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A Pleistocene Record of *Apodemus agrarius* (Pallas, 1771) (Mammalia: Rodentia) in the Magura Cave, Bulgaria

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Abstract: Remains (left upper tooth row and isolated right first upper molar) of the stripe field mouse (*Apodemus agrarius*) collected from sediments older than 50,000 years are described. According to the ecological appearance of the microfauna (predominance of the taxa characteristic of temperate and more or less humid climate, inhabiting forests and meadows) and the evolutionary level of rodents (all taxa are indistinguishable from their recent counterparts), it could be assumed that the remains are from the last interglacial period. This occurrence contradicts the dominating opinions of the late migration of the species in Europe and supports the hypothesis that the uncertain fossil records reported from various European sites represent several expansions of *A. agrarius* or closely related forms during the Pleistocene.

Keywords: Rodentia; *Apodemus agrarius*; fossil molars; Late Pleistocene; Bulgaria; Eemian

Introduction

According to Kowalski (2001), the stripe field mouse, *Apodemus agrarius* (Pallas, 1771), a species of East Asian origin, has appeared in Europe in the Early Holocene and its Pleistocene records are doubtful. The main reason for the doubts is the lack of detailed descriptions and justification of determinations made in the context of the difficulties to distinguish the species from other widespread congeneric species (Fejfar & Horáček 1983; Burghele *et al.* 1994; Aguilar *et al.* 2008). The most ancient well-documented material, determined as *Apodemus* cf. *agrarius,* is from late Pleistocene deposits in SW France (Bouziès-Q, Quercy, ca. 17,417–17,044 years BC). This record demonstrated a more western expansion of the species at the end of the last cold phase of the Pleistocene and is interpreted supporting the hypothesis of the late migration of the species in Europe (Aguilar *et al.* 2008).

Within a multidisciplinary project realised in 2011-2012, small mammal remains were collected from sediments in the Magura Cave, NW Bulgaria. The results, including a preliminary list of the identified taxa, were presented in our previous paper (Ivanova *et al*. 2016). Among the materials, several upper molars showing the characteristic features of *Apodemus agrarius* were found. In the preliminary list they were denoted as *Apodemus* sp. 2. In the course of a further study and analysis, it was found that they certainly belong to *A. agrarius*. The description and publication of these remains are of a special interest as their stratigraphic context shows that they are older than 50,000 years B.P. Below, a description of the molars is presented. They are compared with material which certainly belongs to *Apodemus* ex gr. *sylvaticus – flavicollis*, denoted in our preliminary list as *Apodemus* sp. 1.

Materials and Methods

The Magura Cave is located 25 km north-west of the town of Belogradchik and 35 km south of the city of Vidin (43.7281, 22.5826 decimal degrees) with its entrance situated at about 375 m a.s.l. The sediments from Trench I, in which the remains of small mammals have been found, represent a deposition that has formed distinct and regular layers. The sedimentary

bedding is nearly parallel (fig. 3 of Ivanova *et al.* 2016) indicating that the sediments and associated fossils have been undisturbed. There are no sediments of Holocene age in Trench I (Ivanova 1995). The excavations from 2011-2012 started at layer 13. Sediments were explored in artificial spits of 5 cm. The excavated sediment was labelled according to its square of origin, depth and layer and removed from the cave for wet-sieving. Resultant residues were then dried and picked for taxonomically identifiable small vertebrate bones. Therefore, according to the stratigraphy and the mode of excavation, the admixture of any later small mammal remains can be ruled out.

