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M. MIŠÍK*

MIOCENE SINTER CRUSTS (SPELEOTHEMS) AND CALCRETE DEPOSITS FROM NEPTUNIAN DYKES, MALÉ KARPATY MTS.

(Figs. 1—28)

Abstract: Badenian age of speleothems resulted from the following observations: sinter crusts bored by marine organisms, pebbles of sinter in the transgressive conglomerates, speleothems line the fissures filled with Miocene sands. Relicts of the calcrete deposits were preserved in upper part of fissures; the alternation of sinter crusts and calcrete layers was registered, too. Briefly are described rare occurrences of Cretaceous speleothems and calcretes from the West Carpathians and also an Upper Carboniferous caliche with vadose pisoliths penecontemporaneously dolomitized.

Резюме: Баденский (среднемиоценовый) возраст спелеотем подтвержден следующими наблюдениями: накипные коры просверленные морскими организмами, пристутствие галек накипи в трансгрессивных конгломератах, спелеотемы выстилают стены трещин в основных мезозойских известняках выполненных миоценовыми песками. Реликты кор выветривания (каличе) сохраненные в высших частях трещин. Чередование положений накипи и каличе было тоже установлено. Кратко описаны редкие встречаемости меловых спелеотем и кор выветривания из Западных Карпат как и верхнекарбоновые каличе с вадозными пизолитами, почти одновременно доломитизованными.

Introduction

The West Carpathians territory is rich in caves with dripstone decorations still „living". The recent speleothem growth influences the thinking of many geologists; they suppose all cave speleothems in the territory of Slovakia to be of Quaternary age. Even in the geologic literature of other countries the papers concerning fossil karst phenomena only exceptionally comprise descriptions of the sinter crusts or dripstones from pre-Quaternary periods. It is no doubt that the favourable conditions for the origin of caves with speleothems repeated many times in the course of geologic history. The scarcity of the older cave sinters is due to the fact that they were formed on the continental rising areas and therefore in the overwhelming majority of cases they succumbed to destruction, mechanical erosion and chemical weathering — solution. As the speleothems consist of the coarse-grained calcite aggregates, the loss of their characteristic structures by diagenetic recrystallization is improbable. Thus the lack of pre-Quaternary sinter crusts cannot be explained in such way. The total lack of pre-Quaternary speleothems might be only apparent, as we did not dispose of sufficient criteria to recognize them.

During the study of transgressive Badenian sediments in the surroundings of Bratislava I found out that the sinter crust decoration including stalactites in small caverns in the Triassic and Liassic carbonate rocks is older than

* Prof. RNDr. Milan Mišík, DrSc., Department of Geology and Paleontology, Natural Science Faculty of the Comenius University, Gottwaldovo nám. 19, 886 02 Bratislava.

Uppermost Badenian (older than 14 million years) since the sinter crusts exposed on the acient cliff were bored by organisms of Badenian sea (M. M i š í k, 1976, p. 33). That is attested also by sinter pebbles in the base conglomerates and breccias of Upper Badenian as well as by the neptunian dykes — fissures rimmed with sinter crust and filled with the marine Upper Badenian sands. The Miocene speleothems were found hitherto on four localities and their presence is supposed on two others (Fig. 1).

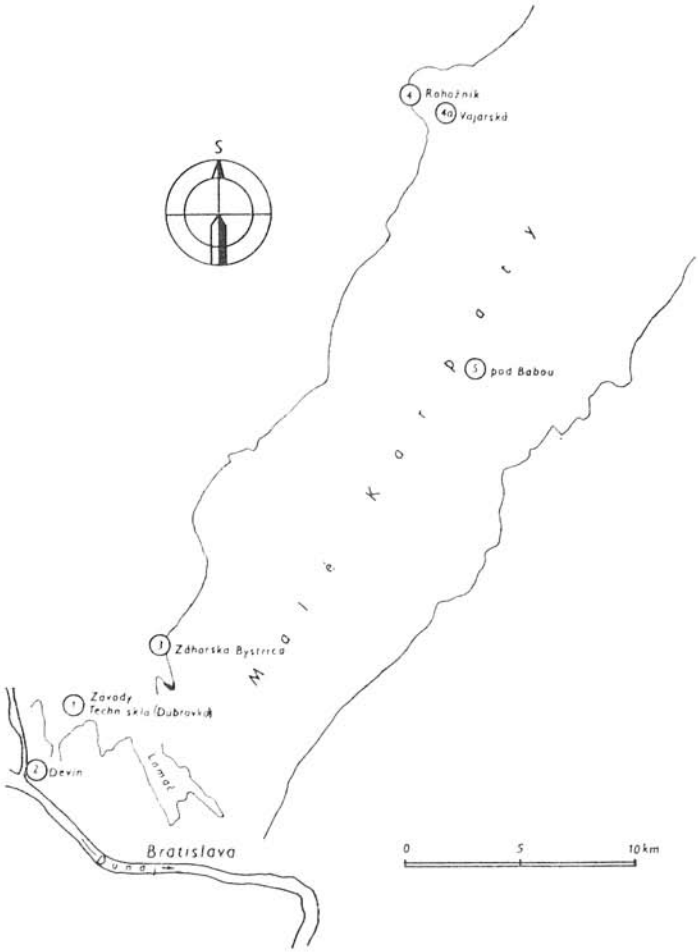


Fig. 1. Localities with Miocene speleothems (on the localities 4a, 5 the age is not proved).

