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PALEOZOIC EVOLUTION OF THE ROMANIAN PART OF THE MOESIAN PLATFORM: AN OVERVIEW

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(13 figures, 1 table)

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ABSTRACT. Based on the review of the litho- and biostratigraphy of the first sedimentary cycle in the northern part of the Moesian Platform (Romania), the Paleozoic evolution of the Moesian realm is presented, along with comments of the proposed models of palaeogeographic affinity. During the Cambrian-Carboniferous cycle, sedimentation largely took place within three main basins, separated by basement highs. Various marine environments prevailed, with episodes of continental deposition during Eifelian and Carboniferous. Restricted, euxinic environments characterized the Late Ordovician-Silurian and Upper Devonian intervals. Marine carbonate platform conditions prevailed throughout the Givetian-Visean times, with restricted lagoonal environments (from brackish to hypersaline) in the Middle Devonian to open sea (normal marine) environments in the Carboniferous. In the Romanian part of the Moesian platform coarse clastics accumulated in the Ordovician and most of the Middle Devonian, while the Silurian and Lower Devonian are mainly pelitic. Carbonate rock accumulation expanded at the end of the Middle Devonian and peaked during the Early Carboniferous. Lithology and facies of carbonate sediments suggest that latest Middle to Upper Devonian carbonate sedimentation took place in tidal flat conditions, from supratidal, sabkha, to intertidal and subtidal, euxinic environments. Detrital sedimentation with local coal measures prevailed during the Lower and Upper Carboniferous, with clastics interfingering in places with carbonate sediments.

KEYWORDS. Biostratigraphy, isopach maps, lithofacies maps, lithostratigraphy, Moesian Platform, Paleozoic, palaeocontinental affinity

1. Introduction

The Moesian Platform is a major structural unit of the Carpathian and Balkans foreland, appearing like an indenter in the Alpine mobile belt. In Alpine palaeogeography Moesia was part of the East European Platform, as result of Paleozoic accretion. However, the processes and the timing of accretion to the East European Platform are questions still strongly debated.

Moesia lies at the SE margin of the East European Craton in the SE part of the Trans-European Suture Zone (TESZ) (Fig. 1A), a fundamental terrane boundary separating the Precambrian craton from the cluster of terranes originating from Gondwana and accreted to its western margin throughout the Paleozoic (Yanev, 1993; Yanev & Boncheva, 1995; Gee & Zeyen, 1996; Haydoutov & Yanev, 1997; Pană, 1997; Pharaoh, 1999, Yanev *et al*., this volume). As these terranes forming the basement of Central Europe are largely concealed, or involved in the Alpine structures of the Carpathians and Balkans in the SE Europe, their affinities are difficult to establish. Despite the great progress made in the knowledge of litho- and biostratigraphy of the Moesian cover, the pre-Mesozoic paleocontinental affinity of Moesia is still poorly known, because palaeomagnetic data are lacking even for outcrop areas, the largest part of macrofauna is not relevant to establish palaeocontinental affinities and modern, reliable geochronological and provenance data are still missing. Nevertheless, starting with the nineties, several models attempted to explain the pre-Alpine palaeogeography of Moesia based on the existing biostratigraphic and lithostratigraphic data, as well as on new geochemical, geochronological and micropaleontological studies, most of them still in progress. The present paper intends to review the litho- and biostratigraphy of the Paleozoic successions in the northern part of the Moesian Platform, located in Romania, as most of these data are published in local journals, in books and PhD theses written in Romanian language. On this basis the Paleozoic evolution of the Moesian realm will be presented, along with comments of the proposed models of palaeogeographic affinity.

2. Tectonic framework of Moesia

The Moesian Platform forms an E-W elongated structural unit surrounded to the north and west by the South Carpathians and to the south by the Balkans, with its axis approximately parallel to the Danube River (Fig. 1B). Geophysical and borehole data indicate that the northern and southern margins of the platform are progressively buried beneath the sedimentary successions of the Neogene Carpathian and Balkan foredeeps, to join at depth the orogenic units. The platform includes three geographical units – the Romanian Plain and the Dobrogea Highlands, situated in the northern, Romanian part and the Prebalkan Highlands, located in the southern, Bulgarian part of the platform. Excepting the areas of Central and South Dobrogea, where basement or cover successions are exposed, the geology and structure of the platform are known only from drillings for oil industry and geophysical investigations.

In Romania, the platform is separated from the Carpathian belt by a deep fracture – the Pericarpathian Fault – oriented E-W and dipping north, with its eastern part curved northward. Along this fault, the geological formations of the platform lie at great depths. Within the Neogene deposits, the Pericarpathian Fault represents the overthrust of the Miocene sediments of the Getic Depression onto the Miocene deposits of the platform (Popescu *et al*., 1967; Barbu, 1973; Dumitrescu & Săndulescu, 1968) (Fig. 2). The Cretaceous nappe systems of the South Carpathians were overthrusted onto the northern margin of the Moesian Platform during the Miocene (Săndulescu, 1984; Ştefănescu & Working group, 1988; Visarion *et al*., 1988). In Bulgaria, the Balkans overthrust the southern margin of the platform along the North Prebalkan Fault – a north verging Eocene thrust (Dumitrescu & Săndulescu, 1968; Săndulescu, 1984; Tari *et al*., 1997 and references therein) (Fig. 1B).

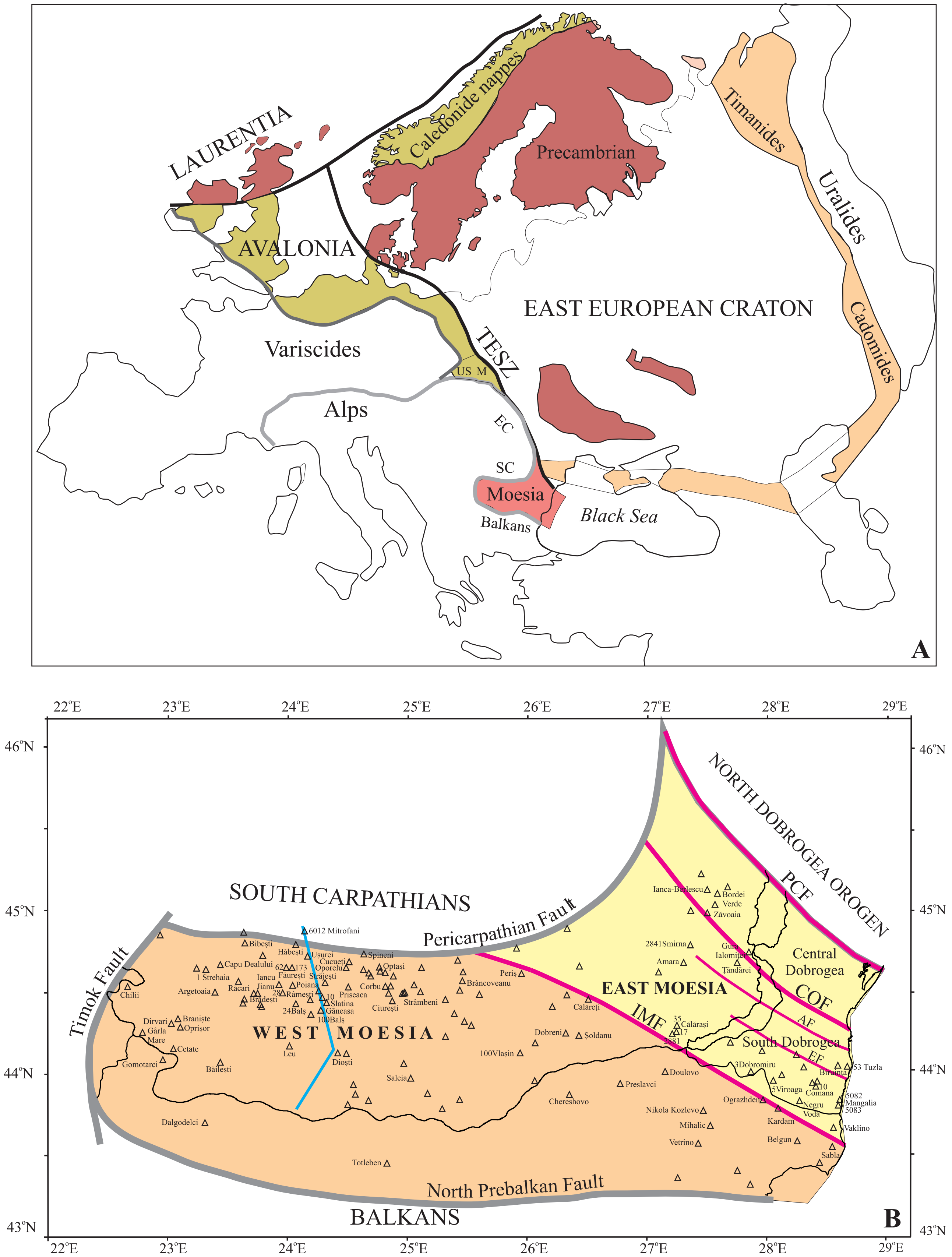


Fig. 1. A) Present-day location map of the Moesian Platform on the map showing the basement structure and Phanerozoic deformation belts in Europe. Grey line: Alpine deformation front. Abbreviations: TESZ – Trans-European Suture Zone; EC – East Carpathians; SC – South Carpathians; US – Upper Silesia; M – Małopolska. B) Simplified tectonic map showing the boundaries, major faults and tectonic blocks of the Moesian Platform, as well as the distribution of the main boreholes which intercepted the Paleozoic formations (compiled after Beju, 1972; Răileanu *et al.*, 1968; Paraschiv, 1974; Yanev & Boncheva, 1995). The blue line represents the location of the geological section presented in Fig. 2. Abbreviations: PCF – Peceneaga-Camena Fault; COF – Capidava-Ovidiu Fault; IMF – Intramoesian Fault; AF – Agigea-Rasova Fault; EF – Eforie Fault.

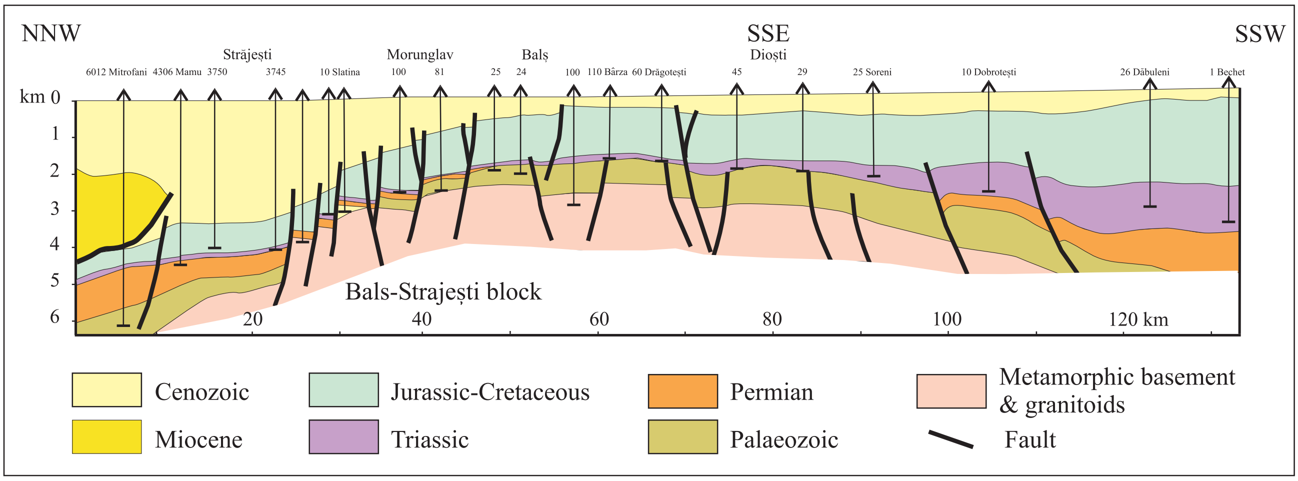


Fig. 2. Geological cross-section in West Moesia between the Carpathian Foredeep and the Danube, showing the Balş-Optaşi high and the main structural levels of the platform below the overthrust of the Miocene sediments of the Getic Depression on the northern platform margin (modified after Matreşu, 2004). Location of the section is shown in Fig. 1.

The north-eastern margin of the Moesian Platform joins the North Dobrogea Orogen along the Peceneaga-Camena Fault, running NW from the Black Sea shore south of the Danube Delta to the Vrancea zone in the East Carpathians Bend zone. A 10 km step of the Moho along the Peceneaga-Camena Fault is shown on seismic sections (Rădulescu *et al.*, 1976), the north-eastern Moesian margin representing the hanging wall of this long-lived crustal fault. Large scale translations are supposed to have occurred along the Peceneaga-Camena Fault since the Late Permian (Seghedi, 2001).

The Intramoesian Fault, with a throw of 1000 m in the pre-Jurassic formations (Popescu *et al.*, 1967; Paraschiv, 1974), divides the Moesian Platform into two blocks unequal in size, differing in crustal properties, structural trend of deep faults, basement constitution and lithostratigraphy of the cover successions (Gavăt *et al.*, 1963, 1966, 1967; Barbu & Vasilescu, 1967; Barbu *et al.*, 1969; Constantinescu *et al.*, 1976; Enescu, 1987; Visarion *et al.*, 1988; Săndulescu & Visarion, 2000). These two parts of Moesia are referred to as: Danubian and Dobrogean (Paraschiv, 1974, 1979), Wallachian/Wallachian-Prebalkan and Dobrogean sectors (Săndulescu, 1984; Săndulescu & Visarion, 1988; Visarion *et al.*, 1988), or simply, West and East Moesia (Barbu, 1973) (Fig. 1B).

East Moesia extends eastward up to the Black Sea shelf and occupies Central and South Dobrogea and their continuation west of the Danube. This area is characterized by NW-SE trending crustal faults (Gavăt *et al.*, 1963; Barbu & Vasilescu, 1967; Barbu, 1973; Dumitrescu & Săndulescu, 1968), the most important of them being the Peceneaga-Camena and Capidava Ovidiu Faults (Fig. 1B). West Moesia occupies in Romania the Romanian Plain and in Bulgaria almost exclusively the northern part of the country. Only in the NE Bulgaria a very small part could belong to West-Moesia (Săndulescu, 1984). West Moesia is characterized by the dominant E-W trend of major faults, intersected by a system of N-S or NE-SW faults (Gavăt *et al.*, 1963, 1966, 1967; Barbu & Vasilescu, 1967; Barbu, 1973; Paraschiv, 1974, 1979; Săndulescu & Visarion, 1988; Visarion *et al.*, 1988).

3. Geological background of the Moesian Platform

Only Cenozoic sediments of the Moesian cover are at outcrop north of the Danube, but various cover sequences or even basement rocks are exposed South and East of the Danube along tributaries, in the highlands of Central and South Dobrogea and in the Prebalkan Plateau. The Neoproterozoic (Cadomian) basement, with remnants of its Jurassic cover, crop out in Central Dobrogea; Lower and Upper Cretaceous formations are exposed in the central-eastern part (South Dobrogea), while Cenozoic sediments are exposed in the western and northern part of the platform, in South Dobrogea and in places along the right bank of the Danube, in Bulgaria. The geological constitution of the concealed part of the Moesian realm is known from drillings for hydrocarbon deposits and from few structural boreholes. The most important boreholes which penetrated the Paleozoic sediments are shown in Fig. 1B.

