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# Bánovská kotlina Depression (northern part of the Danube Basin); Neogene stratigraphy and geological development

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*Abstract:* During the compilation of Explanatory Notes to the Geological Map of the Danube Lowland – Nitrianská pahorkatina Upland, new investigation, carried out in the Bánovská kotlina Depression, has brought new information on its Neogene sediments stratigraphy. On this basis we have redefined stratigraphic range of the Svinná Formation (Lower Badenian) and divided the so far homogeneous Ruskovce Formation into 3 lithostratigraphical units. The lower part has been assigned to the Kamenec Formation. The epiclastic volcanic sandstones and claystones, with layers of recarbonized claystones found as overlying it, have been ranged to the Handlová Formation. The presence of the mentioned formations has not been known from the Bánovská kotlina Depression till now. We have ranged the pyroclastic rocks found above the Handlová Formation to the Ruskovce Member (redefined Ruskovce Formation), which represents the peripheral member of the Vtáčnik Formation.

*Key words:* Danube basin, Bánovská kotlina Depression, Neogene, stratigraphy, geological development

## Introduction

The Bánovská kotlina Depression (Fig.1) has been distinguished by Vass et al. (1988) as an autonomous part of the Danube Basin. From the geographical point of view it forms the northern part of the Nitrianska pahorkatina Upland.

Throughout the Neogene, the Bánovská kotlina Depression was a part of several basins. In the Lower Miocene (Eggenburgian), it was a part of the basin extending in E - W to ENE - WSW direction from the region of the present-day fore-deep through the northern area of the Vienna Basin, the Ilavská kotlina Depression as far as the Hornonitrianska kotlina and Turčianska kotlina Depressions (Gašparik, 1969; Hók et al., 1998; Kováč et al., 1989; Kováč & Baráth, 1996). In the Middle Miocene, it had a development common with the Hornonitrianska kotlina Depression and in the Upper Miocene with the Danube Basin.

With a revising study of sediments of some boreholes in the Bánovská kotlina Depression area we could obtain new data. On their basis, the stratigraphy scheme of the mentioned depression, used so far, has been changed (Tab. 1).

After thorough study of sediments from the boreholes DB-3 and DB-6 in the area of Ruskovce, it has been shown that the originally uniform Tuffitic-Detrital Formation (Brestenská et al., 1980), designated later as the Ruskovce Formation (Kováč et al., 1993b; Vass in Keith et al., 1994) has to be divided into the lower Kamenec Formation and overlying equivalents of the Handlová Formation. From the original Ruskovce Formation only its uppermost part, cropping out in the area under study, has remained. Therefore, we designate it currently as the Ruskovce Member of the Vtáčnik Formation (Šimon in Pristaš et al., 2000a).

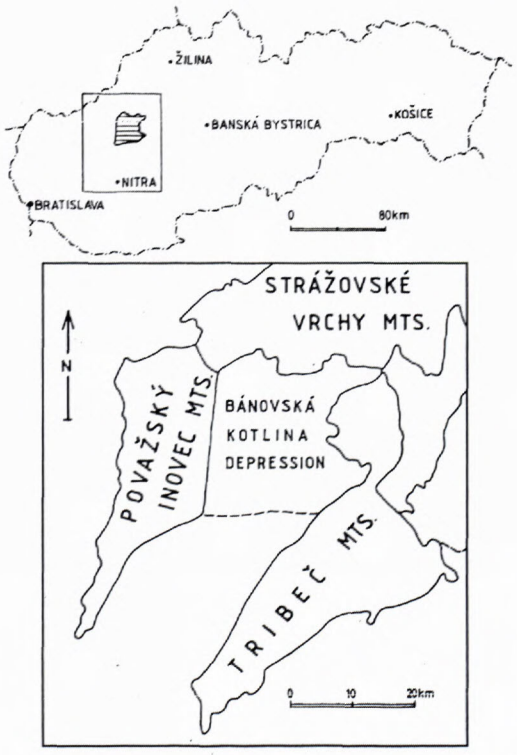


*Fig. 1 Geological position of the Bánovská kotlina depression (in the sense Vass et al., 1988)*

This fact has also contributed to the reconstruction of geological structure of the Badenian and Sarmatian sedi-

| Period | Epoch | Stages | | LITOSTRATIGRAPHY OF BÁNOVSKÁ KOTLINA DEPRESSION | | |
|---|---|---|---|---|---|---|
| | | | | Brestenská et al., (1980) | Vass in Keith et al., (1994) | Fordinál et al. (in this paper) |
| NEOGENE | PLIOCENE | Dacian | | *Dacian sediments* | *Volkovce Formation* | *Volkovce Formation* |
| NEOGENE | NEOGENE | Pontian | | *Coal formation* | *Beladice Formation* | *Beladice Formation* |
| NEOGENE | NEOGENE | Panonnian | upper | *Tuffo-detritic formation* | *Ruskovce Formation* | *Hlavina Member* |
| NEOGENE | NEOGENE | Panonnian | middle | | | |
| NEOGENE | NEOGENE | Panonnian | lower | | | |
| NEOGENE | NEOGENE | Sarmatian | upper | | | *Ruskovce Member* |
| NEOGENE | NEOGENE | Sarmatian | middle | | | |
| NEOGENE | NEOGENE | Sarmatian | lower | *Pelite formation* | *Svinná Formation* | |
| NEOGENE | NEOGENE | Badenian | upper | | | *Handlová Formation* |
| NEOGENE | NEOGENE | Badenian | middle | | | *Kamenec Formation* |
| NEOGENE | NEOGENE | Badenian | lower | | | *Svinná Formation* |
| NEOGENE | NEOGENE | Karpatian | | *Pelitic formation* | *Bánovce Formation* | *Lakšáry Formation* |
| NEOGENE | NEOGENE | Otnangian | | *Flyshoid formation* | | *Bánovce Formation* |
| NEOGENE | NEOGENE | Egenburgian | | *Schlier formation* | *Čausa Formation* | *Čausa Formation* |
| | | | | *Basal formation* | *Klačno Member* | *Klačno Member* |

*Tab. 1 Litostratigraphic column of the Neogene fill of the Bánovská kotlina Depression (hiatus are marked with black lines)*

ments in the basin's fill. The sediments of the Svinná Formation (pelitic formation) were compared by Brestenská (in Brestenská et al., 1980) with overlying clays, i. e. the Koš Formation in the Hornonitrianska kotlina Depression and ranged to the Upper Badenian. The presence of sediments of the Kamenec Formation (higher part of the Lower Badenian - Middle Badenian) and the occurrence of palynomorphs of the Lower Badenian age (Planderová, 1991) in strata overlying them have made the Upper Badenian age of the formation untenable. We have to take into consideration the Lower Badenian age of the Svinná Formation. Under these circumstances, it becomes easier to explain the presence of brackisch microfauna in the formation. We explain their presence as a consequence of sea ingressions into the limnic environment. The presence of the marine Lower Badenian is also proved from the region of the Central Slovakian neovolcanics (Gašpariková in Blaško et al., 1989) and supposed in the Hornonitrianska kotlina Depression (Elečko in Šimon et al., 1997).

**Stratigraphy of Neogene sediments**

Neogene sediments of the Bánovská kotlina Depression are formed by Miocene to Pliocene sediments.

The oldest Neogene sediments are of the Eggenburgian age. They are represented by the Čausa Formation. It is resting transgressively and disconformably on the pre - Neogene substratum, either on formations of the Central Carpathian Paleogene or on Alpine-folded units of the central Western Carpathians of the Mesozoic age.

Coarse-grained basal sediments are represented by the Kľačno Conglomerate. The bulk mass of the formation is formed by grey calcareous clay/claystones and silt/siltstones with sandy laminations and shaly disintegration (schlier). The schlier is resting directly on the Kľačno Conglomerate or the passage is formed by their alternation with calcareous layered sandstones.

The Čausa Formation is cropping out mainly in the northern part of the depression (Fig. 2).

**The Kľačno Conglomerate** represents marine littoral deposits. It is formed predominantly by conglomerates and sandstones, in which pelitic thin beds are found. The mentioned conglomerate is resting disconformably and transgressively on the considerably dissected Mesozoic substratum. These sediments are bordering the southern margin of the Strážovské vrchy Mts. between villages Trenčianske Mitice and Krásna Ves and the eastern margin of the Považský Inovec Mts. near the village Dubodiel. Most occurrences are only denudation remnants with relatively small area and thickness. The thickness of sediments verified by boreholes near Horné Motešice and Dolné Motešice attains about 40 m (Kollárik, 1962; Mikuláš, 1968).

