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203 - 212

PRE-ALPINE EVOLUTION IN THE SOUTHERN CARPATHIANS AND ADJACENT AREAS

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Abstract: Different associations of pre-Alpine metamorphic rocks were conserved in the main Alpine tectonic units of the Southern Carpathians: Supragetic, Getic, Danubian. Prior to the Alpine cycle they were joined by Variscan napping and by pre-Variscan tectonic transport on the deep-seated ductile shear zone. Thus, the Alpine units include fragments of the Variscan continental crust with different geological evolution in the Paleozoic and in the pre-Cambrian.

Key words: Southern Carpathians, basement, Variscan nappes, pre-Variscan shear zones.

Position in the Alpine belt

The Southern Carpathians include the inflexion of the European Alpine chain in front and to the north of Stilles's "Walachischer Sporn", covered by the Paleozoic and Mesozoic sedimentary sequence of the Moesian Platform. They are cut by the Danube and extend geographically from the Prahova Valley in Romania to the Timoc Valley in Serbia. Geologically they are interposed between the mentioned Moesian Platform of the foreland and the Tethyan ophiolitic suture, represented by the Vardar Zone (partly covered by sediments of the Pannonian Depression) and by the Mures Zone (in the Southern Apuseni Mts. and in the basement of the Transylvanian Depression; Fig. 1).

The main structural units of the Southern Carpathians belong to the Median Dacides (Getic and Supragetic units), thrust over the Marginal Dacides (Danubian units), squeezing between them elements of the External Dacides (Cretaceous Sinaia-type flysch; Debelmas et al. 1980; Sandulescu 1984) - Fig. 1.

The Median Dacides are represented by pre-Cambrian and Paleozoic metamorphics and a Mesozoic sedimentary cover, grouped in two main sets of Alpine nappes - the Getic and Supragetic units. To the south the Getic units extend in the Sredna Gora and the Supragetic units in the Rhodopes. Northwards the Supragetic units continue in the Central Eastern Carpathian nappes - Bucovinian, Subbucovinian, Infrabucovinian (Fig. 1).

The Marginal Dacides, represented in the Southern Carpathians by the Danubian units, consist mainly of granitoids and pre-Cambrian medium-grade metamorphics, covered by low-grade metamorphic Paleozoic and Mesozoic sequences as well as by the Mesozoic sediments. They extend towards the south in the Bulgarian Stara Planina. In the Eastern Carpathians the equivalents of Danubian units are hidden below the flysch units of the External Dacides and are probably cut by those overthrust on the Moldavide flysch.

As it is shown in Fig. 1 the Median Dacides do not continue in the Slovak Western Carpathians and in the Alps. The Pieniny Klippen Belt and the Magura flysch nappe of Miocene tectogenesis are interposed. The Magura flysch overthrust the Oligocene post-tectonic cover of the Bucovinian Nappe systems and was overriden in its term by the Pieniny Klippen Belt and the Western Carpathian metamorphics, assigned by Sandulescu (1984) to the Internal Dacides.

According to the geotectonic model of Debelmas et al. (1980) the Pieniny Zone represents the trace of the Tethyan suture. This statement involves an African affinity for the metamorphics of the Slovak Western Carpathians and Austro-Alpine units of the Alps (Internal Dacides). Taking into account the geological resemblances between the Eastern and the Western Carpathians, it seems more likely that the Pieniny Zone in fact represents the trace of an intracontinental rifting zone inside the European continental realm (Kräutner 1991). This implies a common European affinity for the Slovak (Tatro-Veporide, Gemeride) and the Romanian Internal Dacides (Bihor unit and Codru-Biharia nappe system) as well as for the Median Dacides. This means that they had a common evolution in the Cretaceous shortening and were separated later by the Neozoic tectogenesis. According to this assumption the position of the Tethyan oceanic crust of the Mures Zone (Transylvanides), between the Apuseni Mts. and the Southern Carpathians, could be explained by a system of transform faults, that was active prior to the Meso-Cretaceous napping and to the Laramian obduction.

The Alpine structure

In the Southern Carpathians the Alpine nappe structure was mentioned in the past (Murgoci 1905) since nappes have been recognised in the European Alpine Belt. Thus, the Danubian Tectonic Window and the Getic Nappe with the Godeanu outlier were separated (Murgoci 1905); later, Codarcea (1940) recognised the Severin Nappe as a rootless Sinaia-type flysch, squeezed between the mentioned units, and Streckeisen (1934) described Supragetic nappes, superposed on the Getic Nappe. For more than fifty years these four tectonic units have been generally accepted as the main Alpine structural elements of the Southern Carpathians (Fig. 2). Recent researches have led to a more detailed mapping and provided proof that the mentioned units have in fact a highly complicated internal structure,

