

AN EARLY PANNONIAN (LATE MIOCENE) TRANSGRESSION IN THE NORTHERN VIENNA BASIN. THE PALEOECOLOGICAL FEEDBACK

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Abstract: The studied sections are situated on the northwestern margin of the Vienna Basin. They represent a characteristic marginal facies of Lake Pannon in the late Miocene Pannonian stage. Biofacies as well as lithofacies point to a transgressive event resulting in the shift from deltaic, riverine conditions to the formation of freshwater marshes and lakes and, finally, in the deposition of offshore clays. Biostratigraphically, the logged sequences correspond to the regional Pannonian mollusc “zone” C. The extraordinarily fine-scaled paleoecological resolution might serve as a basis for a correlation of 4th order changes reported from basinal settings of the northern Vienna Basin. Thus the rapid facies succession on the northwestern margin of the Vienna Basin is interpreted as being linked to major lake level changes rather than to solely local changes in the riverine system.

Key words: Late Miocene, Pannonian, Lake Pannon, Northern Vienna Basin, hydrophytes, paleoecology.

Introduction

The locality of Pellendorf is situated in the political district of Mistelbach in Lower Austria (ÖK 1:50,000, sheets 41, 24). At the locality, Late Miocene gravels and sands are exploited in two pits (Fig. 1). Two sections have been logged in the smaller pit in the NW (logs 1 and 2 sand pit “Max”; N 16° 32' 08", E 48° 30' 00"; No. 041/228 according to the register of Mineral Resources of the Austrian Geological Survey); the third log is positioned in the southeastern pit (log 3 gravel pit “Semrad”; N 16° 32' 12", E 48° 29' 54"; No. 041/227 according to the register of Mineral Resources of the Austrian Geological Survey). The composite thickness of the sections measures 35 m.

The outcrop lies on the Kronberg uplifted block, close to its northwestern margin, which is formed by the Bisamberg fault-zone. Despite their proximity to this fault, the deposits seem to have been little affected by postsedimentary tectonic activities, although some minor listric faults can be detected throughout the outcrop area. In contrast, the NW-SE decrease of thickness of units 2 and 3 (see below) may be explained by synsedimentary activity of the fault-zone.

The area has been studied by Grill (1968), who recognized the gravel sequence as part of the Hollabrunn-Mistelbach Formation and mapped it as Lower Pannonian (Fig. 2). This dating was based mainly on typical molluscs of the Pannonian “zones” B and C sensu Papp (1951, 1953), which were found along the northern margin of the Kronberg uplifted block. The

dating was confirmed by Lueger (1981), who provided data on the landsnail fauna of the Hollabrunn-Mistelbach Formation of the Mistelbach uplifted block and who also integrated the brackish mollusc fauna in his biostratigraphic conclusions.

Within the three measured sections, five characteristic lithofacies can be logged, which are also characterized by distinct biofacies (Fig. 3). The analysis of the various paleocommunities allows a new approach towards the reconstruction of the facies shifts within coastal environments, during a transgressive phase in the northern Vienna Basin.

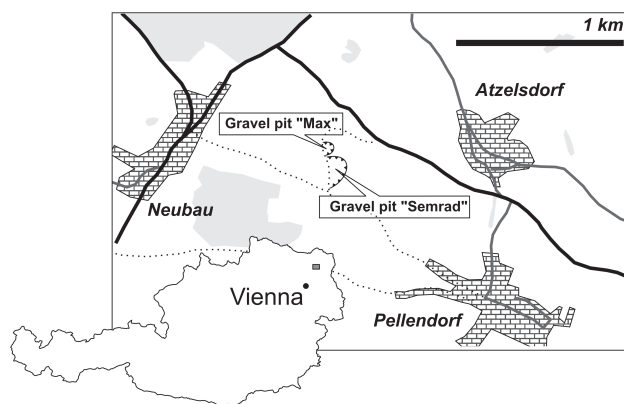


Fig. 1. Geographical position of the investigated outcrops in Lower Austria.

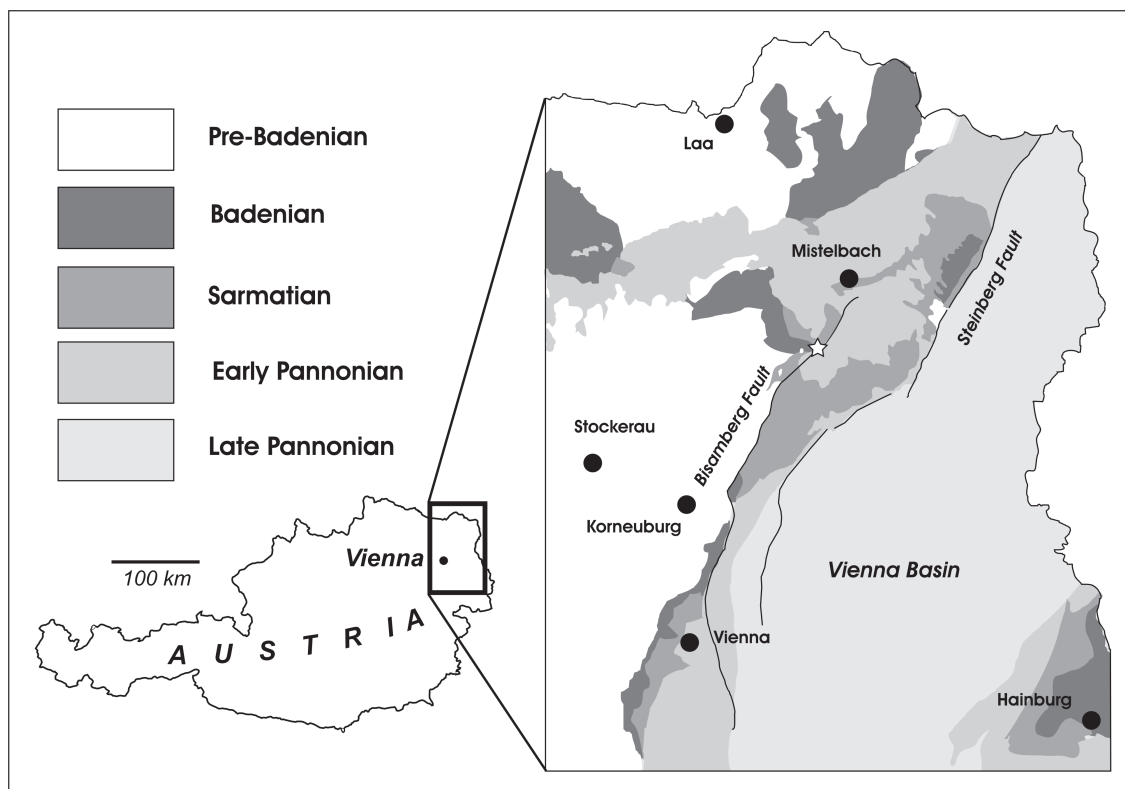


Fig. 2. Geological map of the northern Vienna Basin modified after Grill (1968). The distribution of Early Pannonian deposits roughly reflects the course of the riverine system which discharged into Lake Pannon. The white star indicates the position of the investigated outcrops.

