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GYPSUM KARST IN THE CROTONE PROVINCE (CALABRIA, SOUTHERN ITALY)

KRAS V SADRI V PROVINCI CROTONE (KALABRIJA, JUŽNA ITALIJA)

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Abstract UDC: 5222.54:551.44(450.78)

Mario Parise & Antonio Trocino: Gypsum karst in the Crotone province (Calabria, Southern Italy)

The Calabria region of southern Italy presents remarkable examples of gypsum karst, involving evaporite rocks ranging in age from Trias to Miocene. Triassic evaporites are limited to a sequence of about one hundred meters of thickness in the Coastal Chain, on the western Calabrian coast. Messinian evaporites, on the other hand, extensively crop out to the east, in the Crotone Basin. The present contribution intends to describe the main features of gypsum karst in the latter area, from the surface karst morphology to the development of caves. The Crotone Basin is among the most interesting areas as regards evaporite karst in Italy: a variety of surface karst landforms is there present, including dolines, blind valleys, closed depressions, and deep and narrow canyons intensely affected by slope movements. Many caves are located at the bottom of the dolines, as Grave Grubbo which, with a length over 2,500 meters, is one of the longest Italian caves in evaporites. The study area has experienced several transformations, mostly due to agricultural activity and to scarce attention paid by local administrators toward this unique naturalistic landscape. The high value of Calabrian gypsum karst is thus not fully exploited, and several cases of degradation of the caves have been registered, even with consequences for the quality of water flowing in the karst systems.
Key words: gypsum karst, geomorphology, speleology, degradation, Italy, Calabria.

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Mario Parise & Antonio Trocino: Kras v sadri v provinci Crotone (Kalabrija, južna Italija)

Področje Kalabrije v južni Italiji predstavlja izreden primer krasa v sadri, ki vključuje tudi evaporitne kamnine triasne do miocenske starosti. Triasni evaporiti se pojavljajo v sekvenci debeli okrog sto metrov na področju obmorskega hrbta na zahodni obali Kalabrije. Na drugi strani pa evaporiti mesinske starosti obširno izdanjajo na vzhodu, v krotonskem bazenu. Pričujoči prispevek opisuje glavne značilnosti krasa v sadri (od površinske kraške morfologije do razvoja jam) na vzhodnem predelu Kalabrije. Krotonski bazen je med najbolj zanimivimi področji evaporitnega krasa v Italiji: tam najdemo različne površinske kraške oblike kot so vrtače, slepe doline, zaprte depresije, globoke in ozke soteske, kjer zasledimo intenzivna pobočna gibanja. Številni vhodi jam so na dnu vrtač. Jama Grave Grubbo, dolga prek 2.500 m, je ena daljših jam v Italiji v evaporitih. Na raziskovanem področju je prišlo do številnih sprememb, še posebno zaradi kmetijske dejavnosti in zaradi nezadostne pozornosti lokalnih oblasti do te izjemne pokrajine. Posebna vrednost krasa v sadri v Kalabriji še ni v celoti ovrednotena. Prišlo je namreč do onesnaženja številnih jam in posledično do znižanja kakovosti vode, ki teče v kras.
Ključne besede: geomorfologija, geomehanika, kras, fliš, speleogeneza.

INTRODUCTION

The Crotone province, in central-eastern Calabria (southern Italy) hosts wide outcrops of evaporite rocks where remarkable gypsum karst caves are present. Within the framework of research studies and explorations by the caving club Gruppo Puglia Grotte (Castellana-Grotte), in co-operation with the National Research Council of Italy, we carried out some activities in the territory of Verzino, and particularly in the underground karst system formed by the two main caves in the area: Grave Grubbo and Vallone Cufalo Spring. This article presents the preliminary results so far obtained.

GEOLOGICAL AND MORPHOLOGICAL SETTING

Calabria, the tip of the Italian boot, has a very complex geological history deriving from the presence of units of the Alpine Chain thrusted during Miocene time over units of the Apenninic Chain (Amodio Morelli et al., 1976). In the region, the presence of evaporitic rocks of two different ages has to be outlined: Triassic dolostones and gypsum cropping out in the Coastal Chain, which borders the western side of the region, toward the Thyrrenian Sea; and Messinian evaporites, that are widespread in the Crotone Basin and in the Catanzaro Strait (Ogniben, 1955; Roda, 1964). The most remarkable evidence of gypsum caves in Calabria have been documented and explored in the Messinian evaporites of the Crotone Basin, that are the object of this study.

