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PRE-ALPINE GEOLOGICAL EVOLUTION OF THE EAST CARPATHIAN METAMORPHICS. SOME COMMON TRENDS WITH THE WEST CARPATHIANS

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Abstract: Evolution of the East Carpathian's pre-Alpine metamorphosed lithological and tectonic units is outlined from the Precambrian to the Carboniferous. According to lithologic, lithostratigraphic and metallogenetic data, the possibility of correlation between some of the East and West Carpathian units is suggested.

Key words: pre-Mesozoic basement, comparison between East and West Carpathians.

General remarks

In the Alpine Mediterranean mountain belt, from the geographical point of view, the West Carpathians are the north–western prolongation of the East Carpathians. Common features in the geological structure were also recognized for a long time, e.g. an external zone with flysch deposits and an internal zone with pre-Alpine metamorphic rocks and Mesozoic sequences in Alpine facies. Therefore, the metamorphic zone of the East Carpathians was considered as a direct continuation of the West Carpathian Crystalline Zone.

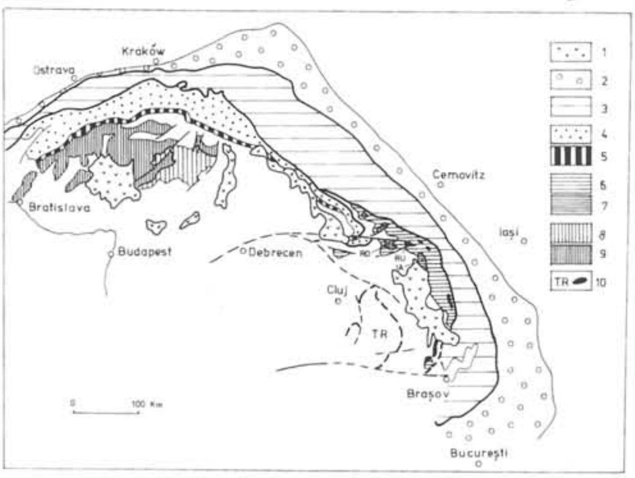

Fig. 1. Tectonic sketch of the East- and West Carpathians (data used from Săndulescu 1984; Kräutner 1988).
1 – Neogene volcanites; 2 – internal and external foredeep (molasse); 3 – Moldavides and external Dacides (flysch); 4–5 – Pienides; 4 – Magura and Dragovo-Petrova Nappe (flysch), 5 – Pienine Klippen Zone; 6–7 – Oriental (Median) Dacides; 6 – Bucovinian Nappe and Subbucovinian Nappe, 7 – Infrabucovinian Nappes; RO – Rodna window, RU – Rusaia window, IA – Iacobeni window; 8–9 – Occidental (Internal) Dacides: 8 – Gemeride Nappe, 9 – Tatro-Veporide Nappes; 10 – Transylvanides (Tethyan oceanic crust). 6 + 8 and 7 + 9 are the two mentioned Dacidic crustal types of metamorphites.

Some years ago it became evident that the relationships between the East and West Carpathian metamorphics are not so simple. Săndulescu (1980, 1984) recognized that in the Maramureş district the southern prolongation of the West Carpathian Klippen Belt (Botiza Nappe) and equivalents of the Măgura flysch (Petrova Nappe) overthrust the post-Mesocretaceous sedimentary cover of the East Carpathian metamorphics (Fig. 1). Therefore, the crystalline zones of the West and East Carpathians belong to different Miocene tectonic units and are separated by the mentioned Pienide Units, interposed between the Median Dacides (East Carpathian Crystalline Zone) and Inner Dacides (West Carpathian Crystalline Zone) (Săndulescu 1980, 1984).

According to the tectonic model of Debelmas et al. (1980), Săndulescu (1980, 1984) the Pienide Units represent elements of the Tethyan ophiolitic suture. This implies that the East Carpathian metamorphics belongs to the European continental border and that the West Carpathian metamorphics are related to the southern (African) plate. But the Inner Dacides have not Dinaric affinities and some lithologic similarities with the metamorphic constituents of the Median Dacides are well known. Therefore, it was supposed that the Inner Dacides belong to an internal Austroalpine-Bihorean block, interposed between the Pienides and a western prolongation of the Tethyan Vardar oceanic zone – the South Pannonian Sfenochasm (Săndulescu, 1984).

It seems likely to suppose that the Tethyan ophiolitic suture zone follows the Drava lineament towards the Insubric lineament and the Pienides represent an intra-continental rifting zone on the southern European border. According to this model the Austroalpine-Bihorean Realm, including the West Carpathian metamorphics, is related to the European continental plate. In this case the position of the Transylvanides (ocean crust ophiolites of the Mureş Zone and of the Transylvanian Nappes in the East Carpathians) may be explained by a fragment of the Tethyan oceanic crust, initially limited by two transform faults (South and North Transylvanian Faults) and successively obducted on continental units of the European border by Mesocretaceous and Laramian overthrusts (Kräutner 1988).

Pre-Alpine nappe structures

Although Variscan nappe structure in the Crystalline Zone of the East Carpathians was presumed a long time ago (Streckeisen 1934; Kräutner 1938) conclusive arguments were mentioned only later (Săndulescu 1972, 1975, 1976; Streckeisen and Hunziker 1974; Zincenco and Vlad 1978 unpubl. data) and finally reviewed by Balintoni (1981) and Mureşan (1983).

