SEQUENCE STRATIGRAPHY OF THE NORTHERN DANUBE BASIN (SLOVAKIA)

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Abstract

Danube Basin Upper Miocene to Pliocene development is well recorded in its sedimentary succession, where three depositional sequences were documented (marked DB1, DB2 and DB3). First lacustrine depositional cycle (DB1) comprises the Lower to lowermost Upper Pannonian sediments (A–F zones sensu Papp 1951) represented by the Ivánka Formation and lower part of the Beladice Formation, deposited in time span 11.6–(9.7?) 8.9 Ma. Second lacustrine to alluvial depositional cycle (DB2) comprises the Upper Pannonian sediments (F, G and H zones sensu Papp 1951) represented by the upper part of the Beladice Formation and Volkovce Formation, deposited in time span 8.9 – 6.3? Ma. Third, alluvial depositional cycle (DB3) comprises the Danube Basin Upper Pliocene sediments represented by the Romanian Kolárovo Formation, dated 4.1? – 2.6 Ma.

Vývoj Dunajskej panvy vo vrchnom miocéne až pliocéne je dobre zaznamenaný v charaktere a faciálnom vývoji jej sedimentárnej výplne, ktorú môžeme rozdeliť do troch depozičných cyklov (nazvaných DB1, DB2 a DB3). Prvý jazerný cyklus (DB1) obsahuje usadeniny spodného, stredného až ranného vrchného panónu (zón A–F v zmysle Papp 1951) a je reprezentovaný sedimentami ivánskeho súvrstvia a spodnou časťou beladického súvrstvia, ktoré sa usadili v rozpätí 11,6–(9,7?) 8,9 mil. rokov. Druhý jazerno–aluviálny depozičný cyklus (DB2) obsahuje usadeniny vrchného panónu (zóny F, G a H v zmysle Papp 1951) a je reprezentovaný vrchnou časťou beladického a volkovským súvrstvím, usadenými v rozpätí 8,9–6,3? mil. rokov. Tretí, aluviálny depozičný cyklus (DB3), tvoria vrchnopliocénne usadeniny severnej časti Dunajskej panvy radené do kolárovského súvrstvia, stupňa roman (4,1?–2,6 mil. rokov).

The Late Neogene history of the Danube Basin is characterized by widespread back-arc rifting and gradual basin infill during the Upper Miocene, followed by the latest Miocene to Early Pliocene uplift and denudation (Kováč 2000, Sacchi – Horváth 2002, Kováč et al. 2006). Basin development is well recorded in its sedimentary succession.

The Early to Middle Pannonian depositional system of the basin northern part (Slovakia) represented margin of the extensive Lake Pannon, with sporadic, short time connections towards the Eastern Paratethys during the earliest Upper Miocene (Magyar et al. 1999). Influence of the Messinian salinity crisis and coeval sea level fall in the Mediterranean, in closed alluvial to residual lake system of the Danube Basin during the Late Pannonian, was overprinted by tectonics, acting in the Western Carpathian orogen during this time (Leever et al. in press, Uhrin et al. 2009).

Basin evolutionary stages from lake to alluvial plain are well recorded in the sedimentary succession of basin, where the deep water setting brackish offshore deposits gradually change to shallow water setting marches and deltaic deposits and are followed by freshwater alluvial sedimentation. The Late Miocene changes of depositional systems in the Danube Basin northern part (Slovakia) were dated by tools of bio- and sequence stratigraphy.

Biostratigraphy of the Upper Miocene sediments of the Danube Basin (Fig. 1) is based mostly in "classical" division to A – H zones following the brackish and freshwater mollusc evolution (sensu Papp 1951, 1953). The mollusc biozonation was correlated with appearance of dinoflagellates and calcareous nanoplankton (sensu Marunteanu 1997). Important group for terrestrial deposits are also fossilised remains of mammalians (MN zones – sensu Kováč et al. 2006, Vlačiky et al. 2008).

New results of this study, as well as comparison with results in southern part of the basin in Hungary (Csató 1993, Vakarcs et al. 1994; Kováč et al. 1999a, b, Juhász et al. 1999, Magyar et al. 1999, Sachi – Horváth 2002), helped to define three depositional cycles – sequences in the northern part of the Danube Basin (Slovakia): the Lower to lowermost Upper Pannonian lacustrine cycle (DB1), the Upper Pannonian ephemeral lakes to alluvial cycle (DB2) and the Upper Pliocene alluvial cycle (DB3). The time span between the Upper Pannonian and Upper Pliocene represents denudation during basin structural inversion stage. Revaluation of existing data also specified till now used time range of the Volkovce Formation in Slovak part of the Danube Basin: instead of the Early Pliocene Dacian stage, the Upper Pannonian stage, sensu Vasiljev et al. (2004) is used (Fig.1).