Description of outcrops with the Miocene speleothems

1. Abandoned quarries above Technical glass-work near *Dúbravka,* Bratislava (formerly Stockerau lime quarry). The carbonate rock strata in the

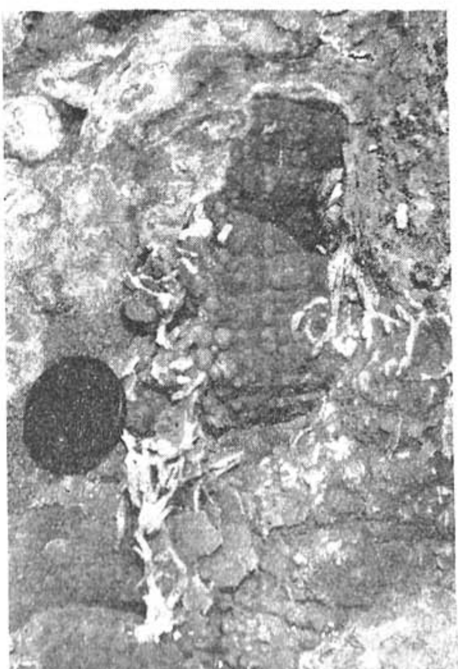
biggest quarry belong according to M. M a h e ľ (1972) to the Liassic of the Malé Karpaty mantle series. They are overlain by the Upper Badenian breccias, conglomerates and sands. Near the eastern entrance there is a rock wall entirely covered with cave sinters, draperies, cave popcorn and stalactites (Fig. 2—4). The stalactites are usually covered with calcite crystals and etched by meteoric agents.

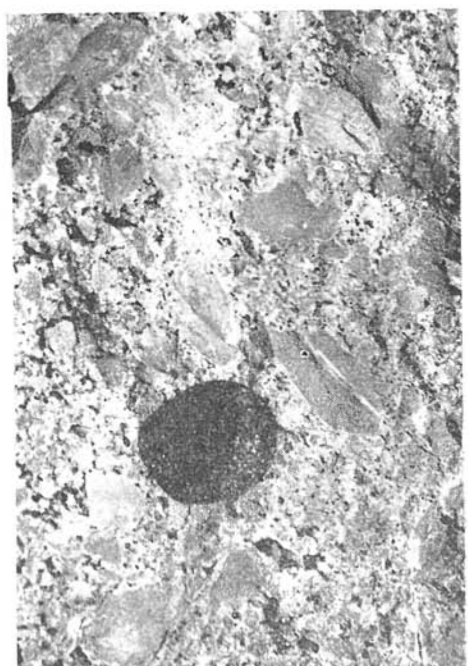
The origin of the sinter crusts is connected with a subvertical fracture plane approximately of E—W trend. Judging from the maximum sinter thickness in several blasted blocks the width of that open fracture should have been more than 60 cm. The fracture direction is parallel to a marginal fault near the end of the Lamač graben. Most of the neptunian dykes filled with Badenian sediments also display a direction approximately parallel to that one of the Lamač depression (NW—SE). Thus the origin of the mentioned fractures (relaxation or radial tectonics) was connected with the forming of the Lamač graben, a young structure transversal to the Malé Karpaty meganticlinal horst. It is clear that the caverns of the described initial Miocene karst had a crevisse-cave nature.

Abundant evidences of the pre-Upper Badenian age of these sinter crusts can be found in the western flank on the exploitation rock step. There are several loose blocks from the last blast-firing formed by Liassic microcrystalline limestones and dolomites with a thin coquinoid layer and some scarce intercalations of oölitic limestone with selectively dolomitized oöids. The Liassic limestones and dolomites with sinter crusts were exposed here as a cliff of the Upper Badenian seashore and both the limestones and the sinters bear traces of the bores made by bivalves, annelids and sponges (Fig. 7). The overlying Upper Miocene sandy gravels (Upper Badenian stage, Kosovian substage — J. Š v a g r o v s k ý in A. P a p p et al., 1978, p. 188) contain pebbles of the same brown-yellowish sinters, sometimes covered with bores, too (Fig. 8). The Miocene age of speleothems can be proved also by fissure fillings. Several types of them may be distinguished:

a) Ancient fissures in the Liassic limestones have mostly double filling; their margins are rimmed with sinters (the older filling) and their middle part is formed by sands. The largest fissure has a direction of 210°—225° and a dip of 70—80°; its width varies between 30—80 cm. Its margins are covered with an interrupted layer of sinter crust 5—10 cm thick, the middle part is filled with coarse-grained sands with diagonal bedding (Fig. 13) comprising some sinter fragments. In the narrowest part of the fissure there is an accumulation of the dolomite fragments to 20 cm size. The lower part of the joint was filled with yellowish and reddish loam, obviously older than the overlying Upper Badenian marine sands in the upper part. The age of sinter crusts (speleothems) is given by vertebrate bones found together with the sinter fragments in the loamy filling. The vertebrate fauna shows Upper Karpatian — Lower Badenian age accordingly to G. R a b e d e r (in A. P a p p et al., 1978, p. 477); teeth of *Rodentia* indicate Lower Badenian (O. F e j f a r 1974, p. 110).

b) Several open fissures were sealed up only with sinter crusts. The maximum thickness of such an open empty fissure estimated from the thickness of sinter crusts in the loose blocks surpassed 60 cm. Sometimes they possess a breccia structure due to the repeated movements along the fault planes.





c) In other cases the fragments of the wall rocks or tectonically triturated fault zones were cemented with the sinter giving a polymict breccia (fig. 5).

d) Sometimes the fissures were filled with laminated limestone close to stromatolites, containing freshwater algae (detailed description see p. 504). These limestone deposits probably of calcrete nature were also attacked by boring organisms what proves their Miocene age. Repeated alternation of calcrete deposits with the speleothems-sinters was noted, too.

