Contents

SLOVAK GEOLOGICAL MAGAZINE

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SLOVAK GEOLOGICAL MAGAZINE

New periodical of the Dionýz Štúr Institute of Geology is a quarterly presenting the results of investigation and researches in a wide range of topics:

- **regional geology and geological maps**
- **lithology and stratigraphy**
- **petrology and mineralogy**
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- **tectonics and structural geology**
- **hydrogeology and geothermal energy**
- **environmental geochemistry**
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- **geological factors of the environment**

The journal is focused on problems of the Alpine-Carpathian region.

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Andrusov D., Bystrický J. & Fusán O., 1973: Outline of the Structure of the West Carpathians. Guide-book for geol. exc. X. Congr. CBGA, Geol. Úst. D. Štúra, Bratislava, 5 - 44.

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1. Editorial Board reserves the right to publish preferentially invited manuscript and to assemble thematic volumes,
2. Editorial Board sits four times a year and closing dates for individual volumes will be on every 15th day of March, June, September and December.

SLOVAK GEOLOGICAL MAGAZINE

DIONÝZ ŠTÚR INSTITUTE OF GEOLOGY, BRATISLAVA

2/95

Foreword

SLOVAK GEOLOGICAL MAGAZINE is a new, wide-range quarterly published by the Dionýz Štúr Institute of Geology in Bratislava since 1995. Our new journal takes advantage of a long-run publishing tradition of the Dionýz Štúr Institute of Geology, and introduces this journal written exclusively in English. The tradition of geological journals have began in Slovakia in 1941 by the "Práce štátneho geologického ústavu" (Works of the State Geological Institute), and 28 issues entittled "Zošit" (Issue), were published by the State Geological Institute. In 1951, the institute has been renamed to the Dionýz Štúr Institute of Geology and its publishing plan has also changed. The "Geological Works" (with a subtitle) "Zošit" (Issue) (1951-1954), and "Správy" (Reports) have been published since 1954 up to now. These non-periodical journals published predominantly in Slovak were later followed by the "Sborník geologických vied - rad Západné Karpaty" (Geological Science Papers - series Western Carpathians), which contained larger, or monographic works. This series was followed in the year 1973 by four series of the "Západné Karpaty" (Western Carpathians) (Geology, Mineralogy-Petrography-Geochemistry-Metallogeny, Paleontology, Hydrogeology-Engineering Geology and Geothermal Energy), published in Slovak or other languages, predominantly English. In 1994 the Editorial Board of the Dionýz Štúr Institute of Geology decided to stop this edition and to replace it by the Slovak Geological Magazine. However, the edition of the Geologické Práce, Správy (Geological Works, Reports) continued in Slovak language to summarize mostly the annual reports and to inform local geological commonity with the results of latest activities.

Apart from the above mentioned journals our institute also publishes the EXPLANATIONS to geological maps, MONOGRAPHS, specialised volumes CONFERENCES-SYMPOSIA-SEMINARS, as well as a number of occasional publications.

SLOVAK GEOLOGICAL MAGAZINE is focused on presenting the results of investigations, preferably from the Alpine-Carpathian orogenic system. However the Editorial Board reserves the right to accept papers describing also works from other regions, provided they conform with the orientation of the magazine. The issues of the SLOVAK GEOLOGICAL MAGAZINE may be, if necessary, monothematic, as is our issue N^{o} 1/95 (hydrogeology).

The aim of our EB is to contact wide geological community, both Slovak and foreign and invites the co-operation of readers and contributors in order to promote our new edition.

JOZEF VOZÁR
Editor in Chief


PRÁCE ŠTÁTNEHO GEOLOGICKÉHO ÚSTAVU
GEOLOGICKÉ PRÁCE
SBORNÍK GEOLOGICKÝCH VIED
REGIONÁLNA GEOLÓGIA ZÁPADNÝCH KARPÁT
VYSVETLIVKY
KU GEOLOGICKEJ MAPE
MIOCENE MICROFLORA
AND ITS
ZÁPADNÉ KARPATY
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MICHAL MAHEĽ

editor of KBGA tectonic map 1 : 1 000 000 teacher and important regional geologist of Slovakia is celebrating his 75th anniversary

In these days, we are remembering the three-quarter-century anniversary of an uncommonly active and scientifically fruitful life of Professor Michal Maheľ. He belongs to the foremost representatives of the first important generation of Slovak geologists, the first steps in geology of which were determined by Nestor of Slovak geological school, Dimitri Andrusov. Professor Maheľ was among the first graduates of this school and its influence had a great effect on his whole scientific work. This influence is reflected above all in the complex approach to regional geological problems. The life-long activity of Professor Maheľ lies in compilation of geological maps and connection of scientific investigations with the application of geology in practice, and, on the other hand, continuous widening of the theoretical geological knowledge.

The result of his more than half-a-century long scientific, research and teaching activities is a considerable number of scientific publications, maps, projects or expertises (over 40), published geological maps and explanations, over 200 contributions and papers in Slovak as well as foreign scientific journals, 20 important projects and realised concepts and proposals, over 50 specialised scientific-technical expertises and proposals.

Michal Maheľ was born on August 19, 1920 in Trhovište, district of Michalovce. He graduated from secondary school in Michalovce in 1939. He studied in the years 1939-1944 at the Faculty of Natural Sciences of the Comenius University in Bratislava and he graduated with a second State Exam (sciences, geography) and doctorate from geology (RNDr.) in 1944.

In the years 1945-1947 he worked at the Slovak Geological Institute (present Dionýz Štúr Institute of Geology), which determined to a considerable extent his activities to concentrate on regional geology and solving regional hydrogeological problems. An important contribution, especially for extending the horizon as well as aims of hydrogeological investigations, was his scientific stay in Grenoble (France).

The years 1949-1952 were a period of intensive teaching activities at the Faculty of Natural Sciences of Comenius University in Bratislava, where, in the year 1949, after submitting the work "Tectonics of the territory between mid-flow of the Váh river and upper Nitra region", he was habilitated for Senior Lecturer.

Since 1952 he worked again at the Dionýz Štúr Institute of Geology, since 1954 as Senior Scientist and in the years 1958-1963 he held the post of Director of the Institute. In the year 1960 he acquired the doctorate in geological sciences (DrSc) after defending his thesis at the Charles University in Prague. He was elected Corresponding Member of the Czechoslovak Academy of Sciences in the year 1962 and a year later also Corresponding Member of the Slovak Academy of Sciences. He was appointed University Professor in the year 1964 and since 1975 he has been a member of the Slovak as well as Czechoslovak Academy of Sciences. He attained these scientific honours on the basis of his tireless scientific and teaching work, mostly immediately after solving serious geological problems and finishing important scientific works.

As a regional geologist he carried out geological survey in various parts of Slovakia, which resulted in compilation of geological maps on various scales and scientific papers on the geological structure of the territories studied. We must particularly point out detailed geological evaluation of the Strážovské vrchy Mts., Malé Karpaty Mts., Slovenský raj region, northern parts of the Spišsko-gemerské rudohorie Mts., Humenské vrchy Hills and partly Považský Inovec Mts. He participated with an important contribution in a Government Project - the compilation of Geological Map of Czecho-Slovakia 1: 200 000, especially as the Editor in Chief of key sheets Banská Bystrica, Žilina and Bratislava, with the book of Explanations. Besides this, he solved a number of hydrogeological problems, aimed at utilisation of mineral water, drinking and technical water sources protection as well as exploration of non-ore raw materials. His work has always been closely connected with solving topical problems of basic geological research. He was the co-ordinator and project manager of several big projects, aimed at solving basic geological and especially tectonic problems of the Western Carpathians.

Professor Maheľ became known in the European as well as world geological community as a leading expert on the Western Carpathians, especially due to the Tectonic Map of the Carpathian-Balkan Region and Adjoining Territories 1:1 000 000, which was the culmination of many years´ work of the KBGA Tectonic Commission and of a wide editorial group under the leadership of Professor Maheľ. His anniversary is coinciding with the - to a certain extent also anniversary - XV Congress of the KBGA in Athens, which, after a period of stagnation, should renew its geological activities, aimed maybe at similar goals, but in different, more economic and effective manner.

Professor Maheľ entered the activities of KBGA in a period of its revival, at the end of the fifties. He was appointed Secretary of KBGA for Czechoslovakia and given the task to prepare Czechoslovak participation at the 4th Congress of renewed KBGA in Kiev. By the decision of this KBGA Congress, Czechoslovakia was granted the leadership of the Tectonic Commission of KBGA, one of the 7 newly formed commissions, and M.Maheľ was appointed its chairman. Under his leadership the Tectonic Commission was rapidly activated and already in the year 1961, at the 5th KBGA Congress in Bucharest, it presented a program of elaboration of basic problems connected with graphic presentation of tectonic structure of the Carpathian-Balkan countries. In this way the Commission also followed the program of the International Commission for World Tectonic Maps. The Congress welcomed this program, since it was necessary to form a common platform - the basis for the work of whole KBGA. It was necessary to compile a tectonic map on a more detailed scale (1:1 000 000), elaborated on principles which would better express the complex structure of the Carpathians, Balkan and Dinarides, on the level of progressing geological knowledge.

The map was finished in the year 1973 and it was published in English and Russian version in 4500 copies. Its publication was sponsored by UNESCO. Explanations were published in the year 1974 (Maheľ, M. (Ed.): Tectonics of the Carpathian-Balkan Regions), and in the year 1983 also a shorter version in Russian.

The publication of the KBGA Tectonic Map 1 : 1 000 000 and the Explanations was the result of a more than 10 years´ work of the KBGA Tectonic Commission and of a more than 50-member editorial team from various KBGA countries.

Theoretical basis of the Tectonic Map project was the new understanding of geosynclinal type in the Alpides, which was considerably more varied and dynamic than the classic couple eugeosyncline - miogeosyncline, as well as new understanding of tectonic processes in the Phanerozoic as a three- to four-stage tectonic system, which was an important step forward in comparison with the two-stage system used in the Tectonic Map of Eurasia 1:2 500 000 (internides, externides). The view on manifestations of folding processes changed as well, stressing especially the importance of the age of formation of tectonic units and thus also the importance of tectonic processes connected with the main folding phase.

Another principle, a basically new one for tectonic maps, was the expression of the relationship between the content, genesis and to a considerable extent also the form of architecture of tectonic units, so-called tectonogroup principle, expressing a set of such tectofacies which reflect most substantially the conditions of formation, i.e. the paleotectonic type of a unit. In this way, the KBGA Tectonic Map became one of first attempts in the world to express differences in crust type.

The compilation of the Tectonic Map 1:1 000 000 of a region with one of the most complex geological structures in the world, as represented by the Carpathians, Alps, Dinarides and the Balkan, and, what more, with differences in particular segments and based on a uniform legend, was possible only at active participation of a wide group of geologist from various countries. A number of scientific conferences was held to meet this goal.

The complete KBGA Tectonic Map was presented to the public in the year 1973 on the 10th KBGA Congress in Bratislava. The reception was spontaneous, pointing out its importance as the basis of thematic paleogeographic, hydrogeological and raw material maps, but also for solving a number of topical problems. It became thus a fundamental work, contributing to the definition of aims of several KBGA commissions in next years.

The KBGA Tectonic Map 1: 1 000 000 became the starting point for further activities of the KBGA Tectonic Commission after the 10th KBGA Congress, leading to the project of Tectonic Map 1: 500 000, aimed at two goals:

- compilation of national tectonic maps 1: 500 000 based on uniform legend
- possible compilation of an atlas of tectonic maps of KBGA countries

Czechoslovakia, and especially Dionýz Štúr Institute of Geology Bratislava and Central Institute of Geology in Prague, took upon them the task of compiling the legend and as well the maquette of first national tectonic map. The spirit and driving force of its preparation was again Professor Mahel', at active participation of several co-workers. The legend of the KBGA Tectonic Map 1:500 000 was complemented and modified every year during sessions of the KBGA Tectonic Commission, consistently with rapid progress of tectonic theories and new geological knowledge.

Tectonic Map of Czechoslovakia (ČSSR) 1: 500 000 in Slovak and English version (editors: M. Mahel' - O. Kodym - M. Malkovský), with brief explanations (M. Mahel' - M. Malkovský) was printed in the year 1984. This map was based on well-tested principles of the KBGA Tectonic Map 1: 1 000 000, however, it was characterised by a more detailed elaboration of magmatic and volcanic rocks, by expressing detailed internal structure of basins, indicating the structure of their basement, as well as by distinguishing paleotectonically different molasse types, expressing the underlie of a considerable part of the Flysch Belt, by a greater stress on internal structure, including nappes in crystalline complexes, by stressing the importance of early Paleoalpine (Kimmerian) folding, by more detailed elaboration of tectonogroups as well as structural elements aimed at expressing lateral changes in the structure of tectonic units as well as the possibility of distinguishing particular tectonic units. However, the following period did not allow to fulfil completely the program of compilation of the KBGA Tectonic Map 1: 500 000 and thus the map of Czechoslovakia was the first, but, hopefully, not the last one in the program created by Professor Mahel'.

We would like to wish Professor Mahel' good health in the next years. We would be glad if the effort he invested during his leadership of the KBGA Tectonic Commission into the preparation of the new 1: 500 000 tectonic map of the KBGA region were not in vain and if it would in future contribute to the knowledge of its tectonic history as well as a more detailed reconstruction of its structure.

P. REICHWALDER, J. VOZÁR

SLOVAK GEOLOGICAL MAGAZINE

The origin and disappearance of Hungarian Paleogene Basins and short-term Lower Miocene Basins in Northern Hungary and Southern Slovakia

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Abstract: The Hungarian Paleogene basins generated in the area of the Western Carpathian - Northern Hungarian terranes before and during their tectonic escape from the Alpine domain as the consequence of the convergence of Afro-Arabian and Eurasian lithospheric plates. The basins disappeared after the main escape movements. Later on, two short-term basins - Fiľakovo/ Pétervásara and Novohrad/Nógrád - replaced the previous ones with regional uplift in- between. Uplift was caused by initial lithospheric stretching as a result of astenosphere rise. The whole process of the tectonic escape finished by counterclockwise rotation (end of the Lower Miocene). The last pulse of the rotation was contemporaneous with the disappearance of the last Lower Miocene basin in the area studied.

Key words: tectonic escape, Hungarian Paleogene basins, Fiľakovo/Pétervásara and Novohrad/Nógrád basins, strike slip movements, horizontal rotation, remanent paleomagnetic declination.

Acknowledgements: This work was supported by the project "Geodynamic development of the Western Carpathians Nr. 17-517-01.

During the Paleogene and Lower Miocene, the convergence of Afro-Arabia and Eurasia (ZIEGLER, 1988) provoked the collision of the Apulian promontory with the Bohemian Massif and subduction in the Outer Carpathians. The suction, or pull in front, caused by the subduction and push-behind exerted by the collision, led to tectonic extrusion, forcing the escape of the Western Carpathian - Northern Pannonian terranes from its home in Central Alps and Dinarides. The escape was driven to the east or north-east into the present Intra-Carpathian region (BALLA, 1984, KÁZMER and KOVÁCS, 1985, BÁLDI, 1986, NEUBAUER and GENSER, 1990, RATSCHBACHER et al., 1991a,b, CSONTOS, et al., 1992, and others) or, according to paleomagnetic evidences, to the Southeast (MÁRTON, 1933). The displacement was as large as 400 km (e.g. KÁZMER and KOVÁCS, 1985). The escape was in the Outer Carpathians compensated by the closing of Flysch troughs and by shortening of the space (i.e., by thrusting).

To the NE escaping Western Carpathian - North Pannonian terranes were confined in the south by a right-lateral shear zone with two important faults (Balaton and Mid-Hungarian lines) and in the north by the Peripieniny fault belt, with left-lateral shear (Fig. 1). Particular blocks between both limiting shear zones were confined by faults of wrench nature. The wrench faults caused opening of basins on both sides of the escaped terrane: the Hungarian Paleogene Basins (HPBs), North and South Buda units in sense of NAGYMAROSY (1990) (Fig. 3a) in south (Fig. 2) and Central-Carpathian Paleogene basin in north. Deposition centres of these basins migrated from west to east (GROSS et al., 1984, BÁLDI and BÁLDI-BÉKE, 1985, BÁLDI, 1986). The HPBs are recently interpreted as retroarc flexural foreland basins (TARI et al., 1992, TARI and SZTANÓ, 1993), but the main argument for such a model - evidence of back-thrusting of the Western Carpathians during the Paleogene, is missing yet.

The gently to the NW dipping reflectors in the pre-Tertiary basement of the Danube Basin (Slovakian part) interpreted as Alpine thrust planes reactivated during the Middle Miocene as low-angle normal faults (TOMEK and THON, 1987), are considered to be SE-vergent thrust planes by TARI et al. (1992). Those reflectors may be in fact thrust planes, but with by the Neogene uplifts overturned inclinations from SE to NW, as it is well visible everywhere on the northern flanks of the Central Western Carpathian "core" mountains (Vysoké and Nízke Tatry Mts., Veľká and Malá Fatra Mts., Tribeč Mts. etc.). The Hurbanovo-Diösjenö line is interpreted (Fig. 1) as to the NW steeply dipping and SE - vergent major thrust belt (TARI et al., 1992). More recent magnetoteluric measurements across the Hurbanovo line (VARGA in DŽUPPA et al., 1993) lead to the conclusion that the line is inclined more gently to the SE, so it can be a NW-vergent thrust fault (see also HORVÁTH, 1993).

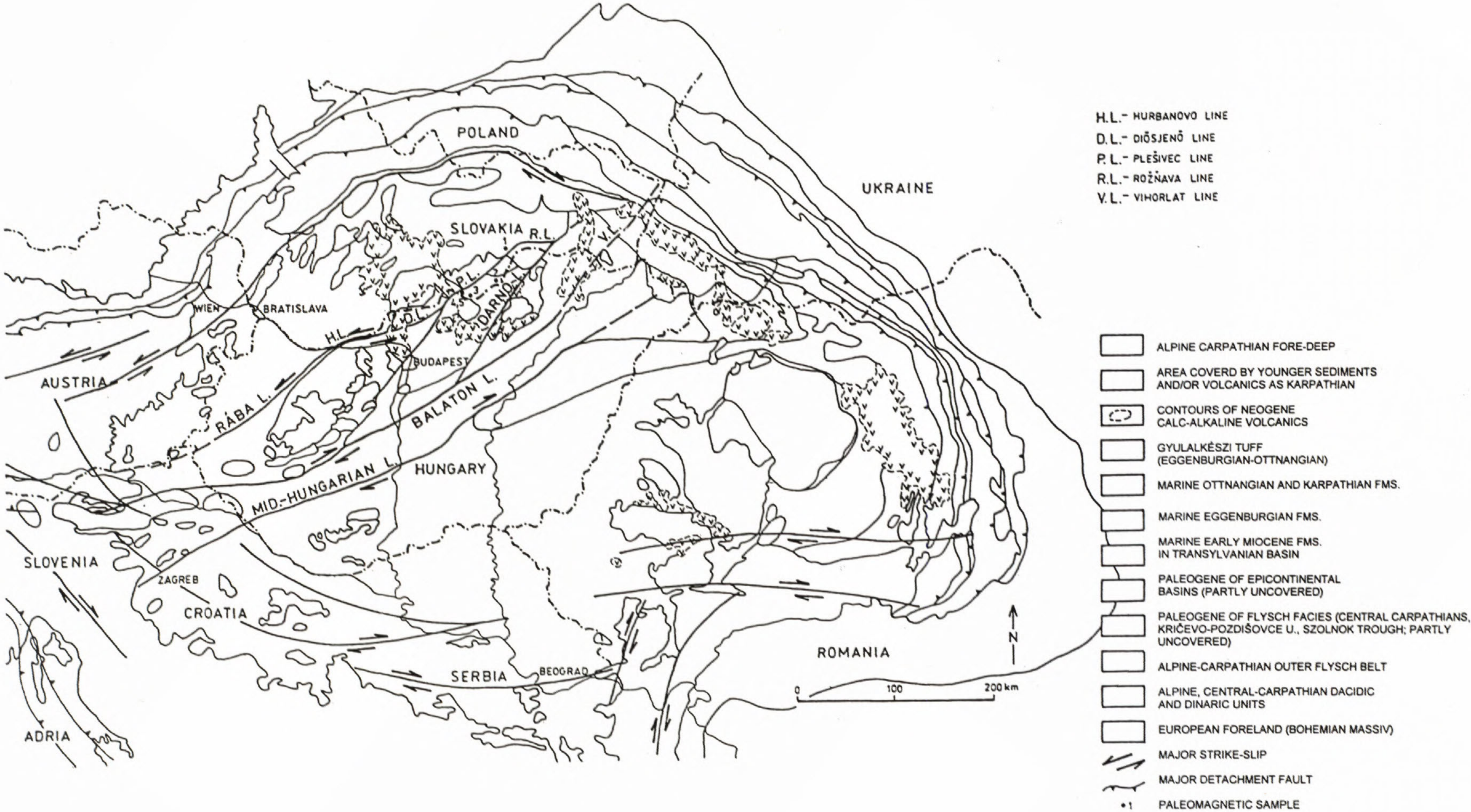

Fig. 1 Geological sketch map of the Carpatho-Pannonian region

The tectonic escape of the Western Carpathian - Northern Pannonian terranes had not only lateral movements, but also the escaping terrane was thrust above a unit equivalent to Penninicum in the Alpine domain. The thrusting is dated as Eocene, or post-Eocene, because the Krichevo-Iňačovce unit with the youngest sedimentary formation Eocene in age, considered an equivalent of Penninicum, is emerging from beneath the Western Carpathian pile of nappes at the floor of the East Slovakian Basin (SOTÁK et al.,1993).

The HPBs are of pull-apart origin (BÁLDI and BÁLDI, 1985, BÁLDI, 1986). Their development was not continuous. The onset of sedimentation was diachronous. Sea transgression was coming from the SW (DUDICH, 1977, DUDICH and KOPEK, 1980) after a long period of subaeral exposure, when karst-bauxite deposits were formed. The sedimentation started in the Carinthian Bay earlier (during the Cuisian) than in the Bakony bay inundated by a shallow sea during the Lutetian. The sea reached the Buda line (BÁLDI, 1986), or facial boundary (TARI et al.,1992). The transgressive progradational sequence started by coarse terrigenous clastics of the Darvastó Formation, graded upward into the neritic limestone of the Szöc Formation (Fig. 4). By the end of the Lutetian the sea became deeper (800–1200m) and bathyal marlstone of the Padrag Formation deposited, having in the upper part distal turbiditic intercalations (TARI et al.,1992).

During the Bartonian the sea transgression reached the NE part of the Bakony and NW part of the Buda (Fig. 4) units, starting with the thick paralic coal-bearing Dorog Formation indicating a humid climate. Later on, the Dorog Fm. was overlain by clastics of the Tokod Formation, neritic limestone of the Szépvölgy Formation and by the bathyal marlstone of the Piszke and/or Buda Formations respectively, with calciturbiditic intercalations. The Szépvölgy and Buda Formations spread further to the NE, covering the whole Buda and NW part of the Bükk units (TARI et al.,1992, for present position of the particular basement units see Fig.3).

During the Eocene the opening of the basins and their subsidence were controlled by a dynamically transforming paleostress field. FODOR (1992), based on brittle deformations study in the Central Hungarian Range (in Buda and Gerecse Hills), assumed the existence of a compressional paleostress field during the Eocene. In such a stress field there were generated antiforms, dextral strike-slips and normal faults. Still during the Eocene the paleostress field changed. Compression was replaced by extension (BERGERAT et al.,1984).

Paleogeographic evidence shows that during the Lutetian the Bakony unit was far away and well separated from the Carpathian Flysch, Central Carpathian or Podhale Flysch seas and Transylvanian sea. Lutetian fauna from Bakony is similar to fauna from Carinthia and both faunas have strong affinity to North Italian faunas, while the faunas of Podhale and Transylvania are rather different (BÁLDI, 1986 and KECSKEMÉTY, STRAUSZ, KÖRMENDI fide BÁLDI, 1986). The coal seams of Dorog Fm. (Bakony) and Carinthian coeval coals indicate humid climate, while the evaporites in the Lutetian of Transylvania indicate an arid one (BÁLDI, 1986). However, in the late Lutetian and early Priabonian the distance between the Bakony sea and Podhale sea shortened due to lateral translations inside the escaping terranes, the paleogeographic barriers, likewise, were suppressed and a sea strait via Krupina – Zvolen opened to connect both areas (VASS et al.,1979).

During the Oligocene the Bakony and partly Buda units were uplifted and underwent an "Infra-Oligocene denudation" (TELEGDI-ROTH, 1927). Meanwhile in the SE part of the Buda unit and NW part of the BÜKK unit an euxinic sea persisted during the early Kiscellian and a clay sequence of Tard Formation deposited there (BÁLDI, 1986).

During the late Kiscellian the sea rapidly invaded the Buda, Bükk and even Veporic and Gemeric units including Silicicum, Turnaicum and Meliaticum in the area of Ipeľ, Lučenec and Rimava depressions, S. Slovakia (Fig.3b). The sea transgression far to NE (in present day co-ordinates) was facilitated by lateral tectonic approach of the Bakony and Buda units to other above mentioned units. The transgression is marked by an extensive sheet of coarse clastics with coal seams (Harshegy Sandstone; Blh and Hostišovce members of the Číž Formation; BÁLDI 1986, VASS and ELEČKO, 1982) signalising again a humid climate. The southward wandering of boreal fauna indicates cooling (CAVELIER, 1979, fide BÁLDI, 1986). Coarse clastics grade into bathyal claystone/siltstone of the Kiscell Clay with turbiditic intercalations and Lenartovce member of the Číž Formation (HANTKEN, 1868, BÁLDI, 1986, VASS and ELEČKO et al.,1989,1992). At the end of the Kiscellian there was a regressive event marked by the basinward shift in facies and by prograding deltas (e.g. Rapovce delta in the Lučenec depression S. Slovakia, VASS and ELEČKO et al., in lit.).

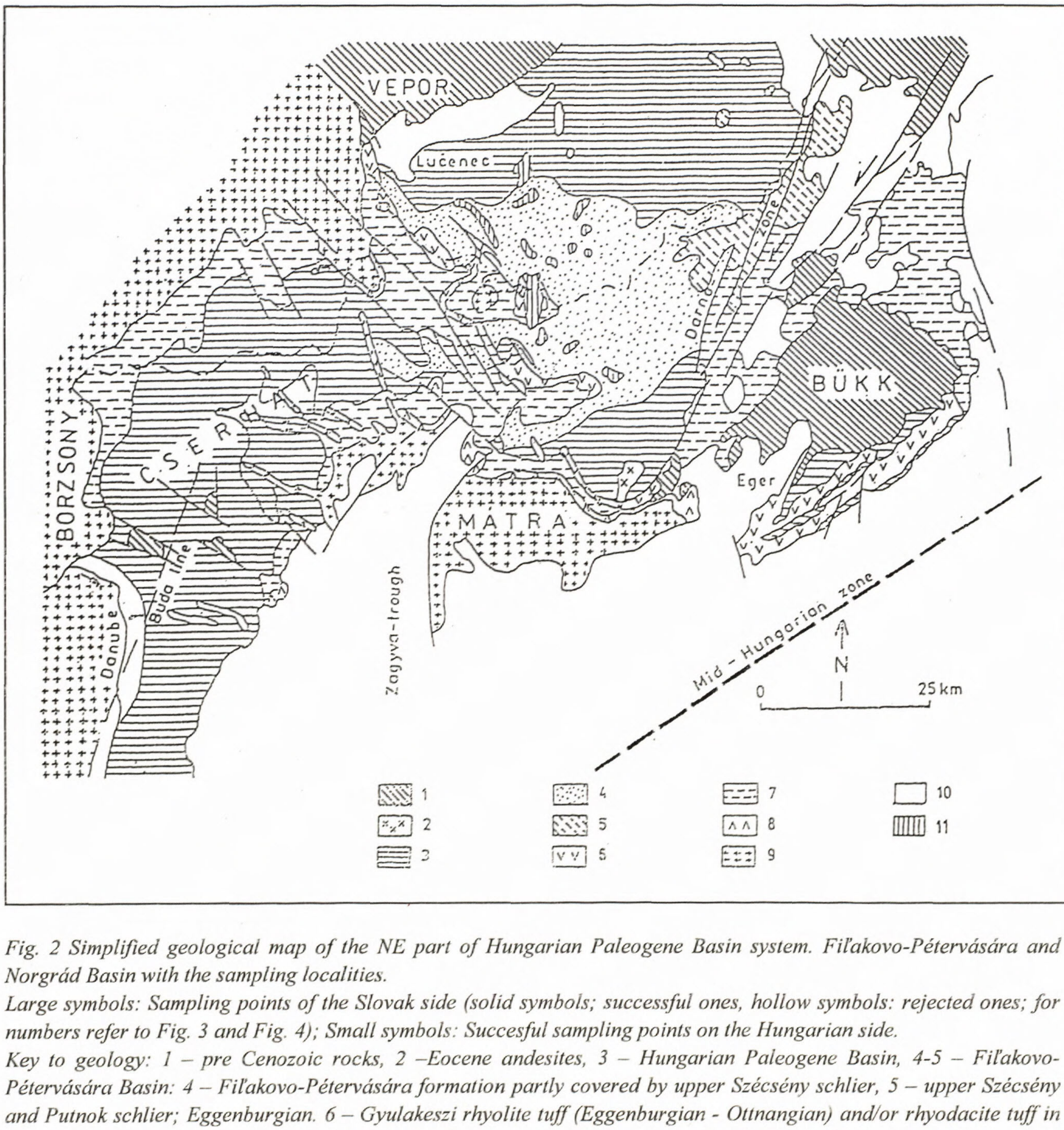

Fig. 2 Simplified geological map of the NE part of Hungarian Paleogene Basin system. Fiľakovo-Pétervására and Norgrád Basin with the sampling localities.

Large symbols: Sampling points of the Slovak side (solid symbols; successful ones, hollow symbols: rejected ones; for numbers refer to Fig. 3 and Fig. 4); Small symbols: Succesful sampling points on the Hungarian side.

Key to geology: 1 – pre Cenozoic rocks, 2 –Eocene andesites, 3 – Hungarian Paleogene Basin, 4-5 – Fiľakovo-Pétervására Basin: 4 – Fiľakovo-Pétervására formation partly covered by upper Szécsény schlier, 5 – upper Szécsény and Putnok schlier; Eggenburgian. 6 – Gyulakeszi rhyolite tuff (Eggenburgian - Ottnangian) and/or rhyodacite tuff in Bukovinka formation (Eggenburgian), 7 – Nógrád - Novohrad Basin. Ottnangian and Karpathian; 8 –" middle rhyolite tuff" and/or Tarr tuff; upper Karpathian - lower Badenian, 9 – Middle (and upper) Miocene vulcanics, 10 – Middle to upper Miocene sediments, 11 – Upper Miocene to Pleistocene basalts

The Egerian marine transgression did not enter the Bakony unit and an alluvial, continental sequence - Csatka (or Mór) Gravel (BÁLDI, 1969, see Fig.4) was deposited there. The marine transgression was directed to the NE (present-day co-ordinates), giving the largest extension of the HPBs to the NE. The transgression exceeded the northern margin of the Kiscell Clay/Číž Fms. Shallow marine clastics of the Panica member, Törökbálint and Eger Sand/Sandstones, (VASS and ELEČKO, 1982, BÁLDI, 1969) and organodetritic carbonatic rocks of the Budikovany member (VASS & ELEČKO, 1982) gradually and laterally pass into bathyal siltstone of the Szécsény Schlier (BÁLDI, 1971, HÁMOR, 1985). Some Miogypsinas and Mollusc taxa occurring in the already mentioned Budikovany member and in the Bretka limestone - a littoral facies of the Szácsény Schlier (SENEŠ in STEININGER et al., 1975) - indicate an increase of southern influence and warming of the climate, particularly during the early Egerian (BÁLDI, 1986). The end of the Egerian is marked again by a regression (BÁLDI, l.c.) with prograding deltas (e.g. Opatová delta in the Ipeľ depression, S. Slovakia, ŠUTOVSKÁ-HOLCOVÁ et al.,1993, Kováčov Sand in Štúrovo Paleogene, SENEŠ, 1958, BÁLDI, 1969). In this time the Bakony unit continued to be subaerally exposed with continental deposition (Csatka gravel). On the NW periphery of the HPBs a sebhka persisted during the Oligocene (Fig.5), indicating a drastic change of climate from humid (early Kiscellian) to arid (VASS et al.,1979). The sebhka deposits of the

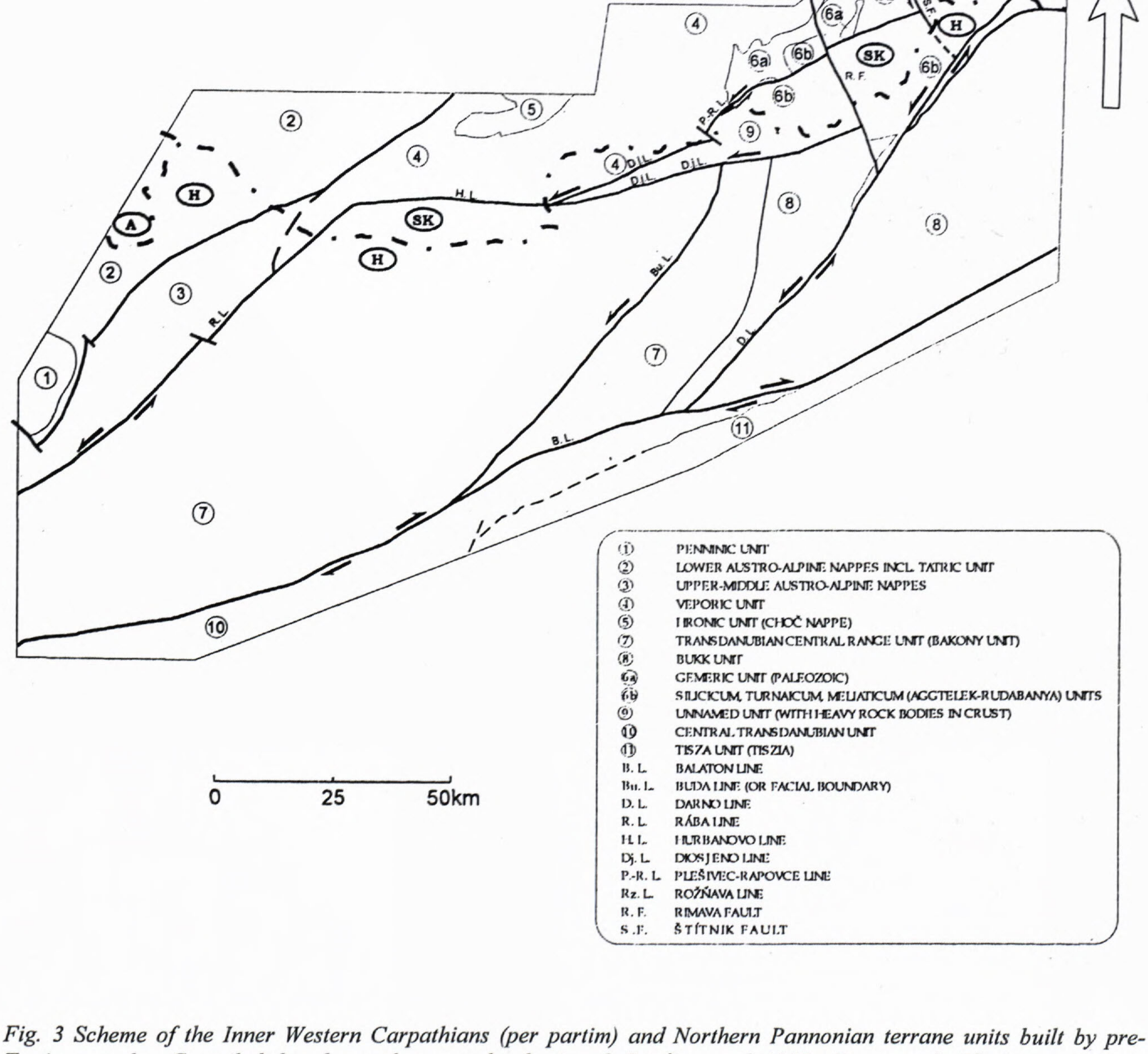

Fig. 3 Scheme of the Inner Western Carpathians (per partim) and Northern Pannonian terrane units built by pre-Tertiary rocks. Compiled by the author on the basis of FUSÁN et al.,1987, DANK and FŰLÖP et al.,1990

Krupina Formation are presently buried by sediments of the Lower Miocene and by Middle Neogene volcanics of Krupinská planina Plateau (Fig.3b). During the Egerian, the climate gradually deteriorated (cooling).

Concerning the paleostress field at the end of the Paleogene and very beginning of the Neogene, compression rotated from vertical to horizontal position. Such stress field produced or rejuvenated the normal faults controlling during the Kiscelian and Egerian the deposition in the partial South Slovakian depressions, particularly in the Rimava depression (VASS et al.,1993, VASS and ELEČKO et al.,1989). After the Egerian, the Plešivec - Rapovce fault belt (PLANČÁR et al.,1977, VASS and ELEČKO et al.,1992) with sinistral strike-slip movements was generated or revived (VASS et al.,1993). In South Slovakia these left-lateral motions caused the last tectonic approach of the Veporic unit to an unnamed unit having heavy rock bodies in the crust (VASS and ELEČKO et al., in lit., see Fig.3). On the surface these motions caused tectonic redistribu tion of Číž and Lučenec Formation along the Plešivec - Rapovce wrench fault (VASS et al.,1993).

On the southern margin of the escaped terranes, there is a well-documented right-lateral shear on the Balaton line, separating the Slovenian Basin and HPBs by approx. 300 km (NAGYMAROSY, 1990, CSONTOS, et al., 1992, see Fig.6). The shearing is dated as post-Egerian.

After the large lateral displacement the HPBs disappeared and from the beginning of the Eggenburgian they were replaced by the Fiľakovo/Pétervásara Basin (Fig.2) with a paleogeographic configuration of a bay (North Hungarian Bay, SZTANÓ, 1994). The mechanism of the basin opening was fairly similar to the HPBs, but the conditions changed essentially. The connection with the Mediterranean through the Slovenian strait (RÖGL and STEININGER, 1983, BÁLDI, 1986, HÁMOR et al.,1988) was closed and the lateral extension of the basin was reduced. The basin - bay opened by the sea ways to the NE (BÁLDI, 1986, SZTANÓ, 1994) and to the N, NNW (in present co-ordinates). On the margins of the basin deposited shallow-water clastics in the tide-dominated coastal environment of the Fiľakovo and/or Pétervásara Formations (SENEŠ in ANDRUSOV, 1965, HÁMOR, 1985)

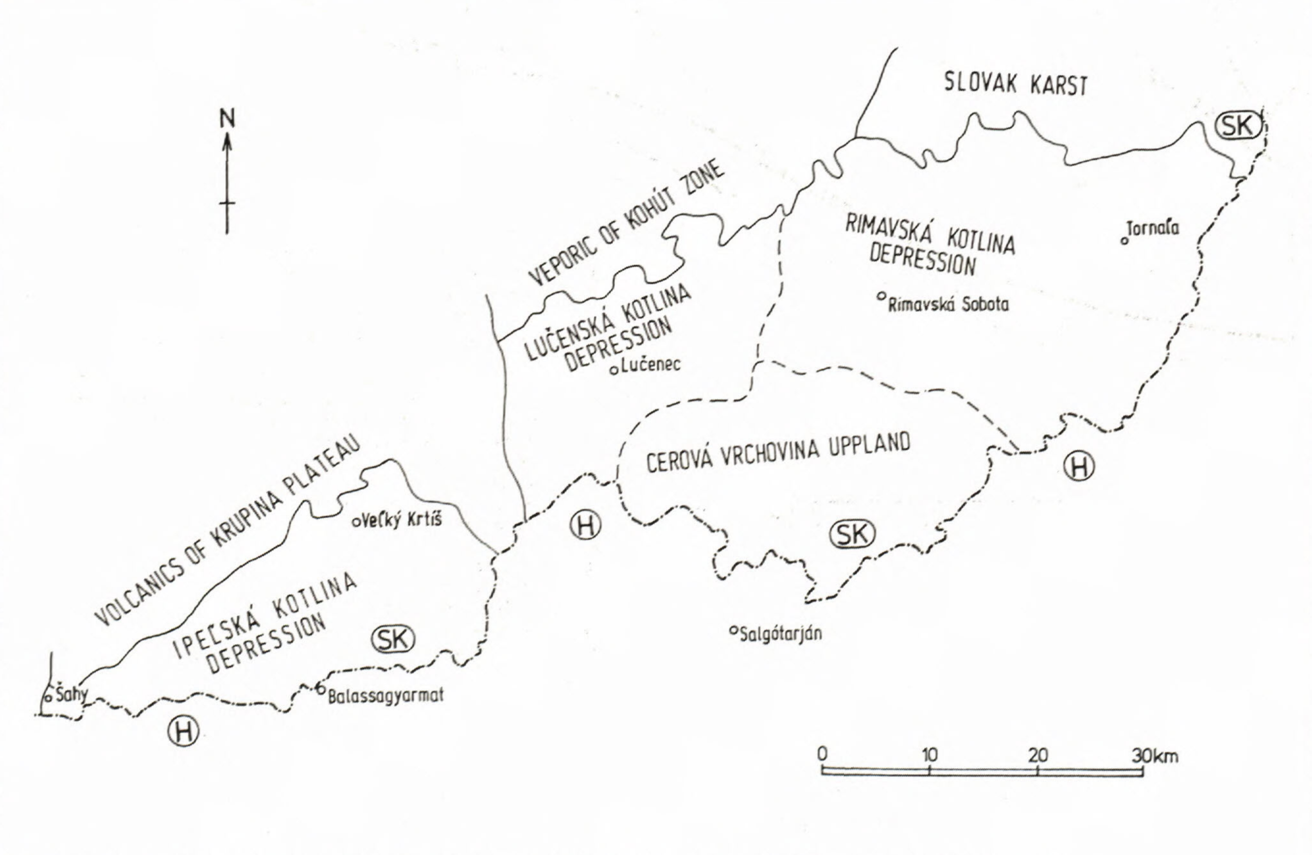

Fig. 3b Regional geological units of Southern Slovakia with respect to units mentioned in the paper

and littoral sandstone rich in fauna (Budafok and Lipovany Sandstone, BÁLDI, 1973, VASS and ELEČKO et al.,1992). In these clastics there are layers, or intercalations, of acidic tuff, in places bentonised. The radiometric age of the tuff is 20,5±0,5 Ma (REPČOK, in VASS and ELEČKO et al.,1992), confirming the Eggenburgian age (according to the radiometric time scale of the Central Paratethys, VASS et al.,1987). Basin facies is represented by siltstone apparently continuing from the Egerian Szécseny Schlier (Čakanovce member of the Fiľakovo Formation, VASS and ELEČKO et al.,1992).

The short life of the Fiľakovo/Pétervására basin ended by regional uplift in the whole area of the present day Pannonian Basin and the sea receded from the territory. Tectonic escape of a large amount of crustal mass provoked an instability in the astenosphere. Activated astenosphere started to rise and a thermal mantle plume formed. Heat flux out of the rising astenosphere was large enough to cause rapid thinning of the continental lithosphere and isostatic uplift. It seems that the uplift or doming preceded the rifting, because signals of tectonic subsidence caused by rifting appeared during the Karpathian (TARI et al.,1992, P.KOVÁČ et al.,1994) approx. 2-3 Ma after the strong manifestation of the uplift in the area. In this order, when the isostatic uplift precedes the rifting or the lithospheric rifting stretching can be classified as active one (KEEN, 1985 and others). Heating of lithosphere besides the uplift caused mobilisation and rise of crustal sialic magmas, supporting the isostatic uplift. Sialic magmas gave origin to extensive areal volcanic activity of rhyodacite/rhyolite nature as it is shown in Fig. 2 (PANTÓ et al.,1966, SZABÓ et al.,1992, LEXA et al., 1993).

At that time the sea completely receded from Southern Slovakia and from the area of present Pannonian Basin, where fluviatile sedimentation took place (Bukovinka and/or Zagyvapálfalva Fms. of S. Slovakia and N. Hungary, Sásvár Fm. of the Mecsek and surroundings, areas of the basins Zala and Drava, Madaras Fm. of the Alföld, Brenberg Fm. of the Soprony area, Fig.7, VASS and ELEČKO, 1982, HÁMOR et al.,1978, KOVÁCS, 1975, VENDL, 1929,1930).

Radiometric age of tuff coming from the Bukovinka Fm. (S. Slovakia) is 19,8 ± 0,2 and 20,1 ± 0,3 Ma (KANTOR et al., and REPČOK in VASS and ELEČKO et al.,1992). The tuff or ignimbrite - "Lower tuff" and/or Gyulakézsi rhyolite tuff (HÁMOR et al.,1979) spreading in N. Hungary and in S. Bükk area originated in a larger time interval, because their radiometric ages are 19–17Ma (HÁMOR et al.,1979). Thus, at least a part of the tuff layers may be younger than Eggenburgian.

Later, during the Ottnangian, the whole region subsided again and a new Novohrad/Nógrád Basin was generated (Ottnangian-Karpathian in age) (Fig.2). Normal faults were responsible for the opening of the basin. These faults were generated or reactivated in the lasting process of rifting. The rifting in the area studied took place in a paleostress field with extension in NW-SE direction (recent coordinates, VASS et al.,1993). The sea penetrated slowly into newly formed grabens, as the Dačov Lom graben in the Ipeľ depression (S. Slovakia, VASS et al.,1979). The sea came into the Pannonian-Carpathian realm through the intradinaric sea way, forming marine deposits in the Bantapuszta area (BAKONY, KÓKAY in PAPP et al.,1973)). Further to the north, sea transgression was preceded by sedimentation in rivers, swamps and lakes, which gave rise to the Salgótarján Formation (NOSEKY, 1930, HÁMOR in PAPP et al.,1973), invaded occasionally by sea (VASS et al.,1987, ŠKVARKA et al.,1991). In Borsód area sea conditions even predominated, which is documented by paralic coal seams (BOHN-HAVAS, 1985) and by the presence of marine calcareous nannoflora (BÁLDI-BÉKE and NAGYMAROSY, 1979, BOHN-HAVAS and NAGYMAROSY, 1985).

