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Original scientific paper

Biostatistic analyses of newly found pteropods (Mollusca, Gastropoda) in the Middle Miocene (Badenian) deposits from the southeastern Medvednica Mt. (Northern Croatia)

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Abstract

Fossil Pteropoda (Gastropoda, Thecosomata) have been recorded in the Badenian marine deposits of the Medvednica Mt. in the area of Čučerje and Marija Bistrica. During the new research of the Middle Miocene deposits in the southeastern part of the Medvednica Mt., new pteropods were found at the Goranec locality. They are preserved as casts and molds, jug shaped and determined as genus *Vaginella* Daudin, 1800. Biostatistics is a crucial tool in vaginellid species-level determination, which is often problematic due to their similar shell morphology and poor preservation. Based on the height, width and apical angle measurements of the collected casts and molds, biostatistical analysis were made and compared with the previous analysis of vaginellids from the Čučerje area. Majority of the specimens belong to *Vaginella austriaca* Kittl, 1886, which is the most abundant pteropod species in the Miocene deposits of the Paratethys. Here presented pteropod records point to the maximum of the Badenian marine transgressions, and contribute to the further palaeoecological and palaeogeographical research in the southwestern part of the Central Paratethys, Pannonian Basin System.

Keywords: Biometry, Pteropoda, *Vaginella austriaca*, Badenian, Medvednica Mt.

1. Introduction

Holoplanktic gastropods, pteropods, have wide horizontal marine distribution and represent an important group in palaeoclimatic, palaeoecological and palaeoceanographic research. Their rapid morphological evolution makes them excellent index fossils (**Pierrot-Bults and Peijnenburg, 2015**). Miocene pteropods are known from various localities from the Pannonian Basin System area, and some of them are index fossils widely used in biostratigraphic research of the Middle Miocene deposits of the Paratethys area (e.g. **Bohn-Havas and Zorn, 1993, 1994, 2002; Bohn-Havas et al., 2004; Zorn, 1991, 1995, 1999**). Their time appearance is also connected with the peaks of the Middle Miocene marine transgressions in the Paratethys (e.g. **Bošnjak et al., 2017 and references therein**). In the Northern Croatia area, which represents the southwestern margin of the Pannonian Basin System (e.g. **Pavelić & Kovačić, 2018 and references therein**), pteropods are recorded in the marine Middle Miocene (Badenian) deposits of the Medvednica Mt. (**Gorjanović-Kramberger, 1908; Kochansky, 1944; Bosak, 2017; Bošnjak et al. 2017**). During the new research of the Badenian deposits in the southeastern part of the Medvednica Mt., new pteropods were found at the Goranec locality (**Figure 1**) (**Derežić, 2018**). They are preserved as casts and molds, belonging to families Cavoliniidae Gray, 1850 and Limacinidae Gray, 1840, which are recorded in this area of the Medvednica Mt. for the first time. Most of the collected specimens belong to the family Cavoliniidae, genus *Vaginella* Daudin, 1800. Biostatistics is a crucial tool in vaginellid species-level determination, which is often problematic due to their similar shell morphology and poor preservation. Based on the height, width and apical angle measurements of the collected casts and molds, biostatistical analyses were made and compared with the previous analyses of vaginellids from the Čučerje area.

Goals of this research were to analyse and describe new pteropod findings on the Medvednica Mt. and to compare them with previous findings from this area in order to contribute to the knowledge of the Badenian marine environments and biostratigraphy of the Middle Miocene in northern Croatia.

