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PALEOALPINE KARSTIFICATION - THE LONGEST PALEOKARST PERIOD IN THE WESTERN CARPATHIANS (SLOVAKIA)

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Abstract: The considerable areal extent and great thicknesses of Middle/Upper Triassic carbonate complexes influenced favourably the formation of karst during subaerial periods. The lower boundary of the Paleoalpine karst period is age-determined by the gradual emergence of the basement - during the Upper Cretaceous in the Central Western Carpathians and even earlier in the Inner Carpathians. The upper boundary can be dated by marine transgression. The start of the transgression is not synchronous and it varies in a broad range from Upper Cretaceous to Upper Eocene and maybe even up to Oligocene/Miocene. The typical products of the period include typical karst bauxites filling karst cavities, ferricrusts, red clays, collapse and crackle breccias with speleothems, freshwater limestones or polymict conglomerates.

Key words: Western Carpathians, Cretaceous, Paleogene, Paleoalpine, longest paleokarst period.

Introduction

Several thalassocratic periods alternated with geocratic ones in the geological history of the Western Carpathians. Thalassocratic periods were characterized by intensive marine deposition, while during the geocratic ones denudation processes dominated on emerged areas. Nevertheless, the geodynamic models of the Western Carpathians have not taken this reality into account. The models accent the importance of marine depositional cycles in the geological record on one hand, and underestimate processes taking place during non-marine periods (gaps) on the other hand.

The rationality of such a view is questioned by the knowledge of the extent and dynamics of Quaternary exogenic processes (fluvial, eolian, karstic etc.) in the Western Carpathians when tens of metres or sometimes more than 100 m thick sequences were formed, especially of eolian, fluvial, periglacial and glacial origin. A variety of surface and underground karst forms and sediments originated on carbonate sediments at that time.

Therefore the question still remains open, which karst phenomena could be formed during periods lasting tens of millions of years, which were climatically favourable with respect to karst or where weathering products and sediments are even preserved. Such questions have been neglected during the research and the attention has been concentrated only on detailed analysis of marine sediments.

This contribution has the aim of directing attention to these facts, also describing sediments and paleogeomorphological forms originated during the longest paleokarst period of the Alpine epoch in the Western Carpathians.

Subaerial evolution of extensive parts of the Western Carpathians was caused by the Paleoalpine collision of the Apulian microcontinent with the European (East European) Platform (Michalík & Činčura 1992). Favourable lithology, tectonics and climate conditioned the origin of Paleoalpine karst. The Paleoalpine karst period has a great areal extent in the Western Carpathians. Its presence is proved by karst sediments and forms in the Central (Krížna, Choč and Strážov Units*) and in the Inner Western Carpathians (Silica Unit*) both on the territory of Slovakia and Hungary.

Tectonic, climatic and lithological conditions for the origin of Paleoalpine karst

The Paleoalpine collision caused partial stabilization leading to the individualization of the Central and the Inner Western Carpathians into quasiplatform basements and to their subsequent geocratic regime (Činčura 1988, 1990). Subaerial evolution of the basement continued over extensive areas in spite of the fact that the Early/Late Cenomanian transgression represented the most extensive of Cretaceous transgressions in the Europe. Upper Cretaceous marine sediments are very rare in the Central and the Inner Western Carpathians. However it cannot be excluded that the surface of the basement was affected by local, eustatically or tectonically induced, Upper Cretaceous ingressions. Numerous pollen grains redeposited into younger sediments (Snopková 1990), continental karst fillings (Mello & Snopková 1973; Marschalko & Mello 1992) and occurrences of karst bauxites (Borza & Martiny 1964) prove Upper Cretaceous subaerial evolution.

The Western Carpathian quasiplatform was encircled by tropical, or subequatorial waters of the Tethys Ocean during the Middle/Upper Cretaceous (Činčura 1987). The surface waters of the Upper Cretaceous oceanic realm were characterized by the temperature decrease from the Equator towards the poles (Lowenstam 1964). This means that temperature latitudinal zonation developed. Therefore, it is reasonable to assume that the latitudinal zonation was also developed above land emerged from the ocean.