The clastic fraction of conglomerates is almost exclusively formed by Mesozoic carbonate rocks (dolomite, limestone), subordinately by vein quartz. The size of pebbles varies from 1 to 6 cm. Larger pebbles are found rarely, they are bound to the base of beds. Besides coarse-grained conglomerates, fine-grained ones are also found, passing into coarse-grained sandstones. Lithification of conglomerate layers depends on the carbonate cement and/or on content of dolomite sand (solid and/or friable layers).

In conglomerates occurring in the villages Horné Motešice, Dolné Motešice, Kostolné Mitice and Krásna Ves, a mollusc fauna has been found. Species significant stratigraphicaly *Pecten hornensis* DEP. - ROM., *Chlamys justiniana* (FONT.), *Anomia ephippium costata* BROCC. and *Pitar schafferi* KAUTSKÝ were identified, indicating an Eggenburgian age (Ondrejičková, 1979; Váňová, 1955).

In pelitic intercalations in conglomerates, an association of foraminifers with prevalence of lagenids and agglutinates was established (Brestenská, 1977).

The Kľačno Conglomerate was formed in gravel mounds at the margin of a rocky coast. Cross bedding caused by wave activity and distinct increase in thickness of layers towards the basin, which was determined by considerable paleo-dip of the coast, has been observed (Baráth & Kováč, 1989). On the basis of mollusc fauna it may be stated that the mentioned clastic sediments were deposited into a normal marine infra-littoral environment.

Pelitic sediments of the Čausa Formation are cropping out at the northern margin of the Bánovská kotlina Depression. They are lying above the Kľačno Conglomerates or their passage is formed by alternation with calcareous bedded sandstones. The greatest verified thickness of Eggenburgian sediments is 204.4* m (the borehole DB-15, 775.0-979.4 m).

Generally there are grey, yellow-grey calcareous siltstones, claystones with sandy admixture with conchoidal and splintery fracture. To the overlying strata their sandy and calcareous character decreases.

In the borehole DB-15, in the interval 775.0-979.0 m, grey and dark-grey solid claystones with the medium grain diameter 0.0083 mm and a low sorting degree occur. The average value of the sorting coefficient SO is 3.41. The distribution character of grain size particles is

* No biostratigraphic markers of the Eggenburgian/Ottnangian boundary were found in analysed material. Therefore Brestenská mentioned Eggenburgian-Ottnangian boundary in the borehole DB-15 in her individual works variously. In the work from the year 1975a she ranged the sediments as follows: Eggenburgian (946.0-979.4 m), Eggenburgian-Ottnangian (630.6-946.0 m), Ottnangian (456.4-630.6 m) and Karpatian (2.5-456.4 m). In the Explanatory Notes to the Geological Map of the Bánovská kotlina Depression 1 : 50 000 (Brestenská et al., 1980) the sediments from the mentioned borehole were ranged to the Eggenburgian (635.0-979.4 m), Ottnangian (456.4-635.0 m) and Karpatian (2.5-456.4 m). In the article from the year 1983 she shifted the Ottnangian-Eggenburgian boundary deeper to the depth of about 913 m (recorded from the schematic profile of borehole DB-15). Ottnangian is generally correlated with regressive part of the Eggenburgian-Ottnangian cycle: representing sea level drop of cycle TB2.1 of Haq et al. 1988 (Papp et al., 1973; Cicha et al., 1998; Rögl, 1998). Based on the ecostratigraphic principle, the Eggenburgian(Ottnangian boundary can be approximately correlated with the boundary between the Čausa and Bánovce Formations (775 m of the borehole DB-15). This lithological change is connected with the basin's shallowing and decrease of its water salinity (for detailed data see below).

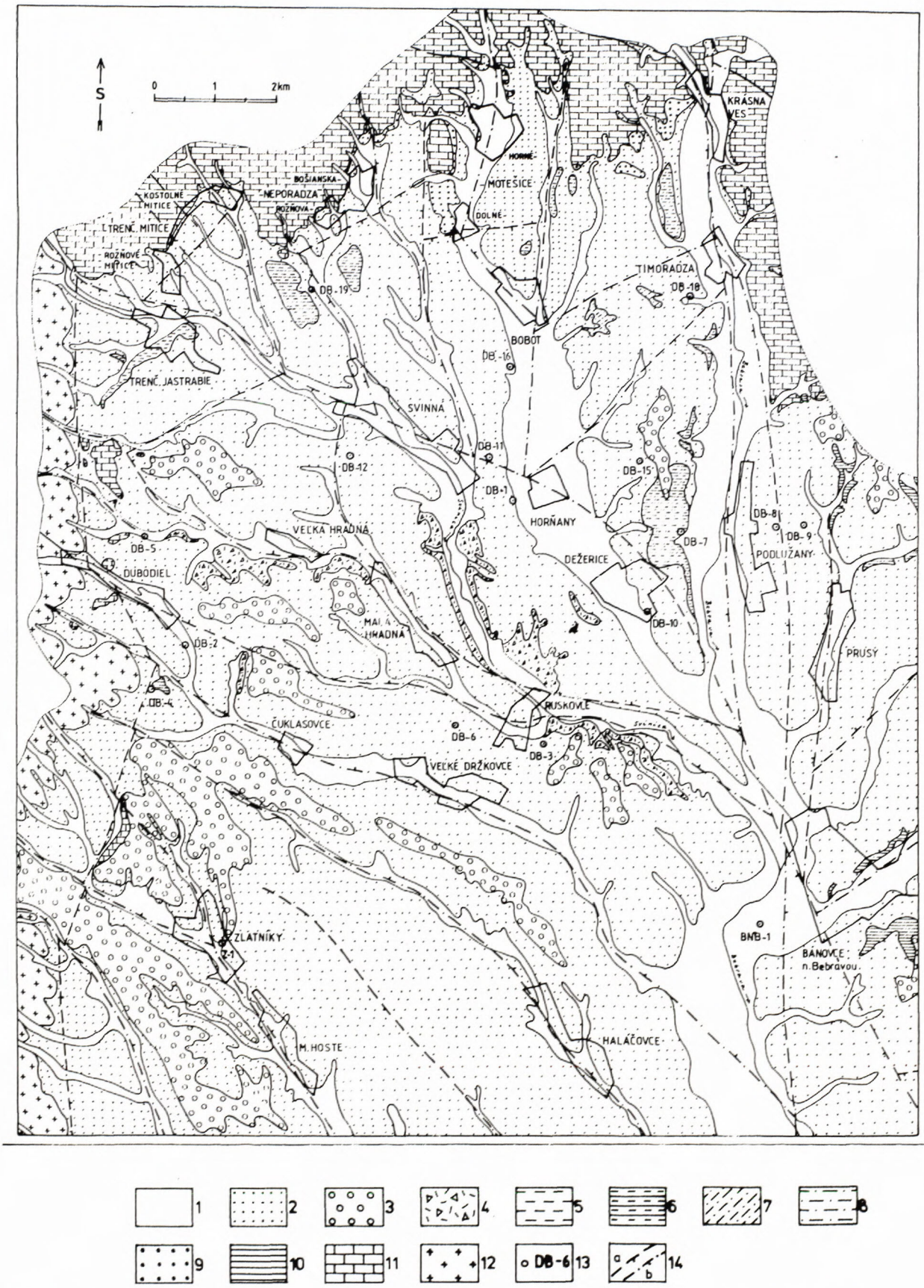


*Fig. 2 Schematic geological map of the Bánovská kotlina Depression (compiled Fordinál 2001, after Pristaš et al., 2000b). QUATERNARY 1 – fluvial sediments 2 – deluvial sediments, PLIOCENE 3 – Volkovce Formation, MIOCENE 4 – Vtáčnik Formation – Ruskovce Member 5-Svinná Formation 6 – Lakšáry Formation 7 – Bánovce Formation 8 – Čausa Formation (pelitic sediments) 9 – Čausa Formation – Kľačno Member PALEOGENE 10 – Borové and Zuberec Formations, 11 – Mesozoic rocks, 12 – metamorphic and granitoid rocks, 13 – borehole, 14 – faults a, assumed b, assumed covered.*

bimodal. The lower part of the mentioned sediments has the Sk values 1.88 and 1.32. The content of heavy minerals is low (mostly up to 2.34 %, exceptionally 12.73 %). High presence of authigenic minerals, like pyrite and siderite is characteristic of these sediments. In schlier layers (the interval of 775-945 m), the layers of acid (rhyodacite and rhyolite) tuffites were found (Marková, 1975).

From the clay minerals, montmorillonite predominates in the schlier lithofacies and kaolinite over montmorillonite in flysh lithofacies (Marková, l.c.).

