

DACIAN BASIN ENVIRONMENTAL EVOLUTION DURING UPPER NEOGENE WITHIN THE PARATETHYS DOMAIN

RADU OLTEANU ⁽¹⁾, DAN C. JIPA ⁽²⁾

⁽¹⁾ "Emil Racovitza" Speleology Institute, 13, 13 Septembrie St, Bucharest

⁽²⁾ National Institute of Marine Geology and Geo-ecology (GeoEcoMar), 23-25 Dimitrie Onciul St, 024053 Bucharest, Romania

Abstract. The present paper describes the paleoecological evolution of the Dacian Basin starting with the Sarmatian time. The Uppermost Sarmatian is strongly regressive with freshwater faunas. However, the Meotian is transgressive and it is characterized by a *Congerina* fauna (indicating reduced salinity) and ostracoda of marine origin. Both groups disappeared at the end of the Meotian (a freshwater episode). The transgression of the Pontian brings about a new fauna (with new morphological structures). During the Middle Pontian, the biodiversity is maximal and the Pontian Sea extends to the Panonian Basin. During the Upper Pontian – Lower Dacian interval, there is a regressive phenomenon which gradually isolates the Dacian Basin from the Euxinian Basin. Two bioprovinces with distinct morphogenetic evolution take shape. In the Romanian, the Dacian Basin is a freshwater lake.

Key words: Dacian Basin, paleoecology, ostracoda, mollusc

INTRODUCTION

The Tethys Ocean was an equatorial basin. Starting with the Paleozoic, it separated the unique protocontinent, Pangea, dividing it into the Laurasia and Gondwana supercontinents.

The Austrian geologist Eduard Suess coined the name Tethys and introduced the idea into scientific literature in 1893. The sea Goddess Tethys, whose name was chosen by Suess, is, in Greek mythology the personification of the fertile ocean.

The Tethys ocean, as conceived by Eduard Suess, has altered significantly with time. Initially, Tethys was imagined as a continuum, uniform oceanic body, encased in the Paleozoic continent Pangea. Later on (Metcalfe, 1999), Tethys was seen as a series of aquatic basins which had occurred and supposedly closed down in the Paleozoic-Mesozoic times.

A collision of the continental plates during the Upper Eocene fractured the Tethys ocean. The current Mediterranean area is its present remnant. The new sea, spread between the two continents (Fig.1), taking shape North of Tethys, was called Paratethys (Laskarev, 1924). Its history, the history of

the events that marked the progress of the geologic time, is mostly that of the faunas undergoing periodical change with every palaeoecologic opportunity (changing from marine to brackish, and, often, to lacustrine). In other words, the history of the Paratethys belongs with the palaeoecologic history.

Configured as an inland sea, the Paratethys spreads from the Alps to beyond the Aral sea. Senes (1979) and Steininger, Papp (1979) subdivided its domain as follows:

- The Western Paratethys (the Rodanian Basin)
- The Central Paratethys (the Panonic and Dacian basins)
- The Oriental/Eastern Paratethys (the Euxinian and Aral-Caspian basins)

Paleobiologic and geodynamic considerations enabled Senes and Marinescu (1974) and Rusu (in 1988) to distinguish four periods in the development of Paratethys: the Proto-Paratethys, the Eo-Paratethys, the Meso-Paratethys, and the Neo-Paratethys (Fig. 2).

The intracontinental Paratethys area separated into a number of basins which often developed independently. It was during the Oligocene that the Paratethys (Fig. 3) evolved as a geographical, even faunal, unity (Rusu, 1977, 1988; Baldi, 1979, 1980), when links with the Mediterranean Sea

were diminishing in the South. Moreover, there were differences occurring between the Western (Alpino-Carpathian or Central Paratethys) area and the Eastern one (spreading to the North and East over the North Sea and the Caspian Sea = Scitic Sea and even further East, the Turanic Sea). It was for the first time that the brackish-water biotypes occurred (in Solenovian=Oligocene) and also the first Euxinian facieses (in Maikopian= Upper Oligocene – Early Miocene) together with the first endemic elements of faunas. Its connections with the Mediterranean basin (Tethys) are discontinuous while the fauna is mostly influenced from the North.

The Lower Miocene is predominantly marine as a consequence of reestablishing connection with Mediterranean through the pre-Alpine pass. East of the Caspian Sea, a fluvial-lacustrine sedimentation (and fauna) was evolving. Starting with the Middle Miocene, the Eastern Paratethys tends to isolate itself, first, ecologically and then, geographically, also. From the beginning of the Late Konkian ("Veseleanka Beds"), the water turns brackish (while the links with the ocean are diminishing). Davidaschvili (1932) found almost 50 endemic mollusc species including the new *Macraea*, *Cardium*, *Ervilia*, *Modiola*, *Cerithium*, *Mohrenstermia* species.

Starting with the Sarmatian, the Paratethys separates itself for good from the Mediterranean Sea, as all connections close down, turning it into a brackish intracontinental sea – a facies which has continued, with certain intermissions, up to the present (the relict basins of the Black and Caspian Seas). From then on, there were two ecosystems evolving at the same time (the brackish one, in Paratethys and the marine, in the Mediterranean basin), with totally different faunas and, consequently, two biostratigraphical scales which are difficult to correlate.

THE APPEARANCE AND EVOLUTION OF THE PARATETHYS DOMAIN

THE FINAL PHASE OF THE TETHYS DOMAIN (UPPER EOCENE, 37 – 34 MA)

The paleogeographic image can be explained entirely through faunas, while their development is traced in the epicontinental areas, littoral and sublittoral, mostly. During the Late Eocene, some domains have become 'classic' due to the abundance and diversity of their fauna – all the basins of Paris, Vincentin, Pannonic, Transilvania, Crimea, developed on the edge of the alpine zones, consolidated by the Cretaceous – Paleocene orogenesis.

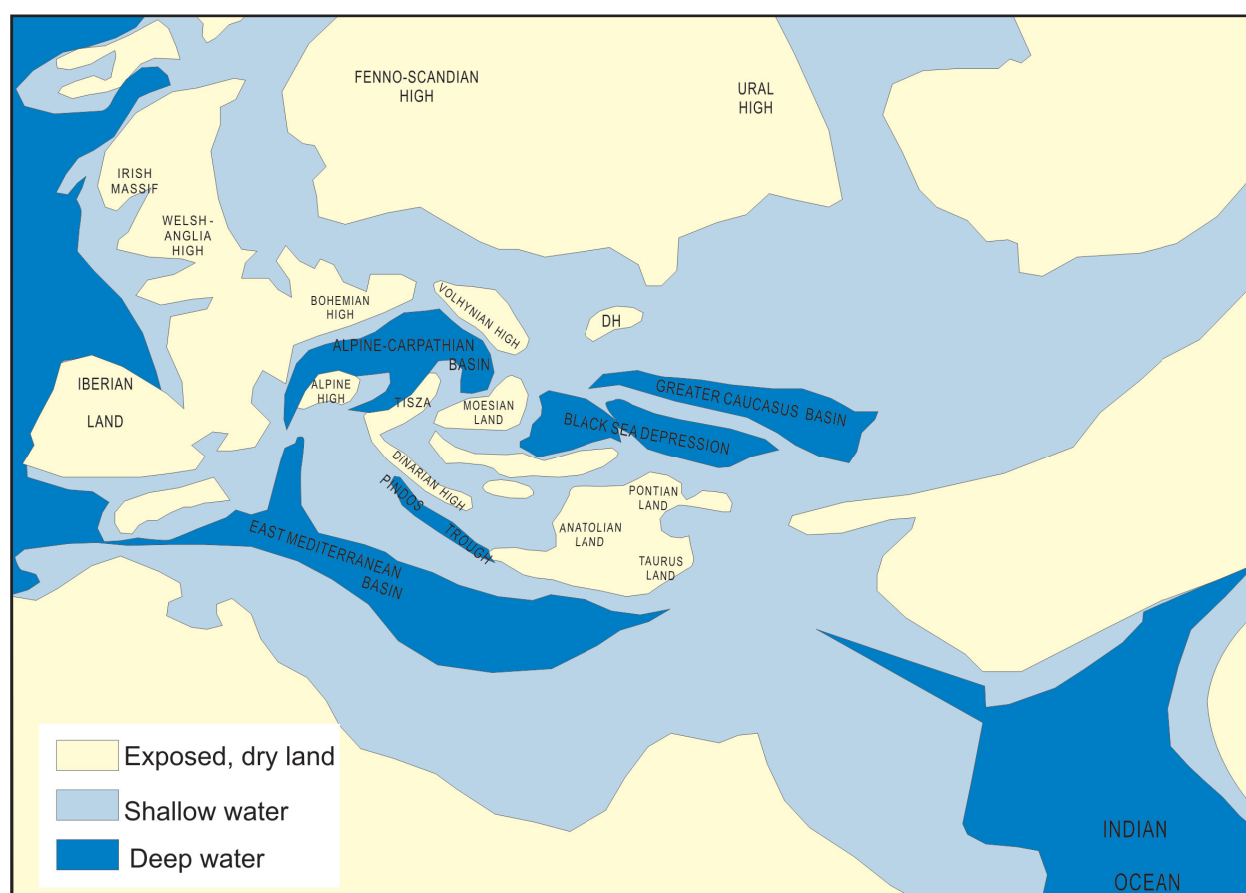


Fig. 1 Paleogeographic configuration during the final existence of the Tethys Domain (Late Eocene, 37-34 Ma). Simplified after Popov S.V., Shcherba, I.G., Stolyarov, A.S., (in: Popov *et al.*, 2004)

Until the end of the Tethys Ocean (during the Upper Eocene), the European continent was mostly covered with water. The Black Sea, the Caspian and the Mediterranean seas are the depression zones. There were wide connections between them and a significant faunal unity (Fig. 1) while the faunal differences between the boreal and the Atlantic-Mediterranean area are still insignificant. The faunas in the Parisian and the Belgian basins, as well as the ones in the North of Germany are quite similar to the faunas in Aquitania and the Mediterranean Sea areas. The connections of the basin with the Northern Sea are cut off during the Upper Lutetian and the basin is totally isolated later. The Stampian is transgressive with Northern faunas. In the Upper Oligocene, the basin is cut off again turning into a freshwater lake whereas the Belgian area is wide open to the North (the Kassel clays, Chattiene).

As regards the intra-Carpathian area (in Transilvania), the post-Senonian and before Middle Lutetian 'lower red clays' sequence reaches over 1,500 m in width (with *Timiriazevia punctata* Clemens, a common species in Wealdean). The 'marnes with *Anomia tenuistriata*' is the first marine sequence. Throughout the Lutetian interval, the benthonic faunae (molluscs and ostracoda) belong almost exclusively to the mesogeene bioprovince; it is in the Priabonian (the "Cluj limestone" and the *Numulites fabianii* complexes) that the faunae exhibit an obvious Northern influence.

At the end of Eocene, there are differences occurring between a West European kind of fauna (in Transilvania and the Panonian basin) and an East Mediterranean one (in Dobrogea and the Varna-Tracia basin) (Sonmez-Gokcen, 1972). That dif-

ference suggests distinct influences and affiliation. Thus the existence of an 'Anatolian bioprovince' can be substantiated.

