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FRONT COVER: Canyon passage in a piping cave, New Mexico (Photo T. Lappin).

BACK COVER: A glaciovolcanic cave passage in Mothra cave, Mount St. Helens, where an ice mantled conduit is buttressed by fumarolic areas. Rock and sediment in the foreground laying on the ice is breakdown debris originating from the walls and ceiling, as the glacier comprises both ice and rock debris from the above crater walls (Photo B. McGregor).

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PAPERS

Caves: Explore, understand and protect

PREFACE

Caves are usually among the first geosites consciously met by common people as geological heritage. People visit caves during vacations, touristic routes or other travels and these are obviously show caves, adequately prepared for such visitors. And these visits can aware at least certain consciousness on the significance of geology and particularly speleology – as a science, knowledge, and practical activity – for the nature as well as human being and economy. However, most show caves are typical karst forms. Consequently, a significant part of the speleological knowledge remains practically completely unknown, because there are thousands of non-karst caves and large regions abounding in such caves. And these caves belong to the most interesting and most spectacular, often unique features, due to their extraordinary or very complex (and therefore unique) genesis, specific shapes and morphologies, or unique occurrence (in areas seemingly "definitely devoid of caves"). Regarding the specificity of these objects, their various and complex, often not fully recognized genesis, such caves and surface forms similar to karst are called pseudokarst.

The International Year of Caves and Karst gives a good opportunity to propagate and disseminate the knowledge about such specific caves, which are normally not popular, unexplored and unknown by normal public, despite their scientific specificity and aesthetic attractiveness. Therefore this issue of the "Pseudokarst Commission Newsletter", just of the special number, namely the 30th one, aims the promotion and popularization of pseudokarst caves. Consequently, it contains mostly short texts illustrated by a lot of pictures, mainly photographs and presents a great diversity of cave genesis, shapes and host rocks. Some papers comprise general reviews of cave occurring in particular countries or large regions, showing the diversity of caves in large areas, such as Russia (Y.S. Lyakhnitsky & I.A. Agapov), but also in smaller ones: Austria (R. Pavuza & P. Oberender), Galicia (M. Vaqueiro-Rodriguez & J.R. Vidal-Romani), Poland (J. Urban et al.). Although the paper describing pseudokarst in the vast area of the western part of United States (D. Medville) presents theoretically only two cave types, the genetical and morphological specificity of these caves is amazing. Other papers describing smaller areas or specific types of caves, perfectly illustrate the great diversity and uniqueness of the pseudokarst cave, such as very unique caves formed owing to the fire and ice "competitions" (C. Stenner & L.J. Florea), as well as quite different caves related to the activity of a typical volcano (P. Crossley & G. Szentes) and – again – totally divergent caves in the weathered, very old from geological viewpoint, granite hills (P. Tarsoly). Even if one concentrates at only one cave, there is a sufficiently large set of genetical problems, environmental interrelations, cultural aspects and picturesque landscapes so as to present them to public, which is adequately shown by the paper on the cave in Brasilia city (C.F. Stumpf & T.G.R. Ribeiro) and on the Enchanted Rock and its cave (G. Szentes). An example from the Moravian-Silesian Beskydy Mts. illustrates how fascinating can be interrelations between human traditions and pseudokarst caves (J. Wagner & I, Baroň).

In this voluminous issue of the Pseudokarst Commission Newsletter we have examples from nine countries all over the world. Nevertheless, numerous examples of pseudokarst features from many countries not represented here can be found among the 29 issues of the Newsletter which can be downloaded as PDF files (see: www.pseudokarst.com).

In a consequence, the material contained in this issue of the "Pseudokarst Commission Newsletter" is destined not only to typical speleologists and cavers. **We would like to present it to all people interested in nature and its specificity of the world. Therefore, we ask all people receiving this issue to distribute it among people who want to know more about these special features around the globe**. We hope that the papers of this issue will rise a little bit the public awareness on the specificity and significance of the pseudokarst caves in order to their better protection, according to the motto of the International Year of Caves and Karst 2021/2021: EXPLORE, UNDERSTAND AND PROTECT.

Jan Urban, Rudolf Pavuza

PSEUDOKARST IN CLASTIC ROCKS IN THE WESTERN UNITED STATES

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Overview

Numerous caves are found in clayey-siliciclastic rocks such as claystones, siltstones, and shales in the western United States (Fig. 1). The caves are found in a variety of host rocks: e.g., the Eocene Wasatch Formation, the Jurassic Morrison Formation, and the Cretaceous Mancos Shale in Colorado, the Paleocene Nacimiento Formation in New Mexico, the Cretaceous Cody Shale in Wyoming, and the Pleistocene/Paleocene Palm Springs Formation in California. Two types of caves developed in clastic rocks are described below: piping caves in swelling soils and those found in shales.

Fig. 1. Areas of the pseudokarst caves occurrence in the western part of U.S.: soil piping caves (red) and shale caves (blue)

Soil Piping Caves

The most commonly occurring of these caves are developed in swelling soils. Soil piping caves in the western U.S. have been described in Parker and Higgens (1990), White and Greenman (2008) and Medville (2017). As of mid-2021 over 700 of these caves have been recorded with over 14 km of passage having been surveyed in them. Although most of the caves are only 50 m to 100 m long, the longest is over 900 m in length and two have vertical extents over 100 m. These caves are variously described as being piping caves, debris-flow caves, claystone caves, mudstone caves, and suffosional caves, among other terms.

The caves are generally found in soils that have a high soluble salt content, especially sodium ions. Specifically, the soils in which the piping caves are found contain montmorillonite, a clay mineral having a high exchangeable sodium capacity. When wetted, the clay swells by up to 600% and when dried it shrinks, resulting in desiccation cracks that allow surface water to move underground and initiate the process of granular transport of the soil/clay particles.

With repeated swell/shrink cycles, the cracks deepen, with most of the swelling and shrinking taking place at the bottom of the cracks. The cracks, small sinks and incipient openings grow deeper until either local base level or a less permeable surface is reached, e.g., a harder sandstone bed or the original gully floor beneath a debris flow. As the openings enlarge, karst-like landforms containing dolines, entrances, and pits develop (Fig. 2).

Fig. 2. Pseudokarst dolines in swelling soils, New Mexico (Photo D. Medville)

Water flowing through the initial openings moves down-valley to an outlet on the valley floor or on a hillside. Once water has established a path from a sink point to an outlet, the initial opening enlarges over time as a result of mechanical removal of the soil grains (corrasion). Over time, the concentrated flow of water removes loose, detachable particles on the conduit walls, gradually enlarging it. The result is a continuous void large enough for human entry, i.e., a piping cave.

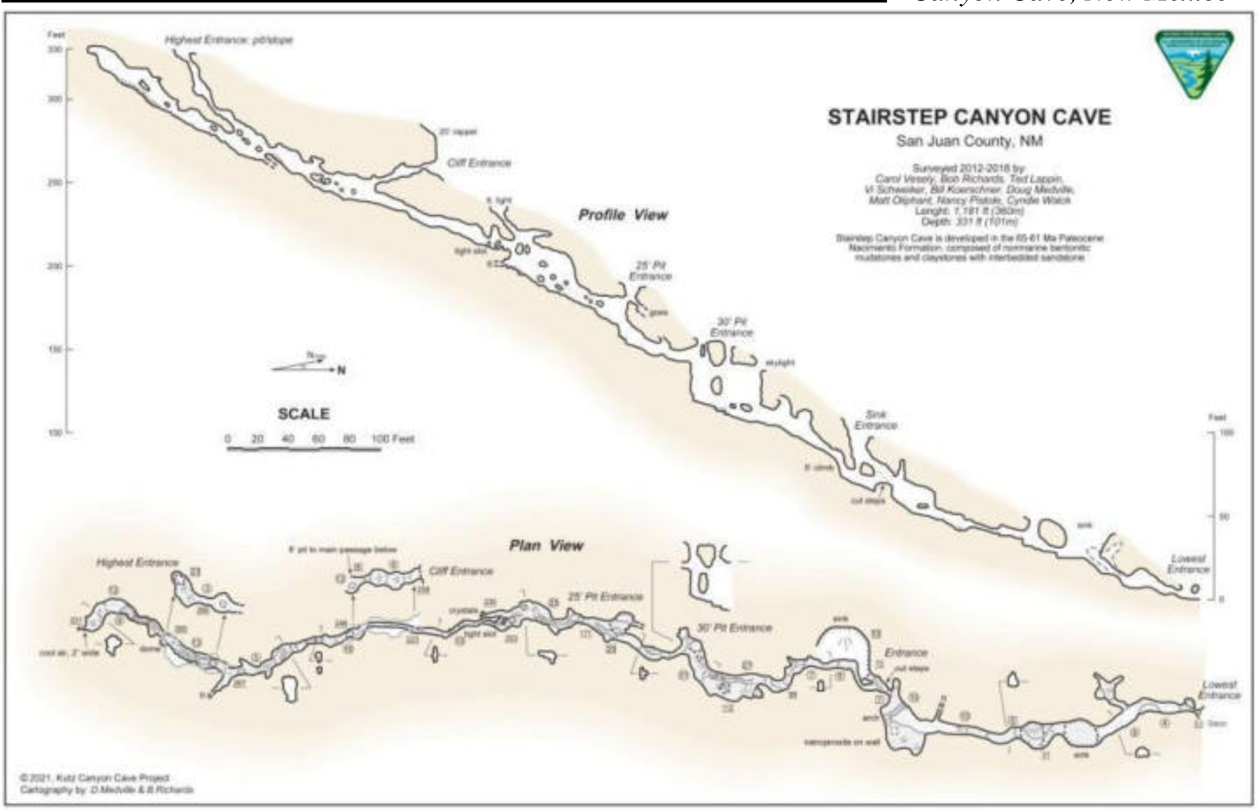
In low-gradient settings passages can be low and wide, while in higher-gradient settings where caves are beneath steep gullies, the passages tend to be more canyon-like (see front cover). These passages are wider at the top where the passage initiates and narrow below as the stream cuts down into the floor, similar to vadose entrenchment in a limestone cave.

The passages in these caves vary from crawlways to spacious tunnels up to 5 m across and high, depending on the stability of the matrix in which the caves form (Fig. 3). Some caves have walls and ceilings that are partially in bedrock (Fig. 4) or have hardened adobe-like walls and ceilings, making them more structurally stable than the term "soil pipe" would imply. Others contain streambeds and seasonally active streams, similar to stream passages seen in limestone caves. As the caves descend through the matrix in which they form, more resistant beds below may be breached. When this happens, internal drops of 5 m to 10 m are seen. Fig. 5 is a map of a piping cave having a vertical extent of over 100 m.

Fig. 3. Piping cave passage, New Mexico, USA (Photo T. Lappin)

Fig. 4. Swelling soil piping cave with a sandstone ceiling, New Mexico (Photo T. Lappin)

Fig. 5. Map and longitudinal cross-section of Stairstep Canyon Cave, New Mexico



As the process of particle removal continues and passages are widened, sections of the passage ceiling may stope upward and collapse, resulting in skylights when viewed from below and pits when viewed from above. Over time, the pits coalesce, and further ceiling slumping and collapse takes place, resulting in a series of remnant natural bridges rather than a continuous subsurface conduit. The resulting topography contains dolines, pits, sinking streams, hanging valleys, and resurgence entrances and resembles a karst topography, even though solutional process is not a factor. Rather, this piped landscape is a form of pseudokarst.

Shale Caves

Pseudokarst landforms, including caves, are also found in Western U.S., within Cretaceous shales. Processes involved in the development of such caves for an area in north-central Wyoming were discussed in Medville (2018). More recently, similar caves have been observed in western Colorado. As with soil piping caves, a swelling clay component of the shale-derived soil allows meteoric water to penetrate the regolith and reach the top of the unweathered shale below. A landform consisting of small soil dolines and blind valleys results (Fig. 6). When surface water contacts the unweathered shale below the regolith, it reacts with pyrite in the shale, producing sulfuric acid. The reactions may be enhanced by the presence of chemolithoautotrophic bacteria such as *Acidithiobacillus ferrooxidans,* as observed in the Wyoming shale caves.

Fig. 6. Cretaceous Cody Shale pseudokarst hillside, Wyoming

The sulfuric acid reacts with calcite in the shale to produce gypsum. The gypsum, having twice the molar volume of calcite, fractures and separates the individual shale beds (Fig. 7). This increases its secondary porosity and allows meteoric water to contact the shale surfaces. As a result of mechanical removal of shale particles (corrasion), open voids develop which, over time, can allow human entry (Fig. 8). Given a sufficient hydraulic gradient and an outlet for water moving through the open voids, canyon-like vadose passages up to tens of meters in height and hundreds of meters in length develop (Fig. 9). Evidence for these processes include the presence of orange-red ferric oxyhydroxides (goethite) on passage walls (Fig. 10), fibrous gypsum fillings between shale beds (Fig. 7), and microscopic framboidal pyrite pseudomorphs. Figure 11 is a map of a 300 m long cave developed entirely in a Cretaceous shale.

Fig. 7. Gypsum fillings between shale beds, Cody Shale Cave, Wyoming (Photo D. Medville)

Fig. 8. Entrance to the Rock Pigeon Cave, Colorado (Photo B. Richards)

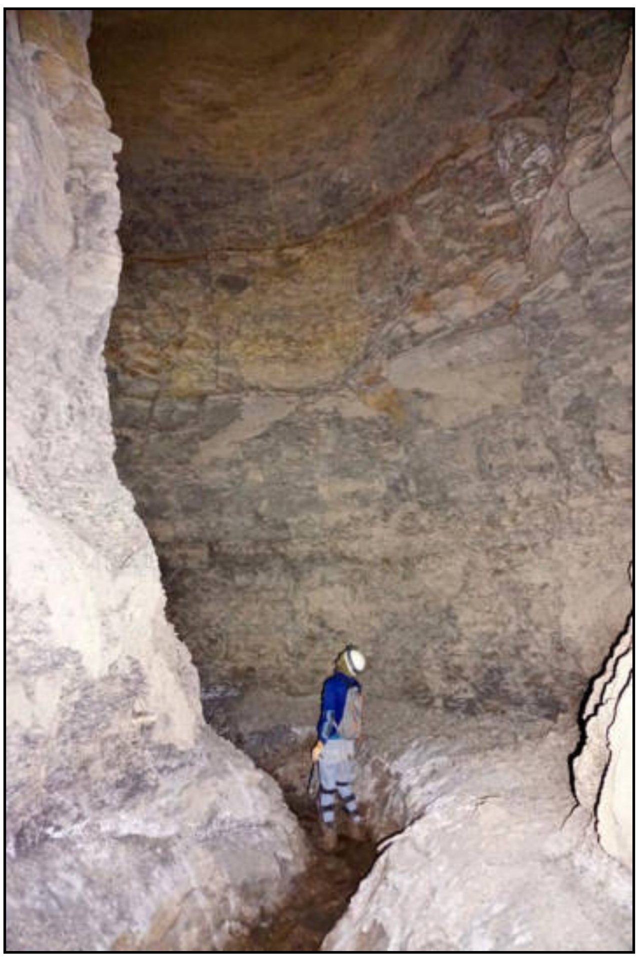


Fig. 9. Vadose passage in a cave in the Mancos Shale, Colorado (Photo B. Richards)

Fig. 10. Ferric oxyhydroxides (goethite) on passage walls, sulfate evaporites at waist level in a shale cave, Colorado (Photo B. Richards)

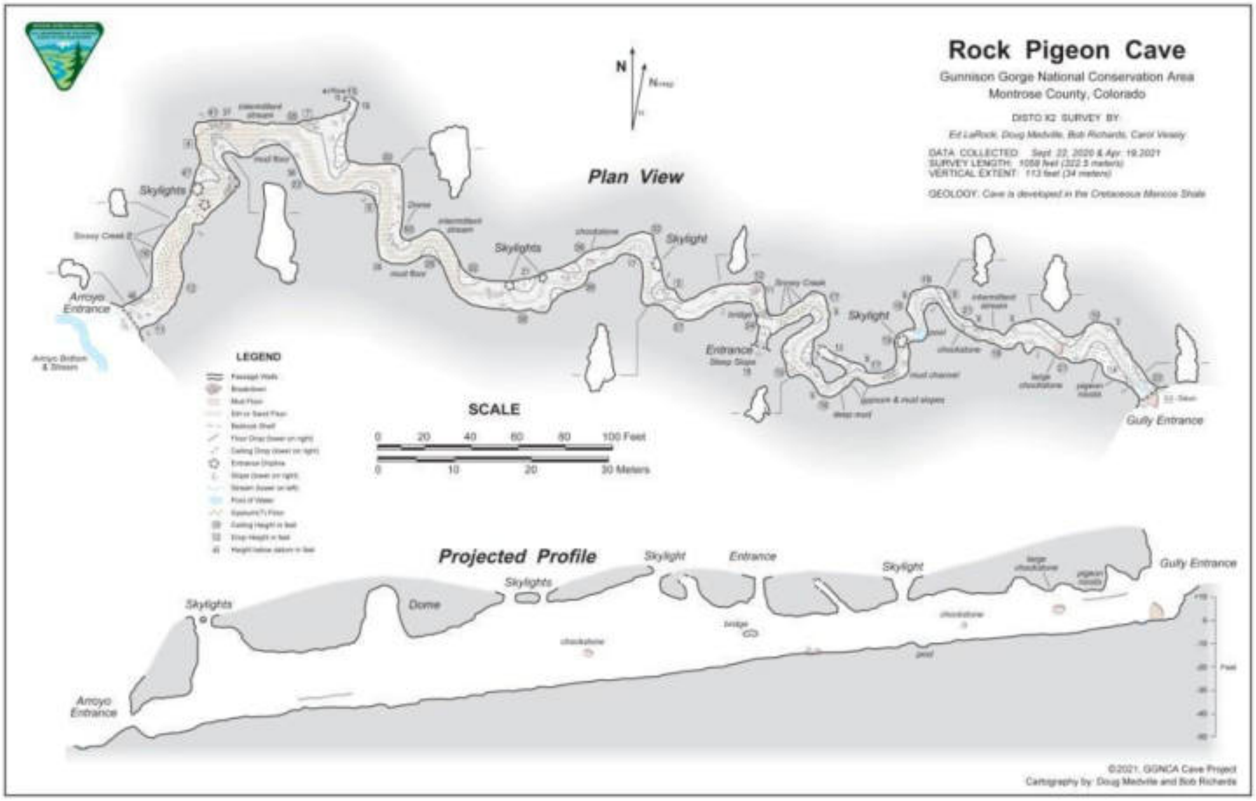


Fig. 11. Map and longitudinal cross-section of Rock Pigeon Cave, Colorado

In addition to gypsum, other sulfate minerals are seen in some of the shale caves, in areas where shale-derived soils contain soluble sulfate salts. These salts can be carried into the caves by entering surface streams. For example, a sulfate content of over 7,000 mg/L and a sodium content of over 4,400 mg/L were measured in one cave stream in the Mancos Shale in western Colorado. As the streams and cave pools seasonally dry, sulfates come out of solution and evaporites such as thenardite (Na_2SO_4) and bloedite ($Na_2Mg[SO_4]_2{\cdot}4H_2O$) are deposited on passage walls and floors (Figs. 10 and 12).

Fig. 12. Sampling sulfate crust in a shale cave, Colorado (Photo B. Richards)

To summarize, vadose shale caves, some of which contain seasonally flowing streams, may represent a previously undocumented type of pseudokarst in clastic rocks. The development of these caves, their age, evolution, transport of materials through them, and their mineralogy are ongoing research subjects.

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DIVERSITY OF "PSEUDOKARST" – PHENOMENA IN AUSTRIA

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1. Introduction

Thorough research on non-karst respectively pseudokarst in Austria is sparse as there was and still is an understandable focus on its vast karst areas where the majority of its more than 16.000 caves mapped so far are situated. But recently it turned out that a distinct percentage of caves even in karst areas are of non-karstic origin and due to frost weathering, mass movements, fluvial erosion, piping processes and others – not related to the classical karstification process. In addition, a small but remarkable part of the mapped caves are situated in non-karst areas, sometimes with a similar morphology – of cave passages and speleothems – to those in karst. Whether it is reasonable to denote those as pseudokarst is not the topic of this compilation, which should just emphasize the variety of cave features off the beaten tracks of the well known karst caves of Austria. Many of the different settings of "pseudokarst" caves in Austria in relation to various host rocks have already been described in this newsletter or as lectures/papers during one of the pseudokarst symposia (e.g. caves in flysch, granites, loess).

2. Caves in different non-karstic rocks

<u>2.1. Flysch</u>

In the foreland of the Northern Calcareous Alps, the Flysch Zone with siliciclastic and calcareous sandstones and claystones stretches from the city of Vienna to the west as a 10-20 km wide hilly to mountainous landscape, which reaches altitudes above 1000 m a.s.l. Despite the fact that the content of dissolved hydrogencarbonate in the springwaters often exceeds those of the Northern Calcareous Alps considerably there is no karstification to observe. Just a handful of caves have been surveyed so far (Pavuza 2013). The longest cave is Windloch near the city of Steyr in Upper Austria (Fig. 1). It is situated on the upper flanks of a huge landslide and genetically related to it. With a surveyed length of 96 m it extends 37 m to the depth, but air tracing and IR-Photography revealed another – at present impassable – access some 100 m below the entrance of the cave (Figs 2 and 3).

Fig. 1. Cave passage of the Windloch (1871/1) near the entrance (Photo R. Pavuza)

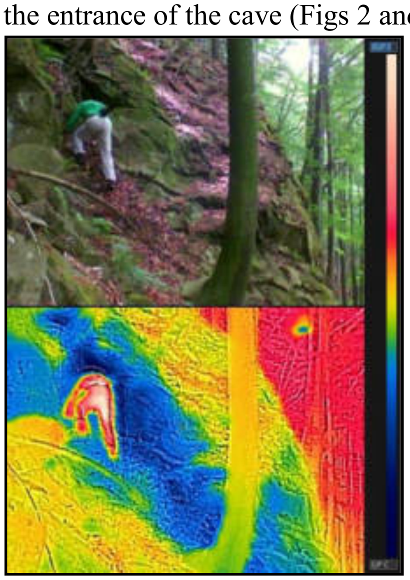

Fig. 2. Outflow of cold air from unsurveyed narrow parts of Windloch some 100 m below the entrance, traced by IR-Photography (Photos R. Pavuza)

There are many other yet unsurveyed areas in the Flysch Zone with a reasonable potential for finding new caves, based on mapped mass movements on recent geological maps and on LIDAR surveys.

2.2. Spring Tufa

Caves in spring tufa and travertine are rare in Austria due to the lack of very large tufa deposits enabling the formation of cave chambers larger than a few cubic meters (Pavuza 2015). Some of them are situated in karst areas built up by limestones, and even showing stalactites – but are not directly related to karst processes. Due to the similarity of forms one might call these caves pseudokarst caves, but bearing in mind that this term does not reveal anything about the process of their formation.

The most prominent example among the handful of tufa caves in Austria is Tuffsteinhöhle (Fig. 3), a small cave located in the pre-alpine karst of western Lower Austria. The age of its formation is not known yet, but might be deciphered in the near future using radiocarbon (^{14}C) dating of embedded gastropods.

Fig. 3. Main chamber of the Tuffsteinhöhle (1827/19) with roots and active speleothems (Photo H. Thaler)

2.3. Granite and Gneiss

In the Austrian part of the Southern Bohemian Massif – generally situated north of the Danube river granite and gneiss in many varieties prevail. Only small stripes of limestones enable the formation of a few karst caves. Spherical weathering and mass movements are the main factors for cave formation in this area. Whereas the two longest adjacent caves in this area – Obere and Untere Saubachlhöhle (Pavuza & Mais 1988) – were surveyed briefly to an overall length of some 500 m, many of the caves especially in the Upper Austrian part of the massif have not been thoroughly surveyed, yet. This applies for instance to the formidable Hinterbergerbach-Schwinde in Upper Austria (Figs. 4 and 5), a cave in an accumulation of huge boulders in a steep valley which might continue for several hundred meters yet to be explored and mapped. In some of the caves in granite (and occasionally in gneiss), there exist non-karstic speleothems which are briefly described in chapter 3.1. There is a lack of knowledge about the ages of the caves as the history of valley evolution in this area and thus the onset of the cave formation remains largely unclear, so far.

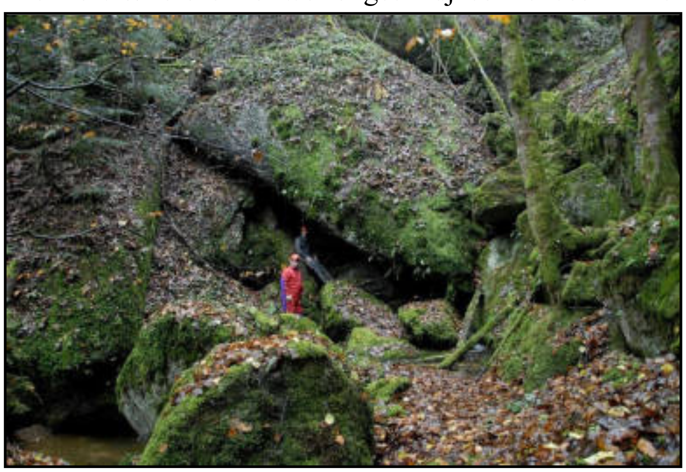

Fig. 4. Entrance to the Hinterber-gerbach-Schwinde (6844/14) (Photo H. Thaler)

Fig. 5. Large chamber in the Hinterber-gerbach-Schwinde (Photo H. Thaler)

2.4. Loess

Loess is abundant in the alpine foreland and a still rather small number of caves has been mapped (e.g. Figs 6 and 7), some of them altering rapidly mainly in the course of heavy rainfall events. They are formed by piping along animal burrows, root channels and cracks and are predominantly situated beneath steep scarps where the hydraulic gradient and hence the water force is high.

Fig. 6. Upwards view in the Wasserschloss (6846/12) near Engelmannsbrunn, Lower Austria (Photo R. Pavuza)

Fig. 7. Lower entrance of the loess cave near Untermarkersdorf (6846/33), Lower Austria. As the piping (circular morphology) has terminated in favour of a more vertical runoff prior to 2012 there was no significant change of wall morphology (see metal screw in red circle) between 2012 and 2018 in the pipe despite the softness of the loess (Photo R. Pavuza)

2.5. Other loose/poorly cemented sediments

Due to the many rivers emerging from the alpine areas there are extended areas with conglomerates in the pre-alpine foreland, some of them not well cemented. Here – due to the lateral erosion of the rivers – many washouts and even spacious caves are forming permanently (Pavuza & Plan 2008). In one of those a rare kind of root stalagmite was discovered (Fig. 24).

2.6. Pseudokarst caves in limestone and dolomite

In the vast karst areas of the Alps range cavers know a peculiar phenomenon: encountering a promising entrance architecture (Fig. 8) of a cave and a sudden ending of the passage without the faintest sign of a continuation (Fig. 9).

Fig. 8. Seiserhöhle (1854/89), view from the inside (Photo F. Volkmann)

Fig. 9. Seiserhöhle, view from the entrance (Photo F. Volkmann)

In this small cave, situated in (otherwise highly karstifiable) Dachstein-Limestone one could recognize remnants of a former phreatic (karst) phase. But due to the abrupt termination of the cave a few meters behind this observation does not make sense. Obviously a coincidence between stratification and joints, thus weakening of the limestone and subsequently a removal of material due to infiltrating water and frost weathering were the main factors of cave formation.

Oberender & Plan (2018) investigated in the course of a thorough study the genesis of the caves (karst and non-karst) in Lower Austria and came to the somewhat surprising conclusion that a large portion (>40%) of the caves in the pre- and high alpine karst in this province are connected to processes not primarily related to karstification. As shown in Fig. 10, most of the caves in carbonate rocks which are not related to karstification are formed by frost weathering (59.6%) and for another 17.5% it is more or less likely that frost weathering is involved. The second most important process that leads to non-karst caves in karst rocks is mass movement. The formation of caves called "abrisskluft" is related to slow mass movement, which is due to shear movements throughout the slope, while rock slide caves are formed by rapidly occurring rock falls. Stream-cut caves are related to the lateral erosion of rivers, as mentioned above.

