

A Stratigraphic Enigma: The Age of the Neogene Deposits of Graz (Styrian Basin; Austria)

Ein stratigraphisches Rätsel: Das Alter der neogenen Ablagerungen um Graz (Steirisches Becken; Österreich)

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Abstract: Neogene sediments have been known for a long time below the alluvial plain and at the surrounding hills of Graz, but the dating of these deposits is still enigmatic. Up to now all biostratigraphic considerations were based on a few, more or less well-documented sites. The evaluation of already known localities, the results of a new mapping campaign and comparisons with the development in more distal areas of the Styrian Basin provide some novel data. Based on this, a more detailed stratigraphic scheme is presented.

Zusammenfassung: Im Stadtgebiet von Graz ist das Vorkommen von neogenen Sedimenten lange bekannt, ihre stratigraphische Stellung jedoch noch immer unklar. Alle bisherigen Korrelationsversuche beruhen auf wenigen, mehr oder weniger gut dokumentierten Fossilfundpunkten. Eine Evaluierung der bereits bekannten Lokalitäten, Ergebnisse einer aktuellen Kartierungskampagne und Vergleiche mit der Entwicklung in distalen Beckenarealen erbrachten neue Ergebnisse. Darauf basierend wird ein detaillierteres stratigraphisches Modell vorgestellt.

Key Words: Styrian Basin; Middle/Upper Miocene; Sarmatian/Pannonian; Biostratigraphy; Micropalaeontology.

Schlüsselworte: Steirisches Becken; Mittel-/Ober-Miozän; Sarmatium/Pannonium; Biostratigraphie; Mikropaläontologie.

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1. Introduction

Graz is the second largest city of Austria and the capital of the federal state of Styria. Geologically, it is located at the south-eastern margin of the Alps, just within the Styrian Basin, which belongs to the Pannonian Basin System (Fig. 1). Rocks of the Upper Austroalpine Graz Paleozoic (FLÜGEL & HUBMANN 2000; HUBMANN et al. 2006) roughly encircle the city in the west, north and northeast, which is mainly founded on the Quaternary alluvial plain of the Mur river.

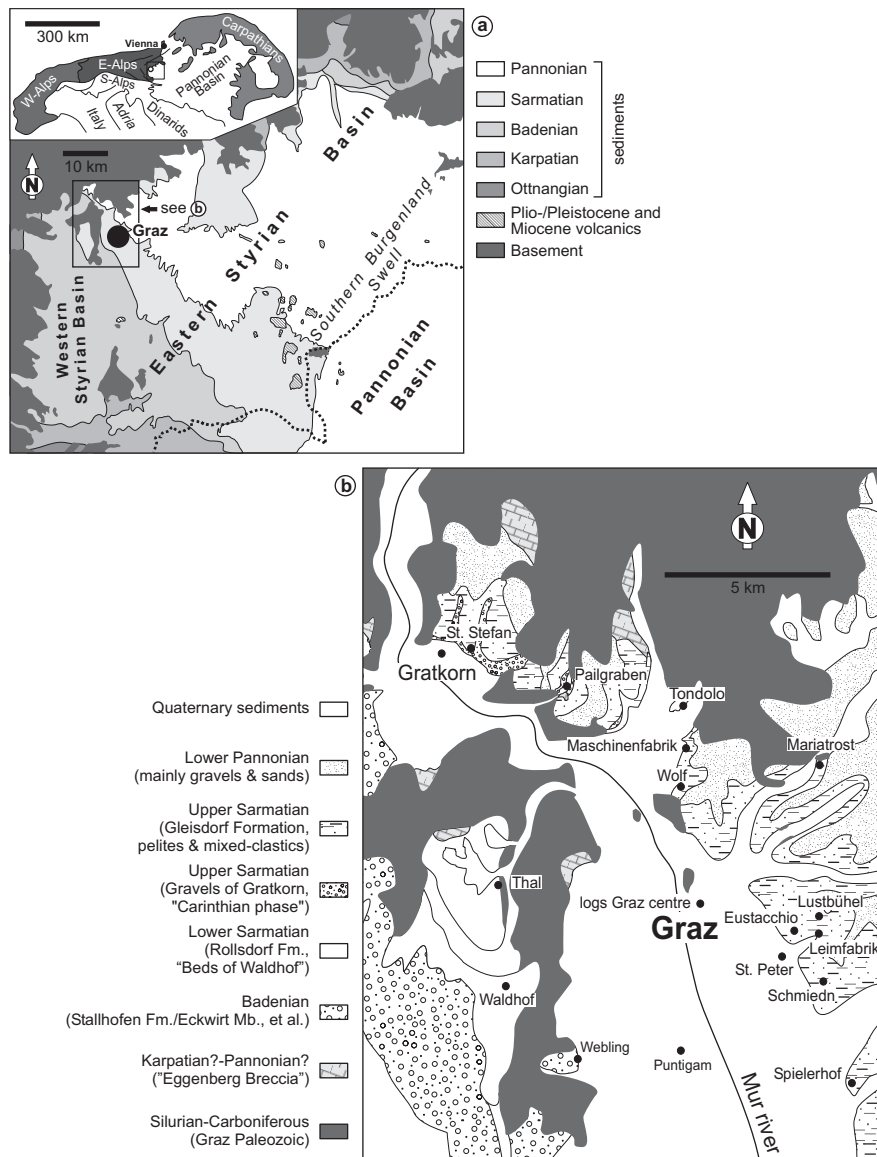
Immediately or some metres below the recent valley surface and at the surrounding hills of Graz Neogene sediments are known for a long time (e.g., HILBER 1893). The dating of these deposits, however, is still enigmatic. Correlations based on lithologic characters suggest ages ranging from the Early to the Late Miocene (HILBER 1893; WINKLER-HERMADEN 1957; FLÜGEL 1961, 1975a, b, 1997; KOLLMANN 1965; EBNER 1983). Only very rare and sometimes questionable geological reports are on hand for the majority of outcrops within the municipal area. Up to now all biostratigraphic considerations were based on a few, more or less well-documented sites (cf. chapter 2; Fig. 1).

Whereas CLAR (1927) referred to a catalogue of about 1,000 documented sites in Graz, more than 4,700 localities were recorded within a major development project ("Baugrund-Datenbank") in the last decades. These provide a well-founded lithologic database for the shallow underground (UNTERSWEIG 1986), however, none of these provided further biostratigraphic information.

Fig. 1: a) Position of the Styrian Basin within the Pannonian Basin System and geologic sketch of the Styrian Basin. b) Simplified geologic map of the north-western margin of the Styrian Basin based on KOLLMANN (1965), EBNER (1983), RIEPLER (1988) and data from H.W. FLÜGEL and M. GROSS.

Abb. 1: a) Stellung des Steirischen Beckens im Pannonischen Beckensystem und geologische Skizze des Steirischen Beckens. b) Schematische geologische Karte des nordwestlichen Beckenrandes basierend auf KOLLMANN (1965), EBNER (1983), RIEPLER (1988) und Daten von H.W. FLÜGEL und M. GROSS.

In the course of a new mapping campaign over hundred micropalaeontologic samples were studied from already known and new locations. Although most samples turned out to be barren of stratigraphically indicative fossils, some new data enable us to discuss the stratigraphy of the Neogene of Graz in more detail.



