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REVIEW

Devonian–Carboniferous pre-flysch and flysch environments in the Circum Pannonian Region

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Abstract: The following Devonian–Carboniferous paleogeographic and Variscan orogenic domains were recognized in the Circum Pannonian Region: Oceanic and arc related environments — Noric Bosnian/Carnic-Dinaric Zone (carbonate dominated passive continental margins) — Inovo Zone (Devonian siliciclastic dominated stable continental margins) — Quartzphyllite Complexes — Carpatho-Balkanic intracontinental rift systems — Variscan Flysch Zone — Carboniferous anorogenic turbiditic siliciclastic sediments at stable margins (Bükk-Jadar Zone) — Carboniferous foredeeps and remnant basins (Veitsch/Nötsch-Szabadbattyán-Ochtiná Zone) related to metamorphic zones (Mediterranean Crystalline Zone) formed already during an Early Carboniferous (Late Devonian) orogenic event. The syn-orogenic Variscan Flysch Zone formed in the suture at the leading edge of the colliding terranes (Noric Composite Terrane and Variscan Carpatho-Balkanic terranes) along the Laurussian margin (Eastern and Southern Alps, Western and Eastern Carpathians, Carpatho-Balkanides) N to W of the bay of the Carboniferous Paleotethys. This collision was connected with deformation and partly low grade metamorphism and occurred during a Serpukhovian-Bashkirian orogenic event which is also indicated by an unconformable Moscovian/Kasimovian continental molasse. The Variscan deformation of the East Bosnian Durmitor and Central Bosnian Terranes, situated in the Carboniferous SW of the Paleotethys, is only weak and not documented in a sufficient way. Bükk, Sana Una, Jadar Block and Drina-Ivanjica Terranes remained during the Carboniferous subsiding passive margins in shallowing upward systems. Therefore they lack any Variscan deformation, their turbiditic siliciclastic environments cannot be assigned as syn-orogenic flysch deposits and they are covered within Bashkirian-Moskovian times conformably by marine shallow water sediments.

Key words: Circum-Pannonian Region, Devonian-Carboniferous, paleogeography, stratigraphy, tectonostratigraphic terranes, Variscan orogeny.

Introduction

The Circum Pannonian Region (CPR) is made up of five Megaterranes: Alcapa, Tisia, Dacia, Vardar and Adria-Dinaria. These Megaterranes include Alpine, Variscan and pre-Variscan tectonostratigraphic units consting of terranes (Fig. 1). For unravelling the complex geological evolution a group of geoscientists working in the CPR prepared a set of "Tectonostratigraphic Terrane and Paleoenvironment Maps of the Circum Pannonian Area" (Kovács et al. 2004). This set of maps includes a map of the "Variscan pre-flysch (Devonian–Early Carboniferous) environments" (Ebner et al. 2004; http//www.geologicacarpathica.sk). The Carboniferous syn-orogenic flysch environments are not shown in this or another map, but they are documented in the stratigraphic columns (Figs. 2–6). This paper focusses on the Devonian–Carboniferous pre- and syn-orogenic sedimentary evolution and its implication for the Variscan orogeny in the CPR.

We specified in this paper those tectonostratigraphic units as "terranes" which follow one of the two terrane categories in the original terrane definition by Keppie & Dallmeyer (1990):

(1) Exotic terranes: although no oceanic remnants can be proven between them, the difference in the evolution of the presently adjacent crustal blocks/fragments is so large, that it cannot be explained by lateral facies transition (typi-

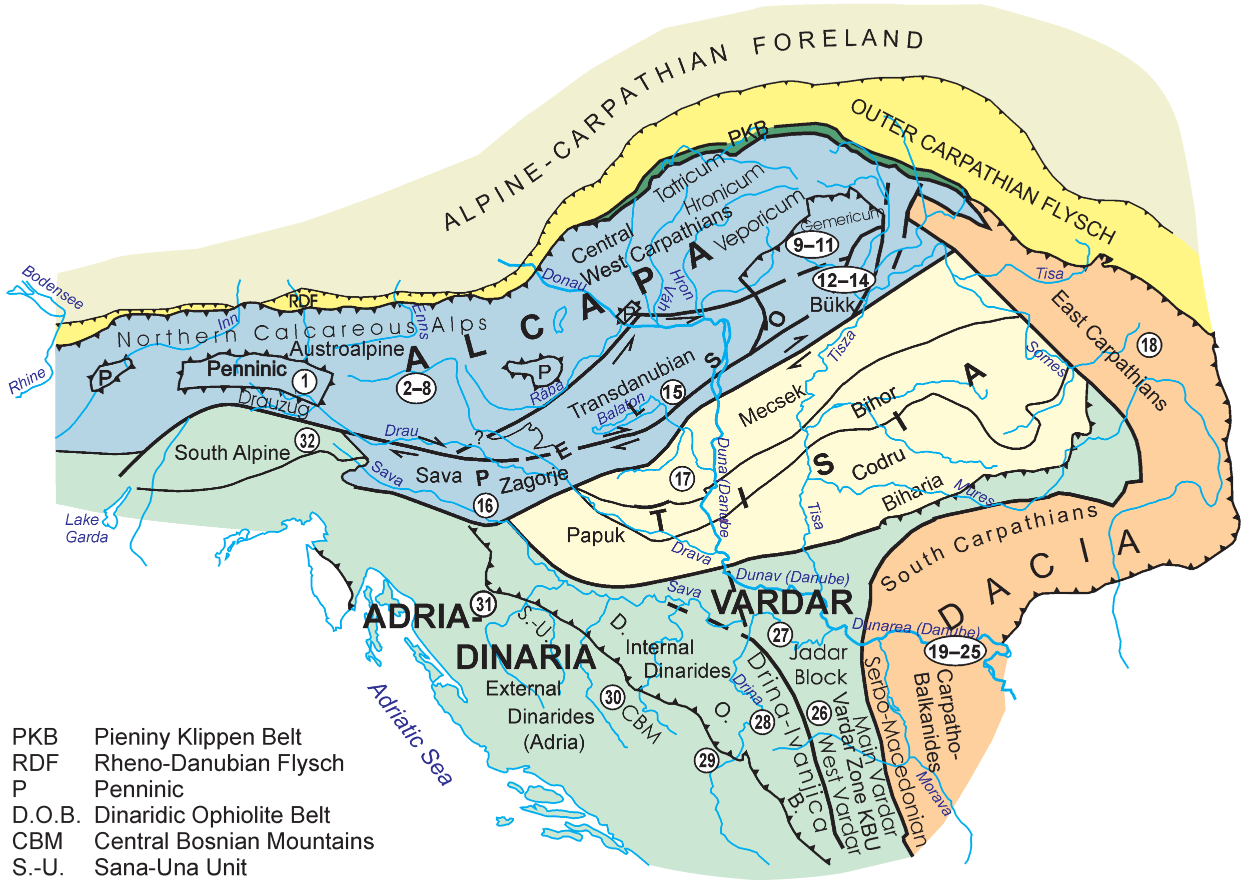

Fig. 1. The Alpine megaterranes and important tectonostratigraphic units of the Circum Pannonian Region. The figures indiacte schematically the position of the described units documented in Figs. 3–7: the Eastern Alps (1–8), the Western Carpathians (9–11), the Pelsonia Composite Terrane (12–16), the Tisia Megaterrane (17), the Eastern Carpathians (18), the Carpatho-Balkanides (19–25), the Vardar Megaterrane (26, 27), and the Adria Dinaria Megaterrane (28–32).

cal examples: the two sides of the Periadriatic/Balaton and Mid-Hungarian Lines/Lineaments; that is these are *displaced terranes* due to strike-slip and related rotational dispersions).

(2) Proximal terranes: even if they show similar evolution, there could be very narrow traces of telescoped oceanic lithosphere (remnants of an oceanic basin), which separated them for certain time of the earth history.

If a later terrane came into existence by amalgamation and accretion of former terranes it is a "***composite terrane***". These can be multiple "composite", like the major terranes of the Circum-Pannonian region, for which we use the term "***megaterrane***".

During our terrane analysis we followed the method described in Howell's (1989) classic monograph. For traditional units their differences regarding geological evolution can be explained by lateral facies transition we use the terms nappe/(facies)zone/unit, for smaller rank units outlier/subzone/subunit.

In the following text Variscan tectonostratigraphic units and terranes will be marked by Italic letters. Generally the nomenclature for Variscan units and terranes follows that used in the IGCP No. 276 Terrane Maps and Terrane Descriptions (Ed. Papanikolaou 1997; Ebner et al. 1997).

Some Carboniferous turbiditic sililiclastic sequences in the Bükk-Jadar-Dinaric domains, previously named as flysch, are devoid of any Variscan deformation. We therefore do not interpret them as syn-orogenic flysch sensu strictu and place the term "flysch" within quotation marks where we referred to the original descriptions. The post-Variscan molasse stage of the CPR is summarized in Vozárová et. al. (2006, 2008). For a better understanding of the late Variscan history some information related to the pre-Devonian and post-Variscan history of the CPR are also included in this paper.

Devonian–Carboniferous sedimentary sequences in the Circum Pannonian Region (CPR)

The ALCAPA Megaterrane

The Eastern Alps

The *Habach Terrane* (*HT*, Fig. 3) in the **Penninic Nappe System** reflects a long lasting history starting in magmatic arc/back arc environments of the Latest Precambrian/Early Paleozoic (Eichhorn et al. 1999) associated with and followed by a montonous fine volcaniclastic sedimentation until the Variscan orogeny. The Carboniferous orogenic climax was connected to metamorphism associated with massive intrusions of I- and S-type granitoids (mainly between 330 and 300 Ma, Finger et. al. 1992; Neubauer et al. 1999). Carboniferous plant fossils provide an argument that post-orogenic sediments are also included within the Habach-Phyllite Group (Höck 1993). During the Alpine cycle the *HT* was overprinted by at least two stages of intensive Late Cretaceous–Paleogene metamorphism (low to medium grade and partly including an early high pressure stage) and deformation (Frank et al. 1987).

The pre-Alpine units of the **Austroalpine Nappe System** may be subdivided into:

a) Medium to high grade Austroalpine Crystalline Complexes, further subdivided into Lower and Middle Austroalpine Crystalline units (Tollmann 1977; Neubauer et al. 1999);

b) Low to very low grade fossiliferous Paleozoics "classically" referred to as "Upper Austroalpine" (Fig. 3; Graywacke Zone, Graz Paleozoic, Gurktal Paleozoic, Gailtal Paleozoic; Schönlaub & Heinisch 1993), and additionally the Austroalpine Quartzphyllite Complexes (Neubauer & Sassi 1993). All these units are regarded as parts of the *Noric Composite Terrane (*Frisch & Neubauer 1989);

c) The Veitsch Nappe of the Graywacke Zone and the Nötsch Carboniferous in the Drauzug record marine post-orogenic Carboniferous environments (Flügel 1977; Ebner et. al. 1991).

For a different view of the tectonic subdivion of the Eastern Alps see Schmid et al. 2004.

The Austroalpine Crystalline Complexes suffered a medium-high grade metamorphism of Early Carboniferous age. At some sites this metamorphism is pre-dated by Silurian/Devonian and older metamorphic events (Neubauer & Frisch 1993; Neubauer et al. 1999). Syn- to post-orogenic Variscan granitoids are frequent (Finger et al. 1992) and in some tectonic units an independent metamorphic/magmatic event is constrained as Permian/Early Triassic in age, meaning that it occurred between the Variscan and Alpine cycle (Schuster et al. 1999). During the Cretaceous orogeny major parts of the Austroalpine Crystalline Complexes were overprinted by an Alpine low grade amphibolite grade or locally even eclogite metamorphic grade overprint (Hoinkes et al. 1999).

In the **Graywacke Zone (GWZ)** of Styria the Noric Nappe consists of some hundreds of meters of ignimbritic Blasseneck porphyroid (Late Ordovician), Silurian limestones, black shales and basic volcanics. Platy, flaser/nodular and sometimes organodetritic limestones were deposited in the Devonian; mostly the sequences end at the transition of the Early- to the Middle Devonian. 200–300 m thick carbonate sequences reach the Frasnian or even the Famennian in the surroundings of Eisenerz. They are dated by some findings of micro- (conodonts, tectaculites) and macrofossils (trilobites, cephalopods, crinoids and stromatoporoids). Major parts of the limestones are metasomatized to siderite/ankerite that formed the famous siderite deposit of the "Styrian Erzberg". After a break in sedimentation lasting until the Late Tournaisian the Devonian limestones are overlain by a thin limestone breccia with mixed conodont faunas and the 100–150 m thick fineclastic Eisenerz Fm (Late Viséan–Serpukhovian) (Schönlaub 1982; Schönlaub & Heinisch 1993).

In the western parts of the GWZ, Salzburg and Tyrol, a carbonate facies prevailed in Devonian times and continued until the early Late Devonian (Wildseeloder Unit). It comprises shallow water dolomites (Schwaz and Spielberg dolomite) with small reefal bodies and is covered by pelagic limestones, cherts and shales of Frasnian age. The siliciclastic Glemmtal Unit, however, includes the some hundreds of meters thick Schattberg Fm with proximal turbidites, and the Lohnersbach Fm with much finer distal turbidite intercalations. Beginning with the Late Emsian the clastics were affected by basaltic volcanism. This magmatism produced a large variety of lavas, sills, pyroclastics and tuffites which are partly explained in terms of seamounts that sometimes emerged above the sea-level. Generally the geochemistry is of transitional to alkali intraplate type. An exception is the 200 m thick tholeiitic Maishofen basalt sill complex. An Early Carboniferous age for the top of the sometimes flysch-like volcaniclastics is suggested (Heinisch et al. 1987; Schlaegel-Blaut 1990; Heinisch & Schönlaub 1993).

The Variscan fold and thrust belt of the GWZ is unconformably covered by continental Permocarboniferous coarse grained molasse sediments (Krainer 1993; Vozárová et al. 2006).

The **Graz Paleozoic (GP)** builds up a stack of Alpine nappes with their individual Cretaceous metamorphic overprint (very low grade — lower amphibolite metamorphic facies; Rantitsch et al. 2005). In terms of stratigraphy it includes a volcaniclastic — carbonatic pelagic footwall which differentiated during the Late Silurian/Early Devonian into carbonate shallow water complexes and deeper, much more basinal environments with ± calcareous shales, siltstones and alkaline volcanics. In the uppermost (Rannach-Hochlantsch) tectonic unit the some hundreds of meters thick shallow water Rannach Group is made up of fossiliferous (corals, brachiopods, algae) limestones, dolomites, and silt-/sandstones of shelf areas with coastal and lagoonal domains and coral-brachiopod bioherms. Around the Middle-/Late Devonian boundary the shallow water facies is replaced by pelagic limestones, rich in conodonts and cephalopods (Forstkogel Grp.). Locally this up to 100 m pelagic carbonate sediments may reach the Early Serpukhovian. Sometimes the Late Devonian sedimentation of pelagic limestones (Steinberg Fm) terminated within the Frasnian/Famennian in a stratigraphic gap, above which sedimentation started again with pelagic limestones (Upper Sanzenkogel Fm) during the late Early Carboniferous. After another hiatus at the top of the Forstkogel Grp. marine carbonate and pelitic sedimentation (Dult Grp.) continued during the Bashkirian. As the GP is only covered by Upper Cretaceous Gosau sediments the existence of a Variscan deformation and low grade metamorphism is suggested only and lacks any field evidence (Ebner & Rantitsch 2000; Ebner et al. 2000).

The low grade metamorphic **Gurktal Paleozoic (GUP)** in Carinthia/Austria and Slovenia N of the Periadriatic Lineament exhibits thick Ordovician to Upper Silurian volcaniclastic sequences. From the latest Silurian to the Late Devonian 400 m thick clastics with m- to deca-m thick carbonatic intercalations, dated by Early and Middle Devonian conodonts, were deposited. They contrast with the >500 m thick phyllitic/metadiabasic Magdalensberg facies which already began within the (?)Middle Ordovician. Locally pre-orogenic sedimentation continued until the late Early Carboniferous (Mioč & Ramovš 1973; Hinterlechner-Ravnik & Moine 1977; Neubauer & Herzog 1985; Schönlaub & Heinisch 1993; Kolar-Jurkovšek & Jurkovšek 1996). Continental molasse began after Variscan deformation within the Late Moscovian–Early Gzhelian (Stephanian). Cretaceous low grade metamorphism is suggested for both the Austrian and the Slovenian parts of the GUP (Rantitsch & Russegger 2000; Fodor et al. 2004).

The Austroalpine Quartzphyllite Complexes include Ordovician to (?) Lower Carboniferous volcanosedimentary formations. Upper Ordovician quartzporphyric formations, Silurian basic volcanics and black shales are the most significant intercalations within the quartzphyllite. Upper Silurian to Lower Devonian clastic sediments resulted from a renewed rift phase, Middle to Upper Devonian limestones record carbonate platforms. The Variscan orogeny was accompanied by thrust tectonics, formation of a foredeep with flysch deposits in front of the incoming thrust sheets and a low grade metamorphic overprint (Neubauer & Sassi 1993).

Late Carboniferous shallow marine, siliciclastic and carbonate fossil rich sequences began within the Late Tournaisian/Viséan in the Veitsch Nappe (VN) of the eastern GWZ and the Nötsch Carboniferous (NC) in the Drauzug. Deformation and low grade metamorphic overprint of the VN are exclusively of Alpine (Cretaceous) age (Ratschbacher 1987; Rantitsch et al. 2004). In spite of its tectonically isolated position the age of the deformation of the NC is not clear. Anchizonal illite crystallinity and anthracitic coal rank indicate metamorphic peak conditions of ca. 260 °C and 6 km burial (Rantitsch 1995).

The Western Carpathians

Syn-orogenic Carboniferous basins in the Western Carpathians reflect the beginning of the Variscan continent-continent collision (Fig. 4). Intensive metamorphic and magmatic processes prevented a complete unequal consolidation of the continental crust, which hence was further deformed during post-collisional relaxation. Fragments of newly formed Variscan continental crust were subsequently incorporated into the major Alpine tectonic units (Tatricum, Veporicum, Zemplinicum and Gemericum), together with relics of the syn- to post-orogenic Late Paleozoic basin fills. With respect to the tectonothermal impacts these fragments reveal the metamorphic zonation of the Variscan crust: the Central Western Carpathian Crystalline Zone (within the Tatricum, Veporicum, Zemplinicum), the Northern Gemeric Zone (within the Northern Gemericum) and the Inner Western Carpathian Crystalline Zone (within the Southern Gemericum) (Vozárová 1998).

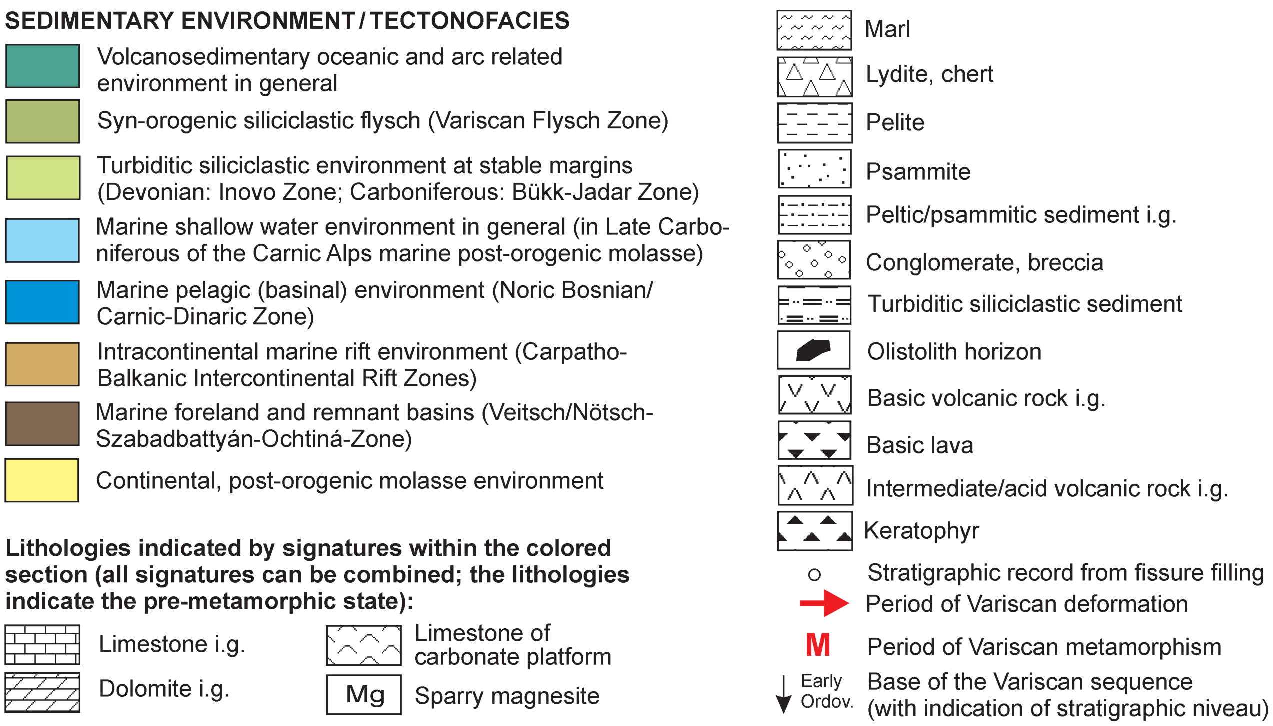

Fig. 2. Legend to the stratigraphic columns (Figs. 3–6) of the Devonian–Carboniferous sequences in the Circum Pannonian Region.

