The Importance of Malm-Neocomian Carbonate Buildups in the Hydrocarbon System of the Moesian Platform*

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Search and Discovery Article #30367 (2014)
Posted October 6, 2014

*Adapted from extended abstract prepared in conjunction with oral presentation at AAPG International Conference & Exhibition, Istanbul, Turkey, September 14-17, 2014, AAPG©2014

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Abstract

The heterogeneous basement of the Moesian Platform is overlain by a very thick sequence of sedimentary deposits. The marine Lias-Lower Cretaceous sedimentary cycle started with a lower clastic (Lias-Dogger) sequence followed by the carbonate Malm-Neocomian cycle. The carbonate sedimentation started in relative deep waters and was uniform. The Upper Tithonic sedimentation was differentiated in a basinal pelagic facies in Central Moesia, a neritic littoral facies with reefal episodes in East and West and a lagoonal-evaporite facies in eastern extremity of the Platform. The dynamics of marine waters has contributed to the spatial development orientation of carbonate buildings, determining reefal buildings of barrier, pinnacle and fringe typ. The hydrocarbon system of Moesian Platform is characterized by alternatively deposits of source, reservoir and seal rocks. The factors controlling the hydrocarbon distribution are the source rocks presence, West-East normal faults trend and the presence of areas of high geothermal gradient. The highest values of geothermal gradient (60°C/100 m) were recorded west of Arges River; the eastern part of the Platform outlines a geothermal minimum anomaly (1.5–20°C/100 m). Source rocks are found in the Silurian, Lower Devonian, Middle Triassic, Upper Lias-Dogger and Badenian-Sarmatian formations (0.5–2.5% TOC). West of the Arges River, liquid hydrocarbons could be generated starting at 1,000m depth. East of the river, liquid hydrocarbons could be generated starting at 2,500m depth. To the east, Devonian bituminous limestone and Silurian schists with Graptolites can compensate the small thickness or lack of the Lias-Dogger bituminous schists. The reservoirs show good primary inter-granular porosity in detritic organogenous and oolitic limestone and secondary fissured and cavernous porosity. Reservoirs from carbonate buildings were sealed at the top by draping of covering formations, laterally by compacted inter-reefal limestone. There are 126 oil and gas fields in the Moesian Platform, located from Devonian to Neogene, from 350m to 4,900m in depth. The majority of the fields are oil-bearing, two-thirds in Mesozoic formations. Seismic data interpretation has found the existence of more than 50 carbonate buildings, more than 20 in the eastern sector of the Moesian Platform.

Introduction

Moesian Platform, a promontory of European Platform, is bordered to the north by the North Dobrogea Orogene and South Carpathians, to the west by the South Carpathians, to the south by the Balkanides and to the east, it continues to the Black Sea. The basement of the Moesian Platform is divided into a western, Wallachian block and an eastern Dobrogean block, separated by an Intra-Moesian fault. The western block is made up of epi- and meso-metamorphic Precambrian rocks; the eastern one is made up of weakly metamorphosed, Upper Vendian-Early Cambrian flyschoid rocks. The crustal thickness in the western block is about 30-33 km, the eastern one having 40-45 km in thickness. The sedimentary cover is thick (>10 km) and becomes thinner with many hiatuses to the northeast in the Dobrogea area. The eastern block is characterized by a NW-SE trending fault system, the western one is characterized by a W-E trending fault system that controls some major basement highs: Craiova-Optasi-Peris and Strehaia-Vidin. Between these basement highs, there are a number of depressions: Lom-Bailesti, Alexandria and Tutrakan-Calarasi basins.

Stratigraphy

The sedimentary cover is subdivided into four sedimentary mega-sequences (Tari et al., 1997; Paraschiv, D, 1979): Middle Cambrian-Upper Carboniferous, Permian-Upper Triassic, Jurassic-Senonian and Paleogene-Quaternary, separated by major unconformities.

1) The Middle Cambrian-Upper Carboniferous mega-sequence can reach 5,500m in total thickness, subdivided into three lithological subunits:

- The lower clastic group (Upper Cambrian-Middle Devonian, Mangalia Formation), with clastic formation in base made up of arkose, quartzite sandstone with silt and shale intercalations. This sequence is overlain unconformable by Silurian graptolite-shale (Tandarei Formation), with an average thickness of 800m, followed by Lower Devonian quartzite sandstone with silts, thickness about 370m.
- The carbonate group (Middle Devonian-Carboniferous, Calarasi Group) composed of massive limestone and dolomites with bituminous limestone and evaporites levels, thickness up to 2,800m.
- The upper clastic group (Middle-Upper Carboniferous, Vlasin Formation) represented by coal succession overlain by silts, marls and sandstones, 700-800m thickness.

2) The Permian-Triassic mega-sequence, with three subunits, red colored continental clastics, evaporite and carbonate rocks, maximum thickness 6,000m in Alexandria Depression.

