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PALAEOZOIC ROCK ASSEMBLAGES INCORPORATED IN THE SOUTH CARPATHIAN ALPINE THRUST BELT (ROMANIA AND SERBIA): A REVIEW

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(5 figures)

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ABSTRACT. The Alpine fold and thrust belt of the South Carpathians overrides the Moesian platform to southeast and the Serbo-Macedonian and Vardar ophiolitic palaeosuture to northwest. The pre-Triassic basement of the South Carpathians is preserved in the Getic/Supragetic and Upper Danubian/Lower Danubian basement/cover nappe systems and is represented by: a, Late Carboniferous-Permian sedimentary deposits and related magmatites; b, pre-Westphalian metamorphic-magmatic suites of Palaeozoic and Neoproterozoic age. Palaeozoic sedimentary and volcano-sedimentary lithological assemblages, palaeontologically dated, are of ?Cambrian-Ordovician-Silurian and Late Devonian-Early Carboniferous ages. The Early Palaeozoic rock-sequences preserved in the Danubian basement are discontinuous covers of the Pan-African terranes or rift-related, allochtonous low-grade successions associated to an inverted ophiolitic-sedimentary-tectonic palaeosuture marking a plate/microplate boundary. The Early Palaeozoic successions in the Getic-Supragetic basement are mainly allochtonous volcano-sedimentary rocks associated with basic and bimodal magmatic rocks marking a back-arc basin and an intracontinental rift, separating Neoproterozoic ± Early Palaeozoic gneissic terranes. Unconformable Late Devonian-Early Carboniferous successions consist of continental-shallow marine, clastic and/or carbonate-dolomite piles (Danubian and westernmost Supragetic) but some volcano-sedimentary grading to coarse-grained clastic successions are also present (Getic basement). Late Carboniferous-Permian, clastic, sometimes coal bearing, continental deposits crop out in both Getic-Supragetic and Danubian basements while volcano-sedimentary successions, associated with acid or bimodal volcanic rocks, crop out mainly in the Danubian units. In contrast with the unmetamorphosed Palaeozoic cover of the Moesian Platform, the Variscan regional prograde metamorphism of the Carpathian Palaeozoic rock sequences ranges from anchizone to greenschist and epidote-amphibolite facies. Early Palaeozoic deformation and metamorphic evolution of the Danubian basement is different in the external and internal domains, suggesting different geotectonic environments before the deposition of ?Late Ordovician-early Silurian formations, and, possible Avalonian-Moravian affinities. Polystage Variscan tectono-metamorphic events are documented for the Getic-Supragetic basement and show Armorican-Bohemian affinities. Both, Danubian and Getic-Supragetic Domains inherited Gondwana derived gneissic-granitic terranes whose Palaeozoic evolution is diversified. The Pan-African gneissic-granitic suites of the External Danubian Domain are slightly involved in Variscan deformation and metamorphism. Different by this, the Neoproterozoic basement of the internal Danubian and Getic-Supragetic Domains were reactivated and rejuvenated in Palaeozoic time, the rifting/dismembering of northern Gondwana being followed by convergence to collision in the Variscan cycle.

KEYWORDS: South Carpathians, Palaeozoic, lithostratigraphy, structure, Variscan, Pan-African, Avalonian

1. Introduction

Neoproterozoic and Palaeozoic sedimentary and magmatic rock assemblages, as well as their metamorphosed equivalents, involved in the Late Carboniferous collision of Laurussia and Gondwana, participated at the building of Phanerozoic Europe by amalgamation of successive Caledonian, Variscan and Alpine orogenic belts (e.g.: Rey *et al*., 1997; Brueckner & Medaris, 1998; Matte, 2001). The reconstruction of the Palaeozoic history and terrane affiliation of the Carpathian area requires a recognition of the inherited pre-Palaeozoic basements, now documented as Pan-African or Cadomian, Gondwana derived, inside of the Variscan belt (Clifford, 1970; Dewey & Burke, 1973; Neugebauer, 1989; Maluski *et al*., 1995; Matte, 2001; Linneman *et al*., 2004) but also in the junction areas of Caledonian foreland and the northern Variscan front (Matte *et al*., 1990; Franke, 2001; Winchester *et al*., 2002).

The Avalonia - Moesia symposium held in Ghent, Belgium, in October 2004, highlighted aspects of the geological evolution of the Phanerozoic Europe in Neoproterozoic and Palaeozoic time, and problems related to the extent and correlation of the pre-Palaeozoic Gondwana and separated microplates, as Avalonia, Armorica and Cadomia (Neugebauer, 1989; Brun *et al*., 2001), lately amalgamated at different times and palaeogeographic position to Baltica-Laurentia or to African Gondwana (Winchester *et al*., 2002 and Winchester *et al*., this volume).

On the Romanian territory, parts of Phanerozoic microplates and orogenic crustal fragments are now incorporated inside of the Alpine Carpathian fold and thrust belt (Săndulescu, 1994; Balintoni, 1997; Neubauer, 2002; Iancu *et al*., in press), while the Carpathian-Balkan foreland includes some Phanerozoic microplates (as e.g. Moesian Platform; Săndulescu, 1994; Haydutov & Yanev, 1997) amalgamated at the East European Plate margin (Pharaoh *et al*., this volume).

Exotic high-grade terranes of Variscan affinities (Ledru *et al*., 1997; Iancu *et al*., 1998; Medaris *et al*., 2003) are incorporated in the pre-Mesozoic basement of the uppermost Cretaceous nappe complex (Getic-Supragetic) of the South Carpathians, while parts of Neoproterozoic Pan-African terranes are preserved in the pre-Palaeozoic basement of the Danubian units (Berza *et al*., 1994; Liégeois *et al*., 1996).

The aim of this paper is to present the dated Palaeozoic low-grade formations in both Danubian and Getic-Supragetic Domains, their geotectonic significance, as well as their relationships with pre-Silurian gneissic basement units (Berza *et al*., 1994; Iancu *et al*., 1998; Medaris *et al*., 2003), as a contribution to the international effort of palinspastic reconstruction of Europe in the last one billion years.

2. Alpine framework

The Alpine fold and thrust belt of the South Carpathians extends E-W from the East Carpathians bend zone to the opposite bend which connects them to the Balkans (Fig. 1). The South Carpathians override the Moesian platform to southeast along the Peri-Carpathian Fault. To the northwest they override the Vardar-Transilvanides ophiolitic palaeosuture together with orogenic units of the Apuseni Mountains derived from the mobile part of Apulian microplate. The bilateral, fan-like shape of the nappe stacks in the South Carpathians is the result of polystage contraction generating crustal thickening in Middle toLate Cretaceous time. The Mesozoic sedimentary, volcano-sedimentary formations and related magmatic rocks are involved in the Cretaceous nappe piles together with pre-Mesozoic terranes incorporated in basement units. Cenozoic sediments seal the fold and thrust belt related structures, filling extensional sedimentary basins in internal areas and sealing also the intra-Sarmatian contact with the Moesian Platform.

The main nappe complexes defined in the Cretaceous contraction stages include, from bottom to top (Fig. 1, inset: the Danubian, Severin and Getic-Supragetic (Iancu *et al.*, in press). Except for the Severin nappe complex, composed of Mesozoic ophiolites and sedimentary rocks, the other units consist of pre-Mesozoic metamorphic-magmatic basement and discontinuous Upper Carboniferous-Permian continental deposits unconformably overlain by Mesozoic sedimentary successions. The basement nappes derived from two distinct microplates in the Late Jurassic-Early Cretaceous time span, i.e. the Getic and the Danubian domains (Săndulescu, 1994; Balintoni, 1997; Iancu *et al.*, in press), their relationships during the Permian being not known.

The constitution of the incorporated pre-Westphalian (Proterozoic and Palaeozoic) basement of the two mentioned microplates reflects their evolution in different geotectonic environments.

3. Palaeozoic-Proterozoic tectono-stratigraphic units in the South Carpathian basement

The pre-Mesozoic basement of the South Carpathians includes Palaeozoic and Neoproterozoic metamorphic terranes, preserved in the Alpine Danubian and Getic-Supragetic Nappes. These nappes have been emplaced during two contraction stages related to convergence-collision events, in the Middle-Late Cretaceous time.

While Neoproterozoic relics are well documented only in the Danubian basement, important differences in the lithostratigraphic characteristics of the Palaeozoic rock sequences, reflecting different geotectonic environments and tectono-metamorphic history can be observed between Danubian and Getic-Supragetic basements.

A simplified geological map of the pre-Mesozoic basement and cover units of the South Carpathians is presented in Fig. 2. This synthesis of the South Carpathians is focused on pre-alpine tectono-stratigraphic units involving Palaeozoic and Proterozoic rock assemblages as they are separated by authors, based on regional and detailed mapping following discriminate petrological criteria and structural analyses. Simplified maps were published in Romanian journals (Iancu & Mărunțiu, 1994a, b; Berza & Iancu, 1994; Iancu, 1998) and some local maps separating pre-alpine tectonic units were used, as e.g.: Balintoni & Iancu (1986); Stelea (1992); Dinică (1989). A huge amount of lithological-petrological data exist in the geological maps 1: 50 000 scale of the Geological Institute of Romania and in published

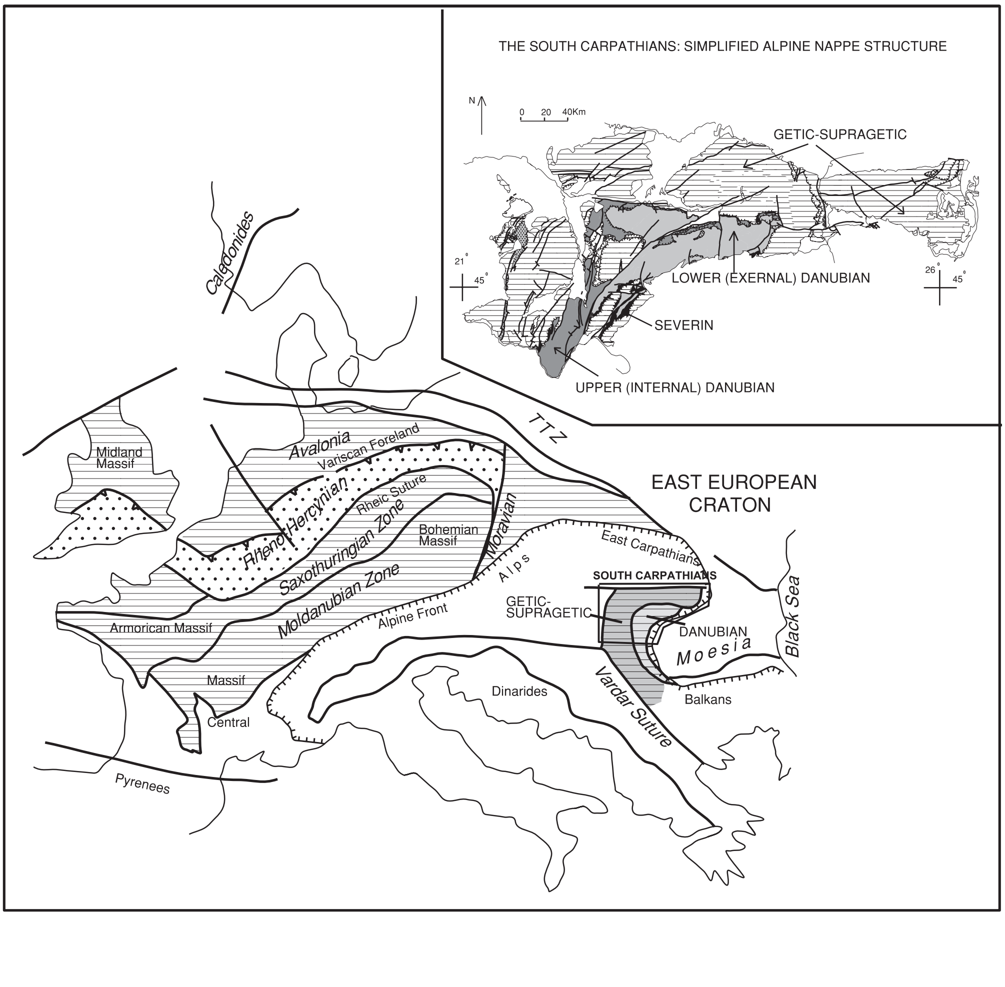


Figure 1. Relative position of the Getic-Supragetic and Danubian pre-Mesozoic basement units incorporated in the Alpine orogenic belt and possible correlation with similar units from the classical Variscan-Armorican terranes and the Variscan foreland. Data compiled from Debelmas *et al.*, 1980; Matte, 2001; Winchester *et al.*, 2002 (from Herbosch & Verniers, 2002). Inset: The South Carpathians: simplified Alpine nappe structure.

papers (e.g. Savu *et al*., 1978; Kräutner *et al*., 1981; Năstăseanu *et al*., 1981; Gheuca & Dinică, 1986; Hann *et al*., 1988; Iancu *et al*., 1987; Gheuca, 1988; Balintoni *et al*., 1989; Berza *et al*., 1994 and related references).

The pre-Westphalian basement of the South Carpathians includes Neoproterozoic metamorphic assemblages, low-grade Palaeozoic (meta-) sedimentary sequences and mafic-ultramafic and granitoid magmatic complexes and bodies. The structural framework related to Palaeozoic and late Neoproterozoic (Variscan and pre-Variscan) tectonic units is represented within the main Alpine basement nappes of the Danubian and Getic-Supragetic Domains, and different signatures are used for Alpine and pre-Alpine tectonic boundaries. Also part of these data were introduced in compiled regional maps (e.g. Kräutner & Krstić, 2002), although there are major differences in our model of the South Carpathian structure and evolution.

