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Late Pleistocene voles (Arvicolinae, Rodentia) from the Baranica Cave (Serbia)

KATARINA BOGIĆEVIĆ[1], DRAŽENKO NENADIĆ[2] and DUŠAN MIHAILOVIĆ[3]

[1]Department of Paleontology, University of Belgrade-Faculty of Mining and Geology, Kamenička Str. 6, P.O. Box 227, 11000 Belgrade, Serbia; ✉k.bogicevic@rgf.bg.ac.rs
[2]Department of Historical and Dynamic Geology, University of Belgrade, Faculty of Mining and Geology, Kamenička Str. 6, P.O. Box 227, 11000 Belgrade, Serbia
[3]Department of Archaeology, Faculty of Philosophy, University of Belgrade, Čika Ljubina Str. 18–20, Belgrade, Serbia

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Abstract: Baranica is a cave system situated in the south-eastern part of Serbia, four kilometers south to Knjaževac, on the right bank of the Trgoviški Timok. The investigations in Baranica were conducted from 1994 to 1997 by the Faculty of Philosophy from Belgrade and the National Museum of Knjaževac. Four geological layers of Quaternary age were recovered. The abundance of remains of both large and small mammals was noticed in the early phase of the research. In this paper, the remains of eight vole species are described: *Arvicola terrestris* (Linnaeus, 1758), *Chionomys nivalis* (Martins, 1842), *Microtus (Microtus) arvalis* (Pallas, 1778) and *Microtus* (*Microtus*) *agrestis* (Linnaeus, 1761), *Microtus* (*Stenocranius*) *gregalis* (Pallas, 1779), *Microtus* (*Terricola*) *subterraneus* (de Sélys-Longchamps, 1836), *Clethrionomys glareolus* (Schreber, 1780) and *Lagurus lagurus* (Pallas, 1773). Among them, steppe and open area inhabitants prevail. Based on the evolutionary level and dimensions of the *Arvicola terrestris* molars, as well as the overall characteristics of the fauna, it was concluded that the deposits were formed in the last glacial period of the Late Pleistocene. These conclusions are rather consistent with the absolute dating of large mammal bones (23.520 ± 110 B.P. for Layer 2 and 35.780 ± 320 B.P. for Layer 4).

Key words: Quaternary, Late Pleistocene, Balkans, Serbia, arvicolids, rodents.

Introduction

The study of the remains of Pleistocene arvicolids and other rodents began in Serbia only recently. In the last twenty years, some faunas from several localities of Late Pleistocene age have been described. The best known of them comes from the Smolućka Cave (Dimitrijević 1985, 1991). Rodent remains of Late Pleistocene age have also been found in some other caves: the Vrelska Cave (Marković & Pavlović 1991; Pavlović & Marković 1991), the Petnička Cave (Dimitrijević 1994, 1997a), the Vasiljska, Popšička and Prekonoška Caves (Dimitrijević 1997a), Risovača (Rakovec 1965; Dimitrijević 1997a; Jovanović & Simić 1998), Pećurski Kamen (Malez & Salković 1988; Medved 1994; Dimitrijević 1997a) and the Mirilovska Cave (Dimitrijević & Jovanović 2002).

Among these sites, the Baranica Cave is by far the richest locality considering the number of mammalian species that have been found in it. It is of particular interest because it is the first locality in Serbia which has yielded large mammal fauna of the Last Glacial Maximum (Argant & Dimitrijević 2007).

This paper is the first in a series aimed at describing the remains of small mammals from this cave. They will provide data on the distribution, migration and evolution of small mammals on the territory of Serbia and hence fill the gap which exists in the knowledge of the fauna from this part of the Balkans and Europe.

The site

The Carpatho-Balkan mountan range stretches in the N–S and NW–SE direction in eastern Serbia. This mountain range consists of a whole series of isolated massifs, made mainly of carbonate rocks — limestones and dolomites of Jurassic and Early Cretaceous age (Stevanović 1994). The limestone massifs are usually separated from each other by Neogene basins, older formations and volcanic rocks (Zlokolica Mandić 1998).

The scientific research of karst in the eastern Serbia began at the end of the nineteenth century (Cvijić 1887), but even before that time, karst forms (especially caves) were described by various scientists and travellers (Ćalić 2007). Despite this early interest, karst regions of eastern Serbia are much less known than those in the adjacent areas — the Dinarides and the Alpides (Stevanović & Filipović 1994).

Since in eastern Serbia isolated limestone masses of smaller area are dominant, the shallow karst of the contact type has been developed. For this reason, the caves that have been formed are shorter than in other karst regions of the world (Djurović 1998).

As opposed to the typical development of karst topography in the Dinarides, the karst regions in the Carpatho-Balkanides lack surficial karst landforms (polje, sinkholes), and usually have vegetational cover (Stevanović & Filipović 1994). Nevertheless, the territory of eastern Serbia is rich in different underground karst forms — Petrović (1976) described more than 130 larger caves.

In the vicinity of Baranica many other caves and rock shelters are found (Vasiljska pećina, Pećina iznad Vrela, Bolvan I, II, III and IV, Gabrovnica, Kožuvarska pećina, etc.). In some of them the remains of Pleistocene fauna and Paleolithic artefacts were discovered (Mihailović 2004), and in Gabrovnica even prehistoric cave paintings — the first of their kind in Serbia (Mihailović & Jovanović 1997).

Baranica is a composite cave system situated in the southeastern part of Serbia, four kilometers south to Knjaževac, on the right bank of the Trgoviški Timok (Fig. 1). Its altitude is approximately 400 meters, 10 meters above the riverbed (Mihailović 2004). It was formed in the so-called Urgonian rocks of the Early Cretaceous age, represented by limestones, bioclastic limestones, sandstones and marlstones. These limestones are whitish to grey, with numerous remains of orbitolinids, crinoids, gastropods, corals, etc. (Jankičević 1978).

In this work, only the fossils from Baranica I are described, but it should be mentioned that there are also some other parts of this cave system — Baranica II, and also Baranica III, in which some large mammal remains have been found.

