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Terranes of West Carpathians - North Pannonian Domain

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Abstract. The kinematic evolution of the West Carpathians arc system was affected in both Variscan and Alpine times. Fragments of newly formed Epi-Variscan crust were incorporated in the Paleoalpine West Carpathians units as evidenced by the repeating subduction, thrusting and transform fault processes. The Epi-Variscan crust gradually amalgamated by crustal thickening during Early to Late Carboniferous collision events, as overriding microplates (evidences of Tatra-Veporic Domain) of Eurasian affinity moved southwards.

The Lower Carboniferous flysch type basins originated in intrasutural embayment continuing in the Upper Carboniferous peripheral basin on the underthrusting plate (relics of Spiš Composite Terrane in Gemeric Domain) of African promontory.

The present West Carpathians have been divided into Outer West Carpathians and Central and Inner West Carpathians.

Crustal development of the Alpine Internides has been strongly influenced by the structural fabric of the Variscan collision orogeny. The Permian - Lower Triassic extension in the area of the former Variscan Externides (Gelnica Terrane in Gemeric Domain) results in continuing rifting in the Middle Triassic and opening of the large sedimentation area of the Meliata Ocean.

The main difference between distinguished structural zones of the West Carpathians is in age of main Alpine phases and intensity of deformational and metamorphic events. They are:

a) Inner West Carpathians - the HP/LT Late Jurassic events;

b) Central West Carpathians - the Lower/Middle Cretaceous;

c) Outer West Carpathians;

1) inner part - the Late Cretaceous/Lower Paleocene;

2) outer part - the Oligocene - Middle Miocene.

These kinematic stages represent the main phases of subduction -thrusting events followed by extension and uplift. Later deformation and emplacement to the present position were connected with Tertiary oblique collision of the West Carpathians - North Pannonian Block and North European platform.

Key words: West Carpathians, kinematic evolution, Variscan terranes, main Alpine deformational and metamorphic events

Introduction

This contribution summarizes the results of researches carried out within the framework of both, the IGCP Project No. 276 entitled: Paleozoic Geodynamic Domains and their Alpine Evolution in the Tethys (1986-1994) and the national project: Geodynamic Evolution of the West Carpathians (1991-1995). The objective of this analysis was to characterize Variscan terranes and to define their setting in the complicated Alpine structure of the West Carpathians.

The West Carpathian-Pannonian domain is characterized by the following development stages:

1. Pre-Alpine evolutionary stages - with predominant structural events from the Devonian/Early Carboniferous, to the Middle Carboniferous- Permian. Possible pre-Variscan evolutionary stages are included. These are preserved as fragments in the Alpine megaunits of the Inner and Central West Carpathians.

2. Pre-Middle-Cretaceous evolutionary stage - beginning of the compressional tectonic regime including the Late Jurassic subduction/accretion events in the Meliata oceanic domain as well as obduction of accretion prism sequences with HP/LT metamorphites.

3. Middle Cretaceous evolutionary stage - the northward migration of the orogenic contraction, revealed by the orogenic flysch sedimentation and successively closing of sedimentary basins from the Gemer-Bükk Domain through the Tatro-Veporic Domain. Shortening and origin of the north-vergent nappe system in the same manner.

4. Late Cretaceous to Paleocene evolutionary stage-comprises the closure of a supposed Penninic-related oceanic domain, origin of perisutural Senonian basin along the northern margin of the Tatric megaunit, the post-nappe Gosau sequences within the Inner West Carpathians.

5. Oligocene to Middle Miocene - northward prograding of the Flysch belt accretionary wedges of Carpathian orogeny, passing gradually into Neogene foredeep molasse depocenter; shortening and nappe

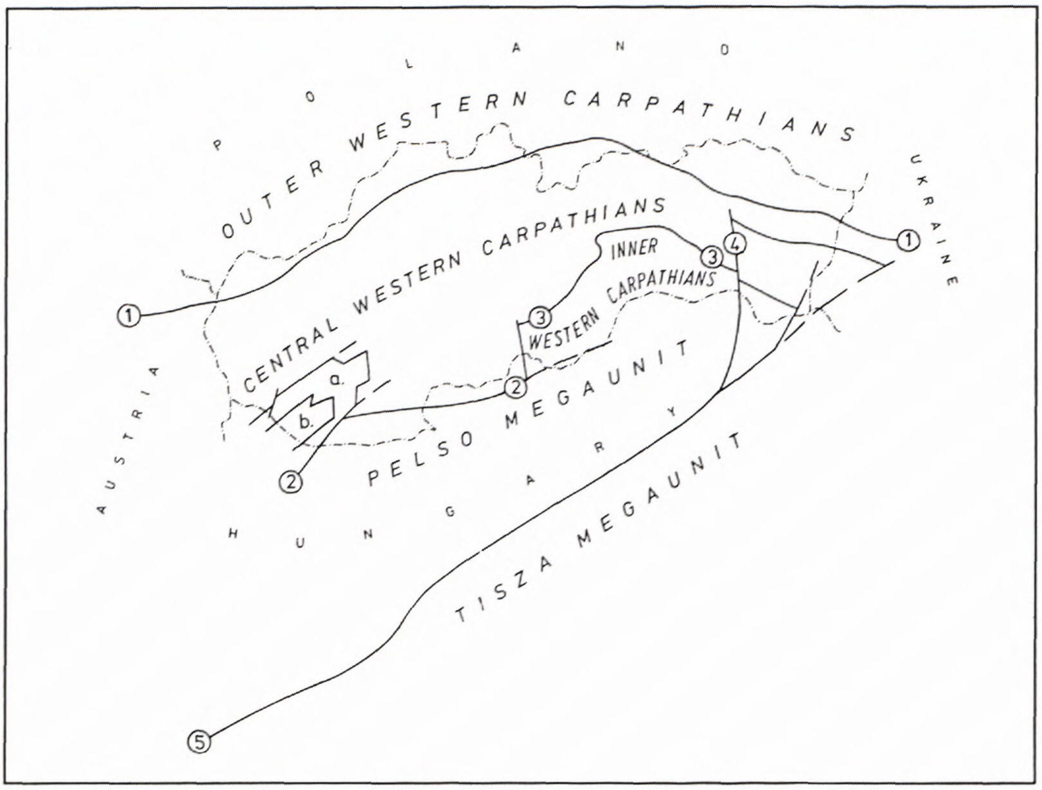

Fig. 1 Distribution of the main tectonic units of the West Carpathian - North Pannonian Domain
Legend: a) Upper Austroalpine Paleozoic, b) Southern Penninicum; 1 - Klippen Belt Lineament, 2 - Rába - Hurbanovo - Diosjenő fault zone, 3 - Lubeník - Margecany line, 4 - Hornád fault system, 5 - Mid-Hungarian Lineament

stacking within the Outer West Carpathians; origin of foreland Central Carpathian Paleogene flysch basin; gradual east-ward closing of Carpathian subduction zone; meanwhile, shearing and extensional tectonics predominated in the Central Inner and West Carpathians.

6. Miocene to Pliocene evolutionary stage represents a concluding phase of the oblique collision with the North European plate in the eastern part of the Outer West Carpathians. At the same time, the transtensional/transpressional tectonic regimes predominated in the western part of the orogeny, but mainly in the Central and Inner West Carpathians.

The above characterization of the West Carpathian - Pannonian Domain has been mainly based on the knowledge of the Pre-Alpine and Paleo-Alpine structural levels.

WC/1. PIENINY TERRANE

This terrane comprises a very complicated system of Alpine N-vergent nappes, which reflect in the gradual intra-Cretaceous subduction and multistage collision events during the Cenozoic. The Pieniny Terrane is composed of:

1. Klippen Belt, which forms a complex of tectonic lenses of Jurassic - Lower Cretaceous, mostly pelagic radiolarites and carbonates, embedded in more plastic Upper Cretaceous - Lower Paleocene marly and flysch complexes.

2. Flysch Zone related to intra-Paleogene and Middle Miocene collision events.

TERRANE BOUNDARIES

The Pieniny Terrane is restricted by the Peri-Pieniny lineament in the south, separating it from the Tatro-Veporic Terrane. The northern boundary is formed by an overthrust plane of the Subsilesian Unit, which is thrust over the Carpathian Foredeep.

OVERSTEP SEQUENCES

1) Post-Alpine overstep sequences:

The post-nappe Gosau sediments were deposited in a perisutural compressional basin at the active northern Central West Carpathians margin (WAGREICH & MARSCHALKO, 1994). The Late Tertiary molassic sediments of the Carpathian Foredeep overstepped or the passive margin of the

North European Plate. Post-Savian sediments rest unconformable on different tectonic units of the Vienna Basin basement. The Vienna Basin basement is composed of the units of Pieniny terrane as well as main paleo-Alpine tectonic units of Tatro-Veporic terrane. Filling of the Vienna basin is variable (fresh water, brackish, marine) with maximum subsidence in the Karpatian-Badenian (VASS, 1982). Remnants of small intramontane depressions (Orava - Nový Targ Basin; Nowy Sacz Basin) overlapped either former suture-lineament (ONT B.) or Flysch Zone (Ns B.)

