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REGIONAL STRATIGRAPHIC SCHEME OF NEOGENE FORMATIONS OF THE CENTRAL PARATETHYS IN THE UKRAINE

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Abstract: Detailed biostratigraphic schemes of Neogene deposits of the Transcarpathian Basin, Carpathians, Carpathian Foredeep and sedimentary cover of the south-western margin of East-European Platform (the Central Paratethys) are compiled and supplemented by new data. The lower boundary of the Miocene of the Central Paratethys is based on planktonic microorganisms (nannoplankton, foraminifera, dinocysts). This boundary lies in the upper part of the Lower Krosno and Middle Menilite "subformations". New lithostratigraphic units are established on the basis of paleontological data: Grushiv and Zhuriv Formations, and two membered division of the Badenian stage are established. Scheme correlation with the stage scales and biostratigraphic standards (nannoplankton, foraminifera) of the Tethys, the Central and Eastern Paratethys, and also with the adjacent territories of Poland, Rumania, Slovakia, Hungary and Russia was carried out.

Key words: Neogene, Paratethys, Carpathians, Transcarpathian Basin, Carpathian Foredeep, stratigraphic scheme, correlation.

Introduction

The first stratigraphic constructions of the Miocene of Western Ukraine are related to the middle of the last century. The base of stratigraphic division of Miocene section was being worked out during dozens of years by some generations of geologists and paleontologists (Laskarev 1903, 1934; Lomnitsky 1874; Teisseyre 1900; Štúr 1859 etc.).

The development of the stratigraphic scheme of the Miocene in its modern form was completed by the works of Vyalov 1951, 1965, 1981), Glushko (1954), Goretsky (1954, 1964), Grishkevich (1961), Kudrin (1953, 1966), Utrobin (1958), Voloshina (1958), Venglinsky & Goretsky (1979), Pishvanova (1972) and Pishvanova & Gruzman (1980). Below a description of Miocene stratigraphy is given, based on the results of the investigations of these scientists.

The proposed Unified stratigraphic scheme also includes the results of the latest investigations in stratigraphy and paleontology, data from drilling and geological-geophysical works.

In the explanatory note the results of stratigraphic investigations and of the study of organic remnants (Foraminifera, nannoplankton, mollusks, spores and pollen) are generalized. The question on the location of the Miocene lower boundary is not considered in the explanatory note, because a special article was devoted to this question (Andreyeva-Grigorovich & Gruzman 1994).

Organic remnants of Neogene deposits

Foraminifera

Foraminifera is one of the main fossil groups by which the stratification of the Carpathian flysch and molasse of Carpathian Foredeep is defined. Associations of the Oligocene and Miocene Foraminifera are represented by plankton and benthos. Agglutinated forms are developed sporadically.

The zonal scale by plankton for Oligocene and Lower Miocene of the Flysch Carpathians was worked out by Gruzman (1984), for the Carpathian Foredeep molassa — by Subotina (1960), Pishvanova (1972) and Trofimovich.

Nannoplankton

In this work the scale of Martini & Worsley (1970) is used. The zone boundaries are established by the appearance of index species. The change of nannoplankton associations is taken also into consideration.

Miocene nannoplankton of the Central Paratethys in the Ukraine limits was studied by Andreyeva-Grigorovich (Andreyeva-Grigorovich & Stupnitsky 1976; Andreyeva-Grigorovich & Turchinova 1985; Andreyeva-Grigorovich & Gruzman 1994), Kulchytsky (1981) Lyulyeva & Prysyazhnyuk (1990) and Savitskaya (1995).

Mollusks

Great contributions to study of the mollusk fauna were made by Lomnytsky (1886), Nedzvedzky (1901), Friedberg (1914, 1911-1928, 1938), Kovalevsky (1935), Czarnotsky (1935), Goretsky (1954, 1964), Kudrin (1953, 1966), Zhyzhchenko (1952), Grishkevich (1961), Korobkov (1951), etc.

Ostracods

The results of the study of ostracods laid the foundation for the stratigraphic division of the Pannonian-Pliocene formations (Sheremeteva 1958) and they were also successfully used during comparison of Sarmatian rocks of the Transcarpathians with complexes of the same age from adjoining territories (Buryndina 1974).

The ostracod fauna is most significant for the detailed stratification of the Pannonian and Pontian deposits. The scheme of stratigraphic division of the Pannonian and Pliocene was based on the results of the study of ostracods by Sheremeta (1958) and Vyalov (1981).

Spores and pollen

Palynological investigations of the Neogene deposits of the Carpathian Foredeep and Transcarpathian Basin began in the 1950s. The whole section of Neogene deposits of the Carpathian Foredeep was systematically studied by Shvareva in the 1950s – 1960s (1972) and by Ivanina and Portnyagina — in 1990s. Details of the Upper Miocene-Pleistocene of the Transcarpathian Basin were studied by Rybakova (1975) and Syabryay & Shchekina (1983).

Leaf flora

Floristic remnants (imprints of leaves) in the Neogene of western regions of Ukraine were preserved in the deposits of the Carpathian Foredeep and Transcarpathian Basin and the adjoining part of East-European Platform. They have been known since the end of the last century, but they were not studied in detail.

The purposeful collection and study of flora began in 1958 in UkrNDGRI. Since 1974 it has been carried out in the State Museum of Natural History of the National Academy of Sciences of Ukraine.

Flora from the deposits of the Carpathian Foredeep (locations Kosiv, Verbovets, Shotynka, Myshyn, Dzhurov, Roshnyato) was dated as Upper Badenian (Shvareva 1983). For the Pliocene, the flora was published monographically (Iliinska 1968).

Lithostratigraphic features of Neogene deposits

Transcarpathian Basin

Egerian. The Grushiv Formation (Petrashkevich & Lozynyak 1989) is the lowest division of the Neogene in the Transcarpathian Basin. It is a mass of lime argillites with interbeds of sandstones with a total thickness of about 250 m. The formation is related to the Oligocene-Early Miocene age (Rupelian-Egerian). Its age analogues are considered to be Lazhivsko (Gurevich 1956) and Dunkovytsi Formations.

Eggenburgian. The Burkalo Formation is spread along the north-eastern flank of the deep. It is composed of grey sandstones, aleurolites and sandy carbonate clays, in which more than 100 species of mollusk with the characteristic *Pecten pseudobeudanti* Dep. & Rom., *P.* cf. *burdigalensis* Lamk. with numerous *Tellina*, and rich complex of foraminifers with fish scales, shark teeth and single imprints of leaves were established. These are undoubtedly the typical marine deposits of the subcoastal zone. Its thickness reaches 80 m. To Burkalo Formation it is possible to relate a 7 m thick bed of dark-grey argillites and clays with the interbeds of sandstones which was identified just under the so-called "Klobukh" tuff. In the rocks, a peculiar fauna of fresh-water and salt-water mollusks has been found: *Galba* sp., *Coretus* cf. *cornu* Brogn., *Gyraulus* sp., *Terebralia bidentata* Defr. This witnesses to the fact that sedimentation took place under conditions of an isolated shallow-water basin.

Karpatian. The Tereshul Formation is observed along the north-eastern margin of the deep. It is formed by variegated (cherry-red, greenish and grey) argillites, aleurolites, sandstones and coarse-pebbled conglomerates with rare interbeds of tuffs and tuffites, and also with streaks and nests of gypsum and anhydrite. The thickness of the formation reaches 100–450 m. The rocks are bedded incomformably on different horizons of pre-Neogene formations, and also on the Burkalo Formation. In separate sections of the formation badly preserved foraminifers from the family *Globigerinidae* of Early Miocene and also redeposited Cretaceous and Paleogene forms have been found.

Badenian. The Badenian rocks are subdivided according to lithofacial features into separate formations (upwards): Novoselitsa (Lower Badenian), Tereblya and Solotvyno (Middle Badenian), Teresva and Baskhiv ones (Upper Badenian).

