1. OVERVIEW ON THE GEOLOGY OF THE CARPATHIANS

(based on M. Sandulescu, 1994 - ALCAPA II, field guidebook)

The geology of Romania is strongly dominated by the alpine Carpathian Folded Belt (Orogen). The foreland of the orogen includes several platforms, as well as the North Dobrogea Orogen (Fig. 1).

1.1. **Carpathian Foreland**

The oldest cratonic unit of the Carpathian Foreland is represented by the East European Platform, represented by its podolo-moldavian sector, so-called Moldavian Platform. The Lower Proterozoic metamorphic basement of the platform is intruded by gabbros, anorthosites and granites. The basement is covered by sedimentary formations developed in several sedimentary cycles: Vendian - Cambrian, Ordovician – Silurian, Devonian, Upper Jurassic – Cretaceous, Eocene and Oligocene. The platform is fractured by several trans-crustal faults. Those situated at the westernmost boundary represent the Tornquist-Teisseyre Fault Zone - TTZ (Trans European Lineament).

The Scythian Platform develops south of the East European Platform, extending from eastern Romania through North Crimea and north Great Caucasus. Towards northwest, it prolongates below the East Carpathians flysch nappes. The folded basement is of Caledonian – Hercynian age involving old metamorphic rocks and Paleozoic ankimetamorphic and sedimentary formations. The sedimentary cover of the platform includes rocks of Upper Devonian, Carboniferous, Permian, Triassic, and Jurassic age. The Neogene formations are common with the whole Carpathian Foreland. The boundary with the East European Platform is a trans-crustal fault system, east of the Siret River. Towards northwest, the contact is more complex being represented by the TTZ, and also supposed thrusting with eastern vergency.

The Moesian Platform is situated in the southern part of the Carpathian Foreland, separated from the Scythian Platform by the North Dobrogea Orogen. The basement consists of Precambrian metamorphic rocks (Kata and/or mesometamorphic rocks of Lower and Middle Proterozoic age, ankimetamorphic of turbiditic type, named “Green Schists”, of Vendian – Lower Cambrian (?) age. The platform cover is thinner and with more gaps in Dobrogea, but it develops towards west in important Paleozoic (Cambrian – Carboniferous) and Mesozoic (Perm Triassic – Cretaceous) sedimentary basins, sometimes reaching more than 6 km thickness. Some specific features of the Moesian basin are to be pointed out: the quartzitic developments in Cambrian and Ordovician, The Graptolitic shales in Silurian, the carbonatic platforms of Upper Devonian (also including evaporites), Mid Triassic and Upper Jurassic-Lower Cretaceous, the Keuper-type development of the Upper Triassic (locally with salt deposits) the chalk-type development of a part of Senonian. Taphrogenic bimodal magmatism (mafic and acid lava flows) is known in Permian and Triassic, generated in an extensive tectonic moment. Several important trans-crustal fractures are to be mentioned. The Peceneaga-Camena Fault, representing the northeastern border of the platform, is the southernmost segment of the TTZ. The Capidava-Ovidiu Fault, south of the previous one, separates the Central Dobrogea from the South Dobrogea. The Intra-Moesian Fault divides the platform into two blocks (Dobrogean and Wallachian), which partly drifted independently during the Carpathian deformations.

The North Dobrogea Orogen (NDO) is the westernmost segment of a Cimmerian Folded Belt, which extends eastwards in South Crimea and further on, joining the Asian Cimmerides. The NDO shows a nappe structure with north0east vergency (towards the Scythian Platform). Three nappes are recognised: Macin, Niculitel and Tulcea, from SW towards the foreland (Fig. 2). The Macin and Tulcea nappes involve continental crust (Precambrian and/or Lower Paleozoic metamorphic formations and granites) and Middle