Material

With the exception of the Characeae gyrogonites the plant material is preserved as oxidized imprints. Especially floating and submerged leaves of aquatic plants are covered by a calcium-rich layer. From washed samples a few poorly preserved coalified fruits were collected.

Molluscs were collected in the field or washed from bulk samples. The preservation of the macrofauna is generally rather poor due to the dissolution of aragonite.

The various groups of organisms were identified by the following authors: Harzhauser — Mollusca, Zorn — Ostracoda, Schwarz — Characeae, Wójcicki — *Trapa* and *Hemitrapa* fruits, Kovar-Eder — remaining plant taxa.

The material is kept in the collection of the Geological-Paleontological Department of the Natural History Museum Vienna (Plants coll. file Nos. 1997B0019, 1999B0056, 2000B0002-11, 2000B0029; Fauna coll. file Nos. 1999B0056/0000; Inv. NHMW2000z0066/0001-0014). A complete list of the documented taxa is presented in Table 1.

Lithological and paleontological description

The composite sections of the two outcrops reveal 5 distinct lithological units (Fig. 4). In the following, these depositional entities are briefly described and typical fossils are introduced.

Unit 1: Hollabrunn-Mistelbach Formation

The more than 12 m thick unit is dominated by layers of cross-bedded, polymict gravels, alternating with sandy layers and rare silt beds. Gravel and sandy gravel beds appear mainly as broad, shallow channels. Bounding surfaces of the lower order defining individual beds can be followed over a distance of almost 100 m. Compound bedding is typical; planar cross-bedding was recognized within gravels. Both channel direction and foreset aggradations reflect transport generally to the E and SE. Gravels are pebble supported to matrix supported. The pebbles are both rounded and subangular with maximum diameter of about 5 cm. Subordinate sandy interbeds with a thickness of about 40 cm can be recognized within gravels. Sands are medium- to fine-grained. Low-angle cross-bedding was recognized within sands. They are relatively well sorted. Trace fossils (subvertical burrows) are rare.

Scattered valves of the bivalves *Plicatiforma latisulca* and *Venerupis (Paphirus) gregarius*, as well as rare shells of the gastropod *Granulolabium bicinctum*, indicate some reworking of Sarmatian fauna deriving from the upper *Ervilia* “zone”. Additionally, sparse lithoclasts of up to 30 cm diameter with abundant moulds of *Granulolabium* sp., floating within the pebbles, also reflect reworking of lithified Sarmatian sediments. Finally, a single, well-rounded valve of *Crasostrea gryphoides* probably derives from Karpatian near-

Table 1: A list of all documented molluscs and plants from the section Pellendorf.

mollusc fauna	unit	abundance	ecological requirements	range in Vienna Basin
aquatic gastropods				
<i>Granulolabium bicinctum</i> (Brocchi)	1	common	brackish-marine (reworked)	Eggenburgian – Sarmatian
<i>Melanopsis bouei</i> (Ferussac)	4	common	freshw./oligohaline-agitated	Sarmatian – Pannonian F
<i>Tinnyea escheri</i> (Brongniart)	4	abundant	freshw./oligohaline-agitated	Eggenburg.– Pannonian H
<i>Stenothyrella ovoidea</i> (Pavlovic)	4	rare	freshw./oligohaline-quiet	Badenian – Pannonian H
<i>Bithynia jurinaci</i> Brusina	2, 3	rare	freshw./quiet-moderately agitated	Pannonian C – Pannonian H
<i>Gyraulus</i> sp.	3	common	freshw./quiet-agitated	-
<i>Radix</i> cf. <i>cucuronensis</i> (Fontannes)	3	common	freshw./quiet-moderately agitated	? – Pannonian H
terrestrial gastropods				
<i>Carychium pachytilus</i> Sandberger	2	very abundant	terrestrial/humid-lakesides	Sarmatian – Pannonian H
<i>Gastrocopta</i> cf. <i>acuminata</i> (Klein)	2	common	terrestrial	Badenian – Pannonian H
<i>Acanthinula</i> cf. <i>trochulus</i> (Sandberger)	2	common	terrestrial/woodland	Pannonian D – Pannonian H
<i>Semilimax intermedius</i> (Reuss)	2	common	terrestrial/humid-woodland	Eggenburg. – Pannonian E
<i>Perpolita</i> sp.	2	common	terrestrial/humid	-
<i>Cepaea</i> cf. <i>etelkae</i> (Halavats)	2	abundant	terrestrial	Pannonian B – Pannonian H
<i>Helicidae</i> indet. [cf. <i>Cepaea</i>]	3	rare	terrestrial	-
bivalves				
<i>Plicatiforma latisulca</i> (Münster)	1	rare	brackish/marine (reworked)	Sarmatian
<i>Venerupis</i> (<i>Paphirus</i>) <i>gregarius</i> (Partsch)	1	rare	brackish/marine (reworked)	Sarmatian
<i>Crassostrea gryphoides</i> (Schlotheim)	1	rare	brackish/marine (reworked)	Eggenburgian – Sarmatian
<i>Congeria partschi partschi</i> Czjzek	5	common	brackish/quiet	Pannonian C – Pannonian D
<i>Limnocardiidae</i> indet. sp. 1	5	rare	brackish	-
<i>Limnocardiidae</i> indet. sp. 2	5	rare	brackish	-
<i>Unio atavus</i> Partsch	4	common	freshw./oligohaline-agitated	Pannonian C – Pannonian E
<i>Anodonta</i> sp. 1	3	abundant	freshw./quiet-moderately agitated	-
? <i>Anodonta</i> sp. 2	3	rare	freshwater-quiet-moderately agitate	-
flora				
flora		unit	abundance lower part of unit 3 A-G	abundance upper part of unit 3, I-J, gravel pit "Semrad"
hydrophytes				
<i>Nitellopsis</i> (<i>Tectochara</i>) <i>majoriformis</i> (Papp) Schwarz (oogonia)	3			very abundant
<i>Stephanochara</i> aff. <i>rochettiana</i> (Heer) Feist-Castel (oogonia)	3			rare
<i>Ceratophyllum schrotzburgense</i> Hantke (leaves, almost entire plants, partly covered with a calcium-layer)	3			abundant in thin layers
<i>Ceratophyllum</i> sp. (fruit imprints)	3			common
<i>Nymphaeaceae</i> indet. (rhizome fragments)	3			abundant in thin layers
<i>Hemitrapa trapelloidea</i> Miki	3			abundant in thin layers
<i>Trapa pellendorfensis</i> Wójcicki & Kovar-Eder (fruit imprints)	3			abundant in thin layers
<i>Mikia pellendorfensis</i> Kovar-Eder & Wójcicki (floating leaves)	3			abundant in thin layers
<i>Decodon</i> sp. (leaves)	3		very abundant, monodominant	common
<i>Carpolithus</i> gen. et sp. indet.	3		common	
<i>Potamogeton</i> sp. (fruit imprints/coalified)	3		rare	rare
<i>Sparganium</i> sp. (fruit imprint)	3			one
woody plants				
<i>Taxodium dubium</i> (Sternberg) Heer	3			monodominant in a thin layer in the gravel pit "Semrad"
<i>Ulmus carpinoides</i> Göppert emend. Menzel	3			rare
<i>Populus balsamoides</i> Göppert	3			rare
<i>Populus populina</i> (Brongniart) Knobloch	3		rare	
<i>Populus mutabilis</i> Heer	3		rare	rare
<i>Smilax sagittifera</i> Heer emend. Hantke	3			one specimen in a thin layer in the gravel pit "Semrad"
<i>Alnus</i> sp. ¹⁾	4			rare
? <i>Fagus</i> sp. ¹⁾	4			rare
<i>Ulmus</i> sp. ¹⁾	4			rare
<i>Acer</i> vel <i>Liquidambar</i> sp. ¹⁾	4			rare
<i>Dicotyledoneae</i> indet. ¹⁾	5			one