The Moesian Platform consists of a folded basement unit overlain by a flat-lying Mesozoic-Cenozoic cover unit. The basement includes Precambrian metamorphic rocks and the overlying, folded Paleozoic formations. The metamorphic basement, known in areas of basement uplift, is highly heterogeneous. A large part of the basement rocks is represented by Neoproterozoic successions which differ in lithology, geochemistry and metamorphism, but metamorphic series have been locally ascribed to the Archean and Paleoproterozoic. An overview of the basement rocks is presented by Seghedi *et al.* (this volume) and Oaie *et al.* (this volume).

According to the age of the youngest folded member of the Paleozoic cover, the Moesian realm displays a heterogeneous basement resulted through juxtaposition of several structural units. The number, extent and age of these units differ from one author to another. Based on the age of the youngest folded member, three major structural units, heterochronous and southward younging were suggested, representing an epi-Proterozoic, an epi-Caledonian and a Variscan unit (Patrulius *et al.*, 1967; Răileanu *et al.*, 1968). Other authors separate only a Cadomian (East Moesia) and a Variscan unit (West Moesia) joined along the Intramoesian Fault (Săndulescu, 1984; Visarion *et al.*, 1988).

The north-eastern unit is exposed in Central Dobrogea between the Peceneaga-Camena and Capidava-Ovidiu Faults and is concealed NW of the Danube in the Romanian Plain. This is the oldest, or epi-Proterozoic ("epi-Baikalian") unit of the platform (Patrulius *et al.*, 1967), with a Neoproterozoic-Eocambrian basement of turbidites, folded in very-low-grade (subgreenschist facies) metamorphic conditions at the Precambrian/Cambrian boundary or in the lowermost Cambrian ("Baikalian" events, Mirăuță, 1964, 1965; Giuşcă *et al.*, 1967). The flat-lying platform cover starts with the Ordovician, overlying the basement above an erosional and stratigraphic gap, corresponding at least to the Middle and Upper Cambrian.

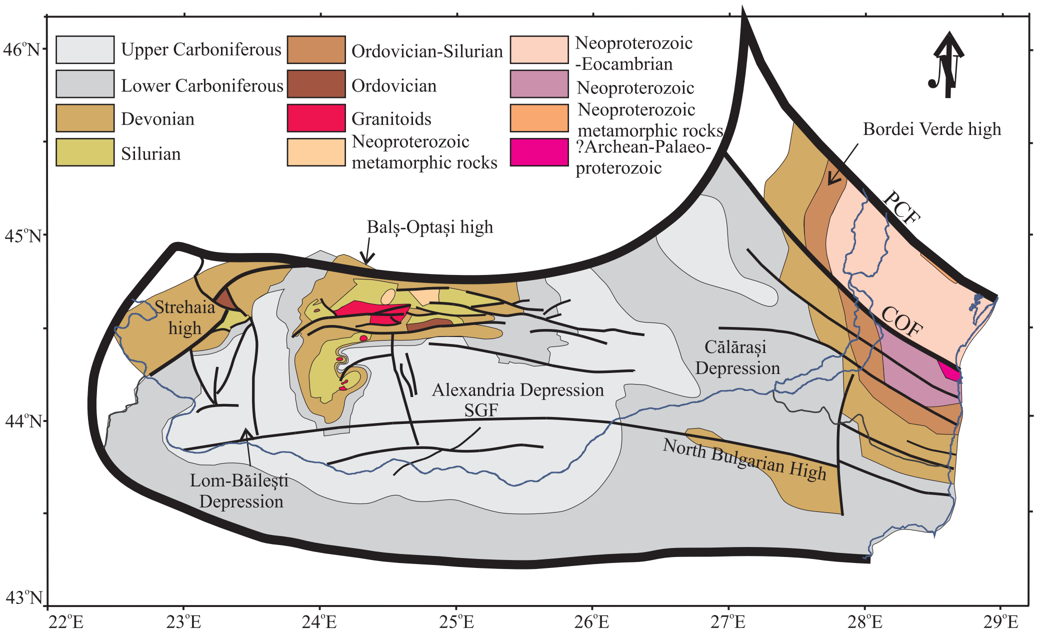


Fig. 3. Permo-Triassic subcrop map, showing the distribution of the Paleozoic formations and the structure of the first structural level in the Moesian Platform (modified after Paraschiv, 1974 and Iordan, 1981). Abbreviations: PCF – Peceneaga-Camena Fault; COF – Capidava-Ovidiu Fault; SGF – Studina-Giurgiu Fault.

The central segment, between the Capidava-Ovidiu and Studina-Giurgiu Faults, underlies the South Dobrogea and the largest part of the Romanian Plain. The Neoproterozoic basement is overlain by moderately dipping Cambrian-Ordovician clastics and/or Wenlock to Lower Ludlow shales. The last folded member of this unit is the Lower Ludlow, overlain above an angular unconformity by a flat-lying succession starting with the Upper Ludlow. The intra-Ludlow unconformity, documented in boreholes 5083 Mangalia, 2881 Călăraşi, 1 Optaşi, 28 Iancu Jianu and 1 Strehaia (Răileanu *et al.*, 1966, 1967; Paraschiv, 1974), is coeval with the Ardennian event, therefore this segment of the platform was interpreted as epi-Caledonian or epi-Ardennian (Patrulius *et al.*, 1967; Răileanu *et al.*,1968).

The southern unit, developed almost exclusively in the Bulgarian part of the Moesian Platform, represents the Variscan segment (Patrulius *et al.*, 1967; Răileanu *et al.*, 1968), where the Devonian and Lower Carboniferous sediments are involved in folding and thrusting (Yanev & Boncheva, 1995; Yanev *et al.*, this volume). The undeformed, flat-lying platform cover starts with the Permian (borehole Rassovo). According to the traditional interpretation, the last deformational events that affected the Paleozoic successions are related to the Asturian or Saalian events of the Variscan orogeny (Late Carboniferous).

4. The structure of the Moesian Platform

Two structural levels with distinct tectonic behavior have been distinguished in the Moesian cover, based on borehole and geophysical data. The lower structural level, corresponding to the Paleozoic-Triassic successions and characterized by structural highs and lows, was initiated in the Lower Paleozoic and reactivated in the Late Paleozoic and Triassic (Pătruţ *et al.*, 1961; Grigoraş *et al.*, 1963; Popescu *et al.*, 1967). The upper structural level, corresponding to the Jurassic-Cretaceous sediments, shows a different distribution of basins and uplifts.

Within the lower structural level, there are several areas of uplift partly or totally devoid of Triassic deposits; the stratigraphic gap on top of these highs cuts as deep as the Lower Paleozoic (Fig. 3). During the Triassic, these areas were either uplifted and subjected to erosion, or suffered a slow subsidence, accumulating thin sedimentary successions which have been easily removed by the post-Triassic erosion. Therefore, the absence of the Triassic sediments from these highs is due to non-deposition, while the gaps within the Paleozoic series are the result of subsequent erosion. The distribution of the main highs and lows is shown in Fig. 3.

The main uplifted area in West Moesia is the Balş-Optaşi high, consisting of two ridges elongated on E-W direction and separated by a major fault. In the central part of the northern, highest ridge, the Silurian deposits are directly overlain by Middle Jurassic clastics. The lower Paleozoic sediments are younging on the limbs of the uplift, plunging beneath the Carboniferous deposits. The southern ridge represents the northern flank of the Alexandria depression. The ridge is pregnant at the Triassic level, as the Triassic sediments are missing in the culmination zone at Balş, where Middle Jurassic clastics directly overlie Permian rhyolites. In this area, the Carboniferous limestones are overlain by a thick volcanic pile of Permian rhyolites and basalts, concealed below the Triassic sediments.

The Strehaia uplift develops west of the Balş-Optaşi high. In the apex of the Strehaia uplift, the Lower Carboniferous deposits are directly overlain by Upper Jurassic sediments.

The Bordei Verde high from the eastern part of the Romanian Plain continues eastward with the outcrop area from Central Dobrogea. In this high the Triassic sediments are missing, or form local patches of thin, lower members, in the subsurface of the Romanian Plain. The uplift culminates with the Neoproterozoic basement from the north-eastern part of East Moesia. In this area, the Paleozoic deposits are progressively thinning eastward, to disappear close to the Danube, where the basement of Neoproterozoic turbidites is directly overlain by Cenozoic (Sarmatian) sediments.

The structural lows separating the uplifts preserve both Paleozoic and Triassic deposits. The depressions are wider in the Paleozoic sediments, but better marked at the Triassic level. These lows (syneclises) represent the cumulate effects of morphologic, subsidence and tectonic controls. The Lom depression from NW Bulgaria and the western part of the Romanian Plain develops between the Strehaia and Balş-Optaşi highs. North of the Danube, this structural low is referred to as the Băileşti depression (or basin). Eastward, the Alexandria depression, representing another depocentre of Paleozoic sediments, separates the Balş – Optaşi high from the North Bulgarian uplift. The Călăraşi depression, with a semicircular shape, is located between the Bordei Verde and North Bulgarian uplifts.

5. Lithostratigraphy of the Cambrian-Carboniferous sediments

Paleontological studies revealed several stratigraphic discontinuities in the Paleozoic deposits of the Moesian Platform (Figs 4 & 5), which were suggested to reflect tectonic events in the neighboring coeval orogenic belts. A sedimentary gap corresponding to the Upper Cambrian-Lower Ordovician was recorded in boreholes 2811 Bordei Verde, 2881 Călăraşi and 28 Iancu Jianu. In borehole 2811 Bordei Verde, the stratigraphic gap corresponding to the Upper Ordovician is marked by a parallel unconformity between the Ordovician and Silurian sediments. This was interpreted to reflect the Taconian events of the Caledonian orogeny (Drăgănescu, unpublished data). The angular unconformity of 30-38° between the Lower and Upper Ludlow (boreholes 2881 Călăraşi and 5083 Mangalia) suggests folding coeval with the Ardennian events (Răileanu *et al*., 1966, 1967; Patrulius *et al*., 1967), followed by a short period of uplift. The stratigraphic gap at the base of the Carboniferous (boreholes 2881 Călăraşi and 5083 Mangalia) was correlated to the Bretonian events (Răileanu *et al*., 1968). The gap between the Dinantian and Namurian (boreholes Răcari, Ciureşti, Amara) corresponds to the Sudetian events (Paraschiv, 1974). According to Paraschiv (1974, 1975), in the southern, Variscan unit from Bulgaria, there is an angular unconformity between the Carboniferous and the Permian (borehole Rassovo), which would correspond to folding in the Asturian (or Saalian) events. New interpretations do not recognize the Carboniferous in this borehole (see Yanev *et al*., this volume).

Most Romanian authors separate a lowermost stratigraphic cycle in the Moesian Platform, representing the Cambrian-Westphalian (Popescu *et al*., 1967; Beju, 1972; Paraschiv, 1974, 1979; Paraschiv *et al*., 1983b). Yanev & Boncheva (1995) and Yanev *et al*., this volume) separate two cycles: an Ordovician (?)-Upper Devonian cycle and a Lower Carboniferous-Upper Permian cycle. An alternative view is that the gaps in the Paleozoic succession divide the sedimentation process into two main stratigraphic cycles (Drăgănescu & Iordan, unpublished data).

The Lower Paleozoic cycle (Upper Cambrian-Ordovician-Lower Ludlow) includes a marine terrigenous succession with a thickness range between 150-400 m. This cycle starts with quartzitic sandstones ascribed to the Lower Ordovician (Tremadocian) (boreholes Bordei Verde, Călăraşi, Iancu Jianu, Corbu) and Cambrian (boreholes Strehaia, Mitrofani, Hăbeşti) (Grigoraş *et al*., 1963; Murgeanu & Patrulius, 1963; Paraschiv, 1974; Muţiu, 1991), followed with lithological discontinuity by a series of dark, graptolite shales. The dark shales include the Arenig and Upper

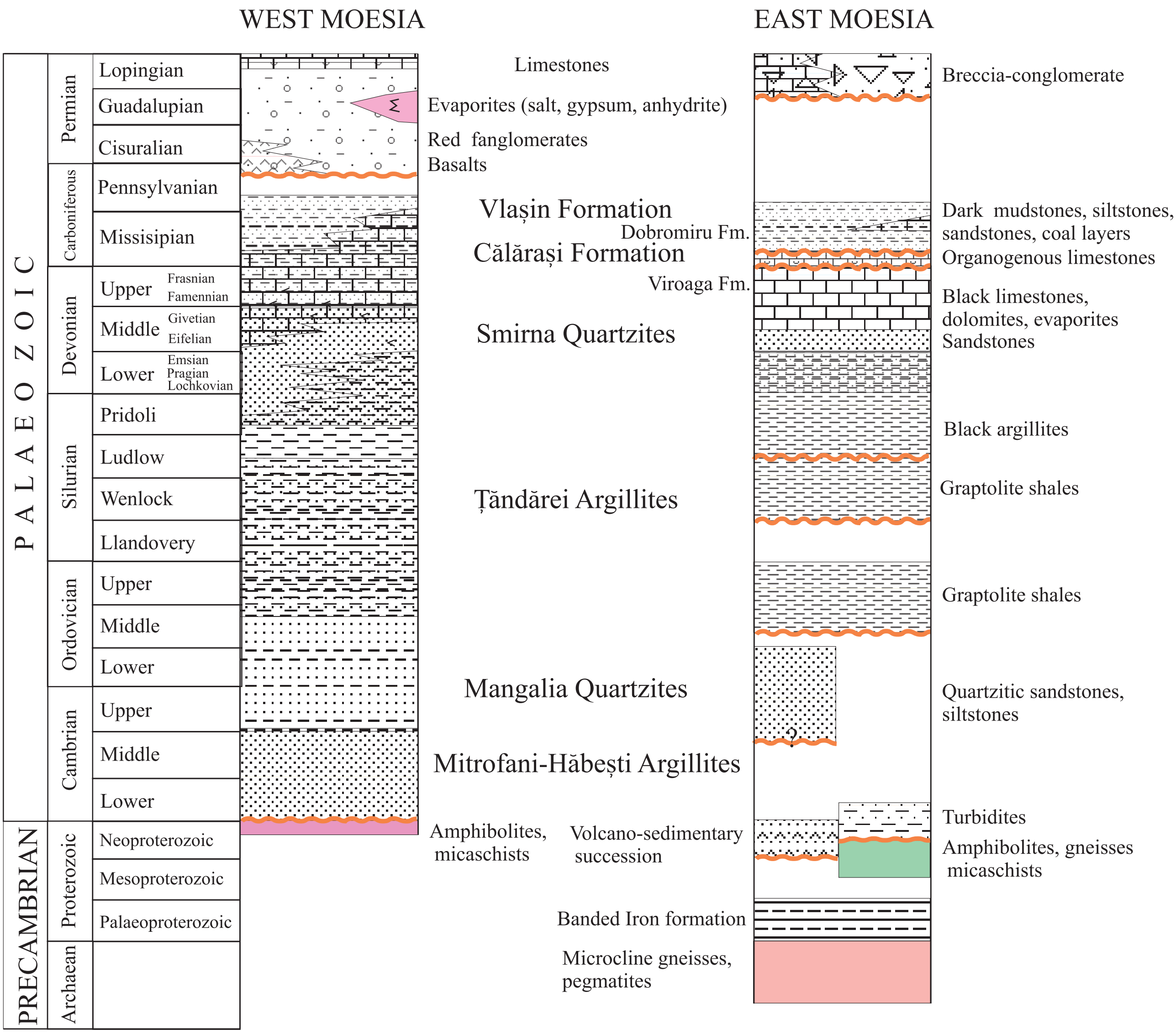


Fig. 4. Composite stratigraphic chart for the Paleozoic formations from East and West Moesia.

