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Late Variscan (Carboniferous to Permian) environments in the Circum Pannonian Region

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Abstract: The Pennsylvanian-Cisuralian late-orogenic and post-orogenic paleoenvironments of the Circum Pannonian Region (CPR) include tectono-stratigraphic sequences developed from the Upper Bashkirian-Moscovian marine early molasse stage up to the Guadalupian-Lopingian post-orogenic stage, with gradual connection to the beginning of the Alpine (Neotethyan) sedimentary cycle. Shallow marine siliciclastic or carbonate siliciclastic overstep sequences started in the internal part of the Variscan orogenic belt during the latest Serpukhovian and Bashkirian–Moscovian. They overlapped unconformably the variably metamorphosed Variscan basement, or weakly deformed and metamorphosed foreland and syn-orogenic flysch sediments of Mississippian to Early Pennsylvanian age. The post-Variscan rifting largely affected the Variscan orogenic belt by reactivation of the Variscan lithosphere. The late- to post-orogenic terrestrial sequences started within the internal part of the Variscan orogenic belt during the Middle/Late Pennsylvanian. It continued gradually to terrestrial-shallow water carbonate-siliciclastic sequences in its external part through the Permian. According to the present configuration, the Alpine (Neotethyan) northward shifting transgression started during the Guadalupian/Lopingian in the South and during the Early Triassic in the North.

Key words: Pennsylvanian–Permian, Variscan post-orogenic stage, Circum Pannonian Region, tectono-paleoenvironments, paleogeography.

Introduction

The Pennsylvanian–Permian succession of the Circum Pannonian Region (CPR) records the change from the Pangaean configuration and compressive regime inherited from the Variscan orogeny, to the development of a broad zone of strike-slip and extensional basins. The subsequent thermal subsidence led to the gradual coalescence of these isolated basins. Large evaporitic sabkha and salt pan to shallow water environments were formed at the beginning of the Alpine orogenic cycle. This was caused by the post-Cisuralian–Early Triassic extension and transgression of the shallow Neotethys Sea over the large CPR area.

The geological relationships of the CPR were demonstrated in a set of “Tectonostratigraphic Terrane and Paleoenvironment Maps of the Circum Pannonian Region” (published by the Geological Institute of Hungary, Budapest; Kovács et al. (Eds.) 2004) for four selected time slices. The presented text is a short explanation and interpretation which is dedicated to the Pennsylvanian-Cisuralian late- and post-Variscan orogenic stage. The Guadalupian–Lopingian Epoch is not documented in this map, although it is very important for interpretation of the beginning of the Alpine orogenic cycle. As the transgression of the Tethys Sea prograded during the Guadalupian–Lopingian up to Early Triassic gradually from the South to the North (according to the present position of units), the distribution of these sediments in the CPR realm is an important phenomenon for the interpretation of Variscan and Alpine geodynamic evolution. To minimize this lack we include brief information on the Guadalupian–Lopingian environments in the Pennsylvanian–Cisuralian explanation text.

In the present fabric all Variscan and pre-Variscan tectonostratigraphic units/terranes are included within the Alpine mega-crustal blocks: ALCAPA, TISIA, DACIA, VARDAR and ADRIA-DINARIA Megaterranes (Fig. 1). The focus of Map 2 (“Late Variscan (latest Carboniferous to Early Permian) environments”; Vozárová et al. 2004; http// www.geologicacarpathica.sk) is to decipher the Late Carbon-

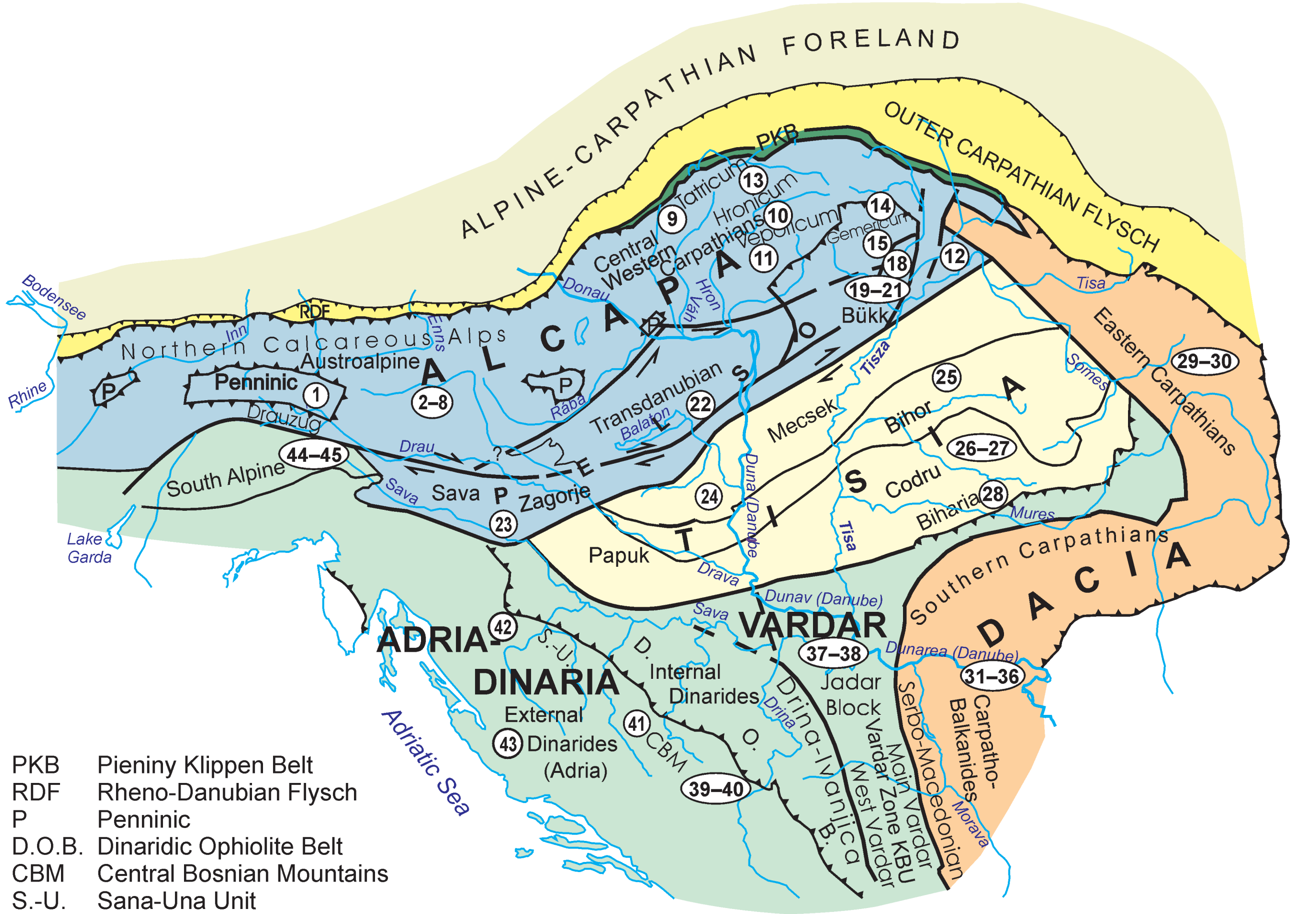

Fig. 1. The Alpine Megaterranes and important tectonostratigraphic units of the Circum Pannonian Region. The numbers indicate schematically the position of the described tectonostratigraphic units documented in Figs. 2–6: the **ALCAPA** Megaterrane — the Eastern Alps (1–8), the Western Carpathians (9–17), the Pelsonia Composite Terrane (18–23); the **TISIA** Megaterrane — the Mecsek-Villányi Zone (24), the Bihor Autochthon (25), the Codru Nappe System (26–27), the Biharia Nappe System (28); the **DACIA** Megaterrane — the Bucovinian-Getic Nappe System (29–33), the Danubian Nappe System (34–36); the **VARDAR** Megaterrane — the Jadar Block (37–38); the **ADRIA-DINARIA** Megaterrane — the E-Bosnia-Durmitor Terrane (39–40), Central Bosnian Terrane (41), the Sana-Una Terrane (42), the Adriatic-Dinaridic Platform (43), the Southern Alps (44–45).

iferous–Permian late- to post-Variscan events and paleogeographical reconstruction within the CPR realm. The explanatory text and stratigraphic columns (Figs. 2–6) also accumulates description of the Guadalupian–Lopingian environments, with the main aim of entering the relations with the beginning of the Alpine geodynamic cycle.

The Carboniferous/Permian (C/P) sequences were described in their present position within the qualifying Megaterranes, with respect to their facies and lithostratigraphic development, sea-level fluctuations, palinspastic reconstruction and disconformities. Corresponding to the explanatory text of the previous Map 1 "Variscan pre-Flysch (Devonian/Carboniferous) environments" (Ebner et al. 2008) the Variscan tectono-stratigraphic units/terranes are marked by italic letters. Therefore, the nomination of the tectonic units generally follows the terms of terrane tectonics as used for IGCP No. 276 "Terrane Maps and Terrane Descriptions" (Ed. Papanikolaou 1997). The description of the *Variscan terranes/units* is in order to their position in the Alpine structural framework.

Pennsylvanian to Permian sedimentary sequences in the Circum Pannonian Region

The ALCAPA Megaterrane

The Eastern Alps

For the tectonic subdivision of the Eastern Alps we use the "classical" tectonic subdivision of Tollmann (1987).

In the Eastern Alps the basement of the internal zones (i.e. the Austroalpine and Penninic nappe system of the Tauern Window) is covered with post-orogenic Upper Paleozoic sediments (Fig. 3). Generally, the post-Variscan sediments display two sedimentary cycles, strongly influenced by climatic changes, vertical tectonics and finally the transgression of the Neotethys Sea:

1. Upper Pennsylvanian/Lower Permian clastic fillings of intramontane basins and acid volcanics (Upper Austroalpine units),

2. Guadalupian-Lopingian continental deposits merging into "Permoskythian" shallow marine sediments of the trans-

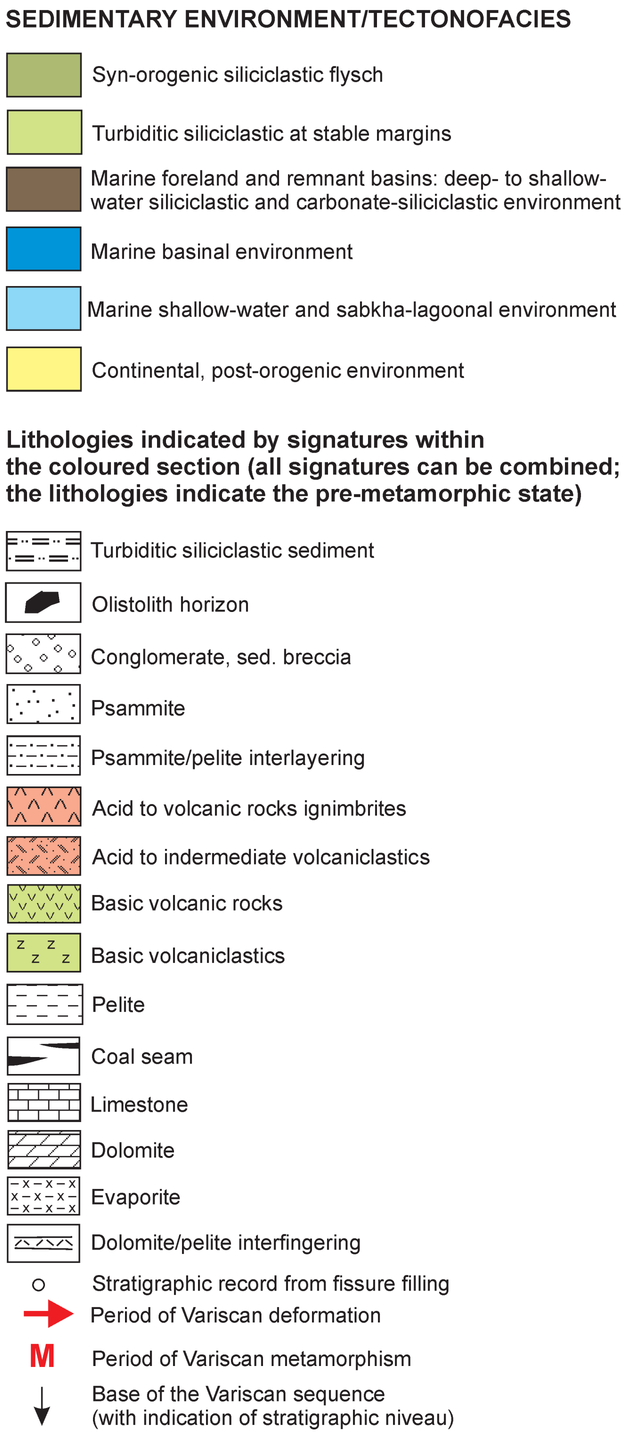

Fig. 2. Legend to lithostratigraphic columns (Figs. 2–6) of the Pennsylvanian-Permian sequences in the Circum Pannonian Region.

gressing Neotethys Sea (Lower and Middle Austroalpine and Penninic units).

Lower and Middle Austro-Alpine and Penninic nappe system

All late to post/Variscan sequences (Fig. 3, col. 1–2) have been deformed and overprinted by Alpine (Cretaceous) metamorphism to phengite- and muscovite schists, metaarkoses, quartzites and porphyroids. Based on the lithological correlations, the whole sequence is generally divided into: i) the lower, coarse-grained Guadalupian?-Lopingian "Alpine Verrucano" (including rhyolitic volcanic materials) and ii) the upper, finer-grained Scythian quartzites ("Skythquarzite")*.

*****Note**: The Early/Lower Triassic period is also known as the Scythian epoch, within the time span between 251 ± 0.4 and 245 ± 1.5 million years ago (ICS Geological time table). It is divided into the Induan and Olenekian stages. The name of "Scythian quartzite" is used for the designation of mineralogically mature, continental quartzose clastic sediments, mainly overlapping the Variscan crystalline complexes, as well as the post-Variscan sedimentary sequences in the internal part of the Alpine-Carpathian Variscan orogenic domain. A lithostratigraphic synonym for these sequences is the Germanic Lower Triassic Buntsandstein.

Compared to the "Skythquarzite" the Permian sediments are immature, rich in feldspars, and locally fragments of acidic rocks and detritus from underlying crystalline complexes. Due to the strong Alpine deformation and overprinting the mutual relationship between these two sedimentary complexes is unclear. On the basis of distinct differences in mineralogical maturity a disconformity between them could be suggested. Further information is given in Tollmann (1964, 1972, 1977), Oberhauser (1980), Krainer (1993).

Upper Austroalpine Nappes

In the Upper Austroalpine units (Fig. 3, col. 3–8) the post-Variscan sediments rest with an angular unconformity above the low- and very low grade Paleozoic sediments of the Graywacke Zone (Noric Nappe), the Stolzalpe Nappe of the Gurktal Thrust System and the Steinach Nappe. The Graz Paleozoic has no post-Variscan Upper Paleozoic sediments.

Gurktal Nappe System (Stolzalpe Nappe)

The Variscan basement in this region is composed of deformed and weakly metamorphosed sedimentary and volcanic rocks of Ordovician to Mississippian age. The youngest rocks of the Variscan basement are represented by more than 20 m of shales and cherts resting on the Upper Devonian limestones. Based on conodonts, these rocks are assigned to the Late Tournaisian or Tournaisian/Visean age (Neubauer & Herzog 1985). This Variscan basement is unconformably overlain by a more than 400 m thick succession of grey, freshwater clastics, designated as the Stangnock Formation (Krainer 1989a,b; Fritz et al. 1990). The lowermost part is composed of polymict conglomerates rich in gneiss clasts, and intercalated, immature, coarse-grained sandstones of a proximal fluvial environment. Based on petrological and geochronological investigations, these gneiss clasts were compared with the "Middle Austro-Alpine crystalline basement" (Frimmel 1986; Frank 1987). The main part of the succession consists of several indistinctly developed fining-upward megasequences containing gravelly braided river system deposits at the base, grading upward into a gravel-sandy facies with characteristic features of meandering river systems. The sandstones contain small amounts of volcanic rock fragments and volcanic quartz indicating the onset of volcanic ac-

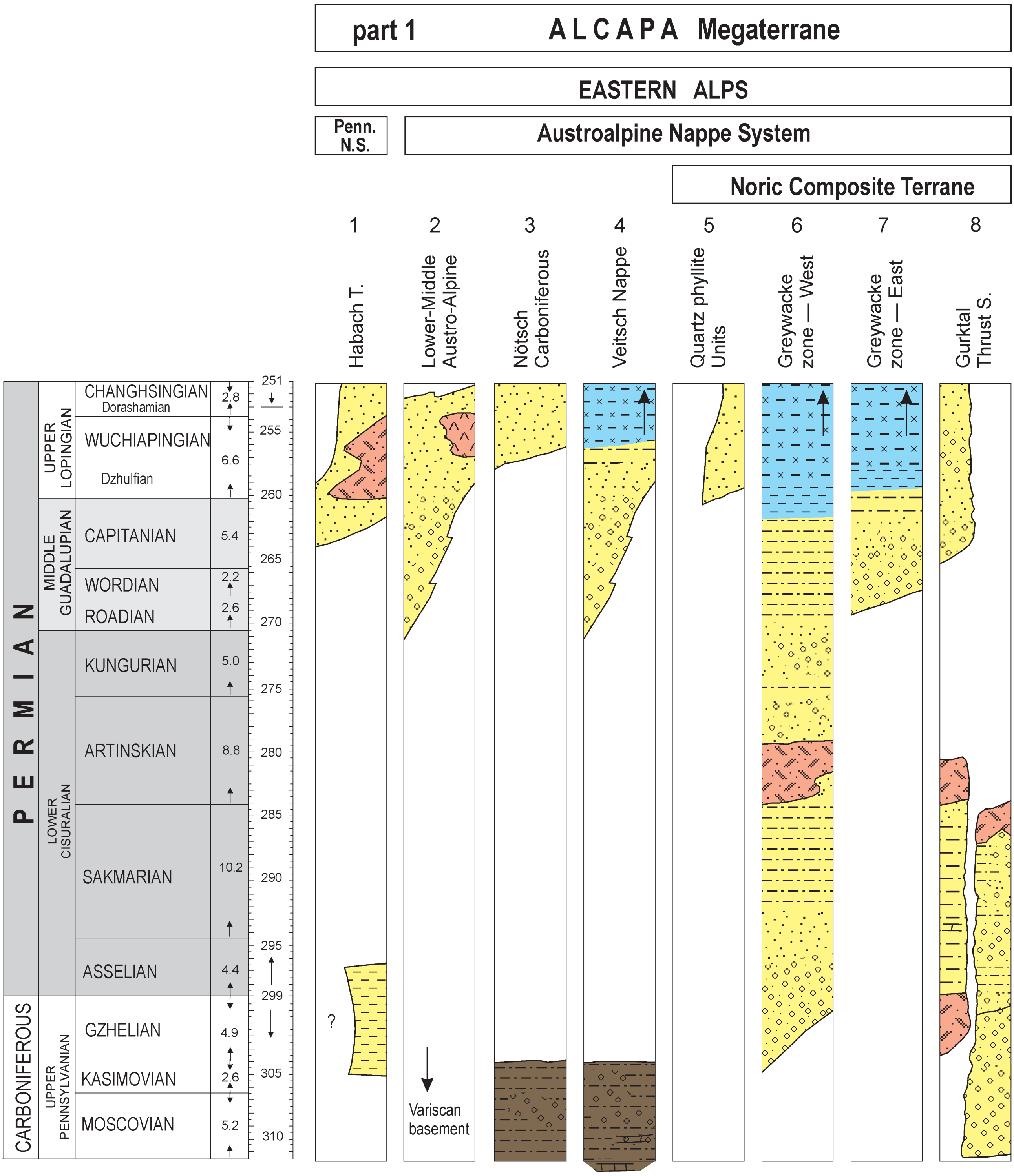

Fig. 3. Pennsylvanian-Permian sequences in the Eastern Alps (part 1 of the ALCAPA Megaterrane). Legend in Fig. 2.

tivity during the latest Pennsylvanian. Several meters of thick dark shales containing abundant well preserved plant fossils are developed at the top of these megasequences. About 80 species of plant fossils have been described from the interbedded shales and thus suggest the Kasimovian–Gzhelian age (Tenchov 1980; Krainer 1989a,b, 1992, 1993; Fritz et al. 1990). Current directions show in the present geographic orientation a distinct eastward trend indicating that the sediments of the Stangnock Formation were deposited in an approximately E-W-trending intermontane basin. The sharp erosional contact at the base of the megasequence is interpreted as a result of synsedimentary block faulting (Krainer 1993).