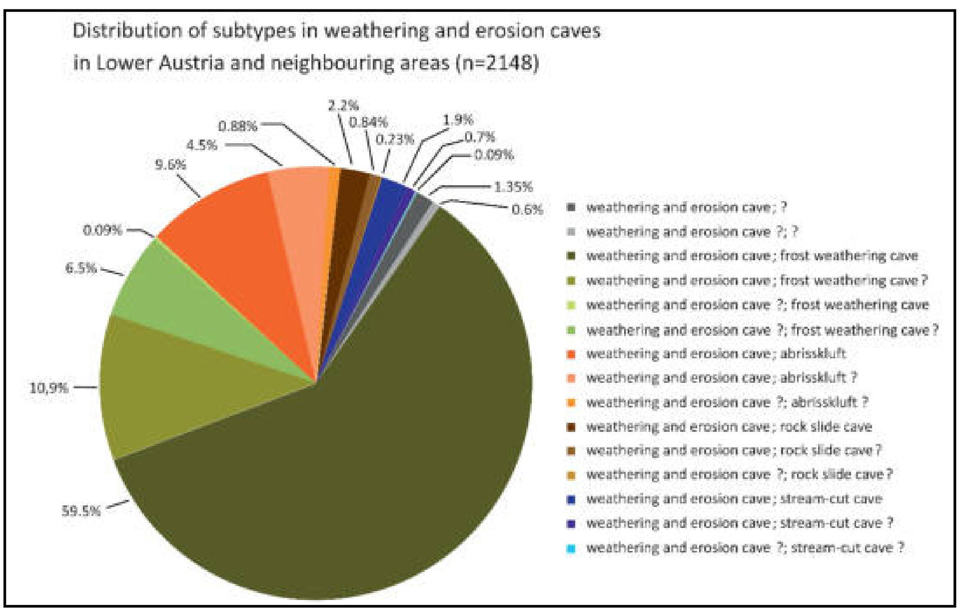

Fig. 10. Distribution of subtypes of weathering and erosion caves in carbonate rocks in Lower Austria and neighbouring southern areas (n=2148, data basis status 2015). The question marks behind the type and subtype designations indicate an uncertainty of the classification

It is interesting that carbonate rocks in combination with a distinctive fissure network favour the formation of frost weathering caves. The fissures are probably widened by corrosion and thus provide a prerequisite for effective frost weathering along the waterway fissures.

A good example of complex cave formation – where more than one process is involved – are five caves near the village of Türnitz, Lower Austria. They are developed in a dolomitic breccia. Plan et al. (2020) found evidence that both slow and fast mass movements, exfoliation and frost weathering were involved in their formation, whereas – from the morphological point of view – they are mostly to be classified as rock slide caves or boulder caves. They look similar to boulder caves in granite and gneiss (Fig. 11).

Fig. 11. In the foreground the small entrance of Anthofgrotte (1837/75), the main entrance lies in the background behind the stairs. The rounded boulders were transported into the valley by mass movements and weathered further on the spot. A stream still flows through the cave in places and shapes the rock (Photo L. Plan)

Fig. 12. In the foreground blocks, in the background weathered and rounded rocks in which Felsenburg (1837/76) with its entrances (a-e) and Bachdurchgang (1837/77a) are developed (Photo L. Plan)

3. Speleothems in different non karstic caves

<u>3.1. Granite and Gneiss</u>

Until 2011 there was no record of speleothems in granite and gneiss in Austria. During the 2nd International Conference on Granite Caves in Sweden (2011) we got to know flowstones reported from granite caves in Galicia (Spain) as well as tiny opal-A-speleothems during the excursions. Right after this event, some examples of pseudokarst-speleothems could be detected in an Austrian granite boulder cave, too. Since then several examples of speleothems consisting of pigotite – an alumo-organic compound, not a mineral (Fig. 13) and opal-A (Fig. 14) could be documented. A first overview (kindly supported by J.R. Vidal Romani, who described these phenomena occurring in Galicia in much bigger dimensions in several papers) was given soon after to call the attention of the Austrian caving community to these phenomena (Pavuza et al. 2015). Besides the two types of speleothems mentioned above, a third type of "bio-helictites" can be observed occasionally. These tiny structures most likely form along abandoned cobwebs that collect rock debris and precipitates (Fig. 15). So far these 3 types of speleothems could be found only in the southern Bohemian Massiv in northern Austria in caves in granite and gneiss. The pigotite speleothems might be datable in the future since it contains organic carbon.

Fig 14. Opal-A stalagmites in the Zwergentunnel (6845/230) (Photo R. Pavuza)

Fig. 13. Pigotite-microgours in the Drachenhöhle (6844/8) (Photo R. Pavuza)

Fig 15. Biogenic helictites in the entrance area of the Drachenhöhle (6844/8), (Photo R. Pavuza)

3.2. Three versions of "pseudokarst" stalactites in an artificial subsurface environment

Apart from the majority of classical karst speleothems – including those built up of gypsum and salt, there exist a variety of other speleothems not related to karst processes, at least in conventional sense. Some examples were discussed in the previous chapter. In a recently unused air raid shelter tunnel built in 1945 near the city of Linz in Upper Austria, the so called Rudolfstollen (a 1,3 km long system of galleries, Fig. 16), three major types of speleothems could be identified. In addition to the more common straw stalactites emerging from concrete fillings of the brick built sectors of the galleries which are of minor interest (Fig. 17) there are dark-brown straw stalactites up to a length of 18 cm and clumsy counterparts at the bottom, but restricted to the westernmost sections of the system (Fig. 18). They consist of Fe/Mn-hydroxides with traces of magnetite and gypsum. The emerging drip waters yield a pH of 2,6 with high amounts of sulfate, iron and aluminium. The source of this extremely acidic water is unknown yet but most likely related to chemical pyrite decomposition, forming sulfuric acid which attacks feldspar and mica of the host rock (gneiss), finally forming Fe/Mn-rich speleothems in the tunnel.

In the middle and eastern part of the Rudolfstollen pure white dripstones fake classical karst speleothems (Figs. 16 and 19). Their genesis differs significantly from karst speleothems, however. The host rock lacks $CaCO_3$ and so does the overlying soil. Determinations of ^{14}C of these speleothems yielded nearly 100 % of modern ^{14}C and the ^{13}C ratio is quite similar to the present outside air likewise. Recent karst speleothems would show much lower ^{14}C contents and ^{13}C would differ significantly from outside air. Following a suggestion of M.A. Geyh (pers. comm.) we favour a model of chemical dissolution of Ca- rich plagioclase probably enhanced by acidic solutions as a result of the weathering of traces of pyrites in the gneiss. Due to comparatively long flow paths the pH increases slowly during the reaction with the rock to more alkaline values, finally enabling the buildup of speleothems in the Rudolfstollen. This model is supported by elevated contents of sodium, the other major cation of the plagioclase group in the drip water as well as the presence of silica.

Due to the high contents of Ca and HCO_3 and a constant and high dripping rate the growth rate of the speleothems is many times higher than in Alpine caves (Fritsch et al. 2016). These speleothems might be one of the best qualified examples for the term "pseudokarst"!

Fig. 16. Main gallery of the Rudolfstollen near Linz, Upper Austria (Photo H. Thaler)

Fig. 17. Straw stalactite emerging from concrete fillings in brick-built sections of the Rudolfstollen (Photo R. Pavuza)

Fig. 18. Iron/manganese hydroxide straw stalactites of the western part of the Rudolfstollen (Photos H. Thaler)

Fig 19. Calcite speleothems of the central part of the Rudolfstollen (Photo R. Pavuza)

3.3. Root Stalagmites

Despite the fact that German speleologist Ahrweiler (2015) rejects the term "root stalagmite" (RS) we propose the perpetuation of this descriptive identifier as the Greek origin is not at all restricted to rocky features - just meaning "dripping" in a wider sense. We also do not agree in his remark that these peculiar features are not rare. At least in Austria the observation of root stalagmites is stagnant despite the fact that we brought it to the attention of cavers several years ago (Pavuza & Cech 2013). Since the first discovery of a group of root stalagmites in 2006 just 12 subsurface objects with RS could be discovered in Austria. In a few cases the RS deteriorated or vanished entirely in the meantime. Within the framework of the Pseudokarst-Newsletter we also gave some reports about the discoveries (e.g. Pavuza & Mayer 2007, Pavuza & Pfarr 2008).

Root stalagmites and related phenomena form where the combination of appropriate plants with constant water dripping rates occur in areas more or less adjacent to the surface. Recently some of the mother plants could be identified with the help of DNA analysis (Grasegger et al. 2019). Nevertheless the parameters and boundaries for the formation of RS remain unclear to a certain degree.

Three representative examples from Austria are given. In 2006 the first RS in Austria were detected in the Güntherhöhle – a classical karst cave – in Lower Austria during a cave-cleaning campaign where the RS were almost removed! This group of several RS (Fig. 20) did not change much during the years and some other RS emerged next to it. Its mother plant was identified as *Prunus mahaleb*. In the Haselgrabenstollen, a short artificial tunnel in gneiss near the city of Linz, several singular RS could be observed with active root-hair development (Fig. 21). Here we observed high dripping rates

Fig 20. First discovered root stalagmite in Austria, Güntherhöhle, Lower Austria (Photo R. Pavuza)

Fig. 21. Active root stalagmite in the Hasel-grabenstollen, Upper Austria (Photo R. Pavuza)

and the tallest examples of RS, so far (Fig. 22). The mother plant turned out to be *Acer pseudoplatanus*. The third example reveals an presumably rare combination of stalagmite and stalactite (stalagnate) in the Wurzelstalagmitenfuge in Lower Austria (Fig. 23), an erosional cave in conglomerate at the slope foot of the Erlauf river valley. The mother plant is *Fagus sylvatica.*

Fig. 22. So far the tallest root stalagmite in Austria, Haselgrabenstollen (Photo R. Pavuza)

Fig. 23. Root stalagnate in the Wurzelstalagmitenfuge, Lower Austria (Photo R. Pavuza)

4. Outlook

There are still vast territories to be explored in non-karst areas in Austria with a good potential for caves. It concerns mainly areas in the granites of the Southern Bohemian Massif, where accumulations of boulders in deep valleys undoubtedly host unmapped cave passages.

In the flysch zone computer-aided studies of LIDAR data combined with up-to-date geological maps will reveal potential zones for caves especially in sectors with large mass movements – the most promising areas for caves in this geological unit.

Detailed studies of the mass movements and dating of cave sediments as well as speleothems may become a tool to set the time limits for the formation and evolution of these pseudokarst caves.

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PSEUDOKARST CAVES IN GALICIA (SPAIN) – A VALUABLE LANDSCAPE FULL OF FORMS AND COLORS

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Abstract. Pseudokarst caves develop in many types of rocks and the subterraneous landscapes they present are the results of the interaction of different processes. Some factors generate collapses conditioned by tectonic structures or as a result of water erosion, other biometeorize the rock and make it soluble, and still others produce deposits that fill the cave with a variety of shapes and colors. In this paper we describe the landscape of the non-karst caves of Galicia. In addition to the beauty that it may present, we also summarize how a section of the history of the Earth is preserved inside that can be used as a very valuable scientific information.

Introduction

In the editorial section of the UIS-Bulletin, vol. 60-2 (2018), Efrain Mercado, UIS Vice-President of Operations, pointed out that "the more we know the more we can protect and conserve". With the help of this paper, including plenty of photos, we want you to discover the caves of Galicia in many types of rocks, the beauty of our non-karst caves, its forms, deposits and the diversity of colors and forms hidden in the dark. Finally, you will discover that there are much more than beautiful landscapes, reading the chapter on the history of the Earth, which is stored and well preserved in the speleothems and biospeleothems that decorate our caves.

Specifically, in the caves of Galicia we have found records of the climate history. Interpretation of these records allows us to compare the data with other regions of the planet and to discover the global connection of the climate. In particular, we get information about the periods of natural global warming and cooling. We live immersed in a global climate crisis currently, and thus it is vital to discover cycles, sequences and trends of the past climate to understand where we are going and what we might expect in the future.

Galicia: territory and caves

Galicia is located in the northwestern part of the Iberian Peninsula. Geographically, it limits to the north with the Cantabrian Sea, to the south with Portugal, to the west with the Atlantic Ocean and to the east with the Principality of Asturias and the ancient Kingdom of Leon. It incorporates an area of 29,559 km^2 where plutonic rocks predominate and outcrops of carbonate rocks and quartzites represent only 1.59% and 14.3%, respectively, of the area surface.

In our region we can find natural caves in carbonate rocks, quartzites, quartz dikes, granites, gneisses and granodiorites as well as in schists, phyllites and slates. There are also artificial cavities, which in some cases have been "naturalized" giving rise to what István Eszterhás called "consequence caves" (Halliday 2007). The number of cavities inventoried in Galicia is not equally distributed by type of rock (Tab. 1 and Fig. 1). This is due in part to the fact that non-kastic areas have not been systematically explored, with the generalized presumption that no caves are to be expected there. Nevertheless, the effort of some cavers and scientists in present time show that this is not true.

Tab. 1. Statistical summary of the Atlas of cavities of Galicia (2021/12/15). Caves developed by marine erosion could be included as pseudokarst caves, but they are indicated separately because they constitute a specific subtype of caves being present in many types of rocks.

Type of caves	Rock type	Number of caves
Shore caves	Quartzite	53
	Plutonic	53
	Slates & others	21
Karst caves	Limestone and dolomites	249
Parakarst caves	Quarzite and Quarz	17
Pseudokarst caves	Plutonic	77
	Slates and others	17
Artificial caves		43
Consequence caves		5

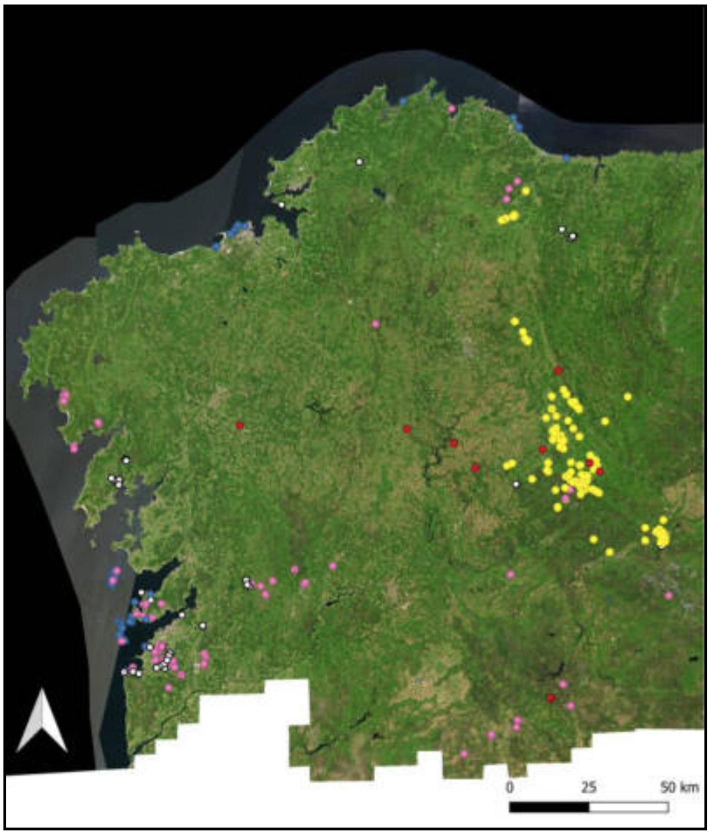


Fig. 1. Data provided by the WMS GeoServer of the Atlas of Caves and Canyons developed by Galician Federation of Speleology. Circle color code: pink – pseudokarst cave; red – parakarstic cave; yellow – karst cave; blue – shore cave; white – artificial cave or consequence cave. Note: one may visit the public section of the atlas following the link http://atlas.espeleoloxia.org. It has been declared as project of special relevance by the regional government due to its destiny to share cave and karst knowledge and to promote the value of Galician cave heritage with cavers, researchers/scientists, government agencies and land managers (natural environment and cultural heritage) or any non-governmental organization interested in karst and caves

A landscape in the darkness

The underground landscape of any cave (karst, parakarstic, or pseudokarst cave) is the result of a series of processes that remove the rock or substrate (collapse, erosion, dissolution, corrosion ..., Fig. 2) which can be superimposed with other constructive or depositional processes (physical, chemical and even biological, Fig. 3). The result is an underground void which is decorated by various elements, forms or morphologies.

A very curious aspect is that some of these morphologies can appear both on the surface and in the cave (e.g. potholes) and that certain morphologies can also appear in caves formed in different rocks, yielding the same geometry although they have not formed by the same processes (Fig. 4). This geometric identity - related to the diversity of rocks and processes - is what Adolfo Eraso (1975/76) called "convergence of forms".

Water is one of the agents that can intervene in the evolution of caves. Many forms we encounter depend on how fast the water moves. Thus, there are forms sculptured in the rock as result of erosion associated with turbulent flows of great energy (Figs. 2b & 5) but as the water currents lose energy, the load carried by the water starts to be deposited. The heaviest elements are deposited first. Thus, deposits graded by size appear: from terraces with rounded gravels to deposits of sand and clay. And in stagnant waters, such as lakes, where there are almost no water currents, rhythmites appear which are banded deposits often tracing depositions of a seasonal nature.

Fig. 2. Roofed canyon of Albarellos (Avión, province of Ourense, Galicia-Spain): The subterranean landscape is determined by erosion and collapse. The greater the volumes produced by erosion, the easier it is for large blocks to be moved. A – level where the blocks on the left move into the passage by sliding on the planes that locally define the sheet structure. B – sinuous gorge partially roofed by large fallen fragments. These fargmentes originate from broken potholes and from the canyon walls themselves (Photos M. Vaqueiro-Rodriguez 2014 & 2015)

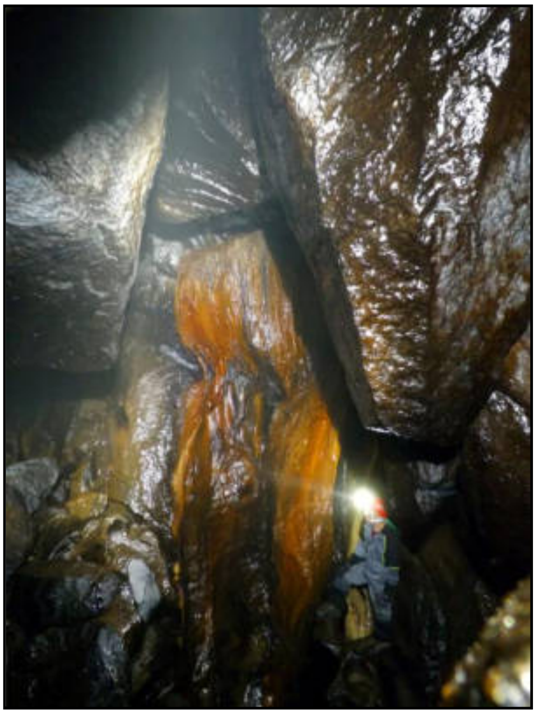


Fig. 3. Roofed canyon of Tronceda (Mondoñedo, province of Lugo, Galicia-Spain): at levels away from turbulent flows, speleothems (and biospeleothems) can grow, consolidating the blocks and preserving previous forms of erosion (Photo M. Vaqueiro-Rodríguez 2016)

However there are still other slow water movements. And they are the ones that give rise to deposits of secondary minerals, called speleothems, in caves. They may be associated with slow dripping of water (dripstones, Figs. 6 and 7), with slow to very slow runoff (flowstones, Figs. 8 and 9), with circulation in fissures and pores (seeping waters speleothems, Fig. 10) or also with stagnant waters (pool speleothems, Figs. 4b and 11) and even related to the superficial condensation of water vapor (Fig. 12).

When the waterflow increases its speed, the forms associated with slow flows may be destroyed. For this reason, the superposition of forms which are associated with different waterflow regimes allow us to discover relative sequences of the history of a certain cave.

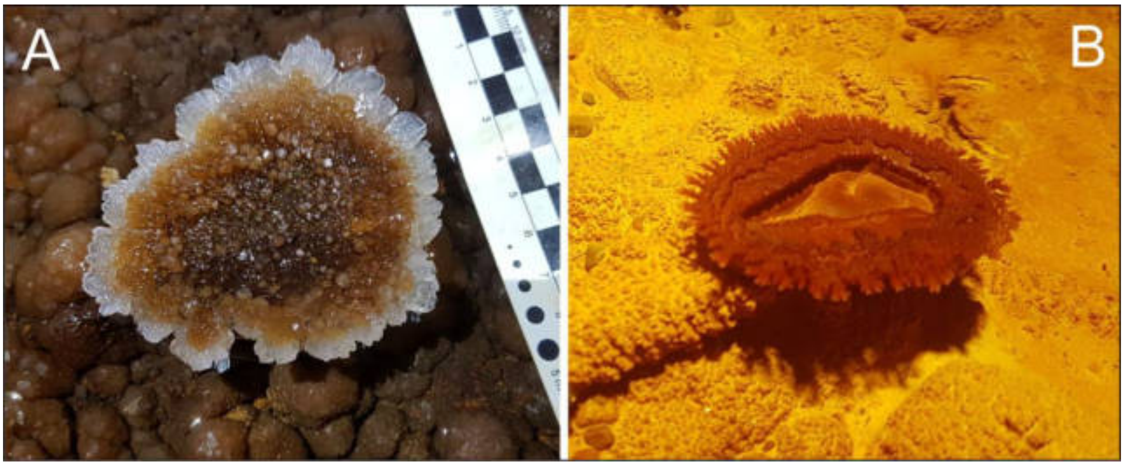


Fig. 4. Similar forms can originate from various processes, diverse environments, and under different conditions. A – karst cave of Buraca das Choias (Folgoso do Courel, province of Lugo, Galicia-Spain): calcite speleothem developed from crystallization at the surface of stagnant water in a little pool. B – granite shore cave of Manueleche (Ons Island, province of Pontevedra, Galicia-Spain): pigotite biospeleothem developed at a paleolevel (about +12 m above present sea level); pigotite is an organic complex rich in aluminum, not a mineral, therefore it does not form crystals and grew on the undisturbed surface of water, possibly induced by filamentous algae (Photos M. Vaqueiro-Rodríguez, 2018)

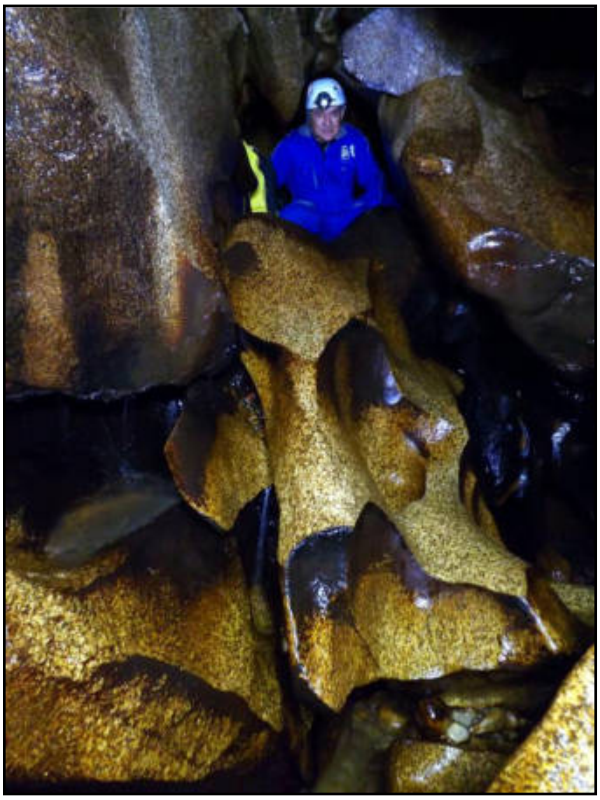


Fig. 5. A Trapa System (Tui, province of Pontevedra, Galicia-Spain): deep narrow flutes (pseudo-scallops). Flutes are concave flow morphologies whose rims flare in downstream direction. In the picture, flutes, nearby potholes and blocks show a brownish crust. This is due to the fact that during a phase without water circulation blocks and forms were covered by a flowstone of pigotite. Recently the stream has been reactivated and the sculpted forms are being exhumed as the pigotite erodes (Photo M. Vaqueiro-Rodríguez, 2013)

Fig. 6. Paleolevel (+10 m above present sea level) in the shore granite cave of Coliño (Ons Island, province of Pontevedra, Galicia-Spain): composite dripstone-flowstone speleothems. (Photo M. Vaqueiro-Rodríguez, 2012)

Fig. 7. Cova dos Mocegos (Carnota, province of A Courña, Galicia-Spain): biogenic opal speleothems, not stalactites because they are not directly associated with dripping water. The visible morphology is induced by the filamentous algae that are part of the microbiota preserved inside the biospeleothem (Photo M. Vaqueiro-Rodríguez, 2014)

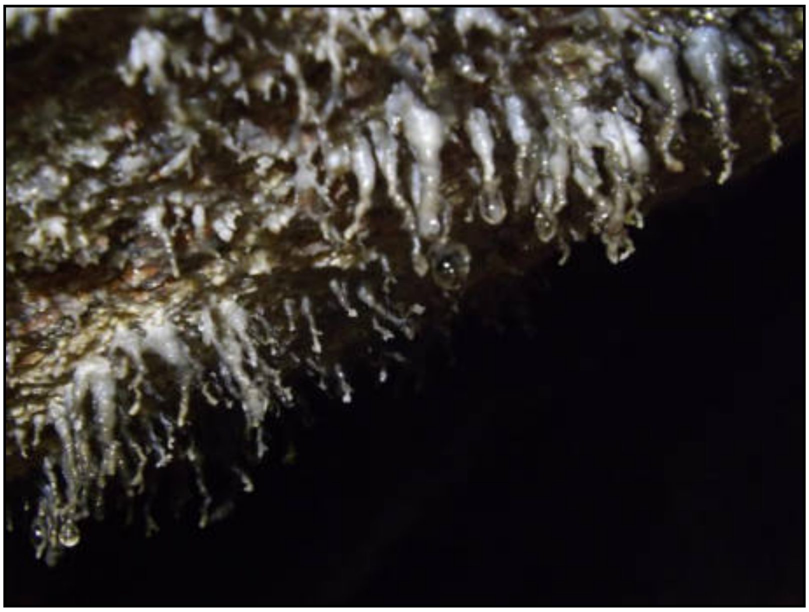
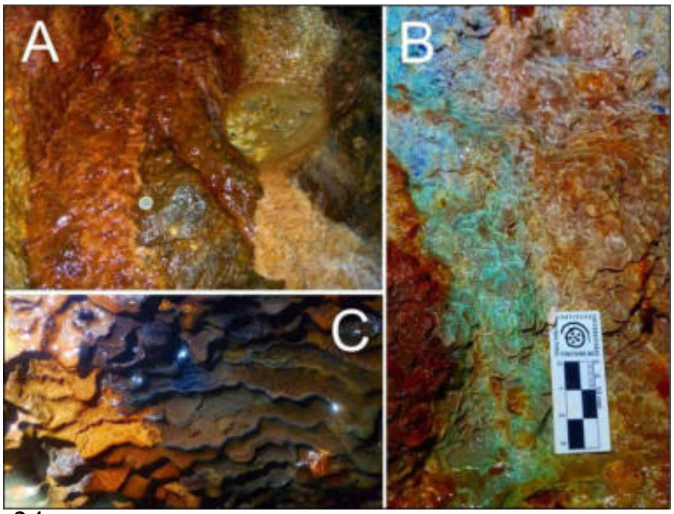


Fig. 8. Microgours: A – pigotite in O Folón System (Vigo, province of Pontevedra, Galicia-Spain). These gours stopped growing 1755 years ago. A sand that fill them sand indicates that currently flowing stream has a capacity to transport sediments and therefore the deposit is being progressively eroded. B – pigotite in As Fighosas (palaeo)-shore cave (Baiona, province of Pontevedra, Galicia-Spain). The water speed is so slow that the pigotite microgours grow even on vertical walls and overhangs. Inside the microgours small microstromatolites, similar to small cauliflowers occur. C – Mina Consuelo (A Ponte-nova, province of Lugo, Galicia-Spain). This delicate, rich in iron, microgour has grown for less than 100 years. D – opal-A in Pala da Osa IV (Castrelo do Val, province of Ourense, Galicia-Spain) (Photo M. Vaqueiro-Rodríguez 2011, 2012, 2021, 2022)

Fig. 9. Consequence caves are also full of colors: A – qanat of Ulleiriño (Baiona, province of Pontevedra, Galicia-Spain): pigotite flowstone has a resinous appearance with colors ranging from honey to ruby. B and C – Mina Consuelo (A Pontenova, province of Lugo, Galicia-Spain): deposits rich in iron, manganese and copper show colors that vary from sky blue to dark blue, also green, black, and a range of ocher, from yellow to reddish (Photos M. Vaqueiro-Rodríguez 2007, 2021)



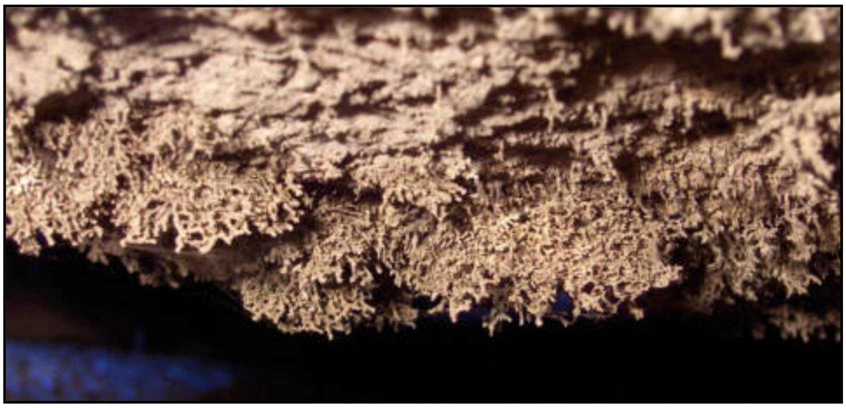


Fig. 10. Sima da Furna (Valença do Minho, Portugal): Grass-shapped deposit of opal-A (Photo M. Vaqueiro-Rodríguez 2007).