Lower and Middle Pannonian sediments of the Danube Basin (A–E zones sensu Papp 1951) deposited in time span 11.6–9.7 Ma are represented in Slovakia by the Ivánka Formation (Priechodská – Harčár 1988, Vass 2002), in Hungary by the Endrőd, Szolnok, Algyő and Újfalu formations (Császár et al. 1997). The **lacustrine depositional sequence (DB 1)** started mostly with erosive sequence boundary (SB 1 type) about which appears various sedimentary facies as: deepwater setting marls, clays and sandy turbidites, deposits of the basin paleoslope or delta-slope and shallow water deposits of marches, lagoons, coastal and delta plain built up by clays, sands and coal seams, depending on actual position of the sedimentary environment in the basin. Transgressive surface (ts) is situated at the base of the Papp's zone D, maximum flooding

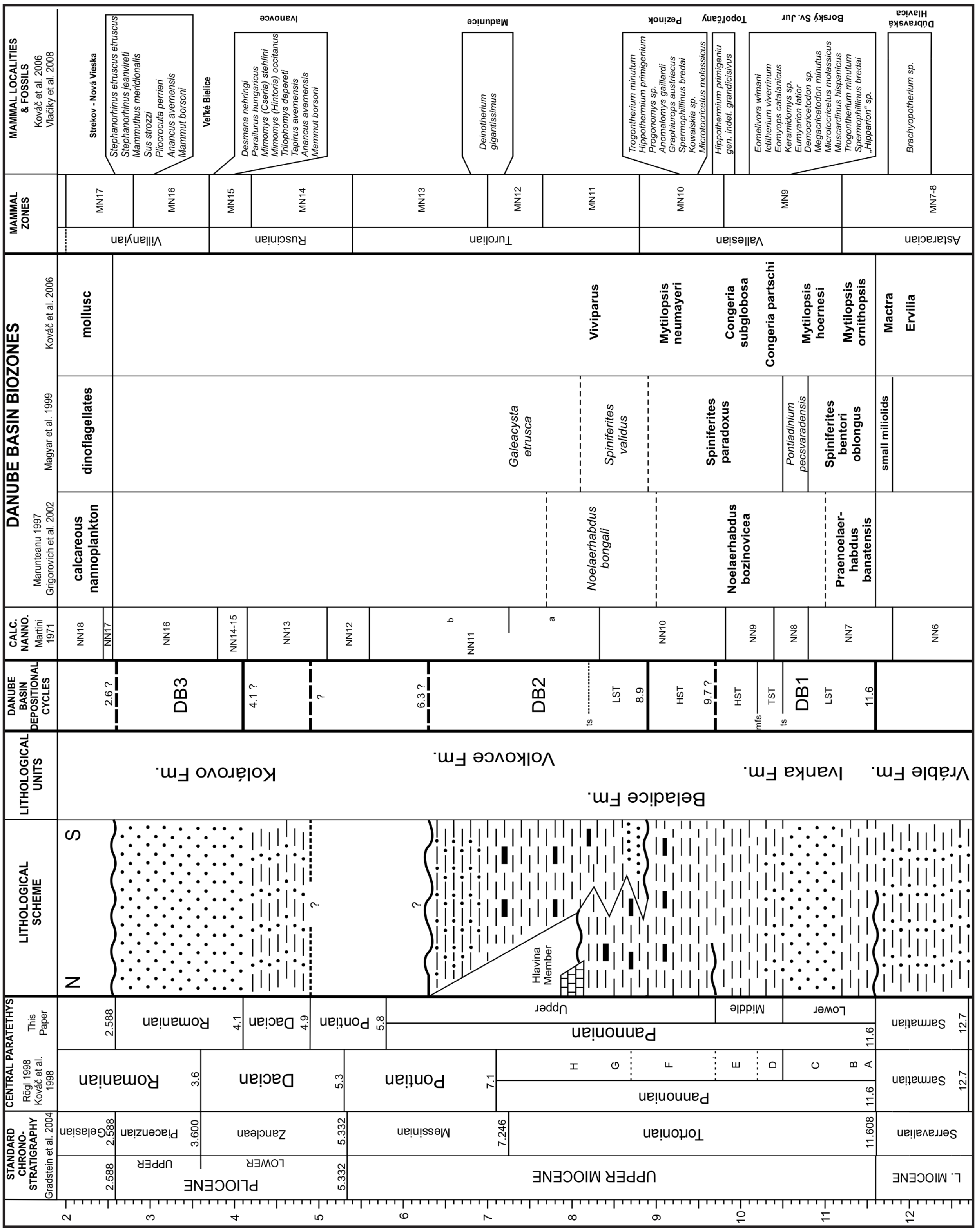

Fig. 1: Litostratigraphic scheme of formations and biostratigraphic zonation in the Danube Basin area. Central Paratethys stratigraphy after Rögl (1998), Kováč et al. (1998), Vasiljev et al. (2004); NN zonation after Martini (1971), Calcareous Nannoplankton after Marunteanu (1997), Andrejeva – Grigorovich et al. (2003a, b), Dinoflagellates after Magyar et al. (1999); Mollusc and mammals after Kováč et al. (2006). Explanatory notes: dots – sand and gravel; dots and lines – silt, sand and clay; lines – marl, clay; rectangles – carbonates; thick lines – coal; undulated lines – erosion; DB – Danube Basin Upper Miocene to Pliocene depositional cycles.
Obr. 1: Litostratigrafická schéma súvrství a biostratigrafická zonácia platná pre oblasť Dunajskej panvy. Stratigrafia centrálnej Paratetýdy podľa Rögl (1998); Kováč et al. (1998), Vasiljev et al. (2004); NN zonácia podľa Martini (1971), vápnitý nanoplanktón podľa Marunteanu (1997), Andrejeva – Grigorovich et al. (2003a, b), dinoflageláty podľa Magyar et al. (1999), mäkkýše a fauna cicavcov podľa Kováč et al. (2006). Vysvetlivky: bodky – piesok a štrk; bodky a čiarky – prachovce, piesok a íly; čiarky – vápnitý íl, íl; obdĺžniky – vápence; hrubé čiary – uhlie; zvlnená čiara – erózia; DB – depozičné cykly vrchnomiocénnych a pliocénnych usadenín Dunajskej panvy.

surface (mfs) is situated in clays at the base of the Papp's zone E (identical with the Vienna Basin, sensu Kováč et al. 1998, Kováč et al. 2004). The sedimentary record of the basin shows at the beginning a retrogradational (A, B, C zones), than agradational (D zone) and later progradational trend (E zone).

