SLOVAK GEOLOGICAL MAGAZINE

Tectono-sedimentary Evolution of Late Paleozoic Basins based on Interpretation of Lithostratigraphic Data (Western Carpathians; Slovakia)

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Abstract: The Carboniferous-Permian basins in the Western Carpathians originated in time and space in consequence of collision events of the Variscan orogeny. The distribution of these basins as well as the lithofacial character of their filling documents the opposite, southern vergency of the Variscan orogeny in comparison with the Alpine branch of the Western Carpathians. The sedimentary basins formed in three zones differing in the type of crust and their position in relation to the Variscan orogenic polarity. They were:

I. thickening continental plate with maximum manifestations of deformation, metamorphism and magmatism connected with subduction/collision events;

II. thrust wedges of oceanic crust;

III. active continental margin with extensive fore-arc basin filling.

On the basis of an analysis of relics of the Carboniferous-Permian sedimentary basin filling, indications of two Variscan collision events were identified.

a) Bretonian-Sudetian - indications in present-day relics in the frame of the paleo-Alpine, Tatro-Veporic and Northern Gemeric realm;

b) Asturian - indications in the paleo-Alpine Southern Gemeric Unit and adjacent Bükkium area in the south.

Both sutures represented the main zones of extension and following shortening in the Alpine orogeny.

Key words: Western Carpathians, Variscan orogeny, southern polarity, Carboniferous-Permian syn- and postorogenic basins, collision events

Introduction

The kinematic evolution of the Western Carpathian orogenic system was affected during both Variscan and Alpine times. Fragments of newly formed Epi-Variscan crust were incorporated in the Paleo-Alpine Western Carpathian units, as indicated by repeated 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 overriding microplates of Eurasian affinity moved southwards. The Lower Carboniferous flysch troughs originated in an intrasutural embayment continuing in the Upper Carboniferous peripheral basin on the underthrusting plate of the African promontory. The post-collisional Permian evolution of the Western Carpathian realm continued by the formation of transtension/transpression and rifting-related sedimentary basins.

The stages of the Variscan orogenic cycle were directly reflected in the tectono-sedimentary development of Late Paleozoic sedimentary basin. The distribution of these basins in time and space indicates a polarity of the Variscan orogeny, which is in the Western Carpathians reverse in comparison with the Alpine orogeny. The result of Variscan orogenic events was the unevenly consolidated continental crust, which, after a short period of stability, was incorporated again in the new orogenic-Alpine cycle.

The fundamental fact that this Late Variscan continental crust was again extensionally segmented in the Alpine tectonic cycle, which led to the formation of new sedimentation basin in the southernmost zones even with oceanic bottom, leads to the greatest difficulty in the reconstruction of the Variscan orogeny in the Western Carpathians. The Alpine compression liquidated the substantial part of the original filling of Late Variscan sedimentation basins, as well as their substrate, and thus only their fragments were preserved in the Alpine-formed tectonic units. Besides the incomplete preservation of the bed successions and often unclear facial relationships, another important problem regarding the reconstruction of the Variscan orogeny is the absence of suitable biostratigraphic dating. The proposed analysis of tectono-sedimentary development of Late Paleozoic basins in the Western Carpathians is based above all on sedimentological-petrographic study complemented by biostratigraphic, geochemical and isotope data.

Like most of other collisional fold belts, the Western Carpathians have been traditionally divided into external and internal structural zones. The main difference between the distinguished structural zones is in the age of the main Alpine events and in the intensity of their deformational and metamorphic effects. The fragments of the Late Paleozoic sedimentary basin filling is 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 Silicic) as well as of the Bôrka and Turňa nappe slivers.

Lithostratigraphic Correlation of the Late Paleozoic Sequences

PERMIAN OF THE TATRIC UNIT

Permian sedimentary sequences are preserved mostly only sporadically and in small thickness, with the exception of relatively more important occurrences, such as in Považský Inovec Mts. and Malá Fatra Mts. Common features are: different angle of deposition on the immediate crystalline basement, continental, predominantly coarse-clastic development, weak manifestations of synsedimentary volcanic activity and erosive covering by mineralogically mature Lower Triassic sediments. The complex crystalline substrate is represented by high-grade (gneisses, amphibolites, migmatites, granulite gneisses) as well as relatively low-grade metamorphic rocks (quartz +muscovite as stable phases) and magmatic rocks (Tatra Terrane sensu VOZÁROVÁ & VOZÁR 1996). Permian sediments are of two types:

- the first (Malé Karpaty Mts., Vysoké Tatry Mts.,. Veľká Fatra Mts.) represents occurrences of coarse-grained arkose and fine-conglomerate sediments with small areal extent, usually only several tens of m thick;

- the second type (Považský Inovec Mts. Malá Fatra Mts.) is relatively better vertically lithofacially differentiated, more extensive, the thickness exceeds the order of 100 m, it is represented above all by coarse-grained arkose sediments and polymict conglomerates, with only minor proportion of shales. A common feature of both occurrence types is the continental, predominantly alluvial sedimentation environment, mineralogically and structurally immature detritus and absolute absence of biostratigraphic dating.

Synsedimentary volcanism of rhyolite composition is sporadic (small occurrences in the Malé Karpaty Mts.; relatively more intensive only in the Považský Inovec Mts.). From a horizon with U-mineralization associated with rhyolite volcanism in the Považský Inovec Mts. there comes also the only radiometric dating of Permian horizons in Tatricum (Pb/U + 280 Ma; ARCHANGELSKIJ & DANIEL 1989, manuscript information).

The chemical composition of Permian rhyolites in Tatricum shows a marked alkalic trend. Zircon typology from rhyolite volcanites and volcanoclastics from the Hundsheim Hills in the continuation of the Malé Karpaty Mts. and from the Považský Inovec Mts. supported the multi-stage character of this volcanism, with a trend from calc-alkaline to low- and high-temperature alkaline magma (BROSKA et al. 1993).

PERMIAN OF THE NORTHERN VEPORIC UNIT

The Northern Veporic unit consists of Variscan and/or pre-Variscan crystalline rock complexes (Tatra Terrane in the sense of VOZÁROVÁ & VOZÁR 1996), as well as overstep Permian formations and Mesozoic envelope series of characteristic lithofacial development. Relics of Permian basin filling generally correspond to continental volcano-sedimentary formations. They overlapped the underlying crystalline rock complexes with distinct unconformity and they are also separated from the overlying Lower Triassic sediments by a hiatus and disconformity. Among several occurrences the sequence of the Ľubietová Gr. (Tab. 1) from the Čierťaž Mts. is the best preserved. It comprises the Brusno and Predajná Fms. (VOZÁROVÁ 1979).

Principal features of the Brusno Fm. are the following: dominant arkosic sediments of psammitic/psephitic grade and evidence of synsedimentary volcanism (the Harnobis volcanogenic horizon). Monotonous, mostly light-gray and greenish-gray coarse-grained sediments indicate an environment of low-sinusoity rivers. Frequent washouts, erosive channels and in fact poorly preserved overbank and crevasse sediments are evidence of quick and chaotic changes of braided alluvia with prevalent autocyclic erosive processes. The provenance of detritus has been proved to be the 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, a part of them containing 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.

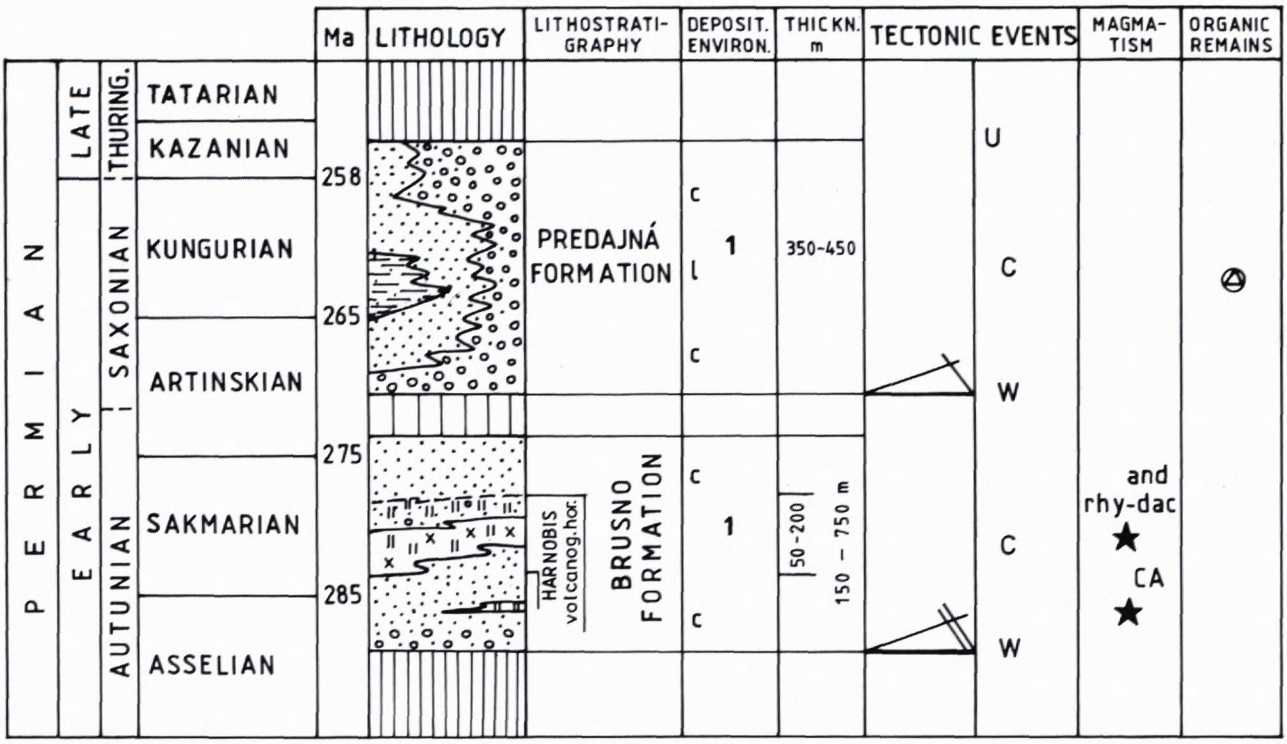
The Saxonian age of the Brusno Fm. is indicated by zoned monosaccate spores - *Florinites* sp., *Punctatisporites* sp., *Reticulatisporites* sp., *Cordaitales* sp. (PLANDEROVÁ in PLANDEROVÁ & VOZÁROVÁ 1982).

The Predajná Fm. overlaps disconformably the Brusno Fm. The 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 the 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 a thick horizon of conglomerates at the base of each of them, are the reflection of synsedimentary tectonics. The second is partially reduced due to pre-Triassic erosion.

Upper Permian age was assigned to the Predajná Fm. according to poor microflora: *Monosulcites minimus gynetaceaepollenites* sp., *Gymatiosphaera* sp., *Karpatisporites minimus* PLAND., *Punctatisporites* sp., *Reticulatisporites* sp., *Florinites* sp. (PLANDEROVÁ & VOZÁROVÁ 1982).