- The lower red clastic group (Permian-Lower Triassic), overlies the Hercinian unconformity, it is composed of clay, silt, sand, sandstones with interbeddings of dolomite limestone, gypsum/anhydrite and salt, 2,700m thickness.
- The carbonate group (Middle Triassic, Alexandria Formation) overlays a shallow water clastic formation, it is composed of neritic limestone and dolomites with marl and anhydrite/salt intercalations, 1,000m thickness.
- The upper red clastic group (Upper Triassic, Segarcea Formation), maximum thickness 1,200m, locally developed, is made up of shale, marls, sands, sandstones and conglomerates, deposited dominantly in continental environment.
- Magmatic activity was common during this mega-sequence, especially in Lower Permian and around the boundary of the Middle-Upper Triassic.

3) The Jurassic-Cretaceous mega-sequence (Lower Jurassic-Senonian), characterized mainly by carbonates and only in part by clastic rocks, with maximum thickness of 3,500m, has also three subunits:

- The continental-neritic clastic group, (Sinemurian-Bathonian), about 600m thickness.

- The massive carbonate group, 1,700m average thickness, developed in both neritic and pelagic facies with reefal buildups. The carbonate group has some siliciclastic intercalations in it, deposited in Albian and Cenomanian.
- The Senonian group, composed of neritic limestone, is missing in western part of Moesian Platform.

4) The Paleogene-Neogene mega-sequence is asymmetric in space and in time, reflecting the influence exerted by the Carpathians uplift:

- The Paleocene-Eocene group, characterized by marls and sandstones and locally by carbonates, is thick in southern part of the Platform (up to 1,600m); it is missing or very thin in North. Paleocene-Eocene and it is followed by a period of weathering exposure and erosion during Late Oligocene and Early Miocene.
- The Neogene group is very thick at the northern part of the Platform, more than 5,500m. The Middle Miocene sediments are thin, deposited in shallow water, made of carbonates and anhydrites. The Upper Miocene sediments are deposited in deep waters, constituted by marls and sandstones.
- The Quaternary formations, composed of conglomerates, sands, clays and loess, are of various thickness (0-200m) and they are developed at the margins of the Platform.

Tectonics

The Baikalian orogenesis defined the major structural lines and the detailed tectonics of the Platform basement. Some of these major lines continued to be active until the end of Triassic, other, in the East, until the Neogene. During the Baikalian emersion, the basement was submitted to denudation that led to the appearance of a strong relief.

The coarse deposits of the first sedimentary mega-sequence indicate important positive movements in the neighboring areas, strong erosion and transport on relatively small distance. These movements diminished and stopped during the Ordovician and Silurian, when sequences of clays and argillites with limestone and sandstones intercalation were accumulated. The lithology became more and more coarse in Devonian, in Eifelian is predominantly represented by gravels, indicating the uplift of the region, both offshore and onshore sectors. Starting with Givetian and in Late Devonian the detrital sedimentation was replaced by the processes of chemical precipitation presuming the flattening or negative movements of the Moesian Platform. A change of sedimentary environment took place after the Breton diastrophism when the entire territory of the Moesian Platform uplifted and was pierced by intrusive magmatic formations. The Early Carboniferous (Tournaisian and Visean) contains marine limestone. At the end of the Visean, in Sudete phase, the bottom of Moesian basin raised again, the western and eastern areas being uplifted. The Sudete phase constituted the beginning of the breaking of Moesian Basin, the carbonate deposits being replaced by pelitic sediments with coal beds and coal marls. The positive vertical movements continued and in the Asturian phase, the Moesian Platform became dry land, followed by intense erosion. The sedimentation resumed in Permo-Triassic, first in lower areas and after, in the northern part of the Platform, some areas remained dry land until Jurassic: Chilii- Strehaia, Iancu Jianu-Fauresti and Bordei Verde promontories. During the Permian and the Lower Triassic, the environment was continental, lacustrine and lagoonal, with red sediments and effusive magmatism. The sub-continental evolution of the Moesian basin was interrupted during the Lower-Middle Triassic when seawaters covered its middle part. After the end of the Middle Triassic, the sub-continental regime with evaporites and red sediments settled again. At the end of the Triassic the basin rose, becoming land exposed to denudation during the Lias. At the beginning of the Dogger, the Moesia territory reached the peneplain stage. The sedimentation started in the central-northern zone with basal gravels followed by clays and marls. The second detrital lithofacies group ends with Dogger. During the Upper Lias-Dogger, the zone of maximum subsidence crossed obliquely the N Craiova-Bals-Optasi-S Peris uplift area, followed by Malm-Lower Cretaceous pelagic sedimentation area settled down on the subsidence area.

The second carbonate lithofacial group starts in the Malm with a general sinking of the platform. The eastern and westernmost parts rose rhythmically and progressively as indicated by the alternation of pelagic and reefal limestone, then only by reefal and peri-reefal limestone. In the central basin, the accumulation of pelagic deposits continued until the Aptian (Paraschiv, 1979). The easternmost part of the Platform raised more, as showed by the Purbeckian carbonate-evaporite facies and by continental-evaporite facies during Lower Cretaceous. The rising of the Platform took place at the end of the Lower Aptian followed by the Albian transgression, with terrigenous deposits accumulated. The immersion lasted from the Albian until the end of the Cretaceous. Under the influence of the Laramian diastrophism the Platform rose again and evolved as land during Paleogene and Lower Miocene, denudation gave rise of a very strong relief. The sinking process of the Moesian platform in front of the Carpathians began in the Savian phase. The sedimentation started in the Badenian. During the Sarmatian, the whole area north of the Danube became the external flank of the Carpathian Foredeep. The Savian movements have had important consequences on the post-depositional evolution of carbonate bodies. Due to the pushing from the North to the South, the Platform and carbonate buildups have undergone rising and lowering on faults from south to the north of about 3,000m. Carbonate buildups have kept northwest-southeast orientation but they were fragmented and can be found in blocks separated by new faults oriented east-west.

