Late Carboniferous to Early Permian time interval in the Western Carpathians: Northern Tethys Margin

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ABSTRACT
Carboniferous to Permian basins reflected compression regime of the Variscan orogeny during the continent-continent collision in final stages. The fragments of these microplates are preserved in the Alpine Western Carpathians basement (CWCZ, NGZ vers. IWCZ). On the basis of sedimentary sequence analysis two zones of continental collision differing in time were established: (1) internal with termination of collision during Bretonian (pre-Sudetian) events, resulting in the syn-collision Tournaisian-Visean flysch; (2) external with termination of collision during pre-Asturian events, comprising the Bashkirian, and in the innermost part of the Western Carpathians (Bükk Mountains in the northern part of Hungary) partly even the Early Moscovian flysch sequences.

KEY WORDS
Peri-Tethys,
Western Carpathians,
Late Variscan orogeny,
Carboniferous-Permian,
syn- and post-orogenic basins,
collision events.

RÉSUMÉ
L'intervalle Carbonifère supérieur à Permien inférieur dans les Carpates occidentales : marge septentrionale de la Téthys. Les bassins d'âge carbonifère à permien reflètent un régime de compression appartenant à l'orogénèse varisque, lors de la collision continent-continent dans les stages finaux. Les fragments de ces microplaques sont préservés dans le socle des Carpates alpines occidentales (CWCZ, NGZ vers. IWCZ). D'après l'analyse des séquences sédimentaires, deux zones de collision continentale peuvent être établies : (1) interne avec la fin de la collision pendant la phase Bretonne (pré-Sudète), entraînant le dépôt du flysch tournaisien-viséen inférieur syn-collision ; (2) externe, avec la fin de la collision pendant la phase pré-Asturienne, comprenant le Bashkirien et, dans la partie la plus interne des Carpates occidentales (Montagne du Bükk dans le nord de la Hongrie), le dépôt de flysch d'âge moscovien inférieur.

MOTS CLÉS
Péri-Téthys,
Carpates occidentales,
orogénèse tardi varisque,
Carbonifère,
Permien,
bassins syn- et post-orogéniques,
collision.

INTRODUCTION

The kinematic evolution of the West Carpathians orogenic system was created during both Variscan and Alpine times. Fragments of newly formed Epi-Variscan crust were incorporated in the Paleo-Alpine West Carpathian units as evidenced by repeating subduction/collision and transform fault processes. The Epi-Variscan crust gradually amalgamated due to crustal thickening during Early to Late Carboniferous collision events, as the colliding microplates of African affinity moved southwards. The Early Carboniferous flysch troughs originated in intrasutural embayment continuing in the Late Carboniferous peripheral basin on the underthrusting plate of the African promontory. The post-collisional Permian evolution of the Western Carpathian realm continued by formation of transtension/transpression and rifting-related sedimentary basins.

Like most of the other collisional fold belts, the Western Carpathians have been traditionally divided into external and internal structural zones. The main difference between distinguished structural zones is in the age of the main Alpine events and in the intensity of their deformational and metamorphic effects. These are: (1) internal zone, the HP/LT Late Jurassic subduction event and Early/Middle Cretaceous collision, followed by nappe stacking; (2) external zone, the Late Cretaceous/Early Paleocene to the Oligocene/Early Miocene subduction/accretion and collision events. The fragments of the Late Paleozoic sedimentary basins filling are preserved only inside of the internal zone, as a part of principal crustal-scale superunits (from N to S: the Tatricum, Veporicum and Gemericum), and several cover nappe systems (Fatric, Hronic and Silic) as well as of the Bôrka and Turňa nappe slivers (Fig. 1).

Relics of the Late Carboniferous sedimentary sequences are proved by lithofacial and biofacial data in a relative wide range of sedimentary environments, from shallow-water marine to paralic and continental. The Early Permian sediments confirm only continental environment as a whole.

GEOLOGICAL FRAMEWORK

Different types of Variscan basement were overstepped by the Late Carboniferous/Early Permian sedimentary sequences. With respect to the metamorphic overprint, independent of the age of metamorphism, the Alpine-Western Carpathian basement may be subdivided into three zones (Fig. 1):

1. The Central Western Carpathian crystalline zone (CWCZ) which comprises mainly metamorphic rocks and huge masses of pre-Mesozoic granitoids. Pieces of pre-Variscan metamorphic crust were most probably included in this zone. Several pre-Alpine terranes were identified within large portion of the CWC-Alpine nappe units (Tatra T., within Tatric, Northern Veporic and Zemplinic Units; Kohút T., within Southern Veporic Unit; Hypoth. Ipoltica T., within Hronic Unit; Vozárová & Vozár 1993, 1996). Nearly all underwent Variscan metamorphism during Early Carboniferous post-dating sometimes such of Silurian/Devonian or also older metamorphic events. Magmatic activity is concentrated into two stages (Rb-Sr; U-Pb: approx. 360-340 Ma and 320-300 Ma; Cambel & Král 1989; Cambel *et al.* 1990).

Rare post-orogenic A-magmatites correspond to Permian age (Rb/Sr: 280-250 Ma; Cambel *et al.* 1989). Geochemical data indicate the operation of subduction system and then collisional-type of orogeny (Hovorka & Petrík 1992; Kohút 1992; Petrík *et al.* 1994, 1995). Granulites and leptynyte-amphibolite complexes with pieces of metaultramafic rocks and regressive overprinted eclogites are integral part of the CWCZ basement (Hovorka & Meres 1989, 1990; Vozárová 1993).

2. The Northern Gemeric zone (NGZ) with relics of the Namurian-Visean flysch and thrust wedges of pre-Carboniferous oceanic crust. This zone represents the Variscan collision suture, amalgamating two major Variscan microplates

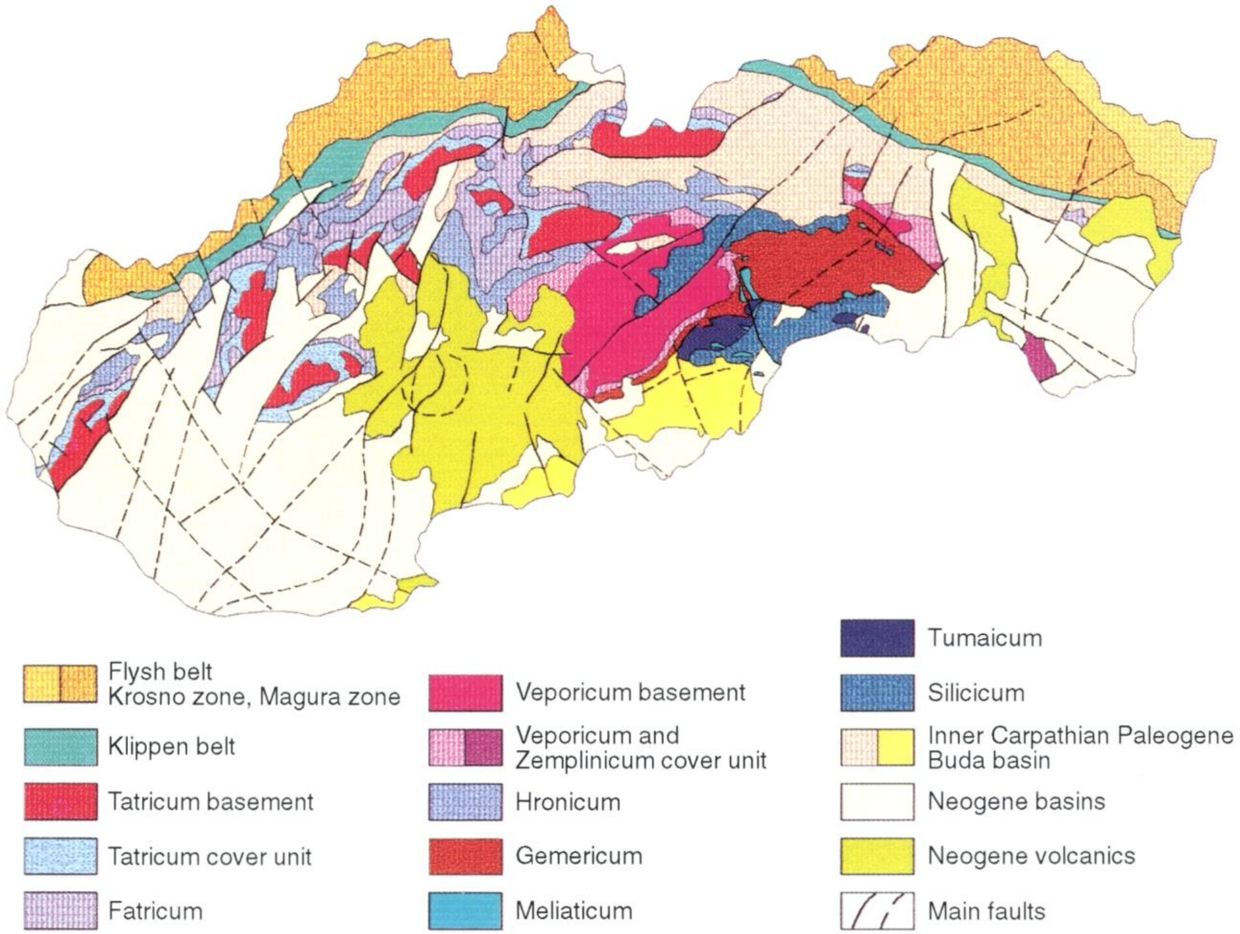

FIG. 1 — Tectonic sketch of the Slovak part of the western Carpathian (see legend Fig. 8).

(Vozárová & Vozár 1987, 1988; Neubauer 1988; Neubauer & Vozárová 1990). To this domain two since undated Variscan terranes (Klátov and Rakovec T.; Vozárová & Vozár 1993, 1996), which differ each of other in tectono-metamorphic development and probably also in the age of protolith. Their gradual amalgamation was taking place in the Early Carboniferous because, as the Uppermost Visean/Serpukhovian is in shallow water carbonate-clastic development (magnesite horizon within the Ochtiná Group) and after stratigraphic hiatus in the Namurian B-C, were unconformably overlapped by the Moscovian marine molasse. This unconformably lying marine molasse partly covered also the Early Carboniferous flysch sequence (eastern part of NGZ), to fix up the Late Variscan thrust sheet structure.

The mutual contact of the pre-Carboniferous crystalline complexes is tectonic, followed by lenses of antigoritic serpentinites.

High-grade crystalline complex (the Klátov T.) consists of mainly amphibolites, less gneisses and meta-ultramafic rocks. Meta-ultramafic rocks and metabasalt were considered as a part of incomplete ophiolite suite (Hovorka *et al.* 1984; Spišiak *et al.* 1985). Findings of regressive overprinted eclogitic rocks make possible to assume a polyphase metamorphic P-T path with previous high-pressure conditions. This is the main reason for recent comparing of this complex with lower-crustal leptinite-amphibolite complexes (Hovorka *et al.* 1992).

