

Biostratigraphic studies on planktonic gastropods from the Tertiary of the Central Paratethys

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In the present paper the latest studies on the distribution and biostratigraphy of planktonic gastropods in the Central Paratethys are summarised. The research was carried out on material from Tertiary deposits of Austria, Hungary and Poland, mainly concentrating on the Badenian (Middle Miocene). In Hungary correlations on palaeomagnetic, nannoplankton and pteropod data were done for several boreholes.

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Introduction

There are two groups of marine planktonic gastropods which are preserved in the fossil record, viz. the heteropods and the pteropods. The pteropods of the Central Paratethys are mainly represented by the Euthecosomata, which in this area are distributed from the Middle Eocene to the Middle Miocene. The Pseudothecosomata and the Heteropoda are rather rare and only recorded from the Early Badenian.

The diagnostic value of pteropods for biostratigraphy has been studied for several decades within different areas of the Central Paratethys. These studies focused mainly on Middle Miocene (Badenian, Sarmatian) deposits, which generally contain the greatest abundance of pteropod species in the Central Paratethys (especially the Early Badenian). Concerning this time period the first comprehensive results came from Rumania (Stancu, 1979) and Poland (Krach, 1981). Despite the poor preservation potential of pteropods a number of concurrences in the stratigraphic range of species have already been outlined.

In the present paper the state of research concerning the biostratigraphic results of

the latest studies on planktonic gastropods in the Central Paratethys is summarised. The distribution of pteropod occurrences in the Tertiary of Austria and Hungary has recently been studied (Zorn, 1991a, b; Bohn-Havas, 1992; Bohn-Havas & Zorn, in press), and the pteropods from the Carpathian Foredeep of Poland, which had been described by Krach (1981), were revised (Janssen & Zorn, 1993). Literature data which could not be checked on the fossil material itself are not included in this report. The reader is referred to the papers cited above for information on the historical research.

Pteropod occurrences in the Middle Miocene of Austria

The sedimentation areas of Austria which yield Middle Miocene planktonic gastropods are the Molasse Zone north of the Danube, the Vienna Basin, the Eisenstadt Basin, the Styriacan Basin and the Lavanttal Basin in Carinthia (Fig. 1).

Only Euthecosomata have been found in all these regions. Eight species could be distinguished, belonging to five genera, viz. *Limacina valvatina* (Reuss, 1867), *L. cf. inflata* (d'Orbigny, 1836), *Creseis spina* (Reuss, 1867), *Clio* sp., *Vaginella austriaca* Kittl, 1886, *V. depressa* Daudin, 1800, and *Cuvierina paronai* Checchia-Rispoli, 1921. The ranges of the various species are summarised together with the Hungarian finds in Fig. 2.

In the Central Paratethys the Middle Miocene is divided into two stages, the Badenian and the Sarmatian. The Badenian is subdivided into Early, Middle and Late Badenian, which correspond to the foraminiferal zones of the Vienna Basin, viz. the Lagenidae Zone, the *Spiroplectammina* Zone and the *Bulimina-Bolivina* Zone. Four pteropod species can be found both in the Early and Middle Badenian. For the Early Badenian these are *Limacina valvatina*, *Clio* sp., *Vaginella austriaca*, and *Cuvierina paronai*, and for the Middle Badenian *L. valvatina*, *Creseis spina*, *Vaginella austriaca*, and *V. depressa*. Three species occur in the Late Badenian (*L. valvatina*, *C. spina*, and *Vaginella* sp.), whereas only one species is known from the Early Sarmatian (*Limacina cf. inflata*).

Most of the species are only known from one or two localities and only two species are widely distributed, viz. *Limacina valvatina* and *Vaginella austriaca*. These two species also show the longest stratigraphical distribution. They are the only Badenian species that also occur in the Karpatian. The other species are restricted to the Badenian or Early Sarmatian, except for *Vaginella depressa*, which is also known from the Eggenburgian of Austria.

