

Speleology

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Speleology is the "science of caves". The aims of simple sciences may be perfectly and unambiguously defined but, in more complex sciences the boundaries between them are always rather uncertain, because these sciences are intimately connected and may be separated only arbitrarily. This is the case in the majority of the natural sciences, Speleology belongs to this type of complex science. The term "cave" is an anthropomorphic idea. Then we say that Speleology is the study of the subterranean world

According to thematic subdivision of the Speleological Abstracts (a publication of the UIS - International Union of Speleology-) we subdivide Speleology in three scientific research areas:

(1) Geospeleology or Physical Speleology

Defined as one of the sciences of the earth, which also include geology, physical geography, karstology, hydrogeology and, of course, the exploration and topography of individual caves.

(2) Biospeleology: the study of subterranean life

This is a branch of biology, or zoology, since the majority of cave dwelling organisms are animals. It includes systematics, morphology and experimental research of cave fauna, but also ecology, biogeography, genetics and evolutionary biology.

(3) Anthropospeleology or Speleo-Anthropology

A part of Anthropology, Archaeology and Paleontology, in related to the past and present of the human being and the caves.

The Aranzadi's Department of Speleology focuses its survey on the territory of Gipuzkoa, the central part of the Basque Country, in the frontier between France and Spain. But, in addition, it also carried out studies in the surrounding territories of Bizkaia, Alava, Navarra, and Basque-French areas of Labourd, Basse Navarre and Zuberoa.

The speleological research in Gipuzkoa started between the end of the last century and the beginning of the present century. Between 1871 and 1930 a group of prehistorians (S. Umerez, C. Lersundi, T. Aranzadi, E. Eguren, J.M. Barandiarán) carried out excavations and archaeological explorations in different shelters and caves: Aizkirri, Aitzbitarte, Urteaga and others caves. Similarly, between 1905 and 1929, the pioneers of Biospeleology, E. Racovitza and R. Jeannel, collected cave-dwelling fauna in several Gipuzkoan cavities, in collaboration with H. Breuil, a famous paleontologist. His results are published in the series "Biospeologica: Enumeration des grottes visitées. Archives de Zoologie Expérimentale et Générale". As well as the outstanding activity developed by the founders of "Biospeologica", there the one carried out by other Basque and Spanish naturalists, such as C. Bolívar, J. Nonidez and F. Bonet, who published several works between 1917 and 1931 on coleopterans, pseudoscorpions and cave-dwelling collembolans, respectively.

This productive initial stage was interrupted by the 1936-War, the Second World War and the post-war period, which marked a long parenthesis in almost all scientific activities, including speleology. In 1946 the Aranzadi Scientific Society is founded, giving rise to modern speleology in the Basque Country. Geological and paleontological campaigns were carried out in the caves of Aralar and Aitzgorri mountains, where the participants were, among others, N. Llopis Lladó and J.Gómez de Larena. With respect to biospeleology, studies on fauna were carried out in several cavities by distinguished researchers such as R.Margalef, E.Balcells, F.Español and M.Rambla, in collaboration with speleologists from the Basque Country. This era established the bases for the record, exploration and systematic study of cavities, and brought about the creation of the Speleological Catalogue of Gipuzkoa.

From 1950 onwards, the exploration of chasms was greatly helped by the appearance of metal ladders and other climbing techniques. The SCA speleological group descends the Ormazarreta 1 Chasm in Aralar which, with its -402 m deep constituted a record for the era. In the Aránzazu valley the great complex of Gesaltza-Arrikruz is explored, with 14 km of subterranean galleries. The works on the Larra massif (Basque Pyreneans) are intensive. In the 60's the Aranzadi group scaled 95 m on one of the walls in the Verna Hall of the Pierre Saint Martin Chasm, finding out the continuation of the cavity at -700 m. This allowed then to reach the bottom, at -1.171 m, which was the world's record of depth for more than a decade. Nowadays, with the discovery of superior entranceways, the P.S.Martin totals -1.342 m. The SCA organized the First Speleological Congress of the Basque Country in 1956: a starting point for execution of periodical conferences and for the later creation of the UEV (Unión de Espeleólogos Vascos) - the Union of Basque Speleologists, an organism which coordinates speleological activities, promoting collaboration between groups that work in the Basque Country.