PROTO-PARATETHYS (THE LOWER-MIDDLE OLIGOCENE)

At the end of the Eocene, movements of the tectonic plates (the drift towards the North of the Indian continent which collides with Asia; the simultaneous rotation of Africa and the compression between Africa and Europe generate the deep reorganization of the Tethys domain and the occurrence of two new marine domains (Fig. 1): the Paratethys domain, in the North and the Mediterranean one, in the South (a relict of the Tethys ocean).

In the Paratethys area, there starts an intensive phase of continentalization. The Eastern Paratethys no longer has communication with the Indian Ocean. Episodic connections with the Northern Sea occur instead (through the "Polish Strait" and the "Rhine Rift"), while the connections with the Mediterranean Sea of the Western and Central Paratethys diminish significantly (are restricted merely to the "Slovenian corridor"). The connections are interrupted in the Late Chattian, when in the "Renan depression" brackish and freshwater faunas start to flourish.

North of the Black Sea area, the facies pertaining to the Euxinian Sea of the Maikopian Series are forming. It is a Mediterranean fauna in Eocene, but it attains distinct characteristics starting with Oligocene when the Northern influences intensify. It is connected through the Northern Ukrainian platform and through the Polish basin. During the Rupelian time there is a slow regression, the waters withdrawing towards the Black Sea depression. A new transgression takes place during the Poltavian (=Chattian).

A strong process of faunal endemism begins in some areas (for example, in Transilvania, where brackish insertions occur) due to a tendency towards regional isolation.

During the Upper Oligocene (Fig. 3) the Paratethys Sea reopens to the world ocean. The North European influence continues to be dominant on the fauna in the Western Paratethys which connects with the North Sea through the "Rhine Rift". The central Paratethys connects with the Mediterranean Sea through the "Slovenian corridor" until the end of the Badenian.

After a brackish water episode (in Solenovian), the marine regime is restored in the Eastern Area. The still randomly intermingling three European bioprovinces *i.e.*, the North-Atlantic, the Mediterranean, and the Ponto-Caspian ("Oriental Paratethys") are finally taking shape. At this point, the biostratigraphic discrepancies become apparent (in the compositions of the fauna and of the desynchronization of the "events").

Hereon, the biostratigraphy turns prolix. The classic layers are being discussed, dismissed, and replaced by other layers, said to be more accurate. In the literature, there are more than 50 new stages in the European space referring to the Mi-

ocene and Pliocene intervals only. That is creating confusion and raises the problem of redefining the "biostratigraphical taxonomy" from a thoroughly different viewpoint.

In the intercontinental area of the Central Paratethys a new biostratigraphic scale was drafted (Senes and Cicha, 1968), apart from the Oriental Paratethys one.

The Oligocene-Miocene boundary is set within the Egerian, while the Miocene-Pliocene limit is placed either somewhere in the Pontian or at the Pontian/Dacian boundary. The demarcation line to the Pleistocene is conventionally agreed upon at 1.8 Ma because the attempt to find a geologic event occurring simultaneously all over the continent has failed.

The boundary between the two main time sequences, ranked as epochs, namely the Oligocene and the Miocene, has generated a debate yet to be settled. In the central area of the Paratethys, the boundary is set at the end of the "Buda Marls", when the *Miogypsinoides complanatus* and the *Paragloborotalia opima opima* species occur, as well as, at the end of the Nannoplancton NP-24 zone, which both mark the beginning of the Egerian (Baldi 1969, 1979, 1984). In Transilvania, the existence of a specific episode called Merian (Moisesescu 1975, 1989) is pointed out. Its upper limit would be set at the "*Cardium lipoldi level*" synchronized with the base of the nannoplankton NP-23 zone.

The faunal evolution in the late Oligocene to early Miocene is influenced by Mediterranean and Indo-Pacific connections (Rögl, 1996). The molluscs community seems to demonstrate similarities during the Egerian and the Caucasian stage.

During the Aquitanian, in the Atlantic bioprovince, sediments, mostly sandy, accumulated with an exceptionally rich fauna. The Bazas and Saucats faunas become the stratotype of the Aquitaine and the Burdigalian. In the Helvetian stage of this area noticeable tropical influences become apparent.

During the Burdigalian (Fig. 4), the Western Paratethys was connected to the Mediterranean Sea through the "Pre-Alpine Pass". In the Central and Oriental Paratethys there is ample regression. With the Burdigalian, the "faunas with giant Pectinids" occur; they are considered to be of "indo-pacific, subtropical" origin (Rögl, 1988). This horizon is a world wide stratigraphic marker level (according to Addicott, 1974, Steininger *et al.*, 1976, Rögl, 1996).

The dissimilarities between the three (aquatic) bioprovinces remain, moreover, they become more prominent which indicates a diminishing faunal "flow". Still, many species, are known to be familiar both with the North Sea and Aquitania, while, the boreal faunas enter the Pannonic area through the "Silesian passage". In the North-German area, after a regressive stage (with coals), the sea advances with a faunal minority of Mediterranean origin. From now on, the fauna becomes entirely holoarctic.

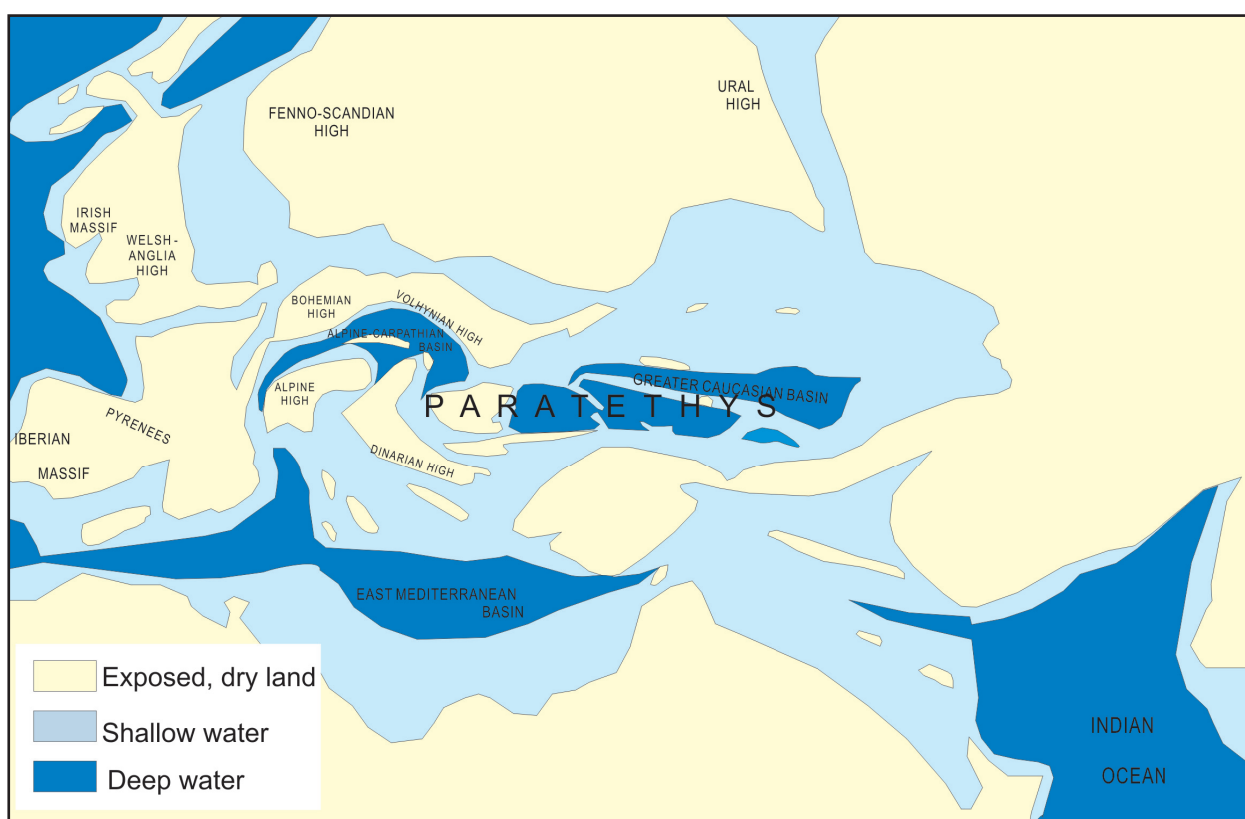


Fig. 3 Paleogeographic configuration during the initial stage of the Paratethys Domain (Early Oligocene, 34-32 Ma). Simplified after Popov S.V., Shcherba, I.G., Stolyarov, A.S., (in Popov *et al.*, 2004)

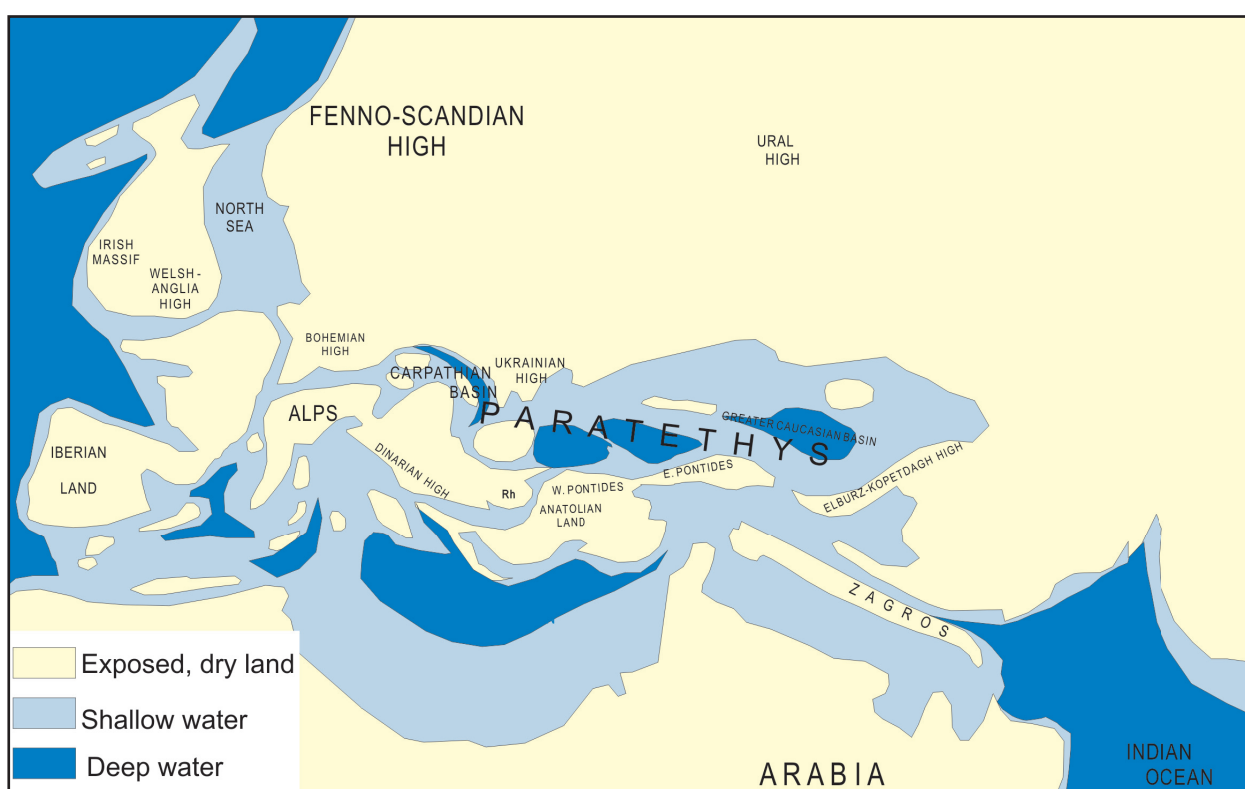


Fig. 4 Paleogeographic configuration of the Paratethys Domain during Early Burdigalian (20.5-19 Ma). Simplified after Popov S.V., Shcherba, I.G., Stolyarov, A.S., (in Popov *et al.*, 2004)

In the Carpathians flysch-type sedimentation continues. The disoxic and anoxic conditions persist (regionally) in the deep water environments (North of the Black Sea depression, the “Maikop Strata” are formed).