From paleomagnetic investigations realised in the North Hungarian Central Range and in South Slovakia it follows that important counterclockwise rotational displacement occurred during the Late Ottnangian (MÁRTON and MÁRTON in lit.). It was the first phase of a rotation as large as 40–50°. Uniform size and direction of the paleomagnetic declination rotation in a large area - between the Ipeľ depression, the Salgótarján region and South Bükk region - suggests rotation of the whole Western Carpathian – Northern Pannonian terranes and/or Pelsó megaunit (DANK and FÜLÖP, 1990); (Fig. 8). However, from the dynamic, physical and spatial point of view - more probable seem individual but uniform and unidirectional rotations of a set of small blocks. Horizontal rotation of the blocks is a tectonic feature associated with pull-apart basins and/or lateral strike-slips. The sense of the rotation depends on the sense of lateral strike-slip (TERRES and SYLVESTER, 1981). The counterclockwise rotation must have been associated with the left lateral

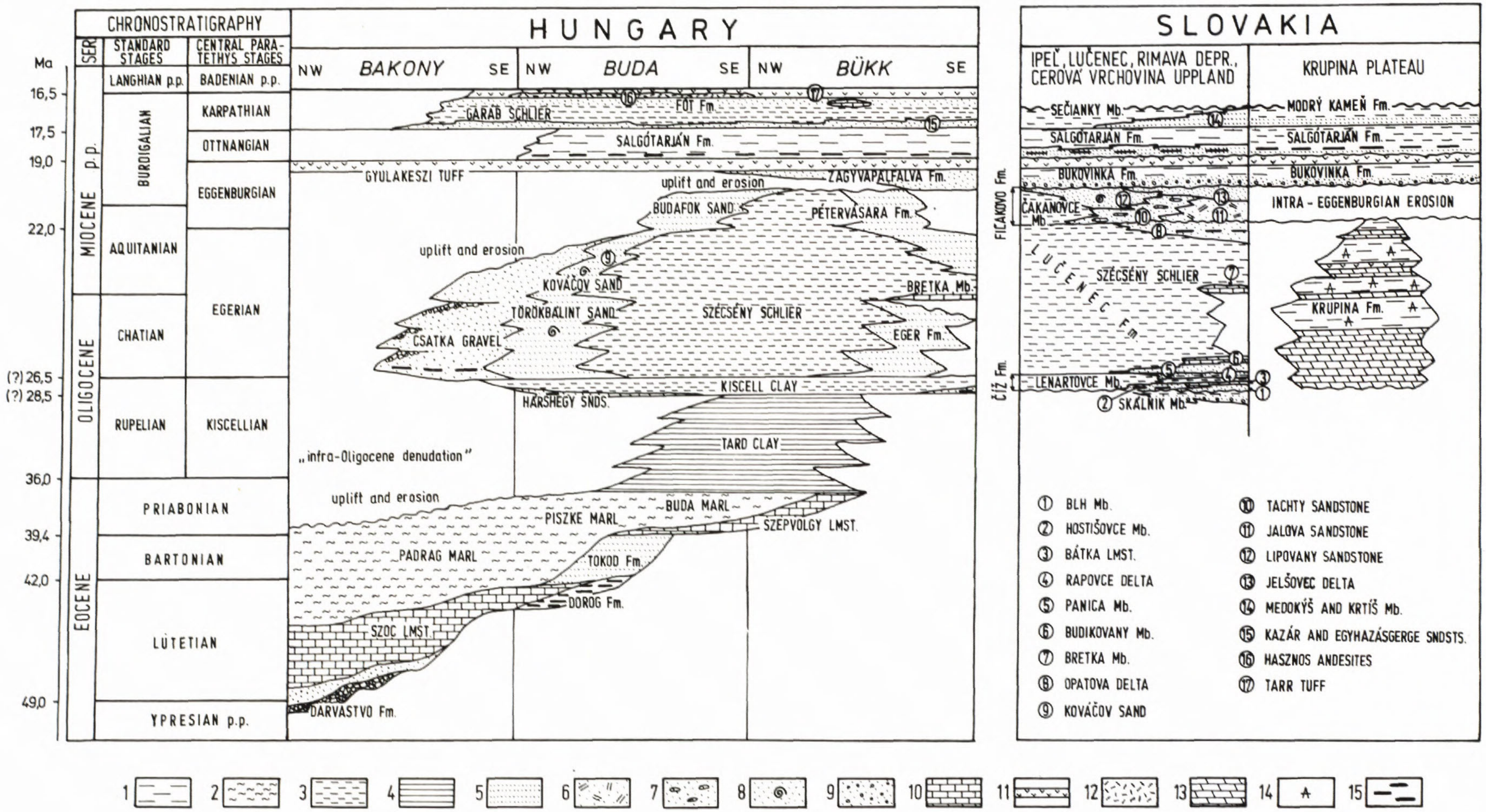

Fig. 4 Simplified litho- and chronostratigraphy of the Hungarian Paleogene Basins, Fiľakovo/Pétervásara and Novohrad/Nógrád Basins. 1 - clay, 2 - marlstone, 3 - calcareous siltstone/claystone (schlier), 4 - euxinic clay/claystone, 5 - sand/sandstone, 6 - cross bedded sandstone, 7 - sandstone with hard banks/concretions, 8 - sandstone rich in mollusc fauna, 9 - gravel/conglomerate and sand, 10 - limestone, 11 - rhyodacite/rhyolite tuff, 12 - andesite volcanoclastics, 13 - evaporitic dolomite, 14 - evaporitic sulfates, 15 - coal seam

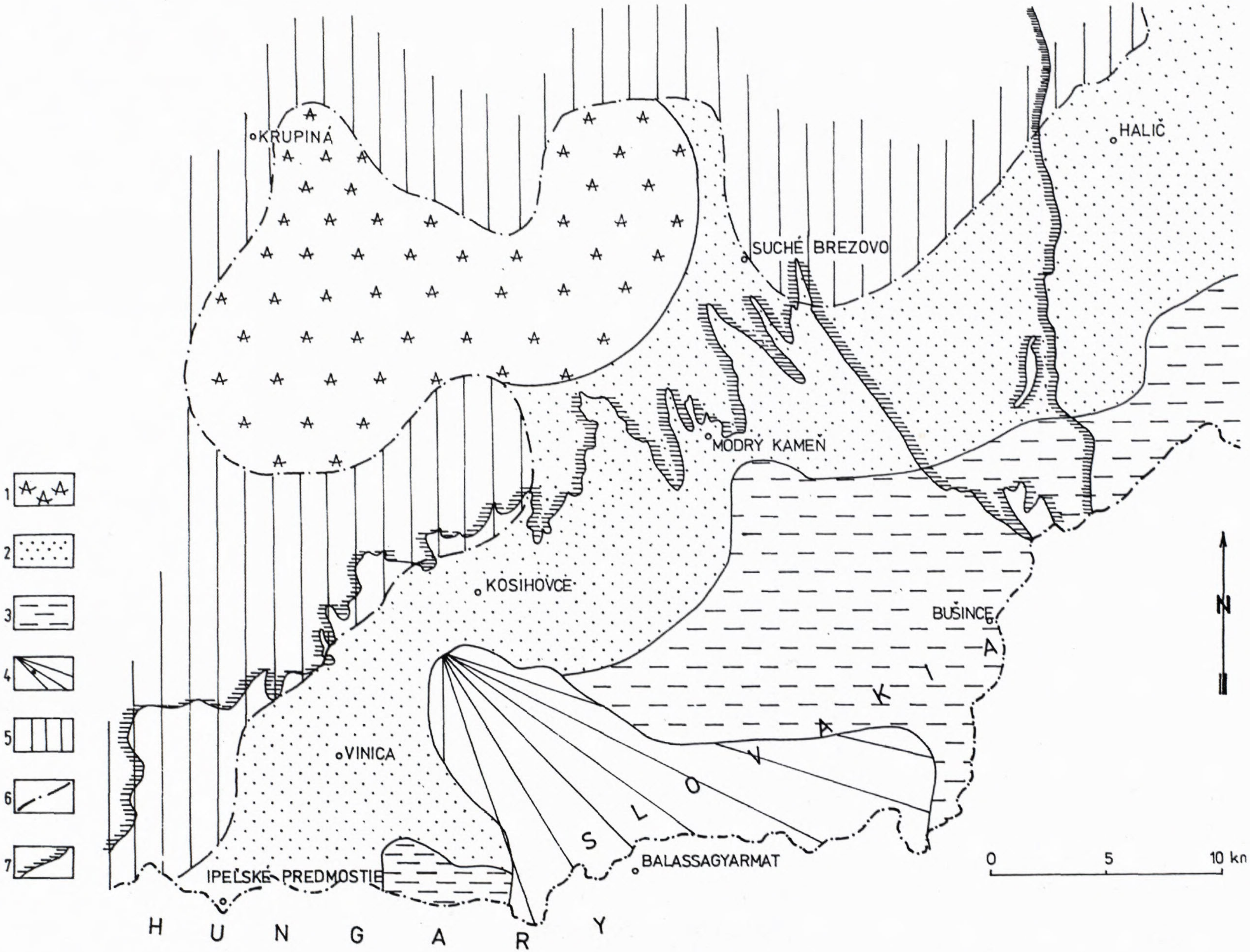

Fig. 5 Section from paleogeographical map of the Egerian in the Ipeľská kotlina depression showing the position of the Krupina Fm with evaporites, buried by Lower Miocene deposits and by neovolcanics of Krupinská planina Plateau (according to VASS et al., 1979).

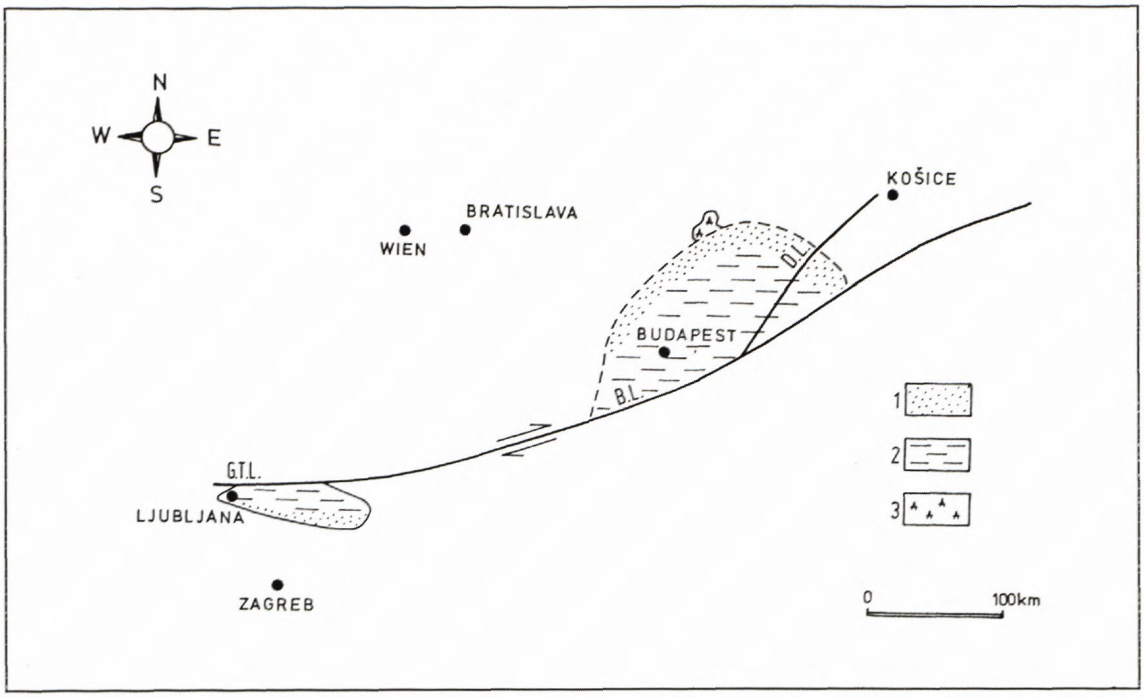

Fig. 6 Lateral displacement of the Slovenian and Hungarian Paleogene Basins after the Egerian (according to CSONTOS *et al., 1992).*

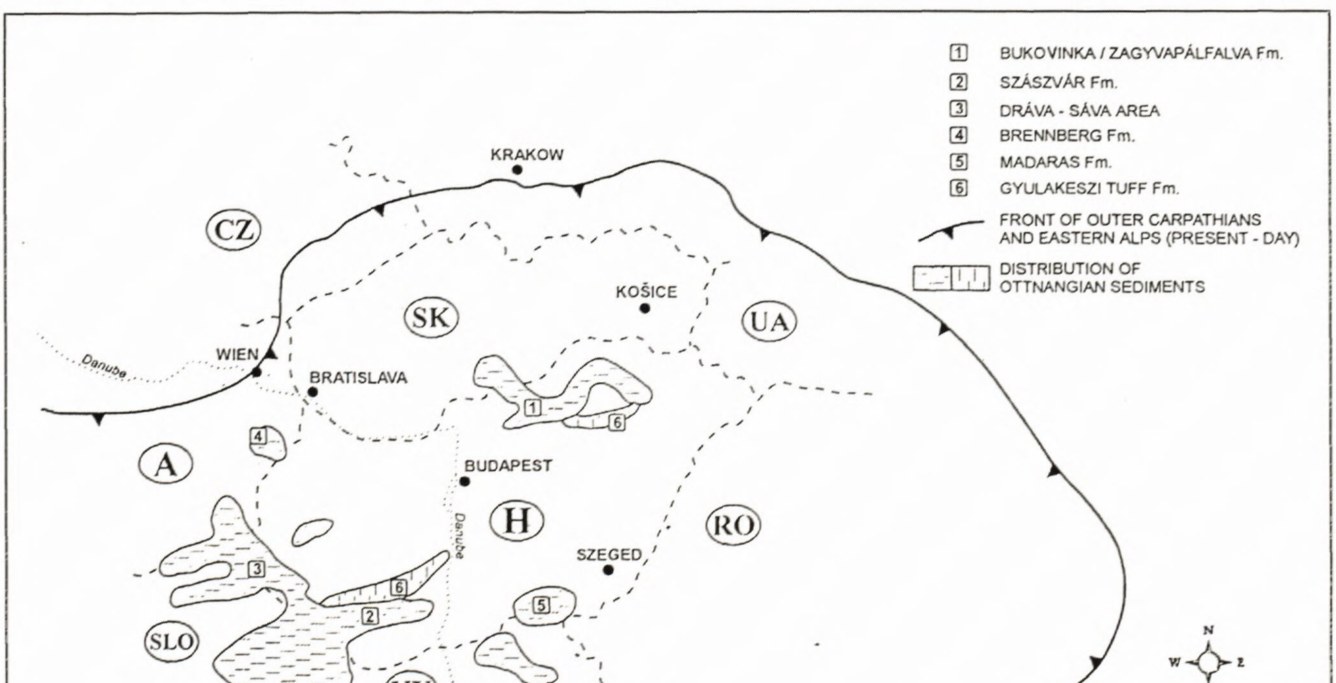

Fig. 7 Continental formations late Eggenburgian early Ottnangian in age, distributed in the "Pannonian" area. Areas in-between are assumed to have been exposed to erosion. The picture clearly documents the regional uplift in the whole area of present-day Pannonian Basin (according to HÁMOR *et al., 1988, modified and completed by the author).*

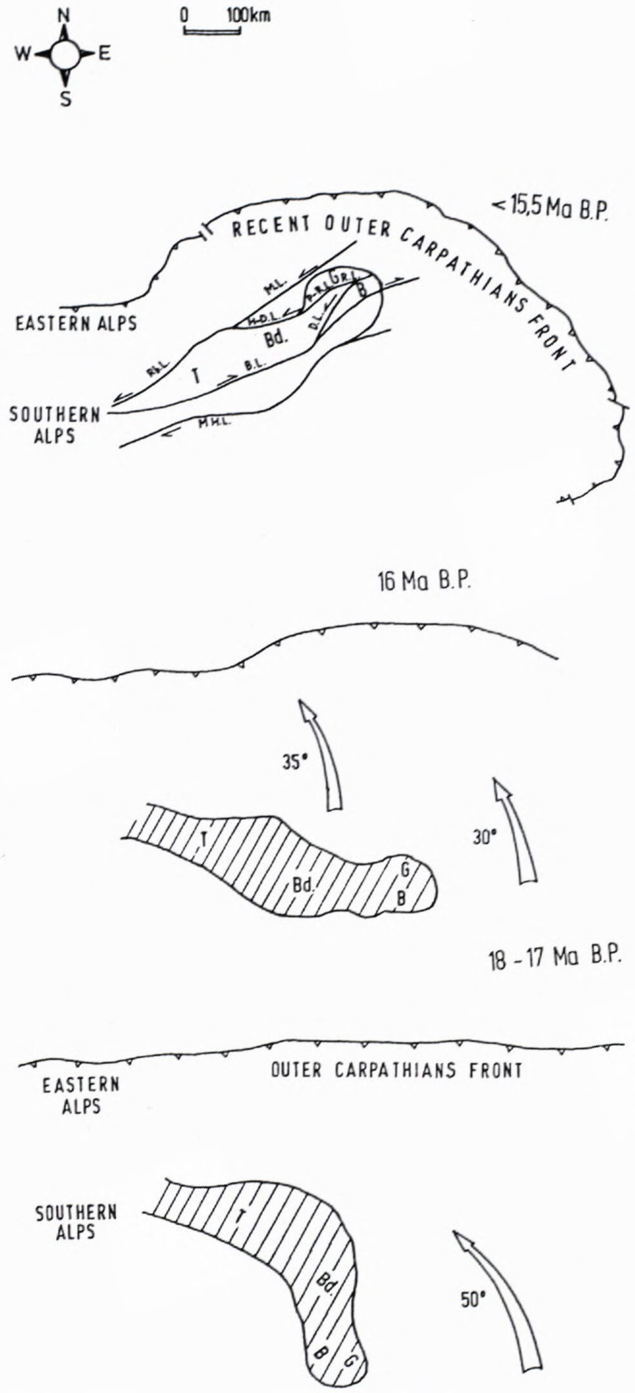

Fig.8 Model of the Lower Miocene counter-clockwise rotation in the area of Southern Slovakia and North Hungarian Central Range.

strike-slip. It is obvious that the area with counterclockwise rotation in the time, when rotation took place, was in a stress field with compression causing left-lateral strike slip movements on the principal faults and fault belts trending in NE-SW direction of present co-ordinates (Fig. 8).Thus, at the end of the Ottnangian the compression rotated from vertical to horizontal position with NNE–SWS direction.

With the beginning of the Karpathian, conditions of sedimentation changed progressively through lagoonal (Medokýš Mb) and littoral (Krtíš Mb) into pure marine, basinal (Sečianky Mb). The marine deposits in Southern Slovakia compose the Modrý Kameň Formation (VASS et al.,1983). In the North Hungarian Central Range the lagoonal Kazár Sandstone and the marine transgressive Egyházgerge Sandstone graded into basinal Garab Schlier, followed by Fót Formation topped by Hasznos Andesites and by products of a new acidic volcanic activity (TarrTuff) appearing on the Karpathian/Badenian boundary (HÁMOR, 1985). The Fót Formation is generally a regressive one. In Etes Trough (Nógrád-Cserhát area, N Hungary) the Fót Formation seems to be a delta: sandy deposits with brackish, oligo-miohaline and freshwater fauna and with fossil soil horizons (HÁMOR, 1985).

By the end of the Karpathian the area studied rose and the Novohrad/Nógrád Basin disappeared. The erosion removed a significant portion of Lower Miocene deposits. After this upheaval event, during the Early Badenian, the subsidence was rejuvenated but only for a very short time. Subsidence occurred in a paleostress field with compression in NNW–SSE direction and sedimentation controlled the NNW–NW trending faults (present day co-ordinates, Vass et al.,1993). Subsidence was followed by a volcanic paroxysm, when magma came from deeper-seated chambers giving rise to calc-alkaline andesites at least partly related to the subducting European plate and/or Pannonian astenolith (Vass et al.,1988), and the sea receded from the area. At that time the second additional counterclockwise rotation as large as 30° took place (MÁRTON and MÁRTON in lit., MÁRTON and FODOR, 1995).

The counterclockwise rotation was accomplished after the Early Badenian. Badenian intrusive bodies of the Šiator – Karancs andesite with garnet (radiometric age is of 15,1 Ma, BALOGH, 1984 e.g. Middle Badenian after VASS et al.,1987) intruded after the rotation, because their remanent magnetisation has Badenian orientation, which is close to recent one. Similar remanent magnetisation have also the host rocks - sandstones of the Fiľakovo Formation, Eggenbrugian in age, which underwent contact metamorphism with temperature of around

550–570 °C (HOJSTRIČOVÁ et al., 1995.). The Curie point was exceeded and the sandstones lost their original remanent magnetisation, which would have been affected by counterclockwise rotation, as proved by paleomagnetic investigation in Southern Slovakia (ORLICKÝ et al., in lit.). Paleomagnetic measurements realised by MÁRTON and MÁRTON (in lit.) on rocks younger as early Badenian in in the area studied have shown no rotation.

Conclusions

The HPBs originated on the Western Carpathian – Northern Pannonian terranes, when the terranes, as the consequence of tectonic extrusion, escaped from the Alpine and Dinaric domain. The tectonic extrusion had been provoked by the convergence of Afro-Arabia and Eurasia, namely by the collision of the Apulian promontory with the Bohemian Massif and by the roll-back effect of the subduction in the Outer Carpathians.

The escaping terranes were confined in south by a right-lateral shear zone – the Balaton and Mid-Hungarian lines and in north by the left-lateral Peripieniny fault belt. Blocks between both limiting shear zones were disturbed by faults of wrench nature causing opening of the HPBs, as well as the Central-Carpathian Paleogene basin.

The marine transgression entered into the newly opened HPBs from the SW. The transgression as well as the basin opening prograded to the NE (in present day co-ordinates) through the Bakony unit, reaching in the end the Bükk, Vepor, Gemer. Silicicum, Turnaicum and Meliaticum units.

After the Egerian a large lateral displacement of the tectonic escape took place and HPBs were closed. After that, two short-term basins were created in the area studied: Fiľakovo/Pétervására Basin of the early Eggenburgian and Novohrad/Nógrád Basin lasting from the late Ottnangian to the end of the Karpathian. In-between, the whole Pannonian area was uplifted as a result of astenosphere rise and lithosphere stretching. The sea completely receded from the area and rhyodacite-rhyolite areal volcanism was active in this time.

Later, during the Ottnangian, the Novohrad/Nógrád Basin opening was caused by rejuvenation of strike-slip movements accompanied by the first pulse of a counterclockwise rotation (50°). At the end of the Karpathian, due to strong compression, the area was uplifted again. and erosion removed a significant portion of the Lower Miocene deposits.

The last sea invasion into area of South Slovakia occurred at the beginning of the Badenian as result of areal subsidence supported by fault tectonics. Then the second pulse of counterclockwise rotation took place (30°). Shortly after strong calc-alkaline volcanism and a new upheaval, the sea was forced out, and never more entered the area of Southern Slovakia as well as a significant part of the North Hungarian Central Range.

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Cleavages and Folds in Changing Tectonic Regimes: The Veľký Bok Mesozoic Cover Unit of the Veporicum (Nízke Tatry Mts., Central Western Carpathians)

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(6 figs., 2 pls.)

Abstract: The Mesozoic Veľký Bok cover unit on northern slopes of the eastern part of the Nízke Tatry Mts. forms the rear, paraautochthonous part of the Krížna nappe system. It is built of several recumbent fold subunits partly differing in their lithostratigraphical signatures. Fold subunits were generated by northward thrusting of the Veporic basement in the rear of the Krížna accretionary wedge, which was later destroyed by gravitational collapse and northward gliding. The Veľký Bok unit suffered additional collisional shortening and backthrusting before being overridden by the higher Choč cover nappe during the Late Cretaceous. The structural associations of several successive deformation stages are described and some aspects of tectonic evolution of the area are discussed.

Key words: Krížna Nappe, Veľký Bok unit, Mesozoic lithostratigraphy, Cretaceous thrusting, tectonic regimes, structural analysis

Introduction

Sedimentary rock sequences with alternating strata of different compositions and competencies, deformed under very low to low grade metamorphic conditions, usually provide a reliable structural record of changing tectonic regimes in a certain orogenic domain. In the Alpine-Tethyan regions, the complicated Mesozoic paleotectonic evolution generated sedimentary successions with variable, although mostly carbonatic lithologies. In the inner zones of orogenic belts, marked by stacking of basement/cover nappes, metamorphism and often penetrative ductile deformation, the primary lithological differences are reflected in rheological layering of sedimentary rock units and occasional recording of changing deformation processes acting within a certain time span. Beautiful examples of lithological and rheological control over the structural recording of deformation processes have been given e.g. by RAMSAY (1967, 1982), BORRADAILE et al. (1982), TALBOT and SOKOUTIS (1992), or PFIFFNER (1993) in large-scale nappe tectonics.

The common tectonic evolution of internal orogenic zones, as can be inferred from structural associations in sedimentary cover units, includes:

(a) shortening through nappe piling and crustal thickening, very low to medium grade metamorphism (depending on the burial depth) and ductile straining usually along flat-lying overthrust shear zones. The index mesoscopic structures are: penetrative bedding-parallel metamorphic foliation, stretching lineation normal to the orogenic front and several generations of intrafolial or recumbent, tight to isoclinal folds;

(b) ductile unroofing of uplifting metamorphic core complexes, extension and transtension, recorded by orogen-parallel stretching lineation within low-angle normal shear zones, possible gravitational gliding of cover units;

(c) out-of-sequence thrusting along steep reverse faults under decreasing ductility, backthrusting and transpression, with mesoscale structures such as high-angle secondary cleavages (usually crenulation), related to late open to tight orogen-parallel trending folds;

(d) "cross folding" along zones with high angles to the orogenic fronts, reflecting oroclinal bending and transpression of internal zones, possibly connected with lateral escape of crustal blocks. Mesoscale structures are typically brittle:kink bands, parallel flexural-slip folds, several sets of joints and slickensides.

Depending on the degree of shortening and crustal thickening achieved during (a) and crustal and lithospheric thermomechanical parameters, the tectonic development proceeds from (a) to (b) and to (d), or from (a) to (c) and (d).There have been described numerous case histories, based on detailed structural and metamorphic studies, for in-

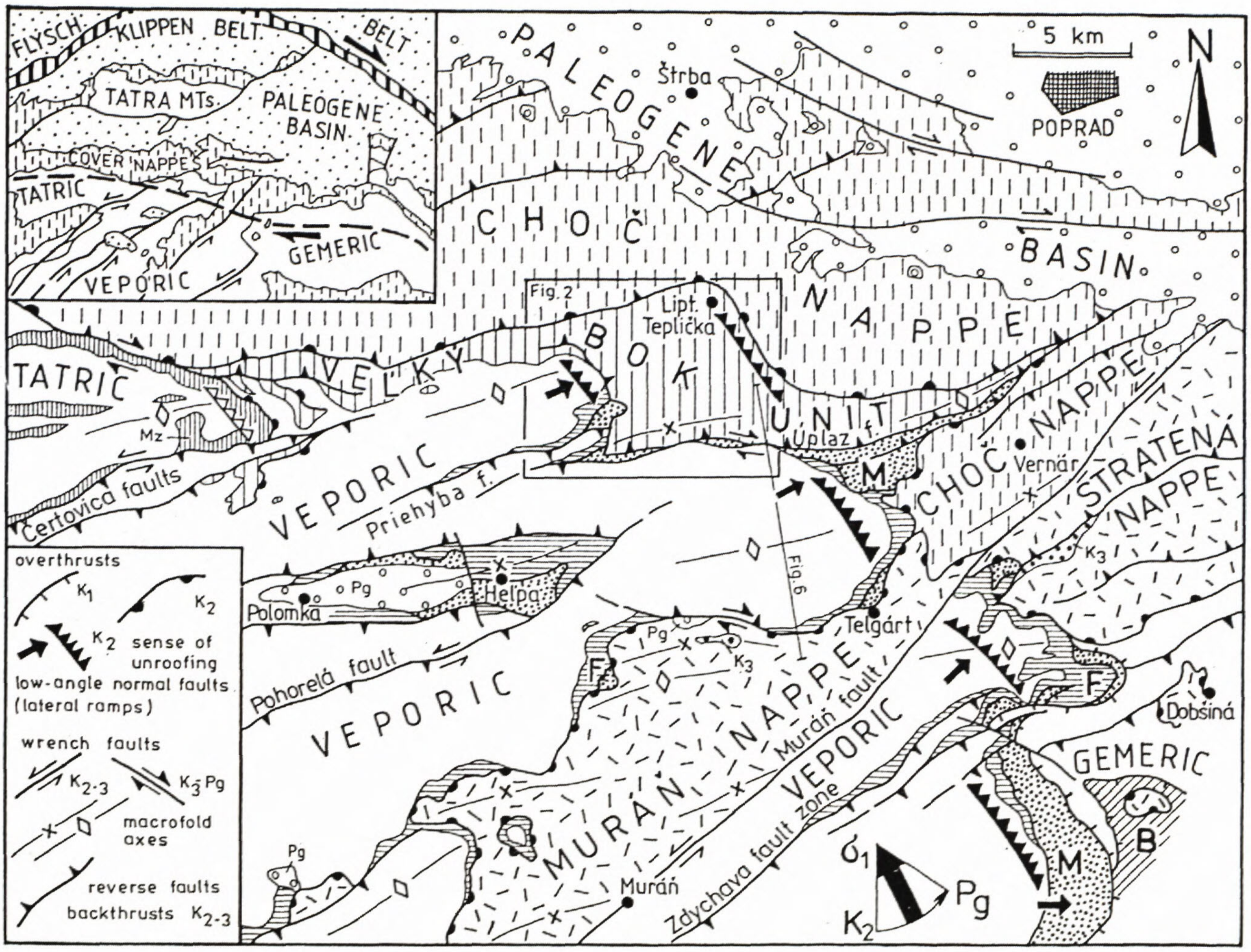


Fig. 1 Tectonic sketch and kinematic framework of principal large-scale structures of eastern part of the central Slovakian Veporic domain. Inset - spatial separation of areas with prevailing sinistral and dextral wrenching in northern Slovakia during the Late Cretaceous and Early Tertiary. The rectangle frames the area examined in this paper (Fig. 2). Abbreviations: F - South Veporic Foederata cover unit (Permian - Triassic), M - South Veporic Markuška Nappe (Devonian - Triassic), B - Meliatic Bôrka Nappe (Permian - Triassic).

stance in the Alps (AYRTON and RAMSAY, 1974; WILSON, 1978; PASSCHIER et al., 1981; SIMPSON, 1982; PLATT and LISTER, 1985; RATSCHBACHER, 1986; PLATT et al., 1989; RATSCHBACHER et al.,1990; SCHULTZ, 1990; HOKE,1990; FRITZ et al.,1991; FROTZHEIM,1992; NEUBAUER ET AL.,1992; HANDY, 1993 etc.), in the Betic Cordilleras (PLATT, 1982; BAKKER et al., 1989; TUBÍA et al.,1992), in the Himalayas (LE FORT, 1975; BURG et al., 1983, 1984), or in the Circumpacific orogens of America (NELSON et al., 1980; NIELSEN, 1982; MATTAUER et al., 1983; MALAVIEILLE, 1987; GOTTSCHALK, 1990). Similar tectonic scenario is common also for the pre-Mesozoic orogenic belts, e.g. for the Caledonides of Northern America and Europe (TEARPOCK and BISCHKE, 1980; KARLSTROM et al., 1982; GOLDSTEIN, 1982; KRUHL,1984; TULL, 1984; GATES, 1987; STELTENPOHL and BARTLEY, 1988), or Variscan belt of Europe (CYMERMAN and STELTENPOHL, 1992; SCHULMANN et al., 1994).

Sometimes (b) and (c) are acting in a close relation or even simultaneously, when uplift and unroofing occur in an overall contractional tectonic setting (e.g. the mid-Cretaceous uplift of the Veporic dome in the Central Western Carpathians - PLAŠIENKA and PUTIŠ, 1993; PLAŠIENKA, 1993; for the general model see WALLIS et al., 1993, and references therein).

The aim and scope of the present paper is to describe the structural record in the Veľký Bok cover unit of the northern Veporic zone, illustrated by a case study in the Liptovská Teplička district, to present its kinematic interpretation and to discuss some aspects of large-scale tectonic structure of the eastern part of the Nízke Tatry Mts.

Regional geology

The Veľký Bok unit is the Permomesozoic sedimentary cover of the pre-Alpine, generally Variscan, crystalline basement of the northern part of the Veporic superunit of the Central Western Carpathians. Veporicum is a thick-skinned upper-crustal thrust sheet overriding the Tatric superunit and partly overthrust by the Gemeric sheet from the SE. Veporicum is subdivided into several partial basement imbrications, defined from surface geology already by ZOUBEK (1931, 1935) and from the Carpathian deep seismic transect 2T (TOMEK et al., 1989, TOMEK, 1993). Generally, Veporicum has been usually correlated with the (Middle) Austroalpine system of the Eastern Alps (cf. HÄUSLER et al., 1993 and references therein), derived from the northern passive Apulian margin (TOMEK, 1993).

The Veľký Bok unit, exposed on the northern slopes of the Nízke Tatry Mts. (Fig. 1), consists of Permoscythian arcosic and quartzose sandstones and variegated shales, Middle Triassic carbonate platform sediments, presumably dolomites, Upper Triassic marine siliciclastic flyschoid Lunz beds and terrestrial-lagoonal Carpathian Keuper formation of variegated shales, sandstones and evaporites. Permotriassic sediments create the pre-rift sequence, the Lower Jurassic syn-rift strata contain some carbonate breccias, sandy crinoidal limestones and calciturbiditic beds. The Middle Jurassic to Lower Cretaceous post-rift sequence is composed mostly of marly, siliceous, or nodular pelagic limestones. The Veľký Bok unit encompasses several more or less independent tectonic subunits (large-scale recumbent folds, partial nappes), in which the lithostratigraphic content slightly varies and indicates their paleogeographic position on a northward facing basinal slope. This slope has been interpreted as a southern passive margin of the broad Krížna (Zliechov) deep-water trough developed by Jurassic rifting and lithospheric extension between the Tatric and Veporic paleogeographic domains (PLAŠIENKA, 1983). The Zliechov basin was diminished by the mid-Cretaceous shortening and its attenuated continental crust was underthrust below the Veporic crustal wedge. The sedimentary filling of the basin was detached from its subducted substratun along a horizon of Upper Scythian (Werfenian) shales, piled up in an over-thickened accretionary complex, and gravitationally spread out towards the north during the Turonian, to form the extensive décollement Fatric (Krížna) nappe system overlying the Tatric Mesozoic cover. The origin of the Krížna nappe has been discussed e.g. by BIELY and FUSÁN (1967), ANDRUSOV (1968), JAROŠ (1971), BIELY (1978), MAHEĽ (1983), PLAŠIENKA (1983, 1991, 1995) and JACKO and SASVÁRI (1990).

Along the rear of the Krížna nappe, the Veľký Bok unit remained more or less confined to the Veporic basement, i.e. in intermediate position between the allochthonous nappe and paraautochthonous Veporic cover. In the studied area, however, it is completely detached from the Veporic substratum and its position is influenced by post-nappe oblique backthrusting.

The Veľký Bok unit, similarly as the whole Krížna Nappe, is overlain by another décollement cover nappe group - the Hronic (Choč) system. This was detached from the presently unknown basement and glided gravititionally with some delay after the emplacement of the Fatric nappes. Their overthrust base is marked by sometimes noteworthy thick rauhwackized carbonate tectonic breccias (see Fig. 3, 4, Pl. II-5), pointing to a hydrotectonically controlled thrusting mechanism.

The structure of the Veľký Bok unit in the area under consideration was studied especially by KETTNER (1937a, b) and ZELMAN (1963, 1967a, b).

Lithostratigraphy

Based on the structural position and lithostratigraphic content, the Veľký Bok unit is divided into three subunits in the area studied:

(1) The Košariská subunit contains only a Jurassic-Lower Cretaceous sequence detached from its Triassic substratum along the Keuper shales and evaporites. It is composed mostly of deep-water pelagic calcareous sediments correlable with a typical sequence of the Krížna (Zliechov) development of the Fatricum. However, due to very low to low grade metamorphism, the whole Veľký Bok unit is very poor in stratigraphically valuable fossils.Therefore, the stratigraphic correlation is

based mainly on lithological criteria.The lithostratigraphical succession is as follows:

(a) Liassic biodetritic crinoidal limestones and grey marly shales, maximum 100 m thick;

(b) greenish-grey siliceous and marly limestones (roughly Dogger - Oxfordian), 100-200 m thick;

(c) pale greenish and pinkish nodular limestones (Kimeridgian), up to 100 m thick;

(d) thick-bedded light grey limestones containing rare Calpionellids (Tithonian, Jánov 1978),100-200 m thick;

(e) thin-bedded to schistose grey, sometimes purple-red marly limestones and marlstones (Neocomian), more than 300 m thick.

The Košariská subunit continues westward as a W-E trending strip and forms the main structural unit in the Ipoltica, Veľký Bok and Malužiná area (Fig. 1).

(2) The Panská hoľa subunit is composed of:

(a) thick complex of Middle to Upper Triassic, thick-bedded to massive dolomites;

(b) the upper part of the dolomite complex is intercalated by a discontinuous, maximum 50 m thick layer of the Lunz beds - alternating dark grey shales and sandstones (Carnian);

(c) the Carpathian Keuper formation (Norian) contains red shales, evaporitic dolomites and sporadic quartzose sandstones, up to 300 m thick;

(d) Lower Jurassic thick-bedded pale grey or pinkish cherty crinoidal limestones, intercalated by grey marly limestones and shales. Sometimes marlstones prevail and biodetritic limestones form occassional graded calciturbiditic beds, resembling the Allgäu formation. The thickness may reach 100-200 m.

The Panská hoľa subunit builds up the southern part of the area studied and continues eastwards into the narrow strip NW of Vernár (Fig. 1), where it contains complete Jurassic to Lower Cretaceous sequence.

(3) The Smrečiny subunit occupies an intermediate structural position between the Košariská and Panská hoľa subunits. However, its restored paleogeographical position is in the southernmost, marginal shelf setting, confined to the Veporic basement. It consists of:

(a) Middle to Upper Triassic dolomites;

(b) sparsely preserved remnants of the Carpathian Keuper rocks;

(c) Lower Jurassic extraclastic breccia limestones directly overlying dolomites and filling the fissures and cavities in them. The Lunz beds and Carpathian Keuper formation are usually missing in this subunit;

(d) thick complex of Liassic cherty crinoidal limestones and marlstones (up to 200 m - Fig. 3, 4);

(e) grey-brown, Mn-bearing marly shales and crinoidal limestones (probably Toarcian, about 50 m);

(f) Middle to Upper Jurassic grey-green marly limestones and marlstones, more than 200 m thick.

This subunit is specific for the area and has no equivalents, as far as its lithofacial development is concerned, in other locations of the Veľký Bok unit exposures.

Structural geology

Sedimentary rock complexes of the Veľký Bok unit were deformed mostly under anchizonal metamorphic conditions (PLAŠIENKA et al., 1989) during the mid-Cretaceous orogenic contraction period of the Central Western Carpathians, followed by Late Cretaceous - Tertiary superimposed, mostly brittle deformations. The structural rock record involves several sets of cleavages, folds, lineations, veinlets and fractures, developed during two principal and several additional Alpine deformation stages (AD). The general trend of straining proceeded from ductile, thrusting-related deformation, through ductile-brittle oblique reverse faulting and backthrusting to brittle strike-slip faulting and transpression (Fig. 5).

AD_1 stage

The first recognizable structural paragenesis consists predominantly of bedding-parallel metamorphic foliation S_{01}, stretching lineation L_1 and cm- to dm- large flow folds F_1.

Spaced foliation S_{01} is well developed only in calcitic rocks, especially marlstones, where it is represented by solution cleavage surfaces enriched in insoluble quartz - fine grained white mica - opaques residuum. The penetrative planar ductile fabric of calcite-rich domains is less frequent, achieved by slight dynamic recrystallization and twinning of larger calcite grains, e.g. crinoid ossicles.

The flattening strain responsible for the formation of S_{01} foliation is documented also by flattening of limestone and chert nodules, buckling of calcite veinlets perpendicular or oblique to foliation (Pl. I-4) and boudinage and pinch-and-swell structures indicating foliation-parallel extension (Pl. I-3).

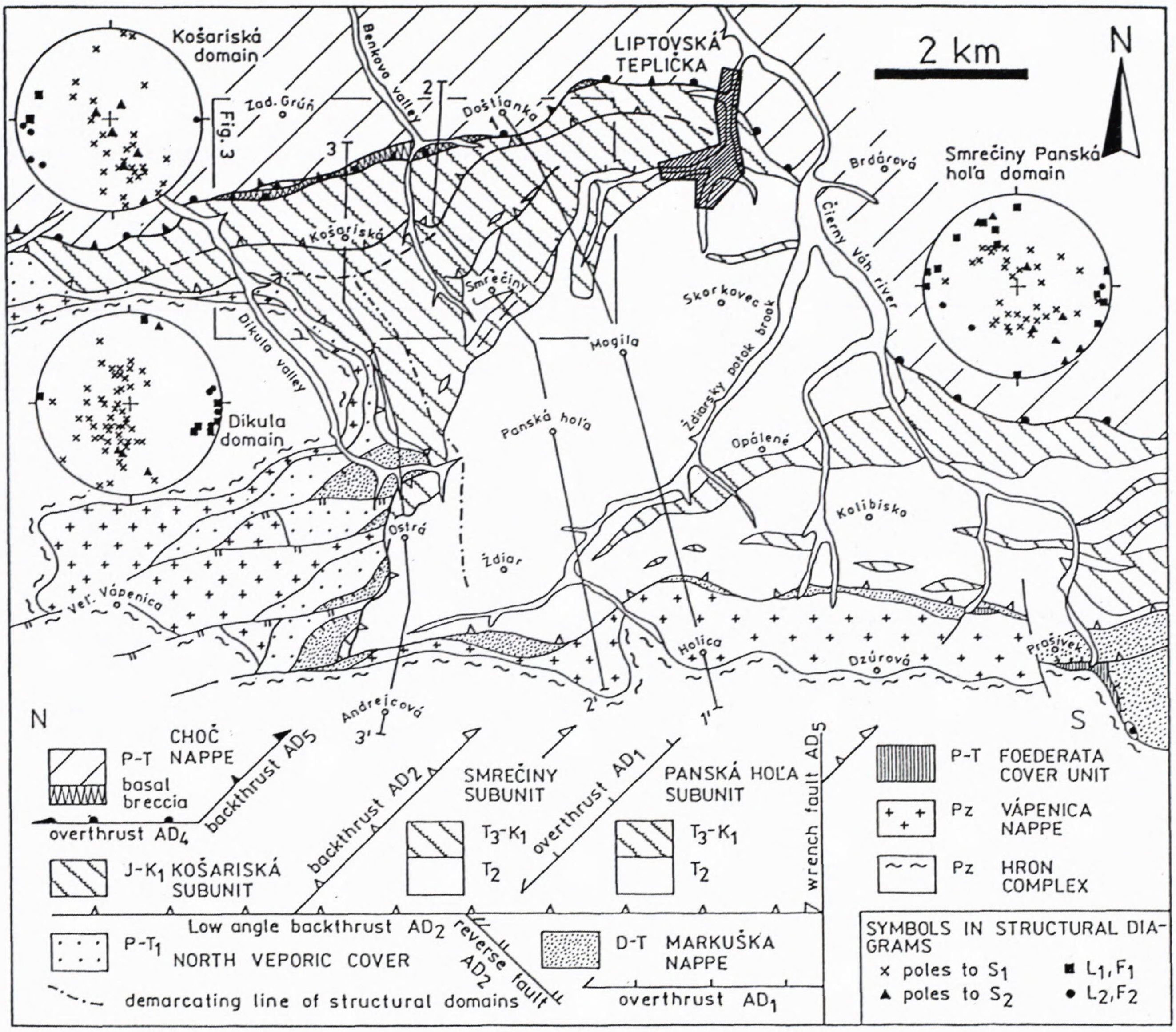


Fig. 2 Principal tectonic and structural domains of the investigated area. Rectangle indicates the area depicted in Fig. 3, lines the profile sections (Fig. 4). Structural diagrams are lower hemisphere, equal-area plots.

Fine-grained white micas from the insoluble material along S_{01} surfaces were dated by the K-Ar method, giving the formation model age of 101 Ma (NEMČOK and KANTOR, 1989).

The S_{01} foliation surfaces sometimes exhibit elongation and segmentation of quartz-mica aggregates or clusters of calcite grains defining the weak stretching lineation L_1. It trends generally NW-SE (Fig. 2). Foliation S_{01} represents the XY plane and lineation L_1 the X axis of the AD_1 strain ellipsoid.

The folds F_1 deforming the S_{01} foliation are very rare, restricted to high-strain ductile shear zones in limy and marly rocks.They are close to the similar type (Pl.I-1, 2), intrafolial flow folds generated by passive amplification of buckling instabilities within an inhomogeneously shear-flowing medium (PLATT, 1983).

Small-scale ductile/brittle, bedding-parallel shear zones indicating generally top-to-the north thrusting occur within the Lower Jurassic marly sequences of the Panská hoľa and Smrečiny subunits (Pl. I-5). North-directed sense of movement within bedding-parallel ductile shear zones was observed also by ZELMAN (1967b), based on deformation features of chert nodules.

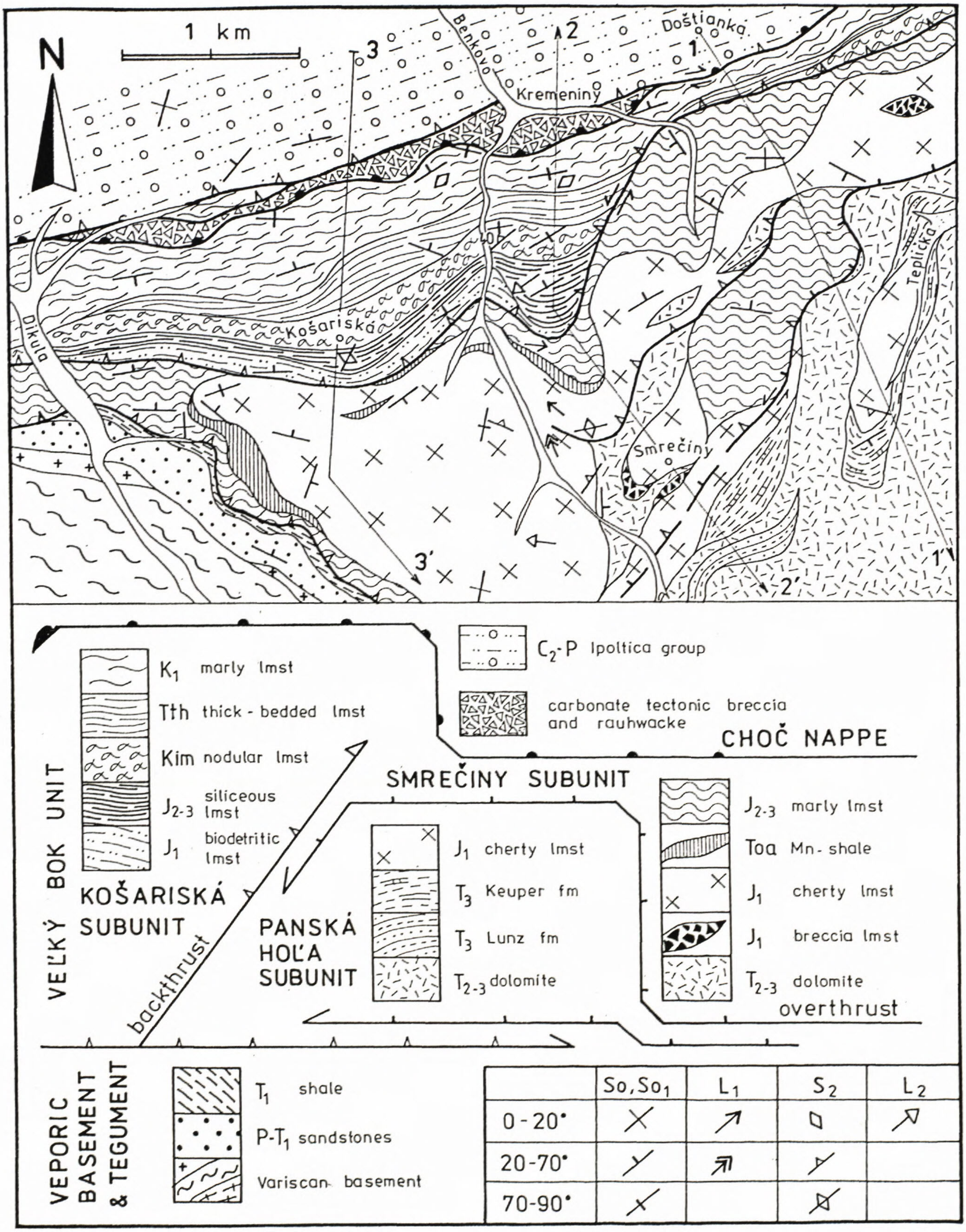


Fig. 3 Geologic-tectonic map of a part of the studied area. Profiles are presented in Fig. 4.