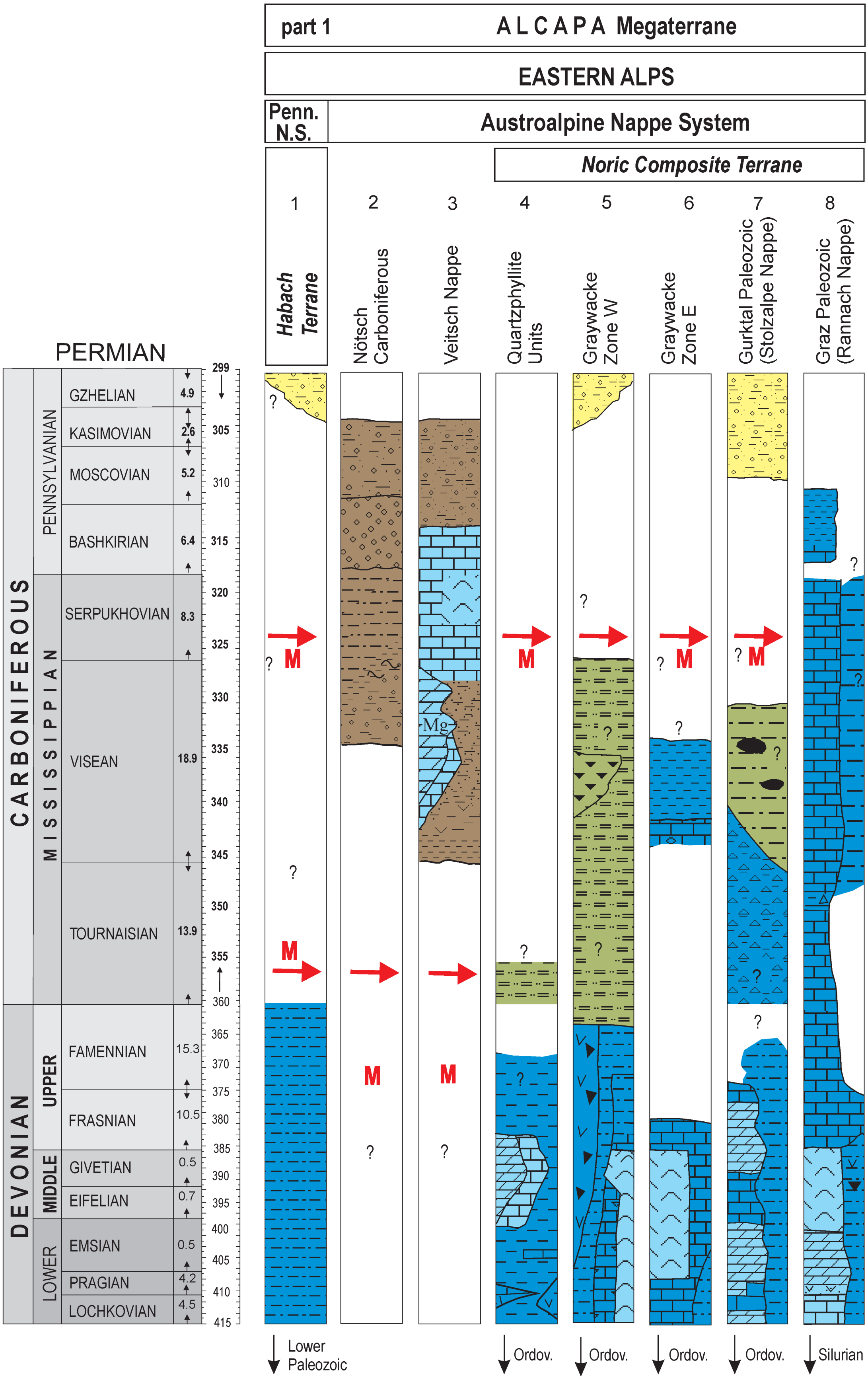

Fig. 3. Devonian/Carboniferous sequences in the Eastern Alps (part of the ALCAPA Megaterrane). Legend in Fig. 2.

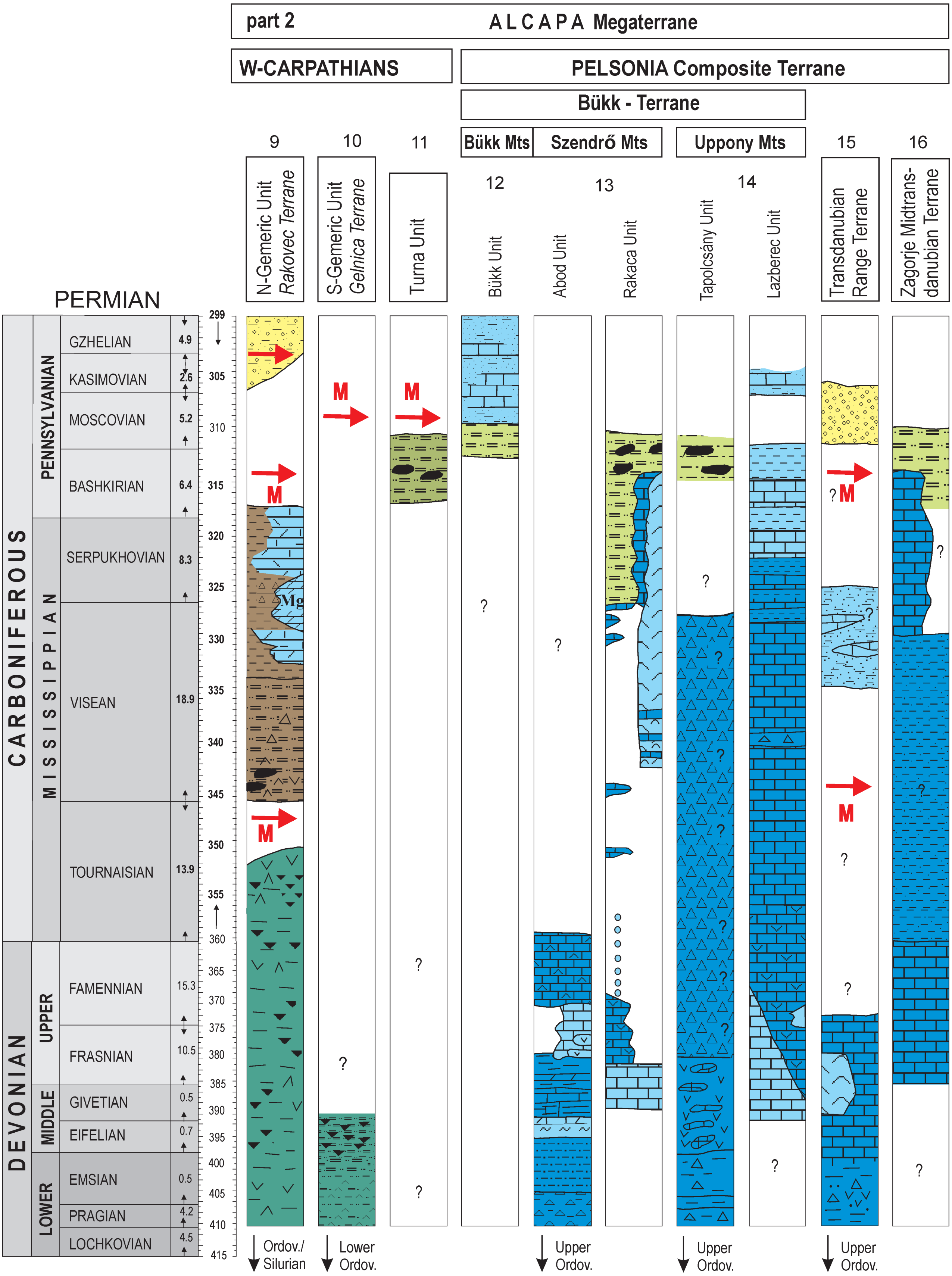

Fig. 4. Devonian/Carboniferous sequences in the Western Carpathians and the Pelsonia Composite Terrane (parts of the ALCAPA Megaterrane). Legend in Fig. 2.

The Alpine **Tatric** and **Veporic Nappe System** include a set of medium to high grade metamorphic pre-Alpine terranes (paragneisses, calc-alkaline to tholeiitic basic and acidic orthogneisses, banded amphibolites, migmatites, granulite facies rocks) besides some low grade metamorphic units amalgamated during the Variscan cycle. The most significant tectonofacies indicate passive and active margins, initial island arcs and oceanic crust. The low grade units are composed of a bimodal volcanic suite within immature clastic sediments. Possibly they are fills of ?Silurian–?Devonian continental intraplate rifts (Miko 1981; Bezák et al. 1998).

Some low-grade metamorphic complexes (metapelites, -graywackes, -carbonates, mafic to intermediate metavolcanoclastics) imbricated within the *Kohut Terrane* (Veporic Unit), include ?Carboniferous magnesites in places (Bezák 1982; Bezák et al. 1998). Variscan deformation/low grade metamorphism was Intra-Carboniferous before the overstep of the volcano-terrestrial molasse formations palynologically dated as Early Gzhelian-Asselian (Late Stephanian–Autunian; Planderová 1980; Vozár & Vozárová 1997, 1988). Early Carboniferous anatectic granitoid magmatism (360–340 Ma; Kohút et al. 1997; Kráľ et al. 1997) is represented by per- to subaluminous granodiorites and granites (Broska & Uher 2001).

The crystalline rocks of the Zemplinic Unit (*Byšta Terrane*) and their Late Paleozoic and Mesozoic cover may be correlated, on the basis metamorphic petrology and Mesozoic facies, with parts of the Tatro-Veporic domain (Vozárová 1989; Faryad 1995; Vozárová & Vozár 1996). The *Byšta Terrane* is composed of paragneisses and micaschists, amphibolites, migmatites and orthogneisses. The existence of granitoids and low-grade metapelites and acid metavolcanics is indicated within the pebble material of the Moscovian-Kasimovian overlap sequence. Deformation and metamorphism occurred before the early Moscovian (Westphalian C) as is indicated by pebbles in post-Variscan conglomerates (Grecula & Együd 1982; Vozárová & Vozár 1988).

The **Northern Gemeric Zone (NGZ)** includes the gneiss-amphibolite complex of the *Klatov Terrane (KT),* interpreted in terms of an oceanic crust environment. The low-grade Rakovec Grp. of the *Rakovec Terrane (RT)* is undated and predominantly composed of tholeiitic metabasalts and metavolcaniclastics associated with a smaller amount of sandy-pelitic and Fe-rich metasediments and small bodies of metagabbrodiorites/-keratophyres with geochemical characteristics close to E-MORB/OIT and island arc basalts (Ivan 1994). Relics of Tournaisian-Viséan flysch of the basal Ochtiná Grp. and thrust wedges of the *KT* and *RT* represent a part of a Variscan collision suture (Vozárová & Vozár 1996, 1997). Ordovician $^{40}Ar/^{39}Ar$ cooling ages of detrital white mica within the Lower Carboniferous Hrádok Fm document Ordovician crustal pieces found within this suture (Vozárová et al. 2005).

At the SW and E-SE boundary of the NGZ the syn-orogenic Tournaisian–Lower Viséan Hrádok and Črmeľ Fm (lower part of the Ochtiná Grp.) have been preserved as relics. In spite of the orogenic/metamorphic reduction their present tickness is estimated as > 1000 m. The whole Tournaisian-Serpukhovian Ochtiná Grp. was deformed under low-pressue greenschist facies conditions before being overlapped by a new Bashkirian-Lower Moscovian sedimentary delta fan/shallow-marine to paralic cycle (Rudňany, Zlatník and Hámor Fm). The metamorphic grade did not exceed the boundary between the anchizone and lower limit of the greenschist facies. Fine-grained muscovite from the Hrádok Fm reflects the complex Alpine (87–142 Ma) overprint (Vozárová et al. 2005).

The *Gelnica Terrane (GT)* of the **South Gemeric Zone**, as a part of the Inner Western Carpathian Crystalline Zone is made up of thick Lower Paleozoic flysch sequences comprising acidic and intermediate volcaniclastics (Gelnica Grp.) (Fig. 4). It is tectonically overlain by the undated Štós Fm, a flyschoid, rhythmical sequence of metapelite/metasandstone. Micropaleontological and U/Pb clastic zircon and SHRIMP datings within the *GT* suggest a wide, Cambrian–Ordovician/Lower Silurian, age range for the volcaniclastics, besides Proterozoic ages from detrital zircons (Cambel et al. 1977; Ščerbak et al. 1988; Vozárová et al. 1998; Soták et al. 1999; Vozárová et al. unpubl. data). The low- pressure greenschist metamorphism and deformation (Sassi & Vozárová 1987; Faryad 1991; Molák & Buchart 1996) occurred before the start of the deposition of the Early Ghzelian–Asselian (Late Stephanian–Autunian) continental sedimentary cover (Planderová 1980; Vozár & Vozárová 1997). Late Jurassic/Cretaceous low-grade metamorphism and polystage tectonic overprint is characteristic (Snopko & Reichwalder 1970; Lexa et al. 2003).

The **Turnaicum Nappe** of the innermost Western Carpathians contains flysch sediments in form of the Bashkirian Turiec Fm found in the Slovenské Rudohorie Mts (Brusnik anticline). Borehole BRU-1 (Ebner et. al 1990; Vozárová & Vozár 1992) indicates the nappe character of the Turna Unit above Meliatic Late Jurassic olistostromes. This flysch was tectonized during a Late Carboniferous Variscan orogenic phase, as is indicated by the strong deformation and angular unconformity of continental redbeds (Ebner et. al. 1990; Vozárová & Vozár 1992).

The Pelsonia Composite Terrane

The Pelsonia Composite Terrane was formed during Alpine times by amalgamation of the Bükk (Bükk, Szendrő, Uppony Mts) and Transdanubian Range Terranes in Hungary and the Zagorje(-Midtransdanubian) Terrane in Croatia. All these Alpine terranes also include pre-Mesozoic units (Kovács et al. 1997, 2000; Pamić et al. 1997).

Bükk Terrane (Szendrő, Bükk and Uppony Mts)

The Paleozoic evolution in the **Szendrő Mts** is characterized by the Abod and Rakaca Subunits. The pre-Middle Devonian sequence of the Abod Subunit consists of black, euxinic radiolarian lydites and siliceous slates, graphitic phyllites (?Silurian to Early Devonian) and grey, partly turbiditic sandstones (?Late Ordovician). In the Middle Devonian a carbonate — siliciclastic ramp did form, with coral bioherms besides deeper water deposits that bear conodonts. In the Late Devonian a carbonate platform developed in restricted areas only, while pelagic basinal carbonate sedimentation, influenced by basic volcanism ("cipollino") was more widespread (Frasnian–Famennian; Kovács 1994; Fülöp 1994; Ebner et al. 1998).

Within the Rakaca Subunit two marble formations (Rakacaszend Marble Fm ?Middle Devonian–Early Frasnian; Rakaca Marble Fm Late Viséan–Early Bashkirian) are separated by a stratigraphic gap. The time interval of this gap is indicated by conodonts of pelagic fissure fillings within the Rakaca Marble. The Rakaca Marble is interfingering with and overlain by the Szendrő Phyllite Fm and in some parts the phyllite occur also between the two marble formations. The "flysch" sedimentation (Szendrő Phyllite Fm) did not start before the Late Viséan or later (Ebner et al. 1991, 1998).

In the **Uppony Mts,** that is within the Tapolcsány Subunit, the biostratigraphic constraints are very poor, except for the limestone olistoliths of two olistostrome horizons. Quartzites and graywackes probably represent the beginning of sedimentation within the Late Ordovician (Ebner et al. 1998). Black radiolarian lydites and siliceous slates were deposited below the CCD. Basic volcanics, probably in a seamount setting, are associated with the deep-water sediments. Limestone olistoliths of pelagic and slope facies in a volcanic matrix extend in age from Wenlockian to Lochkovian (Kovács 1989; Gnoli & Kovács 1992). Light grey to grey siliceous shales/slates may have been deposited until the Late Devonian–Early Carboniferous. A second olistostrome horizon in a fine grained siliciclastic, and marly matrix and pelagic limestone olistoliths (dated by Emsian to Early Famennian conodonts), are tentatively assigned to the middle part of the Carboniferous, that is to the "flysch" stage (Kovács 1992).

In the Lázbérc Subunit the sequence began by the build-up of a ?Middle Devonian to Early Frasnian carbonate platform followed by pelagic carbonate sedimentation associated with basic volcanism until the end of the Famennian. Above the partly volcanogenic carbonate sediments, referred to as "cipollino" in their metamorphosed stage, condensed pelagic "flaser limestones" reach the Viséan, with a characteristic lydite horizon deposited in the Early Viséan (Ebner et al. 1998). From the Late Viséan to the Early Bashkirian mixed carbonate-siliciclastic sedimentation took place in a ramp environment, without any turbiditic activity. A >100 m thick slaty/marly sequence, with some sandstone intercalations, can be assigned to the higher part of the Bashkirian. A <100 m thick sequence of calcareous sandstones–sandy limestones with small lydite and quartz pebbles (Derenek Fm) can be assigned to the "post-Variscan" marine molasse stage. However, no biostratigraphic data are available (Kovács 1992; Fülöp 1994; Ebner et al. 1998; Pelikán 2005).

The stratigraphic base of the sequence outcropping in the **Bükk Mts** is the pre-Upper Moscovian (pre-Podolskian) "flyschoid" Szilvásvárad Fm, characterized by a distal turbiditic shale–sandstone sequence. It is regarded as a partial equivalent of or the continuation of the Szendrő Phyllite Fm (Árkai 1983). It is followed by Late Moscovian–Ghzelian fossiliferous limestones and siliciclastics of the shallow marine Mályinka Fm, its upper parts having been eroded down to different levels. No orogenic movements could be detected between the two formations (Ebner et al. 1991; Fülöp 1994; Pelikán 2005).

In the **Transdanubian Range Terrane** Emsian to Frasnian pelagic limestones, with stylolinids and conodonts and coeval stromatolitic carbonate platforms, overlie the Balaton Phyllite Group (Late Ordovician–Early Devonian). The youngest marine formation is the Szabadbattyán Fm (black shales, bituminous fossiliferous limestone and rare sandstone) of Late Viséan age and a smaller degree of metamorphism. It was deposited after the first Variscan tectonothermal event. Another tectonic event occurred before the sedimentation of the Late Bashkirian–Early Ghzelian (Westphalian–Stephanian) plant bearing terrestrial Füle conglomerate (Lelkes-Felvári 1978; Fülöp 1994). The Variscan thermal overprint was very low to low grade (Árkai & Lelkes-Felvári 1987).

In the **Zagorje — Midtransdanubian Terrane,** and above the pre-Variscan Medimurje medium grade metamorphic complex, the protoliths of the Mt Medvednica metamorphic sequence are found. These consist of medium to fine grained clastics, calcarenites and fossiliferous (conodonts) limestones of Late Devonian to Late Triassic age. They originated within marine shelf and pelagic environments. Diabase dykes and sills are probably of Middle Triassic age. The whole complex underwent a well documented Early Cretaceous very low to low-grade metamorphism (122–110 Ma; Belak et al. 1995; Pamić & Tomljenović 1998). At least parts of the Devonian-Carboniferous formations, dated by conodonts (Đurđanović 1973), are included within the metamorphosed "Medvednica Series" (Pamić & Tomljenović 1998). They can be regarded as equivalents of coeval formations in the Szendrő Paleozoic of the Bükk Terrane.

The TISIA Megaterrane

The Tisia Megaterrane behaved as one large terrane during Alpine evolution. However, earlier it consisted of several terranes amalgamated during the Variscan orogeny. The individual terranes are petrologically different and reveal different metamorphic PT conditions. The Carboniferous orogeny was accompanied by syn- to post-collisional granitoids (Buda et al. 2004). Several smaller units of lower metamorphic grade (Fig. 4) and relics of oceanic crust are imbricated within the larger medium to high grade metamorphic Variscan terranes (Szederkényi 1996 and in Kovács et al. 1997, 2000; Pamić et al. 1997).

Some small very low to low grade metamorphic units (Szalatnak, Horváthertelend, Ófalu, Tázlár) which are part of the Kunságia Terrane in the Hungarian Mecsek-Great Plain unit are remnants of nappes wedged into medium to high grade metamorphics (Szederkényi 1974; Árkai et al. 1996). They represent slices of a Silurian–?Lower Carboniferous pelitic-psammitic pre-flysch sequence with some calcareous and volcanic (basalts, porphyroids) intercalations. With the exception of some conodonts, fossils are missing (Kozur 1984; Szederkényi et al. 1991). Some occurrences of pre-Upper Carboniferous basic/ultramafic rocks are also imbricated within the metamorphic terranes. In Hungary these are regarded as parts or equivalents of the Gyód Serpentinite Fm of the W-Mecsek Mts (Kovács et al. 2000; Szederkényi et al. 1991).

