Geological evolution of the Western Carpathians
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Evolution and structure of the Western Carpathians: an overview

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Abstract

This introductory article reviews all the important aspects of the position, tectonic division, composition, structure and evolution of the Western Carpathians. Emphasis is given to the pre-Tertiary history, but the most important features of the Cenozoic evolution are outlined as well. It is argued for the triple division into the Outer, Central and Inner Western Carpathians (OWC, CWC and IWC, respectively). The Tertiary OWC weld the Alps and Carpathians into a coherent orogenic system. The Slovakocarpathian thrust system of the CWC is an immediate extension of the Austroalpine system, and the Hungarocarpathian units of the IWC are linked to the South-Alpine and Dinaridic belts. Both the CWC and IWC have no direct connections to principal units of the Eastern Carpathians and Balkan. Basement complexes of the CWC (Tatra-Fatra and Vepor Belts) represent the inner Variscan zones with medium- to high-grade metamorphism and abundant granitoid plutons, the southernmost CWC (Gemer Belt) represent the outer, low-grade Variscan accretionary complex. The IWC probably formed the Variscan foreland. There are increasing lines of evidence implying the generally southern polarity of the Variscan orogeny. The Variscan front was reactivated by Permian-Triassic rifting, creating the Meliatic ocean which controlled the Mesozoic evolution of the ancestral Western Carpathians. This was governed by northward stacking of basement/cover sheets in the CWC, following the closure of the Meliatic ocean. The younger outer, Penninic--Vahic oceanic realm was sutured during the latest Cretaceous and Paleogene. Then convergence prograded outward to the OWC, a huge Tertiary accretionary wedge overriding the pre-Alpine North European Platform. Subduction roll-back of the OWC oceanic crust was mainly responsible for the hinterland stretching, formation of the extensive Late Tertiary Pannonian Basin system and large volumes of calc-alkaline volcanism. The Carpathian convergence ceased by the Neogene, along-arc eastward migrating slab detachment below the OWC.

Key words: Western Carpathians, position, tectonic division, lithostratigraphy, structure, Phanerozoic evolution

Introduction

The Western Carpathians create the northernmost, W-E trending orocline of the European Alpides, linked to the Eastern Alps in the west and to the Eastern Carpathians in the east (Fig. 1). The northern Carpathian foreland is formed by the North European Platform, including the basement consolidated during the Paleozoic and the epi-Variscan platform cover of the Bohemian Massif and Polish Platform in the NW and N. This is separated by the Teisseyre-Tornquist Line from the Fennosarmatian (Russian) Platform in the NE. A large part of the Central and most of the Inner Western Carpathians are covered by thick Tertiary sedimentary and volcanic rock complexes related to the Pannonian back-arc basin system (Fig. 5; Encl. 2). The present structural pattern of the Western Carpathians was formed by the Late Jurassic-Tertiary subduction-collision orogenic processes in the Tethyan mobile belt between the stable North European Platform and drifting Apulia/Adria-related continental fragments. One of the most characteristic features of Alpidic evolution of the Western Carpathians is a distinct northward migration of preorogenic and orogenic processes. This includes Mesozoic rifting and extension of the Variscan continental crust, compression and nappe stacking of attenuated continental crust and subduction of longitudinal oceanic basins (e.g. Mahel', 1980, 1981; Birkenmajer, 1986; Rakús et al., 1990; Plašienka, 1991, 1995a; Putiš 1991a, 1992; Soták, 1992; Kozur and Mock, 1996, 1997; Plašienka et al., this volume). Transpression and transtension usually postdated the main shortening stages. The Western Carpathian orogeny faded out during the Late Tertiary by a slab detachment terminating the southeastward subduction of the ocean crust substratum of the Outer Carpathian Flysch Belt (Tomek and Hall, 1993).

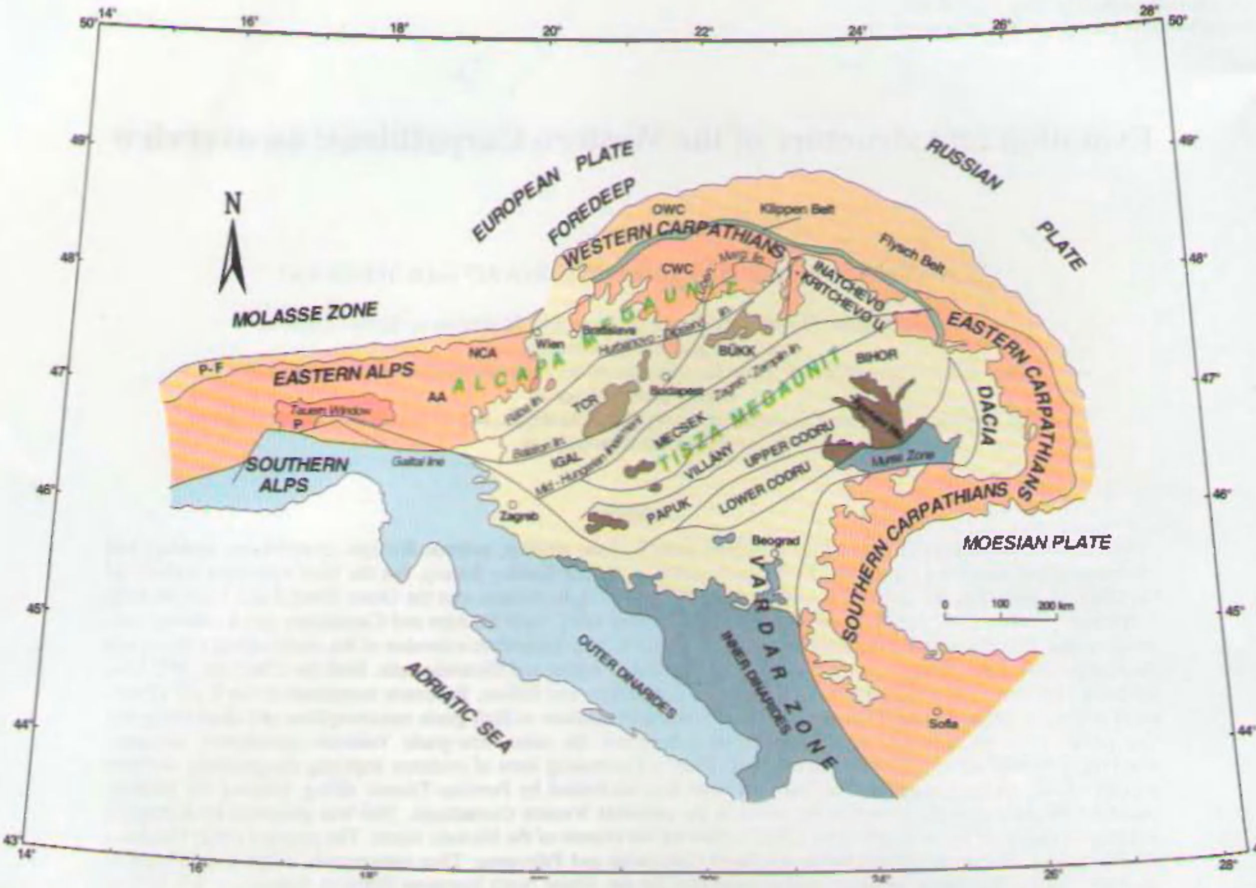


Fig. 1. Tectonic sketch of the circum-Pannonian mountain systems. OWC - Outer Western Carpathians. CVC - Central Western Carpathians. TCR - - Transdanubian Central Range. P-F - Penninic Flysch Zone. NCA - Northern Calcareous Alps. AA - Austro-Alpine structural complex. P - Penninic windows.

The aim of this paper is to provide a brief introduction into the evolution and structure of the Western Carpathians to a reader not familiar with complex Carpathian geological realities presented in this monographic volume. The last extensive and comprehensive English-written review of the Western Carpathian geology in former Czechoslovakia was published in the late sixties (Mahel' and Buday, 1968), on the occassion of the 23rd International Geological Congress held in Prague. This book does not cover all aspects of the complicated Carpathian geology, but reviews the most recent achievements of geological research in Slovakia focusing on the pre-Mesozoic and Mesozoic complexes. The Tertiary evolution of the Western Carpathians is briefly reviewed as well. Owing to many decades of intense geological research a perplexing list of tectonic and lithostratigraphic terms has been developed, and still new are introduced while some older terms are reinterpreted. The terminology applied in this introductory paper is the most widely used and is generally based on terms introduced by Andrusov et al. (1973) and Mahel' (1986). However, some synonyms and names of less important partial units, which are frequently used throughout this volume, are given in the parentheses.

Tectonic division and structure

The Western Carpathians, like most of other collisional fold belts, have been traditionally divided into the outer (northern) and the inner (southern) structural zones, separated by the Pieniny Klippen Belt. Therefore the common practice is to recognize the Outer ("Tertiary") and the Inner ("Mesozoic") Western Carpathians (e.g. Biely, 1989, 1996). Andrusov (1968) used the term "Central Western Carpathians" for zones between the Outer Carpathians and the Hungarian "Zwischengebirge" (in other terminology known as the Pannonian Median Mass, roughly corresponding spatially to our IWC), i.e. as a synonym of the "Inner Western Carpathians" of other authors. However, taking into account the recent achievements in studies of the Mesozoic evolution and structure of the innermost Western Carpathian zones, a strong need for a triple division of the Western Carpathians resulted in their partition into the Outer (OWC), Central (CWC) and Inner Western Carpathians (IWC) (e.g. Mahel', 1986; Kozur and Mock, 1996, 1997). This terminology will be used in the following text (Fig. 2). The triple division also considers the structure of the pre-Tertiary basement, including the inner-

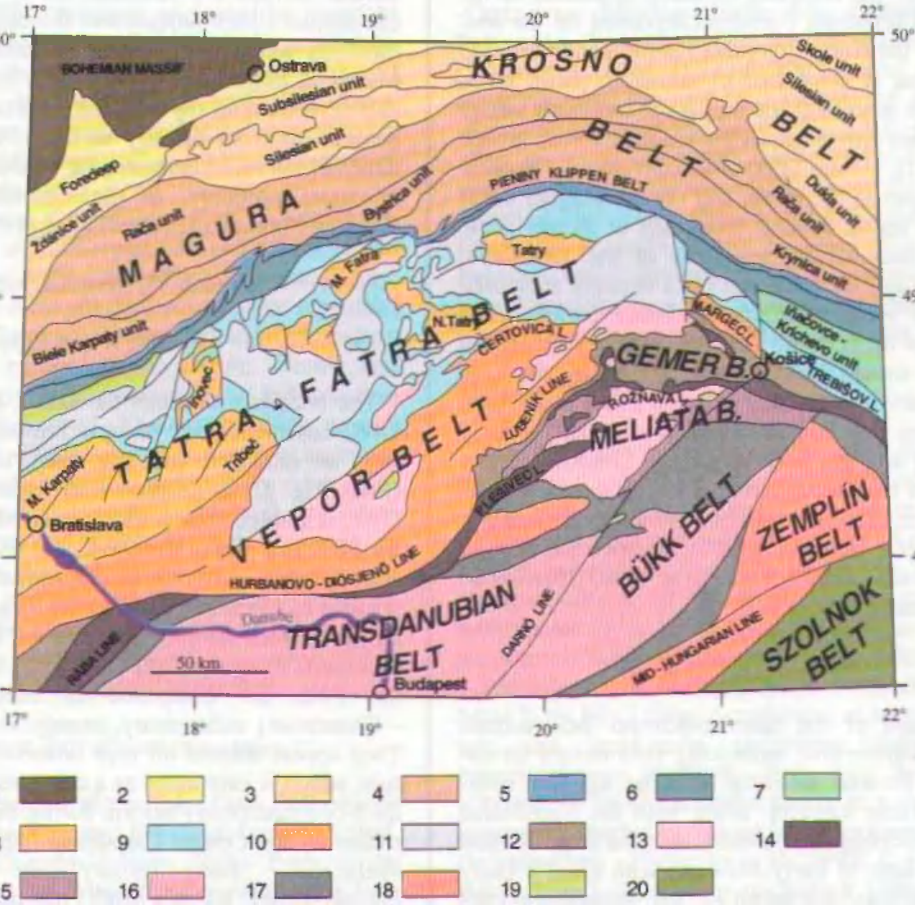


Fig. 2. Schematic tectonic map of the Western Carpathians, stripped off the overstep complexes. 1 - foreland: outer Variscan zones, 2 - foredeep: Tertiary molasse, 3 - OWC: Silesian - Krosno belt, 4 - OWC: Magura belt, 5 - PKB: Oravic units, 6 - PKB: Periklippen belt, 7 - CWC: Penninicum - - Vahicum, 8 - CWC: Tatricum, basement and cover, 9 - CWC: Fatricum (Križna) nappe system incl. Veľký Bok unit, 10 - CWC: Veporicum, basement and cover, 11 - CWC: Hronicum (Choč) cover nappes, 12 - CWC: Gemericum, basement and cover, 13 - CWC & IWC, Silicicum cover nappes, 14 - IWC: Meliaticum suture complexes, 15 - IWC: Turnaicum, 16 - IWC: Mesozoic cover complexes, 17 - IWC: Paleozoic cover complexes, 18 - - IWC: crystalline basement, 19 - Senonian (Gosau) cover, 20 - Szolnok flysch belt.

most Carpathian zones which are largely covered by Tertiary sediments and volcanics (compare e.g. Figs. 2 and 5), the presence of oceanic sutures in the Carpathian structure and the complete Alpine tectonic evolution, not only the morphostructurally expressed Late Tertiary neotectonic development. The three principal Carpathian tectonic domains are limited by two diachronously closed oceanic sutures. The Early Alpine (Late Jurassic, "Cimmerian") Meliatic (Meliata-Hallstatt) suture delimitates the IWC and CWC. Its precise original position is not always clear, especially in sectors covered by Tertiary sedimentary and volcanic complexes. The CWC and OWC are divided by the Pieniny Klippen Belt (PKB). This is assumed to be one of the surface expressions of the Late Cretaceous to Early Tertiary closure of a supposed Penninic-related oceanic domain (the Vahicum - Maheľ, 1981) along the northern Central Carpathian (Tatric) edge. There are only indirect indications of an oceanic suture on the actual erosional surface (e.g. pebbles of oceanic crust rocks and blueschists in Cretaceous flysch conglomerates) - cf. Marschalko (1986), Mišík and Marschalko (1988 and references therein), Dal Piaz et al. (1995), Faryad (this volume). The inferred provenance of this material as external to the CWC (Pieniny or Andrusov Exotic Ridge) has been doubted by Plašienka (1995b).

Outer Western Carpathians

Carpathian Foredeep

The Outer Western Carpathians (OWC) contour the northerly convex arcuate shape of the Western Carpathian orocline. The OWC comprise molassic sediments of the Late Tertiary Carpathian Foredeep deposited on the southern flanks of the North European Platform and the broad Flysch Belt that is composed of numerous thrust units. The Flysch Belt represents the Tertiary accretionary wedge of the Carpathian orogen, generally ranged into two groups (Fig. 2, Encl. 2); (1) the Silesian-Moldavian (or "Krosno-menilite") nappes in the north, and (2) the Magura thrust system in the south. Several thousands of metres thick, mostly siliciclastic flysch sediments of the Jurassic to Early Miocene age were scraped off a strongly attenuated continental, in some parts also probably oceanic crust (continuation of the northern Penninic zones). The inferred oceanic crust should have been produced by the Late Jurassic (probably even earlier in some zones in the east, i.e. approaching the Triassic Transylvanian rift) - Early Tertiary rifting and sea floor spreading. Lithostratigraphy and structure of the Carpathian Flysch Belt is treated in innumerable papers, recent works of significance include e.g. Oszczypko (1992), Schnabel (1992), Winkler and Slaczka (1994), Krejčí et al. (1994), Fodor et al. (1995), Roca et al. (1995), Švábenická et al. (1997).

Silesian-Krosno Belt

Principal units of the Silesian-Krosno Belt include (Fig. 2): the Ždánice unit, embracing sedimentary formations of Late Jurassic to Early Miocene age that overthrust the molasse foredeep along with the Subsilesian unit (Late Cretaceous - Early Miocene); the large Silesian unit (Late Jurassic to Early Miocene with notable Early Cretaceous alkaline volcanism of the teschenite-pikrite association) and the Foremagura-Dukla unit (Cretaceous - Paleogene) overridden by the Magura nappes. The Skole unit (Late Cretaceous to Neogene) forms the frontal parts of the Krosno Belt in the NE part (Fig. 2).

Magura Belt

The Magura Belt is composed of several large thrust units, generally considered as an extension of the Rhenodanubian Flysch Belt of the Alps. The four principal units are (Fig. 2): the huge Rača unit (thick Late Cretaceous to Paleogene, mostly Eocene flysch); the Bystrica unit (Paleocene - - Eocene); the Biele Karpaty unit (Late Cretaceous - - Eocene) and the Krynica unit (Paleogene), the last two juxtaposing the Pieniny Klippen Belt.

Little is known about the nature of the Flysch Belt basement substratum which was shortened and underthrust below the CWC during the Tertiary. In northern Moravia, the Silesian nappes overrode the frontal Variscan zones formed by Early Carboniferous "Kulm" flysch and Late Carboniferous foredeep containing coal measures near Ostrava (Fig. 2). The sources of the Tertiary flysch conglomerates in Moravia, reconstructed as the intrabasinal Silesian basement high, may be similar to the basement of the Brunovistulic terrane consolidated during the Cadomian orogeny (Soták, 1990). This terrane formed the foreland of both the west-verging Carpathian flysch nappes and the east-directed Variscan thrusting along the eastern margins of the Bohemian Massif in Moravia (Dudek, 1980). However, recent studies revealed that the outer Magura units contain granite pebbles showing affinity to inner Variscan zones, i.e. either to the Moldanubian core of the Bohemian Massif, or, more probably, to the Central Alps or Central Western Carpathians (Hanžl et al., 1997).