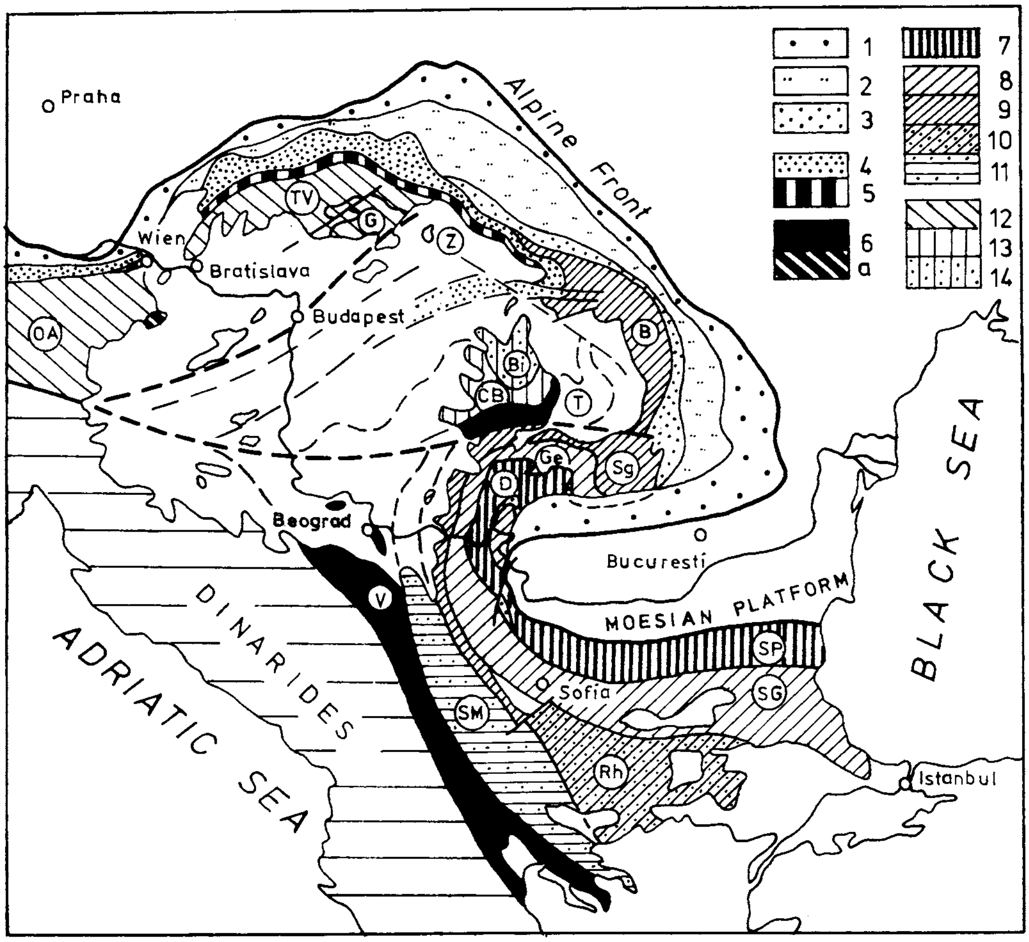

Fig. 1. The main structural units of the Eastern Alps-Carpathians and Balkans (tectonic model after Sandulescu 1984; Kräutner 1988).
Legend: 1 - Neogene molasse deposits; 2 - Moldavides (Neozoic flysch); 3 - External Dacides (Cretaceous flysch); 4 - Magura and Rheno-Danubian flysch; 5 - Pieniny Klippen Zone; 6 - ophiolite zone (Tethyan suture), Transylvanide (T), Vardar zone (V); 6a - Rechnitz Window; 7 - Marginal Dacides (D - Danubian, SP - Stara Planina); 8-11 - Median Dacides: 8 - Getic units (Ge) and Sredna Gora (SG), 9 - Supragetic units (Sg); 10 - Rhodopian units; 11 - Serbo-Macedonian "Massif"; 12-14 - Internal Dacides: 12 - Ost-Alpine (OA) and Tatro-Veporide (Tv) units, 13 - Codru and Biharia units (CB), 14 - Bihor unit (Bi).

due to both Alpine overthrusts and pre-Alpine nappe structure. Regarding only the Alpine history there is evidence that the mentioned structural framework was accomplished successively in the Meso-Cretacoeus and in the Laramian tectogenesis as well as by post-Eocene and/or Oligocene readjustments. Thus, the Getic overthrust surface around the Danubian Window is Laramian, whereas the relationship between Getic and Supragetic units are both Meso-Cretaceous and Laramian.

In the Neozoic some of the nappe surfaces have been cut by improtnant fault systems (Fig. 2), probably related to the demanteling of the Danubian Tectonic Window. The mentioned Alpine tectonic units consist mainly of metamorphic rocks and of an Upper Paleozoic - Mesozoic sedimentary cover (Fig. 3). In the lower units (Danubian) some of the sedimentary sequences (including Upper Cretaceous) were affected by low-grade Alpine metamorphism (chloritoid, pyrophyllite, antracite, chlorite, sericite). The pre-Alpine metamorphics generally differ in the mentioned main Alpine units, suggesting a heterogeneous petrographic and tectonic character of the Paleozoic (Variscan) crust in the realm where the Alpine cycle of sedimentation started. Fig. 3 also shows how the deformation due to the Alpine crustal shortening migrated from the internal part of the chain (Meso-Cretaceous) towards the Moesian foreland (Laramian and Miocene).

The pre-Alpine crust

Excluding the Upper Paleozoic molasse (Upper Carboniferous, Permian), the whole pre-Alpine crust was metamorphosed. Definitely different metamorphic events may be recognised (Variscan and pre-Variscan), but it is obvious that the Variscan event involved the whole, including both Paleozoic sedimentary sequences and pre-Variscan metamorphics. This statement is supported by most of the radiometric ages.

Two types of the pre-Alpine geological relationships between Variscan and pre-Variscan metamorphics may be recognised:

1 - tectonic unconformity due to overthrusts. Pre-Alpine nappe structures have been proved within the Inner and Median Dacides in the Eastern Carpathians (Balintoni 1981; Muresan 1983; Sandulescu 1984; Kräutner 1991) and in the Western Carpathians (Grecula 1987). In the Southern Carpathians they extend over large areas in the Supragetic, Getic and Danubian Alpine units. Direct proof of the pre-Alpine age of these tectonic contacts was mentioned only in the Danubian realm (Fig. 4), where they are covered transgressively by both Permian sediments (Upper Danubian - Cordacea 1940) and Jurassic sequences of low-grade metamorphism (Lower Danubian - Berza 1970). The nappe surfaces are marked by intensive lamination

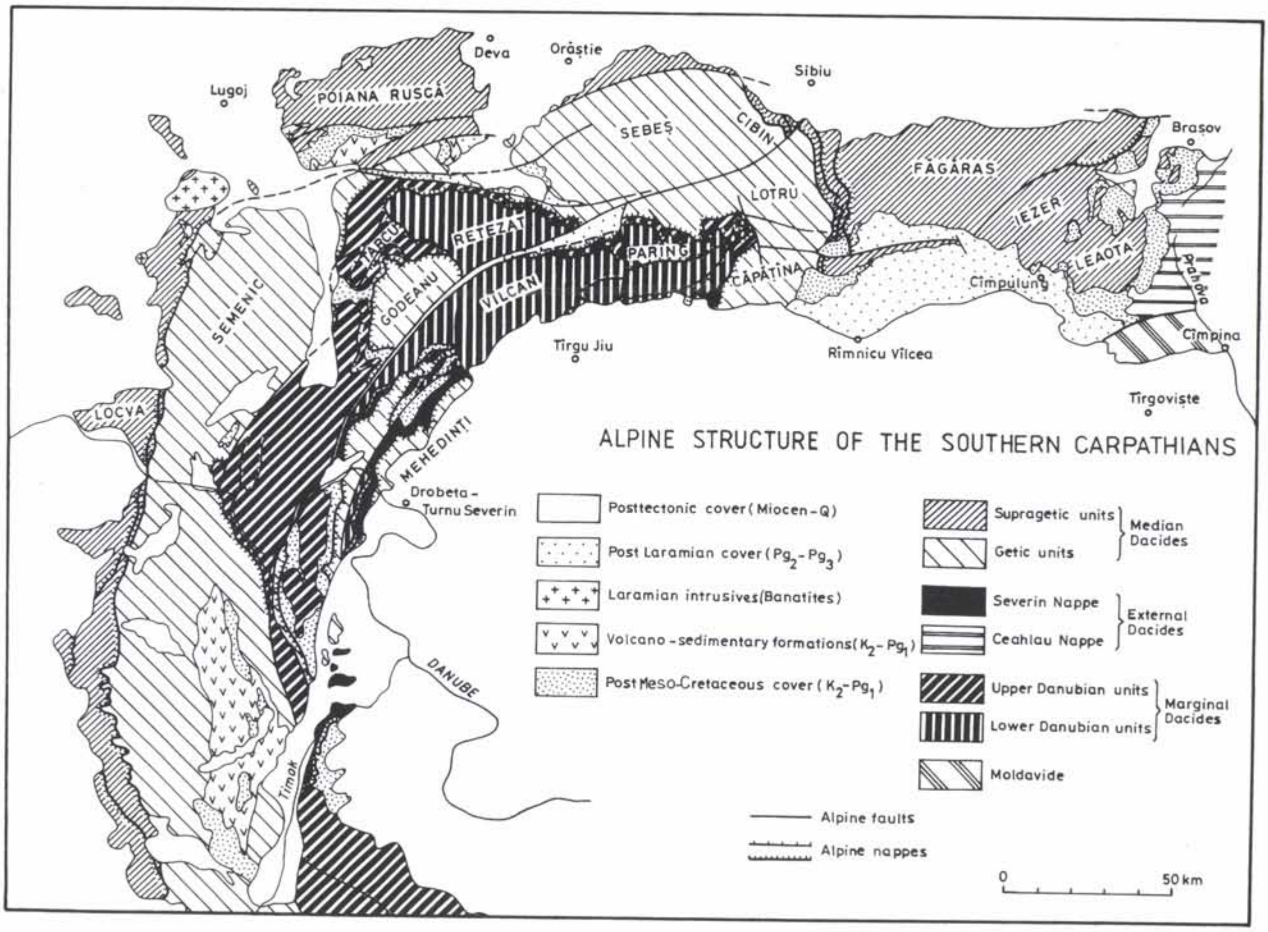

Fig. 2. The main Alpine tectonic units of the Southern Carpathians.