Fig. 11. Granite shore cave of Manueleche (Ons Island, province of Pontevedra, Galicia-Spain): pigotite shelfstone and convoluted forms developed in a little pool. (Photo M. Vaqueiro-Rodríguez 2018)

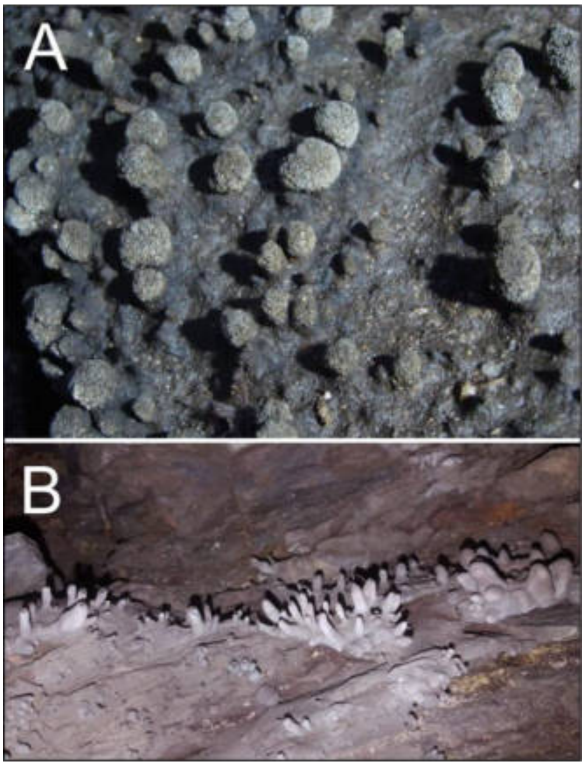


Fig. 12. Terrestrial microstromatolites of opal-A: A – in the granite cave system of A Trapa (Tui, province of Pontevedra, Galicia-Spain). B – in the quartzite cave of Cova Val de Cubela I (Paradela, province of Lugo, Galicia-Spain) (Photos M. Vaqueiro-Rodríguez 2007 & R.M. Varela-Villasante 2021)

About the value and protection of caves

Speleothems grow very slowly by continuous accretion of thin layers of minerals (or other substances). For example, in our karst cavities there are stalagmites that grow between 8 mm and 11 mm every 1000 years (Railsback et al. 2011). On the other hand in our pseudokarst caves there are pigotite (aluminium-bearing organic compounds speleothems, AOS) – biospeleothems whose growth rate is about 191 mm every 1000 years (Sanjurjo-Sánchez et al. 2021).

Speleothems keep an isotopic trace in each layer that allows us to clear up when the layer was formed and gives some information about the environmental conditions (e.g. temperature) during its formation. Based on data from Galicia caves, there could be reconstructed more than 550,000 years of continuous climatic history (Railsback et al. 2017). This is an impressive example of the importance of speleothems as paleoclimatic records. And, furthermore, if a speleothem is made up of a biomineral, fossil DNA can be preserved in its thin layers (Fig. 13) (Vidal-Romaní et al. 2014). For example, we have opal-A speleothems which sizes barely exceed 2 or 3 cm which preserve fossil pollen from more than 3000 years ago demonstrating that these deposits are paleoenvironmental records, too.

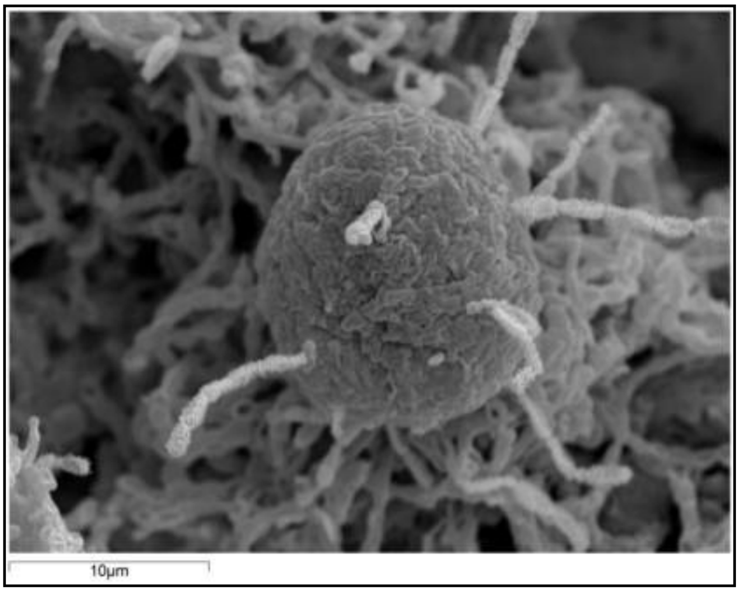


Fig. 13. Germinated pollen grain that was fossilized inside an opal-A biospeleothem in a granite cave. The biodiversity present in these deposits includes, among others, bacteria, testate amoebae, diatoms, algae, polychaetes, mites and pollens. (image obtained by electron microscope by J.R. Vidal-Romaní).

We have already mentioned that we have reconstructed more than half million years of climatic history with the help of deposits located in karst caves in Galicia. The results obtained correspond well with climatic data of the planet at a global level.

However, limestones are concentrated at the eastern margin of Galicia and barely cover 2% of the surface of this region. Therefore, the results do not allow to delve into the study of other local events that have occurred in areas far from the karst. And this is why the pseudokarst, which covers more than 80% of the territory, becomes important: There are many caves (most of them very small when compared to the karst caves), that preserve various deposits (rhythmites, pigotite (AOS), evansite, struvite, opal A), which can potentially contain valuable paleoclimatic and palaeoenvironmental records.

An important advantage is that there are non-karst caves scattered throughout the territory of Galicia. On the other hand the oldest speleothems, we have found up to now, date up to 11,000 years only (pers. comm. J. Sanjurjo 2016) and the rythmites are less than 28,000 years old (unpubl. data), thus restricted to the late Pleistocene and the Holocene so far.

Nevertheless, non-karst caves still constitute a great heritage that stayed almost unnoticed by the public until now and urgently need protection measures.

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RANGITOTO ISLAND
- AUCKLAND'S YOUNGEST VOLCANO AND IT'S CAVES

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Rangitoto is a spectacular – almost symmetrical – volcanic cone that rises from the sea and dominates Auckland's skyline to the north (Fig. 1, Fig. 2). The volcano is the youngest and largest among Auckland's fifty basalt volcanoes. Estimated volume of basalt is two cubic kilometres, which is more than half of total basalts in the volcanic field. The volcanoes are monogenetic and range from 500 to 200 000 years in age. The field is dormant, but we await the next eruption in an unknown time scale. Auckland has a population of almost two million, so it would be interesting.

Fig. 1. Rangitoto island skyline (Photo G. Szentes)

Fig. 2. View of Auckland downtown from Rangitoto Island (Photo G. Szentes)

The volcano has a complex structure that was formed during two different eruptions. They probably occurred 600 and 550 years ago (about 1,400 and 1,450 AD). The older lava cover rises slightly towards the tip of the island, while the overlaying aa lava forms gentle slopes with patches of pahoehoe. The island peak rises to 259 m above the sea level. The – 150 m in diameter – peak crater is 60 m deep. A smaller crater to the west of the main crater and fractions of craters to the north demonstrate that volcanic activity was not just related to a single vent (Thornton 1985). A significant part of the forms vanished as the activity intensified.

Volcanology and geology

The volcanic activity began with a phreatomagmatic explosive eruption (the interaction of magma and water) when the erupting magma from the 80 km deep magma chamber broke through the bottom of the sea. This was followed by a series of ash eruptions that created low cones, which blocked the further encounter between magma and the sea water. Then following lava-pouring phase, interrupted by an explosive slag tuff scattering created a series of slag tuff cones. The tuff also spread on the neighbouring Motutapu Island. The composition of the former alkali basalt is similar to the other volcanoes in Auckland. Initially sludgy (aa) and then ropy (pahoehoe) lava poured out. The geochemical composition of the younger basalt is different from previous basalts, which is understood that the magma formed in a shallower depth of approximately 60 km (Hayward 2019).

Following the traces of the volcanic activity, many interesting formations can be observed on the island's surface. On lower level slopes pahoehoe lava appears, which is transformed into slaggy aa lava at the ends of the lava flows near the coastline. Short but well-developed lava caves and pits can be found in the pahoehoe lava, mainly on the border between the scoria cones and the surrounding lava flows. The drain of the molten lava results in the lava tunnels formation, but if their thin ceiling collapses lava pits or ravines are formed. The slag cone of the summit has a double structure, which can be considered as a remnant of previous eruptions. In some cases the investigations of the slag cone outcrops justify an occasional activity of lava fountains. The lava slag is basically grey in colour, but red discoloration is common in the weathered scoria areas due to its high iron content.

Maori presence

The volcano erupted during the Maori presence. There is no remembrance of the volcanic eruption, but it is known that at the time of the eruption, there were Maori settlements on the neighbouring Motutapu Island. Charcoal and shellfish residues turned up and human and dog footprints were preserved by the tuff. The age of the charcoal was determined at ca. 600 years by the radiocarbon (^{14}C) analysis. The word of Rangitoto translates as "bloody sky", which may refer to the sight of volcanic activity.

Flora of the island

Rangitoto's flora is unique compared to the surrounding islands. More than 200 plant species, ferns and mosses settled over the past 200 years in the relatively soil-less and freshwater-free bare landscape. The development of the flora was a slow process, as on the basalt it takes longer to develop soil. Later, this process accelerated, after lichens and mosses have grown in the fine tuff filled cracks. Through these a spongy and humic acidic fine debris was formed, in which higher plants, such as ferns and shrubs settled around the lava fields. Today, pohutukawa (*Metrosideros excelsa*), the New Zealand Christmas tree, dominates the island (Fig. 3). Their originally little spots gradually merged into a forested area. The trees bloom around Christmas, and its red flowers give the island a great view. This is the largest pohutukawa forest on earth (Millener 1979). The recent elimination of exotic herbivorous and other pests such as possums, wallabies and stoats resulted in the return of bird life and in an explosion of dense ground cover. But the location of caves becomes almost impossible.

Fig. 3. Flowering pohutukawa tree next to the aa lava flow; in the background is the edge of the peak crater (Photo G. Szentes)

Lava Caves

Access to the volcanic surface is difficult due to the sharp lava rock and the bushy pohutukava forest that covers the surface. The caves were found by accident rather than by planned access. This means that there are many new opportunities to explore additional caves. A GPS is essential to relocate them and not get lost.

The shape of the volcano is a lava cone that slopes slightly to the edge of the older crater, where the surface is mainly slaggy aa lava. Within the crater edge, a steep slag tuff cone rises. Most of the caves are located under the lower lava edge (Fig. 4). Some caves even open further down the slope in the direction to the sea.

Fig. 4. Rangitoto Island and the Caves

Kermies Cave. The cave entrance is located northeast of the main crater, hidden in a dense forest. The entrance is dangerous because of the loose semi-welded scoria blocks on the ceiling and floor and the 8 m deep vertical entrances. It also shows that the lava has broken through the slag cone before it surfaced. The upper part of the cave is composed of partly consolidated slag tuff (Fig. 5). The lower cave area is stable basalt lava with interesting lava flow forms and small lava stalactites (Fig. 6). The 176 m long cave is one of the most interesting among the lava caves in Auckland.

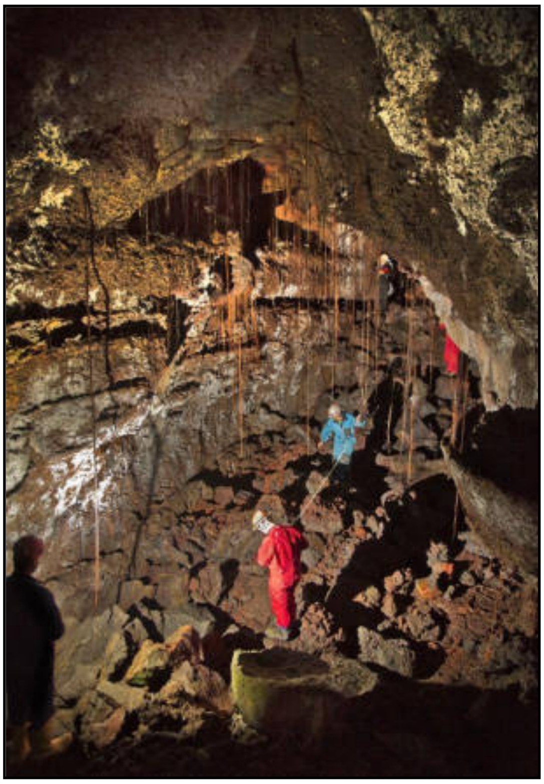

Fig. 5. Upper part of the Kermies Cave. Clearly visible the boundary between the scoria and basalt lava and the penetrating pohutukawa tree roots (photo P. Crossley)

Fig. 6. Lava stalactites in Kermies Cave (photo P. Crossley)

The Tourist Caves (Fig. 7) – the North-, Middle-, South- (Fig. 8), Ladder- and Wallaby Cave (Fig. 9) are five smaller caves open in the middle part of the island. The easily accessible public caves are the most visited caves in Auckland. From the crater edge a marked trail leads to the Middle Cave. The caves are the remnants of branched lava tunnels which were formed in different lava flows. The Central Cave is separated from the South Cave by a ravine, which is good example for thin ceilings which break during the formation of caves. Almost all the lava cave form elements are to be found in these caves.

Fig. 7. The sketch of tourist caves (by P. Crossley)

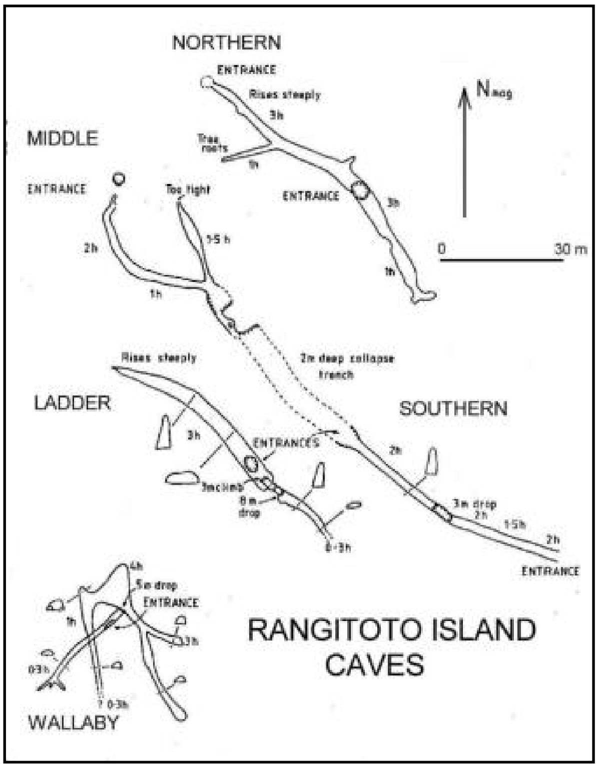

Fig. 8. The Southern Cave of tourist caves (Photo G. Szentes)

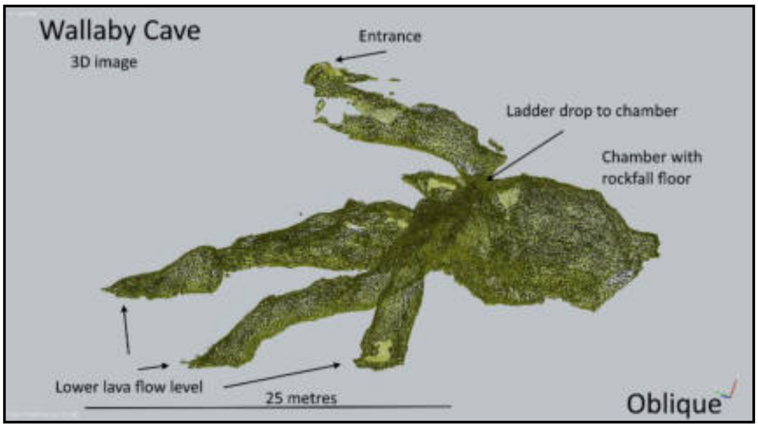

Fig. 9. 3 D image of Wallaby Cave (by P. Crossley)

Caves near the water tank. Halfway of the hiking trail leading to the crater, there is a water tank and a resting place. Four small lava cavities open 100 m west of the water tank. Even though the cavities are less than 20 m long it is worth to visit them because of their spectacular form elements.

Wilson Park Track, which leads northwest of the crater, has several interesting caves. Hidden in the dense forest and opening at the upper edge of the lava field the 60 m long Saddleback Cave (Fig. 10) is the continuation of a collapse-originated ravine. Its wide passage is easy to walk. The 25 m long Lava Spring Cave can be accessed through a narrow opening (Fig. 11). Their origins are linked to the swelling of the lava flow. The formation of the two caves are likely connected with the nearby detected lava vent. To the northwest of saddleback cave lies T Cave beneath a lava ridge. The cave is a 20 m long spacious lava tunnel (Fig. 12) with two entrances. The upper entrance is opened to the surface from the top of the tunnel.

Fig. 10. Saddleback Cave (Photo P. Crossley)

Root Canal (Fig. 13) and Merdé Caves were formed in a pahoehoe lava field on the north side of the mountain. The 230 m long caves are not simple lava tunnels, but they – situated in the same lava field - developed branching and re-meeting passages. The lava field can hide more caves and awaits further exploration (Crossley 2014).

Fig. 11. The narrow entrance to Lava Spring Cave (Photo P. Crossley)

Where the lava approached the coast through a marshy surface the pressure of the heated water vapour created a bladder cave. An example of Lava Bladder Cave is to be found on the south coast of the island (Fig. 14). Near this cave underwater formed pillow lava can be observed during low tides.

Fig. 12. Lava tunnel of T Cave (Photo P. Crossley)

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Fig. 13. The Root Canal Cave's spacious chamber behind the entrance (Photo P. Crossley)

Fig. 14. A lava blister near the coast (Photo P. Crossley)

THE INTERACTION OF FIRE AND ICE —GLACIOVOLCANIC CAVES OF THE CASCADE VOLCANIC ARC, USA

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Introduction

Enhanced thermal flux from volcanic emissions can melt ice and enlarge voids at the interface between the lithosphere and cryosphere. On volcanic edifices mantled with glaciers, glaciovolcanic caves develop in association with this melt and advection of volcanic outputs. This short paper discusses the genesis and morphologies of these phenomena from a pseudokarst perspective and highlights examples around the world, with a focus on current research in the Cascade volcanoes of the Pacific Northwest, USA.

Pseudokarst from volcano-ice interactions

Halliday (2007) identified glacier pseudokarst as one of eight pseudokarst typologies. While this includes englacial conduits and other glacier caves formed by meltwater, Halliday also identified geothermal examples within the category at Mount Rainier, Mount Hood, and Mount Baker. Further categorizing them as glaciovolcanic caves recognizes their volcanic origins (Sobolewski et al. 2022). Caves in the cryosphere may owe their origin to the advection of recharging melt from above and thermal flux from below, as well as the polygenetic combination of these two constituents, much like the distinction between epigenetic and hypogenetic speleogenesis in carbonate rocks (Ford & Williams 2007; Klimchouk 2009). Documented morphologies of glaciovolcanic caves fit the defining elements of pseudokarst identified by Kempe & Halliday (1997) and Halliday (2007) as subsurface drainage through conduit type voids; however, the karst-like morphologies are primarily produced by ablation and melt rather than dissolution.

Examples and locations

Despite significant potential for locations where glaciovolcanism could produce glaciovolcanic caves, there are few locations which are known or studied. Edwards et al. (2020) identified 245 Holocene volcanoes as impacted or having potential impacts due to surrounding ice. The earliest studies of which we are aware were by Giggenbach (1976) at Mount Erebus, Antarctica, Lokey et al. (1972) and Kiver & Steele (1975) at Mount Rainier, USA, although anecdotal documentations are known from earlier field expeditions. These locations still host the most pervasive examples of this cave type, further catalogued at Mount Erebus by Curtis (2010) and at Mount Rainier by Stenner et al. (2022). Further Antarctic examples have since been identified on Mount Melbourne (Liuzzo et al. 2018), and reports exist of glaciovolcanic caves in other locations via photos or anecdotal accounts. Curtis (2016) defined the Mount Erebus examples as fumarolic ice caves, characterized by thermal flux originating from subglacial fumarole vents. The majority of documented glaciovolcanic caves appear related to fumarolic activity; however, other mechanisms such as thermally heated volcanic bedrock, subglacial lava extrusions, or subglacial hydrothermal springs are likely, particularly in large ice-field settings.

The Cascade Volcanic Arc

Studies conducted at the Cascade volcanoes, of the Northwestern U.S. have greatly added to our knowledge of the glaciovolcanic caves identified by Halliday (2007) and others. For example, a substantial cave system on Mount Hood, Oregon was identified and explored between 2011-2015, with the resulting connections revealing Snow Dragon Cave to be 2185 m in length and 292 m deep at its' peak (Pflitsch et al., 2017). Since the 2013 survey, glacial ablation significantly reduced the cave.

A 273 m long remnant, Hot Imagination, reveals some of the substantial change that can occur in glaciovolcanic caves over a short timeframe. Hot Imagination's distinguishing feature is thermal flux derived principally from flowing hot springs in the cave and advection of this thermal water though an englacial conduit (Pflitsch et al. 2017)— a non-fumarolic example of the glaciovolcanic typology.

The most significant present glaciovolcanic examples are the summit cave systems in the overlapping east and west craters at the summit of Mt Rainier. East Crater Cave is currently the longest glaciovolcanic cave in the world at 3593 m (Fig. 1) (Florea et al. 2021a; Stenner et al. 2022). Observations of the summit caves date to the first ascent (Stevens 1876). Recorded morphologies of the main passages have remained similar since the original surveys in the 1970s (Lokey et al. 1972), the result of a dynamic equilibrium with complex relationships involving seasonal weather and fumarole output (Florea et al. 2021a; Stenner et al. 2022). At 308 m of survey, West Crater Cave is much smaller and is characterized by high CO_2 concentrations from fumarole output, negatively buoyant vent gas composition, cave morphology and airflow restrictions (Stenner et al. 2022).

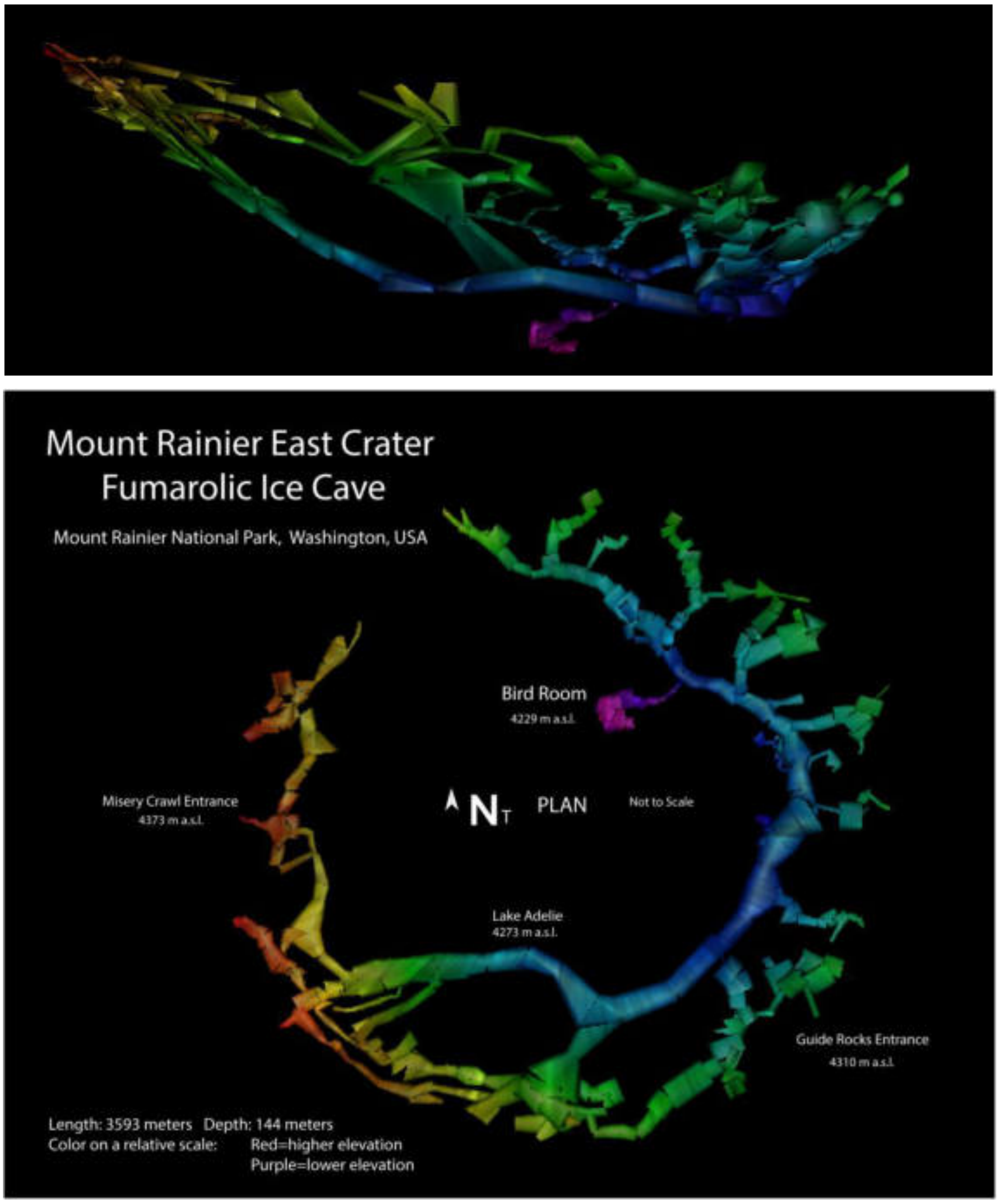

Fig. 1. East Crater Cave at Mount Rainier, USA: A – the profile view; B – the plan view generated from a 3D model. Color indicates depth on a relative scale, red = highest elevations and purple = lowest Elevations. The diameter of the ring passage is approximately 380 m (Cartography C. Stenner)

The dynamic system in the crater of Mount St. Helens provides another example of glaciovolcanic caves. The lava dome that formed in the crater from 1984-1986 was bounded by firn and rapid building up of glacier ice. Heat flux influencing the firn surrounding the lava dome caused new caves to form, which were studied until 1996 by Anderson et al. (1998). The glacier, now known as Crater Glacier, has rapidly advanced since that time (Scott et al. 2008). Continued volcanism and the growth of a new lava dome from 2004-2008 disrupted and obliterated the initial firn cave system (Sobolewski et al. 2021). Fumarole activity surrounding this new lava dome and the continued glacial advance are driving forces in the formation and continued growth of a new cave system (Stenner et al. 2020). Thirteen distinct glaciovolcanic caves have been identified and explored, surrounding the 2004-2008 lava dome in a circumferential pattern (Fig. 2) (Sobolewski et al. 2022).

