Zmiany paleośrodowiska, jako wynik wzajemnego oddziaływania wydarzeń tektonicznych i oscylacji poziomu morza w basenie wschodniosłowackim

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Wzajemne oddziaływanie wydarzeń tektonicznych i zmian poziomu morza wywierały doniosły wpływ na paleośrodowiska w basenie wschodniosłowackim (Ryc. 1). Główne wydarzenia tektoniczne wpływały na głębokość i kształt basenu, co z kolei wpływało na zmiany środowisk sedymentacji. Oscylacje eustatyczne są odzwierciedlone w przybrzeżnych kontaktach wstępujących. W środowiskach odległych od brzegu, względne wzrosty lub spadki poziomu morza zostały określone w wyniku studiów paleoekologicznych asocjacji otwornicowych. Korelacja skonstruowanych krzywych dla paleogłębokości środowisk i przybrzeżnych kontaktów wstępujących z krzywymi globalnych zmian (Haq i in., 1987) wykazują pewne odmienności, głównie wywołane wydarzeniami tektonicznymi podczas rozwoju basenu.

W przeciwieństwie do wczesnomioceńskiego globalnego wzrostu poziomu morza, paleośrodowisko eggenburgu basenu wschodniosłowackiego uległo zmianie od głębokowodnego wysokoenergetycznego do płytkowodnego wysokoenergetycznego w wyniku tektoniki kolizyjnej, po czym w ottnangu nastąpiło wypiętrzenie i hiatus. Transgresja karpatu może być skorelowana z globalnym przybrzeżnym kontaktem wstępującym, ale śródkarpackie wahania poziomu morza były tektonicznie warunkowane w przeciwieństwie do badeńskich wahań, spowodowanych przez globalny wzrost poziomu morza w dolnym badenie i globalny spadek poziomu morza pod koniec środkowego badenu. Transgresja górnego badenu i przybrzeżny kontakt wstępujący to ostatnie dobrze widoczne globalny wydarzenia w zapisie sedymentacyjnym basenu wschodniosłowackiego. Stopniowe spłycenie w sarmacie lub lokalny spadek poziomu morza były głównie warunkowane przez tektonikę synsedymentacyjną podczas rozwoju basenu (Ryc. 4, 5).

Słowa kluczowe: *paleośrodowisko, środowisko sedymentacji, ewolucja tektoniczna, poziom morza, eustazja, trzeciorzęd, Basen Wschodniosłowacki*

Changes of paleoenvironment as a result of interaction of tectonic events and sea level oscillation in the East Slovakian Basin

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S u m m a r y. Interaction of tectonic events and sea level changes had an important influence on the paleoenvironment of the East Slovakian Basin. The main tectonic events influenced the depth and shape of the basin, what led to the changes of sedimentary environment. The eustatic oscillations are reflected in coastal onlaps. In offshore environment, the relative sea level rise or fall were defined by paleoecological study of foraminiferal associations. The correlation of constructed curves for the environment paleodepth and coastal onlap with global reference curves (Haq et al., 1987) shows some discrepancies, mostly caused by tectonic events during the basin development.

In contradiction to the Early Miocene global sea level rise the Eggenburgian paleoenvironment of the East Slovakian Basin was changed from deep water high-energy to shallow water high-energy due to collisional tectonics, followed by uplift and hiatus during the Ottnangian. The Karpatian transgression can be correlated with global coastal onlap but the intra Karpatian sea level oscillations were tectonically controlled unlike the Badenian ones, caused by the global sea level rise in the Lower Badenian and global sea level fall at the end of the Middle Badenian. The Upper Badenian transgression and coastal onlap are the last well observed global events in the sedimentary record of the East Slovakian Basin. The Sarmatian gradual shallowing or local sea level fall were mainly controlled by synsedimentary tectonics during the basin development.

Key words: *Miocene, sedimentary basins, basin analysis, synsedimentary processes, tectonics, paleoecology, paleoenvironment, foraminifers, sea-level changes, indicators, East Slovakian Basin*

Introduction

The aim of this paper is to describe the Miocene relative sea level oscillations in the East Slovakian Basin, based on changes of the paleogeography, microfaunal paleoecology, changes of the sedimentary environment and changes of regional tectonic regimes.

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The East Slovakian Basin is situated in the NW part of the Transcarpathian depression and attains 8–9 km depth (Fig. 1, 2). The basin development started in compressional regime and can be regarded as a relic forearc basin during the Early Miocene. The Middle Miocene crustal stretching controlled formation of the synrift back arc basin development, followed by thermal postrift subsidence during the Upper Miocene (Fig. 3, 4).