Carbonate Buildups on the Moesian Platform

Starting with Callovian, the eustatic sea level rose and shelf flooding produced the rise of the river base level and sediment retention in estuaries, shelf waters remaining clear. The pelagic basinal facies was developed in the central-west part of the Moesian Platform, with micritic limestone deposited, the neritic littoral facies with reefal episodes (submerse platform) was developed in the East and in the western extremity of the platform (Figure 1).

Warm climate and shallow waters determined the starting of carbonate building related with the principal moments of seawaters rising in Kimmeridgian, Berriasian and Upper Valanginian-Lower Aptian. The shallow water environment with high energy on the top of the morpho-structural uplifts from the shelf, with NW-SE orientation, favored the development of bio-constructors (NW-SE oriented) and skeletal and oolitic coarse particle accumulation. The shelf deep waters environment amongst reefs were favorable for micritic carbonate, chemical and biochemical sedimentation. In the Kimmeridgian-Tithonic, the carbonate sedimentation was intense on a large area (Figure 1) with fringe type in the East, barriers and insular buildings near the shelf edge in East and West. After Valanginian and up to Aptian, the northwestern part and the northeastern extremity of the Platform rose systematically and became land. The reefal facies migrated towards the favorable waters in southern areas (Figure 2).

Carbonate sediments growth was determined by the characteristics of marine environment and the contribution of the bio-constructor associations. The marine environment controlled carbonate buildups by influence of topography factors, shelf zonation and dominant dynamic activity of seawaters, determining the models of the carbonate buildups. The buildups were distributed on the morpho-structural uplifts of the bottom of sedimentary basin with NW-SE direction, identically with the Dobrogean main faults direction. Three zones can be observed on the shelf: a slope zone to the north and west with turbulent waters where there was initiated incipient small carbonaceous buildups (1-2 km wide), a central zone in open sea, with clear and normal salinity waters environment with large carbonate buildups (5km wide, 500-600m high) integrally covering the support structures and an eastern zone characterized by intermittent open sea and increased salinity, with narrow carbonate buildups (1-2 km) covering the apexes of support structures. The direction of the marine currents, parallel with shoreline has facilitated the lateral extension of carbonate buildups and their fusion in a reef barrier, parallel oriented with the shore, with NE-SW direction (Figure 3).

Hydrocarbon Generation and Accumulation

Source rocks are considered (Paraschiv, 1979): the Ordovician-Silurian argillito-graptolite schist formation, the Devonian dolomite-evaporite formation, the Middle Triassic carbonate series, the Dogger marno-clayey complex, the Albian and Upper Cretaceous marls, the Badenian, Sarmatian, Meotian and Dacian pelite horizons (Figure 4).

The Moesian platform is characterized by geothermal gradients of 1.5°C/100m to 6°C/100m. The highest values are recorded west of the Arges River, in the most uplifted zone of the metamorphic basement, in the area of Videle-Cartojani oil fields (Figure 5).

At East of the Arges River, geothermal gradient curves show minim anomaly, the lowest values, 1.5 to 2°C/100 m, are situated between Urziceni and Ramnicu Sarat. The maximum threshold of the fluid phase, 120-1,400°C, may be found at the depth of 2,000-2,500m in the western compartment and at 6,000-8,000 m depth in the eastern compartment. Gas with condensate and only methane is expected to be found below the mentioned depths (Paraschiv, 1979). The sector west of the Arges River is characterized by the existence of numerous big oil fields, numerous in carbonate buildings (Figure 6) and the eastern sector is characterized by small oil and gas fields, excepting Bordei Verde area.

The reservoir rocks are considered gravel quartzite series, the Devonian gravel formation (Eifelian) in the Old Red Sandstone facies, also carboniferous limy with fissured limestone and cavern. The Permo-Triassic contains reservoir rocks in all its litho-stratigraphic terms with good porosity and permeability. The Dogger sandstones and sands are very good reservoirs. The Malm-Neocomian contains dolomites and reefal limestone fissured and cavernous carbonate rocks with good porosity and permeability. The early cementation at sedimentation sites maintained the qualities of porosity and permeability after the burial. The cyclic character of the sedimentation and the interruption of sedimentation with weathering exposure of carbonate buildups during the Upper Jurassic-Lower Cretaceous, Valanginian, Barremian-Lower Aptian led to dolomitization, dissolution, levigation, karstifiation of carbonate deposits and increasing of secondary porosity and permeability: Barremian limestone have 13-22% porosity and 600 mD permeability, Lower Cretaceous organogenous limestone with 8-12% porosity and 600 mD permeability, Neocomian dolomitic limestone have 8-12% porosity and 140 mD permeability (Paraschiv, D.,1979). Granular reservoirs are known in Albian, Badenian and Sarmatian. The Pliocene contains sandstones, sand intercalations and microconglomerate beds.