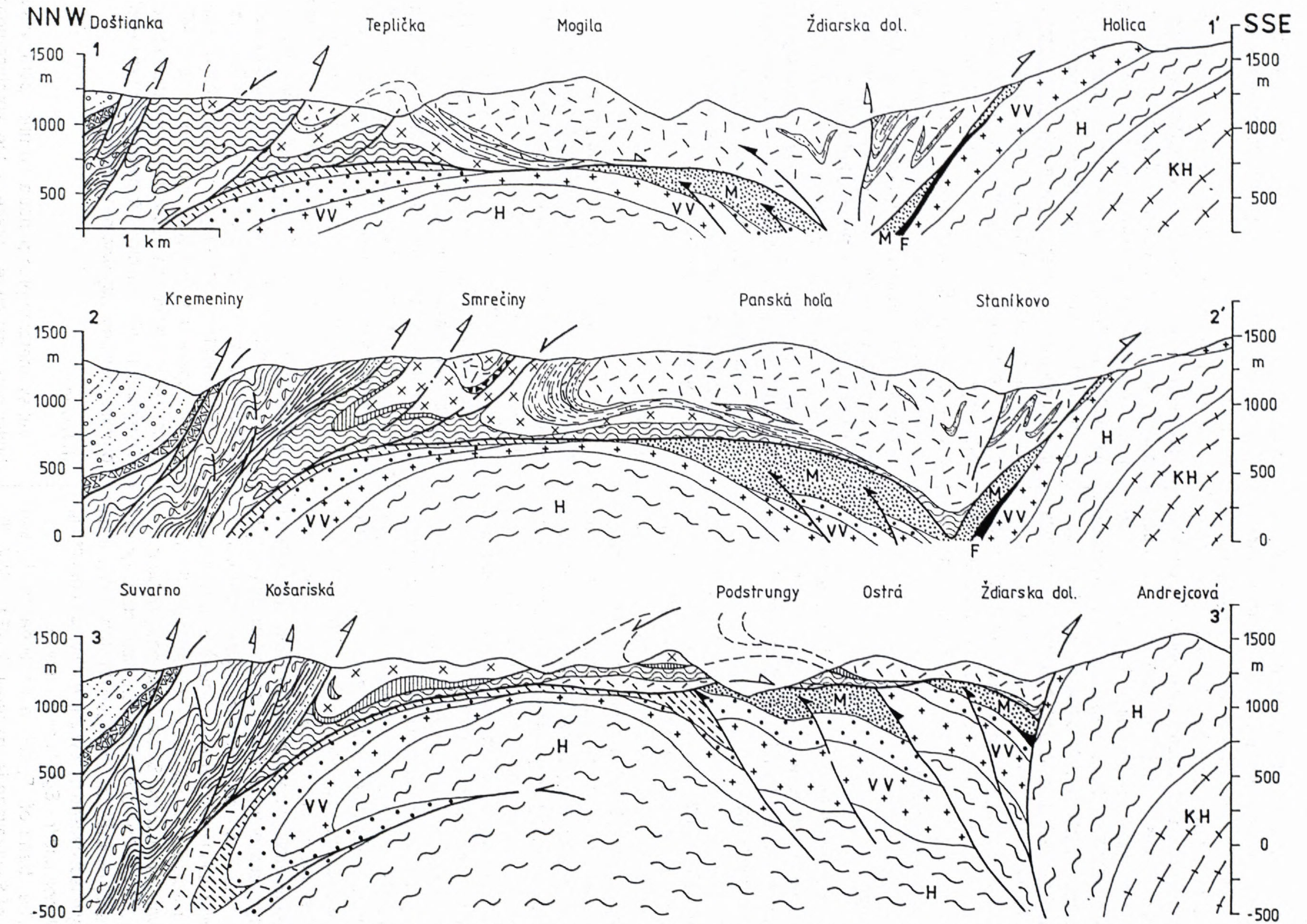


Fig. 4 Tectonic profiles of the area. For the legend see Fig. 3. Additional basement units: M - South Veporic Markuška Nappe (PLAŠIENKA, 1984), VV - Vápenica tonalite nappe (PUTIŠ, 1989), H - metamorphic rocks of the Hron complex (sensu KLINEC, 1966), KH - granitoids of the Kráľova hoľa complex (KLINEC, 1966).

This first structural paragenesis is interpreted to have been initiated by large-scale recumbent folding and overthrusting of partial fold nappes producing tectonic burial sufficient for very low grade metamorphism and ductile straining. Macroscopic recumbent folds to anticlinal synforms have been revealed by geological mapping (Fig. 3, 4; see also KETTNER, 1937a). Both meso- and macroscopic criteria indicate top-to-the N to NW sense of thrusting.

The Panská hoľa and Smrečiny partial subunits were individualized mainly during this stage as recumbent fold nappes. Both have probably overlain the outermost Košariská subunit, however, the present arrangement of the subunits is mainly the result of AD_2 backthrusting.

AD_2 stage

The second deformation stage is characterized particularly by crenulation cleavage S_2 parallel to axial planes of the F_2 folds which deform the AD_1 structural elements.

Solution cleavage S_2 is formed at high angles to primary bedding and bedding-parallel foliation S_{01}, best developed in calcite-rich rocks. Many types ranging from discrete to zonal crenulation cleavage (GRAY,1979) are present. The cleavage spacing and morphology reflect the rock medium. Mesopenetrative planparallel S_2 cleavage has been observed in marly schistose Jurassic and Lower Cretaceous limestones, discontinuous anastomosing surfaces occur in nodular and thick-bedded Upper Jurassic limestones (Pl. I-6).

Intersection of bedding S_0 and foliation S_{01} with cleavage S_2 produces lineation L_2 which is generally axial-parallel to the folds F_2.These are open to tight, upright to overturned, usually asymmetric buckle folds with southern vergency. Formation of crenulation cleavage S_2 slightly postdates the development of initial flexural curvature of the F_2 folds, because of cleavage parallelism in fold cores and limbs (Pl. II-3). Hence the final fold tightness was achieved by flattening along penetrative axial-plane S_2 cleavage. F_2 Folds resemble the so-called "shear folds" (Pl. II-4), however, shear along S_2 cleavage has not been observed. In the limb domains, crenulation cleavage has apparently extensional character (Pl. II-2), which is an illusory effect caused by low angle between preexisting S_{01} foliation and the S_2 flattening surfaces.

The trend of F_2 fold axes, lineation L_2 and strike of S_2 cleavage is generally W-E to SW-NE. Poles to S_{01} and S_2 planes lie on common girdles (Fig. 2) what points to roughly homogeneous AD_2 deformation.

In the macroscopic scale, the most prominent feature of the AD_2 stage is a structural discordance between the cover and basement structures. Asymmetric south-vergent macrofolds are typical for the Veľký Bok cover rocks, while mostly north-directed thrust faults have been observed in the basement and its tegument (Fig. 4 - profile 3). To explain this discordance, a backthrust superposition of the cover during the final phases of the AD_2 stage is assumed. Backthrusting attained some 5 km along the profile in the Dikula valley (Fig. 2, 4).

The Košariská subunit, as the most external and lower one during the AD_1 stage, was exhumed and thrust back in the rear of the backthrust sheet composed mainly of the Panská hoľa and Smrečiny subunits. During backthrusting, the Veľký Bok subunits in the studied area covered the basement units and structures of originally more southern zones and cannot be ultimately regarded as autochthonous or paraautochthonous with respect to the Veporic basement.

AD_3 stage

Structures of this stage can be generally characterized as "cross folding" with NW-SE to N-S trend. They are marked, on the contrary to the AD_1 and AD_2 structures, by typically brittle elements.

The most conspicuous AD_3 structures are the mesoscopic folds F_3 - open, mostly angular (kink) folds or kink bands (Fig. 5). The reason for the origin of these cross folds is not clear. They might have been generated partly by dextral transpression along lateral or oblique frontal ramps during AD_2 backthrusting (e.g. the Dikula ramp, Fig. 1, 2). However, the compressional cross structures have regional extent in the Central Slovakian Veporic block, being at least partly confined to transversal NW-SE fault zones with dextral kinematics (e.g. the Mýto-Tisovec fault zone - MARKO, 1993). This reveals partial spatial and temporal independency of AD_3 structures indicative of a separate deformation stage. Genetical relation of cross folding to processes of oroclinal bending may also be considered.

AD_4 stage

All synmetamorphic penetrative and partly also brittle cross structures precede the emplacement

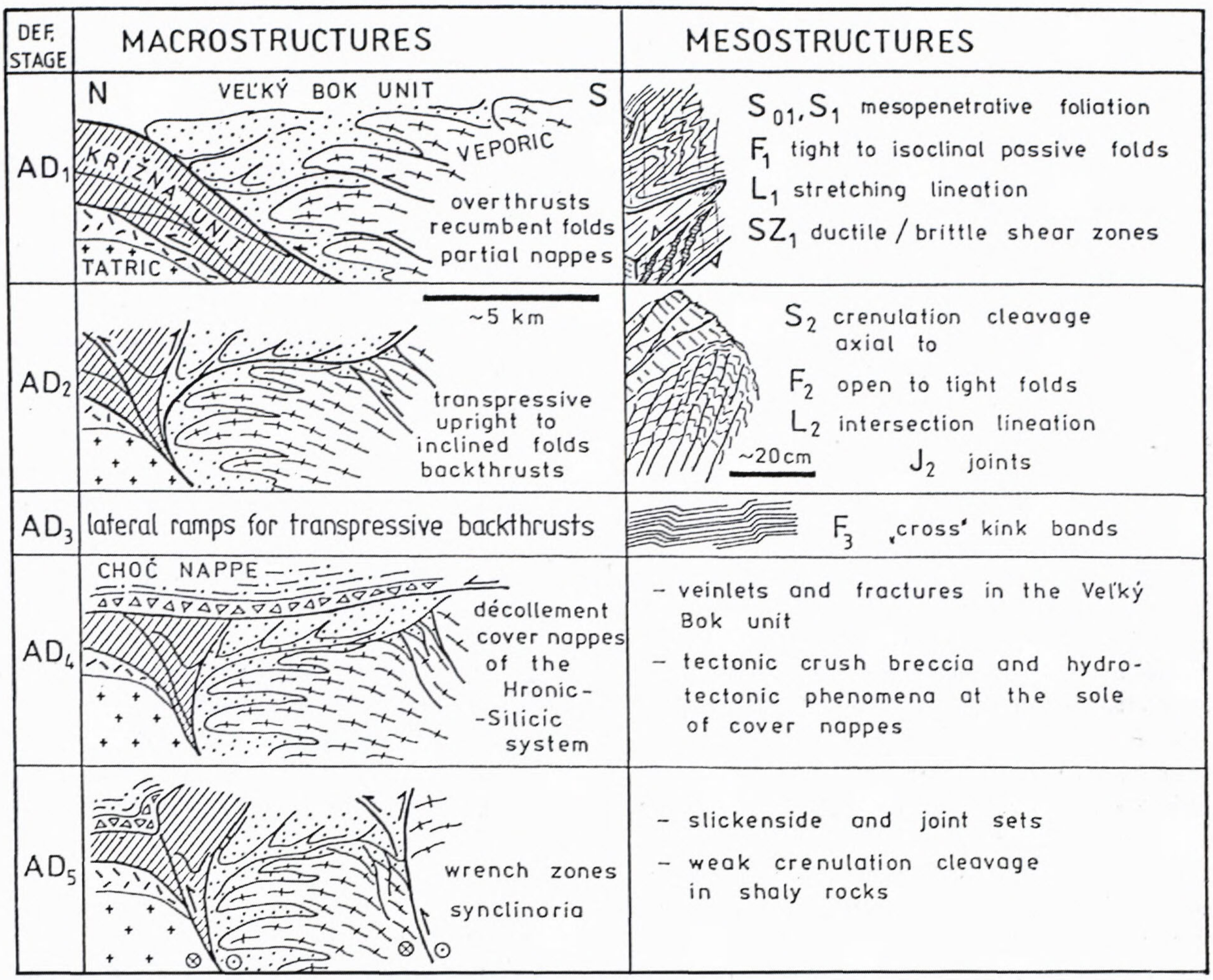


Fig. 5 Synoptic presentation of deformation stages and their main structural elements in the investigated area.

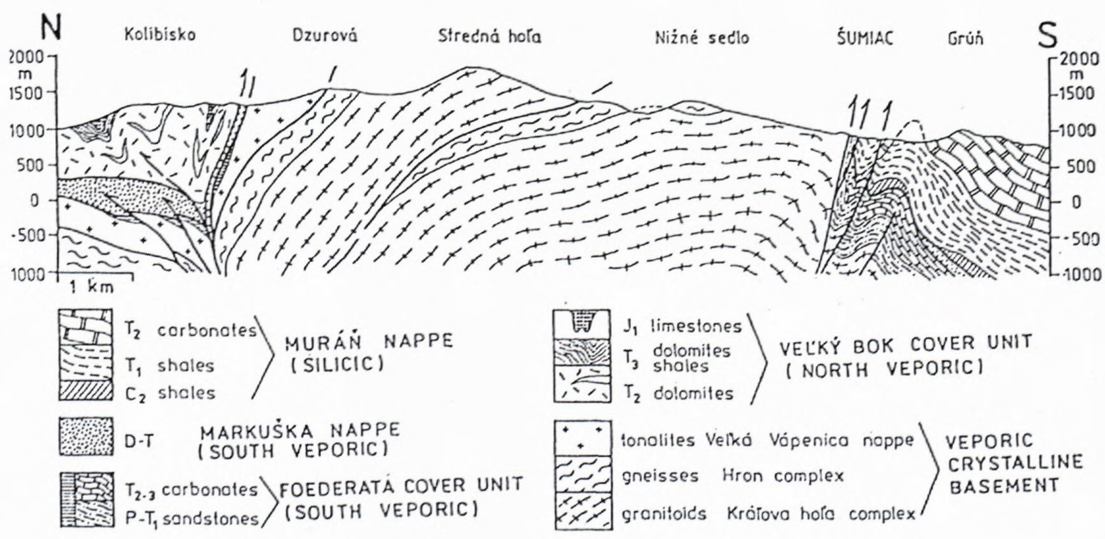


Fig. 6 Cross-section through the eastern part of the Nízke Tatry Mts. showing the transpressive character of boundary faults of the Veporic basement uplift.

event of superficial cover nappes of the Hronic-Silicic system. In the area of interest, thick volcanosedimentary complexes of the Upper Carboniferous - Scythian Ipoltica group belonging to the Hronic Choč nappe overrode the Veľký Bok subunit, mainly its Košariská subunit. The sole of the Choč nappe is formed by up to one hundred metres thick rauhwackized carbonatic tectonic breccia (the Kremeniny tectonic slice of ZELMAN, 1967a). The overthrust had no apparent influence on the structures of its Veľký Bok substratum, except some calcite-filled cracks as manifestations of hydrotectonic phenomena accompanying the thrusting. The breccia is composed of altered fragments of probably mostly Triassic carbonates, dominantly dolomites (Pl. II-5).

AD_5 stage

Post-nappe deformations are more obvious on macroscopic scale than on mesoscopic scale. Generally, AD_5 macrostructures copy the AD_{2-3} ones, having developed in the kinematic framework of roughly N-S shortening with slight dextral transpression along NW-SE to WNW-ESE trending zones and sinistral transpression along SW-NE to WSW-ENE zones (Fig. 1). Some of these zones changed their kinematics in response to CCW rotation of the principal compression axis during the Early Tertiary.

Mesoscale AD_5 structures can be only rarely well defined. In the "Vernár strip" of the Choč nappe (Fig. 1), some traces of subvertical, NE-trending crenulation cleavage S_5 have been observed in the Upper Carboniferous shales. In the Veľký Bok unit of the same area, brittle chevron-type folds in marly slates are regarded as F_5 folds (Pl. II-6).

Several sets of joints and slickensides developed in the Veľký Bok unit were studied by NEMČOK and KANTOR (1989). They distinguished three principal phases of compression, the first with σ_1 directed to the SE (probably our AD_2 stage), the second with NE oriented compression (AD_3 in this work) and the third with N-S contraction (AD_5).

In the Veľký Bok unit, F_2 macrofolds were additionally tightened during AD_5 and sometimes rearranged into fan-wise forms in cross-sections due to slight transpression (Fig. 4, 6). In the investigated area, the originally flat basal plane of the Choč nappe was tilted northward into a steep, or even vertical position (Fig. 4). The adjacent AD_{1-2} structures in the Veľký Bok rocks were occasionally also rotated to the north (Pl. I-6). This phenomenon can be tentatively explained by push-up of the crystalline core of the Nízke Tatry Mts. during the Late Cretaceous - Early Tertiary compression and transpression (Fig. 5, 6).

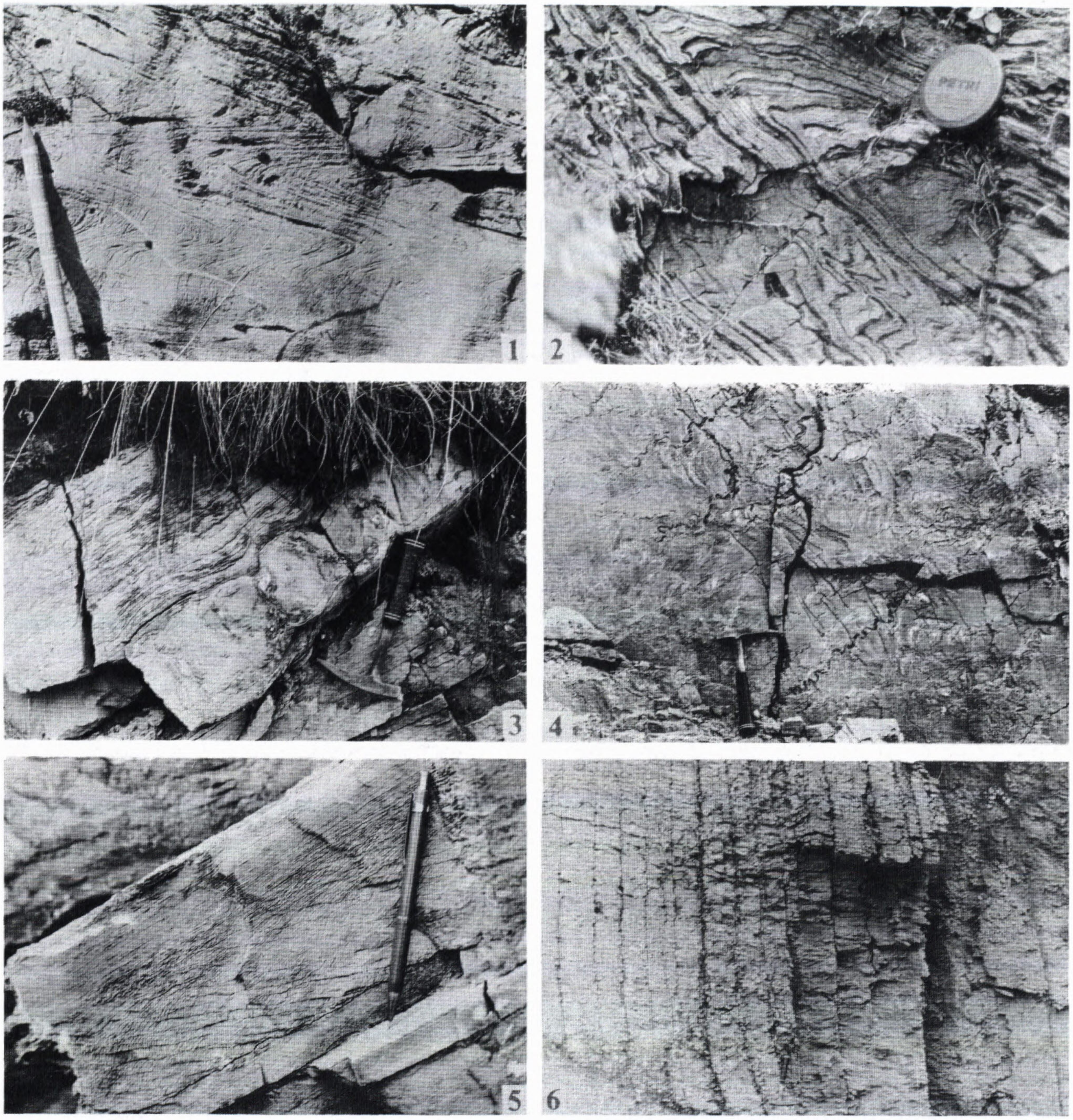
Discussion - Alpine tectonic regimes in the eastern part of the central Slovakian Veporic belt

Structural parageneses of the deformation stages described above record large-scale Alpine tectonic processes in the NE part of the central Slovakian Veporic domain. Tectonic structure and evolution of this part of the Central Western Carpathians is treated in numerous papers, the most outstanding being works of KETTNER (1937a, b, 1958), KUBÍNY (1959), BIELY (1961, 1964, 1978), BIELY and FUSÁN (1967), KLINEC (1966, 1971), BAJANÍK et al. (1979), PLAŠIENKA (1983, 1984, 1993), PUTIŠ (1987, 1989, 1991, 1994), VOZÁROVÁ and VOZÁR (1988), BEZÁK (1991), MARKO (1993), HÓK et al. (1993), MADARÁS et al. (1994) etc. Most of these authors have agreed that the Veľký Bok unit represents the rear part of the Krížna (Fatric) cover nappe system. Paleogeographically, the lithostratigraphical contents of its partial subunits reflect southward shallowing of the broad Krížna (Zliechov) basin developed on a thinned continental crust (JAROŠ, 1971; MAHEĽ, 1980; PLAŠIENKA, 1983). The subunits, usually large-scale recumbent folds, were generated by inversion of extensional north-facing normal faults (PLAŠIENKA, 1991). Some recumbent folds involve also the North Veporic basement, mainly in regions west of the studied area. From this point of view, the structural evolution of the Veľký Bok unit is regarded to reflect the tectonic regimes operative during the origin of the Krížna cover nappe (PLAŠIENKA, 1983), as well as during the subsequent deformation phases of its "root zone", which is an intracontinental suture.

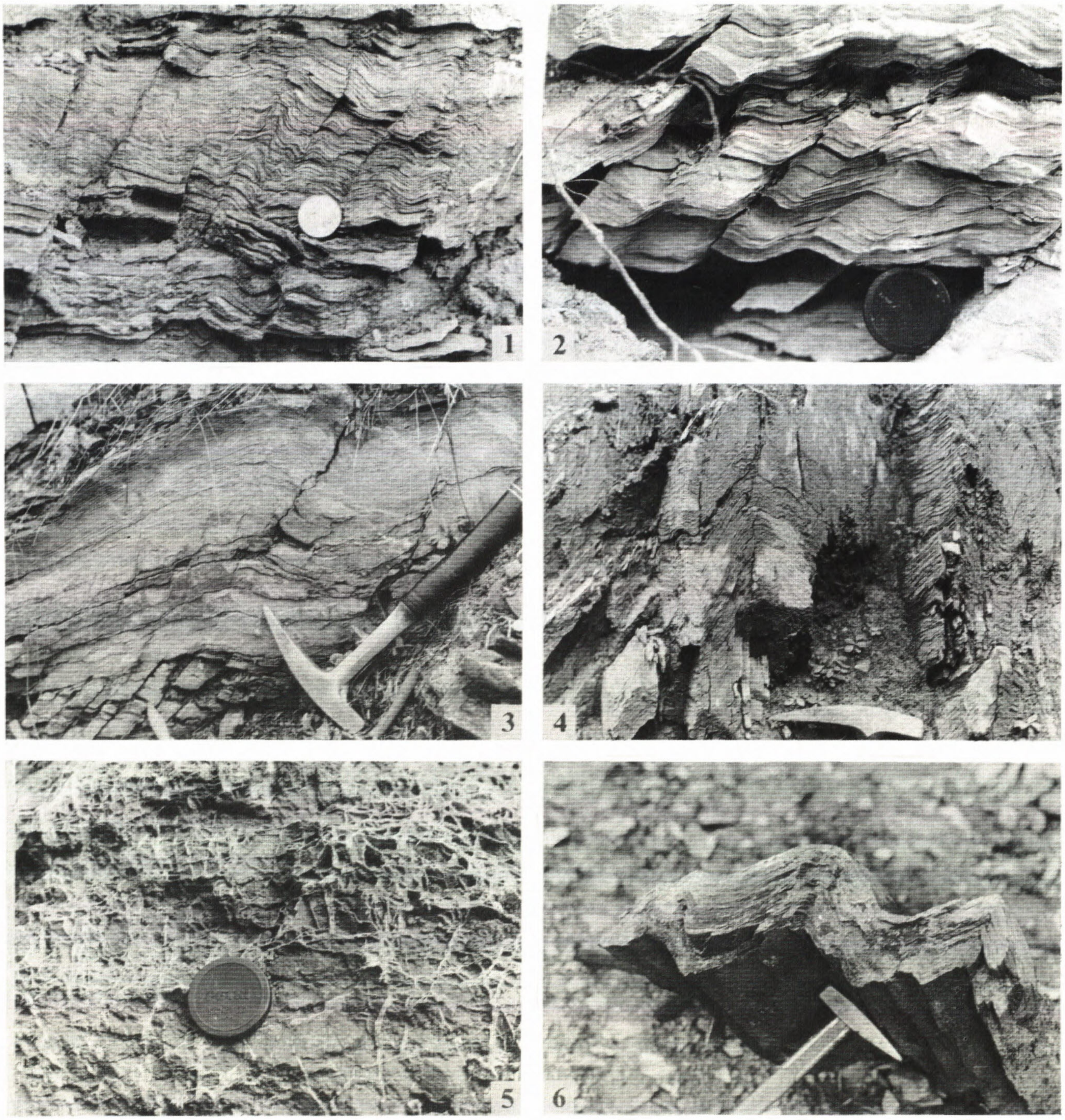
The Alpine history of the tectonic regimes acting in the area under consideration, and their assumed time controls, may be characterized as follows:

(1) The onset of shortening along the southern flanks of the Zliechov basin caused termination of mostly pelagic sedimentation in the Veľký Bok area probably during the Barremian-Aptian.

(2) Inversion of a passive margin into an active one during the intracontinental A-type subduction of



Pl. I. Small-scale structures of the deformation stage AD_1 (1-5). 1 - tight recumbent folds F_1 in the Lower Jurassic limestone of the Panská hoľa subunit, Teplička valley; 2 - subisoclinal fold F_1 in the Middle Jurassic marly limestone, Panská hoľa subunit, Ostrá hill; 3 - pinch-and-swell stretching of a competent allodapic sandy crinoidal limestone bed within the Lower Jurassic marlstones of the Smrečiny subunit, Benkovo valley; 4 - buckled calcite veins in a weakly nodular Upper Jurassic limestone of the Košariská subunit, Benkovo valley; 5 - ductile/brittle shear zone confined to a more competent bed in Lower Jurassic marly limestones of the Smrečiny subunit, Benkovo valley. Parallel lamination in the upper part of the bed is foliation S_{01}, penetrative crenulated surfaces in the centre are antitaxial fibrous calcite veinlets generated by extension normal to S_{01}, inclined spaced surfaces is solution clevage S_1. This geometry indicates top-to-the NW shearing (sinistral in the plane of the photo); 6 - Upper Jurassic nodular limestones of the Košariská subunit, Benkovo Valley. Bedding is vertical, S_2 solution clevage subhorizontal due to AD_5 tilting.



Pl. II. Mesostructures of the AD_2 and later stages. 1 - contractional crenulation cleavage in Lower Jurassic marly limestones, Smrečiny subunit, Benkovo Valley; 2 - apparently extensional crenulation cleavage, Middle Jurassic marly limestone, Smrečiny subunit, Benkovo Valley; 3 - open fold F_2 with contractional axial-plane cleavage S_2 in the core parallel to apparently extensional one in the limbs, Smrečiny subunit, Benkovo Valley; 4 - tight, penetratively parallelly cleaved "shear" folds F_2 in Lower Cretaceous marlstones of the Košariská subunit, Malužiná Valley; 5 - veined dolomite clast from rauhwackized carbonate tectonic breccia at the sole of the Choč nappe, Malužiná Valley (stage AD_4); 6 - symmetric angular folds F_5 in the Middle Jurassic marly limestones of the Panská hoľa subunit, Mlynná Valley near Vernár.

the Krížna basin substratum led to strong compression of marginal halfgrabens and their gradual transformation into large-scale fold thrusts along the trailing edge of the Krížna accretionary wedge. This was generated by décollement of the Zliechov basin sedimentary filling along the horizon of Upper Scythian shales and evaporites. Contemporaneously, in the backstop of the accretionary complex formed by thick-skinned Veporic basement sheet, processes of post-thickening uplift and orogen-parallel extensional unroofing of Alpine metamorphic core complexes occured during mid-Cretaceous times (Hók et al., 1993; Plašienka, 1993; Plašienka and Putiš, 1993; Kováč et al., 1994). Products of erosion of the uplifting domain might have supplied the Albian-Cenomanian flysches as the youngest Krížna basin deposits in front of the accretionary wedge (Plašienka, 1995).

(3) The final forming of the Veľký Bok recumbent folds in the rear of the Krížna accretionary wedge is recorded by mesostructures of the first Alpine deformation stage AD_1. These indicate northward thrusting, vertical flattening and very low to low grade metamorphic imprint of rock complexes buried at some 5-10 km.

(4) Superimposed deformation of the AD_2 stage was probably controlled by collision of the Tatric (northern) and Veporic (southern) margins of the Zliechov basin after its complete diminishing and after thrusting of the Krížna nappe over the Tatric units by northward gravity gliding during the Upper Turonian (Plašienka, 1995). Extreme compression of the intracontinental suture zone led to partial backthrusting in the rear of the destroyed accretionary complex, associated also with sinistral transpression widely recorded along the Veporic SW-NE to WSW-ENE trending basement fault zones (the Čertovica, Pohorelá, Zdychava and Lubeník lines, cf. Putiš, 1991, 1993; Madarás et al., 1994). In higher structural levels and in more NE areas (Fig. 1), dextral transpression along NW-SE to WNW-ESE fault zones prevailed. Overall N-S AD_{2-3} shortening, accompanied by uplift and gravity-driven motion of the Krížna nappe, led to a rapid exhumation of deeper structural levels of the colliding zone built up by the Veľký Bok units and to their backthrusting into the superposition over the Veporic crystalline core complexes, which previously experienced a different structural development terminated by an older, mid-Cretaceous uplift and extension (especially units KH, VV, F and M in Fig. 4 and 6). Top-to-the E to NE extension produced a set of NW-SE trending low-angle normal faults which served as lateral or oblique ramps during AD_2 backthrusting (Fig. 1, 2).

(5) Already during the Upper Turonian or lowermost Senonian, the Veľký Bok unit carrying the structural record of stages AD_1 to AD_3 was exposed on the surface, being immediately overridden by the Choč superficial nappe.

(6) The post-nappe structural evolution is, probably uninterruptedly, characterized by overall N-S shortening in a kinematic framework of conjugate sinistral and dextral wrench zones partly inherited from previous stages (Fig.1). During the latest Cretaceous and earliest Tertiary, the main sinistral wrenching activity was concentrated to the Muráň fault zone (Fig. 1). The discrete fault is accompanied by an en-echelon system of large-scale flower synforms in sedimentary rocks of the Hronic-Silicic cover nappes (Choč, Muráň and Stratená nappes, Fig.1), incorporating also the post-nappe Gosau sediments. The main activity along the Muráň fault ended before deposition of the Paleogene (Eocene-Oligocene) cover sediments. A slight dextral inversion of the Muráň fault due to rotation of σ_1 into nearly W-E position has been interpreted by Marko (1993). In the studied area, the first post-nappe (Senonian) deformations indicate strong N-S compression, followed by slight dextral transpression along the generally W-E trending Priehyba-Úplaz faults bounding the northern edge of the crystalline core of the Kráľova hoľa (easternmost) part of the Nízke Tatry Mts. (Fig. 1, 6). The Priehyba fault zone is a reactivated AD_2 sinistral transpressional system, the Úplaz fault originally formed the southern front of the backthrust Veľký Bok unit (Fig. 1, 2, 4, 5, 6). W-E trending wrench faults restricted also the southern foot of the Nízke Tatry Mts. (Fig. 6) which indicates compressional push-up character of the Nízke Tatry Mts. uplift during the Paleogene (Kráľ, 1977; Kováč et al., 1994). The W-E dextral wrenching was probably induced by anticlockwise rotation of the main compressive stress to roughly NW-SE position during the Late Paleogene (Fig. 1).

(7) The younger tectonic history is poorly constrained because of scarcity of Neogene sediments in the whole area. The distribution of comparatively thick Pliocene and Quaternary fluvial and proluvial deposits in the Horehronské podolie (Upper Hron) valley indicates prolonged uplift of the Nízke Tatry

range controlled by a W-E trending, south dipping normal fault (Pohronie fault) along their southern foot.

Summary and conclusions

Conventional field structural analysis of the Veľký Bok units in the eastern part of the Nízke Tatry Mts. has revealed a complex structural evolution of the area with at least five deformation stages. The principal first two stages with complete structural parageneses developed in decreasing low-grade conditions during the early Late Cretaceous in connection with the generation and emplacement of the Krížna cover nappe (N to NW directed thrusting and recumbent folding, AD_1 stage), followed by backthrusting due to collision in the suture zone (S directed backthrusting and transpression, AD_{2-3} stage). The overthrust of the higher superficial cover nappes (e.g. the Choč nappe) appears to be only a short event driven by potential gravitational forces generated by an overall uplift due to crustal thickening. However, the homelands and transport directions of the Hronic-Silicic cover nappes is not exactly known. After the cover nappe emplacement, the compressional tectonic regime with N-S shortening continued up to the Early Paleogene, when the compression axis slightly shifted to the SE. The final large-scale fault pattern of the whole area (Fig. 1) includes mostly transpressive conjugate fault systems, partly with signs of reversals of their kinematic characters.

Some features of the tectonic scenario described pose several important, "orogen-scale" problems to be unravelled in the near future:

* mechanisms of formation of large-scale cover, or basement-involved recumbent folds at backstops of accretionary wedges - the Veľký Bok partial subunits were derived from domains with partly differing lithostratigraphic content, possibly halfgrabens;
* driving forces and emplacement mechanisms of large allochthonous cover sheets (orogenic contraction vs. gravity gliding) - the overthrust of the Choč nappe seems to be only a surficial episodic event occuring in an actively shortened and hence probably topographically differentiated area;
* crustal-scale compatibility of deformation processes, duration and temporal and spatial overlap of deformation stages and tectonic regimes, as well as their progradation or "polarity" in the evolution of an orogen. This strongly depends on the scale of observation - e.g. in the scale of Fig. 2 deformation stages and tectonic regimes clearly exhibit a time succession and superimposition, while in the scale of Fig.1 these are partly overlapping with generally forelandward (northward) migration.

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Microbiostratigraphy of Pelagic Berriasian and Valanginian Sediments in the Western Carpathians in Relation to the Western Mediterranean Region (Tunisia, France)

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Abstract: The authors of the paper present microbiostratigraphic data from Berriasian and Valanginian sediments of some key profiles in the Western Carpathians, northern Tunisia and southern France. Increased attention has been given to calpionellids, which, due to their paleogeographic spreading, rapid evolution as well as continuous paleontologic record, are important index fossils for detailed microbiostratigraphic zoning of pelagic Berriasian-Valanginian sediments. On the basis of composition and preservation of foraminifer associations the authors characterised bathymetric conditions in the regions studied.

Key words: Lithology, biostratigraphy, calpionellids, radiolarians,calcareous dinoflagellate cysts, foraminifers, Berriasian, Valanginian, Western Carpahtians, Tunisia, France

Introduction

In view of the fact that occurrences of ammonites - representatives of the orthostratigraphic scale - are in Berriasian sediments of the Western Carpathians a great rarity and their more abundant occurrence is dated only from the upper part of the Lower Valanginian (cf. VAŠÍČEK, 1991), stratigraphic studies are based on calpionellid microfauna. Detailed calpionellid zoning (ALLEMANN et al. 1971, REMANE et al. 1986) became the starting point for parabiostratigraphic correlations with other fossil groups - aptychi (VAŠÍČEK, 1991, BORZA – VAŠÍČEK, 1993, VAŠÍČEK et al., 1994), calcareous dinoflagellates (BORZA, 1969, 1984, ŘEHÁNEK, 1992), calcareous nannoplankton (BORZA et al., 1980, HALÁSOVÁ – BORZA, 1992). The least elaborated was the correlation of calpionellids with radiolarians, which we shall treat with increased attention.

To the contrary, biostratigraphy of Berriasian and Valanginian sediments of northern Tunisia and southern France is based, besides on calpionellids, mainly on ammonite and foraminifer classification (cf. BUSNARDO et al. 1979, MAAMOURI – SALAJ et al. 1994). Especially the ammonite group allows to make detailed conclusions on the character of sedimentation environment.

Western Carpathians

a) *Lithofacial evolution*

The character of Berriasian sediments is determined by changes on the boundary of the Jurassic-Cretaceous period. Rapid development of calcareous nannoplankton (especially nannocons), the skeleton remnants of which form 60 and more per cent of the rock, caused rapid fall of the calcite compensation zone level (GARRISON – FISCHER, 1969) and influenced the type of sediments in the whole Tethyan area.

Limestone formations of the biancone facies, locally described also as "Oberalm Beds", "Venetian Biancone Formation", "Calcare Rupestre", "Svaljavska svita" etc.(cf. WIECZOREK, 1988) formed in eupelagic environment, and deposited at the rate from 5 to 30 mm for one thousand years. They contain rich associations of calpionellids and calcareous nannoplankton. Representatives of benthic organisms are practically missing here, remnants of nektonic organism are relatively rare.

Calpionellid-nannocon biomicrites described in older literature as "limestones with *Calpionella alpina*" (KOUTEK – ANDRUSOV, 1927) "limestones of biancone type" (e.g. ANDRUSOV, 1959, K. BORZA, 1969) are also a characteristic Lower Cretaceous facies of the Central Western Carpathians and the Klippen Belt (Ladce Formation of the Manín Unit, Padlá voda Formation of the Vysoká Unit, Osnica Formation of the Zliechov Unit, Lučivná Formation of the Tatricum, lower part of the Pieniny limestone formation of the Kysuce and Pieniny Unit of the Klippen Belt).

This sedimentation of pelagic carbonates of the monotonous "Neocomian" facies continued uninterrupted also during the Valanginian period. The limestones are of micrite or biomicrite character. They differ from Berriasian sediments by their higher proportion of the marly admixture and more frequent occurrence of cherts and marly intercalations. A spotty structure is characteristic for some developments (Mráznica Formation of the Zliechov Unit, upper part of the Pieniny Limestone Formation). Spotty structure is characteristic also of micrite limestones of the Kostolec (Manín Belt) and Rohatá Skala (=Choč) Unit of the Strážov belt (SALAJ, 1995).

Tectonic activity of the finishing Late Kimmerian movements is documented by beds of the Nozdrovice breccia. In the Outer Carpathians, the Oliveta and Kopřivnice limestones deposited on shallow marine elevations (Bašský development). On the other hand, characteristic for basin parts of the Godul development is sedimentation of the Těšín limestones of turbiditic character.

b) *Distribution of microorganic remnants*

Calpionellids (*Calpionellidae* BONET, 1956) were a component of the planktonic ecosystem of the first depth level in the Tethys ocean, on the boundary of the Jurassic-Cretaceous period. The evolution of the branches of this family, according to present knowledge, covered a period of 15 million years (HOUŠA, 1990).

These planktonic microorganisms were rapidly spread by sea currents, which explains the identical composition of associations in the whole area of their occurrence. Their geographic explosion within the Tethyd province includes an area from eastern Mexico, Texas, Venezuela and Cuba in west, to Iran, Oman and Kiogar nappes of Tibet in east.

For this reason, calpionellids, as generally known, are of great stratigraphic importance and they are besides ammonites a key group for fine biostratigraphic zoning of the Middle-Upper Tithonian, Berriasian and Lower Valanginian. The last occurrences of representatives of *Calpionellidae* BONET are associated with the Hauterivian (BORZA, 1984).

The systematic position of calpionellids is determined by the character and structure of their test - lorica. Their lorica is formed by spiral-like arranged calcite prisms, oriented perpendicularly to the surface (AUBRY et al. 1976). In spite of the generally accepted opinion COLOM (1948), BONET (1956), TAPPAN-LOEBLICH, (1968), BORZA (1969), REMANE (1969a, 1978) stated that calpionellids are not fossil tintinnids, since their test consists primarily of calcite. Recent tintinnids represent a substantially more significant morphological group than calpionellids and especially the chemistry of tests is in both groups different. REMANE (1969a) supported his statement of primary calcite character of calpionellid tests by the following arguments:

Findings of sandy foraminifers, which had not been calcified in calpionellid limestones, with different crystallographic orientation of the collar and test, of the genus *Calpionellopsis* COLOM, 1948, which excludes calcification post mortem. On the other hand, tintinnids have organic lorica and at some species the surface is agglutinated. According to REMANE (1978), taxonomic position of *Calpionellidae* BONET, 1956 remains unclear and this author suggests to classify them with protozoans, with unsure systematic position.

The importance of calpionellids for the zoning of the uppermost Jurassic and Lower Cretaceous is determined by their abundant occurrence, rapid evolution, relatively easy identification of taxons, advanced elaboration of biostratigraphic zoning and continuous paleotologic record of the development of individual branches, allowing so-called phyllogenetic control of biostratigraphically important changes in associations.

Although evolutionary changes in this group were not as important as in ammonites, they provide useful boundaries for stratigraphic correlations.

The foundations for calpionella scales have been lain down in the works of REMANE (1969b), LE HÉGARAT – REMANE (1968), K.BORZA (1969), ALLEMANN (1970), CATALANO – LIGUORI (1971), FARÉS – LASNIER (1971). Standard calpionellid biozoning for the Mediterranean province has been elaborated by ALLEMANN – CALTALANO – FARÉS – LASNIER (1971).

On a colloquium in Lyon and Neuchâtel in the year 1973, one of three variants was proposed, to shift the boundary of the Berriasian to the base of the ammonite zone *Berriasella jacobi*, which would result in the boundary Jurassic-Cretaceous running between the calpionellid zones *Crassicollaria* and *Calpionella* (cf. MEMMI-SALAJ, 1975). This variant was generally accepted only in the year 1984 in Sumeg (REMANE et al. 1986). The latest modification of this scale was presented by POP (1994), based on standard zones (*Crassicollaria, Calpionella, Calpionellopsis* and *Calpionellites*), complementing them by the late Valanginian-Hauterivian zone *Tintinnopsella* and dividing further more in detail the above zones into sub-zones.

The applicability of the standard calpionellid zoning for the Western Carpathian region has been demonstrated by BORZA (1969). On the basis of a further detailed study, BORZA (1984) complemented this study by the distribution of microplanktonic remnants of the families *Cadosinidae* WANNER, 1940, *Stomiosphaeridae* WANNER, 1940 and *Calcisphaerulidae* BONET, 1956. A summary description of calpionellid fauna in the Western Carpathians, as well as of reference profiles, was presented by BORZA (1969, 1980). Correlation study of Upper Jurassic - Lower Cretaceous profiles was presented by BORZA – MICHALÍK (1986), REHÁKOVÁ – MICHALÍK (1992).

A continuous fossil record of standard calpionellid zones (*Calpionella, Calpionellopsis, Calpionellites*) in Berriasian and Lower Valanginian pelagic sediments is represented in the profiles Strážovce (BORZA et al. 1980, MICHALÍK et al. 1990 a, BORZA – PETERČÁKOVÁ, 1994), Hlboč (BORZA – MICHALÍK 1987) and Brodno (BORZA, 1969, MICHALÍK et al. 1990 b). In the profiles Brodno and Štramberk (HOUŠA et al. 1993), the distribution of calpionellids was checked by magnetostratigraphic study. For example, the boundary between the calpionellid zones A (*Crassicollaria)* and B (*Calpionella*), corresponding to the boundary Tithonian-Berriasian, is located approximately in the middle of the magnetozone M-19n. The above result may be well correlated with results from profiles in the area of northern and central Italy (cf. HOUŠA et al. 1994).

Radiolarians

Similarly as calpionellids, radiolarians provide to a certain extent the possibility for a wide paleogeographic and stratigraphic correlation. For the Tethyd realm in the greatest detail elaborated is the biozoning of BAUMGARTNER (1984, 1987), which divides the Middle Jurassic - Lower Cretaceous (Bathonian-Hauterivian) on the basis of unit associations (UA) into nine zones.

In spite of the fact that towards the end of the Jurassic period paleooceanographic conditions changed and radiolarians gradually lost their rock-forming importance (DE WEVER, 1989), changes in their associations on the boundary between the Tithonian and Berriasian may be well correlated with calpionellid events.

The Jurassic-Cretaceous boundary is indicated by a significant change on the base of the zone D, where UA 11 appears (Table 1).

The unit association 11 has a wide paleogeographic extension, but its onset is not everywhere quite synchronous. For example, in the profile Fiumo Bosso (Umbria, Italy), UA 11 is found several meters below the boundary of the calpionellid zones A/B (*Crassicollaria/Calpionella*) in the uppermost Tithonian. In the Atlantic region (Blake Bahama Basin) UA 11 is found directly above a sample of the zone *Calpionella,* which corresponds already to the Upper Berriasian. In the profile Svinita (Rumania), the onset of UA 11 was dated on the basis of ammonites in the Upper Berriasian (BAUMGARTNER, 1984, 1987).

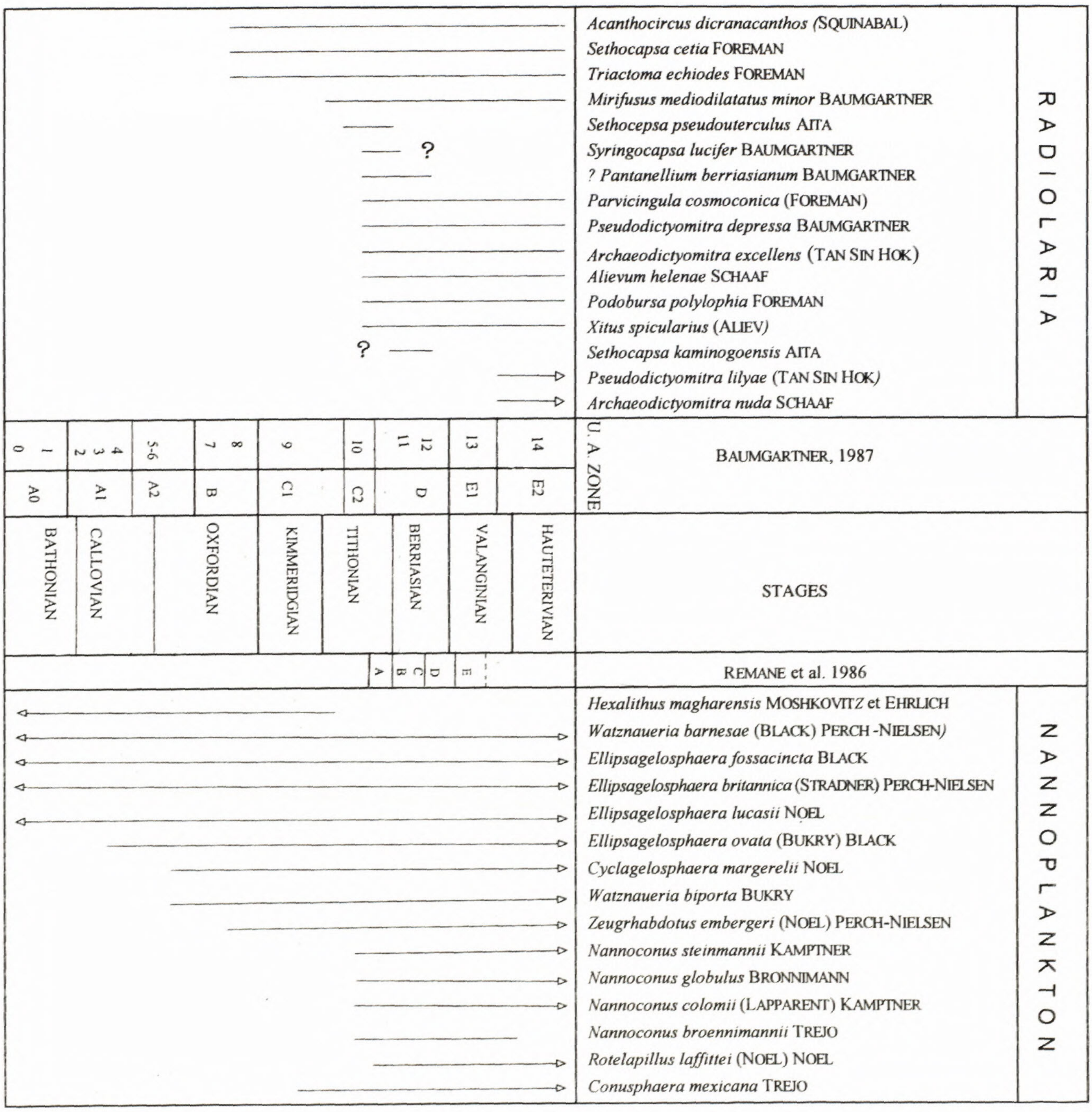
From the above mentioned facts it follows that the onset of this unit association may be confined by the range Upper Tithonian-Upper Berriasian. For this reason, the onset of UA 11 has been tested in the Western Carpathian region in the profile Hrušové (ONDREJÍČKOVÁ et al. 1993), controlled by common occurrence and distribution of calpionellids and calcareous nannoplankton. In the profile Hrušové, similarly as in the profile Fiumo Bosso in Italian Umbria, UA 11 appears in the uppermost Tithonian, below the boundary of calpionellid zones A/B. The onset of UA 11 may be well correlated with the occurrence of calcareous nannoplankton association of the zone CC1 (*Nannoconus steinmanni*). In Lower Berriasian horizons (zone *Calpionella*) of the Hrušové profile, besides typical representatives of UA 11 – *Parvicingula cosmoconica* (FOREMAN), *Obescapsula rusconensis* BAUMGARTNER, *Archeodityomitra excellens* (TAN-SIN-HOK), *Alievum helenae* (SCHAAF), *Xitus spicularius* (ALIEV), *Pseudodytyomitra depressa* BAUMGARTNER - there are found also species described in younger stages than the Berriasian. Here belong *Pseudodityomitra lilyae* (TAN-SIN-HOK) and *Archaeodictyomitra nuda* SCHAAF belong.