Modern SCA speleology is developed for numerous speleologists, such as F. Ruiz de Arkaute, J. San Martin, R. Corcóstegi, A. Arratibel, A. Leibar, P.R. Ondarra, F. Leizaola, P. Sistiaga, J.C. Vicuña, J.A. Martínez, D. Adrian, J. Villota, C. Galán, R. Zubiria, J. Zabala, P. Rigault, D. Dulanto, F. Etxeberria, J. Astigarraga, F. Ugarte, A. Merino, I. Goikoetxea. The works of F.Etxeberria on Physical Anthropology and Paleopathology, and C.Galán in Biospeleology and bats studies have added numerous publications.

An outstanding technical step forward took place at the end of the 1970's, when the old metal ladders were replaced by the technique of "jumars" and ropes alone (= SRT or Simple Rope Technique). This meant that the greatest chasms, abyss and underground systems in the Basque Country could be explored. Speleologists from the SCA, in collaboration with other groups from the ARSIP and the UEV, have participated at different times in the exploration and study of the Budogia 56 Chasm (-1.408 m, the largest chasm in the Basque Country and first integral depth in the world -with one single entranceway-), Lonné Peyret Chasm (-774 m, where F.Arcaute died by hydrocution in the underground river), Ormazarreta system (-576 m, the deepest cave in Gipuzkoa), Ojo Guareña Cave (90 km development, the largest cave in Spain), Caballos-Valle System (60 km development), SI-44 Chasm (42 km) and other big caverns. Over the thirty last years some speleologists from the SCA, especially C.Galán, have also participated in the study of tropical and temperate karstic areas in Venezuela, Brasil, Argentina and Cuba



1. Geospeleology

1.1. The underground world

Ignored, feared, or simply unknown, there is a strange and mysterious world out of view under the earth's surface, ruled of gloom, solitude and silence. The world of these caves is an almost exclusively mineral domain, although it also houses strange forms of life, and has even been used as a temporary residence for men since Prehistorical times. The underground galleries spread through the subsoil in all possible directions: they can take the shape of spectacular chasms or vertical pits, horizontal galleries, or have greatly differing gradients. Their shapes also vary: they can be winding conduits excavated into the bare rock, wide galleries filled with clay or boulders, halls whose vaults and floors are carpeted with extravagant crystallizations or speleothems, real labyrinths between the chaos of blocks, or else underground rivers with waterfalls and rapids, followed by quiet pools and lakes.

Gipuzkoa is a privileged territory with respect to its caves. A quarter of its surface area is covered by massifs which house cavernable rocks. Of these, 1.900 cavities have now been explored and studied, most of which are chasms. The greatest differences in level are presently found in Ormazarreta 2 (in Aralar mountain) and Gazteluko urzuloa (in Degurixa, Aizkorri mountain), with depths of -576 m and -522 m respectively. Regarding extension, the largest dimensions belong to the Gesaltza-Arrikruz system, with 14 km of interconnected galleries.

There are many other important massifs in the Basque Country as a whole, some of which are internationally famous. The Larra massif, or the P.S.Martin Chasm massif, is especially outstanding, located between Navarra and Zuberoa, whose highest point is the Anie peak, 2.500 m high. This massif houses some of the greatest chasms in the world and several caverns which extend for several kilometers. At this moment, the deepest cavities in the Basque Country, all of which located in Larra, are the following:

- Budogia Chasm - Bu56, -1.408 m
- the P. S. Martin Chasm, -1.342 m
- the BT6 Chasm - Soudet River, -1.166 m

The largest caverns are found in:

- the Caballos-Valle System (in Biscay), with 60 kms of galleries
- The above stated P. S. Martin Chasm, with 52.7 kms
- The SI-44 Chasm (Alava), with 42 kms

The annexed tables list the greatest cavities in the Basque Country and Gipuzkoa. 10.000 cavities have been explored and surveyed in the country up to date. This, by itself, gives an idea of the importance and extension of the Basque Country's underground world.



