THE BLACK FLYSCH NAPPE OF THE MARAMUREŞ EAST CARPATHIANS – A "VALAISANNE-TYPE" TECTONIC UNIT?

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The Black Flysch Nappe,which is the innermost unit of the Outern Dacides *s.l*., proceed from a complex rift system (BFRs) which start his extensive history in the Late Lower Jurassic and was deformed during Mid-Cretaceous tectogeneses. The lithostratigraphy of the Jurassic sequence shows similarities with the Grajcarek Serie of the Pieniny-Magura units. The Ceahlău and Bobu nappes (Outer Dacides *s.str*.) proceed from another rift system separated from the BFRs by a continental horst-ridge. Comparing the palinspastic paleogeographies of the Central and Eastern Alps with the West and North-East Carpathians it is possible to conclude that the Black Flysch Rift system prolongate westward, as a "Valaisanne"-type trough, outside and oblique-link ("en coulisses") in respect with the Grajcarek trough, separated to this by the Median Dacides Ridge.

Key words: Outern Dacides; Median Dacides: Pienides; Valaisanne; Rheno-Danubian; Grajcarek; Magura; Black Flysch.

INTRODUCTION

The Outern Dacides develops in front of the Central East Carpathians nappes system, within the Inner Flysch Zone of the Eastern Carpathians and also between the Getic Nappe and the Danubian Unit of the South Carpathians (Fig. 1). The Outern Dacides shows a Mid-Cretaceous and an End-Cretaceous tectogenesis. They group toghether the Black Flysch Nappe (with a Mid-Cretaceous main tectogenesis) and the Ceahlău and Bobu nappes (with an End-Cretaceous main tectogenesis). The Black Flysch Nappe corresponds with the Bely Potok and Civcin units, Ceahlău Nappe with the Rahov and Pietros units and Bobu Nappe with the Burkut Unit, of the Ukrainian East Carpathians.

GENERAL SETTING

Within the northern East Carpathians the main groups of tectonic units (Fig. 2) are, from inward to outward [14,15,18,19]:

– the Pienides, grouping together the Magura Nappe and its correspondents in the Maramureş Mts. (Petrova, Leordina and Wildflysch nappes), the Pieniny Klippen Belt and more inner units (Botiza, Kritchevo, Băbeşti-Tijacevo and Ujgorod) large covered by the north-eastern margin of the Pannonian Neogene Molassic Depression. The Pienides are a segment of the Main Suture Zone of the European Tethyan chains.

– the Median Dacides, it means the Central East Carpathians nappes system, namely the Bucovinian, Subbucovinian and Infrabucovinian nappes. They are basement shearing nappes built up of Precambrian and Caledono - Hercynian metamorphic series and Permian - Lower Cretaceous sedimentary formations.

– the Post-tectonic Cover of the Median Dacides, discordantly overlapping the Central East Carpathians nappes system. It is a sedimentary sequence, sometimes enough thick, of Cenomanian-Lowermost Miocene age, tabular or slyghty deformed. The Post-tectonic Cover of the Median

