

## Karst and speleology in Sicily (Italy)

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### Abstract

The differentiated and complex geological structure of the island of Sicily (25708 sq. km) has permitted that the most important karstic features known in nature were formed. In fact in the very extended outcrops of calcareous rocks, evaporites and volcanic rocks, it is possible to find interesting surface landforms and underground features: there are strictly karstic on limestone terrains, parakarstic on evaporites (gypsum and halite) and pseudokarstic on basalts. At this moment in Sicily there are known and surveyed a few hundred caves that are mainly located in the northwestern part of the coastal chain, in the foreland calcareous areas (Iblean Plateau southeast and Sciacca Mountains southwest), in the messinian Gessoso-solfifera Formation (central and western zones) and in the Mt. Etna volcano. The underground features are not completely known because of the small number of speleological groups operating in a very large territory.

### Riassunto

*A causa della sua complessa e differenziata struttura geologica, la Sicilia può annoverare nell'ambito del proprio territorio (esteso 25708 kmq) i principali fenomeni speleogenetici conosciuti in natura. Infatti, la presenza di estesi affioramenti di rocce carbonatiche, evaporitiche e vulcaniche ha favorito la formazione di interessanti morfologie, superficiali e sotterranee, sia propriamente carsiche (calcari) che paracarsiche (gessi e salgemma) e pseudocarsiche (lave basaltiche). Fino al momento attuale in Sicilia sono state esplorate e documentate alcune centinaia di grotte, ubicate prevalentemente nella parte nord-occidentale della catena costiera, nelle aree di avampaese, anch'esse carbonatiche, dell'Altopiano Ibleo (zona sud-orientale) e di Sciacca (zona sud-occidentale), negli affioramenti della Formazione Gessoso-solfifera messiniana vulcanico del Mt. Etna. Le conoscenze speleologiche della Sicilia non sono ancora del tutto complete a causa dell'esiguo numero di gruppi operanti in un così vasto e complesso territorio.*

### Résumé

*Grâce à sa géologie complexe et différenciée, la Sicile compte sur son territoire (25 708 km<sup>2</sup>) tous les principaux phénomènes spéléologiques connus. En effet, de vastes affleurements de roches carbonatées, d'évaporites et de vulcanites ont favorisé la formation de formes intéressantes, tant superficielles que souterraines, qu'elles soient véritablement karstiques (dans le calcaire), ou parakarstiques (dans le gypse et le sel gemme), ou pseudo-karstiques (dans la lave basaltique). Jusqu'à présent, quelques centaines de grottes ont été explorées et étudiées; elles sont surtout situées dans la partie N.-W. de la chaîne côtière, dans les calcaires de l'avant-pays (plateau Ibléen dans le S.-E., monts Sciacca dans le S.-W.), dans les affleurements de la Formation "Gessoso-solfifera" messinienne (zone centrale et occidentale) et sur l'Etna. Il reste encore beaucoup à faire, car les groupements spéléologiques sont peu nombreux par rapport à l'étendue et à la complexité du domaine à étudier.*

### I. GEOGRAPHICAL AND GEOLOGICAL SETTING

Sicily (Fig. 1), the largest of the Mediterranean islands together with its surrounding minor islands, extends over an area of 25708 sq. km. This vast area, due to its geographical position and its climatic as well as geological conditions, constitutes a typical belt region between the European and African continents.

The island's climate, temperately hot, is characterized by an annual precipitation of 735 mm (the 1921-1970 average), nearly half of which is concentrated during the winter months of November, December and January. The other half is divided between autumn and spring, with the summer months almost completely dry. The annual average temperature oscillates between 19°C on the coastline and 13°C inland (CALOIERO, 1975).

From a morphological point of view, Sicily is predominantly mountainous and hilly. Flatlands account for only 14% of the total surface, and are prevalently located in the coastal areas. Almost the whole northern section of the island is covered by a mountainous relief, a coastal chain which expands from east to west, the Madonie mountains being the highest point with an altitude of 1979 metres. The southwestern appendage of this chain (Sicani Mts.) reaches a maximum elevation of 1580 m above sea level, whereas the eastern-central portion is dominated by Mount Etna volcano, reaching an elevation of 3323 metres.

