Proceedings

of the
11th International Symposium on Pseudokarst

12 - 16 May 2010

Saupsdorf, Germany

Proceedings

of the

11th International Symposium on Pseudokarst

12 - 16 May 2010

Saupsdorf – Saxon Switzerland, Germany

Organizers

International Union of Speleology, Commission for Pseudokarst
Höhlen- und Karstforschung Dresden e.V., Germany

Programme Committee

István Esterhás
Honorary-President of Pseudokarst Commission, Hungary

Jiri Kopecký
Honorary-President of Pseudokarst Commission, Czech Republic

Dr. Jan Urban
President of the UIS-Pseudokarst Commission,
Institute of Nature Conservation, Pol. Acad. Sci., Cracow, Poland

Organizing Committee

Caving Club Höhlen- und Karstforschung Dresden e.V.
Hartmut Simmert – chairman
Bernd Wutzig – vice-chairman
Martina Glauche, Andreas Ludwig, Falk Thieme

Address of the Organizing Committee

Höhlen- und Karstforschung Dresden e.V.
Hohe Str. 48b, 01187 Dresden, Germany

Symposium homepage:
www.hoehlenforschung-dresden.de/symposium

Photo (front cover) by	Ulrike Schinke
Published by	Höhlen- und Karstforschung Dresden e.V.
Edited by	Jana Simmert
ISBN:	

Dresden - Germany, 2011

Preface

Dear Ladies and Gentlemen, dear Guests!

We meet in the same region, and very close to the place in which the 3rd Pseudokarst Symposium was held in 1988. The scenic landscapes of the Saxon Switzerland are the same, as we admired in 1988. However, 22 years from 1988 to 2010 means one human generation, so this time-span gives accurate opportunity to ask about the development of our knowledge, progress of scientific studies and organisation of work. Since the 3rd Symposium in Königstein in 1988 we have several general International Symposia held in different European countries: Czech Rep., Hungary, Italy, Poland, Romania, Slovakia as well as many other international and national meetings concerning various aspects of pseudokarst phenomena – from geology and geomorphology, through biology, archaeology, caving and nature conservation, which were organised all over the Europe and out of this continent. Let me express our thanks for organizers of all these events.

Since the beginning of the eighties of the 20 century the activity in studies of pseudokarst phenomena gradually gained more apparent organisational forms, which was serviced in large part by Mr Jiří Kopecký and his Czech colleagues. And owing to efforts of Mr István Eszterhás, the organisational works were finalized by formal foundation of the Commission for Pseudokarst UIS in 1997. Therefore, both the Honorary Presidents of the Commission, Jiří Kopecký and István Eszterhás are given our gratitude. The Commission under the leadership of Mr Eszterhás focussed its activity on organisation of meetings and symposia as well as publication of Newsletters. Newsletter no 20 has been issued this spring.

Looking at the recent past, we remember the last, 10th Symposium on Pseudokarst in Go-rizia, Italy, in May 2008 and hospitality of our hosts from the Centro Ricerche Carsiche "C. Seppenhofer", so I would like to say our thanks to them, once more. Between that, 10th Symposium and this, 11th Symposium, the pseudokarst scientific session and meeting were organised during the 15th International Congress of Speleology, Kerville, July 2009. Thanks to Jan Paul van der Pas chairing the meeting in Kerville, George Szentes and all other persons attending this meeting. The recent achievement of the Commission is its web-page accessible all over the world – we appreciate the work of Hartmut Simmert.

Since the First Pseudokarst Symposium publications have been the most important, real and persistent effects of the scientific activity in pseudokarst. The materials of all International Pseudokarst Symposia as well as of many other meetings concerning similar scientific problems have been published. They have illustrated the progress in exploration, description and studies of unique and specific formations and phenomena resembling karst but not karstic. And although the scientific definition of the term "pseudokarst" have still not been commonly accepted, we gathered under the motto of pseudokarst again, here in

Saxony Switzerland so as to share our experiences, results of our explorations and scientific studies of such formations and phenomena.

I am sure that this, 11th Symposium on Pseudokarst will contribute to develop our know-ledge about processes producing specific landforms and landscapes recognised as pseu-dokarst and about life in such landscapes. I would like to express our thanks to organisers of this Symposium from the Hoehlen-und Karstforschung Dresden e.V, for their efforts in its preparation and hospitality. And I wish all of participants to get interesting knowledge profiting in your further exploration and scientific work as well as fascinating experiences during field sessions in unusual and picturesque landscapes of the Saxony Switzerland.

The 11th International Symposium on Pseudokarst in Saupsdorf, Saxony Switzerland is open!

Jan Urban
President of the Commission for Pseudokarst UIS

Table of contents

Programme

12 May 2010 (Wednesday)

from 04:00 p.m.	Arrival and registration of participants

13 May 2010 (Thursday)

08:00 – 08:45 a.m.	breakfast
09:00 – 09:20 a.m.	*Jan Urban:* Opening session
09:20 – 09:40 a.m.	*Hartmut Simmert:* Pseudokarst in the Elbe sandstone mountains
09:40 – 10:00 a.m.	*Rudolf Pavuza:* A short treatise on Austrian pseudokarst-speleothems
10:00 – 10:20 a.m.	*Jiri Adamovic:* Lithological controls on sandstone weathering: a proposal of morphofacies for the humid temperate zone of Europe
10:20 – 10:40 a.m.	*Wlodek Margielewski:* Crevice type caves of Polish Flysch Carpathians and their connection with development of surface mass movements
10:40 – 11:00 a.m.	- break -
11:00 – 11:20 a.m.	*Ludovit Gaal:* Current state of tree mould caves research
11:20 – 11:40 a.m.	*Jiri Bruthans:* Sandstone caves with spherical cavities: Did they originate by airflow-induced disintegration during glacial period?
11:40 – 12:00 a.m.	*Laura Sanna:* Two examples of pseudokarst features in South Supramonte (Sardinia, Italy)
12:00 a.m. – 01:00 p.m.	lunch
01:00 – 07:00 p.m.	Excursions E1, E2, E3, E4, E5
07:00 – 08:00 p.m.	dinner

08:00 – 09:00 p.m.	Meeting of the Pseudokarst Commission

14 May 2010 (Friday)

08:00 – 08:45 a.m.	breakfast
09:00 – 09:20 a.m.	*Elzbieta Dumnicka:* Variability of environmental conditions and aquatic fauna composition in Jaskinia Miecharska Cave (Beskidy Mts., Outer Carpathians)
09:20 – 09:40 a.m.	*Radek Mikulas:* Oblique notches and ledges on natural surfaces of porous rocks: a record of past level of soil surface (central and western Europe, north eastern Africa)
09:40 – 10:00 a.m.	*Matthias Arnhold:* Bio speleology of the Elbsandsteingebirge
10:00 – 10:20 a.m.	*Wojciech Gubala:* Bats hibernating in pseudokarst caves in Eastern Beskidy Mountains
10:20 – 10:40 a.m.	break
10:40 – 11:00 a.m.	*Juan-Ramon Vidal-Romani:* Speleothem development and biological activity in granite cavities
11:00 – 11:20 a.m.	*David Holmgren:* Microclimatological survey of the Ice Gulch in the White Mountains, New Hampshire, USA
11:20 – 11:40 a.m.	*Istvan Ezterhas:* Butterflies like the Caves of the Volcanic Rocks
11:40 – 12:00 a.m.	*Rabbe Sjöberg:* Welcome to the 2nd Conference on Granites Caves in Sweden 2011
12:00 a.m. – 01:00 p.m.	lunch
01:00 – 07:00 p.m.	Excursions E1, E2, E4, E5
07:00 – 08:00 p.m.	Lunch

15 May 2010 (Saturday)

08:00 – 08:45 a.m.	breakfast
09:00 – 09:20 a.m.	*Jan Urban:* Caves in the Flysch Carpathians detected by ERT me-

	thod
09:20 – 09:40 a.m.	*Brano Smida:* The longest quartzite caves in the world
09:40 – 10:00 a.m.	*Tomas Lanczos:* Quartzite Caves of the Venezuelan Table Mountains – Speleogenesis
10:00 – 10:20 a.m.	*Tomas Lanczos:* Quartzite Caves of the Venezuelan Table Mountains – Speleothems
10:20 – 10:40 a.m.	Break
10:40 – 11:00 a.m.	*Marcos Vaqueiro:* Pseudokarst in granites - How granite caves are develo-ped
11:00 – 11:20 a.m.	*Georg Szentes:* Presentation of some Abrasion Caves in New Zealand - near Auckland
11:20 – 11:40 a.m.	*Maurizio Tavagnutti:* Pseudokarst phenomena on the island of Malta Presentation of the proceedings of the 10th International Symposium on Pseudokarst
11:40 – 12:00 a.m.	*Jörg Templin:* Erosion and corrosion in quartzite sandstone
12:00 a.m. – 01:00 p.m.	lunch
01:00 – 07:00 p.m.	Excursions E1, E3, E4, E5
07:00 – 08:00 p.m.	lunch
08:00 – xxx p.m.	Closing ceremony

16 May 2010 (Sunday)

08:00 – 08:45 a.m.	breakfast
from 09:00 a.m.	Departure of participants
10:00 a.m. – 01:00 p.m.	Guided sightseeing tour of Dresden

Excursions

E1: Hike (walking tour) to the table mountain “Quirl“ and visit of various small caves
E2: Hike in the area of the Polenztal and visit of the cave „Höhle am Neuweg“
E3: Hike to the Affensteine concerning various pseudokarst phenomena
E4: Cave tour “Tiefe Höhle“ (“Deep Cave”, Bielatal)
E5: Cave tour “Wohlrabhöhle“ (“Wohlrab Cave”, Bielatal)
E6: Cavetour “Ruscherhöhle“ (“Ruscher Cave”, Bielatal)

Location of the meeting place and excursion areas

The Elbe Sandstone Mountains

The origin of the Elbe Sandstone Mountains dates back to the Cretaceous period. At this time almost all of Europe was covered by water. On the bottom sand, clay and chalk were deposited. These sediments were compacted to a homogeneous sandstone board by the pressure of the sea.

This board was broken by the movements of the earth’s crust, cracks and clefts were developed.

After the sea withdrew the sandstone was formed by the ice age, wind and water, whereupon the more solid sandstone put up stronger resistance against erosion. Like that the gorges and valleys between the bizarrely formed jagged sandstone rocks that today give the Saxon Switzerland its special appeal emerged.

The touristic exploration began in the early 19th century. The name Saxon Switzerland goes back to the Swiss painters Anton Graff and Adrian Zingg who were workig in Dresden around 1780.

To preserve the beauty and uniqueness of the Saxon Switzerland with its about 900 climbing summits, 320 caves and a hiking trail network of around 1200 km for climbers, hikers and tourists it was put under protection in 1990. In 1991 the National Park Saxon Switzerland with an area of 93 square kilometers was founded.

Three surface excursions E1, E2, and E3 will guide the participants of the symposium in very different areas with characteristic symptoms of sandstone weathering, which will be showed the spot, explained and discussed.

Interested in Caving can participate to the field trips E4, E5 and E6. Moreover, it follows a number of other ways to get to know in the days of the symposium the beautiful sandstone mountains in the center of Europe. One thing is definitely: the time is of course much too short.

Concerning the geology of the Elbe Sandstone Mountains

Martina Glauche

Höhlen- und Karstforschung Dresden e.V.

Summary

This paper gives a description of the geological situation of the Elbe Sandstone Mountains. For that purpose it gives an overview of the petrography and morphology, the sandstone erosion with its interesting effects, the tectonics of the area and peculiarities.

Introduction and connections between petrography and morphology

The Elbe Sandstone Mountains, also called Saxon Switzerland in the vernacular, belong to the most beautiful low mountain ranges of Germany because of their peculiar scenic appeal. They have an area of around 700 square kilometres and are characterized by bizarre rocks, populated and agriculturally used plateaus, the deeply cut Elbe valley and its canyon-like side valleys.

The Elbe Sandstone Mountains are a subarea of the Saxon Upper Cretaceous that is bound to the NW/SE-striding Elbe Valley Area.

The Elbe Valley Area, also called Elbe Valley lineament, represents a complex fault with expansion and contraction signs in the Cretaceous formations and in the bedrock without recrystallization on the level of today's outcrops. It has been active from the Cretaceous period until today.

The geological layer succession in the Elbe Sandstone Mountains reaches from the Cenoman to the Coniac. A purely sandy facies dominates through which the scenery is coined by curt formations.

The purely sandy facies of the Elbe Sandstone Mountains can be seen alongside the clay-limestone facies west and south-west of the line Pirna-Rosenthal, whose scenery is smooth and even. The facies changes in the Pirna area. This is expressed in the exceptionally rich layer formation.

Because sandstone has a high absorptive capacity – it can absorb up to one tenth of water of its own weight – a considerable part of the run-off water drains away. The water movement is stopped by ponding layers, mostly razor-thin but also up to two decimetres thick, and proceeds partly horizontally to a emersion point. Outcrops of those layers are less characterized by humidity but rather by weathering phenomena (hole series, cavettos up to deep strata caves – here the predominant cave shape).

Where those intermediate layers accumulate the sandstone seems strongly subdivided and with small beds. In the landscape these zones appear slope forming or planarity forming. But if the sandstone is marginally structured steep rock faces are formed.

With the help of the described petrographic-morphologic differences Lam-precht (1927) classified this sandy facies of the Elbe Sandstone Mountains that is poor in fossils (see appendix 1 – revised by H. Rast). The sandstone levels are identified by Roman letters, the separative marginal horizons are written in Greek letters.

Sandstone weathering and mineral generation

The sandstone weathering mainly results from chemical weathering – mechanical forces and influences of the vegetation take inferior effects.

The water circling within the sandstone contains free sulphuric acid and the elements aluminium, potassium and calcium are dissolved away from the binder. If this solution discharges on the rock surface the water (solvent) evaporates and around the emersion points circular secretions of gypsum are formed that cement the sandstone. Only if very much solvent has evaporated also the easily solved alum discharges within the gypsum cementation circles. But in contrast with the gypsum the crystallized alum octahedron do not work cementing but destroying by breaking away single grains of sandstone. In this way deep holes within the gypsum rings are formed, so called honeycombs on the sandstone surface.

But next to the initial cementation also the gypsum contributes to the destruction of the sandstone. The volume increase that is connected to the gypsum secretion leads to the detachment of thick crusts (with the honeycomb structures) and smooth sandstone surfaces are formed on which under suitable circumstances the “honeycomb weathering” can start again.

Particularly good circumstances for chemical weathering are met above the already stated intermediate clay layers where even deep layer weathering (fissure caves) and following avalanches are possible. This kind of destruction can often be seen on the rock structures of the Elbe Sandstone Mountains.

Similarly to the gypsum also iron hydroxide and silicic acid work compacting.

Another phenomenon of the Elbe Sandstone Mountains is the apparition of brown haematite ledges, i.e. some sandstone parts are waterproofed by brown haematite. This brown haematite appears needle iron ore. The pyrite and brown haematite fraction of the sandstone, locally also sandy brown iron ore scree and – especially in the lusatian thrust fault – the tertiary basalt volcanism come into question as iron suppliers.

But not only the chemical weathering alone but also the physical and biological weathering have destroying effects on the sandstone. As examples the caldera-, tub-, clint- and gryke-like weathering formations shall be mantioned. For instance the formation of so called “tubs” starts where there are differences in structure and texture of the sandstone. Under accidental external influences, perhaps the wind-caused drop-out of rougher grains, the influences of inferior plants etc. a chemical and mechanical loosening of the rock surface sets in and smaller hollows are the consequence. The formed “dimples” facilitate the moisture absorption and by thet the attrition of the rock, organisms can settle more intensively andethe chamical, physical and biological weathering work together and find good points of attack.

Next to the mentioned formations you can find small caves in warious walls with left-behind pillars that are called hourglasses. They develop at percolation points of the water escaping at the sides because of the intermediate layers. At these percolation points the binder and quarzite grains are washed away and hollows are formed where also the other weathering formations work. In the end bigger hollows separated by not affected sandstone parts are formed.

Tectonics

The Cretacious sediments of the south-west Elbe Sandstone Mountains are transgressively bedded on the older ground (gneisses of the eastern Ore Mountains resp. Precambrian and Palaeozoic stone of the Elbe Valley Slate Mountains) with few exceptions, so that the to SW prescinded subsoil represents an erosion edge. However the NE boundary of the Elbe Sandstone Mountains is characterized by the Lusatian Fault (also called Lusatian Thrust Fault). The Lusatian granodiorite massif is lifted up on a fault line whose winding course on the north-eastern boundary of the sandstone area corresponds to the granite-sandstone border and is locally thrusted upwards. The higher resistance of granodiorite to erosion led to a higher outcrop than the sandstone at the Lusatian Thrust Fault – characterized by soft mountainous formations.

The nearly WE directed important fault line of the Lusatian Thrust Fault of the granodiorite was approx. 300 to 400 m higher than the already existing sandstone. It runs from Hinterhermsdorf via Altendorf to Hohnstein and separates the granodiorite in the north from the sandstone in the south and with that also two different landscapes. The stone border is hard to recognize in the scenery. The whole tectonic picture is rather complicated and seems to be a clod mosaic (NE/SW, N/S, NW/SE) – here the Lusitian System and the Ore Mountain System are distinguished. The Elbe Sandstone is passed through by a predominantly rectangular fissue system where the two tectonic main directions of the Lusitian Thrust Fault and the Ore Mountains break-off follow. Including the fissures the sandstone is split into cuboid which lead to the term cuboid sandstone.

Both the horizontal and vertical pressure component of the Lusitian Thrust Fault took essential part in forming. In the area around the thrust fault there are two rectangular main fissure plane systems, one in the direction of the pressure, one rectangular to it. The existing cleft fissure system was already formed during the diagenesis – that is to say from the Upper Cretaceous on – and was recoined and emphasized by the following tectonic activities (Lusatian Thrust Fault, Ore Mountains brink, basaltic breakups). The Ore Mountains brink (Oligocene to Pliocene) went on to the excursion area as a step fault which led to the general inclination of 1 – 3° N of the Saxon part of the Elbe Sandstone Mountains.

The rise of basic melts in the desruption zone has to be seen in close connection to the tectonic activities in the Tertiary Period. These volcanites rose up to different altitudes and formed conical and ridge shaped “basaltic mauntains” (Tephrites or Nephelinites, Phonolites - real basalts cannot be found in the Elbe Sandstone Mountains) that stand out from the conifer wooded sandstone massifs, because they were more resistant against weathering than sandstone. Mostly the sandstone formations are called “Steine” (rocks) while while the basic resp. granodioritic elevations are called “Berge” (mountains). In areas where the intrusion peak of the basic volcanites lies deep canyons were formed through the draining of the torn sandstone above. Occasionally volcanites bogged in the sandstone were excavated by weathering processes. For example the Großer Zschirnstein, Großer Winterberg, Kleiner Winterberg, Raumberg, the Vosi vrch and the Tanecnice are made of basaltic material.

References

Lamprecht, F.: Die Schichtlagerung des Turons im sächsisch-böhmischen Elbsandsteingebirge; Ber. d. math.-phys. kl. sächs. Akad. d. Wiss. Leipzig, S. 155-186, Leipzig 1934

Müller, B.; Wächter, K.: Beiträge zur Tektonik der Elbtalzone unter besonderer Berücksichtigung der Lausitzer Störung; Geodät. Geophys. Veröfftl., R. III, Heft 8, Berlin 1970

Pfeiffer, L.: Beitrag zur Petrochemie der sächsischen Tertiärvulkanite, Freiberger Forschungsheft 333, Leipzig 1978

Rast, H.: Geologischer Führer durch das Elbsandsteingebirge, Freiberg 1959

Rast, H.: Zur Geologie der Basalte im Elbsandsteingebirge, Geophys. U. Geologie, Folge3, S. 18-73, Leipzig 1962

Exkursionsführer: „Die Elbezone als Teil des Elbelineaments (Gebiet DDR), Strukturelle Bedeutung und Entwicklung" Gesellschaft für Geologische Wissenschaften, Berlin 1983

Dr. K.-A. Tröger: Vortrag „Geologische Exkursion Elbsandsteingebirge 1975" (Mitschrift)

Exkursionsführer der Gruppe Höhlen- und Karstforschung Dresden im Kulturbund der DDR, FG Geologie, Teil „Abriss der Geologie" von M. Barthel; Rathen, 04.-06.06.1982

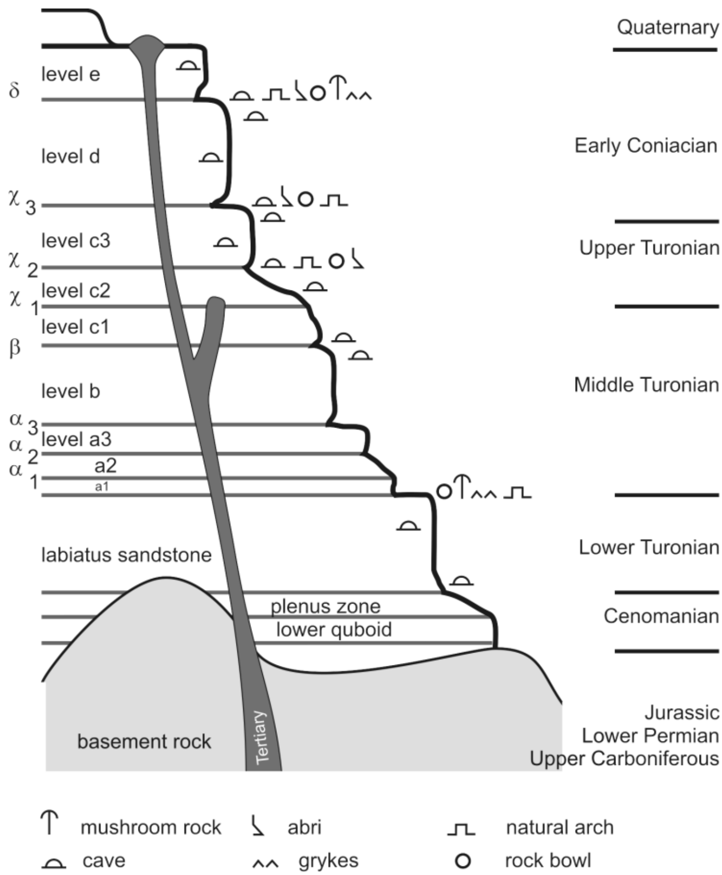


Fig. 1. Idealized geomorphologic profile in Elbsandsteingebirge with characteristic pseudokarst forms (Sources: Excursion guide "pseudo karst features in the Saxon Switzerland" to cavers meeting "Saxon Switzerland` 86 "by 10 to 04/13/1986 p. 2; Ed Börner, F. and Wutzig, B.; on the basis of publications of Mibus, H. - P. 1975, and Vitek 1981 Geological map of the national park region Saxon Switzerland 1:50 000, Saxon State Agency for Environment and Geology, Freiberg 1993)

Excursion I: Table mountain Quirl

Guide: Reinhard Müller

Route: Starting point Pfaffendorf sports ground, Quirl north side, Baumann Cave, Zwergenlöcher (Dwarf Holes), Small and Big Fissue Cave, Biwak Cave, Diebskeller (Thieves Cellar), climb notch, over plateau to south-east point of the Quirl (vantage point, rock bowls), descent to south side via Sterl Cave I resp. via the Kanonenweg (hiking trail). footslope south side to Sterl Cave II, strata fissure cave, back to sprots ground.

The caves of the Quirl

Although also the caves of the Quirl got higher attention through the touristic exploration of the Saxon Switzerland one can assume that as early as in prehistoric times they were visited and inhabited by human beings. During the first surveying of the Diebskeller (Thieves Cellar) proofs for the use of the cave during the Neolihic Period were found. Later, during the Bronze Age, the neighbouring Pfaffenstein accommodated a settlement. Because of the direct neighbourhood it can be assumed that also at this time the Quirl with its many caves was visited by humans.

At the end of the 19th century the caves served as hiding places for the bunch of crooks aroung Sterl. The two caves on the south side of the Quirl are named after him.

1 Concerning the geology of the Quirl

The massif of the Quirl is a solid body with a length of approx. 1000 m in NW-SE direction and a maximum width of 350 m. The plateau of the Quirl is the biggest compact summit surface of all table mountains of the Saxon Switzerland. In the area of the Quirl you can find at least 13 caves, most of them on the north-east side.

The Quirl is set up of the Postelwitz formation (β3 to γ3) and a Pleistocene clay layer in the area of the summit plateau. At the south-east point the upper parts of the level "β 3" crop out. The summit plateau is made of Pleistocene d ecalcified loess that makes the vegetation on the plateau possible by damming up water.

The Layer β3 is set up of clayey-sandy rock and is easily recognized by a distinctive fold resp. a rock edge. The maximum thickness of this layer is 2,0 m. An example for cave formation in the level β3 is the Pferdestall (Horses Stable); also parts of the Baumann Cave are apparently situated in this layer.

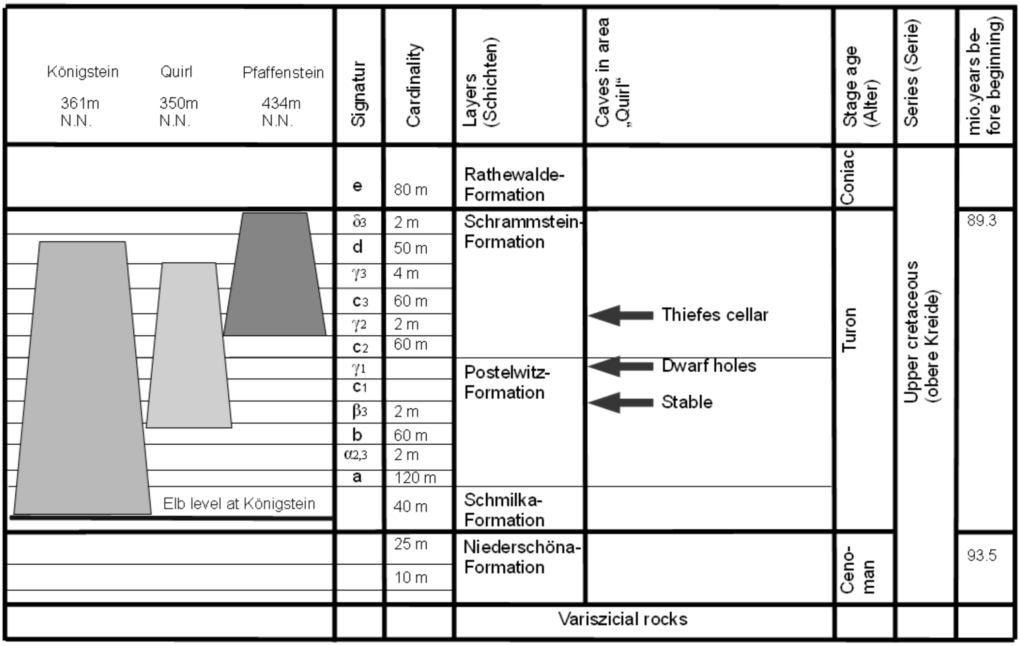


Fig. 2. stratigraficial situation in the area of „Königstein“

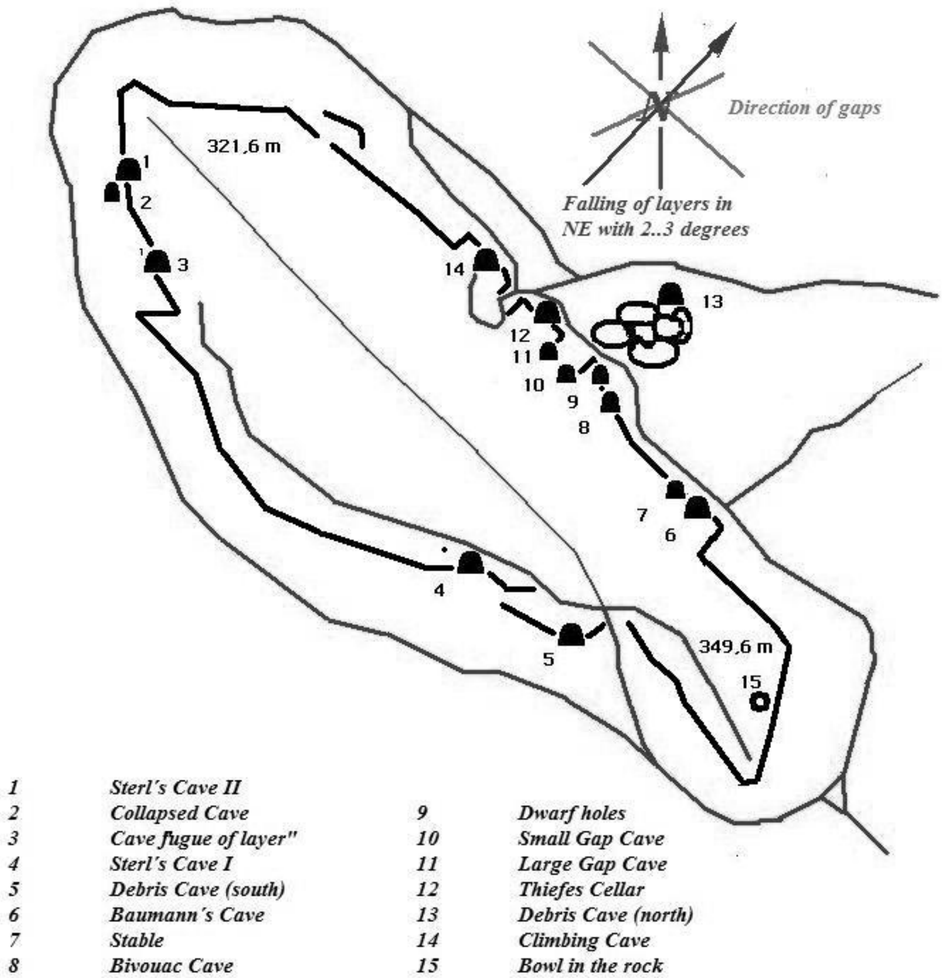
The following layers C1 and C2 are hardly distinguishable and entirely free of caves.

The next speleologically interesting layer is γ2. In this layer with similar condition as β3 lies the biggest strata fissure cave of the Saxon Switzerland, the Diebskeller (Thieves Cellar). C3 is strikingly yellow coloured and built of thick beds.

The layer γ3 is characterized by small grained sandstone and a concise weathering (cavetto). The Quirl does not bear a cave in this layer.

The northeast side has in the range of source horizons many moisture-cave formations. The reason is the northeast dip of the layered complex. On the dry south-west side mainly debris formation and honeycomb weathering lead to speleologically interesting structures. The northsided aquiferous layers (“strata fissure layers”) are formed as abris on the south side of the Quirl.

2 The caves of the Quirl massif



14 smaller and bigger caves are known in the Quirl area. A peculiarity of the Quirl is the fact that here all cave forms, partly in combination can be found. Solely the stone gate cannot be found, whereas in this case it is only a special form of the strata fissure cave. Next to that also other forms of sandstone weathering can be found (hourglasses, honeycomb weathering, alum crusts, etc.).

2.1 Strata Fissure Cave

On the northern side of the Quirl 3 some levels with fugues of layer are distinctive (above β3, γ1 and γ2). On the level above γ3 no strata fissure cave can be found in the nearly missing layer “d”, probably because of the minor formation and with that the missing water storage.

2.1.1 The Diebeshöhle (Thieves Cellar)

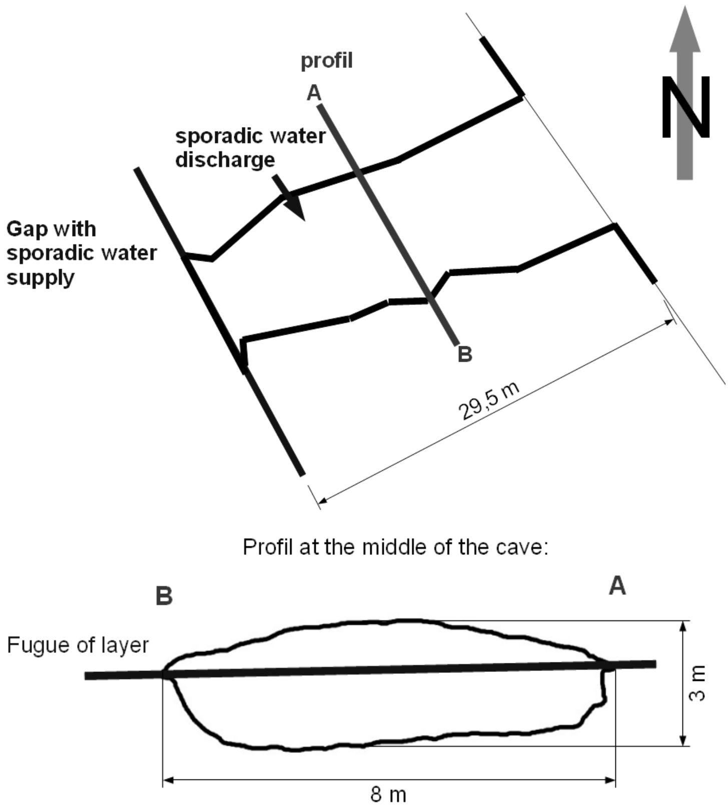


Fig. 3. Ground plan and cross section of the cave "Thieves Cellar"

As the biggest Strata fissure cave in the Quirl and also one of the biggest caves in the Saxon Switzerland is the so called "Thieves Cellar". This cave, also called "Thieves Cave" or "Gutbier Cave" (after the Saxon geologist August von Gutbier) lies above the level „γ2". The cave has a length of 29 m, a maximum width of 8 m and is 2 to 4 m high. At the back a dislocation joint that serves as ground water pipe through the water storing layers above cave level and by that has a major influence on the cave genesis is cut. Significantly the cave ends exactly at this fault.

2.1.2 The Zwergenlöcher (Dwarf's Holes)

The Zwergenlöcher are smaller but nonetheless interesting in their formetions, where a combination of strata fissure cave and joint cave can be found. Also here the strata fissure formation ends in the area of the joint fissure. In the entrance area the fissure is weathered forming hourglasses, the inner parts get bigger and reach 2 x 1,5 m. The cave formation in nearly northern direction takes the shape of a joint fissure cave.

2.1.2 The Schichtfugenhöhle (Strata fissure cave)

On the south-west side of the Quirl the only cave formation bound to a strata fissure can be found, the Schichtfugenhöhle. In this area also the only spring of the south west side, but this spring only carries water after the snowmelt or extensive rainfall. The Schichtfugenhöhle consists of a 2 x 3 m sized strata fissure weathering.

2.2 Joint Caves

Due to tectonic influence during the Tertiary joints and faults were formed withing the sandstone and then represented favoured migration paths for the ground water. In this context you can find erosion and corrosion phenomena in the sandstone. These processes led to the formation of so called joint caves in the marginal areas of the Quirl.

2.2.1 Kleine Klufthöhle and Große Klufthöhle (Small and Big Joint Cave)

North of the Dwarf's Holes you can find two parallel, nearly NE-SW stridung faults, the Small and the Big Joint Cave. Whereas the Small Joint Cave is only accessible for the first 5 m the Big Joint Cave is very high and can be visited horizontally for 8 m. A vertical tour is possible for at least 6 m.

2.2.2 The Kletterhöhle (Climbing Cave)

The only in 1974 discovered cave (first known visit 25 May 1974 R. Winkelhöfer, U. Rathner, W. and H. Heine) is situated above the other cave levels and is only accessible by climbing which explains the late discovery. This cave is a joint on an also NE-SW stridung fault (similar to Kleine and Große Klufthöhle). In the front area the rock is weathered in the course of a strata fissure as an abri. Boulders formed in this context form a debris cave in the area of this abri. The cave might be in the layer „γ3". There are remarkable salt afflorescence inside the cave due to the low humidity.

There is also a joint fissure of the Climbing Cave that can easily be localized on the plateau.

2.3 Collapse caves

This is a special form of the joint caves where a joint was widened by tectonic influences and relatively limited sliding movements so that sliding boulders get jammed in the widened joint and formed the cave.

2.3.1 The Baumann Cave

The Baumann Cave is a collapse cave consisting of several chambers. The single chambers are up to 6 m long and 4 m high. It is one of the biggest caves in the Quirl.

2.3.2 The Bivouac Cave

The Bivouac Cave (also called Bunker Cave or X1) consists of a relatively big main chamber that is connected to a chamber with two passage facilities by a crawling gangway. The anthropogene artefacts (wall, installations) give evidence of the lack of judgment of overcome times.

2.3.3 The Sterl Cave II

This cave was formed when the outer boulder slided a little downhill so that the already existing joint was widened. sliding boulders covered the joint and formed the cave ceiling.

2.4 Debris caves

Debris caves are formed within the rubble of rock masses that were taken off the rock by a debris avalanche. Next to the Sterl Cave I that was formed by nature there is also the Trümmerhöhle (Debris Cave) on the north east side of the Quirl that was formed during the Prussian-Austrian War in 1866 when the old access to the Quirl was blasted.

2.5 Further speleogenetic formations at the Quirl

Next to the dfferent cave types the Quirl shows a series of formations connected closely to the weathering of the sandstone. “Hourglasses” and honeycomb weathering are two examples. Are hourglasses are mainly spread on the more humid north eastern side whereas the honeycomb weathering can be found mainly on the dryer south western side. Areas with low humidity show gypsum and alum efflorescence. In the area of the vantage point on the plateau several “rock bowls” as a form of the locally stronger weathering of the sandstone can be found.

Excursion II: Hohnstein / Polenztal

Guide: Hartmut Simmert

Route: Starting point Hohnstein, Hiking car park „Am ehemaligen Bahnhof", Halbenweg, Kaltes Loch / Gautschgrotte (Gautsch Grotto), Diebskeller (Thieves Cellar) in former mine of Hohnstein, Kleiner Kuhstall (Small Cow Stable), ledge Nashorn, cave "Höhle am Neuweg", Hohnstein.

Hohenstein / Polenztal

The excursion area Hohenstein / Polenztal is situated on the right Elbe bank on the northern boundary of the Saxon Switzerland.

Geomorphologically this area is coined by two faults. On the one hand by the lusatian thrust fault coming arcross Hohnstein from N and NE, a tectonic dislocation at which at the end of the Cretaceous Period (67 m years ago) the older lusatian granodiorite was shelved onto the younger chalkstone (regional fault height approx. 600 m). (Prescher 1975, p. 14). The second fault is the canyon-like erosion valley of the Polenz brook.

The sandstone cropped out in the excursion area lithostratigraphically belong to the Upper Turone and Coniac (sandstone layers c-d-e). Due to the enormous tectonic stress in the contact area of the Lusatian Thrust Fault the sandstones are often pervaded with fissures and capillary cracks that mostly healed with quarzite accumulations / silicic acid and can now be seen as quazite veins, silifications, quarzite layers and slickensides. (Gerth 2006, p. 68)

Our excursion route leads to a variety of geologic and speleologig outcrops on the left Polenz Valley slope.

Starting and finish point of our excursion is the Hohnstein. From the car park in th upper city we go to the southern point of the city, here lies the access to the Schindergraben / Apothekersteig behind the Hotel "Abiente". In the upper valley in the contact area to the Lusitian granite complex a small brook rises and flows through this steep small side valley to the Polenz brook. We walk down the Apothekersteig to a sandstone bridge over the Schindergraben and meet the Halbenweg. This hiking trail leadt approximately horizontally, roughly said on in niveau of the delta 2 layer in the upper part of the Polenz Valley slope. We follow this trail to the left (north west) and have an attractive view over the historic Castle of Hohnstein. The trail leds us suoth around the ledge Großer Halben. It lies in the upper part of the sandstone layer d.

On the mountain side we now see hole layers, hourglasses and strata fissures as characteristic, often horizontally bound weatherig formations.

From the Halbenweg a small path branches off to a vantage point on a wooded ledge. Here we have an impressive outlook into the Polenz Valley. The Polenz Brook rises in the Lusitian granite massif east of Neustadt / Saxony.

After barely 30 km it is united with the Sebnitz Brook becoming the Lachsbach (Salmon Brook) and near Bad Schandau flows into the Elbe.

After this side-trip we follow the Halbenweg to the "Kaltes Loch" (Cold Hole).

Kaltes Loch (Cold Hole) / Gautsch Grotto

The Cold Hole is a NW-SE striding side valley in the left Polenz Valley slope between the rocks Großer Halben und Kleiner Halben. In the upper valley the Gautsch Grotto is situated. It is one of the backward valleys typical for the Saxon Switzerland.

The erosion of the today episodically and with little water flowing brook is dropped behind the one of the receiving stream (Polenz Brook). The valley brink today lies 30 m above the Polens level.

The bottom of the valley of the Cold Hole is covered by boulder akkumulations where also a remarkable debris cave was faormed. The big thrust masses derivate from valley widening wall disruption, mostly from wall areas over deeply weathered layer borders.

From the Halbenweg a signposted path leads to the upper valley and the Gautsch Grotto.

This remarkable natural formation was named after the famous explorer of the Elbe Sandstone Mountains Carl Gautsch (1810 – 1979).

The deeply weatered stratum delta 2 is situated around the arched valley brink and in the foot wall of the ledge “Kleiner Halben”. The walls above of the sandstone layer e form remarkable abris. A small water flow with rather little water supply falls from the wall in the back. Its point of impact on the bottom of the valley lies in a rock basin a few metres below the layer delta 2. The formation of the impact basin that has a 10 – 12 m diameter must have taken place in times of a stronger water supply (Pleistocene, see also Rast 1959, p 119).

From the Cold Hole we take the Halbenweg southwards to the excursion point “Diebskeller” (Thieves Cellar) in a former quarry.

Fig. 4. The Gautsch Grotto near Hohnstein (Photography: H. Simmert 2010)

Diebskeller (Thieves Cellar) near Hohenstein

The former quarry has been levelled and is now wooded and therefore hard to recognize. Only the sandstone paved exit (Steinbruchweg) reminds of this period.

The Tieves Cellar is a strata fissures abri above the layer delta 2. (Börtitz 1962, p. 209)

The Tieves Cellar has an arched ground plan. The range of the daylight entrance is approx. 23 m, the height to the eaves are approx. 3.2 m. The flatly curved ridge of the abri gets lower to the inside. A small abyss water emersion can be seen on the left strata fissures arches. The bottom is covered with sand and sandstone boulders.

A vertical abyss over the strata fissures has been washed out to an up to 1,5 m wide channel with potholes in times of bigger water supply. In these times there is only a small dripping water supply.

Fig. 5. Thieves Cellar in a former quarry near Hohnstein (Photography: B.Wutzig 2009)

We leave the former quarry on the "Begangsteig". This path leads with many bends over the Polenz Valley and on the western side on the level of the layer delta 2. On this path we reach a number of reports of the intensive sandstone weathering and traces of the tectonic stress of the Lusitian Tust Fault.

At first we follow the "Begangsteig" in the northern side of the north going ledge. On our way we can see the "Clementiner Tor", a rock-like perforation a few metres above our heads in a stone ridge.

Kleiner Kuhstall (Small Cow Stable)

The “Small Cow Stable” is a strata fissure tunnel in the foot wall of the climbing summit „Berken von der Duba Wacht“.

This stone tunnel was formed in the area of the strato border layer delta 2 and a NNE-SSW striding vertical joint. (Börtitz 1962, p. 209/210)

The tunnel is approx. 8 m long, in the centre it is approx. 3.5 m wide, the entrance on the south ist approx. 4 m and on the north approx. 8.2 m wide, the entrances are about 1.5 m high. The rocky bottom of the cave is rather uneven and in the south it goes down in stairs.

As an effect of the Lusitian Thrust Fault the outcropping sandstone in the border layer of the lower walls is made of small pieces and has quarzite grains. On the north and west side the layer delta 2 forms a visible terrace.

From the south access of the Small Cow Stable we follow the path going along the wall into the next valley arch. we pass deep strata fissure weatherings and abris, small slicken-sides, stone walls with big areas of honeycomb weathering and two slided wall clods in a rock alley (near forest number 251).

On this trail around a small valley we reach an approx. 16 m long and on strata fissure level 6 m wide stone alley that separates the Nashorngipfel (Rhinoceros Summit) from the ledge.

Fig. 6. Small Cow Stable near Hohnstein, view from the north (Photography: H.Simmert 2010)

Nashorngipfel (Rhinoceros Summit)

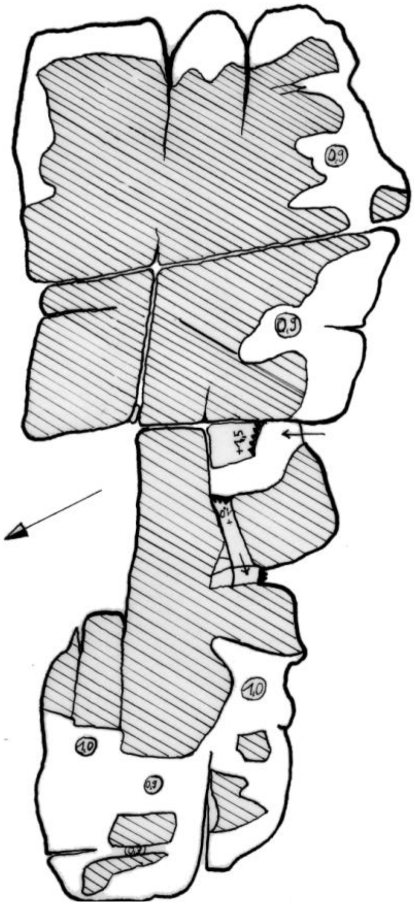


Fig. 7 Horizontal section through the rhino Summit (Cave and Karst Research Dresden, 1981)

At the Rhinoceros Summit you can see an exemplary the strata fissure weathering and cave genesis in the area of the here strongly quarzitic layer delta 2. (Börtitz 1962, p. 210) Through the stone alley we reach the south side of the rock. Next to the deeply weathered strata fissure a small collapse cave was formed at a joint cross. In this cave you can climb over two rock stairs to an upper exit.

The west point of the rock entirely excavated except for some small pillars and the flat strata fissure cave is accessible from three directions.

On the north side of the Rhinoceros Summit the layer delta 2 is vastly covered with soil and boulders. At the Rhinoceros Summit plenty of slickensides and small quarzitic joints can be found.

From the Rhinoceros Summit we walk the same path back to the valley arch and walk through the stone alley next to the forest number -251- onto the massif plateau. Here we follow the forest trail south-east to the Räumigtweg. We follow this hiking trail approx. 200 m to the left (east) until a few metres behind a forking a forest path branches off to the right. It leads eastwards, also past a small wild meadow, to the Neuweg. We follow this path to the right (south) and after approx. 80 m the Neuweg leads down to the Polenz Valley. Right away in the upper valley part we reach the waterfall of the "Waldborn".

The small brook rises a few hundred metres north-east in the contact area to the Lusatian granite complex. With seasonally strongly varying water supply it falls down a barely 10 m high sandstone step and runs dry exactly at the impact point into the "Höhle am Neuweg" (Cave at the Neuweg) below.

Höhle am Neuweg (Cave at the Neuweg)

The cave is situated in the upper part of the Neuweg leading down to the Polenz Valley, belaow the waterfall of the Waldhorn. The cave entrance can be found directly at the foot wall of the strongly bedded, partly overhanging wall, directly south-west next to the Neuweg.

Fig. 8. Stone alley at the Nashorngipfel, view from the south (Photography: B. Wutzig 2009)

Speleomorphologically the “Cave at the Neuweg” is a combination of collapse and debris cave above a strata fissure layer. The longitudinal side of the cave in SSW – NNE is approx. 38 m. The cave has got a temporary cave brook (Börtitz 1962, p. 210). In the instable debris area and in winterly glaciation caution is necessary.

Fig. 9. Terrain situation in the entrance area of the “Höhle am Neuweg”. In the bottom left corner the cave entrance can be seen, in the upper right corner in the background the waterfall glaciated in winter (Photography: B. Wutzig 2010)

Way back to Hohenstein

After the cave tour we ascend to Neuweg to the plateau and follow the now wide forest path north, approx. 1 km to Hohenstein.

References

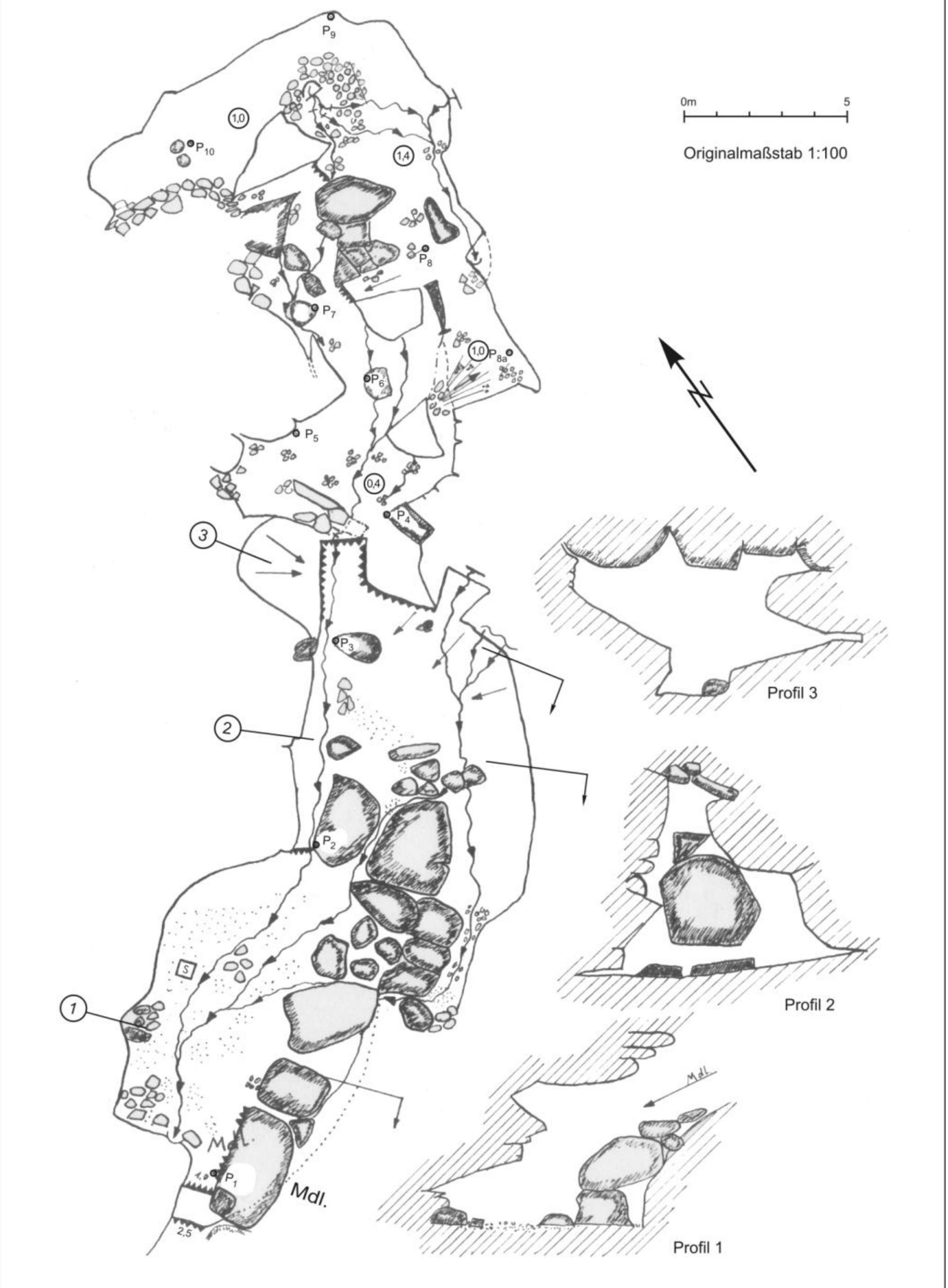
Prescher, H.: Führer zur Naturwissenschaftlichen Lehrschau Hohenstein; Bautzen, 1975

Gerth, A.: Geologische Exkursionen in der Oberlausitz und im Elbsandsteingebirge, Spitzkunnersdorf, 2006

Börtitz, S. und Eibisch, W.: Die Höhlen der Sächsischen Schweiz, Jahrbuch des Staatlichen Museum für Mineralogie und Geologie zu Dresden, 1962

Rast, H: Geologischer Führer durch das Elbsandsteingebirge; Bergakademie Freiberg, 1959

Wanderkarte des Landschaftsschutzgebiet Sächsische Schweiz – Rathen/Hohenstein – 1:10.000, Geodäsie und Kartographie Dresden, Ausgabe 1990



Höhle am Neuweg (Sächsische Schweiz/Hohnstein)

HKD-Reg. 1310-11-17 (5050-NO-E1)

Höhlen- und Karstforschung Dresden e. V.
www.hoehlenforschung-dresden.de

Vermessung: Cornelia Wutzig, Bernd Wutzig, Michael Göldner, Michael Kabus
22.05.1981 und Februar 1990 (FG Höhlen- und Karstforschung im Kulturbund)

Zeichnung: Bernd Wutzig, 03/1990 (digitale Rekonstruktion: Hartmut Simmert 04/2008)

Excursion III: Affensteingebiet/Vordere Sächsische Schweiz

Guide: Bernd Wutzig

Route: Starting point Kirnitzschtal (Kirnitzsch Valley) / Beuthenfall, Car park Beuthenfall, Bloßstock, Zwillingsstiege, to the upper Häntzschelstiege, onto Langes Horn, via Reitsteig to Schneeberger Loch, back via Frienstein and descent to Kirnitzschtal.

Alternative: ascent over Felsklamm, Wilde Hölle, vantage point Carolafelsen, Langes Horn, further as above.

Affensteine

The excursion Affensteine leads us to an attractive part of the Saxon Switzerland on the right side of the Elbe with a pronounced geomorpholocical structure of the landscape. The sandsones forming plateaus, slopes and high rocky formations belong to the stratas of the middle and upper turone to coniac (sandstone layers b-e) (1). These lithostratigraphic layers and the tectonic joint network are characteristic attack poits for an intense sandstone weathering and a requirement for its often horizontally bound makro, meso and mikro forms (Börner 1988, p. 8).

Fig. 10. The Bloßstock, remarkable climbing summit in the Affensteine, Saxon Switzerland Photography: Bernd Wutzig 2009

Starting and finish point of our excursion is the Beuthenfall in the Kirnitzsch Valley.

The Beuthenfall is a brook on the northern valley slope with mostly small water supply that here falls down a stone step.

Over a sandstone bridge we cross the Kirnitzsch brook that rises in the Lusitian granite district not far from Rumburg in the Czech Republic and flows into the Elbe near Bad Schandau.

Our way to the Affensteine leads us on a slightly rising forest road through the Dietrichsgrund and on southwards on the Unterer Heideweg to the Unterer Affensteinweg that here branches off to the west. After a short distance a path branches off uphill to the Bloßstock.