Pre-Alpine nappe structures are argued mainly by two facts: *1.* the Bucovinian Triassic sedimentary sequence covers transgressively the nappe contacts of three different metamorphic piles (Săndulescu 1975; Kräutner et al. 1988 unpubl. data) (Fig. 2) and *2.* the alkaline Ditrău massif with a K-Ar isochron age of 135 Ma (Streckeisen and Hunziker 1974; Kräutner et al. 1976) cut at least other three nappes formed of metamorphic sequences (Balintoni 1981; Mureşan 1983) producing contact metamorphism (Fig. 2). For that reason it is generally accepted that the two upper units (Bucovinian and Subbucovinian) of the Central East Carpathian Nappes are constituted of fragments of pre-Alpine nappes, dislocated and carried by the Alpine overthrust. There are no direct proofs if similar tectonic relationships exist also in the Infrabucovinian Units (Fig. 3).

The pre-Alpine nappes in Bucovinian and Subbucovinian position consist mainly of a single lithostratigraphic unit of metamorphics, while in the Infrabucovinian Units two distinct metamorphic sequences (Precambrian and Variscan) do occur frequently. Another fact is that the same sequence of pre-Alpine tectonic metamorphic unit occurs in both the Bucovinian and Subbucovinian Alpine nappes (Tab. 1). Thus, it was assumed that the mentioned nappe fragments originate in the same pre-Alpine nappe pile (Balintoni 1984; Balintoni et al. 1983). Therefore, the same names came in use for this monolithostratigraphic tectono-metamorphic units in both Bucovinian and Subbucovinian position and a distinct terminology is accepted for the pre-Alpine and for the Alpine nappe framework (Tab. 1).

All the nappes inserted in Table 1 are shear nappes. The youngest deposits included in the pre-Alpine nappes are of Lower Carboniferous age (Tibău Formation). Therefore, the mentioned pre-Alpine nappe structure was assigned to the Variscan tectogenesis.

This Variscan nappe structure is one of the common trends in the pre-Alpine geological evolution of the East and West Carpathian metamorphics, as Variscan nappes have been documented recently by Grecula (1987) in the Gemeric Unit of the Slovakian Carpathians.

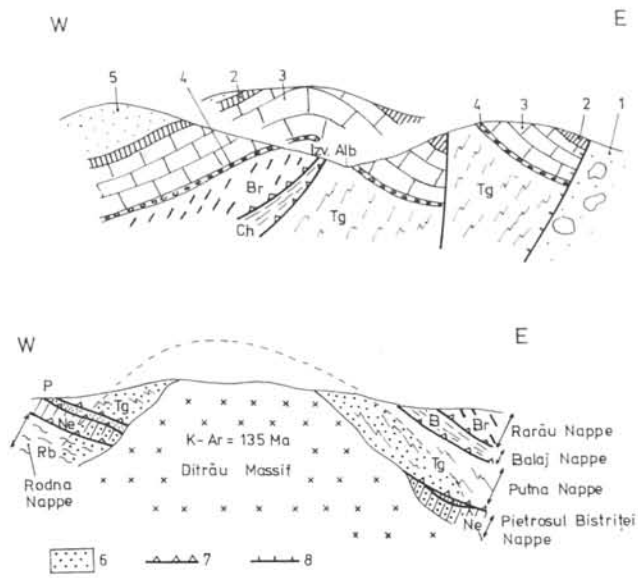

Fig. 2. Geologic arguments for Variscan nappe structure in the East Carpathians. Schematic representation.

A – Variscan nappe contacts covered by the Bucovinian Triassic south of Cîmpulung Moldovenesc; B – Variscan nappes cut by the Ditrău Massif.

1 – Wildlfysch (Barremian – Albian); 2 – jaspers, radiolar silts (Callovian – Oxfordian); 3 – dolomites (Anisian); 4 – conglomerates; 6 – zone of contact metamorphism; 7 – Variscan nappe; 8 – Alpine overthrust; Tg – Tulgheş Group; Ch – Chiril Formation; B – Balaj Formation; Rb – Rebra Group; Br – Bretila Group; Ne – Negrişoara Formation.

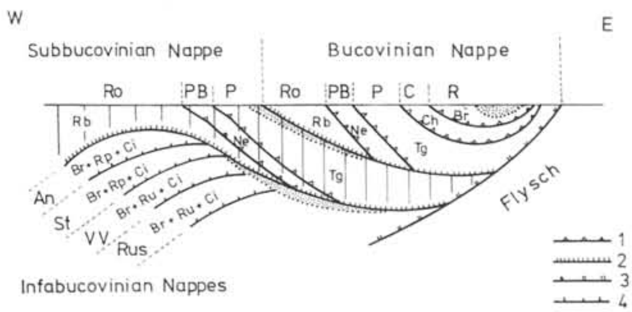

Fig. 3. Model for the Alpine and pre-Alpine nappe structure of the East Carpathian crystalline zone.

1 – Variscan nappe; 2 – Mesocretaceous nappe; 3 – post-Mesocretaceous reactivated overthrust; 4 – Infrabucovinian Alpine or pre-Alpine nappes; 5 – Mesozoic sedimentary cover of the Mesocretaceous nappes; Ro – Rodna Nappe; PB – Pietrosul Bistriței Nappe; P – Putna Nappe; C – Chiril Nappe; R – Rarău Nappe; An – Anieş Nappe; St – Stiol Nappe; VV – Valea Vinului Nappe; Rus – Rusaia Nappe; Tg – Tulgheş Group; Ne – Negrişoara Formation; Ch – Chiril Formation; Rb – Rebra Group; Br – Bretila Group; Rp – Repedea Group; Ru – Rusaia Group; Ci – Cimpoiasa Group.

Table 1. The sequence of Variscan nappes included in the Bucovinian and Subbucovinian Nappes of the Bistrita and Rodna Mts. Infrabucovinian Nappe sequence in the Rodna, Rusaia and Iacobeni tectonic windows.