and by zones of dynamic retromorphism, extended on some hundreds of metres above and below the tectonic contacts (Fig. 5). In the last years pre-Variscan napping was argued in the Southern Carpathians based on blastomylonitic shear zones, including boudins of serpentinites, eclogites (Iancu et al. 1987; Balintoni et al. 1989) as well as juxtaposition of anisofacial matamorphic piles (Sabau 1992, manuscr.);

2 - stratigraphic, metamorphic and deformational uncomformities, as a result of prograde low-grade regional metamorphism in Paleozoic sedimentary sequences and isofacial retrogressive overprint in their basement, formed of medium-grade metamorphics. Both progressive and retrogressive metamorphisms are related to the same event. Such geological relationships have been described in the Infrabucovinian units of the Eastern Carpathians (Kräutner 1972) as well as in the Southern Carpathians (Kräutner 1980). According to this model (Kräutner 1991) a prograde low-grade metamorphic sequence overlies a medium-grade metamorphic pile. Below the primary stratigraphic uncomformity a zone of regional metamorphism developed in the medium-grade basement to a depth of some hundreds of metres (Fig. 5). It represents the effect of the same low-grade metamorphic event that produced the prograde metamorphism in the overlying sediments. Due to the synmetamorphic deformation, the low-grade metamorphic cover usually slipped over its basement. Due to the intensive schistosity in the sliping zone and to the retrogressive overprint in the basement, some authors suspected tectonic (nappe) discontinuities (Hann & Balintoni 1988).

In the Variscan crust of the Southern Carpathians at least three main metamorphic events are suspected by most geologists:

a - Variscan regional metamorphism developed progressively in Paleozoic sediments and retrogressively in pre-Variscan metamorphic piles; **b** - Cadomian, and **c** - pre-Cambrian regional metamorphisms. Some different opinions may be noticed only concerning the status of local sequences in respect to the three events mentioned.

The Variscan crust

As was mentioned, in fact all metamorphic rocks of the Southern Carpathians (excluding Alpine metamorphics on Mesozoic educts) could be considered "Variscan metamorphics", as they were incorporated in the crust submitted to the Variscan metamorphic event. In the following only products of prograde metamorphism on Paleozoic sediments will be considered. Older metamorphic rocks, overprinted by the Variscan event, will be discussed in the ambit of pre-Variscan cycles.

Paleozoic low-grade metamorphic sequences occur in the Danubian units and their continuation in the Stara Planina (e.g. Iskar-type Paleozoic) as well as in the Supragetic units and their equivalents in the Eastern Carpathians (Rusaia, Repedea, Cimpoiasa-type Paleozoic; Kräutner 1987). In the Getic units no Paleozoic metamorphics are known in the Romanian part of the Southern Carpathians.

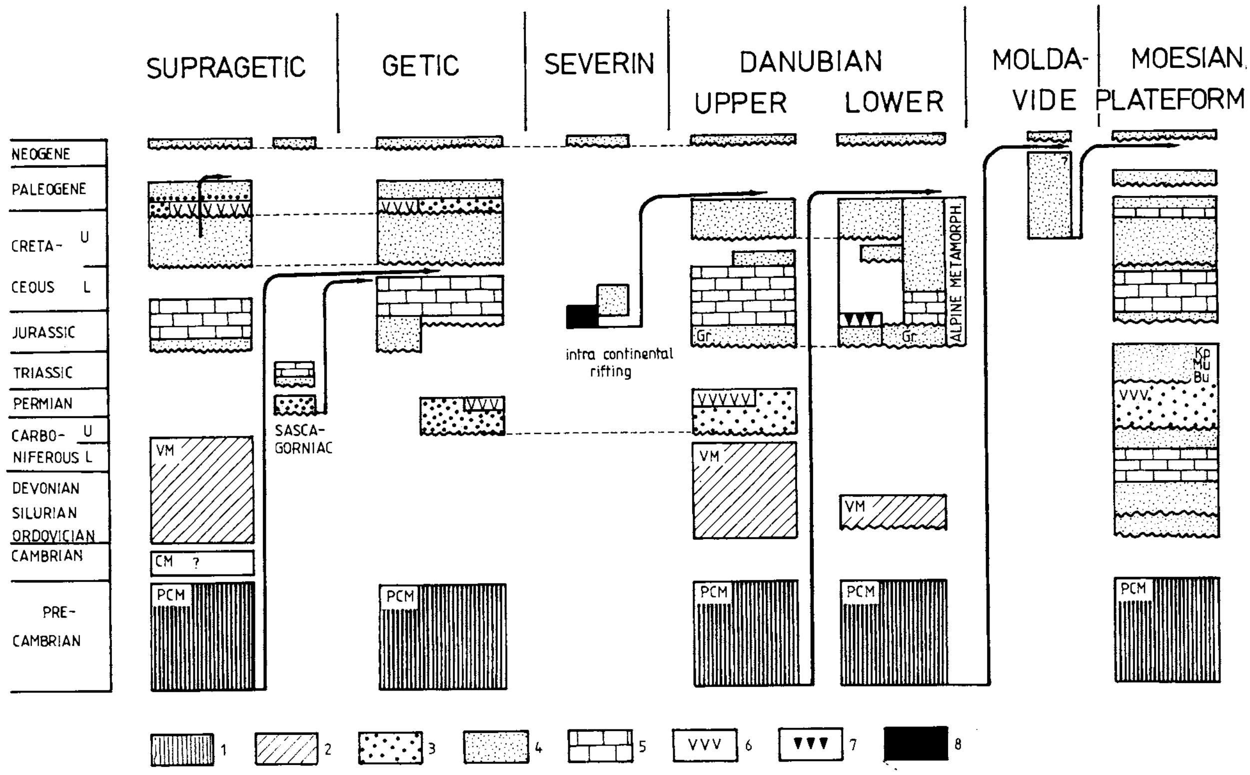

Fig. 3. Accretionary diagram for the main tectonic units of the Southern Carpathians.
Legend: 1 - pre-Cambrain metamorphics (PCM); 2 - Variscan metamorphics (VM); 3 - mainly continental detrital deposits; 4 - mainly marine detrital deposits; 5 - mainly carbonatic and marly deposits; 6 - acid volcanics; 7 - basic volcanics; 8 - oceanic crust. CM - Caledonian metamorphics, Gr - Gresten facies, Bu - Bundsandstein, Mu - Muschelkalk, Kp - Keuper.

The low-grade metamorphic sequences of the Romanian Danubian and Supragetic units are assigned to the Silurian and the Devonian - Lower Carboniferous on the basis of spores, *Achritarchs* and *Chitinosoa* (Kräutner et al. 1973; Maier & Visarion 1976; Visarion & Iancu 1984). Macrofossils and conodonts were reported only from the Danubian units (Mirauta 1964; Codarcea et al. 1964; Stanoiu 1971). Two cycles of sedimentation may be distinguished: Upper Ordovician? - Silurian and Devonian - Lower Carboniferous (Kräutner 1987). They were closed by the Variscan regional metamorphism at about 310 ± 10 Ma ago (Kräutner et al. 1973).