Central Western Carpathians

Pieniny Klippen Belt

The boundary between the OWC Flysch Belt and the CWC basement/cover units is formed by a narrow zone with an intricated structure, the Pieniny Klippen Belt (PKB, Fig. 2). Its position with respect to the OWC and CWC is ambiguous and transitional. Most authors consider the PKB as a part of the OWC, but its inner "Periklippen" zone clearly matches the central Carpathian zones by composition and structure. Being fully aware of some inconsistencies in such ranging, we treat the PKB conventionally as a CWC element in this paper. The surface exposures of the PKB are composed of Mesozoic (Jurassic - - Cretaceous) sedimentary, mostly limestone formations. They appear sheared off their unknown basement substratum, which is interpreted as a con-tinental ribbon rifted off the North European Platform during the Jurassic, and overridden by the Central Carpathian nappes during the Late Cretaceous - Early Tertiary (Fig. 7). Geometrically, the presumed Klippen Belt basement corresponds to the Briançonnais domain (Tomek, 1993) which divides the northern and southern Penninic zones in the Western Alps (see the profile in Encl. 2 after page 38). The Paleogene overstep sequences of mostly flysch lithology of both the OWC and CWC affiliation were partly incorporated into the "klippen" structure by Miocene tectonism (Kováč and Hók, 1996). The PKB is usually subdivided into two belts: the Klippen Belt sensu stricto representing an independent paleogeographic zone (Oravicum sensu Maheľ, 1986) with the typical Czorsztyn and Kysuca units and the Periklippen Belt, built up mainly of the Central Carpathian nappe units and their Senonian - Paleogene cover. The external Czorsztyn unit contains successions representing a pelagic swell environment (Mišík, 1994) with mostly condensed Jurassic and Early Cretaceous limestones and frequent hiatuses, and variegated Late Cretaceous marls terminated by distal flysch sediments. The Kysuca (Pieniny) unit embraces basinal pelagic successions (spotted marls, radiolarites, nodular and cherty limestones) and coarsening and/or shallowing upwards flysch sediments prevailing in the

Late Cretaceous sequence. Transitional successions between the Czorsztyn and Kysuca units represent slope environment, with numerous resediments. Recent data about the stratigraphy and evolution of the PKB are reviewed by Mišík (1997). The peculiar structure of the PKB is marked by rigid blocks, so-called "klippen" of Jurassic-Early Cretaceous limestones flowing in a soft Late Cretaceous-Paleogene matrix. This structure originated by manifold brittle deformation progressing from detachment of sedimentary succession from its underthrust substratum and development of a shallow fold-and-thrust belt (latest Cretaceous - earliest Paleogene), dextral transpression (Paleogene - Early Miocene) and sinistral transtension in the western sector (Miocene).

The Central Western Carpathians (CWC) south of the PKB lie at the heart of the Carpathians, and are the key to understanding of their Alpine, as well as pre-Alpine history. The CWC consist of three principal crustal-scale superunits (from N to S): the Tatricum, Veporicum and Gemericum, and several cover nappe systems (Fatric, Hronic and Silicic), grouped into the Slovakocarpathian thrust system (see below). Thick-skinned Slovakocarpathian crustal superunits comprise the pre-Alpine crystalline basement and its Late Paleozoic-Mesozoic sedimentary cover. The cover nappe systems contain sedimentary (and rare volcanic) suc-cessions detached within the Late Paleozoic or Triassic incompetent strata. Based on the character of the crystalline basement and some special features of the tectonic evolution, the CWC area is divided into three principal morphotectonic belts: the belt of "core mountains" (Tatra-Fatra Belt), the Vepor Belt and the Gemer Belt.

Tatra-Fatra Belt of core mountains

The geological structure of the Tatra-Fatra Belt of core mountains (the Malé Karpaty, Považský Inovec, Tríbeč, Strážovské vrchy, Žiar, Malá Fatra, Veľká Fatra, Nízke Tatry and Vysoké Tatry Mts., Fig. 2), which are Late Tertiary asymmetric horst structures, comprises from bottom to top:

* windows of the Penninic-Vahic oceanic rock complexes;
* the Tatric pre-Alpine crystalline basement and its Late Paleozoic-Mesozoic sedimentary cover;
* the Fatric (Križna) Mesozoic cover nappe system;
* the Hronic (Choč) cover nappe system;
* the overstepping Late Cretaceous (uncommon) and Tertiary (abundant) post-nappe sedimentary and volcanic cover.

Vahicum

The Vahicum (term introduced by Maheľ, 1981; redefined by Plašienka et al., 1995) is the term for the Western Carpathian extensions of the Ligurian-Piemont oceanic basin and for the units derived from its substratum, i.e. for the (Southern) Penninic units. The likely single Vahic unit exposed at the surface is the Belice unit in the Považský Inovec Mts. (Fig. 2). It consists of greenschists and Late Jurassic to Early Cretaceous eupelagic and Senonian flysch anchimetamorphosed sediments (Plašienka et al., 1994). The subsurface Iňačovce-Krichevo unit is known from the pre-Tertiary basement of the Transcarpathian Basin in eastern Slovakia and the western Ukraine (Fig. 2). It is composed of low-grade Triassic carbonates and Quartenschiefer, Jurassic--Cretaceous Bündnerschiefer-type metasediments and Paleogene flysch overlain by obducted serpentinites (Soták et al., 1994, 1997; cf. Baráth et al., this volume). However, the Penninic provenance of the Iňačovce--Krichevo unit was disclaimed by Vozár et al. (1996a). They proposed its direct correlation with the Szolnok unit, a subsurface Senonian-Paleogene flysch unit overthrusting the Tisia terrane in the basement of the Pannonian Basin in eastern Hungary (Fig. 2). Different Penninic-Vahic complexes were overridden by the Slovakocarpathian units diachronously during the latest Cretaceous - Paleogene and exhumed in the Miocene.

Tatricum

The Tatricum is an extensive thick-skinned crustal sheet composed of the pre-Alpine (generally Variscan) crystalline basement and its sedimentary cover. According to the recent interpretation of the Carpathian seismic transect 2T (Tomek, 1993), the Tatric sheet is approximately a 10 km thick, upward convex tabular body rooted in the lower crust below the southward located Veporic wedge. Nevertheless, the marginal northern Tatric zones (the Malé Karpaty, Považský Inovec and Malá Fatra Mts.) show detachment of Mesozoic complexes and large-scale recumbent folding of the basement/cover interface. They may be regarded as a system of local basement sheets or nappes indicating important shortening along the northern Tatric edge (Infratatricum - Plašienka et al., 1997; Korikovsky et al., this volume). According to Tomek (1993), the Tatric sheet is underthrust by remnants of the Ligurian-Piemont oceanic crust (Vahic in the Carpathian terminology, see above) which overlies the Briançonnais (PKB) continental splinter that is fully overthrust by the Central Carpathian units. A very low-grade metamorphic and structural overprint in the surface Infratatric units reveals piling of some 5-7 km of tectonic load which was later removed. Small-scale structural indicators, as well as the macroscopic fold architecture confirm an outward, top-to-NW translation of thrust sheets. The Infratatric units are usually compared to the Lower Austroalpine nappes of the Eastern Alps (see discussion in Häusler et al., 1993). However, the main body of the Tatric sheet is probably Carpathian of their own and has not equivalents in the Eastern Alps.

Despite some zones of the Tatricum exhibiting partial basement reactivation and nappe structures or large-scale recumbent folds, the Tatric basement has a generally well preserved Variscan structures without significant Alpine overprint. The basement is mainly composed of crystalline rocks: medium- to high-grade Early Paleozoic volcano-sedimentary complexes (paragneisses, mica-schists, orthogneisses and amphibolites, phyllites in the Malé Karpaty Mts. being an exception - cf. Krist et al., 1992 and references therein) and several suites of Variscan granitoids intruding mostly the high-grade gneisso-migmatitic complexes (cf. Hovorka and Petrík, 1992; Petrík et al., 1994 and references therein). Banded amphibolite complexes are specified as the leptynite-amphibolite complex (LAC of Hovorka et al., 1994). Metasedimentary complexes were formed mostly from greywacke protoliths. The low-grade rocks in the Malé Karpaty Mts. (Putiš in Plašienka et al., 1991) are partially convergent to the Gemeric Early Paleozoic low-grade complexes. The presence of some pre-Variscan elements has been favoured by several authors (Krist et al., 1992). The crystalline basement complexes are incorporated into several thick-skinned Variscan nappe structures. Generally, the predominant medium- to high-grade complexes overlie the medium-grade ones, the latter cropping out in a few tectonic windows within the Alpidic structure (Putiš, 1992).

The sedimentary cover of the Tatricum consists of varied, although dominantly carbonate lithologies. The Permian red-beds are widespread only in the Infratatric units, otherwise the basement is overlain by Scythian quartzose sandstones and variegated shales. The Middle Triassic is represented by carbonate platform sediments, mostly dolostones, and the Late Triassic by continental Carpathian Keuper formation. Liassic syn-rift strata contain sandy crinoidal limestones and sandstones. The deepening post-rift sequence consists of spotted marls, siliceous and nodular limestones, and Biancône-type well-bedded cherty limestones in the basinal Šiprúň suc-cessions. In the swell successions (South Tatric ridge), the Middle and Late Jurassic is represented by mostly shallow-water sediments, and the Barremian - Aptian Urgonian limestones are also present. The marginal Infratatric successions (North Tatric ridge) are marked by huge bodies of Jurassic scarp breccias (Plašienka et al., 1991). Hyalobasanitic lavas occur in places at the base of hemipelagic mid-Cretaceous sequence which is terminated by Albian-Cenomanian siliciclastic flysch formation containing bodies of conglomerates with partly exotic clasts. The youngest known sediments are the Early Turonian marls which are overlain by the Krížna cover nappe.

Fatricum

The Fatricum (Krížna nappe s.l.) is a system of detached sedimentary nappes overlying the Tatric cover. The Late Scythian shales and evaporites represent the main décollement horizon. However, a wedge-like basement duplex is present in the rear part of the nappe system (Staré Hory and Rázdiel units; cf. Hók et al., 1994; Plašienka and Prokešová, 1996). Some higher detachment horizons (Carpathian Keuper, mid-Cretaceous marls) were activated in the frontal parts of the system. The lithostratigraphical content of the Fatricum is rather similar to the Tatricum, with two complementary types of successions - the widespread basinal (Zliechov, or Krížna s.s.) and restricted ridge-type (Vysoká). For this unit pronouncedly alkaline volcanics (basanites) are characteristic. They mostly bear character of hyaloclastites (Hovorka and Spišiak, 1993). The Manín and some other units occurring in the Periklippen belt are also considered to be constituents of the Fatric system by some authors, the others place them paleogeographically north of the Tatricum (see review by Plašienka, 1995b). The problem lies in the overlying units - the youngest, Cenomanian flysch sediments of the Krížna unit proper (or Early Cretaceous marly limestones in its rear parts) are overridden by the Late Paleozoic or Triassic complexes of the Hronic (Choč) cover nappe system. On contrary, the Manín and related Periklippen units show locally continuous (?) Early-Late Cretaceous successions and the inferred Late Turonian overthrusting event is not evident from the sedimentary record. Consequently, there is no general agreement, whether Senonian sediments of these units represent termination of the continuous Cretaceous succession, or the post-nappe overstep sequence classified as the Gosau group.

Hronicum

The Hronicum (Choč nappe s.l.) is a large cover nappe system overlying the Krížna or Veľký Bok units (Fig. 2). About two thousands of metres thick Late Paleozoic complex occurs in the southern part of the Tatra-Fatra Belt, whereas the youngest Late Jurassic and Early Cretaceous sediments are present only in the frontal nappe parts near the Periklippen zone. The Late Paleozoic - Scythian Ipoltica group (Vozárová and Vozár, 1988) is composed of Late Carboniferous shallow-marine deltaic clastics penetrated by dioritic dykes. These subvolcanic bodies represent an extensive Permian volcanism of continental tholeiitic basalts ("melaphyres"; cf. Vozár, this volume) intercalated within thick red-beds. Middle to Late Triassic successions were derived from a broad dissected carbonate platform with reef cores often forming independent structural units overthrusting neighbouring basinal successions. These "higher nappes" (e.g. the Strážov nappe) were thought to represent outliers of the highermost Silicic cover nappe system by some authors, but recent lithostratigraphic (Polák et al., 1996; Plašienka et al., 1997) and structural (Kováč and Filo, 1992) studies revealed their close relationships to other Hronic successions. Therefore the presence of Silicic outliers was ruled out in the Tatra-Fatra Belt. The Jurassic-Early Cretaceous succession of the Hronicum is composed of pelagic, partly condensed sediments terminated by Hauterivian terrigenous turbidites rich in chrome spinel grains. The overstep Senonian (Gosau group, only along the northern periphery - Fig. 2) and Paleogene sediments typically overlap the Triassic carbonates of the Hronicum in the Tatra-Fatra Belt.

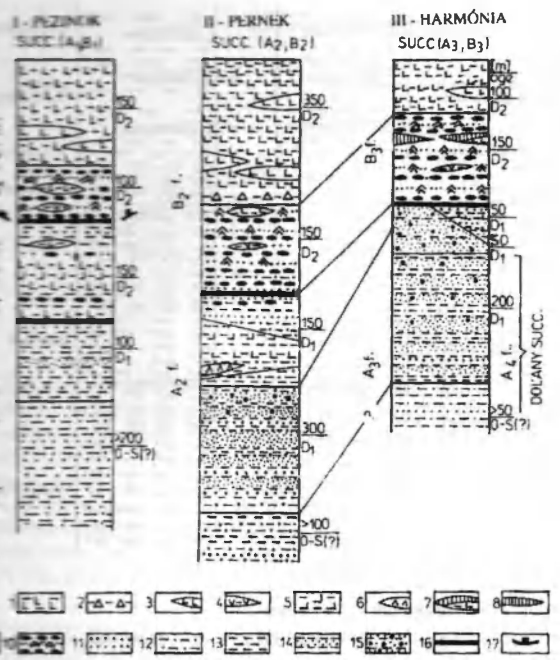


Fig. 3a. Schematic lithostratigraphic column of the Malé Karpaty Mts. crystalline complexes (Putiš in Plašienka et al., 1991). I - Pezinok Succession (Bratislava-Borinka and Pernek-Baba areas, respectively). II - Pernek Succession (Pernek-Kuchyňa area). III - Harmónia Succession. Symbols: 1 - basalts and their tuffs, 2 - volcanic breccias; 3 - gabbros, gabbrodiorites, 4 - schists to quartzites with tuff admixture, 5 - tuffites, 6 - amygdaloid basalto-andesites, 7 - limestones with basalt tuff admixture, 8 - limestones, 9 - marly shales, 10 - bituminous schists and quartzites, 11 - pale quartzites, 12 - clayey sandy shales, 13 - shales, 14 - rhytmic clayey-graywacke sediments, 15 - graywacke sandstones (locally lithic graywackes) intercalated with shales, 16 - the boundary between formations A, B, 17 - tectonic boundary between lithological sequences.

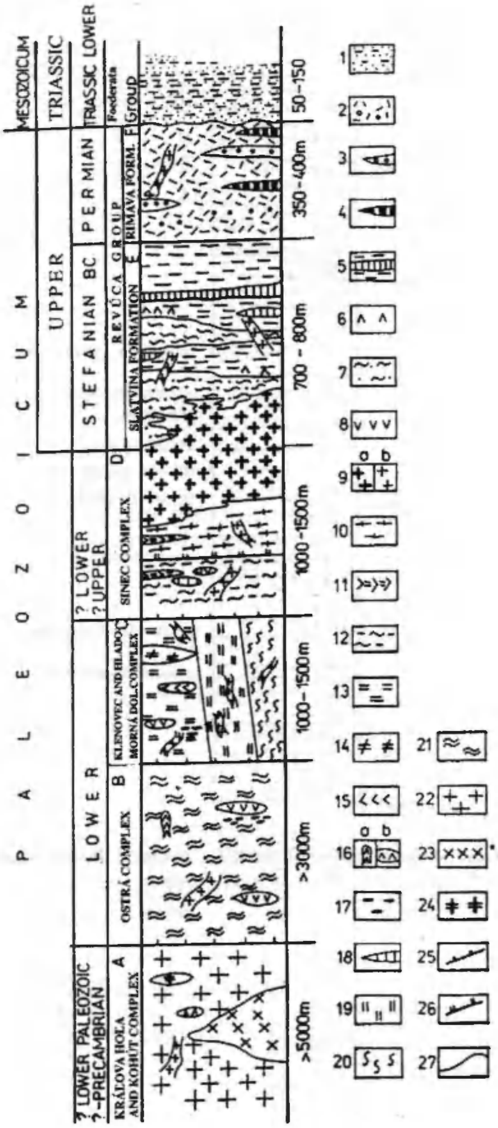


Fig. 3b. Lithostratigraphic scheme of southern Veporicum (Bezák and Vozár, 1987). 1 - bedded quartzose sandstones, subarkoses, sandy shales, 2 - coarse- and medium-grained metamor-phosed sandstones, sandstones with pebbles, 3 - sandy metaconglomerates, locally layers of metamorphosed sandy shales, 4 - metamorphosed rhyolite volcaniclastics and rhyolites, 5 - cyclically alternating metamorphosed sandstones, shales and siltstones interlayered with graphitic schists, 6 - layers of intermediate and basic volcaniclastic rocks, 7 - dominant metasandstones, small bodies of volcanic rocks, 8 - amphibolites, 9 - leucocratic granitoids, 10 - metaconglomerates, metaarcoses, 11 - greenschists, 12 - muscovite-chlorite schists, 13 - biotite-albite schists, 14 - light-coloured schists, 15 - light-coloured gneisses, 16 - a - serpentinites, b - metahornblendites, amphibole metadiorites, 17 - intercalations of graphitic schists, 18 - metacarbonates, 19 - migmatized biotite phyllites, 20 - augen-structured metasandstones, 21 - garnet biotite-chlorite-muscovite schists, 22 - medium-grained biotite granitoids grading into nebulites to stromatites, 23 - banded and augen migmatized gneisses, 24 - enclaves of gneisses, 25 - thrust planes and reverse faults of the 1st order, 26 - thrust planes and reverse faults of the 2nd order, 27 - angular discordance. A - Kráľova Hoľa Complex, B - Ostrá Complex, C - Klenovec and Hladomorná valley Complex, D - Sinec Complex, Revúca Group: E - Slatvina Formation, F - Rimava Formation.

Vepor Belt

The principal Vepor Belt Nízke Tatry Mts-east, Slovenské rudohorie Mts.-west, Branisko Mts., Čierna hora Mts.) comprises:

* the Veporic basement/cover thick-skinned sheet;
* décollement sedimentary cover nappes of the Silicicum system;
* the Late Cretaceous-Tertiary cover rocks.