The areas where the greatest number of species were found are the Vienna Basin and the Eisenstadt Basin. The locality with the richest pteropod fauna of the Vienna Basin is the former Breyer clay pit of Vöslau, where *Limacina valvatina*, *Vaginella austriaca*, *Cuvierina paronai*, and *Clio* sp. were recorded for the Upper Lagenidae Zone. In the Eisenstadt Basin two localities should be stressed, viz. the clay pits of Walbersdorf and Rohrbach, the former yielding *Limacina valvatina*, *Creseis spina* and *Vaginella* sp. (*Bulimina-Bolivina* Zone), and the latter *L. valvatina*, *C. spina* and *V. austriaca* (*Spiroplectammina* Zone). The *Bulimina-Bolivina* Zone of Walbersdorf was correlated with the zones NN7 and N13 (Rögl & Müller, 1976)

Limacina valvatina occurs in the Vienna Basin and the Styriacan Basin almost in the whole Badenian (Upper Lagenidae Zone to *Bulimina-Bolivina* Zone), which is docu-

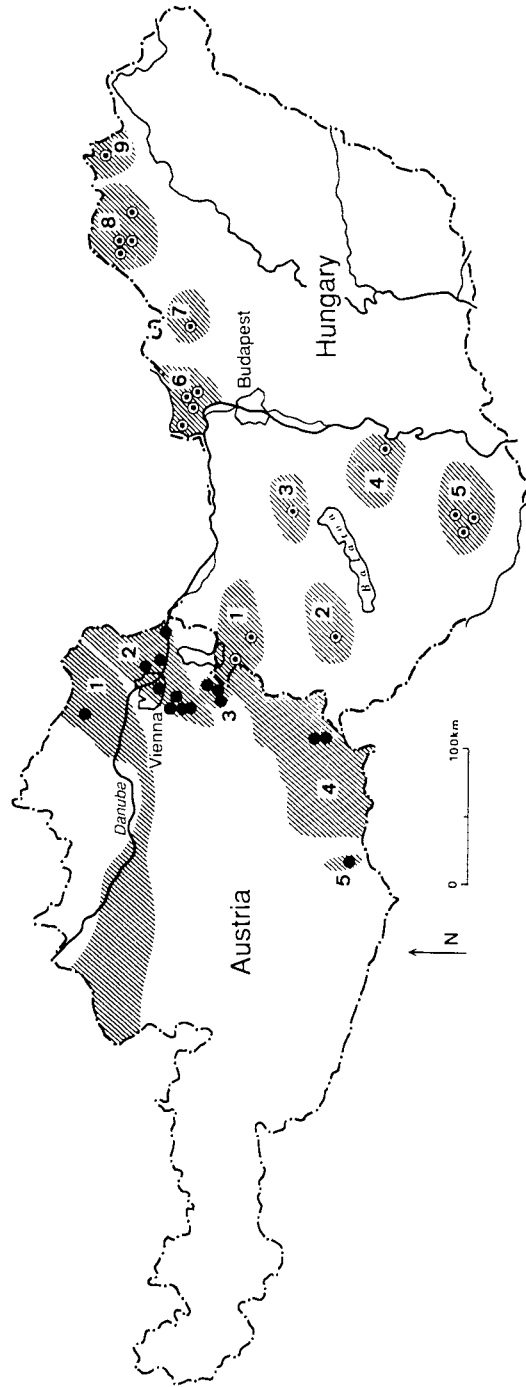


Fig. 1. Tertiary sedimentation areas in Austria and Hungary, with localities yielding Middle Miocene pteropods.
A1: Molasse Zone N of Danube; A2: Vienna Basin; A3: Eisenstadt Basin; A4: Styriacan Basin; A5: Lavanttal Basin; H1: Sopron area; H2: Tapolca Basin; H3: Várpalota Basin; H4: Paks area; H5: Mecsek Mountains; H6: Börzsöny Mountains; H7: Cserhát Mountains; H8: Borsod Basin; H9: Hidasnémeti.