We correlate with the Ľubietová Group also Permian sediments of the cover Čierna Hora series (VOZÁROVÁ &

TAB. 1 PERMIAN OF THE NORTHERN VEPORIC UNIT



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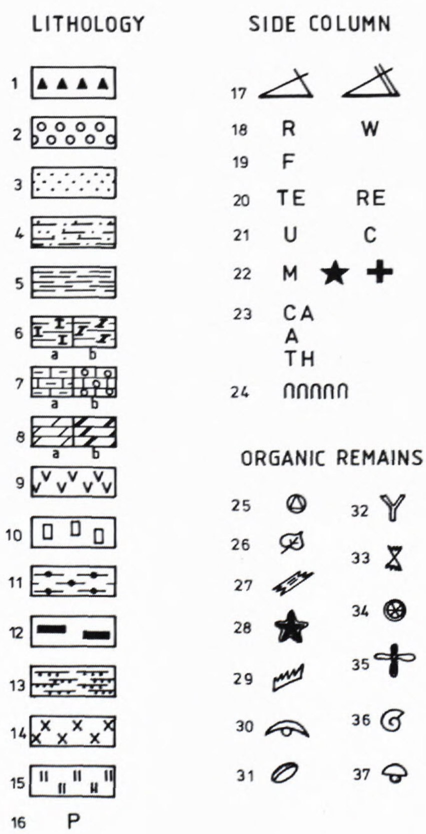


Explanation to tables 1 - 9:

Lithology: *1 - breccias; 2 - conglomerates; 3 - sandstones; 4 - silts; alternating sandstones/shales; 5 - shales; 6 - a) shales with intercalation of limestones, b) shales with intercalation of dolomites; 7 - a) clayey carbonates, b) bioclastics carbonates; 8 - a) dolomites, b) magnesites; 9 - sulfates; 10 - halite; 11 - shales with abundant organic matter; 12 - coal; 13 - turbidites: s = siliciclastic, v = volcanoclastic, c = carbonatic; 14 - volcanics; 15 - volcanoclastics; 16 - phosphorite sandstones.*
Note: All symbols are valid also for metamorhpic equivalents of the rocks

Side - column: *17 - low/high angle unconformity; 18 - rift/wrench induced; 19 - folding; 20 - transgression, regression; 21 - regional uplift/collapse; 22 - metamorphics, volcanics, intrusives; 23 - CA - calc-alkaline magmatic trend; A - alkaline magmatic trend; TH - tholeiitic magmatic trend; additional symbols: rhy - rhyolite; dac - dacite; and - andesite, bas - basalt; 24 - flysch troughs.*

Organic remains: *25 - microfloral assemblages; 26 - plant fragments; 27 - fragments of stems, fragmental plant remains; 28 - crinoids; 29 - conodonts; 30 - trilobites; 31 - brachiopodes; 32 - bryozoas; 33 - bivalvia; 34 - corals; 35 - insects; 36 - nautiloids.*

Additional symbols to depositional environment side-column
1 - mainly continental clastics:
c = coarse grained, f = fine grained, l = lacustrin, d = desertic, lateritic;
2 - evaporites: t = and clastics, c = and carbonates;
3 - deltaic, shallow marine, mainly sandstones;
4 - shallow marine, mainly shales;
5 - shallow marine, carbonates and clastics;
6 - deeper marine (turbidites).

VOZÁR 1988). They are identical, as far as lithology and mineralogic composition, the superposition and probably (they have not been yet biostratigraphically dated) also stratigraphic range are concerned.

Separately there have been distinguished Permian sediments from the Starohorské vrchy Hills (Špania dolina Fm.), Branisko (Korytné Fm.) and Tribeč Mts. (Skýcov and Slopňa Fms.). They have been described in greater detail in the works of VOZÁROVÁ & VOZÁR (1988) and VOZÁROVÁ & VOZÁR in IVANIČKA et al. (1992). Common features of these occurrences are: 1. relatively monotonous lithological composition, i.e. predominantly arkosic detritus, of coarse-arenaceous to fine-conglomerate grain-size; 2. absence or only weak manifestations of syn-sedimentary volcanic activity of rhyolite composition (Tribeč Mts.); 3. in some places more significant proportion of fine-grained lithologic members in the upper part of the sequences (Tribeč, Starohorské vrchy Hills).

Generally, the sediments are poorly sorted, with variable lateral as well as vertical stratification and distinct fining-upward development and consequent change of colors (from greenish-gray and light-gray to violet-red and brownish-red). The sediments correspond to braided alluvia sedimentary environment passing in some places into ephemeral lake deposits.

Poor stratigraphic data are known only in the Starohorské vrchy Hills. The lower part of the Špania Dolina Fm. can be characterized by the microfloral species *Potonieisporites div.* sp., *Punctatisporites* sp., *Nuskoisporites* sp. as Saxonian (PLANDEROVÁ & ČILLÍK 1990). In the upper part of the formation, Upper Permian spore assemblages have been determined (PLANDEROVÁ 1974). The most frequent are bisaccate pollen *Karpatisporites gracilis* PLAND., *Karpatisporites minimus* PLAND., *Klausipollenites staplini* JANS., *Lueckisporites virkkiae* KLAUS, a.o.

The grade of metamorphism of the Northern Veporic Permian deposits did not exceed the lower - temperature part of greenschist facies.

STEPHANIAN AND PERMIAN OF THE SOUTHERN VEPORIC UNIT

Alpine overthrust planes and steep faults separate the Southern Veporic basement and its Late Paleozoic and Mesozoic envelope from the Northern Veporic unit in the north (Muráň line) as well as from the Gemeric unit in the south (the Ľubeník-Margecany line). The Southern Veporic basement consists of several types of low- to medium-grade metamorphic rocks (phyllites, mica schists, albite-biotite gneisses, amphibolites). The occurrences of Al-Fe rich metasediments (KORIKOVSKIJ et al. 1989; KOVÁČIK 1991; MÉRES & HOVORKA 1991) and orthogneisses of magmatic arc provenance (HOVORKA et al. 1987) are special types. These rock complexes together with relics of migmatitized and strongly diaphtorized high-grade metamorphic complexes (?Lower Paleozoic/ ?Proterozoic; BEZÁK 1991) were distinguished as the Kohút Terrane (VOZÁROVÁ & VOZÁR 1996).

The Revúca Group (consisting of the Slatviná and Rimava Fms.) has been defined as the basal part of the envelope sequence of the Southern Veporicum (VOZÁROVÁ & VOZÁR 1982). Generally it represents the upward-coarsening sequence with mutual progradation from deltaic to fluvial environment (Tab. 2).

Stephanian

Well preserved cyclical structure is the main lithological feature of the Slatviná Fm., in spite of its complicated metamorphic evolution during the Alpine orogeny. Multiple vertical alternation of gray metasandstones and dark-gray/black metapelites in low-order sedimentary cycles and their regional unification in two large coarsening-upward regressive cycles indicate a prograding fluvial environment. In reaches of stillwater there tended to develop anoxic bottom conditions, resulting in the formation of graphitic shales. Abundant carbonized plant detritus, relics of various organic remains including insects, tissue fragments, abundant spores of terrestrial plants are indicative of a shallow-water reservoir and proximity of a plant-covered continent. The cyclicity of sediments is the result of changes in the thickness of sandstone bodies, of a variable sandstone/shale ratio, decreasing or increasing grain size of sandstones.

Conspicuous stratification, sharp contacts of beds, tabular and relatively uniform sandstone strata are the main relic sedimentary features. Most others were destroyed by the polyphase Alpine metamorphism, caused by orogenic pressure and by consequent thermal relaxation connected with the intrusion of granitoids (VOZÁROVÁ 1990).

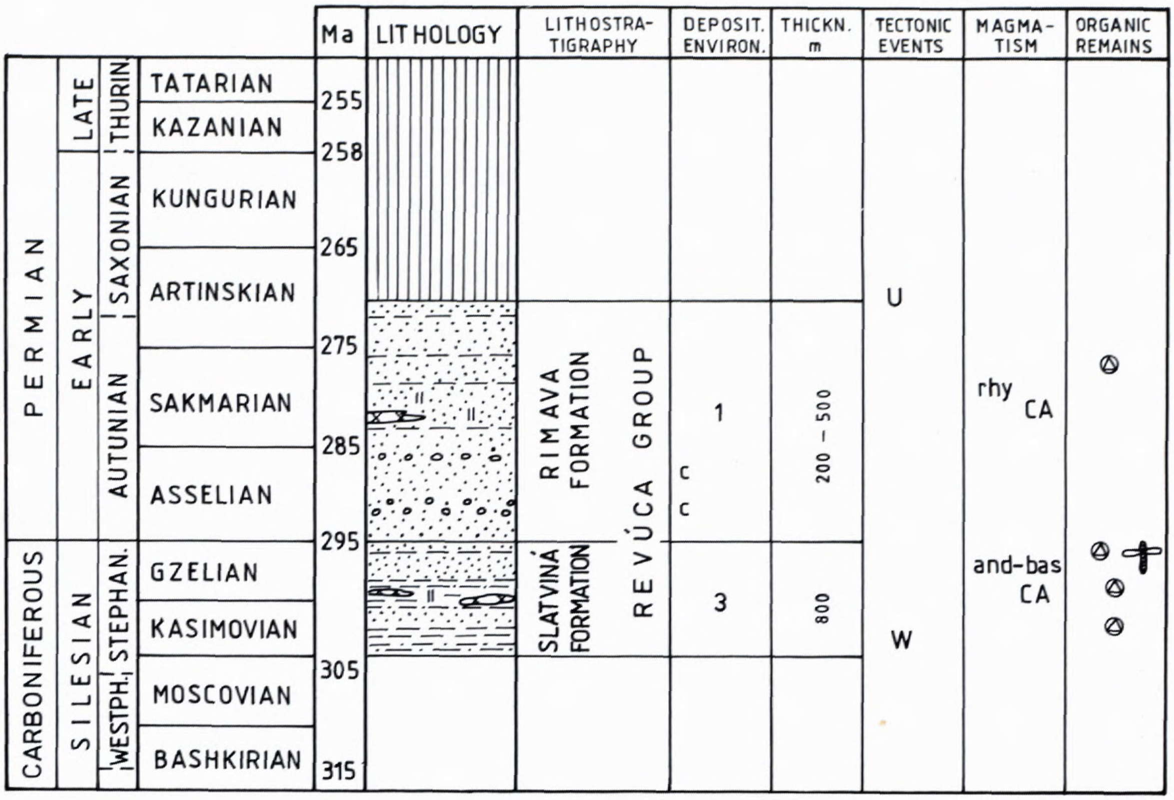
On the basis of abundant pollen of the genera *Potonieisporites*, *Illinites*, *Striatosaccites*, and spores of the genera *Florinites* and the species *Thymospora thiesenii* the Slatviná Fm. is classed with the Stephanian C-D (PLANDEROVÁ & VOZÁROVÁ 1978).

Manifestations of synsedimentary volcanism were not intensive. Dominant are redeposited volcanoclastics associated with local thin effusions of dacite-andesite and basalts.