2. Fossiliferous Neogene sites in the area of Graz

Frequently recorded plant remains (e.g., HILBER 1893; KNOLL 1902; CLAR 1927) and scattered macro-vertebrate fragments (MOTTI 1970, 1975) do not allow a more precise dating and will not be discussed in this paper. For more detailed palaeontologic information see chapter 4 (appendix).

Pailgraben

Location: 15°23'09"E/47°07'42"N, sea level (s.l.) 435 m.

Remarks: This locality was first mentioned by CLAR in 1931 and later described in more detail (CLAR 1938). Although actually outside of Graz it will be discussed herein because of its intermediary and connecting position to the Gratkorn Basin in the north (CLAR 1933; HARZHAUSER et al., submitted). In a westerly ditch greyish, pelitic sediments are badly exposed below coarse and poorly sorted, polymict gravels. Out of these fine-grained sediments CLAR (1938) reported an internal mould of *Modiola marginata*, which was determined by PAPP in FLÜGEL (1958) as *Musculus sarmaticus*. Our own micropalaeontologic investigations yielded only a monospecific foraminiferal fauna with *Aubignyna perlucida*. (cf. Figs. 2a-c).

The coarse gravels are superimposed by 5–10 m thick greyish, plant-bearing pelites, which are rather well exposed in an easterly ditch close to Bogenhof (15°23'37"E/47°07'20"N, s.l. 445 m). Above follow medium- to fine-grained, quartz-rich gravels and sands (gravel pit at 15°23'18"E/47°07'42"N and outcrop in the easterly ditch at Bogenhof) with intercalated pelitic layers. The slopes of the hills become steeper at about a sea level of 480 m, reflecting the composition of quartz-rich, medium- to fine-grained gravels and sands without considerable pelitic intercalations.

Abandoned brickyard Tondolo/Neustift

Location: 15°25'57"E/47°07'11"N, s.l. 395 m.

Remarks: In the course of the enlargement of the brickyard, grey pelites were exposed below quartz- and crystalline-rich, probably Pleistocene (reworked) gravels and terrace loams in 1959 (FLÜGEL 1959).

Today the outcrop is no longer accessible due to recultivation. PAPP (in FLÜGEL 1959) recorded shells of *Ostrea (Crassostrea) gigensis sarmaticus* (now *Crassostrea gryphoides sarmatica*) and *Musculus* cf. *sarmaticus*. For micropalaeontologic studies an old sample (Coll. Geol. Paläont., Landesmuseum Joanneum) from these layers was processed and delivered a poor, nearly monospecific foraminiferal fauna with *Aubignyna perlucida*. Only very few tests of *Ammonia pseudobeccarii* and valves of *Hemicytheria omphalodes* were found additionally (cf. Figs. 2d-i, Fig. 3).

Badly documented drillings ca. 500 m W of this brickyard showed that grey pelites and sands were developed down to 313 m s.l., underlain by "a mixture of sands and pelites with huge boulders" down to 295 m s.l. (FLÜGEL 1997).

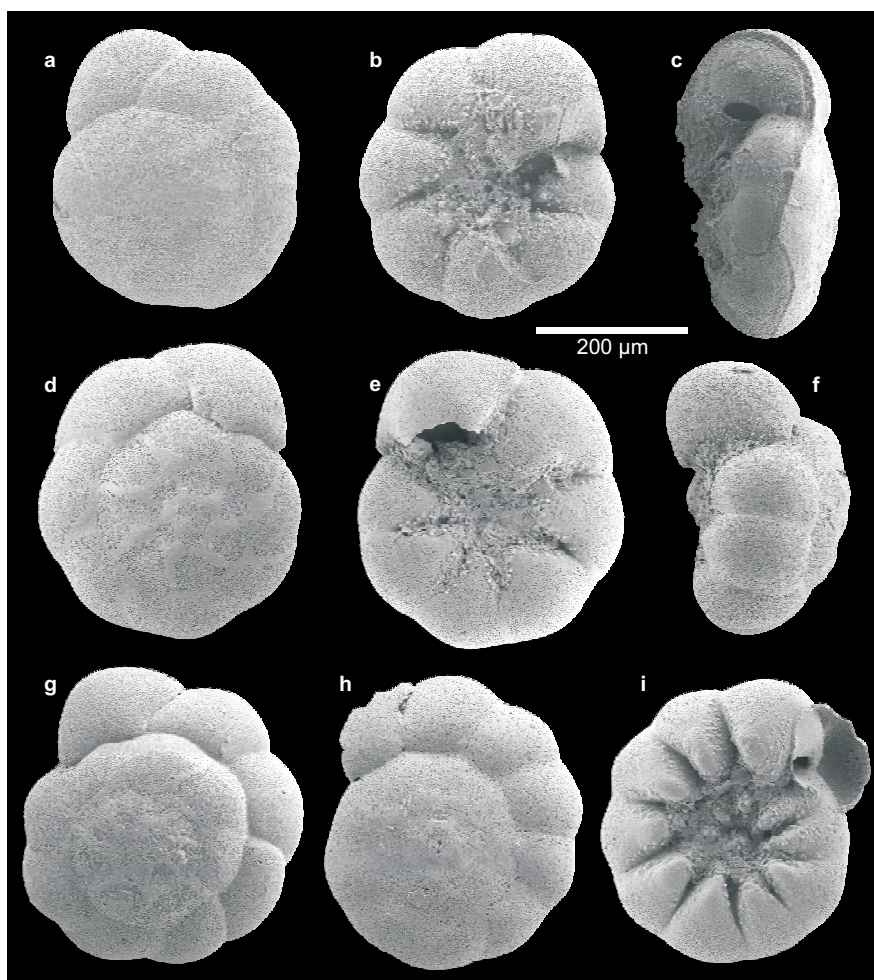


Fig. 2: a-g) *Aubignyna perlucida* (a-c, Pailgraben; d-g, Tondolo). h-i) *Ammonia pseudobeccarii* (Tondolo).

Abb. 2: a-g) *Aubignyna perlucida* (a-c, Pailgraben; d-g, Tondolo). h-i) *Ammonia pseudobeccarii* (Tondolo).

“Maschinenfabrik”/Andritz

Locality: 15°25'50"E/47°06'31"N, s.l. approx. 380m (well location).

Remarks: Only the vague description of HILBER (1893) is available for this locality. The supposed position is based on contemporary maps and HILBER's notice. Within an 80 metres deep well foraminifers were found (detailed occurrences not provided) indicating marine sediments somewhere between 380–300 metres s.l.

