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PALEOKARST BRECCIAS OF THE BIELE HORY MTS. (MALÉ KARPATY MTS., WESTERN CARPATHIANS)

JURAJ ČINČURA

Geological Institute, Slovak Academy of Sciences, Dúbravská 9, 842 26 Bratislava, Czecho-Slovakia

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Abstract: A carbonate breccia complex unconformably overlies limestones and dolomites, of middle to upper Triassic age, of the Veterlín and Havranica units. The clasts of breccia are angular and chaotically settled. They are petrographically consistent with the type of underlying limestones and dolomites. Speleothems and fluvially reworked gravels occur in the breccia complex. The greater part of the breccia complex is distinguished by a red coloured silt-clay matrix with increased content of Al_2O_3. The breccia complex was formed by the destruction of an extensive cave system, which was formed in the limestones and dolomites of the Veterlín and Havranica units at the end of the Paleoalpine phase, during the Upper Cretaceous or Paleocene.

Key words: Malé Karpaty Mts., Upper Cretaceous, Paleocene, subaerial development, paleokarst, collapse breccia, speleothems.

Introduction

The Western Carpathian geological literature includes a whole series of paleogeographical syntheses, whether for individual formations, or lower stratigraphic units. A common feature of these syntheses is that they are usually concerned with the paleogeography of basins. A proportionate place in the paleogeographical syntheses is not given to the neighbouring dry land, the source areas for the basins sedimentation without whose existence it is ultimately difficult to imagine their existence.

Among the wrongly neglected problems of the Western Carpathian paleoland, the problem of paleokarst is one of the most neglected. This is in spite of the evident fact that carbonate complexes, of various ages and various tectonic units of the Western Carpathians, were exposed, during different long periods of the Alpine stage, ,and so were given optimum conditions for the origin of the forms and sediments of surface and underground karst.

The Biele Hory Mts. are situated roughly in the central part of the Malé Karpaty Mts., which are regarded as a link between the Alpine and Carpathian mountain systems, not only as a result of their morphological position, but also of their geological state. The area of the Biele Hory Mts. is formed mainly by the carbonate complexes of the the Veterlín and Havranica units. The relatively complex geological relations on one side, and the covered land on the other side, have led to various attempts to interpret the geological state. The latest research (Michalík 1984; Mahel' 1986; Lintnerová et al. 1988; Buček 1988) interpret the geological situation as follows:

The lower member of the carbonate sequence of the Veterlín and Havranica units are heavy-bedded to coarse-bedded Gutenstein dolomites. In some places brecciated dolomite, which in further text is called paleokarst breccia, are included in it. They are not synsedimentary breccias, but their origin is connected with younger karst processes. The thickness of the dolomite strata is 30 - 50 *m*. In the overlying of Gutenstein dolomites lay morphologically distinct dark Annaberg limestones, with which are also connected the occurrence of breccias. The thickness of the Annaberg limestone is 120 - 200 *m*. The absence of Reifling limestone in the Havranica unit, and the lack of Steinalm limestone in the Veterlín unit, are among the chief differences between the Veterlín and Havranica units. In both units, 50 - 100 *m* of Wetterstein limestones and dolomites overlie these, to which are added their varieties of breccia. If we accept the forereef origin of the breccia, this was even more disposed to karst formation, than pure limestone. Lunzian shale and sandstone strata divide the lower carbonate complex from the upper, to which the Oponitz limestone and Hauptdolomite, or in the Havranica unit the Dachstein limestone, belong (Fig. 3).

With the exception of the latest work (Činčura 1990; Činčura et al. 1991), geographical analyses of the Biele Hory Mts. karst give the existing views. According to them the karst cycle in the Biele Hory Mts. began during the youngest phase of the Miocene (Stankoviansky 1982; Jakal 1983 and others). These views do not take into account the knowledge about karst of the Badenian age in the Malé Karpaty Mts. (Mišík 1980).

Paleokarst breccias of the Biele Hory Mts.

One of the typical features of the geological state of the Biele Hory Mts. is abundant occurrence of carbonate breccia. The carbonate breccia is found directly on the surface, or forms the subsurface parts of the area. Michalík (1984) described the breccia complex, of the Biele Hory Mts. as slope breccia. The exact extent of the breccia complex was shown by detailed mapping work (Michalík 1984; Buček 1988).

