International Union of Speleology

PSEUDOKARST COMMISSION NEWSLETTER

32

International Union of Speleology

PSEUDOKARST COMMISSION

NEWSLETTER

No. 32.

June, 2025

Editors: **Jan Urban, Rudolf Pavuza**

Mail-address: Institute of Nature Conservation PAS,
Al. A. Mickiewicza 33, 31-120 Kraków, Poland

Homepage address: http://www.pseudokarst.com

19. INTERNATIONAL CONGRESS OF SPELEOLOGY

Kraków – Wien

FRONT COVER: Entrance of Macacos Cave, developed in sandstones of the Botucatu Formation, Paraná Basin, Municipality of Ipeúna, State of São Paulo, Brazil (photo C. Stumpf).

BACK COVER: Bat Cave, Pilchers Mountain near Newcastle, New South Wales, Australia (photo Garry K. Smith).

Correspondence addresses:
Jan Urban, Institute of Nature Conservation PAS, al. A Mickiewicza 33, 31-120, Kraków, Poland;
e-mail: urban@iop.krakow.pl
Rudolf Pavuza, Karst & Caves Research Unit, Museum of Natural History, Vienna, Museumsplatz 1/10, 1070 Vienna,
e-mail: rudolf.pavuza@nhm.at

Contents:

page

CAVES IN HARD SILICIFIED ROCKS: AN EXAMPLE FROM BRAZIL

Cintia F. Stumpf, Tulio Gabriel R. Ribeiro, Paola B. Ferreira

Institute of Geosciences, University of Brasília, Brazil (IG-UNB), e-mail: cintia.stumpf@gmail.com

1. Introduction

Caves can develop in a variety of rock types. In addition to traditional karst environments, caves are known to form in sandstones (Aubrecht et al. 2011), quartzites (Sauro et al. 2013), granites (Vidal-Romani et al. 2010), volcanic rocks (Miller et al. 2015), and others. However, caves in hard siliceous rocks, such as chert or silcretes, are far less common due to the rock's low potential for dissolution and disaggregation.

In Brazil, a specific environmental legislation applies to cave environments. The physical characteristics of a cave, such as unique host rocks, minerals, speleothems, or sediments, may oblige strict protection rules. Environmental studies often require comparison with other cavities of the same lithology, making the proper identification of the host rock critical. Additionally, the geological context can influence legal requirements for speleological prospecting. Rocks with low potential for cave formation are subject to less strict evaluation criteria.

This study provides a brief description of a cave developed in silicified rock that may exhibit a unique speleogenesis. Further studies are still required to better understand the host rocks and the cave formation processes.

2. Geological context and local geomorphology

In the region of Bahia, eastern Brazil, a thick carbonate sequence from the Bambuí Group (Neoproterozoic) lies stratigraphically and topographically beneath thick Cretaceous sandstones of the Urucuia Group (Fig. 1).

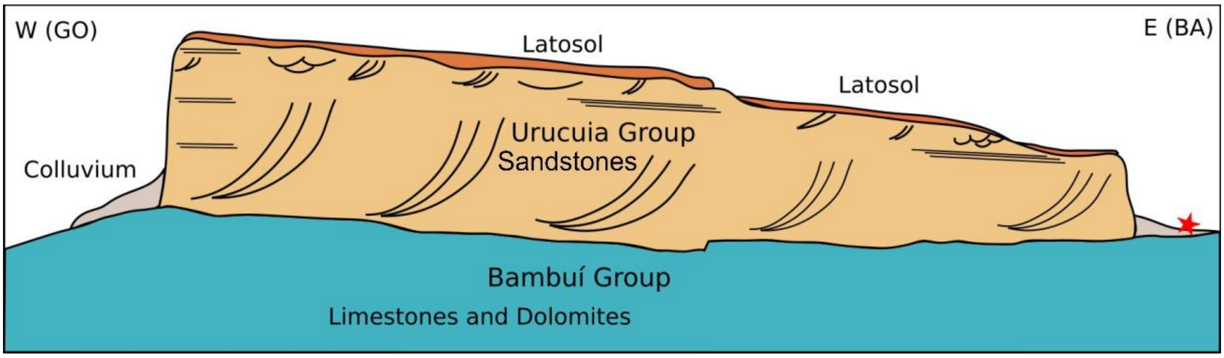


Fig. 1: Schematic presentation of the regional geological context. The sandstones of the Urucuia Group occur over an area of approximately 86,000 km^2, with thickness ranging from 100 m to 600 m. These rocks form a porous aquifer, a water source that shapes the numerous caves in the underlying carbonates of the Bambuí Group. Colluvium sediments and sandy soils cover part of the Bambuí rocks, mainly in the vicinity of the Urucuia erosion front. Red star indicates location context of the studied cave. GO – Goiás State, BA – Bahia State (after Gaspar, 2006, modified).

Regionally, the relief is characterized by steep-sided and flat-topped plateaus formed by the sandstones from the Urucuia Group (Braun, Ramalho 1980). The cave is located in the lower-lying terrain, whose surface consists only of reworked sand material due to the erosion of the mountain escarpment, deposited as quartz-arenitic soils over the rocks of the Bambuí Group (Dardenne 1978). In the geological map, this colluvial cover, i.e. moved or *in situ* sandy soil covers, are mapped as the Urucuia Group, even if there is no outcrop of lithified sandstones.

In the quartz-arenitic low-relief domains, dolines occur occasionally, where carbonate rocks are outcropped. Silicified rock can be found in upper areas associated with the carbonates. The silicified rocks do not outcrop on large areas, and seem to occur associated with the carbonates, restricted to the upper part of the outcrop close to surface, stratigraphically in between these two units (Bambuí and Urucuia groups), never within them. This lithology does not appear on the official geological map available for the region due to the scale (1:1,000,000) of the mapping (Serviço Geológico …, 2025). Although the cave location is mapped as the Urucuia Group (Fig. 2), in the field visit it was noted the cave is in silicified rocks associated with carbonates of the Bambuí Group, that outcrop in dolines, surrounded by the sediment cover derived from the Urucuia Group.

Carbonate caves are abundant within the limestone outcrops in the region. Cavities are also present in the sandstones of the Urucuia Group, though in much smaller quantities and generally associated with the sandstone escarpments. However, the occurrence of cavities is not expected in the plains covered with unconsolidated sandy sediments and neither in hard silicified rocks.

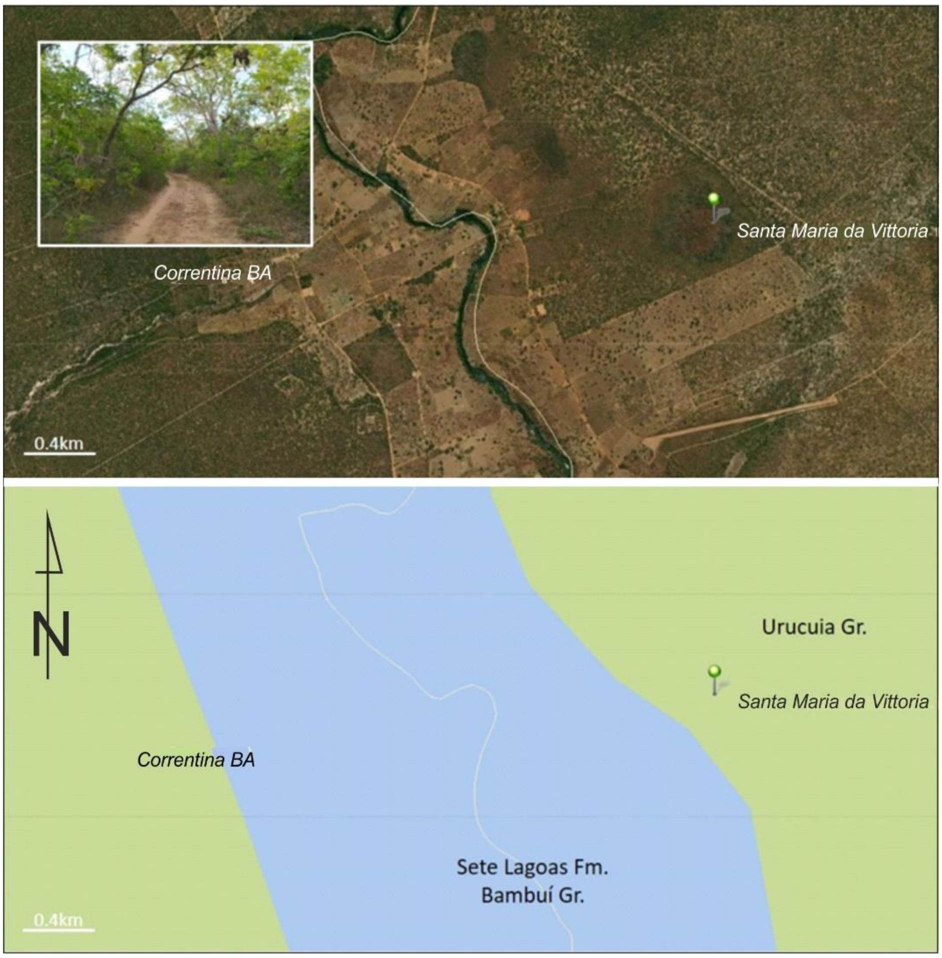


Fig. 2. Location context of the cave (green pin). A – Satellite image of the area: the sandy soil landscape with characteristic vegetation; B – geological map 1:1,000,000 provided by the Geological Survey of Brazil.

3. The cave

The cave, designated as PEA-1008, is located in the municipality of Santa Maria da Vitória, in the western region of Bahia state, Brazil.

The cave has a single entrance at the top of a hill, at the interface between soil and a hard rock cap which is approximately 2 m thick. Despite its relatively short length, with a horizontal projection of 40 m, the cave contains spacious chambers that allow upright walking. From a plan view, the cave primarily consists of interconnected large chambers rather than straight conduits, resulting in a surface area of 368 m² (Fig. 3).

The cave walls consist of exposed rock with a sharp and irregular relief, lacking secondary mineral deposits (both on the walls and ceiling). Condensation and seeping vadose water contribute to wet surfaces throughout the cave, despite the absence of hydrological features such as rivers or lakes. The floor is irregular, with numerous angular blocks ranging from centimeter-scale fragments to large, decametric boulders. Triangular features are common on the roof, likely resulting from fracture-induced detachment of angular blocks, which are now scattered on the cave floor (Fig. 4).

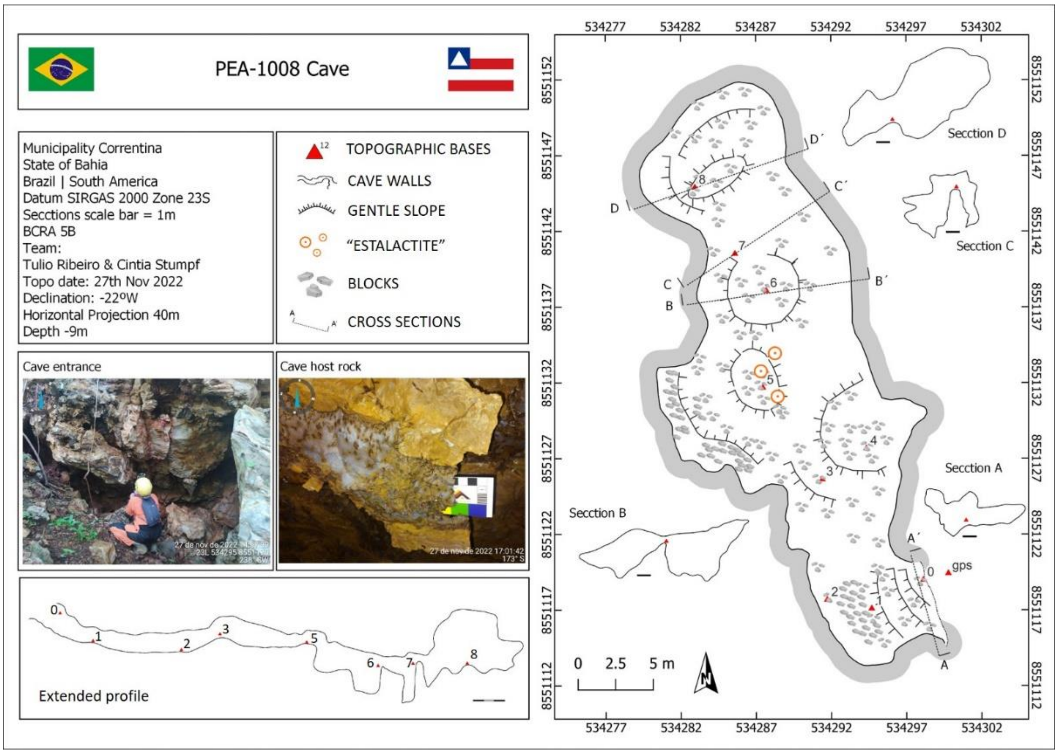


Fig. 3. Map of PEA-1008 Cave.

The host rock is highly competent, characterized by considerable hardness, compactness, and sharp-edged irregularities (Fig. 5). The overall rock lamination is sub-horizontal, with localized brecciated textures. The host rock exhibits various alteration colours, including dark brown, yellowish-brown, and ochre. Exfoliation-like layers are occasionally observed.

Fig. 4. General views of the cave, showing large chambers (A) and triangular shapes on the roof (B and C). D – cave view from the entrance toward the inside (from station 0 to 1) (photo by C. Stumpf).

Fig. 5. Examples of the cave´s host rock: (A) Outcrop inside the cave with horizontal lamination. (B) Detail of a brecciated facies. (C) Fresh rock surface, with light gray and yellowish-brown lamination. (D) Weathered block outside the cave (photo by C. Stumpf).

According to Moore (1952), speleothems are defined as secondary mineral deposits formed in caves. This cave presents structures resembling speleothems, specifically like stalactites, however, we interpret them as part of the host rock, but not secondary deposit formed in the cave. These forms occupy small cavities internal to the rock, which were exposed after the cave formation (Fig. 6). These features were always observed inward the rock, never on the surface of the cave walls or ceiling, as would be expected for dripstones or flowstones. Another evidence is that we found the same features in silicified rocks in other location, outside and far away from the cave, suggesting that these features formed independently of the presence of the cave.

These speleothem-like structures are centimetre-sized botryoidal features, often forming prominent columns resembling stalactites. Unlike typical stalactites, which grow vertically from the roof, these structures frequently develop laterally, connecting with adjacent columns (Fig. 5 C and D). Still, they seem to have formed through a vadose process, as they always develop downward, respecting gravity, despite some variations in orientation. Their coloration ranges from white to various shades of blue and brown, and they are presumably composed of silica, likely in the form of opal.

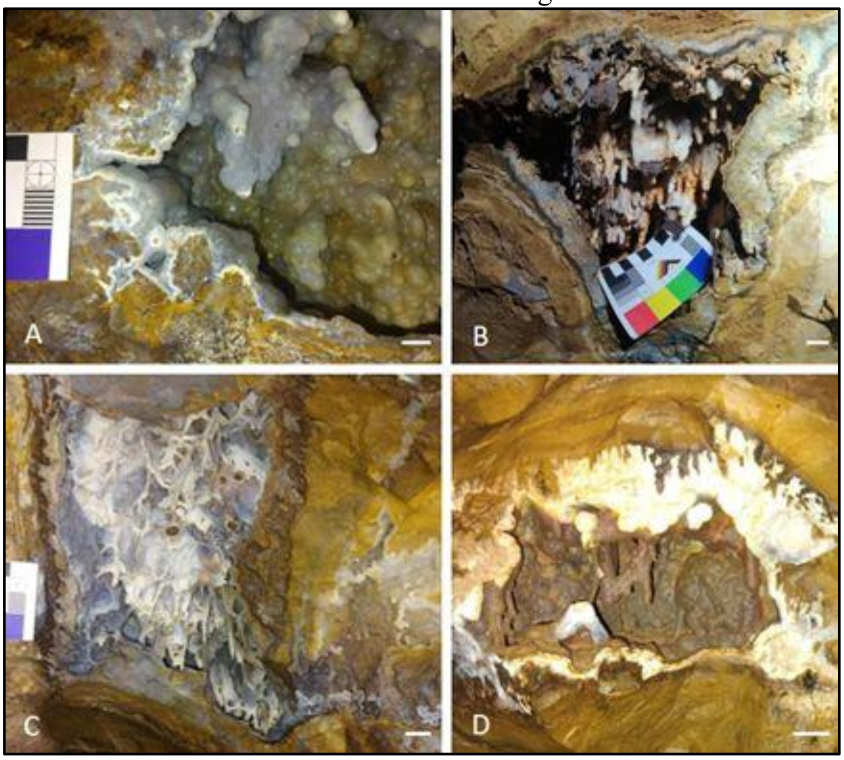


Fig. 6. Speleothem-like forms, likely composed of opal. Scale bar = 1 cm (photo by T. Ribeiro).

