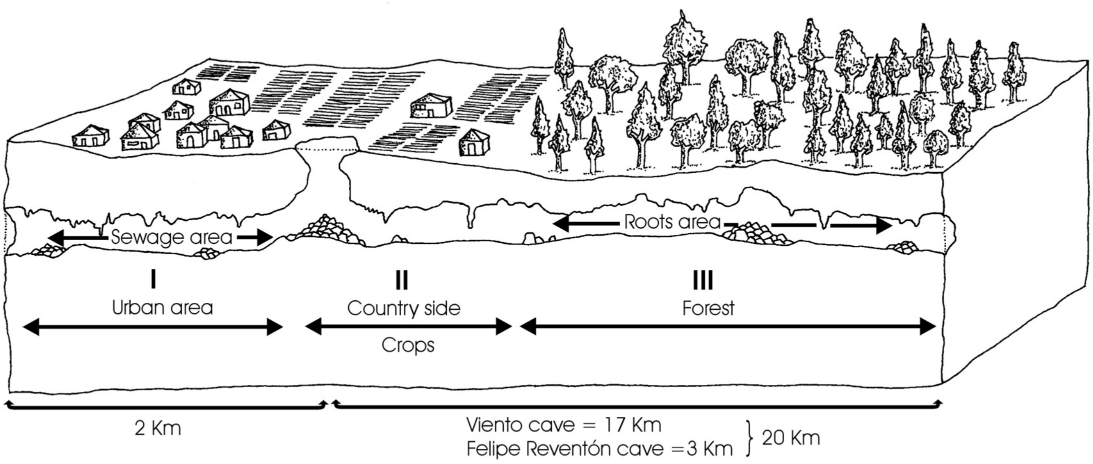

Fig. 2. Different areas of the underground ecosystem according to the nature of the surface habitat

Morphology

The cave is made up of several volcanic tubes that occasionally intersect horizontally, whilst vertically it is laid out in three different depth levels and connected by ledges or pits with drops of up to 15 m. The Ingleses and lower Sobrado galleries are the deepest. At an intermediate depth are the upper Sobrado, Petrólea, Breveritas, Piquetes and Felipe Reventón galleries and nearest of all to the surface there is a small network of fairly narrow and laberintic galleries that connect the passageways of the upper Sobrado gallery to the Breveritas gallery (fig. 1). This lay-out is probably due to the manner in which the cave was originally formed, which according to Wood & Mills (1977) was a three-stage process; first of all the deepest galleries would have been formed (III) which would have opened up to the outside through vertical "jameos" (sky-lights), that are now the shafts that connect this level to the intermediate level (II). After a period of calm in the area, volcanic activity started once again and a new flow was deposited on top of the previous one with a new volcanic tube (level II) that connected down to the lower level through the openings mentioned previously, thus joining together the intermediate and deepest levels. The level that is nearest to the surface (III) was also formed during this second flow, as another of the many

branches that arose from slope drainage below the cooled and solidified surface crust of the lava (see Wood, 1977 for an explanation of the process).
Since the cave is on a very steep slope (11%) and the volcanic tubes generally follow the direction of the slope, there is a tremendous height difference between the cave's top and its bottom of up to 478 metres according to Wood & Mills (1977) and 580 metres according to Montoriol-Pous & De Mier (1974). The average height and width of the galleries is between 2 and 4 metres.
Many of the typical geomorphological structures of volcanic caves such as lateral terraces, lava rivers, lava stalagmites, lava cascades, lava lakes, lateral benchs, etc. In more specific areas there are also interesting gypsum deposits, minerals (Moen, 1972) and cristobalite, a structure of secondary origin, which has silica as its main compound (Izquierdo *et al*. 1995).

The Ecosystem

The surface

The vegetation of the area should be a laurisilva wood, surrounded in its upper part by a Canary-island pine forest. However, this potential vegetation has mainly disappeared as a result of human settlements, farming and livestock practices and forestry. This means that vegetation today is merely what is left of the area's original potential, with a mixed pine forest (*Pinus Canariensis*) speckled with deciduous species (*Myrica faya, Ilex canariensis*, *Laurus azorica*) and heather (*Erica arborea*) on the highest part of the slope, a landscape containing different buildings located near to the crop-growing areas in the middle area and a built-up area at the bottom. The interior of the tubes are affected by the vegetation, since the roots of many of the plants growing above the cave actually penetrate into it.

