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The correlation of the Neogene of Central and Eastern Paratethys segments of Ukraine with the International Stratigraphic Chart based on planktonic microfossils

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Abstract: Detailed analysis of microplankton occurrence (planktonic foraminifera, nannoplankton, dinocysts) in Neogene sediments situated at the north-western and south-eastern margins of Ukraine enabled us to distinguish 10 associations of oceanic plankton which specified the relative age of lithostratigraphic units of various regions and were used as correlation levels within the Central and Eastern Paratethys strata. Moreover, an attempt to correlate regional stages and the International Stratigraphic Chart (ISC) is performed. The Oligocene/Miocene boundary (of ISC) represented by the correlation level I was placed within the Central Paratethys regional stage Egerian and in the middle part of the Eastern Paratethys regional stage Caucasian s.l. The latter regional stage is subdivided by the correlation level into two substages: Lower Caucasian (Chattian of ISC) and Upper Caucasian (Aquitanian of ISC). The correlation level II was placed within the upper part of the Eggenburgian and lower part of the Batisifonian (Sakaraulian) regional stages and is correlated approximately with the middle part of the Burdigalian (of ISC). The base of the Middle Miocene is marked by level IV and was recognized only in deposits of the Eastern Paratethys belonging to the Tarkhanian regional stage. This level corresponds to the lowermost Badenian and Langhian (of ISC) stages. Correlation level V is traced in the Konkian sediments of the Eastern Paratethys and is compared with the Upper Badenian and Lower Serravalian (of ISC) stages. Level VI at the Middle/Upper Miocene boundary is situated in the middle part of the Bessarabian regional substage of the Eastern Paratethys and enables its correlation with the Serravallian/Tortonian boundary (of ISC). Level VII is recognized in the Baherovo Member (Meotian stage), while level VIII is fixed at the top of the Meotian regional stage in the Azov and Black Seas, Crimea and adjacent region named Northern Prichornomorye. Both these levels are also identified in the Berezhnytsya Formation of the Eastern Carpathian Foredeep. Correlation of these sediments is similar to the correlation of sediments of Lake Pannon (Pannonian regional stage), hence with the Tortonian stage (of ISC). Level IX was recognized in sediments of the Azov Member belonging to the Kimmerian regional stage of the Eastern Paratethys and represents the top of the Miocene strata. Level X occurs within the Taman Member of the Black Sea shelf and is correlated with the upper part of Kuyalnikian regional stage; corresponding to the Pliocene/Pleistocene boundary.

Key words: Neogene, Paratethys, biostratigraphy, plankton correlation levels, foraminifers, nannoplankton, dinocysts.

Introduction

The territory between Africa and the European Platform documents a very complex geodynamic development during the whole Cenozoic era (e.g. Kováč et al. 1998; Schmid et al. 2008; Ustaszewski et al. 2010; Handy et al. 2010, 2014). Convergence between these plates led to extreme geodynamic and paleogeographical changes associated with subduction, collision, folding and thrusting of the meso- and neo-Alpine complexes of accretion wedges and emersion of the paleo-Alpine consolidated rear parts of the orogenic systems. These processes leading to development of mountain chains were followed by disintegration of the Alpine Tethys. In the south, the domain of the Mediterranean–Tethys persisted, while the rest of the Valais–Penninic–Magura oceanic realm in the north, together with flooded margins of the European platform and flanks of Alpine-Carpathian orogen represented the realm of the Paratethys Sea (Laskarev 1924), continuing toward the east in the regions of the present Black and Caspian Seas, so covering areas between the Caucasus and Pontides.

From the Late Chattian, the connection between the basins of both aforementioned systems was unstable — the marine straits developed or were destroyed depending on tectonics and sea level changes. Partial or total isolation of individual basins of the Paratethys Sea began to be more and more pronounced in the Miocene to Quaternary times.

The Neogene Paratethys Sea was linked to the Mediterranean for a shorter or longer period through the Alpine Foredeep (Rhone Depression), Northern Dinarides (Slovenia) and through the Aegean and Black Sea regions — possibly also through the territory of Iran and Afghanistan on the east. These links depended upon tectonics of the Alpine chains as well as the development of the Ponto–Taurides and Iranian mountain systems, and evidently also on glacioeustatic fluctuations of the World Ocean.

The changes in Paratethys Sea paleogeography were clearly reflected in faunal evolution — therefore Seneš (1961, 1963)

