THE IDENTITY OF A PARATETHYS BASIN. DACIAN BASIN CONFIGURATION - OUTCOME OF THE CARPATHIAN FOREDEEP ALONG-ARC MIGRATION

Dan C. JIPA

National Institute of Marine Geology and Geo-Ecology (GeoEcoMar), 23-25 Dimitrie Onciul St., 024053 Bucharest, Romania
e-mail: jipa@geoecomar.ro

Abstract. Several large scale geological events controlled the Dacian Basin inception. The Dacian Basin can be defined as the southern Carpathian Foredeep area outlined after a long migration process, where the sediment accumulation was stimulated by the Carpathian orogenic climax and organized within a morphologically closed basin and in a Neogene Paratethys brackish-water ecosystem.

Key words: Dacian Basin, Carpathian Foredeep, Paratethys, along-arc migration

1. INTRODUCTION

The individuality of a sedimentation basin is conferred by the process which decisively contributed to the outlining of the basin territory and to the functioning of its sediment accumulation space.

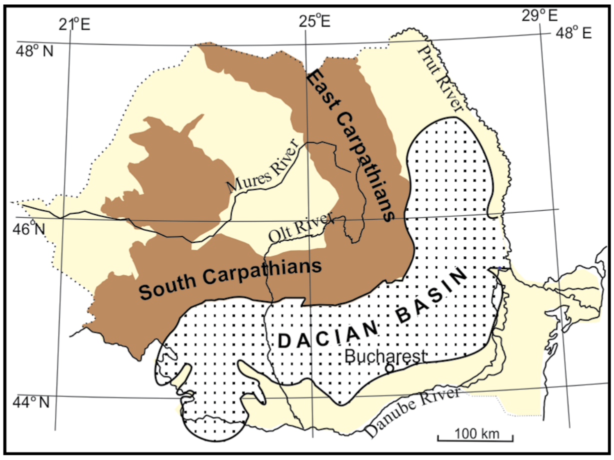


Fig. 1. Dacian Basin paleogeography during the Middle (upper part) and Late Sarmatian *s.l.* From Saulea *et al.* (1969). The south-western boundary of the Dacian Basin after Hamor *et al.* (1988)

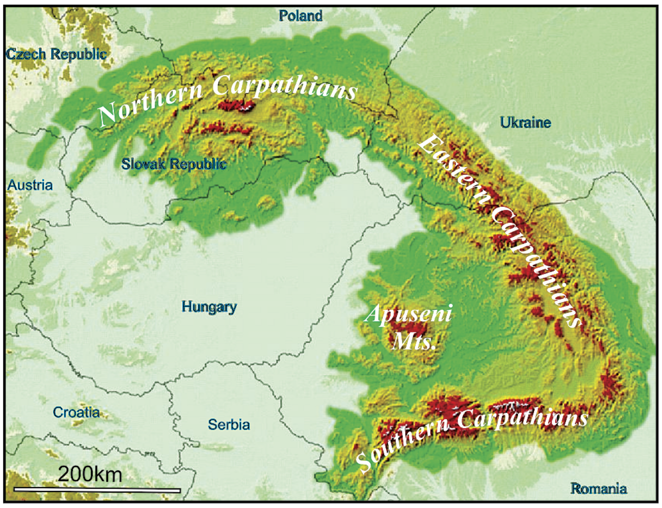
The aim of this paper is to analyze the characters which confer to the identity of the Dacian Basin, one of the marine areas of the Paratethys Domain. The investigations reported in this paper focused, specifically, on the features constraining the inception of the Dacian Basin, in the larger framework of the Neogene Paratethys and the Carpathian Foredeep. This study was required as some of the basin important characters are viewed inadequate to define the individuality of the Dacian Basin.

The study area of this paper is the Dacian Basin space (Fig. 1), examined as a component of both the Paratethys Domain (Fig. 2) and the Carpathian Foredeep (Fig. 3).

2. METHOD AND DATA

In order to answer the proposed objective, the study analyzes the major factors which specifically governed the Dacian Basin sediment accumulation initiation and evolution. The discussion includes a review of the opinions on the Dacian Basin formation from published papers, as well as the presentation of the data resulting from our own investigation.

One of the main approach line is the Neogene evolution of the Carpathian Foredeep area. With this interest in view, data offered by two important paleogeographic atlases were used: Hámor *et al.* (1988) and Popov *et al.* (2004).