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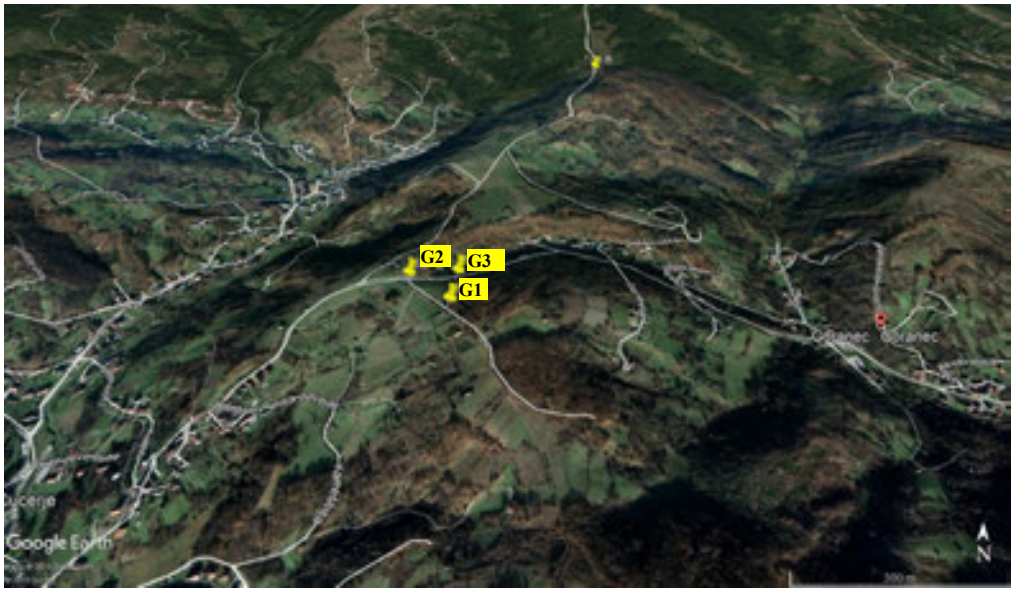

Figure 1: Location map of the investigated area near Goranec locality (**Google Earth**, September 2018). Yellow pins mark here presented investigated outcrops.

2. Methods

During the field research in 2017 the Miocene deposits of the Goranec locality near Čučerje on the SE slopes of the Medvednica Mt. were analysed. Pteropods were collected from three outcrops of the Badenian „pteropod marls" (**Figure 1**), marked as G1 (coordinates 45°53'48.74"N, 16°4'7.58"E), G2 (coordinates 45°53'51.94"N, 16° 4'3.56"E) and G3 (coordinates 45°53'52.12"N, 16° 4'7.94"E).

Collected material was analysed in the Department of Geology and Paleontology, Faculty of Science, University of Zagreb. Laboratory work included wet sieving technique. From each of the three collected samples, 30 dag was crushed and soaked into water with H_2O_2. After 24 hours' samples were sieved through meshes sizes 1000, 500, 250, 125 and 63 μm. Dry specimens were analysed under the stereomicroscope Olympus-SZX10 and photographed with Canon EOS 1100D camera. Photographs were saved in the Quick PHOTO CAMERA 3.0 programme.

Pteropods were analysed in the Croatian Natural History Museum in Zagreb. Vaginellids collected at localities G2 and G3 were chosen for the biostatistical analysis due to the numerous well preserved casts and molds. Specimens were cleaned, photographed, marked with temporary inventory numbers: G-2_L1 to G-2_L15 and G2-D1 to G2-D23 from locality G-2, and G3-1 to G3-38 from locality G3. Collected pteropods are housed in the Croatian Natural History Museum in Zagreb. Height, width and apical angle of the well preserved casts and molds were measured for the biostatistic analyses (**Figure 2**). All measured data were analyzed in the MS Excel program and biostatistic analyses of pteropods was based on the shell height/width ratio and apical angle histograms. Pteropod determination was based on the available literature (**Kittl, 1886; Janssen, 1984; Zorn, 1991, 1999; Janssen and Zorn, 1993, Cahuzac and Janssen, 2010**).

Associated fauna comprised foraminifera, calcareous nannoplankton, ostracods, spicules, echinoids, scaphopods and macrofossils (crustaceans, bivalves, dwellers, fish remains and fossil flora remains). More detailed analysis of associated fauna can be found in **Derežić (2018)**, and for the purpose of this paper only pteropod analyses are presented.

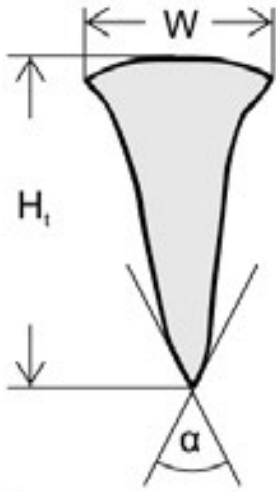

Figure 2: Measured elements of the vaginellids casts and molds from localities G-2 and G-3, Goranec area; W-shell width, H-shell height, α-apical angle (modified after **Bošnjak et al., 2017**).