The types of traps on the Moesian Platform are determined by the tectonic style, the sedimentogenesis and the geological evolution of the area, structural, stratigraphic, lithologic, paleogeomorphic and mixed traps were formed. The traps formed in pre-Jurassic formations are close related to the major structural elements – the N Craiova-Bals-Optasi S Peris uplifted area. Traps in post-Jurassic period are controlled by disjunctive tectonic accidents.

Conclusions

The Moesian Platform has good condition for hydrocarbons generation, accumulation and preservation. There are 126 oil and gas fields, encountered between 350-4900 m depth, the most of them in central-northern part. The oil fields in carbonate buildups are discovered in the central part of the Moesian Platform (Figure 6). There are around 50 bodies of carbonate buildups, identified on seismic lines; NW-SE oriented, 20 in eastern part of the Platform, 3-12 km long and 1-5 km wide, at 1,000-4,000 m depth (Figure 4). The reservoirs from lithostratigraphic traps in carbonate buildings were sealed at the top by draping of covering formations and laterally by compact micritic limestone. In eastern Moesian Platform a few carbonate buildups was pierced by wells, here the Devonian bituminous limestone and Silurian schists with Graptolites can compensate the small thickness or lack of the Lias-Dogder bituminous schists as source rocks. The lack of favorable thermal conditions can be compensated by investigation of deeper structures. The existing Cretaceous oil fields (in Albian reservoirs) in the eastern part of the Platform, at Lipanesti, Padina, Bragareasa, Urziceni, Manasia, (Nr. 20, 23, 24, 26, 27, respectively, Figure 6) encourage the hypothesis of long distance hydrocarbons migration.

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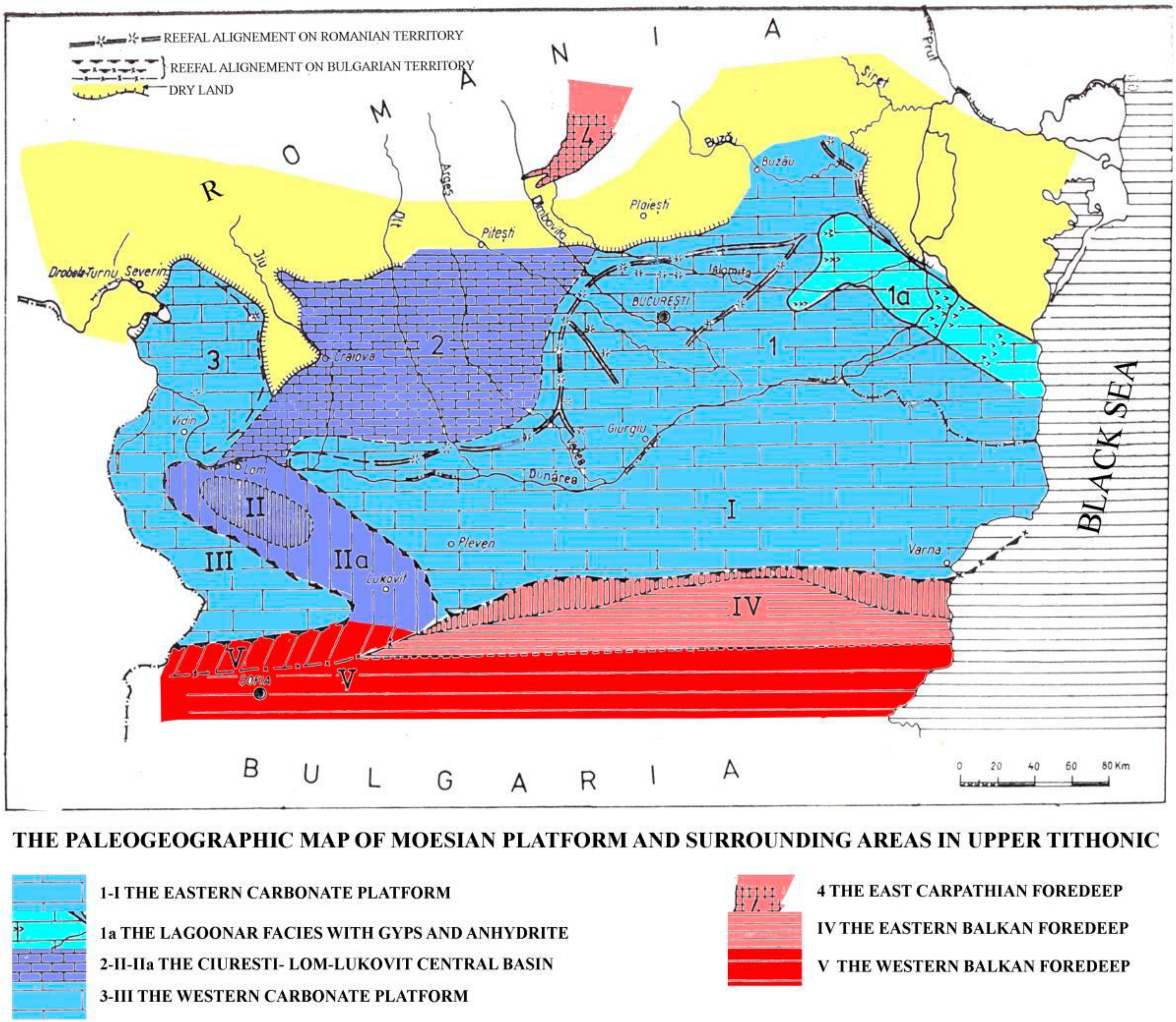

Figure 1. The Upper Tithonic paleogeographic map (modified after Vinogradov, 1978).