Low-grade crystalline complex (the Rakovec T.) is composed predominantly of tholeiitic metabasalts and metabasaltic volcanoclastics, associated with less amounts of sandy-pelitic metasediments and small bodies of gabrodiorites as well as metakeratophyres. The magmatic rocks show geochemical characteristics near to E-MORB/OIT basalts (Ivan 1994) and partly to island arc basalts. Several reasons speak in favour of a back-arc/supra-subduction zone setting of this crust (Vozárová 1993).

3. The Inner Western Carpathian crystalline zone (IWCZ) which is subdivided into two subzones: the Southern Gemeric zone (SGZ), the Turňa-Szendrö-Bükk zone (TSBZ).

Dominant part of the Southern Gemeric zone is composed of the Early Paleozoic volcanogenic flysch formation and its Permian-Triassic cover (the Gelnica T.; Vozárová & Vozár 1993, 1996). A huge mass of volcanogenic flysch comprises a distinct feature of turbidity current and other mass-gravity flow sedimentation (Ivanička *et al.* 1989). Besides of a quantity of redeposited acid to intermediate volcanoclastic material, derived from synsedimentary continental magmatic arc, also detritus from the subduction complex or fragment of oceanic crust are insufficiently present. Regional metamorphism of the SGZ basement did not exceed the low-pressure greenschist facies (Sassi & Vozárová 1987, 1992). The age was proved palynologically within the wide and the most probably not precise range of the Late Cambrian to Early Devonian (Snopková & Snopko 1979). Early Paleozoic ages (497-391 Ma) are also proved by U-Pb dating from zircons in metavolcanics (Cambel *et al.* 1977; Ščerbak *et al.* 1988). The Precambrian age of the continental source area was established from detrital zircons in metasediments (U-Pb; 600-900 Ma; Cambel *et al.* 1977). The SGZ Early Paleozoic flysch sequence (the Gelnica Group) was interpreted as a relic of fore-arc filling related to active continental margin (Vozárová 1993).

Within the Turňa-Szendrö-Bükk zone the pre-Carboniferous complexes are only fragmentary preserved. They are represented mainly by the shallow-water to basinal sequences of passive continental margin of the northern Gondwana promontory (for precise description: Kovács 1989; Fülöp 1994 and others).

The Bashkirian olistostroma flysch complexes are the most typical feature of this subzone. They were described within the Turnaic Unit in the Inner Western Carpathians (Vozárová & Vozár 1992) as well as in the Szendrö and Bükk Mountains (Kovács 1988, 1992). The slight or no Variscan metamorphism is typical for TSBZ Paleozoic complexes. Only exclusion are sequences of the Bashkirian flysch in the Western Carpathian Turnaic Unit, the Variscan regional metamorphism of which reached the low-pressure greenschist facies (Mazzoli & Vozárová 1989).

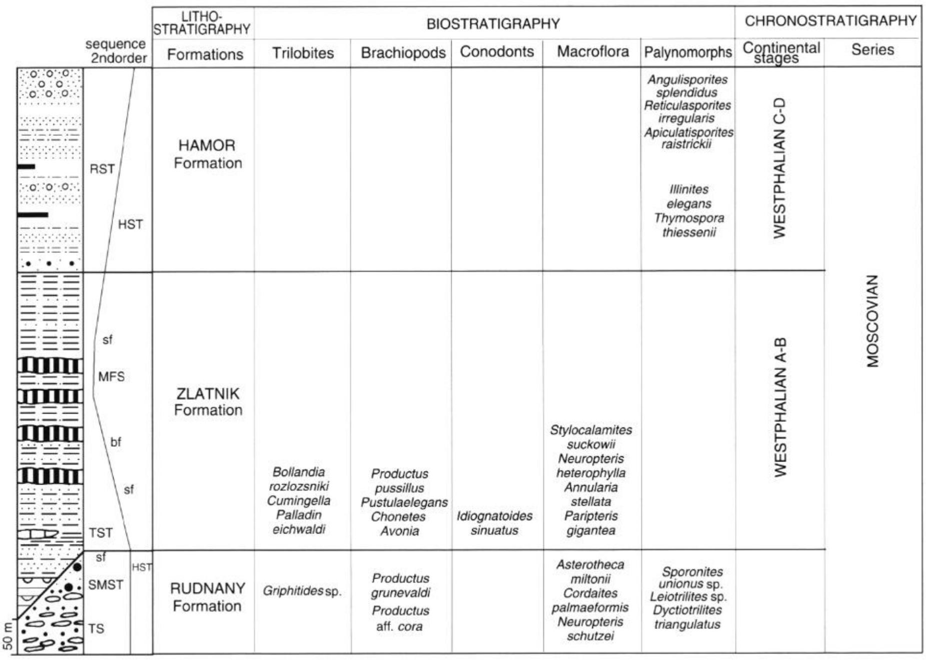

FIG. 2. — The Westphalian of the northern Gemeric Unit (see legend Fig. 8).

UPPER CARBONIFEROUS

MARINE DEVELOPMENT

The Westphalian sequences are preserved within the paleo-Alpine North Gemeric Unit (Fig. 2) as tectonically reduced fragments. Their tectonic setting, related to continental collision, started in the Westphalian A by delta-fan, coarse- grained, very often boulder conglomerates, containing detritus derived from underlying pre-Late Carboniferous rocks complexes. Due to strong Alpine reworking the direct contact of these basement rocks and basal part of the Westphalian deltaic-marine overstep sequences is preserved only in some places. Basal conglomerates of the Rudňany Formation unconformably overlap the gneiss-amphibolite complex of the Klátov Terrane in the vicinity of the Dobšiná town, metasediments and metabasalts of the Rakovec Terrane in the wider area of the Rudňany village, and the Early Carboniferous flysch sequence of Črmel' Formation in the area between Margecany and Košická Belá (more details referring to Variscan and Alpine history of the North Gemeric Terrane *in* Vozárová & Vozár 1993, 1996; Vozárová 1996). Black shales and micaceous grey sandstone intercalations are normal member of the fining upward Rudňany Formation. The floristic finds was determined by Němejc (1947): *Cordaites palmaeformis* Goeppert, *Asterophyllites* cf. *grandis*, *Asterotheca miltonii* Artis, *Neuropteris schutzei* Potonié, *N. gigantea abbreviata* Stockmans.

After initial rapid sedimentation the littoral to shallow-neritic limestones were associated with fine-grained clastic metasediments. This detritic-carbonate lithofacies corresponds to basal part of the Zlatník Formation, from which the Westphalian B-C age is indicated by rich trilobite fauna: *Griffithides dolosinensis* Illés, *Griffithides rozloszniki* Rakusz, 1932; *Cummingella* sp. aff. *balladoolensis* Reed, 1942; *Palladin* sp. aff. *eich-*

waldi Fischer, 1825 (*in* Rakusz 1932; Bouček & Přibyl 1960). Basing on flora findings Němejc (1947, 1953) ranged this sequence to the Westphalian A-B: *Paripteris gigantea, Stylocalamites suckovii, Neuropteris heterophylla, Neuropteris gigantea* Stbg, *Neuropteris flexuosa* Brongiart, *Calamites* cf.*cisti* Brongiart. The conodont *Idiognatoides sinuatus* Harris-Hollingsworth proved Westphalian A age (Kozur & Mock 1977).

Upper part of the Zlatník Formation comprises fine-grained clastic metasediments associated with fine basaltic volcanoclastics and scarce effusions of high-K tholeiitic basalts. It reflects deepening of the Moscovian sedimentary basin. Poor microfloral assemblages proved the Late Carboniferous age, but no accurate division.

Termination of the Moscovian peripheral basin is reflected by the paralic sequence of the Hámor Formation. It is characterized by: (1) distinct cyclical, coarsening-upward shally-sandy-conglomeratic sediments; (2) absence of synsedimentary volcanism; (3) local occurrence of ribbed coal seam. The microfloral assemblages proved the Westphalian D age: *Reticulatisporites irregularis* Kosanke, *Thymospora thiessenii* (Kosanke) Wilson *et* Venkatachala, *Apiculatisporites raistrickii* (Dyb.-Jach.), *Angulisporites splendidus* Bharadw., *Illinites elegans* Kos. (Ilavská 1962 unpublished report; Planderová 1979 unpublished report).

The metamorphic grade in the Moscovian sequences did not exceed P-T condition of the boundary between anchizone and lower limit of the greenschist facies.

CONTINENTAL DEVELOPMENT

Westphalian-Stephanian continental sequences are preserved within the several Alpine Central Carpathian nappe units, such as very strong reduced relics within the Zemplinic, Southern Gemeric and Hronic Units. Direct contact between Wesphalian continental overstep sequence and its immediate basement is expressed only in the Zemplinic Unit.

ZEMPLINIC UNIT

The crystalline rocks of the Zemplinic Unit (Fig. 3), together with their Late Paleozoic and Mesozoic envelope, make up a tectonic horst striking NW-SE, uplifted from the basement of Tertiary filling of the East Slovakian (Transcarpathian) basin. According to the character of crystalline rocks and mainly Mesozoic development it may be correlated with the other units of the Tatro-Veporic domain (Vozárová 1989; Faryad 1995; Byšta Susp. Terr., *in* Vozárová & Vozár 1996). The Zemplinic Westphalian-Stephanian sequence consists of four partial lithostratigraphic units (Čerhov, Luhyňa, Tŕňa, Kašov Formations; *in* Bouček & Přibyl 1959; Grecula & Együd 1982; Vozárová 1986). Their stratigraphic range was established according to macro- and microfloral findings (Němejc 1947, 1953; Němejc & Obrhel 1958; Planderová *et al.* 1981).

Polymictic conglomerates, with grain-supported structure and relatively well-rounded pebble material are dominant lithofacies of the Čerhov Formation. They are interpreted mostly as braided-river deposits. The lithostratigraphic profile consists of repeated small fining-upward sedimentary cycles with prevalent conglomeratic or sandy-conglomeratic components. Minor black shale and siltstone intercalations occur in the upper part of the sequence. The dating, Westphalian D-Stephanian A, is based on dominant microflora: *Triquitrites* sp., *Microleticulatisporites sulcatus* (Wils. *et* Kr.), *Tripartites* sp., *Cyrratriradites trizonarius* Dyb. Jach.

The gradually evolving Luhyňa Formation consists of fine grained lacustrine sediments sandstones, mudstones and shales of grey to black colour, interrupted by episodic events of distal- fan streams. The Stephanian A age was proved mainly by macroflora: *Calamites cistii* Brongn., *Pecopteris* cf. *miltonii* Artis, *Alethopteris* sp., *Asterophyllites trichomatosus* Stur. Microfloral assemblages are indicative of the Stephanian A-B range. Dominant spores are: *Torispora securis* Balme; *Lycospora granulata* Kosanke, *Punctatisporites punctatus* (Kosanke, 1920) emend. Alpern, *Densosporites gracilis* Smith *et* Butterworth, and striate pollen of the genus *Vittatina* are less frequent.