A. Variscan History

Present evidence of the existence of this basement are only pebbles in conglomerates of Upper Cretaceous and Paleogene flysch sequences (ANDRUSOV 1958, HAVLENA 1956, MIŠÍK & MARSCHALKO 1988, etc.). There were found pebbles of Permian red-bed sandstones and siltstones as well as fragments of Namurian A coal black shales and greywackes. Post-orogenic A-type trending magmatic suite of the Lower Permian age was determined from granitic pebbles (U/Pb zircon ages; UHER & PUSHKAREV 1994) of the Pieniny Klippen Belt.

Paragneisses of the Lower Paleozoic, lydites with Vendian spores (TIMOFEEV in KAMENICKÝ & KRÁL 1979) as well as Devonian and Visean limestones (MALÍK 1982) were described from the Cretaceous flysch conglomerates of the Pieniny Klippen Belt and external part of Flysch Belt.

In spite of the rare evidence about the nature of the Variscan and/or stage, the pebble compositions proved the Variscan eventually Pre-Variscan Eurasian provenance of the pre-Triassic pebble material (extra-alpidic crystalline basement).

B. Alpine History

Flysch Zone

Stratigraphy

The sedimentary area of the Flysch Zone was divided into several deep-water throughs, separated each other by submerged ridges. The deep-water, flysch sedimentary environment lasted from the Cretaceous to Eocene - Oligocene in the inner part of the Flysch Zone and from the Eocene to Lower Miocene in the outermost part. The only exception is the Magura group of nappes, in front of which there are also the Jurassic klippen. They are perhaps olistoliths and may represent elements of the Silesian cordillera rather than its primary basement (BIELY 1989).

The Flysch Zone forms the Tertiary accretionary wedge of the Carpathian orogeny, generally ranged into two groups: a) Silesian - Krosno (Moldavian) nappes in the north part; b) Magura group of nappes in the south (linked to the Rheno-Danubian flysch). Several thousand metres thick, mostly siliciclastic flysch sequences were detached from a strongly attenuated continental crust, according to some authors partly truly oceanic (BIRKENMAJER 1988, MAHEĽ 1989, OSZCZYPKO 1992), produced by Jurassic-Tertiary rifting.

Klippen Belt

Stratigraphy

The Klippen Belt represents a composite unit of strongly folded Jurassic and Cretaceous sedimentary series, which were supposedly underlain by continental crust to the north and probably by oceanic crust to the south.

It is assumed that the area of sedimentation of the Klippen Belt was formerly located on the southern margin of the labile North European shelf (RAKÚS et al. 1990). Evidence in favour of this assumption is only clastic detritus in younger sediments (ANDRUSOV 1958). In the Jurassic, extensional listric faults broke up this shelf into a horst (Czorstyn Zone) and a through (Kysuce - Pieniny Zone),related to oceanisation (BIRKENMAJER 1984), with maximum spreading in the Callovian. The opening of the oceanic domain (Vahicum after MAHEĽ 1981; Penninic ocean after RAKÚS et al. 1990) occurred along the Northern transform zone (RAKÚS et al. 1990) and was located between the Czorstyn Ridge to the north and Tatric-Carpathian (Apulian promotory) margin. Intra-Cretaceous S-directed subduction of this oceanic lithosphere gave rise to the ophiolite-bearing marginal thrust belt (MIŠÍK & MARSCHALKO 1988, BIRKENMAJER 1988). The origin of collision melange related to the Pieniny Exotic Ridge (ANDRUSOV 1958, MIŠÍK 1978 and many others) is supported by evidence within the Albian - Maastrichtian flysch conglomerates. The collision events were accompanied by high-pressure metamorphism (glaucophane-lawsonite facies) as well as Late Jurassic - Early Cretaceous island-arc volcanism and syn-collisional magmatism (evidence in exotic pebble materials and heavy minerals spectrum; MIŠÍK & SÝKORA 1981, ŠÍMOVÁ 1985, MARSCHALKO 1986, MIŠÍK & MARSCHALKO 1988, WINKLER & SLACZKA 1992, 1994).

Deformational and metamorphic events

The deformation of the Klippen Belt was multistage and very complicated. First of all, there is evidence of Early Cretaceous subduction related to closure of the Penninic Ocean. High-pressure metamorphism is inferred from pebbles of blueschist metabasalts (K/Ar 138-140 Ma; RYBÁR & KANTOR ex. MARSCHALKO 1986). From this time probably until the Paleocene, the inferred oceanic crust of the Penninic-Vahic domain was subduced southward below the North Tatric margin (MIŠÍK & MARSCHALKO 1986, BIRKENMAJER 1988, PLAŠIENKA 1995). Further deformations were connected with north-vergent Laramide nappe movements and Paleogene phases of folding and large transform movements, simultaneously with gradual closing of the Flysch Zone basins. Depocenters of residual flysch basins were shifted towards the platform foreland passing gradually into foredeep molasse sedimentation during the Neogene. The gradual eastward migration of Outer Carpathian subduction finally led to sinistral transtension and pull-apart opening of the Vienna basin.

Plutonic igneous intrusions

Evidence for syncollisional magmatic activity is provided only by clastic material derived from the Pieniny Exotic Ridge, which was found in the Klape, Kysuca - Pieniny and Manín Units. K/Ar radiometric data from granitoid pebbles proved Jurassic to Cretaceous age (K-Ar 140-90 Ma; KANTOR & RYBÁR 1978 ex MARSCHALKO 1986). This evidence is at variance with the new U-Pb zircon ages, which proved the Lower Permian A-type granitic suite from three occurrences of "exotic" pebbles of the Pieniny Klippen Belt. Barremian alkaline volcanism of the Flysch Zone producing a teschenite-picrite association is related to within-plate rifting processes (HOVORKA & SPIŠIAK 1989).

Time of docking

Time of docking of the Tatra-Veporic Terrane with the Penninic Ocean and with the southern margin of the North-European plate is indicated by termination of closing individual zones of the Klippen Belt sedimentation, gradually during the Late Cretaceous to Lower Paleocene.

WC/2. TATRO-VEPORIC TERRANE

The Tatro-Veporic Terrane contains pre-Gosau nappe units with distinct similarities in their lithostratigraphic and tectonometamorphic development during Variscan as well as Alpine orogenic events. Terranes of different geotectonic settings accreted du-ring the Paleozoic time to form a consolidated crust by the end of the Variscan orogenic cycle. Due to incomplete record, their definition must be considered preliminary. In the present tecto-nic pattern they are incorporated into the main Paleo-Alpine tec-tonic units of the Central Western Carpathians - Tatricum, North Veporicum/Fatricum (in the sense of PLAŠIENKA (1995), into the Fatric paleogeographic realm are placed also the Klape, Manín and related units), South Veporicum, Zemplinicum, as well as within rootless nappes - Hronicum. They contain the following structural levels:

1. Variscan Terranes.
2. Carboniferous-Permian overstep sequences.
3. Epiplatform Triassic formations prograding into extension-related setting in the Jurassic-Lower Cretaceuos.
4. Post-Alpine overstep sequences.

TERRANE BOUNDARIES

The Tatro-Veporic Terrane is separated by the Alpine thrust plane from the overlying North Gemeric Terrane. The northern boundary reaches the peri-Pieninic Lineament, which roughly borders the subvertical Klippen Belt. The Variscan nappe pile has been inverted during the Alpine orogeny.

OVERSTEP SEQUENCES

1. Post-Variscan overstep sequences:

The post-Variscan overstep sequences are generally volcano-terrigenous and continental. They cover their basement rocks with distinct stratigraphic unconformity. They are also separated from the overlying Lower Triassic formations by a stratigraphic hiatus and disconformity. Transpressional sedimentary basins (graben, pull apart basin) originated gradually in time and space, reflec-ting the process of post-suturing uplift and extension of an overthickened crust.

The Permian post-Variscan overstep sediments of the Tatra Terrane are continental (fluvial, lacustrine, alluvial fan, braided river, playas), with a dominant part of clastic detritus, reflecting provenance from an uplifted crystalline basement (VOZÁROVÁ & VOZÁR 1988, VOZÁROVÁ 1990).

Limno-fluvial coal-bearing cyclothemes dated as Lower Stephanian (NĚMEJC in BOUČEK & PŘIBYL 1959; SITÁR in PLANDEROVÁ et al. 1981) are a characteristic lithological member of the Byšta Susp. T. post-Variscan sequence. Intense synsedimentary tectonics was associated with calc-alkaline rhyolite-dacite volcanism.

