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Závada – Bielice Rise – a buried elevation between Bánovce and Rišňovce Depressions in the Danube Basin

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Abstract. Bánovská kotlina Depression (Bánovce Depression) and Rišňovská priehlbina Depression (Rišňovce Depression) are adjacent depressions at the northern margin of the Danube Basin. They had different tectonic and paleogeographic development. The Bánovce Depression started to open in the Eggenburgian and until the end of Early Miocene, sedimentation took place in marine environment there. Sea ingressions penetrated into basin still during the Early Badenian. The Rišňovce Depression started to open only in the Middle Badenian and until the end of Badenian, marine sedimentation survived there. Both depressions were divided by the Závada – Bielice Rise with axis in the ENE-WSW direction and with a combined faulted – folded structure. It originated in the Early Miocene paleostress field with a maximal compression in NW-SE and/or WSW- ENE (recent) directions. Already during the Early Miocene and in the beginning of Badenian, the Rise blocked southward directed ingressions from the Bánovce Depression. On the contrary during the Middle and Late Badenian, it prevented marine transgression from the south, from the Rišňovce Depression to the Bánovce Depression. The Rise preserved its paleogeographic function also during the Sarmatian, when it controlled fluvial deltaic sedimentation (the Ripňany Formation) in the Rišňovce depression, whereas in the Bánovce Depression, the volcano-clastic Ruskovce Member – a peripheral member of the Vtáčnik Andesite Formation, transported by the debris flow type mechanism – deposited. After the Early Pannonian, the Závada – Bielice Rise lost its paleogeographic function and was buried by younger Neogene sediments.

Key words: Danube Basin, Negene, paleogeography, Závada – Bielice Rise, Rišňovce Depression, Bánovce Depression.

Introduction

The Nitrianska pahorkatina Upland – more closely its part, which is surrounded from three sides by the Považský Inovec Mts., Stražovské vrchy Mts. and Tríbeč Mts. – has been further divided by Mazúr & Lukniš (1978) into the Bojnianska pahorkatina and Bánovská pahorkatina Uplands (Fig. 1). This geomorphologic division broadly displays buried Neogene tectonics, hidden by the younger, loaded up geological and geomorphologic processes, and its expression in paleogeography. Geophysical research revealed that both uplands were built on two well detectable depressions in pre- Tertiary basement. The Bojnianska pahorkatina Upland were built on the Ripňany Depression and Bánovská pahorkatina Upland is underlain by the Svinná Depression (Fusán et al., 1971, 1987). In pre-Tertiary relief, the Ripňany Depression had an asymmetric form with the axis of NE-SW direction. The northwestern depression's margin is steeper than the southeastern one. The Svinná Depression has a symmetric, slightly elongated form. Both depressions are divided by a saddle between Prašice and Veľké Bielice (Fusán et al., 1971, 1987; Fig. 2). Brestenská and Vass (unpublished), Vass (in Keith 1989) attributed a paleogeographic importance to the saddle, announcing it as the Závada – Bielice Rise. Whereas both depressions are filled with the Neogene sediments and their tectonic and paleogeographic development was essentially different, they were clearly divided in geological literature. Buday in Maheľ & Buday et al., (1968) described them as the Rišňovská priehlbina and Bánovská kotlina depressions. The same division was applied in regional and geological classification of the Danube Basin (Vass et al., 1988; Fig. 1).

New information about geology of the Banovská kotlina Depression (Bánovce Depression) and an analysis and interpretation of geophysical measurements enabled to define the function of the Závada – Bielice Rise.

Brief characteristics of geology of the Bánovce and Rišňovce Depressions

Comparing with the Rišňovská priehlbina Depression (Rišňovce Depression), the Bánovce Depression is older. The lower part of the Bánovce Depression's fill is formed by the Early Miocene sediments, which indicate begin of depression's opening in the Eggenburgian. The opening took place in a paleostress field with maximal compression in the direction from NW-SE to NNW-SSE (recent co-ordinates; Kováč et al., 1989, 1993; Marko et al., 1995). Predominantly the normal faults of NW-SE direc-

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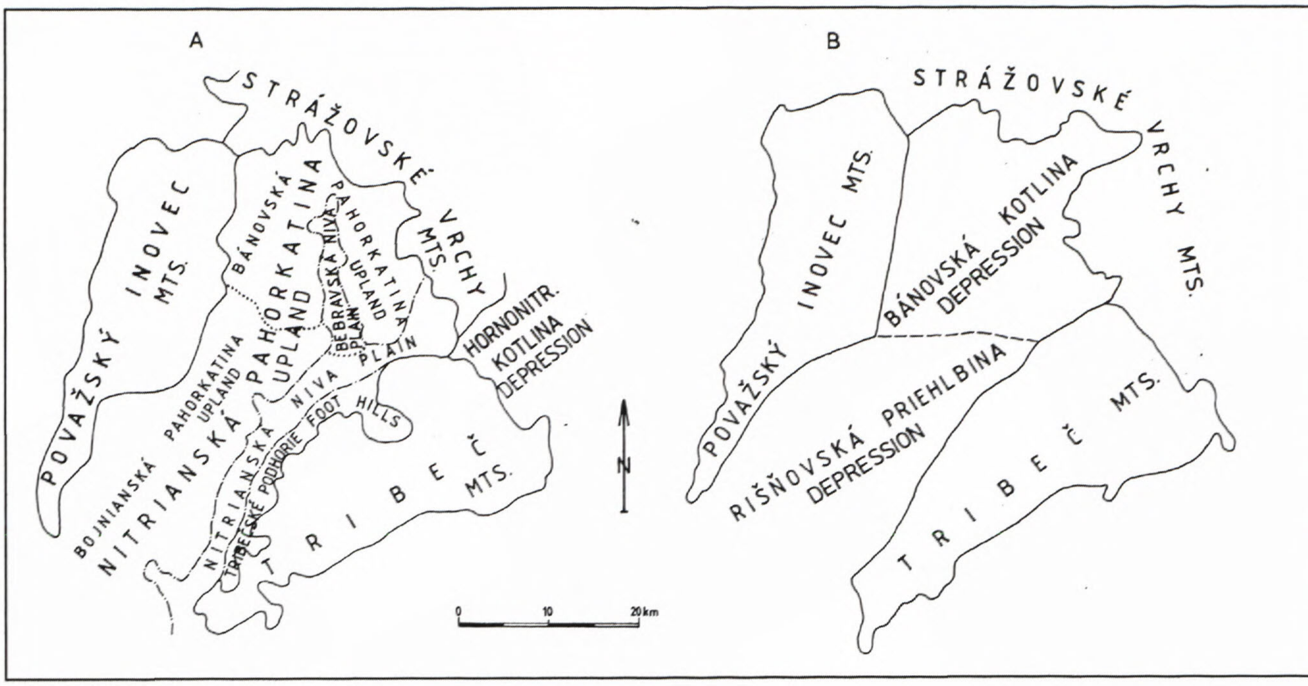

