MAASTRICHTIAN CONTINENTAL GASTROPODS FROM FĂRCĂDEANA (RUSCA MONTANĂ BASIN, ROMANIA)

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Abstract. The Maastrichtian deposits are widespread in the Rusca Montană Basin, and yielded paleofloristic, palynological and vertebrate assemblages similar to those of the neighbouring Haţeg Basin. Although gastropods were mentioned from this area, they were only noted as co-occurrences of palynomorphs or vertebrates. This paper describes the freshwater and terrestrial gastropods recovered from the gray-blue mudstones of the Fărcădeana site. The gastropod assemblage includes representatives of Lymnaeidae, Planorbidae, Physidae, Bithyniidae and Cyclophoridae, again, all taxa being common to those previously mentioned from the coeval deposits of Haţeg Basin. The ecological preferences of the described taxa suggest that the deposits containing them accumulated in a poorly-drained floodplain or pond environment, supporting previous conclusions based on sedimentology and composition of the vertebrate assemblage.

Keywords: Pulmonata, microgastropods, Late Cretaceous.

Rezumat. Gastropode continentale maastrichtiene de la Fărcădeana (Bazinul Rusca Montană, România). Depozitele maastrichtiene au o răspândire largă în Bazinul Rusca Montană şi au furnizat asociaţii paleofloristice, palinologice şi de vertebrate similare celor din Bazinul Haţeg, situat în vecinătate. Deşi gastropodele au mai fost menţionate din această zonă, ele au fost doar notate ca ocurenţe alături de palinomorfe sau de vertebrate. Această lucrare descrie gastropodele dulcicole şi pe cele terestre recuperate din siltitele cenuşiu-albăstrui ale sitului Fărcădeana. Asociaţia de gastropode include reprezentanţi ai familiilor Lymnaeidae, Planorbidae, Physidae, Bithyniidae şi Cyclophoridae, toţi taxonii fiind comuni cu cei menţionaţi anterior din depozitele sincrone ale Bazinului Haţeg. Preferinţele ecologice ale taxonilor descrişi sugerează că depozitele care îi conţin s-au acumulat într-un mediu de câmpie inundabilă slab drenată sau de baltă, susţinând concluziile bazate pe sedimentologie şi pe compoziţia asociaţiei de vertebrate.

Cuvinte cheie: Pulmonata, microgastropode, Cretacicul târziu.

INTRODUCTION

The Rusca Montană Basin is an elongated intramountainous depression, located in the northwestern part of the Southern Carpathians, south of the Rusca Montană Massif and north of the Bistra Valley. It evolved as an active sedimentation area beginning with the Middle Jurassic, when marine sediments, today cropping out mostly in the western part of the basin, accumulated until the Campanian, with a short continental episode during the Albian, when the area was emerged, allowing the accumulation of bauxites (DINCĂ, 1977; BUCUR *et al*., 1983). The overlying Maastrichtian strata make up the thickest and the widest spread lithostratigraphic units of the basin, and are represented by continental deposits, occurring under two different lithofacies: a coarse, unfossiliferous, stratigraphically lower unit, which crops out west of the Rusca Valley, and an upper unit consisting of detritic-volcaniclastic deposits that dominates the area east of the Rusca Valley (Fig. 1) (DINCĂ, 1977; GRIGORESCU, 1990, 1992). The age of the latter unit was estimated based on palynological data, the recognized palynomorphs belonging to the *Pseudopapilopollis praesubhercynicus* zone (BALTEŞ, 1966; ANTONESCU *et al*., 1983). The deposits of this unnamed upper unit yielded a diverse compressive flora, including monocots (several species of *Pandanus*, "*Palmophyllum*" *longirachis*) and subtropical dicots (*Ficus, Credneria, Platanus, Myrtophyllum, Lindera*), as well as rare ferns (*Asplenium*, *Gleichenia*) (e. g. TUZSON, 1913; GIVULESCU 1966, 1968; PETRESCU & DUŞA, 1985), associated with a few thin coal beds (see DUŞA, 1987, for a review). The first Maastrichtian vertebrate remains in the region were reported by CODREA *et al*. (2009) from red, fine-grained overbank deposits and gray channel sandstones cropping out in the eastern part of the basin, and include chelonians, crocodylians, sauropods, ornithopods, theropods and multituberculates (for details see FEIGI *et al*., 2010; CODREA *et al*., 2012). VASILE & CSIKI (2011) described a microvertebrate assemblage from the Fărcădeana site, in the area of Negoiu village, containing anuran, albanerpetontid, crocodylian, lacertilian and theropod remains, as well as eggshell fragments.