The underground environment

The underground ecosystem is divided into three different areas (fig. 2) according to the nature of the surface habitat:
Area I is the place that has undergone greatest change, caused mainly by the large amounts of waste water that come from the buildings at surface level. From a fauna point of view this area can be considered as the most deprived.
Area II has an major fauna content, although there are some deteriorated areas that usually coincide vertically with buildings at surface level or places where visitors to the cave normally congregate.
Area III has the largest fauna content, since it is the best-conserved of the three areas. The majority of this area is underneath a pine forest at surface level, meaning that it contains numerous hanging roots that provide a peculiar habitat for many cave-dwelling species.
Over one hundred and fifty animal species, mainly arthropods have been found to be living in this volcanic tube (Martín, 1992; Martín *et al*, 1995; Oromí *et al*. 1995; Arechavaleta *et al*, 1999). Many are kinds of trogolophiles and trogloxenes, although 36 of them can be considered as true troglobites showing different degrees of adaptation to underground life. Fourteen of the species have only ever been found in this cave (table II). Some of them do not have any direct relations amongst surface-dwelling fauna and are only even known because just a few of their kind have been found. There are indications that species such as *Tyrannochthonius superstes* and *Canarionesticus quadridentatus* may be authentic distributive relicts (Martín, Izquierdo & Oromi, 1989) as the term was meant by Botosaneau & Holsinger (1991).
Coleopterans and araneids are the dominant groups as far as the number of troglobite species go with the interesting peculiarity that both of these groups have genus with several species living in the same cave. In some cases, such as *Dysdera*, there are as many as five troglobite species and a sixth more troglophile (*D. crocota*) living in the same area. As for the numbers of each type, there is a predominance of *Loboptera*. At some times the *subterranea* species of *Loboptera* are more

common and at others the *troglobia* – in the eighties it was the former, whilst in the nineties it was the latter.
A variety of bone remains of vertebrates that have since disappeared from the island or have even become extinct have also been found. Among the former, there are the remains of choughs (*Pyrrhocorax pyrrhococorax*) that can now only be found on the neighbouring island of La Palma (Rando & López, 1996) or the canarian houbara bustard (*Chlamydotis undulata*) that is only found in Lanzarote and Fuerteventura (Rando, 1995). As for extinct species, large numbers of remains of a giant lizards (*Gallotia simonyi*) have been found as well as a giant rat (*Canariomys bravoi*), a partridge (*Coturnix gomerae*) and a small, long-legged, short-winged bird (*Emberiza alcoveri*) (Rando & López op. cit; Rando et al. 1999).

Table II. Troglobites of Viento-Sobrado Cave

	Endemic of Viento Cave	Superficial close-relatives
Arachnida-Araneae		
Agraecina canariensis	Not	Yes
Canarionesticus quadridentatus	Yes	Not
Dysdera ambulotenta ν μ	Yes	Yes
Dysdera esquiveli μ	Not	Yes
Dysdera labradensis ν μ	Not	Yes
Dysdera volcania	Yes	Yes
Dysdera unguimmanis μ	Yes	Yes
Spermophorides reventoni	Yes	Yes
Troglohyphantes oromii μ	Not	Not
Metopobactrus cavernicolous ν μ	Yes	Not
Walkenaeria cavernicola μ	Not	Yes
Arachnida – Pseudoescorpionida		
Lasynochthonius curridigitatus	Yes	Not
Paraliochthonius tenebrarum	Not	Not
Tyrannochthonius setiger μ	Yes	Not
Tyrannochthonius superstes μ	Yes	Not
Malacostracea – Isopoda		
Trichoniscus bassoti	Not	Yes
Venezillo tenerifensis	Not	Yes
Porcellio martini	Not	Yes
Myriapoda – Diplopoda		
Dolichoiulus labradae	Not	Yes
Dolichoiulus ypsilon	Not	Yes
Myriapoda – Glomerida		
Glomeris sp.	Not	Yes

	Endemic of Viento Cave	Superficial close-relatives
Myriapoda – Chilopoda		
Lithobius speleovulcanus	Not	Yes
Criptops vulcanicus ν	Yes	Yes
Hexapoda – Blattaria		
Loboptera subterranea	Not	Not
Loboptera troglobia μ	Not	Not
Hexapoda – Homoptera		
Tachycixius lavatubus μ	Not	Not
Hexapoda – Coleoptera		
Aeletes oromii	Yes	Not
Apteranopsis outereloi ν μ	Not	Not
Domene alticola ν μ	Not	Not
Domene vulcanica ν μ	Yes	Not
Lymnastis subovatus ν	Not	Yes
Lymnastis thoracicus ν	Yes	Yes
Oromia hephaestos ν μ	Yes	Not
Speleovulcania canariensis ν μ	Not	Not
Wolltinerfia martini μ	Not	Not
Wolltinerfia tenerifae μ	Not	Not