Veporicum

Based on surface investigations and deep seismic reflection line 2T (Tomek, 1993), the Veporicum sheet is an imbricated crustal wedge, showing both the subhorizontal nappe structures (Alpine and/or pre-Alpine; cf. Bezák, 1991, 1994; Bezák et al., this volume; Putiš, 1991a, b, 1994) and steep oblique reverse faulting, probably listric on a crustal scale (Hók and Hraško, 1990; Tomek, 1993; Madarás et al., 1994). The Veporic sheet overrides the southern flanks of the Tatric unit, and/or the shortened, previously attenuated basement of the Fatric (Krížna) do-

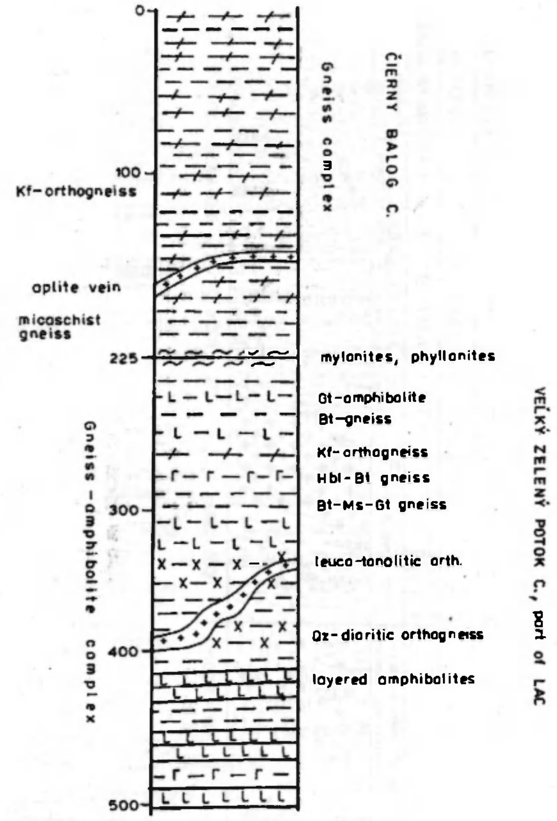


Fig. 3c. Lithological profile of the KV-1 borehole, Pohronská Polhora (Central Veporic zone). (Putiš, original figure).

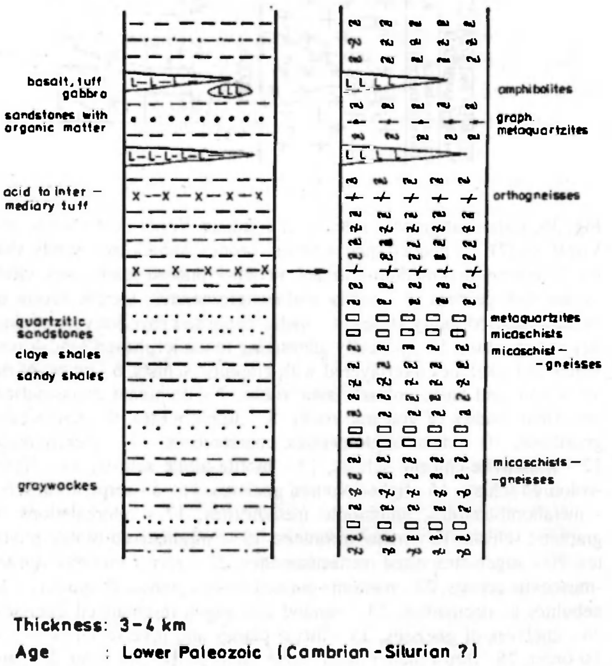


Fig. 3d. Lithostratigraphy of the Hron Complex in the Považský Inovec Mts. and Nízke Tatry Mts. - east (Putiš, original figure).

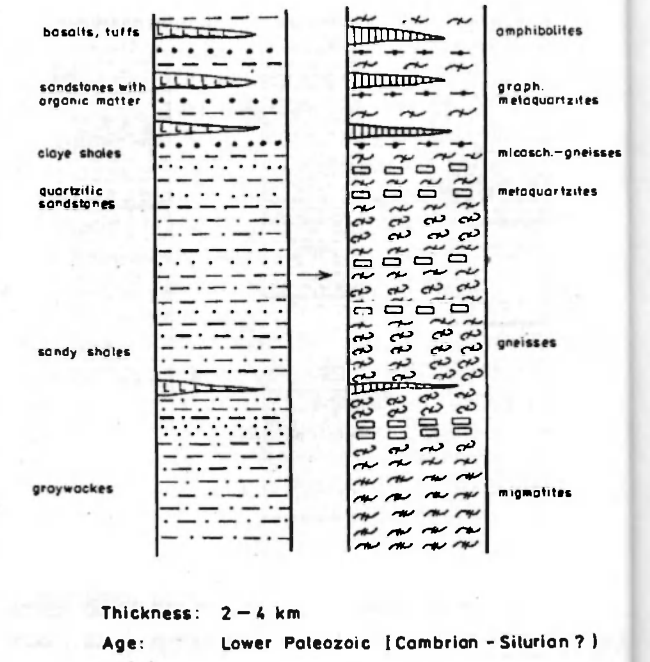


Fig. 3e. Lithostratigraphic columns of the Tatra Complex in the Považský Inovec Mts. and Strážovské vrchy Mts. (Putiš, original figure).

main (Plašienka, 1991). The surface expression of this overthrust plane is called the Čertovica Line which is considered to be an intracontinental suture, formed after an expulsion of the Krížna cover nappe (Biely and Fusán, 1967). Most of surface exposures of the Veporicum are composed of the crystalline basement rocks, the cover complexes are restricted to its peripheries. The Late Paleozoic-Mesozoic sedimentary cover is subdivided into two units - the southern and central Veporic Foederata unit and the northern Veporic Veľký Bok unit. The Foederata unit is only scarcely preserved, consisting of low- to medium-grade metamorphosed and highly strained sedimentary rocks. These comprise an Late Carboniferous clastic sequence deposited within a deltaic environment (Vozárová and Vozár, 1988), Permian-Scythian continental clastics and Middle to Late Triassic, mostly carbonate sediments of a passive margin environment. No Jurassic sediments have been observed. The Veľký Bok unit (named also the Lučatín unit in the western part) is an anchimetamorphosed stack of subunits partly confined to the North Veporic basement and partly corresponding to the rear part of the Krížna cover nappe overriding the Tatricum. The Veľký Bok successions comprise Permian and Scythian red beds, Middle Triassic carbonate platform deposits, and Late Triassic continental Carpathian Keuper formation. The Rhaetian and Early Liassic littoral sediments and continously deepening Late Liassic-Early Cretaceous deposits with typical spotted marls, nodular, cherty and siliceous limestones, radiolarites and thick Neocomian dark marly limestones represent the syn- and post-rift sequences. These correspond well lithologically to the basinal Zliechov succession of the Fatric

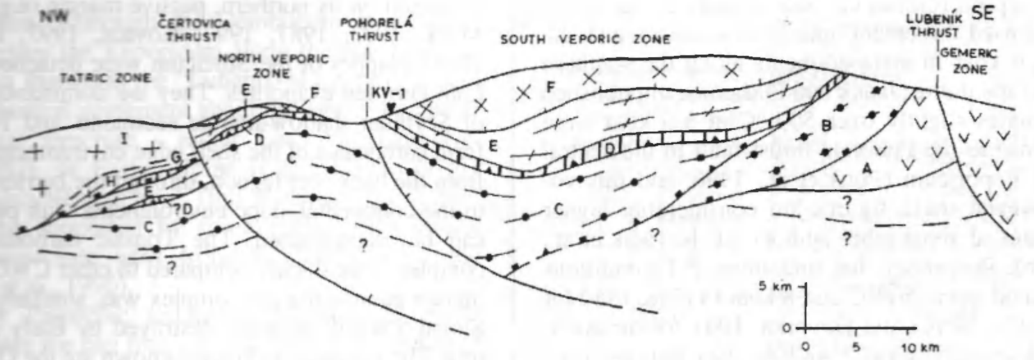


Fig. 3d. Variscan basement of the Veporic zone reactivated by Alpine nappe and thrust faults (Putiš, original figure). A - low grade metamorphic complex. B - low- to medium grade crystalline complex (Kohút Complex: phyllite, greenschist to amphibolite, mica-schist, talc-schist, black schist), C - medium grade complex of the north Veporic (Hron Complex: mica-schist to gneiss, rare amphibolite, metaquartzite), D - medium to hight grade crystalline complex (leptinite-amphibolite complex: cpx-rt metabasite, layered amphibolite, diorite to tonalitic orthogneiss, metagabbro, serpentinite and gr-ky gneiss). E - medium (to high grade) crystalline complex (Čierny Balog and Ľubietová-Muráň Complexes: paragneiss, mica-schist to gneiss, amphibolite, orthogneiss). F - tonalite, granite, granodiorite (303-295 Ma) of the Vepor pluton, G - high grade crystaline complex (LA Complex: analogous with the D as a part of the Tatric basement), H - medium to high grade crystalline complex (Tatra Complex: gneiss, migmatite, amphibolite, orthogneiss). I - granite to tonalite (cca 340 Ma). Structural symbols: triangles - Early Variscan thrust and suture zone; squares - Late Variscan thrust and suture zone; comb line - Alpine reactivation nappe and thrust fault.

cover nappe system, however, there are many indications of southward shallowing and a marginal position of the Veľký Bok unit with respect to the Jurassic-Lower Cretaceous Zliechov basin of the Fatric realm (Plašienka and Prokešová, 1996).

The exposed eastern part of the Veporic superunit in Central Slovakia (the rest is covered by Tertiary sediments and volcanics) shows a dome structure with an onion-like arrangement of the Variscan basement and Permomesozoic cover complexes. The Alpine meta-

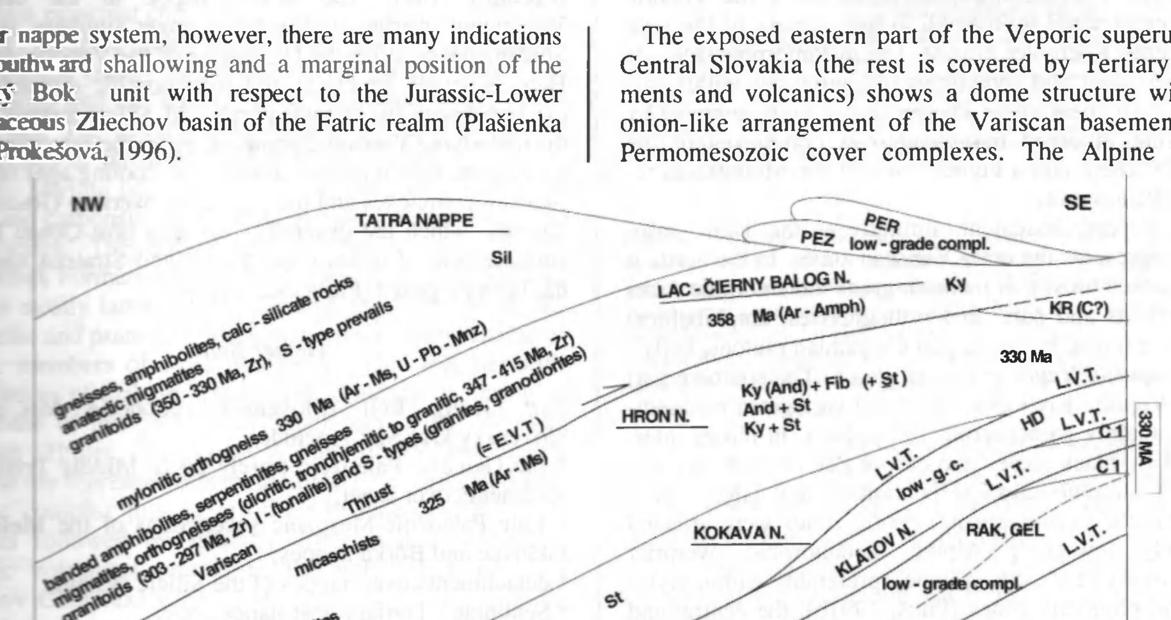


Fig. 3e. Variscan tectonostratigraphy of the Central Western Carpathians basement complexes (Putiš, original figure). Abbreviations of basement complexes: PER = Pernek, PEZ = Pezinok, LAC = leptinite-amphibolite, KR = Kraklová, HD = Hladomorná dolina, RAK = Rakovec, GEL = = Gelnica. Zr = zircon, Mnz = monazite, Amph = amphibole, Ky = kyanite, And = andalusite, Fib = fibrolite, St = staurolite, Ms = muscovite, Sil = = sillimanite. Ar = ^{40}Ar - ^{39}Ar.

morphic overprint reaches ca. 600 °C and 10 kbar in the deepest exposed basement unit (micaschists) and ca. 450°C and 6 kbar in metasediments along the southern periphery of the dome (Janák and Plašienka, unpublished data). Estimates slightly over 500 °C at 8-9 kbar were obtained close to the Pohorelá thrust-fault in the central part of the Veporicum (Putiš et al., 1996, and this volume). However, these figures are considerably higher than estimates of some other authors (cf. Kováčik et al., this volume). Previously, the maximum P-T conditions were estimated as ca. 500°C and 8 kbar (Vrána, 1980 for metagranitoids; Méres and Hovorka, 1991 for metapelites). Thermochronological $^{40}Ar/^{39}Ar$ data indicate cooling and exhumation from ca. 110 Ma (amphiboles) to 90-80 Ma (micas; see Maluski et al., 1993; Dallmeyer et al., 1993, 1996; Kováčik et al., 1996). The Veporic metamorphic core complex was exhumed by a generally east-dipping low-angle normal fault accompanied by a ductile shear zone with top-to-the-east shear sense indicators (e.g. Hók et al., 1993; Putiš, 1994; Madarás et al., 1996). Post-metamorphic elevation of the Veporic dome culminated by a small intrusive body of the Late Cretaceous Rochovce granite. The metamorphic isograds are telescoped and sometimes discontinuous within this extensional shear zone. The presumed units removed by unroofing involved basement/cover complexes of the Gemeric sheet and a higher stack of the Meliatic accretion-collision units.

The Veporic basement, similarly as the Tatric basement, represents the inner Variscan zones. In the north, it is composed mostly of medium-grade metamorphic rocks (micaschists and para- and orthogneisses, amphibolites) that are intruded by the largest Carpathian plutonic body - the composite Vepor granitoid pluton. The southern part of the Veporic basement consists of variegated metasediments, mainly garnetiferous micaschists, in places intercalated by black shales and carbonates, or with rare bodies of amphibolites, serpentinites and talc schists. Whereas the northernmost Veporic zones were affected by only low-grade Alpine metamorphic overprint (Korikovsky et al., this volume), preferably within mylonite and phylonite zones (Putiš, 1991b), the central and southern zones bear characteristics of strong Alpine reactivation in the greenschist to lower amphibolite facies conditions (Putiš et al. 1996, and this volume).

Silicicum

The Silicicum is the highermost and innermost cover nappe system in the CWC, also overlapping the IWC Meliata Belt (Fig. 2). The Silicic nappes were rooted in either the southern or northern peripheries of the Meliatic suture. In spite of numerous recent studies, the precise palinspastic position of the Triassic carbonate platforms of the Silicicum still remains unresolved. For instance a position at the southern margin of the Meliatic ocean was claimed by Hók et al. (1995) and Rakús (1996), on the contrary to most other authors placing the homeland of the Silicicum on its northern, passive margin (e.g. Kozur and Mock, 1973, 1987, 1997; Kovács, 1997; Haas et al., 1995). Nappes of the Silicicum were detached within the Late Permian evaporites. They are dominantly composed of Scythian shallow-marine sediments and Triassic platform carbonates of the shelf edge environment. Transition from the back-reef lagoon, through the barrier reef bodies to the continental slope environments with pelagic facies can be reconstructed. The Triassic carbonate platform complexes are thicker compared to other CWC units. This mature passive margin complex was, similarly as in other Slovakocarpathian units, destroyed by Early Jurassic rifting. The youngest sediments known are the Oxfordian radiolarites and olistostromes, Tithonian shallow-water limestones already representing the overstep sequence. The Silicic nappes are typically topped by the Early Senonian Gosau sediments, though these are only rarely preserved (Fig. 2). On the surface in the Vepor Belt, the Silicicum is represented by the Drienok nappe outlier that overthrusts the Choč nappe and the northern Veporic Veľký Bok (Lučatín) cover. The Muráň nappe in the central Veporicum overlies its Foederata cover similarly as the Stratená nappe along the NE margin of the Veporic dome. Here, a severe structural and metamorphic discordance exists between the unmetamorphosed Silicic nappes and the underlying Veporic complexes. From the reasoning regarding the time relations between the cooling ages of the footwall complexes and the age of the overstep Gosau sediments, which are generally coeval, a post-Gosau final emplacement of at least the Muráň and Stratená nappes has been proposed (Plašienka, 1997).

Gemer Belt

The Gemer Belt (Slovenské rudohorie Mts.-east, Slovenský kras Mts.) includes:

* the Gemeric Paleozoic (rarely up to Middle Triassic) basement/cover sheet;
* Late Paleozoic-Mesozoic successions of the Meliatic Jaklovce and Bôrka nappes;
* detachment cover nappes of the Silicic system;
* Senonian - Tertiary post-nappe cover.

Gemericum

The basement of the Gemericum sheet is composed of the Early Paleozoic to early Late Carboniferous, mostly low-grade metasediments and metavolcanics in-truded by small bodies of Permian granites. Structurally this basement is closely confined to lithologically and metamorphically similar Late Paleozoic volcanosedimentary successions grouped into several principal lithostratigraphic units. The erlier geological investigations (Grecula, 1982) and the seismic line 2T (Tomek, 1993 shows the Gemericum as a relatively thin nappe unit overlying the Veporicum. However, the line G1 (Vozár et al., 1996a), transecting its central part, reveals the Gemericum as a thick-skinned crustal sheet rooted in the

Meliatic suture. Although the Gemericum as a whole clearly overrides the Veporicum along the paleo-Alpine thrust contact known as the "Lubeník-Margecany Line", there is no general agreement about the age of its imbricated internal structure - either Late Variscan (e.g. Grecula, 1982), or Early Alpine (e.g. Ivanička et al., 1989), see also Németh et al. (this volume). The former view may be supported by some preserved Variscan $^{40}Ar/^{39}Ar$ muscovite ages from the Margecany Line (Dallmeyer et al., 1996).

The Early Paleozoic sedimentation basin (Grecula, 1982) indicates the fact that was formed in the vicinity of a rift which was originally of continental character with a successive transition into an oceanic rift. In the vicinity of the axial part of the rift there was formed a deep-water basin with oceanic crust and with successive development of the ophiolite complex (Rakovec complex, Klátov complex). The other parts of the b asin were formed on te transitory and continental type of crust with prevailing alkaline and calc-alkaline volcanism (Gelnica complex).

Three principal complexes are distinguished within the Early Paleozoic rocks: the Gelnica, Rakovec and Klátov Complexes (many authors use term group) which are embraced into the Volovec Group (Grecula, 1982; 1995; Fig. 4a). The lower part (Betliar Formation) is detritic composed of phyllite after black laminated pelite to silt. Pelitic phyllite occurs in the upper part with peculiar lydite and carbonate members. Carbonates are far more rare as lydites. The middle part of the Volovec Gropu (Smolník Formation) is made of variegated green phyllite, again mostly laminated. Beside that, the flysch psammite to pelite and psammite assemblages representing characteristic members of some nappes delimited together with volcanites of diabase-keratophyre formation occurring in the base of this formation. Upper part of the Volovec Group (Hnilec Formation) is built of volcanic rocks. These are represented from the base by a variegated volcanic complex present in all Early Paleozoic developments followed by spatially differentiated volcanites. Basic volcanites prevail in the north (Rakovec and Klátov Complex) whereas rhyolite, dacite and andesite build the sequences in the central and southerly parts of Gemericum (Gelnica Complex).