Small mammal remains were found in layers 26, 27, and 40. The faunal assemblage from layer 26 was characterised by a considerable taxonomic richness and included taxa characteristic of temperate and more or less humid climates, inhabiting forests and meadows, such as *Crocidura leucodon, Talpa* sp., *Rhinolophus* sp., *Myotis blythii, Barbastella barbastellus, Miniopterus schrebersii, Glis glis, Apodemus agrarius, Apodemus* ex gr. *sylvaticus-flavicollis, Clethrionomys glareolus, Microtus subterraneus*. Some steppe and mountain species were also recorded: *Ochotona* sp., *Nannospalax* sp., *Microtus ex gr. arvalis* and *Chionomys nivalis.* The faunal assemblages from layers 27 and 40 were composed predominantly of taxa associated with cool and relatively arid climate with predominance of open vegetation: *Spermophilus* sp., *Mus* sp.*, Cricetus cricetus, Mesocricetus newtoni, Lagurus lagurus, Microtus* ex gr. *arvalis* and *Chionomys nivalis.* The group of the mesophilous species was represented only by *Apodemus* ex gr. *sylvaticus-flavicollis* in layer 27.

Two radiocarbon dates from Trench I (OxA-29785, >50,100 years B.P., layer 23 and OxA-29991, >50,200 years B.P., layer 25; Ivanova *et al.* 2016) indicated that the small mammal remains considered here pre-date 50,000 BP.

The material referred to *Apodemus agrarius* was collected from layer 26 and consisted of a left upper tooth row and an isolated right first upper molar.

The terminology describing positions of the cusps of upper molars (M1 – M3) used herein follows Miller (1912, p. 801) and is diagrammed in Fig. 1. Specimens were studied, measured and photographed using a Zeis 2000 C stereo microscope with AxioCam Erc 5s (5.3 megapixel) camera.

Results and Discussion

The remains referred to *A. agraius* (Figs. 1 and 2:1-2) display characteristics typical of the species: a medium-sized representative of the genus (Table 1) with a narrow M1, which shows a posterior posi-

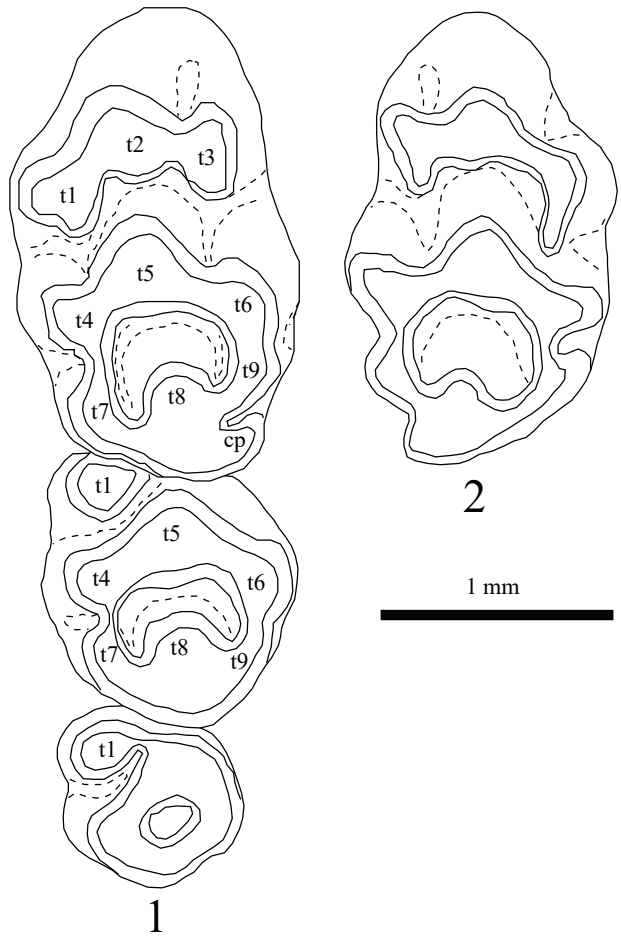

Fig. 1. Occlusal view of left upper tooth row with cusp nomenclature (1) and an isolated right first upper molar (2) of *Apodemus agrarius* from layer 26 of Trench I of the Magura Cave

Table 1. Measurements [mm] of *Apodemus* upper molars (M1 – M3) from layer 26 of Trench 1 , Magura Cave, L – length, W – width