Nonmarine clastic sediments of the Kasimovian–Gzhelian age unconformably overlie the Variscan basement of the Upper Austroalpine Steinach Nappe in the Brenner area. The poorly exposed succession is composed of grey coloured channel, bar and overbank sediments. Thin anthracite seams occur in places. Overbank shales contain well preserved plant fossils. Some assemblages contain about 30 taxa suggesting the Kasimovian age. The facies and mineralogical composition of the sediments are very similar to the Stangnock Formation of the Gurktal Nappe, the sediments were probably deposited in the same intramontane basin (Krainer 1990).

The Permian sequence is divided into two lithostratigraphic cycles, separated by a major hiatus, interpreted by Krainer (1993) as a consequence of the Saalian movements. Proximal to distal alluvial red-beds, grading into fine-grained sandflat-playa complexes with caliche crust and thin algal layers in some places, characterize the Cisuralian (lower cycle) throughout these tectonic units (the Laas Formation in the Drauzug, the Werchzirm Formation in the Gurktal Nappe). In most cases, these sediments overlie with angular unconformity the Variscan crystalline basement (the Gailtal metamorphic rocks in the Drauzug), or different weakly metamorphosed Variscan metasediments. At the NW margin of the Stolzalpe Nappe, the Cisuralian red-beds overstepped the Upper Pennsylvanian sediments of the Stangnock Formation. Flora from the basal parts of these red-beds proved the Cisuralian age (van Ameron et al. 1982; Fritz et al. 1990). Generally, the sediments are rich in clasts derived from the local basement (polymict conglomerates, lithic arenites and greywackes).

In the Drauzug, Stolzalpe Nappe of the Gurktal Thrust System and the westernmost part of the Northern Calcareous Alps, rhyolitic volcanics (ignimbrites, pyroclastic flows) with thicknesses up to 100 m are widespread. Based on the palynological data from lacustrine sediments within the equivalent Bolzano Volcanic Complex of the Southern Alps, the Permian age reaches up to Late Artinskian–Kungurian (Hartkopf-Fröder & Krainer 1990).

The Guadalupian-Lopingian siliciclastic red-bed sediments of the ephemeral braided river and playa system of the Gröden Formation overlie the Cisuralian sediments with the hiatus caused by block faulting. According to Krainer (1993) this hiatus corresponds to the boundary between lower and upper sedimentary cycles. In Drauzug and Gurktal Nappe the maximum thickness of the Gröden Formation is ca. 350 m. These sediments contain large amounts of redeposited acid volcaniclastic fragments derived from the underlying Cisuralian sequence. The Scythian disconformity is represented by the transition to the "Alpine Buntsandstein Formation" which is characteristic in the Drauzug and Stolzalpe Nappe of the Gurktal Thrust System.

Along the Periadriatic Lineament some Upper Permian granitic intrusions are present within the basement of the Drau Range (Nötsch and Eisenkappel granites; Exner 1984).

Graywacke Zone

The whole Carboniferous sequence of the Veitsch Nappe is composed of syn- to late-orogenic sediments which were developed in the narrow post-early orogenic (post-Bretonian event) foredeep and remnant basin zone described as the *Nötsch-Veitsch-Szabadbattyán-Ochtiná Zone* (*NVSOZ*; Ebner et al. 2008). For this reason all Carboniferous sequences from the Veitsch Nappe up to the Moscovian are described together with the Devonian-Carboniferous pre-flysch and flysch environments in the Circum Pannonian Region (Ebner et al. 2008).

In the Veitsch Nappe of the Graywacke Zone, Upper Permian Alpine Verrucano occurs only within the thin Alpine Silbersberg thrust-sheet (Neubauer et al. 1993).

In the Noric Nappe of the Graywacke Zone the Variscan pre-orogenic sequence continues locally until Visean/Namurian levels (Schönlaub 1982). The Variscan pile is overlain with an angular unconformity by conglomeratic formations (Präbichl Formation) which grade upwards in the continental red-beds and sabkha sediments (Hochfilzen Group). At the base of the Calcareous Alps there are thick evaporates ("Haselgebirge"), dated by sporomorphs (Klaus 1965), including some basic magmatic material representing the early Alpine rifting stage. Compared to the Drazug and Stolzalpe Nappe of the Gurktal Thrust System, the mutual transition from continental coarse-grained Guadalupian-Lopingian sediments to lagoonal-sabkha facies is proved at the basement of the Northern Calcareous Alps.

The Western Carpathians

Structural fragments of newly formed epi-Variscan crust were incorporated in the paleo-Alpine Western Carpathian units. Like most of the other collisional fold belts, the Western Carpathians have been traditionally divided into external and internal structural zones. The age of the main Alpine events and the intensity of deformational and metamorphic effects is the main difference between the distinguished structural zones. These are: i) The internal zone, consisting of the HP/LT Late Jurassic subduction event and Early/middle Cretaceous collision, followed by the nappe stacking. This pre-Late Cretaceous nappe system comprises the crystalline massifs with their Late Paleozoic overstep sequences. ii) The external zone, the Late Cretaceous/Early Paleocene to Oligocene/Early Miocene subduction/accretion and collision events. Mišík (in Mišík et al. 1985) subdivided the internal zone of the Western Carpathians into the "Central" and "Inner" part. This triple division of the West Carpathian orogenic belt is more acceptable from the standpoint of the Variscan geodynamic evolution and consequently of the Alpine tectono-thermal cycle.

In the Western Carpathians different types of Variscan basement were overstepped by the post-orogenic Carboniferous/Permian sedimentary sequences. Regardless of their lithological composition and the grade and timing of the Variscan metamorphic overprint, the Alpine-West Carpathian basement can be subdivided into three zones (Vozárová 1998): the Central Western Carpathian Crystalline Zone (CWCZ), the North Gemeric Zone (NGZ) and the Inner Western Carpathian Zone (IWCZ). Relics of these Variscan crustal fragments are preserved within the main Alpine crustal nappe units together with their characteristic post-Variscan overstepped sequences (Fig. 4).

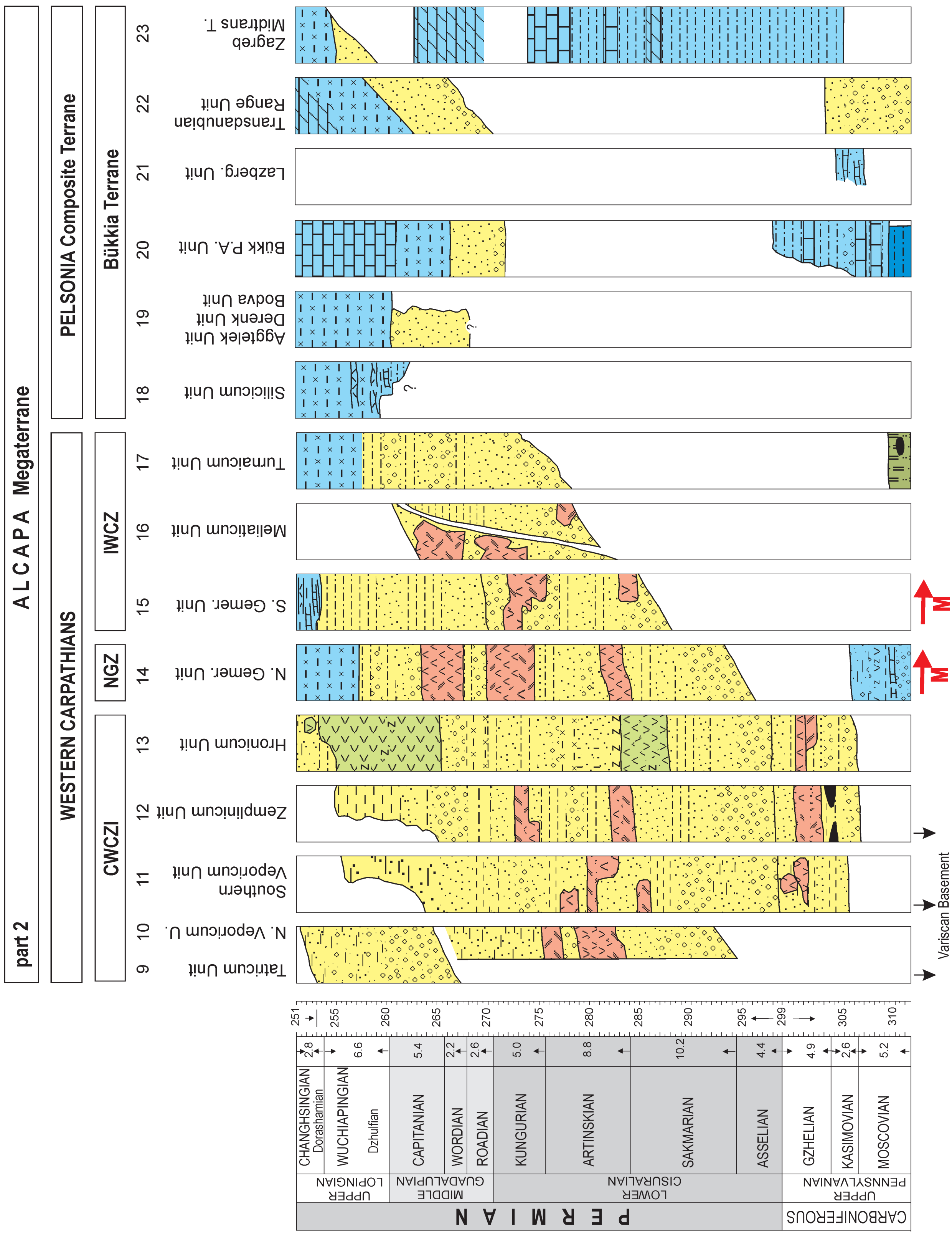

Fig. 4. Pennsylvanian-Permian sequences in the Western Carpathians and the Pelsonia Composite Terrane (part 2 of the ALCAPA Megaterrane). Legend in Fig. 2.

Central Western Carpathian Crystalline Zone

Fragments from the medium to high-grade crystalline basement (the CWCZ crust) are inferred as integral parts of the following Alpine nappe units: Tatricum, Northern Veporicum, Southern Veporicum, Zemplinicum and Hronicum (Fig. 4. col. 9–13).

The Zemplinicum Pennsylvanian sequence consists of four partial lithostratigraphic units (Čerhov, Luhyňa, Tŕňa, Kašov Formations; in Bouček & Přibyl 1959; Grecula & Együd 1982; Vozárová 1986). Their stratigraphic range was established according to macrofloral (Němejc 1953; Němejc & Obrhel 1958) and microfloral findings (Planderová et al. 1981). Polymict conglomerates, with grain-supported structure and relatively well-rounded pebble material derived from the underlying Zemplinic crystalline basement (the *Byšta Terrane*; Vozárová & Vozár 1996), lie unconformably on the basement and build up the dominant lithofacies of the Čerhov Formation (400–600 m thick). They are interpreted mostly as braided-river deposits. Their lithology consists of repeated small fining-upward sedimentary cycles with the prevalent conglomeratic or sandy-conglomeratic components. Minor black shale and siltstone intercalations occur in the upper part of the sequence. The dating, Late Moscovian–Kasimovian, is based on dominant microflora. The gradually evolving Luhyňa Formation (~200 m thick) consists of fine-grained lacustrine sediments — sandstones, mudstones and shales of grey to black colour, interrupted by the episodic events of distal-fan streams. The Kasimovian age was proved mainly by macroflora. Microfloral assemblages also confirm the Kasimovian range. Cyclothems with thin coal seams represent the Tŕňa Formation. The Kasimovian age was inferred from plant findings. The Tŕňa Formation (~800 m thick) can be divided into two large cycles, several hundreds of m thick. The lower cycle contains seven limnic-fluvial cyclothems with coal seams of variable thickness (from several cm up to 160 cm). Generally, the sediments are rich in clastic mica, plant debris, fragments of tree trunks and barks. The distinct cyclicity of fining-upward type, with sets of layers of black shales with thin coal seams and occasionally dark clayey lenses and nodules of limestones, indicate the limnic-fluvial and swamp environments. The second large cycle is characterized by alluvial stream-channel lithofacies, with dominant sandstones and absence of the coal-bearing association. Several levels of calc-alkaline rhyolite-dacite and their volcaniclastics are typical of this part of the sequence. Thick layers of rhyolite-dacite volcaniclastics (incl. ignimbrites) and alluvial, stream-channel and flood plain sediments with dominant sandstones are the dominant lithology of the Kašov Formation (~300 m thick). Based on the microfloral assemblage, the Kašov Formation was assigned to the Kasimovian–Gzhelian.

The Southern Veporicum Carboniferous post-orogenic sequence is represented by the upward-coarsening Kasimovian-Gzhelian sediments of the Slatviná Formation (~800 m thick). Their direct contact with the basement (the *Kohút Terrane*; Vozárová & Vozár 1996) is hard to prove, due to either Alpine tectonic reworking or the contact-thermal effects of the Alpine granitoids. The well preserved cyclical structure, as a multiplied vertical alternation of grey metasandstones, dark grey/black metapelites and their regional unification in two large coarsening upward regressive cycles indicate the mutual prograding from lacustrine-deltaic to fluvial environments. This prograding trend is in contrast to the rapid change of sediment colour, from black or dark grey to light grey/light green, due to changes of climatic conditions, as well as sedimentary environments. In reaches of stillwater anoxic conditions tended to develop, and this led to the formation of black shales. Abundant carbonized plant detritus, relics of tissue fragments and spores of terrestrial plants are indicative of the proximity of a plant covered continent. Conspicuous stratification and cycles, tabular and relatively uniform sandstone strata are the main sedimentary features. Most others were destroyed by the Alpine regional deformation and metamorphism and by consequent thermal relaxation (Vozárová 1990). On the basis of pollen (Planderová & Vozárová 1978) the sediments are classified as Kasimovian–Gzhelian.

The Hronicum has been defined as a rootless mega-structural Alpine unit consisting of two partial nappes: Šturec and Choč Nappes (according to Andrusov et al. 1973). Due to their internal structure and mutual relationships as well as facies characteristics these partial nappes have been distinguished as mainly Triassic complexes. Both Hronic Nappe subunits contain Upper Paleozoic volcano-sedimentary formations, preserved variably as a consequence of tectonic reduction during the nappe thrusting. The remains of these sequences are known in many mountain ranges in the Western Carpathians, and their tectonic position is always equal, between the Veporic/Fatric and Northern Gemeric or higher Mesozoic nappe units.

There is no evidence of the underlying pre-Upper Pennsylvanian sediments, or of the immediate crystalline basement. Tectonic slices of granitoid blastomylonites found in the basal part of the Šturec Nappe might be partly indicative for its composition (Andrusov 1936; Vozárová & Vozár 1979). Data obtained through petrofacies analysis of clastic sediments proved proximity to a dissected magmatic arc source area (the hypothetical *Ipoltica Terrane*; Vozárová & Vozár 1996). The Upper Pensylvanian Nižná Boca Formation (400–500 m thick) is generally a regressive clastic sequence with a distinct tendency of upward coarsening. The most typical feature is the numerous small repeating fining-upward sedimentary cycles. Abundant graded-bedded sandstones with minor mudstone intercalations, as well as layers rich in plant detritus indicate a fluvial-lacustrine delta association. The sequences of the fine-grained sandstones, mudstones and shales of grey to black colour correspond to lacustrine lithofacies. Syngenetic, mostly subaerial dacite volcanism is represented by abundant redeposited volcanogenic material mixed with non-volcanic detritus and more or less by thin layers of dacitic tuffs and exceptionally by small lava flows of dacite.

The rift-related sediments of the Hronicum showed a trend towards of older and older supplies of detrital mica in an upward direction. The $^{40}Ar/^{39}Ar$ cooling ages of detrital white mica from the Nižná Boca Formation, from the stratigraphically lowest sample, yielded age of 309 ± 3 Ma. The samples from the middle and upper portion of the Nižná Boca Formation delivered successively older ages of 318 ± 2 Ma and 329 ± 2 Ma respectively (Vozárová et al. 2005). The time gap between the average cooling in the source area and the age of sedimentation in the basal part of the Nižná Boca Formation may not exceed ~5 Myr, whereas at the top of the same formation this time difference reaches about ~20 Myr. These cooling ages of the source area reflect the development of the Hronicum terrestrial rift and heterogeneity of source area, with gradual rifting and cooling of the lithosphere. Macroflora from the uppermost part of the Nižná Boca Formation indicates the latest Moscovian-Kasimovian age (Sitár & Vozár 1973). Planderová (1979) also distinguished Kasimovian-Gzhelian microflora assemblages.

The Carboniferous/Permian boundary in the CWCZ is either unconformable, where the Permian sediments directly overlie crystalline basement, or conformable, where the uppermost Pennsylvanian sediments continuously prograde into the Cisuralian. Sharp change in sediment colour is related to rapid increase of aridity. The coarse-grained continental sediments of the Tatricum and Northern Veporicum have an unconformable base. The Tatricum Permian sediments are not very thick, and are preserved only in isolated areas (e.g. High Tatra, Low Tatra, and Malé Karpaty Mts), with more important occurrences in the Považský Inovec and Malá Fatra Mts. Common features of these successions include: unconformable overstepping of medium- to high-grade Variscan crystalline basement; continental, proximal to distal braided-alluvial sediments (conglomerates, coarse-grained sandstones). The sediments lack fossils. Scarce presence of rhyolites and their volcaniclastics show a calc-alkaline trend. The U-Pb isotope data from the rhyolites of the Považský Inovec Mts gave an age of ~280 Ma (Archangelskij in Rojkovič 1997).

In the Northern Veporicum, the Lower Permian sequence is represented by the lower part of the Ľubietová Group, comprising the Brusno and Predajná Formations (Vozárová 1979). The Brusno Formation (150–750 m thick) mostly represents arkosic fluvial sandy sediments deposited in low-sinuosity rivers. Coeval rift-related volcanic activity resulted in calc-alkaline dacite effusions, associated with pyroclastic flows (ignimbrites) and epiclastic deposits. Rare andesite/basalts and their volcaniclastics show affinity to a tholeiitic magmatic trend. The Cisuralian age of the Brusno Formation is only provided by the poor assemblage of monosaccate spores. The Predajná Formation (350–450 m thick) overlaps disconformably the Brusno Formation. A hiatus, as a consequence of the Saalian movements, is documented by a change of drainage system, distinct differences in composition of detritus (mica schists, paragneisses, microgranites and reworked Brusno volcanites). Sediments indicate alluvial fan to piedmont flood plain environments with isolated distal ephemeral lakes. Two regional megacycles with polymict conglomerates at the base, both reflect the synsedimentary tectonic. The second cycle is partially reduced due to pre-Triassic erosion. The Cisuralian age was deduced according to the poor microflora (Planderová in Planderová & Vozárová 1982).