Permian

Metasediments of the Rimava Fm. do not display a distinctly cyclic fabric. They consist of thick progressive graded-bedded beds of metasandstones, sandy-metaconglomerates, very often with mutual erosive contacts. Metasediments contain abundant granitoid detritus, the prevalent metasandstones correspond to metaarkoses and arkosic metagraywackes. Discontinuous horizons of

TAB. 2 CARBONIFEROUS AND PERMIAN OF THE SOUTHERN VEPORIC UNIT



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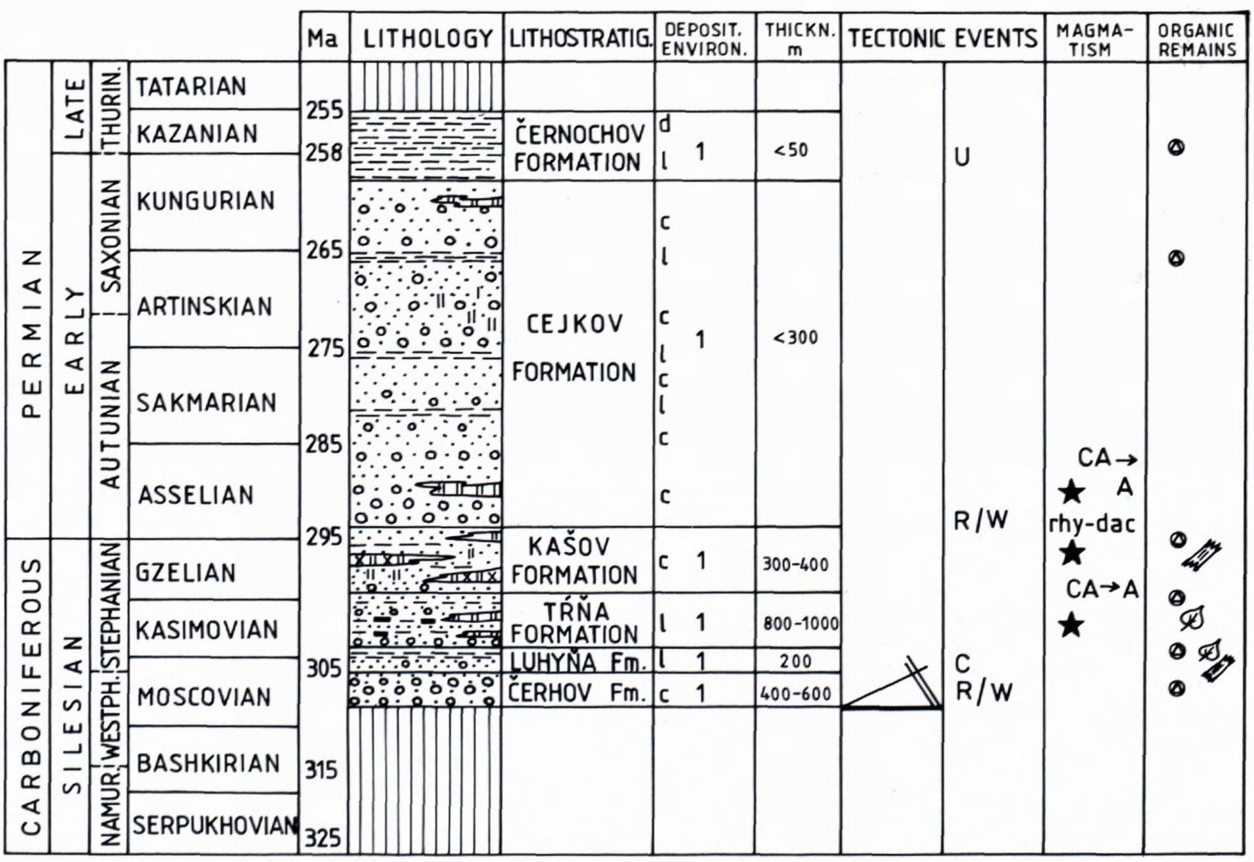
TAB. 3 WESTPHALIAN-STEPHANIAN AND PERMIAN OF THE ZEMPLINIC UNIT



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well rounded medium-sized pebbles of quartz and granitoids are concentrated at the base of thick beds of sandstones. Fine-grained metasediments are only a minor component. They provide some spore species of the genus *Lueckisporites*, ranging the Rimava Fm. with the Lower Permian (PLANDEROVÁ & VOZÁROVÁ 1982).

Sequences of the Rimava Fm. comprise small bodies of rhyolites and rhyolite volcanoclastics. The contact of the Rimava Fm. and overlying Lower Triassic sediments is erosive, with an interruption of sedimentation.

WESTPHALIAN-STEPHANIAN AND PERMIAN OF THE ZEMPLINIC UNIT

The crystalline rocks of the Zemplinic Unit, together with their Late Paleozoic and Mesozoic envelope, make up a NW-SE striking tectonic horst, 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 1991; FARYAD 1995; Byšta Susp. Terr., in VOZÁROVÁ & VOZÁR 1996).

Westphalian - Stephanian

Overlapping unconformably the crystalline basement, the rocks represent a post-orogenic Late Variscan volcano-sedimentary complex documented in numerous drill-holes and by the composition of detritus. The Westphalian-Stephanian sequence consists of four partial lithostratigraphic units (Tab. 3; Čerhov, Luhyňa, Tŕňa, Kašov, Fms.; in BOUČEK & PŘIBYL 1959, GRECULA & EGYŰD 1982, VOZÁROVÁ 1986). Their stratigraphic range was established according to macro- and microfloral findings (NĚMEJC 1947, 1953; NĚMEJC & OBRHEL 1959, PLANDEROVÁ et al. 1981).

Polymict conglomerates, with grain-supported structure and relatively well-rounded pebble material are dominant lithofacies of the Čerhov Fm. They are interpreted mostly as braided-river deposits. The lithostratigraphic profile consists of repeated small fining-upward sedimentary cycles with prevalent conglomerate or sandy-conglomerate 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., *Microreticulatisporites sulcatus* (WILS. et KR.), *Tripartites* sp.

The gradually evolving Luhyňa Fm. consists of fine-grained lacustrine sediments - sandstones, mudstones and shales of gray to black color, interrupted by episodic events of distal-fan streams. The Stephanian A age was proved mainly by macroflora: *Calamites cisti* BRONGN., *Pecopteris cf. miltoni* ARTIS, *Alethopteris* sp., *Asterophyllites trichomonatus* STUR. Microfloral assemblages are indicative of the Stephanian A-B range. Dominant are spores of the species *Torispora securis* Balme, spores of the genus *Lycospora*, *Punctatisporites*, *Densosporites*, and bisaccate striate pollen of the genus *Vittatina*.

Cyclothems with thin coal seams represent the Tŕňa Fm. The Lower Stephanian age was inferred on the basis of plant findings: *Pecopteris cyathes, Cordaites borassifolius, Sphenophyllum emarginatus* BRONGN., *Asterotheca arborescens* BRONGN., *Alethopteris bohemica* FRANKE, *Calamites cisti* BRONGN., *Stigmaria ficoides* (STGB.) BRONGN., *Annularia pseudostellata* POTONIE, *Lepidophloios laricinus* STGB., *Lepidostrobophyllum majus* BRONGN.

The Tŕňa Fm. 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 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 predominant lithologies of the Kašov Fm. Based on the remnants of silicified trunks of araucarites, *Dadoxylon* sp. and microflora assemblages the Kašov Fm. was assigned to the Stephanian B-C. The following microflora assemblages were identified: *Thymospora perverrucosa* (ALP.) WILS.. et VEN., *Colluminisporites ovalis* PEPPER, *Latensina trileta*, *Vittatina ovalis* KLAUS, *Spinosporites* sp., *Disaccites striatiti* sp., *Cordaitina* sp.

Generally, geochemical data of volcanites based on bulk composition, trace elements and REE indicate the calc-alkaline magmatic trend. Results of zircon typology study show mainly higher temperature calc-alkaline to alkaline character (BROSKA et al. 1993).

Permian

A sharp transition from humid to arid climate is characteristic for Permian sediments of the Zemplinic Unit. During the Permian sedimentary development the syn-sedimentary tectonics was less intensive compared to the Westphalian-Stephanian and as a consequence, the rate of sedimentation and volcanic activity were reduced. Generally, deposition proceeded in an alluvial environment with the features typical of a semi-arid and arid region. Multi-colored sedimentary complexes of the Cejkov Fm. comprise proximal and distal alluvial facies (polymict conglomerates and sandstones) alternating with deposits of flood plains 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 Lower Permian age is assigned to the Cejkov Fm. due to the abundance of the species from the genus *Potonieisporites* and *Vittatina*, as well as due to findings of bisaccate pollen of the genera *Jugasporites, Falcisporites* and *Klausipollenites.*

A complex of monotonous violet-red, vaguely schistose mudstones represents the youngest lithostratigraphic unit - the Černochov Fm. A relatively thin (max. 50 m) sequence of a monotonous playa association is unconformably overlain by light-gray quartzose conglomeratic sandstones of Lower Triassic age. Almost massive claystones and mudstones are rich in Al_2O_3 (20-21%) and ferric iron (7%). Poor microflora remains: *Lueckisporites, Striatites richteri, Jugasporites, Limitisporites* correspond most likely to the Thuringian.

Sedimentological and paleoecological data indicate that a short intra-Permian hiatus is possible. Sediments of both formations contain detritus derived from the underlying crystalline basement. The grade of their regional metamorphism did not exceed P-T conditions of anchizone/greenschist boundary.

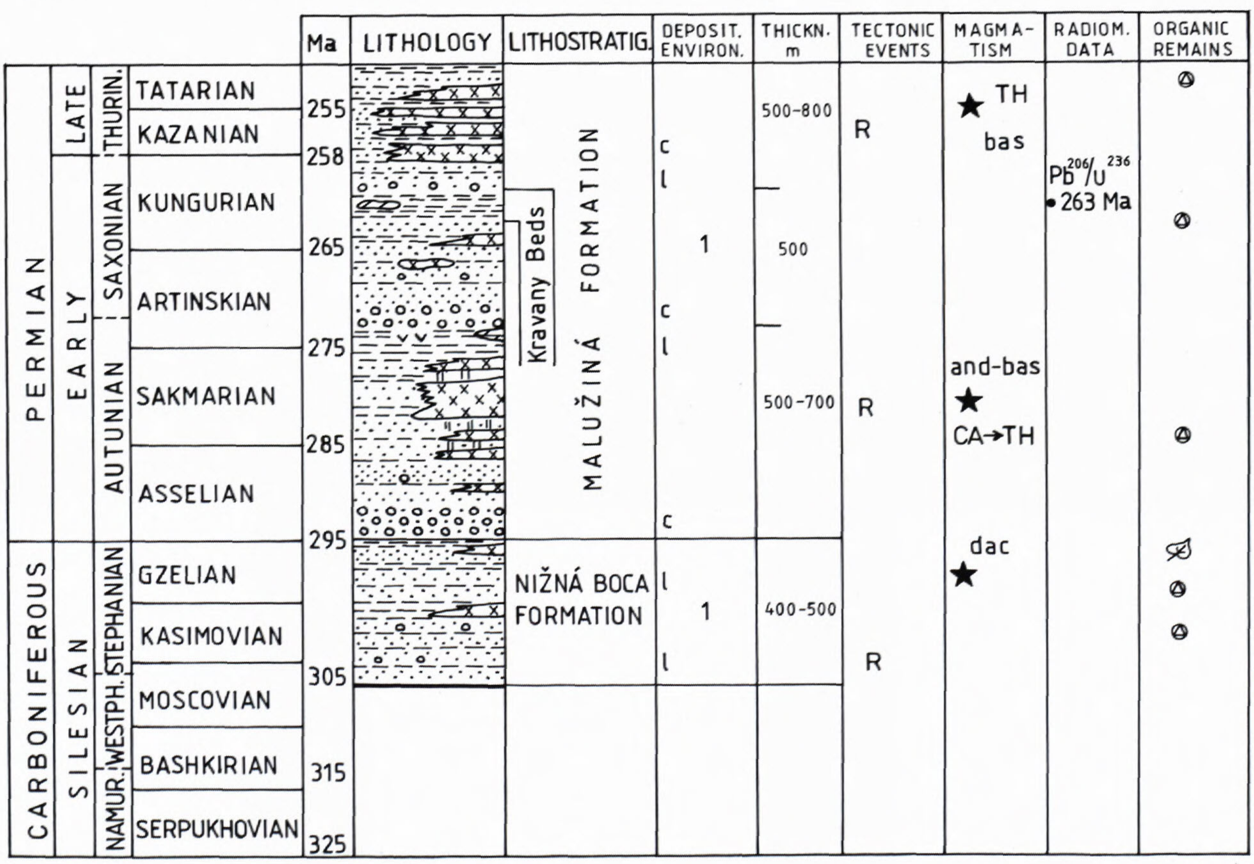
STEPHANIAN AND PERMIAN OF THE HRONIC UNIT

The Hronic Unit has been defined as a rootless megastructural Alpine unit consisting of two partial nappes: the Šturec and Choč Nappes (accord. to ANDRUSOV et al. 1973). Due to their internal structure and mutual relations and facial characteristics the partial nappes have been distinguished as mainly Triassic complexes. Both Hronic nappe units contain Late Paleozoic volcano-sedimentary formations (Tab. 4), 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.