The thermal and pressure gradients between the Tethys Ocean and the European (East European) Platform lying to the north

* after Mahel' 1986

were lower than at the present time when ice covers the poles. Nevertheless, the gradients were large enough to cause seasonal air flow between the continent and the ocean differing in summer and winter periods, bearing signs of monsoons.

Upper Cretaceous monsoons penetrated deeply to the north above the emerged basement belonging to the Kreios (Tollmann 1978). The surface had been levelled to a large extent which evidently facilitated the air flow. The humid warm climate on parts of the Eurasian Plate is indicated by Cretaceous tropical to subtropical karsts e.g. in Poland (Głazek 1989) and in the Bohemian Massif (Bosák et al. 1989).

The tropical climate is evidenced in the Western Carpathian area by coral-algal reefal limestones formed at several sites from Paleogene to Upper Eocene. Barchatova et al. (1979) estimated Paleogene marine paleotemperatures in the Central Western Carpathians at 22.3 to 24.8 °C on the basis of Ca/Mg contents of shells.

The data recently obtained from deep drillings and from their generalization by geophysical methods represent an important source of information on rocks forming the near surface parts of the basement during the Paleoalpine karst period. They resulted in the construction of basement map of covered areas in the Inner Western Carpathians (Fusán et al. 1987). The map represents the assumed truncation of the basement before the Paleogene transgression. However, the relief already reflects neotectonic deformation of the basement and of its Paleogene cover.

The composition of the basement of the Paleogene basal transgressive lithofacies can be obtained where regions have been mapped in detail. The Liptov Basin represents such an example. The Paleogene basal transgressive lithofacies is underlain by the relatively thin Triassic sedimentary complex of the Choč Unit in the south or by Lower Cretaceous clayey limestones and Upper Triassic sediments of the Krížna Unit (Gross et al. 1980). An almost identical situation also occurs at the northern margin of the Liptov Basin.

Mesozoic carbonate complexes underlay Tertiary sequences in the northern parts of the Inner Western Carpathians, while Paleozoic granitoids and crystalline schists together with extensive areas of Mesozoic carbonate rocks were found under Tertiary formations in the southern parts of the Western Carpathians (Fusán et al. 1987).

Surface and near subsurface zones of the basement were composed of carbonate complexes to a great extent before the Paleogene transgression, as can be seen from the data given above. We suppose that the extent of carbonate rocks on the basement surface was even greater at the beginning of subaerial evolution than after a terrestrial period lasting tens of millions of years. The fact that crystalline cores were not exposed everywhere even before the Paleogene transgression is supported by the predominance of carbonate rocks in the basal transgressive lithofacies. Granitoid pebbles have been found only sporadically in the northern parts of the Central Western Carpathians.

Chronology and brief description of forms and sediments of the Paleoalpine karst period

The wide variety of forms and sediments of the Paleoalpine karst period occurring in the present relief enables us to characterize the basic features of the Paleoalpine karst of the Western Carpathians. Certain limits are related to the fact, that the choice of sites had to be adjusted to the possibilities for the explicit dating of the Paleoalpine karst.

The attempt to determine the age of the paleorelief is an estimation of the period in which the relief acquired its basic features. As we are usually dealing with periods of variable length which can represent one or more chronostratigraphic stages, there are two boundaries of the paleorelief age: the lower and the upper ones (method of the minimum and the maximum gap of Esteban 1991).

The lower boundary represents the beginning of subaerial evolution of the relief. The upper boundary means the termination of subaerial relief formation. The lower boundary can frequently be identified with the marine regression and the upper one with the new transgression. Thus, the generally valid and reliable criterion for the determination of the upper paleorelief boundary can be considered the principle of superposition. In the case of buried paleorelief, the upper boundary is determinated by the age of the unconformably overlying formation.

The Paleoalpine karst period in the Western Carpathians exceeds in duration several chronostratigraphic stages, therefore it is necessary to deal both with its lower and upper boundary.

To determine the lower boundary, i.e. the beginning of the Paleoalpine karst period, we can apply the data on the termination of marine deposition, i.e. on the marine regression in individual units of the Western Carpathians. It can be stated generally, that marine deposition terminated earlier in the southern units than in units lying further to the North (Rakús et al. 1989) - Tithonian (135-139 Ma) in the Silica Unit, Aptian (107-114 Ma) in the Choč Unit and Cenomanian (91-96 Ma) in the Krížna Unit. The onset of the Paleoalpine karst period was not synchronous in the Western Carpathians.