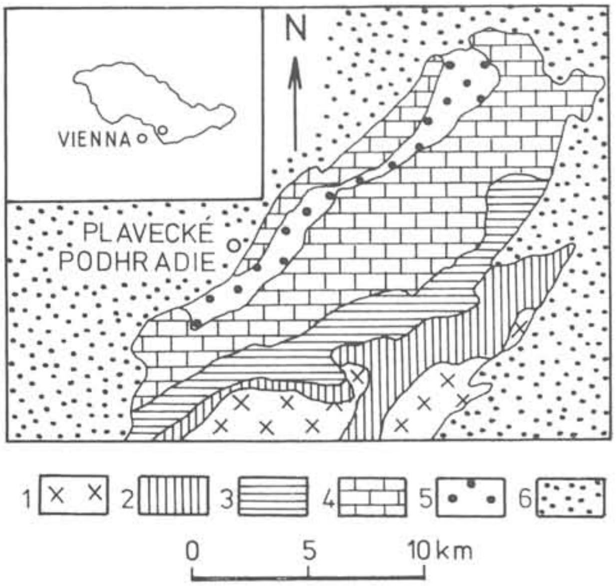

Fig. 1. Schematic map of the Biele Hory Mts. region.
1 - crystalline complex of the Malé Karpaty Mts.; 2 - Tatric, Mesozoic units; 3 - Vysocká unit; 4 - Veterlín and Havranica units (the complex of paleokarst breccia is not distinguished); 5 - Paleogene Bukovská depression; 6 - Neogene and Quarternary Vienna and Danubian Basins.

Carbonate breccias appear unconformably overlying Triassic limestones and dolomites of the Veterlín and Havranica units, especially the Gutenstein dolomites, Annaberg limestones, and Wetterstein limestones and dolomites. They have a close relationship to the two most notable morphological forms - extensive leveled paleokarst plateaux, and monoclinal ridges - which they form in different proportions, together with the limestones and dolomites.

The area of carbonate breccia on the surface of the extensive leveled paleokarst plateaux often exceeds 1 km^2. The thickness of the breccia complex varies from place to place. It often exceeds tens of metres, and in places is over 150 *m*. The petrographic composition of the clasts of the breccia establishes the fact that the breccia complex is composed of very local material, which may derive exclusively from the underlying rocks. Almost 80 % of the clasts in the carbonate breccias which overlie the heavy-bedded to massive Annaberg limestones, are of Annaberg limestone. The remaining clastic material is made up of dolomite or Reifling limestone. The breccia overlying the Wetterstein limestone also has clasts with a similar content, and the breccia overlying the dolomites has a still more monotonous composition, with clasts of dolomite absolutely predominating (Fig. 2).

The base of the carbonate breccia, in essence follows the uneven surface of the limestones and dolomites, and fills various underlying depressions. In places the breccia penetrates to a notable depth. The clasts of the carbonate breccias are characterized above all by the angularity and irregular arrangement of the material. In grain size, there is a wide range of material, extending from fragments with a size of some centimetres, up to megaclasts, which have a size of some hundreds of cubic metres.

The greater part of the carbonate breccia is characterized by a red coloured matrix, with a relatively high content of Al_2O_3 (25 - 35%). In places where megaclasts occur, the red coloured matrix also fills the wider spaces between individual megaclasts and acquires the character of a filler of cracks, or various cavities, widened by the processes of karst dissolution (Sološnica quarry). The red coloured matrix may be characterized by granularity as unsorted. The clay fraction varies from 43 to 78 % of the content, the silt is between 11 and 40 %, and the sand is between 10 and 20 %. The relatively high content of the silt fraction in the matrix indicates the possibility of an eolian ingredient (Fig. 3).

Lenticular beds of laminated marl, coloured red, with a horizon of weakly rounded gravel are found in the breccia complex (e.g. under the summit of Vápenná) (Michalík 1984). This material unambiguously indicates fluvial transport. Various types of multi-coloured speleothems, made of pure calcite, are a relatively frequent part of the breccia complex.

