Geologický ústav Dionýza Štúra
KNIŽNICA
Mlynská dolina 1
817 04 BRATISLAVA



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# History of the Pannonian Basin and its margins in the Cenozoic

DUŠAN ĎURICA*, JURIJ G. NAMESTNIKOV**, TAŤJANA V. STREĽCOVA**, JEVGENIJ G. DONGAROV**

* Český geologický úřad, Kodaňská 10, 101 59 Praha 10
** ВНИИ Зарубежгеология, Москва Б-49, Крымский вал 22

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**История развития территории Паннонской впадины и её оформления в кайнозое**

В статье рассмотрены вопросы, касающиеся распространения и литологического состава осадочных кайнозойских образований Паннонской впадины. Текст иллюстрирован 10 картами.

В истории развития территории Паннонской впадины в кайнозое выделяется три основных седиментационных цикла. Первый, эоценолигоценовый, характеризовался развитием морской трансгрессии в центральной части впадины, а также в отдельных ее краевых частях. Регрессия моря произошла в позднем олигоцене. Второй цикл, миоценовый, начался эггенбург-карпатской морской трансгрессией, охватившей вначале, в основном, юго-западные районы впадины. В баденский век отмечалась кульминация трансгрессии, когда большая часть территории впадины была покрыта мелководным морем. Регрессия моря отмечается в конце сарматского времени. Третий цикл, плиоценовый, отличается новой трансгрессией моря, покрывшей значительные участки Паннонской впадины (паннон-понт). Затем наступила регрессия морского бассейна и накопление континентальных осадков.

В результате проявления первого седиментационного цикла продолжалась заключительная стадия формирования структурных элементов, заложившихся, главным образом, в мезозое. Во второй и третий циклы сформировались современные очертания новой структуры — Паннонской впадины. При этом во время второго цикла заложились, прежде всего, Венская и частично Малая Венгерская, Савско—Дравско—Мурская впадина и впадина Восточно-Словацкого неогена (рис. 9). Во время третьего цикла сформировалась, главным образом, Большая Венгерская впадина (Алфельд) и дальнейшее развитие получили Малая Венгерская и Савско—Дравско—Мурская впадины (рис. 10).

Особенности развития Паннонской впадины в кайнозое и, особенно, в неогене имеют существенное значение при оценке перспектив нефтегазоносности этой территории.

**History of the Pannonian Basin and its margins in the Cenozoic**

The paper discusses the distribution and lithology of the Cenozoic sedimentary formations in the Pannonian Basin.

In the development of the Pannonian Basin area three principal sedimentary cycles have been delimited. The first, Eocene to Oligocene

cycle, the second, Miocene cycle and the third, Pliocene cycle.
In result of the manifestation of the first sedimentary cycle, the development of structural elements, initiated mainly in the Mesozoic, entered the final stage. In the second and third cycles the present-day outlines of a new structure, the Pannonian Basin, were formed. Simultaneously, it was chiefly the Vienna Basin, in part the Minor Hungarian Plain, the Sava-Drava-Mura depression and the Neogene East Slovakian Basin that originated during the second cycle (Fig. 9). In the third cycle the Great Hungarian Plain was generated and the Minor Hungarian Plain and the Sava-Drava-Mura depression continued developing (Fig. 10).
The peculiarities of the development of the Pannonian Basin in the Cenozoic and especially in the Neogene, are of primary importance for evaluating the oil-gas prospects of this area.

In the Upper Paleozoic and Mesozoic the area of the Pannonian Basin extended for the most part in the region of shelf seas, which bordered the ancient Tethys Ocean. The pre-Cenozoic history of this area was terminated by a regional uplift and folding at the end of the Cretaceous period and by the origin of a landmass that existed until the Paleocene (Ďurica et al., 1984). The subsequent geological history of this area was connected with the evolution of the Paratethys sedimentary basin, whose peculiar configuration was controlled mainly by the developmental character of the Alpine-Carpathian-Dinaric orogenic belt.

During the Eocene and Oligocene (Figs. 1, 2) the southern marginal parts and the central part of the Pannonian basin area had subsided. In the marginal parts of its present-day structural plan sedimentation of coarse clastic rocks essentially prevailed; along the longitudinal faults in the central part (Savian depression, Szolnok graben) flyschoid complexes and predominantly carbonate sediments were deposited. The uplift of the Inner Carpathians and Dinarides in the late Oligocene and early Miocene provoked the uplift of the Pannonian basin area, which resulted in the interruption of sedimentation. At that time sedimentation only continued in the NW and E.

At the beginning of the Miocene epoch, in the Eggenburgian, Ottnangian, Karpatian and Badenian, the intensified tectonic subsidence of the Alpine foredeep brought about another transgression in the west of the Paratethys, which extended gradually eastwards. During the Eggenburgian to Ottnangian this caused deposition (Fig. 3) of shallow-water to paralic gravel and sand and in places (in the western part of the basin) of bioclastic bryozoan psammitic-psephitic limestones. The marine transgression proceeded from NW across the area of the present-day Vienna Basin by a narrow channel which connected the Alpine foredeep with the Pannonian Basin. Sedimentation started with basal coarse-clastic deposits to continue with clayey shales enclosing thin sand interlayers. During the Karpatian stage the sea inundated larger areas. At that time the Minor Hungarian Plain and part of the Great Hurgarian Plain were generated, being separated by an elevation in the area of the present-day Pannonian median mass. In the northern part of the Vienna Basin shallow-water marine sediments were laid down, whereas in the southern part, separated by the Spanberg zone, fluviolacustrine sandstones and claystones containing brown-coal seams, and thick gravel beds accumulated. The sea, whose salinity decreased gradually, invaded from the Vienna Basin the Zala depression area by a narrow channel. In