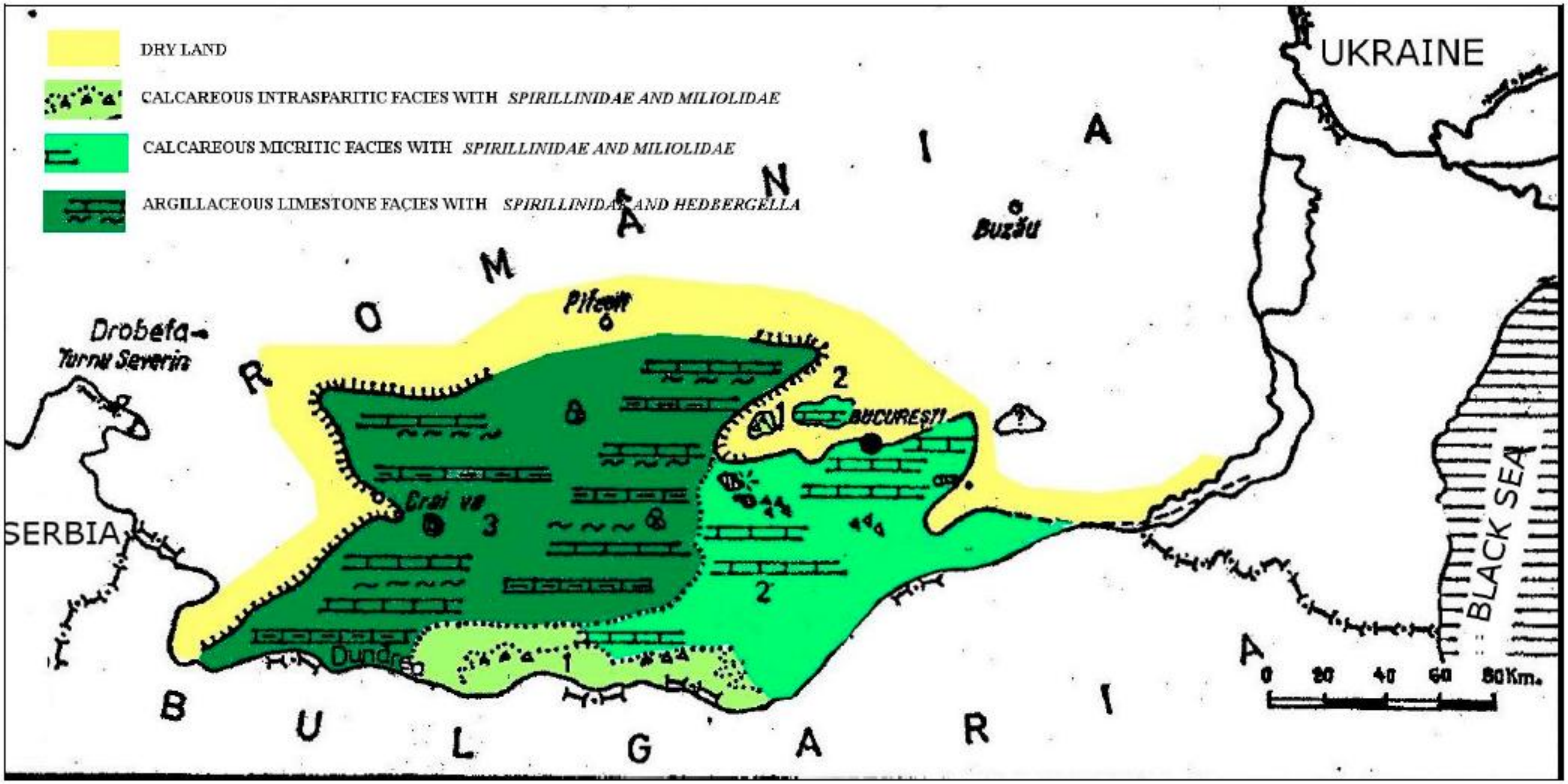

Figure 2. Hauterivian facies map (modified after Costea et al., 1978).