Alpine Nappes	*Pre-Alpine Nappes*	
	name	constitution
Bucovinian Nappe	Rarau Nappe	Bretila Group
	Chiril Nappe	Chiril Formation
	Putna Nappe	Tulghes Group
	Pietrosul Bistritei Nappe	Pietrosul Porphyroides & Negrisoara Formation
	Rodna Nappe	Rebra Group
Subbucovinian Nappe	Rarau Nappe	Bretila Group
	Putna Nappe	Tulghes Group
	Pietrosul Bistritei Nappe	Pietrosul Porphyroides & ? Negrisoara Formation
	Rodna Nappe	Rebra Group
Infrabucovinian Units		
	Rodna and Rusaia tectonic windows:	
Cisa tectonic slide	– Bretila Group	
Anies Nappe	– Bretila Gr. + Repedea Gr. + Cimpoiasa Gr.	
Stiol Nappe	– Bretila Gr. + Repedea Gr. + Cimpoiasa Gr.	
Valea Vinului Nappe	– Bretila Gr. + Rusaia Gr. + Cimpoiasa Gr.	
Rusaia Nappe	– Bretila Gr. + Rusaia Gr. + Cimpoiasa Gr.	
	Iacobeni tectonic window:	
Iacobeni Nappe	– Bretila Gr. + Argestru Form.	
Sarul Dornei Nappe	– Bretila Gr. + Upper Paleozoic sediments	

The main pre-Alpine sedimentary and tectono-metamorphic cycles

An intensive activity of about 25 years, including detailed lithostratigraphic mapping, geochemical, palynological and radiochronological research, led to the pointing out in the East Carpathian metamorphics products of three main pre-Alpine cycles of sedimentation and regional metamorphism (Fig. 4): Precambrian (Pc), Early Caledonian (EC) and Variscan (V). Relict primary relationships have been preserved only between Pa-V and EC-V. All the other initial relationships are disturbed by younger tectonics. Sedimentary and metamorphic discontinuities were mentioned by Rădulescu (1967), Ionescu (1962, 1969) and described by Kräutner (1972) between the Repedea/Rusaia Group (Silurian) and Bretila Group (Precambrian) and between the Tibău Formation (Lower Carboniferous) and the Rebra Group (Precambrian).

The common features of the mentioned discontinuities are: *1.* intensive retrograde metamorphism in the higher metamorphic basement of the Paleozoic low-grade metamorphic cover; *2.* common Variscan deformation of the Paleozoic cover and its retrogressive basement; *3.* partial or total tectonic slipping of the Paleozoic cover over its Precambrian basement. In the past such sedimentary and metamorphic discontinuities have been considered either as gradual metamorphic transitions or as tectonic contacts.

Precambrian

In the East Carpathians rocks of the amphibolitic facies have been assigned to the Precambrian. They are represented by two distinct lithological associations: the Rebra Group (Rb), represented by quartz micaschists, quartzites, marbles, dolomites, amphibolites (with a carbonate-amphibolite association) and the Bretila Group (Br), formed mainly of gneissic and amphibolitic rocks (with a leptino-amphibolite association). Related to the general lithostratigraphic sequence of the Precambrian in the Carpatho-Balkan area, according to Kräutner (1980, 1983, 1988), the Rebra Group corresponds to the upper part of the Carpian-Rhodopian sequence (supergroup) and the Bretila Group to the lower part of the same sequence.

Lithostratigraphic details are shown in Fig. 4 (see also Kräutner 1983).

Arguments in favour of the Precambrian age of the mentioned metamorphics are: *1.* superposition of the Silurian sequences by stratigraphic and metamorphic unconformities; *2.* essential lithologic differences to the well-documented Cambrian (Tulgheş Group) of the East Carpathians; *3.* polymetamorphic character of the rocks; *4.* lithostratigraphic correlation on interregional scale; *5.* "remanent" radiometric ages of 650–850 Ma.

Most of the radiometric ages (K-Ar, Rb-Sr) are rejuvenated by the Variscan event. Only isolated "remanent" ages

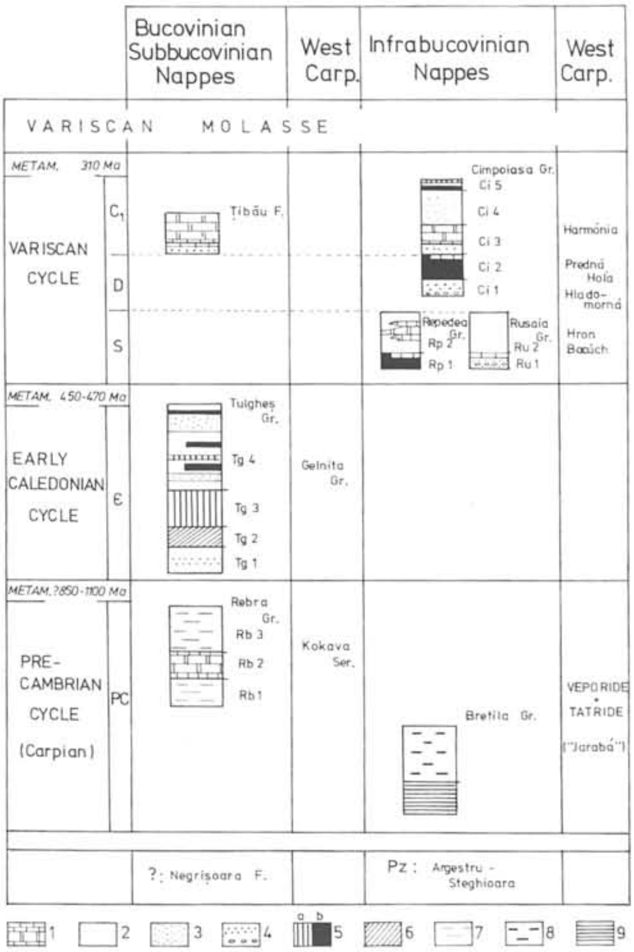

Fig. 4. Pre-Alpine cycles of sedimentation and metamorphism in the East Carpathians and possible equivalents in the West Carpathians: main lithostratigraphic units and their distribution in the Alpine nappe structure.
1 – limestone and dolomite; 2 – sericite-chlorite schists and phyllites; 3 – blasto-detrital quartz-feldspar rocks; 4 – quartzites and quartzite metaconglomerates; 5 – metavolcanics: a) rhyolitic, b) basic (greenschists); 6 – metalydites and graphitic schists; 7 – garnet micaschists; 8 – gneisses; 9 – leptino-amphibolite association.