In the territory of Hungary the Moslavina (Drava) Slavonia Terrane is only known from drillings. In northern Croatia it crops out in the Moslovačka Gora Mt (in our map it is still included in the Tisia Terrane, but Schmid et al. (2008) put it in the Sava Zone (Prošara, Motajica mountains, etc., because of its Late Cretaceous metamorphism) and the Papuk-Krndija Mts. Devonian–Permian sediments are only known from the Radlovac complex of the Papuk-Krndija Mts, which unconformably overlies the pre-Variscan Psunj-Krdija metamorphics. This metaclastic Radlovac complex is intruded by metadiabases/-gabbros (Jamičić 1983; Pamić & Jamičić 1986). The lower part of the complex is composed of graphitic metagraywackes and slates, quartz- sericite schists and arenitic metasandstones. The upper part contains fossil plants of Late Bashkirian–Early Moscovian (Westphalian B and C) and is made up of coarse grained mylonitic metagraywackes and slates which grade into pink clastics (Brkić et al. 1974). The Radlovac complex was metamorphosed under very-low to low grade metamorphic conditions, presumably during the Variscan cycle (Jamičić 1983). However, the radiometric ages, widely ranging form 416.0 ± 9 Ma to 203.9 ± 6.9 Ma (Pamić 1998), are inconsistent.

The pre-Mesozoic units of the Alpine Codru Nappe System outcropping in the Apuseni Mts represents the eastern continuation of the Hungarian Szeged-Békés (Codru) Terrane. Paleozoic sequences are only preserved in a few areas. The Arieseni Unit of the Codru Nappe System is formed by an ?Early Carboniferous metapelitic/-psammitic-conglomeratic sequence (Arieseni Fm). Variscan low grade metamorphism and deformation are evident. The onset of the post-Variscan overstep sequences ranges between Late Moscovian (Westphalian D) and the Permian (ref. in Kräutner 1997). In the Biharia Nappe System Devonian or ?Latest Precambrian metabasalts occur in the Radna (Biharia) unit, whereas the Highis-Poiana unit is formed mostly by a sequence of metaconglomerates, metasandstones and metapelites assigned to the Late Carboniferous. Its low-grade metamorphism is thought to be Alpine. The Variscan pile of the Biharia Nappe System is intruded by Permian granitoids.

The DACIA Megaterrane

The Eastern Carpathians

Pre-Alpine metamorphic units/terranes, forming Variscan nappe structures occur in the **Bucovino-Getic System** of the Eastern Carpathians (Fig. 5). These units extend southwards into the Southern Carpathians of Romania and the Carpatho-Balkanides of E-Serbia (Kräutner 1997; Kräutner & Krstić 2002, 2003). The Variscan nappes mainly include fragments of the pre-Variscan metamorphic Carpian Terrane, made up of Latest Proterozoic polymetamorphic rocks of sedimentary and volcanosedimentary origin (Kräutner 1980). Paleozoic sediments are developed in the *Tulghes Terrane* (part of the Bucovinian and Subbucovinian Nappes) and in the *Rodna Terrane* (part of the Infrabucovinian Nappe).

In the *Tulghes Terrane (TT)* sedimentation of the Tulghes Grp. started during the Early Ordovician with sliciclastic sediments and continued with basinal and slope psammites and pelites, associated with basalts of tholeiitic signature and MORB affinity, until the Silurian. It is not clear whether sedimentation persisted into the Devonian and Early Carboniferous.

In the *Rodna Terrane (RT)* pre-Variscan retrograde gneisses (Bretila Grp.) are covered by low grade metamorphic Silurian–Lower Carboniferous sediments (Fig. 5) in which some individual stratigraphic levels can be outlined on the basis of palynological data (Iliescu & Kräutner 1976, 1978; Kräutner & Vaida 1993). Above the Silurian volcaniclastic Repeda Grp. the transgression of a new sedimentary cycle (Cimpoiasa Grp.) started with the Lower and/or Middle Devonian Gura Fantanii Fm with conglomerates, quartzites and carbonate metasandstones. It is followed until the ?early Late Devonian by the Negoiescu Fm, up to 500 m thick greenschists, metabasalts and metakeratophyre tuffs with small amounts of carbonate layers/lenses at the top. The Late Devonian and parts of the Early Carboniferous are represented by the Prislopas Fm, divided into a quartzite-conglomerate subformation (300 m) and another subformation (300 m) at the top dominated by meta-dolomite, marble and metapelites. Finally the pre-orogenic sequence is closed by the Fata Muntelui Fm, a 550 m thick clastic sequence of alternating metagraywacke and feldspar metasandstones (Kräutner 1989, 1997).

The Variscan orogeny, assigned to the "Sudetic" event (Kräutner 1997) was polyphase and with greenschist metamorphic facies conditions producing retrograde metamorphism in the pre-Ordovician medium-grade metamorphic complexes (Kräutner 1997). In the *RT* Variscan metamorphism developed under low pressure conditions, while in the *TT* a medium-pressure to low-pressure gradient was recorded (Kräutner et al. 1975). Post-Variscan (?)Late Carboniferous–Permian overstep sequences of continental intramontane type are only locally preserved.

The Carpatho-Balkanides of E-Serbia and Bulgaria

In the Southern Carpathians of Romania and the Carpatho-Balkanides of E-Serbia and Bulgaria pre-Alpine units or terranes occur within the Bucovino-Getic and the Danubian Alpine nappe systems (Kräutner 1997; Kräutner & Krstić 2002, 2003). Some of these pre-Alpine terranes have a more restricted extent and therefore they are only specific for small segments of the belt. In the past detailed correlations of tectonostratigraphic units or terranes failed, mainly due to the following reasons:

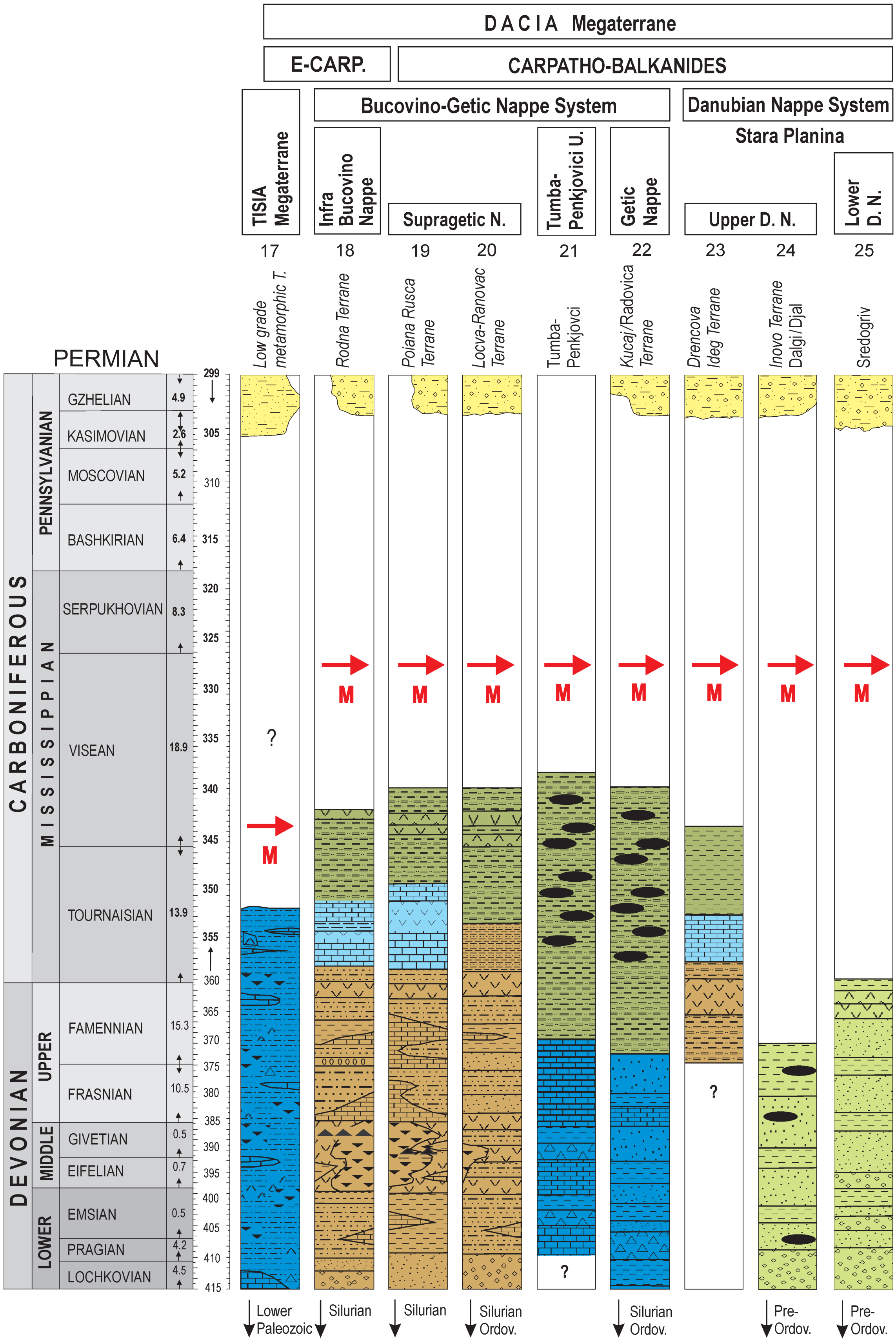

Fig. 5. Devonian/Carboniferous sequences in parts of the Tisia and Dacia Megaterranes (the Eastern Carpathians and the Carpatho-Balkanides). Legend in Fig. 2.

(1) Nappe contacts (both pre-Alpine and Alpine), clearly exposed N of the Danube, are partly obliterated by younger (mostly Neogene) orogen-scale shear zones in Serbia and Bulgaria; ("nappe structure" versus "block structure").

(2) In the earlier Romanian, Serbian and Bulgarian literature no distinction was made between Alpine, Variscan and older structural elements.

(3) South of the Danube important Alpine structural units without northern continuation (e.g. Kraishte and Tumba-Penkjovci) are successively interposed between belt scale structural elements (e.g. Supragetic and Getic).

(4) In Romania, Serbia and Bulgaria some main Alpine units include different pre-Mesozoic lithologies and Variscan tectonic units (e.g. Getic and Kučaj).

These difficulties were overcome by representing a structural model, published in a map covering the area between Oravita/Romania, Niš/Serbia and Sofia/Bulgaria (Kräutner & Krstić 2002, 2003). According to this model the following correlation of Alpine tectonic units and national terminologies is used (Table 1). These Alpine zones include the described Variscan terranes which amalgamated during the Carboniferous between the Serbo-Macedonian Zone and the Proto-Moesian Plate (Haydoutov et al. 1997; Karamata et al. 1997).

In the **Danubian Nappe System** (Fig. 5) the metamorphic units include several pre-Mesozoic crustal pieces joined together by Variscan thrusting and Early Paleozoic obduction. During the Devonian a second Paleozoic sedimentary cycle started. Three main sedimentation areas, corresponding to individual Variscan terranes, can be distinguished:

(1) The *Valea de Braz Terrane* occurs in the N part of the Lower Danubian Nappes. It includes conglomerates, sandstones, shales, concordant rhyolitic layers and macroflora (Valea de Brazi Fm, Stanoiu 1982; Berza & Iancu 1994).

(2) The *Inovo Terrane* is widespread within the Stara Planina (Upper Danubian Nappes). It is marked by several hundreds of m thick, predominantly Devonian, marine coarse to fine grained metaclastics with turbidites and olistostromes (Inovo Fm in Serbia, Dalgi-Djal Fm in Bulgaria; Krstić et al 1999, 2004). These are discordantly deposited onto Late Proterozoic to Early Cambrian low-grade metamorphic volcano-sedimentary island-arc formations (e.g. Berkovica) and unconformably overlain by Upper Bashkirian–Moscovian (Westphalian) lacustrine sediments.

(3) In the western Upper Danubian Nappes, however, the Upper Devonian–Lower Carboniferous *Ideg Terrane* developed. It is composed of a volcano-sedimentary sequence including Late Devonian metabasic rocks, covered by the fossil (incl. conodont) rich sparry Ideg Lmst. of Tournaisian age (300 m; Cordarcea et al. 1960). During the Viséan pelites and fine grained psammites follow (Sevastru Fm; Nastaseanu in Kräutner et al. 1981). Variscan low grade metamorphism and deformation occurred before the onset of early Moscovian (Westphalian C) continental molasse environments (Kräutner et al. 1981).

The **Bucovino-Getic Nappe System**, also extending into the E-Carpathians, includes several metamorphic units made up of pre-Variscan terranes formed in different geotectonic settings. Pre-Variscan medium grade metamorphism is proven by Tremadocian siliciclastic overstep sequences (Kučaj).

In the Supragetic Nappe System thick low grade Paleozoic volcano-sedimentary units were assigned to the *Poiana Rusca Terrane* (Romania) and the *Locva-Ranovac-Vlasina Terrane* (Banat, Serbia and Elesnica Unit in Bulgaria).

In the *Poiana Rusca Terrane* a rift developed above the polymetamorphic Precambrian Carpian Terrane with two distinct sedimentary cycles (Kräutner et al. 1973, 1981; Kräutner 1997). A Silurian metavolcano-sedimentary sequence (Batrâna Grp.) is unconformably followed by a second cycle, beginning with the Lower Devonian Govajdia Grp. This consists of a lower formation of metaquartzsandstones and an upper basinal formation of graphite schists with intercalations of limestones. The following Middle and Upper Devonian Ghelar Grp. is a volcano-sedimentary rift type sequence, including submarine basaltic volcanic structures, which are surrounded by volcaniclastics. At some places the volcanics are covered by massive reefal marbles interfingering with peri-reefal carbonates. Locally intercalations of quartz-keratophyre tuffs indicate bimodal volcanic character. Lahn Dill- and Teliuc-Ghelar type iron ore deposits are related to submarine volcanic rises (Kräutner 1977). Towards the end of the Late Devo-

Table 1: Correlation of the Alpine units in the Carpatho-Balkanides (Romania, Serbia, Bulgaria; Kräutner & Krstić 2002, 2003).

CARPATHO - BALKANIDES		
Southern Carpathians		*Balkanides*
Romania	**Serbia**	**Bulgaria**
Bucovino-Getic Units		
Serbo-Macedonian	Serbo-Macedonian	Jablanica
Supragetic	Ranovac-Vlasina	Elesnica
Not present	Tumba-Penkjovci	Penkjovci, Poletinci
Not present	Lužnica/Kraishte	Kraishte, Osogovo
Sasca-Gornjak	Sasca-Gornjak	Not present
Getic	Kučaj	Sredna Gora
Danubian Units		
Upper Danubian	Stara Planina - Porec	Stara Planina
Lower Danubian	Vrska Cuka - Miroc	Kutlov-Mihailovgrad, Belogradcik

nian up to 200 m thick carbonate members and up to 20 m thick greenschists developed. The Lower Carboniferous Pades Grp. begins with 1000–2000 m thick dolomite and limestone (Hunedoara-Luncani Fm), covered by the Gladna Schist Fm consisting of a rhythmic alternation of phyllite and quartzose metasandstone which could be primarily a flysch sequence. In the upper part, some basaltic and acidic tuffs are intercalated (Fata Rosie Fm) and a set of rhyolite dykes crosscuts the whole sequence. Deformation and metamorphism are assigned to the Variscan orogeny, pre-dating the Early Moscovian (Westphalian C; Kräutner 1997).

In the *Locva-Ranovac-Vlasina Terrane (LRVT)* a first sedimentary cycle includes an Ordovician–Silurian greenschist formation of volcano-sedimentary origin (Locva Grp.). The Devonian is transgressive and begins with a quartzite member covered by a thick basic metavolcanic pile of within plate character (Krstić et al. 2004, 2005a), interlayered with pelitic-psammitic metasediments and some metakeratophyric tuffs (Lescovita Fm, Valea Satului Fm, in Romania; Maier 1974; Visarion & Iancu 1984). The Latest Devonian and Early Carboniferous consists of alternating phyllite, sericitic quartzite, chlorite/sericite schists with local intercalations of basic/acidic metatuffs and metagabbros. Ordovician to Carboniferous ages are indicated by palynomorphs in Romania (Maier & Visarion 1976; Visarion & Iancu 1984) and Serbia (Krstić et al. 2004). The *LRVT* is interpreted as an intracontinental rift zone, but a back arc environment was also discussed (Krstić et al. 2005a). During the Variscan orogeny the terrane underwent polyphase deformation and low grade metamorphism (350 °C, ~3 kb; Ivanović 2000). The onset of sedimentation of the post-Variscan continental cover falls into the Latest Moscovian–Early Gzhelian (Stephanian).

The Tumba-Penkjovci unit is sandwiched between the *LRVT* attributed to the Supragetic Nappe System and the Tithonian-age Ruj flysch attributed to the Lužnica/Kraishte unit. In Serbia the Devonian of the Tumba-Penkjovci Unit is made up of 250 m thick pelagic limestones interlayered by shales and cherts. Lower Devonian ages were proved by tentaculites and conodonts (Krstić et al. 2004). The unit extends into Bulgaria (Penkjovci-Strmolka-Vonska-Polentinci) where the entire Devonian is dominated by carbonate sediments and followed by terrigenous flysch sediments, similar to the flysch of the *Kučaj Terrane.*

The Getic Nappe in Romania continues to the Kučaj Unit of Serbia and to the Sredna Gora in Bulgaria (Table1). The pre-Alpine units include several pre-Variscan and Variscan crustal fragments, docked during the Carboniferous and covered by an identical Permian overstep sequence. Medium grade blastomylonitic belts, with lenses of pre-Variscan eclogites and serpentinites, specifically occur in parts of the Variscan terrane collage. Paleozoic sediments prevail only south of the Danube. In Serbia they are assigned to the *Kučaj Terrane*, which also extends into Bulgaria (Ljubas, Iskar) and Romania (Buceava Fm).

In the *Kučaj Terrane (KUT)* sedimentation began in the Tremadocian with near-shore/shallow sea siliciclastics (Krstić & Maslarević 1990), followed by basinal Silurian graptolite schists (Krstić et al. 2005b), and ~100 m shales and siltstones with intercalations of cherts, limestones, channel-sandstone and some turbidites. Sedimentation prevailed until the Late Frasnian, as indicated by conodonts from dolomitic limestones at the top. Until the Viséan these series are overlain by up to a 600 m thick siliciclastic flysch. Towards the north, the *KUT* is tectonically superposed by Variscan nappes (*Homolje, Jelova, Minis, Ravensca Nappes*) and extends only in a narrow zone referred to as the "*Homolje Paleozoic*" which continues to the Romanian Buceava Fm (Streckeisen 1934; Iancu & Maruntiu 1989). It consists of a basal metaconglomerate and variegated metasandstones cut by small bodies of metadiorite and metagabbro (Iancu & Maruntiu 1989). The Early Carboniferous olistostrome of the *KUT* also occurs in some small tectonic windows (Radovica, Drencova) below the above mentioned Variscan nappes. As indicated by the onset of continental molasse sedimentation Variscan deformation predates Latest Bashkirian–Earliest Moscovian (Westphalian B). The *KUT* also includes batholiths of Variscan I-type granitoids (Sichevita-Neresnica, 310–292 Ma; Gornjani, 304 Ma).

The **Serbo-Macedonian Zone** (SMZ) is located between the Vardar Zone (VZ) on the west, and the Carpatho-Balkanides and the Rhodope Massif in the east. Some authors (Dimitrijević 1997; Sandulescu 1984) regard it as part of the Supragetic Nappe System. In fact the lithologies have strong affinities with those of the Supragetic Carpian sequence. Although both units derived from the same Alpine microplate, the SMZ overthrusts the ophiolitic Vardar Zone (exposed in tectonic windows at Paraćin, Kupinovac, Jastrebac) towards the west, while the Supragetic Units obviously belong to the east-vergent Carpathian system (Kräutner & Krstić 2002). The two units are separated by a prominent, some hundred meters wide, dextral (Vršac and Dušanovo) mylonite zone.

The SMZ consists of high to medium grade metamorphics of Precambrian and Early Paleozoic metasedimentary and magmatic assemblages, originating from different geotectonic settings and representing individual units. They were metamorphosed before Variscan docking in amphibolite or epidote-amphibolite grade, some in eclogite or granulite facies. During the Variscan orogeny the metamorphism encompassed the entire SMZ. It developed up to medium grade (Karamata & Krstić 1994) and generated large areas of greenschists facies overprint. From the Paleozoic (Vlajna, Bujanovac) to the Tertiary (Surdulica) the SMZ was repeatedly intruded by granitoids. The oldest post-Variscan cover belongs to the Permian or Middle Triassic.

The VARDAR Megaterrane

The Vardar Megaterrane (also Vardar Composite Terrane, Karamata et al. 1997) is regarded as an independent Alpine oceanic domain with a complex internal structure that includes the continental Jadar Block Terrane, besides some other smaller continental fragments (e.g. Kopaonik Block; Karamata 2006). The Veleš Series Terrane (VST;

Fig. 6) represents an inherited relic of a Paleozoic ocean. For another interpretation see Schmid et al. (in print).