Representatives of those Permian successions which are lying conformable on the Upper Pennsylvanian include the Cisuralian deposits in the Southern Veporicum, Zemplinicum and Hronicum tectonic units.

The strongly deformed and metamorphosed Southern Veporicum metasediments (200–500 m thick) consist of coarse-grained arkosic metasandstones and rare metaconglomerates with abundant granitic detritus (e.g. the Rimava Formation; Vozárová & Vozár 1982). Occasional lava flows of calc-alkaline rhyolites with their tuffs are present.

The Cisuralian sediments of the Zemplinicum (the Cejkov and Černochov Formations) were deposited in an alluvial fan setting alternating with floodplain or ephemeral lake deposits with calcrete horizons, all showing the typical features of semiarid/arid climatic conditions. Several layers of calc-alkaline rhyolite tuffs are partly present in the formation. The Cisuralian age of the Cejkov Formation (< 400 m) is based on the abundance of the species from the genus *Potonieisporites* and *Vittatina* (Planderová et al. 1981).

The Hronicum Permian sequence (the Malužiná Formation; Vozárová & Vozár 1988) comprises a thick succession of alternating conglomerates, sandstones and shales. Lenses of dolomite, gypsum and calcrete/caliche horizons occur locally. The sediments of the Malužiná Formation (~2000 m thick) were deposited in braided alluvial and fluvial-lacustrine environments under a semiarid/arid climate. Fining-upward cycles of the order of several meters, as well as three regional megacycles (third-order cycles related to synsedimentary tectonics) are recognized. The basal part of each megacycle comprises channel-lag and point-bar deposits, associated laterally with floodplain and levee sequences. The upper part of each megacycle is characterized by playa, rare continental sabkha and ephemeral lake deposits. An important phenomenon is the polyphase synsedimentary rift-related andesite-basalt volcanism with a continental tholeiitic magmatic trend (Vozár 1997; Dostal et al. 2003). The Cisuralian microfloral assemblages correspond approximately to the first and second megacycles (Planderová & Vozárová 1982). This assumption is supported by the $^{206}Pb/^{238}U$ and $^{207}Pb/^{235}U$ dating of 263 ± 11 Ma from uranium-bearing layers of the upper part of the second megacycle (Legierski in Rojkovič 1997). The important magnetostratigraphic data, confirming the position of the Illawara Reversal Horizon were obtained from the upper part of the second megacycle (Vozárová & Túnyi 2003). On the basis of these magnetostratigraphical and biostratigraphical results, the third Malužiná megacycle is considered to be of Late Permian age. The established paleomagnetic latitudes of the Hronicum Permian sediments as well as the volcanic rocks indicate a position below the equator — 7° S of the equator (Krs et al. 1996).

The A-type Permian-Triassic granites occur within the intra-Veporic strike-slip zone (the Hrončok Granite; Petrík et al. 1995) and along the Southern Veporic-Northern Gemeric tectonic contact (the Turčok Granite; Uher & Gregor 1992). The age of the A-type group magmatites is known from the conventional zircon dating: 239 ± 1.4 Ma for the Hrončok Granite (Putiš et al. 2000) and 278 ± 1 Ma for its fine-grained microaplitic equivalent (Kotov et al. 1996).

Northern Gemeric Zone

The Northern Gemeric Upper Bashkirian-Moscovian (Fig. 4, col. 14) basal polymict conglomerates overstep the different lithological members of the Mississippian syn-orogenic sequence, as well as the thrust wedges of two pre-Carboniferous terranes (the *Spiš Composite Terrane* comprising the *Klátov* and *Rakovec Terranes*; Vozárová & Vozár 1996). Within the Northern Gemeric Zone the continental post-orogenic sedimentation started during the Early Permian. All post-orogenic rock complexes within the NGZ were deformed and metamorphosed during the Alpine tectonothermal events under very-low to low-grade greenschist facies conditions.

The shallow-water to paralic Upper Bashkirian-Moscovian formations overstepped unconformably both NGZ pre-Carboniferous crystalline complexes (*Klátov* and *Rakovec Terranes*) as well as the eastern part of the occurrences the Early Carboniferous syn-orogenic Črmeľ Formation (a part of the *Veitsch-Nötsch-Szabadbattyán-Ochtiná Zone*; Ebner et al. 2008). Due to very narrow spatial and compositional relationships between the marine Upper Bashkirian-Moscovian and the syn-orogenic Mississippian sequence, these formations were described in more detail together with the Carboniferous foredeep and remnant basins (Ebner et al. 2008). Important indications are two breaks in sedimentation. The first, was during the Early Pennsylvanian (Bashkirian) and the second one in the Late Pennsylvanian (Kasimovian–Ghzelian). Both hiati in sedimentation were connected with gradual reconstruction of the NGZ sedimentary realm, first in a transpressional and the second time in a transtensional tectonic setting. This assumption is documented by different pre-transgressive erosion steps of individual pre-Pennsylvanian sequences and by their reworked detritic material.

The marine post-orogenic sequence (8–170 m thick) started with delta-fan boulder to coarse-grained polymict conglomerates (the Rudňany Formation), with rock fragments derived from all pre-Pennsylvanian complexes of the NGZ. The 370–380 Ma $^{40}Ar/^{39}Ar$ cooling age data from white clastic mica and gneiss pebble (Vozárová et al. 2005) indicates perfectly the age of the first step of the Variscan collisional suturing in the NGZ. After initial rapid sedimentation the littoral to shallow-neritic limestones and fine-grained clastic sediments were associated with basalts and their volcaniclastics (the Zlatník Formation; up to 400 m thick). Termination of this Late Bashkirian–Moscovian peripheral basin is reflected by cyclical paralic sediments (the Hámor Formation). The lower part of the Late Bashkirian sequence is well biostratigraphically fixed, based on macrofauna: brachiopods, bryozoans, crinoids, gastropods, corals, ammonites and mainly trilobites (Rakusz 1932; Bouček & Přibyl 1960), *Neuropteris* plant debris (Němejc 1953) and *Idiognatoides sinuatus* conodonts (Kozur & Mock 1977).

The origin of the Cisuralian basin was related to the post-Asturian transtension regime. Coarse clastic sediments derived from the collisional belt predominate, and these are associated with bimodal andesite/basalt-rhyolite volcanism. The basal part of the Permian succession (the Knola Formation) contains mostly poorly-sorted conglomerates and breccias of variable thickness (100–350 m). The deposited mudflows were partially eroded by alluvial stream channels. The age of the sediments is not well dated, due to the lack of fossils. The overlying Petrova Hora Formation (750–900 m thick) comprises clastic sediments arranged into fining-upward alluvial cycles. Depositional environments are represented by fluvial and floodplain environments, alternating with playa-lake settings in the topmost parts of the megacycles. Bimodal volcanics and volcaniclastics are the significant member of the Petrova Hora Formation. Analyses of the volcanic horizons indicate that activity was polyphase. The Artinskian-Kungurian ("Upper Rotliegend") microflora was found in the upper part of the Petrová Hora Formation (Planderová in Planderová & Vozárová 1982). Th-U-Pb dating of monazite confirm the Artinskian-Kungurian age 278 ± 11 Ma of rhyolite tuffs (Rojkovič & Konečný 2005).

The Cisuralian-age terrigenous and terrigenous-volcanogenic sequence is overlain by a relatively mature sandy-conglomeratic horizon, containing pebbly material derived from the underlier. The evidence of this "cannibalistic" erosion might have been a consequence of the break in sedimentation at the end of the Cisuralian (Saalian movements) and the beginning of the Alpine sedimentary cycle. However, the biostratigraphic evidence supporting this assumption is missing. Deposition is represented predominantly by alluvial stream-channel deposits grading upwards to salt pan/nearshore sabkha/lagoonal facies with anhydrite-gypsum and salt breccia horizons, associated with small accumulations of sylvite (in the Novoveská Huta Formation, Kántor 1972 in Vozárová 1997). There is a gradual transition from the Guadalupian-Lopingian siliciclastic-evaporitic sequence up to the Lower Triassic siliciclastic-carbonate sediments. The paleomagnetic latitudes of the Northern Gemeric Permian sediments and volcanics indicate their position at a paleolatitude of 8° S of the equator (Krs et al. 1996).

Inner Western Carpathian Crystalline Zone

The Permian post-orogenic sequences were recognized within several Alpine tectonic units in the Inner Western Carpathians (Fig. 4, col. 15–17). The lowermost Inner Western Carpathian Alpine unit is represented by the Southern Gemericum, which is overthrust by the outliers of the Meliaticum, Turnaicum and Silicicum Nappes. The whole stack of the Alpine Inner Western Carpathian nappes is characterized by the distinct northern vergency. The superficial presence of the Variscan basement was acknowledged only within the Southern Gemericum.

The Southern Gemericum basement is mostly composed of thick Lower Paleozoic volcanogenic flysch (the *Gelnica Terrane*; Vozárová & Vozár 1996, 1997). Within this tectonic unit, the Lower Permian continental Rožňava Formation was preserved as a relict basin filling related to the initial stage of post-Variscan rifting. This formation unconformably overlies the low-grade Lower Paleozoic volcano-sedimentary complex of the *Gelnica Terrane*. The Rožňava Formation (300–400 m thick) is subdivided into two large cycles, with conglomerate horizons at the base of each and of a sandstone-mudstone member in their upper part. Sediments were deposited as stream-channel and sheet-flood deposits. Both of the conglomeratic horizons interfinger with rhyolite-dacite subaerial volcaniclastics and rare lava flows. According to monazite ages the Rožňava Formation volcanogenic horizon corresponds to the Artinskian–Kungurian (average age 277 Ma; Vozárová et al. 2008). The chemical composition of these volcanic rocks tends to be of calc-alkaline to alkaline magmatic type. The Cisuralian age of the Rožňava Formation is also confirmed by the presence of microflora (Planderová 1980).

The gradually prograding Štítnik Formation (~400 m thick) is a monotonous complex of cyclically alternating sandstones, siltstones and shales. Lenses of calcareous sandstones and dolomitic limestones with intercalations of shales occur only in its upper part. Thin lenses of phosphatic sandstones are rare. The phosphatic sandstones contain intraclasts of microphosphorites as well as fine-grained apatite crystals within the cement. The sediments contain a relatively high amount of rhyolite/dacite detritus (most probably redeposited from the Rožňava Formation). The sedimentary environment is interpreted as alluvial-lacustrine and lacustrine, with ephemeral high-alkaline lakes in some places, grading into near-shore, lagoonal facies. In contrast to this, the phosphatic sandstones originated in ephemeral eutrophic lakes as a result of phosphorus concentrations due to iron redox cycling (Vozárová & Rojkovič 2000). The Guadalupian-Lopingian age determinations are known only from the uppermost part of the Štítnik Formation (plant and bivalve test remains — Šuf 1963; microflora assemblages — Planderová 1980).

Generally, the Southern Gemeric Permian sequence contains a high amount of mineralogically mature detritus (quartz, metaquartzites), mainly in its basal part. Conspicuous upward fining is accompanied by decreasing of mineral maturity (enrichment in clastic mica, phyllitic fragments and acid volcaniclast).

Mineralogically and geochemically specialized Ss granites (Broska & Uher 2001) are the integral part of this crustal block. These granites have very high initial $^{87}Sr/^{86}Sr$ isotopes ratios, >0.720 (Kovách et al. 1986; Cambel et al. 1990), which indicates a mature continental metasedimentary protolith. The Permian–Triassic age was obtained by zircon single grain analysis (250±18 Ma; Poller et al. 2002). The Permian age was confirmed by Rb-Sr whole rocks and mineral dating (Cambel et al. 1990), monazite microprobe dating (276±13 Ma, 263±28 Ma; Finger & Broska 1999; Finger et al. 2003) and Re-Os isotope molybdenite dating (262.2±0.9 and 263.8±0.8 Ma; Kohút & Stein 2005).

Bôrka Nappe (Meliaticum)

A high pressure/low temperature accretionary wedge rock complex of the Meliaticum suture, assigned to a single tectonic unit termed the Bôrka Nappe, consists of a variable, discontinuous and intensely tectonically-segmented rock package of the ocean bottom and thinned continental crust including Permian complexes among other fragments (Mello et al. 1998). Two tectonic slices of the Permian metasediments have been recognized, namely: i) the Bučina Formation, composed of felsitic rhyolite-dacites and their volcaniclastics, mixed with non-volcanic quartzose detritus; and, ii) the Jasov Formation, composed predominantly of siliciclastic quartzose metasediments, with rare acid volcanics and volcaniclastics at the base. Conglomerates are rich in quartz and metasiliciclastic fragments.

Petrological features of the Permian metasediments, as well as metapelites, marbles and metabasalts from the Mesozoic part of the Bôrka Nappe sequence, point to two dominating metamorphic evolutionary stages (Mazzoli & Vozárová 1998), the first HP/LT stage (P±1.3 GPa, T~550 °C) and the second LP one (P~0.5 GPa and T~400 °C). Both Permian sedimentary formations are lithologically similar to the Cisuralian sediments of the Southern Gemericum. They are interpreted as representing fragments of the initial rift-related basin filling, which were involved in the subduction process during closure of the Meliata Ocean.

Turnaicum (Slovenská skala Nappe)

In the Turnaicum, the Brusník Formation continental redbeds unconformably overlie the Bashkirian syn-orogenic flysch turbiditic strata. Most probably they are of Guadalupian-Lopingian age (no biostratigraphical material was found and it remains undated). The mutual upward prograding of polymict siliciclastic sediments into the Perkupa Formation evaporites is characteristic. The Brusník Formation is dominated by coarse-grained siliciclastics and has a distinct fining-upward tendency, with violet and greyish-violet colour. The whole sequence is composed of three large fining-upward cycles, with mudstone and scarce lenses of carbonates at the top, however, carbonates were found only in a third part of them. The sediments are structurally immature. The prevalent depositional system corresponds to alluvial fan environment. Supracrustal provenance is documented by fragments of metapelites, metasandstones, lydites and metaquartzites. Sediments are rich in quartz and synsedimentary acid volcanic material.

The Guadalupian-Lopingian/Lower Scythian evaporites are the integral part of the Turnaicum as well as mostly Mesozoic Silicicum Nappe system. They have been referred to the Perkupa Formation. The main occurrence is in the Slovak Karst, on the territory of Slovakia (Mello et al. 1997) and in the Aggtelek-Rudabánya Unit of the Aggtelek Karst in northern Hungary (Kovács et al. 1989). Evaporites in both areas are concordantly overlain by the Bódvaszillas Beds (red and grey sandstones and shales — Griesbachian). This uniform Middle-Late Permian/Scythian sedimentary pattern is an integral part of the Alpine sedimentary cycle.

Pelsonia Composite Terrane

The Pelsonia Composite Terrane (Fig. 4, col. 18–23) consists of the Transdanubian Range Unit (the Bakonya Terrane), Zagorje-Mid-Transdanubian Unit, Bükk Unit (Bükkia Terrane) and the Aggtelek-Rudabánya Unit. It is bounded by the Rába-Hurbanovo-Diósjenő Line and the Rožňava Line to the North and by the Mid-Hungarian Lineament to the South (Haas et al. 2001). The juxtaposition occurred during the Late Cretaceous–Early Paleogene.

Pre-Variscan and Variscan basements are not known in the **Aggtelek-Rudabánya Unit**. The Guadalupian–Lopingian in the Aggtelek-Bódva Nappes is characterized by accumulation of a thick evaporite sequence under arid climatic conditions (the Perkupa Formation) related to the transgression of the Neotethys Sea at the beginning of the Alpine sedimentary cycle.

Bükkia Terrane

The shallow-marine Mályinka Formation develops continuously from the flyschoid, deep-water siliciclastic sediments of the Szilvásvárad Formation, apparently without any break in sedimentation. In the older literature the Szilvásvárad turbiditic silicilastics were correlated as the Hochwipfel flysch. However, Ebner et al. (2008) do not refer to these sediments as syn-orogenic flysch due to the lack of any Variscan overprint. The Mályinka Formation consists of fossiliferous shales (brachiopods, crinoids and sometimes trilobites, bivalves, gastropods), sandstones and scarce conglomerates, with three major limestone horizons (two in Late Moscovian, one in Gzhelian). The limestone horizons (each of them several tens of meters) are mostly very rich in fossils (fusulinids, corals, calcareous algae, etc.). The formation represents the time equivalent of the Auernig Group of the Carnic Alps (Ebner et al. 1991), however, there is no evidence for Variscan orogenic events. On the other hand, similarly to the Jadar Block and Sana-Una Terranes, an uplift and erosion took place in the Early Permian.

During the Permian the Bükkia Terrane (Bükk Parautochthon Unit) might have been located in the inner part of the western Tethys (Protić et al. 2000; Filipović et al. 2003). There is a gap in the Cisuralian. The Guadalupian formations, representing the beginning of the Neotethyan sedimentary cycle, overlie the eroded surface of a shallow marine Upper Pennsylvanian series. Mostly the whole Kasimovian-Gzhelian part had been eroded and the overlying Szentlélek Formation rests directly on the Upper Moscovian sediments. The Szentlélek Formation sequence begins with the 170–250 m-thick sandstone and siltstone formation. Whitish-grey and variegated sandstone characterizes the basal part of the lower member of the formation. Quartz grains are predominant in the sandstone. The quantity of mica, feldspar and acidic volcaniclasts is subordinate. Violet and brownish-red sandstone makes up the middle part of the sequence, containing increasing amounts of clastic muscovite.

The lower and middle part of the lower member was formed in a fluvial environment. The upper part of the lower member consists of lilac to reddish siltstone and fine-grained sandstone that formed in an alluvial and/or coastal plain environment. This part of the Permian succession can be correlated with the Val Gardena (Gröden) Formation in the Southern Alps.

The upper member of the Szentlélek Formation is made up of an alternation of greenish-grey claystones, dolomite, gypsum and anhydrite layers. Evaporites predominate in the lower third of the formation. Above the dolomitic limestone horizon dolomites become increasingly important. Dolomitic layers contain foraminifera and ostracode fossils. The small number of species and large number of specimens suggest a high-salinity environment. The ostracode assemblage is indicative of the Guadalupian (Fülöp 1984). The lithofacies and fossils indicate an alternation of the sabkha and subtidal lagoonal environments. The features of this member are very similar to those of the coeval Fiamazza facies of the Bellerophon Formation in the Southern Alps. Similar facies were also reported from the Jadar Block (Filipović et al. 2003).