Schlier sediments of the Čausa Formation contain a rich microfauna. Mainly on basis of the borehole DB-15 the following microfaunal associations were distinguished (Brestenská, 1975a):

1. with prevalence of lagenids and agglutinates
2. with pyritized diatoms and foraminifers
3. with radiolarians

The first association found in the borehole DB-15, in the interval of 965-979 m, is rich and diversified. It is characteristic of lagenids and agglutinates prevalence. The species *Rhizammina* aff. *algaeformis* BRADY, *Bathysiphon taurinensis* SACCO, *Spirorutilus carinatus* (ORBIGNY), *Textularia* ex gr. *gramen* ORBIGNY, *Vulvulina pennatula* (BATSCH), *Semivulvulina* ex gr. *pectinata* (REUSS), *Reticulophragmium acutidorsata* (HANTKEN), *R. rotundidorsata* (HANTKEN), *Cyclammina praecancellata* VOLOSHINOVA, *Nodosaria latejugata* GÜMBEL, *Lenticulina cultrata* (MONTFORT), *L. inornata* (ORBIGNY), *L. clericii* (FORNASINI), *L. mamilligera* (KARRER), *L. arcuatostriata* (HANTKEN), *L. meznericae* (CICHA), *Marginulina glabra* ORBIGNY, *M. hirsuta* ORBIGNY, *Marginulinopsis* aff. *fragaria* GÜMBEL, *Globulina gibba* ORBIGNY, *Sphaeroidina bulloides* ORBIGNY, *Stilostomella elegans* (ORBIGNY), *Bulimina elongata* ORBIGNY and other were found (Brestenská, 1975b). The mentioned association was also established in schlier at the locality Krásna Ves (Brestenská & Lehotayová, 1983). This assemblage is characteristic of stenohaline, lower neritic to upper bathyal foraminifers. High relative abundance of agglutinated species is well comparable with isochronous assemblages from other parts of the Central Paratethys (Bathysiphon-Cyclammina schlier in the Vienna basin (Cicha et al., 1998) and assemblages from the upper part of Szecsény schlier in the Fiľakovo/Pétervására Basin (Halásová et al., 1996). During this interval, broad communication with Vienna basin and the Fiľakovo/Pétervására basin can be expected (Halásová et al., l.c.).

The second association was found in the borehole DB-15, interval 947-964 m. On the contrary to the first association, it is less diversified and is characteristic of pyritized foraminifers and diatoms. Composition of assemblages frequently shifts. From foraminifers, *Saccamina* sp., *Cibicidoides budayi* (CICHA et ZAPLETALOVÁ), *C. ungerianus* (ORBIGNY), *Bulimina elongata* ORBIGNY, *Chilostomella ovoidea* REUSS, *Reophax sp.*, *Caucasina schischkinskaye* (SAMOILOVA), *Virgulinella pertusa* (REUSS), *Cibicides lobatulus* (WALKER et JACOB), *Cribrononion minutum* (REUSS), *Lagena vulgaris* WILLIAMSON, *Siphonina reticulata* (CZJEZEK), *Ammonia* ex gr. *beccarii* (LINNÉ) and *Protelphidium* ex. gr. *granosum* (ORBIGNY) occur most often, Brestenská (1975a; 1977). Assemblages from this interval characterise upper neritic and episodically low-oxic or euryhaline paleoenvironment. They reflect beginning of the basin's isolation.

In both intervals, calcareous nannoplankton was observed (Tab. 2). Assemblages are dominated by *Coccolithus pelagicus* (Wallich) Schiller and *Reticulofenestra pseudoumbilica* (Gartner) Gartner. Occurrence of *Helicosphaera ampliaperta* Bramlette et Wilcoxon enables to correlate these intervals with the transgressive Eggenburgian sediments from the Central Paratethys basins, including stratotype sections in the Lower Austria. *H. ampliaperta* Bramlette et Wilcoxon appears in the middle part of the NN 2 Zone (Fornaciari & Rio, 1996). Reworked Cretaceous, Eocene and Oligocene nannoliths occur mainly in the second interval (Fig. 3).

In the strata overlying both mentioned intervals (the depth 775-945 m), probably bathymetrycally deepest sediments of the schlier formation were found. They contain redeposited radiolarians and represent the third distinguished association. Calcareous nannoplankton was not observed in this interval, with the exception of very rare Eocene and Cretaceous reworked nannoliths. Sediments containing an association with radiolarians were also found in the borehole DB-8 (12-84 m). They are formed predominantly by grey non-stratified clay, with the layers of grey sandstones (Brestenská, 1977; Seneš & Brestenská, 1963). Besides boreholes, the sediments with radiolarians were also found in the outcrops between Trenčianske Mitice and Timoradza (Brestenská, 1977). To the south of Bošianska Neporadza, the vitreous tuffite was also found in these sediments (Marková, 1977).

In sediments of the Čausa Formation, the presence of calcareous nannoplankton was established also in the other sections and boreholes. Their occurrence was recorded in grey calcareous clays in borehole DB-9 (57-58 m). Species *Discoaster aulakos* GARTNER, *D. aster* BRAMLETTE et RIEDEL, *Reticulofenestra excavata* Lehotayová and *R. bisecta* (HAY, MOHLER et WADE) ROTH were determined, presence of *Discoaster druggi* BRAMLETTE et WILCOXON, indicate the NN2 Discoaster druggi Zone (Lehotayová, 1977; 1982).

Pelitic sediments from the localities Kostolné Mitice, Rožňová Neporadza, Horné Motešice, Krásna Ves and from the boreholes DB-15 (815,1-819,2 m) and DB-19 (53,6-53,8 m), with nannoflora containing the species *Coccolithus pelagicus* (WALLICH) SCHILLER, *Cruciplacolithus tenuiforatus* CLOCCHIATI et JERKOVIĆ and *H. carteri* (WALLICH) KAMPTNER was found (Lehotayová, 1976; 1977; 1982; Brestenská & Lehotayová, 1983; Žecová, 1999). *Helicosphaera ampliaperta* BRAMLETTE et WILCOXON, enable to correlate this section with the upper part of NN 2 Zone, i.e. with the Eggenburgian.

In schliers of the Čausa Formation in Rožňová Neporadza, a rich association of molluscs was found, containing the species: *Nucula nucleus* (L.), *N. compta* GOLD., *Yoldia nitida* (BROCCHII), *Anadara diluvii* (LM.), A. darwini (MAYER), *Anadara sp.*, *Glycymeris sp. Modiolus sp.*, *Musculus philippi* (WOLF), *Pinna pectinata brocchii* ORBIGNY, *Pinna* sp., *Lentipecten corneum denudatum*

*Tab. 2 Quantitative representation of calcareous nannofossils in the well DB-15, Horňany (compiled Holcová 2001).*