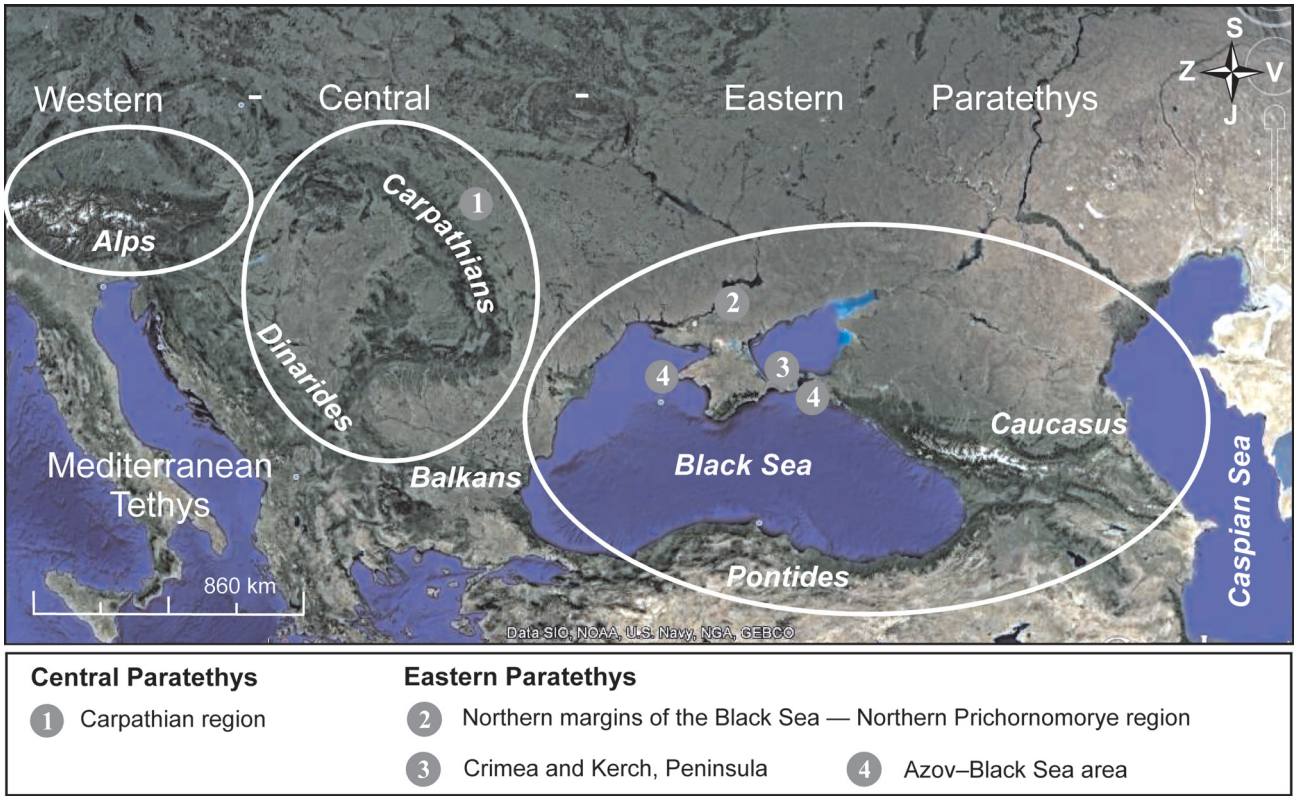

Fig. 1. Neogene basin systems of the Mediterranean Tethys and Paratethys.

considers this region as an independent trans-European bioprovince (Seneš & Cicha 1967) which was divided into three segments (Fig. 1) — Western (Alpine), Central (Carpathian, Balkan) and Eastern (Crimean–Caucasian) Paratethys. The Western Paratethys comprised the region of the Alpine Foredeep (Alpine Molasse Zone) in front of the French, Swiss, German, and Austrian Alps, and the marine sedimentation was restricted only to Early Miocene time. The Central Paratethys included the Carpathian Foredeep and basins of the easternmost margin of the Alps, Carpathians, Pannonian Basin System and basins of the Internal Dinarides and Balkans. The marine sedimentation and short living relations between the Mediterranean and this region existed not only during the Early but also in the Middle Miocene. The Euxinian–Caspian region belongs to the Eastern Paratethys. The accumulation of marine sediments occurred longer here than in the Central Paratethys, up to the Late Miocene–Pliocene–Quaternary times.

History, fundamentals and creation of correlation levels

The problem of recognition of stratigraphical boundaries in the system of Neogene sequences of the Central and Eastern Paratethys, their position in various regions, substantiation and specification of the age of regional stages, as well as correlation with the stages of the International Stratigraphic Chart is a subject of continuous discussion till today. First of all, this problem is connected with the absence of continuous marine sections with pelagic micro-organisms, different development of semi-isolated basins of the Paratethys realm, and also because the level of study of plankton is evidently insufficient (in spite of the long history of investigations of Neogene deposits, but mainly only in marginal facies).

The first, broadly accepted *Neogene stratigraphic scale for the South of Russia and Ukraine* was created by Andrusov (1965) on the basis of mollusc fauna analysis (as other groups were not investigated at that time). He recognized a number of cycles, each of them beginning with deposits with rich marine fauna and ending with a monoform association. These cycles reflected changes in the hydrological regime and were later confirmed by geochemical research in stratotype areas, in particular in rocks of the Kerch Peninsula (Semenenko 1993, 2001, 2003, 2005). The "*Andrusov division of the Ponto-Caspian Neogene*" was later confirmed by study of microfauna as well (benthic foraminifers, ostracodes, etc.). It is necessary to emphasize, that all the information given in this research on basic sections of stratotypes (originally proved with mollusc fauna) was later confirmed. The Lower Miocene biostratigraphy was worked out by Nosovsky and co-workers (Nosovsky et al. 1976; Nosovsky & Bogdanovich 1980; Nosovsky 2001) and the Upper Miocene and Pliocene by Semenenko and Gozhyk (Semenenko 1993, 2001, 2003, 2005; Gozhyk 2006; Gozhyk & Datsenko 2007).