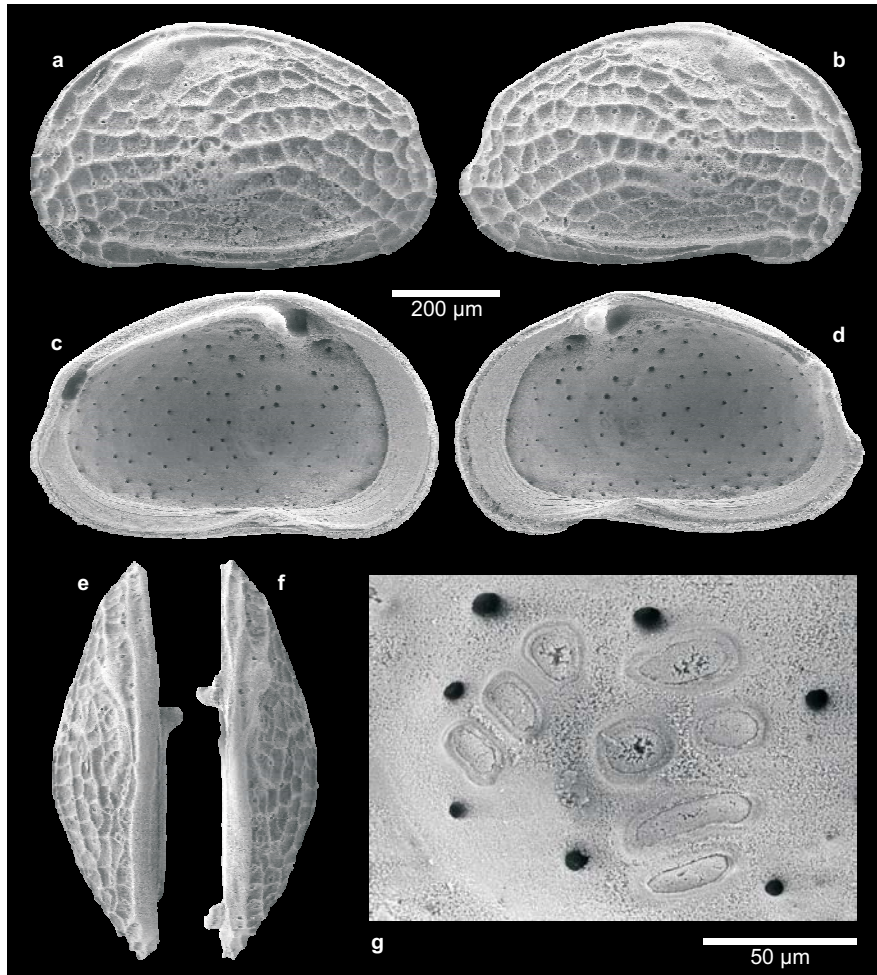


Fig. 3: a-g) *Hemicytheria omphalodes* (Tondolo).
Abb. 3: a-g) *Hemicytheria omphalodes* (Tondolo).

Mariatrost

Locality: 15°29'28"E/47°06'20"N, s.l. 430 m.

Remarks: This outcrop was a temporary casting pit (autumn 2005), which exposed more than 4 metres of grey to yellowish pelites with a few centimetres of oolitic limestone interlayers. Processing the pelites resulted in a poor fauna, which is strongly dominated by *Porosononion granosum* and *Mediocytherideis cejcensis*, associated by scarce specimens of *Porosononion* cf. *granosum*, *Elphidium grilli* and *Loxoconcha* div. sp.

Internal moulds of cardiid-bivalves were collected in the pelites but cannot be determined to higher precision due to their bad preservation. Thin sections of the oolite exhibited foraminifers (miliolids, *Elphidium*, *Ammonia*), scarce bivalve- and gastropod-remains as well as scattered fragments of dasycladacean algae (cf. Figs. 4-5).

Lustbühel/Neue Welt

Locality: 15°29'27"E/47°04'07"N, s.l. 455 m (well location).

Remarks: WAAGEN (1934) noticed "west of Lustbüchl castle, at the street to the set of houses Neue Welt" a drilling of 17 or 26 metres depth in 1932. The base of that well is formed by greyish pelites, which bear a "typical Sarmatian microfauna" determined by BÜRGEL (Geological Survey, Vienna). Unfortunately neither the exact position and depth (base of the well approx. at 430 m s.l.) of this site are known nor the original material can be found at the Geological Survey in Vienna.

"Leimfabrik"/St. Peter

Locality: 15°28'53"E/47°03'31"N, s.l. ?380 m (well location).

Remarks: HILBER (1893) mentioned of a drilling at the glue factory in St. Peter (today's Peterstalstraße 29–32) from 155 metres depth (231 m s.l.; WAAGEN 1934; ?225 m s.l.) very small, badly preserved specimens of "*Rotalia Beccarii*".

Abandoned brickyard Eustacchio/St. Peter

Locality: 15°28'30"E/47°03'40", s.l. 340–370 m (FLÜGEL 1975a, b, 1997).

Remarks: KOLLMANN (1965) recognized the freshwater ostracods *Candona* sp. and *Ilyocypris* sp. in this clay pit. Today this outcrop is completely backfilled. The preparation of some old samples from the collection of the Landesmuseum Joanneum delivered no microfauna.

Schmiedn/St. Peter

Locality: 15°29'18"E/47°02'44"N, s.l. 400 m.

Remarks: Recently, an internal mould-fauna (bivalves and gastropods; Coll. Geol. Paläont., Landesmuseum Joanneum) was found in pelitic layers intercalated in a gravelly-sandy succession in an old sand pit around 150 m E of the restaurant "Zur Schmiedn" at St. Peter. A number of specimens resemble some cardiid, mactrid and semelid taxa and thus may point to a marine (Sarmatian?) environment. Due to their bad preservation a conclusive determination is not possible.

Spielerhof near Raaba/Grambach

Locality: 15°30'10"E/47°01'11"N, s.l. approx. 355 m.

Remarks: FLÜGEL & MAURIN (1957) and KOLLMANN (1965) refer to some fossiliferous grey-green, pelitic strata between 355 and 385 m s.l. (FLÜGEL 1975a) at Spielerhof (just a few hundred metres outside Graz) but gave no faunal list.