| Species | Reworked | 975-976 m | 963.5 m | 959.5 m | 953.5 m | 942.5 m | 914.5 m | 884 - 885 m | 864 - 865 m | 836.5 m | 802.5 m | 769.5 m | 729.5 m | 691.5 m | 675 m | 640.5 m | 625.8 m | 606.8 m | 584 - 585 m | 554.5 m | 535.8 m | 533.4 m | 512.5 m | 491.5 m | 466.5 m | 420.5 m | 353.3 m | 334.4 - 334.6 m | 298 m | 279.5 | 249.5 m | 227.5 m | 202.5 m | 185.5 m | 132.5 m | 105.5 m | 98.5 m | 87.5 m |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Reticulofenestra excavata* LEHOTAYOVA | | 0.0 | 0 | 0.0 | 0.0 | | | | | | | | | | | | | | | | | | | | | | | | | | 0.0 | 0.0 | | 0.0 | 0.8 | 0.0 | 0.0 | 0.0 |
| *Reticulofenestra minuta* ROTH | | 1.4 | 12.9 | 0.0 | 0.0 | | | | | | | | | | | | | | | | | | | | | | | | | | 6.7 | 0.0 | + | 9.8 | 5.3 | 6.0 | 1.1 | 6.6 |
| *Reticulofenestra pseudoumbilica* (GARTNER) GARTNER | | 15.3 | 6.5 | 15.4 | 10.1 | + | | | + | | | | | | | | | | | | | | | | | | | | | | 20.0 | 13.6 | | 4.5 | 5.3 | 12.0 | 4.4 | 1.9 |
| *Reticulofenestra pseudoumbilica* (GARTNER) GARTNER - small-sized | | 9.7 | 2.4 | 0.0 | 0.0 | | | | | | | | | | | | | | | | | | | | | | | | | | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Reticulofenestra daviesi* (HAQ) HAQ | O | 0.0 | 0.8 | 0.0 | 0.8 | | | | | | | | | | | | | | | | | | | | | | | | | | 0.0 | 0.0 | | 0.0 | 0.8 | 2.0 | 0.0 | 0.0 |
| *Reticulofenestra bisecta* (HAY, MOHLER et WADE) ROTH | O | 6.9 | 2.4 | 0.0 | 2.3 | | | | | | | | | | | | | | | + | | | | | | | | | | | 6.7 | 0.0 | | 0.9 | 1.5 | 2.0 | 3.3 | 1.9 |
| *Reticulofenestra bisecta* (HAY, MOHLER et WADE) ROTH - small-sized | O | 4.2 | 4.8 | 7.7 | 0.0 | | | | | | | | | | + | | | | | | | | | | | | | | | | 0.0 | 4.5 | | 0.0 | 1.5 | 0.0 | 0.0 | 0.0 |
| *Reticulofenestra lockeri* MULLER | O | 0.0 | 0.0 | 0.0 | 0.0 | | | | | | | | | | | | | | | | | | | | | | | | | | 0.0 | 0.0 | | 0.0 | 0.8 | 0.7 | 0.0 | 0.0 |
| *Reticulofenestra umbilica* (LEVIN) MARTINI et RITZOWSKI | E | 1.4 | 1.6 | 7.7 | 2.3 | + | | | | | | | | | | | | | | | | | | | | | | | | | 0.0 | 0.0 | | 0.0 | 0.0 | 0.7 | 0.0 | 0.0 |
| *Coccolithus pelagicus* (WALLICH) SCHILLER | | 50.0 | 34.7 | 46.2 | 53.5 | | + | | | | | | | | + | | | | | | | | | | | | | + | | 50.0 | 40.9 | + | 68.8 | 38.3 | 46.0 | 44.4 | 30.2 |
| *Cyclicargolithus abisectus* (MULLER) BUKRY | O | 4.2 | 0.0 | 0.0 | 0.0 | | | | | | | | | | | | | | | | | | | | | | | | | | 0.0 | 0.0 | | 0.9 | 0.0 | 0.0 | 3.3 | 0.9 |
| *Cyclicargolithus floridanus* (ROTH et HAY) BUKRY | | 0.0 | 0.0 | 15.4 | 3.1 | | | | | | | | | | | | | | | | | | | | | | | | | | 0.0 | 0.0 | | 0.9 | 1.5 | 0.7 | 1.1 | 1.9 |
| *Cribrocentrum reticulatum* (GARTNER et SMITH) PERCH-NIELSEN | E | 1.4 | 0.0 | 0.0 | 0.0 | | | | | | | | | | | | | | | | | | | | | | | | | | 0.0 | 4.5 | | 0.0 | 0.0 | 0.0 | 0.0 | 0.9 |
| *Cruciplacolithes sp.* | E | 0.0 | 0.0 | 0.0 | 0.8 | | | | | | | | | | | | | | | | | | | | | | | | | | 0.0 | 4.5 | | 0.0 | 0.0 | 0.0 | 0.0 | 4.7 |
| *Transversopontis pulcher* (DEFLANDRE) PERCH-NIELSEN | O | 1.4 | 0.0 | 0.0 | 0.0 | | | | | | | | | | | | | | | | | | | | | | | | | | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | 0.9 |
| *Helicosphaera ampliaperta* BRAMLETTE et WILCOXON | | 0.0 | 0.0 | 0.0 | 0.8 | | | | | | | | | | | | | | | | | | | | | | | | | | 0.0 | 0.0 | | 8.9 | 15.8 | 2.0 | 10.0 | 0.9 |
| *Helicosphaera ampliaperta* BRAMLETTE et WILCOXON - narrow central opening | | 1.4 | 0.0 | 0.0 | 0.0 | | | | | | | | | | | | | | | | | | | | | | | | | | 0.0 | 0.0 | | 0.9 | 0.0 | 0.7 | 1.1 | 0.9 |
| *Helicosphaera carteri* (WALICH) KAMPTNER | | 0.0 | 0.0 | 0.0 | 0.0 | | | | | | | | | | | | | | | | | | | | | | | | | | 3.3 | 0.0 | | 0.0 | 0.0 | 6.7 | 0.0 | 0.9 |
| *Helicopshaera mediterranea* MULLER | | 0.0 | 0.0 | 0.0 | 0.8 | | | | | | | | | | | | | | | | | | | | | | | | | | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Helicosphaera scissura* MILLER | | 0.0 | 0.0 | 0.0 | 0.8 | | | | | | | | | | | | | | | | | | | | | | | | | | 0.0 | 0.0 | | 0.0 | 0.0 | 0.7 | 0.0 | 0.0 |
| *Pontosphaera multipora* (KAMPTNER) ROTH | | 1.4 | 0.8 | 0.0 | 0.0 | | | | | | | | | | | | | | | | | | | | | | | | | | 0.0 | 0.0 | | 0.9 | 0.0 | 4.0 | 0.0 | 0.0 |
| *Sphenolithus heteromorphus* DEFLANDRE | | 0.0 | 0.0 | 0.0 | 0.0 | | | | | | | | | | | | | | | | | | | | | | | | | | 0.0 | 0.0 | | 0.0 | 0.0 | 0.7 | 0.0 | 0.0 |
| *Sphenolithus moniformis* (BRONNIMANN et STRADNER) BRAMLETTE et WILCOXON | | 5.6 | 0.8 | 0.0 | 0.8 | | | | | | | | | | | | | | | | | | | | | | | | | | 3.3 | 4.5 | | 0.9 | 0.8 | 2.7 | 0.0 | 0.0 |
| *Cricolithus jonesi* COHEN | | 0.0 | 12.1 | 0.0 | 0.0 | | | | + | | | | | | | | | | | | | | | | | | | | | | 0.0 | 0.0 | | 0.9 | 22.6 | 6.7 | 22.2 | 23.6 |
| *Discoaster droogi* BRAMLETTE et WILCOXON | | 0.0 | 0.0 | 0.0 | 0.0 | | | | | | | | | | | | | | | | | | | | | | | | | | 3.3 | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Discoaster deflandrei* BRAMLETTE et RIEDEL | O | 0.0 | 0.0 | 0.0 | 0.0 | | | | | | | | | | | | | | | | | | | | | | | | | | 0.0 | 0.0 | | 0.0 | 0.0 | 2.0 | 0.0 | 0.9 |
| *Discoaster saipanensis* BRAMLETTE et RIEDEL | E | 0.0 | 0.0 | 0.0 | 0.0 | | | | | | | | | | | | | | | | | | | | | | | | | | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | 0.9 |
| *Zyghrabdulus bijugatus* DEFLANDRE | O | 0.0 | 0.0 | 0.0 | 0.0 | | | | | | | | | | | | | | | | | | | | | | | | | | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | 0.9 |
| *Braarudosphaera bigelowi* (GRAN et BRAARUD) DEFLANDRE | | 0.0 | 0.0 | 7.7 | 0.0 | | | | | | | | | | | | | | | | | | | | | | | | | | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Thoracosphaera* sp. | | 0.0 | 0.0 | 0.0 | 0.0 | | | | | | | | | | | | | | | | | | + | | | + | | | + | | 0.0 | 0.0 | | 0.0 | 0.0 | 0.7 | 1.1 | 0.0 |
| *Arkhangelskiella* sp. | C | 0.0 | 0.0 | 0.0 | 0.8 | | | | | | | | | | | | | | | | | | | | | | | | | | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Watzenaueria* sp. | C | 1.4 | 10.5 | 0.0 | 15.5 | | | | | | | | | | | | | | | | | | + | | | + | + | + | | | 6.7 | 13.6 | + | 1.8 | 2.3 | 1.3 | 5.6 | 14.2 |
| *Crethorabdulus sp.* | C | 0.0 | 0.0 | 0.0 | 0.8 | | | | | | | | | | | | | | | | | | | | | | | | | | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Micula* sp. | C | 0.0 | 0.8 | 0.0 | 3.9 | + | | | | | | | | | | | | | | | | | + | | | | | | | | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 | 1.1 | 4.7 |
| *Chiasmolithus* sp. | E | 0.0 | 0.0 | 0.0 | 0.8 | | | | | | | | | | | | | | | | | | | | | | | | | | 0.0 | 4.5 | | 0.0 | 1.5 | 0.0 | 1.1 | 0.0 |
| *Isthmolithus recurvus* DEFLANDRE | E | 0.0 | 0.0 | 0.0 | 0.8 | | | | | | | | | | | | | | | | | | | | | | | | | | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Eifelithus* sp. | E | 0.0 | 0.0 | 0.0 | 1.6 | | | | | | | | | | | | | | | | | | | | | | | | | | 0.0 | 9.1 | | 0.0 | 0.0 | 0.0 | 0.0 | 1.9 |
| Nannolith abundance | | common | common | rare | common | very rare | very rare | absent | very rare | absent | absent | absent | absent | absent | very rare | absent | absent | absent | absent | absent | very rare | absent | very rare | absent | absent | absent | very rare | very rare | absent | very rare | rare | rare | very rare | abundant | abundant | abundant | abundant | common |
| Diatoms abundance | | common | absent | absent | absent | absent | common | absent | rare | rare | absent | absent | absent | absent | absent | rare | rare | absent | absent | absent | absent | common | absent | absent | absent | very rare | very rare | common | very abundant | very abundant | common | rare | common | abundant | abundant | common | absent |
| Radiolaria | | | | | | | | | | | | | | | | | | | | | + | common | absent | very rare | absent | absent | very rare | very rare | absent | very rare | very rare | very rare | very rare | very rare | very rare | very rare | very rare |