It is also necessary to note difficulties of correlation between the stratigraphy of the individual Ponto-Caspian basins and the Mediterranean time scale, which is far from complete — as is proved by the recognized break between

the Tortonian and Zanclean filled with the time of the Messinian evaporite deposition. Therefore, the plankton scale of the Atlantic realm does not coincide with the zonal Pliocene scale of the Mediterranean. However, in the Western and Eastern Black Sea depressions the inherited character of deep-water marine sedimentogenesis has been traced since the Early Paleogene, and nannoplankton and foraminifer associations found in this most complete section enable us to carry out direct correlations with oceanic time scales. Moreover, the cyclicity traced in the Neogene marine sediments of the Azov-Black Sea region is precisely reflected in complexes of various facial compositions on seismic profiles as abiotic events (Maslun et al. 2007), and is also clearly manifested in the development of the microplankton biota — that enabled us to substantiate the recognition of some correlation levels.

Using all published materials on microplankton from the territory of Ukraine, including new, often unpublished data we attempted to carry out biostratigraphic correlation of the Paratethys Sea Neogene sediments. The review attempted to specify maximally the Regional Neogene Chart/Time Scale of the Central and Eastern Paratethys for the territory of Ukraine and to correlate it with the International Stratigraphic Chart/Time Scale (ISC). The papers of Piller et al. (2007), ter Borgh et al. (2013) and Neubauer et al. (2015) were used as etalon/standard for division of the Central Paratethys Neogene, as well as the Mediterranean stages affirmed in ISC (Gradstein et al. (ed.) 2012). For the Eastern Paratethys Neogene the following regional divisions were adopted: Caucasian, Batisifonian (Sakaraulian and Kotsakhurian), Tarkhanian, Chokrakian, Karaganian Konkian, Sarmatian, Meotian, Pontian, Kimmerian, Kuyalnikian (Akchagilian),

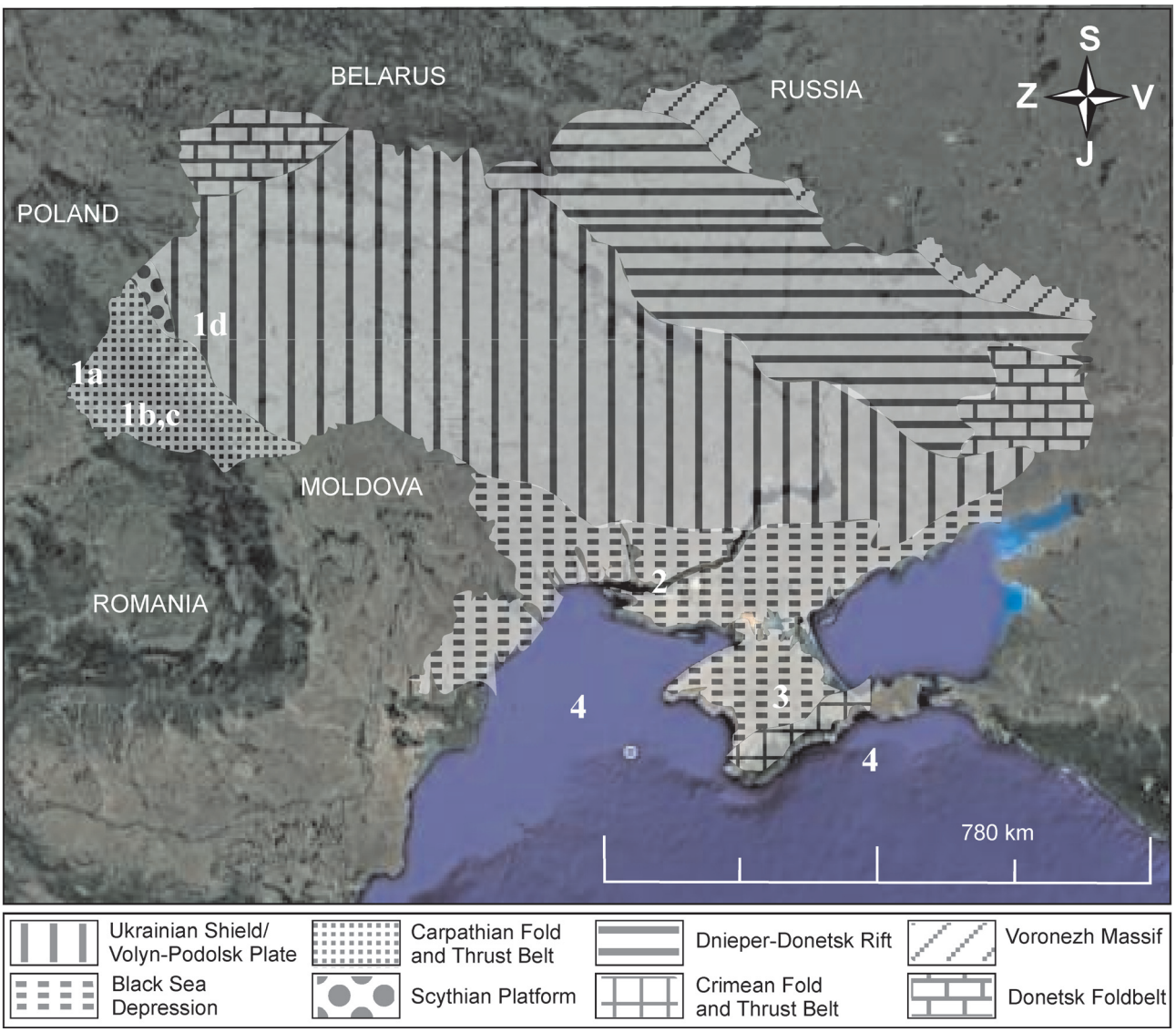

Fig. 2. Distribution of the Neogene deposits of Ukraine. Explanatory notes: Study areas of the Carpathian region — ***Central Paratethys***: 1a — Transcarpathian Basin, 1b — Outer Carpathian nappe units, 1c — Carpathian Foredeep, 1d — Adjacent part of the Eastern European Platform. Study areas of the ***Eastern Paratethys***: 2 — Northern margins of the Black Sea — Northern Prichornomorye region, 3 — Crimea and Kerch Peninsula, 4 — Azov-Black Sea area.