3. Results

Pteropods on localities G2 and G3 were collected form marls, and total 74 casts and molds of *Vaginella* species were determined (**Figure 3**). Also, other representatives of the family Cavoliniidae were found on the investigated localities G2 and G3, and the representative of the Limacinidae on localities G1 and G3. Vaginellid specimens were the most abundant and for that reason chosen for the biostatistical analyses.

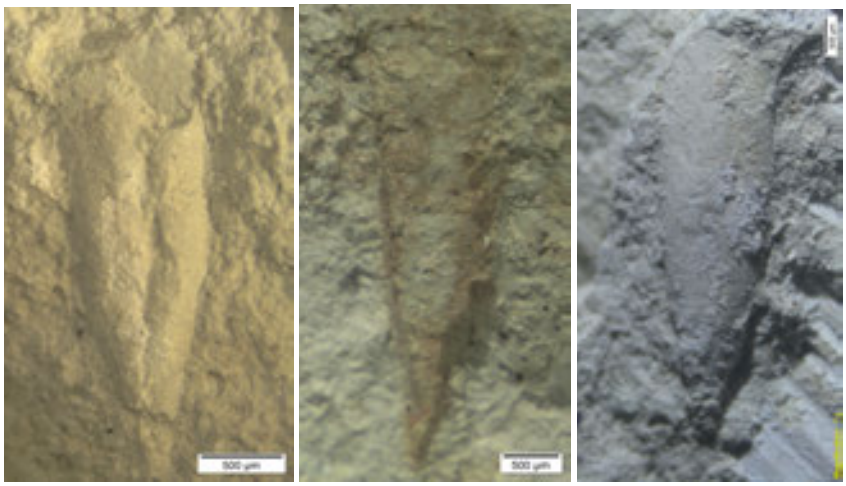

Figure 3: Part of the collected specimens of *Vaginella austriaca* Kittl, 1886 from investigated outcrops: a) specimen G2-L13, outcrop G2; b) specimen G2-L7, outcrop G2; c) specimen G3_20, outcrop G3. Position of the outcrops is shown on **Figure 1**.

Vaginellids have a similar shell morphology, mostly straight, elongated and jar shaped (e.g., **Kittl, 1886; Janssen, 1984; Zorn, 1991; Cahuzac and Janssen, 2010**). In the analysed material most of the vaginellid casts and molds are poorly preserved, and their complete shell is missing. Protoconch is rarely preserved and aperture is missing, it is

damaged or not visible, as well as shell ornamentation of the collected specimens. Vaginellid species-level determination is problematic due to the poor preservation and similar shell morphology, making the biostatistics an inevitable tool in vaginellid determination. Based on the here presented biostatistics analyses and comparation with previous research (e.g. **Bošnjak et al. 2017**) majority of the specimens were determined as *Vaginella austriaca* Kittl, 1886 (**Figure 3**), which is the most abundant pteropod species in the Miocene deposits of the Paratethys.

In analysed specimens shell height (H), width (W) and apical angle (α) were measured (**Figure 2**). **Table 1 and 2** show measured elements of vaginellids, and on **Figure 4 and 5** are shown their shell height/width ratio and apical angle ranges. The abovementioned elements could be measured in all specimens, except for the apical angle in two specimens (**Table 1**, locality G-2) due to the poor preservation, but the specimens were included in biostatistics because of their shell preservation.

Table 1. Measured vaginellids elements, outcrop G2.

SAMPLE	WIDTH, W (mm)	HEIGHT, H (mm)	APICAL ANGLE, α (°)
G-2_L1	1,14	3,25	27
G-2_L2	1,05	3,02	23
G-2_L3	1,3	3,84	20
G-2_L4	1,4	2,44	30
G-2_L5	1,14	1,53	35
G-2_L6	1,4	2,86	37
G-2_L7	1,07	3,75	31
G-2_L8	1,05	3,45	35
G-2_L9	0,89	2,25	21
G-2_L10	2,14	4,02	34
G-2_L11	1,65	4,12	40
G-2_L12	1,25	2,55	31
G-2_L13	1,51	3,4	28
G-2_L14	1	2,02	23
G-2_L15	1,19	1,79	21
G-2_D1	1,57	4,19	21
G-2_D2	0,98	2,43	22
G-2_D3	1,15	2,53	30
G-2_D4	1,93	4,09	32
G-2_D5	1,7	3,32	12
G-2_D6	0,98	2,66	33
G-2_D7	1,33	2,15	29
G-2_D8	0,91	2	28
G-2_D9	0,77	1,53	28
G-2_D10	1,64	3,36	18
G-2_D11	1	2,95	26
G-2_D12	1,2	2,06	/
G-2_D13	1,09	1,93	27
G-2_D14	0,8	2,25	31
G-2_D15	1,05	2,59	25
G-2_D16	0,94	2,86	25
G-2_D17	1,3	2,63	28
G-2_D18	0,74	1,86	12
G-2_D19	0,7	1,81	/
G-2_D20	1,25	3	32
G-2_D21	1,77	3,79	39
G-2_D22	2,55	3,05	25
G-2_D23	0,99	2,52	32