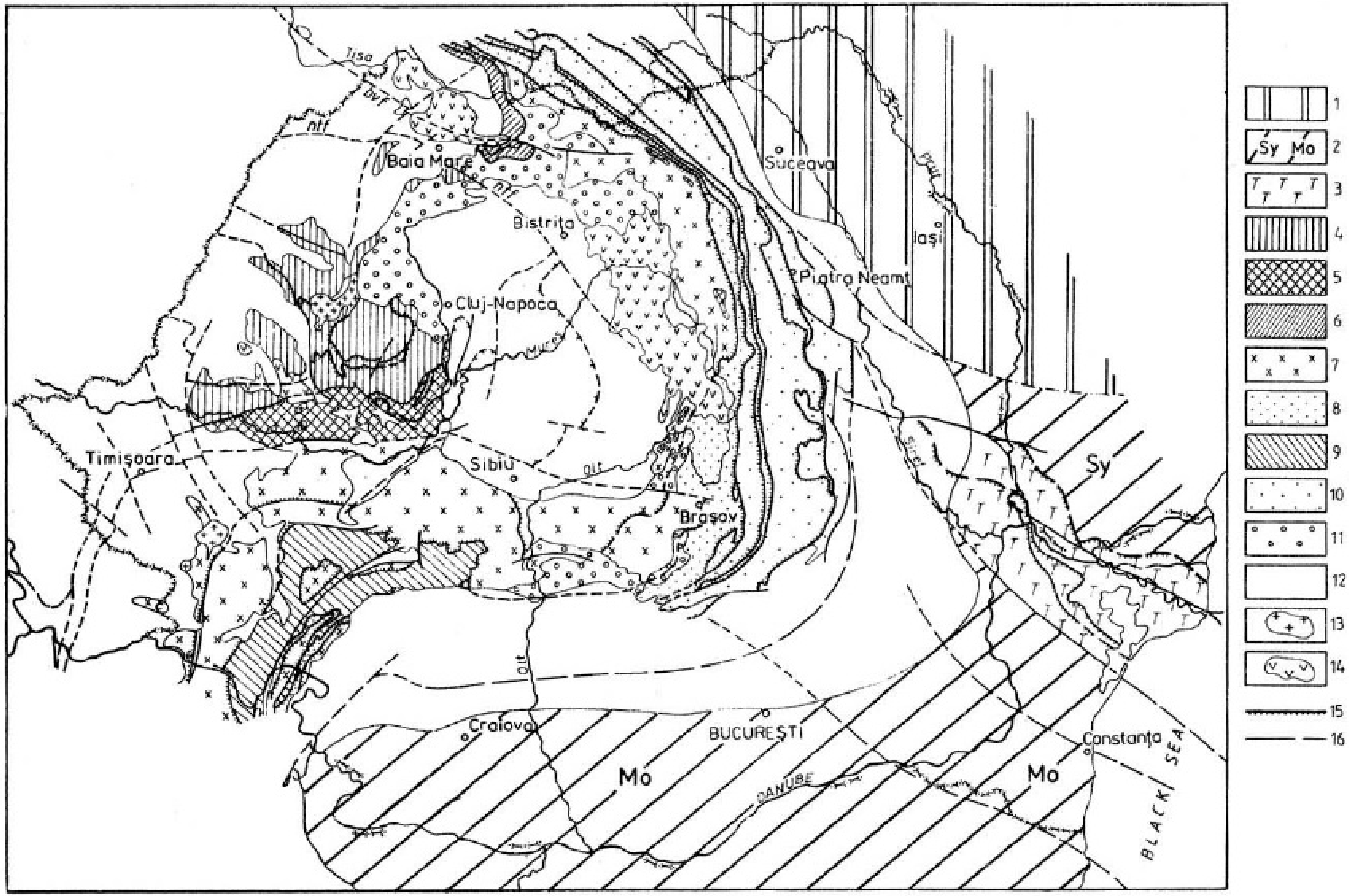

Fig. 1. Tectonic sketch of Romania, Carpathian Foreland: 1 – East European Platform; 2 – Scythian (Sy) and Moesian (Mo) Platforms; 3 – North Dobrogea Orogen; 4 – Inner Dacides; 5 – Transylvanides; 6 – Pienides; 7 – Median Dacides; 8 – Outer Dacides; 9 – Marginal Dacides; 10 – Moldavides; 11 – Post tectogenetic covers; 12 – Neogene Molasse Depression and Foredeep; 13 – Upper Cretaceous – Paleocene magmatic arcs; 14 – Neogene magmatic arcs; 15 - - thrust-sheets; 16 – faults

Paleozoic – Jurassic sedimentary (or ankimetamorphic) formations, while the Niculitel Nappe, with a median position between the two others (Fig. 3), plays the role of a “suture”, built up of a Spatian – Carnian mafic complex (intraplate basalts and pillow-lavas with pelagic carbonate intercalations), followed by a Norian-Lower Jurassic flysch.

The North Dobrogean orogen is issued from the Early Mesozoic intraplate rift, which extended from the Early Triassic until the Upper Triassic, allowing the development of a thinned crust and mafic flows and intrusions in its central part. The compressive movements deformed the North Dobrogea Rift (as well as its correspondent, the South Crimea) in Early Jurassic and in End-Jurassic tectogeneses (Early and Late Cimmerian tectogeneses). The anticlockwise rotation of the Moesian Platform in Jurassic, due to the extension of the Outer Dacidian Rift had an active role in the compression history of the North Dobrogea Orogen.

The structure of the North Dobrogea Orogen prolongates offshore into the Black Sea continental plateau, similar to the Moesian and Scythian platforms. The post-tectonic cover starts with Albian, followed by Upper Cretaceous, the latter cropping out also on-land, in the Babadag Syncline. The North Dobrogea Orogen is also prologated northwest of the Danube River, below a thin Neogene cover. In this area, it is known as The North Dobrogea Promontory. It squeezes out along a major fault – the Trotus Fault –, which was probably the fault that limited the North Dobrogea Rift to the northwest, during its Triassic extension.

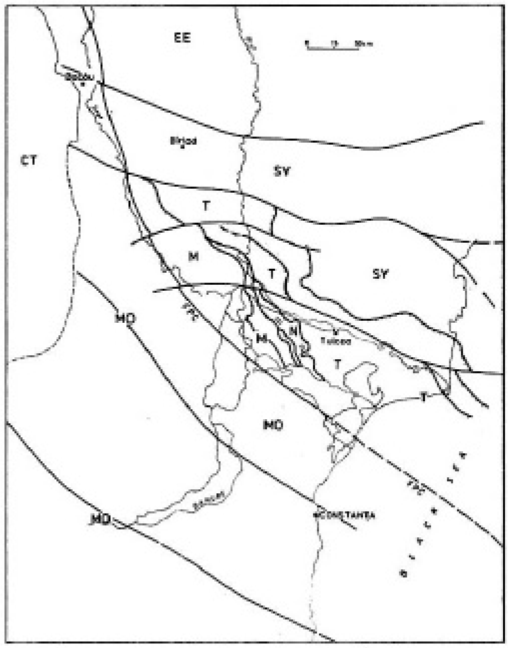

Fig. 2. Tectonic sketch of the North Dobrogea Orogen. EE – East European Platform; Sy – Scythian Platform; Mo – Moesian Platform; M + N + T – North Dobrogea Orogen (M – Macin Nappe, N – Niculitel Nappe, T – Tulcea Nappe), FPC – Peceneaga Camena Fault

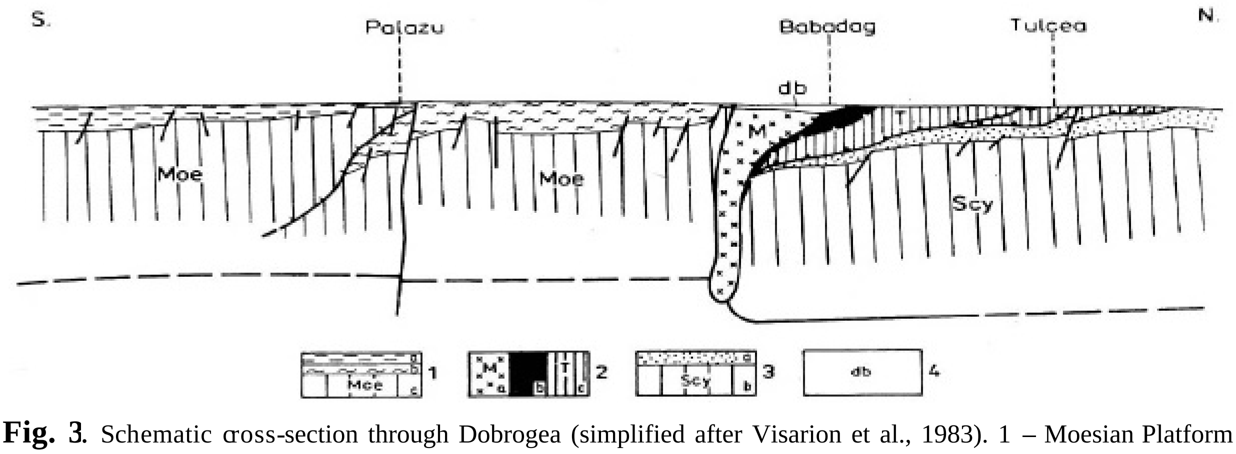

Fig. 3. Schematic cross-section through Dobrogea (simplified after Visarion et al., 1983). 1 – Moesian Platform (a – basement, b – “Green Schists”, c – Paleozoic-Mesozoic formations); 2 – North Dobrogea Orogen (a – Macin Nappe, b – Niculitel Nappe, c – Tulcea Nappe); 3 – Scythian Platform (a – basement, b – Upper Paleozoic-Mesozoic formations); 4 – Babadag Sinclinoria.