4. Origin of the silicified rock

The silicified host rock may have formed through various processes. One explanation suggests that silicified levels precipitated in desert lake environments during the Cretaceous period within the depositional succession of the Urucuia Group. This process is linked to the development of calcretes or silcretes from carbonate rocks in arid conditions, where silica replaced carbonate material under significant evaporation. Calcretes are known to occur in the region, belonging to the Caatinga Formation (Quaternary). These calcretes could have been silicified, with the Urucuia sandstones as a possible source of silica.

Another hypothesis involves tectonic inversion. Here, silicification occurs along contact zones between the Bambuí Group and the Urucuia Group, facilitated by brecciation along boundary horizons.

5. Speleogenesis

The cave's evolution appears primarily driven by rock collapse and blocks displacement. Underlying karst may have contributed to this subsidence, creating space and inducing collapse in the overlying rock unit. No evidence of dissolution was observed inside the cave, nor is such a process expected in this highly inert rock. Further detailed studies are required to define the cave's genesis.
Preliminary field observations indicate:

- absence of preferential fractures: unlike karst caves, no evident fracture planes or bedding surfaces guide dissolution processes;
- carbonate dissolution below: the genesis seems to be related to the dissolution of underlying carbonate units in the Bambuí Group, that created primary void spaces leading to mechanical collapse of the overlying silicified rock;
- chert collapse: the resistant silicified rock acted as a protective cap but eventually collapsed due to underlying dissolution;
- speleothem-like features: internal formations resembling speleothems result from precipitation within vuggy porosity in the host rock, not by secondary cave deposition.
- hybrid genesis: the PEA-1008 cave likely represents a hybrid model where carbonate dissolution in the underlying sequences created voids, later modified by mechanical collapse of the silicified cap, creating the cave.

6. Potential occurrence and legislation

Documenting caves in various lithologies in Brazil is crucial due to environmental protection law. Speleological prospecting is based on potential occurrence of caves. The competent authority recommends the methodology of Jansen et al. (2011), which classifies lithologies by cave potential of occurrence (Table 1).

Table 1: Degree of potential cave occurrence regarding to lithology (after Jansen et al. 2011).

Lithotype	Potential occurrence degree
limestone, dolomite, evaporite, banded iron formation, itabirite, and jaspilite	very high
calcrete, carbonatite, marble, metacarbonate, and marl	high
sandstone, conglomerate, phyllite, shale, phosphorite, graywacke, metaconglomerate, metapelite, metasiltstone, mica schist, mylonite, quartzite, pelite, rhyolite, rhythmite, calcareous-silicate rock, siltstone, and schist	medium
other lithotypes (anorthosite, arkose, augen gneiss, basalt, charnockite, diabase, diamictite, enderbite, gabbro, gneiss, granite, granodiorite, hornfels, kinzigite, komatiite, laterite, metachert, migmatite, monzogranite, olivine gabbro, orthoamphibolite, syenite, sienogranite, tonalite, trohjemite, among others)	low
alluvium, sand, clay, gravel, mudstone, lignite, other sediments, peat, and tuff	unlikely occurrence

From this documentation, environmental authorities determine whether speleological studies are required and may modify the evaluation criteria for the prospective survey grid. This highlights the importance of considering not only the type of rock but also the local geomorphology and other parameters to accurately assess a speleological potential for each area.

Another relevant point is that many environmental professionals and inspectors do not have a geological background, making it less straightforward to evaluate the host rock type. It is common that the lithotype be defined only based on the official available geological maps. For the region of this cave location and also for many regions in Brazil, the national geological service (CPRM) provides the geological map at a scale of 1:1,000,000, which is far from adequate for the scale required in speleological studies. This can lead to significant errors in determining the lithology of the cavity, as these determinations may lack of in-field verification of the actual lithology by geologists/geoscientists.

It is worth noting that a unique genesis, rare cave minerals or speleothems, among other physical characteristics, can ensure the classification of a cavity as highly relevant and guarantee its subsequent legal protection.

7. Conclusions

We documented a rare cave in silicified rock with a horizontal projection of 40 m and speleothem-like features occupying caverns, likely composed of opal and microcrystalline quartz. The cave's genesis is primarily attributed to block collapse, possibly linked to karst processes in underlying carbonate rocks. The silicified host rock's origin may involve silcrete formation under arid conditions, silicification of calcretes, or silica migration facilitated by tectonic activity.

This example emphasizes the importance of geoscientific expertise in speleological studies and environmental licensing.

References

Aubrecht R., Lanczós T., Gregor M., Schlögl J. Šmida B., Liščák P., Brewer-Carias Ch., Vlček L 2011. Sandstone caves on Venezuelan tepuis: Return to pseudokarst? Geomorphology 132, 3–4: 351–365. https://doi.org/10.1016/j.geomorph.2011.05.023

Braun O.P.G., Ramalho R. 1980. Geomorfologia da Bahia. Revista Brasileira de Geografia, Rio de Janeiro 42, 4: 822-861. https://www.rbg.ibge.gov.br/index.php/rbg/article/view/539

Dardenne M.A. 1978. Síntese sobre a estratigrafia do Grupo Bambuí no Brasil Central. In: Anais Do XXX Congresso Brasileiro de Geologia. Recife, v. II: 597–610. https://www.sbgeo.org.br/home/pages/44

Gaspar M.T.P. 2006. Sistema Aquífero Urucuia: Caracterização Regional e Propostas de Gestão, Tese de Doutorado No.76, 204 pp. https://repositorio.unb.br/jspui/handle/10482/6742

Jansen D.C., Cavalcanti L.F., Lamblém H.S. 2012. Mapa de Potencialidade de Ocorrência de Cavernas no Brasil na escala 1:2.500.000. Revista Brasileira de Espeleologia 1, 2: 42–57. https://revistaeletronica.icmbio.gov.br/index.php/RBEsp/article/view/255

Miller A.Z. Pereira M.F.C, Calaforra J.M., Forti P., Dionisio A., Saiz-Jimenez C. 2015. Ana Heva lava tube (Easter Island, Chile): Preliminary characterization of the internal layers of coralloid-type speleothems. Microscopy and Microanalysis 21 (Suppl. S6): 68–69. http://www.journals.cambridge.org/abstract_S1431927614014044

Moore G.W. 1952. Speleothem – a new cave term. National Speleological Society News 10, 6: 2.

Sauro F., Lundberg J., de Waele J., Tisato N., Galli E. 2013. Speleogenesis and speleothems of the Guacamaya Cave, Auyan Tepui, Venezuela. Proc. 16th ICS, v. 3: 298-304. https://uis-speleo.org/wp-content/uploads/2020/08/16th_proceedings-v003.pdf

Serviço Geológico do Brasil (SGB). Mapa Geológico do Brasil, 1:1,000,000, folha SD.23-X-C-II - Santa Maria da Vitória - BA. https://geosgb.sgb.gov.br/ , accessed on 06 Feb. 2025.

Vidal-Romani J.R., Sanjurjo J., Vaqueiro-Rodriguez M., Fernandez Mosquera D. 2010. Speleothems of granite caves. Comunicações Geológicas 97, 1: 71–80. https://www.researchgate.net/publication/215579240_Speleothems_of_Granite_Caves

A SURVEY OF NON-KARST CAVES IN THE KŘIVOKLÁTSKO PROTECTED LANDSCAPE AREA, CZECH REPUBLIC

Karel Žák, Michal Hejna, Martin Majer, Jakub Bohátka

Caving clubs 1-02 Tetuin and 1-04 Zlatý kůň, Czech Speleological Society, e-mail: karel.zak.geo@gmail.com

1. Introduction

The Křivoklátsko Protected Landscape Area (PLA) is located west of the country capital of Prague. The majority of the PLA belongs to the Central Bohemian Region, its smaller part to the Plzeň Region. It is a large (624.97 km^2), geologically and geomorphologically varied upland, which is rich in prominent outcrops on the slopes of river and stream valleys. It also contains abundant isolated rock formations at higher elevations, on remnants of an old peneplain. The area has been protected by the state since 1978. Within the "Man & Biosphere" program, it became a UNESCO Biosphere Reserve in 1977 already. With respect to its geological and geomorphological values, it is surprising that it has not been covered by any systematic non-karst cave survey earlier. Nevertheless, some of the studied caves have been known since the 19th century. Although the actual survey was not systematic and did not cover the whole PLA, 65 small caves have been located and studied. Cave locations were partly obtained by interviewing local experts like rock climbers, foresters, etc.

2. Local geology and rock types hosting the caves

Most of the Křivoklátsko PLA is represented by the almost non-metamorphic Neoproterozoic basement, which consists of submarine basalts, graywackes, shales and silicites – cherts (see Hajná et al. 2017 or Žák J. et al. 2020 for lithology and chronology). The basement is overlain by several younger units in places, including a relic of a Cambrian sedimentary basin (with conglomerates, sandstones, siltstones, shales) famous for its fossils, the Late Cambrian Křivoklát-Rokycany Volcanic Complex (rare basalts, abundant andesites, dacites, rhyolites and volcaniclastics), Ordovician sedimentary and volcanic rocks of the Prague Basin (sandstones, quartzites, siltstones, shales, submarine basalts and pyroclastics) and minor relics of Carboniferous continental coal-bearing strata (conglomerates, arkoses, siltstones, coal). Most of the rocks disintegrate to small-size fragments upon weathering, which was probably the reason why the Křivoklátsko PLA has been long ignored as a potential caving area. Our survey revealed that non-karst caves are relatively frequent here, but mostly small. The largest recorded cave, the Eremitka Cave, has a total length of only 30 m with an altitude difference of 9 m. It is located near the Roztoky municipality, being hosted by a Cambrian andesite. It is of combined crevice and boulder type (Fig. 1).

Fig. 1. Eremitka Cave developed by gravitational displacement of a large block of Cambrian andesite in a steep slope of the Berounka River valley. The photo was taken from the entrance chamber, which is partly penetrated by daylight (photo by M. Majer).

Among the lithologies of the area, the largest number of caves were documented in Neoproterozoic cherts (81.5 %), a smaller number in Cambrian volcanics (9.3 %; more abundant in rhyolites than andesites), and 7.7 % in Ordovician sandstones and quartzites. One cave (1.5 %) was studied in Neoproterozoic graywackes and shales. All the studied caves of the Křivoklátsko PLA were recorded in the database of speleological objects (JESO) managed by the Nature Conservation Agency of the Czech Republic. This short summary of our survey was guided by three rather incoherent aspects, (i) description of caves in Neoproterozoic silicites, (ii) genetically specific caves related to rock unconformities, and (iii) speleothems in the non-karst caves of the study area.

3. Caves hosted by Neoproterozoic chert

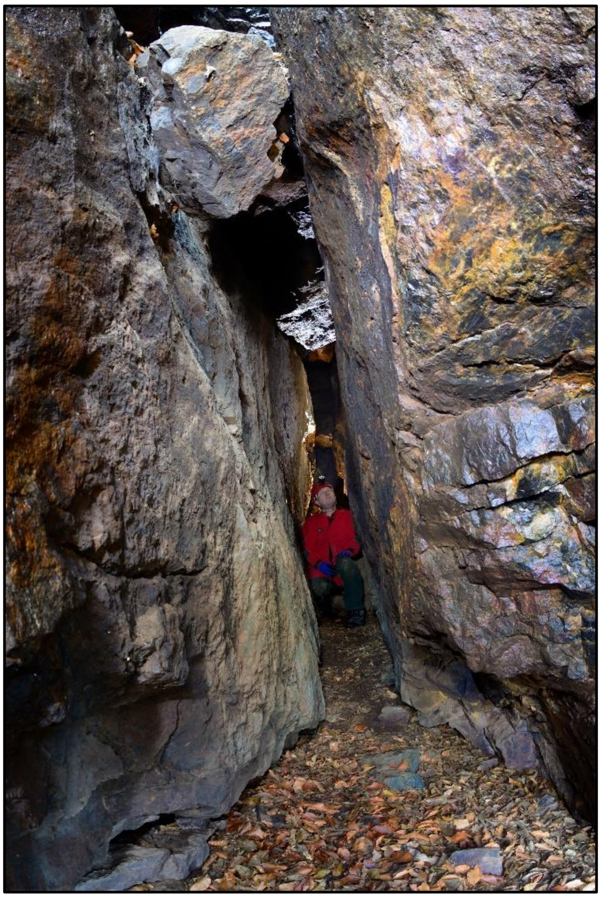
The typical thickness of Neoproterozoic chert lenses (see Ackerman et al. 2023 for rock origin) ranges from several meters to several tens of meters, their length from several tens to several hundreds of meters. Chert lenses are usually enclosed in Neoproterozoic shales and typically contain over 95 % of fine quartz grains. Chert lenses are significantly more resistant to weathering than the ambient shales, forming cliffs or mountains of circumdenudation. Their designation as tors is inappropriate since typical tors were originally surrounded by the same rock type (cf. Michniewicz 2019), not by a quite different rock type as here. Since the term monadnock is mostly used for larger upstanding rocks or hills, we stick to a descriptive term "cliffs of circumdenudation". An important factor for cliff morphology and cave formation is the dip of the chert lens – more prominent cliffs with a higher number of cavities are formed by steeply dipping chert lenses (Fig. 2).

Fig. 2. Dehetnická Cliff near Líšná village, a case of a steeply dipping chert lens. Photo by K. Žák.

The chert cliffs of circumdenudation are most frequently found on remnants of an old peneplain, where the surrounding shale was subjected to weathering for a very long time, in some parts of the area since the Cretaceous. Summits of some of the cliffs in the NE part of the PLA were eroded, and round shapes of the outcrops were formed. This was either a result of wave activity on the shore of the Cretaceous sea, or erosion by Paleogene and/or Neogene rivers.

In some cases, chert cliffs rising above the peneplain are dissected by open crevices into blocks several meters in size. Gravitational movements of these blocks are typically of low magnitude, usually less than 1 m in displacement, i.e., in their initial stage only. No large mass wasting occurs on the slopes. Since the circumdenudation of the chert cliffs started in pre-Quaternary periods already, some of the observed crevices and related caves can be of pre-Quaternary origin: big chert blocks could have sunken into deeply weathered shales located in their immediate surrounding. Nevertheless, the majority of the block movements are most probably related to climatic cycles of the Quaternary and to periods of permafrost formation and thawing.

Based on the character of the block movements, several cave types were identified, similar to those described by Vítek (1983), Gaál (2003), Bella and Gaál (2013) or Lenart (2015). Two most frequently encountered types are (1) toppling-type caves with wider upper parts in cross section. They are V-shaped in cross-section and their ceilings are usually formed by big wedged boulders, and (2) caves due to back-rotation of the moving block, which touches the rock massif in its upper part while its base is transported downslope. The passages are A-shaped in cross section. In several cases, the disintegration of the chert rock resulted in an accumulation of meter-sized blocks. Several small caves of boulder type have been also documented from beneath these bocks. The caves in chert are



numerous but mostly of small size. The biggest ones are 10 to 20 m long but lengths below 10 m are more typical. A typical V-type cave with boulders forming the ceiling is shown in Fig. 3.

Fig. 3. A typical cave with an upwards-widening crevice. V Brlohu Cave near Jablečno village, 8 m long (photo by M. Majer).

4. Unconformity-related caves

We also documented several small but genetically interesting caves, which we consider as a sub-type of bedding-parallel caves or cave niches. With respect to varied geological units of the area (see chapter 1. Introduction), several obvious angular unconformities are present in the region, e.g., between the Neoproterozoic and Cambrian rocks or between the Neoproterozoic and Ordovician rocks. Original weathering surfaces were lying beneath these unconformities and, moreover, lithologies below and above the unconformity often display different physico-chemical properties. In some rare cases, rocks below the unconformity were removed by fluvial erosion or by frost weathering, and the overlying strata survived. The observed cavities are small. They were documented to follow the unconformity between the Neoproterozoic basement and Cambrian volcanics or the unconformity between the Neoproterozoic and Ordovician sedimentary rocks.

A typical example, the Andělka Cave, is shown in Fig. 4. The ceiling of the cavity is formed by a lava flow of Cambrian andesite – the ceiling represents precisely the base of the lava flow. The left side of the photo shows Neoproterozoic graywackes and shales affected by the thermal effect of the lava. The Andělka Cave is only 5 m long and the Neoproterozoic rocks below the unconformity were removed by lateral fluvial erosion of the Berounka River in the Middle Pleistocene. The cave is located about 30 m above the present-day river level, and fluvial activity is documented by the occasional presence of river-bed pebbles. The cave therefore also belongs to the category of fluvial erosion caves.