The first to note the existence of gastropods in the coal-bearing deposits from Rusca Montană was BALTEŞ (1966), who recorded their presence, but without giving any taxonomical details. CODREA *et al*. (2009, 2012) also mentioned the occurrence of rare gastropods in the fine overbank deposits, alongside the vertebrate remains. More information is given by VASILE & CSIKI (2011), documenting the presence of freshwater and terrestrial gastropods including lymnaeids, helicids, planorbids and cyclophorids, but without describing the figured material. Part of that material, as well as other specimens, collected in 2010 and 2011, is described in more detail in this paper.

MATERIAL AND METHODS

Several red- or grey-coloured mudstone beds were sampled from the slopes of Fărcădeana Brook, a tributary of Negoiu Creek, in search of Maastrichtian microvertebrate remains. One of the red mudstone layers only yielded a few gastropod opercula, so it was not sampled any further. Most of the specimens come from the same 2 m thick layer of gray-blue mudstone that produced the fossil microvertebrate remains and fruits described by VASILE & CSIKI (2011).

The gastropod specimens, including fossilized shells, inner moulds, and isolated opercula, were obtained by screen-washing about 500 kilograms of sediment, using 0.71 mm and 2 mm mesh size sieves. The fossil material was sorted from the remaining sediment under a Zeiss-Stemi binocular microscope.

The images used in this paper were taken using a Hitachi S-2600N scanning electron microscope belonging to the Hungarian Natural Sciences Museum in Budapest.

Given the small size of the specimens, the numerical parameters were measured on the pictures, using the ImageJ 1.45s software. Each parameter was measured on all the available specimens, the description of the material including the range of the parameters, followed in brackets by the arithmetic mean of the measurements.

The classification and nomenclature follows that of BOUCHET & ROCROI (2005).