In the Crotone Basin, gypsum is generally present in stratified layers of variable thickness, with micro-cristalline and granular structure. Clay impurities are often intercalated in levels, and give a typical grey to dark colour to the outcrops. Reconstruction of the stratigraphy in the area allowed to identify six depositional sequences, from the Upper Miocene to the Pleistocene (Moretti, 1993; Ferrini & Moretti, 1998). Within this stratigraphy, the terms affected by karst processes are essentially the Vitravo Anhydrites. These unconformably overlie the Maradera Clays, that played an important role in the development of the main karst system of the area, being the hydrogeological barrier which forced the groundwater circulation to develop in the above anhydrites. The Vitravo Formation has a thickness of some 100 meters, and can be subdivided into two members, a lower ruditic, and an higher arenitic as regards grain size (Ferrini & Moretti, 1998).

The Verzino area extends for about 10 km^2, with a hilly landscape carved in the easily erodible Miocene and Pliocene terrains, and with deep fluvial incisions that break the rounded hill landforms. At the surface, a situation of transition between a landscape of clear fluvial origin and the typical karst is common. This transition derives from the contact between soluble rocks (gypsum) and impervious, not soluble, terrains (clays), and results in the development of an hydrographic surface network which combines with a subterranean hydrography in the evaporites.

The surface hydrographic system develops with slightly incised water courses, or deep valleys with vertical walls. The latter include Cufalo Valley and Cornò Valley, both left tributaries of the Lese River, the most important of the area (Fig. 1). Garone Valley is an example of blind valley, since it runs initially in a deep incision, and successively its course becomes less defined and more surficial, until being swallowed just above the doline where Grave Grubbo opens.

The area is located at elevations comprised between 120 and 730 m a.s.l. Climate is typically mediterranean, with a dry summer and abundant autumn rainfalls. As regards vegetation, woods of *Quercus ilex*, and mixed woods of ash-trees and maples have been observed (Latella et al., 2003). These combine with low Mediterranean bush, including *Pistacia lentiscus, Myrtus communis,* etc.