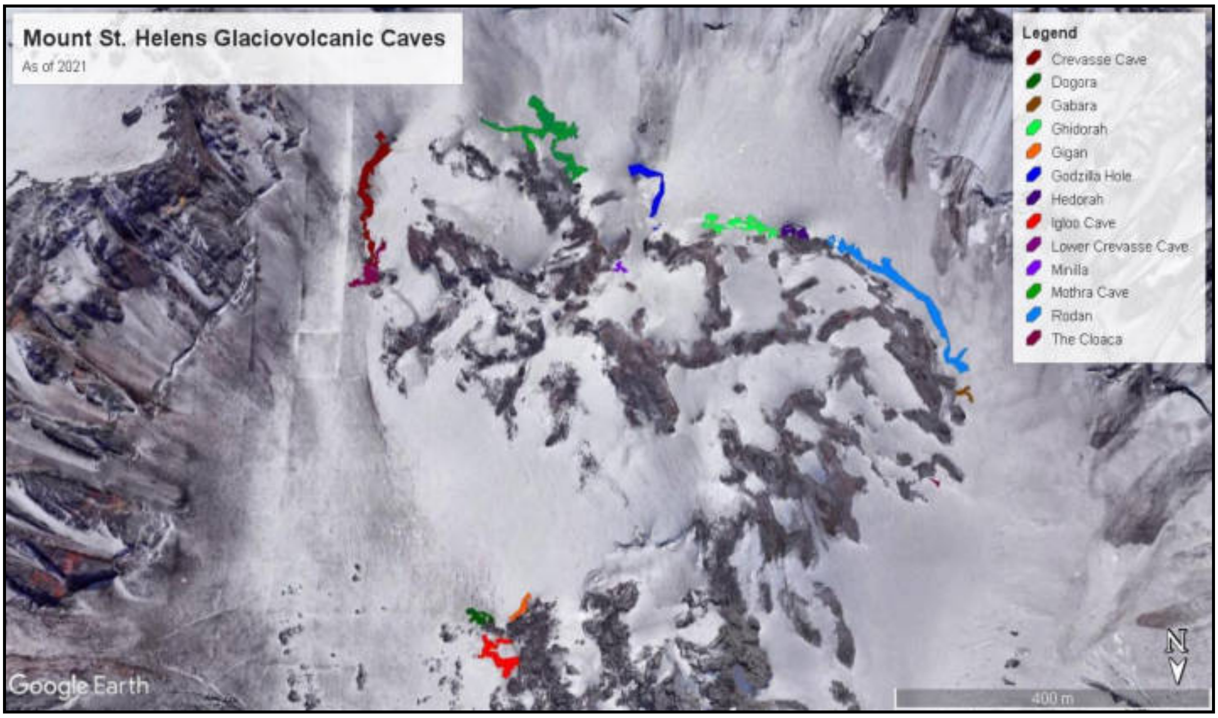

Fig. 2. Map of a plan view of thirteen glaciovolcanic caves in the crater of Mount St. Helens surrounding the lava dome formed from 2004-2008. Image from Google Earth (Cartography C. Stenner)

New examples at Mount Meager, Canada, in the Garibaldi volcanic belt further reinforce the dynamic nature of glaciovolcanic caves and their impacts to volcanic hazard detection (Fig. 3). Two new glaciovolcanic cave entrances were detected in the Job Glacier of the Mount Meager Volcanic Complex, signalling potential changes in the edifice of Canada's only active volcano (Roberti et al. 2018). Continued study of this example includes models of the cave/chimney formation (Unnsteinsson et al. 2020) alongside volcanic hazard and landslide monitoring.

Fig. 3. The large opening of the new glaciovolcanic cave entrance at Mount Meager, Canada. The entrance is over 10 m high and 7 m wide (Photo C. Stenner)

Morphology of glaciovolcanic caves

Glaciovolcanic caves have unique and diverse morphologies distinct from glacier caves and englacial conduits. Morphologic differences between glaciovolcanic and glacier pseudokarst are analogous to the process linked distinction between hypogenic and epigenic karst (Stenner et al. 2022). Glaciovolcanic caves are distinguished by ablation ice scallops covering cave walls and ceilings with sediment and breakdown rock floors visible in areas of increased thermal activity. Hemispherical rooms with dome shaped ceilings are sustained by fumarole output as observed in fumarolic ice caves on Mount Erebus, Mount Rainier, and Mount St. Helens (Fig. 4), (Stenner et. al. 2022; Sobolewski et al. 2020; Curtis & Kyle 2011). Glaciovolcanic caves also have the potential for large conduits, as illustrated by the master circumferential passage in East Crater Cave at Mount Rainier (Kiver & Steele 1975; Stenner et al. 2022). Conduits of this type can be formed by chains of interconnected rooms maintained by atmospheric advection (Florea et al. 2021b). Chimneys to the surface are common at Mount Erebus and result in ice towers extending upwards from the ice surface (Curtis 2016). Other locations display dendritic entrance passages originating at the rock/ice interface or glacier edge that follow the rock/ice margin downward on slopes, connecting to fumarolic areas or conduits (Sobolewski et. al. 2022; Stenner et al. 2020). Rarely, a conduit forms entirely in ice which is elevated from the rock floor of the remaining passages An example from Mothra cave in the Mount St. Helens crater is characterized by fumarolic activity on either side of the ice conduit (see back cover).

Future potential

There is incredible potential for further study in this field given the modest amount of research and data on this form of pseudokarst. Interest in expanding the study of glaciovolcanic caves has grown due to recognition of the utility of unique microclimates as proxies for extraterrestrial ice worlds, providing potential analogs for environments where life may exist outside of Earth (Tebo et al. 2015; Curtis 2020). Concurrently, the study of glaciovolcanic cave development and expansion is providing new pathways for volcanic hazard prediction and monitoring.

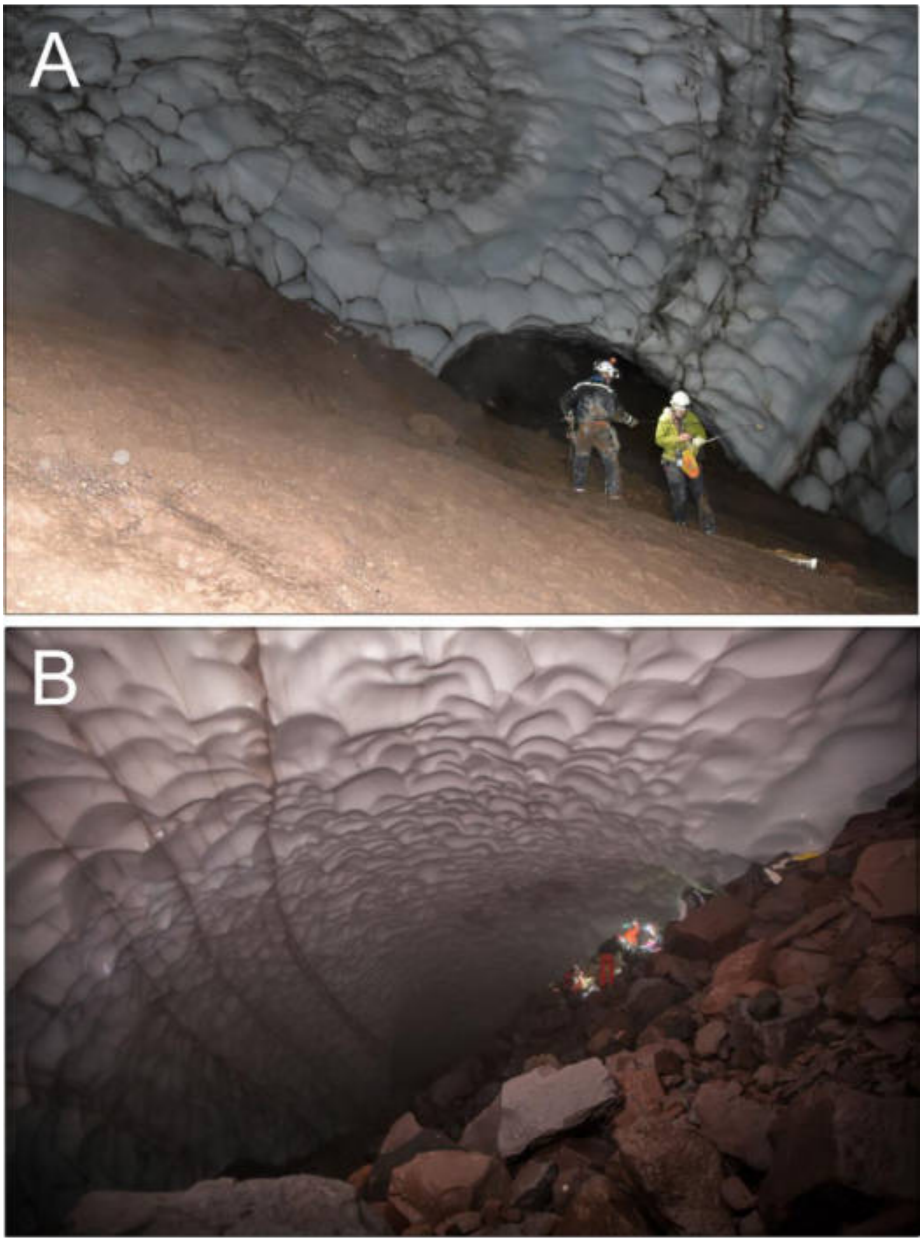

Fig. 4. Inner shapes of the glaciovolcanic caves: A. Hemispherical room in West Crater Cave, Mount Rainier, while explorers test for hazardous atmospheres (Photo T. Wood); B. Large conduit in Mothra Cave, Mount St. Helens (Photo B. McGregor).

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PSEUDOKARST FEATURES IN RUSSIA

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Introduction

There are hundreds of pseudokarst caves of many different geneses in Russia. The authors have thoroughly examined caves of the north-western part of this country. Numerous caves in other regions are described or mentioned based on data of the "Atlas of Caves of Russia" (Shelepin et al. 2019). Lava caves of Kamchatka and vents of gas emissions in the Yamal Peninsula in the Arctic are of particular interest.

Regions with pseudokarst phenomena

Devonian red sandstones are widespread in the vicinity of the Oredezh and Luga river valleys in the **Gatchina District, Leningrad Region**. There are numerous piping (suffusion) grottoes and small caves formed in these rocks. The largest of them is the Svyataya Cave (Fig. 1) (Agapov 2010, 2011; Lyakhnitsky & Vdovets 2008). It is located on the outskirts of the village of Rozhdestveno, near the Nabokov Estate Museum. Currently the cave is 126 m long. It begins with a spacious picturesque grotto up to 5 m high. Further deep down the massif there is the Main Passage, which opens into the flattened Round Chamber. There are several small halls in the cave, part of which are of breakdown origin, and passages connecting them. The arched roofs of the halls are not very stable and sometimes parts fall down. The formation of this cave began in the early postglacial time, about 10 ka ago.

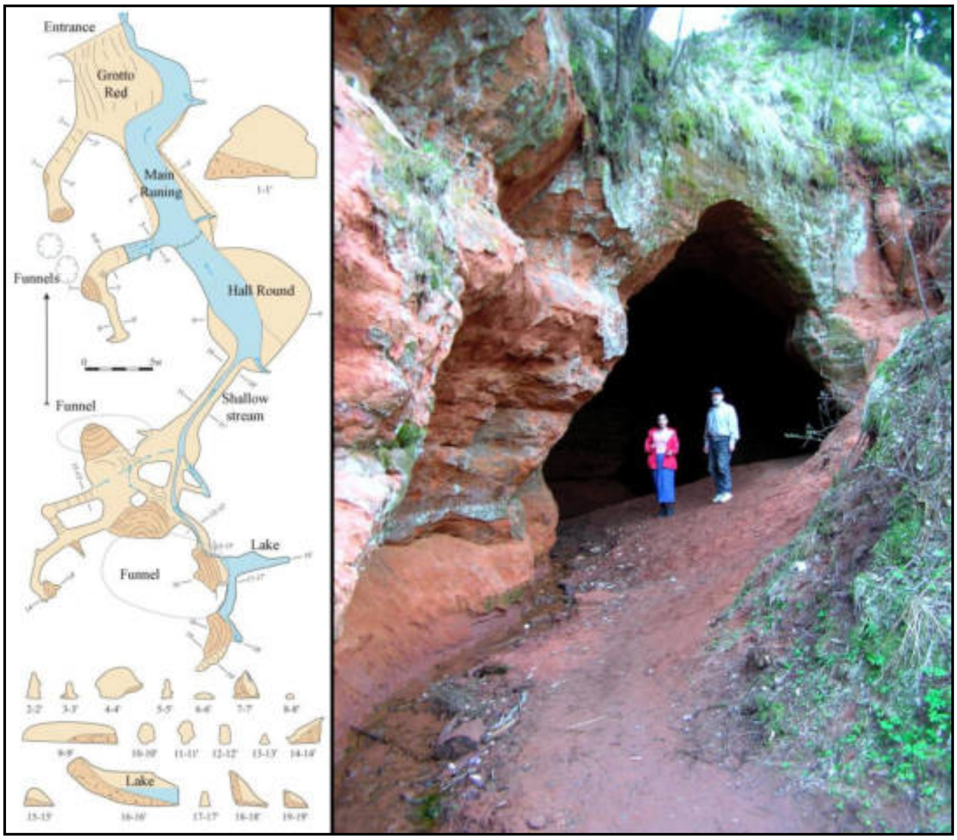


Fig. 1. Svyataya Cave of piping (suffusion) and erosion origin, in the Gatchina District, Leningrad Region, on the outskirts of Rozhdestveno village in the Devonian red sandstone: plan view of the cave and its entrance (Photo Y. Lyakhnitsky)

The Archimedesovskaya Cave is located in the same district, near the village of Khindikalovo (Fig. 2) (Lyakhnitsky & Vdovets 2008). The entrance to the cave is situated in a cliff of the Chernaya River formed by Devonian red sandstones. It was discovered by A.A. Astashenko in 2004 based on hydrological signs. The cave had no connection to the surface. It was discovered during the digging of a three-meter artificial tunnel.

The picturesque Morskoy (Sea) Grotto with a small lake was explored in the cliff of the Obla River in Luga District, Leningrad Region (Fig. 3) (Astashenko & Lyakhnitsky 2019).

Fig. 2. Excavated Archimedesov-skaya Cave in the Leningrad Region (Photo Y. Lyakhnitsky)

Fig. 3. Morskoy Grotto in the cliff of the Obla River (Photo A. Astoshenko)

Four small fracture-gravity and two evorsion caves have been investigated in the Sokanlinna granite massif in the **Vyborg District, Leningrad Region** (Fig. 4) (Agapov et al. 2016). The genesis of two oval-shaped caves was a subject of discussion, but detailed studies have proved that they formed under the action of the pressure flows of sub-glacier water, due to the evor-sion, erosion and cavitation during deglaciation. Another complex of gravity-fractured granitic rock with caves, called Kolinanlinna, is situated nearby. In the past, the Sokanlinna and Kolinanlinna caves were used as refuges by the local population during Russian-Swedish wars.

Various pseudokarst cavities (small caves, grottoes, and rock shelters) of exaration, abrasion, and tectonic origin in eruptive rocks (quartz porphyry) and metamorphic rocks (gneiss, amphibolite) were explored in the **Gogland Island** (Fig. 5), in the center of the Gulf of Finland, Leningrad Region (Agapov & Mizin 2019). A total number of 22 cavities, ranging a length from 2 to 20 m, were explored on this tiny island.

In **Plyussovsky District, Pskov Region**, there is a pseudokarst piping (suffusion) cave, about 20 m long, which was used in the 16th century by monks of the Novye Pechery Monastery as the Posolodino graveyard. An arch and a small chapel were built at the entrance to the cave. The burial chamber was set up in the entrance part, however, there was also a holy spring inside the cave. An underground river channel about 61 m long was explored near the village of Uzhovo in Gdov District, Pskov Region (Agapov 2010).

The Pskov-Pechersky Monastery, **Pskov Region**, being one of the largest cave monasteries in Russia, was founded in the 15th century in a natural erosion-suffusion cave. The hollows of the cave were artificially expanded by monks and reinforced with brickwork. Near the monastery, several small natural caves were explored. They were used by the monks as cells in a later period (Agapov 2019).

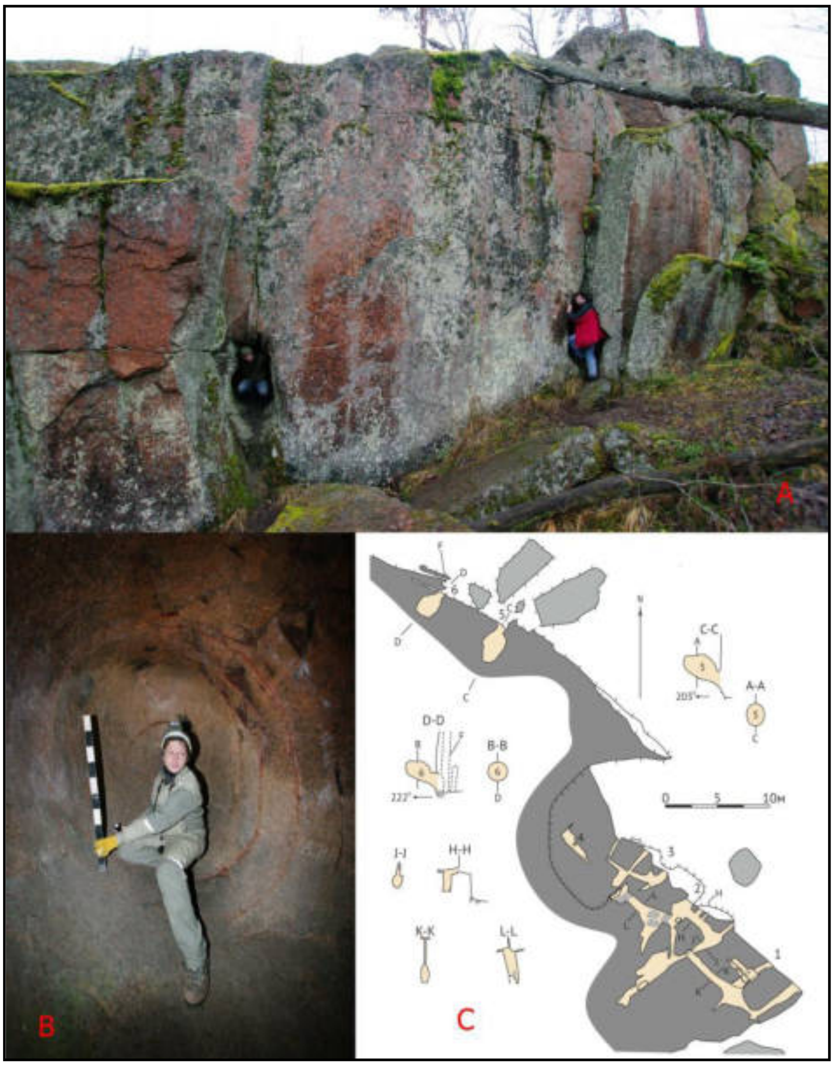


Fig. 4. Caves in the Vyborg district in the Sokanlinna granitic rock massif (Leningrad Region): A – gravitational fracture cave. B – eversion-erosion cave. C – map of the cave site. Topographic survey: Agapov I., Khlebalin, I., Rozhkov V., Lumpova O., Danilova L., 2015-2016 (Photos I. Agapov)

In **Karelia**, in the Northern Ladoga area, there are various small caves in granitic rocks of tectonic origin, which were used by local population as a refuges during military threat in historical time. In the Valaam Archipelago of the Ladoga Lake, some caves in diabases and on the Valaam Island caves of tectonic origin were discovered. They formed as a result of earthquakes caused by the massif uplift after deglaciation. The length of these caves ranges from 4 m to 10 m. On the Svyatoy Island, there is the Alexander Svirsky cave ca. 6 m long, formed during the Ladoga transgression maximum about 3000 years ago. The cave was used by monks of the Valaam monastery as a hermitage in the 14-15th centuries (Agapov 2011). Besides, various caves of tectonic origin have been identified in other areas of Karelia in Mount Vottovaara and on the Pizanets Lake.

In 2014, a gas emission vent formed on the **Yamal Peninsula** at the Arctic Ocean (Shelepin et al. 2019). The initial depth of the vent was over 50 m (Fig. 6). It is circumvallated by rock ejected owing to a process resembling an explosion. The origin of the gas that caused the emission is still debated and the depth of the process has not been finally established yet. Several other similar vents have formed on the Yamal Peninsula meanwhile.

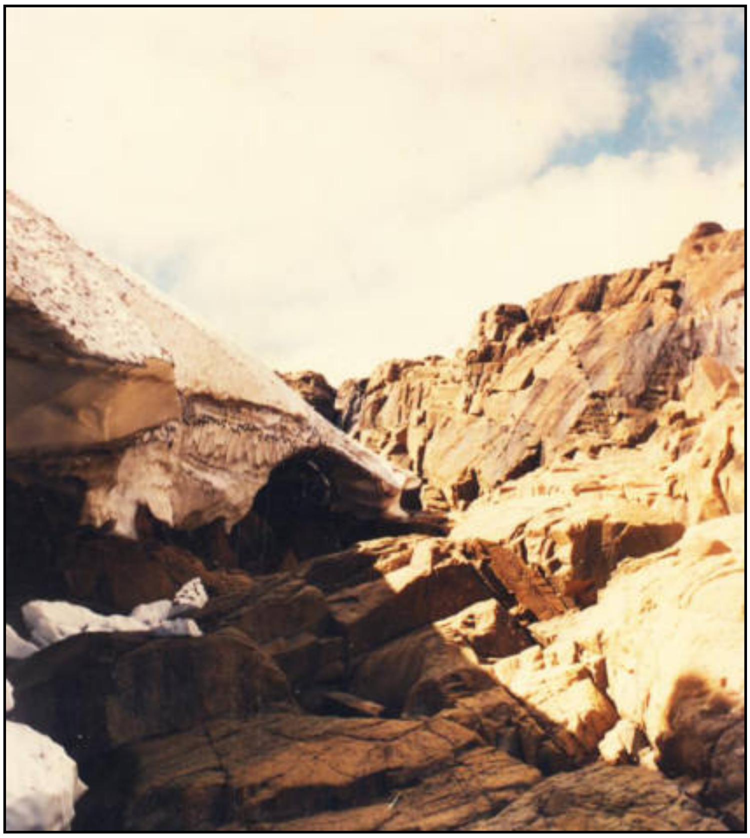
Fig. 5. Suursomerikko-2 Cave of tectonic origin on the Gogland Island. (Photo I. Agapova)

Fig. 6. Vent of gas emission, Yamal peninsula (Photo V.A. Pushkarev)

There are also some ice caves on some **islands of the Arctic Ocean**.

In the **Polar Urals** in the hyperbasite Syum-Keu massif the authors explored a large ice grotto under a waterfall in the firn accumulation of the Pelyang Creek canyon (Fig. 7). However, also tectonic and gravity caves have been found in the Urals.

Fig. 7. Firn grotto Pelyang in the Polar Urals, Syum-Keu massif (Photo Y. Lyakhnitsky).



In the **Western Siberia**, on the Priobskoye Plateau near the city of Barnaul and in other areas, pseudokarst landforms in loess blankets are widespread. Among them are: piping (suffusion) conduits (caves), piping-collapse sinkholes, downwarpings, ditches and wells.

In the **Okhotsk-Chukotka Province**, along the shores of the Chukchi Sea, there are abrasion caves and grottoes: on the Rechnaya Matuga Island – a through grotto, on Spafaryev Island – a rocky arch near Atargan village and a cave with traces of habitation at the Three Brothers Cape in Taui Bay (Shelepin et al. 2019). In the South Sikhote Alin, in coastal cliffs of the Sea of Japan, there are numerous abrasion grottoes. The largest one is located in Vladivostok on the Russky Island, formed in Triassic sandstones. There are volcanic caves on the Shufan Plateau, one of which – Gryaznaya Cave – is 27 m long.

In the **Kamchatka Region**, there are lava tubes formed within streams of volcanic lavas (Fig. 8) (Shelepin et al. 2019). In the slope of the Tolbachek volcano 19 caves were explored in andesite-basaltic lavas. The largest of them is the Tolbachenskaya cave with a length of 540 m and a depth of 11 m. So far 16 caves have been discovered in the Gorely Volcano. One of them, Kontsertnaya Cave, has a large hall with a flat ice floor. Classical music concerts were held there. In the slopes of the Klyuchevskaya Sopka volcano two lava tubes and a grotto in andesite-basalt lava have been explored, one of which is 60 m long. Four caves have been discovered in the Plosky Tolbachek volcano (Shelepin et al. 2019). One of them is the Marina Cave, being 357 m long and 44 m deep.

In Kamchatka, there are geothermal caves in the glaciers adjacent to volcanoes, formed due to a thermal effects at the base of the glaciers. They are located at the Ushakovsky volcano. The largest

of them is 150 m long and 35 m deep. Geothermal caves were also located in the glaciers of the Klyuchevskaya Sopka volcano, as well as the Mutnovsky, Bezymy-anny and Kikhpinnych volcanoes. In the glacier of the Mutnovsky volcano there is a very spectacular, picturesque cave about 1 km long with a translucent multi-colored ceiling (Fig. 9) (Shelepin et al. 2019).

Fig. 8. Lava-tube cave in Kam-chatka near the Tolbachensky vol-cano (Photo I. Vyakhi)

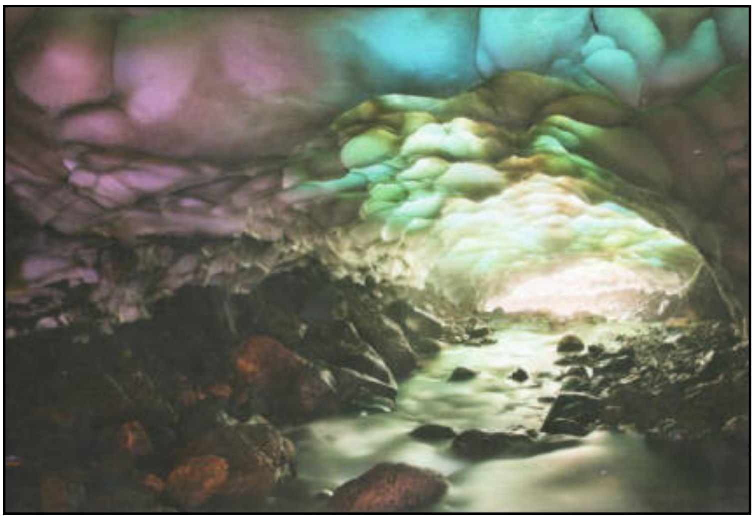


Fig. 9. Snow-firn cave in Kamchatka near the Mutnovsky volcano (Photo N. Belentsova)

In the **Kurils**, on the Urup Island, in the Menshoy Brat volcano, there is an abrasion grotto in basalts with columnar jointing (Fig. 10) (Shelepin et al. 2019). The grotto is interesting for the poly-chromatic coloring of basalts, due to the presence of films of algae and lichens (A.G. Filippov – oral information). Izumrudniy Grotto, a through grotto with three entrances, formed in andesites, is located on the Yankicha Island of the Kuril chain in the area of the active Ushishir volcano. It is very beautiful and is often visited by tourists. The genesis of the grotto is abrasive and its bottom lies below sea level.

To sum up, hundreds of pseudokarst caves of various genesis have been recorded in Russia, so far. The research is ongoing, which will result in discoveries of new caves, soon.

Fig. 10. Abrasion grotto in basalts, the Urup Island, Kurils (Photo L. Zakha-rova).

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PSEUDOKARST CAVES IN POLAND

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1. Introduction

The morphology of Polish territory is characterised by a significant diversity: from Alpine type mountains and medium high to low mountains in the southern part of the country, through various uplands in the central zone, to vast lowlands of flat or hilly relief in the northern part of its area. The geological structure of Polish territory is also highly diverse: from Alpine and Variscan orogens built of magmatic, metamorphic and flysch rocks, through various sedimentary rocks representing all geological periods from the Cambrian to Neogene, to thick cover of Quaternary sediments genetically related to glacial and periglacial environments. Such conditions are responsible for adequately diversified cave genetical types that occur in this territory. Among some 6000 caves recorded in this area up to now, about one third are of non-karst or partly karst origin, and consequently they can be called pseudokarst caves. Among them are also quite large caves ranging a length of 1-2 km (Fig. 1).

Hereafter a short characteristics of the pseudokarst caves in various Polish regions is given. First such description was presented during the 6th Symposium on Pseudokarst in Galyatető (Hungary), in 1996 (Urban 1997), but since that time our knowledge about the caves' occurrence, shapes, sizes and genetical types, as well as possibility of their presentation have been significantly improved.

Fig. 1. Regions of caves' occurrence in Poland (after Urban 1997, modified). Regions: IC – Inner Carpathians, KCU – Kraków-Częstochowa Upland and Woźniki-Wieluń Upland, NB – Nida Basin, OC – Outer Carpathians, RU – Roztocze Upland, SD – Sudetes, SM – Kielce Upland (Świętokrzyskie Mts.), SU – Silesian Upland; colours – areas of caves' occurrence.