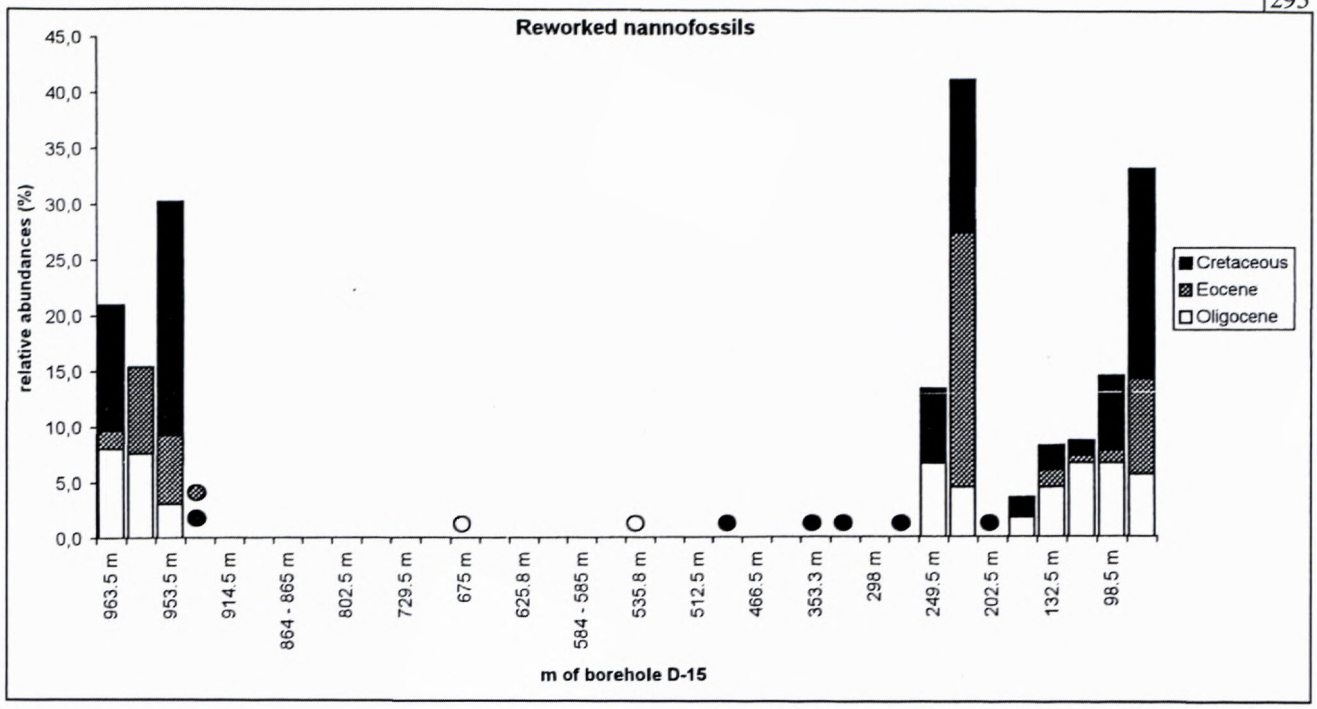


*Fig. 3 Quantitative representation of reworked nannofossils in the well DB-15, Horňany (compiled Holcová 2001).*

(REUSS), *Cyprina islandica rotundata* BRAUN and other (Ondrejičková, 1979).

**The Bánovce Formation s. str.** is formed by alternating clayey and sandy beds (flyschoid formation) with the thin layers of conglomerates. It is resting on the Čausa Formation. Based on its superposition, the Ottnangian age is interpreted for the Bánovce Formation.*

The average grain size of sandy layers is shown by a medium value 0.2 mm. The average of sorting coefficient is 2.17. Silts of the flyshoid formation have the medium grain diameter 0.019 mm, the average So value is 2.89. The particles distribution type is always bimodal and Sk negative. Clays have the least quantitative share in the Bánovce Formation. Their average Md is 0.008 mm, the average So 2.81, the distribution type is bimodal and Sk always negative (Marková, 1975).

It crops out in the northern part of territory, between the Jastrabie and Bebrava (Timoradza) faults, in area between the villages Timoradza, Horňany and Svinná. In the southern part, it is covered by sediments of the Lakšary Formation of Karpatian age. The Bánovce Formation was established in the boreholes DB-15 (456.4-635.0 m) (Brestenská et al., 1980), DB-18 (3-150 m) (Brestenská et al., 1976) and DB-19 (14.3-53.2 m). The greatest thickness of the Bánovce Formation was established in the borehole DB-15, i. e. 178.6 m.

The Bánovce Formation is very poor in organic remnants. In basal sediments of this formation, thecamoebian associations, formed by the *Silicoplacentina* occur. They were established in the borehole DB-15 (635-771 m) (Brestenská 1975a; 1977). Besides thecamoebian, a poor fauna of molluscs was found in the borehole DB-15 at depth of 577.5 m. The species *Mytilus* sp. indet, *Congeria* sp. indet., *Gyraulus trochiformis dealbatus* (BRAUN) and *Ancylus moravicus* RZEHAK were identified there (Ondrejičková, 1975). This fauna may be paralleled with the „Rzehakia Member" of southern Moravia (Ondrejičková, l.c.). Further on, fragments of small bones, fish teeth, carbonized remnants of plants and redeposited foraminifers, radiolarians and skeletal elements of siliceous sponges were found.

**The Lakšáry Formation.** At the base, it is formed by grey medium to coarse-grained calcareous sandstones with scattered pebbles as well as layers of conglomerates and to a less extent also claystones. The pebbles are formed by quartzite, quartz and dolomite. In the most cases they are well rounded. In claystones, laminae of diatomites (up to 1 mm) and worm tubes were found. These sediments were established in the borehole DB-15 (304.0-438.35 m) only. The sediments represent probably the transgressive littoral lithofacies resting with hidden uncorformity on Ottnangian sediments of the Bánovce Formation. The Karpatian age of this sediment is confirmed by occurrence of Karpatian diatoms. Other microfossils in this horizon are similar to microfossils in the Bánovce Formation. These sediments gradually pass into lithofa-

* The Bánovce Formation s.l. of the Ottnangian – Karpatian age has been divided by Vass (2001) in two parts. He assigned the Ottnangian sediments to the Bánovce Formation and for the sediments of the Karpatian age, he took the name from the Vienna Basin – the Lakšáry Formation. He has assumed that the originally outlined Bánovce Formation (s.l. – i.e. of the Ottnangian – Karpatian age) consists of two sedimentation sequences. The different opinion has been presented by Kováč (2000) and Kováč et al., (2001). He has announced that in the Bánovce Formation s.l., by means of sedimentology there cannot be established a transition from the transgressive system tracts to the highstand system tracts. This opinion has been based on the situation found out exclusively in the borehole DB-15. Consequently there cannot be definitely determined which of both opinions is closer to the reality. In this paper we have seized the opinion of Vass (2001).

alternating with grey calcareous claystones (flyshoid development). The occurrence of these sediments was established in the borehole DB-15 (200-304.0 m), as well as on the surface south to the village Trenčianske Mitice.

The upper part of sediments is formed by calcareous claystones (schliers). The formation's Karpatian age has been well documented in its upper part because of index Karpatian foraminifer *Uvigerina graciliformis* P. T. found there, as well as nannoliths *Sphenolithus heteromorphus* DEFLANDRE. The average grain size value of these sediments Md is 0.03 mm (0.007-0.05 mm), average So is 2.58 (1.73-4.63). The distribution character of grain size fractions is mostly bimodal, with the main maximum in grain size fraction 0.05-0.02 mm, the lognormal character of distribution with maximum in category 0.1-0.05 (Marková, 1975) is less found. In these sediments, the occurrence of volcanic glass (DB-15, 26-145,5 m) was established, indicating autochthonous or redeposited products of rhyodacite or rhyolite volcanism.

