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ORIGINAL PAPER

# Small mammals from the opencast lignite mine Gračanica (Bugojno, middle Miocene), Bosnia and Herzegovina

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## Abstract

Small-mammal remains are found in three outcrops in the open pit lignite mine near Bugojno (Bosnia and Herzegovina). Despite the low amount of specimens, two *Democricetodon* species, which differ in size, are identified. The co-occurrence of two *Democricetodon* species is common in many late early and middle Miocene European small-mammal assemblages. The presence of both *D. mutilus* and *D. gracilis* allows a correlation to MN4–MN6.

**Keywords** Mammalia · Rodentia · Middle Miocene · Bosnia and Herzegovina

## Introduction

Small-mammal fossils from Bosnia and Herzegovina are rare. The only assemblage known so far is the late Oligocene assemblage of Banovići discovered during a prospective field campaign in 2007 (de Leeuw et al. 2011; de Bruijn et al. 2013; van der Sar et al. 2017). During the same fieldtrip, a few small-mammal remains were found in the Gračanica open pit lignite mine near Bugojno. The latter small-mammal remains are from three outcrops: an isolated outcrop in the upper part of the coal interval (GRAC1), three lignitic marl levels in the small outcrop directly behind the company buildings (GRAC3a, GRAC3b, and GRAC4; Fig. 1a–d) and a lignite bed which also contained abundant mollusk remains from the basal layers in the mine (GRAC5; Fig. 1e). The levels GRAC3a, GRAC3b, and GRAC4 are situated in the lacustrine marls in the top part of the coal succession. Level GRAC5 is situated in the lower part of the coal, approximately at the level that is known to contain proboscidean remains (see also Mandic et al., in prep., this issue).

The 16 isolated rodent teeth in the fossil assemblages of Gračanica are identifiable to the species level and can be used for a biostratigraphical correlation. The insectivore remains are not identifiable on family level (Table 1).

## Locality, material and methods

The small mammal remains described below were collected during the field campaign of the project "Mollusk Evolution of the Neogene Dinaride Lake System" of Oleg Mandic (NHMW) in 2007. In 2008, some additional samples were taken from GRAC3a, GRAC3b, GRAC4, and GRAC5, resulting in a total of 40 kg of sediment per sample. GRAC1 yielded fragments of an incisor of a rodent and of an insectivore, GRAC3 yielded eight rodent molars and three insectivore molar fragments, GRAC4 contained six rodent molars, and GRAC 5 two rodent molars. In GRAC3 and GRAC4, bone fragments and a few plates of the lizard *Anguine* sp. were found. The insectivore remains, a soricid lower incisor (GRAC1), and two insectivore fragments (GRAC3a) are not described here but mentioned in the fauna list only (Table 1).

This article is a contribution to the special issue "The drowning swamp of Gračanica (Bosnia-Herzegovina)—a diversity hotspot from the middle Miocene in the Bugojno Basin"