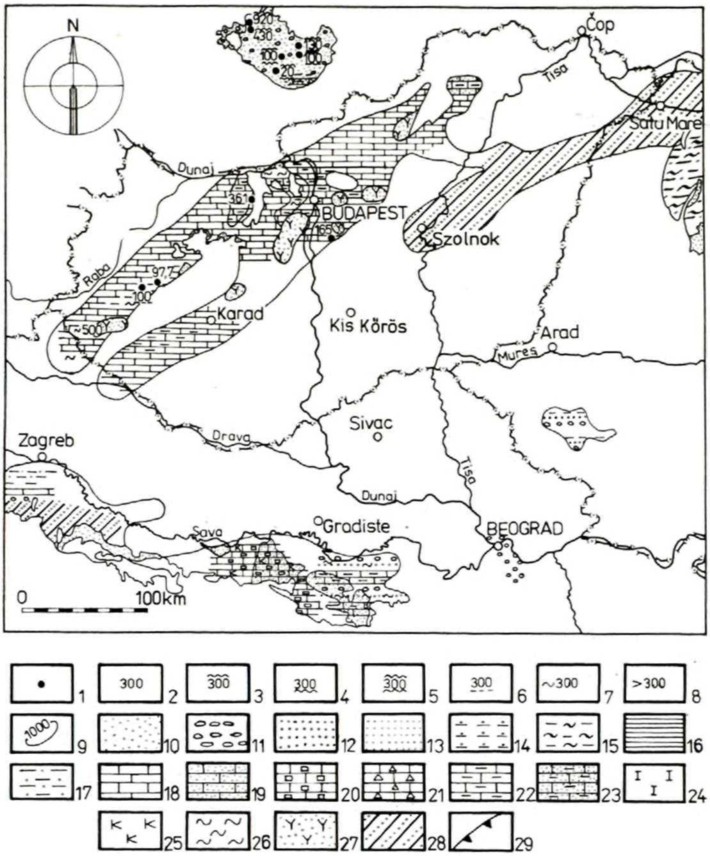


Fig. 1. Scheme showing the present distribution and lithology of Eocene sediments in the Pannonian Basin. 1 — boreholes, 2 — total thickness in m, 3 — incomplete thickness caused by erosion of the upper part of the profile, in m, 4 — incomplete thickness due to erosion of the bottom part of the profile, in m, 5 — incomplete thickness due to erosion in both the upper and bottom parts of the profile, in m, 6 — incomplete thickness because of the paucity of data on the lower part of the profile, in m, 7 — approximate thickness, in m, 8 — thickness based on the higher record, in m, 9 — isopachs, m, 10 — outcrops of sediments of the complex studied. Lithology: 11 — conglomerates, 12 — pea gravel, 13 — sand, sandstones, 14 — siltstones, 15 — clay, claystones, 16 — clayey shales, 17 — sandy-clayey sediments, 18 — limestones, 19 — sandy limestones, 20 — clastic limestones, 21 — biogenic and reef limestones, 22 — marls, clayey limestones, 23 — sandy marls, 24 — Cretaceous sediments, 25 — variegated rock types, 26 — coal-bearing sequence, 27 — volcanogenic rocks, 28 — terrigenous flysch, 29 — overthrust of Outer Flysch Carpathians

the SE part of the depression (between the rivers Mura and Drava) sedimentation was already of fresh-water character (Bodzay, 1968). The area of Sava depression situated farther to the S was a semi-isolated water basin. In narrow littoral zones of it sedimentation began with conglomerates and coarse-grained sandstones and continued with sandy marlstones and claystones with brown-coal seams; sandy limestones deposited in its central part attained a thickness of 500 m at the most. They yielded foraminifers, which indicate a warm (24 °C) sea of rather small depths

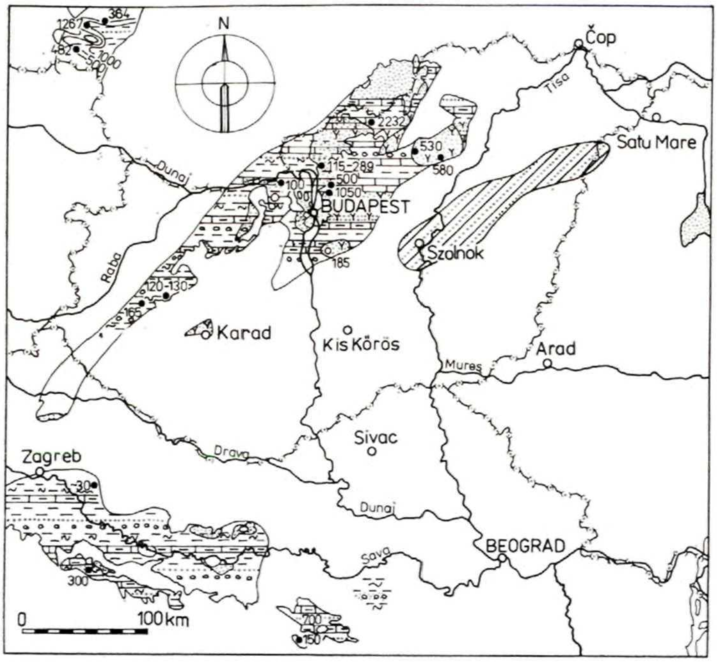


Fig. 2. Scheme showing the present-day distribution and lithology of the Oligocene sediments of the Pannonian Basin. For explanation see Fig. 1


Fig. 3. Map of the thicknesses and lithology of the Eggenburgian-Karpathian sediments of the Pannonian Basin. For explanation see Fig. 1

(< 100 m; Sikic, 1968).

The waters of low salinity flowed by the narrows between the Mecsek-Villány dry land (in the N) and the Papuk area (in the S) into the southern part of the present-day Alföld (the Great Hungarian Plain), where a 100—250 m thick complex of coarse-clastic sediments accumulated, filling the unevenly eroded floor of the water basin. The landmass bordering this basin in the S had probably a high relief, with lakes and swamps in its lower parts. Characteristic of the period dealt with was volcanic activity, as is suggested by interlayers of volcanic rocks in the predominantly sandy-marly and clayey sediments 200—300 m thick. Carbonate material was deposited chiefly in the central parts of water bodies.

In the bay located north of the Mecsek Mts. the lower Miocene gravels and sandstones contain lenses and interseams of brown coal, which yield characteristic freshwater molluscs, and interlayers of calcareous sandstone (with Congeria) and rhyolite tuff (Vadas, 1964). Farther to the N this bay opened into the sea of normal salinity, rich in fauna (fishes, echinoderms, bryozoans, ostracods).

Marine sediments of Eggenburgian and Karpatian age and of increased thickness are concentrated in the N, in the area of the Great Hungarian Plain (Alföld). The sea basin that had developed there had obviously a limited connection with the open sea and was a relict of the Oligocene sea. In salty lagoons in the NW part of the present-day Transcarpathian Basin salt masses of a great thickness accumulated under warm climatic conditions. In a lagoon situated N of the area of the Bözsöny and Cserhát Mts., a marked sedimentation of shallow-water gravel, sand and unconsolidated sandstones containing large Pecten forms and other faunas (Salgótarján drill hole) was followed by deposition of continental gravel, variegated clays with brown-coal seams, and of rhyolite tuffs (Vadas, 1964).