The Upper Berriasian has not been studied so well from the viewpoint of radiolarian zoning to distinguish it separately. Valanginian radiolarian fauna has not been mentioned yet to occur in the Western Carpathian region.

Calcareous dinoflagellates

Calcareous microfossils (cadosinas, stomiosphaeras, calcispherulas) are an important component of the Upper Jurassic - Lower Cretaceous ecosystem. Their suitability for zoning of pelagic sediments of the Western Carpathians was verified in the works of BORZA (1969, 1984), NOWAK (1968), ŘEHÁNEK (1985), having been classified by the authors with a group with unsure systematic position.

Table 1 Correlation scheme of radiolarian and calcareous nannoplankton distribution in relation to calpionellid zones (ONDREJIČKOVÁ et al. 1993)



According to KEUPP (1987), KEUPP et al. (1989), they are at present classified with the group of calcareous dinoflagellate family *Calciodinellaceae* DEFLADRE 1947 emend. BUJAK et DAVIES 1983). In spite of the wider stratigraphic range of some taxons, their distribution may be well correlated with calpionellids. ŘEHÁNEK (1992) distinguished for the Berriasian – Early Valanginian interval the zones *Colomisphaera proxima* and *Cadosina minuta*. The most important profiles for the elaboration of zoning based on calcareous dinoflagellates have been presented in the works by BORZA (1969, 1980).

Foraminifers

Sporadic presence of benthic foraminifers in pelagic sediments of the Berriasian-Valanginian in the Western Carpahtians did not allow so far to elaborate a zoning and its correlation with the above mentioned groups of fossils. In thin sections from Berriasian and Valanginian sequences of the "Neocomian facies" from different tectonic units, the so far unique presence of the genera *Spirillina* EHRENBERG 1843, *Patellina* WILLIAMSON 1858, *Ammodiscus* REUSS 1963, *Lenticulina* LAMARCK 1804, *Nodosaria* LAMARCK 1812 and *Textularia* DEFRANCE 1824 has been recorded. The occurrence of planktonic foraminifers is dated already as Late Hauterivian, by the zone *Globuligerina hoterivica* (SALAJ – SAMUEL 1966). The character of the tests (predominant are thin-walled benthic calcareous and agglutinated forms) as well as of preservation (frequent corrosion) indicates sedimentation in deep-water environment, near to the CCD level with oxygen and light deficiency. Therefore it may be well understood that in the Western Carpathians, in the Berriasian-Valanginian range, planktonic foraminifers are missing.

A poor Valanginian foraminifer microfauna was mentioned by SALAJ – SAMUEL (1966) in the Western Carpathian region from the profile Podskalie (Kostelec unit of the Manín belt). It is sporadically represented by representatives of the genus *Lenticulina* LAMARCK 1804, from which the species *Lenticulina (Lenticulina) guttata* (TEN-DAM) and *L. (L.) muensteri* (ROEMER) could be determined.

Tunisia

a) *Lithology and biostratigraphy*

The best and in fauna richest regions for establishing Lower Cretaceous stratigraphy are Zaghouan and Djebel Oust, situated 60-70 km from Tunis.

Biostratigraphic studies of these sediments are based mainly on ammonites (SOLIGNAC, 1927, CASTANY, 1951, BUROLLET et al. 1983), calpionellids (COLOM et al. 1953, MEMMI – SALAJ, 1975) and foraminifers (STRÁNIK et al. 1972, MAAMOURI and SALAJ, 1974, 1978, SALAJ, 1980, 1984, 1989, MAAMOURI et al. 1994). Radiolarians and calcareous dinoflagellates have not been studied so far in sediments from these areas.

Due to its quality and abundance in fauna, the Djebel Oust area has been proposed as type region for the Lower Cretaceous (CASTANY, 1951), or parahypostratotype of the individual stages (SALAJ, 1980, MAAMOURI, et al. 1994).

The Berriasian is represented by a sequence of dark sub-lithographic (intrabiopelmicrites and micrites) calpionellid limestones, with layers of dark-grey to black marls.

The Berriasian stage in Tunisia is defined from the microfaunistic viewpoint by the zone *Tintinnopsella carpathica/Globospirillina neocomiana* (MEMMI and SALAJ, 1975).

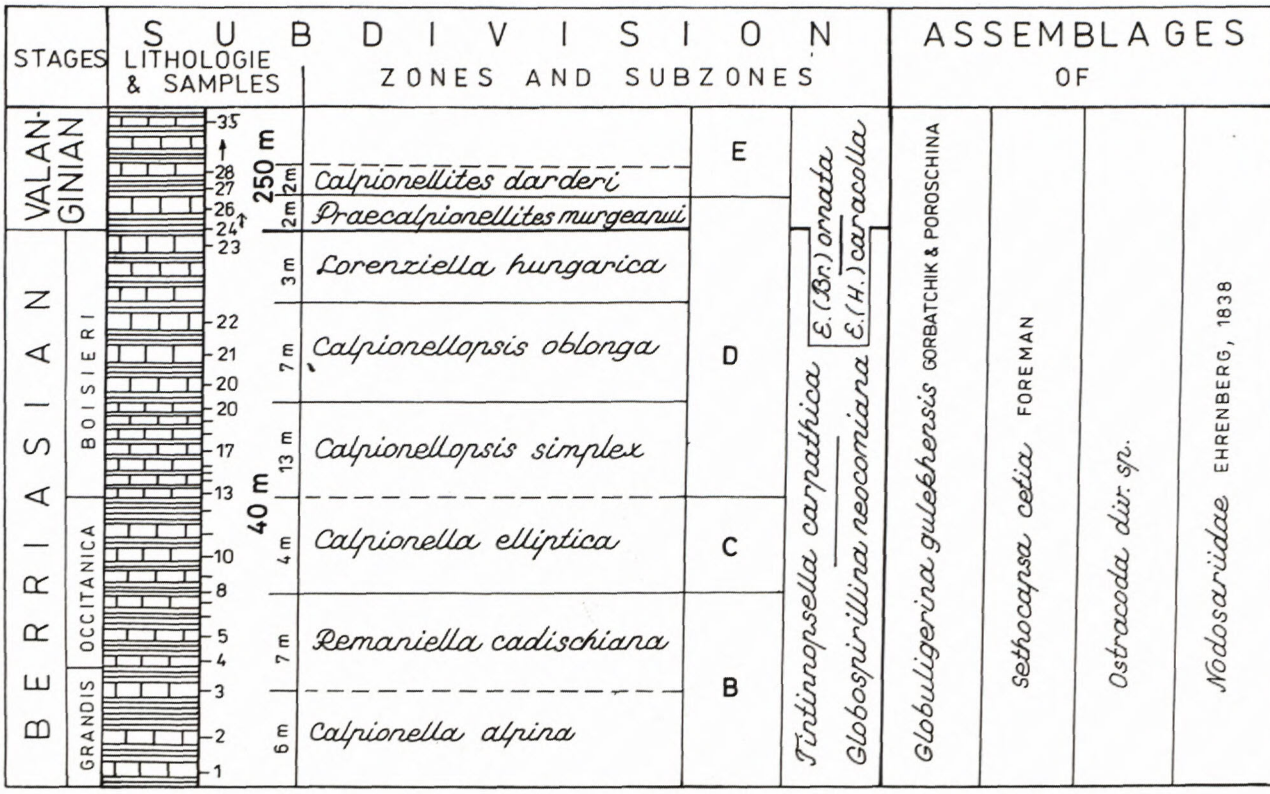
Index species appear on the base of the *Grandis* zone. It is the first appearance of large forms of *Tintinnopsella carpathica* (MURGEANU et FILIPESCU), determining unambiguously the base of the Berriasian. We note that small - primitive *Tintinnopsella carpathica* (MURGEANU et FILIPESCU) specimens appear in the Jacobi zone. This fact has been pointed out by MEMMI – SALAJ (1975), SALAJ (1980) and REMANE (1985). In any case, these small specimens should be described as a new sub-species within the species *Tintinnopsella carpathica* (MURGEANU et FILIPESCU).

The upper boundary of this zone, and thus also the boundary Berriasian-Valanginian, is determined by the appearance of foraminifer species *Epistomina (Brotzenia) ornata* (Roemer) and *Epistomina (Hoeglundia) caracolla* (ROEMER). Biostratigraphic classification of Berriasian and Valanginian sediments from the area of Djebel Oust is represented in Tab. 2.

Marly layers in the Berriasian, from the base of the ammonite *Grandis* zone, are rich in microfauna. It is represented by the following species: *Spirillina minima* (SCHACKO), *Globospirillina neocomiana* (MOULLADE), *Trocholina molesta* GORBATCHIK, *Trocholina vasserodi* GUILLAUME and *Trocholina burlini* GROBATCHIK. From planktonic foraminifers, the presence of the species *Globuligerina gulekhensis* GROBATCHIK et POROSCHINA has been proved and it occurs in the whole Valanginian. From radiolarians there is *Sethocapsa cetia* FOREMAN, passing from the Upper Jurassic into the Berriasian and occurring still in the whole Valanginian. (MAAMOURI et al. 1994).

From benthic foraminifers, besides the above mentioned species, the following ones are found practically in the whole Berriasian: *Rhizammina indivisa* BRADY, *Ammodiscus cretaceous* REUSS, *Dorothia* sp., *Ramulina spinata* ANTONOVA, *Dentalina linearis* ROEMER, *Dentalina* aff. *hilscana* REUSS, *Dentalina deflexa* REUSS, *Nodosaria nuda* REUSS, *Dentalina deflexa* REUSS, *Dentalina gracilis* D´ORBIGNY, *Dentalina nana* REUSS, *Dentalina siliqua* REUSS, *Lenticulina (Saracenaria) parallela* (REUSS), *Vaginulina* aff. *denudata* REUSS, *Lenticulina (Saracenaria) planiscula* (REUSS), *Lenticulina (Lenticulina)* aff. *turgidula* (REUSS), *Lenticulina (L.)*

Table 2 Microbiostratigraphic classfication of the Berriasian in the Djebel Oust region (MAAMOURI et al. 1994)



subangulata (REUSS) and *Lenticulina (Lenticulina) macrodisca* (REUSS).

Besides the above mentioned species, the species *Lenticulina (Lenticulina) nodosa* (REUSS) and *Epistomina (Hoglundina) caracolla anterior* BARTESNTEIN et BRAND occur for the first time in the upper Berriasian with *Favriella boissieri*.

Further species occur in the Upper Berriasian in the area of Zaghouan (Temple des Eaux), where the second standard profile for the Berriasian is found (SALAJ, 1980, 1984): *Verneuilinoides neocomiensis* (MJATLIUK), *Dorothia kummi* ZEDLER, *Conorboides valendiscesis* BARTENSTEIN et BRAND, *Conorboides hofkeri* BARTENSTEIN et BRAND, *Lenticulina (Lenticulina) guttata* BARTENSTEIN et BRAND, *Trocholina infragranulata* NOTH, *Lenticulina (Planularia) crepidularis* (ROEMER), *Lenticulina (Planularia) tricarinella* (REUSS), *Gaudryina chettabaensis* SIGAL and *Heterostomella chettabaensis* SIGAL.

The base of the Valanginian is determined by the ammonite zone with *Kilianella roubaudiana* with *Thurmanniceras pertransiens* (SAYN) in the wider sense (the index species with *Thurmanniceras otopeta* of basal Valanginian has not been proved to occur yet, BUROLLET et al. 1983).

From planktonic foraminifers, the species *Globuligerina gulekhensis* GORBATCHIK et *Poroshina passes* from the Berriasian into Valanginian, from benthic foraminifers determining the base of the Valanginian we have to mention *Epistomina (Brotzenia) ornata* (ROEMER) and *Epistomina (Hoeglundina) caracolla* (ROEMER). The base of the Valanginian is determined from calpionellids by the appearance of *Praecalpionellites murgeanui* (POP). From the lithofacial viewpoint, the Lower Valanginian is built of a marly limestone and marl series (200 to 250 m), defined from the viewpoint of microfauna by the foraminifer association of the zone *Epistomina (Brotzenia) ornata - Epistomina (Hoeglundina) caracolla*, defined by SALAJ (1975). Its base is defined by the appearance of these leading species, while the upper boundary is determined by the species *Epistomina (Brotzenia) djaffaensis* SIGAL and *Lenticulina (Lenticulina) ouachensis* (SIGAL).

We would like to add that the base of the flysch formation, as pointed out by A. - L. MAAMOURI, SALAJ, M. MAAMOURI, MATMATI ET ZARGOUNI (1994), corresponds to the uppermost part of the lower Valanginian, i.e. it still belongs to the zone with *Epistomina (Brotzenia) ornata, Epistomina (Hoeglundia) caracolla.*

The Upper Valanginian is represented by a flyschoid formation (up to 300 m) formed by greenish aleuritic claystones with abundant beds of dark-grey micaceous quartzites, with traces of plant fragments and hieroglyphs. In the middle to upper part of this sequence (200-250 m), decrease in the quantity of quartzites and appearance of rare intercalation of grey marls and grey sometimes even dark-grey to black clayey limestones may be observed, which are relatively abundant and form several horizons in the uppermost part of the Valanginian.

In the immediate underlier of dark bituminous Hauterivian limestones, in a 5 m thick dark marlstone complex, there are rarely present specimens of *Marginulina reticulosa* TEN DAM (A. - L. MAAMOURI, SALAJ, M. MAAMOURI, MATMATI et ZARGOUNI, 1994). Comparing this horizon with the same horizon in the stratigraphic region of Kef el Blidah, dated by ammonites (STRÁNÍK et al. 1972, SALAJ, 1980), this horizon was classified with the lowermost part of the Hauterivian (MAAMOURI et al. 1994).

b) *Biostratigraphic correlation of sediments from the area of Djebel Oust with the hypostratal profile of Angles*

The profile of Angles lying in the road-cut at the foot of Baussayes hill in the French province Alpes de Haute, has been proposed as hypostratotype of the Valanginian by BUSSNARDO – THIEULOY – MOULLADE et al. (1979). The Vocontian Lower Cretaceous bed successsion is represented by a sequence of marly limestones and marlstones. The Valanginian part of the profile attains a thickness of 240 m. An overview of biostratigraphic classification based on ammonites is presented in Table 3, 4. The calpionellid microfauna has been studied in the profile by ALLEMANN et al. (1971).

Foraminifer zones of the Valanginian in the Vocontian trough were defined in detail by MOULLADE (1966, 1974) and redefined again on the Valanginian hypostratotype in relation to ammonite zones (BOUSNARDO et al. 1979).

In view of the importance of the Berriasian and Valanginian on the Djebel Oust profile as well as in the Vocontian trough, one of the authors (Salaj) dealt with a revision of the Berriasian-Valanginian profile of the Vocontian trough (profile Angles - type profile of the Valanginian hypostratotype). This necessity resulted above all from the fact that the presence of eipistominas, important not only for Lower Cretaceous but also Jurassic stratigraphy, has not been reported from this profile.

From the comparison material (profile Angles) it is evident that the most abundant component in the microfauna are representatives of the family *Nodosariidae* EHRENBERG, 1838. Even though in the stratigraphic horizons they are synchronous in age, they have been predominantly redeposited by turbidite wash from the external platform and slope into the basin. This is supported by the taphonomic analysis of these foraminifer associations, which have been damaged by mechanical transport due to turbidites, while their tests are clearly sorted according to size. Juvenile and developing stages of tests are missing in the foraminifer associations. From the above mentioned facts it follows that there are present thanatocenoses from various paleoecologic nests of various depth horizons.

From species important for the Berriasian and Valanginian not described from the Angles profile, we present the following:

In the Berriasian there occur: *Globospirillina neocomiana* (MOULLADE), *Trocholina molesta* GORBATCHIK, *Trocholina burlini* GORBATCHIK, *Conorboides valendisensis* BARTENSTEIN et BRAND, *Conorboides hofkeri* BARTENSTEIN et BRAND, *Lenticulina (Lenticulina) nodosa* (REUSS), *Falsogaudryinella tealbyensis* (BARTENSTEIN) and *Globuligerina gulkensis* GORBATCHIK et POROSHINA.

In the Valanginian, from wihch not more than 40 species have been described, there occur practically about 100 well identifiable species. We shall present only the more important and so far in publications about the Vocontian trough not mentioned ones.

Otopeta zone (6 m)

In this zone, besides the already mentioned index species *Lenticulina (Lenticulina) nodosa* (REUSS), passing into this zone already in the Berriasian, there occur also *Haplophragmoides* sp., *Valvulina fusca* WILLIAMSON, *Dentalina linearis* REUSS, *Bythoceratina* sp. and *Opthalmidium* div. sp.

Petransiensis zone (53 m)

The following species occur in this zone: *Conicospilrillina reussi* ANTONOVA, *Lamarckina reussi* ANTONOVA, *Lamarckina membranaacea* ANTONOVA, *Epistomina (Hoeglundina) caracolla* (ROEMER), *Globuligerina gulekhensis* GORBATCHIK et POROSHINA and *Globuligerina* sp.

Campylotoxum zone (45m)

Besides by Moullade (In BOUSNARDO et al. 1979) described species, the following ones occur in this

Table 3 An overview of the biostratigraphic classification of the Vocontian trough based on ammonites (BUSNARDO et al.,. 1979)

		Lory, 1898	Paquier, 1990	Killian, 1906-13	Mazenot, 1939	Colloque Cretace Inf., 1965	Moullade et Thieuloy, 1967
HAUTERIVIEN (pars)			*Hoplites radiatus* *H. castellanensis*	*Acanthodiscus radiatus* et *L. castellanensis*		*Acanthodiscus radiatus*	*Radiatus*
VALANGINIEN	SUPERIEUR	*Hoplites* cf. *longinodus* *Seynoceras verrucosum*	*Duvalia emerici* et *Seynoceras verrucosum*	*Duvalia emerici* et *Seynoceras verrucosum*	*Neocomites neocomiensis*	*"Lyticoceras"*	*Neocomites* aff. *scioptychus*
							Himantoceras trinodosum
						Verrucosum	*Verrucosum*
	INFERIEUR	*Duvalia lata* et *Hoplites pexiptychus*	*Duvalia conica* et *Hoplites pexiptychus*	*Duvalia conica* et *Kilianella roubaudiana*		*Roubaudiana*	*Roubaudiana*
BERRIASIEN (pars)		*Hoplites boissieri* (pars)	*Hoplites boissieri* (pars)	*Hoplites boissieri* (pars)	*Kilianella* aff. *pexiptycha* et *Thurmannites* aff. *pertransiens*		

Tab. 4 An overview of the biostratigraphic classification of the Vocontian trough based on ammonites (BUSNARDO et al., 1979)

		Le Hegarat, 1968	Thieuloy, 1973	zonation proposée 1978	Espagne Wiedmann, 1975	Bulgarie Nikolov, 1960	Crimée-Caucase Drushchits, 1960
HAUTERIVIEN (p. p.)			Radiatus	Radiatus			
VALANGINIEN	SUPERIEUR		*Teschenites callidiscus*	*Callidiscus*	*Saynoceras verrucosum*	*Neocomites neocomiensis*	*Olcostephanus astieri* *Neocomites neocomiensis*
			Trinodosum	*Trinodosum*			
			Verrucosum	*Verrucosum*			
	INFERIEUR		*Neocomites campylotoxus*	*Campylotoxum*	*Kilianella roubaudiana*	*Kilianella roubaudiana*	*Kilianella roubaudiana*
			Roubaudiana	*Pertransiens*	*Thurmanniceras thurmanni*		
		Thurmanniceras pertransiens	*Pertransiens*	*Otopeta*			*Thurmanniceras thurmanni*
BERRIASIEN (p. p.)		*Boissieri*	*Boissieri*	*Boissieri*	*Berriasella callisto* (p. p.)		

zone: *Lenticulina (Lenticulina) subalata* (REUSS), *Lenticulina (Lenticulina) gibba* (REUSS), *Lenticulina (Lenticulina) turgidula* (REUSS), *Lenticulina (Lenticulina) saxonica* BARTENSTEIN et BRAND, *Lenticulina (Lenticulina) multicella* MOULLADE, *Lenticulina (Lenticulina) catascopium* MITJANICA, *Frondicularia mirodisca* REUSS, *Tristix excavatum* REUSS and *Bolivina textilaroides* REUSS.

Finally, in the zones *Verrucosum, Trinodosum* and *Callidiscus* (120 m), from further important species the following have been determined: *Globospirillina condensa* ANTONOVA, *Globospirillina clara* ANTONOVA, *Globuligerina gulekhensis* GROBATCHIK et POROSHINA, *Globuligerina* sp. and *Epistomina (Brotzenia) djaffaensis* SIGAL. The species *Frondicularia* cf. *bidentata* CUSHMAN corresponds in fact to the species *Frondicularia angusta glabra* (PERNER).

Besides this, attention has been given on the Angles profile to the boundary of Valanginian-Hauterivian boundary. The basal part of the Hauterivian was determined by the ammonite zone *Radiatus* (approx. 5 m). Besides the index species *Haplophragmoides vocontianus* MOULLADE for the Lower Hauterivian zone of the same name, determined by MOULLADE (1966) further important species are found in the basal part of the Hauterivian: *Bigenerina gracilis* ANTONOVA, *Marginulinopsis breyeri* (ZENDLER) and *Marginulina reticulosa* TEN DAM, known better under the name *Marginulopsis djaffaensis* (SIGAL). The latter, due to later description, became the synonym for the species *Lenticulina (Marginulinopsis) reticulosa* (TEN DAM, 1948),

For this reason, the Lower Hauterivian zone *Lenticulina (Marginulinopsis) djaffaensis* defined by A.-L. MAAMOURI – SALAJ (1978) was renamed by A.-L. MAAMOURI – SALAJ – M. MAAMOURI – MATMATI – ZARGOUNI (1994) as *Lenticulina (Marginuinosis) reticulata* zone.

From the above revision it is evident that microbiostratigraphic classification of the Valanginian on the French hypostratorype and in Tunisia is basically identical. The lack of epistominas on the hypostratotype profile of Angles is a result of the fact that their aragonite tests have been dissolved due to greater depth and thus in the majority of cases only their pyritised or limonitised cast have been preserved, sporadically with remnants of the aragonite tests.

Conclusions

From the comparison of the presented biostratigraphic data, especially the composition and preservation of foraminifer associations, conclusions may be made on the character of sedimentation environment in the areas studied.

The sedimentation environment of the monotonous "Neocomian" facies of the Western Carpathians during the Berriasian and Valanginian stage may be characterised as the hemipelagic part of a sea basin, with oxygen and light deficiency, the bottom of which was situated above CCD level, bud significantly below ACD level. This is supported by the sporadic presence of thin-walled agglutinated foraminifers of the genus *Ammodiscus* REUSS, as well as rare occurrence of calcareous benthos with corroded tests, represented above all by the genera *Lenticulina* LAMARCK and *Nodosaria* LAMARCK.

The relatively deep-water conditions of sedimentation predominated during the Berriasian and Valanginian stage in the Vocontian trough. Besides thin-walled agglutinated, relatively rare foraminifers, there occur foraminifer associations redeposited by turbidite wash (BUSNARDO et al. 1979), from the external platform and slope towards the basin. This is supported by the taphonomic analysis of these associations, which have been damaged by mechanical transport due to turbidites and the tests are evidently sorted according to size. The lack of epistominas on the hypostratotype profile of Angles is a result of the fact that their aragonite tests have been dissolved due to greater depth, and thus in the majority of cases only their pyritised or limonitised cast have been preserved, sporadically with remnants of the aragonite tests.

The most optimal conditions for parabiostratigraphic studies based on the distribution of foraminifers are provided by the Lower Cretaceous sediments of Djebel Oust in northern Tunisia. In Berriasian sequences a rich occurrence of benthic foraminifers has been determined, especially the family *Nodosaridae* EHRENBERG. The presence of the genera *Lenticulina* LAMARCK and *Epistomina* TERQUEM is important for the biostratigraphic classification of the Valanginian. The occurrence of epistominas in Tunisia, with frequently preserved aragonite tests, indicates a relatively shallower sedimentation environment. On the basis of a detailed microfacial analysis, calcimetry and abundancy relation of planktonic and benthic foraminifers, MAAMOURI – SALAJ et al. (1994, Tab. 1 a, b, c) stated that Lower Cretaceous sediments of this region deposited in the depth range of 200-500 m (maximally up to 700 m), above ACD level.

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Data on chemical and isotope Composition of Carboniferous and Mesozoic Carbonates of Inner Western Carpathians

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Abstract: Carbonate samples were collected from the Lower and Upper Carboniferous of the North Gemeric Unit, including the stratigraphically undated Dúbrava Beds, which are at present considered to be a part of the Bôrka Nappe and the Upper Carboniferous carbonates of the Turňa Nappe. The principal aim of this work was to identify the differences in the bulk chemical composition, the contents of trace and rare earth elements, as well as the isotope composition of C and O in the studied carbonates, and thus to obtain criteria for correlation of problematic horizons and for the interpretation of carbonate genesis and post-deposition alterations.

Besides these completely analysed samples the studied set comprises single isotope analyses of Mesozoic carbonates of the Turňa and Silica Nappes, as well as additional isotope analyses from eastern occurrences of the Bôrka Nappe and from the Košice and Burda magnesite deposits. The presented results helped to distinguish carbonate rocks of different grade of metamorphism, as well as different sedimentary conditions.

Key words: Inner Western Carpathians, Carboniferous and Mesozoic carbonates, bulk chemical composition, trace and rare earth elements, O and C isotopes, TVI decrepitation analysis

Introduction

Stratigraphic and paleogeographic problems of the Upper Paleozoic have been solved using the method of lithogeochemistry and determination of isotope composition of C and O from selected carbonate horizons of the northern Gemericum. The selected samples included carbonates from biostratigraphically documented horizons as well as horizons so far biostratigraphically undocumented.

33 samples were collected in the first stage, with the aim of determining the feasibility of selected methods and to which degree the obtained results may be interpreted in view of the complex geological development of the studied area, above all the multiphase metamorphic development, hydrothermal-metasomatic alterations, changes in lithologic composition, insufficiently uncovered terrane and many others. The analysed set included samples from Lower Carboniferous sequences of the Ochtiná Formation as well as the Črmeľ Group, from the Upper Carboniferous Zlatník Formation as well as the Turiec Formation from the borehole BRU-1, of the same age. Further samples were taken from the so far problematic, as far as its age is concerned, Dúbrava Beds from the Nižná Slaná depression, which are at present considered to be a part of the Bôrka Nappe.

The principal aim of this work was to identify the differences in the proportions of elements, including rare earth elements, as well as the isotope composition of C and O in the studied samples, and thus to obtain criteria for stratigraphic correlation of so far undated horizons. Of course, the aim of the investigation was also maximum use of the obtained data for the interpretation of carbonate genesis and post-deposition alterations, and thus solving the problems of sedimentation environment.

Besides completely analysed samples, the studied set included also additional analyses of isotope composition of Mesozoic carbonates from the Bôrka, Turňa, Silica Nappes, and the Foederata Group as well as from magnesite deposits from the area of Košice and Burda. The presented work contains first analytical results from the above set. We are aware of the fact that more precise interpretation of the data will require further samples. Because of this, we consider the presented interpretation to be preliminary results and data on geochemical and isotope composition of the carbonates as our contribution to the newly established database on the composition of above all Carboniferous carbonates.

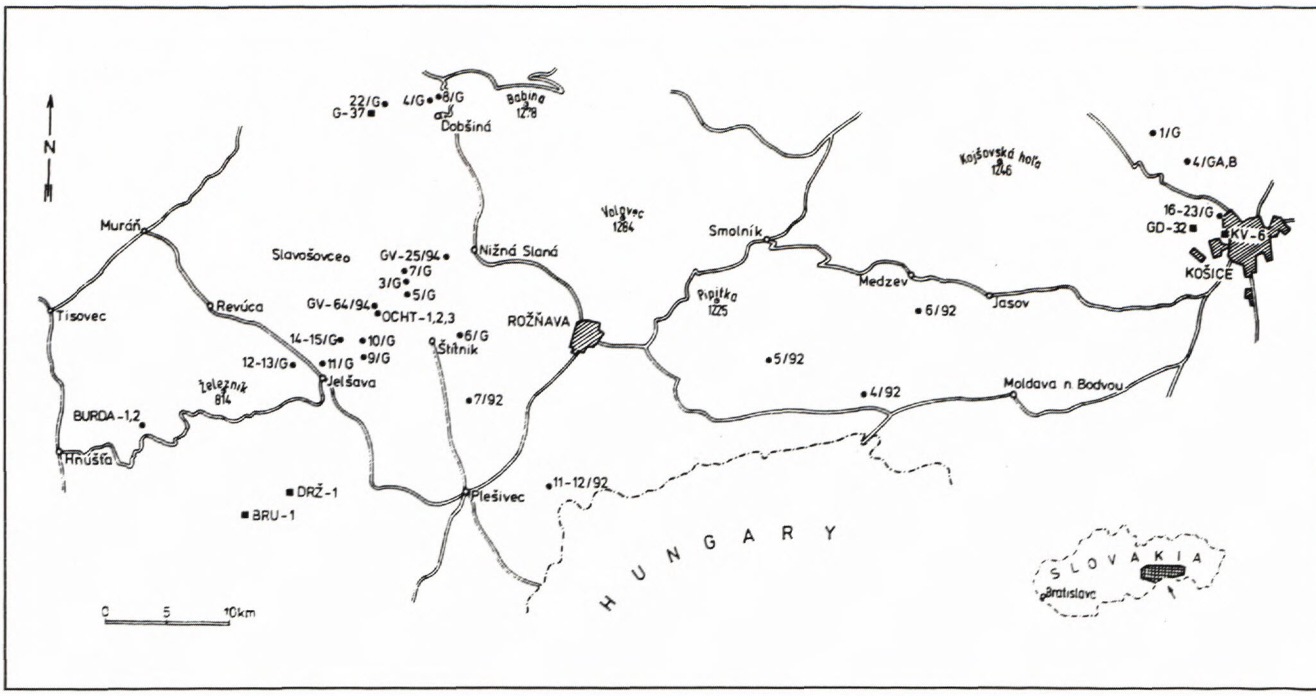


Fig. 1 Location of studied samples.
● – *Samples from surface occurrences and mine adits;* ■ – *samples from boreholes.*

Geological setting and localisation of the samples

Northern Gemericum

Ochtiná Formation - Lower Carboniferous

The upper part of the Ochtiná Formation is characterised by the development of carbonate members, indicating generally in the paleogeographic evolution a stage of shallowing of the original sedimentation basin. 25 samples have been analysed lithogeo-chemically from this sequence, O and C isotope analysis has been made from 16 samples. The material was collected at following localities:

Loc. Ochtiná – the stratigraphic succession starts with black, graphite shales, replaced towards the overlier by heavy-bedded dolomites, in some places with intercalations of dark shales. The dolomites are in their upper part changed into magnesite. 3 samples were taken for isotope study - 1. dolomites; 2. fine-grained limestones with disseminated grains of magnesite; 3. coarse-grained magnesite. The samples are marked as Ocht.-1, Ocht.-2, Ocht.-3. At this locality, the age of the upper part of the Ochtiná Formation was originally biostratigraphically documented on the basis of trilobite, brachiopod fauna, as Namurian B-C (BOUČEK and PŘIBYL, 1960). Later on, this age was stratigraphically re-evaluated and on the basis of conodonts the whole formation was reclassified as Upper Visean - Serpukhovian (KOZUR, MOCK and MOSTLER, 1976).

Loc. S of Markuška – a small lens of grey, fine-crystalline, finely laminated limestones of the Ochtiná Formation. It is found below the main magnesite horizon in the part of the Ochtiná Formation where clastic metasediments with admixture of basic volcanic material are predominant. The sample is marked 7/G.

Loc. Hrádok – a dolomite lens from the underlier of the main magnesite horizon, in the continuation of the Miková-Dúbrava belt. The carbonates are dark-grey in colour, recrystallized, irregularly grained. The sample was taken in the area of the elev. p. 707 and marked 10/G. Sporomorphs of Visean age have been found in the underlier of this carbonate lens (BAJANÍK and PLANDEROVÁ, 1985).

Loc. Burda – a phyllite complex with subordinate metasandstone intercalations, in which there are beds of grey, finely lamelled crystalline limestones. On the geological map of the Slovenské rudohorie Mts. - eastern part (BAJANÍK et al. 1984) they have been included into the Zlatník Formation, however, without biostratigraphic evidence. This has been based on the fact that below the horizon there are in places thin layers of fine-grained metaconglomerates. It is however very probable that they are a part of the Ochtiná Formation, or its youngest members, which have been otherwise reduced. A marginal possibility is that it belongs to younger sequences, equivalent to the Dúbrava beds. This stratigraphic classification is thus still problematic. Samples from this locality have been marked Burda-2, Burda-3.

Loc. Dúbrava-Miková - they belong to the upper part of the Ochtiná Formation, to the main magnesite horizon. They are considered to be equivalent to magnesites from Ochtiná. Samples were taken from the mine Miková (provided by workers of Geological Survey Spišská Nová Ves, Division Rožňava). They are representing dolomites associated with magnesites directly at the deposit. Sample 14/G corresponds to heavy-bedded, dark-grey dolomite and 15/G is fine-grained, massive dark-grey dolomite.

Loc. Bankov-Košice - magnesite layers associated with dark shales and metasandstones. On the geological map of Slovenské rudohorie Mts. - eastern part (BAJANÍK et al., 1984) the whole sequence has been included into the Zlatník Formation, without any biostratigraphic evidence. Litho-logically it is however absolutely identical with the sediments of the magnesite horizon of the Ochtiná Formation. A total number of 7 samples was taken from the deposit Bankov, from different magnesite grain-size varieties: 16/G - fine-grained magnesite, 17/G - coarse-grained magnesite, 18/G - medium-grained magnesite, 19/G - fine-grained magnesite, 20/G - medium-grained magnesite, 21/G - fine-grained magnesite. Sample 23/G was taken from the borehole KV-6, located in the deposit area of Bankov (material provided by dr. Varga).

Besides these further magnesite samples were taken into isotope analysis from magnesite deposits of Burda and Košice only (borehole GD-32).

Čermeľ Group – Lower Carboniferous

Loc. Čermeľ Valley - grey, crystalline limestones form only a few thin lenses among predominant clastic metasediments associated with basic volcanics and volcanoclastics. The age of this lithostratigraphic unit was determined on the basis of sporomorphs as Upper Tournaisian - Visean (SNOPKOVÁ in BAJANÍK, SNOPKOVÁ and VOZÁROVÁ, 1986). The sample from the Čermeľ Group limestones is marked 1/G.

Loc. Kavečany - small magnesite lenses are a part of the uppermost Čermeľ Group. They were correlated with the first magnesite horizon from Ochtiná (ABONYI, 1971). 2 samples were taken from an abandoned quarry: 4/G - nodular magnesite; 4/G-B - coarse-grained magnesite.

Zlatník Formation – Upper Carboniferous

Its lithologic development represents a volcano-sedimentary formation composed mostly of clastic, less of carbonate lithofacies, which on the majority of occurrences is characterised by the presence of basic volcanic and volcano-clastic rocks. Organodetritic limestones form lenticular bodies in the lower part of the Zlatník Formation, associated here with dark shales and lithic graywackes.

Loc. Dobšiná - the carbonates are captured in several tectonic blocks among rocks of the Early Paleozoic Klátov Group. They were to a considerable extent metasomatically altered into siderites. In the past they were economically exploited. These carbonate horizons provided a lot of biostratigraphic information. According to macrofauna, identified for the first time by RAKUSZ (1932) and later re-evaluated by BOUČEK and PŘIBYL (1960), this horizon belongs to the Westphalian B-C. The found flora was classified as Westphalian A-B (NĚMEJC, 1946; 1953), similarly as conodont fauna (KOZUR and MOCK, 1977). Dark-grey organodetritic limestones, irregularly-grained, with an admixture of originally clayey substance, were taken from 3 localities - 1. north-western margin of Dobšiná, loc. Jeruzalemberg, sample 2/G; 2. northern margin of Dobšiná, in the continuation of Kúpeľná Street, sample 8/G; 3. Dobšinská Maša - tectonic contact of the Hámor Formation and Rakovec Group, sample 22/G.

Turňa Nappe

Borehole BRU-1, Turiec Formation - Upper Carboniferous

The borehole has been situated into the Brusník anticline, with the aim of investigating its geological structure. Two tectonic units were reached by the borehole profile: 1. olistostrome formation of Upper Carboniferous age - the Turiec Formation (VOZÁROVÁ, 1992), correlated with the formation of Szendro phyllites from Szendro Mts. (depth 0-598.8 m) and classed with the tectonic unit of Turnaicum; 2. olistostrome and pelagic formations of Jurassic age, compared with the Meliaticum Jurassic (Vozárová and VOZÁR, 1992). For isotope study, carbonates were taken from the Upper Carboniferous formation, from the olistholith horizon, in the interval 75-116 m. They are light-grey, some with clayey admixture, or weakly silicified. The carbonates, predominantly limestones, less dolomites, are irregularly recrystallized, with an admixture of organodetritic material. Conodont fauna, identified by Ebner (EBNER et al., 1990) indicates mixed character. Olistoliths from carbonates from the interval 114-116 m contain conodont fauna of Namurian B - Westphalian A age and in the interval 136-146 m of the span Emsian-Turnaisian and Namurian B - C.

From the borehole BRU-1, 5 samples were taken from depths 76.0m, 86.0m, 95.8 m, 111.5 m, 114.0 m.

The Mesozoic sequences of the Turňa Nappe (Turnaicum) are represented by basin facies of limestones and dark shales in the Middle and Upper Triassic and variegated sediments of evaporite formations associated with "red-beds" in the Permo-Triassic (ex MELLO et al., 1992). The following samples were taken from these sequences:

4/92 - Dvorníky; 6/G - Honce quarry; 9-10/92 - Jelšavská Teplica; the borehole DRŽ-1 from depths 179.1m, 236.6 m, 418.5 m, 443.6 m, 1183.7 m, 1203.8 m.

Bôrka Nappe

Dúbrava Beds

This group includes white crystalline limestone, classified originally by FUSAN (1959), SNOPKO (1966) as Carboniferous and described under the name of Dúbrava Beds. They are associated with metabasalt tuffs, dark shales and metasandstones. The only subordinate lithologic member are here layers of fine-grained metaconglomerates and redeposited rhyolitic material. On the geological map of the Slovenské rudohorie Mts. - eastern part, MELLO (in BAJANÍK et al., 1984) classed a part of the Dúbrava Beds occurrences with the Middle to Upper Triassic of the Meliata Group s.l., based on lithologic similarity with paleontologically documented occurrences. A part of the occurrences - the area of the elev.p. Hrádok, N of Jelšava and S of the village Chyžné - remained classified as Carboniferous, as the equivalent of the Zlatník Formation. This solution however does not correspond to reality, since lithologically as well as by the degree of alteration these occurrences are completely identical with sequences included into the Meliata Group s.l. The Dúbrava Beds are typical not only as far as their lithologic development is concerned, but also by the transitional, medium- to high-pressure type of regional metamorphism in temperature conditions of greenschist facies (VOZÁROVÁ, 1993). In the last time, when compiling the geological map of the Slovenský Kras (Slovak Karst) area, 1 : 50 000 (MELLO et al., 1992), sequences with manifestations of high-pressure metamorphism were distinguished in Meliaticum and defined as a separate unit - the Bôrka Nappe.

A characteristic feature of the Dúbrava Beds from the Nižná Slaná depression, which are also included into the Bôrka Nappe and from which were taken most of samples studied in this work, is the simultaneous occurrence of glaucophanites with green schists. The latter contain actinolites with high Na content in M4 position, which corresponds to medium- to high-pressure conditions (VOZÁROVÁ, l.c.).

From white crystalline carbonates were taken the following samples: dolomites → 3/G - quarry S of Markuška; 9/G - NW of the forester's cottage Hrádok; limestones → 5/G - abandoned quarry N of Ochtiná; 11/G - Jordán Valley, N of Jelšava; 12/G - abandoned quarry S of Chyžné; 13/G - loc. as 12/G; GV-25/94 - W of elev. p. Ždiar; GV-64/94 - NW of Ochtiná village; 5/92 - N of Bôrka village; 6/92 - Šugov valley, S of Medzev.

Bôrka Nappe - eastern part

The dominant member of the eastern part of the Bôrka Nappe are white marbles (samples 5-6/92) which are very closely associated with glaucophanites, and smaller amount of metasediments.

Silica nappe

Non-metamorphosed Mesozoic sequences in the stratigraphic range Lower Triassic to Lower Jurassic (GAÁL - MELLO, in BAJANÍK et al. 1983, MELLO in MELLO et al., 1992). The Lower Triassic is represented by variegated sandy-shaly sediments, yellow and grey carbonate shales and graywackes. In the Middle Triassic, mainly in the Anisian, epiplatform carbonates and dolomites are predominant, replaced in the Ladinian and mainly in the Upper Triassic by sediments of an unstable shelf, alternating with zones of hemipelagic sedimentation (cherty limestones). The Lower Jurassic sequence, preserved rudimentary only, is formed by red nodular and crinoidal limestones, dark biomicrite limestones and radiolarites (Dogger). Mainly the Middle-Upper Triassic limestones were taken into isotope analysis: 7/92 - Ostrý vrch; 11-12/92 Silická Brezová.

Southern Veporicum - Foederata Group

The Foederata Group was defined as Mesozoic part of the cover of the south-Veporic crystalline basement. Carbonate sediments correspond mainly to the Middle and Upper Triassic stratigraphic horizon. Samples for isotope analysis were taken from the borehole G-37 - loc. Dobšiná - Hámor.

Petrographic Characterisation and Degree of Alteration

Northern Gemericum

Lower Carboniferous

Dolomites have in thin sections generally irregularly grained, granoblastic texture, in relics sparite-micrite, rarely with preserved intraclasts of micrite carbonates and with relics of recrystallized tests of crinoids, sometimes foraminifers. In intergranular spaces there is finely dispersed graphite pigment and flakes of metamorphic minerals (sericite, less chlorite and talc). In variable quantities there are oval grains or fine-crystalline aggregates of quartz. Plan-parallel, horizontal lamination has been preserved in crystalline limestones of the Ochtiná Group (loc. Burda and south of Markuška), as well as of the Črmeľ Group, in the form of concentrations of graphite substance and sericite flakes, or pyrite grains. Magnesites are fine- to coarse-sparite, massive, mostly oriented, with marked pseudo-absorption. This sparite aggregate contains finely dispersed graphitic pigment. Besides this, pure, coarse-crystalline magnesite is found in secondary veins. Dolomites are associated with magnesites in one sequence, while the latter, in contrast to bedded dolomites,usually form massive, irregularly restricted bodies. A component of the whole sequence are interlayers of dolomite and graphitic shales and in the underlier of the dolo-magnesite horizon an important layer of basic magmatic rocks. Basic volcanoclastics associated with black shales, metasandstones, mataconglomerates and sporadic bodies of serpentinised ultrabasics complement the lithostratigraphic succession below the magnesite horizon.

Lower Carboniferous sequences in the Gemericum have undergone regional metamorphism reaching PT conditions of the lower part of greenschist facies of low-pressure type. This alteration grade is in carbonates documented by the mineral assemblages: Dol(Mgs)+Tlc; Dol+Qtz; Dol(Mgs)+ +Tlc+Cc+Qtz.Pressure character of metamorphism has been determined from b_0 values of muscovite from associated metapelites (SASSI and VOZÁROVÁ, 1987). Temperature was estimated in the range 350-370 °C, at pressure of 2-3 kbar and relatively high geothermal gradient of 40 °C/km. Recrystallization temperatures corresponding to the epizone have been determined also from illite crystallinity (KI = 0.27-0.35 2 theta, ŠUCHA and VOZÁROVÁ, in press).

Upper Carboniferous

Limestones of the Zlatník Formation have irregularly-grained, biosparite texture, with intraclasts of biomicrite and microsparite texture, with relics of recrystallized tests of crinoids, brachiopods, ostracods, foraminifers. Frequent are secondary veinlets with calcite filling. Metamorphic grade of the Zlatník Formation carbonates corresponds to early stages of epimetamorphism, or the transition between anchi- and epizone. In the more distant associated metapelites (area of Mlynky), corrected illite crystallinities correspond to the value of 0.23 2 theta (ŠUCHA and VOZÁROVÁ, l.c.). In carbonates is the under these conditions stable calcite, along with quartz, associated with small amount of illite and paragonite.

Turňa Nappe

Limestone olistoliths from the Turiec Formation have in the borehole BRU-1 massive, finely lamelled and in some parts also strongly pressure-oriented structure. Their texture is biosparite, in some places microstylolith. In this texture there are chaotically distributed recrystallized fragments of crinoid, ostracod and bivalvian tests. Sporadically, oval bodies with cross-extinction inside have been found, which, according to dr. BOOROVÁ (pers. comm.), correspond to zoospores - *Globochaete* sp. In the crystalline aggregate of calcite there are rhombi of newly-formed dolomite and oval grains and aggregates of quartz. In fine sedimentary laminae, as well as in foliation planes in schistose varieties, there are concentrated besides graphitic substance and pyrite grains also fine phyllosilicate flakes. Fine-crystalline dolomites have also organodetritic textures preserved in relics. The grade of regional metamorphism did not exceed the conditions of lower part of the greenschist facies, which is documented by critical mineral assemblage Ms+Ab in the associated metapelites. Pressure character of the metamorphism has been determined on the basis of b_0 values of muscovites (MAZZOLI and VOZÁROVÁ, 1989). The derived temperatures correspond to values abut 350 °C, at the pressure 2-3 kbar and geothermal gradient of approx. 40 °C/km.