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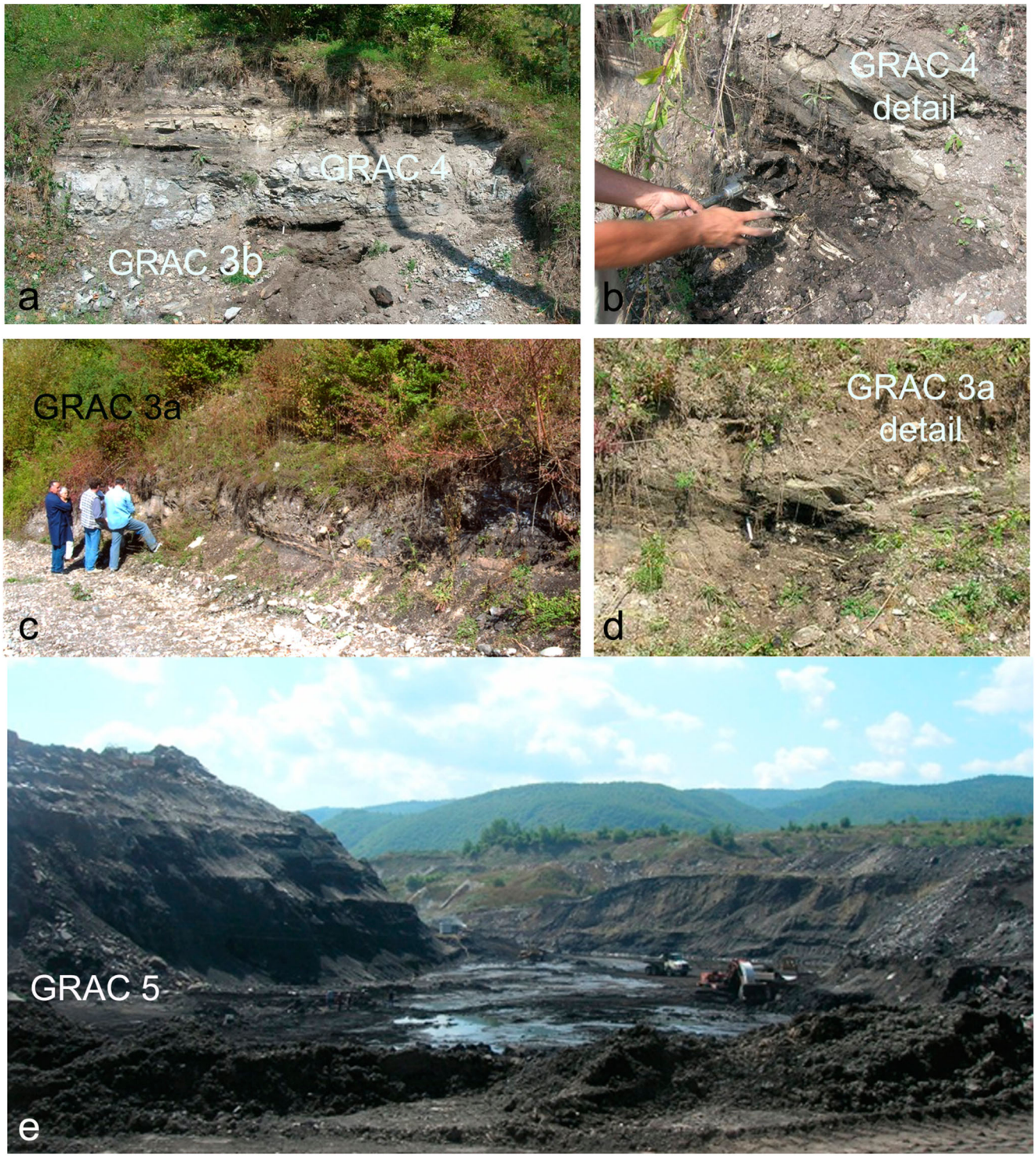


**Fig. 1** The lithostratigraphical position of the small-mammal remains in the Gračanica open pit lignite mine near Bugojno (BH). The levels GRAC3a, GRAC3b and GRAC4 (N43 59 35.1, E17 31 01.0) are situated in lacustrine marls lateral to the top part of the coal succession. Level GRAC5 is situated in the lower part of the coal, approximately at the level that is known to contain proboscidean remains (see also Mandic et al., in prep., this issue). **a** GRAC3b and GRAC4; **b** details of GRAC3b and GRAC4; **c** GRAC3a; **d** detail of GRAC3a; **e** GRAC5 (all pictures are taken in 2007)

The measurements of the cheek teeth were made with an Orthoplan (Leitz) microscope with a precision of 0.01 mm. All teeth are figured as left ones to facilitate comparison. Lower dentition is indicated with lower case letters and upper dentition is indicated with upper case letters. The collection is housed in the Natural History Museum in Belgrade.

The terminology of the parts of molars is from Mein and Freudenthal (1971), except for the term ectoloph=paracone spur. Added terms are anteroloph and anterolophid.

Measurements are in millimeters (mm). Molars from the right side are indicated with dex (dextral) and those from the left side with sin (sinistral). Measurements of the specimens are given as L × W, unless otherwise indicated.