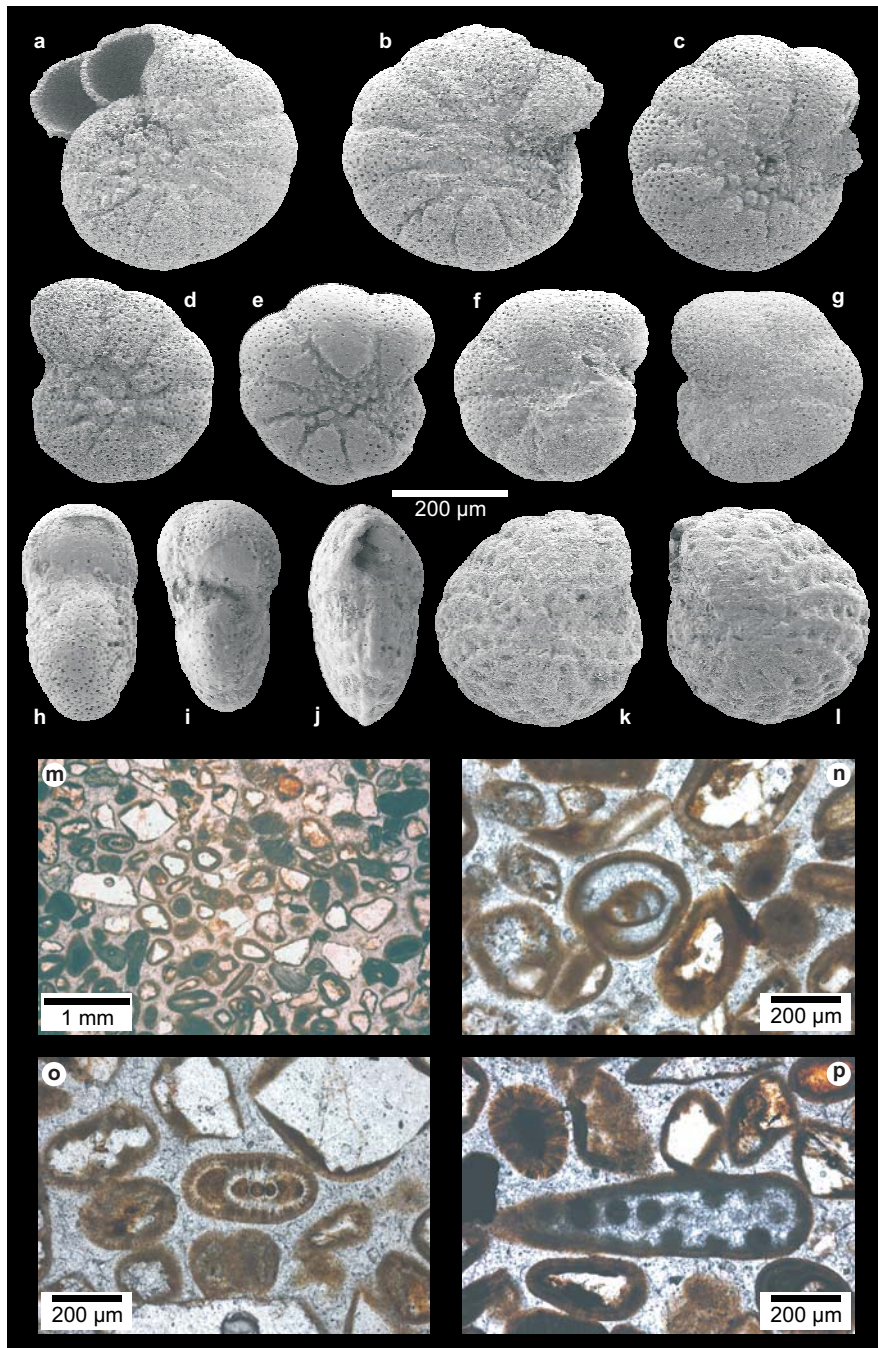


Fig. 4: a-e, h-i) *Porosononion granosum* (Mariatrost). f-g) *Porosononion* cf. *granosum* (Mariatrost). j-l) *Elphidium grilli* (Mariatrost). m-p) thin sections of the oolite from Mariatrost (m, overview; n, miliolid; o, *Elphidium*; p, fragment of a dasycladacean algae).
 Abb. 4: a-e, h-i) *Porosononion granosum* (Mariatrost). f-g) *Porosononion* cf. *granosum* (Mariatrost). j-l) *Elphidium grilli* (Mariatrost). m-p) Dünnschliff des Oolites von Mariatrost (m, Überblick; n, Miliolidae; o, *Elphidium*; p, Dasycladaceen-Fragment).

Today this locality is completely backfilled. In internal mapping reports from KOLLMANN (provided by the RAG, Vienna) the following fauna is cited and assigned to the *Porosononion granosum* Zone: “*Tapes*, *Mactra*, *Cardium*, *Modiola*, *Ervilia* (scarce), *Cerithium* cf. *disjunctum*, *Trochus*, *Nonion granosum*”.

Wells Puntigam I and II

Locality: 15°26'13"E/47°01'52"N, s.l. 340 m (Puntigam I); 15°26'25"E/47°01'58"N, s.l. 338 m (Puntigam II).

Remarks: Two boreholes for water supply of the brewery Puntigam were undertaken in the years 1968 and 1972 (ZETINIGG 1993) and investigated biostratigraphically. Below the approx. 20 metres thick Quaternary cover, RÖGL (1975) recorded Lower Sarmatian strata (*Elphidium hauerinum* Zone, down to 292 m s.l. and *Elphidium reginum* Zone, down to 191 m (well I) resp. 198 m (well II) s.l.), which are underlain by Badenian sediments. For a more detailed description and discussion of the log see FLÜGEL (1975a) and THURNER (1975).

Webling

Locality: 15°23'15"E/47°02'06"N, s.l. 400 m.

Remarks: In the area of Webling coal-bearing pelites and freshwater limestones are known for a long time and compared with Lower Badenian strata of the Rein Basin (W of Gratkorn) due to their mollusc fauna (ROLLE 1856; HILBER 1893; EBNER & GRÄF 1979; EBNER 1983; HIDDEN 1996; FLÜGEL 1997). In contrast, PAPP in FLÜGEL (1959) assigned a very badly preserved gastropod and bivalve steinkern-fauna out of these layers (Kehlbergstraße 54) to the Lower Pannonian. Due to the insufficient preservation of this faunula (only 5 specimens) this biostratigraphic dating remains questionable. Subsequent gastropod findings (HIDDEN 1996) lack a modern revision up to now and are not subject of further discussion within this paper.

3. Discussion

The stratigraphic database for the Neogene of Graz is still very poor and conclusions based on the available information will remain a matter of debate. Neither probable tectonic movements nor erosional events can be shown in detail due to the lack of well-dated outcrops, deep drillings or seismic lines.