The upper boundary, i.e. the termination of the Paleoalpine karst period, can be determined mostly by the progress of the Paleogene (sometimes Cretaceous) transgression penetrating into the Central and Inner Carpathian land from the North as the Central Carpathian facies and from the South as the Buda facies. The onset of the Paleogene transgression was not synchronous all over the Western Carpathians and was accompanied by unequal velocity of the sea progradation. All mentioned facts result in the statement that the termination of the Paleoalpine karst period was not synchronous within the Western Carpathians as illustrated by following case studies.

Brezovské Pohorie Mts.

The carbonate sequences of the Brezovské Pohorie Mts. (for location see Fig. 1) provide data on the earliest phases of the Paleoalpine karst period. Karst depressions in Triassic limestones and dolostones can be observed at numerous sites. They are filled with red clays, often with high kaolinite and smectite contents (Šucha unpubl.), attaining up to 4 m in thickness in places. The paleokarst relief is unconformably covered by Coniacian to Senonian conglomerates and sandstones (86–88 Ma).

The lower boundary of the Paleoalpine karst period cannot be directly identified with the termination of marine deposition during the Lower Cretaceous (Hauterivian, 116–120 Ma), it is younger. The period of erosion has to be taken into consideration. Erosion removed an almost 200 m thick pile covering Triassic limestones and dolostones (Salaj et al. 1987).

The upper boundary of the Paleoalpine karst period is determined by Coniacian transgressive sediments (86-88 Ma; Fig. 4).

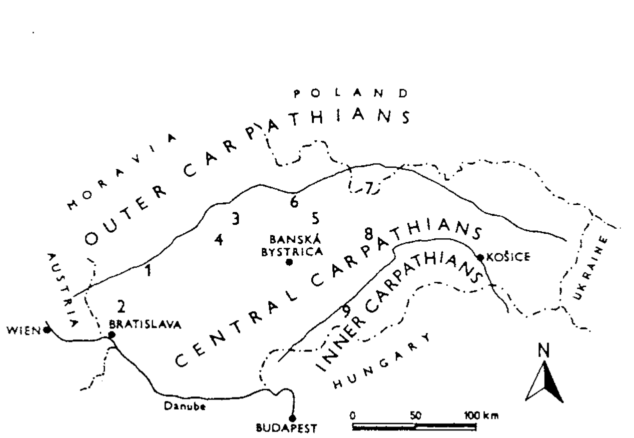

Fig. 1. Schematic map of the Western Carpathians with the location of units. 1 - Brezovské Pohorie Mts., 2 - Malé Karpaty Mts., 3 - region of the middle Váh Valley, 4 - Strážovské Vrchy Mts., 5 - the Liptov Basin, 6 - Chočské Vrchy Mts., 7 - Vysoké Tatry Mts., 8 - Nízke Tatry Mts., 9 - the Slovak Karst.

Malé Karpaty Mts.

Extensive paleokarst plateaus are one of the characteristic surface forms of the central part of the Malé Karpaty Mts. (for location see Fig. 1). The plateau surfaces are composed of Middle/Upper Triassic limestones and dolostones (Annaberg, Gutenstein, Reifling and Wetterstein Formations) and of an overlying younger breccia complex. The breccia complex consists only of limestone and dolostone clasts. Breccias overlying the Annaberg Limestone contain almost 80 % of clasts derived from them, similarly also breccias over the Wetterstein limestones and dolostones. The breccia clasts are angular, unsorted and range from several centimetres up to megaclasts in size. The breccias mostly contain red clay matrix with high alumina contents (25 to 35 %), and the presence of smectite (about 23 %), kaolinite (about 19 %), chlorite (about 23 %) and illite (about 32 %; Šucha unpubl.). Laminated or columnar calcite speleothems are found in the breccia complex. The breccia complex can be assumed to be a paleokarst sediment partly formed of collapse breccias and partly of crackle breccias (Činčura 1992).