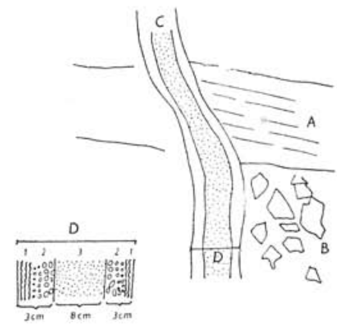


Fig. 6. Neptunian dyke. Quarry close to the northern end of Devín, Bratislava. A — faintly laminated dolomite (Triassic), B — dolomite breccia, C — vertical fissure filled with Miocene sediments. Detail : 1 — stromatolite, 2 — calcrete deposit with intraclasts and oncoliths (primary vertical bedding, allochems display reverse gradation), 3 — marine sandstone of Upper Badenian.

We may summarize that some of the fissures were filled partly with marine sediments, the others contain exclusively „freshwater" deposits. The former represent neptunian dykes.

2. *Devín* — quarry close to the road at the northern border of village. There are exposed the Triassic limestones and dolomites there. A dolomite layer on the left flank is filled with the pseudomorphoses of gypsum crystals proving the hypersaline conditions in the course of their deposition. The Triassic succession is overlain with angular disconformity by the transgressive subhorizontal layers of Upper Badenian (upper part of the quarry). The Triassic complex contains fissures to 15 cm thick, filled with the yellowish sinter crusts. Another joints were filled with freshwater limestone deposit of calcrete type and their middle part sometimes with Upper Badenian sands and sandstones forming „apophyses" from the overlying sand layers (Fig. 6). Thus the calcrete crust is of pre-Upper Badenian or Upper Badenian age.

3. *Záhorská Bystrica* — quarry SE from the village. A brief description of the quarry was given by J. K o u t e k — V. Z o u b e k (1963, p. 35) and M. M i š í k (1967, p. 35—36). Liassic limestones and breccias with rare belemnites and some phyllite blocks (Liassic cliff breccia) are exposed there. In the eastern part of the quarry a reverse fault with phyllites thrust on the

Fig. 2—5. Speleothems of Badenian age (Middle Miocene). Quarry near Dúbravka, Bratislava. — Fig. 2. Draperies, flowstone, stalactites. — Fig. 3. Dripstones covered with calcite crystals; in the broken part the internal structure is visible. — Fig. 4. Cave popcorn. — Fig. 5. Tectonic breccia cemented with Miocene sinter crusts. Photo: M. Mišík.

Liassic may be seen. Conglomerates, breccias and sands of the Badenian age overlie the Liassic carbonate rocks in the western flank. The transgression plane on the Liassic limestones as well as their fragments in the Badenian breccia are densely covered with bores of marine organisms; they were described from this locality by A. Radwański (1968).

Fractures up to 10 cm thickness penetrate the underlying Liassic limestones; they were filled with sinter crusts and druses of yellow or brown prismatic calcite. Other fractures represent neptunian dykes with sinter along their margins and Badenian sands or sandstones in their middle part. Among the pebbles of Upper Badenian conglomerates some rounded sinter fragments were found. The both last mentioned facts show the Badenian age of the sinter crusts.

4. *Rohožník* — small quarry SSE from the village. The Upper Badenian yellow bioherm algal limestones were deposited on the Middle Triassic Wetterstein Limestone. The Badenian seashore was rather steep here. A fossil cliff formed by Wetterstein Limestone bears traces of boring organisms; the cliff breccia contains big blocks of Wetterstein Limestone and some fragments of brown sinter crust. Once more the abrasion of a seashore with karst phenomena including speleothems was evidenced. A thin dyke of freshwater limestone penetrating the marine Badenian limestones shows that the fracturing and fissure filling continued also during the Upper Bedenian.

Another sinter crust occurs in the fractures of a big quarry a the Vajarská hill (Fig. 15, 16) but there is not possible to establish their age. Some fissures and caverns are filled with a cave sediment consisting of the reddish-brown sandstone displaying a globular structure.

5. Abandoned quarry near the road *Pezinok — Baba,* km. 46. Probably Triassic limestones, dolomitic limestones and dolomites are penetrated with numerous caverns. The hollows and fractures are covered with speleothems including stalactites of a lenght up to several dm. The caverns are entirely or partially filled with the coarse-grained sandstone to fine-grained conglomerates with a concretionary cement. The poikilitic calcite cement conditioned a ball structure with balls of dm size or a globular one with the spheres of mm size on the weathered surface (Fig. 17). The sandstones and fine-grained conglomerates or breccias with the globular structure contain numerous fragments of the sericite and chlorite-actinolite phyllites, betraying that a superficial stream transported the material from the north into the