2. Caves in various regions

2.1. Inner Carpathians – Tatra Mts. and Pieniny Mts. (Pieniny Clippen Belt)

The Tatra Mts. are small in size but spectacular mountain group of typical Alpine landscape with ridge heights ranging some 2000 m a.s.l. They are built of a large spectrum of rocks: from magmatic and metamorphic to typical sedimentary ones with predomination of carbonate rocks. Therefore they abound in karst caves (ca. 1000 recorded), among which are the longest and deepest ones in Poland. However, some parts of these caves developed (at least in the early stage) due to non-karst, gravity induced processes as widened joint crevices (Szczygieł 2015), but nobody counted them in this variety of cavities. Apart from the karst formations, some caves have been recorded in granites: 14 crevice type caves (in Vitek's 1993, classification) with the longest Studnia w Mnichu (59 m) cave, and 13 erosional-weathering caves, with the longest Cubryńska Dziura (27 m) (Recielski 2002; Grodzicki 2002, 2016).

The Pieniny Clippen Belt, constituting the northern margin of the Inner Carpathians and including the Pieniny Mts., although much lower (reaching up to 1000 m a.s.l. are characterised also by high topographic gradients. Therefore, among some 125 caves documented in this region and formed mainly in Mesozoic limestones and limestone-siliceous rocks, 75% are of non-karst or partly karst origin. The typical gravity induced caves of initial, dilatational type (according to Margielewski & Urban's 2017, classification), representing ca. 30% of the total cave number. This group includes numerous relatively long caves, with the longest one in the region, Jaskinia w Ociemnem (196 m) (Urban 2022). A specific example of this cave type represents much shorter Czerwony Most cave (Red Bridge, 9 m long) in the Homole Gorge (Fig. 2) unique for the host rock, which is limestone-radiolarite rhythmite (Gubała & Urban 2022). The other gravity induced caves are represented by generally shorter talus type forms. Relatively large number of caves, comprising 25% of their total number are short cavities genetically related to weathering, erosional and gravitational processes active in steep mountain slopes (Urban 2022).

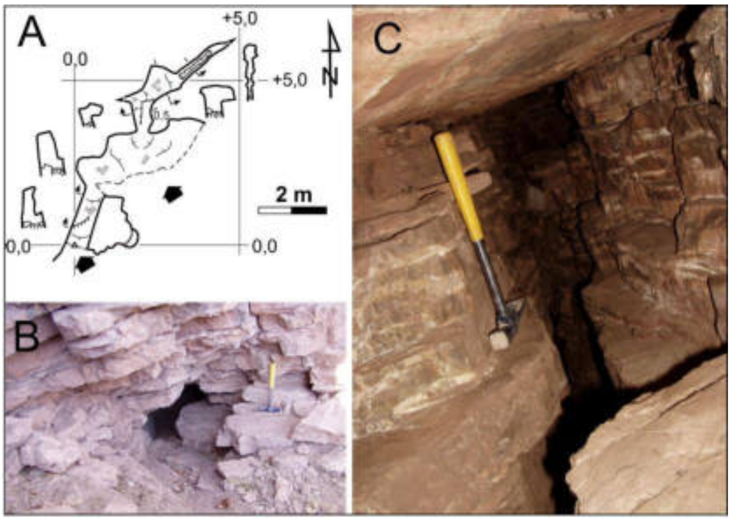


Fig. 2. Czerwony Most cave. A – map (after W.J. Gubała in Gubała, Urban 2022). B – one of the entrances. C – passage.

2.2. Outer Carpathians – Beskidy Mts., Bieszczady Mts. and Carpathian Foothills

The Polish Outer Carpathians are formed of siliciclastic-clayey flysch rocks of mostly Cretaceous-Palaeogene age: sandstone, sandstone-conglomerate and sandstone-siltstone-claystone series with minute inserts and only occasional admixture of carbonaceous rocks/minerals. In the geographic terms they are composed of some mountain ranges and groups reaching a height of 800-1300 m a.s.l. and standing up to 800 m above river valleys. They can be called "Polish pseudokarst paradise", owing to the number and size of non-karst caves. Up to July 2021, 1646 non-karst caves with a total length ranging 27,857 m have been explored and documented in this region. The longest cave, Jaskinia Wiślańska, is 2275 m long. Totally 23 caves are longer than 100 m, while 31 caves are 15 m deep or deeper (Klasek & Mleczek 2018; Gądek 2021). This is due to the geological structure and morphology of the mountains, as well history of caves' exploration. The exploration of these caves has been particularly intensive since the 70-ties of the 20th century, when the Bielsko Biała Speleoclub intensified its activity and subsequently the Beskidy Caving Club and "Malinka Group" started their exploration.

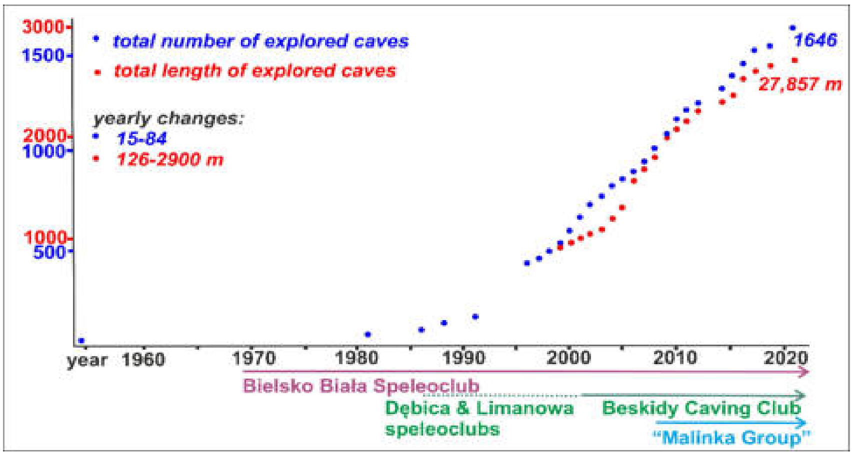


Fig. 3. Progress in cave exploration in Polish Outer Carpathians interrelated with the activeness of speleological clubs (after Urban & Margielewski 2013, updated).

Most caves in the Outer Carpathians are of gravitational origin, developed owing to the slope gravitational deformations of various scales. Therefore, in order to their categorisation two criteria were considered: morphogenic criterion, determining the relation of the cave development to the stage of a slope failure, and geomechanic criterion, describing the nature and range of massif deformation connected with cave development (Margielewski & Urban 2017). According to this first criterion, three types of caves are distinguished: initial caves, formed prior to the main slope failure, subsequent caves, formed during the main slope deformation (i.e. landslide), and intermediate caves genetically connected with both initial and main phases of slope modification. The geomechanic criterion allows to distinguish also three cave types: dilational (dilatational) caves developed due to the simple rock dilation, dilatancy caves formed due to the fissure macrodilatancy – much advanced process of massif deformation, spatially related to shear zones of landslides, as well as boulder caves formed in totally disintegrated rock masses of landslide colluvia (Fig. 4).

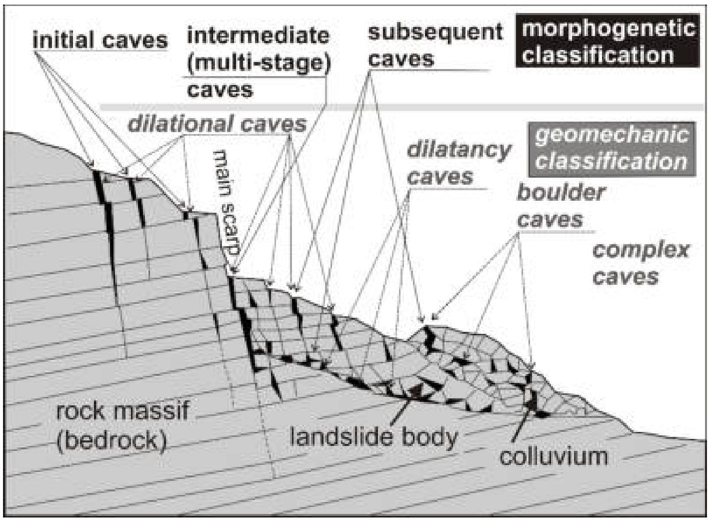


Fig. 4. Conceptual model and proposal of non-karst cave classification (after Margielewski, Urban 2017)

From among more than one thousand gravitational caves of the Beskidy Mts. and Bieszczady Mts. two examples were selected as illustrations. The first is Diabla Dziura cave (Devil Hole, 365 m long and 42 m deep) situated in the western segment of the Bukowiec Hill range (Fig. 5A) and formed in very thick-bedded sandstones. This cave is practically one crevice parallel to the range axis, divided by rock blocks and slabs into three irregular storeys (Fig. 5B). The galleries of the uppermost storey are relatively irregular, low and narrow, with oblique walls (Fig. 5C), while the lowermost store comprises one vertical, narrow but high (up to 20 m) crevice (Fig. 5B, D). According to the geomechanic criterion Diabla Dziura cave represents the dilational type, as an extensional crevice opened and widened owing to the spreading developed within the mountain range, limited from both (northern and southern) sides by steep slopes, and moreover, cut by landslide in the northern slope (Fig. 5A). This spreading is perfectly documented by a shape of the opposite gallery walls in Fig. 5C. In the some places of the uppermost storey a slight contribution of toppling or backward rotation is observed (Margielewski & Urban 2004; Pánek et al. 2010). In the morphogenetic classification the cave belongs to the initial type, because its formation precedes further massif disintegration by the development and expansion of the landslide that exists in the northern slope of this part of the Bukowiec Hill range (Fig. 5A) (Margielewski & Urban 2004; Pánek et al. 2010).

The second cave presented here, Jaskinia Wiślańska (2275 m long and 41 m deep), the longest one in the Polish Outer Carpathians, differs significantly from the described above Diabla Dziura cave. It is formed also in very thick-bedded sandstones, but represents a maze system of – more or less narrow – passages connecting irregular and somewhere spacious chambers. The uppermost part of the cave comprises a set of quite irregular cavities among chaotically situated blocks, whereas passages and chambers of its middle and lower parts developed among joints, most of them being parallel to the slope extent. The opening and widening of these cavities was caused not by simple spreading, but various – vertical, rotational and horizontal – displacements of large blocks, somewhere for quite long distances (Figs. 6B, C), which occurred within the deep part of the landslide body, close to the sheer zone of this mass movement. Therefore, the cave represents the subsequent type in morphogenetic classification. According to the geomechanic criterion its lower and middle part comprise a dilatancy cave, while its upper, chaotic part is a boulder cave. This cave is also one of the rare ones in the region, which bear (non-carbonaceous) speleothems,

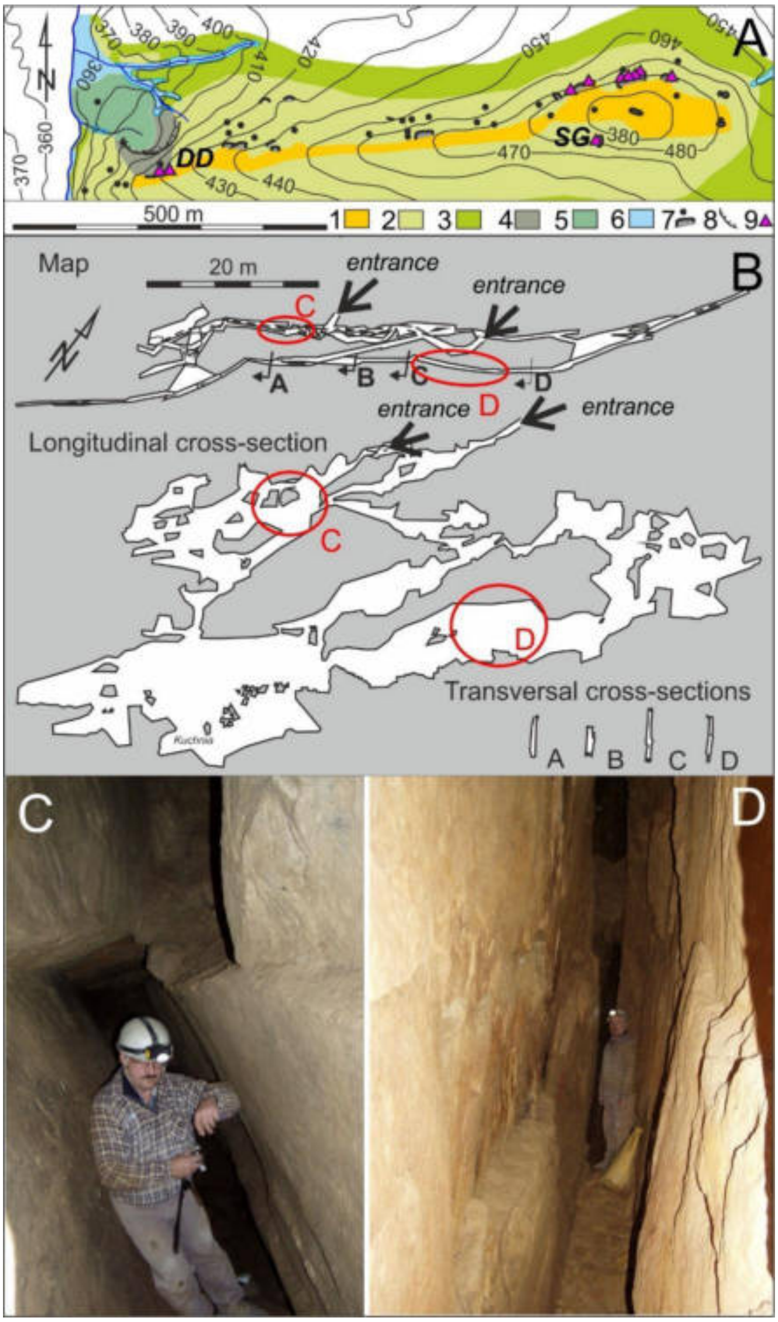


Fig. 5. Diabla Dziura cave. A – situation of Diabla Dziura and Schronisko w Grzybku caves in the Bukowiec Hill (map after Mleczek et al. 2021, modified); explanation of symbols: 1 – hill range, 2 – slope carved in pre-Quaternary rocks (sandstones), 3 – slope covered by deluvial and weathering sediments, 4 – landslide main scarp, 5 – landslide colluvium, 6 – area of fluvial erosion and accumulation, 7 – sandstone crags, 8 – rock scarp, 9 – cave entrance. B – map and cross-sections of the cave (after Ganszer & Mleczek 1997, simplified); red ovals indicate places of the photographs C and D. C – passage in the upper part of the cave; the shape of the opposite walls perfectly illustrate a horizon-tal shift of the rock massif widening the crevice. D – narrow and high gallery in the lower part of the cave (Photos J. Urban)

The gravitational caves of the Outer Carpathians have formed since the Late Pleistocene. As datings of carbonaceous speleothems (rather rare in these caves – Urban et al. 2015) indicate, during the Holocene the intensifications of caves' formation or modification were correlated with general mass movements' acceleration in periods of climate moistening and cooling (Margielewski & Urban 2017).

Apart from gravitational caves, in the sandstones of the Polish Outer Carpathians some caves of weathering, weathering-erosional and weathering-erosional-gravitational origin occur. They are genetically and spatially related to crags (rock landforms) and much shorter (usually several meters long) than gravitational ones, but often representing a spectacular shape and microrelief. Such small cave are also in crags of the Bukowiec Hill (Fig. 8).

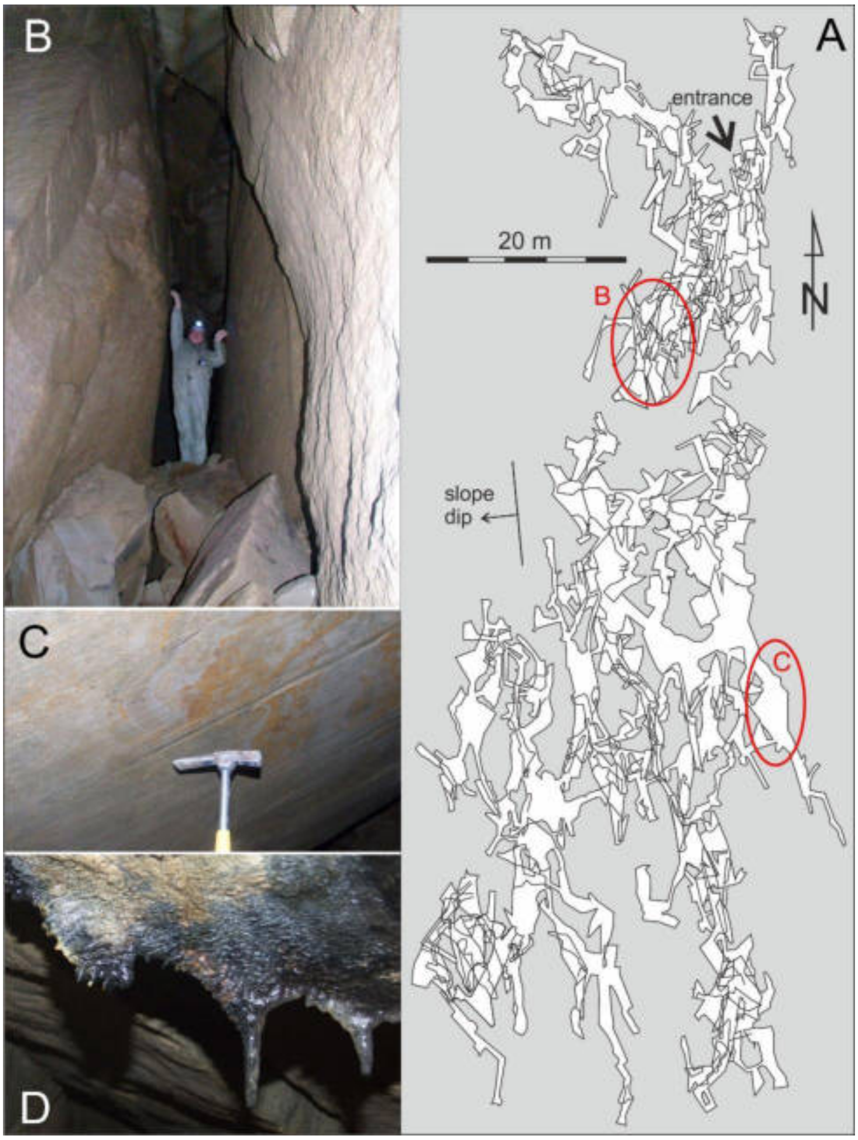


Fig. 6. Jaskinia Wiślańska cave. A – map (after Szura 2009, simplified); red ovals indicate places of the photographs B and C. B – Wyśnie Dno chamber; the caver points the differences of vertical position of the identical depositional structures on opposite walls. C – the grooves on the ceiling (slightly dipping) are specific slickensides – traces of relative movements of blocks. D – speleothems built of an argillo-siliceous, not yet crystallised substance (Photos J. Urban)

Fig. 7. Schronisko w Grzybku (Shelter in the Mushroom) – cavities of a total length ranging 3 m, originated due to the selective weathering of sandstone in the crag (Photo J. Urban)

2.3. Sudetes with foothills

The knowledge of non-karst caves in the Sudetes and their foothills has been steadily broadened during the last 30 years, especially in the first decade of the 21st century. Until the mid-90's of the 20th century merely 12 pseudokarst caves with a cumulative length of 135 m were surveyed and mapped, according to the detailed list provided by Pulina (1996). A decade later Wojtoń (2006) listed as many as 62 caves with a length exceeding 3 m (585 m of cumulative length). Seven years later, according to the same author, the list of documented and measured pseudokarst caves of the Sudetes reached the number of 160 ones, with the total length of 2960 m (Wojtoń 2013).

Within the Polish part of the Sudetes, there are two main regions where pseudokarst caves do occur. The first one are the Stołowe Mts. in the Central Sudetes – a classic stepped-tableland shaped by sandstones and fine-grained rocks of the Upper Cretaceous age. While not included in the elaboration by Pulina (1996), this area was pointed out by this author as the one where non-karst caves of various type and origin are very likely to occur. This was confirmed by Zyzańska & Zyzański (2008a) who surveyed as many as 105 pseudokarst caves – 75 of them became subject of a detailed measurement and mapping,documenting the total length of ca. 2150 m. Two caves – Jaskinia na Potoku 1 (280 m long) and Jedynka cave (230 m) are mentioned as 5th and 7th longest cave in the Sudetes, respectively (Wojtoń 2013). Most of the surveyed caves are located within three zones: Mt Szczeliniec Wielki mesa – 28 caves, Białe Skały cliff lines – 23 caves and small canyons of Piekło and Stekelnice creeks – 12 caves (Zyzańska & Zyzański 2008a). Regarding the locations, caves differ by their origin. Caves of Mt Szczeliniec Wielki are mainly the crevice- and roofed-cleft-type, being developed in partly disintegrated and densely jointed sections of the sandstone cliff lines. Apart from Jedynka cave, none of them exceeds the length of 100 m (with Jaskinia w Jagodowym Wąwozie cave being 95.5 m long and Jaskinia pod Zwisającą Skałą cave – 59 m).

Cave systems in the Stekelnice valley are of different origin, being developed within thick boulder covers mantling the valley bottom. The longest of these boulder caves is Jaskinia na Potoku 1, attaining the total length of 280 m, while the Jaskinia na Potoku 2 is 163 m long and Jaskinia z Paprotką – 47 m. Jaskinia w Wąwozie na Łuku Drogi cave, located nearby, in the bottom of a left tributary valley, is 141.7 m long. An interesting peculiarity of the sandstone caves in the Stołowe Mts. are the root stalagmites – convex forms of biogeomorphological origin. As many as 51 such objects, reaching maximum height of 30 cm, were identified during the fieldworks conducted between 2002 and 2007 (Zyzańska & Zyzański 2008b).

The second region, where pseudokarst caves are relatively numerous, is situated in the Western Sudetes, within the granitic Karkonosze-Izera Massif. 44 caves were surveyed within the northern slopes of the Karkonosze Mountains, Karkonosze Foothills, Rudawy Janowickie Mts. (Szmytkie 2004; 2005a) and in isolated hills of the Jelenia Góra Basin (Migoń 2000; Szmytkie 2005b). Migoń & Szmytkie (2007) presented four types of caves in the region: crevice caves, roofed clefts, boulder/talus caves, overhangs and shelters as well as caves of complex morphology. The longest crevice caves are Pustelnia cave (24 m) located at Mt. Witosza (Łomnickie Hills in the Jelenia Góra Basin) (Fig. 8) and Dziurawy Kamień cave (19.5 m), located at the northern slope of Mt. Chojnik in the Karkonosze Foothills (Fig. 9). Boulder/talus caves are considerably less extensive, with none of them exceeding the length of 10 m (Schronisko Starościńskie cave in the Rudawy Janowickie Mts., of the length of 9 m, is the longest one). The longest granite cave in the Polish Sudetes is Jaskinia w Fajce, which is 36 m long and of complex morphology, including six entrances, long, straight crevice in the lower part and the upper part containing irregular chambers roofed by big boulders (Szmytkie 2004).

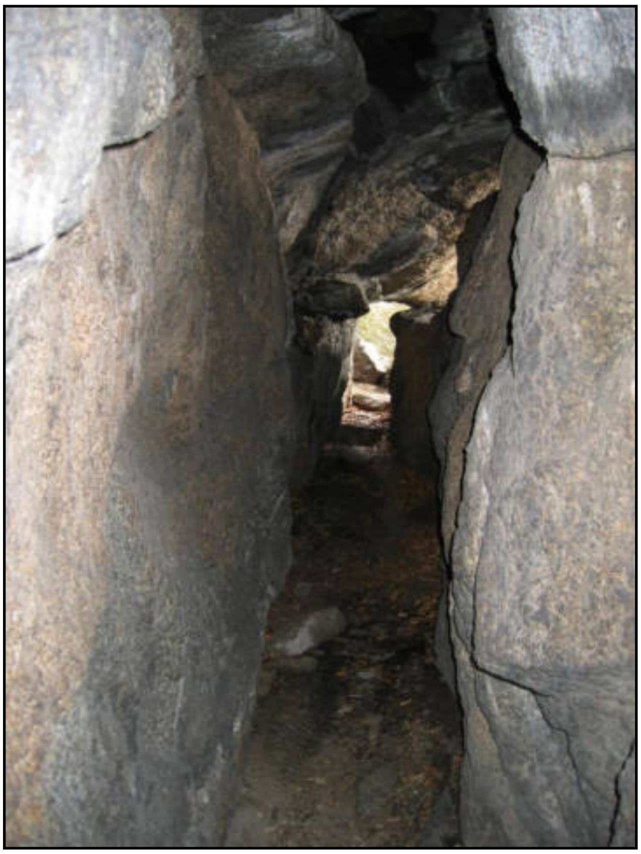


Fig. 8. Pustelnia cave at Mt. Witosza in the Łomnickie Hills, Jelenia Góra Basin (Photo P. Migoń)

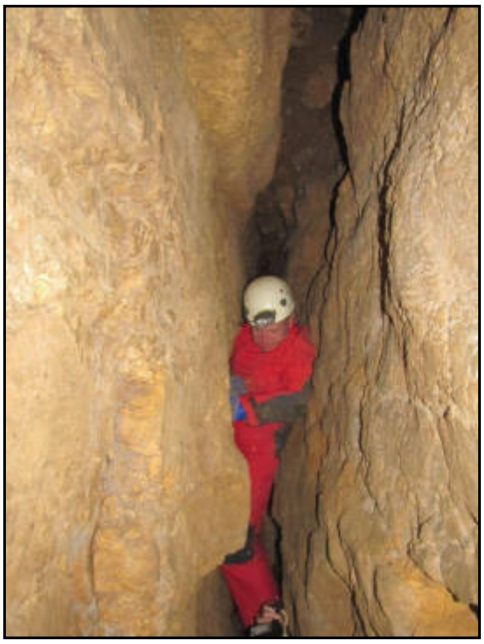
Fig. 9. Dziurawy Kamień cave at Mt. Chojnik, Karkonosze Foothills (Photo P. Migoń)

Apart from the two regions already described, as many as eight small sandstone caves were recognized in the Kaczawskie Foothills (Pulina 1996; Wojtoń 2006). Four of them are located in the Huzarski Skok rocks in the Bóbr river valley, including the longest one – Jaskinia Pandurów, which is 13 m long. These objects are of crevice type, while two caves in the Drążnica valley, near Złotoryja – Wilcza Jama and Niedźwiedzia Jama caves – are of the overhang/niche type. Five small sandstone caves are also located in the Zawory area, Central Sudetes. Among them, three ones formed in Triassic sandstones of the Czartowskie Skały crags and two in Cretaceous sandstones of the Gorzeszowskie Skały cliffs. None of these caves exceed the length of 7 m.

The Wałbrzyskie Mts. in the Central Sudetes are represented by six fissure, shaft-like caves developed in volcanic rocks (Upper Carboniferous rhyolites) – within the slopes of Mt. Mniszek. The largest one – Podłużna Szczelina II – is 63 m long and 36 m deep (Wojtoń 1998, 2006; Daszkiewicz 2006).

Fig. 10. Entrance to Mała Młocka cave in the Bystrzyca valley, Bystrzyckie Mts. (Photo K. Jancewicz)

Finally, singular caves formed in hornfels and gneiss. The only cave developed in hornfels is located in the Izerskie Mts. in the Western Sudetes. It is called Zbójeckie Schronisko and its total length is 18 m (Wojtoń 2006). Mała Młocka cave, located in the Bystrzyca river valley in the Bystrzyckie Mts (Central Sudetes) developed in Palaeozoic gneiss. It is 9 m long and of uncertain origin with the entrance in densely-jointed rock wall zone (Fig. 10); here, however, the anthropogenic factor cannot be excluded (Rzonca & Buczyński 2004).



2.4. Central Polish Uplands – Silesian Upland

In the Silesian Upland – a relatively flat, occasionally hilly region – some 70 rather short caves (usually several meters long, with the longest one ranging 107 m), developed in the Middle Triassic carbonates, have been recorded. Most them are of karst origin, however, the contribution of other processes: gravitational, erosional and anthropogenic, is often discernible in these caves formation. The longest cave developed due to interaction of karst and gravity is Jaskinia Chełmska, 23 m long (Fig. 11). Eight other, much shorter ones are described as pseudokarst caves (Pawełczyk & Rogala 2010).

Fig. 11. Jaskinia Chełmska – passage formed in Triassic limestones owing to interaction of gravity and rock dissolution (Photo J. Urban)

2.4. Central Polish Uplands – Kraków-Częstochowa Upland and Woźniki-Wieluń Upland

Apart from the Tatra Mts., the Kraków-Częstochowa Upland and the northern part of the Woźniki-Wieluń Upland are the regions famous for their karst caves developed in Upper Jurassic limestones. Some 2000 caves of a length ranging several ten, occasionally several hundred meters and a depth up to several ten meters have been explored in this area up to now (Gradziński & Szelerewicz 2004). Owing to the relatively high topographic gradient (deep canyons, rocky monadnocks and hills), among the caves are also gravity induced ones of the crevice type and boulder (talus) type (according to Vitek's, 1983, and Bella & Gaál's, 2011, classifications). However, it is relatively difficult to estimate their number. Conservative estimation suggests that there are slightly more than 10% non-karst caves, but they represent less than 5% of the total length of the caves (Urban 1996). Especially the boulder caves are usually very short (Fig. 12).