Clasts of Jurassic or Lower Cretaceous carbonates were found in a part of the breccia complex, completing clasts of the Triassic rocks (Michalík 1984). Their occurrence indicates that the possible lower boundary of paleokarst breccia origin probably lies in mid-Cretaceous. This age limits the possible beginning of the Paleoalpine karst period in the region. The termination of the karst period is documented by denudation relics of Paleogene sediments on the surface of paleokarst plateaus; their age being Lower Eocene (46-53 Ma; Fig. 4).

Strážovské Vrchy Mts.

Karst bauxites (according to the classification of Bárdossy 1982) were found in the Strážovské Vrchy Mts. at numerous sites, especially in the wider surroundings of Mojtín (for location see Fig. 1). Bauxites overlie Triassic limestones and dolostones belonging to the Choč or the Strážov Unit (Borza & Martiny 1964). All the bauxite occurrences situated on the karstified surface of the carbonate complexes - in sinkholes, solution widened fissures, or smaller depressions - belong to two structural types. Bauxites with the homogeneous-massive structure originated by the bauxitization of material redeposited primarily from the lateritic weathering crust. Bauxites with the heterogeneous-chaotic structure underwent probably multiple secondary redeposition (Kandera et al. 1989). The Paleoalpine karst had an important role in the preservation of bauxites in its natural surface traps. Numerous red coloured clays outcrop in karst depressions similar to the position of bauxites. Red clays contain smectite (13 to 17 %), kaolinite (8 to 9 %), chlorite (about 10 %), and illite (over 21 %; Šucha unpubl.).

The age of the lower boundary of the Paleoalpine karst can be estimated only from the termination of marine deposition in the Choč Unit (Aptian, 107-114 Ma) and in the Krížna Unit (Cenomanian, 91-96 Ma), indicating the beginning of the karst period can probably be connected with the mid-Cretaceous. The upper boundary of the karst period is documented by denudation relics of Lower Eocene basal conglomerates (46-55 Ma; Fig. 4) overlying bauxites.

The Liptov Basin

The Liptov Basin (for location see Fig. 1) is an extensive depression (50 by max. 15 km) formed by sediments of the Central Carpathian Paleogene. Paleogene sediments unconformably overlie the uneven, karstified basement composed of carbonate sequences of the Choč and the Krížna Units. Karst cavities and depressions in limestones and dolostones are sometimes filled with redeposited weathering products (yellowish brown clays) or directly by basal conglomerates.

Concerning the dating of the upper boundary of the Paleoalpine karst period, the Liptov Basin represents the model territory. The succession in the termination of karst processes related to the velocity of prograding marine transgression can be shown in detail.

The marine transgression penetrated the Basin from the North and the West southwards by embayments in locally rugged karst relief. Later, the sea penetrated to the already existing barrier of the Nízké Tatry Mts. The coast line was uneven, separated into numerous embayments and rocky promontories. The existence of groups of islands cannot be excluded. Islands represented the summits of gradually flooded karst relief.

The marine transgression, on its southward progress, penetrated the karst relief during the Late Lutetian (Gross et al. 1980). The origin of carbonate breccias, conglomerates and limestones resulted from the planation of uneven karst relief of the basement in the first transgression phase. The nature of organic remains indicates a shallow-marine, warm and illuminated environment. The sea gradually flooded the whole area of the present Basin during the Priabonian (31-34 Ma). The elevated threshold in the eastern part of the Basin was flooded only at the end of the Late Eocene (31-34 Ma; Fig. 2).

The transgression progressed on the karstified surface of limestones and dolostones at a rate of 10 to 12 km per 1 Ma in the first phase at the end of the Middle Eocene, while it decreased only to 1 to 6 km per 1 Ma in the Late Eocene (31-34 Ma).

The age of the lower boundary of the Paleoalpine karst period can be estimated only on the basis of the termination of marine deposition during the Aptian (107-114 Ma) in the Choč Unit and during the Cenomanian (91-96 Ma) in the Krížna Unit (Fig. 4).