The Upper Carboniferous-Permian overstep sequence of the Kohút Terrane is generally regressive, prograding from shallow-water (intracontinental lake or

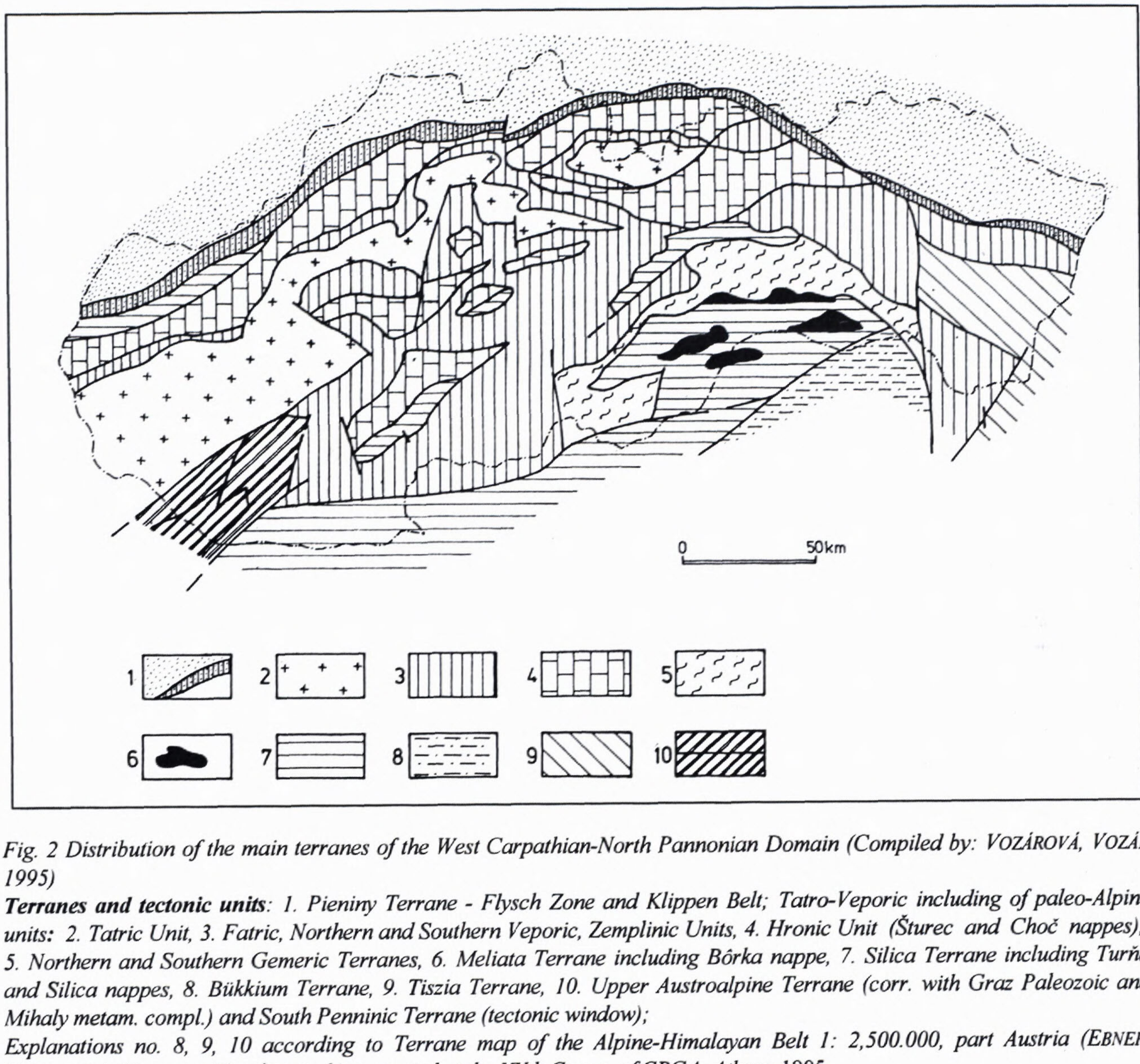

Fig. 2 Distribution of the main terranes of the West Carpathian-North Pannonian Domain (Compiled by: VOZÁROVÁ, VOZÁR 1995)

***Terranes and tectonic units**: 1. Pieniny Terrane - Flysch Zone and Klippen Belt; Tatro-Veporic including of paleo-Alpine units: 2. Tatric Unit, 3. Fatric, Northern and Southern Veporic, Zemplinic Units, 4. Hronic Unit (Šturec and Choč nappes), 5. Northern and Southern Gemeric Terranes, 6. Meliata Terrane including Bôrka nappe, 7. Silica Terrane including Turňa and Silica nappes, 8. Bükkium Terrane, 9. Tiszia Terrane, 10. Upper Austroalpine Terrane (corr. with Graz Paleozoic and Mihaly metam. compl.) and South Penninic Terrane (tectonic window);*

Explanations no. 8, 9, 10 according to Terrane map of the Alpine-Himalayan Belt 1: 2,500.000, part Austria (EBNER, NEUBAUER), Hungary (KOVÁCS et al.) presented at the XVth Congr. of CBGA, Athens 1995

paralic basin) to alluvial environment. Synsedimentary tectonic activity is reflected in large regressive cycles. Clastic detritus was derived from a cut magmatic arc. Palynological data proved Stephanian C-D to Lower Permian age (PLANDEROVÁ & VOZÁROVÁ 1982).

The Hronic Unit comprises an Upper Carboniferous - Permian thick continental clastic sequence (derived from the Ipoltica Susp. Terrane) with characteristic lava flows of continental tholeiitic basalts developed in rifting - related setting.

2. Post-Alpine overstep sequences:

The rare occurrences of Senonian sediments are evidently post-tectonic (mostly preserved in the western part of the area). They started as continental, lacustrine deposits and in a short time passed into marine environment. More widespread is the Lutetian transgression in the Central Carpathian Basin. The emergent Central Carpathian zones, with Variscan terranes and their overstep sequences as well as Mesozoic cover, were the source of clastic filling for this basin.

The last stage of post-Alpine overstep events was the sedi-mentation in Tertiary inter- and intramontane basins, evoked by disintegration of the back arc area within the newly formed Carpathian arc into partial blocks. The process was associated with a turn from dextral to sinistral transpression during the Lower Miocene, and was accompanied by antiklockwise