Fig. 1: Relief of pre-Tertiary basement in area between the Považský Inovec, Strážovské vrchy and Tribeč Mts. The Ripňany and Svinná Depressions divided by the Prašice – Veľké Bielice saddle (after Fusán et al., 1971, 1987)
Explanation: 1 – basement relief isohypses (above sea level)

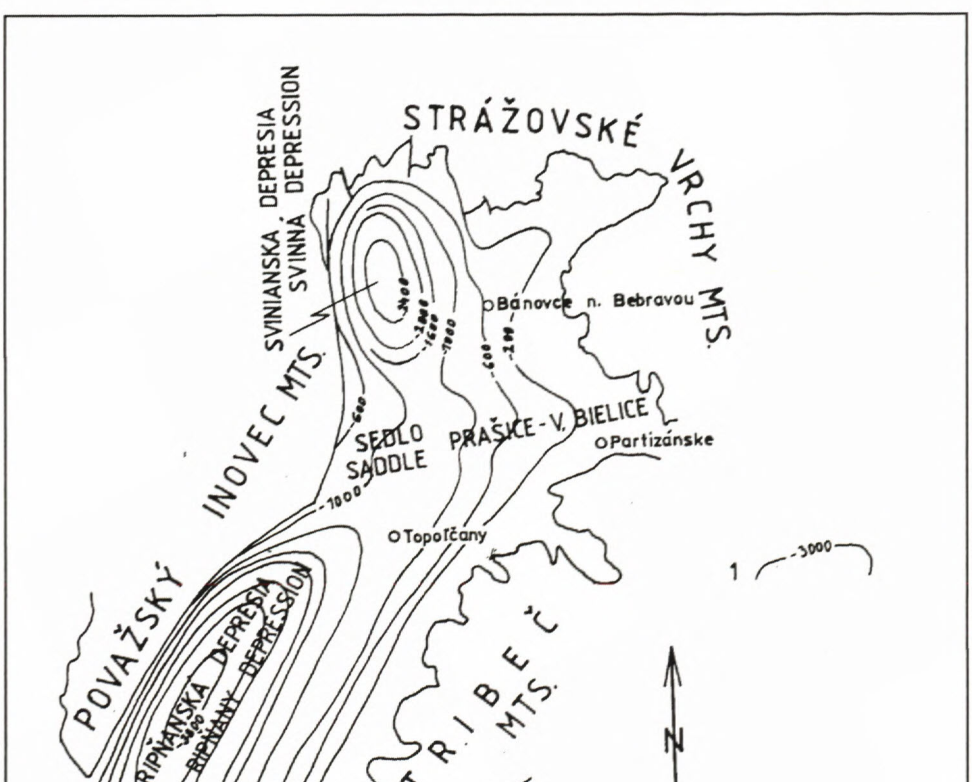

Fig. 2: A – Regional geomorphological division of the Nitrianska pahorkatina Upland (Mazúr & Lukniš 1978);
B – Regional geological division of the Danube Basin's bay between the Považský Inovec, Strážovské vrchy and Tribeč Mts. (Vass et al., 1988)