1.2. Karstic areas in Gipuzkoa

Gipuzkoan caverns have been formed by the infiltration of water on rocks, which can also be dissolved in spite of its compactness. These rocks are limestone, and are composed of calcic carbonate (CaCO₃). Rain-water (loaded with CO₂) is capable of dissolving 150 to 200 mgs of rock per litre of water going through the karst. In this way, very slowly, after several millenniums, the water circulating underground succeeds in forming a network of galleries. The distribution of caverns in the territory of Gipuzkoa is a consequence of the way in which the limestone rock massifs containing them are distributed.

Gipuzkoa has a surface area of almost 2.000 km² and has an uneven mountainous relief with deep valleys which leads to the Cantabrian Sea. Its climate, typically atlantic, is very humid and therefore extremely suitable for the development of karstification. Yearly rainfalls are between 1.500 and 2.000 mm.

The total of karstic areas is around 480 km², which is equivalent to a quarter of the surface of the territory. 350 km² (72% of the karstic areas) correspond to 4 large massifs: Izarraitz, Ernio, Aralar and Aizkorri. These massifs have the largest cavities and underground systems and are in turn the most important mountains in Gipuzkoa with 1.000 to 1.550 m high. Karstic areas include 130 km² more, which correspond to a series of small massif and isolated outcrops of limestone, located in the periphery of the main massifs.

All the karstic areas in Gipuzkoa are spread over two great structural regions, the northern and southern anticlines of the Folded Basque Arch. These buckled structures are found in two longitudinal strips located in the North (Izarraitz - Ernio) and in the South (Aitzgorri - Aralar) of the territory.

The distribution of the Gipuzkoan karstic areas is the result of the geological processes which have governed the sedimentation and formation of limestone rocks in the hot seas which flooded the region during the Jurassic and Cretacic periods, 200 to 65 million years ago.

These sedimentary rocks formed under the sea, emerged during the Eocene period, around 45 million years ago, forming the pyrenaic range and the Basque mountains which are part of the Pyrenees. The progressive rising of the range is a consequence of the collision and knitting together of the continental Iberian and European plates, the former of which presently lies beneath the latter.

The progressive elevation of the range was accompanied by the deformation of its covering of sedimentary rocks, which were gradually strenuously buckled, comprising the structure which we now know as the Arco Plegado Vasco (Folded Basque Arch). But, at the same time, the surface area was reduced and cut down by erosion, forming the mountain and valley relief as it exists today. The calcareous massifs stand out in this relief as abrupt mountains, since they have resisted erosion better than other terrains formed by comparatively softer rocks.



We have to point out that the Folded Basque Arch is part of the pyrenaic structure and more specifically the so-called French Norpyrenaic Area. This structure runs through the Basque Country and continues along the continental platform of the Cantabrian Sea to the Le Danois bank, located 150 km NW far from Bilbao.

The limestone now existing in Gipuzkoa and in the North of the Basque Country (from Biscay to Zuberoa), was deposited on the European plate when the Gulf of Biscay was being formed. This European nature of Gipuzkoan karst is an important factor which controls and explains the colonization and later evolution of the troglobitic fauna living in our caverns, common to Europe, and clearly different from that inhabiting Iberian karsts.

Depending on their age and lithology, the karstifiable formations existing in Gipuzkoa basically comprise: the reef limestone of the Urgonian Complex (from the Aptian-Albian stage, Lower Cretaceous period) and the Jurassic limestone and dolomite (especially that of Dogger-Malm). There may be other karstic phenomena, less important, in small limestone outcrops from the Late Cretaceous period (mainly from the Cenomanian and Maestrichtian-Danian ages).