It seems that the Getic realm and the Severin Alpine intracontinental rift zone separated two domains of different Paleozoic sequences (Fig. 6):

The *Silurian cycle* of sedimentation is represented in the Supragetic area mainly by metapsammitic-pelitic rocks, with scarce carbonatic or quartzitic intercalations and with a substantial contribution of basic metavolcanics (e.g. Batrina Group in the Poiana Rusca Mts., Kräutner et al. 1973; and Locva Formation s.s. in the Locva Mts., Maier 1976). On the contrary, in the Upper Danubian realm metapsefitic (Baicu-Sucu metaconglomerate) and metapsammitic sequences (Brusturi Formation) prevail. In the Lower Danubian realm only quartzitic schists and slates are known (Valea Izvorului Formation; Stanoiu 1971).

The *Devonian - Lower Carboniferous cycle* was recognised only in the Supragetic and Upper Danubian realms. It is characterized by Devonian basic metavolcanis (volcano-sedimentary formations), very extensive in the Supragetic units (Ghelar Formation in the Poiana Rusca; Valea Satului Formation at Bosca; Lescovita Group in the Locva Mts.) but less developed in the Upper Danubian realm (Drencova Group). In the Lower Carboniferous the sedimentation was more differentiated, producing important volumes of dolomites and limestones in the area of the Poiana Rusca (Hunedoara dolomites), whereas in all other units psammito-pelitic sequences prevail.

Specifically, products of basic and acid volcanism are present in the Lower Carboniferous sequences of the Supragetic realm, whereas in the Danubian units no Lower Carboniferous metavolcanics are known.

It is with mentioning the similar lithostratigraphic sequence of the Devonain - Lower Carboniferous from the Poiana Rusca and of the Cimpoiasa Group from the Infrabucovinian units (Anies, Stiol, Valea Vinului Nappes) of the Rodna Mts. in the Eastern Carpathians. It may be also stressed that the mentioned sequences suggest a similar geological evolution with the Devonian - Lower Carboniferous of the Rheno-Hercynian, Saxo-Thuringian and Silesian (Jesenik) zones of the Central Europe (Kräutner 1989). This may be considered as one of the arguments in favor of the fact that the Alpine sedimentation realm was superposed on a Variscan crust, quite similar to that exposed in Central Europe. This assumption is also supported by similar Devonian metallogenetic events, marked by the Lahn-Dill and Teliua-Ghelar iron ores (Kräutner 1970, 1977).

The *Variscan metamorphism* (K-Ar = 310 ± 10 Ma, Kräutner et al. 1973) developed in the greenschists facies over the whole area included in the Alpine tectonic units of the Romanian

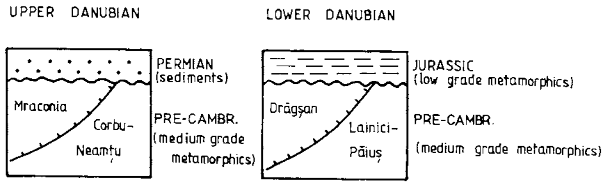

Fig. 4. Geological proofs for pre-Alpine nappe structure in the Danubian units (proper names indicate different metamorphic, lithostratigraphic units assigned to the pre-Cambrian).

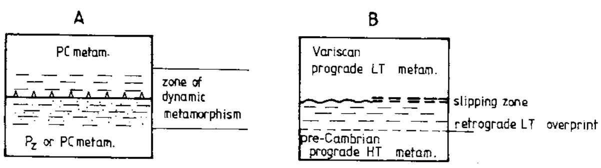

Fig. 5. Models for the two main geological relationships between different sequences of pre-Alpine metamorphites and related retrogressive overprints. A - tectonic unconformity (nappe structure); B - stratigraphic, metamorphic and deformational unconformity.

Southern Carpathians, Eastern Carpathians and Apuseni Mts. An increase of the Variscan metamorphic intensity (temperature) may be observed from the Lower Alpine tectonic units (Valea Izvorului, Drencova sequences) to the upper units as Locva, Bosca. It culminates in the Poiana Rusca crystalline with development of garnet + biotite + plagioclase An_{15}, during a postkinematic thermic apex (Kräutner et al. 1976, 1981). The application of geobarometry based on b_0 values of K-micas in metapelitic rocks indicates a Barrovian type metamorphism for the Poiana Rusca crystalline (Kräutner et al. 1976), while from the Eastern Carpathians a low-pressure character was recorded for all Paleozoic low-grade metamorphic sequences (Kräutner et al. 1975). In addition, this suggests a pressure gradient of the Variscan metamorphism, crossed by the tectonic zones interposed between the Supragetic realm of the Southern Carpathians and the Infrabucovinian area of the Eastern Carpathians.

The Early Caledonian crust

Apart from the Corbu Zone of the Upper Danubian unit of the Southern Banat, only metamorphic sequences from the Supragetic realm have been suspected of being related to the Early Caledonain metamorphic event. In the past they were assigned to the "Baikalian" or "Cadomian" cycle. The mentioned metamorphic piles have metamorphic characters and lithostratigraphic sequences, quite different from the Variscan and pre-Cambrian metamorphics. They have been assigned to the Cambrian (or Late pre-Cambrian) due to scarce palynologi-