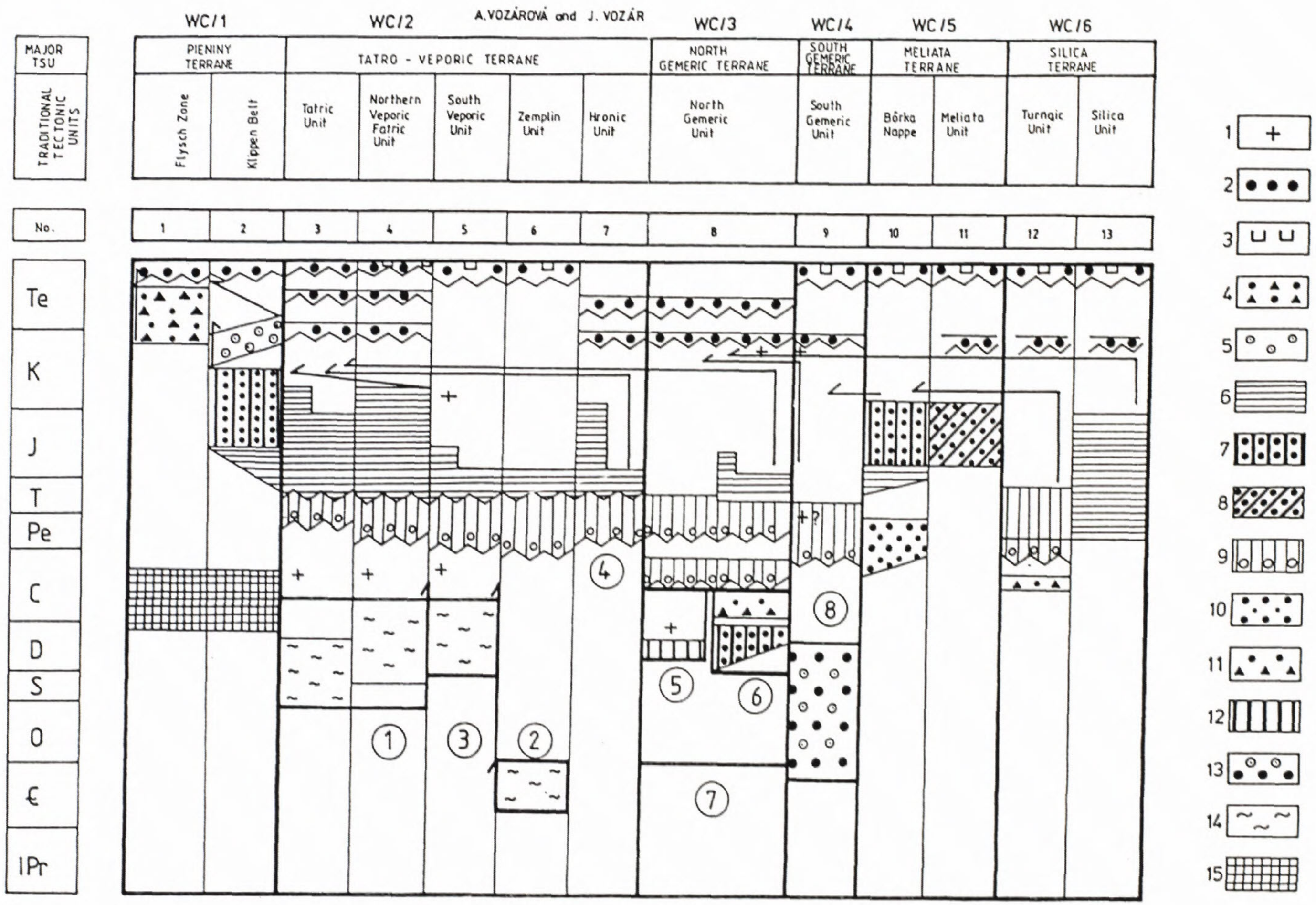

Fig. 3 West Carpathian - North Pannonian Domain

1 - Late, post-orogenic plutons S and I-S type, 2 - Post-Alpine overstep sequences, 3- Tertiary volcanics of Western Carpathian arc and back-arc area, 4 - Orogenic Flysch Belt formations, 5 - Deep-water and flysch-olistostroma Klippen Belt formations, 6 - Shalow-water and basinal facies related to Triassic/Jurassic extension regime, 7 - Complexes containing subduction related HP/LT metamorphics with to affinity oceanic crust, 8 - Subduction complexes (melanges, olistostroma), 9 - Late Variscan overstep sequences with passive continental margin formations in overlier, 10 - Rift-related sequences, 11 - Variscan flysch orogenic sequences, 12 - Lower crust island arc complexes with enclaves of subducted oceanic crust, 13 - Volcanogenic flysch with for-arc related setting, 14 - High grade metamorphic crust, two or more geodynamic settings (non differenciated), 15 - Extra-alpidic massifs of unknown geodynamic setting

Number for the Variscan Terranes - see text: *1. Tatra Terrane; 2. Byšta Suspected Terrane; 3. Kohút Terrane; 4. Ipoltica Suspected Terrane; 5. Klátov Terrane; 6. Rakovec Terrane; 7. Spiš Composite Terrane; 8. Gelnica Terrane.*

rotation of rigid basement blocks. Compression from the NE-SW to the NNW-SSE controlled sedimentation in the area of the Hornonitrianska kotlina Depression (HÓK at al. 1995) during the Late Pannonian to Quaternary. The transtensional tectonic activity culminated during the Badenian and Sarmatian, having been accompanied by intense andesite and rhyolite volcanism (NEMČOK & LEXA 1991). The Pliocene to Quaternary period is characterised by extensional overall uplift, with minor volcanic activity of alkali basalts. The origin of the Neogene basins was connected with two structural stages. The older (Early Miocene) originated as a part of a marine back arc basin, formed to the south of the Klippen Belt (connection with eastward migration of subduction of the Carpathians). During the Middle Miocene a mantle diapir caused heating and rifting of continental crust (Central Slovakia; Danube Lowland).

A. Variscan Terranes

Tatra Terrane (1)

Stratigraphy

The Tatra Terrane consists of medium- to high-grade paragneisses interlayered with calc-alkaline to tholeiitic basic and acid orthogneisses and migmatites (KORIKOVSKIJ et al. 1987 a,b; SPIŠIAK - PITOŇÁK 1990; JANÁK 1991; JANÁK et al. 1988; etc.) as well as of low-grade complexes (CAMBEL 1954; MIKO 1981; BAJANÍK et al. 1979; PUTIŠ 1983). Banded amphibolites are very specific. Sometimes they are associated with metaultrabasites. The latter are characterised by a primitive REE distribution and show some affinity either to the initial island-arc stage or to crustal fragments of oceanic affinity (SPIŠIAK - PITOŇÁK 1991). Relics of older HT/HP eclogite as well as granulite facies rocks were pointed out by HOVORKA - MÉRES (1989, 1990), VOZÁROVÁ (1993a).

Some low-pressure greenschist complexes (Jánov Grúň Complex and Predná Hoľa Complex: MIKO 1981, BAJANÍK et al. 1979) are in tectonic contact with the ,mentioned higher metamorphic complexes, reflecting thrusting during Late Variscan collision (this tectonic contact is fixed by the Permian overstep sequences). Both low-grade complexes comprise acid and basic volcanics and their volcanoclastics. This bimodal volcanic suite as well as the im-mature character of the clastics sediments (with grains of quartz, feldspars, clastic micas) support a possible continental intraplate (?) rifting origin of this sequences.

According to biostratigraphic data the low-grade metamorphosed complexes are mostly Silurian - Devonian and Middle - Upper Devonian in age (CAMBEL - ČORNÁ 1974, KLINEC et al. 1975, BAJANÍK et al. 1979, PLANDEROVÁ 1983, 1986). They represent sequences deposited most probably on a continental crust or on a transitional crust of an extension-related back-arc.

Byšta Suspected Terrane (2)

The crystalline rock complexes (Byšta Formation according to VOZÁROVÁ 1991) are correlated to the Tatra Terrane. Prevailing rocks are paragneisses, amphibolites and migmatites. Mineral assemblages indicate PT conditions of upper amphibolite facies (T = 650-680 °C, P = 4-5 kbar, VOZÁROVÁ 1991; 600-650 °C, 5,5-6,5 kbar, FARYAD 1995) associated with anatectic reworking of a part of the gneiss substrate. Data from boreholes realised on the territory of Hungary pointed to the presence of low-grade metamorphic rocks, the mutual relations of which were interpreted by PANTO (1965) as a tectonic - Late Variscan south-vergent thrust of higher-grade crystalline rocks on low-grade metamorphites. This opinion was confirmed by pebble material in Late Variscan conglomerates (VOZÁROVÁ & VOZÁR 1988) and by the fact that Carboniferous sequences cover both above mentioned complexes. Rb/Sr muscovite data from gneisses give 962-984 Ma (PANTO et al. 1967). These data require confirmation and are not sufficient for assuming Late Proterozoic age of metamorphism. Later overprint is suggested by K/Ar amphibole age - 307 Ma (LELKES-FELVÁRI & SASSI 1981).

Kohút Terrane (3)

Characteristic features of the KOHÚT Terrane are:

a) relics of a Lower Paleozoic/?Proterozoic basement, represented by acid- and basic gneisses of amphibolite facies and hybrid granitoids. These rocks are migmatitized and strongly diaphtorized (BEZÁK 1991);

b) Lower Paleozoic metamorphic complexes of upper green-schist/amphibolite facies whose mutual contacts are tectonic, while the main differences are in lithology;

c) a low-grade metamorphic complex containing magnesites, probably of ?Lower Carboniferous age;

d) distinct Alpine high-pressure reworking (VRÁNA 1964, MAZZOLI et al. 1992, MÉRES & HOVORKA 1992), which was associated with Alpine reheating connected with mildly alkaline granitoid intrusions and regional contact metamorphism (VOZÁROVÁ & KRIŠTÍN 1985, KORIKOVSKIJ et al. 1986, VOZÁROVÁ 1990a).

Protolith of some mica schists shows high-maturity and continental crust provenance (KOVÁČik 1991, KORIKOVSKIJ et al. 1989, MÉRES & HOVORKA

1991). Bulk chemical composition and trace elements as well as REE patterns of orthogneisses indicate magmatic arc provenance (HOVORKA et al. 1987).

Ipoltica Suspected Terrane (4)

The existence of this terrane is suggested only by circum-stantial evidence, as for example the composition of Upper Car-boniferous - Permian overstep sediments, which were involved in the Hronic nappes. Due to Alpine nappe transport only slivers of strongly deformed granitoids were appear in the basal part of the Šturec Nappe. They were described as "segments a of squeezed out basement" (ANDRUSOV 1936; VOZÁROVÁ - VOZÁR 1979).

The mineral composition of sandstones as well as the kind of pebbles in the overstep sequences indicate their provenance in a continental magmatic arc with typical volcano-plutonic petrofacies (VOZÁROVÁ 1990). This continental magmatic arc was completely destroyed during the Alpine orogeny. It should be mentioned that the Ipoltica Suspected Terrane was probably of Variscan age.

Deformational and metamorphic events

Multistage development of deformational and metamorphic events has been recorded within crystalline complexes of the Tatra Terrane. Possible pre-Variscan or Early Variscan as well as Variscan metámorphism have been suggested (BEZÁK et al. 1992).

The earliest events were connected with granulite/eclogite facies metamorphism (700-750°C and 10-14 kbar, JANÁK et al. 1995; 675-770°C and 6-10 kbar, VOZÁROVÁ 1993), followed by amphibolite facies metamorphism. Further retrograde processes were connected with Late Variscan and Alpine shear metamorphism. Values between 380-301 Ma have been determined from paragneisses by means of Rb/Sr whole-rock and muscovite isochrons (BAGDASARYAN et al. 1983, BURCHART 1968). K/Ar hornblende ages of 554 and 882 Ma were obtained from gabbroamphibolites. U/Pb zircon ages from para-gneisses proved 581-551 Ma (CAMBEL et al. 1977).