Institutional abbreviations

NHMW, Natural History Museum in Vienna, Austria. NHMB, Natural History Museum in Belgrade, Serbia. UU, Utrecht University, the Netherlands

Other abbreviations

GRAC, Code for the Gračanica locality, Bosnia and Herzegovina Country codes: BH, Bosnia and Herzegovina; GER, Germany

Abbreviations for measurements and descriptions

N, Number of specimens; R, Range of measurements; L, Length; W, Width; sin, Sinistral; dex, Dextral

## Systematic palaeontology

Order Rodentia Bowdich, 1821
Subfamily Cricetinae Fischer, 1817
*Democricetodon* Fahlbusch, 1964

*Democricetodon mutilus* Fahlbusch, 1964
(Fig. 2a–j)

**Locality:** Gračanica (BH).
**Material and measurements:** Thirteen molars from three lignitic marl levels, GRAC3a, GRAC3b, GRAC4, in the small outcrop directly behind the company buildings (Fig. 2a–e, h–j; Table 1) and two molars from GRAC5 at the lowermost level of the coal outcrop in the mine (Fig. 2f–g).

### Description

**M1:** The simple anterocone of the M1 is connected to the protocone by the anterolophule, which has a short labial spur. The protolophule is double and the metalophule connects the hypocone to the posteroloph. The mesoloph is of medium length and is connected to the anterior base of the hypocone by a very short posterior spur. The sinus is transverse and is partly closed by a small ridge on the anterolingual base of the hypocone.
**M2:** The two M2s differ in the lingual anteroloph, which connects to the protocone in one and continues along the lingual edge towards the base of the hypocone in the other. The labial anteroloph connects to the paracone. The metalophule is short in one and absent in the other. The mesoloph is of medium length and the sinus is transverse and is completely closed on its lingual edge in one and in the other M2 almost closed by a small ridge on the anterolingual base of the hypocone.
**m1:** The anteroconid of the m1 is always simple and near to protoconid and metaconid. The anterolophids are low and the anterolophulid is short. The metalophulid is short, absent in one, and the hypolophulid is directed anteriorly. The mesolophid is of medium length and the sinusid is in all m1s directed forward.
**m2:** The labial anterolophid is short in one and continues along the lingual edge towards the hypoconid in the other. The lingual anterolophid is either short or fused with the metaconid due to wear. The metalophulid and hypolophulid are both short and directed forward. The mesolophid is short in one and long in the other m2. The sinusid is directed forward.
**m3:** The m3s have a short lingual anterolophid and the labial anterolophid is connected to the anterolabial border of the protoconid. The metalophulid, connected to the anterolophid, and the hypolophulid are very short. A minute entoconid is distinguishable in the less worn m3. The sinusid, closed by a narrow ridge, is slightly curved backward.
**Discussion:** All these specimens are within the range of the morphological and metric variation of *Democricetodon mutilis*. This species is mainly known from western and central Europe (MN4-MN7/8; most occurrences are in MN5 and MN6 localities. Wessels and Reumer 2009; The NOW Community 2019). A few occurrences are reported from Serbia: Sibnica (MN4; Marković et al. 2016), Bele Vode and Lazarevac (MN6; Marković 2008); the eastern-most occurrence of this species is in Sibnica.
The characteristics in the upper molars, such as a mesoloph of medium length or longer and a double protolophule, combined with the characteristics in the lower molars, such as a short to medium length mesolophid and a not always present metalophulid, are as in *Democricetodon mutilus*. This morphology is considered to be more evolved than that of *D. franconicus* Fahlbusch, 1966. The measurements are about the same as for *Democricetodon mutilus* from Sibnica (Marković et al. 2016).

*Democricetodon gracilis* Fahlbusch, 1964
(Fig. 2k)

**Locality:** Gračanica (BH).
**Material and measurements:** One second upper molar, M2 dex (GRAC3b-2) from the lignitic marl level GRAC3b (Fig. 2k; Table 1).
**Description:** The M2 has a short lingual anteroloph and a long labial anteroloph connected to the paracone. The protolophule is double and the metalophule is simple and transverse. The mesoloph is long and the sinus is transverse. A paracone spur and a mesostyl are present.