Stephanian

There is no evidence of either the underlying pre-Stephanian sediments or of the immediate basement. Tectonic slices of granitoid blastomylonites found in the

TAB. 4 STEPHANIAN AND PERMIAN OF THE HRONIC UNIT



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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 Fm. - is generally a regressive clastic sequence with distinct tendency of upward coarsening (VOZÁROVÁ 1981). 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 gray to black color 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 bodies of dacite.

Macroflora from the uppermost part of the Nižná Boca Fm. indicates its Stephanian B-C age. SITÁR & VOZÁR (1973) described well preserved relics of *Asterotheca miltoni* ARTIS, *Asterotheca arborescens* BRONGN., *Cordaites palmaeformis* GOEPP. and *Callipteridium gigas* GUTT. Several fragments of Westphalian/ Stephanian flora were determined by NĚMEJC (in MAHEĽ 1954) in strongly tectonically reduced remains of the easternmost Nižná Boca Fm. occurrences (Slatviná and Vojkovce vill.): *Calamites* sp., *Lepidostrobophillum majus, Asterotheca miltoni, Stigmaria ficoides, Palmopteris furcata.* The palynological analysis of PLANDEROVÁ (1973) distinguished two microflora assemblages: the Stephanian A-B - *Torispora securis* BALM., *Lycospora pusilla* (IBR.) SOM., *Verrucosisporites pergranulatus* (ALP.) SMITH., *Crassispora kosankei* (POT. KREMP.) BHARADW., *Laevigatosporites vulgaris* (IBR.) ALP. DOUB., *Thymospora pseudothiessenii* (KOS.) ALP. DOUB., - the Stephanian C-D: *Laevigatosporites* div. sp., *Cyclogranisporites densus* BHARADW., *Lycospora pusilla* (IBR.) SOM., *Foevalatisporites junior* ROS., *Planisporites kosankei* (KNOX) POT. KR. *Cadiospora magna* KOS., *Allatisporites verrucosus* ALP., *A. hexalatus* ALP., *Potonieisporites* div. sp. and *Disaccites striatiti.*

Permian

The Permian sequences of Malužiná Fm. are developed gradually from the underlying Nižná Boca Fm. 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 in 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, 1984).

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

The microflora proved the Lower and Upper Permian age of the Malužiná Fm. The following assemblages were described by PLANDEROVÁ (1973; in PLANDEROVÁ & VOZÁROVÁ 1982): - Autunian: *Spinosporites exiguus* UPTHAW - HEDL., *Thymospora* div.sp., *Punctatisporites speciosus* KALIB., *Cordaitina* div.sp., *Illinites unicus* KOS., *Vittatina* div. sp., a. o. - Autunian-Saxonian: *Latensina trileta* ALP., *Potonieisporites novicus* BHARADW., *P. radiosus* SCHWARZ, *Jugasporites delassaucei* KLAUS, *Vittatina ovalis* KLAUS, - Thuringian: *Calamospora nathorstii* KLAUS, *KLAUSipollenites* div.sp., *Carpathisporites sittleri* PLAND., *Lueckisporites parvus* KLAUS, *Vittatina angulistriata* KLAUS, *Monosulcites minimus* COOKSON, a.o.

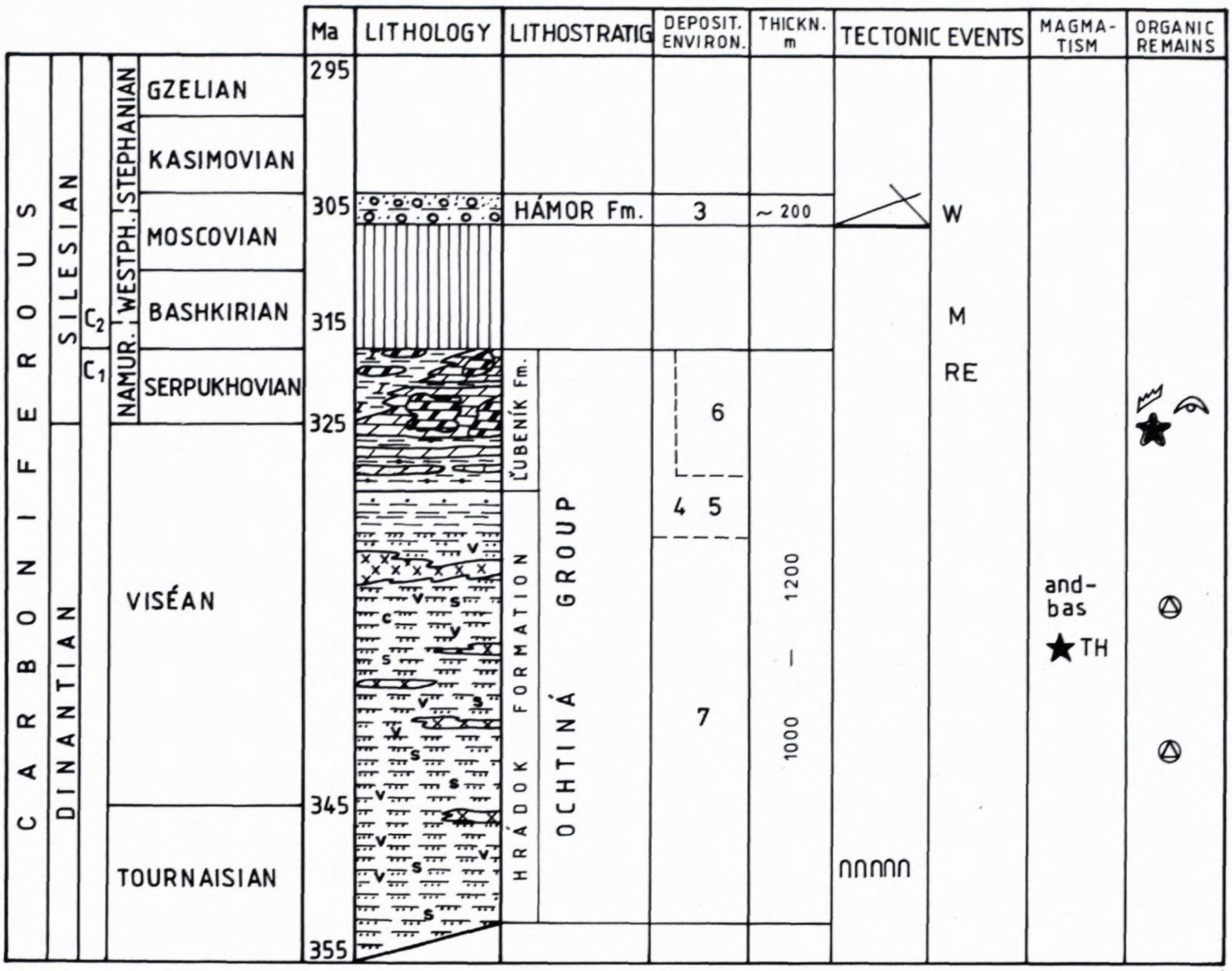
The Autunian-Saxonian microflora assemblages correspond approximately to the first and second megacycles. This assumption is supported by $^{206}Pb/^{238}U$ and $^{207}Pb/^{235}U$ dating of 263 and 274 Ma from uranium-bearing layers of the uppermost part of the 2nd megacycle (LEPKA in ROJKOVIČ et al. 1992).

Sediments of both formations contain detritus derived from: 1/granitoids and high-grade metamorphics, 2/ dacite and andesite/basalt synsedimentary volcanics, 3/ low-grade metamorphics. Generally the grade of regional metamorphism did not exceed P-T conditions of diagenesis/anchizone boundary.

CARBONIFEROUS AND PERMIAN OF THE NORTHERN GEMERIC UNIT

The Alpine Northern Gemeric Unit contains two by the metamorphic development significantly differing pre-Carboniferous terranes - the Klátov and Rakovec Terranes (sensu VOZÁROVÁ & VOZÁR 1993, 1996). The Klátov Terrane is composed mostly of amphibolites, less gneisses, serpentinites and their hydrothermally-metasomatic derivatives, rarely Ca-silicate rocks (SPIŠIAK et al. 1985), as well as orthogneisses, plagiaplites, tonalites and granitoids found in fragments of Westphalian conglomerates (VOZÁROVÁ & VOZÁR l.c.). The Rakovec Terrane, on the other hand, contains basic metavolcanics and metavolcanoclastics associated with a minor amount of metapelites and metasandstones, with sporadic occurrences of intermediary and acid metavolcanics. While the grade of regional metamorphism reached in the Klátov Terrane the P-T conditions of the

TAB. 5 CARBONIFEROUS OF THE NORTHERN GEMERIC UNIT: SW part



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higher-temperature amphibolite facies (Hovorka & Spišiak 1981, Bajaník & Hovorka 1981 and others) of medium to high pressure (findings of retrograde-metamorphosed eclogitic rocks; Hovorka et al. 1994), in the Rakovec did not exceed P-T conditions of greenschist facies. On the basis of their composition show a marked affinity to the oceanic and lower continental crust. Along with them, relics of the filling of Carboniferous-Permian, orogenic to post-orogenic sedimentation basins have been preserved in the Northern Gemeric Unit.

Turnaisian - Visean - Serpukhovian

Sedimentary sequences corresponding to this stratigraphic range have been preserved in the form of tectonically restricted relics at the SW and E-SE boundary of the Northern Gemeric Unit and they are tectonically strongly reduced due to its Alpine thrusting on the Southern Veporic Unit lying below (Tab. 5, 6). In spite of the tectonic reduction and the reduction of the original thickness due to regional metamorphism, present thickness of these sequences is estimated at 1000 m and more.

SW part of the Northern Gemeric Unit (Tab. 5): Lower Carboniferous sequences are in this part separated from the footwall (Southern Veporicum; Ľubeník-Margecany Line) as well as hanging wall (Southern Gemericum; Hrádok Line) tectonically, by thrust lines. This sequence was originally defined as the Ochtiná Fm. and included into the Dobšiná Gr. along with other Middle Carboniferous formations (Vozárová in Bajaník et al. 1981). In view of its different tectonometamorphic development and stratigraphic position we distinguished this sequence from the Dobšiná Gr. and we define it as an independent lithostratigraphic unit of a higher order. While preserving the priority rule, we left the original name of the lithostratigraphic unit and we changed only the general part of the name - "group" instead of "formation". Within the

Ochtiná Group. we distinguish two formations - the lower Hrádok and upper Ľubeník Fm.

The Hrádok Fm. consists of flysch-like dark-gray and black clastic sediments - metaconglomerates, metasandstones, metapelites, interlayered with metabasalts, metadolerites and basaltic metavolcanoclastics. Very rare rocks, found only in thin layers are lydites and siliceous metapelites. Slabs of ultramafic rocks (?oceanic crust fragments) indicated by antigorite serpentinites and talc-tremolitic schists have been reported. Sedimentary structures indicate turbidity current flows, gravity slides and grain flows as a transport system.