The Early Miocene sedimentary sequences

The Egerian marine depocenters of the eastern margin

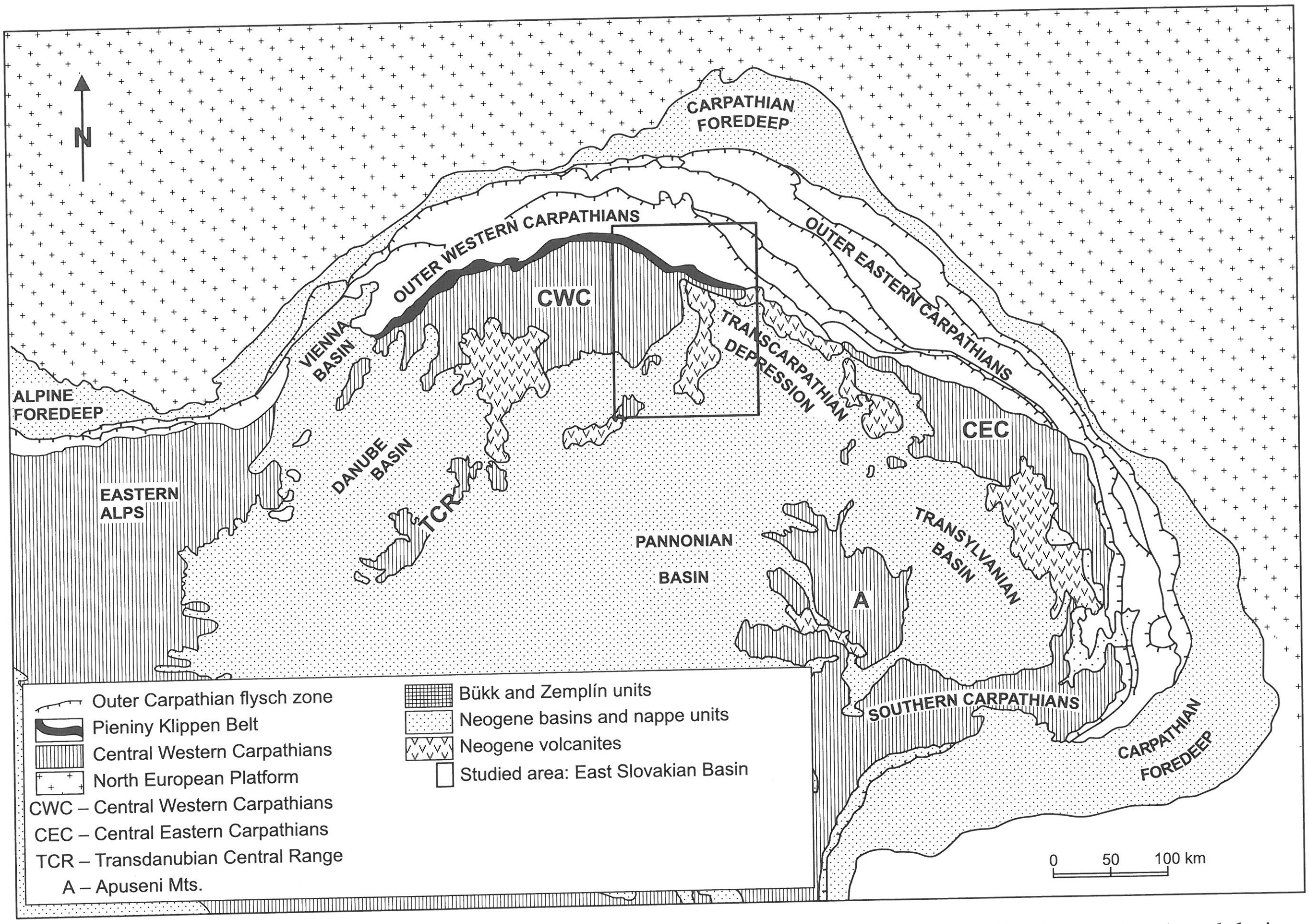


Fig 1. Geological sketch of the Carpathians and the Pannonian Basin System. (The position of Fig. 2 is marked)
Ryc. 1. Schemat geologiczny Karpat i systemu basenu panońskiego (prostokąt pokazuje położenie ryc. 2)

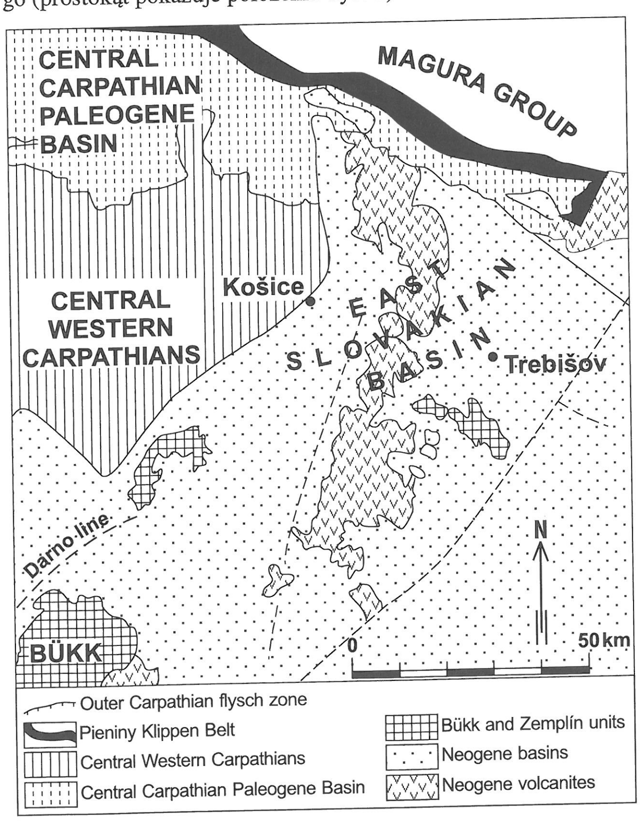


Fig. 2. Geological sketch of the East Slovakian Basin
Ryc. 2. Schemat geologiczny basenu wschodniosłowackiego

of the Central Western Carpathians were developed during the disintegration of the Central Carpathian Paleogene Basin (Kováč et al., 1995), whereas their distribution followed the CWC nappe thrust front orientation (Jiříček, 1981).