Deformation and metamorphism (in the range of T= 500-560°C or 400-500°C at P=4-5 kbar) of the Lower Paleozoic complexes are connected with termination of Variscan orogeny. The youngest sediments are probably Lower Carboniferous in age and radiometric data (Rb/Sr whole rock age 319±5 Ma, CAMBEL et al. 1979) confirm syn- and late collision events.

Plutonic igneous rocks

There are a great volume of granitoid rocks of Devonian/Carboniferous age. Geochronological data are grouped on a time level: Rb/Sr isochron: 393 and/or 300 Ma; U/Pb zircon: 350 and 300 Ma; (CAMBEL et al. 1990). Magma differentiation ranged from leucocratic granite and granodiorite to tonalite. Several petrological criteria have been recently suggested for granitoid dis-crimination (BROSKA & GREGOR 1992, PETRÍK & BROSKA 1989, 1992, HOVORKA & PETRÍK 1992, KOHÚT 1992). Two petrological families could be thus distinguished: the first older (S-type) associated with metamorphism and anatexis, and the second younger initiated by rising of hot mafic magmas of mantle origin (I-type or mixed I-S type). Some indications of Permian magmatic activity point to WPG type (HOVORKA & PETRÍK 1992). Intrusion into the shear zone generated during Variscan collision-transpression is the most likely model for magma emplacement, as applied by KOHÚT & JANÁK (1995) for the Tatra granitoid pluton.

Time of docking

Time of docking of the KOHÚT and Ipoltica Terranes with the Tatra Terrane is indicated by the age of granitoid intrusions, which are considered to have formed as an immediate consequence of the docking event. It occurred probably during the Early Carboniferous.

B. Alpine History

The Late Variscan newly formed crust (Tatra Composite Terrane in the sense of VOZÁROVÁ & VOZÁR 1992) became an epiplatform area (together with the Austroalpine realm), with shallow-water sedimentation throughout the Triassic. Only exception is a differentiated type of the Upper Triassic in the Hronic Unit (a dolomite vs. Lunz facies). This area was gradually differentiated starting in the Middle Triassic and continuing mainly during Middle to Late Jurassic times, as a result of listric fault activity and active extension (RAKÚS et al. 1990). Sporadic occurrences of alkali basalt sills and lava flows within the Tatric and Krížna Nappe Mesozoic sequences proved an extensional, within-plate setting (HOVORKA et al. 1982). During the Upper Jurassic/Lower Cretaceous, abyssal environment prevailed, with some narrow zones of shallow-water sedimentation. Several sedimentary basins were created, later Fatric (Krížna) and to the north the Klape and Manín sedimentary areas.

Deformational and metamorphic events

The closing of the sedimentary basins and the connected overthrusting of Central Western Carpathian Nappes came to an end before the Late Turonian. The northward migration of orogenic contraction during the Cretaceous is revealed by the start and termination of orogenic flysch sedimentation: in the Hronic Valanginian-Hauterivian, in the Fatric Lower Albian - Lower Cenomanian, in the Tatric Middle to Late Albian - Lower Turonian, in the Klape Middle Albian - Middle Cenomanian. A distinct northvergent imbricate structure inside the mentioned units is characteristic as well as large synmetamorphic recumbent folds accompanied by ductile deformation. As concerns Alpine metamorphism, anchizone conditions have been recorded in Tatric as well as Zemplinic sequences (T = 210-270 °C; MILIČKA et al. 1991) and a transitional to epizone in North Veporic units (300-350 °C by means of illite crystallinity, PLAŠIENKA et al. 1989). These epizone conditions were accompanied by increasing intensity of strain and synmetamorphic ductile deformation. Rock complexes in front of nappes are nearly non-deformed.

The Mesozoic rock complexes of the South Veporic Unit under-went a relatively high grade of Alpine metamorphism, reaching conditions of medium/high pressure greenschist facies - determined by means of Ctd+Ky mineral compatibilities (VRÁNA 1964) and b_0 values of K-mica (MAZZOLI et al. 1992). The sediments were strongly ductile-deformed, contemporaneously with metamorphism and the first deformational stage - Eo-Alpine compression and an upthrust from SE to NW (MADARAS et al. 1995). Subsequent extension was connected with Cretaceous uplift (Ar/Ar muscovites data from blastomylonites give 84-94 Ma, MALUSKY et al. 1993). FT ages of apatites (89±10 and 53±7 Ma, KRÁL 1982) document multistage uplift and extension regime.

The emplacement of the Hronic nappes took place at near-sur-face level. The overthrust was accompanied only by brittle defor-mations. PT conditions of burial metamorphism correspond to dia-genesis (T in range of 100-150°C based on IC average values, ŠUCHA & EBERL 1992) in the greater part of the sequence. The pum-pellyite-prehnit assemblage proved anchizone conditions described near local shear zones (T around 200 °C, VRÁNA & VOZÁR 1969).

Plutonic igneous activity

Alpine heating is documented by regional contact metamorphism (VOZÁROVÁ & Krištín 1985; KORIKOVSKIJ et al.1986; VOZÁROVÁ 1990) only in the South Veporic Unit. K/Ar and Ar/Ar biotite ages from crystalline schists as well as Late Variscan metasediments give a range from 140 to 85 Ma (KANTOR 1960; KRÁL et al. 1995). Geochemical characteristics show affinity to calc-alcaline and alkaline, from normal to fractionated I/S type (HRAŠKO et al. 1995). Intrusion post-dated the Alpine regional metamorphism (VOZÁROVÁ 1990), connected with movement along shear zones in extensional regime.

Time of docking

The Lower-Middle Cretaceous time of docking the Tatro-Veporic and North Gemeric Terranes is indicated by the age of the youngest sediments within the rootless Hronic Unit as well as the Senonian overstep sequence.

WC/3. NORTH-GEMERIC TERRANE

The North-Gemeric Terrane is composed of:

1. Variscan Klatov and Rakovec Terranes which are inferred to have been amalgamated in the Upper Devonian/Carboniferous to form the Spiš Composite Terrane.
2. Upper Carboniferous-Permian shallow marine to continental overstep sequences.
3. Stable continental shelf-related Alpine sequences, with manifestation of rifting in the Upper Triassic-Jurassic.
4. Post-Alpine overstep sequences.

TERRANE BOUNDARIES

The North-Gemeric Terrane is restricted by Alpine thrusts in the hanging-, as well as in the footwall. Locally the northern boundaries are covered by post-Alpine overstep sequences. The Klátov Terrane is bounded by pre-Alpine thrust against the Rakovec Terrane.

OVERSTEP SEQUENCES

1. Post-Variscan overstep sequences:

The Upper Carboniferous sequences related to collision setting started in the Westphalian A by delta-fan, coarse-grained sediments, containing fragments of metamorphosed rocks from the Rakovec and Klatov Terranes. After initial rapid sedimentation the marine peripheral basin was deepened and fine-grained metasediments were associated with high-K tholeiitic basalts and their volcanoclastics. The final stage is documented by the subsequent paralic environment and interruption of sedimentation during the Stephanian.

Continental Permian sequences overstepped a slightly deformed filling of the Westphalian peripheral basin as well as the Rakovec and Klátov Terrane complexes. Coarse-clastic sediments derived from the collision belt are associated with bimodal basalt-rhyolite volcanism. The development of this basin was connected with the post-Variscan transpression stage.

2. Post-Alpine overstep sequences

There are preserved only as small relics of Upper Cretaceous coarse-grained marine sediments. More distinct are the Upper Paleocene-Eocene to Lower Oligocene clastic sediments which partly cover the northern Alpine thrust boundaries of the North-Gemeric Terrane.

1. Variscan Terranes

Klátov Terrane (5)

Stratigraphy

The Klátov T. represents a complex of amphibolite facies rocks of oceanic crust affinity, pre-Westphalian in age, as they were reworked within the Westphalian conglomerates (ROZLOŽNÍK 1965; VOZÁROVÁ 1973).

Radiometric data support the Variscan age of metamorphism (380-280 Ma, K/Ar: CAMBEL et al. 1980; 320-281 Ma, K/Ar: KANTOR et al. 1981). In addition, some data from amphibolites yielded 391-448 Ma (K/Ar: KANTOR 1980). Due to this wide variability of data, specific radiometric research should be attempted in order to ascertain the more precise age of the metamorphism.

The Klátov T. consists mostly of amphibolites accompanied by serpentinized spinel peridotites (only antigorite serpentinites and their hydrothermal - metasomatic derivates have been found), gneisses, rare marbles and Ca-silicate rocks (SPIŠIAK et al. 1985). The Klátov T. was penetrated by veins of plagiaplites. Fragments of these rocks are often found in Westphalian conglo-merates together with pebbles of tonalite and trondhjemite magmatites (VOZÁROVÁ 1973).