Fig. 4. The unconformity-related Andělka Cave, located near Roztoky municipality (photo by M. Majer).

5. Non-calcareous speleothems

Any substantial presence of calcareous speleothems in non-karst caves is limited to cases when a carbonate admixture is present in the surrounding rock (e.g., Urban et al. 2015). In the Křivoklátsko PLA, we observed thin coatings on cavity walls, formed by porous, soft secondary calcite of subsoil type. It typically occurs in caves in Cambrian andesites. Andesite contains small quantities of secondary carbonate, which was the source of calcium. More interesting speleothems were found in a small cavity not reaching the size of a cave, located close to the angular unconformity between the Neoproterozoic and Ordovician rocks near the town of Žebrák. The observed stalactites are a maximum 5 mm thick and 20 mm long (Fig. 5). Some of them resemble soda straws. An X-ray diffraction analysis confirmed the presence of only a single mineral – goethite, α-$Fe^{3+}O(OH)$. Goethite is relatively common in caves, sometimes forming stalactites (Hill, Forti 1997).

Fig. 5. Goethite speleothems in a small cavity located close to the Neoproterozoic/Ordovician – at Holý vrch Hill near the town of Žebrák, Křivoklátsko PLA. The longest stalactites reach 2 cm in length (photo by K. Žák).

6. Conclusions

Numerous small cavities can be found even in areas traditionally considered poor in non-karst (pseudokarst) caves, if a detailed survey is applied. The present survey covered a part of the Křivoklátsko Protected Landscape Area and revealed 65 non-karst caves of mostly very small dimensions. The longest crevice- and boulder-type Eremitka Cave in Cambrian andesites is 30 m long, with an altitude difference of 9 m.

Acknowledgments

The study was partly financed by the Nature Conservation Agency of the Czech Republic under the contract S/04754/SC/24. We wish to thank PhDr. Karel Sklenář for his help in gathering historical literature. The help of local expert Marian Beke and informal paper reviews by Jan Lenart and Jiří Adamovič were greatly appreciated.

References

Ackerman L., Žák J., Kachlík V., Pašava J., Žák K., Pack A., Veselovský F., Strnad L. 2023. The significance of cherts as markers of Ocean Plate Stratigraphy and paleoenvironmental conditions: New insights from the Neoproterozoic–Cambrian Blovice accretionary wedge, Bohemian Massif. Geoscience Frontiers 14: 101478. https://doi.org/10.1016/j.gsf.2022.101478

Bella P., Gaál Ľ. 2013. Genetic types of non-solution caves. In: Filippi, M., Bosák, P. (Eds.), Proceedings 16th International Congress of Speleology: Brno, Czech Speleological Society: v. 3: 237-242.

Gaál Ľ. 2003. Genetické typy rozsadlinových jaskýň na Slovensku (Genetic types of crevasse caves in Slovakia). Slovenský kras 41: 29-45 (in Slovak with English abstract).

Hajná J., Žák J., Dörr W. 2017. Time scales and mechanisms of growth of active margins of Gondwana: A model based on detrital zircon ages from the Neoproterozoic to Cambrian Blovice accretionary complex, Bohemian Massif. Gondwana Research 42: 63-83. https://doi.org/10.1016/j.gr.2016.10.004

Hill C., Forti P. 1997. Cave minerals of the world. National Speleological Society, Huntsville, 463 pp..

Lenart J. 2015. Morphological patterns of crevice-type caves in sedimentary rocks of the Outer Western Carpathians (Czech Republic). Journal of Cave and Karst Studies 77: 165-176. http://dx.doi.org/10.4311/2014ES0113

Michniewicz A. 2019. Tors in Central European Mountains – are they indicators of past environments? Bulletin of Geography, Physical Geography Series 16: 67-87. http://dx.doi.org/10.2478/bgeo-2019-0005

Urban J., Margielewski W., Hercman H., Žák K., Zernitska V., Pawlak J., Schejbal-Chwastek M. 2015. Dating of speleothems in non-karst, sandstone caves – methodological aspects and practical application, Polish Outer

Carpathians case study. Zeitschrift für Geomorphologie 59 (Suppl. 1): 185-210. http://dx.doi.org/10.1127/zfg_suppl/2015/S-00180
Vítek J. 1983. Classification of pseudokarst forms in Czechoslovakia. International Journal of Speleology 13: 1-18. http://dx.doi.org/10.5038/1827-806X.13.1.1
Žák J., Svojtka M., Hajná J., Ackerman L. 2020. Detrital zircon geochronology and processes in accretionary wedges. Earth-Science Reviews 207: 103214. https://doi.org/10.1016/j.earscirev.2020.103214

CAVE MAP GRADING BASED ON THE EXAMPLE OF THE NON-KARST CAVES IN THE BAKONY MOUNTAINS, HUNGARY

Peter Tarsoly

Óbuda University Alba Regia Faculty, Department of Geoinformatics, H-8000, Székesfehérvár, Pirosalma u. 1-3, e-mail: tarsoly.peter@amk.uni-obuda.hu

Abstract: The International Union of Speleology adopted a classification system for cave maps in summer 2010. The index numbers assigned to cave maps refer to the accuracy of survey, mapping and quality control. The aim of the present study was to grade the maps of the non-karstic caves of the Bakony Mountains, based on the non-karstic cave register, maintained by the Volcanospeleological Collective of the Hungarian Speleological Society. A total of 205 non-karstic caves are found in the Bakony Mts. In the course of the cave map classification only three categories were found: UIS 0-0, UIS 3-4-A and UIS 4-4-AF. Unmapped caves (UIS 0-0) account for 27% of all caves (55), of which 42% (23) have not yet been mapped, 11% (6) have been destroyed by collapse, 7% (4) have been filled in by humans, 35% (19) have been excavated and 5% (3) are known only from literature. 53% of all the caves (109 caves) are classified as UIS 3-4-A. This means that directions were measured by compass, distances by tape, slopes by estimation; a scale map was already made in the cave to ensure the accuracy of the survey, but the accuracy of the survey and mapping was not specifically checked. 20% of the caves (41 caves) are classified as UIS 4-4-AF. For these caves, bearings were measured with compasses, distances with tape measures or handheld laser rangefinders, and slopes with inclinometers. To ensure the accuracy of the survey, a scale map was already made in the cave, but the accuracy of the survey and mapping was not specifically checked, and the cave entrance was determined using a GNSS receiver with decimetre accuracy.

1. Introduction

The documentation of a cave is always based on a good map. While in the case of a large cave, a good map provides information on the spatial coordination of the cave, helps to plan further researches and explorations, and often presents the results of the different disciplines, in the case of small caves (< 50 m) the aim is usually only to show the outline of the cave. While for a large cave, in addition to the traditional plan, longitudinal and transversal cross-sections, the depiction of the cave on a three-dimensional drawing is usually necessary to investigate the relationships between the individual research results, for small caves a three-dimensional representation is rarely needed and provided (Eszterhás, Tarsoly 2015). In principle, small caves are surveyed and mapped in the same way as large caves, but due to their size, specific solutions and simplifications can be envisaged for them, that would lead to survey/mapping errors in larger caves (Tarsoly, Eszterhás, 2016), e.g. measuring distances only for few centimetres, measuring angles only for 2-5°, fewer cross-sections, sketchy longitudinal-section etc. All of these could lead to interpretation confusion, twisting of polygon lines and measurement errors in a complex cave system, but for caves of a few meters or tens of meters in length, these simplifications have no significant impact on mapping due to the short distances. Quality certification is important in all aspects of life, including cave maps. In general, underground surveys, especially of caves, are not usually considered to be very accurate. However, everyone knows that there is a significant difference between the accuracy of a cave survey carried out with a compass, and a total station or a laser scanner, as well as the accuracy of the maps produced from the results of these surveys. The quality of a cave map needs to be defined according to some standard grading system.

2. The development of the grading system

The grading system introduced in 2002 by the British Cave Research Association (BCRA) to assess the accuracy of cave maps (https://bcra.org.uk/surveying/) has been used worldwide, but has never been officially recognised by the International Union of Speleology (UIS). Although the BCRA has repeatedly revised the gradings, updates have not necessarily been passed on to international users, and several countries, such as Australia (ASF - Australian Speleological Federation), have developed their own grading system (https://caves.org.au/). To clarify this confusing situation, the UIS „Survey and mapping" working group has reviewed the existing grading systems and developed an official UIS grading system. At the 15th International Congress of Speleology in Kerrville (USA, 2009), the working group discussed the BCRA and ASF mapping grades, their use, limitations, and possible upgrades for international use. Most of the participants agreed that the use of a grading system in speleological mapping was needed to inform the map user of the expected accuracy of the map. After a discussion, it was seen that the current ASF standards quite closely match the expectations of the group and that they could be upgraded for UIS use. The grading system currently in use was approved by the UIS international delegates in the summer of 2010 and is still in use after a slight modification in 2012 (https://digitalcommons.usf.edu/cgi/viewcontent.cgi?article=1046&context=ijs).

3. The UIS cave map grading system

The notation for the grading of a cave map is for example: UISv1 4-2-BC (Häuselmann 2011). The first tag, "UISv1", refers to the version number of the rating system and can be omitted, "4" indicates the survey grade, "2" – the map detail and "BC" – the grading of the map. The grading system does not apply to underwater caves because their survey and mapping require specific methods and solutions. If a cave has been mapped using more than one technique, the grade should be assigned to the one that covers most part of the cave, which is usually the lower grade. In the case of larger caves, all the relevant details of the survey and mapping should be given in a separate description, and details should be given if parts of the cave have been surveyed and mapped using different technologies. The grading system is shown in Tables 1 to 3.

Table 1. Survey grades

Gra-ding	Description	Precision length [m]	Compass [°]	Clino [°]	Expected error ratio [%]
-1	No map available.	-	-	-	-
0	Ungraded.	-	-	-	-
1	Sketch from memory, not to scale.	-	-	-	-
2	Map compiled from annotations, sketches and estimates made in the cave. No instruments used.	-	-	-	-
3	Directions measured by compass, distances measured by chord, pace, or body dimensions. Significant slopes estimated.	0.5	5	-	10
4	Compass and tape/handheld laser rangefinder survey, using deliberately chosen and fixed stations. Slopes measured by clinometer or horizontal and vertical components of line.	0.1	2	2	5
5	Compass and tape/handheld laser rangefinder survey. Directions and slope by calibrated instruments, distances by fibreglass or metallic tape, handheld laser rangefinder or tacheometry.	0.05	1	1	2
6	Survey or triangulation using calibrated, tripod-mounted instruments for directions and slope. Distances by calibrated tape, precise tacheometry, or calibrated handheld laser rangefinder.	0.02	0.25	0.25	1
X	Survey by theodolite or comparable means (total station, laser scanner).	variable	variable	variable	variable

Notes to Table 1:

-1 - The cave map is not yet available.

0 - Usually historical or other old maps whose survey cannot be graded. No survey or map is available, cave is only mentioned in literature, or possibly the cave is destroyed.

3 - Relatively simple instruments without accurate readings meet the grade.

4 - Only if basepoints were used for the surveying, except for small caves where basepoints are not necessarily required. The map must be drawn to scale within the cave.

5 - Only if rectangular coordinates have been calculated for all points.

X - Models of total stations and laser scanners and measuring techniques may vary. Therefore, all X-grade surveys should include in the description of the cave: a description of the instruments and techniques used and an estimate of the probable accuracy of the survey.

Table 2. Map detail grades

0	Ungraded.
1	Sketch from memory. Not to scale but indicates approximate proportions.
2	Details from annotations, sketches and estimates of directions and dimensions made in the cave.
3	Details from drawings made in the cave. The drawing has not to be to scale, passage dimensions can be estimated.
4	Details from drawings made in the cave to scale, based on measurements of significant details with respect to surveyed points, usually at least grade 4. All details of general speleological interest should be shown with sufficient accuracy so as not to be appreciably in error at the mapping scale. Passage dimensions measured.

Table 3. Suffixes qualifying maps

A	Nothing has been done to obtain additional certainty of accuracy.
B	Survey loops are closed and adjusted.
C	Survey is depended on instruments and people which have been checked and corrected for the effects of possible anomalies.
D	Survey is checked and corrected by different methods.
E	Survey data has not been transcribed manually but has been downloaded electronically.
F	Entrances have been precisely measured.

Notes to Table 3:

C - Equivalent to grade 5 in Table 1.

D - The key locations in the cave have been located relative to the surface by radiolocation or other electromagnetic methods.

E - The use of a data recorder eliminates errors due to typing.

F - The coordinates of the entrance were determined either by GNSS (to an accuracy of at least decimetres) or by a minimum of 4th order measurement. The coordinate taken from the map corresponds to survey grades 1-3, the coordinates determined by conventional direction and distance measurement, satellite positioning correspond to one of the grades 3-X depending on the accuracy of the instruments and methods used.

4. Non-karst caves of the Bakony Mountains

The Bakony Mountains, covering an area of 4000 km^2, form the most extensive region of the Trans-Danubian Mountains between the Lake of Balaton and Marcal River (Fig. 1). The geological formations reveal many differing aspects. Various calcareous, silici-ferrous and organogenic sediments, as well as volcanic rock formations representing the time span from the Palaeozoic to the Holocene, occur there. They are characterised by a typical medium mountain morphology, which includes plateaus at various elevations, and tectonic blocks framed by faults interspersed with intermontane basins. In the southern and western segments of the mountains basalt cones and basaltic sheets are frequently found. In the central area the variously sloping landscape is inclined towards the blocks.

Predominant constituents of these mountains are limestones and dolomites with extensive karst areas abounding in karst caves. Of course, from the point of view of non-karst cave occurrence these areas are insignificant. Relatively less common is the occurrence of silici-ferrous (sandstone and conglomerate) and basalt rocks, however 185 non-karstic caves have been explored in these rocks so far (Table 4) and, in addition, 20 artificial cavities, considered as caves, are listed there, too (nonkarstic.geo.info.hu). Among them, 82 caves have developed in basalt (Fig. 2). These caves can be found in most of the basalt hills such as Badacsony, Mt Kovácsi, and Mt Szent György. Forty one caves are listed in the geyserite of the Tihanyi Peninsula. Thirty-five non-karst caves appear in Miocene calcareous conglomerate of the South Bakony, and 13 caves are known in the Pannonian silici-ferrous sandstone of the Kali Basin. Furthermore, 13 caves have developed in basaltic tuff and one in loess. The artificial cavities were generally dug in basaltic tuff (Tihany Peninsula) and in Pannonian fine sandy clay (Balatonkenese town). Some of the non-karst caves have a syngenetic origin, for example the gas bubble cavities in Szigliget-hill and the cavities in the Tihany Peninsula, have been formed by gaseous explosion.