Cyclothems with thin coal seams represent the Tŕňa Formation. The Early Stephanian age was inferred on the basis of plant findings: *Pecopteris*

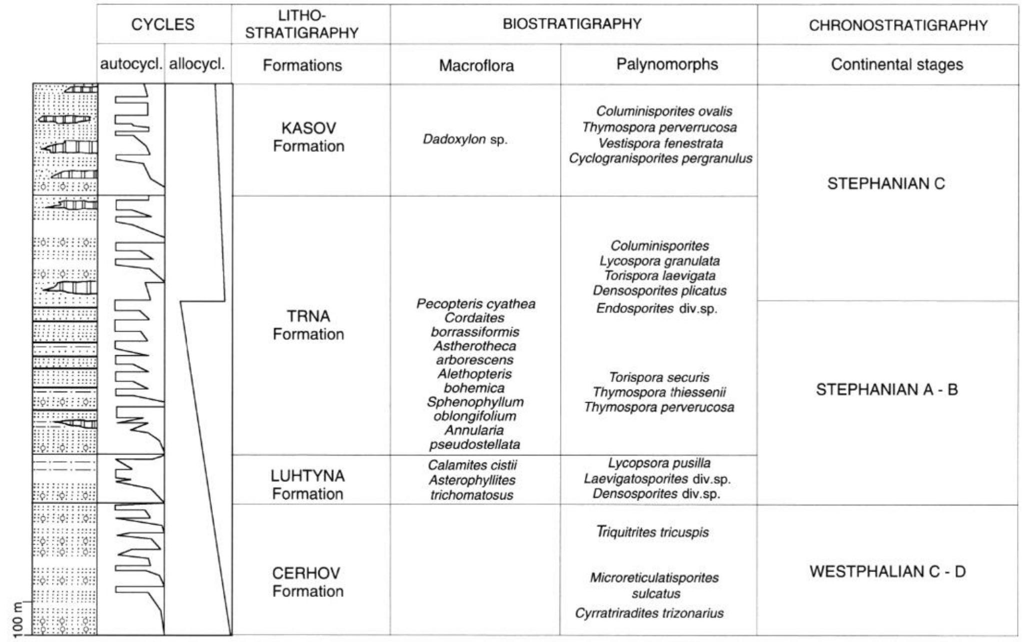

FIG. 3. — The Westphalian and Stephanian of the Zemplinic Unit (see legend Fig. 8).

cyathea Schlotheim, *Cordaites borassifolius* Sternberg, *Sphenophyllum emarginatum* Brongn., *Asterotheca arborescens* Brongn., *Alethopteris bohemica* Franke, *Calamites cistii* Brongn., *Stigmaria ficoides* (Sternb.) Brongn., *Annularia pseudostellata* Potonie, *Lepidophloios laricinus* Sternb., *Lepidostrobophyllum majus* Brongn, *Pecopteridium* cf. *costeii* Zeiller. The Tŕňa Formation can be divided into two large cycles (several hundreds of m thick). The lower cycle contains seven limnic- fluvial cyclothems with coal seams of variable thickness (from several cm up to 160 cm). Generally, the sediments are rich in clastic mica, plant debris, fragments of tree trunks and barks. Distinct cyclicity of fining-upward type, with sets of layers of black shales with thin coal seams and occasionally dark clayey lenses and nodules of limestones, indicate limnic-fluvial and swamp environments. The second large cycle is characterized by alluvial stream-channel lithofacies, with dominant sandstone members and absence of the coal-bearing association. Several levels of rhyolite-dacite, calc-alkaline volcanoclastics are typical for this part of sequence.

Thick layers of rhyolite-dacite volcanoclastics (including ignimbrites) and alluvial, stream-channel and flood plain sediments with dominant sandstones are predominating lithologies of the Kašov Formation. Based on the microfloral assemblages, the Kašov Formation was assigned to the Stephanian B-C. The following microflora assemblages were identified: *Thymospora perverrucosa* (Alp.) Wils. *et* Ven., *Columinisporites ovalis* Peppers, *Latensina triletus* Alpern, *Vittatina ovalis* Klaus, *Spinosporites* sp., *Disaccites striatiti* div. sp., *Cordaitina* sp., *Vestispora fenestrata* (Kos.) Wils. *et* Ven., *Cyclogranisporites pergranulus* Alp.

HRONIC UNIT

The Hronic Unit (Fig. 4) has been defined as a rootless megastructural Alpine unit consisting of two partial nappes: Šturec and Choč nappes (accord. to Andrusov *et al.* 1973). Due to their internal structure and mutual relations as well as

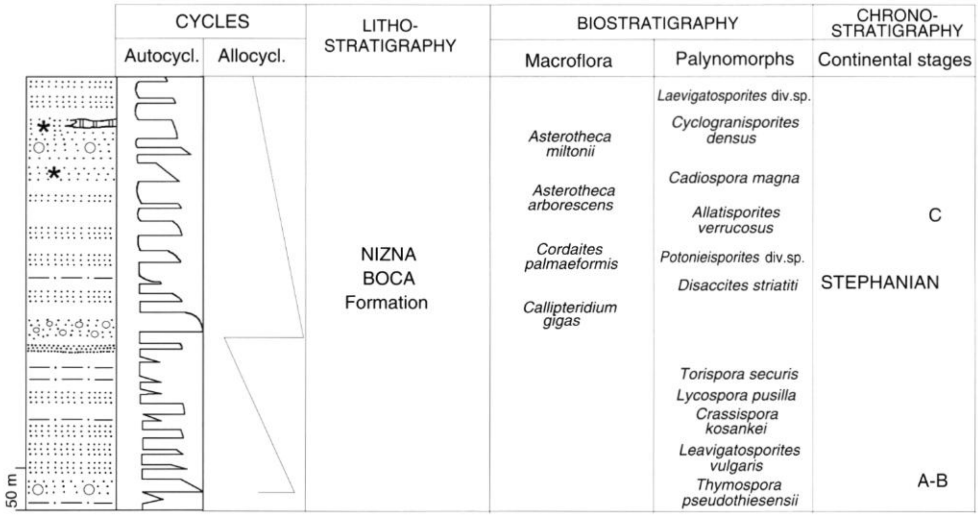

FIG. 4. — The Stephanian of the Hronic Unit (see legend Fig. 8).

facial characteristics the partial nappes have been distinguished as mainly Triassic complexes. Both Hronic nappe units contain Late Paleozoic volcano-sedimentary formations, preserved variably as a consequence of tectonic reduction during the nappe thrusting. Remains of these sequences are known in many mountain ranges in the Western Carpathians, whereby their tectonic position is always equal, between the Veporic/Fatric Unit and Northern Gemeric Unit resp. higher Mesozoic nappe units.

There is no evidence neither for the underlying pre-Stephanian sediments nor for the immediate crystalline basement. Tectonic slices of granitoid blastomylonites found in the basal part of the Šturec nappe might be partly indicative of its composition (Andrusov 1936; Vozárová & Vozár 1979). Data obtained through petrofacial analysis of clastic sediments proved an affinity to a magmatic arc source area (the hypothetical Ipoltica Terr., Vozárová & Vozár 1993).

The Stephanian, Nižná Boca Formation, is generally a regressive clastic sequence with a distinct tendency of coarsening upward. Numerous small repeating fining-upward sedimentary cycles are the most typical feature. Abundant graded-bedded sandstones with minor mudstone intercalations, as well as layers rich in plant detritus indicate a fluvial-lacustrine delta association. Sequences of fine-grained sandstones, mudstones and shales of grey to black colour correspond to lacustrine lithofacies. Syngenetic, mostly subaerial dacite volcanism is represented by abundant redeposited volcanogenic material mixed with non-volcanic detritus, less by thin layers of dacitic tuffs and exceptionally with small lava flows of dacite.

Macroflora from the uppermost part of the Nižná Boca Formation indicates its Westphalian-Stephanian age. Sitár (*in* Sitár & Vozár 1973) described well-preserved relics of *Asterotheca miltonii* Artis, *Asterotheca arborescens* Brongn., *Cordaites palmaeformis* Goepp. and *Callipteridium gigas* Gutb. The similar flora was determined by Němejc (*in* Mahel' 1954) from strongly tectonically reduced remains of the easternmost Nižná Boca Formation occurrences: *Calamites* sp., *Lepidostrobophyllum majus*, *Stigmaria ficoides* (Sternb.) Brongn., *Astherotheca miltonii* Artis, *Palmatopteris furcata* Potonié. Basing on palynological analysis Planderová (1979) distinguished two microflora assemblages: (1) the Stephanian A-B, *Torispora securis* Balm., *Lycospora pusilla* (Ibr.) Som., *Verrucosisporites pergranulus* (Alp.)

Smith., *Crassispora kosankei* (Pot. Kremp.) Bharadw., *Laevigatosporites vulgaris* (Ibr.) Alp. Doub., *Thymospora pseudothiessenii* (Kos.) Alp. Doub., (2) the Stephanian C, *Laevigatosporites* div. sp., *Cyclogranisporites densus* Bharadw., *Lycospora pusilla* (Ibr.) Som., *Foveolatisporites junior* Ros., *Planisporites kosankei* (Knox) Pot. Kr., *Cadiospora magna* Kos., *Allatisporites verrucosus* Alp., *A. hexalatus* Alp., *Potonieisporites* div. sp. and *Disaccites striatiti.*

SOUTHERN VEPORIC UNIT

The Southern Veporic basement is a composite and very strong Alpine reworked segment of the Variscan crust. Dominant part of this basement consists of several types of low- to medium-grade metamorphic complexes. The occurrences of Al-Fe rich metasediments (Korikovskij *et al.* 1989; Kováčik 1991; Meres & Hovorka 1991) and orthogneisses of magmatic arc provenance (Hovorka *et al.* 1987) are special type. Besides of these rock complexes relics of migmatitized and strongly diaphtorized high-grade crystalline complexes were distinguished (?Proterozoic in age; Bezák 1991). The Carboniferous cover is represented by upward-coarsening sequence of the Stephanian sediments (the Slatviná Formation). Their direct contact with the basement is hard to prove, due to either Alpine thrusting or contact-thermic effects of younger granitoids (Vozárová & Vozár 1982; Vozárová 1990).

Well-preserved cyclical structure as a multiply vertical alternation of gray metasandstones and dark-gray/black metapelites and their regional unification in two large coarsening upward regressive cycles indicate mutual prograding from deltaic to fluvial environment. This prograding trend is, on the contrary to the rapid change of sediment colour from black or dark-gray to light-gray/light-green, due to changes in sedimentary environment as well as climatic conditions. In reaches of stillwater there tended to develop anoxic conditions, resulting in formation of black shales. Abundant carbonized plant detritus, relics of tissue fragments, spores of terrestrial plants are indicative of the proximity of plant covered continent.

Conspicuous stratification and cyclicity, tabular and relatively uniform sandstone strata are the main sedimentary features. Most others were destroyed by the Alpine regional tectonometamorphism and by consequent thermal relaxation (Vozárová 1990).