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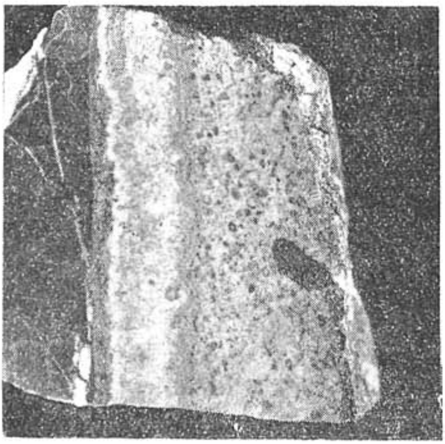
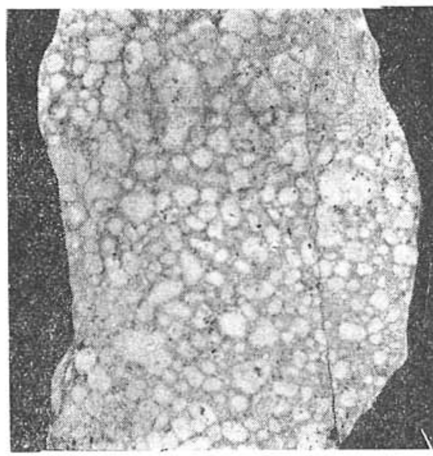
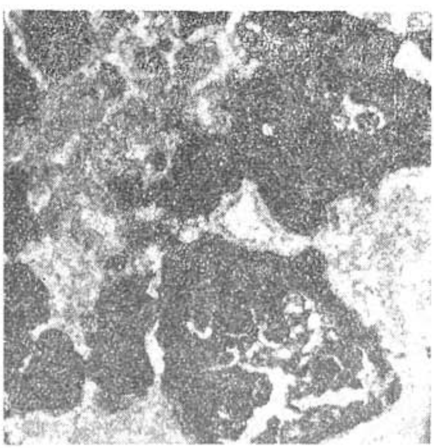
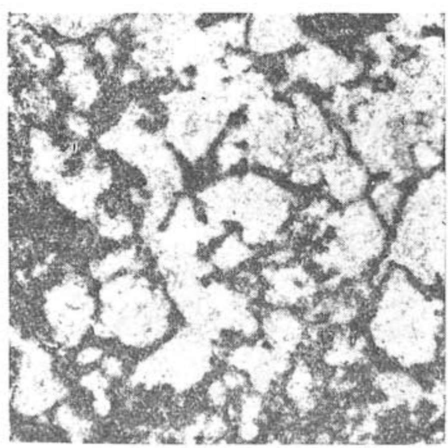
Fig. 7. Fragment of a speleothem (sinter crust) in the Miocene calcrete. The calcrete was exposed on the shore of Upper Badenian sea and bored by marine organisms. Dúbravka. Polished slab. Natural size. — Fig. 8. Pebble of the Miocene sinter crust with bores from sandy gravels of transgressive Upper Badenian. Dúbravka. — Fig. 9. Vertical fissure in Triassic dolomites (on the left) filled with Badenian calcrete. Older filling exhibits stromatolitic or cryptalgal structure, a younger one is represented by intramicrite with rare oncoliths. Polished slab. Natural size. Devín, Bratislava. — Fig. 10. Calcrete filling of a fissure — intramicrite with rare oncoliths. Polished slab. 2×. Devín. — Fig. 11. Intraclast with desiccation cracks in the Miocene calcrete. Dúbravka. Thin section No. 5776. 11×. — Fig. 12. Algal structure in the calcrete. Dúbravka. No. 5774. 23×. Photo: L. Osvald.









small caves. There is no possibility to decide between the Quaternary or pre-Quaternary age of the speleothems from this locality.

Calcrete deposits from the fissures including neptunian dykes

Fissures filled with freswater limestone deposits occur at the localities 1 and 2. One may expect that the bedding in the filling of the subvertical fractures should be roughly perpendicular to the fracture walls, as no folding or major bending took place since the Upper Badenian. Such a bedding was observed only on the filling of marine sands (Fig. 13). On the contrary the freshwater limestones in the neptunian dykes frequently possess a lamination parallel to the walls of the subvertical fissures (Fig. 6, 9). That means that the ancient open fissures were not permanently filled with water. The vadose water intermittingly flowed along the fissure walls, made them humid and favoured the growth of *Cyanophyta*. The mucilaginous algal mats and coatings trapped sandy, silty and muddy grains. Mechanical trapping was probably accompanied with the biologically conditioned preciptation of $CaCO_3$ and during the dry periods also by evaporative precipitation. In this way originated stromatolitic structure, so-called flat stromatolites, mostly very thin ones with frequent interruptions (Fig. 9, 18). One may describe them as „crytalgal" structures but algal filaments are frequent in them. Several laminae contain intraclasts up to 3 mm size (Fig. 10, 11, 23). These stromatolitic structures represent a primary vertical bedding and not the gravitation filling of an open fissure.

Periodical desiccation is reflected on the presence of syneretic cracks within the intraclasts (Fig. 11) and intricate synsedimentary brecciation (Fig. 21, 22). The intraclasts themselves were formed by the cracking in the course of sediment desiccation. Sometimes the shrinkage pores may be also seen under the microscope. Pellets are not rare. According to the classification of R. L. Folk the most current structures are intrasparite and dismicrites. The rounded milky-white bodies 1—5 mm in diameter belong probably also to the intraclasts however their rounding during the transport can hardly be imagined. Their origin by circumgranular cracking (M. Esteban, 1973, p. 109) is more plausible. Some round bodies are probably oncoliths with faint concentric structure (Fig. 10, 23). Exceptionally the nucleus of an oncolith was formed by a grain of pertite (1 mm) obviously proceeding from the Malé Karpaty granitoid massif. The maximum thickness of that calcrete limestone filling was about 10 cm.

The individual generations of the fissure filling were separated by the „inicial cement" what is in fact a rudimentary sinter crust, the formation of which was repeatedly interrupted by new algal-mat cover and additional