3.1. Danubian basement

Late Neoproterozoic zircon U/Pb ages of magmatic protoliths in Danubian basement (Berza *et al*., 1994) polymetamorphic formations (Fig. 2) range between 780 to 570 Ma, indicating Pan-African timing (Liégeois *et al*., 1996; Duchesne *et al*., 1998), or Cadomian affinities (*sensu* Brun *et al*., 2001), inherited from this northernmost part of Gondwana. Contrasting geothermal gradients are characteristic for the Drăgşan (almandine-staurolite-kyanite-sillimanite) and Lainici-Păiuş (almandine-cordierite-andalusite-sillimanite) terranes (Berza *et al*., 1994; Iancu *et al*., 1990). The Pan-African tectono-metamorphic evolution is dated by K/Ar and Ar/Ar and monazite U/Pb data at 580-560 Ma (Grünenfelder *et al*., 1983, Dallmeyer *et al*., 1994). Apparent Ar/Ar hornblende ages of 596-591 Ma (diorite sample, external Danubian) dates magmatic cooling of late Neoproterozoic magmatic rocks, but hornblende and muscovite Ar/Ar ages in the 300-296 Ma range (Dallmeyer *et al*., 1998) document for Variscan (re-?) heating of the Pan-African basement, confirming also K/Ar ages of 600-500 Ma of migmatites and granitoid bodies (Grünenfelder *et al*., 1983).

Drăgşan and Lainici-Păiuş terranes are involved in Palaeozoic (Variscan) collisional-type structures in the Lower Danubian basement, where a Mid-Carboniferous thrusting of Drăgşan on Lainici-Păiuş terranes is well documented by stratigraphic relations (Berza *et al*., 1994; Berza & Iancu, 1994). In the Upper Danubian basement of the Southern Banat, a pre-Westphalian nappe stack and tectonic melange in the Almaj-Ţarcu Mountains includes also low-grade volcano-sedimentary and olistostrome sequences of Early Palaeozoic age (Iancu *et al*., 1990).

An important marker in the Danubian basement is the Tişovita - Iuţi ophiolitic complex (Mărunţiu *et al*., 1997) and related oceanic-type sediments, obducted and dismembered in the mentioned pre-Westphalian nappe stack north of the Danube Gorges (Southern Banat). Southwards, similar mafic-ultramafic cumulate slices outcrop in the Deli Jovan (Serbia) and Tcherni Vrah (Bulgaria) massifs of the "Thracian suture" (Haydutov, 1989; Haydutov & Yanev, 1997; Savov *et al*., 2001).

The zircon U/Pb 563±3 Ma age (von Quadt *et al*., 1998) of the gabbro from the Tcherni Vrah ophiolitic complex, suggests that the Thracian oceanic crust generation and rifting occurred in the latest Neoproterozoic time preceding the Early Palaeozoic (Cambrian-Ordovician) continental magmatic arc evolution.

Reactivated gneissic units (Drăgşan and Lainici-Păiuş) of pre-Silurian Pan-African basement are involved in collisional-type structures in the Southern Banat and the resulted nappe stack and tectonic melange from Almaj-Ţarcu Mountains includes also low-grade volcano-sedimentary and olistostrome sequences of Early Palaeozoic age (Iancu *et al*., 1990).

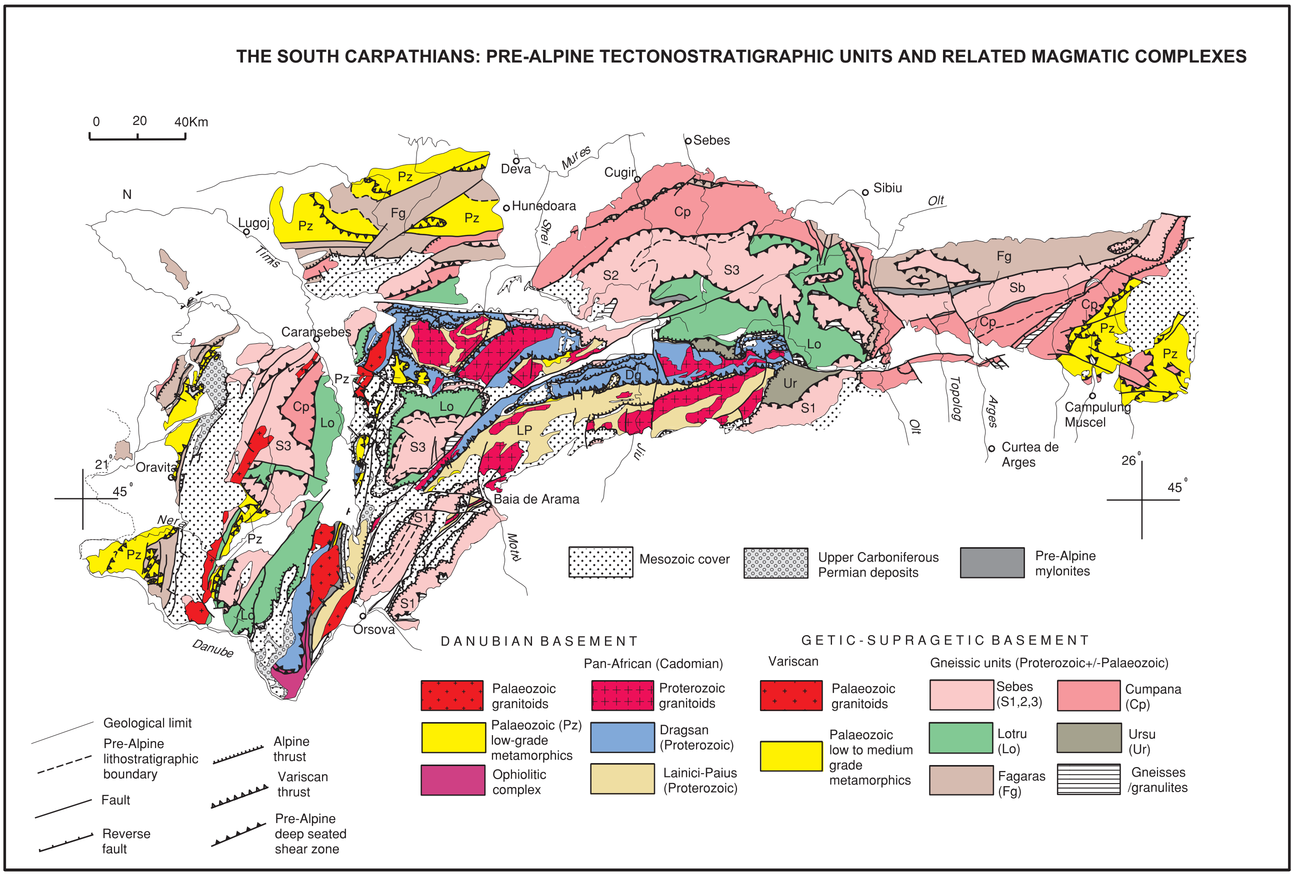


Figure 2. Palaeozoic and Proterozoic tectonostratigraphic units and related magmatic complexes. Geological-structural synthetic sketch.

Superposed continental arc granitoids (Sfârdinu and Cherbelezu), crosscutting the pre-Westphalian nappe pile, are well preserved north of Danube, on the Romanian bank. The LP-HT shear zone related metamorphism can be connected to the high thermal gradients of the magmatic arc (Iancu *et al*., 1997a), as the S-C'-C" structures marking major thrust faults are characterized by andalusite-cordierite-sillimanite progressive blastesis. Unconformable Upper Carboniferous-Permian sedimentary cover seals this nappe stack.

3.2. Getic-Supragetic basement

Neoproterozoic and/or Lower Palaeozoic protoliths in the Getic-Supragetic basement (Fig. 2) are represented by medium-high grade metamorphic terranes (Bercia, 1975; Savu *et al*., 1978; Hann *et al*., 1988; Gheuca, 1988; Gheuca & Dinică, 1986; Balintoni *et al*., 1989 and references herein; Iancu *et al*., 1998; Săbău & Massonne, 2003) involved in polystage Palaeozoic nappe stacks (Iancu & Mărunțiu, 1994a, b; Iancu *et al*., 1998). These "gneissic units" (Ledru *et al*., 1997) generally considered of Proterozoic age are poorly constrained as concerns protoliths ages and timing of regional metamorphic evolution. Significant participation of Precambrian components is suggested by εT_{DM} model ages of 1.92-2.06 Ga and εNd values of -10.5 to -14.5 from different gneisses (Pană, 1998).

So far, controversial Proterozoic protolith zircon U/Pb ages are reported only for the Cumpana-type orthogneisses (1.6 Ma, Pavelescu *et al*., 1983; Draguşanu & Tanaka, 1999), especially due to method and isochron interpretation.

Recent laser ablation $^{40}Ar/^{39}Ar$ analyses on magmatic biotite from coronitic metagranites (eastern part of the South Carpathians) gave 745 Ma age (Axente *et al*., in press). The tectonic melange, including tectonic blocks of the mentioned metagranites, exhumed eclogites, as well as Lower Palaeozoic (Ordovician) greenschists, is an important structural marker inside of a Variscan nappe pile inherited in the Getic-Supragetic basement (Iancu *et al*., 1998).

Also, preliminary zircon U/Pb isotopic data (Balintoni *et al*., 2004) announce an important contribution of Lower Palaeozoic crust (acid magmatic protoliths, including different Cumpana type gneisses) with inherited Palaeoproterozoic cores in the "gneissic" basement of the Getic-Supragetic units. This age array fits well with the Variscan Armorican Terrane Assemblage from Western Europe, of peri-Gondwanan origin (Winchester *et al*., this volume).

The mentioned data account for the contribution of Proterozoic and Lower Palaeozoic metasedimentary and magmatic protoliths at the constitution of the gneissic basement in the Getic-Supragetic domain and allow us to figure just "undifferentiated Proterozoic-Lower Palaeozoic" metamorphic-magmatic basement in Figure 2**.** Different by these, the Palaeozoic sedimentary and volcano-sedimentary successions of low-grade metamorphism are better dated as palaeontological content was preserved in the most important protoliths (Fig. 3).

The metamorphic evolution of the gneissic units and associated HP rocks, separated by Iancu *et al*. (1998), was recently dated in the time span of the Variscan cycle (*sensu* Matte, 2001**;** Faure *et al*., 1997), between 360-300 Ma, as follows: 309-320 Ma cooling Ar/Ar ages on muscovite and hornblende (Dallmeyer *et al*., 1998) and 319 Ma Sm/Nd age on garnet peridotite (Ducea *et al*., 2001); 323-358 Ma - Sm/Nd isochron age - on different amphibole and mica bearing gneisses (Drăguşanu and Tanaka, 1999); 332-338 Ma zircon Pb/Pb ages for a shear zone related pegmatite (Ledru *et al*., 1997); 357-331 Ma Ar/Ar ages (Maluski, in Iancu *et al*., 1997b and Axente *et al*., in press) and 354-344 Ma Sm/Nd ages on eclogite and granulite samples (Ducea *et al*., 2001; Medaris *et al*., 2003).

The main metamorphic feature of the internal terranes (gneissic units, *sensu* Rodgers, 1997) in the Getic-Supragetic basement is the contrasting regional metamorphic evolution in the separated tectono-stratigraphic units. HP (granulite and eclogite facies) occurrences are frequent in Sebeş, Lotru and Cumpăna units (Gheuca, 1988; Iancu & Mărunțiu, 1994a; Iancu *et al*., 1998; Săbău & Massonne, 2003) while LP metamorphism is characteristic for the Ursu unit (Săbău *et al*., 1987; Hann *et al*., 1988) or as younger imprint in other units (Hîrtopanu, 1986). The PT history of individual units is characterized by different geothermal gradients and peak-metamorphic conditions (Iancu *et al*., 1998; Medaris *et al*., 2003) and retrograde PT paths and suggests a step by step evolution, from subduction to collision in Eo-Variscan and Neo-Variscan events respectively, while late- and post- collision history are dated at 320-309 Ma (Ar/Ar data, Dallmeyer *et al*., 1994; 1998).

The contrasting lithology and metamorphic history of the separated tectono-stratigraphic units: Sebeş, Lotru, Cumpăna, Ursu and Făgăraş (Fig. 2), (Iancu *et al*., 1998; Medaris *et al*., 2003), is also supported by diversified shear zone related metamorphic parageneses confined to the main pre-Mesozoic tectonic boundaries. Various mylonites, from low- to medium-grade, up to eclogite-facies, are present and tectono-metamorphic inversion (Iancu, 2004) frequently marks the major metamorphic discontinuities in the Variscan nappe stacks (Iancu & Mărunțiu, 1994b; Iancu *et al*., 1998; Medaris *et al*., 2003).

4. Lithology and structure of the Palaeozoic low-grade successions

The Palaeozoic rock assemblages are preserved in the pre-Mesozoic basement of both Danubian and Getic-Supragetic Cretaceous nappe stacks building the South Carpathians.

Dated Palaeozoic successions show a metamorphic imprint in anchizone-green schist to epidote-amphibolite facies conditions. The current degree of knowledge is restricted by the scarcity of fossil content and/or old palaeontological determinations, which would need revision, as well as by the lack of isotopic data in most areas.

For a long time, the lack or uncertain palaeontologic or isotopic ages created confusions and discordant opinions which are reflected by different maps of the Geological Institute of Romania and conflictual papers (e.g.: Gherasi *et al*. 1973; Solomon *et al*., 1976; Maier, 1974; Stănoiu, 1976, 1982; Kräutner *et al*., 1981; Năstăseanu *et al*., 1981; Dimitrescu *et al*., 1990; Mureşan, 2000). Consequently, the chronostratigraphic position is difficult to precise because of the contradictory interpretation of the palaeontological/micropalaeontological content.

Detailed mapping and petrological research using comparative and discriminate structural and mineralogical-petrographical criteria (Iancu & Mărunțiu**,** 1994a; Iancu, Mărunțiu, Seghedi, unpublished data), as well as better preserved palaeontological content (e.g.: Maier & Visarion, 1976; Năstăseanu *et al*., 1981 and references herein; Visarion & Iancu, 1984; Iancu & Visarion, 1988; Vaida, 1999), allow us to separate (on maps) and describe those Palaeozoic Formations with a significant development in the South Carpathians basement nappes.