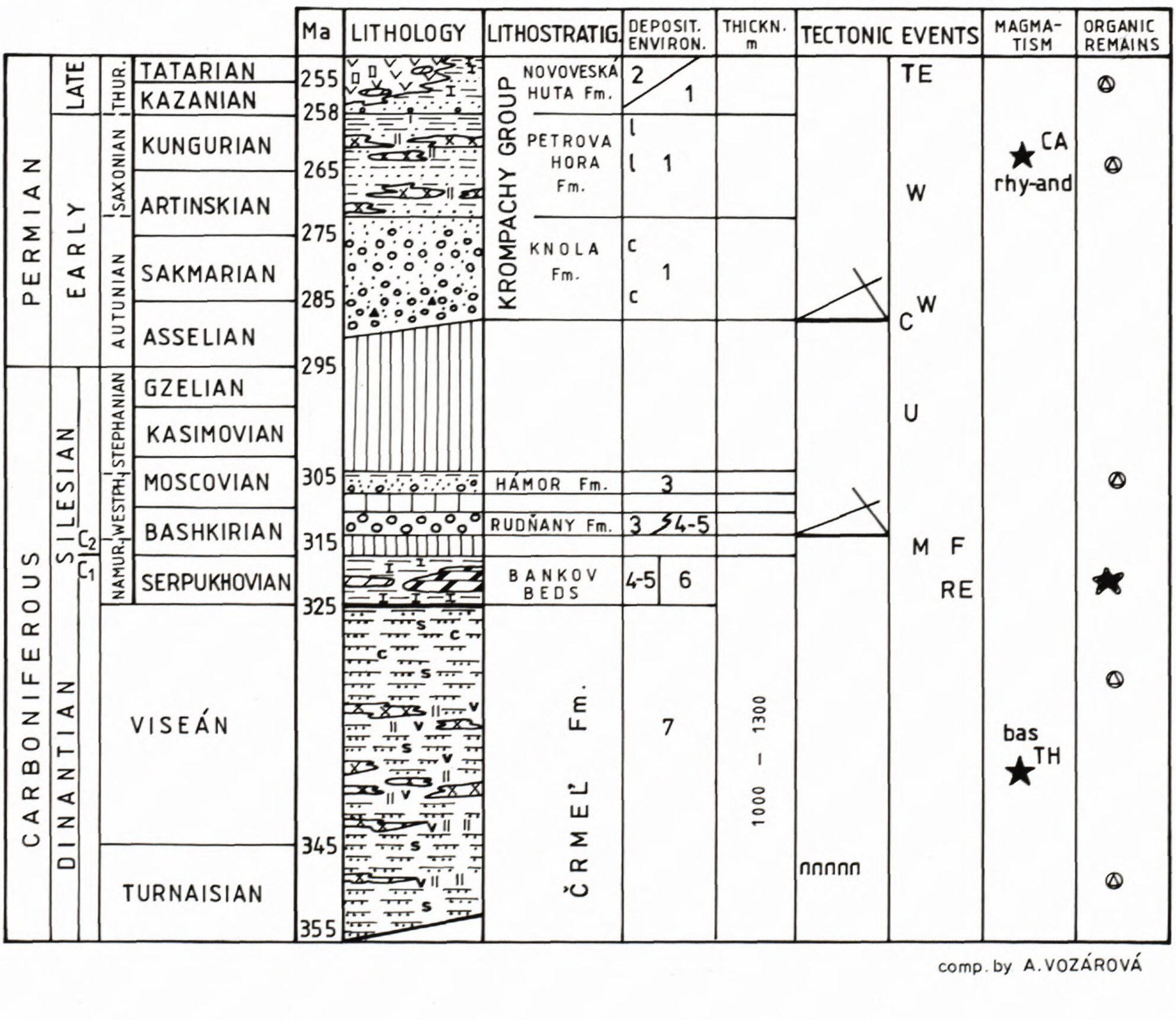
A monotonous complex of dark-gray metapelites, overlying relative coarse-grained basal part of the Hrádok Fm., yielded microfloral assemblages indicating Upper Turnaisian - Visean age (PLANDEROVÁ 1982, BAJANÍK & PLANDEROVÁ 1985). The following microfloral assemblages were described: *Tumulispora varituberculata* (ZIEBER) POT. NAUM., *Tetraporina glabra, Vallatisporites verrucosus* HACQUE, *Lophosphaeridium finitimus* TSCH., *Dyctyotriletes submarginatus* PLAYF.

The basic volcanic rocks of the Hrádok Fm. belong to tholeiites with distinct N-MORB affinity.

Sedimentation in shallow-water neritic and littoral environment is a characteristic feature of the Ľubeník Fm. The sequence consists of black shales, dolomitic shales, well-bedded dolomites and massive coarse-grained magnesite. Most dolomites show pellintrabiosparite texture comprising pellets, intraclasts of micrite texture and bioclasts, consisting of fragments of Echinodermata, Lamellibranchiata, Foraminifera, Ostracoda, a.o.

On the basis of trilobite fauna, the age of the Ľubeník Fm. at the loc. Ochtiná was determined as Namurian B-C by BOUČEK & PŘIBYL (1960). Index forms of trilobites: *Phillipsia margaritifera* ROEMER, *Paladin eichwaldi* (FISCHER). Later, KOZUR & MOCK (in KOZUR et al. 1976),

TAB. 6 CARBONIFEROUS AND PERMIAN OF THE NORTHERN GEMERIC UNIT: E-SE part



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based on the first findings of conodonts, holothurian sclerites and ostracods, classed the sediments from loc. Ochtiná with the uppermost Visean and Serpukhovian. In the lower part of the sequence, conodont fauna was found: *Paragnathodus commutatus* (BRANSON and MEHL 1957) and *Paragnathodus nodosus* (BISCHOFF 1957), in the upper part there was *Gnathodus bilineatus bollandensis*.

E and SE part of the Northern Gemeric Unit (Tab. 6): The Lower Carboniferous sequence of the Črmeľ Fm. was described as a distal flysch complex, consisting of alternating pelites, fine-grained sandstones, basic to intermediate volcanites and volcanoclastics, subsidiary carbonates and lydites. Small amounts of acid volcanoclastic detritus are unevenly dispersed in the sediments.

The Turnaisian-Visean age was indicated by microfloral assemblages (Snopková in BAJANÍK et al. 1984): *Convolutispora labiata* PLAYFORD, *C. subtriquetra* PLAYF., *Foveosporites oppositus* PLAYF., *F. insculptus* (PLAYF.) var. minor, *Schopfites claviger* SULIVAN, *Prolycospora claytonii* TURN., *Schulzospora* cf. *campyloptera* (WALTZ) HOFFM. STAPL. et MALL., a.o.

Lower Carboniferous sequences in the eastern and south-eastern part of the Northern Gemericum were originally defined and the Črmeľ Group. In view of the stratigraphic range and lithology equal to the sequences of the Ochtiná Group we assign the general part of the name "group" to the lower category - formation, and, under the name Črmeľ Formation, we incorporate this lithostratigraphic unit into the Ochtiná Group. The Črmeľ Fm. may be correlated, on the basis of the flysch development, the same type of basic volcanism (tholeiites with N-MORB affinity) with the Hrádok Fm. in the west. However, there are differences, such as the absence of fragments of ultrabasics and conglomerate turbidites, the substantially smaller number of graphitic shale horizons, considerably higher proportion of lenses of laminated crystalline limestones, allowing to distinguish this sequence as a separate formation within the Ochtiná Gr.

In the eastern part, there are preserved also shallow-marine sediments of the Ľubeník Fm., with magnesites. Its relationship to the Črmeľ Fm. is however in the eastern occurrences tectonic. Stratigraphically, the horizon with magnesites near Košice has not been documented by fauna. In view of certain lithological differences (the presence of beds with redeposited carbonate fragments; absence of horizons with fauna) we assign to this horizon the name Bankov Beds, classified as a member of the Ľubeník Fm.

Generally, Lower Carboniferous sequences in the Northern Gemericum were regionally metamorphosed in P-T conditions of the low temperature greenschist facies of lower-pressure type (illite crystallinity index, Šucha, p.c.; b_0 values of muscovites - SASSI & VOZÁROVÁ 1987 - estimated temperatures of 350-370°C at low pressures and high geothermal gradient of approx. 40°C/km).

Westphalian A-D

From the original definition of Carboniferous lithostratigraphic units of Gemericum, we left only Westphalian sequences in the Dobšiná Gr.. The most completely preserved ones are in the northern part (Tab. 7). In the eastern part, only two of them have been preserved (Rudňany and Hámor Fms., Tab. 6) and in the western part there are only relics of the Hámor Fm. (Tab. 5).

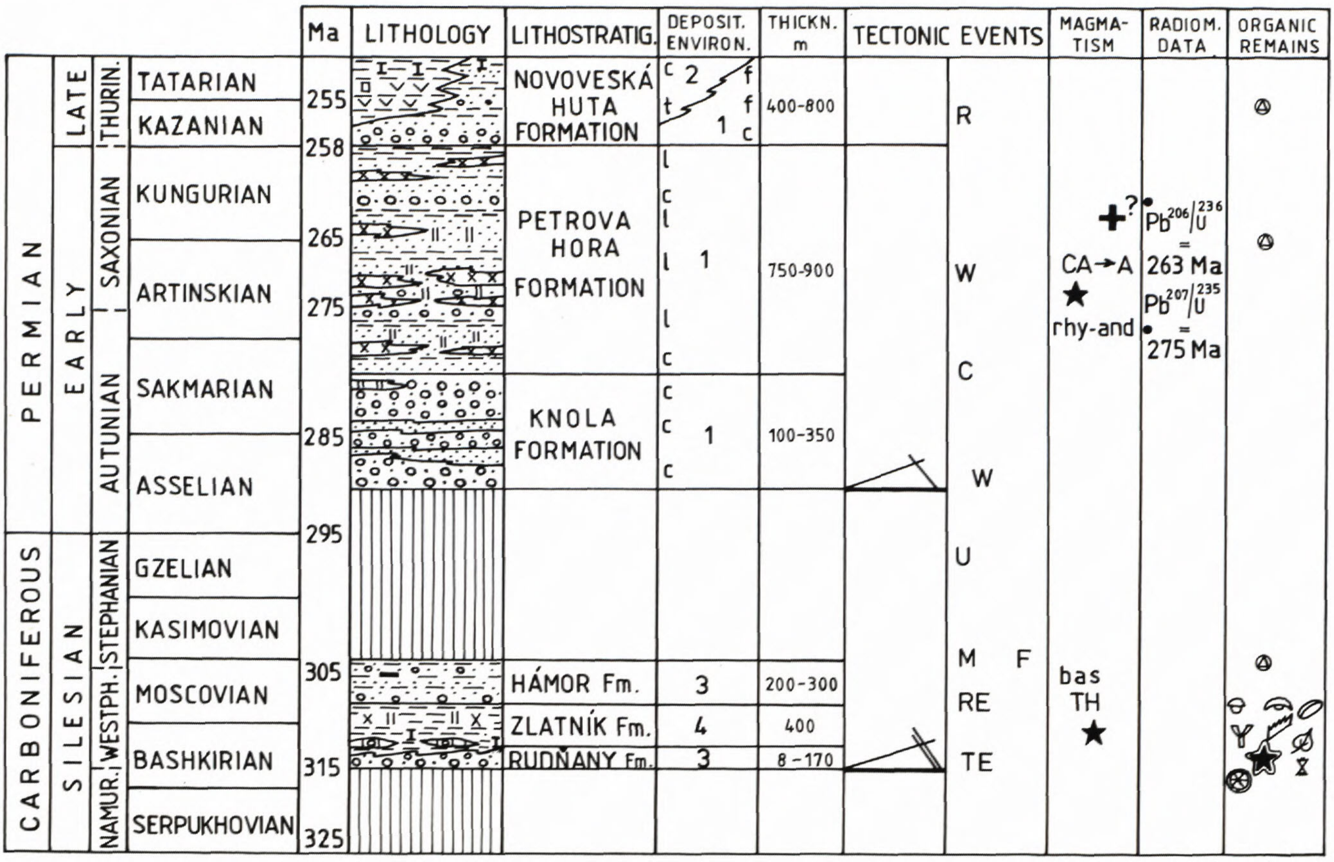
The Westphalian sequences are preserved within the paleo-Alpine North Gemeric Unit as tectonically reduced fragments. Their tectonic setting, related to continental collision, started in the Westphalian A by delta-fan, coarse-grained, very often boulder conglomerates, containing detritus derived from the underlying pre-Upper Carboniferous rock complexes. Direct contact of this 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 (Tab. 7), metasediments and metabasalts of the Rakovec Terrane in the wider area of the Rudňany village (Tab. 7), and the Lower Carboniferous flysch sequence of Črmeľ Fm. in the area between Margecany and Košická Belá (Tab. 6). Black shales and micaceous gray sandstone intercalations are a normal member of the upward fining Rudňany Fm. The floristic finds were determined by NĚMEJC (1947): *Cordaites palmaeoformis*, *Asterophyllites* cf. *grandis*, *Asterotheca miltoni*, *Neuropteris schützei*, *N. gigantea*, *N. gigantea abbreviata*.