Attempts to determine the ages of Early Paleozoic basin filling were unsuccessful. According to palynologic data the black shale sequence is most frequently assumed to represent Late Silurian to Early Devonian (Snopková and Snopko, 1979) however sporomorph assemblages occupy also the age span from Cambrian to Carboniferous. Zircon ages from four rhyolite localities in the upper part of Early Paleozoic complex using Pb/U method are about 350 m.a, what is Late Devonian (Shcherbak et al., 1988). Other rock complexes may only be related to such dated levels from superposition as younger or older. The lower boundary of Early Paleozoic remains problematic in lithological as well as in stratigraphic sense. Isotopic rock age of source areas in the lower parts of Early Paleozoic is from clastic zircons of sandstone determined as about 650 m.a.

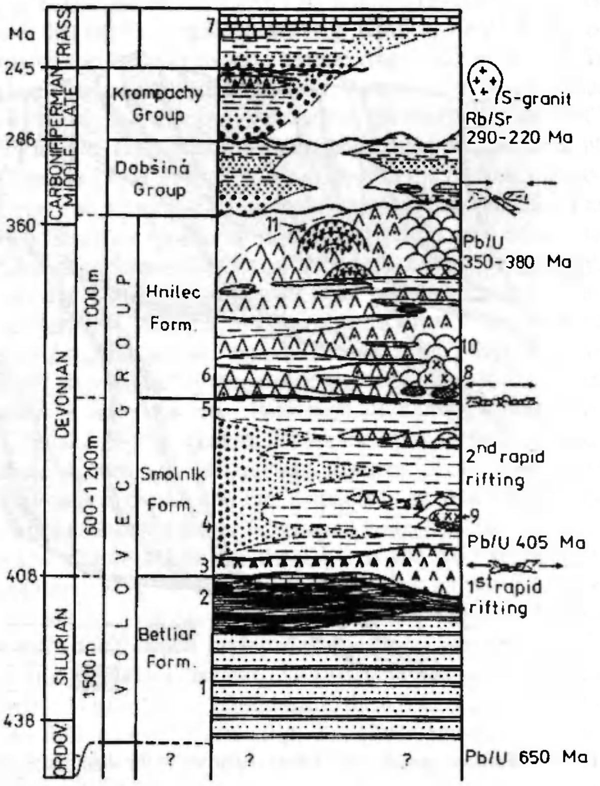


Fig. 4a. Paleozoic lithostratigraphic column of the Gemericum (Grecula, 1982). 1 - coarse laminated metapelite to metasandstone, 2 - - black schists with lydite and carbonate lenses, 3 - basalt-keratophyre volcanic rocks with stratiform ore-bearing horizont, 4 - psammitic and psephitic sequences, 5 - phyllites and schists, 6 - acid and intermediate volcanic rocks, 7 - carbonate; 8 - ultrabasic rocks, 9 - rhyolite and keratophyre, 10 - basaltic lava and pyroclastics, 11 - rhyolite domes.

(l. c.), hence the sandstone is younger. The upper part of Early Paleozoic should be Pre-Late Viséan (Kozur et al., 1976). The Late Paleozoic complexes are lying discordantly on the Early Paleozoic footwall.

The Late Paleozoic basin in the boundary zone of Gemericum and Veporicum was formed from beginning as one common sedimentary basin being gradually wider and filled (Grecula, 1994). The source of the material of sedimentary basin was represented by rock complexes of Gemericum and Veporicum. These were folded and metamorphosed before the origin of Carboniferous basin, so in the fundamental features also the Variscan nappe setting was completed. Generally also the present relations of Veporicum and Gemericum were fixed, i.e. the nappe overthrust of Gemeric units on the simultaneously formed nappe units of Veporicum.

The North Gemeric (Rakovec and Klátov terranes) Carboniferous complexes (Dobšiná Group; Vozárová and Vozár, 1988) consist from the Ochtiná Formation with both the conglomerate-shale and magnesite developments. The upper formations are distinctive mainly in the Dobšiná-Rudňany development of Carboniferous. They are represented by the Rudňany Formation (conglomerate-

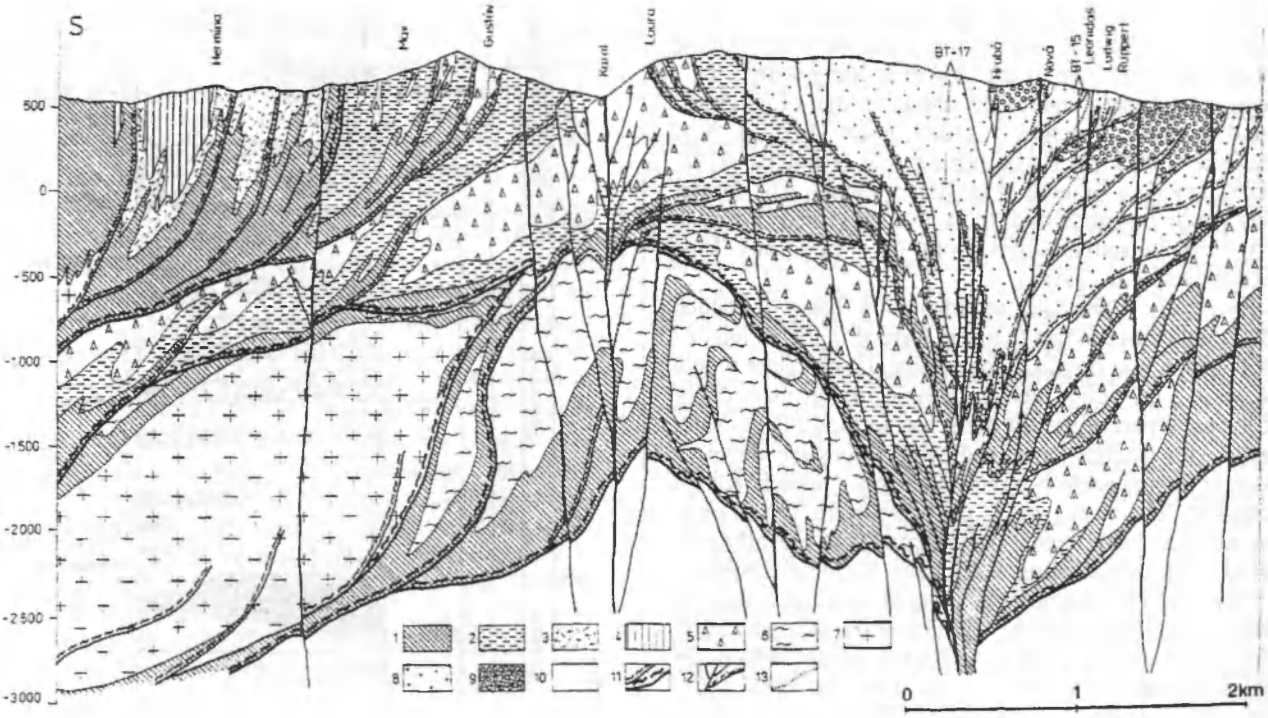


Fig. 4b. Variscan and Alpine tectonic strutures in the detail cross-section through the northern part of Gemeric area Nálepkovo - Bindt (Grecula, 1994), compiled using the geophysical modelling of the heavy, light and magnetic complexes (Grecula, Kucharič and Mikuška, 1992). 1 - formation of black metapelites, 2 - formations of the greenish metapelites, 3 - basalt-keratophyre volcanic complex, 4 - metapsammites, 5 - rocks of the diabase volcanism, 6 - gneisses and amphibolites (1 - 6 - Early Paleozoic), 7 - granite (Upper Carboniferous - Lower Permian), 8 - Carboniferous rock complexes, 9 - Permian complexes, 10 - footwal of the Rakovec nappe, 11 - Variscan nappe and overthrust sheets, 12 - faulting of nappes and nappes connected with Alpine transpression, 13 - ore veins (e.g. Max) of siderite-sulphidic formation.

-sandstone development), the Zlatník Formation (volcanic rocks) and the uppermost Hámor Formation (conglomerate-sandstone-shale development).The South Gemeric Permian-Early Triassic Gočaltovo Group in its lower part contains the Rožňava Formation (conglomerates, sandstones and shales).

The Permian sequences on the north ofGemericum are represented by the Krompachy Group. It is divided to the basal Knola Formation (conglomerate-sandstone formation), the Petrova hora Formation (volcanogenic rocks) and the Novoveská Huta Formation (shale-sandstone one).

Metamorphic overprint of Gemeric rocks occurred in several events. The assemblage of the gneiss (metasemipelite) and amphibolite distigueshed from the Late Devonian to Early Carboniferous (320-370 Ma; Kantor in Cambel et al, 1990). The mixture occurs as the relict of an earlier regional metamorphism-M1 of the a low-pressure (3-4 kbar) conditions, well dis-tinguished in the chlorite-biotite (500°C), biotite (550°C) and cummingtonite (650°C) zone, respectively (Radvanec, 1992; 1994).

During the Variscan collisional events a nappe tectonic style was formed (Figs. 4b and 4c; Grecula, 1982). Variscan nappes originated already before the beginning of Carboniferous sedimentation and their formation terminated before the beginning Permian to Triassic (Alpine) evolution cycle (Grecula, 1994).

Variscan nappes are fold nappes with characteristic structural and lithologic content reflecting certain parts of riftogenic sedimentary space. Central part of the rift basin with oceanic crust is represented in the Rakovec nappe. To the contrary, marginal parts of deep-sea depression preserved in the Kojšov nappe. Transition development with rock sequences of a passive continental margin is characteristic for the Mníšek nappe. Southerly nappes (Prakovce, Humel, Jedľovec and Medzev nappes) generated from sediments in dissected basin over continental crustal type.

Alpine destruction of Variscan nappes is significant (Grecula, 1997) within shear and transpression zones of NE and NW strike with fan-type of thrusts-faults (Figs. 4b and 4c). Large horizontal slips occurred along them. Shear zones of horizontal slip movements played the main role during Alpine events. They represent not only shear and slip zones but also that of spatial reduction generating local thrusts mainly in Permian and Mesozoic units. Shear zones and related deformations are very probably the result of global transpression during Paleo-Alpine events in the Western Carpathians.

The Mesozoic sedimentary cover of the Gemericum is poorly known and seldom preserved. It probably consists of shallow-marine clastics (Scythian) and presumably Middle Triassic carbonate platform sediments that occur in the western part of the Gemericum, below outliers of the Meliatic Bôrka nappe.

Meliaticum

The Meliaticum is represented by the Bôrka and Jaklovce nappe units (sensu Kozur and Mock, 1995, 1997; Mello et al., 1997; Németh, 1996 in the Gemer Belt, overlying the Late Paleozoic-Early Mesozoic cover rocks of the Gemericum. The Bôrka nappe is of eminent importance because of the presence of blueschists formed from the Middle Triassic basalts and Triassic-Jurassic slates (cf. Faryad, 1995; Faryad, Faryad and Henjes-Kunst, this volume). Some Meliatic nappe outliers contain bodies of dismembered ophiolites, including serpentinized peridotites and tholeiitic basalts of the inferred Middle Triassic age (Hovorka, 1979; Ivan et al., 1994). Late Paleozoic-Scythian metasediments and early Middle Triassic platform carbonates are also present. Triassic oceanic rocks lacking blueschists (Jaklovce unit) are located in a pinched synform in the NE part of the Gemer Belt (Fig. 2). However, they probably represent an outlier of a Meliatic nappe overthrust from the south, and not an independent "Folkmár suture" formed from the northern branch of the Meliata ocean, as assumed by Kozur and Mock (1995, 1997).

Silicicum

The Silicicum is represented by the Stratená nappe in the Stratenská hornatina Mts. and the Galmus zone along the northern periphery of the Gemer Belt. Several small outliers occur also in the central part (Končitá and Radzim hills, Opátka nappe in the east). The Silica nappe s.s. that occurs in the Slovak Karst region and in the Aggtelek Karst in northern Hungary is ranged already to the Meliata Belt of the Inner Western Carpathians. The dominantly Triassic carbonate complexes of the Silica nappe are locally topped by remnants of Senonian fresh-water limestones, conglomerates and pelagic marls of the overstepping Gosau group.

Inner Western Carpathians

The Inner Western Carpathians (IWC) encompass Paleozoic and Mesozoic sedimentary (mostly carbonatic) complexes showing affinity to the South Alpine and Dinaridic facies belts (e.g. Haas et al., 1995; Trunkó, 1996). They are unmetamorphosed or were only slightly metamorphosed during the Early Cretaceous (cf. Árkai et al., 1995; Lelkes-Felvári et al., 1996 and references therein). The boundary between the CWC and IWC is formed by the suture representing the Meliatic ocean. Because this suture is mostly covered, there is no general agreement about its along-strike trend. Most probably it follows some important subsurface geophysical anomaly zones Rába-Hurbanovo-Diósjenő-Plešivec-Rožňava-Trebišov (Fig. 2). However, based on the affinity of the Gemeric units to the southern Tethyan zones, most authors classify the Gemericum as a part of the IWC (e.g. Kozur and Mock, 1996, 1997). Some Hungarian authors infer that the Gemer-Bükk unit (e.g. Kovács, 1992a, 1997) is part of the Pelso (Pelsonia) terrane (e.g. Haas et al., 1995) which was assembled with other Western Carpathian units only during the Miocene to create the "North Pannonian Unit" (Csontos et al., 1992), later renamed as the ALCAPA Unit (Csontos, 1995). However, the Lubeník Line is clearly a pre-Tertiary structure and in spite of that several segments of the Meliatic suture which were reactivated during the Tertiary, no far-reaching lateral transport along it was proved. On contrary, close pre-Tertiary evolutionary links between the Pelso terrane and the CWC (e.g. margins of the Meliatic ocean present in both megaunits) and the presence of clastic material of the CWC provenance in some overstep sequences in the Pelso units (Transdanubicum - Paleogene, Bükkicum - Senonian; cf. Trunkó, 1996), speak rather for their pre-Tertiary juxtaposition. Accordingly, the present relations of the CWC and IWC units as depicted in Fig. 2 appear to be generally inherited from the Late Jurassic-Cretaceous collision stage.

The southern limit of the IWC is the Mid-Hungarian lineament (Fig. 2; Zagreb-Zemplín discontinuity belt of Grecula and Varga, 1979), a large-scale Tertiary dextral wrench fault which juxtaposes Western Carpathian units against the Tisia terrane (Tisza-Dacia Unit of Csontos, 1995). Within these boundaries, the IWC are subdivided into four tectonic belts (Fig. 2). These are the Meliata, Transdanubian (Bakony), Bükk and Zemplín Belts.

Meliata Belt

On the surface, the Meliata Belt covers the area of the Slovak Karst continuing to the Aggtelek Karst and Rudabánya Mts. in northeastern Hungary. From bottom to top, it is built up by:
* Triassic-Jurassic oceanic accretionary complex of the Meliaticum;
* Late Paleozoic to Jurassic active margin complex of the Turnaicum;
* Late Permian to Jurassic passive margin complex of the Silicicum;
* Senonian and Tertiary cover complexes.

Meliaticum

The outstanding tectonic importance of the Meliata unit s.s., as a representative of the Meliaticum superunit, was firstly recognized by Kozur and Mock (1973). It consists of numerous slices, olistostrome and mélange-like bodies and olistoliths of platform carbonates (Anisian), pelagic oceanic sediments (Late Anisian - Oxfordian) and dismembered ophiolites, all dispersed in mostly Jurassic distal flysch matrix (Kozur and Mock, 1997). Meliatic complexes show steeply dipping, generally fan-wise imbricated structure with clear top-to-the-north sense of shearing at the northern margin of the suture and with the opposite along its southern margin (Hók et al., 1995). Their upper parts have been partly incorporated into an evaporitic mélange (similar to the Haselgebirge of the

Eastern Alps; cf. Réti, 1985) at the sole of the overriding, generally flat-lying Silica cover nappe.

Turnaicum

Very low grade metasedimentary complexes of the nappe units classified generally as the Turnaicum (or Tornaicum, more-or-less corresponding to units designated by Kozur and Mock, 1997, as the "South-Rudabányaicum"), are regarded to be derived from the southern flanks of the former Meliatic ocean. They are composed of mid-Carboniferous wildflysch formation (Vozárová and Vozár, 1992a), Permian red-beds, mostly basinal Triassic carbonates and Jurassic flysch formations locally with small intrusions and abundant pebble material of calc-alkaline volcanics. The Turnaic nappes overlie, and in principle are parts of the Meliatic accretionary complex. The higher Silicic nappes show a distinct metamorphic and structural discordance at their bases.

Silicicum

The Silica-Aggtelek nappe is the type unit of the Silicicum, forming large karst plateaux at the Slovakian /Hungarian border. It is marked by Late Permian evaporites, very thick Scythian shallow-marine syn-rift sediments and a huge Triassic carbonate platform. The shelf edge setting of this platform is indicated by a distinct passage from the backreef and reef facies in the north (Wetterstein, Dachstein Fm.) to the slope and basinal pelagic facies in the south (Hallstatt, Zlambach Fm.). In general, the Silica-Aggtelek nappe covers subhorizontally the strongly disturbed and often subvertically oriented beds of the underlying Meliatic and Turnaic units (Reichwalder, 1982), though it is also affected by post-nappe large-scale folding related probably to Early Tertiary transpression. Some other smaller units of ambiguous position are sometimes affiliated to the Silicicum as well, namely the Bódva and Szőlősardó nappes (Kovács, 1997). However, Kozur and Mock (1987, 1997) range the Szőlősardó unit to their South-Rudabányaicum (i.e. Turnaicum).

Transdanubian Belt

Only the eastern part of the Transdanubian Belt (or Bakony Belt, cf. Kázmér, 1986) reaches the surface in the Balaton Highland, Velence, Bakony, Vértes and Gerecse Mts. and Buda Hills (known altogether as the Transdanubian Central Range), located to the SW of the loop of the Danube river (Fig. 2), and in several small islands east of the Danube near the village Csővár.

Transdanubicum

The belt is probably built up by a single tectonic superunit, the Transdanubicum (designated also as the Bakonyicum). The following rock complexes are present from bottom to top:

* rather hypothetical pre-Variscan high-grade crystalline basement;
* Early Paleozoic (from the Ordovician to the Early Carboniferous), only slightly metamorphosed volcanosedimentary formations (Balaton Highland), intruded by Late Paleozoic subalkaline granites (Velence Mts.);
* thick Permian to Cretaceous sedimentary cover complexes;
* Tertiary overstep sequences.