At present the VST is included within the Main Vardar Ophiolitic Suture Zone (Karamata 2006). The oldest parts of the VST are dated by pollen as Devonian to Early Carboniferous in age (Grubić & Ercegovac 1975). The ~500 m thick lower part of the VST above serpentinite begins with amphibolite and chlorite/sericite schists, with thin lenses of quartzite. In the ~500 m thick middle part phyllite and quartz/sericite/chlorite schists include thick beds and lenses of microcrystalline limestone, marble and quartzite. The ~400 m thick upper part is dominated by marble. Most likely this volcano-sedimentary association formed in an island arc setting (Karamata 2006). The age of metamorphism (up to greenschist and amphibolite metamorphic grade) is not clear. According to Karamata (2006) the VST was transported above oceanic crust and docked to units more to the E during the Late Jurassic.

The **Jadar Block Terrane** (JBT) is an exotic terrane displaced into the Vardar Zone in the Late Cretaceous (Filipović et al. 2003). The JBT inculdes autochthonous and allochthonous (Likodra Nappe) elements, with individual Late Paleozoic evolutions (Fig. 6). In the autochthonous unit a >1000 m thick sequence of alternating arenites and siltstones with rare microconglomerates (Vlašić Fm) was deposited from ?Middle Devonian to Carboniferous times in a deep water basin. Late Devonian and Tournaisian ages were obtained due palynomorphs (Ercegovac & Pešić 1993). Thin intercalations with cherty limestone are dated by conodonts of Latest Tournaisian and Early Viséan age. The Late Viséan and Serpukhovian part with sedimentological "flysch" characteristics includes trace and plant fossils. In the NE of the JBT (Ub-area) the Middle Devonian to Viséan sediments are formed by conodont bearing pelagic limestones (~100 m thick Družetić Fm) of an intrabasinal swell. The Carboniferous part of this formation has a thickness of 15 m only (Filipović 1974; Filipović et al. 1975). A regressive phase starts at the beginning of the Serpukhovian at the top of the "flysch" with the Stupnica Sandstone Fm and continued until the early Bashkirian (conglomeratic Županjac Fm) formations (Filipović et al. 1975, 2003; Filipović 1995; Protić et al. 2000, Krstić at al. 2005).

After a stratigraphic hiatus a new sedimentary cycle with the characteristics of continental and marine molasse sediments and gravity slided materials starts with the Ivovik Fm (20–50 m) within the Moscovian. Its silty matrix includes Devonian and Lower Carboniferous limestone clasts, plant bearing horizons and levels of Late Moscovian marine brachiopod and fusulinid faunas. The Kriva Reka Fm in the southern part of the JBT is predominatly composed of massive limestones with fusulinids and conodonts indicating a Late Moscovian to Earliest Asselian age (Protić et al. 2000; Filipović et al. 2003; Krstić at al. 2005).

The allochthonous unit (Likodra nappe) is dominated by a shallowing upwards siliciclastic sequence. The ?Lower Carboniferous "flysch" (laminated sandstones and siltstones with trace fossils only) is followed by the Đjulim Fm (30 m), an alternation of bedded limestones with siltstones and shales. Conodonts indicate Early Serpukhovian to Early Bashkirian ages. The Rudine Fm (60–80 m), composed of bioherm-type massive bedded limestone with corals and other reef-builders, calcareous algae, brachiopods and other fossils, is also part of the Early Bashkirian. The following Stojkovići Fm (20–60 m) consists of thick siltstones/sandstones with megaflora and Bashkirian brachiopods. At the top is the Stolice Limestone Fm (>100m) consisting of a biohermal limestone with Bashkirian fusulinids, corals, calcareous algae, bryozoans, etc. (Filipović 1995; Protić et al. 2000; Filipović et al. 2003; Krstić at al. 2005). The Carboniferous of the JBT is covered by a shallow marine Middle Permian overstep sequence.

The metamorphic degree in the JBT is generally the anchimetamorphic zone, except the SW marginal zone which is metamorphosed within the lower greenschist metamorphic facies (Dobrić et al. 1981). The thrusting of the Likodra nappe occurred during the "Saalic" phase before the Middle Permian transgression (Filipović 1995).

The ADRIA-DINARIA Megaterrane

The Adria-Dinaria Megaterrane (Figs. 1, 6) 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 & Krstić 1996; Neubauer et al. 1997; Karamata et al. 1997; Pamić et al. 1997; Haas et al. 2000; Pamić & Jurković 2002; Karamata 2006). All the above mentioned terranes are of Alpine age. However, they include pre-Mesozoic sequences and the information regarding the Devonian–Carboniferous sedimentary sequences and grade of Variscan metamorphism is poor and not sufficiently well investigated in some areas. Nevertheless the grade of Variscan metamorphism and deformation seem to be weak or even absent in some areas of the Dinarides.

The Dinarides

In the Drina-Ivanjica Terrane (DIT) the footwall of the Paleozoic is an intensely folded pre-Variscan low grade metamorphic volcanosedimentary ?Late Precambrian–?Early Ordovician complex (Drina Fm). Silurian and Devonian sediments are not yet recorded in the autochthonous cover. The 500–600 m thick Carboniferous sequence ("Golija Fm") begins with lydites, pelites and limestone intercalations containing Tournaisian and Early Viséan conodonts. The Middle Viséan to Early Serpukhovian is composed of an alternation of pelagic conodont bearing limestones and clastic sediments interfingering with olistostromatic clastics with limestone blocks of Devonian and Viséan ages. Basic lava flows and tuffs are another important features. The top of the Variscan sequence is formed by a siliciclastic "flysch" (Birač Fm; 350–700 m) with typical sedimentary structures, floras and ammonoidea of Early Bashkirian age (Filipović & Sikošek

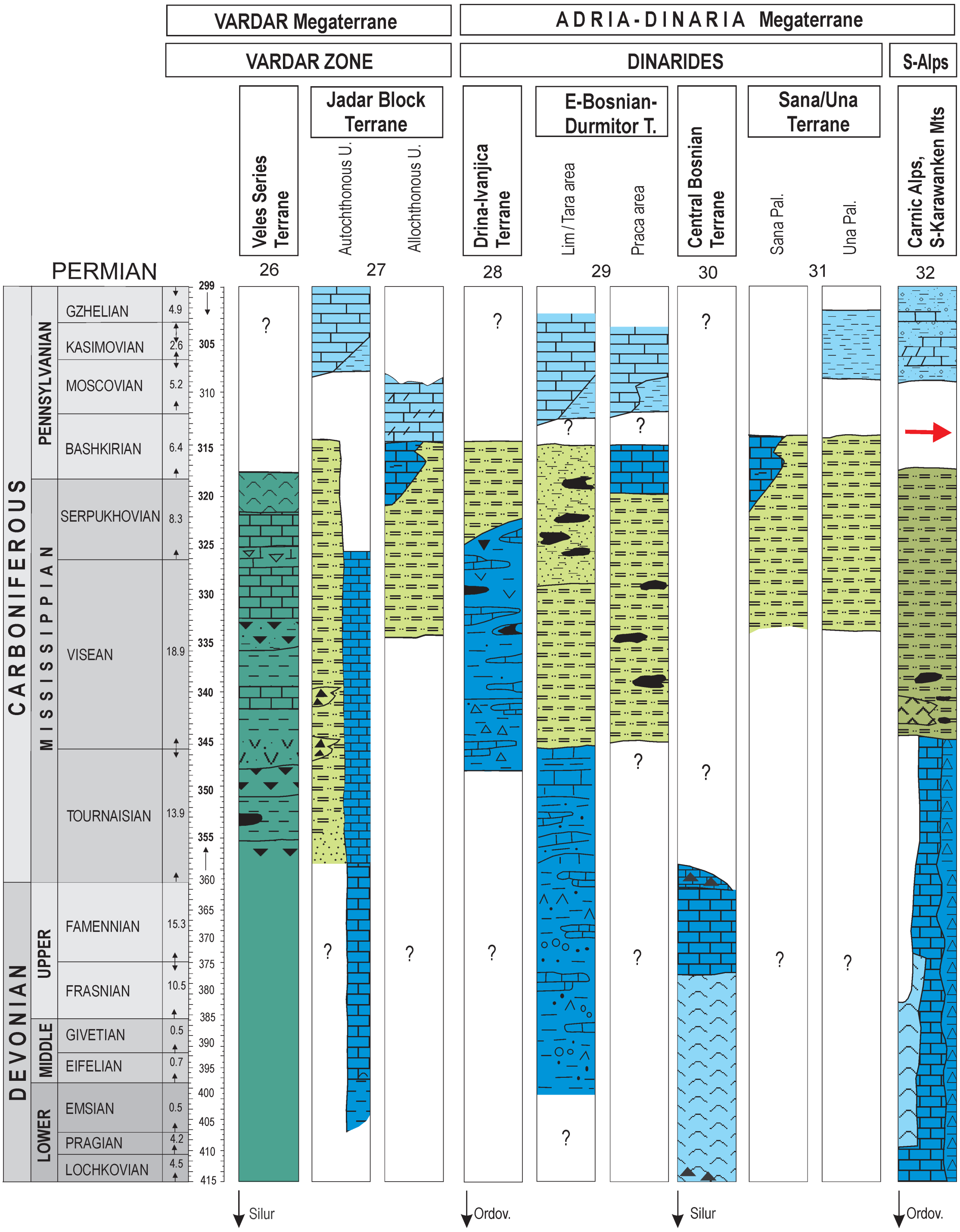

Fig. 6. Devonian/Carboniferous sequences in parts of the Vadar and Adria-Dinaria Megaterranes. Legend in Fig. 2.

1999; Krstić et al. 2005a). Moscovian olistostromes are observed in some localities in NE Bosnia. They include components with Tournaisian, Bashkirian and Lower Moscovian foraminifers.

The non-metamorphic to anchimetamorphic Carboniferous is transgessively overlain by Lower Triassic red beds (Kladnica Fm) without any distinct discordance (Dimitrijević 2001). Since the tectonic features are almost the same within the whole Carboniferous–Triassic sequence it is concluded that Variscan tectogenesis did not play an important role within the DIT (Ćirić & Gaertner 1962; Filipović & Sikošek 1999).

In the DIT metamorphism and deformation was polystage. The oldest deformations (NW verging and folds and thrusts) should be placed somewhere between the Middle Carboniferous and the (?)Middle Permian. The metamorphism is up to the greenschist facies, but there is no proof of any Variscan thermal overprint (Djocović 1985; Karamata et al. 1997; Pamić & Jurković 2002).

The Paleozoic of the **East Bosnian-Durmitor Terrane** (EBDT) outcrops in the Lim and Tara areas (SW Serbia, N and NE Montenegro) and in the Prača region (SE Bosnia). In the Lim and Tara area the low grade metamorphic Middle Devonian to Late Carboniferous sequence consists of sandstone, shale, limestone, conglomerate lenses and sporadically quartz keratophyre. Late Devonian to Early Carboniferous pelagic limestones and silty sediments may represent the end of the pre-flysch stage pre-dating the Carboniferous "flysch" (up to 700 m thick turbiditic graywackes, siltstones and shales). Some Devonian limestones are regarded as representing olistoliths. The "flysch" is superposed by fine clastics with olistoliths with limestone blocks dated by conodonts and foraminifera between the Late Viséan and the Bashkirian. At the top shallow water limestones with corals, brachiopods, fusulinids and algae indicate a new sedimentary cycle, similar to the evolution in the Jadar Block Terrane (Krstić et al. 2005a).

In the Prača area all the records of Silurian/Devonian limestones are found as olistoliths situated within the Lower Carboniferous "flinch". The olistoliths include pelagic limestones with conodonts, tentaculites or reef limstones (the former Kleck Lmst. Fm) with corals and hydrozoans. The Early Carboniferous is proved by some fossil findings (goniatites, flora, ichnofossils). The famous fauna of the Prača Beds with autochthonous and allochthonous elements (goniatite, brachiopod, coral, pelecypod) derives from shales and limestone lenses; plants of Early Viséan age are from sandstones (Ramovš et al. 1990). Above the Prača Beds the Carboniferous sequence resembles that found in the autochthonous units of the Jadar Bock Terrane. It includes a Lower Carboniferous "flysch" sequence, 400 m thick Middle Carboniferous massive limestones and olistostromes (Filipović & Jovanović 1994; Karamata et al. 1996; Krstić et al. 2005a; Karamata 2006).

The Carboniferous of the EBDT is overlain by Middle Permian clastics and the Late Permian Bellerophon Fm (Pešić et al. 1988). The lack of strong Variscan deformations is generally accepted. The metamorphic overprint up to greenschist facies is restricted to areas close to post Middle Permian granitoids (Dimitrijević 1997; Karamata et al. 1997).

The pre-Variscan sequence in the **Central Bosnian Terrane** (CBT) is metamorphosed up to lower amphibolite facies conditions. Low grade metamorphic clastics are followed in the Late Silurian by fossiliferous (corals, conodonts, bryozoans) limestones and dolomites of a carbonate platform. Pelagic limestones with conodonts occur in the Famennian and the Tournaisian. In all levels bodies, lenses and (?) sills of rhyolites are frequent (Karamata & Krstić 1997; Krstić et al. 2005a; Hrvatović et al. 2006). The post-Carboniferous sequence began within Late Permian coarse clastics, evaporites and the Bellerophon Fm (Hrvatović et al. 2006).

The existence of a Variscan deformation/metamorphism is not yet certain (Hrvatović 1998).

Pamić & Jurković (2002) report four geochronological groups within the Paleozoic rocks. Subordinate Variscan (343 ± 13 Ma), post-Variscan (278.8–247 Ma), early Cretaceous and Eocene-Oligocene groups of ages can hardly be interpreted in respect to Variscan events. According to Hrvatović (1998) major folding and metamorphism probably commenced within the Triassic.

In the **Sana-Una Terrane** (SUT) the Carboniferous "flysch" predominates. In the Sana region this "flinch" is overlain by bedded limestones with conodonts of late Viséan age. They are correlated with the Đjulim Fm of the allochthonous Jadar Block Terrane. A new ("post-Variscan") sedimentary cycle starts with shallow water limestones (Stara Rijeka Fm) of Bashkirian age which rarely yield marine shallow water fossils and fusulinids. The following Eljdiste Fm (sandy and marly limestones) includes a rich brachiopod fauna. In the Una region the Blagaj Fm above the Carboniferous "flysch", an olistostromatic unit with Devonian, Lower and Middle Carboniferous limestone clasts with foraminifers, corals and conodonts, is correlated with the "molasse" type Ivovik Fm from the autochthonous Jadar Block Terrane. Disconformities between the Blagaj Fm and the Carboniferous "flysch" are not yet proven. These sequences are covered by Middle Permian clastics (red breccias and conglomerates, sandstones, shales and evaporites) followed by Lower Triassic formations (Karamata et al. 1997; Grubić et al. 2000; Protić et al. 2000; Grubić & Protić 2003; Krstić et al. 2005a).

Within the **Adriatic Dinaric Platform** Middle Carboniferous to Permian Paleozoic formations occur in the Gorski Kotar, Velbit and Lika Mts. They are of "post-Variscan" age and similar to the Auernig Fm and Rattendorf Fm in the eastern Southern Alps (Ramovš et al. 1989). Therefore they are regarded as overstep sediments above an unkown basement (Karamata et al. 1997; Pamić et al. 1997). They include Moscovian fossiliferous limestones, Kasimiovian sandstones and Gzhelian conglomerates. In some limestone pebbles Devonian and Early Carboniferous fossils were found (Ramovš et al. 1989; Sremac & Aljinović 1997; Pamić & Jurcović 2000).

The Eastern Southern Alps

In the eastern **Southern Alps** (Fig. 6) the classical, fossiliferous Paleozoic domains are concentrated in the Carnic Alps, along the Austrian-Italian and the S-Karawanken Mts near the Austrian–Slovenian border. They are part of the *Noric Composite Terrane* (Frisch & Neubauer 1989) or of the *Carnic-Dinaric Microplate* (Vai 1994, 1998).

In the Carnic Alps the oldest strata dated by megafossils are Late Ordovician in age. The Ordovician/Silurian boundary level is dominated by stratigraphic gaps, the Silurian by a strong facies differentiation. The Devonian facies zones are presently distributed into individual nappes or tectonic slices. Carbonate platform organdetric limestones only developed until the Frasnian/Famennian boundary. Then they were replaced uniformly by cephalopod limestones, lasting with very reduced thicknesses until the Tournaisian/Early Viséan. Variegated shales, cherts and siltstones (Zollner Fm) were accumulated within the most basinal facies realm (Herzog 1988; Kreutzer 1990, 1992; Schönlaub & Heinisch 1993; Schönlaub & Histon 2000).

The pre-flysch sediments are followed by 1000 m thick sliciclastic flysch (Hochwipfel Fm; Spalletta et al. 1980; Ebner 1991a,b; Heinisch & Schönlaub 1993; Vai 1998; Perri & Spalletta 1998; Schönlaub & Histon 2000). In the Italian part conodonts point to pelagic sedimentation until the Late Viséan (Spalletta & Perri 1998). Volcaniclastic and basic volcanics (Dimon Fm), representing intraplate alkalibasalts, occur at the base of the Hochwipfel Fm (Läufer et al. 1993). The age of the Hochwipfel Fm, Middle Viséan–Serpukhovian, is indicated by a plant bearing horizon and other sites with plants, as well as the up to 10 m thick intercalation of the Kirchberg Limestone with conodonts from the Viséan/Serpukhovian boundary (v. Ameron et al. 1984; Flügel & Schönlaub 1990, v. Ameron & Schönlaub 1992).

The Variscan climax (Carnic phase, Vai 1975) occurred between the Bashkirian and Early Moscovian. It formed a south-verging fold and thrust belt (Venturini 1990). Variscan deformation is documented by a spectacular angular unconformity. The oldest post-Variscan sediments (Waidegg Fm, Malinfier horizon) of the Myatchkovo Substage of the Moscovian Stage are transgessively followed by the marine/terrestrial molasse type cover of the Auernig Grp., mainly belonging to the Kazimovian and Gzhelian Stages (Fenninger et al. 1976; Venturini 1990, 1991). The stratigraphy and facies in the Slovenian part of the S-Karawanken Mts are similar to the Carnic Alps (Ramovš 1971, 1990; Schönlaub 1971; Buser 1980). The thermal overprint only reaches anchizonal conditions and is regarded as equal or higher than the Alpine thermal overprint (Läufer 1996; Rantitsch 1997).

Reconstruction of and relationships between the Devonian–Carboniferous facies realms within the CPR

Hudge areas of the Alcapa, Tisia, and Dacia Megaterranes are made up of Variscan-age medium to high grade metamorphics which are pervasively intruded by syn- to post-orogenic I- and S-type granitoids (Finger et al. 1992; Neubauer & Frisch 1993; Balogh et al. 1994, Szederkényi in Kovács et al. 1997, 2000; Buda et al. 2004). Major deformation and metamorphism occurred during the Variscan orogeny, that is largely within the Early Carboniferous. However, these units also include pre-Variscan elements and an Alpine metamorphic overprint is also frequent. The nature of the protoliths and relation to the individual geotectonic cycles often cannot be restored in a sufficient way. These units were affiliated to the **Mediterranean Crystalline Zone** (Flügel 1990) and part of the **Moldanubian** and **Median Crystalline Zones** (Matte 1986, 1991; Franke 1989; Ebner et al. 2004; Buda 2004, http//www.geologicacarpathica.sk).

The **non- to low grade metamorphic Paleozoic units** generally began within the Ordovician and their former basement is not known. Late Ordovician porphyroids are important for interregional lithostratigraphic correlations. The Silurian is made up of marine clastic and volcanosedimentary units, basic alkaline volcanics, black shales, lydite and limestones which became more dominant towards the Late Silurian. Devonian-Carboniferous pre-flysch sediments are mainly formed by carbonatic-clastic sequences of shelf and passive continental slope environments. Oceanic including arc related domains and intracontinental rift formations are restricted. Siliciclastic successions, sometimes of flysch type, predominately follow the shelf and passive continental margins within the Early Carboniferous. However, in some areas of the Carpatho-Balkanides siliciclastic flysch was already deposited within the Late Devonian. Despite the intensive discussions concerning the primary position of these Paleozoic series some major facies domains were recognized (Frisch & Neubauer 1989; Flügel 1990; v. Raumer & Neubauer 1993; Neubauer et al. 1997; Vai 1994, 1998; Ebner et al. 2006, 2007).

Devonian–Early Carboniferous pre-flysch environments

The individual Devonian-Early Carboniferous pre-flysch (pre-orogenic) environments are distributed as follows (see also map of Ebner et al. (2004) and http//www.geologicacarpathica.sk):

Oceanic and arc related environments

The existence of Devonian–Carboniferous (Paleotethyan) oceanic environments is strongly under discussion and areas with extensive ophiolitic crust are missing in the CPR. However, we also include arc related volcano-sedimentary units and back arc environments in this domain.

Within the **Eastern Alps** candidates for Variscan oceanic environments are found within the medium grade Middle Austroalpine Crystalline Units. The *Plankogel Terrane* is a Paleozoic suture (melange) zone in which ocean floor elements accreted to the continental margin of Laurussia. The Koriden Gneiss complex (*Koriden Terrane)* interpreted as metamorphic flysch was formed in an accretionary wedge setting on the northern margin of this convergent system (Frisch & Neubauer 1989; Neubauer et al. 1997).