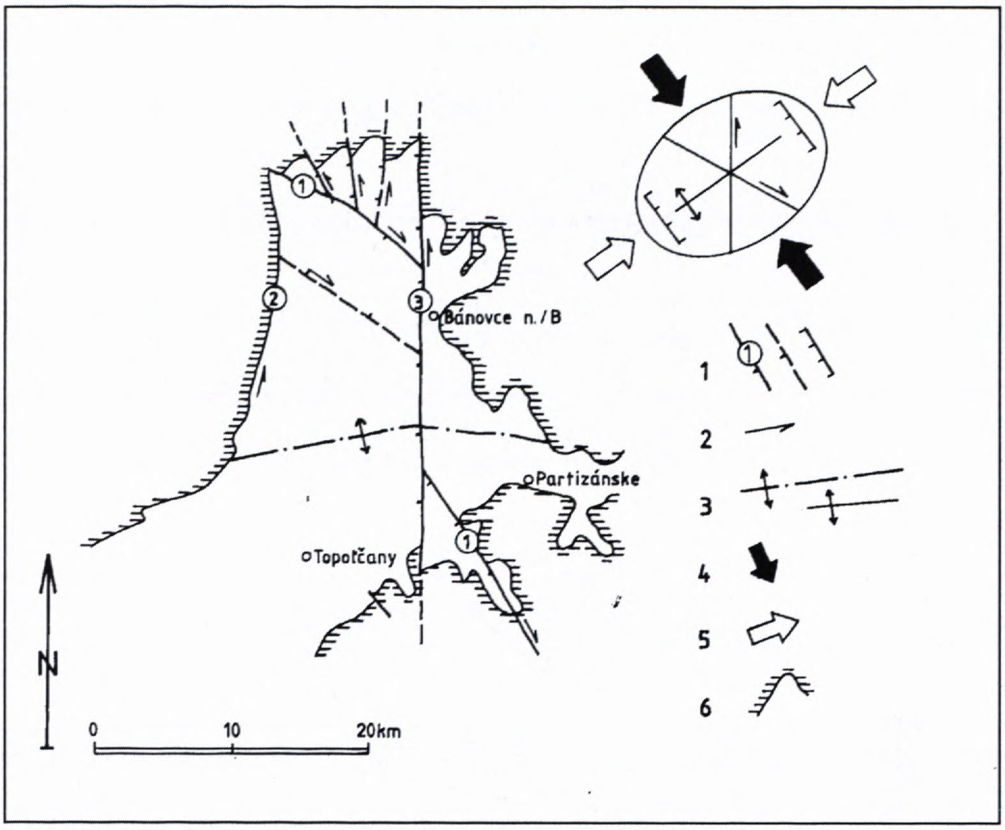

Fig. 3: Main faults controlling opening and sedimentation in the Bánovce Depression during the Early Miocene. Coexisting stress field after Kováč et al., (1989, 1993) and Marko et al., (1995) in recent coordinates.
Explanation: 1 – normal faults, 2 – strike slip direction, 3 – fold structure axis, 4 – maximum compression direction, 5 – maximum extension direction, 6 – present margin of the Bánovce Depression
Significant faults:
1 – Jastrabie Fault; 2 – Dubodiel Fault; 3 – Bebrava (Timoradza) Fault

tion, with possible right slip component, were active during opening of the Bánovce Depression. The Jastrabie Fault (Maheľ 1969) was most significant dividing the depression's Early Miocene fill from the younger one (Fig. 3). The fault is deep seated, which has been documented by Blakely gravity gradients (Tkáč et al., 1997). Left slips on the N-S directed faults boosted depression's opening. However these faults manifested themselves during the later depression filling periods as the normal faults. So they are revealed also in actual patterns of the depression's geology. At the depression's eastern margin, the Bebrava Fault outlines the Neogene from the Paleogene and Mesozoic of the Stražovské vrchy Mts. in the depression's present pattern. The fault is of an inverse character, while the Paleogene sediments occur on its eastern side, they are missing on the western side. The Neogene sediments have a reverse distribution (Fordinal et al., in press.). The Bebrava Fault is deep seated, which is confirmed by Blakely gravity gradient. Spatial relations between the Jastrabie and Skýcov Faults (Maheľ 1969) and Bebrava Fault in Fig. 3, support an idea that the Jastrabie and Skýcov Faults are two fragments of the same fault, which has been obliquely disturbed by about 15 km long right slip of the Bebrava Fault. The segmentation had to take place before the Miocene, while right slip of this length has not been observed in other structure elements of the Bánovská kotlina Depression. For example, the Závada – Bielice Rise does not show any sign of the right slip segmentation. In actual pattern, horst of the Považský Inovec Mts. is outlined from the Bánovce Depression by the Dubodiel Fault (Závada F.; Maheľ 1969) at the depression's western margin. Northward of the Dubodiel village, its activity during the Eggenburgian is indicated by conglomerates of the Eggenburgian age. In the Bánovce Depression, they represent a marginal facies of the Čausa Formation (Elečko & Fordinál in Pristaš et al., 2000). Also in this case, deep seating of the fault has been confirmed by Blakely gravity gradient (Fig. 4).

The Early Miocene stress field pressure conditions enabled formation of fold structures oriented straight to the direction of maximal compression. Already during this period, generation of the Závada-Bielice Rise were probably beginning, preventing the sea to break from the Bánovce Depression southward to recent area of the Danube basin. But optimal conditions of the elevation formation originated in paleostress field, which was deduced from the brittle deformation measurements for the Ottnangian – Early Badenian period by Marko et al. (1995).

Sea encroached into the opening Bánovce Depression already during the Eggenburgian. In the Early Miocene (Eggenburgian to Karpatian) clastic sediments of the Čausa, Bánovce and Lakšáry Formations deposited (Brestenská et al., 1980; Brestenská in Samuel & Gašpariková 1983; Vass 1999; Elečko & Fordinál in Pristaš et al., 2000). In that time the Bánovce Depression was a part of – or at least in connection with – the west-Slovakian shear zone, where similar smaller depressions with a marine environment were opened out (Marko & Kováč 1996). These depressions ceased at the end of Early Miocene. The opening and filling of the Bánovce Depression went on also during the Middle Miocene, but connection with the sea was limited. Sea ingressions, indicated by the brackish fauna occurrence in the Svinná