Baranica is a dry karst cave, without a stream. It has two entrances — the larger one to the south and the smaller one to the east. The cave consists of a small semicircular chamber (6.80×4.0 m) connected by narrow passages to the north and west with the rooms I and II (Fig. 2). Room I is situated on the north and its approximate dimensions are 3×2.4 m. Room II is bigger and filled with sediment which was deposited through the opening in the western part of the room

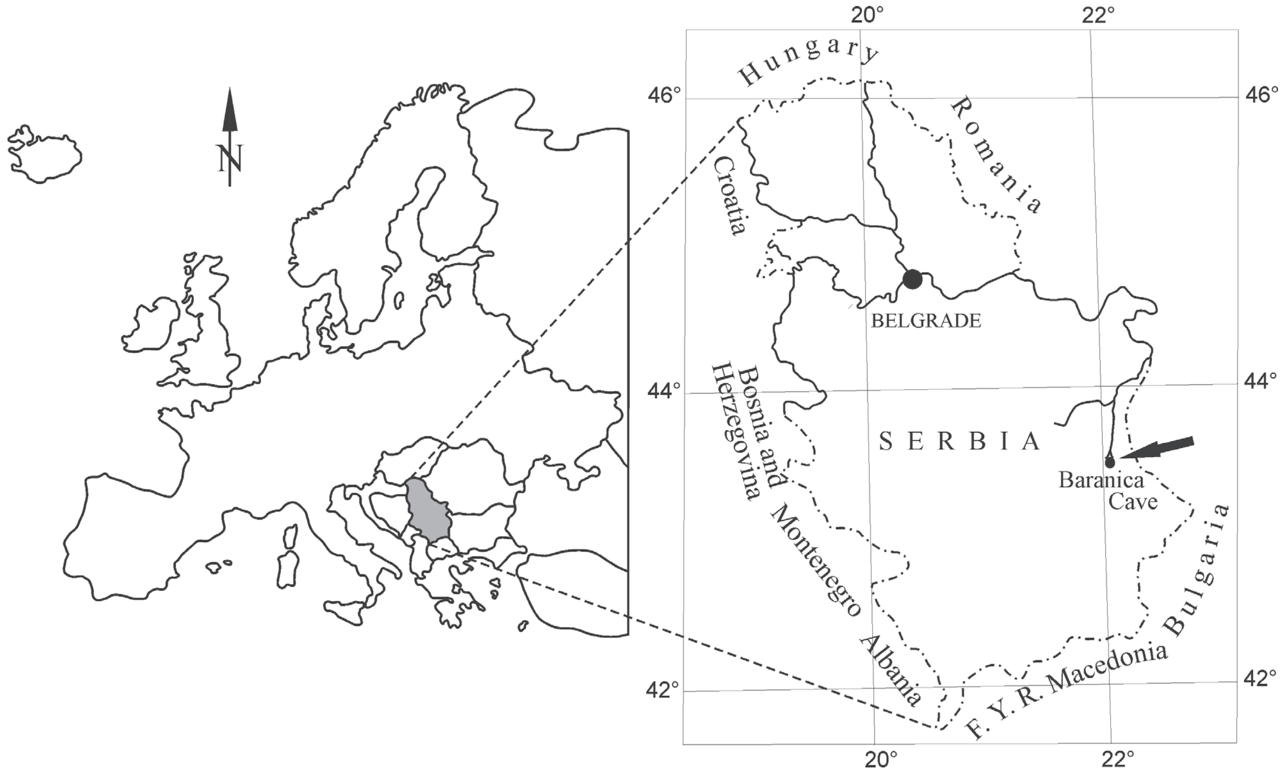

Fig. 1. Geographical position of the Baranica Cave.

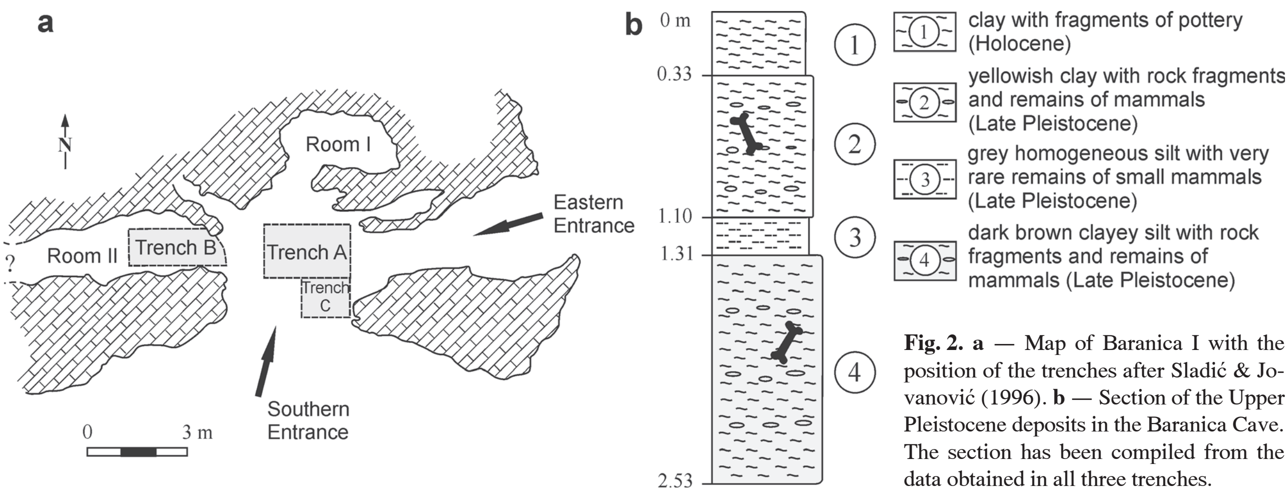

Fig. 2. a — Map of Baranica I with the position of the trenches after Sladić & Jovanović (1996). **b** — Section of the Upper Pleistocene deposits in the Baranica Cave. The section has been compiled from the data obtained in all three trenches.

(Sladić & Jovanović 1996). The total extension of Room II is not known yet.

During the 1994–1995 excavations, three small trenches were opened — trench A (2.5×1.5 m), generally oriented east–west; trench B in the entrance of Room II, and trench C in the southern entrance of the cave (Fig. 2a).

The trenches were dug to depths of between 2 and 2.5 meters, but the bedrock has not yet been reached (Mihailović 2004).

The cave floor is covered with clastic sediments. The clastic material consists of weathering detritus and breakdown (fragments of broken bedrock of various sizes). Both autochthonous and allochthonous sediments are present in this cave, although their relative proportions are not known. It seems, however, that in the entrance area the autochthonous component is predominant (as showed by the presence of abundant fragments of Cretaceous limestones and fossils), while in Room II most of the sediment material came from the outside, through the opening in the ceiling (Sladić & Jovanović 1996).

Also, there are no typical stream deposits, such as gravels and sands, in this cave. In the interior, the amount of rock debris is small, and sediments are more compact, while in the entrance sediments are less compact and contain more rock fragments and blocks.

The excavations revealed the profile of the sediments composed of four sub-horizontal geological layers, some of which have been disturbed by post-depositional processes, including modern human activities (treasure hunters digging). The main criteria for distinguishing the layers were the colours of the sediments and amount of rock fragments. The sequence of deposits, from the top to the bottom, is as follows (Fig. 2b):

1. Surficial clay of Holocene age (approximately 30 cm thick). Fragments of prehistoric and Roman pottery were found in this layer, which indicate the Holocene age.

2. Yellowish clay (80 cm thick) — with coarse rock fragments and the remains of large and small mammals. Two horizons were distinguished in this unit, 2a and 2b, which differ mainly in colour (2b being somewhat darker). In this layer numerous remains of large mammals were found — bison, horse, rhinoceros and other species. Some Upper Paleolithic artefacts (two flint blades and a small endscraper) and a fireplace were also found in the upper part of this layer, indicating that Paleolithic man made short visits to this cave (Mihailović et al. 1997).