In the **Western Carpathians** the gneiss-amphibolite complex of the *Klatov Terrane* is interpreted in terms of oceanic crust. Due to the Alpine overprint the entire geochronology is problematic. The undated Rakovec Grp.

(*Rakovec Terrane*) is mainly made up of basic metavolcanics, smaller amounts of tholeiitic basalts and intermediate/acidic volcanics and interpreted in terms of an ensimatic island arc situated on back arc oceanic crust (Ivan 1994; Vozárová & Vozár 1997). The S-Gemeric Gelnica and Štós Fm represent a longlasting Paleozoic volcanosedimentary environment. The Gelnica Grp. is dated by microfossils to the range from the Ordovician to the ?Early Devonian and possibly the Štós Fm may continue until Late Devonian–?Lower Carboniferous (Snopková & Snopko 1979; Vozárová et al. 1998; Soták et al. 1999). Quantities of redeposited acidic and intermediate volcaniclastic material, derived from coeval magmatic arcs (Vozárová & Ivanička 1996), are insufficiently present beside mature detritus from the continental margin as well as basic and ultrabasic debris. This indicates that the sediments may represent a long lasting forearc basin flysch, connected with an active continental margin (Vozárová 1993). The newest zircon SHRIMP age data indicate Cambrian-Ordovician (Vozárová et al. 2007). Sediments of the Štós Fm represent distal turbidites with very rare basalt fragments (olistoliths?). The Štós Fm is unconformably covered by the Lower Permian continental deposits. This suggests that the Štós Fm is either an equivalent of the Devonian-Early Carboniferous flysch or an integral part of the Gelnica Grp.

In the **Tisia Megaterrane** some small oceanic occurrences are imbricated within the Variscan metamorphic domains. They are relics of oceanic crust obducted before the onset of Variscan metamorphism (Szederkényi in Kovács et al. 1997, 2000).

In the East Carpathians the upper parts of the *Tulghes Terrane* exhibt some magmatic, sedimentary and metallogenetic features which could be compared with the Gelnica Grp. But in contrast to the Tulghes Grp. the Gelnica Gr. was connected with an active continental margin setting and not with an extension setting. For the Tulgheş Group in Romania, the lithostratigraphic sequence indicates an evolution of sedimentation from a siliciclastic platform to a basinal environment with turbiditic fans and intercalated lava flows and tuffs of basaltic composition during Ordovician-Silurian times. The continental breakdown is marked by intensive volcanic activity of bimodal character. The mafic parts of the magmatic activity are tholeiites of within-plate character. In the late deep basinal stage, the flysch deposits are followed by pelitic sediments associated with submarine basaltic flows of tholeiitic signature and MORB affinity. In conclusion, the deposition of the Tulgheş Group appears to have occurred in a prevailing extensive environment, which evolved from an epicontinental platform to a rifting basin with a final stage of crustal thinning. This evolution can be placed either in an immature back-arc basinal setting, or in a continental rifting system. There are no data about how the *Tulghes-Gelnica Terrane* evolved later in Devonian and Carboniferous times (Kräutner & Bindea 2002).

In the **Carpatho-Balkanides** of E-Serbia the Variscan terranes include fragments of layered oceanic crust covered by island-arc volcanics (Tisovita, Deli Jovan, Zaglavak). They are interpreted as obducted parts of a dismembered latest Proterozoic oceanic crust (Kräutner 1999; Kräutner & Krstić 2002). Only small tectonic lenses of undated serpentinites in the **South Carpathians** (Vadul Dobri in the Poiana Rusca Mts; Agadâci in Banat) could possibly represent remnants of Devonian–Lower Carboniferous oceanic crust.

The several hundreds of m-thick Veles-Series of the **Vardar Zone** is composed of basic metavolcanics, quartzite, schists and marbles. They are considered to represent back arc and island arc sediments of an oceanic system that forms a Paleozoic precursor of the Vardar ocean (Karamata et al. 1997; Karamata 2006).

Carbonate dominated Devonian–Lower Carboniferous passive continental magins (Noric Bosnian/Carnic-Dinaric Zone)

Neubauer & Frisch (1989) affiliated the low grade to unmetamorphosed Devonian of the Eastern and eastern Southern Alps to a passive continental margin related to the *Noric Composite Terrane (NCT)*. In parts of the Middle Austroalpine Crystalline Units the medium grade Micaschist-Marble Complex (Neubauer & Frisch 1989; Frisch & Neubauer 1993) may also be part of this terrane and correlated with biostratigraphically well dated Devonian sequences of the *NCT*. Due to some similarities to the Bosnian Paleozoics Flügel (1990) referred to this domain as the Noric Bosnian Zone, in which strong relationships occur to the Bükk, the Jadar Block and Central Bosnian Terranes (Ebner et al. 1998, 2006; Filipović et al. 2003). But earlier Vai (1994, 1998) referred some parts of the Noric Bosnian Zone (Carnic Alps, Dinarides and Bükk Mts) to the Carnic Dinaridic Zone, with marine post-Variscan and Early Alpine (Middle–Later Permian) development. This was due the fact that the biofacies of the Eastern Alps was attributed to the Bohemian and Rhenish domain opposite to that of the Carnic Alps as part of the Uralian biofacies, although the lithofacies is similar in some features (Vai 1991, 1998). All these areas were summarized in the Devonian–Early Carboniferous map of the CPR (Ebner et al. 2004, http//www.geologicacarpathica.sk) in one unit related to the Noric–Bosnian or Carnic-Dinaridic zones. In account of a diverse Late Carboniferous to Permian evolution we prefer to distinguish a "Noric" evolution in the Eastern Alps in contrast to the "Dinaridic" evolution in the eastern Southern Alps, Bükk, Jadar Block and Central Bosnian Terranes.

The Devonian evolution of the entire domain is that of rifted passive continental margins. Monotonous volcaniclastic sequences (quartzphyllite units) of the outer passive margin interfingered with carbonate pelagic and platform environments that evolved after the end of the major rift stage within the late Early Devonian and extinguished significantly during the early Late Devonian. Nevertheless, pelagic domains with flaser- and nodular limestones and deep water basinal environments with shales and lydite occurred beside these carbonate platforms until the Early Carboniferous (Ebner 1991a; Vai 1998). Generally the limestones are well dated by fossils. Conodonts are most useful for the pelagic limestones — corals, stromatopora and brachiopods for the carbonate platform areas. The facies patterns implies spatially and temporarily enhanced rates of subsidence in an extensional regime. If volcanism occurred, it was related to rifting and was mostly of alkaline geochemical character (Loeschke & Heinisch 1993). Devonian volcanism is missing in the eastern Southern Alps but it is well pronounced in the Eastern Alps and the Uppony Mts.

The differences between the Devonian sediments of the Noric and Dinaridic evolution are significant. Besides the absence of volcanics and the lack of dolomite the only weak terrestrial sediment input is the main characteristic feature for the Carnic Alps. A strongly differentiated carbonate facies also represented the transition from a relatively thin pelagic domain to more than 1000 m thick shallow water complexes with a pronounced facies transition of reef, back reef and intertidal lagoonal domains. Besides this a nearly carbonate free cherty/pelitic basinal environment developed in a progressive but not uniformly deepening basin. The maximum of the barrier-type reef formation was within the Givetian to Frasnian and ended near the Frasnian/Famennian boundary by drowning and the evolution of an uniform pelagic carbonate cephalopod-trilobite-ostracode-conodont facies (Kreutzer 1990, 1992; Schönlaub & Heinisch 1993; Schönlaub & Histon 2000). In the S-Karawanken Mts atoll-like reef complexes only reached some 300 m (Rantitsch 1990).

In the Eastern Alps reef growth was less pronounced. The Lower–Middle Devonian shallow water complexes reflect the evolution of lagoons and shorelines, rich in dolomite, strongly influenced by clastic sediment input and some intercalations of alkaline basic volcanics. Organdetritic shallow water formations with coral-stromatopora and brachiopod faunas are of biohermal character; nevertheless a very few reef complexes did form. The shallow water complexes also drowned in the Frasnian and were followed by pelagic environments (Hubmann et al. 2006).

The Devonian of the Bükk Terrane has strong affinities to both, the Eastern Alps and the Carnic Alps. In the Szendrő Mts the Middle Devonian of the Abod Subunit is identical to coral-bearing formations of the Rannach Grp. in the Graz Paleozoic due to fine grained siliciclastic input and identical coral faunas (Mihály 1978; Ebner et al. 1998). Within the northern and southern marble zones of the Rakaca Subunit a carbonate platform evolved from the ?Middle Devonian/Early Frasnian until its drowning in the Late Frasnian.

In the Uppony Mts the Talpolcsány Subunit in general, has a close relationship to the basinal facies of the Carnic Alps with quartzites and graywackes at the base and deep-water siliceous pelitic±euxinic sediments (Zollner Fm) from the Silurian onwards until the Early Carboniferous. The only exception is the basic volcanism in the Uppony Mts. However, limestone olistoliths in the volcanic matrix are identical with contemporaneous formations in the Carnic Alps. In the Lázbérc subunit the carbonate platform drowned at the end of the Famennian as indicated by volcanogenic influenced pelagic limestones ("cipollino"; Kovács 1989; Ebner et al. 1998).

The Devonian of the Jadar Block Terrane exhibits basin (Jadar Trough) and swell (West Serbian Sill; Western Serbian facies) geometries (Krstić et al. 1988; Flügel 1990). The latter, is formed in some parts by Middle and Upper Devonian nodular limestones and shales with pelagic faunas (cephalopods, condonts). It has strong affinities to parts of the Graz Paleozoic and the Bükk Terrane, respectively, and to the pelagic facies of the Carnic Alps.

A characteristic feature of the Central Bosnian Terrane (Bosnian Swell) is the intensive keratophyric volcanism (Karamata et al. 1996; Hrvatović et al. 2006) while the late Lower Devonian brachiopod limestone, Middle Devonian reef, and Upper Devonian flaser limestones resemble those of the Carnic Alps. This is opposite to the Croatian Trough (Medvednica Mts near Zagreb) where the fine clastic input of the Devonian metaclastites and the inclusion of clayey limestones are more similar to the Eastern Alps (Krstić et al. 1988; Flügel 1990).

In the Eastern and eastern Southern Alps as well as the Bükk Terrane the Devonian pre-flysch environments lasted in pelagic sequences of pelites, lydites and nodular/flaser limestones of restricted thickness until Viséan/Serpukhovian times (Ebner 1991; Ebner et al. 1991, 1998, Schönlaub & Histon 2000). This transgressive trend is indicative for wide parts of the Alpine-Mediterranean Paleozoics as demonstrated by the propagation of "Goniatitico Rosso" and a succeeding (lydite)-radiolarite facies (Vai 1998). This trend is also responsible for the Jadar Block Terrane where a thin condensed pelagic carbonate sequence with conodonts and cephalopods continued across the Devonian-Carboniferous boundary until the Serpukhovian (Filipović 1974; Filipović et al. 1975) and also the Drina-Ivanjica Terrane with Late Tournaisian and Early Viséan black pelites, lydite and pelagic conodont bearing limestones (Filipović & Sikošek 1999).

In some areas pelagic limestones include subaerial erosional gaps and karstification across the Devonian-Carboniferous boundary. The time span of these gaps may extend from Frasnian to Early Viséan times in maximum, but mostly it ends within the Late Tournaisian (Ebner 1991a). During the Carboniferous transgression mixed conodont faunas infiltrated the paleokarst relief. Such karst reliefs burried by pelagic carbonate sediments are impressively documented within the Carnic Alps, S-Karawanken Mts and the Eastern Alps (Graz Paleozoic, Graywacke Zone; Tessensohn 1974; Ebner 1991a; Ebner et al. 1991; Schönlaub et al. 1991). In contrast, Vai (1998) also discussed a model with submarine gaps and the filling of extensional cracks for the eastern Southern Alps. In the Szendrő Mts (Rakaca Subunit) the Late Frasnian to Middle Viséan is represented by a hiatus. Pelagic fissure fillings/neptunian dykes with mixed conodont faunas of all missing zones bear witness to pelagic sedimentation during this time. This hiatus can be explained by strong submarine currents, which permanently swept the pelagic lime from the surface of the drowned platform into fissures/cracks which opened sporadically (Kovács 1992).

At the Devonian-Carboniferous boundary the O and C_{org} isotopic patterns of carbonate reflect global glacial eustatic oscillations. These may be responsible for short lived stratigraphic gaps and for changes in the oceanic environment leading to the formation of thin intercalations of black shales (Kaiser 2005). As the gaps do not occur in the entire area it is concluded that Late Devonian/Early Carboniferous synsedimentary movements may exceed the magnitude of oceanic oscillations and may be regarded as the major reason for subaerial erosion and karstification. The $\delta^{18}O$ values of apatite in conodonts indicate tropical–subtropical conditions with temperatures between 22–30 °C for the surface seawater of the Carnic Alps (Kaiser 2005). In some sections of the Graz Paleozoic with continuous sedimentation the beginning of the Early Carboniferous transgression is marked by a lydite or lydite-phosphorite horizon. A lydite horizion in the same position was also found in the Lázbérc Subunit of the Uppony Mts (Kovács 1992; Ebner et al. 1998).

In some parts of the Noric Bosnian/Carnic Dinaric Zone the pelagic carbonate facies reaches the Latest Tournaisian–Viséan and was superposed by flysch type siliciclastics. In the Graz Paleozoic, Bükk Terrane and parts of the Jadar Block Terrane ± continous carbonate pelagic sedimentation lasted until the Serpukhovian and was followed by shallow water limestones, or siliciclastics. Erosional disconformities and stratigraphic gaps are frequent at these levels but until now no angular unconformities were recorded (Ebner 1991b; Kovács 1992; Filipović et al. 1995; Ebner et al. 1998; Ebner et al. 2000; Protić et al. 2000; Filipović et al. 2003).

In some places of the Szendrő Mts (Rakaca Subunit) Upper Viséan basinal limestone covers after a hiatus the Devonian platform, elsewhere the sililciclastic "flysch" was directly sedimented onto the platform. The southern marble zone of the Rakaca Subunit is intercalated between a Late Viséan and Early Bashkirian basinal facies or is interfingered through a brecciated transitional slope facies with the basinal facies. In spite of metamorphism and lack of fossils the Late Viséan to Early Bashkirian age of this platform is well constrained. A more diverse situation is found S of Rakacaszend, where the lower part of the platform interfingers with Lower Viséan crinoidal limestone, thus indicating the slope setting of a "Walsourtian reef" (Kovács 1992).

Siliciclastic dominated Devonian stable continental margins (Inovo Zone)

(1) *Kučaj Terrane* of E-Serbia and W-Bulgaria

The sequence follows graptolite schists within the Lochkovian. It is composed of approximatly 100 m thick hemipelagic shales, siltstones, cherts, limestones, channel sandstones and occasional turbidite layers. This channeled slope environment changed to a syn-orogenic flysch within the Late Devonian (Krstić et al. 2004, 2005a).

(2) Inovo Fm of the Stara Planian Porec Unit of E-Serbia and W-Bulgaria.

The clastic Inovo Fm of the Stara Planina Porec Unit (= Upper Danubian Unit), some hundreds of meters thick, is dominated by coarse grained turbiditic clastics with intercalations of thin bedded finer sediments formed on the lower part of a passive continental slope. Debris/grain flows, turbidites and olistostromes are frequent. Late Silurian to early Middle Devonian stratigraphic levels were dated by palynomorphs and plants (Krstić et al. 1999, 2004, 2005a). Equivalents of the Inovo Fm occur in the S part of Upper Danubian Porec segment (Ravna Reka Fm), the Lower Danubian Kutlov Unit (Sredogriv Fm) and the Belogradcik Unit (Raianovska Fm).

Quartzphyllite Complexes

The biostratigraphic control of Quartzphyllite Complexes of the Eastern and Southern Alps is poor. These units are regarded as the fills of Early Ordovican to Early Carboniferous basins affiliated to marginal parts of the *Noric Composite Terrane* (Frisch & Neubauer 1989; Neubauer & Sassi 1993). After a renewed pulse of rifting during the Silurian and Lower Devonian the early basinal rift environments were followed by passive continental margins with Middle to Upper Devonian carbonate platforms. Similar evolutions may be identified in the low grade metamorphic sequences of the Pelsonia Composite Terrane (Transdanubian Range Terrane; Zagreb-Midtransdanubian Terrane/Mt Medvednica metamorphic sequence) and some small low grade tectonic inclusions of pelitic-psammitic sequences with a few calcareous and volcanic (basalts, porphyroids) intercalations in the Tisia Megaterrane. All these complexes, except the Mt Medvednica metamorphic sequence, were deformed and metamorphosed during the Variscan orogeny.

Carpatho-Balkanic Intracontinental Rift Zones (CBRZ)

Intracontinental rift basins of Rheno-Hercynian type (as named in the Devonian–Early Carboniferous map of the CPR; Ebner et al. 2004a, http//www.geologicacarpathica.sk) evolved during the Devonian above pre-Variscan metamorphics and different Silurian sediments of the Eastern Carpathianas (*Rodna Terrane),* Carpatho-Balkanides (*Poiana Rusca Terrane, Locva-Ranovac-Vlasina Terrane; Ideg Terrane*) and possibly within the Tisia Megaterrane (Apuseni Mts). During the Early/Middle Devonian the beginning of a renewed rifting phase is documented by coarse grained clastics and psammito-pelitic sediments followed by basaltic and keratophyric volcanics. Small intercalations of partly reef-derived limestones occurred in both areas within the Late Devonian (East Carpathians: Cimpoiasa Grp.; South Carpathians: Ghelar Grp.). These rift sediments were topped by thick Early Carboniferous (Tournaisian) shallow water carbonate sediments (Eastern Carpathians: 300 m thick upper part of the calcareous/dolomite Prislopas Fm; Southern Carpathians: 300 m thick sparry Ideg Lmst. in the Danubian Unit and the > 1000 m thick Hunedoara-Luncani dolomite in the Pades Group of the Bucovino-Getic Nappe System). The Variscan pile is closed by thick siliciclastics interpreted as syn-orgenic flysch.

The *Bistrita Terrane* in the Eastern Carpathians is now devoid of a Devonian–Lower Carboniferous cover. This zone is interpreted as a continental rise which was originally situated between the Rodna rift in the Eastern Carpathians and the Poinana Rusca rift of the Southern Carpathians. Nevertheless, Early Carboniferous palynomorphs in limestones (formerly called Tibau Fm), actually interpreted as infiltrations within the Precambrian basement rocks (Rebra Grp.), demonstrate that the *Bistrita Terrane* was at least partially covered by sediments during the Late Carboniferous (Kräutner 1997). In the South Carpathians a similar continental rise may be suspected in the Supragetic Bocsa Nappe (Banat), interposed between the rift sytems of the *Poiana Rusca* and *Locva-Ranovac-Vlasina Terranes.*

Although the lithological sequences in the *Rodna Terrane, Poiana Rusca Terrane* and *Locva-Ranovac-Vlasina Terrane* are roughly similar, some local individualities support their origin in different sedimentation basins. Differences mainly involve the amount and type of carbonate deposits, detrital input, flysch development and metallogeny associated with rift volcanism:

In the *Poiana Rusca Terrane* carbonate deposits predating the flysch-like sedimentation are extremely thick (> 1000 m) and the Lower Carboniferous rhythmic detrital input is large, suggesting a relatively high subsidence rate. Intensive metallogeny with iron ores of the Lahn-Dill and Teliuc-Ghelar types as well as base metal vein systems are related to the late rhyolitic phases. In the *Rodna Terrane* carbonate and flysch-like deposits are less developed, probably due to a lower subsidence rate. Lahn-Dill type iron ores show only a small incipient development. In the *Locva-Ranovac-Vlasina Terrane* carbonate deposits are missing, late flysch-like development is intensive, the initial clastic sediments are locally feldspar rich and the specific metallogeny is missing.

Devonian/Carboniferous siliciclastic turbiditic environments

In the CPR the pre-flysch sediments are followed during the late Early Carboniferous by siliciclastic turbiditic sequences. Partly they were interpreted as syn-orogenic flysch. They are not documented in the CPR terrane maps (Kovács et al. 2004; http//www.geologicacarpathica.sk). The only exception is the Kučaj flysch which already began within the Late Devonian and which is therefore shown in the Devonian–Early Carboniferous map together with the pre-flysch environments (Ebner et al. 2004, http//www.geologicacarpathica.sk).

Flysch environments interpretred as syn-orogenic (Variscan Flysch Zone)

Flysch sensu strictu forms in a syn-orogenic collisional setting. Therefore, typical flysch sequences were included immediately after sedimentation in the evolving orogenic belt and indicated at the top by changes towards post-orogenic molasse sediments and a clear unconformity (Füchtbauer 1988).