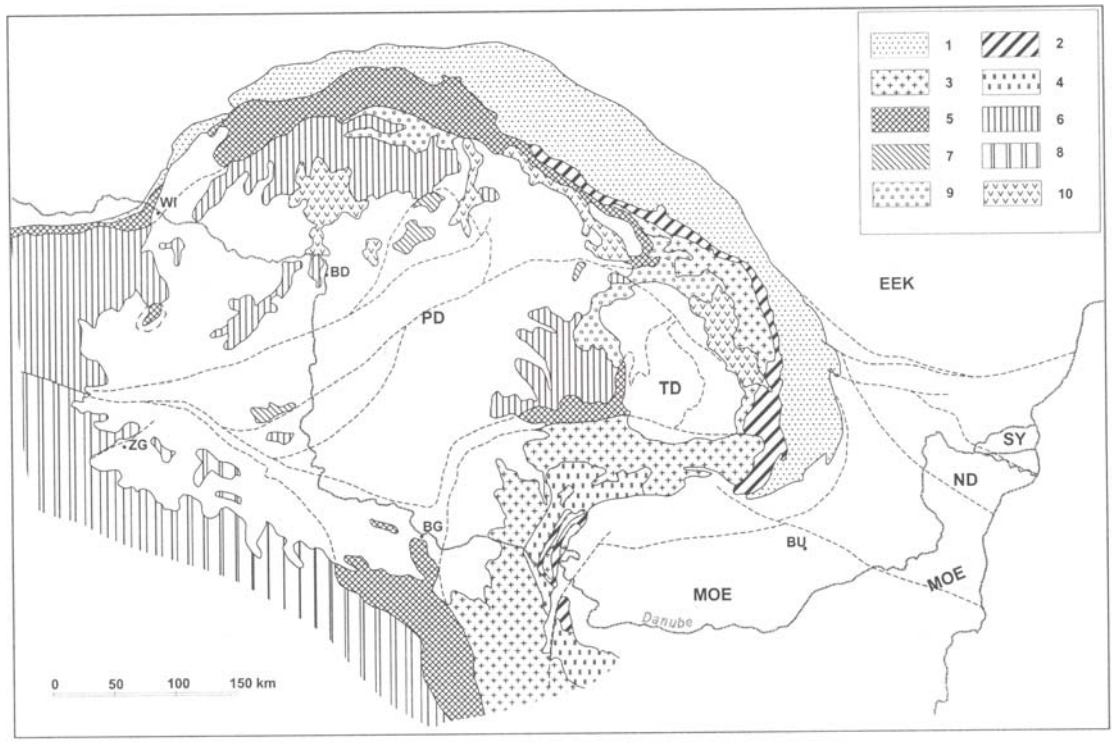

Fig. 1. Tectonic Sketch of Carpathian-Western Black Sea areas: 1 – Moldavides, 2 – Outern Dacides, 3 – Median Dacides (Centr. East Carp. Nappes, Getic & Supragetic Nappes), 4 – Danubian Unit, 5 – Main Tethyan Suture, 6 – Pre-Apulian Units, 7 – Bukk-Meczek Bloc, 8 – Apulian (Dinaric) Units, 9 – Tertiary Post-tectogenetic Cover, 10 – Neogene Volcanics, TP – Transylvanian Depression, PD – Pannonian Depression, MOE – Moesian Platform, SY – Skythian Platform, EEK – East European Kraton, ND – North Dobrogea Orogene, BD – Budapest, BG – Beograd, BU – Bucharest, W – Wien, ZG – Zagreb.