A wide stratigraphic range of the Early Paleozoic sediments and an absence of any stronger Variscan metamorphism and tectonism indicate the position of the IWC zones out of inner mobile Variscan zones. On the other hand, a thick crust below the Transdanubian Belt points to the presence of a continental basement under the Paleozoic formations. This might be the Cadomian or Panafrican basement of the "Southern Continent", a drifting Africa-related fragment in the lower plate position during the Variscan collision after locking of the South-Variscan (Massif Central, or Rheic, or Prototethys) ocean. This basement would be related to the Celtic terrane as a constituent of the Noric composite terrane (Frisch and Neubauer, 1989), and/or the Intra-Alpine terrain of Stampfli (1996). It may be inferred that this basement appears at the bottom of Tertiary basins between the Plešivec and Darnó lines (Fig. 2) around the Slovakian/Hungarian border where it was reached by some deep drillings and its fragments occur as xenoliths in Miocene andesites (Hovorka and Lukáčik, 1972). The Veporic provenance of these high-grade metamorphic rocks, proposed by these authors, seems to be less probable if the general course of the Meliatic suture is taken into consideration.

The Permian-Triassic succession of the Transdanubicum represents a strongly subsiding, extensive carbonate platform. The most conspicuous facies are Permian continental red-beds substituted by shallow-marine evaporites and dolomites in the NE direction, similarly as in the Belerophon Formation of the Southern Alps (Haas and Budai, 1995; Haas et al., 1995). These are overlain by the Scythian coastal deposits with restricted input of terrigenous material. An Anisian carbonate ramp was replaced by Ladinian-Early Carnian carbonate platforms and intervening pelagic basins with remarkable acidic volcanism (Buchenstein fm.) that reflect a rift event. Middle-Late Carnian marly formation with considerable terrigenous influx (Raibl event) that sealed the Ladinian rugged topography are followed by thick Norian-Early Liassic shelf carbonates. Pelagic Late Triassic facies occur in the SE part of the Transdanubian Belt (Buda Hills, Csővár islands, cf. Kozur and Mock, 1991; Kozur, 1993; Haas et al., 1997). They probably represent a shelf slope facies approaching the Tethyan oceanic realm.

The Jurassic-Early Cretaceous sediments of the Transdanubicum display variegated lithologies, often of the pelagic swell "Ammonitico Rosso" facies with numerous condensed horizons and hiatuses (cf. Császár and Haas, 1984; Kázmér, 1986; Trunkó, 1996; Faupl et al., 1997). At the northern periphery of the Transdanubian Belt (Gerecse Mts.), neighbouring the Meliatic suture, an outstanding Early Cretaceous succession occurs. It consists of coarsening-upward flysch sequence containing pebbles and heavy minerals of an ophiolitic provenance, interpreted as witnesses of the closing period of the Meliatic ocean located northwards (see review by Császár and Árgyelán, 1994, and references therein). Internal zones are marked by coeval Urgonian-type buildups. Several independent horizons of bauxite deposits originated during the Late Cretaceous.

Based on the surface data, the structure of the Transdanubian Belt seems to be quite simple, dominated by a large SW-NE trending megasynform with the core filled with Jurassic-Cretaceous sediments. Pre-Mesozoic complexes crop out along the SE limb of this pre-Senonian structure (Balla and Dudko, 1989). This limb is also complicated by SE-verging reverse faults. The northern, covered limb juxtaposing the Rába-Hurbanovo Line may have a nappe structure (reactivated as extensional low-angle faults during the Late Tertiary), as inferred from the seismic data (Horváth, 1993) and from the near-suture position. However, Balla (1994) considers the Rába Line as a subvertical wrench-fault. The western part of the megasynform is sealed by the Senonian sediments of the Gosau group. Late Cretaceous lamprophyre dykes penetrate the Velence granite and Mesozoic sediments (Horváth and Ódor, 1984; Kázmér, 1986). In the eastern part, the overstepping sequence began by Eocene transgression.

Bükk Belt

The principal Bükk Belt (Igal-Bukk in a broader sense), exhibited in the Darnó, Uppony, Szendrő and Bükk Mts. of northeastern Hungary, comprises:
- very low-grade Paleozoic complexes;
- Mesozoic formations of several nappe units;
- Senonian post-nappe sediments (Uppony Mts.);
- Tertiary overstep sedimentary and volcanic complexes.

The Ordovician-Permian sediments and rare volcanics occur in the northern part of the belt (Fig. 2). During the Variscan orogeny, they mostly represented a carbonate platform (Uppony Mts.) of the passive margin of the "Southern Continent" terminated by syncollisional mid-Carboniferous flysch (Szendrő Mts., akin to the Hochwipfel flysch formation, cf. Kovács, 1992b; Ebner, 1992). An overstepping Permian sequence consists of red-beds and shallow-marine carbonates. However, only Alpine tectonism and metamorphism is documented (Árkai et al., 1995). Therefore the presence of a pre-Variscan basement in the deep substratum is likely.

Bükkicum

Mesozoic (Triassic - Jurassic) successions are generally grouped into the Bükkicum (Bükkium) superunit, consisting of two principal types of units. The lower "Bükk Paraautochthon" (Fennsíkum in terminology of Kozur and Mock, 1987, 1997) represents a Triassic carbonate platform complex with noteworthy Ladinian calc-alkaline volcanism. The platform was drowned by the Early Jurassic and basinal pelagic sediments, often radiolarites deposited until the Oxfordian. The paraautochthonous units show an imbricated structure with a distinct southern vergency in the Bükk Mts., opposite to the thrusting polarity recorded in the northerly exposed Paleozoic complexes of the Szendrő Mts. These are overlain by outliers of the Szarvaskő-Mónosbél nappe system (Csontos, 1988), consisting of dismembered ophiolite complexes, including pillow-lavas of the Jurassic age (Balla et al., 1983; Downes et al., 1990), but slivers of Triassic oceanic rocks are present as well (Darnó Mts. - Dosztály and Józsa, 1992). These ophiolites probably represent obducted fragments of the oceanic crust of a back-arc basin opened due to southward (partly intra-oceanic?) subduction of the Meliatic ocean during the Jurassic (Fig. 7). The back-arc was closed immediately after suturing of the Meliatic ocean in this area. However, it may have extended southwestwards to connect the Dinaridic-Vardar ocean that was closed considerably later.

In the NE part of the Bükk Mts. a nappe outlier of Late Triassic platform carbonates occurs, described as the Silicic Kissfensík nappe (Csontos, 1988). However, the Silicic affiliation of this outlier has not been confirmed (cf. Kovács, 1997).

The Bükk Belt extends SW-ward into a strip between the Balaton-Darnó and Mid-Hungarian Lines, the so-called Middle Transdanubian unit or the Igal zone. It is completely covered with Tertiary sediments, according to borehole data it consists of strongly disturbed and internally variable complexes of dominantly Triassic formations showing contrasted affinities to neighbouring units (cf. Bérczi-Makk et al., 1993). The northern part is composed mostly of Late Paleozoic-Triassic platform carbonates, the southern strip involves basinal sediments, olistostromes and dismembered Mesozoic ophiolites affected by a very low-grade metamorphism (Kázmér, 1986; Árkai et al., 1991). Probably the Igal zone, its southern part in particular, represents an imbricated suture complex connected SW-ward with the northernmost exposures of Dinaridic ophiolites (Pamić, 1997).

Zemplín Belt

The position and connections of the last, Zemplín Belt of the IWC, are controversial. The only small surface exposure of this belt in the Zemplínske vrchy Mts. in south-eastern Slovakia exhibits high-grade crystalline basement rocks of possibly pre-Variscan age (see Faryad and Vozárová, this volume). The Carboniferous of the Zemplinicum is represented by the Stephanian with the fluvial-limnic type sediments, characterized by greywacke-arcose association of rocks and by a horizon of black shales with coal layers. There is gradual transition to the Permian. The Permian is variegated in continental

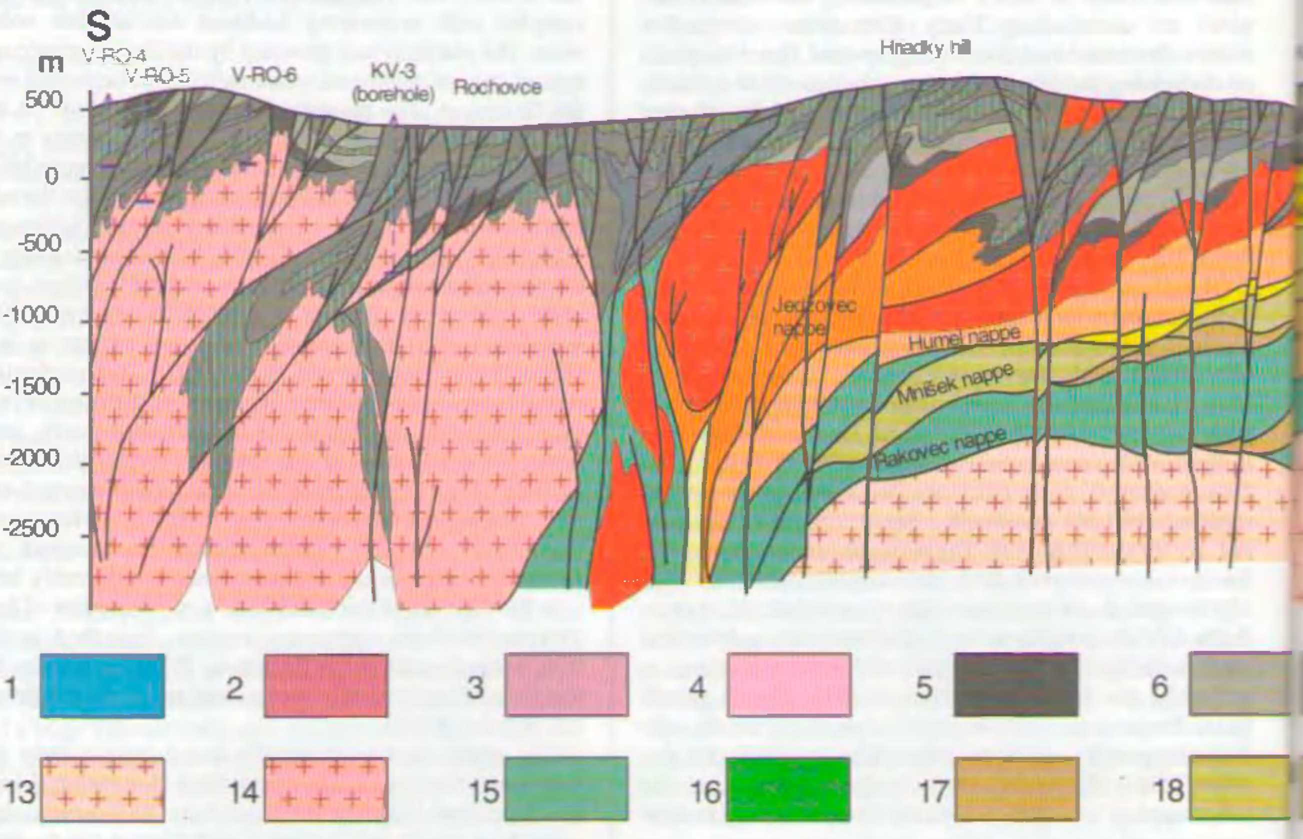
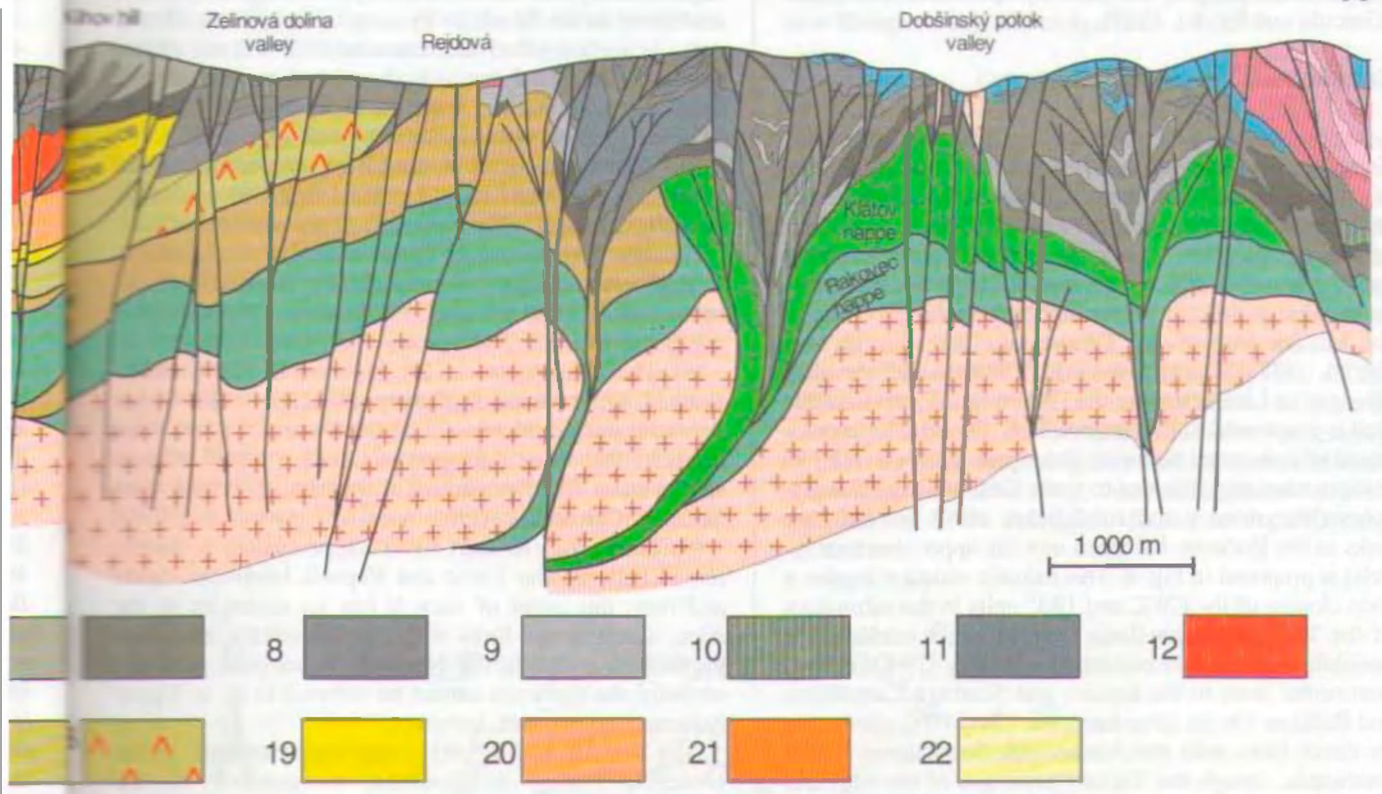


Fig. 4c. Variscan (nappes) and Alpine (fan-thrusts and overthrusts) tectonic style depicted on the north-south trending profile through the western part of Gemericum (G
1994). Variscan nappes with the Early Paleozoic rock sequences and their tectonic overprint in Alpine transpressional zones together with the Late Paleozoic and Trias
quences. 1 - Triassic carbonates and shales, 2 - violet and reddish basal conglomerate with the attitude of sandstones and shales, 3 - green and violet shales, 4 - acid and
mediary volcanics (2-4 - verrucano facies in the northern part of Gemericum), 5 - polymict conglomerate with the attitudes of arcose sandstones and schists, 6 - quartzite
the intercalations of arcose sandstones, 7 - black and grey laminated schists with the intercalations of sandstones, 8 - alternation of black schists and micaceous sand
9 - grey and black micaceous sandstones, 10 - green laminated schists, 11 - fine-grained green (often amphibolitic) sandstone with the clasts of amphibolites and meta
(5-11 - Late Paleozoic with the overthrust and fan-like tectonic style in Alpine transpression zones), 12 - Gemeric granite (Upper Carboniferous-Permian) as a part of V



um (Gn... 13 - granites and crystalline schists of Veporicum. 14 - Upper Permian and Jurassic-Cretaceous granite blocks in Alpine tranpression zone. Variscan nappes (consis-
d Trias... the Early Paleozoic rocks of Gemericum): 15 - Rakovec nappe (Rakovec ophiolite complex: metabasites, various types of phyllites, rarely metagabbros, amphibolite,
cid and ... jasper), 16 - Klátov nappe (Klátov amphibolite-gneiss complex), 17 - Kojšov nappe (deep-water metapelites, rarely volcanic rocks), 18 - Mníšek nappe (metasilt-
uartzite... and metapelites, bimodal volcanic complex, porphyroid, large bodies of K-rhyolites), 18a - rhyolite complex of the Mníšek nappe. 19 - Prakovce nappe (thick complex
s sands... metasandstones and graywackes, porphyroids), 20 - Humel nappe (laminated metasiltstones, black schists, lydites, carbonates, locally rich siderite deposits), 21 - Jedľovec
d metab... metasandstones, black and green schists, lydites, rarely gabbrodiorite, basalt-keratophyre complexes, stratiform polymetallic deposits), 22 - Medzev nappe (metapeli-
t of Va... porphyroids), 14-18 - Gelnica complex.

Fig. 4d. 2D gravimetric and magnetic model of the western part of Gemericum used for construction of the profile on Fig. 4c (Mikuška and Kucharič, 1992 in Grecula, 1994). 1 - light mass, 2 - heavy mass, 3 - magnetic light mass, 4 - magnetic heavy bodies.

to lagoonal facies with acid volcanics. Conglomerates, sandstones and quartzites occur in the Early Triassic and higher is developed the Triassic platform carbonates (Grecula and Együd, 1977).

Zemplinicum

According to deep reflection seismic data, the Zemplinicum superunit overthrusts units in the substratum of the Neogene Transcarpathian Basin, including the Iňačovce-Krichevo unit (Vozár et al., 1996b). Lateral links of the Zemplinicum are ambiguous, however. Vozárová and Vozár (1988, 1992b) considered it to be a Veporic element, whereas most other researchers found it to be akin to the Mecsek Belt of the Tisia terrane (e.g. Grecula and Együd, 1977; Grecula and Varga, 1979). Along the Mid-Hungarian Line bounding the IWC from SE, the Zemplín Belt is juxtaposed to the Szolnok Belt (Fig. 2). This is composed of imbricated Senonian-Paleogene mostly flysch formations showing affinities to some Central Carpathian flysches (Nagymarosy and Báldi-Béke, 1993). Evolutionary links to the Iňačovce-Krichevo unit (its upper structural levels) is proposed in Fig. 8. This tectonic situation implies a loop closure of the CWC and IWC units in the substratum of the Transcarpathian Basin (Fig. 2) which excludes the possibility of a direct continuation of any CWC or IWC continental units to the Eastern and Southern Carpathians and Balkans. On the other hand, the CWC-IWC system has its direct links with the Austroalpine-Southalpine system westwards, though the Tertiary evolution of the Alps and the Western Carpathians differed considerably.