1) field observation only, no material collected.

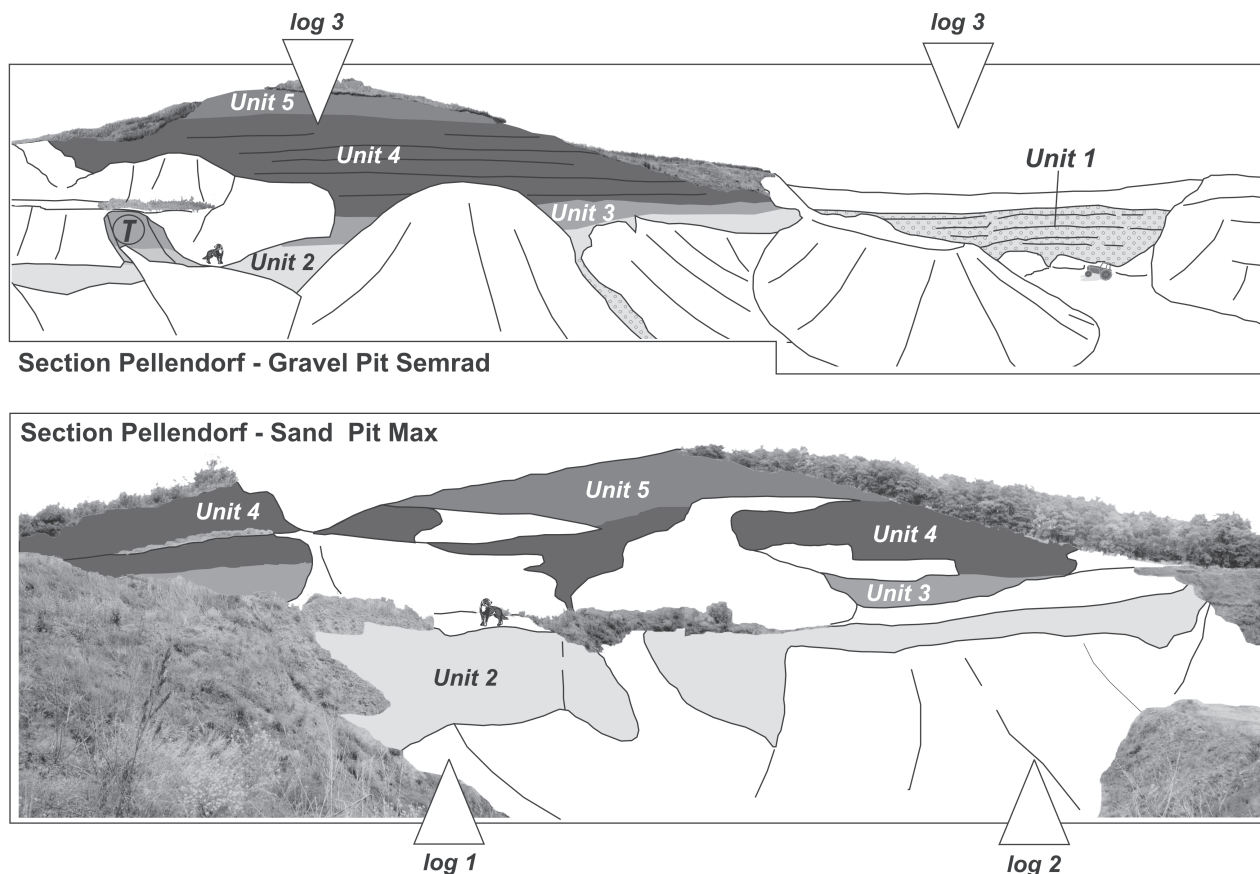


Fig. 3. Sketch of the outcrop situation of two pits during the year 2000. The units differentiated in this paper are indicated by different shadings (not to scale, due to perspective bias). The thickness of the units can be deduced from the logs in Fig. 3. “T” marks the position of the *Taxodium*-bearing layers.

shore deposits, which are widespread in the adjacent Korneuburg Basin.

Due to the absence of index fossils, such as *Mytilopsis ornithosis* (Brusina) or *Melanopsis impressa* Klein, the biostratigraphic correlation of the unit is difficult at the locality. Nonetheless, equivalent deposits on the Mistelbach and Kronberg uplifted blocks represent the Hollabrunn-Mistelbach Formation and were dated to the Pannonian “zone” B/C by Grill (1968) and Lueger (1981). According to Roetzel et al. (1999) most of the formation was deposited during the Pannonian “zone” C, on the basis of molluscs and mammal faunas.

Unit 2: Sand with terrestrial gastropods

In the southeastern section, the underlying gravelly unit displays a slight fining upwards, reflected by the predominance of sandy layers in the uppermost 2 m of the unit. This part is overlain by about 2 m of fine- to medium-sand with high silt content. In the corresponding section in the northwest, this unit is markedly thicker, attaining a thickness of at least 12 m.

Its basal part consists of cross-bedded fine sands with thin lenses and irregular horizons (max. 10 cm thick) of gravels with a maximum pebble diameter of about 5 cm. Erosional relics of mudstone float within the sands. The sedimentary structure resembles a “cut and fill”. Relics of roots were rec-

ognized locally. Upsection, 2 m of rippled fine sands and, finally, horizontally laminated or low angle cross-bedded fine-sands follow. Thin (few cm thick) gravel lags form the base of the sets (pebbles max. 1 cm in diameter). The top part of the unit is formed by horizontally laminated very fine sand to silt of about 1 m thickness.

In both sections, low dip-angle cross-bedding and trough-bedding can be observed. In situ roots occur only in the north-western section. Besides analogous lithology, the correlation of the beds is confirmed by the striking abundance of terrestrial gastropods. Reworked Sarmatian is not represented by molluscs as in unit 1 but by rare tests of foraminifers (*Elphidium* spp.). In contrast to the well-preserved landsnails, these reworked elements show strong limonitic colouring.