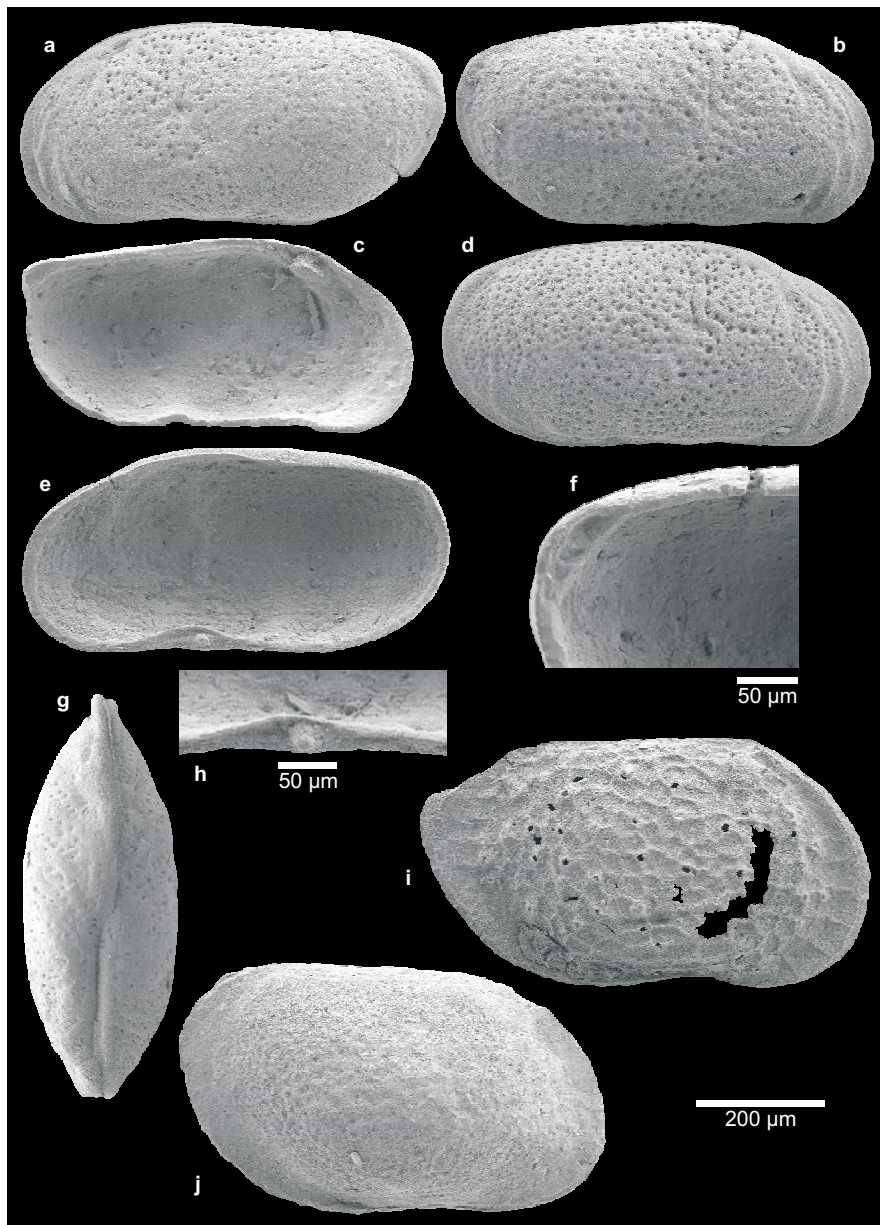


Fig. 5: a-h) *Mediocytherideis cejcensis* (Mariatrost). i) *Loxoconcha* sp. 1 (Mariatrost). j) *Loxoconcha* sp. 2 (Mariatrost).

Abb. 5: a-h) *Mediocytherideis cejcensis* (Mariatrost). i) *Loxoconcha* sp. 1 (Mariatrost). j) *Loxoconcha* sp. 2 (Mariatrost).

But, integrating all data and comparisons with the development in more distal areas of the Styrian Basin allow the tentative reconstruction of a stratigraphic scheme (Figs. 6-7). In addition to the aforementioned localities, the profiles of one abandoned brickyard (Wolf/Andritz: 15°26'11"E/47°05'55"N, s.l. of the base 390 m; KNOLL 1902; WINKLER-HERMADEN 1957) and three deep drillings are included in this reconstruction (Gollner: 15°26'44"E/47°04'02"N, s.l. 356 m; Holzplatz = Kaiser-Josef-Platz, 15°26'48"E/47°04'07"N, s.l. 357 m; Seifenfabrik: 15°27'13"E/47°04'10", s.l. 360 m; FLÜGEL 1975a; MAURIN 1975).

The grey pelites of the Pailgraben and Tondolo localities are correlated with each other and are assigned to the Lower Sarmatian (*Elphidium reginum* and/or *Elphidium hauerinum* Zone; FLÜGEL 1959). *Musculus sarmaticus* as well as *Crassostrea gryphoides sarmatica* and *Hemicytheria omphalodes* refer to a Sarmatian age. Even though *Aubignyna perlucida* is known up to the present it has its last occurrence in the Central Paratethys in the Early Sarmatian (RUPP 1986; SCHÜTZ et al. 2007) and *C. gryphoides sarmatica* reaches its acme in Lower Sarmatian deposits (PAPP 1974).

These sediments are topped by coarse, polymict gravels at the Pailgraben and questionably also at Tondolo, which seem to reflect the wide ranging sea level fall at the end of the Early Sarmatian known as the "Carinthian phase" (WINKLER 1927; HARZHAUSER & PILLER 2004). It appears that these gravels (termed "Gravels of Gratkorn" in the Gratkorn Basin) taper off to the south(-east) in the direction of the open basin (KOLLMANN 1965). The southeasternmost equivalent is exposed at the base of the clay pit Wolf/Andritz. WINKLER (1927; WINKLER-HERMADEN 1957) recognized the so-called "Carinthian Gravel" approx. 35 km south-east of Andritz in the region of Jagerberg and mapped it further to the east. He proposed a drainage pattern from the south-west into the Styrian Basin, an idea which was followed later by SKALA (1967). On the contrary, KOLLMANN (1965) discussed a drainage pattern from the (north)-east (HANSELMAYER 1967, 1969). The "Gravels of Gratkorn" are considered to be another tongue of sediment of this "Carinthian phase" from the north-west into the Styrian Basin.

Lower Sarmatian deposits are not reported in the area of Graz between locality Tondolo and the boreholes at Puntigam. In the boreholes Puntigam pelites with minor gravelly and sandy intercalations are attributed to the *Elphidium hauerinum* and *Elphidium reginum* Zone down to s.l. 191 m (well I) resp. 198 m (well II). Similar sediments below as well as underlying coralline algal-limestones (well I) down to the Paleozoic basement (well II) are correlated with the Upper Badenian (RÖGL 1975).

From a lithostratigraphic point of view the Lower Sarmatian pelites below the coarse clastics of the "Carinthian phase" at Pailgraben and Tondolo are supposed to be equivalent to the Rollsdorf Formation (sensu HARZHAUSER & PILLER 2004; KRÄINER 1984; FRIEBE 1994). The "Beds of Waldhof" (FLÜGEL 1961; RIEPLER 1988) of the westerly Thal Basin are also placed into this formation (HARZHAUSER & PILLER 2004).

Above the coarse gravels ("Carinthian phase") mainly pelitic, sometimes plant-bearing strata of variable thickness (5–20 m?) are developed, still exposed at the Pailgraben and once mined in the brickyards of Wolf/Andritz and Eustacchio/St. Peter.

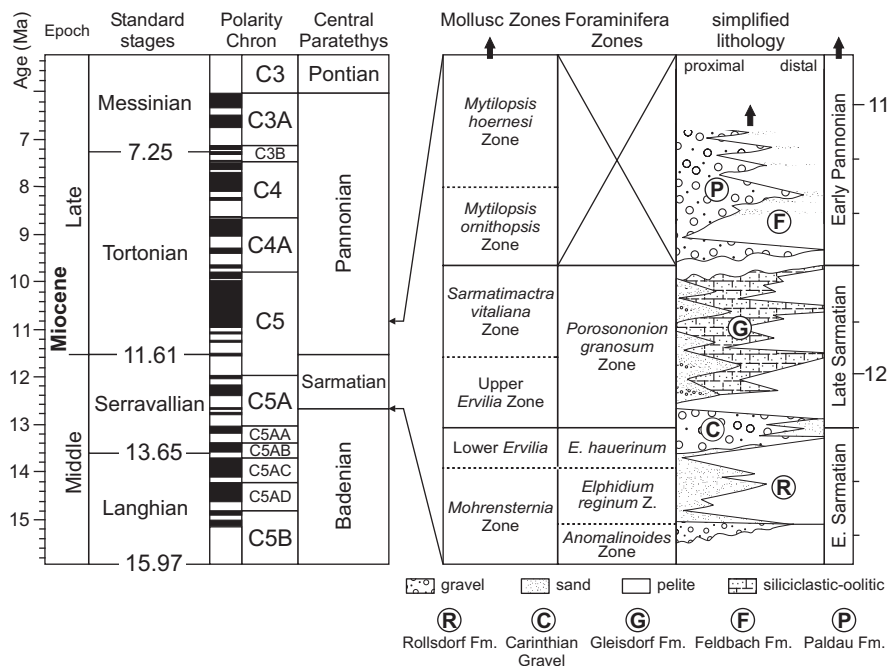


Fig. 6: Stratigraphy of the Sarmatian and Early Pannonian strata of the Styrian Basin (main formations are indicated; modified after HARZHAUSER & PILLER 2004 and LOURENS et al. 2004).
 Abb. 6: Stratigraphie der sarmatischen und unterpannonischen Sedimente im Steirischen Becken mit den wichtigsten lithostratigraphischen Einheiten (verändert nach HARZHAUSER & PILLER 2004 und LOURENS et al. 2004).