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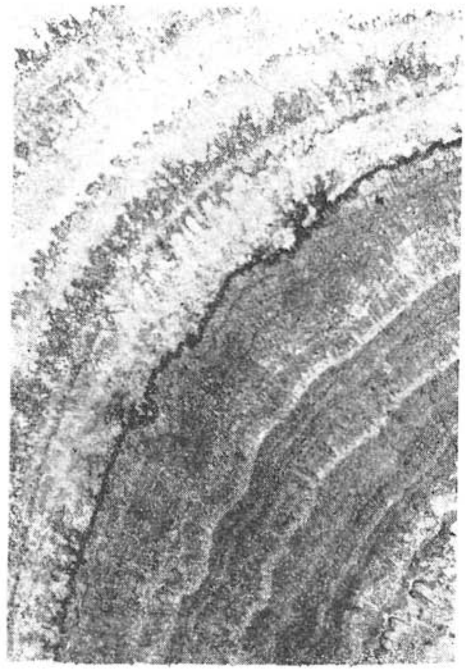
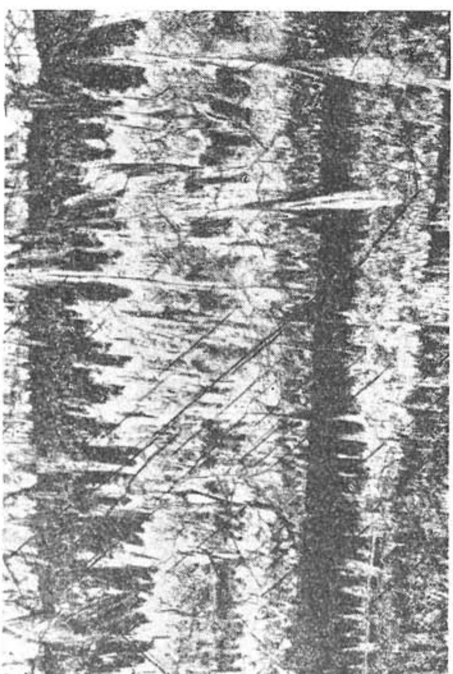
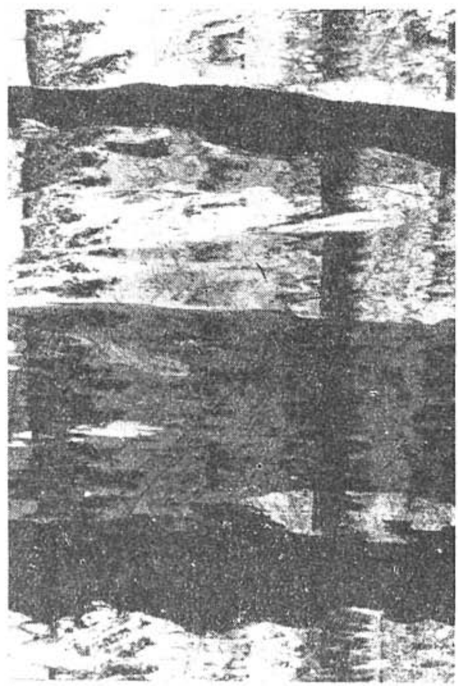
Fig. 13. Fissure in the Liassic carbonate rocks filled with cross-bedded marine sands of Upper Badenian. Dúbravka. Photo: M. Mišík, — Fig. 14. Miocene stalactite in thin section. Dúbravka. No. 11277. 4,5×. — Fig. 15. Sinter crust — speleothem of uncertain age (Quaternary ? Miocene ?), filling a fissure in the Triassic limestones. Rhythmic growth, „supergraines" formed by neomorphism. Quarry Vajarská near Rohožník. No. 4685, 11×. — Fig. 16. The same. Crossed nicols. Fig. 14—16 photo: L. Osvald







micritic sediment. The sinter rim appears sometimes to be partly peeled out (Fig. 23). Repeated alternation of the sinter and stromatolite laminae in the fissure filling is not rare (Fig. 18) and reflects the oscillation of the environmental conditions. A fragment of typical sinter crust enclosed in calcrete limestone was illustrated on Fig. 7. The sinter crusts are always corroded on the contact with the following micrite layer (Fig. 19, 20).

In the brown micrite coloured due to organic matter there are abundant calcite grains and small crystals — products of desintegrated algal structures. Sometimes it is rather difficult to distinguish them from the broken off crystals of the inicial cement (Fig. 23, „crystall silt" of R. L. Dunham, 1969). Exceptionally a calcite aggregate was found with crystals growing perpendicularly to algal filaments (Fig. 24) very similar to *Eucladium* figured from calcareous tufa by G. Irion — G. Müller (1968, p. 166, Fig. 11). Another algal structure with partitions somewhat reminding *Bacinella* was also enregistered (Fig. 12).

The calcrete limestone filling obviously took place in a small depth of a few meters under the ancient surface where the evaporation was more intensive and the fissures were still sufficiently illuminated with daily light to render possible the algal assimilation. In the case figured on Fig. 6, the depth under the ancient surface may be estimated on 5 m considering the field relations. With the depth the quantity of sinter crust within the fissure filling probably increased at the expense of the freshwater stromatolitic calcrete limestone.

From the figured neptunian dyke (Fig. 6) a detail description of the filling is given as example:

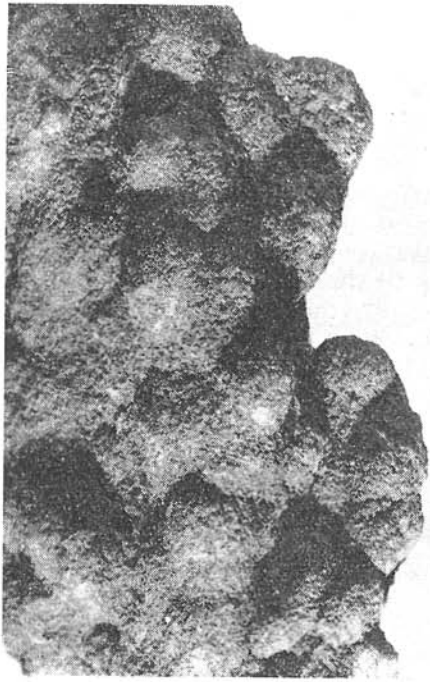
Surrounding rock: dark grey Middle Triassic dolomite with ghosts of „S" deformed strongly compacted pellets.