The Novoselytsa Formation is bedded transgressively on Mesozoic and Paleogene deposits of the deep basement and on Miocene rocks of the Burkalo and Tereshul Formations. On the present day surface it is traced as a continuous narrow stripe along the deep north-eastern margin. Its thickness changes from some dozens to 980 m.

The formation consists of light-green to bluish-white rhyolite-dacite tuffs and tuffites with interbeds of grey argillites, marls, aleurolites and tuffogenous sandstones. In some sections in the formation's middle and lower parts, thin beds of conglomerates are found. Their various pebbles are fastened by light-green tuff cement. Sometimes veiny volcanic formations of acid composition are present. A rich complex of foraminifers typical for Candorbulina universa Zone is characteristic of this formation. In the "transitional group of strata" between tuffs and overlapping clays the Uvigerina asperula Zone is singled out, and also a complex of mollusks and brachiopods which point to the typical marine conditions of the sedimentary basin.

The Tereblya Formation is laid conformably on the Novoselytsa one and is represented by terrigeneous-chemogenous formations. Within it one can clearly see the lower mainly

clayey Lower Tereblya "subformation" and the upper halogenous Upper Tereblya "subformation".

The thickness of the lower "subformation" varies from a few metres to 360 m.

The grey and white crystalline salt of the Upper Tereblya "subformation" with packets and lenses of grey clays is bedded as massive bodies in salt cheeks and because of this its thickness changes from the first metres up to 1197 m. In the formation clays a poor complex of small foraminifers is met.

Flysch-like interbedding of dark-grey argillite-like clays and light-grey sandstones, aleurolites, with occasional horizons of tuffs and tuffites, are characteristic of the Solotvyno Formation. Near Solotvyno the horizons (16–20 and 90–110 m) of rhyolite-dacite tuffs are widely spread. In the western direction these horizons are gradually wedging out.

From organic remnants Foraminifera, Radiolaria, single mollusks, echinoids, fish and insect skeletons were found here. The formation's thickness varies from some dozens to 1220 m.

The Teresva Formation in the Solotvyno part of the deep is mainly on the present day surface, and in Mukachevo part of the region it is overlapped by thick formations of the Upper Miocene and Pliocene.

The formation's lower layers in Danylovo-Solotvyno part are composed of sandy-clayey rocks with a great number of pyroclastic formations, among them the most known is the Nankovo horizon of rhyolite-dacite tuffs. Towards the northeastern margin of the deep the formation becomes more sandy and enriched with lenses and thick horizons of conglomerates. In the formation the following "subformations" are distinguished (from below): the Glod, Nankovo, Shandrovo, Nyachiv, Tyachiv and Vulkhivets "subformation".

In the south-western direction, the coarse- and medium-pebbled rocks gradually change into more fine-clastic and clayey formations, so the Teresva Formation becomes lithologically monotonous. The Teresva Formation contains rich remnants of mollusks, echinoids, foraminifers and numerous imprints of leaves.

In the Ruski Komarivtsi area a thick (more than 600 m) intrusive body of granodiorite-porphyries is connected with Upper (and partly Middle) Badenian deposits. The maximum thickness (1770 m) of the Teresva Formation is found in well Apshytsa-1, and in average it is 500–700 m.

The Baskhev Formation completes the Upper Badenian section of the Transcarpathian Basin. It is composed of two lithofacial types of sediment: shallow-water, littoral and comparatively deep-water ones. The first of them is composed of clayey-sandy rocks with thick conglomerates, and the second one is composed of clays and the interbeds of aleurolites and sandstones. Littoral deposits contain rich complexes of marine, salt-water and fresh-water mollusks, and also foraminifers (zone Ammonia galiciana = Ammonia beccarii). The formation thickness is 30–150 m.

Sarmatian. The rocks of the Sarmatian complex are conformably bedded on the Badenian formation, but up the section they are gradually replaced by Pannonian in one case, and in the other — they are eroded, or with a stratigraphic break are overlapped by Dacian-Romanian or Eopleistocene deposits. On the basis of lithological and especially paleontological differences, the Sarmatian rocks are subdivided into the Lower Sarmatian Dorobrativ and Lukiv Formations and the Middle Sarmatian Almash Formation.

The Dorobrativ Formation consists of clays with interbeds of aleurolites, sandstones, tuffs, tuffites and sometimes of conglomerates. The formation contain rich mollusk complexes with *Ceratoderma inopinata* and foraminifers (Anomalina badenensis Zone). The formation thickness reaches 300–800 m.

The Lukiv Formation is lithologically close to the Dorobrativ Formation. In its composition grey carbonate clays prevail with interbeds of aleurolites, sandstones, tuffs, seldom limestones, conglomerates, siderites and dolomites. The rocks contain a great number of mollusks (Cardium transcarpathicum Zone), foraminifers (Quinqueloculina sarmatica and Q. reussi Zones), ostracods and numerous imprints of leaves. The formation's thickness is 50–300 m.

The Almash Formation. In its lower part clays with interbeds of aleurolites, sandstones, occasionally tuffs and tuffites are widely developed. The upper part is formed by clays with thick groups of light-grey sandstones and the interbeds of limestones and coquina, with lenses of coal and interbeds of siderites, dolomites, liparite tuffs and tuffobreccia. The formation contains a rich fauna of mollusks, foraminifers (Porosonion subgranosus Zone with Articulina problema and Bolivina sarmatica Subzones), ostracods, fish skeletons, Diatomeae, plant remnants. The formation's thickness is 30–180 m.

Pannonian. The Iziv Formation is composed of grey, greenish-grey clays with interbeds of sandstones, tuffs, tuffites, limestones. The rocks contain hardly any foraminifers, but ostracods are widely spread, and the marine mollusk complexes are replaced by the salt-water littoral species of *Congeria* and *Melanopsis*. The formation's thickness varies from 50 to 500 m.

Pontian. The Kosheliv Formation overlaps conformably the Iziv Formation and is formed by various-grained sandstones with the interbeds of sandy clays, with lenses and interbeds of lignite. The uppermost part of the formation is represented by variegated (red, greenish and grey) clays and conglomerates. The rocks contain ostracods and fresh-water mollusks (*Planorbis* sp., *Ancylus* sp.). The formation's thickness varies from 100 to 500 m.

Dacian and **Romanian.** The deposits of the Ilnitsa, Gutyn and Buzhor Formations are related to these two stages.

The Ilnitsa Formation includes grey, greenish, sometimes red clays, tuffs, tuffites, tuffosandstones, lignites, limestones, siderites and lava andesites. These rocks unconformably overlay the Kosheliv Formation. On the older Miocene formation of the deep its total thickness reaches 500 m in the western part of Mukachevo area of the deep. The Ilnitsa Formation stratigraphically unconformably are overlain by variegated clays with pebble beds of the Eopleistocene Chop Formation.

The Carpathians and Carpathian Foredeep

Molassa Neogene formation of the Carpathian Foredeep overlays in the most cases the flysch deposits with stratigraphic unconformity; here and there a gradual transition is ob-