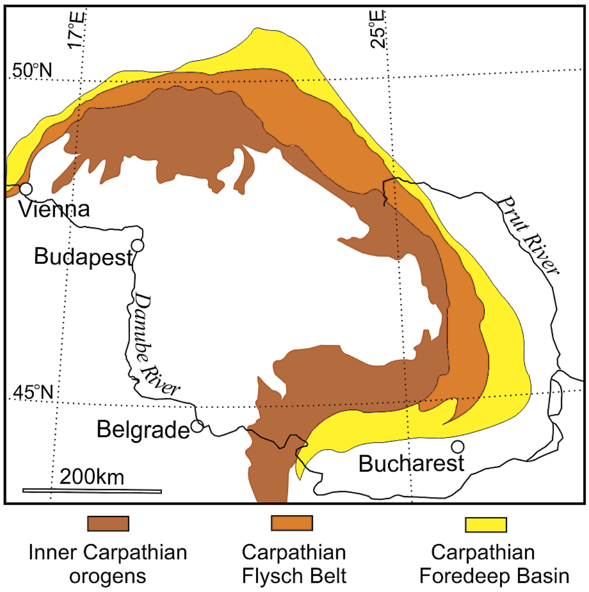


Fig. 2. The Carpathian Foredeep area. Modified, from Săndulescu (1984). Carpathians image modified, from the Project "Network of Carpathian protected areas and Ramsar sites".

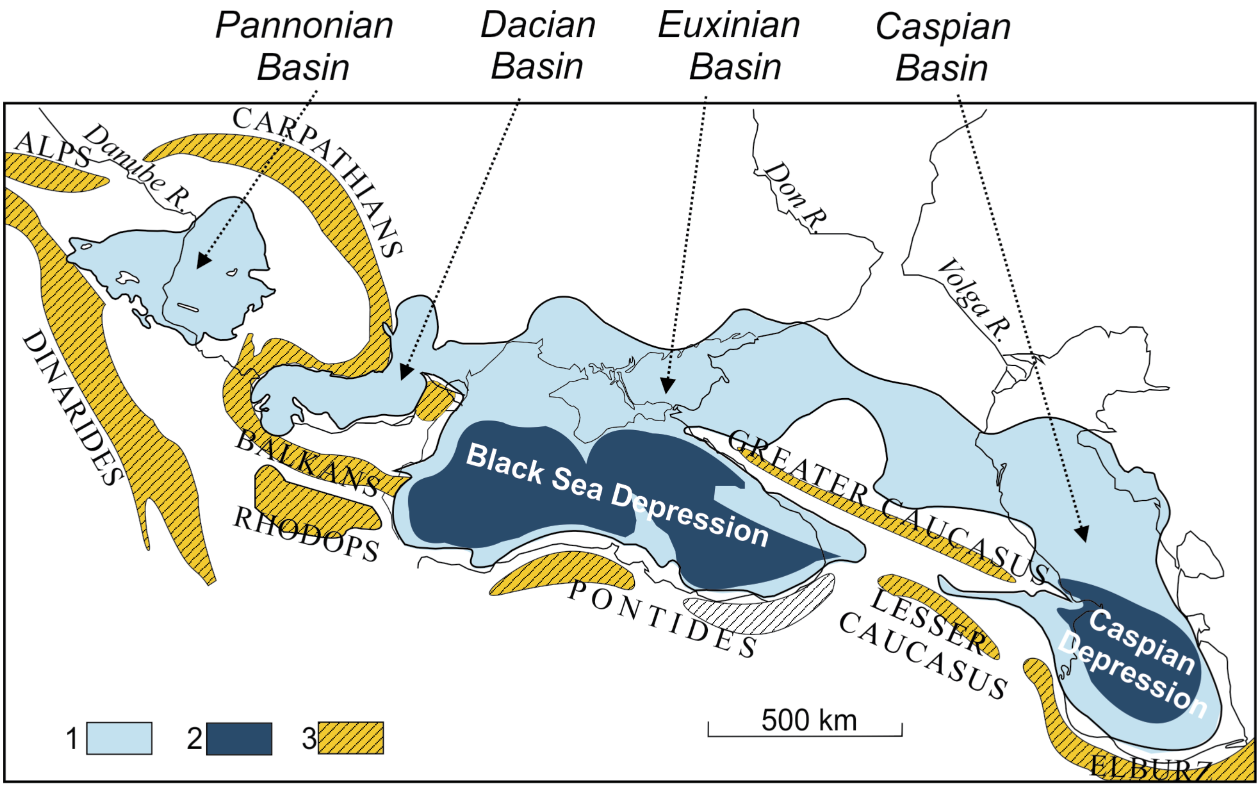


Fig. 3. Paratethys Domain during the Early Maeotian. Simplified, from Popov *et al*. (2004).
Caption: **1**. Shallow marine. **2**. Deep marine. **3**. Mountain range.

The chronostratigraphic scale used in this paper compiles data from Harzhauser and Harzhauser and Piller (2004), Krijgsman *et al*. (2010)**,** and Hohenneger *et al*. (2014) (Fig. 4). The Sarmatian stratigraphic name used in this paper is that of the *sensu lato* (*s.l.*) meaning, with the Volhynian, Bessarabian and Khersonian substages.