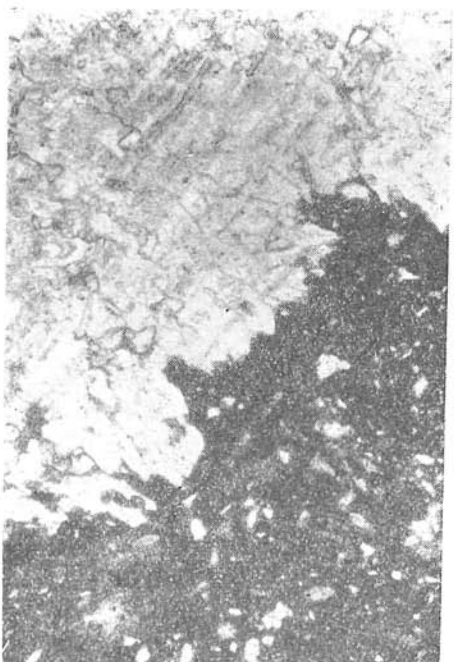
Neptunian dyke: A. cream-coloured limestone of calcrete type:

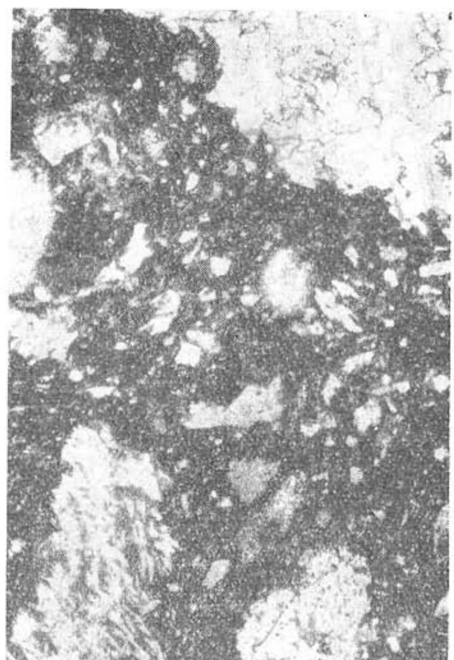
2 mm	— micritic lamina with the relicts of sheaf algal fibres
0,15	— cement rim irregularly bent (partly by gravitational sliding?) with acicular calcite crystals sticked into the ancient void
0,8—2 mm	— micrite laminae with small-scale undulations, probably stromatolite
3—5 mm	— layer with abundant shrinkage pores and indistinct lamination with organic incrustations
20 m	— layer of intramicrite with rare oncoliths (the allochems display a reverse graded bedding, i.e. their size increases towards the middle of the neptunian dyke, up to 4 mm); intraclasts are brown-yellow contrasting with the pale cream-coloured interstitial matter.

B. Sandstone, more precisely lithic arkose with the calcite cement, in the middle part of the neptunian dyke. Median diameter is 0,4 mm, grains possess the angular shape. Approximate composition: quartz — 55 %, feldspars — 25 % (plagioclase, ortoclase, microcline, pertite), micas — 10 % (muscovite, weathered biotite, chlorite), rock fragments — 10 % (dolomites, limestones, phyllites up to 4 mm). Sparry calcite cement with a single foraminifer of rotalian type — Upper Badenian marine sediment.

Fig. 17. Coarse-grained sandstone with globular structure (concretionary cementation). Cave sediment of uncertain age (Quaternary ? Miocene ?). Abandoned quarry km 46 near Baba. Natural size. — Fig. 18. Alternation of speleothem sinter laminae (grey) and calcrete laminae (white) in the Miocene filling of a fissure. Dúbravka. Polished slab. 2,3×. — Fig. 19—20. Corrosion of the sinter crust with calcrete deposit. The fragment of the corroded speleothem float in a micritic calcrete. Dúbravka. No. 3821. 11×. Photo: L. Oswald







The calcrete limestones of the fissure filling enclose besides the fragments of sinter crust also some corroded fragments of the host rock (grey Triassic limestone). Completely corroded outlines show that they are not fragments of a tectonic breccia derived from the fissure walls during the tectonic movements. They represent slope debris from the immediate proximity washed into the fissures. Clastic grains of quariz and feldspars from the granitic eluvium are only exceptionally present within the freshwater limestone filling. After the marine transgression the character of sedimentation radically changed carrying sands into the fissures from the granites outcrops some kilometer distant from the locality.

Attribution of described freshwater limestones to calcrete deposits

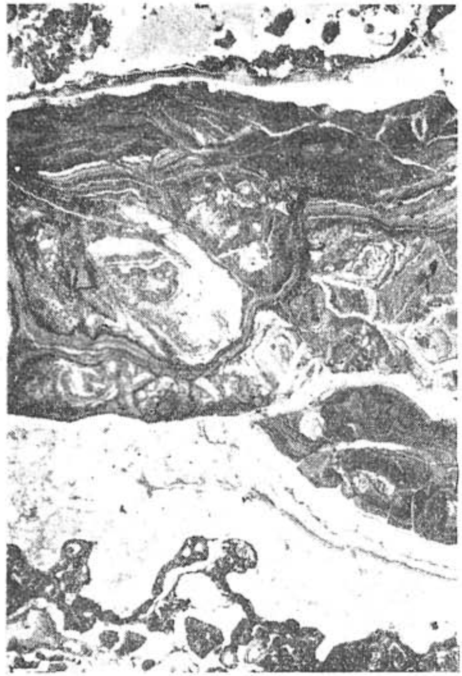
Calcrete, partly synonymous with caliche, nari, duricrust is a secondary fine-grained carbonate formed in soil profile. Calcrete is common in arid and semi-arid environments and may be also developed in humid areas with over 150 cm annual rainfall provided the rains are interspersed with periods of high evaporation (N. P. J a m e s, 1972). The signs of calcrete are as follows: laminated coatings around grains (calcrete pisolites, sometimes polygonal, oöids), reverse grading, microstalactitic cement, tepee structure, laminated stromatolite-like cryptalgal deposits, pellets, brecciation in situ, granulation (degrading recrystallization, secondary chalk) producing secondary „mud-supported" structure, floored voids and desiccation cracks (J. F. R e a d, 1976, R. J. D u n h a m, 1969 etc.).