The existence of Variscan flysch in the **Eastern Alps** is the subject of discussion. Shales of the Dult Grp. in the Graz Paleozoic show scarce evidence of olistostromes, pelagic limestone/lydite breccias and allodapic limestones (Ebner et al. 2000). Possibly the clastic sequences of the Dornerkogel Fm could be interpreted as syn-orogenic flysch (Neubauer et al. 2001). But because of the lack of an unconfomity within the Paleozoic sequence until the Early Bashkirian and the absence of a Variscan molasse the existence of of such a syn-orogenic flysch basin is quite speculative. In the western Graywacke Zone a Carboniferous age for the top of the sililciclastics with extensive basaltic formations is not documented. In the eastern Graywacke Zone blackshales (Eisenerz Fm) are younger than Late Viséan and in the Gurktal Paleozoic the youngest limestone intercalations within clastic sequences are of Viséan age. The unconformable superposition with continental molasse indicates that the possible interval for the Variscan deformation is latest Viséan–Kasimovian (Krainer 1992, 1993; Schönlaub & Heinisch 1993). For the Austro- and Southalpine Quartzphyllite Complexes syn-orogenic flysch before basin closure and low grade metamorphism (350–320 Ma; Viséan to Bashkirian) is suggested but not proved (Neubauer & Sassi 1993). Possibly, the "Diabaszug of Eisenkappel" (pillow lavas, sills, tuffite, clastic sediments) also has a Carboniferous age (Schönlaub & Histon 2000).

The sedimentation of the pelagic pre-flysch in the **eastern Southern Alps** (Carnic Alps, S Karawanken Mts) lasted until the Tournaisian/Viséan boundary and predates the beginning of the 600–1000 m thick syn-orogenic flysch (Hochwipfel Fm; Tessensohn 1971; Spalletta et al. 1980; Ebner 1991b; Vai 1998; Schönlaub & Histon 2000). Locally this change still took place during the Late Viséan (Spalletta & Perri 1998). The transition to a flysch environment was the subject of intensive debates until the recognition of a wide variety of paleokarst features and related structures (e.g. collapse breccias, fissures, silicret regolite, paleo-speleothems, polymetallic-baryte-fluorite mineralizations). This was caused by a global sea-level drop during the Tournaisian. Presumably starting within the Early Viséan the transgression of the Hochwipfel Fm was due to sea-level rise and/or syn-sedimentary tectonics affecting the collapse and drowning of the emerged carbonate blocks (Tessensohn 1974; Schönlaub et al. 1991; Schönlaub & Histon 2000). In Slovenia some tens of meters thick micritic limestones and only rare olistostromes indicate distal positions of the flysch basin in contrast to the Carnic Alps. Another special feature in Slovenia is the inclusion of porphyroidic materials in a sequence with Early Carboniferous conodonts (Ramovš 1971, 1990; Schönlaub 1971).

The flysch character is well demonstrated by turbidites, pebbly mudstones, chaotic debris flows, limestone and chert breccias, olistostromes and olistoliths (Tessensohn 1971; Spalletta et al. 1980). Two distinct types of mud supported breccias and con-

glomerates occur at the base of the flysch. Monomictic angular, grey-black chert breccias represent intrabasinal formations just before the material became involved in debris flows. The polymictic type has rounded cherts, granites and metamorphics from the extrabasinal hinterland which were reworked before transportation to the remaining syn-orogenic sedimentary basin (Spalletta & Venturini 1988). Olistolith limestone clasts also yield shallow water fossils (Hexaphyllia, fusulinids and algae). They derived from a carbonate shelf primarily situated N of the Carnic domain which was later totally destroyed by tectonic activities (Flügel & Schönlaub 1990). The basic volcanics of the Dimon Fm represent intraplate alkalibasalts at the climax of the extensional period before the environment turned to an active plate tectonic margin in a collisional regime (Läufer et al. 1993; Schönlaub & Histon 2000). Plant remains suggest that that age of the Hochwipfel flysch is Middle Viséan to Serpukovian (v. Ameron et al. 1984; v. Ameron & Schönlaub 1992). It is followed by the Variscan deformation and the onset of the Auernig molasse within the Late Mitachkovo substage of the Moscovian stage (Schönlaub & Histon 2000).

Whether the Štós Fm in the S-Gemeric basement of the West Carpathians was part of the Gelnica Grp., or whether it represents Carboniferous-age syn-orogenic flysch, was already discussed. In the Silica Unit the Bashkirian Turiec Fm. represents a syn-orogenic flysch (Ebner et al. 1990; Vozárová & Vozár 1992). It consists of black phyllites, metasiltstones and metasandstones with carbonate olistostromes and T_{d-e} turbidite layers of volcaniclastics of the subalkaline rhyolite-dacite magmatic group. Paraconglomerates are predominantly made up of intraformational detritus. The olistostrome consists of carbonate olistoliths ranging from tens of meters to a decimeter in size. They contain conodont mixed faunas of Bashkirian and Emsian-Tournaisian ages. Sporomorph assemblages from the matrix are of Bashkirian (Namurian B–Westphalian A) age (Planderová in Vozár et al. 1989). The pelagic carbonate blocks indicate a passive margin setting of Noric Bosnian/Carnic Dinaridid-type as the source area opposite to an active continental margin as the hinterland of the acidic volcaniclastics and phyllitic materials. Based on sedimentological criteria and age the Turiec Fm was correlated with the Szendrő Phyllite Fm as well as the Carboniferous flysch complexes of the Carnic Alps.

The **Eastern** and **Southern Carpathians** have a similar late Variscan sedimentary record. Shallow water carbonates at the top of the Carpathian rift basins are superposed by some hundreds of meters thick silicilclastic sediments. The Fata Muntelui Fm of the Eastern Carpathians is composed of coarser grained feldspar rich psammites in comparison to the Sevastru Fm of the Southern Carpathians which is mainly composed of black phyllite with fine grained inclusions of metapsammite. In the Pades and Lescovica Fms quartzitic sequences prevail and layers of mafic magmatic rocks occur in the upper part. Besides some lithological features a syn-orogenic flysch setting is constrained by the Variscan low grade metamorphic overprint and the unconformable superposition by continental molasse within the early Moscovian (Westphalian C; (Kräutner 1989, 1997; Kräutner & Nastaseanu 1990)).

In the **Carpatho-Balkanides** a syn-orogenic flysch system (Kučaj-Zvonce flysch) is well established in the Getic Kučaj-Sreda Gora units of E-Serbia and W-Bulgaria. In the *Kučaj Terrane* a 100 m thick Devonian channeled slope facies prevailing until the Late Frasnian is followed by Carboniferous siliciclastic flysch about 600 m thick. It represents various sedimentologically well constrained realms of an upwards retrogradational system with inner to outer fan and even basinal environments and the respective olistostromatic and turbidite facies zones. Exceptions are the Rtanj and Suva Planina with a progradational succession from the outer and mid fan complex towards a channeled supra fan and inner fan slope. Sedimentation took place within a N–S elongated basin. In spite of locally different directions in sediment transport the main source areas are suggested in the E and NE. The minimum age of the flysch, as constrained by palynomorphs and conodonts is Viséan. The Variscan event is documented by a low grade metamorphic overprint and unconformable superposition of continental clastics, dated as Late Kasimovian to Early Gzhelian (Stefanian B and C) by plants (Maslarević & Krstić 1987a,b; Krstić & Maslarević 1990; Krstić et al. 2004, 2005a).

The terrigenous flysch of the Tumba-Penkjovci (also described as Lužnica) Unit in E-Serbia is similar to that of the *Kučaj Terrane*. However the paleogeographic relationships are not clear. The Alpine units hosting this zone are correlated with the Penkjovci-Poletinci (described also as W-Kraishte) Zone in Bulgaria where the >1000 m thick pelitic-psammitic Katina Fm, with some intercalations of limestone and lydite, is dated by conodonts as Famennian to Tournaisian. Further south conglomeratic levels are also included (Technov 1989).

Carboniferous turbiditic sliciclastic sediments on stable margins interpreted as anorogenic (Bükk-Jadar Zone)

Turbiditic sliciclastic sediments, often with typical sedimentological flysch features, are conformably followed by shallow marine fossiliferous sediments in the Bükk, Sana Una, Jadar Block and the Central Bosnian Durmitor Terranes. The turn to these shallow water environments is connected with shallowing upward trends in the turbiditic sequences and sometimes also with distinct stratigraphic gaps. There is no proof of any tectonic unconformity or break in metamorphism before the beginning of this new sedimentary cycle, which was often assigned in the literature as "molasse" type or "post-Variscan". We do not regard the turbiditic siliciclastics with the lack of any Variscan overprint as syn-orogenic flysch. As these anorogenic turbiditic sequences were described as flysch in the past we further use the term "flysch" in the previous chapter but within quotation marks. Ebner (1991b) named these turbiditic sililciclastics as "filling up type flysch". It may represent the evolution of a long lasting passively subsiding continental margin which later changed into a shallowing margin (Ebner 1991b; Karamata & Vujonović 2000; Ebner et al. 2006).

Anorogenic turbiditic siliciclastics are well described in the **Bükk Terrane**. The Szendrő Phyllite Fm did not start before the Late Viséan or later in the Rakaca Subunit of the

Szendrő Mts. However, after cessation of carbonate deposition in the Early Bashkirian, turbiditic siliciclastic deposition took over. Taking into account the situation in the nearby Bükk Mts it possibly continued until Early Moscovian times. The sequence shows a fining-upward character. The lower proximal part is rich in olistostromes with intraformational and older limestone clasts, whereas its middle and upper parts are of a more distal turbidic type (Kovács 1992; Fülöp 1994; Ebner et al. 1998). These parts are identical in facies and pre-metamorphic mineral composition to the "flysch" of the Bükk Mts. Conodonts indicating Middle Devonian to Lower Bashkirian ages were recorded from the olistolithic limestone materials (Kovács 1992; Fülöp 1994). Their opposite structural orientation indicates individual structural settings during the Alpine (Cretaceous) orogeny. The lithofacies is as in the Carnic Alps but the tectonofacies is anorogenic. Definite similarities particularly between the Carboniferous formations of the Szendrő Unit and the Medvednica Unit of the Zagorje-Midtransdanubian Terrane should also be mentioned. However, a detailed comparative study is missing.

Fine grained sililciclastic sediments of the Éleskő Fm in the Talpolcsány Subunit of the Uppony Mts. include Devonian olistolithic materials. They are tentatively interpreted as part of Middle Carboniferous siliciclastics formerly described as "flysch" (Kovács 1992).

The distal turbiditic shale-sandstone Szilvásvárad Fm, pre-Late Moscovian (pre-Podolskian) in age, is the oldest formation in the Bükk Mts. It could be partially an equivalent or continuation of the Szendrő Phyllite Fm (Árkai 1983). It is followed by Upper Moscovian–Gzhelian fossiliferous limestones and siliciclastics of the shallow marine Mályinka Fm, the upper parts of which have been eroded to different levels. There is no evidence for any orogenic movements or a metamorphic event between the two environments (Árkai 1983; Ebner et al. 1991; Fülöp 1994; Pelikán 2005).

In the autochthonous units of the **Jadar Block Terrane** (JBT) a >1000 m thick siliciclastic sequence (Vlasić Fm) was deposited besides pelagic limestones from the ?Middle Devonian until the Serpukhovian. Tournaisian to Serpukhovian levels are proved by fossils. The upper turbididtic parts include life-traces and drifted plant fossils. A regressive trend (Early Serpukhovian–Early Bashikrian) associated with the "Erzgebirge" event caused conglomerates and sandstones followed by a stratigraphic gap at the top of the Vlasić Fm. The beginning of the new ("post Variscan") sedimentary cycle was during the Late Moscovian with graviational transported "wildflysch" sediments (Ivovik Fm) which were activated by the "Asturian" event and deposited in "molasse" depressions near to elevated areas in the Ub region. Nevertheless, no angular unconformities were observed between the Vlasić and Ivovik Fms (Filipović 1995; Protić et al. 2000; Filipović et al. 2003; Krstić et al. 2005).

Bluish grey limestones with intercalations of shales (Đjulim Fm) with the significant Serpukhovian–Lower Bashkirian *Declinognathodus-Idiognathoides* condont-fauna are found at the top of the Carboniferous turbiditic siliciclastics occurring in the allochthonous units of the JBT. The sedimentary evolution ends without any disconformity with carbonate formations, rich in shallow water fossils, within the Moscovian (Filipović 1995; Filipović et al. 2003; Krstić et al. 2005). On the other hand, a definite angular discordance (about 30°) can be recognized betwen the Kriva Reka Formation and the overlying Middle Permian siliciclastics–evaporites (Filipović et al. 2003).

The Carboniferous siliciclastic evolution of the **Sana Una Terrane** exhibits laminated silt- and sandstones. These are topped in the Sana Unit by Serpukhovian–Moscovian fossiliferous limestones similar to those of the Jadar Block allochthonous. They contrast with the sequence of the Una Unit which include a stratigraphic gap beween the Bashkirian siliciclastics and the Upper Moscovian olistostromatic Blagaj Fm which can compared with the Jadar Block autochtonous units (Protić et al. 2000).

In summary there are strong affinities between the Bükk, Jadar Block and Sana Una Terranes and a Variscan deformation is not evident within the Bashkirian–Moscovian sequence (Ebner et. al. 1991, 1998; Filipović 1995; Protić et al. 2000; Filipović et al. 2003). The Rannach nappe of the **Graz Paleozoic** is another domain where stratigraphic gaps are frequent within the Carboniferous but no angular unconfomities are evident at least until tle Late Bashkirian (Ebner et. al. 2000). On the other hand the sedimentological characteristics of the turbiditic sequences are a connecting feature to the syn-orogenic flysch of the Carnic Alps and Karawanken Mts. But the latter reveals a distinct Intra-Late Carboniferous deformation event (Carnic phase) and a well established angular unconfomity at the contact to the post-orogenic marine/terrestrial Auernig molasse which is similar in bio-/lithofacies to the Mályinka Fm in the Bükk Terrane, the Ivovik/Kriva Reka Fm in the Jadar Block autochthonous and the Blagaj Fm of the Una Unit (Ebner et. al. 1991, 1998; Protić et al. 2000; Filipović et al. 2003). On the other hand, equivalents of the Lower Permian Rattendorf Group and Trogkofel Fm of the Carnic Alps are missing in all the three units, indicating uplift, some tectonic movements and erosion prior to the Middle Permian.

Turbiditic siliciclastic Carboniferous is also known from the **East Bosnian Durmitor Terrane** (EBT) and the **Drina-Ivanjica Terrane** (DIT). However oberservations on the sedimentary character, the age and the influence of the Variscan orogeny are scarce. In the EBT Early Carboniferous to Bashkirian siliciclastic sequences (Karamata & Vujnović 2000) are superposed by olistostomes and shallow water limestones similar to the Jadar Block Terrane (Filipović 1995; Krstić et al. 2005). Significantly the post-Carboniferous sediments began within the Middle/Late Permian. In the DIT Tournaisian pelitic/lyditic pre-flysch sediments are followed by Carboniferous siliciclastics which include olistoliths with Silurian and Devonian carbonate blocks. As there is no sedimentary record from the Bashkirian–Triassic the interpretation of the Late Variscan history is quite speculative but could be similar to that of the EBT (Filipović & Sikošek 1999).

Carboniferous foredeep and remnant basins (Veitsch/Nötsch–Szabadbattyán-Ochtiná–Zone)

The Veitsch/Nötsch–Szabadbattyán-Ochtiná–Zone (VNSOZ) situated in the ALCAPA Megaterrane is not shown in the Devonian–Early Carboniferous terrane map of the CPR (Ebner et al. 2004; http//www.geologicacarpathica.sk). The sedimentation of this zone began during the Late Tournaisian/Viséan, that is after the Late Devonian–Early Carboniferous climax of the Variscan orogeny when the internal metamorphic zones of the Intraalpine Variscides (Mediterranean Crystalline Zone, MCZ, sensu Flügel 1990) were formed. The VNSOZ is post-tectonic in respect to the MCZ and includes marine foredeeps (Eastern Alps, Transdanubian Range Terrane) as well as remnant basins (West Carpathians). The VNSOZ is contemporaneous to the much more externally situated pelagic domains of the Noric Bosinan/Carnic-Diaridic zones which were deformed during Intra-Late Carboniferous tectonic phases. At least the Veitsch Nappe of the Graywacke Zone in the Eastern Alps lacks all signs of Variscan deformation and metamorphism (Ratschbacher 1987; Ebner 1992; Ebner et al. 2006).

In the **Eastern Alps** the Late Devonian/Early Carboniferous climax was connected with medium grade metamorphism. After deformation, metamorphism and intrusion of syn-orogenic granitoids (Finger et al. 1992; Neubauer et al. 1999) marine, molasse like fore deep environments did form in the Veitsch Nappe of the Graywacke Zone and the Nötsch Carboniferous of the Drauzug (Flügel 1977; Neubauer & Vozárová 1990; Krainer 1992, 1993; Ebner 1992; Neubauer & Handler 2000).

The sequence of the Veitsch Nappe resembles the evolution of a shallow carbonate/clastic shelf, sometimes interfingering with hypersalinar lagoons, lensoid bioherms and basic volcanics. The sequence began with the Steilbachgraben Fm, up to 230 m of graphitic metapelites–psammites, limestones/dolomite, and sparry magnesite within the Late Viséan. Devonian ages of detrital micas can be related to a pre-Carboniferous metamorphic source area which was part of the MCZ (Neubauer & Handler 2000). The bedded to massive limestones of the Serpukhovian to Bashkirian Triebenstein Fm are about 300 m thick. At the top there is the Moscovian Sunk-Fm (50–150 m) made up of coarsening upwards siliciclastic deposits with plant fossils and seams/lenses of graphite. It was formed along a regressive shore line with distributary bay and river dominated delta environments (Ratschbacher 1987; Krainer 1992, 1993). Heavy mineral spectra derived from a metamorphic hinterland are dominated by anatectic granitoids (Ratschbacher & Nievoll 1984).

The Nötsch Carboniferous in the Drauzug consists of Late Viséan–Kasimovian sediments, deposited in a shelf/upper continental slope environment. Two clastic formations (Erlachgraben Fm some 100 m; Nötsch Fm, 400–600 m) are intercalated by the Badstub Fm (350–400 m). The latter has a green matrix of reworked amphibolite, rounded crystalline and a few limestone clasts with conodonts of Late Viséan–Early Serpukhovian age. Fossils (brachiopods, bivalves, trilobites, gastropods, corals, crinoids, bryozoans, few cephalopods, ostracods, small foraminifers, few conodonts, plants and trace fossils) are frequent (Schönlaub 1985; Schönlaub & Flügel 1990; Krainer 1992, 1993).

The Szabadbattyán Fm (Late Viséan) in the **Transdanubian Range Terrane** is made up of ~100 m thick black, bituminous limestones with intercalations of shales and sandstones and marine shallow water fossils (corals, brachiopods, algae). The continental Füle conglomerat (Late Bashkirian–Early Gzhelian; Westphalian/Stephanian), occurring in a short distance to Szabadbattyán, is the proof for an Intra-Late Carboniferous tectonic event between the two formations (Lelkes-Felvári 1987).

Parts of the Mediterranen Crystalline Zone of the **Western Carpathians** were formed during Late Devonian/Early Carboniferous tectonics and metamorphism in a collision zone suturing units of the Western Carpathian Crystalline Zone and the North Gemeric Zone (formation of the *Spiš Composite Terrane* by amalgamation of the *Klatov* and *Rakovec* Terranes; Vozárová & Vozár 1996, 1997). The sedimentation of the Ochtiná Grp. of the North Gemeric Zone started after amalgamation and metamorphism of the *Spiš Composite Terrane*.

The basal Hrádok Fm and Črmeľ Fm are proximal to distal flysch complexes above an unknown basement. The turbidite clastic wedges derived from both sides of the supposed suture and covered the rest of the intrasuture remnant basin. The Hrádok Fm consists of dark-grey and black metaconglomerates, -sandstones, and -pelites interlayered with metabasalts, -dolerites and basalt metavolcaniclastics of tholeiitic N-MORB affinity. Thin layers of lydites and siliceous metapelites are rare. Slabs of ultramafic rocks (?oceanic crust fragments) have also been reported. Turbidity current flows, gravity slides and grain flows are indicated by typical sedimentary structures as the dominant sediment transporting mechanisms. A monotonous complex of dark-grey metapelites above the coarse-grained basal part yielded microfloral assemblages of Late Tournaisian-Viséan age (Bajaník & Planderová 1985).

In the E and SE part of the North Gemeric Zone the distal flysch of the Črmeľ Fm is composed of alternating metapelites, fine-grained metasandstones, basic to intermediate metavolcanites/meta-volcaniclastics, subsidiary metacarbonates and lydites. Small amounts of acidic volcaniclastic detritus are unevenly dispersed. The Tournaisian-Viséan age was indicated by microfloral assemblages (Snopková in Bajaník et al. 1984).

The shallowing upwards trend is a characteristic feature of the Ochtiná Group. The upper lithostratigraphic unit, the Lubeník Fm, consists of black metapelites, dolomite schists and well-bedded dolomites, which were partly metasomatized to massive coarse-grained magnesites. Dolomites and dolomite limestones are rich in fossils (echinodermata, lamellibranchiata, foraminifera, bryozoa, algae etc.). In summary, foraminifera indicate Late Viséan (Plašienka & Soták 2001), trilobites Serpukhovian (Bouček & Přibyl 1960) and marine algae (Mamet & Mišík 2003) resp. conodonts Late Viséan to Serpukhovian ages (Kozur et al. 1976).

Near Košice shallow-marine sediments of the Lubeník Fm. with magnesites are tectonically isolated from the

Črmeľ Fm. Due to some specific differences (occurrence of redeposited carbonate fragments; absence of fauna) they are named the Bankov Beds (Vozárová 1996).