Bloßstock

The Bloßstock forms a massive 80 m high rock tower as the nortern point of the ledge Langes Horn, it stratigraphically belongs to the wall forming sandstone layers c3 and d.

Traces of the corrosive and erosive sandstone weathering can especially be found in the lower parts of the Bloßstock west wall. As a likely side effect of the Tertiary volcanism you can find typical brown haematite accumulation (limonite) as joint-bound but also shapeless meandering brown haematite ledges.

From the Bloßstock a mountain trail leads us through the Großes Bauerloch to the lower entrance of the Zwilligsstiege (Twin's Stairs). The climbing passages of this demanding staircase are constructed with solid iron clamps as climbing assistance. As steep forest track this way leads onto the Oberer Affensteinweg (Upper Affenstein Trail). We follow this hiking trail to the left (east) to the entrance of the upper part of the Häntzelstiege (Häntzschel Stairs). In corrosively widened joints of the sandstone level this also fully constructed staircase leads to the summit plateau of the ledge Langes Horn (Long Horn).

Langes Horn (Long Horn)

From the ledge Langes Horn you have an impressive view over the erosion landscape of a part of the front Saxon Switzerland with its bizarrely divided rock massifs, deep erosion areas and table mountains – partly with Tertiary volcanic intrusions of basaltic rocks.

On the Langes Horn we can find a variety of weathering forations of the Createaceous sandstone.

Grykes that trace the typical sandstone cuboid formation and other karst-forms especially at the outcropping rock areas as well as bizarre stone formations as weathering remains and single hourglasses.

Numerous only 1-2 cm wide joints in the outcropping rocks are healed with brown haematite accumulation.

We now leave the Langes Horn to the south and follow the hiking trail Reitsteig eastwards to the Winterberg (Winter Mountain). After approx. 400 m we reach a distinctive appearance of grykes.

Grykes above the Schneeberger Loch (Schneeberger Hole)

The grykes on the massif plateau above the Schneeberger Loch are a descriptive example for the weathering formations in exposed location. They are applied in the sandstone of the layer d, where joints cross, striding NEE-SWW and NNW-SSE. Also in this outcrop brown haematite accumulations as joint filling can be found. (Börner 1988, S. 9)

As a further often horizontally bound weathering formation some rock bowls (Kamenitsa) can be found on the summit plateau.

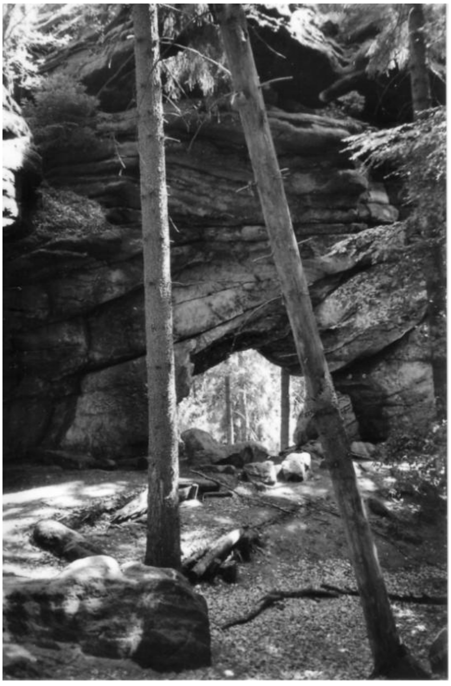
At the exposed south point of the plateau above the Schneeberger Loch and on the summit plateaus of the rock towers in front we can look upon numerous channel forms. From our point of view we have a marvellous view over the rock scenery around the Schmilka caldera down to the Elbe Valley.

Fig. 11. Filigree sandstone arch on the Langes Horn (Photography: B. Wutzig 2009)

Fig. 12. Grykes above the Schneeberger Loch (Photography: B. Wutzig 2009)

Stone Gate (Kleiner Kuhstall/Small cow Stable) and Strata Fissure Cave in the Schneeberger Loch

Fig. 13. Flat rock bowl on the plateau above the Schneeberger Loch (Photography: B. Wutzig 2009)



From the fork Reitsteig – descent to the Frienstein (forest number 177) we go on approx. 60 m towards the Winterberg and walk from the Reitsteig southwards through a small stone alley to the bottom of the Schneeberger Loch.

At the south-west end of the ledge the remarkable stone gate can be found.

The strata fissures and joint bound fissure is approx. 8 m wide, has a maximum height of 3.8 m and is approx 4 m deep. The bottom of the stone gate is flat and covered with some boulders from the jointed and small pieced sandstone ledge. (cmp. Börtiz 1962, p. 215/216)

Through the strata fissure cave in the Schneeberger Loch we walk through the stone gate and follow the path at the bottom of the sandstone ledge on the level of the strata fissure layer.

Fig. 14. View of the stone gate from the north (Photo: B. Wutzig 2009)

Speleologically seen it is a big Abri in the area of the horizontal strata fissure and a vertical joint in the stone wall. The span width of the abri measures approx. 25 m, the maximum depth approx. 7 m, the height below the eaves approx. 3.5 m, the average chamber height at the back approx. 2 m. The flat bottom is covered with sand. (vgl. Börtitz 1962, p. 216)

From the Schneeberger Loch we take the same trail back to the crest path Reitsteig and leave it at the forest number 177 to the north on the descent to the Frienstein.

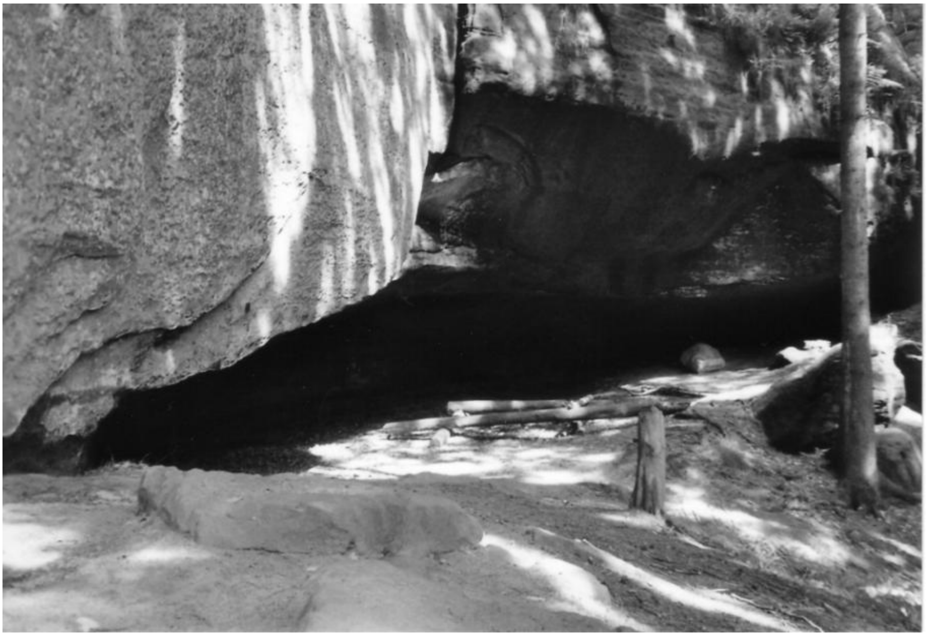


Fig. 15. Strata fissure cave in the Schneeberger Loch (Photo: B. Wutzig 2009)

Frienstein (Vorderes Raubschloss/Front Thieves Castle), Frienstein-höhle (Frienstein Cave)

The Frienstein is a big ledge between the Kleiner Winterberg (Small Winter Mountain) and the Affensteine. Like many other "stones" in this area it carried a castle complex in the Middle Ages, hence today the Name "Vorderes Raubschloss".

We reach the Frienstein summit at the south side at the niveau of the border layer delta 2. The west side of the Frienstein is coined by strata fissure weathering, a sandy terrace and coarsely pieced boulders derivating from debris avalanches.

At the north side the path leads down through a big chockstone and as a small ledge to the east side to the Frienstein Cave.

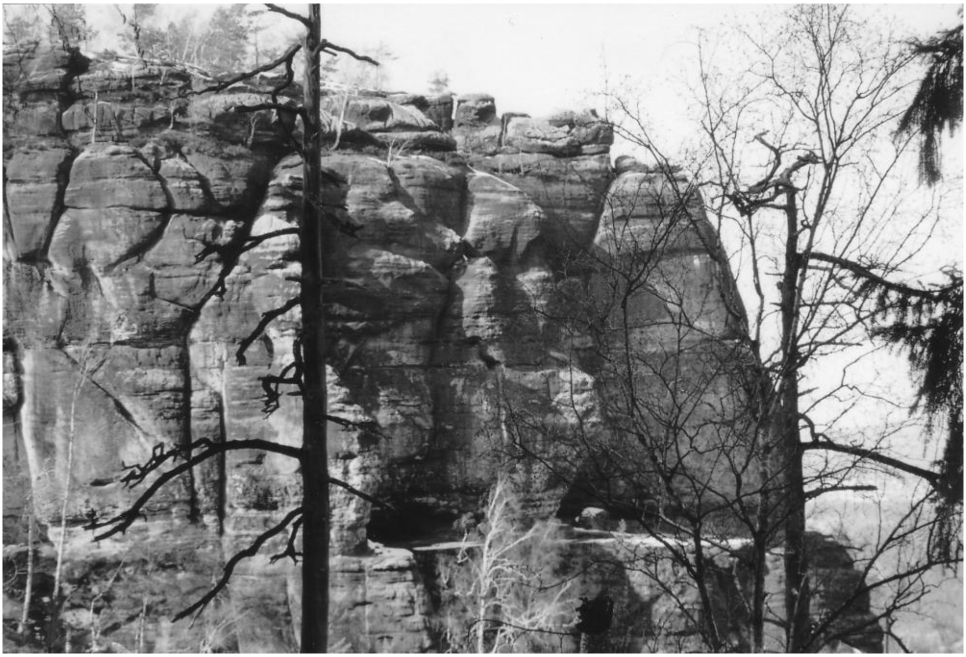


Fig. 16. View to the Frienstein Cave from the Upper Affenstein Trail (Photography: B. Wutzig – 2010)

The Frienstein Cave is a typical cave formation in the contact area of the water damming layer delta 2, the sandstone layer e above and a vertical SW-NE striding joint. At the bottom of the north eastern cave entrance is covered with coarsely pieced debris from the excavated joint area.

The strata fissure part of the cave goes as a tunnel around a rock pillar. The bottom of the cave is covered with sand. In front of the entrance the layer delta 2 forms a terrace from which you have a marvellous view over the Kleiner Zschand. (cmp. Börtitz 1962, p. 215)

Back to the Beutenfall in the Kirnitzschtal

From the Frienstein we take the Friensteinstiege down to the Königsweg. We follow this trail to the west until the forking Hinterer Heideweg. Via the Vorderer Heideweg in the Dietrichsgrund and the forest road back to the Kirnitzsch Valley and the Beuthenfall.

Ascension alternative Wilde Hölle (Wild Hell)

If the Zwillingsstiege should not be accessible on the excursion day we take this attractive alternative.

From the lower Affensteinweg we take the south-eastern branching forest path through the Kleines Bauernloch up to the gorge Wilde Hölle. Shortly before the access to the gorge we take a side trip on the left (east) to the foot of the ledge. In the lower parts sandstone honeycombs and bizarrely filigree brown haematite accumulations can be seen.

On the same path we go back to the Wilde Hölle.

The gorge “Wilde Hölle” (Wild Hell) is a classic example for an intense sandstone weathering in the intersection area of a strata fissure layer and a vertical joint that in this case also serves as an erosion channel of a temporary brook.

Over staricases and boulders we descent through a short gorge into a calder. The brook falls down a stone step in the caldera wall, mostly only as dripping water, into a flat sandstone basin at the bottom. In the very wet caldera wall we can see another flat strata fissure weathering formation.

The descent leads over an iron staircase out of the caldera onto a forest trail up to the Upper Affenstein Trail. Not far from this crossing we take the eastern uphill path onto the ledge Langes Horn and with that we are again on our actual excursion route.

Fig. 17. The gorge Wilde Hölle in the Affensteine (Photography: B. Wutzig 2009)

References

Rast, H.: Geologischer Führer durch das Elbsandsteingebirge, Bergakademie Freiberg 1959

Börner, F., Stork, D., Wutzig, B.: Exkursionsführer 3. Symposium über Pseudokarst (Internes Arbeitsmaterial), ZFA für Höhlen- und Karstforschung im Kulturbund der DDR. Königstein 1988

Börtitz, S und Eibisch, W.: Die Höhlen der Sächsischen Schweiz, Jahrbuch des Staatlichen Museum für Mineralogie und Geologie zu Dresden, 1962

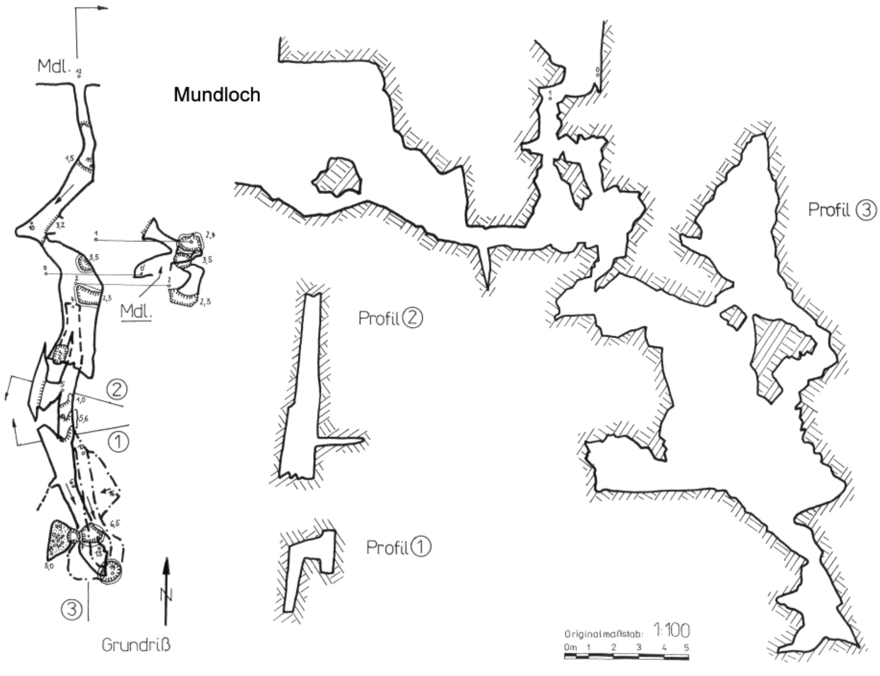
Wanderkarte des Landschaftsschutzgebiet Sächsische Schweiz – Schrammsteingebiet – 1:10000. Geodäsie und Kartographie Dresden Ausgabe 1990

Excursion IV: “Tiefe Höhle” (Deep Cave)

Guide: Falk Thieme

Route: Drive by car into Bielatal (Biela Valley), parking at Ottomühle (Otto mill, about 1 hour), from here walk about 30 minutes to the cave with a slight increase.

The cave is located near the restaurant in Bielatal Otto mill on the left side slope above the cave “Bennohöhle”. She was for some time the deepest cave in the Saxon Switzerland, hence the name. The explorers tried to find at the end of excavation by a sequel in the depths - to no avail. It is a characteristic of the Saxon Switzerland gap cavity. The cave is formed by mass movement of large blocks, to drop the preconceived tectonic fissures in the valley.



Map of the “Tiefe Höhle” Drawing: Frank Börner (1985) - Reproduced with kind permission

In the input column you climb over the block (also including crawl possible) and rises about 10 meters down to a corner. This one we follow to the left and passes through a constriction into a larger chamber. In the back of this room you climb ca. 2m from a narrow point and follows the column filled with blocks horizontally about 5m. The column opens up to a 13m deep shaft. You have two ways of achieving the shaft floor: in the main shaft or abseiling, climbing down into the small shaft on the right side. At the shaft base is the Book of Caverns and you can visit the excavation site.

For the cave-tour shaft-cave equipment is recommended. Skilled climbers navigate the cave without any equipment. For the excursion we have installed a rope ladder and a fixed rope.

Excursion V: "Wohlrabhöhle" (wohlrab cave)

Guide: Jörg Templin

Route: Drive by car into Bielatal (Biela Valley), parking at Ottomühle (Otto mill, about 1 hour), from here walk about 20 minutes to the cave with a slight increase.

Fig. 18. In the narrow crevices of Wohlrabhöhle (Photo: Jörg Templin)

The cave was discovered in the 70s and still is the deepest known cave in the Saxon Switzerland. It is situated in the upper Biela Valley in the south-west part of the Saxon Switzerland. Starting point is the car park OTTOMÜHLE. From the southern part of the car park you cross the Biela below. After following the main hiking trail for approx. 150 m upstream the Biela you walk up the slope. The joint cave is situated in a group of rocks between Schildkröte/ Schildkrötenturm and Kanzelturm.

The orifice of the cave lies in a vertical gap opening to the outside. Following this gap for approx. 20 m horizontally you get to the actual roping point. The following main pit is 32 m deep. Via a approx. 7 m high climbing spot and two further pits that are connected by horizontal parts you get to the deepest point of 45 m. But this is only accessible through a very narrow pit. The deepest point has got two cave lakes on ground water level.

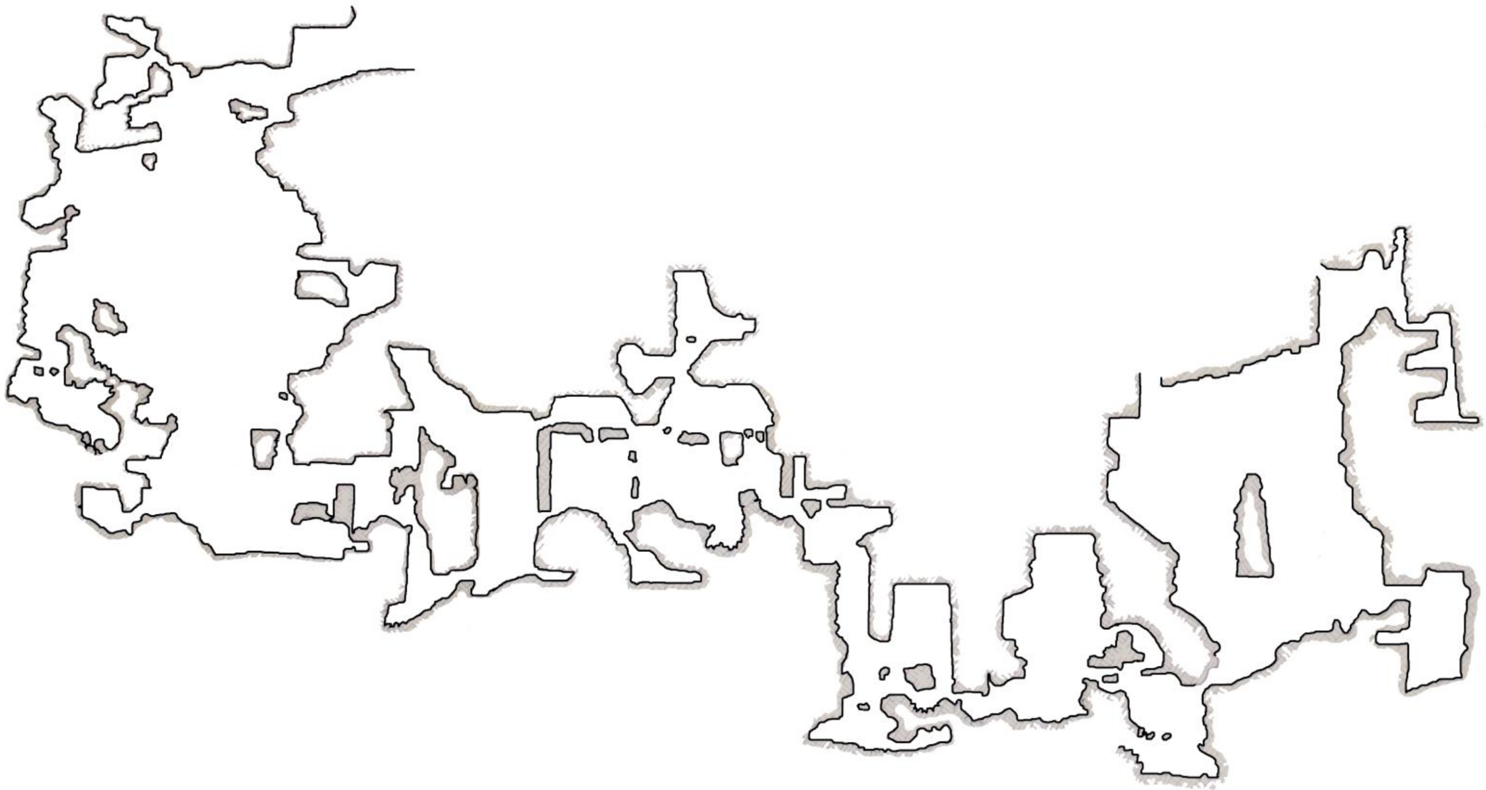


Fig. 20 Cross-section of Wohlrabhöhle (no scale) Drawing: F. Börner, S. Müller 1985 - Reprinted with kind permission**.**

Excursion VI: "Johannes-Ruscher-Cave"

Guide: Jörg Templin

Route: Drive by car into Bielatal (Biela Valley), parking at Ottomühle (Otto mill, about 1 hour), from here walk about 20 minutes to the cave with a slight increase.

Johannes- Ruscher – Cave

The cave is situated in the Upper Bielatal in the south-west part of the Saxon Switzerland. Starting point is the car park OTTOMÜHLE. Following the main hiking trail in the direction of the Grenzplatte you walk through the BIELAGRUND and pass the recuing hut. After crossing the BIELA you take the rising left hand trail parallel to the BIELA towards the EISLOCH. Passing by the group of rocks STUMPFER KEGEL you take the steep track and on the right hand sided group of rocks you come to an entrance of this joint cave. 16 metres above this you can find a second entrance. Via both you get through narrow pits to the horizontal centre part and climbing down to the bottom of the cave. The total depth of the cave is 43 m and the total length is 86 m. It was discovered in 1978. Speleologists grade the visit of the cave as difficult.

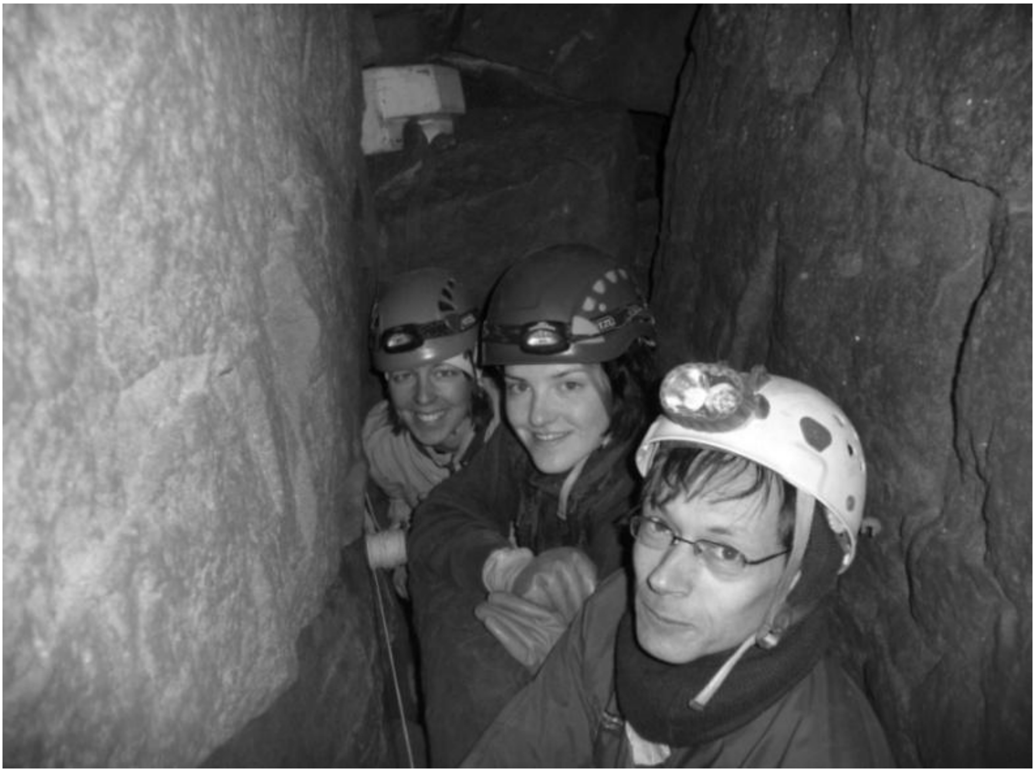


Fig. 21. During the new surveying in February 2010 (Photo: Jörg Templin)

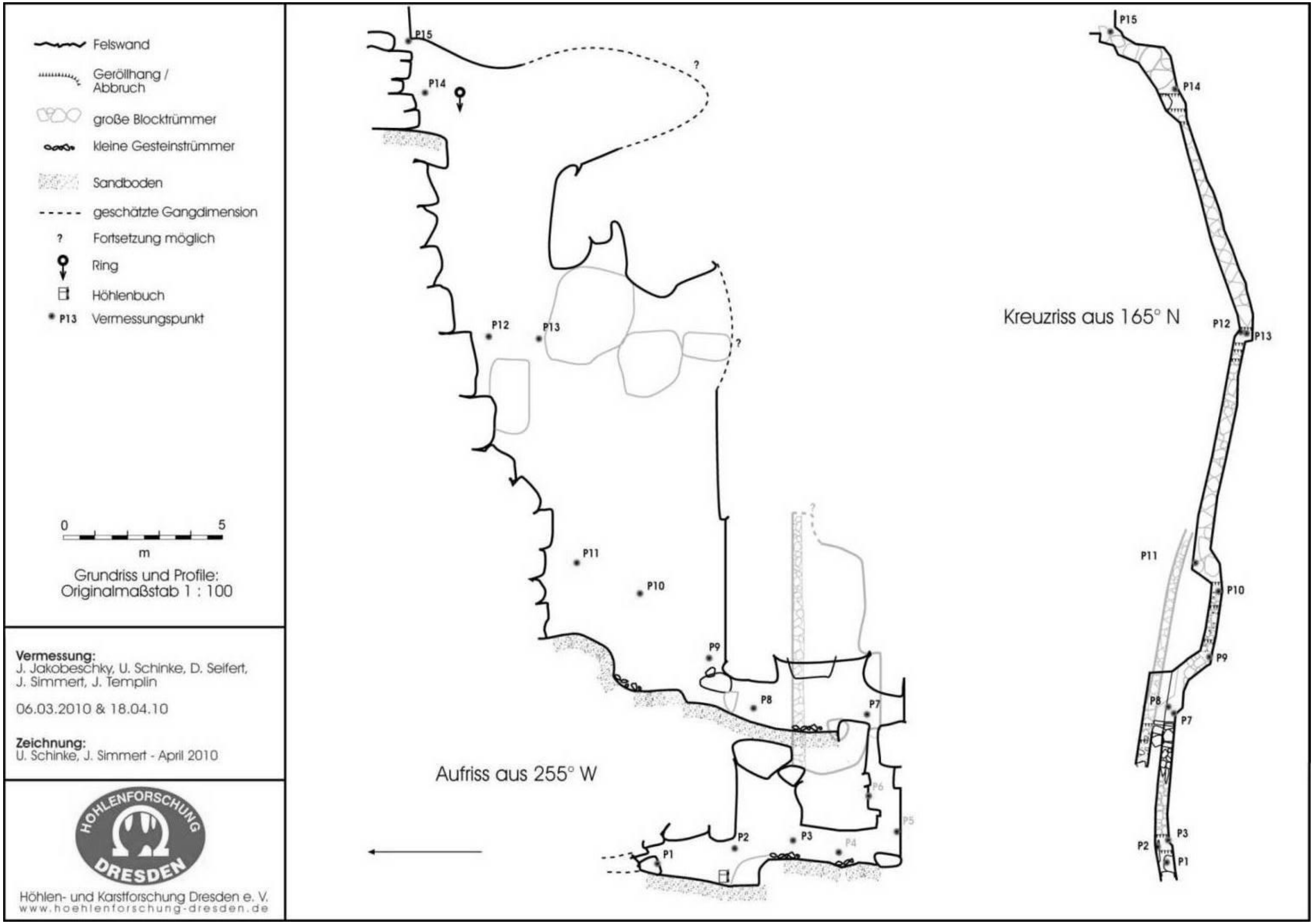

Felswand
Geröllhang / Abbruch
große Blocktrümmer
kleine Gesteinstrümmer
Sandboden
geschätzte Gangdimension
?
Fortsetzung möglich
Ring
Höhlenbuch
P13
Vermessungspunkt
0
5
m
Grundriss und Profile:
Originalmaßstab 1 : 100
Vermessung:
J. Jakobeschky, U. Schinke, D. Seifert,
J. Simmert, J. Templin
06.03.2010 & 18.04.10
Zeichnung:
U. Schinke, J. Simmert - April 2010
HÖHLENFORSCHUNG
DRESDEN
Höhlen- und Karstforschung Dresden e. V.
www.hoehlenforschung-dresden.de
Aufriss aus 255° W
Kreuzriss aus 165° N
P1
P2
P3
P4
P5
P6
P7
P8
P9
P10
P11
P12
P13
P14
P15

Fig. 22. Tunnel formation on a strata fissure. The sand is preserved. (Photography: H. Simmert)

Fig. 23. Cave formation through disruption of boulders from the rock unit (Photography: H. Simmert)

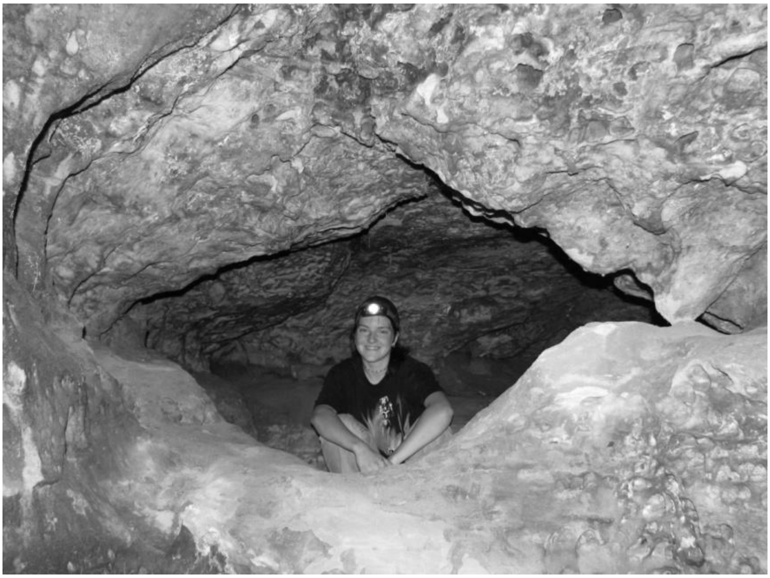


Fig. 24. Cave formation through strata fissure weathering in the table mountain Quirl (Photography: H. Simmert)

Fig. 25. Quarzite speleothemes in the climbing cave (table mountain Quirl) (Photography: H. Simmert)

Proceedings

Lithological controls on sandstone weathering: a proposal of morphofacies for the humid temperate zone of Europe

Jiří Adamovič[1] – Radek Mikuláš[1] – Jana Schweigstillová[2]

[1]Institute of Geology AS CR, Czech Republic
[2]Institute of Rock Structure and Mechanics AS CR, V, Czech Republic

The landforms developed on sandstones and conglomerates are typically described as discrete phenomena with no genetic interrelationships, and their lithological controls are as yet poorly understood. The concept of micro- and mesoscale sandstone morphofacies is employed as a key to the understanding of sandstone weathering processes in the realm of humid temperate zone.

The type of microforms on steep cliff faces is a function of sandstone lithology (grain size, sorting, cementation, tectonic deformation), climate, and local conditions (microclimate, height above cliff base, height above local base level, vegetation, etc.). In our research, we eliminated the effect of climate by restricting our observations to the humid temperate zone, typical for central and western Europe. Such climate is favourable for the complexity of sandstone microrelief, as it combines warm summers with sufficient solar irradiation and noctidiurnal temperature variations, cold winters with regular frost and snow cover, and more or less evenly distributed precipitations throughout the year. Local effects were respected by documenting cliff faces at various settings within one site. This approach permitted us to describe the relationships between the sandstone relief and sandstone lithology with the least possible bias.

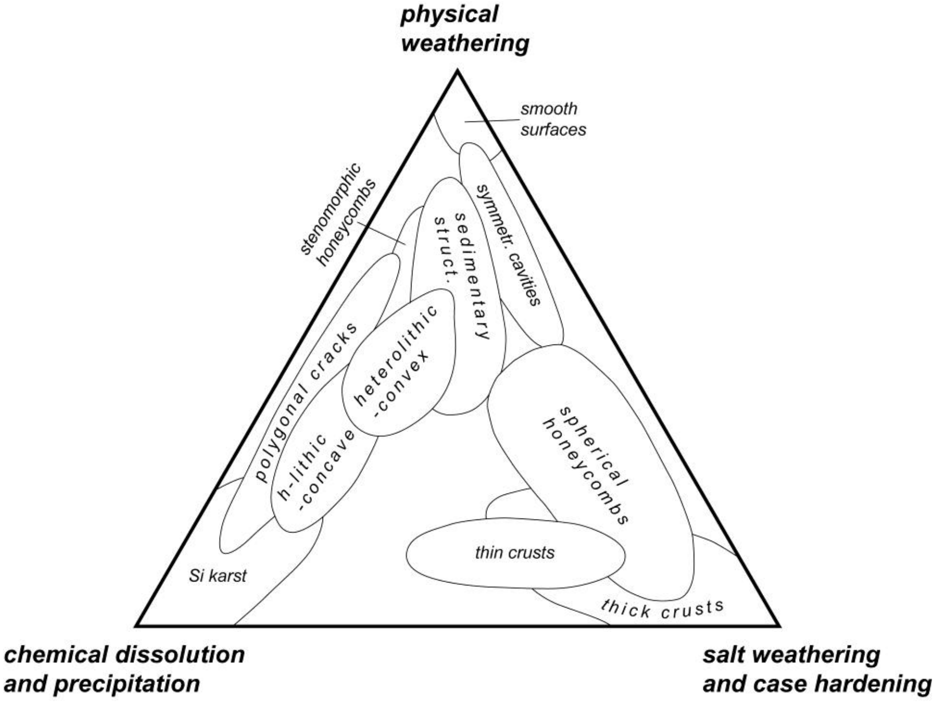
Outcrop documentation concentrated on sandstone districts of the Bohemian-Saxonian Cretaceous Basin (Kokořín area, Bohemian Paradise, Bohemian-Saxonian Switzerland, Lusatian Mts., Broumov area), Moravian, Polish and Slovak Carpathians, the Petit Suisse region at the Luxembourg–Germany border, and the sandstone/quartzite districts in the Paris Basin (Fontainebleau, Larchant) in France. The lithological parameters recorded in the field and in the lab included clast and cement composition, sedimentary textures and structures, jointing and faulting, rock crust formation and composition of speleothems and salt efflorescences, pore size distribution, and technological properties of rocks. The observed weathering patterns were grouped into eleven morphofacies, each characterized by a specific set of micro- to mesoforms. A tentative list of the morphofacies is presented here, best fitting to moderately inhomogeneous sandstones.

Morpho-facies	Principal relief-shaping lithological factor	Typical microforms	Type locality
smooth surfaces	no cementation, weak lithification, fine to medium grain size	poorly developed linear-arranged honeycomb pits, rhombic honeycomb pits, Trittkarren, rock windows, rounded pillar tops	Apolena Cliffs near Jičín, Bohemian Paradise, CR
symmetrical cavities	weak cementation, fine to medium grain size	flat-bottomed cavities of triangular or oval shapes, cellular honeycomb pits, rock windows	Komín Gorge, Kokořín area, CR
sedimentary structures	horizontal stratification and cross-bedding, poor sorting, moderate cementation	low-relief ledges, linear-arranged honeycomb pits	Dědovy kameny Cliffs, Svojkov near Česká Lípa, CR
spherical honeycombs	massive or poorly stratified structure, medium grain size, moderate cementation	spherical honeycomb pits: solitary, forming grids or irregular ledges, Wandkarren	Kobylka Gorge near Mšeno, Kokořín area, CR
thick rock crusts	sulphate rock crusts, fine grain size, presence of clay or carbonate matrix	undulating surfaces, shallow tapering honeycomb pits	Rač Plateau, Kokořín area, CR
thin rock crusts with case-hardening function	opal crusts/coatings on cliff surface, medium grain size	honeycomb pits with prominent linings	Chipka Pass near Berdorf, Luxembourg
heterolithic – concave forms	strong cementation with weakly cemented enclaves	spherical or tunnel-shaped cavities	Čertůvky Cliffs, Chřiby Mts., CR
heterolithic – convex forms	strongly cemented tabular/ lenticular beds or concretions in less cemented sandstone	high-relief ledges, tensional columns, mushroom rocks	Perekop near Berdorf, Luxembourg
stenomorphic honeycombs	shear faults with silica cementation, deformation banding	stenomorphic honeycomb pits, ribs	Horní skály Cliffs near Rynoltice, Lusatian Mts., CR
polygonal cracks	evenly distributed silica cement, macropore volume reduction	polygonal cracks, rock basins	Apremont-Bizons near Barbizon, France
siliceous karst forms	strong silica cementation, strong macropore and micropore volume reduction	facetted surfaces, rock basins, silica speleothems	Milštejn, Lusatian Mts., CR

Physical weathering, like frost weathering, solar irradiation or wind abrasion, were long believed to be the only processes of sandstone relief shaping. In the last two decades, other factors have been also proved to play a role. Quartzose sandstones were shown to be partly shaped by chemical dissolution of grains and/or cement (Young 1986). The high degree of silica dissolution in such cases is explained by elevated pH values or elevated temperatures of pore waters, or by high flushing rates over a prolonged time. Even if quartz dissolution removes only a minor proportion of the rock volume, it is critical for landform evolution: large masses of loose residue are then easily removed by physical transport. The same obviously applies to sandstones with unevenly dispersed carbonate cement. Crystallization of salts and silica from pore waters has been also revealed to be responsible for the formation of a range of microforms, especially honeycomb pits (Cílek 1998, Mikuláš 2001, Williams and Robinson 2001) Substances dissolved in pore water act in two opposite directions: 1. salt weathering – crystallization of salts in pores in a near-surface zone ca. 1 m broad, 2. case hardening − the precipitation of cement at or near the rock surface, which results in the formation of rock crusts of variable morphology, thickness and durability.

Each of the outlined sandstone weathering morphofacies is characterized by a specific combination of physical weathering, salt weathering/case hardening, and chemical dissolution of clasts and cement. The estimated shares of these processes for separate morphofacies are expressed in the ternary diagram below.

This study was funded by project No. IAA300130806 of the Grant Agency AS CR.



References

Cilek V. (1998): Fyzikálně chemické procesy vzniku pískovcového pseudokrasu. In Cílek V. and Kopecký J. eds., Pískovcový fenomén: klíma, život a reliéf. Knih. Čes. speleol. Spol., 32: 134-153. Praha. (in Czech, English abstract)

Mikuláš R. (2001): Gravity and orientated pressure as factors controlling “honeycomb weathering” of the Cretaceous castellated sandstones (northern Bohemia, Czech Republic). Bull. Czech Geol. Surv., 76: 217-226.

Williams R.B.G. and Robinson D.A. (2001): Experimental frost weathering of sandstone by various combinations of salts. Earth Surf. Process. Landforms, 26: 811-818.

Young R.W. (1986): Tower karst in sandstone: Bungle Bungle massif, northwestern Australia. Z. Geomorph. N. F., 30: 189-202.

Biospeleology / Saxony sandstone - caves

Matthias Arnhold

Höhlenforschergruppe Dresden e.V.

Summary

The Elbe Sandstone Mountains are situated in the far Southeast of Germany, only a few kilometers from Dresden, between the Erzgebirge and the Lausitzer Bergland. It extends from Pirna across the Czech border to Decin in Bohemia. The German part is named Saxon Switzerland and is 368 square kilometers wide. Over thousand of years heavy water and wind erosion made a fascinating variety of shapes: mesas, canyons, rock needles and sandstone-caves. This biospeleological lecture gives an overview over the cave fauna and cave flora.

The Elbe Sandstone Mountains are divided in Sächsische Schweiz and Böhmische Schweiz (Ceské Svýcarsko). It gives us a many-sided open space in plants and animal world experience. By help of observations and information in cadastral documents of caves numerous animals could be proved in the area. In general the living conditions often are marked in the area by relatively steady temperatures, low annual temperature variations, high air humidity and nearly absolute darkness. The food offer is low. The occurence of "real" cave animals (Troglobionte) is limited. The most of these animals are arthropods. Water-inhabiting cave animals play no essential rule in the sandstone caves, because steady water aggregations are extremely seldom. To the troglophielen kinds are counted particularly bats, cave-spending the winter butterflies, diptera, gliridae and salamander. Some specific features are the occurence of luminous moss (schistostega osmundacea) and root stalagmits (Wurzelstatagmiten).

Some local kinds

Arthropod (arthopoda)

- insects (insecta) / diptera: trichoptera, limonia nubeculosa, culex pipiens, heleomyzidae
- insects (insecta) / neuroptera: myrmeleon formicarius (a specialist in the fine sand is the antlion, he digs a funnel and waits for prey)
- butterflies (lepitoptera): scoliopteryx libatrix, inachis io, triphosa dubitata
- spiders (araneida): meta menardi, meta meriane, nesticus cellulanus...(The caves csoss spider – meta menardi, is a specialist. This spider captures its prey by a net and as a hunter. Throughout all territory it lives.)

Mollusc (mollusca)

- snails (gastropoda): morlina glabra, balea biplicata, limax cinereoniger, arion rufus, arion fuscus

Grasshopper (salatoria)

- rhaphidopharidae

Water inhabitant (There are few water caves.)

- hirudinea, gammarus fossarum, dugesia gonocephala, planorbis planorbis

Vertebrate (vetebrata)

- bats (chirotera): myotis daubentoni, rhinolophus hipposderos, myotis mytos,...
- rodent (rodentia): microtus agrestis, gliridae,...

Mushrooms (mycobionta)

- basidomycetes (many species, due to lack of light there are specific shapes and colors)

Root stalagmits

- A special feature in the sandstone caves are the root stalagmits. They are not made of limestone, they are a network of roots. This is a real feature and is tied to moist sites

Moss (bryophyta)

- Luminous moss (schistostega osmundacea)

Fig. 1. Root stalagmit

Fig. 2. Meta Menardi

Fig. 3. Myrmeleon formicarius

Sandstone caves with spherical cavities: Did they originate by airflow-induced disintegration during glacial period?

Jiří Bruthans[1], Petr Jenč[2], Zdeňka Churáčková[1], Jana Schweigstillová[3], Petr Mikuš[1]

[1] Charles University in Prague, Faculty of Sciences, Czech Republic
[2] Department of archeology and speleoantropology of the Regional museum and gallery in Česká Lípa, Czech Republic, Institute of Rock Structure and Mechanics of the ASCR, Czech Republic

Many sandstone caves in so-called Bohemian Paradise (Czech Republic) contain spherical cavities. By shape they resemble hydrothermal karst caves, for example Sátorkö-puszta (Hungary).

Caves were mapped in horizontal plane and vertical sections. Thickness of the sedimentary fill was measured by soil probe. In several caves carbonate sinters covering surface of spherical cavities were found and sampled. Cave sinters in 4 sandstone caves in the Bohemian Paradise were dated by means of 14C and U/Th methods.

Caves are typically several meters or few tens of meters long. They are open in rock face; thickness of overburden is commonly just several meters. Sedimentary fill in the caves is mostly several decimeters thick. In vertical sections the upward chimneys and pockets are mostly deeper than hollows in the floor filled by sediment. In many cases the fractures does not affect the shape of the spherical cavities. This means that fractures are either younger than caves or they did not affect the cave formation.

Cave sinters were deposited 5-13 kyr BP. Sinters proved that sides of studied caves did not retreated even few mm for at least last 8 kyr BP. This demonstrates that caves were created by processes, which does not operate at recent time. Based on dating and archeological evidence, the caves were created prior Holocene, probably in glacial time.

Remarkable similarity with some hydrothermal karst caves indicates possibility that fluid convection mechanism may be responsible for origin of these caves. We believe that originally bedding plane-guided or join-guided caves were extended by repeated freeze/melt cycles in sandstone subjected to permafrost conditions. Heat was transported by flowing air in convection cells. In summer time the relatively warm air was entering the caves, where it was cooled down by cold sides of passages. Condensated water was acting in sandstone below the floor of cave. Sand grains from decomposed sandstone were transported out of caves by periodic streams. Hypothesis is supported by measurement of air flow in caves during summer, which is the same as proposed by the model.

Research was supported by institutional project no. MSM0021620855 and grant project IAA300130806 (GA AV ČR).

Variability of environmental conditions and aquatic fauna composition in Jaskinia Miecharska Cave (Beskidy Mts., Outer Carpathians)

Elzbieta Dumnicka[1], Czesław Szura[2]

[1] Institute of Nature Conservation, Polish Academy of Sciences, Kraków, Poland
[2] Speleoclub Bielsko-Biała, Poland

Jaskinia Miecharska Cave, formed in the sandstone rocks, is a single Polish pseudokarst cave with a stream flowing into its passages from earth surface and passing by the greater part of its galleries (Margielewski et al. 2007). Moreover in the lower part of the cave a pool is found. The majority of cave galleries and chambers is situated 10 – 20 m below earth surface, but in few points cave passages reach to the ground level.

In September 2009 in one of such places stream water found a new way inside the cave bringing inside large amount of organic matter (leaves, plant's remains, etc.), washed out from the soil. At this time in the subterranean sector of the stream the availability of food for aquatic fauna distinctly increased. Also the number of organisms, representing "surface-water" forms such as larvae of aquatic flies and caddis-flies considerably increased, but these species survived in the subterranean sector of the stream for a short time only. Populations of permanent cave waters inhabitants stated previously in the cave stream (Dumnicka 2008, 2009), such as: polychaetes (Hrabeiella periglandulata), oligochaetes (Rhyacodrilus falciformis, Marionina argentea, Cernosvitoviella spp.) and crustaceans (Niphargus tatrensis) continue to exist.

The relative abundance of terrestrial oligochaete species increased, probably due to the bigger organic matter content in the sediments – comparable to that found in the soil. In the same time the composition and density of fauna found in the pool did not change in comparison to that stated in years 2006 – 2007. In the waters of Jaskinia Miecharska cave some environmental parameters such as temperature, conductivity, pH value, content of calcium, magnesium, sulphates and chloride are stable or almost stable but other parameters such as nutrient and oxygen concentrations and the amount of organic matter in the sediments could change considerably depending on the magnitude of water flow. Such variations influence mainly the abundance of fauna, but species composition of permanent cave water inhabitants is almost stable. Nevertheless monitoring of environmental parameters as well as the situation of the cave dwelling species should be continued due to its uniqueness.

References

Dumnicka E., 2008. Stream bottom fauna in the Jaskinia Miecharska cave, Silesian Beskid (Poland). Zacisk, special issue: 14 – 15.

Dumnicka E., 2009. Diversity of oligochaete fauna inhabiting epigean and hypogean sectors of a stream flowing through a non-karstic cave in Beskidy Mts. (Poland). Subterranean Biology, 7.

Margielewski W., Urban J. Szura C. 2007. Jaskinia Miecharska cave (Beskid Slaski Mts., Polish Outer Carpathians): case study of a crevice-type cave developed on a sliding surface. Nature Conservation, 63: 57 – 68.

Butterflies like the Caves of the Volcanic Rocks

István Eszterhás

Honorary President of the Pseudokarst Commission
Isztimér; Hungary

After the comparsion in more than two hundred karst and non-karst caves in turns out that the habitats of the troglophile butterflies are 2-3 times larger in the non-karst caves. These butterflies are using the caves as resting place in the daytime, as well as allowing the imago to overwinter in the caves. The study presents three prevalent species of Central Europe, which are charasreistic for the non-karst caves in Hungary, too. The majority of the butterfly species are accidentally got into the caves, but three of them purposely reside in the caves. The three species are the Tissue (Triphosa dubitata L.), the Herald Moth (Scoliopteryx libatrix L.) and the European Peacock (Inachis io L.)

Up to now in twenty-one non-karst caves of Hungary were found troglophile butterflies. Also in seventeen non-karst caves of the adjacent areas (mountains ranging into Austria and Slovakia) troglophile butterflies are to be found. In 30 caves, only 1 species is to be found. Two species are living in 5 caves (Ebeckého jaskyňa, Klafterlucke, Komín na Ragáči, Labirintová jaskyňa, Nyáryho jaskyňa) and all of the three species were found in 3 caves (Blindstollen, Csörgő-lyuk, Rózsa Sándor-barlang). – See the tabling!

There are more reasons that the butterflies to be found in caves that were formed in the volcanic rocks. One of them is that some caterpillar of the troglophile butterflies solely feed upon leaves of the plants, which grow in carbonate-free soil. The spreading of the vegetal nourishment of their caterpillars obviously affects the density and proportions of the butterflies in a cave. The berrybearing alder (Frangula alnus), the goat willow (Salix caprea) and the aspen (Populus tremula) grow solely in lime free soil. Therefore the Tissue (Triphosa dubitata) and the Herald Moth (Scoliopteryx libatrix) can be observed rarely in karst caves, whilst their occur frequently, sometimes in a mass in the non-karst caves.

No. and Caves:	Countries and Towns:	Triphosa dubitata:	Scoliopteryx libatrix:	Inachis io:
1. Araszoló-barlang	H, Raposka	O		
2. Arzgrube	A, Lockenhaus		O	
3. Asbest-werkstollen II.	A, Rechnitz		O	
4. Asbestwerkstollen III.	A, Rechnitz		O	
5. Blindstollen	A, Bernstein	O	O	O
6. Csörgő-lyuk	H, Mátraszentimre	O	O	O
7. Dreifrauen-höhle	A, Althodis		O	
8. Ebeczkého jaskyňa	SK, Hajnáčka		O	O
9. Galériás-barlang	H, Háromhuta	O		
10. Gotthartkluft	A, Markt Neuhodis	O		
11. Halász Árpád-barlang	H, Nagyvázsony	O		
12. Heanzenstein-Felsdach	A, Bernstein	O		
13. Hodisbach-stollen	A, Markt Neuhodis		O	
14. Josef-Polatschek-Kluft	A, Markt Neuhodis	O		
15. Kalapos-kői-barlang	H, Bozsok	O		
16. Kis-barlang	H, Fony			O
17. Kis-barlang	H, Legyesbénye	O		
18. Kis-kői-bazaltbarlang	H, Szilaspogony			O
19. Kis-Szilvás-kői-hasadék	H, Salgótarján		O	
20. Klafterlucke	A, Rechnitz	O	O	
21. Kleine Beerriegelzelle	A, Lockenhaus			O
22. Komín na Ragáči	SK, Hajnáčka		O	O
23. Kőajtós-barlang	H, Nagygörbő		O	
24. Labirintová jaskyňa	SK, Stara Basta		O	O
25. Lepke-barlang	H, Telkibánya			O
26. Lepkés-barlang	H, Nagygörbő		O	
27. Lepkés-barlang	H, Szokolya			O
28. Lepkeszárny-barlang	H, Regéc			O
29. Marcinek-barlang	H, Salgótarján	O		
30. Nyáryho jaskyňa	SK, Stara Basta		O	O
31. Póklak	H, Háromhuta	O		
32. Pokol-lik	H, Kapolcs		O	
33. Pulai-bazaltbarlang	H, Pula		O	
34. Redlschlag-stollen	A, Redlschlag		O	
35. Róka-lyuk	H, Fony	O		
36. Rózsa Sándor-barlang	H, Fony	O	O	O
37. Sinterspalte	A, Lockenhaus			O
38. Sziklakonyha	H, Somlóvásárhely	O		

In the non-karst caves of Hungary (and of adjacent areas) occurring troglophile butterflies

Current state of tree mould caves research

Ludovít Gaál

Slovak Caves Administration, Liptovsky Mikulas, Slovakia

Tree mold caves belong to the most interesting pseudokarst underground spaces. They originate by pyrogenic (born out), mechanical (weathering) and biogenic (by bacteria, fungi) removing of tree trunks covered by lava or volcanoclastic material. According to our knowledge they have been researched as early as beginning of 20th century in Slovakia (Kmet, 1902) and Japan (Ishihara, 1929). Several hundred well researched tree mould caves occur in Japan, less in United States (e. g. Greeley & Hyde 1972, Owen 2008) and Central Europe (Slovakia, Hungary, Czech Republic). Tree mould caves occur also in Canary Islands (Socorro, in verb.), probably in Haiti and Romania but their documentation is absent.

Lot of classifications of tree mould caves have been proposed in the past. The most of them in Japan but these relate only for lava tree mold caves. Ishihara (1929), Tanaka (1995) and Ogawa (1996) proposed classification according to features and structures of lava tree mould caves, Honda (1999) according to their formation process and Tachihara et al. (2002) by their morphological shapes. Bella & Gaál (2007) proposed the classification of tree mould caves according to their genetic process. They distinguish the following types: syngenetic pyrogenic caves, epigenetic mechanical weathering caves, epigenetic biogenic destructive caves and the combination of the two last types. However in case of older tree mould caves we can hardly distinguish the mechanical weathering and biogenic destructive caves or its combination.

Several new tree mould caves have been researched during last years in Slovakia and Hungary. Especially important is the finding of Miocene andesite lava tree mould cave in 3 localities in Slovakia: Vihorlat (Jaskyňa pod Dúpnou finding by Tomasz Mleczek), Ostrôžky Mts (Jánošíkova skrýša) and Polana Mts (Brankova skrýša). In all cases the cylinder-shape of body drifted by fluent andesite lava is apparent. In northern Hungary 2 new tree mould caves have been found by geologist Peter Prakfalvi in 2008. Both caves originated in Miocene andesite conglomerate on the distal part of Lysec volcano which is situated in Slovakia. Some tree mould caves have been described by Gradziński (2008) in travertine of Slovakia.

Less known in pseudokarst literature is an interesting compound tree mould cave in Miocene lahar named Jeskyně skřítku (Babůrek et al. 1990).

References

Babůrek, J., Bořecký, V. & Chvátal, P. 1990: Trpaslíčí jeskyně – dutiny v pyroklastických horninách Doupovských hor. Acta Musei Thermae Carolin. 1, Karlovy Vary, 6-40.

Bella, P. & Gaál, Ľ. 2007: Tree mould caves within the framework of cave genetic classification. Nature Conservation, 63, Kraków, 7–11.