The sequence was deposited in deep water high-energy environment with rich dinoflagellata assemblages of two types — the first one with *Deflandrea spinulosa* and other deflandreas and the second one with *Chiropteridium partispinatum* and other chorates cysts — is restricted to the NW-SE trending zone near Prešov and reaches 500 m thickness (Hudáčková, 1996). Foraminiferal assemblage with *Almaena osnabrugensis* (Roemer), *Bolivina fastigia* Cushman, *Globigerina ouachitaensis* Howe et Wallace and *Virgulinella chalkophila* (Hagn) documents the open marine conditions. The sequence partly deposited by turbidite currents is composed predominantly of clays, siltstones and fine grained sandstones often bearing detritus of plants and subangular clasts (Rudinec, 1989).

The Eggenburgian basin depocenters widened southeastwards, following the Klippen Belt suture zone (Fig. 4).

The Prešov Fm. covers with an angular discordance the older Paleogene and Egerian sediments (Vass & Čverčko, 1985). The most essential part of this shallowing upward sequence is formed lithologically by dark-grey marine claystones and siltstones with sporadic sandstone intercalations reaching a thickness up to 1000 m (Rudinec, 1978). Typical foraminiferal assemblages with *Pappina bononiensis primiformis* (Papp et Turnovsky), *Lenticulina arcuatostriata* (Hankten), *Cyclammina acutidorsata* (Hantken) and *Spiroplectinella carinata* (Orbigny) point out the outer shelf neritic conditions (Zlinská, 1992).

The Čelovce Mb., a lateral equivalent of the Prešov Fm. upper part, transgressively overlies the Paleogene sedi-