1.2. **Carpathian Folded Belt (Carpathian Orogen)**

The Carpathian Orogen is a segment of the Tethyan chain, which joins the Alps to the west and the Balkans and Rhodopes to the south. The Carpathian folded area includes deformed remnants of the oceanic crust bearing Tethys and its strongly deformed continental margins. The orogen is the result of several tectonic moments in Cretaceous (the inner zones) and Miocene (outer zones). The post-tectogenetic covers develop above deformed units of the inner zones in Upper Cretaceous and/or Paleogene. Two Neogene molassic depressions (Transylvanian and Pannonian) overlie important parts of the inner zones and their post-tectonic covers. A Neogene molassic Foredeep is situated along the outer margin of the Orogen. Two calk-alkaline magmatic arcs, one Senonian-Paleocene, and the other one, younger, of Neogene age are related to important subduction processes.

The Main Tethyan Suture Zone (MTS) groups together different tectonic units constituted of ophiolitic complexes and sedimentary formations, which both proceed from the Tethyan oceanic crust bearing area. It prolongates north of the Danube from the Vardar Suture Zone and, passing below the southeast corner of the Pannonian Basin, crops out in the South Apuseni Mts/Southern Apusenides (Metaliferous Mts). There, the north vergent units are constituted of Jurassic ophiolitic complexes and Upper Jurassic and Cretaceous sedimentary formations resulted from a complex paleogeography (calcareous platforms, pelagic rocks, flysch formations). These units are actually prolongated below the Neogene Transylvanian depression (and some Paleogene post-tectogenetic formations) (Fig. 4). There they represent only a part of the MTS; the other part is represented by the “root zone” of the Transylvanian nappes, obducted from there towards east above the Central East Carpathians units (the proximal European continental margin area in respect with the MTS). The Transylvanian nappes are constituted of ophiolitic complexes (serpentinites, pillow lavas, etc.) of different ages (following different moments of the Tethyan spreading processes), extended from Mid Triassic to Mid/Upper Jurassic. They are overlain by sedimentary piles (mostly limestones but starting with radiolarites of cherty limestones). The youngest sedimentary levels known in some Transylvanian nappes are of Barremian (- Lower Aptian?) age. The MTS units described above constitute the Transylvanides, structurated during Cretaceous. North of the Transylvanian Depression, the MTS is represented by the Pienides, a group of units, which relay the Transylvanides “en echalon” and have recorded Cretaceous and Lower Miocene tectogeneses. In Romania, the Pienides consist of Botiza Nappe with the Poiana Botizei Klippen Zone in its frontal part (southeast prolongation of the Pieniny Klippen Belt), the Petrova and Leordina Nappes (equivalent of the Magura Nappe). In Poiana Botizei Klippen Zone, a Middle Jurassic – Upper Cretaceous pelagic succession (radiolarites/cherty and Calpionella-bearing limestones/dark shales/”couches roughes”) is known. In Petrova and Leordina nappes, a Maastrichtian-Paleocene flysch is developed (“Inoceramia Beds” type); well-developed Paleogene flysch formations are known in all Pienidian nappes. The actual general structural shape of the Pienides is due to the Lower Miocene (Burdigalian) tectogeneses, when the nappes were overthrusted above the post-tectogenetic cover (neoautochton) of the Median Dacides (Central East Carpathians nappes). The traces of the Cretaceous tectogeneses are visible only in the Poiana Botizei Klippen Zone (where formations of this age were preserved). The Lower Miocene transport of the Pienidian nappes was directed and/or accentuated by several important fractures with strike-slip components, mainly the North Transylvanian Fault (ntf) and the Bogdan Voda Fault (bvf) (Fig. 1). Consequently, escape tectonics processes were developed.

The Inner Dacides (ID) which are part of the Foreapulian Block (figs. 4 and 5) are situated west and north of the salient bended MTS. In Romania, this group of units is cropping out in the Apuseni Mts. (Northern Apusenides). It was also reached by drillings

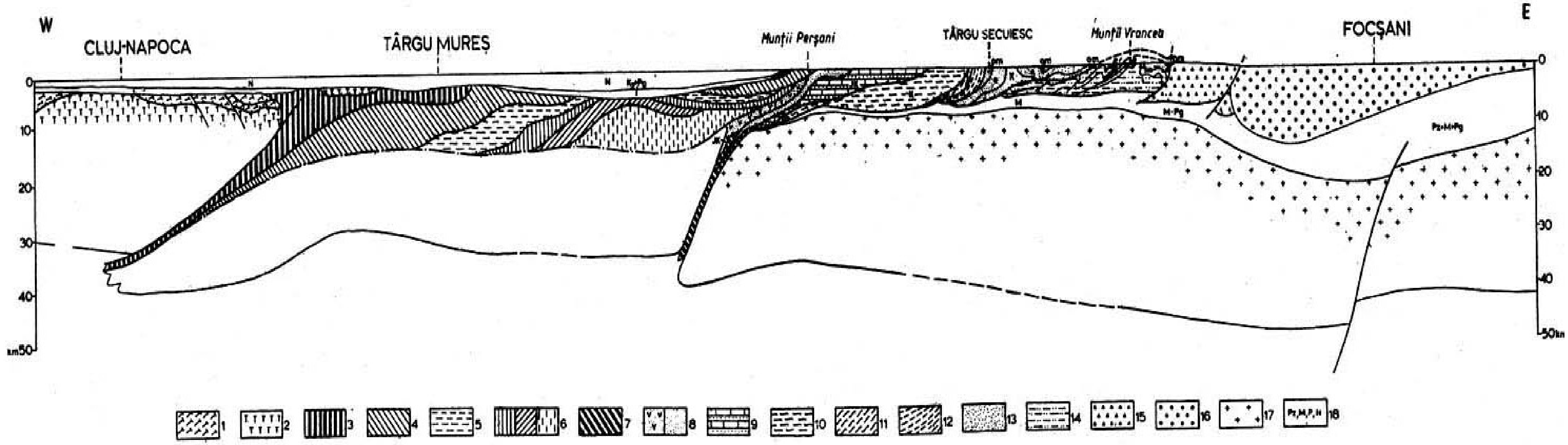

Fig. 4. General cross-section through the Romanian Carpathians (according to Sandulescu, 1994). Inner Dacides (1 + 2): 1 – Codru-Arieseni Nappe system; 2 – Bihor Unit; Main Tethyan Suture: 3 – Transylvanides; Median Dacides(4 – 6): 4 – Bucovinian Nappe; 5 – Subbucovinian Nappe; 6 – Infrabucovinian Nappes; Outer Dacides (8 + 9): 8 – Black Flysch Nappe; 9 – Ceahlau Nappe; Moldavides (10 – 15): 10 – Convoute Flysch; 11 – Macla Nappe; 12 – Audia Nappe; 13 – Tarcau Nappe; 14 – Marginal Folds Nappe; 15 – Subcarpathians Nappe; Foredeep: 16 – Focsani Depression; Underthrusted elements (17 + 18): Crystalline basement; 18 – sedimentary formations (Pz – Paleozoic, Mz – Mesozoic; Pg – Paleogene).