Unit 3: Hydrophyte-pelite

In the southeastern gravel pit “Semrad”, the sandy unit 2 is overlain by about 2.3 m of interbedded silt and clay with scattered fine-sand layers. Towards the northwest this unit thickens considerably, attaining more than 5 m thickness in the sand pit “Max”. The unit is characterized by clayey mudstone beds with highly subordinate sandy interbeds. Mudstones are horizontally bedded. High contents of plant remnants are very characteristic. Fine micaceous sands are well sorted and form

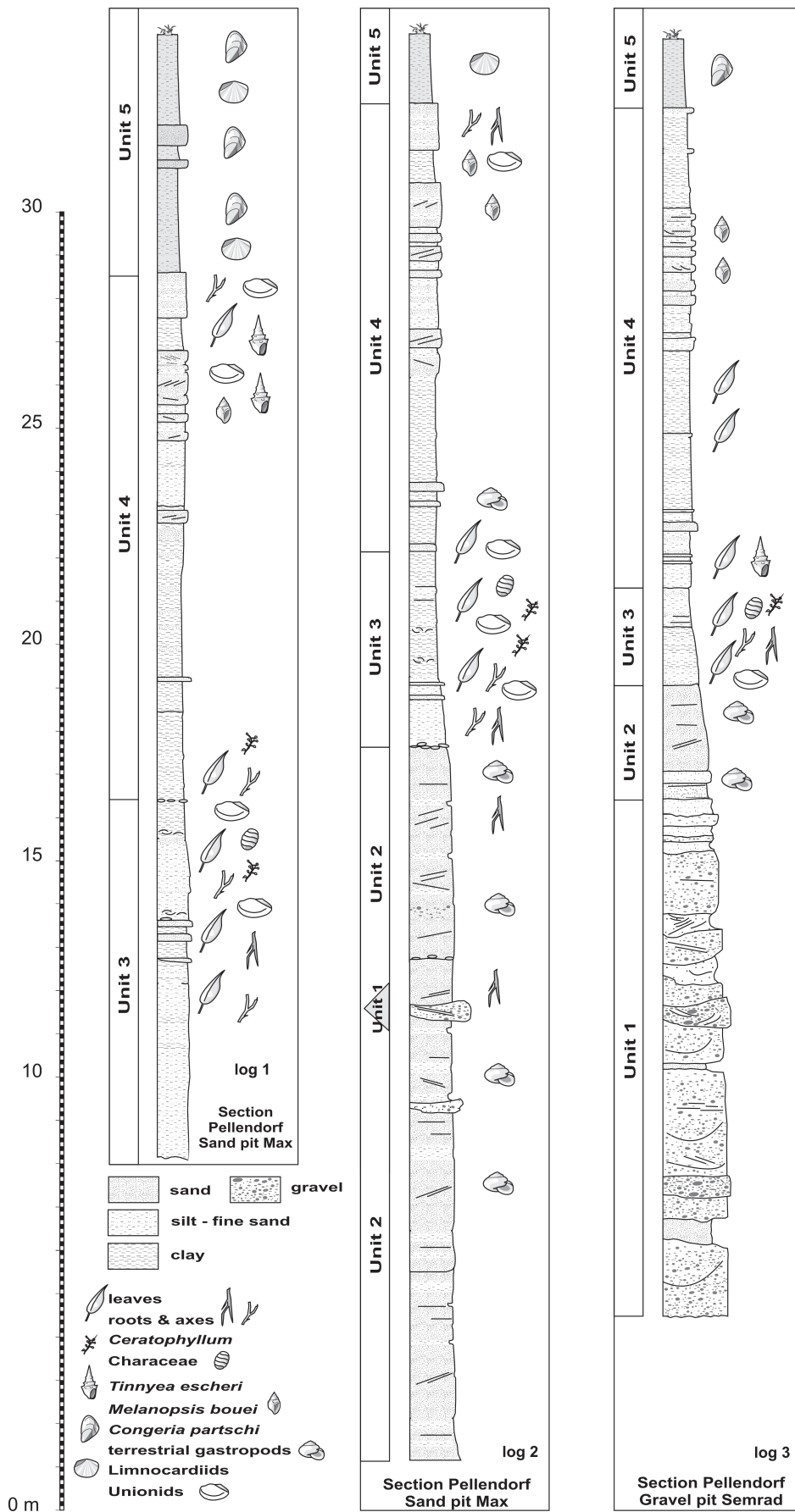


Fig. 4. Three composite logs of the investigated sections. Symbols mark the occurrence of characteristic fossils. A correlation of the logs with the proposed units in Fig. 2 is warranted by the legend-bar aside each log. The boundary between units 4 and 5 corresponds more or less to a single topographic level.

generally tabular beds of max. 15 cm thickness. Sands are horizontally bedded and well sorted. At the base of this unit, marl clasts of about 10 cm diameter are common.

The most characteristic feature of this unit is the hydrophyte-rich flora, which enables the correlation of the three outcrops. The fossil preservation indicates parautochthonous fossilization conditions.

The hydrophyte pelite can be subdivided into two parts. The lower — slightly coarser grained — part (layers A–G in Fig. 5) bears the first reported fossil mass-occurrence of *Decodon* leaves, although *Decodon* leaves are common at various European sites (Kvaček & Sakala 1999). Partly disintegrating fruits (*Carpolithus* gen. et sp. indet.), petioles and slender stem fragments, as well as clusters of poplar leaves (*Populus populina* and *P. mutabilis*), occur occasionally there.

The upper part (layers I–J in Fig. 5) is diverse in aquatic plants: *Nitellopsis* (*Tectochara*) *majoriformis* and *Stephanochara* aff. *rochettiana*, Nymphaeaceae — rhizomes, *Ceratophyllum schrotzburgense* and *Ceratophyllum* sp. — fruits, *Hemitrapa trapelloidea* and *Trapa pellendorfensis* — nuts, *Mikia pellendorfensis* — leaves, *Potamogeton* sp., and cf. *Sparganium* sp. (Kovar-Eder et al. submitted). These remains are mainly concentrated in several thin, marly layers, but to a lesser extent also occur between them. Other (woody) taxa are very rare.

Among the molluscs the gastropod *Bithynia jurinaci* and anodontid bivalves are most abundant. In contrast to the underlying unit, remains of helicids are rare, usually fractured, and occur mainly in the lower parts of the unit.

An only locally exposed silty/clayey layer in the northern part of the gravel pit “Semrad” yielded rich findings of *Taxodium dubium* twigs (monodominant) and isolated *Taxodium* cone scales as well as a leaf of *Smilax sagittifera*. Judging from the position in this log (indicated by “T” in Fig. 3) this layer can be correlated to the hydrophyte pelite, possibly to its upper part.

Unit 4: Interbedded mudstone

The silty unit 3 passes without marked lithological changes into a unit of interbedded mudstone with sand and silt layers. Only the abrupt absence of hydrophyte-bearing layers allows a good separation of the base of unit 4. In the southeastern part of the investigated area this unit attains about 11 m in thickness, but reaches up to about 12 m towards the north-western pit.