On the basis of abundant pollen of the genera *Potonieisporites* Bhardw., 1957, *Illinites* Kos, 1950, *Striatosaccites jizba*, and *Florinites* S.W. *et* B., 1944 and the species *Thymospora thiessenii* (Kos.) Wils. *et* Venk. The sediments are classed with the Stephanian C (Planderová & Vozárová 1978).

EARLY PERMIAN

Generally, the Early Permian sequences are represented by continental, mainly coarse-grained sedimentary formations, the origin of which was first of all related to transpressional and then extensional tectonic regime. Integral part of these formations are volcanites and their volcanoclastics, among them the calc-alkaline rhyolite-dacite less andesite and continental tholeiitic andesite-basalts are the most extensive.

The Early Permian sediments prove mostly very low structural and mineral maturity. They show provenances from the uplifted and tectonic rejuvenated crystalline basement or uneven cut magmatic arc. The prevalent sediments deposited in alluvial or fluvio-lacustrine and ephemeral lake environment, as well as semiarid to arid climatic conditions caused the absence of horizons containing fauna and flora. Biostratigraphical data are supported by microfloristic investigations, based on relative poor pollen and sporomorph spectrum.

CENTRAL WESTERN CARPATHIANS CRYSTALLINE ZONE

Within the Central Carpathians crystalline zone the superposition of the Early Permian deposits is the following:

– unconformably lying on the crystalline basement;

– gradual prograding from the underlying Stephanian sediments with the sharp change of sediment colour due to rapid climatic alternations.

A representative of the first type formations is

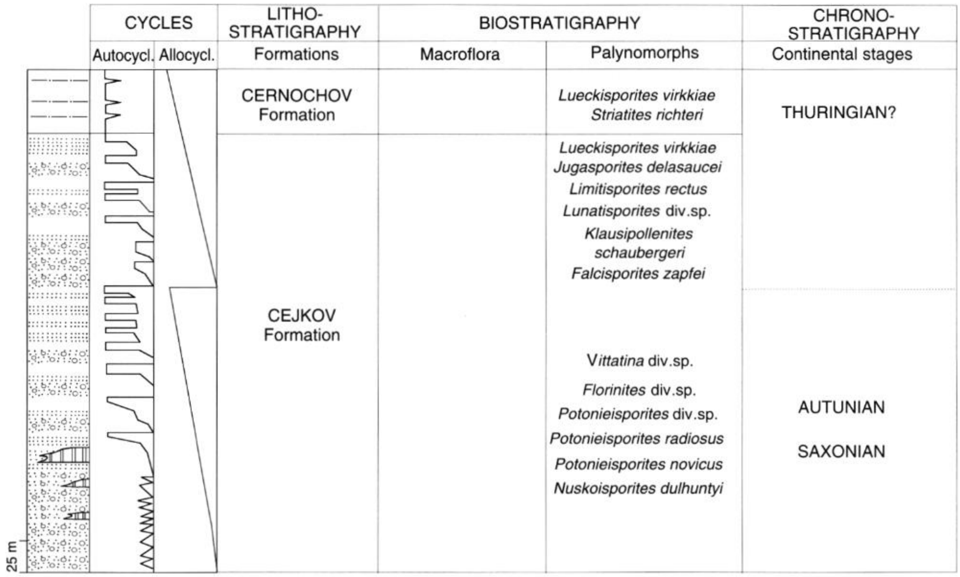

FIG. 5. — The Autunian and Saxonian of the Zemplinic Unit (see legend Fig. 8).

the sequence of the L'ubietová Group comprising the Brusno and Predajná Formations (Vozárová 1979).

Principal features of the Brusno Formation are the following: dominant arkosic sediments of psamitic/psephitic grade and evidence of synsedimentary volcanism (the Harnobis volcanogenic horizon). Monotonous, mostly light-grey and greenish-grey coarse-grained sediments indicate an environment of low-sinuosity rivers. Frequent washouts, erosive channels and in fact poorly preserved overbank and crevasse sediments are evidences of quick and chaotic changes of braided alluvia with prevalent autocyclic erosive processes. The provenance of detritus was proved to be underlying crystalline basement, mainly the granitoid and migmatite rock complexes (Vozárová 1979). The Harnobis volcanogenic horizon consists mostly of dacite effusions associated with dominant pyroclastic tuffs, in part of them ignimbrites and epiclastic deposits. Less frequent are andesites and their volcanoclastics. According to their chemical composition the volcanics correspond to calc-alkaline variety with affinity to subalkaline magmatic trend. The age of the Brusno Formation is not reliably biostratigraphically dated.

The Predajná Formation overlaps disconformably the Brusno Formation. Hiatus is documented by a conspicuous change of the drainage system as well as of the source area, the latter being reflected in distinct differences in composition of the detritus (mostly micaschist, paragneisses, microgranites and the Harnobis volcanics). Variegated polymict clastic sediments indicate an alluvial fan and piedmont flood plain sedimentary environment with isolated distal ephemeral lakes. Two regionally developed megacycles, with thick horizon of conglomerates at the base of each of them, are reflection of the synsedimentary tectonic. The second is partially reduced due to pre-Triassic erosion.

The Permian age of the Predajná Formation was assigned according to poor microflora: *Monosulcites minimus* Cookson, *Gnetaceapollenites* sp., *Gymatiosphaera* sp., *Karpatisporites minimus* Pland., *Punctatisporites* sp., *Reticulatisporites* sp., *Florinites* sp. (Planderová *et* Vozárová 1982).

The grade of metamorphism of the North

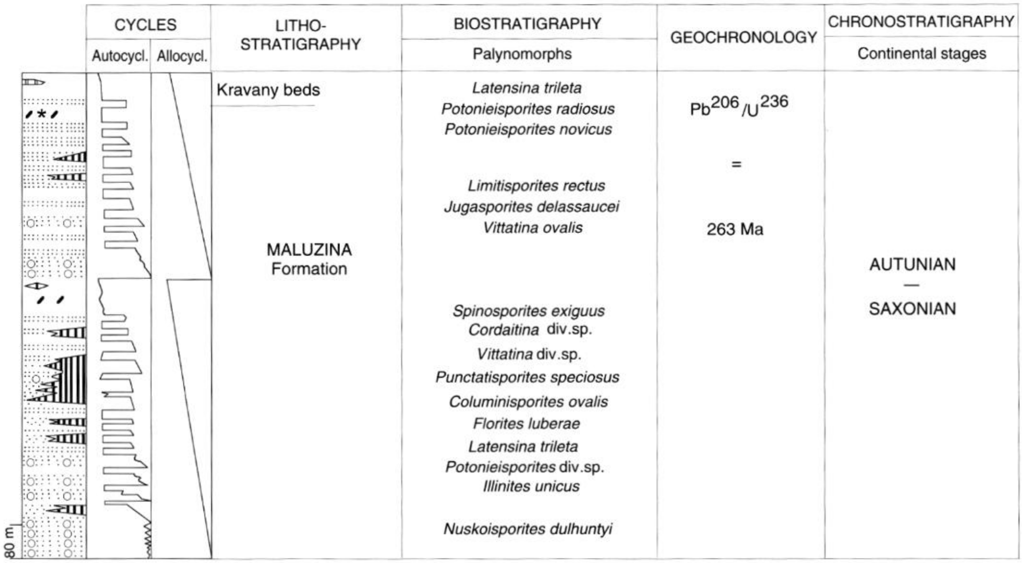

FIG. 6. — The Autunian and Saxonian of the Hronic Unit (see legend Fig. 8).

Veporic Permian deposits did not exceed the boundary between anchizone and the lower-temperature part of greenschist facies.

Representatives of the second type of formations are the Early Permian deposits in the Zemplinic, Southern Veporic and Hronic Units.

A sharp transition from a humid to arid climate is characteristic for Permian sediments of the Zemplinic Unit (Fig. 5). During the Permian sedimentary development the synsedimentary tectonics was less intense compared to the Westphalian-Stephanian and, as a consequence, the rates of sedimentation and volcanic activity were reduced. Generally, the deposition proceeded in an alluvial environment with the typical features of semi-arid and arid regions. Many coloured sedimentary complexes of the Cejkov Formation comprise proximal and distal alluvial facies (polymict conglomerates and sandstones) alternating with deposits of flood plain or of ephemeral arid lakes (mudstones alternating with shales and fine-grained sandstones and calcrete horizons). Characteristic, poorly sorted sediments resemble fossil mudstone and debris-flow. A part of this sequence includes several layers of rhyolite tuffs. The Early Permian age of the Cejkov Formation is assigned for abundance of the species from the genera *Potonieisporites* and *Vittatina*. The assemblages of sporomorphs are: *Potonieisporites radiosus* Schwarz, *P. novicus* Bhardw., *Nuskoisporites dulhuntyi* Pot. Klaus, *Vittatina* div. sp., *Florinites* div. sp. (Planderová *et al.* 1981). The microflora from the upper part of the Cejkov Formation proved the Late Permian: *Lueckisporites virkkiae* (Pot. Klaus), *Jugasporites delasaucei* Klaus, *Limitisporites rectus* Lesch., *Lunatisporites* div. sp., *Klausipollenites schaubergeri* (Pot. Klaus) Lesch, *Falcisporites zapfei* (Pot. Klaus) Lesch. (Planderová *et al.* 1981).

A complex of monotonous violet-red, vaguely schistose mudstones represents the youngest lithostratigraphic unit, the Černochov Formation. Relatively thin (max. 50 m) sequence of monotonous playa association is unconformably overlain by light-grey quartzose conglomeratic sandstones of Early Triassic age. Almost massive claystones and mudstones are rich in Al_2O_3 (20-21 %) and ferric iron (7 %). Poor microflora remains, *Lueckisporites wirkkiae* (Pot. Klaus), *Striatites richteri* (Klaus) Jizba, *Jugasporites lueckuides* Klaus, *Limitisporites rectus* Leschik, *Klausipollenites schaubergeri* (Pot. Klaus) Iansonius correspond most likely to the Thuringian. Sedimentological and paleoecological data indicate that a short intra-Permian hiatus is possible.

The Early Permian sequences of the Hronic Unit (Fig. 6, the Malužiná Formation) are developed gradually from the underlying Stephanian. They comprise a thick succession of red beds which consist of alternating conglomerates, sandstones and shales. Lenses of dolomites, gypsum and calcrete/caliche horizons occur locally. Fining-upward cycles of the order of several meters, as well as three regional megacycles arranged above each other, are most typical. An important phenomenon is the polyphase synsedimentary andesite-basalt volcanism with continental tholeiitic magmatic trend (Vozár 1977, 1983).

Generally the sediments of the Malužiná Formation originated, in fluvial and fluvial-lacustrine environment, at permanently semiarid/arid climate. Basal parts of the three megacycles consist of chanel-lag and point-bar deposits, associating laterally with flood plain and natural levee sequences. Upper part of megacycles is characterized by a playa, scarce inland sabcha and ephemeral lake associations.