A major event is the Ottnangian-Kotsakhurian. The sudden “burst” of the *Rzehakia* species, together with the *Congerii*, *Melanopsidae* and *Eoprosodacnae* validates the existence of a brackish-water biofacies resulting in their excessive and mostly exclusive growth. The extension of that ecologic episode across Paratethys supports the hypothesis of a general event (generated by isolation as well as by a huge regression along with the setting up of certain detrimental facies that favoured the “eruption” of those eccentric, unknown or previously minor faunas).

MESO-PARATETHYS (KARPATHIAN – BADENIAN)

According to the fossil faunas, the Karpathian from the Central Paratethys is a Late-Burdigalin sequence. Meanwhile, numerous species of foraminifera and ostracoda (Zorn, 1995) generate the luxuriant Badenian fauna. Obviously, the boundaries are no more – and cannot be any more – than merely “transitional”.

A large transgressive phase (Rögl, 1996) in the entire Circum-Mediterranean area generated a new basal Badenian fauna. The Langhian correlates with the Lower Badenian due to the existence of *Praeorbulins* (Cita & Premoli Silva, 1968) and of the *Orbulina universa* species in both areas. (including the Serravallian stage). Within intra-Carpathian area, the Pannonian basin was flooded during the Lower Badenian (Moravian). The occurrence of the first evaporites throughout the Paratethys domain is equally important to substantiate the existence of a warm climate (with *Orbulina suturalis*) (Fig. 5).

The faunas of the Eggenburgian – Badenian time interval are similar to the ones found in the Pad Valley, the Rhone Depressions and the Vienna basin. That supports the idea that permanent links existed through the Drava-Sava-Vincentin corridor (the transdinaric or Slovenian corridor).

Within the Paratethys, the faunal segregation process increases. The central Paratethys was separated from the Western one when the “Bohemian massif” emerged; it connected instead, with the Mediterranean through the ‘Slovenian corridor’.

The Oriental Paratethys is clearly quasi-isolated, with its faunas and its distinct stratigraphy (the Sakaraulian,

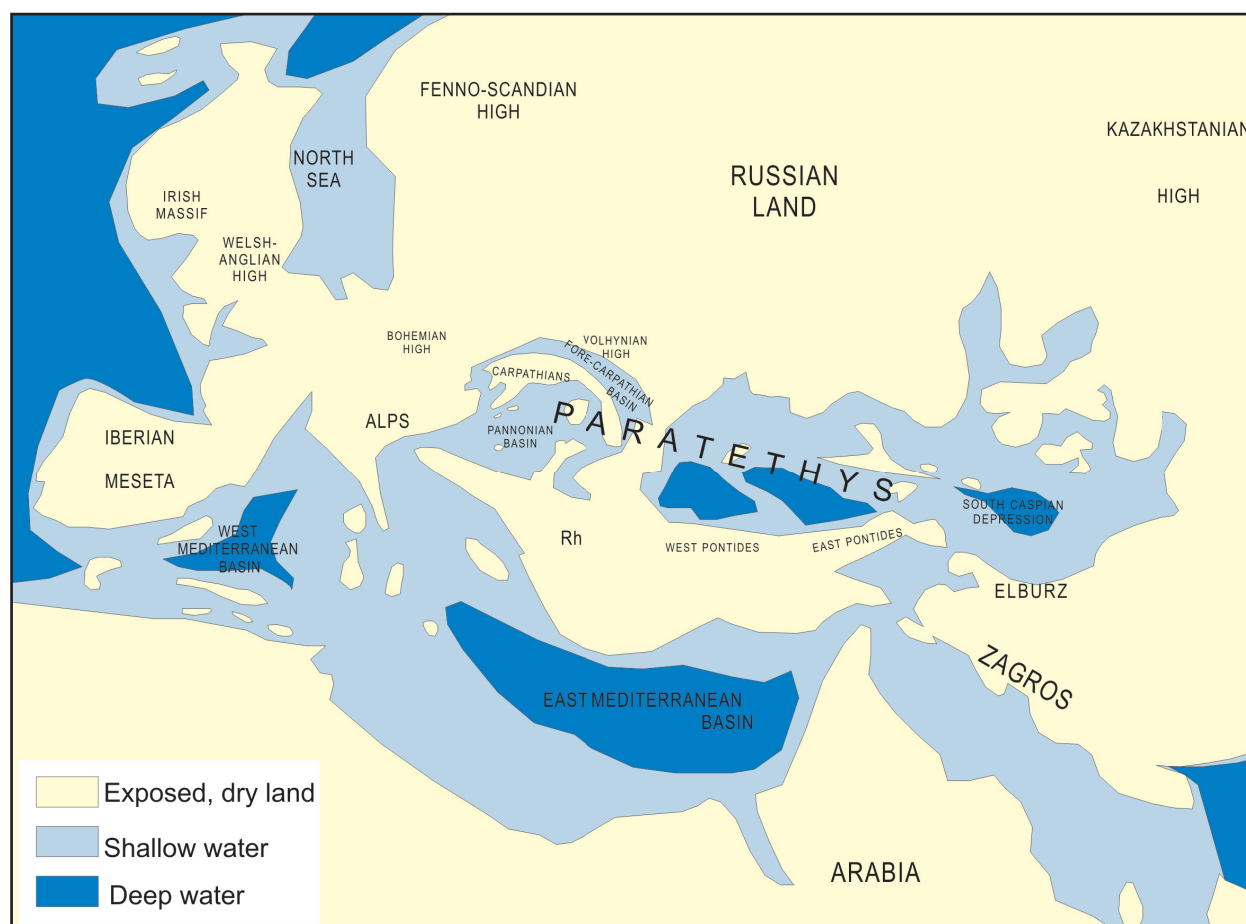


Fig. 5 Paleogeographic configuration of the Paratethys Domain during Early Badenian (16 - 15 Ma). Simplified after Goncharova, I.A., Shcherba, I.G., Khondkarian, S.O., (in Popov et al., 2004)

Tarkhanian, Tschokrakian, Karaganian and the Lower Konka levels, all of them, considered nowadays contemporary with the Miocene).

The Sakaraulian correlated to the Acvitanian-Burdigalian and the Eggenburgian. Many ostracod species are common (*Cytherella postdenticulata* Oertli, *Senesia philippi* (Reuss), *Hermanites sakaraulensis* Schneides (closest to *H. haidingeri*), *Loxoconcha punctatella* (Reuss), *Cushmanidea bradiana* (Lnkls.), *Cytheretta ovata* (Egger), *Xestoleberis tunida* (Reuss), *Krithe galericum* Schneider etc) (Schneider, 1963). After the Kotsakhurian brackish-water episode the Tarkhanian transgression restored the marine conditions (Nevesskaya et al., 1984, 1987, *vide* Rogl, *op. cit.*).

The Tarkhanian is marine (with marine species: *Pterigocythereis calcarata*, *Costa edwardsi*, *Bosquetina carinella*, *B. zalanyi*, *Loxoconcha carinata*, *Eucythere alexanderi*, Schneider, 1956, and *Flexus plicata*, *F. triebeli*, *Bythocypris lucida*, "*Trachyleberis*" *prestwichiana*, Suzin, 1965). Andrusov, (1918) and Davidaschvili, (1932), (*vide* Amitrov, 1975) found molluscs species: *Nucula placentina* Lamarck, *Pecten denudatus* Riss, *Nassa tamanensis* n sp, *N. rostorcorum* n sp, four *Turboniella* species, *Leda fragilis* Chemn., *Ostrea cochlear* Poli. etc, all of them suggesting the pre-Lower Badenian time. During the Lower Badenian two new taxa appeared, *Acanthocythereis histrix* (Reuss) and *Verrucocythereis verrucosa* (Reuss). The ostracod community is larger (*Mutilus* (?) *polyptichus* (Reuss), *Cytherella postdenticulata* Oertli, *Bythocypris lucida* (Seguenza), *Mutilus aff. deformis* (Reuss), *Aurila philippi* (Reuss), *Urocythereis seminulum* (Reuss), *Quadracythere sulcatopunctata* (Reuss), *Bosquetina carinella* (Reuss), *Costa reticulata* (Reuss), *Flexus triebeli* (Ruggieri), *Cushmanidea longa* (Reuss), *Occultocythereis bituberculata* (Reuss), *Cytheropteron vespertilio* (Reuss), *Eucytherura pygmaea* (Reuss), *Hemicytherura aff. videns* (G.W.Muller), *Ruggieria tetraptera tetraptera* (Seguenza), *Loxoconcha punctatella* (Reuss), *Loxoconcha aff. hastata* (Reuss).

Likewise, the marine Tschokrakian faunas correlate admirably with the Middle-Upper Badenian (similar with the Costei ostracod and foraminifer community, from Transilvania).

Schneider (*op. cit.*) found an ostracod community with: *Paracytheridea aff. triquetra* (Reuss), *Phlyctenophora kalikzii* (Schneider), *Leptocythere rugosa* (Schneider), *Pontocythere suzini* Schneider, *Pseudocytherura aff. caudata* Sars, *Semicytherura filicata* (Schneider), *Semicytherura aff. acuticostata* (G.W.Muller), *Semicytherura aff. inversa* (Seguenza), *Ruggieria tetraptera tetraptera* (Seguenza), *Costa edwardsi* (Roemer), *Falunia plicatula* (Reuss), *Cytheridea mulleri* (von Munster), *Eocytheropteron inflatum* Schneider, *Loxoconcha aff. carinata* (Lienenklaus), *Loxoconcha carinata alata* Schneider, "*Trachyleberis*" *prestwichiana* (Jones – Sherborn).

In 1956, Suzin completed it with: *Pontocythere vitrea* Suzin, *Paradoxtoma eusiforme* Brady, *Semicytherura aff. reticulata* (Lienenklaus), *Cytheropteron obesum* Schneider, *Cushmanidea lithodomoides* (Bosquet), *Cytherella aff. compressa* (von Munster), *Cytherella gracilis* Lienenklaus.