In the Badenian age the transgression continued to extend (Fig. 4). The sea inundated a considerable part of the Pannonian Basin area, forming a shallow-water basin divided by numerous archipelagos. The shoreline was presumably very dissected and created many bays and lagoons. The Vienna Basin, the Minor Hungarian Plain, the Great Hungarian Plain and the Transcarpathian Basin became more distinctly outlined at that time.

In the Vienna Basin area the sea expanded and flooded further sectors of the landmass. Along their margins, mainly in the SE part, Lithothamnion limestones originated under paralic conditions. In the interior of the basin clayey marls with numerous sand intercalations were laid down at a depth of 100—200 m. The thickness of sediments ranges from 100 to 600 m along the margins and the 1000 or more metres in the central parts.

In the area of the Minor Hungarian Plain the subsidence was maximum along the northern and southern margins. The character of sedimentation in these two parts is fairly coincident. In result of extending transgression, at the base of the profile there are coarse-clastic rocks (conglomerates, sands, detrital and Lithothamnion limestones), covering the eroded surface of older formations. Coalified and pyritized plant remains and frequent detailed cross-bedding provide evidence of their littoral origin. In the central parts the Badenian sequence shows a more monotonous, clayey-marly character. The thickness of the accumulated sediments was considerably controlled by the relief of those parts of the sea floor that had been flooded not long ago. For example, in the Nagylengyel area the thickness of deposits changes from 80 to 210 m over short distances (Vadas, 1964).

The Sava depression was, the same as before, a semi-isolated shallow-water basin with a large number of narrow channels and minor bays, where bituminous marls and sands were laid down; at other places (in the neighbourhood of Tuzla) salt deposits of a great thickness occur at the base. In the northern part of this basin tectonic activity of a fault zone extending along the present-day course of the river Drava obviously revived. As a result, sedimentation attained there maximum thicknesses, and the products of submarine volcanic effusions are involved in the rock complex.

The principal volcanic activity, corresponding in time to the intensive fold and nappe deformations in the Outer Carpathians, occurred in the N and NE of the region studied and along the middle course of the river Tisa. Extensive massifs, predominantly of rhyolite tuffs and andesite lava were produced; lava flows and stratovolcanoes also formed in a large number. In places, the tuffs display a well discernible stratification produced by water environment. Volcanic rocks occasionally alternate with marine carbonate sediments (Szeki-Fux et al., 1981).

The basin of the Great Hungarian Plain is divided into two parts by a narrow island belt, which follows the river Tisa in a nearly N—S direction. The western part was occupied by shallow-water basin with small islands. The dissected shoreline of both the basin and islands created numerous bays. In some of them (e. g. NW of the Mecsek Mts.) evaporites were deposited besides clastic and volcanogenic rocks, whereas in others (in the central

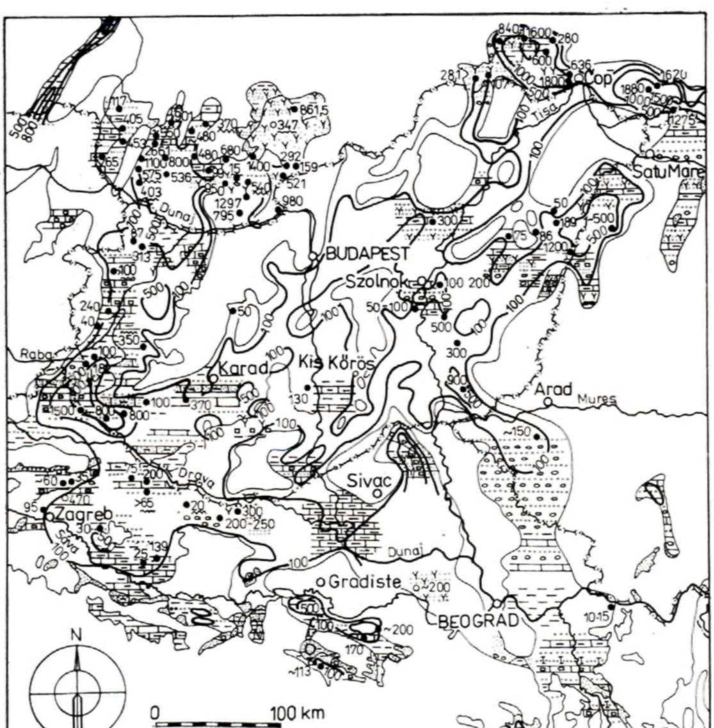


Fig. 4. Map showing the thicknesses and lithology of the Badenian sediments of the Pannonian Basin. For explanation see Fig. 1

part of the eastern shore) clays and marls were laid down where warm water greatly predominated over cool currents. In the Velebit area, barrier reefs were created in the southern part of the narrow channel, which separated the Mecsek-Villány island from the submeridional island belt (extending along the present-day course of the river Tisa). Clastic sediments prevailed in the northern part of the channel.

The eastern part of the basin of the Great Hungarian Plain had a shape of a narrow submeridional water basin widening to the N, where it was separated from the Transcarpathian Basin area by a broad sill. The eastern shore of this basin was also limited by a zig-zag dissected shoreline with many bays; the relief of the sea floor was likewise very uneven. Warm climate and isolate position (calm, pure water) were favourable for the formation of reef limestones and occasionally of gypsum (Şimleu-Silvaniei bay). Frequent tuffs and tuffites have been assessed in the profiles (which may point to the existence of a fault zone that separated the Pannonian block from the Transylvanian block in the E. The largest bay from which an inlet issued to the S, along the present-day course of the river Tamiš (Timişul) occurred in the contemporary valley of the river Maruš (Mureşul, Maros). Along the coast coral limestones interlaid with calcareous sandstones, fine-grained conglomerates and sands were deposited. In the interior parts marly and clayey rocks with interbeds of sand accumulated at a thickness of up to 200 m (Mutihac — Jonesi, 1974).

In the Badenian age the area of the Transcarpathian Basin separated and subsided intensely; it represented an intermontane depression in the hinterland of the uplifting Carpathian orogen. The subsidence of the basin was compensated by the cumulation not only of clastic and volcanogenic rocks but also of a thick salt complex; the total thickness of deposits in this narrow isolated furrow attains up to 1500 m.