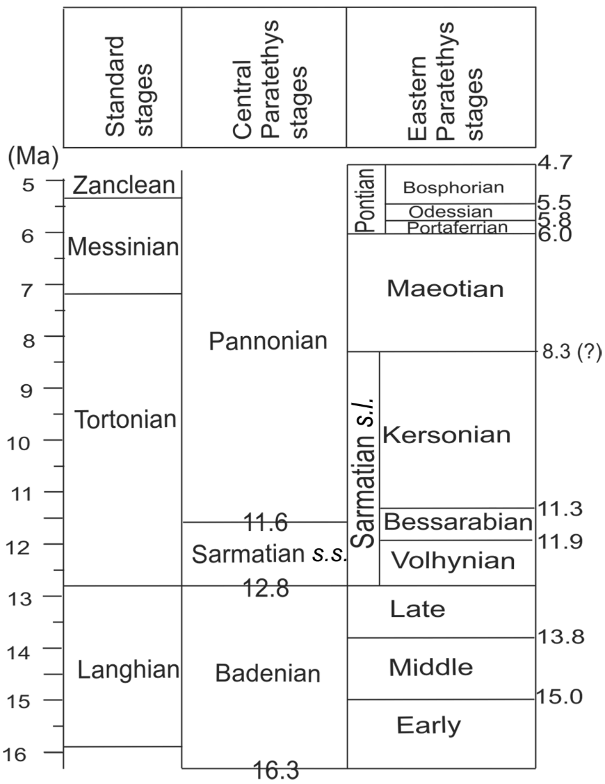


Fig. 4. Chronostratigraphic scale of the Middle and Late Neogene from the Central and Eastern Paratethys. Compiled from Harzhauser and Piller (2004), Krijgsman *et al*. (2010) and Hohenneger *et al*. (2014).

3. GEOLOGICAL SETTING

Carpathian Foredeep. This important unit is a foreland periphery basin in relation with the moving Carpathian front (Oszczypko *et al*., 2012). The foreland basin extends continuously from the western extremity of the Northern Carpathians to the western end of the Southern Carpathians (Fig. 3).

The Carpathian Foredeep was active during the Upper Miocene – Pliocene – Lowermost Pleistocene time interval (Săndulescu, 1984). The sediments of the foredeep basin cover the adjacent parts of the Moldavian, Scythian and Moesian platforms.

The age of the foredeep sediments becomes younger and younger to the east and the southeast, along the basin. Sediment thickness varies from several hundred meters in the western part of the foredeep to several kilometers in the Carpathian Bend area.

The depocenters of the East Alpine-Carpathian Foredeep show frequent transversal and longitudinal shifts. The along-arc depocenter migrations have been followed by Meulenkamp *et al*. (1996) along a 1700 m distance.

Paratethys Domain. Outlined in the terminal Eocene time, subsequent to the Tethys closure, the intercontinental sea extending from the Alps to the Aral was named Paratethys (Laskarev, 1924). During its development**,** the Paratethys Domain experienced stages of connection and separation to the oceanic realm, and changed from an open unitary sea into a string of basins (Rőgl, 1998**,** 1999). The marine isolation strengthened during the Sarmatian *s.l.* time, when the four Paratethysian basins (Fig. 2) became brackish water units, with the salinity steadily diminishing.

Dacian Basin. Located between the Pannonian and the Euxinian basins, the Dacian Basin was the smallest water body of the Paratethys (Fig. 2).

According to Saulea *et al*. (1969), the Dacian Basin had developed since the Middle to Upper Sarmatian *s.l.*, following the mid-Sarmatian Attic orogenesis.

During its paleogeographic evolution, the Dacian Basin sea was, initially (Late Sarmatian *s.l.*), largely open to the Euxinian Basin. Subsequently, since the Maeotian, the communication with the Euxinian Basin was severed, the Dacian Basin turning almost a land-enclosed sea.

Three main sedimentary paleoenvironment systems are separated within the Dacian Basin: the northern fluvial, the central shallow marine and western deep marine sedimentary environmental units (Jipa and Olariu, 2009, 2013).

Evolving from the origin as a Late Sarmatian *s.l.* brackish sea, the Dacian Basin water salinity decreased close to the fresh water values, during the Late Pontian and Early Dacian.

The Dacian Basin filled out with Carpathian-derived sediments, earlier in the western deep water depression, and, finally, in the eastern part of the basin. During the Romanian time, the Dacian Basin was already filled out and its territory became a fluvial transport and accumulation area.

3. DATA PRESENTATION AND INTERPRETATION

3.1. The major Dacian Basin features

Sedimentary facies changes at the Dacian Basin inception. The Bessarabian sediment accumulations, at the base of the Dacian Basin, display a significant facies change, compared to the underlying sediments. Subsequent to the dominant clayey-silty subjacent deposits, the cropping out Bessarabian and Kersonian deposits from the western Dacian Basin are conglomeratic (Marinescu, 1978). Eastward from the Drobeta Turnu-Severin town, in the Colibasi area, the conglomerates appear from the lower part of the Bessarabian and, occasionally, since the terminal Volhynian (Fig. 5).