Table 2. Measured vaginellids elements, outcrop G3.

SAMPLE	WIDTH, W (mm)	HEIGHT, H (mm)	APICAL ANGLE, α (°)
G-3_1	0,93	3	25
G-3_2	1,4	4,23	37
G-3_3	1,16	4,44	14
G-3_4	1,65	4,14	34
G-3_5	0,86	2,2	21
G-3_6	1,07	2,75	26
G-3_7	1,91	3,79	37
G-3_8	1,23	3,81	29
G-3_9	1,44	3,21	35
G-3_10	0,77	3,09	18
G-3_11	1,14	2,21	11
G-3_12	1,21	2,79	32
G-3_13	1,26	2,6	19
G-3_14	0,9	2,09	21
G-3_15	1,27	4,26	20
G-3_16	0,86	2,72	22
G-3_17	0,68	4,11	14
G-3_18	0,72	2,59	27
G-3_19	1,02	2,93	27
G-3_20	1,58	5,51	24
G-3_21	1,14	2,88	34
G-3_22	1,16	3,16	27
G-3_23	1,26	3,53	20
G-3_24	1,02	3,77	31
G-3_25	1,48	3,86	30
G-3_26	1,07	2,72	24
G-3_27	1,23	3,19	25
G-3_28	1,26	3,37	28
G-3_29	0,89	2,91	17
G-3_30	1,09	2,65	20
G-3_31	0,91	2,67	19
G-3_32	0,88	3,12	23
G-3_33	0,93	3,07	25
G-3_34	1,16	3,95	22
G-3_35	1,19	3,17	32
G-3_36	0,79	1,84	35
G-3_37	0,77	2,86	24
G-3_38	0,82	2,61	22

Shell height/width ratios of vaginellids (**Figure 4a and 5a, Table 1 and 2**) show their similar height and width range, which fits well with previous research on vaginellids from Medvednica Mt. and the Central Paratethys area as well (**Bošnjak et al., 2017 and references therein**). Apical angle values are in the range typical of vaginellid species, and it can be seen on **Figures 4b and 5b** that most of the specimens have values between 20° and 40°, typical for *Vaginella austriaca* species (e.g. **Cahuzac and Janssen, 2010**).

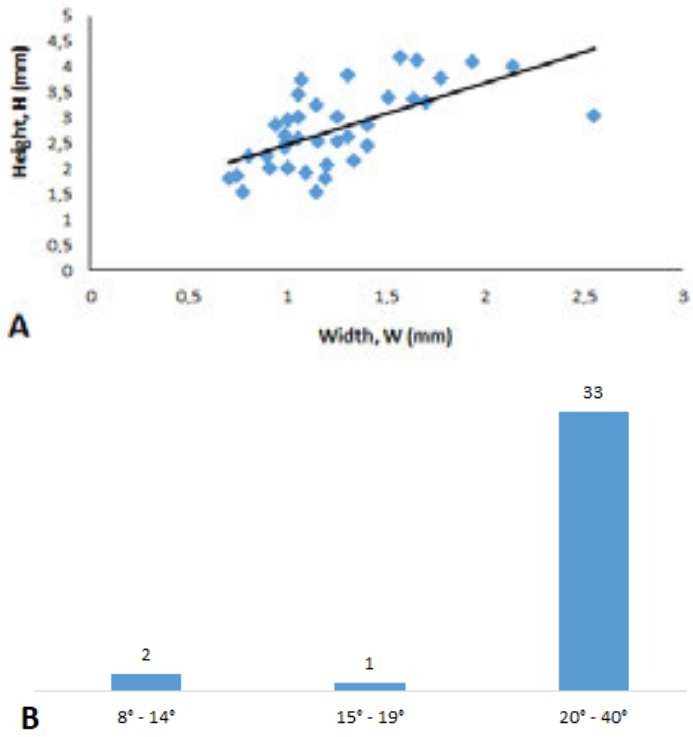

Figure 4: Biostatistical analysis of *Vaginella austriaca* Kittl, 1886 from locality G-2. **a)** shell height and width ratio; **b)** apical angle values.