1.3. The largest cavities in Gipuzkoa: May 2005

In the following lists appear after the name of the cave, the karstic massif and the depth (A) and development (B) in meters.

A. The deepest caves		B. The longest caves	
1. Ormazarreta 2. Aralar.	-576 m	1. Gesaltza-Arrikruz. Aitzgorri.	14.000 m
2. Gazteluko urzuloa. Aitzgorri.	-522 m	2. Aixako zuloa. Izarraitz	8.000 m
3. Arbeloko leizea AR-1. Aralar.	-500 m	3. Ormazarreta 2. Aralar.	6.815 m
4. Maikutxa 3. Izarraitz.	-488 m	4. Ondarreko zuloa. Aralar.	3.200 m
5. Gaztelu 3. Aitzgorri.	-444 m	5. Leizebeltz. Aralar.	2.504 m
6. Leizebeltz. Aralar.	-345 m	6. Mandobide 1. Aitzgorri.	2.300 m
7. Sabesaia-eize aundia 2. Ernio.	-340 m	7. Altxerri. Orio.	2.225 m
8. Santutxoko leizea. Ernio.	-300 m	8. Sabesaia-Leize aundia. Ernio.	2.200 m
9. Malkorriko leizea. Aralar.	-286 m	9. . Mallueta. Izarraitz.	2.000 m
10. Aitzbeltzko leizea. Izarraitz.	-279 m	10. Iritegi. Aitzgorri.	1.880 m

1.4. The largest cavities in the Basque Country: May 2005

In the lists below appear after the name of the cavity, the karstic massif and abbreviation of the territory: Na = Navarra; Zu = Zuberoa; Gi = Gipuzkoa; Bi = Biscay; Al = Alava; Ca= Cantabria. The depths (A) and developments (B) are given in meters.



A. The deepest caves		B. The longest caves	
1. Sima de Budogia Bu-56. Larra. Na.	-1.408 m	1.Caballos-Valle. Carranza. Bi-Ca.	60.220 m
2. Sima P.S.Martin. Larra. Na-Zu.	-1.342 m	2. Arrestelia. Larra. Zu.	57.061 m
3. Sima BT6 - Río de Soudet. Larra. Zu.	-1.170 m	3. Sistema Kakouetta. Larra. Zu.	53.950 m
4. Gouffre Partages. Larra. Zu.	-1.097 m	4. Sima SI-44. Salvada. Al.	45.000 m
5. Arrestelia. Larra. Zu.	-838 m	5. Sistem Atxuriaga. Galdames.Bi.	28.000 m
6. Sima An--8. Larra. Na.	-811 m	6. Sima Lonné Peyret. Larra. Zu.	24.341 m
7. Sima Lonné Peyret. Larra. Zu.	-807 m	7. Gouffre Partages. Larra. Zu.	23.918 m
8. Sistema Arphidia. Larra. Zu.	-745 m	8. Sistema Kakouetta. Larra. Zu.	23.000 m
9. Couey Lodge DS30. Larra. Zu.	-733 m	9. Sistema Arphidia. Larra. Zu.	22.575 m
10. Sistema Arphidia. Larra. Zu.	-712 m	10. S. Budogia Bu-56. Larra. Na.	15.000 m



2. Biospeleology

2.1. Cave fauna

Biospeleology studies the fauna which lives in caverns. Taking samples or collecting fauna from inside the caves can be carried out by means of direct collecting, in normal speleological outings, or else, more advantageous, in successive outings, by setting "traps" in the cavity. These traps attract the cave-dwellers and are checked several days later. We would like to emphasize the fact that cave-dwelling fauna is fragile and vulnerable. Collections in caves only make sense when dealing with research projects, with set objectives, and when it's been previously decided where the collected specimens will be deposited and which specialists will study them.