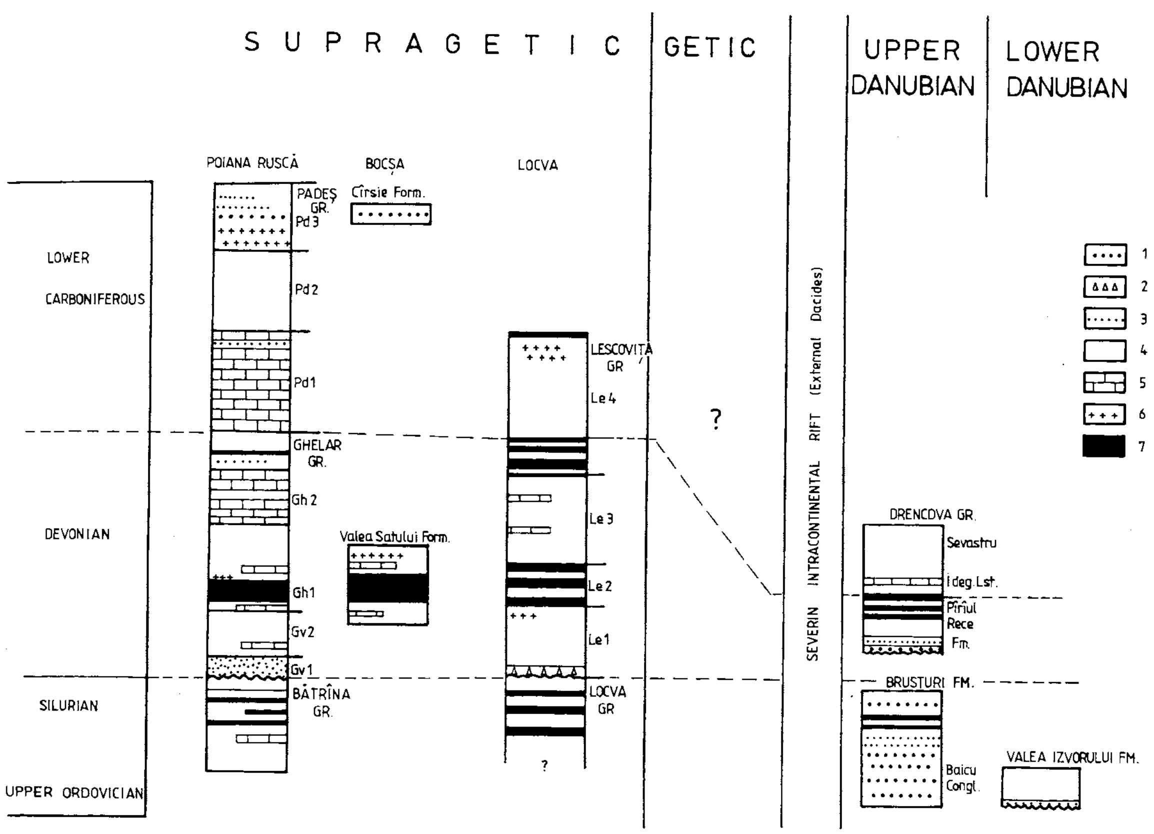

Fig. 6. Lithostratigraphic sequences of low-grade metamorphic Paleozoic in the main Alpine tectonic units of the Southern Carpathians. *Legend:* 1 - metaconglomerates; 2 - metaarcoses; 3 - quartzitic rocks; 4 - metapelites and metapsammites; 5 - marbles and dolomites; 6 - acid metavolcanics; 7 - basic volcano-sedimentary formation.

cal data (Cordacea & Iliescu 1969) and to the fact that the Variscan metamorphic sequences start with the Silurian (may be also Upper Ordovician) over the whole area of the Eastern Carpathians. Another support may be the fact that in the Bucovinian and Subbucovinian units of the Eastern Carpathians well documented Early Caledonian metamorphics (including Cambrian sequences) are wide spread (Kräutner 1987).

Two types of lithologic associations were assigned to the Early Caledonian cycle:

1 - *Sibisel (Cibin) type* sequences consisting in the lower part of a basal epidote-actinolite amphibolite, followed by a sequence of marbles, dolomites, carbonatic schists (amphibolite-carbonate formation, cca 50 - 150 m thick), and in the upper part of a monotonous pile of quartzose muscovite-chlorite schists with newly formed biotite and garnet (Fig. 7). The mentioned palynomorphs are from the carbonatic schists. The Early Caledonian metamorphism developed in the greenschist facies by an early synkinematic phase (actinolite + epidote + albite; quartz + muscovite + chlorite + albite) followed by a late/or postkinematic growth of biotite and garnet. Below the mentioned prograde metamorphic pile, in its medium-grade metamorphic basement of Cumpana-type, a zone of regional retromorphism developed, due to the influence of the Early Caledonain metamorphism, on the basement of the initial Lower Paleozoic sediments (Kräutner 1980).

Due to the small thickness of the Sibisel-type sequences conserved below pre-Alpine and Alpine overthrust surfaces, in some places the mentioned picture (Fig. 7) was disturbed by younger retrogressive overprints (Fig. 7). This is why some authors (e.g. Hann & Balintoni 1988) include the Sibisel type sequences, together with pre-Cambrian Fagaras or Cumpana type assemblages in sole retrogressive piles, related to dynamic overprints in overthrust zones. It is noteworthy to stress that the mentioned picture of prograde Early Caledonain metamorphism and polyphasic (Early Caledonain and Variscan or Alpine) retrogressive overprint on Early Caledonain and pre-Cambrian metamorphics may be recognized only by careful examination on piles of sufficient thickness to conserve prograde relics.

2 - *Leresti-Leaota-Bocsita Drimoxa-type piles* represented mainly by albite/or oligoclase porphyroblast schists. Their correlation over the whole area of the Carpathians was recently proposed by Dimitrescu (1990). No concludent data on their age are available, therefore they could also be assigned to the Late pre-Cambrian. Mostly tectonic contacts are pressumed with other metamorphic piles. Only in the Leaota and Locva Mts. Variscan metamorphics (Calusu Formation, Leresti Group) were assumed in transgressive superposition.

The pre-Cambrian crust

The largest part of the Supragetic, Getic and Danubian units of the Southern Carpathians are constituted of medium-grade metamorphic sequences assigned to the pre-Cambrian. The radiometric ages are usually regenerated by the Variscan and Alpine events. Direct arguments for the pre-Cambrian age exist only for the Danubian realm where K-Ar ages of 650 Ma (Grünenfelder et al. 1983) have been recorded and U-Pb Concordia ages of 610± 30 Ma from zircon of granitoids intruding older metamorphic rocks. The mentioned granitoids and metamorphics are covered transgressively by a Silurian sequence (Valea Izvorului Formation) with macrofossils, and in Serbia Silurian sediments (Kucaj Zone, Krstic & Maslarevic 1990) cover the metamorphic basement. In the Getic units only Variscan and Alpine K-Ar ages (336 ± 140) were recorded, and Bagdasaryan (1972) mentioned a Rb/Sr age of 836 Ma from biotite of the Sebes-Lotru series. In the Supragetic area the oldest K-Ar ages are of about 480 Ma (Pavelescu et al. 1975) obtained from the Albesti granitoids; the Variscan cycle of sedimentation started with the Silurian; lithostratigraphic correlations with the Eastern Carpathians support a pre-Cambrian age.

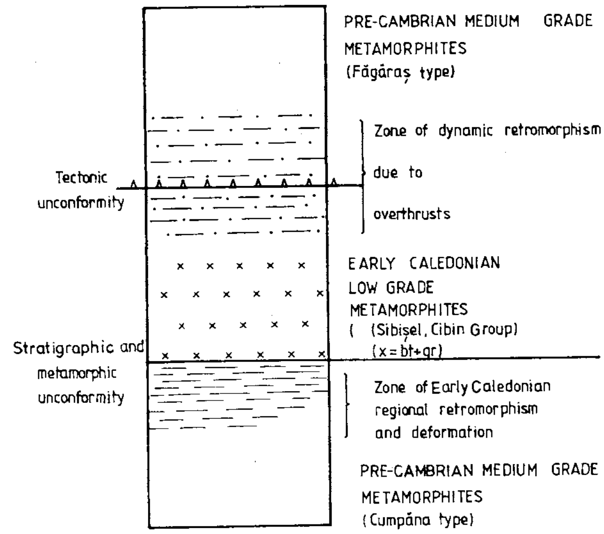

Fig. 7. Retrogressive overprint related to the geological relationships between Early Caledonain and pre-Cambrian metamorphic piles.

As it is shown in Fig. 8, the metamorphic sequences assigned to the pre-Cambrian have a quite different lithologic and lithostratigraphic constitution in the main Alpine units. Thus, it is evident that the Variscan cycle of sedimentation started on an older basement including parts of different pre-Cambrian crustal elements. Partly, in the Supragetic realm (as well as in the Eastern Carpathians), those pre-Cambrian crustal fragments were involved in an Early Caledonian belt. Only tectonic relationships are known between the different pre-Cambrian piles. In the last years it became evident, that the tectonic contacts are not only due to the Alpine and Variscan deformation, and that synmetamorphic pre-Cambrian napping may also be recognised by wide spread blastomylonitic zones, including anisofacial bodies of eclogites and serpentinites (Hann 1983; Iancu et al. 1987; Balintoni et al. 1989; Sabau 1992 - manuscr.).