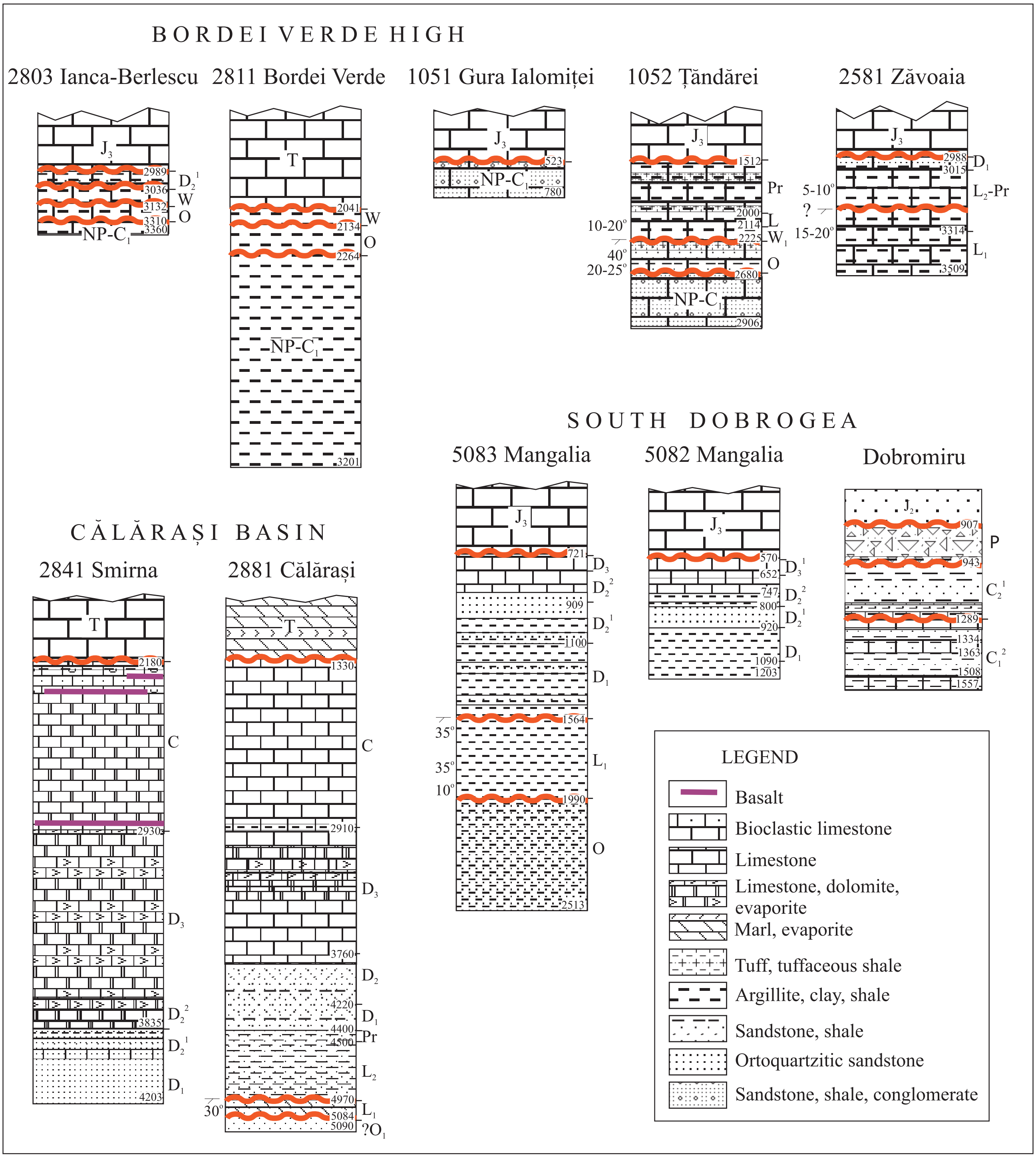


Fig. 5. Borehole logs of the main boreholes from East Moesia (modified after Răileanu *et al.*, 1967; Iordan, 1972, 1981; Rickards & Iordan, 1975; Iordan *et al.*, 1987a,b)

Llandovery-Lower Ludlow intervals (boreholes Bordei Verde, Călăraşi, Zăvoaia, Tuzla, and Optaşi). This cycle terminates with the Ardennian phase, which resulted in folding of the sediments from the central tectonic unit. After a short episode of uplift, the sea invaded again the area in the Upper Ludlow. In the northern tectonic unit, the sedimentation process was resumed only in the Devonian.

The upper Ludlow-Namurian cycle includes two terrigenous series separated by a carbonate one. The overall thickness of this cycle ranges between 2000-3500 m (in boreholes Mangalia, Călăraşi, Smirna, Amara, Strehaia, Cetate). A lagoonal-evaporitic facies characterizes the Upper Devonian, while paralic, coal-bearing clastics are widespread in the upper, terrigenous series.

The lower terrigenous series shows a marine facies and includes two sequences: a lower sequence (Upper Ludlow-Lower Devonian) of dark clays and argillites (with Gigantostraceans and *Cardiola* in its lower part and brachiopods, trilobites, bivalves and tentaculites in its upper part), and an upper sequence of argillites and sandstones (Middle Devonian) with brachiopods and psilophytal plants.

The carbonate series comprises: a lower sequence of black limestones and dolomites representing the Upper Devonian developed in lagoonal facies (with interbeds of evaporites and clays containing spores and trilobite debris); an upper sequence of light colored, marine limestones and dolomites, rich in foraminifer and brachiopods of Dinantian-Lower Namurian age, interbedded at top with coal-bearing clastics.

The upper terrigenous sequence has accumulated in paralic conditions consequently to the Sudetian events. This sequence shows a molasse facies, consisting of bituminous shales and sandstones with coal interbeds. The sequence yielded upper Namurian microflora and, in the western part of East Moesia, also lower Westphalian flora (Paraschiv *et al.*, 1973; Paraschiv, 1974, 1975; Paraschiv & Popescu, 1980). This cycle was followed by the Late Variscan (Asturian) events, when the area was uplifted for a longer time interval (Paraschiv, 1974, 1979, 1982).

Detailed lithological and sedimentological information for the Paleozoic deposits from the southern, North Bulgarian part of the platform are given by Spassov (1971, 1972, 1974, 1987), and Yanev & Boncheva (1995 and references therein).

The lithostratigraphy of the Paleozoic deposits was established for the entire Moesian realm in Romania disregarding the differences between East and West Moesia, and there are still disagreements between various authors. According to Paraschiv & Popescu (1980), Paraschiv (1982), Patrulius (1963), Iordan *et al.* (1987a, 1987b) and Iordan (1988, 1990, 1992a, b), the main lithostratigraphic units of the northern Moesian realm include: the Mitrofani-Hăbeşti shales (Middle Cambrian), dominated by trilobites associated with scarce brachiopods and merostomates; the Corbu-Mangalia orthoquartzites (Cambro-Ordovician), dated on palynomorph assemblages (Beju, 1972, 1973); the Ţăndărei-Călăraşi graptolite shales (Ordovician-Prídolí), dated on graptolites; the Mangalia-Oprişor argillites (Lochkovian-Emsian); the Smirna quartzitic sandstones (Eifelian); the Călăraşi carbonate Formation (Givetian-Lower Visean); the Viroaga limestones (Famennian); the Dobromiru Formation (Middle-Upper Visean); the Vlaşin Formation (Namurian-Westphalian); the Cetate-Dobromiru conglomeratic breccia (Patrulius, 1963; Iordan *et al.*, 1987b) (latest Carboniferous-Permian). Lithological boundaries are often diachronous, suggesting facies progradation from south to north. Detailed facies description are given in Paraschiv (1974, 1979), Paraschiv & Năstăseanu (1976), Iordan *et al.* (1985, 1987a, 1987b) and Iordan (1988; 1990; 1992a, b).

6. Lithofacies of Paleozoic deposits

6.1. Cambro-Ordovician

In East Moesia the presence of Cambrian is not yet documented by fossils. It is assumed that the lower part of the shallow marine quartzitic sandstones from borehole 5083 Mangalia, which in their upper part contain Ordovician palynological assemblages, would represent the Cambrian (Paraschiv *et al.*, 1983 b). The Ordovician includes lower sandstones and orthoquartzites with shale interbeds, overlain by glauconite-bearing shales (boreholes Bordei Verde, Ţăndărei and 5083 Mangalia) (Murgeanu & Patrulius 1963; Beju, 1972). The shales contain graptolites, palynomorphs, together with inarticulate and acrotretid brachiopods.

In West Moesia, the Cambrian succession was intercepted in five boreholes (Fig. 5). The complete succession of the Cambrian was recovered in borehole 28 Balş, where it consists of lower, black quartzites, followed by grey shales overlain by greenish siltstones and sandstones (Paraschiv, 1974). The total thickness of the complex is about 260 m and it is unconformably overlain by Ordovician glauconite-bearing shales, dated on acritarchs (Beju, 1972; Paraschiv, 1974). In the other boreholes, only parts of the Cambrian succession have been intercepted. A 200 m thick non-fossiliferous complex of orthoquartzites interbedded with quartzitic sandstones in borehole 5510 Mitrofani was ascribed to the lower Cambrian. In borehole 5034 Mitrofani, the Middle and Upper Cambrian consist of about 200 m of black shales with scarce interbeds of argillaceous limestones and quartzitic sandstones, which yielded trilobites and brachiopods (Muţiu, 1991); the black shale facies continues into the Ordovician and Silurian. In borehole 4250 Hăbeşti only middle Cambrian black shales were intercepted. Borehole 1 Strehaia bottomed in black quartzites overlain by red-purple or greenish sandstones ascribed to the Cambrian; there is a metamorphic discontinuity between the lower greenschist facies, black quartzites, and the overlying unmetamorphosed sandstones and siltstones (Paraschiv, 1974). According to Paraschiv (1974), the existence of a Cambrian limestone facies, probably removed by erosion, is suggested by clasts of limestones with Cambrian trilobites, reworked in the Permian conglomerates NW of Vidin (Spassov, in Paraschiv, 1974, 1979); for the limestone clasts, paleoflow directions indicate a northern source located on Romanian territory.

6.2. Silurian

In East Moesia the Silurian successions, ranging in thickness between 100-700 m, overstep the folded Neoproterozoic-Early Cambrian (?) basement (borehole Tuzla), or Ordovician strata (boreholes Bordei Verde, Ianca-Berlescu, Ţăndărei, Călăraşi and Mangalia). The angular unconformity between the Lower and Upper Ludlow, recorded in boreholes Călăraşi and Zăvoaia, is accompanied by a change in facies from black shales to argillites. The Silurian sediments show the typical graptolite shale facies, classical in the lower part (Wenlock-Lower Ludlow) (Grigoraş, 1956; Iordan, 1981, 1990; Paraschiv & Muţiu,1976) and mixed in the upper part (Late Ludlow and Přídolí), with predominant small bivalves, flattened orthocone cephalopods, tiny brachiopods and crinoidal ossicles, along with scarce graptolites (Iordan, 1981, 1990).

In West Moesia, the Silurian sediments (up to 1200 m thick in borehole Capu Dealului) overstep Ordovician successions, excepting the Balş-Optaşi high, where they overstep the metamorphic basement (Paraschiv, 1979). The Silurian formations are conformably or unconformably overlain by Devonian clastics or in places by Mesozoic sediments. In West Moesia there are palynological indications for the Llandovery (Iordan *et al.*, 1985), but its presence is still debatable. The Silurian develops in the mixed or shelly fauna facies, similar with that from the western, Podolian margin of the East European Craton (Patrulius & Iordan, 1974; Iordan *et al.*, 1985). In several boreholes along the northern and western platform margins, purple, basic vitroclastic tuffs, fine-grained epiclastic rocks and seldom coarse volcaniclastics form layers 15 to 30 m thick, usually interbedded in the Wenlock successions (Paraschiv, 1978, 1986; Muţiu, 1991).

Detailed lithological and biostratigraphical studies in the western part of West Moesia (Iordan *et al.*, 1985) showed that the upper Silurian in borehole Gârla Mare develops in the facies of black argillites, while the lower and middle Silurian, as well as the upper Silurian in borehole Oprişor show the facies of green siltstones. The green siltstones display a fine lamination due to orientation of detrital phyllosilicates, especially chlorite. The siltstones contain thin interbeds of green feldspathic sandstones with glauconite pellets. Both siltstones and sandstones may contain clusters of bryozoan debris, dissociated echinoderm plates, comminuted shells of pelecypods, brachiopods and ostracods, trilobite shield debris and micrite lithoclasts. With increasing content of bioclastic material, rocks pass to very coarse encrinites with sparse bryozoans and rugose coral debris, in a matrix of chlorite-rich green sandstone. In borehole Gârla Mare, the upper Silurian shows the facies of black argillites with sandstone interbeds, facies which covers the entire Ludlow – Eifelian interval. In borehole Oprişor, the same facies is only Lochkovian-Eifelian in age. The obvious diachronism of the boundary between the green siltstones and black argillites is connected to a prograding, regressive sequence; the green siltstones were interpreted to represent a prodelta, while the black argillites to represent a deltaic succession (Baltres, in Iordan *et al.*, 1985). The black argillite facies shows an upward coarsening trend in Gârla Mare borehole, being sandier, and thus more proximal, than the same facies in the Oprişor borehole, where the sandstone occurs toward the top of the sequence, demonstrating its progradational nature.

6.3. Devonian

On the northern and western Moesian Platform margin there is an angular unconformity between the Silurian and Devonian (Paraschiv, 1974). The unconformity was also recorded in borehole 5083 Mangalia from South Dobrogea (Răileanu et *al*., 1966). The lithostratotype of the Moesian Devonian was established in boreholes 5082 Mangalia and 2881 Călăraşi (Răileanu et *al*., 1967). The Devonian succession includes a basal, argillite facies (Early Devonian), a sandstone facies (Early Devonian-Eifelian) and an upper, carbonate-evaporite facies (Givetian-Famennian) (Iordan, 1981).

The basal facies, representing the continuation of the pelitic facies of the Silurian, consists of various argillites, argillaceous shales, marly or sandy argillites, dark siltstones with subordinate grey quartzitic sandstones, interbedded with coquinas. The sandstone facies includes quartzitic sandstones, argillaceous sandstones, orthoquartzites, and quartzitic conglomerates, with minor interbeds of black argillites and dolomitic limestones. In boreholes 5083 Mangalia and 2881 Călăraşi, red arkoses were found toward the top of the sandstone facies.