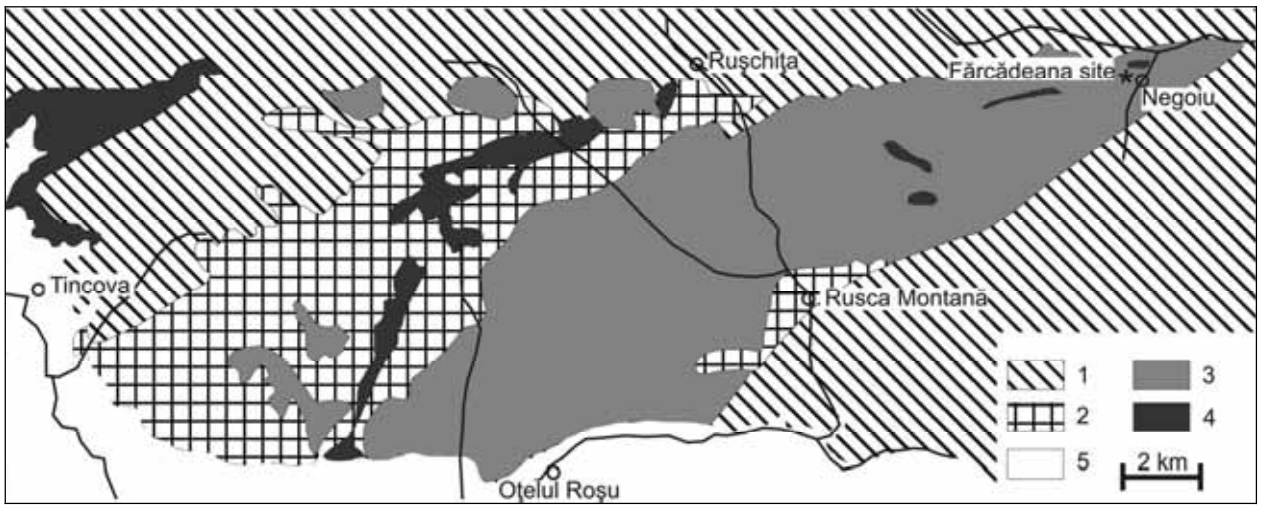

Figure 1. Simplified geological map of the Rusca Montană Basin. 1. Metamorphic units; 2. Pre-Maastrichtian Mesozoic sedimentary deposits; 3. Maastrichtian continental deposits; 4. Volcanic intrusions; 5. Neogene and Quaternary deposits. Limits of units based on STRUTINSKI *et al*. (1983). / Figura 1. Harta geologică simplificată a Bazinului Rusca Montană. 1. Unităţi metamorfice; 2. Depozite sedimentare mezozoice pre-maastrichtiene; 3. Depozite continentale maastrichtiene; 4. Intruziuni vulcanice; 5. Depozite neogene şi cuaternare. Limitele dintre unităţi sunt bazate pe cele indicate de STRUTINSKI *et al*. (1983).

RESULTS AND DISCUSSIONS

Informal group Pulmonata CUVIER 1817
Clade Hygrophila FÉRUSSAC 1822
Superfamily Lymnaeoidea RAFINESQUE 1815
Family Lymnaeidae RAFINESQUE 1815
Lymnaeidae indet. (Fig. 2a)

Material: 1 specimen.

Measurements: shell height (estimated): 1.59 mm; maximum width: 0.998 mm; apical angle: 50°.

Description: Ovate-oblong sinistral shell made of 2.5 rapidly increasing rounded-convex whorls. The apex is rounded. Short spire and inflated last whorl, slightly larger than half of the shell. The suture line is moderately deep, inclining to 18-20° from horizontal. Faint growth lines can be seen in some of the specimens. The aperture area is not preserved, therefore its shape and size could not be estimated. These morphological features are most similar to those reported for the genus *Lymnaea*, with the notable difference that most extant species of this genus have a dextral shell. BAKER (1911) notes, however, that even among the extant American species of *Lymnaea*, there are some that have a dextral shell. Given these information, it is not impossible for the material described above to belong to a sinistral-shelled species of the genus *Lymnaea*.

Paleogeographical distribution: *Lymnaea* is known from the Lower Cretaceous of North America (BAKER, 1911; YEN, 1951), the Albian-Aptian of China (PAN & ZHU, 2007) and the Maastrichtian of France (OPPENHEIM, 1895; FABRE-TAXY, 1969). In Romania, the genus was mentioned from the Maastrichtian continental deposits of the Densuş-Ciula Formation, being represented by two species, *L. dilatata* and *L. maastrichta*, the latter announced as new species (PANĂ *et al*., 2002), but not yet formally described.

Ecology: Recent lymnaeids inhabit diverse plant-rich water bodies, from transient water pools and oligotrophic swamps, to large lakes or shallow streams, preferring stagnant waters, where they can be found floating at the surface, or in the near-shore area, many times just out of the water (BOWDICH, 1822; ZITTEL, 1887; GROSSU, 1955). Although the lymneids are usually vegetarian, consuming stems of water plant, algae or vegetal detritus, they can switch to a carnivorous and detrivorous diet based on the available food resources, thus feeding on small fish, newts, animal carcasses, insect larvae, other gastropods, or even their own eggs (BAKER, 1911). Recent lymnaeids are the major prey item for some fish, bird or insect species (BAKER, 1911).