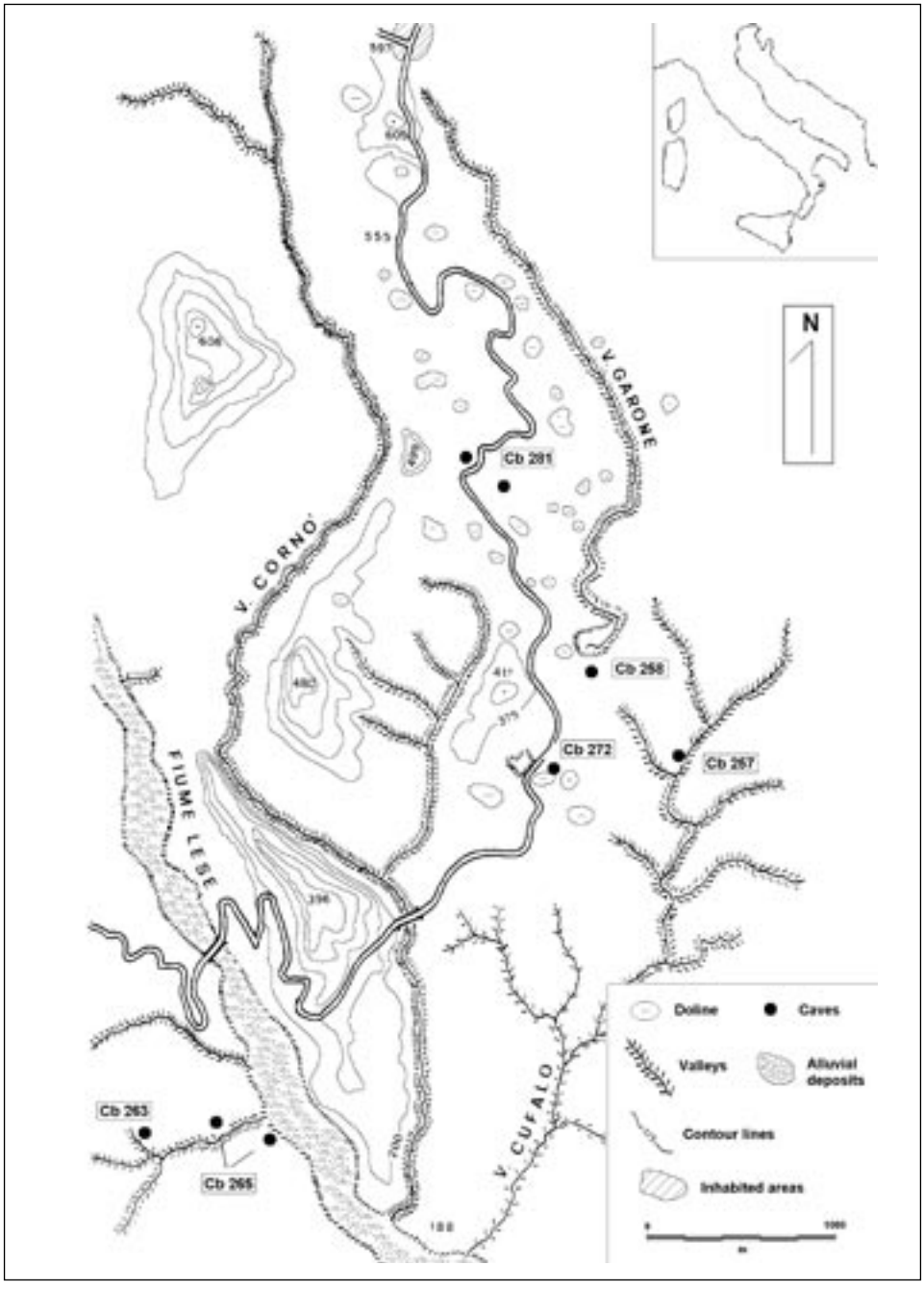

Figure 1: Location map, showing the main surface karst landforms and entrances to the caves (modified after AA.VV., 1994).

Within the several dolines that characterize the area, woods of *Quercus pubescens*, associated with ash-trees, hornbeams and elms are present. On the rare bare gypsum outcrops, vegetation is represented by *Euphorbia spinosa, Cistus incanus, Gypsophila arrostii,* and by evergreen phanerophita.

A peculiar environment is registered nearby the main springs in the area, and within the deepest dolines and valleys: there, the constant shade allows development of conditions favouring a consistent development of Hepatics *(Pellia endiviifolia, Conocephalum conicum)*, mosses *(Cratoneuron commutatum)*, and ferns *(Adiantum capillus-veneris)*, combined with nitrophila species such as *Parietaria diffusa* (Latella et al., 2003).

Karrenfields on the exposed outcrops of gypsum are very frequent, with deep and narrow karren separated by cutting divides. The high solution of gypsum favours formation of karst microforms which represent one of the several naturalistic attractions of the area.

One of the most peculiar surface features of the Verzino territory is represented by dolines, extremely diffuse over the whole area (Fig. 1), and often distributed following the main fault and fracture systems (that is, NNW-SSE and NW-SE), or produced by development of karst processes in the valleys through retrogression of the swallow hole.

Dolines are mostly of conical shape, but collapse dolines are also present. The latter are more spectacular, with vertical walls in continuous danger of further detachments of rock, and with the bottom characterized by big heaps of huge rocks, fed by the ancient rockfall and topple events.

Presence of dolines is often evidenced by thick vegetation, which makes difficult the access to the underground caves, where present. Distribution of the dolines marks the many discontinuity systems in the evaporites. Asimmetric dolines are often a transition to blind valleys: they have the longest slope on the upslope side, while a steep and short slope is on the downvalley side.

As regards their genesis, two types of dolines in gypsum can be distinguished: a) point recharge doline, when a surface water course, even if ephemeral, infiltrates at a swallow hole; b) cover doline, when the swallow hole in the gypsum is covered by clastic deposits, and therefore not immediately recognizable from the surface (Ferrarese & Sauro, 2001; Sauro, 2003).

Dolines with smooth slopes are often modified by man for agricultural practices. This may result in development of linear erosion, through the formation of rills and gullies, since it is frequent that man tries to cultivate also slopes with medium to high acclivity. Local increases in erosion are thus registered, as frequently observed in karst environments of other European countries (Frumkin, 1999; Nicod & Salomon, 1999; Parise et al., 2004), and widespread areal erosion and badlands are common (Fig. 2).