and Apsheronian — modifying the division of Popov et al. (2004), Vasiliev et al. (2011) and Stoica et al. (2013).

For the purpose of definition of correlation levels, the most complete sections of the Central Paratethys were studied in north-western Ukraine (Transcarpathian Basin, Outer Carpathian nappe units, Eastern Carpathian Foredeep and the adjacent part of the Eastern European Platform). The Eastern Paratethys sequences were studied in south-eastern Ukraine, at natural sections and boreholes in the Northern Prichornomorye region adjacent to the Crimea and Kerch Peninsula and the Azov-Black Sea area (Fig. 2). The results of integrated techniques were used as well, including bio-, litho-, cyclo- and magnetostratigraphic investigations for some temporal intervals. The detailed analysis of the distribution of microfossils (planktonic foraminifers, nannoplankton and dinocysts) in the Neogene deposits enabled us to recognize 10 associations of marine plankton (correlation levels) that gave a possibility to specify the age and diachronous nature of lithostratigraphic units and so contributed to division of the Neogene sedimentary record. Definition of levels with similar associations of marine plankton also enabled correlation in the framework of the Central and Eastern Paratethys regional stages and demonstrated their positions in relation to the ISC stages.

Definition of the correlation levels

Correlation level I represents the lower boundary of the Neogene time interval. It is substantiated by three planktonic groups in the Carpathian region and traced by the last appearance of the dinocysts *Membranophoridium aspinatum*, *Chiropteridium galea*, nannoplankton assemblage with *Sphenolithus delphix* and the first appearance of the planktonic foraminifer *Globoquadrina dehiscens*. It is traced in the middle part of the Grushevo Formation of the Transcarpathian Basin (eastern part of the Central Paratethys) and in the upper part of the Krosno and Menilite formations of the Outer Eastern Carpathians of Ukraine (Andreeva-Grigorovich 2004). In the Eastern Paratethys realm, the lower boundary of the Miocene is substantiated by dinocysts. It is conventionally traced in the rhythmic flysch-like sequence belonging to the Caucasian regional stage (Karadzhalganian — see e.g. Neubauer et al. 2015), which was recognized as an analogue of the Aquitanian on the basis of benthic foraminifers, ostracods, spores and pollen. Due to the almost complete absence of carbonate facies, the nannoplankton and planktonic foraminifers are present only in the borehole sections of the Azov-Black Sea aquatory. The boundary is conventional and is traced in the rhythmic flysch-like sequence of the Kerleut Formation (Maslun et al. 1989, 2005, 2007; Gozhyk et al. 2006; Gradstein et al. (ed.) 2012) accounting for the change of complexes with *Globigerina ciperoensis*, *Gl. praebulloides* and the biota complex without foraminifers but with a significant content of sponge spicules and fish skeletons. Higher, at the level of the NN1 Zone, a mixture of the Oligocene and Lower Miocene foraminifers is found. This situation is characteristic for the interval of "*Maikop sediments*" practically of the whole Crimean-Caucasian region. On this basis the Caucasian regional stage s.l. was divided into two substages: Lower Caucasian s.str (Oligocene) and Upper Caucasian (Lower Miocene) in the interval from 23.03 Ma (lower boundary of the Aquitanian) — to ~20.43 Ma was placed the lower boundary of the Sakaraulian and Burdigalian stages.

The Chattian/Aquitanian boundary in the Central Paratethys deposits of Ukraine has been placed in the Grushevo, Krosno, and Menilite formations and ranked as the Egerian regional stage (Fig. 3). In the Eastern Paratethys, it is traced between the Lower Caucasian regional sub-stages (Chattian) which include the Askania, Gornostay and a part of the Kerleut formations and the Upper Caucasian (Aquitanian) which includes the Chernobaivsk, Batisifon, and Arabat formations and the top — upper part of the Kerleut Formation (Fig. 4).

Correlation level II traced in the nannoplankton zone NN3 contains the foraminifers *Globigerinoides primordius*, *Globigerinella obesa* and was recognized in the upper part of the Illichivsk Formation of the Azov and Black Sea shelf and is considered to be an analogue of the upper part of the "Batisifonian Formation" of Crimea and related to the Batisifonian regional stage (Sakaraulian and Kotzakhurian — see e.g. Neubauer et al. 2015). In the Central Paratethys we compare these deposits with the Burkaliv Formation (Transcarpathian Basin) deposited in the eastern part of the Central Paratethys and to the lower part of the Stebnik Formation (Carpathian Foredeep) ranked approximately to the Upper Eggenburgian and Lower Burdigalian of the ISC (Andreeva-Grigorovich 2005).