Gaál, Ľ. 2003: Tree mould caves in Slovakia. International Journal of Speleology, 32, 1–4, 107–111.
Gaál, Ľ., Tachihara, H. & Urata, K. 2004: Hot and cold way of origin of the tree mould caves. In Gaál, Ľ. Ed. Proceedings of the 8th International Symposium on Pseudokarst, Teplý Vrch. Liptovský Mikuláš, 14–21.
Gradziński, M. 2008: Origin of a unique tree-mould type cave in travertine based on examples from the village Lúčky (Liptov, Slovakia). Slovenský kras, 46, 2, 325–331.
Greeley, R. – Hyde, J. H. 1972. Lava Tubes of the Cave Basalt, Mount St. Helens, Washington. Bulletin of the Geological Society of America, 83, 8, 2397–2418.
Honda, T. 1999: Classification of lava tree molds with/without remelted inner surface according to its formation process. In (Barone, N., Bonaccorso, R. & Licitra, G. eds.): Proceedings of the IXth International Symposium on Vulcanospeleology, Catania, Italy, 123–124.
Ishihara, H. 1929: Shiseki-meisho-tennekinenbutsu Chosa Hokokusho (4). Yamanashi Pref. Kofu.
Kmeť, A. 1902: Ďalšie výzkumy z obvodu Sitna. Časopis Muz. Slov. spol. 5, 111-113.
Ogawa, T. 1986. The formation of lava caves. Communications, 9th International Congress of Speleology, 2, Barcelona, 47–51.
Owen D. E. 2008. Geology of Craters of the Moon. Craters of the Moon National Monument and Preserve, National Park Service, 23 s.
Tachihara, H. – Sawa, I. – Kuroishikawa, Y. – Ogawa, T. – Honda, T. – Kim, B. – Makita, T. – Watanabe, N. – Ninata, H. – Nakaue, K. 2002: The shape classification and formation model by observation of lava tree-mold. The Review of Osaka University of Economics and Law, 84, Osaka, 1-46.

Pseudo karst landforms in the Adriatic side of north-east Apennine (Italy)

Sandro Galdenzi

Jesi (AN), Italy

Abstract

The review of the caves and landforms in the north east Apennine led to the identification of different types of pseudokarst phenomena, developed in different geomorphic and stratigraphic settings both in karst-bearing and insoluble sedimentary rocks

The most favourable places for non-karstic caves or landforms are the thick slabs of competent rock, generally limestone, overlying claystone and marl. Depressions, open cracks and shafts (up to 165 m deep) are common in these areas subject to landslide movements. Bedding caves and niches on the contrary develop in the sedimentary rocks where claystone and thick permeable layers alternate.

Water flow can occur inside the vertical caves, but it is not implied in their genesis and generally has only a secondary importance during the cave evolution. On the contrary, the large inclined caves (up to 250 m long) in claystone can develop from stream water erosion on the floor after a first, embryonic karst passage was formed inside an overlying calcarenitic layer

Introduction

Karst landforms are well known in the north east Apennines, where many small caves and some important cave systems, such as Monte Cucco and Frasassi (Galdenzi, 2004; 2009), develop in the limestone outcrops of the mountainous inlands. Surface landforms, on the contrary, are less developed; few polje-like endoreic areas ("Piani") are known, while dolinas are not common. Small limestone outcrops are also in the eastern hilly zone, near the Adriatic Sea. Surface karst and some caves are also in the narrow outcrops of Messinian gypsum

Pseudokarst landforms develop in different geologic settings owing to different processes, but they are not well described in the existing scientific literature. A geologic guide (Guerra, 2001) incorrectly cites one of the most important gypsum caves of the region as pseudokarst. On the contrary, some caves were referred to gravitational movements but reported as karst (Berluti Lorenzini et al., 2003)

The present paper offers a review of the existing pseudokarstic landforms, mainly caves, that were not formed by solutional processes. They will be described according to the Vitek classification (1983). In this paper, all the landforms produced mainly by solutional processes will be considered as karstic, without regard to the characteristics of the rocks or the type of the chemical process

Geographic setting

The studied region, in central Italy, is found on the Adriatic side of the appennic chain between the valleys of Marecchia and Tronto Rivers, and can be divided in two main parts, that differ in terms of litology, altitude, and morphology (Fig. 1). In the inland, a mountainous landscape prevails in the Apennines, with mainly carbonate rocks. Two main ridges develop from NNW to SSE, parallel to the Adriatic coast line. In the south, these ridges join and the altitude increases, exceeding 2000 m in the Laga and in the Sibillini Mountains (M. Vettore, 2474 m). Near the Adriatic Sea, the Apennine is bordered by a 40 km wide hilly zone, with prevailing weakly lithified marine terrigenous rocks. The altitude ranges between 200 and 600 m and increases up to over 1000 m in the southern part of the region.

The climate is temperate sub-continental in the main valleys and apenninic continental in the mountains. The annual average temperature varies between 10 and 13°C, depending mainly on altitude. In January the average temperature is lower than 6 °C, while in July it can exceed 25 °C. The average amount of precipitation varies between 700 mm year-1 in the valley and 1800 mm year-1 in the mountains. Precipitation generally reaches a maximum in autumn and spring, while evaporation exceeds precipitation in summer. The south-eastern part of the area has lower precipitation and higher temperature than the inner and northern zones.

Geologic setting

This sector of the Apennines consists of a fold-and-thrust belt, verging North-East (Fig.1), formed owing to the converging movements between European and African plates that involved the Mesozoic-Tertiary marine sedimentary succession (Crescenti et al., 2004, with references)

The mountains correspond mainly to outcrops of the Umbria-Marche-Romagna marine succession, that deposited in the Tethyan continental domain from Triassic to lower Miocene (Regione Marche, 1991). The oldest outcropping unit is the Early Jurassic carbonate platform, overlied by hemi-pelagic limestone (Jurassic – Eocene) and marl (Oligocene – Miocene)

In the Montefeltro, in the north-west, the Miocene deposits of the Umbria-Marche-Romagna succession are overthrust by Ligurian and Subligurian Units in the Marecchia Valley klippe (Fig. 1). The Ligurian Units mainly consist of mudstone and marl, while Subligurian Units are mudstone deposits containing clasts, conglomerates and a thick competent level, formed by San Marino Fm. (limestone) and Monte Fumaiolo Fm. (sandstone). This level has an important morphologic result in the surrounding argillaceous rocks.

The Apennine tectonic uplift reached its acme in the late Miocene – lower Pliocene, and was accompanied by the deposition of thick siliclastic foredeep units, with a progressive eastward migration of the thrust fronts and foredeeps. The sedimentary evolution was also influenced by the salinity crisis that occurred in the Mediterranean Sea during the Messinian (late Miocene), which caused the deposition of evaporites (gypsum and salt), shales and organic marls

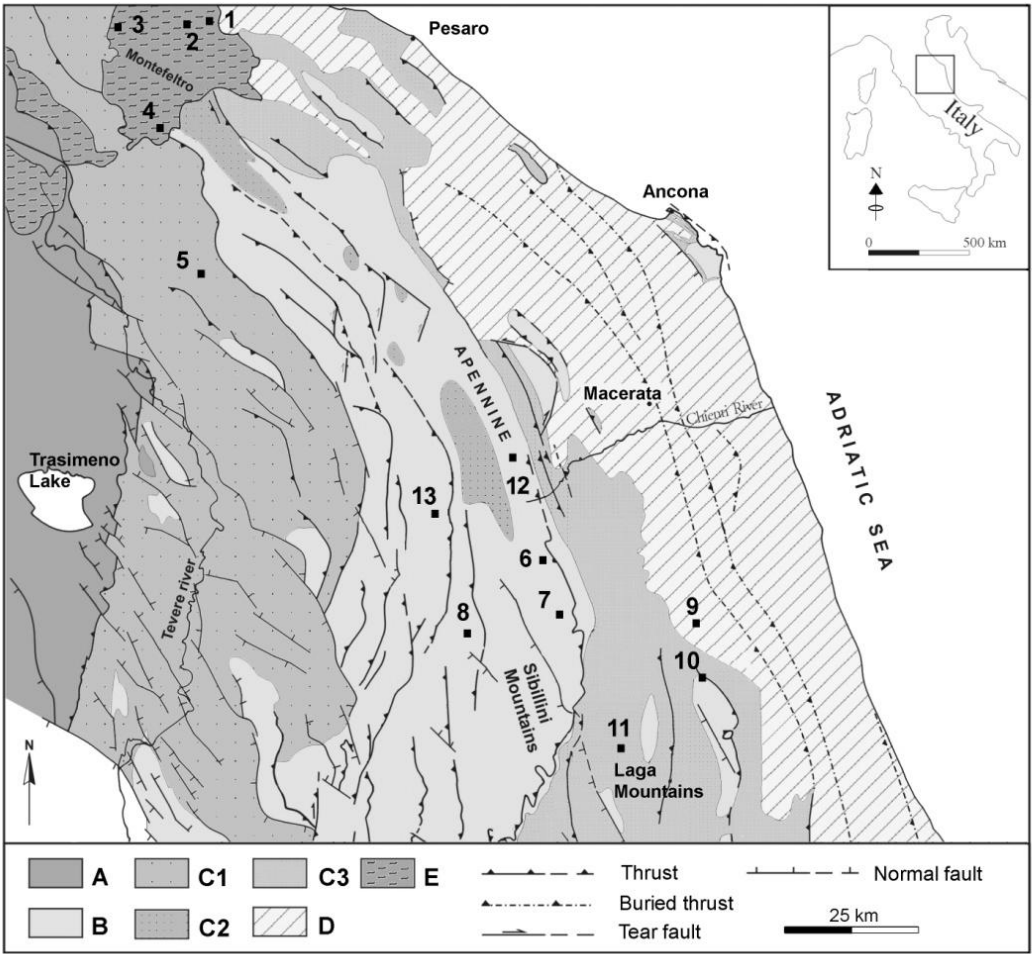


Fig. 1. Geologic map, showing the location of the sites studied

A – Tuscany Units; B – Calcareous, marly-calcareous and marly Umbria-Marche succession (Lias-Miocene); C – Umbria-Marche siliciclastic turbiditic deposits: (1) Internal (Preapennine) area (Burdigalian-Tortonian); (2) Intra-Apennine basins (Tortonian-Messinian); (3) Foothill area (Messinian); D – Plio-Pleistocene peri-Adriatic succession; E – Liguride and Subliguride Units.
1 – San Marino; 2 – San Leo; 3 – gypsum caves; 4 – Sasso Simone; 5 – Apecchio; 6 – Voragine Arcobaleno; 7 – Ambro Valley; 8 – Panico Valley; 9 – Fossa del Lupo; 10) San Marco travertine; 11) Laga caves; 12) Sant'Eustachio caves; 13) Piano di Monte Lago

The Miocene turbidites and evaporites outcrop in the hilly inland, generally close to the limestone mountains of the Apennines Chain. (Fig. 1). In the south-east sector the Miocene turbidites are known as Laga Formation, mainly arenitic, whose thickness gradually increases toward the south and exceeds 3000 m in the Laga Mountains.

The Plio-Pleistocene succession (~ 3000 m thick) characterizes the Adriatic hilly zone, it is mainly formed by hemipelagic mudstones and contains some thick, conglomerate-rich turbidites, overlain by shallow marine deposits. The lower levels of Plio-Pleistocene succession are folded and involved in the buried thrust fronts produced into the foredeep during the latest evolutionary stages of the Apennines uplift.

At the end of lower Pleistocene, the compression in the frontal zone was accompanied by a general isostatic uplift, that also produced a tilting to the north-east. Pliocene marine deposits were uplifted at over 1000 m of altitude, and the fast deepening of the valleys destroyed a pre-existing low relief energy paleosurface. In the South of the region, the rise of thermal water from the Mesozoic carbonate units also deposited some important travertine plates inside the valleys.

Surface pseudokarst mesoforms

Dolinas are uncommon in the limestone outcrop of the Apennines, while in the same area similar close depressions due to human activity are quite diffuse. Small old quarries, used to get freestone, are known in many places. Some holes derive from excavation due to quarring or collapse in mines, while small hollows dug by charcoal burners are common in the woods. All these structures can sometimes be confused with true dolinas, when the soil fills mask their original shape and function.

Fig. 2. Kettle hollows in Val di Panico (Sibillini Mountains).

In the mountains, dolina-like features produced by natural processes are known in the alluvial deposits of the Piani (a polje-like tectono-karstic landform) and are also represented by kettle hollows in the moraines of the glacial cirque in Val di Panico, near Monte Bove in the Sibillini Mountains (Fig. 2).

Artificial caves

In the region, many caverns or tunnels were dug by humans for different reasons, and these artificial voids are generally easily distinguished by natural caves. In a few cases, however, some groups of caverns are probably due both to karst processes and human activity, and it makes it difficult to consider whether each single phenomenon is natural or artificial.

Many small caverns develop in a specific lithofacies of the Lower Jurassic limestone, represented by a low cemented grainstone. These levels are highly permeable, and the seepage of water makes the development of wide, low deep bedding-caves very common (Galdenzi, 1983). This limestone is easy to carve due to the uniform size of the grains and the low cementation. For this reason, this lithofacies was quarried in the past and used as decorative stone in public buildings. In some localities, as in Sant'Eustachio caves, the quarries were inside caves, completely or at least partly excavated by humans, where recognizing the importance of natural and artificial contribution can be difficult.

In the Monte Lago area, a group of small caves were produced mainly by sulphuric acid speleogenesis due to pyrite oxidation (Galdenzi et al., 2008). Some of these caves show evidence of human modification, and it was already suggested that they were in part dug by man to get limonite deposits. The subsequent discovery of an ancient mine in the same place confirms that mining contributed to the creation of some parts of the existing caves.

Weathering caves

Small, superficial caves produced by weathering are known in many different settings, but they are quite common in the periglacial breccias of the mountain zones and in the Laga Formation, where the most beautiful and significant examples are situated.

Periglacial breccias

Slope deposits consisting of limestone and chert breccias formed diffusely in the mountain zone during the cold periods of Pleistocene, when glacial or periglacial conditions extended in the whole zone. The seepage water circulation produced calcite precipitation, therefore breccias are irregularly cemented, alternating hard beds, completely lithified, with prevailing low or not cemented levels

The general deepening of valleys and the running water in the slopes caused the differential erosion of the breccias, where the low cemented beds were removed, producing small caves supported by the cemented layers (Fig. 3). Small shelter caves are known in different places, and some of them can have a certain speleologic interest.

Sandstone

Different types of caves are known in the Miocene siliclastic turbidites (Laga Fm.), comprising bedding caves and niches (sensu Vitek, 1983). This unit is formed by sandstone and claystone, that alternate in different percentages, varying from mainly fine deposits to almost pure sandstone, in thick strata divided by thin layers of claystone. This last lithofacies is the most favourable for the cave formation, that typically occurs below the thick sandstone levels, for the alteration of the underlying clays. These bedding caves can be quite wide (Fig. 4) and were often used as temporary shelter in the mountains or as sheep-fold and deposits near the villages

Fig. 3. Differential erosion in periglacial breccias (near Monte Lago)

Fig. 4: Noce Andreana Cave, in the Laga Mountains.

Niches inside the sandstone levels are common, mainly consisting of tafoni with different sizes, sometimes in groups of small hollows and cupolas (Fig. 5). The tafoni are often associated with honeycomb and other erosional wall features (Fig. 6)

Caves and tafoni are less common in the Plio-Pleistocene sandstones, probably because these deposits are less lithified than Laga Fm., and it doesn't favour their development and preservation.

Fig. 5: A group of small tafoni in Noce Andreana Valley.

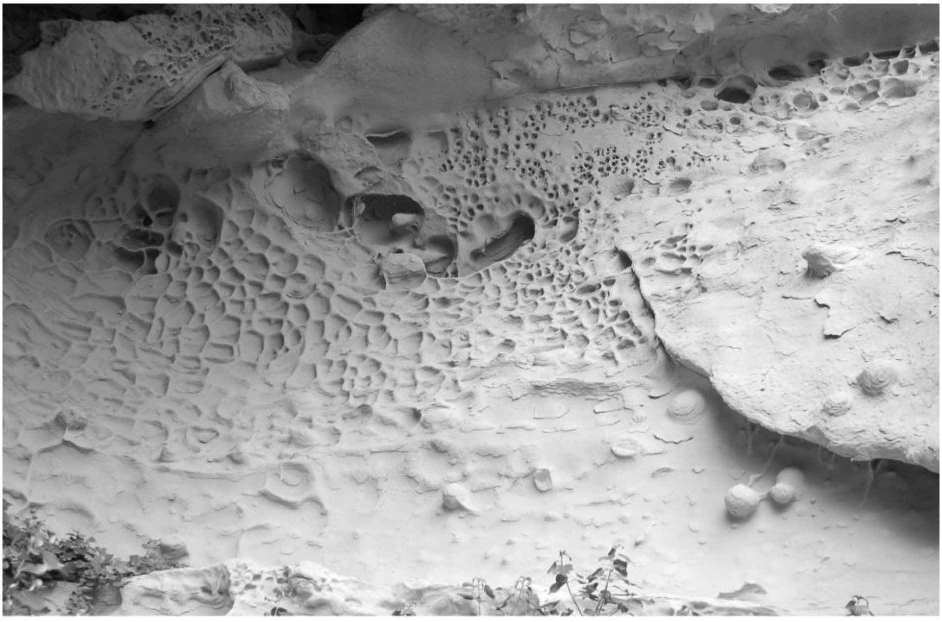


Fig. 6: Wall erosion in the Laga Mountains

Landslide caves

Cracks and caves formed by extensional movement in coherent rocks can form anywhere close to steep slopes and cliffs, but important systems of open and debris-filled cracks or caves are related to specific stratigraphic and geomorphic settings, generally inside karst-bearing rocks:

- upper Miocene gypsum, a few tens of meters thick, overlying shales;
- Miocene limestone and sandstone, over 100 m thick, overlying clasytone in the Montefeltro region;
- Pleistocene travertine, up to 100 m thick, overlying Miocene marls in the Tronto Valley;
- Pliocene conglomerate levels, a few tens of meters thick, interbedded with claystone.

These thick layers of competent rocks overlying soft and low-permeability argillaceous materials are affected by diffuse gravitational phenomena that produce the pseudokarst morphologies. Similar phenomena can also develop in the mainly carbonate Umbria-Marche succession, where the interbedded marl formations represent the detachment surface.

Messinian gypsum

The Messinian evaporitic sequence, mainly constituted by shales and organic marls, often contains gypsum strata that sometimes are a few tens of meters thick. Surface erosion easily removes the weak overlying shale and clay, and the gypsum layer can remain in relief, bordered by steep slopes, where small fissures and crevasses form, due to the effect of gravity

San Marino Formation

In the Montefeltro region, inside the mainly argillaceos rocks of Ligurian and Epiligurian successions, the San Marino and Monte Fumaiolo Fms. (Miocene) represent an important competent level, over 100 m thick. The San Marino Fm. consist of organic limestone, while the overlying Monte Fumaiolo Fm. has an arenitic composition, and the whole level has an important morphologic result in the surrounding sliding argillaceous hills

The outcrops of these formations are generally bordered by steep cliffs, and sometimes they form isolate rocky slab bordered by steep cliffs on all their sides, as in San Leo, Sasso Simone, and Simoncello (Fig. 7). Peacks and cliffs were often utilized to build castles and fortified towns in the Middle Ages, but they are also interesting for karst and pseudokarst landforms. This competent level is affected by diffuse instability phenomena, due to local block falls and deep-seated gravitational movements (Cancelli et al., 1987).

Close to the steep cliffs extensional movements cause a progressive widening of the joints, and produce toppling and block falls in the cliff walls, also favoured by the seepage of water to the underlying argillaceous substratum. Some of these cases are well studied to define the geotechnical parameters and stabilize the cliffs near built-up areas or castles. Depressions, cracks and small fissure or crevasse caves are known near these cliffs. The deepest reported cave in this setting is located in Tausano, a hamlet near San Leo, and it is unexplored owing to the danger of rock falls (the deepth was estimated in ~ 80 m, Bambini R., personal communication).

Fig. 7. Sasso Simone. Miocene limestone overlying claystone in the Montefeltro (Photo: Roberto Bambini).

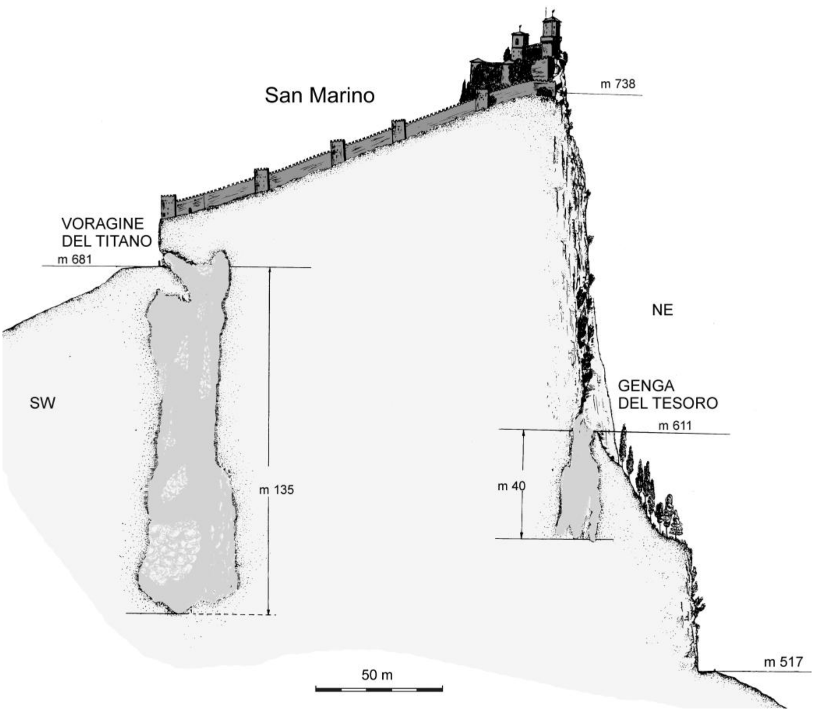


Fig. 8. Voragine del Titano, San Marino Republic. (re-drawn, based on survey: Biondi P.P., Bentini L. - G.S. Faentino, 1963)

More important phenomena are produced by deep-seated movements that involve the whole rocky slab overlying the claystone substratum. The cambering of the competent level and the extensional movements produce important fractures that cross the whole slab. On the surface, depressions, open or debris-filled cracks, and sometimes caves develop parallel to the marginal cliffs. The infiltration and percolation of water through the open fractures to the argillaceous substratum enhance the progress of landslides.

Open fractures can prosecute into deep and wide crevasse caves. The most important is in San Marino Republic, where two caves open near the top of the steep fortified cliff, inside the same fracture. The most important cave is the Voragine del Titano, that was joined by speleologists with the Genga del Tesoro, reaching a total depth of ~160 m (Fig. 8). The features of the caves are only influenced by breakdown and block collapse. In the same limestone slab the groundwater drainage can also form active karst caves.

Pleistocene travertine

In the southern part of the region, the rise of thermal sulfidic water from the buried carbonate Umbria-Marche succession formed wide travertine plates that overly Miocene marls (Boni and Colacicchi, 1966). The travertine is constituted by pure limestone, up to 100 m thick, deposited in lenticular terraced bodies in the southern side of the valley of Tronto river. The depositional setting produces morphologic conditions similar to those described for San Marino Fm.. Isolate slabs of competent limestone overlies claystones and marls, that have a long-term ductile behaviour, also for the imbibition due to seepage of water trough the limestone.

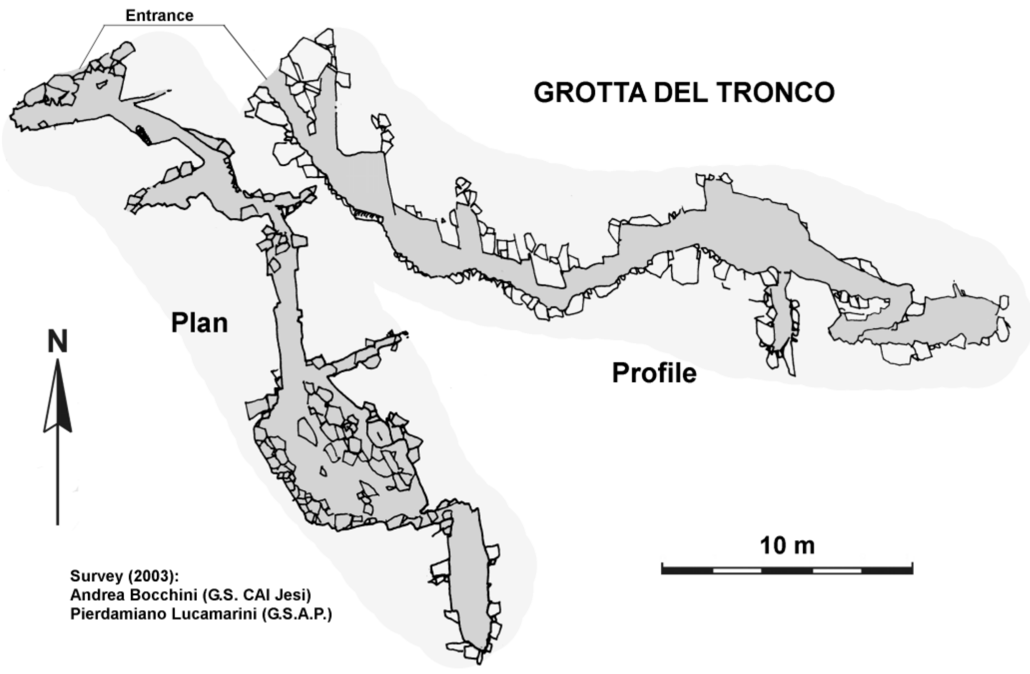


Fig. 9. Crevasse caves in the Colle San Marco travertine

Several small caves are known in one of the largest travertine plates (Colle San Marco, near Ascoli Piceno). They are located at the foot of the main cliff, inside a set of orthogonal open fractures produced by extensional gravitational movements in the travertine slab (Fig. 9). The caves are only weakly modified by the solutional or depositional action of seepage water, and can cut small pre-existing karst caves, developed before sliding produced the main void (Berluti Lorenzini et al., 2003).

In the surface of the slab long linear depressions and open cracks produced by extensional movements were explored, reaching a depth of ~ 30 m, without any evidence of solution processes (Selvaggio R., personal communication).

Umbria-Marche carbonate succession

Important deep-seated gravitational movements develop in the Meso-Cenozoic carbonate sequence, where they are favoured by the rapid deepening of the valleys that produced steep slopes in the Middle and upper Pleistocene. The interbedded marl formations represent the failure surfaces, and the slides involve the whole thickness of the overlying competent levels. The rock fracturing produces closed depressions, cracks and caves in the surface. Slides often occur in the Scaglia Rossa Fm., that is thin-bedded and overlies an important Cretaceous marl level, the Marne a Fucoidi Fm. (Farabollini et al., 1995)

Most interesting examples are in the Sibillini Mountains: a shaft cave (Voragine Arcobaleno) represents the crown of a slide, where some open crevasses descend 10-20 m from the surface in the Scaglia Rossa Fm. In the Ambro Valley, a large slide involves the Jurassic succession, that contains a middle Jurassic marl level (Fig. 10). The slide involves the overlying levels, over 100 m thick, consisting of cherty limestone and chert, and formed long surface depressions and cracks partly filled by debris in the detachment zone (Fig. 11).

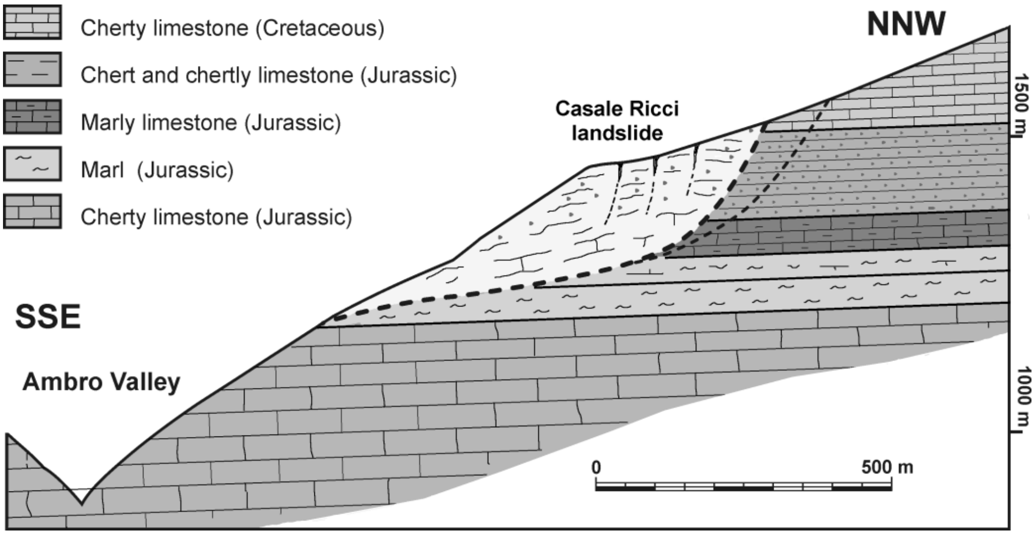


Fig. 10. Geologic section of Casale Ricci slide - Ambro Valley (Sibillini Mountains)

Fig. 11: Pseudokarst cracks in the Casale Ricci slide.

Pliocene conglomerates

An interesting cave (Fossa del Lupo) is known at Monte dell'Ascensione (m. 1103), inside coarse-grained turbidites interbedded in the Pliocene hemipelagic claystone (Cantalamessa et al., 2009). Some conglomerate levels a few tens of meters thick are exposed on the south-western mountain side (Fig. 12). Here in the steep slopes the claystone levels are deeply eroded by running water, while the north eashern slope is less inclined. The cave opens as a sinking shaft near the top of the mountain and descends inside weakly cemented conglomerate. Some successive shafts quickly reach ~ 75 m of depth, where the cave

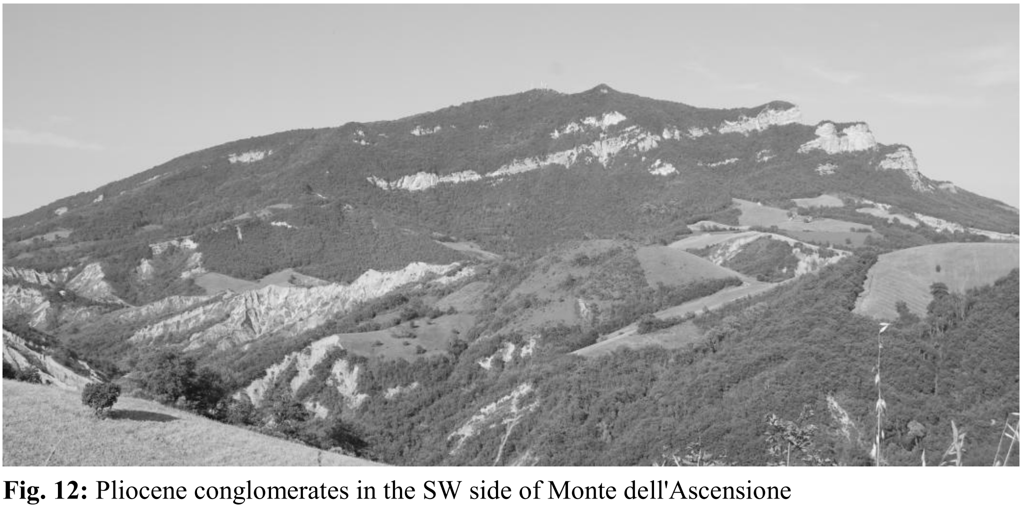


Fig. 12: Pliocene conglomerates in the SW side of Monte dell'Ascensione

continues along a vertical narrow fissure in a gently inclined passage, explored up to -80 m (Fig. 13). An active flow of water occurs in the lowest part of the cave. The cave development can be related to the opening of fissures in the conglomerate levels, probably produced by extensional gravitational movements.

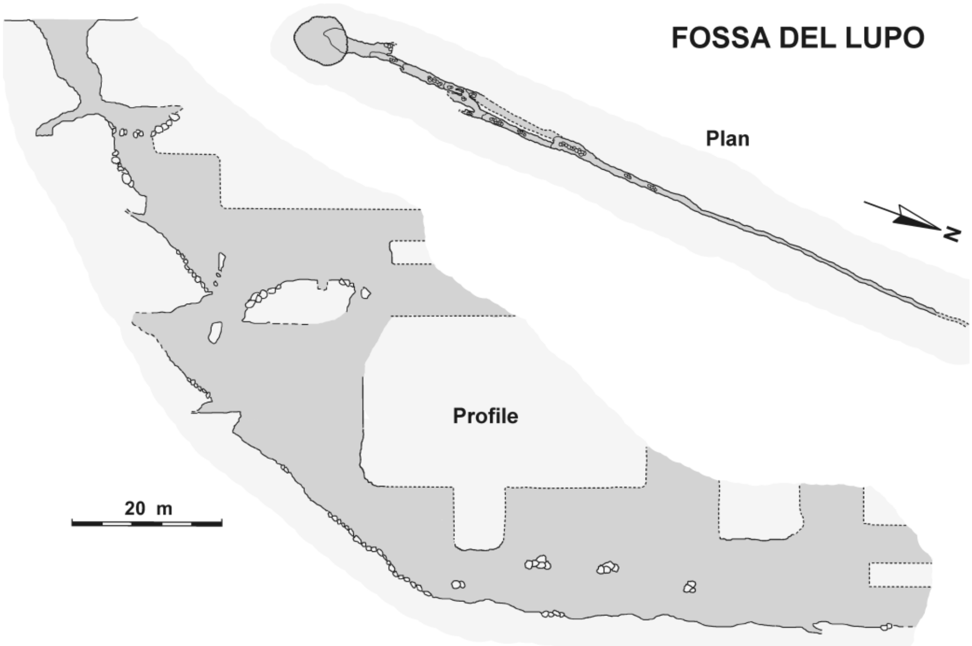


Fig. 13. Fossa del Lupo (re-drawn, based on survey by Gruppo Speleologico Marchigiano, 1983).

Deep caves in claystone

Some caves with a significant wideness develop in part or almost completely inside claystone. This type of cave occurs in specific stratigraphic setting, where thick soluble layers overly the claystone.

The cave development begins in the permeable layers owing to karst solution, but the cave widening continues as a result of stream erosion in the subjacent insoluble rocks. After the deepening of the stream, the growth of the pre-existing karst passage ceases, and the cave development continues only due to erosion caused by the flow of water in the claystone. Caves that have a similar origin are known in two different settings

Miocene turbidites

Two caves are known near Apecchio, in the north-western part of the region into Miocene turbidites, an alternation of claystone and sandstone with some thick calcarenitic layers. Each cave is ~ 250 m long (Bani and Girelli, 1999) and has a gravitational section, almost entirely developed in the low permeable and insoluble claystone, with a flat ceiling represented by the overlying calcarenite layer (Fig. 14). This first stage of cave development is due to solutional processes in the limestone, testified by the meandering ceiling channel.

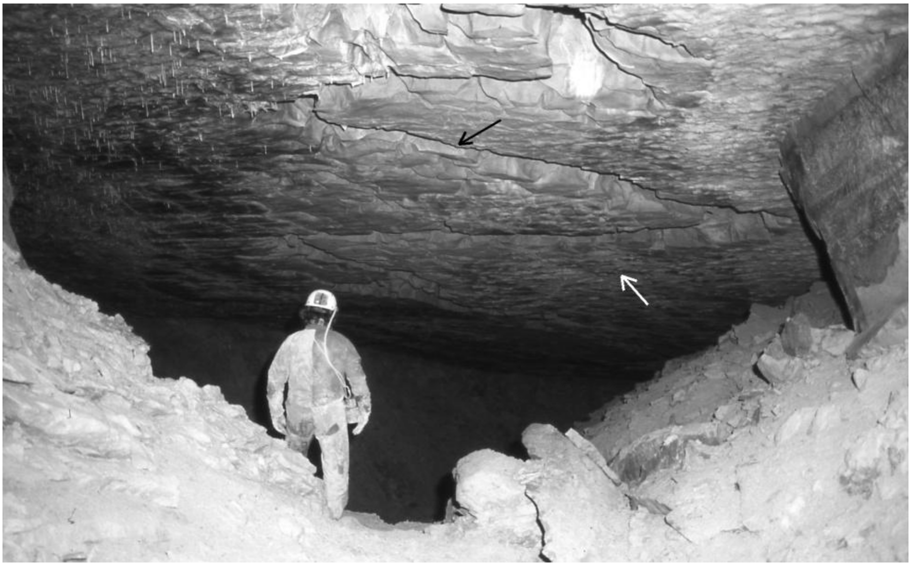


Fig. 14. The Volpe Cave, near Apecchio, developed inside Miocene claystone. The arrows indicate the ceiling channel.

The passage evolution continues due to the erosion of the claystone, until the stream water leaves the karst channel and entirely flows in the underlying insoluble layers. Stalactites in the cave ceiling are formed by dripping water coming from the calcarenite.

The prevailing role of mechanical erosion of clay in the cave formation induces to consider these caves non-karstic, even if their development begins inside the calcarenitic level with the contribution of solution processes.

Messinian evaporites

A similar evolution occurs also in some caves in Messinian evaporites, where gypsum and shale layers alternate. Some caves develop in the Montefeltro (Fig. 1) inside the gypsum-rich bodies of the evaporitic succession, and their pattern is completely conditioned by the attitude of the karstified bodies. They keep near the surface and are often related to sinking points in small blind valleys or dolinas, but a slow recharge of water also comes through permeable gypsum or arenitic beds, where the water has acquired a high content of dissolved sulphates and sulphide. A large part of the cave passages often develop in part or completely inside the shale underlying gypsum.

The development of the caves occurs due to karst dissolution inside the gypsum beds, but the deepening of the stream often cuts the underlying shales (Fig. 15). The importance of the two processes changes in different zones of the same cave, ranging from passages entirely developed in the gypsum beds or in the shales.

Even if the erosional processes locally can play an important role in the evolution of many passages, the caves are more correctly considered as karst phenomena. In contrast to the turbidite caves, such as Volpe Cave, these caves are closely related with the infiltration and the flow of water through the gypsum beds. Furthermore, they are often directly connected to classical surface karst features, such as dolinas and blind valleys

Conclusions

In the region several know caves were not formed by karst processes. Many bedding caverns and niches, with a short development, are created by differential weathering in sedimentary rocks formed by different lithologies, where the degradation of argillaceous layers or less cemented levels is the main cause of the cave widening

Fig. 15. A passage in a gypsum cave of Montefeltro, partly developed in the underlying shales (Photo: R. Bambini).

Gravitational movements are the main cause of pseudokarst cave development. Crevasse caves with similar origin are known in different geologic settings, and are more common in the presence of thick layer of competent rocks overlying claystone or shale. Solutional processes only in part contribute to the cave widening, and the water mainly have a weak encrusting action on the cave walls. Fractures and caves, however, can promote the infiltration of water inside the rock mass and in soluble rocks it contributes to feeding a karst circulation. In the presence of a low-permeable cover, the cave can also act as a sinking point, with running water flowing inside (Fossa del Lupo).

Some caves can be formed in part by solutional karstic processes, in part by simple water erosion. It occurs where strata of soluble and argillaceous rocks alternate. The cave development begins in the soluble layers for solutional processes, but the cave get wider owing to the erosion of the subjacent non-soluble rocks. The relative importance of the two processes highly changes, also inside the different parts of the same cave. These caves can be referred or not to karst based mainly on the general hydrologic and geomorphic setting

Acknowledgments

I wish to thank Roberto Bambini and Rosario Selvaggio, who provided useful information on the caves. Roberto Bambini also provided the photos in figures 7 and 15.

References

Berluti Lorenzini M., Bocchini A., de Carolis D., Lucamarini P. & Recchi G., 2003. Dati preliminari sul carsismo dei travertini a Sud di Ascoli Piceno, Italia centrale. Atti XIX Congresso Nazionale di Speleologia, 2: 61-66, Bologna.

Bani M. & Girelli L., 1999. Speleogenesi nel flysch dell'Appennino Umbro-Marchigiano. Speleologia, 40: 5-12.

Boni C. & Colacicchi R., 1966. I travertini della valle del Tronto. Memorie Società Geologica Italiana, 5: 315-339

Cancelli A., Pellegrini M. & Tosatti G., 1987. Alcuni esempi di deformazioni gravitative profonde di versante nell'Appennino settentrionale. Memorie Società Geologica Italiana, 39: 447-466.

Cantalamessa G., Di Celma C., Potetti M., Lori P., Didaskalou P., Albianelli A. & Napoleone G., 2009. Climatic control on deposition of upper Pliocene deepwater, gravity-driven strata in the Apennines foredeep (central Italy): correlations to the marine oxygen isotope record. In: External Controls on Deepwater Depositional Systems. Society for Sedimentary Geology Special Publication N. 92: 247–259.

Crescenti U., D'Offizzi S., Merlino S. & Sacchi L., Eds., 2004. Geology of Italy, Special Volume of Italian Geologic Society for the 32th International Geologic Congress, Florence, p. 234.

Farabollini P., Folchi Vichi D'Arcevia C., Gentili B., Luzi L., Pambianchi G. & Viglione F., 1995. La morfogenesi gravitativa nelle formazioni litoidi dell'Appennino centrale. Memorie Società Geologica Italiana, 50: 123-136.

Galdenzi S., 1983. Le cavità d'interstrato nel Calcare Massiccio: un esempio nella gola del torrente Rudielle (Marche). In: Atti XIV Congresso nazionale di speleologia, Bologna 1982. Le Grotte d'Italia, (s. 4) 11: 467-474.

Galdenzi S., 2004. Il carsismo nella regione marchigiana. In: Galdenzi S. (Ed.) - Frasassi 1989-2004: gli sviluppi nella ricerca. p. 6-20, Jesi.

Galdenzi S., Paggi S. & Pistolesi E., 2008. Le grotte di Sefro. UTJ, Jesi, 32 pp.

Galdenzi S., 2009. Hypogene caves in the Apennines (Italy). In: Alexander B. Klimchouk A.B. & Ford D.C. (Eds.), Hypogene speleogenesis and karst hydrogeology of artesian basins. Ukrainian Institute of Speleology and Karstology, Special Paper 1: 101-115.

Guerra M., 2001. San Leo e Maioletto. In: Ciarapica G. & Passeri L., Eds., "Appennino Umbro Marchigiano". Guide Geologiche Regionali, 7(2): 23-29.

Regione Marche, 1991. L'ambiente fisico delle Marche. 256 pp., S.E.L.C.A. Firenze.

Vitek J., 1983. Classification of pseudokarst forms in Czechoslovakia. International Journal of Speleology. 13: 1-18

Microclimatological survey of the Ice Gulch in the White Mountains, New Hampshire, USA

David Holmgren, Andreas Pflitsch

Workgroup of Cave & Subway Climatology, Department of Geography,
Ruhr-University Bochum, Germany

Due to their change from the Ice-buildup phase to the ice-depletion phase during the year, ice caves, such as the "Schellenberger" ice cave in Bavaria, can be seen as an outstanding climate indicator for short-term and long-term changes within the climate of their respective region. Alongside the frequently well-known and often enlarged show caves there are also so-called ice gulches, in which we can find ice-carrying parts during the whole year due to their extraordinary topography. The significant detail about these ice holes or little cave-like formations that are often situated in the talus pseudokarst is that the ice can outlast in altitudes, which are far below the summery snowline. During the fall of 2008 the Workgroup of Cave & Subway Climatology of the Department of Geography of the Ruhr-University Bochum started, in cooperation with the Mount Washington Observatory in NH (USA), a microclimatic analysis of a perennial ice carrying gulch in the White Mountains.

The so-called "Ice Gulch" is a gulch situated in the North-American Appalachian Mountains with an east-southeast alignment and an average hillside-inclination of 14%. It can be located 16km north of Mount Washington in NH on the eastern flank of Mt. Crescent at a height of 605 – 770 m above sea level. The steep towering cliffs with a height of about 85 – 100 m on the northeastern- and southwestern side limit the insolation conditions throughout the whole year. Additionally, the width of the gulch – about 80 m - reduces the insolation conditions. The debris is made up of blocks of granite with an average diameter of about 0,6 – 1,5 m, in some cases blocks can be found in the gulch with a diameter of up to 3 m. Annually new blocks of debris fall into the Ice Gulch due to frost wedging.

One characteristic of the gulch is a permanent ice between rocks of a former toppling in an altitude of just 670m above sea level; in contrast to this Mount Washington with its height of 1917m is ice-free from May to September.

The project's goal is a microclimatic analysis of this particular ecosystem with the following questions:

- Determination of the number of ice carrying holes and caves;
- Determination of the thickness of each single piece of ice during the ice-minimum in the fall and during the peak in the spring;
- Variability of ice occurrence and ice capacity in relation to the weather over a duration of many years
- Determination of the microclimatic situation within the gulch, especially in the area of hollow spaces, but also along the negative edges of vegetation, plus in comparison to the weather conditions within the region.

Ever since October 2008 progressive studies based on the temperature measurements of temperature loggers that had been placed in various places within the gulch, have been carried out. During the times of the potential ice minimum and during their peaks thermal pictures of the blocks of granite and the bodies of ice were taken. From the middle of October 2008 and 2009, as well as from the beginning of June 2009 ice stock measurements on the bodies of ice were being conducted, to be able to assess the extent and thickness at the times of the potential minimum and peak.

In October 2009 another gulch with a comparable ecosystem was added to the project. The Mahoosuc Notch is located a few kilometers northeast of the Ice Gulch and was also equipped with temperature sensors, to add on to the previous researches and to offer additional hints to the understanding of this special climatope.

Furthermore, the researches are supposed to offer hints concerning the climate change in New England.

Quartzite Caves of the Venezuelan Table Mountains – Speleogenesis

Tomáš Lánczos[1], Roman Aubrecht[2], Ján Schlögl[2], Miloš Gregor[3], Lukáš Vlček[4], Branislav Šmída[5], Charles Brewer–Carías[6], Federico Mayoral[6]

[1] Department of Geochemistry, Faculty of Natural Sciences, Comenius University, Bratislava, Slovakia
[2] Department of Geology and Palentology, Faculty of Natural Sciences, Comenius University, Bratislava, Slovakia
[3] Institute of Geology, Faculty of Natural Sciences, Comenius University, Bratislava, Slovakia
[4] State Nature Conservancy of Slovak Republic – Slovak Caves Administration, Liptovský Mikuláš, Slovakia
[5] Slovak Speleological Society, Liptovský Mikuláš, Slovakia
[6] Grupo Espeleológico de la Sociedad Venezolana de Ciencias Naturales, Caracas, Venezuela

The recently most accepted model for the genesis of the sandstone caves in the Venezuelan tepuis is the arenization concept presented by Martini (1979). The term "arenization" involves the dissolution of the cements in the arenitic rocks, with subsequent erosion and winnowing of the loose sand material. If the "arenization" theory was true, most of the sandstone caves could really be attributed to karst as the dissolution is considered there to be trigger process of the cave formation.

This model is fully accepted for description of quartzite caves e.g. by Briceño et al. (1991). The arenization model was also used to explain the origin of the Aonda karst system of the Auyán table mountain in Venezuela by Mecchia and Piccini (2009). However, our findings gained during two expeditions in 2007 and 2009 on the Macizo de Chimanta and Roraima table mountains in Venezuela showed that the role of quartz and/or quartz cements dissolution dominancy is questionable, therefore we propose use term "pseudokarst" for these phenomena, instead of the term "karst".

Geological and geomorphological research showed that most feasible way of the caves genesis is winnowing and erosion of unlithified or poorly lithified arenites. The unlithified arenitic beds were restricted by well-cemented overlying and underlying rocks. There is a sharp contrast between these well-lithified rocks and the loose sands which is the content of the poorly lithified to unlithified beds. They are only penetrated by well-lithified pillars formed by vertical finger-flow of the diagenetic fluids from the overlying beds. Such finger flow is typical for loose sands and soils only with containing beds with sharp difference of hydraulic conductivity. The pillars are apparently more resistent against erosion, whereas the surrounding loose sands are easily eroded. The caves are formed by erosion by flowing water accessing the poorly lithified beds through clefts. Collapse of several superposed winnowed horizons can create huge subterranean space, e.g. the Gran Galeria Karen y Fanny of the Cueva Charles Brewer cave, the biggest known quartzite cave in the world. Futher propagation of the collapses upward can lead to large collapse zones which are commonly observed on the tepuis.

Quartz and/quartz cement dissolution is also present but probably plays neither the trigger role, nor volumetrically important role in the cave-forming processes. The strongest observed dissolution/precipitation agent is the condensed air moisture which is most likely the main agent contributing to growth of siliceous speleothems. As such, it can be active only after, not before the cave is created.

Another frequently observed phemomenon in the cave systems of the Macizó del Chimantá is the red coloured mud, so-called “barro rojo” often forming huge flow bodies, up to 5-6 m in diameter. Following the results of X-ray difraction analyses this material contains kaolinite and goethite which originated by weathering of alumosilicate minerals, i.e. by their incongruent dissolution in acidic waters. Following this finding we suppose that the above described proces probably also contribute to the quartzite caves speleogenesis by weathering of sandstone layers with higher alumosilicate minerals contents (e.g. feldspars, mica, etc.).

Summarizing the information presented in the paper we conclude that the most important factor of quartzite caves speleogenesis is the predisposition of the quartzite rock bodies propagated in non-uniform lithification leading to their non-uniform erosion. Other two observed processes are corrosive. Alumosilicate weatherig (lateritization) may significantly contribute to the cave genesis, whereas quartz and/or quartz cement dissolution by condensed air moisture is less significant for the speleogenesis. The lateritization in broader sense is the only factor for which we may admit the studied caves can still be ranked among karst phenomena.

References

Biceño,H. O., Schubert, C., Paolini, J., 1991: Table-mountain Geology ans Surficial Geochemistry: Chimantá massif, Venezuelan Guyana Shield. Journal of South American Earth Sciences, 3, 179–194.

Martini, J.E.J., 1979: Karst in Black Reef Quartzite near Kaapsehoop, Eastern Transvaal. Ann. South Afr. Geol. Surv., 13, 115-128.

Piccini, L., Mecchia, M., 2009: Solution weathering rate and origin of karst landforms and caves in the quartzite of Auyan-tepui (Gran Sabana, Venezuela). Geomorphology 106 (2009) 15–25.

Quartzite Caves of the Venezuelan Table Mountains – Speleothems

Tomáš Lánczos[1], Roman Aubrecht[2], Ján Schlögl[2], Ľubomír Kováčik[3], Miloš Gregor[4], Lukáš Vlček[5], Branislav Šmída[6], Charles Brewer–Carías[7], Federico Mayoral[7]

[1] Department of Geochemistry, Faculty of Natural Sciences, Comenius University, Bratislava, Slovakia
[2] Department of Geology and Palentology, Faculty of Natural Sciences, Comenius University, Bratislava, Slovakia
[3] Department of Botany, Faculty of Natural Sciences, Comenius University, Bratislava, Slovakia
[4] Institute of Geology, Faculty of Natural Sciences, Comenius University, Bratislava, Slovakia
[5] State Nature Conservancy of Slovak Republic – Slovak Caves Administration, Liptovský Mikuláš, Slovakia
[6] Slovak Speleological Society, Liptovský Mikuláš, Slovakia
[7] Grupo Espeleológico de la Sociedad Venezolana de Ciencias Naturales, Caracas, Venezuela

Caves formed in silicate rocks often host siliceous speleothems formed dominantly by opal. Unlike in carbonate speleothems, microbial mediaition is much more common during formation of siliceous speleothems. Siliceous speleothems commonly represent small forms, rarely exceeding 2 cm in size. The speleothemes occurring in the investigated quartzite caves of the Venezuelan quartzite caves of the Macizo del Chimanta and Roraima table mountains during our expeditions in 2007 and 2009 are characterized by enormous variability in size and morphology and most of them bear signs of microbial origin.

Many of the speleothems remind classical stalactites and stalagmites known from limestone caves but their structure and genesis are different. Apart from variable shapes, the microbial speleothems show identical principal texture, corresponding to various stages of their evolution.

They consist of two principal zones: Laminated columnar stromatolite, consisting of finely laminated non-porous layers of pure compact opal, intercalated by some zones of filamentous microbialite, with thin filaments oriented in the direction of the stromatolite growth. SEM study of the etched surfaces of the columnal stromatolite showed that it mostly consists of concentric laminae formed by dense parallel tubes representing casts after filamentous microbes. The microbes are most similar to filamentous cyanobacteria from the order Oscillatoriales (Golubic, 1976). In other places, irregular, larger-scale, double-layered cross-sections of microbe tubes occur. They resemble casts after cyanobacterial cells of the genus Cyanostylon or Entophysalis (Golubic, 1976).

Strongly porous zone peloidal microbialites formed by white chalk-like opal, represents accumulation of microbial peloids and forms mostly the outer zones of the speleothems. The peloids are densely packed, arranged in concentric laminae. The size of peloids varies from 0.1 to about 0.3 mm. Microscopic study revealed that the peloids are formed by Nostoc-type cyanobacteria. Fungal hyphae, metazoan and plant remains also subordinately contribute to speleothem construction.

In many places, initial colonization of the surface by Nostoc-type cyanobacteria was observed, forming mats and shrubs covering the underlying arenites. The microbial filaments are commonly encrusted by white silica, whereas the surrounding arenites are intact. This is a strong evidence that the microbes were not only passively encrusted by silica but the encrustation was microbially mediated, either by their metabolism, or by changing physico-chemical cionditions.This phenomenon is common in the limestones but it was not yet evident for the siliceous microbialites. Presence of cyanobacteria, which are otherwise phototrophic organisms in caves is not so surprising as it seems to be. Some cyanobacteria do not withstand an excess solar light that can damage their cells (Vincent and Roy, 1993; Quesada and Vincent, 1997).Some of them produce protective pigments in extracellular sheath (e.g.. Lyngbya estuarii produces pigment scytonemine - Kylin, 1937); others are even able to protect themselves against the excess light by boring the substrate, e.g. endolithic boring cyanobacteria Hormathonema and Hyella (Golubic, 1976). The genera Fisherella and Calothrix are even able to change their mode of life to slow heterotrophic in complete darkness (Whitton, 1987). The most convincing fact is that some cyanobacteria, e.g. Geitleria calcarea and Scytonema julianum were found to live in caves (Friedman, 1955; Bourelly and Depuy, 1973). It is obvious that the cyanobacteria in Venezuelan caves are also adapted to heterotrophic life mode.