The outcrop area of the most important Palaeozoic successions from the basement of the South Carpathians is presented in Fig. 3 and their contents are illustrated by lithological columns for Danubian (Fig. 4A) and Getic-Supragetic (Fig. 4B) basement units.

A detailed description of the Lower Palaeozoic (?Cambrian-Ordovician-Silurian) and Middle Palaeozoic (Devonian-Lower Carboniferous) formations will be presented, from the bottom to the top of the Cretaceous nappe

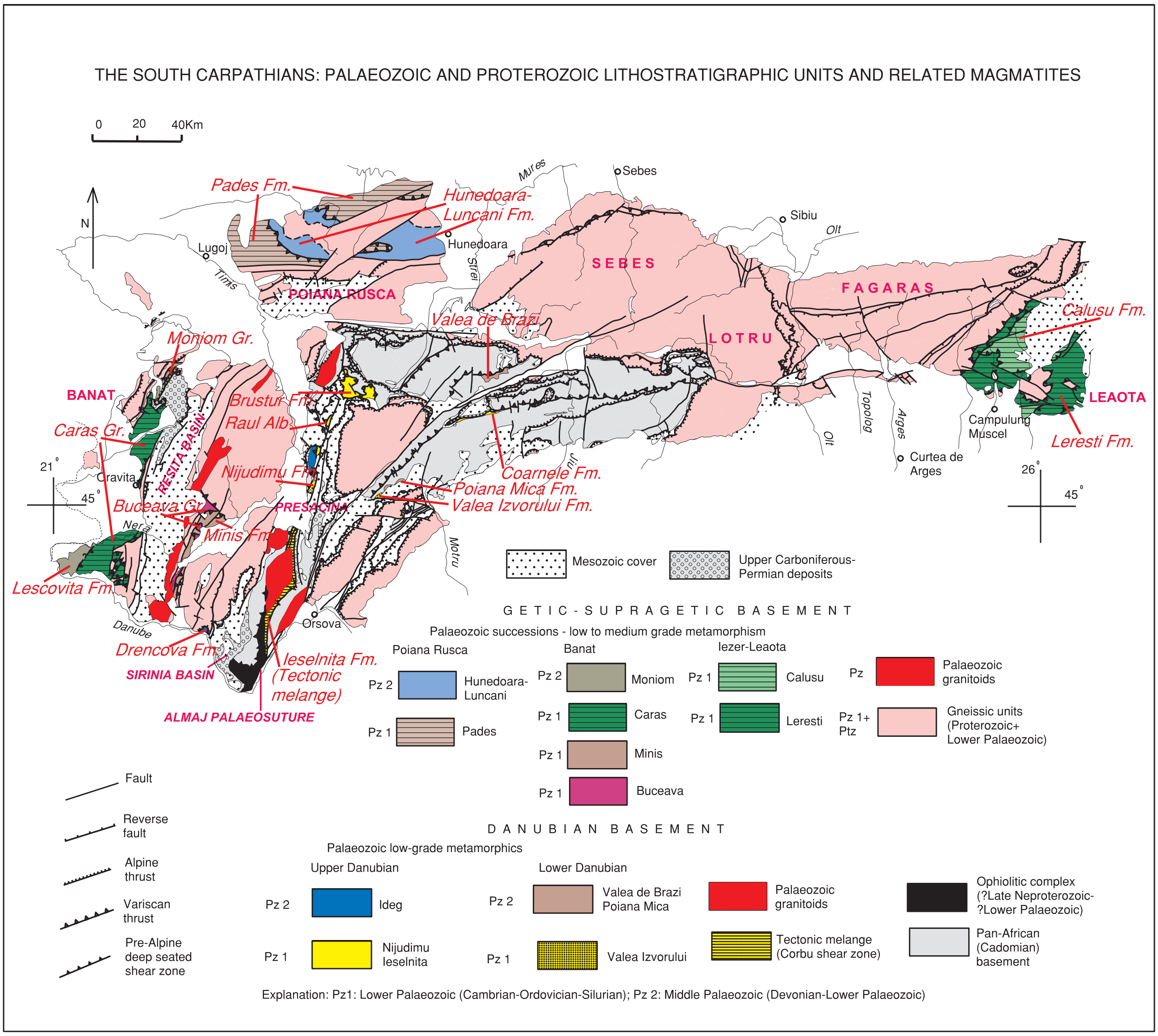


Figure 3. The South Carpathians: Palaeozoic low-grade metasedimentary and volcano-sedimentary successions and Proterozoic gneissic basement (undifferentiated).

pile, as follows: Lower Danubian, Upper Danubian and Getic-Supragetic.

4.1. Palaeozoic successions in the Danubian basement

The Palaeozoic successions cropping out in the Danubian basement are represented in Figure 4A.

4.1.1. Lower Danubian basement

In Palaeozoic time, the *External Danubian basement* related to the Cretaceous Lower Danubian nappe system represented the closest terrane to the Moesian plate. The low-grade metasedimentary formations overlying medium-grade polymetamorphic rocks of the Neoproterozoic basement are discontinuously preserved beneath the unconformable, well constrained Lower and/or Middle Jurassic covers. Sometimes, in the absence of palaeontological and isotopic data, the preserved Palaeozoic sequences cannot be distinguished from those of Mesozoic age on the basis of lithology or metamorphic degree only, due to the Alpine deformation and low-grade metamorphic imprint.

The identified and described "formations" are unconformable successions but in many cases, their soles are tectonic discontinuities. In some areas, successive "formations" can be grouped as continuous chronostratigraphic entities and in this case we used the term "Group" following the international recommendations. We used in some cases the term "sub-formation" were different or contrasting lithological associations can be observed inside of a "Formation".

a. Lower Palaeozoic (Upper Ordovician - Lower Silurian)

Early Palaeozoic formations are mainly clastic, consisting of mature quartz-rich sedimentary rocks, grading to siltic and pelitic rocks exposed as thin (tens to some hundreds of metres) and discontinuous covers, unconformably lying on different gneissic-granitic late Neoproterozoic basement units (Berza & Iancu, 1994; Berza et al., 1994) of Pan-African affinities (Liégeois et al., 1996).

Valea Izvorului Formation

The Valea Izvorului Fm. (Stanoiu, 1971) is preserved beneath the Jurassic-Cretaceous cover, unconformably lying on the late Neoproterozoic Lainici-Păiuş Group (Stănoiu and Iancu, in Bercia et al., 1977), mostly terrigenous rock sequences metamorphosed in LP-HT conditions (Berza et al., 1994). The lithology and palaeontological assemblage including Coelenterates, Trilobites, Briozoans and Brachiopods were described by Stănoiu (1972). This palaeontological

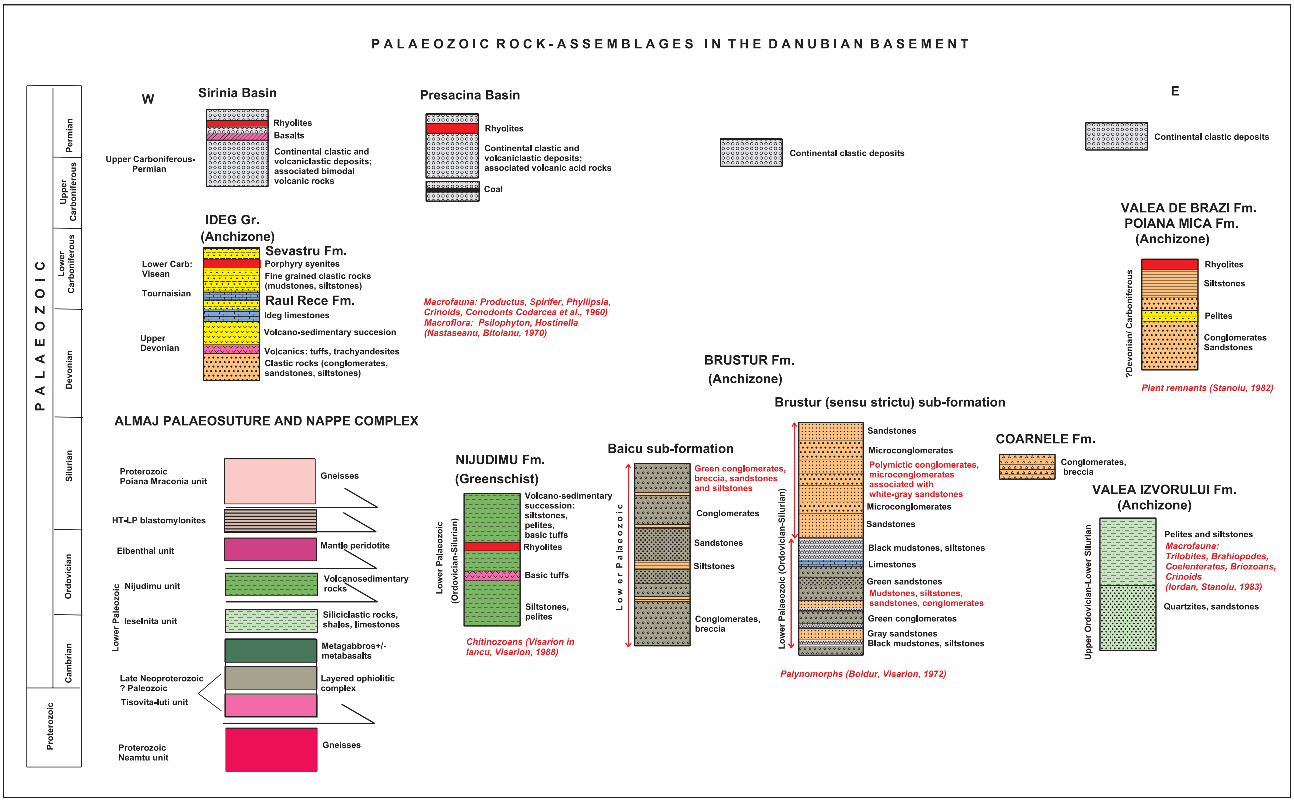
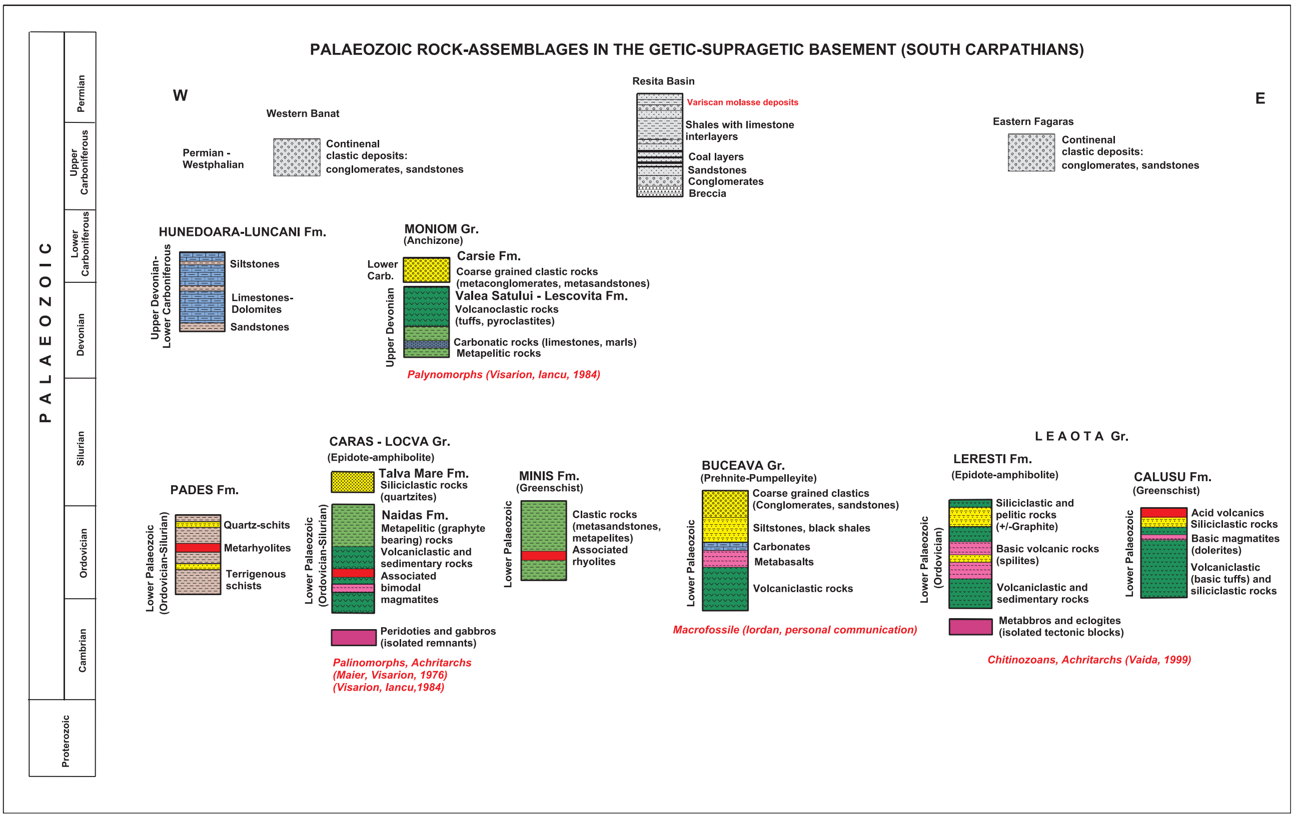


Figure 4. A. Palaeozoic low-grade successions in the Danubian basement: Lithologic columns.

B. Palaeozoic low-grade successions in the Getic-Supragetic basement: Lithologic columns.



association was initially described as macrofauna specific for the Late Ordovician, but after revision it was ascribed to the early Silurian (middle-upper Llandovery) (Iordan & Stănoiu, 1993). The palynological content identified by Iliescu (in Stănoiu, 1976) in the Valea Izvorului pelitic rocks suggests an Ordovician-Silurian time span for their sedimentation age.