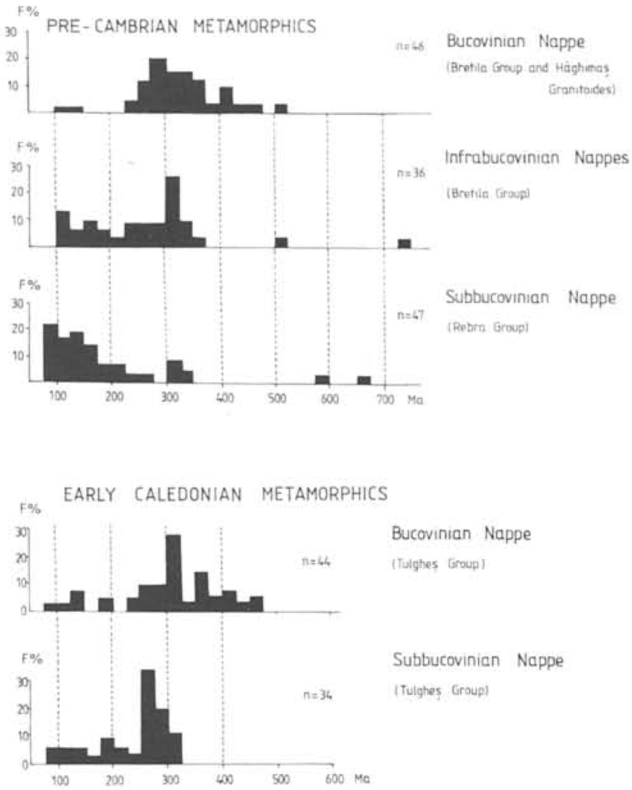

Fig. 5. K-Ar ages of the East Carpathian metamorphics: frequency histograms.

were recorded: 595–650 Ma (K-Ar), 800 Ma (Pb-Pb), 650 Ma (U-Pb), 529 Ma (Rb-Sr), 850 Ma (interpretation of K-Ar isochrones). The rejuvenation seems to be of variable intensity in different Alpine nappes (increasing in the lower Alpine tectonic units), as for example suggested by the K-Ar ages of rocks from the Bretila and Rebra Groups shown in Fig. 5.

In the East Carpathians for most of the isotopic ages the Variscan overprint is weell proved by the fact that for the Bretila Group values of 330–340 Ma (Rb-Sr whole rock isochrone on gneisses), 300 Ma (U-Pb zircon age on migmatite); 70–340 Ma (K-Ar ages) have been recorded, while the mentioned geological relationships prove that the gneisses and migmatites of the Bretila Group are definitely older than the overlying low-grade metamorphic sequence palynologically documented as Silurian in age (Repedea and Rusaia Groups).

The Precambrian metamorphism developed polystadially in the amphibolite facies: kyanite + staurolite + almandine + plagioclase (25 An) + muscovite + biotite + quartz. At least three successive mineralogical reorganizations are evident due to different deformational conditions, as for example mineral growth in S_1, interkinematic growth of K-feldspar, new mineral growth in S_2. In the Rebra Group a supplimentary low pressure event is marked by a mainly postkinematic formation of andalusite, cordierite, sillimanite (Balintoni and Gheuca 1987). This event was recognized only in the Rodna Nappe of the Bucovinian Realm. It was, therefore, only of local extend and it is probably due to a limited zone of high thermal flux (thermic dome?).

Cambrian: Early Caledonian Cycle

In the East Carpathians the Tulgheş Group is assigned to the Early Caledonian Cycle. It could be possible that other rock associations also belong to this cycle, as for example the Negrişoara Formation and the Pietrosul porphyroids (metadacites), for which U-Pb zircon ages of 473, 414 Ma were recorded by Scherbak (unpublished data).

The Cambrian age of the low-grade metamorphic sequence of the Tulgheş Group is well documented by concordant palynological data (Iliescu et al. 1983) and radiometric data as for example Pb-Pb ages of 540–610 Ma (Vîjdea and Anastase 1975) and U-Pb zircon ages of 560–640 Ma from porphyroids (Boiko et al. 1975). The K-Ar ages are mostly rejuvenated by the Variscan event, but isolated values reach 450–470 Ma (Kräutner et al. 1976). Thus, an Early Caledonian regional metamorphism, probably in the Sardic phase, was assumed. This conclusion agrees with the facts that according to palynological data (Veryhacium) the Lower Ordovician may be included in the upper part of the Tulgheş sequence and that the Variscan cycle starts in the East Carpathians with the Silurian. Directly over the Tulgheş Group only Lower Carboniferous Variscan metamorphics (Tibău Formation) have been considered in a transgressive position (Bercia et al. 1976; Kräutner 1972).

The metamorphic unconformity between the Variscan and Caledonian metamorphics was inferred also from the polymetamorphic characters of the Tulgheş Group and from the b_0 values of K-white micas of metapelitic schists (Kräutner et al. 1975). In the Variscan metamorphics micas with low phengitic content prevail, suggesting low-pressure conditions of the metamorphism. The Tulgheş micas show a bimodal distribution represented by a collectivity of Barrovian type phengitic varieties, considered as Caledonian, and by a second collectivity with low b_0 values related to the Variscan low pressure metamorphic overprint (Fig. 6).