3. Ash grey homogeneous silt (20 cm thick) — with rare small mammal remains. It underlies Layer 2 in the northern part of trench A. The upper part (3a) contains rare small mammal remains, while the lower one (3b) is paleontologically sterile.

4. Dark brown clayey silt (more than 120 cm thick) — with coarse rock fragments. In this sediment, two horizons can also be differentiated:

4a — compact sediment with rock fragments;

4b — homogeneous sediment without rock fragments.

In this layer, remains of both large and small mammals are scarcer than in Layer 2. Some Paleolithic artefacts were also found (Mihailović et al. 1997).

The investigations in Baranica I began in 1994 and have been conducted jointly by the Faculty of Philosophy from Belgrade and the National Museum of Knjaževac. They were part of a research project on the prehistory of the Knjaževac area, which includes trial excavations in several caves in the vicinity of this site.

From 1995 to 1997, some Upper Paleolithic artefacts were found in Baranica I (Mihailović et al. 1997) and some large mammal remains in both Baranica I and II (Dimitrijević 1997b, 1998). Samples for analysis of arvicolid (and other small mammal) remains were taken only from Baranica I.

The abundance of remains of both large and small mammals was already noticed in the early phase of the research. In addition to the mammal remains, this cave also yielded some remains of other animals and plants (birds, reptiles, amphibians, fish, gastropods and seeds; Bogićević 2008). Some pollen grains were also extracted from hyena's coprolites (Argant & Dimitrijević 2007). General remarks on the fossil fauna from Baranica with the preliminary faunal list were published in several papers (Dimitrijević 1997b, 1998, 2004). Although some species and groups have been described more thoroughly (subterranean voles in Brunet-Lecomte et al. 2001, horses in Forsten & Dimitrijević 2004, carnivores in Salčin 1996), the fauna from Baranica (especially small mammals) is still poorly known. Only two unpublished master theses (Krantić 1997; Jovanović 2005), and one conference abstract (Bogićević 2004) contain a partial analysis of the rodent fauna from Baranica.

Material and methods

During the 1995 excavation, some sediment samples were taken at 22 sampling points in Baranica I: six in Layer 2, one in Layer 3 and 15 in Layer 4. (Layer 3 is represented by only one sample, because it was thought to be without fossils.) All samples were screen-washed on three screens of 2, 1 and 0.5 mm mesh. The sample size was not large, approximately 50 kg of sediments in total. Only a few teeth were found in the sample from Layer 3, but Layers 2 and 4 have proved to be rather rich in vertebrate remains. More than four hundred arvicoline teeth were identified to the species level and are included in this study.

The material is fairly well preserved, with almost no traces of dissolution. All skeletal elements are present, but the faunal list is based exclusively on teeth (mainly M_1). All the teeth that could be determined to the level of species are listed, but only M_1 were measured. The dimensions are given in mm. The method of measurements is described in Nadachowski (1982). The SDQ index (the enamel band (Schmelzband) differentiation quotient) was measured by the method originally proposed by Heinrich (1978). For the morphological elements of arvicolid teeth, the terminology of van der Meulen (1973) and Nadachowski (1982) is employed. The names of the morphotypes of M_1 are after Nadachowski (1982, 1984a, 1985). The teeth were drawn under a binocular microscope.

The minimum numbers of individuals (MNI) were calculated according to the number of M_1 in most cases, but also based on the numbers of some other teeth when they were characteristic enough for species determination. These numbers were used for calculating the percentage of species in the arvicoline fauna.

The material described in this paper is stored at the Department of Paleontology of Belgrade University, under the inventory numbers BAR 2/6–15, BAR 3/2–5 and BAR 4/12–25. The data on the Pleistocene distribution of particular arvicolid species in Europe were taken mainly from Kowalski (2001).

All of the material described in this paper comes from Baranica I, hence, for the sake of simplicity, the name “Baranica” will be consistently used instead of “Baranica I”.

Systematic paleontology

Order: **Rodentia** Bowdich, 1821
Family: **Cricetidae** Fischer, 1817
Subfamily: **Arvicolinae** Gray, 1821
Arvicola Lacépède, 1799

Arvicola terrestris (Linnaeus, 1758)
(Fig. 3)

Material and dimensions: Layer 2: M^1 sin., M^1 dext., M^2 sin., M^2 dext., M^3 sin., M^3 dext., M_1 dext. (L = 4.1 mm; A = 1.72 mm), M_2 sin., M_2 dext. BAR 2/6.

Layer 3: M^1 sin., M^2 sin. BAR 3/2.

Layer 4: 2 M^1 dext., M^2 sin., 2 M^3 sin., M^3 dext., 2 M_1 sin. (L = 4.03; 4.07 mm; A = 1.62; 1.69), 2 M_1 dext. (L = 4.07; -; A = 1.69; 1.48 mm), 2 M_2 sin., M_2 dext., M_3 dext. BAR 4/12–16.

Description: The molars are large, rootless, with abundant crown cement in re-entrant angles (Fig. 3). The enamel is thicker on the concave side of the triangles (“positive” or *Arvicola*-differentiation). On the first lower molars, the anterior cap is broadly confluent with T4 and T5. All the third upper molars show a more complicated shape — so-called “exitus” morphotypes (Nadachowski 1982) — with three dentine triangles, more or less closed.

Comments: The enamel thickness quotient (SDQ index after Heinrich 1978) of M_1 is 90.11 in Layer 2 (only one tooth measured) and 92.48, with a range of 89.37–94.66 (n = 3) in Layer 4. Lower values of the index (less than 100), such as these, are typical for geologically younger (Late Glacial and Holocene) and recent populations of *Arvicola terrestris* (Heinrich 1978, 1987). The dimensions of M_1 (average length greater than 4 mm) are also in agreement with the proposed young age of the populations from Baranica (the older populations had a somewhat smaller M_1; Maul et al. 2000).

Arvicola terrestris was among the most common rodent species in the Late Pleistocene of Europe. Populations of this species have been found (although usually represented by a small number of specimens) throughout Europe, both in warm and cold periods of the last glacial (Kowalski 2001; Cuenca-Bescós et al. 2008).

It was also found in the Pleistocene deposits of several caves in Serbia — the Smolućka and Vrelska Cave (Dimitrijević 1997a) and in Montenegro — Crvena Stijena (Malez 1975) and Mališina Stijena (Bogićević & Dimitrijević 2004).

Table 1: Dimensions of M_1 of *Chionomys nivalis*.