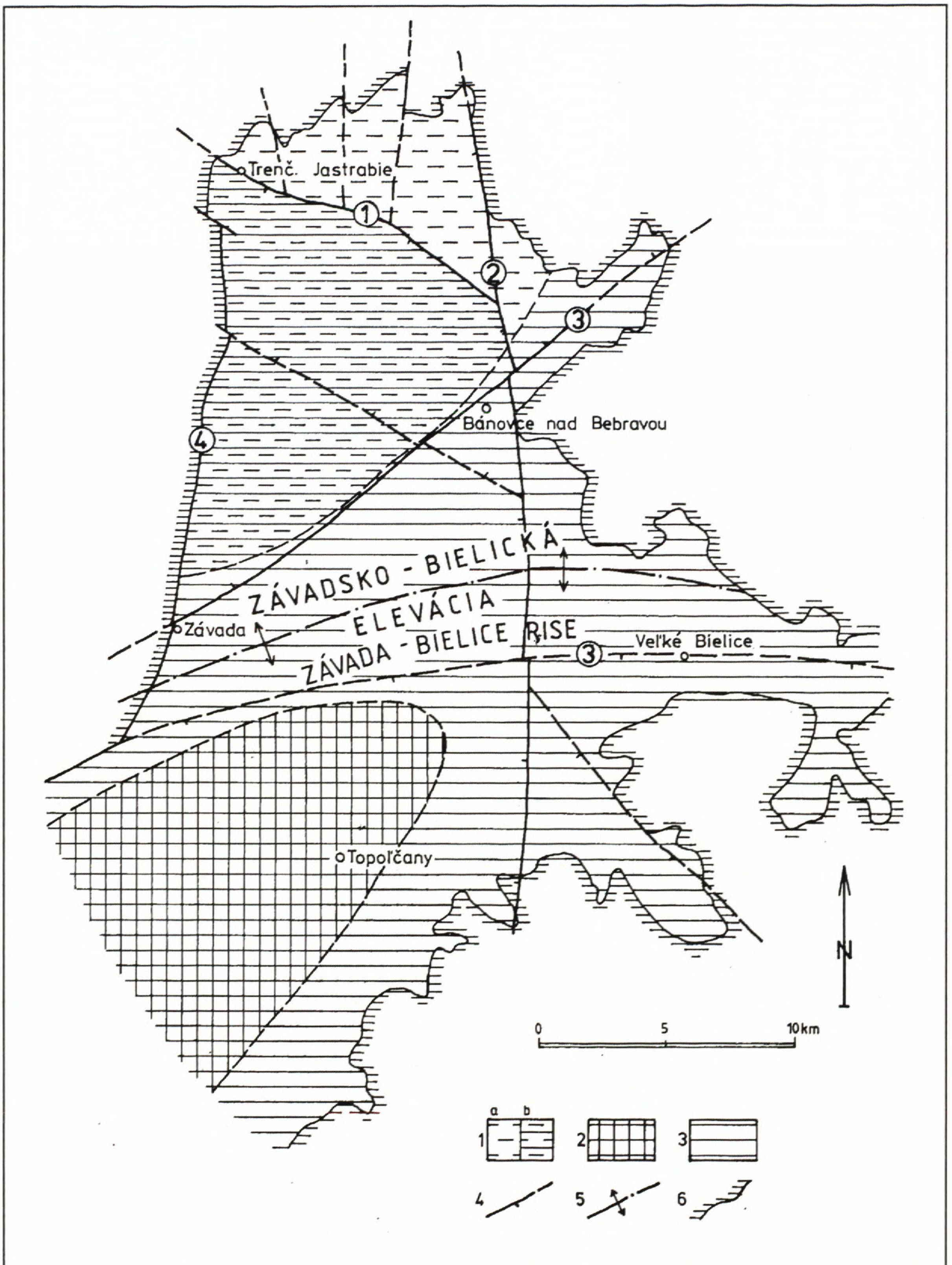

Fig. 4: Paleogeographic manifestations of the Závada – Bielice Rise.
Explanation: 1 – Early Miocene marine fill of the Bánovce Depression (Eggenburgian – Karpatian), a – at surface, b – hidden, 2 – marine sediments of the Middle Miocene (Middle and Late Badenian) in the Rišňovce Depression, 3 – brackish to freshwater sediments of the Middle Miocene to Pliocene, 4 – faults, 5 – elevation axis, 6 – margin of the basin
Significant Faults:
1 – Jastrabie Fault; 2 – Bebrava (Timoradza) Fault; 3 – faults outlining the Závada – Bielice Rise (in sense Fusán et al., 1987); 4 – Dubodiel Fault

Formation (Brestenská et al., 1980), reached the Bánovce Depression from the east, from the Hornonitrianska kotlina Depression and/or Handlovská kotlina Depression, where Elečko (in Šimon edit. 1997) assumes marine sedimentation during the Early Badenian. Marine sediments were reliably established in the Kordíky Formation in the borehole HV-9 (Gašpariková in Blaško et al., 1989) at the boundary of the Hornonitrianska kotlina and Žiarska kotlina Depressions. Connection to the open sea southward through the Rišňovce Depression was not possible, while this depression did not exist then. The younger Middle Miocene sediments that went on to fill the Bánovce Depression (Kamenec Formation, equivalent of the Handlová Formation and Ruskovce Member) have an affinity to the Middle Miocene development in the Hornonitrianska kotlina Depression (Šimon in Pristaš et al., 2000). Connection of both depressions took place in the area between raising Tríbeč Mts. and Strážovské vrchy Mts. There is no evidence that during the Middle Miocene, even when the Rišňovce Depression was already being formed, a connection between the Rišňovce and Bánovce Depressions existed. The Bánovce Depression joined with the Rišňovce Depression only during the Late Miocene and Pliocene.

The Rišňovce Depression began to open during the Middle Miocene. Opening had been preceding by a long-term emergence and denudation. Erosion of the pre-Tertiary structures removed rocks of the Hronicum, most of the Veporicum rocks (Krížna nape) and outcropped the Tatricum (Fusán et al., 1987). The Rišňovce Depression were opening out in a stress field with maximum compression in the NE-SW (Vass et al., 1993, Hók et al., 1995), to NNE-SSW (Marko et al., 1995) directions, as showed by brittle deformation measurement results. In this stress field normal faults of the NE-SW to NNE-SSW directions controlling depression margins were active (Fig. 5). Western flank of the depression was controlled by the synsedimentary Majcichovo and Sládkovičovo Faults (Buday in Buday et al., 1967, in Maheľ & Buday et al., 1968). Smoother inclining eastern flank of the depression was controlled by the Veľké Zálužie Faults or fault complex (Pěničková & Dvořáková in Gaža et al., 1985; Fig. 6). The Majcichov Western Fault and eastern Veľké Zálužie Faults are manifested by horizontal Blakely gravity gradients (Fig. 5). Sea transgressed into the opening depression from the south-west, from central part of the Danube Basin, which already started to subside as an unit, with exception of the Kolárovo elevation. Throws on faults outlining the Rišňovce Depression were synsedimentary. From the Middle Badenian to the end of Sarmatian, they were contributing to accumulation of sediments more than 2000 m thick (without decompaction; Vass & Pereszlényi 1998). In relation to the thermal back-arc Danube Basin opening by a heterogeneous lithosphere stretching mechanism, the Rišňovce Depression was a part of the outer zone with an initial subsidence. Thermal effect of the lithosphere stretching, spreading from basin centre to the outer zone, was manifested by the upper crust faulting and stretching, which caused a synrift sedimentation (Lankreijer et al., 1995; Vass & Pereszlényi 1998).