Similar as for the mentioned Precambrian rocks the rejuvenation of the K-Ar ages in the Tulgheş Group increases towards the lower Alpine tectonic position (Fig. 5).

Due to tectonic contacts the lower part of the Tulgheş Group is not known in the East Carpathians. According to interregional lithostratigraphic correlations it was assumed that the Tulgheş Group represents the upper part of the Marisian sequence (Supergroup) (Kräutner 1983, 1984).

Sequences of the Tulgheş Group occur only in the Putna Unit of the Bucovinian and Subbucovinian nappes. Some lithologic contrasts allow a good lithostratigraphic classification. In the lower part occurs a quartzose formation of a detrital origin (Formation Tg_1). It is overlain by a typical association of graphite quartzites, graphitic schists, metagreywacke and limestones (Formation Tg_2), followed by a rhyolitic volcano-sedimentary formation (Formation Tg_3). The upper part of the sequence corresponds to the postvolcanic waning stage. Alternances of phyllitic and coarse-grained blastodetrital schists appear, with some intercalations of acid metavolcanics, greenschists and metabasites. Lithostratigraphic details are shown in Figs. 4 and 7.

Two specific metallogenetic events are related to the Tulgheş Group, generating 1. massive and disseminated pyrite and Cu, Pb, Zn sulfide ore deposits of Kuroko type (Kräutner 1984, 1989) associated with the rhyolitic volcano-

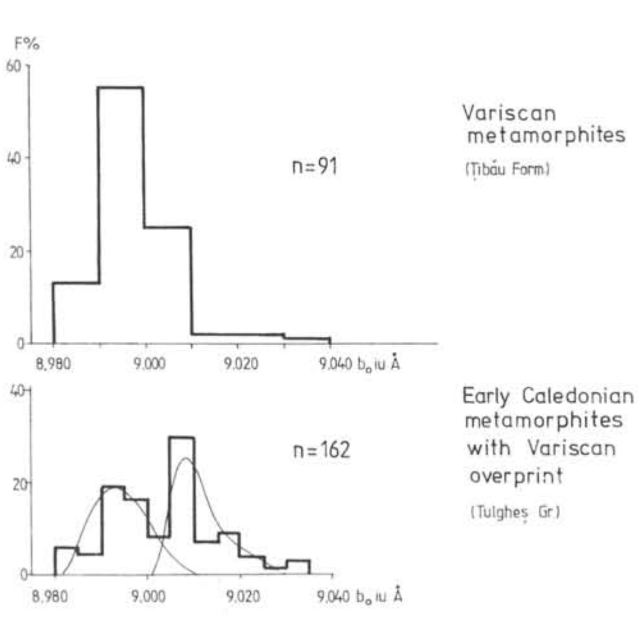

Fig. 6. Frequency diagrams for the Variscan and Early Caledonian K-white micas of the East Carpathian metamorphics.

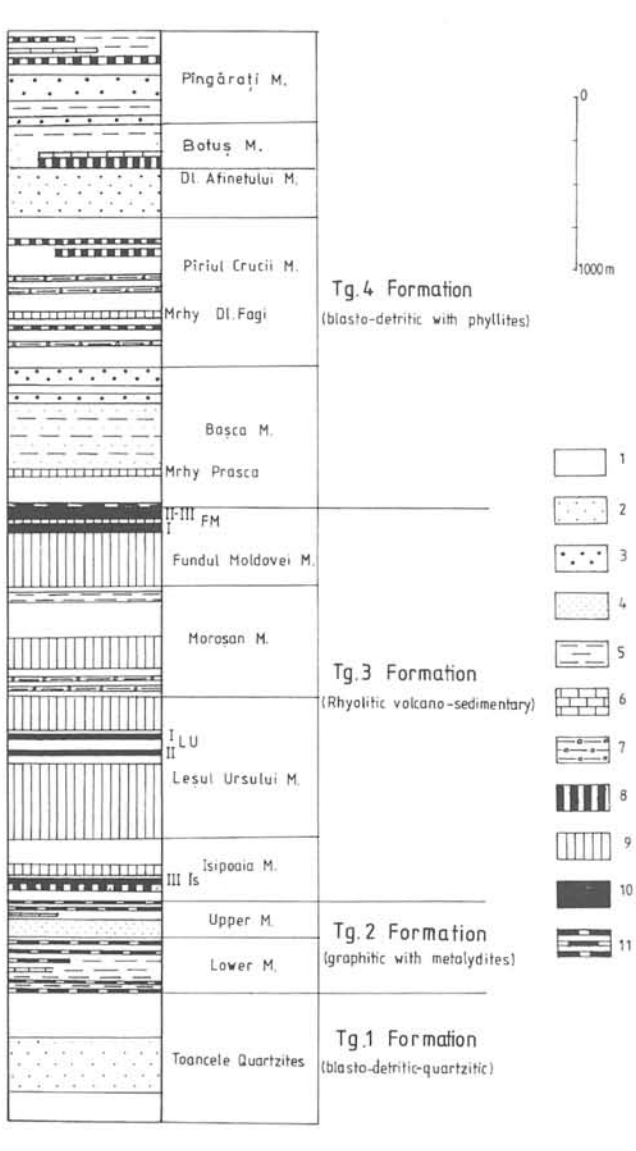

Fig. 7. Lithostratigraphic sequence of the Tulgheş Group: stratotype for the Bucovinian Nappe of the Bistriţa Mts.
1 – sericite-chlorite schists and phyllites; 2 – quartzites; 3 – blasto-detrital quartz-feldspar rocks; 4 – metagreywacke – Piriul Ursului horizon; 5 – grey phyllites, graphitic schists; 6 – limestones; 7 – albite porphyroblast sericite-chlorite schists; 8 – greenschists; 9 – rhyolitic metavolcanics; 10 – sulfide ore horizon; 11 – graphite quartzite (metalydite).

sedimentary formation (Tg_3) and 2. massive and banded manganese carbonate ore deposits and baryte deposits (Vodă and Vodă 1982) intercalated in the graphite quartzites of the Formation Tg_2.