In the middle of the Miocene epoch (in Sarmatian age) the western Paratethydian sea lost its connection with the ocean and decreased considerably in size. The northern Alpine marginal foredeep was closing and immediately afterwards the Pannonian Basin also became isolated (Fig. 5) and changed into a basin of medium salinity with a specific endemic fauna. The relation between the land and sea remained almost unchanged from the Badenian age, but the dissection of the shore increased owing to uneven epeiorogenic movements. A large number of small islands appeared. As a result of isolation of the basin, the salinity of water gradually decreased and the supply of terrigenous material from the dry land increased.

The Vienna Basin also became isolated in the Sarmatian age. In its central part, sedimentation of marly facies dominated in contrast to the near-shore parts, where sand, sandstones, conglomerates, and clastic Leitha limestones composed of fragments of older carbonate rocks accumulated.

In this period the basin in the Minor Hungarian Plain preserved broadly the same outline as it had in the Badenian. The sediments also show the same lithological composition and definite manifestations of interruptions of sedimentation are not frequent. The regressive character of the Sarmatian basin is demonstrated by the replacement of the marine fauna by the brackish. The interior parts of the basin are distinguished by the sequences of marly-clayey rocks, which attain the greatest thickness in the N (up to 500 m). In the southern part of the basin (in the Zala depression) sediments containing a larger amount of sandy material, trans-

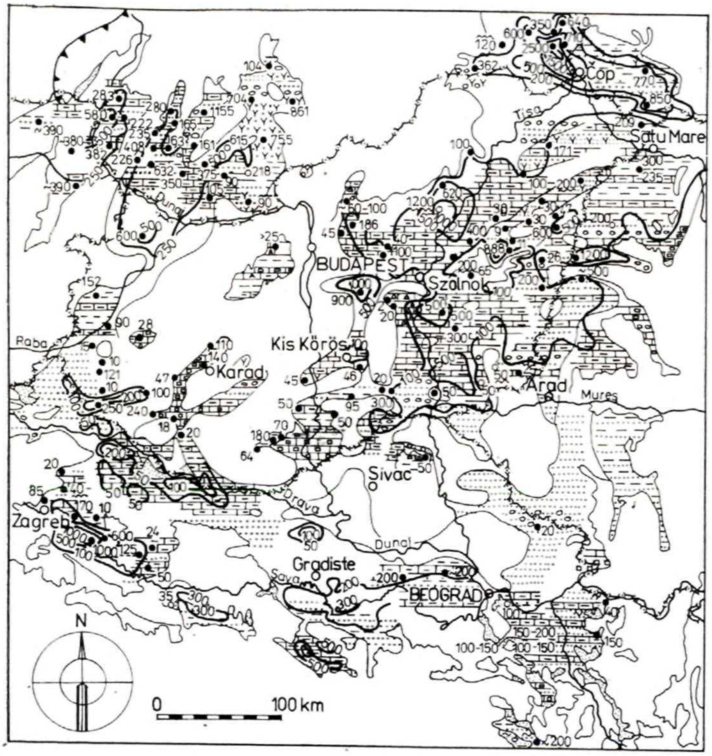


Fig. 5. Map showing the thicknesses and lithology of the Sarmatian sediments in the Pannonian Basin. For explanation see Fig. 1

ported by sea currents, were deposited. A direct connection with the Styrian Basin was blocked by the South Burgenland sill. The two basins might have been interconnected in the area of the present town of Szombathely (Bodzay, 1968). The thickness of Sarmatian deposits varies considerably; in the area of Budafa it is 413 m, Obornak — 476 m, Nagylengyel — 183 m, and Bužak — 47 m (Vadas, 1964). This can be explained either by later (pre-Pannonian) erosion or by wedging out of deposits on the elevated parts of the basin floor.

For the time being we have no conclusive evidence of the connection between the northern and southern parts of the Minor Hurgarian Plain NE of Ikervár, but the connection with the Drava and Sava depressions in the S is doubtless.

In the Sarmatian the area of the Sava depression was a narrow furrow running from NW to SE. Clayey rocks attained major thicknesses only in the axial zone (more than 1000 m near Stružec). Limestones, marlstones and sand were laid down along the western margin. At the eastern margin the Sarmatian deposits show a rhythmical structure with a predominance of marls (84 %) over sand, sandstone and limestone beds. On account of their proximity to the depression margin in the area of the Papuk Mts., which was exposed to strong tectonic movements, the sediments succumbed to repeated erosion. Their present thickness is very small (about 20 m in the area of Lipovljani, Bujavica, etc.) but it may have been of the order of 150 m.

In the area of the Drava depression the basin axis followed the present course of the river Drava; the basin was filled with marly sediments. Eastwards (towards the southern part of the Great Hungarian Plain) the depth and salinity of the sea gradually decreased. Along the southern margin isolated bays and lagoons occurred; rich flora growing in their waters of very low salinity provided material for the formation of coal seams in the sandy-clayey sequences.

The major part of the Great Hungarian Plain was occupied by a shallow-water basin with a rather monotonous claystone-limestone sedimentation. Along the margins of the basin and in bays predominantly clastic sediments (conglomerates, small-size gravel, sandy marls with coal interseams) and oolithic and biogenic limestones (mainly in the interior parts of bays) were deposited. The type of sediments suggests an arid climate alternating with humid intervals (Jambor, 1976). The presence of a large number of islands conditioned a frequent reduction of sediment thickness and a lateral alternation of facies. Of much importance were volcanogenic formations, both submarine and terrestrial. Two parallel zones of volcanic rock development can be traced, whose course coincides with the margins of the Szolnok graben. At the same time, structural elements such as the Szeged and Tótkomlós spurs and Makós depression were initiated.

In the area of the Transcarpathian Basin the segment of maximum subsidence diminished and moved westwards. Volcanic activity continued.