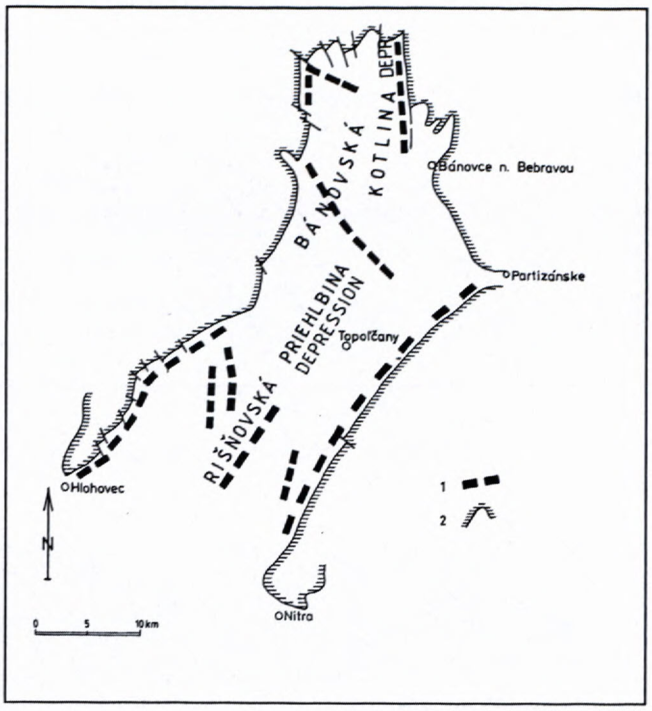

Fig. 5: Blakely horizontal gravity gradients indicating deep seating of some faults in the Bánovce and Rišňovce Depressions Explanation: 1 – horizontal gravity gradients, 2 – margin of the Bánovce and Rišňovce Depressions.

In northern part of the Rišňovce Depression, marine sedimentation was replaced by deltaic one with a dominant river influence during the Sarmatian. From the north to the Hlohovec-Nitra horst, the depression was filled up by sediments of the Ripňany Formation. These sediments are without marine or brackish fauna and have no signs indicating a sea reworking of delta (Fordinál & Elečko 2000). According to their age, the deltaic sediments range from the Sarmatian to the Early Pannonian. A river forming the Ripňany delta was flowing from the Hornonitrianska kotlina Depression (Fig. 7). In the Hornonitrianska kotlina Depression, this river (paleostream of the Nitra river) deposited coarse detritic sediments of the Lehota Formation (Late Badenian – Early Sarmatian). Delta sediments of the Ripňany Formation could be deposited by smaller streams flowing into the Rišňovce Depression from the northwest and/or north i.e. from the Považský Inovec Mts., which had been risen then (F.T. apatite cooling age is 16 Ma, Král in Kováč et al., 1994).

The upper part of the Rišňovce Depression is formed by Caspian-type brackish and freshwater sediments of the Pannonian, Pontian and the Pliocene (the Ivánka, Beladice and Volkovce Formations). These sediments represent margins of the Danube Basin postrift development. Comparing with the basin's central part the sediments thickness is significantly reduced there (Vass & Pereszlényi 1998).

The different Miocene development in the Rišňovce and Bánovce Depressions points to paleogeographic function of the Závada – Bielice Rise. Fusán et al., (1987) outlined the elevation by faults. Its southern limitation is

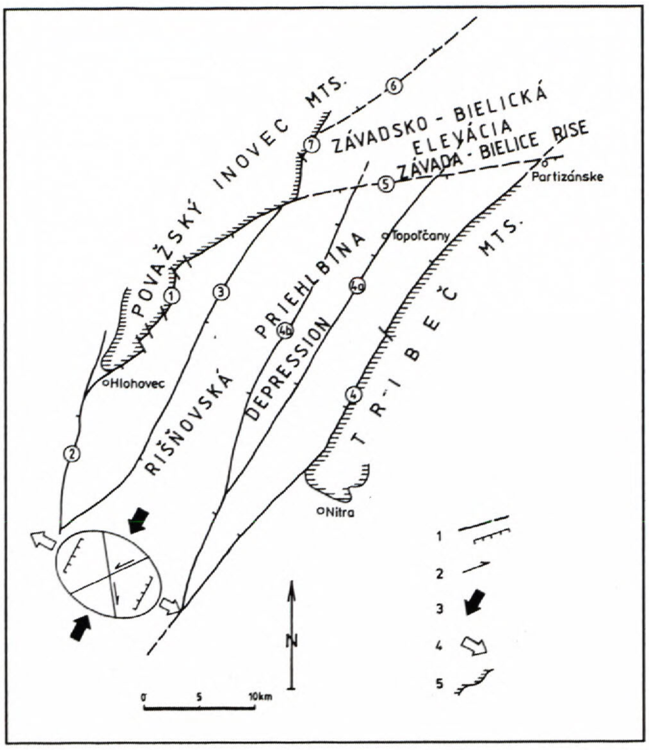

Fig. 6: Main faults of the Rišňovce Depression and diagram of a stress field enabling depression's opening in the Middle and Late Badenian.
Explanation: 1 – normal faults, 2 – strike slips direction, 3 – maximum compression direction, 4 – maximum extension direction, 5 – margin of the Rišňovce Depression
Significant faults: 1 – Majcichov Fault, 2 – Eastern Trnava (Váh) Fault, 3 – Sládkovičovo Fault, 4 – Eastern Veľké Zálužie Fault, 4a – Western Veľké Zálužie Fault, 4b – Middle Veľké Zálužie Fault, 5,6 – marginal faults of the Závada – Bielice Rise (5 – continuation of the Majcichov Fault in sense Buday et al., 1967).