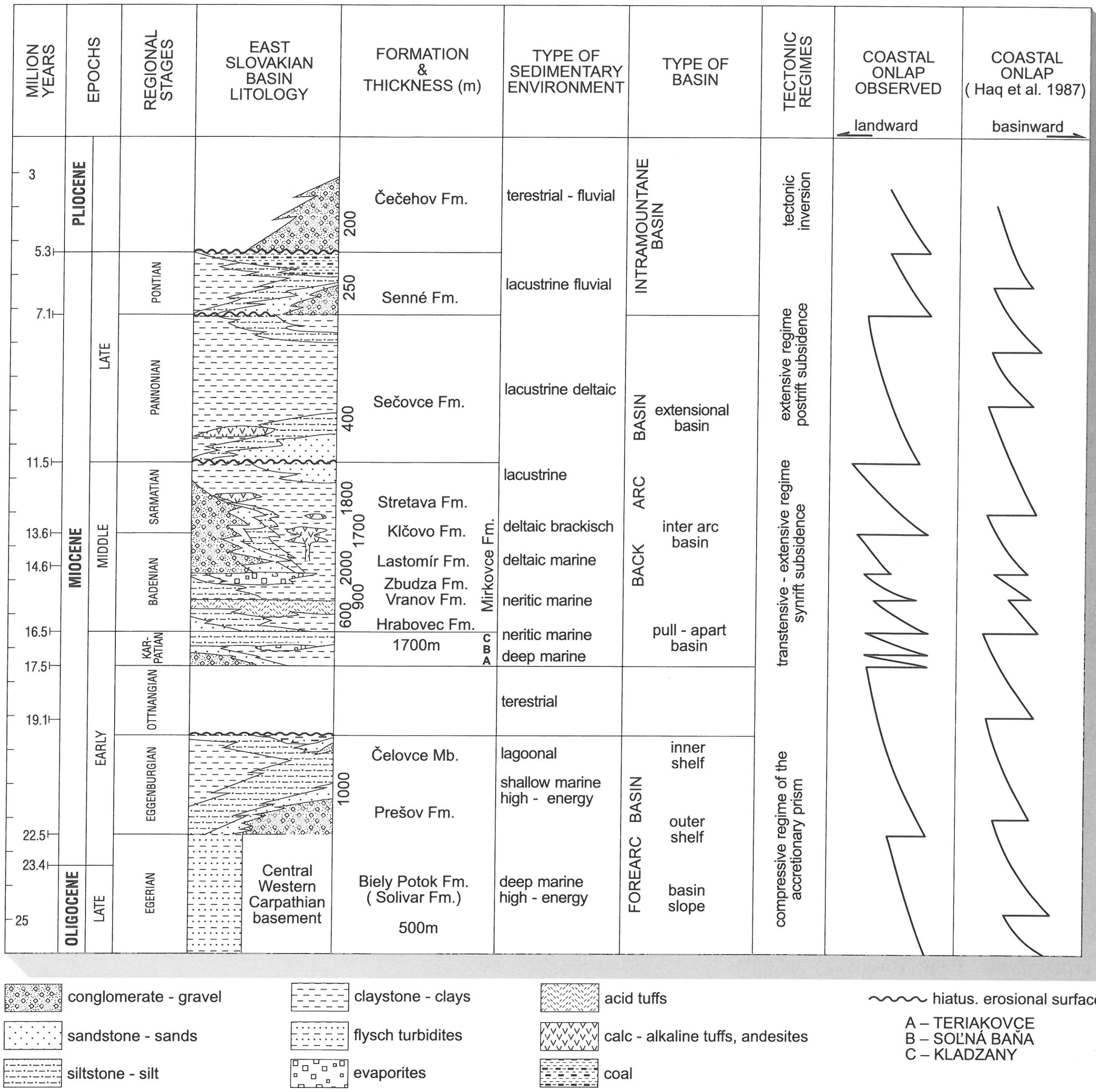


Fig. 3. Neogene formations, lithostratigraphy and maximal thickness of the East Slovakian Basin fill, coastal onlaps and tectonic regimes
Ryc. 3. Formacje neogeńskie, litostratygrafia i maksymalna miąższość wypełnienia basenu wschodniosłowackiego, przybrzeżne kontakty wstępujące i reżimy tektoniczne

ments. The siltstones and claystones in the lower part of the sequence were deposited in the shallow marine inner shelf environment. They gradually pass into the lagoonal, coal bearing layers overlain by plant detritus bearing siltstones, sandstones and conglomerates. The mentioned sequence documents the shallow water high-energy littoral environment allowing a wide spectrum of depositional processes ranging from gravitational flows to turbidites (Janočko, 1993). The rapid input of coarse clastic material indicates the surface uplift of the basin margin associated with isolation and decrease of salinity. The changes in sedimentary environment, as well as the high-energy conditions are well documented by shallow water foraminiferal assemblages with *Ammonia beccarii* (Linné), *Porosononion aff. subgranosum* (Egger), *Nonion commune* (Orbigny), *Elphidium sp.*, *Lenticulina meznericsae* (Cicha), *Cibicidoides budayi* (Cicha et Zapletalová), reached in the bed load redeposits of neritic fossils of the same age: *Uvigerina hantkeni* Cushman, *Bulimina elongata* Orbigny and *Lenticulina sp.* (Fig. 5).

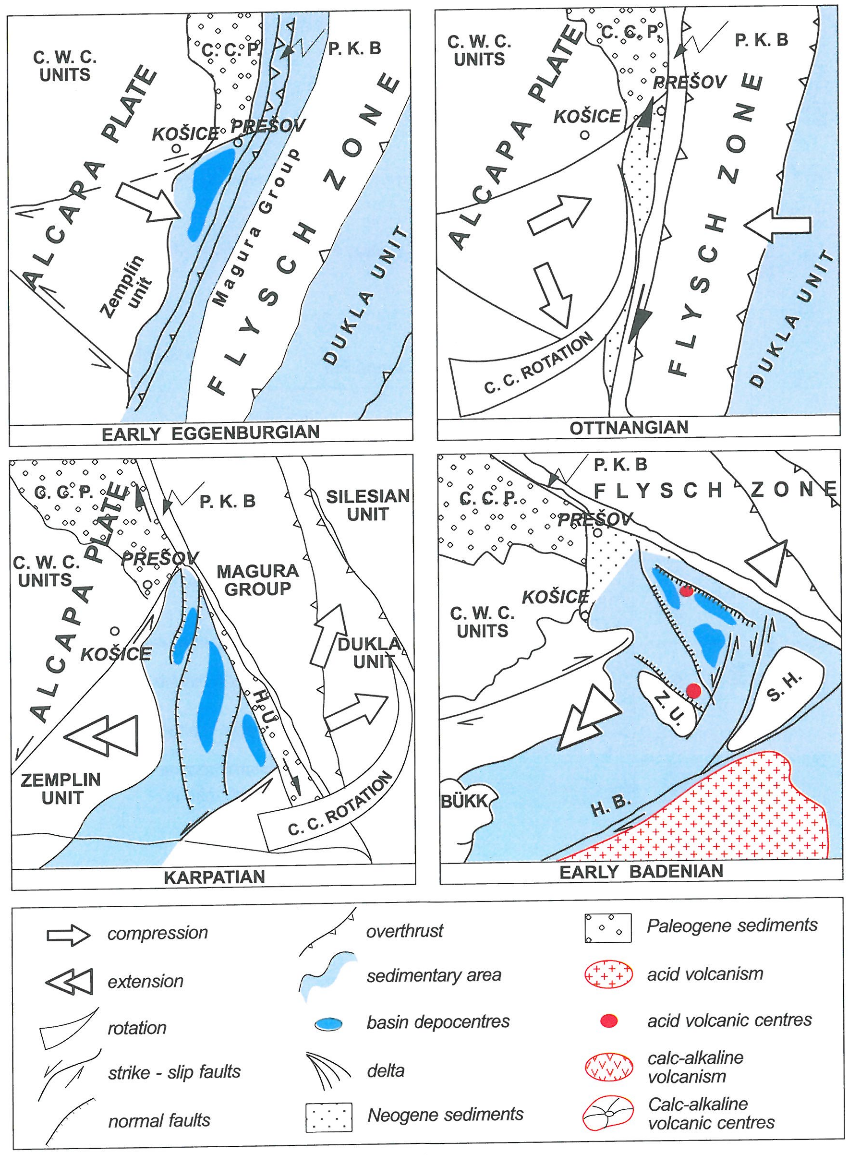
The Ottnangian compressive regime led to the uplift of the Central Western Carpathians active margin, marked by a hiatus in the East Slovakian Basin (Rudinec, 1978, 1989).