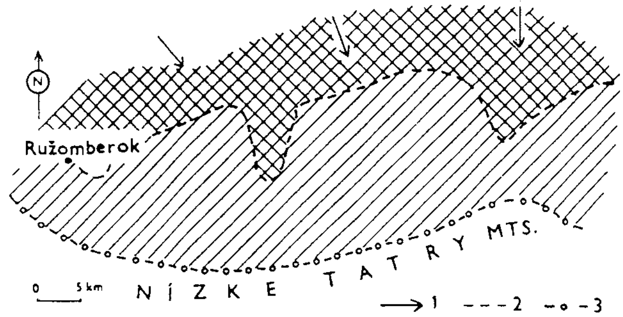

Fig. 2. Schematic sketch of the progress of the Paleogene transgression in the Liptov Basin. 1 - direction of the transgression, 2 - supposed coastline in the Upper Lutetian, 3 - supposed coastline in the Upper Priabonian.

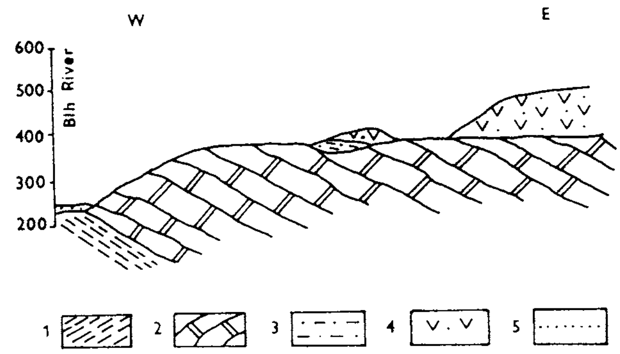

Fig. 3. Schematic profile of the Drienčany Plateau (according to Gaál 1982). 1 - sandstones and shales, Lower Triassic, 2 - limestones, Middle/Upper Triassic, 3 - calcareous silts, Egerian, 4 - andesite volcanoclastics, Miocene, 5 - alluvium.

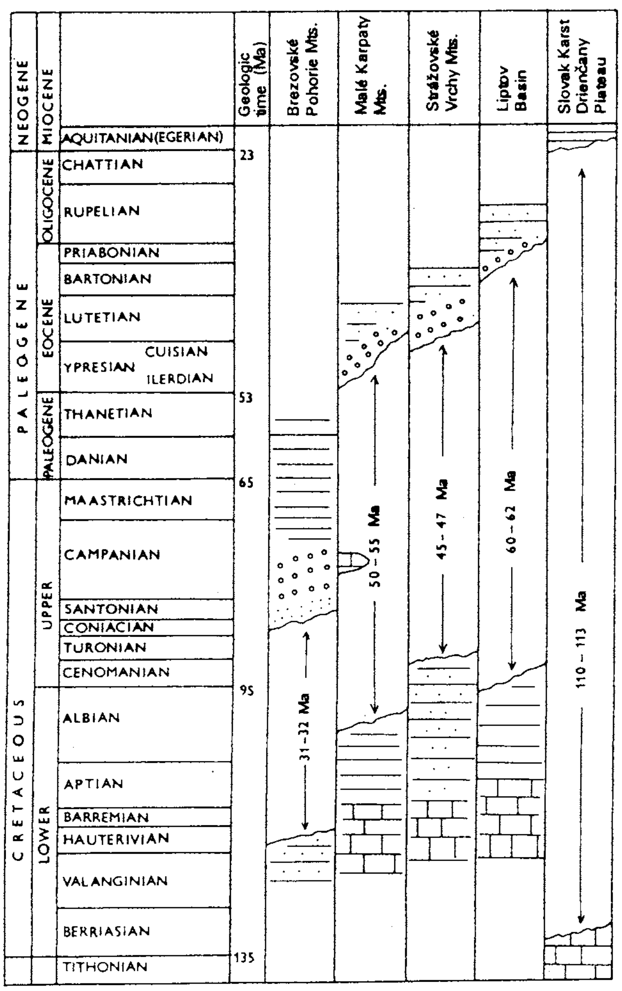

Fig. 4. The time-span of the Paleoalpine karst period in different parts of the Western Carpathians (geological time-table in Ma).