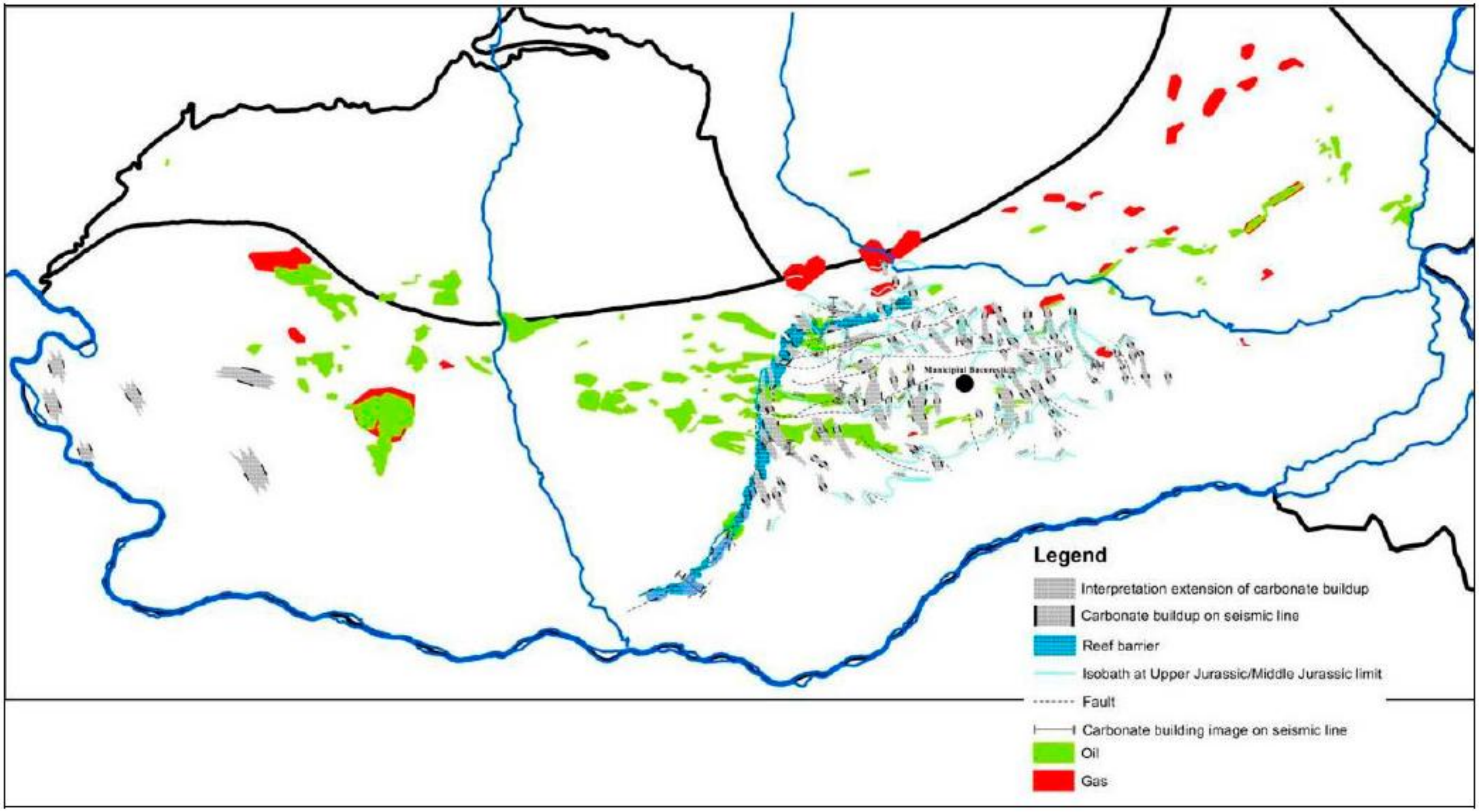

Figure 3. Carbonate buildups and oil and gas fields on Moesian Platform. The reefs have been identified in wells and on seismic sections, interpreted based on seismic stratigraphic principles.