The lithostratigraphic succession of the Valea Izvorului Formation includes a lower, thin quartzite member (white quartzite and quartz- feldspar-rich sandstones, 30 m thick) and an upper, mainly pelitic member (250-300 m thick). Clasts are represented by quartz grains and finer, siltic matrix, of feldspar, white mica, biotite, chlorite (sometimes replacing biotite or presumed radiolarians) and pyrite (Iordan & Stănoiu, 1993), while "pelitic" beds are siltic to siliciclastic muds.

Valea Izvorului quartzites are massive or banded while pelitic and siltic rocks display a S_1 slaty cleavage or schistosity generally paralleling the S_0 bedding.

Coarnele Formation

The Coarnele Fm. (Stănoiu, 1972, 1976) is lithologically similar to the Valea Izvorului Formation and its age is probably also Upper Ordovician - lower Silurian, as suggested by the palynological association (Visarion, in Solomon et al., 1976). The Coarnele Formation, 30-40 to 200-300 m thick, consists of white quartzite and quartz rich sandstones and coarse-grained conglomerates with quartzite boulders in a pelitic recrystallized matrix.

These rocks rest unconformably on the late Neoproterozoic basement of the Dragsan Group (mainly mafic and mafic-felsic volcanic rock assemblages metamorphosed in MP-MT conditions). Sometimes, the unconformity is difficult to recognize because of the common folding of both Proterozoic retrogressed gneisses and prograde low-grade Lower Palaeozoic sequences, as well as because of the strong Alpine metamorphic imprint (Berza & Iancu, 1994). Quartzite sandstones and siltstones of the Coarnele Formation preserve small-scale (decimetre-size) B_1 folds and related axial-plane or oblique S_1 cleavages.

Both formations have the metamorphic fraction represented by recrystallized quartz and white micas in quartzites and by fine neoblasts of white mica, chlorite and epidote in metapelitic rocks. They are cleavage related and frequent quartz veins crosscut the bedding and/or cleavage. Local isolated outcrops of coarse-grained metaconglomerates show subangular flattened boulders and dynamically recrystallized quartz-chlorite-sericite rich matrix.

The age of this deformation and of this metamorphic event is not yet documented. A Palaeozoic, pre-Permian age is indicated by field relations, as the Palaeozoic sediments exposed in the external Danubian Domain were folded together with their metamorphic basement prior to the deposition of the unconformable Permian and Liassic successions.

b. Middle Palaeozoic (Upper Devonian - Lower Carboniferous)

As geological data suggest, two formations correspond to this time span: Valea de Brazi and Poiana Mică.

Valea de Brazi Formation

A thin continental succession (100-200 m) is exposed in the southern Retezat Mountains on top of the Proterozoic basement of the Lainici-Paius Group (Stănoiu, 1982; Berza *et al.*, 1988). This sequence includes coarse-grained red and green conglomerates alternating with siltstones grading to pelites with plant debris and coals, and discontinuous rhyolite flows or sills. Initially ascribed to the Devonian (Stănoiu, 1982), based on plant remains, this succession was later reconsidered as an Upper Carboniferous-Permian formation due to reinterpretation of the same palaeontological content (Stănoiu & Lejal-Nicole, oral communication).

Metre to decametre-size open folds affects Valea de Brazi Formation and axial-plane cleavages are partly penetrative or refracted. Incipient metamorphic blastesis is of very low-grade but there are no mineralogical data to constrain the deformation. Shear bands and foliations at the top of the folded sequence are related to overthrust of a unit with Dragsan-type basement on the unit with Lainici-Paius-type basement and Valea de Brazi cover (Fig. 3).

Poiana Mica Formation

The Poiana Mica Fm. is a continental sequence of approximately 80-100 m thick, exposed in the Culmea Cernei-Mehedinți Mountains. Its Palaeozoic age is indicated by geological evidence: it overlies unconformably the late Neoproterozoic metamorphic-magmatic basement (Lainici-Păiuş gneisses and related granitoids) and the Upper Ordovician-lower Silurian sequence of Valea Izvorului Formation (Stănoiu and Iancu, in Bercia *et al.*, 1977), being overlain by Liassic sediments.

The lithological association is dominated by coarse-grained clastics (conglomerates, sandstones), grading to fine-grained (siltic to pelitic) members; thin rhyolites sills are associated and deformed together with the sedimentary succession. The deformation is accompanied by the development of slaty cleavage in metasediments and shear bands in the rhyolite lenses. Newly crystallized minerals include chlorite, white mica, epidote/clinozoisite, carbonate and quartz indicating a metamorphic grade in the lower greenschist facies conditions.

The age of this deformation is difficult to determine in the absence of any isotopic data, as the overlying Jurassic-Cretaceous sequences in the area are affected by a very low to low grade Alpine regional metamorphism and the separation of a Palaeozoic imprint is not yet proved.

4.1.2.Upper Danubian basement

a. Lower Palaeozoic (?Cambrian-Ordovician-Silurian)

Nijudimu Formation

The Nijudimu Formation is a low-grade metamorphic volcano-sedimentary succession, previously considered as a retrograded Proterozoic basement unit.

The palynological content includes acritarchs, chitinozoans and scolecodonts. An Ordovician-Silurian age was assumed for this formation (Iancu & Visarion, 1988), based on the chitinozoan assemblage (including Lagenochitina, Conochitina and Desmochitina) and acritarchs (Baltisphaeridium microspinosum and Baltisphaeridium multispinosum Eis.), which were considered specific forms for Ordovician sequences described in Poland (Gorka, 1969) and the Baltic regions (Eisenack, 1959).

The lithological association of the Nijudimu Formation includes about 200 m of metavolcanic rocks (basic tuffs and/or flow laminae, andesites and scarce acid tuffs), followed by 100-150 m of fine-grained clastic rocks (metapelites, metasiltstones), including volcaniclastic layers.

The pre-metamorphic minerals and fabrics are obliterated by regional deformation and prograde, widespread metamorphism at greenschist facies conditions (chlorite and stilpnomelane zones). At mezoscopic scale, the metapelitic rocks exhibit a penetrative S_1 foliation and intrafolial B_1 folds while folded bedding could be observed at microscopic scale only. In basic (green) rocks, the metamorphic phases are dominant: chlorite, epidote/clinozoisite, albite, and stilpnomelane, iron oxides and subordinate sericite, calcite, rutile. Muscovite, chlorite, albite, quartz are the dominant phases in acid metavolcanic and metapelites. B_1 related axial plane foliations and sheared folds are dominant, but frequent refracted or distorted cleavages at bedding interface are related to sliding and flexural folds (Iancu & Visarion, 1988), pointing to a high degree of shortening.

Ieselnița Formation (redefined "Corbu" Formation)

Isolated slabs and lenses of oceanic-type sediments (siliceous rocks, black shales, siltstones and carbonates), crop out in the

Almaj Mountains area, within the Almaj tectonic complex interlayered with dismembered ophiolites and gneisses inside of a pre-Late Carboniferous nappe stack (Fig. 3). The Ieselnița Formation (Iancu, unpublished report 1999) is a low-grade sequence preserved as discontinuous slabs inside of the mentioned nappe stack. A post-nappe strike slip system led to the formation of a linear mylonitic belt and the resulted tectonic melange includes various dismembered gneisses (Mărunțiu & Seghedi, 1983; Dinică, 1989), tectonitic ophiolites (gabbros, peridotite, basalts; Mărunțiu et al., 1997), Early Palaeozoic HT-LP mylonites (Iancu et al., 1997a) and lens-shaped bodies of undated Palaeozoic rocks.

The Ieselnița Formation is discontinuously preserved in the mentioned pre-Upper Carboniferous tectonic melange (Figs 3 and 4A), forming an N-S oriented, lens-shaped area, between Sfârdinu and Ponicova valleys, the most representative sequence cropping out in the Ieselnița valley.

The lithological association of the Ieselnița Formation consists of siliciclastic sandstones and pelites, limestones, pyroclastic rocks, sedimentary and volcanic breccias, spatially associated with volcanics (basic tuffs and basalts, as well as rhyolites and trachytes).

The internal structure of some tectonic sheets show the existence of some decimetre to metre-size alternating beds of sandstones-siltstones-breccias (+/-sulfide pods) or siltstones-pelites-black shales and siliciclastic rocks including discontinuous levels of massive carbonate rocks/limestones (with crinoidal ossicles) and acid pyroclastic or basic volcanics.

Pre-metamorphic fabrics of both sedimentary and magmatic rocks are preserved and B_1 folds and S_1 cleavages are also visible at metre to decametre-scale. Sub-horizontal bedding or lamination S_0 surfaces are preserved in metasedimentary rocks and are folded and crosscut by S_1 sub-vertical cleavages. S_1-related metamorphic phases are chlorite-actinolite-albite-epidote/clinozoisite/-calcite in basic rocks and chlorite-muscovite-quartz-calcite in metasedimentary rocks.

Lithological association suggests a deep marine (rift-related) environment, and it is congruent with the proximity of the basic-ultrabasic Tişovița-Iuți massif (Figs 2 and 3). The latter (Mărunțiu *et al.*, 1997) is part of the "Thracian" palaeosuture (Haydutov & Yanev, 1997; Savov *et al.*, 2001), exposed south of Danube, for which a 563 Ma zircon U/Pb age was determined by von Quadt *et al.* (1998) pointing to a late Neoproterozoic age.

At regional scale, the Ieselnița Formation, as an inverted remnant basin, together with the ophiolitic palaeosuture (basic-ultrabasic complex) marks a Lower Palaeozoic (pre-Devonian) plate/terrane boundary (Iancu *et al.*, 1997a); the two crustal blocks (Fig. 4A) consist of Proterozoic gneissic-granitic basement units (Drăgşan and Lainici-Păiuş, Iancu *et al.*, 1990; Berza *et al.*, 1994) and are crosscut by Palaeozoic (?pre-Devonian) magmatic-arc related granitoid suites (Stan, 1982; Iancu, 1998) with known isotopic ages of 393-372 Ma (Rb/Sr and K/Ar, Mânzatu *et al.*, 1974).

Brustur Formation

The Brustur Formation was redefined as a unitary Palaeozoic megasequence and cartographically separated by Iancu *et al.* (1990). Some parts of the succession are known from older publications as individual sequences of green "tuffaceous rocks" and conglomerates (Gherasi, 1937; Gherasi *et al.*, 1973). Some dismembered sequences, of the Brustur Formation, cropping out in some small alpine tectonic windows, were previously described as "Râul Alb Formation" by Năstăseanu (1975) and Kräutner *et al.* (1981).

The Early Palaeozoic age (Ordovician-Silurian) of the Brustur Formation is supported by the palynological content, represented by acritarchs and chitinozoan associations including: *Trodysphaeridium, Tasmanites, Hystoicliotriangulatum sp., Achantodiacrodium sp., Leiofusa sp., Conochitina and Desmochitina sp.* (Visarion, unpublished data and Morariu, 1976). The Raul Alb sequence was assigned to the Lower to Middle Ordovician on the basis of a palynological content with *Leiofusa sp., Leioarachnitum vitatum, Lophosphaeridium rarum* (Boldur & Visarion, 1972).

The Brustur Formation is an upward fining sequence, consisting of three main lithofacies associations (Iancu *et al.*, 1990):

a. Baicu Conglomerates associated with subordinate green sandstones and siltstones;

b. Green sandstones and siltstones with subordinate Baicu conglomerates, black mudstones, white arkosic sandstones, limestones;

c. Polymictic microconglomerates and conglomerates associated with white-gray sandstones.

The stratigraphic, field relationships allow us to distinguish two sub-formations (members): a lower one, Baicu, and Brustur *sensu strictu*, at upper part of the succession.

The distinctive feature of the Brustur Formation is that it was sourced mainly by the latest Neoproterozoic mafic-ultramafic cumulates of the Tişovița-Iuți palaeosuture, with minor contributions from the pan-African Drăgşan Terrane, marking an active tectonic environment and a Lower to Middle Palaeozoic plate boundary (Iancu *et al.*, 1997a). A description of the main lithofacies units will be presented, as follows:

- *Green conglomerates and sandstones* are associated in thick successions (tens to hundreds of metres thick) including a basal coarse conglomerate lithofacies grading upward to a dominantly green sandstone lithofacies. Thin interlayers of green sandstones and siltstones rich in amphibole clasts are present in conglomerate beds but they are dominant in the median part of the Baicu member (Fig. 4A). The thick (3-6 m) conglomerate levels are massive, without internal structure and contain large, angular or rounded boulders of green rocks (gabbros, amphibolites, serpentinites) but quartz-feldspar- and mica-rich gneisses are also present; smaller clasts are green rock or mineral fragments (e.g. amphibole, feldspar). Some sorted beds contain microconglomerates levels grading at the top to coarse-grained, laminated sandstones and, sometimes, they are interbedded with thin beds (centimetre to metre-size) or lenses of green and black sandstones. Isolated beds of detrital limestones and black slates are present and large (several metres) blocks of ultramafic rocks are embedded in the black slates and shales. The conglomerate lithofacies is considered as a proximal fan deposit at high discharge and sediment load, typical for upper flow regime conditions (Seghedi, in Iancu *et al.*, 1990) while lower flow regime is suggested by preserved horizontal laminations in sandstones and siltstones beds.
- *White-gray sandstones, microconglomerates and conglomerates* characterize the upper part of the megasequence and are involved in metre to decametre-size folds, associated to kilometre-size folds of a large-scale synclinorium.

Well-sorted microconglomerates and conglomerates, with rounded clasts of white colored rocks (gneisses, granites, and quartzites) are representative for this facies. The dominant alternating microconglomerates-conglomerates-sandstones include, at different levels, black shales and mudstones. Conglomerates are massive, with erosional, irregular contacts with the underlying beds while upward grade at coarse or medium-grade sandstones; the sandstones are bedded or lenses shaped, with erosional base and contain frequent intraclasts of mudstones or black shales.