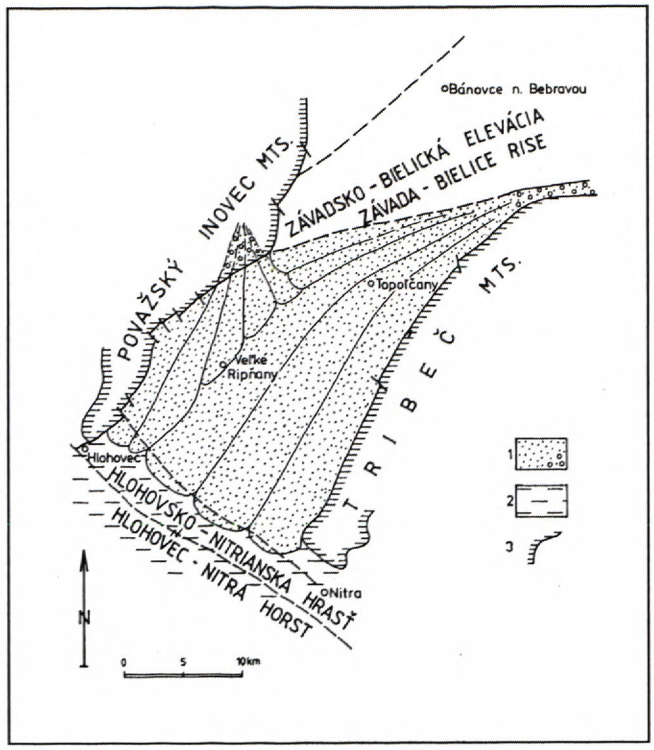

Fig. 7: Distribution of the Ripňany Formation (Sarmatian – Lower Pannonian) interpreted as a deltaic complex controlled in the north by the Závada – Bielice Rise and in the south by the perpendicularly directed Hlohovec – Nitra horst.
Explanation: 1 – Ripňany Formation (Sarmatian – Lower Pannonian), 2 – Vráble (Sarmatian) and Ivánka (Pannonian) Formations, 3 – margin of the Považský Inovec and Tribeč Mts.

distinct on the Map of total Bouguer anomalies (Tkáč et al., 1997). The northern limitation of the elevation has been defined by the fault, which was synsedimentary during the Early and Middle Miocene. This is indicated by 800 m thick Svinná Formation on the downthrow block, i.e. in the Bánovce Depression (Brestenská et al., 1980). Elevation's paleogeographic influence can be observed already in the Early Miocene, when the elevation was the southern limitation of the Bánovce Depression and the sea could not break from there further to the south. Though a fold character of this elevation may not be excluded. Direction orientation of the Závada – Bielice Rise was best matched with paleostress in the Ottnangian and Early Badenian (Marko et al., 1995). Then during the maximum compression in the NNW-SSE direction, folds with axis oriented in the ENE-WSW direction, which is the axis direction of the Závada – Bielice Rise, could be formed (Fig. 4).

We know that the geological and especially facial development of the Middle Miocene was contrasting in the Bánovce and Rišňovce Depressions. The Svinná Formation representing the Early Badenian in the Bánovce Depression comprises along with freshwater organic remnants also brackish ostracodes and foraminifers of the species *Ammonia beccarii*. This points to sea ingressions most probably from the Hornonitrianska kotlina Depression (Elečko & Fordinál in Pristaš et al., 1999). In the Rišňovce Depression the Early Miocene sediments are missing, while the depression began to open and the sea intruded there only in the Middle Miocene. But this ingression did not reach the Bánovce Depression, where the Middle and Upper Miocene development took place in a freshwater environment (Fig. 4). Sea ingression into the Bánovce Depression was hindered by the Závada – Bielice Rise. It was so rigid that the faults opening the Rišňovce Depression did not break through this elevation, they have died away there (Fig. 6). The Ripňany delta during the Sarmatian and Early Pannonian in the Rišňovce Depression was fed by the paleo-Nitra river's clastic material. This was transported over a breakthrough in horst of the Tríbeč Mts. Delta fan was formed south of the Závada – Bielice Rise (Fig. 7). The elevation also controlled southern margin of the Ruskovce Member (Middle Sarmatian) distribution.

The Ruskovce Member represents a complex of upward coarsening alluvial fans – Gilbert deltas. Coarse-grained clastic material was transported by streams of „debris flow" type (Kováč et al., 1993). It had a genetic affinity to the Vtáčnik Formation, which participated in structure of the volcanic Vtáčnik Mts. and forms a member of this formation (Šimon in Pristaš et al., 2000). Differently from the Ruskovce Member, the delta of the Ripňany Formation represents a delta built by a river mouthing into the Danube Basin of that time.

After the Early Pannonian the Závada – Bielice Rise lost its paleogeographic function and waters of a lake occupying the Danube Basin transgressed also into the Bánovce Depression. The Bánovce Depression was unified with the Rišňovce Depression then and through this with the Gabčíkovo Depression.

Discussion

During the Early Miocene a large part of the present Danube Basin area was emerged and exposed to a denudation. The Paleogene sediments, which had been more likely distributed there, were removed during this denudation. In the Bánovce Depression and its surrounding, the Paleogene sediments have been spared thank to the fact that they were covered by the Early Miocene sediments. The Paleogene sediments were not even removed from the Závada – Bielice Rise, especially from its eastern part. They are cropping out there (in the area of Hradište and between towns Bánovce nad Bebravou and Partizánske). This fact points to a delayed formation of the elevation comparing to the Early Miocene uplift of the future Danube Basin area. It looks like the elevation originated in the Early Badenian. Presence of the Paleogene sediments points also to the fact that the elevation was not strongly exposed. But its uplift was sufficient to play role of a paleogeographic dividing line between the Rišňovce and Bánovce Depressions. But rising of the elevation did not caused its deep erosional destruction. Therefore the Paleogene has been preserved in the elevation area but its thickness should be smaller than in the basement of the Bánovce Depression.