The Supragetic realm is formed mainly of pre-Cambrian metamorphics, but Variscan and Early Caledonian sequences also extend over large areas (Fig. 9). Their geological relationships are schematically represented in Fig. 8. The rocks assigned to the pre-Cambrian seem to originate in a single lithostratigraphic sequence, described as Carpian Supergroup (Kräutner 1980). Equivalent sequences are exposed in the Eastern Carpathians (Bretila and Rebra Groups) as well as in the southern extension of the Supragetic units in the Rhodopes (Rhodopian Supergroup; Kozhukharov & Dabovsky 1980). Excepting the Fagaras Nappe (Fagaras Mts.) this sequence is only fragmentarly conserved in different tectonic units. However the position in the general sequence may be easily roughly recognised due to its characteristic lithologic constitution and lithostratigraphic superposition.

The lower part of the Carpian sequence was described in the

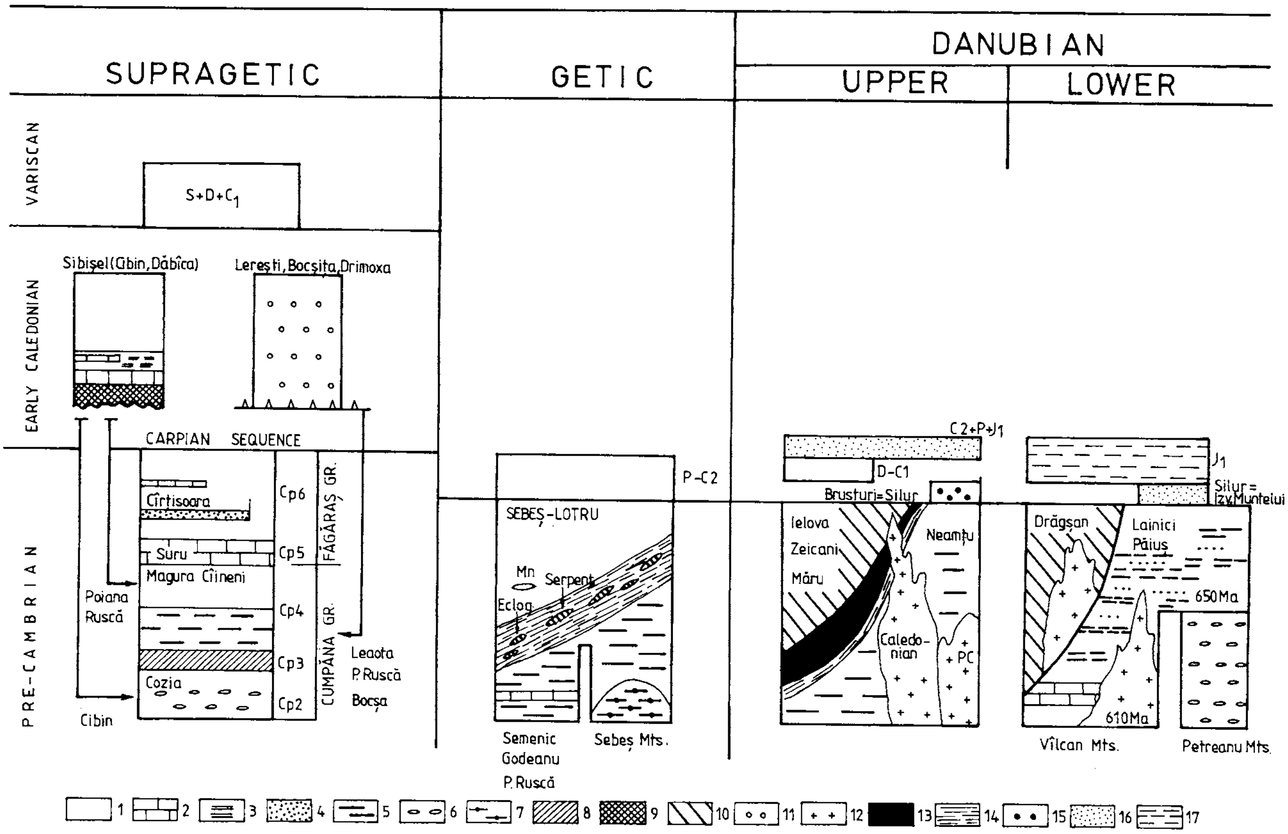

Fig. 8. The main lithologic content and structural features of the pre-Variscan metamorphic sequences in the major Alpine tectonic units of the Southern Carpathians.

Legend: 1 - metapelito-psammitic sequences; 2 - marbles and dolomites; 3 - carbonatic schists; 4 - quartzites; 5 - paragneisses; 6 - augengneisses; 7 - granitoidic gneisses; 8 - leptino-amphibolitic formation; 9 - epidote-actinolitic schists; 10 - mainly amphibolitic sequence; 11 - albite-porphyroblast schists; 12 - granitoids; 13 - ophiolitic oceanic crust; 14 - shear zones with blastomylonites and mylonites; 15 - Baicu metaconglomerate with pebbles of ophiolitic rocks; 16 - detrital sediments ± low-grade metamorphism; 17 - low-grade metamorphic mesozoic sequence.

Southern Carpathians as Cumpana Group (Fig. 8). It consists of a gneissic pile with subordinate amphibolite intercalations and a micaschist sequence (Magura Ciinenilor Formation) at the top. In the gneissic pile a leptino-amphibolitic association is intercalated. It was used as a lithostratigraphic marker. Important masses of augen gneisses (Cozia gneiss; equiv. Laz, Lunca Cernii, Tincova, Tilva Drenii gneisses) developed in the lower part of the gneissic sequence.

The upper part of Carpian sequence is represented in the Southern Carpathians by the Fagaras Group. It consists of a lower amphibolite-carbonatic association (Suru Formation) including an alternation of marbles, dolomites, amphibolites, micaschists, quartzites and an upper quartz-micaschist association (Cirtisoara Formation) with scarce intercalations of amphibolites, marbles and quartzites.

Although tectonic discontinuity was presumed between the Cumpana and Fagaras Group in the Fagaras Mts. (Balintoni et al. 1986) there are conclusive arguments in favour of a normal superposition, only locally disturbed by infraformational faults. The pre-Cambrian metamorphism developed quite homogeneous in the whole pile, as it was mentioned also for the Carpian sequence of the Eastern Carpathians and of the Rhodopes (Kozhukharov & Kozhukharova 1977). It reaches the amphibolite facies in Barrovian conditions (almandine + staurolite + kyanite) and polystadial evolution. In the Early Caledonian, Variscan and Alpine events, retrogressive overprints of regional and/or dynamic types penetrated over large areas, giving the rocks a polymetamorphic character.

The Getic realm is formed on the Romanian part of the Southern Carpathians, only by the pre-Cambrian metamorphic rocks, assigned to the Sebes-Lotru Group. In the past they were considered as a homogeneous rock association. But in the last years a polymetamorphic character (Hartopanu 1975, 1978) and an internal highly complicated tectonic structure were recognised (Iancu et al. 1987; Balintoni et al. 1989; Sabau 1992, manuscr.), explaining why earlier suggestions for their lithostratigraphic subdivision were successful only on restricted areas and failed for regional correlations.