Some speleothems, e.g. the cobweb stalactites represent mostly inorganic precipitates, encrusting various structures, such as spider threads. There are also large inorganically precipitated stalactites and flowstones. Comparing the size of the speleothems from various caves, there seem to be dependence between the cave size and speleothems size. Cueva Charles Brewer and Cueva Colibri hosts the largest recorded silica speleothems (up to several dm in size) whereas those in other caves were not so large (cm to dm. size).

The reason for the size dependence between the caves and the speleothems is yet unclear. One of the possible explanations would be that the larger the cave is, the more siliceous material undergoes the dissolution/reprecipitation cycle. Larger cave corridors and galleries e.g. of the Cueva Charles Brewer have several times larger surface than other caves available for the condensed air moisture which plays the most important role in the cycle.

References

Bourelly, P., Depuy, P. (1973): Quelques stations françaises de Geitleria calcarea, Cyanophycée cavernicole. Schweiz. - Z. Hydrol., 35, 136-140.

Friedman, I. (1955): Geitleria calcarea n.gen. et n.sp., a new atmophytic lime-encrusting blue-green alga. - Bot. Not., 108, 439-445.

Golubic, S. (1976): Organisms that build stromatolites. In: Walter, M.R. (ed.): Stromatolites. Developments in Sedimentology 20, Elsevier, 113-126.

Kylin, H. (1937): Über die Farbstoffe und die Farbe der Cyanophyceen. - K. Fysiogr. Sällsk. Lund, Förh., 7, 131-158.

Quesada, A., Vincent, W.F (1997): Strategies of adaptation by Antarctic cyanobacteria to ultraviolet radiation. - Eur. J. Phycol., 32, 335-342.

Vincent, W.F., Roy, S. (1993): Solar ultraviolet-B radiation and aquatic primary production: damage, protection, and recovery. - Envir. Rev., 1, 1-12.

Whitton, B.A. (1987): The biology of Rivulariaceae. In: FAY, P. & van BAALEN, C. (eds.): The cyanobacteria – a comparative review. Elsevier, 513-534.

Crevice type caves of Polish Flysch Carpathians and their connection with development of surface mass movements

Włodzimierz Margielewski[1], Jan Urban[1], Czesław Szura[2]

[1] Institute of Nature Conservation, Polish Academy of Sciences, Kraków, Poland
[2] Association for the Caves Conservation „Malinka Group",Wisła, Poland

The crevice type caves developed due to the widening of fractures (dilation) along the discontinuity surfaces within rock massifs (joints, faults) owing to the unloading of shearing stresses. The caves, which are yielded by tension surfaces, represent the initial stage of gravitational fragmentation of slopes in the Flysch Carpathians. Propagation of fractures (as tearing surfaces) is continued till the extend of marginal strain and destruction of rock massif due to the gravitational movement of its fragment. Various types of subsequent movements can be distinguished: fall, topple, lateral spreading, rock flow or landslides – translational, rotational, compound or their combination. Crevice type caves could form during the initial stage of mass movements (e.g. Jaskinia Zbójecka Cave in the Gorce Mts.) or contribute to development of successive generations of mass movements within previously formed landslides (as Jaskinia Złotopieńska Cave in Łopień Mt., Beskid Wyspowy Mts.) (Margielewski, Urban, 2003, Margielewski, 2006).

Occasionally the crevice type caves developed along the sliding (failure) surfaces of landslides due to fissure macrodilatancy – a process of rock massif bulk in volume increase within the destruction zone due to the opening of fractures and increasing of their density during the movements. The example of such a form (developed due to the dilatancy process) is the Jaskinia Miecharska Cave in the Beskid Śląski Mts. – maze system of widened fractures totally 1810 m long, formed within the sliding zone of consequent-rotational landslide (Margielewski et al., 2007).

Common occurrence of non-karstic caves in the Flysch Carpathians (more than 1000 caves have been explored there – Klassek, Mleczek, 2009) indicates, that the mountains slopes represent various stages of gravitational disintegration. Extremely strong initial factor (e.g. intensive rainfalls, earthquakes) can generate frequent finalization of mass movements (landslides), which were previously prepared in the process of the tension cracks' propagation. This thesis is confirmed by radiocarbon datings of stalactites occasionally occurring in the crevice type caves.

The crevice type caves, as forms important for the geo- and biodiversity (bats, invertebrate fauna) of the mountainous areas (environments) represent object requiring protection, although some of them can be arranged for tourist access.

References

Klassek G., Mleczek T. 2009. Eksploracja i inwentaryzacja jaskiń polskich Karpat fliszowych (wrzesień 2008-sierpień 2009) (in Polish). In: Szelerewicz M., Urban J., Dobrowolski R. (eds.), Materiały 43. Sympozjum Speleologicznego, 16-18.10.2009, Zamość. Sekcja Speleol. PTP im. Kopernika, Kraków: 62-65.

Margielewski, W., 2006. Structural control and types of movements of rock mass in anisotropic rocks: case studies in the Polish Flysch Carpathians. Geomorphology 77, 47–68.

Margielewski, W., Urban, J., 2003. Crevice-type caves as initial forms of rock landslide development in the Flysch Carpathians. Geomorphology 54, 325-338.

Margielewski, W., Urban, J., Szura, C., 2007. Jaskinia Miecharska cave (Beskid Śląski Mts., Polish Outer Carpathians): case study of a crevice-type cave developed on a sliding surface. Nature Conservation 63(7), 57-68.

This research is supported by a scientific project No. N N306522738 granted by the Polish Ministry of Sciences in 2010-2013.

Oblique notches and ledges on natural surfaces of porous rocks: a record of past level of soil surface (central and western Europe, northeastern Africa)

Radek Mikuláš, Jiří Adamovič

Institute of Geology AS CR, Prague, Czech Republic

Oblique notches and ledges corresponding to the presumed/proved past levels of soil surface were recognized as a recurring pattern on sandstone cliffs. They were found on rock formations of the Upper Cretaceous sandstones of the Bohemian Cretaceous Basin (Czech Republic), and have been briefly reported by Mikuláš (2001, 2007). In several past field seasons, they were documented in more detail there, and analogous shapes/patterns were recognized in another areas, namely Petite Suisse (Luxembourg), Fontainebleau Forest (France) and Gíza Plateau at Cairo (Egypt). The diversity in lithologies and climatic conditions among the above mentioned areas enables us to present a relatively detailed and "robust" description of oblique notches/ledges, and to suggest their genetic classification. Also, we attempted to outline the possibilities of their interpretation, which concern especially the reconstruction of the development of past soil levels and possible man-made modifications of the outcrops.

Three morphogenetic types (1, 2, and 3) of oblique forms have been recognized within the moderately humid temperate zone of Europe; another type (4) falls to the dry subtropical zone of northern Africa. Morphogenetic Type 1 is characterized by its clear "ledge" form, and is presumably of salt- and mechanic-erosion origin. Type 2 is represented by an "overhanging step" that develops under a strong influence of case hardening (see figure). Type 3 occurs as oblique "notches" on mechanically persistent but (in the specific climate/composition) relatively easily soluble rock. Type 4 is of aeolian origin; it is specific, e.g., by larger dimensions. Despite the differences in the shape and origin, all the forms of oblique ledges/notches represent the record (often the only decipherable record) of events of sedmentation/erosion of loose substrates (soil, talus, sand dunes).

In the sandstone landscapes of central Europe (Czech Republic, SE Germany), only minimum loose sediments (taluses, slope deposits, fills of caves and abri) are pre-Holocene in origin (e.g., Cílek and Žák 2007). It is because the glacial periods were characterized by a rapid development of the rock morphology and rapid loss of loose sediments (low base level, sparse vegetation cover, and frost erosion) which were thus deposited far from their source areas. Considering the present rate of processes on sandstone surfaces, the present surfaces preserve only exceptionally pre-Holocene features. Consequently, the geologic record conveyed by microrelief, including the record encoded in oblique ledges/notches, is nearly exclusively the record of Holocene settings and events. The present study shows that oblique ledges (especially if preserved in multiple sets) document much more frequently erosion events than episodes of sedimentation. Two circumstances could easily activate the erosion of loose material in sandstone landscapes during the Holocene: 1, pluvial episodes; 2, Neolithic and early modern deforestation.

At present, correlation has been done only in a few cases in the realm of the Bohemian Cretaceous Basin (Czech Republic), where human adaptation of certain sites connected to the change of ground level was directly or indirectly dated. However, future research can be focused, among others, to the effort to correlate individual prominent ledges/notches with climatic fluctuations and/or regional and local changes of the human landscape management. We also suggest that the future research of oblique features of microrelief should be done in combination with excavations of loose material. Thus, the chance to test the reliability of oblique features as a geomorphological memory record should be further tested, not only in rather clear historically dated situations (where the origin of an oblique form is connected with human intervention in loose material of known age), but also for complex terrains.

Oblique forms of similar or clearly different origin may have the same information potential in all the as yet studied areas, i.e. Petite Suisse, Fontainebleau Forest and Giza Plateau. The ledges/notches may reflect climatic changes, direct human land-forming activity or indirect influence of human population. This seems to be very promising especially for the area of Giza Plateau, which has been studied – adequately to the contemporary knowledge and methods – since Antique times; in such cases, written record of related human activities, re-burials of buildings and also climatic events should be retrieved and compared with the geomorphic record.

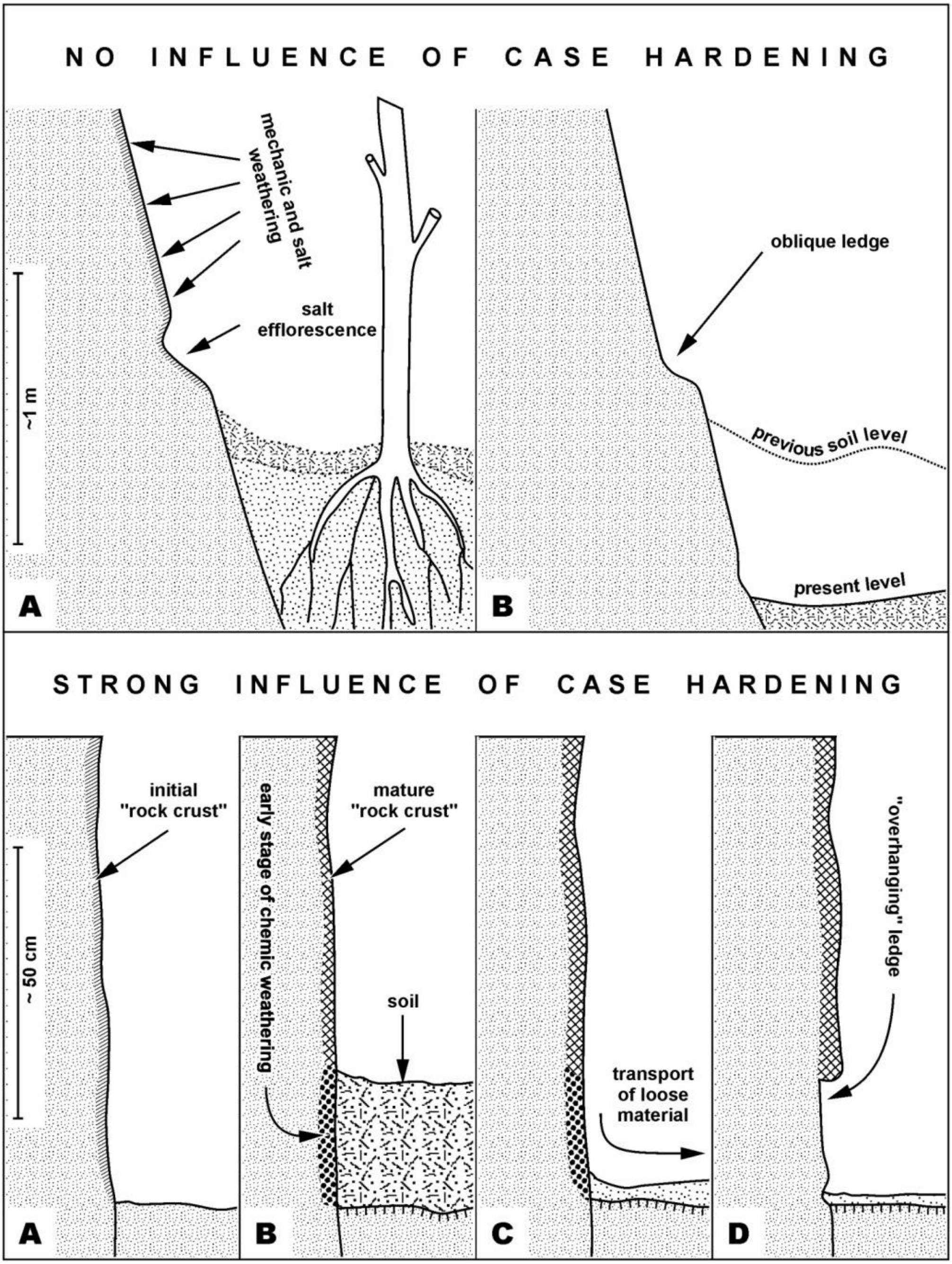
This study was funded by project No. IAA300130806 of the Grant Agency AS CR.

References

Cílek V. & Žák K. (2007). Late Glacial and Holocene sedimentation under sandstone rock shelters of Northern Bohemia (Czech Republic). In : Härtel H., Cílek V., Herben T., Jackson A. & Williams R. (eds.): Sandstone Landscapes. – Academia, Praha, p. 133-138.

Mikuláš R. (2001): Poznámky ke vzniku některých prvků mikroreliéfu pískovcových skal. – Ochrana přírody, 56, 1: 19-21. Praha.

Mikuláš R. (2007): Microforms of the sandstone relief. In: Härtel H., Cílek V., Herben T., Jackson A. & Williams R. (eds.): Sandstone Landscapes. – Academia, Praha, p. 66–75.



Origin of oblique forms of microrelief on surfaces of poorly litihfied sandstones of the Bohemian Cretaceous Basin, Czech Republic (schematic drawing). Top: Type 1; no influence of case hardening; a "normal" step is formed. Bottom: Type 2; strong influence of case hardening; a "reverted", "overhanging" step is formed.

A short treatise on Austrian Pseudokarst-Speleothems

Rudolf Pavuza

Department of Karst and Caves, Museum of Natural History Vienna,

Summary

Actual examples on pseudokarst speleothems in Austria comprise four locations of root stalagmites, two examples of biogenic, non-karst-stalactites and calcitic and limonitic speleothems in gneiss and granite. The latter have been reported frequently from abandoned mines in different geologic settings forthermore.

Root stalagmites

- four caves/tunnels/shelters with r.s. in Austria (as of 2/2010)
- sometimes two different spots in each cave
- 12 individual r.s. altogether
- in limestones, gneiss and granite so far
- 5 to 10 meters from cave entrances at most
- severe alterations controlled by dripping rates
- r.s. are obviously not abundant in Austrian caves, mines & tunnels

The four locations are situated in entirely different geological settings far away from each other.

In 2006 during a cave-cleaning action in the “Güntherhöhle” (2921/2), a small karst-cave of possible hydrothermal origin in the SE corner of Lower Austria near Hundsheim, a group of four broad-based root stalagmites below a moderately dripping wall section could be located, accompanied by a group of free standing juvenile stalagmites (Pavuza & Mayer, 2007). Since then the situation has not changed much. The biggest stalagmite barely reaches 10 cm. During the wintertime distinct icing could be observed, whereas dripping sometimes declines to nearly zero during dry periods without major deteriorations of the root stalagmites.

The most likely corresponding plant, situated come 10 m apart from the root-stalagmites is a wild pear (Pyrus pyraster).

The age of these examples remain unclear despite the fact that they are situated along the often used walkway in the cave.

Fig. 1. Root stalagmites in the "Güntherhöhle" (Hundsheim, Lower Austria)

In a vast second world war tunnel ("Rudolfstollen"), constructed in coarse gneiss of the southern bohemian massif in the city of Linz (Upper Austria) two groups of root stalagmites have been detected in 2007 (Pavuza, 2008).

They formed behind an entirely walled entrance where the roots subsequently penetrated this structure.

In this case during the dry period, where the feeding dripwater almost declines to zero there a severe deterioration can be observed. The root stalagmites loose nearly all of their fine, light coloured roots – a process which is enhanced by feeding isopoda producing dark columns similar to the well known root stalagmites described from several locations in Europe. The tallest individual reaches barely 10 cm. Some smaller individuals have vanished as the feeding dripwater changed its path.

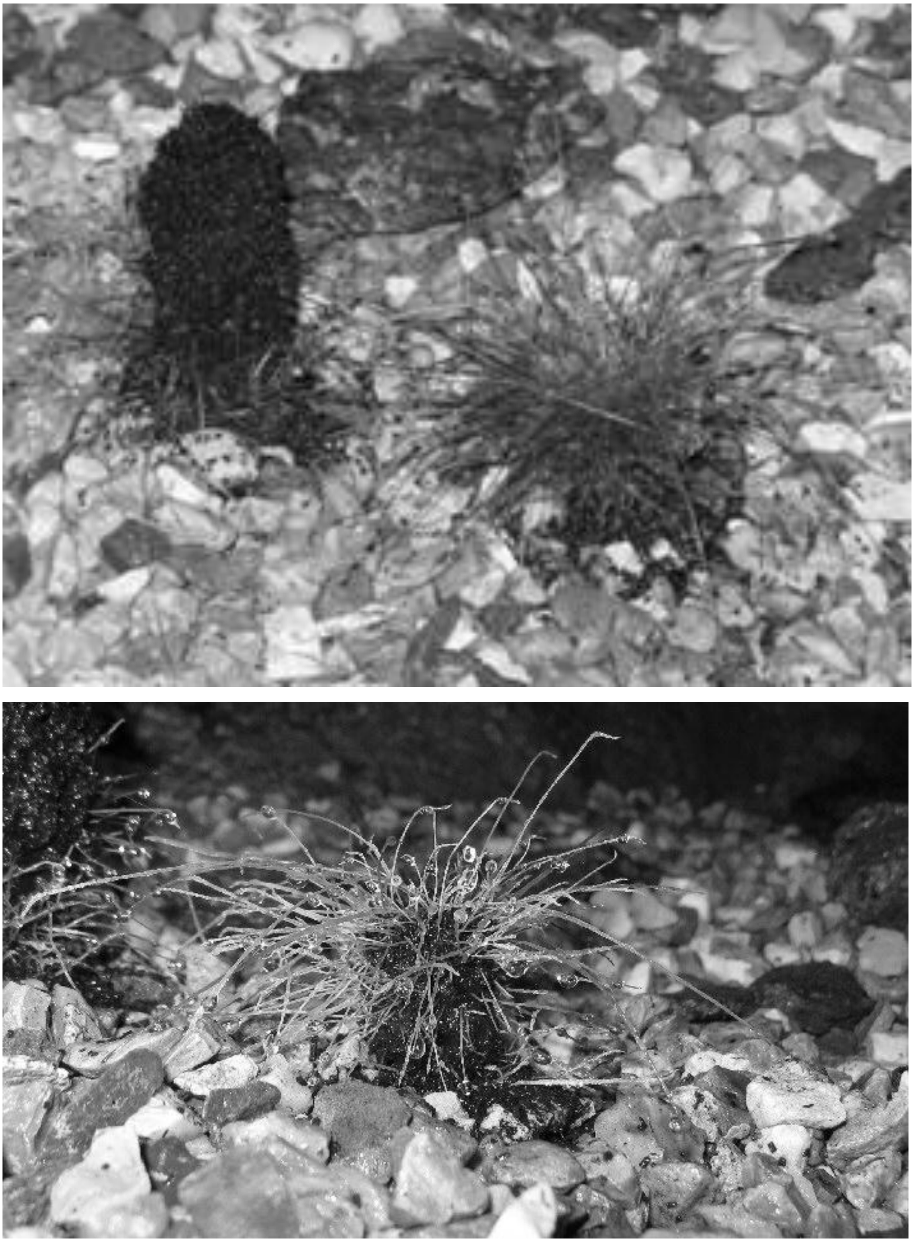


Fig. 2. Root stalagmites in the “Rudolfstollen” in Linz, Upper Austria

The third location lies in the Greywacke zone in central Styria near the city of Leoben. Situated in a so far unmapped, nameless cave in paleozoic limestones a massive root stalagmite, being some 15 cm tall, with striking hair-roots and a dripping hole could be observed by the Austrian caver Harald Pliessnig (Pavuza, 2010). This spot lacks closer investigation so far.

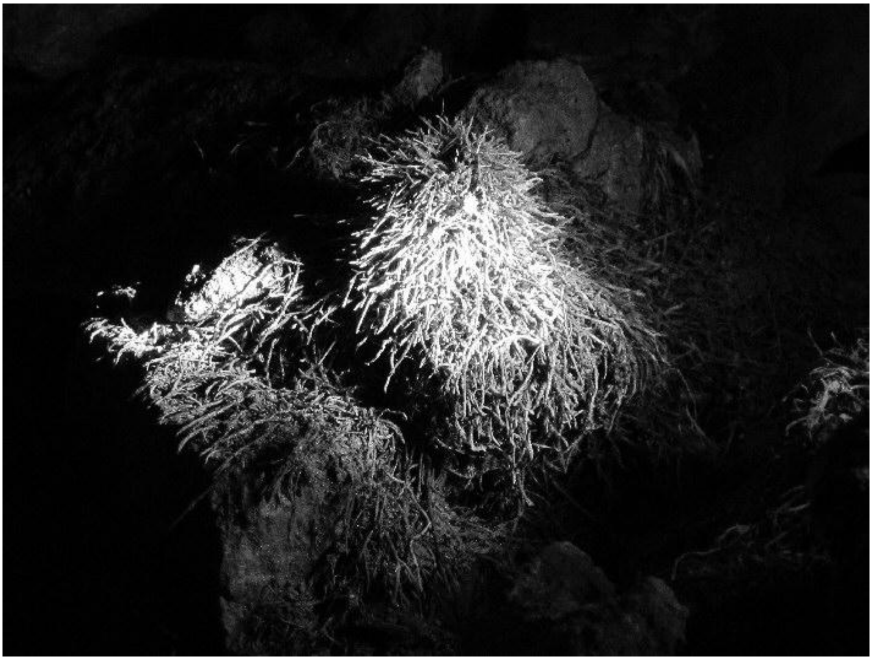


Fig. 3. Root stalagmite in an unnamed cave near Leoben (Styria)

The most recent discovery has been reported from the "Luagalucka" (6845/170), a small cave in coarse-grained granites of the southern bohemian massif near Altmelon in Lower Austria. Near the entrance a peculiar stalagmite formed composed of degraded organic debris most likely surrounding a root core.

Biogenous stalactites

Near the entrance of caves and small shelters with an increased water flow some stalactite-like features an be observed, consisting of slimy coatings of bacteria respectively branches of certain mosses in combination with algae and bacteria.

In no case it was possible so far to monitor the development of these features over a longer period in order to document their development and consistency.

Slimy bacterial stalactites

During an expedition Austrian caver Eckart Herrmann discovered peculiar stalactites composed of a jelly-like matrix in the "Schneekarturm – Halbhöhle" (1712/54))in the high alpine mountain range of the "Gesäuse" (Styria) at an altitude of 1820 m a.s.l. This small cave is most likely related to physical weathering of the dolomitic host rocks and can be considered as a pseudokarst-cave within a karst area.

Investigations showed that the matrix of the tiny, up to 3 cm long stalactites is comprised of Blue Algae (Nostoc sp.). In this environment Green Algae (cf. Palmella sp.), Diatoms (Navicula sp.) and Wheel Animalcule (Rotaria sp.) encounter an ideal substrate. The feeding dripwater seems to be persistent even during the dry summer months. Moderate but distinct light still enables photosynthesis.

Being the only known habitat in Austria currently, it is obvious that this phenomenon probably exists elsewhere too, but may have be overlooked so far due to its limited potential occurrence near the cave entrances and its small size.

Fig. 4. Bacterial stalactites in the “Schneekarturm-Halbhöhle”, Gesäuse (Styria)

Moss related stalactites

Spring tufa can be encountered in karst areas as well as non karst areas with a certain amounts of carbonate content (like sandstones, shales…).

In an area dominated by glacial sediments in the Lammer Valley near Annaberg (Salzburg), surrounded by the high alpine karst massifs of Tennengebirge and Dachstein, a tufa producing spring emerging from glacial moraines formed a tiny cave where incrustations of mosses, algae and bacteria form stalactite-like, somewhat clumsy dripstones – “biogenic pseudo-stalactites” – up to a length of 15 cm. It can be assumed that the growth rate of these features exceeds the ones of karst-speleothems by several orders of magnitude.

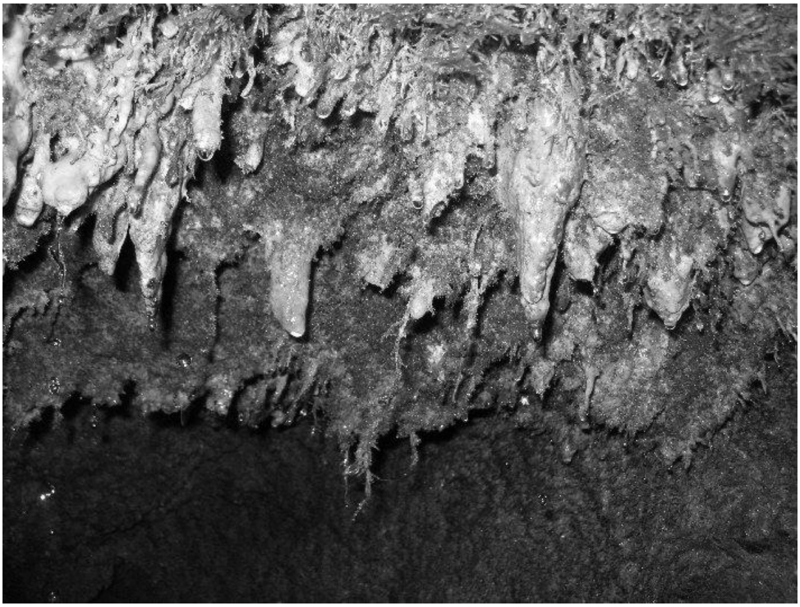


Fig. 5. Tufa-stalactites in a small shelter near Annaberg (Salzburg)

Calcitic and limonitic speleothems in non-karstic rocks

In the Rudolfstollen in Linz (Upper Austria) - already mentioned as a location of root stalagmites – calcitic and limonitic dripstones emerge from gneisses that lacks noteworthy amounts of calcite. Therefore other sources of Calcium including loess sediments as well as chemicals for measures against mosses in the gardens above have to be taken into account.

Fig. 6. Straw-Stalactites in the Rudolfstollen (Linz, Upper Austria)

The growth rate of the dripstones is remarkable, forming distinct white sinter decorations of certain parts of the tunnel within 60 years. The formation of these features is identical to karst-dripstones whereas the tunnel and the initial process is non karstic.

Tests with tablets below dripstones yielded grow rates of ~10 cm/cm2 in 60 years.

In remoter parts of the Rudolfstollen where the overlay consists only of a few centimetres of soil above the gneiss the tunnel lacks white dripstones, instead there are a few brown straw stalagmites consisting mainly of limonitic minerals. Features like this are more common in mines.

Fig. 7. Limonitic straw stalactites in the Rudolfstollen (Linz, Upper Austria)

An example of peculiar calcitic popcorn sinter could be observed recently in the Pfaffenhaus (6841/1), a small cave in coarse grained granites of the Southern Bohemian Massif in Upper Austria still lacking a scientific investigation.

Fig. 8. Calcitic popcorn sinter in the Pfaffenhaus (N Linz, Upper Austria)

Outlook

There is a certain variety of aberrant features in caves that can be subsumed under the term “pseudokarst” although some occur in karst caves too. Our investigations included comparatively few caves and tunnels and thus there is a good chance to encounter more of these features probably overlooked by cavers so far.

A study comparing the environmental settings of the different root stalagmites more thoroughly is in preparation, as well as DNA studies to identify the corresponding mother plants, where a direct determination is not possible.

References

Pavuza, R. & Mayer, A.(2007): First Evidence of root stalagmites in an Austrian Cave.- Newsletter/Nachrichtenbrief Comm. Pseudokarst UIS, Nr.16:3-4

Pavuza, R.(2008): Root stalagmite in an artificial cavity. – Newsletter/Nachrichtenbrief Comm. Pseudokarst UIS, 18:10-11.

Pavuza, R.(2010): Short remark on the third finding of root-stalagmites in Austria.- Newsletter/ Nachrichtenbrief UIS-Comm.Pseudokarst, 21:14-15.

Speleothem development and biological activity in granite cavities

Vidal Romaní, J.R.; Sanjurjo Sánchez J.; Vaqueiro M & Fernandez Mosquera, D.

[1] Instituto Universitario de Xeoloxía Isidro Parga Pondal, Coruña, Spain.
[2] CEM. c/ Manuel de Castro 8-3ºD, 36201 Vigo, Spain.

The weathering of the granitic rocky massifs is carried out not only on their surface but also inside their fissure system when this latter is partially open and allows the water circulation. In the fissure system the microbiological activity has an important role as it accelerates the weathering. The mobilization of the ions coming from the rock minerals depends on the water pH that is affected by the microbiological activity. The chemical elements of the rock minerals are mobilized in a different way; some of them (Na, K, Ca, etc.) are evacuated quickly by the water flow being dragged far away from their original situation. Others such as Al and Si, the most abundant ones, contributing to the formation of new minerals, will be deposited close to their initial position, creating deposits considered as speleothems by their genesis and morphology.

The speleothem mineralogy is very varied: evansite, struvite, pigotite, taranakite, allophane, hematites, etc.. Up to now, the prevailing mineralogies in the described speleothems are three from greater to minor frequency according to their citations in the literature: opal-A, pigotite and evansite. For the case of Si, the opal-A (biogenic opal) speleothems will be formed. When it is Al that precipitates, evansite speleothems will be formed. In the last case, when the water transports humic acids abundantly, the pigotite speleothems will be produced. Early descriptions reports named the deposits as coralloids, crusts, speleothems, etc. Later, by analogy with calcareous speleothems, the nomenclature is stalactites for deposits associated with a punctual output of the water at the roof of the rock cavity, stalagmites for the ones due to the dripping on the ground of the cavity and flowstones for the ones deposited by laminar water flow. Most of them have been described in varied geographic-climatic environments: temperate humid (Spain, Portugal, United Kingdom, Germany, Poland, Czhec Republic), tropical (Brasil, Venezuela, Madagascar, Hawaii), arid (Australia, Argentina, Nigeria, Namibia, Mexico, U.S.A., etc.). This paper is focused on the three main mineralogical (quantitatively speaking) types of speleothems : opal-A, pigotite and evansite.

Opal-A speleothems

These types of speleothems are formed by amorphous biogenic silica (opal-A). Si comes from the dissolution of the crystalline quartz (mainly) and other silicate minerals (mica, feldspar). The Si dissolution depends on the water pH. In natural environments (with pH values between 5-8), the Si dissolution included in stable crystalline structures is very low. However, after the biogenic weathering by different microorganisms the silicates are degraded in biogenic opal that is easily mobilized in dissolution. These microorganisms accelerate the Si dissolution by means of the production of organic acids of low molecular weight (mainly oxalate) determinative in the biochemical weathering of the granite minerals.

Pigotite speleothems

They form incrustations on the granite walls of fissures and caverns. Pigotite has been first described as an organic substance considered to derive from the decay of moist moorlands above. It consists in organic acids combined with alumina and Fe oxide. The quantity of water present in this mineral is therefore in some degree variable, but always large.

Evansite speleothems

Al3(PO4)(OH)6.6H2O. They occur as speleothems on the walls, roof or ground of granite fissures. Evansite is always amorphous and most of the time contains Al, Si, Fe, H2O and organic matter.

The following morphological types of speleothems are distinguished: cylindrical and in crusts or sheets. The first ones are associated to water circulation by dripping or to movements by capillarity. The second ones or flowstones are associated with laminar water flows. Three types of cylindrical speleothems are distinguished: (1) Stalactites: formed on the high part of the rock fissures or the roof or caves of cavities when the weight of the drop surpasses the surface tension (when dripping is produced). (2) Grass-shaped stalagmites: multiple associations of very thin cylindrical forms (maximum 1 mm) and associated with the roof or ground of cavities. (3) Anti-stalactites: The speleothems grow by capillary circulation of the water from a clast agglomerate bed of amorphous silica soaked in water.

The second ones, flowstones, are layered speleothems produced by laminar flow of the water. They may appear on the roof, ground or base of the cavity. Three types are distinguished. (1) *Flowstone*: continuous covers of the rocky surface with variable thicknesses. (2) *Gour-dams*: accumulations of opal-A clasts with lineal and sinuous development that may hold water temporarily contributing to opal precipitation in the maximum overspill rim. They are normally associated with flat, little-sloped surfaces or even subvertical surfaces when the flow speed does not go beyond the forces of the water adherence to the sliding surface. (3) *Rimstones*: lineal speleothems with deposition halos on the perimeter of the fissure, when the water is spread on strongly sloped rocky walls or even on the roof or rocky cavities by superficial tension. They may have some micra of thickness.

At least for opal-A speleothems, the biological influence on the speleothem development does not finish with the first deposition but is renewed after each new episode of rainwater circulation. The re-dissolution and later re-precipitation of biogenic opal will give rise to speleothems with an accretion texture in rhythmic layers. In this stage it is frequent to observe diatoms which take advantage of silica remobilised and grow colonies where water concentrates. Also mites and polychetes have activity in the speleothem using for their subsistence the organic matter content of the same speleothem.

The last stage in the speleothem development is the so-called azoic stage where S of organic origin is combined with the Ca of the plagioclases, and using the substratum of amorphous silica (silica gel) gypsum crystals develop with an excellent idiomorphy. In all types of speleothems the oversaturation by water evaporation causes the precipitation of the elements and solubilised compounds originating speleothems of pigotite (fulvic acids), evansite (Al and Si phosphates) and opal-A.

Two examples of pseudokarst features in South Supramonte (Sardinia, Italy)

Laura Sanna[1], Jo De Waele[2], Salvatore Cabras[3]

1Associazione Speleologica Progetto Supramonte, Sassari (Italy)
2Istituto Italiano di Speleologia, Bologna (Italy)
3Gruppo Speleo Ambientale Urzulei, Urzulei (Italy)

Introduction

Supramonte is an extremely well karstified plateau located in Central-East Sardinia (Italy) and is well known due to its intricate enormous network of cave passages and tunnels, the most extensive of the island. The area hosts a wide variety of landforms (karren, dolines, sinkholes) and complex underground streams, which are partially developed on the contact between carbonate rocks and the granite/metamorphic basement. Groundwater erosion of the impermeable beds at the lower contact with the carbonate rocks is commonly recognized inside Sardinian cave systems (i.e., Su Colostrargiu, S'Eni 'e Istettai, Su Mammucone, Lovettecannas, Su Clovu, Su Palu, Su Crabargiu caves). Recently, pseudokarst features have been revealed strictly connected with the karst ones. Nondissolutional processes have been discovered in the deeper parts of two caves in South Supramonte (Fig. 1) and have formed a huge chamber (Perdeballa cave) and a large passage (S'Orale 'e Su Mudrecu cave) completely hosted in non-carbonate rocks.

Study area

Supramonte massif occupies an area of approximately 170 km2, almost 80% of which is composed of carbonate rocks. It is characterised by an almost 1 km thick Middle Jurassic-Lower Cretaceous sequence composed of dolostones and limestones covering a crystalline Palaeozoic Variscan basement made out of metasediments and metavolcanic rocks, injected with granitic batholites and late intrusive dikes during Carboniferous and Permian. The transition from granites and phyllites to the overlying Mesozoic carbonate platform is often characterised by the outcropping of siliciclastic sediments related to continental to transitional environments.

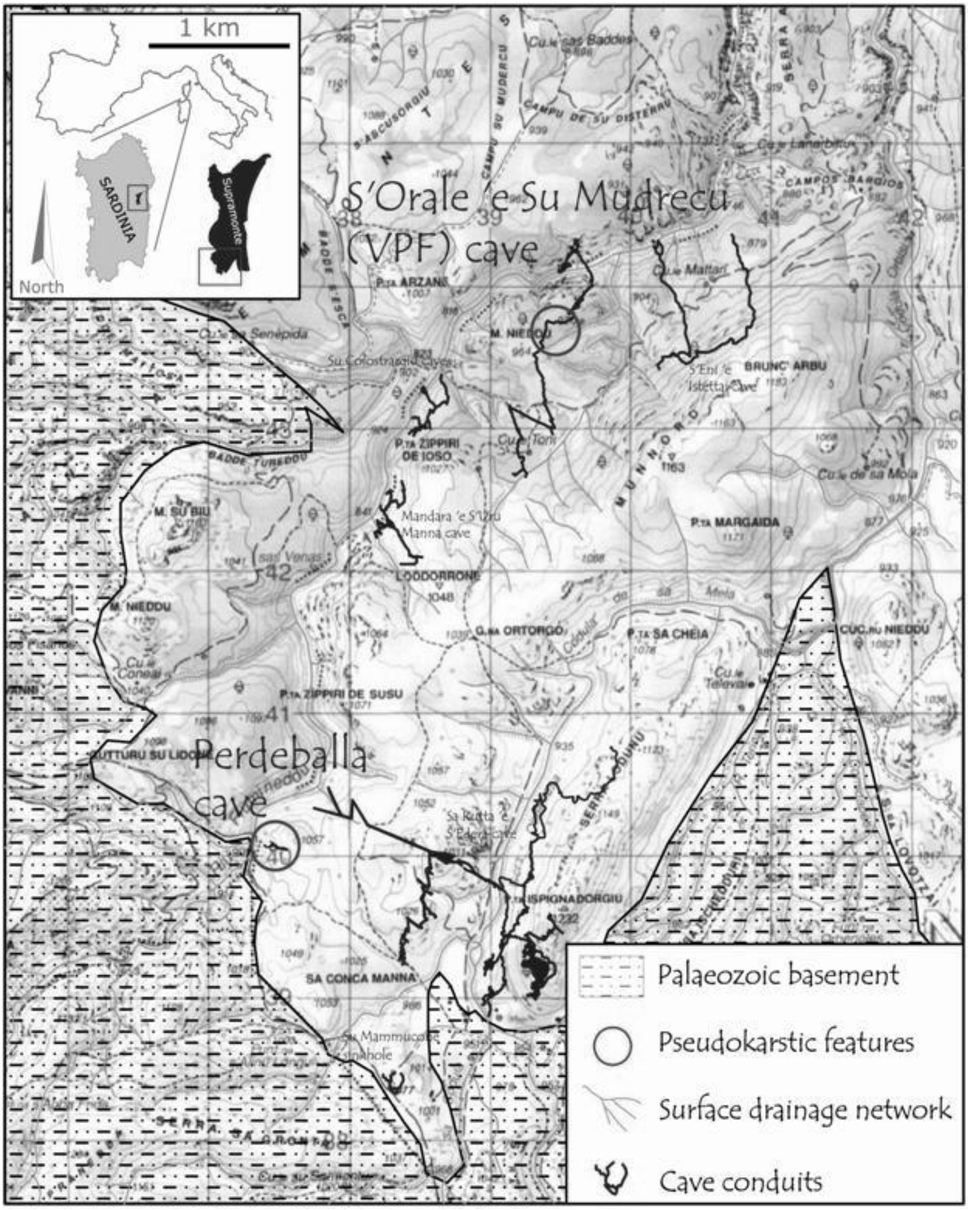


Fig. 1. Southern part of Supramonte with the plans of the most important karst

Caves and pseudokarst features

Since the last ten years the major explorations made in the South Supramonte have enabled speleologists to make detailed investigations on the transition between impermeable basement and carbonate platform that greatly influences the asset of all caves discovered in this area. Two of those cavities show evident pseudokarst characters in some part of their structure.

Perdeballa is one of the most beautiful caves on the southwestern side of Supramonte and was discovered in April 2004 by cavers of GASAU. This 680 m long cave is constituted of small shafts in the Jurassic basal dolostone up to about -70 m from the entrance where well decorated rooms develop for half their heights in Palaeozoic metamorphic rocks. It is deepened up to -88 m, where a narrow passage allowed to explore a huge void 20 m large and 10 m high, in which walls and ceiling is made of phyllites underlying the dolostone. White stalactites and draperies hang from the ceiling (Fig. 2) while the bended floor is obstructed by a muddy boulder choke, except for a funnel-shaped sink covered by flowstone.

Fig. 2. The chamber completely developed in phyllites inside Perdeballa cave (Photo by Riccardo De Luca)

S'Orale 'e Su Mudrecu cave (also called VPF) is the second deepest cave of Sardinia and was found in autumn 2001 on the bed of the almost dry Flumineddu canyon by ASProS cavers. Currently it reaches a development of more than 4500 m and after limestone and dolostone vertical shafts up to a depth of 340 m, a small underground river follows horizontal passages close to the contact between Mesozoic dolostones and sandstones and the Palaeozoic basement. Several metres of passages with flat dolostone ceiling are arranged inside massive sandstones with localized, thin lignitiferous horizons with plant fragments, and subordinately in badly stratified quartzose conglomerates; the most exceptional feature is represented by a 5 m large circular conduit excavated into quartz veins-bearing black phyllites.

Morphogenesis

Although physical erosion features are quite ubiquitarious in the Supramonte cave systems, developed on the contact with non-carbonate rocks, the karst-type morphologies found in Perdeballa and VPF caves can be related to mechanical grain removal of particles by flowing water interpreted as piping pseudokarst. The sandstones also undergo bedding collapse, in turn caused by subsurface erosion along the main fracture systems that started on underlying phyllites. The evolution of these features seems attributable to the hydraulical connection with the karst conduits, testifying even a multiprocess for the speleogenesis of these caves.

Conclusions

Pseudokarst types identified in Perdeballa and VPF caves are the first example of piping phenomena reported in Supramonte. These morphologies are formed in phyllites by subsurface drainage along the fault planes, locally involving collapse of overlying sandstones. Further observations will allow to better define its role on the karst evolution of this area.

References

Cabras I., Cabras S., Mereu M., Murru A. (2008). La Grotta di Perdeballa, una scoperta inattesa nel Supramonte di Urzulei. In: Atti del XX Congresso Nazionale di Speleologia. Iglesias, April 27-30, 2007: 407-410.

Cabras S., De Waele J., Sanna L. (2008) – Caves and karst aquifer drainage of Supramonte (Sardinia, Italy): a review. – Acta Carsologica, vol. 37/2: 227-240.

Crobu V., Cabras S., Corongiu C., Melis G., Moi M., Porcu P.P., Sanna L. (2009) – Sotto il Supramonte infinito. Speleologia 60, Anno XXX: 16-29.

What is Pseudokarst?

Hartmut Simmert

Höhlen- und Karstforschung Dresden e.V., Germany

The preparation and carrying out the 11th International Symposium on Pseudokarst was a good opportunity to express and agree on what is meant by pseudokarst. What is being researched, what is the point and why do professional and hobby scientists meet to exchange knowledge about it?

To anticipate the question: there was almost no communication about the term in 2010 and also this paper cannot answer this question satisfactory or completely. How could the combination of terms "pseudokarst" be better, if there are multiple views and ideas about the term Karst itself? Terms are tools of thinking and serve communication, to make oneself understood. But even if one does not have a definitive answer it is nonetheless possible and necessary to describe one's own opinion concerning this topic.

Interpretation attempt: history of the term

When the term "pseudokarst" was first used in literature (Knebel 1906) the geologist wanted to express that the lava caves and the structures hanging from the ceiling have nothing to do with karst, despite the commonly spread opinion. He named those phenomena Pseudokarst:

> *"Man kann aber auf den Lavafeldern nur von einer "Pseudo-Verkarstung" reden, da der Übergang von der Horizontalentwässerung in die Vertikalentwässerung - also die Verkarstung - in den Karstgebieten auf andere Ursachen zurückzuführen ist. Ist es doch eine ganz andere Art von Zerklüftung, als die, welche in Karstgebieten sich findet." (von Knebel 1906, S. 183)*

> *"But in the fields of lava one can only speak of "Pseudo Karst Phenomena" because the transition from horizontal to vertical drainage - that is to say Karst development - in Karst areas is attributable to other causes. Because it is a sort of cleft formation very different from that which can be found in Karst areas." (von Knebel 1906, p. 183)*

I interpret his opinion in a way that Knebel did not use the term as a working title but as a drastic attempt to correct wrong opinions.I am certain: Knebel did not want to estalish a new scientific term but simply delimit from the wrong use of the term Karst. He did not want to use the term to say what the phenomena are but to show what they are not, that is to say: certainly not Karst.

Interpretation attempt: part terms

"Pseudo" comes from the greek word for false or wrong. So pseudokarst is "false karst"? This is why forming this term absurd because it shows what it is not although it looks like it. This is about the same as calling bananas pseudo-cucumbers. The opposite happened later: the term was spread and established over the years. It would be more convenient to create a new term that does not collide with other established terms. Other names like "mesokarst", "semikarst" and "nonkarst" are not better there. Even "thermokarst" is misleading because it could mean a particular form of Karst.

What is Karst?

While the term Karst was originally used for landscapes formed through solution of limestone and dolomite by water (more specifically: carbonated water) only, it was later extended to gypsum and salt stone, because they are easily soluble by water as well. So the central feature of Karst is solution (as process or result). But even this term is used in many ways. Next to various colloquial uses (to solve a task or a problem, etc.) it is also used in chemistry and physics. While in physics a mechanic or kinetic loss of link is meant, chemistry has a different use for the term solution: a substance is being dissolved by another substance (solvent), if it exists in an ionized state after the neutralization of the attracting forces. This process, known as dissociation, can be reversible or irreversible. We know that dissolved gypsum can become gypsum in overconcentrated solvent, also as a different mineralization structure. Dissociation of limestone takes the detour of hydrogenated carbonate ant calcite.

And the other minerals on this planet?

All rocks are influenced by natural stress and destruction. At the surface and close to it there are various forms of erosion. Corrosion requires solution by water. Although principally all minerals and rock consisting of them can be dissolved but there are significant differences concerning:

- solution rate,
- soluble quantities per litre and
- solution conditions (pressure, temperature, accompanying substances etc.).

For instance basalt or granite are regarded not soluble while gypsum and salt are easily dissolved. But because of the existence of landscapes without easily soluble rocks or soil forming sediments that show similar or equal features, the term pseudokarst was established for these phenomena. Often all phenomena of Karst can be found there: dolinas, collapse sinkholes, ponors, subterranean drainage, brook seepage, grykes, caves, etc. Here the formation of these features is a result of tectonics, boulder movements, erosion, suffosion, etc. There are also true solution processes that are of minor importance. But: they are there. Also granite shows exogene forms that indicate solution phenomena. Corrosive features can be found in many sandstone caves (solution cavities, cave sinters). How could there be diatoms or fossile wood if silicon dioxide was not soluble in water? During a working conference in 1997 eight different forms of pseudokarst were distinguished:

"...with notably different implications for extrsterrestrial habitats....
1. Rheogenic pseudokarst
2. Glacier pseudokarst
3. Badlands and piping pseudokarst (including loess)
4. Permafrost pseudokarst
5. Talus pseudokarst (including boulder fields and roofes streamcourses)
6. Crevice pseudokarst
7. Compaction pseudokarst
8. Consequent pseudokarst"
(Halliday 2007, p. 104)

Here the dilemma becomes clear: not one in these eight forms has got anything to do with Karst. Neither the lava caves nor the phenomena in loess clay or ice or permafrost soil. Also the so called consequent caves do certainly not belong to Karst. Because of the wrong term there are no pseudokarst areas for me, also our Elbe Sandstone Mountains are not a pseudokarst area. But it is also not a Karst area although there is no doubt about the existence of Karst processes: rock solution and reversible processes connected to it. The landscape is vastly coined by erosion, not corrosion. Predominantly the binder between the grains of sand loses its strength or is dissolved before the grain itself. There are erosion processes in Karst areas just as well - just think about the extremely weathered rock wall above the entrance to Stefans Cave (Southern Harz Mountains, Germany). It is not fixed how big the portion of corrosion processes forming a landscape has to be for Karst areas. So categorizing a landscape is again at one's own discretion.

In 1982 Czech cavers and Karst researchers first organized a Pseudokarst Symposium, already with international participants. In this time these conferences take place in Europe on an international level approximately every two years. The third symposium was organized by cavers from Dresden in 1988 in Königstein, conference venues in many parts of Europe were found in the later years. Since 1997, the UIS has an independent Pseudokarst Commission. Many scientists, institutions and interested people who are occupied in research in this field became members of this commission. The last Symposium in the Saxon Switzerland took place in 2010.

In the end, let us come back to the initial question and ask differently: what do we mean by "Pseudokarst"? After years of work in sandstone caves I decided for myself to explain the term like this:

The term Pseudokarst describes geomorphologic phenomena or parts of a landscape that shows qualities or features of Karst genesis although the rock forming mineral or soil forming sediment is not regarded capable of forming Karst.

This is how I put it on Wikipedia in 2010. Let us see how it will change through the help of other authors in the future. I also know many geologists who simply refuse to use the term. It's use is only justified by the notorious application and the absence of a better scientific term. To get further in terms of content the term should possibly be avoided and a better description should be used.

By the way, a short summary concerning the history of the term can be found in an article of István Eszterhás that does not yet exist in literature form but only as a web article.

- first use by Walther von Knebel in "Höhlenkunde mit Berücksichtigung der Karstphänomene" (1906)
- classification of pseudokarst phenomena in loess and clay sediments by F. P. Savarenskij (1931)
- especially Russian and italian scientists work and publish in this field, using the term, in the middle of the 20th century; later also Bohemian Geologists (see Eszterhás, 2008)

With this opinion, how can you be in a "Pseudokarst Commission" and organize a "Symposium on Pseudokarst" with a good conscience? We became part of the Commission not only because we work in a sandstone area but also because we appreciate the work of the colleagues and do not want to become heated in the discussion about the scientific term. This very same commission has decided to keep the term after numerous discussions because it is clear it is supposed to desribe.

References

Knebel, W. von: Höhlenkunde mit Berücksichtigung der Karstphänomene. Druck und Verlag von Friedrich Viehweg u. Sohn, Braunschweig, 1906

Florida, G.: Un particolare fenomeno pseudocarsico manifeste da algune argile. Bollentino della Societa el Sciencia Naturale ed Economiche di Palermo (vol. 23), p. 10-19. 1941

Kosack, H. P.: Die Verbreitung der Karst- und Pseudokarsterscheinung über die Erde. Petermanns Geographische Mitteilungen (vol. 96), Gotha, p. 16-22. 1952

Striebel, T.: Höhlenbildung in "nicht verkarstungsfähigen" Gesteinen: Welche Formen sind Karstformen? In: Laichinger Höhlenfreund, 40 (1), Laiching, p. 31-52. 2005

Halliday, W. R.: Pseudokarst in the 21st century. Journal of Cave and Karst Studies (vol. 69, no. 1), p. 103-113. 2007

Winkelhöfer, R. H.: Das Elbsandsteingebirge ist ein Sandsteinkarstgebiet. http://www.geoberg.de/2010/06/12/das-elbsandsteingebirge-ist-ein-sandsteinkarstgebiet/ (last accessed: 2010/11/01). 2010

Translation from: Mitteilung Höhlen- und Karstforschung Dresden e. V., vol. 1/2010 (37), ISSN 1864-0974, p. 2-6: "Was ist Pseudokarst?", translated by Jana Simmert

Pseudokarst in the Elbe Sandstone Mountains

Hartmut Simmert

Höhlen- und Karstforschung Dresden e.V., Germany

The origin of the Elbe Sandstone Mountains dates back to the Cretaceous period. In this time our area was covered by a flat sea. The rivers from the near mountains brought sand, but also clay and chalk were deposited in the broad estuary of the rivers. Despite local differences occurred in the entire area to relatively homogeneous deposits. These sediments were compacted to a homogeneous sandstone board by different binders and the pressure of the own weight and the water. After the retreat of the sea (elevation of the area) immediately began the weathering.

The sandstone plate was broken by the movements of the earth's crust. The first small cracks and crevices of the valley developed into chasms and valleys, leaving mesas and pinnacles. The landscape has been shaped by different events in the Tertiary and Quaternary (uplift of the Ore Mountains in the south, Lusatian Thrust in the north). Today's weathered forms have been dominated by the ice age.

The Saxon Switzerland is inhabited for centuries. First economies are agriculture and timber industries, including fishing and use of selected areas as a trade route. In the valleys there are board mills and handicraft. From the middle of the 17th Century the population increases considerably. In the main valleys developed in the 19th and 20 Century some industry, such as shipbuilding in the Elbe Valley. In the quarries the sandstone was mined and shipped on barges all over Europe.

Artists, travelers and the local historian as the pastor Götzinger made the Elbsandsteingebirge nationally and internationally known. It wraps itself a tourism that leads to today, people from all over the world come here.

So the touristic exploration began in the early 19th century. The name Saxon Switzerland goes back to the Swiss painters Anton Graff and Adrian Zingg who have worked and taught at the Art Academy in Dresden around 1780.

At the end of the 19th Century developed the free climbing that goes from here in the world. Nearly 100 years ago, the first mountain rescue service was established here.

To preserve the beauty and uniqueness of the Saxon Switzerland with its hiking trail network of around 1200 km and about 1000 climbing summits with more than 15.000 routes the area was put under protection. In 1991 the National Park Saxon Switzerland with an area of 93 square kilometers was founded.

Situated in the Saxon Switzerland, in addition to many small caves we find a number of different pseudo-karst phenomena. The majority of these have already been presented at various conferences, such as on the 3th Pseudokarst-Symposium 1988 in Königstein.

On our excursions we will see these forms:

- Caves
- Mushroom rocks
- Abri

- Rock arch
- Corrie / rock bowl (Kamenitsa)
- Crikes and clints
- Speleotheme

In the area of the Saxon Switzerland there are currently three active speleological associations. There are also a number of individuals that are dedicated to topics of caving. Main areas of research in present are:

- the further collection and documentation of objects
- the search for new objects
- the anthropogenic influences on the ecology of the caves
- the cave biology

Currently there are no quantitative research on the relationship between weathering and karstification of the quartz sand stone, but only general observations. The discussion about the definition of pseudo-karst will be continued in our own research group, the term is used because of his little blur.

Geomorphology of the largest sandstone caves in the world on the Proterozoic table-mountains Churí and Roraima (Gran Sabana, Venezuela) and their research in the years 2002 - 2009

Branislav Šmída et al.