The Karpatian sediments overlay transgressively the Eggenburgian strata and the pre-Neogene basement of the East Slovakian Basin (Fig. 4). The shape of the basin and the sedimentary facies distribution were controlled by the activity of NW–SE trending dextral strike slip faults and NE–SW ranging faults, situated along the Seredne horst at the southern margin of the basin (Kováč et al., 1995). The total thickness of the Karpatian shallowing upward sequence attains 1700 m (Vass et al., 1988).

The basal Teriakovce Fm. (Vass & Čverčko, 1985), over 500 m thick contains conglomerates, sandstones and siltstones in the lower part followed upwards by sandy-clayey sequence. The marine microfauna documents the open marine, deep neritic to shallow bathyal zone evidenced by the deep water low oxic conditions tolerating foraminiferal taxa, e.g. *Pappina parkeri breviformis* (Papp et Turnovsky), *P. bononiensis primiformis* (Papp et Turnovsky), *Lenticulina calcar* (Linné), *L. inornata* (Orbigny), *L. cultrata* (Montfort), *Uvigerina graciliformis* Papp et Turnovsky, as well as planktonic *Globigerina ottnangiensis* Roegl, *G. praebuloides* (Blow) (Zlinská, 1992).

Upwards, the Solná Baňa Fm. was deposited. Isolation of the East Slovakian Basin in this time led to the salt crystallization. The 250 m thick sequence, representing an evaporite event consists of claystones, siltstones with sporadic sandstone layers, gypsum, anhydrite and salt (Fig. 3, 5).

The Karpatian sedimentation continued by deposition of variegated clays and silts with thin sandstone intercalations of the 1300 m thick Kladzany Fm. representing a large surface wash. Mixed foraminiferal assemblages composed of the inner shelf taxa tolerant to salinity changes: *Elphidium macellum* (Fichtel et Moll), *E. fichtelianum* (Orbigny), *Ammonia beccarii* (Linné) and stenohaline forms of the outer shelf, e.g. *Uvigerina graciliformis* Papp-Turnovsky or *Cyclammina karpatica* Cicha et Zapletalová point out to the deposition in shallow to deep neritic high-energy environment (Zlinská, 1992).



It is important to note that the transtensional tectonic regime disintegrated the Karpatian sedimentary area during the Lower Badenian (Fig. 4). Some parts continued subsiding, others were uplifted. This is reflected in the redeposition of the Karpatian microfauna in the Lower Badenian sediments of the Mirkovce Fm. (Kaličiak et al., 1990).

The Middle Miocene sedimentary sequences

During the Middle Miocene the East Slovakian Basin development was controlled by the transtensive regime. Two separated depocenters can be distinguished, the Košice depression on the west and the Trebišov depression in central and eastern part (Fig. 4) The shape of the basin was formed predominantly by NW–SE and NE–SW trending faults (Kováč et al., 1995).

On the western flanks of the East Slovakian Basin the 630 m thick Mirkovce Fm. (Karoli & Zlinská, 1988) was deposited during the Early to Middle Badenian. The monotonous marine pelites deposited in low-energy environment are characterized in the lower part of the sequence with *Praeorbulina — Orbulina — Uvigerina macrocarinata* Papp et Turnovsky foraminiferal assemblages pointing out the neritic environment (Zlinská, 1992). In the upper part of the open marine deep neritic sequence the planktonic foraminifera, e.g. *Globigerina decoraperta* Takayanaki-Saito, *G. druryi* Akers, *G. nepenthes* Todd, bentic taxa with *Uvigerina aculeata orbignyana* Czjzek, *U. acuelata acuelata* Orbigny and agglutinated forms, e.g. *Cyclammina vulchoviensis* Venglinsky and *C. zemplinica* Cicha et Zapletalová are present.

In the central and eastern part of the East Slovakian Basin, the Lower Badenian Nižný Hrabovec Fm. represents a new high-energy cycle, composed of the 500–600 m thick volcano-sedimentary complex (Vass & Čverčko, 1985). The sequence contains the planktonic foraminifera taxa, e.g. *Praeorbulina glomerosa* (Blow), *Orbulina suturalis* Broenniman, *Globigerinoides quadrilobatus* (Orbigny), *G. trilobus* (Reuss) pointing out to the open marine neritic conditions (Fig. 5).