Links of pre-Tertiary units

Assuming the general trends of paleogeographic and paleotectonic evolution and lateral structural links of units building the Western Carpathians as defined above, the principal tectonic superunits may be grouped into several orogenic-scale tectonic systems showing the following connections:

(1) The Western Carpathian Foredeep is a part of spectacular double-loop of frontal molasse zones of the Alpine and Carpathian oroclines;

(2) The Silesian-Krosno units of the OWC are Carpathian of their own, wedging out by the Waschberg zone in the easternmost Alps, but widening eastwards to build up the **Moldavide system**, the main constituent of the Outer Dacides in the Eastern Carpathians;

(3) The Magura units, on the other hand, have direct links to the Rhenodanubian flysch zone in the Eastern Carpathians, but disappear eastwards by merging with the PKB in Ukraine;

(4) The Pieniny Klippen Belt, the Oravic units in particular, are typical for the Western Carpathians only, in both the evolutionary and structural aspects;

(5) The Vahic Belice and Iňačovce-Krichevo units of the CWC are regarded to be Penninic oceanic elements occurring in tectonic windows.

In a broader sense, the Magura, Oravic and Vahic units represent the Western Carpathian **Pennine system**. Geometrically, but not evolutionary, the Magura system is analogous to the Northern Peninic (Valais) zone, Oravic units were sheared off an intraoceanic continental ribbon similar to the Briançonnais high and Vahic oceanic units show many similarities with the units derived from the Ligurian-Piemont ocean in the Alps and Apennines.

(6) The Tatricum is a crustal sheet present in the Western Carpathians only, but the Infratatric units may be well correlated with the Lower Austroalpine units;

(7) The Veporicum, a large crustal-scale basement wedge best corresponds to the Middle Austroalpine basement units with the typical Cretaceous metamorphic overprint;

(8) The Gemericum is the highermost CWC thick-skinned nappe sheet displaying affinities to the Upper Austoralpine basement units in the Central Eastern Alps (Gurktal and Graz nappe systems) and partly also to some units of the Grauwackenzone underlying the Northern Calcareous Alps;

(9) The Fatric (Krížna) cover nappe system is clearly rooted between the Tatric and Veporic basement sheets and from this point of view it has no analogies in the Alps, albeit facies links with the Kieselkalk zone and Frankelfels nappe in the Northern Calcareous Alps are obvious; the Fatricum cannot be referred to as an Upper Austroalpine element, however;

(10) The Hronic (Choč) cover nappe system, if the Mesozoic history is assumed, corresponds to the Bajuvaric-Tirolic nappe system of the Northern Calcareous Alps, though considerable differences exist, too (e.g. the huge Late Paleozoic volcanosedimentary Ipoltica Group, nowhere present in the Alps);

(11) Nappes of the Silicicum are correlable with the Upper Austroalpine Juvavic nappes in both the lithostratigraphic and structural (overriding of Meliatic elements) aspects.

The units labelled (7) - (11) are essential for the central zones of the Eastern Alps and Western Carpathians. The commonly used term "Austroalpine units" is plausible for them. Nevertheless, taking into account considerably different Tertiary history of the CWC with respect to the Alps, namely the almost unchanged Cretaceous edifice of the CWC, we adopt the new term **Slovakocarpathian system** proposed by Kozur and Mock (1997). No lateral connections with the Eastern Carpathian units are demonstrable for this system.

(12) The position and lateral links of units coming from basins and margins of the Meliatic oceanic realm belong to the most debated in the recent Alpine and Carpathian literature. The units ranged to the Meliaticum itself represent an important oceanic suture, therefore they should be considered as a principal dividing element in the Carpathian edifice. Unfortunately, there is no general agreement about the lateral prolongations and links to the Triassic-Jurassic Tethyan oceanic system of the Meliatic ocean (compare, e.g. Kovács, 1997, and Kozur and

Mock, 1997; the whole problematics is thoroughly reviewed also by Trunkó, 1996). Before things will be more clear, we suggest to use a provisional term **Meliata system** for the Meliaticum s.s. (incl. the Bôrka and Jaklovce nappes in the CWC Gemer Belt), Turnaicum (South-Rudabányaicum) and units derived from the Szarvaskő back-arc basin.

(13) The uppermost Austroalpine to South-Alpine affinities of the Transdanubicum were postulated by many authors;

(14) The Bükkicum, more precisely the Bükk "paraautochthonous" units, display a lot of Dinaridic features;

(15) The questionable position of the Zemplinicum was already mentioned, we infer its more-or-less independent position with respect to both the CWC and the Tisia terrane.

Although important wrench movements may have taken place along the sutures of the Meliata system during the Tertiary, the units from their both sides display close interrelationships in the Alpine, and even in the pre-Alpine times. We therefore consider all the units described to belong to single, the Western Carpathian orogenic framework. For the last three, innermost Western Carpathian superunits we propose the unifying term **Hungarocarpathian system**.

Overstep complexes

Subsequent to the main periods of deformation of the underlying units, the overstep sequences also exhibit general younging from the inner towards the outer Carpathian zones. For the IWC and CWC, the post-nappe cover starts with Early Senonian sediments of the **Gosau Group**. However, these are only rarely preserved along the outer margin of the CWC and in the IWC (Fig. 2), and most of the CWC are covered only by deposits of the **Central Carpathian Paleogene Basin** (CCPB). CCPB sediments include Early Eocene transgressive, southwards younging carbonate clastics and nummulitic limestones followed by thick deepening Eocene-Oligocene turbiditic flysch complex. In the IWC, these are replaced by sediments of the **Buda Paleogene Basin**. In the PKB, the

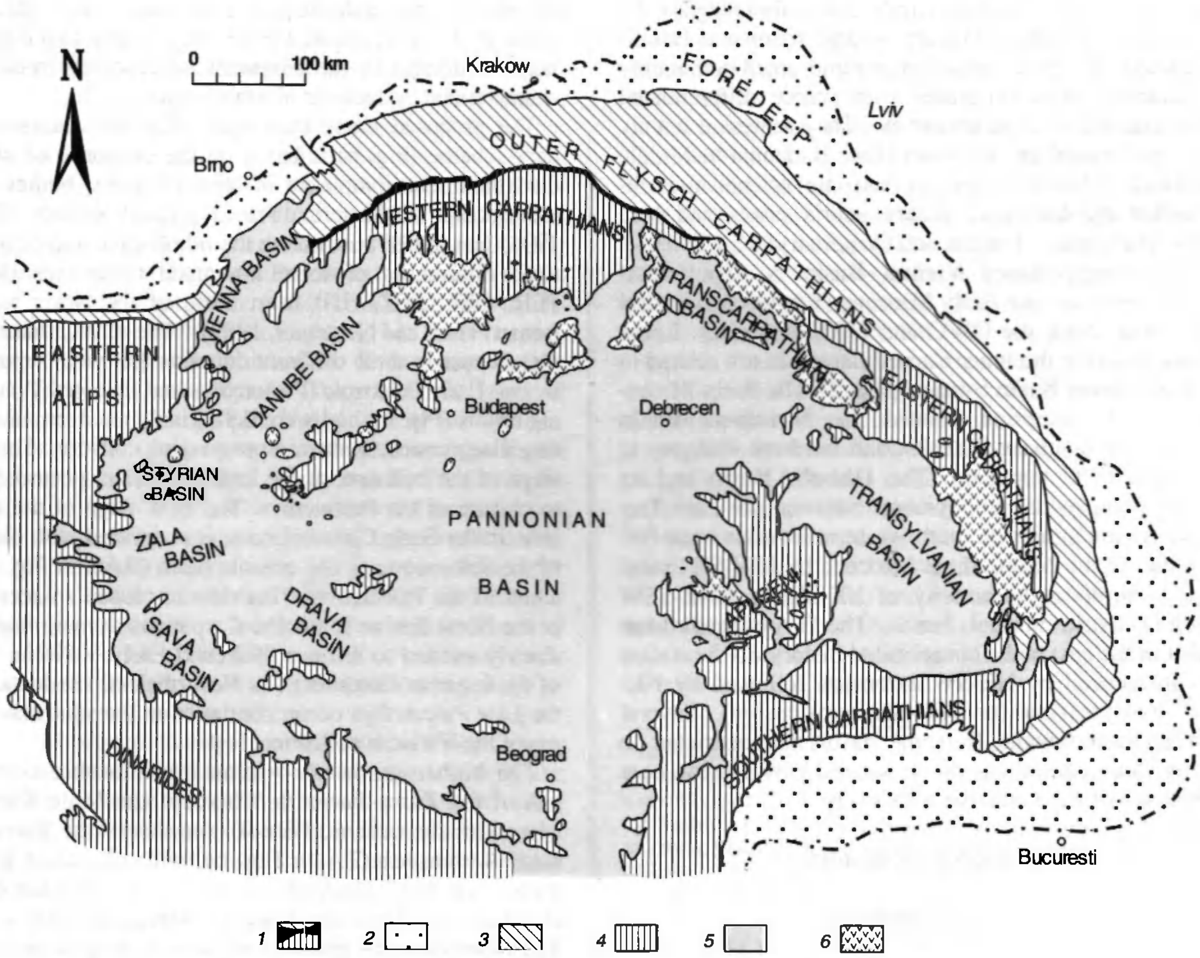


Fig. 5. General distribution of the Late Tertiary basins in the Carpathian realm. 1 - Pieniny Klippen Belt, 2 - Tertiary Molasse Zone, 3 - Flysch Belt, 4 - pre-Neogene units of inner orogenic zones, 5 - Neogene basins, 6 - neovolcanic areas.

Senonian and part of the Paleogene rocks are involved in thrust tectonics and the overstep complex begins with the Early Miocene sediments. These were furthermore deposited in the compressional basins of the wrench furrow type (Marko et al., 1991). In the OWC, Early Miocene rocks are only partly affected by out-of-sequence thrusting in the inner Magura Belt, but largely incorporated in the Silesian-Krosno nappes. The outermost Carpathian Flysch nappes, representing the disturbed inner parts of the molasse foredeep, also involve Sarmatian deposits.

During the Miocene thrusting in the OWC, the hinterland Carpathian zones were largely influenced by lithospheric stretching, basin formation and volcanism (see review by Kováč et al., this volume). The Western Carpathian neovolcanics are generaly divided into four types (Lexa et al., 1993). Dacite and rhyolite areal type volcanism associate with the initial stage of the back-arc extension (Early Miocene). Areal type of andesitic volcanism is represented by widespread association of intermediate to basic andesites predominantly forming stratovolcanoes with considerable con-tent of differentiated rocks and subvolcanic intrusive rocks (Early Badenian - Early Panonian). From the geotectonic point of view, the areal type of andesitic volcanism can be indirectly related to the subduction of Pieniny-Magura oceanic basement. Basalt-andesitic to andesitic volcanism is represented dominantly by andesitic stratovolcanoes with scarce differentiated rocks and subvolcanic intrusives. They represent mainly developed island arc volcanics (Late Badenian to Middle Sarmatian). Alkali-basaltic to basanitic volcanism is represented by diatremes, maars, scoria cones and lava flows (Pannonian - Pontian and Quaternary).

The lozenge-shaped **Vienna Basin** is a pull-apart basin formed by late Early Miocene (Karpatian) sinistral wrenching along the OWC and CWC boundary. Large basins covering the inner Carpathian zones are related to the **Pannonian Basin System** (Fig. 5). The Early Miocene NE-SW extension opened the **Novohrad Basin** (Nógrád) in southern Slovakia and northern Hungary at the CWC/IWC boundary. The **Danube Basin** and its northern finger-like embayments between pre-Late Tertiary core mountains of south-western Slovakia were formed during the Middle-Late Miocene by NW-SE extension, controlling the activity of NE-SW to NNE-SSW trending listric normal faults. The **Transcarpathian Basin** in the east had a complicated history, its formation was influenced by NE-SW extension followed by NE--SW transpression (or NW-SE transtension). Several smaller intramontane Neogene basins are restricted to western and central Slovakia, located between the core mountains of the Tatra-Fatra Belt (Fig. 5).

Paleotectonic history

Paleozoic evolution

According to the present views, the Western Carpathian pre-Alpine basement developed generally in the inner and southern outer Variscan zones of Central Europe (e.g. Plašienka, 1991; Vozárová and Vozár, 1992b; Ebner, 1992; Putiš, 1992, 1994; Bezák, 1994; von Raumer and Neubauer, 1993). The inner zones consist of three main generalized superposed lithotectonic units (Bezák, 1994; Bezák et al., this volume): (1) the gneisso-migmatitic Upper Unit intruded by granitoids, (2) the Middle Unit composed of gneisses, mica-schists, grani-toids and subordinate low grade metamorphic rocks, (3) the greenschist facies Lower Unit. These were formed by meso-Variscan (380-340 Ma) collisional crustal thickening and overprinted by neo-Variscan (340-260 Ma) hinterland extension and emplacement of granitoid plutons. The overthrust plane of the Upper Unit is often accompanied by the presence of the "leptynite-amphibolite complex" (LAC - Hovorka et al., 1992a, 1994, and this volume) and scarce remnants of rocks metamorphosed in eclogitic or granulitic facies (cf. Hovorka et al., 1992a; Janák et al., 1996; Putiš et al., this volume). These high grade rocks are believed to represent original lower crus-tal complexes exhumed due to Variscan collision along the "Main Variscan Thrust Plane" (Hovorka et al., 1994). This thrust plane is best exposed in the Tatra Mountains, where the associated high-grade ductile shear zones indicate top-to-the-south thrust stacking (Fritz et al., 1992; Janák, 1994). The pre-granitoid contractional structures in the basement metamorphic rocks are characterized by Jacko et al. (this volume).

The proposed Early Paleozoic-Carboniferous evolutionary scheme (Fig. 6) is based on the existence of individual basement complexes in form of nappe bodies. The introduction of the term "Pre-Carpathian terrane" (Putiš, 1994) was aimed at stressing the lithological and paleotectonic differences of some low-grade complexes (RAK, PER, GEL, PEZ, HD) from those of the Noric terrane (sensu Frisch and Neubauer, 1989). The CWC basement rocks occur in three different domains that were separated by two Early Paleozoic (Prototethys and Paleotethys) oceanic basins (Fig. 6), and were definitively amalgamated during diachronous southward progressing collision. The first stage of the collision, at the Late Devonian, occurred due to closure of the Prototethys. The next stage of the collision, in the Early Carboniferous, is connected with closure of the Rakovec back-arc oceanic basin (RAK in Fig. 6) as a part of the Paleotethys. This closure caused an accretion of the Noric terrane to the Pre-Carpathian domain that was already welded to the overthickened Early Variscan crust of the Ligerian Cordillera (?). Nevertheless, subduction of the Late Paleotethys ocean continued at the southern margin of the Variscan collisional belt.

The higher grade pre-Alpine metamorphic complexes of the *Tatra-Fatra Belt* (except the Malé Karpaty Mts. with the oceanic Pernek complex) - the Tatra basement complex (TA in Fig. 6), with abundant granitoids, exhibit similarities with the Moldanubian, Helvetic and Penninic domains. Metasediments of the Tatra complex are inferred to have originated in a former passive, later an active margin with dominant greywackes and pelites.

The varied medium-grade basement complexes of the *Vepor Belt* resemble, at least partly, the Austroalpine complexes. Variable lithologies of the LAC (basic, intermediate, ultramafic, less pelitic protoliths, Fig. 6) and the Čierny Balog complex (pelitic-psammitic, tonalitic, acidic, less basic protoliths, Fig. 6) could indicate an Early Paleozoic (back-arc?) rifting of a continental margin. The Hron-Kokava terrane complexes developed on a large passive continental margin characterized by a few km thick flyschoid sequence (especially the Hron complex), less carbonatic-skarnoid, basic, ultramafic and black shale intercalations (Kokava complex).

Part of radiometric data within the North Veporic basement indicate pre-Variscan protolith ages of some Devonian-Carboniferous metamagmatic rocks. For example layered metadiorites-amphibolites of the Veľký Zelený potok complex (LAC) contain a zircon population which consists of transparent euhedral or subeuhedral prismatic pink-brown zoned grains. They appear to be of magmatic origin. The fractions define a discordia line with a lower intercept age of 346 ± 0,9 Ma (Kotov in Putiš et al., 1996, and this volume), interpreted as the primary emplacement age, or closely dating the age of immediately followed amphibolite facies metamorphic recrystallization. An upper intercept age of ca 514 Ma (one group, Kotov, personal communication) and 2066 Ma (another group) demonstrates the presence of older zircon component in the source rocks of those metadiorites. Similarly, the rhyolite-dacite volcaniclastics of the Gelnica complex contain zircons of a wide age spectrum: 352-577 Ma (U-Pb, Cambel et al., 1990; Shcherbak et al., 1988) indicating the Early Carboniferous to Precambrian source rocks.

The leptynite-amphibolite complexes (LAC) are usually located at the soles of the higher-grade metamorphic crustal sheets, e.g. the basis of the Tatra nappe in the Nízke Tatry Mts,- and Vysoké Tatry Mts.; the basis of the Čierny Balog nappe (the Veľký Zelený potok complex), or they formed an individual Klátov nappe thrust over the Rakovec one (Figs. 3g, 4c and 6). Therefore the presense of LAC might indicate collisional suture zones within the thinned active continental margin occurring north of Prototethys (Stampfli, 1996) and/or within the "Ligerian Cordillera" (Matte, 1986, 1991). Some relics of high-pressure rocks - retrograded eclogites (Hovorka et al., 1989; Janák et al., 1996 and this vol.; Putiš et al., this vol.) could reflect an advanced collisional stage or an overthickened continental crust.

The postorogenic collapse in the inner Variscan zones of the ancestral Western Carpathians is marked by the formation of large anatectic granitoid plutons of either the Early Carboniferous (within the Tatra complex; cf. Cambel et al., 1990) or Late Carboniferous-Early Permian age (within the Čierny Balog complex; cf. Bibikova et al., 1990; Petrík et al., 1994; Kotov et al., 1996; Kráľ et al., Petrík and Kohút, this volume). This indicates a southward migration of orogenic processes that is interpreted as a south-vergent collision (Fritz et al., 1992; Putiš, 1992). An earlier stage of postcollisional collapse is also documented by $^{40}Ar/^{39}Ar$ cooling data on amphiboles (357 ± 0,6 Ma, Dallmeyer et al., 1993, 1996) from amphibolite of the Veporic basement (Veľký Zelený potok complex). A later stage of ca. 330 Ma was dated by the same method on muscovite of a granitic orthogneiss from the Tatra complex (Fig. 6) in the Nízke Tatry Mts. (Dallmeyer et al., 1993, 1996).