Slovak Speleological Society, Bratislava, Slovakia

The longest quartzite caves in the world (state on December 31, 2009), compiled by B. Šmída

1	Cueva Ojos de Cristal	16.1 km	-73 m	Venezuela	Roraima	SSS-ČSS-SVCN / SVE-OUCC
2	Cueva Muchimuk-Colibri	8.0 km	-160 m	Venezuela	Churí	SSS-ČSS-SVCN
3	Cueva Charles Brewer	7.3 km	+110 m	Venezuela	Churí	SVCN-SSS-ČSS
4	Gruta do Centenário	4.7 km	-481 m	Brasil	Inficionado	Grupo Bambuí
5	Gruta da Bocaina	3.2 km	-404 m	Brasil	Inficionado	Grupo Bambuí
6	Cueva Juliana	3.0 km	-45 m	Venezuela	Churí	SSS
7	Sima Auyan-tepuy Noroeste	2.9 km	-370 m	Venezuela	Auyantepuy	SSI-SVE
8	Gruta das Bromélias	2.7 km		Brasil	Ibitipoca	
9	Cueva Zuna	2.5 km	-90 m	Venezuela	Churí	SSS-SO PD Velebit
10	Cueva de la Araña	2.5 km		Venezuela	Churí	ČSS

SVCN - Grupo Espeleológico de la Sociedad Venezolana de Ciencias Naturales, SSS – Slovak Speleological Society, ČSS – Czech Speleological Society, SVE – Sociedad Venezolana de Espeleología, OUCC – Oxford University Cavin Club, SSI – Societa Speleologia Italiana

In January and May 2009, under the leadership of Mr. Charles Brewer-Carías, Mr. Branislav Šmída, Mr. Marek Audy and Mr. Federico Mayoral the 4th and 5th international speleological-scientific expeditions were performed with participants from Venezuela, Slovakia, Czech and Croatia on one of the mesetas (tepuy) of the Chimantá massif in Venezuela, called as Churí.

More than 14 km of cave passages were explored.

The largest system named by us as Cueva Muchimuk-Colibri is 8 km long and starts in the abyss which is about 200 m long, 100 m wide and 120 m deep. The cave is formed by huge branches where the average width of galleries is about 20 to 50 m. A large labyrinth of smaller river channels is formed there, too. The system has 8 entrances; 5 of them are situated directly on the outer, 500 m high wall in the northern corner of the tepuy. The largest entrance is formed by the 80 m wide portal, partially covered by giant fallen blocks. In the cave, several until now not described forms of biospeleothems and mineral aggregates were found.

The entrance of the Cueva Colibri was discovered by us in January 23, 2009 and its exploration was realized under difficult circumstances during 6 days long stay of 9 cavers and scientists on the northern part of the massif. The entrance of the Cueva Muchimuk was discovered by us in May 29, 2009.

The next cave, Cueva Juliana, discovered by us in 2007, was prolonged up to 3 km. For the first time in quartzite caves the standard digging methods were applied. In this cave, giant forms of champignon-type biospeleothems were recognized with diameters up to 1 m.

Other very important result of the expeditions was discovery of the connection between the Cueva Charles Brewer and the Cueva del Diablo (Devil´s cave) to one common system with actual length of more than 7,3 km.

The Cueva Zuna was mapped to the length of 2,5 km. The newly discovered Cueva Yanna is almost 1 km long. Some other smaller caves were found, too.

Fig. 1. Galería Orinoco in Cueva Charles Brewer (Photo by J Stankovič, B. Šmída, D Bakšić and V Guľa 2009)

Simultaneously with the classical speleological exploration, scientific investigations were performed, too by a scientific team from the Comenius University in Bratislava. Geological, geomorphological and biological conditions were investigated repeatedly in the underground and the surface, water samples were analysed and also microclimatic conditions were evaluated.

The Cueva Muchimuk-Colibri system is now the 2nd longest and 2nd volumetrically largest quartzite cave in the world!

The entire actual length of the cave systems of Churí explored by us is now more than 28,5 km.

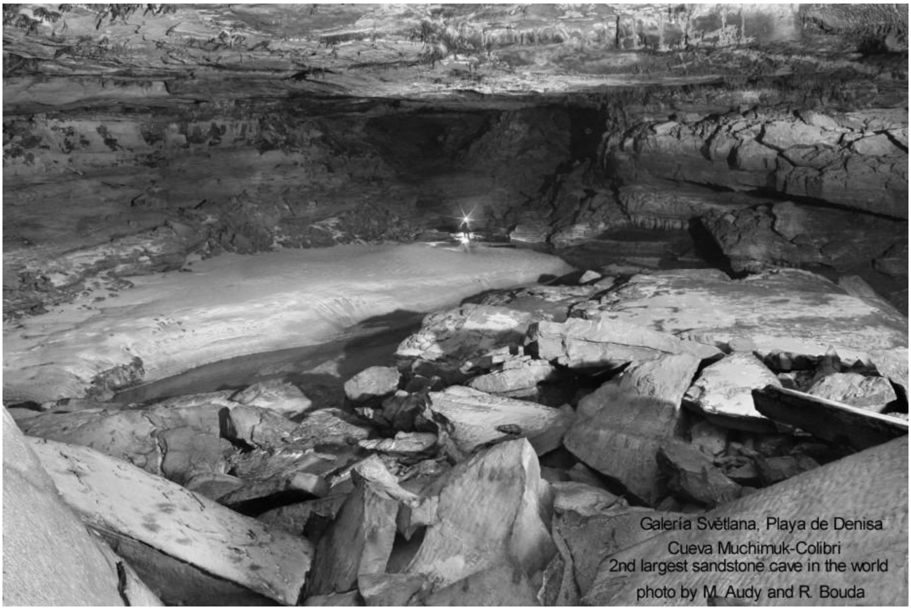


Fig. 2. Cueva Muchimuk-Colibri (Photo by M. Audy and R Bouda 2009)

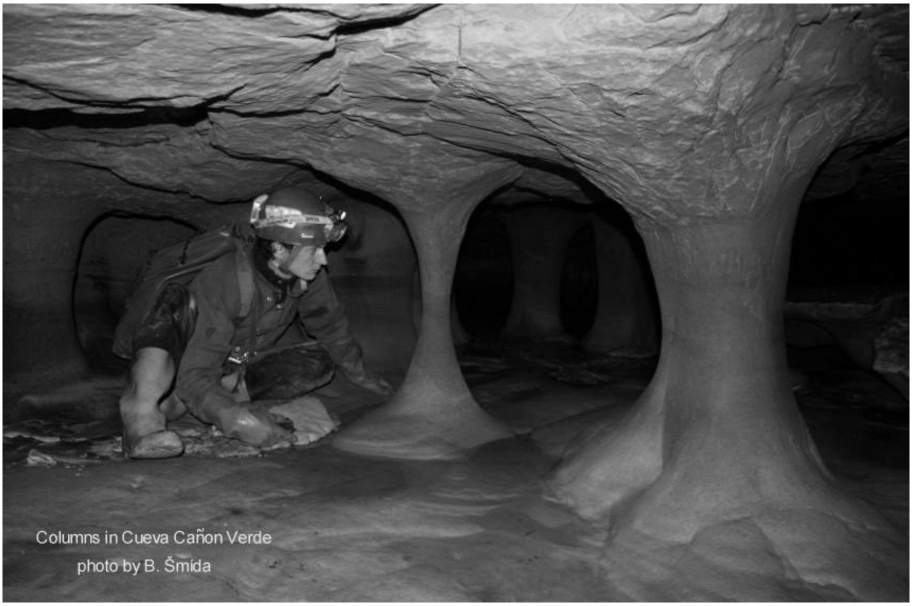


Fig. 3. Columns in Cueva Canon Verde (Photo by B Šmída 2007)

The expeditions were covered by the GE SVCN (Grupo Espeleologico de Sociedad Venezolana de Ciencias Naturales) in cooperation with Faculty of Natural Sciences – Comenius University Bratislava and its Speleoclub UK, Slovak Speleological Society (SSS), Czech Speleological Society (ČSS) and SO Velebit Zagreb. The scientific research was financed by the projects VEGA 1/0246/08 and APVV 0251-07, as well as from private financial resources.

Fig. 4. Cerro Autana and Lago Leopoldo (Photo by Ch Brewer-Carías)

Fig. 5. Biospeleothems,Champignones, and a fly, photo by B Šmída 2005

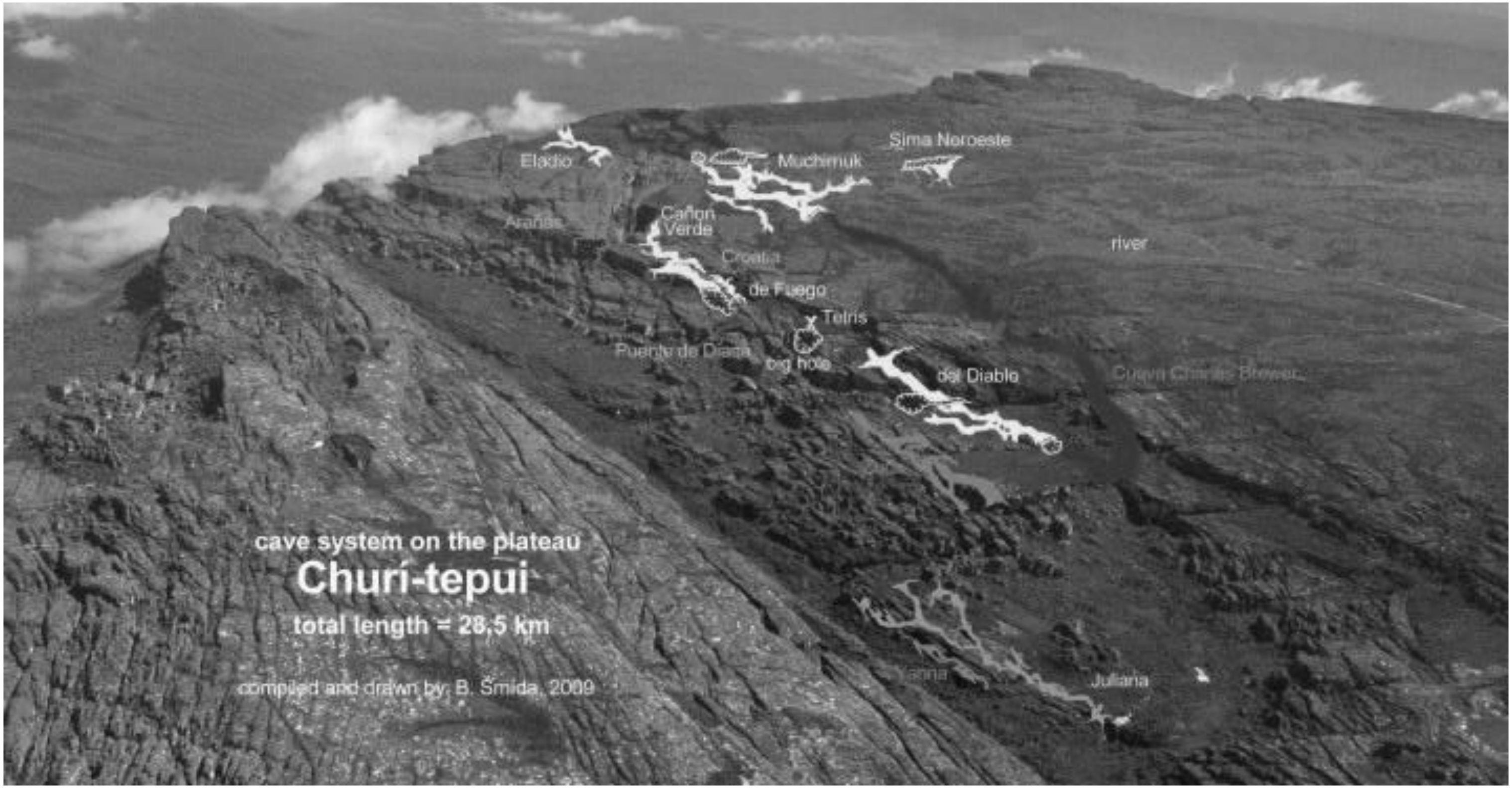


Fig. 6. The cave system in the sandstone plateau Churí, Chimantá Mts, Venezuela, after our 5 expeditions from 2004 to 2009. compiled and drawn by Branislav Šmída

Presentation of some Abrasion Caves in New Zealand near Auckland

George Szentes

Bad Vilbel, Germany

Abstract

The rim of an ancient volcano extends along the coast of the Tasman Sea to the west and northwest of Auckland City. The rugged, rocky coast is mainly composed of coarse volcanic gravel and finer tuffaceous interbeddings.

Over millions of years the volcanic sequence has undergone significant tectonic deformation and as a consequence the formation is cut by many faults of various dimensions. This rock formation – mainly the unstable rock along the fault zones – is suitable for abrasion cave development. Along the fault zones of the 25 km long coastal area many caves have developed with various shapes and lengths. The recent connection of the caves to the sea and their elevation above sea level are very different, which reflects the geomorphological and climatic changes of the recent past.

Introduction

I presented a paper on the relict abrasion caves near the village of Whatipu at the 9. International Symposium on Pseudokarst in Bartkowa, Poland (Szentes 2007). Along the coastline of the Tasman Sea to the north of Whatipu the remains of the heavily eroded Oligocene Waitakere Volcano can be traced for a further 25 km. In most places the coarse volcanic gravel and the tuffaceous intercalations are suitable for abrasion cave development. The study of several smaller cavities, rock shelters and bigger caves has allowed us to understand the development and the recent stages of the caves, which depend on several geological, geomorphological and oceanographical factors. The most importants factors are the tectonic situation and the local influence of the tidal range. Some of the caves have interesting and important historical roles concerning the Maori natives and the European immigrants. In some caves – particularly in those which are mainly influenced by the tidal effect – a specific ecosystem has evolved.

Description of the investigated area

The investigated area lies to the west and northwest of Auckland City between the longitude E 174o30’04” and 175o24’30” and at a latitude between S 36o49’50” and 37o02’45” along the coastal area of the Tasman Sea (Fig 1.). The coastal region and the hinterland - the Waitakere Mountains - are the remains of the heavily eroded Oligocene Waitakere Volcano, which once stood a massive 3000 m high (Balázs 1981).

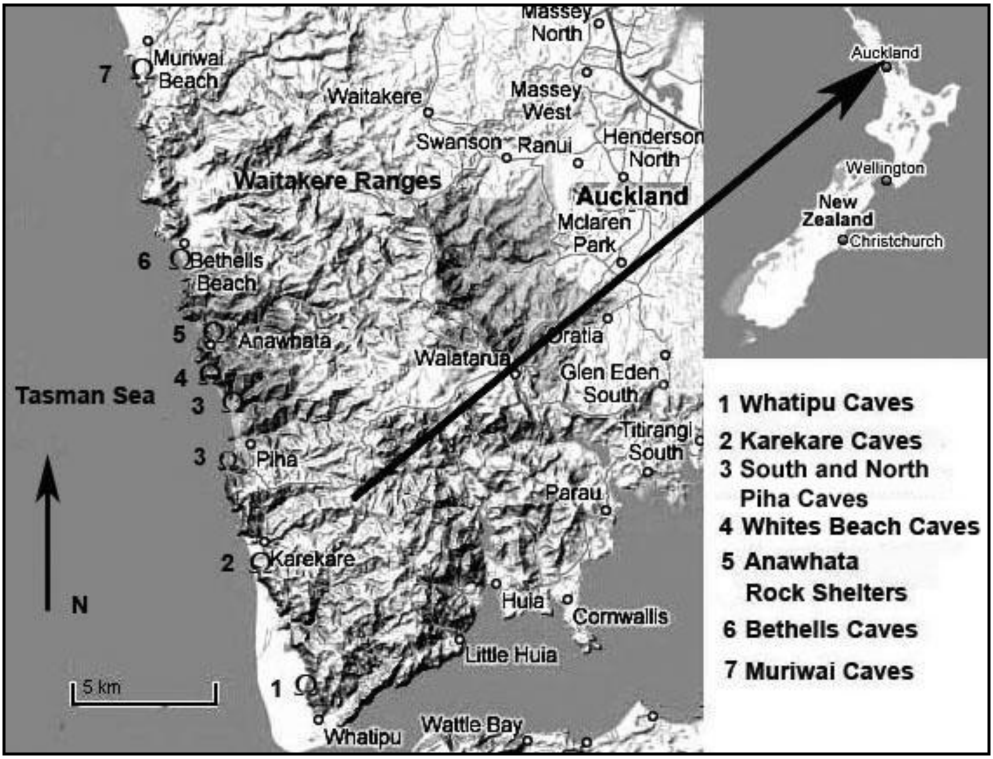


Fig.1.: Location of the investigated area

The region is chiefly composed of Manukau Breccia, which is the product of a period of volcanic activity 12 – 25 million years long from the Upper Oligocene to the Middle Miocene.The rock formation consists of coarse andesite breccia with interbedding of fine tuff, lapilli and marine sediment layers (Hayward 1976). Iinterbedded andesite lava banks and pillow lava together with dyke rock intrusions can frequently be observed. The rugged, up to 300 m high Manakau Breccia bluffs of the West Coast, in which the caves were formed, consist of mainly shallow marine andesitic breccia, andesite tuff, conglomerate, sandstone and siltstone and a mixture of gravel and sand left behind by the underwater lahars. The rocky coast is dissected by flat sandy beaches, where it is possible to acces the region. The base rock below the volcanic formation is composed of Cretaceous sediments, Eocene mudstones and Oligocene muddy limestone (Thornton 1985). The southern part of the formation is cut by generations of NE – SW and NNE – SSW trending faults, while in the northern part the NW – SE trending faults are dominant. These faulty belts result in loose zones in the rock formation, which are of decisive importance for cave development.

The chasms between the cliffs and the hilly hinterland are covered by the typical temperate rain forest of New Zealand (Ombler 2001).

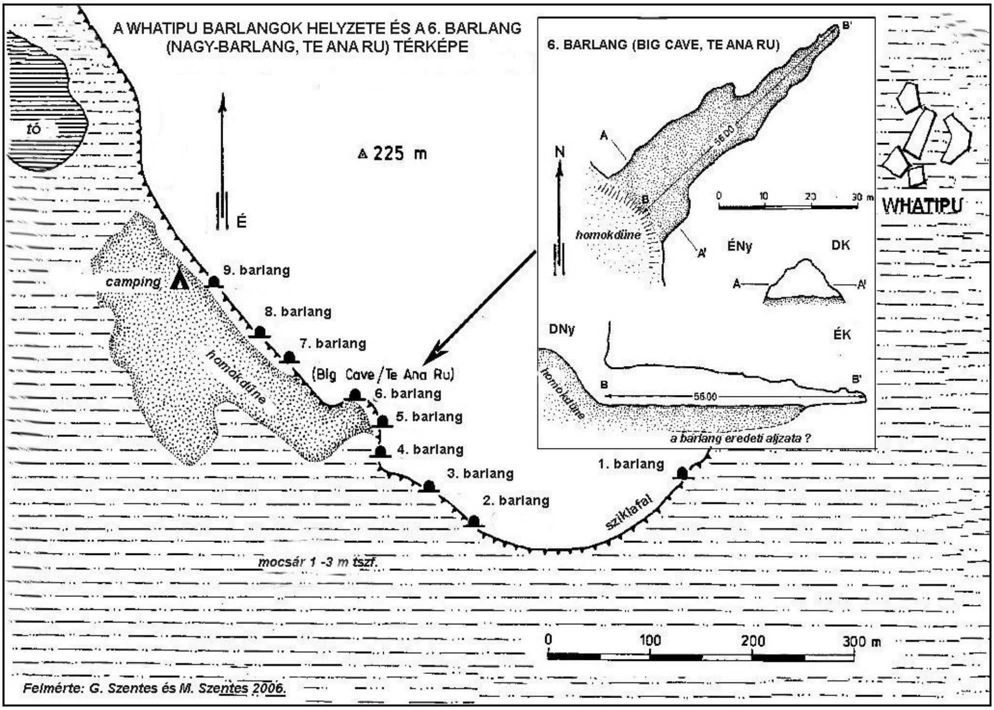


Fig.2.: Location of the Whatipu caves and survey of the Cave 6. (Big Cave, Te Ana Ru)

Cave development

The development of the caves depends on the surrounding rock quality, the loose rock zones along the faulty belts and the joint systems, as well as the present and past relationship between the cave and the loose rock zone to the tidal range. Intermittent stratification has also played a part in the formation of the cavities.

The caves have basically been formed by abrasion. The diameter of the coarse gravel pices in some places exceeds several metres. From the loosened cementing material large gravel pieces have fallen out and in their place remain large hollows. Where these hollows are within the tidal range the abrasion is able widen the holes forming caves or rock shelters. Where the abrasion effect prevails, and when the hollows in the tidal range coincide with a tectonic belt more resilient and larger, typical abrasion caves can be formed. In the hard and fine grained tuffaceous formation cave development is to be found only in faults and fissures. Here the caves have narrow, high and sometimes long and branching passages. Of course, caves can be formed by various combinations of the above mentioned effects and the occasional stratification of the Manukau Breccia can also affect cave development. The abrasion cave development can intensified along the andesite dykes which intruded into the tuff and agglomerate and later fragmented.

The relationship of the caves to the sea, and to the tidal range varies. The study area is influenced by the Westland Current and occasionally by the West Auckland Current. The maximum tidal range is 2.9 m in height. This is a high wave energy coast with waves of 1.5 – 2.5 m on average. Many caves are partly or wholly flooded by the tidal waves and the wave attack widens the cavity. In other instances the caves open at the recent limit of the tidal range and the waves barely (only when there is a storm tide) reach the caves and thus the widening effect here is only sporadic. Some caves, have no longer any contact with the sea, because of the rapid acceleration of coastal sand flat and dunes. This is due to the fact the littoral sand movement longshore to the north is largely driven by a Southern Ocean derived swell. Heavy storm wave action often causes beach erosion, moving sand to offshore bars.

Choking by sand is the main reason for the destruction of the caves. Windblown dune sand intrudes into the holes and chokes the passages. Many caves fall the victim to the collapse of the surrounding rock. These collapses can reach the surface forming narrow canyons, which may be widened by the tidal waves. In other case the remains of a collapsed cave appear as a rock shelter.

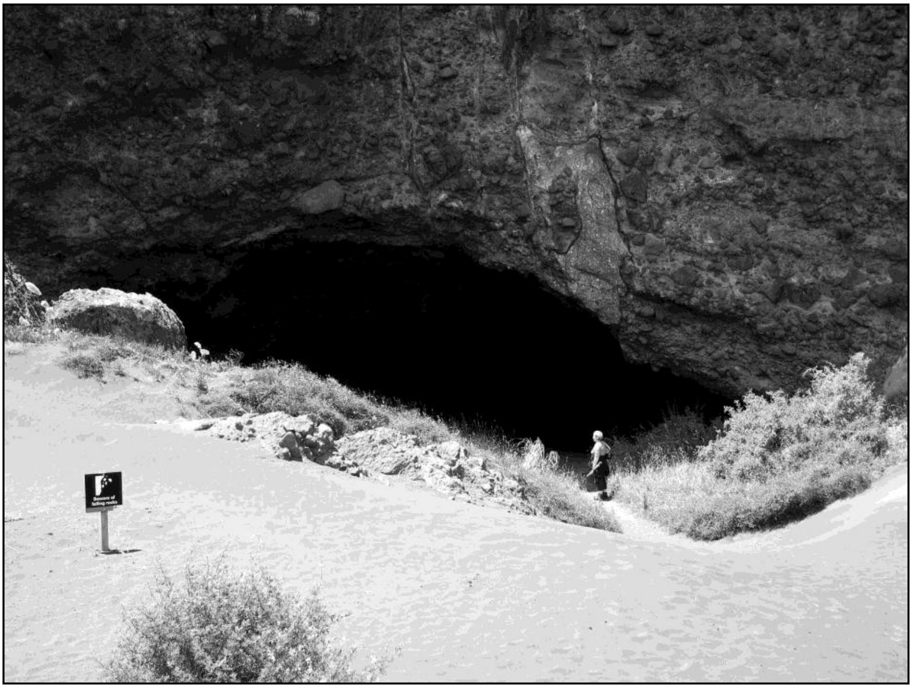
Speleothems in these caves are rare. In some places a millimeter thin brownish-reddish, ferric-manganiferous coating can be observed on the walls, which has precipitated from the seeping water. In one case a 15 cm long dark red stalactite was observed, which as well as the iron and manganese content includes carboniferous material. The carbonate content originated from the limey interbedded sediments. Due to the high magnetite and ilmenite content the sand filling the caves is often black. This black sand is typical of the west coast of the North Island.

I have to mention a few words how the ecosystem has evolved in the caves. There are significant differences between the flooded caves and the caves, which have no any longer any contact with the sea.. In the flooded caves the walls are covered with large masses of sand-tolerant black mussels (Modiolus neozelanicus) and rock barnacle (Elminius plicatus). A high neap tide species red alga (Bostrychia arbuscula) and high colour green algae (Dictyosphaeria cavernosa) cover the walls of the twilight zone. The tidal waves carry large quantity of both living and dead creatures into the caves and those which are still alive become unintentionally trogloxene. On the moist walls of those caves which are no longer subject to tidal waves living green and red algae species are to be found, whilst in the dryer part of the caves insects, spiders and resident birds are occasional cave dwellers. Bats were not observed, not even in the dryer parts of the caves. In some higher elevated rock shelters glowworms (Arachnocampa luminosa) can be observed.

Field observations (Description of the caves)

In seven sections of the coastal region abrasion caves, rock shelters and initial cave developments were studied.

At the 9. International Symposium on Pseudokarst I described in detail the relict abrasion caves near the village of Whatipu. Nine caves open at the foot of a 800 m long steep volcanic conglomerate cliff, which represents the former coast line. The 56 m long Cave No.6 (Fig. 2, Pict. 1.), the Big Cave or in Maori Te Ana Ru has the largest and well-known opening. This cave has his own history (Williams-Niven-Turner 2000). It served as shelter for travelling parties in pre-European times. In the last years of the 19th century the cave was used by the local timber-mill workers for social events and even had a dance floor. Today a 1 km wide scrubby sand flat lies between the caves and the Tasman Sea. This is just the latest phase of a longer term process, in which a huge volume of sand is slowly being moved northwards up the coast by currents and long-shore drift (Dench--Parore 2001).



Pict. 1: Entrance to the Whatipu Cave 6. (Big Cave, Te Ana Ru), in the forefront the intruding sand dunes

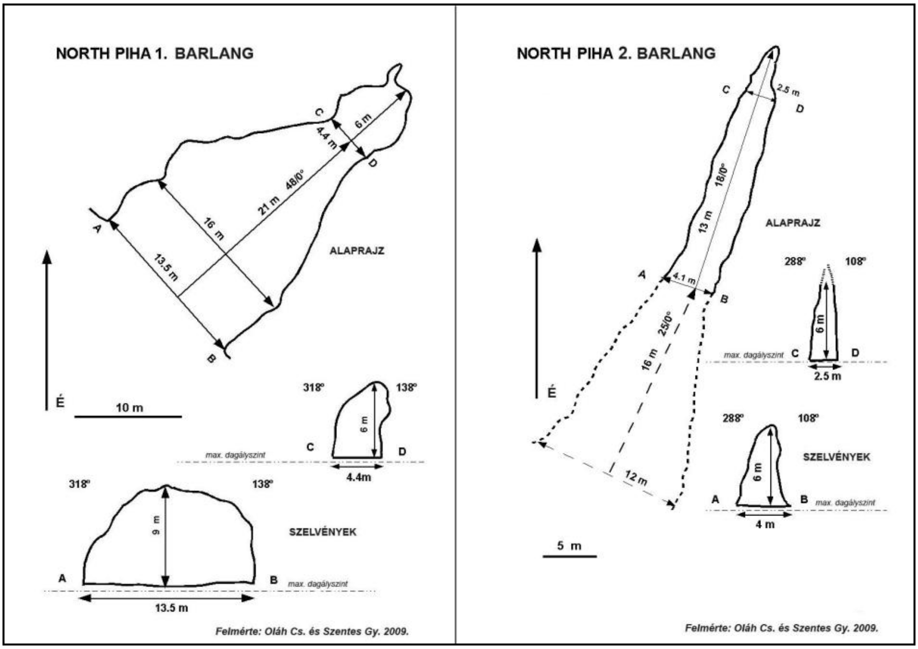
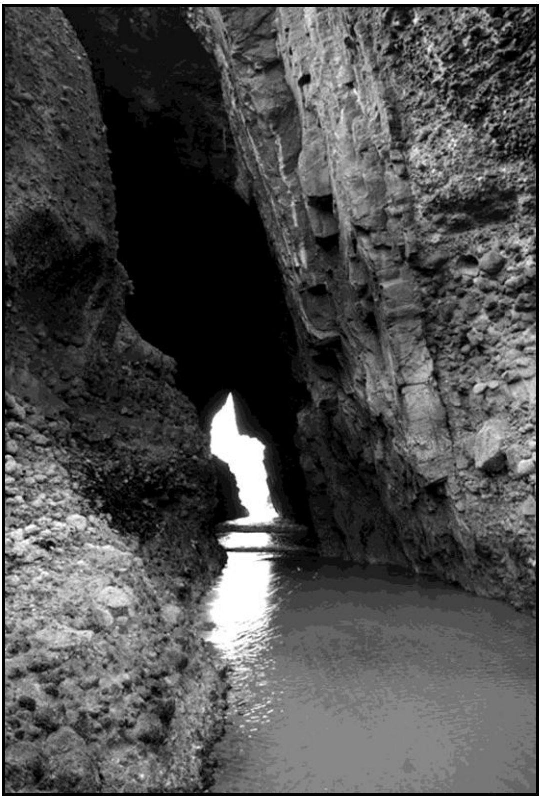


Fig.3.: Surveys of the North Piha Caves 1. and 2.

Pict. 2: Karekare; fragmentation originated rock shelters (the bigger one is the Maori Shelter Cave) in the Cave Rock

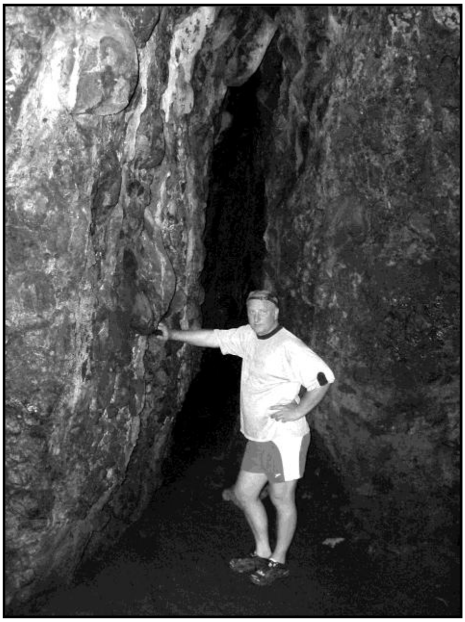


Pict. 3: The Keyhole has formed by the abrasion along an andesite dyke, which intruded into the agglomerate

Pict. 4: Large chamber in the North Piha Cave 1.

The next coastal region is to be found on the outskirts of the settlement and beach of Karekare. Along the coast only smaller rock shelters are to be found. On the valley slope behind the coast line, 50 m above sea level two rock shelterrs open in coarse andesite breccia (Pict. 2.). The name of the elevationis Cave Rock. The bigger shelter, the Maori Shelter Cave, has an entrance 8 x 10m with a 5 m bay, while the size of the smaller shelter is 5 x 5 m. The rock shelters are sacred places of the Maoris, indicate the historical and archaeological significance of the region. As regards the morphology of the hillside and the valley, the abrasion effect is unlikely to have influenced cave development. The caves are examples of how caves can be formed by fragmentation along fault lines after fragments of gravel have fallen out leaving large hollows in their place.

Further north lies Piha Beach. In thesouthern part of the beach one cave and one rock shelter and in northern section of the beach four caves are to be found (Cameron-Hayward-Murdoch 1997). In the South opens the Keyhole, a 46 m long through cave, which passes across the Taitomo Island (Fig 7. Pict 3). The island is surrounded by the sea only at high tide. The name of the island means in Maori a through cave, which passes across the hill. The Keyhole itself is a 12 – 14 m high and 4 - 5. m wide crevice, which has developed by the abrasion along into the agglomerate intruded NNW – SSE trending andesite dike. Oposite to the southern end of the island a rock shelter is to be found, which has developed also along an andsite dyke. The rock shelter is permanently flooded. In the northern part of the Piha Beach the No. 1 cave has a 13 x 9 m large entrance and a 27 m long and 10 m high abrasion chamber (Fig. 3.,Pict 4.), which was formed by the intense effect of abrasion along the fault belts. Inside the cave the tectonic structure can be easily observed. At present the waves reach the cave rarely, only when there is a storm tide due to the accumulated dune sand, which forms a dam in front of the entrance. Fifty metres



Pict.5: The main passage in the North Piha 4. follows a fault line

away No. 2 cave is to be found. The entrance is at the end of a 16 m long broken fissure, which is a collapsed part of the cave (Fig.3.). The cave itself is a 13 m long, 6 m high and 2 – 3 m wide passage, which was formed along a NE-SW trending fault. The accumulated dune sand also blocks the tidal waves from the cave. No. 3 cave is a fissure 19 m long over 10 m high 0.5 – 2 m wide (Fig. 5.). This tectonic cave is the continuation of a 10 m long open fissure, which is the collapsed section of an abrasion hole. The tidal waves reach the cave occasionally. No. 4 cave consist of a rock shelter and a group of cave passages (Fig. 4.). The rock shelter is the remains of a break down chamber, from where passages lead along NE – SW trending faults. The longest passage is 27 m long, 4 m wide and 5-6 m high (Pict. 5.). Close by are 8 m long and a 4 m long passages. The rock shelter and the caves are partly filled in by the intruding dune sand, which separates them from the tidal range.

Pict.6: The numbers show the entrances of the five caves in Whites Beach

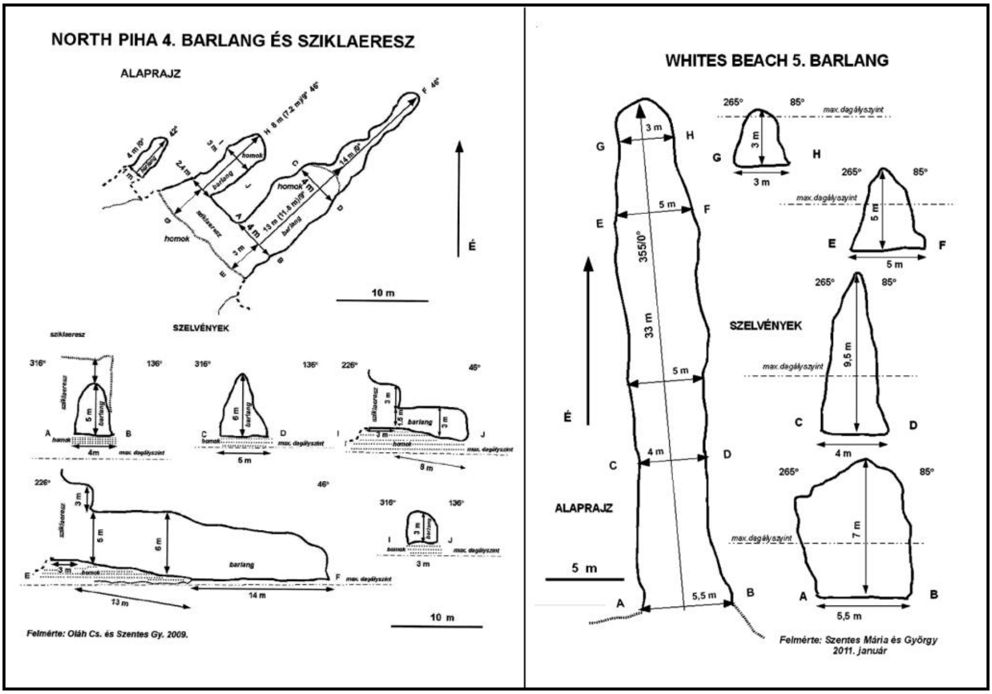
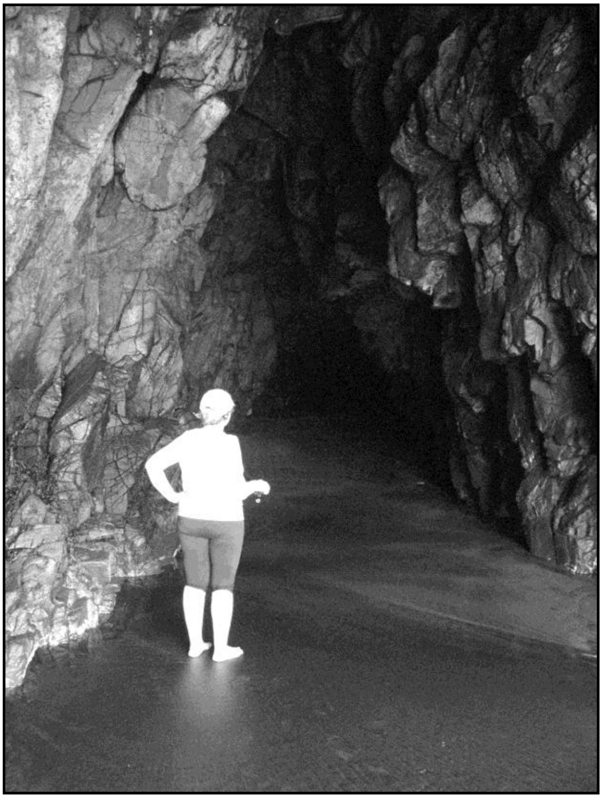


Fig.4.: Survey of the North Piha Cave 4. and the Rock Shelter and the Whites Beach 5. Cave



The sand banks of Whites Beach lie north of Piha Beach. The beach is surrounded by 200 m high cliffs. At the foot of the andesite agglomerate rock wall five caves have developed (Pict.6). Four closed by caves ranging in length from 5 m to 20 m. The cave entrances and the caves themselves are partially filled by rock debris, which has broken down from the relatively loose surrounding rock. The dominant fault lines, which relate to the cave development can be observed easily in agglomerate rock wall. The fifth cave is a 33 m long wide passage (Fig. 4,Pict. 7), which has developed along a N- S trending fault line. Fine grained, loose sand covers the floor.

Pict.7: The passage of the 5. Cave in Whites Beach

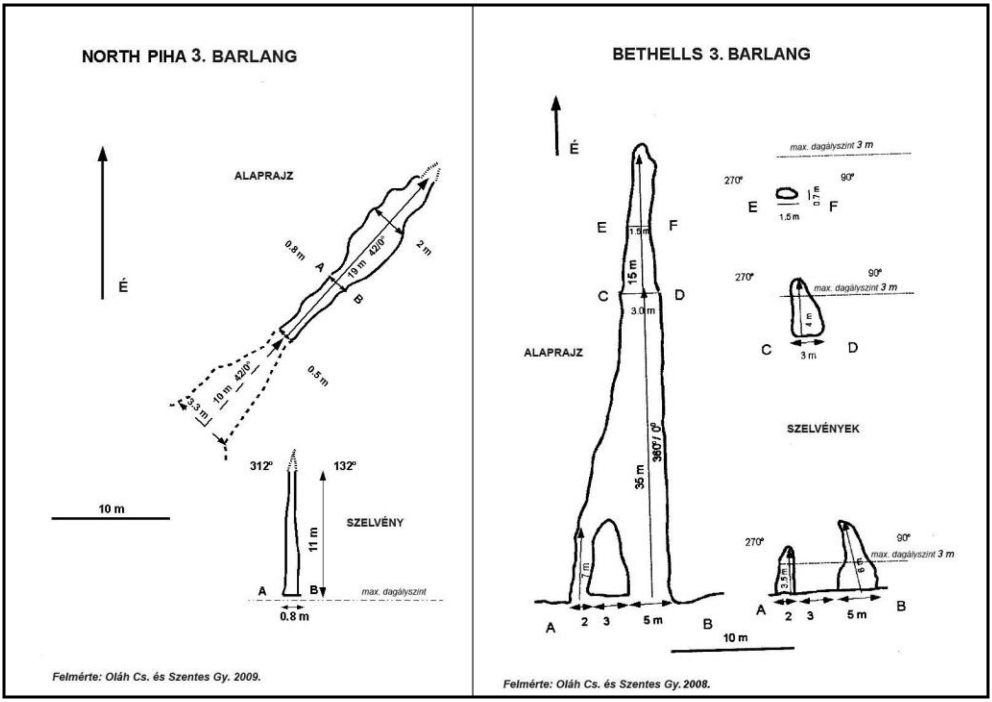


Fig. 5: Surveys of the North Piha Cave 3. and Bethells Beach 3.Cave

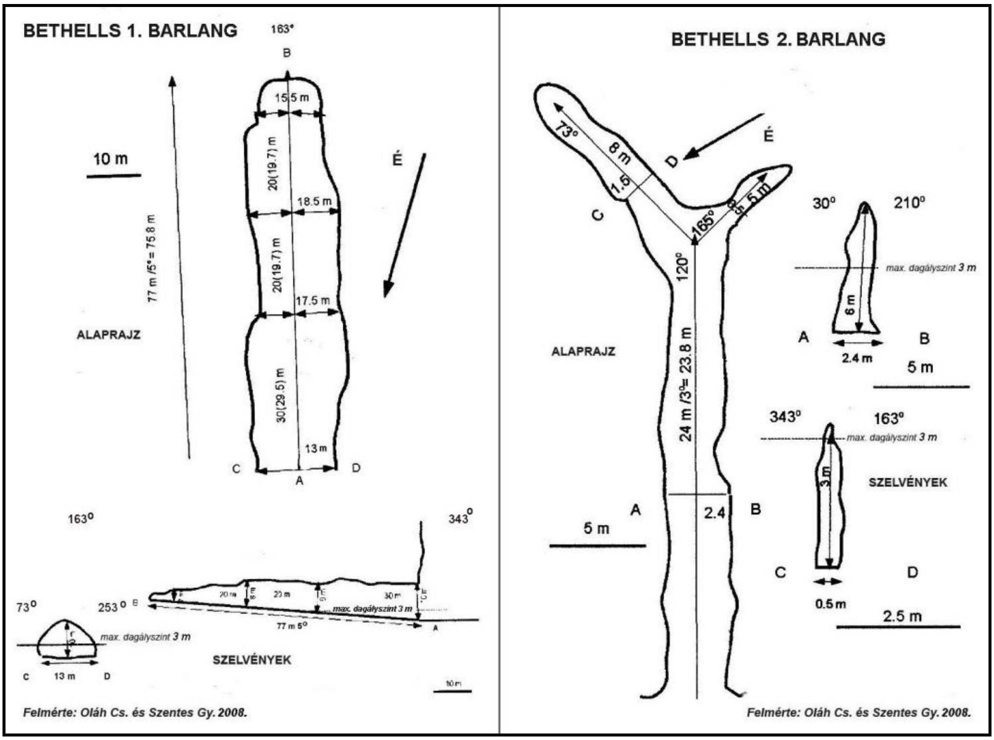


Fig. 6: Surveys of the Bethells Beach 1. and 2. .Cave

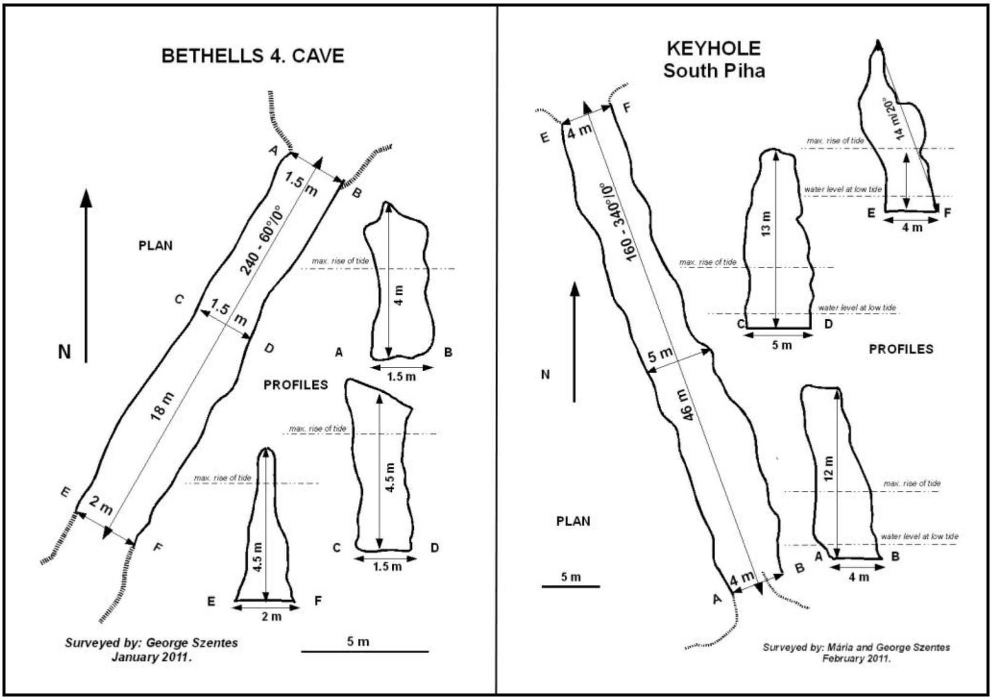


Fig. 7: Surveyes of the Bethells Cave 4. and the Keyhole

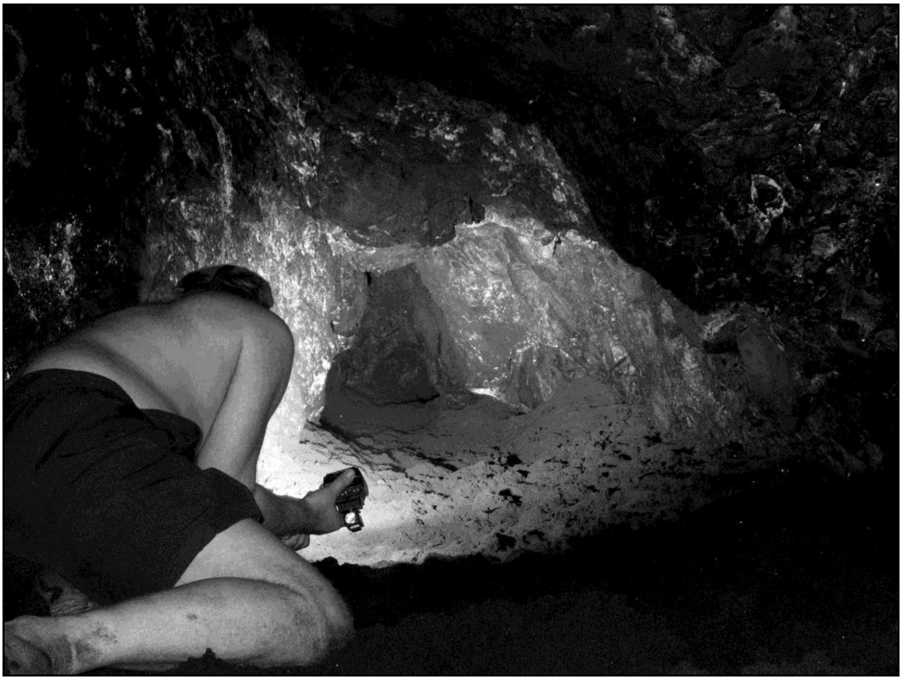
Pict. 8: In an agglomerate block of the Anawhata Beach a rock shelter has formed

Anawhata Beach is noteworthy for its spectacular cliffes. There is also a smaller river, which falls into the sea. The rock formation is coarse andesite agglomerate with tuff interbeddings. The steeply dipping layers and the vertical faulty zones are conspicuous. In an agglomerate block in the central region a 30 m long and 9 m deep rock shelter has formed, which is within the tidal zone (Pict. 8.). The floor of the rock shelter is covered by fine sand. Many holes formed as a result of rock breakdown or fault line determined narrow fissures appear in the steep rock (Pict.9.) wall. At the foot of the wall smaller rock shelters open. The name of the area -Anawhata- means in Maori uplifted rock shelter or hole for food storage. Both names would appear relevant.

Pict. 9: In the Anawhata Beach many holes formed as a result of rock breakdown or fault line determined narrow fissures appear in the steep rock wall

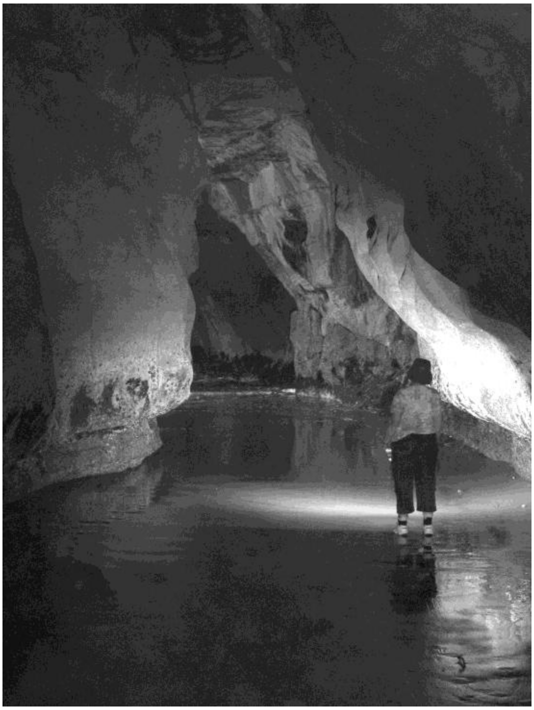
Pict. 10: The wide entrance of the 1. Cave in Bethells Beach

Further northward Bethells Beach, is located, where four caves were studied. No. 1 cave is to be found in the southern part of the area (Fig 6.). The wide cave entrance is visible from afar (Pict. 10.). At high tide the cave is inaccessible. It is flooded to a height of 3 m. The 70 m long, 20 m wide and 10 m high hole is one of the most spectacular caves in the region. Opposite, No. 2 cave opens (Fig. 6.). This cave is a 24 m long fissure passage, which bifurcates near the termination. It has formed along a NW-SE trending fault in the relatively fine grained tuffaceous formation. In one place on the wall a brownish-reddish stalactite like speleothem can be observed. No. 3 cave is a N –S trending fissure passage. In the first section of the cavity the abrasion effect is easily recognizable, whilst in the second part of the hole the tectonic forms are the dominant. A major part of the cave is filled in by sand (Fig. 5., Pict.11.). No. 4 cave opens in the northern part of the area. It is a 18 m long, 1.5 m wide and 4 m high through cave, which has developed along a NE – SW trending fault and widened by the abrasion (Fig. 7.).



Pict 11: The Bethells Cave 3. partly filled with sand and the crawl is the only way to advance

Muriwai Beach is the northernmost part of the study area. Here two caves were investigated. The 18m long, 4 m wide and 7 m high No. 1 cave was formed along a NW-SE trending fault in fine grained tuff (Fig. 8.). From the rim beside the cave the tidal movement can be directly observed. At high tide 3 m high water floods the cave and the ingress of the tidal waves has an effect as far as the end of the cave, while at low tide the cave can be visited dry-shod. No 2. cave is the longest cave in the study area. The 120 m long passage system has formed in fine grained tuff, in an overhanging cliff (Fig. 8.). The development of the cave is the result of the complex effect of abrasion. From the western foot of the cliff a 44 m long, 6m wide and 10 m high passage leads along a NW-SE trending fault into a large chamber (Pict 12.). In the chamber a wide entrance overlooks the sea (Pict. 13.). Several narrow passage open from the chamber. One of the passage can be followed to the sea, the other passages gradually narrow. In this wide cavity the incoming tide is spectacular and the tide-related ecosystem can be observed in considerable detail.



Conclusion

Certainly many areas are suitable for abrasion cave development along New Zealand‘s several thousand kilometre long coastline (Crossley 1988). The present study has investigated the caves of a characteristic coastal area, which is composed of volcanic gravel, tuffaceous interbeddings and has a specific morphology. The unique coastal currents of the Tasman Sea have played an important part in the formation and present-day position of the caves. It would suggest that there is potential for carrying out speleological studies for other coastal regions.

Pict.12: The main passage of the 2. Muriwai Cave at the beginning of the high tide

Pict. 13: The Sea Entrances to the Muriwai Cave 2

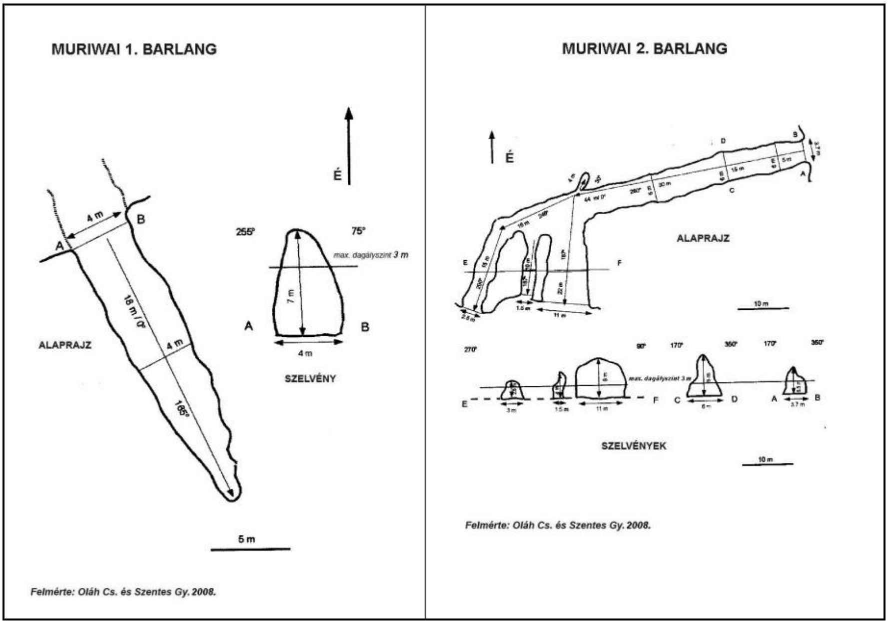


Fig.8: Surveys of the Muriwai Caves 1. and 2.

References

Balázs, D. (1981): Ausztrália, Óceánia, Antarktisz - Panoráma Kiadó, Budapest p.559-563.

Cameron, E. - Hayward, B. - Murdoch, G. (1997): A Field Guide to Auckland, Exploring the Region's Natural and Historic Heritage - Random House, Auckland p 178-179.

Crossley, P.C. (1988): The New Zealand Cave Atlas - North Island, NZSS p 2-12.

Dench, A. – Parore, L. A. (2001): Walking the Waitakere Ranges, New Holland Publishers, Auckland, p 12-27

Hayward, B. W. (1976): Lower Miocene Stratigraphy and Structure of the Waitakere Ranges and the Waitakere Group. New Zealand Journal of Geology and Geophysics 1976. vol 19. No 6. p 871 -895

Ombler, K. (2001): National Parks and other Wild Places in New Zealand - New Holland Publishers (UK) Ltd. p 34-36.