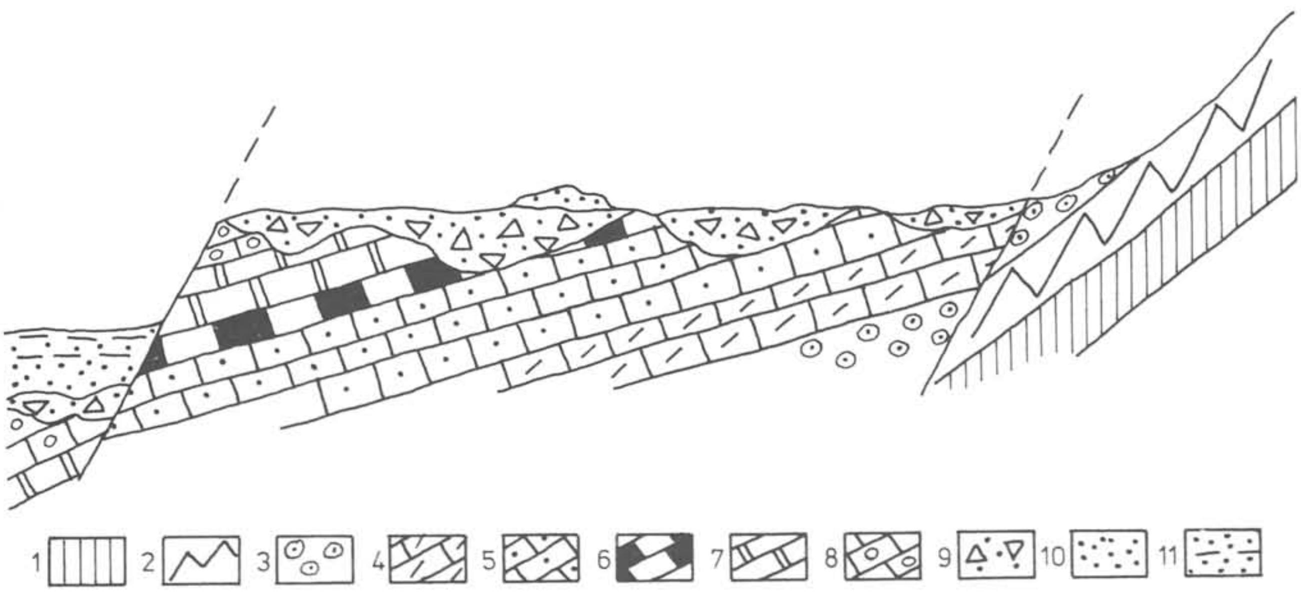

Fig. 2. Schematic geological profile near Plavecké Podhradie (arranged with the use of data from Michalík 1984).
1 - basic effusion; 2 - clay with volcanoclasts (1, 2 - Malužinská formation); 3 - quartzite; 4 - Gutenstein dolomite; 5 - Annaberg limestone; 6 - Reifling limestone; 7 - Wetterstein limestone; 8 - Wetterstein dolomite; 9 - breccia complex; 10 - basal transgressive lithofacies (Cuisian); 11 - clayey facies.

Until now the breccia of the Biele Hory Mts. was usually identified as slope or talus sediment, or as synsedimentary breccia. If we allow the possibility that the breccia originated on slopes, or on piedmonts, we must ask the question, what steep slopes existed in the period of their origin, and how were these hypothetical slopes composed of limestone and dolomites of the Veterlín and Havranica units, so that in places almost monomict breccia was formed.

Talus and slope breccias are above all the product of mechanical weathering, the disintegration of rocks. However the content of Al_2O_3 (roughly between 25 and 35 %) in the matrix of the breccia indicates rather processes of more intensive chemical weathering in the period of the formation of the breccia. The relatively high content of Al_2O_3 are evidence more in favour of a relatively level relief, and not of steep slopes. No arguments exist for the accumalation of red earth waste from weathering, with a high content of Al_2O_3, on steep slopes. Accumalations of red earth with an increased content of Al_2O_3 may rather be sought in depressions of a not very divided surface of limestones or dolomites (compare Andrusov et al. 1958; Borza & Martiny 1964; Borza et al. 1969; Činčura 1973), or below their surface. Surface depressions or underground spaces in carbonate complexes function as traps for fine silt and clay materials.