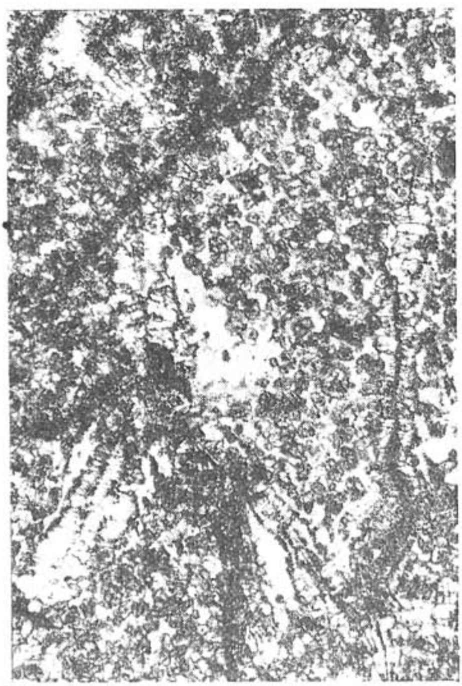
M. E s t e b a n (1973) stressed the pelletal or clotted texture originating by agglutination of micrite, channel texture, gravitational dissolution (dissolution of the lower parts of grains) and alveolar texture (according to his illustrations they are probably shrinkage pores). Describing the Eocene caliche from Spain he distinguishes: 1. lower part — conglomerate caliche (alternation in situ of the underlying limestones into rounded fragments with abundant *Microcodium* probably of bacterial origin), 2. upper part — pisolitic caliche with shrinkage cracks, several stages of brecciation, redeposition of fragments and their dissolution.

Similar cases of the Pre-Quaternary caliche or calcrete deposits were relatively seldom described, e.g. R. J. D u n h a m (1969) mentioned them from Permian, D. B e r n o u i l l i — C. W. W a g n e r (1971) from Liassic, R. A. W a l s et al. (1975) from Carboniferous. Rare quotations are obviously caused by the frequent erosion of fossil caliche deposits. Also if their less typical lower parts are preserved, they remain unnoticed.

According to J. F. R e a d (1976, p. 66) laminated calcrete may also be precipitated on walls of horizontal to subvertical fissures and irregular ca-

Fig. 21. Calcrete (caliche) of Badenian age. Upper part of a vertical fissure. Dúbravka. No. 2509. 5×. — Fig. 22. The same. No. 3323. 8,5×. — Fig. 23. Calcrete in fissure filling (photo rotated about 90°). The older sediment (on the bottom) is a crystal silt; follows a cement rim partly torn off by sliding, than intraclasts sometimes with faint concentric structure (oncoliths ? concentric cracks ?). Devín. No. 3055. 12,5×. — Fig. 24. Freshwater algae (cf. Eucladium ?) in the calcrete. Devín. No. 3056. 27×. Photo: L. O s v a l d





vities. Hence, the described freshwater limestone fillings having many features in common, correspond to the calcrete deposits. There is, of course, a question about the climatic conditions of the area under study during the Badenian time. Typical arid conditions are not supposed, notwithstanding there are several salt and gypsum deposits of the Upper Badenian age in the Carpathian foredeep and in the East Slovakian Basin. In the Malé Karpaty Mts. area the calcrete soil profile was probably developed during the Badenian on the surface of Mesozoic limestones, but the calcrete deposits were entirely removed by erosion and marine abrasion except for the fracture filling within the underlying rocks. The Upper Badenian transgression onto the subsiding elevation cutting the abrasion terraces was described from this locality by D. Andrusov (1969).

Thus the limy calcrete deposits were preserved only as lining of fissure walls. It comprises micrite, intraclasts, lithoclast and oncoliths washed from the softer part of calcrete soils into the fissures, bound by algal mats and partly by evaporative precipitation with abundant signs of the desiccation structures. In this case there are no sharp boundaries between algal stromatolites, cryptalgal structures and calcretes as e.g. J. F. Read (1976) tries to trace.

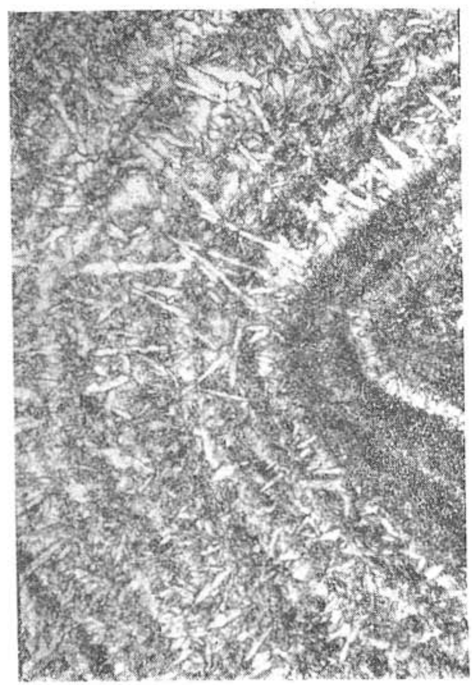
A small superficial relict of Badenian calcrete was found near the altitude point 336 m on the NW slopes of Devínska Kobyla. Some loose blocks crop out there under the loess deposits in a deep road-cut. This yellow to brownish micritic limestone deposit contains abundant algal filaments, aggregational pellets, desiccation cracks and voids etc. Typical calcrete structure such as manyfold brecciation (fig. 21, 22) may be seen also in the uppermost parts of fissures.