In general, four genetically related groups of Variscan granitoids are distinguished within the Western Carpathian pre-Alpine basement (Petrík et al., 1994; Uher and Broska, 1996; Petrík and Kohút, this volume). The oldest group (ca. 380-400 Ma) embraces S-type peraluminous, ductile deformed orthogneisses. The second group is represented by somewhat younger (around 350 Ma) undeformed anatectic granites and granodiorites closely related to the main metamorphic events, the third group consists of younger (ca. 300 Ma) large granodioritic to tonalitic massifs approaching the I-type, with typical mafic enclaves. The last group is formed by isolated smaller bodies of A-type postorogenic granites related to Permian rifting (280 Ma and younger) and the special Gemeric Sn-bearing S-type granites.

The Gemeric basement complexes are akin to the Noric terrane complexes (e.g. to the basement of the Southern Alps, low-grade complexes of the Upper Austroalpine Graz Paleozoic unit and the Grauwackenzone, as well as in the IWC Transdanubian and Igal-Bukk Belts; cf. Frisch and Neubauer, 1989; von Raumer and Neubauer, 1993).

In the southern accreted domain the Early Paleozoic basin (Grecula, 1982) has been formed in the vicinity of a rift (?450 Ma) within a Pre-Carpathian terrane which was originally of continental character with a successive transition into an oceanic rift (420-400 Ma). At the same time, the Paleotethys ocean separated the Pre-Carpathian and Noric terranes. In the vicinity of the axial part of the rift there was formed a deep-water basin with oceanic crust and with successive development of the ophiolitic complex (380-350 Ma; Rakovec complex) in a back-arc position (Ivan, this volume) with respect to the Paleotethys northward subduction which started in the Late Devonian[1]. The other parts of the basin were formed on the transitional and continental type of the crust with prevailing flyschoid sedimentation and calc-alkaline and alkaline volcanism (Gelnica complex). The Gelnica complex deposited probably at the distal nor-

[1] Radvanec (1997a, b) presented a model in which the northward subduction of a Paleozoic oceanic domain in the inner Western Carpathians zones persisted until the Early Mesozoic and was followed by Triassic collision and Jurassic exhumation of high-pressure metamorphics. Blueschist facies rocks in both, the northern Gemericum and Meliata units are regarded as the records of the only one, Late Paleozoic to Mesozoic subduction/collision process, and only the Carboniferous age of their protoliths is assumed. However, this model considers only the metamorphic signatures of the units dealt with. It does not take into account the general structural-tectonic evolution of the area and its time constraints, especially the Permian, Triassic and Jurassic protolith ages of the Meliatic blueschists.

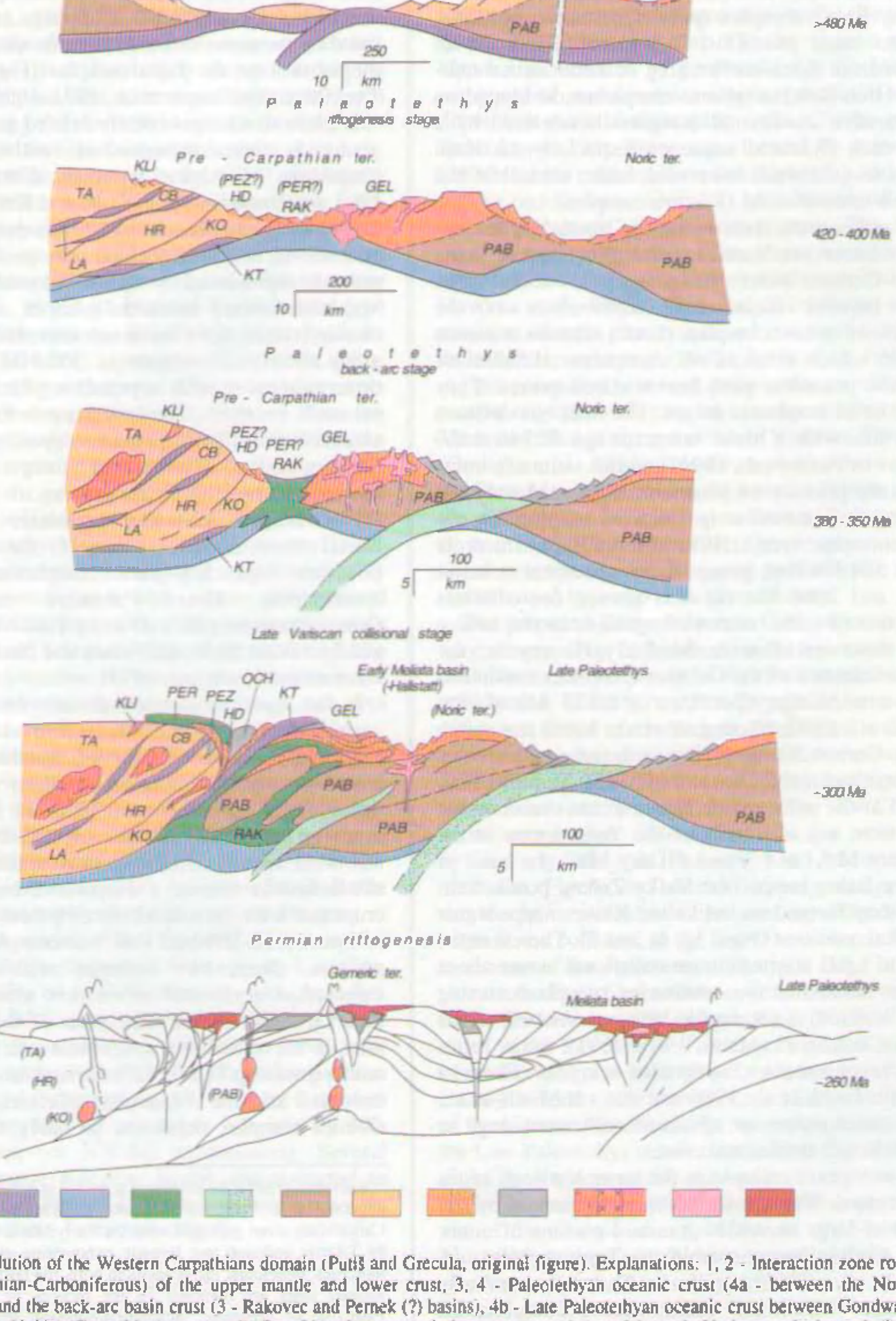


Fig. 6. Paleozoic evolution of the Western Carpathians domain (Putiš and Grecula, original figure). Explanations: 1, 2 - Interaction zone rocks (1 - Pre-Devonian, 2 - Devonian-Carboniferous) of the upper mantle and lower crust, 3, 4 - Paleotethyan oceanic crust (4a - between the Noric and Pre-Carpathian terranes) and the back-arc basin crust (3 - Rakovec and Pernek (?) basins), 4b - Late Paleotethyan oceanic crust between Gondwana promontory and Variscan Pre-Alpidic (Carpathian) terranes. 5 - Panafrican basement. 6 - basement complexes of the early Variscan collision belt. 7a - Paleozoic complexes of the Late Variscan collisional stage (Pre-Carpathian terrane metamorphic complexes and the Noric terrane slightly to unmetamorphosed complexes are undivided). 7b - Pre-Carpathian terrane complexes. 8 - Carboniferous complexes. 9a - Early Carboniferous granitoids. 9b - Late Carboniferous granitoids. 10 - plutonic-volcanic igneous rocks. 11 - Permian (Early Triassic). Abbreviations of basement complexes: TA = Tatra, LA = = Leptynite-amphibolite, CB = Čierny Balog, HR = Hron, KO = Kokava, KLI = Klinisko, PEZ = Pezinok, PER = Pernek, HD = Hladomorná dolina, RAK = Rakovec, KT = Klátov, OCH = Ochtiná, PAB = Panafrican basement. Chronostratigraphical table was used after Gradsteine and Ogg, 1996.

thern margin of a Gondwana related continental fragment with an older Cadomian (or Panafrican) basement which could be a provenance of the material filling of the Gelnica basin (U/Pb age of clastic zircons from metapsammites is 650 Ma. Shcherbak et al., 1988).

Subduction of the Paleotethys ocean lasted up to the Triassic and finally led to opening of the Meliatic ocean (Figs. 6 and 7). The Early Variscan convergent processes created the accretionary terrane from Early Paleozoic sedimentary-volcanic sequences. This terrane represented the basement on which from the original Rakovec and Klátov oceanic space originated the isolated Late Carboniferous sedimentary areas of the remnant basin type (Grecula, 1987, 1994; Vozárová and Vozár, 1992) or collision and post-collision basins (Vozárová and Vozár, 1997). These basins originated in the zone of obducted ophiolite suite and this environment essentially affected also lithological filling of remnant basins (redeposited material of the Early Paleozoic basic rocks). Post-convergent tectonic events in the western and southern parts of Gemeric domain caused the development of basins of extensional type, transversally oriented to remnant basins (Nižná Slaná depression; Grecula, 1994). In the eastern part of Gemericum the Carboniferous Črmelicum basin is regarded by M. Grecula (in press) and Gazdačko (personal information) as a forearc type basin. The forearc type basins retained a deep-marine underfilled character throughout their evolution. Emergent outer ridge of accretionary prism dominated as sediment supply for the basin, following major uplift and exhumation of high-grade metamorphic rocks of the initial volcanic zone roots. Crystalline source played more important role as a source of detritus causing locally anomalously quartz-rich rock composition. Their filling is preserved in the western and eastern part of Gemericum in contact zone with the tectonic unit Veporicum. Both types of Carboniferous basins were probable interconnected in the advanced stage of their development (in Triassic era). After climax of Variscan tectonic events the remnant basins vanished and after Asturian orogenic phase started the Permian continental molassic sedimentation. Vozárová and Vozár (1997) divided Carboniferous--Permian basins to the deep-to shallow-marine post-Bretonian intrasutural basins and shallow-marine post-Sudetian peripheral basins which are unconformably covered by post-Sudetian continental sediments.

The development of the Late Paleosoic basins, formed in the areas with extensional tectonics continued also during Permian, and probable also in Triassic and Jurassic (Grecula, 1994). The extensional basins merged with the Triassic-Jurassic sedimentary area of Meliaticum. The recent field lithological evaluation by Gazdačko and Németh (personal information) suggests the presence of Late Paleozoic rocks also in central part of Gemericum.

From above mentioned evolutionary model of the CWC we can draw the next *conclusion:* In the southern zones of the present Western Carpathians, the Variscan convergence gradually ceased. The low grade terranes include the Rakovec oceanic suture zone (Devonian - - Early Carboniferous), and the Gelnica suspect terrane (?Ordovician - Devonian volcanogenic flysch formations, cf. Hovorka and Méres, this volume). Part of this accretionary complex is built of Early Carboniferous volcano-sedimentary formations (e.g. Ochtiná, Črmeľ, Krakľová) which represent remnant basins or transtensional furrows between amalgamated basement superunits. The mid--Carboniferous olistostrome and flysch complexes (Turnaicum, Szendrő Mts.) and mostly unmetamorphosed carbonate platform units in the IWC of northern Hungary were detached from the Precambrian (Cadomian or Panafrican) crystalline basement of a Gondwana-related drifting "southern" continental fragment (Noric terrane). The basement of the Zemplín island of SE Slovakia (cf. Grecula and Együd, 1977; Faryad and Vozárová, this volume) may belong to this terrane (Putiš, 1992). The post-collisional Late Variscan evolution in the southern zones of the Western Carpathian realm proceeded by uplift and erosion and was followed by transtension indicated by subalkaline acid magmatism in the Permian (Uher and Broska, 1996; Kotov et al., 1996; cf. Figs. 6 and 7).

During the post-collisional Late Paleozoic evolution, Late Carboniferous shallow-marine molassic sediments and Permian red-beds were deposited in several longitudinal basins in the later Slovakocarpathian area. The original position of the Permian rift, with continental tholeiitic basalts (Ipoltica Group of the Hronic cover nappe system; Vozárová and Vozár, 1988), is not exactly known, however. This rift was aborted later, but was a site of considerable Triassic post-rift subsidence.

Mesozoic evolution

Based on the sedimentary (almost continuous throughout the Mesozoic) and structural rock record, the Mesozoic paleotectonic evolution of the ancient Western Carpathian area can be differentiated generally into four principal periods, partly overlapping in space and time: (1) platform stage (Early to Late Triassic), (2) rifting, extensional tectonic regime, thinning of the crust (Middle Triassic - Middle Cretaceous), (3) compressional tectonic regime, thickening of the crust (Late Jurassic - Late Cretaceous), and (4) transpressional - transtensional tectonic regime and partial disintegration of the stacked crust (Late Cretaceous).

The Mesozoic sedimentary cycle in the Slovakocarpathian area began with Triassic epicontinental sedimentation on a stabilized, peneplenized post-Variscan continental crust. Gradual, southward intensifying subsidence may have been caused by Meliatic back-arc rifting and eustatic control (Michalík, 1994), but also by thermal downwarping (sag basin) as a process terminating the Variscan evolution, after the post-collisional delamination of the thickened mantle lithosphere and extensive Permian rifting. Scythian piedmont-beach clastics and Middle Triassic carbonate platforms covered the whole

Slovakocarpathian area. The Late Anisian breakaway of the Meliatic rift had its expressions mainly in the southern Slovakocarpathian and in the Hungarocarpathian zones, where the carbonate ramp was disintegrated into elevating and subsiding domains (Fig. 7). The siliciclastic Lunz (Raibl) event finished the syn-rift sequence of this restricted Early Alpine distension period. Broad Late Triassic carbonate platforms covered the southern Slovakocarpathian zones, establishing a mature passive margin of the Meliatic ocean. Inner (northern) lagoonal to terrestrial Late Triassic Carpathian Keuper zones of the Tatricum and Fatricum (Krížna) domains probably directly communicated with the Germanic Keuper Basin in the north. The southern, Hungarocarpathian margin of the Meliatic ocean strongly subsided during the Triassic and was affected by arc volcanism in the neighbourhood of the Paleotethyan subduction zone (Fig. 7).

At the beginning of the Jurassic, the Slovakocarpathian area suffered a strong tensional impulse. Rebuilding of the paleogeographic pattern took place at that time and longitudinal deep-marine basins and elevated highs were established for the next 100 Ma (Fig. 7). The Slovakocarpathian domain, together with the Austroalpine realm, was separated by the Penninic (Vahic) oceanic rift from the European shelf to form an independent microplate (Kreios plate of Michalík and Kováč, 1982). The 50-100 km broad trough of the Fatric domain was formed between the Tatric and Veporic zones, which became a sedimentary area of the later Krížna cover nappe. A similar, but probably narrower trough appeared inside the Tatricum, separated by the elevated South Tatric ridge. This Šiprúň basin and the Vahic (South Penninic) ocean were divided by a narrow, fault bounded basement high - the North Tatric ridge. The climax of the distension period is heralded by small submarine extrusions of hyalobasanitic lavas of upper-mantle origin during the late Early Cretaceous (Hovorka and Spišiak, 1988, 1993; Spišiak and Hovorka, 1997).

The distension event in the Slovakocarpathian areas was contemporaneous with the commencement of the convergence along the southern margin of the Meliatic ocean and development of an active margin. Units from the northern periphery of the IWC record an active margin setting till the Oxfordian in the east and up to Albian in the west (Gerecse Mts.). However, the terrigenous clastic imput in the synorogenic sediments was very weak, indicating a low topographic expression of the active margin. Also the hinterland Hungarocarpathian areas were flooded, albeit representing elevated pelagic swells. Thus olistostromes contain mostly intrabasinal sedimentary and calc-alkaline volcanic material.

Several lines of evidence point to the presence of a narrow back-arc basin related to the southward subduction of the Meliatic ocean during the Middle - Late Jurassic, preserved in the Igal zone (?) and in the Bükk Mts. (Szarvaskő ophiolites). These were obducted southwards in the latest Jurassic - earliest Cretaceous, after the final locking of the Meliatic ocean in the meridian of the Gemericum (Fig. 7).

The northward migration of the Jurassic-Cretaceous orogenic contraction in the CWC is revealed by the onset and termination of the synorogenic terrigenous flysch sedimentation occurring in the foreland trench-type basins: Liassic to Oxfordian in the Meliaticum, Middle Jurassic-Oxfordian in the Silicicum, Valanginian-Hauterivian in the Hronicum, early Albian-early Cenomanian in the Fatricum, late Albian-early Turonian in the Tatricum and Senonian in the Vahicum (west) to Eocene (east). Shortening and nappe stacking prograded in the same manner (cf. Plašienka, 1997).

Locking of the Meliatic ocean took place before the Kimmeridgian (Kozur, 1991). Glaucophanized basalts from the base of the Meliatic accretionary complex (Bôrka nappe) overridding the southern, Gemeric margin of the Slovakocarpathian system yielded the Late Jurassic age of the HP-LT metamorphism (150-160 Ma, $^{40}Ar/^{39}Ar$ on phengites - Maluski et al., 1993, Dallmeyer et al., 1996; Faryad and Henjes-Kunst, this volume). Shortening prograded by crustal thickening in the southern Slovakocarpathian zones during the Early Cretaceous. Paleotectonic evolution of the Veporic core complex progressed from (1) deep burial during the latest Jurassic - earliest Cretaceous in a lower plate position of the Meliatic suture, (2) early Cretaceous thermal equilibration and softening, (3) mid-Cretaceous exhumation by east-verging unroofing due to underplating of the more northern Tatric-Fatric crustal sheet, elevation is well constrained by thermochronological data (reviewed by Plašienka, 1997), (4) transpression (late Cretaceous) and later transtension (Early Tertiary) accompanying and post-dating exhumation. The Veporicum is a part of the nucleus of the Cretaceous West Carpathian orogenic lid, the western part of which was largely destroyed by young Tertiary extension. The uplift was accommodated by eastward unroofing of the overlying units (Gemeric and probably also some higher "exotic" units).

Structurally, the underthrusting of zones with attenuated continental crust in the Slovakocarpathian system (e.g. the Fatricum - see Plašienka et al., this volume) is recorded by the paragenesis of the first Alpidic deformation stage AD_1: subhorizontal ductile/brittle shear zones, large recumbent folds and basement/cover nappes formed under very low- to low-grade metamorphic conditions. Basement shortening finally led to the collision of domains with thicker crust (e.g. South Tatric ridge vs. the northern tip of the Veporic wedge after underthrusting of the Fatric basement), expressed by the AD_2 stage: orogen-parallel macrofolds with subvertical axial plane cleavages, local backthrusting and transpression. Both stages display a foreland-ward (northward) polarity (Plašienka, 1995a).