Fig. 1a

DIVISION		STAGE	FORAMINIFERA	MOLLUSKS	OSTRACODS	PLANTS	TRANSCARPATHIAN BASIN
PLEISTOCENE							*Chop Formation: Mottled clays, sandstones pebble gravel (= 600 m)*
PLIOCENE		DACIAN-ROMANIAN					*Buzhor Formation: Basalts, andesite-basalts, microdolerites (100 m)*
				Planorbis Unio Melania	*Candona albicans, C. convexa,C. combiba, Cyclocypris laevis,C. globosa, Iliocypris bradyi, I. gibba, Limnocythere inopinata, Darvinula stevensoni*		*Ilnitsa Formation: Clays, aleurolites, sandstones, tuffs, lignites (500 m)* / *Hutin Formation: Andesites, basalts, dacites, liparites (> 500 m)*
MIOCENE	UPPER	PONTIAN		*Planorbis grandis Melania escheri Unio*	*Candona lobata, C. labiata C. balcanica, C. acuminata C. dorzoarcuata*	*Glyptostrobus europaeus, Populus balsamoides, Salix varians, Alnus nogradiensis, Castanea atavia, Parrotia pristina, Rhus quercifolia, Acer trilobatum, Gingko adiantoides*	*Koshelevo Formation: Variegated clays, conglomerates, clays (80–450 m)*
		PANNONIAN		*Congeria ungula-caprae, C. subglobosa, Melanopsis bouei etc., Congeria partschi, C. hoernesi, Melanopsis impressa, M. fossilis, Limnocardium halavatschi*	*Hemicytheria reniformis, H. tenuistriata, H. schneideri, Leptocythera nodigera L. lacunosa, Laxoconcha granifera etc. Hemicytheria lorenthei, H. pokorny, H. foliculosa, Leptocythere lacunosa, Eucypris sieberi, Herpetocypris obscissa, H. reticulata, H. aspera, Paracypris lunata, P. rakosiensis*		*Iziv Formation: Clays, sandstones, aleurites, tuffs, rarely marls, limestones, lignites (30–400 m)*
		SARMATIAN	Zone Porosononion subgranosus	*Cardium pium, C. finitima, C. sarmaticum, C. politiognei, C. plicatofittoni, Tapes naviculatus*	*Xestoleberis luteae, X. elongata Hemicytheria sarmatica, H. subangusta, Leptocythere plana, L. tenuis, Cipridеis seminulum, C. punctillata etc.*	*Pterocarya castaneifolia, Phyllites, Fagus, Carpinus, Castanea, Zelkova ungeri*	*Almash Formation: Clays, aleurolites, sandstones, marls, tuffs (50–480 m)*
			Zone Quinquloculina sarmatica, Q. reussi	*Cardium transcarpaticum (=Cardium gleichenbergense). C. plicatum, Modiola sarmatica, Mactra eichwaldi etc.*		*Salix denticulata, Carya denticulata Carpinus grandis, Fagus orientalis, F. haidingeri, Castanea atavia, Myrica deperdita, Pterocarya castaneifolia, Zelkova ungeri, Platanus aceroides, Rhus quercifolia, Vitis teutonica*	*Lukiv Formation: Clays, sandstones, aleurolites with horizons tuffs (400 m)*
			Zone Anomalina badenensis	*Cerastoderma inopinata, Cardium volhynicum. Abra alba, A. reflexa, A. reflexa elongata, Ervilia dissita, Modiolus naviculoides maximus etc.*		*Populus melanaria, Liqidambar europaea, Parrotia pristina, Rosa petraschkevitschii, Gleditschia allemanica, Rhamnus media, Hedera helix, Salix angusta, Carpinus marmaroschica, Castanea atavia Acer subcampestre, Platanus aceroides*	*Dorobrativ Formation: Clays, sandstones, aleurolites, rarely conglomerates, horizons tuffs, volcanic rock (700 m)*

Fig. 1b

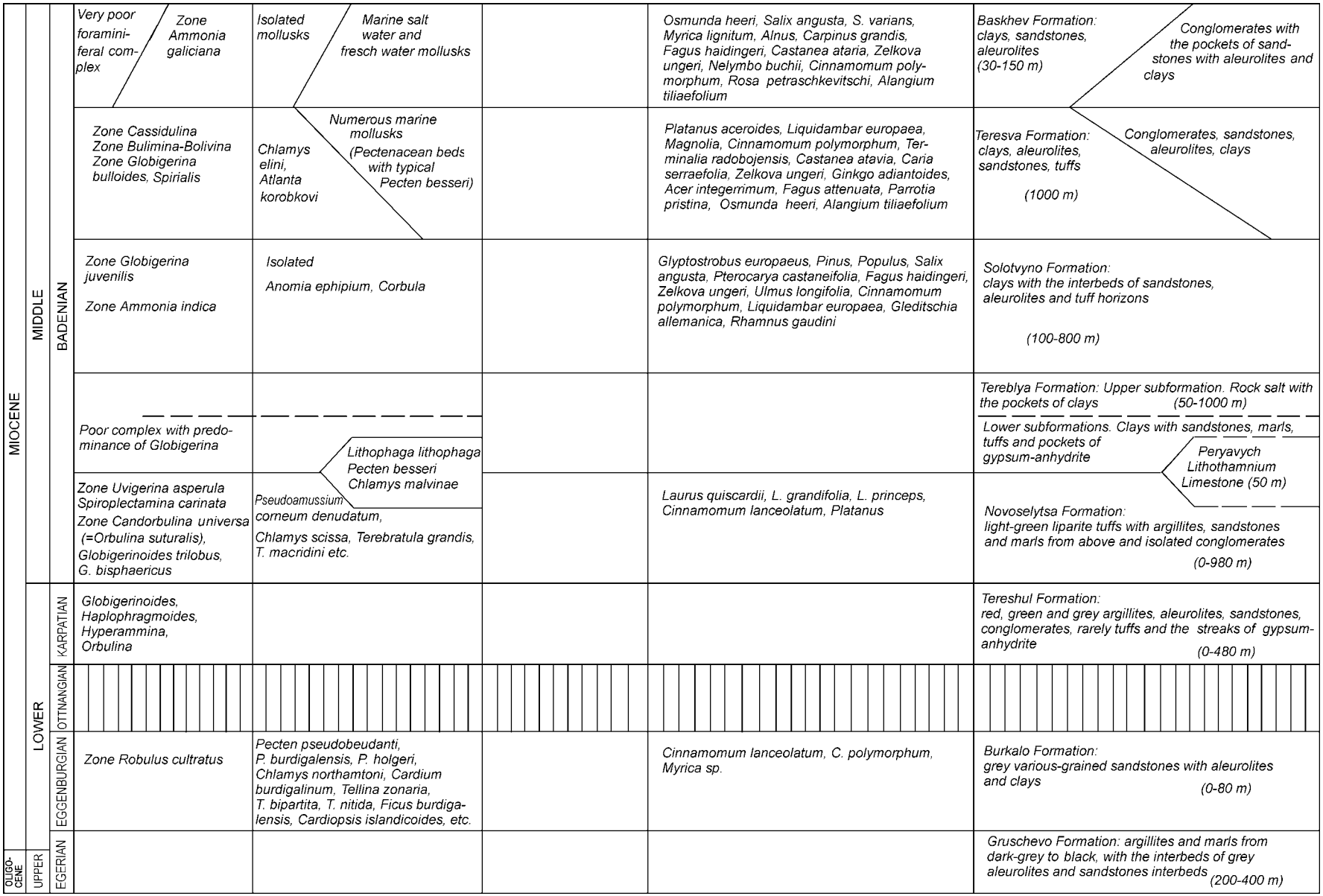

Fig. 1a-b. Regional stratigraphic scheme of Neogene deposits of Transcarpathian Basin.

served. In the Chechva Basin (Marginal skyba) the Menilite series, by which the flysch complex ends, gradually looses the flysch indications and comes to the Polyanitsa Formation.

Egerian. In the Oriv and Marginal skybas and in the Boryslav-Pokuttya Nappe the Oligocene-Neogene boundary comes in the floor of the Upper Menilite "subformation". In the southern skybas of the Skyba zone and in the Silesian (Krosno) zone this boundary is fixed in the section of Krosno Beds at the stratigraphical level that comes above the Holovets horizon of stripped limestones. The data of Andreyeva-Grigorovich & Gruzman (1994) indicate that the upper part of the Upper Menilite and Krosno beds belongs to the Miocene.

Menilite Formation. The most powerful and full section outcrops in the Marginal skyba along the river Chechva, where three "subformations" are clearly distinguished: Lower Menilite, Middle Menilite (Lopyanka) and Upper Menilite ones.

In the floor of the Upper Menilite "subformation" a 2–10 horizon of black flints is traced, above which the succession (400 m) of black argillites with interbeds of sandstones and aleurolites is bedded. In the middle part a succession (500 m) of dark grey, mainly limed argillites with separate interbeds of sandstones is found. In the succession top the horizon (70 m) of Chechva dacite tuffs, tuffites, tuffigenic argillites and aleurolites is bedded. Above it black bitumenic argillites with the interbeds of sandstones, aleurolites and rarely marls are found. In the Upper Menilite Beds *Globigerinoides trilobus* (Reuss) appears, and this makes it possible to relate them to the bottom of the Miocene.