As a result of the complex tectonic changes that have conditioned Sicily's present structural order, the island can be divided into three different areas: northwest, central and south, with their respective geology. The northwestern section of the island is dominated by an overlapping thrust structure made up of various types of terrains with corresponding various ages between the Palaeozoic and the Tertiary. The various rock types of this structure are: crystalline and metamorphic rocks in the N.-E. portion (Peloritani Mts.), predominantly terrigenous rocks in the central-northern portion (Nebrodi Mts.), limestones and silica-carbonate rocks in the northwestern portion (Madonie, Termini, Trabia, Palermo, Trapani and Sicani Mts.).

The central and mid-western section of the island changes composition with the presence of sedimentary foredeep terrains of mio-pliocene age constituting the Caltanissetta (central) and Castelvetro (mid-western) basins. In these areas evident terrigenous deposits as well as evaporite outcrops, part of the Gessoso-solfifera Formation of Messinian, can be seen.

In the southernmost section of the island, precisely in the Sciacca and Iblean Plateau areas (the southwest extremity), extensive outcrop formations, predominantly limestone, constitute the foreland of the orogenic structure, being partially deformed the first one and stable the second one.

#### H. FORMER STUDIES ON KARST AND SPELEOLOGY

Scientific research of surface and underground karst phenomenon, done by geographers and naturalists, goes back to the 19th century. Previously, in Sicily, studies of caves were done by ancient scholars strictly from a historical and legendary point of view.

Between the second half of the 19th century and the first half of the 20th century, an intense increase of scientific research took place, resulting in multiple palaeontological and archaeological finds. However,

during this period, the first detailed and systematic investigations of karst areas in Sicily may be attributed to MARINELLI (1899, 1900, 1911, 1917); also during this period, a detailed description of the Santa Ninfa (Trapani) area by GEMMELLARO (1915) brought to light information about the numerous superficial features (dolines) and underground cavities. In the following decade, authors belonging to various speleological groups continued to analyze information about this subject, leading to a more precise understanding of the karst phenomenon. Many articles have consequently been written about individual caves in Sicily, reporting their specific characteristics.

However, a few authors, FABIANI (1932), DE STEFANI (1941) and SAIBENE (1957) had a more general approach to this argument.

In recent years, following a large increase in speleological studies in Sicily, coupled with previous reconnaissance work done in these areas, multiple new publications have come to light, accounting for a thorough inventory as well as detailed descriptions of the various karsts. Recently, thanks to various regional and international conferences, the preservation and protection of these areas have also become a popular argument for research, as seen in the following: AA.vv. (1977, 1986, 1987, 1989, 1991), BRUNELLI & SCAMMACCA (1977), CALVARUSO *et al.* (1978), GUIDI *et al.* (1980), LICITRA (1985), MADONIA *et al.* (1983), MANNINO (1985), PANZICA LA MANNA (1989).

#### III. DISTRIBUTION OF KARST AND SPELEOGENETIC FEATURES

As a result of its complex geological constitution, conditions favourable to the formation of speleogenetic and karst features are found in Sicily. In fact the simultaneous presence of carbonate, evaporite and volcanic terrains has permitted the establishment and development of important surface as well as underground forms. This is a result of dissolved limestone and dolomitic-limestone outcrops and the solubility of halite and gypsum rock. For example, within the massive Mount Etna volcano, these particular chemical and physical characteristics of the magma have created numerous lava flow galleries.

The following description of principal karst forms and their distribution throughout the Sicilian territory takes into consideration the geo-lithological scheme previously mentioned.

## A. Calcareous rocks

### 1. Carbonate reliefs

Carbonate reliefs in Sicily to be mentioned are, from east to west :

- a) the outcrops scattered throughout the Nebrodi and Peloritani Mts., the most important being the Rocche del Crasto, 1315 m;
- b) the Madonie Mts.;
- c) the Trabia-Termini I. Mts.;
- d) the Palermo Mts.;
- e) the Trapani-S. Vito Lo Capo Mts.;
- f) the Sicani Mts., south of Palermo, with the appendage of Sciacca area;
- g) the Iblean Plateau, extreme southeast, with an average elevation of 700 m.