To the uppermost part of the megasequence, sandstones and black mudstones appear in upward fining sequences, sometimes interbedded with coarse-grained green rocks. This lithofacies suggests a deposition in low viscosity flows and upper flow regime conditions possibly related to a distal fan environment and even chanallized flows (Seghedi, in Iancu *et al*., 1990).

- *Massive black sandstones and limestones*. The black sandstones occur as individual thick beds (metres to several centimetres thick) in the described facies associations or as intraclasts in their upward coarser beds. They show sharp bases and irregular, eroded top, suggesting a deposition from suspension particles in a standing water environment. The limestone is discontinuous and irregular beds, with a thickness of several centimeters to a metre, crop out as interlayers between conglomerates and green sandstones and preserves crinoidal ossicles.

The outcropping area of the Brustur Formation from the Țarcu Mountains area is characterized by a kilometre-sized synformal structure designated by the thick green conglomerate member at bottom and fine-grade siltic at top. The base of the folded megasequence is strongly sheared and truncated by a pre-Alpine thrust fault while its top is an erosional surface. The internal structure of the basal part reveals massive, coarse-grained and unsorted conglomerate beds and angular to flattened boulders with a recrystallized matrix; multistratified sequences from the middle-upper part of the formation display a widespread B_1 folding of the S_0 at mezoscopic scale and coexisting sedimentary and metamorphic fabrics and mineral phases. The folded bedding (S_0) is associated with S_1 axial-plane or fan-like, refracted S_1 cleavages and metamorphic recrystallization.

The metamorphic phases are: chlorite, albite, sericite, calcite, epidote/clinozoisite, stilpnomelane (in green rocks) and white mica (sericite/phengite), chlorite, quartz, albite, in quartz-feldspar rocks, pointing to lower greenschist facies conditions. The carbonate-rich rocks are strongly recrystallized, domain fabrics paralleling the cleavage surfaces a mezoscopic and microscopic scale. An incipient metamorphic differentiation and fluid circulation is underlined by calcite and quartz bands and veins.

The Palaeozoic age of this deformation and metamorphic stage is constrained by the overlying, unconformable Permian and Jurassic continental deposits (Berza & Iancu, 1994). A second generation of B_2 folds, microfolds (kink or crenulation type) and S_2 cleavages could be related to the alpine regional deformation.

b. Middle Palaeozoic (Upper Devonian-Lower Carboniferous)

Ideg Group: Râul Rece, Sevastru and Drencova formations

The Râul Rece, Sevastru and Drencova formations of Late Devonian-Early Carboniferous age unconformably overly the older basement consisting of Late Neoproterozoic gneissic-granitic basement and Lower Palaeozoic sequences (Năstăseanu *et al*., 1988). Although direct relationships with the Lower Palaeozoic formations have not been identified, their contrasting lithological and deformational features suggest that there was a break in sedimentation between the Lower and Upper Palaeozoic successions, both overlying a late Neoproterozoic basement.

A continuous volcano-sedimentary succession of Late Devonian- Early Carboniferous age (Râul Rece and Sevastru formations, Năstăseanu, 1979; Năstăseanu *et al*., 1988) is exposed in the western part of the Țarcu Mountains.

The Upper Devonian succession (*Râul Rece Formation*) (Năstăseanu, 1979; Năstăseanu *et al*., 1981) is a coarse clastic succession, 1000 m thick, grading upward to a shallow-marine carbonate and pelitic sequence of Tournaisian age of about 600 m (*Sevastru Formation*); associated basic tuffs are present mainly in the lower part of the sequence but trachiandesitic or porphyry syenitic sills and dykes are also known in both formations (Russo-Săndulescu, in Năstăseanu *et al*., 1988). The age is constrained by palaeontological evidence: Devonian macroflora (*Psylophiton goldschmidtii, Psilophyton kräuseli, Hostinella sp., and Pseudosporochuus sp*. identified in the middle part of the Râul Rece Formation (Năstăseanu, 1979); Tournaisian macrofauna (e.g. *Productus antiquatus, Spirifer tornacensiss, Spirifer striatus, Syringopora cuspidata, Phyllipsia gemulifera*) identified and described by Codarcea *et al*. (1960) in the Ideg limestone beds lying at the transitional part of the coarse clastic Râul Rece sequence and the black slates of the Sevastru Formation (Codarcea *et al*., 1961; Năstăseanu *et al*., 1981); the same sparry to detrital limestone beds contain recrystallized crinoidal debris and conodont species (*Siphonodella crenulata*, *Perycyclus zone*) (Mirăuța, 1964).

The megasequence forms a pre-Permian asymmetric synclinorium, with the internal structure controlled by the thick-bedded lower sequence, including limestone beds, where S_0 is the dominant structural element. Refracted S_1 cleavages are frequent in the alternating (centimetre to tens of centimetres) coarse and fine-grained beds, while sliding (intra-bedding) microfolds are present in quiet thicker beds (tens of centimetres thickness) in the multistratified layers. The black pelitic-siltic sequence of the Sevastru Formation is characterized by two sets of penetrative slaty cleavage resulting in a high degree of fissility in rhomboidal microlithons.

A very-low grade metamorphic imprint is marked by the S1 related neoformation of chlorite, sericite, calcite, and quartz +/- epidote/clinozoisite. The deformation age of the Upper Devonian - Lower Carboniferous succession is pre-Permian (Variscan), as constrained by the unconformable red beds of the Permian continental cover, overlying the western-central part of the synclinorium.

One hundred kilometres southward, on the Danube left slope, a sequence of coarse-grained clastic rocks (200 m thick), grading upward to about 800 m of fine-grained clastics (black pelitic to siltic beds and interbedded sandstones and limestones at the upper part), are associated with volcanic rocks (pyroclastic and basic flows or sills) (Drencova Formation*)*. A palynological association identified in black pelitic rocks (*Emphanisporites minutus and Emphanisporites radiatus*, Năstăseanu & Bițoianu, 1970) and scarce macrofauna remains (*Plectogyra*) in sparry limestone blocks (Răileanu & Rusu, 1962) reworked in the pelites suggest a Devonian, possibly Early Carboniferous age (Năstăseanu *et al*., 1981).

4.2. Palaeozoic successions in the Getic-Supragetic basement

The Palaeozoic rock assemblages of the Cretaceous Getic-Supragetic nappe system (Fig. 4B) (Iancu *et al*., in press) consists of continental coal-bearing deposits of Late Carboniferous-Permian age (plant remains and coal bearing) (Năstăseanu *et al*., 1981), unconformably overlying the metamorphosed successions of Palaeozoic and Proterozoic age (Kräutner *et al*., 1981).

The Palaeozoic-dated sedimentary and volcano-sedimentary successions are metamorphosed in relatively low-grade conditions (from anchizone or sub-greenschist to greenschist and epidote-amphibolite facies) and their palynologic content was preserved either as rich associations or as scarce remains (Kräutner *et al*., 1981; Năstăseanu *et al*., 1981 and references herein). Unfortunately, specific fauna or isotopic ages are still missing so, this review will refer at published papers and larger time spans (as e.g. Early Palaeozoic) will be used in case of uncertain ages.

4.2.1. Lower Palaeozoic (?Cambrian-Ordovician-Silurian-?Early Devonian)

Caraş-Locva Group: Naidaş, Rafnic and Dognecea formations

(Supragetic basement, western Banat area)

The "Caraş Group" (Iancu & Mărunţiu, 1994a; Iancu, 1998) and a part of the Locva Series (Maier, 1974) includes different sedimentary and volcano-sedimentary formations of early Palaeozoic age (Ordovician-Silurian) (Maier & Visarion, 1976 and Visarion & Iancu, 1984, based on achritarcs and chitinozoans content: *Conochitina, Clathrochitina, Desmochitina*) cropping out in the basement of the Supragetic nappes in western Banat area. Main features of the constituent formations are: prevalence of volcano-sedimentary rock associations of mafic and bimodal volcanics; widespread epidote-amphibolite facies; polystage deformation and intense shortening effects (Iancu, 1985b; Iancu & Mărunţiu, 1994a).

Detailed mapping of the Palaeozoic successions were performed in various areas of Banat (Maier, 1974; Constantinof, 1972; Iancu, in Năstăseanu *et al*., 1985), but different local names were used for some parts of the succession (Locva Series, Maier, 1974 and Vodnic Group, Iancu, 1985b), mainly because of poor age and correlation data.

Various opinions were published concerning the content and palaeontological ages of the different "complexes" included in the "Locva Series" (Maier, 1974), a name recently used by Kräutner & Krstić (2002) for a large-scale compilation map, north (Romania) and south of Danube river (Eastern Serbia and Bulgaria). Our mapping and petrological studies (Iancu, 1986a; Iancu & Mărunţiu, 1994a), revealed that the Lower Palaeozoic formations are in tectonic relationships with two underlying units, consisting of a gneissic complex in the eastern part of the Locva massif (Bocsiţa-Drimoxa, possibly late Neoproterozoic in age) and of a low-grade, Upper Devonian- Lower Carboniferous sequence in the western part of the massif (Lescoviţa Formation).

Naidaş Formation.

In the central part of the Locva massif, a dominantly volcano-sedimentary formation is characterized by intimately associated mafic and acid volcanic and subvolcanic rocks (metatuffs, metabasalts, metadolerites, metarhyolites and metarhyodacites), interlayered with terrigenous clastics (metagraywackes, metapelites, white and black quartzites). Scarce and dismembered metagabbros and metadiorites bodies are spatially associated.

The initial thickness of the formation is difficult to estimate because of high erosion effects, Alpine and pre-Alpine tectonic boundaries and folding; the thickness of graywackes and pelites was probably more than 300-400 m. Pre-metamorphic fabrics are very well preserved in all the magmatic, inherited protoliths.

This "bi-modal" magmatic association is a tholeiitic to alkaline, differentiated suite. Its geochemical features suggest an intracontinental rifting environment (Mărunţiu *et al*., 1993).

Rafnic Formation.

This formation is well exposed in the Caraş valley basin and might represent a lateral or an upper member of the Naidaş formation. The most frequent lithologies are basic metatuffs and flows (possibly metabasalts) and green metatuffitic rocks with interlayered metapelites.

In both sedimentary and magmatic rocks, the pre-metamorphic lithologies are extremely difficult to identify due to extensive metamorphic recrystallization and differentiation, but widespread development of basic (green) and pelitic rocks suggests an intra-continental rift environment. Associated gabbroic and peridotitic dismembered cumulates could suggest a developing oceanic type basin.

Dognecea Formation

The Dognecea Fm. is the uppermost lithostratigraphic unit in the Caraş Group, and a gradual transition from the Rafnic Formation can be observed (Iancu, 1998). The transitional sequence includes metric to decametric cycles of alternating metapelites, metapsamites and basic metatuffs, followed by a thick succession (at least 200-300 m) of metagraywackes, grading to graphite-bearing metapelites associated with thin quartzite and marble beds.

The preserved pre-Alpine structure involving the rock assemblages of the Caraş Group is represented by a large scale (100 kilometres long and approximately 30 kilometres wide) asymmetric synformal succession, tectonically truncated at the bottom (eastern part of the Locva massif) by a Palaeozoic thrust fault. The footwall, underlying unit is built by? Neoproterozoic gneisses and metagranites (Bocsiţa-Drimoxa Formation, Iancu, 1986a).

Pre-metamorphic fabrics of the Caraş-Locva rock assemblage are better preserved in magmatic protoliths; large, tabular bodies of rhyolites display porphyritic texture and bipiramidal quartz and K-feldspar phenocrysts, while marginal-chilled structures are visible together with shear bands and metamorphic foliations. Also basic rocks are frequently easy to recognize by their pre-metamorphic textures as e.g.: pillow structures in basalts (Maier, 1974); massive textures in gabbros (lately deformed as flasser-gabbros); inherited magmatic relics are also present, as: pyroxenes, amphibole, plagioclase, partly replaced by metamorphic phases. By contrast, in metasedimentary rocks metamorphism and deformation obliterate the pre-metamorphic features.

High amplitude (decametre-size) open folds and associated metre-size drag folds of the S_0-$_1$ banding and foliation characterize the internal structure of the unit. A first generation of B_1 folds is visible in outcrops and thin sections, sometimes coexisting with S_1 foliation (intrafolial or sheared folds) but B_2 folds are mainly open, concentric folds and S_2 foliation has a different behavior in metapelites (as a penetrative, dominant foliation) in respect with interlayered sequences (refracted foliations) or in massive rocks (partly penetrative).

Paragenetic associations suggest that the M_1 deformation of the Caraş Group took place in upper greenschist to epidote-amphibolite facies conditions (Iancu, 1986b). Equilibration in epidote-amphibolite facies was attained at chlorite, albite-biotite and garnet zones in rocks of different lithologies (metapelitic, metabasic and meta-acid/felsic), but prograde metamorphic map zonality was not realized. The "retrograde path" is marked by a partial re-equilibration in greenschist facies conditions.

The lithological associations and metamorphic-deformational features point to a pre-orogenic extension-related depositional environment of the Caraş Group in Early Palaeozoic time (Ordovician-Silurian), marking a Palaeozoic intracontinental suture zone.

Leaota Group: Lereşti and Căluşu formations

(Getic basement, eastern South Carpathians, Iezer-Leaota Mountains)

Monotonous successions of volcano-sedimentary rocks associated with scarce dismembered basic magmatic bodies (metagabbros) are exposed in the easternmost part of the South Carpathians (Iezer-Leaota Mountains). Both formations were mapped and described as low-grade, Palaeozoic sequences unconformably lying on an older basement by Dimitrescu *et al*. (1971, 1974), Popovici (1978), Tatu & Robu (1987), or as retrograded Precambrian rocks by Gheuca & Dinică (1986).