The microflora proved the Early and Late Permian age of the Malužiná Formation. The following assemblages were described by Planderová (1973; *in* Planderová & Vozárová 1982): (1) Autunian: *Spinosporites exiguus* Upthaw-Hedl., *Thymospora* div. sp., *Columinisporites ovalis* Peppers, *Punctatisporites speciosus* Kalib., *Cordaitina* div. sp., *Illinites unicus* Kos., *Vittatina* div. sp.; (2) Autunian-Saxonian: *Latensina trileta* Alp., *Potonieisporites novicus* Bharadw., *P. radiosus* Shwarz., *Jugasporites delassaucei* Klaus, *Vittatina ovalis* Klaus; (3) Thuringian: *Calamospora nathorstii* Klaus, *Klausipollenites* div. sp., *Carpathisporites sittleri* Pland., *Lueckisporites parvus* Klaus, *Vittatina angulistriata* Klaus, *Monosulcites minimus* Cookson.

The Autunian-Saxonian microflora assemblages correspond approximately to the first and second megacycles. This assumption is supported by $^{206}Pb/^{238}U$ and $^{207}Pb/^{235}U$ dating of 263 and 274 Ma from uranium-bearing layers of the uppermost part of the second megacycle (Lepka *in* Rojkovič *et al.* 1992).

Sediments of both formations contain detritus derived from: (1) granitoids and high-grade metamorphics; (2) ?synsedimentary or a little older dacite volcanics; (3) andesite/basalt synsedimentary volcanics; (4) low-grade metamorphics. Generally the grade of regional metamorphism did not exceed P-T conditions of diagenesis/ anchizone boundary.

The strongly Alpine reworked metasediments of the Southern Veporic Unit consists of coarse-grained metaarkoses, meta-arkosic wackes and meta-conglomerates with abundant granitoid detritus. Fine-grained metasediments are only minor component. They provide very poorly preserved spore species of the genus *Lueckisporites*, ranging these sequence with the Early Permian (Planderová & Vozárová 1982).

NORTHERN GEMERIC ZONE (FIG. 7)

Continental Permian sequences overlapped slightly deformed relics of the Westphalian peripheral basin filling as well as all pre-Westphalian complexes of the North Gemeric Zone. Prevalent coarse-clastic sediments derived from the collision belt are associated with bimodal andesite/basalt-rhyolite volcanism. The development of the Permian depositional realm was connected with post-Asturian transpression/ transtension stage, as a result in extensional regime during the Late Permian-Mesozoic time.

Following are the characteristic features: (1) multi-coloured clastic sediments with dominant violet and violet-red; (2) gradual fining-upward; (3) cyclicity manifested within the framework of small cycles as well as megacycles; (4) bimodal calc-alkaline volcanism.

The basal part (the Knola Formation) contains mostly poorly sorted polymict conglomerates and breccias of extremely variable thickness, with pebble material reflecting the composition of the direct underlier. The coarse-grained sediments overlapped different parts of both pre-Carboniferous crystalline complexes as well as irregurally eroded surface of the Westphalian formations. They represent fossil mudflows, partly reworked in some places, relieved by alluvial, mainly stream channel deposits. Age of these sediments is not determined, due to lack of fossils' remains.

Volcanics and volcanoclastics of bimodal magmatic association are the main features of the

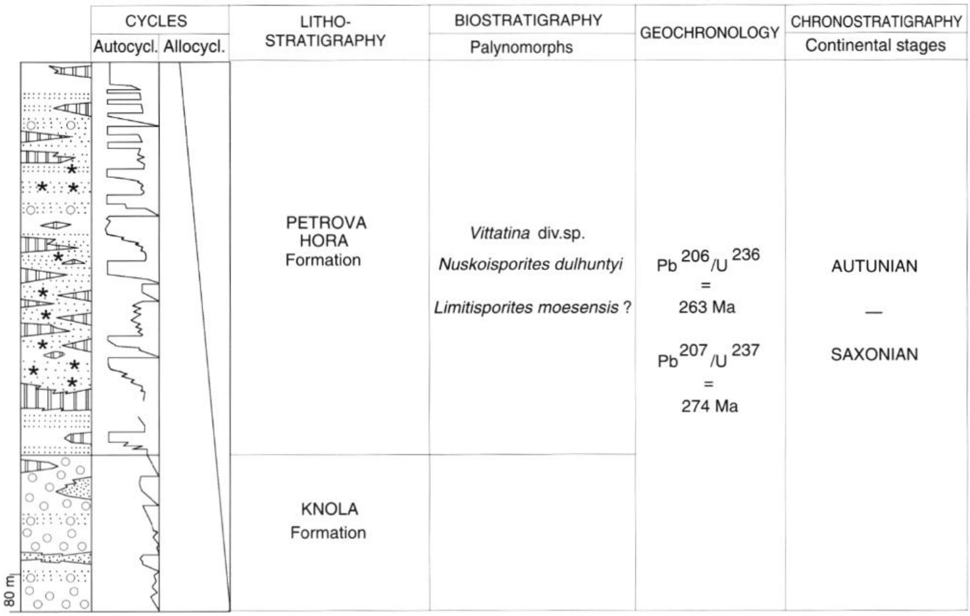

FIG. 7. — The Autunian and Saxonian of the North Gemeric Unit (see legend Fig. 8).

Petrova Hora Formation. The polyphase volcanic activity manifested regional and time relations to large sedimentary cycles. Sediments are characteristic by low degree of maturity and mixture of syngenetic volcanic and non-volcanic detritus. Among the most striking features are the fining-upward alluvial cycles, with channel lag, pointbar and flood plain lakes facies alternating with playa lake subenvironment at the topmost part of large cycles.

The microflora found in the upper part of the Petrova Hora Formation proved Saxonian age: *Limitisporites moesensis* (Grebel) Klaus, *Vittatina* div. sp., *Nuskoisporites dulhuntyi* Klaus (Planderová 1979 unpublished report). This age is supported by isotopic analysis of sulphides from volcanogenic horizons: $^{206}Pb/^{236}U$ = 263 Ma; $^{207}Pb/^{235}U$ = 274 Ma (Novotný & Rojkovič 1981).

The Autunian-Saxonian terrigenous and terrigenous-volcanogenic sequences are overlapped by a relatively mature sandy-conglomerates horizon, with contents of pebble material derived from direct stratigraphic underlier. This could have been a consequence of the break in sedimentation after Saxonian, but biostratigraphic evidence to support this assumption is missing. Alluvial, stream channel deposits prograde gradually upward to the inland sebkha and near-shore sebkha/lagoonal facies, with anhydrite-gypsum and salt breccia horizons (the Novoveská Huta Formation). Isotopic analysis of sulphur shows the results close to data on the Late Permian-lower part of the Early Triassic (Kantor *et al.* 1982). There are gradual transitions up to the *Claraia clarai* horizon.

The grade of metamorphism of the Permian rock complexes did not exceed the P-T condition of anchizone.

INNER WESTERN CARPATHIANS CRYSTALLINE ZONE

The Early Permian sediments were developed only within the Southern Gemeric Unit (Fig. 8). Late Variscan, post-orogenic overstep sequences of the Southern Gemeric Unit are represented only by the Permian to Early Triassic continental and near-shore, lagoonal-sabcha formations.

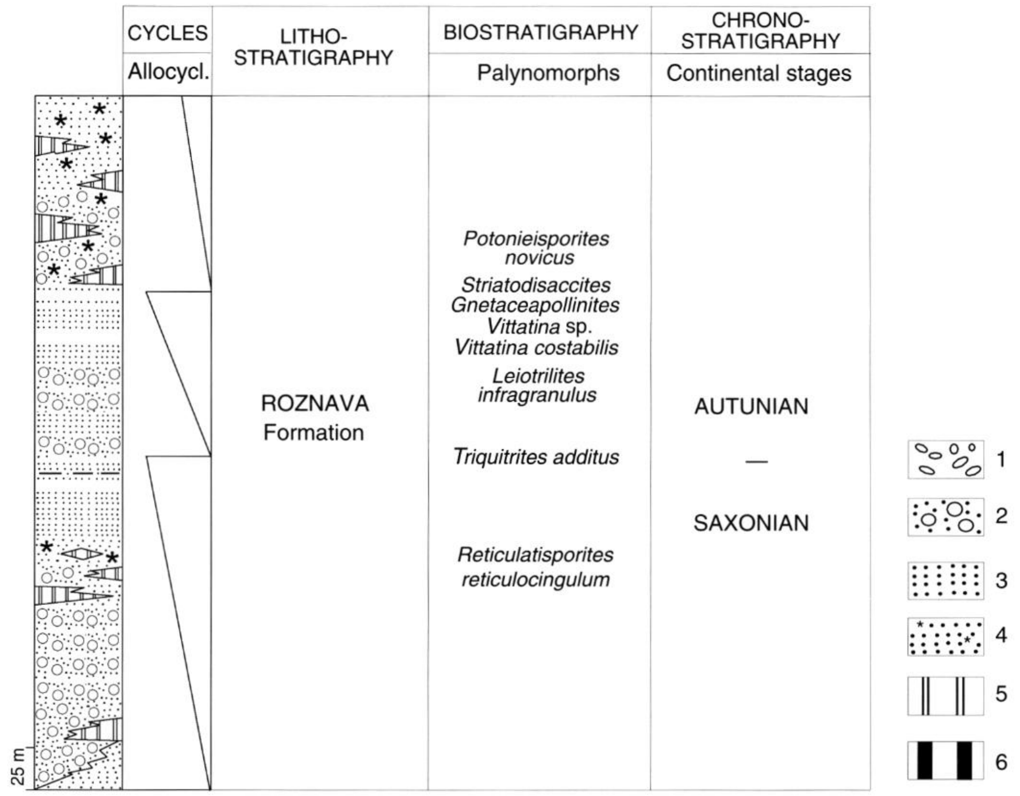

FIG. 8. — The Autunian and Saxonian of the South Gemeric Unit. **1**, delta-fan, shallow marine boulder conglomerates; **2**, marine conglomerates; **3**, marine sandstones; **4**, sandstones with admixture of volcanoclastic detritus; **5**, acid to intermediate volcanics; **6**, andensite-basalt volcanics.

They unconformably overlapped their Early Paleozoic basement, the volcano-sedimentary flysch of the Gelnica Group (defined together as the Gelnica Terr., Vozárová & Vozár 1993, 1996). Generally, the Early Permian volcano-sedimentary complexes are characterized by a high content of mature detritus, mainly in their basal part. Conspicuous upward fining is accompanied by relative decrease of compositional maturity and grain-size of sediments. Sediments represent the relics of sedimentary basin filling which originated in transpression/transtension regime, prograded to the initial stage of post-Variscan rifting. The whole sequence is subdivided into two lithostratigraphic units: the Rožňava and Štítnik Formations.

Characteristic lithotype of the Rožňava Formation are the oligomict, quartzose conglomerates, with indistinct stratification. The whole sequence is subdivided vertically into two large cycles, with conglomerate horizons at the base of each and sandstone-shale member between their two. Dominant are stream channel and sheet-flood deposits, with unimodal transport system. Both conglomeratic horizons are connected with rhyolite-dacite subaerial volcanism. Their chemical composition correspond to calc-alkaline magmatic type. The Early Permian age of the Rožňava Formation is assumed on the basis of microflora, with the predominant species of the genera *Potonieisporites, Striatodisaccites, Vittatina* sp. and mainly the form *Triquitrites additus* Wils. *et* Hofm., *Potonieisporites novicus* Bharadw., *Vittatina costabilis* Wils (Planderová 1980).