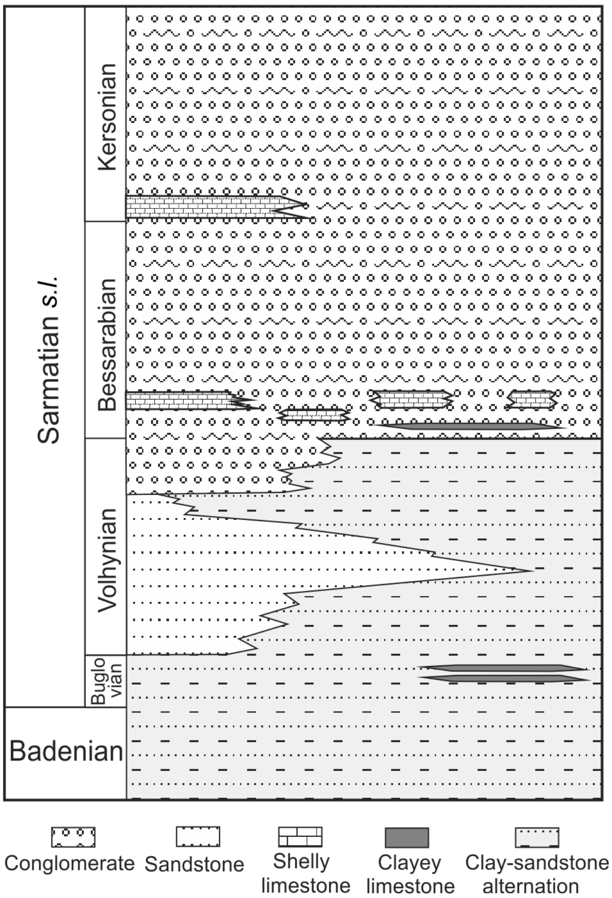


Fig. 5. Litho-stratigraphic succession of the Sarmatian *s.l.* deposits from the western Dacian Basin. Simplified, from Marinescu (1978).

In most geological sections from the western Dacian Basin, the conglomerate deposits date from the Middle Bessarabian (Fig. 6). The ruditic sedimentation did not appear abruptly; it was preceded by thin Late Badenian and Volhynian sandy or gravelly events.

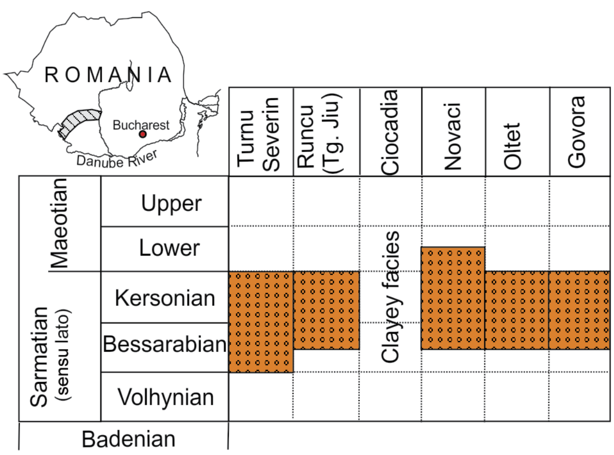


Fig. 6. Areal and stratigraphic distribution of the conglomerates occurrences in the western Dacian Basin. Modified, from Marinescu (1978).

Similar facies changes, with clear paleoenvironmental implications, were also revealed in the northern extremity area of the Dacian Basin. In outcrops from Putna River (Vrancea county), between the Poduri and Colacu villages (Fig. 7), there is transition from the marine, lower part, to the alluvial upper part of the Sarmatian *s.l.* Well-bedded, dominantly clayey deposits with marine microfauna (Fig. 8A) crop out at the base of the sedimentary succession. The succession gradually continues with clay deposits**,** showing frequent sandstone and siltstone interbeds with wave ripples and current sedimentary structures (small-scale cross lamination and sole casts) (Fig. 8B). The upper part of the Sarmatian *s.l.* appears as a thick alluvial succession of silty-clayey deposits alternating with poligenetic medium to coarse-grained sandstones (Fig. 8C), with infrequent fresh water organic remains.

Salinity drop and the Dacian Basin inception. The Late Sarmatian *s.l.* onset of the Dacian Basin sediment accumulation took place in the framework of a new, brackish ecosystem. Based on the faunal analysis, Pană (1966), Marinescu (1978) and Saulea *et al.* (1969) concluded that the Late Sarmatian *s.l.* 16 to 18‰ water salinity was dominant in the early stage of the Dacian Basin development. The Pontian deposits with *Congeria rhomboidea* (Papaianopol *et al.*, 1995) indicated salinity values of 5-10 ‰, which decreased to about 3 ‰ during the Early Dacian.

Dacian Basin and the Carpathian Foredeep migration. A longitudinal sedimentary migration process developed at the scale of the entire Carpathian Foredeep (Figs. 9 and 10). The depocenter foredeep migration study was investigated by Meulenkamp *et al.* (1996). Their results indicate the eastward migration started during the Egerian, reached a high development in the Later Badenian**,** and ceased for three million years. After this residential time, the along-arc depocenter migration started again southeastward, during the Volhynian**,** and lasted up to the Late Miocene (approximately at 11.5 Ma).