Superfamily Planorboidea RAFINESQUE 1815
Family Planorbidae RAFINESQUE 1815
Genus ?*Gyraulus* CHARPENTIER 1837
?*Gyraulus* sp. (Fig. 2b)

Material: 3 specimens.

Measurements: maximum diameter: 2.097-2.958 (2.518) mm.

Description: Plan-spiral dextral shell with 4.5 whorls and sunken spire. Upper side of shell moderately concave and lower side slightly concave. Suture impressed. Surface not ornamented and periphery not carinated. All specimens are damaged, missing the aperture. The size of the spire whorls is increasing gradually, to the contrast with the considerable size increase present at the level of the last whorl, a distinctive character of *Gyraulus* (e.g. MEIER-BROOK, 1983). However, since none of the specimens is complete, lacking the aperture and even fragments from the periphery of the body whorl, the assignment of these specimens to *Gyraulus* is only tentative, a similar morphology occurring in other genera, such as *Bathyomphalus* or *Anisus*. Based on similar material, PANĂ *et al*. (2002) announced a new taxon, *Palaeoanisis septemgiratus*, which was not subsequently formally described.

Paleogeographical distribution: *Gyraulus* was reported from the Lower Cretaceous of Germany (HUCKREIDE, 1967), China (YANG *et al*., 1979; PAN & ZHU, 2007) and Japan (ISAJI, 2010), as well as from the Lower? Cretaceous of the United States (YEN, 1951) and the Upper Cretaceous of Mexico (PERRILLIAT *et al*., 2008), becoming a common occurrence in the Miocene basins of Western Europe and Central Paratethys (e.g. WENZ, 1923, 1942; HERZHAUSER & KOWALKE, 2002; BINDER, 2004; BULIĆ & JURIŠIĆ-POLŠAK, 2009). Recent representatives of the genus are among the most widespread planorbids in the world, occurring in Europe, Asia, Africa, Australia and Tasmania, respectively North America (BAKER, 1945; MEIER-BROOK, 1983).

Planorbidae indet. (Fig. 2c)

Material: 5 specimens (1 shell and 4 inner moulds).

Measurements: maximum diameter: 2.187-3.083 (2.67) mm; shell height: 1.2 mm;

Description: Dextral discoidal shell with 2.5 whorls. Upper side convex because of the slightly raised spire. Lower side convex. Whorls gradually increasing in size from the protoconch to the last whorl, one of the important features in which this taxon differs from *Gyraulus*. The aperture is oval, wider than high. A conspicuous peripheral carina can be seen in the only specimen where the shell is preserved, but this is not visible on the inner moulds.

Paleogeographical distribution: Among the planorbids, the genus *Planorbis* was reported e. g. from the Upper Cretaceous of southern France (ZITTEL, 1887; OPPENHEIM, 1895). In the Cretaceous of Romania *P. planorbis* (LINNAEUS, 1758) was mentioned from the Haţeg Basin (PANĂ *et al*., 2002).

Ecology: Recent planorbids live near the shores of slow-flowing or stagnant waters, and are rarely found in waters exceeding two meters in depth (BAKER, 1945; GROSSU, 1955). Some small-sized planorbids, such as *Gyraulus*, are abundant in small pools, which sometimes dry out completely. Planorbids prefer vegetal food, while also ingesting small grains of sand, useful in the mechanical digestion of the food (BAKER, 1945). Planorbids are a source of food for many animals that live or feed in water-logged areas, like freshwater fish, water birds, turtles, frogs, newts, leeches, odonate nymphs or crayfish (BAKER, 1945).

Family Physidae FITZINGER 1833
Genus *Physa* DRAPARNAUD 1801
cf. *Physa* sp. (Fig. 2d)

Material: 1 specimen.

Measurements: shell height: 1.63 mm; maximum width: 1.28 mm; spire height: 0.6 mm; height of last whorl: 1.03; apical angle 70.5°.