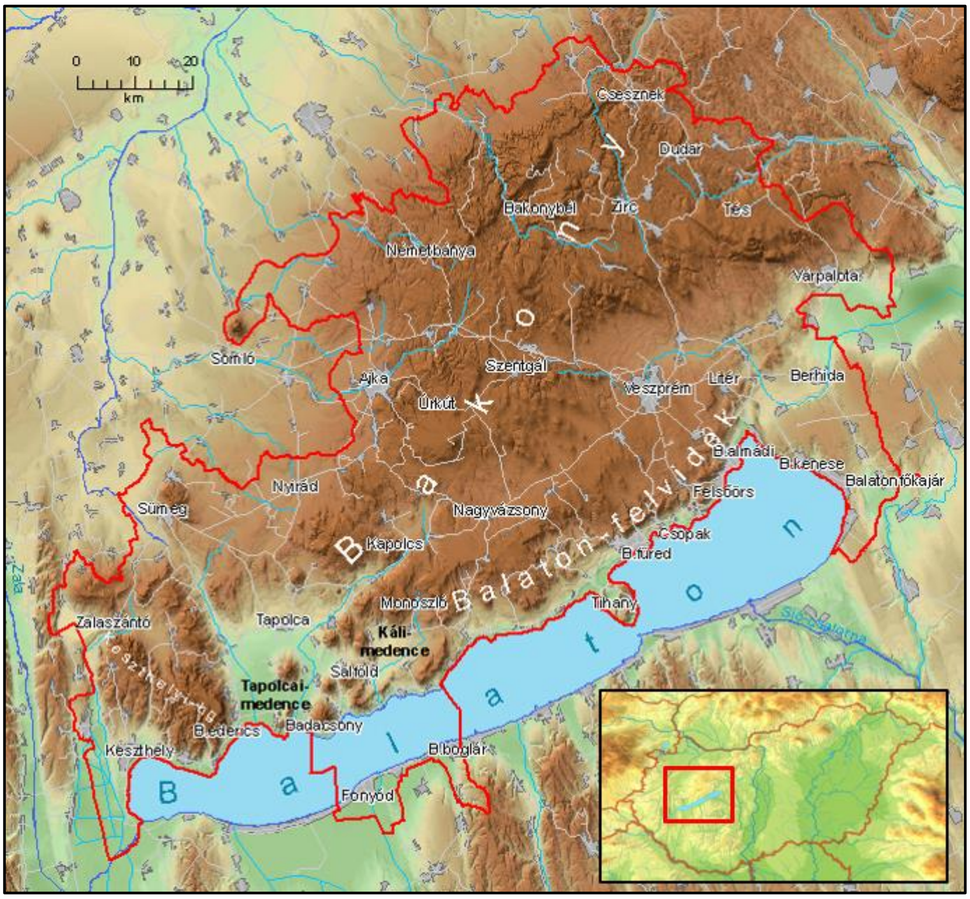
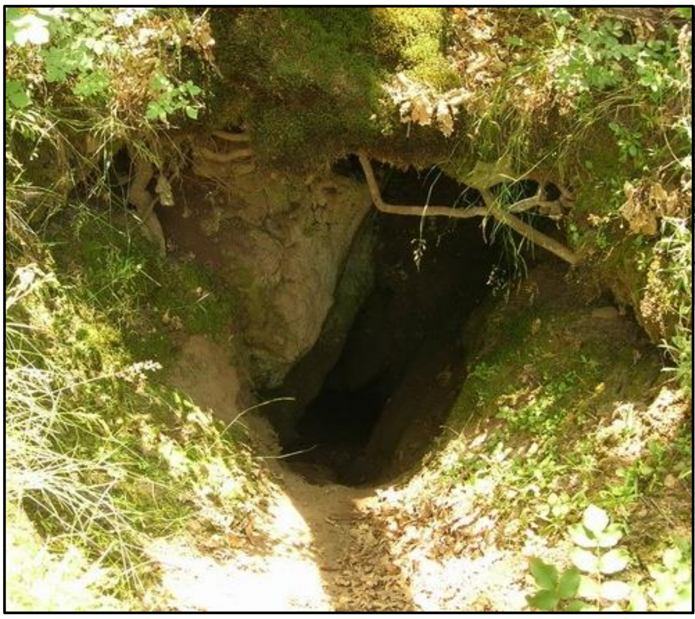
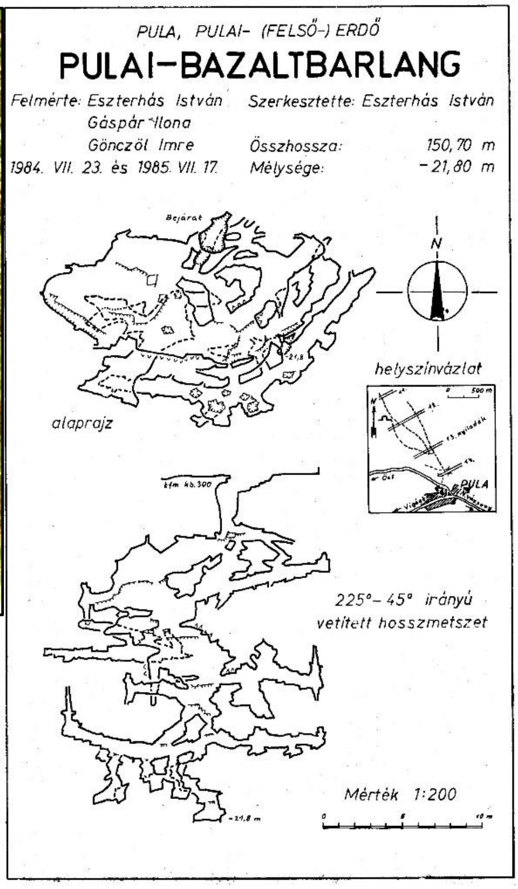


Fig. 1. The Bakony Mountains (source: magyarorszag. terkepek.net).





Fig, 2. The longest non-karst cave in the Bakony Mountains is the Pulai-bazaltbarlang, 151 m long, (source: termeszetvedelem.hu)

Table 4. Non-karst caves over 10 m long in the Bakony Mountains.

No.	Name	Host rock	Place	Length	Depth
1.	Pulai-bazaltbarlang	basalt	Pula	151 m	/-22 m
2.	Halász Árpád-barlang	basalt	Nagyvázsony	72 m	/-6 m
3.	Panka-aknabarlang	basalt	Badacsony	58 m	/-18m
4.	Pokol-lik	basalt	Kapolcs	51 m	/+3 m
5.	Remete-barlang	basalt	Zalaszántó	39 m	/20 m
6.	1-es Sárkány-jégbarlang	basalt	Tapolca	32 m	/-10 m
7.	Halápi-bazaltlyuk	basalt	Zalahaláp	ca. 30 m	
8.	Araszoló-barlang	basalt	Raposka	26 m	/-10 m
9.	Vadlány-lik	basalt	Nagygörbő	24 m	/-4 m
10.	Gödrösi Explózios-barlang	basalt tuff	Tihany	16 m	/-6 m
11.	Ternye-barlang	basalt	Badacsonytomaj	14 m	/+5 m
12.	Forrás-barlang	geyserite	Tihany	14 m	/+2 m
13.	Kőkamra	basalt	Nagygörbő	12 m	/+4 m
14.	Orgonabillentyű – barlang	basalt	Badacsonytomaj	11 m	0 m
15.	Pulai-bazalttufabarlang	basalt tuff	Pula	10 m	/+2 m
16.	Fehér-parti 1-es barlang	geyserite	Tihany	10 m	/+1 m

In the overwhelming majority of cases the non-karst caves have developed by postdiagenetic processes. Typically, the caves formed along the fault surfaces. The Pokol–lik cave in Kapolcs village and the Remete cave in Zalaszántó village are fissure caves (according to Vitek's 1983, classification), which were formed at the same time as the wall of the basalt rock formation. In contrast the fissure cave of Tátika developed perpendicular to the basalt rock wall. The basalt cave in Pula village and the caves between the basalt columns of the Badacsony Mountains and Mt Szent György are the results of rock fragmentation (Fig. 3).

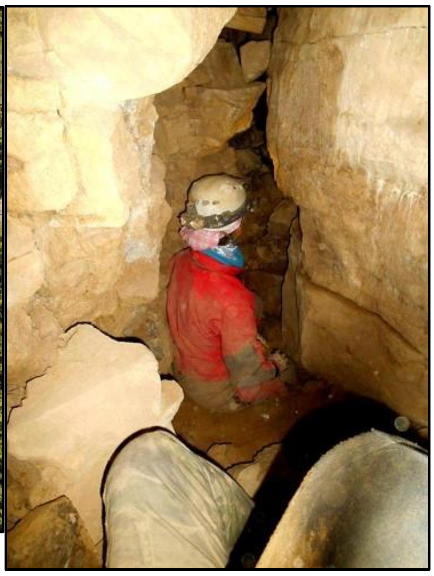


Fig. 3. Basalt columns in the Badacsony Mountains and the Panka-aknabarlang cave, whose entrance is between the columns (photo P. Tarsoly).

Forty caves in the Tihanyi Peninsula have developed in geyserite as a result of alkaline dissolution. In the talus deposits of the basalt cones, typical atectonic caves such as the Vadlán-lik in Mount Kovácsi or the Sárkány Ice Caves in Mt Szent György were found. In the Tihanyi Peninsula near the Kis-erdő-tetői Rock Shelter non-cave size tafoni are observed in the basaltic tuff.

5. Grading of maps of the non-karst caves in the Bakony Mountains

The non-karstic cave register of Hungary, maintained by the Volcanospeleological Collective of the Hungarian Speleological Society (Szentes et al. 2018-2019), contains data on 205 caves in the

Bakony Mountains. For 11% (23) of the caves no map has been made, for 22% (45) no photographic documentation is available and for 10% (21) neither a map nor a photograph is available. These are generally caves which are known only from literature, or which exist only according to legends, or which have been destroyed by quarrying or have been filled in. After the grading of the cave maps, only three categories occurred: UIS 0-0, UIS 3-4-A and UIS 4-4-AF (Fig. 4). Unmapped caves (UIS 0-0) represent 27% of all ones (55 caves); 42% of them (23 caves) have not been mapped, 11% (6 caves) have been destroyed by collapses, 7% (4 caves) have been filled in by humans, 35% (19 caves) have been destroyed by quarrying and 5% (3 caves) are known only from literature. 53% of the whole number of caves (109 caves) are graded as UIS 3-4-A. This means that directions were measured by compass, distances by tape, and slopes by estimation; a scale map was already made in the cave to ensure the accuracy of the survey, but the accuracy of the survey and mapping was not specifically checked. 20% of the caves (41) have a UIS 4-4-AF rating. In these caves, directions were measured with a compass, distances with a tape measure or handheld laser rangefinder, and slopes with a clinometer. To ensure the accuracy of the survey, a scale map was already made in the cave, but the accuracy of the survey and mapping was not specifically checked, while the cave entrance was determined using a GNSS receiver with decametric accuracy.

The official register of caves in Hungary is kept by the National Cave Register (www.termeszetvedelem.hu), which includes both karst and non-karst caves. The difference between the Collective's register and the National Cave Register is that some of the caves classified as UIS 3-4-A in the Collective's register have coordinates measured by GNSS receiver in the National Register, with the same map material, so the qualifying suffix would be graded as AF here too. However, the purpose of this study was only to classify the data in the Collective's register.

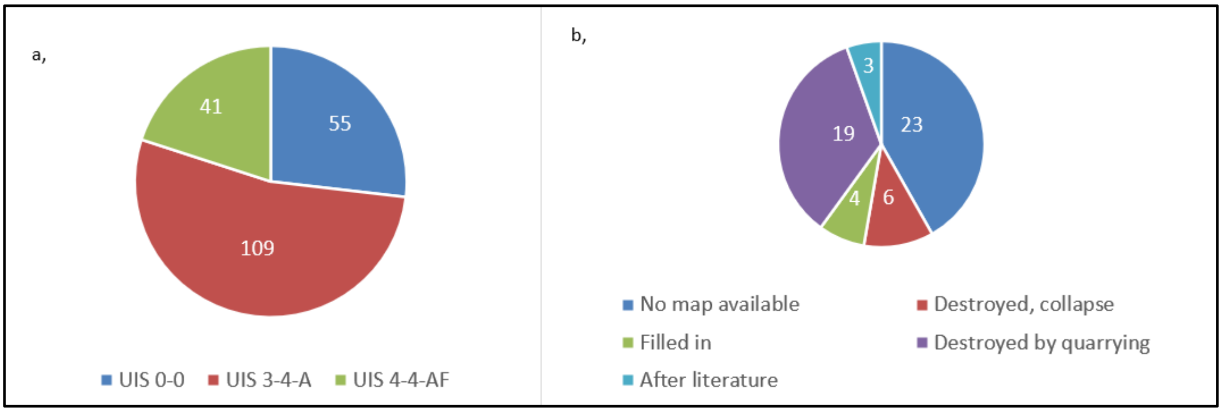


Fig. 4. Grading of maps of non-karst caves in the Bakony Mountains (a); and classification of unmapped caves into different categories (b).

Summary

The International Union of Speleology (UIS) adopted a grading system for cave maps in summer 2010. The index numbers assigned to cave maps refer to the accuracy of survey, mapping and quality control. The aim of the presented study is to classify the maps of the non-karst caves in the Bakony Mountains, based on the non-karst cave register of the Volcanospeleological Collective (Hungarian Speleological Society). A total of 205 non-karst caves are known in the Bakony Mountains. The grading of the cave maps revealed only three categories: UIS 0-0, UIS 3-4-A and UIS 4-4-AF. Unmapped caves (UIS 0-0) represent 27% (55 caves) of the total, of which 42% (23 caves) have not been mapped, 11% (6 caves) have been destroyed by collapse, 7% (4 caves) have been filled in by humans, 35% (19 caves) have been destroyed by quarrying and 5% (3 caves) are known only from literature. 53% (109 caves) of the whole number of caves are classified as UIS 3-4-A. This means that directions were measured by compass, distances by tape, and slopes by estimation; a scale map was already made in the cave to ensure the accuracy of the survey, but the accuracy of the survey and mapping was not specifically checked. 20% of the caves (41) have a UIS 4-4-AF rating. For these caves, bearings were measured by compass, distances by tape measure or handheld laser rangefinder, and slopes by clinometer. A map to scale was already made in the cave to ensure the accuracy of the survey, but the accuracy of the survey and

mapping was not specifically checked, while the cave entrance was determined using a GNSS receiver with decametric accuracy.

References

Eszterhás I., Tarsoly P. 2015: Kisméretű barlangok térképezése, MKBT Vulkánszpeleológiai Kollektívájának évkönyve, Isztimér,: 39-62/

Häuselmann P. 2011. UIS Mapping Grades. International Journal of Speleology 40: IV-VI. https://digitalcommons.usf.edu/ijs/vol40/iss2/15 .

Szentes G., Eszterhás I., Tarsoly P. 2018-2019. Magyarország nemkarsztos barlangjainak katasztere: Magyar Karszt- és Barlangkutató Társulat Vulkánszpeleológiai Kollektíva, Szerkesztette: nonkarstic.geo.info.hu

Tarsoly P., Eszterhás I. 2016. Barlangméréseknél használt szögmérő eszközök összehasonlító vizsgálata, MKBT Vulkánszpeleológiai Kollektívájának évkönyve, Isztimér: 41-48.

PECULIAR SUBAQUATIC "PSEUDO-DRIPSTONES" FROM LAKE HALLSTATT, AUSTRIA

Rudolf Pavuza

Karst and Cave Research Group, Natural History Museum Vienna, Austria; e-mail: rudolf.pavuza@nhm-wien.ac.at

Abstract: Some years ago divers reported about up to one meter long "stalactites" in Lake Hallstatt at a depth of about 10 m to 40 m. Lake Hallstatt is an inner Alpine lake which filled after the recess of the Würmian glaciers some 15 ka ago. Initial speculations about an early post-glacial age of possible speleothems or tufa – formed prior to the infill of the glacial valley giving rise to the current lake – had to be abandoned soon as included wooden remnants, recovered during a recent dive action, yielded an age of only a few hundred years. Different but still preliminary investigations and historic data point towards a compelling subaquatic origin in recent times – some 200 years ago – based on a rare combination of natural and anthropogenic factors (landslides, hydrothermal mineral waters, waste material from salt processing, other waste water inflow) which established an environment where microorganisms could precipitate $CaCO_3$ by a special metabolism that has not yet been clarified (e.g. ureolysis, denitrification, ammonification and others). It looks as if this process came to a halt rather recently. This break has possibly based on the termination of the input of Ca-rich saline waste material as well as the onset of a strict waste water management of the adjacent village in the second half of the past century. So far we have not been able to find a comparable occurrence of such formations elsewhere.
This short paper is a synopsis of an extensive publication in German language with many more pictures and drawings (Greger et al. 2024).

Introduction

Lake Hallstatt is situated in a highly picturesque location in the middle section of the Northern Calcareous Alps (Fig. 1) in a steeply incised, long glacial valley in Upper Austria (Fig. 2). The village was – in part – copied by Chinese architects and built in China - albeit laterally inverted - on a 1:1 scale in 2014.