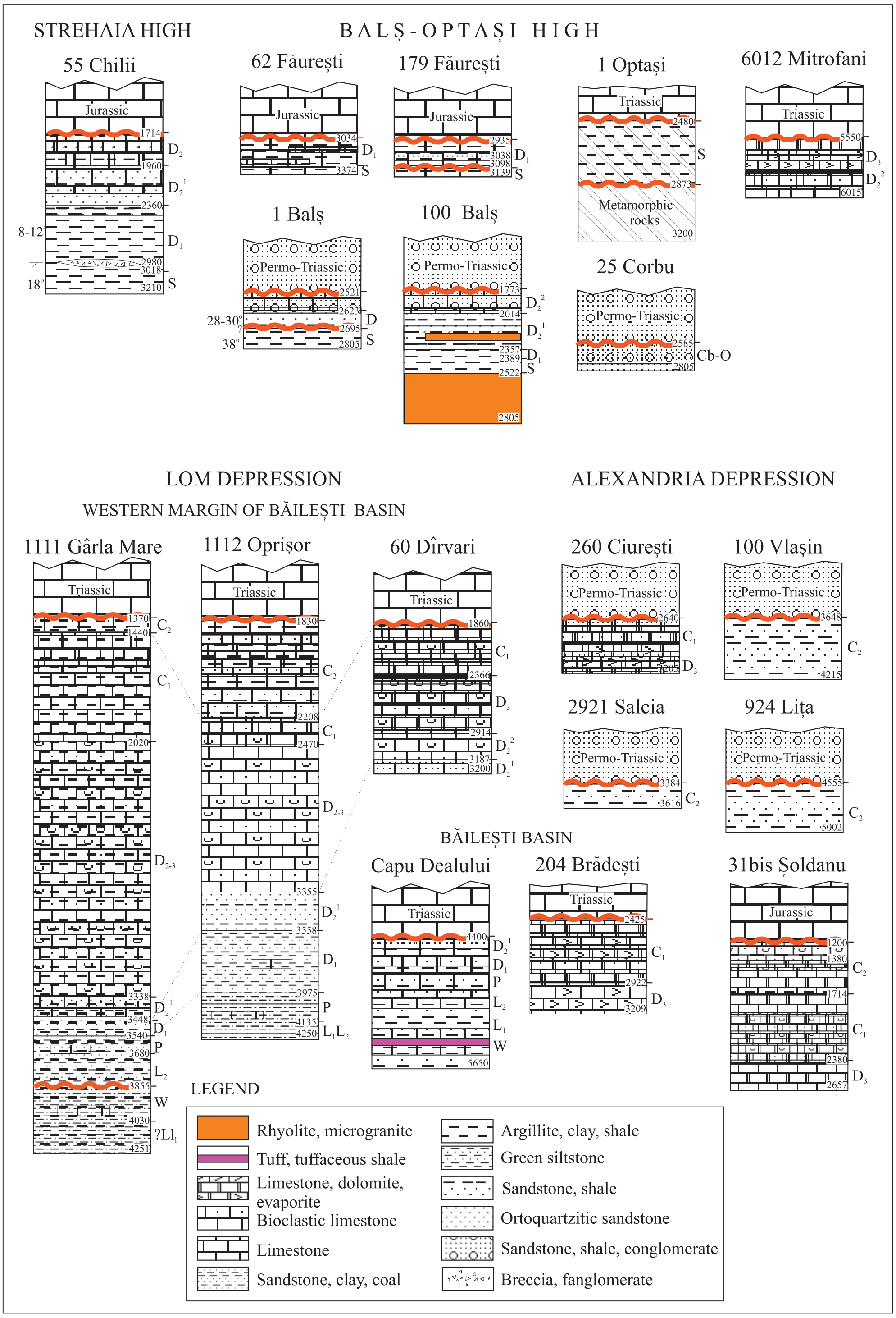


Fig. 6. Borehole logs of the main boreholes from West Moesia in Romania (after Paraschiv, 1974; Iordan *et al.*, 1985).

The bio- and lithofacies of the Givetian- Famennian carbonate-evaporite succession consists of organogenic limestones, dolomites and black limestones interbedded with evaporites and seldom black argillites and sandstones. Several facies types were revealed by microfacies studies, characterizing various tidal-flat environments, from supratidal to intertidal (Vinogradov & Popescu, 1984). The supratidal environment includes anhydrite-mudstones and dolostones, usually barren and only seldom with Ostracods and Cyanophycean nodules, showing various structures from laminated to *fenestrae* and desiccation or dissolution breccias; interbeds of clays rich in plant debris frequently occur. Intertidal environments produced stromatoporoidal boundstone and bioclastic wackestone with gastropods, bivalves and calcispheres. The transition between the two environments is indicated by stromatolithic wackestone with cyanophyceans and ostracods, algal peletal wackestone associated with *Stromatoporella* boundstone; oncolithic grainstone, grainstone-packstone with crinoids and brachiopods, wackestone with crinoids, dasycladaceans, gastropods, and characean debris, peletal wackestone.

6.4. Carboniferous

Boreholes in the southern part of the Romanian Plain (West Moesia) recorded continuous sedimentations across the Devonian-Carboniferous boundary (Fig. 6); along the northern margin of the Moesian Platform the thickness of limestones decreases and there is an unconformity and gap between the carbonate complex and the Lower Paleozoic (Răileanu *et al.*, 1964). Locally (borehole Balş), a conglomerate layer occurs at the base of the limestones, which directly oversteps the Lower Paleozoic. South of the Danube, in North Bulgaria (borehole Gomotarci), an erosional surface occurs at the base of the Carboniferous limestones. To the east, the same erosional surface occurs at the base of the limestone facies in the upper part of the Upper Devonian (Famennian) (boreholes Preslavci, Doulovo) (Yanev & Boncheva, 1995).

The Carboniferous succession of the Moesian Platform is represented by a lower, carbonate succession (Călăraşi and Dobromiru Formations – the unit starts already in the Givetian and continues in the Visean-Namurian) (Iordan, 1988) and an upper, terrigenous succession of paralic type (Vlaşin Formation, Namurian-Westphalian) (Paraschiv & Popescu, 1980). The boundary between the carbonate and terrigenous sediments is heterochronous. In several boreholes from West Moesia (Călăraşi, 31bis Şoldanu, 90 Periş), the limestone facies develops up to the lower part of the Namurian. South of the Danube, the terrigenous sedimentation started in the Lower Carboniferous (Spassov, 1972; Yanev & Boncheva, 1995), to become dominant in the northern part of the platform only at the beginning of the Upper Carboniferous (Namurian). This boundary is also diacronous: in tectonic blocks affected by normal faulting, the Visean or Namurian sediments directly overlie the Middle Devonian. Locally (borehole Brădeşti), the Westphalian paralic clastics overlie Lower Carboniferous carbonates.

The Lower Carboniferous sediments include limestones and dolomites devoid of evaporites. In East Moesia, there is a regional stratigraphic gap corresponding to the Tournaisian – Lower Visean (Iordan, 1999). In South Dobrogea, the Middle-Upper Visean (268 m thick in borehole Dobromiru) shows a mixed facies, including seven layers of black limestone (with thicknesses from 0.80 to 11.50 m), interbedded with black and grey argillites and siltstones, as well as with dark sandstones rich in plant debris (Iordan *et al.*, 1987b; Iordan, 1999). Based on this transitional facies to the Upper Carboniferous clastics, a continuous sedimentation between the limestone and the detrital complex was suggested (Răileanu *et al.*, 1964).

The Visean bio- and lithofacies includes endothyracee and algae (Paraschiv & Năstăseanu, 1976; Pană, 1997). On large areas various facies of the outer platform develop (Vinogradov & Popescu, 1984). The barrier facies is represented by boundstones (with tabulates, stromatopores, Rhodophycean algae), oncolithic grainstones, grainstones-packstones with crinoids, brachiopods, bryozoans, bivalves, annelids, tubiphytes, moravamminids, gastropod coproliths. Relatively deep, open marine environments are indicated by packstones (with Crinoids, Brachiopods, Bryozoans), wackestones with Crinoids, Brachiopods, Bryozoans, Ostracods, sponge spicules and spongolithic wackestones associated with spongolithic silicolites and clays.

The terrigenous-paralic Vlaşin Formation (Paraschiv & Popescu, 1980; Paraschiv *et al.*, 1983b) consists of clays, siltstones, sandstones rich in plant remains, with limestone intercalations and coal layers. The lithofacies is deltaic in the Baskirian and sabkha in the Moskovian and Baskirian (Pană, 1997). In places (Smirna borehole in East Moesia), basic and acid volcanic rocks are interbedded in the clastics. They were interpreted as Carboniferous intrusives (Paraschiv, 1986), but the association of basalts and rhyolites rather suggests that the volcanic rocks are connected to the Permo-Triassic bimodal volcanism widespread in West Moesia.

7. Biostratigraphy of the Cambrian-Carboniferous successions

A detailed zonation of the Paleozoic formations in the subsurface of the Romanian Plain and South Dobrogea is based on macrofaunal assemblages (graptolites, trilobites, tentaculites, brachiopods, bivalves, corals, crinoids, placoderms) and plants (Grigoraş, 1956; Murgeanu & Spassov, 1968; Spassov, 1971, 1974, 1987; Iordan, 1981; 1984; 1985; 1988; Iordan & Spassov, 1989; Iordan, 1990; 1992a, b; 1999; Muțiu, 1991), as well as on conodonts, foraminifers and palynological assemblages (Venkatachala & Beju, 1961, 1962; Venkatachala *et al.*, 1969a, 1969b; Beju, 1971, 1972; Paraschiv, 1972; 1974; 1975; Năstăseanu & Paraschiv, 1973; Paraschiv *et al.*, 1973; Paraschiv & Năstăseanu, 1976; Iordan, 1999; Pană, 1997). A synthetic biostratigraphic zonation is shown is Tab. 1.

7.1. Cambrian

Black shales in boreholes Mitrofani and Hăbeşti from the northwestern part of West Moesia have yielded trilobites, attesting the lower and middle parts of the Middle Cambrian (Muțiu, 1991). The trilobites are represented by *Eccaparadoxides* cf. *oelandicus* Sjögr., associated with the subzone fossil *Paradoxissimus* cf. *pinus* Holm., while *Triplagnostus praecurrens* (Wester) and *P. paradoxissimus* (Wahl) are associated with *P.* cf. *gracilis* (Boeck), *P. sjögreni* Linn., P. sp, and *Peronopsis falax* (Linn). The trilobites were found in association with brachiopods *(Lingulella feruginea* Salt.) and merostomates (*Hyolites* cf. *oelandicus* Holm) (Iordan, 1999). Revision of the trilobite fauna confirmed the presence of the widely distributed, fragmentary specimens of the trilobites *Paradoxides (Paradoxides*) species undetermined and agnostids (Rushton & McKerrow, 2000).

7.2. Ordovician

Although macrofaunal remains are known only in the north-western part of East Moesia (Ţăndărei, Bordei Verde boreholes), palynological assemblages documented the presence of the Ordovician both in the SE and NW parts of East Moesia, as well as along the northern and south-western margin of West Moesia (Tab. 1). The Ordovician is

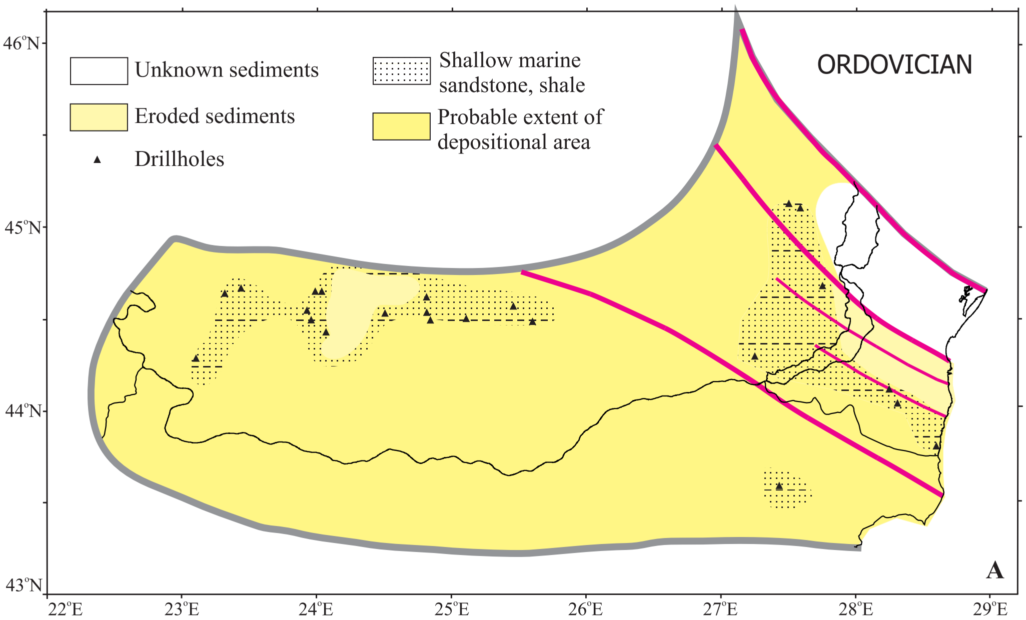
		GRAPTOLITES	TENTACULITES	TRILOBITES	BRACHIOPODS	BIVALVES	DIVERSES	CONODONTS	CHITINOZOANS	PALYNO
PERMIAN							Foraminifers Ostracods	*Neospatodus profundus* *Spatognatodus whitei*		
CARBONIFEROUS	WESTPHALIAN				*Choristites mosquensis* *Productus carbonarius* *Dictyoclostus retiformis*	*Janeia primaeva*	Goniatites fragments Plant remains (Calamites, Stigmaria)			C_3
	NAMURIAN					*Echondria densistriata* *Posidonia corrugata*	Foraminifers Holthurian sclerites			C_2
	VISEAN				*Gigantoproductus giganteus* *Dictyoclostus semireticulatus*	*Aviculopecten interstrialis*	Fusulinids, Archaediscids, Crinoids, Fenestella *Lithostrotion portlocki*	*Ligonodina fragilis* *Gnathodus commutatus* (Cu II periciclus - Cu III goniatites)		
	TOURNAISIAN				*Daviesella llangolensis* *Megachonetes zimmermani*		Calamites sp. Forams, Algae	*Syphonodella isosticha*		C_1 microspores
DEVONIAN	FAMENNIAN				*Cyrtospirifer archiaci zone*		Holothurian sclerites, Ophiurids, Moravamminids Calcispheres, Algae	*Palmatolepis crepida*		D_3
	FRASNIAN		*Homoctenus krestovnikovi*	Proetids (undeterminable)	*Mucrospirifer bouchardi zone*					
	GIVETIAN		*Tentaculites conicus*		*Mucrospirifer mucronatus zone* *Fimbrispirifer venustus zone* *Leptostrofia rotunda*		Crinoids, Gastropods Ostracods *Amphipora ramosa*	*Acodus unicostatus* *Icriodus angustus* *Icriodus nodosus*		D_{2b}
	EIFELIAN		*Nowakia maureri*	*Dipleura fornix* *Pilletina asiatica* *Pseudocr. prostellans*	*Rhipidamella penelope* *Schizophoria multistriata* *Schellwienella umbraculum* Chonetidae	*Nuculites elipticus* *Paracyclas rugosa*	Placoderms, Ostracodems Psilophital plants Crinoids, Euripterids Ostracods			D_{2a}
	EMSIAN				*Mutationella podolica* *Fimbrispirifer trigeri*	*Orthonota triplicata* *Grammysia mangalica* *Actinopteria costata*	*Kloedenella turgida ventrosa* *Bolia haraganensis*		*Bursachitina riclonensis*	D_{1c}
	PRAGIAN		*Volynites velainii* *Nowakia acuaria*		*Scuchertella euzona* *Delthyris infans*	*Ctenodonta nassoviensis*	Bytocypris Gastropods Crinoids		*Bulbochitina bulbosa* *Urochitina simplex* *Eisenachitina bohemica*	D_{1b}
	LOCHKOVIAN	*uniformis?*					Orthoceratids Corals Crinoids	*Icriodus woschmidti*	*Fungochitina lata* *Cingulochitina ervensis* *Cingulochitina plusquelleci*	D_{1a}
SILURIAN	PRIDOLI	***trangrediens?*** ***ultimus***	*Tentaculites tenuis*	*Acaste dayiana*	*Mesodouvillina subinterstrialis* *Eospirifer achmidti*	Cardiolids Lunulacardiids Dualins	*Favosites gothlandicus*		*Eisenackitina filifera* *Urnochitina kameli* *Urnochitina urna*	
	LUDLOW	***inexpectatus-formosus*** ***bohemicus*** *incipiens* ***scanicus*** ***nilssoni***			*Howellella bragensis* *Calymene sp.*		Crinoidal ossicles Orthoceratids *Triplasma formosum*		*Conochitina pachycephala*	G_2
	WENLOCK	***lundgreni*** *radians* *firmus* ***centrifugus-murchisoni***			*Leptaena rhomboidalis* *Isorthys clivosa* *Morinorhynchus orbignyi*	*Cardiola interrupta* *Butovicela migrans*	Orthoceratids		*Conochitina subcyatha* *Conochitina tuba* *Conochitina proboscifera*	G_1
	LLANDOVERY	***insectus***								
ORDOVICIAN	ASHGILL CARADOC									O_3
	LLANDEILO LLANVIRN				*Lingulella dawisii* Acrotretids Lingulella fragments					
	ARENIG TREMADOC	***hirundo*** ***extensus***								O_1
CAMBRIAN	UPPER MIDDLE LOWER			*Paradoxides paradoxissimus* *Peronopsis fallax* *Eccaparadoxides cf. oelandicus*	*Lingulella feruginea*		*Hyolites cf. oelandicus*			K