Following upwards, the Middle Badenian up to 600 m thick Vranov Fm. was deposited (Vass & Čverčko, 1985). The sequence started with sands and clay intercalations, followed by dark calcareous clays with sporadic tuff and tuffite layers. The depth of the sedimentary environment was neritic, but also a shallow bathyal, nutrient rich open marine environment cannot be excluded what is marked by agglutinated foraminifera assemblages with *Cyclammina vulchoviensis* Venglinsky, *C. complanata* Chapman, *Spiroplectammina carinata*

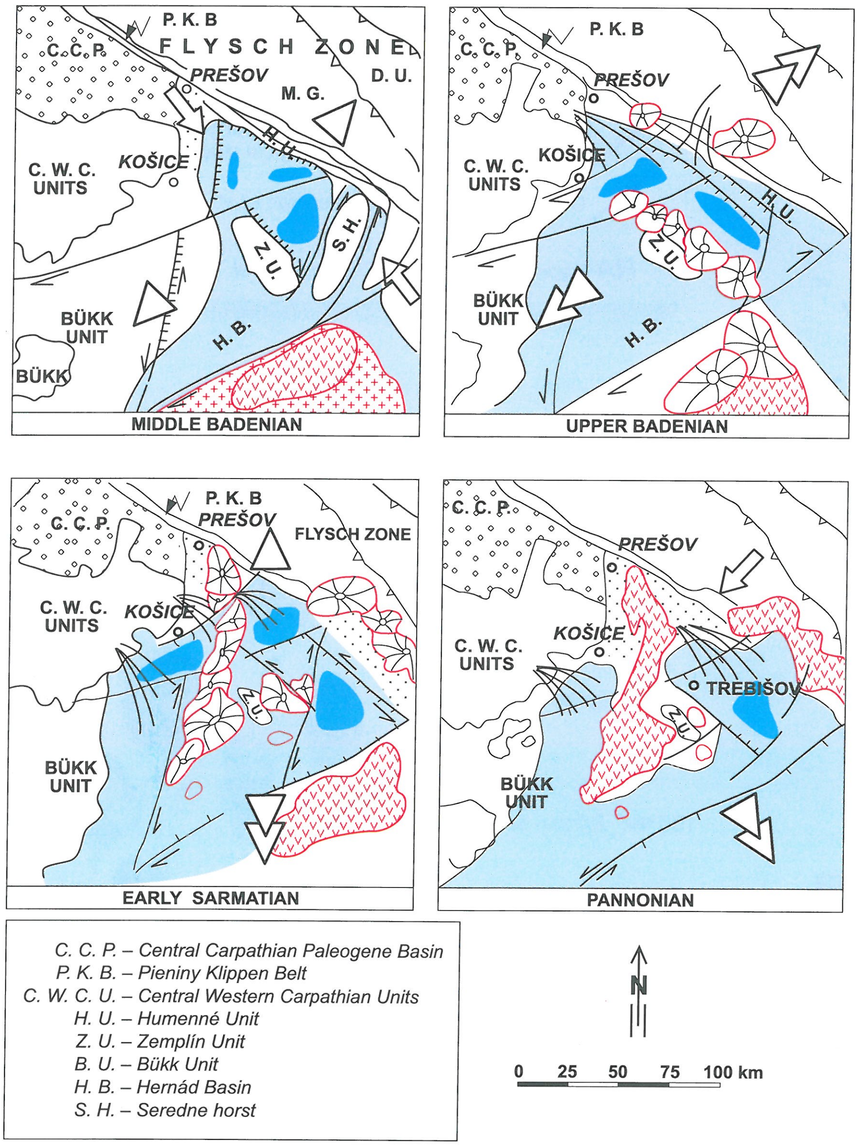


Fig. 4. Palinspastic reconstruction of the East Slovakian Basin evolution during the Miocene
Ryc. 4. Palinspastyczna rekonstrukcja ewolucji basenu wschodniosłowackiego w miocenie

(Orbigny) and planktonic taxa, e.g. *Globigerina praebulloides* (Blow), *Globorotalia mayeri* (Cushman et Ellisor) (Zlinská, 1992). The end of the Middle Badenian sedimentary cycle is represented by the shallow water lagoonal salt deposition (Fig. 3, 5). The Zbudza Fm. (Vass & Čverčko, 1985) with poor (redeposited?) planktonic foraminifera assemblages, e.g. *Orbulina, Globigerina* and low oxic *Bulimina* reaches maximal thickness of 300 m.

During the Upper Badenian a deltaic system reaching the depression from the NW developed in the East Slovakian Basin (Fig. 4). The configuration and development of the delta fan lobes were influenced by tectonic activity (Rudinec, 1989; Janočko, 1993).

The lower Lastomír Fm., up to 2000 m thick (Vass & Čverčko, 1985) is characterized by dark calcareous clays and claystones with sandy intercalations in its marginal parts, representing the delta front to prodelta deposits with neritic *Bulimina—Bolivina* assemblages, pointing out to the stratification of water masses with low oxic conditions at the bottom (Fig. 5).

The upper Klčovo Fm., up to 1700 m thick (Vass & Čverčko, 1985) represents the progradational delta plain to delta front sequence deposited during the Upper Badenian and Lower Sarmatian (Fig. 3). The sequence in its lower part contains a mixture of shallow water littoral assemblages with *Ammonia, Anomalina badenensis* (Orbigny), *Elphidium, Nonion* and small miliolides and neritic assemblages containing *Globigerina, Bulimina and Bolivina*. In the upper part of the sequence only the shallow water *Elphidium* taxa are present.

The Sarmatian sedimentary environment was characterized by a gradual decrease of salinity due to the isolation of the Paratethys sea in the Carpathian–Pannonian area from the Mediterranean. In the marginal parts of the East Slovakian Basin the environment of the delta plain and delta front prevailed (Fig. 4). The deltas were much smaller then the Upper Badenian ones. Minor fan and braided type deltas dominated (Janočko, 1993).