In the Pannonian age, which in our concept included the upper part of the Sarmatian and the Meotian, the connection of the freshwater isolated basin of the western Paratethys with the world ocean was renewed temporarily. The salinity of

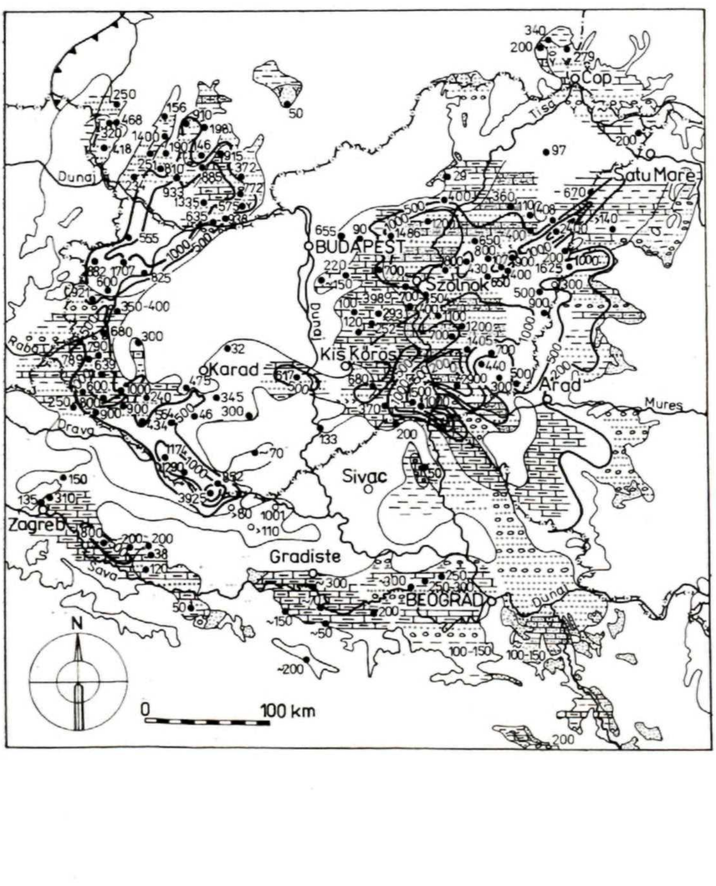


Fig. 6. Map showing the thicknesses and lithology of the Pannonian sediments in the Pannonian Basin. For explanation see Fig. 1

its water highly increased and the composition of fauna changed. The connection, however, was soon interrupted again and the sea decreased in extent already towards the end of the Pontian, and monotonous brackish fauna inhabited its waters of decreasing salinity. In the subsequent period of a continuing uneven uplift of the northern part of the Alpine orogen, the Paratethys basin definitively disintegrated into a number of separate water basins interconnected with narrow channels.

This sequence of processes was reflected markedly in the evolution of the Pannonian Basin (Fig. 6). Transgression proceeded gradually from W to E. The fact that between Lake Balaton and the Danube only upper Pannonian deposits are developed (Szeles, 1971) indicates that in the Sarmatian the greater part of this area was dryland, not yet flooded by the sea. At the same time a complete Pannonian profile originated in the area between the lower courses of the rivers Körös and Tisa. To the N, NE and SE of this area the profile begins with sediments of the upper lower Pannonian or the upper Pannonian. The faunal studies have demonstrated that the Pannonian sea, which had a brackish character at the beginning became gradually a freshwater basin. A characteristic feature is the development of lake bodies as a result of the disintegration of the uniform marine basin and of a supply of fluvial material. At the base of the lacustrine and lagoonal deposits there are coarse clastic deposits, being overlain successively by fine-grained sediments, river deposits and marshy coal-bearing sediments. Freshwater limestones were formed occasionally in the near-shore zone. The climate in the early Pliocene was warm, continental (Vadas, 1964).

In the Pannonian Basin a new transgression proceeded from the end of the Miocene until the beginning of the Pliocene epoch. The Pannonian-Pontian sea flooded the largest area of the Pannonian Basin during the entire Neogene period. At that time subsidence was intensive as is evidenced by maximum thicknesses of sediments accumulated (> 5000 m). The following five principal areas of subsidence have been established: the Minor Hungarian Plain, the Zala, Drava and Sava depressions and the Great Hungarian Plain.

The Vienna Basin became gradually enclosed at the beginning of the Pliocene. In its central parts predominantly clayey marls at a thickness of up to 1500 m were accumulated at that time. The near-shore zones display the influence of large rivers flowing from the Alps. Shallow bays slowly changed into swamps, where thick lignite complexes developed. Towards the end of the Pontian the Vienna Basin area began to rise. Sedimentation was terminated by deposition of varied clays, small-grained conglomerates, fresh-water limestones and variegated loams.

In the Minor Hungarian Plain, the Pannonian sedimentation was rather monotonous; fine-grained rocks attained there a thickness of up to 1000 m. The variance of sediment thicknesses, wedging out of beds, cross and diagonal stratification of deposits point to their shallow-water origin, whereas the transgressive type of lower Pliocene sediments in sectors that were uplifted until the beginning of sedimentation reveal the extension of the sedimentary basin. In the S, in the area of river Zala, sedimentation occured under the conditions of an open basin and was compensated by subsidence.

At the beginning of the Pontian age (Fig. 7) the Minor Hungarian Plain continued to subside. The sequence of sediments was of a homogeneous character, consisting of clays and clayey marls with lignite and sand seams and interbeds of pea gravel. Variegated clays of the upper horizons indicate continental conditions, which were a result of sea regression starting towards the end of the Pontian. Along the river Raba an occurrence of volcanic material has been established.

At the beginning of the Pliocene, the largest and deepest Drava graben occurring in the southern part of the Pannonian Basin, almost separated from the Sava graben. The character of sedimentation in both of them was very similar. Brackish sediments were replaced by freshwater deposits higher up in the profile. Sedimentation compensated for intensive subsidence. In the Drava graben a large amount of sand was transported into the interior, whereas marly rocks dominated along the margins (Kranjec et al., 1976). The thickness of sediment is maximum in the very narrow axial zone, obviously in relation with tectonic movements along the fault zone. In the early Pannonian, subsidence in the S part of the Sava depression occurred prevalently along the W—E running fault. Towards the end of the Pannonian the major structures were initiated to gain their definitive form during the early Pontian (Hermita, 1973).