The whole Tournaisian-Serpukhovian sequence was deformed and weakly metamorphosed before the Bashkirian. The new Bashkirian-Lower Moscovian sedimentary cycle is represented by a delta fan/shallow-marine to paralic overlapped sequence (the Hámor Fm) which occurs only in tectonically reduced fragments. These sediments are lithologically similar to the Sunk Fm. in the Eastern Alps. Due to the strong Alpine tectonics the basement-cover contacts are preserved only in some places.

Paleogeographic reconstruction, discussion and conclusions

• Paleogeographic zonation

The outlined features in stratigraphy, sedimentary, orogenic and metamorphic facies characterize the following domains as the important Variscan paleogeographic zones within the Devonian–Carboniferous evolution of the CPR (Flügel 1990; Neubauer & Vozárová 1990; Neubauer & Handler 2000; Ebner et al. 2006):

♦ Mediterranean Crystalline Zone (MCZ; Flügel 1990; = Peri-Mediterranean Metamorphic Belt Neubauer & Handler 2000) and part of the Moldanubian Zone (Matte 1986; Matte et al. 1991; Buda et al. 2004; Klötzli et al. 2004)

♦ Oceanic and arc related zones (OAZ)

♦ Veitsch-Nötsch-Szabadbattyán-Ochtiná Zone (VNSOZ)

♦ Noric Bosnian/Carnic-Dinaric Zone (NBZ/CDZ)

♦ Carpatho-Balkanic Intracontinental Rift Zone (CBRZ)

♦ Inovo Zone (IZ)

♦ Variscan Flysch Zone (VFZ)

♦ Bükk-Jadar Zone (BJZ)

Mediterranean Crystalline Zone (MCZ)

The metamorphism and deformation of the MCZ and parts of the Moldanubian Zone with the medium to high-grade metamorphic complexes of ALCAPA and TISIA are mainly of Late Devonian/Early Carboniferous age. However, sometimes they directly follow Silurian/Devonian and older metamorphic events. This suggests an early Variscan orogeny which was related to the active Laurussian margin (Neubauer & v. Raumer 1993; Neubauer et al. 1999; Neubauer & Handler 2000). The MCZ extends from the Eastern Alps to the Carpathian arc and includes a major Carboniferous suture zone primarily situated between parts of the MCZ and the fossil bearing NBZ/CDZ to the south. This orogenic collage was analysed in terms of terrane tectonics by Frisch & Neubauer (1989), Neubauer et al. (1997), Vozárová & Vozár (1996, 1997), Szederkényi in Kovács et al. (1997, 2000), Kräutner (1997) and Neubauer & Handler (2000). The Variscan metamorphic complexes of the Dacia-Megaterrane (Serbian Macedonian Massif, metamorphic units of the Romanian Bucovino-Getic and Danubian Units) were accreted to the Proto-Moesian or the East European Plate during the Carboniferous. The intensity of the medium–high grade metamorphic impact depends on the position in the Variscan pile. This metamorphism also retrograded the pre-Variscan metamorphic units which exhibited a higher metamorphic grade. Locally these complexes are intruded by granitoids of Late Carboniferous to Early Permian age (Krstić & Karamata 1994; Kräutner 1997).

Oceanic and arc related domains (OAZ)

Oceanic and arc related environments in the CPR are remnants of the Mid-Paleozoic Paleo-tethyan oceanic domains between Laurussia and Gondwana (Frisch & Neubauer 1989; v. Raumer 1998; Neubauer 2002; v. Raumer et al. 2003). As dismembered elements they are included in the MOZ. They may form parts of the South Gemeric Unit, and occur as small slices along suture zones and terrane boundaries in the Tisia-Megaterrane and the Carpatho-Balkanides. The Vardar Zone is regarded as an oceanic system which still remained open during the Variscan orogenic period (Karamata et al. 1997; Karamata 2006).

All the oceanic domains are hard to correlate and the affiliation to well defined Paleozoic oceanic systems is quite speculative due to the fragmentation during Variscan accretion and severe Alpine tectonics after the consolidation of the Variscan crust. Paleomagnetic data from individual terranes of the Carpatho-Balkanic Variscan terrane collage suggest that during the Early Devonian some terranes were situated most probably along the same latitude but differ strongly in paleolatitude (Table 2): *Stara Planina Terrane* 4°N, *Kučaj Terrane* and *Locva-Vlasina-Ranovac Terrane* 39°S (Milićević 1996; Krstić et al. 1996). This suggests a north–south oceanic separation in this segment between Laurasia and Gondwana of at least 35° of latitude (~4000 km). After the Carboniferous collision the *Kučaj Terrane* had a paleolatitude of 8°N (Karamata 2006).

Veitsch-Nötsch-Szabadbattyán-Ochtiná Zone (VNSOZ)

The VNSOZ in the ALCAPA-Megaterrane evolved after the formation of the MCZ in its foreland (Veitsch/Nötsch, Szabadbattyán) or as a remnant basin, related to sequential suturing of the Variscan orogenic belt in the Western Carpathians (Flügel 1977, 1990; Neubauer & Vozárová 1990; Ebner et al. 1991, 1998; Ebner 1992; Vozárová 1996). Fragments of ultramafic rocks and doleritic dykes inside the huge turbiditic filling of the lower part of the Ochtina Gr. indicate oceanic crust provenance. Mixing of this detritus with the quartzose to quartzolitic character of the bulk of the Ochtiná metasandstones implies recyclying of sedimentary and metasedimentary sources without a significant contribution from unroofing of the deep crustal basement. Subaqueous ashflow tuffs (basic to intermediate), apparently derived from presumed arc eruptions were indicated. The uplifted interior was the source of older increments of the orogenic suture (465 Ma $^{40}Ar/^{39}Ar$ ages of

Table 2: Paleozoic paleomagnetic data of the CPR.

Terrane/Unit	Age	Latitude	References
N margin Gondwana	Early Devonian	10°S	Kent & Van der Voo
Noric Bosnian Terrane Graz Paleozoic	Emsian	8°S	Fenninger et al. 1997
W-Graywacke Zone	Silurian Middle Devonian	47°S 24°S	Schätz et al. 2002 Schätz et al. 2002
Carnic Alps	Devonian/Carboniferous Viséan Late Pennsylvanian	30°S 14°S 14°S–4°N	Schätz et al. 2002 Scholger & Mauritsch 1994 Heinz & Mauritsch 1980
Nötsch Carboniferous	Viséan	4°N	Heinz & Mauritsch 1980
Western Carpathians	Late Paleozoic	7–8°S	Krs et al. 1993 Scholger & Mauritsch 1994
Capatho Balkanic Terranes *Locva-Ranovac–Vlasina Terrane*	Paleozoic Lower Devonian	30/40°S 39°S	Karamata 2006
Ranovac Terrane	Late Bashkirian– Early Gzhelian	5°N	Pantić & Dulić 1991 Milićević 1996
Stara Planina Terrane	Early Devonian	4°N	Karamata 2006
Kučaj Terrane	Ordovician Silurian Early Devonian Late Devonian Latest Moskovian– Early Gzhelian	29–25°S 20–14°S 16°S 5°S 5°N	Krstić et al. 1996 a,b, Milićević 1996, 1998
Jadar Block Terrane	Latest Moskovian– Early Gzhelian	4°S	Pantić & Dulić 1991 Milićević 1996

clastic mica, Vozárová et al. 2005). As convergence proceeded, the synorogenic turbidite sedimentation in the remnant basin (Turnaisian-Viséan) was succeeded by shallow-water carbonate-siliciclastic (Serpukhovian) and deltaic siliciclastic (Moscovian) sedimentation. This evolution reflects the change of basin architecture, from turbiditic remnant ocean basin to shallow-water/deltaic foreland basin floored by a continental substratum.

The primary basement of the VNSOZ is partly uncertain. However, there is some evidence for a primary Devonian–?Early Carboniferous metamorphic basement in the Veitsch Nappe of the Eastern Alps (Neubauer & Handler 2000) and that the *Rakovec* and *Klátov Terranes* amalgamated after or partly ?diachronous to the onset of the Carboniferous Ochtiná Group in the Western Carpathians. Naturally, the basement beneath such late-synorogenic sedimentary sequences is usually uncertain because they were detached and overrode the continental margin. There is no proof of a Variscan deformation of the VNSOZ in the Veitsch Nappe (Ratschbacher 1987) whereas basin closure due to continuation of convergence is documented by a hiatus during the Lower Bashkirian (Namurian B–C) in the Western Carpathians (Vozárová 1996).

Noric Bosnian (NBZ)/Carnic-Dinaric Zone (CDZ)

(Flügel 1990) first summarized the entire domain, which represents the carbonate dominated Devonian–Early Carboniferous passive continental margin of the *Noric Composite Terrane* (Frisch & Neubauer 1989 = *Noric-Bosnian Terrane* Neubauer & Handler 2000), as the Noric Bosnian Zone. Characteristically, it includes parts of the Eastern and eastern Southern Alps which have strong affinties to the Bükk, Jadar Block, and Central Bosnian Terranes. According to Vai (1994, 1998) significant differences in the Permian distinguish the Eastern Alps with the "Noric" evolution in contrast to the "Carnic-Dinaridic" evolution in the other domains.

It is not known, whether all these domains formed a connected facies realm/terrane or if they were part of individual terranes of similar type (e.g. European Hunic Terranes Stampfli 2000; v. Raumer et al. 2003) which were separated by the opening of the Paleotethys from the Peri-Gondwana margin. Anyhow, sedimentation during the drift stage of the terranes until the Early Carboniferous was dominated by predominantly carbonate pelagic and platform environments sometimes interfingering with monotonous clastic sequences at the outer passive margins (Quartzphyllite zones). Carbonate platform environments were extinguished within Frasnian times and were replaced by an uniform pelagic and basinal facies with flaser (nodular) limestones, shales and lydites (Vai 1998). Local stratigraphic gaps between the Late Devonian and the Viséan resulted from erosion/karstification and synsedimentary block movements (Ebner 1991a; Schönlaub & Histon 2000). Acidic to intermediate volcanics are significant for the Devonian/Early Carboniferous of the Central Bosnian Terranes (Karamata et al. 1997; Hrvatović 2006). Significantly overall the pelagic limestones were followed during the late Early Carboniferous, except for the Central Bosnian Terrane, by siliciclastic turbiditic sediments which were interpreted either as syn-orogenic flysch or anorogenic sliciclastic sediments on stable margins (Ebner 1991b; Ebner et al. 2006).

Carpatho-Balkanic Intracontinental Rift Zone (CBRZ)

The CBRZ in the Carpatho-Balkanides and Eastern Carpathians (described as Intercontinenal rifting zones of Rheno Hercynian type in the CPR map Ebner et al. 2004, http//www.geologicacarpathica.sk) evolved above a pre-Variscan metamorphic basement (Kräutner 1997; Karamata et al. 1997). Lower Devonian siliciclastic deposits are followed by marine psammito-pelitic sediments, intercalated with rift related bimodal volcanics, until the Late Devonian/Early Carboniferous. These sequences are overlain by thick shallow water carbonate sediments, that predate the onset of clastic flysch type siliciclastics during the Viséan. These rift basins of similar character were affiliated to individual Variscan terranes. However, the *Rodna Terrane* in the Eastern Carpathians and the *Ideg Terrane* in the South Carpathians could have been connected before Alpine dispersion (Kräutner 1997). It is suggested that this Rodna Rift was separated from the South Carpathian rift basins in Supragetic position (*Poiana Rusca Terrane, Locva-Ranovac-Vlasina Terrane*) by a submerged continental ridge of Carpian metamorphics (*Bistrita Terrane*). The two Carpatho Balkanic rift sequences of the Supra Getic Unit, (*Poiana Rusca Terrane* and *Locva-Ranovac-Vlasina Terrane),* were possibly also separated from each other during the Middle Paleozoic by an other submerged ridge (Bocsa Nappe). In the Serbian literature the *Locva-Ranovac-Vlasina Terrane* has an alternative interpreation as a back arc environment (Krstić et al. 2005a; Karamata 2006).

Inovo zone (IZ)

In the Devonian–Early Carboniferous map of the CPR (Ebner et al. 2004a, http//www.geologicacarpathica.sk) all non to low grade metamorphosed Devonian to Lower Carboniferous siliciclastic units were summarized by one colour and further differentiated into flysch type and non flysch type depositional enviroments. We distance ourselves from this concept in this paper because:

(1) We affiliated the siliciclastics of the South Gemeric zone to arc related and oceanic domains.

(2) There are no autochthonous Devonian sediments in the Drina-Ivanjica Terrane and the oldest Carboniferous (Tournaisian) pelitic-lyditic-carbonate sediments are there of pelagic pre-flysch type Filipović & Sikošek (1999).

Flügel (1990) affiliated the two environments mentioned above beside some Western Mediterranean Paleozoics into the Betic Serbian Zone which represents an area with long lasting Paleozoic (Silurian–Bashkirian) clastic deep water facies on stable continental margins with remnants of deep sea fan complexes.

Devonian clastic deep water sediments of this character are found in the Carpatho-Balkanides in the *Kučaj* and *Inovo Terrane* where the predominantly sililciclastic sediments turned to syn-orogenic flysch type sediments during the Late Devonian/Carboniferous (Krstić et al. 1999, 2004, 2005a). However, it is suggested that the *Kučaj* and *Inovo Terrane* had separate depocentres as constrained by paleomagnetic data (Milićević 1996). In the Carpatho-Balkanides the Middle Devonian facies pattern of the individual Variscan terranes of the Bucovino-Getic is complex (Fig. 7). Besides continental dry lands (Serbian Macedonian Massif and Kraishte units) continental slope environments which are dominated by fine siliciclastic sediments are related to Carpatho-Balkanic Rift Zones and stable continental margins of the IZ, occurring in the *Kučaj* and *Inovo Terranes*.

Variscan Flysch Zone (VFZ)

The formation of the VFZ began within the late Early Carboniferous. This zone was established on top of parts of the NBZ/CDZ (Eastern and eastern Carnic Alps) and the CBRZ. The only exception is the *Kučaj Terrane* where syn-orogenic flysch was already deposited during the Late Devonian (Ebner 1991b; Krstić et al. 2005a; Ebner et al. 2006).

The formation of Viséan–Bashkirian syn-orgenic flysch (Fig. 8) in the Eastern and eastern Southern Alps is due to the flexuring down of the NW-parts of the *Noric Composite* and related *Terranes* and N-directed A-subduction just before their accretion to the already consolidated MCZ to the Laurussian continental margin (Neubauer & Handler 2000; Schönlaub & Histon 2000). Closing of the flysch basins by deformation, sometimes low grade metamorphism, and an unconformable superposition by molasse sediments was the result of this Intra-Late Carboniferous (Serpukhovian–Moscovian) collision in the Alpine to Carpathian segment. With the sole exception of the marine/terrestrial Auernig Fm of the Carnic Alps the molasse is continental (Vozárová et al. 2006). Olistoliths are mainly derived from the pre-orogenic passive continental margin of the *Noric Composite Terrane*. The flysch of the Turna Unit is suggested to have formed in a similar position (Ebner et al. 1990; Vozárová & Vozár 1992). The syn-orogenic flysch environments of the Eastern Carpathians and the Carpatho-Balkanides were formed in a similar geodynamic environment before the Intra-Carboniferous amalgamation of the Carpatho-Balkanic Variscan terranes to the E-European and Proto-Moesian plate. Overall the post-orogenic molasse is of continental type (Kräutner 1997; Karamata et al. 1997; Ebner et al. 2006; Vozárová et al. 2006). To the W the VFZ may extend to the W-Mediterranean areas (Engel 1984; Ebner 1991b). Blocks of Early Carboniferous fossiliferous shallow water limestones in the VFZ of the Mt Noire and Carnic Alps indicate a paleogeographic relation of the flysch basin with VNSOZ-type domains on the Laurussian margin (Engel 1984; Ebner 1991b; Flügel & Schönlaub 1991). Syn-orogenic flysch of the VFZ may be followed to the east along the Laurussian magin as far as to the N-Dobrogea, Caucasian Main- and Forerange zone and the Scythian Platform (Ebner 1991b).

Bükk-Jadar Zone (BJZ)

The impact of the Intra-Late Carboniferous collision diminished in a southeasterly direction from the Eastern

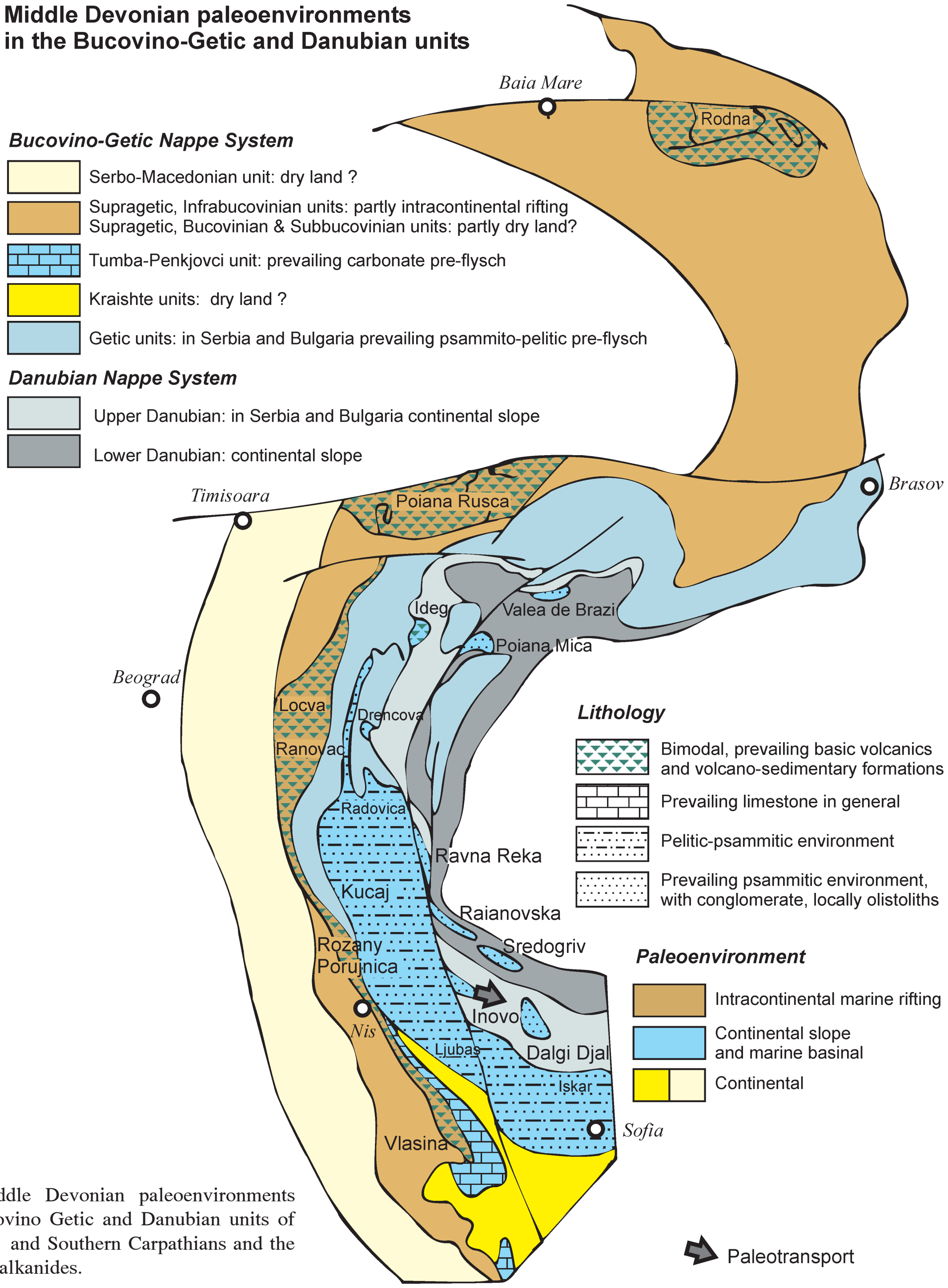

Fig. 7. Middle Devonian paleoenvironments in the Bucovino Getic and Danubian units of the Eastern and Southern Carpathians and the Carpatho-Balkanides.

Alps and eastern Southern Alps and seems to be missing in the Bükk, Sana Una and Jadar Block Terranes or to be only weak in the Drina-Ivnajica or problematic in the East Bosnian Durmitor and Central Bosnian Terranes. At least the Bükk, Sana Una and Jadar Block Terranes may be situated during the Carboniferous on the back side of the drifting *Noric Bosnian* and related *terranes* and close to the Paleotethys ocean (Fig. 8). These parts (summarized as the BJZ) represent subsiding but still passive continental margins. First the sedimentation became turbiditic and olistostromatic but significantly the sequences were not subsequently deformed. This anorogenic turbiditic facies was terminated during the Bashkirian by stratigraphic gaps and a turn to characteristic marine shallow water sediments. Major tectonic deformation, unconformities and metamorphic overprint are totally missing (Ebner 1991b; Ebner et al. 2006; Vozárová et al. 2006).