Based on new petrological data, Iancu & Mărunţiu (1994a, b) have redefined these formations as Lower Palaeozoic successions with a regional Variscan prograde metamorphism at upper greenschist to epidote-amphibolite facies conditions (Iancu, 1998). Both formations are tectonically emplaced in a Variscan nappe pile and can represent inverted remnants of an early Palaeozoic rift, now squeezed between two units consisting of gneissic polymetamorphic rocks (Iancu *et al*., 1998; Iancu, 2004).

The Early Palaeozoic, Ordovician age of Lereşti and Căluşu formations is documented by identified and described palynomorphs (Vaida, 1999), including Chitinozoans and acritarchs.

They can be correlated with volcano-sedimentary succession of the Caraş Group from the Supragetic units, Banat area (Dimitrescu, 1990; Iancu & Mărunțiu, 1994a).

Lereşti Formation

The Lereşti Fm. is a monotonous succession of metapelitic-metapsamitic (metagraywackes) rocks, subordinate basic volcanoclastics and thin, quartz-feldspar and quartz rich beds; scarce basic meta-magmatic rocks are preserved (e.g. gabbros and dolerites) while post-metamorphic granites are frequent.

Căluşu Formation

The Căluşu Fm. is a volcano-sedimentary lithological association consisting dominantly of basic volcanoclastics (tuffs) and subordinate metasedimentary rocks (siliciclastic and metapelites); scarce but widespread magmatic rocks were recognized (e.g. metadolerites and metarhyolites).

Various HP metabasic rocks crop out at the bottom of the Lereşti Formation, as tectonic blocks inside of an exhumed tectonic melange (Bughea complex, Iancu *et al*., 1998; Medaris *et al*., 2003). The composition and nature of protoliths is difficult to establish, although some gabbroic rocks are still recognizable in the lower metamorphosed protoliths. Anyway, they could represent dismembered basic magmatic cumulates marking an Ordovician intraplate rift, and a direct correlation of the Leaota Group (Lereşti and Caluşu Formation) with Caras Group (western Banat) suggest an important intracontinental rift developed inside of a pre-Ordovician plate.

Both formations are tectonically bounded and involved in a Variscan nappe stack (Iancu *et al*., 1998; Axente *et al*., in press) together with polymetamorphic gneissic units of uncertain Neoproterozoic-EarlyPalaeozoic age.

Internal structures of the Lereşti Formation are characterized by regional folding (B_1, tens of centimetres to metre-size to in amplitude) in epidote-amphibolite facies conditions and development of penetrative S_1 foliation and schistosity. Widespread M_1 metamorphic recrystallization and differentiation led to a homogenous re-equilibration of the entire succession at peak metamorphic conditions in epidote-amphibolite facies conditions. Prograde metamorphism is suggested by blastesis-deformation relationships in metapelitic rocks, better illustrated by synkinematic albite porphyroblasts (sometimes of millimetric dimension) and preserved inclusions (e.g. euhedral and zoned garnet, muscovite, biotite oligoclase, epidote, quartz) marking internal, Si foliations.

By contrast, the Căluşu Formation attained greenschist facies metamorphic conditions and mineral parageneses of epidote-amphibolite facies are locally present; associated basic rocks (dolerites) preserve magmatic structures and mineral phases.

Ar/Ar mineral ages of 331-345 Ma were obtained on rocks from Lereşti and Căluşu formations, as well as from mylonitic rocks on different protoliths, including eclogites and gneisses (Maluski, in Iancu, 1998; Axente *et al*., in press). Other Ar/Ar data (Dallmeyer *et al*., 1994) on metamorphic rocks from the South Carpathians basement are compatible with recently published petrological and isotopic data which documented thermo-tectonic events characterizing Variscan tectogenesis (Ledru *et al*., 1997; Medaris *et al*., 2003).

Tâlva Mare Formation

(Supragetic basement, western Banat)

An unconformable, thin sequence (about 100-200 m thick) of clastics overlies the probably Neoproterozoic polymetamorphic gneissic basement (the Bocşița-Drimoxa Formation, Iancu, 1984). A possible Early to Middle Palaeozoic age (?Silurian or ?Devonian) could be presumed for the Tâlva Mare Formation based on the geological relationships and correlation of the pre-Permian formations in area.

White quartzites and mica-rich, quartz-feldspar sandstones with a flat-lying banding and large, open folds represent the dominant lithofacies. Muscovite, chlorite, epidote neoformation and quartz recrystalllisation a low-grade metamorphism of the Tâlva Mare Formation.

The lithological assemblage of these mature, quartz rich sandstones suggests a shallow marine depositional environment and passive continental margin setting.

Buceava Group: Agriş and Şopot formations

(Getic basement, Eastern Banat)

The Buceava Group is exposed in the central part of the Banat area, where it forms discontinuous outcrop areas within a folded Palaeozoic (Variscan) nappe stack (Iancu & Mărunțiu, 1989), subsequently incorporated in the Cretaceous Getic nappe complex (Iancu *et al*., in press).

The redefined Buceava Group (Iancu & Mărunțiu, 1989; Iancu, 1998) includes two distinct formations (Agris and Sopot formations). An Early Palaeozoic, Ordovician age, could be taken into account based on geological evidence: macrofauna remains of a possible Ordovician age (Iordan, oral communication); unconformable Upper Carboniferous overlying conglomerates; crosscut by the Sichevița-Poniasca granitoids (which yielded monazite U-Pb ages of 350-328 Ma (Grünnenfelder in Birlea, 1976) and K/Ar of 300+/-15 Ma (Soroiu *et al*., 1970).

Isolated and tectonically dismembered occurrences of the sequence are scattered in the dome-shaped Variscan antiformal structures which form a 70 km long alignment running N-S from the Miniş valley to Danube river. Southward, similar outcrop areas of Lower Palaeozoic successions are known from the geological maps of Eastern Serbia (Dimitriević, 1997; Kräutner & Krstić, 2002).

Agriş Formation

This formation is exposed in the northernmost antiformal "windows" and is mainly represented by basic magmatic rocks (basalts, gabbros, diorites), sedimentary fine-grained clastic rocks (siliciclastic beds and shales) and limestones suggesting oceanic-type crustal. Chemical features of the basaltic rocks suggest a back-arc origin in a suprasubduction rift basin active during the Early Palaeozoic (Mărunțiu *et al*., 1993).

Southwards, coarser-grained clastic successions including decimetric to metric interbedded sandstones and microconglomerates, form poorly sorted turbidites sequences.

Şopot Formation

The Şopot Fm. is a coarse-grained, mainly conglomeratic sequence (of red to greenish color), unconformably overlying older, polymetamorphic-gneissic basement. The succession includes conglomerates and sandstones, as well as subordinate siltstones and associated volcanic and subvolcanic magmatic rocks (basalts, diorites, and plagiogranites). Both these magmatic rocks and gneissic basement rocks are frequently reworked in the uppermost conglomerate levels (beds).

Although no age data are available, an Early to Middle Palaeozoic (pre-Carboniferous) time span can be presumed as they are involved in the same nappe stack as the Agriş Formation, but a different tectonic sheet or imbrication is suggested by their unconformable relationships with the gneissic basement.

Pre-metamorphic mineral phases and fabrics are well preserved in both sedimentary and magmatic protoliths of the Palaeozoic formations composing the Buceava Group, as the penetrative deformation and associated sub-greenschist facies metamorphic neoformation had a differentiated behavior and intensity.

Meta-magmatic rocks, sometimes of sub-kilometric dimension, preserve magmatic phases (e.g. pyroxenes, plagioclase, amphibole), partly replaced by pseudomorphous aggregates of metamorphic phases (plagioclase replaced by pumpellyite, epidote, carbonates) and fabrics (intergranular and "amigdaloid" texture in basalts), especially in the internal parts of the magmatic bodies, while their margins are strongly sheared, foliated and recrystallized or tectonically dismembered.

Associated black shales are foliated or sheared and carbonate rocks are recrystallized. The coarse-grained clastic rocks (metaconglomerates, metasandstones) contain boulders and lithic clasts of various compositions, in a foliated matrix.

The lithological assemblage was deformed in sub-greenschist to greenschist facies conditions. A prograde metamorphism in prehnite-pumpellyite facies conditions was identified in basic rocks, especially replacing magmatic plagioclase but chlorite, carbonate, epidote, actinolite are also present as psedomorphs (on mafic magmatic relics) or as S1 oriented phases in sheared magmatic rocks. The metamorphic phases in metasedimentary rocks are: chlorite, white mica (sericite, fengite), carbonate, quartz.

Shear zone deformation and low-grade metamorphism are related to Variscan tectonic boundaries in the whole nappe pile.

Miniş Formation

(Getic basement, Central Banat)

The Minis Formation is a distinct clastic succession exposed in the central Banat area, tectonically overlying the Buceava Group. The name "Miniş series" was introduced by Codarcea (1940) who identified a part of this succession included within it retrograde gneissic rocks (mainly amphibolites) and some parts of the Buceava Group previously described. Its contrasting lithology, low-grade metamorphic imprint and structural-tectonic discordance allowed us to separate this succession as a Palaeozoic, pre-Carboniferous succession even if no age data are known. It is involved in the same Carboniferous nappe pile as the Buceava Group, together with polymetamorphic gneissic complexes (Iancu & Mărunţiu, 1994a).

This monotonous succession includes mainly coarse to fine-grained clastic rocks (sandstones, microconglomerates, siltstones and pelites), minor basic metatuffs and scarce metarhyolites sub-volcanic bodies, deformed and metamorphosed together in greenschist facies conditions (stilpnomelane and biotite zones). The stratigraphic thickness cannot be deduced because of tectonic boundaries, both at bottom and top, but outcropping areas open an approximately 300 to 400 m thick succession, intimately folded.

The corresponding metamorphic rocks (meta-lithofacies) are: chlorite-muscovite-quartz schists, sometimes graphite bearing; biotite/stilpnomelane chlorite-muscovite quartz schists; feldspar-rich quartzites; albite-muscovite-chlorite bearing metarhyolites; actinolite-chlorite-epidote-albite (green) schists.

Pre-metamorphic features as bedding and clastic composition of the interbedded layers of sandstones and microconglomerates are preserved but metamorphic fabrics are dominant.

Mesoscopic folds (metre to decametre-size) and associated, flat or sheared intra-folial microfolds (syn-schistosity folding) are related to B1 folding but subsequent B2 folds and S_2 foliations are also present. A high degree of metamorphic recrystallization (quartz) and neoformation (chlorite, white mica, and biotite/stilpnomelane) is visible in metapelitic rocks and metamorphic differentiation and fluid circulation are suggested by widespread metamorphic quartz segregation as bands and veins.

Padeş Formation

(Supragetic basement, Poiana Ruscă Mountains)

The pre-Mesozoic basement of the northern Poiana Ruscă Massif exposes Palaeozoic successions of low-grade metasedimentary rocks and minor associated volcanic rocks as well as medium-grade, polymetamorphic lithological assemblages of uncertain/undated Neoproterozoic - ?Early Palaeozoic age (Balintoni & Iancu, 1986). Older published papers and geological maps of this area contain the so-called "epimetamorphic" series (Kräutner et al., 1969) considered as metasedimentary/metavolcanic successions of ?Ordovician/Silurian - Devonian - Early Carboniferous age, with a presumed gap at the Silurian-Devonian boundary (Kräutner et al., 1981; Mureşan, 2000).

The separation of the ?Lower Palaeozoic clastic succession (Pades Formation) in respect with younger Upper Devonian - Lower Carboniferous (mainly carbonate-dolomite strata) as well as both of them in respect with the older polymetamorphic rock assemblages, was realized by Balintoni & Iancu, (1986) based on regional structural profiles and petrological studies. Anyway, a high degree of uncertainties remains concerning the age data of the mentioned Palaeozoic successions, their tectono-stratigraphical relationships and metamorphic-deformational events.

The Padeş Formation is a monotonous sequence of metasedimentary rocks (pelites, sandstones) with minor associated acid metatuffs and rhyolites. Pre-metamorphic structures and mineral phases are preserved in both, sedimentary (blastodetrital structures, Kräutner *et al.*, 1981) and magmatic rocks (quartz and K-feldspar fenocrysts, Balintoni & Iancu, 1986). The described metamorphic equivalents of the mentioned rocks are quartz-sericite/-stilpnomelane phyllites, quartz-muscovite-biotite-chlorite schists, quartz-albite-epidote-muscovite schists, and metarhyolites.

The Padeş Formation crops out in two separate areas, as tectonically bounded remnant sequences because of the Alpine/Cretaceous nappe structures and no relationships with other Palaeozoic formations are observed.

The prograde metamorphism of this lithological association attained chlorite/stilpnomelane and biotite zones of the greenschist facies (Papiu, 1956; Kräutner *et al.*, 1981) and retrograde readjustment is at the chlorite zone level. The S_1 foliations are dominant and B_1 folds are of small scale (intrafolial) or of larger, mesoscopic scale; B_2 folds and S_2 cleavages and crenulation were reported by all the mentioned authors. The "early Caledonian" deformation claimed by (Kräutner, 1987) as responsible for the metamorphic evolution of this sequence could be related to a pre-Late Devonian tectogenetic period (?Eo-Variscan, *sensu* Ledru *et al.*, 1994, Faure *et al.*, 1997), as K/Ar data of 363, 313 and 329 Ma were reported for different parts of the "epimetamorphic" succession (Kräutner *et al.*, 1973).

4.2.2. Middle Palaeozoic (Upper Devonian - Lower Carboniferous)

Moniom Group: Valea Satului-Lescoviţa and Cârşie formations

This megasequence was separated and defined by Iancu (1985a) based on detailed mapping and petrological studies of low-grade pre-Mesozoic rock assemblages exposed in the Supragetic nappe complex (Iancu, 1985b).