Correlation level III is substantiated through the analysis of available data on the nannoplankton and foraminifers, which enabled us to recognize the boundary of the Lower–Middle Miocene deposits of the Alma Depression. The complex of nannoplankton from zone NN4 and the foraminifer *Globigerinoides bisphericus* in turn enabled us to correlate these deposits with the Batisifonian and the lowermost Tarkhanian (Kamyshlak Member). Therefore, the Lower Miocene deposits of the Eastern Paratethys in the territory of Ukraine incorporate the upper part of the Caucasian s.l. and Batisifonian regional stages and can be correlated with the Central Paratethys regional stages: upper part of the Egerian, Eggenburgian, Ottnangian and Karpatian and compared to the Aquitanian and Burdigalian stages of the ISC (Figs. 3 and 4).

The position of the Lower and Middle Miocene boundary, both in the stratotype site (Kerch Peninsula) and the whole Eastern Paratethys is a subject of discussion. Various scientists have traced it differentially. Andrusov (1965) put it at the base of the Chokrakian regional stage, Zhizhchenko and Merklin related it to the base of the Tarkhanian, moreover Nosovsky and co-authors (Nosovsky et al. 1976) expanded the volume of the Tarkhanian including into it the Kamyshlak Member (Lower Tarkhanian), layers with *Lentipecten denudatum* (Middle Tarkhanian or Tarkhanian s. str.) and the Yurakivka Member (Upper Tarkhanian or Spirialis clays). They traced the Middle Miocene boundary at the bottom of the Kamyshlak Member (Tarkhanian s.l.). Later, Nosovsky and co-authors considered the greater part of the Spiralis clays as the Chokrakian deposits and traced the Middle Miocene boundary at the base of the Chokrakian regional stage again (Nosovsky 2001).

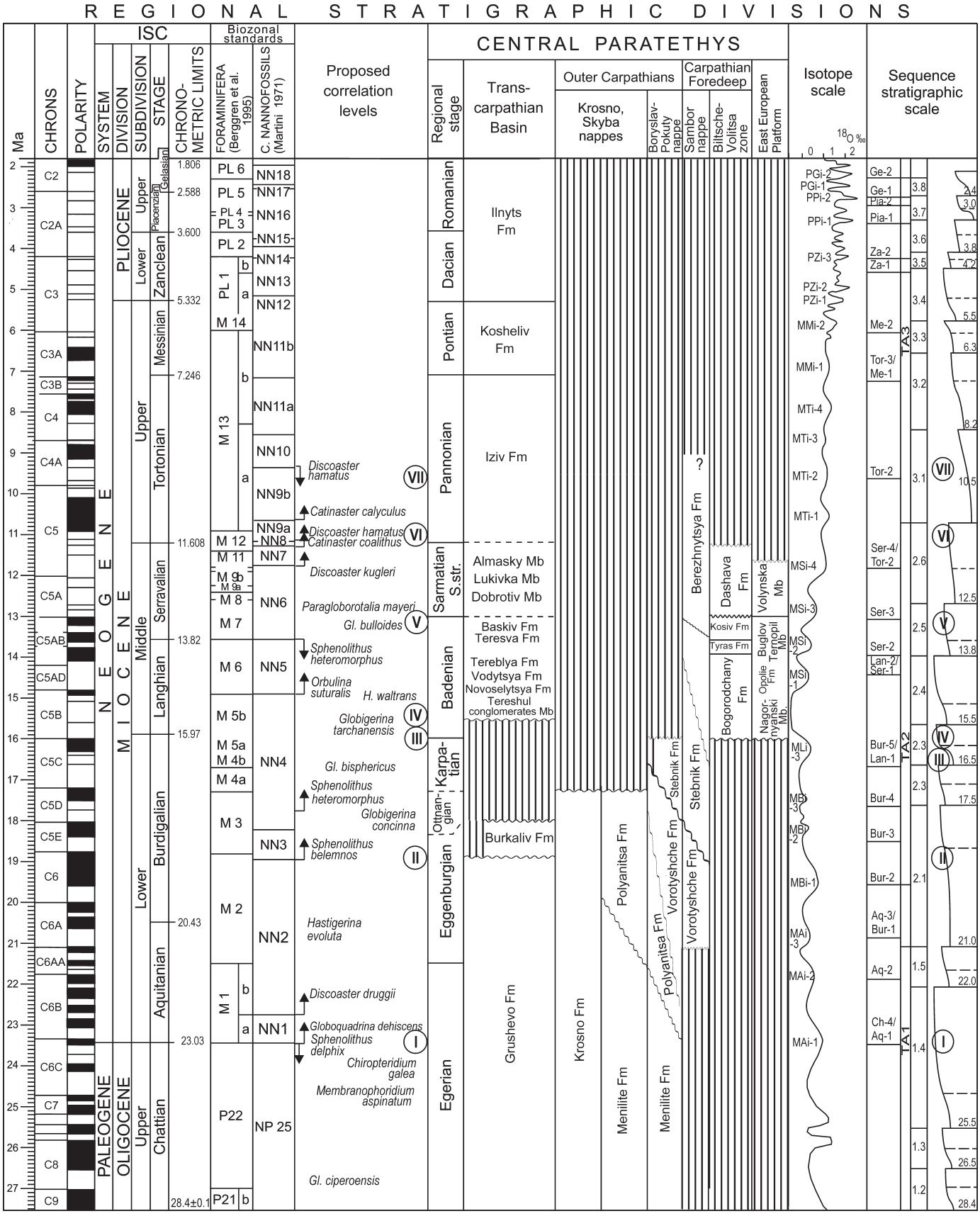

Fig. 3. Correlation of the Neogene sediments of the Central Paratethys of Ukraine with the International Stratigraphic Chart (Gradstein et al. 2012).