The Krosno Formation is represented by the rhythm interbedding of grey micaceous sandstones and aleurolite with argillites. The lower part belongs to the Egerian, upper part-to the Eggenburgian or perhaps the Ottnangian.

Eggenburgian. Polyanitsa Formation. In the basin of the Chechva River in the Marginal skyba between the Polyanitsa and Upper Menilite deposits the main transition is observed. In the Boryslav-Pokuttya Nappe in the floor of the Polyanitsa Beds conglomerates (Rushor) appear; they lay with scouring at different horizons of the Menilite deposits.

The Polyanitsa Formation is composed of grey, yellowish-grey and brown argillites and clays, which are interbedded with sandstones. In the upper parts of the section small pockets and streaks of gypsum appear. The total thickness reaches 600 m.

The presence of the typically Miocene species *Globorotalia minutissima* Boli, *Globigerina woodi connecta* Jenkins, *Globoquadrina langhiana* Cita & Gelati and also the poor complex of the nannoplanktonic zone NN 2 – NN 3 indicate that the Polyanitsa Formation belongs to the Lower Miocene.

Vorotyshcha Formation. Its division (Vyalov 1951, 1965) into two "subformations": Lower Vorotyshcha and Upper Vorotyshcha seems to be the best established. In the eastern part of the deep the Sloboda conglomerates stratigraphically correspond to the middle part of the Vorotyshcha Formation; here the Upper Vorotyshcha salt-bearing formations facially replace the Dobrotiv Beds.

The Lower Vorotyshcha "subformation" is represented by a succession (600–800 m and more) of grey gypsed lime clays with interbeds of sandstones and the breccia-like sandy-clay rocks, cemented by rock-salt. In the separate parts potassium salts appear. In the whole section two parts are distinguished: the lower one — terrigeneous and the upper one — salt-bearing.

At the north-west the total thickness of Lower Vorotyshcha deposits sharply decreases and is not more than 100–200 m.

In the Lower Vorotyshcha deposits a poor fauna of *Chiloguembelina*, *Bolivina* and *Globigerina* is observed. The number of them sharply decreases along the section. Near the village of Ivan Franko, nannoplankton corresponding to the zone NN2 according to the Martini scale (Eggenburgian) have been identified.

The Sloboda conglomerates are represented by coarse and fine pebbles and include interbeds of gravelites, various-grained sandstones and in some times by the groups of strata of salinized sandy-clay rocks in the lower part of the section. The total thickness ranges from a few metres up to 1000 m and more.

Upper Vorotyshcha "subformation". It is mainly composed of salt-bearing breccias and clays with the interbeds of sandstones and aleurolites, and also by the beds and lense-like bodies of rock and potassium salts. The total thickness is 400–800 m.

The Stebnyk potassium-bearing region is located in the zone of the Upper Vorotyshcha salt-bearing deposits; occurrences of potassium salts are known between Blazhiv and Popeli and between Modrych and Drogobych. By the way, near Stebnyk three potassium-bearing horizons have been discovered with thicknesses from 60 to 100 m.

The deposits are faunistically characterized badly, and the majority of investigators conditionally refer to them as Upper Eggenburgian.

The Dobrotiv Formation is a grey flyschoid succession (600–800 m) of sandstones, aleurolites and argillites. Various texture signs, including the imprints of traces of vertebrates feet (birds, artiodactyla and felines) are very characteristic of the deposits.

To the north-west from the Bystritsa Nadvirna, the Dobrotiv Formation is conformably bedded on the Sloboda conglomerates and is overlain by the Stebnyk Formation.

Ottnangian. The Stebnyk Formation is formed by the rhythm interbedding of red, pink, greenish-grey argillites, aleurolites, sandstones, rarely conglomerates and marls. In the area of Drogobych and Dobromyl the Stebnyk Formation is mainly composed of different-grained sandstones with thicknesses often reaching 3–5 m. To the south-east of Drogobych the sections become more clayey.

Between the rivers Chechva and Lyuchka the Stebnyk Beds are represented by the flyschoid alternation of sandstones, aleurites and argillites, among which separate interbeds of copper sandstones appear.

The total thickness of Stebnyk deposits varies from 500 to 3000 m. Such great changes of thickness give birth to doubt about steadfast character and stable stratigraphical volume of the formation. Especially debatable is the stratigraphical volume of the so-called "Lanchyn facies" of the Stebnyk Formation. Its deposits (thickness to 200–300 m) are represented by blue-grey clays with interbeds of sandstones.

The Stebnyk Beds contain little paleontological evidence, but they are assigned to the Ottnangian. A nannoplanktonic com-

Fig. 2a

SYSTEM	DIVISION	SUBDIVISION	STAGE	SUBSTAGE	REGIONAL STRATIGRAPHIC SUBDIVISIONS					
					ZONE			CHARACTERISTIC FOSSIL COMPLEXES		
					FORAMINIFERA		NANNOPLANKTON	FORAMINIFERA	NANNOPLANKTON	MOLLUSKS
					PLANKTON	BENTHOS				
NEOGENE	MIOCENE	UPPER	SARMATIAN	LOWER		*Quinqueloculina reussi*	*Beds with Calcidiscus macintyrei*	*Quinqueloculina reussi, Q. complanata, Q. costata, Articulina problema, Ammonia stellifera, Elphidium aculeatum, E. reginum, Porosononion subgranosus*	*Calcidiscus macintyrei, Cyclicargolithus floridanus, Reticulofenestra pseudoumbilica*	*Abra reflexa, A. alba, var. scynthica, Cardium lithopodolicum, Ervilia podouca var. infrasarmatica, Monhrensternia sarmatica*
						Anomalina badenensis	*Beds with Braarudosphaera bigelowi subsp. parvula*		*Calcidiscus leptoporus, Coccolithus pelagicus, Reticulofenestra pseudoumbilica*	
		MIDDLE	BADENIAN	UPPER		*Ammonia galiciana Cassidulina crista*	*Discoaster kugleri (NN7)*	*Bogdanowiczia pocutica, Hyperammina granulosa, H. vialovi, Cyclammina pleschakovi, Textularia subangulata, Quinqueloculina consobrina, Globigerina decoraperta, G. bulloides, G. quinqueloba, G. foliata, Bulimina elongata, B. subulata, Bolivina dilatata, Ammonia galiciana, Cassidulina crista, C. punctata, Pullenia sexacamerata*	*Calcidiscus leptoporus, Helicosphaera kamptneri, Discoaster exilis, Sphenolithus abies, Braarudosphaera bigelowi, Reticulofenestra pseudoumbilica*	*Chlamys elini, Ch. galiciana, Ch. neumayeri, Ervilia pusilla, Venus cincta, Spirialis subtarchensis*
						Bogdanowiczia pocutica				
						Bulimina-Bolivina	*Discoaster exilis (NN6)*			
					Globigerina decoraperta				*Sphenolithus heteromorphus, S. abies, Helicosphaera kamptneri, H. sellii, Cyclicargolithus floridanus, Reticulofenestra pseudoumbilica, Discoaster adamanteus, D. variabilis*	*Amussium cristatum, Pseudoamussium corneum denudatum*
				LOWER		*Uvigerina asperula*	*Sphenolithus heteromorphus (NN5)*	*Orbulina suturalis, Globigerinoides bisphaericus, Globoquadrina altispira, G. dehiscens, Globigerina nepenthes, Globorotalia mayeri, Cibicides ungerianus, Uvigerina asperula*		
					Orbulina suturalis					
		LOWER	KARPATIAN			*Quinqueloculina distorta*	*Helicosphaera ampliaperta (NN4)*	*Quinqueloculina distorta*	*Cyclicargolithus floridanus, C. abisectus, Sphenolithus delphix, S. cf. heteromorphus, Helicosphaera ampliaperta, H. kamptneri, H. intermedia, Pontosphaera multipora*	*Neritina picta Lucina dentata Leda fragilis*
					Globigerina bollii			*Globigerina bollii, Globigerinoides bisphaericus, Globorotalia mayeri*		
					Globigerinoides bisphaericus					
			OTTNANGIAN				*Sphenolithus belemnos (NN3)*	*Globoquadrina langhiana, G. dehiscens, Globigerinoides trilobus*	*Helicosphaera kamptneri, H. euphratis, H. bramlettei, H. cf. ampliaperta, Sphenolithus belemnos, S. moriformis*	
			EGGENBURGIAN				*Discoaster druggii (NN2)*	*Globigerina pseudoedita, G. juvenilis, Turborotalia brevispira, T. minutissima, Cassigerinella chipolensis, Chiloguembelina gracillima, Cibicides borislavensis*		
			EGERIAN	UPPER	*Globigerinoides trilobus*		*Triquetrorhabdulus carinatus (NN1)*	*Globigerinoides trilobus,*	*Triquetrorhabdulus carinatus, Sphenolithus dissimilis, Discoaster druggii, Helicosphaera kamptneri*	
					Globigerinoides primordius			*G. primordius*		