Szentes, G.. (2006): Relict Abrasion Caves in New Zealand, 9. International Symposium on Pseudokarst, Proceeding, Nature Conservation, Vol. 63 (6) 2007, p 69-76.

Thornton, J. (1985): Field Guide to New Zealand Geology - Reed Publishing (NZ) Ltd., Auckland p 147-150.

Williams, J.-Niven, C.- Turner, P. (2000): New Zealand - Lonely Planet, Melbourne, Auckland, London p 172-173.

Erosion and corrosion in quartzite sandstone

Jörg Templin

Höhlen- u. Karstforschung Dresden

Introduction

In recent times the genesis of cavities in sandstone and especially the formation of atectonic fissure caves is newly interpreted. In particular the erosion respectively the solution of the binder or even of the quartzite grain is being researched. In my opinion this is often about conceptual interpretation, because on the whole people agree.

This presentation is an attempt to show differences in interpretations and to suggest conceptual sharpness.

Terms

Erosion – Subrosion

Erosion is explained as destruction by water and ice. In the context of the genesis of cavities we take into account the „…flushing effect of flowing water (erosion)…“, that“…also takes part in the removal of the weathered pieces.“ (Börtitz, Eibisch 1962)

„Lixiviating processes of the ground water below the surface of the earth are summarized by the term Subrosion.“ (Reinsch 1991) There is chemical (lixiviation, karst processes) and mechanical (suffosion) subrosion. Frank Börner includes „…corrosion and underground erosion.“ concerning the genesisi of atectonic fissure caves in the Biela Valley (Börner). Regarding argillacious cement it comes to a neutralization of the friction forces between the pelitic debris(< 0,063 mm). This is a physical (mechanical) destruction process. Whereas the chemical solution of the cement is a form of chemical erosion and here p. e. R. H. Winkelhöfer speaks of a SiO_2 Karst process (Winkelhöfer 2003), F. Börner about corrosion in general (Börner). Both (SiO_2 Karst processes and corrosion) are regarded chemical solution processes.

Mechanical erosion through salt-crystal growth weathering will have to be treated separately because minerals are being transformed chemically during the hydration.

Ein zu klärender Übergangsbereich ist die mechanische Verwitterung durch Salzsprengung, da bei der eigentlichen Hydratisierung Minerale chemisch verändert werden. (Viete et al. 1960)

Chemical erosion

„Contains the complete dissolution or entire transformation of the chemical contents of the mineral substances of rocks.“ (Reinsch 1991)

Or defined similarly:

“Chemical erosion summarizes all processes which cause a transformation of rocks through chemical reactions and conversions.” (Viete et al. 1961)

Karst/ Karst processes

"The term Karst is of Indo-Germanic origin (as in karre for rock or karg) and was derived from the Kras landscape between Trieste in Italy and the Sneznik Mountain in Slovenija as a geomorpholically typical area for similar landscapes throughout the world by german geographers in the 19th century." (Kettner 1959)

Also G. Viete und H. Reichert write:

"... 2. an area morphologically and geologically created by karst processes, i. e. by solution activity of water above or below the surface. Depending of the dominating type of rock limestone and gypsum karst can be distinguished. (Viete et al. 1960)

Concerning the mrphology the authors speak of geologic organs (gypsum), lixiviation runway in the form of limestone pavements (limestone) and grykes (gypsum), cavities, caves, dolinas (depression areas up to 20 m deep and 100 m wide) and poljes (connected dolinas as depression areas). (Viete et al. 1960)

These are terms for the solution processes or also corrosion in carbonate and sulphate karst.

Also R. H. Winkelhöfer speaks of grykes in sandstone areas. He sees them and the formation of the "sacrificial bowls" (bowl grykes) on the mountains Quirl and Pfaffenstein as SiO_2 karst processes because they originate from the solution of the "... minerals quartz and the silicates..." (Winkelhöfer 2003). He also mentions the solution of "quartz silicic acid".

Solution processes in sandstone

The destruction of sandstone and the eventual formation of new minerals in and on the sandstone are regarded as part of the chemical erosion (corrosion) in the acknowledged specialized literature (Beyer, Rast, Beeger, Börtitz/ Eibisch, etc).

Mineral structures of sandstones (selection)

To be able to give a statement concerning solution processes we have to examine the sandstone compounds. The sandstones regarded here are called quartzite sandstones in literature. At the present time this includes:

- Sandstone with > 95% quartzite grains, grain binder silicious, calcareous, argillaceous linked or a multiple mix (Reinsch 1991)

Some examples:

1. Quartzite sandstone of Königstein and the Upper Biela Valley (according to Beeger 1962)

Labiatus sandstone, quantitative determination

Major components:

Grained: quartz (90%), glauconite, Feldspar (microline, plagioclase, probably albite and oligoclase), mica (mainly muscovite, as well as biotite)

Cement: mainly indirect grain linkage, partly direct (pore cement)

- often thin cemented selvages of serizite (mica with K and OH) and limonite around the mineral grains

- pore cement: finest quartz and mica-like minerals in equal portions of 8%

- Pores in the pore cement of 0,02 mm

- granulitic converted silicate minerals to the clay mineral illite (Beeger 1962)

2. Sandstone (according to Damaschun, Jekosch 1991)

Cotta

according to the investigation of the author: "… from the quarry of the Lohmgrund as well as the variety no. 12 from Neundorf (south of Pirna)…" (Damaschun, Jekosch 1991) and with that labiatus sandstone
"A typical feature of the Cotta sandstone is a **fine grain structure**, occurrence of **glauconites** (content: single grains up to 2%) and **amphiboles**, a relatively loose grain structure, little grain linkage as well as a **high share of pore filling material with clay minerals, mica, Fe-oxides and –hydroxides**. …" (Damaschun, Jekosch 1991)

- Quartz: 55%-65
- Glaukonite: 1%-2%
- Mica: 1%-2%
- Feldspar: < l%
- Rutile, zircon, amphiboles: < l%
- Cement: 20%-30% (clay and mica minerals, partly chloritinated; Fe-hydroxides and -oxides; **little silicified**)
- Pores: 10%-20% (Beeger 1962)

Posta

according to the investigation of the author: from Postelwitz (1907) and Reinhardtsdorf (1890) and with that sandstone layer **a**.

"… Typical features of the Posta sandstone are:

- a pronounced grain linkage, wide pores,
- an irregular arrangement
- the already mentioned relatively high portion of metamorphous quartz
- low portions of cement." (Damaschun, Jekosch 1991)
- Quartz 65%-75%
- Feldspar <1%
- Amphiboles < l%
- Cement : 3%-5% (hydromuskovite, little silicified)
- Pores: 20%-30% (Beeger 1962)

3. Statements of S. Grunert (2007)

The distribution of grain sizes of the **Posta sandstone** forms a closed spectrum. The quartz grains of the sand fraction are arranged in grain linkage. Because of the coaxial growth during the genesis they are connected punctually **without showing a recognizable cement.** Mostly **cement is entirely missing**...

The grains of the Cotta sandstone are arranged in grain linkage as well and are linked up tightly. The grain gussets, partly also the pores between the grains, are filled with pelitic material that is mainly consisting of phyllosilicates. This binder is **not directly** taking part in the linkage of the sandstone, so it is **wrong say clay linkage when talking about Cotta sandstone**... Cotta sandstone is linked siliciously, too." (Grunert 2007)

Concerning the cement of labiatus sandstone we can summarize:

Beeger	Damaschun/Jekosch	Grunert
• indirect grain linkage (silicious) partly linked with serizite and limonite • pore cement quartz and clay minerals	• little grain linkage • clay and mica minerals, • Fe-hydroxide and -oxides; • **little silicification**	• **silicious** • pelitic Schichtsilikate with indirect grain linkage

Concerning the cement of Posta sandstone we can summarize:

Damaschun/Jekosch	Grunert
3%-5% (hydromuskovite, some silicification) pores 20%-30%	Quartz grains of the sand fraction with Grain linkage quartz grains connected punctually **without showing a recognizable cement** binder almost entirely missing

Even if Grunert recognizes the cement of both types as silicious resp. the quartz grains as connected both sandstone types have different technical propertys.
The Posta sandstone is more resistant to erosion than the Cotta sandstone. Grunert investigated this during tests of 42 different sandstones from the most important quarry areas of the Saxon Switzerland. Among other qualities compared to the Cotta sandstone the Posta sandstone has got:

- higher maximum compression strength

		(x)	(a)
σ_{dl}	Gesamtstichprobe	478 kp/cm²	127 kp/cm²
	Postaer Sandstein	545 kp/cm²	98 kp/cm²
	Cottaer Sandstein	388 kp/cm²	104 kp/cm²

(Grunert 2007)

- ang a higher grain linkage stability

		(x)	(a)
ξ,	Gesamtverteilung	84,7 kp/cm²	20,0 kp/cm²
	Postaer Sandstein	92,3 kp/cm²	20,7 kp/cm²
	Cottaer Sandstein	74,5 kp/cm²	14,0 kp/cm²

(Grunert 2007)

- concerning the fabric features there are distinctive differences in the binder (pore filling)

		(x)	(a)
Z	Gesamtverteilung	6,81 Masse -%	5,46 Masse -%
	Postaer Sandstein	2,93 Masse -%	1,59 Masse -%
	Cottaer Sandstein	11,98 Masse -%	4,36 Masse -%

(Grunert 2007)

Amongst others, the higher portion of pores with easier soluble pore fillings and the resulting weaker grain linkage are the reasons for the lower erosion resistance of Cotta sandstone as labiatus sandstone. In this report the grain distribution is not clearly considered. But the author refers to Beeger who points out the changes in grain size between Königstein and the Upper Biela Valley. He describes a layer of coarse-grained sandstone in the Upper Biela Valley with visible rock pillars like the Herkulessäulen, Mühlenwächter, Wiesenstein etc. (Grunert 2007)

Chemical solution processes (Corrosion) in sandstone

1. Oxydation weathering

Conversion from cubic pyrite to brown haematite and acid sulphur

$$4FeS_2 + 10H_2O + 15O_2 \rightarrow 4FeOOH + 8H_2SO_4$$

accumulation of brown haematite because of the pyrite content of the sandstone resp. tertiary basalt volcanism

2. Hydratation weathering

by

- water agglomeration in the molecular range
- boundary surface reactions
- water agglomeration to single cationes
- water enclave into the structure

Gypsum — $CaSo_4$ x 2 H_2 O
formation of potassium alum — $KAl(SO_4)_2 \cdot 12\ H_2O$
sodium alum — $NaAl(SO_4)_2 \cdot 12\ H_2O$
transformation of mica/illite (Schichsilikat) to
swellable montmorillonites (clay mineral) — $Al_2\ [(OH)_2\ |\ Si_4O_{10}]\ ^{\cdot}\ nH_2O$
(Viete 1960)

These reactions above cause erosion processes by vapour pressure balance between interior crystal water and the steam partial pressure of the air.

The created crystallization pressure is a sign for mechanical erosion (salt-crystal growth).

Alum blooming in the Wohlrab cave, wall area at approx. 30 cm depth (Seifert/Templin, HKD, march 2010)

Potassium and natrium are provided by the clay minerals (silicates). sulphates may be brought in by water resp. be formed during the pyrite genesis. The carbonates have to come from cement because the water in the entire sandstone area (except Zeschnik) react clearly acidic. (Börtitz 1962)
The formation of swellable clay minerals leads to their transportation because of the circulating water (suffosion).

3. Protolyse – silicate weathering

Protolysis of feldspar:

$$2\ KalSi_3O_8 + 8\ H_2O \rightarrow 2\ KOH \quad + 2\ Al\ (OH)_3 + \quad 2\ H_4\ Si_3\ O_8$$

orthoclase — caustic potash — free poly silicic acid

According to the opinion of the author this solution reaction is very rare in the cemented quartzite sandstones of the Elbe Sandstone Mountains. Although Beeger expects low coaline deposits in the sandstone of Königstein he judges them by a sparse feldspar portion. (Beeger 1962)

The silicic acid as cement in quartzite sandstones "…can be delivered by the diagenetic dissolution into stable silicates in the sand during the early diagenesis…" (Reinsch 1991)

4. Solution of quartz in quartzite sandstone

"The dissolution of quartz is a normal hydratation and silicic acid is formed.

SiO_2 (solid) + H_2O $\longleftrightarrow$ H_4SiO4 (fluid)" (Winkelhöfer 2003)

"Most of the silicic acid comes from the sandstone itself, partly from the solution of the silicic acid inherent in the quartz grains of the sandstone, partly from the drivage of silicious sandstone components, especially feldspar." (Winkelhöfer 2003)

The SiO_2 in the formula above is no crystalline quartz but amorphous.

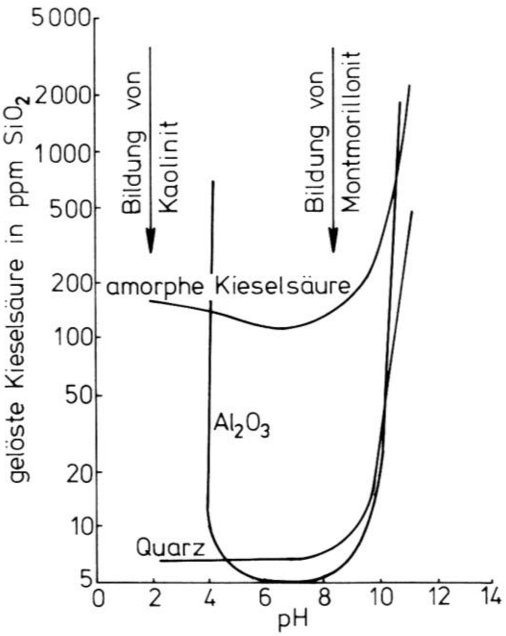
Solubility in mg/l at 25 °C (Benedix 1999)

amorphous quartz	crystalline quartz
120	2,9

Consequently amorphous quartz itself is an erosion or transformation product.

In this amorphous quartz the spatial translation order is not recognizable, just like in "real quartz".

So the cement of the silicic cortex (cemented quartz grains) on sandstone rocks could mainly be precipitated silicic acid that primarily takes its origin in the dissolved silicic gel of the cement. But also this solution process only works at high pH value:



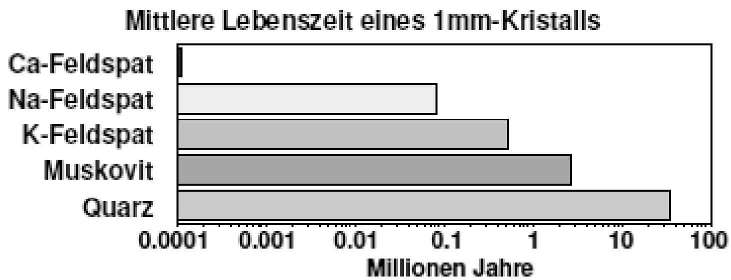
solubility of quartz, amorphous silicic acid and Al_2O_3 at 25°C depending on the pH-value (according to Correns et al. 1949), ppm = parts per million (Börtitz 1962)

As mentioned above the water in the Elbe sandstone area has a pH-value of <7. (Börtitz 1962)

In general we have to state: "high pH-values that allow alkali silicate solutions to exist can rarely be found in natural water. …however, their occurrence cannot be denied completely. For instance in the pore solutions of decomposing volcanic material relatively high pH-values can be reached. Also evaporation processes in certain geologic cases can cause the pH-values of pore solutions close to the surface of the earth to rise." (Landmesser)

Crystalline quartz itself is soluble only with difficulty, only at a pH-values >9, as shown above. Compared to other silicious minerals it is the least soluble mineral.

The formation of silicic cortex is stated with 0.1 – 0.2 mm per 100 years in specialized literature, without indications to research results. (Friedrich 2002)



Cavity formation in the sandstone and Karst processes

To speak of SiO2 Karst processes during the cavity formation in quartzite sandstone is considered worth thinking over by the author for the following reasons:

1. The silica crust formation exists on sandstone rocks, but it is not a main phenomenon and its formation conditions should be analyzed exactly in the future.
2. The formation of caves by SiO2 Karst processes plays a minor role because the solution processes are very protracted. Reasons for that are the low solution of real quartzites respectively of the quartzite silica gel and the low portion of feldspar as necessary supplier of the silica gel.
3. Especially the formation of fissure caves (atectonic and also tectonic) is mainly caused by hydratation weathering (swelling processes) of the clay and the following suffosion. Also the hydration of the salts alum and gypsum and connected to that their later mechanical weathering through crystallization contributes to the cave genesis.
4. Allowing the use of the term SiO2 Karst process changes the original nomenclature of the terms Karst/Karst processes. It should be inspected if this serves an unopposed professional examination.
5. If the term SiO2 Karst process was acknowledged as chemical weathering many weathering processes in the Elbe Sandstone Mountains that are mainly of chemical nature would be Karst processes. Then at least half of the Elbe Sandstone Mountains would be Karst mountains.

References

Beeger, H.-D.: Petrographische und technische Eigenschaften des Labiatussandstein: Jahrbuch des Staatlichen Museums für Mineralogie und Geologie zu Dresden 1962

Benedix, R.: Chemie für Bauingenieure, Teubner Stuttgart, Leipzig 1999

Börner, F.: Atektonische Klufthöhlen im oberen Bielatal/ Elbsandsteingebirge.

Börtitz, S., Eibisch, W.: Die Höhlen der Sächsischen Schweiz; in : Jahrbuch des Staatlichen Museums für Mineralogie und Geologie zu Dresden 1962

Damaschun, F., Jekosch, U.: Untersuchung der Gesteine (Brandenburger Tor) Das Brandenburger Tor 1791 – 1991, Verlag Willmuth Arenhövel Berlin 1991

Friedrich, J.: Diplomarbeit 2002, Bergsport und Naturschutz im Nationalpark Sächsische Schweiz Bildungsprogramm für die Kletterausbildung in der Sächsischen Schweiz

Grunert, Doz.Dr.rer.nat.habil. S., Dipl.- Geol.: Statistische Untersuchungen zur Aussagefähigkeit petrophysikalischer Messergebnisse über die Eigenschaften kieselig gebundener Sandsteine aus der Sächsischen Schweiz, Geologica- Saxonica- Journal, Heft 52/53 (2007) 23–68

Kettner, R.: Allgemeine Geologie. Bd. 2. Berlin (Deutscher Verlag der Wissenschaften) 1959,

Landmesser, M.: Zur Entstehung von Kieselhölzern, in extraLapis No./ : Versteinertes Holz

Reinsch, D.: Natursteinkunde; F. Enke Verlag Stuttgart 1991

Viete, Wagenbreth, Hunger, Reichert: Geologie Band 1; S.212; Bergakademie Freiberg; VEB Deutscher Verlag der Wissenschaften; 1960

Winkelhöfer, R.H.: Die innere Verkarstung des Sandsteines- eine kleine Bestandsaufnahme zur Höhlengenese im Kreidesandstein, in DER HÖHLRNFORSCHER, Mitteilungsblatt der HFG Dresden 2003

www.wzw.tum.de/bk/pdfs/vorlesungen/bk1_ws/verwitterung.pdf

Caves in the flysch Carpathians detected by ERT method

Jan Urban[1],Tomas Panek[2], Petr Taborik[2], Jan Hradecky[2], Włodzimierz Margielewski[1],Czesław Szura[3]

[1] Institute of Nature Conservation, Polish Academy of Sciences, Kraków, Poland,
[2] Department of Physical Geography and Geoecology, Faculty of Science, University of Ostrava, Czech Republic
[3] Association for the Caves Conservation „Malinka Group", Wisła, Poland

Introduction

The caves formed owing to the gravitational deformation of mountain slopes are very common in Polish Outer (flysch) Carpathians and represent majority of about 1100 caves explored in this region up till now. Among them are numerous relatively long caves – 34 caves are longer than 100 m, the longest is Jaskinia Wiślańska Cave – 2275 m (Klassek, Mleczek 2009, Szura 2009). These caves are important subjects of scientific research into processes shaping mountain slopes

Gravitationally induced cavities differ from other non-karst caves, e.g. weathering or erosional forms in their location underground and accessibility. They are formed owing to relatively deep transformations of rock massifs, resulting in widening of cracks or total disintegration of the rock massifs producing irregular voids amongst displaced rock blocks. Such cavities, genetically not related to the superficial processes, are often not opened to the ground surface (resembling in this some karst systems, especially hypogenic karst). Therefore the identification and exploration of them (widened cracks or irregular voids) is not easy and various methods are applied for their detection, e.g. analysis of maps, geomorphological observations, observations of warm air escapes etc. The geophysic methods have not been used for this purpose in the region. The electrical resistivity tomography (ERT), enabling to image discontinuities and other elements in the bedrock framework, seems to be adequate method to detect such cavities. It was applied for geomorphological interpretations, also for landslide structure reconstruction (e.g. Lapenna et al. 2003, Schrott, Sass 2007, Sass et al. 2008). This paper reports and discusses the first attempt of application of the geophysic methods, just ERT, for detection of non-karst, gravitationally induced caves in siliciclastic, flysch rocks and in mountainous area.

Regional settings

Outer Carpathians, called Beskidy (in Polish) or Beskydy (in Czech language), are formed of siliciclastic-clayey flysch rocks of predominantly Cretaceous-Palaeogene age: sandstones, sandstone-shale heterolithes, shales and conglomerates (Fig. 1). The mountainous region is dissected by river valleys several tens to 800 m deep and mountain slopes are often steep and formed of altered series of sandstones, shales and heterolithes. Such morphology and geological structures are conducive to development of gravitational mass movements, which are the most effective processes shaping the slopes (e.g. Margielewski 2006). The slope mass destruction generates formation of subsurface discontinuities and voids, which are caves when accessible for people. According to Viték's (1983) classification two genetic-structural types of caves can be distinguished there: 1) crevice type caves representing joints or systems of joints widened by tension (extension) strains in rock massifs and 2) talus type caves representing irregular voids formed among distinctly displaced (shifted and rotated) rock blocks. These first (crevice) type caves are usually formed during slow processes of slope fragmentation preceding landslide formation, while the latter (talus) type caves are formed usually during the main stage of landslide formation and are typical for landslide main body (Margielewski, Urban 2003a). However the genesis of these caves is not always strictly connected with their shape, outline and situation within rock massifs and slopes.

Fig. 1. Situation of the study sites at the background of the geological map of Polish Carpathians: 1 – Jaskinia Malinowska site, 2 – Diabla Dziura site, 3 – Jaskinia Miecharska site

To examine various condition of the ERT method application, the caves representing different genetic and morphological types were chosen, as follows:

- Jaskinia Malinowska Cave situated in the Beskid Śląski Mountain Range, western part of the Beskidy (Fig. 1) and representing typical crevice cave preceding a landslide formation (Margielewski, Urban 2003a) – 3 ERT profiles
- Diabla Dziura Cave situated in the Rożnów Foothill of the central part of the Beskidy.(Fig.1) – a system of (sub)vertical crevices developed close to the landslide head scarp, thus preparing the rock massif for the next phase of landslide development (Margielewski, Urban 2003b..
- Jaskinia Miecharska Cave and landslide surrounding it with 16 small caves, situated in the Beskid Śląski Mountain Range (Fig. 1); the main cave is a maze system of passages formed within large landslide body during the mass movements producing this form (Margielewski et al. 2007, 2008)

Methods

The maps of the Jaskinia Malinowska and Diabla Dziura caves are used after cave inventory (J. Ganszer and M. Rachwaniec in: Pulina, 1997a, and J. Ganszer and T. Mleczek in: Pulina, 1997b), whereas maps of the Jaskinia Miecharska Cave and surrounding landslide were made by authors recently. Detailed geomorphological observations at studied sites were conducted by authors several years ago and recently (Margielewski, Urban 2003a, b, Szura 2006, Margielewski et al 2007, 2008)

The ERT profiles were performed in June 2009. The two-dimensional electrical resistivity tomography is a geophysical technique based on differences of ground (bedrock) electrical properties (conductivity-resistivity), which are conditioned by lithology, structure, occurrence of (tectonic, sedimentary or other) discontinuities and cavities as well as water/air saturation of porous or/and fractured rocks. It enables to image a bedrock resisitivity pattern as deep as several tens meters. The resistivity image is a result of digital multiphase interpretation of hundreds of electrical signals measured in the bedrock by each two electrodes, in effect of applying current (electrical) signals into the ground through other two electrodes arranged in multi-electrode and multi-cable straight-line profiles (Milsom 2005)

Totally 14 ERT profiles were performed; 3 at the Jaskinia Malinowska site, 3 at the Diabelska Dziura site and 8 at the Jaskinia Miecharska site. The length of the profiles ranged from 63 m to 355 m. The electrode spacing (distance) ranged from 2 m to 5 m

From the three most frequently used electrode systems (Dipole-Dipole, Wenner and Wenner-Schlumberger) the Dipole-Dipole array appeared to be the most useful for the purpose of study (Pánek et al. 2010) and the results of application of this array is reported hereafter. This array consists in two current electrodes situated on one side of the multi-cable profile and two potential electrodes (measuring the signal) on its other side. This system is especially suitable for the detection of vertical structures (Milsom 2005)

The methodological aspects of the ERT method application for the imaging of caves and slope (landslide) structures at the studied sites are reported and discussed in the other paper (Pánek et al. 2010)

Study sites and results of field works

Jaskinia Malinowska site

Jaskinia Malinowska Cave (245 m long, 20 m deep) is situated in the upper part of the southern slope of Mt. Malinów (1117 m asl.) formed of the Upper Godula beds (Upper Cretaceous) representing very thick-bedded sandstones and conglomerates (with rare shale inserts), which are slightly inclined to the south-southwest (Margielewski, Urban 2003a). The cave, accessible through shaft ca 10 m deep, comprises a gallery composed of several straight-line sections, which follow two diagonal joint sets: D1 (300-310º) and D2 (20-25º). The main gallery is spacious and up to 10 m high in its central and western part, whereas the eastern segment of the cave represents narrow passages among rock blocks (Fig. 2 A-C). As observations of the cave walls proved, the cave was formed due to the extension and slight tilt of the downslope part of rock massif (Margielewski, Urban 2003a). This process of rock massif deformation can be also defined as dilation – a growth of volume without the change of shape.

Three ERT profiles were performed in this site – two ones parallel to the slope dip and one along the slope countours (Fig. 2 A). Two of them could test the ERT efficiency in cave detection, since they crossed the cave passages

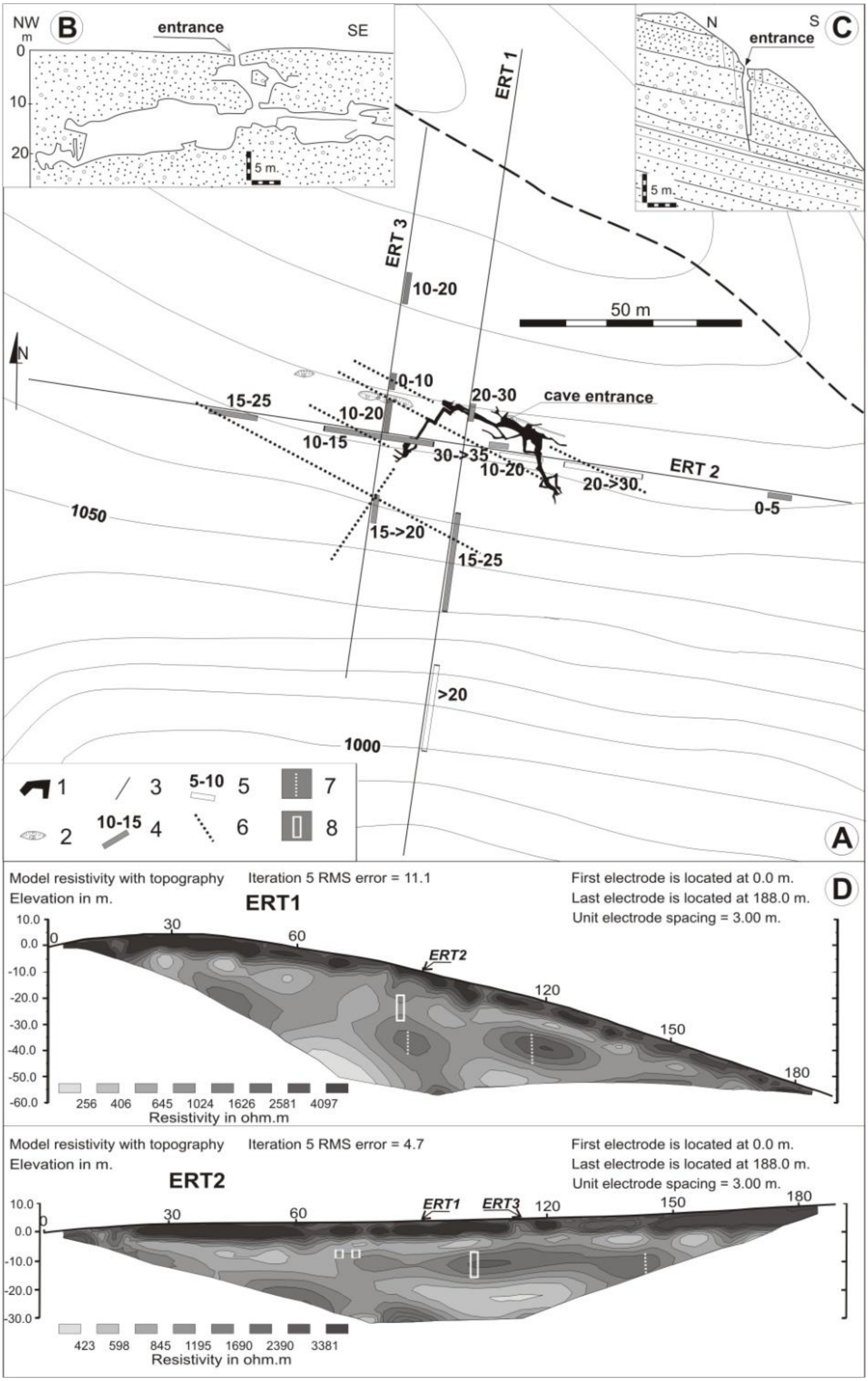
Cave passages usually overlap high resistivity anomalies on the profiles, although the shapes of these anomalies are not similar to the outline of the galleries. The high resistivity body marks also the surface depression situated west of the cave. It suggests that high resistivity anomalies preferentially record widened fractures or densely fractured zones (fracture arrays). Assuming that the fractures correspond to the joint sets controlling the development of explored cave galleries, the presumable pattern of fractured zones expanding the Jaskinia Malinowska Cave can be constructed (Fig. 2 D)

Diabla Dziura site

Diabla Dziura Cave (365 m long and 42 m dip) is situated within hill ridge stretched east-west and formed of very thick-bedded sandstones of the Ciężkowice Formation, which slightly dip to the south. On the northern slope of the range two generations of landslide movements, represented by two head scarps are discernible. Upper part of the higher and older scarp displays the rock cliff in which the cave entrances are situated. The landslide main body (colluvium) lies at the foot of the range slope, 40-50 m below the ridge (Fig. 3 A, B, D).

The Diabla Dziura Cave is composed of a few vertical and subvertical fractures situated very close each to other and often combined in one system of vertically elongated voids. The fractures are subparallel to the ridge direction and widened due to the tensional (dilational) translation of massif to the north, transversal to the ridge (Fig. 3 D, E). The widened fractures are extremely deep (although divided by rock blocks into three or four "storeys"), thus the cave is practically the deepest one in Polish part of the Beskidy (Margielewski, Urban 2003b) and reaches the level of the slope foot Three ERT profiles transversal to the ridge and cave were performed there. The longest one crossed the cave and both generations of landslides. Two shorter profiles were situated east of the cave (Fig. 3 A)

(see previous page) **Fig. 2.** Jaskinia Malinowska site; A – map of the cave and its surroundings (cave map after Rachwaniec M. in Pulina 1997a); B – longitudinal cross-section (after Ganszer J. in Pulina 1997a); C – conceptual transversal cross-section (after Margielewski, Urban 2003a, modified); D – ERT 1 and ERT 2 profiles. Symbol explanations: 1 – cave, 2 – surface depression, scarp, 3 – ERT profile, 4 – apparent high resistivity anomaly and its depth in meters, 5 – less apparent high resistivity signal and its depth in meters, 6 – densely fractured zone (on map) inferred from ERT; 7 –densely fractured zone inferred on ERT profile, 8 – schematic cave gallery cross-section on ERT profile. Steeply dipping ERT profiles on map are shortened according to their projection on horizontal plane.



NW
m
B
entrance
SE
0
10
20
5 m.
C
N
S
entrance
5 m.
ERT 1
ERT 3
ERT 2
50 m
N
10-20
0-10
15-25
10-20
10-15
20-30
cave entrance
30->35
10-20
20->30
0-5
1050
15->20
15-25
>20
1000
1
2
3
4
5
6
7
8
5-10
10-15
A
Model resistivity with topography
Elevation in m.
Iteration 5 RMS error = 11.1
ERT1
First electrode is located at 0.0 m.
Last electrode is located at 188.0 m.
Unit electrode spacing = 3.00 m.
D
ERT2
256 406 645 1024 1626 2581 4097
Resistivity in ohm.m
Model resistivity with topography
Elevation in m.
Iteration 5 RMS error = 4.7
ERT2
First electrode is located at 0.0 m.
Last electrode is located at 188.0 m.
Unit electrode spacing = 3.00 m.
ERT1
ERT3
423 598 845 1195 1690 2390 3381
Resistivity in ohm.m

Two large high resistivity anomalies are the main elements of the longest profile (Fig. 3 E). They are most likely a sandstone series cut and displaced by fault. The sandstone body in the northern (left), upper side of the fault is underlain by low-resistive elongated body – most probably shale series, which is confirmed by small shale outcrop at the slope foot. The resistivity signal produced by large (high and long) fractures forming the cave overlap the sandstone high resistivity body and can be distinguished only in the uppermost part. The sandstone high resistive body is also marked in the central profile, although its northern, upper part (in upper side of fault) displays distinct variability of resistivity, which can be caused by the occurrence of fracture arrays

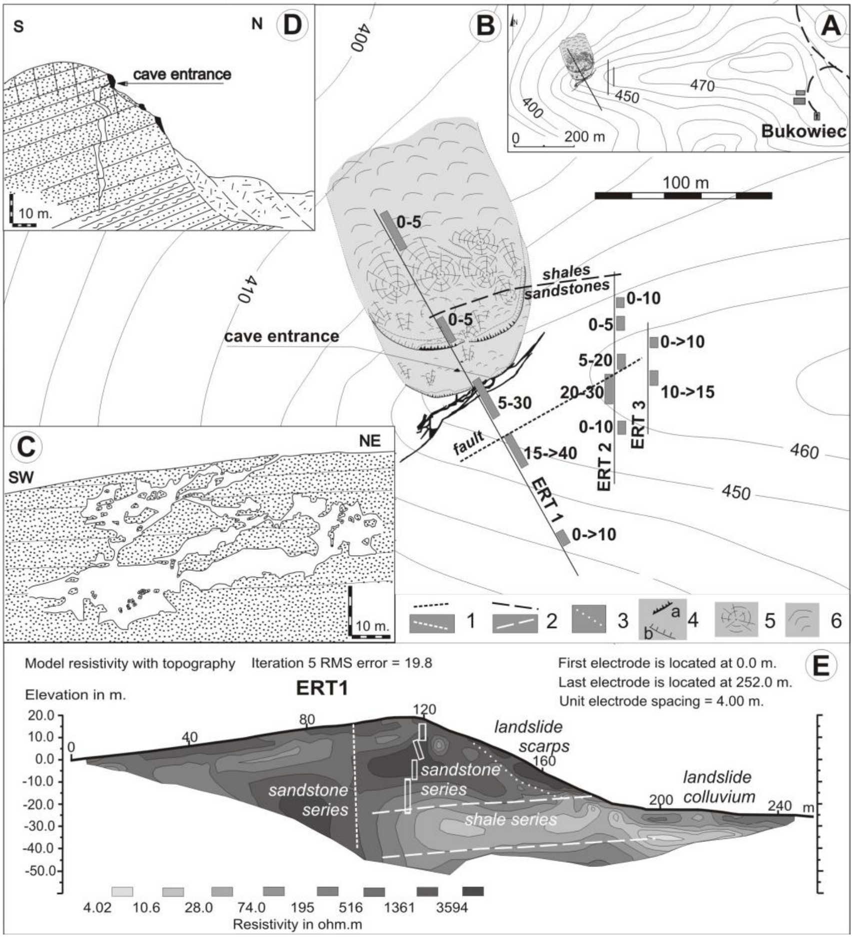


Fig. 3. Diabla Dziura site: A – topographic situation of the site; B – map of the cave and its surroundings (cave map after Ganszer J. and Mleczek T. in Pulina, 1997b, simplified); C – longitudinal cross-section (after Ganszer J, Mleczek T. in Pulina 1997b, simplified); D – conceptual transversal cross-section (after Margielewski, Urban 2003b,); E – ERT 1 profile. Symbol explanations: 1 – fault inferred from ERT profile, 2 –lithological boundary inferred from ERT profiles, 3 – tension zone (cutting surface) and potential sliding surface on ERT profiles, 4 – landslide scarps: a – rocky, b – soil, 5 – landslide body (colluvial rampart), 6 – creeping and colluvial tongue; other symbols – see Fig. 2. Steeply dipping ERT profiles on map are shortened according to their projection on horizontal plane.

The landslide pattern is the second structure clearly imaged on the main (longest) ERT profile (Fig. 3 E). The landslide body (colluvium) is displayed by several oval and horizontally elongated high resistivity anomalies overlying low resistivity bodies similar in shape. Such an image is caused by inconsistent mixture of crushed sandstone and shale rocks saturated by water in the deeper part. Slightly circular shape of narrow and inclined low resistivity zone in the slope above the landslide body suggest its genetic connection with lanslide formation or preparation. Therefore, it can be cutting surface and potential shearing (sliding) zone of the landslide, which is less resistive probably due to the higher humidity.

Jaskinia Miecharska site

Jaskinia Miecharska cave (1810 m long, 56 m of the vertical extension, 10-20 m deep undreground) developed within the landslide situated in the southern slope of Mt. Malinowska Skała range, just above the Malinka stream. The landslide, ca. 350 m long (S-N) and 200 m wide (W-E) (Fig. 4A), is formed of the Upper Godula beds (Upper Cretaceous) comprising the series of thick-bedded sandstones with shale inserts (several centimeters to 30 cm thick), which dip 20º to the south, thus practically parallel to the slope. Consequently, the landslide represents intermediate deep slip-consequent gravitational movement displaced along the bedding planes (which is confirmed by the underground stream in the cave, flowing on the sliding surface, which does not sink into the rock basement untouched by deformations, thus devoid of widened joints – Fig. 4 B). The landslide was formed during at least two stages of mass movements. The oldest stage is represented by the highest head scarp and the trench at its foot, whereas the younger landslide generations are represented by several scarps, trenches and landslide bodies (with rock packets and rock forms) in the central part of this area as well as landslide body and colluvium dissected with several depressions in its lower segment (Fig. 4 A) (Margielewski et al. 2007, 2008).

The Jaskinia Miecharska Cave is a maze system of passages formed along diagonal (D1) and transversal (T) joint sets within the landslide body of the central part of the landslide zone. The cave system is composed of some crevice type galleries (formed owing to simple widening of joints), but some of its passages represent voids formed among chaotically displaced (shifted, turned, rotated) rock blocks. Some galleries and chambers are spacious, up to 10 m high and 10-30 m long. Observations in the cave suggest its formation due to the process of the fissure macrodilatancy – growth of the rock material volume and change of its shape due to the propagation and widening of fractures (Margielewski et al. 2007, 2008)

Within the landslide zone, there are also 16 minor caves, situated usually close to the scarps and trenches and 3-34 m long (Fig. 4 A) (Pánek et al. 2010)

Eight ERT profiles were performed at this site: Six profiles are more or less parallel to the slope dipping – longitudinal to the landslide zone. Three of these longitudinal profiles cross the main structures (landforms) of the landslide zone. Two ERT profiles are transversal to the landslide zone, parallel to the slope contours (Fig. 4 A)

The first observation of ERT profiles (Figs. 4 and 5) is that the high resistivity bodies overlap large galleries and chambers of the Jaskinia Miecharska Cave, thus the cave is properly detected by this geophysic method. However, there is much higher number of high resistivity anomalies on the profiles than cave galleries accesible in the landslide, which suggests that there are numeroous not accessible cavities or/and not only apparently widened cavities are imaged as high resistivity anomalies, but densely fractured zones, as well.

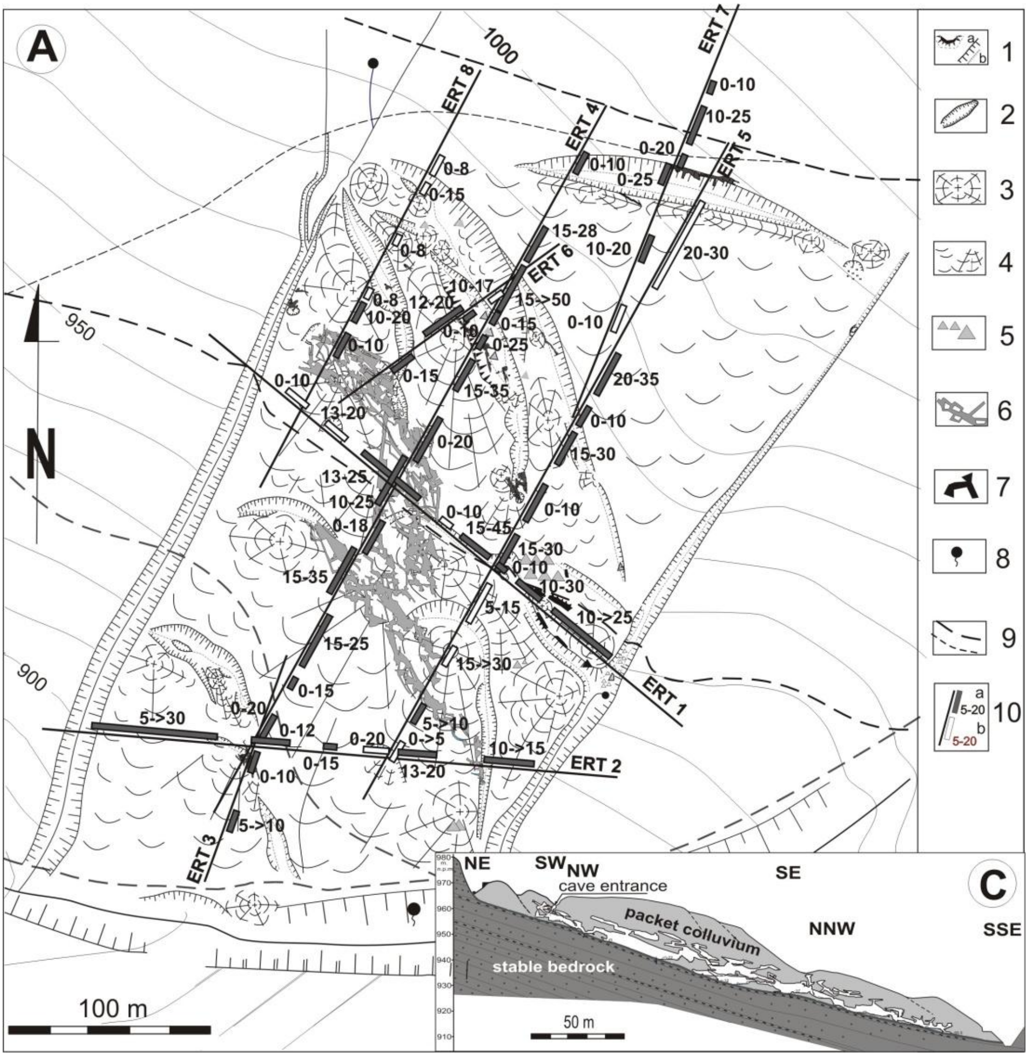


Fig. 4. Jaskinia Miecharska site: A – a map of landslide and cave (after Margielewski et al., 2007); steeply dipping ERT profiles are shortened according to their projection on horizontal plane. B – longitudinal cross section of the Jaskinia Miecharska Cave. Explanation of symbols: 1 – landslide scarps, a) rocky, b) soil; 2 – landslide depression, trench; 3 – landslide body – rampart; 4 – landslide body – colluvial tongue; 5 – rock forms, crags; 6 – contours of Jaskinia Miecharska Cave; 7 – contours of other, small cave; 8 – spring; 9 – forest pathes 10 – ERT profile with marked high resistivity anomalies: a – apparent high resistivity signal and its depth in meters, b – less apparent high resistivity signal and its depth in meters

Numerous and distinct oval high resistivity bodies occur within the main landslide body at the depth 10-20 m, close to the largest cave galleries of the cave. They are accompanied by less frequent (several) low resistivity anomalies of similar shapes and sizes (marked by A letter in Fig. 5). Most of them are situated at the straight-line zone, which can be identified with landslide sliding zone and simultaneously with the boundary between the gravitationally disintegrated massif and stable basement and landslide sliding surface (zone) observed in the cave. The second type of high resistivity anomalies are represented by wedge-like and lenticular bodies, situated shallow underground usually within or near scarps and trenches, close to some small caves discovered in the site (marked by B letter in Fig. 5).

Discussion and results

The air-filled subsurface voids, as caves, should be expressed by ERT as high-resistivity anomalies (e.g. Milsom 2005). It is true for the study sites – large cave galleries and chambers are usually imaged by the high resistivity bodies independently of a type of caves and stage of slope evolution. However, the reverse relation that each high resistivity anomaly means the cavity (potential cave) has not been proved and doubtful or even denied, since, the high resistivity feature attributes also the sandstone body most probably lacking the cavities, as the deeper sandstone series at the Diabla Dziura site and the rock basement (below the cave galleries and sliding surface – Fig. 4 B) at the Jaskinia Miecharska site.

Besides of cave detection, at each site (representing different type of caves and slope modifications) different structures of the rock massif were imaged and detected by ERT.

In the case of very slightly disintegrated and lithologically monotonous rock massif forming slope at the Jaskinia Malinowska site the main structures detected by ERT are most probably fractured zones (Fig. 2). Their pattern is related to the joint sets and indicates that the network of initial fractures prepared the rock massif to landslide formation is much larger than it is visible in the cave

At the Diabla Dziura site the lithological structures are accurately recorded by ERT on the main (longest) profile. Such image was most probably possible to obtain owing to distinct lihological diversity. The lithology even confuses the cave detection at this site. Consequently, the ERT method evidences the lithological control of the gravitational slope disintegration and cave development, which was assumed (postulated), but not so clearly perceived (proved) on the basis of direct field observations (Margielewski, Urban 2003b). Moreover, the structures of landslide are distinctly visible in this profile. Its elements are displayed by slightly less resistive zone of potential shearing surface of rotational landslide as well as landslide body and colluvium characterized by variable, in deeper part low resistivity driven by lithological variability and water saturation (Fig. 3)

In the case of Jaskinia Miecharska site, where the gravitational structure (landslide) is much more complicated, the high resistivity bodies overlap numerous cave galleries/chambers of different types, however the connection of great number of anomalies with the underground voids was not proved. Nevertheless, two genetic types of zones favorable for cavities' (caves') occurrence have been proved. The first type is represented by oval entities (numerous high resistivity and rare low resitivity anomalies) situated close to the sliding zone and the bottom of landslide body. Most probably they are characteristic for the zone od highly differentiated fracturing and displacement of rock massif (as e.g. Jaskinia Miecharska Cave), which can be described as zone of differentiated bulk-density

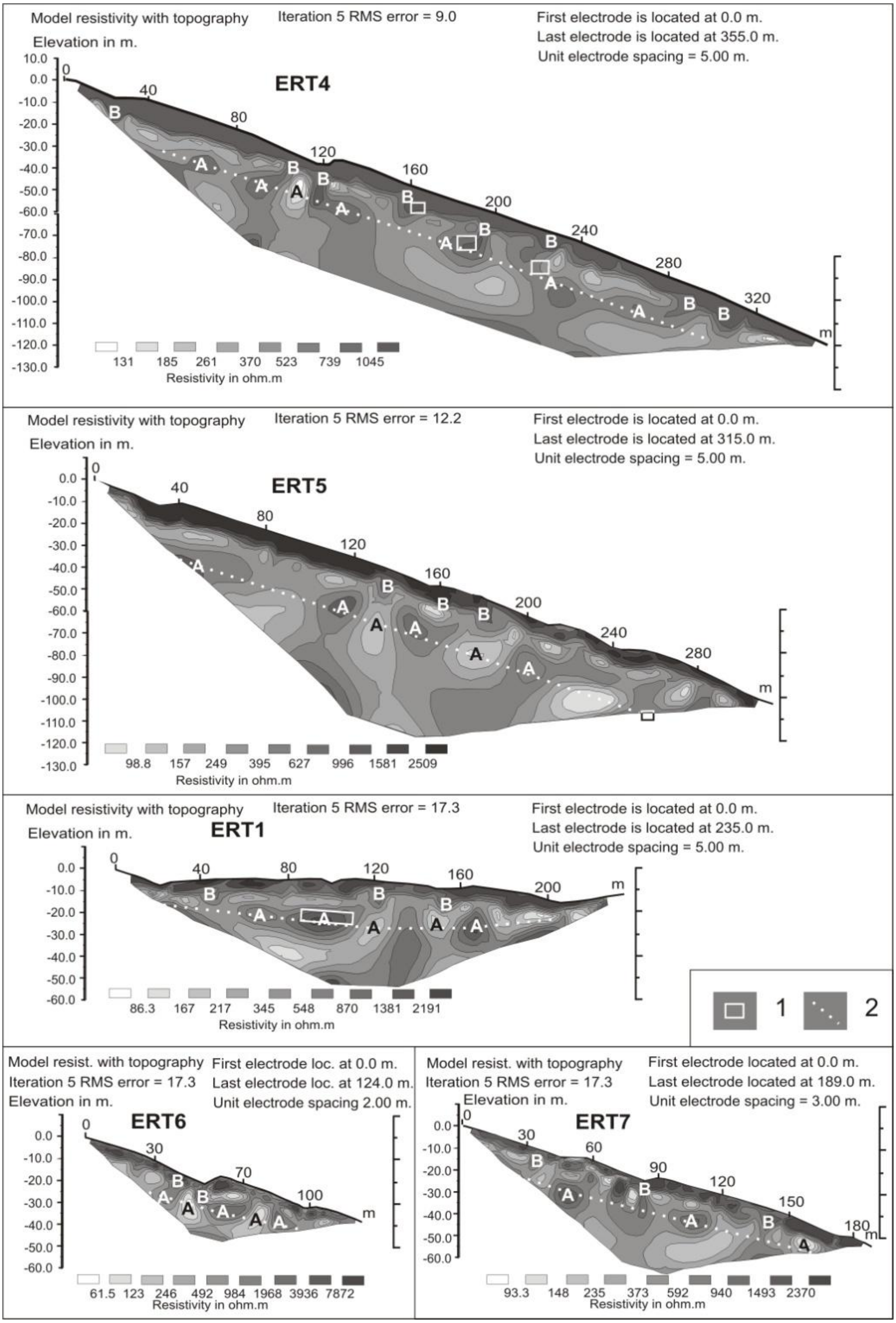


Fig. 5. Selected ERT profiles of the Jaskinia Miecharska site. Symbol explanations: 1 – schematic cave gallery cross-section, 2 – landslide sliding surface observed in the cave and inferred from the ERT profiles. Explanation of letters in the text

of rock massif (more or less densely accumulated block-debris material), transformed by fissure macro-dilatancy process (Margielewski et al. 2007, 2008). However, the water distribution (underground water stream existing in the Jaskinia Miecharska Cave) can also influence the resistivity pattern near the boundary between lower in situ rock massif and upper, displaced rock masses, which is sliding (failure) surface of the landslide.

The second type of high resistivity anomalies, represented by lenticular or wedge-like and vertically elongated bodies, are most probably connected with apparent tension zones within the landslide trenches. This is why they are often (but not always) situated within or close to the scarps, trenches and small caves. Most of them can be probably defined as dilation zone of landslide (Margielewski et al. 2007, 2008)

Conclusions

The electrical resistivity tomography ERT technique (Dipole-Dipole system) is adequate method to interpret structures of slopes formed of the siliciclastic-clayey flysch rocks, which undergo to the gravitational deformations, especially if the rocks are lithologically differentiated. It displays the main lithological features as well as systems of densely fractured zones. The resistivity pattern of slope can also reflect the differentiation of general bulk-density of gravitationally disintegrated rock massif within complex landslide forms

ERT is also appropriate method to detect underground air-filled spaces within these structures, if they are sufficiently large, however, not only accessible and potential caves are reflected as high resistive entities in the ERT profiles. Consequently, this method can not be used as direct and unequivocal “detector” of caves (strictly cavities) occurrence. Nevertheless, the Dolny Waserszlog Cave (34 m long) at Jaskinia Miecharska site was found and explored in summer 2009 on the basis of the ERT profiles data, near the place, where three crossing profiles detect shallow high resistivity body

References

Lapenna V., Lorenzo P., Perrone A., Piscitelli S., Sdao F., Rizzo E., 2003. High-resolution geoelectrical tomographies in the study of Giarrossa landslide (southern Italy). Bulletin of Engineering Geology and Environment, 62: 259-268.

Margielewski W., 2006. Structural control and types of movements of rock mass in anisotropic rocks: case studies in the Polish Flysch Carpathians. Geomorphology 77, 47–68

Margielewski W., Szura C., Urban J., 2008. Jaskinia Miecharska cave, (Beskid Śląski Mts., Outher Carpathians) – the largest non-karst cave in the flysch Carpathians. Zacisk, Spec. Issue: 7-13

Margielewski W., Urban J., 2003a. Crevice-type caves as initial forms of rock landslide development in the Flysch Carpathians. Geomorphology, 54: 325-338.

Margielewski W., Urban J., 2003b. Direction and nature of joints controlling development of deep seated mass movements: a case study of Diabla Dziura cave (Polish flysch Carpathians). Geomorphologia Slovaca, 3 (1): 58-59

Margielewski W., Urban J., Szura C., 2007. Jaskinia Miecharska cave (Beskid Śląski Mts., Polish Outer Carpathians): case study of a crevice-type cave developed on a sliding surface. Nature Conservation, 63 (7): 57-68

Milsom J. 2005. Field geophysics, the geological field guide series. Wiley, Chichester

Pánek T., Margielewski W., Tábořík P., Urban J., Hradecký J., Szura C. 2010. Gravitationally-induced caves and other discontinuities detected by 2D electrical resistivity tomography. Case studies from Polish Flysch Carpathians. Geomorphology (in print)

Pulina M., (Ed.) 1997a. Jaskinie Polskich Karpat fliszowych, v. 1 (in Polish). Pol. Tow. Przyj. Nauk o Ziemi, Warszawa

Pulina M., (Ed.) 1997b. Jaskinie Polskich Karpat fliszowych, v. 2 (in Polish). Pol. Tow. Przyj. Nauk o Ziemi, Warszawa

Sass O., Bell R., Glade T., 2008. Comparison of GPR, 2D-resistivity and traditional techniques for the subsurface exploration of the Öschingen landslide, Schwabian Alb (Germany). Geomorphology, 93: 89–103.