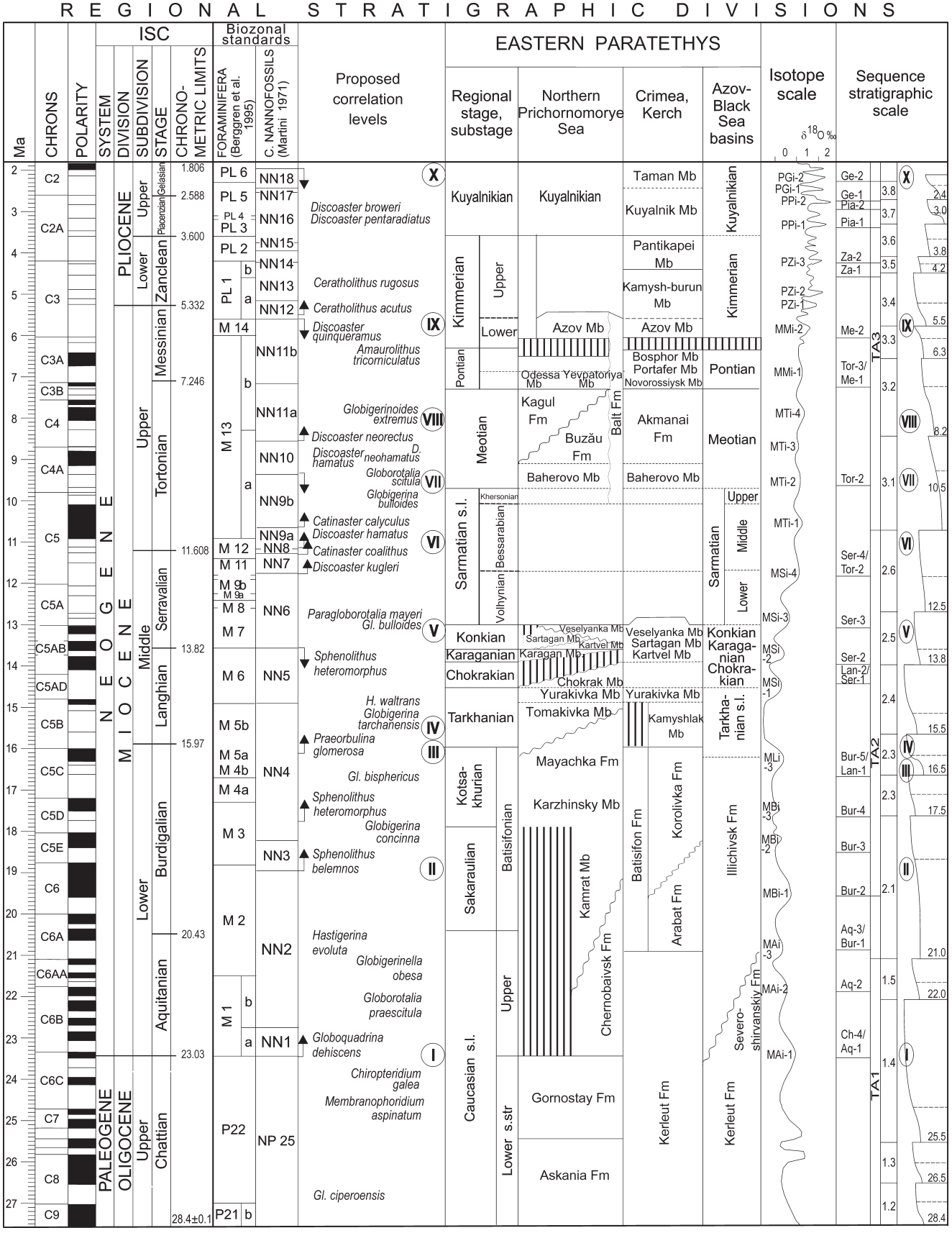

Fig. 4. Correlation of the Neogene sediments of the Eastern Paratethys of Ukraine with the International Stratigraphic Chart (Gradstein et al. 2012).

In the Sambor Zone of the Eastern Carpathian Foredeep, the Lower/Middle Miocene boundary is diachronous and is traced in the sub-salt bearing layers with the complex of nannoplankton of the NN4 Zone — which is also recognized in the upper part of the Stebnik Formation and the lower portion of the Balychi Formation. In the Biltsche-Volitsa Zone of the Eastern Carpathian Foredeep and within the sedimentary cover of the Eastern European Platform, the base of the Middle Miocene deposits (Lower Badenian regional substage) occur in the basal part of the Bogorodchany Formation, as well as at the basis of the Nagornyanski Member containing nannoplankton of the NN4 Zone upper part (Fig. 3). The overlying Opolie Formation on the platform contains the NN5 and M6 zones. In the Transcarpathian Basin the Lower Badenian sediments were deposited above an erosional surface. They are built up by the Tereshul Conglomerate Member of the Novoselytsya and Vodytsya formations (NN5 Zone — *Sphenolithus heteromorphus* and M6 — *Orbulina suturalis*).