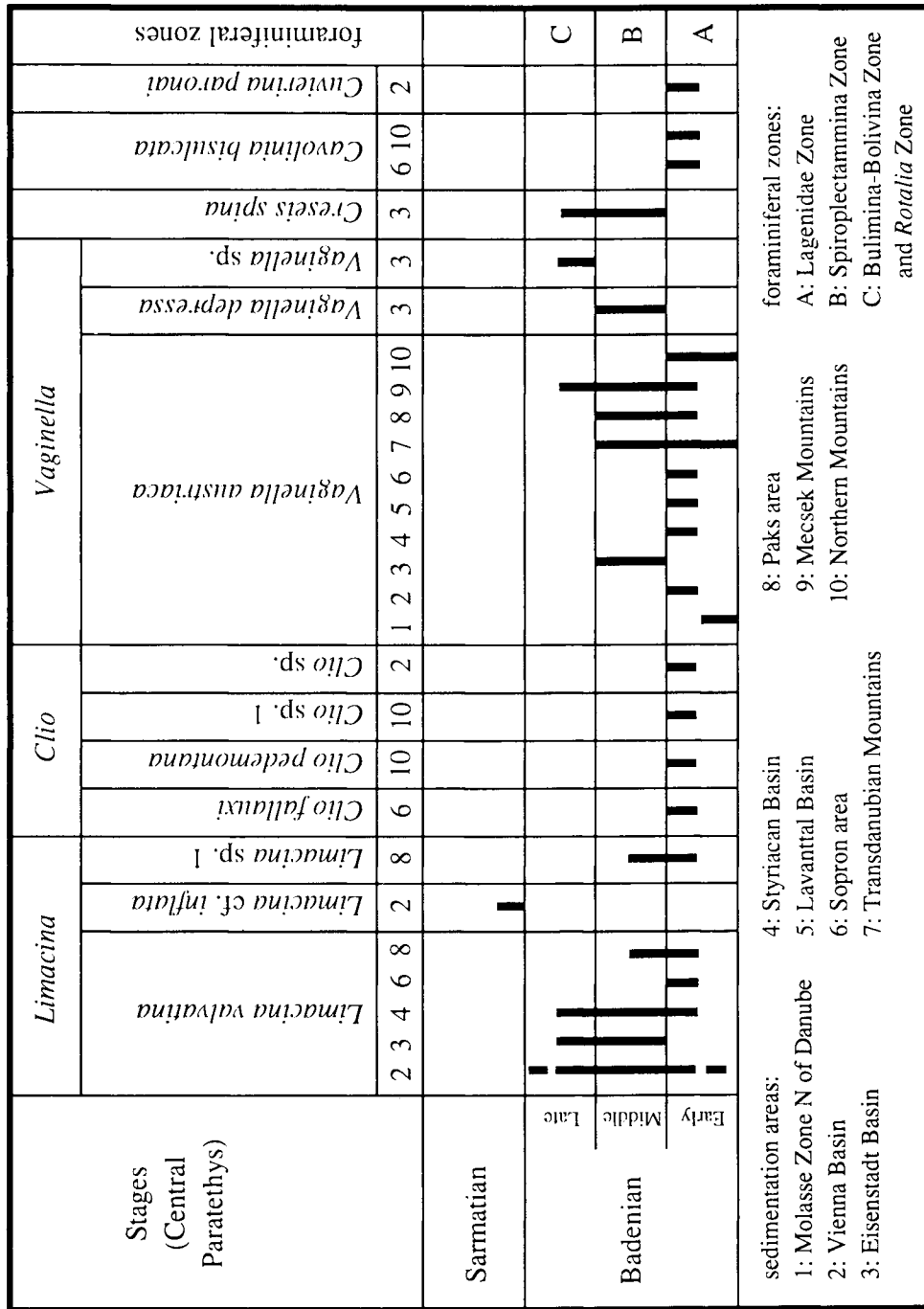


Fig. 2. Stratigraphic ranges of the Austrian and Hungarian pteropods in the different sedimentation areas. The Tapolca and Várpalota basins are taken together as Transdanubian Mountains, and the Börzsöny Mountains, the Cserhát Mountains, the Borsod Basin and Hidasnémeti are combined into the Northern Mountains.

mented by the Aderklaa boreholes in the Vienna Basin and the borehole Blumau-1 in the Styriac Basin. *Limacina* shows a mass occurrence at the base of the Late Badenian in both basins (Čtyroký et al., 1968; Kollmann & Rögl, 1978). This mass occurrence is known from many areas in the Central and Eastern Paratethys.