The Slovak Karst

Extensive paleokarst plateaus represent the characteristic feature of the Slovak Karst (for location see Fig. 1). Plateaus planate Middle/Upper Triassic limestones of the Silica Unit. The variety of surface karst forms occurs on plateau surfaces, while caves and shafts occur in the subsurface. The presence of the Paleoalpine karst period in the present relief is documented by relic ferricrusts (Kováčik 1955), by kaolinic clays and also by karst bauxites from Drienovec. Karst depressions filled with Upper Cretaceous (Mello & Snopková 1973; Marschalko & Mello 1992) on the surface of the paleokarst plateau in the Gombasek Quarry clearly prove the Paleoalpine karst in the present relief.

The subsided block of the Drienčanský Karst provides the most favourable conditions for dating the Paleoalpine karst period, at least in a part of the Slovak Karst. Blocks of the Drienčanský Karst represent the paleokarst plateau planated in Middle/Upper Triassic limestones and dolostones of the Silica Unit. The planated surface also contains younger erosional relics of shallow-marine calcareous silts and volcanoclastics (Gaál 1982; Fig. 3).

The start of the Paleoalpine karst period, in the Slovak Karst, is indicated by the termination of marine deposition during the Tithonian (135-139 Ma) in the Silica Unit. The upper boundary of the period is shown by unconformably deposited Egerian calcareous clays (23 Ma) on the surface of the Drienčanský Karst (not in the whole Slovak Karst; Fig. 4).

In the neighbouring region of the Juhoslovenská Kotlina Depression, the Kiscelian (Oligocene) Skálnica and Blh Members, the oldest parts of the kaolin clays in the Western Carpathian region, transgressed onto islands of karstified Triassic limestones (Vass et al. 1989; Kraus 1989, p. 212).

Conclusions

The contribution defines the Paleoalpine karst period especially in the frame of time. It also describes some characteristic karst forms and sediments of this longest karst period in the Western Carpathians.

The lower boundary of the Paleoalpine karst period is age-determined by the gradual emergence of the basement - during the Late Cretaceous in the Central Western Carpathians and even earlier in the Inner Carpathians.

The upper boundary can be dated by marine transgression. The start of the transgression is not synchronous and it varies in a broad range from Upper Cretaceous (Brezovské Pohorie Mts.) to Upper Eocene (a part of the Liptov Basin) and maybe even up to Miocene (a part of the Slovak Karst).

Karst forms and sediments originated during the Paleoalpine karst period were extensively destroyed by later processes and they have been preserved mostly as relics.

In conclusion, it has to be pointed out that the underestimation of processes active in a terrestrial environment results in a constricted view of the geodynamic evolution of the Western Carpathians.

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References

Andrusov D., 1965: Geology of Czechoslovak Carpathians. Vol. 3. *Veda*, Bratislava, 1-392 (in Slovak).

Bárdossy G., 1987: Karst bauxites. *Elsevier*, Amsterdam-Oxford-New York, 1-441.

Barchatova N.N., Berlin T.S., Nemkov G.I. & Portnaya E.L., 1979: Paleobiography and paleotemperatures of Eocene seas in Eurasia indicated after Numulitidae. *Vopr. Mikropal.*, 22, 93-98 (in Russian).

Borza K. & Martiny E., 1964: Weathering crusts, bauxite and "terra rossa" in Slovak Carpathians. *Geol. Sbor. Slov. Akad. Vied*, 9-26 (in Slovak, German abstract).

Bosák P., Horáček I. & Panoš V., 1989: Paleokarst of Czechoslovakia. In: Bosák P. (Ed.): *Paleokarst. A systematic and regional review. Academia*, Praha, 107-135.

Činčura J., 1987: Climate dynamics in the beginning of neoid geomorphologic stage in the West Carpathian Mts. *Geol. Zbor. Geol. Carpath.*, 38, 5, 601-614.

Činčura J., 1988: Epiquasiplatform features of the Central West Carpathians. *Geol. Zbor. Geol. Carpath.*, 39, 5, 577-587.

Činčura J., 1990: Characteristic features of Paleoalpine and Epipaleoalpine landmass of the West Carpathians. *Geol. Zbor. Geol. Carpath.*, 41, 1, 29-38.

Činčura J., 1992: Paleokarst breccias of the Biele Hory Mts. (Malé Karpaty Mts., Western Carpathians). *Geol. Carpathica*, 43, 2, 105-110.

Esteban M., 1991: Paleokarst: practical applications. In: *Paleokarst and paleokarstic reservoirs*. University of Reading, 89-94.