The Early Caledonian regional metamorphism developed in the greenschist facies under Barrovian conditions. Locally, the "biotite in" isograde was depassed and an intermediate spessartine-almandine garnet (30 spess; 57 alm) formed. The paragenesis consists of biotite + spessartine − almandine + albite (2−7 An) + chlorite + muscovite + quartz. A polystadial evolution of the metamorphism is marked by successive synkinematic and inter- or postkinematic growth of the mentioned minerals, due to changes of the deformation during the same period of regional thermal rise (Fig. 8). Two Caledonian schistosity planes (S_1, S_2) developed. Lately, a new deformation (S_3 kinks) and a porphyroblastic overgrowth of muscovite, biotite, albite and garnet appear. This could be either Caledonian or related to the Variscan event. Taking also into consideration Variscan and Alpine retrograde chloritizations of garnet and biotite, a polymetamorphic character of the Tulgheş Group may be accepted.

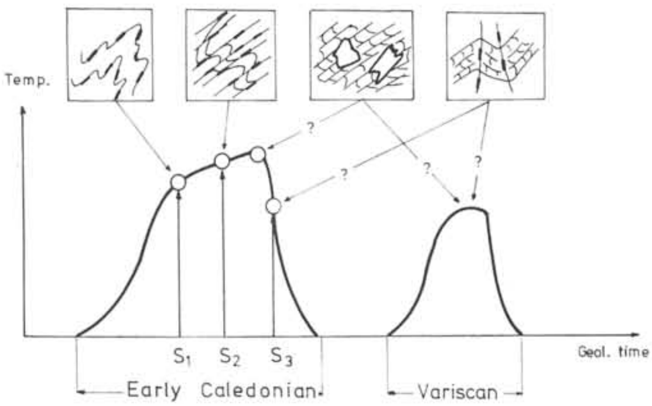

Fig. 8. Polystadial and polymetamorphic development of the Early Caledonian metamorphites of the Tulgheş Group; relationship between mineral growth, deformation and thermal regime.

Silur–Lower Carboniferous: Variscan Cycle

Sequences of the Variscan Cycle occur mainly in the Infrabucovinian units of the Rodna and Rusaia tectonic windows (Rusaia, Repedea and Cimpoiasa Groups). In the Subbucovinian Nappe a carbonatic formation (Tibău Formation) is assigned to the Variscan crystalline, while in the Bucovinian Realm no representatives are known.

This low-grade metamorphic sequences were first assigned to the Paleozoic on the basis of crynoid fragments (Kräutner and Mirăuţă 1970). Later on, detailed palynological research made possible the indentification of Silurian (Rusaia, Repedea Groups), Devonian (lower part of the Cimpoiasa Group) and Lower Carboniferous sequences (Tibau Formation, upper part of the Cimpoiasa Group) on the basis of acritarchs, chitinozoa and spores (Iliescu and Kräutner 1975, 1976, 1978). Other Variscan metamorphics are only fragmentarily exposed in the Iacobeni and Borca tectonic windows (Argestru and Steghioara Formations).

In contrast to the Precambrian and Early Caledonian sequences the mentioned Variscan sequences show semnificative differences in their facial development. Lithostratigraphic details are represented in Figs. 4, 9 (see also Kräutner 1987).

For the Silurian three main realms may be inferred. Their initial relative position is indicated in Fig. 9.

1. A continental area without sediments in the Bucovinian and Subbucovinian domains, therefore with internal position in respect to the realm of the Median Dacides.

2. A domain including the Repedea Group of the Anieş and Stiol Nappes, in which Variscan Cycle starts with a basic submarine volcanism (Stiol Formation) and continues with a period of pelitic sedimentation (Fîntina Formation). To the end of this period reefs were locally built, surrounded by extended perireefal carbonatic deposits.

3. In external position the realm of the Rusaia and Valea Vinului Nappes developed. It is characterized by the Rusaia Group that derives from an area with detrital sedimentation over the whole time span. (Pîrîul Omului and Rodunda Formations).

In the Devonian no important changes appeare in the distribution of the three main sedimentation domains (Fig. 9):

1. In the Bucovinian and Subbucovinian Realm the continental regime persists.

2. In the Infrabucovinian Realm a trend towards homogenization is marked including the area of the Valea Vinului Nappe in the Stiol-Anieş domain. In this domain the sedimentation starts in the lower Middle Devonian (Kräutner and Vaida 1990) with detrital deposits (Gura Fîntînii metaconglomerates and quartzites) followed by a pelitic sequence with local dolomitic intercalations. The main part of the sequence consists of basic metavolcanics and tuffs with a maximal thickness of about 500 *m* (Negoiescu Formation). Reefs developed on the submarine volcanic structure and locally iron ores of the Lahn-Dill type were formed.

During the Upper Devonian(?), but especially in the Lower Carboniferous, the sedimentation area extended from the Infrabucovinian Realm westward over the Subbucovinian area. A carbonatic formation (Tibău Formation in the Subbucovinian Nappe and upper part of the Prislopas Formation in the Stiol Nappe) developed over the main part of the sedimentation area, suggesting shallow water deposition, probably in a platform stage. The latest deposits (Fată Muntelui and Buhăescu Formations) are exposed only in the Stiol Nappe. They are represented by a thick sequence of metagreywacke and small intercalations of basic and acid metavolcanics on the top.