	Layer 2				Layer 4				
	n	**min.**	**max.**	**median**	**n**	**min.**	**max.**	**mean**	**SD**
L	3	2.88	3.3	2.97	16	2.46	3.5	2.84	0.25
a	5	1.32	1.7	1.38	20	1.05	1.85	1.37	0.18
a/L*100	3	46	52	46	16	42	53	48	2.98
B_1/W_1	7	4	23	11	18	3	21	8.37	5.22

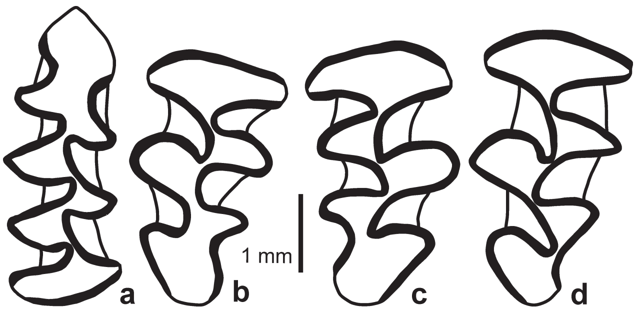

Fig. 3. *Arvicola terrestris* (Linnaeus, 1758). **a** — M_1 dext. (BAR 4/14), **b** — M^3 sin. (morphotype C), **c** — M^3 dext. (morphotype D), **d** — M^3 sin. (morphotype E). (Names of morphotypes after Nadachowski 1984a.)

Chionomys Miller, 1902

Chionomys nivalis (Martins, 1842)
(Fig. 4)

Material: Layer 2: 5 M_1 sin., 2 M_1 dext. BAR 2/7.

Layer 4: 12 M_1 sin., 11 M_1 dext. BAR 4/17. (For dimensions, see Table 1.)

Description: The dentine triangles are massive. The triangles T1–T4 on M_1 are closed, while T5 can sometimes be confluent with the anterior lobe. However, most of the M_1 from Baranica (73.3 %) have five closed triangles and the anterior part of the tooth is in the shape of an arrow or a spear (this is a progressive or “nivalid” morphotype; Fig. 4c–d). The second most frequent is the transitional morphotype (“nivalid-ratticeps” after Nadachowski 1984a; Fig. 4b) with 23.3 %,

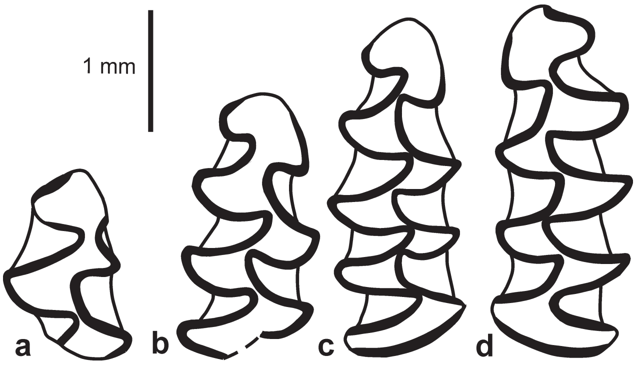

Fig. 4. *Chionomys nivalis* (Martins, 1842). **a** — M_1 dext. (morphotype B — “gud”), **b** — M_1 dext. (morphotype C), **c** — M_1 dext. (morphotype D_1), **d** — M_1 sin. (morphotype D_2). (Names of morphotypes after Nadachowski 1984a.)

while only one tooth showed a so-called "gud" morphotype, with broadly confluent T5 and T6 and a well developed BRA4 and BSA4 (Fig. 4a). No tooth showed a structure characteristic for *Microtus oeconomus* (Pallas, 1776) ("ratticeps" morphotype after Nadachowski 1984a).

Comments: The small values of the B_1/W_1 ratio clearly indicate that the teeth from Baranica belong to *Chionomys nivalis* and not to *Microtus oeconomus*. In the latter species, this ratio is much larger; meaning that the triangle T5 is less separated from the anterior loop. The values of this ratio measured in *C. nivalis* from Bacho Kiro, Bulgaria (Nadachowski 1984a) varied from 1 to 24 (3–23 in Baranica), while the mean values in different layers are 7–11; in Baranica 11 in Layer 2 and 8 in Layer 4.

In recent populations of this species in Serbia, the morphotype frequency distribution is very similar to that observed in the Pleistocene deposits of Baranica. For example, in a recent population from the Stara Planina Mountain (an area of similar altitude and geographically very close to Baranica), 66.8 % of the teeth showed the "nivalid" morphotype, 16.6 % "nivalid-ratticeps", while the "gud" morphotype was not present at all (Kryštufek 1990).

This species inhabited mountainous areas of Europe in the Middle and Late Pleistocene (Kowalski 2001). During the latter period, the snow vole was widespread mostly in the northern part of the Balkan Peninsula (Terzea 1972; Rabeder 2004; Toškan & Kryštufek 2007; Toškan 2009), but their remains have also been found in some caves and shelters of the southern Balkans — in Montenegro (Crvena Stijena, Mališina Stijena, Trebački Krš — Malez 1975; Dimitrijević 1999; Bogićević & Dimitrijević 2004) and Serbia (the Vrelska and Smolućka Cave) (Dimitrijević 1997a). These facts are not in accordance with the conclusions of some authors (Terzea 1972; Toškan & Kryštufek 2007) that during the Late Pleistocene, this species was distributed only to the north of the Danube and Sava Rivers. It is assumed that *Chionomys nivalis* migrated southwards during the Holocene and replaced the species *Dinaromys bogdanovi* (Martino, 1922) that had similar ecological preferences (Kryštufek 2004).

Microtus Schrank, 1798

Microtus (*Microtus*) *arvalis* (Pallas, 1778) and
M. (*Microtus*) *agrestis* (Linnaeus, 1761)
(Fig. 5)

Material: Layer 2: 21 M_1 sin., 17 M_1 dext., M^2 dext. BAR 2/8–9.

Layer 3: 2 M_1 sin., 3 M_1 dext. BAR 3/3.

Layer 4: 61 M_1 sin., 60 M_1 dext., 4 M^2 sin., 4 M^2 dext. BAR 4/18–20. (For dimensions: see Table 2.)

Description: The typical "arvalid" morphotypes (Fig. 5a–b; the names of morphotypes after Nadachowski

Table 2: Dimensions of M_1 of *Microtus arvalis/agrestis*.

	Layer 2					Layer 3				Layer 4				
	n	min.	max.	mean	SD	n	min.	max.	median	n	min.	max.	mean	SD
L	22	2.45	2.97	2.8	0.15	3	2.9	3.14	3	64	2.41	3.31	2.87	0.22
a	22	1.31	1.66	1.53	0.09	3	1.59	1.66	1.62	64	1.24	1.90	1.53	0.14
a/L*100	22	51.8	56.7	54.6	1.14	3	51.6	55.3	54.8	64	50.5	57.4	53.3	1.43
(LT4/LT5)*100	22	56.2	82.6	71.84	6.41	3	65.6	71.4	68.7	64	51.60	84.00	67.50	6.91