These fine clastics can be traced into the Gratkorn Basin where they are also underlain by very similar, polymict gravels called there “Gravels of Gratkorn”. An Upper Sarmatian terrestrial gastropod fauna occurs in the uppermost part of the gravels (clay pit St. Stefan; HARZHAUSER et al., submitted). Remarkably, the freshwater crab *Potamon proavium* was found (GLAESSNER 1928; GROSS & KLAUS 2005) both in the clay pit St. Stefan and the brickyard Wolf/Andritz. In the course of building projects these fine clastics are frequently encountered at the base of the hills in the eastern Graz area (informally named Peterstal Member; FLÜGEL 1997). Due to strong erosional processes during the Quaternary a differentiation between the lower fine clastics (Rollsdorf Fm., “Beds of Waldhof”) and that of the “Peterstal Mb.” is rather difficult in the area of Graz.

The fine clastics of the “Peterstal Mb.” grade into gravels (“Ries Formation”) through an up to 30m thick transitional succession of gravelly-sandy-pelitic-alternations (informally denominated Lustbühel Member; FLÜGEL 1997).

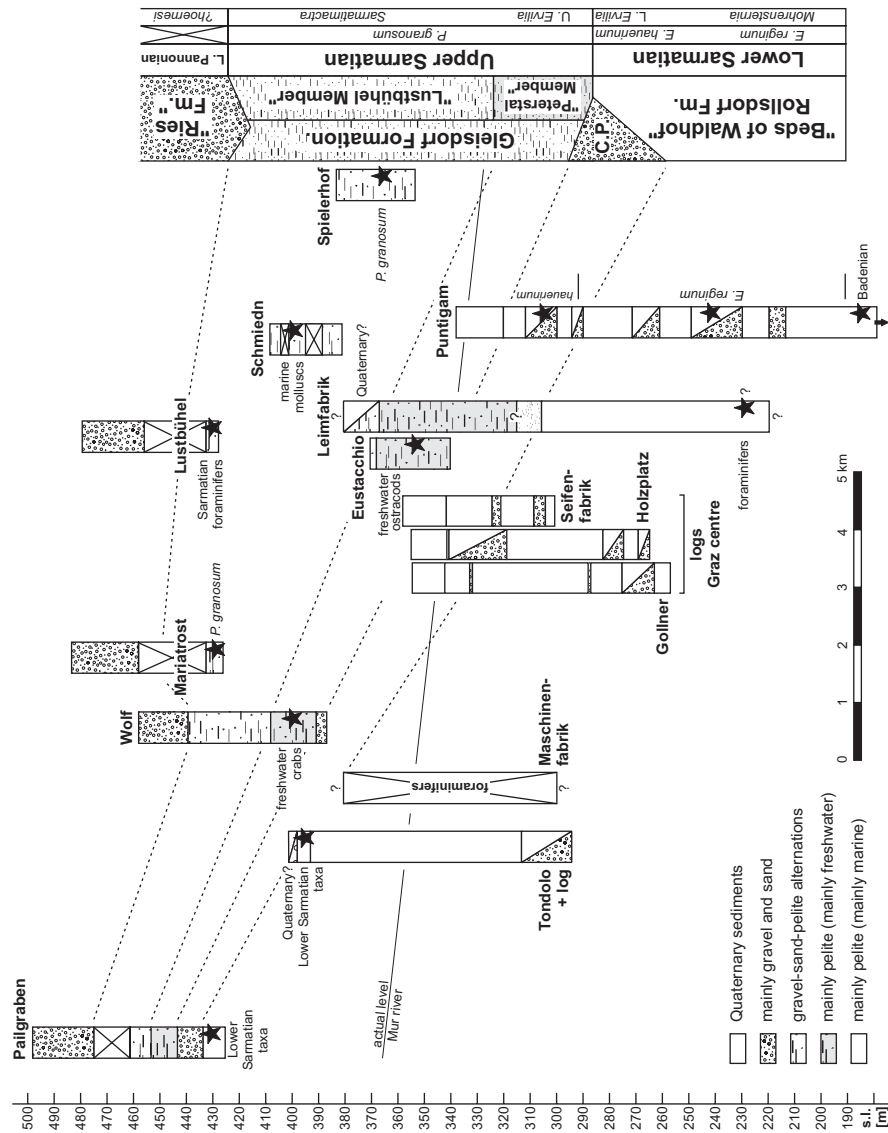


Fig. 7: Stratigraphic scheme of the Neogene deposits of Graz (C.P. = Carinthian phase, E = Elphidium, L = Lower, P = Porosonion, U = Upper).
 Abb. 7: Stratigraphisches Schema der neogenen Ablagerungen um Graz (C.P. = Carinthische Phase, E = Elphidium, L = Unter, P = Porosonion, U = Ober).

Due to the transitional character of the “Lustbühel Mb.” its differentiation from the underlying “Peterstal Mb.” and the overlying “Ries Fm.” is difficult in the field.

Genetically the pelites of the “Peterstal Mb.” seem to be related with the onset of the transgression at the beginning of the Late Sarmatian. While marine marls are deposited in the open Styrian Basin, freshwater or, at the most, reduced marine conditions developed in the more marginal area of Graz due to strong freshwater input and/or restricted pass-ways.

In the upper parts of the mixed-clastic “Lustbühel Mb.” the recently discovered site Mariatrost as well as the locality Spielerhof (FLÜGEL & MAURIN 1957) provide evidence of a Late Sarmatian age.

Thin oolitic layers, highly characteristic for the Upper Sarmatian (PILLER & HARZHAUSER 2005) and the predominant occurrence of *Mediocytherideis cejcensis* and *Porosononion granosum* point to the upper *Porosononion granosum* Zone at Mariatrost. The locality Lustbühel refers to a Sarmatian age (WAAGEN 1934) as well as possibly the internal moulds from the locality Schmiedn/St. Peter.

Lithostratigraphically, the pelites of the “Peterstal Mb.” and the mixed-clastics of the “Lustbühel Mb.” are attributed to the Gleisdorf Formation sensu HARZHAUSER & PILLER (2004; KOLLMANN 1965; FRIEBE 1994). While several mixed-siliciclastic-carbonatic parasequences can be distinguished in many parts of the Styrian Basin, in the Graz area sea level oscillations are expressed mainly by alternations of coarse- to fine-grained clastics in Late Sarmatian times.

The topmost Neogene strata at the northern and eastern hills of Graz comprise quartz-rich gravels and sands with only very subordinate fine clastic layers (informally named “Ries Fm.”; KOLLMANN 1965; FLÜGEL 1997). Without any well-founded biostratigraphic proof they are traditionally correlated with Lower Pannonian gravels of the open Styrian Basin (Paldau Formation; KOLLMANN 1965; GROSS 2003). Lowermost Pannonian (*Mytilopsis ornithopsis* Zone) pelitic strata with a typical endemic Lake Pannon fauna (dreissenids, ostracods, etc.), which are widespread in more distal areas (Feldbach Formation; GROSS 2003), are supposed to be completely eroded (KOLLMANN 1965).