The evaporitic dolomite series passes gradually upward into dark grey bituminous limestone, ~170–260 m thick (Nagyvisnyó Limestone). In the lower part of the formation limestone and dolomite layers alternate, showing an upward-decreasing trend of dolomitization. Corals and calcareous sponges were found in the topmost bed of the lower member. Above this bed medium-bedded, dark grey to black limestone predominates, punctuated by thin black shale layers. In the upper part of the formation limestone and marl layers alternate, and marl with calcareous nodules is typical. In some layers brachiopods and molluscs can be found in large quantities, while trilobites are rare. The formation is very rich in microfossils. Calcareous algae (*Mizzia, Gymnocodium* etc.) commonly occur in rock-forming quantity (Fülöp 1994). The quantity of benthic foraminifera is also remarkable (Bérczi-Makk et al. 1995). The ostracode assemblage is extremely rich in species as well (Kozur 1985). On the basis of the fossils the Nagyvisnyó Limestone can be assigned to the latest Guadalupian–Lopingian (Kozur 1985; Fülöp 1994). The large amount of dasycladacean algae in the Nagyvisnyó Limestone clearly indicates a euphotic, subtidal, low-energy inner shelf depositional environment. The faunal assemblage suggests normal-salinity marine conditions. The formation shows close similarities with the Badiota facies of the Bellerophon Formation in the Southern Alps, the Slovenian Žažar Formation, the Croatian Velebit Formation and especially the Dinaridic (W Serbian) Jadar Formation (Pešić et al. 1988; Filipović et al. 2003; Sremac 2005).

Bakonyia Terrane (Transdanubian Range Unit)

Very low to low grade metamorphism of the thick Early Paleozoic succession took place in the second part of the Mississippian (320–340 Ma). The Pennsylvanian molasse-type terrestrial deposits that contain clasts of the previously metamorphosed Lower Paleozoic basement were not affected by metamorphism. In the Cisuralian (274 ± 1.7 Ma) peraluminous, S- or S/A-type alkali granodioritic magma intruded into the Variscan metamorphic complex, leading to the formation of granite, granodiorite and quartz diorite intrusions, all along the Balaton Lineament that is considered to be a continuation of the Periadriatic Lineament (Buda et al. 2004).

Uplifting and denudation due to the Late Pennsylvanian–Cisuralian orogenic movements were followed by regional subsidence in the Guadalupian. In this stage, remarkably thick terrestrial series began to accumulate in the southwestern part of the Transdanubian Range. The northeastern part of the Transdanubian Range was subjected to marine inundation. Alluvial, coastal plain, peritidal and subtidal lagoon facies occurred coevally. This pattern is very similar to that which developed in the Southern Alps at the same time (Val Gardena Formation = Bellerophon Formation) (Haas et al. 1988).

In the Balaton Highland area, continental red-beds covering a considerable area represent the Guadalupian–Lopingian (Balatonfelvidék Sandstone — an equivalent of the Val Gardena Sandstone in the Southern Alps). In this area its thickness may reach 500–800 m. There is a significant north-eastward reduction of the formation thickness to ~150 m only.

Generally, the sequence begins with a coarse clastic member which is made up of conglomerate–sandstone–siltstone cycles bounded by unconformities. The conglomerate pebbles are derived from Lower Paleozoic metamorphic rocks and dacite. In some parts of the Balaton Highland coarse polymict breccia (fanglomerate) occurs at the base of the formation. The upper member of the formation consists of sandstone–siltstone cycles, occasionally with intraformational conglomerate at the base of the cycles. The sand grains consist predominantly of rock fragments and quartz. As a rule, the percentage of feldspar grains is less than 20 modal %. The matrix is illitic with hematite and micritic dolomite or gypsum. Matrix-supported conglomerates in the lower segment member are formed by proximal, upper alluvial fan facies. The clast-supported sandy conglomerate indicates the middle fan. Cycles with sandstone and siltstone beds, which are characteristic of the upper part of the formation, mark a distal fan environment, from alluvial plain to coastal plain. The commonly occurring cross-bedded sandstone beds are channel deposits (point bar, channel bar, channel fill) and the siltstone layers are floodplain sediments (Majoros 1983). The sequence is poor in fossils, but coalified plants, imprints of leaves and stems, and silicified trunks occasionally occur. In the Balaton Highland the Guadalupian-Lopingian sporomorph assemblage has been found 250–300 m beneath the P/T boundary (Barabás-Stuhl 1975).

NE of the Balaton Highland an evaporitic formation consists of siltstone, dolomite, anhydrite and gypsum. These appear above the red sandstone and partly interfingering with them (Tabajd Evaporite). Dolomite and anhydrite form concretions, nodules, laminae and thin beds within the red or greenish-grey siltstones. The sedimentary environment of the evaporitic siltstone formation was the coastal sabkha where sulphate precipitation and dolomitization took place in the ground-water fluctuation zone under arid conditions. Sporomorphs, found in some layers are essentially the same, as the assemblage from the upper segment of the red sandstone formation (Barabás-Stuhl 1975).

In the northeastern part of the Transdanubian Range the upper segment of the Permian is represented by a cyclical lagoonal facies consisting predominantly of dolomite (Dinnyés Dolomite). It is underlain by the evaporitic siltstone unit and interfingers with it. The thickness of the formation is 200–300 m. It consists of grey and dark grey, bituminous dolomite with interlayers of nodular anhydrite or gypsum. The evaporate nodules indicate sabkha facies in a periodically desiccated lagoon. The laminated or locally fenestral, laminated bituminous dolomites represent intertidal–supratidal facies. The peloidal, calcareous algal, foraminiferal or ostracodal wackestone microfacies indicate the subtidal lagoon environment, whereas the oolitic, bioclastic grainstones point to ooid shoals. The lagoonal dolomite is rich in calcareous algae, foraminifera and ostracods (Góczán et al. 1987). This microfauna and the algal association were reported in the Tethys region from the eastern part of the Southern Alps as far as China in the Guadalupian–Lopingian.

Zagorje-Midtransdanubian Terrane

Between Balaton and the Mid-Hungarian Lineament, the basement of the Cenozoic sequences is made up of Upper Paleozoic-Mesozoic formations, significantly different from the corresponding horizons of the neighbouring structural units. This strongly sheared zone was named Zagorje-Midtransdanubian Zone by Pamić & Tomljenović (1998) and recently the Sava Composite Unit by Haas et al. (2000).

The Permian sequences show significant facies relationships with coeval formations of the Carnic Alps, the South Karawanken, the Sava Folds and the Inner Dinarides. It indicates the original location of these sheared blocks in the junction area of the Southern Alps and Dinarides (Haas et al. 2001).

The Cisuralian succession consists predominantly of fine siliciclastic sediments (grey quartz sandstone and dark grey shale) with interlayers of fossiliferous, dark grey, dolomitic limestones and subordinately, lenses of reef talus breccia. Algae and foraminifera were found in the carbonate layers (Bérczi-Makk & Kochansky-Devidé 1981). This carbonate-clastic sequence can be fairly well correlated with the Trogkofel strata of the South Karawanken. Above this succession light grey dolomite and dolomitic limestone are exposed. They are assigned to the Guadalupian–Lopingian.

The TISIA Megaterrane

The TISIA Megaterrane forms the basement of the Pannonian Basin south of the Mid-Hungarian Lineament. This lithospheric fragment broke off from the southern margin of Variscan Europe during Jurassic times. After complicated drifting and rotation it took its present position during the Early Miocene (Balla 1986; Csontos et al. 1992; Horváth 1993). This pre-Neogene basement crops out only in two relatively small, isolated mountains in South Transdanubia — the Mecsek and Villány Mts. Within the crystalline basement of the TISIA Megaterrane, three pre-Alpine terranes have been distinguished, separated from each other by major fracture zones (Szederkenyi 1997). Their post-Variscan sequence is represented in the Mecsek-Villány Zone column (Fig. 5, col. 24).

Slavonia-Dravia Terrane

The *Slavonia-Dravia Terrane* is located in the southeastern part of Transdanubia, extending southward into eastern Croatia. It is necessary to mention that every part of the *Slavonia-Dravia* unit in Hungary is covered by younger formations and it is confirmed by deep-drillings.

Babócsa Subunit: A non-metamorphic Pennsylvanian molasse-type sequence oversteps unconformably in southern part of the crystalline basement as erosional remnants above them. The crystalline rocks are identical with the medium-grade crystalline rocks of the Drava Basin as well as the Papuk-Krndija Mountains of East Croatia (Pamić & Lanphere 1991). The Teseny Sandstone Formation consists of a cyclic grey and dark grey conglomerate, sandstone, siltstone, shale and thin anthracitic coal seams. Rich plant remnants indicate the Late Moscovian–Kasimovian age.

A Pennsylvanian "molasse-type" sequence shows poor affinity to the Radlovac Formation (Pamić 1998) and an excellent one to the Apuseni Mountains Pennsylvanian formations (Bleahu et al. 1976). Certain relationships are recognized with the coal-bearing Carboniferous complexes of Silesia and Germany. Permian deposits are unknown in this subunit.

Baksa Subunit: Similarly to the *Babócsa Subunit* the Pennsylvanian "molasse-type" sandstone sequence had unconformably overlain the crystalline basement. This thick coal-bearing grey-coloured sandstone-claystone sequence of Late Moscovian and Kasimovian age contains a rich flora characterized by typical ferns, *Equisetum* and *Sphaenophyllum* (Hetényi et al. 1971). This sedimentary formation is over-

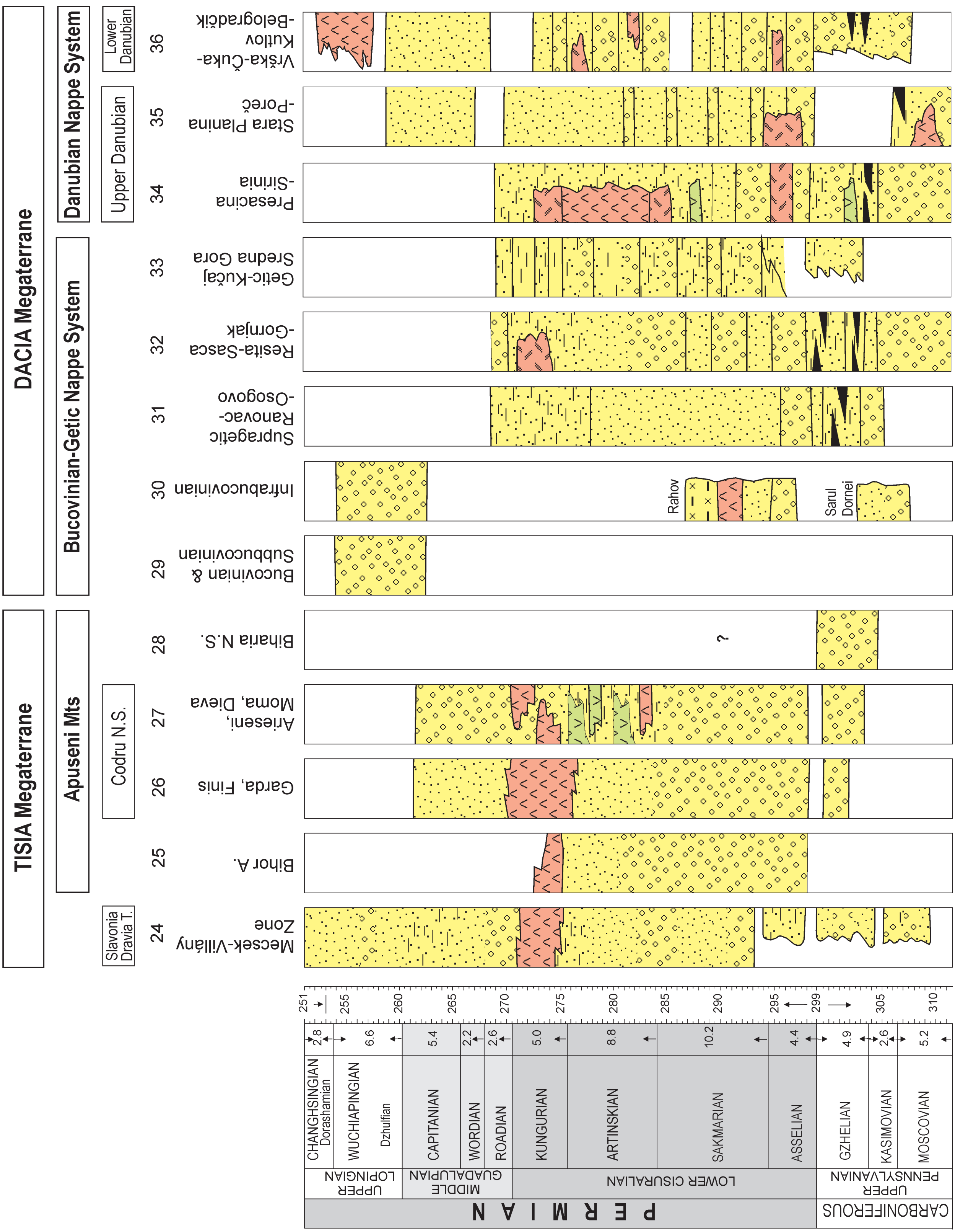

Fig. 5. Pennsylvanian-Permian sequences in the TISIA and DACIA Megaterranes (the Eastern Carpathians and Carpatho-Balkanides). Legend in Fig. 2.

lain by a complex of violet-brown siltstone and fine-grained sandstone. Several thin rhyolite tuffs and dolomitic marl intercalations also occur. Amphibian footprints suggest Kasimovian–Gzhelian age (Barabás-Stuhl 1975).

The Late Pennsylvanian strata pass without a sharp boundary into the Permian sequence, which represents a thick and complete Cisuralian "red-beds" formation (Barabás-Stuhl 1988). This characteristic sedimentary rock-column is finished by a thick acidic volcanic and volcano-sedimentary rock-complex. It is represented by a rhyolitic lava complex and related pyroclastics (ignimbrites, tuffs) more than ~800 m thick. After a considerable gap, the Early Triassic conglomerates and red sandstones settled down on the erosional surface of the volcanic mass (Fazekas et al. 1981, 1987).

The crystalline complex of the *Baksa Subunit* has the same affinity to the *Babócsa Subunit*, namely the crystalline complexes of the East Slavonian Papuk, Ravna Gora, Psunj, Krndija and Moslovacka Gora Mountains. Significant similarity can be recognized in lithology, lithostratigraphy and metamorphic evolution to the *Csongrád Subunit* of the *Békésia Terrane*. There is still no acceptable explanation for this similarity.

Kunságia Terrane

The *Kunságia Terrane* extends over the area located between the Middle Hungarian Lineament and the Villányi-Mecsekalja-Szigetvar Fracture Zone. An eastward continuation towards the Apuseni Mts can be postulated, but true connection between them is still lacking.

Mórágy Subunit: There are five smaller and variable bodies, which represent several types of thrust outliers, mostly of Variscan nappe remnants wedged into the crystalline rocks of the *Mórágy Subunit*. Grey, non-metamorphosed fossil and occasionally organic matter rich sandstones (the Nagykörös Sandstone) are wedged into the NE continuation of the Mecsekalja Line. They are tentatively regarded as Pennsylvanian. Nearly a complete Permian rock-column overstep sequence covers the granitoid deep-basement of the Western Mecsek Mountains. A continuous and undisturbed "molasse" sequence about ~3200 m thick consists of four sedimentary and one volcanic formation. They are the Korpád Sandstone, Gyűrűfű Rhyolite, Cserdi Conglomerate, Boda Aleurolite and Kővágószőlős Sandstone Formations (Fülöp 1994). The last of them contains a uranium-bearing level.

The Korpád Sandstone consists of predominantly red, coarse-grained sandstone and polymict conglomerates. The whole sequence displays cyclicity, with intercalation of red-brownish mudstones at the top of individual cycles. On the basis of sporomorph and macroflora the age of this formation is Cisuralian (Barabás-Stuhl 1981). The Gyűrűfű Rhyolite is a rather monotonous complex of lava flow alternating with ignimbrites. The top part of this formation is characterized by an erosional surface (Fazekas et al. 1987). The whole rock Rb-Sr age is 277±45 Ma (Balogh & Kovách 1973). The Cserdi Conglomerate transgressively overlies the eroded surface of the Gyűrűfű Rhyolite. A fluvial cyclic red-beds (conglomerate–sandstone–siltstone) sequence gradually passes upward into the overlying Boda Siltstone. The formation is made up of thick, monotonous, reddish-brown siltstone with scarce intercalations of fine-grained sandstone and dolomitic marls. Sedimentary structures indicate lacustrine environment in an arid/semiarid climate. The phyllopods proved the Cisuralian age (Fülöp 1994). According to the sporomorphs the formation belongs to the Guadalupian–Lopingian (Barabas-Stuhl 1981). The Guadalupian–Lopingian age is thus better constrained. The youngest Kővágószőlős Sandstone Formation consists of well-bedded fluviatile coarse- to fine-grained sandstone and a lacustrine-paludal siltstone. Numerous grey interlayers contain the Guadalupian-Lopingian macroflora (Heer 1877). After a small hiatus, found on the top of the Permian rock-column, the Early Triassic red-bed layers (so-called Jakabhegy Sandstone Formation), overstep the Permian formations. In other parts of the *Mórágy Subunit* (northern part of the Great Hungarian Plain and Tolna County of SE Transdanubia) small remnants of the Cisuralian Korpád Sandstone Formation with thin Gyűrűfű Rhyolite lava overlay the crystalline complex (Vajta and surroundings). The younger Permian rocks are missing in this area.

The crystalline complex of the *Mórágy Subunit* shows similarity in lithology, lithostratigraphy, metamorphic evolution and tectonic setting to the basement of Szolnok-Debrecen Upper Cretaceous-Paleogene flysch (Ebes) and the northernmost hills of Apuseni Mountains (Bükk, Ciko, Salaj Magura, Meszes). The Permian sequences of the Western Mecsek show a rather unique development. Any other thick and continuous Permian rock formations can be found in the Pannonian Basin. In the Villány and Apuseni Mountains small isolated relics of the Permian rock complexes are settled on the erosional surface of the *Mórágy*- and *Kőrös Subunits*, as-well-as on the crystalline complex of the *Békésia Unit* (Vajta, Kecskemét, Nagykőrös, Kelebia, Kiskunmajsa, Tótkomlós, Nagyszénás, Battonya, Kékkut, Balaton Highland).

Kőrös Subunit: It forms the crystalline basement of so-called Villány Zone (except the crystalline basement of strictly regarded Villány Mountains, which belongs to the *Slavonia-Dravia Terrane*). The *Kőrös Subunit* forms a ~250 km long synclinorium structure with migmatite-granitoid bodies in its axial zone, similarly to the *Mórágy Subunit*. Within this zone, there are five elongated small (15–25 km long) S- and I-type biotite metagranite-granodiorite bodies (Buda 1985, 1995). This subunit also contains small enclaves of crystalline rock bodies (amphibolite and eclogite and low-grade metamorphic rocks).

As an overstep sequence the Cisuralian red sandstone (the Korpád Sandstone Formation) and thin rhyolite lava flows overlay it (the north-eastern continuation of Villány Permian association up to the Danube River). The younger Permian sedimentation was missing in this area (Fülöp 1994). The crystalline rocks of the *Kőrös Subunit* correspond to south-western continuation of the so-called Bihor Autochthon (Bleahu et al. 1975).

Békésia Terrane

Remnants of the Upper Paleozoic overstep sequences are rare within the *Békésia* Variscan basement. They are present only within the *Kelebia* and *Batonya* Subunits.

Kelebia Subunit: It is made up of low- and medium-grade, strongly-folded two-micaschists with rare chlorite schist intercalations. This rock complex shows mainly the effect of Barrowian metamorphism, with a weak Variscan thermal overprinting in some places. The Cisuralian rhyolite lava (Gyűrűfű Rhyolite Formation) and small erosive remnants of the Korpád Sandstone Formation overlap the erosional surface of the metamorphic basement rocks in the north Serbian area (the Kelebia locality). Another independent Cisuralian rhyolite volcanic body was found at Kiskunmajsa (Fazekas et al. 1981)

Due to their metamorphic grade and structural style the *Kelebia* crystalline rocks form a rather individual structural rock mass. The north Serbian (Vojvodina) crystalline basement shows similar development near Subotica and Sombor.