Our approach of the foredeep migration process focused on the paleogeographic shifts of the successive sediment accumulation areas. The first paleogeography atlas of the Neogene from the Central and Eastern Europe (Hámor *et al.*, 1988) clearly evidenced the progressive along-arc migration, affecting the sedimentary accumulation from the Carpathian Foredeep and from the platform margin (Fig. 9). On the paleogeographic maps, the east/southeast sedimentation area shift is evident, with tens of kilometers progress during the Badenian**,** and hundreds of kilometers during the Sarmatian *s.l.* - Maeotian time.

The paleogeography information from the Paratethys paleogeography atlas (Popov *et al*., 2004) also reveals the sedimentary migration from the Carpathian Fordeep (Fig. 10). Making use of modern reference geography elements, the Early Badenian - Maeotian western/northern extremities of the sediment accumulation areas migrated about 1400 km from the Vienna area toward the Danube Delta area.

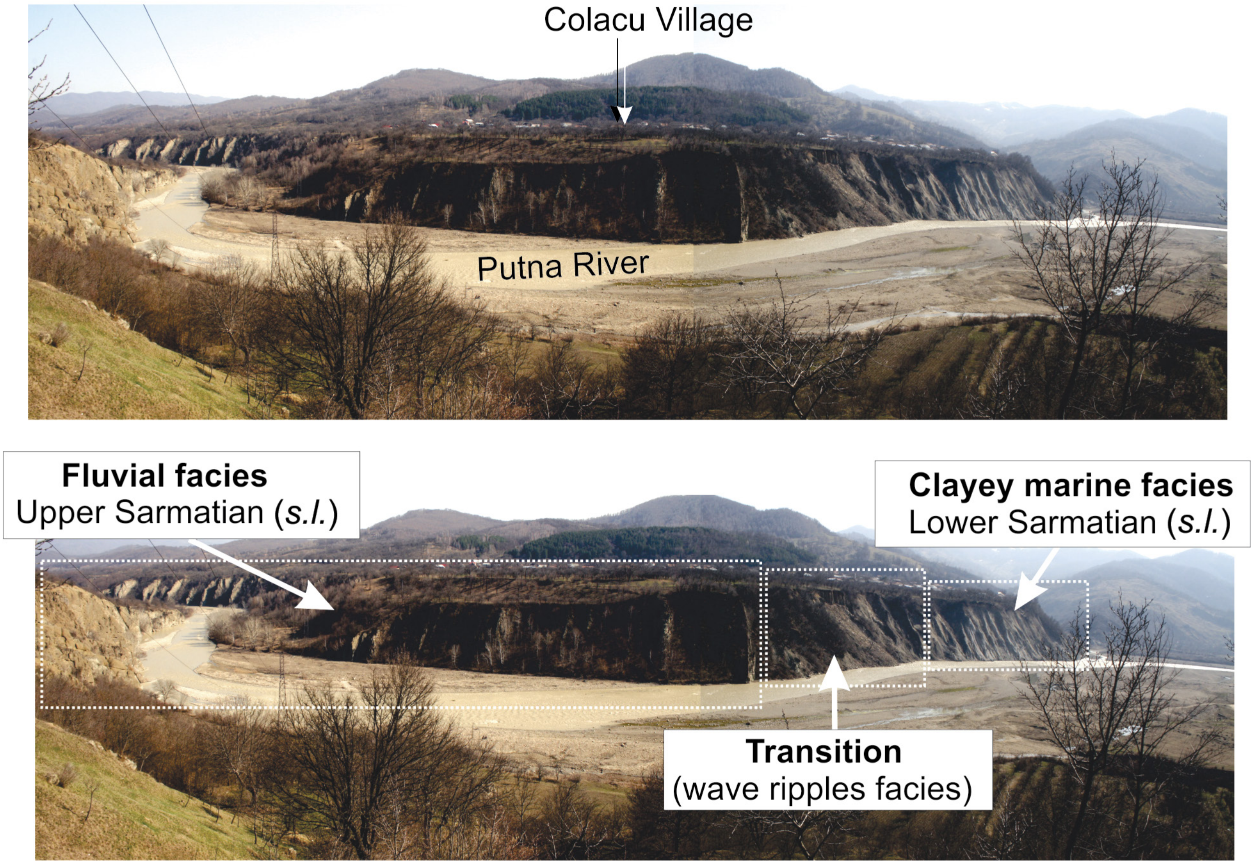


Fig. 7. Sedimentary succession of the Sarmatian *s.l.* deposits, cropping out on the Putna River (Vrancea County).

Fig. 8. Sarmatian *s.l.* deposits from the Putna River area. **A**. Marine clay deposits. Lower part of the Sarmatian *s.l.* **B**. Transition facies in the middle part of the Sarmatian *s.l.* succession. Clayey deposits with sandstone interbeds, showing wave ripples and current structures. **C**. Fluvial sandstones in the upper part of the Sarmatian *s.l.* deposits.