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 Fm., from which the Westphalian B-C age is indicated by rich trilobite fauna: *Griffithides rozlozsniki* RAKUSZ, 1932; *Cummingella* sp. aff. *balladoolensis* RED, 1942; *Palladin* sp. aff. *eichwaldi* FISHER, 1925 (in Rakusz 1932; BOUČEK & PŘIBYL 1960). Based on flora findings, NĚMEJC (1947; 1953) ranged this sequence to the Westphalian A-B: *Paripteris gigantea*, *Stylocalamites suckovi*, *Neuropteris heterophylla*. The conodont *Idiognatoides sinuatus* proved Westphalian A age (KOZUR & MOCK 1977).

The upper part of the Zlatník Fm. comprises fine-grained clastic metasediments associated with fine metabasaltic volcanoclastics and scarce effusions of high-K tholeiitic basalts. It reflects the deepening of the Westphalian sedimentary basin. Poor microfloral assemblages proved Upper Carboniferous age, but not an accurate division.

The termination of the Westphalian peripheral basin is reflected by the paralic sequence of the Hámor Fm. It is characterized by: 1. distinct cyclical, coarsening-upward arrangement of shally-sandy-conglomeratic sedi-

TAB. 7 CARBONIFEROUS AND PERMIAN OF THE NORTHERN GEMERIC UNIT: N part



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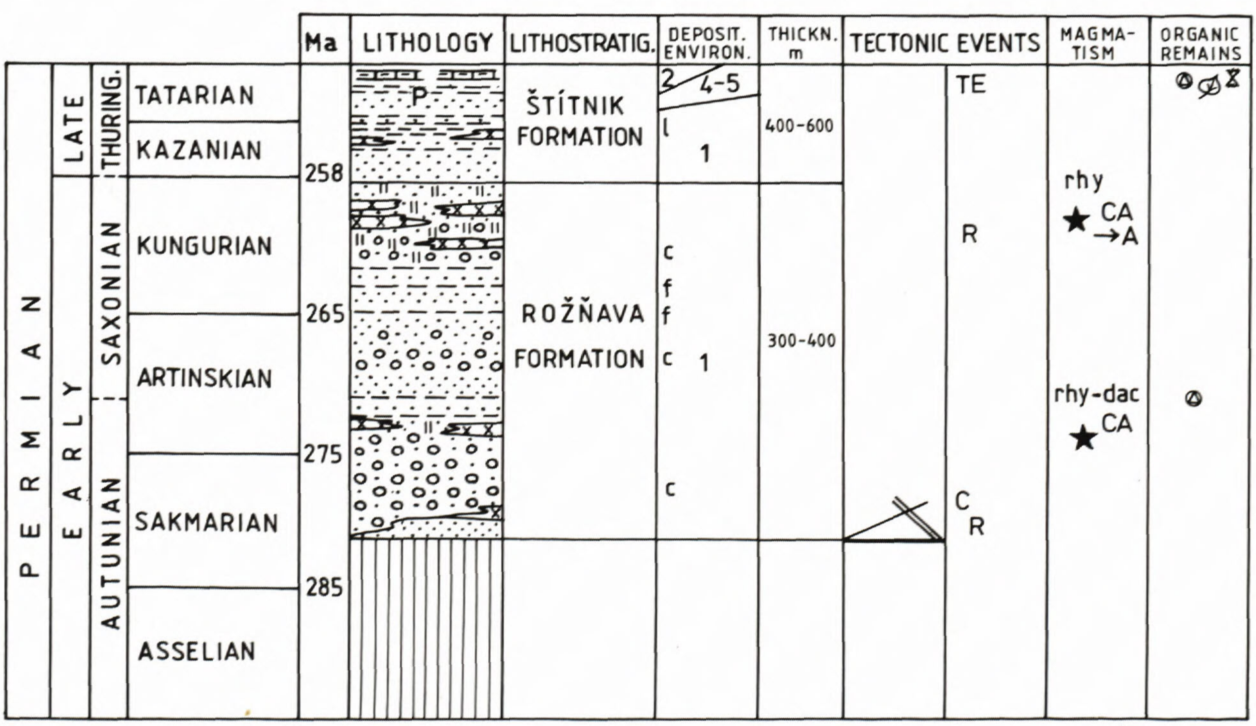
TAB. 8 PERMIAN OF THE SOUTHERN GEMERIC UNIT



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ments; 2. absence of synsedimentary volcanism; 3. local occurrence of a ribbed coal seam; 4. abundant mineralogical mature, quartz detritus. Poor microfloral assemblages proved the Westphalian D age: *Reticulatisporites irregularis* KOSANKE, *Thymospora thiessenii, Apiculatisporites raistrickii* (DYB.-JACH.), *Angulisporites splendidus* BHARADW., *Illinisporites elegans* KOS. (ILAVSKÁ 1961 in CHMELÍK et al. 1962; PLANDEROVÁ, manus. report).

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

Permian

Continental Permian sequences overlapped slightly deformed relics of the Westphalian peripheral basin filling as well as all pre-Westphalian complexes of the Northern Gemeric zone with the exclusion of W and SW occurrences of the Ochtiná Group (see Tab. 5). 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 the post-Asturian transpression/transtension stage, as a result of extensional regime during the Late Permian-well as with Lower Triassic time.

The following are the characteristic features: 1/ multicoloured clastic sediments with dominant violet and violet-red; 2/ gradual upward fining; 3/ cyclicity manifested within the framework of small cycles as well as megacycles; 4/ bimodal calc-alkaline to alkaline volcanism.

The basal part (the Knola Fm.) 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 irregularly eroded surface of the Moscovian formations. They represent fossil mudflows, in some places partly reworked by flows, relieved by alluvial, mainly stream channel deposits. The age of these sediments has not been determined, due to a lack of fossils remains.

Volcanics and volcanoclastics of bimodal magmatic association are the main feature of the Petrova Hora Fm. The polyphase volcanic activity manifested a regional and time relationship with large sedimentary cycles. Sediments are characterized by a low degree of maturity and a mixture of syngenetic volcanic and non-volcanic detritus. Among the most striking features are the fining-upward alluvial cycles, with channel lag, pointbar and floodplain lakes facies alternating with playa subenvironment at the topmost part of large cycles.

The microflora found in the upper part of the Petrova Hora Fm. proved Saxonian age: *Limitisporites moesensis* (GREBEL) KLAUS, *Vittatina* div. sp., *Nuckoisporites dulhontyi* KLAUS (PLANDEROVÁ in BAJANÍK et al. 1977). This age is supported by isotopic analysis of sulfides 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 pebble material derived from the direct stratigraphic underlier. This could have been a consequence of the break in sedimentation after the Saxonian, but biostratigraphic evidence to support this assumption is missing. Alluvial, stream channel deposits prograde gradually upward to the inland sabkha and near-shore sabkha/lagoonal facies, with anhydrite-gypsum and salt breccia horizons (the Novoveská Huta Fm.). Isotopic analysis of sulfur shows results close to Upper Permian - lower part of the Lower Triassic (KANTOR et al. 1982). There are gradual transition up to the *Claraia clarai* horizon.

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

PERMIAN OF THE SOUTHERN GEMERIC UNIT

Late Variscan, post-orogenic overstep sequences of the Southern Gemeric Unit are represented only by the Permian to Lower Triassic continental and near-shore, lagoonal-sabkha formations (Tab. 8). They unconformably overlapped their Early Paleozoic basement, the volcano-sedimentary flysch of the Gelnica Gr. and metasediments of the Štós Fm. (defined together as the Gelnica Terr., VOZÁROVÁ & VOZÁR 1993, 1996). Generally, the Permian volcano-sedimentary complexes are characterized by a high content of mineralogically mature detritus, mainly in their basal part. Conspicuous upward fining is accompanied by a relative decrease of mineralogical maturity. Sediments represent the relics of sedimentary basin filling which originated in a transpression/transtension regime, which prograded to the initial stage of post-Variscan rifting. The whole sequence is subdivided into two lithostratigraphic units: the Rožňava and Štítnik Fms.

Characteristic lithotype of the Rožňava Fm. are oligomict, quartzose conglomerates, with indistinct stratification. The whole sequence is dismembered vertically into two large cycles, with conglomerate horizons at the base of each and a sandstone-shale member between them. Dominant are stream channel and sheet-flood deposits, with unimodal transport system. Both conglomerate horizons are connected with rhyolite-dacite subaerial volcanism. Their chemical composition corresponds to calc-alkaline magmatic type. The Lower Permian age of the Rožňava Fm. is assumed on the basis of microflora, with the predominant species of the genera *Potonieisporites, Striatodisaccites, Guetaceapollenites, Vittatina* sp., *Urtemis trigonius* and mainly the form *Triquitrites additus* WILS.. et HOFM.. (PLANDEROVÁ 1980).

The gradually prograded Štítnik Fm. is a monotonous complex of cyclically alternating sandstones, siltstones and shales. Lenses of carbonate 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 a relatively high amount of rhyolite/dacite detritus (? synsedimentary or redeposited from the Rožňava Fm.). The sedimentary environment is interpreted as alluvial-lacustrine and lacustrine, with high-alkaline lakes in some places, prograding into near-shore, lagoonal-sabkha facies. Age determinations are known only from the uppermost part. The Upper Permian was proved on the basis of a cone slice and twig of *Pseudowoltzia liebeana* (GEIN) FLOR., and leaves of the genus *Sphenozamites*, as well as remains of bivalvian shells of the genus *Carbonicola* McCOY 1855 (ŠUF 1963). Microfloral assemblages confirm the Lower Triassic age of this horizon (PLANDEROVÁ 1980).

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

PERMIAN OF THE MELIATIC UNIT (BÔRKA NAPPE)

Tectonic slices of volcano-sedimentary sequences intensively pressure-deformed, lying in tectonic position on the Southern Gemeric basement and its cover, were recently assigned to the Bôrka Nappe (in Geol. map of the Slovak Karst, MELLO et al. 1996). The Permian age of these sequences has no been biostratigraphically supported, it is estimated only on the basis of their lithologic development. Two formations have been distinguished, classified previously as higher-metamorphosed members of the Permian cover of the Southern Gemericum, although their thrust tectonic position has been known (REICHWALDER 1973, BAJANÍK et al. 1984).

The Bučina Fm. is composed of a set of rhyolite volcanoclastics and felsitic rhyolites mixed with a small amount of non-volcanic quartzose detritus, of psammitic or psephitic grain-size.

The Jasov Fm. is composed predominantly of clastic sediments - oligomict conglomerates, sandstones and shales, with only a small amount of acid volcanics and volcanoclastic at the basal part. It is characterized by considerable decrease of the grain-size towards the upper parts.