Description: Oval-shaped sinistral shell with three rounded, slightly convex whorls, separated by deep sutures, rapidly increasing in size. The conical spire is short and it has a rounded-obtuse apex. The last whorl is globular and twice the size of the spire. The inner moulds are ornamented by narrow longitudinal troughs, increasing in number with the size of the whorl they appear on. The aperture is poorly preserved; it appears to have been of a rounded triangular shape. The small size of the recovered specimens suggests they might belong to *P. pygmaea* (NICOLAS, 1890), described from the Cretaceous of Provence. The assignment of the specimen to the genus *Physa* is only tentative, given the large size of the platforms placed at the level of the suture, a feature not common in this genus.

Paleogeographical distribution: Cretaceous *Physa* has been reported from the Aptian-Albian of China (PAN & ZHU, 2007), from the Campanian of Mexico (PERRILLIAT *et al*., 2008), throughout the Cretaceous of the United States (YEN, 1951; HARTMAN, 1989, 1998) and from the Upper Cretaceous of France (ZITTEL, 1887; OPPENHEIM, 1895; FABRE-TAXY, 1959). In the Cretaceous of Romania, the species *P. patula* is present in the Maastrichtian continental deposits of the Haţeg Basin (at Sânpetru, Tuştea, Fântânele, Budurone) (PANĂ *et al*., 2002).

Ecology: Recent lymnaeids inhabit stagnant (ponds, lakes, or marshes) or slowly flowing plant-rich waters, usually floating at the water surface (GROSSU, 1945).

Clade Littorinimorpha GOLIKOV & STAROBOGATOV 1975
Superfamily Rissooidea GRAY 1847
Family Bithyniidae GRAY 1857 (syn. Bulimidae GUILDING 1828)
Genus *Gastrobulimus* WENZ 1940
Gastrobulimus sp. (Fig. 2e)

Material: 1 specimen (inner mould).

Measurements: height (save for the missing protoconch): 2.468 mm; maximum width: 1.4 mm; height of spire (save for the protoconch): 0.547 mm; height of the last whorl: 1.92 mm; apical angle: 56°.

Description: Oval-conical dextral shell, slightly inflated, consisting of four whorls. The spire is short, representing about a quarter of the height of the shell. The whorls are separated by deep horizontal suture lines. The last whorl is very high. The aperture area is damaged, but it appears to have been of a laterally compressed oval or falciform shape. No impressions of possible ornamentation or growth lines can be seen on the inner mould.

Paleogeographical distribution: The occurrence of *Gastrobulimus* in the continental Maastrichtian of the Haţeg Basin was mentioned by PANĂ *et al*. (2002), from the Pui site, and also by ANTONESCU *et al*. (1983) from Vălioara and Sânpetru. Other Cretaceous occurrences of the genus include those from the Maastrichtian of France (OPPENHEIM, 1895; FABRE-TAXY, 1959) and from the Santonian-?Campanian of Hungary (BANDEL & RIEDEL, 1994). Bulimids are common in the Paleogene of Western and Central Europe, subsequently extending their distribution eastward, as they occur in the Neogene of Central-Eastern and Eastern Europe (WENZ, 1928; 1942).

Informal group Architaenioglossa HALLER 1890
Superfamily Cyclophoroidea GRAY 1847
Family Cyclophoridae GRAY 1847
Genus *Rognacia* OPPENHEIM 1895
Rognacia sp. (Fig. 2f)

Material: 13 specimens.

Measurements: shell height: 1.13-1.74 (1.349) mm; spire height: 0.744-1.199 (0.894) mm; height of last whorl: 0.362-0.748 (0.492) mm; maximum width: 0.715-1 (0.88) mm; apical angle: 25.5-42.5° (32.2°).

Description: The conical dextral shell is high, and has six convex whorls that are separated by deep sutures. The protoconch is rounded, and the subsequent whorls gradually increase in size up to the last one, which makes up about one-third of the entire shell height. The whorls are set with numerous axial ribs. The aperture is not preserved in any of recovered specimens and thus its shape could not be reliably estimated.