Taxa	specimen	M1		M2		M3		LM1-M3
		L	W	L	W	L	W	
A. agrarius	Fig.1:1	1.99	1.20	1.24	1.13	0.80	0.77	3.77
	Fig.1:2	1.87	1.16	-	-	-	-	-
A. ex gr. *sylvatucus-flavicollis*	Fig.1:3	2.00	1.36	1.34	1.25	-	-	-
	Fig.1:4	1.96	1.17	-	-	-	-	-

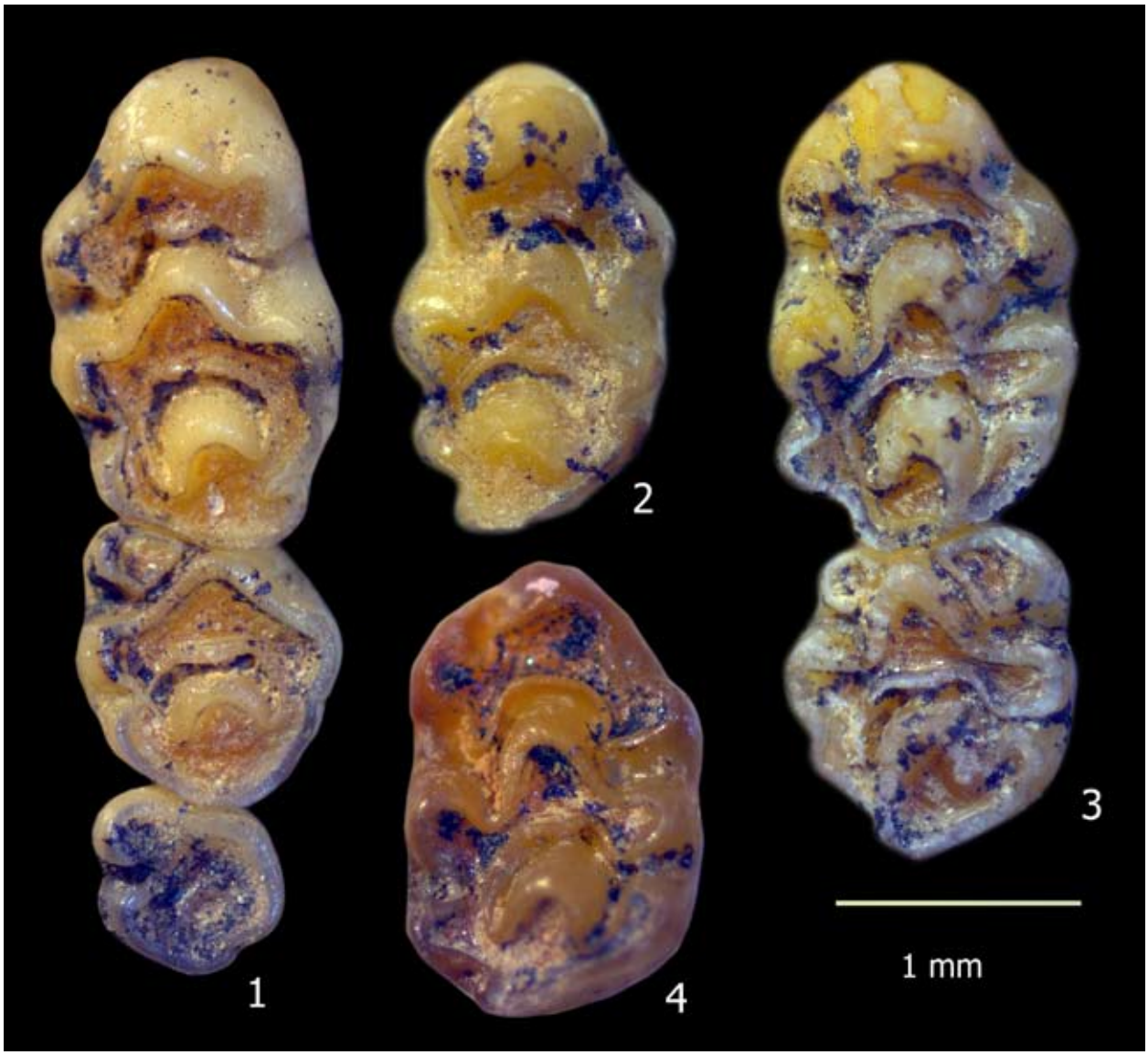

Fig. 2. Molars of *Apodemus* species from layer 26 of Trench I of the Magura Cave. 1-2. *A. agrarius*. 3 – 4. *A.* ex gr. *sylvaticus – flavicollis*. 1. M1-M3; 2 – M1; 3. M1-M2; 4. M1

tion of cusp t1 in relation to cusp t2 and a connection between cusps t4 and t7; M2 lacks cusp t3.