During the Aptian - Cenomanian, the compression axis shifted northwards to the area of northern Veporicum and Fatricum. An underthrusting zone was set up along the north Veporic edge, in which attenuated continental crust of the Fatric (Krížna) Mesozoic basin was thrusted underneath the Veporicum (Jaroš, 1971; Plašienka,

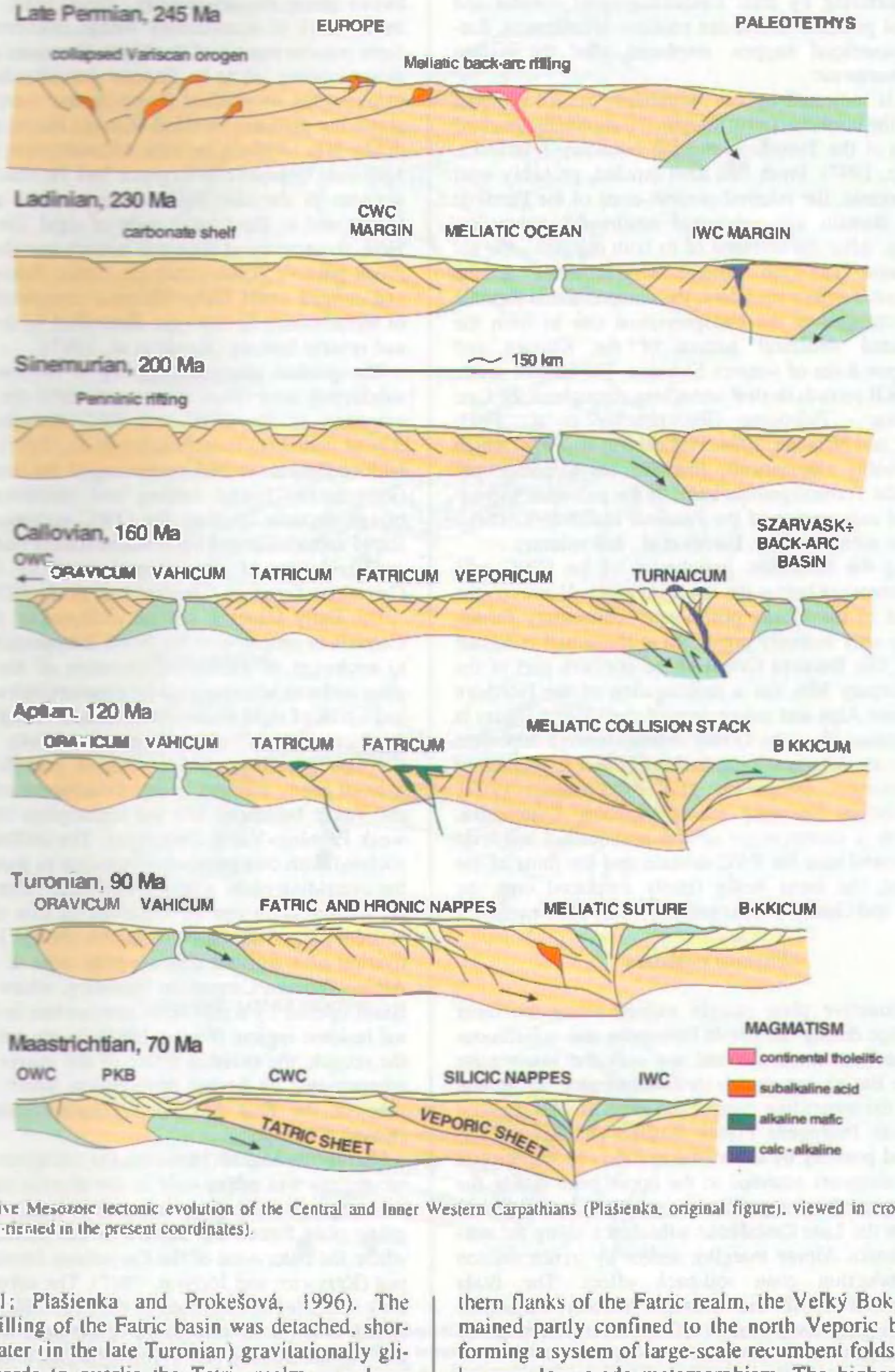


Fig. 7. Tentative Mesozoic tectonic evolution of the Central and Inner Western Carpathians (Plašienka, original figure), viewed in cross-sections (roughly N-S oriented in the present coordinates).

1983, 1991; Plašienka and Prokešová, 1996). The Mesozoic filling of the Fatric basin was detached, shortened and later (in the late Turonian) gravitationally glided northwards to overlie the Tatric realm as a huge Křižna nappe system. The sedimentary cover of the southern flanks of the Fatric realm, the Veľký Bok unit, remained partly confined to the north Veporic basement forming a system of large-scale recumbent folds affected by very low grade metamorphism. The higher, Hronic and Silicic nappe systems are composed of numerous sheets differing by their lithostratigraphic content and structural position. These are rootless décollement, flat-lying superficial nappes, emplaced after the Krížna nappe overthrust.

As it is indicated by the sedimentary record of some units of the northern Tatric margin, the shortening reached this area at the Turonian/Senonian boundary (Plašienka, 1995a, b, 1997). From this time onward, probably until the Paleocene, the inferred oceanic crust of the Penninic (Vahic) domain was subducted southwards below the Tatricum. After the collision of its both margins - the active Tatric and the passive Oravic ones at the Cretaceous/Tertiary boundary, the compressional tectonic regime changed to the transpressional one to form the complicated structural pattern of the Klippen and Periklippen Belts of western Slovakia. The eastern sector of the PKB records dextral wrenching throughout the Late Cretaceous - Paleogene (Ratschbacher et al., 1993; Nemčok and Nemčok, 1994; Plašienka et al., 1998) which was probably kinematically linked to the Miocene opening of the Transcarpathian basin by the pull-apart mechanism and exhumation of the Penninic Iňačovce-Krichevo unit in its substratum (cf. Baráth et al., this volume).

During the Senonian, peripheries of the CWC area were submerged below the sea level again. However, the remnants of the Gosau post-nappe sedimentary formations are only scarcely preserved at the actual erosional surface. The Brezová Group of the northern part of the Malé Karpaty Mts. (as a prolongation of the Northern Calcareous Alps and substratum of the Vienna Basin) is an exception. Here the Gosau sediments were deposited in a fore-arc compressional basins at the active northern CWC margin (Wagreich and Marschalko, 1995). Epicontinental Senonian sea (presumably Campanian, mainly as a consequence of the pronounced sea-level rise) covered also the IWC domain and the units of the Silicicum, the latter being finally emplaced onto the Veporic and Gemeric areas probably only afterwards.

Cenozoic evolution

A destructive plate margin existed along the outer CWC edge during the whole Paleogene and voluminous flysch sedimentation affected not only the lower plate (Magura Basin), but, due to its downwarping, the frontal parts of the overriding continental plate as well (Central Carpathian Paleogene Flysch Basin). The flexure was generated possibly by subcrustal erosion of lower crustal oceanic elements accreted to the upper plate during the preceding subduction periods (as proposed by Wagreich, 1995, for the Late Cretaceous subsidence along the northern Eastern Alpine margin), and/or by trench suction and subduction zone roll-back effect. The Buda Paleogene Basin in the internal Western Carpathian zones has been interpreted as a flexural retroarc basin by Tari et al. (1993).

Further compression at the beginning of the Neogene resulted in accelerated closing of the Paleogene fore-arc basins above the active CWC thrust front. The frontal thrust stack of accretionary wedge overthrust the southern passive margin of the North European plate, where thrust loading led to its flexural downbending (Fig. 8). Depocentres of residual flysch basins were shifted towards the platform foreland (Krosno Basin) passing gradually into foredeep molasse sedimentation in the Early Miocene. Oblique convergence had far-reaching consequences in the rear, thickest part of the accretionary wedge and in the frontal parts of rigid Tatric buttress. Here, the activity of a dextral wrench corridor generated broad positive flower structure, closed Paleogene basins and created small Early Miocene compressional basins of wrench-fault furrow type controlled by dextral shears and reverse faulting (Kováč et al., 1997).

The gradual along-arc closing of Alpine-Carpathian subduction zone (from the west towards the east) led to extrusion of the CWC and IWC domains from the Alpine collision (Ratschbacher et al., 1991), associated with continuous crustal shortening of the orogenic front. Compression forced folding and thrusting of flysch trough deposits creating the OWC accretionary prism. Rapid subsidence and high sedimentation rate characterized evolution of the internal zone of the Eastern Carpathian foredeep (Meulenkamp et al., 1996).

The Early Miocene oblique collision of the Western Carpathian orogen with the North European Platform led to a change of movement direction of the overriding plate and was accompanied by counterclockwise rotation and uplift of rigid basement blocks, creating the present "core mountains" (Kováč et al., 1994), inside the Carpathian collage. Block rotation probably occurred over an gently inclined crustal detachment zone between the Tatric basement and the underlying, rheologically weak Penninic-Vahic complexes. The collision was associated with compressional tectonics in frontal parts of the overriding plate, where a turn from dextral to sinistral transpression can be observed in this time. In the western part of the Carpathians this change led to an activation of a sinistral displacement zone at the Eastern Alpine-Western Carpathian boundary, where the Vienna Basin opened by a pull-apart mechanism in transtensional tectonic regime (Fodor, 1995). In the eastern part of the orogen, the twisting effect of the moving plate was compensated by dextral transtension which led to opening of the East Slovakian (Transcarpathian) Basin (Kováč et al., 1995).

During the Middle Miocene, the compressional tectonic regime was active only in the accretionary prism in the orogenic front. Deep subsurface load of the downgoing plate forced the flexure of the platform margin, where the outer zone of the Carpathian foredeep developed (Krzywiec and Jochym, 1997). The subduction rollback effect led to extension of the overriding plate, associated with synrift subsidence in the back-arc area (e.g. the Vienna, Danube and Transcarpathian Basins - Kováč et al., 1993, 1995, 1997; Lankreijer et al., 1995). The lithospheric stretching and rise of the mantle below the

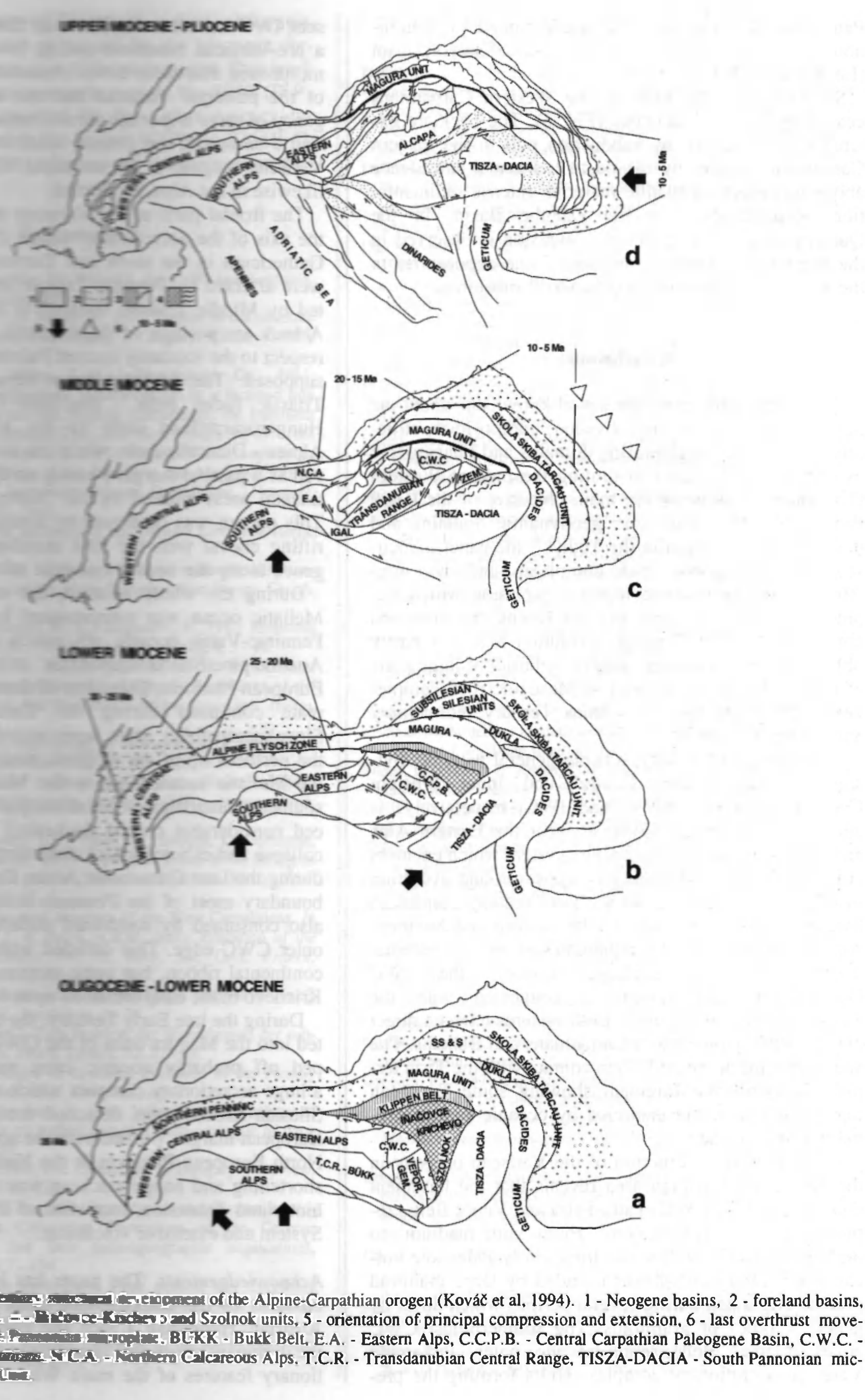


Fig. 8. A sketch of the Tertiary structural development of the Alpine-Carpathian orogen (Kováč et al, 1994). 1 - Neogene basins, 2 - foreland basins, 3 - Pieniny Klippen Belt, 4 - Iňačovce-Kričevo and Szolnok units, 5 - orientation of principal compression and extension, 6 - last overthrust movements. ALCAPA - North Pannonian microplate, BÜKK - Bükk Belt, E.A. - Eastern Alps, C.C.P.B. - Central Carpathian Paleogene Basin, C.W.C. - - Central Western Carpathians, N.C.A. - Northern Calcareous Alps, T.C.R. - Transdanubian Central Range, TISZA-DACIA - South Pannonian microplate, ZEM - Zemplín Unit.

Pannonian Basin System was accompanied by voluminous acid, and later intermediate calc-alkaline volcanism (Lexa et al., 1993).

Subduction at the front of the Western Carpathians ceased by the Late Miocene (Fig. 8). The back-arc extension was induced by subduction pull in the Eastern Carpathians, and/or by the post-rift thermal subsidence above upwelled hot mantle material. Intense sedimentation occurred only in the Danube Basin. In the Quaternary, a positive tectonic inversion is observed in the Western Carpathians, and only some depocentres in the Vienna and Danube Basins are still subsiding.

Conclusions

The paper summarizes the actual knowledge about the position, regional tectonic division, composition, structure, links to the neighbouring domains and Phanerozoic evolution of the units constituting the present Western Carpathians. Following the main objective of the IGCP Project No 276 "Paleozoic geodynamic domains and their Alpidic evolution in the Tethys", the paper is focused on the Paleozoic rock complexes and their pre-Alpine and paleo-Alpine tectonic evolution which impressed the main features of their recent structures and compositions. The Cenozoic evolution has only partly obliterated these features, mostly by burial of large parts of the pre-Mesozoic, as well as Mesozoic rock complexes below in places a very thick Tertiary sedimentary and volcanic cover.

For the sake of brevity, a triple general tectonic division into the Outer, Central and Inner Western Carpathians (OWC, CWC and IWC, respectively) is adopted. The Tertiary OWC connect the Eastern Alps and the Carpathians into a unified system which encloses crustal blocks with differing composition and evolution inside the Carpathian orocline. The Western Carpathian domain shows direct links to the Eastern and Southern Alps. The CWC Slovakocarpathian system is a continuation of the Austroalpine system, the IWC Hungarocarpathian system is connected with the Southalpine-Dinaridic units. Both systems have no direct connections to the Eastern Carpathians and Balkans. The southern limit of the IWC is in contact with the Tisia terrane, a continental fragment showing some European margin affinities, but encircled by oceanic sutures probably from all sides.

Provisional reconstruction of the Variscan orogeny in the Western Carpathian area reveals that the basement complexes of the CWC (Tatra-Fatra and Vepor Belts) represent the internal orogenic zones with medium- to high-grade metamorphism of thick Early Paleozoic volcanosedimentary complexes intruded by large granitoid plutons originated during several periods which differ by genetical types of granitoids. The southernmost CWC zones (Gemer Belt), represent the outer, low-grade Variscan accretionary complex. Units forming the present IWC represent the Variscan foreland composed of a pre-Variscan basement and its low-grade to unmetamorphosed Paleozoic cover. Assuming this distribution of the principal Variscan tectonic zones and the vergency of some important thrust contacts preserved in the Tatric basement, the general southwards polarity of the Variscan orogeny in the ancestral Western Carpathians, likewise in the Alps, is inferred.

The frontal parts of the Variscan orogen, likely along the axis of the accretionary wedge (between the Alpine Gemericum in the north and Turnaicum in the south), were affected by Permian-Triassic rifting that culminated by Middle Triassic opening of the Meliatic ocean. A back-arc position of the Meliatic oceanic basin with respect to the southerly located Paleotethys subduction is supposed. The Meliatic basin separated two distinct Triassic facies belts - the later IWC domain with Hungarocarpathian units in the south shows South Alpine - Dinaridic links, while the northern margin evolved as a passive margin passing northwards into epicontinental areas marked by the "Germanic" facies trend. This pattern was destroyed by extensive Early Jurassic rifting coeval with the first manifestations of convergence along the southern margin of the Meliatic ocean.

During the whole Jurassic, the consumption of the Meliatic ocean was compensated by widening of the Penninic-Vahic oceanic rift which separated the later Austroalpine-Slovakocarpathian units from the North European Platform. Extension of distal parts of the lower plate continued during the Cretaceous when the Slovakocarpathian units were accreted step-by-step to the northern tip of the orogenic wedge prograding from the Meliatic suture. Due to the Meliatic collision, the southern Austroalpine-Slovakocarpathian units experienced considerable crustal thickening and then orogenic collapse and exhumation of metamorphic core complexes during the Late Cretaceous. At the Cretaceous/Paleogene boundary most of the Penninic-Vahic oceanic rift was also consumed by southward underthrusting below the outer CWC edge. This collided with the Oravic (PKB) continental ribbon, but some remnant basins (Iňačovce-Krichevo in the east) remained open until the Eocene.

During the late Early Tertiary, the convergence relocated into the Magura units of the OWC. These were scraped off probably oceanic crust substratum to create a huge accretionary complex which was, along with the Silesian-Krosno units detached mostly from the distal European margin, pushed over the southern flanks of the North European Platform in the Neogene. The foreland shortening and nappe stacking was associated with the hinterland distension, formation of the Pannonian Basin System and extensive volcanism.

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