Paleogeographical distribution: *Rognacia* was described for the first time from Upper Cretaceous continental deposits of southern France (OPPENHEIM, 1895). The taxon was mentioned from the Maastrichtian of Romania by PANĂ *et al*. (2002), from Fântânele, Budurone and Pui, in the continental deposits of the Haţeg Basin.

Genus *Ischurostoma* BOURGUIGNAT 1874
Ischurostoma sp. (Fig. 2g)

Material: 4 specimens.

Measurements: shell height: 2.49-3.09 (2.87) mm; spire height: 2.02-2.37 (2.19) mm; height of last whorl: 0.47-0.8 (0.68) mm; apical angle: 16.5-23.3° (19.62°).

Description: The conical dextral shell is high and consists of seven whorls separated by deep sutures. The whorls increase in size gradually up to the last one, which makes up for almost one-third of the shell. The aperture is subcircular, slightly higher than wide. No traces of a possible ornamentation can be seen on the surface of the shell.

Paleogeographical distribution: *Ischurostoma* was described for the first time from, and occurs commonly in, the Eocene of France (BOURGUIGNAT, 1891), where it is present throughout the Paleogene (NOULET, 1868; WENZ, 1926; FAURÉ, 2007). In Romania, the taxon was reported by PANĂ *et al*. (2002) from the Maastrichtian Fântânele, Tuştea, Sânpetru and Pui sites in the Haţeg Basin.

Ecology: Cyclophorids are terrestrial gastropods, living in humid environments, in shaded areas, under fallen trees or among the fallen leaves (ZITTEL, 1877).

Indeterminate (cyclophorid?) opercula (Figs. 2h, i)

Material: around 1,600 isolated opercula.

Two inner moulds of low and wide-shelled gastropods were found with attached opercula. The opercula outline is circular and both the inner and outer sides are concave. The inner side is smooth, while the outer side shows a dexterous plane spiral pattern, each spiral arm being made of tightly packed prisms, arranged parallel to each other, and oriented obliquely to the spiral arms. These opercula also occur isolated, as the most abundant fossil remains, representing more than 95% of all the fossils (gastropod, vertebrate and fruits) yielded by the Fărcădeana site. The two inner moulds still having attached opercula are poorly preserved, leaving insufficient information for a taxonomical assessment.

Isolated opercula similar to those described here were assigned by PANĂ *et al*. (2002) to cyclophorids, and are common in the continental Maastrichtian of the Haţeg Basin (being recorded at Pui, Fântânele, Budurone, Tuştea,

General Berthelot 1 & 2, Crăguiş; see also VASILE *et al*., 2011). Cyclophorids are the only terrestrial gastropods recovered so far from the Fărcădeana site. Among the aquatic gastropods currently known from Fărcădeana, only the bithyniids have opercula. Unlike the opercula described here, the bithyniid opercula grow around eccentric nodes (ZITTEL, 1887). Recent planorbids are known to secrete an operculum during arid periods, when the water bodies dry out, but such opercula are parchment-like (GROSSU, 1955), and hence not likely to be preserved and fossilized. Therefore, until new data from the site becomes available, these opercula are assigned to cyclophorids.