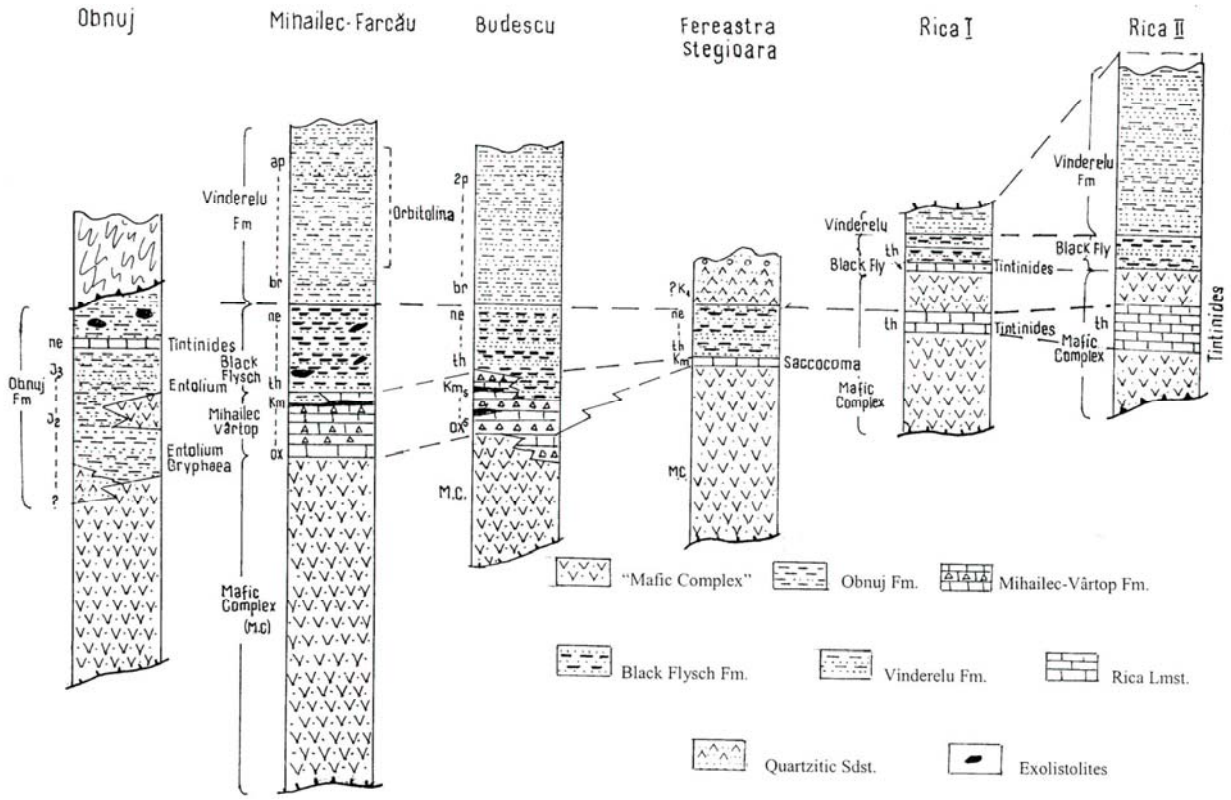

Fig. 2. Correlative lithostratigraphic columns in the Black Flysch Nappe.

Dacides is overthrusted, in the Maramureş Mts., during the Lower Miocene by the Pienides, namely the Magura Nappe.

– the Outern Dacides *s.l.* grouping together the Black Flysch, the Ceahlău and the Bobu nappes In fact the most important areal extension of the Outern Dacides is represented by the Ceahlău and Bobu nappes in the East Carpathians and the Severin (= Ceahlău) Nappe in the south Carpathians. The Black Flysch Nappe have a peculiar position, frame and evolution and must be analysed separated from the Outern Dacides *s. str.*

– the Moldavides which groups together the most important part of the Flysch Zone of the East Carpathians, units which have Lower, Middle and early Upper Miocene tectogeneses.

The Pienides are the northern and western segments of the Main Tethyan Suture Zone of the Carpatians. This one crops out in the Southern Apusenides (Transylvanides) and prolongate below the Transylvanian Molasse Depression. The North Transylvanian Fault (NTF) shift the suture left-lateraly, into the Pienides. It is important to emphasized that the Pienides, north of the North Transylvanian Fault, progressively overthrust the Median and the Outern Dacides as well as their post-tectogenetic cover (Fig. 2). Consequently the last two group of units are no more outcropping in the Western Carpathians. How they prolongate below the Pienides is a disputable problem.

GEOLOGY OF THE BLACK FLYSCH NAPPE

The Black Flysch Nappe was firstly separated by Bleahu[3]. Later, general and detailed, structural and lithostratigraphic data were provided by Sandulescu[13,15,17]. They completed the knowledge concerning this unit.

The Black Flysch Nappe shows a very imbricated structure with different lithostratigraphic succesions. A common feature is, for each scale, the lowermost sequence represented by the "Mafic Complex" (pillow-lava basalts, spilites, mafic tufs and pyroclastics, schallsteins, stromatites and doleritic dyckes)[10].

There are at least seven different sub-units (scales) which may be reccognised within the Black Flysch Nappe, each of them with a specific lithostratigraphy (Fig. 3). In the innemost scale (Obnuj-Vârtop) the "Mafic Complex" is overlapped by the Obnuj Formation (dark-gray siltic-argilaceous sequence, with quartzitic sandstones intercalations) of Middle Jurassic-Neocomian age[17]. At several levels in the Middle Jurassic are discontinuously intercalated mafic rocks, mostly pyroclastics.In the Budescu Scale the Obnuj Formation is restricted to the Middle Jurassic being overlapped by the Black Flysch.