**Table 1** Table with all faunal elements in the Gračanica open pit lignite mine near Bugojno (BH)

| | | | | | | |
|---|---|---|---|---|---|---|
| **Class** | Reptilia Laurenti, 1768 | | | | | |
| **Order** | Squamata Oppel, 1811 | | | | | |
| **Family** | Anguidae Gray, 1825 | | | | | |
| | | **Level/coll. Nr.** | **Item** | | | |
| | *Anguine* sp. indet. | GRAC3 and GRAC4 | Osteoderm | | | |
| **Class** | Mammalia Linnaeus, 1758 | | | | | |
| **Order** | Eulipotyphla Waddell, Okada an Hasegawa, 1999 | | | | | |
| **Family** | Soricidae Viret and Zapfe, 1951 | | | | | |
| | | **Level/coll. Nr.** | **Item** | | | |
| | Soricidae indet. | GRAC1-1 | Lower incisor | | | |
| | Insectivora indet. | GRAC3a-10 | Fragments | | | |
| **Order** | Rodentia Bowdich, 1821 | | | | | |
| **Family** | Muridae Illeger, 1811 | | | | | |
| **Genus** | *Democricetodon* Fahlbusch, 1964 | | | | | |
| | *Democricetodon mutilus* Fahlbusch, 1964 | | | | | |
| | | **Level** | **Dental element** | **Side** | **Length** | **Width** |
| | | GRAC3a-1 | m1 sin | sin | 1.61 | 1.13 |
| | | GRAC3a-2 | m1 sin | sin | 1.57 | 1.09 |
| | | GRAC3b-1 | m1 sin | sin | 1.49 | 1.07 |
| | | GRAC4-1 | m1 dex | dex | 1.60 | 1.05 |
| | | GRAC5-1 | m1 dex | dex | 1.52 | 0.94 |
| | | GRAC3a-3 | m2 sin | sin | 1.36 | 1.23 |
| | | GRAC5-2 | m2 sin | sin | 1.44 | 1.19 |
| | | GRAC3a-4 | m3 sin | sin | 1.49 | 1.25 |
| | | GRAC3a-5 | m3 sin | sin | 1.27 | 1.12 |
| | | GRAC3a-6 | m3 dex | dex | 1.31 | 1.15 |
| | | GRAC4-2 | m3 dex | dex | 1.32 | 1.00 |
| | | GRAC4-3 | M1 dex | dex | 1.95 | 1.29 |
| | | GRAC4-4 | M2 dex | dex | 1.48 | 1.36 |
| | | GRAC4-5 | M2 sin | sin | 1.46 | 1.26 |
| | | GRAC4-6 | M3 dex | dex | – | 1.21 |
| *Democricetodon gracilis* Fahlbusch, 1964 | | | | | | |
| | | GRAC3b-2 | M2 dex | dex | 1.15 | 0.97 |

## Discussion

The long mesoloph, a double protolophule, and a transverse metalophule are characteristics interpreted as more primitive than those of *Democricetodon mutilus*. The M2 is also smaller than in *Democrictodon mutilus* and in *D. franconicus*. This molar is therefore tentatively assigned to *Democricetodon gracilis*, which is present in many European, and a few Anatolian, MN4-MN6 assemblages (Wessels and Reumer 2009; The NOW Community 2019).

## Biostratigraphy

*Democricetodon* comprises a large number of species that differ in the frequency distribution of details of the dental pattern and in size. *Democricetodon* is known from the earliest Miocene in Turkey, where it is represented by species that are not known from Europe (local biozones correlated to MN1-3; Theocharopoulos 2000). *Democricetodon gracilis* and *D. mutilus* are regarded as descendants of *Democricetodon franconicus*, which has its origin in Anatolia. *Democricetodon franconicus* is also present in the MN4 assemblages Aliveri and Karýdia (Greece) and is considered to be more primitive than *D. franconicus* from Erkertshofen (type-locality; MN4; GER), the oldest record of a *Democricetodon* in western Europe (Theocharopoulos 2000).

Although in the Gračanica assemblage the amount of fossils is quite low, the presence of two species of *Democricetodon*, a small and a large one, is common in many early and middle Miocene western European assemblages (van der Meulen et al.