Other localities where *L. valvatina* occurs are in the Vienna Basin Baden-Sooß and Vöslau (Upper Lagenidae Zone), the Mannsdorf-1 borehole (*Spiroplectammina* Zone) and the Hainburg boreholes (*Bulimina-Bolivina* Zone). In the Eisenstadt Basin this species is known from the Middle (Rohrbach) and Late Badenian (Walbersdorf). In the Molasse Zone and the Lavanttal Basin it has not been found, but for the 'Mühl-dorfer Schichten' from the Lower Lavanttal, which correspond to the Upper Lagenidae Zone, Beck-Mannagetta (1952) mentions the find of a pyritised '*Spirialis*'. It is very likely that this record belongs to *L. valvatina*.

Vaginella austriaca is most abundant in the Upper Lagenidae Zone known from the Vienna Basin (Baden, Baden-Sooß, Vöslau, and borehole Aderklaa-78), the southern Styriac Basin (near Fuggaberg; pers. comm. F. Stojaspal, Vienna) and the Lavanttal Basin (Mettersdorf). In the Molasse Zone it is only found in the Lower Lagenidae Zone (Grund). It has also been found in the *Spiroplectammina* Zone of the Eisenstadt Basin (Rohrbach, Forchtenau).

Clio sp., as well as *Cuvierina paronai*, are restricted to the Upper Lagenidae Zone of the Vienna Basin, and found in Vöslau and Baden-Sooß respectively. *Limacina* cf. *inflata* was found to be the only pteropod species in the Early Sarmatian (boreholes Aderklaa-82 and -92).

Two species which were only documented in the Eisenstadt Basin are *Creseis spina* and *Vaginella depressa*. *C. spina* is recorded from the *Bulimina-Bolivina* Zone (Walbersdorf) and the *Spiroplectammina* Zone (Rohrbach), and *V. depressa* from the *Spiroplectammina* Zone (Forchtenau).

Pteropod occurrences in the Middle Miocene of Hungary

Middle Miocene deposits yielding pteropods can be encountered in a large area in Hungary. Their detailed study has been greatly promoted by an intensive exploration activity carried out in the past decades. SW Transdanubia and the Great Hungarian Plain so far have not yet been explored for pteropods, but a number of occurrences of planktonic gastropods are known near Sopron, the Little Hungarian Plain, near Paks, and in the Miocene basins in the Mecsek Mountains, the Transdanubian and the Northern Mountains (Fig. 1).

The results obtained during the recent studies of pteropods provide the opportunity to perform a preliminary evaluation of the biostratigraphy. This is enhanced by the fact that a number of localities of Miocene pteropods have already been subject to up-to-date stratigraphic study and results from nannoplankton and foraminifer examinations have been available. Moreover, an integrated stratigraphic analysis of several new localities is in the course of being executed, allowing for co-ordinated nannoplankton, foraminifer, and pteropod examinations, as well as magnetostratigraphic, isotope-stratigraphic and radiometric dating. All these provide a firm basis for the development of the biostratigraphy based on planktonic gastropods in Hungary.

Pteropods that have so far been identified in the Badenian deposits in Hungary are

Limacina valvatina, *Limacina* sp. 1, *Clio fallauxi* (Kittl, 1886), *Clio pedemontana* (Mayer, 1868), *Clio* sp. 1, *Vaginella austriaca*, and *Cavolinia bisulcata* (Kittl, 1886). The pteropods are most frequently encountered in the open-water Badenian Clay and Szilágyi Clayey Marl Formations.

As shown by our examinations performed hitherto, the greatest diversity is shown by the deposits assigned to the Badenian Clay Formation near Sopron (four species) and in the Northern Mountains (five species). As far as the other localities are concerned only from one to three species are identified at each locality.