below the Pannonian Basin and the northwestern Transylvania. The ID consists of several north and northeast vergent nappes consisting of metamorphic rocks (and locally granites) and sedimentary formations. The metamorphic series are pre-Cambrian and Paleozoic. The sedimentary succession starts (in the southern unit) with molassic Upper Carboniferous and mostly Permian. The orthoquartzitic Lower Triassic is followed by a carbonatic Triassic sequence, more shallow water to the north (tectonically deeper units) (where the Upper Triassic is missing) and progressively deeper water to the south (higher units) the southernmost one showing a Hallstadt-type lithofacies. The Lower Jurassic (paralic in the north, deep water in the south follows the model. Middle Jurassic (condensed carbonatic rocks), Upper Jurassic (carbonatic platform) and Cretaceous (pre-Senonian) (bauxites followed by neritic-urgonian-type limestones, marls and turbidites) formations were preserved from erosion only in the northern units; nevertheless, a turbiditic Tithonian-Neocomian sequence is known in the southern one. The overthrusting processes are (Upper?) Turonian in age. The structured and partly eroded nappes were overlapped by a Senonian post-tectonic cover, showing the Gosau lithofacies. The stratigraphic gap is continued in some areas with Paleogene epicontinental formations.

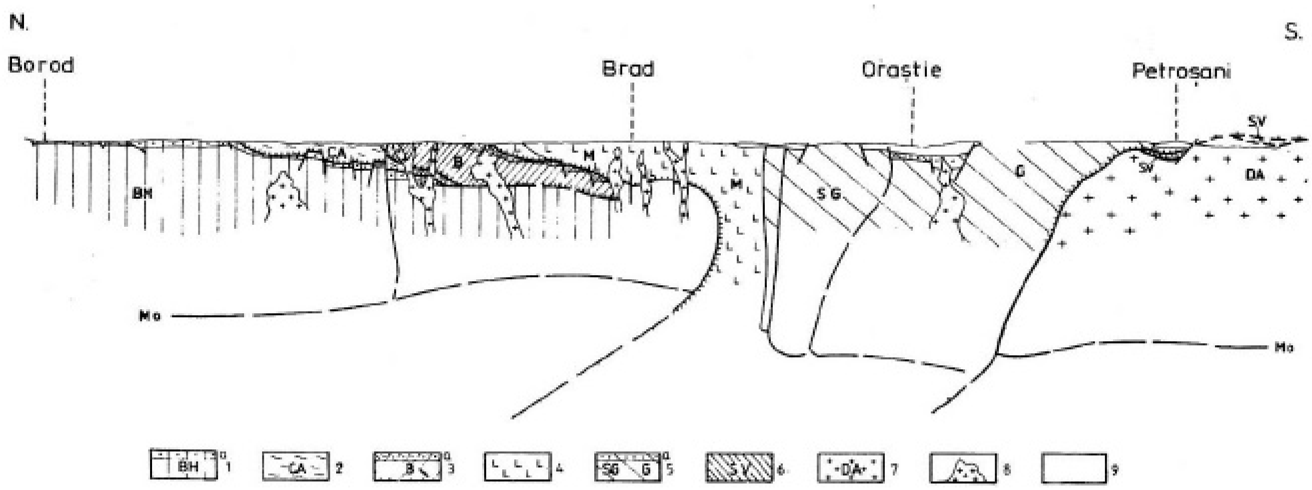

Fig. 5. Structural cross-section through the Apuseni Mts. and the South Carpathians. 1 – Bihor Unit (a – sedimentary formations); 2 – Codru-Arieseni nappe system; 3 – Biharia nappe system (a – Gossau Formation); 4 – Transylvanides (main tethyan Suture), 5 – Getic and Supragetic nappes (a – sedimentary formations); 6 – Severin Nappe; 7 – Danubian; 8 – Severin Paleocene calc-alkaline intrusions (Banatites); 9 – post-tectonic covers.

The ID/MTS tectonic relationships are complex: while in the southern sector the Transylvanides are "back-thrust", in the Senonian, above the Inner Dacides, in the northern sector the ID thrust the Pienides, in the Lower Miocene. This important changing is determined by transcrustal fault (ntf) which, crossing the MTS and its continental borders, allowed opposite and composite translations of different panels. The north vergent ID/MTS tectonic relationships are supported by drilling and geophysics around the Romania/Ukraine border area.

The Median Dacides (MD) are situated on the opposite side of the MTS in respect with the ID. The MD units crop out in the Central East Carpathians and an important part of the South Carpathians. They proceed from the nearest strip towards the MTS to the European continental margins. These units are basement-shearing nappes, each of them involving metamorphic rocks and their sedimentary envelops. In the Central East Carpathians, the nappes are (upside/downside): Bucovinian, Subbucovinian, and Infrabucovinian nappes. The latest correspond to the Getic Nappe (Domain), the former two to the Supragetic nappes, of the South Carpathians. The mesometamorphic series with a complex premetamorphic

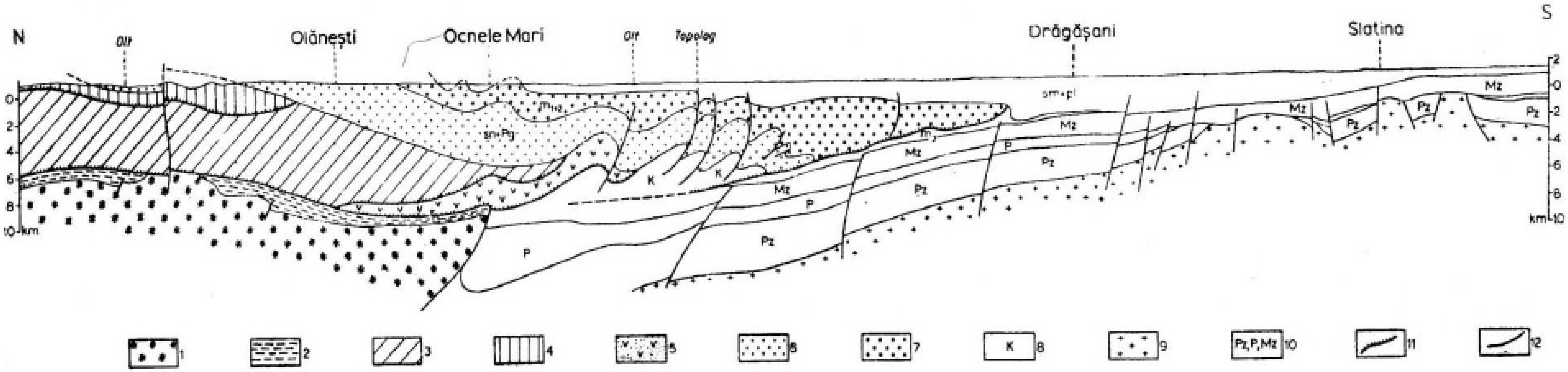

Fig 6. Geological cross-section through the South Carpathians and the Moesian Platform (along Olt Valley). 1 – Danubian crystalline; 2 – Danubian sedimentary formations; 3 – Getic Nappe; 4 – Supragetic nappes; 5 – Severin Nappe; 6 – Senonian-Paleogene; 7 – Miocene; 8 – undivided Cretaceous; 9 – basement of Moesian Platform; 10 – sediemntary cover of the Moesian Platform; 11 – overthrust; 12 – thrust; sm+pl – Neogene molasses of the Foredeep and Moesian Platform.

composition and a polymetamorphic pre-Cambrian and Paleozoic history are dominant within the metamorphic formations. The epimetamorphic series proceeds from terrigenous or volcano-sedimentary formations (Lower and Middle Paleozoic); their metamorphism could be Caledonian and/or Hercynian.