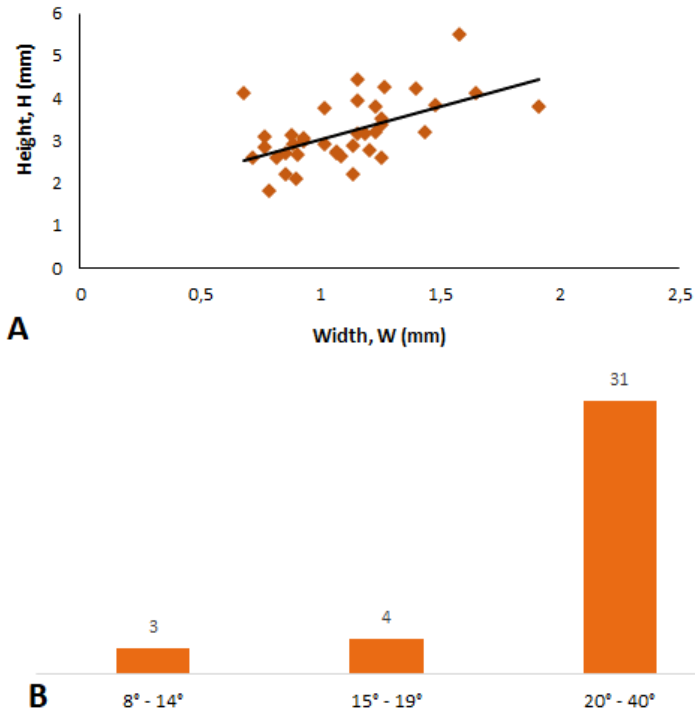

Figure 5: Biostatistical analysis of *Vaginella austriaca* Kittl, 1886 from locality G-3. **a)** shell height and width ratio; **b)** apical angle values.

4. Discussion

Vaginella species have variable morphology, on the species level and on the inter-species level, which together with their poor preservation mostly as casts and molds makes their species-level determination difficult (e.g. **Zorn, 1991; Janssen and Zorn, 1993; Cahuzac and Jannsen, 2010**). During the vaginellid evolution in Miocene their shell became more elongated, and several *Vaginella* species have a similar shape. Therefore, their determination can be based on statistics of shell morphology, taking the apical angle value as one of a distinguishing characteristic. However, that can be the case only in very well preserved specimens. Although the here presented vaginellids are poor preserved, apical angle values were additional diagnostic element for part of the collected specimens which could be determined. **Cahuzac and Janssen (2010)** describe apical angle values for *Vaginella* species, and here present specimens (**Table 1 and 2, Figure 4 and 5**) comprise ranges of *V. austriaca* (20°-40°), *V. acutissima* (c. 15°-18°) and *V. lapugyensis* (c. 8°-13°). As seen on **Figures 4b and 5b** most specimens show apical angle values typical for *Vaginella austriaca* species. Several specimens have apical angle values which correspond to *V. acutissima* and *V. lapugyensis* species (e.g. **Cahuzac and Janssen, 2010**) (**Figures 4b and 5b**), but they were determined as *V. austriaca* as well. Vaginellid casts and molds can be altered due to the diagenetic processes, and their shape and dimensions could be changed. That could be one of the reasons why several specimens have lower apical angles than 20° (**Figures 4b and 5b**), the lower limit for *V. austriaca* species, and the morphology and height/width ratio of the shell similar as the other specimens. These results are also in accordance with previous research from Medvednica Mt. (e.g. **Bošnjak et al., 2017**). Bearing all that in mind, specimens were determined as *Vaginella austriaca*.