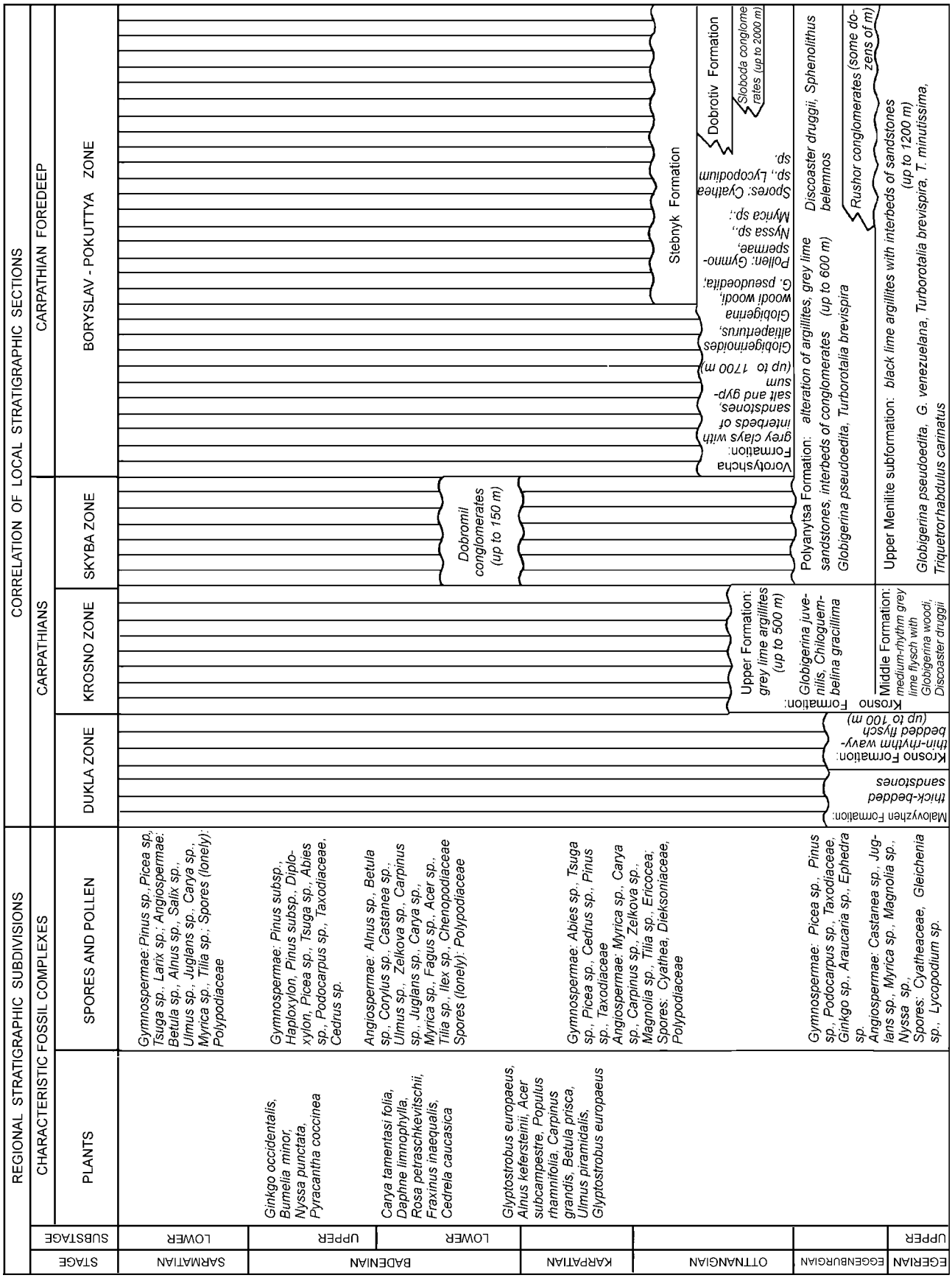
REGIONAL STRATIGRAPHIC SUBDIVISIONS
CORRELATION OF LOCAL STRATIGRAPHIC SECTIONS
CHARACTERISTIC FOSSIL COMPLEXES
CARPATHIANS
CARPATHIAN FOREDEEP
STAGE
SUBSTAGE
PLANTS
SPORES AND POLLEN
DUKLA ZONE
KROSNO ZONE
SKYBA ZONE
BORYSLAV - POKUTTYA ZONE
EGERIAN
EGGENBURGIAN
OTTNANGIAN
KARPATIAN
BADENIAN
SARMATIAN
UPPER
LOWER
UPPER
LOWER
LOWER
Ginkgo occidentalis, Bumelia minor, Nyssa punctata, Pyracantha coccinea
Carya tamentasi folia, Daphne limnophylla, Rosa petraschkevitschii, Fraxinus inaequalis, Cedrela caucasica
Glyptostrobus europaeus, Alnus kefersteinii, Acer subcampestre, Populus rhamnifolia, Carpinus grandis, Betula prisca, Ulmus piramidalis, Glyptostrobus europaeus
Gymnospermae:Pinus sp.,Picea sp, Tsuga sp., Larix sp.: Angiospermae: Betula sp., Alnus sp., Salix sp., Ulmus sp., Juglans sp., Carya sp., Myrica sp., Tilia sp., Spores (lonely): Polypodiaceae
Gymnospermae: Pinus subsp., Haploxylon, Pinus subsp., Diploxylon, Picea sp., Tsuga sp., Abies sp., Podocarpus sp., Taxodiaceae, Cedrus sp.
Angiospermae: Alnus sp., Betula sp., Corylus sp., Castanea sp., Ulmus sp., Zelkova sp., Carpinus sp., Juglans sp., Carya sp., Myrica sp., Fagus sp., Acer sp., Tilia sp., Ilex sp., Chenopodiaceae Spores (lonely): Polypodiaceae
Gymnospermae: Abies sp., Tsuga sp., Picea sp., Cedrus sp., Pinus sp., Taxodiaceae
Angiospermae: Myrica sp., Carya sp., Carpinus sp., Zelkova sp., Magnolia sp., Tilia sp., Ericocea; Spores: Cyathea, Dieksoniaceae, Polypodiaceae
Gymnospermae: Picea sp., Pinus sp., Podocarpus sp., Taxodiaceae, Ginkgo sp., Araucaria sp., Ephedra sp.
Angiospermae: Castanea sp., Juglans sp., Myrica sp., Magnolia sp., Nyssa sp.; Spores: Cyatheaceae, Gleichenia sp., Lycopodium sp.
Malovyzhen Formation: thick-bedded sandstones
Krosno Formation: thin-rhythm wavy-bedded flysch (up to 100 m)
Krosno Formation: Upper Formation: grey lime argillites (up to 500 m) Globigerina juvenilis, Chiloguembelina gracillima
Middle Formation: medium-rhythm grey lime flysch with Globigerina woodi, Discoaster druggii
Dobromil conglomerates (up to 150 m)
Polyanytsa Formation: alteration of argillites, grey lime sandstones, interbeds of conglomerates (up to 600 m) Globigerina pseudoedita, Turborotalia brevispira
Upper Menilite subformation: black lime argillites with interbeds of sandstones (up to 1200 m) Globigerina pseudoedita, G. venezuelana, Turborotalia brevispira, T. minutissima, Triquetrorhabdulus carinatus
Rushor conglomerates (some dozens of m)
Vorotyshcha Formation: grey clays with interbeds of sandstones, salt and gypsum (up to 1700 m) Globigerinoides altiaperturus, Globigerina woodi woodi, G. pseudoedita; Pollen: Gymnospermae, Nyssa sp., Myrica sp.; Spores: Cyathea sp., Lycopodium sp.
Stebnyk Formation
Dobrotiv Formation
Sloboda conglomerates (up to 2000 m)