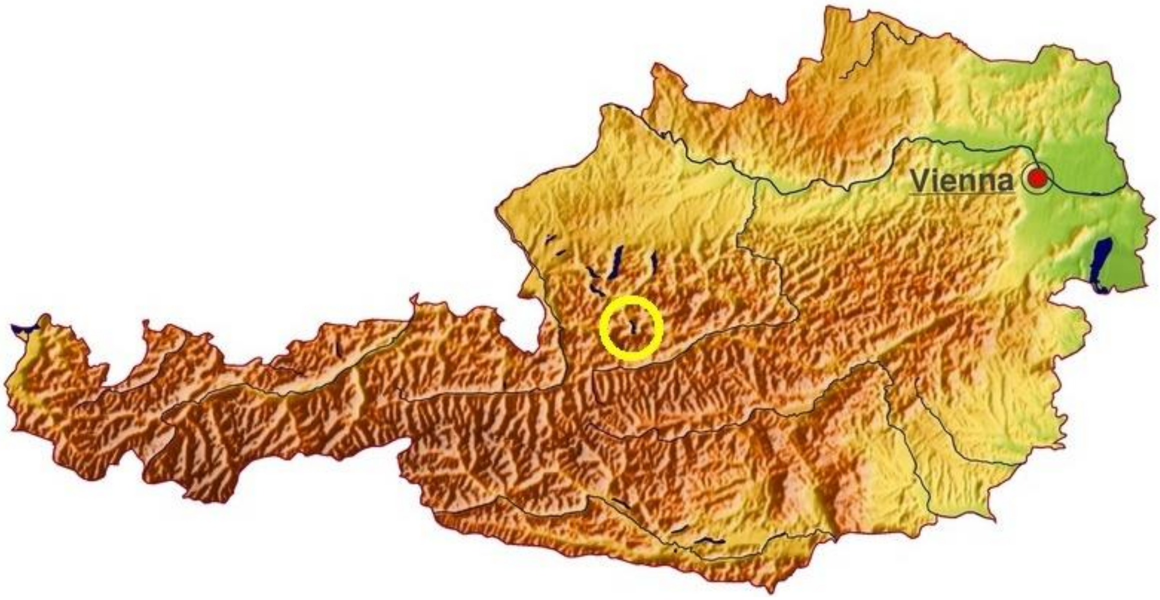


Fig. 1. Location of Hallstatt in Austria.

The genuine town itself lies perched between the steeply ascending "Salzberg" (= salt mountain) where salt has been mined since prehistoric time and the lake on an extension of the narrow coastal strip formed by river sediments and landslides (Fig. 2). Adjacent to the village the bottom of the lake descends steeply, reaching a depth of more than one hundred meters.

The vicinity of the ancient salt mine and therefore possibly "valuable trash" in the lake has long attracted divers. A local dive guide provided pictures of subaquatic "speleothems" (together with wild

speculations) to speleologists in 2021 and subsequently a small, preliminary scientific study with the help of diving geologists was carried out.

Fig. 2. View of Hallstatt and the adjacent "Salzberg" (=Salt Mountain) from the east. The valley with the creek feeding the alluvial fan on which the village lies, as well as a mining building – high above the village – can be seen, too (photo W. Greger).

Geological framework

The village of Hallstatt and Lake Hallstatt itself is surrounded by various karst massifs of which the Dachstein is the best known due to its UNESCO-World Heritage status as well as the type location of the wide spread upper Triassic "Dachstein Limestone" which forms the mountain ranges east, south and – in part – west of the lake, gently dipping northward. West of the village salt has been mined in an intruding Permo-Triassic salt dome since prehistoric time.

During the Pleistocene a presumably already existing proto-valley valley was excavated by glaciers until about 15 ka before present. The thickness of the glacier reached 1000 m at times. Subsequently the water of inflowing creeks and rivers filled the depression, forming the present-day Lake Hallstatt. There is no documentation of notable fluctuations of the level of the lake in historic times.

Results of divings and investigations

The four dives in autumn/winter 2022 provided direct evidence of a protruding alluvial fan in the area close to the shore east of the centre of Hallstatt, which had already been recorded by the geophysical prospection of an interdisciplinary team (Fig. 3).

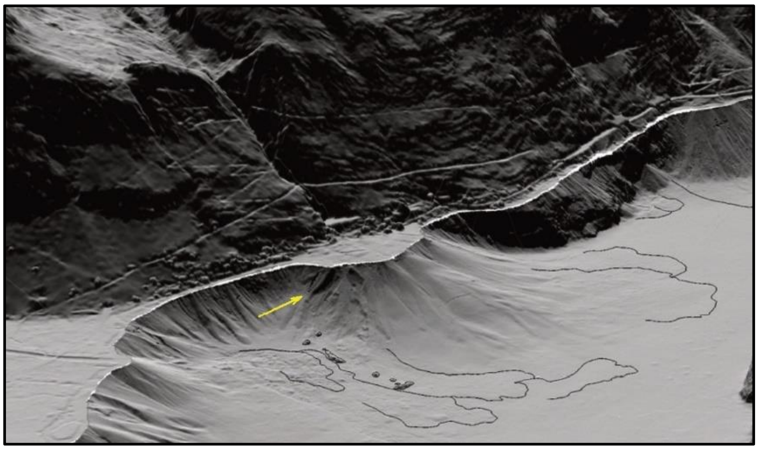
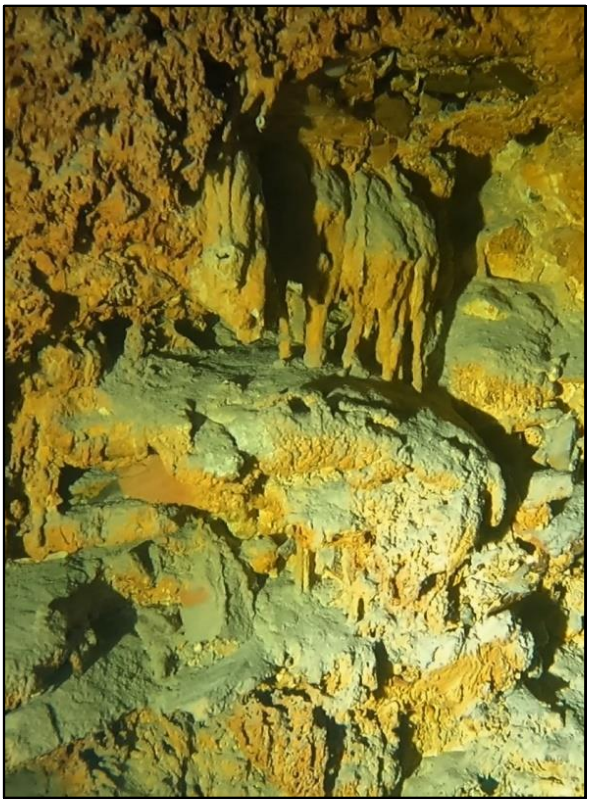


Fig. 3. 3D-visualisation of the lake bottom, shoreline and adjacent mountain slope at the western shore of Lake Hallstatt in the area of the village of Hallstatt. The yellow arrow marks the ridge with the subaquatic formations (Detail from a LIDAR-based terrain model, by courtesy of M. Strasser, Univ. Innsbruck).

This area was heavily overprinted by a massive landslide in 1809 where an area of about 500 m^2 of the shoreline slipped into the lake. On the western wall of the now modified alluvial fan the section of a depth from 10 m to almost 40 m shows an extensive overgrowth by yellowish, relatively coarse crystalline calcite, in part covered by grey mud.



Particularly on overhangs, this calcitic sinter is visually reminiscent of classic stalactites and flowstones (Figs. 4 and 5), but above all of calcareous tufa because of its obvious softness and texture (Fig. 6).

Fig. 4. "Pseudo-dripstones" and flowstones at a depth of -25,6 m, height of the stalactite-group in the upper centre is about 30 cm (photo C. Macherhammer, from video).

Fig. 5. Subaquatic "pseudo-dripstones" at -35 m depth, length of the "stalagmites" is about 40 cm, orange formations were obviously later covered with grey mud (photo C. Macherhammer, from video).

However, in relation to the entire shoreline of Lake Hallstatt, this phenomenon is spatially very limited and no other traces of such formations in the lake have been reported so far.

Due to the given time limit – the landslide of 1809 – the classification as "speleothems" or "spring tufa" very quickly became unlikely as the lake was formed several thousand years before the landslide, as already explained.

By means of ^{14}C determination, the age of an obviously reworked piece of wood trapped in the sinter (Fig. 7) was found to be some 800 years old which is also the absolute maximum age of the sinter formations covering the wood. Determinations of the stable isotopes ^{18}O and ^{13}C yielded values (δ^{18}O: -8 ‰ and respectively δ^{13}C: -10 ‰) very similar to common alpine speleothems but quite different from dripstones deriving from concrete and also from Triassic limestones in the catchment area of the lake.

Fig. 6. Closeup of a "dripstone" sampled during the divings in 2022 (photo R. Pavuza).

Fig. 7. Embedded wood (apparently reworked, grown 800 years b.p.) at a depth of -38,5 m, size of the wood approximately 20x15 cm (photo C. Macherhammer, from video).

Of particular relevance is the already mentioned slippage of the shore area and the relocation of the shore by several meters in 1808, combined with evidence that various calcareous materials were deposited in this area before – and in some cases after – the slippage (fire debris, operational waste from the brewing pans, wood ash).

Discussion

It is possible that locally inflowing, higher mineralized waters, influenced by the neighbouring saline and probably also hypothermal waters played a certain role in the formation. Thermal waters are to be found in a spring some 4 km to the north, directly on the shore with a water temperature of 24°C as well as in wells in the immediate vicinity of the formations with a thermal faint anomaly of about 5°C. These waters can be associated hydrochemically with the Permo-Triassic salt deposit to the west of the lake, which extends to great depths. Currently, however, there is probably little or no inflow in the sliding mass itself, at least there was no evidence of this during the dives. Nevertheless the geological and hydrogeological conditions in the vicinity of the deposit make this option appear possible for past periods. In addition, the inflow of wastewater from the local area up to the end of the last century must be taken into account, which makes – for instance – the genesis of limestone production through ureolysis (Fig. 8) likely. Alternative possibilities of its formation – like leaching of concretes or accumulation of limestone debris mud on biogenic material (like algae filaments) is unlikely because of the isotopic characteristics (^{18}O and ^{13}C)

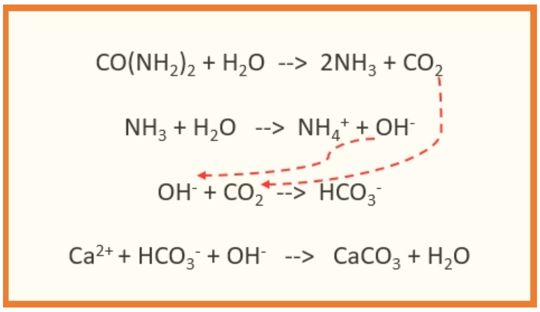


Fig. 8. Ureolysis as a possible path to the precipitation of limestone (urea as source) in Lake Hallstatt (from Zhu, Dittrich, 2016, slightly modified).

of the samples. In fact, analysis of the calcite yielded trace amounts of nitrogen (0,1 %), as well as noticeable millimetre-sized holes in the samples that may be interpreted as degassing voids formed during the decomposition of organic residues.

After weighing up the conceivable hypotheses, the dripstones were formed subaquatically after 1808, presumably with the involvement of cyanobacteria and other bacteria whose metabolism enables lime excretion through processes like ureolysis, denitrification, ammonification and others (see: Zhu, Dittrich 2016). The resulting features are possibly somewhat similar to the phenomenon of "pool fingers", which have already been detected in some caves also in Austria. However, the water depth there is considerably less and comparability is therefore only possible to a very limited extent.

If one looks at all the options together, a – probably very rare – interplay of various factors could have occurred here (Fig. 9).

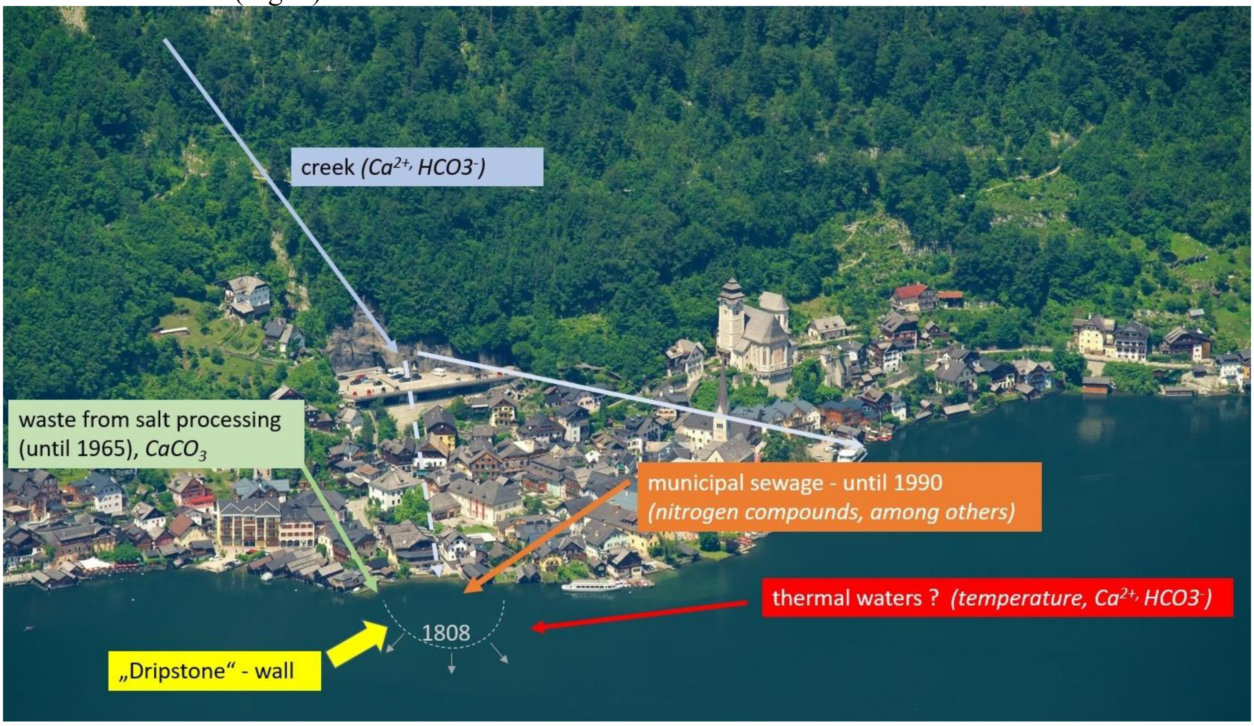


Fig. 9. Synopsis of factors responsible for the genesis of the subaqueous formations near Hallstatt (aerial view). The dotted blue line is the former creek-bed at the time of the shore slippage 1808.

Outlook

The peculiarity of the “pseudo-dripstone” formations lies less in their age than in the rarity of such formations at the depth level encountered in Lake Hallstatt. Subaqueous calcitic sinter formations are quite rare globally and are not known in this quantity and origin to the divers involved, at least not in the wider area. The international literature on this subject is also extremely sparse (e.g. Davis et al. 1990 or Sanna, Forti 2015) and the phenomena described there are hardly directly comparable with the formations encountered in Lake Hallstatt.

However, a special microbiological and geochemical investigation going beyond this initial presentation, including the molecular biological identification of the organisms involved and their contribution to the formation of the sinter wall requires sound funding and far more elaborate and careful sampling, but would certainly be desirable for the future.

A certain degree of basic protection of the deposits is provided by the authorities through the strict ban on recreational diving, but in the event of any absolutely necessary technical projects in the delicate adjacent shore area, special care should be taken to protect these formations of superregional importance, taking into account the probably unstable lake shore near Hallstatt.

The author of this short summary is interested in comments or possibly comparable observations. Additional information (in German language) and more representative photos and figures can be found in Greger et al. (2024).