Conclusion

Knowledge of geology of the Bánovská kotlina and Rišňovská priehlbina Depressions supported by numerous geophysical indications shows that both depression structures were evolving independently until the Upper Miocene and/or Pliocene. This happened thanks to the presently buried Závada – Bielice Rise. The elevation was of folded – faulted character. Its function can be observed from the Early Miocene and especially from the Badenian, when it divided both depression structures causing a diametrically different sedimentation type within them. The Bánovce Depression was reached by the sea during the Early Miocene, so in this depression the Lower Miocene is represented by marine facies. Sea ingressions encroached into the depression also during the Early Badenian. In the Rišňovce Depression south of the Závada – Bielice Rise, the Lower Miocene and Lower Badenian sediments are missing. Later during the Middle and Late Badenian sedimentation took place in a nonmarine environment in the Bánovce Depression. On the contrary southward of the Závada – Bielice Rise, the Rišňovce Depression was reached by the sea from the south, the Middle and Upper Badenian are represented by marine facies there. The contrasting development went on also in the Sarmatian and Early Pannonian. The Rišňovce Depression was filled by delta sediments (the Ripňany Formation) then, while in the Bánovce Depression deposited peripheral volcano-clastic sediments of the Ftáčnik Formation (Ruskovce Member) representing upward coarsening alluvial fan sediment facies with the transport mechanism of „debris flow" type.

References

Blaško, D., Juriš, F., Tupý, P., Lafférs, F., Hruškovičová, M., Malý, S. & Klubert, J., 1989: Handlová – východ – VP – uhlie. Záverečná správa a výpočet zásob (Final report on Handlová - East brown coal – in Slovak). Manuscript, Geol. Survey of SR, Bratislava.

Brestenská, E., Havrila, M., Kullmanová, A., Lehotský, I., Remšík, A., Vaškovský, I., Gross, P. & Maheľ M., 1980: Geologická mapa a vysvetlivky k regiónu Bánovskej kotliny M = 1 : 50 000 (Geological map and Explanatory Notes to the Bánovce Depression Region in the scale 1:50 000 – in Slovak). Manuscript, Geol. Survey of SR, Bratislava.

Buday, T., Cicha, I., Hanzlíková, E., Chmelík, F., Koráb, T., Kuthan, M., Nemčok, J., Pícha, F., Roth, Z., Seneš, J., Scheibner, E., Stráník, Z., Vaškovský, I. & Žebera, K., 1967: Regionální geologie ČSSR, díl II. Západní Karpaty, zv. 2, (Regional Geology of Czechoslovakia, vol. II./2 – in Czech). Ústř. Úst. Geol., Academia, Praha, 7 – 651.

Fordinál, K. & Elečko, M., 2000: Ripnianske súvrstvie – sladkovodné sedimenty sarmatu a spodného panónu rišňovskej priehlbiny (Ripňany Formation – a Sarmatian and Early Pannonian fresh water sedimentary assemblage of the Rišňovce Depression – in Slovak with English summary). Mineralia Slovaca 32, Bratislava, 55 – 60.

Fordinál, K., Elečko, M., Šimon, L. & Holcová, K., (in press): Bánovská kotlina Depression (northen part of the Danube Basin); Neogene stratigraphy and geological development. Slovak Geol. Mag., Geol. Survey of Bratislava.

Fusán, O., Biely, A., Ibrmajer, J., Plančár, J. & Rozložník, L., 1987: Podložie terciéru vnútorných Západných Karpát (Basement of the Tertiary of the Inner Carpathians – in Slovak with English summary). Geol. Úst. D. Štúra, Bratislava, 5 – 123.

Fusán, O., Ibrmajer, J., Plančár, J., Slávik, J. & Smíšek, M., 1971: Geologická stavba podložia zakrytých oblastí južnej časti vnútorných Západných Karpát (Geological Structure of the Basement of the Covered Southern Part of the Inner West Carpathians – in Slovak with English summary). Západ. Karpaty 15, Bratislava, 1– 173.

Gaža, B., Pěničková, M., Dvořáková, V., Altanová, G., Jihlavec, F., Nemeček, V. & Uhmann, J., 1985: Závěrečná zpráva vyhledávacího průzkumu na živice v podunajské pánvi v letech 1973-1983 (Final report on the oil and gas exploration in the Danube Basin in the years 1973-1983 – in Czech). Manuscript, Geofyzika Brno. 1-131.

Hók, J., Šimon, L., Kováč, P., Elečko, M., Vass, D., Halmo, J. & Verbich J., 1995: Tectonics of the Hornonitrianska kotlina Depression in the Neogene. Geol. Carpathica, 46, 4, Bratislava, 191–196.

Keith, J.F., j.r., Vass, D., Kanes, W.H., Pereszlényi, M., Kováč, M. & Král, M., 1989: Sedimentary basins of Slovakia, Part II. Final report on the hydrocarbon potential of Danube Lowland Basin, vol. 1, Manuscript Univ. South Carolina ESRI, Technical Report 89-0019, 1– 143.

Kováč, P., Baráth, I., Holický, I., Marko, F. & Túnyi I., 1989: Basin opening in the Lower Miocene strike-slip zone in the SW part of the Western Carpathians. Geol. Carpath. 40/1, Bratislava, 37 – 62.

Kováč, M., Nagy, A. & Baráth, I., 1993: Ruskovské súvrstvie – sedimenty gravitačných tokov (sz. časť Bánovskej kotliny) [Ruskovce Formation - deposits of sediment gravity flows (NW part of the Bánovská kotlina depression) – in Slovak with English summary]. Miner. Slov. 25, 2, Bratislava, 117 – 124.

Lankreijer, A., Kováč, M., Cloetingh, S., Pitoňák, P., Hlôška, M. & Biermann, C., 1995: Quantitative subsidence analysis and forward modelling of the Vienna and Danube Basins. Tectonophysics, 252, Amsterdam, 433 – 451.