Karst processes were active in the complexes of carbonate rocks of the Veterlín and Havranica units, during the period of their subaerial development. An underground karst was evidently formed at the same time as the surface karst. The existence of underground spaces is indicated not only by the presence of speleothems in the breccia complex, but also by the discovery of fluvial sediments in the breccias, which we identify as the sediment of cave streams.

The fact that the petrographic composition of the clasts in the breccias is relatively homogeneous, indicates that for a long period the underground spaces had ceilings and walls composed of one or two stratigraphic members (Annaberg limestones and Reifling limestone, or Wetterstein limestone and dolomite). Relatively little other material reached the underground spaces, by way of vertical karst chimneys, passing through various strata.

The area and spacial extent of the breccia complex, indicates that in the period of its formation, it may be presumed that an important cave system existed in the Biele Hory Mts. The collapse of this cave system - it may be thought to have been the natural destruction of a cave system in the period of its senility, but seismic causes may not be entirely excluded, especially if we take into account the position of the cave system on the boundary between the Central Western Carpathians and the assuredly mobile zone of the Outer Western Carpathians - was one of the concluding phases of the formation of the clasts of the breccia complex.

The great extent of the breccia, not all of which is marked by the presence of speleothems, indicates that not all the breccia originated by the collapse of underground spaces. Part of the breccia probably represents so called mantle breccia, which is formed by processes of karst dissolution on the surface and immediately below the surface.

We consider the red coloured matrix to be mainly a product of weathering, which was formed outside the area of occurrence of carbonate rocks. The insoluble residue of limestone is evidently also included in the red earth. Fine-grained soils and products of weathering were already washed into surface depressions and underground spaces, during the existence of the cave system. However the washing of material into the spaces between the clasts probably occurred after the destruction of the cave system. Up to now, no signs have been observed in the breccia, which would show that clasts fell into a swamp of red earth. This is also one of the reasons, why we think that there was an additional filling of the spaces between clasts with fine-grained material from weathering.

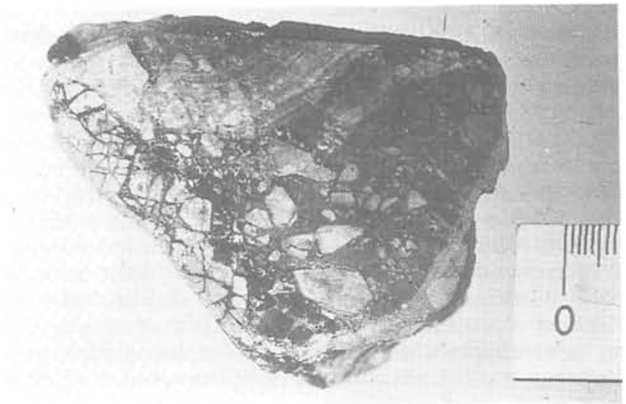

Fig. 3. Paleokarst breccia with speleothem and red coloured matrix, Baborská (J. Váňa).

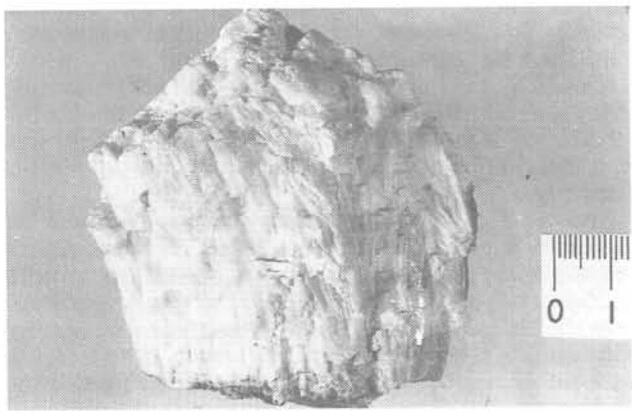

Fig. 4. Speleothem from the breccia complex, Baborská (J. Váňa).