The oldest pteropod findings have been found in the Middle Eocene deposits, and the most abundant pteropod records are in the Middle Miocene deposits connected with the timing of the marine transgressions (e.g. **Zorn, 1991; Bohn-Havas and Zorn, 1993, 194; Bohn-Havas et al., 2004**). Most various and numerous pteropods from the Miocene deposits of the Central Paratethys are *Clio* Linnaeus, 1767, *Limacina* Bosc, 1817 and *Vaginella* Daudin, 1800. *Vaginella austriaca* species is considered as the most widespread geographical and stratigraphical pteropod species in the Badenian of the Central Paratethys (**Janssen, 1984; Zorn, 1991, 1995, 1999; Bohn-Havas and Zorn, 1993, 1994; Bohn-Havas et al., 2004**). Time range of recorded *Vaginella austriaca* in the Miocene deposits of the Paratethys area corresponds to the peak of the Middle Miocene marine transgressions (e.g. **Rögl et al., 2007; Zorn, 1991; Bohn-Havas et al., 2004; Bošnjak et al., 2007 and references therein**).

Vaginella austriaca was recorded on the Medvednica Mt. in Čučerje area by **Gorjanović-Kramberger (1908)**, **Kochansky (1944)**, **Basch (1983)**, **Avanić et al. (1995)**, **Bosak (2017)** and **Bošnjak et al. (2017)**. In the area of the Paratethys Sea, this species is recorded in the Middle Miocene deposits of Austria (Karpatian, Badenian; after **Janssen 1984; Bohn-Havas and Zorn 1993, 1994; Janssen and Zorn 1993; Zorn 1991, 1999**), Bulgaria (Badenian after **Zorn, 1999** and **Nikolov, 2010**), Czech (Karpatian and Lower Badenian after **Zorn 1991, 1999**), Poland (Lower and Middle Badenian; after **Zorn 1991, 1999; Bohn-Havas and Zorn 1993, 1994; Janssen and Zorn 1993**), Hungary (Lower Badenian after **Zorn, 1991; Bohn-Havas and Zorn, 1993, 1994; Bohn-Havas et al. 2004**; and NN5 nannozone after **Bohn-Havas and Zorn, 1993; Bohn-Havas et al., 2004 and Selmeczi et al., 2012**), Romania (Lower Badenian after **Zorn 1991, 1999; Janssen and Zorn 1993; Bohn-Havas and Zorn 1994**), Slovenia (**Mikuž et al. 2012 and references therein**), Serbia (**Stevanović 1974**). Outside Paratethys this species is known from the Miocene deposits of the Mediterranean area (e.g. **Zorn, 1991; Janssen and Little, 2010**), North Sea Basin (e.g. **Cahuzac and Janssen, 2010; Janssen, 2012 and references therein**) and the Aquitaine Basin (e.g. **Cahuzac and Janssen, 2010 and references therein**).

5. Conclusions

Simply shaped tests of cavoliniid pteropods are not easy to determine on the species level. Simple statistic methods, taking into consideration height/width ratio and apical angle value can be of great help in this process.

High abundance of cavoliniid specimens collected in the research area (Goranec near Čučerje, Medvednica Mt.), similar to the other parts of the Paratethys Sea, provide a good foundation for statistical analyses. On the other side, poor preservation and plastic deformation complicate the biometrical analyses.

Biostatistical research has shown that most of the collected specimens belong to the cavoliinid species *Vaginella austriaca*, making it the most abundant pteropod during the Miocene in the research area, similar to the whole Paratethyan pelagic realm.

6. References

Avanić, R., Pavelić, D., Brkić, M., Miknić, M. and Šimunić, A. (1995): Lapori i biokalkareniti Vejalnice [*Marls and biocalcarenites from Vejalnica*]. In: Šikić, K. (Ed.): Geološki vodič Medvednice. Institute of Geology, Zagreb, INA-Industrija nafte, d.d., Zagreb, 159−164 (in Croatian).

Basch, O. (1983): Basic Geological Map of SFRY 1:100.000, Geology of the Ivanić-Grad sheet, L 33-81. Geološki zavod, Zagreb (1980), Savezni geološki zavod, Beograd, 1–66 (in Croatian).

Bohn-Havas, M. and Zorn, I. (1993): Biostratigraphic studies on planktonic gastropods from the Tertiary of the Central Paratethys. Scripta Geologica Spec. Issue 2, 57–66.