Table 1. Biostratigraphic chart for Moesia (modified after Iordan, 1999).

characterized by the graptolite *hirundo* zone (Iordan, 1992b) and by O_1 and O_3 palynomorph zones (Beju, 1972, 1973). Palynozone O_1 characterizes the Lower Ordovician, with acritarchs, together with undetermined chitinozoan fragments.

In East Moesia, black argillites and grey-greenish glauconitic siltstones from Bordei Verde borehole yielded an Arenig fauna consisting of graptolites *Didymograptus hirundo* (Salt.), *D.* cf. *extensus* (Hall) and the inarticulate brachiopods *Lingulella* aff. *davisii* Mcoy (Murgeanu & Spassov, 1968). In Ţăndărei borehole, scarce, minute acrotretid brachiopods were recovered together with *Lingulella* and fragments of *?Didymograptus*. The macrofauna and the palynological data suggest Tremadocian and Caradoc-Ashgill ages (Iordan, 1981, 1992b; Beju, 1972; Iordan & Spassov, 1989).

Palynological assemblages identified in boreholes along the northern platform margin attest the Tremadocian-Arenig (palynozone O_1) and Caradoc-Ashgill Stages (palynozone O_3) (Popescu *et al.*, 1967; Beju, 1972, 1973; Paraschiv & Beju, 1973). Upper Cambrian-Lower Ordovician clastics, overstepping the metamorphic basement in boreholes Balş and Ţăndărei, contain small-sized acritarchs of palynozone O_1, some significant for palaeocontinental affinity: *Archaeohystricosphaeridium janicevsky* Timofeev, *A. arenigum* Timofeev, *A. minor* Timofeev, *Cymatiogalea boulardii* Deunff, *C. bellicosa* Deunff, *C. polygonomorpha* Gorka, *Michrystridium shintonensis* Downie, *Tasmanites* sp, and *Leiofusa* sp. (Beju, 1971, 1972). The assemblage of palynozone O_3 consists of Acritarchs with simple or branching spines, dominated by various species of large-sized acritarchs: *Baltisphaeridium longispinosum* (Eis.), *B. stellaeformae* (Timofeev), *B. cognitum* (Timofeev), *Veryhachium trisulcatum venetum* Deunff (Beju, 1972). Associated chitinozoans are large-sized specimens: *Lagenochitina shelvensis* Jenkins, *L. maxima* Tagourdeau & de Jekhovsky, *Conochitina insueta* Umnova, *C. claviformis* Eis., *Cyathochitina calyx* (Eis.), *C. campanulaeformis* (Eis.), *Desmochitina minor* Eis. First representatives of *Ancyrochitina* Eis. occur subordinately.



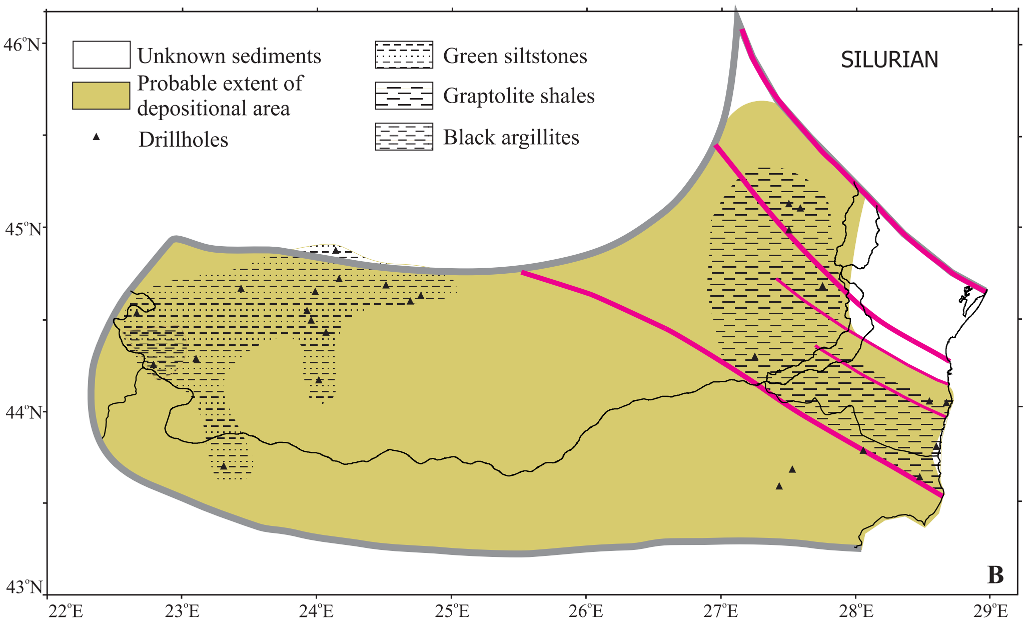


Fig. 7. Lithofacies maps of the Ordovician (A) and Silurian (B) sediments of the Moesian Platform.

In the southern part of the West Moesian (in Bulgaria), the presence of the Ordovician is not yet proved by faunal evidence. However, it is assumed that sediments drilled by borehole Vetrino (NE Bulgaria) at 2989-3002 m depth belong to the Ordovician (Spassov & Yanev, 1966; Iordan & Spassov, 1989; Yanev, 1993).

7.3. Silurian

In East Moesia the Llandovery corresponds to a regional gap (Iordan, 1981, 1982, 1984). In borehole Gârla Mare from West Moesia, the succession underlying the Wenlock strata was assigned to the Llandovery based on acritarchs (*Acanthodiacrodium)* and chitinozoans (*Cyathochitina cilindrica*, *Rhabdochitina spp*.) that do not occur at stratigraphic levels higher than the lower Silurian (Iordan *et al*., 1985).

The lower Wenlock is documented by the presence of the *insectus-centrifugus, murchisoni* and *firmus* zones; the upper Wenlock is proved by the *radians* and *lundgreni* zones (Iordan & Rickards, 1971). The lower Ludlow zones *nilssoni-scanicus* and *incipiens* were documented in the entire platform area. The palynological zone G_1 of chitinozoans and acritarchs (Early Silurian-Wenlock) was identified only in East Moesia (Beju, 1972). The zone G_2 (Ludlow) was documented in the entire area of north Moesia, dominated by cylindrical-spherical, ornamented forms of small-sized chitinozoans. The assemblage also contains acritarchs and trilete spores.

7.3.1. East Moesia

The Lower Wenlock graptolite assemblage yielded by the black shales from Ţăndărei and Bordei Verde boreholes includes *Retiolites geinitzianus* Barr., *Barrandeograptus pulchellus* (Tullb.), *Monograptus priodon* (Bronn), *M. firmus* (Bouč.), *M. pseudocultellus* Bouč., *M. kolihai* Bouč., *Monoclimacis vomerina vomerina* Nich., *M. vomerina basilica* (Lapw.), *M. linnarsoni* (Tullb.), *Pristiograptus praedubius* (Bouč.), *P.* cf. *dubius* (Suess), *Cyrtograptus murchisoni* Carr., C. sp.1. (Iordan, 1981, 1990).

Black shales from Ianca-Berlescu and Bordei Verde boreholes provided an Upper Wenlock graptolite assemblage and few characteristic bivalves and orthocone nautiloids (Iordan, 1981, 1990). The association includes graptolites *Plectograptus praemacilentus* Bouč. et Münch, *Monograptus flemingii* (Salter), *Monoclimacis flumendosae* (Gort.), *Pristiograptus dubius* (Suess), *P. pseudodubius* (Bouč.), *Cyrtograptus trilleri* Eisel, *C. lundgreni* Tullb., bivalves *Butovicella migrans* (Barr.), *Cardiola* sp. cf. *C. interrupta* Sow., and cephalopods *"Orthoceras"* sp. ex. gr. *primaevum* (Forbes), *Geisonoceras* sp., *Michelinoceras* sp.

The Lower Ludlow zones *nilssoni-scanicus* and *incipiens* documented in the entire area of the platform were identified in Tuzla-Costineşti, Mangalia, Călăraşi, Ţăndărei and Biruinţa boreholes (Iordan, 1981, 1990). In the shelly fauna facies, these graptolite zones are attested by the following assemblage: *Holoretiolites (Balticograptus) balticus* Eis., *Plectograptus macilentus* (Törnq.), *Monograptus uncinatus* Tullb., *M. incipiens* (Barr.), *Monoclimacis micropoma* (Jaeck.), *Pristiograptus dubius* (Suess), *Saetograptus collonus* (Barr.), *S. chimaera* (Tullb.), *Bohemograptus bohemicus* (Barr.), *Lobograptus scanicus* Tullb., *Neodiversograptus nilssoni* (Barr.).

In boreholes Călăraşi, Zăvoaia, Ţăndărei and Biruinţa, the Upper Ludlow incorporates the *bohemicus* and *inexpectatus* zones (Iordan, 1981, 1990). A mixed fauna was identified, with predominant small bivalves, flattened orthocone cephalopods, tiny brachiopods and crinoidal ossicles, as well as scarce graptolites. The faunal assemblage includes bivalves [*Dualina* sp. aff. *D. fidelis* (Barr.), *Lunulacardium* cf. *evolvens* Barr., *Cardiolita* ex.gr. *C. bohemica* Barr.], cephalopods [*"Orthoceras"* cf. *primaevum* (Forbes), *Parakionoceras* sp., *Geisonoceras* sp., *Michelinoceras* sp.] and graptolites [*Bohemograptus bohemicus* (Barr.), *Pristiograptus grigoraşii* Iordan, *Linograptus posthumus* (Richter), *Neodiversograptus* sp. ex. gr. *N. nilsoni* (Barr.)] (Iordan, 1981).

The Přídolí was identified in the mixed type of the graptolite shale facies. Black shales recovered from Călăraşi, Zăvoaia and Ţăndărei boreholes contain scarce graptolites of the *ultimus-formosus* zone [*Monograptus* ex gr formosus Bouč., *M.* sp. A, *M.* sp. 1, *Saetograptus rarus* (Teller), *Pristiograptus grigoraşii* Iordan, *Linograptus posthumus* (Richter), *L.* sp. 1]. The faunal assemblages contain predominantly bivalves of *Cardiolidae, Lunulacardiidae* and *Antipleuridae* families [*Cardiolita* cf. *bohemica* (Barr.), *C.* cf. *fortis* (Barr.), *"Cardiola" insolita* Barr., *Lunulacardium undulatum* Barr., *Dualina* sp.], flattened orthocone cephalopods [*"Orthoceras" vertebratum* (Barr.), *Geisonoceras rivale* (Barr.)], tiny brachiopods (*Orbiculoidaea* sp., *Leptostrophia* sp., *Plectodonta* sp., *Howellella* sp.) and crinoidal ossicles (*Crotalocrinus* sp., *Scyphocrinites* sp.).

Palynological studies attested the presence of Přídolí in borehole 1052 Ţăndărei, based on *Conochitina lagenomorpha* Eisenack, 1955 and *Desmochitina urna* Eisenack, 1934 (Beju, 1972; Iliescu, 1976). Borehole 2581 Zăvoaia yielded well represented *Urnochitina urna* (Eisenack, 1934), *Urnochitina kameli* Boumendjel, 1987, *Linochitina klonkensis* Paris & Laufeld, 1981 (in Paris *et al*., 1981) and *Bursachtina krizi* Paris and Laufeld, 1981 (in Paris *et al*., 1981) (Vaida *et al*., in press), along with the very short-ranging (top Přídolí) *Eisenackitina filifera* Eisenack, 1955 and *Eisenackitina lagenomorpha* Eisenack, 1955. A detailed description of the Silurian-Lochkovian chitinozoan assemblages is presented by Vaida *et al*. (in press).