Fig. 2b

Fig. 2c

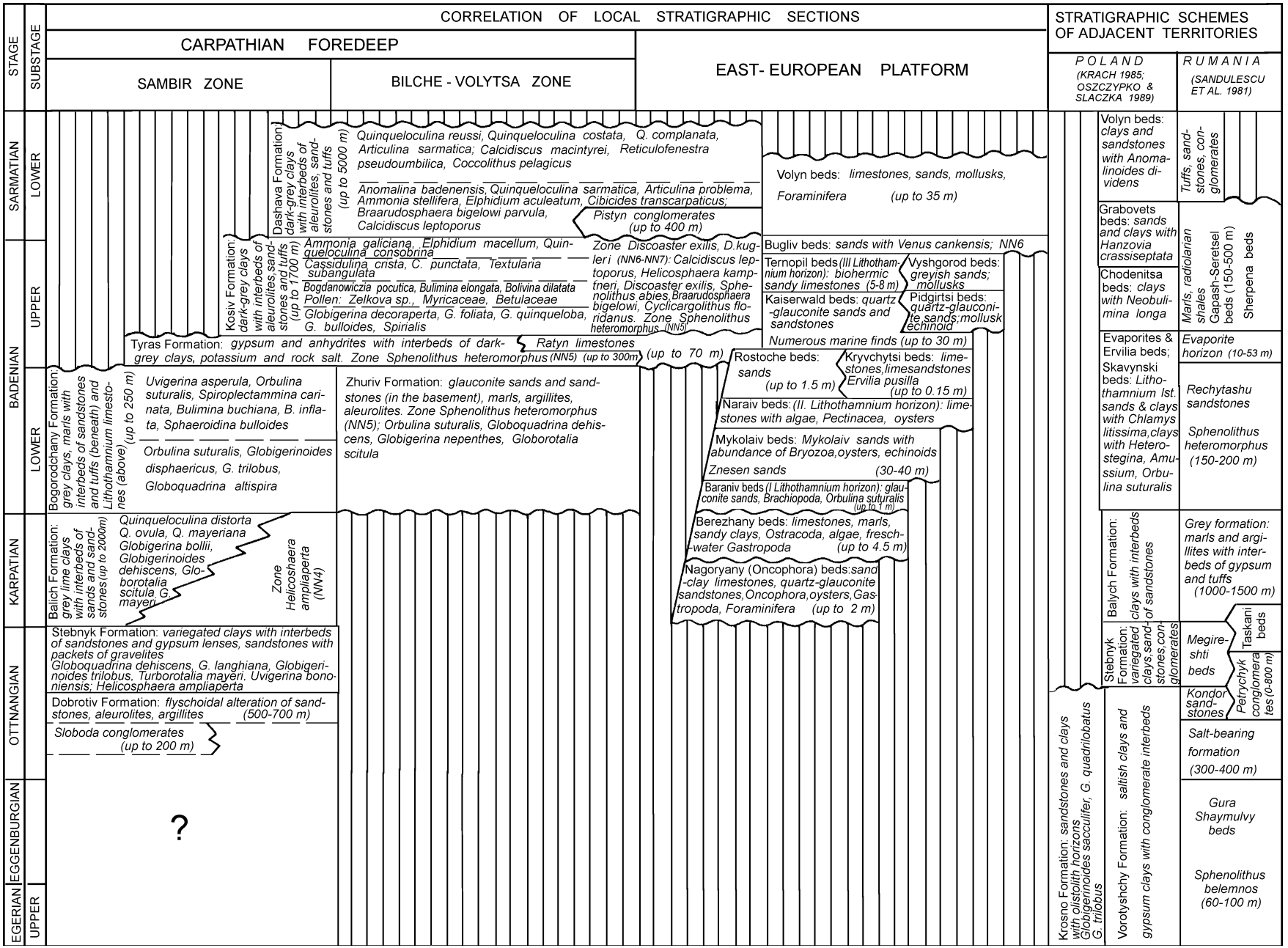

Fig. 2a-c. Regional stratigraphic scheme of Neogene deposits of Carpathian Foredeep.

plex analogous to the zone NN 4 Martini (Andreyeva-Grigorovich & Stupnitsky 1976) was discovered in the lower part of the section near Nadvirna and it indicates the Early Miocene age.

Karpatian. The Balych Formation is represented by a succession (up to 600 m) of grey and greenish-grey lime sandy-clay rocks. In the lower part of its section the interbeds of pink and coffee clays and argillites are often observed. In these deposits the finds of *Globigerina* are known which up the section change into *Quinqueloculina* — Quinqueloculina distorta Zone (Pishvanova 1972), ostracods and small gastropods. Pishvanova (1972) noted that in the lower part of the Balych Formation the Globigerina bollii Zone can be distinguished. At the same stratigraphic level, together with *Globigerina bollii* Cita & Premoli-Silva, Khrushchov (1980) also mentioned finds of the following species: *Biorbulina bilobata* Orb., *Praeorbulina glomerosa* Orb., *Orbulina universa* (Iede.) (single ones). This may indicate that the enclosing rocks are Lower Badenian. Despite this fact the majority of geologists are eager to assign the Balych Formation to the Karpatian, though this question needs more detailed study.

Badenian. In the section of upper molasse in Lower Badenian two formations are distinguished: the Bogorodchany Formation (in the Sambir Zone) and the Zhuriv Formation (in the Bilche–Volytsa Zone); then in Upper Badenian — the Tyrassian Formation and the overlying Kosiv Formation.

The lower part of the Bogorodchany Formation is composed of marls, lime argillites and acid tuffs, where there are many globigerinides (Orbulina suturalis Zone). The upper part is represented by grey clays and argillites which have rare interbeds of sandstones and marls. In the deposits numerous *Uvigerina* are observed (Uvigerina asperula Zone), and also *Lagenida* and *Buliminida*. From mollusks there are *Amussium* cf. *cristatum* Bron. and *Pseudoamussium corneum denudatum* (Rss.). The total thickness of the formation does not exceed 150 m.

The Zhuriv Formation is transgressively deposited over the basement of the molasse complex of the Bilche–Volytsa Zone. Its lower part is formed by grey and greenish glauconite sandstones. The middle part is represented by alternation of sandstones, argillites and marls. The section ends with a packet (3–5 m) of dark lime argillites and marls which include planktonic foraminifers of Orbulina suturalis Zone and nannoplankton of NN5 Sphenolithus heteromorphus Zone.

The total thickness of the Zhuriv Formation reaches a few dozen metres.

The Tyrassian Formation is composed of gypsum and anhydrites with interbeds of clays and limestones; in separate places in the section interbeds and groups of strata of rock-salt, and even of potassium salts appear. The thickness and lithological composition of the deposit greatly vary (from 10–40 m to 100–300 m).

In some dark-grey argillites the planktonic foraminifers and the associations of nannoplanktonic zone NN5 are met.

Kosiv Formation. In the south-eastern part of the foredeep, where the formation reaches the maximum thickness (up to 200 m), in the section four parts are distinguished: Verbovets, Prut, Kolomiya and Kovalivka beds.