Within the median scales (Farcău and Mihailec-Paulic) the "Mafic Complex" is of Middle Jurassic age. Above it develops a dominantly limy-breccious formation with inlayerings of stromatites, radiolarites, basalts and mafic tufs: the Mihailec-Vârtop Formation, of Oxfordian-Kimmeridgian age. It is overlaped by the Thitonian-Neocomian Black Flysch (polymictic arenites alternating with graphitic silts and clays). Sedimentary klippen (exolistholites) built up of Lower Triassic quartzites and Middle Triassic carbonate rocks are hosted at different levels of the Black Flysch Formation. The youngest lithostratigraphic unit is the Vinderelu Formation, a sandy-marly flysch of Barremian-Aptian age.

Within the outer scales – Rica I and Rica II – the "Mafic Complex", which show two levels of Tithonian limestones (Rica Limestones) reach the Tithonian in age (Fig. 3).

It is overlapped by the Black Flysch (Tithonian (?)-Neocomian) and the Vinderelu Flysch (Barremian-Aptian). A peculiar lithostratigraphic succession cis known in the Ştevioara Scale (which crops out in a tectonic window in the Vaser hydrographic basin – Ştevioara Brook – below the Subbucovinian Nappe). The "Mafic Complex" is overlapped by Kimmeridgian red limestones, followed by the Black Flysch.

It is important to stress out the heterochronous development of the upper boundary of the "Mafic Complex": from the Lower/Middle Jurassic in the inner scales, at the Middle/Upper Jurassic in the median scales. Within the external scales the "Mafic Complex" rech the Thitonian or even the Tithonian/Neocomian boundary. It is difficult to precise if the mafic activity start in the whole domain corresponding with the Black Flysch Nappe at the same moment, it means around the Lower/Middle Jurassic boundary. But it ends at more and more younger moments from inward toward outward. This may be one of the hypothetical conclusions but it is not the only one. It was possible that within the whole Black Flysch rifting domain the genesis of each graben – corresponding to different scales – occurs at different moments, successively younger from inward to outward; each graben opening starting with the "Mafic Complex" genesis.

The whole Black Flysch Nappe is metamorphosed in a hP/lT metamorphic facies. Mostly in the "Mafic Complex" it were found pumpellyit and prehnite[10] and even blue amphiboles[11]. The age of the hP/lT metamorphism

is of Midd-Cretaceous age (post-Aptian). Non metamorphosed Cenomanian post-tectogenetic formations covers discordantly the structurated Black Flysch Nappe as well as the contact with the Central East Carpathians Nappes System.

The metamorphism of the Black Flysch Nappe was synchronous with the imbrication of the different scales (metamorphic schistosity pararel with the overthrusting surfaces). The both are prior in respect with the Mid-Cretaceous (Upper Albian) overthrusting of the Black Flysch Nappe, which is synchronous with that of the Central East Carpathains Nappes.

The Black Flysch Unit have, logically, evolved from a different rift system as the other different nappes of the Outern Dacides (Fig. 4). This conclusion is clearly stressed out by:

– the fact that the Black Flysch Nappe is metamorphosed in a hP/lP metamorphic facies, which are absent in the Ceahlău-Bobu Nappes and,

– the fact that the Black Flysch nappe was tectonised in the Middle Cretaceaous, together with the Central East Carpathians Nappes, while the Ceahlău and Bobu, where tectonised, slightly in the Middle-Cretaceous and with major intensity at the end of the Cretaceous.