The basinal brackish facies is represented by the Lower to Middle Sarmatian, 1800 m thick Stretava Fm. (Vass & Čverčko, 1985) built up of a monotonous complex of calcareous clays intercalated with sands and rhyolite volcanoclastics. The sequence contains the shallow water foraminiferal taxa, e.g. *Elphidium reginum* (Orbigny), *E. aculeatum* (Orbigny), *E. macellum* (Fichtel et Moll), *E. samueli* Zlinská, *Articulina articulinoides* Gerke-Issaeva, *A. problema* Bogdanowicz and mioliolides (Fig. 5).

The overlaying Upper Sarmatian Kochanovce Fm. was deposited in the freshwater environment with coal deposition and it represents a lateral equivalent of the Stretava Fm. upper part (Vass & Čverčko, 1985).

The Late Miocene sedimentary sequences

During the Upper Miocene the East Slovakian Basin became a part of the back arc Pannonian Basin System, where the postrift sedimentation was controlled by thermal subsidence at this time (Horváth et al., 1988; Royden, 1988). The thickness of the Pannonian and Pontian deposits attains 700–800 m (Rudinec, 1989). Alternating claystones, sandstones, conglomerates, tuffs and coal seams were deposited in the lagoonal, latter lake and fluvial environments (Fig. 3, 4).

Conclusions

The aim of the study was to discuss the sedimentary history and development of the East Slovakian Basin from the viewpoint of interaction between the regional tectonic events forced by the subduction in front of the orogen and the back arc extension and global sea level changes (Fig. 3).

The Early Miocene development. The Early Miocene collision between the Western Carpathians and the North European Platform was associated with the compressive tectonic regime. The Egerian deep water high-energy sedimentation on the Central Western Carpathian eastern margin continued in a relic forearc basin (*sensu* Einsele, 1992). Due