Ultramafic rocks and metabasalts of the Klátov T. are con-sidered to be a part of a dismembered ophiolite suite (HOVORKA & IVAN, 1985). Amphibolites are geochemically close to N-MORB basalts (IVAN 1992). The Klátov T. rock complexes represent an ancient subducted oceanic crust with fragments of lower crust of an island arc (VOZÁROVÁ 1993b; IVAN 1994). The finds of regressive overprinted eclogitic rocks (HOVORKA et al. 1994) allow to assume a previous high-pressure event.

Deformational and metamorphic events

The rocks complexes of the Klátov T. underwent metamorphism under higher-temperature amphibolite facies (T= 520-630 C , P= 4-6 MPa) and part of them even eclogite facies conditions, and subsequently, greenschist-facies retrograde alterations. The prograde as well as retrograde metamorphic stages are pre-Westphalian because both kinds of metamorphic mineral assemblages were determined in gneiss and amphibolites pebbles of the Westphalian conglomerates (VOZÁROVÁ 1993b).

The whole gneiss-amphibolite complex is overprinted by Alpine deformation and shear metamorphism reaching max. greenschist facies along the Alpine thrust and shear zone.

Plutonic igneous intrusions

Evidence of the presence of tholeiitic-series magmatites.

Rakovec Terrane (6)

Stratigraphy

The Rakovec T. consists of rock sequences of the Rakovec and Črmeľ Groups. The Rakovec Group is composed mainly of basic metavolcanoclastics, accompanied by tholeiitic basalts and small amounts of intermediary and acid volcanics. The bulk composition and REE contents of the Rakovec Group metabasalts suggest primary island arc tholeiites (BAJANÍK 1981) or E-MORB/OIT basalts (IVAN et al. 1992). Only small amounts of metapelites, fine-grained metasandstones and lenticular interlayers of carbonatic rocks or cherts occur here. The predominant tholeiitic metabasalts and metavolcanoclastics suggest for the Rakovec Gr. an ensimatic island arc setting, having originated probably on back-arc oceanic crust. The Rakovec Group is biostratigraphically undated. The pre-Westphalian age of the protoliths as well as of metamorphism is documented by the occurrence of pebbles in Westphalian conglomerates (VOZÁROVÁ 1973).

The Črmeľ Group was described as a sequence of alternating pelites, sandstones, basic volcanics and volcanoclastics, subsidiary acid volcanolastics, carbonates and lydites metamorphosed under low-grade conditions. The sequence has distinct sedimentary features of distal flysch. The Upper Tournaisian-Visean age is indicated by microflora (BAJANÍK et al. 1986). The predominant tholeiite, low-K metabasalts and the flysch-type sediments re-present probably the filling of a remnant basin (relics of marginal basin with ocean floor), which formed in the first stage of collision.

Deformational and metamorphic events

With regard to petrological data we may assume two Late Variscan metamorphic events: i) first, to the blueschist-facies transitional metamorphism (linked to subduction processes), which is documented by relics of Na-Ca amphiboles (HOVORKA et al. 1988) amidst actinolite crystals in metabasalts of the Rakovec Gr.; ii) second, corresponding to low-pressure greenschist facies conditions. It was estimated from analytical results based on b_0 geobarometry on K-white micas, which indicated a narrow thermal ran-ge of 350-370 °C at a relatively high metamorphic thermal gra-dient of approx. 40-45 °C/Km (SASSI & VOZÁROVÁ 1987, SASSI, R. & VOZÁROVÁ 1992).

Plutonic igneous intrusions

The Rakovec Terrane is pierced by small bodies of gabbrodiorite, gabbros and doleritic dykes, related to back-arc ophiolitic crust.

Time of docking

The docking of the Rakovec and the Klátov Terranes was pre-Carboniferous, connected probably to the Bretonian events as it is supported by the origin of the intrasuture Črmeľ flysch basin.

Spiš Composite Terrane (7)

The Klátov T. and Rakovec T. are inferred to have been amalgamated prior the Lower-Carboniferous (Bretonian events).

The Lower Carboniferous Ochtiná tectonostratigraphic unit was formerly described as an independent terrane (VOZÁROVÁ & VOZÁR 1992), due to its only tectonic contact to the hanging- and footwall. Coexistence with the Spiš Composite Terrane is documen-ted by affinity of the Ochtiná clastic material to the rock complexes of the Rakovec and Klátov Terranes.

The lower part of the Ochtiná tectonostratigraphic unit consists of flysch-like clastic sediments - metaconglomerates, metasandstones, metapelites, interlayered with basaltic metavolcanics and metavolcanoclastics. Deep-sea fans were derived from converging plate margins (intrasuture embayment) of a huge mass of detritus, among them pieces of oceanic and island arc crust. Slabs of ultramafic rocks indicated by antigorite serpentinites as well as granitoid detritus have been reported. The mechanism of their emplacement is connected with gravitational, mass flow sedimentary processes. The Tournaisian-Visean age of this part of the Ochtiná unit has been proved by microflora (BAJANÍK & PLANDEROVÁ 1985). The flysch sedimentation was gradually replaced by shallow-water, pelitic-carbonate facies of Upper Visean-Serpukhovian age (conodonts; KOZUR & MOCK & MOSTLER 1976).

Deformational and metamorphic events

The Lower Carboniferous sequences was deformed in the pre-Westphalian. The collision and crustal thickening processes gave rise to progressive regional low-pressure metamorphism of the Lower Carboniferous complexes but, on the other hand, the Rakovec sequences were mostly completely reworked under low-pressure conditions.

Time of docking

The docking of the Spiš Composite Terrane was the pre-Westphalian. During the continuing collision event the Lower Carbo-niferous flysch basins were closed. The initial stage of the perisutural basin began in the Westphalian A with coarse-clastic deposits of delta-fan type, associated in space with shallow-marine littoral and neritic environments. They cover the meta-morphosed complexes of the Spiš Composite Terrane with distinct unconformity. Termination of the existence of this basin, accompanied by its partial destruction, occurred during the Stephanian. The post-collision Permian sequences were adjusted by transform strike-slip movement and/or renewed rifting. They overlapped even weakly deformed and anchimetamorphosed sedimentary filling of the Westphalian peripheral basin.

2. Alpine History

During the Alpine cycle the Variscan Spiš Composite Terrane and its post-Variscan overstep sequences became a part of the passive continental margin. Direct provincial affinity to the North Gemeric Variscan basement seem to have, besides their overstep sequence, only the Lower Triassic evaporitic and shallow-marine clastic to carbonate formations. The Middle Triassic to Lower Jurassic (Stratená and Galmus Gr.), shallow-water sediments of epiplatform type are rather in tectonic position (part of the rootless Silica Nappe). However, it is more probable that this sequence is primary Mesozoic cover above the Spiš composite Terrane.

WC/4. SOUTH-GEMERIC TERRANE

The South-Gemeric Terrane contains the following structural levels:

1. Variscan Gelnica Terrane volcanogenic flysch sequences.
2. Upper Stephanian-Permian to Lower Triassic overstep sequences.
3. Post-Alpine overstep sequences.

TERRANE BOUNDARIES

The Gelnica Terrane is restricted by Alpine thrusts in the hanging - as well as in the footwall.

OVERSTEP SEQUENCES

1. Post-Variscan overstep sequence

Upper Stephanian-Permian to Lower Triassic volcano-sedimentary complexes characterized by a high content of mature mineralogical detritus related to transform/strike-slip setting. They reflect the initial stage of post-Variscan rifting. Filling relics of this basin are mostly represented by quartzose conglomerates and sandstones, associated with a lower amount of Ca-Alk rhyodacites and their volcanoclastics. They are resting with an unconformity on folded and metamorphosed Gelnica Terrane rocks. Sediments represent a continental, alluvial-lacustrine formation, which has a distinct cyclic structure and is passing upward into near-shore, lagoonal-sebkha facies. A characteristic feature is decreasing grain-size and also distinctly diminishing mineralogic maturity of sediments in the same direction.

2. Post-Alpine overstep sequences

They are represented by near-shore to continental Eocene-Oligocene sediments, relatively wide-spread Upper Miocene-Pliocene continental sediments and andesite volcanoclastics, as well as Pleistocene proluvial dirty gravels.

A. Variscan Terranes

Gelnica Terrane (8)

Stratigraphy

It consists of the Gelnica Group and the Štos Formation, latter formerly classified as a part of the North Gemeric Rakovec Group. Generally, the Gelnica Group consists of a thick flysch sequence comprising acid to intermediate volcanoclastics, with distinct features of turbidite currents and gravity mass flows (IVANIČKA et al. 1989). Dominant calc-alcaline volcanism was related to an active continental margin which testifies to rela-tively long-lasting subduction processes. Tholeiitic basalts with affinity to CAB, E- even N-MORB basalts occur subordinately as well (BAJANÍK 1981, IVAN 1992). The proximity of an active con-tinental margin is documented by a huge mass of chemically mature terrigenous sediments, mixed with continental margin arc-related rhyolite-dacite volcanoclastic material.