Note: ν rare; μ vulnerable. After criteria from Recomendation nº 36 (1992) of Council of Europe

Energy flows

The main energy source for the underground ecosystem comes from the roots of surface vegetation and from small troglophile or trogloxene arthropods that access the cave through entrances, cracks or through the layer of earth that separates the cave from the surface (Martín *et al*., 1995). In addition to lava tubes, within the lava flow there are also numerous retraction cracks that increase quite considerably the network of passageways along which the troglobites can wander. Roots are especially numerous under the pine forest and provide sustenance for troglophilic species such as the plant-eating beetle *Rhizophagus ferrugineus* or the troglobite *Tachycixius lavatubus*. When they die they become food for other saprophagous, troglophile and troglobite species which in their turn become prey for (mainly troglobite) carnivores.

The most numerous troglophiles are small dipterous of the *Megaselia* genus, the larva of which live an endogeous life in the soil layer above the cave, and when they become adults they scramble up to the surface where the imago flies off in search of food and a mate. However, during its wanderings in the soil it sometimes enters the cave where it may even mate and lay eggs if it can find excrement remains or other organic matter such as the corpse of the giant troglobite spider *Dysdera labradensis*. It is extremely common for these flies to fall prey to carnivorous beetles and araneids. *Megaselia* is extraordinarily abundant both near to the entrances and in the parts that are furthest away, whenever there is a thick layer of soil. Other species that also penetrate the cave include diplopods (*Blaniulus guttulatus*), snails (*Caracollina lenticula* and

Oxychilus alliarius) and collembola (*Acherongia huetheri*). These species and the *Megaselia* provide a significant amount of energy to the biomass, especially in the galleries nearest to the surface (Martín et al., 1995).

If we just consider the troglobite species, a comparative analysis of the biomass in the different biotypes gives rise to an inverted pyramid in which zoophaga predominate. This is an ecological contradiction which can only be explained by the abundance of troglophile and trogloxene detritovores at the base of the trophic pyramid representing the energy source upon which the underground ecosystem is based (fig 3.) This ecosystem structure is characteristic of volcanic tubes in the Canary Islands and has been found in other caves (Martín, 1992).

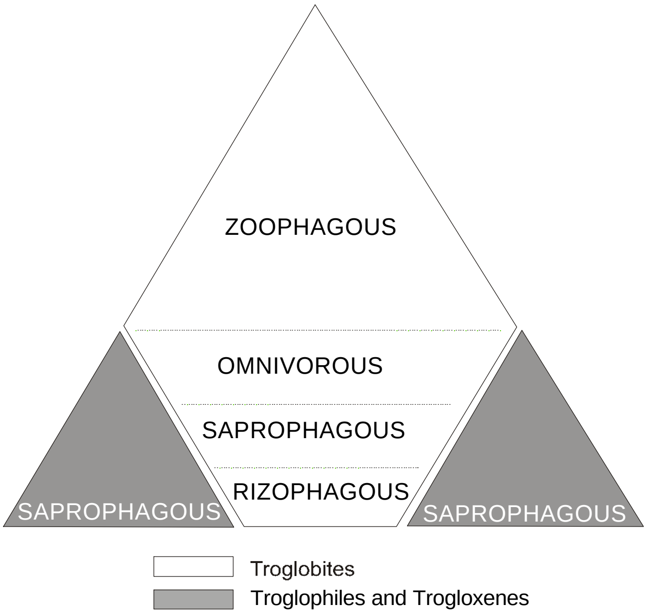

Fig. 3. Biomass and trophic levels in the underground ecosystem of Viento-Sobrado cave, after datas of Martín (1992)

Relations between the underground ecosystem and the surface environment.

As a result of the absence of primary production in the subsoil and dependency on energy from the surface, the underground ecosystem's main characteristic is its lack of energy, which has lead the most adapted species to keep their populations to a minimum and to develop peculiar lifestyles. Figure 4 shows how the use that the surface is put to may affect the underground ecosystem either directly or indirectly . In the case of direct effects, it is the presence of mankind in the cave that provides the transformation vector and as for indirect effects these are those arising from surface soil use such as building, farming practices, and waste water. This interrelation means that any conservation strategy put into operation to protect the cave must include precise regulations both on what goes on in its interior (visits and research) and what occurs at surface level (farming and urban use).