Remarkable, but in their consequences already unknown, are the affinities of the Bükk Terrane, situated at the ?northwesternmost part of the BJZ, to the Rannach

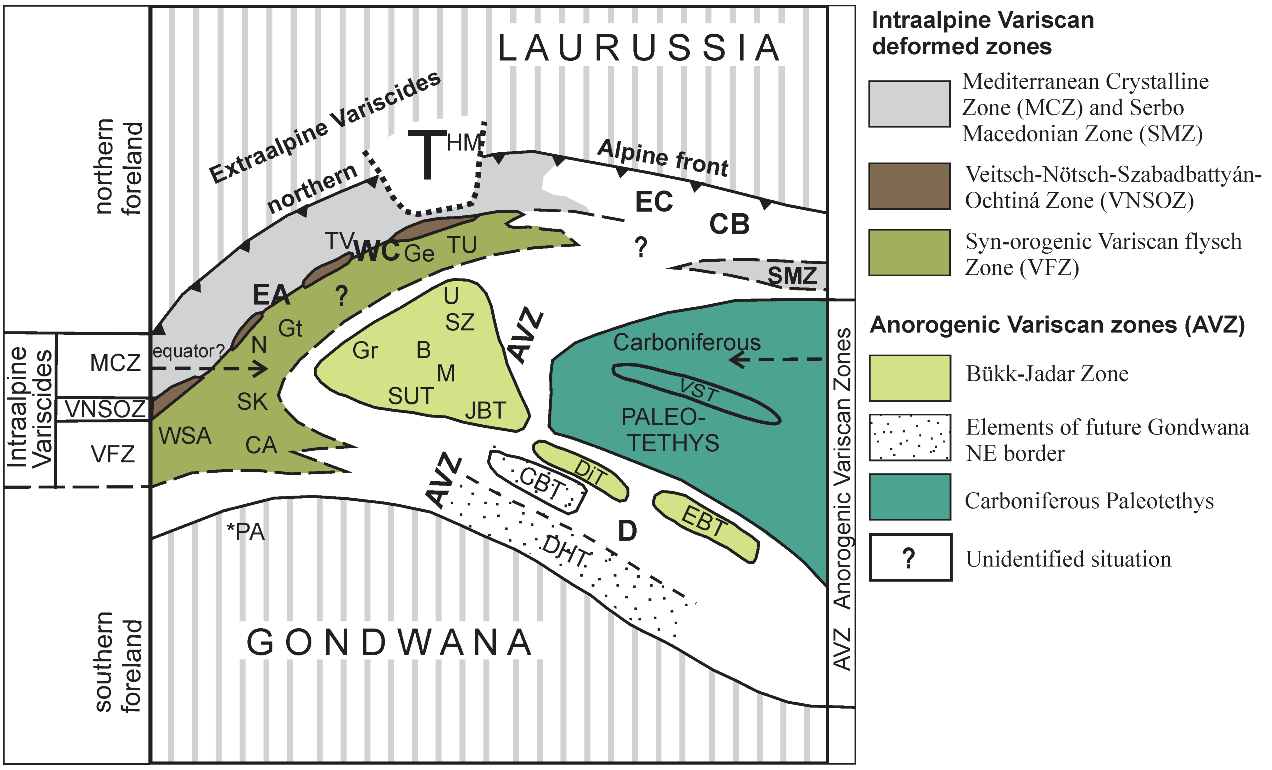

Fig. 8. Cartoon of the Viséan/Serpukhovian paleogeographic restoration and Variscan orogenic zoning in the Circum Pannonian Region (based on Ebner et al. 1991, 1998, 2006, 2007 and Karamata 2006). The correlation to and the situation in the Eastern Carpathians and the Carpatho-Balkanides is not clear. Size, boundaries and positions of the units are strongly schematized and not in scale. The position of the equator is only tentative. **Intraalpine Variscan deformed zones:** — 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. — Syn-orogenic siliciclastic flysch sediments of the Variscan flysch zone (VFZ): deformed during the (?)Late Viséan until Intra-Late Carboniferous orogeny. **Anorogenic Variscan zones (AVZ):** — 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 remained 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 — Medvednica Mts, N — Noric Nappe (Graywacke Zone), T — segment of later Tisia Megaterrane, Tu — Turna Unit, TV — Tatro-Veporic Units, SK — South Karawanken Mt, 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.

nappe of the Graz Paleozoic. In the latter Carboniferous carbonate sedimentation lasted until the Bashkirian and an orogenic impact is not known during this time (Ebner 1976; Ebner et al. 1991, 1998, 2000, 2006). Another enigma is the occurrence of marine Permian and other "Southalpine" Triassic clasts in Upper Cretaceous "Gosau"-conglomerates covering the Graz Paleozoic. These pebbles are absolute exotic for the Eastern Alps and can be considered for a primary position of parts of the Graz Paleozoic close to domains with a marine Permomesozoic cover of South Alpine/Dinaric type (Flügel 1980; Ebner et al. 1991; Ebner & Rantitsch 2000).

In respect to their Late Devonian/Carboniferous evolution the Bükk, Sana Una and Jadar Block terranes were primarily situated close together. During the Alpine opening of oceanic tracts and late orogenic Late Cretaceous–Tertiary strike slip movements, they became separated from each others and displaced as terranes to their present positions (Protić et al. 2000; Filipović et al. 2003). Taking into account the sedimentary facies, orogenic zonation and paleomagnetic data the Eastern Alps and eastern Southern Alps should have a closer but more western position to the Laurussian Early Carboniferous collision zone (Fig. 8). The sedimentation of Bellerophon type limestones in the Late Permian was another characteritic feature pointing to the paleogeographic realtionships within the JBZ as well as to the Carnic Alps (Pešić et al. 1988; Filipović et al. 2003). Further to the SE the turbiditic sequences of BJZ-type may extend as far as to Chios, Karburun and the Pontides (Ebner 1991b).

• Orogenic events

During the past the Variscan orogenic events in the CPR were affiliated to the "classical" Variscan tectonic phases (Bretonic, Sudetic, Asturian) established for other parts of the Central European Variscan belt. Knowing the problems by doing this, Vai (1975) established the Carnic phase between the Late Serpukhovian and Early Moscovian as the major orogenic phase for the Carnic Alps. Due to the poor stratigraphic constraints, the problematic use of tectonic phases defined for other paleogeographic domains and the geodynamically diverse positions of the orogenic zones, we distinguish the following tectonic events and domains in the CPR (Ebner et al. 2006):

(1) Accretion of terranes to the Laurussian margin accompanied by a predominantly medium grade metamorphism during an (Late Devonian-) Early Carboniferous orogeny. These metamorphic terranes are presently part of the Mediterranean Crystalline Zone. Post-orogenic marine sedimentation in respect to this event started within the late Early Carboniferous and is represented in the Veitsch-Nötsch-Szabadbattyan-Ochtiná Zone.

(2) A Mid- to Intra-Late Carboniferous (Serpukhovian/Bashkirian) collisional event occurred at the end of the syn-orogenic flysch stage in the Eastern Alps, the eastern Southern Alps, the Western and Eastern Carpathians and the Carpatho-Balkanides. During this event the *Noric Composite* and related *terranes* collided with parts of the Mediterranean Crystalline Zone of the Laurussian margin. The Variscan terranes of the Carpatho-Balkanic segment collided with each other and/or Proto-Moesia. post-orogenic marine and continental molasse began within the eastern Southern Alps within the Late Moscovian. The onset of continental molasse in the other domains of the CPR-Variscan belt began during the Kasimovian-Ghzelian.

(3) The Carboniferous sequences of the Bükk, Sana Una und Jadar Block Terranes are characterized by turbididitic and olistostromatic siliciclastics without any Variscan deformation. Possibly they were also part of the before mentioned colliding terranes but with a position on the anorogenic "back side" of the terranes closer to the Paleotethys. Therefore no distinct Variscan deformation or metamorphism was detected. The change of the "Variscan to the post-Variscan stage" is marked by shallowing upwards trends, stratigraphic hiati (Late Bashkirian–Early Moscovian) and the sedimentological change of turbiditic siliciclastic sediments to carbonate shallow water sediments, only.

(4) The Veles Series Terrane was not affected by Carboniferous deformation/metamorphism. It remained as an inherited island arc element in the Mesozoic Vardar ocean until its inclusion into the Main Vardar Ophiolite Zone during the Late Jurassic (Karamata 2006). For another interpretation see Schmid et al. (2007 in print).

(5) The Intra-Carboniferous tectonic evolution of the Central Bosnian, East Bosnian Durmitor and Drina-Ivanjica Terranes which were later included in the NE borderzone of Gondwana SW of the Paleotethys is not documented in a sufficient way. The Variscan impact seems to be partly missing or of very weak intensity (Karamata 2006).

(6) Persisting Gondwana–Laurussia convergence during the Late Carboniferous–Early Permian after the climax of the Variscan orogeny gave rise to the exhumation of the Variscan belt, which was dissected by far ranging strike slip faults (the global Pangean transform zone Smith & Livermore 1991). These processes were related to the indentation of Gondwana derived elements in sectors of the Variscan belt ("Paleo-Alpine" indenter; Neubauer & Handler 2000) and may be responsible for some Permian tectonic events occurring in parts of the CPR (Vozárová et al. 2006).

• Origin of terranes

Elements of the Variscan CPR terrane collage derived from the Mid-Paleozoic oceanic domains between Laurussia and Gondwana and from the northern margin of Gondwana (v. Raumer 1998; Neubauer 2002). During the Late Silurian a group of terranes (Gotic Terranes Golonka et al. 2006 cum lit., European Hunic Terranes Stampfli 2000; v. Raumer et al. 2003) was separated by the opening of the Paleotethys from the Peri-Gondwana margin. The accretion of these terranes to the active Laurussian margin during the Devonian/Early Carboniferous marks the onset of the Variscan orgeny followed by a final intra Late Carboniferous continent/continent collision due to the continuous N-drift of Gondwana (Matte 1986, 1991; Frisch & Neubauer 1989; Franke et al. 1995; Stampfli 1996; Neubauer 2002; v. Raumer et al. 2003). Another model (Vai 1991, 1998) suggests a relatively stable epicontinental sea during the Early Paleozoic which was later disturbed by oblique dextral rift perturbation for the CPR. Thus the *Carnic-Dinaric Plate* was separated from Gondwana during the Mid-Paleozoic and during the Early Carboniferous by the opening of a new branch of the Paleotethys from the Uralian/Kazakhstan Plate. The dextral displacement finally resulted in the collision of the *Carnic-Dinaric Plate* with central Europe.

However, the positions of the individual terranes during the Variscan evolution is quite speculative. The scarce paleomagnetic data, suggesting some paleogeographic positions of the individual terranes, are summarized in Table 2.

The Eastern Alps and Carnic Alps, have a quite diverse biofacies. Therfore Vai (1991, 1998) affiliated the Eastern Alps to the Bohemian and the Carnic Alps to the Uralian biofacies. However, this contrast is weakened by the consideration of fauna exchange and paleo-oceanic currents Schönlaub (1993). This and the strongly scattering picture of the Paleozoic paleomagnetic data (Table 2) suggest that these areas were not assembled in one single terrane (*Noric Terrane*, v. Raumer & Neubauer 1993) but rather in a group of terranes with similar sedimentary character (part of the *European Hunic Terranes*, Stampfli 2000; v. Raumer et al. 2003).

The Carpatho-Balkanic terranes with intracontinental rift environments (*Rodna Terrane, Poiana Rusca Terrane, Locva-Ranovac-Vlasina Terrane)* may derive from rifting systems primarily situated on the southern continuation of Variscan Europe, now involved in the Alpine orogen. These rift systems were separated by more or less emerged continental rises (*Bistrita Terrane*, Bocsa Nappe). North of the Alpine front, such types of Variscan structures including rifting zones may be recognised in the sequence of the Rheno-Hercynian and Saxo-Thuringian zones separated by the "Mitteldeutsche Schwelle".

The Carpatho-Balkanic terranes which docked during the Carboniferous to the Moesian Plate derived from oceanic domains situated during the Early Paleozoic beween Gondwana and the continental masses that later became Eurasia in the north. Some relics of oceanic crust along the boundaries of the Variscan terranes are most probably parts of Cadomian oceanic crust, typical for pre-Variscan terranes in the Carpatho-Balkanides (Haydoutov et al. 2004). The primary position of the individual terranes was far from each others. In summary the terranes were transported during the Paleozoic until the Late Carboniferous from up to 30–40 °S to a near equatorial position (Karamata 2006). The *Kucai/Ranovac Terranes* had a palaeolatitude of 5 °N and a Laurasian position due to Eurasian flora after the Variscan collision during the Moscovian/Kasimovian (Pantić & Dulić 1991; Milićević1996; Karamata 2006). Some paleogeographycally fixed positions of the individual terrane wanderpaths are outlined in Table 2.

The history of the terranes SW of the Carboniferous Paleotethys which were later included in the Gondwana NE margin is not well constrained. It is suggested that all units derived rather from different parts and not from one Paleozoic superunit (Karamata & Vujonović 2000). First the Central Bosnian Terrane docked to the Dinaride Block during ?Early Carboniferous–Middle Permian (Karamata et al. 1997; Karamata 2006). This is followed by the East Bosnian Durmitor and Drina-Ivanjica Terranes, but with uncertain age. During the Carboniferous the Sana Una Terrane was still connected with the Jadar Block Terrane and closely associated with the later NE margin of Gondwana as indicated by a latitude of 4 °S and Gondwana type flora (Pantić & Dulić 1991).

• Post Variscan (Pennsylvanian) configuration

After the peak of Variscan deformation and metamorphism the CPR (Fig. 8) was part of Pangea and located in the north and west of the eastward opening bay of the still open parts of the Paleotethys. Moesia, Rhodopes, the pre-Mesozoic units of Alcapa and Tisia were sutured in the N to the Laurasian arm of Pangea whereas Adria and adjacent terranes in the W were situated close to Gondwana (Flügel 1990; Vai 1998; Karamata et al. 2003; Karamata 2006; Golonka et al. 2006). Karamata (2006: Fig. 6) locates the Central Bosnian, East Bosnian Durmitor and Drina-Ivanjica Terranes on the SW margin of the Paleotethys close to Adria. The Sana Una, Jadar Block and Bükk Terranes are still connected with each others and located in a much more western position of the end of the Paleotethys. However, the termination of the Paleotethys at this time is still an open question. The collision zone of the *Noric Composite Terrane* to the central European margin (Southern and Eastern Alps) was clearly located further to the west. The northern part of the present day Tisia-Megaterrane was part of the European Helvetic-Moldanubian zone (Kloetzi et al. 2004), whereas the southern part of Tisia (Slavonia) has affinities to the West Carpathian Tatro-Veporic Crystalline (Buda et al. 2004). The existence of Variscan medium grade and granitoid zones in the S Pannonian domain (Tisia-Megaterrane) and the most remarkable feature that the modern Western Carpathians and Tisia are separated by non-metamorphic areas of Dinaridic origin are due to major Tertiary terrane movements (Csontos et al. 1992). The feature of the terrane concept in the pre-Neogene basement of the Pannonian Basin is, that, separated by the Mid-Hungarian or Zagreb-Zemplín Line, the Zagorje-Bükk Zone on the north is related to the southerly Carnic-Dinaridic Zone, whereas on the south the Mórágy Complex in the basement of the Alpine Mecsek Zone, is related to the northerly Moldanubian Zone. So, here is a textbook example of "displaced terranes"!

Paleomagnetic data indicating the geographical positions of the Variscan collision zone are scarce (Table 2). Nevertheless, during Moscovian–Kasimovian the Jadar Block Terrane had a latitude of 4 °S on the Gondwana side of Paleotethys and parts of the E-Serbian Carpatho-Balkanides with a paleo-latitude of 5 °N were situated on the Laurussian margin of the Paleotethys (Pantić & Dulić 1991; Milićević 1996). The Inner Carpathian parts had a nearly equatorial position during Late Carboniferous (Krs et al. 1996).

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TECTONOSTRATIGRAPHIC TERRANE AND PALEOENVIRONMENT MAPS OF THE CIRCUM - PANNONIAN REGION

Variscan Preflysch (Devonian-Early Carboniferous) Environments

1 : 2 500 000

0 25 50 75 100 125 km

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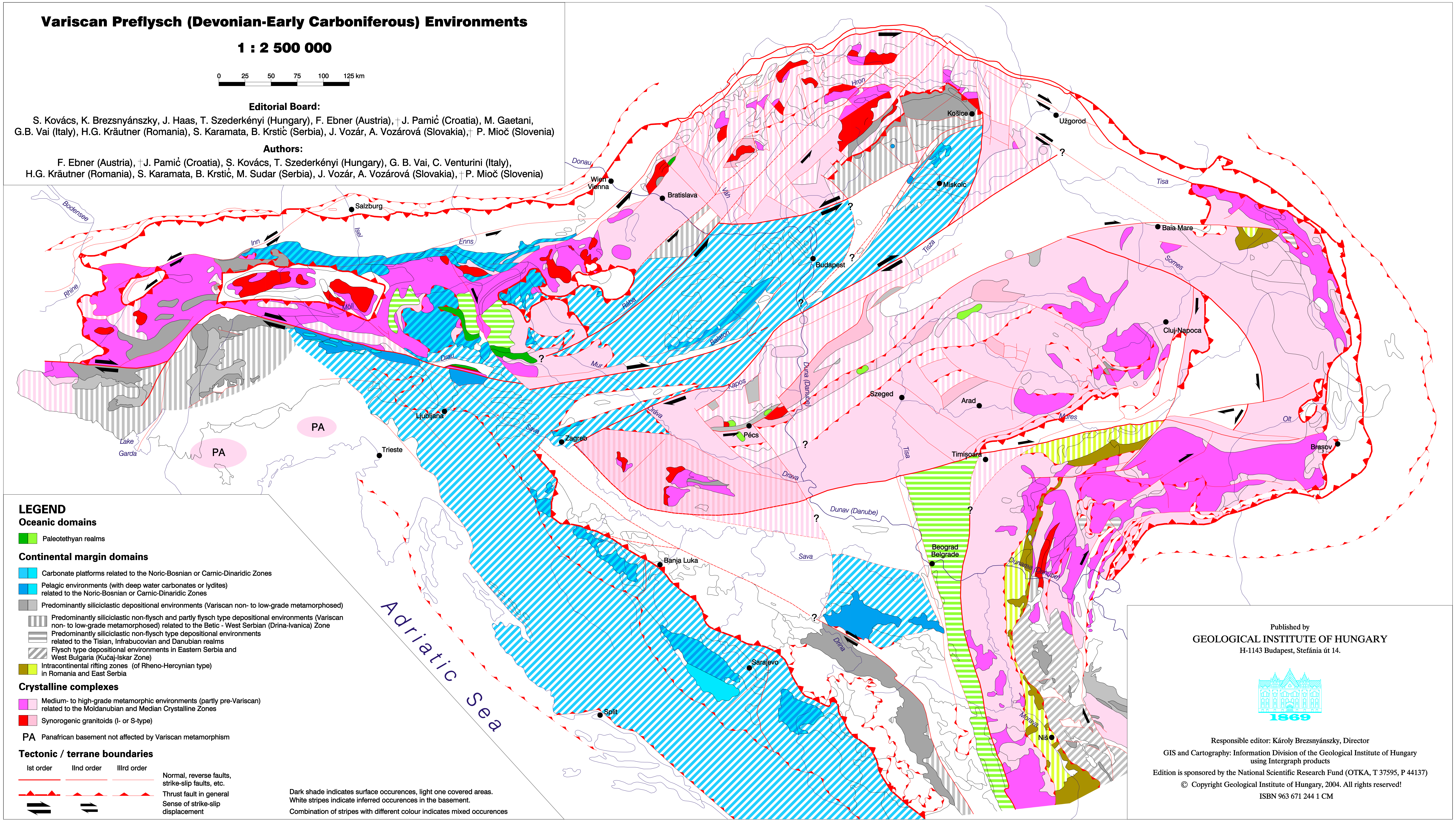

LEGEND

Oceanic domains

Paleotethyan realms

Continental margin domains

Carbonate platforms related to the Noric-Bosnian or Carnic-Dinaridic Zones

Pelagic environments (with deep water carbonates or lydites) related to the Noric-Bosnian or Carnic-Dinaridic Zones

Predominantly siliciclastic depositional environments (Variscan non- to low-grade metamorphosed)

Predominantly siliciclastic non-flysch and partly flysch type depositional environments (Variscan non- to low-grade metamorphosed) related to the Betic - West Serbian (Drina-Ivanica) Zone

Predominantly siliciclastic non-flysch type depositional environments related to the Tisian, Infrabucovian and Danubian realms

Flysch type depositional environments in Eastern Serbia and West Bulgaria (Kučaj-Iskar Zone)

Intracontinental rifting zones (of Rheno-Hercynian type) in Romania and East Serbia

Crystalline complexes

Medium- to high-grade metamorphic environments (partly pre-Variscan) related to the Moldanubian and Median Crystalline Zones

Synorogenic granitoids (I- or S-type)

PA Panafrican basement not affected by Variscan metamorphism

Tectonic / terrane boundaries

Ist order	IInd order	IIIrd order	
			Normal, reverse faults, strike-slip faults, etc.
			Thrust fault in general
			Sense of strike-slip displacement

Dark shade indicates surface occurences, light one covered areas.
White stripes indicate inferred occurences in the basement.

Combination of stripes with different colour indicates mixed occurences

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