The MD sedimentary formations show several sequences which are more or less expressed sedimentary cycles: Upper Carboniferous and/or Permian molasses (locally developed), quartzitic (late) Lower Triassic followed by carbonatic Middle Triassic, detrital Lower Jurassic, sandy marly Middle Jurassic (locally ending with radiolarites), neritic or pelagic calcareous Upper Jurassic – Neocomian. With the Lower Cretaceous (wildflysch in Bucovinian, calcareous in Infrabucovinian nappes) the MD succession ends in the Central East Carpathian nappes, there the Upper Cretaceous (molassic Cenomanian, almost marly Turonian-Senonian) representing the post-tectonic (post-nappe) cover. In the South Carpathians, the Lower Cretaceous is mostly calcareous ending with glauconitic Albian. The Upper Cretaceous rocks are molassic in the lower part, followed by marly-sandy formations and ending with turbiditic or volcano-sedimentary sequences. The Upper Cretaceous rocks seal some Mid-Cretaceous compressive structures, but are also involved into the end-Cretaceous deformations (Fig. 6).

The post-tectonic cover of the East Carpathians MD are preserved in some subsiding areas (gulfs) on their western slope, being partly covered by the eastern parts of the Transylvanian Depression and the East Carpathians volcanic arc. The Upper Cretaceous formations are followed by Lutetian molasses, Priabonian limestones, marls or flysch and Oligocene – Lower Miocene (alternating), pelitic (partly bituminous) and arenitic sequences. The post-tectonic cover of the South Carpathians MD starts in Paleogene molasses followed by on their southern slopes by Oligocene marly-sandy formations and Lower Miocene conglomerates.

The Outer Dacides group together a strip of units, which proceed from a Jurassic – Lower Cretaceous paleo rift, developed within the European continental margin. In the East Carpathians (Black Flysch, Baraolt and Ceahlau nappes) they are built up of Jurassic intraplate basalts and/or Tithonian-Lower Cretaceous flysch formations (locally with conglomerates in the Upper Aptian and Albian). Some marly Upper Cretaceous formations are known in the Ceahlau Nappe. In the South Carpathians (Severin Nappe), the Jurassic ophiolites are followed by Tithonian-Lower Cretaceous flysch. The Outer Dacidian units (nappes) were twice deformed: during the Mid-Cretaceous and end-Cretaceous tectogenetic moments. In the South Carpathians they are sandwiched between the Getic Nappe and the Marginal Dacides (Danubicum). In the East Carpathians they are partly overthrust by the MD and run parallel with their external border. The Outer Dacides represent a satellite suture in respect to the MTS.

The Marginal Dacides (MAD) (Danubian) crop out in a huge half-window, below the Getic and Severin nappes (fig. 1). The major part of the Danubian units of basements shearing type, involving crystalline formations and their sedimentary envelope. Pre-Cambrian mesometamorphic rocks (mostly metaclastics and/or amphibolitic, with serpentinite bodies), with important retromorphic processes, are intruded by numerous granitic, granodioritic and dioritic massifs of Latest pre-Cambrian or lowermost Cambrian age. Near the Danube, a gabbro-peridotitic massif (Iuti) may represent a part of the pre-Cambrian or Paleozoic ophiolitic suture, included into the pre-Alpine basement of the MAD. Paleozoic, slightly metamorphic quartzose, conglomeratic, sandy and shaly rocks are thin and discontinuosly developed. The "envelope" formations include Permian and Mesozoic rocks. The Permian molasses (with rhyolitic intercalations) are discordantly followed by Lower Jurassic paralic and/or marine deposits (Gresten lithofacies). Middle Jurassic is sandy calcareous while, during the Upper Jurassic and part of Lower Cretaceous, carbonatic platforms develop in external parts and basinal formations in the internal parts. Albian and Cenomanian show pelagic marly formations followed, during Senonian and Turonian, by a wildflysch (olistostrome) formation (which includes blocks of very different sizes generated from the Danubian, Severin and Getic domains. In the western part of MAD, below the Getic Nappe and above the internal Danubian units, the Arjana Unit is developed. It is a complex nappe consisting of sedimentary and volcano-sedimentary formations (quartzitic sandstones and coarse-grained Lowermost Jurassic, alternating shales, limestones, trachytes and alkaline basalts lavas and tuffs of Lower (?) Middle and Upper Jurassic age/ Neocomian limestone/ Upper Cretaceous wildflysch). It was generated by transitional strip between the Danubian and Severin domains (the boundary strip between the MAD and the Outer Dacidian paleorift).

The actual structure of the MAD is the consequence of two main tectogenetic periods, a Mid-Cretaceous (Aptian-Albian) one and an End-Cretaceous (Senonian) one. Anchimetamorphic events occur in connection with both of them. At the end of Cretaceous, the entire MAD area was tectonically covered by Getic (together with Severin) Nappe. Erosional processes occur since the earliest Cenozoic. The Paleogene post-tectonic covers are common for the MD and MAD.

The Moldavides are the outermost Carpathian units (Fig. 7). They correspond to a major part of the East Carpathian Flysch Zone (excepting the Outer Dacidian nappes). From inside to outside, they are: Convolute Flysch, Macla, Audia, Tarcau, Marginal Folds and Subcarpathian nappes. These nappes are sedimentary allochtonous bodies overthrust progressively above foreland elements. The stratigraphic succession, showing different lithofacies, extends from the Lower Cretaceous up to the Lower Miocene. During this interval, the detrital rocks were supplied by two main sources: an external source situated in the foreland, and an internal source represented by the “cordilleras” or, mostly in Cenozoic, by the still structured internal units of the East Carpathians. The highly subsiding trough migrated from inside to outside since Lower Cretaceous (Convolute Flysch area) until the Paleogene (Tarcau area) and even Lower Miocene (Subcarpathian area).