Mesozoic sequence of the Turňa Nappe: Generally the grade of metamorphism of the Mesozoic Turňa Nappe rock sequences reaches anchizone P-T conditions.IC - averages maximally correspond to the boundary of anchi- and epizone (about 300 - 350 °C; ARKAI in ARKAI & KOVÁCS, 1986 from the loc. Zádielske Dvorníky). These results are in accordance with the chlorite-chloritoid metamorphic assemblage, which was ascertained in metasediments associated with the carbonate horizon (loc. Honce; VOZÁROVÁ unpubl. inf.).

Bôrka Nappe

Carbonates of the Dúbrava Beds have in general strongly pressure-oriented textures and according to their recrystallization grade and composition they belong to calcite and calcite-dolomite marbles. In the granoblastic, strongly oriented aggregate with pressure twin lamellae, besides calcite there has been sporadically preserved also aragonite, which is the critical metamorphic mineral of the high-pressure assemblage. Besides quartz, there are in small amounts associated chlorites, phengite and rarely also glaucophane and in dolomites also talc. No relics of organic remnants have been found in them. This mineral assemblage, as well as critical metamorphic mineral assemblages in metabasalt volcanics, occurring together with carbonates in one horizon, allow to interpret PT conditions of the formation of the Dúbrava Beds as greenschist facies of medium- to high-pressure type (T=400-450 °C, P = about 8-10 kbar, geothermal gradient 15 °C/km; VOZÁROVÁ, 1993; FARYAD, 1995).

Silica Nappe

The carbonatic sequence of the Silica Nappe has undergone diagenetic effect only.

Foederata Group

The Alpine metamorphism corresponds to the higher pressure range of greenschist facies. Pressure conditions were estimated by means of b_0 values of muscovites (MAZZOLI et al., 1992).

Lithogeochemical characterisation

Methods

For lithogeochemical study, fresh samples were collected from surface outcrops, mines and borehole profiles, weighing 1 to 5 kg. Complete silicate analysis has been made from the samples, as well as the determination of selected trace elements and a part of lanthanoid-group elements (Tab. 1, 2, 3). The same group of samples was subjected to C and O isotope analysis. Chemical analysis of oxides was made in the laboratory of Dionýz Štúr Institute of Geology (GÚDŠ) and trace elements were analysed in laboratories of E.L., spol. s r.o., Spišská Nová Ves, using AAS and ICP. The elements of the group of lathanoids were determined in laboratories of Geoindustria š.p., Praha-Černošice, using INNA.

Interpretation of results

An important and relatively strongly varying component is SiO_2, the carriers of which are above all allotriomorphic aggregates of low-metamorphic quartz and in dolomites and magnesites to a limited extent also talc, which is a side-product of low-grade metamorphism. The value of Al_2O_3/SiO_2 was used to characterise the silici-clastic admixture in carbonates, especially for expressing the relative proportion of quartz and phyllosilicates (sericite, paragonite, chlorite). Numerical values of this ratio vary in the range of 0.01 to 0.48, while in the majority of samples they are below 0.1, supporting thus our original assumption. Values above 0.3 indicate, according to YUDOVIČ (1981), predominance of originally clayey substance in the insoluble residue, i.e. in the metamorphic stage of phyllosilicates.

From Tab. 3 it follows that these values are higher only in four of the total number of samples, and thus in these samples we may assume more significant admixture of originally clayey substance. Based on this we may assume that in the majority of samples the trace elements as well as rare earths and Na, K, Mn are associated largely with the carbonate component.

P_2O_5 quantities vary in all carbonate groups approximately in the same way. They are derived from phosphatic carbonates formed from fossil phosphatic tests of organisms.

The distribution of indicative elements, as well as C and O isotopes in carbonates is shown in Tab. 3 and on Fig. 1, 2. The value of Mg/Ca in Lower Carboniferous dolomites varies in the range 0.90-0.95, which is somewhat lower than in ideal dolomite stoichiometry. A little greater differences were recorded in dolomites of the Bôrka Nappe (0.88-0.99). According to FOLK and LAND (1975), Ca surplus in dolomites is controlled mainly by the original salinity. In the sense of this hypothesis, salinity is

TAB.1 Abundances of main oxides in the Lower-, Upper Carboniferous and Dúbrava Beds carbonates (in %)

	14/G	15/G	10/G	Ocht-1	7/G	1/G	Burd-2	Ocht-2	16/G	17/G	19/G	20/G	21/G	4/G-A	4/G-B	2/G	8/G	Bru-1	Bru-1	Bru-1	Bru-1	Bru-1	3/G	9/G	11/G	6/G	5/G	12/G	13/G	GV-25/94	GV-64/94
																		95.80	76.00	111.50	86.00	114.00									
SiO_2	21.06	4.49	7.28	8.08	2.29	21.45	1.72	13.40	10.02	12.40	5.04	6.82	4.46	12.38	7.15	3.57	3.32	3.96	18.62	4.39	7.49	5.11	8.33	13.70	6.39	2.28	4.94	7.78	4.48	0.37	4.30
TiO_2	0.05	0.01	0.05	0.04	0.03	0.17	0.00	0.07	0.02	0.09	0.06	0.04	0.01	0.03	0.03	0.05	0.01	0.05	0.22	0.06	0.15	0.12	0.00	0.01	0.00	0.00	0.01	0.04	0.00	0.01	
Al_2O_3	1.24	0.44	0.43	0.98	0.15	2.93	0.82	1.05	0.89	1.40	0.38	0.89	0.76	0.59	0.50	0.25	0.19	0.87	7.50	1.64	1.32	1.87	0.11	1.41	0.05	0.11	1.11	0.05	0.16	0.03	0.30
Fe_2O_3	1.59	1.53	0.88	0.75	0.12	0.13	0.26	1.40	1.28	2.13	1.30	0.85	1.61	0.32	0.53	0.26	0.17	0.65	2.31	1.47	0.72	1.57	0.37	0.89	0.04	0.09	0.14	0.06	0.03	0.11	0.12
FeO		0.12	0.18			0.56			0.70	0.73	0.75	0.90	0.49	0.37	0.11	0.22	0.18		0.19	0.13	0.11		0.12	0.31	0.20		0.20		0.04	0.09	0.07
MnO	0.17	0.15	0.18	0.16	0.03	0.03	0.03	0.47	0.12	0.19	0.16	0.14	0.09	0.05	0.05	0.10	0.09	0.18	0.15	0.48	0.20	0.16	0.03	0.05	0.02	0.03	0.02	0.01	0.01	0.04	0.01
MgO	16.33	19.12	18.02	18.82	0.66	0.56	0.62	0.66	36.36	33.51	41.68	39.47	41.92	39.56	41.91	0.51	0.86	0.85	1.17	0.62	0.68	31.62	19.24	17.26	19.69	2.53	1.03	0.75	1.07	0.38	0.58
CaO	24.10	28.06	27.90	29.34	55.28	41.16	55.35	42.47	0.70	0.65	0.44	0.40	0.47	0.97	1.25	53.69	53.14	53.18	36.67	51.32	52.36	18.99	28.48	24.29	31.36	53.79	51.87	53.72	54.55	54.57	52.46
Na_2O	0.03	0.03	0.02	0.03	0.02	0.84	0.07	0.03	0.30	0.31	0.18	0.39	0.28	0.08	0.06	0.01	0.33	0.03	0.13	0.03	0.06	0.07	0.02	0.27	0.01	0.02	0.06	0.01	0.01	0.02	0.01
K_2O	0.02	0.07	0.06	0.05	0.03	0.69	0.10	0.25	0.08	0.06	0.05	0.10	0.08	0.02	0.01	0.06	0.04	0.22	2.01	0.37	0.91	0.21	0.03	0.25	0.02	0.03	0.21	0.02	0.04	0.03	0.03
P_2O_5	0.24	0.20	0.52	0.07	0.08	0.15	0.16	0.16	0.15	0.06	0.08	0.49	0.16	0.21	0.16	0.20	0.15	0.16	0.18	0.14	0.06	0.16	0.03	0.10	0.09	0.11	0.70	0.20	0.23	0.01	0.04
H_2O^-	0.03	0.08	0.01	0.00	0.01	0.02	0.02	0.02	0.03	0.02	0.04	0.03	0.03	0.02	0.01	0.05	0.04	0.00	0.01	0.00	0.01	0.02	0.01	0.02	0.02	0.02	0.00	0.01	0.01	0.03	0.10
H_2O^+	35.16	45.21	44.42	41.73	41.40	31.43	40.91	40.12	49.70	48.57	49.75	49.64	49.84	45.57	47.85	41.23	41.58	39.75	30.66	38.68	35.86	40.91	43.44	41.50	42.24	40.89	39.89	37.16	39.29	0.11	0.01
CO_2																														43.56	41.75
SO_3	0.25	0.35																		0.55										0.16	
Σ	100.27	99.86	99.95	100.05	100.10	100.12	100.06	100.10	100.35	100.12	99.91	100.16	100.20	100.17	99.62	100.20	100.10	99.90	99.82	99.88	99.93	100.81	100.21	100.60	100.13	99.90	100.18	99.81	99.92	99.51	99.77

*H_2O^+ loss on ignition (at 900 °C), contained are mainly the abundances of CO_2 to a lesser extent the organic matter and rare $(OH)^-$

TAB. 2 Trace elements contents for the Lower-, Upper Carboniferous and Dúbrava Beds carbonates (ppm)

	14/G	15/G	10/G	Ocht-1	7/G	1/G	Burd-2	Ocht-2	16/G	17/G	19/G	20/G	21/G	4/G-A	4/G-B	2/G	8/G	Bru-1	Bru-1	Bru-1	Bru-1	3/G	9/G	11/G	6/G	12/G	13/G	GV-25/94	GV-63/94
																		95.8	76.0	111.5	86.0								
As	18.30	1.70	6.10	4.40	5.40	3.00	0.50	5.80	0.40	1.50	0.60	2.60	1.60	0.20	0.30	2.70	1.30	3.40	2.60	2.30	11.20	0.40	0.50	0.30	0.50	0.30	1.00	0.50	5.70
Ba	17.00	21.00	18.00	24.00	31.00	190.00	25.00	24.00	6.00	15.00	22.00	26.000	18.00	8.00	3.00	46.00	32.00	118.00	170.00	92.00	146.00	28.00	66.00	11.00	25.00	28.00	36.00	30.00	5.00
Cu	9.00	3.00	3.00	6.00	4.00	6.00	4.00	6.00	4.00	2.00	4.00	2.000	3.00	2.00	2.00	9.00	5.00	7.00	9.00	5.00	16.00	3.00	7.00	2.00	3.00	3.00	4.00	14.00	6.00
Li	15.00	14.00	12.00	11.00	18.00	32.00	20.00	12.00	10.00	6.00	7.00	7.000	7.00	3.00	1.00	17.00	17.00	18.00	16.00	18.00	16.00	11.00	13.00	11.00	17.00	17.00	16.00		2.00
Ni	14.00	2.00	5.00	7.00	6.00	5.00	2.00	13.00	8.00	6.00	8.00	6.000	5.00	5.00	3.00	2.00	1.00	6.00	9.00	9.00	6.00	1.00	4.00	1.00	0.50	3.00	1.00	2.00	6.00
Pb	4.50	2.30	2.10	2.20	1.50	2.50	1.80	3.00	1.00	2.20	1.70	1.600	1.10	0.20	1.00	3.70	2.30	4.40	4.80	4.80	5.00	2.50	9.60	0.20	1.00	0.20	0.60	7.00	2.00
Rb	2.00	1.00	3.00	1.00	0.50	10.00	0.50	3.00	2.00	2.00	1.00	0.050	2.00	2.00	1.00	0.50	0.50	7.00	24.00	7.00	18.00	99.00	3.00	1.00	0.50	0.50	0.50	2.00	3.00
Sb	3.50	0.30	0.40	1.40	1.30	0.40	0.20	2.70	0.90	0.40	0.50	0.005	0.60	0.20	0.30	0.60	0.30	0.70	1.00	0.40	2.40	0.50	2.70	0.10	0.20	0.05	0.10	0.10	1.00
Sr	34.00	38.00	124.00	29.00	414.00	3395.00	275.00	36.00	2.00	10.00	12.00	7.000	3.00	1.00	1.00	235.00	234.00	187.00	170.00	288.00	172.00	143.00	355.00	124.00	197.00	154.00	211.00	194.00	40.00
V	20.00	7.00	8.00	0.50	27.00	12.00	5.00	10.00	16.00	10.00	8.00	3.000	7.00	23.00	6.00	3.00	5.00	9.00	16.00	14.00	18.00	14.00	19.00	8.00	2.00	2.00	1.00	2.00	2.00
Y	12.00	4.00	3.00	8.00	5.00	6.00	7.00	9.00	5.00	8.00	6.00	4.000	4.00	4.00	4.00	6.00	6.00	14.00	13.00	16.00	14.00	1.00	6.00	1.00	1.00	0.50	1.00	2.00	2.00
Zn	3.00	1.00	5.00	0.50	3.00	6.00	2.00	0.50	3.00	6.00	6.00	3.000	2.00	3.00	1.00	1.00	2.00	11.00	7.00	6.00	5.00	3.00	36.00	0.50	5.00	0.50	0.50		2.00
Zr	10.00	7.00	6.00	1.50	5.00	68.00	6.00	7.00	16.00	8.00	9.00	7.000	10.00	22.00	7.00	5.00	4.00	14.00	38.00	16.00	25.00	5.00	12.00	6.00	1.50	5.00	6.00	5.00	2.00
U	0.90	1.60	0.30	1.30	3.90	1.30	0.60	3.90	1.00	2.50	0.60	0.500	0.30	0.50	0.30	1.90	1.40	0.20	0.90	0.30	0.40	1.20	2.00	0.50	0.30	0.70	0.30		
Th	1.20	0.40	0.40	4.10	0.20	1.90	0.90	0.40	0.60	1.00	0.30	0.400	0.40	0.70	0.30	0.20	0.30	1.20	9.30	0.30	1.90	0.20	0.80	0.20	0.10	0.05	0.10		
Sc	2.53	0.97	0.74	5.24	0.66	2.76	1.31	1.39	1.41	2.21	0.69	1.180	1.11	1.82	1.50	0.70	0.59	1.87	8.63	0.73	2.81	0.41	1.96	0.26	0.17	0.22	0.29		

TAB. 3 Geochemical and isotopic data for the Lower-, Upper Carboniferous and Dúbrava Beds carbonates

		Al_2O_3/SiO_2	Ca (%)	Mg (%)	Mn (ppm)	Na (ppm)	Sr (ppm)	Zn (ppm)	K (%)	U (ppm)	Th (ppm)	$(Sr/Ca)10^3$	$(Na/Ca)10^3$	Mg/Ca	$\delta^{18}O_{PDB}$	$\delta^{13}C_{PDB}$	$\delta^{18}O_{SMOW}$
Lower Carboniferous Northern Gemericum												MOLAR	MOLAR	MOLAR			
dolomites	14/G	0.06	17.25	9.92	1318.00	222.00	34.00	3.00	0.016	0.09	1.20	0.20	2.24	0.950	-12.31	1.39	19.38
	15/G	0.10	20.08	11.62	1154.00	225.00	38.00	1.00	0.058	1.60	0.40	0.19	1.95	0.950	-17.99	0.80	13.63
	10/G	0.06	19.97	10.95	1374.00	148.00	124.00	5.00	0.050	0.30	0.40	0.62	1.29	0.900	-17.42	-0.06	14.12
	Ocht-1	0.12	21.00	11.43	1264.00	222.00	29.00	1.00	0.041	1.20	4.10	0.14	1.85	0.910	-15.96	2.39	15.62
limestones	7/G	0.06	39.57	0.23	219.00	148.00	414.00	3.00	0.025	3.90	0.20	1.05	0.65	0.009	-7.49	2.28	23.14
	1/G	0.14	29.46	0.19	219.00	6157.00	3395.00	6.00	0.570	1.30	1.90	11.50	36.44	0.010	-13.72	-3.87	16.71
	Burda-2	0.48	39.62	0.21	219.00	519.00	275.00	2.00	0.083	0.60	0.80	0.69	2.28	0.009	-5.90	1.10	24.78
	Ocht-2	0.08	30.40	0.23	3626.00	222.00	36.00	1.00	0.207	0.40	0.90	0.12	1.27	0.012	-16.34	2.21	15.23
magnesites	16/G	0.09	0.50	22.10	934.00	2225.00	2.00	3.00	0.066	1.00	0.60	0.40	0.44	0,02*	-16.37	0.36	14.91
	17/G	0.11	0.46	20.36	1483.00	2300.00	10.00	6.00	0.050	2.50	1.00	2.17	0.50	0,02*	-16.86	-1.20	14.41
	19/G	0.07	0.32	24.89	1264.00	1335.00	12.00	6.00	0.041	0.60	0.30	3.75	0.42	0,01*	-16.05	-0.93	15.24
	20/G	0.13	0.28	23.97	1099.00	2893.00	7.00	3.00	0.083	0.50	0.40	2.50	1.03	0,01*	-15.30	1.21	16.02
	21/G	0.17	0.34	25.48	714.00	2077.00	3.00	2.00	0.066	0.30	0.40	0.88	0.61	0,01*	-16.29	-0.16	14.99
	4/G-A	0.05	0.69	24.04	385.00	593.00	1.00	3.00	0.017	0.50	0.70	0.14	0.08	0,03*	-19.64	-4.03	11.54
	4/G-B	0.07	0.89	25.47	385.00	445.00	1.00	1.00	0.008	0.30	0.30	0.11	0.05	0,03*	-19.63	-3.90	11.55
														*Ca/Ca+Mg			
Upper Carboniferous Northern Gemericum																	
limestones	2/G	0.07	38.43	0.29	769.00	74.00	235.00	1.00	0.050	1.90	0.20	0.61	0.33	0.012	-13.02	0.89	18.03
	8/G	0.06	38.04	0.17	714.00	2448.00	234.00	2.00	0.032	1.40	0.30	0.61	11.22	0.007	-12.64	0.35	18.62
Borehole Bru-1 Upper Carboniferous - Turnaicum																	
	95,8 m	0.22	38.06	0.51	1373.00	222.00	187.00	11.00	0.183	0.20	1.20	0.49	1.02	0.022	-10.66	-0.29	19.88
	76,8 m	0.40	26.18	0.71	1154.00	964.00	170.00	7.00	1.670	0.90	9.30	0.65	6.42	0.045	-9.93	1.37	20.63
	111,5 m	0.37	36.74	0.37	3736.00	222.00	288.00	6.00	0.307	0.30	0.30	0.78	1.05	0.017	-11.52	-1.07	18.99
	86,0 m	0.18	37.48	0.41	1538.00	445.00	172.00	5.00	0.755	0.40	1.90	0.46	2.07	0.018	-11.38	0.20	19.13
dol.	114,0 m	0.36	22.63	11.54	1264.00	297.00			0.174	0.05	1.30		2.29	0.840	-11.40	-1.37	19.11
?Upper Triassic - ?Jurassic Bôrka Nappe																	
dolomites	3/G	0.01	20.38	11.69	220.00	148.00	143.00	3.00	0.025	1.20	0.20	0.70	1.27	0.950	-12.03	0.80	18.46
	9/G	0.10	17.39	10.49	385.00	2003.00	355.00	36.00	0.207	2.00	0.30	2.04	20.07	0.990	-17.94	-5.59	13.58
	11/G	0.01	22.45	11.96	165.00	74.00	124.00	1.00	0.016	0.50	0.20	0.55	0.57	0.880	-12.19	-0.92	19.51
limestones	6/G	0.05	38.50	1.54	220.00	148.00	197.00	5.00	0.025	0.30	0.10	0.51	0.67	0.066	-4.95	1.94	25.76
	5/G	0.22	37.13	0.62	165.00	445.00			0.174	0.20	0.40		2.09	0.027	-10.08	0.41	20.47
	12/G	0.01	38.45	0.45	55.00	74.00	154.00	1.00	0.016	0.70	0.05	0.40	0.33	0.018	-7.41	0.03	23.23
	13/G	0.03	39.05	0.65	55.00	74.00	211.00	1.00	0.033	0.30	0.10	0.54	0.33	0.027	-6.73	0.90	23.93
	GV-25/94	0.08	39.13	0.23	22.00	148.00	194.00		0.025			0.49	0.66	0.009			
	GV-64/94	0.07	37.55	0.20	54.00	74.00	141.00	5.00	0.025			0.37	0.34	0.009			

TAB. 4 Contents of REE (ppm) in the Lower-, Upper Carboniferous and Dúbrava Beds carbonates (chondrite values used for normalization after Boynton, 1984)

	LOWER CARBONIFEROUS															UPPER CARBONIFEROUS							DÚBRAVA BEDS						
	14/G	15/G	10/G	Ocht-1	7/G	1/G	Burd-2	Ocht-2	16/G	17/G	19/G	20/G	21/G	4/G-A	4/G-B	2/G	8/G	Bru-1	Bru-1	Bru-1	Bru-1	Bru-1	3/G	9/G	11/G	6/G	5/G	12/G	13/G
																		95.80	76.00	111.50	86.00	114.00							
La	6.80	1.50	1.60	16.50	2.00	9.20	3.80	4.40	0.90	0.90	0.90	1.70	1.30	2.70	2.30	3.40	2.20	8.80	27.00	2.70	15.60	13.40	0.70	3.40	0.80	0.60	1.80	0.300	0.50
Ce	11.30	3.70	3.00	33.80	4.20	19.40	5.70	8.20	3.90	2.70	2.60	2.70	2.60	3.40	6.30	5.10	3.50	15.40	55.80	4.80	44.10	35.40	2.10	9.90	1.70	0.90	6.40	0.900	1.10
Nd	5.00	3.00	2.00	13.00	2.00	8.00	3.00	4.00	2.00	2.00	2.00	1.00	2.00	1.00	3.00	3.00	1.00	7.00	18.00	3.00	12.00	11.00	1.00	4.00	1.00	0.50	3.00	0.500	1.00
Sm	0.72	0.56	0.24	2.36	0.46	0.63	0.50	0.77	0.44	0.70	0.20	0.24	0.26	0.54	0.48	0.48	0.38	1.27	2.51	0.46	2.02	1.81	0.37	0.77	0.12	0.06	0.37	0.060	0.06
Eu	0.31	0.04	0.13	0.84	0.09	0.32	0.13	0.30	0.19	0.29	0.09	0.09	0.11	0.21	0.21	0.40	0.22	0.49	0.71	0.20	0.68	0.60	0.10	0.33	0.01	0.03	0.14	0.020	0.02
Tb	0.20	0.10	0.05	0.60	0.10	0.05	0.20	0.20	0.10	0.30	0.05	0.10	0.05	0.10	0.20	0.10	0.10	0.30	0.40	0.10	0.50	0.40	0.10	0.20	0.05	0.05	0.10	0.050	0.05
Yb	1.00	0.30	0.30	1.60	0.40	0.60	0.60	0.70	0.60	1.00	0.30	0.50	0.40	0.30	0.30	0.50	0.40	1.10	1.40	0.60	1.50	1.40	0.20	0.50	0.10	0.05	0.30	0.050	0.05
Lu	0.16	0.04	0.05	0.22	0.07	0.13	0.10	0.10	0.09	0.16	0.05	0.08	0.06	0.04	0.04	0.06	0.06	0.14	0.22	0.08	0.21	0.23	0.02	0.07	0.01	0.01	0.04	0.005	0.01
La_{cn}	21.94	4.84	5.16	53.23	6.45	29.68	12.26	14.19	2.90	2.90	2.90	5.48	4.19	8.71	7.42	10.97	7.10	28.39	87.10	8.71	50.32	43.23	2.26	10.97	2.58	1.94	5.81	0.970	1.61
Ce_{cn}	13.99	4.58	3.71	41.83	5.20	24.01	7.05	10.15	4.83	3.34	3.22	3.34	3.22	4.21	7.80	6.31	4.33	19.06	69.06	5.94	54.58	43.81	2.60	12.25	2.10	1.11	7.92	1.110	1.36
Nd_{cn}	8.33	5.00	3.33	21.67	3.33	13.33	5.00	6.67	3.33	3.33	3.33	1.67	3.33	1.67	5.00	5.00	1.67	11.67	30.00	5.00	20.00	18.33	1.67	6.67	1.67	0.83	5.00	0.830	1.67
Sm_{cn}	3.69	2.87	1.23	12.10	2.36	3.23	2.56	3.95	2.26	3.59	1.03	1.23	1.33	2.77	2.46	2.46	1.95	6.51	12.87	2.36	10.36	9.28	1.90	3.95	0.62	0.31	1.90	0.310	0.31
Eu_{cn}	4.22	0.54	1.77	11.43	1.22	4.35	1.77	4.08	2.59	3.95	1.22	1.22	1.50	2.86	2.86	5.44	2.99	6.67	9.66	2.72	9.25	8.16	1.36	4.49	0.14	0.41	1.90	0.270	0.27
Tb_{cn}	4.22	2.11	1.05	12.66	2.11	1.05	4.22	4.22	2.11	6.33	1.05	2.11	1.05	2.11	4.22	2.11	2.11	6.33	8.44	2.11	10.55	8.44	2.11	4.22	1.05	1.05	2.11	1.050	1.05
Yb_{cn}	4.78	1.44	1.44	7.66	1.91	2.87	2.87	3.35	2.87	4.78	1.44	2.39	1.91	1.44	1.44	2.39	1.91	5.26	6.70	2.87	7.18	6.70	0.96	2.39	0.48	0.24	1.44	0.240	0.24
Lu_{cn}	4.97	1.24	1.55	6.83	2.17	4.04	3.11	3.11	2.80	4.97	1.55	2.48	1.86	1.24	1.24	1.86	1.86	4.35	6.83	2.48	6.52	7.14	0.62	2.17	0.31	0.31	1.24	0.160	0.31
$(La/Yb)_{cn}$	4.58	3.36	3.32	6.95	3.38	10.34	4.27	4.23	1.03	0.61	2.01	2.29	2.19	6.05	5.15	4.59	3.72	5.40	13.00	3.03	7.01	6.45	2.35	5.05	5.37	8.08	4.03	4.040	6.70
$(La/Lu)_{cn}$	4.41	3.90	3.32	7.79	2.97	7.35	3.94	4.56	1.04	0.58	1.87	2.21	2.25	7.02	5.98	5.90	2.33	6.53	12.75	3.51	7.72	6.05	3.64	5.05	8.32	6.26	4.68	6.060	5.19
$(Eu/Sm)_{cn}$	1.14	0.19	1.44	0.94	0.52	1.35	0.69	1.03	1.15	1.10	1.18	0.99	1.13	1.03	1.16	2.21	1.53	1.02	0.75	1.15	0.89	0.88	0.71	1.14	0.23	1.32	1.00	0.870	0.87
$(Ce/La)_{cn}$	0.63	0.95	0.72	0.78	0.81	0.81	0.57	0.71	1.66	1.15	1.11	0.61	0.77	0.48	1.05	0.57	0.61	0.67	0.79	0.68	1.08	1.01	1.15	1.12	0.81	0.57	1.36	1.140	0.84

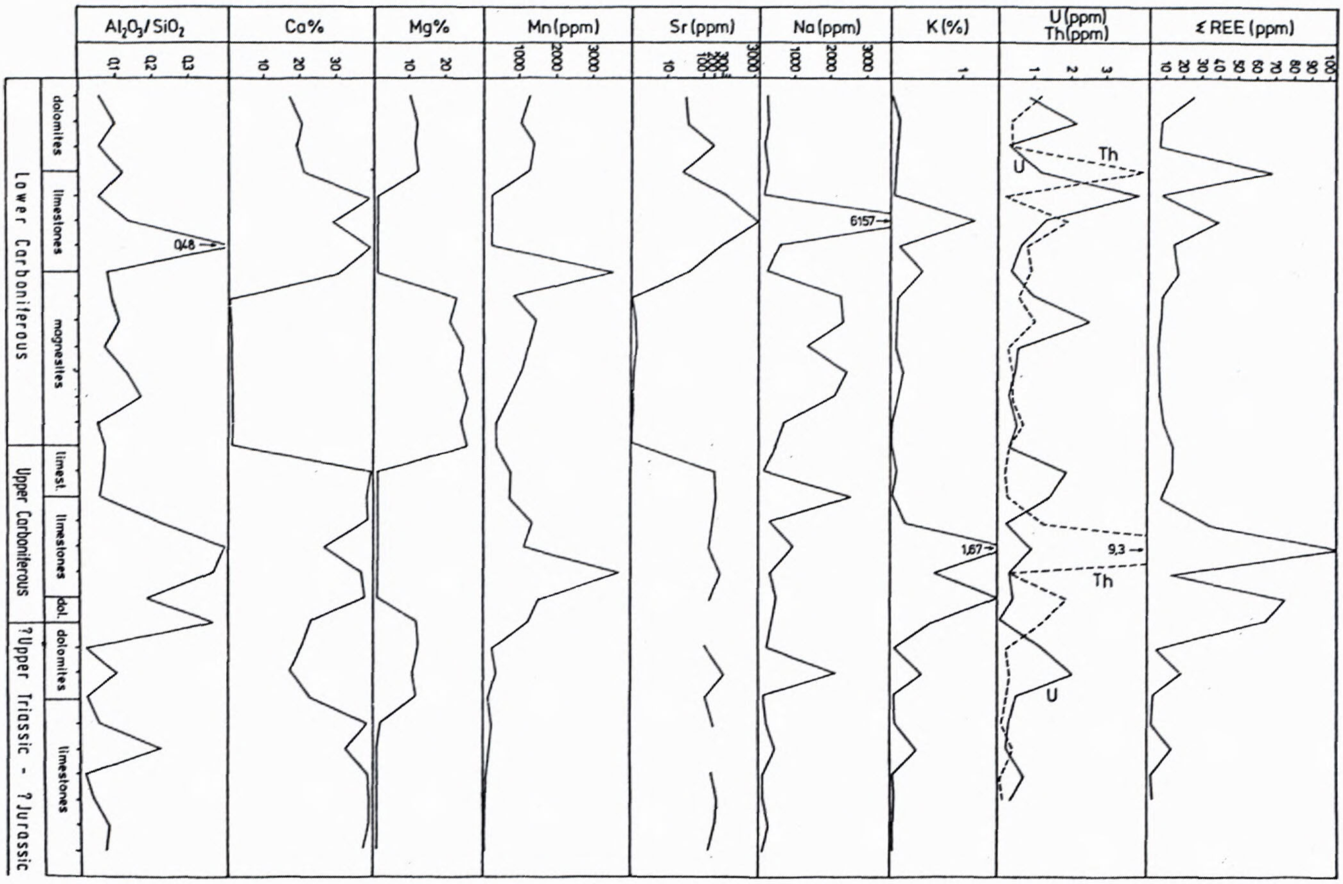


Fig. 2 Distribution of Al_2O_3/SiO_2, Ca, Mg, Mn, Sr, Na, K, U, Th and rare earth elements in carbonates of the Lower and Upper Carboniferous and in the Dúbrava Beds.

reduced due to mixing with meteoric water, leading to increasing Mg/Ca values in dolomite in spite of their decrease in solutions. Mg/Ca values in limestones are low, varying generally within 0.01-0.04. In our case we must assume mixing of the solutions and migration of their salinity in diagenetic as well as later on in the metamorphic processes. However, in spite of approximately same temperature conditions of metamorphism of Lower Carboniferous and ?Mesozoic carbonates significant differences may be observed in their Mn and Sr/Ca values, considered generally the indicators of open diagenetic system.

Mn contents in Carboniferous rocks vary in the order of thousands (dolomites and limestones of the Lower Carboniferous - 1174 ppm, n = 8; dolomites and limestones of the Upper Carboniferous - 1507 ppm, n = 7), while in ?Mesozoic carbonates of the Dúbrava Beds only in tens of ppm (149 ppm, n = 9). Mn contents in magnesites are approximately identical with other types of Lower Carboniferous carbonates (895 ppm, n = 7). Extreme increase of Mn in Carboniferous carbonates may be explained by Mn source in migrating reduction pore water in an open system, during complex post-sedimentary alterations.

Sr contents in Lower Carboniferous carbonates are considerably higher than in associated dolomites and magnesites (limestones = 36-3395 ppm; dolomites = 29-124 ppm; magnesites = 1-36 ppm), due to their greater capacity to substitute Sr for Ca (Fig.2, 3). Upper Carboniferous limestones have relatively levelled Sr contents, in the range of 170-288 ppm, but generally lower than average values presented in literature. Similar Sr contents have been determined also in carbonates of the Dúbrava Beds, while there are no greater differences between dolomites and limestones (limestones = 141-211 ppm; dolomites = 124-355 ppm).

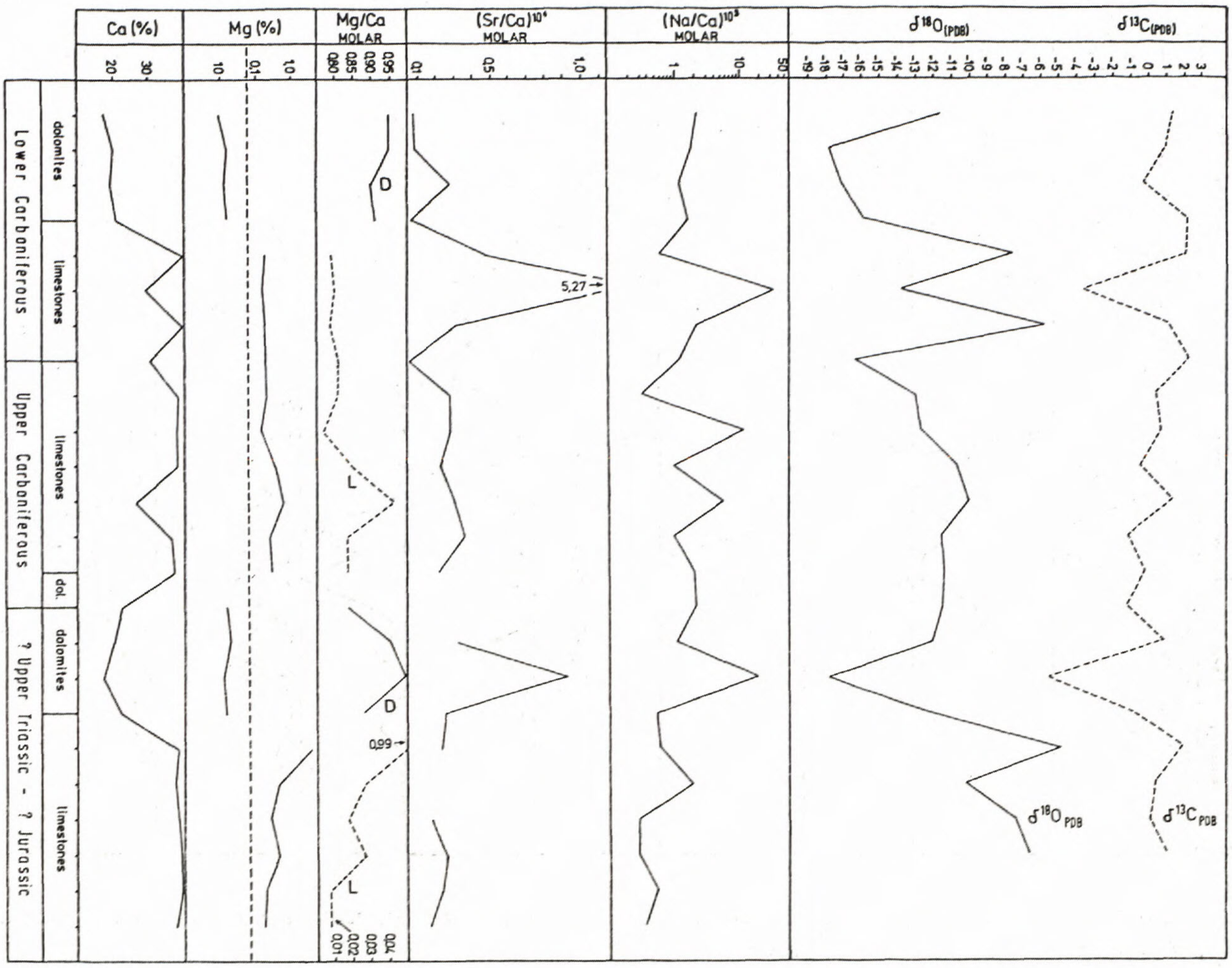


Fig. 3 Relationship of Mg, Sr, Na to Ca and isotopes of oxygen and carbon in dolomites and limestones of the Lower and Upper Carboniferous and in the Dúbrava Beds.

The relationship between Sr (expressed as 1000·Sr/Ca) and Mn (in ppm) provides information on the original sedimentation environment and diagenetic conditions (BRAND and VEIZER, 1980). In the analysed set of limestone samples, a marked division may be observed in the Sr as well as Mn contents (Fig. 4). Limestones of the Dúbrava Beds have relatively low Sr/Ca as well as Mn. On the Sr/Ca vs. Mn (Fig. 4) diagram they are all lying in a relatively narrow interval, in the high-Mg-calcite zone, within Mn values not exceeding $x \pm s$, and thus also the degree of openness of the diagenetic system. It must be assumed that during the complex post-diagenetic alterations of these limestones Sr was strongly depleted. It is probable that the original composition corresponded to HMC, with normal Mn values. Almost all Carboniferous limestones display increased Sr/Ca values as well as Mn, in the major part of them they are extremely high. In a part of them Mn values do not indicate exceeding of the degree of system openness, while Sr was depleted less than in the previous group. This may indicate than at least a part of the carbonate in original samples was open low-Mg calcite (original sparite cement) and/or aragonite. A substantial part of the Carboniferous limestones is depleted in Sr and at the same time enriched in Mn. This means that the whole diagenetic system was open and considerably influenced by meteoric water and, later on, also by chemistry of metamorphic fluids.

Na contents are generally higher in carbonates of the Carboniferous than in the Dúbrava Beds. This applies to limestones as well as dolomites. Generally highest average Na values are in magnesites. Considering that Na contents and values of Mg/Ca, Sr/Ca and Na/Ca may be indicators of salinity in the sedimentation environment (LAND and HOOPS, 1973; SASS and KATZ, 1982), Carboniferous and Dúbrava Beds carbonates formed in different sedimentation environment. Carboniferous carbonates formed probably in generally shallow, subtidal environment, not excluding alternation with higher-salinity conditions. This suggests dolomite formation as the result of early diagenetic alteration of aragonite sediment. This would be indicated by positive correlation between Sr/Ca and Na/Ca and antipathetic covariance with Mg/Ca. Distribution of δO^{18} and δC^{13} shows in dolomites and limestone negative correlation with Sr/Ca and Na/Ca (Fig.3). Some extreme Na contents are probably connected with enrichment during metamorphic processes and it is thus not possible to interpret them from the viewpoint of sedimentation environment.

Marked dependence between Th, K and Al_2O_3 concentration was determined only in limestones of the Upper Carboniferous Turiec Formation. In other sample sets the contents of K, Th,U do not correlate positively with maximums of Al_2O_3/SiO_2. This means that they may be boded also in carbonates. In general, anomalous U and Th contents have not been determined in any of the samples. However, Th quantities show good positive correlation with rare earths.

The carbonate sets display certain differences in the distribution, but above all in total REE contents (Fig. 1; 5a,b,c,d). This is a reflection of their mineralogical composition and probably, to a certain extent, of their different paleo-setting. A common feature of all three sets is their strong enrichment with LREE with approximately same steepness of the distribution curve, as well as identical trend of REE enrichment depending on the chemical composition of carbonates. In all three sets the highest REE contents were determined in dolomites. There are substantial differences in REE totals and the character of Eu anomaly (Tab. 4).

Average REE contents in the set of Lower Carboniferous carbonates are following: dolomites ® x = 27.75 ppm (s.d. = 28.62; v. = 819.3; n = 4); lime-

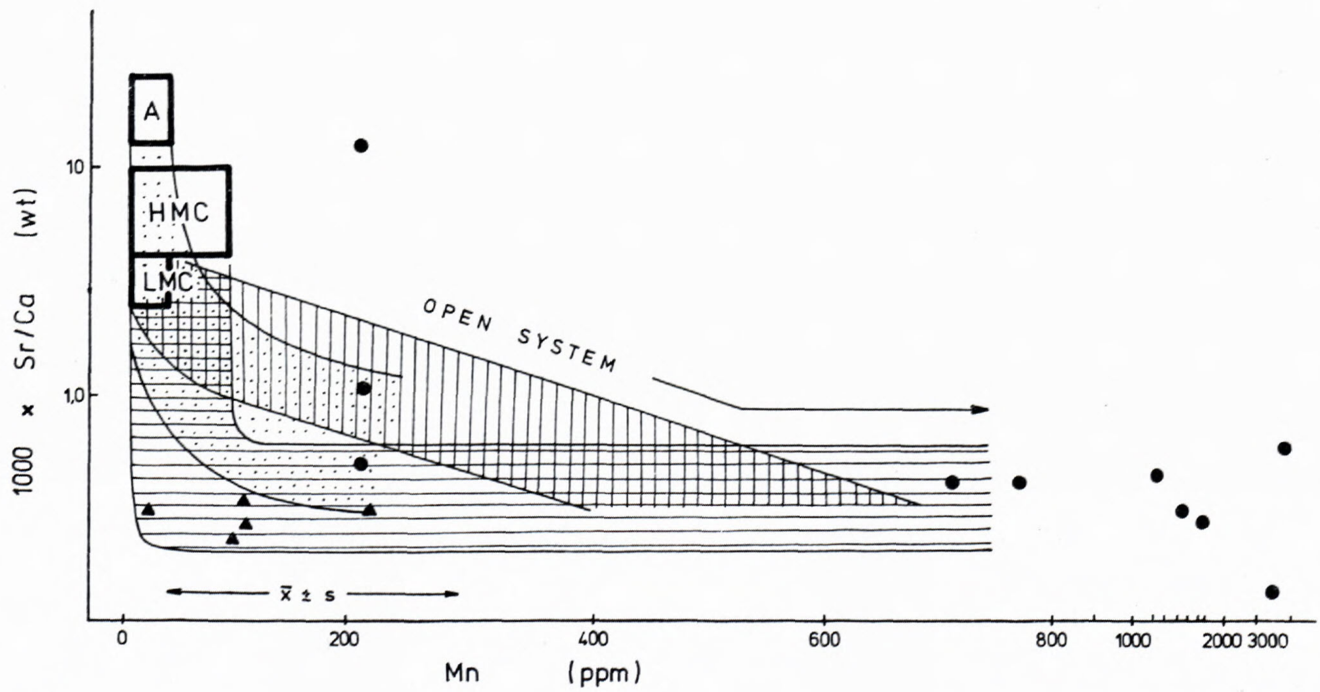


Fig. 4 Relationship between Sr (expressed as 1000 Sr/Ca) and Mn, studied in samples of the Lower and Upper Carboniferous and in the Dúbrava Beds. Diagram after BRAND-VEIZER (1980).

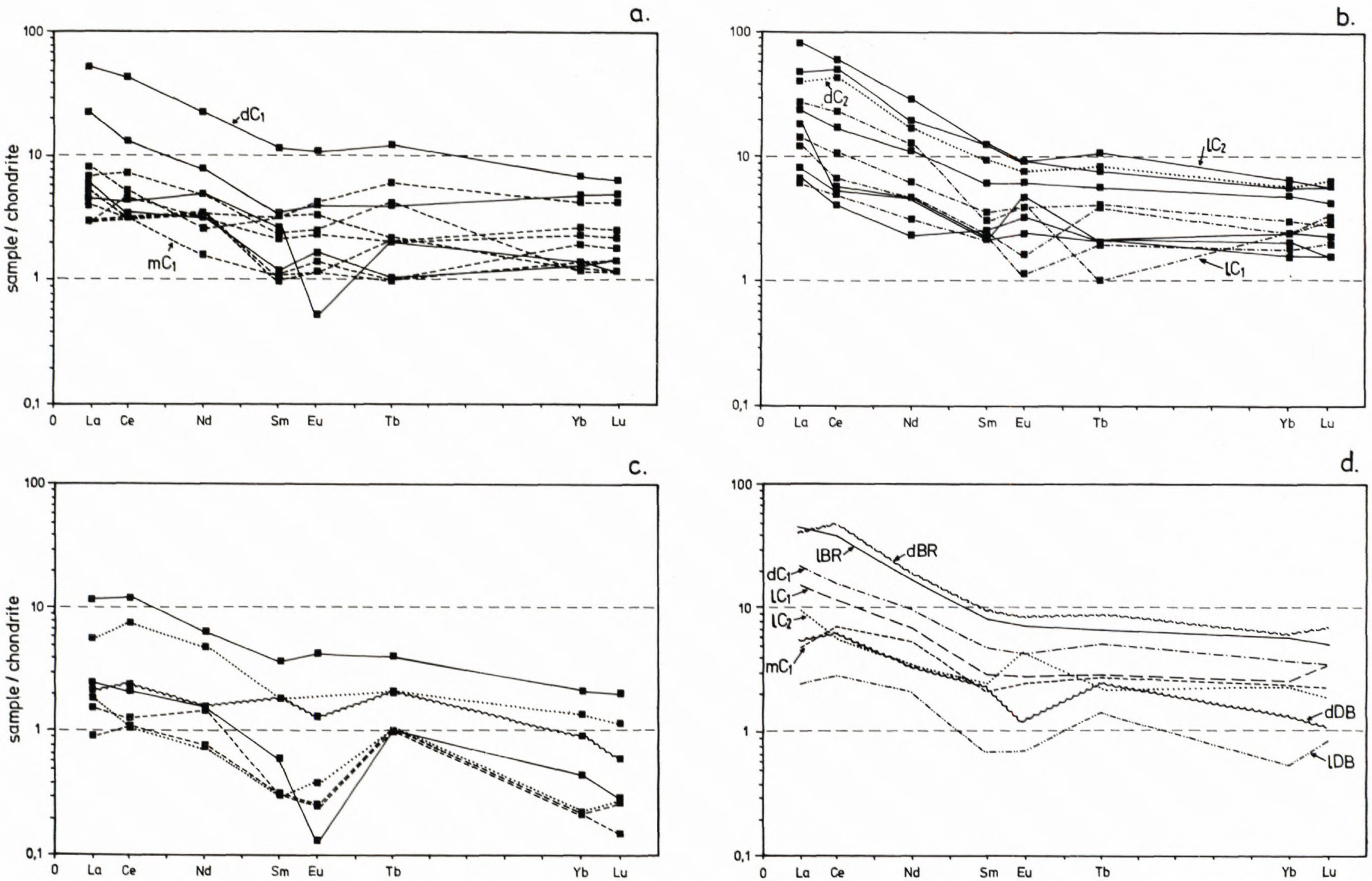


Fig. 5 Chondrite-normalized distribution curves of rare earth elements. a) dolomites (dC1) and magnesites (mC1) of the Lower Carboniferous, b) limestones of the Lower Carboniferous (lC1), limestones (lC2) and dolomites (dC2) of the Upper Carboniferous, c) limestones (dashed and dotted line) and dolomites (full and undulating line) of the Bôrka Nappe, d) average distribution curves for limestones (lC1), dolomites (dC1), and magnesites (mC1) of the Ochtiná Formation, limestones of the Zlatník Formation (lC2), limestones (lBr) and dolomites (dBr) of the Turiec Formation from the borehole BRU-1 (Turňa Nappe), limestones (lDb) and dolomites (dDb) of Dúbrava Beds, Bôrka Nappe. All values normalised after BOYNTON *(1984).*

stones ® x = 20.06 ppm (s.d. = 12.75; v. = 162.6; n = 4); magnesites ® x=8.11 ppm (s.d. = 2.26; v.= 5.11; n = 8). Dolomites and limestones have approximately the same course of the distribution curve, with average contents of $(Eu/Sm)_{cn}$ = 0.90-0.94 and $(La/Lu)_{cn}$ = 5.84-5.03. Slightly positive Eu anomalies are displayed by samples with higher contents of Na, Mn and in the case of limestones also Sr. The distribution curve in magnesites is relatively the flattest, with slightly positive Eu anomaly, correlating with their higher Na and Mn contents ($(Eu/Sm)_{cn}$ = 1.10; $(La/Lu)_{cn}$ = 2.14).