THE CAVES

The Verzino territory hosts the most remarkable evidence of gypsum caves in Calabria (Table I). They represent about one quarter of the total development of caves in the region, even if numerically are only 4% of the overall number of calabrian caves (Ferrini & Moretti, 2003).

The caves are very simple and with a linear pattern which follows the bedding in the evaporites, and is generally structurally-controlled (Larocca & Lorusso, 1994; Genghini, 1995). Galleries connect the inflow points with the outflow areas. Connections between the two is very rapid, and develops essentially along the main draining gallery. In this, minor tributaries may converge, but generally they are of limited discharge, or, with time, are clogged by sediments, or because of the formation

of gypsum crystals, both of neo-formation or deriving from secondary gypsum (hydration of anhydrites). This explains that the caves are formed by a principal sub-horizontal gallery, developed at the level of the local water table, with limited outcomes by secondary tributaries. Vertical pits are only present at the inflow (shaft or collapse dolines) and outflow points. Sediments are present in both the forms of gravity-related deposits (falls enlarging the original chambers) and alluvial deposits left after flood passages.

Importance of the gypsum caves at Verzino is further evidenced by some peculiar speleothems (Forti & Chiesi, 1995). In some cases their growth is influenced by the presence of animals in the cave systems: at Vallone Cufalo, for example, a large biogenic flowstone made by upper living organisms has been described by Poluzzi and Minguzzi (1998). Its origin has also to be related to anthropogenic activities in the area where the cave opens, since olive oil factory wastes were discharged into the cave; over these wastes, a large community of larvae of a troglobic insect *(Tricoptera Wormaldia)* developed, resulting in the formation of the flowstone, which final morphology was the result of the combined action of larvae living activities and kinetic energy of the flowing water (Poluzzi and Minguzzi, 1998; Forti, 2001).

In addition, the Verzino caves represent remarkable sites for biospeleology, hosting large colonies of bats, as well as other animals: the list of stygobionts identified in the gypsum caves of the area includes a new species of the Copepod *Parastenocaris*, and the Copepods *Diacyclops paolae* Pesci and Galassi, 1987; *Nitorrella stammeri* Chappuis, 1938; and *Elaphoidella* sp. Among the Amphipods, a new species of *Niphargus*, belonging to the group of *Niphargus orcinus* (Latella et al., 1999).

Figure 3 shows the directions of development of the caves located in the map of Figure 1: from

Figure 2: Surface landscape in the study area: note the contact between gypsum rocks and the clayey deposits, the latter marked by widespread erosion and badlands.

cave to cave, different directions prevail, with the two longest caves (Grave Grubbo, Cb 258; and Vallone Cufalo Spring, Cb 257) showing a similar pattern. Further considerations may be drawn subdividing the sample of caves into two groups: those west of the Lese River (Grave di Trabbese, Cb 263; and Grotta del Palummaro, Cb 265), and all the remaining, that are located, on the other hand, on the west side of the river (Fig. 4). The first group has a quite wide distribution of directions, the main one being WNW-ESE, whereas the western group is more concentrated toward a NE-SW pattern. As a consequence of the length of Grave Grubbo and Vallone Cufalo Spring, the overall population (last rose diagram in Fig. 4) has again a prevailing NE-SW pattern.