In the Lakšáry Formation, three micropaleontological types of association were distinguished from the base upwards (Brestenská, 1977):

1. very poor association with rare occurrence of fish remains and reworked foraminifers
2. association with prevalence of diatoms
3. an abundant association of planktonic foraminifers

The first association has been directly linked to Ottnangian associations. It is characteristic of basal and flyshoid sediments. Only fragments of fish bones and fish teeth together with carbonized plant remnants are found in it. Cretaceous reworked nannofossils occur in the upper part of this horizon. In the claystone layer (DB-15; 388-400 m) laminae of diatomites, 1 mm thick. The species „*Actinocyclus undatus* (CLEVE) RATRAY (predominating species), *Coscinodiscus gorbunovii* SHESH. var. *ethmodiscoides* MOISS, *C. pannonicus* f. *minima* HAJÓS, *C. variabilis* KRASSSKE, *Cyclotella meneghiniana* KÜTZ., *Melosira praeislandica* JOUSÉ, *M. praeislandica* JOUSÉ f. *curvata* JOUSÉ, *Stephanodiscus astrea* (EHR.) GRUN. var. *minutula* (KÜTZ) GRUN., *Synedra rumpens* KÜTZ. var. *fragilarioides* GRUN and Chrysostomatacea were determined there. This is a mixed association of marine planktonic and freshwater forms indicating the Karpatian age (Hajós in Brestenská et al., 1976).

The second association has been characterized by a rich occurrence of diatoms. Concerning the lithology, this is the uppermost part of flyshoid formation and the lower part of pelitic (schlier) formation of the Karpatian age.

Sediments characteristic of a rich diatom occurrence were found in the boreholes DB-15 (95-288 m), DB-16 (40-100 m), they also crop out in surroundings of the village Bobot. In the lower part of these sediments only sporadic, minute, discoid, non - pyritized diatoms and scarce foraminifers, represented mainly by the species *Ammonia* ex. gr. *beccarii* L. occur. In the borehole DB-15 (185.5 m), notable endemic foraminifer of the genus *Montspeliensina* was found. This genus appeared in the Ottnangian of Upper Austria and then in the Medokýš Member of the Novohrad Basin (Holcová, 1996). Occurrence of the genus indicates marine communication among these areas. Damaged ostracode tests of the genera *Cytheridea* and *Xestoleberis* Scarcela were also scarcely present. The middle part is similar to the lower part, only diatoms are represented in a larger amount and they are pyritized. The upper part of sediments with predominating diatoms represents a transition between the association with rich occurrence of diatoms and the association with an abundant plankton. In this part discoid pyritized diatoms also predominate, but layers with foraminifers are more frequent, richer and more diversified. From benthic foraminifers the species *Praeglobobulimina pupoides* (ORBIGNY), *Heterolepa* ex gr. *dutemplei* (ORBIGNY), *Valvulineria complanata* (ORBIGNY), *Melonis soldanii* (ORBIGNY), *Stilostomella elegans* (ORBIGNY) etc. are most often found. The plankton is represented by pteropods and by the foraminifers *Globigerina praebulloides* BLOW and *Globigerina angustiumbilicata* BOLLI (Brestenská, 1977).

Changes in calcareous nannoplankton assemblages and relative abundance of reworked nannoliths in this interval of the borehole DB-15 well correlate with a lithological change in the level 200 m (Tab. 2, Fig. 3). Rare nannofossils with high abundance of reworked species and dominance of *Coccolithus pelagicus* (WALLICH) SCHILLER and *Reticulofenestra pseudoumbilica* (GARTNER) GARTNER occur in the flyshoid sediments. In overlying schlier, abundant assemblages with common *Cricolithus ionesi* COHEN characteristic of the Karpatian assemblages also in other Central Paratethys basins, were observed. From the stratigraphical point of view, appearance of the NN 4 Zone index species *Sphenolithus heteromorphus* DEFLANDRE is important. Low abundance of reworked nannolith may reflect highstand deposits.

The third association has been characterized by rich assemblages of foraminifers with abundant plankton. Sediments, in which the mentioned association has been found, were present in the boreholes DB-7 (87-150 m), DB-10 (112-177 m), DB-15 (7-95 m), DB-16 (0-70 m), DB-17 (0-201 m) and in surface outcrops of the Karpatian deposits (Dežerice, Bobot).

From benthic forms of foraminifer assemblages, *Bathysiphon taurinensis* SACCO, *Haplophragmoides vasiceki* CICHA et ZAPLETALOVÁ, *Budashevaella wilsoni* (SMITH), *Reticulophragmium karpaticum* CICHA et ZAPLETALOVÁ, *Lenticulina depauperata* (REUSS), *L. cultrata* (MONTFORT) are found, from planktonic forms *Globigerina praebulloides* BLOW, *G. angustiumbilicata* BOLLI, *G. ciperoensis ottnangensis* RÖGL and *G. quinquelobata* NATLAND (Brestenská, 1977) occur. These assemblages indicate the lower neritic, stenohaline environment.

Besides foraminifers, molluscs also occur in sediments of the Karpatian age. In the borehole DB-15 (75.8-80.9 m) *Amusium* sp. and *Pinna* sp. have been identified and in the borehole DB-17 (41.0-154.0 m) *Venus* sp., *Aturia aturi* BASTEROT, *Clio (Balantium) bittneri* (KITTL), *C. (B.) pedemontanum* (MAYER) a *?Vaginella* sp. have been found (Ondrejičková, 1975).

In the assemblage of sporomorphs found in Karpatian sediments in the borehole DB-10 (148.0-176.0 m), the Middle Miocene plant elements have been present. There are represented by tropical plants of the genus *Lygodium*

and families Gleicheniaceae, Sapotaceae, Hystrichosphaeridae and *Deflandrea*, which indicate a marine environment, are also abundant. Forms of the genera *Engelhardtia*, *Pterocarya*, *Carya* and family Myricaceae have been also found in a large amount . The mentioned assemblages of plants indicate a warm subtropical climate (Planderová, 1965).

Generally, the pollen spectrum has been characterized by a rich occurrence of marine plankton, pollen grains of coniferous and cryptogam plants. The composition of sporomorphs indicates a warm subtropical climate and the presence of marginal swamps, in which Taxodiacea-Nyssaceae-Mastixiceae dominate (Brestenská et al., 1983; Planderová, 1984).

Besides the borehole DB-15, calcareous nannoplankton was analysed in sediments at the localities Dežerice, Rožňové Mitice and in the borehole DB-19 (13.5-13.7 m) (Lehotayová, 1976; 1977; 1982; Lehotayová in Brestenská et al., 1980; Žecová, 1999). The species *Coccolithus miopelagicus* BUKRY, *C. pelagicus* (WALLICH) SCHILLER, *Coronasphaera mediterranea* (LOHMANN) GAARDER, *Cyclococcolithus rotula* KAMPTNER, *Cyclicargolithus floridanus* (ROTH et HAY) BUKRY, *Helicosphaera carteri* (WALLICH) KAMPTNER, *H. ampliaperta* BRAMLETTE et WILCOXON, *Pontosphaera multipora* (KAMPTNER) ROTH, *Reticulofenestra bisecta* HAY-MOHLER-WADE, *R. pseudoumbilica* (GARTNER) GARTNER have been found, indicating the NN-4 Zone.

Sediments of the Lakšáry Formation were generally found in the borehole DB-7 Podlužany (8.7-150.0 m) (Brestenská, 1977; originally ranged to the Eggenburgian (Seneš & Brestenská, 1963), DB-10 Dežerice (112.5-177.0 m), DB-15 (2.5-456.3 m), DB-16 Bobot (0-100 m) (Brestenská et al., 1976), DB-17 (Zemianske Mitice (0-201 m) (Brestenská 1977) and DB-19 Rožňová Nepomoradza (2.1-14.3 m) (Žecová, 1999).

**The Svinná Formation** is resting disconformably on older Miocene sediments. As for its stratigraphy, it was ranged to the Upper Badenian (Brestenská et al., 1980) and Upper Badenian to Lower Sarmatian (Vass in Keith et al., 1994). Occurence of the Kamenec Formation (upper part of the Early Badenian – Middle Badenian, see later) at its roof points to the Early Badenian age of the Svinná Formation.