The number of specimens is generally small (1 to 15), except for *Vaginella austriaca* (15 to 20) and *Limacina valvatina*, that has been identified in mass occurrence (150) in a single locality (Paks 4/c).

Vaginella austriaca is the pteropod showing the greatest spatial and temporal distribution in the Badenian of Hungary. It is very frequently encountered in the nannoplankton zone NN5. However, it could not be found in nannoplankton zone NN6, even not in boreholes in which this species is frequently encountered in the deeper parts of the section, i.e. NN5 (boreholes Nagygörbő-1, Paks-4/c, Tekeres-1, and Szokolya-2). Of the seven pteropod species identified in the Hungarian Badenian *V. austriaca* is the only one occurring in the Lower Lagenidae Zone (Tapolca Basin, Cserhát Mountains, Borsod Basin) and can be found at virtually all localities of deposits assigned to the Upper Lagenidae Zone, accompanied by *Limacina valvatina*, *Limacina* sp. 1 and *Cavolinia bisulcata*. In the *Spiroplectammina* Zone it has been recorded from three areas (Tapolca Basin, Mecsek Mountains and the vicinity of Paks), accompanied by *Limacina valvatina*. From the *Bulimina-Bolivina* Zone it has been collected at a single locality (W Mecsek Mountains), without further associated pteropod species.

The occurrence of *Vaginella rzehaki* Kittl, 1886 was recorded from the Badenian argillaceous deposits assigned to the Upper Lagenidae Zone near Szokolya (Báldi, 1960a, b). Recently, however, this taxon was synonymised with *Vaginella austriaca* (see Janssen & Zorn, 1993).

The pteropod species exhibiting the second greatest areal distribution is *Cavolinia bisulcata*, which is found near Sopron (borehole Sopron-89), Szokolya (borehole Szokolya-2) and in the Borsod Basin (boreholes Putnok-5 and SÁta-75). Its occurrence is restricted to the Early Badenian, nannoplankton zone NN5 and the Upper Lagenidae Zone. Near Sopron its accompanying pteropod species are *Vaginella austriaca*, *Clio fallauxi* and *Limacina valvatina*, in the Borsod Basin it is found together with *Clio pedemontana* and *Vaginella austriaca*, and near Szokolya with *Vaginella austriaca*.

The genus *Limacina* is represented by two species, viz. *Limacina valvatina* and *Limacina* sp. 1. The latter is known from one borehole only (Paks 4/c), whereas the former could be identified in three boreholes (Sopron-89, Balf-3 and Paks-4/c). In localities near Sopron, assigned to the Upper Lagenidae Zone, as well as in the upper part of borehole Paks-4/c *L. valvatina* occurs as a single specimen only. However, mass occurrences of this species are found in deposits penetrated by borehole Paks-4/c in the depth range of -560 to -566 m. This part of the borehole is assigned to nannoplankton zone NN5 (M. Báldi-Beke, pers. comm.). It is found together with *Clio fallauxi* near Sopron and with *Vaginella austriaca* near Paks.

The genus *Clio* is represented by three species in the Badenian deposits in Hungary, viz. *Clio fallauxi*, *C. pedemontana*, and *Clio* sp. 1. They are known from two areas

and only in Early Badenian deposits. *C. fallauxi* is encountered near Sopron, in the Upper Lagenidae Zone, together with *Limacina valvatina*, *Vaginella austriaca* and *Cavolinia bisulcata*. *Clio pedemontana* and *Clio* sp. 1 are only known from sediments assigned to nannoplankton zone NN5 in the Borsod Basin, occurring together with *Cavolinia bisulcata* and *Vaginella austriaca*.

Summarizing it can be stated that pteropods occur, wherever the appropriate biofacies is present, almost throughout the Badenian of Hungary, although with varying frequencies and geographical distribution. No pteropods have so far been found in the Sarmatian of Hungary.