Battonya Subunit: Biotite-muscovite granodiorite with enclaves of medium- and high-grade metamorphic rocks occur on both (NW and SE) sides of the broad granitoid body (25–30 km wide) and characterize this subunit. According to Buda (1995) these peraluminous rocks show mixed crustal/mantle origin of the destructive plate margin setting. On the erosional surface of the *Battonya Subunit* a huge Gyűrűfű Rhyolite Formation volcano developed with a diameter of at least ~30 km at its base. Due to the powerful pre-Triassic erosion this volcano was eroded nearly to its root. The age of volcanism, dated by the Rb-Sr whole rocks method gave very wide time span around 240 ± 45 Ma (Balogh & Kovách 1973).

The Apuseni Mountains

The Apuseni Mts are the product of several tectonic cycles, the last of which, the Alpine cycle has been best defined and precisely delimited. The Alpine orogeny gave rise to two geological units, the Northern Apuseni and the Southern Apuseni, differing in the character and age of Alpine sedimentary sequences as well as the timing of tectonothermal processes. Variscan post-orogenic sediments are known only within the Northern Apuseni Mts. In the Northern Apuseni Mts three main zones can be differentiated on the basis of their structural and paleogeographical history: 1. Bihor Autochthon, 2. Codru Nappe System, 3. Biharia Nappe System (Bleahu et al. 1981). These main Alpine zones represent the eastern continuation of the TISIA Megaterrane basement units of the Pannonian Basin (Fig. 5, col. 25–28).

Bihor “Autochthon”

The Permian deposits represent the oldest sedimentary cover of the pre-Alpine metamorphic basement. This is assigned to the *Somes Terrane*, consisting of paragneisses, mica schists, leptyno-amphibolite sequence and migmatites, considered pre-Variscan (Kräutner 1997). The Variscan deformational and tectono-thermal events are mostly represented by retrogressive greenschist facies metamorphism (Kräutner 1997; Dallmeyer et al. 1994: 316–306 Ma ^{40}Ar-^{39}Ar ages) and penetration of late orogenic igneous intrusions (Muntele Mare Granitoids, 278 Ma zircon age; Pana et al. 2002). In some areas a distinct Alpine thermal overprinting was recorded (ca. 100–120 Ma ^{40}Ar-^{39}Ar ages; Dallmeyer et al. 1994).

The Permian overstep sequence is mostly represented by quartzitic breccia containing fragments from the metamorphic basement, scarce bodies of rhyolites and acid welded pyroclastics. Locally, the breccia is underlain by argillaceous silty shales and vermicular sandstones.

Codru Nappe System (Békés-Codru of TISIA)

Most of the Codru Alpine Units are cover nappes, containing sedimentary sequences ranging from the Permian to the Early Cretaceous (Bleahu et al. 1981). Fragments of the pre-Permian terranes were conserved only in the deeper units of the nappe system: the *Codru Terrane* in the Finis-Gârda Nappe and the Variscan low-grade Lower Carboniferous metapsamites and metapsefites (Arieseni Formation) in the Arieseni Nappe. The *Codru Complex* consists of polymetamorphic ortho-amphibolites, paragneisses, micaschists and quartzites (^{40}Ar-^{39}Ar ages of 405 Ma for amphibole, 373 Ma for muscovite; Dallmeyer et al. 1994). Integral parts of the *Codru Complex* are pegmatites (K-Ar ages of 356 Ma for muscovite; Pavelescu et al. 1975) and intrusive bodies of trondhjemite, quartz-diorite and orthoclase granite, microcline and muscovite granites (Codru Granitoids). Variscan and Alpine deformational events are documented by retrogressive greenschist facies overprint.

Post-Variscan overstep sequences are preserved in most of the Codru Nappe System, excluding the uppermost units (Vascau and Golesti Nappes) formed only by Mesozoic deposits. They are represented by the Permian varicoloured sediments, locally associated with acid and basic volcanic rocks. Changes of facial development and character of volcanism in different tectonic units suggest that in the Codru Nappe System distinct parts of an intracontinental rift basin are preserved, ranging from the continental edge of the Bihor realm (Bihor “Autochthonous” and Valani Nappe) through a slope (Finis-Gârda Nappe) to the main basin zone (Dieva-Batrânescu and Moma-Arieseni Nappes). In the lower part of the nappe pile, the deposits underwent a weak Alpine metamorphism.

Within the Finis-Gârda Nappe the Permian overstep sequence includes, from the bottom to the top, the following formal lithostratigraphic units (Bleahu et al. 1981): (1) the Laminated Conglomerate Formation (latest Pennsylvanian–Cisuralian) consisting of oligomictic metaconglomerates, associated with laminated metasandstones and purplish metapelites; (2) the Vermicular Sandstone Formation composed mainly of red lithic sandstones with bioglyphes (burrow fillings), interbedded with shales and sandy shales; (3) the Rhyolitic Formation formed mainly of ignimbrites (Stan 1981), locally interbedded with tuffs and tuffaceous sandstones; (4) the Feldspathitic Formation represented by feldspathitic sandstones.

The lithological sequence of the Arieseni Nappe (Bleahu et al. 1981) starts with (1) the Laminated Conglomerate Formation, followed by (2) the Vermicular Sandstone Formation which shows its largest development in this unit. The equivalent of the Rhyolitic Formation (3) consists mainly of detrital feldspathitic sediments, and ignimbrites/rhyolites occur only as subsidiary element. Sporadic occurrences of basalts may be mentioned. On the top of the whole sequence the Oligomictic

Formation (4) was distinguished. It may be considered a lithostratigraphic equivalent of the Feldspathitic Formation of the Finis-Gârda realm. Here the quartzose character of the sandstones becomes more evident and the amount of the feldspar component decreases.

In the Moma and Dieva-Batrânescu Nappes the rifting related bimodal volcanism show the largest extent. The sedimentary pile (Bleahu et al. 1981) includes from the base to the top: (1) the Laminated Conglomerate Formation; (2) the Volcanic Formation, in which three members have been distinguished. The Lower Rhyolite Member (2a) includes mainly ignimbrites (also cinerites in the Moma Nappe) in which the dacitic rocks are associated towards the upper part (in the Dieva-Batrânescu Nappe). The Mafic Member (2b) is formed of basalts, andesite-basalts, spilitic rocks and anamesite flows, associated with intercalations of basaltic tuffs (Stan 1987). Spilitization and hydrothermal alteration are largely extended processes, so that most of the available analytical data (Stan 1980, 1983) are not suitable for discrimination of tectonic environments. These volcanics are interbedded with shales, silty shales, siltstones and fine reddish-violet sandstones. In the Moma Nappe, the amount of detrital rocks is higher than in the Dieva-Batrânescu unit. The Upper Rhyolitic Member (2c) (or "feldspathitic member with upper rhyolites") consists prevailingly of detrital material represented by conglomerates, feldspathitic and arkosic sandstones and shales. Several levels of rhyolitic ignimbrites and acid tuffs are present. The rhyolitic roots of these volcanics are crosscutting the Mafic Member. A decrease of volcanic material marks the transition to the Oligomictic Formation (3) on the top of the Permian sequence (only in the Dieva-Batrânescu Nappe).

Biharia Nappe System

This nappe system includes the uppermost Alpine units of the Northern Apuseni, comprising from the bottom to the top: (1) the Highis-Poiana Nappe, (2) the Biharia Nappe (incl. Radna Nappe of the Drocea Mts), (3) the Muncel-Lupsa Nappe and (4) the Baia de Aries Nappe. All these nappes are constituted mainly of metamorphic rocks, assigned to different pre-Alpine terranes, which underwent successively pre-Variscan, Variscan and Alpine tectono-thermal overprints. In the *Biharia Terrane,* considered a pre-Variscan ophiolitic crustal fragment (Dimitrescu 1994), the pre-Variscan granitoids are recorded in the Gilau and Biharia Mts (described as Lunca Larga Granitoids — Balintoni 1994; 490 Ma zircon age — Pana et al. 2002). In its western part (Radna Unit; Balintoni 1986) the *Biharia Terrane* was intruded by the Highis Granitoids during the Permian (266–264 Ma zircon age — Pana et al. 2002).

Post-Variscan overstep sequences are represented by largely extended detrital deposits, mainly conglomerates, assigned to the Late Pennsylvanian. They are intensively overprinted by a low-grade Alpine metamorphism. Locally this pile is covered by the Permian deposits, somehow similar in facial development to the Permian deposits of the Codru realm.

(1) In the Highis-Poiana Nappe the Upper Carboniferous deposits were described as the Paiuseni Formation (in the Highis and Biharia Mts). In the Highis Mts the Paiuseni Formation is represented mainly by metaconglomerates with intercalations of fine-grained metasediments and scarce occurrences of acid metatuffs. Supplementary intercalations of metaquarzites, chlorite-carbonate schists, marbles and metarhyolites occur. The whole sequence is penetrated by intrusive bodies of rhyolites, micrograntes, gabbros and diorites, assigned to the Permian. The Paiuseni Formation is unconformably covered by Permian metasandstones and metasiltstones assigned to the Cladova Formation ("Black Series"). It may represent an equivalent of the Vermicular Sandstone Formation of the Codru realm. The black rock colour is due to a distinct thermal contact effect which produced a martitized hematite pigment.

(2) In the Biharia Nappe, the Late Pennsylvanian is represented by a metaconglomerates and phyllites sequence, described in this unit as the "Gritty-Conglomeratic Formation" (Bleahu et al. 1981). It covers unconformably different parts of the *Biharia Terrane*. Towards the east, no Late Paleozoic sediments are recorded, the *Biharia Terrane* being directly overstepped by the low-grade metasediments of the Lower Triassic Belioara Formation.

(3) In the Muncel-Lupsa Nappe no post-Variscan overstep sequences are known.

(4) In the Baia de Aries Nappe the Permian cover deposits occur only in its easternmost part (Baisoara), where red conglomerates locally cover the metamorphic rocks of the pre-Variscan *Baia de Aries Terrane.* These conglomerates may be an equivalent of the Laminated Conglomerate Formation of the Codru realm.

The common feature of the post-Variscan sequence within the Northern Apuseni nappe units is the pre-Triassic stratigraphic hiatus and the discordant position of the mineralogically mature Lower Triassic quartzose sediments, overlapping different parts of the Permian sequence.

The DACIA Megaterrane

The Eastern Carpathians

Within the Infra-Bucovinian, Sub-Bucovinian, and Bucovinian Nappe Systems the Variscan cycle is represented by Lower Paleozoic to the Lower Carboniferous continental rifting related formations (the *Rodna* and *Bistrita Terranes*). They were deformed and metamorphosed probably during the intra-Late Carboniferous (Sudetian) movements under LP-LT conditions in the Infra-Bucovinian realm, and MP-LT conditions in the Bucovinian and Sub-Bucovinian domains (Kräutner et al. 1975). During the subsequent Variscan shortening, these low-grade metamorphic rocks were involved in an extensive Variscan nappe system (Kräutner 1997).

Pennsylvanian/Permian late- and post-orogenic Variscan sequences are not preserved in most parts of the Eastern Carpathians. Relics of continental or marine sediments occur only in restricted parts of the Bucovinian Nappe System (Fig. 5, col. 29–30). They overstep mostly the Precambrian continental crust, which was overprinted in greenschist facies during the Variscan metamorphic event.

In the Bucovinian and Sub-Bucovinian Nappes only continental breccias of reworked basement material occur, reaching thicknesses of some tens of meters (Haghimas Breccia; Muresan 1970). They are transgressively overlain by the Lower Triassic siliciclastic sediments. In the Eastern Rodna Mts red quartzose breccia also occur, grading into the Lower Triassic conglomerates and sandstones. Thus the Guadalupian/Lopinghian age may be envisaged for these continental deposits.

In the Infra-Bucovinian area, Late Pennsylvanian and Cisuralian deposits are locally found. The Late Pennsylvanian consists of grey sandstones and microconglomerates (Neagra Sarului/Borcut-Ulm Formation), exposed only in the Sarul-Dornei/Neagra Sarului Nappe. The Cisuralian reddish conglomerates with scarce intercalations of sandstones and siltstones occur in the same unit. In the deepest Infra-Bucovinian units (Poleanca Unit) of the Northern Maramures and Rahov Mts, the Cisuralian is represented by red and grey siltstones, sandstones and conglomerates, interlayered with rhyolites and basalts. The Guadalupian/Lopinghian reddish conglomerates prograding into the Lower Triassic siliciclastics are known from the Infra-Bucovinian Petriceaua Unit (Maramures Mts).

The Southern Carpathians

The main Alpine structural units of the Southern Carpathians, the Supragetic, Getic and Danubian Nappe Systems, are all composed of post-Variscan, Pennsylvanian-Cisuralian continental deposits, which unconformably overstep different Precambrian-Cambrian and low-grade Lower Paleozoic crystalline rock complexes, as well as the Variscan nappe structures in which these are involved. Molasse-like sedimentation started in the Late Moscovian and prograded continuously to the Cisuralian (Fig. 5, col. 31–36). The post-Variscan overstep sequences, as well as the metamorphic basement complexes are discordantly covered by the Lower Jurassic deposits, in which the Alpine sedimentation cycle starts in this part of the orogenic belt.

The post-Variscan overstep sequence formed in two principle domains with distinct internal structures, possibly separated by emerged ridges (Kräutner 1996: fig. 3). Thus the Lower Danubian realm corresponds to the eastern mostly emerged continental one. The Upper Danubian realm includes two molasse basins (Presacina sedimentation zone in the East and Sirinia sedimentation zone in the West) separated by a small emerged zone (Iablanita-Rudaria). In the eastern Getic realm sedimentary rocks do not document the Late Paleozoic sedimentation. This presupposed emerged zone separated the sedimentation zone of the western Getic realm from the adjacent Resita and Sasca-Gornjak area (Resita sedimentation zone). The Supragetic area included an easternmost basin system (Ranovac, south of the Danube).

Lower Danubian: Permian red conglomerates and sandstones are reported only from two restricted areas (South Retezat Mts, Tismana-Vâlcan Mts).

Upper Danubian: The Upper Moscovian–Kasimovian sediments occur only in the Sirinia Zone (Nastaseanu et al. 1981; Kräutner et al. 1981; Cucuiova Formation according to Stan 1987). They consist of grey-blackish detrital sequences with coal beds. Sedimentary breccias and polymict conglomerates with crystalline rock detritus constitute most of the lower part of this sequence, while in the upper part sandstones, sandy shales and shales prevail. Age constrains are given by plant fossils (Bitoianu 1973) including *Neuropteridae*, *Alethopteridae* (Late Moscovian) and *Pecopteridae* (Kasimovian). Locally basic pyroclastics lava flows (basalts, basaltic andesites, rarely andesite) are intercalated in the middle part of the sequence (Stan 1987).

The Cisuralian follows after a short stratigraphic hiatus. It is widespread in both the Sirinia and Presacina Zones and covers unconformably Carboniferous sediments and older rocks. The Cisuralian has been assigned according to flora remnants and lamellibranches (Nastaseanu et al. 1973). In the Presacina zone the red-beds sequence consists of a lower conglomerate-sandstone member (300 m) and an upper sandy-clayey member (500 m).

In the Sirinia Zone red alluvial and lacustrine conglomerates, sandstones and shales with lenses of limnic limestones represent the basal part of this sequence. It also includes a few basic volcanics, pointing to a bimodal character of the Permian volcanism. The middle part mainly consists of rhyolite-dacite volcanics and their pyroclastic rocks. Red-beds with conglomerate, sandstone and shales form the top of the sequence. In the rhyolitic-dacitic pile, two volcanic assemblages have been distinguished (Stan et al. 1986; Stan 1987): the lower Povalina Formation, formed by mixed dacitic conglomerates and microconglomerates, alternating with red sandstones, shales, sporadically limestones, with ignimbritic rhyodacitic bodies; the upper Trescovat Formation, formed by rhyolitic ignimbrites.

Eastern Getic Nappe: Permian red conglomerates are exposed in a restricted area (Cioclovina, Eastern Sebes Mts; Stilla 1985). A Jurassic overstep sequence covers most of the older metamorphic complexes.

Western Getic Nappe and Resita Nappe: In the Resita sedimentation zone a widespread post-Variscan overstep sequence formed, ranging in age from the Moscovian to the Cisuralian.

The Late Pennsylvanian is represented by coarse-grained deposits of continental facies in which three successive lithostratigraphic and biofacies units have been recognized (Nastaseanu et al. 1981; Kräutner et al. 1981): (i) The Doman Beds (Moscovian) — 300 m thick, formed of basal continental conglomerates and breccias with blocks and pebbles of crystalline rocks. The Doman conglomerates are massive, without obvious bedding, suggesting a torrential sedimentation of piedmont type. They pass gradually into (ii) the Lupacu-Batrân Beds — 200–400 m thick, represented by siliciclastic fluvial sandstone-conglomerate complex, which prograde to sandy shales with paleoflora remnants and coal beds. The plants recovered indicate the Late Moscovian–Kasimovian (Bitoianu 1973). The Lupacu-Batrân Beds also extend into the marginal parts of the Resita sedimentation zone (Secu area), where the coarse-grained Doman and Lower Lupacu-Batrân Beds as well as the Lupac Beds are missing. (iii) The Lupac Beds — 150–300 m thick, are lacustrine sediments represented by black shales and argillaceous sandstones with ferruginous concretions and coal intercalations. They contain rich plant remnants indicating the Kasimovian (Bitoianu 1973; Dragastan et al. 1997).

The Cisuralian sediments follow concordantly, without a break in sedimentation. The sequence consists of two formations (Nastaseanu et al. 1981), both assigned to the Cisuralian on the basis of macroflora (Nastaseanu et al. 1973) and palynological records (Antonescu & Nastaseanu 1976).

The lower, Black Clay Formation (150–300 m), consists of black argillaceous rocks, with intercalations of fluvial sandstones, conglomerates and occasionally lacustrine limestones. The upper, Red Sandy-Conglomerate Formation (1000–1500 m), is represented by a sequence of conglomerates, sandstones and red clays.

Supragetic Nappe: In Romanian territory only small occurrences of the Upper Pennsylvanian overstep sequences were preserved: (i) Doman Beds like conglomerates interbedded with coarse-grained sandstones in the Bocsa Unit; (ii) metric and decimetric alternations of conglomerates and grey sandstones similar to the Lupacu-Batrân Beds lithofacies at Brebu and Valeapai; (iii) in the Valeapai sequence, the Permian deposits are absent and hornblende dacites and their pyroclastics are characteristic.

Serbian Carpatho-Balkanides

The East Serbian units are directly connected with the Southern Carpathians and Balkanides and Krajištides (Fig. 5, col. 31–36). Regarding the different Paleozoic successions, several Variscan tectonostratigraphic units (Terranes) have been distinguished in Eastern Serbia. They had individual geological histories up the end of the Visean and a common history after docking in Late Paleozoic times. From the western to the eastern part of the Serbian Carpatho-Balkanides the following terranes (units) has been defined: *Ranovac-Vlasina-Osogovo* (Suprageticum), *Kučaj* (Geticum), *Stara Planina-Poreč* (Upper Danubicum) and *Vrška Čuka-Miroč* (Lower Danubicum) (Krstić & Karamata 1992; Karamata & Krstić 1996; Kräutner & Krstić 2001). The Pennsylvanian-Permian terrestrial sediments, which correspond to part of the Moscovian and to the Kasimovian–Gzhelian, overlay unconformably different older rocks. They belong from the Riphean–Cambrian to the Lower Paleozoic low-grade metamorphic rocks and Tournaisian-Visean flysch to passive continental margin formations.