The age of the entire megasequence is ?Middle/Late Devonian - Early Carboniferous based on palynological content (Visarion & Iancu, 1984). No direct relationships with previously described Lower Palaeozoic sequences and

?Neoproterozoic polymetamorphic basement is known for the Valea Satului Formation, while Lescovița Formation, cropping out in the western part of the Locva massif (Maier, 1974; Maier & Visarion, 1976) tectonically underlies Caraş Group formations. Similar sequences crop out south of Danube, in the Morava zone (Milosavljevic, 1993).

This metamorphosed megasequence has a thin unconformable cover of Upper Carboniferous conglomerates and thick sequences of unmetamorphosed clastic deposits (conglomerates, sandstones and coal bearing pelites) resting on the composite basement of the Getic nappe crop out in the underlying Cretaceous Getic nappe (Năstăseanu *et al.*, 1981; Iancu, 1985b).

The sedimentary succession, established after detailed mapping of the folded and metamorphosed formations of the Monion Group, includes two well defined lithological associations: the Valea Satului volcano-sedimentary Formation and the Cârşie Formation. They represent a continuous succession of approximately 400 to500 m thickness; the top of the succession is truncated by a Variscan thrust fault, but conglomerate beds of Early Carboniferous age were used as markers in establishing the whole megasequence.

Valea Satului-Lescovița Formation

Alternating sedimentary clastic-carbonate and volcaniclastic rocks are intimately associated with basic-acid volcanic rocks and isolated basic magmatic rocks (gabbros, diorites) are also present as deformed bodies. From bottom to top, the sequence includes: metapelites-metasiltstones with metric carbonate beds; basic tuffs and coarse-grained volcaniclastic (greenish-purple agglomerates); metapelites-metasiltstones with metric marls and limestones beds; quartz-feldspar-rich sandstones and felsic tuffs. At the upper part of the formation, scarce metric metaconglomerates layers are interbedded in metasandstones.

Palynomorphs in metapelitic rocks include specific spores for Devonian as *Retusotriletes*, *Archeozonotriletes* and *Brochotriletes*, but Devonian-Carboniferous, large circulation genera, as *Punctatisporites*, *Leiotriletes*, *Convolutispora*, *Lophotriletes* were also identified (Visarion & Iancu, 1984). A special significance was mentioned for more evolved morphological features of some spores (*Hymenozonotriletes*, *Auroraspora*, and *Samarisporites*), pointing to a developing Middle Devonian macroflora. Associated acritarchs (*Hyrtellosphaeridium adductus, Hyrtellosphaeridium microsaetosum*) are small, circular in form, suggesting a Late Devonian age (Staplin, 1961, referred in Visarion & Iancu, 1984).

Cârşie Formation

This formation consists of mainly coarse-grained (conglomerates, microconglomerates) clastic rocks grading to finer-grained (siltstones, pelites) rocks; the coarse-grained conglomerates (with tens of centimetre-size boulders) are generally massive and unsorted, but intimately alternating metre to decametre-size beds are also present and upward coarsening sequences seem to be the youngest terms. Sedimentary structures, as graded bedding and sorted clasts are frequently preserved.

The Upper Carboniferous age of this formation was deduced on the base of spores content (Visarion & Iancu, 1984). Besides of some large circulation genera in the Carboniferous (*Leiotriletes*, *Granulatisporites*, *Apiculatisporites*), other Lower Carboniferous specific forms were identified (*Densosporites*, *Convolutispora*, *Verrucosisporites*). Other identified forms of *Waltispora* and *Tripartites* genera reported in Visean and Namurian (Clayton *et al*., 1977; Turneau, 1979, referred in Visarion & Iancu, 1984) support the pre-Westphalian age of the described formations.

The general structure involving the Moniom Group succession is characterized by NE – SW-oriented kilometre-scale open folds with a major anticline plunging to SW and two additional synclines, partly cut by thrust faults.

Metre to decametre-size open folds of the bedding are visible in outcropping coarse-grained or massive sequences but sub-metric folds and penetrative S_1 cleavages and foliations are present in interbedded fine-grained rocks (e.g. siltstones, pelites, marls and limestones). Inside of the folded conglomerate-sandstone beds, differentiated internal structures suggest a pure-shear type deformation and metamorphic blastesis which is controlled by bedding while interstratified sequences are characterized by S_1-related neoformation paralleling cleavage and schistosity.

Volcaniclastic and magmatic rocks are usually strongly sheared even if pre-metamorphic fabrics are recognizable.

The prograde regional metamorphism corresponds to lower greenschist facies and is revealed by neoformation of chlorite, actinolite, albite, epidote/clinozoisite, calcite in basic metamagmatic rocks and chlorite, white mica and quartz in clastic rocks. Actinolite, sometimes S_1 oriented, and calcite is dominant metamorphic phases in marbles and limestones.

The age of the folding and related metamorphism is late Variscan (Sudetic phase), as constrained by Early Carboniferous protolith ages and by unmetamorphosed Westphalian-Permian sedimentary cover in Getic-Supragetic Domains (Năstăseanu *et al*., 1981).

Younger, simple shear deformation effects are spectacular in the mylonitic conglomerates at the eastern (lower) tectonic boundary whose matrix was dynamically recristallysed; an $^{40}Ar/^{39}Ar$ whole-rock age dates this Middle Cretaceous thrust at 118 Ma (Dallmeyer *et al*., 1994).

Hunedoara-Luncani Formation

This sequence was identified as a limestone-dolomite formation inside of the "epimetamorphic" rock assemblages, mapped and described as a part of the "Poiana Ruscă Group", a sedimentary succession of Silurian-Devonian-Early Carboniferous age (Kräutner *et al*., 1981; Mureşan, 2000).

The redefined Hunedoara-Luncani Formation (Balintoni & Iancu, 1986) is a Middle Palaeozoic, carbonate, mainly dolomite, platform-type sequence unconformably overlying older medium grade polymetamorphic rock assemblages of Neoproterozoic age. The stratigraphic unconformity is also underlined by a structural-metamorphic discordance.

The Hunedoara-Luncani Formation is a thick carbonate succession (1500-3000 m) of reef dolomites and limestones (Papiu *et al*., 1963) with thin interbeds (decimetre- to metre-sized) of siltic-pelitic rocks; thin and discontinuous beds of quartz-carbonate sandstones underline the base of the carbonate succession. A metre-scale bedding and lamination is visible in many outcrops.

Its Early Carboniferous age was established on the base of palynological content including *Leiotriletes gulaferus*, *Leiotriletes adnatus*, *Dictyotriletes gulaferus* (Iliescu, in Kräutner *et al*., 1973).

At regional scale, large synclines of carbonatic rocks crop out between antiforms of polymetamorphic, retrograded rocks. The internal structure is controlled by metre- to decametre-size bedding of the carbonatic rocks, but small scale S_1 foliations parallel to S_0 are visible in clastic beds, as well as penetrative S_2 cleavages (Kräutner *et al*., 1981; Balintoni & Iancu, 1986).

The prograde metamorphism is at lower greenschist facies conditions as chlorite, sericite, epidote, quartz and carbonates recrystallization are widespread. K/Ar age values of 320-275 Ma (Kräutner *et al*., 1973) suggest a late Variscan tectono-metamorphic event and are in good agreement with geological data.

5. Lithostratigraphic chart and correlation of Palaeozoic formations

The lithological features of the described successions are extremely diversified as a consequence of the depositional and geotectonic setting in Palaeozoic time as illustrated in the simplified lithostratigraphic chart from Fig. 5.

Pre-Upper Carboniferous low-grade Palaeozoic formations

Direct correlation of the low-grade metamorphosed Palaeozoic successions discontinuously preserved in the different units of the South Carpathian basement are difficult to realize but an attempt will be presented, following the figured lithostratigraphic columns (Figs 4A & B) and chart (Fig. 5).

A. Danubian basement (Figs 4A & 5)

Pre-Upper Ordovician to lower Silurian sedimentary remnant sequences are preserved only in the Internal Danubian basement and they are associated with the inverted rift related to latest Neoproterozoic ophiolites (Tişoviţa-Iuţi and coeval mafic-ultramafic complexes south of Danube, Serbia) and ?Cambrian-?Ordovician remnant sedimentary deposits (Ieselniţa and Nijudimu formations). The described ophiolitic-sedimentary and tectonic "suture" (Fig. 4A) marks a pre-Silurian nappe stack and plate boundary involving different Pan-African terranes (Seghedi *et al*., this volume): the Drăgşan terrane (oceanic and island-arc related terranes), in the uppermost pre-Westphalian nappe piles and the Lainici-Păiuş terrane (terrigenous, platform-type successions), in the lower units (Fig. 3).

?Late Ordovician successions of coarse-grained green conglomerates-sandstones-breccias grading to finer grained clastic rocks (Brustur Formation) crop out in the Internal Danubian basement and they are sourced from the pre-Ordovician ophiolitic palaeosuture and reactivated Pan-African basement units and mark a remnant accretionary basin. The pre-Upper Devonian, post-nappe granitoids cropping out north of Danube (Figs 3 and 5) suggest a continental magmatic arc environment in a convergent plate boundary. Its palaeotectonic position could be the frontal part of the Variscan orogenic belt (*sensu* Matte *et al*., 1990) or its northern foreland, suggesting Avalonian affinities (*sensu* Winchester *et al*., this volume)

All the described pre-Silurian formations are characterized by deformation in various metamorphic conditions (from anchizone to greenschist and epidote-amphibolite facies) and thrust related tectonics.

?Upper Ordovician-lower Silurian shallow marine deposits (Valea Izvorului and Coarnele formations), are preserved in the External Danubian basement and unconformably seal older Pan-African metamorphic-magmatic complexes in a passive continental regime; no direct relationships with older Palaeozoic formations are known.

Upper Devonian-Lower Carboniferous continental successions (Valea de Brazi and Poiana Mică formations) crop out in the external Danubian basement while shallow-marine, platform-type deposits (Ideg Group) are preserved in the internal Danubian basement. These formations unconformably cover the older described rock assemblages and display very low-grade metamorphism related to a pre-Permian, late Variscan deformation event.

B. Getic-Supragetic basement (Figs 4B & 5)

Ordovician volcano-sedimentary sequences are preserved in the Getic-Supragetic basement and are represented by: the Buceava Group (eastern Banat and corresponding units south of Danube, Kräutner & Krstić, 2002), a volcano-sedimentary formation marking a back-arc rift basin in a suprasubduction environment; the Caraş-Locva Group (western Banat and Serbo-Macedonian terranes; Karamata, 1982; Dimitrescu, 1990; Kräutner & Krstić, 2002) and the Leaota Group (easternmost South Carpathians and parts of the Tulgheş Group, East Carpathians; Kräutner, 1987), represented by volcano-sedimentary associations and basic or bimodal magmatic rocks, suggesting a large scale intracontinental rift. Different by these, a dominant terrigenous succession (probably sourced by a continental environment) with minor acid volcanics (Padeş Formation) is preserved in the westernmost Supragetic basement.

?Upper Ordovician-?Silurian (undated) quartzites and sandstones (Tâlva Mare Formation) unconformably overly polymetamorphic basement of probable Neoproterozoic age and suggest the deposition of mature sediments in a shallow-marine continental passive margin.

Upper Devonian-Lower Carboniferous formations with contrasting lithologies are present in two different areas and continental geotectonic settings: a volcano-sedimentary formation grading to coarse-grained clastics (Moniom Group, in the western Banat area) and a carbonatic, platform-type sequences (Hunedoara-Luncani Formation, in the Poiana Ruscă massif).

Upper Carboniferous-Permian deposits

Upper Carboniferous-Permian sedimentary deposits are represented by continental clastic successions, bearing coals and plant remnants (Biţoianu, 1973; Antonescu & Năstăseanu, 1976; Semaka, 1970; Popa, 1999) sometimes associated with basic or acid volcanic rocks (Stan, 1987; Seghedi *et al*., 2001). They are preserved in both Danubian and Getic-Supragetic Domains as unconformable continental cover deposits with molassic characteristics (Năstăseanu *et al*., 1973; Seghedi *et al*., 2001) laying on metamorphosed sequences of Palaeozoic-Proterozoic age and different associated granitoid suites.

The Upper Carboniferous-Permian continental, sometimes coal-bearing deposits (as e.g. Reşiţa Basin), cropping out in the Getic-Supragetic Domain (Fig. 4, simplified from Năstăseanu *et al*., 1981) are related to crustal extensional basins (Seghedi *et al*., 2001) formed at the collapse stage of the Variscan orogeny (Năstăseanu *et al*., 1973) as in classical terranes from the European foreland of the Alpine belt (e.g. Ledru *et al*., 1994; Matte, 2001). The underlying basement units include, besides of low-grade Palaeozoic successions, and Variscan nappe stacks involving gneissic terranes with widespread eclogite, granulite and subordinate peridotite bodies (Iancu *et al*., 1998; Medaris *et al*., 2003).

In the Danubian Domain, Late Carboniferous-Permian volcano-sedimentary deposits are present in some continental basins (e.g. Sirinia and Presacina, Fig. 3) or as thin (condensed) cover deposits; they are mainly red conglomerates and sandstones associated with rhyolites and pyroclastic rocks (Stan *et al*., 1986; Stănoiu& Stan, 1986; Seghedi *et al*., 2001) sometimes lying directly on metamorphic-magmatic Pan-African assemblages, suggesting deposition on highly exhumed or eroded older terranes.

6. Discussion

Both Danubian and Getic-Supragetic basements are characterized by thin and discontinuous low-grade Palaeozoic successions marking two sedimentary cycles: during the Cambrian-Ordovician-Silurian period and the second during the Late Devonian - Early Carboniferous; their geotectonic settings and tectono-metamorphic evolution are, however, different.

During the Early Palaeozoic, the *Danubian basement* was the closest terrane to the Moesian basement, whose thick Palaeozoic marine successions lack evidence of deformation and metamorphism.