7.3.2. West Moesia

The shelly fauna recovered along the western margin of West Moesia, in Gârla Mare and Oprişor boreholes, documented the Wenlock, Ludlow and Přídolí (Iordan, 1984; Iordan *et al*., 1985). The Wenlock contains *Lisostrophia* (L.) cf. *cooperi* Ams., *Mesopholidostrophia* sp., *Morinorhynchus* cf. *orbigny* (Dav.), *Isorthis* aff. *clivosa* Walm., *Leptaena rhomboidalis* (Wahl.), *Atrypa* aff. *reticularis* Linn.). The Lower Ludlow zones *nilssoni-scanicus* and *incipiens* were documented in Făureşti, Capu Dealului and Uşurei boreholes (Iordan, 1981, 1990). The Ludlow includes *Fardenia* cf. *wieniukovi* (Kozl.), *Howellella* cf. *bragensis* (Wenj.), *Strophodonta* sp., *Triplasma formosum* (Prantl), *Zellophyllum* aff. *conicus* Bulv., *Phaulactis* sp., *Pentagonocyclus* sp., *Anthinocrinus* sp., *Pisocrinus* sp. and *Calymene* sp. (in Capu Dealului borehole) (Iordan, 1999). The Přídolí association contains the *tenuis* and *dayiana* zones, with *Tentaculites tenuis* Sow., *Tentaculites* cf. *ornatus* Sow., *Uniconus* sp., *Acaste dayiana* Richter, *Mesodouvillina subinterstrialis* Kozl., *Eospirifer* cf. *schmidti* Lindstr., *Leptostrophia* sp., *Spondilostrophia* sp., *Shaleria* sp., *Strophochonetes* sp. *Favosites gothlandicus* Lamk., *Acrophyllum* sp., *Pentagonocyclus acanthaclus* Yelt.

Palynological studies revealed the following chitinozoan biozones in boreholes Oprişor and Gârla Mare (Vaida & Verniers, this volume): *Conochitina proboscifera*, *C. tuba*, *C. subcyatha*, *C. pachycephala*, *Urnochitina urna*, *U. kameli* and *Eisenachitina filifera*.

7.4. Devonian

7.4.1. Lochkovian

The presence of the Lochkovian in the argillites from boreholes 5082 Mangalia, 5083 Mangalia and 62 Făureşti is indicated by the *Icriodus woschmidti* conodont zone (Răileanu *et al*., 1967). This association consists of *I. woschmidti* Ziegl., *Panderodus unicostatus* (Brans. *et* Mehl),

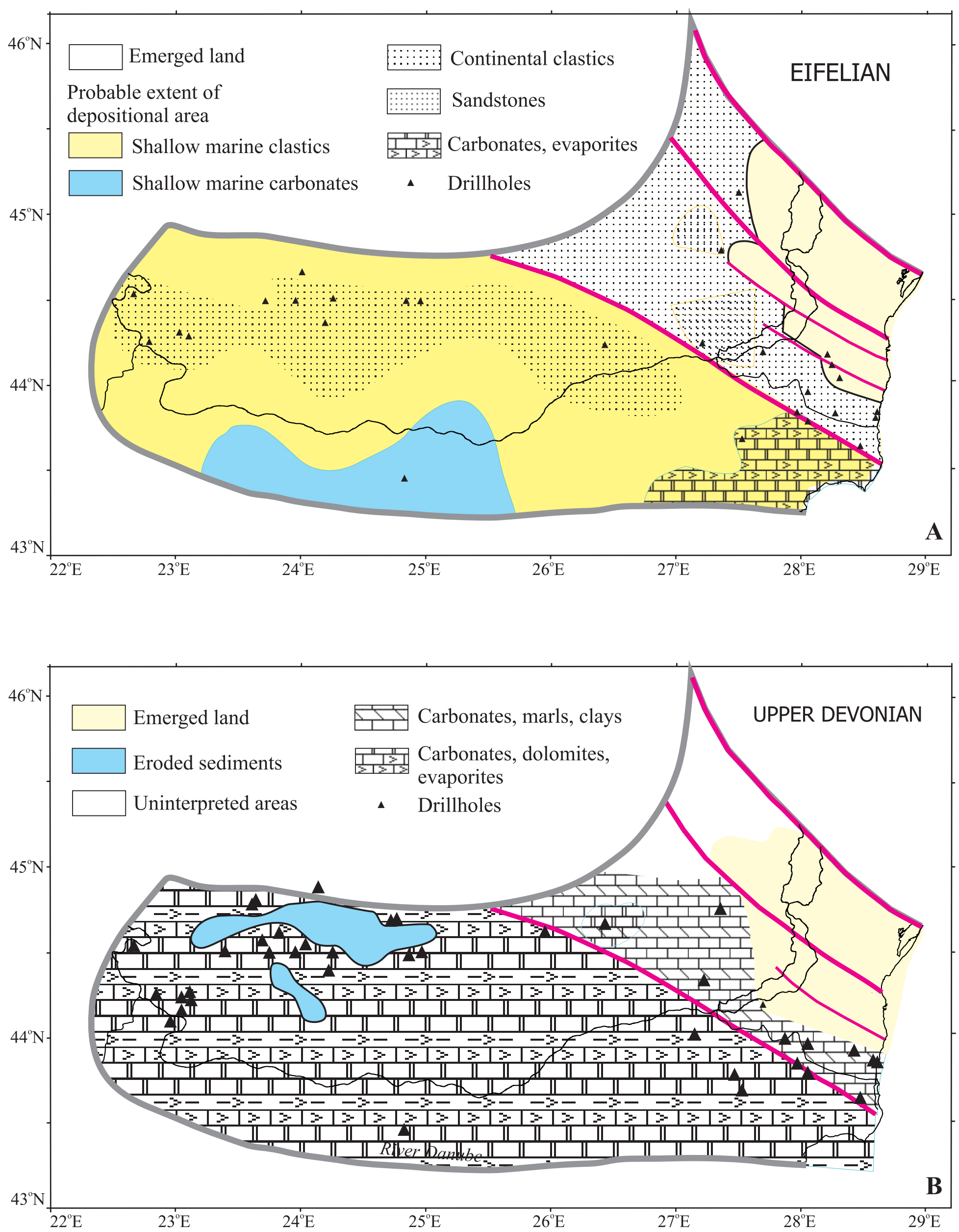


Fig. 8. Lithofacies maps of the Eifelian (A) and Upper Devonian (B) sediments of the Moesian Platform.

P. gracilis (Brans. *et* Mehl.) *Pseudooneotodus beckmanii* (Bish. et Ziegl.), *Ligonodina* sp. (Mirăuţă, in Iordan *et al.*, 1985), as well as brachiopod fragments (*Atrypa* cf. *reticularis* Linn., *Stropheodonta* sp.), corals (*Acmophyllum* sp.) and orthoceratidae (*Jovelania* sp.).

Two global chitinozoan biozones typical for the Lochkovian were identified in the Moesian realm from Bulgaria and Romania. *Eisenackitina bohemica* and *Urochitina simplex* biozones appear in Dalgodelci and Kardam boreholes (Lakova & Yanev 1989; Lakova, 1993, 1994, 1999), as well as in boreholes Călăraşi and 5082 Mangalia from East Moesia (Beju, 1972; Vaida *et al.*, in press). The Lochkow assemblage also contains *Bursachitina oviformis* Eisenack, 1972 (Lakova, 1993; Vaida *et al.*, in press).

The presence of *Cingulochitina plusquelleci* Paris, 1981, with a very short-range in the late Lochkovian, is significant for palaeogeographical affinities, this species being identified only in northern Gondwana. Accompanying species are *Angochitina chlupaci* Paris and Laufeld, 1981 (in Paris *et al.*, 1981), *Cingulochitina ervensis* (Paris, 1979, in Babin *et al.*, 1979), *C. serrata* (Taugourdeau & de Jekhowsky, 1960), *Angochitina filosa* Eisenack, 1955 and *Bursachitina oviformis* Eisenack, 1972 (Vaida *et al.*, in press).

7.4.2. Pragian

The presence of the Pragian is attested by the tentaculites zones *Nowakia acuaria* and *Voliynites velainii*, identified in argillites from boreholes 5082 Mangalia and Oprişor (Iordan, 1967, 1981; Iordan *et al.*, 1985, 1987a). Besides the zone species, the tentaculites assemblage includes *Tentaculites gyracanthus* (Eaton), *T. straeleni* Maill., *T. ornatus* (Sow.), *Prolationus praelongus* Ljasch., *Multiconus macarovici* Iordan, *Corniculina* sp., along with brachiopods [*Schuchertella euzona* (Fuchs), *Chonetes omaliana* de Kon., *Delthyris dumontianus* (de Kon.), *D. infans* Dahmer, *Mutationella podolica* Kozl.], bivalves (*Ctenodonta nassoviensis*), crinoids, ostracods, corals and gastropods (*Coelocyclus* sp., *Sinuitina* sp., Horny & Iordan, 1993).

7.4.3. Emsian

The Emsian faunal assemblage is dominated by trilobites and bivalves, with subordinate brachiopods, gastropods, orthocerathidae, corals, crinoids, bryozoans and ostracods. In Mangalia and Călăraşi boreholes three trilobite zones were identified: *Pseudocryphaeus prostellans, Pilletina asiatica* and *Dipleura fornix* (Iordan, 1967, 1981, 1988). The assemblage includes the species *Pseudocryphaeus prostellans*

(Richt.), *P. asteriferus* Haas, *Pilletina asiatica* (Vern.), *P. pectinata* (Roem), *P. hammerschmidti* (Roem.), *Parahomalonotus gervilei rumaniana* Iordan, *Burmeisteria răileanui* Iordan, *Dipleura fornix* Haas.

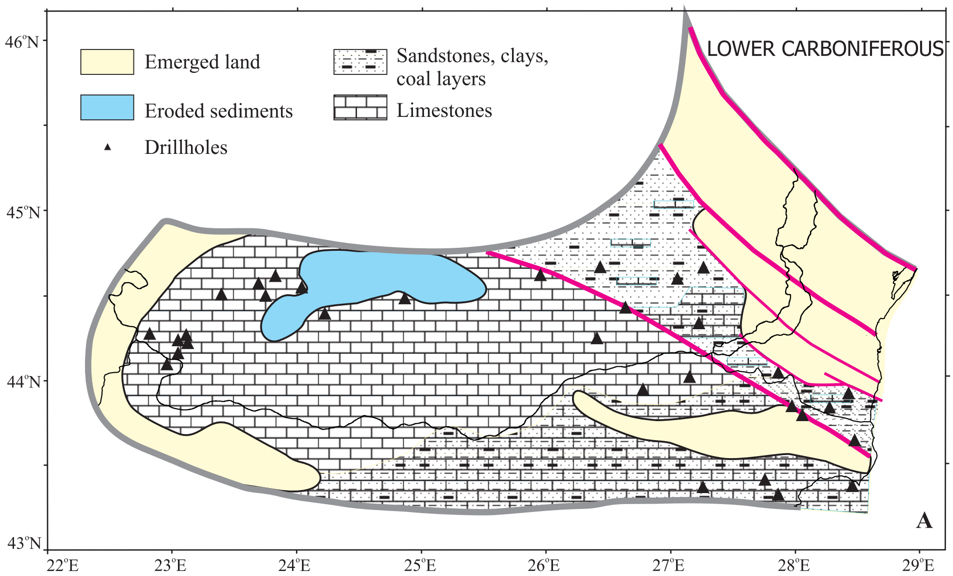
The brachiopods indicate a Lochkovian-Emsian age. The most representative species are: *Leptostrophia index* Havl., *Schizophoria multistriata* (Hall), *Mutationela podolica* Kozl., *Schelwienella umbraculum* (Schl.), *Chonetes unkelensis* Dahm., *Fimbrispirifer trigeri* (Vern.)., *F. daleidensis* (Stein.), *Najadospirifer najadum* (Barr.), *Costispirifer arenosus* (Conrd.). Bivalves include *Actinopteria costata* (Goldf.), *Leiopteria* sp., *Parallelodon mandelensis* (Dahm.), *Orthonota triplicata* Fuchs, *Paracyclas rugosa* (Goldf.), *Carydium inflatum* Dienst., *Cypricardinia* sp., *Praectenodonta* sp., *Grammysia mangalica* Iordan, *G.* aff. *armorica* Mun. Ch., *Grammysioidea inaequalis calatica* Iordan, *Nuculites ellipticus* (Maur) and *Paleosolen costatus* Sandb.

7.4.4. Eifelian

The Eifelian (Smirna quartzitic sandstone, Iordan, 1981) was identified in boreholes Mangalia, Călăraşi, Smirna, Oprişor and Gârla Mare. The clastic facies is characterized by abundance of psilophytal plants, placoderm and ostracoderm fishes and subordinately by brachiopods, tentaculites, crinoids, bivalves, gastropods, corals, eurypterids, ostracods and conodonts. The most important species of psilophital plants are *Pseudosporochonus krejcii* Pot. et Bern., *Aneurophyton germanicum* Kr. et Weyl., *Calamophyton primaevum* Kr. et Weyl., *Hyenia* sp. (Răileanu *et al.*, 1966; Iordan *et al.*, 1985). Placoderm and ostracoderm fishes (*Lunaspis broilii* Gross, *L.* sp., ?*Wijdeaspis* sp. Obrucev, *Drepanaspis* sp., ?*Kiaeraspis* sp.) (Patrulius & Iordan, 1969, 1970), brachiopods (*Fimbrispirifer* sp., *Rhipidomella penelope* (Hall), *Leptostrophia rotunda* Bulb., *Markitoechia marki* Havl.) and crinoids (*Cupressocrinus crassus* Gold.) are associated with the tentaculite *Nowakia maureri* Zagora and *Homoctenus* cf. *hanusi* (Bouc. et Prantl.), that attest the presence of the *N. maureri* zone.

7.4.5. Givetian

The base of the Givetian-Lower Visean carbonate-evaporite succession (Călăraşi Formation *s. str.*) was identified in boreholes Mangalia, Călăraşi, Viroaga, Oprişor and Gârla Mare (Iordan, 1981, 1984; 1987a, b). The Givetian is attested by the tentaculites and brachiopod zones *Tentaculites conicus, Fimbrispirifer venustus* and *Mucrospirifer mucronatus*. The faunal assemblage consists of the species *Tentaculites conicus* Roem., *T. bellulus potomacensis* (Pross.), *Homoctenus* sp., *Strophodonta* (S.) *demissa* (Conr.),



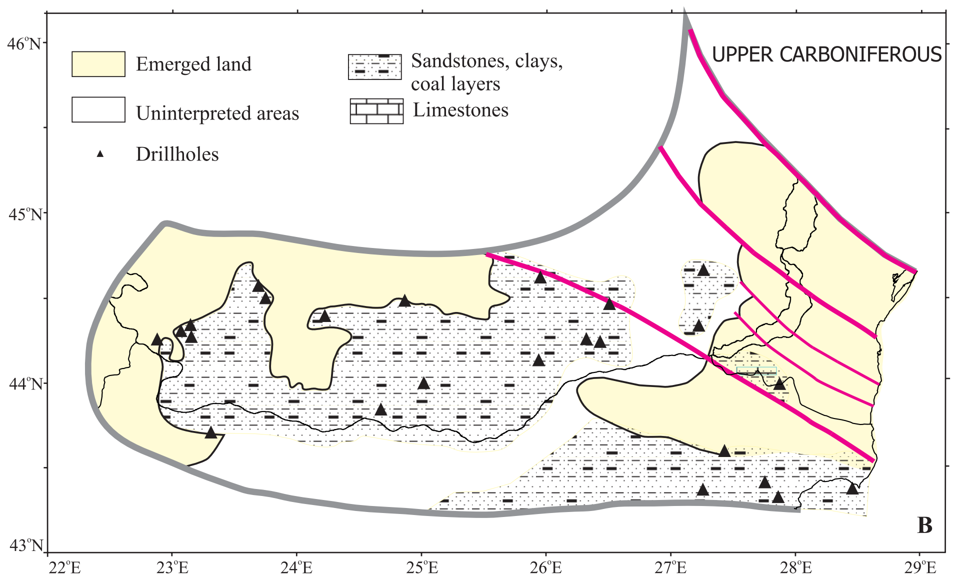


Fig. 9. Lithofacies maps of the Lower Carboniferous (A) and Upper Carboniferous (B) sediments of the Moesian Platform.