The Variscan regional metamorphism developed in the greenschist facies, in low pressure conditions (Kräutner et al. 1975). Locally, the "biotite in" isograde was depassed. A polystadial evolution of the metamorphism is marked by successive mineral growth on two schistosities (S_1, S_2) and postkinematic blastesis of chloritoid, stilpnomelane, zoisite, as well as late kink type deformation (S_3) with metamorphic mobilization of quartz, chlorite and calcite.

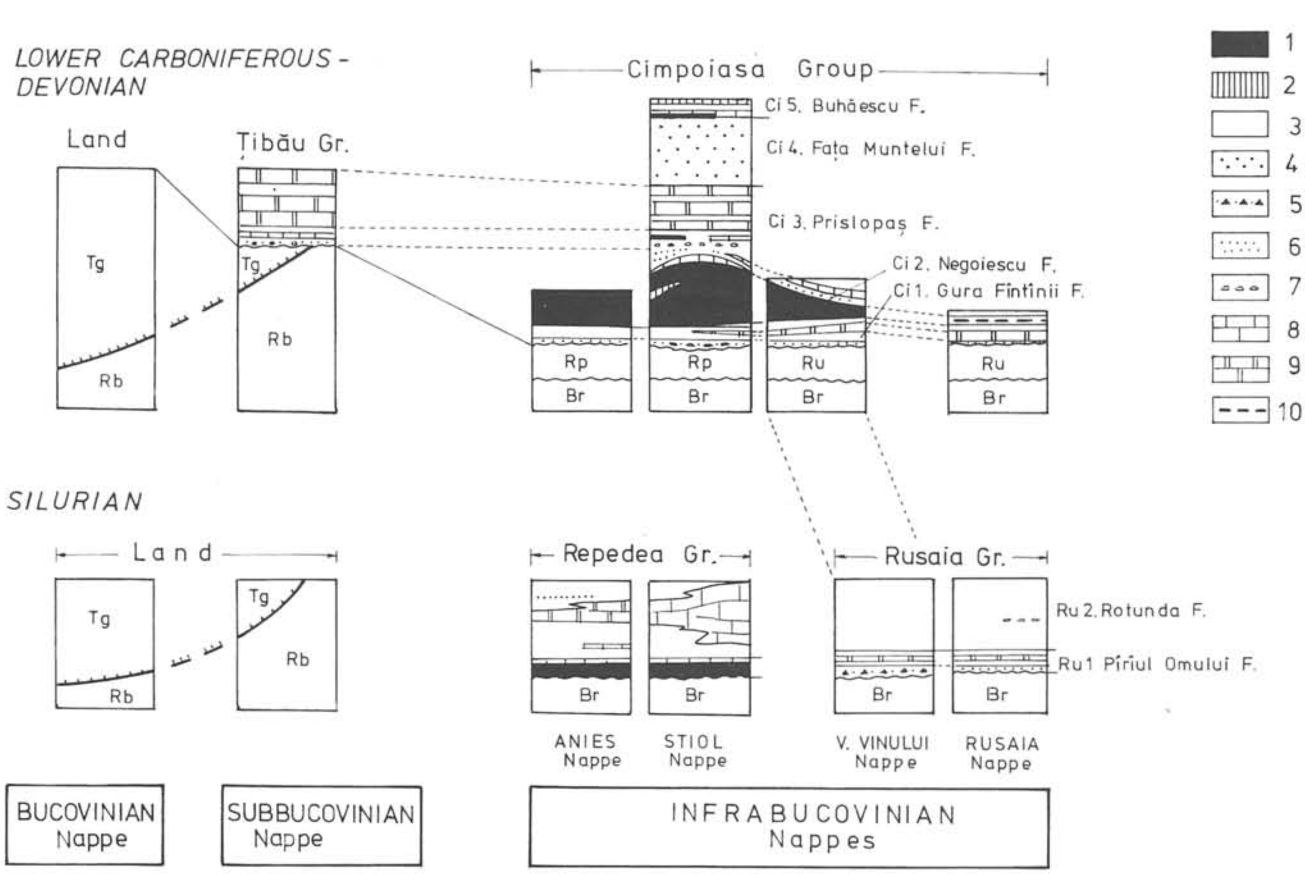

Fig. 9. The main facies areas of the Paleozoic sedimentation in the East Carpathians.
1 – basic volcanics; 2 – acid volcanics; 3 – pelites and aleurites; 4 – sandstones, greywacke; 5 – arkoses; 6 – quartzitic sandstones; 7 – conglomerates; 8 – limestones; 9 – dolomites and limestones; 10 – carbonatic sandstones; Rp – Repedea; Ru – Rusaia; Tg – Tulgheş; Rb – Rebra; Br – Bretila.

Some similar trends in the West Carpathians

Lithologic, lithostratigraphic and metallogenetic resemblances between the Tulgheş Group and the Gelnica Group of the Gemerides were mentioned in the past (Földvary and Pantó 1950; Kamenický 1980; Kräutner 1983, 1987, 1988). The palynological data only partly support the stratigraphic correlations due to the fact that in rocks assigned to the Gelnica Group Silurian–Lower Devonian palynomorphs were mentioned, as well (Snopková and Snopko 1979; Ilavský et al. 1985; Planderová 1982).