Conservation

The Viento-Sobrado cave has the greatest concentration of troglobite fauna and the largest variety of geomorphological structures of all the caves in the Canary Islands, which makes it a unique place (Oromí & Martín, 1995). However, the nearby development of harmful activities and the affluence of visitors who are attracted by the cave's own natural value are both seriously damaging the possibility of conserving the cave's self-same natural values. The three main threats that affect the underground ecosystem are pollution, human presence and building at surface level.

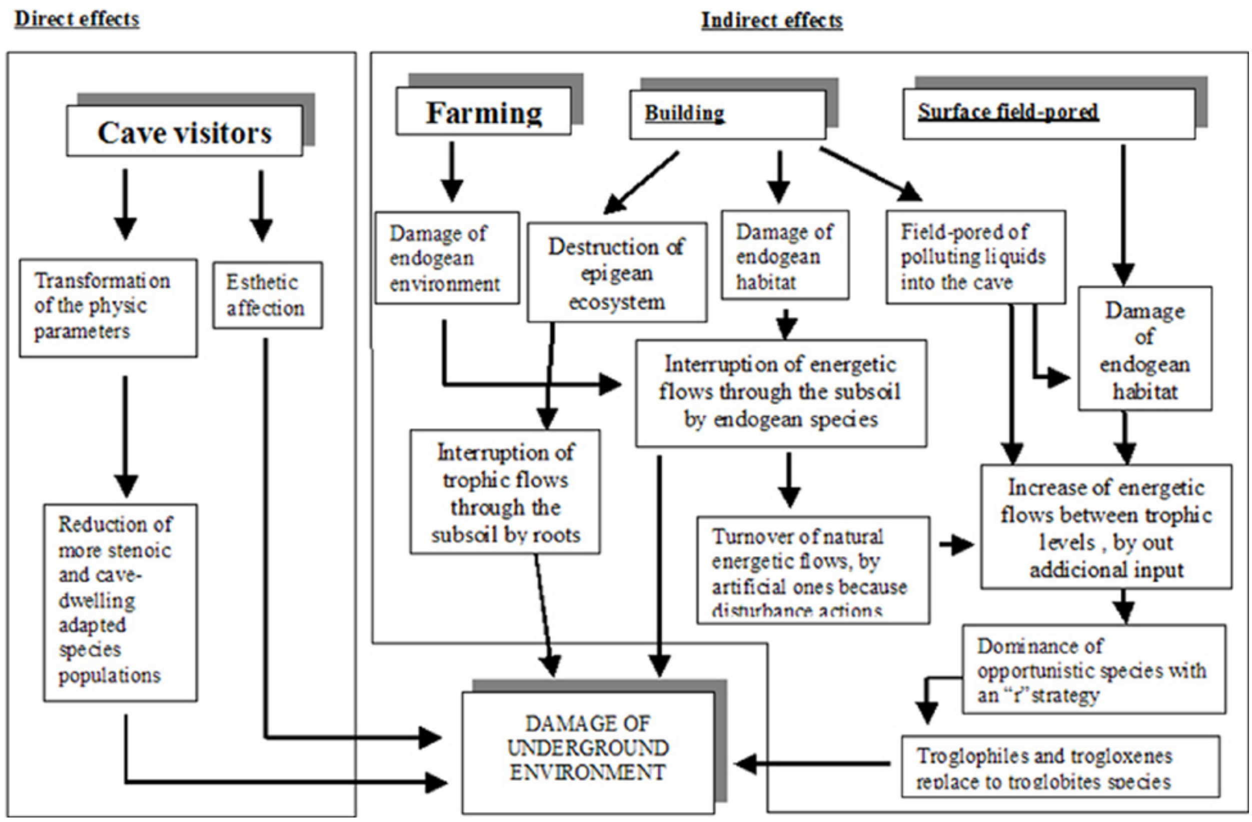

Fig. 4. Effects on underground environment of the different human uses

Pollution

The waste water that has been dumped inside the volcanic tube has profoundly affected the troglobite and troglophile fauna especially in the Piquetes gallery and the northern branch of the Breveritas gallery. In the southern branch of this gallery and also the Belén gallery this pollution only affects some areas and is less concentrated. Waste water has an excess concentration of nitrates, way above the normal level of underground water and in almost all cases is present within a 50 metres radius of surface buildings. Some polluting organochlorines such as lindane, DDT and derived metabolites have been found in the sediments of some areas of the caves. These appear due to bioaccumulation in species such as *Loboptera troglobia* and demonstrate the presence of these pollutants in trophic chains (Oromí *et al*. b, 1995). One characteristic of the fauna where the greatest levels of pollution are found is the dominance of opportunistic species with an "r" ecological strategy (troglophiles and trogloxenes) at the expense of specialists with a "K" strategy (troglobites) as occurs in the most polluted sector of the Piquetes gallery (Martín et al., 1995).