### 2. Surface karst features

The karst morphology that characterizes the surface limestone landforms of Sicily is represented by dolines, blind valleys and poljes. These are vastly diffused throughout the chain with an advanced stage of evolution. A large concentration of these forms is found throughout the Madonie Mts. and in particular on the Pizzo Carbonara massif. Here, the geometry and disposition of the depressions are regularly controlled by tectonic directors. Of particular interest, the Piano Battaglia polje, where running water is partially drained by ponors.

In the Iblean Plateau there are numerous fluvio-karstic incisions that completely drain the area, locally called "cave". These incisions consist of vertical wall gorges oriented along the main tectonic directors that have conditioned the structural order in this area. The internal streams of these gorges are often engulfed by ponors and reappear further in the valley. The last types of limestone landforms to be mentioned are of small size and can be found in almost all outcrops. Most of them are present, however, in the Palermo and Trapani mountainous areas. This area houses the most complete selection of this type of karst features represented by rills (*rillenkarren*), runnels (*rinnenkarren*), holes, corrosion basins (*kamenitze*) and rounded karren (*rundkarren*); the discovery of these last landforms was facilitated by deforestation and other anthropic changes.

### 3. Craves

The carbonate outcrops of Sicily include numerous caves of various size. Some of these are quite notable in size, although not comparable to other regions in

Italy. The best known and explored areas are those represented by the mountainous reliefs between the Madonie Mts. and Trapani and between the S. Calogero Mt. (Sciacca) and the Iblean Plateau. To date, about 400 have been discovered .

Proceeding from west to east, the most important explored and documented caves are found on Mount Inici, in the Trapani Mts. The "Grotta dell'Eremita" (dev. 4500 m, depth -300 m) and the "Abisso dei Cocci" (2000 m, -300 m), still in the phase of exploration, are both among the deepest and largest caves found in all the island. They are characterized by large inactive phreatic galleries and "corrosion domes" probably related to previous hydrothermal phenomenon.

In the south, on Mount S. Calogero (near Sciacca), there is a large underground system made up of a series of cavities, each one hydraulically and genetically interrelated. These are characterized by a circulation of vapour saturated air coming from the underground hydrothermal aquifer. Inside the caves temperatures reach 40°C. The largest caves are the "Stufe di S. Calogero" (over 500m dev.) and the "Labirinto Aspirante" with an internal well which is 104 m deep.

Within the mountainous region of Palermo, Mount Pellegrino (600 m above sea level) houses over 50 caves. The most important of these are the "Grotta Addaura Crapara" (2 km long), inactive resurgence with a horizontal trend, and the "Abisso della Pietra Selvaggia" (170 m deep, with a vertical trend and an obvious tectonic origin).

Towards the east, in the Madonie, the caves to be mentioned are the "Abisso del Gatto", a meandering cave with an active ponor (-323 m deep and 1 km long) and the "Abisso del Vento" (-210 m deep and 2 km dev.) situated on a sub-orthogonal faults network.

Finally, the Iblean Plateau area presents a large number of caves; those explored to date are approximately 100, generally horizontal in trend with an average length less than 100 metres. The "Grotta di Villasmundo" (2,5 km long with active and inactive passages of richly ornate speleothems) and the "Grotta Palombara" (800 m long, 80 m deep, with alternating inactive phreatic galleries and vast collapse rooms) are numbered among the karst system in the eastern area .

## B. Evaporites

### 1. Evaporite outcrops

In Sicily the most complete evaporite outcrops of the Mediterranean Region (deposited during the Messinian) are made up of the Caltanissetta Basin (central portion) and the Castelvetrano Basin (west of Sicani Mts.). The Ciminna Basin constitutes an outcrop of minor dimension situated about 40 km SW of Palermo.

The most important evaporites to be mentioned are the macrocrystalline series of gypsum constitution.