Stratigraphic conclusions

Various views on the age of the breccia complex, overlying the carbonate rocks of the Veterlín and Havranica units, have been pronounced. These views in essence suppose a very wide possible age range for the breccia complex - from Triassic to Neogene (compare Mahel' 1972), or from Post-Albian to Pre-Eocene (Michalík 1984). We consider the supposed Triassic and Neogene ages as two extreme views, with regard to which we want to take a standpoint.

Depositional relations exclude a Neogene age for the breccia complex. The age of the overlying strata, that is the age of the basal transgressive lithofacies, determines the upper boundary of its possible age. In the Sološnica quarry, organodetrital limestone of Cuisian age overlies the paleokarst breccia with the red earth matrix. This limestone does not bear any traces of the karst processes, even after collapse, which shows that the karst in the underlying rocks is older than the Cuisian. Eroded relicts of organogenic to organodetrital limestones of Lower Eocene age are preserved, overlying the breccia complex, around Baborská.

If we analyse the development of the carbonate platform, from the point of view of suitable conditions, for the origin of karst during the Triassic, we come to the following conclusions.

Theoretically the origin of karst may be supposed after the deposition of the basal Gutenstein dolomites, which are considered to be shallow-water supratidal sediment. However the thickness of the Gutenstein dolomites (especially in the Veterlín unit, 30 - 50 *m*) does not give the best conditions for the origin of karst. Clasts of the overlying Annaberg limestones and Wetterstein limestones and dolomites are also present in the breccia complex, which does not speak in favour of the interruption of sedimentation after the deposition of the Gutenstein limestones. With regard to the signs of aridity during the sedimentation of the Gutenstein dolomites, there cannot be a karst of the humid zone, which is shown by the occurrence of speleothems.

A karst phase after the deposition of the Annaberg limestones appears improbable. There are gypsum and anhydrite pseudomorphs in the Annaberg limestone (Lintnerová et al. 1988), and its clasts occur in the breccias, together with clasts from the overlying Reifling limestone. The gradual facies transition from Reifling to Wetterstein limestones excludes the possibility of the origin of karst after the deposition of the Reifling limestone.

A more probable period of origin for karst during the Triassic could be the phase which followed the deposition of the Hauptdolomite of the Veterlín unit, where this sediment is the youngest part of the carbonate sequence of Triassic age. However if we really want to suppose a Triassic age for the breccia, some conditions must be satisfied.

Above all paleokarst of Upper Triassic age must be traceable on the surface of the Hauptdolomite, and must follow the Upper Triassic depositional conditions. However the carbonate breccias lie unconformably on the limestones and dolomites of Triassic age.

However in spite of this fact, it still remains an open question, whether karst processes could occur, especially in the Veterlín unit, during the period, when sedimentation of Hauptdolomite, or Dachstein limestone and the overlying Kössen beds, continued in the Havranica unit. This possibility may not be abandoned, especially with regard to future research. With regard to the hypothetical paleokarst, of Upper Triassic age (especially in the Veterlín unit), it may be stated, that up to now paleokarst sediments cannot be identified, which satisfy the conditions, for their attribution to the Triassic age.

Clasts of carbonate rocks of the Jurassic and Lower Cretaceous ages are also found in part of the carbonate breccia complex (Michalík 1984). This fact indicates with the highest probability that the age of the paleokarst breccia is Upper (or Middle?) Cretaceous to Paleocene.

Up to now the relationship to the paleokarst, of the individual eroded remnants of Rudist limestones from the north western slopes of the Malé Karpaty (Vajarská, Rozbehy), or of the south eastern part (near Dechtice), is not clear (oral communication from E. Köhler, J. Michalík).

Sediments of Upper Cretaceous age (Campanian) from Vapenková Skala near Rozbehy have an uncertain tectonic position. It is impossible to exclude their connection with the Upper Cretaceous facies in the Myjavská Pahorkatina Mts. (Köhler & Borza 1984). Finds of marine sediments of the Campanian age on the one hand, could reveal a limited paleokarst phase, both in the Uppermost Cretaceous and the Paleocene. On the other hand, however, these finds do not exclude the possibility of the existence of an older paleokarst phase, of Middle Cretaceous? to Campanian age, at the conclusion of the Paleoalpine stage.