The lower boundary of the “Ries Fm.” remains highly interpretative in geologic maps not only due to scattered outcrops and poor dating but also because of supposed large erosional gaps and sediment reworking and mixing. For example, the hiatus with channels up to 60 m depth in distal basin areas at the Sarmatian/Pannonian boundary (Kosi et al. 2003) points to such processes.

4. Appendix – Micropalaeontological notes

4.1. Foraminifers

Genus *Aubignyna* MARGEREL, 1970

Aubignyna perlucida (HERON-ALLEN & EARLAND, 1913)

Figs. 2a-g

- 1913 *Rotalia perlucida* n.sp. – HERON-ALLEN & EARLAND: 139, pl. 13, figs. 7-9.
1986 *Aubignyna perlucida* (HERON-ALLEN & EARLAND) – RUPP: 56, pl. 4, figs. 5-7.
1998 *Aubignyna perlucida* (HERON-ALLEN & EARLAND) – RÖGL: 139, pl. 2, figs. 10-14; pl. 10, figs. 1-2.
2007 *Aubignyna perlucida* (HERON-ALLEN & EARLAND) – SCHÜTZ et al.: 458, pl. 6, fig. 2.

Material: (Nearly) monospecific assemblages occurred in the former brickyard Tondolo/Neustift (149 tests; Coll. Geol. Paläont., Landesmuseum Joanneum, Inv.No. 203 812). Also recorded in the locality Pailgraben (45 tests; Coll. Geol. Paläont., Landesmuseum Joanneum, Inv.No. 203813).

Description: Flat low trochospiral test with 7–8 chambers in the final whorl; periphery rounded somewhat lobate; spiral side with 2½ to 3 whorls and with backward curved, slightly incised intercameral sutures, in the earlier whorls limbate; umbilical side with small deep umbilicus, commonly filled by sediment; intercameral umbilical sutures slightly curved, wide and deeply incised, accompanied by series of small pustules; aperture a low basal slit, also accompanied by small pustules along the base of the apertural face; wall thin, translucent, with rather coarse perforations; apertural face with a semi-circular non-perforated area; the penultimate chamber is connected by a funnel-shaped foramen (cf. Fig. 2b).

Stratigraphic distribution: Species of the genus *Aubignyna* are already recorded from the Early Miocene Ottnangian of the Upper Austrian Molasse Basin (RUPP & HAU-NOLD-JENKE 2003), and from the Karpatian of the Korneuburg Basin (RÖGL 1998). *A. perlucida* is mentioned from the Badenian and Early Sarmatian of the Vienna Basin by RUPP (1986) and SCHÜTZ et al. (2007).

Palaeoecology: In ecological studies from the northern Adriatic Sea, JORISSEN (1988) found this species in very shallow, well aerated muddy environment with rich nutrient supply.

Genus *Ammonia* BRÜNNICH, 1772

***Ammonia pseudobeccarii* (PUTRJA, 1964)**

Figs. 2h-i

- 1964 *Streblus pseudobeccarii* n.sp. – PUTRJA: 129, pl. 15, figs. 3-4.
1998 *Ammonia pseudobeccarii* PUTRJA – RÖGL: 135, pl. 2, figs. 1-6.
2007 *Ammonia pseudobeccarii* (PUTRJA) – SCHÜTZ et al.: 458, pl. 6, fig. 4.

Material: Brickyard Tondolo/Neustift. The single specimen observed agrees with the features of the species (Coll. Geol. Paläont., Landesmuseum Joanneum, Inv.No. 203 814).

Description: In the group of ammonias, this species is small, flat trochospiral, with about 9–11 chambers in the final whorl. Periphery rounded, slightly lobate. Spiral side with slightly backward curved intercameral sutures; umbilical side with open umbilicus, filled with small pillars and granules; umbilical intercameral sutures radial, deeply incised, with small granules along the sutures. Wall smooth, medium fine perforate.

Stratigraphic distribution: From the Early Miocene to the Sarmatian in Austria.

Palaeoecology: This species is comparable with the recent *Ammonia parkinsoniana* (D'ORBIGNY), which lives at water depths of 10–20m. It occurs in clayey and silty sediments with raised organic content in the Korneuburg Basin.

Genus *Porosononion* PUTRJA in VOLOSHINOVA, 1958

***Porosononion granosum* (D'ORBIGNY, 1846)**

Figs. 4a-e, h-i

- 1826 *Nonionina granosa* – D'ORBIGNY: 128, no. 17. [nomen nudum]
1846 *Nonionina granosa* D'ORBIGNY – D'ORBIGNY: 110, pl. 5, figs. 19-20.
1857 *Nonionina subgranosa* – EGGER: 299, pl. 14, figs. 16-18.
1958 *Porosononion subgranosum* (EGGER) – PUTRJA in VOLOSHINOVA: 135, pl. 1, figs. 7-8; pl. 13, fig. 1; pl. 16, fig. 1.

- 1985 *Elphidium (Porosononion) granosum* (d'ORBIGNY) – PAPP & SCHMID: 47, text-fig. 6, pl. 37, figs. 1-6.
 1987 *Porosononion granosum* (d'ORBIGNY) – WENGER: 297, pl. 13, figs. 11-12.
 1998 *Porosononion granosum* (d'ORBIGNY) – CÍCHA et al.: 119, pl. 74, figs. 4-5.

Material: A nearly monospecific benthic foraminiferal fauna is present at the locality Mariatrost (59 tests; Coll. Geol. Paläont., Landesmuseum Joanneum, Inv.No. 203 815).

Description: Planispirally coiled, flat bi-umbilicate; periphery broadly rounded, slightly lobate; umbilicus wide, filled with small pillars and granules, pillars varying in thickness; intercameral sutures slightly curved to radial, incised. Aperture indistinct, a basal row of small openings. Wall thick, coarsely perforated. Some variations in dimensions of the test are observed (8–12 chambers), Oligocene and Early Miocene specimens are generally smaller, and this is also the case in more muddy sediments.

In the present material different stages of development of the umbilical area are present. The thickness of pillars varies between fine granules and thick blocky structures. Number of chambers lies between 8 and 10. According to the internal mould of *P. granosum* from the Vienna Basin, a distinct typical elphidiid canal system is developed (PAPP & SCHMID 1985, text-fig. 6, contributed by H.-J. HANSEN, Copenhagen). Therefore this genus is attributed to the Elphidiidae.

Stratigraphic distribution: The species is present from the Late Oligocene to the end of Sarmatian (CÍCHA et al. 1998).

Palaeoecology: *P. granosum* and related species are present at reduced or strongly varying salinity at shallow water depth. The tests in muddier environment are smaller and thinner, increasing in size and wall thickness with sand content.

***Porosononion cf. granosum* (d'ORBIGNY, 1846)**

Figs. 4f-g

Material: Locality Mariatrost (1 test; Coll. Geol. Paläont., Landesmuseum Joanneum, Inv.No. 203816).

Remarks: A single specimen was observed, which does not fall in the normal variety of *P. granosum*. This specimen shows 7½ chambers in the final whorl, but differs by a small umbilicus, obviously not filled with pillars. The precise definition is difficult as the umbilical area is obscured by clay flakes.