Generally, the unit displays a slight coarsening upwards trend, resulting in the predominance of silty layers towards the top. Basal mudstones are massive, lacking any distinct sedimentary structures, whereas horizontal lamination becomes common in the upper part of the unit. There, several sandy interbeds were recognized within the mudstones. The content of sand slightly rises at the top of the profile. Sands are fine-grained, well sorted, and micaceous. Horizontal bedding is the typical internal feature of sands, but climbing ripples are also observed in this upper part.

The basal part is poor in macrofossils, with only scattered and poorly preserved leaf fragments, rare *Tinnyea escheri*, unionids and helicids. Upsection follows an interbedded sub-

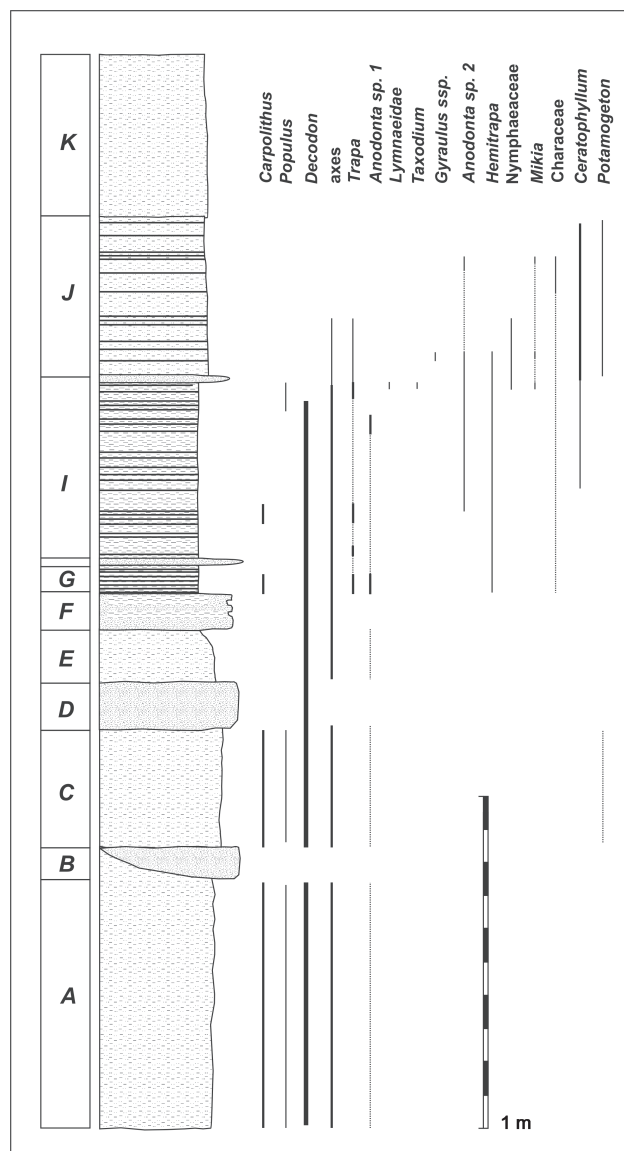


Fig. 5. Detail of log 1. The drawing documents the different inventory of the hydrophyte-bearing levels of subunits A to J. Note clear change from *Decodon*-dominated assemblages towards *Ceratophyllum*-dominated layers. The cyclicity in the amalgamation of plant-bearing layers is well developed in subunit I but indistinct in the overlying part. The shift from *Decodon*-, *Trapa*- and axes-bearing strata towards *Ceratophyllum*- and Nymphaeaceae-yielding layers in subunit J may reflect a slight deepening of the depositional environment.

unit with cross-bedded fine- to medium-sand and silt with abundant *Melanopsis bouei*, *Unio atavus*, and *Tinnyea escheri*. Finally, in the top of unit 4, sand, clay and silt are interbedded, bearing again *Melanopsis bouei*, *Unio atavus* and *Tinnyea escheri*; occasionally, in situ stems of about 5 mm diameter and scattered leaf-fragments are also present. Cross-bedding is missing in this part of the unit.

Unit 5: *Congerina partschi* — clay

All sections are topped by up to 5 m of dark, greenish, bluish and greyish clay with scattered bivalves. This unit repre-

sents the youngest Miocene deposit in the investigation area and is usually covered by a thin layer of Quaternary soil. Two layers of well-sorted fine- to medium-sand are intercalated in the otherwise rather homogeneous clay. Generally, the unit is poor in macrofossils, but bears small clusters of articulated *Congeria partschi*. Similarly, rare *Limnocardium* ssp. appear in clusters, being mainly represented by gaping but still articulated valves. Among the rich ostracod fauna, *Hungarocypris auriculata* is most abundant along with *Loxoconcha* sp., *Amplocypris* sp., *Leptocythere* sp. and *Aurilia* sp.

Biostratigraphy

The biostratigraphic significance of the terrestrial gastropods in unit 2 is rather low. The association corresponds fully to the Pannonian faunas described by Lueger (1981, 1985), therefore a Sarmatian age can be excluded. Similar faunas from the Hollabrunn-Mistelbach Formation are dated to the Pannonian "zones" B and C on the basis of typical melanopsids and congerias and the characteristic morphotype of *Cepaea etelkae* (Lueger 1981).

The top unit can be dated by *Congeria partschi partschi*, which is restricted to the Pannonian "zones" C and D in the northern Vienna Basin (Papp 1953). It is not possible to separate these two "zones" any further only on basis of the occurrence of *Congeria partschi partschi*. A dating to "zone" C is supported by the absence of large congerias typical for "zone" D, such as *Congeria subglobosa*. In addition, the size and shape of the specimens differ from those of "zone" D, when the species had its optimum (Papp 1951).

A further hint towards "zone" C derives from the occurrence of *Hungarocypris auriculata* (Reuss), which is restricted to the early Pannonian "zones" A–C. Correspondingly, Grill (1968) also mapped the area as Lower Pannonian ("zone" B/C).

The biostratigraphic resolution of the extraordinary flora, however, is rather poor. The stratum typicum of *Nitellopsis* (*T.*) *majoriformis* in Eichkogel near Mödling (Papp 1951) is dated to "zone" H and correlated to the mammal stage MN 11 (Bruijn et al. 1992). Further occurrences are described from Turkey (Mädler & Staesche 1979). Some of them can be correlated to the mammal stages MN 6, 9, and 15 (Bruijn et al. 1992). Therefore, they cannot contribute to a more detailed local dating. *Stephanochara rochettiana* is documented from the Late Chattian (MP 30, Late Oligocene) to the Middle Miocene (possibly until mammal zone MN 7; Mädler & Staesche 1979). The appearance of an "affine" form of *S. rochettiana* in the Pannonian may be interpreted as a further evolutionary development.