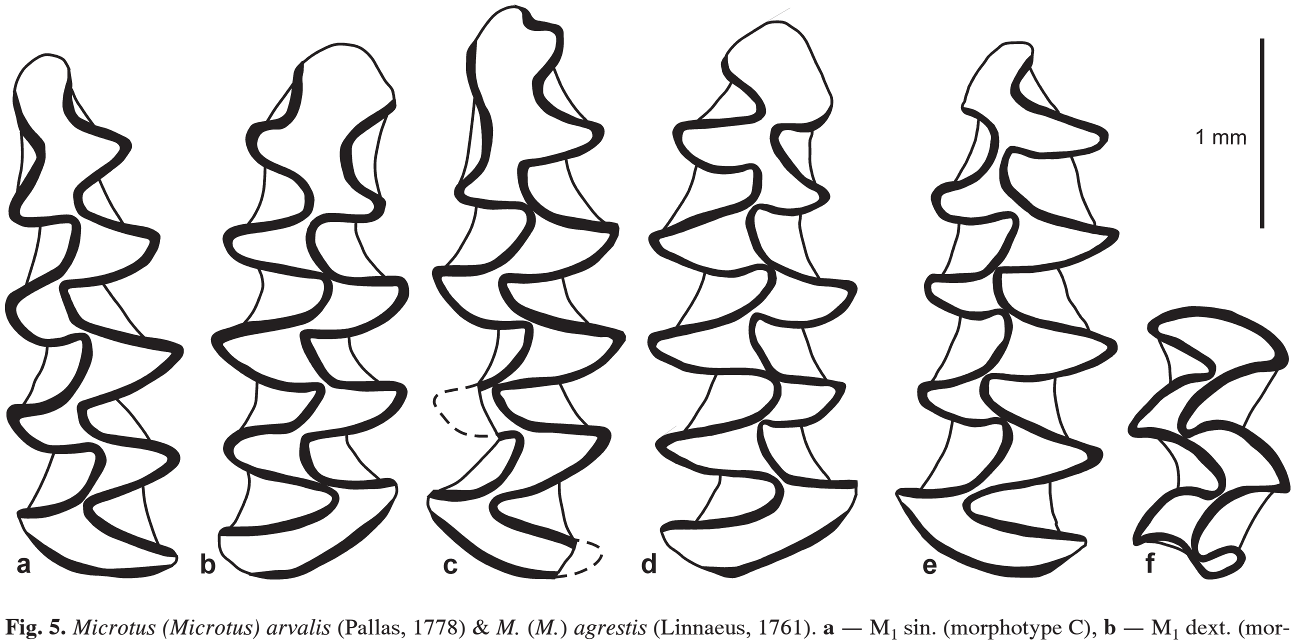

Fig. 5. *Microtus (Microtus) arvalis* (Pallas, 1778) & *M.* (*M.*) *agrestis* (Linnaeus, 1761). **a** — M_1 sin. (morphotype C), **b** — M_1 dext. (morphotype D), **c** — M_1 sin. (morphotype F), **d** — M_1 dext. (morphotype G — "maskii"), **e** — M_1 sin. (morphotype I — "extratriangulatus" after Nadachowski 1985), **f** — M^2 dext. (with exsul-loop). (Names of morphotypes after Nadachowski 1984a).

1982, 1985) are the most abundant in all layers (89 % in Layer 2; 100 % in Layer 3; 87 % in Layer 4). The other morphotypes are much less common: "maskii" (Fig. 5d) — 5.4 % in Layer 2; 4 % in Layer 4; the morphotype with an additional lingual syncline — LRA6 (Fig. 5c) — 5.4 % in Layer 2; 5 % in Layer 4; and the "extratriangulatus" morphotype (Fig. 5e) — 4 % in Layer 4. The average length of M_1 is 2.8 mm in Layer 2 and 2.87 mm in Layer 4.

Only 9 out of 166 M^2 that were found in Baranica have a well-developed additional triangle (1 in Layer 2 and 8 in Layer 4).

Comments: It is almost impossible to distinguish these two species on the basis of isolated teeth. The only unambiguous difference between them is the presence of an additional medial triangle on the posterior side of M^2 (Fig. 5f), which is well developed only in *M. agrestis* (Zimmermann 1956).

The M_1 of *M. arvalis* are somewhat smaller and in recent specimens, the length ranges from 2.4 to 2.9 mm, while in *M. agrestis*, this value varies from 2.75 to 3.4 mm; with mean values about 2.6 and 2.9 mm, respectively (Nadachowski 1982, 1984a; Gromov & Polyakov 1992). In Layer 2, there were no specimens longer than 3 mm and the percentage of small specimens was larger than in Layer 4. However, the finding of a M^2 with a well-developed additional triangle proves the presence of the species *M. agrestis* in Layer 2. On the other hand, large teeth are quite numerous in Layer 4 (about 31.8 %).

It is sometimes considered that these species can be distinguished on the basis of the symmetry of the lingual and labial dentine triangles. These triangles are more symmetrical in *M. arvalis*, and rather asymmetrical in *M. agrestis* (Chaline 1972). The measure of this symmetry/asymmetry is an index that is obtained by dividing the lengths of the triangles T4 and T5 (Nadachowski 1984b). The best results in distinguishing between the two species could be obtained by plotting the length of M_1 against the LT4/LT5 index (Nadachowski 1984b). Values of this index lower than 65 (typical for *M. agrestis*) were documented in 13.6 % of the teeth from Layer 2 and in 32.8 % from Layer 4.

Considering all these data, it could be concluded that both species were present in the material. However, *M. agrestis* is relatively abundant in Layer 4, while it almost disappears in Layer 2.

It could also be observed that the complexity of the anteroconid (A/L ratio) gradually increases. In Layer 4, this ratio was 53.3; in Layer 3 (measured on only 3 specimens) 53.9, and in Layer 2—54.6. The value in Layer 4 is similar to that in the Italian locality Castelcivita, with an estimated age of approximately 30,000–40,000 years (Maul et al. 1998), and in Croatian localities (Vindija — Layer G, Marlera I, Mujina Cave), with an age of approximately 27,000–45,000 years (Mauch Lenardić 2007). The ratio in Layer 2 is very close to the ratio in recent populations of these species (Maul et al. 1998). Small values of A/L (<52) are typical for the species *M. 'arvalinus'*, which is the probable ancestor of *M. arvalis* (Maul & Parfitt 2009).

Only three M_1 with the morphological characteristics of these species were found in Layer 3, but all of them are rather large, so they probably belonged to *M. agrestis*. This is interesting, because in most Balkan localities of the Late Pleistocene age, *M. arvalis* is much more common. In the Bacho Kiro Cave, *M. agrestis* was more numerous than *M. arvalis* only in two periods: at the beginning of the last glacial and in the middle of this period (Nadachowski 1984a). After the latter maximum (at the beginning of the "Pleniglacial II"), this species totally disappeared from the studied area. At present, *M. agrestis* occurs neither in Bulgaria (Nadachowski 1984a), nor in Serbia south of the Sava and Danube (Kryštufek et al. 1989). In Baranica, the "*agrestis*-peak" in Layer 3 is followed by an almost total disappearance of this species in Layer 2. Since these caves are situated in the same geographical area (the Stara Planina Mountain Range), the comparison is justified. Hence, for Layer 2, an age slightly older than 20,000 years B.P. could be proposed (in that period, *M. agrestis* disappeared from the area of the Bacho Kiro Cave) and for Layer 3, older than 30,000 years (second "*agrestis*-peak" in Bacho Kiro).