Schrott L., Sass O., 2007. Application of field geophysics in geomorphology: advances and limitations exemplified by case studies. Geomorphology, 93: 55–73

Szura C., 2006. Jaskinia Miecharska – beskidzki gigant (in Polish). Jaskinie, 2 (43): 6

Szura C., 2009. Jaskinia Wiślańska – fliszowy gigant w natarciu (in Polish). Jaskinie, 3 (56): 19-21

Vitek, J., 1983. Classification of pseudokarst forms in Czechoslovakia. International Journal of Speleology, 13: 1-18

Pseudokarst in granites: How granite caves are developed - the case of Galician caves

Vaqueiro R., M.[1]; Costas V., R [1]; Suarez P., R.M. [1]; López M., J.M. [1], Vidal R. J.R.1,2

[1] Clube Espeleolóxico Maúxo, Vigo, Spain.
[2] Instituto Universitario de Xeoloxía Isidro Parga Pondal. Coruña, Spain.

Introduction

The relation between discontinuities and subterranean network drainage is analyzed for two granitic systems of cavities: O Folón and A Trapa located at the Galiñeiro Sierra (A Trapa) and in Fragoselo-Coruxo hills (O Folón), both in Pontevedra (Galicia, NW Spain). The genesis and evolution of the two cave systems are not yet known in detail though, based on the geomorphological data, an approximate sequence may be established. The formation of these cavities starts in the Tertiary Period s.l., as the age supposed for the thick cover of alterites exposed in the close tectonic basin of Porriño-Tui (Miocene age). But the formation of these cavities does not begin till alterites are eliminated by erosion and the rocky substratum becomes exposed subaerially. At first, the runoffs circulated directly over the rock but the involved watercourses were of second order and discontinuous, related to the seasonality as proved by the fact that no specific forms (gorges, rocky channels, etc.) were developed on surface. Later, when the tight fissure network had been cleaned of alterites, the water was forced to circulate in depth at high velocities and it was at that moment when O Folón and A Trapa caves started to develop. Anyway, the outline of the two subterranean systems is mainly defined by the system of discontinuities, of endogenous origin (final intrusive stage of the granitic body), which have not been modified substantially. At present, the cavities at the bottom of two small valleys are partially covered by blocks mobilized down the slope by gravity. Therefore, the sequence of formation that defines the two studied cave systems is as follows: 1st: a long episode of edaphic weathering that credibly ends with the climatic change that begins in the Pliocene and is guided by the changes in the base level (of tectonic origin). 2nd: elimination of the regolith cover by the erosion carried out by the runoffs or the action of the fluvial drainage network of the Miño River for A Trapa and the Oitabén-Verdugo rivers for O Folón. 3rd: slope processes associated with the dismantling of the regolith cover with release of residual blocks which are accumulated at the bottom of the slopes. 4th: erosion of the subterranean rocky bed by the water channelized through the pseudokarstic system of A Trapa and O Folón (essentially development of pot hole and polished surfaces). And 5th: development of speleothems (pigotite, evansite and opal-A) in the inactive cave levels of the subterranean drainage network. The datings carried out for these deposits (from 1.8 to 3 kyr BP) and the ages of the remains of anthropic origin found in these pseudokarstic systems (from the Bronze Age to the Neolithic Age) confirm that at the end of the Pleistocene both caves were already defined approximately with their present aspect, though some later subsidences were produced in certain zones of both caves. The morphology of the conduits is related firstly to the characteristics of the discontinuity system (orientation, opening grade of the fissure related at the same time to the movement of the blocks which delimit it). Secondly, it depends on the incision process of the drainage network (normally vertical) that gives rise up to 3 types of transversal profiles of conduits. The conduits of phreatic type are originated when the water circulation is produced lineally through the partially open fissures though the section may extent acquiring an elliptical shape due to enlargement along discontinuity planes.

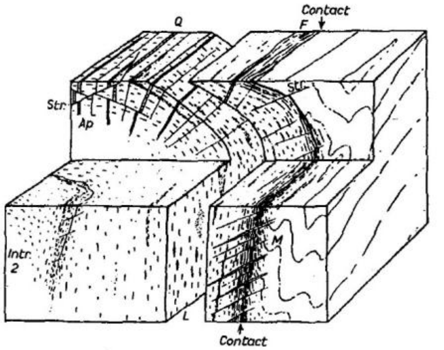
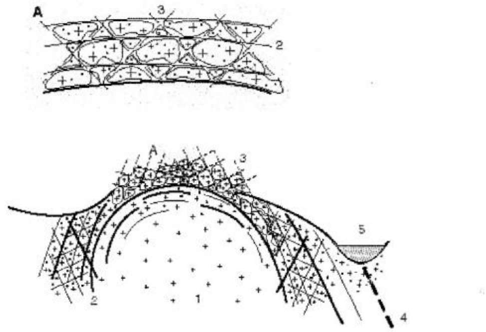


FIG. XII–19. BLOCK DIAGRAM OF PART OF A BATHOLITH, WITH A SUBSIDIARY INTRUSION, DISSECTED ALONG A FOLIATION SURFACE

M, Marginal thrusts, some with injected aplite: *F*, flow layers, and foliation; *L*, linear flow structure; *Q*, cross joints, some with injected aplite; *Str.*, planes of stretching. Schistosity parallel to the granite contact is developed in the wall rocks, and the axes of folds are tilted away from the intrusion.



(1) Batolito granítico. (2) Sheet structures. (3) Familias conjugadas de fracturas y diaclasas. (4) Fractura supuesta. (5) Río.
(A) Chaos de boules (boulders with tafoni and gnammas developed by Protoclastic failure)

Fig. 1. Sketches of an intrusive body of granite in which it is showed the main systems of fractures. To the left, block diagram of a pluton showing the schistosity/foliation developed parallel to the granite contact fading to the inner part of the magmatic body (Hills E.S. 1963 Elements of structural Geology, Sherbon Hills Ed.). To the right another model showing the sheet structure.

If the disposition of the original fissure is vertical or verticalized, the development of the conduit will be similar to incise and vadose incise conduits. Finally, vadose conduits are originated by the water circulation along a subhorizontal planar fissure or at least not very inclined, for example shear bands corresponding to the sheet structure. It is specially evident the relationship between families of discontinuities and the outline of the subterranean network. This is recognized in the longitudinal profile of both cave systems with step-like section alternating subhorizontal and vertical steps. Since the movements of blocks are produced along the slopes and the development axis of both systems follows the talweg, this effect allows the creation of new spaces. For A Trapa, this occurs either downward, essentially on the western slope of the valley, or along the axis of the talweg in the chaos located at the bottom of the valley. The circumstances are quite different for O Folón where the prevailing discontinuity system is subhorizontal and the displacements are exclusively on the vertical and not lateral. All the cases of hollows of either greater (Big Doline) or smaller dimensions have been developed by vertical movements.

Erosional granite cave systems

In this paper there are only considered those granite caves or granite cave systems which have been formed directly by flowing water. These systems are defined as erosion caves (erosionhoehlen) and two subtypes are considered:

- Boulder fragment caves or erosion boulder caves (blocktruemmerhoehlen; erosionsueberdeckungshoehlen):

  "If a rock slide occurs within a narrow, water-carrying gorge, the creek is first blocked by boulders. It erodes these boulders by finding a new way and forms water-carrying cavities and caves. Later there may occur further rock slides caused by continued erosion. Such caves may occur generally in deeply incised, water-carrying gorges in rock beds crossed by joint or fissure networks." (Striebel, 1996).

- Structural caves (tektonikgebundenehoehlen):

  "Related to zones of fragmentation and subsequent alteration in granite massif, cavities may be found, produced as a result of the canalization of underground water through them and of the erosion of rock altered there" (Vidal Romaní, 1989)

Until now, there have been studied about 126 granite caves closed to the Granite and Migmatitic Domain in the western part of Galicia (Northwest of Spain) and Portugal. There are included nine samples of erosion caves, from which only five of them are structural systems (ordered by survey date): O Folón (Vigo), A Porteliña (Vigo), A Cunchosa (Cangas), O Cebro (Pindo) and A Trapa (Tui).

All these structural systems have a similar structure:

- A narrow vadose canyon that is cut into the valley floor, filled and covered by rock edges making a bounded chaos of blocks. The blocks that fill the gorge are developed from edges of rock produced in situ, but also many blocks are provided by mass wasting downward valley slopes or cliffs collapses (tallus).
- It always exists an underground water-carry, usually a sinking stream, that is, a superficial stream pirated into the cave system

In this paper only O Folón and A Trapa systems are taken into consideration because they are the best developed multi-level cave systems studied in the area.

Forms and structural fabric in granite caves

In granite bodies, there are distinguished 3 systems of fractures: horizontal and vertical, mainly planes, and the curved joints of exfoliation of variable orientation. This last system is due to shear stress that acts on the rock during the intrusive stage:

"Sketches presented by Thomas (1978) and also Twidale (1982), and in them it may be seen that the frequency of the planes of discontinuities fades progressively with the depth when moving from the outer to the inner part of the pluton. According to this, the morphology of the different types of granite forms would be predetermined by the characteristics of the jointing (frequency, morphology, dimensions, relati-

onship among joints, spatial orientation, etc.) and, therefore, the morphology of the granite landscapes will depend more on the endogenous factors (essentially tectonics and jointing) than exogenous factors (erosion, weathering) though it is undoubtedly that these latter contribute decisively in the process as they help to expose the rock on surface. This does not go against the fact that the exogenous processes (eolian, fluvial, glacial, of marine erosion, of chemical etching, etc.) are able to generate specific forms like rills, pits and pans, pot holes, etch platforms, ventifacts, etc.." (Vidal Romaní, 2008)

Patterns of cave passages

The passages that make up granite caves tend to be of two types, those that are more or less horizontal and those that are more or less vertical. By definition passages are the voids defined by continuous limits or/and granite blocks, large enough for human entry.

Voids enclosed inside granite cave systems can be divided in three groups: those limited by continuous rock, those defined by removed but not collapsed blocks, and finally the collapsed areas.

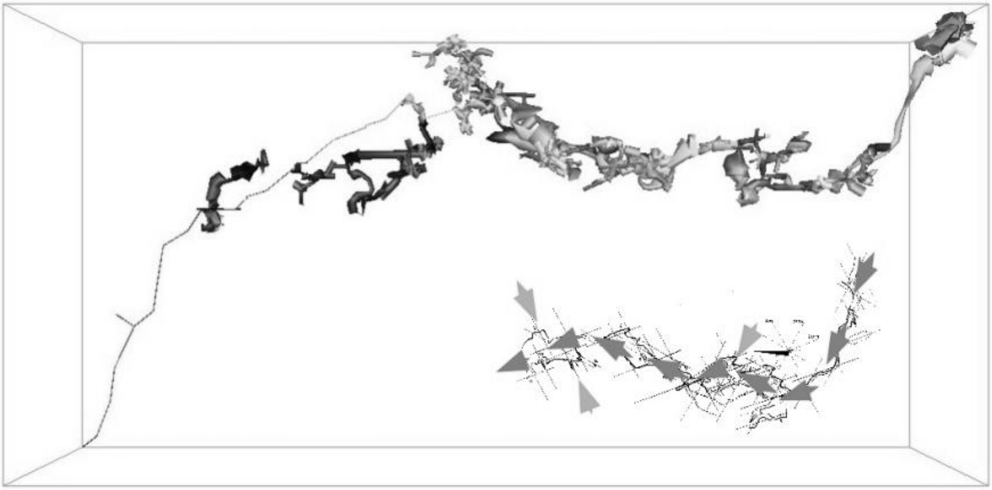
The distribution and geometry of passages within a cave are dictated by a combination of local lithologic, structural and hydrologic factors (Veni, 2005). In the granite cave system of O Folón (Vigo) and in A Trapa (Tui), these systems capture the superficial waters as in the classic karst channelizing them in the subterranean cavities. Palmer and Veni use the terms "sinking stream", "tap-off passages" and "pirated into" to describe this phenomenon. Subterranean water circulation formed passages along discontinuities which tend to be narrow and linear, with tight-angle turns and intersections with other passages. Then subterranean water-carry seems to be developed and adapted to the local conjugated subvertical discontinuities (Vaqueiro et alli, 1998; Vaqueiro, 2003; Vaqueiro et alli, 2006). (See fig. 2).

This correlation between subvertical discontinuities and the subterranean drainage has been observed in other granite cave systems: A Porteliña (Vigo), A Cunchosa (Cangas) and O Cebro (Pindo)

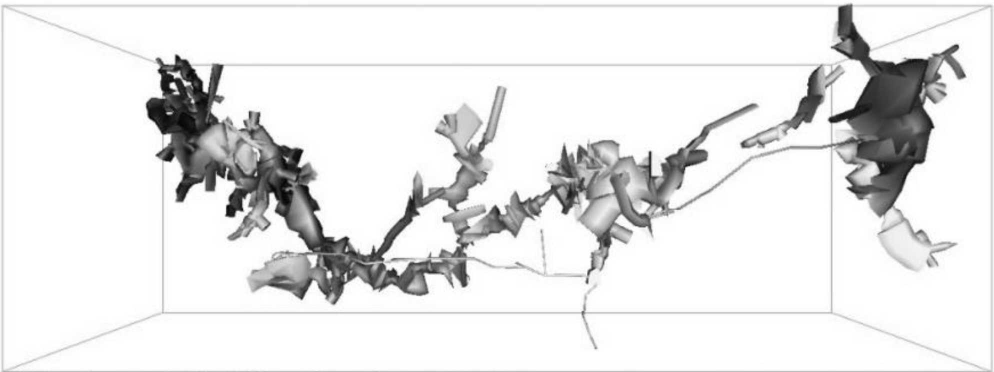
Also, the collapses and other vertical movements of blocks seem to be determined by the same sets of discontinuities

In accordance with Palmer (2005), the most common cave pattern is a network maze, which consists of intersecting fissures/fractures arranged in a pattern like that of city streets. Locally, and related to horizontal discontinuities, there exists a braided pattern of intersecting tubes, usually arranged two- dimensionally along a single parting or discontinuity (anastomosic mazes)

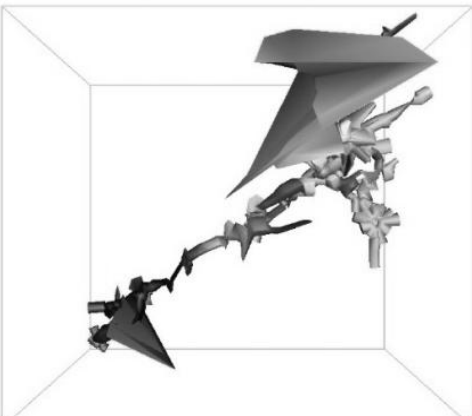
(see next page) **Fig. 2.** Patterns of cave passages from four different structural systems: Plant views from O Folón, A Trapa and A Furna systems are plotted in mode "colour by depth" (this option causes the cave to be a colour by depth where the deepest part of the cave is coloured Blues and Purples, while the highest parts of the cave are coloured Red and Yellows). Drainage is always from the highest part of the system to the deepest level. Survey plant views from O Folón and A Porteliña show the correlation between the subvertical sets of fractures and the main water-carry. They have been distinguished the sinking stream (dark blue arrows) and subterranean springs (light blue arrows)



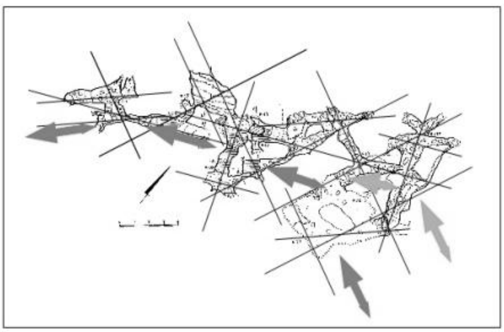
"O Folón" granite cave system



Sector Feveros-DKD: "A Trapa" granite cave system



"A Furna" granite cave



"A Porteliña" granite cave system

Passage morphology

In granite systems it is interesting to consider and classify two types of passages: first, neo-passages developed by opening fractures; and second, conduits or water-carry passages. The first type cuts the oldest cave pattern when collapses or block movements are produced.

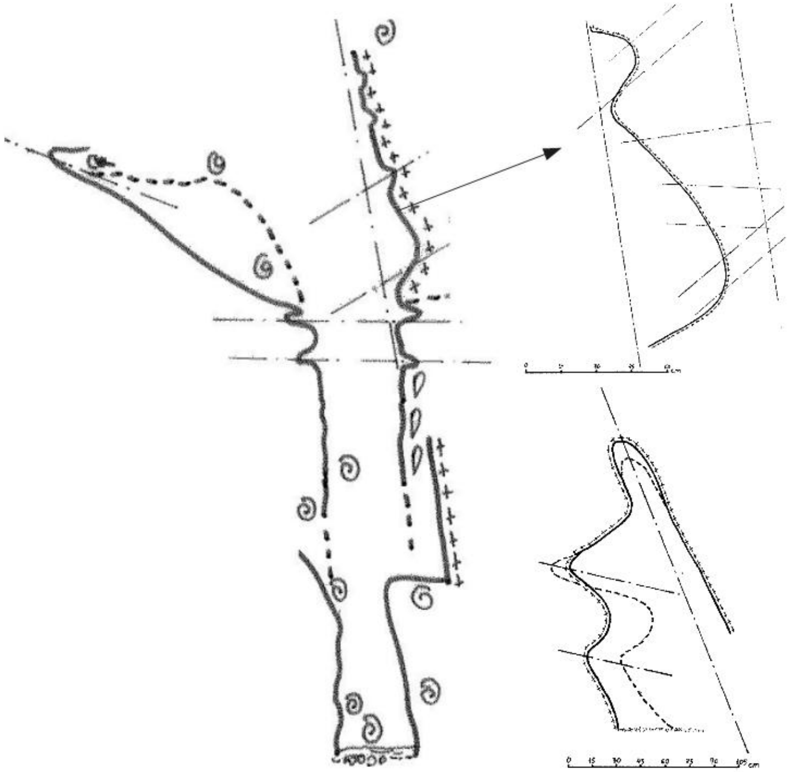


Fig. 3. Cross-sectional patterns of conduits.

By definition, conduits are those voids (passages) that transmit or also have capacity to transmit turbulently flowing water in karst (Veni, 2005).

It is important to note that in granite systems a "conduit cross-section" is determined from partial passages surveyed and projected over the same cross-section plane: due to the chaos of blocks it is impossible to visualize directly the conduit morphology and their limits are obtained from superimposed and correlated voids. This "union" of partial passages, closing the voids between continuous rocky walls, are called "complex cross-sections" and represent the transversal profile of the subterranean canyon developed by the erosional water stream.

The morphology of the conduits is related firstly to the characteristics of the discontinuity system (orientation, opening grade of the fissure related at the same time to the movement of the blocks which delimit it). Secondly, it depends on the incision process of the drainage network (normally vertical) that in karstic systems gives rise up to 3 types of transversal profiles of conduits: phreatic, vadose and incised passages.

The cross-sectional patterns of passages observed in granite systems are similar to those described by Veni (2005) for karstic systems s.s.. The most common cross-sectional patterns are vadose and incised passages.

The upper and intermediate levels of a keyhole cross-sectional pattern have circular to elliptical cross- sections. It has been observed that these levels are closed and adapted to the shear bands related to the sheet structure, and almost the size and form of the cross-section is directly correlated with the structural fabric of the shear band: usually, the ellipses will be horizontal or diagonal, depending on whether the passage is enlarged along the pseudo-foliation of the shear band, but what is most relevant is that the enlargement of the cross-sections is confined along the shear band. The symmetry of these elliptical conduits could be produced by a roughly equal water pressure on all walls.

Water levels in aquifer naturally decline over time as the land surface erodes, allowing groundwater to discharge from progressively lower elevations. Consequently, passages on cave level will often drain and become modified by the new vadose hydrologic conditions. The most common change is the incision of passage floors to drain water to the descending water table

When a vadose passage is related to a vertical discontinuity (fracture or shear band), the final conduct is relatively high and narrow in cross section, especially where the hydraulic gradient is steep (waterfalls: O Folón and A Trapa Systems). But also vadose conduits may be broad when they are originated by water circulation along a subhorizontal planar fissure or at least not very inclined, for example exploiting a shear band corresponding to the sheet structure.

As their flow is gravitational, most vadose passages tend to have a strong component down the dip of the rock strata. In karstic caves phreatic passages show no consistent relation with the dip, except when that is the only direction to potential outlets or when prominent fractures also extend in that direction. But in granite systems main conduits are related to the shear bands enclosed by the sheet structure and passages evolve adapted and bounded by the structural fabric.

In many cases, water from one passage will be captured or pirated into another passage with a steeper hydraulic gradient. These passages are known as tapoff passages. In granites caves the most important changes observed on cave morphology have been produced by an abrupt change in the water carry, commonly by a pit or shaft, which pirated the water in a deep level.

Cave development

Given that caves are formed by flowing water, cave development is strongly controlled by base level elevation. These caves are developed in the vadose zone (above base level), and underground streams carve narrow canyons that lead downward in the fastest manner possible until the base level is reached (Anthony, 2005).

O Folón Cave has developed taking advantage of the discontinuity system of the granite massif. The formation of the cavity is carried out in two stages. During the first one, the subedaphic weathering advances in depth along the system of discontinuities encompassed with the incision of the drainage network (ruled by isostatic, eustatic or tectonic movements). Weathering produces alterites that infilled the discontinuities by water infiltration.

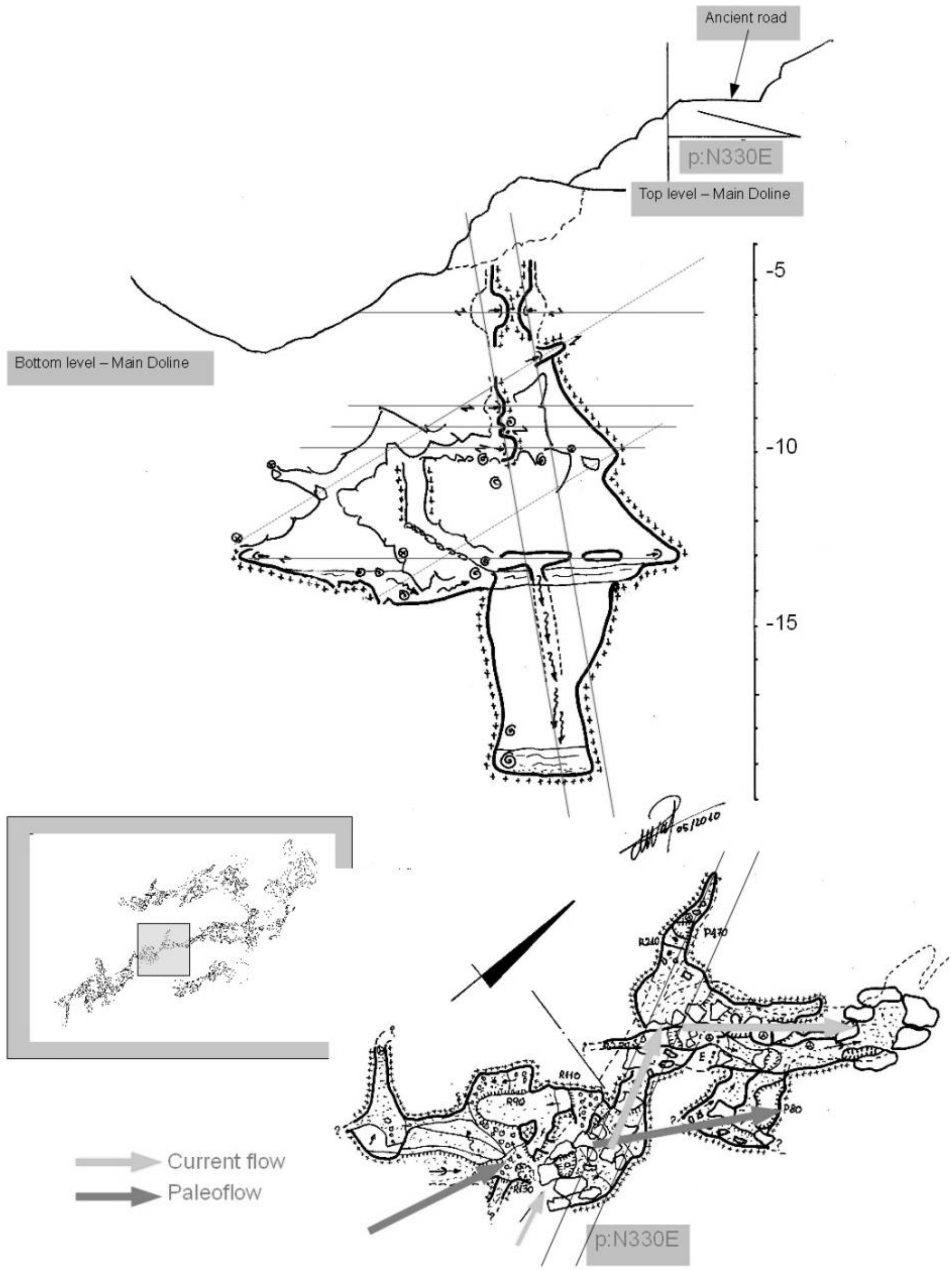


Fig. 4. Complex cross-section: Sector Pozo Cabrón - Cova da Cascada - X:Xebas. O Folón Cave. In this figure are showed the correlation between like key-hole passages and the main structural discontinuities: Many broad circular to moderately elliptical, smooth-walled tubes are sit over a narrow vadose canyon that is cut into its floor. These circular-elliptical tubes are developed and bounded along horizontal to moderately sloping shear bands.

During the second stage, water infiltrations produce mechanical erosion thus cleaning of alterites progressively, and the cavity becomes free of obstacles. So, water circulation becomes easier and the erosion contributes to enlarge the pseudokarstic system producing other types of forms as potholes, rills, etc.. Once there exists a great availability of space, the rock blocks may move or fall giving rise to the present aspect of the cavity, mix of block chaos and straight passages along the big discontinuities

Comparing many complex cross-sections along the system, different superimposed paleo-levels or paleo-flows have been observed (Vaqueiro, 2007).

Shear bands and polished elliptical cross-sections have been measured (location inside the system, passage direction, i.e. the compass bearing (azimuth) measured from the location, and the inclination or slope angle of the pseudofoliation or passage dip). Values are resumed in table 1 and are partially showed in figure 5.

Point	Dip	Direction	System	Notes
Pozo Bernardiño	25,2º	N345ºE	Fc	
Folón XIII	18,3º	N220ºE	Fc	
Salida Folón XIII	14,7º	N345ºE	Fc	
Laberinto Superman	11,9 – 12,7º	N330ºE	Fc	
Laberinto Superman	24,5º	N10ºE	Fs	
Burbulla	71,0º		Fv	
Paso da Moura	22,7º	N10ºE	Fc	
Cascada	23,7º – 20,1º		Fc	Archaelogical remain FL-1
Encorvada	20,0º	N15ºE	Fc	
Arañeira	29,2º	N315ºE	Fs	
Sifón Xemelgos	11,2º	N350ºE	Fc	
Pozo Xemelgos	70,2º	N240ºE	Fv	Archaeological remains FL-28/29
Pozo Xemelgos	36,0º	N60ºE	Fs	
Pozo Xemelgos	12,5º	N350ºE	Fc	Archaeological remains FL-28/29
Rastro II – Areal	13,0º – 12,0º	N350ºE	Fc.	
Fondo Areal	78,0º	N280ºE	Fv	Archaeological remain FL-11
Rampa X.Xebas	22,0º – 32,0º		Fc	
Rampa X.Xebas	12,0º		Fc	
Laberinto X.Xebas	28,0º		Fs	
Laberinto X.Xebas	85,0º		Fv	
Pozo Cabrón	78,6º	N240ºE	Fv	
Pozo Cabrón	11,5º		Fc	

Tbl. 1. Data related to the main fracture systems of O Folón. Three groups of discontinuties takes an important role directing the cave development: One, denoted by Fc are shear bands characterized by a planar foliation which dip less than 20º; a second group, denoted by Fs, are big planar discontinuities dipping between 20 to 38º and seems to be related with subterranean rock slides; and the third group, denoted by Fv, are subvertical planes typically N170ºE and also N60ºE characterized by a strong dip sheet structure and also with a subvertical pseudo-bedding or suvertical foliation). Main incised vadose canyons are related to Fv.

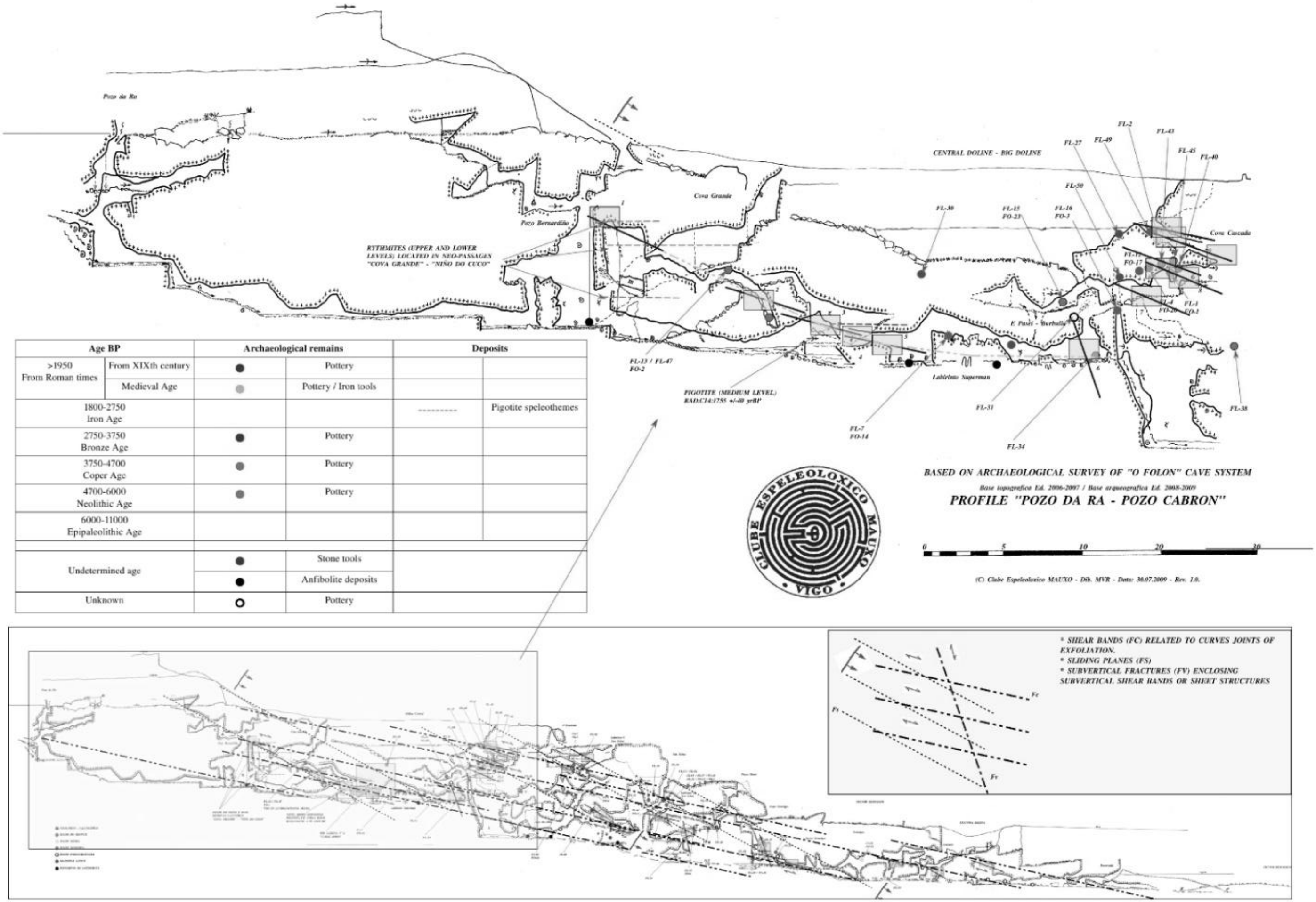


Fig. 5. Correlation between conduits and the main fracture systems of O Folón. Detailed profile of Central Doline. Archaeological remains (age and type), detritic deposits and dated pigotite deposits are pointed

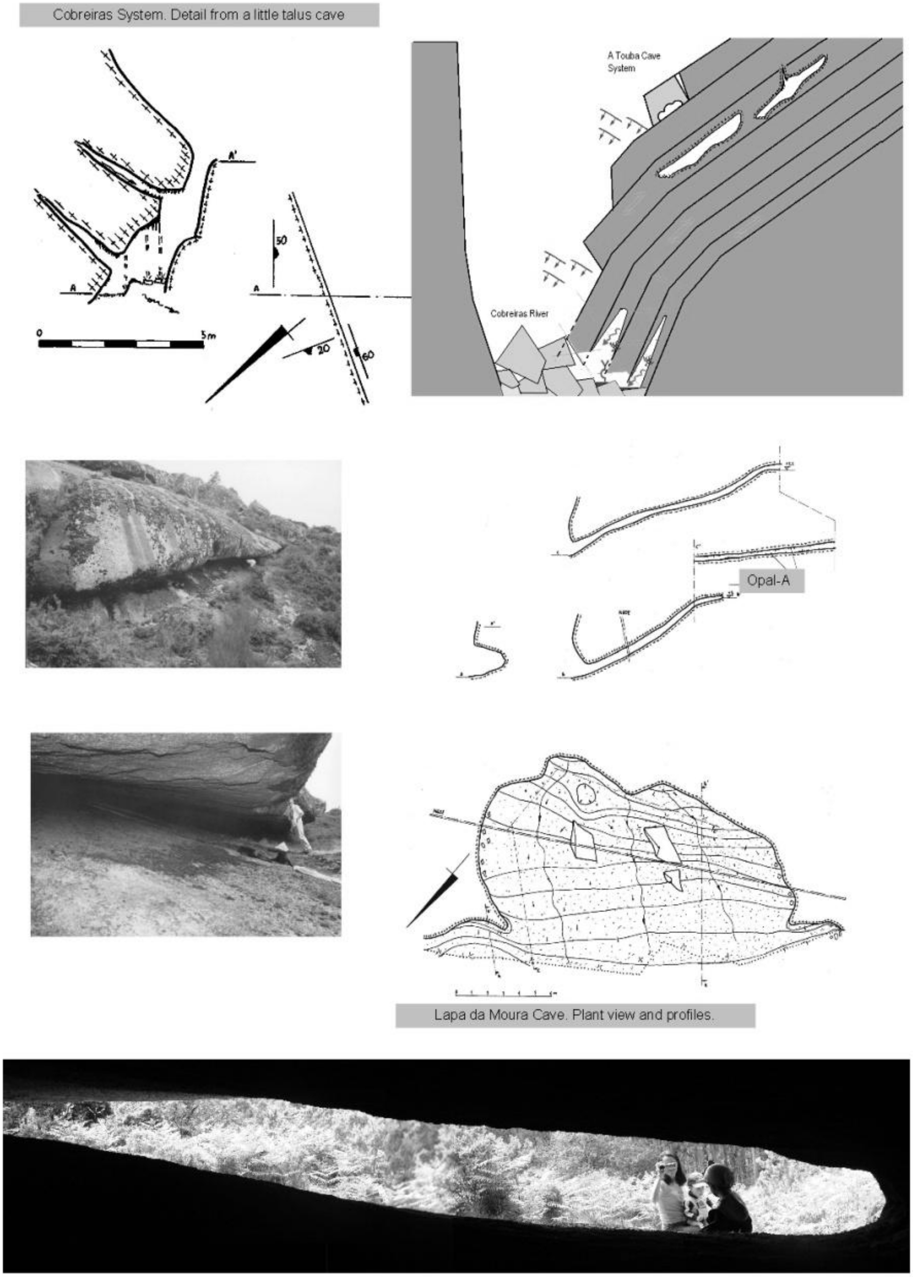


Fig. 6. Discontinuities between sheets structures and their associated shears bands may have associated cavities and subterranean drainages. Two samples are showed: First a talus cave from Cobreiras - Touba do Brión cave system. And second, Lapa da Moura cave, a tafoni cave developed inside a shear band. In these examples water springs in caves flowing along the sheet planes.

The importance and the role of these shear bands can be analyzed in other types of caves: there have been studied many small caves, tafoni-like caves, related to shear bands and sheet structures: subterranean water spring is channelized though the shear band. This stream exploited stretching planes and in general all the joints (cross, longitudinal and flat-lying) to penetrate from the upper shear band to the inner and subjacent levels (see fig. 6).

Conduit stability

The stability of the conduit is determined primarily by the fracture systems affecting its ceiling or vault (orientation of the discontinuities with respect to the pipe axis) and the characteristics intrinsic to the material. The curved joints of exfoliation of variable orientation (sheet structures, shear bands,…) where broad levels of incised and vadose conduits are developed are discontinuities of great continuity cut also by the other families of discontinuities like stretching planes. Rocky wedges or large unstable blocks are developed.

The stability of the conduit is determined from three factors: the size of blocks (effective distance between discontinuities and degree of fracturation); the shear strength between the blocks (relation between the roughness index of the joint and the alteration-weathering inside the joint) and the local stress state (relation between the hydraulic affection by water flowing across joints and the stress reduction factor of the rock massif). Note that structural systems are started out from the surface and the passages are located relatively close to the terrain surface (no more than 12 m below the surface), and then there is a low tensional stress with sub-superficial open fractures

Cave evolution

It is important to note that collapses are produced when a subjacent void exists

Two types of collapses have been observed: breakdown collapses of conduits and rock-slides.

In the first type, breakdown is produced by a vertical movement of ceilings over the main subterranean canyon. Given that the collapsed rock will fill more space than when it was intact, it could extend to the upper cave levels and prevent further collapses. In this case, cave pattern is shown. In the second type, a big subterranean landslide is produced affecting important zones of the cave system. In O Folón and A Trapa systems, these global movements seem to be guided by discontinuities, probably stretching planes, like dip slopes. In the case of O Folón, almost three big rockslides have been found out in different areas. The most important was in the big Central Doline, and it is formed by a landslide developed over a discontinuity which dips about 28º to the centre of the doline. Slides cause the opening of vertical fractures in the perimeter of the doline, many of them forming neo-passages. The distance between the two borders of the fractures are more than 2 m, and it implies a sliding of about 2,3 m

These rockslides fill subjacent voids blocking previous subterranean water stream. Two associated phenomena have been observed: first, upstream the doline, a pool is formed and the water remains at the same elevation (the border of the doline) for long periods of time. Given that the cave stream is a sinking river, water stream fills the system till reaching the limit of the new doline and then the stream overflows. The second phenomena is that water erodes these collapsed blocks by finding a new way and forms a new water-carrying cavities and conduits. In O Folón cave, this new conduit is an incised canyon developed by cutting the floor of previous flow-level. The water stream exploited also transversal discontinuities (see also the plant view in figure 4), forming a new narrow meander-anastomosed channel which drained water in favour of a low level while abandoned levels remain as paleo-flow levels. As the new drainage is developed down the collapse, permanent sumping areas are developed.

Varves deposits, rhythmite deposits have been found out upstream the doline preserving the record of the pool once occupying the abandoned level. These deposits are located inside neo-passages.

Dating cave events

Dating deposits located in cave passages allows scientists to correlate the development of the cave with regional events

Five types of cave deposits in granite caves are considered: detritic and fluvial deposits; varves and rythmites; speleothems of pigotite; bones; and prehistoric to historic remains.

Although granite systems are related to Pliocene erosional paleosurfaces, until now all dated deposits have been related to Holocene events.

(see Tbl. 2).

	Age BP	O Folón	A Trapa	O Cebro	O Forno	Other granite caves
	>1950 From Roman times	X			X	X
	1800-2750 Iron Age	Pigotite Varves				X
	2750-3750 Bronze Age	X		X	X	X
Holocene events	3750-4700 Coper Age	X			X	X
	4700-6000 Neolithic Age	X				X
	6000-11000 Epipaleolothic Age					
Pleistocene events						
Pliocene events	2800 kyr	Paleosurface				

Tbl. 2. Datings in the granite systems closed to the Atlantic coast in Galicia.

The datings carried out for pigotite speleothems (from 1.8 to 3 kyr BP) and the ages of the remains of anthropic origin found in these systems (from the Bronze Age to the Neolithic Age) confirm that at the end of the Pleistocene both caves have been already defined approximately with their present aspect, though some later subsidences were produced in certain zones of both caves

Discussion

The formation of the Galician cavity systems in granites is due to the usage of the structural fabric of rocky massifs by the weathering processes. The shear strain developed during the granite emplacement in the outer part of the granite intrusion generates first the sheet structure system and later the radial one. The weathering processes during the Lower Tertiary (Paleogene) were canalized preferably through the discontinuities leaving them filled with regolith. Later, the caves were formed by the circulation of water through the discontinuity planes cleaning the fissures and eventually enlarging them by physical erosion and allowing the formation of bigger conduits, so this explains that all the cavity systems are invariably associated with the rock structure. The water that fed the underground streams proceeded from the superficial drainage pirated through the network of discontinuities.

The main subterranean conduits show a morphology tightly related to sheeting planes of highly variable attitude from subhorizontal to subvertical dip. Nevertheless, the water circulation was able to create new shapes on the channels other than the previous defined by the structure. The typical key-hole cross-section of the channels is thus a neo shape due to the continued incision of the subterraneous stream related to the lowering of the regional base level.

The channels habitually show cross-sections either circular or elliptical. Both shapes seem to be related to water circulation in phreatic conditions. There have been observed shelving developments when the stream affects the successive slabs of the sheet structure during continued channel incision.

So, the cave systems progress at first by the stream incision but subsequently by collapse/sliding of the slabs forming the walls of the channel into the void created by the water erosion. Sometimes the underground movements are recognized on surface by fields of dolines roughly aligned by the main axis of the subterraneous stream.

Internal subsidences are also responsible for changes in the hydraulic regime of the stream transforming temporarily sections of the course in pool areas as showed by the rythmites that partially infill the caves. In turn, the abandon of parts of the channel for stream migration lets the growing of different types of speleothems as stalactites, stalagmites and flowstone whose dimensions depend on the magnitude and speed of the external contributions of water to the cavity. It may be thought that these types of deposits coincide with the end of the active stage of the cavity. The datings by radiocarbon of these speleothems allow to establishing that the growth stage of the speleothems starts at the last stage of the evolution of the caves and continues at present.

Acknowledgements

We thank Ana Martelli for reviewing the paper English version. The work and surveys would not have been done without the help of friends in the “Clube Espeleolóxico Maúxo” - Speleological Association. Special thanks to Begoña Barreiro, Reinaldo Costas, Xavier Groba, Rosa Suárez, Tereixa Otero and José Miguel López (Zrus) who took part intensively in taking the data for the elaboration of the cartography of O Folón and A Trapa.

Materials included in this paper are part of the Ph.D. Thesis of M. Vaqueiro

References

Anthony, D.M. (2005) "Multilevel Caves and Landscape Evolution", Encyclopedia of Caves (David C. Culver & William B. White). Elsevier. pp: 397-400.

Groba González, X. & Méndez Quintas, E. (2008) "Human Occupations during Recent Prehistory in the Granite Caves of the Western Coast of Galicia", Cadernos do Laboratorio Xeolóxico de Laxe, Volume 33, Ed. Universidade da Coruña, 2008, pp. 115-126.

Hess, J. W. (2005) "Pits and Shafts", Encyclopedia of Caves (David C. Culver & William B. White). Elsevier. pp:444-447

Palmer, A. N. (2005) "Passage Growth and Development", Encyclopedia of Caves (David C. Culver & William B. White). Elsevier. pp: 440-444.

Striebel, T. (1996) The genetic classification of Some Types of Non-Karstic Caves. Proc. Of Intern. Working Meeting "Preserving of Pseudokarst Caves", Rimavska Sobota, Slovakia - Salgotarjan, Hungary. PP. 46-57

Twidale C. R. and Vidal Romani J.R. (2005) - Landforms and geology of granite terrains. A.A. Balkema Publishers Leiden. Great Britain.

Vaqueiro Rodríguez, M., Costas Goberna, J.B., Groba Gonzalez, X., García, García, M., García García, E.M., Rodríguez, F., Alonso Cuevas, F., Pérez, A., Míguez, A.I., Vázques Vaamonde, D., Sueiro Rodriguez, J., García Vázquez, C. (1998)"The Hercinical Granitical Caves On The Mountain Maúxo and its surroundings (Province of Pontevedra, Galicia, Spain)". Proceedings of International Working Meeting Caves in Sandstone and Granites. Department of Hidrology, University of Bayreuth. Ed. Mitteilungsheft der Höhlenforschungsgruppe Balustein, Nr. 15(1), pp. 1-22.

Vaqueiro Rodríguez, M. (2003) - "Caracterización de cavidades de bloques graníticos y cuevas estructurales de Vigo-Tui, (Galicia, España). Análisis morfoestructural del sistema de O Folón." Cadernos Laboratorio Xeolóxico de Laxe. Coruña. Vol. 28, pp. 231-262.

Vaqueiro Rodríguez, M. (2005) "The Cave-Complex “A Touba do Brión – Cobreiras” cavernous weathering related to mass wasting downward sheeting planes". Cadernos Laboratorio Xeolóxico de Laxe. Coruña, Vol. 30, pp. 193-212.

Vaqueiro Rodríguez, M., Barreiro Ben, B., Costas Vázquez, R., Suárez Pérez, R. & Groba Gonzalez, X. (2006).- "Relation between structure and morphology in the development of the granite cave of "O Folón" (Vigo, Galicia-Spain)". Cadernos Lab. Xeolóxico de Laxe. Coruña. Vol. 31, pp. 87 - 103.

Vaqueiro Rodríguez, M.; Barreiro Ben, B; Costas Vázquez, R.; Suárez Pérez, R.(2007). Mapping and modelling of granite cavities: Problems in the representation of forms and work scale. Proceedings International Conference on Granite Caves. A Coruña, 2007. Vol. 33, pp.

Vaqueiro Rodríguez, M.; Groba González, X. and Vidal Romani, J.R. (2007) The Granite Structural System of “O Folón”. Coruxo – Vigo (Galicia, Spain). Poster: Special Edition for The

International Conference on Granite Caves. Artes Gráficas ROEL. Vigo, 2007. Depóstio Legal: VG 855-2007.
Veni, G. (2005). "Passages". Encyclopedia of Caves (David C. Culver & William B. White). Elsevier. pp 436-440.
Vidal Romani, J.R. (1989).- "Granite geomorphology in Galicia (NW España)". Cuadernos Laboratorio Xeolóxico de Laxe 13: 123-124.
Vidal Romani, J.R. & Vaqueiro Rodríguez, M..(2006)- "Types of granite cavities and associated speleothems: genesis and evolution". Nature Conservation. Institute of Nature Conservation, Polish Academy of Sciences, Cracow. Nr.63, pp: 41-46.
Vidal Romani, J.R. (2008).- "Forms and structural fabric in granite rocks". Cuadernos Laboratorio Xeolóxico de Laxe 33: 175-198.
Vidal Romani, J.R.; Sanjurjo Sánchez J.; Vaqueiro M & Fernandez Mosquera, D. (2010)- Speleothem development and biological activity in granite cavities. Issue4, November (in press).

Actual List of the Longest Quartzite Caves in the World (25 Longer than 1 km) (January, 2010)

Lukáš Vlček[1,2,3]

[1] Slovak Speleological Society, Liptovský Mikuláš, Slovak Republic
[2] State Nature Conservancy of Slovak Republic – Slovak Caves Administration, Liptovský Mikuláš, Slovak Republic
[3] Grupo Espeleológico de la Sociedad Venezolana de Ciencias Naturales, Caracas, Venezuela.

Abstract

The speleological exploration and research of quartzite karst caves began only half century ago. The quartzite karst areas rich in caves are located in Guyana Highland (Venezuela, Brazil), Minas Gerais and Mato Grosso area (Brazil) and Northern Transvaal or Cape Peninsula in South Africa. But the most abundance of caves represents the areas of quartzite karst of the table mountains (tepuis) in Venezuela. First in detail explored caves were Cueva del Cerro Autana on Autana tepuy and caves on Sarisariñama plateau, explored in ´70. Important progress constituted the discoveries on Auyán tepuy in ´80 and ´90. Very important discoveries of caves brought the exploration of plateaus Roraima and Churí (Macizó Chimantá massif) in the beginning of century. Nowadays, 25 localities in the world are longer than 1 km. Many of them are active fluvial caves with horizontal corridors, similar to the corridors in caves of classical limestone karst with rare biologically mediated opal speleothems. The list of the longest quartzite caves, longer than 1 km consists of 25 localities: Cueva Ojos de Cristal (Crystal Eyes Cave) in Venezuela – 16.14 km/-73 m, Sistema Muchimuk – Colibri in Venezuela – 8.0 km/-160 m, Cueva Charles Brewer (+Cueva del Diablo) in Venezuela – 7.5 km/-110 m, Gruta do Centenario in Brazil – 4.7 km/-481 m, Gruta da Bocaina in Brazil – 3.2 km/-404 m, Cueva Juliana in Venezuela – 3.0 km/-45 m, Sima Auyán-tepuy Noroeste in Venezuela – 2.95 km/-370 m, Gruta das Bromélias in Brazil – 2.75 km, Cueva Zuna in Venezuela – 2.52 km/-90 m, Sistema de la Araña in Venezuela – 2.5 km, Sistema Akopán (Cueva Akopán + Cueva dal Cin) in Venezuela – 2.5 km, Magnet Cave in South Africa – 2.49 km, Sima Aonda Superior in Venezuela – 2.128 km/-136 m, Sima Aonda in Venezuela – 1.88 km/-383 m, Bat´s – Giant´s – Climber´s System in South Africa – 1.63 km, Caverna Aroe Jari in Brazil – 1,4 km, Toca do Chico Lino in Brazil – 1,35 km/-15 m, Krem Dam in India – 1.35 km, Sima Acopán 1 in Venezuela – 1.376 km/-90 m, Sima de La Lluvia de Sarisariñama in venezuela – 1.352 km/-202 m, Gruta Alouf in Brazil – 1.20 km/-294 m, Sima Menor in Venezuela – 1.158 km/-248 m, Cueva Yanna in Venezuela – 1.08 km/-40 m, Sima Aonda 2 in Venezuela – 1.05 km/-325 m, Cueva Eladio (Cueva del Maripak) in Venezuela – 1 km.

Foreword

The most number of quartzite-karst caves are localized in the area of Venezuela´s table mountains. The quartzite speleology began right on this geographic area more than 30 years ago... Why are just the caves so extraordinary and important discovery in the area of Guyana Highlands? All the table mountains – tepuis are builded by non-karstic sedimentary rocks – particularly by quartzites and quartzitic sandstones, represents one kind of world´s most resistant rocks!

Autana & Sarisariñama – the beginning of quartzite karst explorations

The speleology in world´s quartzitic massifs began on tepuis Autana (Colveé, 1972, 1973; Urbani – Szczerban 1974; Szczerban – Urbani, 1975; Szczerban – Gamba, 1973; Brewer-Carías, 1972, 1973a, 1976a; Galán, 1982; Pérez La Riva, 1976; Pérez La Riva – Reyes, 1976) and Juaua-Sarisariñama (Urbani – Szczerban 1974; Szczerban – Urbani 1975; Szczerban – Gamba, 1973; Brewer-Carías 1973b, 1976b; Nott, 1975). On Autana (1400 m n. m., Fig. 1), was known the cave, mentioned in Indian´s legends, wroted for the first time in 1782. In 1971 was explored and measured in lenght 395 m by expedition leaded by Ch. Brewer-Carías and after was in detail described (e. g. Urbani – Szczerban, 1974; Brewer-Carías, 1976b). Cueva del Cerro Autana became the first in detail explored cave in quartzite rocks in the world.

Mt. Sarisariñama (2300 m n. m., Fig. 2) has on its top two huge vertical depressions with up to 350 m (!) in diameter and with their walls the same deep. Cave depressions Sima manor, 314 m deep and Sima menor, 248 m deep, explored in 1974 by scientific expedition leaded again by Ch. Brewer-Carías, are drainaged to resurgences kilometres away (e. g. Brewer-Carías, 1973b, 1976b, 1983; Urbani – Szczerban, 1974; Szczerban – Urbani, 1975; Szczerban – Gamba, 1973). The volume of 18 millions m3 makes from Sima Mayor (Sima Humboldt sensu De Bellard, 1974a, b; 1975; resp. Sima Brewer-Carías sensu Brewer-Carías, 1974) the 5th bigest karstic cavern in the world. This locallity was explored by two expeditions: first leaded by Ch. Brewer-Carías (e. g. 1973; 1976b, 1980) and second – Polish-Venezuelan expedition leaded by F. Urbani (e. g. Zawidzki – Urbani – Koisar, 1976; Dyga – Székely – Zawidzki, 1977; CEDV, 1976; Kuczynski, 1976 a, b; Koisar – Solicki, 1977 a, b; Urbani, 1976). From the bottom part of the smaller chasm – Sima Menor (or Sima Martel sensu De Bellard, 1974a, b, 1975; resp. Sima Gibson sensu Brewer-Carías, 1974) lead off two branches to the cave segments called Cueva de la Cascada and Cueva de los Guácharos. Nearby those localities is located an another huge carstic colaps, called Sima de la Lluvia with the lenght 1.352 km, including Cueva de los Cristales branch.

Venezuela´s tepuis (Auyán etc.)