The presence and abundance of *Trapa* is characteristic of the Pannonian in Austria. In the last years, numerous water-nut-bearing localities have been discovered in the Styrian and the Molasse Basins. However, this is the first record of *Hemitrapa* from Austria and the first one of *H. trapelloidea* from Europe. *H. heissigii* Gregor, however, is known from several localities in Southern Germany (Gregor 1982; Gregor & Schmid 1983; Riederle & Gregor 1997; Schmitt & Butzmann 1997; Riederle 1997) which are correlated (partly by mam-

mals, partly by regional geology) to the Mittlere Serie Dehms, mammal stages MN 5 upper part/MN 6, correlated to the Badenian (Böhme et al. 2002, and pers. commun. K. Heissig 2002). Note that the lack of *Trapa* at these sites is more probably stratigraphically based than facies biased. In fact, in Pellenzendorf we are dealing with the first definitive co-occurrence of *Trapa* and *Hemitrapa* (even on the same bedding-planes) (Kovar-Eder et al. submitted).

In conclusion, the co-occurrence of the ostracod *Hungarocypris auriculata* and the bivalve *Congeria partschi partschi* clearly dates the top unit into the Pannonian "zone" C. From a strict biostratigraphic point of view the underlying units could be correlated with the "zones" B or C. The absence of the otherwise ubiquitous index fossils of "zone" B (*Melanopsis impressa*, *Mytilopsis ornithopsis*) renders a dating to "zone" B very unlikely. In addition, the *Melanopsis bouei*–*Tinnyea escheri* assemblage of unit 4 is unknown from "zone" B, but is commonly detected in the "zones" C and D in the Vienna Basin and the Eisenstadt Sopron Basin (own observation Harzhauser).

Paleoecological interpretation

Unit 1

The gravel and sand beds of unit 1 are interpreted as distributary channels of the coarse-grained delta (braided delta) close to the delta front. Proximity to the shoreline is also supported by the total absence of any deposits of the interdistributary area. The close proximity is a characteristic feature of most localities of the Hollabrunn-Mistelbach Formation in the surroundings of Mistelbach. The deposits derive from a fluvial system which invaded the northern Vienna Basin from the northwest.

Unit 2

The layers of gravels recognized within unit 2 reflect a genetic and spatial relation of unit 1 and 2. Unit 2 is a product of deposition in the interdistributary area close to the distributary channels (levees, crevasses). Gravels can be interpreted as lag horizons reflecting the maximum erosion during floods. Broad erosional channels were cut in the flat interdistributary area and filled with sands. Alternation of high and low discharge is reflected by structures of the upper flow regime and the occurrence of root traces and Ca concretions, which might be reworked caliche.

Aside from reworked Sarmatian foraminifers, the fauna of unit 2 consists nearly exclusively of gastropods, which mainly derive from the adjacent woodland habitats bordering the river. This is reflected by the abundance of *Carychium pachyphilus* and *Semilimax intermedius*. Carychiidae indicate humid lakeside environments and moist foliage (Lueger 1981; Harbeck 1996). Similarly, the late Neogene representatives of *Semilimax* are interpreted by Binder (1977) and Lueger (1981) as inhabitants of humid woodland areas. *Semilimax* feeds on plants, various decaying organic matter, and on small worms. Correspondingly, *Acanthinula aculeata*, as an extant

relative of *Acanthinula* cf. *trochulus*, prefers woodland environments, where it takes shelter in shrubs or within the foliage (Ložek 1964; Fechter & Falkner 1989).

The other taxa, such as the abundant *Cepaea* cf. *etelkae*, may also derive from the less humid hinterland. *Cepaea* settles humid and rather arid environments and therefore cannot be used as facies indicator. According to Lueger (1981), *Cepaea etelkae* might have lived in the hinterland at some distance from the swampy, riverine biotas. Distant relatives of *Gastrocopta acuminata* such as *Gastrocopta theeli* and *Gastrocopta serotina* are considered by Ložek (1964) to prefer woodland and wooded steppe areas as well as open terrestrial habitats.

No littoral elements of Lake Pannon, such as *Caspia*, *Hydrobia*, or *Micromelania*, are found in this unit, indicating strictly freshwater conditions. On the other hand, freshwater taxa are also rare. Only *Bithynia jurinaci* Brusina is recorded on the basis of a single operculum. This species is thought to prefer standing waters of lakes and to avoid agitated water. As documented by the sediment structures, swift water caused conditions which were probably not suitable for the establishment of dense vegetation and thus herbivorous molluscs such as *Bithynia* are scarce; lymnaeids and planorbids are entirely absent.

Unit 3

This unit is the result of quiet deposition within the inner distributary area (distal in relation to distributary channels). Sandy interbeds reflect major floods (channel overflow) and short periods of more agitated waters.

The mollusc fauna and the flora indicate quiet freshwater marshland or a shallow swampy lake habitat. Most of the extant relatives of the recorded taxa avoid agitated water and shun brackish waters.

The living representatives of *Anodonta* are adapted to slowly running water of small rivers (e.g. *Anodonta anatina*) as well as to quiet lake environments like *Anodonta cygnea*. In respect to the lithology, the Pellenendorf species seems to represent rather an inhabitant of muddy bottoms in quiet water. The extremely abundant Bithyniidae are detritus-feeding and/or browsing freshwater molluscs that either scrape with their radula or are ciliary feeders (Frömming 1956; Gray 1988). They display their maximum abundance in shallow freshwater around 2–3 m depth, settling especially quiet or little agitated waters with rich vegetation. Some species, however, can tolerate salinities up to 8–11 ‰ (Korpás-Hódi 1983). At Pellenendorf the species is most abundant in layers with charophyte gyrogonites. Correspondingly, *Bithynia jurinaci* is associated with gyrogonites at the sections Eichkogel, Götzendorf, Stixneusiedl, and Leobersdorf (Papp 1951; Rögl et al. 1993; Troll 1907).

Thus, *Bithynia jurinaci* seems to have lived in large populations in very shallow, quiet water within charophyte-“meadows”. Similarly, the planorbids and *Radix* cf. *cucuronensis* bear witness to rich hydrophyte vegetation in a quiet to moderately agitated, shallow freshwater habitat. The representatives of *Radix* feed on algae and decaying plant debris but would accept carrion as well.

The scarcity of landsnails, represented only by rare fragments of helicids, may also point towards rather low energetic conditions, which allowed only little influx from riverine environments and from the hinterland.

The unit has been investigated and logged in detail (subunits A–J in Fig. 5). Additionally, in subunits G–J each layer with plant accumulations was precisely studied and its content documented. 41 layers were observed in these subunits. *Decodon* is the most characteristic element in the basal, slightly coarser-grained part (subunits A–G). Upsection, in subunits G–I, 28 layers could be separated; they are characterized by mass-occurrences of *Decodon* leaves. The only modern species, *Decodon verticillatus*, forms large monospecific stands, for example in coastal freshwater marshes in the southeast of the US. The lower plant parts are submerged, partly floating, while the higher ones are emergent. Additionally, accumulations of stems predominate in subunit I. Some kind of cyclicity is documented by a conspicuous “crowding” of the layers into four groups of 7, 7, 6, and 8 layers, respectively. We refrain from interpreting this remarkable cyclicity in a wider context, although future investigations might offer a key for this interesting feature.