The Early Pannonian age of the sequence lower part is proved by occurrence of Mytilopsis ornithopsis and Mytilopsis hoernesi biozones in shallow water setting, the upper part of the sequence is of the Middle Pannonian age, proved by occurrence of Congeria partschi and Congeria subglobosa biozones (Fordinál in Nagy et al. 1995, Fordinál 1997). The mentioned time span is justified also by endemic nanoplankton of the Praenoelaerhabdus banatensis and Noelaerhabdus bozinovicae biozones (Andrejeva-Grigorovich et al. 2003a, b, Kováč et al. 2008) which can be correlated with standard NN9 and NN10 zones (Martini, 1971), as well as by presence of MN 10 and MN 9 Mammal biozones (Kováč et al. 2006).

Upper Pannonian sediments of the Danube Basin (F, G & H zones v sensu Papp 1951) deposited in time span 9.7–6.3? Ma are represented in Slovakia by the Beladice and Volkovce formations (Priechodská – Harčár 1988, Vass 2002), in Hungary by the Zagyva and Hanság formations (Császár et al., 1997). Sedimentary environment of above mentioned formations, ergo **ephemeral lake to alluvial depositional sequence (DB 2)** can be characterized by wide range of sub-facies from fluvial, deltaic, ephemeral lake to marches and dry land-terrestrial deposits. The sequence started with erosion boundary at basin margins (SB 1 type), in basin centre a continual sedimentation was observed (SB 2 type). The Hlavina Member of the Beladice Formation, represented by freshwater limestone dated to 8.2 Ma (Fordinál – Nagy 1997), is positioned about the transgressive surface (ts) of the sequence and below the maximum flooding surface (mfs) situated in the Volkovce Formation clay lower part. The sedimentary record has commonly a coarsening upward trend.

Age of the Late Pannonian sequence base is proved by presence of Mytilopsis neumayri – Mytilopsis zahalkai biozone (Fordinál 1994) and MN 10 Mammal biozone, followed by Viviparus sp. biozone and MN 12-13 Mammal biozones (Musil 1959).

Upper Pliocene sediments of the Danube Basin Slovak part are represented by the Kolárovo Formation (Priechodská – Harčár 1988, Vass 2002), dated 4.1?–2.6 Ma. The third "depositional sequence" of the Danube Basin northern part is built up by **fluvial to alluvial sediments (DB 3)**. Since the deposits represent a true alluvial to continental facies, it is very hard to determine surfaces used by "classical sequence stratigraphy", we can only state on some places erosive contact with the underlying strata, or they transgressive character and coarsening upwards trend of deposits. Romanian age of sequence is proved by MN 15,16,17 Mammal biozones (Fejfar 1961, 1966, Fejfar – Heinrich 1985, Vlačiky et al. 2008).

Results

- Up to date time correlation of the Upper Miocene and Pliocene sedimentary fill of the Danube Basin northern part (Slovakia) with the formations from the southern part of basin (Hungary)
- Revised biostratigraphy and definition of depositional cycles: Lower to earliest Upper Pannonian lacustrine cycle DB1, Upper Pannonian ephemeral lake to alluvial cycle DB2 and Upper Pliocene alluvial cycle DB3

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