The caves were explored also on another Venezuela´s tepuis. From Guaiquinima tepuy are known caves up to 130 m long (Szerban – Urbani – Colveé, 1977; Urbani, 1977). Caves on plató Sierra de Pacairima (Pacaraima) described Urbani (1977), Pérez La Riva (1977); (Bo. 4 – Bo. 7). National Speleological Cataster enumerate caves from Yuruaní tepuy

(Galán, 1982), Sierra Marutani (Bo. 9 – Bo. 19), Kukenán tepuy (Bo. 22 – Bo. 25), Acopán and Amurí (Bo. 40 – Bo. 53), Cerro Chirikayén (Bo. 90 – Bo. 91), small cavities from Río Aponguao catchment (Bo. 20 – Bo. 21). Galán (1988) enumerates the caves on partial tepuis of Jaua-Sarisariňama (3), Guaiquinima (9), Eutobarima (1), Aonda (8), Urutany (2), Auyantepuy Norte (1), Tramén (1), Aguapira (15), Kukenán (5), Roraima (1) a Yuruani (2), in the vicinity of Santa Elena de Uairén – El Paují (4), Mt. Aponguao (2), Serrania Pereña (2), Chimantá (1) a Autana (3). In 1988 were 60 known quartzite caves in Venezuela, in total lenght of 14.504 km from states Estado Bolívar (57) and Territorio Federal Amazonas (3). Small caves were discovered on Ilú tepuy (Bo. 33), in Districto Cedeño (Bo. 56 – Bo. 82), Chimantá (Briceño – Schubert, 1992; Meaztu et al., 1995; SVE, 1994). In Venezuelan´s cave bibliography state Ghneim (1999) all localities from Catastro Espeleológico Nacional; all "Bo." (Bolívar state) are created in quartzites (91 locallities), and some another are in Territorio Amazonas ("Am.") (e. g. Cueva del Cerro Autana). Nowadays, we know more than 150 quartzite caves in Venezuela. Some from these are very interesting sites.

In ´80 was explored Sima Aonda on Auyán tepuy (2560 m n. m.). International expeditions leaded by Venezuelan, Italian and Polisch cavers explored here hundrets metres deep tectonic valleys with water streams connected occasionally by horizontal tunnels. These caves described by Galán (1983a, b, 1984), Inglese – Tognini (1993), Pezzolato (1993, 1996), Piccini (1994), Gori et al. (1993), Barnabei et al. (1993), Carreño (1996), or Piccini – Mechia – Preziosi, Mecchia et al., Pezzolato et al. and Barnabei in monographic issue of Progressione (Bernabei, Ed., 1994) et al., became the deepest caves of South America and world´s deepest in quartzite. Sima Aonda Superior, 2,1 km long and initially 320 m, afterwards 362 m deep (Martínez, 1989; Urbani – Bordón, 1997), Sima Aonda 2325 m deep and Sima Auyan-tepuy Noroeste, 2.95 km long and 370 m deep (Barnabei et al., 1993; Bellomo et al. 1994; Bernabei, Ed., 1994; Piccini, 1995; Mecchia – Piccini, 1999).

Caves in Brazil and rest of the world

Another caves were discovered in Brazil (area of Mato Grosso and Minas Gerais state, e.g. Wernick – Pastore – Pires Neto, 1977; Auler, 2002; Travassos – Guimarães – Varella, 2008), in Tchad, Niger, Algeria (e.g. Busche – Erbe, 1987), South Africa (e.g. Martini, 1981, 1982, 1984, 1985). Gruta das Bromélias in Ibipotica massif, Minas Gerais state has 2.75 km (Auler, 2004), also Magnet Cave (2.49 km; Martini, 1990, 1994) in Northern Transvaal and Bat´s/Giant´s/Climber´s Cave System in Cape Peninsula (1632 m; Truluck, 1996) in South Africa became to the top 15 of world´s longest quartzite caves. In Brazilian Mato Grosso upland was in 1999 described Caverna Aroe Jari, 1.4 km long (Borghi – Moreira, 2000, 2002). In the and of ´90 the Brazilian cavers explored, some already in ´50 discovered, fissure caves Grutta do Centenario (3.8 km long/481 m deep), Grutta da Bocaina (3.2 km long/404 m deep) and Gruta Alaouf (1.2 km long/294 m deep) in Pico do Inficionado, Minas Gerais state (Faverjon, 2003; Auler, 2002; Rubbioli, 1996, 1998, 2001, 2003; Dutra 1996b; Dutra, 1997; Hirashima, 1997; Perret 2001; Sausse 2001; Chaimovicz, 2001; Rodríguez – Silverio, 2002; Dutra – Rubbioli – Horta, 2005) and other quartzite caves (e. g. Dutra 1996a). Rubbioli (1996) wrote, that the first map of quartzite cave was drowed in 1952 (Grutta do Centenario). In Meghalaya area between India and Bangladesh is located 1.297 km long sandstone inlet cave Krem Dam, which corridors are open for the public as part of show cave (Oldham, 2003).

Exploration in Venezuela 2002 – 2009

The historic mark in the quartzite speleology was the year 2002, when was discovered unique cave in Venezuela (Šmída – Audy – Vlček, 2003). During the Czech-Slovak expedition from 2003 (Audy, 2003; Šmída – Audy – Vlček, 2003; Audy – Šmída, 2003; Vlček, 2004; Šmída et al. 2005b) were discovered extensive continuance of this cave, and another horizontal corridors on Roraima tepuy in border territory between Venezuela, Brazil and Guyana. Kilometres long active fluvial system of horizontal corridors in Cueva Ojos de Cristal (The Crystal Eyes Cave) was in the time of it´s discovery world´s unique (Fig. 3). Cave was surveyed and documented during 2003 – 2007. This cave was for certain time the longest one in Venezuela (currently, limestone cave Cueva del Samán is the longest one in Venezuela – 18 km long) and nowadays, it is the longest quartzite cave in the world. After 2006, was 15.28 km long and 73 m deep (Vlček – Šmída, 2007). In 2007 were some new corridors in Cueva Ojos de Cristal measured and the length of whole cave rised to 16 140 m (Šmída et al., 2008a, b, c, d; Vlček et al., 2008).

In Chimantá massif (2698 m n. m.), Ch. Brewer-Carías discovered in 2004 another cave, which becam the greatest quartzite cave in the world. It was documented also by Czech-Slovak-Venezuelan speleologists in 2004 – 2007 (Fig. 4). Cueva Charles Brewer (The Charles Brewer Cave) was 4800 m long and consists of only two giant branches (Brewer-Carías, 2005a). The chambers are someplace 100 m (!) wide with flat ceilings in the 40 m (!) hight. The volume of chambers is comparable with the greatest chambers from limestone caves in Laos, Borneo or New Guinea (Šmída – Audy – Mayoral, 2005a, b, c, d, e; Šmída et al., 2004a, b; Audy – Šmída, 2005 a, b; Šmída et al., 2005a, 2007; Šmída – Brewer-Carías, 2005; Šmída – Brewer-Carías – Audy, Eds., 2005). On Chimantá were discovered and documented by Czech-Slovak-Venezuelan and Croatian speleologists many of large caves, in 2007. One of them, also Sistema de la Araña (Šmída et al., 2007; Audy – Tásler – Brewer-Carías, 2008; Šmída et al., 2008 a, b, c, d, e), 2.5 km long. The unusual an interesting biospeleothems were observed in these caves (Aubrecht, 2005; Aubrecht et al. 2007, 2008; Brewer-Carías, 2005b).

After the discoveries of Cueva Ojos de Cristal, came the Venezuelan-Spainish-English team of cavers to Roraima, remapped the part of system and renamed it to Cueva Roraima sur (Galán – Herrera, 2005; Galán – Herrera – Carreño, 2004; Galán – Herrera – Astort, 2004; Carreño – Urbani, 2004; Carreño – Blanco, 2004; Galán et al., 2004; Pérez – Carreño, 2004; Carreño et al., 2005). On Wei-Assipu (called also Roraimita, 2400 m a. s. l.) discovered the Venezuelans also small caves (Carreño – Nolla – Astort, 2002), on Kukenán tepuy the Slovak expedition also small horizontal fluvial caves (Vlček – Šmída, 2007). Cerro Aracaima massif in Brasilian part of Guyana Highland in 2006 brought an important discovery – Abismo Guy Collet (Epis, 2006) 670.6 m deep – the deepest quartzite cave in the world. Slovak-Venezuelan-Croatian expedition in 2009 discovered and documented new huge caves in Chimantá massif and connected Cueva Charles Brewer with Cueva del Diablo to one cave system, 7.5 km long, documented Cueva Juliana (3.0 km long), Cueva Zuna (2.52 km long), Cueva Yanna (1.08 km long) and discovered and documented Cueva Colobri (4.0 km long). This expedition with following one Slovak-Czech-Venezoelan expedition discovered in 2009 two very important caves, which were connected to one large system Sistema Muchimuk – Colibri with length of 8.0 km and denivelation 160 m (Šmída, 2009). This cave system is genetically connected with Cueva Charles Brewer. By the results of the last survey and measuring the ends of their main passages are located just few meters, one from the other. Audy – Kalenda (2010) and group of scientists and explorers lead by Ch. Brewer-Carías mean about one cave system included these two caves with length of 17.8 km.Nowadays, the cave system Cueva Charles Brewer with the hall "Gran Galería Karren y Fanny" (400 000 m3) and the passages of average 30 × 60 m, is the largest cave in quartzites in the world. The Italian team in the same time on the same place discovered new corridors in Sistema Akopán (2.5 km long) and Cueva del Maripak (Cueva Elladio, 1 km long). Until now, to the table mountains of Venezuela were realized more than 40 speleological expeditions, were explored and documented 18 karstic areas with more than 150 quartzite caves with total lenght about 60 km.

The list of 25 quartzite caves longer than 1 km

1) **Cueva Ojos de Cristal (Crystal Eyes Cave, Jaskyňa kryštálových očí)**
16.14 km/-73 m
Venezuela
Roraima tepuy, Estado Bolívar
B. Šmída et al. (SSS, CSS, GE SVCN, SVE 2003 – 2007)

2) **Sistema Muchimuk – Colibri**
8.0 km/-160 m
Venezuela
Churí tepuy, Estado Bolívar
B. Šmída et al. (SSS, CSS, GE SVCN, 2004 – 2009)

3) **Cueva Charles Brewer (+Cueva del Diablo)**
7.5 km/-110 m
Venezuela
Churí tepuy, Estado Bolívar
B. Šmída et al. (SSS, CSS, GE SVCN, 2004 – 2009)

4) **Gruta do Centenario**
4.7 km/-481 m
Brazil
Serrra do Caraça, Minas Gerais
G. M. Dutra (Grupo Bambuí, 2005)

5) **Gruta da Bocaina**
3.2 km/-404 m
Brazil
Serrra do Caraça, Minas Gerais
G. M. Dutra, (Grupo Bambuí, 2005)

6) **Cueva Juliana**

3.0 km/-45 m
Venezuela
Churí tepuy, Estado Bolívar
B. Šmída et al. (SSS, GE SVCN, 2007 – 2009)

7) **Sima Auyán-tepuy Noroeste**
2.95 km/-370 m
Venezuela
Auyán tepuy, Estado Bolívar
F. Urbani (SVE, 1996)

8) **Gruta das Bromélias**
2.75 km/
Brazil
Conceição da Ibitipoca, Minas Gerais
A. S. Auler (2004)

9) **Cueva Zuna**
2.52 km/-90 m
Venezuela
Churí tepuy, Estado Bolívar
L. Vlček et al. (SSS, GE SVCN, 2007 – 2009)

10) **Sistema de la Araña**
2.5 km/
Venezuela
Churí tepuy, Estado Bolívar
M. Audy et al. (CSS, GE SVCN, 2007)

11) **Sistema Akopán (Cueva Akopán + Cueva dal Cin)**
2.5 km/
Venezuela
Akopán tepuy, Estado Bolívar
www.tepui.info (La Venta, 2009)

12) **Magnet Cave**
2.49 km/
South Africa
Northern Transvaal
J. Martini (1990, 1994)

13) **Sima Aonda Superior**
2.128 km/-136 m
Venezuela
Auyán tepuy, Estado Bolívar
F. Urbani (SSI, SVE, 1996)

14) **Sima Aonda**
1.88 km/-383 m
Venezuela

Aonda tepuy, Estado Bolívar
SVE (1983), SSI, SVE (1993 – 1996)

15) Bat´s – Giant´s – Climber´s System
1.63 km/
South Africa
Cape Peninsula
T. Truluck (1996)

16) Cueva Eladio (Cueva del Maripak)
1,7 km/
Venezuela
Churí tepuy, Estado Bolívar
SSS, CSS, La Venta (2009)

17) Caverna Aroe Jari
1,4 km/
Brazil
Chapada dod Guimarães, Mato Grosso
L. Borghi, M. I. C. Moreira (SBE, 1999)

18) Toca do Chico Lino
1,35 km/-15 m
Brazil
Laminárias, Minas Gerais
G. M. Dutra (1996)

19) Krem Dam
1.35 km/
India
Meghalaya
T. Oldham (2003)

20) Sima Acopán 1
1.376 km/-90 m
Venezuela
Acopán tepuy, Estado Bolívar
UEV, SVE (1993)

21) Sima de La Lluvia de Sarisariñama
1.352 km/-202 m
Venezuela
Sarisariñama, Estado Bolívar
FPA, SVE (1976)

22) Gruta Alouf
1.20 km/-294 m
Brazil
Minas Gerais
M. Faverjon et al. (2003)

23) Sima Menor
1.158 km/-248 m
Venezuela
Sarisariñama, Estado Bolívar
FPA, SVE, GE SVCN (1976)

24) Cueva Yanna
1.08 km/-40 m
Venezuela
Macizó del Chimantá, Estado Bolívar
L. Vlček et al. (SSS, GE SVCN, 2009)

25) Sima Aonda 2
1.05 km/-325 m
Venezuela
Aonda tepuy, Estado Bolívar
SSI, SVE (1993)

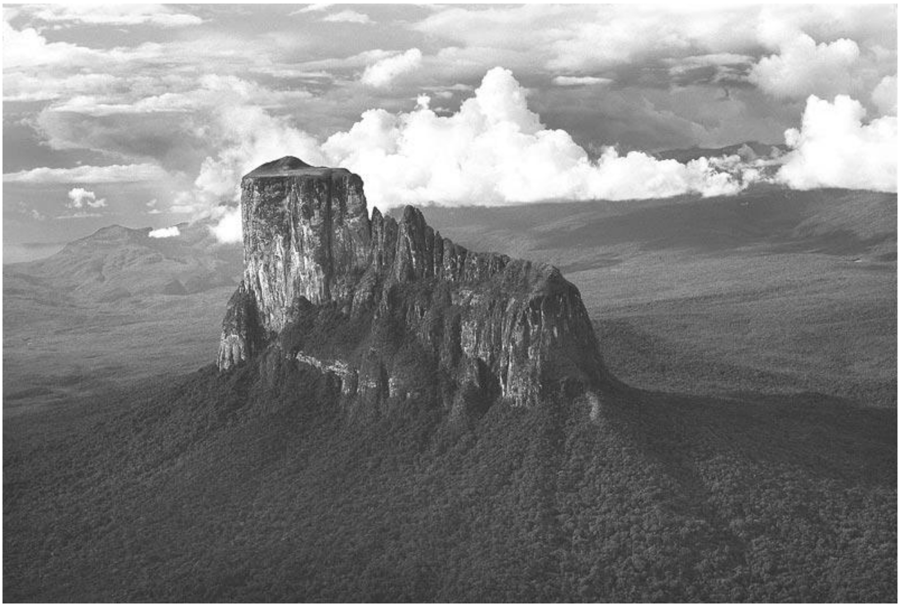


Fig. 1. Cerro Autana – one of the smallest tepuis, with Cueva del Cerro Autana (395 m) – the first in detail explored quartzite cave. Photo by Ch. Brewer-Carías

Acknowledgements

I am grateful to the Ministry of Education of Slovak Republic for financial assistance, then to APVV agency for grant No. 0251-07 and VEGA agency for grant No. 1/0246/08.

Fig. 2. Top of Sarisariñama plateau with quartzite-karst collapses more than 300 m in diameter. Photo by Ch. Brewer-Carías

Fig. 3. Cueva Charles Brewer (7.5 km) – the most spacious cave in quartzite rocks in the world. Photo by J. Stankovič

Fig. 4. Cueva Ojos de Cristal (16.14 km) – the longest one in quartzite rocks. Photo by P. Medzihradský

References

Aubrecht, R. – Brewer-Carías, Ch. – Kováčik, Ľ. – Mayoral, F. – Schlögl, J. – Šmída, B. – Vlček, L. – Lánczos, T., 2007. Microbial composition of opal stromatolites in Venezuelan sandstone caves. 9th International Symposium on Fossil Algae, Croatia, 204–205.

Aubrecht, R. – Brewer-Carías, Ch. – Šmída, B. – Audy, M. – Kováčik, Ľ., 2008. Anatomy of biologically mediated opal speleothems in the world's largest sandstone cave Cueva Charles Brewer, Chimantá Plateau, Venezuela. Sedimentary Geology, Elsevier, Amsterdam, 203, 181–195.

Aubrecht, R. – Brewer-Carías, Ch. – Šmída, B., 2005. Opálové biospeleotémy jaskyne – petrografická analýza. In: Šmída, B. – Brewer-Carías, Ch. – Audy, M. (Eds.). Cueva Charles Brewer – najväčšia kvarcitová jaskyňa sveta. Spravodaj Slovenskej speleologickej spoločnosti (mimoriadne číslo), Liptovský Mikuláš, 36, 3, 84–96.

Aubrecht, R. – Lánczos, T. – Šmída, B. – Brewer-Carías, Ch. – Mayoral, F. – Schlögl, J. – Audy, M. – Vlček, L. – Kováčik, Ľ. & Gregor, M. 2008. Venezuelan sandstone caves: a new view on their genesis, hydrogeology and speleothems. Geologia Croatica, Zagreb, 61/2–3, 345–362.

Audy, M. – Kalenda, P. 2010: Nástín geneze jeskyní silikátového krasu Guayánské vysočiny. In: Bosák, P. – Novotná, J. (Eds.): Speleofórum 2010, Česká speleologická společnost, Praha, 29, (in press).

Audy, M. – Šmída, B., 2003. Kryštálové Oči (Československá výprava do křemencového krasu venezuelské Guyany). In: Bosák, P. – Novotná, J. (Eds.): Speleofórum 2003, Česká speleologická společnost, Praha, 22, 60–63.

Audy, M. – Šmída, B., 2005a. Jeskyně Charles Brewer. Mamutí jeskyně v kvarcitech Guyanské vysočiny. Vesmír, Praha, 84 (135), 1, 20–29.
Audy, M. – Šmída, B., 2005b. Největší kvarcitová jeskyně světa Cueva Charles Brewer. In: Bosák, P. – Novotná, J. (Eds.): Speleofórum 2005, Česká speleologická společnost, Praha, 24, 58–62.
Audy, M. – Tásler, R., 2008. Tepui 2007 – Sistema de la Araña. In: Bosák, P. – Novotná, J. (Eds.): Speleofórum 2008, Česká speleologická společnost, Praha, 27, 44–49.
Audy, M., 2003. Křemencový kras venezuelské Guayány. Vesmír, Praha, 82 (133), 5, 256–265.
Auler, A., S., 2002, Karst areas in Brazil and the potential for major caves – an overview. Boletín de la Sociedad Venezolana de Espeleología, Caracas, 36, 29–36.
Auler, A., 2004. Quartizite caves of South America. In: Gunn, J. (Ed.): Encyclopedia of cave and karst science. New York: Fitzroy Dearbom. 611–613.
Bellomo, R. – Gori, S. – Rigamonti, I. – Tognini, P. – Trezzi, G. – Forti, P., 1994. Il Sistema "Aonda Superior" dell´Auayantepui. Resconto della spedizione speleologova italiana "Venezuela 92". El Guácharo, Caracas, 33, 1–93.
Bernabei, T. – Mecchia, M. – Pezzolato, P. – Piccini, L. – Preziosi, E., 1993. Tepuy´93: ancora Venezuela! Speleologia (Soc. Italiana Speleologia), 29, 8–21.
Bernabei, T. (Ed.), 1994: Tepuy 93. Progressione, Comm. Grotte Eugenio Boegan, Trieste, 30, 1–120.
Borghi,L. – Moreira, M., I., C., 2000. The Aroe Jari cave region, chapada Dos Guimaraes, Mato Grosso state, Brazil. Bolletín informativo de la comisión de geospeleología, Federación Espeleológica de América Latina y el Caribe – FEALC, 36, 1–7.
Borghi,L. – Moreira, M., I., C., 2002. Caverna Aroe Jari, Chapada dos Guimarães, MT: Raro exemplo de caverna em arenito. In: Schobbenhaus, C. – Campos, D., A. – Queiroz, E., T. – Winge, M. – Berbert-Born, M., L., C. (Eds.): Sítios Geológicos e Paleontológicos do Brasil. DNPM/CPRM – Comissão Brasileira de Sítios Geológicos e Paleobiológicos (SIGEP) – Brasília, 481–489.
Brewer-Carías, Ch. 1972. Cerro Autana, Elite descubre otra maravilla del Mundo. Revista Elite #2457, Caracas, 27.10.1972, 36–43.
Brewer-Carías, Ch., 1973. Las Cuevas del Cerro Autana. Diario El Nacional. Suplemento Séptimo Día, 25.2.1973, Caracas, 5.
Brewer-Carías, Ch., 1973. Proyecto de Exploración de las Mesetas de Jaua, Guanacoco y Sarisariñama. Suplemento del Boletín de la Sociedad Venezolana de Ciencias Naturales. Caracas, 30, 127, 1–32.
Brewer-Carías, Ch., 1974. En busca de los orígenes. El Farol, Caracas, 18–23.
Brewer-Carías, Ch., 1976a. Las Cuevas del Cerro Autana. Revista Natura, Sociedad de Ciencias Naturales La Salle, Caracas, 58, 33–48
Brewer-Carías, Ch., 1976b. Las Simas de Sarisariñama. Boletín de la Sociedad Venezolana de Ciencias Naturales, Caracas, 22, 132–133, 549–625.
Brewer-Carías, Ch., 1983. Sarisariñama. Editorial Arte, Caracas, 1–228.
Brewer-Carías, Ch., 2005a. El descubrimiento y la exploración de la Cueva Charles Brewer. (Ako bola objavená jaskyňa Charles Brewer). In: Šmída, B. – Brewer-Carías, Ch. – Audy, M. (Eds.). Cueva Charles Brewer – najväčšia kvarcitová jaskyňa sveta. Spravodaj Slovenskej speleologickej spoločnosti (mimoriadne číslo), 36, 3, 8–11.
Brewer-Carías, Ch., 2005b. Las Espeleotemas de la Cueva Charles Brewer. (Speleotémy). In: Šmída, B. – Brewer-Carías, Ch. – Audy, M. (Eds.). Cueva Charles Brewer – najväčšia kvarcitová jaskyňa sveta. Spravodaj Slovenskej speleologickej spoločnosti (mimoriadne číslo), 36, 3, 65–83.
Briceño, H. – Schubert, C., 1992. Geomorfología. In: Huber, O. (Ed.): El Macizo de Chimantá. Escudo de Guayana, Venezuela. Un Ensayo Ecológico Tepuyano, Caracas, 61–74.

Busche, D. – Erbe, W., 1987. Silicate karst landforms of the southern Sahara (northeastern Niger and southern Libya). Zeitschrift für Geomorphologie, Supplementband, 64, 55–72.
Carreño, R. – Blanco, F., 2004. Notas sobre la exploración del Sistema kársico de Roraima Sur, Estado Bolívar. Boletín de la Sociedad Venezolana de Espeleología, Caracas, 38, 45–52.
Carreño, R. – Nolla, L. – Astort, J., 2002. Cavidades del Wei-Assipu-tepui, macizo del Roraima, Brazil. Boletín de la Sociedad Venezolana de Espeleología, Caracas, 35, 36–45.
Carreño, R. – Pérez, W. – Galán, C. – Herrera, F. – Astort, J. – Blanco, F. – Villareal, O. – Cura, I. del – Pérez, M. A. – García, G., 2005. Los 6,1 km de la Cueva Roraima sur, Estado Bolívar: La cueva de mayor desarrollo en rocas cuarcítitas. Bolletín informativo de la comisión de geospeleología, Federación Espeleológica de América Latina y el Caribe – Fealc, 55, 27–28.
Carreño, R. – Urbani, F., 2004. Observaciones sobre las espeleotemas del Sistema Roraima Sur. Boletín de la Sociedad Venezolana de Espeleología, Caracas, 38, 28–33.
Carreño, R., 1996: Actividades espeleologicas Venezolanas desce 1990 hasta 1995. Boletín de la Sociedad Venezolana de Espeleología, Caracas, 30, 1996.
CEDV, 1976. Expedicion espeleologica Polaco-Venezolana 1976, a la meseta de Sarisarinama, Estado Bolivar. Boletín de la Sociedad Venezolana de Espeleología, Caracas, 7 (13): 101–119.
Cigna, A., A., 1978. A Classification of Karstic Phenomena. International Journal of Speleology, 10, 1, 3–9.
Colvée, P., 1972. "Consideraciones Geológicas sobre el Cerro Autana". Informe D.I.A. i-1 de la División de Investigación aplicada, MOP-CODESUR. Enero 1972, 1–12.
Colvée, P., 1973. Cueva en Cuarcitas en el Cerro Autana. Boletín de la Sociedad Venezolana de Espeleología, Caracas, 4, 1, 5–13.
De Bellard, E., 1974a. Exploration preliminaire du pleteau de Sarisariňama (Venezuela). Spelunca, Paris, 4, 99–101.
De Bellard, E., 1974b. Los grandes abismos del tepu ide Sarisariňama. Sociedad Venezolana de Geología, Circular, 63, 35–36.
De Bellard, E., 1975. Descubrimiento en Venezuela del mayor abismo del mundo. Bolletín de Sociedad Venezolana Ciencias Naturales, 31, 130–131, 624–632.
Dutra, G., 1996a. Cavernas em Quartzito na Região de Luminária – MG. O Carste, Grupo Bambuí de Pesquisas Espeleológicas, 8, 2, 26–31.
Dutra, G., 1996b. Geologia Informal da Região do Pico do Inficionado. O Carste, Grupo Bambuí de Pesquisas Espeleológicas, 8, 3, 56–59.
Dutra, G., 1997. O Maior Desnivel do Mundo em Quartzito. O Carste, Grupo Bambuí de Pesquisas Espeleológicas (ediçao. Espec.), 9, 62–69.
Dutra, G., M. – Rubbioli, E., L. – Horta, L., S., 2005. Gruta do Centenário, Pico do Inficionado (Serra da Caraça), MG. A maior e mais profunda caverna quartzítica do mundo. (SIGEP 20). In: Schobbenhaus, C. – Campos, D., A. – Queiroz, E., T. – Winge, M. – Berbert-Born, M. (Eds.): Sítios geológicos e paleontológicos do Brasil, 1, 431–441.
Dyga, R., T. – Székely, K. – Zawidzki, P., 1976: A venezuelai Sarisariñama-fennsík homokkőaknái. Karszt és Barlang, Budapest, 1-2, 43–46.
Epis, L., 2006. Recorde Mundial de Profundidade. Expedição Amazona 2006 – Terra misteriosa. InformAtivo SBE, Sociedade Brasileira de Espeleologia, 92, 30–36.
Faverjon, M., 2003. Alaouf! O Carste, Grupo Bambuí de Pesquisas Espeleológicas, 15, 2, 70–77.
Galán, C. – Herrera, F. – Astort, J., 2004. Génesis del Sistema Roraima Sur, Venezuela, con notas sobre el desarrollo del karst en cuarcitas. Boletín de la Sociedad Venezolana de Espeleología, Caracas, 38, 17–27.
Galán, C. – Herrera, F. – Carreño, R., 2004. Geomorfología e hidrología del Sistema Roraima Sur, Venezuela, La mayor cavidad del mundo en cuarcitas: 10,8 km. Boletín de la Sociedad Venezolana de Espeleología, Caracas, 38, 2–16.

Galán, C. – Herrera, F., 2005. Génesis de la Cueva Roraima sur, Venezuela: La cavidad de mayor desarrollo del mundo en cuarcitas. Bolletín informativo de la comisión de geospeleología, Federación Espeleológica de América Latina y el Caribe – Fealc, 55, 21–22.
Galán, C. – Herrera, F., F. - Carreño, R. – Pérez, M. A., 2004. Roraima Sur System, Venezuela: 10.8 km, world´s longest quartzite cave. Boletín de la Sociedad Venezolana de Espeleología, Caracas, 38, 53–60.
Galán, C. – Lagarde, J., 1988. Morphologie et èvolution des cavernes et formes superficielles dans les quartzites du Roraima (Venezuele). Karstologia, 11–12, 49–59.
Galán, C., 1982. Notas sobre la Morfología de la Cueva del Autana y comentarios sobre las formas Pseudoaarsicas desarrolladas en Cuarcitas del Grupo Roraima, Guayana Venezolana. Boletín de la Sociedad Venezolana de Espeleología, Caracas, 10, 19, 115–128.
Galán, C., 1983a. Expedición a la Sima Aonda. Boletín de la Sociedad Venezolana de Espeleología, Caracas, 20, 99–103.
Galán, C., 1983b. La sima Aonda, -362m. Venezuela. Spelunca, Paris, 14, 2, 14–17.
Galán, C., 1984. Las mayores cavidades del mundo para 1984. Boletín de la Sociedad Venezolana de Espeleología, Caracas, 21, 96.
Galán, C., 1986. Informe general de la expedición efectuada al tepuy Yuruaní. Boletín de la Sociedad Venezolana de Espeleología, Caracas, 22, 84–85.
Galán, C., 1988. Cavernas y formas de superficie en rocas silíceas precámbricas del Grupo Roraima, Guayana, Venezuela. Boletín de la Sociedad Venezolana de Espeleología, Caracas, 23: 1–12.
Ghneim, K., 1999. Índice general del Bolestín de la Sociedad Venezolana de Espeleología, Nos. 1 al 32, 1967–1998. Bolestín Informativo de la Comisión de Geospeleología, Federación Espeleológica de América Latina y el Karibe – Fealc, 9, 1–14.
Gori, S. – Inglese, M. – Tognini, P. – Trezzi, G. – Rigamonti, I., 1993. Auyantepuy, speleologia tropikale nelle quarziti. Speleologia, 28, 23–33.
Herrera, R., 1976. Analisis fisico-quimicos de aguas carsicas. El Guácharo, Caracas, 1/2, 8/9.
Hirashima, H., 1997. A Corda Hayato!!! O Carste. 9, 3, 67–69.
Chaimovicz, F., 2001. A Quebrada da Gruta da Bocaina e Outras Historias emocionantes do Inficionado. O Carste, Grupo Bambuí de Pesquisas Espeleológicas, 13, 2, 108–111.
Chalcraft, D. – Pye, K., 1984. Humid tropical weathering of quartzite in southeastern Venezuela. Zeilschrift fur Geomorphologie, 28, 321–332.
Inglese, M. – Tognini, P., 1993. Auyantepuy. The devil´s Mountain. The international Caver Magazine, 6, 3–10.
Koisar, B. – Solicki, T., 1977a. Wyprawa na mesete (1). Kamienne sciany. Poznaj swiat – Magazyn geograficzny, 25, 8, 18–25.
Koisar, B. – Solicki, T., 1977b. Wyprawa na mesete (2). Wiezniowie Sarisariñama. Poznaj swiat – Magazyn geograficzny, 25, 9, 21–28.
Kuczynski, M., 1976a: Expedicion espeleologica polaco-venezolana 1976 a la meseta de Sarisarinama, Alto Acura, Estado Bolivar. UIS Buleltin, 1, 3.
Kuczynski, M., 1976b: Sarisariñama 1976. Taternik, Warsawa, 3/76, 123–127.
Maeztu, J. – Ipiña, J. de – Alangua, F. – Laktasa, I., 1995. Catálogo de cavidades exploradas en el macizo de Chimantá. Karaitza, España, 4, 33–44.
Martínez, J., 1989. Venezuela, Sima Aonda (-362 m). Desnivel – revista de montaña, España, 49, 52-55.
Martini, J., E., J., 1981. The control of karst development with reference to the formations of caves in poorly soluble rocks in the eastern Transvaal, South Africa. Proceedings of 8th International Congress of Speleology, Bowling Green, Kentucky, 1, 4–5.

Martini, J., E., J., 1982. Karst in Black Reef and Wolkberg Group quartzite of eastern Transvaal escarpment, South Africa. Boletín de la Sociedad Venezolana de Espeleología, Caracas, 10, 19, 99–114.
Martini, J., E., J., 1984. Rate of quartz dissolution and weathering of quarzite. Bulletin of South African Speleological Association, 25, 7–10.
Martini, J., E., J., 1985. Caves of South Africa. Karstologia, 5, 1, 39–44.
Martini, J., E., J., 1990. Magnet: a large quartzite cave system in the Eastern Transvaal. Bull. S. Aft. Speleol. Assoc., 31.
Martini, J., E., J., 1994. Magnet Cave, Transvaal: Now believed to be South Africa's longest quartzite cave. Bull. S. Aft. Speleol. Assoc., 33.
Mechia, M. – Piccini, L., 1999. Hydrogeology and SiO2 geochemistry of the Aonda Cave System, Auyan-Tepui, Bolivar, Venezuela. Boletín de la Sociedad Venezolana de Espeleología, Caracas, 33, 1–11.
Nott, D., 1975. Into the Lost World. Prentice Hall, Englewood Clifts, New Jersey, 1–186.
Oldham, T., 2003. The Caves of Meghalaya. http://www.showcaves.com/english/in/region/ MeghalayaOldham.html. (date: 1. 1. 2006)
Pérez La Riva, W. – Reyes, C., 1976. Cueva del Cerro Autana. Boletín de la Sociedad Venezolana de Espeleología, Caracas, 7, 13, 81–85.
Pérez La Riva, W., 1976. Ascenso al Cerro Autana, Territorio Amazonas. Boletín de la Sociedad Venezolana de Espeleología, Caracas, 7, 13, 114–116.
Pérez La Riva, W., 1977: Nuevas wxploraciones espeleologicas en la Sierra de Pacairima, Guyana Venezolana. Boletín de la Sociedad Venezolana de Espeleología, Caracas, 8, 16, 235–241.
Pérez, M., A. – Carreño, R., 2004. Exploration of the Roraima Sur Cave, Bolívar State, Venezuela, the longest quartzite cave in the world. NSS Convention Abstracts, Journal of Cave and Karst Studies, 116.
Perret, J. – F., 2001. Caraça. Um Ponto Alto de 99. O Carste, Grupo Bambuí de Pesquisas Espeleológicas, 13, 2, 100–105.
Pezzolato, P., 1993. Tepuy 93. Progressione, Comm. Grotte Eugenio Boegan, Trieste, 29, 46–48.
Pezzolato, P., 1996. Venezuela. Tepuy "Terra senzo tempo". Progressione, Comm. Grotte Eugenio Boegan, Trieste, 34, 27–33.
Piccini, L., 1994. Aspetti geologici e geomorfologici del settore nordoccidentale dell'Auyan-tepuy (Est. Bolivar, Venezuela). Progressione, Comm. Grotte Eugenio Boegan, Trieste, 30, 14–26.
Piccini, L., 1995. Karst in Siliceous Rock: Karst landfoms and Caves in the Auyan-tepuy (Est. Bolivar, Venezuela). International Journal of Speleology, 24, 41–54.
Rodríguez, R. – Silverio, M., O., 2002. CNC – Cadastro Nacional de Cavernas do Brazil. InformAtivo SBE, São Paulo, 79, 8–12.
Rubbioli, E., L., 1998. Into the "Devil's Throat". Gruta do Centenário – The world's deepest quartzite cave. International Caver, 22, 19–24.
Rubbioli, E., L., 1996. O Pico do Inficionado. A exploração da gruta mais profunda do Brasil. O Carste, Grupo Bambuí de Pesquisas Espeleológicas, 8, 3, 46–49.
Rubbioli, E., L., 2001. Gruta da Bocaina o Desafio Continua. O Carste, Grupo Bambuí de Pesquisas Espeleológicas, 13, 2, 98–99.
Rubbioli, E., L., 2003. A Nova Entrada da Gruta da Bocaina co Encontro com o et no Pico do Inficionado. O Carste, Grupo Bambuí de Pesquisas Espeleológicas, 15, 2, 57–65.
SVE, 1994. Cavidades Estudiadas en la Expedición al Macizó de Chimantá, 1993. Boletín de la Sociedad Venezolana de Espeleología, Caracas, 28, 34–51.
Szczerban, E. – Gamba, J., 1973. Cuevas y simas en areniscas Precámbrias de la Formación Roraima, Territorio Federal Amazonas y Estado Bolívar, Venezuela. Boletín de la Sociedad Venezolana de Espeleología, Caracas, 4, 2, 226.

Szczerban, E. – Urbani, F. – Colvée, P., 1977. Cuevas y simas en cuarcitas y metalimolitas del grupo Roraima, meseta de Guaiquinim, Estado Bolívar. Boletín de la Sociedad Venezolana de Espeleología, Caracas, 8, 16, 127–154.

Szczerban, E. – Urbani, F., 1974. Carsos de Venezuela. Parte 4: Formas Cársicas en areniscas Précambricas del Territorio Federal Amazonas y Estado Bolívar. Boletín de la Sociedad Venezolana de Espeleología, Caracas, 5, 1, 27–54.

Šmída, B., 2009. Obrovská jaskyňa Cueva Muchimuk vo Venezuele – ako bola objavená a preskúmaná. Spravodaj Slovenskej spleologickej spoločnosti, Liptovský Mikuláš, 40, 2, 52–58.

Šmída, B. – Audy, M. – Biord, H. – Mayoral, F., 2005a. Cueva Charles Brewer (Chimantá) and Cueva Ojos de Cristal: the greatest quartzite caves of the world (table-mountains, Venezuela). Bulletin of the SSS (special edition, for the 14th Speleological Congress UIS in Greece), Liptovský Mikuláš, 3–10.

Šmída, B. – Audy, M. – Biord, H. – Mayoral, F., 2005b. Cueva Charles Brewer (Chimantá) and Cueva Ojos de Cristal: the greatest quartzite caves of the world (table-mountains, Venezuela). Proceedings of the 14th International Congress of Speleology (electronic version), Athens.

Šmída, B. – Audy, M. – Brewer-Carías, Ch. – Vlček, L. – Mayoral, F. 2008. Caves of Macizó Chimantá and Roraima Tepuy in La Gran Sabana area (Estado Bolívar, Venezuela). In Hajna N. Z. & Mihevc A. (Eds.): 16th International Karstological School "Classical Karst", Karst Sediments, 16th – 21st June 2008, Postojna, Guide Book & Abstracts, 108.

Šmída, B. – Audy, M. – Mayoral, F. – Carnicero, L., A., 2004a. Expedícia Chimantá 2004, alebo objavovanie Cueva Charles Brewer – najväčšej kvarcitovej jaskyne sveta. Spravodaj Slovenskej spleologickej spoločnosti, Liptovský Mikuláš, 35, 2, 3–14.

Šmída, B. – Audy, M. – Mayoral, F. – Carnicero, L., A., 2004b. Expedition Chimantá 2004 or discovering of Cueva Charles Brewer – the largest quarzit cave in the world. Bulletin of the Slovak Speleological Society, Liptovský Mikuláš, 35, 2, 3–14.

Šmída, B. – Audy, M. – Mayoral, F., 2005a. Cueva Charles Brewer – la plus importante grotte du monde creusée dans les quartzites (massif du Chimantá, Venezuela). Spelunca, Paris, 97, 27–35.

Šmída, B. – Audy, M. – Mayoral, F., 2005b. Cueva Charles Brewer: Largest quartzite cave in the world. NSS News, National Speleological Society, 63, 1, 13–14, 31.

Šmída, B. – Audy, M. – Mayoral, F., 2005c. Into the Lost World. Descent, Abergavenny, 183, 36–38.

Šmída, B. – Audy, M. – Mayoral, F., 2005d. Cueva Charles Brewer. Regards, 58, 9–12.

Šmída, B. – Audy, M. – Mayoral, F., 2005e. Cueva Charles Brewer. The largest quartzite cave in the world (Chimantá massif, Venezuela). Journal of the SSS, Sydney Speleological Society, Sydney, 49, 1, 3–12.

Šmída, B. – Audy, M. – Vlček, L., 2003. Expedícia Roraima, Venezuela, január 2003 – Cueva Ojos de Cristal (Kryštálové oči). Spravodaj Spravodaj Slovenskej speleologickej spoločnosti, Liptovský Mikuláš, 34, 2 (special issue), 1–192.

Šmída, B. – Brewer-Carías, Ch. – Audy, M. – Mayoral, F. – Vlček, L. – Aubrecht, R. – Lánczos, T. & Schlögl, J. 2008. The longest quartzite caves of the world: Cueva Ojos de Cristal (16.1 km) and Cueva Charles Brewer (4.8 km) and other giant caves on Venezuela table-mountains tepuy Roraima and Chimantá discovered by our 7 expeditions in 2002 – 2007. Spelunca Mémories, Vercors 2008 Proceedings, IVth European Speleological Congress, Fédération française de spéléologie, 33, 239–243.

Šmída, B. – Brewer-Carías, Ch. – Audy, M. – Mayoral, F., 2007. Expedícia TEPUY 2007, stolové hory Chimantá a Roraima, Venezuela: oficiálna správa o výsledkoch. Spravodaj SSS, Liptovský Mikuláš, 38, 1, 78–80.

Šmída, B. – Brewer-Carías, Ch. – Audy, M. – Vlček, L. – Mayoral, F. – Aubrecht, R. – Lánczos, T. – Schlögl, J. 2008. Exploračné sumárum o kvarcitových jaskyniach objavených v rokoch 2004

– 2007 v masíve Chimantá, Venezuela (Ľudia, objavy, lokality, literatúra). Spravodaj Slovenskej speleologickej spoločnosti, Liptovský Mikuláš, 39, 1, 90–102.
Šmída, B. – Brewer-Carías, Ch. – Audy, M. – Vlček, L. – Mayoral, F. – Aubrecht, R. – Lánczos, T. – Schlögl, J., 2008. Exploračné sumárum o kvarcitových jaskyniach objavených v rokoch 2004 – 2007 v masíve Chimantá, Venezuela (Ľudia, objavy, lokality, literatúra). Spravodaj Slovenskej speleologickej spoločnosti, Liptovský Mikuláš, 39, 1, 90–102.
Šmída, B. – Brewer-Carías, Ch. – Audy, M., Eds., 2005. Cueva Charles Brewer – najväčšia kvarcitová jaskyňa sveta. Speleoexpedície do masívu Chimantá 2004, Venezuela. Spravodaj Slovenskej speleologickej spoločnosti, Liptovský Mikuláš, 36, 5 (special issue), 1–178.
Šmída, B. – Brewer-Carías, Ch. – Mayoral, F. – Vlček, L. – Aubrecht, R. – Lánczos, T. a kol., 2008. Speleoexpedícia TEPUY 2007 (stolové hory Chimantá a Roraima, Venezuela). In.: Bosák, P. – Novotná, J. (Eds.): Speleofórum, 27, Česká speleologická společnost, Praha, 49–57.
Šmída, B. – Brewer-Carías, Ch., 2005. Descripción, morfología, génesis, hidrología y perspectivas de la Cueva Charles Brewer. Náčrt genézy jaskyne a perspektívy jej pokračovania. In: Šmída, B. – Brewer-Carías, Ch. – Audy, M. (Eds.). Cueva Charles Brewer – najväčšia kvarcitová jaskyňa sveta. Spravodaj Slovenskej speleologickej spoločnosti (mimoriadne číslo), 36, 3, 26–31, 97–101.
Travassos, L. E. P. – Guimarães, R. L. – Varella, I. D., 2008. Áreas cárstocas, cavernas e a estrada real. Pesquisas em Turismo e Paisagens Cársticas, Campinas, SeTur/SBE, 1, 2, 107–120.
Truluck, T., F., 1996. The Survey of Bat´s/Giant´s/Climber´s Cave System. www.darklife.co.za/caves/wcape/Table_Mountain/Bats_Giants_survey_and_exploration.htm (date: 9.12.2000)
Urbani, F. – Bordón, C., 1997. Spedizione "Auyán-tepui 1992" – Venezuela, riposta a Mauro Inglese. El Guácharo, Caracas, 40, 8–11, 1997.
Urbani, F., 1976. Polish-Venezuelan Expedition Studies Sarisarinama Caves. NSS News, National Speleological Society, 34, 11, 194–195.
Urbani, F., 1977. Novedades sobre Estudios Realizados en las Formas Carsicas y Pseudocársicas del Escudo de Guayana. Octubre 1977. Boletín de la Sociedad Venezolana de Espeleología, Caracas, 8, 16, 175–197.
Urbani, F., 1993. Quartzite Caves in Venezuela. Caves & Caving, 61, 32–33.
Vlček, L. – Šmída, B., 2007. Objavy členov Slovenskej speleologickej expedície Roraima – Kukenán 2006 na stolovej hore Roraima v Guayanskej vysočine (Venezuela). Aragonit, Liptovský Mikuláš, 12, 89–93.
Vlček, L. – Šmída, B., Brewer-Carías, Ch. – Audy, M. – Mayoral, F.– Aubrecht, R. – Lánczos, T., 2008. Prírodovedecká expedícia Chimantá – Roraima 2007: výsledky speleologických výskumov na stolových horách La Gran Sabany (Estado Bolívar, Venezuela). Aragonit, Správa slov. jaskýň, Liptovský Mikuláš, 13, 2, 34–46.
Vlček, L., 2004. Horizontal quartzite-karst caves in Venezuela – one of the newest geomorphological discoveries. Proceedings of the 8th International Symposium on Pseudokarst, Teplý vrch, Slovakia, 57–61.
Wernick, E. – Pastore, E., R., B. – Pires Neto A., 1977: Cuevas en Areniscas, Rio Claro, Brasil. Boletín de la Sociedad Venezolana de Espeleología, Caracas, 8, 16, 99-107.
www.tepuy.info (date: 15.03.2009)
Zawidski, P. – Urbani, F. – Koisar, B., 1976. Preliminary Notes on the Geology of the Sarisariñama Plateau, Venezuela, and the Origin of its Caves. Boletín de la Sociedad Venezolana de Espeleología, Caracas, 7, 13, 29–37.

List of participants of the 11th International Symposium on Pseudokarst

Jiří Adamovič, Czech Republic, Institute of Geology AS CR, Rozvojová 135, 165 02 Praha 6, adamovic@gli.cas.cz

Matthias Arnhold, Germany, HFG Dresden e.V., Finkenweg 6, 01237 Dresden, matthias.arnhold@mailbox.tu-dresden.de

Udo Bräunig, Germany, Heinrich-Heine-Str. 5, D-82152 Martinsried, udobraeunig@live.de

Jiri Bruthans, Czech Republic, Charles University in Prague, Faculty of Sciences, Albertov 6, 128 43 Praha 2, bruthans@natur.cuni.cz

Petra Cech, Austria

Reinaldo Costas-Vazquez, Spain, Mauxo Speleological Association, Redondela, 4-2 D; E36209 Vigo (Pontevedra), reymaugio@hotmail.com

Elzbieta Dumnicka; Poland, Institute of Nature Conservation, Polish Academy of Science, al. A. Mickiewicza 33, 31-120 Kraków, dumnicka@iop.krakow.pl

Istvan Esterhasz, Hungary, Köztársaság u. 157, H-8045 Isztimér

Ludovít Gaál, Slovakia, Správa slovenských jaskýň, pracovisko Rimavská Sobota, Železničná 31, 979 01 Rimavská Sobota, gaal@ssj.sk

Sandro Galdenzi, Italy, Viale Verdi, 10 60035 Jesi (AN), galdenzi.sandro@tiscali.it

Martina Glauche, Germany, Höhlen- und Karstforschung Dresden e.V., Wiesenweg 3 01454 Ullersdorf mglauche@dresden.de

Alessio Glessi, Italy, Centro ricerche Carsiche "C. Seppenhofer", via Marega, 50, 34170 Gorizia, glsgianni@libero.it

Giovanni Glessi, Italy, Centro ricerche Carsiche "C. Seppenhofer", via Marega, 50, 34170 Gorizia, glsgianni@libero.it

Wojciech Gubala, Poland, Chiropterological Information Centre, Cave Protection Group "Grupa z Malinki", Hallera st. 16/15, 38-300 Gorlice, wojtekjgubala@gmail.com

Werner Hollender, Austria, Rasumofskygusse 34/17 A-1030 Vienna

David Holmgren, Germany, Workgroup of Cave & Subway Climatology, Department of Geography, Geographisches Institut, Gebäude NA 4/170, Ruhr-Universität Bochum, D-44780 Bochum, david.holmgren@rub.de

Norbert Horn, Germany, Höhlen- und Karstforschung Dresden e.V., Marienallee 1, 01099 Dresden, nmhorn@freenet.de

Balciar Igor, Slovakia, Slovak Caves Administration, 11, 031 01 Liptovský Mikuláš, balciar@ssj.sk

Jens Jakobeschky, Germany, Höhlen- und Karstforschung Dresden e.V., Platanenstr. 10, 01129 Dresden, J.Jakobeschky@t-online.de

Sabine Jakobeschky, Germany, Höhlen- und Karstforschung Dresden e.V., Ludwig-Kossith-Str. 54, 01109 Dresden, Sabine.Jakobeschky@dgbrechtsschutz.de

Oldrich Jenka, Czech Republic, ZO ČSS 5-03 Broumov, Smetanova 357, CZ-549 54 Police nad Metují, o.jenka@seznam.cz

Erich Knust, Germany, HFG Karlsruhe, Mainzer Str. 29, 76199 Karlsruhe, eknust@gmx.de

Jiri Kopecky, Czech Republic, ZO ČSS 5-03 Broumov, Husova ul. 154, 550 01 Broumov – Velká Ves, kopecky@atlas.cz

Jirka Kopecky, Czech Republic, ZO ČSS 5-03 Broumov, Husova ul. 154, 550 01 Broumov – Velká Ves, kopecky@atlas.cz

Christopher Krafft, Sweden, Swedish Speleological Society, Meteorvägen 1 D, 175 60 Järfälla, ckrafft@gmail.com

Tomas Lanczos, Slovakia, Department of Geochemistry, Faculty of Natural Sciences, Comenius University, Mlynská dolina, G-235, 842 15 Bratislava, Slovakia

Jose Miguel Lopez-Mosquera, Spain, Mauxo Speleological Association, OS CASÁS, 26; E36316 Vincios-Gondomar, (Pontevedra), zrus.lope@gmail.com

Andreas Ludwig, Germany, Höhlen- und Karstforschung Dresden e.V., Ernst-Thälmann-Str. 7, 04808 Lüptitz

Helga Ludwig, Germany, Höhlen- und Karstforschung Dresden e.V., Ernst-Thälmann-Str. 7, 04808 Lüptitz

Rune Magnusson, Sweden, Sveriges Speleologförbund, Marknadsvägen 177, SE-183 78 Täby, rune.magnusson@abc.se

Włodzimierz Margielewski, Poland, Institute of Nature Conservation, Polish Academy of Sciences, Al. A. Mickiewicza 33, 31-120 Kraków, margielewski@iop.krakow.pl

Radek Mikuláš, Czech Republic, Institute of Geology AS CR, Prague, Rozvojová 269, 165 02 Praha 6, mikulas@gli.cas.cz

Reinhard Müller, Germany, Höhlen- und Karstforschung Dresden e.V.

Alexandra Müller, Germany, Höhlen- und Karstforschung Dresden e.V.

Barbara Pape, Austria, TFC Hannibal, Am Kaisermühlendamm 5/12, 1220 Vienna, bpape1@a1.net

Rudolf Pavuza, Austria, Dept. Of Karst and Caves, Museum of Natural History Vienna, Museumsplatz 1/10/1, A-1070 Vienna speleo.austria@netway.at

Laura Sanna, Italy, Associazione Speleologica Progetto Supramonte, Via Decimario 3 - 07100 Sassari, speleokikers@tiscali.it

Marvin Schmidt, Germany, Höhlen- und Karstforschung Dresden e.V.

Dirk Seifert, Germany, Höhlen- und Karstforschung Dresden e.V., Eibenstocker Stra. 70, 01277 Dresden, dirk_seifert@gmx.de

Hartmut Simmert, Germany, Höhlen- und Karstforschung Dresden e.V., Hohe Straße 48b, 01187 Dresden, hartmut.simmert@t-online.de

Jana Simmert, Germany, Höhlen- und Karstforschung Dresden e.V., Friedrichstraße 52, 01067 Dresden, jana.simmert@mailbox.tu-dresden.de

Martina Simmert, Germany, Hohe Straße 48b, 01187 Dresden

Ulrike Simmert, Germany, Hochschulstraße 38, 01187 Dresden

Rabbe Sjöberg, Sweden, Swedish Speleological Society (SSF), Bodviksvägen 14, 913 42 Obbola, rabbe.sjoberg@telia.com

Branislav Šmída, Slovakia, Slovak Speleological Society, Liptovský Mikuláš, Mlynská dolina, pav. B-1, 842 15 Bratislava 4, brano.smida@gmail.com

Veit Stremel, Germany, Höhlen- und Karstforschung Dresden e.V., Wippermühle 1, 06567 Rottleben

Georg Szentes, Germany, MKBT, NSS, Höhlenforschergruppe Rhein-Main, Alte Frankfurter Str. 22 B, D-61118 Bad Vilbel, szentesg@aol.com

Maurizio Tavagnutti, Italy, Ricerche Carsiche "C. Seppenhofer", Via Ristori, 31-34170 Gorizia, mtavagnutti@libero.it, seppenhofer@libero.it

Jörg Templin, Germany, Höhlen- und Karstforschung Dresden e.V., Damaschkesraße 34, 02625 Bautzen, Joerg.Templin@gmx.de

Falk Thieme, Germany, Höhlen- und Karstforschung Dresden e.V., Rahnstr. 25, 01129 Dresden, falkthieme@googlemail.com

Aurora Toplikar, Italy, Centro ricerche Carsiche "C. Seppenhofer", via Marega, 50, 34170 Gorizia, glsgianni@libero.it

Jan Urban, Poland, Instytut Ochrony Przyrody PAN, al. A. Mickiewicza 33, 31-120 Kraków, urban@iop.krakow.pl

Jan Paul van der Pas, Netherlands, Speleo Nederland, Vauwerhofweg 3, 6333 CB Schimmert, jpgvanderpas@hetnet.nl

Marcos Vaqueiro-Rodriguez, Spain, Mauxo Speleological Association, Manuel de Castro, 8-3°D, E36210, Vigo (Pontevedra), mauxo@mauxo.com, mvaqueiro@frioya.es

Zuzana Varilová, Czech Republic, Správa NP České Švýcarsko, Pražská 52,407 46 Krásná Lípa, z.varilova@npcs.cz

Juan Ramon Vidal-Romani, Spain, Institute of Geology "Isindro Parga Pondal", Instituto Universitario de Xeoloxia. Universidade de A Coruña, Campus de Elviña s/n 15071 Coruña, xemoncho@udc.es

Lukas Vlcek, Slovakia, Slovak Speleological Society, Liptovský Mikuláš, Slovak Republic, Hodžova 11, 031 01 Liptovský Mikuláš, lukasvlcek@yahoo.com

Bernd Wutzig, Germany, Höhlen- und Karstforschung Dresden e.V., Gussmannstr. 31, 01217 Dresden