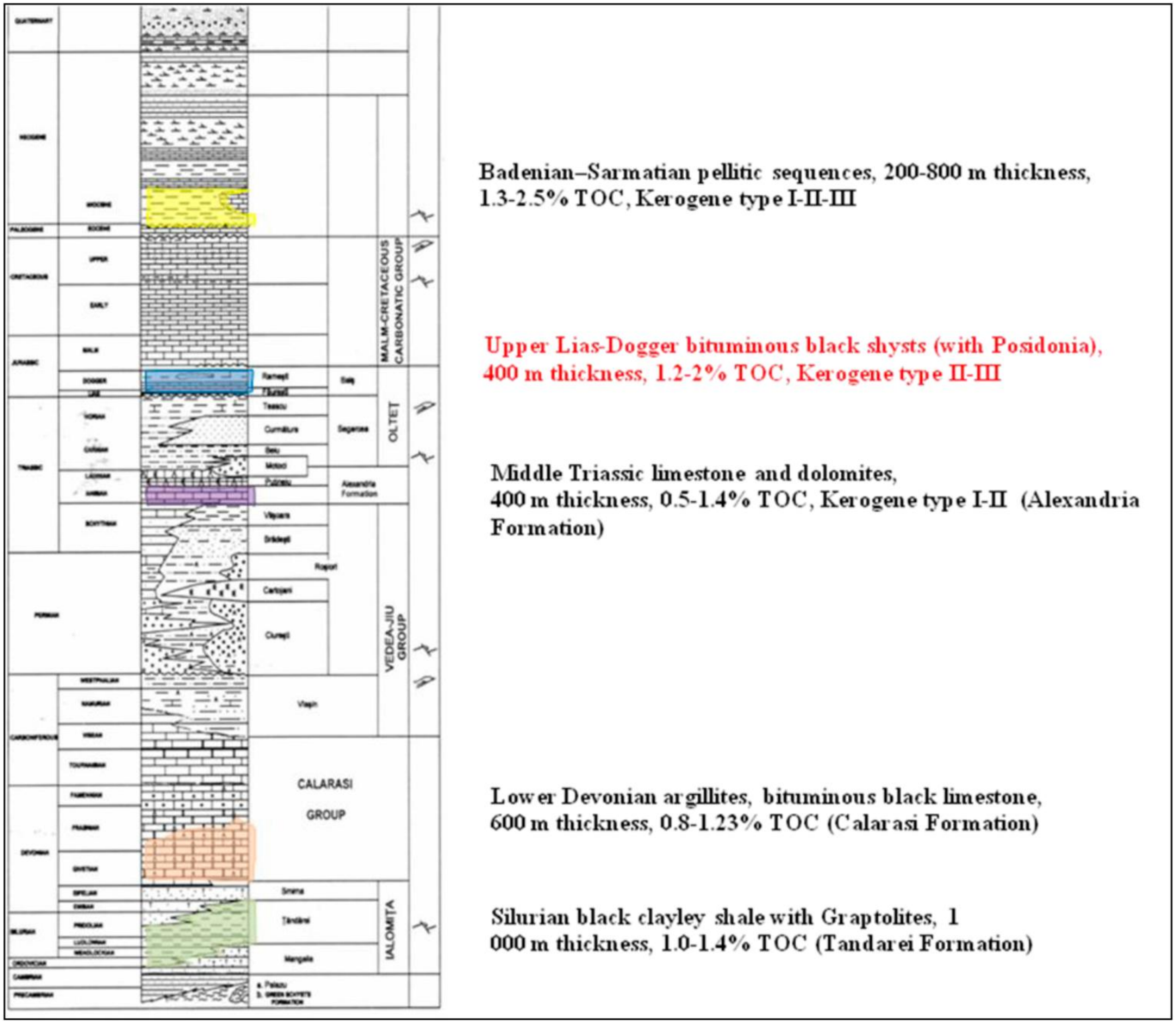

Figure 4. The source rocks in the Moesian Platform (modified after Paraschiv, 1979).