In the N the area of the Drava graben was connected through a narrow channel with the area of the Great Hungarian Plain. In the Pannonian this was a basin elongated in NE direction, with very dissected shoreline and many embayments. The littoral zones differ in sedimentary facies from the interior parts, where marly rocks were chiefly deposited. Along the present-day course of the river Tisa runs a characteristic broad belt of sandy marls

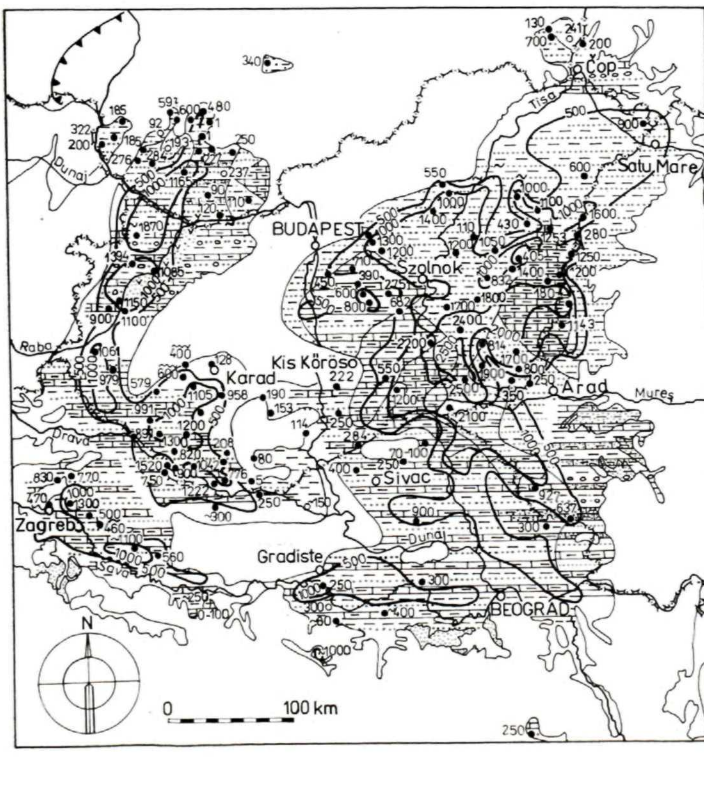


Fig. 7. Map showing the thicknesses and lithology of the Pontian sediments in the Pannonian Basin. For explanation see Fig. 1

with sand interbeds. At the northern and eastern margins of the basin, the Pannonian sediments show a transgressive character; at many places they flatten out the relief eroded in the earlier epochs. They consists of alternating and thinning-out marls, clays and sand, with basal beds of breccia and conglomerate interlaid with coal seams (Mutihac — Jonesi, 1974). Towards the axial part of the basin they are replaced by the marl facies. Judging from the facies composition and a prominent change of thicknesses, the Tótkomlos and Szeged spurs and the Makós depression continued to develop.

At the onset of the late Pontian a fairly broad connection of the Pannonian Basin was opened with the Dacian (Moesian) plate and through the Iron Gate area with the Euxinic region; the extent of sea transgression diminished simultaneously (Nevesskaja — Stevanovič, 1985).

During the Pontian there was no essential difference between the facies composition of the near-shore and interior parts of the sedimentary basin. The bottom relief became more levelled out and the salinity of water steadily diminished. The southern part of the Great Hungarian Plain was affected by strong subsidence (northern Banat), whereas the northern part was uplifted, which caused the origin of a number of fresh-water lakes. The Pontian sediments are, in general, of more clayey nature, but continental sandy-clayey sediments with interseams of coal clay and lignite, containing terrestrial flora and fauna predominate in the upper part of the profile (Baltes — Moldavanu, 1981). Warm, dry clima in the early Pliocene fostered erosion and denudation of the adjacent dry-land. In the SE the shallow-water basin was filled with coarse-grained material supplied

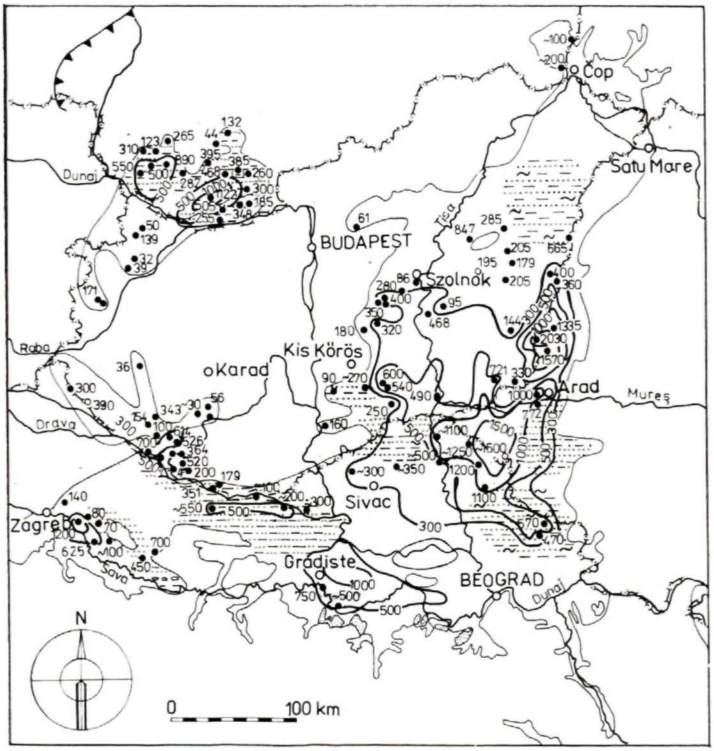


Fig. 8. Map showing the thicknesses and lithology of the Levant-Dacian sediments of the Pannonian Basin. For explanation see Fig. 1

from the landmass. The occurrence of identical flora in sediments of various ages (from N to S) indicates that the climate was warming up in the same direction.

At the end of the Pontian, in the Levant-Dacian stage, the Pannonian Basin was definitively enclosed (Fig. 8). An extensive part of its area dried out completely and the parts filled with very low-saline water decreased considerably. Sedimentation occurred predominantly in the basin of the Great Hungarian Plain, in the Minor Hungarian Plain and in the Drava-Sava area. Sandy clay, cross-bedded clayey sand and marsh peat were deposited in them. The zones at the eastern margin of the Pannonian Basin were the sites of maximum subsidence. Continental, in places freshwater muddy sediments were laid down in the higher lying areas. The Minor Hungarian Plain became gradually enclosed completely and dried out; stream erosion played an important role in its further development.

In general, three sedimentary cycles can be established in the Cenozoic history of the Pannonian Basin. The first, Eocene to Oligocene cycle was characterized by transgression extending in both its central and several marginal areas. The sea retreated in the late Oligocene. The second, Miocene cycle began with the Eggenburg-Carpathian transgression, which first invaded only the south-western parts of the basin. The transgression culminated in the Badenian, when a shallow sea flooded the major part of the area. After the regression towards the end of the Sarmatian, the third, Pliocene cycle brought a new transgression. The sea flooded a considerable part of the Pannonian Basin (in the Pannonian to Pontian). There — after, the sea retreated definitively and continental sedimentation set in.