The subunits (I–J) differ distinctly in their species composition. Rooted plants with submerged and floating leaves (Nymphaeaceae, *Trapa*, *Potamogeton*) indicate shallow and quiet water conditions. Although the true affinity of *Mikia pellenendorfensis* is still unclear (Kovar-Eder et al. submitted), these leaves undoubtedly represent long-petiolate floating leaves of a possibly rooted plant. Entirely submerged and free-swimming (sometimes fixed on the ground by “rhizoids”) is *Ceratophyllum*. The Characeae may have lived in depths of up to several meters. They easily succumb to competition by phanerogams and, if light conditions permit, are competitive in deeper waters. A high pH-value (hard water) is indicated by the Characeae and by the calcium-rich coat mainly on *Ceratophyllum schrotzburgense* shoots and *Mikia pellenendorfensis* leaves. The reduction of CO₂ due to photosynthetic plant activity causes calcium carbonate precipitation on the ground and on submerged or floating plant organs. On *C. schrotzburgense* this layer bears the outlines of the epidermal cells in turgescence state, thus indicating its precipitation during the plant's life-time. Although well known from modern hydrophytes, this phenomenon was first reported from the fossil record on *Potamogeton* leaves from Wörth and Reith in the eastern Styrian Basin (Pannonian C, Kovar-Eder & Krainer 1990, 1992). *Ceratophyllum* and *Trapa* point to a nutrient-rich environment. For the Characeae, Nymphaeaceae, and *Potamogeton* this is less clear, because their modern species include indicators of eutrophic and oligotrophic conditions. Although *Trapa* prefers calcium-poor conditions, the Characeae need calcium-rich waters or waters with a high content of dissolved calcium carbonate.

Finally, planorbid gastropods are mainly found in this subunit J. The cyclicity observed in layers G to I switches towards a much looser amalgamation of layers in subunit J. Usually the cycles of subunit J do not exceed 3 layers per cycle (of 3 or 5 cycles).

The Characeae, too, indicate periodic changes of the ecological parameters: *Nitellopsis* (*T.*) *majoriformis* in subunit I

is represented by well-calcified, mature gyrogonites, documenting favourable conditions for completing the reproduction phase. Those from subunit J are immature, pointing to a deficit during the calcification process.

Taxodium dubium, *Populus balsamoides*, *P. mutabilis*, *P. populina*, and *Ulmus carpinoides* are characteristic azonal tree taxa, and *Smilax sagittifera*, a vine, documents various wetland habitats, possibly riparian forests, in the wider surroundings of Lake Pannon.

The Volga delta in the Astrakhanskiy Biosphere Reserves (N margin of the Caspian Sea) offers a mosaic pattern of reed and aquatic habitats that may serve as a modern analogue in landscape pattern. Many of the aquatic plants such as the Characeae, Nymphaeaceae, *Ceratophyllum*, *Trapa*, and *Potamogeton* are documented in the vegetation types differentiated there (Baldina et al. 2001). A difference from the modern Volga delta is the documentation of fossil genera (*Hemitrappa*, *Mikia*) and the presence of *Decodon*, which is restricted nowadays to the southeast of the US.

Unit 4

The abrupt termination of the hydrophyte-rich layers indicates a change of the sedimentary environment towards lagoonal conditions with an alternation of quiet deposition and upper flow regime. Generally, transport and deposition took place under slightly higher energetic conditions compared to unit 3.

The rare and poorly preserved leaf remains in this unit document tree taxa from riparian and/or hinterland forests.

A paleoecological interpretation of this unit based on the mollusc fauna is difficult due to the contradictory data on the ecological requirements of the documented molluscs in the literature.

The frequent *Tinnyea* seems to have been a strictly freshwater-bound form from swift fluvial environments (Lueger 1980; Müller et al. 1999; Harzhauser et al. 2002). This interpretation is strongly supported by the fact that all recent representatives of the related genera *Melanatria*, *Brotia*, and *Potadoma* are exclusively freshwater dwellers, which favour riverine environments. Furthermore, *Brotia* is rarely found in quiet water (Brandt 1974). Similarly, *Melanopsis bouei* is interpreted by Geary et al. (1989) as a freshwater dweller, which might also have tolerated slightly higher salinities. *Melanopsis sturi*, as a direct descendant of *Melanopsis bouei*, is reported by Korpás-Hódi (1983) from lagoonal, partly swampy, quiet-water facies, which indicate oligohaline to freshwater conditions. In respect to the highly variable ornamentation of the *bouei*-group, which often coincides with different lithofacies, the animals seem to have lived both in quiet habitats and in agitated water.

Unio atavus is often found associated with *Tinnyea escheri* (Harzhauser & Kowalke 2002; Lueger 1977), pointing also towards freshwater conditions. According to Lueger (1980), *Unio atavus* preferred slowly running rivers. At Pellendorf, however, the articulation of the valves of *Unio atavus* points to a rather short transport. In contrast, Korpás-Hódi (1983) and Müller & Szónoky (1990) interpret the descendant *Unio*

mihanovici as an inhabitant of shallow, aerated and agitated oligohaline water with salinities up to 3 ‰.

A comparable, but more diverse association is presented by Korpás-Hódi (1983) as the *Viviparus sadleri*–*Unio atavus* paleoassociation. This association bears species of the genera *Unio* and *Melanopsis* in common, which are the direct descendants of the described species. The Hungarian author interprets the paleoassociations as occupying oligohaline, agitated water of few meters depth close to an estuary.

Unit 5

This unit represents an offshore facies characterized by levlbottom conditions. The muddy lake bottom was mainly settled by the bivalve *Congeria partschi*, which was a suspension feeder on the sediment surface. According to Korpás-Hódi (1983), *Congeria partschi* preferred an aphytal, nutrient-rich subzone of the shallow sublittoral zone. Rather calm conditions with very weak agitation are indicated by the articulated preservation of the bivalves. The deposition therefore took place beyond the wave base, which is placed by Korpás-Hódi (1983) at a depth of 10–15 m below the surface of Lake Pannon. This species indicates salinities of about 10–16 ‰.

Suspension-feeding bivalves strongly predominate in the shelly fauna, whilst gastropods are absent. Typical taxa from the sandy marginal facies, such as *Melanopsis*, are completely missing. This cannot be explained simply by sampling effects, because ostracods are well documented in the sieving samples, whereas fragments of gastropod shells are absent. Thus the lack of herbivorous gastropods also hints at an aphotic sublittoral zone where the lake bottom was depleted of plants.

The intercalations of two thin sandy beds may have been caused by high-energy events that transported sand into the basin. Besides heavy storms, the Bisamberg fault zone — at that time still active — may be a possible trigger for the input of shoreface sediment.