References

Davis D.G., Palmer M.V., Palmer A.N. 1990. Extraordinary subaqueous speleothems in Lechuguilla Cave, New Mexico. NSS-Bulletin 52, 2: 70-86. https://www.researchgate.net/publication/292415663_Extraordinary_subaqueous_speleothems_in_Lechuguilla_Cave_New_Mexico

Greger W., Idam F., Leutner N., Macherhammer C., Mandl G.W., Pavuza R., Reschreiter J., Wirobal K. 2024. Die Unterwassersinter im Hallstätter See (Hallstatt/Oberösterreich). Speldok-31, 59 pp. https://hoehle.org/downloads/speldok_31.pdf

Sanna L., Forti P. 2015.Subaqueous anti-stalactites: a new type of speleothem from the old aqueduct of Sassari (Sardinia, Italy). Hypogea 2015 – Proc. Intern. Conf. of Speleology in Artificial Cavities: 511-518. https://www.researchgate.net/publication/273630566_Subacqueous_antistalactites_a_new_type_of_speleothem_from_the_old_aqueduct_of_Sassari_Sardinia_Italy

Zhu T., Dittrich M. 2016. Carbonate precipitation through microbial activities in natural environment and their potential in biotechnology: a review. Frontiers in Bioengineering and Biotechnology, 4: 1-21. https://www.frontiersin.org/journals/bioengineering-and-biotechnology/articles/10.3389/fbioe.2016.00004/full

NEW INSIGHT INTO CAVE FORMATION PROCESSES IN ANHYDRITE WEATHERING ZONES OF ATLANTIC CANADA

Adrian Jarzyna

University of Warsaw, Department of Tectonics and Geological Mapping, Warsaw, Poland; email: a.jarzyna@uw.edu.pl

Introduction

One of the unusual types of caves, quite rarely encountered in the natural world, are those formed in the weathering zone of anhydrite rocks. Called hydration caves or, less frequently, swelling caves (Quellungshöhlen in German), they are genetically related to the hydration of calcium sulfate and its transformation into secondary gypsum, which is described by the reaction $CaSO_4 + 2H_2O \rightarrow CaSO_4{\cdot}2H_2O$ (Bella 2011, Jarzyna et al. 2022). This process is characterized by "rapid" – in terms of geological time, lasting months/years/decades – changes in the rock structure consisting in a volume change, which is an effect of replacing anhydrite crystals with gypsum in an open system by displassive crystallization growth (Zanbak, Arthur 1984, Jarzyna et al. 2022). Their occurrence is limited to a few places in the world (Fig. 1A, B). The least known are those on the Alebastrovye Islands (Russia). Another site in the Harz Mountains (Germany) became a pioneering site for research on these rock cavities (Reimann 1987). In the Lviv region (Ukraine) and in Nova Scotia (Canada) a comprehensive methodological approach was used to carry out

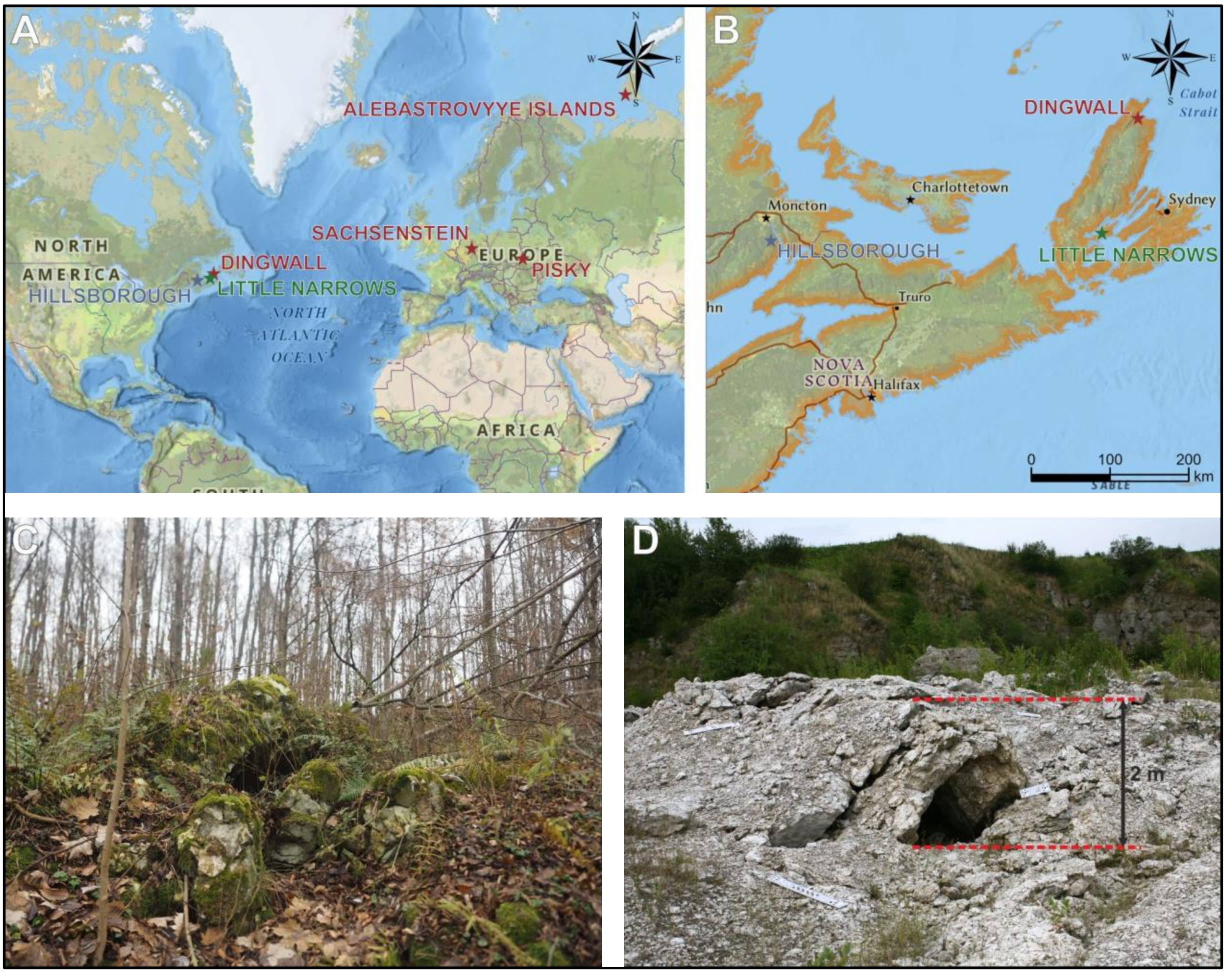


Fig. 1. A, B – location of anhydrite weathering zones with hydration caves and cavities; C – destruction stage of evolution of the Waldschmiede Cave (2021); D – rapid growing hydration cave at Pisky Quarry, Ukraine (photo D. Ługowski, 2016).

the research of anhydrite weathering (Jarzyna et al. 2020, Bąbel et al. 2020). Some of these weathering zones, like in the gypsum-anhydrite plateau of the Harz Mountains, are natural, and some, like in the Pisky quarry, Ukraine, were created through quarrying. These caves are characterized by a length of up to 10 m and a height of up to 2 m, while the shape is usually dome-like, less often the tepee-like. A peculiar example of caves was represented by the Waldschmiede Cave, the highest documented such cavity to date, but destroyed in the 1960s (Fig. 1C). Another example includes the rapidly growing hydration cave in the Pisky site in Ukraine; this cave was formed incredibly quickly, reaching above 1 m height in 5 years, now also destroyed by human activities (Fig. 1D).

Sites in Atlantic Canada

Dingwall Quarry

Of particular interest is the occurrence of the Carboniferous anhydrite weathering zone (Viséan, Windsor Group), a rock group extending from southeastern New Brunswick to the northern margin of Nova Scotia in the Cape Breton Island. It is within this rock group that the largest site of weathered anhydrite rocks has been documented to date at Dingwall Quarry, an abandoned gypsum quarry (Reimann, Vladi 2003). Detailed and comprehensive analysis of this site from a morphological, structural, petrographic and geochemical perspective has provided insight into the genesis, temporal development and morphology of the anhydrite hydration landscape. The documentation has shown the occurrence of several hundred hydration forms, and detailed documentation of several dozen of them has shown the presence of 48 caves, with entrances commonly accessible to adult persons. In most of the caves, the length was less than 4.6 m, the width was less than 3.0 m, and the height was less than 0.85 m, while 3 caves were longer than 8.00 m and higher than 0.80 m (Jarzyna et al. 2022).

New research: Little Narrows Quarry and Hillsborough

New studies in 2023, during my internship at the Acadia University, have revealed new sites of Carboniferous anhydrite gypsification at two sites in Atlantic Canada. In the first of them, at the Little Narrows Quarry, new deformations were identified 7 years after the cessation of human activity in this part of the quarry. We owe this information to Amy Tizzard from the Nova Scotia Natural Resources and Renewables). I made the new observations in a team with John Waldron, Mo Snyder, Jesse Demaires and Tilda Hughes.

The Little Narrows Quarry has been active since 1949 and is located on the south side of the Saint Patricks Channel, approximately two miles east of the village of Little Narrows, Victoria County, Nova Scotia, Canada. Here, in the southern part of the quarry we studied the area (200 × 170 m) of anhydrite outcrop characterized by outgoing process of gypsification. The original structure of the rock here has admittedly changed by diagenetic processes of the dehydration-hydration cycle. Altered rock structure also presents distinct flow folds due to ductile properties of the rock marked by rare carbonates intermediate layers. The hydration landscape is very incipient here, yet we recognized three hydration forms here, two dome-shaped and one tepee-shaped (Fig. 2). Their dimensions are maximum 2 x 4 m, the internal cavities are definitely too small with a height of up to 0.2 m (Fig. 2A, B) to meet the definition of a cave that could accommodate an adult human inside. At the site some ridges several meters long and about 0.2 m high were also identified.

Observations at the Little Narrows site were carried out using the airborne photogrammetry method based on the Structure from Motion tool. An unmanned aerial vehicle (Air 2S model), precise GPS with RTK corrections and Metashape software, known for its effectiveness in this type of 3D modeling, were used. The pixel size in the field of the obtained model is 5.87 mm/pix for the orthophotomap and 1.17 mm/pix for the Digital Elevation Model (Fig. 3).

The second site to be identified was the former Kings Gypsum Quarry in Hillsborough, New Brunswick. Here, in an area densely covered with trees, there are several smaller outcrops of gypsum-anhydrite rock, including three areas characterized by the occurrence of deformations created during gypsification of anhydrite. Deformation include fractures (Fig. 4B) and small domes with cavities and long ridges up to 0.2 m high (Fig. 4A).

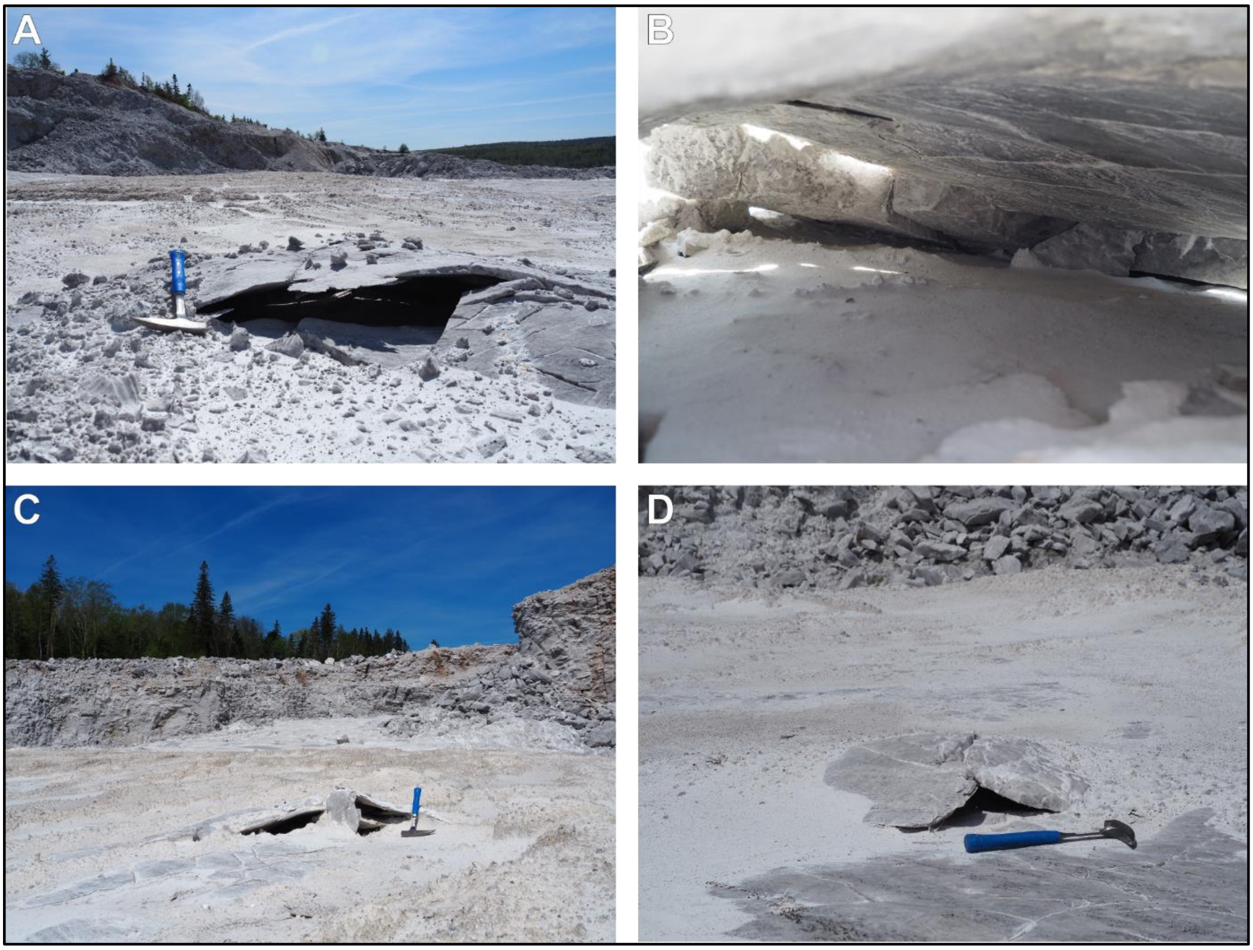


Fig. 2. Anhydrite weathering zone at the Little Narrows Quarry: A, B – the largest cavity within the study area and its interior (B); C, D – hydration tepees with dimension 2 × 1.5 m (C) and 1.3 × 0.9 m (D) in plan; note the very thin, up to a few centimeters thick detached anhydrite layer (photo A. Jarzyna, 2023).

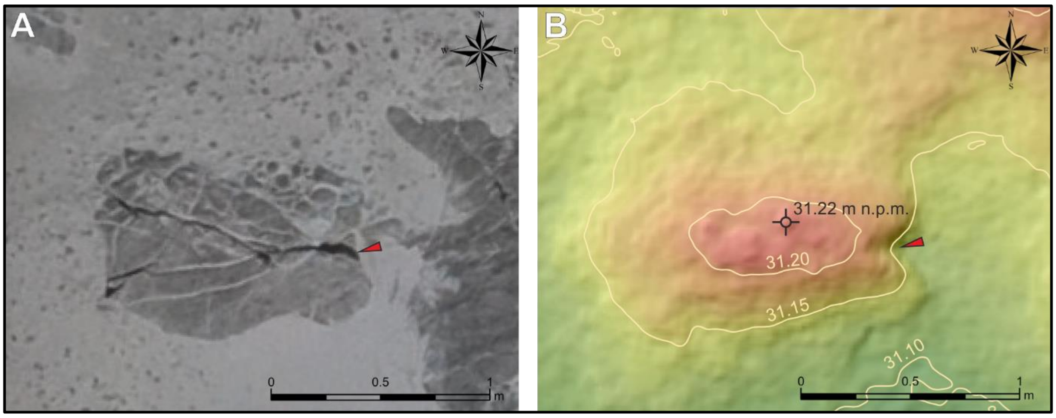


Fig. 3. Results of photogrammetric documentation of anhydrite rocks at the Little Narrows Quarry shown with hydration landforms visible in Fig. 2D: A – orthophotomap; B – digital terrain model.

Discussion and conclusions

The key differences between the newly identified (and described above) anhydrite weathering sites is the overall degree of gypsification. At the Little Narrows, due to the short gypsification time, we observe a predominance of anhydrite, which, according to microscopic observations, occurs here in an amount of over 90%. In the case of the Hillsborough, however, the degree of gypsification is advanced and the amount of anhydrite is about 30-60%. Also like Hillsborough, the extensively explored Dingwall Quarry has a similar level of anhydrite gypsification. So, Little Narrows Quarry is characterized by an initial process of transformation compared to the mature or old stage of transformations at the Hillsborough and Dingwall Quarry.

However, the main discernible, morphological difference is in the intensity of deformation produced during gypsification of anhydrite, including the presence of hydration caves. While at the Little Narrows Quarry this can be explained by an initial stage of anhydrite transformation, at the Hillsborough site the presence of low amount of deformations including hydration caves requires further investigation.

Fig. 4. Anhydrite weathering zone at the King Gypsum Quarry, Hillsborough: A – small hydration cavity with visible domal shape; B – extensive open fractures occurred on the small hill (photo A. Jarzyna, 2023).

References

Bąbel M., Olszewska-Nejbert D., Nejbert K. (Eds.) 2000. The weathering of anhydrite and gypsum rocks. GIMPO Agencja Wydawniczo-Poligraficzna, Warsaw, pp. 294.

Bella P. 2011. Geneticke typy jaskýn. Speleologia Slovaca 2. Verbum, Ružomberok.

Jarzyna A., Bąbel M., Ługowski D., Vladi F., Yatsyshyn A., Olszewska-Nejbert D., Nejbert K., Bogucki A. 2020. The unique hydration caves and recommended photogrammetric methods for their documentation. Geoheritage 12 (27): 1–15.

Jarzyna A., Bąbel M., Ługowski D., Vladi F. 2022. Petrographic record and conditions of expansive hydration of anhydrite in the recent weathering zone at the abandoned Dingwall gypsum quarry, Nova Scotia, Canada. Minerals 12 (58): 1–40.