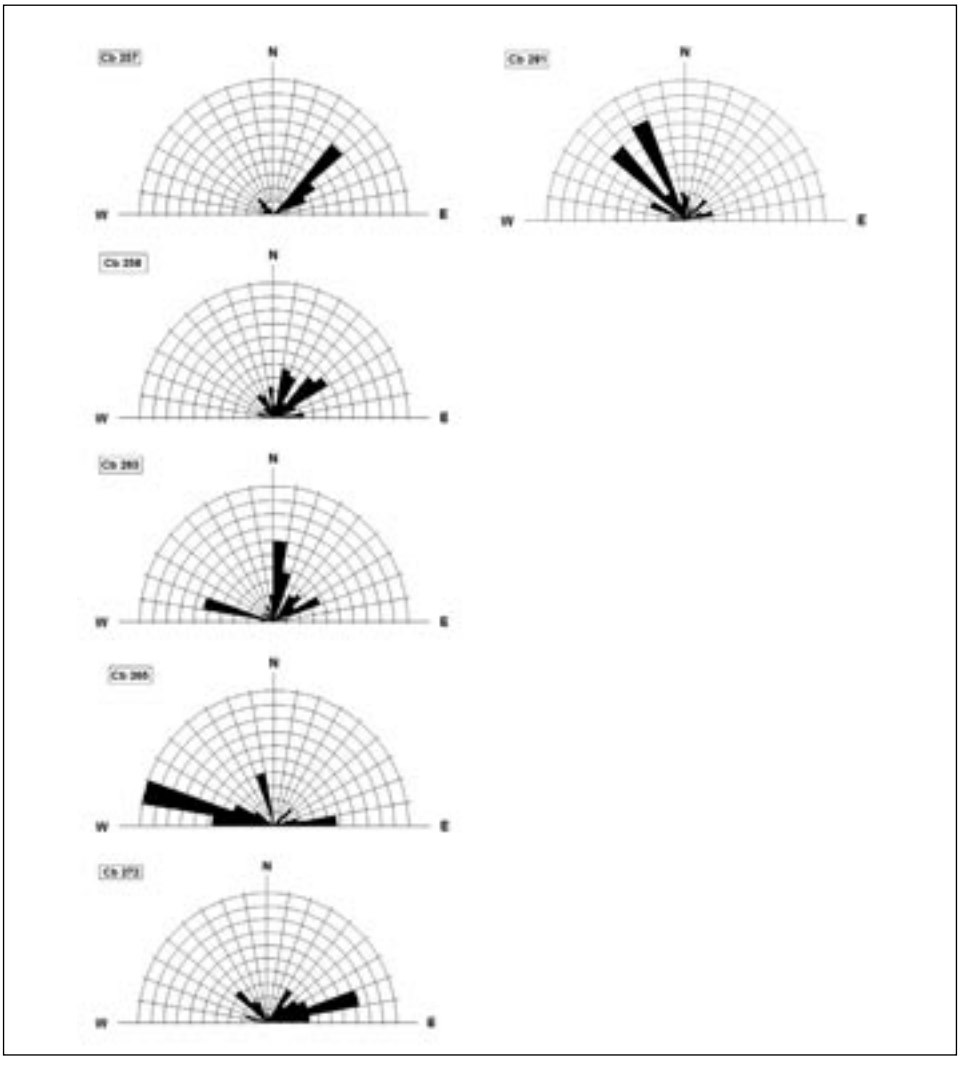

Figure 3: Rose diagrams showing the directions of development for the main caves in the area (location shown in Fig. 1; for numbering refer to table I).

The main cave is the system formed by Grave Grubbo (Cb 258) and the Vallone Cufalo spring (Cb 257): it has an overall length of 2,830 meters, which makes it the second longest gypsum italian cave, after the Spipola-Acquafredda system (10,500 m).

The two caves are separated by an intervening sump, which has been recently passed. The connection between the two caves has been proved by tracing tests performed on december 1993, by using fluorescein, by Gruppo Speleologico Sparviere and Gruppo Speleologico Imperiese CAI (Larocca & Lorusso, 1994), and has also been proved through hydrogeological and geochemical research (De Paola et al., 1994a, b): analysis of water samples from Grave Grubbo and Vallone Cufalo allowed to classify the waters as calcium-sulfates, following Langelier & Ludwig (1942). In addition, the waters have been chemically analyzed by means of the Schoeller's chart (Schoeller, 1975), that did not point out to any change in their chemistry, further indicating that the same water flows into the two caves.

Grave Grubbo is the most important cave in the Verzino area. Its name, and precisely the term *grave* derives from the pre-Latin term *grava*, which means pit or hole. This word, that is generally used to describe deep landforms of the karst surface, in some italian regions has a different meaning: for example, in Veneto (north-eastern Italy) *grava* is used to describe gravelly soil, beach, from the vulgar Latin *grava* – of Celtic origin – meaning sand, gravel, gravelly beach (Battaglia, 1961-2003; cf. also with the French *grève* which means shingle, pebbly river-bed, and with the English term *gravel*, along with its corresponding Spanish *grava*) (Parise et al., 2003). Moving to southern Italy, where a very different historical and linguistic background developed, *grave* is used in most of the cases to indicate a vertical shaft or abyss, generally produced by rock falls from the vault of an original karst cave. This meaning is particularly widespread in Apulia, where it is always related to the presence of caves (Parise et al., 2003). In Calabria, on the other hand, a similar diffusion of the term is registered, at least in some parts of the region, but *grave* is here used to indicate mostly