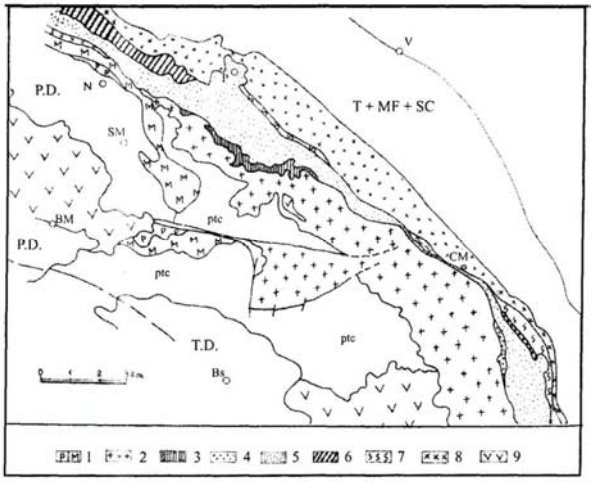

Fig. 3. Tectonic Sketch of the Inner Zones of the northern East Carpathians: 1 – Pienides: P – Pieniny Klippen Zone, M – Magura Group; 2 – Central East-Catpathians Nappes; 3 – Black Flysch Nappe; 4 – Baraolt Nappe; 5 – Ceahlău-Rahov Nappe; 6 –Bolu-Burkut Nappe; 7 – Convolute Flysch Nappeş 8 – Audia Nappe; 9 – Neogene Volcanic Zone; T+MF+SC – Tarcău, Marginal Folds and Subcarpathian nappes; TD – Trensylvanian Depression; PD – Pannonian Depression; ntf – North Trensylvanian Fault; ptc – Post-tectonic Cover. BM – Baia Mare, Bs – Bistriţa, CM – Câmpulung Moldovemesc, N – Novoseliţa, P – Pietros Mt., SM – Sighetu Marmaţiei, V – Vijniţa.

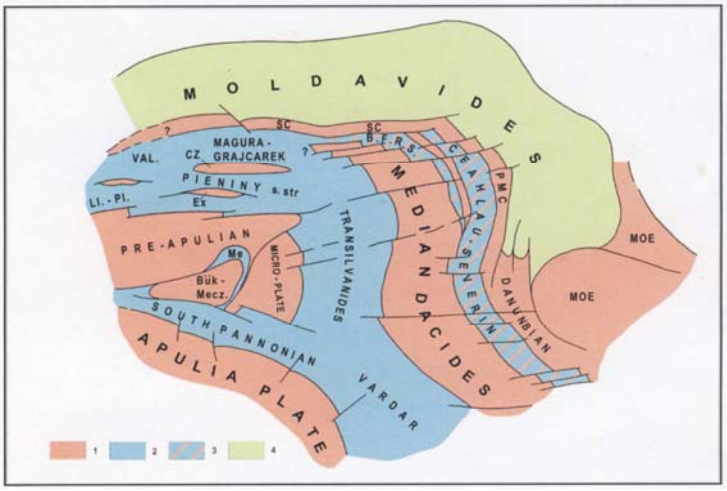

Fig. 4. Retrotectonic-Palispastic Sketch of the Carpathian Tethys an its continental Margins at the end of the Jurassic: 1 – Oceanic Crust, 2 – Within-Plate oceanic-type crust, 3 – Thinned and "oceanized" crust, 4 – Continental-type crust. B.F.R.S. – Black Flysch Rift System, cs – Silesian Cordillera, pmc – Peri-Moldavian Cordillera, Cs – Csorstyn Ridge, Ex – Andrusov "Exotic" Ridge, Si – Silica Suture, Moe – Moesian Platform. W – Wien, BP – Budapest, BG – Beograd, BC – Bucureşti.

Concluding, the Black Flysch Nappe proceed from a very complex rift, which was in the nearest proximity with the Median Dacidic continental Ridge. It was very probably separated by a continental horst structure in respect with the Ceahlău-Bobu rift system, namely the Outern Dacides *s.str.*

GEOLOGY OF THE CEAHLĂU AND BOBU NAPPES

The Ceahlău Nappe have a external position in respect with the Black Flysch one and overthrust the Bobu Nappe (Fig. 2). It is known in the Ukrainian Carpathians as the Rahov and Pietros nappes (including a small part of the Burkut Nappe also) and prolongate within the South Carpathians as the Severin Nappe. The nappe shows a complex structure being structurated in several sub-units (digitations).