Vrška Čuka-Miroč Terrane (Lower Danubian)

This easternmost unit of the Serbian Carpatho-Balkanides is characterized by the absence of Mississippian syn-orogenic flysch deposits. The post-Variscan stage started with the Kasimovian-Gzhelian continental sequence, which unconformably overlaps the Riphean-Cambrian greenschists (Krstić et al. 2005). The basal part of this sequence consists of polymict alluvial conglomerates, containing rock debris from the underlying schists, granites and metaquartzites. Fluvial-lacustrine sandstone and shales with scarce thin coal seams prograde upward, with an overall thickness of ~230 m. The Kasimovian/Gzhelian age is deduced from macroflora remains: *Pecopteridae*, *Neuropteridae*, *Cordaitea* (in Krstić et al. 2005). Within the uppermost part of this succession are conglomerates, which contain limestone cobbles with Cambrian trilobite fauna. This material is exotic to the underlying basement and appears to have been transported from the region north or northeast of Vrška Čuka. The Kasimovian/Gzhelian deposits gradually pass upwards into Permian red-beds (Vrška Čuka), or they are overlain by the Liassic sediments (Miroč area).

Stara Planina-Poreč Terrane (Upper Danubian)

Fluvial and lacustrine sediments of Late Bashkirian–Moscovian age unconformably overlie the Tournaisian-Visean flysch sequence in the northern (Poreč) part of the *Stara Planina-Poreč Terrane*. The lower part of the Moscovian sequence is composed of polymict conglomerates (over 300 m thick) with gneiss, greenschist and metaquartzite pebbles (braided river or fan delta deposits; Krstić & Maslarević 1997). The upper part of this succession consists of lacustrine sandstones and shales, which contains Moscovian macroflora. The presumed age is deduced from the macrofloral remains: *Asterophyllites equisetiformis*, *A. charaeformis*, *Mariopteris sauveuri*, *Lepidodendron simile*, *Calamites cistii*, *Paripteris gigantea*, *Sigillaria scutellata*, etc. (Krstić et al. 2005).

Permian rocks are red sandstone and shale, alternating with pyroclastics and volcanic flows, wich lie discordantly over pyroxene gabbro of Glavica (at Donji Milanovac) and green schists on the left side of the Porečka reka. Bogdanović & Rakić (1980) thus distinguish two Permian horizons: terrigene and volcanic-sedimentary.

The terrigene horizon forms the lower part of the Permian with conglomerate breccia at the base to sandstone and shale to red sandstone and shale intercalated with freshwater limestone on the top. The volcanic-sedimentary horizon is composed of red sandstone, shale, volcanic breccia, tuffs and rhyolite/dacite extrusions.

The Moscovian of the Stara Planina region consists only of volcano-sedimentary limnic sediments (dacite-andesite and their volcaniclastics, mixed with siliciclastic sediments). They unconformably overlie the Devonian sediments, basic and acid magmatites, as well as the Proterozoic greenschists. Thin coal seams within dark shales are an integral part of this succession. The ?Ducmantian-Bolsovian is inferred from the rich macroflora (Krstić & Maslarević 1970; Krstić et al. 2005). After a long stratigraphic hiatus the Moscovian sediments in the Stara Planina region were overlapped by the Permian continental red-beds.

Kučaj Terrane (Geticum)

The post-Variscan continental sedimentation started during the Kasimovian–Gzhelian. The continental, fluvial-lacustrine deposits overstep unconformably on the thick low-grade metamorphosed Tournaisian-Visean flysch succession (Krstić et al. 2004, 2005). The Kasimovian-Gzhelian fining upward sequence consists of polymict conglomerates, graywackes and shales with scarce coal seams and occasionally siderite nodules. The Kasimovian–Gzhelian age corresponds to the macrofloral remains: *Asterophyllites equisetiformis*, *Annularia stellata*, *Asterotheca asborescens*, *Alethopteris bohemica*, *Callipteridium gigas*, *Cordaites borrassifolius*, etc. (Pantić 1955a,b). Gradual transition into the Permian red-beds is characteristic (Krstić et al. 2005).

Ranovac-Vlasina-Osogovo Terrane (Suprageticum)

The terrestrial Kasimovian-Gzhelian sediments, up to 150 m thick, unconformable overlapped the low-grade Paleozoic complex (Ordovician?–Visean?). They consist of polymict conglomerates and coarse-grained sandstones alternating with microconglomerates and shales with occasional thin coal seams. The associated fossil plant assemblage corresponds to the Kasimovian–Gzhelian and is identical to that in the adjacent Kučaj Unit. The Kasimovian-Gzhelian fluvial and lacustrine sediments pass upward into the Permian red-beds.

Serbian-Macedonian Massif

The Serbian-Macedonian Massif (composite terrane) represents a unit composed of amalgamated terranes located between the Vardar Zone in the West, the Carpatho-Balkanides and the Rhodope Massif in the East. It is finally influenced by the eastward subduction of the west situated Vardar Ocean, during the (Middle-) Late Jurassic to Late Cretaceous.

Precambrian and Lower Paleozoic (Cambrian to Devonian) sedimentary and magmatic rock assemblages, originated in different geotectonic settings and represent separate tectonic units, that is terranes. They are composed of volcanic-sedimentary (rift?) association of tholeiitic WP basalts and psamitic-pelitic sediments, continental slope turbiditic sediments, terrigenous sediments on plateaus, shallow water (shelf) carbonate (calcitic and dolomitic) sediments, all penetrated by basaltic (WP) dykes, as well as continental sands and clays. The younger formations are more abundant in the western and northern parts of this composite domain. The Massif was repeatedly intruded by granitoids (from Ordovician to Cenozoic). The whole Massif has a poly-tectonometamorphic history, but during the Variscan orogeny all the units were equalized under medium-grade metamorphic conditions (Karamata & Krstić 1996). The metamorphic suite comprises gneisses, micaschists, amphibolites, marbles, quartzites, locally with eclogitic and granulitic facies relicts. S-type granite intrusion at Bujanovac and Ogražden probably belong to the Carboniferous, but exact dating does not exist. The oldest post-Variscan cover sediments are ?Permian quartzose sandstones and clays (in the Macedonian part), or Middle Triassic limestones (in the Serbian part). However, they are not the characteristic post-Variscan sediments, consequently, they are not presented in the lithostratigraphic column.

The VARDAR Megaterrane

The VARDAR Megaterrane is considered an independent Alpine oceanic domain with a very complex internal structure. The relics of Carboniferous island arc sequence (the Veles Series) and oceanic crust, inherited from an Early Paleozoic domain and transported and docked to units to the E during the Late Jurassic, form the Main Vardar Belt (Karamata 2006). The Kopaonik Block represents a crust remnant detached from the north-eastern border of Gondwana during the Late Triassic. It created a ridge separating the Main Vardar Ocean from the Western Marginal Vardar Ocean Basin in the West that existed from the Late Jurassic and was closed in the latest Cretaceous (Vardar Zone Western Belt — VZWB; Karamata 2006). To this newly formed VZWB, the Jadar Block Terrane was incorporated in the Late Cretaceous (Filipović et al. 2003; Karamata 2006).

The Carboniferous of the Vardar Zone is stratigraphically poorly documented. The only known complex is Veles “Series” represented by variable rocks: amphibolites, different greenschists metamorphic rocks, serpentinites, quartzites, microcrystalline limestones, marbles. Its protholite was composed of basalts and their volcaniclastics mixed with siliciclastic sediments and associated with pelagic limestones and cherts, formed most likely in back-arc setting (Krstić et al. 2005). The whole sequence was metamorphosed under P-T conditions ranging from amphibolite to greenschist facies, presumably during the middle Carboniferous. Palynomorphs, which were extracted from the part greenschists rocks, gave the Carboniferous age (Grubić & Ercegovac 1975).

Jadar Block Terrane

The Pennsylvanian sedimentary complexes contain both, the autochthonous and allochthonous nappe units of the Jadar Block Terrane (Fig. 6, col. 37–38).

Autochthonous unit: After a stratigraphic hiatus the Late Carboniferous continental to shallow marine sediments disconformably overlie the anchimetamorphosed Devonian-Mississippian turbidite siliciclastic and pelagic complexes (Ramovš et al. 1990; Krstić et al. 2005). The following shallow-water marine or continental sediments reflect regression after climax of the Variscan orogenesis. The lower part of this sequence (the Ivovik Formation) contains Devonian and Mississippian limestone clasts in a silty matrix. The upper part is characterized by several different facies. Fossiliferous lagoonal to shallow marine silty carbonates and siltstones rich in plant, fusulinid and brachiopod remains are characteristic. The fauna corresponds to the Late Moscovian of the Donetsk and Moscow Basins and Russian Platform. In the western part the shallow marine sediments are interfingering with continental deposits. The Moscovian (Podolsky Horizon) age was proved by fusulinid fauna. The youngest Carboniferous sediments were found only in the southern part of the Jadar Block Unit. They correspond to shallow marine massive limestones, which are rich in Late Moscovian and Kasimovian-Gzhelian fusulinids and conodonts (the Kriva Reka Formation).

Allochthonous unit: Pennsylvanian sediments were recognized in the Likodra Nappe. They continuously followed above the Mississippian deep-water turbiditic siliciclastic sediments and transitional Serpukhovian-Bashkirian fossiliferous limestones and siltstones (the Djulim Formation). In the older literature these turbiditic siliciclastics were assigned as “Kulm” flysch facies. However, Ebner et al. (2008) do not refer to these sediments as syn-orogenic flysch due to the lack of any Variscan overprint. They are conformably overlain by the Upper Bashkirian massive and bedded limestone rich in fusulinid fauna (the Rudine Formation). These sediments vertically alternate with a complex of limestones and siltstones, which contain rich plant remains as well as fusulinids and brachiopods of Bashkirian-Early Moscovian age (the Stojkovići Formation). The Bashkirian fauna assemblages are similar to those of the Donetsk Basin, Russian Platform and Urals. The Lower Moscovian association corresponds more to the Cantabrian Mts fauna in NW Spain. The youngest lithostratigraphic unit in the Likodra Nappe is a complex of recrystallized limestones (the Stolice Formation) rich in Bashkirian microfauna (Krstić et al. 2005).

After a stratigraphic hiatus the Pennsylvanian formations in both, autochthonous and allochthonous units, are transgressively covered by the Guadalupian-Lopingian continental clastics, which were followed by the Bellerophon limestone facies. The Variscan and Alpine evolution of the Jadar Block Unit can be compared with those sequences in the Bükkia Terrane (Filipović et al. 2003).

The ADRIA-DINARIA Megaterrane

The ADRIA-DINARIA Megaterrane consists of the Drina-Ivanjica Terrane, the Dinaric Ophiolite Belt, the East Bosnian-Durmitor Terrane, the Central Bosnian Terrane, the Sana-Una Terrane, the Adriatic-Dinaric Platform (= Dalmatian-Herzegovinian Composite Terrane; Karamata et al. 1997) and the Southern Alps. The latter are separated from the Dinarides by a Miocene strike-slip zone only (Karamata et al. 1997; Pamić et al. 1997; Haas et al. 2000; Pamić & Jurković 2002; Karamata 2006). All these terranes are of Alpine age. However, they include pre-Mesozoic sequences. The information regarding the Devonian-Carboniferous sedimentary sequences are summarized by Ebner et al. (2008). In the ADRIA-DINARIA Megaterrane the grade of Variscan metamorphism and deformation seems to be weak or even absent. Similar tectono-sedimentary development during the Carboniferous and Permian occurred in the Dinarides and Southern Alps realm.

The Dinarides

The Carboniferous and Permian sequences of the Dinarides are represented within several Alpine terranes. In the eastern Dinarides they occur in two different terranes: the Drina-Ivanjica (W and SW Serbia) and the East Bosnian-Durmitor (the Lim area of SW Serbia, N and NE Montenegro). The Carboniferous in the central Dinarides (Prača Unit) still remains as a part of the East Bosnian-Durmitor Unit. In the Central Bosnian Mts the Pennsylvanian–Permian continental to shallow water sedimentary sequences are missing. During the Late Pennsylvanian–Permian, this part of the Dinarides belonged to the Gondwana passive margin of the Paleo-Vardar Ocean (Karamata 2006).

Drina-Ivanjica Terrane

Carboniferous deep-water siliciclastic sedimentary sequences of Drina-Ivanjica Terrane (Dimitrijević in Karamata et al. 1997) conformably overlie the pre-Mississippian low-grade to anchimetamorphic complexes. Main occurrences are known from the Drina Anticlinorium and in the western part of the Ivanjica Block. This Visean-Serpukhovian olistostrome flysch trough was closed during the Early Bashkirian times. The late Variscan "molasse-like" sediments are unknown. The Carboniferous succession is directly unconformably overlain by the Lower Triassic continental clastic sediments. Whole Paleozoic complexes underwent the distinct Alpine overprinting up to condition of the greenschist facies. The Alpine metamorphism based on radiometric data range from 170–160 Ma to 130–120 Ma ages (Milovanović 1984).

East Bosnian-Durmitor Terrane

Within the East Bosnian-Durmitor Terrane, the siliciclastic turbidite and olistostrome sedimentation also existed during the Bashkirian time (Krstić et al. 2005). This deep-water turbiditic siliciclastic environment was gradually changed upward into the shallow-water carbonate platform environment. The uppermost part of the Carboniferous succession consists of shallow marine limestones, rich in corals, brachiopods, rostroconchs, fusulinids and algae, corresponding to the Moscovian and Kasimovian–Gzhelian (Krstić et al. 2005). The mutual substitution of deep-water siliciclastic and carbonate platform sedimentation is spatially and temporally unequal. Lithological and stratigraphic equivalents of these carbonate sediments are known in the Jadar Block Terrane. However, Variscan metamorphism is not proved. The regional greenschist facies metamorphism seems to be the Alpine (Dimitrijević in Karamata 1997). The Carboniferous sedimentary sequences are unconformably covered by the Guadalupian-Lopingian clastics, in the Prača area, with Lower Triassic clastics and limestones also occurring in the Lim and Tara area (Krstić et al. 2005).

Central Bosnian Terrane

The post-Carboniferous sequence began with the Guadalupian-Lopingian coarse clastics, evaporites and the Bellerophon Formation (Hrvatović et al. 2006). They determine the beginning of the Alpine sedimentary cyclus. The presence of a Variscan deformation and/or metamorphism is not proved. Major folding and metamorphism probably commenced within the Triassic (Hrvatović 1998).

Sana-Una Terrane

The oldest formation in the Sana-Una Unit are Lower and middle Carboniferous turbidites (Javorić Flysch Formation), mostly composed of metasandstones, metasiltstones and with olistostromes of variable thickness.

Turbidites (with thickness of ca. 250 m) contain redeposited composite brachiopodal fauna of the Bashkirian or Moscovian age, as well as remains of paleoflora. The prevailing turbidite sedimentation ceased from time to time, or was replaced with fluxoturbidites or olistostromal shocks. A longer interval of the bottom clayey-silty sedimentation involved the development of the primary siderite iron ore beds (Ljubija, Prijedor). The olistostromes are mainly composed of limestone olistoliths of different age (Devonian, Lower Carboniferous, middle Carboniferous). Their thickness varies from 1 to 90 m (Grubić & Protić 2003). The whole Carboniferous sequence is anchimetamorphosed, but no Variscan deformation and metamorphic event was proved (Krstić et al. 2005).

The relatively long stratigraphic hiatus was ended by the unconformably resting Guadalupian-Lopingian continental clastics (red breccias and conglomerates, sandstones, shales and evaporites), which were followed by the transgressive Lower Triassic clastic formation (Karamata et al. 1997).

Adriatic-Dinaridic Platform

The geotectonic belt of the Internal and External Dinarides extends for about 1000 km from the Southern Alps to the Hellenides in Greece. It was derived primarily from Late Paleozoic–Triassic rifting off the Gondwana margin (Vlahović et al. 2005; Balini et al. 2006). During the Mesozoic–Cenozoic time, the region of the External Dinarides, which includes the karst regions of Slovenia, Croatia, Hercegovina and Montenegro, comprised the carbonate platform often called the Adriatic Carbonate Platform (e.g. Vlahović et al. 2005) or as Adria Terrane by Pamić et al. (1997).

Paleozoic rocks outcrop in the Dinarides at several localities in Croatia: Lika Region, Velebit Mts, Gorski Kotar, the Banovina Region, Medvednica Mts and in oil exploratory-wells in Zebanec (Hrvatsko Zagorje) (Sremac 2005).

The Lika Region and the Velebit Mts represent the best known and the most completely developed Carboniferous-Permian sequence in Croatia, showing partial analogy with the Carnian Alps. In the Lika Region predominantly shallow marine Carboniferous deposits are documented by numerous floral and faunal fossil findings (for references see Sremac 1991, 2005).

In the Velebit Mts lower and upper late to post-Variscan cycles can be recognized. In the lower cycle Kasimovian-Gzhelian argillaceous shales intercalate with fusulinid sandstones, oolitic grainstones, lime mudstones and quartz-conglomerates and probably represent shallow marine setting related to the tectonically active area. At some localities sedimentation from the Late Pennsylvanian concordantly continued to Lower Permian deposits represented by lenses of Sakmarian Rattendorf limestones isolated within clastics.

The upper cycle Middle–Upper Permian to Triassic rocks of the Velebit Mts have an undefined position in relation to the lower cycle and comprise two distinct stratigraphic units: probably Lower Guadalupian (possibly partly Cisuralian in lower parts) clastic Košna Formation (partly equivalent of clastic Trogkofel Limestone), and the Guadalupian-Lopingian Velebit Formation (carbonates) in ascending order. The Velebit Formation represents a well defined platform carbonate sequence. Shallow subtidal, intertidal and supratidal sabkha environments can be recognized. Transgressive/regressive cycles were caused by glacio-eustatic sea-level oscillations (for the references see Sremac 1991, 2005; Aljinović et al. 2003; Aljinović et al. 2008).

The Gorski Kotar Region is represented by predominantly clastic deposition. The clastic sedimentary complex consists of an isolated occurrence of Kasimovian-Gzhelian Triticites sandstones and of Permian orthoquartzitic to polymict conglomerates, sandstones and thin-bedded sandstone-shale intercalations. These sediments were deposited near the active tectonic belt, mainly as fan delta deposits. According to the microfossil assemblage in resedimented limestone blocks and clasts, especially according to pyritized albaillellacean radiolarians (Sremac & Aljinović 1997; Aljinović & Kozur 2003), the Guadalupian age can be inferred for the entire Paleozoic clastic sedimentary complex of Gorski Kotar, thus correlated with the lower cycle of late to post-Variscan sediments.

The Velebit Mts and Gorski Kotar Region started to develop as a part of the Carboniferous to Cisuralian epeiric platform formed by northern Gondwana accumulating shallow marine carbonates and terrigenous clastics. In the Late Cisuralian this primary setting was punctuated by intermittent rift-related extensional tectonics that broke the platform into several horsts and grabens isolated from the main carbonate platforms in the Southern Alps, whereas the clastic rocks in the Gorski Kotar in western Croatia filled the Permian interplatform basins (grabens) prior to the Early Triassic carbonate deposition (Sremac 2005; Aljinović et al. 2008).