A pertinent character of the Sebes-Lotru crystalline consists in the fact that blastomylonitic zones (belts) are interposed between piles of different lithologic constitution: e.g. mainly micaschists piles versus gneissic and amphibolitic sequences. Another peculiar fact consists in the presence of widely extended zones across the Sebes, Lotru, Cibin, Capatinii and Mehedinti Mts. including bodies of peridotitic (serpentinitic), garnet peridotitic, eclogitic and granulitic rocks. These rocks originating partly in the subcontinental upper mantle (garnet peridotites) are retrogressively overprinted by the medium-grade metamorphism of the Sebes-Lotru crystalline. They probably represent a tectonic melange along transcrustal shear zones that have

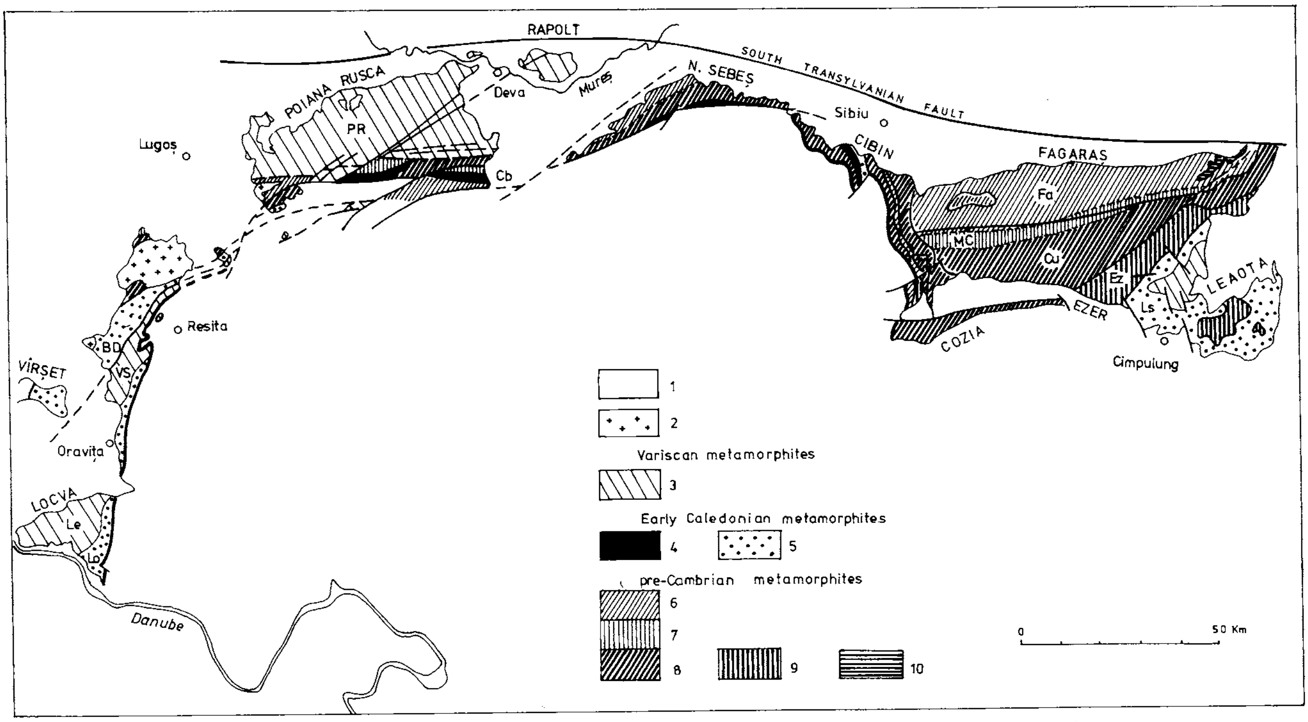

Fig. 9. The main lithologic units of the pre-Alpine metamorphic crust from the Supragetic realm of the Southern Carpathians.
Legend: 1 - sedimentary cover; 2 - Laramian intrusives (banatites); 3 - Variscan low-grade metamorphic sequences (Silurian - Lower Carboniferous); 4 - Cibin (Sibisel, Dabica) type low-grade metamorphic sequences (Cb); 5 - albite porphyroblast schist sequences; 6-8 - Carpian Supergroup: 6 - Fagars Group (Fa), 7-8 - Cumpana Group (Cu), 7 - Magura Ciineni micaschist formation (Mc), 8 - Topolog and Cozia gneissic Formation; 9 - Ezer gneissic Group (Ez); 10 - Strimba gneiss Formation. PR - Poiana Rusca crystalline, VS - Valea Satului Formation, Le - Lescovita Group, BD - Bocsita-Drimoxa Formation, Lo - Locva Formation, Ls - Leresti Formation.

been active prior or synchronous to the oldest decelable Sebes-Lotru metamorphism (M_1) (Maruntiu 1987; Iancu et al. 1987). Recently Sabau (1992, manuscr.) stressed that along such zones rock volumes with contrasting metamorphic history are in juxtaposition. Thus the mentioned author concluded that synmetamorphic, deep-seated ductile nappe structres are hidden by a general overprint due to a late metamorphic event (M_2).

The mentioned data require a new structural-metamorphic model for the Sebes-Lotru crystalline, able to integrate the older local lithostratigraphic data with the the new concept of a polycrustal constitution. Some attempts have been made by Iancu & Sabau (unpubl. data). In its highest degree of simplification the mentioned model is represented in Fig. 8. It strongly resembles the model for the Moldanubian crystalline of the Bohemian Massif and support the mentioned resemblances between the Variscan and pre-Variscan crusts of Central Europe and the Eastern European Alpine Belt (Kräutner 1989).

The metamorphic history of the Sebes-Lotru crystalline may be only roughly outlined due to different opinions based on experiences from different investigated areas:

M_1 - the first metamorphism of the pelite-psammitic sequence developed in the amphibolite facies under Barrovian conditions at 550 - 650 °C and cc 10 Kb (Ky + St + Alm + Mu + Ru) (Sabau 1992 - manuscr.). This event was concomitent to the mentioned transcrustal tectonic transport of fragments originating in the upper part of the subcontinental mantle (garnet peridotite, peridotite) and in the lower part of the continental crust (eclogite, granulite). The two crustal segments juxtaposed by the respective deep-seated shear zone were welded by M_1 and the anisofacial rocks retrogressively overprinted by the same M_1.

M_2 - second metamorphic event affected the whole mentioned tectonic framework in a medium-grade condition of low pressure at 680 - 710 °C and 5 - 6 Kb (Sill + Bt + Cord + Ilm) (Sabau 1992 - manuscr.). According to Sabau (1992, manuscr.) this event was accompanied by a second deep-seated napping producing blastomylonitic zones and three tectonic units that may be considered the main paleostructural elements of the Sebes-Lotru crystalline, welded by M_2.

M_{2-3} - late postkinematic growth due to a thermal apex closed the evolution of M_2. According to Iancu et al. (1987) this late event may be related to anatectic processes generating both migmatic neosome and granite-granodorite diatexites of local extent.

M_{4-n} - post pre-Cambrian retrogressive overprints on restricted areas due to the Variscan low-grade metamorphism and to Alpine dynamic metamorphism.

The Danubian realm. The metamorphic basement of the Danubian realm consists mainly of pre-Cambrian metamorphics, covered locally by Variscan and Alpine low-grade metamorphic sequences (Fig. 10). The pre-Cambrian crust is marked in both Upper and Lower Danubian units by two types of lithologic associations: 1 - prevailing amphibolitic pile (Dragsan Group in Lower Danubian and Ielova-Zeicani Maru sequences in Upper Danubian position); 2 - mostly gneissic and quartzitic pile with local intercalations of marbles and amphibolites (Lainici-Paius Group in Lower Danubian and Neamtu Group in Upper Danubian position). A pecularity of the Danubian realm consists in important massifs of granitoid rocks, intruded in both mentioned crustal types, covering about 50 per cent of the exposed surface. An intrusion age of about 610 Ma is suggested by a zircon Concordia diagram (Grünenfelder et al. 1983).