Davidaschvili (*op. cit.*) offers a long list of molluscs, most of them, endemic elements (almost 50 species). Dominant taxa are: *Venus konkensis* Sokolov, *V. marginata* Hoernes, *Mac-tra bajarunasi* Andrusov, *Donax tarchaniensis* Andrusov, *Tapes vitalianus* Andrusov, *Spaniodontella intermedia* Andrusov și *S. crassidens* Andrusov, *Modiola volhinica* Hoernes, *M. marginata* (Eichwald), *Ervilia praepodolica* Andrusov, *E. trigonula* Sokolov, *Mohrenstermia inflata* Andrusov, *Cardium* (six endemic species), *Cerithium* (five species), *Trochus* (12 endemic species and subspecies), *Leda* (4 species). All of them suggest that the beginnings of the ecologic isolation process occurred before the Central Paratethys areas (salinity reduction).

During the Karaganian time, that results into a poor fauna, presumably generated by a sharp decline in salinity. Ossipov (1932) found seven *Spaniodontella* species, and some *Unio*, *Mohrenstermia*, *Sandbergeria*, *Nassa*, *Planorbis*, *Lymnea* and *Helix* species, suggesting an oligohaline restricted biotop. Such community with brackish and lacustrine species shows a regional facies with fluvial-continental influences.

Schneider (*op. cit.*) found some ostracod species: *Candona ex gr. candida* Muller, *Herpetocypris reptans* (Baird), *Darwinula stevensoni* (Brady & Stevenson), *Loxoconcha truncata* Schneider, "*Cythereis*" *declivis* Schneider (both are juvenile specimens), *Loxoconcha aff. bairdii* Muller (new species).

The Konkian (biostratigraphically matched with the Kosovian, Rogl, 1998) and its thoroughly marine fauna suggest a reopening of the Paratethys towards the marine West (Nevesskaya et al., *op. cit.*). It is the time of the ecosystem change in two steps, "*Venus konkensis* Beds", belong to Konkian s. str. and "*Veseleanka* Beds" belong to the Buglovian stage). A significant reduction in biodiversity occurred, 316 mollusc species and almost 200 ostracod species within the Upper Badenian and 140 mollusc species and 41 ostracod species within the Konkian. During the last sequence of the succession ("*Veseleanka* Beds") the community is more reduced. The following mollusc species are dominant: *Acanthocardia andrussovi*, *Venus konkensis*, *Mac-tra basteroti konkensis* and *Ervilia pusilla* – *trigonula* - *podolica*, *Congerina sandbergeri*, *Cardium kokupicum*, *C. praeaplicatum*, *C. ruthenicums*, *Cerithium konkensis*, *Mohrenstermia* etc. (Ossipov, *op. cit.*).

Schneider (*op. cit.*) described the following ostracod community: *Cytheridea muelleri* (von Munster), *Pterigocythereis calcarata* (Reuss), *Falunia plicatula* (Reuss), *Mutilus deformis* (Reuss), *Aurila punctata* (von Munster), *Carinocythereis carinata* (Roemer), *Hermanites haidingeri* (Reuss), *Aurila similis* (Reuss), *Cytheretta aff. tenuipunctata* (Bosquet), *Loxoconcha aff. bairdii* Muller (new species), *Loxoconcha aff. laevatulula* (Normann) (new species), *Bairdia explicata* Schneider, *Phlyctenophora affinis* Schneider, *Hemicytherura videns* Muller, *Semicytherura bacuana* (Schneider), "*Cytheridea*" *parangusta* Zalany (juvenil), *Pontocythere mediterranea* Schneider, *Amniccythere tenuis* (Schneider).

During the Konkian s. l. a new fauna "wave" appeared. Most of them are endemic species characterized by larger intrapopulational variability. It is another type of community

generated by a particular ecology, a slow transition between the marine ecosystem and the brackish-water ecosystem. The process occurred on the Volhino-Podolian area.

We think that it was not an actual geographic isolation (geographic barriers like the continental spaces), but rather an ecological one. The Eastern Paratethys area has slowly started to turn brackish, while in the Western part, the faunal communities are exclusively marine. The faunae were restrictively and selectively migrating in all directions, which made the biostratigraphical correlation hardly possible.

South-West of Transylvania, there are several Badenian fossiliferous deposits which are an indicator of a large and direct connection with the Mediterranean; similarly, West of the Dacian basin. By contrast, the rest of the Carpathic area (that is, Northern Transylvania and the central part of the Dacian basin) is characterised by a specific litho- and bio-stratigraphical sequence: the "marls (tufa) with *globigerinae*", "salt breccia", "radiolar schists" and "marls with *Spiratella*". The existence of salt supports the hypothesis of dessication in Transilvania and in the sub-Carpathian fosse from Moldavia to Muntenia.

The fossiliferous deposits from Lăpuşiu, Coştei, Delineşti (in that order of succession) in the South-Western Transylvania,

correlated well to the Badenian from Vienna Basin (Nussdorf, Kostel etc, Brestenska & Jiricek, 1975). The literature assumes the closing of the "Slovenian corridor" during the Upper Badenian (Fig. 6). The existence of the luxuriant mollusc fauna (Rado-Moisescu, 1965, more than 350 species) and ostracoda from Buituri (Latest Badenian) invalidates such an assumption

At the "Buituri level" there is an extremely rich Mediterranean fauna (*Hemicytherura videns* (G.W.Muller)*, *Semicytherura sanmarinensis* Ruggieri, *Semicytherura retipunctata* Ruggieri, *Falunia* (*Hiltermannocythere*) *hartmanni* (Caraion)*, *Carinocythereis carinata* (Roemer)*, *Costa edwardsi edwardsi* (Roemer), *Costa napoliana* Puri*, *Pseudocytherura calcarata* (Seguenza), *Aurila convexa* (Baird)*, *Aurila* aff. *cicatricosa* (Reuss), *Mutilus badenicus* Olteanu, *M. aenigmaticus* Olteanu, *Cytheridea acuminata* (Bosquet)*, *Loxococoncha rhomboidea* (Fischer)*, *L. quadricornis* Ruggieri, *Semicytherura punctata* (G.W.Muller)*, *Costa edwardsi runcinata* (Baird)*, *Henryhowella assperrima* (Reuss)*, *Pterigocythereis jonesi*, (Baird)*, "*Cythereis*" *polygonata* Rome*, *Ruggieria tetraptera uncostata* Olteanu, *Bythoceratina unica* Olteanu) ("nowadays species from the Black Sea, Schornikov, 1969), while the "marls with *Spiratella*" show links with the Eastern area. Such segregation brings to mind the existence of an ecological barrier.

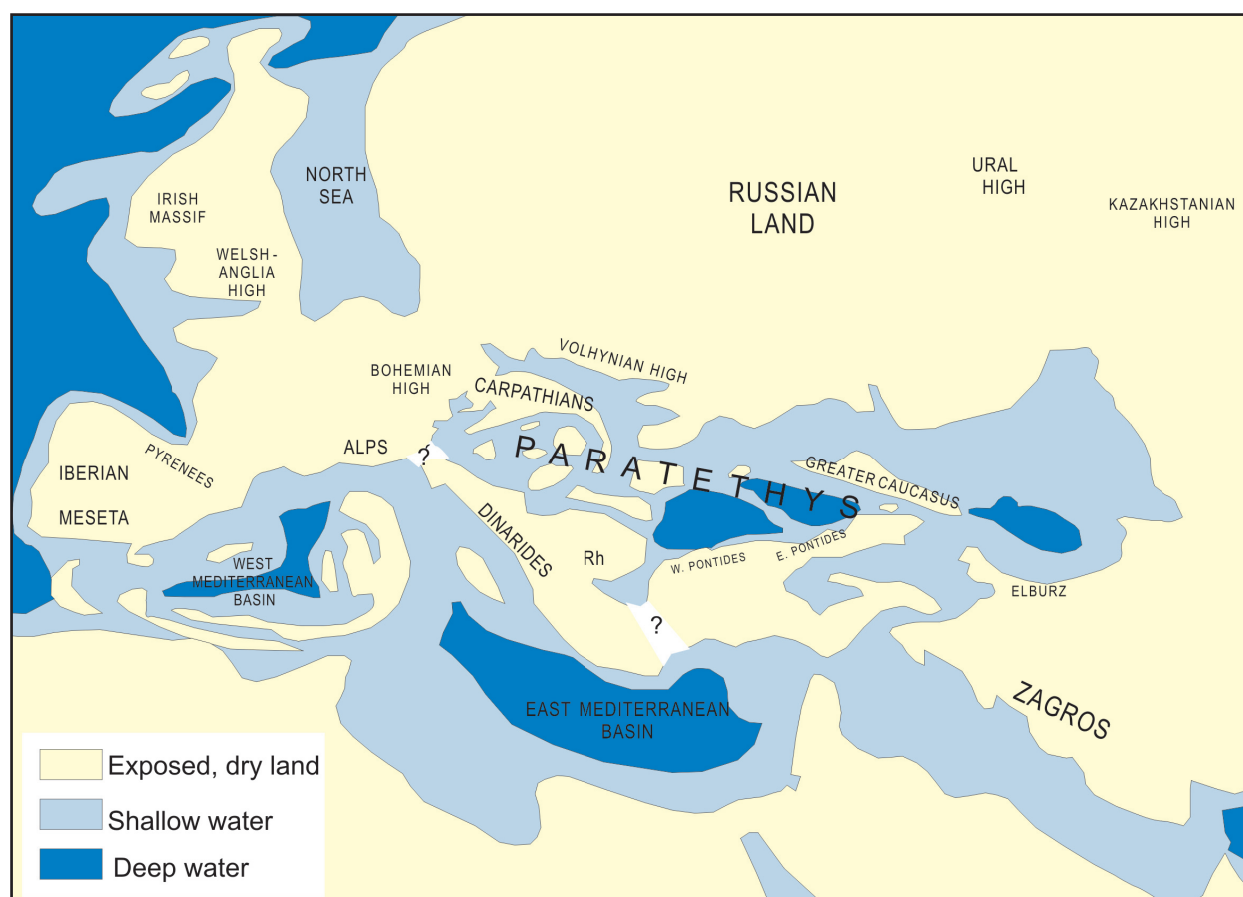


Fig. 6 Paleogeographic configuration of the Paratethys Domain during Late Burdigalian (14 - 13 Ma). Simplified after Ilyina, L.B., Shcherba, I.G., Khondkarian, S.O., Goncharova, I.A. (in Popov et al., 2004)

The features that differentiate the faunae of the Central and Eastern Paratethys are significant indeed. Yet, there are enough shared traits to support the random connection between them.

NEO-PARATETHYS (SARMATIAN-RECENT)

The Neo-Paratethys is characterized by specific faunae at all levels of the faunal spectra. Beginning with the Sarmatian time (Fig. 7) the biggest intercontinental brackish basin in the geological history of Europe took shape. During the Volhinian, it displayed the maximum areal extension and a clear faunal uniformity. The Sarmatian begins ca 13 Ma (Rogl *op. cit.*) but it ends differently in the two areals. The correlation is questionable.