### 2. Surface karst features

Almost all Sicilian gypsum outcrops are characterized by conspicuous varieties of small and large size karst features. Most of these forms are present, such as dolines and blind valleys found in the areas between Caltanissetta and Agrigento towns. The dolines are genetically traced to surface solution and collapse. They are closely bound by the drainage of ponors into underground patterns.

The blind valleys instead are more often formed on clay terrains, before coming to the gypsum opposite slope. Particular complex forms are made up of karst gorges seen in some sectors as dry valleys or natural bridges. An example is the Vallone Ponte, 20 km north of Agrigento.

In other Sicilian evaporite zones, subsidence depressions can be found. They are often present in superficial deposits which overlay karst rocks; these depressions can also form small lakes.

Even the smaller karst features are diffuse throughout outcrops of various gypsum lithofacies. Their characteristics are determined by their position, their exposition, their bedding as well as their lithology.

*Rillen*, one of these morphologies, are mostly located on fine-grained lithofacies, like gypsarenites, gypsopelites and alabastrine gypsum; the best example found in the Contrada Scaleri, about 10 km NW from Caltanissetta, where are also present solution basins. The runnels instead prevail in selenitic lithofacies with pluricentimetric crystals.

The last of the karst microforms that should be mentioned are those limited examples of halite *rillen* in the Contrada Raineri zone: these have sharp crests and a very fast growth rate, even seasonal.

### 3. Caves

At the present time the knowledge of underground evaporite karst phenomena in Sicily is incomplete. Most of the explored caves are made up of ponors and resurgences. They are prevalently horizontal and both active as well as inactive. There are also present examples of "tectonic" caves caused by the intense fracturing of gypsum reliefs.

Among the caves in Sicily over 1 km in size, the largest are: the "Grotta di Santa Ninfa", the "Grotta di S. Angelo Muxaro" and the "System of Mount Conca". The first one, located in the western part of the island, is a resurgence with overlaid and intersecting passages (both active and inactive); the second one, located near Agrigento, is an active ponor with inactive levels. Lastly, the system of Mount Conca, located in Caltanissetta zone, is a ponor 800 m long and 108 m deep with wells formed by waterfalls and an active resurgence, horizontal and 250 m long.

In most cases, these caves, especially those inactive, show notable gypsum and calcite speleothems in the forms of both stalactites, coralloids and stardust. The presence of sulphuric water inside the caves sometimes influences the formation of these speleothems as well as the speleogenesis. Lastly, alluvial deposits of different grain-size, are also present: sometimes these deposits are incised due to changes of the karstic base level.

## C. Volcanic rocks

### 1. Mount Etna lavas

The volcanic rocks of speleogenetic interest in Sicily are formed in Mount Etna. Situated on the island's east coast, this volcano reaches an altitude of 3323 m. From a geological point of view, Etna is an active volcano of recent formation, the first eruptions were registered about 5-700,000 years ago. The chemical composition of Mt. Etna lava can be generally classified as basaltic-alkaline. This, coupled with a high temperature and a 10°-20° slope, creates a favourable situation for the formation of numerous caves during an eruption.

### 2. Caves

Mt. Etna's speleogenetic phenomenon can be traced to three different mechanisms forming three types of caves:

a) surface rheogenetic caves which form in the body of the lava flow as it travels downwards, commonly known as tubes or galleries;

- b) fissure caves, connected to the emptying of the eruption fissure at the end of the volcanic activity ;  
 c) pneumatogenetic caves, caused by the expansion or explosion of gas contained in the magma mass.  
 The lava tubes are the most diffuse of these types and create the longest and deepest caves. Nowadays over 200 caves have been found in Mt. Etna, including: "KTM - 'Tre Livelli" system, 1750 m long, 400 m deep, made up of three different superimposed galleries ; "Immacolatella - Micio Conti" complex, also of speleobiological interest ; "Grotta delle Palombe" varied in type, 250 m long, 65 m deep ; "Grotta del Gelo", with a small underground perennial glacier ; "Grotta dei Lamponi", 600 m long.

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