Fusán O., Biely A., Ibrmajer J., Plančár J. & Rozložník L., 1987: Basement of the Tertiary of the Inner West Carpathians. *GÚDŠ*, Bratislava, 1-123 (in Slovak, English abstract).

Gaál Ľ., 1982: Stratigraphy and facies relations among Triassic limestones of the Silica Nappe in Driečany karst. *Geol. Práce, Spr.*, 77, 29-48 (in Slovak).

Głazek J., 1989: Paleokarst in Poland. In: Bosák P. (Ed.): *A systematic and regional review*. Academia, *Praha*, 77-105.

Gross P., Köhler E. et al. 1980: Geology of Liptov Basin. *GÚDŠ*, Bratislava, 1-242 (in Slovak, English abstract).

Kandera K., Gerthoferová H. & Kraus I., 1989: Structures and textures of bauxite in the Strážovské Vrchy Mts. *Miner. slovaca*, 21, 2, 571-576.

Kováčik J., 1955: The residual iron ore deposits of the Plešivec plateau. *Geol. Sbor. Slov. Akad. Vied*, 6, 3-4, 232-251 (in Slovak).

Kraus I., 1989: Kaolins and kaolinite clays of the West Carpathians. *Západ. Karpaty, Ser. Min. Petr. Geoch. Metalog.*, 13, 1-287 (in Slovak, English abstract).

Lowenstam H.A., 1964: Paleotemperatures of the Permian and Cretaceous periods. In: *A. E. M. Nairn* (Ed.): *Problems of paleoclimatology. Interscience Publ.*, London-New York-Sydney, 227-248.

Mahel' M., 1986: Geological structure of Czechoslovak Carpathians. Paleoalpine units 1. *Veda*, 1-510 (in Slovak).

Marschalko R. & Mello J., 1993: Turbidites as filling of cavities in Triassic limestones of the Silica Nappe (Western Carpathians, Plešivec Karst Plateau). *Geol. Carpathica*, 44, 1, 35-42.

Mello J. & Snopková P., 1973: Upper Cretaceous age of the cavity fillings of Triassic limestones in Gombasek quarry. *Geol. Práce*, Spr., 61, 239-253 (in Slovak).

Michalík J., 1984: Some remarks on developmental and structural interpretation of the NW part of the Malé Karpaty Mts. *Geol. Zbor. Geol. Carpath.*, 35, 4, 489-504.

Michalík J. & Činčura J., 1992: Cretaceous shallow marine clastics and continental/freshwater deposits in the Western Carpathians, Czechoslovakia. *Cretaceous Research*, 13, 157-166.

Rakús M. and the IGCP National Working Groups 1989: Evolution of the northern margin of Tethys. Stratigraphic sections. *Mem. Soc. Geol. Fr.*, N.S., 154 (II), 135-214.

Roth Z., 1980: Western Carpathians - Tertiary structure of Middle Europe. *Knih. Ústř. Úst. geol.*, 55, 1-128 (in Czech).

Salaj J., Began A., Hanáček J., Mello J., Kullman E., Čechová A., Šucha P. 1987: Explanations to the geological map of Myjavská Pahorkatina, Brezovské and Čachtické Karpaty 1:50,000. *GÚDŠ*, Bratislava, 1-181 (in Slovak, English abstract).

Salaj J. & Priechodská Z., 1987: Comparison of the Gosau type of Senonian and Paleogene between the Myjavská Pahorkatina Highlands and the Northern Calcareous Alps. *Miner. slovaca*, 19, 6, 499-521 (in Slovak).

Snopková P., 1990: Redeposited palynomorphs in Paleogene sediments of the West Carpathians and their significance for paleogeography. *Geol. Práce, Spr.*, 91, 49-59 (in Slovak).

Tollmann A., 1978: Plattentektonische Fragen in den östalpen und der plattentektonische Mechanismus des mediterranen Orogens. *Mitt. österr. Geol. Gesell.* (Wien), 69, 291-351.

Vass D., Elečko M. et al., 1989: Geology of Rimavská Kotlina Depression. *GÚDŠ*, Bratislava, 1-161 (in Slovak, English abstract).