In Eastern Paratethys Saulea *et al.* (1969), Saulea (1995) emphasize the significance of the presence and migration of the Chisinau-Orhei-Camena barrier reef. The movement towards the South (which takes place beginning with the Upper Badenian up until the Middle Sarmatian) is evident with intense subsidence in front of the Eastern Carpathians. This reef facies suddenly ceases during the Middle Basarabian.

It is followed by a strong regression which simultaneously affects both the South Dobrogean promontory and the Eastern end of the Dobrogean ridge.

The facies, that Saulea *et al.* (*op. cit.*) called "continental-deltaic" which emerged in the Lower Sarmatian, in the Septentrional part of the Carpathian avantfosse, extends into the Upper Sarmatian covering the foreland also. This leads to the closing of the aquatic basin of the avantfosse in the North. Consequently, it may be said that the paleogeographic area configuration of the Dacian basin was completed in the Upper Sarmatian.

The major processes that led to the configuration of the Dacian Basin were the following:

- the broadening of the sedimentation area of the Carpathian avantfosse. It started to extend (to the East and to the South) in the Upper Badenian continuing during the Lower and Middle Sarmatian;
- the closing of the aquatic basin of the Carpathian fosse during the Middle and Upper Sarmatian due to the emergence of the Northern part of the avantfosse and the setting up of a continental facies.

The occurrence of the Dacian Basin as an independent aquatic unity is one of the consequences of the movements pertaining to the attic phase (Saulea *et al.*, 1969). The separation of the Dacian Basin from the Pannonian Basin is another consequence of the attic movements. Meanwhile, the connection between the Dacian Basin and the Oriental Paratethys continues into the Upper Pontian.

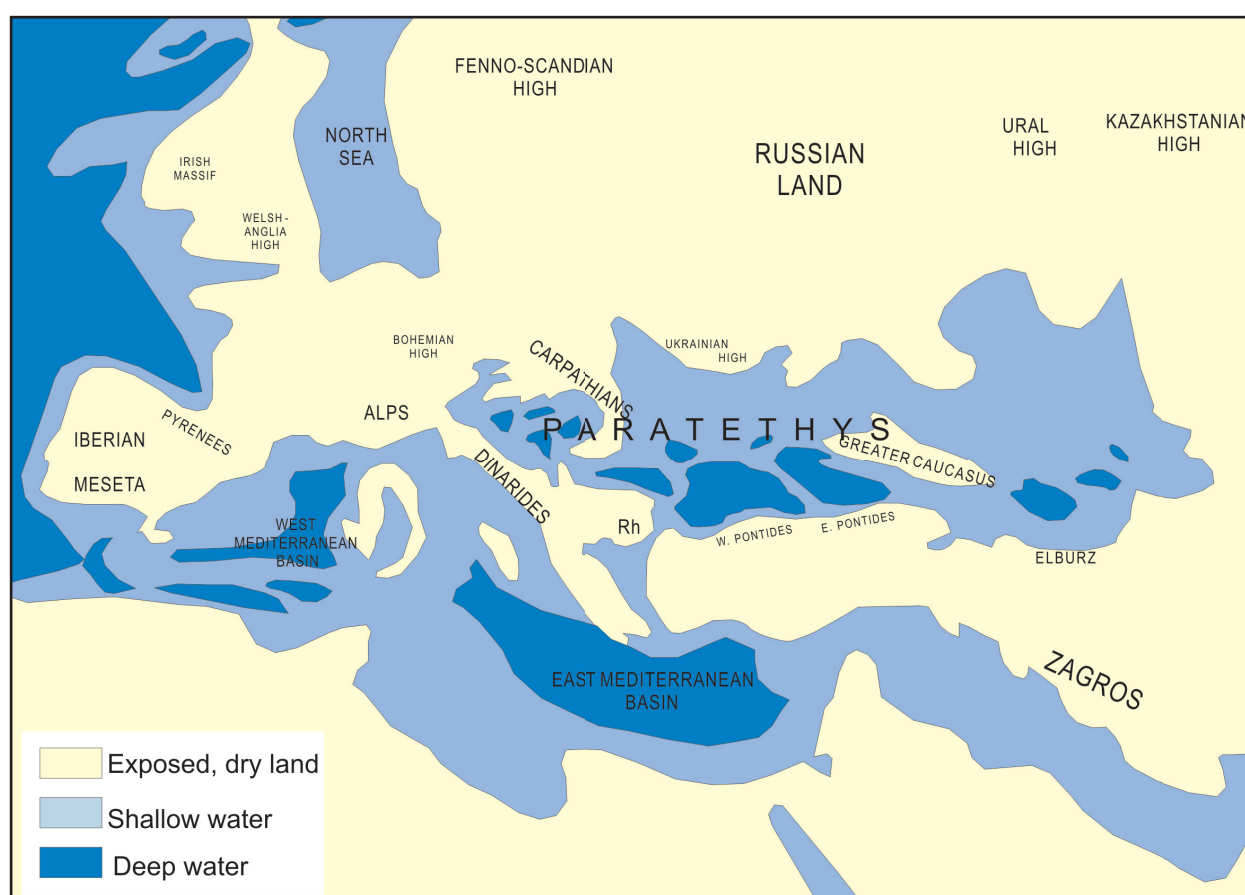


Fig. 7 Paleogeographic configuration of the Paratethys Domain during Sarmatian s.l. (12 - 11 Ma). Simplified after Paramonova, N.P., Shcherba, I.G., Khondkarian, S.O., (in Popov *et al.*, 2004)

In the Central Paratethys area (including the Dacian basin), the Sarmatian is transgressive. In the Eastern Paratethys (Volhinia, Bassarabia, Northern Black Sea) only, there is a gradual succession from the marine to the brackish faunas, with all the faunal changes generally encountered starting with the Upper Konkian.

Gradually, the new 'residual' eurihaline communities become dominant and the intra-specific diversification processes increase. Distinct philogenetic lineations occur, with distinct morphogenetic directions, starting from several previous typologies while the 'opportunistic' species of marine (Badenian) origin are slowly disappearing.

The cases of the *Limnardiidae*, of some of the ostracoda or some of the foraminifera shows a remarkable 'selection of species' when the new brackish ecosystem is established. The Volhinian had still preserved a great number of previously existing foraminifera and ostracoda. The Basarabian is an epoch of maximum biodiversity (dominated by new mollusc, ostracoda and foraminifera species), their morphogenesis following individual tracks. At the Lower and Middle Sarmatian level, the faunas display uniformity and quasi-unity both in the central and in the Eastern Paratethys basins. Throughout, littoral or deep to shallow areas are identified. They are examples of local

or regional situations which do not alter the overall image (*i.e.*, metacommunity). The regional biotope with *Conger* on the Moldave platform is an example (Jeanreanu, 1963).

The Upper Sarmatian (Chersonian) is a short and atypical temporal sequence for the general evolution of the faunas. The diversity of the faunas on the whole is sharply reduced (the existence of several small sized *Mactrae* and of several species of ostracoda). There are only some endemic foraminifera species known (Bica Ionesi, 1968, Natalia Paghida-Trelea, 1968). The Late Sarmatian ends with freshwater facies (with *Candona*, *Cypris*, *Darwinula*) resulting in the extinction of all the "Sarmatian type" faunas (more precocious in the Moldavian Platform, called "the Balta-Paun formation", Ionesi *et al.*, *op. cit.*).

The post-Sarmatian period, in the Paratethys area is characterized by the following processes:

- The colmatation of the aquatic basins in the Central Paratethys (the Pannonic and Dacian basins)
- The action of ample eustatic movements in the Euxinian-Caspian region
- The almost entire separation of the Black Sea from the Caspian.

As compared to the Sarmatian Sea, the geographical area of the Neo-Paratethys diminishes sharply during the Maeotian.

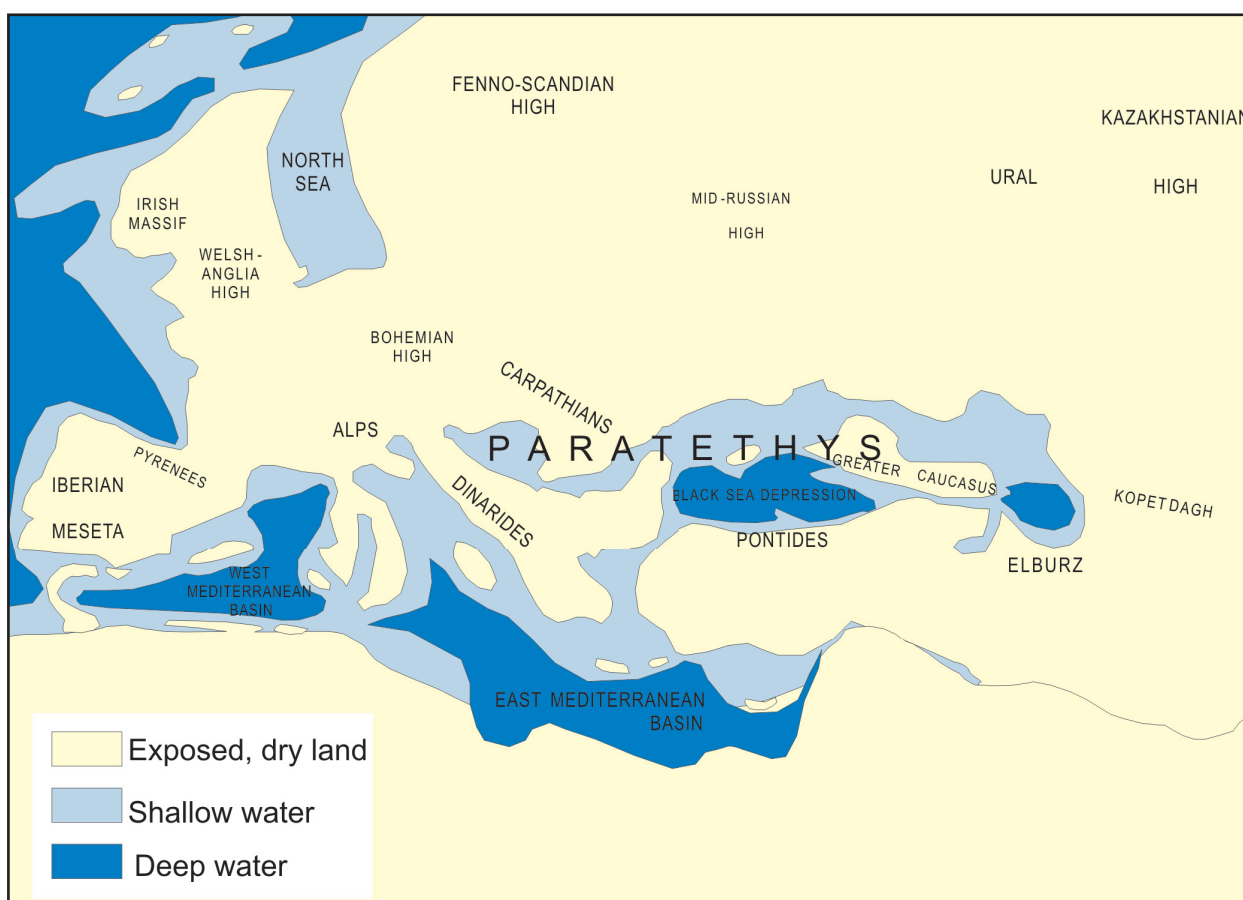


Fig. 8 Paleogeographic configuration of the Paratethys Domain during Early Meotian (8.5 - 7 Ma). Simplified after Ilyina, L.B., Shcherba, I.G., Khondkarian, S.O., (in Popov *et al.*, 2004)