Correlation of palaeomagnetic, nannoplankton and pteropod data from Hungarian boreholes

In Hungary most of the Middle Miocene pteropod occurrences are known from boreholes. These were examined for both foraminifers and nannoplankton. The stratigraphic range of pteropods within the Badenian has been correlated with Grill's (1941, 1943) foraminiferal zones, commonly used for the local stratigraphy in the Vienna Basin, and with the nannoplankton zones. For the latter the following correlation has been used: the Lower and Upper Lagenidae Zone correspond to the upper part of zone NN5, the *Spiroplectammina* Zone correlates with zone NN6 and the *Bulimina-Bolivina* Zone with zone NN7.

In Fig. 3 the vertical distribution of pteropods within zone NN5 is plotted for a few boreholes of major importance (Nagyvarosy, 1985). Pteropods occur in the Hungarian Badenian only in the upper part of zone NN5, and they are hardly found in the Lower Lagenidae Zone, where only small numbers of *Vaginella austriaca* were found. Subsequently, this species is followed in the Upper Lagenidae Zone by *Limacina valvatina*, *Limacina* sp. 1, *Clio pedemontana*, *Clio fallauxi*, *Clio* sp. 1, and *Cavolinia bisulcata*. This increasing diversity coincides with an important increase in numbers of specimens and of the geographical distribution.

After this 'acme', which can be well-dated as it does not exceed the upper boundary of zone NN5, the amounts of pteropods show an abrupt and rapid decrease. Deposits correlated with zone NN6 do not yield pteropods, and the major part of our data even reflect the complete absence of planktonic gastropods. On the other hand, *Limacina* and *Vaginella* have been identified from the *Spiroplectammina* Zone in three areas, suggesting that the lower boundaries of nannoplankton zone NN6 and the *Spiroplectammina* Zone are not synchronous.

The *Bulimina-Bolivina* Zone contains a poor pteropod fauna (*Vaginella austriaca*, *Vaginella* sp.) in Hungary. The 'Limacina-bearing horizon' that is encountered over vast areas in the Paratethys has so far not been identified in Late Badenian deposits in Hungary.

Two boreholes containing pteropods were also subject of palaeomagnetic tests, viz. Sopron-89 and Berhida-3, and the results support the above-mentioned examinations. The Karpatian/Badenian boundary is generally dated at 16.8 Ma BP. For the borehole Berhida-3 the first appearance of *Vaginella* is assumed at 16.5 Ma BP (Kókay et al., 1991). In the borehole Sopron-89 *Vaginella austriaca* appears at around 16.7 Ma BP, and *Clio fallauxi*, *Cavolinia bisulcata* and *Limacina valvatina* appear at about 16.5 Ma