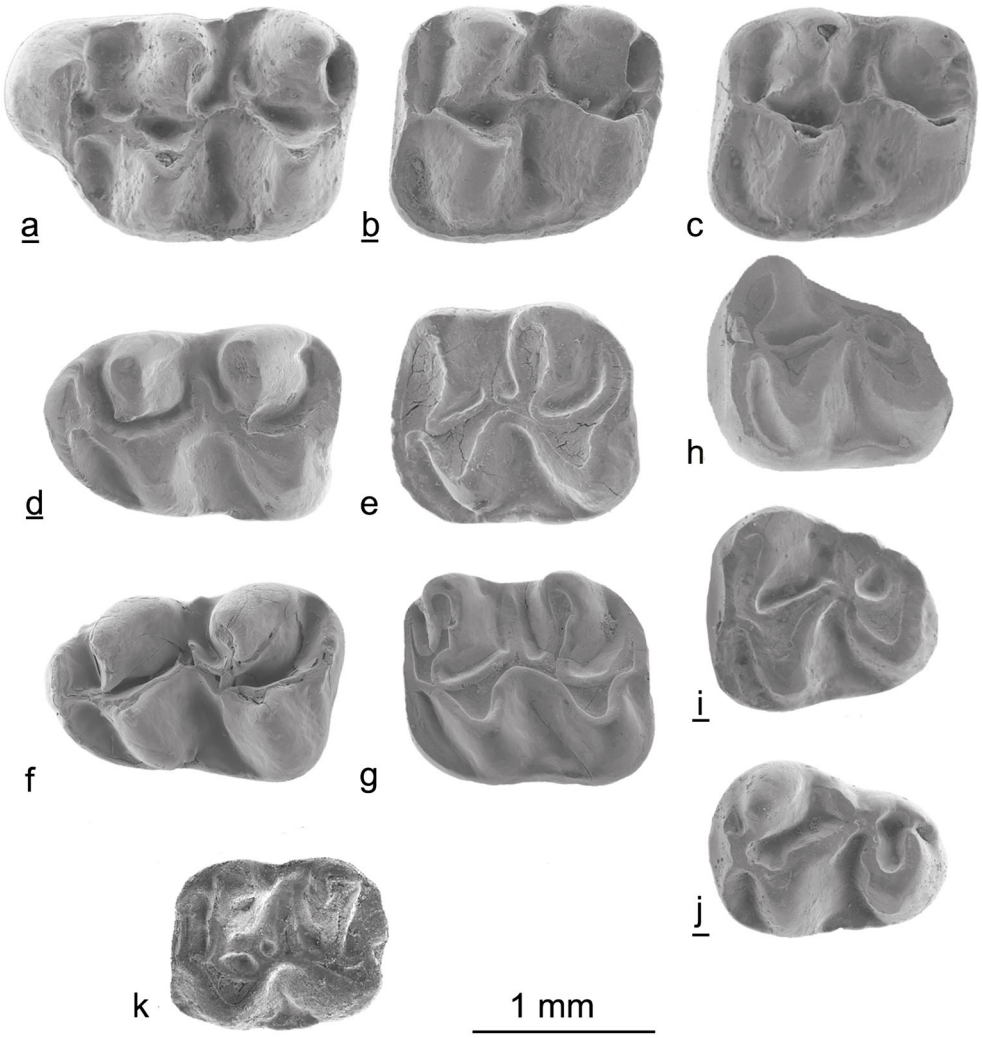


**Fig. 2** *Democricetodon mutilus* Fahlbusch, 1964. **a** GRAC4-3 M1 dex; **b** GRAC4-4 M2 dex; **c** GRAC4-5 M2 sin; d: GRAC4-1 m1 dex; **e** GRAC3a-3 m2 sin; **f** GRAC5-1 m1 dex; **g**: GRAC5-2 m2 sin; **h**: GRAC3a-4 m3 sin; **i**: GRAC3a-6 m3 dex; **j**: GRAC4-2 m3 dex. *Democricetodon gracilis* Fahlbusch, 1964. **k**: GRAC3b-2 M2 dex. All specimens are figured as left ones, the reversed specimens are indicated by underlining of its letter on the figure

2003) and also in early Miocene assemblage of Serbia (Marković and Milivojević 2016), Greece, and Turkey (Theocharopoulos 2000).

*Democricetodon multilus* and *Democrictodon gracilis* co-occur in many localities (The NOW Community, 2019); in France in MN4, in Germany in MN4-MN6, in Austria in MN5 and in Switzerland in MN5 (and only one in MN6), thus the co-occurrence of these two species allows us to correlate the Gračanica small mammal assemblages to MN4-MN6.

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## Compliance with ethical standards

**Conflict of interest:** The authors declare that they have no conflict of interest.



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