It is asserted that during the Upper Miocene (Maeotian, 8.5 to 7 Ma) (Fig. 8), in the Eastern Paratethys, a "corridor" opened towards the Indian Ocean (Chepaliga, 1995). There are no concrete examples (with one exception, namely, Abchazia, the Atapi Valley, where the marine-level (with *Mutilus polyptichus* (Reuss), *Hemicytheria* sp.n., *Callistocythere* sp.n, and *Loxoconcha* sp.n) in the Lower Meotian is intercalated among brackish faunas with two morphotypes of *Cyprideis* sp.). Nevertheless, the Maeotian community in the Northern-Black Sea area appears to be uniform and relatively compact (it is symbolically named "the *Dosinia* complex"). The fact that such uniformity is not to be found in the Western areas (in the Dacian basin) suggests that the "marine influx" originates from the East (South of the Caspian Sea?) and not entirely from the South (from the "Aegean" Sea, Gillet, 1961, Semenenko & Ljulieva, 1978). In the Dacian Basin, after the Uppermost Sarmatian fresh-water levels a new brackish-water community appeared (with *Drobetaella*, *Severinella*, *Hemicytheria*, *Loxoconcha*, *Maeotocythere* species). It was followed by the "Dosinia level" (with *Modiola incrassata*, *Ervilia minuta*, *Pirenella caspia*, *P. disjunctoides*, *Caspia minor* and two ostracod species *Mutilus parabulgaricus* Olteanu and *Maeotocythere sulakensis* Suzin only), a fresh-water level (with *Leptanodon-*

ta), a large level with brackish ostracods (*Hemicytheria* - 22 species, *Loxoconcha*, *Xestoleberis*, *Maeotocythere*, *Stanchevia*) and finally, the last two short fresh-water levels, with *Unio*, *Helix* and *Reticulocandona* and the second one, with *Congeria novorossica-navicula-panticaepea*, this with frequently Pontian ostracods in Eastern and central areas of the basin). The history of the Dacian Basin during the Maeotian time was a successive opening and isolation phases with "cosmopolite" and endemic taxa, respectively. The absence of *Limnocardiids* and foraminifers (except for *Ammonia beccari*) and the last occurrence of *Mutilus*, *Hemicytheria*, *Xestoleberis* species are the specific features of the Maeotian metacommunity. The luxuriant *Congeria* species evolution suddenly interrupted.

No Maeotian taxa crossed the Pontian boundary.

The correlation of the Pontian with Mediterranean scale is disputable (Khondkarian *et al.* 2004).

In the Lower Pontian (the Upper Messinian) (Fig. 9), the Gibraltar closes down while the Mediterranean Sea becomes an enclosed lake (5.8 Ma). On the edges, evaporites and gypsum are being deposited. During the next time (5.8 – 5.6 Ma) the sea level rises forming the so-called "Lago mare" with brackish waters (and implicitly brackish faunas). Eventually, 5.6 Ma,

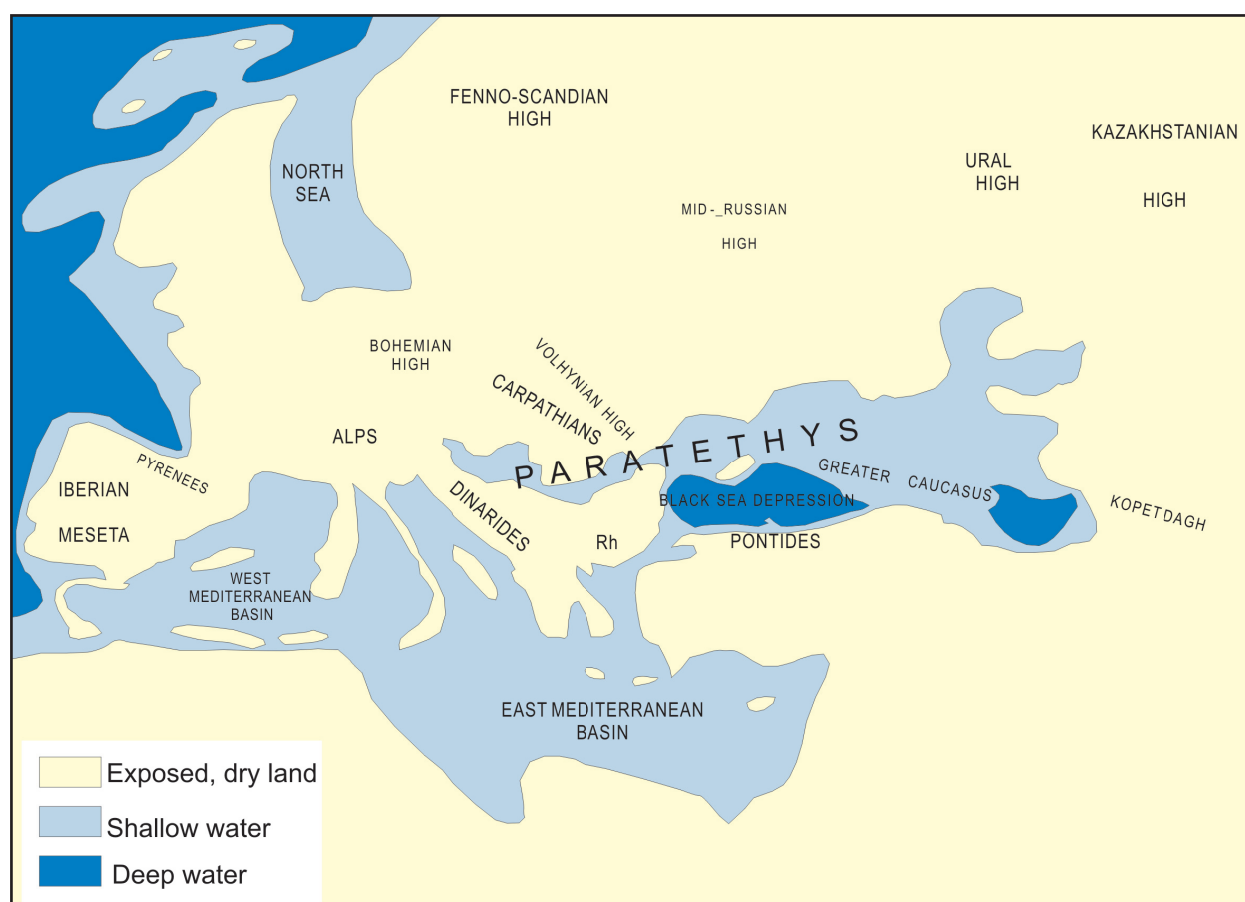


Fig. 9 Paleogeographic configuration of the Paratethys Domain during Early Pontian (6.1 – 5.7 Ma). Simplified after I.G., Khondkarian, S.O. Shcherba, S.V. Popov (in Popov *et al.*, 2004)

the sea level decreases sharply and massive areas of land are exonded. Still, the brackish faunas which occur meanwhile invade the Eastern Paratethys across the Aegean Sea and the Pre-Pontida (or the area located just North of it). In other words, there are several separate phases: the first is a phase characterized by hypersalinity, followed by the refilling of the basin and the dilution of the water to the brackish "Pontian type" (around 0.010% salinity). Similarly, we must remember that the (hypersaline) Dead Sea still receives river influx from the Jordan Valley without turning brackish. Likewise, the salinity of the Caspian Sea does not decrease under 0.06%. It is true though, that the warm climate and the intense evaporation are responsible for it (but the Mediterranean had the exact same conditions at the time).

The Early Pontian is strongly transgressive. A new wave of fauna migration spread through the Eastern seas (neo-*Limnocardids* as *Chartoconcha*, *Pseudocatillus*, *Prosodacna*, *Pachydacna*, *Tauricardium*, *Caladacna*, *Pontalmyra*, *Phyllocardium* etc. and new ostracod types as *Bacunela*, *Pontoniella*, *Euxinocythere*, *Pontoleberis*). It is possible but unlikely they originate from the Pannonian area.

The question of the origin of the brackish faunas in the South of France, the Italian Peninsula and the Aegean basin remains a mystery. The question is whether those influences and movements or morphogenetic evolutions, respectively, are unique to this area (Olteanu, 2000, 2003). The maximum sea extent occurred in the Pannonian Basin in the Portaferian time.

The semi-enclosed Dacian basin continues to be under the "faunal umbrella" of the Euxinian bioprovince, in spite of the fact that, starting in the Upper Pontian, it tends to become isolated. In its Western region, more fresh levels appeared. During the Post-Pontian, there is a gradual, but persistent retreat and freshening of the waters, as, after the Middle Pontian, the Moldavian Platform is emerging (Ionesi *et al.*, 2005). Lacustrine formations occur. The flora is an indicator of warm climate (Ionesi *et al.*, *op. cit.*).

The Euxinian basin is the only one which stays brackish throughout this interval. The Pontian can be directly correlated with the Dacian basin fauna (and the Portaferian fauna, with the Pannonian basin). The differences occur in Post-Pontian, when the biostratigraphic nomenclature becomes cor-