Correlation level IV with nannoplankton of the NN5 Zone and foraminifers *Praeorbulina glomerosa*, *Globigerina tarchanensis* was recognized in deposits of the Tarkhanian Formation s.str. and lower part of the Spirialis Clay. Towards the end of accumulation of the Spirialis Clay and in the Chokrakian time the connection to marine aquatories deteriorated and salinity declined. The benthos is also steadily abundant but as early as in the Karaganian time the connection is lost, and the plankton of the NN5 Zone is found only in the north-western shelf together with the elfidio-nonionella foraminiferal complex (Maslun et al. 2007).

The above mentioned facts indicate significant differences in the foraminiferal plankton associations of the Central and Eastern Paratethys at the beginning of the Middle Miocene. For the Eastern Paratethys the most characteristic is an older complex that includes the top of zone NN4 and lower portions of the NN5 Zone together with a foraminifer association with *Praeorbulina glomerosa*. In the Central Paratethys, this interval in the majority of regions is distinguished by a sedimentation break, and the Lower Badenian is represented by the calcareous nannoplankton zone NN5 and foraminifers with *Orbulina suturalis*. The data stated above enabled us to compare the Tarkhanian, Chokrakian and Karaganian regional stages of the Eastern Paratethys with the Lower Badenian in the Central Paratethys and the Langhian stage of the ISC (Figs. 3 and 4).

At the end of the Early Badenian (NN5) and beginning of the Late Badenian (NN6) salt accumulation took place in the Transcarpathian Basin and Carpathian Foredeep. The established **correlation level V** enables us to correlate deposits of the Eastern Paratethys Konkian stage with the Upper Badenian substage of the Central Paratethys and the Lower Serravalian of the ISC. In the Eastern Paratethys, the typical marine sedimentation is renewed after the partial isolation and desalination that is indicated by the appearance of the marine nannoplankton association of the NN6 Zone and foraminifers *Globigerina bulloides*, *Gl. cognata*, *Paragloborotalia mayeri* and others at the base of the Konkian (Andreeva-Grigorovich & Nosovsky 1976; Maslun et al. 2006). In the Central Paratethys, the marine sedimentation continued during the whole Late Badenian; in sediments nannoplankton of the lower part of the NN6 Zone was recognized, as well as the planktonic foraminifera *Globigerina bulloides*, *Gl. concinna*, *Velapertina indigena* etc. Only in the latest Badenian the links to the marine aquatories became worse, except in the Sambor zone. The marine association of the NN6 Zone in the Teresva and Baskiv formations became poorer, and euryhaline species with a wide stratigraphic range prevailed (Fig. 3).

The Sarmatian deposits in the Central and Eastern Paratethys usually contain calcareous nannoplankton of the euryhaline species *Braarudosphaera bigelowii*, *Reticulofenestra pseudoumbilicus*, *Calcidiscus macintyrei*, *Sphenolithus abies* that often form monospecies complexes depending on environmental conditions in a sedimentary basin (Andreeva-Grigorovich 2006). Benthic foraminifers are abundant — miliolids, elfidia, sacammines and others predominate. The recognized marine plankton associations of the Eastern Paratethys in sediments of the Sarmatian s.l. enabled us to specify the time span of the Sarmatian s.str. in the Central Paratethys (Fig. 3) and to put the **correlation level VI** inside the Bessarabian regional sub-stage (Fig. 4), as well as to substantiate the Middle/Upper Miocene boundary.

In sediments dated as the Sarmatian and Pannonian regional stages (Slovakia, Poland, Romania, and Ukraine) the nannoplankton of zones NN6, NN7, NN8, NN9, NN10 and NN11 have been recognized. For the Eastern Paratethys, the nannoplankton of the NN8 Zone was found for the first time in the Middle Sarmatian deposits of Georgia, then in the Near-Azov region (Semenenko 2003; Semenenko et al. 2009), sections of the Azov-Black Sea shelf (Semenenko 1987; Maslun et al. 1989; Gozhyk et al. 2010) and in the Dacian Basin in Romania (Mărunțeanu 1977, 1991, 1999; Lulieva 1991; Semenenko & Lulieva 2006) and so together with the NN9a in the Eastern Slovakia part of the Transcarpathian Basin), it represents the **correlation level VI.**

The Middle Miocene Langhian and Serravallian stages (of ISC) correspond in the Central Paratethys to the Badenian and Sarmatian s.str. regional stages, and the Middle/Upper Miocene boundary is situated at the top of the Sarmatian s.str. (Fig. 3). In the Eastern Paratethys region, the Middle Miocene includes the Tarkhanian, Chokrakian, Karaganian, Konkian, Lower Sarmatian s.l. — Volhynian sub-regional stage, and the lower part of the Middle Sarmatian s.l. — Bessarabian sub-regional stage. The Middle/Upper Miocene boundary is traced in the middle part of the Bessarabian sub-regional stage (Fig. 4).