Based on b_o muscovite values (MAZZOLI, SASSI & VOZÁROVÁ 1992), P-T conditions of regional metamorphism correspond to medium/high-pressure greenschist facies (T = 400-450°C; P = 9-10 kbar; geothermal gradient approx. 10°C/km). The measurements were made on phyllites from the upper part of the Jasov Fm., in which the metamorphic assemblage quartz + muscovite + paragonite + albite, with a small amount of pyrophyllite and chlorite has been determined. They are associated with muscovite-chlorite-chloritoid phyllites.

CARBONIFEROUS AND PERMIAN OF THE TURNAIC UNIT

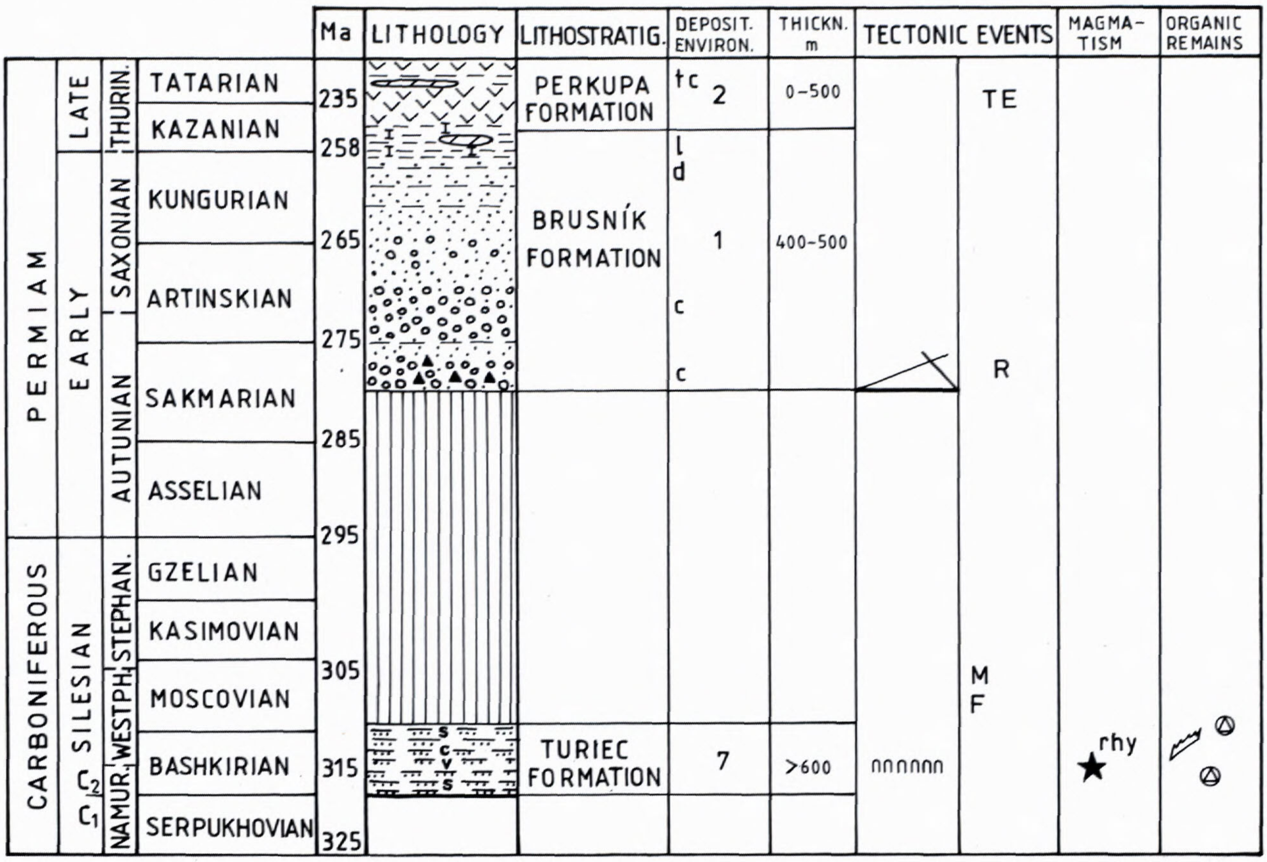
Late Paleozoic sequences assigned to the Turnaic Unit (Tab. 9) emerge to the surface from the tectonic underlier of the Silica Nappe in the southern part of the Slovenské rudohorie Mts., in the anticlinal structure near Brusník. The borehole BRU-1 (VOZÁROVÁ & VOZÁR 1990, 1992 a, b) allowed to determine their thrust tectonic position on the Upper Jurassic olistostrome sequence of Meliaticum. In the southern part of the Slovenské rudohorie Mts., they occur thus only in the form of nappe outliers in the tectonic overlier of Meliaticum (outliers of the Bôrka Nappe or Meliaticum s.s.) and in the tectonic underlier of the Silica Nappe.

Namurian B - Westphalian A

The sequence of black phyllites, metasiltstones and metasandstones with structural features of distal turbidite sedimentation, interrupted by episodic deposits of gravitational slides and a gravity current, including the carbonate olistostrome body, were defined as the Turiec Fm. (VOZÁROVÁ 1992). From the entire turbidite sequence only the Bouma facies T_{d-e} have been preserved. Horizontal lamination, positive-graded within a small rhythm, is predominant. Associated there are thin graded-bedded metasandstone interbeds (maximum thickness 10-15 cm). Gravity current deposits are represented by layers of redeposited acid volcanoclastics and paraconglomerates. The bulk chemical composition of redeposited volcanoclastics shows their relationship to the rhyolite-dacite group of the subalkaline magmatic series. The paraconglomerate beds show positively graded bedding, with erosional contact with the underlying beds and predominant content of intraformational detritus.

The olistostrome consists of carbonate olistoliths ranging from tens of meters to decimeters in size. They are composed of limestones of two types: medium- to light-gray recrystallized limestones; black-gray clayey, unevenly recrystallized ones. Olistoliths of dark-gray limestones from the borehole BRU-1 contain conodonts whose age corresponds to the Zone "Idiognathoides" i.e. Namurian B - Westphalian A (EBNER et al. 1990). The dating is based on remains of *Idiognathoides* cf. *corrugatus* (HARRIS and HOLLINGSWORTH 1933); *Streptognathodus* sp., *Idiognathoides* sp. Mixed conodont fauna was found in the lower part of this olistostrome: *Idiognathoides* sp. (Namurian B - Westphalian A) and *Polygnathus* sp. (Emsian - Tournaisian).

TAB. 9 CARBONIFEROUS AND PERMIAN OF THE TURNAIC UNIT



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Sporomorph assemblages of the Namurian B - Westphalian A from the matrix of the olistostrome were determined by PLANDEROVÁ (in VOZÁR et al. 1989): *Tripartites vetustus*; *Anulatisporites bacatus* DYB., JACH.; *Cingulizonates loricus*; *Securisporites locatus*; *Densoisporites crassigranifer* are the most typical.

Metasediments of the Turiec Fm. underwent low-pressure greenschist-facies regional metamorphism (Mazzoli & VOZÁROVÁ 1989).

Permian

Variegated, polymict coarse-clastic sediments resting unconformably on dark phyllites and containing phyllite fragments at their base, have always been considered to be of Permian age because of their continental red-beds type of deposits. They were described as a separate lithostratigraphic unit, denoted as the Brusník Fm. (VOZÁROVÁ & VOZÁR 1988).

The Brusník Fm. is characterized by dominant coarse-clastic sediments, a distinct tendency to fining upwards and dominant violet and gray-violet colors. In its internal structure three large sedimentary cycles were distinguished, each of them exceeding 100 m in thickness. Basic lithological types at the base of cycles are represented by polymict conglomerates in the middle part by lithic sandstones, in the upper part by sandstones alternating with siltstones and sandy shales. Among clastic sediments there are scarce irregular layers of redeposited acid volcanoclastic material, and in the upper part of the third large cycle there are small lenses of carbonates.

The assumed age of the Brusník Fm. is Lower Permian, in view of the fact that it is associated, with gradual transitions, with the evaporite Perkupa Fm. (borehole DRŽ-1, MELLO et al. 1994), which, on the basis of analogy with other evaporite occurrences in this zone, is most probably of Upper Permian age.

The Perkupa Fm. is composed of a complex of red and greenish-gray shales, with dolomite concretions on their base and beds of gypsum/anhydrite and dolomites in the upper parts.

PERMIAN OF THE SILICIC UNIT

Locally preserved evaporite sequences of the Perkupa Fm., assumed to be Upper Permian, are the oldest known sediment on the base of the Silica Nappe.

They are connected with the overlying, biostratigraphically documented Lower Triassic sediments by gradual transitions. The Perkupa Fm. is composed of greenish-gray, less gray to dark-gray shales, gypsum/anhydrite and dolomites. A characteristic feature is the presence of anhydrite-arenites and evaporite sedimentary breccias, indicating mobile sedimentation conditions, redeposition of evaporites into relatively deeper part, most probably a tectonically formed rift sedimentation basin.

Reconstruction of collision and post-collision variscan orogeny stage

The majority of sedimentary basins may be classified from the point of view of crust type, on which the basin originated, further, on the basis of the relative position to the plate margin and character of plate interaction taking place during filling up of the sedimentary basin (BALLY & SNELSON 1980, MIALL 1984). The plate tectonics theory shows that all these three fundamental parameters are changing with time. That implies that to the same mobile belt basins of various structural foundation and origin may be linked.

From the point of view of these criteria Carboniferous-Permian basins of the Western Carpathians belong to the type of peri- and epi-sutural basins, which were associated with formation of a compression megasuture. They were founded on continental or transitional to oceanic crust in a time and space succession depending on final closure of the Variscan mobile zone. It is evident that the Epi-Variscan continental crust formed by gradual accretion of terranes in the subduction-collision process, which at the beginning was finalized in Devonian - Lower Carboniferous and later terminated in Upper Carboniferous - Permian times. This process was accompanied at first by transpression/transtension and then extension regime associated with the origin of tectonically active sedimentary basins, located on both sides of the supposed Variscan suture.

Lithostratigraphic and sedimentologic analysis of Late Paleozoic basins suggests that the Variscan Terranes, recognized in the Paleo-Alpine Tatra-Veporic Domain, were gradually colliding from intra-Devonian to Middle Carboniferous time. The period of colliding is reflected by syn-collision magmatites, which had inherited VAC (CAG) features, related to previous subduction processes (HOVORKA & PETRÍK 1992, BROSKA & GREGOR 1992, KOHÚT 1992, 1996, PETRÍK et al. 1994, a.o.). These Variscan Terranes have been a part of the continental, overriding plate, composed of torn relics of Pre-Variscan crust (probably Precambrian) and of Caledonian-Variscan volcanic/magmatic arcs and convergent basins (represented by the Tatra T. including Byšta susp. T. and the Kohút and hypothetical Ipoltica T.). As a consequence of syn- and post-collisional magmatism a thickened continental crust formed, on which sedimentary basins were founded in a strike/slip and extensional regime in two stages.

The older, Westphalian-Stephanian ones are represented by huge wedges of clastogenic formations deposited in a continental or deltaic/shallow-water sedimentary regime. They are accompanied by acid to intermediate ensialic volcanism. The sedimentary basins of this stage are represented by volcanic-sedimentary formations preserved in Alpine-formed units of the Zemplinicum, Southern Veporicum and Hronicum (formations of the Zemplín, Ipoltica and Revúca Groups). The sedimentary regime continued in Westphalian-Stephanian basins, and gradually also in the Permian. A distinct change of climatic conditions was, however, taking place when the warm and humid climate was replaced by dry arid and semiarid climate. In the Permian generally clastic alluvial, fluvial-lacustrine formations of "red-beds" type formed in these basins. The determining feature of these basins is synsedimentary volcanism, mostly alkaline to calc-alkaline, and in zones of maximum extension of continental tholeiite type (Ipoltica Group; VOZÁR 1977).