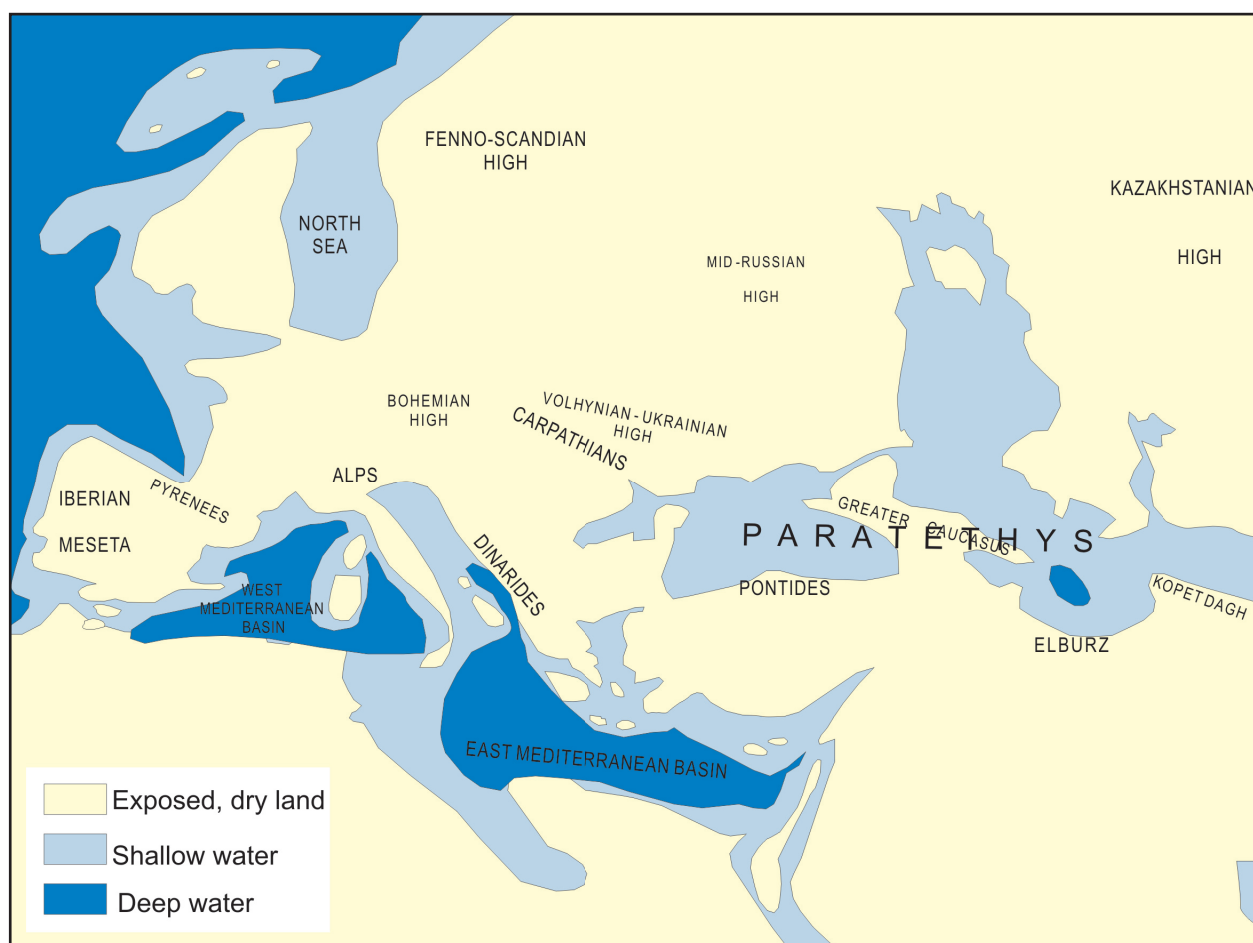


Fig. 10 Paleogeographic configuration of the Paratethys Domain during Late Romanian (3.4 – 1.8 Ma). Simplified after I.G., Khondkarian, Paramonova, N.P., S.O. Shcherba, (in Popov *et al.*, 2004)

respondingly intricate (and more accurate). In the Northern Euxinian area, the first freshwater episode to appear is in the Kuialnikian time. (Contrary to the Black Sea deep basin, which stayed brackish, as it was in the Kimmerian, preserving the same type of evolutionary line of the fauna. Consequently, the Kuialnikian cannot be accepted but as a marginal, shallow final facies of the Kimmerian stage, a facies which presumably continued the „Azov Beds” dominated by the *Congeria* species). During the Late Dacian time, the Dacic Basin was isolated. Its low brackish-water rich fauna (Olteanu, 1995) is different from the Kimmerian fauna (three common species only). There are two directions in fauna evolution in the two bioprovinces with different (paleo) ecology, low salinity in the Dacian Basin and higher and constant salinity in the Euxinian Basin.

The upper limit of the Pontian was conventionally set to coincide with the Miocene/Pliocene boundary, which should begin with the Zanclean (in the Mediterranean Sea), with the Dacian (in the Dacian basin), with the Kimmerian (in the Euxinic basin) and the Babadzhanian (in the Caspian area), around 5.3 Ma (Popov *et al.*, 2004).

During the Romanian stage, the Dacian basin was isolated. It became a large lake with a rich community of fresh-water molluscs (*Unionidae*, more 70 endemic species, *Melanopsidae* and *Viviparidae*) and ostracods (*Candona s. l.*, *Cypris s. l.*). The Middle Romanian is characterized by a specific ostracod community: *Cypris mandelstami*, *Zonocypris membranae*, „*Eucypris*” *famosa*, *Kowalevskiella sp.* (that community includes Upper Pliocene species existing also in the Caspian area).

A variety of ecosystems are known for the Dacian basin development, from marine (Badenian), through all the brackish phases (Sarmatian - Dacian) to the fresh-water ecosystem (Romanian).

In the Upper Pliocene (3.4 – 1.8 Ma) (Piacentian and Gelasian in the Mediterranean basin; Romanian, in the Dacian basin and Akchiaghilian in the Pontic-Caspian area), in the Paratethys domain, the Pliocene orogenic movements shaped the general features of the present-day geography (Fig. 10).

After the „*Congeria rhomboidea* Beds” (Portaferrian), the Pannonian basin was almost completely filled up, except for two regional depressions.

In both areas there is the abundant, but exclusively endemic ostracoda and mollusc species. In Slovenia, the „*Paludinae Beds*” represent an essential break up from the previous community, while in the satellite „Baraolt basin” (Jekelius, 1932) a „residual fauna” with the (dominant) *Pachidacna fuchsi*, and the *P. abichiiformis* (inherited from the Pontian fauna) and few new taxa, together with the last species of „*Hungarocypris*” and with deviant forms of *Caspiolla* and *Amplocypris* (Olteanu, 2003) survived to prove the continuity of the faunal evolution in the Post-Pontian or even newer oligohaline and lacustrine facies. In the final part of the sequence (at Racos and at Bodos-Baraolt) forms of *Unio* - looking like certain spe-

cies from the Romanian of the Dacian basin (in the *Pristinunio pristinus* and *P. mutabilis* group) (Olteanu, Lubenescu, *in press*) - were found. The above support a most likely correlation (with the Romanian and the Pleistocene) as our knowledge deepens and extends.

The Euxinian basin is isolated although there occur random connections with the Caspian basin through the Manici corridor (Northern Caucasus). The Kuialnikian-Gurian-Ceaudian episodes (conspicuous in the NE area of the Euxinian basin), each of them with specific community, (Imnadze, 1971) imply an intense eustatic „play” and an implicit hydrochemical one (yet, it cannot be claimed that the area turned „lacustrine”. Ancient or recent, the Black Sea has never been a freshwater lake).

The Caspian basin (as well as the whole geographical area belonging to the Paratethys) is now a low salinity one (as compared to the Pliocene average). The water level movement compared to the present-day level of the Black Sea, reaches high levels (up to 500m). In the „Akchiaghilian Episode” a lower level and a freshwater upper level occur (confirmed by ostracoda, Mandelstam *et al.*, 1962). In the middle level of the Akchiaghilian, the sea extends towards the North (along the Volga - Ural depression axis), for nearly 2,200 km and Westwards towards Taman-Crimea across the Kuban depression. The Black Sea boreholes brought to light ‘exotic’ faunal elements of a rather high salinity (of marine origin in a Sarmatian “typology” (*Avimactra*, *Avicardium*, *Miricardium*, *Andrusella*, *Kirkiziella*) which naturally, raises the question: Where did they come from? Likewise, where did the Mediterranean brackish fauna come from?). (Olteanu, 2001). The mollusc fauna suggests that the salinity exceeded the Pliocene average. That brackish insertion-transgression (along with its specific fauna of uncertain origin) seems to be generated by a South Caspian possible corridor through the Upper basin of the Euphrat that would have linked that basin to the Southern marine area (Steininger *et al.*, 1985, Chepalyga, 1995).

The likely chronostratigraphic correlation between the Romanian and the Akchiaghilian was generally agreed upon, while the next episode, Apscheronian, belongs to the Lower Quaternary. The boundary with the Pleistocene is again conventionally set (at 1.8 Ma) just because it is generally impossible to put together a correlation of any kind of geological ‘events’.

The Dacian Basin area was ephemerally invaded by the Euxinian waters during the Upper Dacian (in the Lehlou - Alexandria area is the one constant level, 0.10cm with Kimmerian ostracods) and, for the last time, during the Apscheronian (with the mollusc fauna in Barbosi - Galati, Macarovici, Costetchi, 1973, with *Didacna crassa*, *D. aff pseudo-crassa*, *Adacna plicata*, *Corbicula fluminans*, *Viviparus sadleri*, *V. pseudo-sadleri*, *V. diluviensis* etc and Bandrabur, 1960, *Unio pictorum*, *Unio sp.*). The ostracoda fauna in Barbosi sequence is particularly rich: *Amnicythère precaspia* (Livental), *A. quinquetuberculata* (Livental)*, *A. multituberculata* (Livental)*, *A.*

bacuana (Livental)*, *A. striatocostata* (Schweyer)*, *A. cymbula* (Livental)*, *A. propinqua* (Livental)*, *A. variabituberculata propinqua* (Livental), *A. unicornis* (Schweyer), *Euxinocythere bosqueti* (?) *propinqua* (Livental), *E. aff. ergeniensis* (Schweyer), *E. post-kuialnica* n. sp., *Candona mandelstami* (Schweyer), *C. liventalina* (Evlachova), *C. elongata* (Schweyer)*, *Limnocythere (Scordiascia) aff. sharapovae* (Schweyer), *Tyrrhenocythere pontica* (Livental), *Loxoconcha petasa* (Livental), *L. eichwaldi* (Livental), *Cytherissa* new sp. (*recent species in the Black Sea). It suggests a large western lagoon of the Black Sea.

During the Karangatian (the Riss-Wurm interglacial period) the Bosphorus opens up and the Black Sea area is invaded by organisms from the Mediterranean basin, including many marine ostracod species: *Pterigocythereis jonesi*,

Carinocythereis carinata, *Loxoconcha aff. granulosa*, *L. lepida*, *L. aff. elliptica*, *Semicytherura aff. sanmarinensis*, *S. aff. acuticostata*, *Mediocythereis* n. sp., *Sclerochilus* n. sp., *Echinocythereis* n. sp., *Hemicytheria* n. sp. etc. The second opening of the Bosphorus takes place during the Sourozkian episode: *Lepocythere multipunctata*, *L. macallena*, *Loxoconcha granulata*, *Cytheridea aff. acuminata*, while the last opening, during the Upper Neo-Euxinian: *Hemicytherura videns*, *Callistocythere diffusa*, *C. flavidofusca*, *C. mediterranea*, *C. ramosa*, *C. fabaeformis*, *Costa edwardsi runnecinata*, *Urocythereis margaritifera*, *Loxoconcha rhomboidea*, *Aurila convexa*. (three brackish ingressions in the Danube Delta) (Olteanu, 2004). Three moments, three migration waves and three types of colonists signify different ecological features during the Black Sea recent history.