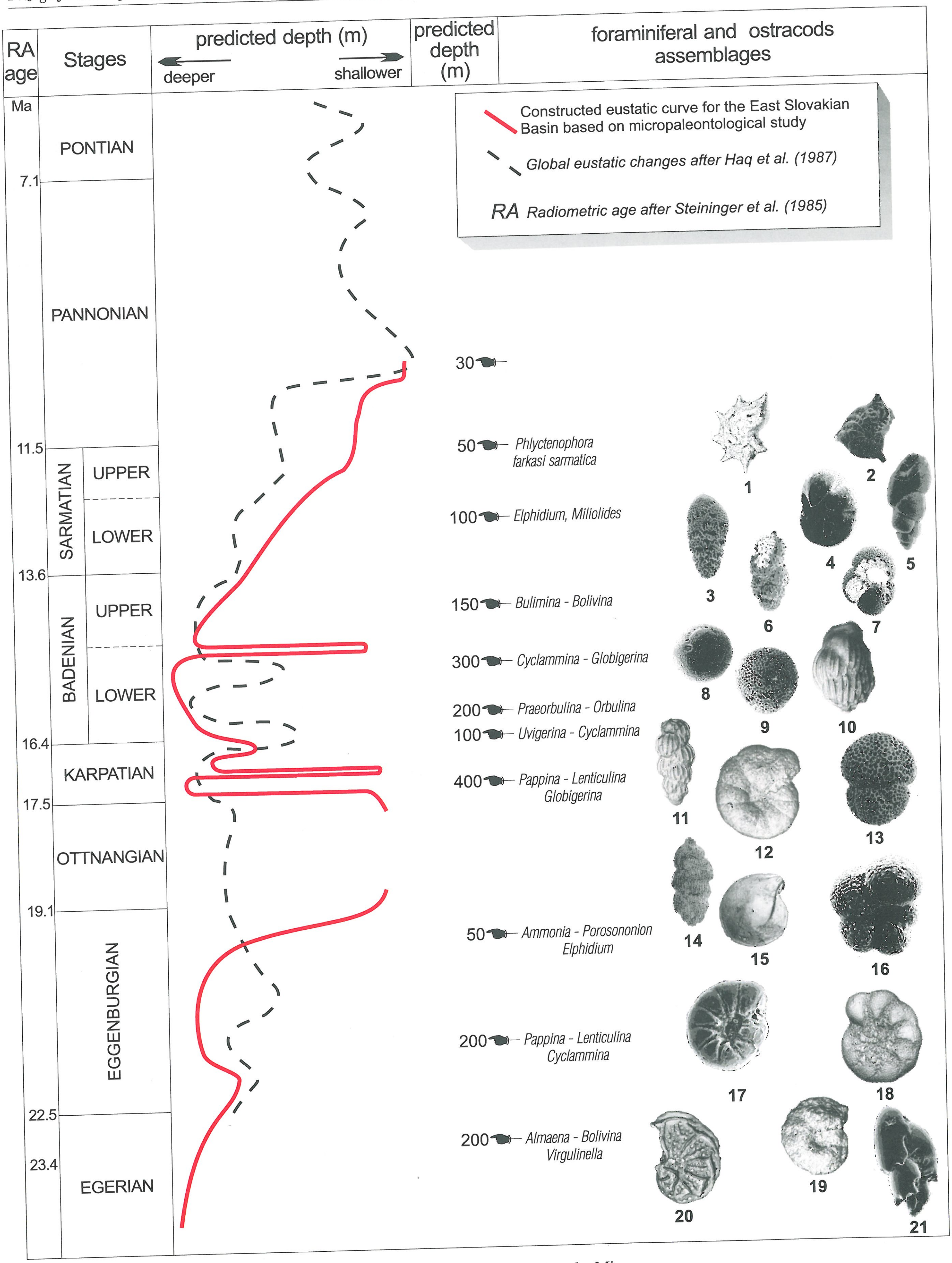


Fig. 5. Constructed eustatic curve and depth of the East Slovakian Basin during the Miocene
1— *Elphidium aculeatum* (Orb.), 2 —*Elphidium reginum* (Orb.), 3 — *Bolivina hebes* Macfadyen, 4 — *Valvulineria complanata* (Orb.), 5 — *Bulimina elongata* (Orb.), 6 — *Uvigerina aculeata orbignyana* (Orb.), 7 — *Globigerina bulloides* (Orb.), 8 — *Orbulina suturalis* Broenn., 9 — *Praeorbulina glomerosa* (Blow), 10 — *Uvigerina macrocarinata* Papp-Turn., 11 — *Uvigerina graciliformis* Papp-Turn., 12 — *Cyclammina* sp., 13 — *Globigerinoides trilobus* (Rss.), 14 — *Pappina bononiensis primiformis* (Papp-Turn.), 15 — *Lenticulina cultrata* (Montfort). 16 — *Globigerina ottnangiensis* Roegl, 17 — *Ammonia beccarii* (L.), 18 — *Elphidium (Porosononion) granosum* (Orb.), 19 — *Cyclammina acutidorsata* (Hantken), 20 — *Almaena osnabrugensis* (Muenster), 21 — *Virgulinella chalkophylla* (Hagn)
Ryc. 5. Skonstruowana krzywa eustatyczna i głębokość basenu wschodniosłowackiego w miocenie

to compression the high-energy sedimentary environment of the basin was changed from deep to shallow water during the Eggenburgian. Later on, the compression forced the uplift of the area marked by hiatus in the sedimentary record of the East Slovakian Basin in the Ottnangian (Haq et al., 1988; Fig. 3).

The global sea level fall and rise on the short term eustatic curve (Haq et al., 1987) between 22.5–22 Ma can be correlated with the Eggenburgian transgression in the East Slovakian Basin. The Haq et al., (1987) curve oscillations upwards are not documented because of tectonically controlled basin evolution and hiatus during the Ottnangian.

Due to the Karpatian changes in the overriding plate movement, the Central Western Carpathian margin was deformed by wrench tectonics, which opened the East Slovakian pull-apart Basin during the Karpatian. The change from transpressional to transtensional tectonic regime was associated with initial rifting and was accompanied by acid volcanism (Lexa et al., 1993).

The Karpatian transgression, well documented by coastal onlap was strengthened by tectonics and can be correlated with the global short term sea level oscillation at 17.5 Ma (Haq et al., 1987). The 1700 m thick finning upward sequence represents a transition from the deep neritic low-energy to the shallow neritic high-energy environment. The intra Karpatian salinity crisis is regarded as the tectonically controlled local sea level fall due to basin isolation (Fig. 3).

The Middle Miocene development. During the Middle Miocene, the subduction roll-back effect has caused the extension in the overriding slab, followed by rifting and subsidence in the back arc area (Vass et al., 1988; Kováč et al., 1995). The crustal stretching was associated with mantle updoming, accompanied by acid and later calc-alkaline volcanism in the East Slovakian Basin (Szabó et al., 1992; Lexa et al. 1993).

The Lower Badenian sea level rise, which can be correlated with the global sea level oscillation at 16.5 Ma (Haq et al., 1987) led to the deepening of the sedimentary environment of the East Slovakian Basin. The synrift crustal extension was associated with voluminous acid volcanism, whose products were deposited in the high-energy environment of neritic depth.

Upwards, the Middle Badenian part of the sequence was deposited predominantly in the deep neritic (to shallow bathyal) low-energy open marine conditions with low aeration on the basin bottom. To the climatic conditions and fall of the sea level between 15.5 ± 15 Ma (Haq et al., 1987) can be referred the lagoonal shallow water salt deposition et the end of the Middle Badenian (Fig. 3).

The Upper Badenian to Sarmatian high-energy deltaic sedimentation of the shallow neritic to littoral sequence can be regarded as a consequence of local tectonics. In contradiction to oscillations on the short term curve (Haq et al., 1987) a continuous shallowing (or sea level fall) is observed in the East Slovakian Basin (Fig. 5).

The Upper Miocene development.At the end of the Middle Miocene the settlement of convergence and subduction velocities took place in the Western to Eastern Carpathians junction (Royden, 1993). The slab detachment (*sensu* Wortel & Spakman, 1992) as it was described by Tomek and Hall (1993) was followed by regional uplift of the Carpathians front.

The Upper Miocene development of the East Slovakian Basin represents the postrift stage of back arc basin evolution in the Pannonian Basin System, where the thermal subsidence dominated. The extensional regime was associated with some compressional events preceding the Pliocene tectonic inversion of the area (Kováč et al., 1995). No correlation with short term curve of Haq et al. (1987) was possible.

The authors wish to express their gratitude to the grants N.13052/96, N. 24076/97 and N. 24007/97 for financial support.

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