Correlation level VII corresponds to the marine plankton association with *Discoaster hamatus*, *D. neohamatus*, *D. neorectus* and others (NN9–NN10 zones) and planktonic foraminifers *Globigerina bulloides*, *Gl. brevispira*, *Globorotalia scitula*, *Globigerinoides trilobus*, *Paragloborotalia mayeri* and abundant benthic foraminifers. It is traced in the Meotian sediments of the Baherovo Member and Akmanai Formation at the Kerch Peninsula and Azov-Black Sea region (Maslun et al. 1989, 2007; Shniukov & Grigorjef 1990; Gozhyk et al. 2011). In the Central Paratethys, the analogous nannoplankton associations without planktonic foraminifers are found in the lower part of the Berezhnytsya Formation

(marine analogue of the Lake Pannon sediments) in the Sambor Zone of the Carpathian Foredeep in Ukraine, Poland and Romania (Semenenko & Pevzner 1979; Andreeva-Grigorovich 2006). This gives us a reason to compare the Khersonian and Meotian stages of the Eastern Paratethys with the Lower Pannonian deposits of the Central Paratethys and with the Lower Tortonian of the ISC (Figs. 3 and 4).

Correlation level VIII is recognized in the boundary deposits of the Meotian and Pontian regional stages of the Eastern Paratethys (Novorossiysk Member) on the basis of planktonic foraminifers *Globigerinoides extremus* and rare nannoplankton findings (*Amaurolithus primus*, *A. delicatus*, *A. tricorniculatus*) at the top of the Meotian strata. It is necessary to point out the presence of the endemic *Isolithus semenenko* in the Pontian of the Kerch–Taman region and Black Sea coast of the Caucasus (Lulieva 1989). It is also widespread in the Late Pannonian sediments of Austria, Serbia and Croatia (Ćorić 2004).

The Miocene–Pliocene boundary at the level of 5.322 Ma is "fixed" between the Messinian and Zanclean stages of SCI, and most usually between the Pontian and Kimmerian in the Black Sea (Euxine) Basin of the Eastern Paratethys. The position of this boundary in the Central Paratethys is uncertain (e.g. Neubauer et al. 2015).

Correlation level IX is recognized in the sediments of the Azov Member, which belongs to the Kimmerian regional stage (Fig. 4). It is a nannoplankton association with *Ceratolithus acutus* (NN12 Zone). This level is traced in the Dacian deposits of south-western Ukraine (nearby t. Reni — Pevzner et al. 2003). In some sections, *Ceratolithus rugosus* is met together with *C. acutus*. The appearance of nannofossils of the younger NN13 Zone also confirms the Pliocene age of Kimmerian deposits above the Azov Member. This level characterizes the Miocene/Pliocene boundary and therefore should correspond to the Messinian and Zanklean of the ISC.

Correlation level X represents the last appearance of *Discoaster brouweri* and *Discoaster pentaradiatus* (Fig. 4). The Pliocene/Pleistocene boundary in marine sediments (1.8 Ma) is related to the extinction of this genus. This level is recognized in the Taman Member (Middle and Upper Akchagylian) of Eastern Crimea and the Akchagylian sediments of the Caspian Basin (Yasamal valley, Azerbaijan — Semenenko & Lulieva 1978, 2006).

Discussion–conclusions

The recognized *correlation levels* substantiated by microfossils give the possibility of a more exact comparison between the Regional stages of the Central and Eastern Paratethys and the ISC (Figs. 3, 4). The determined marine plankton associations testify to the inherited cyclic sedimentation in the Neogene basins of the Paratethys and enable us to trace possible migration routes of the foraminiferal and nannoplankton biota in the marine water masses of the whole Paratethys.

The presence of the Tarkhanian plankton association (top of NN4 Zone and the lowermost part of NN5 Zone and *Praeorbulina glomerosa*) in the deposits of the northwestern shelf and central depression of the Black Sea in Ukraine, Russia, and Bulgaria (Varna region), the Sea of Azov, and Central Georgia gives a basis for supposing the existence of one whole marine basin system that was united with the Mediterranean region. However, starting in the Late Tarkhanian, the sedimentation regime in the basin changed. The shift in depositional environment was connected with the geodynamics of the Black Sea area, which led to changes in its morphostructure and evidently disturbed the links to the Mediterranean and Central Paratethys regions. Tectonic processes in the Central Paratethys domain were followed later by a vast marine transgression in the Early Badenian (time of nannoplankton NN5 Zone and the first common appearance of *Orbulina suturalis* (Fig. 3).

The determination of oceanic nannoplankton associations in zones NN8 and NN9 in the Sarmatian sediments of the Eastern Paratethys enables us to conclude that the desalination of the Sarmatian basins was not simultaneous for the whole Paratethys and is characteristic for the marginal facies (Figs. 3 and 4). The marine sedimentation continued till the mean time of the ISC Tortonian stage (Middle Sarmatian transgression in the Eastern Paratethys).

The presence of the nannoplankton complexes and planktonic foraminifers in sediments of the Eastern Paratethys during the Early Meotian, Pontian, Kimmerian and Kuyalnikian (Taman Member, Upper Pliocene) testifies to the periodical relations between the Eastern Paratethys and open marine aquatories. The analysis of the available data demonstrates that in the Kimmerian, namely at the Miocene–Pliocene boundary, the Mediterranean, Black and Caspian Seas existed in outlines close to their recent ones. The presence of discoasters in the Upper Pliocene sediments proves the connections of both the Caspian and Black Seas to the Mediterranean Sea till the beginning of the Pleistocene, and in deeper parts of the aquatories the inherited sedimentogenesis is observed in the Quaternary as well.

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