Dacian Basin and the Carpathian clastic influx. Within the Paratethys Domain, there is a common border between the Euxinian and the Dacian basins. The two basins are in a giant to dwarf relationship, the Euxinian Basin (shelf and depression area) outsizing about eight times the Dacian neighbor.

Regarded at the level of the water surface, the Dacian Basin comes into view as a small annex of the Euxinian Basin. Considered at the bottom level, where the sediments accumulate, the Dacian Basin shows the quite different image of an independent, land-enclosed basin. The paleocurrent directions trend indicates that the incoming clastic material, almost entirely of Carpathian provenance, was retained in the Dacian Basin accumulation area and did not reach the Euxinian area.

3.2. What defines the individuality of the Dacian Basin?

Dacian Basin – the post-collision foreland of the Romanian Carpathians. Saulea *et al*. (1969) have been the first to stratigraphically outline the Dacian Basin. These authors also stated the Attic orogenesis controlled the Dacian Basin Middle-Late Sarmatian (*s.l.*) inception.

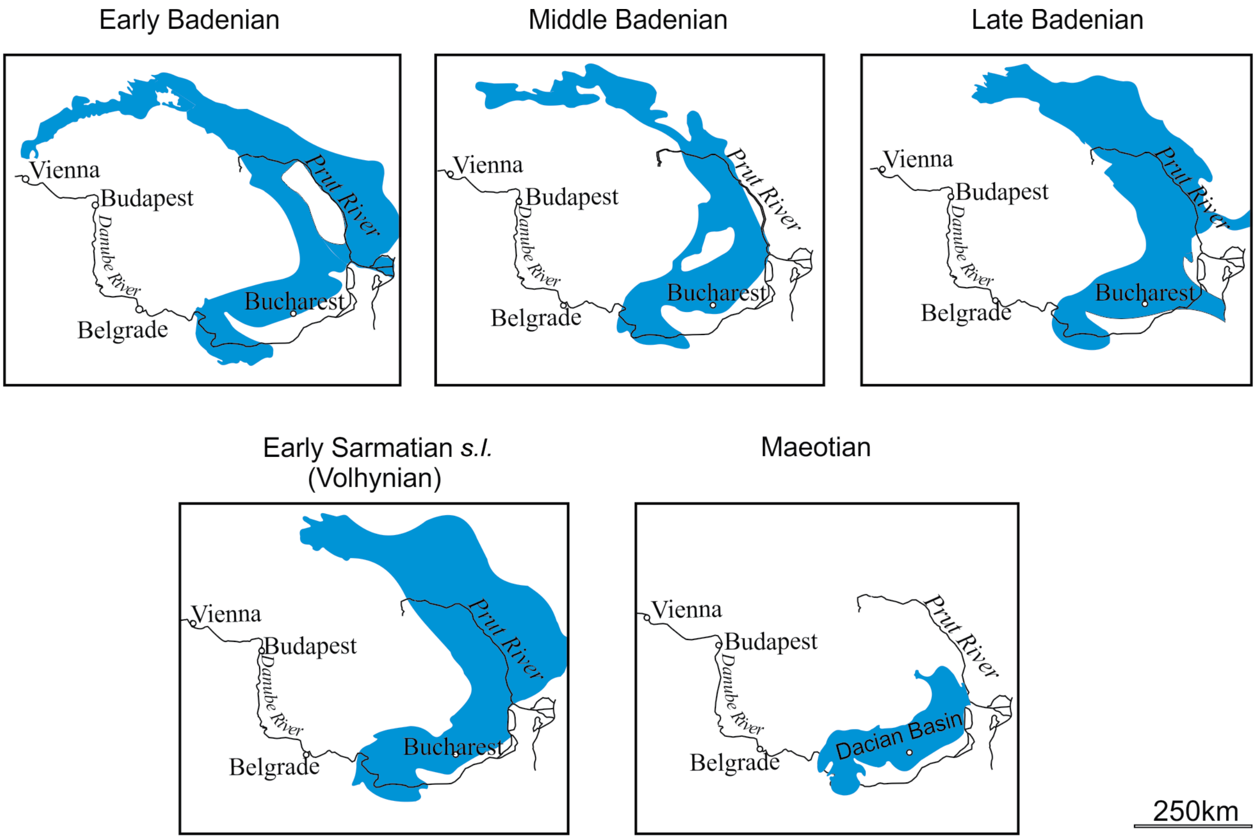


Fig. 9. Areal, along-arc migration of the successively younger Neogene sediment accumulations from the Carpathian Foredeep and the western foreland. The migration is revealed by the shifting of the western/northwestern end of the sedimentation area. Simplified from Hamor *et al*. (1988).

The Sanders *et al*. (1999) thermochronology study pointed out the connection between the Eastern Carpathians erosion history and tectonic evolution, revealing the main lines of the Dacian Basin early development. According to Sanders *et al*. (1999), subsequent to the Oligocene start, the Carpathians uplift reached the climax in the Late Badenian - Sarmatian time (15 - 11 Ma), triggered by the European continental margin underthrust. The uplift activated a strong erosion process and, implicitly, a vigurous clastic material influx for the Dacian Basin initial stage. This explains the occurrence of the coarse-grained, Late Sarmatian *s.l.* sediment accumulation in the base of the Dacian Basin sedimentary succession.