The explication of the described peculiar feature — alternation of speleothems and calcrete layers — requires additional studies.

Other pre-Quaternary speleothems and calcrete phenomena in the West Carpathians

Besides the Miocene speleothems described in this paper there is already a short note about the Cretaceous speleothems from the Outer West Carpathian Flysch Zone. V. Houša (1965) quoted caverns of Lower Cretaceous pre-Albian karst from Štramberk which are rarely filled with breccias composed from the fragments of Štramberk Limestone cemented by cave sinters. From the Carpathian foreland in the Kraków area R. Gradziński — A. Radomski (1976) found fossil sinters, flowstones and cave pearls of the Paleogene to Lower Miocene age.

Fig. 25. Sinter crust of Cretaceous age derived from the Pieniny Exotic Ridge. Pebble from the Upper Cretaceous conglomerates. Oravský Podzámok—III. No. 8717. 20×. — Fig. 26. Vadose pisolites in the caliche crust formed during a short emersion of the Lower Namurian bioherm. Caliche deposit was penecontemporaneously dolomitized. Abandoned magnesite quarry, Ochtiná. Polished slab. 1,7×. — Fig. 27. The same in thin section. No. 1718. 4,5×. — Fig. 28. Detail of a vadose pisolite. Acicular structure is due to dolomitic pseudomorphoses probably after aragonite. 30×. Photo: L. Osvald



Up till now the unique specimen of the Cretaceous speleothems in the Pieniny Klippen Belt represents a pebble of brown cave sinter crust of 3 cm size (Fig. 25) found in the Creteceous conglomerates proceeding from Pieniny Exotic Ridge (M. M i š í k 1978, p. 41).

Cretaceous calcrete (caliche) of the pre-Upper Santonian age is probably represented by several pebbles in Senonian conglomerates and small dykes in the underlying limestones near Dobšínska Ľadová jaskyňa, Stratenská hornatina Mts. (M. M i š í k — M. S ý k o r a, 1980).

I use the occasion to call attention to an interesting case of Upper Carboniferous caliche I found in Ochtiná (abandoned magnesite quarry), Spišsko-gemerské rudohorie Mts. The age of the carbonate rocks at the locality containing abundant corals is Upper Visean to Lower Namurian (H. K o z u r — R. M o c k — H. M o s t l e r, 1976). A small relict of pisolitic caliche — pisolitic dolomite — originated probably during a short emersion of coral reef. There are typical vadose pisolites corresponding to the description of R. J. D u n h a m (1969) frequently broken during the growth (Fig. 26, 27). The pisolitic deposit was penecontemporaneously dolomitized preserving the fine structure of pisolites (Fig. 28) originally perhaps aragonite needles.

It would be useful to look for the futher localities with pre-Quaternary speleothems. In Malé Karpaty Mts. there is a task to check if the whole Borinka and Smolenice karst speleothems including Driny caves open to visitors are of Qaternary age. It is necessary to check the Badenian and Karpatian conglomerates at the N and NE margin of Malé Karpaty Mts. (localities Smolenice, Trstín, Nádaš, Jablonica) if they do not contain sinter pebbles. The transgression planes and base conglomerates of the Central Carpathian Paleogene seems to be another attractive topic for investigation.

The direct age determination of speleothems will perhaps be possible in the future due to the $^{230}Th/^{234}U$ method by which some dripstone samples were already dated on 300 000, 760 000 and 1 250 000 years (P. T h o m p s o n, 1973 ex W. B. W h i t e, 1976, p. 291). But there are no experiences yet with the speleothems several million years old (e. g. the age of described Miocene speleothems from Malé Karpaty Mts. should be about 15 million years).

Conclusions

Miocene speleothems such as sinter-crust draperies, stalactites, cave popcorn developed on Mesozoic carbonate rocks, were found in the SW part of Malé Karpaty Mts. Their datation is based on relations to the transgressive Upper Badenian sediments. Sinter crusts in caverns of an ancient cliff were bored by marine organisms, the pebbles of those speleothems are present in the base conglomerates.

Sinter crusts rimmed also fissure walls — neptunian dykes — filled with Upper Badenian marine sands. In the deeper parts of the fissures some sinter fragments were found in loams containing terrestric microvertebrates of Lower Badenian age. Karst phenomena mainly small crevisse caves are connected with the origin of open fractures (to 80 cm thick) accompanying the subsidence of the transversal Lamač graben.

In the near-surface parts of fissures the walls were lined with freshwater limestone of calcrete type (to 10 cm thick). It consists predominantly from a stromatolite-like deposit with frequent filaments of *Cyanophyta*. On the algal mats adhered abundant intraclasts with desiccation cracks and pores, washed into the fissures; towards the ancient surface appear the structures of repeated brecciation in situ. The calcrete deposits from the ancient surface were entirely removed by erosion; their relicts were preserved only in fissures sometimes combined with neptunian dykes. Interesting cases of alternation of the speleothems with calcrete layers were observed. The deeper parts of joints without daily light and beyond reach of intensive superficial evaporation were filled with sinter crusts.

Besides these fossil speleothems and calcretes described in detail some other occurences from the West Carpathians could be mentioned. Cretaceous karst of Pieniny Exotic Ridge is documented only by a sinter pebble from the Upper Cretaceous conglomerates. Pre-Upper Santonian calcretes in Stratenská hornatina Mts., removed by erosion, are known only as pebbles from Senonian conglomerates. An interesting occurence of the Carboniferous caliche (calcrete) with vadose pisolites penecontemporaneously dolomitized was found at the locality Ochtiná, Spišsko-gemerské rudohorie Mts.; its origin took place during temporary emergence of the Namurian bioherm.

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