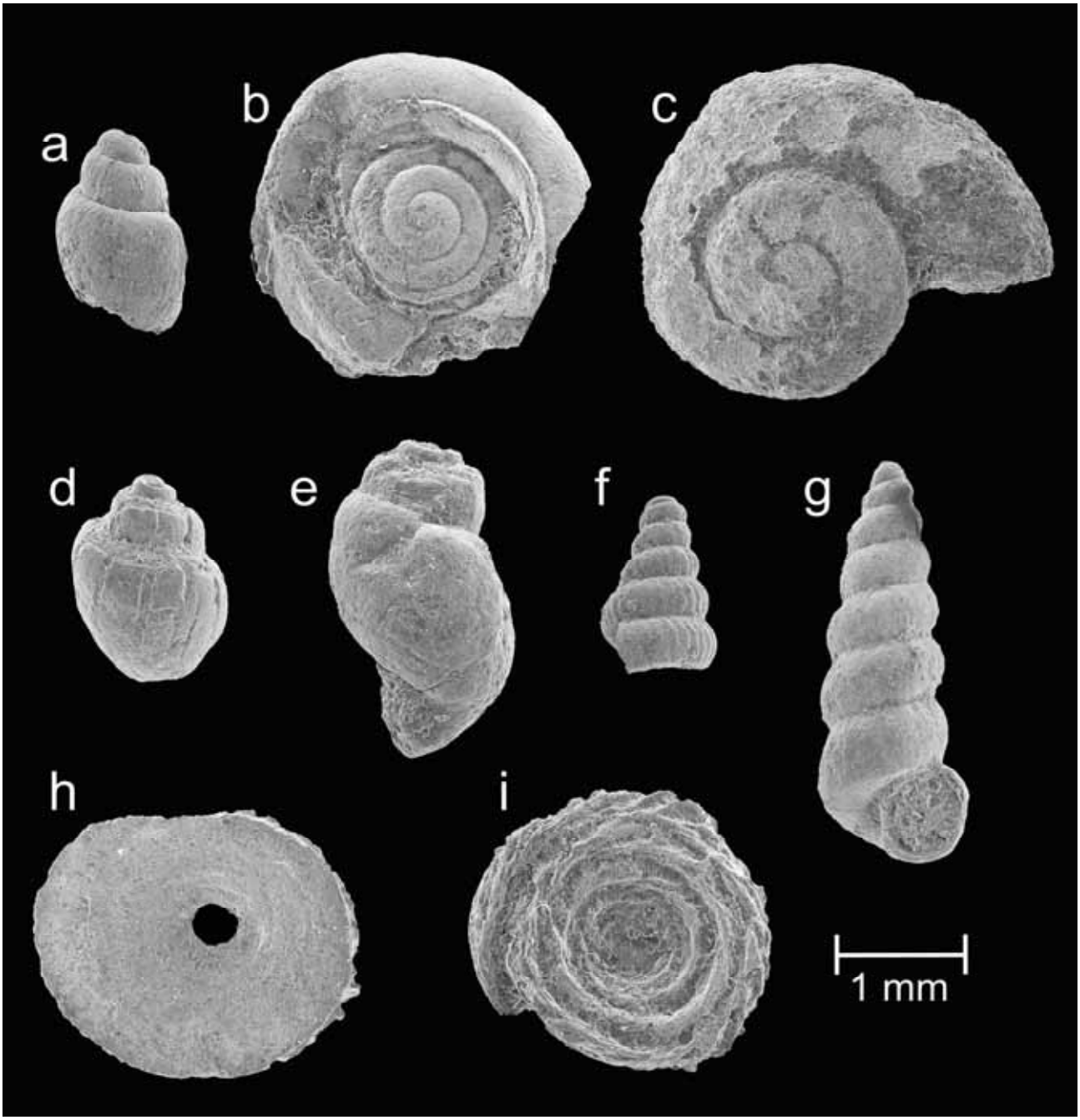

Figure 2. Maastrichtian fresh-water and terrestrial gastropods from Fărcădeana. Rusca Montană Basin. a. Lymnaeidae indet., abapertural view; b. ?*Gyraulus* sp., apical view; c. Planorbidae indet., apical view; d. cf. *Physa* sp., abapertural view; e. *Gastrobulimus* sp., abapertural view; f. *Rognacia* sp., abapertural view; g, *Ischurostoma* sp., apertural view; h. Undetermined (cyclophorid?) operculum, inner view; i. Undetermined (cyclophorid?) operculum, outer view (original). / Figure 2. Gastropode maastrichtiene dulcicole şi terestre de la Fărcădeana, Bazinul Rusca Montană. a. Lymnaeidae indet., vedere abaperturală; b. ?*Gyraulus* sp., vedere apicală; c. Planorbidae indet., vedere apicală; d. cf. *Physa* sp., vedere abaperturală; e. *Gastrobulimus* sp., vedere abaperturală; f. *Rognacia* sp., vedere abaperturală; g, *Ischurostoma* sp., vedere aperturală; h. Opercul nedeterminat (cyclophorid?), vedere internă; i. Opercul nedeterminat (cyclophorid?), vedere externă (original).