The most specific lithostratigraphic unit of these nappes is the Tithonian-Neocomian Sinaia Formation – a limy flysch of more than 4,500 m stratigraphic thickness. At the base of this Formation both in the East Carpathians (pillow-lava basalts) and South Carpathians (basalts, pillow-lava, serpentinites and peridotites)[8,12,16], are discontinuously developed. The mafic-ultramafic rocks are frequently overlaped by Callovian-Oxfordian radiolarites.

The Barremian-Aptian of the two nappes is also developed in turbiditic,polymictic,lithofacies of several thousand meters in thickness. The Albian is sandy massif and/or conglomeratic. The Cenomanian-Senonian is developed in a pelagic varriegated marly facies.

PALEOGEOGRAPHICAL - PALINSPASTIC EVOLUTION OF THE OUTERN DACIDES *SENSU LATO*

The Outern Dacidian *s.l.* (ODsl) group toghether the Black Flysch, the Ceahlău and the Bobu nappes. They proceed from at least two complex rift systems, extended within the outernmost European Continental Margin of the Tethyan Ocean. The Tethyan oceanic crust started to be generated, within the Vardar-Carpathians Realm, possibly since the Anisian but certainly since the Ladinian and continue to spread until Callovian or the Lowermost Tithonian. The continental crust bearing ridge, situated between the Tethyan Ocean and the Outern Dacidian *s.l.* rift systems correspond to the Median Dacides Ridge (MDR).

The differences between the geological constitution and evolution of the Black Flysch Nappe *vs* Ceahlău and Bobu nappes, support the idea they proceed from different paleotectonic structures (see above). The complex rift corresponding to the Black Flysch Nappe spreaded earlier (Uppermost Liassic) as that corresponding to the Ceahlău and Bobu Nappes (Bajocian-Bathonian). The two rift systems – Black Flysch and Ceahlău-Bobu – were separated until the Mid-Cretaceous tectogenesis by an elevated, continental crust, horst-licke ridge. This may explain the different evolution of the sedimentation and magmatic activity in the two rifts areas:

– the complex mafic magmatism extended from the Toarcian until the Tithonian in the Black Flysch Nappe *vs* restricted Mid Jurassic (Bajocian-Bathonian) of the mafic magmatism of the Ceahlău and Bobu Nappes.

– hP/lT post-Aptian metamorphism and thrustings within the Black Flysch Rift *vs.* only folding and thrusting, with axial schistozity, within the Ceahlău-Bobu Rift.

– the Mid-Cretaceous overthrusting of the Black Flysch Nappe, together and in front of the Central East-Carpathians nappes over the inner part of the Ceahlău Nappe.

– the absense of End-Cretaceous overthrustings within the Black Flysch Nappe *vs.* the overthrusting, in the Uppermost Senonian, of the Ceahlău and Bobu nappes over the Moldavides, namely the Convolute Flysch Nappe.

COMPARATIVE REGIONAL CORRELATIONS

The most logical western correlation of the inner group of units of the East Carpathians is to compare them with the Pienides of the Western Carpathians and further westward with the Eastern and Central Alps. For this reason it is necessary to enlarge the analyse of the Roumanian Carpathians, mainly concerning the position and the structure of the Main Tethyan Suture Belt.

The **Main Tethyan Suture Belt (MTS)** runs, south of the Danube (Shumadija-Beograd area) along the Vardar Zone. North of the Shumadija zone it branch out in, at least, two branches:

– the *Transylvanides*[13,14,19] which crops out in the Southern Apusenides and prolongate below the Transylvanian basin, joining north of the North Transylvanian Fault (NTF) the Pienides (Fig. 1) and

– the *South Pannonian Suture*[5,16,19] which is the ophiolitic suture trending out the Dinarides from the Carpathian Realm – in fact the very complicated area of the central and south Pannonian domain joining westward the Insubric Line (Fault).

Another Tethyan suture within the Carpathian domain is:

– the *Meliata Suture* (Fig. 4) which trend the Gemerides in respect with the Buckk domain and which may be considered a branch of the South Pannonian one.

The **Pre-Apulian Domain** group together, within the Carpathians innermost area – it means south and westward in respect with the MTS – the *Northern Apusenides* and the *Central West Carpathians* as well as the *Austro-Alpine Nappes* [5,16,19].