Reimann M. 1987. Quellungshöhlen am Südharz. Internat. Symp. Zechstein, Hannover 1987.

Reimann M., Vladi F. 2003. Zur Entwicklung der sog. Zwergenkirche am Sachsenstein bei Walkenried, Landkreis Osterode am Harz, Niedersachsen und vergleichende Beobachtungen zur rezenten Entstehung von Quellungshöhlen in einem aufgelassenen Gipssteinbruch bei Dingwall, Nova Scotia, Kanada. Mitteilungen des Verbandes der deutschen Höhlen- und Karstforscher 49: 75–77.

Zanbak C., Arthur R.C. 1986. Geochemical and engineering aspects of anhydrite/gypsum phase transitions. Bull. Assoc. Eng. Geol. 23: 419–433.

OBSCURE NON-CARBONATE CAVES AROUND NEWCASTLE, NEW SOUTH WALES, AUSTRALIA

Garry K. Smith

Newcastle and Hunter Valley Speleological Society, e-mail: gksmith29@icloud.com

Introduction

The nearest limestone karst areas to Newcastle are more than two hours' drive away. Despite this, there are plenty of caves in non-carbonate rocks, close to Newcastle. The definition of caves being, any cavity large enough for humans to enter, which extends beyond daylight, so rock shelters and overhangs are not considered here.

It is hoped this article will inspire cavers to look beyond their local karst areas to find and document non-carbonate caves. Exploration can be exciting as these caves often contain features and biota of scientific interest. There are also many questions that relate to these caves. For example, how did they form and what invertebrates are found within them?

Caves around Newcastle

As briefly discussed in "Caves Australia" no. 220 (Smith 2022) and "Pseudokarst Commission Newsletter" no. 31 (Smith 2024), there are many sea caves along the coastline south of Newcastle in the Munmorah State Conservation Area (Fig. 1). Each of these sea caves contains features of interest. An example being the Pink Cave, so named because of the vivid bubble gum coloured calcite coating on the rocks. Another is Ghosties No. 2 South Cave, which is formed in sandstone and conglomerate rock, yet contains calcite flowstone (Smith 2024). A caver just has to be inquisitive and seek answers as to why the rocks are coloured pink or why calcite Speleothems occur in non-carbonate rocks and this can lead to a whole new field of learning.

Fig. 1. Location of caves described in this paper.

Less well known are the boulder caves that are scattered around the nearby Watagan Mountain Range to the west of Newcastle (Fig. 1). These include some good examples of boulder (talus) caves at Gap Creek (Smith 2013, 2019). The largest is Bangalow Rock Pile Cave (I6E-68), with more than 60 m of passages (Fig. 2). To the inquisitive caver, questions arise as to how these caves occurred and what troglobiotic fauna live in them.

Fig. 2. The entrance to Bangalow Rock Pile Cave (I6E-68) in the Watagan Mountain (photo Garry K. Smith).

Then there are the large crevice and boulder (talus) type caves at Pilchers Mountain, developed due to mass movements, which are among some of the best examples of such caves in Australia (Smith 2007) (Fig. 3 and back cover). There are 14 caves with the deepest being 46 m. The process which formed these caves and chasms is quite interesting (Fig 4). The chasms and gorges have created zones of micro-climate which have allowed pockets of subtropical rainforest to thrive. This is in stark contrast to the more open woodlands and grazing pastures surrounding the gorges.

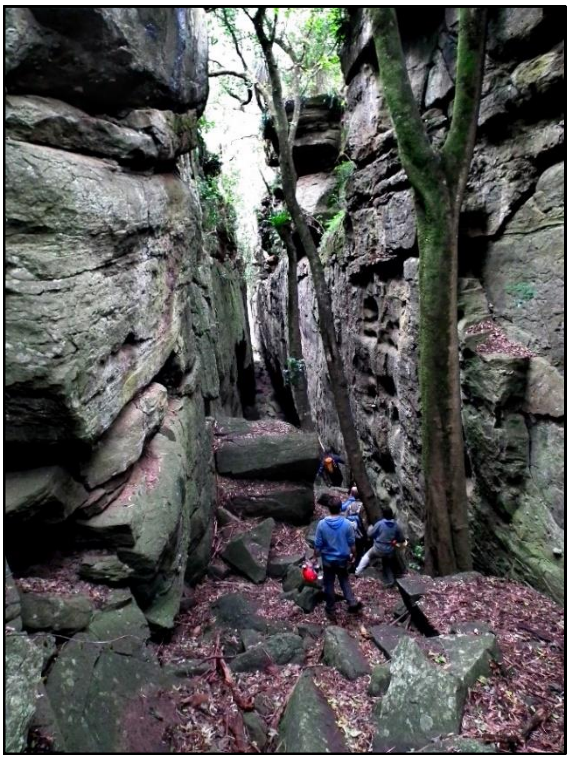


Fig. 3. The Main Gorge at Pilchers Mountain, which has resulted from mass movement (photo Garry K. Smith).

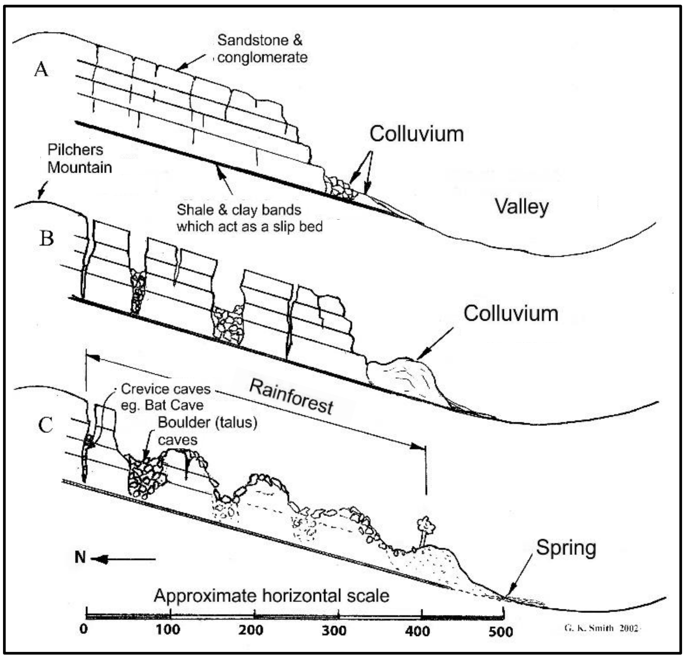


Fig. 4. Sequence of events leading to formation of caves and chasms at a slope of Pilchers Mountain – a model.

Other types of non-carbonate caves are piping caves, of which there are two examples in the outer suburbs of Newcastle. Formed in quartz sandstone and conglomerate rock, these caves are relatively uncommon compared to other types of caves. Crokers Creek Piping Cave was detailed in Caves Australia No. 217 (Smith 2021a) (Fig. 5).

Fig. 5. Garry Smith, author of this paper, in Crokers Creek Piping Cave (CQ-48) (photo T. Durney).

However there are many small fissure and stream erosion caves in sandstone and conglomerate rock, which are less well known. Despite being created in non-carbonate rock, some even contain reasonable examples of calcite speleothems.

Small crevice and boulder caves

Mt Sugarloaf is part of a sandstone/conglomerate mountain range situated to the west of Newcastle. Various parts of the range are under the administration of New South Wales National Parks, while other areas are managed by Forestry. On the highest peak (412 m a.s.l.) there is an amazing tourist lookout with a 360 degree view, and a little further down the mountain are three huge communication towers and a large day use picnic area. But what tourists do not realise, is that further along the mountain range, there are a number of crevice type caves created by the gravitational movements of sandstone blocks. At the top of the ridge the slippage of the large blocks has created a small gorge, but beneath there are two reasonable size caves (Fig. 6). Land Slide Cave (I6B-20) has a survey length of 31 m and maximum depth of 6 m. The cave is generally dry and dusty, however after substantial rain becomes quite damp. Its main chamber is 27 m long x 2.5 m wide x 2.3 m high (Figs. 7 and 8). There are a number of tree roots in the main chamber. Nearby in the same slip line as I6B-20 is Fault Cave (I6B-2). It has a survey length of proximally 45 m and maximum width of 3 m and depth of 14 m. Both caves are known to often shelter several Horseshoe Bats (*Rhinolophus megaphyllus).*

Fig. 6. Newcastle & Hunter Valley Speleological Society and Sydney University Speleological Society members in the small gorge above the crevice caves at Mt Sugarloaf (photo Garry K. Smith).

Fig. 7. In Land Slide Cave (I6B-20) at Mt Sugarloaf (photo Garry K. Smith).

Another cave, located on the side of the mountain range, below the two previously described caves, is Old Lady Cave (I6B-1), so named because of the great number of Granny's Cloak

Moths (*Speiredonia spectans*) found inside. This cave was formed by a section of the cliff line breaking free and the base of the large slab slipping away from the break point. This cave has 3 entrances, one of which opens to a 2 m vertical drop. The floor of the cave is near horizontal over its survey length of 23 m, and the maximum passage width is 2 m. While not a particularly large cave the sheer numbers of moths often found inside is quite amazing.

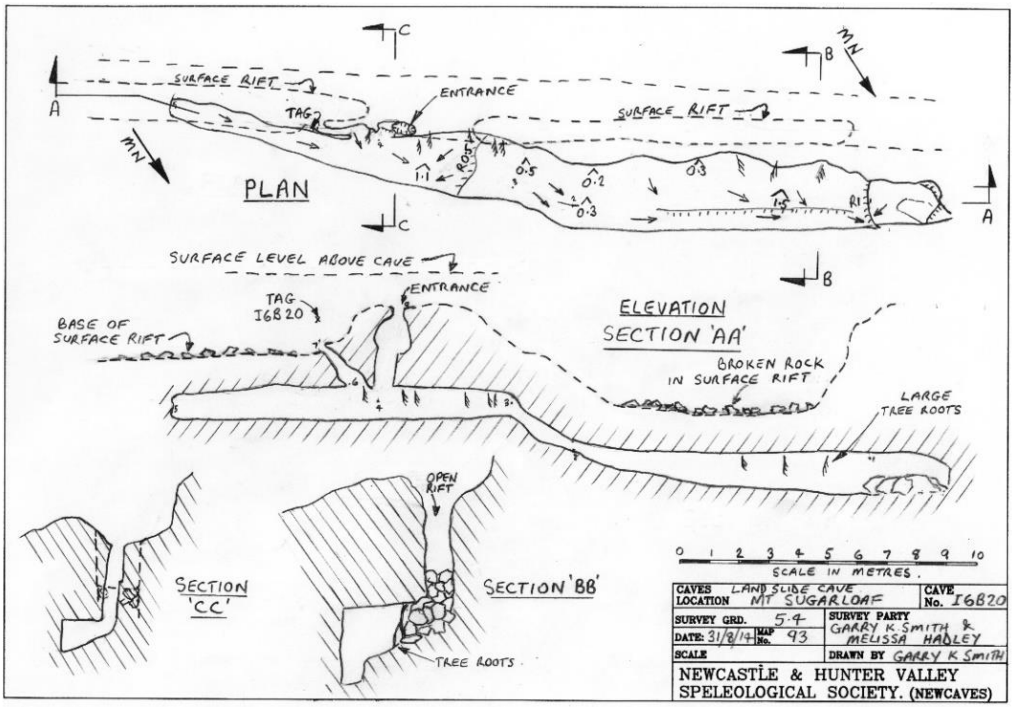


Fig. 8. Map of Land Slide Cave (I6B-20) at Mt Sugarloaf.

I discovered Land Slide Cave, Fault Cave and Old Lady Cave by accident in the late 1970's while wandering around the bush. Fortunately they are in obscure locations well away from tourist trails, so are rarely visited.

The search for information and answers can lead down some interesting paths. Such was the case of finding many Granny's Cloak Moths resting in a local cave within several metres of predatory bats. This observation led to a search for information on the subject and the summary article about how the moths co-exist with their predators appeared in Caves Australia No.217 (Smith 2021b).

Cavers should keep their ears open as word of mouth can unexpectedly lead to locating caves hidden in residential backyards. One such example is a crevice cave located under a small cliff in the backyard of a house in Cardiff Heights, a suburb of Newcastle. I first visited this cave in 1971 after a few enquiries revealed its exact location and led to a subsequent exploration trip. Now called Tickhole Tunnel Cave (I6B-19), it has a survey length of 40 m (Fig. 9). The cave was created by a section of approximately 6 m high cliff breaking free, slipping several metres and splitting into large boulders up to 15 m in length. Because the cave is created by the cavity between large boulders, the passage shape is rather irregular (Fig. 10). The damp environment in the cave, provides ideal conditions for fauna such as Leaf Tailed Gecko lizards (*Phyllurus platurus*), Glowworms (*Arachnocampa richardsae*) and Cave Crickets (*Australotettix montanus*) (Smith 2003).

Fig. 9. In Tickhole Tunnel Cave (I6B-19) (photo Garry K. Smith).

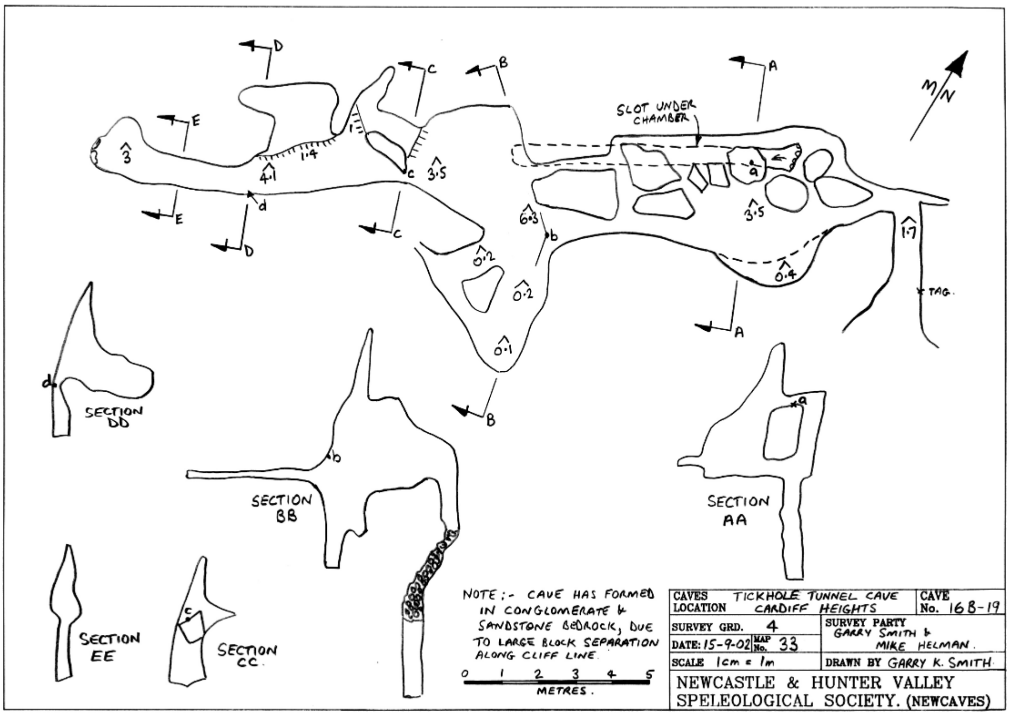


Fig. 10. Map of Tickhole Tunnel Cave (16B-19) at Cardiff Heights, Newcastle.