CONCLUSIONS

The Maastrichtian gastropod assemblage from Fărcădeana, Rusca Montană Basin, is fairly diverse, including both freshwater (lymnaeids, planorbids, physids, bithyniids) and terrestrial (cyclophorids) taxa.

All the freshwater gastropod families identified in the fossil material recovered from Fărcădeana have recent representatives that inhabit stagnant or slowly flowing waters. The terrestrial taxa recovered from the same site also prefer humid microhabitats, such as the vicinity of ponds. These ecological preferences support previous conclusions reached based on sedimentological and vertebrate assemblage information. The fossiliferous mudstones from Fărcădeana are gray-coloured, suggesting a poorly-drained paleoenvironment, in which oxygen supply was insufficient for the available iron to combine into ferrous compounds. On the other hand, ferric compounds are present, represented by ferric oxide yielding the green-gray colour of the sediments, respectively by sulphide, occurring as fine pyrite crystals. The microvertebrate assemblage is dominated by water-dwelling taxa, such as the amphibians (anurans, albanerpetontids). Altogether, the available information suggests that accumulation of sediments took place in a hydrodinamically quiet waterlogged environment, such as a pond, or an abandoned secondary channel from a poorly-drained area of the floodplain. Since chances of transport are low in such an environment, the fossil assemblage must be autochthonous or, at most, para-autochthonous, thus closely reflecting the composition of the original biocoenosis.

The gastropods here reported represent an important addition to the Maastrichtian fauna of the Rusca Montană area. Most of them belong to herbivorous taxa, and thus sat near the base of the food chain in aquatic to peri-aquatic environments. If not exactly the major food source, gastropod surely represented an important addition to the diet of small vertebrates, or that of other invertebrates (insects, insect larvae) that inhabited these biotopes. The large number of isolated opercula (around 1,600) shows that, even though they were small, gastropods compensated in numbers and transferred important amounts of mass and energy from the primary producers to predators placed higher in the trophic chain.

All the gastropod taxa identified so far in the Maastrichtian of Rusca Montană Basin were also reported from coeval continental deposits of the neighbouring Haţeg Basin (see PANĂ *et al*., 2002). The similarities between the palynomorph (ANTONESCU *et al*., 1983), plant (e.g. MĂRGĂRIT & MĂRGĂRIT, 1967; PETRESCU & DUŞA, 1983), vertebrate (e.g. CODREA *et al*., 2009, 2012; GRIGORESCU, 2010; VASILE & CSIKI, 2011), and now the gastropod assemblages described from the Maastrichtian continental deposits of the two sedimentary basins suggest that these underwent a similar evolution during this time interval, with land connections in place, allowing the different taxa to spread between and to colonize both areas.

ACKNOWLEDGEMENTS

This work was supported by, and is a contribution to, the CNCSIS Grant 1930/2009. ŞV also benefited from POSDRU/88/1.5/S/61550 "Doctoral studies in the field of Life and Earth Sciences", project co-financed through Sectorial Operational Program for the Development of Human Resources 2007-2013 from the European Social Fund. Fellow geologists Bogdan Săvescu and Răzvan Andrei, as well as Mr. Dumitru Huzoni and the family of Mr. Moise Brăilă are thanked for their technical and logistical support. The reviewers – Theodor Neagu (The Romanian Academy, Bucharest), Vlad Codrea (Babeş-Bolyai University, Cluj-Napoca) and Mihai E. Popa (University of Bucharest) – as well as Mirela Popa (Babeş-Bolyai University, Cluj-Napoca) are thanked for their comments on the previous versions of the text, their suggestions proving to be very useful in improving this paper.

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Received: March 31, 2012
Accepted: July 23, 2012