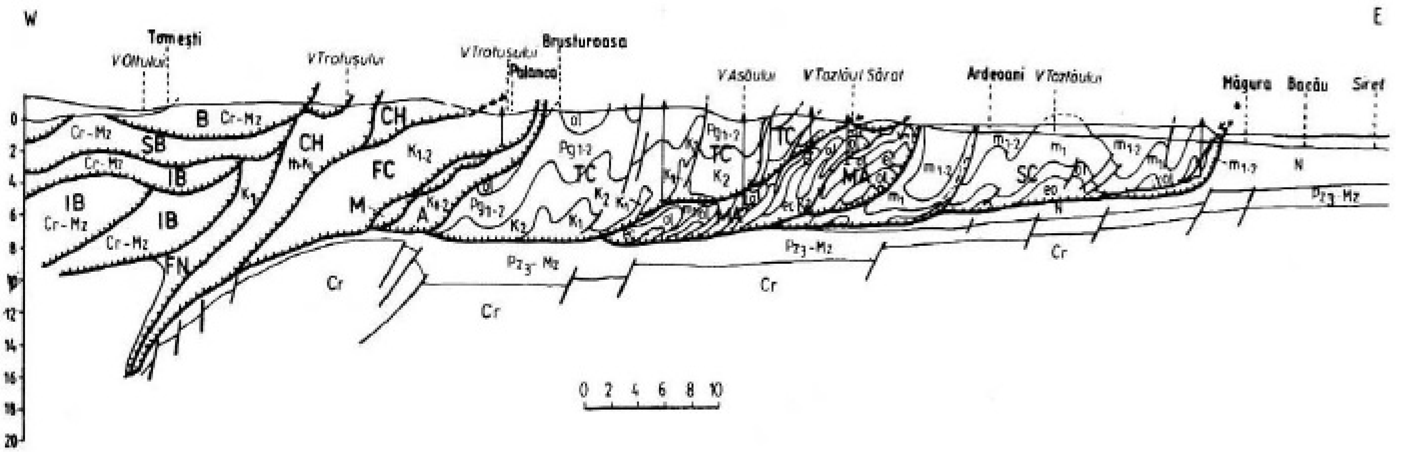

Fig. 7. Geological cross-section through the East Carpathians Flysch Zone (in Central Moldavia). B – Bucovinian Nappe; SB – Subbucovinian Nappe; IB – Infrabucovinian Nappe; FN – Black Flysch Nappe; CH – Ceahlau Nappe; FC – Convolute Flysch Nappe; M – Macla Nappe; A – Audia Nappe; TC – Tarcau Nappe; MA – Marginal Folds Nappe; SC – Subcarpathian Nappe; Cr – crystalline formations; Pz_3 – Upper Paleozoic; Mz – Mesozoic; N – Neogene; TH – Tithonian; k_1 – Lower Cretaceous; k_2 – Upper Cretaceous; Pg_1 – Paleocene; Pg_2 – Eocene; ol – Oligocene; m_1 – Lower Miocene; m_2 – Middle Miocene.

The Lower Cretaceous formations show two main lithofacies: the external Black Shales development, covering the Audia, Tarcau and Marginal Folds domains, relatively thin (600 – 900 m) and dominated by euxinic sedimentation and the inner, Convolute Flysch developments, several kilometers thick (5 – 6 km), developed in a subsiding flysch trough supplied by an inner source area (the Peri-Moldavian Cordillera). In the Convolute Flysch Trough, the turbiditic subsiding sedimentation continues up to the Turonian (even Lower Senonian?), while in the Black Shales domain, a condensed variegated very thin sequence, partly deposited below the CCD level, sedimented in the Upper Vraconian – Lower Senonian time span. In Senonian, the main flysch lithofacies migrated to the exterior, the more specific of them being known in the Tarcau domain (calcareous flysch). Sandy flysch developed to the exterior (Audia domain) while the external lithofacies are of pelagic nature. The highest subsiding flysch area migrated again in the Paleogene (Tarcau domain) determining the development of many lithofacies, from the proximal sandy one in the inner part, to the distal shaly-calcareous one in the external part. The double source areas, in foreland and hinterland, were still existing. During the Oligocene and Early Miocene a specific bituminous-quartzitic sandy lithofacies develops in the external part of the Moldavides (external Tarcau, Marginal Folds and Subcarpathian nappes). Synchronously, the flysch development is known in the inner part of the Tarcau Nappe.

Following an evaporitic event (salt and gypsum), of (Middle) Burdigalian age, the Lower and Middle Miocene molassic formation start (Tarcau, Marginal Folds and Subcarpathian nappes) which are included in the thrust-sheets. The post-nappes molasses are developed in the Foredeep.

The main tectogenetic moments, which structured the Moldavides, are of Burdigalian, Badenian and Sarmatian age. Some precursory foldings are recorded in the Convolute Flysch and Audia nappes during the End-Cretaceous time.

The Foredeep is filled with Upper Miocene – Pliocene – Lowermost Pleistocene molasses entirely supplied by deformed rising Carpathians. They cover the most of the external parts of the East and South Carpathians and a part of the neighboring platforms. In the Carpathian Bend area and in the southern Subcarpathians, the inner part of the Foredeep is folded (Plio-Quaternary deformations). The most subsiding segment of the Foredeep is situated in front of the Carpathian Bend (Focsani Depression) where about 10 km of the Upper Miocene – Lowermost Pleistocene molasses were accumulated.

The Transylvanian Depression and Pannonian Basin. They are Neogene, molassic depressions developed above the Inner Carpathians deformed units and their post-tectonic cover. There are Middle and Upper Miocene and Pliocene formations, sandy and/or coarse grained, partly in schlier facies, with an evaporitic level in the Lower Badenian (salt layer in the Transylvanian Depression). Volcanic tuffs developed at different levels.

The magmatic activity during Mesozoic and Cenozoic, in the Carpathian area may be summarized as following:

1. Ophiolitic complexes developed in the oceanic crust bearing Tethys (preserved in the Transylvanides = MTS) during Middle Triassic – Upper Jurassic; Jurassic ophiolites are known in a part of the Outer Dacidian paleorift (preserved in the Severin Nappe), synchronous with intra-plate basalts, in the same paleorift (East Carpathians Outer Dacides).
2. Alkaline magmatism of Jurassic age developed developed in the extensive margins of the Outer Dacidian paleorift (in the frontal part of the Median Dacides and the innermost part of the Danubian (Marginal) Dacides).
3. Calk-alkaline magmatism developed during the compressive history of the Carpathians, connected with subduction paleoplanes. Two main periods were documented: Senonian – Paleocene in the South Carpathians (Getic and Supragetic

areas) and the Apuseni Mts. (North Apuseni = Inner Dacides) and Neogene in the East Carpathians and Apuseni Mts. The first period is predominantly intrusive with a few extrusive structures being preserved. The second one shows an important volcanic arc in the East Carpathians (with some outcropping subvolcanic and/or hypoabyssal bodies) and a smaller arc in the Apuseni Mts.

4. Intracontinental basalts of Plio-Quaternary age (Persani Mts. And Mures Corridor) are connected to the deep (transcrustal) faults.

1.3. **Geotectonic history**

The End-Proterozoic (Panafrican) cratonization is recognised in the whole Carpathian foreland and, as relics, in the whole Carpathian Orogen. This huge cratonic area, actually preserved in the East European Platform, was split , south and west of the former one, within Paleozoic mobile areas. The Scythian Platform proceeds from one of them, the Paleozoic metamorphic series of the Carpathians from another branch. Within the last ones, remnants of a Paleozoic oceanic crust-bearing domain seem to be acceptable. A second large cratonization occurs after Lower Carboniferous, including the Carpathian area and its foreland.