Bohn-Havas, M. and Zorn, I. (1994): Biostratigraphische Studien über planktonische Gastropoden im Mittel-Miozän von Österreich und Ungarn. Jubiläumsschrift 20 Jahre Geologische Zusam-menarbeit Österreich–Ungarn 2, 73–85.

Bohn-Havas, M. and Zorn, I. (2002): Biostratigraphic correlation of planktonic gastropods in the Neogene of the Central Paratethys. Bulletin T. CXXV. de l'Académir Serbe des Sciences et des Arts, Classe des Sciences mathématiques et naturelles, Sciences naturelles 41, 199−207.

Bohn-Havas, M., Lantos, M. & Selmeczi, I. (2004): Biostratigraphic studies and correlation of Tertiary planktonic gastropods (pteropods) from Hungary. Acta Palaeontologica Romaniae 4, 37−43.

Bosak, L. (2017): Dubokomorske miocenske naslage Vejalnice (sjeveroistočno od Čučerja) [*Deep marine Miocene deposits from Vejalnica (NE from Čučerje)*]. Diploma Thesis, University of Zagreb, Faculty of Science, Zagreb (in Croatian with English summary).

Bošnjak, M., Sremac, J., Vrsaljko, D., Aščić, Š. and Bosak, L. (2017): The „Miocene Pteropod event" in the SW part of the Central Paratethys (Medvednica Mt., northern Croatia). Geologica Carpathica, 68, 4, 329-349. doi: 10.1515/geoca-2017-0023.

Cahuzac, B. and Janssen A. W. (2010): Eocene to Miocene holoplanktonic Mollusca (Gastropoda) of the Aquitane Basin, southwest France. Scripta Geologica, 141, 1-193.

Derežić, I. (2018, submitted): Miocenski „pteropodni lapori" Goranca (okolica Čučerja, Medvednica) [Miocene „Pteropod marls" (vicinity of Čučerje, Medvednica Mt.]. Diploma thesis, University of Zagreb, Faculty of Science, Zagreb, submitted.

Gorjanović-Kramberger, D. (1908): Geologische Übersichtskarte des Königreiches Kroatien-Slavonien. Erläuterungen zur geologischen Karte von Agram, Zone 22, Col XIV. Nakl. Kralj. zemalj. vlade, Odjel za unut. poslove, Zagreb, 1–75 (in Croatian and German).

Janssen, A.W. (1984): Type specimens of pteropod species (Mollusca, Gastropoda) described by Rolle (1861), Reuss (1867) and Kittl (1886), kept in the collection of the Naturhistorsiches Museum at Vienna. Meded. Werkgr. Tert. Kwart. Geol., 21, 2, 61-91.

Janssen, A.W. (2012): Systematics and biostratigraphy of holoplanktonic Mollusca from the Oligo-Miocene of the Maltese Archipelago. Bolletino Museo Regionale di Storia Naturale di Torino 28, 2, 197−601.

Janssen, A.W. and Zorn, I. (1993): Revision of the Middle Miocene holoplanktonic gastropods from Poland, published by the late Wilhelm Krach. Scripta Geologica Special Issue 2, 155-236.

Janssen, A.W. and Little, C.T.S. (2010): Holoplanktonic Gastropoda (Mollusca) from the Miocene of Cyprus: systematics and biostratigraphy. Paleontology, 53, 5, 1111-1145.

Kittl, E. (1886): Ueber die miocenen Pteropoden von Oesterreich- Ungarn mit Berücksichtigung verwandter Vorkommnisse der Nachbarländer. Annalen des k.k. Naturhistorischen Hofmuseums, Bd. 1, Heft 2, 47−74 (in German).

Kochansky, V. (1944): Fauna marinskog miocena južnog pobočja Medvednice (Zagrebačke gore) [*Miozäne marine Fauna des südlichen Abhanges der Medvednica, Zagreber Gebirge*]. Geol. vjesnik Hrv. drž. geol. zav. Hrv. drž. geol. muz. 2/3, 171−280 (in Croatian with German summary).

Mikuž, V., Gašparič, R., Bartol, M., Horvat, A. and Pavšić, J. (2012): Miocene pteropods from Polički Vrh in Slovenske gorice, northeast Slovenia [*Miocenski pteropodi s Poličkega Vrha v Slovenskih goricah*]. Geologija, 55, 1, 67-76 (in Slovenian with English summary).