Kováč, M., Kráľ, J., Márton, M., Plašienka, D. & Uher, P., 1994: Alpine Uplift History of the Central Western Carpathians: geochronological, paleomagnetic sedimentary and structural data. Geol. Carpath., 45, 2, Bratislava, 83 – 96.

Maheľ, M., 1969: Zlomy a ich úloha počas mezozoika vo vnútorných Karpatoch (Faults and their role in the Mesozoic of the Inner Carpathians – in Slovak with English summary). Geol. Práce, Spr. 47, Bratislava, 7 – 29.

Maheľ, M., Buday, T., Cicha, I., Fusán, O., Hanzlíková, E., Chmelík, F., Kamenický, J., Koráb, T., Kuthan, M., Matějka, A., Nemčok, J., Pícha, F., Roth, Z., Seneš, J., Schneibner, E., Stráník, Z., Vaškovský, I. & Žebera, K., 1968: Regional Geology of Czechoslovakia, part II. West Carpathians. Ústř. Úst. Geol. Praha, 1 – 723.

Marko, F. & Kováč, M., 1996: Rekonštrukcia miocénnej tektonickej evolúcie Vaďovskej kotliny na základe analýzy štruktúrneho a sedimentárneho záznamu [Reconstruction of the Miocene tectonic evolution of the Vaďovce Depression, based on the analysis of structural and sedimentary record (Western Carpathians) – in Slovak with English summary]. Mineralia Slovaca 28, Bratislava, 81 – 91.

Marko, F., Plašienka, D. & Fodor, L., 1995: Meso-Cenozoic tectonic stress fields within the Alpine-Carpathian transition zone: a review. Geol. Carpath. 46/1, Bratislava, 19 – 27.

Mazúr, E. & Lukniš, M., 1978: Regionálne geomorfologické členenie Slovenskej socialistickej republiky (Regional geomorphologic division of the Slovak Socialist Republic – in Slovak with Russian & German summary). Geogr. Čas., 30, 2, Bratislava, 101–125.

Pristaš, J., Elečko, M., Maglay, J., Fordinál, K., Šimon, L., Gross, P., Polák, M., Havrila, M., Ivanička, J., Határ, J., Vozár, J., Tkáčová, H., Tkáč, J., Liščák, P., Jánová, V., Švasta, J., Remšík, A. & Žáková, E., 2000: Vysvetlivky ku geologickej mape Podunajskej nížiny - Nitrianskej pahorkatiny 1 : 50 000 (Explanatory Notes to Geological map of Danube Lowland – Nitrianska pahorkatina Upland 1 : 50 000 – in Slovak with English summary). Geol. Survey of SR, Bratislava, 1 – 250.

Pristaš, J., Elečko, M., Fordinál, K., Šimon, L., Polák, M., Ivanička, J., Vozár, J., Töröková, I., Žecová, K., Zlinská, A., Slamková, M., Boorová, D. & Kernátsová, J., 1999: Vysvetlivky ku geologickým mapám Bánovskej kotliny 1:25 000, listy: 35-231 (Trenčianská Turná, časť), 35-232 (Motešice, časť), 35-233 (Dubodiel, časť) a 35-233 (Uhrovec, časť) (Explanatory Notes to Geological maps of the Bánovce Depression in the scale 1: 25 000 – in Slovak). Manuscript, Geol. Survey of SR, Bratislava.

Samuel, O. & Gašpariková, V., 1983: 18th European Colloquy on Micropaleontology. Excursion Guide. Geol. Úst. D. Štúra, Bratislava, 1- 215.

Šimon, L., Elečko, M., Lexa, J., Kohút, M., Halouzka, R., Gross, P., Pristaš, J., Konečný, V., Mello, J., Polák, M., Vozárová, A., Vozár, J., Havrila, M., Kőhlerová, M., Stolár, M., Jánová, V., Marcin, D. & Szalaiová, V., 1997: Vysvetlivky ku geologickej mape Vtáčnika a Hornonitrianskej kotliny 1:50 000 (Explanatory Notes to Geological map of Vtáčnik Mts. and Hornonitrinska kotlina Depression 1:50 000 – in Slovak, with English summary). Geol. Survey of SR, Bratislava, 1 - 281.

Tkáč, J., Šefara, J., Tkáčová, H., Šantavý, J., Kubeš, P. & Husák, Ľ:, 1997: Mapa geofyzikálnych indícií a interpretácií. Región Nitrianska pahorkatina [Map of geophysical indications and interpretations (MGII). Region Nitrianska pahorkatina Upland – in Slovak]. Manuscript, Geofond, Bratislava, 1 – 29.

Vass, D., 1999: Litostratigrafia neogénu Západných Karpát (Lithostratigraphy of West Carpathian Neogene – in Slovak). Manuscript, Geol. Survey of SR, Bratislava.

Vass, D., Began, A., Kahan, Š., Köhler, E., Krystek, I., Lexa, J. & Repčok, I., 1988: Regionálne geologické členenie Západných Karpát a sev. výbežkov Panónskej panvy na území ČSSR (Regional - Geological Division of West - Carpathians Mts. and N Promontories of Pannonian Basin on Czechoslovak Territory – in Slovak with English summary). Geol. Ústav D. Štúra Bratislava, Geofond Bratislava, Vojenský kartografický ústav Harmanec.

Vass, D., Hók, J., Kováč, P., & Elečko, M., 1993: Sled paleogénnych a neogénnych tektonických udalostí v juhoslovenských kotlinách vo svetle napäťových analýz (The Paleogene and Neogene Tectonic Events of the Southern Slovakia Depressions in the Light of the Stress-field Analyses – in Slovak with English summary). Miner. Slovaca 25, Bratislava, 79 – 92.

Vass, D., & Pereszlényi, M., 1998: Assymetric lithospheric stretching in Danube Basin. Slovak Geol. Mag. 4, Bratislava, 61 – 74.