Stream erosion caves

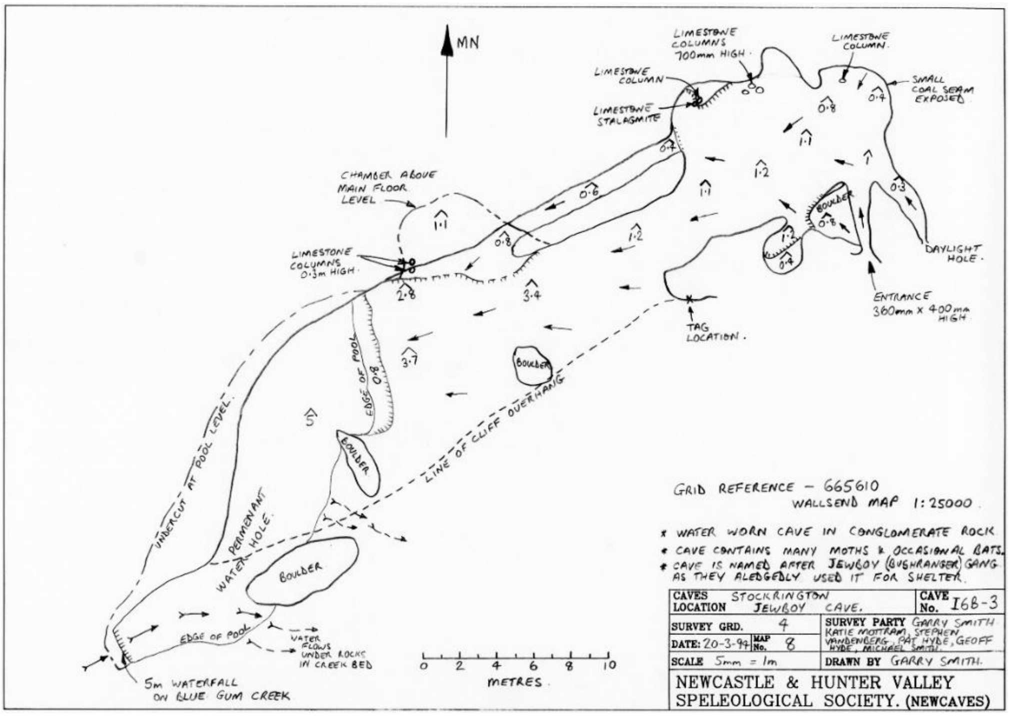
A good example of a stream erosion cave is Jewboy Cave (I6B-3) located near Seahampton, to the west of Newcastle. This cave has been created at the base of a waterfall by preferential erosion of a soft fine-grained sandstone layer (Smith 2015). The cave begins at the base of a waterfall as an overhang and transitions into a cave of reasonable extent with an average ceiling height of just over 1 m and chamber width of 10 m. The survey length is 57 m. At the back of the cave is a tight second entrance. Besides calcium carbonate flowstone there are a number of calcite stalactites and columns up to 0.7 m high (Figs. 11 and 12). It is uncommon to find such a quantity of calcite speleothems occurring in a cave formed in non-carbonate host rock.

Fig. 11. Garry Smith, the author of this paper, in Jewboy Cave (I6B-3) at Stockrington, despite being created in quartz sandstone and conglomerate host rocks, it contains calcite columns (self-photo Garry K. Smith).

However even small non-karst caves can lead to some interesting history if cavers want to delve into it. The Jewboy Cave, was named after the Jewboy Gang who allegedly used it as a hideout while on the run from the law (Smith 1994). This notorious group of seven outlaws was led by escaped convicts Edward Davis "Jewboy". The gang robbed from property owners in a wide area through the Hunter Valley in 1839-40. During a holdup one of the gang members shot and killed a store clerk at Thomas Dangar's store in Scone, before the gang was tracked down and six were captured in December 1840. After their trial in Sydney, they met their fate at the gallows in March 1841 (Bergman 1966).

Other smaller stream erosion caves, occur in the Newcastle region, however are not discussed here.

Fig. 12. Map of Jewboy Cave (16B-3) at Stockrington.



Closing remarks

Hopefully this article will inspire cavers to look more closely around their local area for obscure caves that are often overlooked in the quest to find caves in karst areas. Take notice and ask questions when talking to locals as conversations can lead to some surprising caves located in suburban backyards and local bushland. Besides surveying, it can prove quite rewarding when investigating the geology, fauna and associated history of these non-karst local caves.

Note: This article (with some differences) was first published in Caves Australia No. 222, December 2022: 17-21.

References

Bergman G.F.J. 1966. Davis, Edward (1816–1841). Australian Dictionary of Biography, Melbourne Univ. Press. Retr. 30.04.2021 – via National Centre of Biography, Australian Nat. Univ.

Smith G.K. 1994. Story of the Jewboy Gang. Newcaves Chronicles 3: 15.

Smith G.K. 2003. Tickhole Tunnel Cave – 15th September 2002, Newcaves Chronicles 19: 21 and 42.

Smith G.K. 2007. Tectonic and talus caves at Pilchers Mountain, New South Wales. Helictite 40, 1: 11–20.

Smith G.K. 2013. Gap Creek – Boulder Caves. In: Proceedings of the ASF 29th Biennial Conference, 6th-11th January 2013, Galong, NSW: 3-13.

Smith G.K. 2015, Jewboy Cave and Mt Sugarloaf – 31st August 2014. Newcaves Chronicles 43: 11-13.

Smith G.K. 2019, Gap Creek Valley and Boulder Caves within the Watagans National Park. Helictite 45: 1-10.

Smith G.K. 2021a. Our Kedumba and Crokers Creek piping caves, karst (?) caves in non-carbonate rocks. Caves Australia 217: 5-7.

Smith G.K. 2021b. Granny's Cloak Moth *(Speiredonia spectans).* Caves Australia 217: 20-22.

Smith G.K. 2022. Sea caves south of Newcastle, NSW. Caves Australia 220: 11-15.

Smith G.K. 2024. Sea caves south of Newcastle, New South Wales, Australia. Pseudokarst Com. Newsletter 31: 57-64.

IN MEMORIAM

WILLIAM R. HALLIDAY
(1926 – 2024)

William R. Halliday: Contributions to Pseudokarst Studies

Dr. William R. Halliday, one of the fathers of American caving and speleological studies, passed away on September 20, 2024 at 98 years of age. Bill lived a long and productive life. He wrote several books about caves and caving adventures, founded numerous caving organizations in the United States, and wrote prolifically about all types of caves and their origin. He was the President of the IUS Commission on Volcanic Caves, active in the IUS Pseudokarst Commission, and founder of the Hawaii` Speleological Survey, among many other achievements.

Bill had a strong interest in all aspects of cave development and forms of caves, including those developed beneath landforms that have the morphology of classical karst, but which are non-solutional in origin, i.e., pseudokarst.

Perhaps Bill's earliest contribution to the pseudokarst literature was a 1954 article in a regional publication titled appropriately "Pseudokarst": (Salt Lake Grotto Technical Note 25, Nov. 1954). He followed this with a more formal discussion in the July 1960 issue of the National Speleological Society Bulletin: "Pseudokarst in the United States" in which he described pseudokarstic features in the western United States including caves developed in basalt flows, beneath glaciers, and in poorly consolidated sediments. Bill's interest in the subject continued with chapters on piping caves and pseudokarst in the Encyclopedia of Caves and Karst Science (Gunn 2004) where he provided a working definition of the term, an extensive discussion of various aspects of pseudokarst, and classified the major types of landforms and processes involved in its development.

Bill's last contribution to pseudokarst literature appeared in the June 2021 issue of the regional publication: Rocky Mountain Caving (vol. 39, no. 2) when he was 95 years old; 67 years after his first report on pseudokarst. Titled "Mega-Patterns in Southwestern Karst and Pseudokarst", he described a variety of non-solutional features found throughout the western U.S., including crevice caves in sandstones, littoral caves, soil pipes, vertical walled overhung sinkholes in sandstones and vertical breccia pipes.

Bill was active, curious, and productive to nearly the end of his life. He concluded his last report writing: "I wish you 70+ years of caving as joyous as mine. To all, the best of caving forever".
Farewell, Bill. You will be sorely missed.

Douglas Medville (photo G. Szentes)

William R. Halliday: Honorary Member of the Pseudokarst Commission

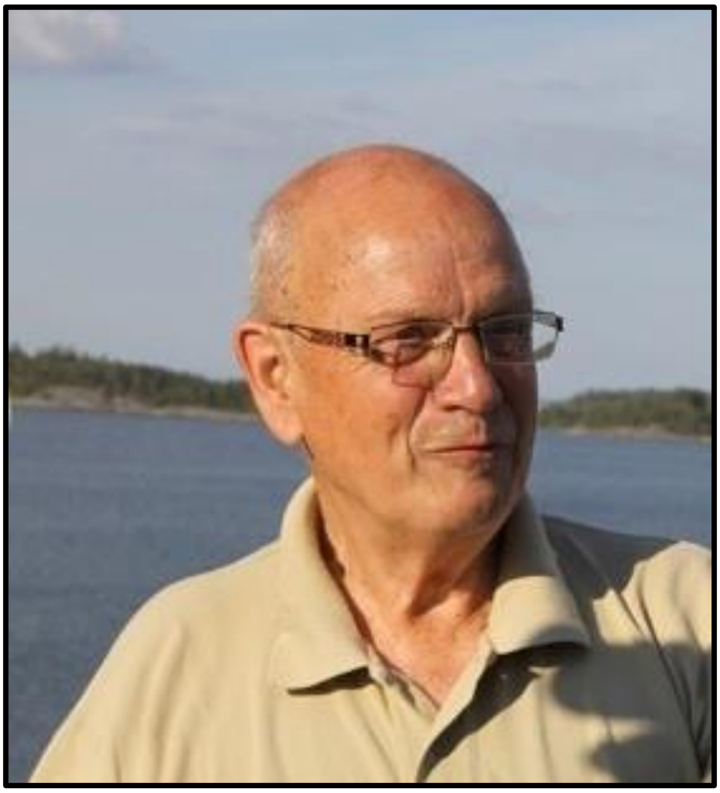
I have never met Bill Halliday face to face, but I was corresponding with him for at least several years in the last period of his professional activeness. He was preparing a monograph on pseudokarst and asked me about the state of research and knowledge on the pseudokarst caves in Central Europe. But when he found out that I was editing the "Pseudokarst Commission Newsletter" he wrote several papers published in Nos. 20 (2010), 21 (2010), 22 (2011) of the "Newsletter" and described non-karst caves in various protected regions of North America. He was very friendly, not keeping a distance in his letters, but completely professional. Only the last months of our contact were not so optimistic, because Bill was aware of his deteriorating condition and progressing eyes disease and he was worried about his work, tried to find somebody who could continue his projects. He very consciously decided to end his professional work in the late spring 2017, writing in one of the last letters: "It has been a very special honor and a pleasure having been associated with all of you on the Commission. My best wishes for great success in the future."

Very soon later the Commission members decided to nominate him a Honorary Member of the Pseudokarst Commission.

Jan Urban

IN MEMORIAM

RABBE SJÖBERG
(1941 – 2024)



As a young man, Rabbe moved from Täby near Stockholm where he grew up to Nordmaling along the northern coast of the Bothnian Sea. This was in the mid-1960's, and Rabbe just got his first position as a physical education teacher. As an avid outdoor person, and a skilled ornithologist, he started to explore the surroundings, and soon found his first caves. One of the first caves he (re-)discovered was the tunnel type cave, Tjuv-Antes grotta (Thief-Ante's cave), a cave that he would return to regularly for the rest of his career as speleologist, and would in many ways change his life.

Tjuv-Antes grotta belongs to a peculiar type of rather small but beautiful pear-shaped marine abrasion caves, tunnel caves, that would be the first major research subject for Rabbe. Like so many other academic speleologists, his first step into scientific speleology was as an enthusiastic amateur, and he soon started investigating the genesis of the Scandinavian tunnel caves. At that time, the dominating interpretation of their genesis (put forward most vocally by "the father of Swedish speleology", Leander Tell, 1895-1980) stated that they were glacial phenomena (interpreted as horizontal glacial potholes, formed by subglacial meltwater streams). But Rabbe soon noted that all known tunnel caves were situated under the highest postglacial sea level and directed towards the sea, strongly indicating that they were of marine origin. That idea did not originate with Rabbe, something that he was the first to admit, but opposing the leading authority on Swedish speleology, Leander Tell, shows an integrity and courage in thought, and also a talent to interpret field observations without falling back to prevailing theories. During numerous field studies over several years, visiting all known tunnel caves in Sweden (and many marine abrasion caves elsewhere), and knowing that he had to present a strong case, Rabbe collected enough data to convincingly show that the tunnel caves are of marine origin.

Rabbe was never fond of theoretical reasoning or mathematical models, but rather grounded his hypothesis in empirical data collected during his many field studies. After defending his licentiate thesis on the genesis of tunnel caves in 1986, Rabbe turned his focus on the much more complex “boulder” and “fracture” caves in the Archean bedrock of Sweden. Some of them had previously been interpreted as being of neotectonic origin, that is originating during recent (postglacial) earthquakes, but only a few studies focusing on single locations had then been published. This interpretation was also supported by Rabbe, but with vastly more field data than any of his predecessors. In the 1990’s, Rabbe started collaborating with Nils-Axel ‘Niklas’ Mörner (1938-2020) at Stockholm University. The first part of that collaboration resulted in a Ph.D. thesis: *Bedrock caves and fractured surfaces in Sweden, occurrence and origin*, successfully defended by Rabbe in 1994. Mörner shared Rabbe’s view on the presence and impact of large earthquakes in early Holocene of Sweden, triggered by glacial isostatic adjustment after the Weichselian glaciation. Together, they continued to collaborate on the research on neotectonics and Swedish bedrock caves, a collaboration that only ended with the passing of Mörner in 2020. They continued to gather field data supporting their theory, now modified for at least some caves to also include an origin due to rapid phase transition of methane hydrate to methane gas (“methan hydrate explosions”), triggered by earthquakes. Their views on paleoseismicity and the origin of Swedish pseudokarst were summarised in a paper published in International Journal of Speleology in 2018: *Merging the concepts of pseudokarst and paleoseismicity in Sweden: A unified theory on the formation of fractures, fracture caves, and angular block heaps.*

Recently, Rabbe’s and Niklas’ ideas about neotectonic and methane gas venting origin of many larger "fracture caves" in Sweden has been questioned and alternative explanations ("glacial ripping", first published by Adrian Hall et al. in 2020) has been proposed. His last major paper published in June 2022, in the magazine “Grottan”, was about the origin of Bodagrottorna ("Så bildades Bodagrottorna") that can perhaps be seen as some kind of rebuttal to a paper by Adrian Hall and Maarten Krabbendam, published in the previous issue, but without going into polemic. Rabbe published his last piece in “Grottan” one year ago, a retrospect on a meeting that he and SSF (Sveriges Speleologförbund – Swedish Speleological Society) arranged in 1973.

Fortunately, Rabbe’s interest in caves coincided with the founding of Sveriges Speleologförbund (the Swedish Speleological Society). He could not attend its very first meeting on Gotland in 1966, but he was among the very first paying members in the society. Rabbe soon became one of the most prolific writers in the Swedish caving magazine “Grottan”, with numerous contributions on all aspects of caving and speleology. He also served as board member for nearly two decades, as well as in many other roles. He was thus a very well deserved Honorary Member since 2018.

But caves and speleology also had other, perhaps even more important impacts on the life of Rabbe. In 1984, the (then) Czechoslovak speleological club Orcus Bohumín contacted Rabbe for a visit to Sweden. The person in charge of communication was Ljuba Šromová, and Rabbe and Ljuba quickly found each other. Only two years later, they married and Ljuba moved to Umeå. They didn’t only share a love of caves, but also traveling and not the least of their dogs.

We, in the Swedish Speleological Society, together with his many friends and colleagues in Sweden and abroad, will sorely miss Rabbe. But we are at the same time very grateful for his willingness to share his enthusiasm and knowledge through numerous contributions that will be with us for many more years to come.

Johannes Lundberg (photo Ch. Pfarr)

This memory (with some modifications) was published in UIS Bulletin vol. 66-2, December 2024: 63-64.

Editorial note

This issue of the Pseudokarst Commission Newsletter is “thinner” than the last two ones (nos. 30 and 31), but the subjects of papers are not less fascinating or unique, yet not described or hardly met in geomorphological and speleological journals. The articles on sometimes bizarre phenomena, which are sometimes actually classified as pseudokarst, sometimes located in the “grey” area between karst and non-karst, come from North and South America, Australia and Europe and underline the global relevance.

Such a wide range of described phenomena, landforms and problems aptly refers to the discussion currently underway on our blog concerning the change of the name of our Commission, which renewed the consideration about the term "pseudokarst" itself. An exact definition of the term "pseudokarst" seems to be a never-ending story, respectively a potentially impossible task – as can be seen in our blog. Besides numerous serious works of not only the Commission members – where the Newsletter gives an impressive proof – on the physico-chemical processes involved in caves and landscapes to a certain degree similar to classical karst features, the term "pseudokarst" has been questioned from time to time. But at the same time, it always turned out that the boundaries of the “karst” phenomenon itself were not really well defined. So then – where does "pseudokarst" begin or end?

Again, for many of us this terminological discussion is probably much less important than investigating the processes involved, and there is still a lot of work to be done – for example, quantifying more thoroughly the corrosion/erosion relationship in different “pseudokarst settings” – a tricky, non-trivial task!

In this Newsletter issue – as usually – we also had to say goodbye to the colleagues who worked hard on pseudokarst and had been familiar to us for decades.

Rudolf Pavuza, Jan Urban