Reconstruction of the course of the paleokarst processes

The possibility of the existence of several karst phases during the Upper (or Middle?) Cretaceous and Paleocene may not so far be clearly established. Indirectly, their existence is suggested by the island like occurrence of marine sediments of Santonian age, in areas close to the district of the Biele Hory Mts. Karsts in the Bohemian Massif, which belong to two main periods of the pre-Cenomanian and post-Santonian, also do not continue without interruption (Bosák 1989).

If we try to analyse the paleokarst processes, which led to the origin of the breccia complex in the Biele Hory Mts. from the point of view of time, we arrive at the view, that there was a longer karst period, which would in a chronostratigraphic sense be equivalent to a period longer then one stage. However it is probable, that the karst processes did not continue during this longer period unceasingly with equal intensity, and locally shorter interruptions of the karst processes may not be excluded.

We attribute, conditions suitable for the origin of a regional extension of Late Paleoalpine karst in the Western Carpathians, above all to the global tectonic factors, the result of which was the Middle Cretaceous collision of the margin of the Apulian micro-continent with the margin of the European platform. As a result of the collision, the basic features of the Upper Cretaceous paleogeography of the Central Western Carpathians were formed, including the origin of the basement of a quasi-platform (Činčura 1988).

Eustatic movements of the sea level during the Upper Cretaceous caused changes in the exogenetic modelling of the neighbouring Central Carpathian land. Above all, we have in mind the changing relations between erosion, transport and sedimentation.

For the neighbouring unsubmerged dry land, the transgressive phase meant a raising of the erosional base. We suppose that the raising of the erosional base was reflected in the exogenetic modelling in the form of a reduction in fluvial activity. Above all, there was a weakening, not only in vertical, but also in lateral erosion. The raising of the erosional base meant not only a decline in the quantity of material transported by streams, but also that a refinement of the granular fraction of the transported material towards the dust and clay fractions, due to a lowering of the carrying capacity of the streams. Above all, surface run-off and surface rinsing of the finer part of the weathered cover, belong to the process of surface modelling.

For the development paleokarst relief, on the neighbouring dry land, the transgressive phase connected with the raising of the erosional base, meant a slowing down of the rate of karst processes, and the filling in of existing karst depressions with fine rinsed material, originating from the products of weathering.

The phase of marine regression caused a lowering of the erosional base of streams on the neighbouring land. The lowering of the erosional base meant, above all, a revival of fluvial erosion in river basins, which led to the deepening of streams, not only in their own deposits, but also into the underlying rock. At the same time, the quantity of material transported by streams began to rise, and the variety of grain size also increased.

For the development of relief therefore, marine regression combined with a lowering of the erosional base, meant a revival of karst processes, and their extension to a greater depth in the carbonate complexes, and therefore the formation of new deeper cave levels.

In the Gosau basin of the Myjavská Pahorkatina (Salaj & Priechodská 1987), fresh water sediments of Turonian to Lower Coniacian age bear witness to regression and the emergence of land, during the beginning of the Senonian. These fresh water sediments were submerged by the advancing transgression of the Coniacian Sea. The Coniacian transgressive cycle ended the sedimentation of silt marls.

Santonian sedimentation was characterized by a significant subsidence of the entire basin. However in the upper Santonian, a significant short term shallowing occurred, and there was sedimentation in a bracico-limnic environment. In the youngest Santonian the marine regime was renewed again, which meant another transgression (compare Salaj & Priechodská l.c.).

After a short period of shallower sedimentation, during the Upper Campanian to Lowest Maastrichtian, there was another return to pelagic sedimentation. In the Uppermost Maastrichtian, and during the Lower Danian, a significant shallowing occurred (Salaj & Priechodská l.c.).

During the Upper Cretaceous then, significant eustatic movements of the sea occurred, in the Myjavská Pahorkatina. Regressive movements of the sea were characteristic of the following periods: *1.* part of the Turonian to Lower Coniacian, *2.* Upper Santonian, *3.* Upper Campanian to Lowest Maastrichtian, *4.* Uppermost Maastrichtian to Lower Danian.

Significant regressive phases in the region of the Biele Hory Mts., meant above all falls in the erosional base. Due to the phases of regression, repeated revivals of vertical erosion occurred on land, and the karst processes revived in extensive areas of the carbonate complexes of the Veterlín and Havranica units. Karst also developed on land during periods when the erosional base was higher, but this was relatively less important, than during regressive phases, when optimum conditions for the development of karst existed.