Human presence

The amount of waste within the cave is directly proportional to the frequency and number of visitors. Waste includes calcium carbide remains, batteries, paper, plastic, candles, food remains, etc. Some of the cave's walls have even been vandalised with paint.

Together with this, those who visit the cave also bring about climatic changes, which result on occasions in changes to surrounding temperature and in the air content, especially in those galleries where there is less air circulation (Arechavaleta *et al*, 1996). This can cause temporary two to three degree temperature changes in the most frequently visited areas, which may be the reason behind their more limited amount of troglobite fauna (Martín *et al*. 1995).

Buildings

With the only exception of the surface area above the section of the cave known as "Piquetes", the rest of the ground above the cave has been classified as non-building land by the administration. However, in recent years many buildings have been constructed on some occasions directly above the volcanic tube. Neither these buildings nor the ones located directly above "Piquetes" have a sewer system, so sewage is dumped directly onto the subsoil, causing serious ecological damage.
A second effect of urbanisation, whether it takes the form of buildings, roads or any other action that changes the surface, is that it interrupts the energy flows that support the underground ecosystem, either through the destruction of vegetation or via the elimination of the soil layer where the troglophile and trogloxene species live and which are the foodstuff for the troglobites that live underground.

What the government is doing

The Viento cave meets the criteria recommended by the Council of Europe in 1992 for selecting habitats according to their biological value (table III) and which include an urgent need for measures to be adopted to ensure that habitats are maintained in as "natural" a state as possible (Juberthie, 1995). The corresponding public nature conservation body met this need by setting up a preventive protection system called the Plan for Regulating Natural Resources. This plan contained the precise measures to be taken to eradicate any threats to natural habitats and to guarantee their conservation. This preventive system was passed by an order dated the 20th December 1994, (B.O.C, 1994) and the mentioned Plan for Regulating Natural Resources in the Viento-Sobrado cave was formally approved in a Canary-Island Government Decree (B.O.C., 1998) after a public and institutional consultation process where all the interested parties were invited to a hearing to make their comments on the Plan (Izquierdo, 1998).
The plan was approved with the go-ahead of the main social and political groups of the region and the owners of the land where the cave is located.

Table III. Staus of criteria for selecting underground habitats of biological value for the contracting parties of "Convention on the conservation of european wildlife and natural habitats" in the Viento-Sobrado cave

CRITERIA*	STATUS
Presence of species adapted to subterranean life	36 troglobites
Presence of vestigial species	To see table I
Presence of vulnerable species	To see table I
Presence of endemic species	36 troglobites and several troglophiles and trogloxenes
Presence of rare species	To see table I
Presence of bats	Not
Relatively high biodiversity	Yes
Originality of the habitat	Yes due to it volcanic origin
Scientific value	Very high
Vulnerability of habitats	Yes, due to the threatens former comented

* after Recomendation nº 36 (1992) of Council of Europe

The Plan lays down a series of measures to be directly and immediately applied and others, that will have to be developed later through new regulations. The following are the main points of the plan: (fig. 5).

The scope of the Plan is the best-preserved part of the cave and does not include the Piquetes gallery (area I in fig. 2) since it is already badly affected by decades of solid waste and sewage that have entered from outside.

A large area of the land above the cave will receive the category of "ecologically sensitive area" and any authorised use to which the land is put will have to undergo an impact study to examine any possible effect said use would have on the underground ecosystem.

Chemical fertilisers for farming, intensive livestock rearing, phytosanitary treatments, forestry treatment, reforestation using exotic species and land movement will all be strictly limited.

No building will be allowed directly above the cave nor on a 100-metre wide strip of land on either side of the cave, except for the construction of a visitors' centre near to one of the cave's entrances to control access and provide information about the cave and its surroundings.

A maximum of 30 people will be allowed inside the gave at any one time and groups should be less than 15 people.

No rubbish shall be dumped inside the cave.

Research and education activities will be promoted in accordance with the public use plan which should be written for the area.