Upper Carboniferous limestones display considerable differences in the total REE contents. In the Northern Gemericum unit, in the Zlatník Formation, average REE content is 10.45 ppm (s.d.= 3.66; v. = 13.4; n = 2) and in the Turňa Nappe, in the Turiec Formation, average REE contents reach as much as 57.27 ppm (s.d. = 42.1; v. = 1775.4; n = 4). This trend is preserved also in the dolomite sample (REE = 64.01). High REE contents are directly depending on increased quantity of the originally clayey admixture in these rocks, which was enriched in organic substance. Distribution curves of the Turiec Formation carbonates have more marked LREE and HREE fractionation, with corresponding average $(La/Lu)_{cn}$ = 8.64 values in the Turiec and 4.85 in the Zlatník Formation. While limestones of the Zlatník Formation display slight positive Eu anomaly (average value $(Eu/Sm)_{cn}$ = 1.13), in the Turiec Formation they have negative Eu anomaly - (Eu/Sm) = 0.88.

Carbonates of the Dúbrava Beds are characterized by the lowest REE contents from the studied sets. The same trend is preserved here as well, i.e. higher quantities in dolomites (x=8.66 ppm; s.d.=8.66; v.=74.9; n=3) than in limestones (x = 4.75 ppm; s.d.= 4.94; v = 24.4; n = 4). Moreover, dolomites are depleted in Eu (average value $(Eu/Sm)_{cn}$ = 0.50), while the average chondrite-normalized Eu/Sm value in limestones is 1. LREE vs. HREE fractionation is in both carbonate types approximately the same.

From the above analysis it follows that rare earth distribution and their total contents are associated with i) phyllosilicates, thus in pre-metamorphic state clayey component, and ii) substitution with Ca, Th, Mn, Na and Sr. Fig. 6 shows relationships of REE contents and their LREE enrichment to CaO and Al_2O_3. Carbonates of the Dúbrava Beds are in comparison with other sets significantly depleted in REE and, at the same time, on the chondrite-normalized curve they display relatively higher HREE enrichment in relation to LREE, in comparison with carbonate sets of the Lower and Upper Carboniferous (Fig. 5d). This means that their composition was less affected by terrigenous source and, to the contrary, the source of HREE enrichment was most probably synsedimentary volcanism. They formed in an area more distant from the continent, in deeper sedimentation environment, and, on the contrary, carbonates of the Lower and Upper Carboniferous of Gemericum formed in a shallow basin situated near the continent. The latter is supported by lithological characteristics as well as the character of found fauna communities.

REE contents in Lower and Upper Carboniferous carbonates of Gemericum as well as Turnaicum are similar to typical REE curves presented by Ronov et al. (1974) for sedimentary carbonates as well as for sparite-magnesite deposits of the Eastern Alps (Morteani et al., 1982). Dolomites and limestones of the Dúbrava Beds, on the contrary, with their low REE contents, negative Eu anomaly and relative HREE enrichment in relation to LREE, remind of the isotope composition of oceanic water (Hogdahl et al., 1968). Generally it may be stated that Carboniferous sets enriched in rare earth elements display positive Eu anomaly, or at least a very flat course of the normalized curve. To the contrary, decrease of the bulk rare earth contents in carbonates of the Dúbrava Beds is directly proportional to the negative Eu anomaly (Fig. 5d). In the majority of Lower Carboniferous samples there is a slightly negative Ce anomaly. According to Morteani et al. (1982), this anomaly indicates marine sedimentation environment. However, it was also documented that the clay component may mask this anomaly.

Generally, we may observe a depletion of LREE in magnesites in comparison with associated limestones and dolomites. This may be evidence that magnesites formed by Mg-metasomatism of pre-existing carbonates. This may have been caused by the fact that Mg^+ ion has a radius more similar to HREE and thus LREE are during Mg-metasomatism substituted along with Ca^+. Morteani et al. (1982), Kiesl et al. (1990) as well as Morteani and Neugebauer (1990) explain this process by Mg-metasomatism of pre-existing dolomites, either by higher-temperature fluids generated in the process of low-grade regional metamorphism, or by irregular increase of geothermal gradient caused by thrusting. The theory of Mg-metasomatic origin of magnesites is supported also by enrichment in Ni, Co, Cr and Sc in Lower Carboniferous dolomites and magnesites, while these con-

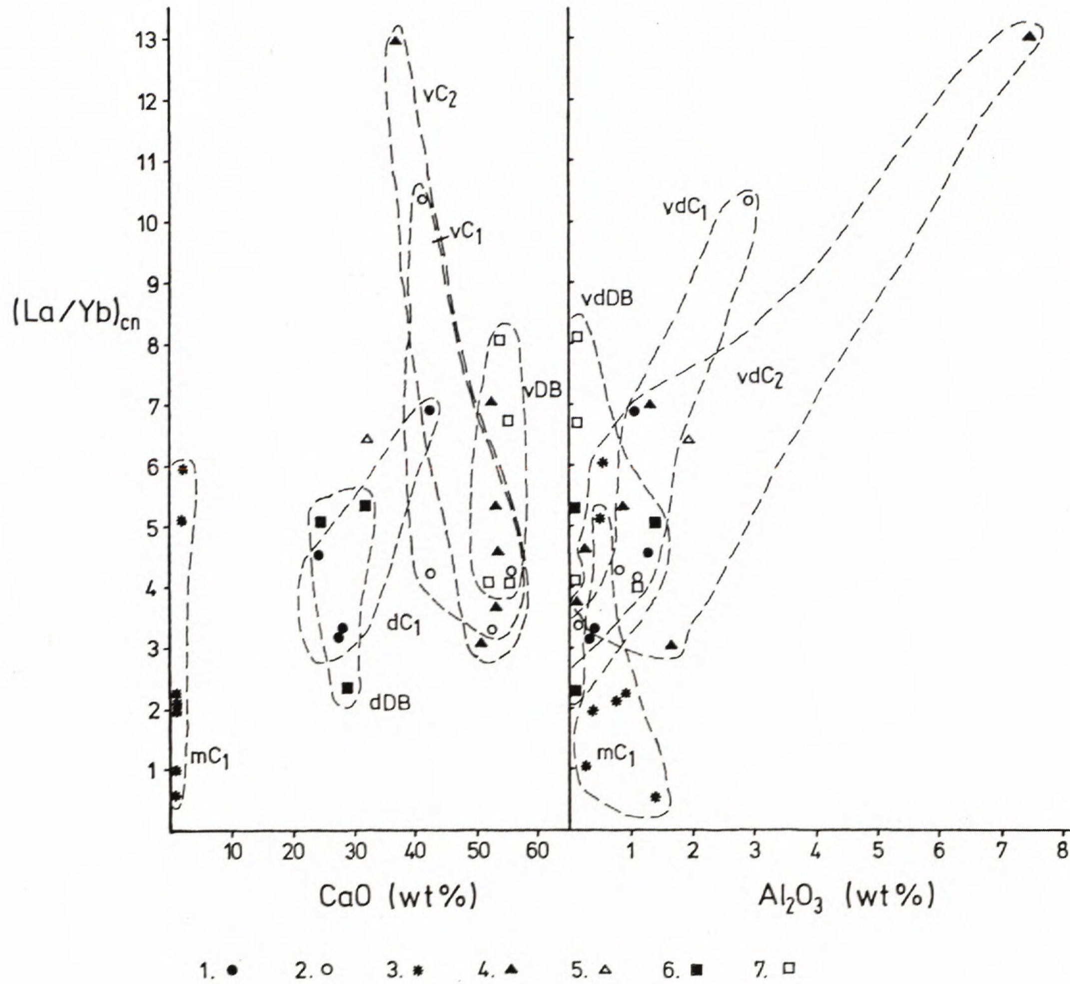


Fig. 6 The relationship of (La/Yb)cn to CaO (wt.%) and Al_2O_3 (wt.%). Explanations: carbonates of the Lower Carboniferous - 1– dolomite dC1 (full circle); .2– limestone vC1 (empty circle); 3– magnesite mC1 (asterisk); carbonates of the Upper Carboniferous - 4 – limestone vC2 (full triangle); 5 – dolomite dC2 (empty triangle); Mesozoic carbonates of the Bôrka Nappe - 6 – limestone vDB (empty square); 7–. dolomite dDB (full square).

tents evidently do not correlate with increased Al (in contrast to carbonates from the borehole BRU-1).

From other micro-elements, there have been determined the contents of B, Ba, Co, Cr, Cu, Li, Ni, Pb, Rb, V, Y, Zn and Zr. From them, B, Ni, Cr, Co, Cu, Y, Sc and in a limited number of samples also U and Th exceed average values for carbonates (Tab. 2).

Isotope Composition of Oxygen and Carbon

Data on isotope composition of carbonates from the Western Carpathian area are available in the works of DEMOVIČ et al. (1972), VEIZER et al. (1976), KANTOR et al. (1981-1993), HLADÍKOVÁ et al. (1987), LINTEROVÁ et al. (1992). They brought information predominantly on isotope composition of limestones and dolomites of Mesozoic and younger age.

Into this work we included, besides Carboniferous carbonates of Gemericum, Turnaicum and Dúbrava beds, for comparison also samples of carbonates of the Silica Nappe, from further occurrences of the Bôrka Nappe, from the Foederata Group of the Southern Veporicum envelope, from Turnaicum in the borehole DRŽ-1 as well as further samples from the magnesite deposit Bankov near Košice (samples from the collection of dr. Ďurkovičová and from the depository of the Department of Isotope Geology at GÚDŠ, Tab. 5).

Methods

For analyses of isotope composition of oxygen and carbon we selected 73 bulk samples of limestones, dolomites and magnesites. In some samples we analyzed also secondary veins. The homogeneity and mineral composition of the samples were checked radiometrically. 20-30 mg of a sample were used for the analysis, the samples were crushed in agate mortar, heated in vacuum at 470 °C for 30 min. to remove organic carbon. CO_2 was released by a reaction with 100 % H_3PO_4 at 25 °C for calcites and 100 °C for magnesites and dolomites. Gaseous CO_2 samples were measured by standard method on a mass spectrometer MAT 250.

The isotope ratios of $^{18}O/^{16}O$ and $^{13}C/^{12}C$ were investigated in carbonate minerals, presented as d per mil, in relation to international standards in PDB or SMOW. The results of isotope analyses are listed in Tabs. 5, 6 and shown on Figs. 7-9.

Interpretation of results

The Črmeľ Group

3 samples were analysed - 2 magnesites from Kavečany, with different structure (coarse-grained and nodular) and laminated limestone from the Črmeľ Valley.

All samples are characterised by high contents of the light carbon isotope - with values of $\delta^{13}C_{PDB}$ of -3.87 to -4.03 ‰ - different from other magnesite samples. Due to limited number of analyses it is now difficult to comment the low values of $\delta\ ^{13}C_{PDB}$, however, the high Sr/Ca and Na/Ca ratios allow to assume that these rocks sedimented originally in shallow marine environment. It is not possible to exclude yet an influence of interstitial solution chemistry in the post-diagenetic processes resulting from genetic relationship with basic rocks. A more precise answer to this problem requires analyses of a greater number of samples.

The Ochtiná Formation

This formation contains the largest number of analysed samples (31). Mineralogically they are limestones, dolomites and predominantly magnesites.

Data on isotope composition indicate evident smaller variance of the values of $\delta\ ^{13}C_{PDB}$ and great differences of the isotope composition of oxygen. The lowest light oxygen isotope contents yield limestone samples from the localities of Burda and Markuška. The values of $\delta\ ^{18}O_{PDB}$ and $\delta\ ^{13}C_{PDB}$ approach values for marine unaltered Carboniferous sediments from the Gobler Formation in the Sacramento Mts. (ALGEO et al., 1992). MARGARITZ et al. (1°990) studied isotope composition of marine limestones of Upper Carboniferous age in North America and the determined the values of $\delta\ ^{13}C_{PDB}$ are in the range of +2 to +4‰ and $^{18}O_{PDB}$ -9.6 to -3.8‰. MEYERS and LOHMAN (1985) mentioned for marine limestones of Mississipian age $\delta\ ^{13}C_{PDB}$ of +4‰ and $^{18}O_{PDB}$ -1.5‰.

Isotope composition of least altered carbonate rocks of the Ochtiná Formation is consistent with the range mentioned by Veizer et al. (l.c.) for Carboniferous limestones and dolomites. For the sample with the lowest content of light oxygen isotope we calculated the value of sea water paleotemperature in the Carboniferous (Tab.7), it however yielded an unrealistic value, which confirms opinions on increasing light oxygen isotope contents during geological stages by gradual equilibration of marine limestones with isotopically lighter meteoric water. The decrease of the values in our samples represents for $\delta\ ^{18}O_{PDB}$ 3 to 4‰.

Another group of samples distinguished in the Ochtiná Formation on the basis of isotope composition of oxygen consists of limestones and dolomites from the borehole KV-6 (Košice-Bankov) and dolomite from Dúbrava (mine Miková), with mean values of $^{18}O_{PDB}$ -12.31 to -10.50‰. Isotope composition of oxygen in the rest of dolomite and magnesite samples is relatively homogenous, in the range of -17.99 to .14.99‰. Isotope composition of carbon for all 3 distinguished sample groups indicates marine origin of carbonate sediments altered into magnesites. An exception is only a magnesite sample from secondary vein the $\delta\ ^{13}C_{PDB}$ of which, -5.51‰, indicates probable presence of meteoric water during its formation. Isotope composition of carbon in the studied magnesites in the range of -1.55 to +2.37‰ leads to the assumption that alteration of limestones into dolomites and magnesites was caused by solutions not very different from marine water, at increased temperatures.

. KRALIK et al. (1989) summarised the results of isotope analyses of magnesites and classified them in 3 groups:

1. Cryptocrystalline to fine-grained magnesites genetically associated with ultrabasic rocks have carbonisotope composition in the range of $\delta\ ^{13}C_{PDB}$ -6 to -18‰ and the values of $\delta\ ^{18}O_{SMOW}$ +22 to +29‰.

2. Fine-grained Qarternary to recent magnesites forming in evaporite environment are characterised by high contents of heavy carbon as well as oxygen isotopes ($\delta\ ^{13}C_{PDB}$ +1.7 to +4.6‰ and $^{18}O_{SMOW}$ +32 to +38‰). Older magnesites of this type forming

extensive stratiform deposits have $\delta\ ^{13}C_{PDB}$ +2 to +3‰ and $^{18}O_{SMOW}$ +25 to +37‰. Smaller unconnected layers and concretions have $\delta\ ^{13}C_{PDB}$ -2 to -6‰ and $^{18}O_{SMOW}$ +18 to +22‰. To this group have been assigned also magnesites of Eastern Alps and Western Carpathians (sedimentary magnesites genetically connected with evaporites of Upper Permian - Lower Triassic age, Smižany, Nov. Huta).

3. Coarse-grained magnesites having a wide range of $\delta\ ^{13}C_{PDB}$, -7.5 to +4‰ as well as $^{18}O_{SMOW}$ values - +13 to +17‰.

The analytical results of Lower Carboniferous magnesites show rather that the majority of samples belongs to group No.3. On the basis of isotope analyses of C, O and rare earth element, as well as of selected elements contents we may consider that the genesis of the Lower Carboniferous magnesites was complicated, polygenetic. Relatively high Na contents in magnesites as well as Sr contents in some associated samples of limestones and dolomites, as well as the distribution of Sr/Ca and Mn, in spite of their low-metamorphic alteration, is evidence of their probable formation in shallow-marine, in some places not excluding even evaporite environment. REE contents, which are higher than in typical sedimentary magnesites, as well as the course of normalised REE curve and marked Mn-enrichment signalise Mg input by metasomatic processes. The assumed Mg source may be derived from the associated basic and ultrabasic rocks as well as intraformational crinoid detritus, with high MgCO3 contents (Bathurst, 1975, Neugebauer, 1978). Estimated temperatures of low-metamorphic solutions attained 300-350 °C, and thus we may assume that magnesite formed at temperature increase and almost constant Ca/Ca+Mg (Cc+Dol + +Mgs equilibrium reaction according to T-X diagram of Johannes, 1970).

Zlatník Formation

We analysed 3 samples from rocks of this formation, collected in the surroundings of Dobšiná. In two of them (2/G, 8/G) there were abundant secondary veinlets, which were subjected to analysis as well. Isotope composition of oxygen as well as carbon of these samples is very similar and comparable with values determined in the borehole BRU-1, in its upper parts. Isotope composition of the secondary veinlets is also not very different. The third sample, Dobšiná-Hámor (22/G) has substantially different isotope composition. The grade of alteration recorded in petrographic description as well as geological setting - a scale on the contact of the Hámor Formation and Rakovec Group - indicate the possibility of higher-grade metamorphism, which is reflected in the oxygen isotope composition similar to values characteristic for dolomites and magnesites of the Ochtiná Formation. Isotope composition of carbon in this sample indicates that it formed in marine environment and its metamorphism occurred at higher temperatures without participation of light carbon of organogenic origin.

Turiec Formation - borehole BRU-1

Differences in the isotope composition of oxygen are not significant, they vary within $\delta\ ^{18}{}_{OPDB}$ -11.85 to -9.93 ‰. More marked are differences in the isotope composition of carbon. Towards greater depth the values become more negative - lighter isotope content increases. Differences in isotope composition of carbon may have been caused by the inhomogeneity of the original sediment (olistoliths of shallow- as well as deep-water carbonates mixed within one horizon). Decrease of $\delta^{13}C_{PDB}$ values may have been affected by CO_2, released by decomposition of organic substance abundant in the rocks. Isotope analyses of secondary veinlets separated from limestones of three deeper levels indicate higher contents of light C isotope than in the original sediment.

Dúbrava Beds

Unclear stratigraphic classification of some localities of the Dúbrava Beds initiated the investigation of isotope composition of carbonate rocks in this area. Five of the studied 6 samples occupy on the O/C diagram (Fig. 7) a field with $\delta^{13}C_{PDB}$ = -0.92 to 0.80 ‰ and $\delta^{18}O_{PDB}$ = -12.19 to -6.73 ‰. An exception is the sample from the locality Hrádok, having substantially different oxygen ($\delta^{18}O_{PDB}$ = -17.94 ‰) as well as carbon ($\delta^{13}C_{PDB}$ = -5.59 ‰) isotope composition, enriched substantially in light isotopes of both elements. At the first five samples (Chyžné 12/G, 13/G, Ochtiná 5/G, Markuška 3/G and Jelšava 5/G) the differences in carbon isotope composition are small, they vary in the range of -1 to +1 ‰. They are similar to marine shallow-water sediments, at the diagenesis of which meteoric water played an important role. Differences in the

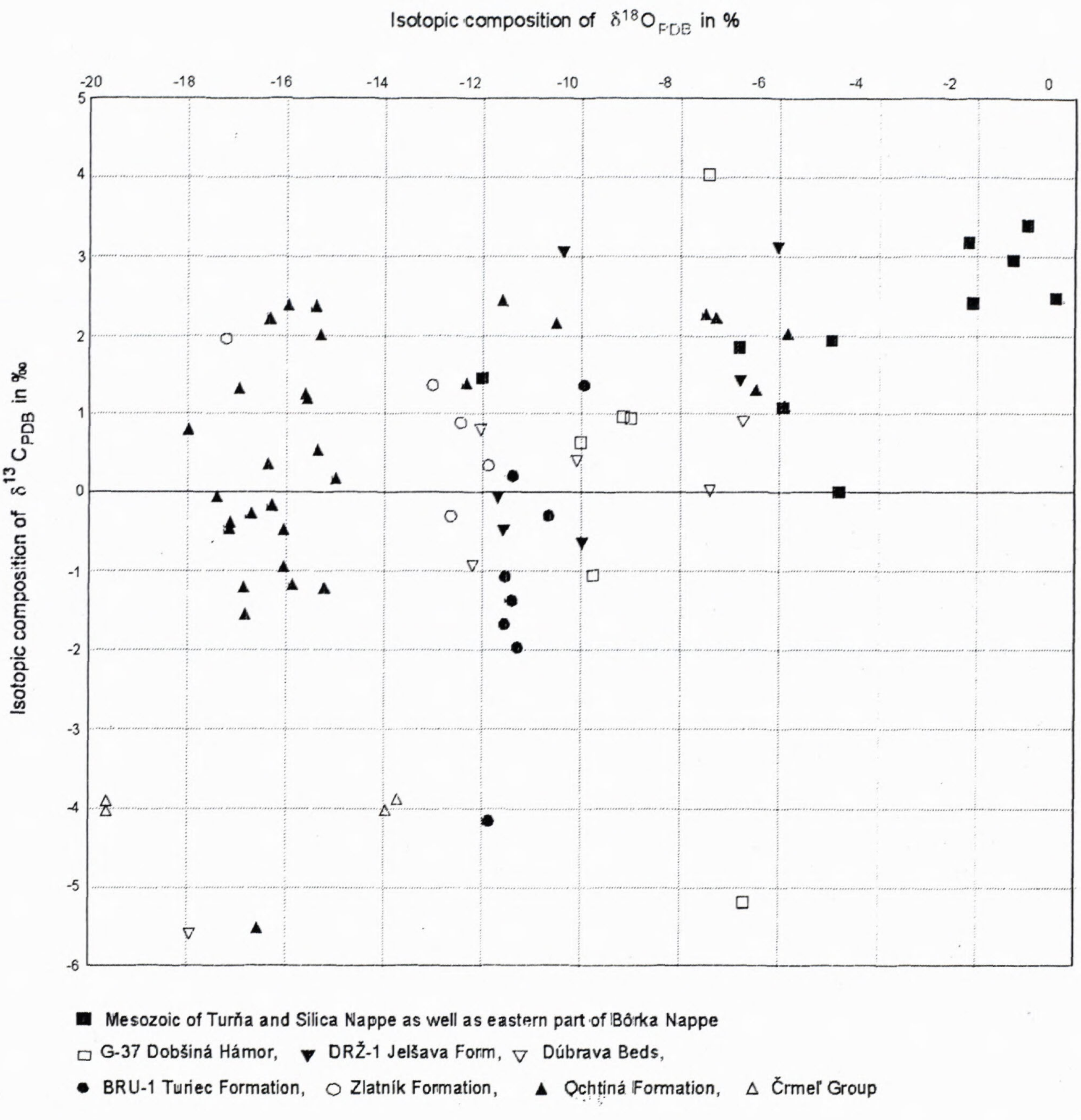
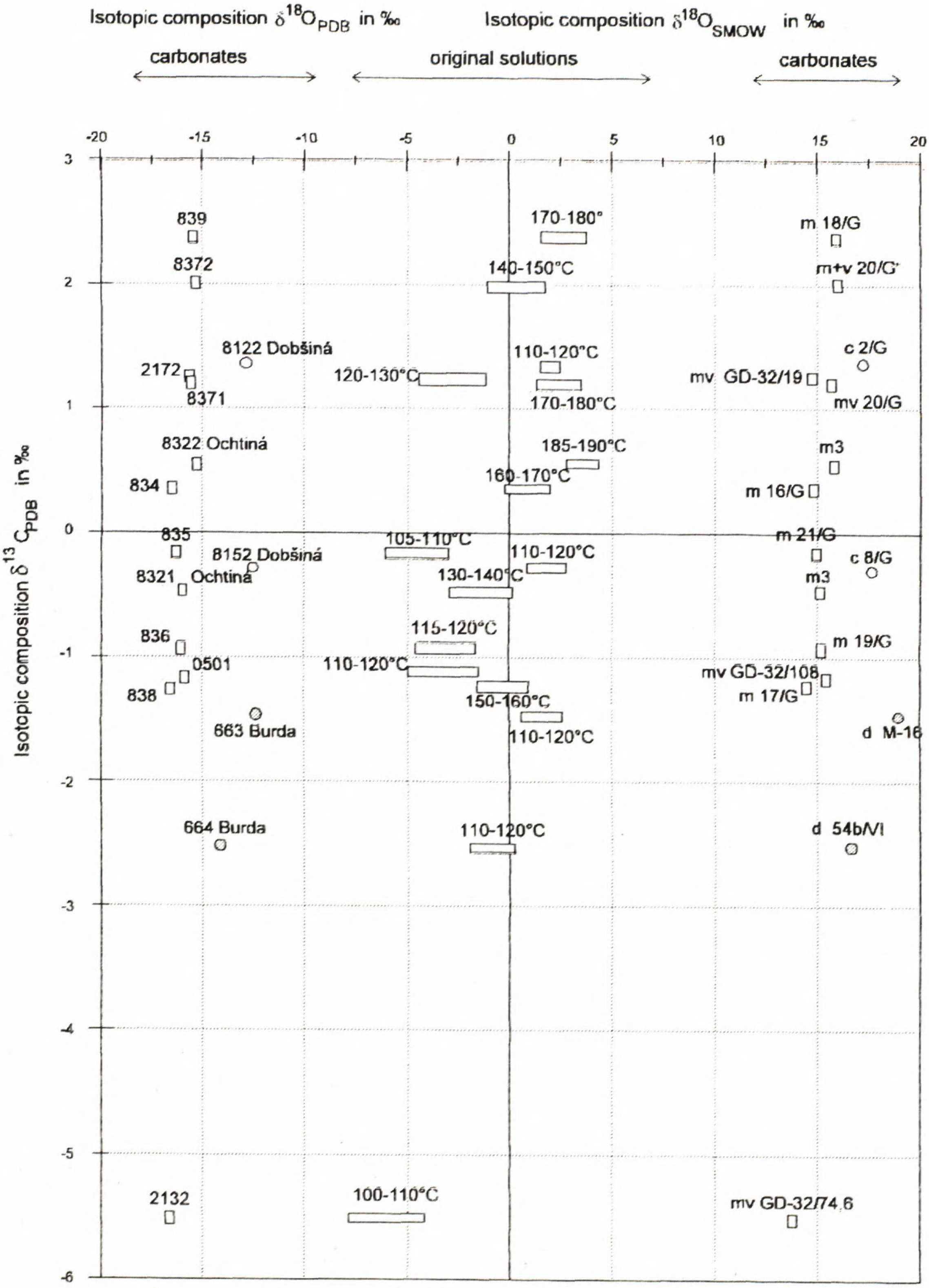


Fig. 7 Isotope composition of oxygen and carbon in the studied carbonates.

isotope composition of oxygen are more significant. Samples of Chyžné 12/G, 13/G have $\delta^{18}O_{PDB}$ values near to -7 ‰, similarly as higher-metamorphosed Mesozoic limestones. The other 3 samples (limestones from Ochtiná and dolomite from Jelšava) approach by their isotope composition of $\delta^{18}O_{PDB}$ = -12.19 to -10.08 ‰ the composition of carbonates from the Zlatník Formation, Brusník anticline as well as the borehole G-37. Very marked is the distribution of projection points on the graph of O/C isotope relationship (Fig. 7). Metamorphic manifestations and pressure effects of the same character have been recorded in petrographic description of samples of these rocks. It is evident that isotope composition of C and O in the described set of carbonates had been influenced primarily by metamorphic solutions. The relationship of Sr/Ca to Mn, the generally low REE contents and relative enrichment in LREE indicate, in controversy with isotope composition, rather deep-water environment of origin.



c - calcite, d - dolomite, m - magnesite, v - vein or veinlet

xxxx - laboratory number (on the left side of the Fig.) xxXX - geological number (on the right side of the Fig.)

xxx-xxx°C - TVI decrepitation temperatures

▭ - assumpionaly range of the isotopic compositioin of the original solutions

Fig. 8 Isotope composition of carbonates and their source solutions with TVI temperatures.

tab. 5

Laboratory number	Carbonate	*Zones of metamorphism	Geological number	Lokality	Occurrence	Formation	Age	Measured isotopic composition of carbonates in permil δ 13CPDB	δ 18OPDB	δ 18OSMOW
O1 623	limestone			Dobšiná	ice cave		Senonian	0.01	-4.79	25.92
O1 891	limestone	ANC	5/92	Bôrka		Bôrka Nappe	Jurassic?	1.46	-12.00	18.50
O1 885	limestone	DIA	7/92	Ostrý vrch		Silica Nappe	Norian	2.96	-1.26	29.57
O1 890	limestone	DIA	11/92	Silická Brezová	quarry	Silica Nappe	Norian	2.47	-0.40	30.46
O1 887	limestone	DIA	12/92	Silická Brezová	quarry	Silica Nappe	Middle Norian	3.41	-0.99	29.84
O1 883	limestone	ANC	4/92	Dvorníky		Turňa Nappe	Karnian	1.08	-5.93	24.75
O1 892	limestone	UPGSF	6/92	Medzev		Bôrka Nappe	Karnian	1.85	-6.81	23.85
O1 888	limestone	ANC	10/92	Jelšavská Teplica		Turňa Nappe	Karnian	3.18	-2.17	28.63
O1 886	limestone	ANC	9/92	Jelšavská Teplica		Turňa Nappe	Anisian	2.42	-2.09	28.71
O1 810	limestone	ANC-GSF	6/G	Honce	quarry	Turňa Nappe	Middle-Late Triassic	1.94	-4.95	25.76
O1 825	dolomite	UPGSF	11/G	Jelšava	old quarry	Dúbrava Beds	Jurassic?	-0.92	-12.19	19.51
O1 829	limestone	UPGSF	13/G	Chyžné	quarry, S from the Chyžné	Dúbrava Beds	Jurassic?	0.90	-6.73	23.93
O1 820	limestone	UPGSF	12/G	Chyžné	quarry, S from the Chyžné	Dúbrava Beds	Jurassic?	0.03	-7.41	23.23
O1 809	limestone	UPGSF	5/G	Ochtiná	quarry	Dúbrava Beds	Jurassic?	0.41	-10.08	20.47
O1 811	limestone	UPGSF	3/G	Markuška	quarry	Dúbrava Beds	Jurassic?	0.80	-12.03	18.46
O1 824	dolomite	UPGSF	9/G	Hrádok	exposure	Dúbrava Beds	Jurassic?	-5.59	-17.94	13.58
O1 494	limestone	GSF		Dobšiná-Hámor	borehole G-37/652,5	Foederata Group	Triassic	0.64	-10.01	20.54
O1 490	limestone	GSF		Dobšiná-Hámor	borehole G-37/850,5	Foederata Group	Triassic	-1.05	-9.75	20.81
O1 492	limestone	GSF		Dobšiná-Hámor	borehole G-37/879,0	Foederata Group	Triassic	4.05	-7.44	23.20
O1 4912	dolomite	GSF		Dobšiná-Hámor	borehole G-37/882,0	Foederata Group	Triassic	0.97	-9.16	21.42
O1 4911	limestone	GSF		Dobšiná-Hámor	borehole G-37/882,0	Foederata Group	Triassic	-5.19	-6.69	23.97
O1 489	limestone	GSF		Dobšiná-Hámor	borehole G-37/898,0	Foederata Group	Triassic	0.95	-9.00	21.59
O1 914	calcite	DIA-ANC		Držkovce	borehole DRŽ-1/179,1-4	Jelšava Formation	Lower Triassic	3.06	-10.37	20.18
O1 913	limestone	DIA-ANC		Držkovce	borehole DRŽ-1/236,6-237	Jelšava Formation	Lower Triassic	-0.65	-9.96	20.60
O1 915	limestone	DIA-ANC		Držkovce	borehole DRŽ-1/418,5-8	Jelšava Formation	Lower Triassic	-0.48	-11.56	18.95
O1 912	limestone	DIA-ANC		Držkovce	borehole DRŽ-1/443,6-444	Jelšava Formation	Lower Triassic	-0.07	-11.68	18.83
O1 916	dolomite	DIA-ANC		Držkovce	borehole DRŽ-1/1183,7	Perkupa Formation	U. Permian - L. Triassic	1.43	-6.79	25.08
O1 908	dolomite	DIA-ANC		Držkovce	borehole DRŽ-1/1203,8	Perkupa Formation	U. Permian - L. Triassic	3.12	-6.05	24.62
O1 791	limestone	LPGSF		Brusník	borehole BRU-1/76	Turiec Formation	Upper Carboniferous	1.37	-9.93	20.63
O1 795	limestone	LPGSF		Brusník	borehole BRU-1/86	Turiec Formation	Upper Carboniferous	0.20	-11.38	19.13
O1 7921	limestone	LPGSF		Brusník	borehole BRU-1/95,8	Turiec Formation	Upper Carboniferous	-0.29	-10.66	19.88
O1 7922	calcite veinlet			Brusník	borehole BRU-1/95,8	Turiec Formation	Upper Carboniferous	-4.15	-11.85	18.64
O1 7931	limestone	LPGSF		Brusník	borehole BRU-1/111,5	Turiec Formation	Upper Carboniferous	-1.07	-11.52	18.99
O1 7932	calcite veinlet			Brusník	borehole BRU-1/111,5	Turiec Formation	Upper Carboniferous	-1.67	-11.54	18.97
O1 7981	limestone	LPGSF		Brusník	borehole BRU-1/114	Turiec Formation	Upper Carboniferous	-1.37	-11.40	19.11
O1 7982	calcite veinlet			Brusník	borehole BRU-1/114	Turiec Formation	Upper Carboniferous	-1.96	-11.28	19.24
O1 8121	limestone	ANC	2/G	Dobšiná	exposure	Zlatník Formation	Upper Carboniferous	0.89	-12.45	18.03
O1 8122	calcite veinlet		2/G	Dobšiná	exposure	Zlatník Formation	Upper Carboniferous	1.37	-13.02	17.44
O1 8151	limestone	ANC	8/G	Dobšiná	quarry behind the asbestos quarry	Zlatník Formation	Upper Carboniferous	0.35	-11.88	18.62
O1 8152	calcite veinlet		8/G	Dobšiná	quarry behind the asbestos quarry	Zlatník Formation	Upper Carboniferous	-0.30	-12.64	17.84
O1 830	limestone	ANC-GSF	22/G	Dobšinská Maša	exposure	Zlatník Formation	Upper Carboniferous	1.95	-17.23	13.11
O1 666	calcite	LPGSF	1/M	Burda	mine	Ochtiná Formation	Lower Carboniferous	1.31	-6.47	24.20
O1 822	limestone	LPGSF	3	Burda	left site of cuarry	Ochtiná Formation	Lower Carboniferous	2.03	-5.85	24.81
O1 823	limestone	LPGSF	2	Burda	right site of quarry	Ochtiná Formation	Lower Carboniferous	1.10	-5.90	24.78
O1 8412b	dolomite	LPGSF		Košice	borehole KV-6/290	Ochtiná Formation	Lower Carboniferous	2.45	-11.58	20.14
O1 8412a	limestone	LPGSF		Košice	borehole KV-6/290	Ochtiná Formation	Lower Carboniferous	2.17	-10.50	20.04
O1 8411	calcite veinlet			Košice	borehole KV-6/290	Ochtiná Formation	Lower Carboniferous	-1.20	-15.21	15.18
O1 816	calcite	LPGSF	7/G	Markuška	cut in the brook	Ochtiná Formation	Lower Carboniferous	2.28	-7.49	23.14
O1 816 C.	calcite(control.a.)	LPGSF	7/G	Markuška		Ochtiná Formation	Lower Carboniferous	2.23	-7.28	23.36
O1 826	dolomite	GSF	10/G	Hrádok	exposure	Ochtiná Formation	Lower Carboniferous	-0.06	-17.42	14.12
O1 828	dolomite	LPGSF	14/G	Dúbrava	mine Miková	Ochtiná Formation	Lower Carboniferous	1.39	-12.31	19.38
O1 831	dolomite	LPGSF	1	Ochtiná	lower part of quarry	Ochtiná Formation	Lower Carboniferous	2.39	-15.96	15.62
O1 827	dolomite	LPGSF	15/G	Dúbrava	mine Miková	Ochtiná Formation	Lower Carboniferous	0.80	-17.99	13.53
O1 833	dolomite	LPGSF	2	Ochtiná	lower part of quarry	Ochtiná Formation	Lower Carboniferous	2.21	-16.34	15.23
O1 2171	magnesite	LPGSF		Košice	borehole GD-32/19	Ochtiná Formation	Lower Carboniferous	1.32	-16.96	14.30
O1 2172	magnesite	LPGSF		Košice	borehole GD-32/19	Ochtiná Formation	Lower Carboniferous	1.26	-15.61	14.77
O1 2121	magnesite	LPGSF		Košice	borehole GD-32/66,5	Ochtiná Formation	Lower Carboniferous	-1.55	-16.82	14.45
O1 2132	magnesite	LPGSF		Košice	borehole GD-32/74,6	Ochtiná Formation	Lower Carboniferous	-5.51	-16.57	13.78
O1 0501	magnesite	LPGSF		Košice	borehole GD-32/108	Ochtiná Formation	Lower Carboniferous	-1.16	-15.87	15.43
O1 0502	magnesite	LPGSF		Košice	borehole GD-32/108	Ochtiná Formation	Lower Carboniferous	0.18	-14.99	16.34
O1 834	magnesite	LPGSF	16/G	Košice	mine	Ochtiná Formation	Lower Carboniferous	0.36	-16.37	14.91
O1 579	magnesite	LPGSF		Košice		Ochtiná Formation	Lower Carboniferous	-0.45	-17.16	13.18
O1 577	magnesite	LPGSF		Košice		Ochtiná Formation	Lower Carboniferous	-0.26	-16.71	13.63
O1 8322	magnesite	LPGSF	3	Ochtiná	back part of quarry	Ochtiná Formation	Lower Carboniferous	0.54	-15.35	15.96
O1 8321	magnesite	LPGSF	3	Ochtiná	back part of quarry	Ochtiná Formation	Lower Carboniferous	-0.47	-16.06	15.24
O1 578	magnesite	LPGSF		Košice		Ochtiná Formation	Lower Carboniferous	-0.38	-17.14	13.19
O1 838	magnesite	LPGSF	17/G	Košice	mine V-601	Ochtiná Formation	Lower Carboniferous	-1.20	-16.86	14.41
O1 8371	magnesite	LPGSF	20/G	Košice	mine PB-05-01	Ochtiná Formation	Lower Carboniferous	1.21	-15.58	15.73
O1 8372	magnesite		20/G	Košice	mine PB-05-01	Ochtiná Formation	Lower Carboniferous	2.01	-15.30	16.02
O1 835	magnesite	LPGSF	21/G	Košice	mine PB-05-02	Ochtiná Formation	Lower Carboniferous	-0.16	-16.29	14.99
O1 836	magnesite	LPGSF	19/G	Košice	mine PB-05-03	Ochtiná Formation	Lower Carboniferous	-0.93	-16.05	15.24
O1 839	magnesite	LPGSF	18/G	Košice	mine SB-05-2	Ochtiná Formation	Lower Carboniferous	2.37	-15.40	15.91
O1 813	limestone	GSF	1/G	Črmeľ údolie	exposure	Črmeľ Group	Early Carboniferous	-3.87	-13.72	16.71
O1 813	limestone	GSF	1/G	Črmeľ údolie	exposure	Črmeľ Group	Early Carboniferous	-4.01	-13.96	16.48
O1 840	magnesite	GSF	4/GB	Kavečany	quarry SE from altitude H. bok	Črmeľ Group	Early Carboniferous	-3.90	-19.63	11.55
O1 842	magnesite	GSF	4/GA	Kavečany	quarry SE from altitude H. bok	Črmeľ Group	Early Carboniferous	-4.03	-19.64	11.54

*Zones of Metamorphism: DIA-ANC = zone of diagenesis - zone of anchimetamorphosis; ANC = zone of anchimetamorphosis; ANC-GSF = zone of anchimetamorphosis - green schist facies; UPGSF = upper part green schist facies; GSF = green schist facies; LPGSF = lower part green schist facies

Isotopic composition of O & C of some carbonates from the Ochtiná and Zlatník Formation, their TVI decrepitation temperature and probable isotopic composition of original solutions
[calculated according to Aharon1988]

Laboratory number	Carbonates	Notice	Geol. number	Locality	Occurrence	Formation	Age*	Measured isotopic composition of carbonates in ‰			TVI	TVI	Calculated isotopic composition of original solutions with M1, D1 in ‰		Calculated isotopic composition of original solutions with M2, D2 in ‰	
								δ 13CPDB	δ 18OPDB	δ 18OSMOW	in °C from	in °C to	δ 18OSMOW from	δ 18OSMOW to	δ 18OSMOW from	δ 18OSMOW to
8152	calcite	secondary veinlet	8/G	Dobšiná	quarry behind the asbestos quarry	Zlatník Formation	U.C.	-0.295	-12.638	17.835	100	120	0.77	2.75		
8122	calcite	secondary veinlet	2/G	Dobšiná	exposure	Zlatník Formation	U.C.	1.368	-13.020	17.441	110	120	1.40	2.35		
864	dolomite		54b/VI	Burda	mine, O. level	Ochtiná Formation	L.C.	-2.538	-14.824	16.792	110	120	-0.81	0.23	-1.92	-0.82
863	dolomite		M-16	Burda	mine, I. level	Ochtiná Formation	L.C.	-1.480	-12.544	19.146	110	120	1.55	2.59	0.44	1.54
8321	magnesite	coarse-crystalline	3	Ochtiná	back part of quarry	Ochtiná Formation	L.C.	-0.471	-16.056	15.236	130	140	-0.75	0.12	-2.90	-1.86
8322	magnesite	fine-grained	3	Ochtiná	back part of quarry	Ochtiná Formation	L.C.	0.539	-15.352	15.962	185	190	4.06	4.37	2.72	3.08
2132	magnesite	veinlet		Košice	borehole GD-32/74,6	Ochtiná Formation	L.C.	-5.514	-16.566	13.784	100	110	-5.25	-4.15	-7.99	-6.69
835	magnesite	fine-grained	21/G	Košice	mine PB-05-02	Ochtiná Formation	L.C.	-0.158	-16.292	14.992	105	110	-3.46	-2.94	-6.13	-5.48
0501	magnesite	veinlet		Košice	borehole GD-32/108	Ochtiná Formation	L.C.	-1.161	-15.869	15.429	110	120	-2.50	-1.50	-5.04	-3.83
836	magnesite	fine-grained	19/G	Košice	mine PB-05-03	Ochtiná Formation	L.C.	-0.934	-16.048	15.244	115	120	-2.19	-1.69	-4.62	-4.02
2172	magnesite	veinlet		Košice	borehole GD-32/19	Ochtiná Formation	L.C.	1.260	-15.614	14.767	120	130	-2.16	-1.22	-4.49	-3.37
8371	magnesite	vein of white magnesite	20/G	Košice	mine PB-05-01	Ochtiná Formation	L.C.	1.207	-15.578	15.729	170	180	2.87	3.52	1.33	2.12
8372	magnesite	veinlets in the white magnesite	20/G	Košice	mine PB-05-01	Ochtiná Formation	L.C.	2.008	-15.299	16.017	140	150	0.90	1.70	-1.08	-0.11
838	magnesite	coarse-grained	17/G	Košice	mine V-601	Ochtiná Formation	L.C.	-1.198	-16.858	14.408	150	160	0.09	0.85	-1.72	-0.82
834	magnesite	medium-grained	16/G	Košice	mine	Ochtiná Formation	L.C.	0.357	-16.373	14.909	160	170	1.35	2.05	-0.32	0.51
839	magnesite	medium-grained	18/G	Košice	mine SB-05-2	Ochtiná Formation	L.C.	2.374	-15.403	15.909	170	180	3.05	3.70	1.51	2.30

Age*: U.C. - the Upper Carboniferous, L.C. - the Lower Carboniferous

The very different isotope composition of dolomite from the locality Hrádok (9/G) may have been influenced by meteoric water penetrating along the Hrádok thrust line near which the sample was collected.

Mesozoic carbonates of the Silica and Turňa Nappes

Mesozoic limestones of the Silica Nappe are the least metamorphosed carbonate sediments from the studied set. They formed in marine neritic environment. Data on isotope composition of oxygen - $\delta^{18}O_{PDB}$ = -17 to -0.40 ‰ show that their diagenesis took place in marine environment as well. The $\delta^{13}C_{PDB}$ values of these limestone vary from 2.42 to 3.41 ‰. Similar data from limestones of this type have been presented by KANTOR et al. (1992) and FABRÍCIUS et al. (1970) from brachiopod and mollusc tests from Hallstatt limestones of Eastern Alps. The authors calculated from these data water environment temperature with values of 16.7 to 29.7 °C. From data of our analyses we calculated paleotemperatures according to EPSTEIN et al. (1953), varying in the range of 18.2 - 25.6 °C, if we consider the $\delta^{18}O_{SMOW}$ value of marine water 0 ‰. The results of these calculation are listed in Tab. 7. For a comparison there is included the paleotemperature calculation for two samples of the Turňa Nappe (Dvorníky, Honce, Jelšavská Teplica), a sample from the eastern occurrences of the Bôrka Nappe (Medzev, Bôrka) and of the lowest-metamorphic Carboniferous limestone. For these four samples, disproportionally high temperatures have been obtained, even at water environment value of -1 ‰. The data indicate higher metamorphic grade of these samples.

Table 7

Sample No.	Locality	$\delta^{18}O_{PDB}$‰	t°C at dw=-1	t°C at dw=0
887	Silická Brezová	-0.99	16.5	20.9
890	Silická Brezová	-0.40	14.0	18.2
885	Ostrý vrch	-1.26	17.6	22.1
886	Jelšavská Teplica	-2.09	21.4	26.1
888	Jelšavská Teplica	-2.17	21.7	26.5
883	Dvorníky	-5.93	41.1	46.9
810	Honce	-4.95	35.7	41.2
892	Medzev	-6.81	46.2	52.3
823	Burda 2	-5.90	40.9	46.0

Bôrka Nappe (eastern part)

The second group of samples of Mesozoic age consists of Triassic and Jurassic (?) limestones of the eastern part of the Bôrka Nappe. In comparison with the previous group, its isotope composition is different - higher contents of light oxygen as well as carbon isotopes ($\delta^{13}C_{PDB}$ 1.09 to 1.85 ‰, $\delta^{18}O_{PDB}$ -12 to -4.95 ‰). The results indicate higher metamorphic grade, documented also by the calculated paleotemperatures (Fig. 8). Metamorphism has been proved also in the sample from Medzev - Šugov Valley, where crystalline limestones occur in association with glaucophanites. Exceptionally high light oxygen isotope contents are in the sample from Bôrka, indicating the highest metamorphic grade from the sample group studied.

KANTOR and MIŠÍK (l.c.) presented in their work $\delta^{13}C_{PDB}$ values for different limestone and dolomite types of Mesozoic age from the Western Carpathians ranging from 0.68 to 3.58 ‰, $\delta^{18}O_{PDB}$ -8.01 to -0.48 ‰, and LINTNEROVÁ et al. (l.c.) from the Veterlín Series of the Malé Karpaty Mts. $\delta^{13}C_{PDB}$ of 0.5 to 3.6 ‰ and $\delta^{18}O_{PDB}$ of -6.3 to -2.2 ‰. The isotope composition of limestones from the Malé Karpaty Mts. has been interpreted by these authors as influenced by meteoric water during diagenesis of a part of the studied limestones. This problem has been studied in greater detail by LINTNEROVÁ in MICHALÍK et al. (1993).

We extended the original sample material to include also samples from the borehole DRŽ-1 (Držkovce), which was complexly lithologically as well as stratigraphically evaluated in the final report of MELLO et al. (1994). We analysed four limestone samples from the Jelšava Beds (Lower Triassic) and two dolomite samples from the Perkupa Formation (Upper Permian-Lower Triassic). Both lithostratigraphic sequences belong to the Turňa Nappe (Turnaicum).

On the basis of data on isotope composition of carbon it may be stated that limestone from the depth 179.1 m formed in deeper-marine environment ($\delta^{13}C_{PDB}$ = 3.06 ‰). Isotope composition of oxygen ($\delta^{18}O_{PDB}$ = -10.37 ‰) would indicate higher temperature at deep burial of the sediments during diagenetic alterations, without the participation of meteoric water. The rest of limestone samples (from depths of 236, 418 and 443 m) indicate shallow-water environment ($\delta^{13}C_{PDB}$ = -0.05 to -0.07 ‰) and the presence of surface water in diagenetic processes.