The gradually prograded Štítnik Formation is a monotonous complex of cyclically alternating sandstones, siltstones and shales. Lenses of carbonatic sandstones and dolomitic limestones with intercalations of shales occur only in its upper part. Thin lenses of phosphatic sandstones and sediments with extremely high content of albite (albitolites) are exceptional. Sediments contain relatively high amount of rhyolite/dacite detritus (?synsedimentary or redeposited from the Rožňava Formation). Sedimentary environment is interpreted as alluvial-lacustrine and lacustrine, with high-alkaline lakes in some places, prograding into near-shore, lagoonal-sabcha facies. Age determinations are known only from the uppermost part. The Late Permian was proved on the basis of cone slice and twig of *Pseudovoltzia liebeana* (Geinitz) Florin, and leaves of the genus *Sphenozamites*, as well as remains of bivalve tests of the genus *Carbonicola* McCoy, 1855 (Šuf 1963). Microfloral assemblages confirm the Late Permian-Early Triassic age of this horizon (Planderová 1980).

Generally, sequences of the Southern Gemeric Permian are distinctly dynamometamorphically deformed, with grade of metamorphism reaching P-T conditions of anchizone to low-temperature part of greenschist facies.

Within the Inner Western Carpathians (the Turnaic Unit; TSBZ) the continental red-beds unconformably overlying the Bashkirian flysch are most probably the Late Permian in age (since biostratigraphical undated).

DISCUSSION

The Carboniferous-Permian sedimentary basins of the Western Carpathians originated in time and space as a consequence of collision/subduction events of Variscan orogeny. The topical distribution of these basins, as well as the lithofacial character of their filling, document southern polarity of the Variscan orogeny of the Western Carpathians, responsible for the opposite vergency in comparison with that in the Alpine branch. Basins originated gradually as a consequence of microplate interaction.

The beginning of collisional events was connected with the Bretonian movements and development of the Early Carboniferous flysch remnant basin sequences preserved within the Northern Gemeric Unit. The prolongation of collision carried on closing the Early Carboniferous flysch basin and caused hiatus during Namurian B-C. The Sudetian movements gave rise to the Bashkirian-Moscovian marine peripheral basin, whose basal sequences fixed the Early Carboniferous flysch and both two pre-Carboniferous complexes (fragments of crust with oceanic/supraoceanic affinity). Closing of this basin was connected with Asturian events and is reflected in hiatus during Stephanian. The North-Gemeric Early and Late Permian continental red-beds sequences originated under transpression/transtension and extension post-orogenic regime.

Due to these compression events, the different evolution basins were established on formerly overthrusted continental plate, whose fragments are dismembered within the several CWCZ Alpine megaunits. Continental sedimentation under humid climatic conditions was characteristic for this part of the plate during the Late Carboniferous. These relics are preserved within the Alpine Zemplinic, Hronic and Southern Veporic Units. Sequences from the last of them are very strong Alpine reworked. Generally, a characteristic feature for these developments is gradual prograding into the Permian arid/semi-arid red-beds formations. The sedimentary basins were established in pull-apart and extensional tectonic setting (most probably in back-arc position). The latest stage of this process affected the formations which were incorporated into the Northern Veporic and Tatric Units (Saxonian even Thuringian).

Particular features have been observed in the Permian formations of the Southern Gemeric unit. Their mineral extremely mature detritus, as compared with other contemporal sediments of the Western Carpathians unit allows to correlate them with other early-Alpine riftogenic tectofacies of the Alpine-Mediterranean domain. They were most probably already connected with the previous Baskhirian flysch zone sedimentation (TSBZ), characteristic for the South-Alpine/Dinaric development. Discovering the

Baskhirian flysch sediments (the Turiec Formation, Vozárová 1992) within one of the topmost tectonic units of the Inner Western Carpathians (Turňa Nappe) confirms this assumption (Vozárová & Vozár 1992; Vozárová 1996).

From the point of view of comparison of Carboniferous-Permian sequences in the Alpine-Carpathian arc, the position of synorogenic flysch sediments in space and time is an important criterion (Ebner 1991). The Tournaisian-Visean (pre-Sudetic) flysch, which is preserved in the Northern Gemeric Zone (NGZ), reflects the stage of convergence. This flysch trough contained shreds of oceanic crust (serpentinites) as well as detritus from a collisional fold-thrust belt and from the rejuvenated basement (source of low-grade metasediments and metavolcanites as well as granitoides and gneisses). Its most probable paleotectonic position was that of residual basin, arising with oblique collision. This is testified by gradual transition from flysch environment to terrestrial-carbonate, shallow-water sediments of Serpukhovian age.

Synorogenic, pre-Sudetic flysch sediments are represented in the Eastern Alps, in the Stolzalpe Nappe (Gurktal thrust system) in central Carinthia (Neubauer & Herzog 1985). They are also covered by Late Carboniferous molasse sediments (Murau area), which is, however, on the contrary to the NGZ, in continental development. Early Permian sediments in both units indicate continental environments (Ebner *et al.* 1990a). An equivalent of the Late Visean-Serpukhovian shallow-marine horizon with magnesites (upper part of the Ochtina group in the NGZ) is development in the Veitsch Nappe of the Grauwackenzone (Neubauer & Vozárová 1990). Equally also lithological characteristics and the paleoenvironment of the Carboniferous from Noetsch are comparable with marine molasse sediments in the NGZ.

In the Southern and Eastern Carpathians siliciclastic and/or siliciclastic-carbonate sequences of Early Carboniferous were described (Nastaseanu 1987; Nastaseanu & Krautner 1990; Krautner 1990), which, however, are poorly proved biostratigraphically (Infrabucovinian N., Bucovinian N., Supraghetic N., Danubian Unit) and from sedimentological point of view are of untypical flysch development. A feature common in both compared areas is Variscan metamorphism of Early Carboniferous complexes. Well correlable sequences are, however, continental Late Carboniferous and Permian from the Central Western Carpathians (CWCZ) and in the Ghetic Unit in Romania described by Nastaseanu *et al.* (1973) and Nastaseanu (1978). In the Apuseni Mountains (Biharia and Codru Nappe system) continental Late Carboniferous and Permian sediments with andesite-basaltic riftogenic volcanism are known, similarly as in the Hronic Unit in the CWCZ.

Relics of Late Devonian-Early Carboniferous flysch formations were also described in the region of the Balkanides and in the Kraishtides (Yanev & Spasov 1985; Tenchov 1990). They are covered by Westphalian and/or even Permian continental deposits.

The pre-Asturian flysch, which is preserved in the Inner Western Carpathians (IWCZ) in the Turnaic Unit, has its continuation in the Szendrö and Uppony Mountains in northeastern Hungary, where, it was described in details by Kovács & Péro (1983) and Kovács (1987). This flysch has its equivalents in the Southern Alps and Karawanken (Ebner *et al.* 1991). The flysch complexes are Variscan low-grade metamorphosed (Mazzoli & Vozárová 1989; Ebner *et al.* 1990b). The pre-Asturian flysch complexes are usually covered by shallow-water or even deltaic sediments of Westphalian to Stephanian age. An exception is the Turnaic Unit (IWCZ) where the marine molasse is missing and the flysch is covered by Permian, continental sediments (riftogenic stage of the Alpine cyclus).

In the Bükk Mountains the pre-Asturian flysch reaching even the Westphalian is continuously replaced by shallow-marine sediments of Late Westphalian-Stephanian age (Kovács & Péro 1983). The sediments are not Variscan-metamorphosed and only in places affected by weak Alpine metamorphism (Arkai 1983). Permian sediments are lagoonal-nearshore marine, interrupted by a short-dated Middle Permian event of continental sedimentation only. An analogous development of the Permian is also the Carnic Alps and Karawanken (Ebner *et al.* 1990; Ramovš *et al.* 1990).

In the Transdanubian Mid-montains Unit the Carboniferous is represented by Visean limestones (Földvari 1952) and Westphalian-Stephanian conglomerates (Mihaly 1980). These sequences as well as all pre-Carboniferous complexes show South Alpine-Dinaric affinity. The Late Carboniferous-Permian continental sediments unconformably overlapped medium- and high-grade Variscan and pre-Variscan metamorphic rocks of Tisia Unit in the southeastern part of Hungary (Mecsék and Villany Mountains, Kassai 1976). Complexes of the Tisia Unit as well as its Carboniferous-Permian enveloppe have no equivalent in the Western Carpathians.

In the context of stratigraphic age of the sedimentologically well established flysch sequences and clastic/volcanoclastic piles which take in synorogenic position, the following comparison can be done:

1. Internal zone of Alpine Variscides belt with pre-Sudetic flysch environment: CWCZ joined with NGZ in the Western Carpathians, eastern Grauwackenzone and Gurktal thrust system and Carboniferous of Noetsch area in the Eastern Alps, nappe thrust system of Bucovinian and Ghetic Units in the Eastern and Southern Carpathians in Romania, part of Balkanides and Kraishtides in Bulgaria. This zone comprises mainly medium- and high-grade metamorphic basement with huge masses of pre-Mesozoic granitoids, as a result of predominantly Variscan metamorphism and magmatism. With respect to these characteristics, this zone corresponds to the Mediterranean crystalline zone (MCZ) defined by Neubauer & Raumer (1993). The pre-Sudetic flysch zone covered by Visean-Serpukhovian marine molasse, which is designated as the NGZ in the Western Carpathians, has continuation in the high Eastern Alps Units (Noetsch-Veitsch-Ochtina zone according to Flügel 1990, North Gemeric-Veitsh zone after Neubauer & Vozárová 1990). It is interpreted as an intrasutural basin amalgamating two major Variscan microplates (Vozárová & Vozár 1988; Neubauer & Vozárová 1990) or as southern extension of the MCZ (Neubauer & Raumer 1993).

2. External zone of alpine Variscides belt with pre-Asturian flysch environment: IWCZ with Turnaic Unit, Szendrö Mountains and Uppony Mountains and Bükk Mountains in Hungary, southern Alps and Karawanken. The basement of this zone is either unknown or consits of dominantly shallow-water carbonates including pelagic limestones. An exception is the Southern Gemeric Unit (IWCZ) with the long-timing Early Paleozoic Flysch sequence. This external zone could be correlated with the Noric-Bosnian and Betic-Serbian zones distinguished by Neubauer & Raumer (1993).

CONCLUSION

The distribution of Carboniferous-Permian basins in time and space as well as the lithofacial character of their filling indicate a reverse polarity (southern) in comparison with the Alpine orogeny. The results of Variscan orogenic events was the unevenly consolidated continental crust which, after a short period of stability (from the south to the north in the Late Permian/Early Triassic to Middle/Late Triassic), was incorporated again in the new orogenic Alpine cycle.