The Lower Danubian basement preserves a thin and condensed ?Upper Ordovician - lower Silurian cover of mature quartzites-sandstones, unconformably overlying Pan-

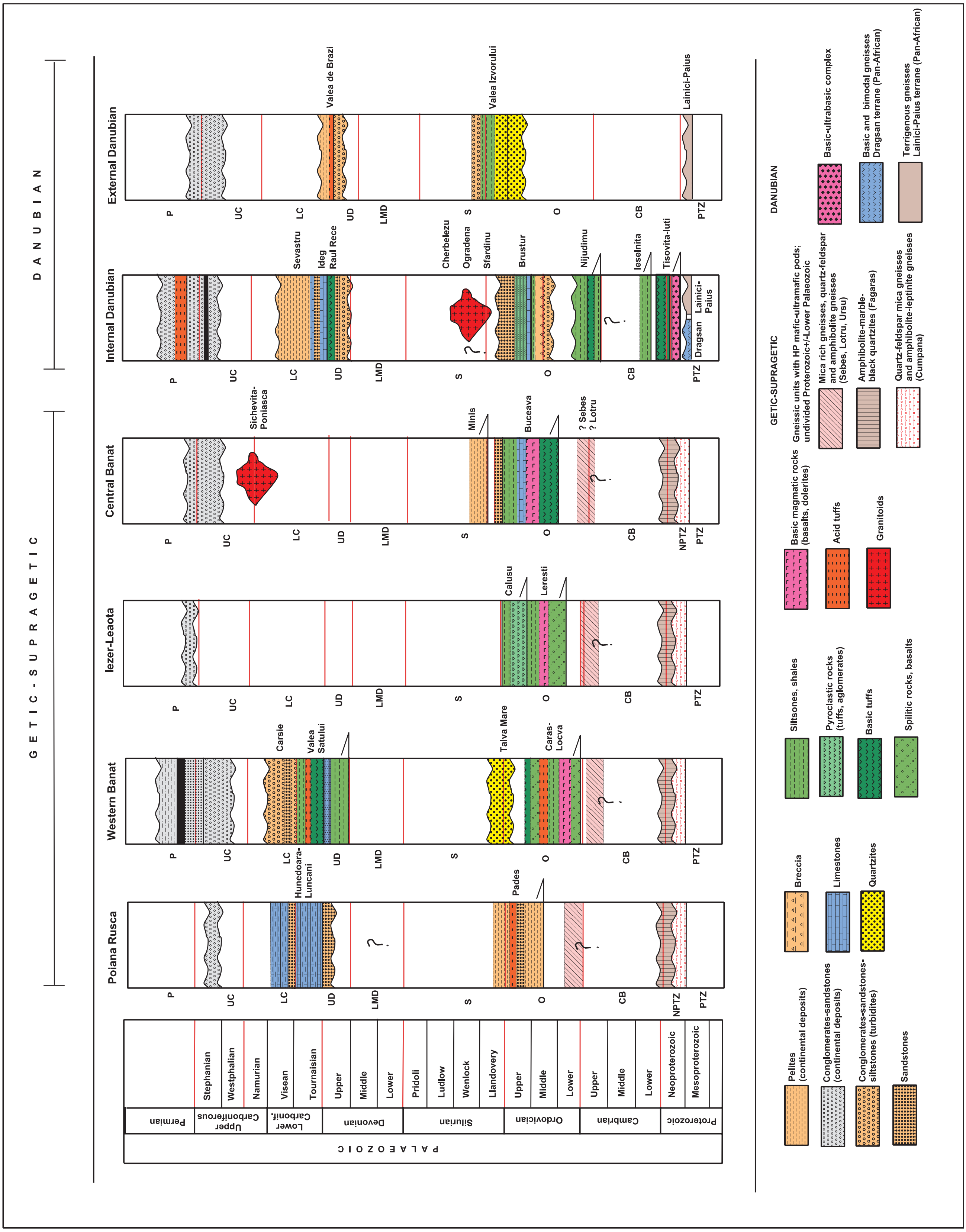


Figure 5. Lithostratigraphic chart of the Palaeozoic low-grade successions, the associated magmatic rocks and Neo-Proterozoic basement from the South Carpathians (Danubian and Getic-Supragetic Alpine units).

African basement units, suggesting a passive continental margin related to the northern Gondwana continent (Winchester *et al*., this volume).

Different by this, the Upper Danubian basement incorporated a Late Neoproterozoic-Early Palaeozoic short-living mobile belt involving two different Pan-African terranes and an ophiolitic-sedimentary-tectonic suture zone, later crosscut by magmatic arc granitoids. This palaeosuture represents a clue for deciphering the Phanerozoic history of the European Variscan foreland, now incorporated inside the alpine belt.

The deposition of unconformable Upper Devonian-Lower Carboniferous clastic-carbonatic, shallow-marine successions affected by late Variscan deformation in very-low-grade conditions marks a sedimentation and deformation break, probably related to pre-Upper Devonian convergent/collision processes. Upper Carboniferous and Permian red beds unconformably overly the older deformed sequences, as the sole of the Jurassic-Cretaceous cover.

The *Danubian basement* preserves geological proof for an Early Palaeozoic (pre-Silurian) magmatic arc activity following the closing of a Late Neoproterozoic suture (ophiolites and deep marine basin remnants), which is characterized by a short living mobile belt including nappe stacking and tectonic inversion in Middle Palaeozoic (?pre-Late Devonian) time. Possible correlation with Avalonian terranes can be envisaged (Winchester *et al*., this volume), but late Palaeozoic pre-Permian contraction and nappe emplacement in the Danubian basement may be compared with Moravian terrane, involving also Cadomian cores (Brunovistulicum, Schulmann *et al*., 1991). This assumption is also supported by Neo-Variscan deformation in low-grade conditions of the Upper Devonian-Lower Carboniferous platform-type deposits lying on the Neoproterozoic basement.

The most external part of the Phanerozoic Danubian domain can be correlated with the westernmost part of the Palaeozoic Moesian Platform, while suspect terranes of a latest Neoproterozoic-Early Palaeozoic ophiolitic-sedimentary-tectonic suture zone, preserved in the Upper Danubian basement, could be a part of the Variscan front and its northern foreland including Moravian and/or Avalonian remnant terranes (Verniers *et al*., 2002; Winchester *et al*., this volume).

The Getic-Supragetic basement incorporated well-preserved rock assemblages of medium-HP metamorphics of oceanic and continental origin, resembling the Variscan terranes and history (Ledru *et al*., 1997; Medaris *et al*., 2003) from the Bohemian massif, suggesting possible Rheic (Early Palaeozoic) and Armorican (Neoproterozoic) affinities. Also the Getic-Supragetic basement includes, in its external (western) parts, Early Palaeozoic, low-grade successions with intracontinental features while the Late Devonian-Early Carboniferous rocks are continental volcano-sedimentary and carbonatic, platform type successions.

The Palaeozoic tectono-metamorphic evolution of the *Getic-Supragetic basement* can be assigned to the Variscan polystage evolution (Iancu *et al*., 2003) and compared with terranes from the Variscan belt of western Europe: the “Eo-Variscan” extension (older than 425 Ma), corresponds to Ordovician oceanic opening (Rheic and Galicia-Southern Britany oceans; Matte, 2001), while the middle Variscan (425-375 Ma) and Neo-Variscan (350-320 Ma) periods can be related to a convergent and collisional Variscan (Hercynian) cycle (Ledru *et al*., 1994; Faure *et al*., 1997; Roig, 1997; Matte, 2001).

7. Conclusions

The Palaeozoic rock assemblages are preserved in both Getic-Supragetic and Danubian basements of the Cretaceous nappe stacks and they are represented by:

a. The latest Neoproterozoic-Early Palaeozoic pre-orogenic, extension- and rift-related magmatic complexes

They are associated to dismembering of older continental plates (Gondwanan- or Cadomian-derived and opening of new oceanic domains (Rheic ocean, *sensu* Matte, 2001) and separating different continental microplates largely corresponding to Avalonia and Armorica (Winchester *et al*., this volume).

The mafic-ultramafic ophiolitic complex cropping out in the Upper Danubian basement, north of Danube, includes (Mărunţiu *et al*., 1997; Seghedi *et al*., this volume): mantle peridotite (harzburgite and dunite-chromitite pods); layered cumulate rocks of ultramafic to mafic composition (dunite, troctolite, gabbro) with minor intrusions (clinopyroxenite); subordinate plutonic effusive rocks (isotropic gabbro, basalt, dolerite), all of them tectonically dismembered and involved in Palaeozoic, pre-Westphalian inversion processes (Iancu, 2004). The age of this pre-Westphalian ophiolites complex is still debated (Late Neoproterozoic-Early Palaeozoic), as only one zircon age of U/Pb 563±3Ma (von Quadt *et al*., 1998) was determined for Tcherni Vrah ophiolites massif (south of Danube; Savov *et al*., 2001). This ophiolites complex together with Lower Palaeozoic formations marking a pre-Westphalian palaeosuture and plate boundary (Iancu *et al*., 1997a) could be related to the opening of an oceanic domain (?Rheic) in the northern peri-Gondwana (including the pan-African belt) divided in Avalonia and Armorica microplates.

b. The pre-Late Carboniferous (pre-Westphalian) sedimentary and volcano-sedimentary successions (and their metamorphosed equivalents)

Palaeontologically dated pre-Westphalian sedimentary and volcano-sedimentary lithological assemblages belong to the ?Cambrian-Ordovician-Silurian and Upper Devonian-Lower Carboniferous in the Danubian and Getic-Supragetic basements. There are few and uncertain reported data as arguments for continuous successions corresponding to the upper Silurian-Middle Devonian(Fig. 5).

Pre-Palaeozoic gneissic units figured on the presented maps (Figs 2 and 5) were generally referred to as thick lithostratigraphic series of Pan-African Neoproterozoic ages in the Danubian basement (Lainici-Păiuş and Drăgşan terranes) and of Neoproterozoic/-Early Palaeozoic ages in the Getic-Supragetic basement (Cumpăna, Făgăraş, Sebeş, Lotru and Ursu terranes/units).

Discontinuous Palaeozoic rock-sequences/successions (Figs 3 and 5) are preserved in the Danubian Domain as unconformable covers resting directly on Neoproterozoic basement as Valea Izvorului and Coarnele formations (Early Palaeozoic) and Râul Rece-Sevastru or Valea de Brazi and Poiana Mică formations (Devonian-Lower Carboniferous). Other dismembered successions display tectonic relationships with older Early Palaeozoic-Neoproterozoic metamorphic and magmatic complexes (e.g. Nijudimu and Brustur formations).

Palaeozoic successions cropping out in the Getic-Supragetic are grouped in:

Lower Palaeozoic (Ordovician-Silurian) sequences: Caraş-Locva and Leaota Groups; Buceava Group; Miniş, Tâlva Mare and Padeş formations;

Middle Palaeozoic (Upper Devonian-Lower Carboniferous sequences): Moniom Group and Hunedoara-Luncani Formation.

c. Palaeozoic granitoids spatially associated to different metamorphic-magmatic terranes

Palaeozoic subduction and collision type granitoid suites mark magmatic arcs developed in different time spans of Early and/or Middle toLate Palaeozoic (Variscan) tectono-magmatic events. Except of widespread anatectic and intrusive granites inside of the gneissic terranes, the most important Palaeozoic plutonic granitoids, related to

Neoproterozoic Drăgşan terrane and Lower Palaeozoic successions, crop out in the Upper Danubian basement (Figs 2 and 3) marking a pre-Westphalian or even a pre-Devonian magmatic arc (Ogradena, Cherbelezu, Sfârdinu and ?Muntele Mic massifs; Stan, 1982; Iancu, 1998). Field relationships and tectonic position of the mentioned granitoid suites are diversified and a longer Palaeozoic geotectonic history can be presumed. The largest intrusive granitoids cropping out in the Lower Danubian basement are figured as Neoproterozoic in age (Fig. 2) in base of the known age determinations (Liégeois *et al*., 1996; Berza *et al*., 2002). Inside of the Getic basement, Carboniferous, late Variscan intrusions (Sicheviţa-Poniasca granitoids) crosscut a folded nappe stack involving also Paleozoic formations but are reworked in Westphalian-Permian molasse deposits (Iancu, 1998).

The tectono-metamorphic features of the Palaeozoic formations and the preserved (inherited) Pan-African/ Cadomian basement units, now incorporated in the South Carpathian thrust belt (Getic-Supragetic and internal Danubian), allow us to identify different crustal fragments involved in the Variscan tectogenetic events as amalgamated and/or tectonically juxtaposed pre-alpine tectono-stratigraphic units and nappe piles (Figs 2 and 3). The deformation and low-grade metamorphism of the Lower Palaeozoic formations and their Pan-African basement from the external Danubian could be effects of "pre-Variscan", Acadian events, as described in the Variscan foreland or Avalonian terranes (Verniers *et al*., 2002; Winchester *et al*., this volume). Different by these, the Palaeozoic successions from the Moesian Platform are clearly related to areas situated outside of the Variscan front and do not show any effects of regional deformation and metamorphism.

d. Upper Carboniferous-Permian sedimentary deposits and related magmatic rocks

The Westphalian-Permian sedimentary deposits from the South Carpathians (Getic-Supragetic and Danubian) are continental, molassic deposits (Năstăseanu *et al*., 1981; Popa, 1999) related to the collapse stage of the Variscan cycle. They formed in extension-related basins or as alluvial to fluvial deposits (Seghedi *et al*., 2001). The main sedimentary successions (Resiţa and Sirinia basins) contain coal layers (Figs 3 and 4), plant remnants and palynological associations specific for the Upper Carboniferous-Permian time span: pteridophytes, pteridosperms, conifers (taxonomic revision, Popa, 1999), as well as fauna content (fresh water bivalves). Permian volcaniclastic-epiclastic deposits are interbedded with continental red beds (Seghedi *et al*., 2001) and associated with acid (rhyolites, dacites) or bimodal volcanic rocks (especially in the Danubian Domain), suggesting a magmatic activity related to uplift/extension processes following the continental Variscan collision.

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