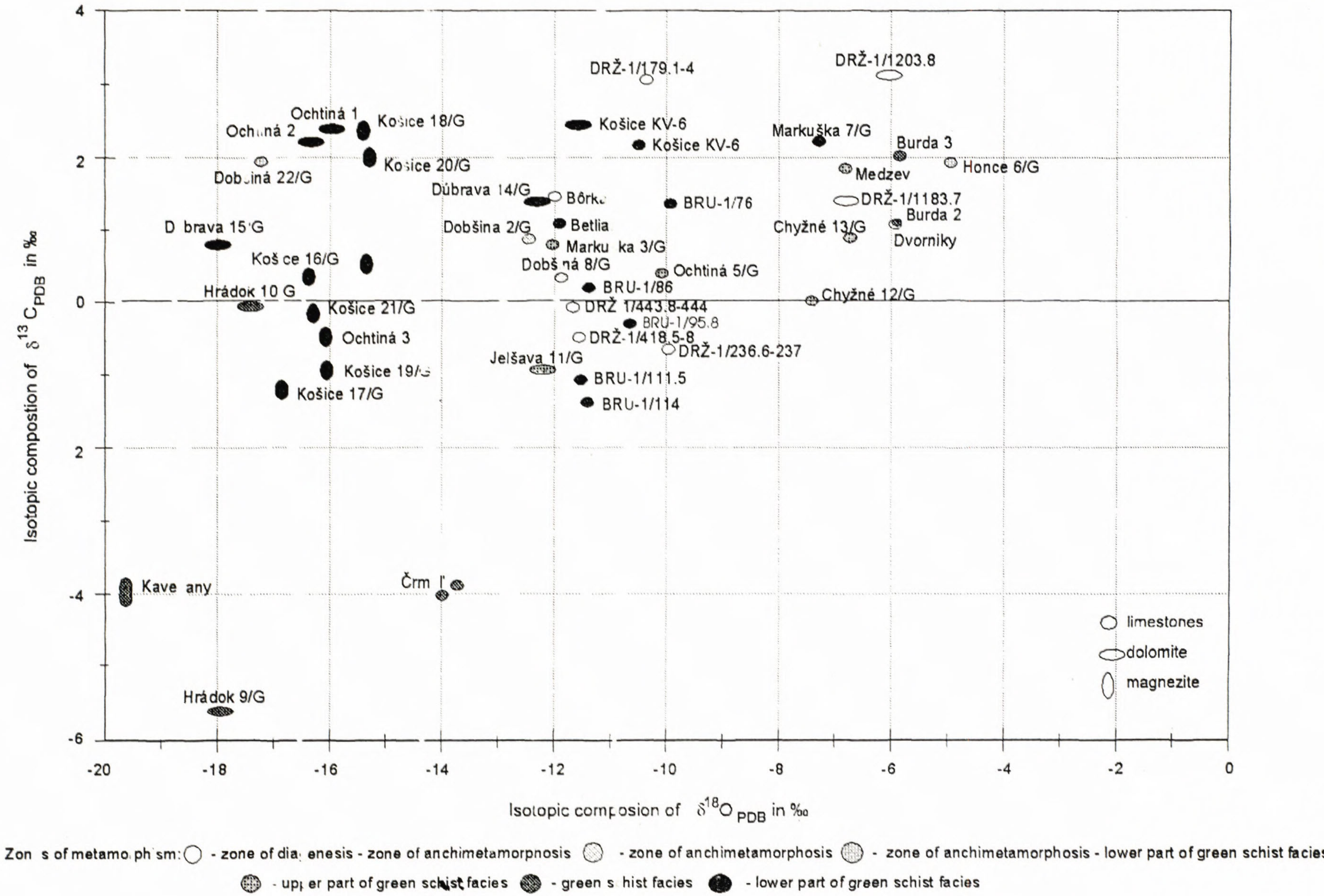


Fig 9 Relationship of the isotope composition of O and C in carbonates depending on the grade of regional metamorphism.

Dolomites from the lower part of the evaporite formation (from depths of 1183, 1203 m) contain more heavy oxygen as well as carbon isotope than limestones from the upper part of the formation. Since at these samples we must also assume alterations in greater depths, we must consider the isotope composition (enrichment in heavy O, C isotopes) to be a product of hypersaline environment, similar to "sebkhas" of the Persian Gulf. The presence of a several 100 m thick evaporite layer supports the probability of the formation of the studied dolomites in this way. Dolomites of such origin have not been so far isotopically recorded in the Western Carpathians.

KANTOR and MIŠÍK (1992) proved on the basis of their isotope composition the formation of the dolomites in schisohaline environment.

Foederata Group of Veporicum

Sample material comes from the borehole G-37 (Dobšiná-Hámor),from which there are not sufficient data on its stratigraphic classification. Material from the borehole has not been evaluated in detail - according to present knowledge the rocks from the depth 625 - 989 m, the analyses of which are presented, should belong to the Mesozoic metamorphic complex of the Foederata Group, which is a part of the Veporicum crystalline complexes. In this levels of the borehole, there occurred also evaporite sediments (850 - 868 m), which, on the basis of the isotope composition of sulphur, were classified by Kantor (KANTOR et al., 1982) as Middle to Upper Triassic.

Isotope composition of carbon and oxygen in 4 limestone and 1 dolomite sample are characterised by considerable variability. We assume that the great variability in the isotope composition of carbon indicates frequent changes of sedimentation environment during the formation of carbonate shallow-water rocks (from depths of 625.5, 850.5 and 898 m) having $\delta^{13}C_{PDB}$ of -1 to +1 ‰ and hypersaline ones from the depth of 879 m ($\delta^{3}C_{PDB}$ = 4.05 ‰).

Isotope composition of oxygen in all samples indicates higher grade of pressure reworking which underwent rocks in the lower part of the borehole G-37. This is indicated also by the distribution of gypsum and anhydrite, which, except for a continuous layer, occurs in the carbonate rocks in the form of an irregular network of fine veinlets (Tab. 5, Fig. 7).

For a comparison, the sample of the Senonnian freshwater limestone from the Dobšiná ice cave has, consistently with its origin, the lowest content of heavy carbon isotope, approaching zero value.

Application of thermometric study and isotope analyses in determination of possible isotope composition of source solutions of the studied carbonates

From the studied set of carbonate samples, suitable ones were selected for thermometric investigations. Decrepitation TVI analysis yielded values in the range of 100 to 190 °C measured on sixteen samples, which could be evaluated (Tab.6). These temperatures are more or less consistent also with the relationship of the liquid and gaseous phase observed at microscopic study of the carbonates.

Results of TVI decrepitation analyses and isotope analyses of oxygen - $\delta^{18}O_{SMOW}$ of the studied carbonates have been used to calculate estimated isotope composition of the source solutions. The relation of fractionation alpha factors between the carbonates and water has the following general form:

$$1000 \ln a_{carbonate\text{-}water} = \delta_{carbonate} - \delta_{water} = A.10^6.T^{-2} + B,$$

where T is absolute temperature and A and B are constants. In our case, we used constants applied by AHARON (1988):

	A	B
for $CaCO_3$	2.78	-2.89
for $dolomite_1$	3.06	-3.24
for $dolomite_2$	3.23	-3.29
for $magnesite_1$	2.95	-2.16
for $magnesite_2$	3.53	-3.58

Estimated values of oxygen isotope composition in source solutions of the carbonates studied, based on measured TVI decrepitation temperatures and oxygen isotope composition in SMOW, are listed in Tab. 6. We used for calcites one set of constants, for dolomites and magnesites both (above). These data are in the graph on Fig. 8. We consider here values calculated using constants for $magnesite_2$ and $dolomite_2$.

TVI decrepitation temperature of secondary carbonate veinlets varies from 100 to 130 °C. Estimated isotope composition of oxygen in source solutions is different for various carbonates, the TVI decrepitation temperatures of which vary from 100 to 130 °C.

E.g., for magnesite from the sample 01_2132 (Košice borehole GD-32) it is as much as -7.99 ‰ $d^{18}OSMOW$, which suggests enrichment of source solutions by meteoric water. Interesting is the value of $d^{13}CPDB$ in this sample - -5.51 ‰. It is practically the isotopically lightest carbon in the whole set studied. Lower values of isotope composition of oxygen in source solutions are obtained also from magnesite veinlets of the same borehole, from the depth 108 and 190 m. $\delta^{13}C_{PDB}$ in these two samples is near to zero (± 1 ‰).

Low TVI decrepitation temperatures (105 to 120 °C) were measured in samples 19/G and 21/G with $\delta^{18}O_{SMOW}$ +15.1 ±0.1 ‰. They are fine-grained magnesites for which we estimate isotope composition of oxygen in the source solutions between $\delta^{18}O_{SMOW}$ -5 and -6 ‰.

On the basis of thermometric and isotope studies we can assume that magnesite veinlets in the borehole GD-32 from the depth 19 and 108 m formed under the same conditions and from similar source as fine-grained magnesites of the samples 19/G and 21/G.

Another group consists of coarse-grained to medium-grained magnesites of the samples 16/G, 17/G, 18/G and 20/G from Košice, for which TVI decrepitation temperatures have been determined in the range of 140 to 180 °C. Isotope composition of these magnesites is $\delta^{13}C_{PDB}$ from -1.2 to +2.4 ‰, $\delta^{18}O_{PDB}$ from -16.85 to -15.4 and $\delta^{18}O_{SMOW}$ from +14.4 to +16.1 ‰. Similar data on isotope composition of magnesites from Košice have been presented by GUILLOU and LETOLLE (1986). These data allow to assume common origin for this group of magnesites. This is supported also by the calculated isotope composition of oxygen in source solution, varying in the range of $\delta^{18}O_{SMOW}$ -1.7 to +1.5 ‰. Such isotope composition of oxygen in source solution is near to isotope composition of oxygen in marine water.

We are confronted with a noteworthy situation concerning the magnesite sample from Ochtiná 3 (Fig. 8). In this sample, coarse-grained magnesite (01_8321) is intersected by younger fine-grained magnesite (01_8322). For the coarse-grained magnesite, TVI decrepitation temperature of 130-140 °C has been measured. From these data, $\delta^{18}O_{SMOW}$ of -2.9 ‰ has been calculated for the source solution.

TVI decrepitation temperature for fine-grained magnesite is 185-190 °C, with $\delta^{18}O_{SMOW}$ of +2.42 ‰ for the source solution. In contrast to Košice, a higher TVI decrepitation temperature has been measured here for the more fine-grained type, and thus also a different oxygen isotope composition for the source solution. This means that fine-grained magnesite in Ochtiná formed at different conditions than in Košice.

For two dolomite samples from the mine Burda (01_663 and 01664) with the values of $\delta^{13}C_{PDB}$ -1.48 and -2.54 ‰, $\delta^{18}O_{PDB}$ -12.54 and -14.82 ‰, $\delta^{18}O_{SMOW}$ +10.15 and +16.79 ‰, respectively, TVI decrepitation temperatures have been measured for both samples in the range 110-120 °C. From this, values of oxygen isotope composition in source solution were estimated at $\delta^{18}O_{SMOW}$ +0.44 and -1.92 ‰. On the basis of these data it may be assumed that marine water participated in their formation.

At last, we shall mention isotope composition of two secondary calcite veinlets in limestones of the Zlatník Formation from Dobšiná (8/G and 2/G): $\delta^{13}C_{PDB}$ -0.29 and +1.37 ‰, $\delta^{18}O_{PDB}$ -12.64 and -13.02 ‰, $\delta^{18}O_{SMOW}$ +17.84 and +17.44 ‰. TVI decrepitation temperatures measured for these calcites were from 100 to 120 °C. From these values we may estimate the isotope composition of oxygen in source solution - $\delta^{18}O_{SMOW}$ +0.75 and +1.40 ‰. The source of oxygen in these solutions may have been in marine water (buried one as well).

Conclusions

Significantly higher concentrations of Mn, Sr, Na, U, Th and rare earth elements have been found in Carboniferous carbonates, as compared with carbonates with the Dúbrava Beds. With the exception of carbonates from the borehole BRU-1, no direct dependence of these elements on Al contents could be observed. These differences result from different sedimentation conditions (shallow-water, in places with increased salinity, vs. deep-water), as well as different interaction grade in the diagenetic system, influence of meteoric water, or chemical composition of metamorphic fluids.

REE contents as well as the course of normalised curve in Carboniferous carbonates are similar to values mentioned for sedimentary carbonates and magnesite deposits in the Eastern Alps. Dolomites and limestones of the Dúbrava Beds, to the contrary, approach by their low REE contents, more marked negative Eu anomaly as well as relative HREE enrichment in relation to LREE, the isotope composition of oceanic water.

Considerable depletion in REE occurred in magnesites, as well as relative enrichment of HREE in relation to LREE, in comparison with associated limestones and dolomites. We explain this by Mg-metasomatism of pre-existing dolomites, solutions enriched in Mg from the associated basic and ultrabasic rocks, although intraformational source (crinoid detritus) has been considered as well. This is indicated by general REE decrease, characteristic of basic and ultrabasic rocks, as well as enrichment in Cr, Ni, Co, Sc in some of the samples.

When evaluating the distribution of oxygen and carbon isotopes in carbonates of the sets studied we must bear in mind several standpoints, above all the sedimentation environment, age classification and grade of metamorphism (Fig. 9). Since geological structure of Gemericum is complex, the development of each rock group, or even of separate samples, was complicated, affected by polyphase processes.

The oldest, Lower Carboniferous carbonates belong to two sets - the Ochtiná Formation and the Črmeľ Group. Their extent of study, as far as isotope composition is concerned, is not the same. In the Ochtiná Formation significant differences may be observed in the isotope composition of oxygen, in the direction limestones - dolomites - magnesites. With advancing alteration, the proportion of the light oxygen isotope, and to a lesser extent also of carbon, increases. Rocks of the Ochtiná Formation are metamorphosed in conditions of the greenschist facies, values of their isotope composition correspond to the grade of metamorphism, age of the sediment as well as shallow-water sedimentation environment.

On the basis of isotope composition of magnesite from this formation we assume that alteration of limestones to magnesites occurred at the presence of solutions similar to marine water. This has been confirmed also by results of a detailed isotope and paleothermometric study, which has shown that two solution types participated in the formation of magnesites:

a) solutions, where $\delta^{18}O_{SMOW}$ of -1.7 to +1.5‰ is similar to the composition of marine water. These values have been calculated for coarse-grained magnesites with decrepitation temperature of 140-180 °C.

b) solutions with isotope composition of $\delta^{18}O_{SMOW}$ of -8 to -4.5‰, determined in magnesites with decrepitation temperatures of 100-130°C, in which influence of meteoric water is evident.

Isotope composition of carbon from carbonates of the Ochtiná Formation corresponds to marine carbonates.

Different isotope composition of carbon - higher content of the light isotope - has been recorded in rocks of the Črmeľ Group. In view of the small number of analysed samples we cannot consider it sufficiently representative. It could indicate the influence of freshwater environment at their formation, or diagenesis, or a connection with basic rocks associated with them in the Črmeľ Group.

The set of rocks from the borehole BRU-1 comes from a carbonate olistostrome of Upper Carboniferous age. The grade of metamorphism corresponds to the boundary anchizone - epizone. This is reflected in small differences in the isotope composition of oxygen and its higher values in relation to the Ochtiná Formation.

Approximately the same values of $\delta^{18}O$ and $\delta^{13}C$ are in samples from the Zlatník Formation, which are, as far as age is concerned, comparable with carbonates from the borehole BRU-1. They represent shallow-water organodetritic limestones, changed only to a very low metamorphic grade. Different values of $\delta^{18}O$ are in the sample from Dobšiná (22/G), the isotope composition of which has been affected by water circulating along the fault, near which the sample was located.

A separate group of samples are limestones from the Dúbrava Beds. Isotope composition of oxygen varies in them in the range of $\delta^{18}O_{PDB}$ -12 to -6‰, at small differences in the isotope composition of carbon. They are rocks metamorphosed in the upper part of the greenschist facies. Their isotope composition of oxygen has however higher values than in the weakly metamorphosed rocks of the Zlatník Formation, the equivalent of which it has been considered by a part of geologists (Fig. 8). To the contrary, the measured isotope composition of oxygen in some samples approaches values of metamorphic Mesozoic complexes of the Bôrka Nappe (Medzev - Šugov, Bôrka).

From this, affinity of the Dúbrava Beds to the metamorphic Mesozoic in the eastern occurrences of the Bôrka Nappe may be derived, as assumed in the geological map of Slovenské rudohorie - eastern part (BAJANÍK et al., 1984), Slovenský kras

(MELLO et al., 1992), as well as on the basis of petrographic analysis metabasaltic rocks of the Dúbrava Beds sequence.

Exceptionally different isotope composition (high content of the light carbon as well as oxygen isotope) displays the dolomite sample from Hrádok, originally also included into Dúbrava Beds. Its composition, however, reminds rather of carbonates of Lower Carboniferous age, enriched in light carbon. Similar values of isotope composition of carbon reach, besides samples from the Črmeľ Group, only secondary carbonate veinlets, in which we assume the participation of surface water in their formation.

Another problematic group are samples marked Burda 2,3. In the geological map of Slovenské rudohorie Mts. (l.c.), they were included into the Zlatník Formation. ABONYI (1971) correlated them with the Dúbrava Beds. During field investigation, even their classification with the Ochtiná Formation has not been omitted. However, their isotope composition trends to the Dúbrava Beds as well as limestones of the Ochtiná Formation from the underlier of the magnesite horizon. However, it is not possible to solve this problem unequivocally, due to the small number of analysed samples from this horizon.

We could distinguish in the Mesozoic rocks very well rocks of different grade of metamorphism (Silica, Turňa and Bôrka Nappes, Foederata Group), as well as different sedimentation conditions.

The results of the study of carbonate sediments of the Carboniferous to Mesozoic showed the possibility of application of this method and helped to solve some controversial problems. They may be used to parallelize rocks and to gain further, independent data on the condition of their formation, as well as subsequent processes. They also showed the necessity of a detailed knowledge of the studied rocks for correct interpretation of the results of isotope analyses.

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Lithostratigraphy of Radiolarian Limestones and Radiolarites of the Envelope Sequence in the Veľká Fatra Mts.

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Abstract: For the first time it was possible to obtain radiolarians from radiolarian limestones and radiolarites of the envelope sequence in the Veľká Fatra Mts. On the basis of biostratigraphic analysis, the age of the formation has been established as Upper Bathonian - Callovian.
Key words: radiolarites, radiolarians, Upper Bathonian - Callovian, Envelope Unit, Western Carpathians, Veľká Fatra Mts.

Introduction

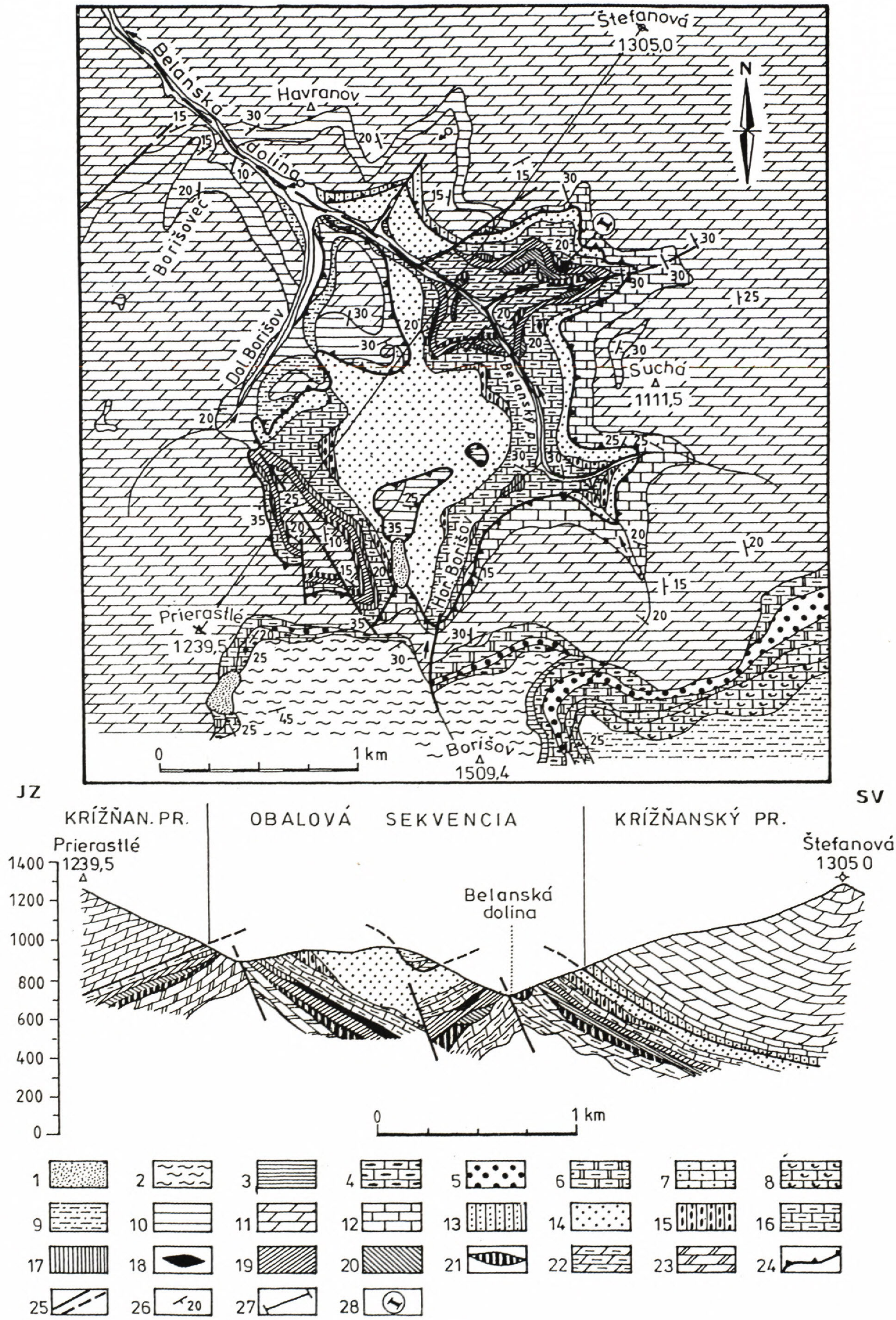
Within the project "Geodynamic Model of the Western Carpahtians", we started in the last time to analyse, besides radiolarian limestones and radiolarites of the Krížna nappe in the central part of the Western Carpathians, also the same formation from envelope sequences. The envelope sequence of the Veľká Fatra Mts. is very well exposed in the Belianska Valley (the side valley Došná – Fig. 1) where it occurs in the form of a tectonic window and where the whole stratigraphic succession is exposed, from the Middle Triassic to the Poruba Member of the Albian.

Lithology

A complete profile across the raldiolarite and radiolarian limestone formation is exposed on the SW ridge of Štefanová. The direct underlier consists of a dark marly shale formation alternating with dark spotted limestones (Allgäu Formation - Fleckenmergel) of the Toarcian age (MIŠÍK – RAKÚS, 1964). The total thickness of the radiolarite formation does not exceed 4 m. This profile displays one of the highest radiolarite frequencies in this formation, in envelope sequences as well as in the Krížna nappe.

The lower part of the profile is formed by red platy (5–15 cm) limestones. They are fine-grained to massive, slightly marly limestones of biomicrite texture, with predominant radiolarian microfacies (Fig. 2). Above them, there is a bed of red, violet shales, passing into red, strongly laminated limestones. Laminae filled with micro-organisms, predominantly radiolarians, less frequently fragments of crinoids, alternate here with signs of gradation. The latter are lighter in colour and strongly quartzified. Dark laminae are significantly poorer in the micro-organic component, with a higher proportion of clay component and increased FeO content. It is a microturbidite layer (DIERSCHE, 1980; SCHLÄGER, W. & SCHLÄGER, M., 1969) or pelagic turbidites (Kälin et al., 1979). Next is a passage formed by red, platy (10–15 cm) radiolarian limestones with frequent nodules of red radiolarites alternating with red clayey shales. The limestones are strongly biomicritic, with a predominance of radiolarian microfacies. Following is a single layer (20 cm) of dark brown radiolarites in the whole formation, which yielded identifiable radiolarites. After a thin layer (3 cm) of clayey shales there follows a bed of red massive radiolarite in which radiolarians have been found as well. Following is a section of 80 cm thick, thin-bedded red radiolarian limestones, with sporadic nodules of red radiolarites and intercalations of red clayey shales. Microfacially, they are biomicrites with a monotonous filling of organic remnants consisting of radiolarians. Above them there is lying another conspicuous layer (25 cm) of red radiolarites, which yielded again identifiable radiolarians. The upper part is formed by several beds of red radiolarites, microfacially biomicrites of the radiolarian microfacies. The silicite layers and nodules may be described as siliceous-calcareous radiolarites (DIERSCHE, 1980). By their composition they correspond to silica-calcareous biomicrites with a relatively high frequency of radiolarians, which are mostly calcified, a substantially lower quantity preserved their original siliceous tests.

The chemical composition confirms the character and type of radiolarites (chem. analysis No. 493, geol. sample No. VF-10/73, locality: Belianska Valley – Došná, analyst: MIKLEOVÁ, May 14, 1975).



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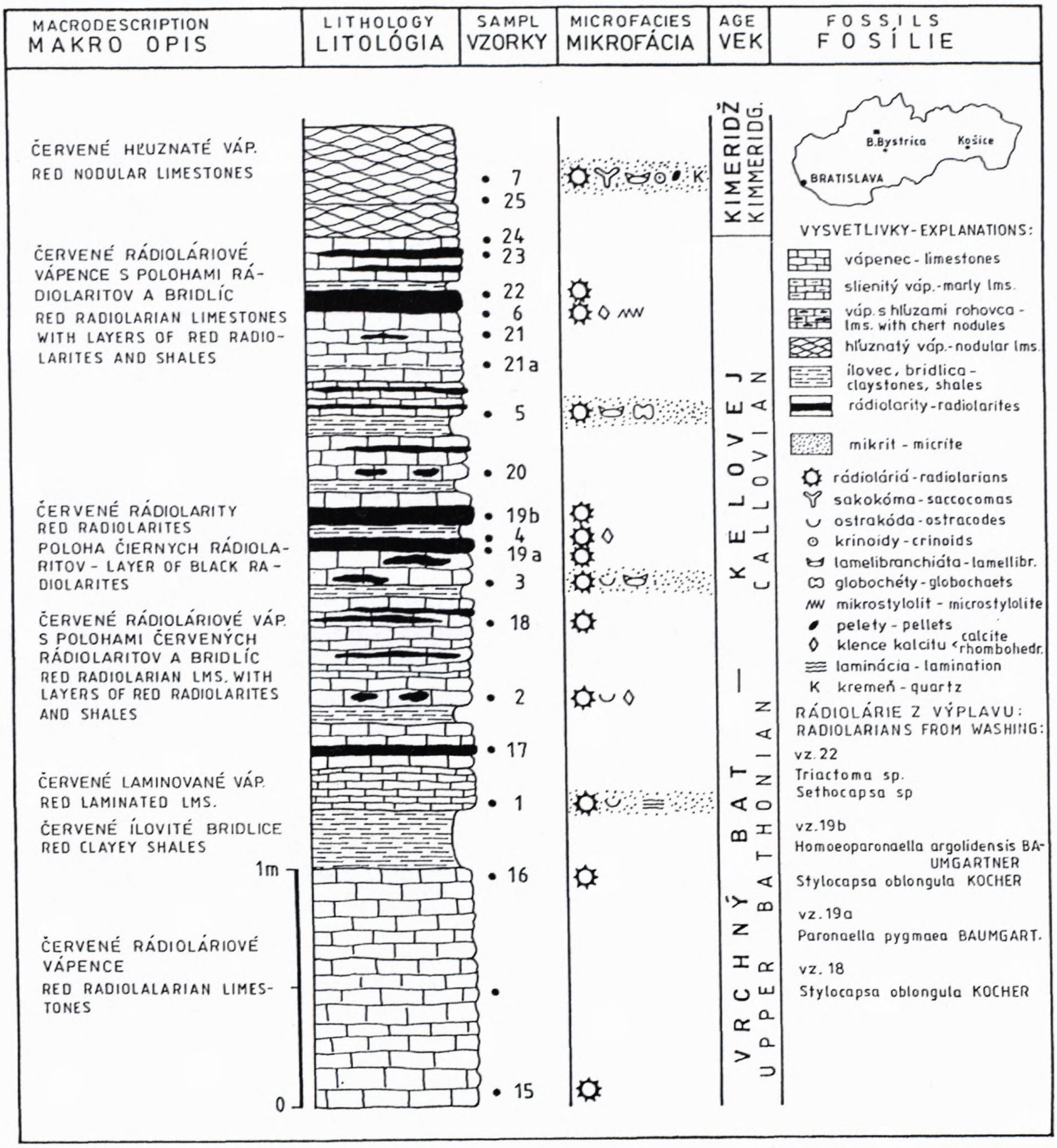

Fig. 2 Lithostratigraphic section, locality: Belianska Valley – Došná, envelope unit, Veľká Fatra Mts.

Fig. 1 Geological map of the area of Borišov
1– Quaternary; 2–13 Krížna nappe: 2– marly limestones, shales (Berriasian–Barremian); 3 – marly platy limestones (Kimmeridgian); 4 – radiolarian limestones, radiolarites (Upper Callovian - Oxfordian); 5 – siliceous Fleckenmergel (Aalenian); 6 – Allgäu Member - Fleckenmergel (Lotharingian); 7 – Kopienec Formation (Hettangian – Sinemurian); 8 –Fatra Member (Rhaetian); 9 – Carpathian Keuper (Norian); 10 – Podhradie Limestones (Ladinian); 11 –. Ramsau Dolomites (Ladinian); Gutenstein Limestones (Anisian); 13 – Lúžna Formation (Lower Triassic); 14–23 Envelope sequence: 14 – Poruba Formation (Albian – Cenomanian); 15 – dark-grey, black cherty limestones (Aptian); 16 –. Lučivná Formation (Upper Berriasian - Lower Aptian); 17 – red nodular limestones (Kimmeridgian); 18 – radiolarian limestones, radiolarites (Upper Bathonian – Callovian); 19 – Allgäu Formation - Fleckenmergel (Domerian - Toarcian); 20 – Trlenská Formation (Hettangian – Sinemurian); 2 1– Carpathian Keuper (Norian); 22 – Došná Formation (Ladinian–Lower Carnian); 23 – Ramsau Dolomites (Ladinian); 24 – ovethrust lines; 25 – faults : established, assumed; 26 – strike and dip of strata; 27– profile line; 28 – studied lithostratigraphic profile.

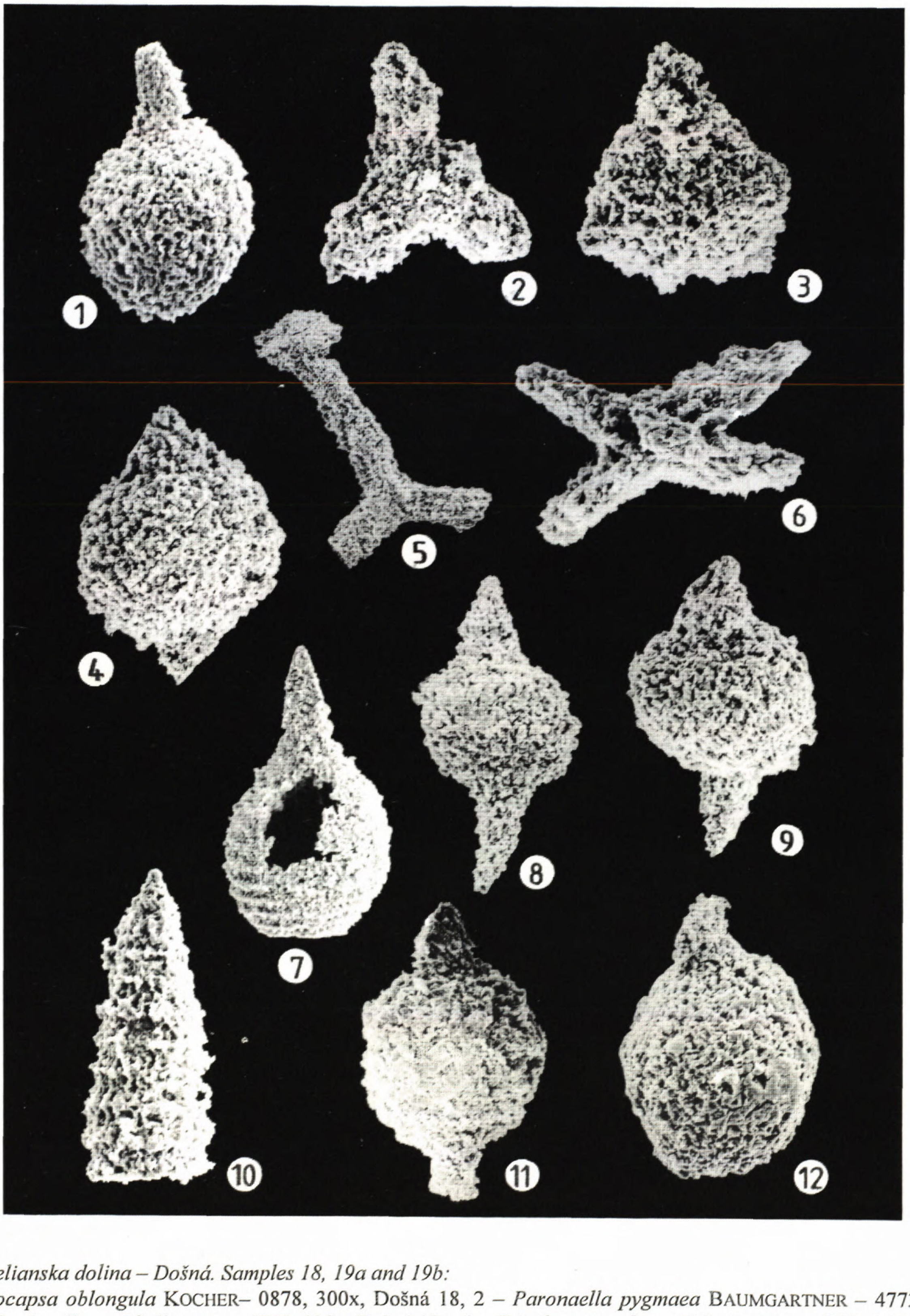

Fig. 3 Belianska dolina – Došná. Samples 18, 19a and 19b:

1 – *Stylocapsa oblongula* KOCHER– 0878, 300x, Došná 18, 2 – *Paronaella pygmaea* BAUMGARTNER – 4773, 175x, Došná 19a, 3 – *Eucyrtidiellum sp.* – 4775, 190x, Došná 19a, 4 – *Tricolocapsa* cf. *yaoi* MATSUOKA – 4772, 160x, Došná 19a, 5 – *Homoeoparonaella argolidensis* BAUMGARTNER – 4752, 100x, Došná 19b, 6 – *Pseudocrucella* sp. – 4765, 190x, Došná 19b, 7 – *Mirifusus fragilis* BAUMGARTNER – 1363, 100x, Došná 19b, 8, 9 – *Podobursa* sp. – 4753, 135x, - 4757, 160x, Došná 19b, 10 – ? *Parvicingula* cf. *decora* (PESSAGNO – WHALEN) – 1371, 150x, Došná 19b, 11– *Mirifusus* sp. – 4760, 150x, Došná 19b, 12 – *Stylocapsa* cf. *oblongula* KOCHER – 4764, 300x, Došná 19b.

Result in %:

SiO_2	52,390	CaO	26,250
Al_2O_3	2,420	MgO	0,590
Fe_2O_3	0,480	Na_2O	0,400
FeO	0,360	K_2O	0,120
TiO_2	stopy	CO_2	15,740
MnO	0,004	loss by dryinf	–
P_2O_5	0,025	loss by burning	19,400

Above the whole complex there is a formation of red nodular limestones of Kimmeridgian age.

Fossil content

Radiolarians have been found in all collected samples marked in the profile, however, their preservation is imperfect and in many cases unsuitable for identification. Different calcification degrees may be observed in thin sections, from slight disturbance to total replacement of the siliceous material in the test by calcite. The fossils, after extraction from rock, appear only as cores. For the extraction, hydrofluoric acid diluted 1 : 9 or 2 : 8 with water was used. The listed radiolarians are from samples No. 18, 19a, 19b and 22.

Sample No. 18 (lab. sample No. 1070): ? *Aracheospongoprunum* sp., *Triactoma* sp., *Eucyrtidiellum* sp., *Podobursa* sp., *Stichocapsa* sp., *Stylocapsa oblongula* KOCHER, *Tricolocapsa* sp., sponge spicule.

Sample No. 19a (lab. sample No. 1071): *Paronaella pygmaea* BAUMGARTNER, *Eucytidiellum* sp., *Tricolocapsa* cf. *yaoi* MATSUOKA.

Sample No. 19b (lab. sample No. 1072): ? *Archaeospongoprunum* sp., *Cenosphaera* sp., *Homoeopronaella argolidensis* BAUMGARTNER, *Paronaella* sp. ?, *Pseudocrucella* sp., *Triactoma* sp., *Tritrabs* sp., *Archaeodictyomitra* sp., *Eucyrtidiellum* sp., *Transhsuum, Mirifusus fragilis* BAUMGARTNER, *Mirifusus* sp., *Parvicingula* cf. *decora* (PESSAGNO – WHALEN), *Podobursa* sp., *Stylocapsa* ef. *oblongula* KOCHER.

Sample No. 22 (lab. sample No. 1074): *Triactoma* sp., ?*Mirifusus* sp., *Podobursa* sp., *Sethocapsa* sp.

In all samples, representatives of Nassellaria predominate over Spumellaria in the radiolarian communities. However, we must note that in spite of the abundant occurrence of radiolarians in all thin sections, due to their bad preservation in the sediment, only a part of the radiolarian association could be identified. For the identified species, we suggest the following stratigraphic ranges expressed in Unit Associations (UA), according to BAUMGARTNER (1984). They are: *Stylocapsa oblongula* KOCHER (sample No. 18) occurs in UA 3-5, *Paronaella pygmaea* BAUMGARTNER (sample No. 19a) in UA 3-10, *Homoeoparonaella argolidensis* BAUMGARTNER in UA 1-10 and *Mirifusus fragilis* BAUMGARTNER in UA 0-5 (sample No. 19b). From the above facts it follows that the narrowest stratigraphic range is ascribed to *Stylocapsa oblongula* KORCHER, which occurs in UA 3 to UA 5, corresponding according to BAUMGARTNER (1987) to the upper part of zone A1 and lower part of zone A2. The above range corresponds to the time interval of Upper Bathonian – Callovian, according to the chronostratigraphic scale of O´DOGHERTY et al. (1989).

Discussion

Upper Jurassic sequences of radiolarites and radiolarian limestones in the Pieniny section of the Klippen Belt have been divided by BIRKENMAJER (1977) into the lower radiolarite formation of Sokolica, classified as Bathonian – Callovian in age, and upper radiolarites of Czajakowa – Oxfordian to Kimmeridgian.

While in the predominant part of the Krížna Nappe radiolarites of the Western Carpathians the age of the formation has been determined as Upper Callovian to Oxfordian (POLÁK – ONDREJIČKOVÁ, 1993), in the radiolarite formation of the envelope sequence in the Veľká Fatra Mts. Upper Bathonian-Callovian age has been determined. When correlated with the above mentioned radiolarites in the Pieniny Klippen Belt, radiolarites of the envelope sequence in the Veľká Fatra Mts. would correspond to the Sokolica Formation and Krížna nappe of the Czajakowa Formation.

The determination of accurate age of radiolarian limestones and radiolarites in the Krížna nappe, as well as in the envelope sequence, is accompanied by the problem of the stratigraphic position of the underlying Allgäu Formation (Fleckenmergel), which in the majority of outcrops in the Šiprun sequence have the Toarcian age (MIŠÍK & RAKÚS, 1964). In a few cases, a formation of siliceous Fleckenmergel occurs above, classified as Aalenian in age. It is very probable that the age is Aalenian-Lower Bathonian. It is very improbable and not supported by any evidence that there is a hiatus. There is a similar situation in the Krížna nappe of the Veľká and Malá Fatra Mts., where, in view of the stratigraphic position of the Allgäu Formation (Lotharingian-Domerian) (RAKÚS, 1964), the range of the siliceous Fleckenmergel is ?Toarcian – Lower Callovian ?.

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Sedimentary Records of Early Cretaceous Tectonic Activity in the Alpine-Carpathian Region

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Abstract: Several types of allodapic limestone bodies have been recognized in the topmost Jurassic/Lower Cretaceous pelagic carbonates of the Central Western Carpathians. Limestone breccia layers inserted in monotonous sequences of calpionellid/nannocone biomicrites indicate a distinct relief rejuvenation of the basin bottom by synsedimentary tectonics during this time. These clastics, called Nozdrovice Breccia Beds, are interpreted as talus debris accumulations along active submarine fault slopes.

Key words: sedimentology, paleotectonics, sedimentary breccia, Early Cretaceous, Western Carpathians

1. Introduction

The Berriasian brecciated complex, called "Nozdrovice Breccia Beds," was previously described (BORZA et al., 1980) as an isochronous body produced by a single sea-bottom denivelization event during Late Cimmerian movements.

During sedimentological and microbiostratigraphical study of Upper Jurassic and Lower Cretaceous sequences in the last years, we sampled in detail several tens of Western Carpathian sections. We observed that the brecciated beds built of limestone fragments derived from underlying carbonate formations are a characteristic feature of the majority of Berriasian/Lower Valanginian profiles. Five of the sections (Fig.1) have been selected for closer investigation of the lithological content of these beds, as well as of their time and space relationships.

2. Geodynamic setting

Although the main Neo-Cimmerian collisional zone running meridionally from the Asian Cimmerides terminated in Crimea and Dobrogea, Jurassic east-vergent movement of the "Kreios" and Apulian microcontinents in the Mediterranean also resulted in a collision with the Rhodopean-, Serbian- and Marmarosh microcontinents. The transversal (Teisseyre - Tornquist-, or Pyrenean-) throughs in the cratonic Palaeurope were also re-activated. Traces of Neo-Cimmerian (both tensional and compressional) deformations are recognizable both in the Eastern Alps (TOLLMANN, 1987) and the Western Carpathians (MICHALÍK, 1990).

Oxfordian to Berriasian Ernstbrunn, Štramberk, Vršatec, Raptawicka Turnia and other formations (REHÁKOVÁ,1995) represent products of reef carbonate sedimentation on blocks elevated by tension of the basement (MICHALÍK, 1995). These platforms yielded clasts which supported frequent calciturbidites (Barmstein Limestone) in the slope and basin deposits. On the other hand, some basin infillings (Jasenina Formation of the Fatric Basin) usually do not contain any conspicuous fluxoturbidite intercalations. The wide-spread *Ammonitico Rosso* - type facies was related to hampered or even condensed sedimentation on deeper elevations in pelagic environment. Gradual increase in the sedimentation rate during the latest Jurassic was conditioned by increased carbonate production by benthic (reef building)- as well as by planktonic organisms (by saccocomas, globochaetes, and during the latest Tithonian also by calpionellids).

Neo-Cimmerian deformation of the outer Tethyan shelves changed the eustatic and hydrodynamic regime in the basins (MICHALÍK, 1990). The re-organization of the paleogeographic pattern in wider area of the Mediterranean Tethys, connected with a change of sea current regime, stimulated (brought about) the Berriasian/ Valanginian quantitative "boom" in plankton development. This changes are reflected in the character of the sediments (VAŠÍČEK et al., 1983, 1994, MICHALÍK & VAŠÍČEK, 1989). Isolines of deposition rate of microplanktonic remnants (REHÁKOVÁ & MICHALÍK, 1984) indicate two important revolutions: the first one on passage of the *Crassicollaria*- and *Calpionella* Zones probably resulted from syn-sedimentary tectonic processes, the second one on the *Calpionellopsis*- and *Calpionellites* Zones boundary could have been induced by a change in sea current regime (possible by upwelling).

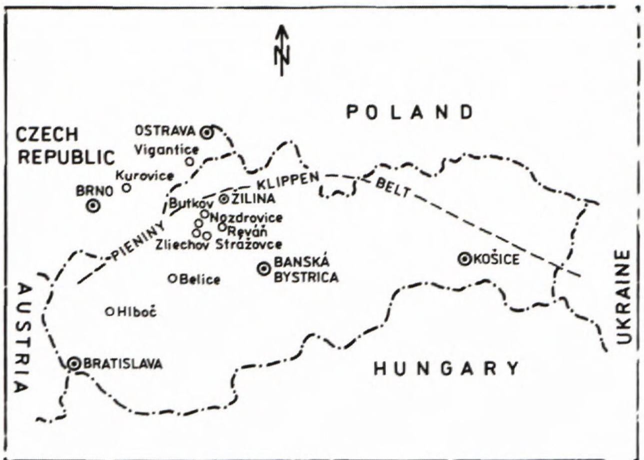

Fig. 1 Localization of the sections and localities mentioned in the text in the frame of Western Carpathians.

Conspicuous Berriasian subsidence supported the facies variability of the sedimentary area (MICHALÍK et al., 1991, SOTÁK, 1989). Reef growth on the margin of Outer Carpathian (Beskydic) carbonate platforms ended, biogene limestones (Olivetská Hora Formation), crinoidal limestones and breccias (Dursztyn Limestone Formation) covered the surface of former elevations. Nannocone biomicrites covered rapidly the area, characterized during Tithonian by pelagic facies. Cherty limestones with marly intercalations were deposited on basin bottoms (Pieniny Limestone Formation). They formed in well-aerated eupelagic environment. Deeper bottom of the Penninic Oceanic Trough, lying below the CCD level, was probably characterized by radiolarite and silicite sedimentation. Basin environments of the Central Carpathians produced biomicrite limestones of "biancone" type (Oberalm-, Padlá Voda- and Osnica Formations, cf. REHÁKOVÁ & MICHALÍK, 1992). They are poor in benthic fossils, rests of nektonic organisms occur rarely, but skeletons of microplanktonic organisms form a substantial part of the sediments. In shallower zones, typical biancone passes into "sublitho-graphic" limestones, as the Butkov section shows (Ladce Formation).

3. Limestone breccia beds in the J/K sequences

3.1. *Butkov section* (Fig.2)

Thick pelagic Kimmeridgian - Barremian limestone sequence belonging to the Central Carpathian Manín Unit was described in detail by BORZA et al. (1987) and by MICHALÍK & VAŠÍČEK (1987).

The oldest breccia beds were identified in the topmost part of the Tithonian red nodular limestones (Tegernsee Formation, parallelized by BORZA & MICHALÍK, 1986, with the Czorsztyn Limestone). The matrix of this breccia consists of brownish marly packstone with abundant *Saccocoma* sp. and *Globochaete alpina* LOMB. and with rare *Crassicollaria intermedia* (DURAND DELGA), *C. parvula* REMANE, and *Calpionella alpina* LORENZ. The clasts (1 to 40 mm in size) were derived from pink grey wackestones containing *Crassicollaria intermedia*, *C.brevis* REMANE, *C. massutiniana* (COLOM), *Tintinnopsella remanei* BORZA, *T. carpathica* (MURG.& FILIPESCU), *Calpionella alpina*, radiolarians, *Saccocoma* sp., globochaetes, juvenile ammonites, aptychi, crinoid columnalia and fragments of bivalve shells.

Berriasian sequence is strongly reduced by synsedimentary (?) erosion. It is represented by thin (1-5 m) limestone breccia beds capped by thin-bedded pale micritic limestones. The clasts were derived from Upper Tithonian and Lower Berriasian limestones, the matrix is formed of pale wackestone.