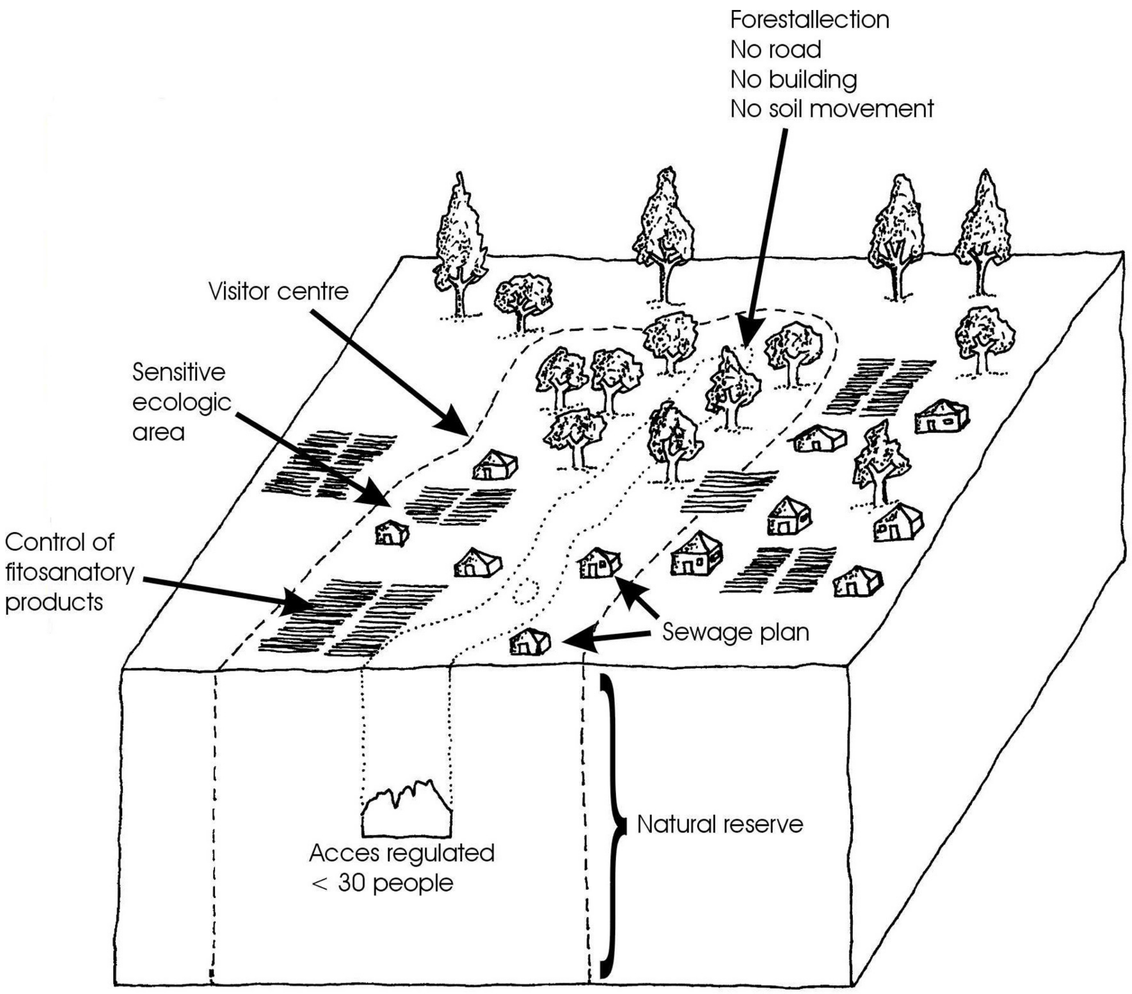

Fig. 5. Measures to be taken to eradicate any threats to underground environment and to guarantee their conservation

In the medium term it is hoped that the necessary steps will be taken in canarian parlament for the underground environment of the area designated as an ecologically sensitive area to be declared Special Nature Reserve – a category which is equivalent to level IV of the UICN's international nomenclature. In this way, the cave would become part of the Canary-Islands Network of Protected Natural Areas.
All of this is in addition to the recent purchase by the public administration of the land at the entrance to the cave, so as to effectively control the accesses in accordance with what is stipulated in the Plan for Regulating Natural Resources. A research projected subsidised by the European Union within its LIFE invested programme is also being carried out with a view to refine the conservation measures and finalise the fauna inventories.

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