Developed between the Eastern and Southern Carpathians Orogen and their foreland (the Moldavian, Scythian and Moesian platforms), the Dacian Basin is considered a foreland basin. Leveer (2007) regards the Dacian Basin as the post-collision foreland of the Romanian Carpathians. Actually, the foreland basin quality belongs to the entire Carpathian For-

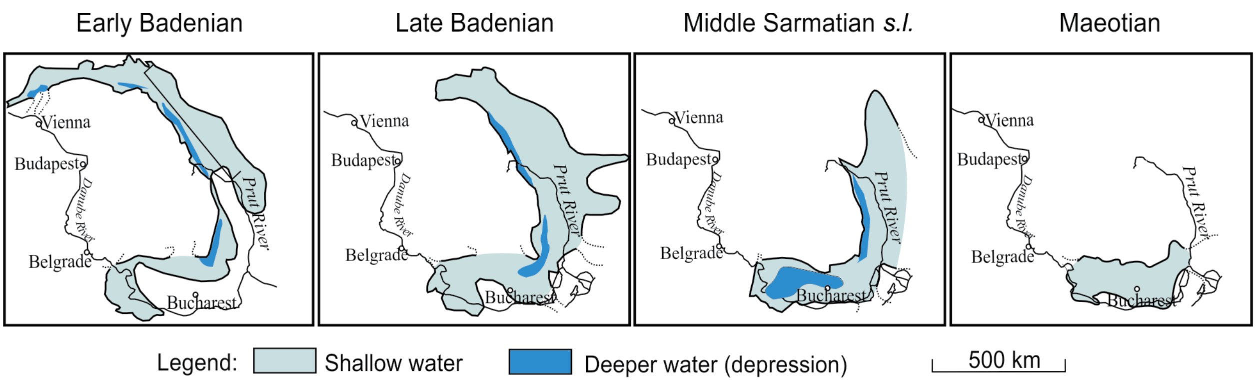


Fig 10. Middle and Late Neogene Carpathian Foredeep (and western foreland) sediment accumulations. The western or northwestern extremities of the sediment accumulation area are shifting, revealing the migration along the longitudinal axis of the foredeep basin. Simplified, from Popov *et al*. (2004).

deep. It is due to the Dacian Basin only as a component of the Carpathian Foredeep.

The structural-tectonic identity of the Dacian Basin is discussed by Rabagia *et al*. (2006). The authors' opinion is that no Dacian Basin subsidence mechanism can be defined, due to the heterochronic characteristic of the basin deformation, as well as to the absence of the Bessarabian discordance, in some parts of the basin.

Dacian Basin sedimentary area. A specific Carpathian source-area supplied the Dacian Basin. The Dacian sediment accumulation area is the sole collector of the Carpathian clastic material influx (Jipa and Olariu, 2009**,** 2013). The detrital supply is dispersed within a closed depresionary area. This makes the Dacian Basin a distinct, independent clastic sedimentary system.

Dacian Basin-brackish sea with decreasing salinity. Brackish fauna, along with normal marine fauna, was found in the Late Badenian deposits underlying the Dacian Basin sedimentary succession (Popa-Dimian, 1962; Y. Babucea and A.M. Piliuta, in Marinescu, 1978), which reveals the beginning of the salinity drop. The brackish fauna turned dominant during the Late Sarmatian *s.l*., in the same time with the onset of the Dacian Basin sediment accumulation.

The Late Sarmatian *s.l*. salinity drop is a feature of the entire Paratethys, not only of the Dacian Basin. As a result of the second isolation stage of the Paratethys Domain, the brackish condition started to be set up since the Badenian within the whole Paratethys (Rőgl, 1998). Based on bioecological information, the water salinity state was evaluated to 16-18 ‰ in the Pannonian and Dacian basins**,** and to 14-15 ‰ in the Euxinian and Caspian basins (Kojumdgieva, 1969).

Dacian Basin – the Carpathian Foredeep in the final migration stage. The along-arc migration of the sediment accumulation area (Figs. 9 and 10) marked the evolution of the Carpathian Foredeep. In this context, the Dacian Basin relates to the last development phase of the migration**;** therefore, the Dacian Basin stands for the southern Carpathian Foredeep.

4. CONCLUSIONS

The Dacian Basin is the effect of several large scale geological events. Analyzing unconnectedly the major characteristics of the Dacian Basin, none of these events could confer**,** alone**,** full identity to the basin.

The sediment accumulation unit named Dacian Basin is, however, a tenable notion. The viability of the Dacian Basin concept is jointly granted by the final stage of the Carpathian Foredeep along-arc migration, the summit of the Carpathian orogenesis, the closed basin relief**,** and the drastic salinity change of the Paratethys sea. Accordingly, the Dacian Basin can be defined as the southern foredeep area outlined after a long migration process, where the sediment accumulation was stimulated by an orogenic climax and organized within a closed-morphology basin and in a brackish-water ecosystem.