The relatively ?long-lasting subduction processes are proved by biostratigraphical data: according to palynomorphs and acri-tarchs the age of the Gelnica Group is Upper Cambrian - Lower Devonian (IVANIČKA et al. 1989, SNOPKOVÁ & SNOPKO 1979). U, Pb isotope data of zircons from metavolcanoclastics confirm a wide range of their ages: $^{207}Pb/^{206}Pb$: 392 - 577 Ma, $^{207}Pb/^{235}U$: 392 - 573 Ma, $^{206}Pb/^{238}U$: 391 - 497 Ma (CAMBEL et al. 1977, Ščerbak et al. 1988). A Proterozoic age of continental source is indicated by U/Pb zircon data from metasediments, ranging between 651 and 940 Ma (CAMBEL et al. 1977).

The Štós Frm. consists of a rhythmical sequence of metapelites and metasandstones with only scarce occurrences of small metabasalt bodies. In spite of its tectonic position above the uppermost part of the Gelnica Gr. complexes it comprises the same provenance types of detrital material as the previous one. The age of the Štós Frm. has not been biostratigraphically dated.

Data provided by distribution of flysch facies, petrofacial analysis of metasandstones, heavy mineral assemblages and zircon typology as well as bulk chemical composition and REE pattern of metavolcanics make it possible to interpret the Gelnica Terrane rock complexes as a forearc basin setting associated with an active continental margin.

Deformational and metamorphic event

The age of the Gelnica Terrane regional metamorphism has not been confirmed by radiometric dating. Geological evidence suggests a pre-Permian age as its fragments are found in the overlying continental molasse formation whose basal part was palynologically dated as Upper Stephanian-Autunian (PLANDEROVÁ 1980). These data do not rule out the possibility that the tectonometamorphic processes are of intra-Carboniferous, pre- or post-Westphalian age.

The grade of metamorphism reaches the lower part of low-pressure greenschist facies. Diffractometric muscovite b_0 values suggest a fairly narrow temperature range of 350-370 °C at a pressure of about 2-3 kbar. This signals a rather high geothermal gradient during the climax of metamorphism - 40°C/km (SASSI & VOZÁROVÁ 1987, MAZZOLI & VOZÁROVÁ 1989). Early Paleozoic rocks of the Gelnica Terrane have been isoclinally folded with an axial planar cleavage.

Plutonic igneous intrusions

The Gelnica Terrane was intruded by leucocratic granite whose radiometric ages are very contrasting. Rb/Sr whole-rock ages give 346 Ma and 282-224 Ma and subordinately 159-144 Ma (KOVACH et al. 1986, CAMBEL et al. 1989). The only Alpine ages were proved by K/Ar muscovite - 141 Ma and K/Ar biotite - 132 and 97 Ma (KANTOR & RYBÁR 1979). According to petrological data it exhibits marks of syn-collision, S-type granitoids (HOVORKA & PETRÍK 1992). Rb/Sr whole-rocks ages are probably mixed and they reflect the age of protolith. A better understanding of the plutonic igneous activity in the Gelnica Terrane requires further geochronological radiometric research. Strong effort is necessary in order to cla-rify whether the age values belong to two magmatic events or not.

Time of docking

The Carboniferous-Permian time of docking of the Gelnica Terrane with the Spiš Composite Terrane has not been proved with satisfaction till now. The main reason is: - completely different the Late Variscan development in both areas; - insufficient radiometric dating of stitching granitoids, which are situated in the contact between them (Hnilec area). Further radiometric data are necessary to confirm or contradict the Variscan age of these stitching magmatites. Time of docking of the Gelnica Terrane with a more southern zone of Variscan range (Bükkium T.?) can be inferred from the break of sedimentation and absence of the Middle Carboniferous marine molasse. Most probably it could take place during the Moscovian.

B. Alpine History

The Mesozoic cover of the Variscan Gelnica Terrane is unknown due to its tectonic removal during the Alpine orogeny. Only Lower Triassic lagoonal-sabkha facies developed continuously from Permian "Verrucano" type sediments have been preserved.

Deformational and metamorphic events

The Alpine metamorphic history reached from the anchizone to lower greenschist facies, as ascertained from metamorphic mineral assemblages in the Permian and Lower Triassic sediments. Concerning the Alpine overprint of Variscan rock complexes, affected were mainly rocks along strike-slip faults, overthrusts and shear zones.

Plutonic igneous intrusions

The wide-spread intra-crustal shearing reflected collision events which took place in the Lower Cretaceous and caused most probably reheating or even a syn-collisional magmatic event (Rb/Sr whole rocks: 149-159 Ma, KOVACH et al. 1989, loc. Dlhá dolina valley, Podsúľová).

Time of docking

The time of docking of the Gelnica Terrane with the Szendrö-Bükk subunit is indicated by closing of the Meliata oceanic trough and succeeding crustal thrusting during the Upper Jurassic/Lower Cretaceous.

WC/5. MELIATA TERRANE

The Meliata Terrane can be described as a disrupted terrane, represented by HP/LT active continental and oceanic slivers, as well as by the thrust-outliers of the Middle/Upper Jurassic olistostromatic accretion prism sequences. All these units contain evidence of closing of the Meliata oceanic domain, following the Permian? - Middle Triassic rifting and opening of the Meliata ocean.

TERRANE BOUNDARIES

The Meliata Terrane is bounded by Alpine thrusts. It is sand wiched between the South-Gemeric (below) and the Silica (above) Terranes.

OVERSTEP SEQUENCES

The post-Alpine overstep sequences are represented by near-shore to continental Eocene-Oligocene sediments, as well as Upper Miocene-Pliocene sediments and volcanoclastics.

Bôrka Nappe

Stratigraphy

The most distinct features of the Bôrka Nappe rock complexes are: 1. Alpine high-pressure metamorphism which affected rocks of diferent stratigraphic horizons; 2. Presence of metabasalts with ophiolitic affinity; 3. Thrust outlier position above different parts of the South Gemeric Variscan basement or its Permian-Lower Triassic overstep sequence and below overthrust mass of the Silica and Turňa Nappes.

The Bôrka Nappe comprises a deformed complex of metasediments and metavolcanics with distinct foliation, crenulation cleavage and stretching lineation. The whole sequence consists of several lithostratigraphic units, each of which shows very specific lithological features (in MELLO et al. 1992). Phyllites, meta-sandstones, metaconglomerates with lesser amouts of metarhyo-lites and their metavolcanoclastics as well as thrust outliers composed predominantly of products of acid volcanism are supposed to be Permian in age. This assumption is supported by similarity of their lithologic composition to the authochtonous South Gemeric Permian deposits. The most characteristic lithostratigraphic unit of the Bôrka Nappe is the horizon of metabasalts and associated metavolcanoclastics which are gradually connected with white marbles in the underlier and rhythmic metapelites, metasandstones in the overlier. The stratigraphic range of this complex is assumed to be Upper Triassic-Lower Jurassic ? (without any biostratigraphic data). According to bulk chemical composition, trace element distribution as well as REE pattern, the Bôrka Nappe metabasalts show affinity to N-MORB, ocean floor and/or within-plate basalts.

Meliata Unit

Stratigraphy

The Meliata Unit on the territory of the Western Carpathians is known as: 1. blocks tectonically reworked into the basal melange of the Silica Nappe; 2. rootles thrust outliers of the Upper Jurassic olistostromatic sequences. They are tectonically overridden by the Silica and Turňa rock complexes.

The salinar melange consists of Lower Triassic marly shales with blocks of serpentinites (HOVORKA & ZLOCHA 1974; HOVORKA 1985). Their size ranges from 10 m to several 100 m or even km^2 below the Tertiary filling of the Košická nížina Lowland (PLANČÁR et al. 1977). The Middle/Upper Jurassic olisthostromatic formations contain fragments of Anisian platform carbonates, red Ladinian radiolarites (DUMITRICA & MELLO 1982) as well as fragments of oceanic basalts and deep-water sedimentary rocks. Single ?olistoliths are situated amidst Middle/Upper Jurassic black shales (MELLO et al. 1975; MOCK et al. 1993). In addition to oceanic basalt olistolite, a horizon of coarse-grained polymict breccias with redeposited rhyolitic clasts as well as acid volcanoclastic turbidites were described from the borehole BRU-1 (VOZÁROVÁ & VOZÁR 1992). Radiolarites from associated siliceous shales proved Callovian-Oxfordian *age (Eucyrtidellum unumaensis*, Yao 1979; ONDREJIČKOVÁ 1992). This acid volcanic detritus might be related to a hypothetic island arc, assumed by KOZUR (1991).

DEFORMATIONAL AND METAMORPHIC EVENTS

Incompletely preserved sequences of the Bôrka Nappe underwent high-pressure metamorphism due to subduction-accretion processes during the Upper Jurassic orogeny (REICHWALDER et al. 1995; FARYAD 1995; VOZÁROVÁ & MAZZOLI in prep.). The age of metamorphism has been proved by Ar/Ar method from fengite (155 Ma, MALUSKI et al. 1993; 150 - 165 Ma, FARYAD & HENJES-KUNST 1995). P-T conditions estimated for the peak of metamorphism are 400-450 °C, pressures 10-12 kbar, at metamorphic thermal gradient of approx. 10 °C/Km. The same pressure character has been confirmed by means of b cell dimension of muscovites (MAZZOLI et al. 1992). Slices of rock complexes with mineral assemblages corresponding to the transitional greenschist/blueschist facies have been also ascertained. Petrological analysis indicates P-T paths produced by crustal thickening model, in which, after early blueschist facies, metamorphism continued by fairly isobaric thermal relaxation and then rapid uplift.