The formation is represented by aleuritic grey clays which alternate with separate interbeds of loose aleurolites, sandstones, tuffs and tuffites. In the deposits (especially in the Verbivtsi and Prut beds) mollusks (*Chlamys, Ervilia, Spirialis* etc.) and foraminifers are found. Four zones: 1 — Globigerina decoraperta and Spirialis; 2 — Bogdanowiczia pocutica and Bulimina-Bolivina; 3 — Cassidulina crista, and 4 — Ammonia galiciana (= Ammonia beccarii) in strict sequence can be established on the basis of foraminiferal fauna.

In the basins of the rivers Pistynka and Rybnytsa, the Kosiv Formation consists of a succession (to 100 m) of clays with interbeds of various-grained sands and sandstones, gravelites and conglomerates ("Pistynka conglomerates"), which were formed in fresh-water lagoons. Stratigraphically these deposits correspond to the Bugliv Beds. Probably their upper part already belongs to the bottom of the Sarmatian. In the north-western part of the foredeep in the region of Dobromyl-Khyriv the thickness of the so called "Radych conglomerates" can be regarded as their stratigraphic analogue.

Sarmatian. In the Carpathian Foredeep, Sarmatian deposits are mainly spread in the Bilche-Volytsa and Sambir zones.

The Dashava Formation unites a thick complex (from a few hundred to 4000 m) of grey clay deposits with interbeds of aleurolites, sandstones, tuffogenic rocks (tuffs, tuffites, bentonite clays). In separate parts of the section the number of sandstones grows, and they compose about 50 % of all the rocks. Here and there conglomerates appear.

The Dashava Formation is usually divided into two "subformation"s: a—the lower one, more sandy (Anomalina badenensis Zone), and b—the upper one with a larger content of tuffogenic rocks (Quinqueloculina reussi Zone). Despite the facial variability of the Dashava deposits, the presence in the section of tuffogenic rocks makes it possible to divide them into separate horizons. In particular, Vishnyakov et al. (1979) worked out the unified synonymics of the horizons and proposed the detailed scheme of correlation. In the Lower Dashava "subformation" they distinguish 17 horizons (synonymics from ND-17 to ND-1); in the Upper Dashava-14 (synonymics from VD-14 to VD-1) sand-clay horizons (cyclites).

The Sarmatian age of the Dashava Formation is proved by the foraminiferal fauna and by fauna of bivalve mollusks, gastropods and ostracods.

South-western margin of East-European Platform

Karpatian. Nagoryany (Oncophora) Beds (Goretsky 1962). The Miocene section in the platform begins with marine shallow-water coastal formations which are bedded transgressively on a Mesozoic basement. They are represented by various-grained grey and greenish quartz-glauconite sands with lime sandstone interbeds (10–15 cm). The lower part includes pebbles of silicites, white quartz and Devonian sandstones. In some places sands are replaced by organogenic sandy-clay limestones. These deposits include a rich complex of mollusks — *Rzehakia (Oncophora) socialis* (Rzehak), *Nucula nucleus* (Linne) etc. Foraminifers and algae are also find. The thickness of the Nagoryany Beds does not exceed 2 m.

The Berezhany fresh-water beds are deposited with a break on the Nagoryany ones and are represented by fine-

grained light limestones, marls and green clays. Organic remnants of fresh-water ostracods, oogonium chare alga and fresh-water gastropods are often found. These deposits are related to the upper part of the Karpatian, on the basis of their location under beds of the Lower Badenian with *Amussium denudatum* (Reuss). The thickness of the beds reaches 7 m.

Badenian. The Baraniv Beds (the first Lithothamnium horizon) are deposited with unconformity on the Berezhany Beds or older formations. The beds are formed by greenish-grey glauconite lime sands and sandstones with a rich mollusk fauna. Lithothamnium nodules are characteristic of these deposits. Sometimes this horizon is wholly composed of Lithothamnium limestones. The thickness of the beds does not exceed 1 m.

The Mykolaiv Beds unite rocks which are laterally quite variable in lithological composition. They were deposited between two Lithothamnium horizons (Baraniv and Naraev beds). These beds include: the Mykolaiv quartz and quartz-glauconite sands and sandstones; Znesennya deltaic quartz sands with silicified wood; Pidgaytsi bryozoan marls; Sverzhkovets detritus bryozoan limestones; Pomoryany-Zolochiv Beds — dark-grey and greenish clays and quartz sands with interbeds of brown coal.

In Mykolaiv Beds the foraminiferal complex with *Candorbulina universa* Jedlitschka *(Orbulina suturalis)* has been identified, and this makes possible to correlate the country rocks with the Zhuriv and Bogorodchany Formations of the Carpathian Foredeep. The maximum thickness of the Mykolaiv Beds is 30–40 m.

The Naraev Beds (the second Lithothamnium horizon) are composed of Lithothamnium limestones which represent the accumulation of Lithothamnium nodules and other alga. Sometimes these beds are composed mainly of lime detritus, and in the direction to the bank line they change into sandstones with separate algal nodules. Besides numerous remnants of alga the Naraev Beds contain pectenides, oysters and foraminifers. The thickness of the beds varies from 1 to 25 m.

The Rostochya Beds — a thin (some cm) layer over the Ervilia horizon, composed of quartz and quartz-glauconite sands and sandstones. The fauna of these deposits is analogous to the complex of the Baraniv Beds. This fact caused some difficulties in the stratification and correlation of Miocene sections.

The Kryvchytsi (Ervilia) Beds — a thin (10–15 cm) layer of light-grey limestone or lime sandstone which is overfilled with shells *Ervilia pusilla* Eichwald. The mollusks *Chlamys, Cardium, Modiolus, Hydrobia* are also found. In spite of its small thickness the Ervilia horizon plays an important marking role in stratification of the Miocene section of the platform. The Kryvchytsi Beds are partly replaced by the Rostochyn Beds.

The Kaiserwald Beds are spread over a large territory and are represented by a thick (more than 30 m) mass of quartz-glauconite sands and sandstones with a marine fauna of mollusks and foraminifers. To the south and the south-west they are substituted by Ratyn limestones, which, in their turn, partly correspond to gypsum and anhydrites of Tyrassian Formation. This formation is deposited transgressively on Lower Badenian formations or on the pre-Miocene basement.

The Pidgirtsi Beds — quartz and quartz-glauconite sands with a thickness of 10–20 m, which contain marine fauna of mollusks, echinoids, foraminifers. They correspond to the upper part of the Kaiserwald Beds in the riverside parts of the Basin.

The Ternopil Beds (the third Lithothamnium horizon) are developed only in the north-east of the territory. They are represented by limestones with Lithothamnium nodules which are cemented by green-grey glauconite sandstones. In the upper part of these deposits limestones are interbedded with clay glauconite sands. The thickness of the beds is 5–8 m. The fauna complex of the Ternopil Beds is composed, apart from Lithothamnium, of remnants of gastropods, bivalve mollusks, bryozoans, serpulites and colonial corals. In the north-east the third Lithothamnium horizon is replaced by the green glauconite sands of the Vyshgorod Beds.

The Bulgiv Beds are represented by grey and green-grey quartz sands with shell detritus. Laskarev, who distinguished the Bugliv Beds in 1897, divided them into three parts: lower part (horizon V, modern Vyshgorod beds) with Tortonian (Badenian) fauna: middle part (horizon G) with Tortonian and Tortonian-Sarmatian fauna; upper part (horizon D) with Sarmatian fauna.

The investigators which studied the Bugliv Beds after Laskarev (?), interpreted their lithological volume and stratigraphic position differently. For a long time the question of the age of these formations was discussed — Tortonian (Badenian) or Sarmatian? The supporters of both variants supported their constructions quite confidently, but the question was not solved. In 1966 the problem of the Bugliv Beds was discussed at a special symposium. The materials from it were published. In the article of Vyalov & Grishkevich (1970) the question of the age and lithological volume of Bugliv Beds was analysed in details. The authors identify the Bugliv Beds (s.s.) in the volume of horizon G only, which includes the complex of mollusks with *Venus konkensis* Sokolov media and the microfaunistic association with *Ammonia beccarii* (Linne). Horizon D with the coplex of foraminifers with *Anomalina badenensis* (Orbigny) was excluded by them from the Bugliv Beds and related to the Sarmatian.