REFERENCES

Hámor, G. *et al*. (Eds**.**), 1988. Neogene paleogeographic atlas of Central and Eastern Europe. Hungarian Geological Institute, Budapest**.**

Harzhauser, M., Piller, W.E., 2004. Integrated stratigraphy of the Sarmatian (Upper Middle Miocene) in the western Central Paratethys. *Stratigraphy***, 1***/1,* 65-86.

Hohenneger, J., Ćorič, S., Wagreich, M., 2014. Timing of the Middle Miocene Badenian Stage of the Central Paratethys. *Geologica Carpathica***, 65**/*1*, 55-66.

Jipa, D.C., Olariu, C., 2009. *Dacian Basin. Depositional architecture and sedimentary history of a Paratethys sea. Geo-Eco-Marina Special Publication*, **3**. GeoEcoMar, Bucharest. 264 p.

Jipa, D.C., Olariu, C., 2013. Sediment routing in a semi-enclosed epicontinental sea: Dacian Basin, Paratethys domain, Late Neogene, Romania. *Global and Planetary Change***, 103**, 193-206.

Kojumdgieva, E., 1969. *Les fossiles de Bulgarie. VIII. Sarmatien*. Académie Bulgare des Sciences**,** 223 p.

Krijgsman, W., Stoica, M., Vasiliev, I., Popov, V.V., 2010. Rise and fall of the Paratethys Sea during the Messinian Salinity Crisis. *Earth and Planetary Science Letters***, 290**, 183 -191.

Laskarev, V., 1924. Sur les équivalents du Sarmatien supérieur en Serbie. Recueil de traveaux offert à M. Jovan Cvijič par ses amis et collaborateurs**,** 73-85. Drzhavna Shtamparija. Beograd**.**

Leveer, K. A., 2007. *Foreland of the Romanian Carpathians. Controls on late orogenic sedimentary basin evolution and Paratethys paleogeography*. PhD thesis, Vrije Universiteit Amsterdam**,** 182 p.

Marinescu, F., 1978. *Stratigrafia Neogenului superior din sectorul vestic al Bazinului Dacic*. Editura Academiei**,** 156 p.

Meulenkamp, J.E., Kovac, M., Cicha, I., 1996. On Late Oligocene to Pliocene depocentre migrations and the evolution of the Carpathian-Pannonian system. *Tectonophysics***, 266**, 301-317.

Oszczypko, N., Oszczypko-Clowes, M., 2012. Stages of development in the Polish Carpathian Foredeep basin. *Central European Journal of Geosciences***, 4**/*1*, 138-162.

Pană I., 1966. Studiul depozitelor pliocene din regiunea cuprinsă intre Valea Buzăului și Valea Budureasa, Inst. Geol.**,** *St. Tehn. Econ*., **J**, *1*, 136 p.

Popa-Dimian, E., 1962. Contribuții la studiul paleontologic al Tortonianului din Subcarpați (Crivina și Valea Muscelului) cu privire specială la stratele cu Venus konkensis. *Dări de Seamă*. Șed. Com. Geologic, **XLVII**, 185-198.

Papaianopol, I., Jipa , D., Marinescu, F., Ţicleanu, N., Macaleţ, R., 1995. *Upper Neogene from the Dacic Basin*, Guide to Excursion B2, Xth RCMNS Congress, *Rom. J. Stratigraphy*, **76**/*1*, 43 p.

Popov, S.V., Rögl, F., Rozanov, A.Y., Steininger, F.F., Shcherba, I.G., Kovac, M. (Eds.), 2004. Lithological-Paleogeographic maps of Paratethys. Late Eocene to Pliocene, *Courier Forschungsinstitut Senckenberg*, **250**, 46 p.

Rögl, F., 1998. Paleogeographic considerations for Mediterranean and Paratethys seaways (Oligocene to Miocene), *Ann. Naturhist. Mus. Wien*, **99A**, 279-310.

Rögl, F., 1999. Mediterranean and Paratethys, facts and hypotheses of an Oligocene to Miocene paleogeography (Short overview), *Geologica Carpathica*, **50**/*4*, 339-349.

Rabagia, T., Tarapoanca, M., Matenco, L., 2006. *In ce masura se poate defini un "Bazin Dacic" din punct de vedere structural - tectonic?* www.danubianenergy.com. 32 pp.

Sanders, C.A.E., Andriessen, P.A.M., Cloetingh, S.A.P.L., 1999. Life cycle of the East Carpathian orogen: Erosion history of a doubly vergent critical wedge assessed by fission track thermochronology, *Journal of Geophysical Research*, **104**, 95-12.

Saulea, E., Popescu,I., Săndulescu, J., 1969. *Atlas litofacial. VI – Neogen, 1:200.000*. Institutul Geologic, București. 11maps.

Săndulescu, M., 1984. *Geotectonica Romaniei*, Editura Tehnică**,** 335 p.