The earliest Mesozoic rifting occur in the North Dobrogea – South Crimea aulacogene, a possible pull-apart extensive structure connected with the strike-slip movements of the TTZ lineament. The rifting processes are relevant since Spathian and continue during the whole Triassic.

The Tethyan oceanic spreading starts in the Middle Triassic (the oldest ophiolites proceeding from the Transylvanian domain) separating the European continental margin from the Foreapulian Block (Fig. 8). The processes continue during Jurassic, propagating into the Pienidian domain (Fig. 8). The opening of Tethys was followed by a compressional period of North Dobrogea, as a result of the northeast rotation movement of the Moesian block. This movement is also connected with the rifting processes in the Outer Dacidian area. At the Middle/Upper Jurassic boundary, the spreading (in the Tethyan oceanic area) and the rifting (in the Outer Dacidian area) reach their maximum size. The End-Jurassic compression in the North Dobrogea Orogen is a consequent result. The earliest important crustal shortenings in the Carpathian area was recorded in the latest Tithonian/earliest Berriasian, within the oceanic Tethys. It is contemporary with the overthrust of Vardarian ophiolites above the Serbo-Pelagonian Massif, but of less amplitude (Fig. 8).

It generated subduction to which it is connected, above the oceanic crust, a calc-alkaline arc, actually involved into the structure of the Transylvanides (Metalliferous Mts.) (Fig. 5). The compressional processes involved into the European continental margin (Median Dacides) as well as a part of the oceanic domain (Transylvanides and the obducted Transylvanian nappes), in the Mid-Cretaceous time (Fig. 9). Since the Lowermost Cretaceous, North Dobrogea was integrated in the stable (cratonic) Carpathian Foreland. End-Turonian (pre-Gossau) compressional events affected the Apulian Block (Inner Dacides) generating their actual structure. The End-Cretaceous determined the final closing of the oceanic Tethys in the Transylvanian sector while only partial shortening in the Pienidian one. End-Cretaceous deformations were recorded in the Median (South Carpathians), outer, and Marginal Dacides (Fig. 9).

Starting with the Early Paleogene, the immobile areas, receiving important flysch sedimentation, remain the Pienidian and the Moldavidian domains (Fig. 9). The Pienidian mobile area was limited to the south by the North Transylvanian Fault, which separated it by the not yet sutured Transylvanides. The Moldavides, with important flysch subsidence developed above thinned continental crust. The southwestern end of the Moldavidian flysch troughs is connected with the Intramoesian Fault. To the west, the Paleogene formations

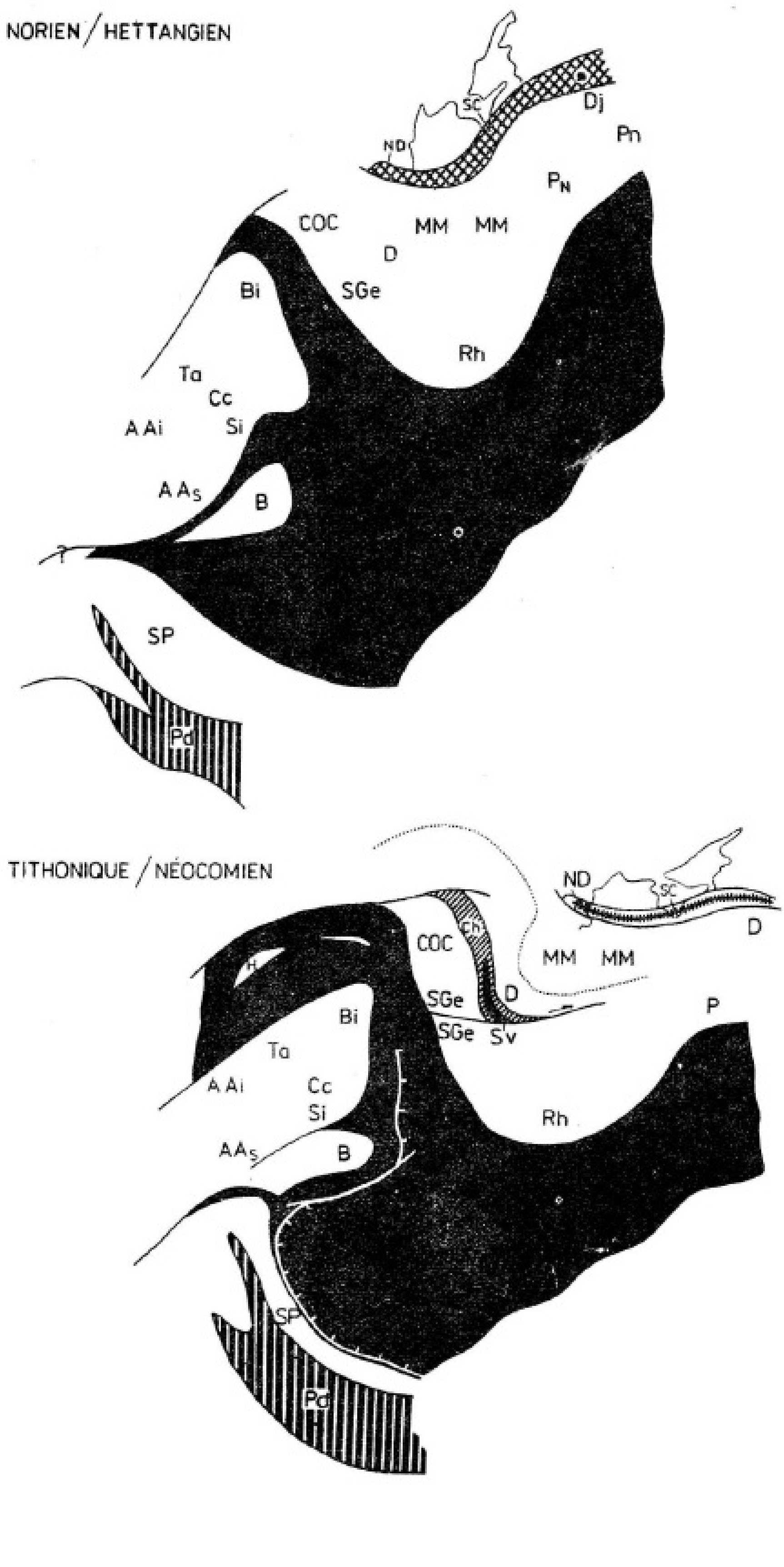

Fig. 8. Palinspastic sketches of the Carpathians and their Foreland in Triassic and Jurassic (similar key as figure 9).