On the basis of filling relics of Carboniferous-Permian basins in the Western Carpathians two zones of continental collision differing in time were identified:

– the *internal zone*, with termination of collision during Bretonian-Sudetian events, resulting in syn-collision Early Carboniferous flysch and marine Late Carboniferous perisutural basin as well as continental, back-arc transpression basins;

– the *external zone*, with termination of collision during Asturian events (IWCZ). This zone is represented by the Baskhirian flysch and the Late Westphalian/Stephanian marine perisutural basin (relics preserved only on the territory of northern Hungary) and the post-orogenic continental Permian deposits (Southern Gemeric and Turnaic units on the territory of Slovakia).

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REFERENCES

Andrusov D. 1936. — Subtatric nappes in Western Carpathians. *Carpathica*, Praha 1: 5-50.

Andrusov D., Bystrický J. & Fusán O. 1973. — Outline of the Structure of the West Carpathians: 1-44, *in Guidebook for Geological Excursion, X. Congress of CBGA*. Dionýz Štúr Institute of Geology, Bratislava.

Arkai P. 1983. — Very low- and low-grade Alpine regional metamorphism of the Palaeozoic and Mesozoic formations of the Bükkium. NE Hungary. *Acta Geologica Hungaricae*, Budapest 26: 83-101.

Bezák V. 1991. — Metamorphic conditions of the Veporic unit in the Western Carpathians. *Geologický Zborník Geologica Carpathica*, Bratislava 42 (4): 219-222.

Bouček B. & Přibyl A. 1959. — Geological conditions of Zemplínske vrchy Hills in Eastern Slovakia. *Geologické Práce Zošit*, Bratislava 52: 185-222 [in Czech].

— 1960. — Revision der Trilobiten aus dem slowakischen Oberkarbon. *Geologické Práce, Správy*, Bratislava 20: 5-50 [in Czech].

Cambel B., Sčerbak N. P., Kamenický L., Bartnickij J. N. & Vesel'ský J. 1977. — Nekotoryje svedenija po geochronologii kristalinikuma Zapadnych Karpat na osnove dannych U-Th-Pb metoda. *Geologický Zborník Geologica Carpathica*, Bratislava 28 (2): 243-259 [in Russian].

Cambel B. & Král' J. 1989. — Isotopic geochronology of the Western Carpathian crystalline complex: the present state. *Geologický Zborník Geologica Carpathica*, Bratislava 40 (4): 387-410.

Cambel B., Bagdasaryan G. P., Gukasyan R. Kh. & Veselský J. 1989. — Rb-Sr geochronology of leucocratic granitoid rocks from the Spišsko-gemerské rudohorie Mts. and Veporicum. *Geologický Zborník Geologica Carpathica*, Bratislava 40 (3): 323-332.

Cambel B., Král' J. & Burchart J. 1990. — *Isotope geochronology of the Western Carpathian crystalline. Monography.* VEDA, Bratislava, 183 p. [in Slovak, Engl. res.].

Ebner F. 1991. — Flysch sedimentation related to the Variscan orogeny within the circum-mediterranean mountain belts, *in* Baud A., Thelin P. & Stampfli G. (eds), Palaeozoic geodynamic domain and their alpidic evolution in the Tethys, *Mémoires de Géologie*, Lausanne Neswletter No. 2 IGCP No. 276: 55-70.

Ebner F., Fenninger A., Gollner H., Holzer H. L., Neubauer F., Nievoll J., Ratschbacher L., Stattegger K., Tschelaut W., Thalhammer O. & Zier Ch. 1990a. — Stratigraphic correlation forms of Palaeozoic units in Austria. *Rendiconti della Società Geologica Italiana*, Roma 12 (1989): 213-239.

Ebner F., Vozárová A., Straka P. & Vozár J. 1990b. — Carboniferous conodonts from Brusník Anticline (South Slovakia): 249-251, *in* Minaříková D. & Lobitzer H. (eds), *Thirty Years of Geological Cooperation between Austria and Czechoslovakia*. Ústřední ústav geologický, Praha.

Faryad Sh. W. 1995. — Geothermobarometry of metamorphic rocks from the Zemplinicum (Western Carpathians, Slovakia). *Geologica Carpathica*, Bratislava 46 (2): 113-126.

Flügel H. W. 1990. — Das voralpine Basement im Alpin-Mediterranean Belt - Überblick und Problematik. *Jahrbuch Geologische Bundesanstalt*, Wien 133: 181-221.

Földvary A. 1952. — A szabadbattyani ólomerc es kövületes karbonelófordulás. *A Magyar Tudományos Akadémia Müszaki Tudományok Osztályának Közleményei*, Budapest 5: 25-53 [in Hungarian].

Fülöp J. 1994. — *Magyarország geologiája. Paleozoikum: monography*, Volume 2. Akadémiai Kiadó, Budapest, 445 p.

Grecula P. & Együd K. 1982. — Lithostratigraphy of Upper Palaeozoic and Lower Triassic strata of the Zemplínske vrchy Mts (SE Slovakia). *Mineralia Slovaca*, Bratislava 14 (3): 221-239 [in Slovak].

Herzog U. 1988. — Das Paläozoikum zwischen Poludnig und Oisternig in den Östlichen Karnischen Alpen. *Carinthia II*, Insbruck 47: 1-121.

Hovorka D., Dávidová Š., Fejdi P., Gregorová J., Határ J., Kátlovský V., Pramuka S. & Spišiak J. 1987. — The Muráň Gneisses: the Kohút Crystalline Complex, the Western Carpathians. *Acta Geologica et Geographica Universitatis Comenianae*, Bratislava ser. Geologica 42: 5-101.

Hovorka D. & Méres Š. 1989. — Relicts of high-temperature metamorphic of the Tatro-Veporicum crystalline of the Western Carpathians. *Mineralia Slovaca*, Bratislava 21: 193-201 [in Slovak, English abstract].

— 1990. — Clinopyroxene-garnetic metabazites of the Tribeč Mts. *Mineralia Slovaca*, Bratislava 22 (6): 533-538 [in Slovak].

Hovorka D. & Petrík I. 1992. — Variscan granitic bodies of the Western Carpathians: the backbone of the mountain chain: 57-66, *in* Vozár J. (ed.), *The Paleozoic Geodynamic Domain and their Alpidic Evolution: Western Carpathians, Eastern Alps, Dinarides: Special Volume IGCP No. 276.* Dionýz Štúr Institute of Geology, Bratislava.

Hovorka D., Méres Š. & Ivan P. 1992. — Pre-Alpine Western Carpathians basement complexes: Geochemistry, Petrology, Geodynamic setting. *Terra Nova*, Abstract Supplements 2 (4): 32.

Ivanička J., Snopko L., Snopková P. & Vozárová A. 1989. — Gelnica Group-Lower Unit of Spišsko-gemerské rudohorie Mts. (Early Palaeozoic, West Carpathians). *Geologický Zborník Geologica Carpathica*, Bratislava 40 (4): 483-501.

Kantor J., Ďurkovičová J., Rybár M., Garaj M.,

Ferenčíková E. & Hašková A. 1982. — *Genesis of Western Carpathian evaporites based on sulphur isotopes. Manuscript.* Geofond, Bratislava, 256 p. [in Slovak].
Kassai M. 1976. — A Villányi-hegység északi elöterének perm képzödményei. *Geologica Hungarica*, Budapest Series Geologica 17: 11-109 [in Hungarian].
Kohút M. 1992. — The Vel'ká Fatra granitoid pluton - an example of a Variscan zoned body in the Western Carpathians: 79-92, *in* Vozár J. (ed.), *The Paleozoic Geodynamic Domain and their Alpidic Evolution: Western Carpathians, Eastern Alps, Dinarides: Special Volume IGCP No. 276.* Dionýz Štúr Institute of Geology, Bratislava.
Korikovskij S. P., Dupej J. & Boronikhin V. A. 1989. — High-ferrugineous metasediments from Kokava nad Rimavicou (Veporicum). *Mineralia Slovaca*, Bratislava 21: 251-258 [in Slovak, English abstract].
Kovács S. 1987. — Olistostromes and other deposits connected to subaqueous mass-gravity transport in the North Hungarian Paleo-Mesozoic. II. *Földtani Közlöny*, Budapest 117: 101-119.
— 1988. — Olistostromes and other deposits connected to subaqaeous mass-gravity transport in the North Hungarian Paleo-Mesozoic. *Acta Geologica Hungaricae*, Budapest 31 (3-4): 263-287.
— 1989 . — Geology of North Hungary: Palaeozoic and Mesozoic terraines: 15-21, *in XXIst European Micropaleontological Colloqium 1989.* Guidbook for geological excursion, Budapest.
— 1992. — Stratigraphy of the Szendrö-Uppony Palaeozoic (Northeastern Hungary): 93-108, *in* Vozár J. (ed.), *The Paleozoic Geodynamic Domain and their Alpidic Evolution: Western Carpathians, Eastern Alps, Dinarides: Special Volume IGCP No. 276.* Dionýz Štúr Institute of Geology, Bratislava.
Kovács S. & Péro Cs. 1983. — Report on stratigraphical investigations in the Bukkium (Northern Hungary): 58-65, *in* Sassi F. P. & Szederkenyi T. (eds), *IGCP No. 5, Newsletter 5.* Szeged, Padova.
Kovács S. & Lelkes-Felvari G. 1990. — Stratigraphic correlation forms of Palaeozoic units in Hungary. *Rendiconti della Società Geologica Italiana*, Roma 12 (1989): 295-303.
Kovácik M. 1991. — High Al and Fe micaschists from the southeastern Veporicum: protolith and regional metamorphism. *Mineralia Slovaca*, Bratislava 23: 23-32 [in Slovak, English abstract].
Kozur H. & Mock R. 1977. — Erster Nachweis von Conodonten im Paleozoikum (Karbon) der Westkarpaten. *Časopis pro mineralogii a geologii*, Praha 22 (3): 299-305.
Mahel' M. 1954. — Stratigraphic and tectonic setting of Western Gemerides Palaeozoic complexes. *Geologický Sborník Slovenskej Akademie Vied*, Bratislava 5 (1): 146-174 [in Slovak].
Mazzoli C. & Vozárová A. 1989. — Further data concerning the pressure character of the Hercynian metamorphism in the West Carpathians (Czechoslovakia). *Rendiconti della Società Italiana di Mineralogia e Petrologia*, Roma 43 (3): 635-642.
Méres Š. & Hovorka D. 1991. — Geochemistry and metamorphic evolution of the Kohút crystalline complex mica schists (the Western Carpathians). *Acta Geologica et Geographica Universitatis Comenianae*, Bratislava ser. Geologica 47 (1): 15-66.
Mihaly S. 1980. — Oberkarbonische Pflanzenreste vom Kohegy bei Fule (Transdanubian, Ungarn). *Veszprém Megyei Múzei Közlöny* 15: 21-28 [in Hungarian].
Nastaseanu S. 1978. — Considérations préliminaires sur l'existence d'un système de nappes alpines dans la zone de Resita a Lupac (Banat). *Dări de Seăma ale Institutul de Geologie i Geofizică*, Bucarest 64: 89-106.
— 1987. — Upper Palaeozoic molasse deposits in the Romanian South Carpathians, *in* Flügel H. W., Sassi F. P. & Grecula P. (eds), Pre-Variscan and Variscan events in the Alpine-Mediterranean mountain belts, *Mineralia Slovaca*, Bratislava Monography series: 371-378.
Nastaseanu S. & Kräutner H. G. 1990. — Geotraverse D in the South Carpathians: stratigraphic correlation forms. *Rendiconti della Società Geologica Italiana*, Roma 12 (1989): 339-348.
Nastaseanu S., Stanoiu I. & Bitoianu C. 1973. — Corelares formatiunilor hercinice (Westphalian-Permian) den partes vestica a Carpatilor Meridionali. *Annuarul Inststitului de Geologie*, Bucarest 40: 71-109 [in Roumanian].
Neubauer F. 1988. — The Variscan orogeny in the Austroalpine and Southalpine domains of the Eastern Alps. *Schweizerische Mineralogische Petrographische Mitteilungen*, Zurich 68: 339-349.
Neubauer F. & Herzog U. 1985. — Das Karbon der Stolzalpendecke Mittelkärntens. Implikationen fur die variszische Orogeneze im Ostalpin. *Anzeiger Österreichische Akademie der Wissenschaften*, Wien Mathematisch-Naturwissenschaftliche Klasse 6: 105-109.
Neubauer F. & Raumer J. F. von 1993. — The Alpine basement-linkage between Variscides and East-Mediterranean Mountains Belts: 641-663, *in* Raumer J. F. von & Neubauer F. (eds), *Pre-Mesozoic Geology in the Alps.* Springer, Berlin.
Neubauer F. & Vozárová A. 1990. — The Nöetsch-Veitsch-North Gemeric zone of Alps and Carpathians: correlation, paleogeography and significance for Variscan orogeny: 167-171, *in* Minařikova D. & Lobitzer H. (eds), *Thirty Years of Geological Cooperation between Austria and Czechoslovakia: Festive Volume.* The Geological Survey, Praha and Wien.
Němejc F. 1946. — Contribution to knowledge of