The Upper Berriasian - Valanginian Ladce Formation contains a record of the third breccia event. Pale cream to brownish wackestones with marly admixture contain *Calpionella elliptica* CADISH, *Calpionella alpina, Tintinnopsella carpathica, Remaniella cadischiana* (COLOM), *Calpionellopsis simplex* (COLOM), *Calpionellopsis oblonga* (CADISCH), *Cadosina fusca fusca* WANNER, ostracods, radiolarians, crinoids, aptychi, foraminifers and frequent clasts of older (Berriasian) limestones.

The clasts (up to 35 mm large) in the youngest breccia beds were eroded from pale gray biomicrites with clay admixture, pyrite, clastic quartz and glauconite grains, and with abundant nannoconids, infrequent *Calpionella alpina, C. elliptica, Tintinnopsella carpathica, Stomiosphaera echinata* NOWAK, radiolarians and other microorganisms. This association indicates latest Valanginian (or even Early Hauterivian ?) age.

3.2. *Hlboč section* (Fig.2)

This section exposes Callovian – Hauterivian sequence of pelagic limestones belonging to the Vysoká Nappe of Fatric. It was described by BORZA & MICHALÍK (1987, 1988), MICHALÍK et al. (1988, 1990).

Well-bedded reddish nodular limestones (Tegernsee Formation) with an association of Upper Tithonian microfossils (*Crassicollaria intermedia, C. massutiniana, C. brevis, Saccocoma* sp., globochaetes, radiolarians, calcareous dinoflagellates) contain intercalations of brecciated limestones. The microfossils occurring in their clasts (size of 10–20 mm) indicate Middle- to Late Tithonian age.

The successive Padlá Voda Formation starts with almost massive pale grey limestones (wacke-stones of the *Globochaete (Calpionella* micro-facies) with large cherts. Its base is locally limited by sharp erosive contact followed by thick sedimentary breccia. 10 to 30 (rarely up to 70) mm large limestone clasts came from both Upper Tithonian- and contemporaneous Lower Berriasian strata.

Another breccia bed crops out in the upper (Lower Valanginian) part of the formation. It is com--posed of grey limestone clasts derived from underlying complexes belonging to the *Calpionella*- (more rarely also to the *Crassicollaria*-) Zones.

3.3. *Nozdrovice section*

Poorly exposed section belonging to frontal nappe slices of the Krížna Nappe in the Strážov Mts (MICHALÍK J. & VAŠÍČEK Z., 1980) exhibits a sole (50 - 60 cm thick) layer of brecciated limestone intercalated in a sequence of Lower Valanginian pale marly limestones. The clasts, attaining the size of several milimeters, contain Berriasian (rarely also Tithonian) microfossil association.

3.4. *Zliechov section (*Fig.2)

The Central Carpathian Zliechov Unit belongs to the Krížna Nappe, which forms several digitations with different facies development (deepening southwards) of their Lower Cretaceous sequences in the Strážov Mts.

A thick (over 100 m) sequence of Berriasian pelagic limestones exposed in the Vápenica digitation by the Rovnianska Valley below the Zliechov village contains huge submarine channel breccia intercalations. They are composed of limestone clasts (0,2–20, more rarely up to 60 cm in size) derived from Upper Tithonian strata characterized by crassi-collarian microfacies. The matrix of the breccias consists of biomicrite with Early Cretaceous microplankton associations of both Alpina and *Remaniella* Subzones. The Upper part of the sequence is built of well-bedded wackestones with occasional submarine slump bodies and with several fine grainstone intercalations of turbiditic origin. The microfauna association indicates appurtenance to the *Elliptica* Subzone.

3.5. *Reváň section* (Fig.2)

The section is located in the area of the Fačkov Pass between the Strážov- and Malá Fatra Mts. A forest road escarpment exposes the Lower Cretaceous sequence of the Zliechov Nappe. Its Berriasian to Valanginian part is built of marly limestones and marlstones with intercalations of limestone breccia. Heterogeneous clasts of wackestones to packstones attain a size of 0,5 to 15 cm. Turbidite- and grain-flow intercalations (50 - 120 cm) of dark grainstones appear in higher part of the sequence.

3.6. *Strážovce section* (Fig.2)

The section exposed by a road escarpment between the villages Zliechov and Čičmany in the central part of the Strážov Mts (BORZA et al., 1980) records well relatively deep pelagic Upper Jurassic and Lower Cretaceous carbonate sedimentation.

The first carbonate breccia beds occur in the Berriasian sequence of thick - bedded calpionellid wackestones (Osnica Formation). They contain 1 to 2 mm large clasts of biomicrite limestones with Crassicollaria derived from the underlying Upper Tithonian Jasenina Formation.

Conspicuous layers of the Nozdrovice Breccia Beds are intercalated in the Lower Valanginian thin-bedded marly wackestones with microfossils of the Calpionellopsis Zone. Their subangular clasts (0,5–10 cm) were derived from both the Berriasian Osnica Limestone- and the Tithonian Jasenina Formations.

Discussion

Nozdrovice Breccia composed of older limestone clasts represents a special type of allodapic deposits occurring in the Tithonian/Valanginian strata. All the breccias mentioned above consist exclusively of limestone clasts. However, Berriasian calpionellid limestone from a unit of probably Penninic origin near Bielice in Považský Inovec Mts contains besides limestone fragments also clasts of crystalline schists.

It is noteworthy that such kinds of breccia occur not only in the Central Western Carpathians, but also in the Outer Carpathian localities. The Berriasian pelagic limestone sequence from Vigan-tice (REHÁKOVÁ et al., 1995) in northern Moravia contains hererogenous breccia intercalations with clasts of Tithonian limestones, dolomites, basic volcanics, crystalline schists, as well as concentrations of crinoidal columnalia and aptychi. Similar breccia beds are known from the Kurovice section located in the Magura Unit.

Berriasian "Aptychenkalk" (Fasselgraben Beds) from Reidl Quarry in the Ybbsitz Klippen Zone of

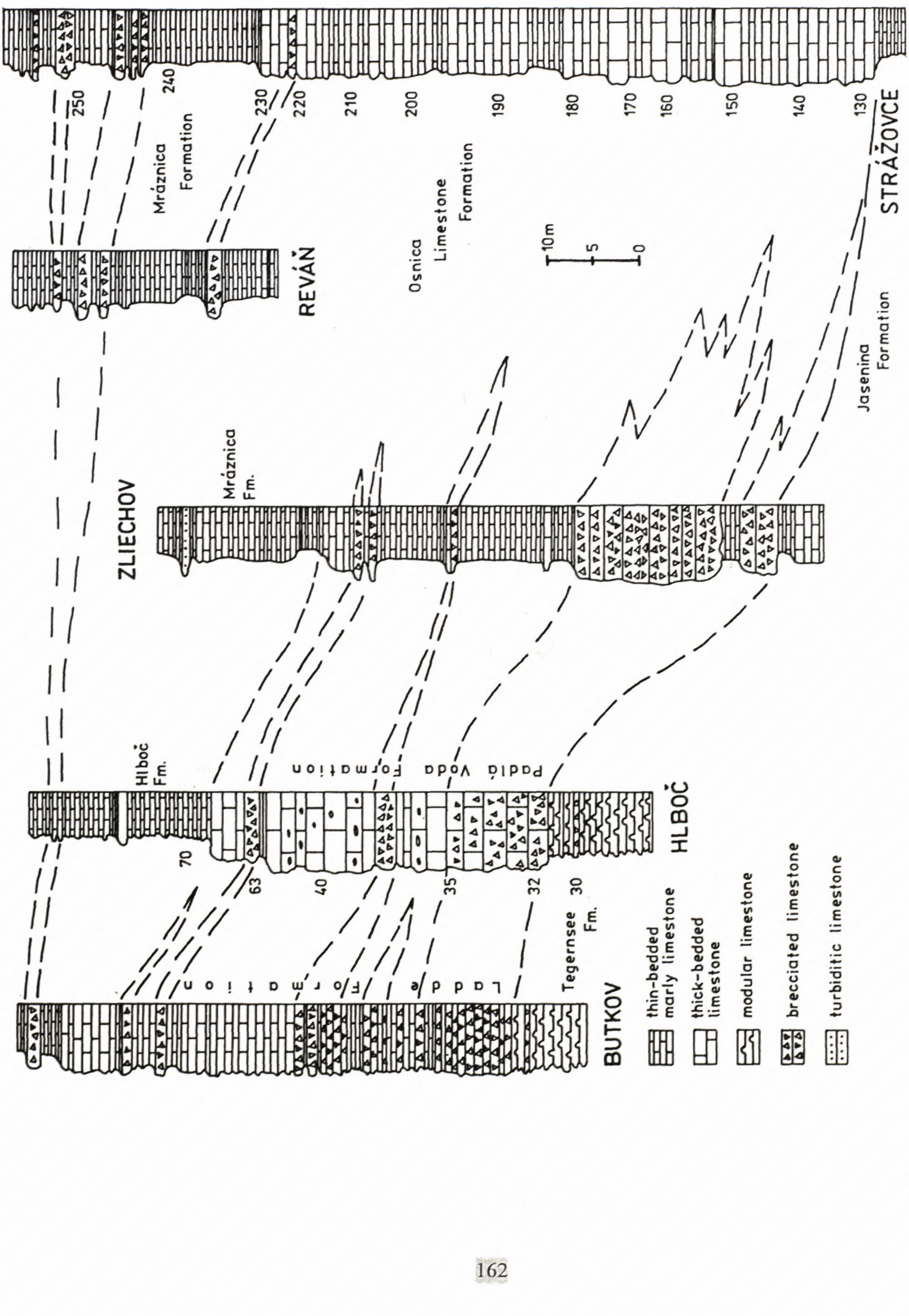

Fig. 2 Lithostratigraphic logs of five sections through topmost Jurassic and Lower Cretaceous deposits from Central Western Carpathians. Correlation of the breccia beds is discussed in the text.

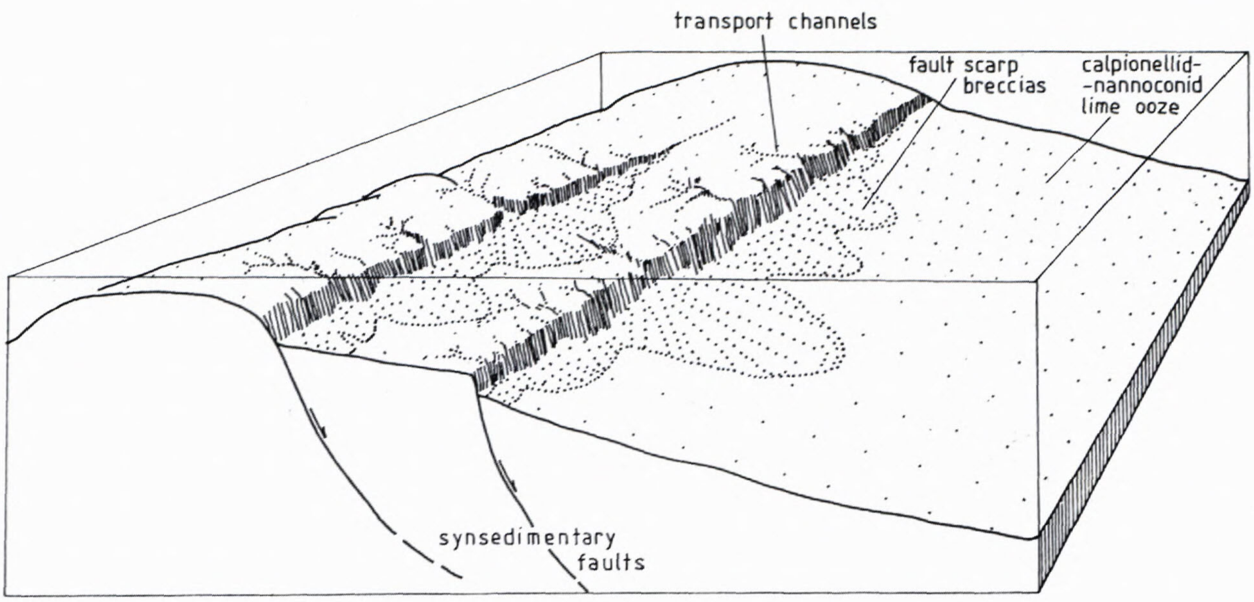

Fig. 3 Genetic model of the Nozdrovice Breccia environment.

Eastern Alps contains similar breccia beds with clasts of Tithonian limestones, vein quartz grains and crystalline pebbles.

Surprisingly, uppermost Jurassic/Lower Cretaceous breccias have been reported also from the Hungarian Mecsek Mts. Moreover, some of these breccias contain not only fragments of Berriasian and Upper Jurassic limestones, but also of Triassic carbonates (dr. S. KOVÁCS, pers. comm.).

Conclusions

A detailed study of Upper Jurassic/Lower Cretaceous carbonate sequences indicates the existence of several types of breccia bodies.

1. Tithonian breccias are usually connected with elevation facies. They occur frequently in slope facies of the "Ammonitico Rosso" nodular limestones. The clasts are derived exclusively from isochronous rocks. It seems that their origin is not closely related to synsedimentary tectonics.

2. Berriasian breccias form huge bodies or intercalations in the Lower part of "Biancone" type limestone complexes. Their material was derived from both underlying Tithonian and isochronous Lower Berriasian pelagic formations.

3. Uppermost Berriasian/Valanginian breccias occur as marked intercalations in marly sequences. They contain clasts of Tithonian- and Berriasian limestones.

The Nozdrovice Breccia indicates distinct relief denivelisation of the basin bottom at the beginning of Early Cretaceous. It was accumulated in talus cones along foot of active submarine fault slopes (Fig. 3).

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The First Appearance of Dactylioceratides in the Western Carpathians

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Abstract: In this article a horizoned assembly of Upper Domerian Ammonites is described, in which appear the first representatives of *Dactylioceras*. In the Western Carpathians, similar to other areas of the Tethys, the first appearance of *Dactylioceras* coincides with the Upper Domerian - Hawskerense subzone. The Western Carpathians occurrences repeatedly suggest that in the Tethyan realm many Liassic Ammonite genera are precocious in comparison to NW Europe.

Key Words: Ammonites, Dactyolioceras, first appearance, Upper Domerian, West Carpathians

Introduction

Dactylioceratids represent an index group of Ammonites the importance of which for the detailed stratigraphy of the Lower Toarcian is generally recognised. The majority of stratigraphers usually relate their first appearance to the Lower Toarcian time level. Although this assumption is plausible, it should be borne in mind that in the Tethyan palaeobiographic domain the first *Dactylioceratids* start appearing already in the Late Domerian - a fact frequently ignored by many ammonitologists.

The appearance of the first *Dactylioceratids* in the Late Domerian attests to their diachroneity of about 3 MA which may cause certain problems in time correlations between the NW Europe and the Tethys.

The following description concerns the *Ammonites* found at a locality in Northern Slovakia situated geologically in the Orava section of the Western Carpathians "Klippen Belt". Based on the succession of horizoned *Ammonites,* first *Dactylioceratids* are located in the uppermost part of the Domerian Hawskerense subzone. This stratigraphic position is in good agreement with other regions of the Tethys (FUCINI, 1935; GAKOVIC, 1986; SAPUNOV, 1974).

Locality Havranský vrch (Fig. 1)

This locality was already known to C. M. PAUL (1868) who described Lotharingian fossils from it. Later ANDRUSOV (1931) identified here many Lotharingian Ammonites. In the seventies this area was studied by HAŠKO (1975, 1977) including the compilation of a detailed geological map and fine-tuning of the local stratigraphy on the basis of a collection of horizoned Ammonites.

The geological setting of this locality is represented by an overturned, more or less complete succession of Jurassic - Lower Cretaceous sediments (Fig. 1):

1. At the base of the profile appears a relatively thick sequence of the "Allgäu Formation" (i.e. "Fleckenmergel" spotty limestones) of Sinemurian - Lotharingian age (ANDRUSOV, 1931).

2. Upwards the "Allgäu Formation" passes into a light-grey, greenish or reddish biomicritic, medium-bedded (approximately 20 cm) partly pseudonodular limestone of Pliensbachian age (RAKÚS in HAŠKO, 1977).

3. Beige to grey-greenish, well-bedded limestones with marly intercalations overlie the "Algäu Formation."

4. Following is the sequence of grey, well-bedded (5-10-25-50 cm) partly quartzose spotty limestones alternating with bedded (3-15 cm) grey marlstones with *Juraphyllites* cf. *planorboides* RAKÚS, *Juraphyllites* sp. *Dactylioceras (Eodactylites simplex*, FUC.,*Dactylioceras pseudocommune* FUC., *Dactylioceras* sp., (Upper Domerian).

5. The same as the underlying sequence (5) but containing *Partschiceras* gr. *anonymum* (HAAS), Canavaria (*Emaciaticeras* gr. *emaciatum* (CAT.)., Upper Domerian.

6. At the top there are grey, spotty, biomicritic limestones with *Partschiceras* gr. *anonymum* (HAAS), *Pleuroceras hawskerense* (YOUNG & BIRD), and *Amaltheus* sp., Upper Domerian. The Toarcian

Limestones (= *Ammonitico rosso*) lie approximately 8-10 m higher up.

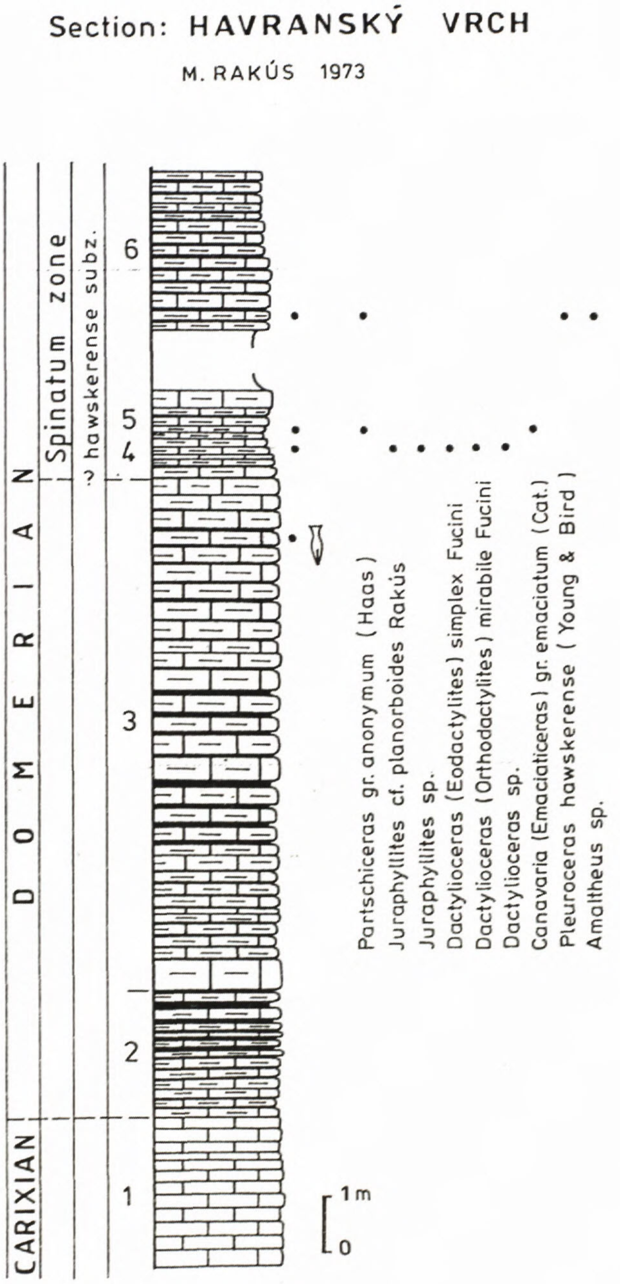

Fig. 1

Systematic

***Phylloceratida* ARKELL, 1950**
***Phylloceratidae* ZITTEL, 1884**
***Partschiceras* FUCICI, 1920**

***Partchiceras* gr. *anonymum* (HAAS, 1913)**

Material: One incomplete, sculptured cast, which represents a part of the whorl (levels 5 and 6).
Notes: Specimen from the locality Havranský vrch is in good accordance with the original depiction of the specimen (HAAS, 1913). Recently the specimen was exhaustively characterized by FATINI-SESTINI, 1971).
Stratigraphic range: Pliensbachian (FANTINI-SESTINI, 1971)

In the Western Carpathians this species is known from the Domerian (RAKÚS, 1964).

***Juraphylitidae* ARKELL, 1950**
***Juraphyllites* MüLLER, 1939**

***Juraphyllites* cf. *planispiroides* RAKÚS, 1993**
(pl. 1, fig. 5)

Material: One compressed and incomplete specimen (level 4)
Notes: Our specimen is in good correspondence with original description and depiction of the species described by author (1994).
Stratigraphic range: Lotharingian to Domerian in Tethyan realm

***Juraphyllites* sp.**

Together with the above mentioned species, a partly conserved specimen of costate juraphyllitid has been found. More detailed determination was not possible owing to bad preservation (level 4).

Family ***Amaltheidae* HYATT, 1867**
Genus ***Amaltheus* DE MONTFORT, 1808**

***Amaltheus* sp.**

Notes: At the Havranovský vrch locality an incomplete specimen of Amaltheus was found together with *Pleuroceras*. Discoidal, oxycone shape of conche, sigmoidal ribs and crenulated keel leave no doubt that our specimen is indeed an *Amaltheus*. It is a little surprising that Amaltheus was found with *Pleuroceras*. However, we would like to emphasize that this Amaltheus assemblage is situated (approximately 1,5 m) above the first appearance of primitive *Dactylioceras*.

Stratigraphic range: Domerian, Spinatum zone, hawskerense subzone

Pleuroceras HYATT, 1867

Pleuroceras hawskerense (YOUNG & BIRD, 1828)
(pl. 1, fig. 4)

1828 *Ammonites hawskerensis* YOUNG & BIRD, p. 258, pl. XIV, fig. 6
1958 *Pleuroceras hawskerense* (YOUNG & BIRD) - HOWARTH: 45, text. fig. 18, pl. 9, fig. 3, 5-8, pl. 10, fig. 4 (cum. syn.)
1961 *Pleuroceras hawskerense* (YOUNG & BIRD) - DEAS et al.: 472, pl. 71, fig. 4
1980 *Pleuroceras hawskerense* (YOUNG & BIRD) *elaboratum* (SIMPSON) - WIEDERMAYER: 51, pl. 3, fig. 1, 22
1985 *Pleuroceras hawskerense* (YOUNG & BIRD) - SCHLATTER: 5, pl. 1, fig. 3, pl. 2, fig. 1

Material: Two more or less complete specimens (level 6)
Notes: All the basic characteristics of the specimens from Havranský vrch are in good accordance with specimens shown by HORWATH (1958).
Stratigraphic range: Upper Domerian, Spinatum zone, hawskerense subzone.

Dactylioceratidae HYATT, 1867
Dactylioceras HYATT, 1867

Dactylioceras (Eodactylites) SCHMIDT - EFFING, 1972

Notes: The subgenus *Eodactylites* was introduced by SCHMIDT - EFFING in 1972 (p. 91) without being accompanied by a diagnosis or bibliographic reference. Later the same author (1981, p. 31) corrected this error by designating his new subgenus as type species of *Dactylioceras pseudocommune* FUCICI, 1935. Further the same author included here also the species *D. (E.) simplex* FUC. (cf. p. 31). This broader understanding of subgenus *Eodactylites* is in contradiction with the original SCHMIDT - EFFING diagnosis. The typical specimen of *D. (E.) pseudocommune* is devoid of prominent primary ribs with tuberles in the juvenile or subadult stages (cf. FUCINI, 1935, pl. 9, fig 1-3).

Because of this, the systematics of the late Domerian and early Toarcian *Dactyloceratids* is still unclear. We assume that for the time being the SCHMIDT-EFFING'S conception is correct. I would like to remark, however, that this solution is not quite satisfactory.

Dactylioceras (Eodactylites) simplex (FUCINI, 1935)
(pl. 1, fig. 4)

1935 *Dactylioceras simplex* n. sp. - FUCINI: 86, pl. 9, fig. 4, 5
1973 "*Catacoeloceras*" *simplex* (FUC.) - GUEX: 509, pl. 12, fig. 11
1981 *Dactylioceras (Eodactylites) simplex* FUCINI, 1935 - HILLEBRANDT 85, SCHMIDT - EFFING: 31, text. fig. 12, 16, pl. 1, fig. 1-4 (cum. syn.)
1982 *Dactylioceras* cf. *simplex* FUCINI - SCHLATTER: 761, pl. 1, fig. 2-3
1985 *Dactylioceras (Dactylioceras)* cf. *simplex* (FUCINI 1935) - SCHLATTER: 6
1986 *Dactylioceras (Dactylioceras) simplex* FUCINI, 1935 - GAKOVIČ: 78, pl. 5, fig. 1a-c

Material: Two partly preserved specimens (level 4)
Notes: Our specimen is featuring strong primary ribs, terminated distinct ventrolateral tubercles, branched to bi- or trifurcated secondary ribs are in good agreement with the original description and depiction by Fucini (1935, p. 78, pl. 9, fig. 4, 5).

Recent description of the species by GAKOVIC (1986, p. 78, pl. 5, fig. 1a-c) shows the same characteristics. Moreover, from Gakovic's depiction it is evident that juvenile-subadult stages of simplex species have simple, prominent primary ribs with tubercles. This ontogenetic stage shows certain relationship with *Coeloceratinae* HAUG, 1910 sensu WIEDENMAYER, 1917
Stratigraphic range: Upper Domerian, Spinatum zone, hawskerense subzone to Lower Toarcian.

Dactylioceras pseudocommune FUCINI, 1935
(pl. 1, fig. 2,3)

1935 *Dactylioceras pseudo-commune* n. sp. FUCINI: 86, pl. 9, fig. 1-3
1966 *Dactylioceras pseudocommune* FUCINI - FISCHER: 26, pl. 1, fig. 5, pl. 4, fig. 3, 6
1972 *Dactylioceras (Eodactylites) pseudocommune* FUCINI, 1935 - SCHMIDT - EFFING: 91, pl. 3, fig. 1a-c; pl. 18, fig. 7, text. fig. 15
1973 *Dactylioceras (Dactylioceras) pseudocommune* FUCINI - HOWART: 253, pl. 1, fig. 1 (cum. syn.)
1973 *Dactylioceras pseudocommune* (FUCINI) - GUEX: 508, pl. 12, fig. 2
1974 *Dactylioceras (Eodactylites) pseudocrassulosum* (FUC.) - ELMI: 47, pl. 1, fig. 12

Material: One incomplete specimen and several fragments of whorls (level 4).
Notes: Types of ribs, identical intercostal distances and mode of bifurcation of secondary ribs are in good

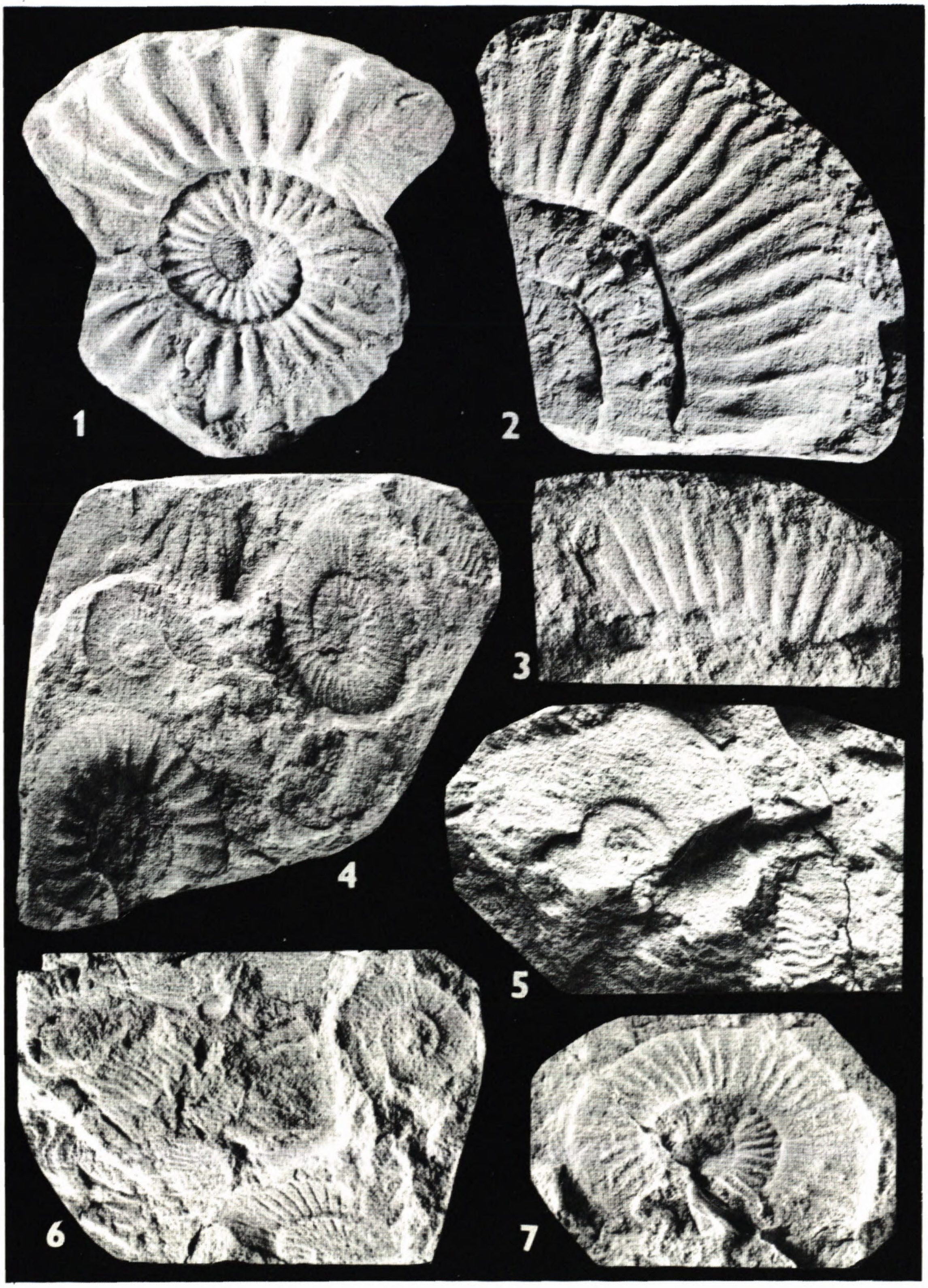

Fig. 1 Pleuroceras hawskerense (YOUNG & BIRD); Upper Domerian, Spinatum zone, hawskerense subzone; loc. Havranský vrch, level no. 6; 0,5x

Fig. 2,3 Dactylioceras pseudocommune FUCINI; Upper Domerian, Spinatum zone, hawskerense subzone; loc. Havranský vrch, level no 4, fig. 3, 0,5x, fig. 3, 1x

agreement with the original conception of species by FUCINI (1935).
Stratigraphic range: Upper Domerian, Spinatum zone, hawskerense subzone.

***Hildoceratidae* HYATT, 1867**
***Arieticeratinae* HOWARTH, 1955**
***Canavaria Gemmellaro*, 1886**
***Canavaria (Emaciaticeras)* FUCINI, 1931**

***Canavaria (Emaciaticeras)* gr. *emaciatum* (CATULLO, 1853)**
(pl.1, fig. 7)

Material: One partly deformed specimen; (level 5)
Notes: Although our specimen is insufficiently preserved, we are convinced that the principal characteristics as the size, section of whorls, involution, ribbing and ventral part of whorls are close to FUCINI's (1931)depiction. It should be noted, however, that the systematics of this group of *Arieticeratinae* is unclear and each author follows his own concept of classification.
Stratigraphic range: Upper Domerian, Spinatum zone, hawskerense subzone

Observation on the first appearance of Dactylioceratids in the Tethyan Realm

The first appearance of the genus *Dactylioceras* in NW Europe is linked to Lower Toarcian "Tenuicostatum Zone" (ARKELL, 1957; DEAN et al., HORWATH, 1973; SCHLATTER, 1985 and others).

This stratigraphical setting is automatically applied by the majority of stratigraphers also to the Tethyan realm, notwithstanding the long established fact that in the Tethyan domain the first *Dactylioceras* were reported from the Upper Domerian FUCINI, 1935` CANTALUPPI and SAVI, 1968). Observations of these authors are, however, disputed by Horwath (1973` 271/272).

Meanwhile, the occurrence of *Dactylioceratids* has been proved at further three, from each other quite distant localities: Algeria (Djebel Nador, Hauts Plateaux de Tiaret; SAPUNOV, 1974), Spain (Cordilleras Beticas; BRAGA, 1983) and Bosnia (in the vicinity of towns Gacko and Nevesenije; GAKOVIC, 1986). At each of these localities the *Dactylioceratids* were found within the assemblages of Upper Domerian Ammonites, especially with *Lioceratoides* or *Emaciaticeras.* In Spain, according to Braga' s information (l. c., p. 334), *Dactylioceras* sp. (=*D.* gr. *pseudocommune*) is situated in the Middle Domerian "Bertrandi subzone" which is the earliest reported appearance of this genus.

In the Western Carpathians the first *Dactylioceratids* occur slightly below (approximately 1,5 m) the assemblage of *Pleuroceras hawskerense* and Amaltheus, which corresponds to the Upper Domerian.

As a conclusion, all the above mentioned informations would seem to provide enough convincing evidence for the view that, in the Tethyan realm, the first *Dactylioceras* appear in the Upper Domerian. This conclusion should not be surprising bearing in mind that in the NW Europe, the first *Dactylioceras* are also found in the Upper Domerian (cf. HORWATH, 1958, p. XI or SCHMIDT-EFFING, 1972, p. 140). On the other hand their mass occurrence should, however, be identified with the Lower Toarcian *Tenuicostatum* zone.

Conclusion

The appearance of the *Dactylioceras*, similar to other groups of Ammonites in the Tethyan bioprovince, is precocious in comparison with NW Europe or the boreal bioprovince.

Fig. 4 Dactylioceras (Eodactylites) simplex FUCINI, Upper Domerian, Spinatum zone, hawskerense subzone; loc. Havranský vrch, level no 4, nat. size
Fig. 5 Juraphyllites cf. planispiroides RAKUS; Upper Domerian, Spinatum zone, hawskerense subzone, loc. Havranský vrch, level no 4; 0,5x
Fig. 6 Dactylioceratidae div. sp. (probably juvenil stages of D. pseudocommune); Upper Domerian,spinatum zone, hawskerense subzone; loc. Havranský vrch, level no 4, nat. size
Fig. 7 Canavaria (Emaciaticeras) gr. emaciatum (CATULLO) Upper Domerian, Spinatum zone, hawskerense subzone; loc. Havranský vrch, level no 5; 0,5x

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First Evidence of the Turolian Carnivorous Species *Perunium ursogulo* ORLOV, 1948 (*Mustelidae, Mammalia*) from Slovakia

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Abstract: The first acquisition of the *Perunium ursogulo* ORLOV, 1948 from the Turolian (Upper Miocene) of Borský Jur (Slovakia) is described here, presenting this rare gigantic mustelid species with lower left M_1. There are very few paleontological localities, atwhich this taxon could exist. Evidence of this *Perunium ursogulo* ORLOV ,1948 from Borský Jur (Lower Turolian, MN 11) is the northernmost finding of this species.

Key words : *Perunium* - *Mustelidae* - Carnivora - Upper Miocene

Abbreviations : LM_1 = length of M_1, WM_1 = width of M_1, ZIBA = Zoological Institute, Comenius University, Faculty of Natural Sciences, Bratislava

Introduction

Peruniids (*Peruniidae, Mustelidae*) are large or medium sized mustelids of Miocene. A typical cranial feature of this little known subfamily is the short rostral part. The skull is extraordinarily larger than in the greatest specimen of recent *Gulo gulo* (wolverine). The relatively high braincase is very similar to the ursid *Thalarctos maritimus.* Basicranial region is narrow with small mastoid. Zygomatical arcs are significantly broader. High and robust mandibula has a strongly formed symphysal part. The upper fourth premolar is architectonically related to the *Martes* type. Inner cusp (protocone) is lower and connected with paracone. Parastyle has an important secondary cusp. Enamel of the lower dentition is smoother than in *Gulo* specimen. The lower M_1 is longer, with higher protoconid. The absence of metaconid tubercule is diagnostically important. Talonid consists of a longitudinal, hypoconidal ridge (ORLOV, 1948).

Except for some isolated and briefly reported finds (SCHMIDT-KITTLER, 1976), the best collection of peruniids remains the one from Moldovian (ORLOV, 1948). There are probably no further papers dealing with the description of this species. A new species of *Perunium* was recently found on the deposits of Lothagam (Turkana, Kenya). This African species will be described in the near future (L.WERDELIN, in prep.).

Systematical part

Classis *MAMMALIA* LINNAEUS,1758
Ordo *CARNIVORA* BOWDICH, 1821
Subordo *FISSIPEDIA* BURMEISTER, 1791
Superfamilia *ARCTOIDEA* FLOWER, 1869
Familia *MUSTELIDAE* SWAINSON, 1835
Genus *PERUNIUM* ORLOV, 1948
Species *URSOGULO* ORLOV, 1948

Synonymy: *Pliogulo gigas* VOZNESENSKY, 1937 *Plesiogulo* VOZNESENSKY, 1939 *Plesiogulo* PIDOPLIČKO, 1938
Type: Skull No. 268 with incomplete mandibular arc (Geological Institute, Academy of Sciences, Kiev (Ukraine)
Type locality: Grebenniki,Tiraspol District, Moldovian
Type level: Turolian, Miocene
Material: M_1 - first lower left molar (M_1 sin., inf.), ZIBA-002
Age: Upper Pannonian, MN11, Lower Turolian
Locality: Borský Jur, Western Slovakia (see Fig.1)

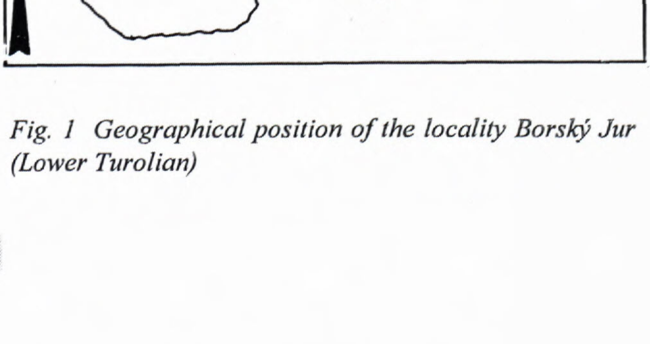

Fig. 1 Geographical position of the locality Borský Jur (Lower Turolian)

Locality

The occurrence Borský Jur is located northwest of Bratislava, in the vicinity of the village Sekule. Basic sediments are after marine chronostratigraphy - Pannonian clays (Upper Pannonian, MN 11). After mammalian biochronostratigraphy these sediments correspond to the Lower Turolian. More details concerning geological background and vertebrate fossils are available in LUPTÁK (in press).

Description of material

The whole M_1 sin.inf. with well formed three tubercules and two strong, flattened roots is preserved (Fig.2). The crown base is longitudinal in the outline. Anterior part has strong curving of the paraconid cusp (in the medial course). The trigonid length reaches approximately three-fourths of the whole molar length. The talonid is remarkably simplified (one-fourth of molar length) and is formed by a single ridge-shaped hypoconid. This ridge stretches from the place of junction to posterior protoconid edge. This structure is turned into the central part and has a transversally oblique pattern. The shallow cave with cuneiform pattern is located on the lingual side of the talonid. The lingual margin of the talonid is separated from postero-lingual wall of protoconid by a narrowed notch. The posterior cingulum of talonid is expressive, mainly in the buccal side.

The protoconid is the highest tubercule from whole carnassial (two fifths more than in adjacent paraconid). On the lingual wall of the posterior part, very strong inner edge developed, rising from basal cingulum to the top of the cusp. This edge has different lingual inner walls. The first wall - in the posterior part has a convex pattern and it is triangular in the outline. The ridged area of posterior edge is formed extraordinarily. The second wall is half size larger and has concave character with lacking lower anterior part. The basal cingulum is slightly structured and lies below this tubercule. It is possible to observe a similar, but smaller edge on the buccal side. Most of the interior part of the wall is strongly disrupted. On the protoconid/talonid bounds there is a vertical incision.

Paraconid has apparently developed also an inner edge. This edge is crossing to the back line of the tooth. The buccal wall is without edge and has a concave pattern. Basal and anterior cingulum of this cusp is simple and expressive. The transitional

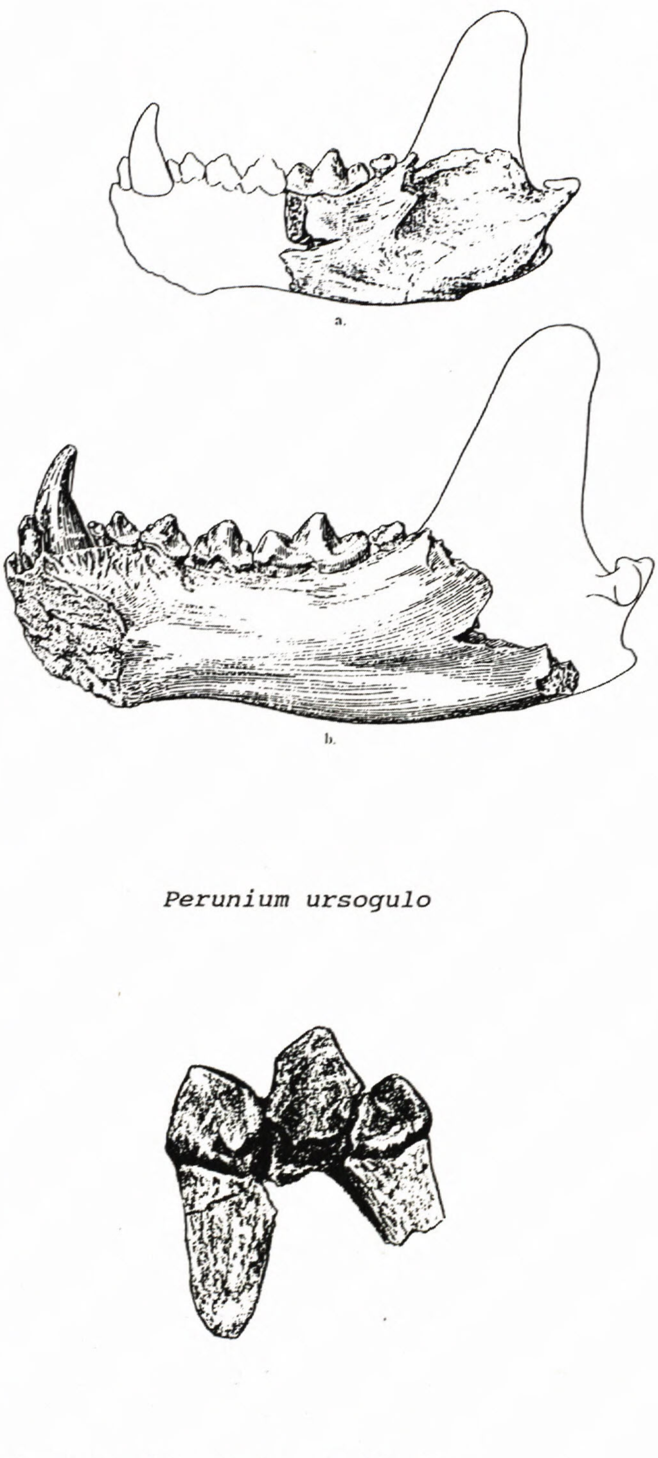

Fig. 2 Perunium orsogulo ORLOV, 1948.
A – Left mandibular fragment No. 269b in buccal view (Grebenniki, Moldova, after ORLOV, 1948), B – Right mandibular fragment No 269a in lingual view (Grebenniki, Moldova, after ORLOV, 1948), C – Lower left molar M_1 ZIBA - 002 (Borský Jur, Slovakia).

part between paraconid and protoconid was broken. On the top of the paraconid there is a longitudinal occlusal surface. The molar is broadest in the central part. The tooth was originally two rooted and belonged to an adult specimen (LUPTÁK, 1993).
Measurements: LM_1 = 23.6, WM_1 = 9.5 (in mm)

Comparison and phylogenetical status

After a detailed research of major tubercules and investigation of Moldavian specimens, it is clearly indicated that M_1 from Borský Jur belongs to the rare gigantic mustelid species of Perunium ursogulo ORLOV, 1948. All species marks which had been recognized by ORLOV (1948) are present. They are the following features of M_1-carnassial :

1. broadest molar in the central part
2. only from hypoconid built talonid
3. on the same level lying paraconid and hypoconid
4. protoconid - highest cusp of the tooth
5. fine lingual trigonid incision

The genus name has been established by ORLOV in 1948 on the ground of fossil finds from Grebenniki in Moldovian. Unfortunately, only cranial and mandibular material is known. Together with this genus, named after old Slavonic god Perun, to the subfamily *Peruniinae* belongs also the genus *Eomellivora wimani* having a greater and longer M_1. The forms *Eomellivora tenebrarum* are similar in dimensions. *Eomellivora wimani* generally formed strong anterior and basal cingulum, significantly broader M_1 and little medially curved paraconid part. Protoconid and paraconid are developed on the lateral side. The trigonid edge in Perunium is composed of these two cusps in the centre of longitudinal axis of M_1. The majority of differences between the species is based on signs of the other dentition than M_1 and cranial features (size of rostrum, jaws, braincase, basicranium, etc.).

The genera *Perunium* and *Eomellivora* are not the members of the subfamily *Mellivorinae.* Since 1948 they are distinguished in the subfamily *Peruniinae* ORLOV, 1948, of large-sized, to the wolverines or honeybadgers related mustelids. Except for *Mega-lictis ferox* MATTHEW (1907) they are the largest known mustelid forms of all times. *Plesiogulo brachygnathus* SCHLOSSER from the Lower Pliocene of China has similar size to *Perunium ursogulo.* From the European locality Montpellier there is known *Plesiogulo monspessulanus* (VIRET, 1939). This species has Middle Pliocene age and is larger than *Plesiogulo brachygnathus* (ZAPFE, 1948). Both *Plesiogulo genera* are significantly geologically younger.

Other genera from the subfamily *Mellivorinae*, like *Promellivora, Promellivorodon*, are of no importance for further comparison.

Conclusions

The first acquisition of M_1 *Perunium ursogulo* ORLOV, 1948 from the territory of Slovakia is presented. The molar M_1 from this gigantic extinct mustelid species contributed to the so far few finding sites in the European Miocene. The locality Borský Jur is the northernmost site of this form. The age of the fossil find is Upper Pannonian (MN 11). The species characteristics of the molar which were recognized in Moldovian specimens have been presented here as well.

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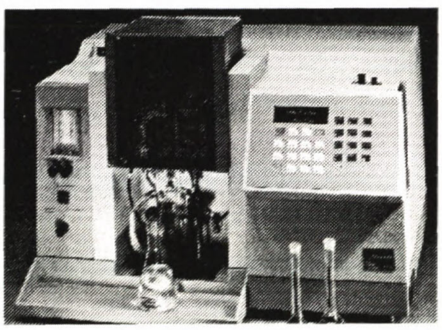

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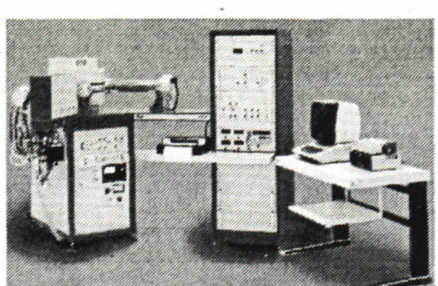

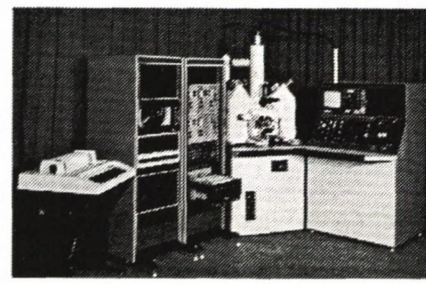

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