The lithologic and metallogenetic correlations between the Tulgheş Group and the Gelnica Group are based on the same sequence of two main rock associations: *1*. In lower position, an alternation of graphite quartzites (metalydites) graphitic schists and limestones (Formation Tg_2, Betliar Formation). Syngenetic manganese ores of the Iacobeni type are locally intercalated in the metalyditic rocks (Čučma, in the West Carpathians). *2*. In upper position, a volcanosedimentary formation of mainly rhyolitic constitution (Formation Tg_3, Hnilec + Smolník Formations). In the lower part of this sequence disseminated and massive pyrite and Cu (±Pb, Zn) sulfide ores occur at Smolník, Bălan and Leşul Ursului (Isipoaia). Similarities between the Smolník and Bălan ore deposits were mentioned since 1950 (Földvári and Pantó 1950; Kräutner 1984). Recently they were confirmed by some common geochemical characters as for example Ni : Co and $\delta^{34}S$ partition in pyrite, the main sulfide constituent of the mentioned ores (Cambel and Jarkovský 1967; Kantor and Rybár 1970; Kräutner et al. 1990).

Concerning the Precambrian sequences, lithologic resemblances may be mentioned between the Rebra Group and the garnet micaschists with dolomite and limestone intercalations of the "Klenovec Zone" (Kokava Series). Both in the East and in the West Carpathians talc metamorphic deposits are linked with the mentioned dolomitic rocks (Drăgoiasa, Mutnik). The Bretila Group consists of a gneiss amphibolic association and augen gneisses, semblable with those of the Veporide and Tatride crystalline. Extended zones of diaphthoresis, due to regional retrogressive overprints represent another common character. Correlations between the Jarabá and Bretila Groups were suggested also by Kamenický (1980).

In the Alpine nappes of the East and West Carpathians two main typical associations of metamorphic rocks can be distinguished:

1. Precambrian gneisses and gneiss-amphibolite associations (Bretila, Tatro-Veporide crystalline) covered by Silurian–Devonian and Lower Carboniferous Variscan metamorphites (Rusaia, Repedea, Cimpoiasa, Hron, Predná Hoľa, Hladomorná, etc.). Large zones of regional retrometamorphism developed in the mentioned medium-grade metamorphites situated under the Variscan low-grade metamorphic cover.

2. Cambrian sequences of low-grade metamorphic volcano-sedimentary formations of rhyolitic constitution, associated with greenschists, metalyditic rocks and thick piles of phyllites and blastodetrital schists. According to palynological data, Silurian–Lower Devonian (Gemeride) and Lower Carboniferous (Subbucovinian Nappe, Tibău Formation) Variscan sequences can also be present. This type of rock assemblages was implicated in Variscan nappe structures both in the East and in the West Carpathians.

The two mentioned rock assemblages occur in distinct Alpine tectonic units: *Type 1* – in the Infrabucovinian Units of the East Carpathians and in the Veporide-Tatride Units of the West Carpathians. *Type 2* – known only in the Subbucovinian and Bucovinian Nappes and in the Gemeride Nappe. Therefore, in both segments of the Carpathians metamorphic piles of type 1 form the lower tectonic units, representing external parts of the Dacides in comparison with the upper tectonic units constituted of metamorphics related to type 2.

This peculiar distribution suggests that the two mentioned piles of metamorphic rocks originate in distinct crustal segments of the Variscan basement of the Alpine belt. Due to the mentioned lithologic similarities it may be supposed that the metamorphic basement of the Bucovinian, Subbucovinian and Gemeride Realms includes fragments of the same Variscan crustal zone and that the Infrabucovinian, Vepor and Tatric Realms derive from another common Variscan basement, of different lithologic constitution (Fig. 10).

The tectonic relationships between these two Variscan crustal zones appear in the Mesocretaceous tectogenesis. Therefore, it can be inferred that they formed a Dacidic zone that included both the "Median Dacides" of the East Carpathians and the "Inner Dacides" of the West Carpathians (sensu Săndulescu 1980). This Mesocretacous Dacidic zone was probably split in the Upper Cretaceous when the development of the Pienine Zone started. As already mentioned, the present relationships are due to a Miocene tectogenesis by which the West Carpathian segment of the mentioned Dacidic zone, situated south of the Pienine Zone, was overthrust on the East Carpathian segment from the north–eastern part of the Pienine Zone. For this reason, it seems that there is no concludent support to range the Mesocretaceous nappes of the crystalline zones of the East and West Carpathians in different Dacidic domains.

According to this model the East and West Carpathian crystalline zones belong both to the European continental border of the Tethys and the interposed Pienine Zone represents a secondary split and, therefore, not the closing (consuming) zone of the Tethyan oceanic crust.

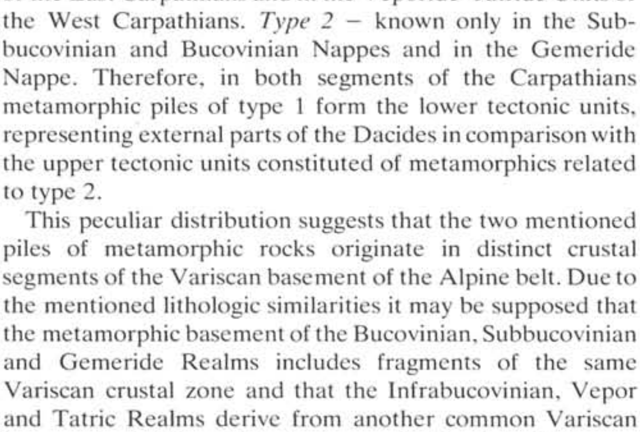

Fig. 10. Model for the initial position and lithologic constitution of the Alpine nappes with metamorphic rocks in the East Carpathians. Possible equivalences with the West Carpathians. Tg – Tulgheş; Tb – Tibău; Rp – Repedea; Ru – Rusaia; Ci – Cimpoiasa; Ne – Negrişoara; Rb – Rebra; Br – Bretila.

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