Fig. 12. Boulder (talus) type cave in the Sokole Góry Hills (Photo J. Urban)

2.5. Central Polish Uplands – Nida Basin (Ponidzie)

Among slightly more than 100 caves documented in this hilly region, most ones developed in Neogene gypsum rock and are principally karst forms (with subsequent activity of other processes, as e.g. ceiling breakdowns). Only one cave, formed in Cretaceous marls, Jaskinia w Antolce (16 m long) is typical dilational (crevice) form (Gubała et al. 1998).

2.6. Central Polish Uplands – Kielce Upland (Świętokrzyskie Mts.)

In the geological term the Kielce Upland represents the Palaeozoic Core and Permian Mesozoic Margins of the Świętokrzyskie (Holy Cross) Mts. formed of various sedimentary rocks with significant share of limestones, dolomites, sandstones and quartzitic sandstones. These rocks formed numerous hilly ranges and groups reaching a height of low mountains. Most caves are of karst origin: 92 caves of a length usually several ten to several hundred meters (up to 3670 m long Chelosiowa

Jama-Jaskinia Jaworznicka system), but 58 non-karst caves have been also recorded there. The pseudokarst caves are much shorter than karst ones, ranging usually a length of several meters. The longest is Jaskinia Ponurego cave (25 m), formed owing to gravitational toppling and rotation (around the vertical axis) of a large boulder (Fig. 13). Almost all these caves are spatially and genetically connected with sandstone (or quartzitic sandstone) crags and comprise weathering-erosional cavities or gravity induced forms (Urban & Kasza 2009).

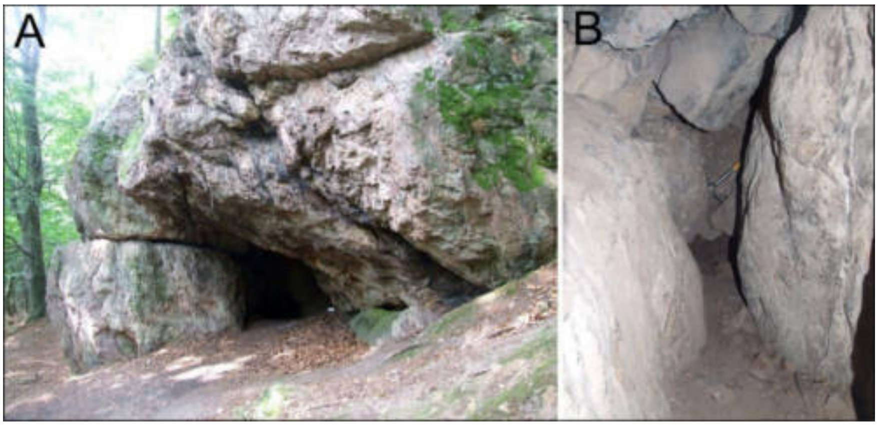


Fig. 13. Jaskinia Ponurego cave in crags built of quartzitic sandstones. A – entrance. B – passage (Photo J. Urban)

Among the most interesting caves are Jama Agi (Agnes' Den) and Tomkowa Dziura (Thomas' Hole) situated in the rock cuesta (Fig. 14) of the Piekło pod Niekłaniem (Hell near Niekłań Village) crag group (Fig. 14), the most spectacular crag group in the region (Urban & Gagol 2008). The caves are only 8 m long each, but they have been formed owing to subsurface weathering and water erosion: leaching out and washing down sand grains, developed principally along fissures (joints). This process, acting not only within the caves, but along other fissures, has been responsible for shaping of the cuesta (Fig. 14A) (Urban 2005).

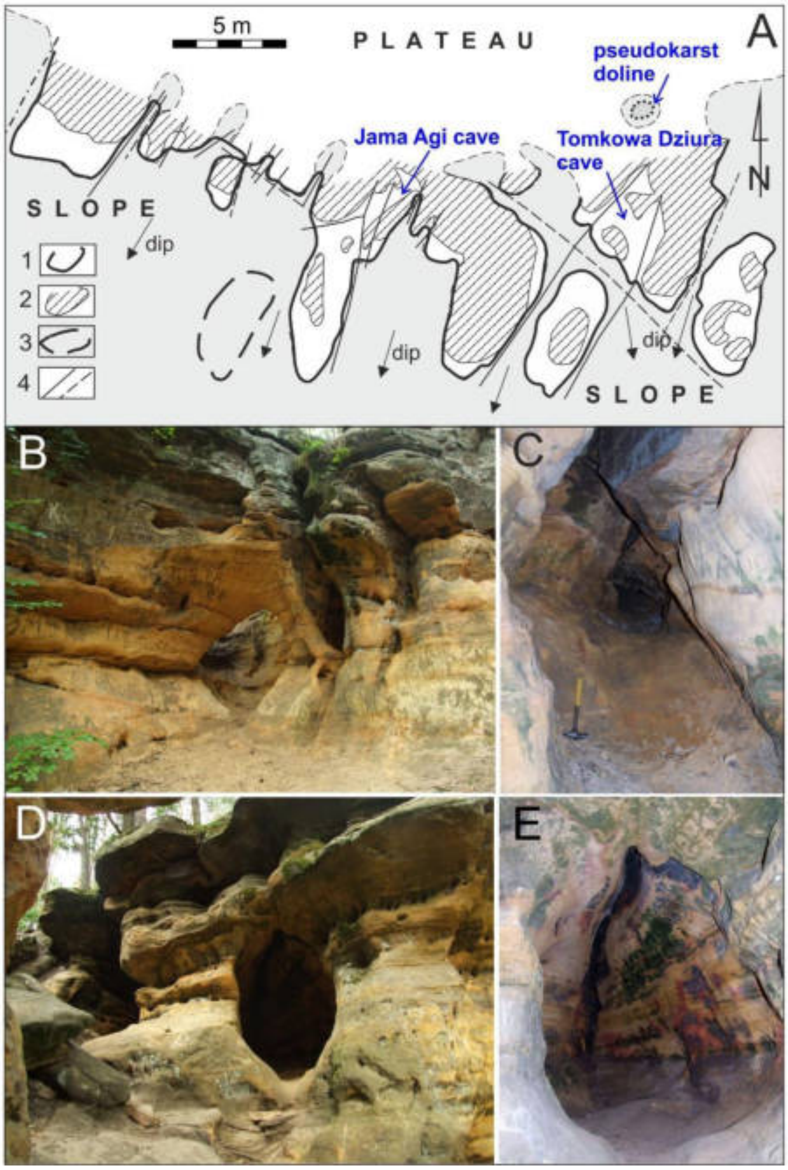


Fig. 14. Jama Agi and Tomkowa Dziura caves within the rock cuesta of the Piekło pod Niekłaniem crag group. A – map (after Urban 2005, modified); explanation of symbols: 1 – upper contour of the crags (hoodoo rocks, rock spurs), 2 – lower contour of the crags, 3 – contour of the boulder (ex situ rock), 4 – joints observed and suggested. B – entrances of Jama Agi cave. C – passage of Jama Agi cave. D – entrances of Tomkowa Dziura cave. E – eastern chamber of Tomkowa Dziura cave (Photos J. Urban)

2.7. Central Polish Uplands – Roztocze Upland

In the Roztocze region some 10 short caves, occurring mainly in Neogene limestones, have been recorded, up to now. The longest, Jaskinia Diabelska (Devil Cave, 21.5 m long), and some other caves are of weathering-karst origin. However, there are several caves developed due to weathering-erosional-gravitational processes acting on steep slopes. An adequate example of these caves is Jaskinia Chmielna cave, 14 m long (Fig. 15),

Fig. 15. Entrance to Jaskinia Chmielna cave that comprises the cavity developed in steep slope (Photo J. Urban)

2.8. Central Polish Uplands and mountain foothills (forelands) – loess and other silt covers

In some places of the Central Polish Uplands vast and relatively thick (up to 30 m) loess covers occur. Covers of clayey-silts similar to them are also observed in the Carpathian and Sudetes foothills and forelands. In these sediments characteristic conduits developed mainly due to the piping and zoogenic processes, somewhere with human contribution, have been noticed. They are not subjects of speleological exploration, however such trials were undertaken in the Nida Basin (Fig. 16) (Urban 2004).

Fig. 16. Pseudokarst forms in loesses of the Polish Uplands. A – conduit of a diameter ranging ca 30-80 cm in the Świętokrzyskie Mts. B – well of a depth ranging several meters in the Nida Basin (Photos J. Urban)

2.9. Polish Lowlands

In the vast area of Polish Lowlands only some 20 short caves have been already recorded, however almost all them represent unique and very interesting objects from a scientific point of view. The reason of their uniqueness is that this area is completely covered by Quaternary, glacial, fluvioglacial and aeolian, generally not lithified sediments: clays, sands, silts and gravels. Consequently, the majority of these caves are spatially and genetically connected with rare (unique) bodies of extremely young sandstones, comprising Late Pleistocene (to, possibly, Holocene) sands cemented with calcite. The sandstone bodies are characterised by various size – from several meters to several ten meters – and shapes, among which, apart from irregular bodies, the most common are horizontal slabs often associated with vertical columns. And just the topographic positions of these last formations (e.g. in steep slopes of river/stream valleys or in faces of artificial pits) connected with adequate gravitational or erosional processes were responsible for the caves development (Urban et al. 2007).

The most spectacular example of these caves is Groty Mechowskie (Grottos in Mechowo Village) cave – the longest one in this group, ranging a length of 61 m. It constitutes a set of cavities formed under the sandstone slabs and among the sandstone colonnade (Fig. 17). It is situated at a base of steep slope of a stream valley and developed due to the combination of some factors: subsurface water erosion, gravitation as well as probably zoogenic and surely anthropogenic activity. These latter were intensive during the last two hundred years, since the first detailed description and map of this cave which was published in 1829. But the natural cavity was not much older, because the U-series datings of the calcite speleothems indicate that they are not older than several hundred years (Urban et al. 2007).

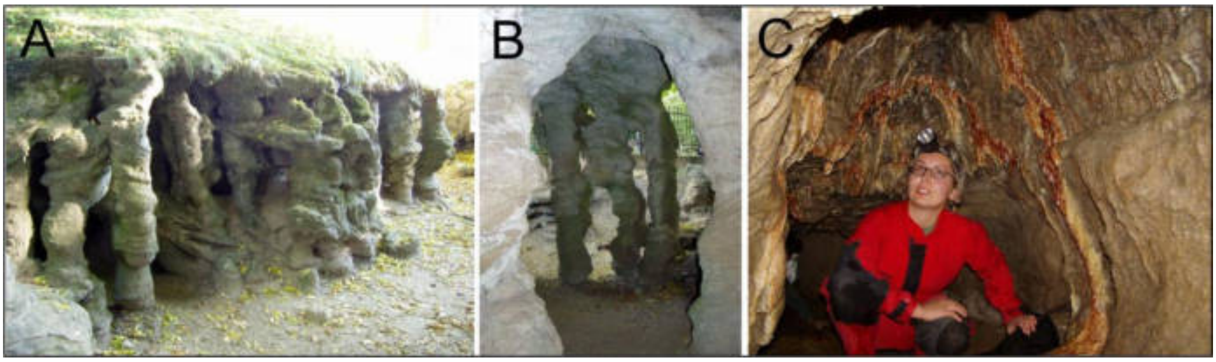


Fig. 17. Groty Mechowskie cave. A – sandstone colonnade at the entrance. B – sandstone columns from the cave chamber. C – calcite flowstones and stalactites in the main passage (Photos J. Urban)

Genetically very interesting are also two other caves: Bajka I (19 m long) and Bajka II (10 m), that were formed under the sandstone slab situated in the upper part of a steep slope of a valley. The reason of creation of these caves was water flow (percolation) through the sands under the slab, which has initiated slow creep of the sands toward the valley axis and their slow wash down (Fig. 18). As indicated by speleothem datings, also these caves are not older than several hundred years (Urban et al. 2007).

Apart from the caves related to the sandstone bodies there are two caves developed in boulder clays and one – in Neogene silts and sands outcropped in the sea shore cliff (Urban et al. 2007).

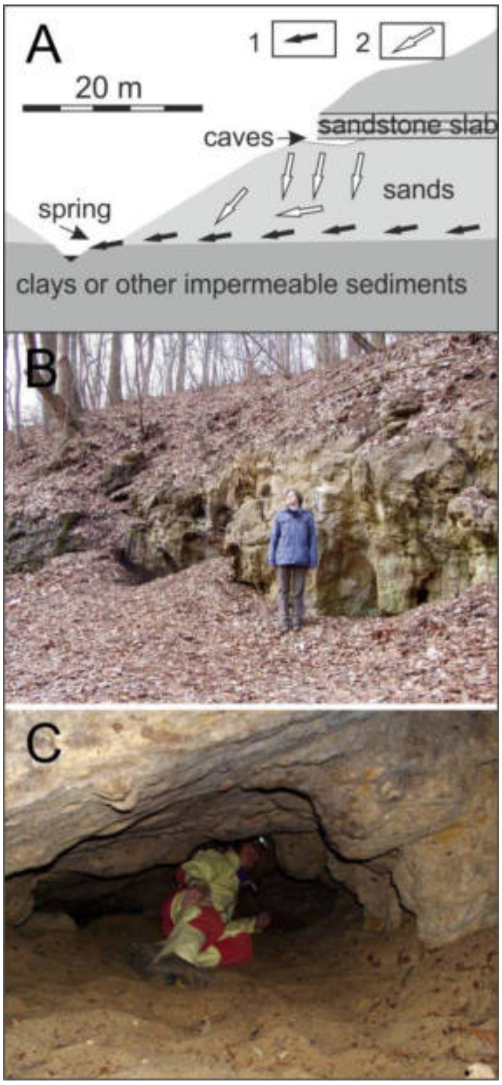


Fig. 18. Bajka I and Bajka II caves. A – model of the caves development presented on the slope and valley cross-section; explanation of symbols: 1 – water subsurface flow, 2 – creep of sands (after Urban et al. 2007, modified). B – slope with the rock cliff under which cave entrances are situated. C – main chamber of Bajka I cave (Photos J. Urban)

Conclusions

There are two principal conclusions based on the review of Polish pseudokarst caves. The first one postulates that the occurrence, nature, size and shape of a non-karst cave is strictly related to morphology (topographic gradient etc.), while the secondary factor is lithology and, afterwards, other local features as hydrology, climate. These agents and features are adequately responsible for the significant variety of the pseudokarst caves in Polish territory. The second idea, arising from the description given above, is that there is no region in our globe surely devoid of caves. So, we can expect caves everywhere …

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WOOLSACK CAVES AND TALUS CAVES IN GRANITES OF THE VELENCE HILLS, HUNGARY

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The Velence Hills in Hungary cover a surface of 40 km^2 in the central part of the Transdanubia extending from the town of Szekesfehervar to the village of Pazmand. The hills are mainly composed of Palaeozoic granite. During the Variscan orogeny the granite magma intruded into the Silurian-Devonian argillaceous rocks forming a batholith. Peculiar landforms have been developed in a consequence of 300 million years long formation and denudation of the granite massif. Greater and smaller groups of tors emerge from the saprolite covering granite ridges. The tors were formed during the earlier period of tropical climate owing to the water affected weathering of the granite. After the partial denudation of the saprolite the tors were exposed (Fig. 1). The tors are usually rounded off, forming the so-called woolsacks (Horváth et al. 2004; Eszterhás 2009). Between the rounded boulders, which are more or less touching one another, passable holes, so called woolsack caves are to be found. In the granite of the Velence Hills also talus type caves occur.

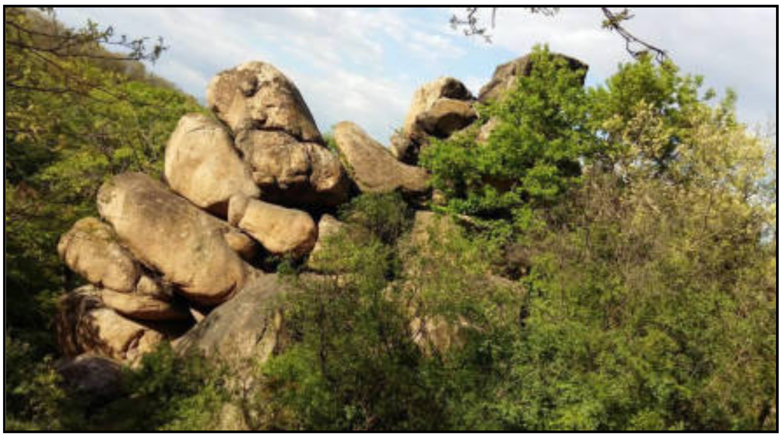

Fig. 1. The Pandur-stone and, at the left, the entrance of the Zsivány Cave as woolsack cave (Photo P. Tarsoly)

The Velence Hills are divided into two main units (Fig. 2): the West-Velence (I) and the East-Velence (II) (Ádám 1993; Horváth et al. 2004). The West-Velence area contains two smaller parts: the Szekesfehervar unit (A) and the West-Velence unit (B). The East-Velence area contains also two smaller parts: the East-Velence unit (C) and the Nadap-Pazmand Mts. (D). In the West-Velence unit and in the East-Velence unit 48 woolsack caves and talus caves have been discovered and explored.

The Velence Hills are the smallest and oldest mountains in Hungary. The short summary of their geological development is the following (Ádám 1993; Horváth et al. 2004; Eszterhás 2009):

1. Silurian-Devonian – deposition of the clayey sedimentary rocks.
2. Lower Carboniferous – granite intrusion:
    a. granite batholite formation,
    b. metamorphism of clayey rocks into phyllite,
    c. jointing of the granite massif.
3. Upper Carboniferous – a new magma intrusion in the upper Carbonic:
    a. dikes (granite porphyry, pegmatite, aplite),
    b. pneumatolytic and hydrothermal ore deposits.
4. Mesozoic – terrestrial denudation.
5. Eocene – andesite volcanism (in the eastern part).
6. Miocene – peneplanation.
7. Pliocene – marine transgression.
8. Quaternary – terrestrial denudation.

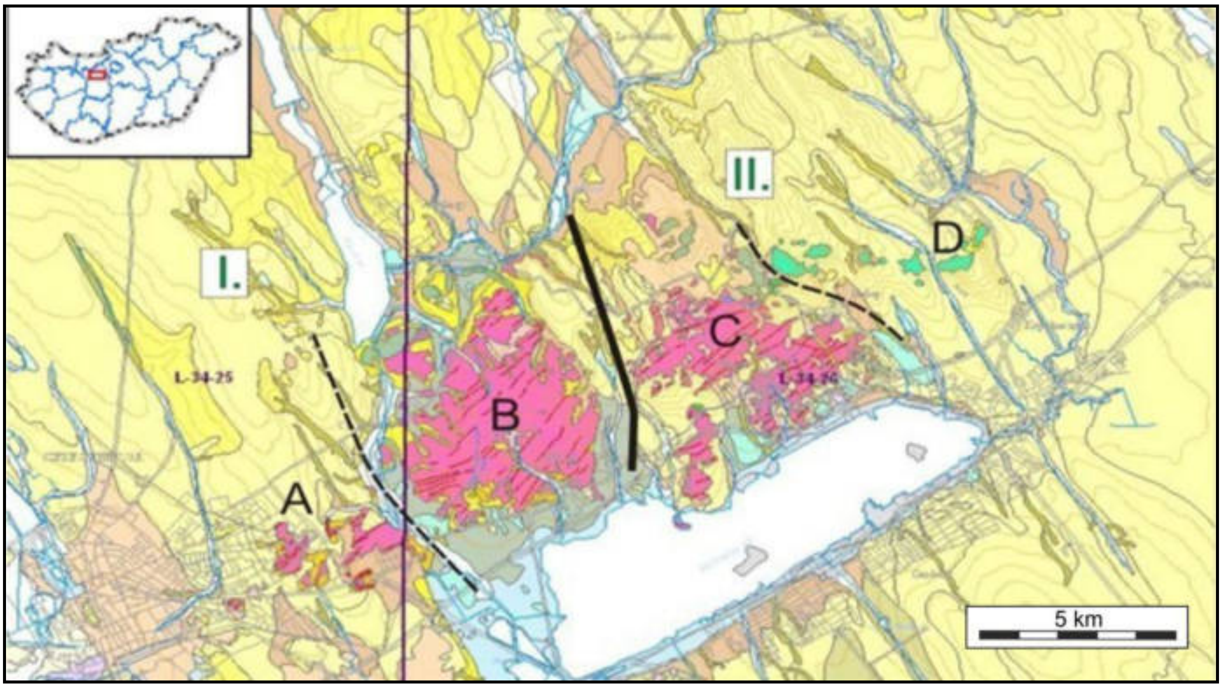

Fig. 2. Geological map of the Velence Hills (source: www.mafi.hu), Symbols: I – West-Velence area, II – East-Velence area, A – Szekesfehervar unit, B – West-Velence unit, C – East-Velence unit, D – Nadap-Pazmand Mountains. Colours – geological outcrops: violet – porphyric granite; pale violet – biotitic granite; green – silicified, argillised andesite; yellow and pale yellow – loess and sandy loess; yellowish green – proluvial-deluvial deposits of ephemeral streams (angular debris, clays and sands); grey – slope (redeposited) and proluvial deposits together (clays, sands and gravels); yellowish grey – epimetamorphic series (argillaceous, silty, sandy slate, lydite with quartz veins and nodules; blue – proluvial deposits (sand); white – water

The disintegration of the granite beneath the surface has lasted for ca. 300 million years. The magma cooling had resulted in three dimensional fracturing, whereas the granite boulders were rounding off, due to the chemical weathering of feldspars and micas. Subsequently, water has removed the decayed and accumulated products of this weathering, called saprolite. The weathering has been selective, the rocks forming dikes are more resistant, therefore the thickness of the saprolite has been very diversified. After the denudation of the saprolite harder heads of dikes appeared at the surface in forms of smaller or bigger groups of balanced and rounded boulders (Fig. 3).

Fig. 3. The Cube Stone in Pakozd (Photo P. Tarsoly)

The residual material filling the fissures and spaces in between the rounded boulders has been gradually removed due to gravitational and erosional processes and empty spaces – cavities, have become accessible as woolsack caves (the term “woolsack” is related to the crags, in which these caves occur, because these crags look like sacks full of wool, devoid of sharp edges). Further widening of the cavities (caves) has proceeded owing to chemical and mechanical weathering (Eszterhás 2009)., e.g. the temperature alteration causing rock surface disintegration (Fig. 4).

Apart from the woolsack caves which are principally *in situ* landforms (occurring in residual rock massifs not displaced, or relatively slightly displaced after the saprolite removal), in the Velence Hills also other, talus type, caves occur. The talus type caves formed owing to gravitational movements of large blocks, often piled up on mountain slopes (Fig. 5).

Fig. 4. The rock shelter of Nadap was formed in between large granite blocks (Photo P. Tarsoly)

Fig. 5. Talus type cave in Mount Polák (Photo P. Tarsoly)

In the Velence Hills 48 caves have been explored up to now. 25 caves (20 woolsack caves and 5 talus type caves) are formed in granite, 15 ones (12 of the talus type) are formed in andesite agglomerates, one cave is formed in quartzite and 7 caves have been recorded in loess, but these last ones represent artificial, anthropogenic cavities, made in the Bronze Age. The longest woolsack cave is 14 m long Zsivány Cave, which is a short, but complex system (Fig. 6). The longest andesite cave is 12 m long Pirofillit-bánya Barlangja (Cave of the Pirophyllite Mine). The total length of the caves and man-made holes in the Velence Hills ranges 277 m: caves in granite – 100 m, caves in andesite – 76 m, anthropogenic cavities in loess – 101 m.

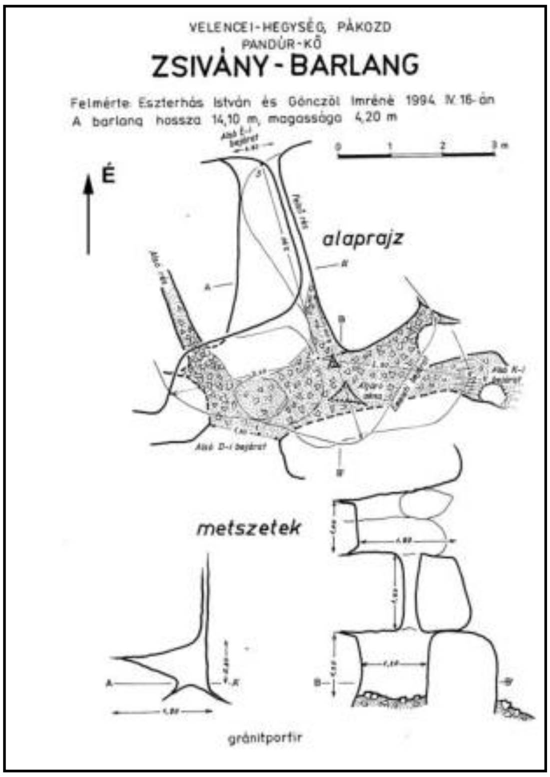

Fig. 6. Map of the Zsivány Cave; important translations: alaprajz – map of the cave, metszetek – cross-section, E – north (mapped by I. Eszterhás and I. Gönczöl, 1994)

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A LITTLE BUT GENETICALLY INTERESTING CAVE IN SILICICLASTIC ROCKS, BRASILIA CITY, BRAZIL

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Brazil covers a huge territory in South America (Fig. 1). Within its boundaries, there are many areas of cave and karst occurrence. According to the national inventory, most of the caves and karst landforms occur in the terrains formed of carbonaceous rocks (54%), whereas only 17% are hosted in siliciclastic-clayey rocks (ICMBio 2020). In this paper we would like to present a modest cave called Volks Clube, located just at the center of Brazil, in its capital, Brasília city and developed in siliciclastic rocks.

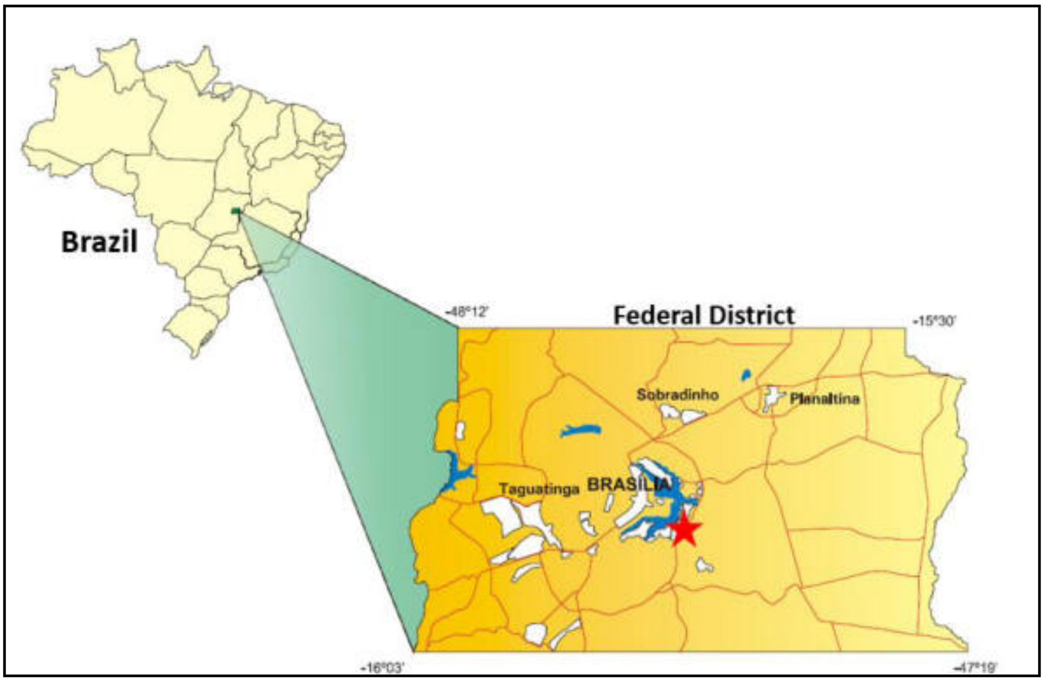

Fig. 1. Location of Volks Clube Cave (red star) in Brasilia city (of a shape resembling an airplane) within the Federal District. White polygons represent urban areas, while blue ones are water bodies (east of Brasilia is the Paranoá Lake) (after Martins et al. 2004, modified)

The Volks Clube cave is located in the urban area of Brasília city. Due to the easy access, the cave is commonly visited by the public, although it does not have any visitor infrastructure or tourism management. The surroundings of the cave are included in the area of nature protection, which aids to the preservation of vegetation cover, comprising Brazilian savanna, so called "Cerrado". The climate is characterized as tropical, with a warm and rainy summer and dry winter.