SELECTED REFERENCES

- AGALAROVA D.A., 1967 - Mikrofauna Ponticiskih otlojenii Azerbaidjana i copredelnih paionov, Iz. Nedra, 124, XXIV pl., Leningrad
- ARCHAMBAULT-GUEZOU J., 1976 - Etude de Dreissenidae du Neogene europeen et revue stratigraphique des niveaux correspondants de la Paratethys, Trav. Lab. Pal. Univ. Paris
- AIELLO G., BARRA DIANA, BONUDACE G., 2000 - Systematics and biostratigraphy of the ostracoda of the Plio-Pleistocene Monte S. Nicola section (Gela, Sicily), Bull. Soc. Pal. Italica, 3 (1), 83-112, Modena
- AMITROV O. V., 1975 - Tarchanian, In: Stratotypes of Mediterranean Neogene Stages, II, 187, Eds. Steininger F.F., Nevesskaya L.A., Bratislava
- BOTNARIUC N., 1985 - Cu privire la relațiile dintre ordinea taxonomică și organizarea sistemică a materiei vii, In: Revoluția biologică, G. Zarnea Ed., Ed. Acad. RSR
- BRESTENSKA EDITH, 1975 - Ostracoden des Egerien, 377-411, pl. I-XII, In Chronostratigraphie und Neostatotypen, OM, Bd. 1, Bratislava
- BRESTENSKA EDITH, JIRICEK R., 1976 - Ostrakoden des Badenien der Zentralen Paratethys, 405-421, Pl. I-IX, In: Chronostratigraphie und Neostatotypen, Miozan, M-4, Badenien, Bratislava
- CARAION ELENA FRANCISCA, 1967 - Fauna RSR, Crustacea (Ostracoda), Fam. Cytheridae (Ostracode marine și salmastre), 164, text-fig. 43, Ed. Acad. RSR, București
- CARBONNEL G., 1978 - L'espece Cyprideis pannonica (Mehes), 1908 (Ostracoda) dans la Tethys au Messinien (Miocene), Docum. Lab. Geol. Fac. Sci. Lyon, nr. 72, 79-97, 3 fg., 3 tabl., 1 pl., Lyon
- CHEPALYGA A.L., 1995 - East Paratethys - Tethys marine connections along Euphrat passage during Neogene, Abstracts 10th Congress RCMNS, Romanian Journ. Strat. 76, 7, 149-150, București
- DANIELOPOL D.L., OLTEANU R., LOFFLER H., CARBONEL P., 1990 - Present and past geographical ecological distribution of Cytherissa (Ostracoda, Cytherideinae), Bull. Inst. Geol. D' Aquitaine, 47, 97-118, Bordeaux
- DAVIDASCHVILI L.C., 1930 - Fossils of the Meotie Beds, Tr. Gas. Iss. Naft. Inst. IX, Moskva-Leningrad
- DAVIDASCHVILI L.C., 1933 - Fossils of the Apscheronian Beds, Tr. Gas. Iss. Naft. Inst., XII, Moskva-Leningrad
- FREELS D., 1980 - Limnischen Ostracoden aus Jungtertiar und Quartar der Turkey, Geol. Jahrb. B. 39, Hannover
- GLIOZZI E., 1998 - A late Messinian brackish water ostracod fauna of Paratethyan aspect from Le Vicenne Basin (Abruzzi, central Apennines, Italy), Paleo Geography, Climatology, Ecology, 151, 191-208
- GONTCHAROVA I. A., 1975 - Karaganian, Konkian, Kozachurian, Sakaraulian In Stratotypes of Mediterranean Neogene Stages, II, 171, 175, 177, 183, Eds. Steininger F.F., Nevesskaya L.A., Bratislava
- IMNADZE Z. A., 1971 - O nekotorykh novii vidakh Ostracodovoi fauni Pliotenoviih otlojenii Zapadnoi Gruzii, Tr. VNIRI, CXV, 79-83, pl. I, Moskva
- IMNADZE Z.A., 1975 - Materiali po geologii i neftegazonosnosti Gruzii, Iz. "Metniereba", b. 188, 149-151, Tbilisi
- IMNADZE Z.A., KARMISHINA G.L., 1980 - Comparison of Pliocene Ostracoda complexes in Northern and Eastern Black Sea region, Voprosi Strat., v. 5, 131-148, Leningrad
- IONESI BICA, 1968, Stratigrafia depozitelor miocene de platformă dintre valea Siretului și valea Moldovei, Ed. Academiei RSR, București
- JEANRENAUD P., 1963 - Contributions a l'etude des couches a faune d'eau douce du Sarmatien de la Plateforme Moldave, An. St. Univ. A.I. Cuza, II, IX, Iași
- JEKELIUS E., 1932 - Die Molluskenfauna der dezise stufe der Beckens von Braşov, Mem. Inst. Geol. Rom., 2, Bucureşti
- JONES R.W., SIMMONS M.D., 1997 - A Review of the Stratigraphy of Eastern Paratethys (Oligocene - Holocene), with Particular Emphasis on the Black Sea, In: Regional and petroleum geology of the Black Sea and surrounding region, Robson A.G. ed., 39-52, AAPG Memoir nr. 68
- MANDELSTAM M.I., MARKOVA L.P., POZIEVA T.P., STEPANAITYS N.E., 1962 - Ostracodi Pliotenoviih i Pos-Pliotenoviih otlojenii Turkmenistana, Iz. Akad. Nauk., Turmenskoi SSR, 388, XLVI pl., Ashabad

- NEGADAEV-NIKONOV K.N., 1968 - Ostracodi sredne I verhnepleistoteni-
vii otlojenii Moldavii, Akad. Nauk Moldavskoi SSR, 1-84, pl. I-X,
Kisinev
- ROGL F., BERNOR R.L., DERMITZAKIS D., MULLER CARLA, 1991 - On the Pontian
Correlation in the Aegean (Aegina Island), Newsl. Strat., 24 (3) ,
137-158, Berlin-Stuttgart
- ROGL F., 1996, Stratigraphic correlation of the Paratethys Oligocene
and Miocene, Mitt. Ges. Geol. Berg. Osterr. 41, 65-73, Wien
- RUSU A., 1988 - Oligocene events in Transylvania (Romania) and the
first separation of Paratethys, D. S. Inst. Geol. Geofiz., 72-73, 207-
223, București
- MACAROVICI N., COSTEȚCHI GEORGETA, 1973 - Sur les Depots de Bărboși-Ba-
bele entre le Siret et le Prut, A. Univ. Al.I. Cuza, Iași, II, Geol., T.XIX,
131-149, Iași
- MOISESCU V., 1971 - Stratigrafia depozitelor Paleogene și Miocen-inferio-
are din regiunea Cluj-Huedin-Romanași (NW-ul Bazinului Tran-
silvaniei), An Inst. Geol. Geofiz., XLVII, 200, București
- NEVESSKAYA L.A., GONCHAROVA I.A., ILJINA L.B., PARAMONOVA N.P., POPOV S.V.,
VORONINA A.A., CHEPALYGA A.L., BABAK E.V., 1987 - History of the Para-
tethys, Ann. Inst.Geol. Publ. Hung., 70, 337-342, Budapest
- OLTEANU R., 1978 - Ostracoda from DSPD Leg 42 B, In: Initial Report of
the Deep sea Driling Project, v. XLII, 2, Washington-La Jola
- OLTEANU R., 1979 - Significances biostratigraphique de ostracodes
meotiens et pontiens du bassin Dacique, D. S., Inst. Geol., LXIX,
Bucuresti
- OLTEANU R., 1989 - New Ostracodes from Paratethys Upper Neogene,
Memoires Inst.Geol., 34, Bucuresti
- OLTEANU R., 1995 - Dacian Ostracodes, In Chronostratigraphie und Ne-
ostratotypen, Bd. IX, Dacien, 268-313, XXXVI pl., Ed. Acad. Roma-
ne, Bucuresti
- OLTEANU R., 1997 - Ornamental pattern of th Pontic Cycle Ostracoes
and their biostratigraphical significance, An. Univ. "A.I.Cuza", tom
XLII-XLIII, Iasi
- OLTEANU R., 1998 - Ontogeny and Phylogeny of Sarmatian Limnocardii-
ids (Bivalvia), Rev. Roum. Geol., nr. 42, Bucuresti
- OLTEANU R., 1998 - The Meotian Ostracodes and their problems (eco-
logical significance), Jour. Pal., Inst. Geol. Rom., 56-72, 4 fig.text.,
București
- OLTEANU R., 1998 - Brackish-water faciesses and their correlation, an
essay on the objectivity, 126-143, Ann. Univ. A. I. Cuza, S. Geol.,
II, 4, Iasi
- OLTEANU R., 1998 - Orthogenesis and Orthoselection. Leptocythere
lineages in brackish- water Neogene (Ostracoda), Rev. Roum. Ge-
ologie, T. 42, 141-153, pl. I-VIII, Bucuresti
- OLTEANU R., 1999 - The Loxoconcha genus (Crustacea, Ostracoda) wi-
thin Paratethys area, Memoires Inst. Geol. Roman, 37, Bucuresti
- OLTEANU R., 2000 - Darwinismul în căutarea ordinei sau sofismul în pa-
leontologie, 324, 56 txt-figs., Ed. Enciclopedică
- OLTEANU R., 2003 - The last representative of the „Pannonian” realm
(Ostracoda, Crustacea), in Chronostratigraphie und Neostrato-
typen, Pliozan, Pl 2, Romanien, 350-361, pl. I-VII, București
- OLTEANU R., 2004 - Transgressive and regressive phases in the Black Sea
history, Travaux de l'Institut Speologie „Emil Racoviță”, București
- OLTEANU R., 2004 - Black Sea transgressions during the late Holocene,
Proceedings of the Romanian Academy, 1, Iulie-Septembrie
- OLTEANU R., 2004 - Oscillations of the Black Sea level during Miocene-
Pliocene times, Geo-Eco-Marina 7-8, 2003-2004, București
- OSSIPOV S. S., 1966 - Characteristic fossils of the Crimea and Caucasus,
Tr. Gas. Iss. Neft. Inst., III-IV. Moskva-Leningrad
- POPOV, S.V., ROGL, F., ROZANOV, A.Y., STEININGER, FRITZ F., SHCHERBA, I.G., KOVAC,
M. (EDS) 2004 - Lithological-Paleogeographic maps of Paratethys.
Late Eocene to Pliocene. 46 pages, maps 1-10 (annex). Courier
Forschungsinstitut Senckenberg, Band 250. Frankfurt am Main
- SCHNEIDER G.F., 1949 - Miotenovaia fauna ostracod Kavkaza i Krama, Tv.
Neft. Geol. Inst., nov. ser. 89-179, Leningrad-Moskva
- SCHNEIDER G.F., 1953 - Fauna ostracod iz Miotenovih otlojenii zapadnoi
ciasti Ukraini, VNIGRI, II (V), 101-123, Leningrad-Moskva
- SCHORNIKOV E.I., 1969 - Podclass ostracoda, ili rakusovie raki, In Opre-
delitel fauni Cernogo I Azovscogo Morei, 163-217, XLII pl., Iz. "Na-
ukovo Duka", Kiev
- STANCEVA MARIA, 1990 - Upper Miocene Ostracodes from Northwest
Bulgaria, Geol. Balcanica, nr. 5, Sofia
- TAKTAKISVILI I.G., 1978 - Ob Evpatoriscom gorizonte Cernomorsko-Cas-
piscogo bassena, Inst. Paleobiologii, Ed."Metniereba", 3-50, Tbilisi
- VEKUA MZIA LAURA, 1975 - Ostracodi Kimmeriskih I Kuialnitkih otlojenii
Abhazii i ih stratigraficescoe znacenie, Ed. "Metniera", 137, XX
pl., Tblisi
- ZORN IRENE, 1998 - Ostracoda aus dem Karpat (Unter Miozan) des kone-
uburger Beckens, Brtg. Pal., nr. 23