Microtus arvalis and *M. agrestis* are among the most common of all Pleistocene rodents in Serbia and Montenegro. Their remains have been found in the Smolućka, Vrelska, Vasiljska and Petnička Cave in Serbia (Dimitrijević 1997a), as well as in Mališina Stijena (Bogićević & Dimitrijević 2004) and Trebački krš (Dimitrijević 1999) in Montenegro.

Microtus (Stenocranius) gregalis (Pallas, 1779)
(Fig. 6)

Material: Layer 2: 4 M_1 sin., 3 M_1 dext. BAR 2/10. (For dimensions: see Table 3.)

Description: The first lower molar of this species has a poorly developed ("gregalo-arvalid") or completely absent BSA4 ("gregalid" morphotype). It differs from the similar (and probably ancestral) species *M. gregaloides* (Hinton,

Table 3: Dimensions of M_1 of *Microtus gregalis* (Layer 2).

	Layer 2				
	n	**min.**	**max.**	**mean**	**SD**
L	6	2.43	3.00	2.78	0.21
a	6	1.23	1.53	1.45	0.11
a/L*100	6	51	54	52.5	1.05

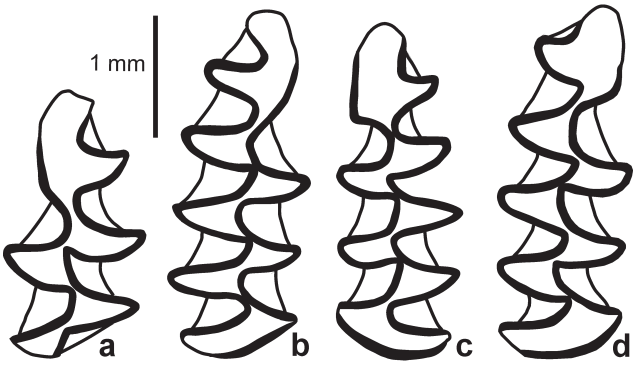

Fig. 6. *Microtus* (*Stenocranius*) *gregalis* (Pallas, 1779). **a** — M_1 sin., **b** — M_1 dext. (a, b — morphotype A — "gregalid"), **c** — M_1 sin., **d** — M_1 dext. (c, d — morphotype B — "gregalo-arvalid"). (Names of morphotypes after Nadachowski 1984a.)

1923) in having a longer anteroconid complex (>52) and T5 separated from T6 (Maul & Parfitt 2009).

Comments: The transitional "gregalo-arvalid" morphotype is sometimes, although very rarely, found in *M. arvalis* and a little more often in *M. agrestis*, but the "pure" "gregalid" morphotype is characteristic for *M. gregalis* (Nadachowski 1982). In the Late Pleistocene populations of *M. arvalis/agrestis* from Serbia, the transitional morphotype has only been found in a few localities (Smolućka and Hadži Prodanova Cave) and always with a very low frequency (Dimitrijević 1991; Bogićević 2008).

The oldest record of this species comes from the Early Pleistocene deposits of Western and Central Europe (Maul 1990). *Microtus gregalis* is a steppe and tundra dweller and it was very abundant and widespread in Europe during the cold episodes of the Late Pleistocene (Nadachowski 1982), even in Spain (Pokines 1998; Sesé 2005; Cuenca-Bescós et al. 2008). It has also been found in some other localities in the Balkans (Kozarnika and Cave 16 in Bulgaria — Popov 2000; Popov & Marinska 2007) but this is the first time it has been found in Serbia.

Microtus (Terricola) subterraneus (de Sélys-Longschamps, 1836) (Fig. 7)

Material: Layer 2: 3 M_1 sin., 7 M_1 dext. BAR 2/11.

Layer 3: 3 M_1 dext. BAR 3/4.

Layer 4: 12 M_1 sin., 11 M_1 dext. BAR 4/21. (For dimensions: see Table 4.)

Description: The first lower molar of *Microtus* (*Terricola*) *subterraneus* (Fig. 7) is characterized by the presence of a so-called "*Pitymys*-rhombus" (broadly connected triangles T4 and T5) and by its small dimensions. The relative length of the anteroconid (A/L ratio) is about 51, in both Layers 2 and 4.

Table 4: Dimensions of M_1 of *Microtus* (*Terricola*) *subterraneus*.

	Layer 2					Layer 4				
	n	min.	max.	mean	SD	n	min.	max.	mean	SD
L	9	2.25	2.58	2.46	0.11	18	2.31	2.70	2.53	0.11
a	9	1.17	1.35	1.26	0.06	18	1.17	1.47	1.31	0.09
a/L*100	9	49	52	51.2	0.97	18	49	54	51.6	1.69

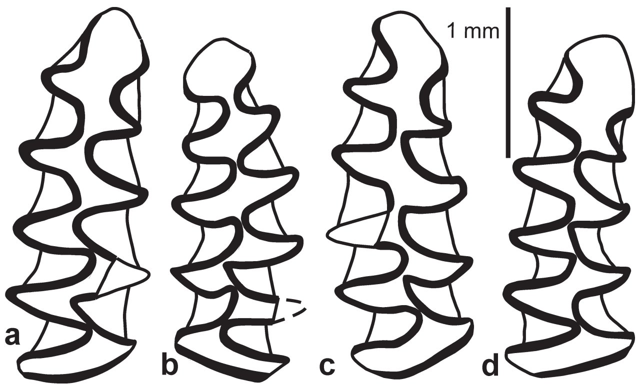

Fig. 7. *Microtus* (*Terricola*) *subterraneus* (de Sélys-Longchamps, 1836). **a** — M_1 dext. (morphotype A), **b** — M_1 sin. (morphotype B — "maskii"), **c** — M_1 dext. (morphotype C), **d** — M_1 dext. (morphotype with broad connection between T1 and T2). (Names of morphotypes after Nadachowski 1984a.)

Comments: The morphology of the M_1 is similar to those of the recent species *Microtus subterraneus* and *Microtus multiplex* (Fatio, 1905), but according to the length of M_1 (mean value 2.46 mm in Layer 2 and 2.53 mm in Layer 4), the material from Baranica is more similar to the smaller species — *Microtus subterraneus*.

A detailed morphometrical analysis based on recent and fossil material from Serbia and Montenegro (Brunet-Lecomte et al. 2001) showed that the populations from Baranica have an intermediate taxonomic position between *M.* (*T.*) *grafi* Brunet-Lecomte, Nadachowski & Chaline, 1992 and *M.* (*T.*) *brauneri* (Martino, 1926). The systematic position of *M.* (*T.*) *grafi* is not yet clarified, hence it could be treated either as a subspecies of *M. (T.) subterraneus* (more probable) or as a distinct, but very closely related species (Brunet-Lecomte et al. 2001).

This species was found at several Late Pleistocene localities in Serbia — the Smolućka and Vrelska Cave (Dimitrijević 1997a), the Vasiljska Cave and Pećurski kamen (Brunet-Lecomte et al. 2001). The only known Pleistocene locality of this species in Montenegro is Trebački krš (Dimitrijević 1999). It was also found in Holocene deposits of the Vrućа Cave in Montenegro (Brunet-Lecomte et al. 2001).