Devonochonetes scitulus (Hall), *Atrypa reticularis kuzbasica* Rzhon., *Fimbrispirifer venustus* (Hall), *Mucrospirifer mucronatus* (Conr.), *Amphipora ramosa* Phill. (Iordan 1967, 1981, 1988; Iordan *et al*., 1985).

7.4.6. Frasnian

The Frasnian is attested in Mangalia borehole by the brachiopod zones *Homoctenus krestovnikovi* and *Mucrospirifer bouchardi*. This assemblage includes the species *Homoctenus krestovnikovi* Ljash., *Dicricoconus* sp. A., *Tentaculites* sp. F ex. gr. *T. straeleni* Maill., *Chonetes rowei* Cl. et Sw., *Athyris vittata* Havl., *Mucrospirifer bouchardi* (Murch.), *Mediospirifer audacula* (Conr.), *Spinocyrtia* aff. *martianoffi* (Stuck.) (Iordan, 1967, 1981, 1988).

7.4.7. Famennian

The Famennian (Viroaga Limestones), identified only in Viroaga borehole from South Dobrogea, is attested by the zones *Cyrtospirifer archiaci* and *Palmatolepis crepida* (Iordan *et al*., 1987a); this assemblage includes the species *Cyrtospirifer archiaci* (Murch.), *C. tchernychevi sibirica* Ivania, *C.* spp., *Productella* sp., *Athyris* sp., *Megachonetes* sp., *Polygnathus nodocostatus* Brans. et Mehl., *Palmatolepis stoppeli* Sand., *Icriodus cornutus* Sand., along with holothurian sclerites, ophiuroids, Moravamminids and calcispheres.

7.5. Carboniferous

The Devonian/Carboniferous boundary, in a continuous sequence of the carbonate facies, was intercepted only in borehole Călăraşi, where the conodont *Siphonodella isostycha* attested the presence of the Tournaisian in dark limestones (Paraschiv, 1974). South of the Danube, the Devonian/Carboniferous boundary lies within the *Quasiendothyra cobeitusana* zone (Spassov, 1972).

All stages of the Carboniferous system have been attested on the basis of conodont zones and age indicator fossils like brachiopods, bivalves, goniatites, fenestelide

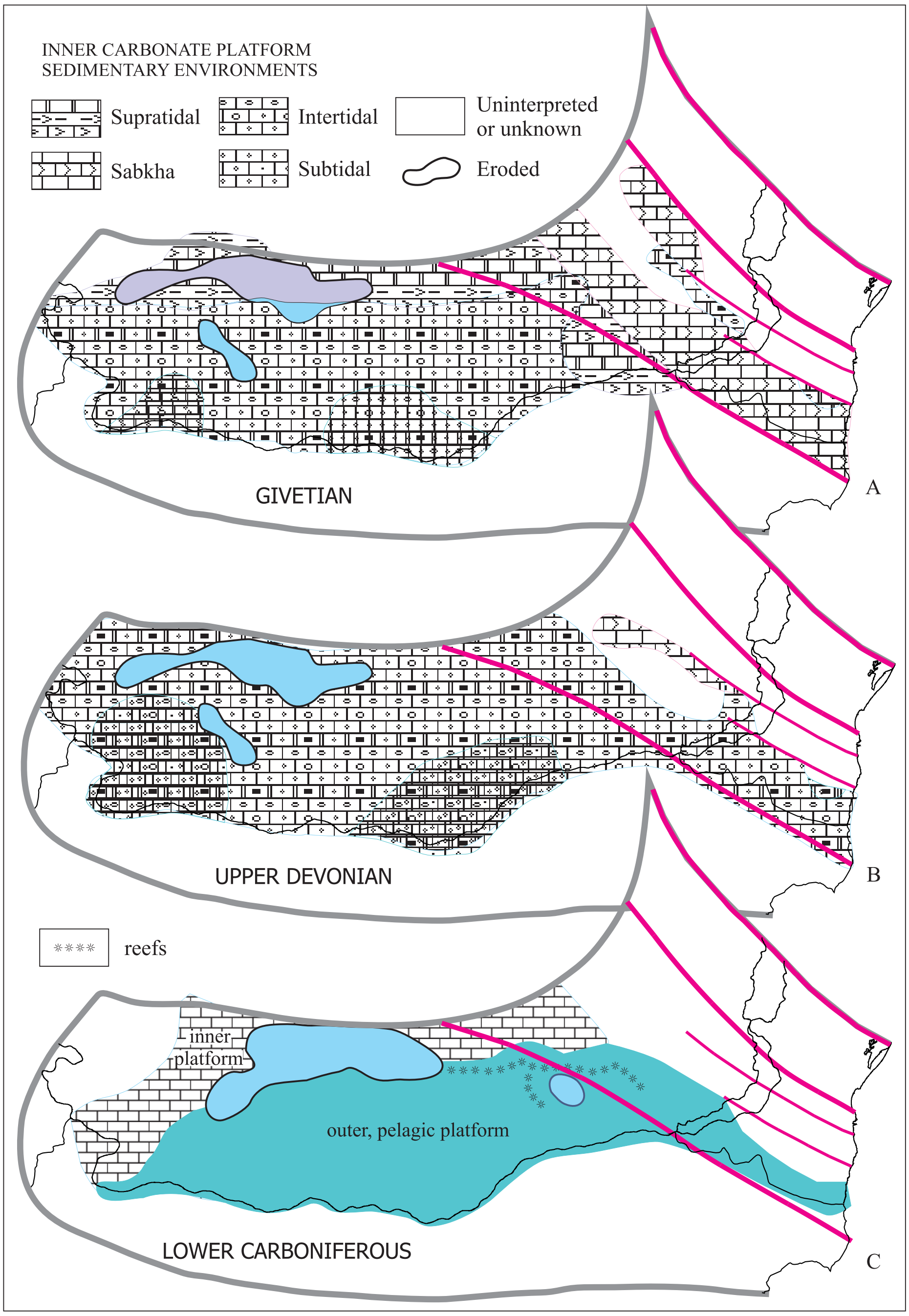


Fig. 10. Palaeogeographic maps of the Givetian-Lower Carboniferous carbonate-evaporite succession of the Moesian Platform in Romania (modified after Vinogradov & Popescu, 1984). North of the Danube, the Givetian and Upper Devonian environments characterize the inner carbonate platform; in the Lower Carboniferous the inner platform is confined to the northern and western margins of the platform, the largest part of the area being occupied by the outer, pelagic platform; reef build-ups develop at the boundary between the inner and outer platform in the central-eastern part of West Moesia and on both sides of the Intramoesian Fault.

bryozoans, corals, and foraminifers. The Tournaisian is attested by *Syphonodella isosticha* Zone. The Visean is proved by assemblages of brachiopods (*Megachonetes zimmermani*, *Daviesella llangolensis* (Dav.), *Dictyoclostus semireticulatus*, *D. multispiniferus*, *Gigantoproductus giganteus*, *G. bisati*), bivalves (*Aviculopecten interstrialis)*, foraminifers (*Endothyra bradyi*) and spores (*Koninckopora inflata*, *Eostafella mosquensis*, *Lithostrotion portlocki* and *Ligonodina fragilis* zone) (Iordan, 1999). The Namurian-Westphalian is attested by *Dictyoclostus retiformis*, *Productus carbonarius, Posidonia corrugata*, *Janeia primaeva*, goniatites, orthoceratids and plant remains (*Calamites*, *Stigmaria*).

In borehole Brâncoveanu, two palynozones have been established in the West Moesian clastic Carboniferous succession, consisting of trilete spores of Pteridophytes: *Tripartites and Rotaspora* zone (palynozone C_2) indicating the Namurian, while palynozone Cb_2 – Cb_3 indicates the Namurian – Lower Westphalian transition (Paraschiv & Popescu, 1980). Both zones show a good correlation with those found in other boreholes from East and West Moesia.

8. Paleozoic palaeogeography

Lithological and biostratigraphic data from Romania indicate that following the Cadomian deformation and uplift, the marine environment covered the Neoproterozoic basement of West Moesia in Lower Cambrian. In the southern part of East Moesia (South Dobrogea) the Neoproterozoic basement was overstepped probably later, in latest Cambrian, while the Cadomian basement of Central Dobrogea was covered by the sea only in the Ordovician. This might suggest a northward progradation of the marine domain in the Paleozoic. Biostratigraphic correlations suggest a distinct evolution of the Paleozoic sedimentation in the Eastern and Western parts of the platform (Pană, 1997). A series of lithofacies maps is shown in Figs 7 to 10. Based on borehole information, the

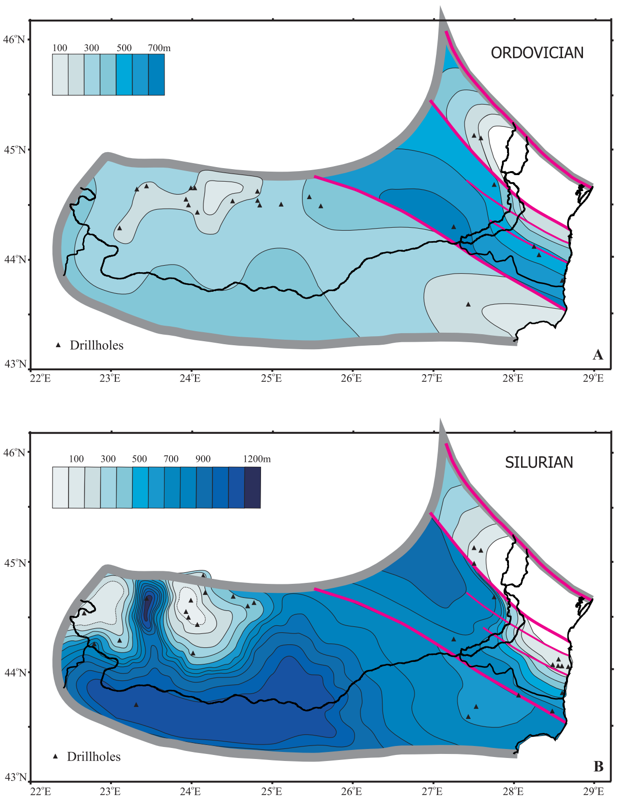


Fig. 11. Isopach maps for the Ordovician (A) and Silurian (B) of the Moesian Platform.

distribution and thickness of the Paleozoic sediments is illustrated in a set of isopach maps (Figs 11-13).

The subsiding, shallow marine continental platform established in the Cambrian, accumulated fine-grained siliciclastic sediments throughout the Ordovician-Lower Devonian times. Acritarchs, together with well-preserved chitinozoans, indicate depths around 200 m, weak currents and moderate temperatures (10-15°C) for the shallow, Upper Ordovician epicontinental basin (Paraschiv, 1974, 1979; Iordan, 1999). A cold climate is suggested by the presence of glauconite in Ordovician shales. The distribution of isopachs indicates clear differences between East and West Moesia (Fig. 11A). In West Moesia the wide sedimentary basin was shallower, with thinner sediments (100-200 m) on top of Strehaia, Balş-Optaşi and North Bulgarian highs, which were submerged and interconnected. The depocentres (400 m of sediments) were located in the depressions of Lom and Alexandria which started to deepen. In East Moesia, the depocentre was located in the Călăraşi basin, east of the IMF. The area of Central Dobrogea was already a fault-bounded emerged land, but South Dobrogea was still submerged. Distribution of isopachs suggests that South Dobrogea represented a rifted block, probably a half-graben. Sinistral displacement took place along the Capidava-Ovidiu Fault.

Stratigraphic relations indicate northward advance of the Silurian sea in both East and West Moesia. Silurian sediments overstep Ordovician clastics in the southern part and the Neoproterozoic basement in the northern part of East Moesia, above a stratigraphic gap corresponding to the Llandovery. The graptolite shale facies of the Silurian in East Moesia, classical in the lower part and mixed in the upper part, indicates a sedimentary environment typical for restricted, euxinic basins, with reducing conditions favored by complete lack of bottom currents and large amounts of decomposing organic material. Presence of ostracods, tentaculites and brachiopods in the faunal assemblage indicates that atop the euxinic environment there was a superficial layer with normal marine conditions, favoring development of nektonic and planktonic fauna (Paraschiv, 1974). Still waters and low depths are indicated by the presence of chitinozoans (Paraschiv *et al*., 1983b). All these suggest that Silurian sedimentation took place in a shallow marine environment, represented by a large epicontinental basin developed on the continental shelf. Shallowing of the East Moesian basin started in Přídolí times, as indicated by the accumulation of the mixed facies of graptolite shales. The shelly fauna facies of the Silurian in West Moesia, devoid of graptolites and containing shallow water macrofaunal assemblages, suggests a shallower depositional environment compared to East Moesia, and similar with that from the western margin of the East European Craton. The interbedded tuffs and fine-grained volcaniclastics suggest a coeval explosive basic volcanism.

The isopach map (Fig. 11B) again indicates differences between East and West Moesia. A large E-W oriented basin existed in the southern part of West Moesia, with a deep N-S branch representing the depocentre, where the Silurian sediments attained a maximum thickness of 1200 m (in borehole Capu Dealului). The orientation of the shallower Călăraşi basin is very poorly constrained. The northern part of South Dobrogea still represented a tectonic high, but the sea started to retreat southward.

Prevalence of the marine environment in the Lower Devonian of East Moesia is suggested by macro- and microfauna. Crinoids, bivalves and brachiopods indicate a marine environment, and coquinas made up mainly of brachiopods suggest an onshore depositional environment. Icrioid conodonts also indicate shallow depths of the Lower Devonian basin, the shoreline being located in the vicinity of Mangalia and Călăraşi (Pană, 1997). Local eurypterid remnants indicative of lagoonal environments suggest local subcontinental conditions. Plant remains, associated with placoderms, Agnatha and brachiopods suggest a lagoonal, perilittoral environment (Răileanu *et al*., 1967; Iordan, 1981). The presence of both marine and fresh-water fauna, as well as of continental plants, together with the upward coarsening trend of the lower Devonian clastics, suggest a deltaic environment; considering probably of fan-delta type.

The sandstone dominated facies, with placoderm and ostracoderm fishes and psilophital plants, indicates that sub-continental, freshwater environments prevailed in the Eifelian. Local, short marine ingressions are indicated by marine faunal assemblages (brachiopods, tentaculites, crinoids, bivalves, gastropods, corals, ostracods and conodonts), yielded by local interbeds in continental sediments at Călăraşi and Mangalia. The overall features of the Eifelian, with red sandstones and continental fauna in East Moesia, suggest that the area was part of Laurussia (the "Old Red Continent", Paraschiv, 1974), formed after the destruction of the Iapetus Ocean subsequent to the Lower Devonian collision of Balonia (Baltica & Avalonia) with Laurentia. The accumulation of coarse clastics indicates considerable input from the adjacent uplifted areas, with a low energy relief, well organized hydrographic network and short distance of alluvial transport. Local evaporite layers and red colored rock sequences are indicative of warm and arid climate in the Eifelian.