In the region of the Adria units in Slovenia, the Upper Pennsylvanian-Permian sequence occurs in the framework of two structural units: i) the Trnovo Nappe that is partly preserved west of Ljubljana, and ii) the Hrušica Nappe that passes over in the overthrust structure of the External Dinarides. The stratigraphic position of these beds below the Val Gardena (= Gröden) Formation is only partly defined. The main reason are complex tectonic conditions, lack of stratigraphic marker horizons and fossils within the monotonous clastic sedimentary rocks, dark grey shale, grey lithic quartz sandstones and quartz conglomerates.

The sedimentary succession, which is at least 1650 m thick, was divided into three lithological units: the lower shale, the sandstone conglomerate and upper shale (Mlakar 1987, 1994, 2003; Mlakar et al. 1993). Incontestably dated are only rocks of the sandstone subunit, attributed on the basis of fossil plant remains to Early Pennsylvanian (Kolar-Jurkovšek & Jurkovšek 1985, 1986, 1990, 2002). A strong erosional unconformity is found within the sandstone-conglomerate unit, dividing the sedimentary succession into two parts. The lower part, consisting of the lower shale and basal part of the sandstone-conglomerate unit constitute a regression, deltaic-fluvial sequence (Mlakar et al. 1993). The erosion unconformity is overlain by coarse-grained conglomerate with larger limestone clasts and blocks that have partly been dated, and attributed to Silurian, Devonian and Late Moscovian ages (Ramovš & Jurkovšek 1976; Ramovš 1990). Conglomerates above the erosion surface are most probably a product of alluvial fans and/or fan deltas. They constitute a transgressive sequence (the upper shale unit) representing the second sedimentary cycle. In the upper shale unit the sequence of the marine ingressions with dominant clastic sedimentation is expected. This sequence is unconformable overlain by the clastic Val Gardena Formation (= Gröden Formation), even the contact is mostly tectonic. The Val Gardena Formation red-beds (fluvial-lacustrine and playa environment) are passing into the Bellerophon Formation (Skaberne 2002).

The sedimentary rocks of the Ortnek Formation or the so called "clastic Trogkofel beds" occur below the Val Gardena Formation south of the Sava Folds, in Lower Carniola at Ortnek (Ramovš 1963, 1968). In its basal part, quartz conglomerates followed by quartz sandstones are developed. They pass gradually into shaly mudstones with lenses of various (coral, brachiopod and fusulinid, brecciated crinoidal) massive-reef limestones, calcareous breccias and angular conglomerates. The fauna dates these rocks to the Sakmarian–Artinskian. The macrofauna shows close relations with the South-Alpine assemblages, whereas most of the fusulinid microfauna are more similar to the Asian faunal province.

The Southern Alps

In the eastern Southern Alps (Carnic Alps, Karawanken, Southern Karawanken Mts), Pennsylvanian-Permian sediments overlie unconformably the Variscan basement. This basement was folded and, in the western part, slightly metamorphosed during the Moscovian. Within these late and post-Variscan sedimentary sequences, two cycles can be recognized. They are separated by a main unconformity (Cassinis et al. 1988; Massari et al. 1988).

The Eastern Southern Alps (Carnic Alps, Southern Karawanken and Julian Alps)

The deformed Variscan basement in the Carnic Alps and Karawanken Mountains terminated by the syn-orogenic flysch of the Hochwipfel Formation (Ebner et al. 2008) is unconformably overlain by a thick sequence of the Upper Pennsylvanian and Cisuralian deltaic and shallow marine siliciclastic and carbonate sediments (Fig. 6, col. 44). They were deposited in discrete basins formed by block and wrench faulting subsequent to the final phase of Variscan activity (Venturini 1982, 1990a,b; Krainer 1993). The lowermost cycle is composed of Kasimovian-Gzhelian to Cisuralian deltaic to shallow marine sediments. The uppermost cycle begins with continental to shallow marine clastics of the Gröden Formation.

The basal Bombaso Formation is formed by immature coarse-grained clastic wedges, rich in pebbles of radiolarian cherts, arenites, volcanics and Silurian to Lower Mississippian limestones (Fenninger et al. 1976; Venturini 1990). The Pramollo Member has been regarded for a long time as the base of the Bombaso Formation. The new field investigations indicate a clear relationship to the Hochwipfel Formation (Schönlab & Histon 2000).

The overlying Auernig Group (with maximum thickness of 1200 m) consists of quartz-rich conglomerates (deltaic-beach environment), trough- and hummocky-crossbedded sandstones (shoreface), bioturbated siltstones, shales and fossiliferous limestones. In the upper part of the Auernig Group, the studied lithofacies form clastic-carbonate transgressive and regressive cycles. In general, sea-level lowstands are marked by coarse-grained clastic sediments, whereas sea-level highstands are marked by limestones (Krainer 1993). Cycle formation is related to eustatic sea-level changes caused by the Gondwana glaciation (Massari & Venturini 1990). Sediments of the Auernig Group contain a rich Kasimovian-Gzhelian association of fauna and plant fossils (Passini 1963; Gauri 1965 — brachiopods; Kochansky-Devide & Ramovš 1966; Kodsi 1967 — bryozoans; Kahler 1983, 1985; Wagner 1984; Fritz & Boersma 1986 — flora; Flügel 1987 — sponges; Hahn et al. 1989 — trilobites; Flügel & Krainer 1992; Krainer 1995; Samankassou 2003 — algae; Forke 2007 — fusulinids).

The Permian forms a thick sequence of different, in most cases shallow marine carbonates and clastic sediments, divided into the Rattendorf Group and Trogkofel Group, which were marked by Krainer (1993) as the lower cycle, and the upper cycle with the Tarvis Breccia, Gröden Formation and Bellerophon Formation, from the base to the top.

The Rattendorf Group sedimentary assemblages were deposited in shallow marine environments, with sedimentary patterns changed from near-coast and inner shelf to outer shelf. The basal, Schulterkofel (= Lower Pseudoschwagerina) Formation (Krainer 1995) of the latest Gzhelian age is a sequence of thin clastic sediments (sandstone, siltstone, seldom conglomerates) and near-coastal to inner shelf limestones (Homan 1969; Flügel 1974, 1977; Buggisch et al. 1976). Four transgressive/regressive cycles have been recognized (Homann 1969; Samankassou 1997; Forke et al. 1998), similar to the Auernig Group, caused by glacio-eustatic sea-level changes of the Gondwana glaciation (Krainer 1993). The Grenzland Formation is a clastic sequence of quartz-rich conglomerates, cross-bedded sandstones, siltstones and red shales, with thin intercalations of limestones. These sediments were deposited in a shallow marine near-coastal environment. Based on fauna and plant fossils the Grenzland Formation is of Middle Asselian to Early Sakmarian age (Fritz & Boersma 1984; Kahler 1985; Boersma & Fritz 1986; Forke 2002).

Time equivalents to the Grenzland Formation, in which siliciclastic facies predominate, crop out in the famous locality of Permian rocks and fossils in the Southern Karawanken — the Dolžanova Soteska and Born Formations (Forke 2002). There, dark bedded biodetritic limestones, marls and sandy crinoidal siltstones are overlain by a grey and red limestone facies. Massive bioturbated wackestones of the lower part of this unit grade upward into crinoidal wackestones and bioclastic wacke- to packstones with more diverse fauna. They are followed by thick-bedded greyish to pale red limestones, which pass into the characteristic dark red bioclastic grainstones. Especially, the latter are exceptionally rich in productid and spiriferid brachiopods, as well as in other fossils of different groups (Heritsch 1933; Ramovš 1963; Hahn et al. 1989). The top of the unit is brecciated and it shows clear karst features that indicate subaerial exposure. The described unit, as well as the following mixed clastic-carbonate succession, with biohermal bodies (coral patch-reefs), have traditionally been regarded as the “carbonate and clastic Trogkofel beds” (Heritsch 1933, 1939; Ramovš 1968; Kochansky-Devidé 1970; Buser 1974, 1980; Kahler & Kahler 1980; Kahler 1983). However, detailed studies of fusulinid assemblages revealed an older, Middle-Late Asselian age (Buser & Forke 1996; Forke 2002).

The upper part of the Rattendorf Group sequence is represented by the open marine platform carbonate with a few thin clastic intercalations (the Zweikofel Formation; Flügel 1971, 1977; Flügel et al. 1971; Krainer 1995). The Late Sakmarian age is based on fusulinids (Kahler 1985; Forke 2002).

Sediments of the Rattendorf Group are overlain by ~400 m of thick-bedded and massive limestones of the Trogkofel Group (Trogkofel, Tressdorf, Goggau Limestones — Flügel 1980, 1981). All these limestones were deposited in shallow,

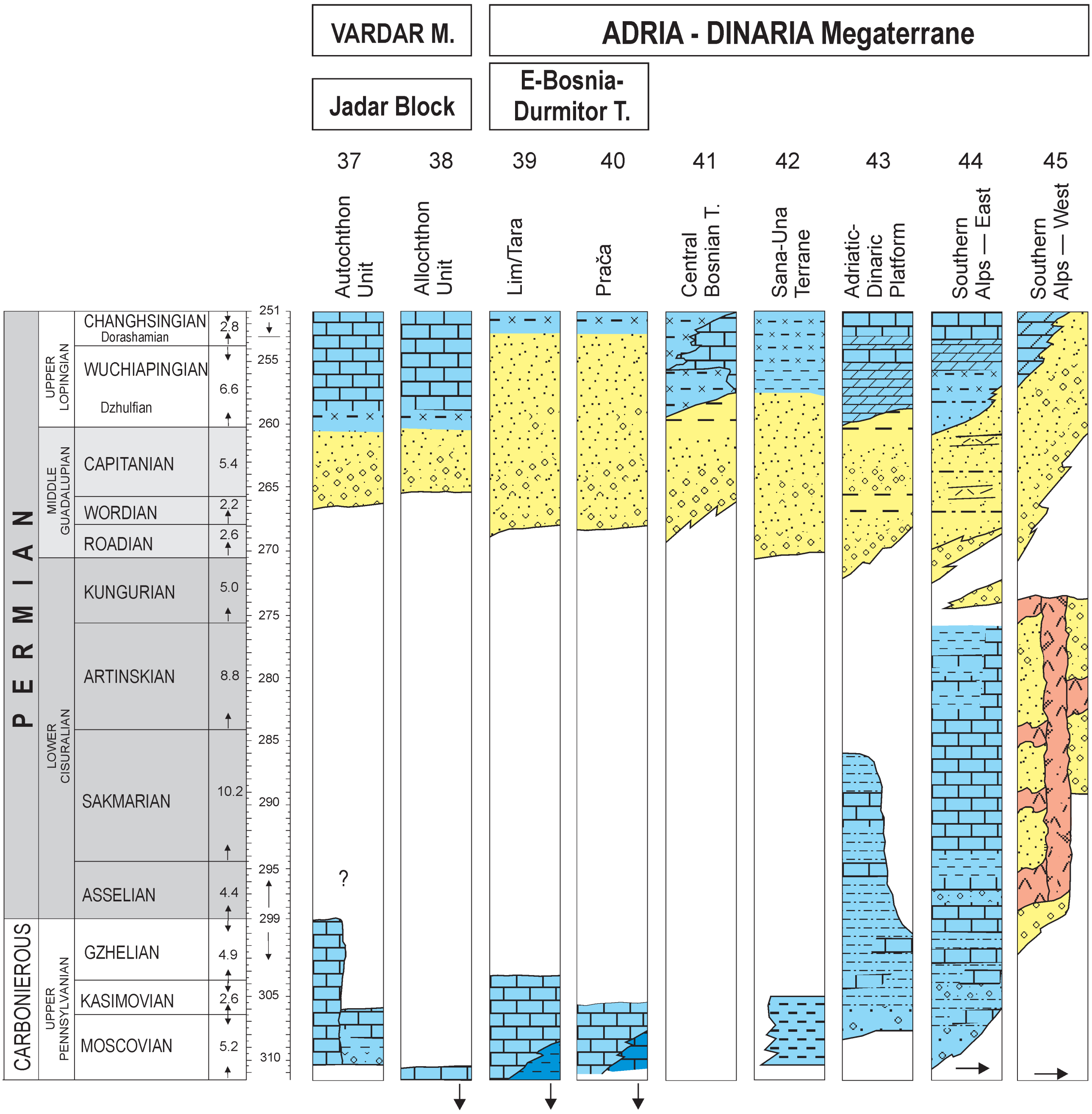

Fig. 6. Pennsylvanian-Permian sequences in the VARDAR and ADRIA-DINARIA Megaterranes. Legend in Fig. 2.

restricted and open marine shelf-lagoons with only minor bathymetric differences. On the basis of fusulinids, the lower part of the Trogkofel Limestones is dated to the Early Sakmarian, the Tressdorf Limestone to the Early Artinskian and the Goggau Limestone as the Late Artinskian (Flügel 1980; Kahler & Kahler 1980; Kahler 1986; Forke 2002).

In the Southern Karawanken, equivalents of the Zweikofel Formation and Trogkofel Limestone are only known from tectonically isolated occurrences (Ramovš & Kochansky-Devidé 1979; Novak & Forke 2005). The youngest (Late Artinskian) fusulinid fauna could be identified in thick-bedded light grey to white limestones and breccia, correlated with the Goggau Limestone, at Javorniškу rovt and Krajnska Gora (Novak & Forke 2005).

After a hiatus, due to block faulting movements, the Guadalupian-Lopingian sediments discordantly overlie the Trogkofel Group sequence, with the Tarvis Breccia in its basal part. It is interpreted as a scarp foot fan deposit and proximal debris flows and ranges from a few meters up to about 200 m. Limestone clasts derived from the underlying Trogkofel Group are the most frequent pebble material. Intercalations of red siltstones and claystones with caliche concretions are interpreted as being a part of evaporitic sedimentation within a coastal sabkha (Kober 1984). The Tarvis Breccia probably corresponds to the *Misellina* Zone (Buggisch & Flügel 1980) and is referred to as the "Saalian orogenic phase".

The boundary between the Tarvis Breccia and the overlying Gröden Formation conglomerates is marked by the first appearance of rhyolitic volcanic clasts. The Gröden Formation (0–800 m) rests upon rock complexes of different ages, including the Tarvis Breccia, Auernig Group, Hochwipfel Formation and even Devonian reef limestones, indicating strong block faulting tectonics. The Gröden Formation sediments are of fluvial, playa and shallow water origin (Buggisch 1978; Ori & Venturini 1981; Farabegoli et al. 1986). Only in the eastern Julian Alps (surroundings of Bled) the "*Neoschwagerina* Limestones" occur as the time equivalent of the Val Gardena (= Gröden) clastic sedimentary rocks. Fine-grained limestone breccia and small massive build-ups indicate a gently dipping carbonate ramp. Bedded shallow platform carbonates dominate in the upper parts (Flügel et al. 1984). Rich fusulinoidean fauna places this sequence in the Early Capitanian stage (upper part of *Neoschwagerina craticulifera* Zone; Kochansky-Devidé & Ramovš 1955). It could be inferred that these beds represent the same transgressive episode, confined within the Val Gardena Formation on a wide area of the eastern Southern Alps and Dinarides (Venturini 1990; Sremac 2005).

In the upper part, the Val Gardena (= Gröden) Formation is interfingering with the Bellerophon Formation facies. This sequence is composed of evaporitic sediments at the base (sabkha), followed by bituminous dolomites, well-bedded organodetritic grainstones (open-marine shelf) and bioclastic mudstones (restricted shelf), rich in faunal fragments (Buggisch 1974).

The Dolomites and Western Southern Alps

Dolomites

Late to post-Variscan sedimentation started during the lowermost Permian and was controlled by the strong extensional block-faulting tectonic and volcanic activity (Fig. 6, col. 45). As in the Carnic Alps and Karawanken the sequence shows two evolutionary stages, which are separated by a major unconformity: i) the lower cycle (Cisuralian)–Ponte Gardena/Waidbruck Conglomerate and the acidic Bolzano Volcanic Complex; b) upper cycle Guadalupian?–Lopingian — Gröden Formation and Bellerophon Formation.

The low-grade metamorphic Variscan basement (Brixen quartzphyllite) is locally overstepped by coarse-grained alluvial fan conglomerates (Ponte Gardena/Waidbruck conglomerate) of very variable thickness (maximum 200 m) deposited under semiarid climatic conditions. In many places, the Variscan basement is directly covered by the Bolzano Volcanic Complex or the Gröden Formation prograding gradually to the Bellerophon Formation. The Bolzano Volcanic Complex consists of lati-andesitic to rhyolitic volcanic rocks (lavas, ignimbrites, tuffs) with several intercalations of fluvial and lacustrine sediments. At the top of this sequence, lacustrine sediments composed of black siltstones and shales, thin algal layers and thin silica layers occur. Within these sediments Artinskian-Kungurian palynomorph assemblages were found (Hartkopf-Fröder & Krainer 1990). Radiometric age determinations on biotite showed ages of ~270 Ma for the Bolzano Volcanic Complex (D'Amico et al. 1980; D'Amico 1986). In the Carnic Alps and Southern Karawanken Mts age-equivalent sediments lack any volcanic material. The Guadalupian-Lopingian sediments of the upper cycle unconformable overlie the Bolzano Volcanic Complex or the Variscan basement directly. They are similar to those of the Carnic Alps and the Southern Karawanken Mts and can be divided into two lithostratigraphic units: the Gröden Formation (Val Gardena Sandstone) and Bellerophon Formation.

Lombardy

Late- to post-Variscan sediments (Fig. 6, col. 45) with synsedimentary volcanic rocks were deposited in several graben-like basins (Collio, Tione, W-Trompia, Boario, Treggiovo, and Orobic Basins) and overstepped the Variscan basement (Cassinis 1985, 1986; Cassinis & Perotti 1997). The Upper Pennsylvanian-Cisuralian part of the sequence (lower cycle) is represented by thick fluvial and lacustrine sediments, rhyodacitic volcanic rocks and their pyroclastic flows (Collio Formation, Treggiovo Formation) divided into several members (Cassinis 1966; Ori et al. 1986). Flora and mainly microflora suggest a Late Artinskian age (Ufimian) for the Collio Formation, and a younger age (Kungurian–Ufimian) for the Treggiovo Formation (Remy & Remy 1978; Cassinis & Doubinger 1991; Barth & Mohr 1994). The tetrapod footprints (Ceoleoni et al. 1986, 1987, 1988) assemblages are similar to those of the Oberhof and Rotterode Formations of the German Rotliegend (the "Upper Autunian" by Haubold & Katzung 1975; Haubold 1996). The time interval covered by the tetrapod-bearing sediments is constrained by the radiometric data obtained from volcanic rocks at the base and the top of the Collio and Treggiovo successions, which are from ~283 ± 1 Ma for the base of the Collio, up to 280 ± 2 Ma for the topmost volcanic horizon (mean $^{206}Pb/^{238}U$ age; Schaltegger & Brack 1999). The second cycle (?Guadalupian–Lopingian) is characterized by clastic red-beds of a fluvial sedimentary system (Verrucano Lombardo), time equivalent of the Gröden Formation (Val Gardena Sandstone) and the Bellerophon Formation in the Dolomites (Cassinis 1966; Cassinis et al. 1988; Ori et al. 1986).