As a result of the manifestations of the first sedimentary cycle, the structural elements that had been initiated in the Mesozoic, entered the final stage of their development. The present-day outlines of a new structure — the Pannonian Basin — were formed in the second and third

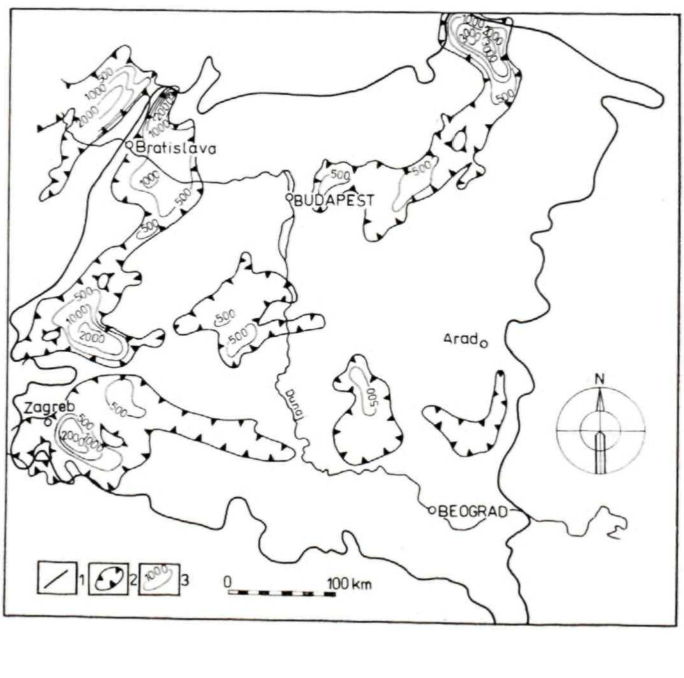


Fig. 9. Scheme showing the distribution of areas of uninterrupted Miocene sedimentation and the total thicknesses of sediments. 1 — boundary of the Pannonian oil-gas bearing basin, 2 — boundary of areas with uninterrupted sedimentation, 3 — isopachs, in m

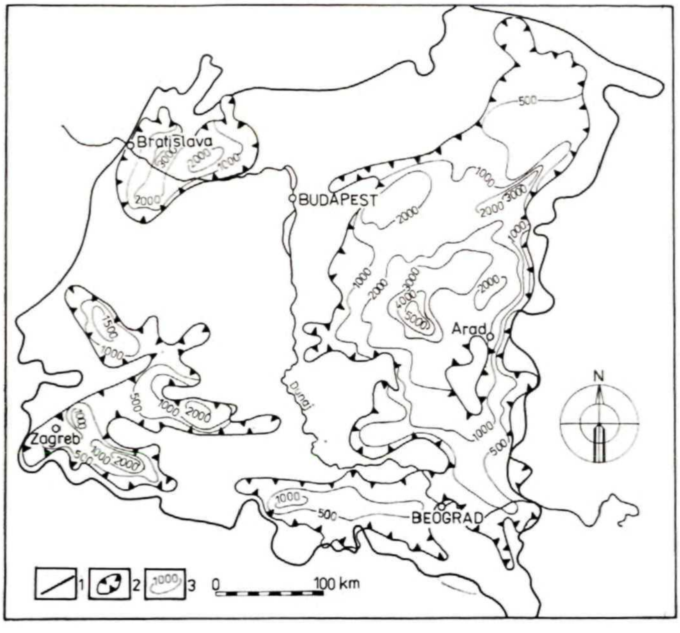


Fig. 10. Distribution of areas with uninterrupted sedimentation during the Pliocene, and total thicknesses of the deposits. 1 — boundary of the Pannonian oil-gas bearing basin, 2 — boundary of the areas of uninterrupted sedimentation, 3 — isopachs, in m

cycles. During the second cycle were also founded the following structures: the Vienna Basin, partly the Minor Hungarian Plain, the Sava-Drava-Mura depression and the Neogene East Slovakian Basin (Fig. 9). In the course of the third cycle the Great Hungarian Plain (Alföld) was created as a most important structure, and the Minor Hungarian Plain with the Sava-Drava-Mura depression continued to develop (Fig. 10).

The peculiarities of the development of the Pannonian Basin in the Cenozoic, and especially in the Neogene, are of primary importance for the evaluation of the oil-gas prospectives of this region. If taken into due consideration, they will certainly assist in almore effective planning of geological-prospecting works for oil and natural gas.

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# Kenozoický vývoj panónskej panvy a jej okrajov

V mladšom paleozoiku a mezozoiku sa územie panónskej panvy rozprestieralo väčšinou v oblasti šelfových morí lemujúcich dávny oceán Tetýdy. Predkenozoický vývoj tohto územia sa skončil jeho regionálnym výzdvihom a vrásnením na konci kriedy a vznikom pevniny, ktorá existovala do paleocénu. Ďalší geologický vývoj tohto územia súvisí s vývojom sedimentačnej oblasti Paratetýdy, ktorej zvláštnosti rozšírenia určil predovšetkým charakter utvárania alpsko-karpatsko-dinárskeho orogénneho pásma.

V kenozoiku možno vo vývoji panónskej panvy vymedziť tri sedimentačné cykly. Prvý, eocénny až oligocénny, je charakteristický rozšírením morskej transgresie v centrálnej časti panvy, ako aj v jej jednotlivých okrajových častiach. V neskorom oligocéne došlo k regresii mora. Druhý cyklus, miocénny, začal egenbursko-karpatskou morskou transgresiou, ktorá spočiatku postihla hlavne juhozápadné oblasti panvy. V bádene, keď väčšiu časť územia panvy zaplavilo plytké more, transgresia kulminovala. More ustúpilo koncom sarmatu. Tretí cyklus, pliocénny, sa vyznačoval novou morskou transgresiou, ktorá zaplavila značnú časť panónskej panvy (v panóne až ponte). Potom nasledovala regresia mora a akumulácia kontinentálnych sedimentov.