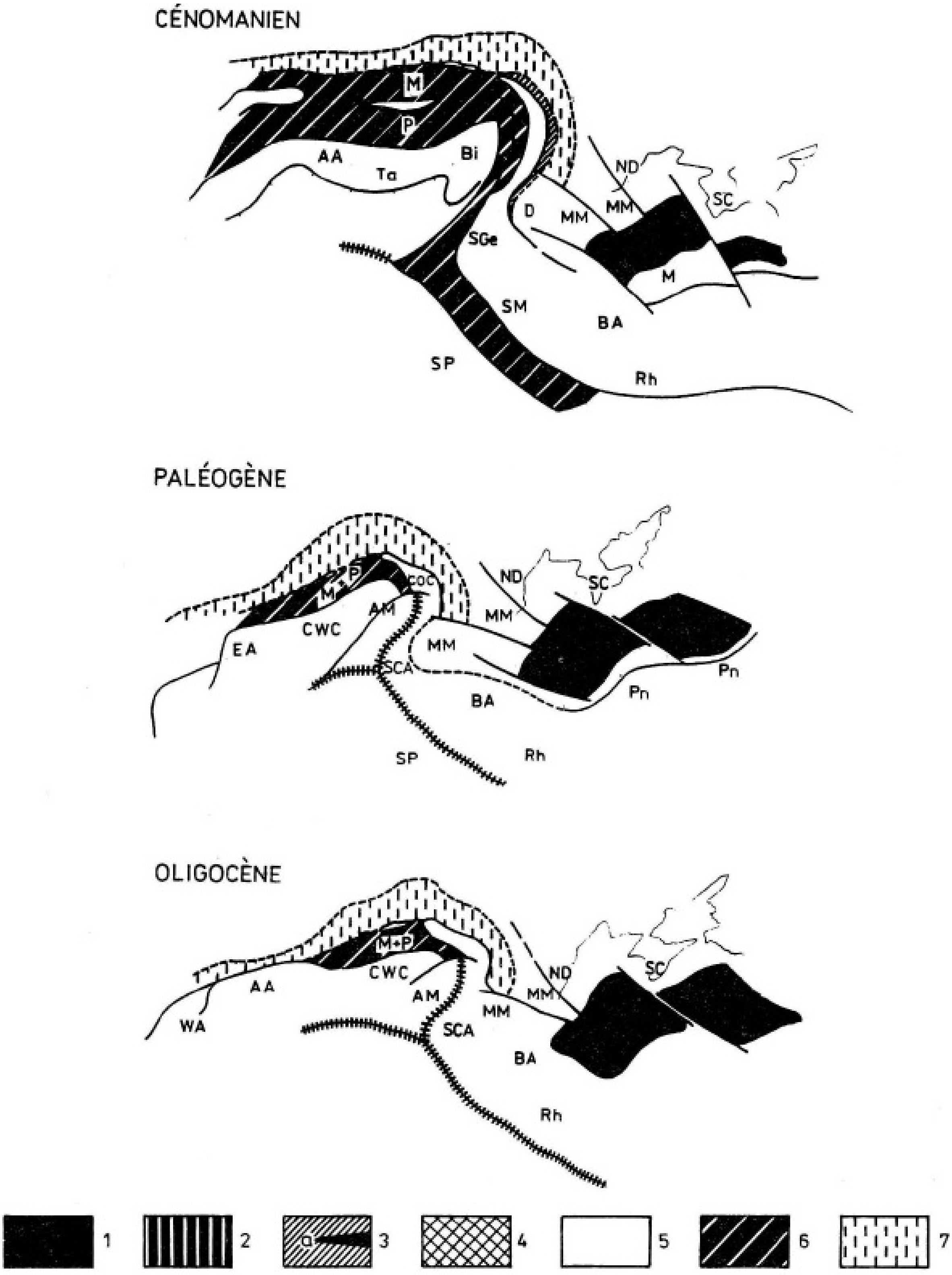

Fig. 9. Palinspastic sketches of the Carpathians and their Foreland in Cretaceous and Paleogene. 1 – Tethyan oceanic crust; 2 – Thinned and/or oceanic crust (Pindus); 3 – Thinned and oceanic (a) crust (Outer Dacides); 4 – North Dobrogea – South Crimea Cimmerian rift; 5 – Continental crust; 6 – deformed oceanic crust; 7 – Thinned crust (Moldavides); AA – Austroalpine; Aai – Lower Austroalpine; Aas – Upper Austroalpine; AM – Apuseni Mts.; B – Bukk; BA – Balkanides; Bi – Bihor; Cc – Choc; Ch – Ceahlau; COC – Central East Carpathians; CWC – Central West Carpathains; D – Danubian; Dj – Djirula; EA – Eastern Alps; MM – Moesia; M – Magura; ND – North Dobrogea; P – Pieniny Klippen; Pd – Pindus; Pn – Pontides; Rh – Rhodopes; SC – South Crimea; SCA – South Carpathians; Sge – Getic and Supragetic; Si – Silicicum; Sv – Severin; SP – Serbo-Pelagonian; Ta – Tatrides; WA – Western Alps.

represent a small (proto) foredeep of the South Carpathians showing lateral lithofacial changes. The Pienides and the Moldavides will be deformed during Lower Miocene (Pienides and Inner Moldavides) and Middle – Upper Miocene (Outer Moldavides). In the inner parts of the Carpathians, deformed in Cretaceous time, the Paleogene (mostly Eocene and Oligocene) extensional basins were developed. In some parts (western Central East Carpathians) they start in Upper Cretaceous (following the Mid-Cretaceous tectogenesis). Post-tectonic covers were accumulated.

The consumption of the Tethyan oceanic crustal well as of the Outer Dacidian rift (oceanic or thinned) and Moldavidian thinned crust generated several calc-alkaline arcs of Senonian – Paleocene age (in the North Apuseni and the South Carpathians) and Neogene age (in the Apuseni Mts. And along the inner part of the East Carpathians).

The actual twice-bended shape of the Carpathians is a result of a mutual interaction during the Cretaceous and Miocene deformations, of the Moesian block, showing western translations, and the Foreapulian block, with eastern translations and clockwise rotations. The western wandering of the Moesian Platform is connected with the opening of the Western Black Sea, which starts in the Albian and continues during the Upper Cretaceous and in some periods of the Cenozoic.

The recent history of the Carpathians is dominated by the development of the Neogene molasse basins: The Transylvanian and the Pannonian above the inner parts of the still structured Carpathians and the Foredeep along the outer border of the chain and, partially, above the foreland. The Transylvanian Depression and the Pannonian Basin developed above two tectonic groups: the strongly deformed Carpathian units and the slight or non-deformed post-tectonic basins.

The youngest deformations recorded in the Romanian Carpathians arc situated to the outer part of the Carpathian Bend. It is of Lower Pleistocene age (the Wallachian "Phase"). The deformed area is limited by two important transcrustal faults: the Intra-Moesian Fault (with left-lateral Neogene translations) in the west and the Peceneaga – Camena Fault (right lateral translations) in the northeast. The panel shaped in this way moved towards the Carpathian Bend generating the Pleistocene deformations. The high seismic area of Vrancea is situated within this panel.