Sediments of the Svinná Formation deposited in a freshwater environment, but in some horizons, the foraminifers *Ammonia* ex gr. *beccarii* (L.) and ostracods of the genera *Amnicythere* and *Mediocypris* have been found. Presence of the ostracod genus *Mediocypris* indicates the Middle Miocene age of the Formation. Generally, the occurrence of the above mentioned foraminifers and ostracods poits to the short-term sea ingressions (Brestenská, 1965; 1969; Brestenská in Brestenská et al., 1980). In the Middle Miocene, the most proximate existence of a marine environment was in the Hornonitrianska kotlina Depression, namely during the Early Badenian (Gašpariková in Blaško et al., 1989). Discovery of the mentioned sea ingressions also points to the Early Badenian age of the Svinná Formation.

Finding of a microfloral assemblage in sediments of the borehole DB-6 (462 m) represents another argument for the Early Badenian age of this Formation. It was correlated with the assemblage detected in the marine Early Badenian sediments of the borehole HV-9 (450-710 m) from the Hornonitrianska kotlina Depression (Planderová, 1991).

Sediments of the Svinná Formation are formed predominantly by grey claystones. They have splintery or shaly jointing and contain carbonized remnants of plants. Within claystones, rare layers of fine grained sandstones with silt and tuffit admixtures and coal layers occur. In the basal part of the formation marly limestones have been found.

On the basis of a distinct geomagnetic anomaly, we assume an occurrence of volcanic bodies in the basal part of the Svinná Formation. Following a volcanological analogy, the mentioned complex represents extrusive dome-shaped andesite bodies.

This formation is widespread in the Bánovská kotlina Depression, south of the Jastrabie fault. The Svinná Formation crops out near Dežerice, Vlčkov, Horňany, Svinná, Veľká Hradná and in the neighbourhood of Trenčiasnske Jastrabie and Dubodiel (Fig. 2), (Brestenská et al., 1980). It was encountered in the boreholes DB-1 Svinná (10-59 m) and DB-2 Dubodiel (6-100 m).

Fossil remnants found in the Svinna Formation may be divided into two groups (Brestenská, 1977):

1. autochthonous, with ostracodes (*Candona, Darwinula, Iliocypris, Mediocypris, Amnicythere*), foraminifers (*Ammonia* ex. gr. *beccarii* (L.)), fragments of molluscs, remnants of fish (teeth, bones, otoliths), oogoniums of characeans, carbonized and pyritized plants remains (*Glyptostrobus europeus* (BRNGT) HEER).

2. allochthonous, including redeposited remnants of marine microfauna (skeletal fragments of siliceous sponges, radiolarians, foraminifers; Cretaceous to Lower Miocene).

Redeposited paleothanatocenoses of foraminifers are represented by forms of Cretaceous age (globotruncanas), which are found very rarely, further by foraminifers of Paleogene and Lower Miocene age. These paleothanatocoenoses are sorted by size (Brestenská l.c.).

On the basis of amount of individual autochthonous and allochthonous elements, the Svinná Formation was divided into three parts (Brestenská l.c.).

The lower part of the mentioned formation was encountered by the borehole DB-12 (1025-1199 m) only. Occurrence of redeposited planktonic foraminifers of the Early Miocene age is characteristic of this section. From autochthonous elements, the fragments of mollusc shells, remnants of fish and very rare ostracods have been represented.

The middle part of the Svinná Formation has been characterized by prevalence of autochthonous elements, thin-walled ostracods and oogoniums of characea. From ostracods, the genus *Amnicythere* has been found in the higher section of the middle part and in its lower part tests of the genus *Mediocypris* occur.

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The upper part has been characterized by the occurrence of mollusc fragments and concretions. Ostracodes, fish remnants as well as redeposited elements are represented rarely.

**The Kamenec Formation** was not known in the Bánovská kotlina Depression up to now. It has been defined in the Hornonitrianska kotlina Depression as a formation of epiclastic volcanic conglomerates and sandstones with non-volcanic material (Konečný et al., 1983) representing a succession of volcano-clastic, volcano-sedimentary and sedimentary rocks with autochthonous pyroclastics, which deposited from the Early to Middle Badenian in a fluvial, lacustrine and terrestrial environment. Its material originated from the Badenian volcanics of the Vtáčnik Mts., Kremnické vrchy Mts. and Štiavnické pohorie Mts. In the Hornonitrianska kotlina Depression, the Kamenec Formation is overlying marine sediments of the Early Badenian age (Šimon et al., 1997).

In the the Bánovská kotlina Depresion in the boreholes DB-3 (125.0-307.7 m) and DB-6 (117.6-450.0 m), the lower part of the so-called Tuffite-Detrital Formation (Brestenská et al., 1980), later the Ruskovce Formation (Kováč et. al., 1993b; Vass in Keith et al., 1994) was corelated to the Kamenec Formation (Šimon in Pristaš et al., 2000a) on the basis of the rock lithology and petrography of the pebbles. Planderová (1991) correlated a microfloral assemblage distinguished in the mentioned sediments in the borehole DB-6 (240 m) to the assemblage found out in sediments with coal of the Kamenec Formation (so-called Nováky layer) in the Hornonitrianska kotlina Depression [VTH-2 (21.0-78.5 m); VTH-3 (74.0-78.0)].

Based on the mentioned data we removed this lower part from the Ruskovce Formation s.l. assigning it to the Kamenec Formation.

The formation has high lateral variability in its lithological composition. The rocks consist predominantly of suboval and perfectly oval fragments of andesites and fragments of non-volcanic material. Matrix is sandy, tuffaceous-sandy or sandy-clayey.

Rock fragments are formed by hypersthene-amphibolic andesite, amphibole-pyroxenic andesite, hypersthene-amphibolic andesite with garnet, pyroxenic andesite, quartzite, quartz, granite gneiss and limestone. The size of fragments is from 0.5 to 5 cm and they are represented in the amount from 0 to 50 %. The colour of andesites is light-grey, dark-grey, brown or black. In fine beds of claystones and siltstones, there is a coal substance (i.e. recarbonized small woods, for instance in the borehole DB-6 at depth of 135-152 m or 287-296 m). Described part of the Formation represents a relic of the distal zone of the Štiavnica stratovolcano, which developed here also to the north-western part of the stratovolcano and this area has preserved owing to the sunken tectonic block in the Bánovská kotlina depression only.

**The Handlová Formation** was not known in the Bánovská kotlina Depression up to now. It was described in the Hornonitrianska kotlina Depression only (Čechovič, 1959, Konečný et al., 1983, Vass, 2001), where it is formed by clayey-sandy and tuffite sediments, which gradually transfer into dark to black claystones with coal seams. Thickness of the Formation is 50 m. It is overlying the Kamenec Formation.

Similar situation has been found out also in the Bánovská kotlina Depression, where gray epiclastic volcanic sandstones with interlayers of dark carbonized claystones and coaly clays (former a part of the Ruskovce Formation s.l.), have been identified. The microflora with sporomorphs domination of the subspecies *Polypodiaceoisporites gracillimus semiverrucatus* W. KR. have been distinguished there. Sporomorphs of the genera *Quercus, Salix, Eleagnus* etc. (Planderová, 1991) have been present in lesser amount. Planderová (l.c.) correlated the above mentioned microflora to the coal seams microflora of the Handlová Formation in the Hornonitrianska kotlina Depression. In the Bánovská kotlina Depresion these sediments reach the thickness of just 10 m.

We assigned these sediments to the Handlová Formation on the basis of their lithology, superposition (overlying the Kamenec Formation), as well as after the occurrence of similar microfloral assemblage.

**The Ruskovce Member of the Vtáčnik Formation**, former the Tuffite-Detrital Formation (Brestenská in Brestenská et al., 1980) and the Ruskovce Formation (Kováč et. al., 1993b; Vass in Keith et al., 1994). Sediments of the Ruskovce Formation were assigned to the Sarmatian – ?Panonian (Brestenská et al., 1980, Kováč et al., 1993b, Vass in Keith et al., 1994) according to their analogy with sediments of the Hornonitrianska kotlina and Turčianska kotlina depressions.

After petrographical study there has been found out that volcanic rocks forming the upper part of the Ruskovce Formation s.l. (look at the Kamenec Formation) belong to the Vtáčnik Formation (Šimon in Pristaš et. al., 2000a) of the Middle Sarmatian age (Ďurkovičová in Šimon et al., 1994). As for their hierarchy, we have had to redefined them as a Member i.e. the Ruskovce Member having been assigned to the Middle Sarmatian.

It is formed by redeposited pyroclastics, epiclastic volcanic claystones, sandstones and conglomerates. The conglomerates are formed by andesites of subangular, suboval, oval or perfectly oval shape. The andesites are of porous, foamy as well as compact structure. The size of fragments is 1-20 cm (mostly 1-10 cm). Concerning their petrography, they consist generally of pyroxenic andesites, in less amount amphibole-pyroxenic andesites. Sporadically also other petrographic types of andesites, typical of Central Slovakian neovolcanics, are present. The matrix is predominantly sandy-tufaceous. In the case of redeposited pyroclastics the matrix contains small shreds and fragments of yellow or light-white pumice. In sediments of the Ruskovce Member, non-volcanic material is sporadically also present.