Nikolov, P. (2010): Holoplanktonic gastropods from the Middle Mio-cene of Bulgaria and their stratigraphical significance. National Conference with international participation "GEOSCIENCES 2010", Bulgarian Geological Society, 87−88 (in Bulgarian).

Pavelić, D. and Kovačić, M. (2018): Sedimentology and stratigraphy of the Neogene rift-type North Croatian Basin (Pannonian Basin System, Croatia): A review. Marine and petroleum geology, 91, 455-469.

Pierrot-Bults A.C. and Peijnenburg K.T.C.A. (2015): Pteropods. Encyclopedia of marine geosciences, Springer Science+Business Media, 1-10, ISBN 978-94-007-6644-0.

Rögl, F., Ćorić, S., Hohenegger, J., Pervesler, P., Roetzler, R., Scholger, R., Spezzaferri, S. and Stingl, K. (2007): Cyclostratigraphy and transgressions at the Early/Middle Miocene (Karpatian/Badenian) boundary in the Austrian Neogene basins (Central Paratethys). Scripta Facultatis Scientarium Naturalium Universitatis Masarykianae Brunensis, Geol. 36, 7-12.

Selmeczi, I., Lantos, M., Bohn-Havas, M., Nagymarosy A. and Szegő, E. (2012): Correlation of bio- and magnetostratigraphy of Badenian sequences from western and northern Hungary. Geologica Carpathica. 63, 3, 219−232.

Stevanović, P. (1974): Neue Paleogeographisch-Ökologische Beiträge zur Kenntnis des Tortons bei Belgrad. Académie Serbie des Sciences et des Arts, Classe des Sciences Mathématiques et Naturelles, Bulletin Tome LI No 13 (1973), Beograd, 1−13.

Zorn, I. (1991): A systemtic account of Tertiary pteropoda (Gastropoda, Euthecostomata) from Austria. Contributions to Tertiary to Quaternary Geology, 28, 4, 95-139.

Zorn, I. (1995): Planktonische Gastropoden (Euthecostomata und Heteropoda) in der Sammlung Mayer-Eymar im Naturhistorischen Museum in Basel. Eclogae Geologicae Helvetiae, 88, 3, 743-759 (in German).

Zorn, I. (1999): Planktonic gastropods (pteropods) from the Miocene of the Carpathian Foredeep and the Ždánice Unit in Moravia (Czech Republic). Abhandlungen der Geologischen Bundesanstalt, 56, 2, 723-738.
Google Earth, https://www.google.com/intl/hr/earth/

Abstract in Croatian

Biostatistička analiza novih nalaza pteropoda u srednjomiocenskim (badenskim) naslagama jugoistoične Medvednice (sjeverna Hrvatska)

Fosilni mekušci iz skupine pteropoda (Gastropoda, Thecosomata) do sada su bili zabilježeni u morskim badenskim naslagama Medvednice u okolici Čučerja i Marije Bistrice. Daljnjim istraživanjem srednjomiocenskih naslaga u jugoistočnom dijelu Medvednice, na lokalitetu Goranec, prikupljeni su novi brojni uzorci pteropoda vrčastog oblika, sačuvanih u obliku kamenih jezgri i otisaka. Na temelju njihove morfologije zaključeno je da pripadaju rodu *Vaginella* Daudin, 1800. U određivanju vrsta ove skupine često se primjenjuju biostatističke metode zbog slične morfologije kućice i lošeg fosilnog očuvanja, kada je razlikovanje vrsta otežano. Na temelju mjerenja visine i širine te apikalnog kuta kućice obrađenih primjeraka napravljena je biostatistička analiza, te usporedba s ranije zabilježenim nalazima ovoga roda u okolici Čučerja. Zaključeno je da većina primjeraka pripada vrsti *Vaginella austriaca* Kittl, 1886, koja je i inače najbrojnija vrsta pteropoda u miocenskim naslagama Paratethysa. Nalazi zabilježenih fosilnih pteropoda upućuju na maksimum morskih transgresija tijekom badena što doprinosi daljnjim paleoekološkim i paleogeografskim istraživanjima jugozapadnog ruba Centralnog Paratethysa, odnosno Panonskog bazenskog sustava.

Ključne riječi: biometrija, pteropodi, *Vaginella austriaca*, baden, Medvednica.