Discussion

A sequence stratigraphical concept for the Pannonian of the northern Vienna Basin was recently introduced by Kováč et al. (1998). This was also integrated in the Carpathian and Pannonian Basins sequence stratigraphical model of Baráth & Kováč (2000) and Hudáčková et al. (2000). Kováč et al. (1998) based their interpretation mainly on the drillings at Malacky, Jakubov and Suchohrad in Slovak territory of the northern Vienna Basin. The proximity of these boreholes to the herein presented section Pellendorf allows a direct comparison and renders an integration of our observations within the Slovak scheme mandatory.

According to Kováč et al. (1998) and Hudáčková et al. (2000), the Pannonian "zones" A and B are part of a late 3rd order highstand systems tract or falling-stage systems tract of the Carpathian-Pannonian Cycle 6. In the northern Vienna Basin this phase is represented by various delta-associated facies. The following 3rd order systems tract starts with thick deltaic sand bodies of a lowstand systems tract which is corre-

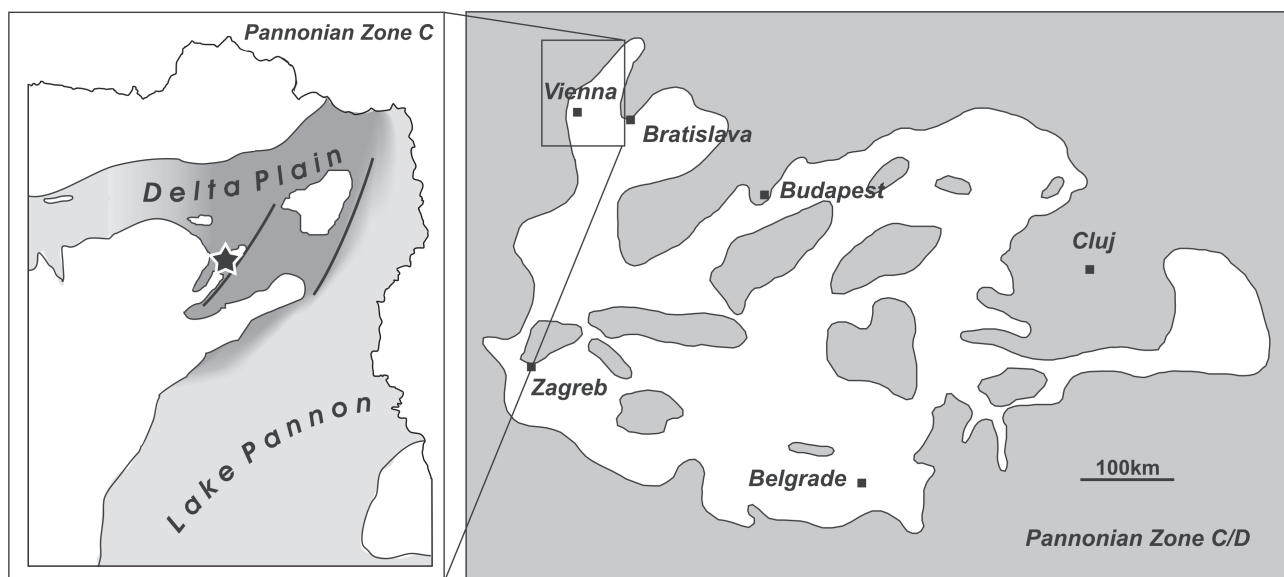


Fig. 6. Paleogeography of the Pannonian Zones C/D after Magyar et al. (1999). The detail shows an attempt at a paleogeographical reconstruction of the investigation area during the formation of the hydrophyte-bearing pelite (unit 3). The Bisamberg Fault and the Steinberg Fault are partly drawn to emphasize the importance of these tectonically active zones during the Early Pannonian.

lated with the Pannonian “zone” C. In the basin a distinct erosive surface marks the boundary between this Carpathian-Pannonian Cycle 7 and the foregoing 3rd order cycle. The late “zone” C and “zone” D are regarded as part of the transgressive systems tract which culminates in the maximum flooding surface within the “zone” E.

The small-scale pattern observed in the three sections of the Kronberg uplifted block may best be correlated with the 4th order systems tracts during this early CPC 7. Kováč et al. (1998) divided the Pannonian “zone” C into a larger part which represents a 4th order LST and the beginning of a TST, which mainly correlates with the early “zone” D. Although no accurate biostratigraphic dating of the basal unit of gravels at the section Pellendorf is possible, we intend to correlate this sedimentary unit with the LST of the Pannonian “zone” C. During this phase the deposits of the Hollabrunn-Mistelbach Formation in the broader surroundings of Mistelbach reflect a coarse-grained delta (braided delta) system. An extensive delta plain developed in the area under study along the western margin of the northern Vienna Basin, and the river shed its load far into the basin (Fig. 6). Progradation of the delta was also observed at several other localities in the investigation area during the mapping (by S. Nehyba). With the progradation of the delta front facies during the Pannonian “zone” C, freshwater marshes and small lakes developed in the delta plain (unit 3). No brackish water reached these biotas and thus a diverse hydrophyte flora accompanied by various freshwater molluscs thrived in the marshes. These were bordered by riparian forests in the wider surroundings of Lake Pannon. Local tectonics might have supported the formation of ponds and depressions, indicated by considerable lateral differences in the thicknesses.

In the entire investigation area these calm environments were abruptly replaced by riverine or even estuarine conditions with swift and agitated water. These strong shifts in fa-

cies point to a backstepping of the deltafront in a landward direction and to a take-over by riverine settings in the former marshes. Upsection, the overlying clay with *Congeria partschi* can definitely be attributed to the 4th order TST of the late Pannonian “zone” C. We therefore interpret units 3 to 5 to represent a retrogradational parasequence set within a 4th order systems tract.

However, such depositional systems are very sensitive to any fluctuation of the relative sea level, base level or sediment supply. Thus, the main problem in the presented sequence stratigraphic interpretation is the shift of the distributary channel, resulting in strong changes of sediment supply.

Conclusions

Due to its position close to the Bisamberg Fault, a sedimentary sequence of about 35 m thickness of the Pannonian “zone” C escaped from erosion at the margin of the Kronberg uplifted block. This marginal sequence is exposed in two sand and gravel pits close to Pellendorf in Lower Austria. They correspond to about 150 m of basinal sediment reported by Kováč et al. (1998) from drillings in the northern Vienna Basin. The slight NW-SE decrease in the thickness of units 3 and 4 is probably related to synsedimentary tectonic activity of the adjoining Bisamberg fault-zone. If so, the decrease of thickness-difference from unit 3 to 4 might indicate maximum tectonic movement during the deposition of unit 3, and a deceleration of movement during the deposition of unit 4.

Here, in the vicinity of Mistelbach, the “Paleo-Danube” terminated in a braided delta system in the northern Vienna Basin during the Early Pannonian lowstand. Freshwater ecosystems developed in the delta plain; displaying similarities with modern habitats of the Volga delta bordering the Caspian Sea. Later during the Pannonian “zone” C, the rising sea level

caused a landward backstepping of these freshwater environments. The transgression finally culminated in the take-over by sublittoral environments of Lake Pannon followed by the establishment of basinal *Congerina* assemblages.

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