On the basis of contemporary ideas, the following scheme may be proposed for the progress of karst processes:

1 - Geokratic development, caused by global tektonic factors meant the uplift of former carbonate platforms above sea-level. Continuing subaerial development of these units, was a reflection of a whole trend to temporary stabilization, or kratonization of the Central Western Carpathians, that is to the origin of a lower floor-basement - of the Epipaleo-Alpine quasiplatform (Činčura 1988).

2 - Karst dissolution of the carbonate complexes of the Veterlín and Havranica units, as also the origin of surface and underground karst forms, took place under conditions of monsoon or subequatorial climatic conditions (Činčura 1987, 1988). Karst processes occurred not only in the chemically relatively pure limestones, but also in dolomite complexes.

3 - Internal sediments originated in the underground spaces of the karst. In the vadose zone of the underground spaces calcite speleothems formed from satisfied solutions, especially in places, where CO_2 could freely escape. Fine products of weathering were washed underground. Cave streams deposited internal fluvial sediments - clays and silts, partly red in colour, together with weakly reworked limestone and dolomite pebbles, or material of alochthonous origin. The occurrence of speleothems indicates significant humidity in the period of karst formation (Fig. 4).

4 - The gradual destruction of underground cave spaces probably occurred in the natural way, in the stage of senility of the system, with the loss of stability by the ceilings and walls of the underground spaces. Seismic causes may not be entirely excluded, in relation to the position of the area near the mobile northern margin of the Central Western Carpathians. Karst waters continued to circulate among the collapsed materials, and the formation of speleothems continued.

5 - During the existence of an extensive cave system, a significant part of the products of weathering were only transported through the system. After collapse occurred, the interclastic spaces were gradually filled.

6 - The transgressing Paleogene sea (Cuisian) penetrated to the relatively leveled surface, which was formed by the limestone and dolomites of the Veterlín and Havranica Units and the overlying paleokarst breccias. The leveling of the surface is shown not only by the small thickness of the basal transgressive lithofacies, but also by the preponderance of organogenic and organodetrital limestone over conglomerate. After the deposition of the basal beds, sedimentation continued with the deposition of clayey beds.

7 - The sediments of clayey beds and the basal transgressive lithofacies preserved the paleokarst forms and sediments of the Biele Hory Mts. The beginning of removal of the preserving beds was probably connected with the Helvetian or Savian phases. Blocks of rock, belonging to the basal transgressive lithofacies, are found in conglomerates of Karpatian age, in the neighbouring Bukovská depression (oral communication, E. Köhler). This fact indicates, that with the greatest probability, only the clayey beds were denuded and gradually removed during the Karpatian, while the rock forming the basal transgressive layer, still overlay the karst breccia. During the Miocene or Pliocene, where exhumation of the paleokarst sediments and forms occurred, karst processes were again revived in places. The discovery of paleokarst of Badenian age in the Malé Karpaty shows this (Mišík 1980). However in various places, eroded remnants of the sediments of the basal lithofacies (Cuisian), overlying the paleokarst breccias, have been preserved up to the present. The conception presented by us does not exclude the existence of younger karst forms in the Biele Hory Mts. However we think that those who determine geological ages should use geologically relevant criteria.

Conclusion

A complex of carbonate breccias is found, overlying the carbonate sequence of Triassic age, of the Veterlín and Havranica units of the Biele Hory Mts. On the basis of the character of the material of the carbonate breccia, the presence of speleothems and internal fluvial sediments, we suppose their paleokarst origin. We think that they are partly collapse and partly mantle breccia. The possible period of origin of the paleokarst breccia is connected with the periods of the Upper (Middle?) Cretaceous and Paleocene. The karst processes occurred in conditions of monsoon or subequatorial climate.

Translated by M.C. Styan

References

Andrusov D.,Borza K.,Martiny E. & Pospíšil A., 1958: Sur l'origine et le temps de formation des "terra rossa" de la Slovaquie centrale et méridionale. *Geol. Sbor.* (Bratislava), 9, 1, 27 - 39 (in Slovak, French abstract).