The thickness of the Eifelian clastics is relatively uniform and differences between East and West Moesia are much attenuated (Fig. 12A). The basins become considerably shallower, with maximum sediment thickness of 300 m. The sea continues to retreat southward from the northern part of South Dobrogea. The north-eastern part of East Moesia was uplifted land.

A shallow marine carbonate platform was established in the Givetian in the entire Moesian realm, and carbonate sedimentation continued up to the late Visean (Figs 8B & 12B). The sudden change in sedimentation coincides with the global climate warming (Pană, 1997). During its

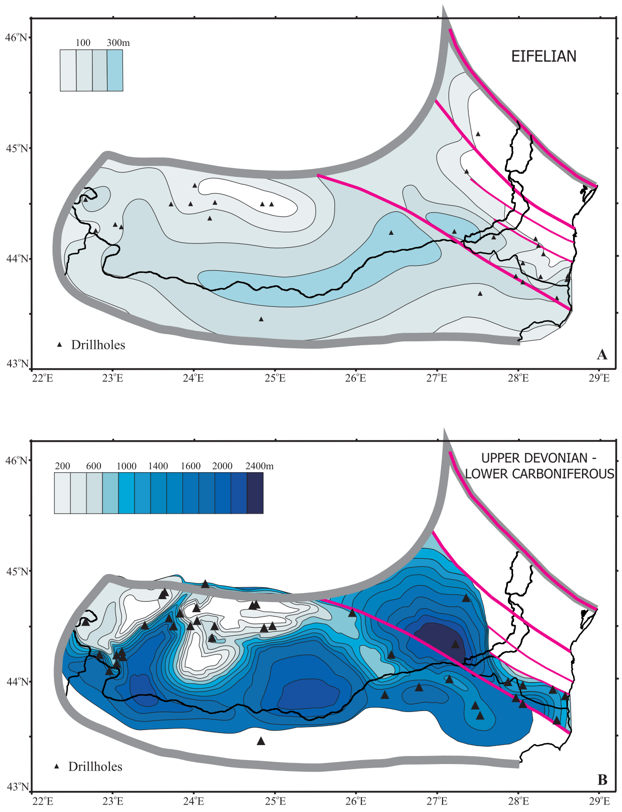


Fig. 12. Isopach maps for the Eifelian (A) and Upper Devonian-Lower Carboniferous (B) (the latter modified after Paraschiv, 1974).

latitudinal migration, in the Givetian the Moesian block has reached the tropical arid zone (Yanev, 1995; Yanev *et al*., this volume). Until the end of the Devonian, the platform developed in warm, tropical climate, favoring chemical deposition of evaporite beds and dolomites. The shallow sedimentary basin was divided into several lagoons separated by deeper channels, where sedimentation took place in restricted, euxinic conditions, favoring hydrocarbon formation. Presence of both anhydrite and gypsum in the carbonate sediments may suggests interfingering of distal and proximal supratidal environments. The development of two different facies at Călăraşi, an eastern facies with evaporites, and a western one with dark, bituminous organogenous limestones, suggests tectonic activity and uplift in the hanging wall of the Intramoesian Fault. Eastward, at Mangalia, a deeper basin is indicated by palmatolepsid conodonts (Pană, 1997).

At the end of the Devonian, the southern and south-western margins of Moesia become active margins of Andean type, with formation of arc-type structures in the south-west (Yanev & Boncheva, 1995; Haydoutov & Yanev, 1997). Excepting its southern border, the area of Dobrogea was an emerged land. A rapid northward migration of the platform to the tropical domain (Yanev, 1995) is marked by the disappearance of tentaculites and invasion of supratidal zones by stromatoporoids (Pană, 1997). Iordan (1999) explains the extinction of the proetids, tentaculites, atrypids and corals due to the presence of the Kellwasser Bioevent (F/F) in the upper Devonian sediments (Frasnian) of the Moesian Platform; this is also suggested by the dark, bituminous facies of limestones.

The restricted conditions attenuated towards the end of the Devonian, when establishment of an open sea environment is indicated by limestone deposition. The open sea environment prevailed throughout the Lower Carboniferous, when the limestone facies occupied a large sedimentary basin, developed between the Rhodope and Getic domains, including the Danubian realm of the South Carpathians (Patrulius & Neagu, 1963).

A process of gradual replacement of carbonate sedimentation by terrigenous deposition in continental, lacustrine or deltaic environments started in the Lower Carboniferous (Fig. 9A). Terrigenous, often coal-bearing clastics, progaded northward from the southern part of the platform and became dominant in the northern part of Moesia in the late Carboniferous. The diminishing of the depositional area at the end of the Namurian is interpreted as a consequence of the Sudetic events in the Variscan belt (Paraschiv, 1974, 1979; Iordan, 1992a). Accumulation of the Carboniferous continental facies, initially with paralic influences, then lacustrine, is possibly connected to the closure of the Rheic Ocean (Pană, 1997).

It is assumed that the Paleozoic clastics were sourced by the Balş-Optaşi high (Popescu *et al*., 1967), or by the Prebalkans and the external Danubian nappes of the South Carpathians (Săndulescu, 1984). The distribution of the coal-bearing clastics is highly discontinuous (Fig. 9B) and abrupt facies changes or interfingering of terrigenous and carbonate sediments were explained as result of morphological changes of the basin floor, with thicker clastics accumulated in basins and thinner carbonates on highs (Paraschiv & Popescu, 1980). Such basin geometry suggests a large fore deep basin, where accumulation of clastics was controlled by thrust bounded highs. Vertical facies distribution, with coal-bearing clastics progressively overstepping carbonate platform sediments, as well as the folds and thrusts revealed in the Paleozoic sediments in the southern part of Moesia (Yanev & Boncheva, 1995), are consistent with a fore deep basin setting. Sediments from the northern part of the platform, with constant dips of 10-20°, do not show structural evidence for Late Carboniferous

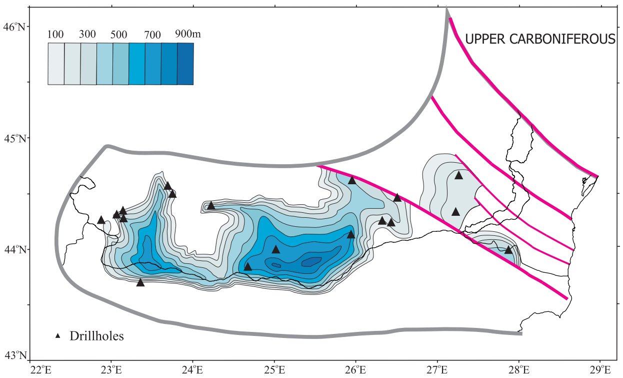


Fig. 13. Isopach map for the Upper Carboniferous of the Moesian Platform (modified after Paraschiv, 1974).

deformation, and could possibly represent the foreland of the Variscan belt from the Balkans, where Late Carboniferous thrusting and granite emplacement is documented by geochronological evidence.

In the Late Carboniferous, the largest part of Moesia started to be emerged and eventually became a continental area (Figs 9B & 13), where a warm and humid climate stimulated the development of terrestrial flora. Interfingering of limestones containing marine macrofauna, with shales and sandstones rich in continental macroflora, indicate that throughout the Namurian-Westphalian the deposition took place largely in shallow marine, continental and deltaic environments. In East Moesia, the delta lied between a large land mass and a narrow uplift, presently located to the north and south, respectively, while a shallow marine sedimentary basin was located south-eastward, as suggested by remnants of carbonate facies preserved west of Mangalia (Pană, 1997). Paleoecological evaluation indicates that shelf sedimentation took place at water depths between 5-20 to 30 m, the algal facies with foraminifers indicating subtropical climate.

The lithofacies evolution during the Paleozoic was strongly influenced by the climate: cold climate during upper Ordovician-Silurian; warm climate in the lower-middle Devonian; cooling in the upper Devonian, followed by a warm period corresponding to the Lower Carboniferous transgression (Pană, 1997). According to Yanev (1993, 1997) and Yanev *et al.* (this volume), the facies changes suggest rapid northward migration towards the equator during the Devonian. In Givetian the platform was very close to the equator, while in the Visean it was already in northern latitudes, evolving in the subtropical zone according to the algal flora (Yanev & Boncheva, 1995; Yanev, 1997; Pană, 1997). In the Permian, the Moesian platform was in the temperate zone according to the fusulinid faunas and other calcareous foraminifers (Pană, 1997).

9. Palaeocontinental affinities of Moesia

The establishment of Moesian palaeocontinental affinities represents a difficult task, due to lack of reliable evidence. The complete lack of palaeomagnetic data, poor reliability of geochronological data regarding the basement rocks, lack of provenance data for the Lower Paleozoic clastics, as well as controversial interpretations of the significance of paleontological data in establishing affinities are major difficulties in the attempt to constrain the paleogeographic affinities of Moesia. The main question is if Moesia represents indeed a unique terrane, as defined by Yanev (1993, 1997) and Haydoutov & Yanev (1997), or if East and West Moesia represent distinct terranes, as suggested by Oczlon *et al.* (submitted).

The model supporting a North Gondwanan origin of the Moesian terrane is based on facies analysis of the Paleozoic successions of Moesia and on the differences in Lower-Middle Paleozoic sedimentation between Moesia and the East European Platform (Yanev, 1993; Yanev & Boncheva, 1995; Haydoutov & Yanev, 1997). The Moesian and East European Plates show differences in lithology and thickness of the Ordovician-Silurian and Devonian successions and the same facies of the Carboniferous sediments (Yanev & Boncheva, 1995). Silurian successions indicate pelitic sedimentation on the Moesian plate, contrasting with the gaps corresponding to the Llandovery and Ashgill on the SW margin of the East European Platform. Haydoutov & Yanev (1997) distinguished the Moesian and Balkan terranes, both showing North Gondwanan affinity, but separated successively from the North African margin: the first to separate was the Moesian terrane, lacking the Ordovician glacial diamictites, which are instead present in the Balkan terrane. The following scenario was suggested: northward migration of the Moesian terrane after separation from the North African margin of Gondwana and Devonian docking to the East European Platform, followed by Upper Carboniferous-Permian collision between the Moesian and Balkan terranes (Yanev *et al.*, this volume).

A northern Gondwanan origin for Moesia was suggested on the basis of palynomorphs (including acritarchs, chitinozoans and spores) (Beju, 1972; Iliescu, 1976; Iordan *et al.*, 1985; Lakova, 1995) and macrofaunas (Iordan 1972; Iordan & Rickards, 1971; Iordan *et al.*, 1985) identified in the northern part of the platform. However, the Middle Cambrian trilobites recovered from boreholes in West Moesia suggest Baltican affinities (Muțiu, 1991). Revision of the trilobite fauna confirmed the Baltican affinities (Rushton & McKerrow, 2000), as the agnostid species *Acadagnostus* and *Triplagnostus* are more representative of Swedish rather than Bohemian faunas. An alternative explanation is that *Peronopsis fallax* (Linnarsson), apparently showing some affinities with species associated with the Baltican margin, is a widely recorded member of an outer shelf fauna, which may have been able to cross geotectonic boundaries (Rushton, in Winchester *et al.*, in press).

The model of Winchester *et al.* (2002a, b, c) and Winchester (2003) suggests that a major promontory – the Bruno-Silesian Promontory – was established at the end of the Cambrian on the SW margin of Baltica. This promontory included the Bruno-Silesian, Łysogory and Małopolska terranes close to their present location, and probably Moesia in a northern location (Winchester *et al.*, in press). During accretion of Far East Avalonia and Armorica Terrane Assemblage, this promontory favored breaking of the tips of these terranes and their further displacement to SE (Winchester *et al.*, in press). The regional unconformity at the base of the Silurian succession in East Moesia (Iordan, 1984) may suggest a Late Ordovician uplift, in connection with collision of Avalonian fragments immediately to the south and associated deformation (Winchester *et al.*, in press).

Analyses of the differences in lower Paleozoic facies and paleontological assemblages, basement types and provenance, suggest that East and West Moesia might represent two distinct Paleozoic terranes (Oczlon *et al.*, submitted). The main conclusions of this study are presented below. The peri-Gondwanan affinity of East Moesia is based on the presence of Lower Ordovician cold-water acritarchs *Cymatiogalea bellicosa* and *C. boulardii*. These acritarchs are exclusively related to peri-Gondwanan cold-water environments and do not occur on the temperate Lower Ordovician shelves of Baltica (Servais *et al.*, 2003). The detrital zircon spectrum from the Late Neoproterozoic turbidites of Central Dobrogea (Żelaźniewicz *et al.*, 2001a, b) indicates a contemporaneous active/accretionnary margin and Archean/Grenvillian sources unrelated to Baltica, probably related to Avalonia. Baltican affinities of West

Moesia are based on similar early Middle Cambrian trilobites, the typically West Baltican succession of Cambrian clastics and Lower Silurian carbonate facies. Within East Moesia, the northern part of South Dobrogea, with a metamorphic basement resembling the Archean and Paleoproterozoic rocks of the Ukrainian Shield (Giuşcă *et al*., 1967), is interpreted as a block displaced from the East European Craton. It is suggested that West Moesia might represent a proximal Baltica-derived terrane, broken off and displaced during latest Ordovician-Silurian collision with Avalonia. By Silurian, both East and West Moesia, juxtaposed along the Intra-Moesian Fault, were located on the SW Baltica margin, as indicated by Silurian facies and shelly fauna in carbonates. According to this scenario, through the Upper Paleozoic - Lower Cretaceous times Moesia was translated SE-wards along the East European craton margin to its present position.

However, preliminary palynological studies reveal that Lower Devonian – Lochkovian chitinozoans from the main boreholes in East Moesia indicate a dominant North Gondwanan affinity, being similar with those found in typical Gondwanan terranes: Bohemia, Armorican Massif, Montagne Noire, and various areas from Spain, Tunisia, Algerian Sahara, Morocco, Libya (Vaida *et al*., in press). The presence of the accompanying species *Cingulochitina plusquelleci*, which has a very short range in late Lochkovian and is quoted only in northern Gondwana, strengthens the north Gondwanan affinity (Vaida & Verniers, this volume; submitted). These data are in good agreement with those yielded by boreholes in West Moesia (Lakova, 1995).

The North Gondwanan affinity suggested by the Přídolí-Lochkovian chitinozoans from East and West Moesia (Lakova, 1993, 1999; Vaida *et al*., in press) is difficult to reconcile with the model of Winchester (2003); Winchester *et al*. (in press), which assumes that Moesia was attached to the western margin of the East European Craton by the Upper Cambrian. On the other hand, the North Gondwanan affinity of East Moesia in the Prídolí-Lochkovian, indicated by chitinozoans (Vaida & Verniers, this volume; submitted), conflicts with the Avalonian affinity (Oczlon *et al*., submitted) indicated by the angular unconformity between the Lower and Upper Ludlow. An Avalonian affinity of East Moesia would be consistent with such an unconformity, which could be related to accretion to Baltica or could reflect such events (Oczlon *et al*., submitted; Winchester *et al*., in press).

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