Genus *Elphidium* DE MONTFORT, 1808

***Elphidium grilli* PAPP, 1963**

Figs. 4j-l

1963 *Elphidium flexuosum grilli* – PAPP: 272, pl. 12, figs. 7-8.

2007 *Elphidium grilli* PAPP – SCHÜTZ et al.: 458-459, pl. 7, fig. 4.

Material: Locality Mariatrost (3 tests; Coll. Geol. Paläont., Landesmuseum Joanneum, Inv.No. 203817).

Description: Test planispirally coiled, lenticular, biumbonate, sides of investigated specimens slightly inflated, periphery keeled. Umbilicus flat, centre somewhat depressed, filled with small knobs at the end of thickened chamber walls. Chambers are numerous, in the investigated specimen 14, in PAPP's figure >17 in the final whorl, and narrow. The interocular space between the chambers (sunken sutures) is bridged by 5–7 ponticuli. The chamber wall is smooth. The aperture consists of multiple basal openings, and in well preserved material also of areal apertures.

Remarks: Description and figures of PAPP are not very explanative. The investigated specimen was compared with material of different Sarmatian horizons and from different facies.

The species is characterized by nearly flat chamber sides and thin walls in the more clayey facies of Early Sarmatian (e.g., Vienna Basin: Siebenhirten, Petronell). The specimens are more robust, inflated with vaulted chamber sides in more calcareous facies (e.g., Styrian Basin, Early Sarmatian, *Elphidium reginum* Zone of deep drilling Arnwiesen-1) and in sandy environment (e.g., Vienna Basin, Late Sarmatian, *P. granosum* Zone at Sarmatian type locality Nexing). These forms compare better with the investigated material, but do not allow a stratigraphic interpretation.

Stratigraphic distribution: Throughout the Sarmatian, but with some occurrences also in the Late Badenian (CÍCHA et al. 1998).

Palaeoecology: *Elphidium* has its richest occurrences in shallow marine environments with changing salinities.

4.2. Ostracods

Genus *Mediocytherideis* MANDELSTAM, 1956

Subgenus *Mediocytherideis (Mediocytherideis)* MANDELSTAM, 1956

Mediocytherideis (Mediocytherideis) cejcensis ZELENKA, 1989

Figs. 5a-h

- 1989 *Ishizakiella cejcensis* n. sp. – ZELENKA: 16-19, fig. 1.
1990 *Leptocythere cejcensis* Zelenka – ZELENKA: 265, pl. 2, fig. 4.
1998 *Leptocythere cejcensis* Zelenka – FORDINAL & ZLINSKA: 142, 144-146, pl. 5, fig. 5.
2000 *Leptocythere* cf. *cejcensis* Zelenka – SZCZETCHURA: 85, 89, pl. 7, figs. 1-2.

Material: Locality Mariatrost (143 mostly strongly compressed carapaces; Coll. Geol. Paläont., Landesmuseum Joanneum, Inv.No. 203818).

Description: Females rhomboidal, swelled posteriorly, males subovate; surface pitted and ornamented with low, $\pm$ concentric ribs in the anterior third and posteriorly; hinge of the right valves consists of an elongated anterior tooth passing into a very slightly crenulated bar, a posteromedian smooth bar and four posterior toothlets; hinge of the left valves: below a something widened groove lies a small tooth anteriorly, posteromedian only a smooth bar can be observed in the present material, followed by a crenulated socket posteriorly; a snap-knob is well developed ventrally; inner lamella anteriorly wide, with a posteroventral angularity; further detail (e.g., marginal pores, muscle scars) unknown due to insufficient preservation.

Remarks: These leptocytherid ostracods are assigned to *Mediocytherideis* s.str. according to the diagnoses given by KRSTIC & MCKENZIE (1991). The subgenus *Sylvestra* DORUK, 1973 differs by its more convex dorsal margin and two toothlets in the middle part of the hinge of the left valves. *Ishizakiella* MCKENZIE & SUDIJONO, 1981 displays six posterior toothlets in right valves and lacks the ventral snap-knob. *Chartocythere* has often a compact posterior tooth in the right valves and a crenulated posteromedian hinge element (cf. BONADUCE et al 1990; KRSTIC & MCKENZIE 1991; GLIOZZI et al. 2005).

Stratigraphic distribution: Uppermost Sarmatian in the Vienna Basin (ZELENKA 1989, 1990; FORDINAL & ZLINSKA 1998), Sarmatian in the Carpathian Foredeep (SZCZETCHURA 2000).

Palaeoecology: Shallow, brackish waters (KRSTIC & MCKENZIE 1991).

Genus *Hemicytheria* POKORNY, 1955

***Hemicytheria omphalodes* (REUSS, 1850)**

Figs. 3a-g

- 1850 *Cypridina omphalodes m.* – REUSS: 75, pl. 10, fig. 7.
2004 *Hemicytheria omphalodes* (REUSS, 1850) – TOTH: 137, pl. 4, figs. 1-2.
[partim]
2006 *Hemicytheria omphalodes omphalodes* (Reuss) – FORDINAL et al.: 124,
figs. 4, 6.
2006 *Hemicytheria omphalodes* (REUSS 1850) – GROSS: 45-47, pl. 20, figs.
1-12.

Material: Locality Tondolo/Neustift (4 valves; Coll. Geol. Paläont., Landesmuseum Joanneum, Inv.No. 203819).

Remarks: For further synonyms and discussion see GROSS (2006).

Stratigraphic distribution: Middle (Upper Badenian, predominately Sarmatian) to ?Upper Miocene (?Lower Pannonian) in the Central Paratethys (Gross 2006).

Palaeoecology: Shallow, brackish (oligo- to polyhaline) waters.

Genus *Loxoconcha* Sars, 1866

***Loxoconcha* sp. 1**

Fig. 5i

Material: Locality Mariatrost (1 right valve; Coll. Geol. Paläont., Landesmuseum Joanneum, Inv.No. 203820).

Remarks: Only one badly preserved specimen with abraded ornamentation is available. The internal features are not visible. This right valve has some affinities to the "Sarmatian" *Loxoconcha kochi* in the sense of CERNAJSEK (1974), FORDINAL & ZLINSKA (1998) and GROSS (2006).

However, it differs markedly from the original description of this taxon (MEHES 1908; GROSS 2004). Close relationships seem to exist with *Loxoconcha laeta* STANCHEVA, 1963 (STANCHEVA 1963, 1990; OLTEANU 2000) but identification is not possible based on this valve.

Stratigraphic distribution in the Paratethys realm: *L. kochi*: Middle to Upper Miocene (mainly Sarmatian); *L. laeta*: Middle to Upper Miocene (mainly Sarmatian).

Palaeoecology: Probably reduced marine waters.

***Loxoconcha* sp. 2**

Fig. 5j

Material: Locality Mariatrost (6 badly preserved specimens; Coll. Geol. Paläont., Landesmuseum Joanneum, Inv.No. 203821).

Remarks: Abraded and deformed carapaces to not enable a specific determination. Some affinities refer to *Loxoconcha porosa* MEHES, 1908 of the “*rhomboidea* group” (KRSTIC 1972; MEHES 1908; ZELENKA 1990).

Palaeoecology: Probably reduced marine waters.

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