Clethrionomys Tilesius, 1850

Clethrionomys glareolus (Schreber, 1780) (Fig. 8)

Material: Layer 2: M^1 sin., 2 M^1 dext., 3 M^2 sin., M^3 dext., 3 M_1 sin., 2 M_1 dext., 2 M_2 sin. BAR 2/12–13.

Layer 4: 7 M^1 sin., 4 M^1 dext., M^2 sin., 6 M^2 dext., 5 M^3 sin., 8 M^3 dext., 4 M_1 sin., 4 M_1 dext., 4 M_2 sin., M_2 dext., M_3 sin., 2 M_3 dext. BAR 4/22–23. (For dimensions: see Table 5.)

Description: Not only the first lower molars, but also the other teeth of this species could be distinguished by the presence of roots and a characteristic rounded shape of the dentine triangles. All the molars have two roots. The enamel is thinner on the convex sides of the triangles and thicker on the concave ones. Only in one M_1 were T1 and T2 completely closed. In all the other specimens, there was a more or less broad connection between these triangles (Fig. 8).

Comments: All the M^1 from Baranica have two roots, a characteristic which is typical (after Radulescu & Samson 1992) of populations from the last glacial period and the Holocene, while some of the earlier representatives of the species could have three roots. The dimensions of the M_1 from Baranica (Table 5) are very similar to those of Cave 16 in Bulgaria (Popov 2000).

Several localities of Late Pleistocene age in Serbia yielded remains of this species: the Smolućka, Vrelska, Vasiljska, Petnička, Hadži Prodanova and Canetova Cave (Dimitrijević 1997a; Bogićević 2008). In Montenegro this species was found only in Trebački krš (Dimitrijević 1999).

Table 5: Dimensions of M_1 of *Clethrionomys glareolus*.

	Layer 2				Layer 4				
	n	**min.**	**max.**	**median**	**n**	**min.**	**max.**	**mean**	**SD**
L	3	2.25	2.49	2.4	6	2.13	2.58	2.36	0.15
a	3	0.87	1.02	0.99	6	0.84	1.08	0.98	0.09
a/L*100	3	39	42	40	6	39	44	41.67	1.75

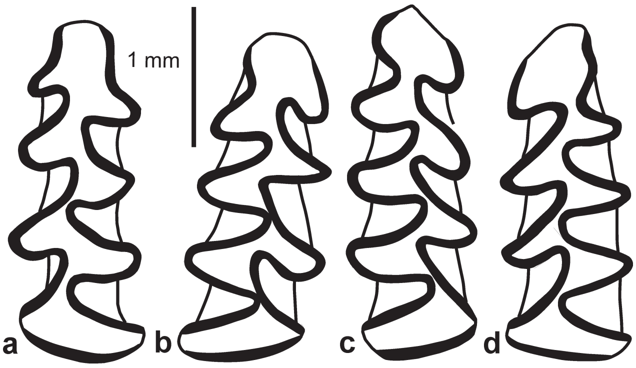

Fig. 8. *Clethrionomys glareolus* (Schreber, 1780). **a** — M_1 sin. (morphotype A), **b** — M_1 dext. (morphotype B), **c** — M_1 dext. (morphotype B/C), **d** — M_1 sin. (morphotype C — "maskii"). (Names of morphotypes after Nadachowski 1984a.)

Lagurus Gloger, 1841

Lagurus lagurus (Pallas, 1773)
(Fig. 9)

Material: Layer 2: 7 M^1 sin., 7 M^1 dext., 5 M^2 sin., 3 M^2 dext., 4 M^3 sin., 2 M^3 dext., 4 M_1 sin., M_1 dext., 2 M_2 sin., M_2 dext., 5 M_3 sin., 5 M_3 dext. BAR 2/14–15.

Table 6: Dimensions of M_1 of *Lagurus lagurus*.

	Layer 2			Layer 4		
	n	**min.**	**max.**	**n**	**min.**	**max.**
L	2	2.46	2.55	2	2.46	2.67
a	2	1.26	1.38	2	1.32	1.47
a/L*100	2	51	54	2	54	55

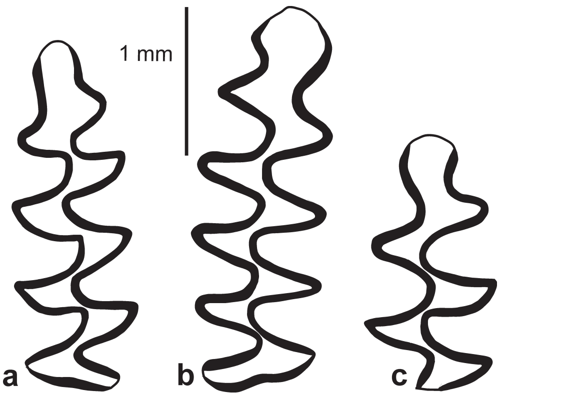

Fig. 9. *Lagurus lagurus* (Pallas, 1773). **a** — M_1 sin. (morphotype B), **b** — M_1 dext. (morphotype C), **c** — M_1 sin. (morphotype D). (Names of morphotypes after Nadachowski 1984a.)

Layer 3: M^1 sin., 2 M^1 dext., M_1 sin., M_1 dext., M_3 dext. BAR 3/5.

Layer 4: 3 M^1 sin., M^1 dext., 2 M^2 sin., M^2 dext., M^3 sin., M^3 dext., mand. sin. (M_1–M_2), M_1 sin., 4 M_1 dext., M_2 sin., 4 M_2 dext., 4 M_3 sin., M_3 dext. BAR 4/24–25. (For dimensions: see Table 6.)

Description: The molars of *Lagurus lagurus* are characterized by a complete lack of cement in the synclines. The lingual and labial triangles are of approximately the same size (Fig. 9). There is a small interruption of the enamel on BSA4 of the M_1. The upper teeth of this species have a "laguroid protuberance" (small additional lingual triangle).

Comments: The "lagurid" morphotype (Fig. 9b; morphotype C after Nadachowski 1984a) dominates — it was developed in 77 % of the M_1, while only one tooth shows a primitive "transienid" morphotype (Fig. 9a). It is also typical for the Late Pleistocene populations of this species from Bulgaria — it has been found in about 70 % M_1 in the Cave 16 (Popov 2000) and 84 % in Bacho Kiro (Nadachowski 1984a).

Remains of this steppe species were found in Serbia only in the Pleistocene deposits of the Vrelska Cave (Pavlović & Marković 1991).

Discussion

Paleoenvironment

A more detailed interpretation of paleocological conditions will be given in a subsequent paper, when the analysis of the whole material from the Baranica Cave has been completed. In this paper, only some preliminary conclusions, drawn on the basis of the presence of arvicoline species and the previous knowledge of fauna and flora (large mammals, pollen), will be presented.