Cave	*no.*	*elevation at the entrance (m a.s.l.)*	*Length (m)*	*depth (m)*
Cufalo Valley Spring (Grotta dello Stige)	Cb 257	180	575	+ 21
Grave Grubbo	Cb 258	265	2260	+ 3,5 - 75
Cave of the Fossil Spring	Cb 259	260	28	+ 2
Grave di Trabbese	Cb 263	280	147	- 29
Grotta di Nasone	Cb 264	170	72	+ 9
Grotta del Palummaro	Cb 265	145 (lower) 215 (upper)	621	+ 70
Grave di Cacova	Cb 267	580	35	0
Antro del Torchia	Cb 272	281	428	- 77
Grave dell'Agrumeto	Cb 276	205	29,5	- 6
Grave dei due Manfred	Cb 281	396 (lower) 408 (upper)	208	+ 12
Grave Tetra	Cb 282	345	75	- 20

Table 1: Main caves in the study area.

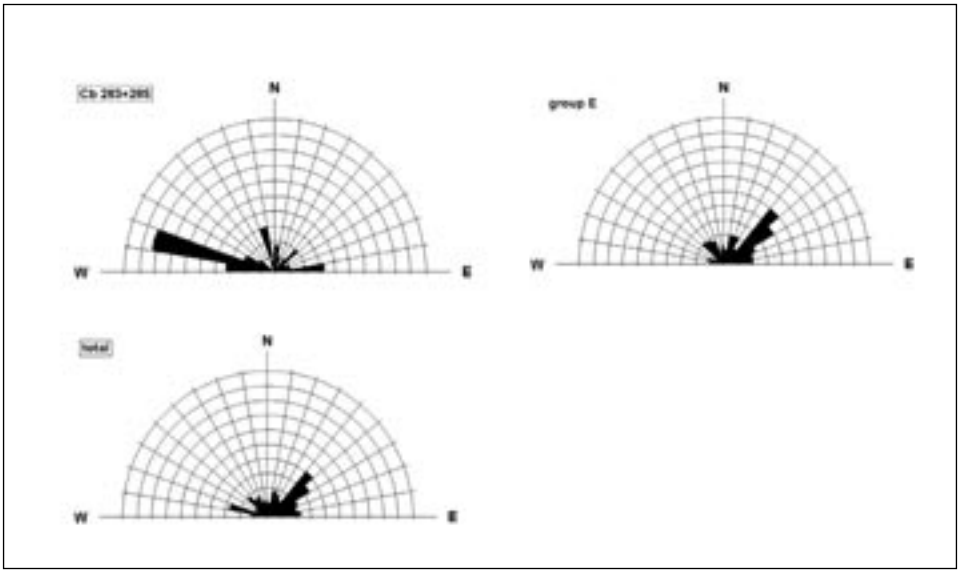

Figure 4: Rose diagrams for the two sub-groups of caves (western group, eastern group), and for the overall sample of caves.

Figure 5: Entrance to Grave Grubbo (Cb 258): note the fallen blocks, and the deformations due to load of overhanging rocks in the gypsum layers at the vault.

Figure 6: Passing the old "terminal" sump at Grave Grubbo: the recent explorations allowed to add to the overall survey of the cave over 330 meters behind this point.

Figure 7: Entrance of Vallone Cufalo cave (Cb 257): even here the access is marked by a number of detached blocks.

a surficial karst landform, namely a doline. Even though very often they have been produced by collapse processes, calabrian *grave* does not necessarily present an access to underground caves (in this sense, Grave Grubbo is therefore an exception). As regards the term Grubbo, in the local dialect it means hole.