Borza K. & Martiny E., 1964: Verwitterungsrinden, Bauxitlagerstätten und "Terra rossa" in den slowakischen Karpaten. *Geol. Sbor.* (Bratislava), 15, 1, 9 - 26 (in Slovak, German abstract).

Borza K.,Činčura J. & Martiny E., 1969: Herkunft der Roterden der SW Slowakei. *Geol. Zbor.* (Bratislava), 20, 2, 351 - 359.

Bosák P., 1989: Paleokarst of CSSR. *Knih. Čes. Speleol. Spol.* (Praha), 39 - 40 (in Czech).

Buček S., 1988: Dasycladacean algae and Triassic biostratigraphy of the Biele Hory Mts. (Malé Karpaty Mts.). Manuscript, arch. Geol.Inst.Slov.Acad.Sci., Bratislava, 1 - 258 (in Slovak).

Činčura J., 1973: Weathering crusts on the carbonate rocks of the Western Carpathians and their relation to climate and relief. *Slov. Kras* (Liptovský Mikuláš), 11, 23 - 25.

Činčura J., 1987: Climate dynamics in the beginning of Neoid geomorphological stage in the West Carpathian Mts. *Geol. Zbor. Geol. carpath.* (Bratislava), 38, 5, 601 - 614.

Činčura J., 1988: Epiquasiplatform features of the central West Carpathians. *Geol. Zbor. Geol. carpath.* (Bratislava), 39, 5, 577 - 587.
Činčura J., 1990: Characteristic features of paleoalpine and epipaleoalpine landmass of the West Carpathians. *Geol. Zbor. Geol. carpath.* (Bratislava), 41, 1, 29 - 38.
Činčura J., Gross P. & Köhler E., 1991: The proofs of the Cretaceous - Paleocene paleokarst in the Malé Karpaty Mts. *Slov. Kras* (Liptovský Mikuláš), 29, 69 - 82 (in Slovak, English abstract).
Jakal J., 1983: Karst relief and its significance in the geomorphological picture of thje West Carpathians. *Geogr. čas.* (Bratislava), 35, 2, 160 - 183 (in Slovak, English abstract).
Köhler E., 1988: Ecosystems of Paleogene reef and biohermal limestones in West Carpathian. Manuscript, arch. Geol. Inst. Slov. Acad. Sci., Bratislava, 1 - 86 (in Slovak).
Köhler E. & Borza K., 1984: Oberkreide mit Orbitoiden in den Kleinen Karpaten. *Geol. Zbor. Geol. carpath.* (Bratislava), 35, 2, 194 - 204.
Lintnerová O., Masaryk P. & Martiny E., 1988: Trace elements distribution in Triassic carbonates from Veterník and Havranica nappes (the Malé Karpaty Mts.). *Geol. Zbor. Geol. carpath.* (Bratislava), 39, 3, 301 - 322.
Mahel' M., 1972: Geotectonic position of the flysch in the Eastern Alps, Carpathians, Balkan and Dinarides. *Geol. Zbor. Geol. carpath.* (Bratislava), 23, 2, 209 - 225.
Mahel' M., 1986: Geological structures ofthe Czechoslovak Carpathians. Paleoalpine units l. *VEDA*, Bratislava, 1 - 503 (in Slovak).
Michalík J., 1984: Some remarks on developmental and structural interpretation of the NW part of the Malé Karpaty Mts. (West Carpathians). *Geol. Zbor. Geol. carpath. (Bratislava), 35, 4, 489 - 504.*
Mišík M., 1980: Miocene sinter crusts (speleothems) and calcrete deposits from neptunian dykes, Malé Karpaty Mts. *Geol. Zbor. Geol. carpath.* (Bratislava), 31, 4, 495 - 512.
Salaj J. & Priechodská Z., 1987: Comparison of the Gosau type of Senomanian and Paleogene between the Myjavská pahorkatina Highlands and the Northern Limestone Alps. *Miner. slovaca* (Bratislava), 19, 6, 499 - 521 (in Slovak, English summary).
Stankoviansky M., 1982: Geomorphology of the karst areas of the Malé Karpaty Mts. *Geomorph. Conf.*, Praha, Charles Univ., 233 - 242 (in Slovak).