The absence of a cusp t3 is a diagnostic character of *A. agrarius* (see Miller 1912) that allows its differentiation from the other European and oriental representatives of the genus (Musser *et al*. 1996). Additionally, the features of the first upper molar allow to confidently distinguish *A. agrarius* from *A.* ex gr. *sylvaticus-flavicollis* when isolated. In *A.* ex gr. *sylvaticus-flavicollis* M1 is wider in occlusal view, the anterior arch is symmetric (cusp t1 is not shifted posteriorly), cusps t4 and t7 are easily separated (Fig. 2:3-4).

Observations of the available lower molars (3 m1 and 1 m2) from layers 26 and 27 indicated that they were likely attributable to *Apodemus* ex gr. *sylvaticus-flavicollis* based on the well-developed lateral cingular cusps on m1 and m2 and a well-differentiated anterior cusp on m1, distinct from the other two cusps of the anterior lamina.

Comparison of the M1's from the Magura Cave attributed to *Apodemus agrarius* with a large sample (N=40) of modern species from Bulgaria showed an important difference. The rear cingular tubercle (cp) of the M1 in the fossil form was relatively well developed (Figs. 1 and 2:1–2), while in the modern comparative material from Bulgaria it was absent. On the other hand, according to the illustrations and descriptions presented by Musser *et al.* (1996) and Aguilar *et al.* (2008), this tubercle is expressed with a variable frequency in other recent and fossil populations. So far, due to the insufficient fossil material of the *agrarius*-lineage it is difficult to assess the taxonomic significance of this variability.

Considering that the small mammal species from layers 26, 27 and 40 were morphologically close to those of the modern type, it could be concluded that these layers are of Late Pleistocene age. Given the available radiocarbon dates and the lower limit of the Late Pleistocene according to generally accepted biostratigraphic schemes (Fejfar *et al.* 1998; Markova 2007; Maul & Markova 2007), it can be concluded that the age of the fauna of these layers is between 50,200 and 130,000 years BP. In this context, the available findings from the Magura Cave are consistent with the hypothesis, that "… the *agrarius* lineage or lineages related to this one expanded towards the west at several times in the past, but these events were not followed by a rather long-lasting settlement" (Aguilar *et al.* 2008). Most probably, having in mind the ecological preferences of the modern species, these invasions were related to the mild and humid climate episodes (Spitzenberger & Engelberger 2014). The microvertebrate assemblage from layer 26 is in favor of this hypothesis. As previously pointed out (Ivanova *et al.* 2016), the small mammals, amphibians and reptiles showed that layer 26 had probably been deposited in a climate similar to the present day one (or even warmer) and a mosaic landscape in the vicinity of the cave with wetlands, deciduous forests and open areas. In contrast, the microvertebrates from layer 27 lying below present a cool, dry continental climate and herbaceous vegetation (steppes) in the vicinity of the locality. It can be assumed that these layers reflect the well-pronounced climatic variation of the last interglacial period presented within isotope stage 5e (Shackleton *et al.* 2003) or some warm/cold episodes of the isotope stages of 5a-5d – 4 – 3. Thus, the occurrence of *A. agraius* in layer 25 of Trench I is consistent with other reports from neighbouring areas for the presence of this species in Europe during Eemian, e. g. Cave 13 in the Lupsa Valley, Romania (Burghele *et al.* 1994). Having in mind that these reports are based on unpublished remains, the finds of *Apodemus agrarius* from layer 26 of the Magura Cave can be considered, to date, the most ancient well-documented material of this species.

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