Regarding the geological context, the cave is formed in siliciclastic rocks of the Paranoá Group, aged Mesoproterozoic Era (1.0 – 1.6 Ga), as part of the external zone of the Brasília fold and thrust belt. These rocks are strongly tectonically deformed, representing various faulting geometries and folding styles with vergence to the east (Fonseca et al. 1995). These rocks present low grade metamorphism (Campos et al. 2013), which means that despite the old age and deformation, the rocks underwent slight transformation. The Paranoá group is composed of different types of meta-sedimentary rocks, such as meta-conglomerates, meta-pelites, meta-marls, meta-arenites and meta-limestones (Fig. 2). These rocks formed in shallow marine environment, and the relative changes of content of the sandy and clayey material were connected with the basin depth variations during the deposition (Campos et al. 2013).

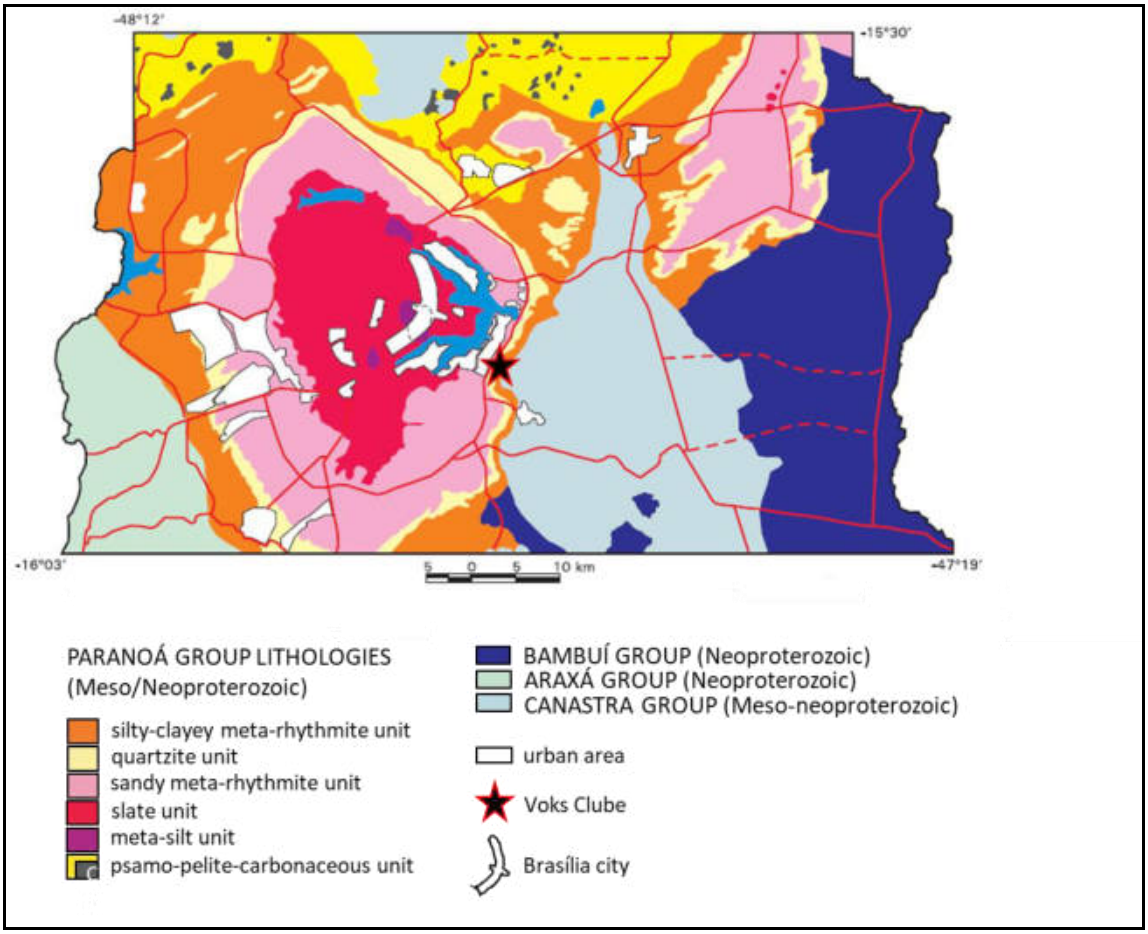

Fig. 2. Simplified geological map of the Federal District; please, notice the structural dome in the center of the map. Carbonates occur only in the north part of the district (gray shading) (after Campos & Freitas Silva 1999, modified).

The Volks Clube cave is formed in a meta-rhythmite unit of a thickness varying from 100 m up to 150 m, composed of regular intercalations of meta-siltstone and meta-claystone, spaced from 1 cm up to 3 cm (Campos 2004). Although the silt-clay fractions prevail, there are also thin layers of fine-grained, pinkish to reddish quartzites. The overall rock appearance in outcrops is very picturesque: layered rocks with colors ranging from a grayish red to light brown of varying tonality in accordance with different weathering intensities (Fig. 3).

Brasília city is located at a high plateau area with an altitude around 1100 m a.s.l. The valleys dissecting the plateau are controlled by the impermeable units, like this silty-clayey meta-rhythmite in which the Volks Clube cave occurs, with small infiltration capacity and larger erosional potential.

The Volks Clube cave is a single conduit of a linear to meandering shape, that was sculpted by the erosional force of an underground water stream (Fig. 4), a tributary of the main Tabocas River. The gallery dips according to the hydraulic gradient of the stream that formed the cave (Fig. 5D). There are two entrances to the cave: the main, upper entrance (Fig. 6), where the superficial stream is captured (sinking stream) and the second, lower one, where the same stream leaves the cave so as to flow again on the ground surface (resurgence – Fig. 5B). Both side walls of the conduit are tilted in the direction of the central channel carved by the water, therefore the walking down the gallery occurs mainly next to the waterbed. It is a short cave (in relation to many others being subjects of exploration) of a length reaching 82 m. Nevertheless, it might be significant considering river erosion of siliciclastic, non-permeable rocks, such as these forming the Volks Clube cave.

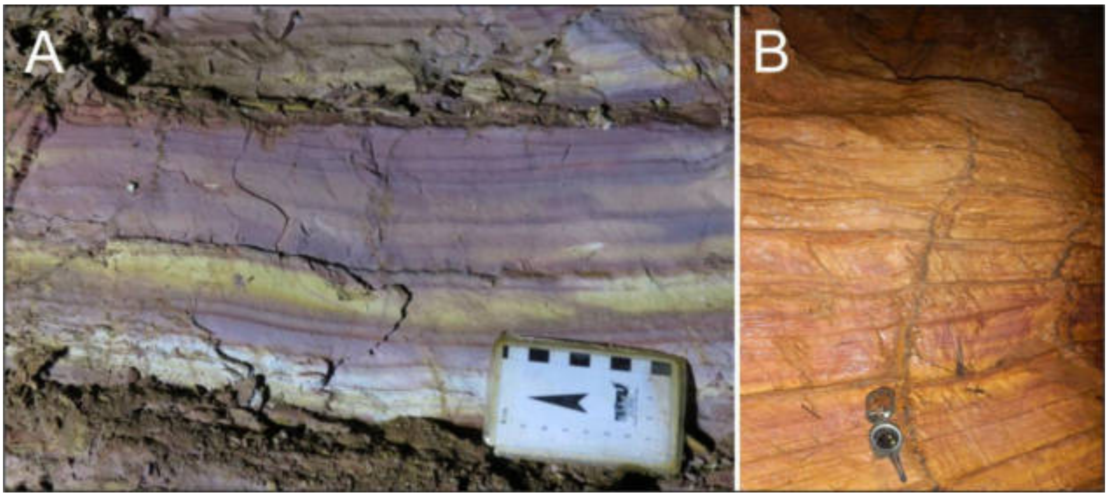

Fig. 3. Close views of the cave wall. A – the lamination of siltstone-claystone rhythmite, marked by the color differentiation from purple and grayish red, to occasional pale orange (centimeter scale at the bottom right) (Photo C. Stumpf). B – the vein crossing the rock layers (Brunton compass as a scale) (Photo T. Ribeiro)

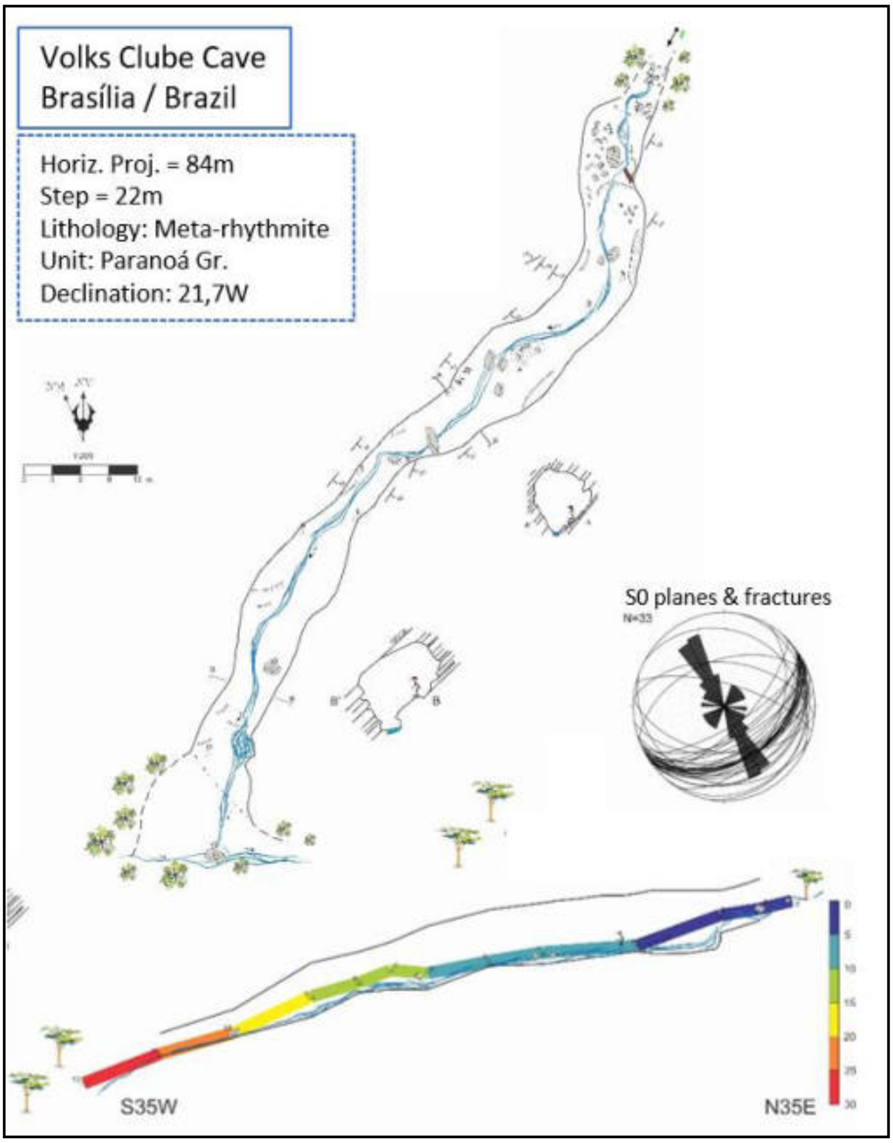

Fig. 4. Map and longitudinal cross-section of the Volks Clube cave (after Stumpf & Ribeiro, 2019, modified)

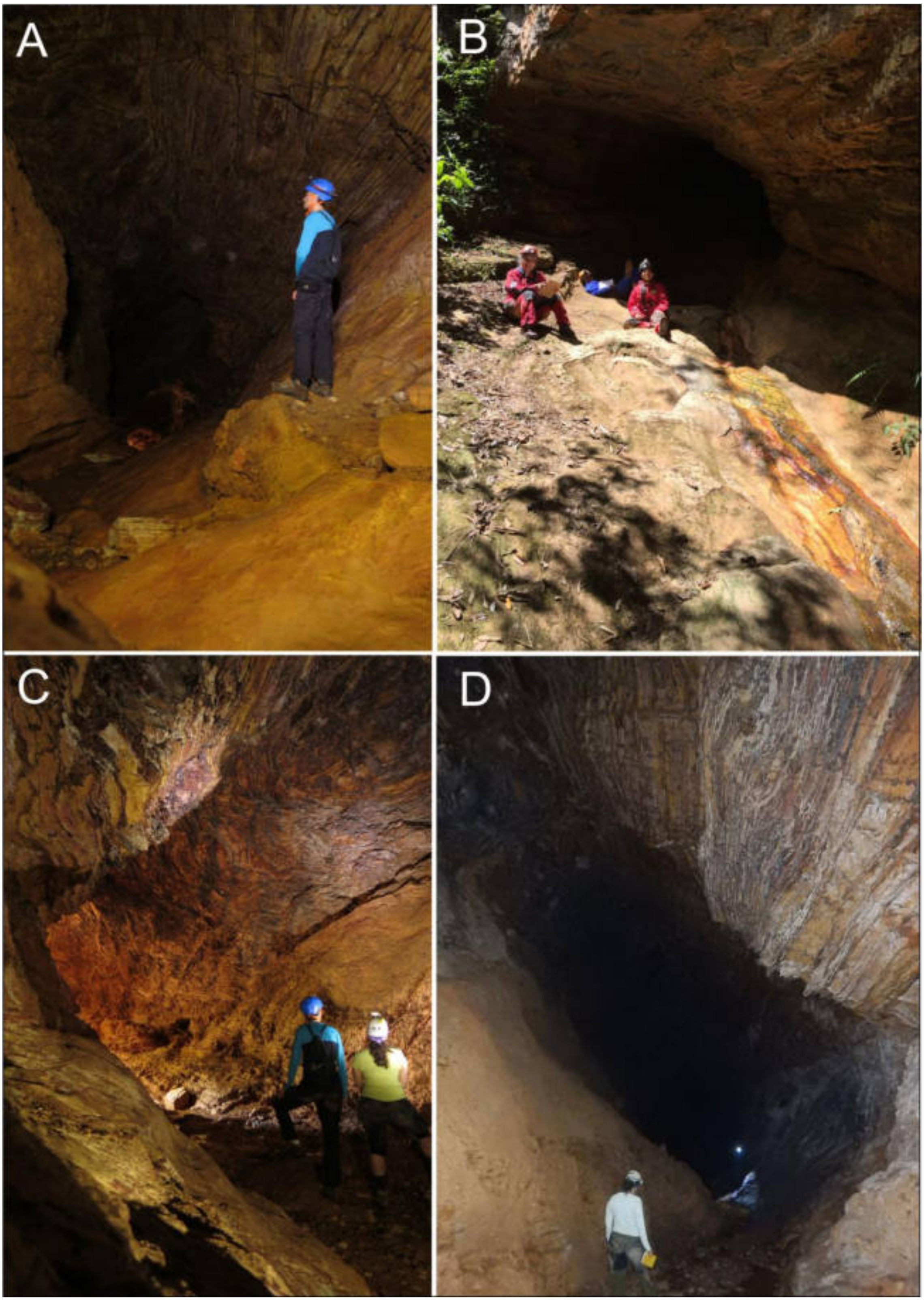

Fig. 5A. Volks Clube cave. A – conduit, the light at its end is the second, lower entrance of the cave (Photo C. Stumpf). B – second, lower cave entrance – resurgence; streambed is visible on the right side of the picture (Photo C. Stumpf). C – View toward the upper entrance on the left side (Photo C. Stumpf). D – close to the upper entrance, view toward the inner part of the cave: the streambed is partly covered by pebbles (Photo T. Ribeiro)

It is accurately documented that structural geology plays an important role in the morphological control and development of caves, mainly in non-carbonaceous rocks (Zatorski 2014). Therefore, we performed an expedition to search for evidences proving the structural control of the Volks Clube cave, and we could observe some interesting structures. The cave entrance was developed in a fold axial zone (Fig. 6A). Clearly exposed parasitic folds in the NW limb of the main fold, constitute a part of cave celling and wall (Fig. 6B). The parasitic folds have axial planes parallel to the main fold orientation.

Fig. 6. First, upper entrance of Volks Clube cave. A – the fold axis in the ceiling and both its limbs in the walls; that evidence a strong control of rock structure on the entrance morphology (Photo C. Stumpf). B – parasitic folds in the ceiling (Photo V. Carneiro)

Close to the main entrance, the cave morphology seems to be related to the fold shape, but just a bit further downstream, the gallery drifts apart from the fold axial zone, and starts to follow the bedding, with mean inclination by 40° to the southeast. Consequently, the average conduit direction is N35E-S35W, parallel to the strike of bedding planes.

Numerous fractures have the preferential direction NW-SE and dip towards NE and SW, as is shown in the stereogram and rose diagram (Fig. 4). These fractures are dispersed in rocks around the cave, but they seem not to have influenced the speleogenesis, since they are principally not concordant to cave elongation and shape, and are mainly sealed, often filled with quartz (as shown on Fig. 3B). From the analysis of fractures, we could calculate the directions of strain tensors: $\sigma 1$ = 17/331, $\sigma 2$ = 68/190 and $\sigma 3$ = 13/061. Summarizing, the rock layers in this fold limb, as well as some fold axial planes, dips to southeast parallel to $\sigma 1$ vector. The quartz veins are also parallel to $\sigma 1$ and perpendicular to $\sigma 3$, suggesting that this joint set represents filled tension joints.

A few sites of speleothems occurrence have been recorded. The speleothems are coralloids, occurring mainly close to the upper entrance, possibly due to higher evaporation effects (Fig. 7). The coralloids developed following the bedding planes, where fluids percolate easier. The cave stream, even with low flow, has a high hydraulic energy, sufficient for the effective transport of sediments that are washed out the cave through the lower entrance (resurgence). Hence, the cave is almost free of detrital sediments, with walls and floor formed of exposed and slippery rocks.

Fig. 7. Coralloid speleothems near the upper entrance. Their occurrence partly reflects the pattern of layers forming a kink fold on cave wall (the scale up-right – ca. 5 cm) (Photo C. Stumpf)

The ground relief in the vicinity of the stream from its spring to the cave entrance is smooth with a topographic gradient of 11 cm/m. In the satellite image, it is possible to observe its original prolongation – generally straight channel that poured into the main Taboca River (light green line on Fig. 8). However, the cave development caused the capturing the stream due to much higher hydraulic gradient toward the main river ranging 26 cm/m. The original (former) channel starting from the cave upper entrance, is now dry, and it works mostly canalizing water during heavy rain episodes (Fig. 8). The water flow into the cave is probably the main factor that led to the drying of the original channel. However, a dam constructed above the slope (NW of the stream) might have potentially reduced the surface water recharge of the stream in this stretch (Fig. 8).

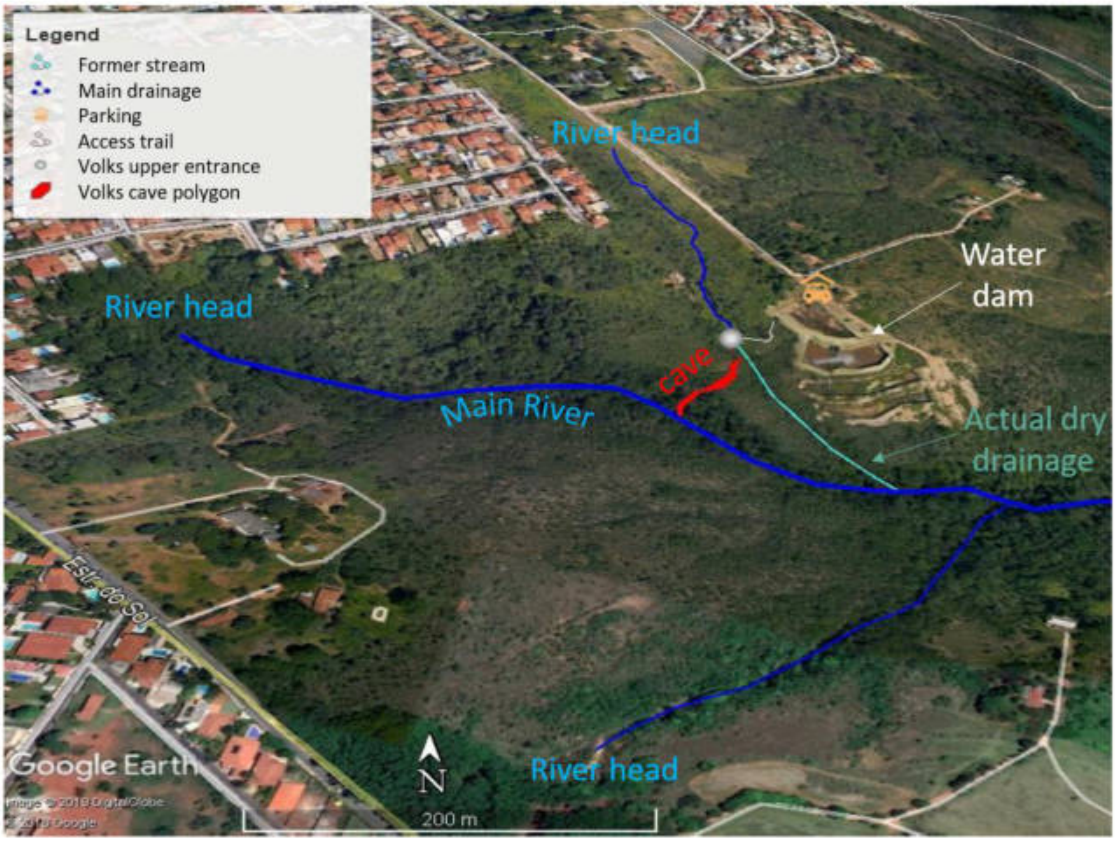

Fig. 8: Satellite image showing the area of the main Taboca River and its tributaries (blue lines) as well as the Volks Clube cave (red line) and a dry, former/original channel of the stream currently flowing through the cave (light green line)

The case of Volks Clube cave confirms the thesis that speleogenesis is controlled by geological structures and ground morphology. Possibly the water (and subsequent fluvial) erosion has acted most intensively within the weakened zone of the fold hinge line and then along discontinuities of bedding planes, secondary also on fracture planes. The fluvial erosion has sculped the cave floor as a streambed. The considerable inclination of the cave conduit imprint energy to the water course, increasing the erosion efficiency. The natural instability of the fractured rock layers might have played an important role in the gallery enlargement due to rock falls.

It is very important that this small, simple cave is located within an area of environmental protection, which allows human occupation and sustainable use of the resources. This natural zone is surrounded by residential area, and may suffer pressure from the urban infrastructure and markets. A symbol of modernism architecture, Brasília city, was built in 60s to be the capital of the country. It was projected by the famous Brazilian architect Oscar Niemyer and the urbanist Lucio Costa, and declared humanity patrimonial by UNESCO in 1987. The new capital induced significant and fast development of this region, previously low populated, and increased the need of infrastructure and residence expansion for the growing population. Therefore, the areas around the center of Brasília are being intensively urbanized, as it is in the case of the area surrounding Volks Clube cave.

An important point that comes out with increasing population is the preservation of the water resources, indispensable for communities to survive and thrive. It is fundamental to preserve the native vegetation that surround the cave and the heads of the water streams/rivers, as well as in its margins, avoiding erosion and siltation of surface waters. In Brasília, the surface water and subsurface aquifers must be preserved. These aquifers present low capacity of water reservation (Campos 2004). Another important feature that must be observed and cared is the water contamination. High hydraulic conductivity in fissure type aquifers may spread contaminants very fast. The sanitary protection of the residences around the cave need to be taken seriously. The inadequate occupation of the land and watershed impacts directly not only the environment, but also the society that depend on the resource, as well. It is required to preserve and manage this cave properly to attain sustainability of the city development.

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THE ENCHANTED ROCK

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The Enchanted Rock granite mountain locates in the Llano Uplift about 27 km north of Fredericksburg, Texas, United States (Fig. 1). The State Natural Area is known for its massive granite dome, interesting rock formations, and the Enchanted Rock Cave.

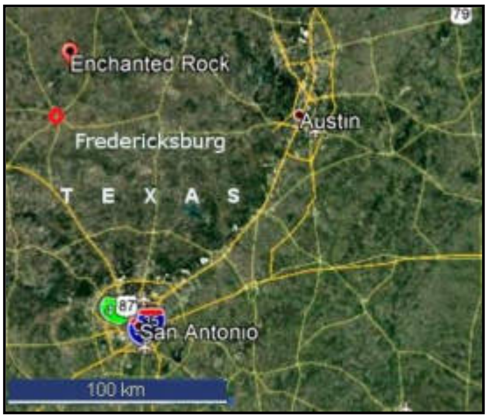


Fig. 1. Location of the Enchanted Rock

Upon arrival to the park, the first thing to notice is the large dome of pink-hued granite rising 130 m from the plain. The prominent granite dome is visible for long distance from the Llano Uplift surrounding it (Figs. 1 and 2). The weathered dome, standing above the surrounding area, is recognised by geologists as a monadnock. The rock is actually the visible above-ground part of a segmented ridge, being the surface expression of a large igneous batholith of the middle Precambrian age, formed about 1080 million years ago. The granite that intruded into earlier metamorphic schists, was gradually exposed by uplifting and erosion through the geologic ages. The Enchanted Rock acquired its dome shape through a process of "exfoliation" that occurs when natural heating and cooling processes cause the granite to flake off in thin, curving layers (Fig. 4). However, other forms of weathering are also observed (Fig. 5).

Fig. 2. The Enchanted Rock (Photo G. Szentes)

Fig. 3. View from the summit (Photo G. Szentes)

Fig. 4. Near the summit; lighter stains on the ground surface mark places of recent exfoliation (Photo G. Szentes)

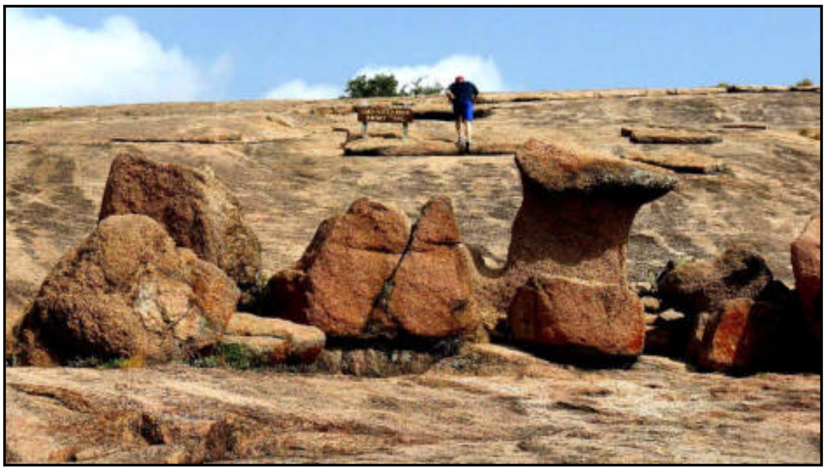


Fig. 5. Rock Summit Trail; forms of granite weathering (Photo G. Szentes)

The name "Enchanted Rock" comes from an interpretation of Native American folklore and tradition. Indians also believed the Rock to be enchanted because of the eerie sounds emitting from the huge dome at night. The sounds at night have most often been heard after a hot day. Geologists accredit this peculiarity of sound to changes in the temperature of the rock. A cool night following a hot day causes the granite to expand and contract, thereby emitting a creaking sound.

A fascinating feature are the small pools of water present in depressions on the rock. The pools also have miniature bogs. In the bogs tiny species of quillwort develop, a vascular spore-bearing plant distantly related to ferns and found nowhere else in the world (Fig. 6).

Fig. 6. Miniature bogs in small pool on the granite surface (Photo G. Szentes)

The rock contains the roughly 450 m long Enchanted Rock Cave, one of the longest granite talus caves in the world. To reach the cave one needs to ascend the granite dome following the Rock Summit Trail up to the dome's peak at the elevation of 560 m a.s.l. There is the cave (Fig. 7).