Excluding the Alpine overthrusts, important pre-Alpine nappe structures were reported from the Danubian realm. In

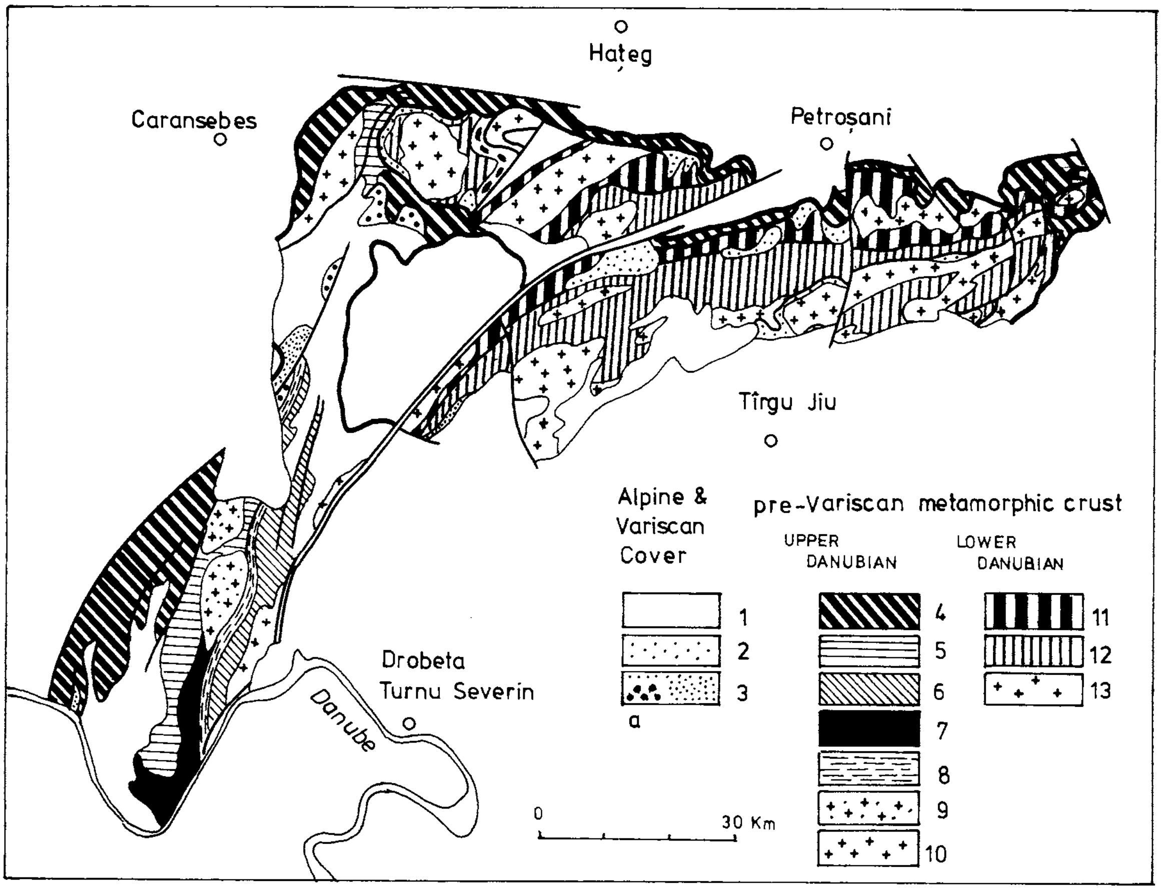

Fig. 10. The main lithologic units of the pre-Alpine metamorphic crust from the Danubian realm of the Southern Carpathians.
Legend: 1 - Upper Paleozoic, Mesozoic and Neozoic sedimentary cover; 2 - Alpine low-grade metamorphic sequences (Jurassic - Cretaceous); 3 - Variscan low-grade metamorphic sequences (Silurian - Lower Carboniferous), 3a - Baicu metaconglomerates; 4 - mainly amphibolitic association (Ielova, Maru, Zeicani); 5 - gneiss-amphibolitic association (Mraconia, Poiana Marului); 6 - mainly gneissic association (Neamtu); 7 - pre-Variscan oceanic crust; 8 - shear zone with intensive dynamic retromorphism; 9 - Early Caledonain granitoids (Cherbelezu, Sfirdinu); 10 - pre-Cambrian granitoids (Ogradena, Muntele Mic); 11 - mainly amphibolitic association (Dragsan); 12 - mainly gneissic association (Lainici-Paius, Bodu); 13 - pre-Cambrian granitoids (Susita, Tismana, Novaci, Oltet, Retezat, etc.).

the Lower Danubian units the amphibolite pile is overthrust on a regionally extended gneissic sequence (Berza et al. 1983). The respective tectonic contact is transgressively covered by Jurassic deposits of low-grade Alpine metamorphism (Figs. 4, 8). In the Upper Danubian realm the mainly amphibolitic (Ielova) sequence overthrusts the gneissic (Neamtu) pile along an important shear zone with intensive retromorphism (Corbu Zone) associated with a slab of ophiolitic rock association (Tisovita-Iuti ophiolitic complex; Maruntiu 1987). The ophiolites and their tectonic contact are transgressively covered by Lower Carboniferous sediments and are cut by the Cherbelezu granitoids assigned to the Lower Paleozoic (Maruntiu 1987). Pebbles of the mentioned ophiolitic rocks are included in the Silurian Baicu-Sucu metaconglomerate. These facts suggest that the two types of pre-Cambrian continental crust were involved in a collision with a Lower Paleozoic or pre-Cambrian ocean type crust and the mylonitic belt with the ophiolite slab represent relict parts of the suture zone.

The metamorphism of the amphibolitic sequence developed in medium-grade conditions of Barrovian-type (Alm + St + Ky). It was followed by Variscan and Alpine low-grade metamorphic overprints leading to a locally extended polymetamorphic character of the pile. The gneissic crust exhibits a more complex metamorphic evolution. Granitoid intrusions and extensive arteritic migmatization induced a high-heat flow, allowing the regional occurrence of sillimanite, andalusite and cordierite. Retrogressive overprints are related to Variscan and Alpine events.

Concluding remarks

Some characteristic pre-Alpine association of metamorphic rocks were conserved in the main Alpine units of the Southern Carpathians: Supragetic, Getic, Danubian. Prior to the Alpine cycle they have been juxtaposed by Variscan napping and by pre-Variscan tectonic transport on deep-seated ductile shear zones including fragments from the upper part of the subcontinental mantle (garnet peridotite, serpentinites) and from the lower continental crust (eclogites, granulites). In the Danubian realm a paleosuture with slabs of a pre-Variscan oceanic crust was conserved.

Some Paleozoic metamorphic sequences in the Carpathians, comparable to the Central European Paleozoic of Rheno-Hercynian and Jesenik type, as well as the mentioned pre-Variscan lithologic association and structural features, support the idea of a similar trend in the geological evolution of the pre-Alpine basement of the Carpathians and of the Variscan crust of Central Europe.

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