Low temperature part of anchizone (250-300 °C), transitional low/medium pressure type is characteristic for rock complexes of the Meliaticum (ARKAI in ARKAI & KOVÁCS 1986). They reached a low stage of deformation, except for crushed zones. Rigid rocks, mainly basalts and coarse-grained breccias, do not show any signs of cleavage. The dark shales are plastic-deformed.

Time is docking

Time of docking of the South-Gemeric Terrane with the southern continental margin of the Meliata Ocean is determined on the basis of the age of high-pressure metamorphism related to Late Jurassic subduction-accretion events. The following was a subsequent uplift due to extension of an overthickened accretionary wedge (REICHWALDER et al. 1995).

Further history was connected with nappe emplacement during Middle Cretaceous events.

WC/6. SILICA TERRANE

The Silica Terrane represents fragments of disappeared continental block, originally situated to the south of the Meliata ocean. It is composed of thrust-outliers of the Middle Carboniferous flysch as well as rift-related Permian red-beds and evaporites, following by shalow-water carbonate deposition.

The shallow-water Middle Anisian carbonate ramp was disrupted with beginning of the opening of the Meliata oceanic domain. There were deposited shelf/slope and deep water facies, mainly in the Jurassic (DUMITRICA, MELLO 1982). In the Hungarian part (the Bodva Unit) are known acid volcanics, which seem to represented the volcanic arc developed above the Meliata subduction zone (KUBOVICS et al. 1990). Evidence about this volcanic activity was found also inside of the Upper Jurassic olistostrome of the Meliata Unit (borehole BRU-1; VOZÁROVÁ & VOZÁR 1992).

TERRANE BOUNDARIES

The Silica Terrane is separated by basal thrusts in the hanging-, as well as in the footwall.

OVERSTEP SEQUENCES

The Upper Cretaceous continental overstep sediments were described by MELLO & SNOPKOVÁ (1973). Redeposited Upper Cretaceous sporomorphs (SNOPKOVÁ in VASS et al. 1982) as well as pebbles of Upper Cretaceous carbonates were found in the Eocen-Oligocene conglomerates (VASS et al. 1994).

For further post-Alpine overstep sediments see Meliata Terrane.

Turňa Unit

Stratigraphy

On Slovak territory this unit contains:
1. Olistostrome, flysch sediments of Bashkirian age;
2. Continental to evaporitic Permian sequences;
3. Basin facies of marbles, calcareous slates, allodapic limestones and sandstones mostly of Middle to Upper Triassic age.

The Middle Carboniferous flysch sequence (borehole BRU-1, VOZÁROVÁ & VOZÁR 1992) contains a horizon of carbonate olisto-strome with conodont fauna corresponding to the Idiognathoides zone (EBNER et al. 1990). This lithostratigraphic unit (Turiec Form., VOZÁROVÁ 1992) was compared with South Alpine type Carboniferous flysch facies, as it is known from Szendrö and Karawanken - South Alpine mountain ranges. The coeval Western Carpathian Middle Carboniferous sediments represent the post-orogenic, marine molasse stage. The Permian continental red-bed deposits overlapped with unconformity the Middle Carboniferous flysch sediments. The Upper Permian - Lower Triassic horizon is characterised by evaporitic sedimentation, which had features of rifting processes (redeposited evaporite clasts, intraformational breccias). Sedimentation from the Middle-Late Anisian till the Late Norian took place in basinal conditions. Black shales with layers of allodapic limestones interrupted the carbonate sedimentation in the Carnian. Carbonates deposited after this event are rich in cherts (for more details see MELLO et al. 1992).

Deformational and metamorphic events

The Middle Carboniferous metasediments underwent low-pressure greenschist facies metamorphism. The geobarometric estimation based on b_0 values of muscovites proved the low-pressure of about 2-3 kbar at a temperature of max. 350-370 °C (MAZZOLI & VOZÁROVÁ 1989).

The Variscan age of metamorphism is assumed on the basis of phyllite fragments in the overlying Permian conglomerates. Distinct metamorphic foliation is cut by younger cleavage, the age of which is most probably Alpine. Parallely to this cleavage there crystallized columnar porphyroblast of chloritoids.

Based on IC-averages from Mesozoic rocks, P-T conditions of Alpine metamorphism correspond to the boundary of anchi- and epizone (T about 300°) at the transition between medium and higher pressure (ARKAI in ARKAI & KOVÁCS 1986).

Silica Unit

Stratigraphy

The non- or slightly metamorphosed Mesozoic sequence in the stratigraphic range of Lower Triassic to Lower Jurassic builds large karstic plateaus on the Slovak territory. According to MELLO (in BAJANÍK et al. 1983, in MELLO et al. 1992), the Lower Triassic is represented by variegated sandy-shaly sediments, yellow and grey carbonate shales and graywackes. In the Middle Triassic, mainly in the Anisian, epiplatform carbonates are predominant. During the Ladinian and mainly the Upper Triassic, rifting was replaced by sediments of an unstable shelf, alter-nating with zones of hemipelagic sedimentation (cherty lime-stones). Lower Jurassic sediments, preserved rudimentally only, are represented by Liassic-Doggerian spotty marls and in some places by red, pelagic limestones overlain by Callovian-Oxfordian radiolarites (DUMITRICA & MELLO 1982).

Deformational and metamorphic event

The Silica Unit is in upper plate position, mostly non-metamorphosed or reaching only diagenetic recrystallization. Based on C averages, the regional transformation of the Silica rock complexes corresponds only to medium- or late-diagenetic stages (temperatures did not reach 200°C).

The structure of the Silica Unit is formed by flat, mesoscale synclines and anticlines, with imbrications on their limb. These imbrications show northern vergency (HÓK et al. 1995). The emplacement of Silica Unit onto the Turňa Unit with the Middle Carboniferous flysch sequence as well as onto the obducted ophiolites of the Meliata Unit and the HP/LT Bôrka Nappe complexes took place in the Lower Cretaceous, subsequently to the closure of the Meliatic oceanic basin. Senonian karstic dolina filling with remnants of plants (MELLO & SNOPKOVÁ 1973) seems to date this emplacement.

Time of docking

The time of docking of the Silica Terrane with the Meliata Terrane is indicated by the age of the Senonian overstep sequence (MELLO & SNOPKOVÁ 1973).

Conclusion

In agreement with the concept and the objectives of the IGCP Project No. 276 "Paleozoic geodynamic domains and their alpidic evolution in the Tethys", the analysis of terrains of the Western Carpathian-Northern Pannonian territory has been focused to characterise the development during the Variscan stage.

As postulated in the IGCP 276 Project, a brief outline of the Mesozoic and Tertiary overstep sequences has been made in order to construct the map of Variscan terrains, observed in the Alpine structures. All the findings of both authors have been used to construct the map of the Variscan terrains at a scale 1:2, 500 000, part Western Carpathians, presented by EBNER et al. in 1995 at the XV. Congress of the CBGA in Athens.

The co-operation in the construction of the map allowed for a co-ordinated plotting of the geological boundaries, or links between the geological units across national boundaries, so that the units with dominant standing in Austria (southern Penninicum - Rechnitz, Upper Austroalpine U. - Graz-Paleozoicum), or in Hungary (Bükkium - Pelsómegaunit, or Tisza megaunit, with continuation into the Pre-Tertiary basement in the Eastern Slovakia) could be characterised in detail in the explanations, edited by the authors: Ebner, Neubauer (Eastern Alps), or Kovács et al. (Hungary). This is why we did not address these units in our study and we refer to the papers of the above mentioned authors.

The correlation of delineated dominant Western Carpathian units with the Eastern Alps suggests that:

- Flysch zone and the Klippen belt are well correlable with the corresponding units in the Alps, in particular, the Flysch zone of the Western Carpathians corresponds with the Northern Penninicum
- The Tatricum can be correlated with the Lower Austroalpine
- The Veporicum, including its nappe units, derived from this zone, correlates with the Middle Austroalpine Units.
- The Upper Austroalpine Units can be correlated with the Hronicum, Gemericum and Silicicum Units of the Western Carpathians.

A particular standing has the Meliaticum Unit, represented in the Eastern Alps by a complicated scaly zone, located in the footwall of theMesozoic of Upper Austroalpine Units. A more complex evidence concerning the Meliaticum Unit are available in Hungary, with a proven continuation into the Vardar Zone.

The units assigned to the innermost part of the Western Carpathians due to particularities in their development (the Silica and the Turňa Nappes), have been formed as north vergent nappe units and they can evidently be linked with the Bükkium Unit, in their root zones.

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