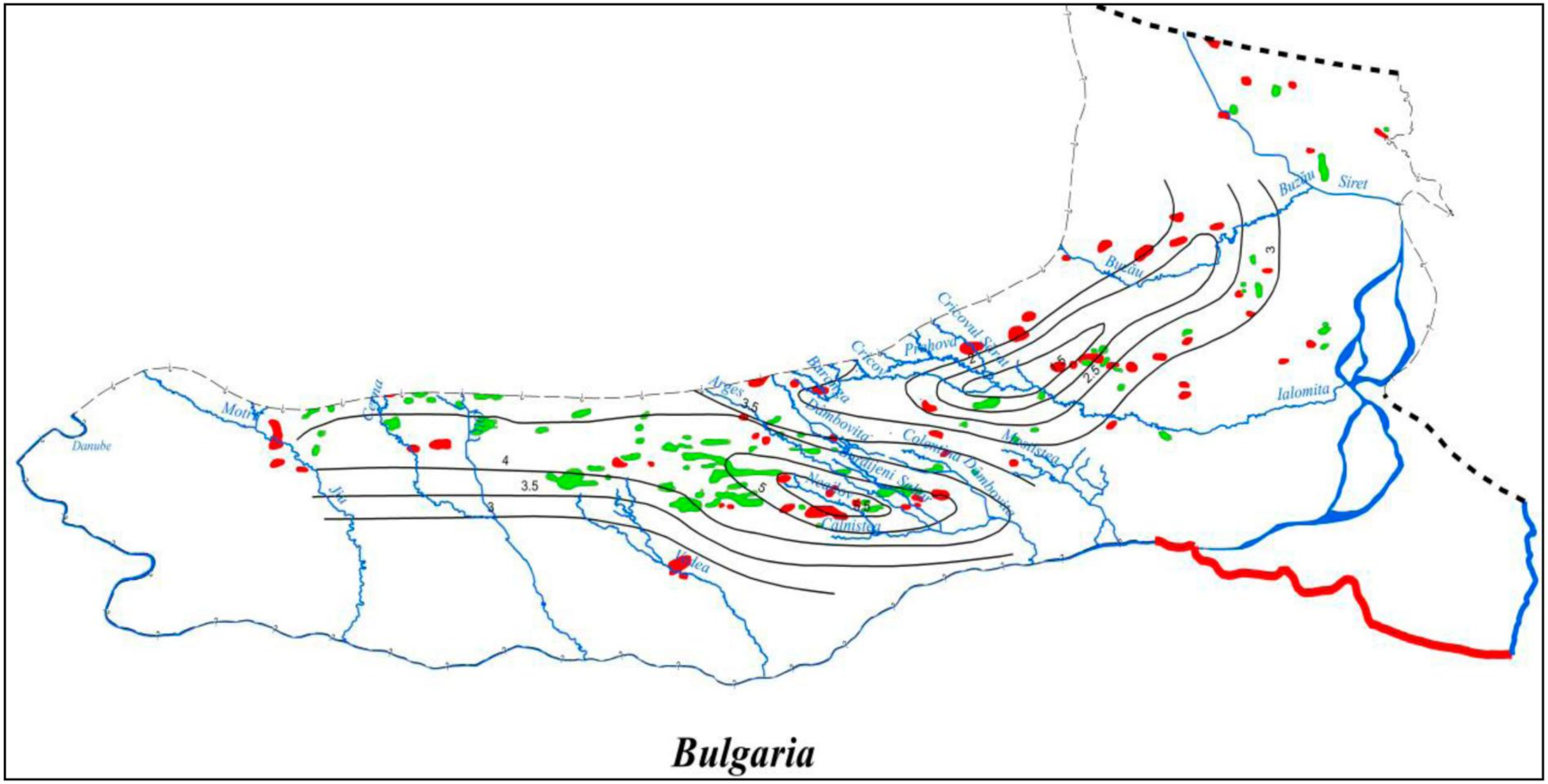

Figure 5. Oil and gas fields and geothermal gradient curves in the Moesian Platform (modified after Paraschiv, 1979).

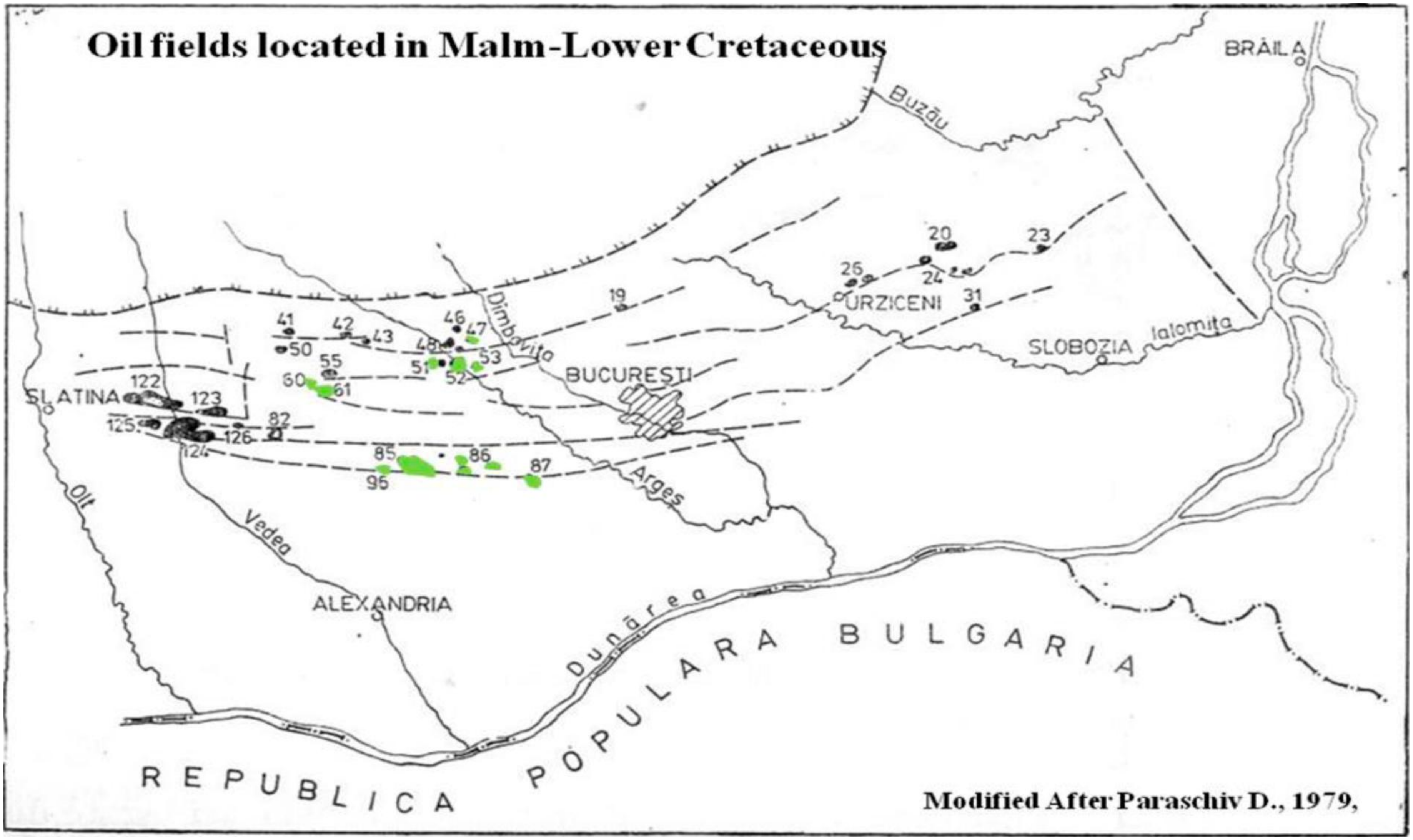

Figure 6. The oil fields located in Malm-Lower Cretaceous reefal facies: 47 Serdanu, 51 Petresti, 52 Corbii Mari, 53 Poiana, 60 Stefan Cel Mare, 61 Izvoru, 85 Blejesti, 86 Videle, 87 Balaria, 96 Talpa.