Sarmatian. The Volyn Beds with scouring are deposited on the Bugliv and older formations (Paleozoic and Cambrian). It consists of a polyfacial complex of carbonate, sandy and sandy-clay deposits. They are limestones of different composition and genesis, grey and yellow sands with a rich fauna of Sarmatian mollusks and redeposited Badenian forms, oolithic sandstones or limestones, alteration of marls and limestones, conglomerate interbeds. The thickness of the Volyn Beds reaches 35 m.

Conclusion

The stratigraphic constructions of past years, the results of analysis of the latest geological, geophysical, paleontological and sedimentological data and materials from drilling on the Neogene of the Transcarpathian Basin, Folded Carpathians, Carpathian Foredeep and the south-western edge of the East-European Platform are the basis for the proposed regional stratigraphic scheme of the Neogene of the western regions of Ukraine (Fig.1a,b;Fig.2a-c).

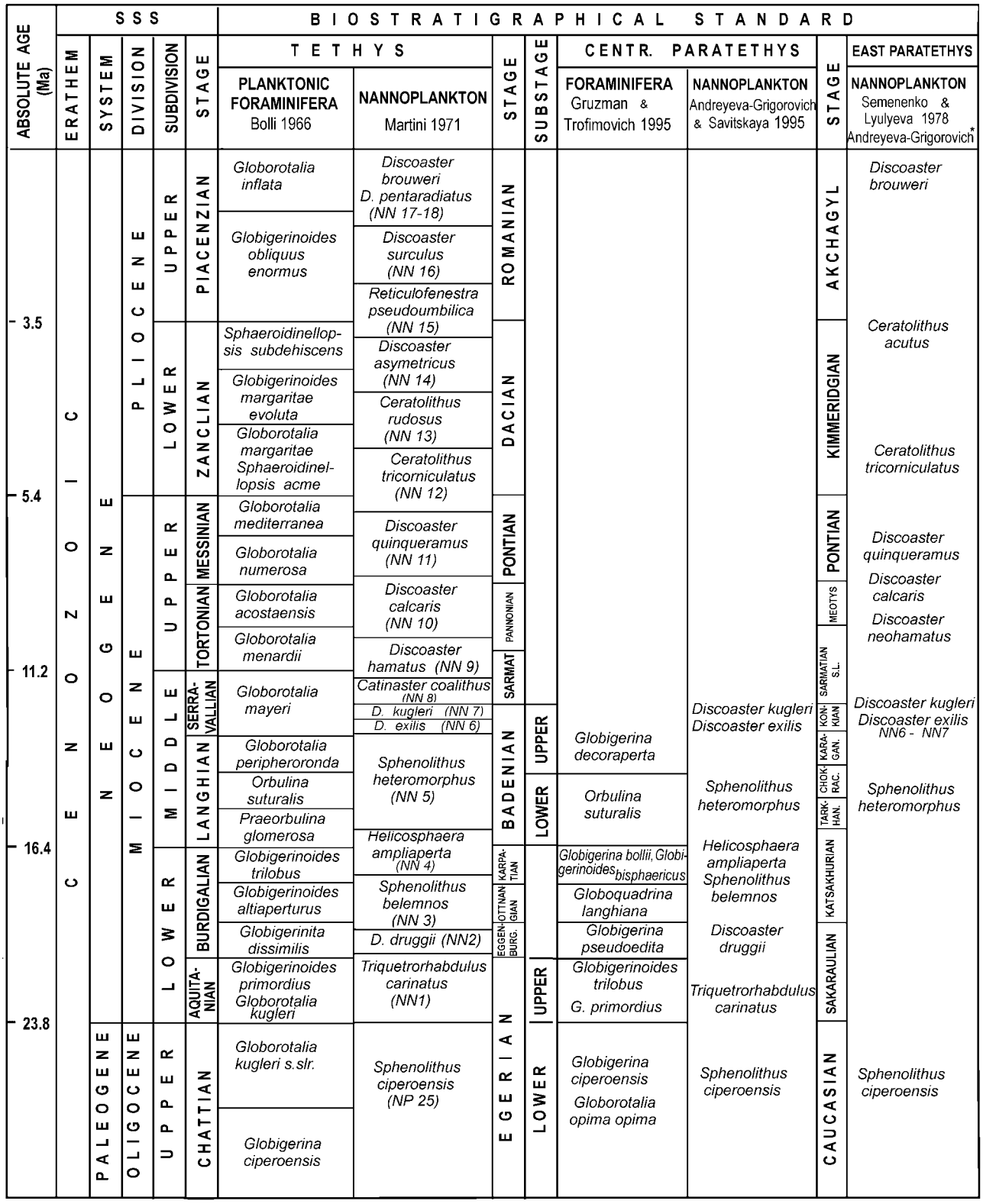

Fig. 3. The correlation of stage and zonal scales of Neogene deposits of the Tethys and Paratethys (*Andreyeva-Grigorovich & Nosovsky (1976), Nosovsky & Andreyeva-Grigorovich (1987) Andreyeva-Grigorovich & Gruzman (1994)).

This scheme solves a number of questions on the classification and correlation of the Neogene formations on a modern level.

1 — Correlation of the biostratigraphic subdivisions of the Neogene of the Western Paratethys with the Mediterranean scale is fulfilled by the foraminifers and nannoplankton (Fig. 3).

2 — Correlation with the Eastern Paratethys is done on the basis of nannoplankton.

3 — Correlation of the Neogene of the Outer Carpathians with the formations of the same age in the Polish and Rumanian parts of the region is carried out. For the Inner Carpathians such correlation is done with the sections of Hungary, Slovakia and Rumania.

4 — The connections of Sarmatian basins of the Western and Eastern Paratethys are established.

For the Folded Carpathians and Carpathian Foredeep:

5 — The Paleogene-Neogene boundary is substantiated paleontologically by planktonic foraminifers, nannoplankton and dinocysts. On the basis of the latest materials this boundary lies in the floor of the Middle Krosno and Upper Menilite "subformations".

6 — By planktonic foraminifers and nannoplankton the zones in Egerian–Upper Badenian are distinguished.

7 — Division of the Upper Badenian–Lower Sarmatian according to benthos foraminifera is done in greater detail.

8 — Stratification of the lower molasse of the Carpathian Foredeep is specified: correlation of the Sloboda conglomerates with the middle part of the Vorotyshcha Formation is substantiated (according to the present ideas these conglomerates are the age analogue of the Polyanitsa and Vorotyshcha Formations). The coarse-cobbled horizon in the floor of the Polyanitsa Formation in Pokuttya is distinguished with the name of Rushor conglomerates.

9 — The supposition of the facial replacement of the Balych Formation by the Stebnyk Formation upper horizons is expressed.

10 — In the floor of the upper molasse complex under the Tyrassian (gypsum-anhydrite) Formation in Bilche-Volytsa Zone of Carpathian Foredeep the thickness, composed by glauconite sandstones below and dark clays in the top, is distinguished as the Zhuriv Formation.

11 — The Badenian stage in the Miocene sections of the pre-Carpathians is divided into two substages; the upper one begins with the gypsum-anhydrite horizon (Tyrassian Formation).

For the Transcarpathian Basin:

12 — The formations of Carpathian regiostage are distinguished.

13 — In the deep Solotvyno part the lowest level of the Miocene section (Egerian-Eggenburgian) is identified — dark-coloured terrigeneous deposits being distinguished as the Grushiv Formation.

14 — The stratigraphic scheme of the Pannonian deposits is made more detailed.

15 — A new structural-facial division of the deep pre-Neogene basement is proposed.

16 — The flora of the Upper Badenian formations (Teresva Formation) from the sections of the rivers Bolshaya Ugolka and Teresva (Burkalo spring) is monographically processed.

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