floral remnants and stratigraphical division of Permo-Carboniferous of Slovakia. Rozpravy II. *Třídy České Akademie Věd*, Praha 56 (15): 1-34 [in Czech].

— 1953. — *Introduction to Stratigraphy of Coal Basins of ČSR based of Macroflora*. Czechoslovak Akademie of Science, Praha, 173 p. [in Czech].

Němejc F. & Obrhel J. 1958. — Evaluation of some plant impressions from Permian-Carboniferous of Slovakia. Zprávy o geologickych vyskumech v roce 1957. *Ústřední ústav geologický*, Praha: 165, 166 [in Czech].

Novotný L. & Rojkovič I. 1981. — Uran-mineralization in Western Carpathians: 327-347, *in* Mahel' M. (ed.), *Važnejšie problémy geol. vývoja a stavby Československa. Smolenice 1979*. Dionýz Štúr Institute of Geology, Bratislava [in Slovak].

Petrík I., Broska I. & Uher P. 1994. — Evolution of the Western Carpathian granite magmatism: age, source rock, geotectonic setting and relation to Variscan structure. *Geologica Carpathica*, Bratislava 45: 283-291.

Petrík I., Broska I., Bezák V. & Uher P. 1995. — The Hrončok (Western Carpathians) type granite - a Hercynian A-type granite in shear zone. *Mineralia Slovaca*, Bratislava 27: 351-364 [in Slovak, English abstract].

Planderová E. 1973. — Palynological research in the melaphyre series of the Choč Unit in the NE part of the Nízke Tatry between Spišsky Štiavnik and Vikartovce. *Geologické Práce Správy,* Bratislava 60: 143-168 [in Slovak].

— 1980. — New results about age of "Rožňava - Železník Group". *Geologické Práce Správy,* Bratislava 74: 113-128 [in Slovak, English abstract].

Planderová E. & Vozárová A. 1978. — Upper Carboniferous in the Southern Veporicum. *Geologické Práce Správy,* Bratislava 70: 129-141 [in Slovak, English abstract].

— 1982. — Biostratigraphical correlation of Late Palaeozoic Formations in the West Carpathians: 67-71, *in* Sassi F. P. & Varga I., *IGCP No. 5, Newsletter 4*. Košice, Padova.

Planderová E., Sitár V., Grecula P. & Együd K. 1981. — Biostratigraphical evaluation of graphite shales of Zemplín island. *Mineralia Slovaca*, Bratislava 13: 97-128 [in Slovak, English abstract].

Rakusz Gy. 1932. — Die Oberkarbonischen Fosilien von Dobšiná und Nagyvisnyo. *Geologica Hungarica*, Budapest Series Paleontologica 8: 1-219.

Ramovs A., Hinterlechner-Ravnik A., Kalenic M., Karamata S., Kochansky-Devide V., Krstic B., Kulenovic E., Mirkovic M., Petrovsky P., Sremac J. & Temkova V. 1990. — Stratigraphic correlation forms of the Yugoslav Palaeozoic. *Rendiconti della Società Geologica Italiana*, Roma 12 (1989): 359-383.

Rojkovič I., Franců J. & Čáslavský J. 1992. — Association of organic matter with uranium mineralization on the Permian sandstones of the Western Carpathians. *Geologica Carpathica*, Bratislava 43: 27-34.

Sassi F. P. & Vozárová A. 1987. — The pressure character of the Hercynian metamorphism in the Gemericum (West Carpathians, Czechoslovakia). *Rendiconti della Società Italiana di Mineralogia e Petrologia*, Roma 42: 73-81.

Sassi R. & Vozárová A. 1992. — Pressure character of the Variscan metamorphism in the Gemericum and Veporicum (West Carpathians, Czechoslovakia). *Bollettino della Società Geologica Italiana*, Roma 111: 33-39.

Schönlaub H. P. 1985. — Das Karbon von Nötsch und sein Rahmen. *Jahrbuch der Geologischen Bundesanstalt*, Wien 127: 673-692.

Sitár V. & Vozár J. 1973. — Die ersten Makrofloren Funde in dem Karbon der Choč Einheit in der Niederen Tatra (Westkarpaten). *Geologický Zborník Geologica Carpathica*, Bratislava 24 (2): 441-448.

Snopková P. & Snopko L. 1979. — Biostratigraphy of Gelnica Series of Spišsko-gemerské rudohorie Mts. on the basis of palynological study. *Západné Karpaty*, Bratislava séria mineralógia, petrológia, geochémia, metalogenéza 5: 57-102 [in Slovak, English abstract].

Ščerbak N. P., Bartnickij J. N., Mickevič N. J., Stepanjuk L. M., Cambel B. & Grecula P. 1988. — U-Pb radiometric data of the Modra granodiorite from the Malé Karpaty Mts. and the Early Palaeozoic porphyroide of the Spišsko-gemerské rudohorie Mts. (Western Carpathians). *Geologický Zborník Geologica Carpathica*, Bratislava 39 (4): 427-436 [in Russian, English abstract].

Šuf J. 1963. — Ergebnisse der geologischen Untersuchungen im Gebiete von Štítnik. *Geologické Práce Správy*, Bratislava 27: 63-68 [in Czech].

Tenchov Y. G. 1990. — Stratigraphic correlation forms of the Palaeozoic in Bulgaria. *Rendiconti della Società Geologica Italiana,* Roma 12 (1989): 423-433.

Vozár J. 1977. — Magmatic rocks of tholeiite serie in the Permian of the Choč Nappe (Western Carpathians). *Mineralia Slovaca*, Bratislava 9 (4): 241-258 [in Slovak, English abstract].

— 1983. — Position and characteristics of Permian volcanism in palinspastic profile of Geotraverse C (West Carpathians): 187-199, *in* Sassi F. P. & Szederkenyi T. (eds), *IGCP No. 5, Newsletter 5*. Szeged, Padova.

Vozárová A. 1979. — Lithofacial characteristic of the Permian in NW part of the Veporic Unit. *Západné Karpaty*, séria mineralógia, petrológia, geochémia, metalogenéza, Bratislava 6: 61-116 [in Slovak, English abstract].

— 1986. — Problems of lithostratigraphical division of Permo-Carboniferous of Zemplínske vrchy Hills and characterization of Luhyòa Formation

Regionálna geoléogia. *Západných Karpát*, Bratislava 21: 39-45 [in Slovak].
— 1989. — Petrology of crystalline rocks of Zemplinicum: 97-104, *in* Papanikolaou D. & Sassi F. P. (eds), *IGCP No. 276, Newsletter No. 1.* Geol. Soc. Greece, Athens.
— 1990. — Development of metamorphism in the Gemeric/Veporic contact zone (Western Carpathians). *Geologický Zborník Geologica Carpathica*, Bratislava 41 (5): 475-502.
— 1993. — Variscan metamorphism and crustal evolution in the Gemericum. *Západné Karpaty*, Bratislava séria mineralógia, petrológia, geochémia, metalogenéza 16: 55-117 [in Slovak, English abstract].
— 1993. — Provenance of the Gelnica Group metasandstones and relationship to paleotectonics of the sedimentary basin. *Západné Karpaty*, Bratislava séria mineralógia, petrológia, geochémia, metalogenéza 16: 7-54 [in Slovak, English abstract].
— 1996. — Tectono-sedimentary Evolution of Late Palaeozoic Basins based on Interpretation of Lithostratigraphic Data (Western Carpathians; Slovakia). *Slovak Geological Magazine*, Bratislava 3-4 (96): 251-271.
Vozárová A. & Vozár J. 1979. — Nižná Boca and Malužiná Fms. - new lithostratigraphic units in Late Paleozoicum in Hronicum. *Mineralia Slovaca*, Bratislava 11 (5): 477, 478 [in Slovak].
— 1982. — New lithostratigraphic units in Southern part of Veporicum. *Geologi-cké Práce Správy*, Bratislava 79: 27-54 [in Slovak].
— 1987. — West Carpathian Late Palaeozoic and its paleotectonic development, *in* Flügel H. W., Sassi F. P. & Grecula P. (eds), Pre-Variscan and Variscan events in the Alpine-Mediterranean mountain belts, *Mineralia Slovaca*, Bratislava Monography series: 469-487.
— 1988. — *Late Palaeozoic in West Carpathians: Monography*. Dionýz Štúr Institute of Geology, Bratislava, 314 p.
— 1992. — Tornaicum and Meliaticum in borehole Brusník, BRU-1, Southern Slovakia. *Acta Geologica Hungaricae*, Budapest 35 (2): 97-116.
— 1996. — Terranes of West Carpathians - North Pannonian Domain. *Slovak Geological Magazine*, Bratislava 1 (96): 61-83.
Yanev S. & Spassov C. 1985. — Lithostratigraphy of the Devonian flysch between Tran and Temelkovo (SW Bulgaria). *Paleontologia, Stratigrafia, Lithologia*, Sofia 21: 89-97 [in Bulgarian].

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