V eocéne a oligocéne (obr. 1, 2) poklesli južné okrajové časti a centrálne časti územia panónskej panvy. V okrajových častiach jej dnešného štruktúrneho plánu prevládala v podstate sedimentácia hrubých klastických hornín a v centrálnej časti sa pozdĺž pretiahnutých zlomov ukladali flyšoidné komplexy (sávska depresia, szolnocká priekopa) a prevažne karbonátové sedimenty. Výzdvih vnútorných Karpát a dinaríd vo vrchnom oligocéne a spodnom miocéne vyvolal tiež zdvih panónskej panvy, čo prerušilo sedimentáciu. V tomto období vznikali sedimenty iba na SZ a V.

Na počiatku miocénneho veku (v egenburgu — otnangu, karpate a bádene) vyvolali silnejšie tektonické poklesy alpskej predhĺbne novú transgresiu v západnej Paratetýde, ktorá sa postupne rozširovala na východ. V egenburgu až otnangu zapríčinila sedimentáciu (obr. 3) plytkovodného a paralického štrku a piesku, miestami (v západnej polovici panónskej panvy) machovkových organickodetritických piesočnato-štrkových vápencov. More úzkym prielivom, spájajúcim alpskú predhĺbeň s panónskou panvou, transgredovalo od SZ cez oblasť, v ktorej sa teraz rozkladá viedenská panva. Toto časové obdobie charakterizuje vulkanická činnosť, následkom ktorej je vznik prevažne piesočnato-slienitých a ílovitých sedimentov s mocnosťou do 200—300 m, obsahujúcich menšie vložky vulkanitov. Karbonátový materiál sa akumuloval hlavne v centrálnej časti vodných paniev.

Egenbursko-karpatské morské sedimenty dosahujú zvýšenú mocnosť na severe, vo Veľkej dunajskej nížine (Alfölde). Morská panva, ktorá sa tam utvorila, zrejme nemala dostatočné spojenie so šírym morom a bola reliktom oligocénneho mora.

V bádene sa transgresia ďalej rozširovala (obr. 4). More zaplavilo značnú časť územia panónskej panvy a predstavovalo plytkovodnú panvu, rozčlenenú početnými súostroviami. Pobrežie bolo pravdepodobne veľmi členité, s množstvom zálivov a lagún. V tomto období získala výraznejšie obrysy Malá a Veľká dunajská nížina, ako aj zakarpatská a viedenská panva. Vo viedenskej panve sa more rozšírilo a zaplavilo ďalšiu súš. Na jej okrajoch, hlavne v juhovýchodnej časti, sa v paralických podmienkach tvorili litotamniové vápence. Vo vnútorných častiach panvy sa v hĺbke 100—200 m usadzovali ílovité sliene s početnými vložkami piesku. Mocnosť akumulovaných sedimentov pri okrajoch kolíše od 100 do 600 m, v centrálnych častiach dosahuje aj viac ako 1000 m.

V sarmate stratila morská panva západnej Paratetýdy spojenie s oceánom a jej rozmery sa veľmi zmenšili. Severná alpská okrajová predhlbeň sa uzatvára, hneď po nej sa izoluje i panónska panva (obr. 5), ktorá sa mení na poloslanú vodnú nádrž so špecifickou endemickou faunou. Vzťah medzi súšou a morom v nej zostáva skoro rovnaký ako v bádene, ale členitosť pobrežia sa následkom nerovnomerných epiorogenetických pohybov zväčšuje.

V panóne, zahrňujúcom podľa nášho poňatia vrchnú časť sarmatu a meot, sa dočasne obnovilo spojenie vysladenej izolovanej panvy západnej Paratetýdy so svetovým oceánom. Jej voda nadobúda veľkú salinitu, mení sa zloženie fauny. Toto spojenie sa však opäť rýchle prerušilo a už pred koncom pontu sa more značne zmenšilo, znovu vysladilo, čo sa odrazilo v jednotvárnej brakickej faune. Pokračujúci nerovnomerný výzdvih severnej časti oblasti alpínskeho vrásnenia spôsobil definitívny rozpad paratetickej panvy na rad vodných nádrží spojených úzkymi prielivmi.

Uvedený sled procesov sa výrazne prejavil i vo vývoji panónskej panvy (obr. 6). Transgresia postupovala od západu na východ. Podľa výsledkov výskumu fauny nadobudlo panónske more, ktoré bolo spočiatku brakické, sladkovodný charakter. V spodnom pliocéne vládla teplá kontinentálna klíma.

Na konci miocénu až po začiatok pliocénu sa teda na území panónskej panvy spočiatku rozšírila nová morská transgresia. Panónskopontské more pokrylo v panónskej panve najväčšie územie za celé obdobie neogénu. Dochádzalo k intenzívnym poklesom, o čom svedčia maximálne mocnosti (viac ako 5000 m) akumulovaných sedimentov. Vymedzilo sa 5 hlavných subsidenčných oblastí: Malá dunajská nížina, salská, drávska a sávska depresia a Veľká dunajská nížina.

V ponte nepozorovať podstatný rozdiel vo faciálnom zložení príbrežných a vnútorných častí sedimentačnej panvy. Reliéf dna sa viac vyrovnal, voda sa stále viac vysladzovala. Na konci pontu (v levantsko-dáckom období) sa panónska panva definitívne uzavrela (obr. 8). Značná časť jej územia sa celkom vysušila a plocha vodnej panvy s veľmi slabou salinitou sa hodne zmenšila. Sedimentácia prebiehala prevažne vo Veľkej dunajskej nížine, ale i v Malej dunajskej nížine a v sávsko-drávskej oblasti. Zóny maximálnej subsidencie sa viažu hlavne na východný okraj panónskej panvy.

Vcelku možno povedať, že v dôsledku prejavov prvého sedimentačného cyklu pokračovalo záverečné štádium utvárania štruktúrnych prvkov, ktoré vznikli predovšetkým v mezozoiku. V druhom a treťom cykle sa vytvorili dnešné obrysy novej štruktúry — panónskej panvy — a počas druhého cyklu vznikla predovšetkým viedenská panva, sčasti Malá dunajská nížina, sávsko-drávsko-murská depresia a východoslovenská neogénna panva (obr. 9). V treťom cykle sa vytvorila hlavne Veľká dunajská nížina (Alföld) a ďalej sa vyvíjala Malá dunajská nížina a sávsko-drávsko-murská depresia (obr. 10).

Zvláštnosti vývoja panónskej panvy v kenozoiku, ale hlavne v neogéne, majú podstatný význam pri hodnotení perspektív ropoplynonosnosti tohto územia. Ak sa budú brať do úvahy, budú sa môcť cieľavedomejšie plánovať ďalšie geologickoprieskumné práce na ropu a zemný plyn.