The correlation of the **Pienides** with the **Eastern Alps** may be summarized as follows:

– the Magura Nappe clearly prolongate, following the outcrops, into the Rheno-Danubian Flysch Zone;

– the Pieniny Klippen Belt crops out in the

Wiener Wald area, between the Austro-Alpine nappes and the Rheno-Danubian Flysch units[7,9].

The Magura oceanic trough was considered, in the West Carpathians, the most external trough of the Main Tethyan Oceanic Belt[1,2]. The Magura trough is an, external, part of the Pienidian Oceanic Domain (POD) which group toghether also the Pieniny Trough and at least two continental ridges – the Czorstyn Ridge and the Andrusov "Exotic" Ridge – as well as some inner (south-ward seated) troughs which correspond with, at least, the Krichevo, Băbeşti-Tijacevo and Ujgorod units[18].

Taking into account that the Rheno-Danubian Flysch originated from the Valaisanne Zone[5,6,20] it may be supposed by consequence that the Valaisanne Trough prolongate within the Magura through and that the Grajcarek Serie is a "Valaisanne" sequence !?

If the Rheno-Danubian Flysch Belt should have a Liguro-Piemontais origin the Magura Trough may be still correlated with the Valais one but it remain some disputable problems.

Is the Liguro-Piemontais and its correspondents within the Eastern Alps and the Western Carpathians, continuously separated by continental "Briançonais" – type ridges in respect with the Valaisanne-Magura trough[15] ? Or, eastward of the Central Alps, the two oceanic domains – Liguro-Piemontais and Valaisanne-Magura – communicated directly and only discontinuously some continental crust ridges, as for exemple the Hochstegen, the Andrusov"Exotic"Ridge or the Czorstyn one, separated them[5,6,18].

The **Maramureş East Carpathians** transect offer the possibility to analyse with more details the paleogeography of the European continental margin, corresponding to the Inner East Carpathians. The main conclusions should be (Fig. 4):

– the nearest continental areal in respect with the Main Tethyan Oceanic Domain is the Median Dacides Ridge (MDR);

– in the nearest outside vicinity of the MDR develops the Black Flysch Rift system (BFRs) which start its extensive history – marked by the mafic magmatic activity – since the Lower Jurassic and continues (but only in the outernmost areas) until the Tithonian ;

– outside in respect with the BFRs and separated by an continental crust horst are situated the Ceahlău-Bobu Rift system. (CBRs).

– in this picture the MDR may be "theoretically" compared with the "Briançonais" and the BFRs, toghether or without CBRs, with a "Valaisanne" – type Zone.

One of the difficulties, accepting the above mentioned hypothesis, is to compare a Jurassic-Cretaceous palinspastic paleogeography (the Median and the Outern Dacides *s. l.* in the East Carpathians, which have a Cretaceous tectogenesis) whith a Jurassic-Paleogene palinspastic paleogeography (Magura and Pieniny Klippen Belt in the Western Carpathians, which shows a Cretaceous and End-Paleogene tectogenesis).

It is also a problem to conclude if the Median Dacides Ridge have had a similar palinspastic position with the Czorstyn Ridge or – this is more than likely – "en coulisses" (oblique-link) position, prolongating along the northern (outern) border of the Grajcarek Trough. Following the second hypothesis the Black Flysch Rift system was the outernmost trough of the Tethyan Oceanic Domain in a "valasanne" – type position. If accepted, this hypothesis is supported, also, by the Jurassic lithostratigraphy of the both troughs, which should be a positive reason. In this case the Ceahlău-Bobu Rift system (ODRs) closed independently toward the West Carpathians (Fig. 4).

Another problem is: how far the Mid-Cretaceous toghether deformed MDR and BFRs prolongate outside of the Grajcarek-Magura trough.

The same and consequently problem is the question: how far the Median Dacides and the Black Flysch Nappe prolongate actually westward below the Magura Group overthrust.

There are no reasons to prolongate the rift system corresponding to the Ceahlău and Bobu nappes (Outer Dacides *s. str.*) toward west. It is more than likely that it close along several left-lateral stricke-slip fault.

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