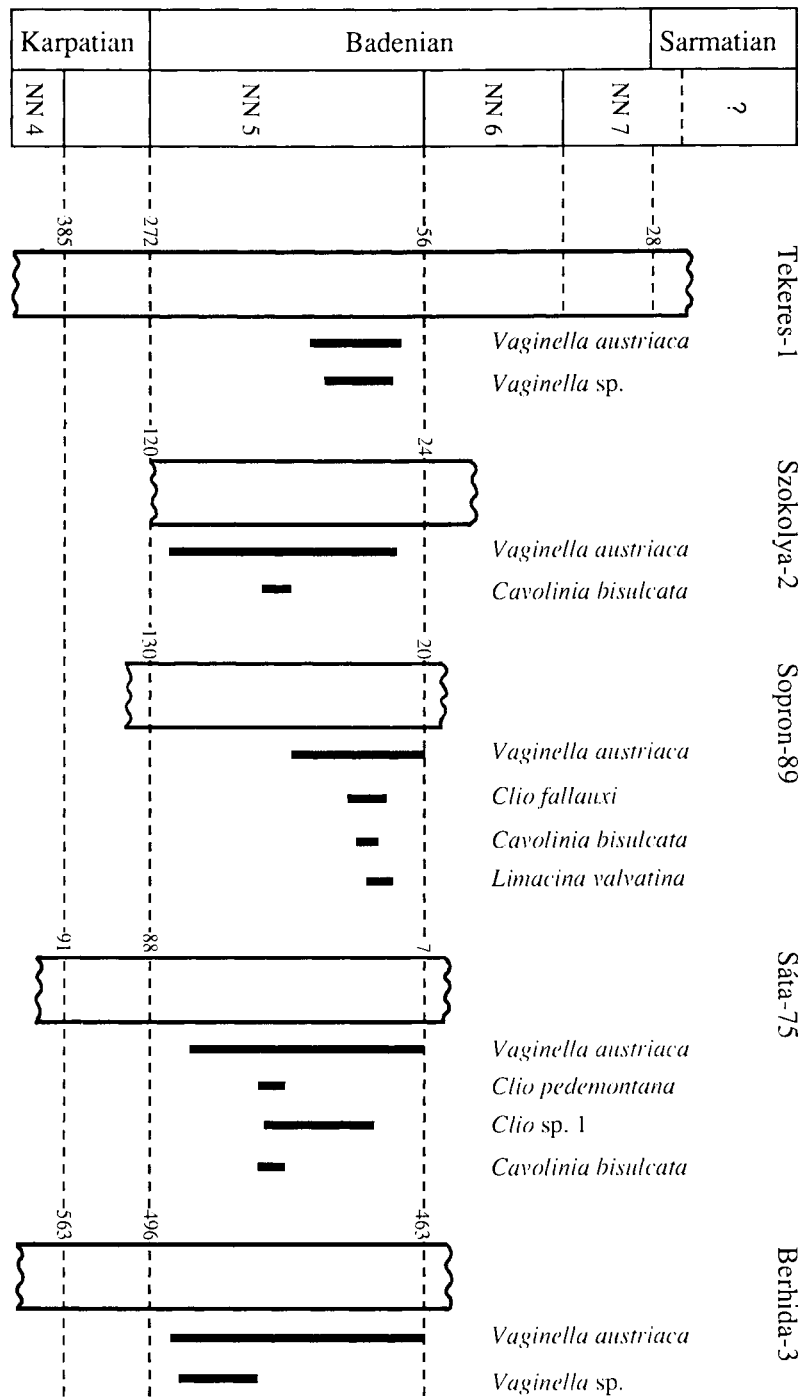


Fig. 3. Occurrence of pteropod species within nannoplankton zone NN5 for some Hungarian boreholes.

BP (M. Lantos, written comm.). In these boreholes too, *Vaginella* is the first pteropod to appear, later followed, at almost the same level, by the other pteropod species.

Comparison between the Austrian, Hungarian and Polish results in the Badenian

The information on the Polish pteropods is taken from Janssen & Zorn (1993). There appear to be only two species which occur in all three countries Austria, Hungary and Poland, viz. *Limacina valvatina* and *Vaginella austriaca*. Whereas in Austria and Poland *L. valvatina* is found in almost all strata of Badenian age, it is absent during the Late Badenian of Hungary. *V. austriaca*, on the contrary, is absent from the Late Badenian of Austria and Poland, whilst it is present in Hungary.

In the Lagenidae Zone quite a number of species are found, that are restricted to this zone. *Clio fallauxi* and *C. pedemontana* are known from Hungary and Poland. In Austria we only found one protoconch of *Clio*, which cannot be identified at the species level. *Cuvierina paronai* is recorded from Austria, and *Cavolinia bisulcata* from Hungary. In Poland *Limacina miostralis* (Kautsky, 1925) and two pseudothecosomatid species occur, viz. *Peracle lata* (Krach, 1979) and *Peracle* sp. In Austria *L. miostralis* is found in the Karpatian. *Styliola subula* (Quoy & Gaimard, 1827), recorded from the Early Badenian of Poland, is probably also present in the Late Badenian.

In the Middle and Late Badenian only few species are known which are restricted to these parts. In the Late Badenian *Limacina gramensis* (Rasmussen, 1968) is represented in Poland and *Vaginella* sp. in Austria. *Vaginella depressa* is known from the Middle Badenian of Austria.

Creseis spina is documented for the Early and Middle Badenian of Poland, and for the Middle and Late Badenian of Austria. Additionally, in Hungary *Limacina* sp. 1 occurs in the Early and first half of the Middle Badenian, and *Clio* sp. 1 in the Early Badenian.

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