Cave-dwelling fauna in Gipuzkoa comprises several groups of terrestrial and aquatic invertebrates (generally minute in size) and a few vertebrates (such as bats). Most strict cave-dwellers or troglobites in Gipuzkoan caves are derived from ancient fauna, of the tropical and subtropical kind, which lived in the region during the Tertiary period. Their closest relatives have disappeared from the earth's surface and they are therefore real "living fossils", relics from other eras, which have managed to survive and evolve in the caves until our days. Their interest is therefore considerable. An extremely high proportion of troglitic forms are exclusively endemic to the Basque Country.

Until now, studies in Gipuzkoan caves have been carried out on 380 animal species belonging to 45 orders of 12 different zoological classes, with biological, biogeographic and ecological data. Gipuzkoan karst and their geological and climatic evolution during Mesozoic and Cenozoic have been studied. We have also investigated the most important biotopes, cavernicolous synusia and biocoenoses from about 400 Gipuzkoan caves. Colonization, speciation processes in caves and morphological changes in cave-dwellers have been subject of study. Today, the SCA Biospeleological Collection has more than 7.000 specimens of cavernicolous animals.

83 taxa are trogliphiles and 102 taxa are troglobites. The latest one belongs to 18 invertebrates orders: Bassomatophora, Stylommatophora, Pseudoscorpionida, Limicolae, Opiliones, Araneida, Cyclopoida, Harpacticoida, Bathynellacea, Isopoda, Amphipoda, Glomerida, Craspedosomida, Iulida, Lithobiomorpha, Collembola, Diplura and Coleoptera.

11 genera and 95 species are forms exclusively endemic to the Basque Country, many of which are only known in the world of one or a few Gipuzkoan caves. The discovery of taxa news to science, such as the coleopterons *Hydraphaenos galani*, *Aranzadiella leizaolai*, and *Kobiella galani*, is a demonstration of the importance of Gipuzkoan cavernicolous fauna. The cave fauna of the Basque Country constitutes a biogeographic region, whose central core embraces Gipuzkoa, the zones N and NE Biscay, SW Labourd and NW Navarra. We emphasize the affinities of this fauna with the French Norpirenaican one.



In addition, the bats fauna from the Basque Country is very rich and diverse, with 22 species in 10 genera and 3 families. Many bats in the region are cavernicolous troglloxens and many others hibernate in caves.

New evidence obtained from comparative ecological and evolutionary studies from tropical and lavic cave-dwellers of South America, Caribe and Canary islands, permitted us to modify the current biospeological knowledge. The classic theory and new models are being reviewed and discussed, and we have presented a new global interpretation of cave fauna evolution. We have postulated sympatric and parapatric speciation as alternative models to explain the origin of new cavernicolous species, both troglobites and troglrophiles, in the presence of gene flow. This process occurs gradually by habitat drift and divergent selection through intrinsic mechanisms of pre-copula isolation, and could also imply a quick divergence promoted by factors like neoteny, paedomorphosis and genetic recombination. Data from temperate troglobites from the Basque Country, compared with tropical troglobites from Brazil and Venezuela, permit us to open new lines of research in Biospeleology.

Today, we are carrying out surveys about morphological and physiological changes in evolution of cavernicolous animals from Gipuzkoan and Navarran caves, especially about processes of neoteny, allometric and heterochronic changes, and some aspects of developmental biology.

2.2. Subterranean Ecology

Ecology is the section of biology concerned with the relationships between living organisms and their environment.

Subterranean ecology includes data about the different habitats of cave-dwelling organisms, subterranean biotopes, synusia and biocoenoses. The chemical, physical and climatic factors, and their action on the physiology of cave animals are also analyzed. It involves other aspects such as the nutrition and feeding sources of the cave animals and their metabolism and reproductive behaviour. Processes of development and life-strategy are also an essential part of study.