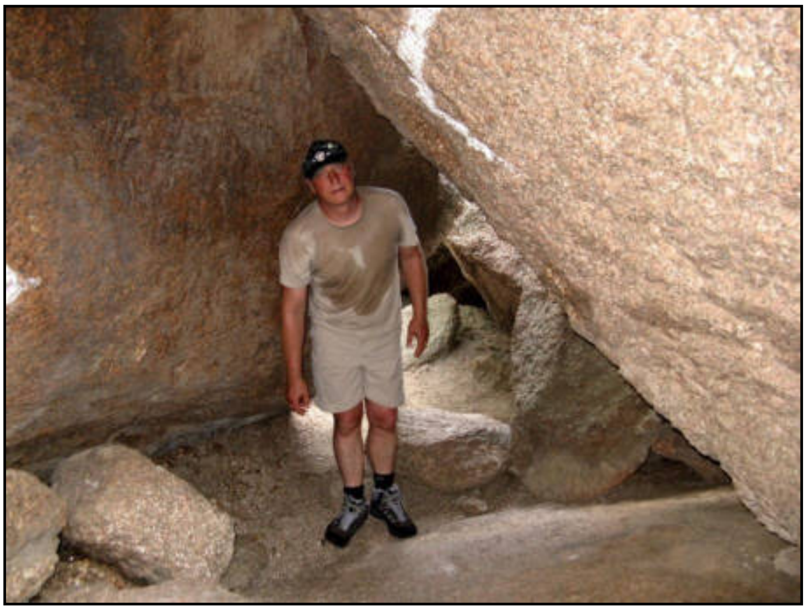
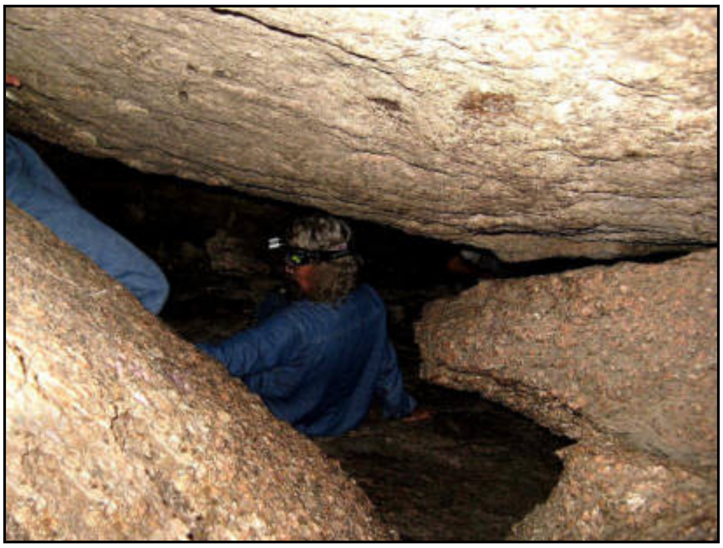


Fig. 7. Enchanted Rock Cave, entrance zone (Photo G. Szentes)

The Enchanted Rock Cave is a talus cave, formed by boulders falling into a ravine but leaving a space underneath big enough to access. After crouching to get through the entrance, there is ample light and plenty of space to maneuver in. The first room empties out into part of the ravine that is open with no rocks overhead. Downward passages are formed

Fig. 8. Enchanted Rock Cave: descending into the deeper section (Photo G. Szentes)



among the accumulation of boulders. Instead of an underground water stream, stalactites and flowstones, this cave is a labyrinth through a pile of large chunks of broken rocks (Figs. 8, 9, 10). Warming and cooling of the granite caused fracturing of the bedrock. Some chunks are as big as buildings and the boulders are jammed in over that no light manages to get down to these deep part of the cave.

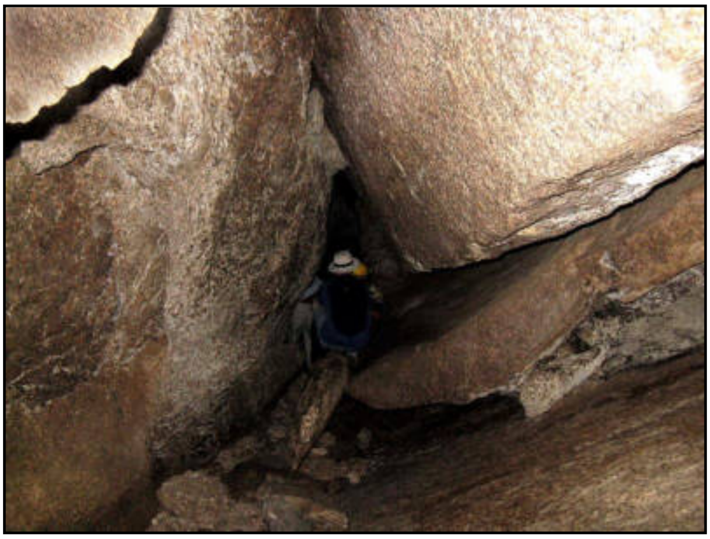
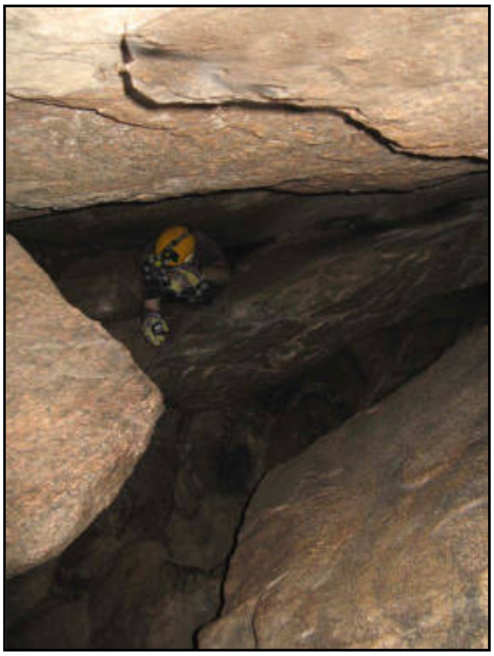


Fig. 9. Enchanted Rock Cave, space among the huge granite boulders (Photo G. Szentes)

Fig. 10. Enchanted Rock Cave, among the granite boulders (Photo G. Szentes)



MYTHS AND REALITY ABOUT PSEUDOKARST CAVES IN THE RIDGE OF MT. RADHOŠŤ (CZECH REPUBLIC)

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Something from mythical history

The mountain ridges of the Moravian-Silesian Beskydy and Silesian Beskydy Mountains in the Outer Western Carpathians (Czech Republic, Fig. 1) are made up of sandstone and claystone of Mesozoic and Paleogene flysch. They are known for their cave systems and surface geomorphological features, which are not related to classical karst processes. The formation of caves is conditioned by deep slope gravitational processes. The hard layers of the Godula sandstones alternate with the soft layers of claystone, which act as sliding surfaces during the formation of cleft spaces.

Fig. 1. Oblique airborne photo of Mt. Radhošť eastern part and Pustevny, with the summit peaks of Moravskoslezské Beskydy Mts.: Mt. Čertův mlýn, Mt. Kněhyně, Mt. Smrk and Mt. Lysá hora in the background (Photo I. Baroň, Map: ČUZK)

The history of discovering caves in the ridge of Mt. Radhošť in the centre of the mountain chain is connected with the history of the settlement of the Beskydy Mountains and the interest of the first inhabitants of these mountains in the mysterious underground. The first documented information about the caves in this part of the Western Carpathians contained myths and legends about "mysterious holes" in the ridges and peaks and came from the first Slavic inhabitants. Mt. Radhošť's elongated ridge attracted the most attention (Fig. 1). It got its name from the ancient Slavic god of war Radegast, whose statue, according to the legend, stood on the ridge of Mt. Radhošť (Fig. 2).

Fig. 2. The god Radegast statue on Mt. Radhošť (Photo J. Wagner)

The legend says that in Starý Radhošť saddle, there was a cave in the depths under the idol Radgost's, in which the gods gathered. On the day of the summer solstice, pagan gods came into this Slavic sacristy from the underground and answered questions to ordinary mortals.

According to the legend, similar underground spaces also stretched under the mythical castle, which according to folklore stood on Mt. Radhošť. The ridge has also become a sacred place for the newly coming inhabitants of the Beskydy Mountains – the Wallachians, whose colonization dates back to the beginning of the 15th century. Legends in various variations circulated among the old Wallachians about the Radhošť underground and its treasures. The heart of the mountain is described in them as a huge, deep cave, in the middle of which a clear stream flows. A stone footbridge leads across the stream, a huge dog or dragon sits on it and guards the treasures. There is also a well-known legend about an orphan who got into the interior of the mountain and from there took home a golden roof.

According to oral tradition, at the beginning of the last century, there were still living some people who often passed through the corridors inside Mt. Radhošť (Fig. 3), which were so wide that a loaded cart pulled by two horses from one side of the mountain to the other would pass them.

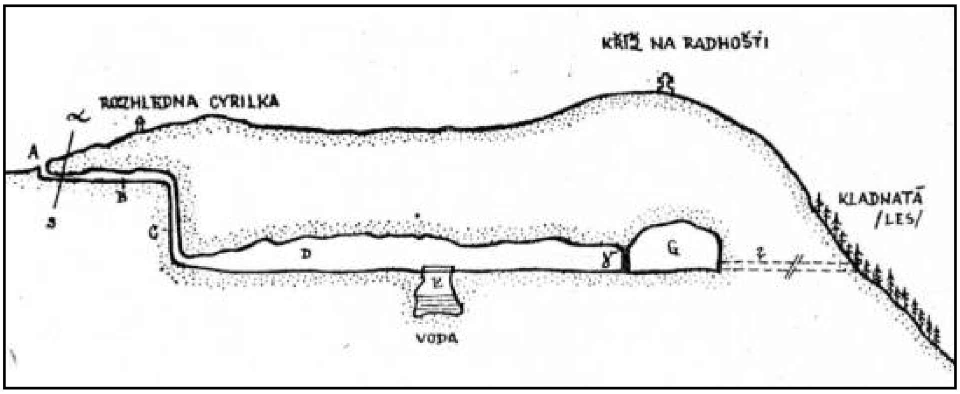

Fig. 3. Idealised sketch of the caves in Mt. Radhošť (by Přikryl 1895 in Wagner et al. 1990).

The Pustevny settlement is the most prominent touristic part of the ridge of Mt. Radhošť. Originally, only the bell tower and the hermit's abode stood in the Pustevny, and not far from it lies the entrance to the Cyrilka Cave, the longest cave in the Moravian-Silesian Beskydy (Figs. 4 and 5).

Fig. 4. Part of the Old Chamber in Cyrilka Cave (Photo J. Wagner)

Facts about the discovery of the Cyrilka Cave in reality

Probably the greatest attention and interest of researchers attracted the caves in Mt. Radhošť after 1755, when a map by Vratislav of Monse was published. The original of this plan was allegedly deposited in the František Museum in Brno. However, the original drawing by Vratislav of Monse disappeared from the manuscript and therefore, some researchers believe that the copy was a forgery and that Vratislav of Monse never visited the Radhošť underground.

Fig. 5. Hibernating Lesser Horseshoe Bats (Rhinolophus hipposideros) in Cyrilka Cave (Photo J. Wagner)

However, it is interesting that the Beskydy writer and historian B. Strnadel-Četyna compared the location of old huts on the ridge of Mt. Radhošť with their location on the map of Vratislav of Monse and came to the conclusion that they were identical. This can be explained by the fact that pastoralists actually used the underground space to store dairy products.

Another manuscript dealing with the underground of Mt. Radhošť dates back to 1830 and it is the so-called "Osmerka Book" by Jan Šebesta, who describes the serching of a treasure in Mt. Radhošť. There were described the paths for treasures underground, but also the inscriptions carved into the walls of the underground spaces, all written in the local Lašský dialect. It is interesting that the more modern descriptions of the cave coincide in many aspects with the descriptions in the legends, in which a bridge over a watercourse or a black dog guarding the treasure is always added. However, the real basis therefore seems to have existed.

Members of the ORCUS Speleological Club, who continue the exploration and documentation of the pseudokarst caves in these mountains and monitoring of hibernating bats (Fig. 5), have been dealing intensively with the systematic research on the ridge of Mt. Radhošť since 1969. During several years of exploration at the end points of the system, in 1976 they managed to penetrate into hitherto unknown parts of the cave, called the "New Part". The length of the cave was thus extended by 210 m to a total length of 375 m (Figs. 6 and 7).

Fig. 6. Character of the Cyrilka Cave interior controlled by the gravitational cleft opening (Photo J. Wagner)

During the new mapping of this cave in 2011 (Fig. 8), other cleft passages of Cyrilka Cave were discovered. The total length of the cave is now 552 m (Lenart et al. 2018). Cyrilka Cave is the second longest pseudo-karst cave in the Czech Republic just after Teplická Cave 1,065 m long.

Fig. 7. Exploration of Cyrilka Cave is associated with high risk of rockfall of unstable boulders and blocks (Photo J. Wagner)

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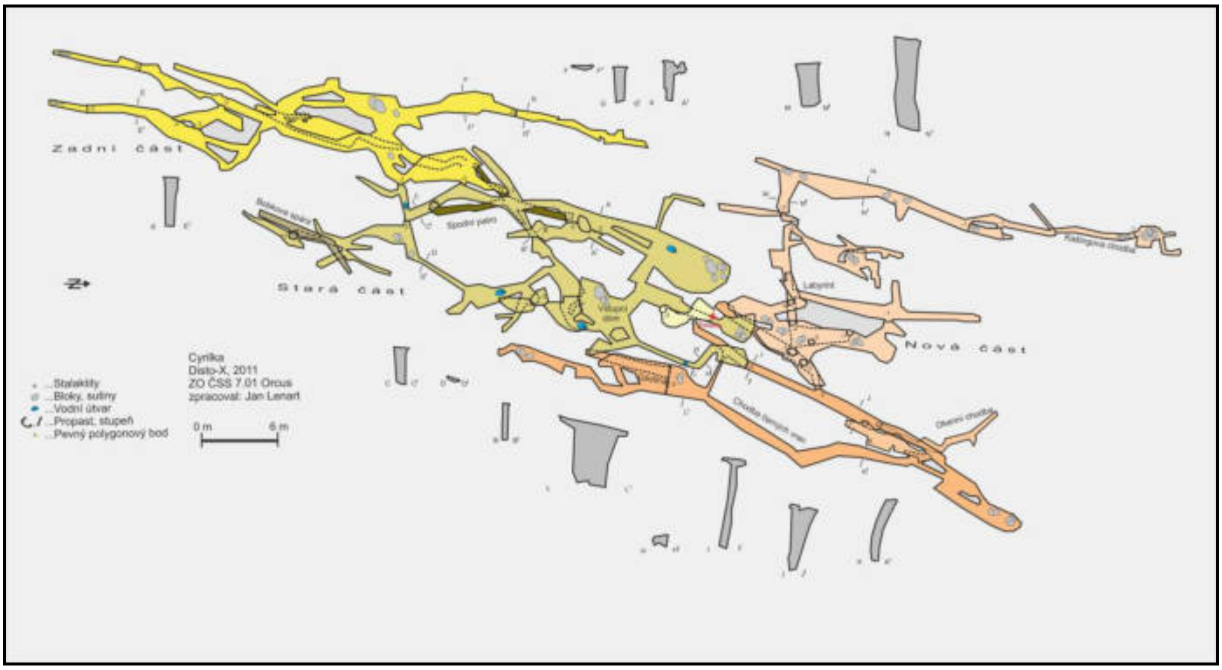
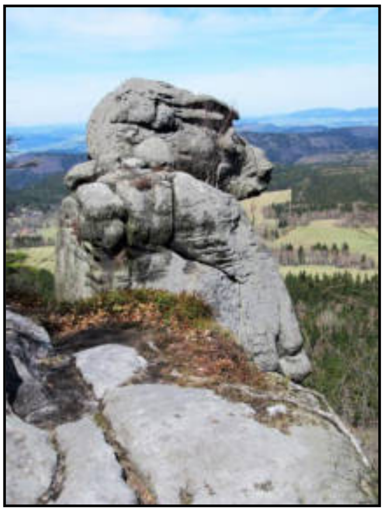
Fig 8. Speleological map of Cyrilka Cave (after Lenart et al. 2018)





14th INTERNATIONAL SYMPOSIUM ON PSEUDOKARST SUDETES, SOUTHWESTERN POLAND

Announcement

It is a pleasure to announce that the 14th International Symposium on Pseudokarst will be held on **22-26th May 2023** in the Sudety Mountains, southwestern Poland. The main conference venue will be in the village of **Karłów** (the Centre of Training and Education of the Stołowe Mountains National Park https://www.pngs.com.pl/pl/turystyka/euryst11.html) in the central part of the **Stołowe Mountains sandstone tableland**. However, online participation in the scientific sessions (23-24th May) will be also possible.

Field sessions will comprise of local geosites (including the mesa of Mt Szczeliniec Wielki and the Skalniak plateau), as well as excursions to the Broumov Highland, Czechia, and granite caves of the Western Sudetes.

A guidebook and abstract volume will be provided for participants during the Symposium meeting. The geomorphological and geological materials presented during the scientific sessions can be published in the volume of Studia Quaternaria (http://www.studia.quaternaria.pan.pl/) after normal reviewing procedure.

More detailed programme will be provided in the 1st Circular, which will be distributed in the autumn 2022 as well as at the Symposium webpage: 14pseudokarst.wonders4you.com.

During the Symposium in 2023 the meeting of the UIS Pseudokarst Commission will be held, however the online **meeting of the Commission** preceding the 18th International Congress of Speleology is planned in the mid of June 2022.

Photo K. Jancewicz

IN MEMORIAM

ISTVÁN ESZTERHÁS

(1941 – 2020)

István Eszterhás, the **Honorary President of the UIS Pseudokarst Commission**, died on 2nd August 2020.

Born in January 1941 in the historical Hungarian town of Eger, István graduated from the Földes Ferenc Secondary School in the city of Miskolc. He studied at the University of Eger where he got a teaching degree in biology, geography, and art. Then, for the first three years, he was employed as a teacher in the village of Jósvafő, the central settlement of the Aggtelek Karst Mountains. and the following 34 years, until 2001, in the Transdanubian village Isztimér. As an autodidact he gained substantial knowledge in volcanology, speleology, nature conservation and cartography.

He started his caving activity in the 1960s, mainly by exploring and surveying local limestone caves in the Aggtelek Mountains and the Transdanubian karst regions. In the vicinity of his home village in the Bakony Mountains, he visited and explored 58 caves, among which was the protected and spectacular Alba Regia Cave. He conducted bio-speleological studies over 5 years and collected and catalogued 225 species from the cave, including a completely new species.

Beside speleology he dealt with etymology of topographic names and editing various maps and guidebooks. He assisted in shooting a documentary nature movie for Hungarian television on the Bakony Mountains and Alba Regia Cave.

In 1983 he turned his attention to the pseudokarst and non-karst caves in Hungary and soon became a leader of the Volcanospeleological Collective of the Hungarian Speleological Society, an organisation with 15 permanent members, who are occasionally assisted by some other cavers. Every summer he organised exploration camps in the non-karst regions of Hungary in order to explore and document new caves. Participating in these camps, he introduced numerous young cavers to pseudokarst phenomena, as well as the geology and geomorphology of the region. Participants of these camps have listed and surveyed 1,246 non-karst caves; in 40 of these caves they discovered nearly 1000 m of new passages.

István studied the development of non-karst caves and determined new genetic types, such as consequence caves, holes formed by alkaline solution, and fumarole cavities. He also found and described types of speleothems previously unknown in Hungary, such as siliceous stalactites and hisingerite discs.

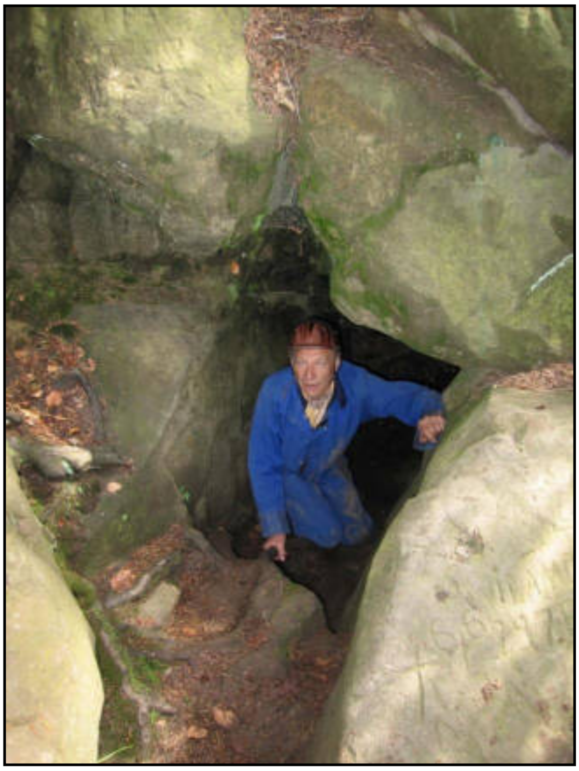
István's opening speeches during the 9th International Symposium of Pseudokarst in Bartkowa, Poland, 2006 (left), and the 10th International Symposium of Pseudokarst, in Gorizia, Italy, 2008 (right)

He solved the problem of ice development in low elevation basalt caves and has classified ca. 200 species of animals and 18 species of fungi.

He and his colleagues edited the Cadastre of Non-karst Caves of Hungary, which is a recapitulation of many years of research. The Cadastre website presents the details of 1,246 non-karst caves in 20 regions. It can be visited using a link: http://nonkarstic.geo.info.hu.

István's speleological activity was not limited to Hungary. He studied lava caves in Tenerife and Iceland and was invited as an expert to investigate a cave opened by basalt quarrying in Ortenberg, Germany. He also helped to complete the cave cadastre of the Burgenland, the easternmost province of Austria.

István was also active in several speleological organisations. He was a member of the Committee of the Hungarian Speleological Society. Moreover, he was one of the founding members of the UIS Pseudokarst Commission and its President between 1997-2008. Since 2008 he was the Honorary President of this Commission. He gave lectures at the Pseudokarst symposia in Hungary, Slovakia, Poland, Italy, Germany and Spain, as well as the International Granite Cave Symposium. He organized the 6th International Symposium on Pseudokarst in Galyatető, Hungary.



Istvan in the entrance of Diabla Dziura (Devil Hole, Polish Carpathians, Ciężkowice Foothills), during the excursion of the 9th Symposium in Bartkowa, 2006.

Four volumes of books and 130 professional papers relating results of his research have been published in Hungarian, English and German, and he co-authored five books. Between 1998 and 2009 he was the editor-in-chief of the bilingual Pseudokarst Newsletter (Newsletter/Nachrichtenbrief of the UIS Pseudokarst Commission).

In 1984 he was awarded with the title “Excellent Educationist”. For his research in the field of speleology, the Hungarian Speleological Society awarded him the “Vas Imre Medal” in 1999 and the “Kadic Ottokar Medal” in 2010.

Istvan is measuring a temperature in a sandstone cave in Hungary

Since 2000 he was a member of the famous Explorers Club, based in New York City, and in 2002 he received the “21st Century Outstanding Scientist” and the “Top 1,000 Outstanding Scientist” recognition and plaque from the International Biographical Centre in Cambridge.

István was married to his wife, Babika, for 56 years, and had a daughter Emőke.

We lost an active and professional speleologist and a good friend.

George Szentes

Istvan in a discussion before a field survey

IN MEMORIAM

NILS-AXEL MÖRNER
(1938 – 2020)

Nils Axel ("Niklas") Mörner was a head of the Department of Paleogeophysics and Geodynamics at Stockholm University 1991 until 2005, when he retired. Between 1981 and 1989 he was the chairman of INQUA Neotectonic Commission, and in 1999-2003 he was active in the INQUA Sea-level Commission. He had a very broad knowledge and engagement which also included pseudokarst. As a collaborator of the Pseudokarst Commision he, in 2011, co-arranged the 2nd Granite Cave Conference in Sweden with a 4 day long excursion along the northern Swedish Coast. On the spot he made it impressively clear to the international participants how postglacial tectonics – caused by isostasy – has created or overformed many of the tremendous granite caves in Sweden.

He published some 700 papers in a variety of topics *(see UIS Bulletin, 62(2): 27-28, 2020)*. As a scientist he was active until the very last days of his life. On the 16th October 2020 he passed away after a very short illness. He leaves an empty space which will never be filled.

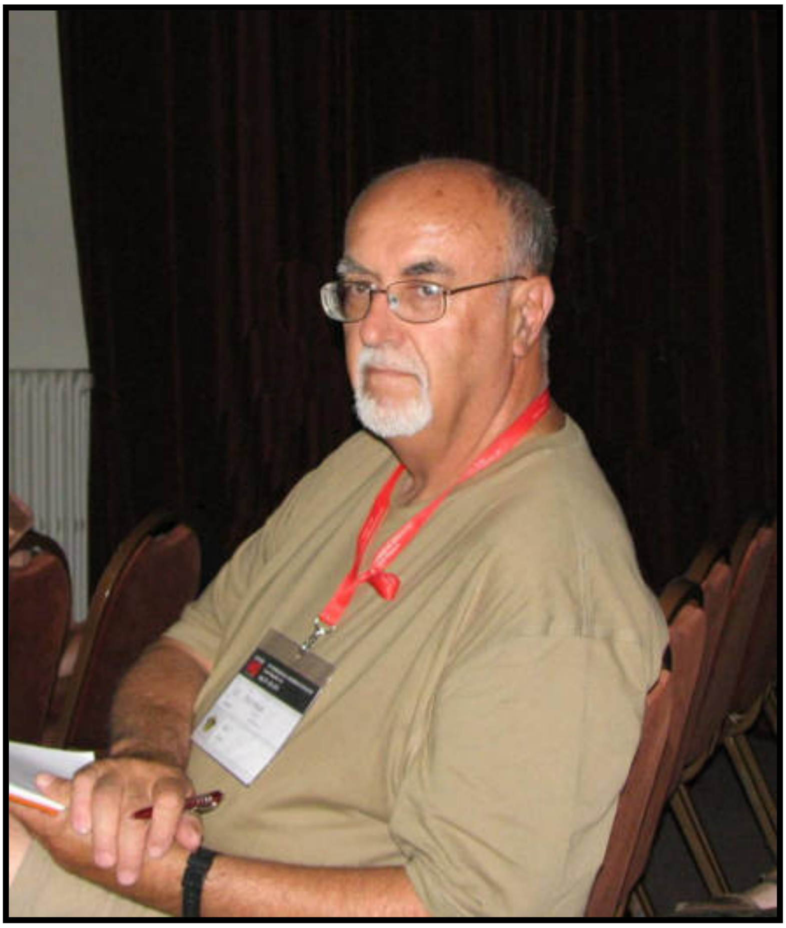
Rabbe Sjöberg

Niklas above Boda Cave, Sweden (2011) at a rock most probably displaced by earthquakes (Photo R. Pavuza)

IN MEMORIAM

ERICH KNUST

(1947 – 2021)



Erich Knust – for half of a century head of the Karlsruhe Caving Club (Germany) – was not interested only in "classical" caves, but in all subsurface environments (like mines, cellars, water supplies, etc.) and, naturally, all forms of pseudokarst. He was a member of the UIS Pseudokarst Commission from its beginning and attended several Pseudokarst-Symposia – for instance the 3rd Symposium in Königstein, 1988 (former DDR), where he had a paper about peculiar tubular caves in south-west Germany. More recently many of us met him at the so-far last Pseudokarst-Symposium in Kuncice in 2015. He made also contributions to the Pseudokarst Commission Newsletter issues. We will remember his calm, imperturbable attitude and good manners adequate for a gentleman.

The German speleological community has lost one of its most active members, who was in charge of the cave inventory of the province of the Rhineland-Palatinate. Furthermore he coordinated the German cadastre of dolines.

Rudolf Pavuza

Editorial note

As you have noticed in this issue of the Newsletter, we have decided to continue the issuing without a German translation of the papers. The translation into German claimed a significant workload of the editorial team and raised the costs of the more extensive printed issue and the mailing. Since several years there is no financial support from the UIS Bureau for producing and mailing printed materials – an understandable, nevertheless adverse fact that we have to take into account.

As for the current issue we have to refrain from mailing the printed version of the newsletter at the moment as there are certain postal restrictions concerning many countries due to the current pandemia and other problematic and tragic issues. Nevertheless some printed copies will be available at the upcoming symposium.

Moreover we have to consider the future of the newsletter. Do we want to continue in the current mode and who will be in charge of it ? Or do we prefer something like a "pseudokarst-blog" with the possibility to contribute for all members of the commission permanently (papers, reports, news, thoughts)?

Naturally, the next symposium would be the best auditorium to discuss these (and many other) topics concerning the organisation, work and efficiency of the commission. This will occur in 2023 hopefully – on the spot and online. The adequate opportunity for recapitulation of the Commission activities, among which is also edition of the Pseudokarst Commission Newsletter will be the online meeting of the Commission planned in the mid of June 2022. We therefore encourage all members of the Pseudokarst Commission to prepare their ideas concerning the addressed topics for the upcoming event.

Rudolf Pavuza, Jan Urban