A further group of graben and half-graben type basins was founded in Permian times (Autunian-Saxonian) and originated as a result of post-collision intra-plate extension. Their substratum were magmatic and crystalline massifs of the Tatra Terrane. The filling relics of these Permian basins are preserved in Alpine-formed units of the Tatricum and Northern Veporicum. In sedimentary basins founded in Permian times syngenetic volcanic activity was relative to previous group weak or not manifesting at all. From lithofacies representing preserved filling relics of Permian basins mostly wedges of coarse-clastic sediments coming from the environment of alluvial fans or braided rivers are found.

The model of most sedimentary basins founded on the Late Paleozoic Tatroveporic Domain respectively the Slovak Superterrane (name derived from the "Slovak block" MÁŠKA & ZOUBEK in BUDAY et al. 1960; "Slovakides" MAHEĽ 1983; "Slovakic Terrane" PLAŠIENKA 1991) is characterized by:

I. Prevailingly medium and small dimensions of sedimentary basins, in which intense tectonic activity at fault margins is indicated by conglomerate wedges. An exception, as to size and shape, is the Ipoltica Group rift trough, at which a considerably long (350-500 km) and well developed system of transversal and longitudinal transportation is supposed;

II. Manifestations of synsedimentary tectonics, as proved by development of megacycles of regional extension and of local intraformation disconformities, also by volcanic activity, mostly polyphase;

III. Clastic detritus coming from the immediate substratum bordering the margin of sedimentary basins or from synsedimentary volcanic centers;

VARISCAN orogene	INTERNIDES						EXTERNIDES						
relics in paleo-Alpine units	T	NV	SV	Z	H	NG	SG	M	TU	S	U	SZ	B
character of substratum of Late Paleozoic basins	continental crust					thrust wedges of ceanic crust	consuming plate boundary fore-arc basin filling		disrupted continental crust, attenuated in places				
tectono-thermal development	Devonian - Carboniferous tectono-thermal activity with maximum deformation, magmatism and metamorphism						weak or/lack of symptoms of magmatism; metamorphism more advanced than anchimetamorphism/low temperature greenschist facies						
main collision events	Bretonian - Sudetian						Asturian						
depositional system	continental: Permian ——→ Upper Carboniferous ——→ marine: shallow-water Moscovian and Serpuchovian ——→ deep-water post-Bretonian flysch ——→						continental to sabcha-lagoonal: Permian ——→ .sabcha to shallow-water: Permian ——→ .marine: shallow-water Stephanian ——→ deep-water post-Sudetian flysch ——→						
provenance	continental block prov. ——→ cut magmatic arc prov. ——→ orogen. provenance ——→						continental block provenance mixed - with recycled orogen provenance ——→						

Explanation to symbols:

T - Tatric Unit; NV - Northern Veporic U.; SV - Southern Veporic U.; Z - Zemplinic U.; NG - Northern Gemeric U.; SG - Southern Gemeric U.; M - Meliatic U.; TU - Turnaic U.; S - Silicic U.; U - Upponyi Mts.; SZ - Szendrö Mts.; B - Bükk Mts.

Tab. 10 Scheme of tectono-sedimentary evolution of the Western Carpathian Carboniferous-Permian basins.

IV. The petrofacial analysis of clastic sediments indicates a double provenance from the rejuvenated continental basement and truncated volcanic arc;

V. High-rate sedimentation.

The Late Paleozoic basins included into the Paleo-Alpine Gemeric Domain originated not only on two different types of the substratum, but also in different time.

Basins, the substratum of which was the Spiš Composite Terrane, originated on the oceanic crust and destroyed ensialic arc as well as high metamorphic fragments of lower continental crust. Lower Carboniferous remnant basins were of specific intrasutural position, represented by sequences of the Ochtiná Group. They are characterized by flysch type of sedimentation, with slabs of serpentinized ultrabasites (? of oceanic crust), upward shallowing and gradual replacement of flysch formations by shallow-water, littoral-neritic sediments. The filling of these basins was deformed and metamorphosed towards the end of the Lower Carboniferous (Vozárová 1993), probably due to Sudetian movements (finds of the Črmeľ Fm. rock fragments in pebbles of Westphalian conglomerates; Vozárová 1973). The development of Lower Carboniferous basins was terminated with the origin of the Variscan compression suture. In the Variscan orogeny, the Spiš Composite Terrane represented a intricate relic of oceanic/continental crust, on which at first the Lower Carboniferous flysch basins, and then shallow-marine peripheral basin formed in the Westphalian A-B. At the base it contains coarse-clastic deposits of delta-fan type, in which there are found detritus coming from Spiš Composite T. rock complexes, but also fragments of granitoids orthogneisses, tonalites, mica schists and mineralogically mature metasandstones. This exotic fragmentary material came from a newly forming collision suture, in which also parts of the active continental margin were destroyed. As a consequence of transform movements along the suture zone the peripheral basin changed its boundary and its sedimentation was interrupted. Shallow-marine sedimentation was terminated in the Westphalian D by a paralic sequence. Due to the supposed transform movements the basin was moderately deformed and the sediments weakly metamorphosed. Continental Permian sediments are resting unconformably on various lithological members of Westphalian formations and have all features of sedimentation in transtensional zone originated on the thickened continental crust with calc-alkaline to alkaline bimodal volcanism. Tectonic stabilization of the whole region was terminated by development of Upper Permian - Lower Triassic evaporite formations.

Quite a different development in the termination of the Variscan orogeny is reflected in the sedimentary basin formed on the Gelnica Terrane. The relic of its sedimentary filling is represented by formations of the

Gočaltovo Group, generally of Lower Permian to Upper Permian - Lower Triassic age (Šuf 1963, Planderová 1980). The basin was founded in a strike/slip fault regime, in which distinct extension was predominating in later development. The sedimentary filling, which is prevailingly continental and only in the upper parts transitional, lagoonal-marine, therefore has some features of rift formations. It is mainly high mineralogical maturity of sediments, which is in contradiction with their structural immaturity. A further feature is distinct decrease in the maturity grade of sediments in upward direction (Vozárová 1977). The associated volcanism is subaerial, highly siliceous. Although at the beginning of the development of the Gočaltovo Group sedimentary basin transpression/transtension forces (pebbles of quartz and blastomylonite deformed cataclastically) were active, extensional tectonic later prevailed, continuing also in the Early Alpine stage. Mineralogically mature sediments of the Gočaltovo Group were compared with the Alpine - Mediterranean "Verrucano" formations, defined by Cassinis et al. (1979) as riftogenic tectonofacies of the Alpine cycle. For this reason we suggest that the Permian sedimentary basin originated on the basement of the Gelnica Terrane as a post-collision basin, distinctly linked with Alpine rifting culminating with the formation of the Meliata ocean.

Of particular importance for reconstruction of the Variscan orogene is therefore the occurrence of the Middle Carboniferous flysch tectonic slice (Turiec Formation; Vozárová 1992), which was identified in borehole BRU-1 (Vozár et al. 1989) in the Brusník anticline. This flysch sequence was correlated lithologically (Vozárová & Vozár 1990, 1992a, b) and stratigraphically (Ebner & Vozárová et al. 1990) with the Szendrö Phyllites Formation in northern Hungary and with other Southern Alpine Middle Carboniferous flysch occurrences. The stratigraphic range of the Turiec Formation is Namurian B - Westphalian A (Bashkirian). It is a formation not compared with other Carboniferous occurrences in the Western Carpathians, as the Namurian B-C is missing in the Western Carpathians and the Westphalian A is in the development of the Post-Sudetian marine molasse. Regarding to the Turiec Formation containing a carbonate olistostrome (olistoliths of carbonates from the passive continental margin and also volcanoclastic rhyolite turbidites - island-arc detritus?) we may suppose that there is a relic of flysch trough genetically connected with the termination of the Western Carpathian Variscan externides. We may put the closing of this trough in connection with Asturian movements, its filling being deformed and metamorphosed in greenschist facies of low-pressure type (Mazzoli & Vozárová 1989). The Post-Asturian molasse is represented by continental Permian conglomerates of the Brusník Formation.

Conclusion

1. The origin of Carboniferous-Permian basins in the Western Carpathians is associated in time and space with collision events of the Variscan orogeny.
2. The distribution of Carboniferous-Permian basins in time as well as the lithofacial character of their filling documents the southern polarity of the Variscan orogene in the Western Carpathians.
3. The Carboniferous-Permian basins originated in three zones differing in the type of crust and position regarding to Variscan orogene polarity.

They are:

a) The Slovak Superterrane in which there formed terranes belonging to the upper continental plate with maximum manifestations of magmatism and metamorphism connected with convergent regime. In present-day Alpine structure the Tatra, Kohút and hypothetical Ipoltica Terranes are relics of this continental plate, which besides probable fragments of Precambrian crust contained also element of converging margins - relics of magmatic arcs or back-arc basins connected with Variscan orogeny. In this innermost zone of the Variscan orogeny only continental Upper Carboniferous-Permian molasse basins associated with transform fault and extensional regime have been preserved.

b) The Spiš Composite T., composed of the Klátov and Rakovec Terranes, which represents a relic of a plate with loer contineral and oceanic to transitional crust (perhaps of the type of developed back-arc basin in the sense of the interpretation of Ivan et al. 1994). The sedimentary basins, which originated in this zone, reflect the succession of Variscan collision. This relic of the Variscan suture is composed of tectonically pressed slices of oceanic crust, probably also including the destroyed ensimatic island arc and relics of continental crust and destroyed collision and post-collision Carboniferous-Permian basins. The latter are represented by filling relics of ?deep- to shallow-marine Post-Bretonian intrasutural basins and a shallow-marine Post-Sudetian peripheral basin. They are unconformably covered by Post-Asturian continental molasse.

c) The Gelnica Terrane represents a relic of forearc basin filling, associated with an ensialic arc on an active continental margin. On its basement a Post-Asturian continental basin originated in extensional regime. It is very probable that the Gelnica Terrane was palinspastically connected with a flysch trough, the relics of which were found in the form of a tectonic nappe outlier in borehole BRU-1 and its continuation is in the Szendrö Mts. If this assumption is correct, the Middle Carboniferous flysch trough represented by the Turiec Formation and Szendrö Phyllites Formation was linked with a convergent regime of the Western Carpathian Variscan externides. The closing of this basin was connected with Asturian movements. This zone is palinspastically directly connected with the South Alpine-Dinaride flysch zone, connections of which with lagoonal - shallow-marine formations of the African plate passive margin are evident.

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

a) Inner branch, with termination of collision during Bretonian-Sudetian events. It consist of two main domain: the Slovak Superterrane, which reflects intense dynamo-metamorphism, deformation and magmatism resulting in a long-lasting and strong uplifting and preserved only post-collisional Upper Carboniferous and/or Permian continental cover; the Spiš Composite T. inside of which Lower Carboniferous synorogenic flysch, Upper Carboniferous and Permian marine to continental post-collisional cover as well as slices of the multi-stage metamorphosed oceanic and lower continental crust have been preserved.

b) Outer branch, with termination during Asturian events. It is represented by the Early Paleozoic Gelnica T. volcanogenic fore-arc flysch and rifting-related its Permian cover with palinspastic relations to the Bashkirian flysch trough in the Turnaic Unit.

Both sutures represented zones of extension and crustal shortening in the Alpine orogeny. Especially the Asturian suture represented the zone of maximum extension and rifting, which led eventually to the origin of the future Meliata Ocean.

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