The initial anthropocentric vision of the caves as isolated and individualised geographical units has been deeply modified. The attention of researchers has been directed towards new hydrogeological and geochemical aspects. The ecology of caves as an object of study has been substituted, in recent research lines, by the karst processes and the functionality of karst (and caves in other lithologies: lava and cuarcitic rocks) as a whole. Caves have become an integrated component of the karst systems. Both ecology and population genetics of the subterranean organisms depend on the degree to which the caves are or not islands within the karst system, so it is important to know more precisely the internal structure and the connections between the components of the system.

Water circulating through the karst is revealed as the main vector that puts energy into the subterranean ecosystem. The changes in the terrain permeability produced by the increasing size of the karst conduits and by the increase in intercommunication between



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voids in the endokarst, gradually modify the characteristics of subterranean spaces receptive to population by cave organisms. This fact favours an increase of ecological niches and biotopes simultaneous to the increase of structural complexity. The discovery of the MSS (underground subsurficial medium) extended the presence of troglomorphic organisms beyond the limited environment of karst caves. This meant an extension to the tendency initiated in the study of cave aquatic fauna on the interstitial and anchihaline habitats. Today scientists are paying more attention to the transmission and interchanges of water, air, materials, food, organisms and genes through the karst.

The high levels of carbon dioxide and the high natural radioactivity in the air of the deep cave environment seem to be a very important ecological factor in the life and evolution of troglobites. Recent discoveries of troglobitic cave species in the tropics and in medium-sized subterranean voids have modified the classic vision based on the ecology of the temperate limestone caves. The SCA biospeleologists are developing studies about a variety of aspects in this line.

A synopsis of Gipuzkoa cave fauna (taxonomic data) is presented in the spanish version.



3. Speleo-Anthropology

Speleo-Anthropology is a part of Anthropology. The study of man's past comprises many aspects, but it is a fact that caverns have been used by human beings since ancient times and are at the same time an extraordinarily efficient conserving medium, which has permitted the storing and preserving of many vestiges of this past.

In Gipuzkoa, many interesting anthropological sites are found in caves. They can house the material remains (osseous) of human beings, the remains of a culture (archeological objects, cave paintings), and the remains of animals they ate or coexisted with in other eras (paleontological remains).

The use of caves by human beings dates from the remote past (Prehistory) right up to the present day. For this reason, caves can also house vestiges of interest for Historical Archeology and/or Ethnography. Some of the caves and chasms in the Basque Country have legends attached to them; others were used as a place for worship or for religious practices; and some have utilitarian uses, as a sheepfold, cellar or place for cultivating mushrooms. On top of this, there are the underground conduits which have been put to good use for supplying farmhouses, factories and villages with water.

In the Izarraitz massif there is the Urteaga Cave and the Ekain Cave. The first one is remarkable due to its site with human cranes and paleontological remains from the Upper Paleolithic age. The second cave is notable due to its spectacular Magdalenians cave painting, especially of horses, bison and bears.

The Udalaitz massif, located in the SW part of Gipuzkoa, has the Lezetxiki Cave, a site with some of the most ancient layers in Basque Prehistory. A human humerus dated as being about 310.000 years old (Lower Paleolithic period) comes from the VII layer. This period corresponds to a cold stage of the Riss glaciation. On layers VI and V (above the former) Mousterian industries and human molars were found; these levels correspond to the final Riss (230.000 years BP) and to the interglacial Riss-Würm (186.000 years BP). The human remains mentioned all belong to Neanderthal beings. In the northern part, on a spur leading from mount Pagoeta to Orío, there is the Altxerri cave, famous for its prehistoric paintings and engravings, especially fishes, bison and deers.

In the Aralar massif many abyss have ancient bones of Pleistocene mammals, such as the cave-bears *Ursus spelaeus*, mammoth and woolly rhinoceros, lions and panthers of the caverns.

Many other caves and shelters in Gipuzkoa have anthropological and paleontological remains and many of them have been discovered by SCA speleologists. Today, its study is the task of specialists (anthropologists and archeologists), and we remit to the correspondent departments of the SCA for more details.