Individual layers are formed by laterally shaped beds. Sometimes lenticular layers occur. The beds have mostly chaotic arrangement of fragments. They have either a supporting structure of fragments or a supporting structure of matrix. In the case of fine layers, the beds are massive, rarely laminated. In some beds, diagonal and cross bedding is present. Occurrence of the Ruskovce Member

was established in the boreholes DB-3 (2.0-114.8 m) and DB-6 (45-111 m).

The Ruskovce Member is a succession of volcanoclastic rocks of volcanic-sedimentary origin, evolving during development of the Vtáčnik stratovulcano. Its sediments were formed by fluvial streams, rapid downwash, lahars and mud flows, rock debris flows and avalanches. The shallow sedimentary environment was systematically controlled by fault activity enabling the deposition of the Gilbert type „fan delta" (Kováč et al., 1993b). The Ruskovce Member of the Vtáčnik Formation represents the distal part of the Vtáčnik stratovolcano, which developed in the Middle Sarmatian.

**The Beladice Formation** of the Upper Pannonian to Pontian age (in the sense of Fordinál et al., 2001) overlies the sediments of Paleogene age (on the Závada-Bielica elevation) and underlies sediments of the Volkovce Formation (Dacian).

Sediments of the Beladice Formation are formed by blue-green, grey and dark-grey clays with interlayers of black coal clays or thin horizons of lignite. The sediments consists also of sands and clayey gravels. The gravel is polymict and fine grained. Towards the basin's margin, number of gravel beds as well as their thickness increase. In sediments of the Beladice Formation, there have been found Ostracodes *Candona (Candona)* sp., *Candona (Fabaeformiccandona)* sp., *Ilycypris* ex gr. *gibba* (RAMDOHR), *Amnicythere* sp. and *Pseudocandona marchica* (HARTWIG). Additionally, redeposited foraminifers and radiolarians have been established (Brestenská et al., 1980).

The marginal member of the Beladice Formation is the Hlavina Member of the Late Pannonian age. It consists of freshwater limestone, which crops out in a quarry in the village Malé Kršteňany. The limestone contains gastropod fauna with the species: *Aegopinella orbicularis* (KLEIN), *Leucochroopsis kleini* (KLEIN), *Tropidomphalus* (*Mesodontopsis*) cf. *doderleini* (BRUSINA), *Aplexa* cf. *subhypnorum* GOTTSCH *Viviparus* sp. (TÖRÖKOVÁ & FORDINÁL, 1999).

**The Volkovce Formation** of the Pliocene age has the largest areal extension on the territory of the Bánovská kotlina Depression. Sediments of the Volkovce Formation are overlying Lower (Čausa Fm., Lakšáry Fm.), Middle (Svinná Fm., Ruskovce Fm.) and Upper Miocene (Beladice Fm.) sediments.

Occurrence of gravels and sands is characteristic of the Volkovce Formation. The gravel is mostly poorly sorted and interlayers of clayey sands or sandy clays are also present. The pebles are of various size and roundness degree. At the basin's margin even larger boulders are not rare. The pebles consist mainly of vein quartz and quartzites. Further on, granites, schists, Mesozoic limestones, dolomites, Paleogene sandstones, conglomerates and limestones with nummulites occur. According to their character and superposition, we consider the sediments for fluvial to fluviolacustrine.

Sediments of the Volkovce Formation were found in the boreholes DB-5 (1.4-3.0 m) and DB-9 (2-41 m) (Seneš & Brestenská, 1963).

## Geological development

In the Early Miocene the territory of the Bánovská kotlina Depression was a part of the system of depressions, which were extending as wrench furrows at the margin of the Klippen Belt. These depression of E-W to ENE-WSW directions were extending from the northern margin of the Vienna Basin through the middle Váh valley to the Bánovská kotlina, Hornonitrianska kotlina and Turčianska kotlina depressions (Kováč et al., 1989). They originated due to the Savic orogenic movements. The depressions were parts of a dissected archipelago with clastic sedimentation (Kováč et al., 1993a).

At the beginning of the Lower Miocene, the territory of the Bánovská kotlina Depression was encroached by the Eggenburgian sea. On pre-Teriary rocks and/or Paleogene sediments revealed by erosion, coarse clastic sediments (the Kľačno Conglomerates) and later during sea deepening, also sandy and pelitic sediments (schliers) of the Čausa Formation deposited. The tuffitic horizons within these sediments indicate the coeval distant centres of acid volcanism. To the end of the Eggenburgian a shallowing of sedimentary environment and salinity decrease took place.

In the Ottnangian, communication with open sea was restricted as shown by the mollusc fauna (*Mytilus* sp. indet., *Congeria* sp. indet, *Gyraulus trochiformis dealbatus* (BRAUN), *Ancylus moravicus* RZEHAK) indicating a reduction of environment's salinity.

During the Karpatian, normal marine sedimentation was gradually renewed. In the lower part of the Karpatian, conditions of isolation still persisted (sea with reduced salinity) as indicated by the poor fauna. In the upper part, sedimentation environment deepened and the presence of rich microfaunal associations points to a connection with open sea. Also in sediments of the Karpatian age, layers of tuffites indicating coeval acid volcanism are found.

An independent development continued also in the Middle and partly in the Upper Miocene. At that time, the Závada-Bielice elevation played a significant role, separating the Danube Basin's area of the Rišňovce depression from geological development of the present-day Bánovská kotlina Depression area.

After orogenic processes in the Early Badenian, an emergence and denudation of the Lower Miocene sediments took place. This is testified by lack of the Upper Karpatian sediments (Globigerinoides sicanus Zone) (Lehotayová, 1976; 1977; Kováč et al., 1999) as well as by a large amount of the redeposited Lower Miocene foraminifers in the Lower Badenian Svinná Formation.

During the Middle Miocene, the synsedimentary Jastrabie fault predisposed an area south of the fault to sedimentation.

The Svinná Formation of the Lower Badenian age, formed by claystones and sandstones with layers of lignites, originated under limnic freshwater conditions with irregular sea ingressions from an area of the Hornonitrianska kotlina Depression and from territory of the present-day Central Slovakian neovolcanics. This environment can be most likely characterized as a semi-closed

depression with insufficient circulation of water masses and reduction conditions at the floor as indicated by the rich occurrence of organic substance, clay ironstones, pyrites as well as rarely occuring phosphates. This depression became occasionally a shallow marginal part of the sea, due to temporary marine ingressions. Marine ingressions resulted in transitory brackish conditions as shown by the occurrence of foraminifers and ostracodes. Presence of acid and intermediate elements as well as tuffite layers in the upper part of the Svinná formation point to a contemporary volcanism. This formation attains greatest thickness in the Bánovská kotlina Depression.

During subsequent parts of the Badenian, sediments of the Kamenec Formation (the Lower - Middle Badenian) were gradually evolving under freshwater conditions from the underlying formation. They are formed by epiclastic volcanic claystones, breccias, and conglomerates with non-volcanic material. In the Upper Badenian, in a swampy environment, preconditions for development of sediments containing carbonized plant remnants, an equivalent to the Handlová Formation, were created. Predisposition to coal sedimentation was presumably not so distinct as in the Hornonitrianska kotlina Depression (essentially reduced thickness, absence of coal seams). After a short period of erosion in the Middle Sarmatian, the conditions for formation of prograding alluvial fans, associating with the gravitational flows of „grain flow and debris flow" type were created. They were transported from the area of the present-day Vtáčnik Mts. into a swampy-lacustrine environment at the territory of the present-day Bánovská kotlina Depression (Ruskovce Member, Vtáčnik Formation) (Kováč et al., 1993b). The andesite material in gravitational flows testifies the products of several volcanic phases.

In the Middle Miocene, connection between sedimentation areas of the Bánovská kotlina and Hornonitrinska kotlina depressions was most likely throughout the area of the southern part of the „Chalmová Island" and through an area around the town Partizánske.

In the Upper Miocene the Závada-Bielice elevation lost its barrier function and the Bánovská kotlina Depression became a part of the Danube Basin's bay. Sediments of the Upper Miocene (upper part of the Pannonian and Pontian - the Beladice Formation) and the Pliocene (Dacian - the Volkovce Formation) are present. They originated under fluvio-limnic conditions of sedimentation (gravels, sands and variegated clays). At the Depression's margins, the layers of sandstones, fine grained conglomerates and/or breccias occur.

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