The depositional and geodynamic domains in the Circum-Pannonian realm during the Pennsylvanian–Permian

The ensuing locking of the Variscan subduction system and the subsequent Pennsylvanian-Permian disintegration of the Variscan fold belt was probably the combined result of dextral shear, gravitational collapse of the over-thickened crust, and possibly back-arc extension related to post-orogenic steepening and decay of the N-dipping Paleotethys subduction zone (Jowett & Jarvis 1984). However, the Late Pennsylvanian and Cisuralian fault systems are clearly multi-directional, and affected not only the Variscan fold belt, but also large parts of its foreland. It is likely that dextral translation of Gondwana margin relative to Laurussia was the principal mechanism that governed their development (Ziegler 1988).

The post-Variscan period brought an intense crustal reequilibration and reorganization under an alternating transtensional and transpressional tectonic regime. The crustal reequilibration and tectonic activity was controlled by subsidence of intramontane basins, mostly with a major strike-slip component in their deformational history. Following the main phases of Variscan compression, thermal relaxation of the crust occurred in Pennsylvanian–Cisuralian times, creating the rifts and graben that allowed accumulation of the first stage of post-orogenic sedimentation.

Contemporaneous deep-crustal fracturing triggered widespread intrusive and extrusive magmatism characterized by a highly variable chemical composition — continental tholeiitic andesite/basalts, calc-alkaline to alkaline acid to intermediate volcanites and their volcaniclastics. The extensive rift-related tectonics and related extensional magmatic activity probably in response to changes in the regional stress field and subsequent thermal equilibration of the lithosphere have played an important role in the geodynamic evolution of sedimentary basins. Synsedimentary volcanism was an important source of the clastic filling of sedimentary basins as well as a very important stratigraphic marker.

Within the ambit of the CPR several Pennsylvanian–Permian paleogeographic zones were recognized, based on spatial relation to the Variscan orogenic belt, the timing of sedimentation, character of sedimentary environments and the structural type of sedimentary basins (Fig. 7). The following geodynamic domains can be generally distinguished:

1. *Continental strike-slip and rift-related basins of the internal part of the Variscan orogenic domain*;

2. *Continental and marine shallow-water extensional basins of the external part of the Variscan orogenic domain*;

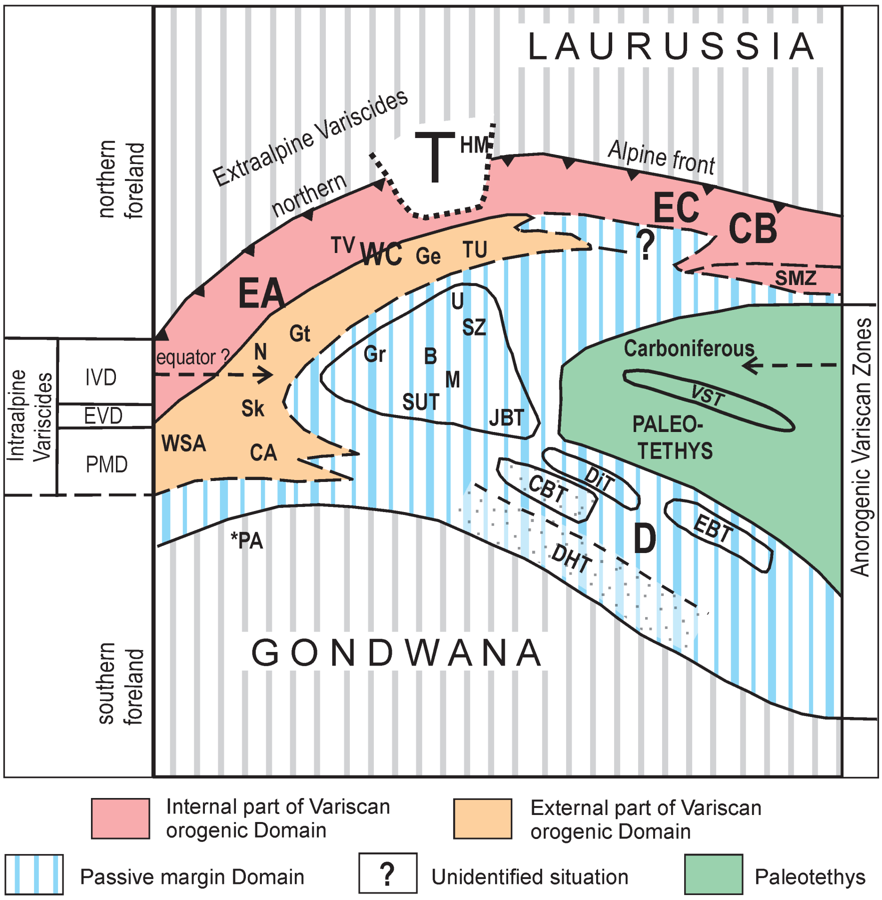

Fig. 7. Cartoon of the late Variscan (Carboniferous/Permian) paleogeographic restoration and post-Variscan zoning in the Circum Pannonian Region (modified after Ebner et al. 2008). Size, boundaries and positions of the units are schematized and are not to scale. The position of the equator is only tentative. **1** — *Continental strike-slip and rift-related basins of the internal part of the Variscan orogenic domain:* **IVD** — Mediterranean Crystalline Zone (MCZ) with Late Devonian–Early Carboniferous deformation and metamorphism and SMZ with polystage Variscan overprint; Veitsch-Nötsch-Szabadbattyán-Ochtiná Zone (VNSOZ): post orogenic sediments (marine foredeeps, remnant basins) in respect to the MCZ. **2** — *Continental and marine shallow-water extensional basins of the external part of the Variscan orogenic domain:* **EVD** — Prevailing continental sediments generated in the zone of typical or atypical Visean-Bashkirian flysch, characteristic of Variscan deformation, partly with a slight metamorphic overprint; syn-orogenic siliciclastic flysch sediments of the Variscan flysch zone (VFZ): deformed during the (?) Late Visean until the Intra-Late Carboniferous orogeny. **3** — *Continental to marine shallow-water basins related to passive margin domain:* **PMD** — Pelagic carbonate and turbiditic siliciclastic sediments lacking any Variscan deformation of the Bükk-Jadar Zone; Elements of the future Gondwana NE border without Carboniferous syn-orogenic flysch sediments and lack of Variscan or suspected Variscan deformation; Paleotethys with the Veles Series Terrane remaining as an open oceanic domain during the final Variscan period. * *PA = Panafrican basement* — without Variscan overprint from the northern margin of Gondwana, explored in AGIP drillings in front of the Southern Alps (Vai in Ebner et al. 2004). **Further Abbreviations: B** — Bükk Mts, **CA** — Carnic Alps, **CBT** — Central Bosnian Terrane, **CB** — Carpatho-Balkanides, **D** — Dinarides, **DHT** — Dalmatian Herzegovinian Terrane, **DIT** — Drina Invanjica Terrane, **EA** — Eastern Alps, **EBT** — East Bosnian Durmitor Terrane, **EC** — Eastern Carpathians, **Ge** — Gemeric Units, **Gr** — Rannach Nappe of the Graz Paleozoic, **Gt** — Gurktal Nappe, **HM** — Helvetic Moldanubian Unit, **JBT** — Jadar Block Terrane, **M** — Medvenica Mts, **N** — Noric Nappe (Graywacke Zone), **T** — segment of later TISIA Megaterrane, **Tu** — Turnaic Unit, **TV** — Tatro-Veporic Units, **SK** — South Karawanken Mts, **SMZ** — Serbo-Macedonian Zone, **SUT** — Sana-Una Terrane, **U** — Uppony Mts, **Sz** — Szendrő Mts, **VST** — Veles Series Terrane, **WC** — Western Carpathians, **WSA** — Western Southern Alps.

3. *Continental to marine shallow-water basins related to passive margin domain.*

The established geodynamic domains of this area correspond to paleogeographic and paleotectonic reconstructions, published by Scotese & McKerrow (1990), Rakús et al. (1998), Golonka (2000, 2002), Golonka et al. (2000, 2006).

Distinctive aspects of the Carboniferous-Permian sedimentary basins associated with strike-slip setting are longitudinal and lateral asymmetry shape, episodic rapid subsidence, strong lateral facies changes with local unconformities, and stratigraphic and facial contrast among different basins within the same sedimentary realm. Basin fill was derived from multiple basin-margin sources that changed through time as a result of continued lateral movement along the basin-margin faults. Rift-related basins provide many common tectono-sedimentary elements; including, asymmetry along low-angle and listric border faults with large accumulation on one side, fault movements contemporaneous with sediment infill with facies coarsening along the border fault, and rapid erosion of basement rocks. For both tectonic settings intensive synsedimentary volcanism is characteristic. Due to later erosion, reworked volcanic materials became an integral part of the sedimentary filling sources.

Continental strike-slip and rift-related basins of the internal part of the Variscan orogenic domain

Within the main part of ALCAPA (Eastern Alps, CWCZ in the Western Carpathians), TISIA and DACIA Megaterranes (Eastern and Southern Carpathians), the post-orogenic Pennsylvanian–Cisuralian sequences are represented mostly by continental coarse-grained clastic sediments, generally. In the Moscovian sequences lacustrine-deltaic and fluvial-limnic environments are dominant, with coal seams formed in the humid climate. The Cisuralian is characteristized by the braided alluvial and playa/aeolian environments in arid/semiarid climate. The post-orogenic sedimentary basins were established in transpressional/transtensional and extensional setting first in the Moscovian-Kasimovian (Phase 1) and later in the Cisuralian (Phase 2). The synsedimentary volcanism was dominantly acidic- to intermediate and/or rhyolite-basalt bimodal calc-alkaline, rich in ignimbrites and explosive products. In the axial part of extensional, rift-related basins the volcanites of the continental tholeiitic magmatic suite are dominant (Hronicum in the Central Western Carpathians; Moma and Dieva Nappes in Northern Apuseni Mts).

The post-orogenic sedimentary sequences of the internal part of the Variscan orogenic domain overstepped their metamorphic basement with angular unconformities. With respect to their creation the following types of basement are recognized: 1. medium- to high-grade crystalline core complexes with huge masses of syn- and late orogenic magmatites (Variscan terranes in the Central Western Carpathians, Lower and Middle Austroalpine, in the Penninic system *Habach Terrane*, Tisia crystalline basement units, Bihor Autochthon and Codru Nappe System in the Apuseni Mts, units in the Bucovinian-Getic Composite Terrane in the Eastern and Southern Carpathians; = Mediterranean Crystalline Zone; Ebner et al. 2008), 2. Variscan low-grade metamorphic complexes derived from the Lower Paleozoic volcano-sedimentary sequences of different tectono-environment — oceanic domain, pre-flysch stage, marine intracontinental rift-related settings (Quartzphyllite Unit, part of Graywacke Zone and Gurktal Nappe and Drauzug in the Eastern Alps, part of Tisia crystalline basement, Biharia Nappe System in Apuseni Mts and partly crystalline basement of the Western, Eastern and Southern Carpathians) and Mississippian foreland and remnant basins (Nötsch-Veitsch-Szabadbattyán-Ochtiná Zone in the Western Carpathians and Eastern Alps; Ebner et al. 2008).

The sedimentary filling of these basins contains clastic detritus derived from the immediate basement and is generally characteristic of a rapid sedimentation, low-grade of mineral and structural maturity, sedimentary cyclicity (VI. and III. order cycles) and distinct synsedimentary volcanism. The stratigraphy of the continental Pennsylvanian-Cisuralian succession in the CPR is based on lithostratigraphic or allostratigraphic principles. The reason for this is the lack of proper guide fossils of regional importance.

The Variscan fold belt was apparently characterized by considerable relief which became progressively degraded during the Cisuralian. The erosion products accumulated in intramontane basins, many of which had been established starting in the Permian. In these basins, sedimentation was only temporarily interrupted at the end of the Cisuralian (i.e. Saalian unconformity) and resumed with the accumulation of coarse fluviatile clastics under increasingly arid conditions. The changes of the source area and directions of sedimentary transport were reflected within sedimentary formations. In many places, however, there is no clear distinction between “Autunian and Saxonian sediments”, due to the lack of fossils and the poorly-defined chronostratigraphic-biostratigraphic boundary (Lower Rotliegend-Upper Rotliegend 265–290 Ma in continental formations, Menning 1995). Following the main stages of Variscan compression, thermal relaxation of the crust occurred in Early Permian times, creating the rifts and grabens that allowed accumulation of the first phase of sedimentation.

Extension of rifting in the internal zone of the CPR Variscides occurred coevally with thrusting and strike-slip faulting further to the South. The timing and extent of individual stages of extension and rifting throughout the internal part of the CPR Variscides rift systems is still uncertain, as the dating of Pennsylvanian and Cisuralian red-beds is imprecise. There is no doubt that the thermal signature of the Permian rifting was a significant control of the subsequent Mesozoic evolution of the CPR lithosphere. The beginning of the Alpine cycle in this zone was shifted from the Late Permian up to the Early Triassic. The Permian sediments in the whole zone of the internal part of the Variscan orogenic domain are discordantly overlapped by the extremely mineral mature sediments of the Early Triassic “Buntsandstein” facies.

Continental and marine shallow-water extensional basins of the external part of the Variscan orogenic domain

The Pennsylvanian and/or Permian basins were generated in the zone of atypical or typical Variscan flysch domain. The late Variscan deformation of the Mississippian flysch sequence is characteristic, partly with a slight metamorphic overprint. Post-orogenic sedimentation began during the Late Moscovian and Kasimovian–Gzhelian with shallow water siliciclastic-carbonate sedimentation with a distinct unconformity. Sedimentation continued gradually to the dominant carbonate facies up to the Artinskian-Kungurian (Southern Alps). In contrast to this, in the Turnaic Unit (Inner Western Carpathians) the Bashkirian flysch sediments are unconformably overstepped by the Guadalupian-Lopingian continental red-beds prograding gradually into the evaporites. In the Southern Gemeric Unit, the long lasting Early Paleozoic flysch of the *Gelnica Terrane* is unconformably overstepped by mineralogically mature Cisuralian continental sediments associated with the rhyodacite volcanism. Similarly, in a part of the Carpatho-Balkanides the Mississippian siliciclastic turbidite sequences are disconformably covered by the continental Moscovian (Stara Planina-Poreč Unit) or Kasimovian-Gzhelian clastic sediments associated with acid to intermediate volcanites and thin coal seams in some horizons (*Kučaj*, *Vrška Čuka-Miroč*, *Ranovac-Vlasina-Osogovo Terranes*). The Pennsylvanian formations either gradually prograde into the Cisuralian coarse-grained clastic sediments or are followed by long lasting breaks in sedimentation (Poreč region).

In the area of the Dolomites and Western Southern Alps, the Variscan post-orogenic rift-related sedimentary sequences directly overlap the variably metamorphosed and deformed Variscan crystalline basement.

Gradual sedimentation and progradation from continental to sabcha-lagoonal/shallow marine environment is characteristic of sedimentary basins in this geodynamic domain.

Continental to marine shallow-water basins related to passive margin domain

The gradual continuation of deep-water turbidite siliciclastic sedimentation from the Mississippian up to the Bashkirian or Moscovian is characteristic of this geodynamic zone. Later, sedimentation is followed either by shallowing and interfingering with shallow water carbonate and siliciclastic-carbonate formations or breaking of sedimentation and stratigraphic hiatus. The Variscan regional metamorphism and deformation is unknown in this realm. This zone includes vast areas of the ADRIA-DINARIA Megaterrane, the Dinarides (Velebit Mts, Sana-Una, Central and Eastern Bosnian, Drina-Ivanjica Terranes), the Jadar Block in Vardar Zone and the Bükk Composite Terranes.

The relatively long lasting stratigraphic hiatus in this geodynamic domain was the time equivalent of the thermal relaxation and subsidence of lithosphere, which were introduced during the Pennsylvanian–Cisuralian within the internal and external Variscan orogenic domain by an intensive phase of wrench faulting. On the other hand, in the vast area of the ADRIA-DINARIA Megaterrane a period of increased rifting activity started during the Late Permian. This is reflected in the development of a short lasting period of continental, mainly braided alluvial coarse-grained sedimentation in the Guadalupian. This continental sedimentation continued progressively into the Lopingian–Induan sabkha-lagoonal and shallow water evaporate — carbonate shelf. All these formations are an integral part of the Alpine sedimentary cycle. The development of a new interior rift system in this domain paved the way for the later Mesozoic break-up of Pangea and reorganization of plate boundaries (Ziegler 1988). It necessary to mention, that some parts of the Adria-Dinaria domain (the Jadar Block and Drina-Ivanjica Terrane) contain information about the existence of pre-Guadalupian thrusting or thrust-faulting and possible deformation (the supposed thrusting of the Likodra Nappe during the “Saalic” phase before the Middle Permian transgression; Filipović 1995).

Conclusions

Within the ambit of the Circum Pannonian Region several Pennsylvanian–Permian paleogeographic zones were recognized, based on spatial relationship to the Variscan orogenic belt, the timing of sedimentation, character of sedimentary environments and the structural type of sedimentary basins.

Continental strike-slip and rift-related basins of the internal part of the Variscan orogenic domain were developed within the main part of the ALCAPA (Eastern Alps, Western Carpathians), TISIA and DACIA Megaterranes (Eastern and Southern Carpathians in Romania and Serbia-Bulgaria). The post-orogenic Pennsylvanian–Lower Permian sequences are generally represented mostly by continental coarse-grained clastic sediments. Acidic- to intermediate and/or rhyolite-basalt bimodal calc-alkaline synsedimentary volcanism, rich in ignimbrites and explosive products, was dominant. In the axial part of rift-related basins the volcanites of the continental tholeiitic magmatic suite were associated.

Continental and marine shallow-water extensional basins of the external part of the Variscan orogenic domain were developed within minor parts of the ALCAPA (Inner Western Carpathians), DACIA (the Carpatho-Balkanides) and ADRIA Megaterranes (the eastern and western part of the Southern Alps, Dolomites). The Pennsylvanian and/or Permian basins were generated in the zone of atypical or typical Variscan flysch. The late Variscan deformation of the Mississippian flysch sequence, partly with a slight metamorphic overprint is characteristic. Generally, post-orogenic sedimentation started in the Late Moscovian/Kasimovian-Gzhelian with an unconformable lying marine shallow water siliciclastic-carbonate sequence. Sedimentation continued gradually to the dominant carbonate facies up to the Artinskian-Kungurian (Southern Alps). In a part of this domain (Carpatho-Balkanides) the Mississippian flysch sequences are disconformably covered by the continental Moscovian/Kasimovian-Gzhelian or Cisuralian (Southern Gemeric Unit in the IWCZ) clastic sediments associated with acid to intermediary volcanites. In some part of this domain, the Bashkirian flysch sedimentation is followed by a long lasting break in sedimentation (Poreč region in Carpatho-Balkanides, Turnaic Unit in IWCZ), which is documented by the Guadalupian-Lopingian unconformity of continental red-beds overstep sequence.

Continental to marine shallow-water basins related to passive margin domain are characterized by the gradual continuation of deep-water turbidite siliciclastic sedimentation from the Mississippian up to the Bashkirian or Moscovian. In the Kasimovian–Gzhelian the sedimentation is followed by shallowing with shallow water carbonate and siliciclastic/carbonate formations or breaking of sedimentation and stratigraphic hiatus. The Variscan regional metamorphism and deformation is unknown in this realm. This zone includes vast areas of the ADRIA-DINARIA Megaterrane — the Dinarides (Velebit Mts, Sana-Una, Central and Eastern Bosnian, Drina-Ivanjica Terranes), the Jadar Block in the Vardar Zone and the Bükk Composite Terranes in the ALCAPA Megaterrane.

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