The Grave Grubbo entrance (Fig. 5) is at the bottom of a large collapse doline, 115 m wide and 30 m deep, that strikes W-E with its longest axis. Approaching the entrance by walking over huge rockfall deposits, it is possible to reach the access where some big blocks are piled up in a 6 m deep pit. The first explorations date back to 1988, when a team of cavers from the Gruppo Speleologico Fiorentino CAI began to explore the cave, for more than 1,5 km of its length (Adiodati and Giambalvo, 1988). The western diramations of Grave Grubbo (Cinderella Branch, Squared Gallery) show morphologies typical of the gypsum caves, with a meandering pattern, and development of deep incision and erosion both at the pavement and in the rock walls. Fluvial piracy is frequently observed, with the minor tributaries that are captured by the main flow of the subterranean water course. Branch of the River (Ramo del Fiume), on the other hand, is wider and evidently structurally-controlled: being the main direction of water flow, this part of the cave is rich in sediments with thickness up to 2-3 meters, that have been successively re-incised by later flooding events. Rock falls and blocks, even of great size, characterize the largest chambers and caverns, produced by cavern breakdown processes. Erosion is in fact the main process acting in shaping the cave, due to high solubility and low resistence of gypsum, and to alternance of long dry periods with flash flood of great force. In addition, the abundant presence of fine sediments as silts and clays (allogenic materials transported from outside) further favours the development of mechanical erosion, and promotes in this way evolution of the cave through instability processes.

Figure 8: Development of rills and linear erosion along a steep slope on the right side of Vallone Cufalo.

For many years, explorations stopped at a sump, that was recently passed (Fig. 6), which allowed us to complete the survey of the cave, adding over 350 meters, and bringing the overall length of Grave Grubbo at 2260 meters (Table I). The cave ends with a terminal sump, which is likely to be in connection with the downvalley Vallone Cufalo Spring. Entrance of the latter is again marked by detached gypsum blocks, that also characterize long stretches of the valley (Fig. 7). Vallone Cufalo discharge is comprised between 40 l/sec and about 200 l/sec.

LAND USE CHANGE

Man is strongly changing the landscape at Verzino in the last tens of years. All the transformation are related to attempts in using the land for agriculture, but often the result is a severe land degradation and increase in the erosional processes. The many swallow holes in the area have often been modified to i) facilitate the underground drainage and avoid the surface runoff (and the deriving erosion, due to the clayey terrains) in the cultivated fields, and, at the same time, ii) slow down the passage of water to have available the amount needed for agriculture, in an area which is characterized by poor rainfall values. The two actions are in some way contrasting, and reaching the correct balance between the two is not an easy task. Especially when performed by unskilled farmers (which is rather common) the result is a strong increase in erosion (Fig. 8), diversion of the natural surface runoff, loss of vegetation, until favouring or even promoting slope instability processes along the borders of dolines and valleys.

Two main solutions have been in fact performed in the Verzino area in order to control the water drainage (Burri, 2003): 1) realization of man-made channels; 2) filling up of the swallow hole. The first solution is generally performed at the largest dolines and in the blind valleys, where the possibility of water stagnancy is quite high, in case the natural drainage system is not able to quickly absorb the water flow. The second solution, on the other hand, derives from the fear of rapid inflow, and the related high erosive power by running water, which may result in deep erosion of wide sectors of land, including the cultivated areas. Filling up is carried out with eterogeneous materials, thus it is frequent that, with time, the swallow hole opens again, sometimes even with larger size.

Figure 9: Unstable rocks, showing wide open cracks, at the rim of the doline where Grave Grubbo opens.

A further problem is the fragility of the underground karst environment (Parise & Pascali, 2003), and the hazards that are present at the surface. Many caves present the access at the bottom of collapse dolines that are severely affected by instability processes (rock falls and topples, with additional material deriving by erosion of the clay cover). Approaching the entrance may be sometimes difficult, and dangerous (Fig. 9). Nevertheless, in the past years several guided tours have been organized locally, bringing also children and young scholars in the caves. In addition to the hazards just mentioned, these tours are often carried out without any

concern as regards biospeleology of the cave systems, even during hibernation period of the bat colonies. Thus, it clearly arises the need to safeguard, on one side, the natural environment of the karst system and its overall ecosystem, and, on the other, avoid the possibility of dangerous situations in the dolines, and in the caves as well.

In conclusion, the gypsum caves in the Verzino territory are a remarkable example of high-value naturalistic sites, but they urgently need a specific attention and safeguard by local administrators in order to protect these peculiar environments, and exploit them in the most appropriate and sustainable way.

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