Remains of large mammals have been found in both Baranica I and II. The composition of fauna in these two caves is very similar. It could not be determined in which layers the remains of particular species were found (a complete description of the large mammal fauna has not yet been published), but, according to some earlier reports (Mihailović et al. 1997), it could be concluded that most of them come from Layer 2. The large mammal fauna contains some species indicative of cold climate, such as *Gulo gulo* (Linnaeus, 1758) and *Coelodonta antiquitatis* (Blumenbach, 1799), while species indicative of warm climate, such as roe deer and wild boar are completely absent (Argant & Dimitrijević 2007).

Several pollen grains found in a hyena's coprolite from Baranica indicate an open landscape with the presence of steppe taxa (Argant & Dimitrijević 2007).

Since extant arvicolines have a distribution that is mainly controlled by the climate, a method has been developed to use the number of arvicoline species for an estimation of some climatic parameters, notably temperature — a greater number of species is typical for places with a colder climate (Montuire 1996; Montuire et al. 1997). This method was applied to the faunas from some Hungarian and Central European localities of Pleistocene age. The number of arvicoline species in Baranica (8 species in Layer 2 and 7 in Layer 4) corresponds to some "cold" localities of Central Europe, with mean annual temperatures of –2.4 °C and 0.4 °C, respectively (Montuire 1996). According to this method, the mean temperatures for July was 14.7 °C in Layer 2 and 16.3 °C in Layer 4, while the mean temperatures for December were –19.9 °C and –15.8 °C, respectively. Although we think that these results should be accepted with caution, they seem to indicate that the deposits were formed under rather cold conditions.

It should be mentioned that the estimates for Layer 2 are similar to the temperatures, obtained by some other methods, during the Last Glacial Maximum in this part of Europe ("vole thermometer" method — Kordos 1987; BIOME3 terrestrial biosphere model — Guiot et al. 2000; species distribution modelling — Fløjgaard et al. 2009, etc.).

Among all the micromammal remains at the Baranica Cave most of them belong to arvicolines (Bogićević et al. 2011). The most abundant among the vole species are *Microtus arvalis* and *M. agrestis* (Table 7). They comprise 43.7 % of the arvicoline remains in Layer 2, 33.3 % in Layer 3 and even 61.6 % in Layer 4. *Lagurus lagurus* and *Microtus subterraneus* are also very common. The compositions of the arvicoline fauna in Layers 2 and 4 are generally very similar, however, some differences should be emphasized, such as the somewhat lower percentage of *Lagurus lagurus* in Layer 4 and the presence of a boreal species — *Microtus gregalis* — in Layer 2.

In all three layers, inhabitants of open grasslands and relatively dry areas are predominant (*Microtus arvalis* and *M. agrestis*, *Lagurus lagurus*). Since *Lagurus lagurus, Microtus gregalis* and *Microtus agrestis* no longer live in the vicinity of the cave, it can be assumed that the climatic conditions were much more dry, cold and steppe-like than today. The climate was particularly cold during the formation of Layer 2. Such conclusions fit well with the results of palynological analysis (Argant & Dimitrijević 2007).

As is the case with large mammals, forms that indicate woodland conditions are rare.

Age of the fauna

As early as during the preliminary investigations (Mihailović et al. 1997), it was established that the deposits of Baranica are of Late Pleistocene age. A preliminary study of the large mammal fauna and cultural stage of the archaeological artefacts indicated an age between 15,000 and 40,000 years for Layer 2 (Mihailović et al. 1997).

There were no extinct forms among the arvicolines. Nevertheless, the fauna differs considerably from the recent one by containing species that are no longer present in the extant fauna of Serbia (*Lagurus lagurus*, *Microtus gregalis*), or in the vicinity of the cave (*Microtus agrestis*).

We could conclude from the composition and ecological characteristics of the fauna (the presence of boreal species of both large and small mammals), that both Layers 2 and 4 were formed under conditions of a cold and dry climate, characteristic of a glacial period. Layer 2 was formed during a very cold period, which could correspond to the Last Glacial Maximum, about 20,000 years ago.

The evolutionary stage of the *Arvicola* enamel (the mean value of the SDQ index is well under 100), rather complicated anteroconids in *Microtus arvalis* and *M. agrestis* and the predominance of progressive morphotypes in *Lagurus lagurus* in Layer 4 are also typical for the Last Glacial. The SDQ index (92.48) in this Layer is slightly higher than in the Central European localities of Kemathenhöhle (with an estimated age of about 31,400 years B.P.; value of SDQ index — 89.23), Peskö (estimated age — 34,600 B.P.; SDQ index — 89.31) and Istállóskö (estimated age — 36,400 B.P.; SDQ index — 89.54); and much lower than in Burgtonna (estimated age — 80,000 B.P.; SDQ index — 99.65) (Heinrich 1987). Hence, it can be supposed that the age might be older than in the former localities, but much younger than in the latter one. However, since the extant populations of the species in southern Europe were shown to have higher values of the SDQ index than the northern ones (Röttger 1987), Layer 4 might be of similar or slightly greater age than the above-mentioned localities (Kemathenhöhle, Peskö, and Istállóskö).

The greater size of M_1 of *Arvicola terrestris* is also in agreement with the proposed age. A gradual increase in length of this tooth was already well documented in many European populations (Maul et al. 2000). According to Heinrich (1987), an average length of M_1 greater than 4 mm is characteristic for populations from the Late Weichselian.

Lately, some bone remains from Baranica have been absolutely dated at the Oxford laboratory by AMS method: a second phalanx of a giant deer (BAR 97/19/16; OxA-13827) from Layer 2 in Baranica I has been dated to 23,520±110 B.P. ($\delta^{13}C$ –19.415 ‰), while a third molar of a cave bear (BAR 97/80/1; OxA-13828) from Layer 4 has been dated to 35,780±320 B.P. ($\delta^{13}C$ –20.980 ‰) (Pacher & Stuart 2008; Dimitrijević in prep.). These data are rather consistent with the age estimated on the basis of arvicoline remains.

Table 7: Abundance of individual taxa of arvicolids.

Species	Layer 2				Layer 3				Layer 4			
	NISP	%	MNI	%	NISP	%	MNI	%	NISP	%	MNI	%
Arvicola terrestris	9	6.8	1	2.1	2	12.5	1	11.1	14	5.4	2	2
Chionomys nivalis	7	5.3	5	10.4	–	–	–	–	23	8.8	12	12.1
Microtus arvalis & *M. agrestis*	39	29.6	21	43.7	5	31.2	3	33.3	129	49.4	61	61.6
Microtus gregalis	7	5.3	4	8.3	–	–	–	–	–	–	–	–
Microtus subterraneus	10	7.6	7	14.6	3	18.8	3	33.3	23	8.8	12	12.1
Clethrionomys glareolus	14	10.6	3	6.3	–	–	–	–	47	18	8	8.1
Lagurus lagurus	46	34.8	7	14.6	6	37.5	2	22.2	25	9.6	4	4

Conclusions

In this paper, the remains of eight species of arvicolines from Layers 2, 3 and 4 have been analysed. On the basis of their study, it was concluded that the associations from Layers 2 and 4 (Layer 3 is very poor in fossils) are very similar in composition and that they were formed during cold episodes of the last glacial, under conditions of an open environment and dry climate.

The method for temperature estimation (described by Montuire 1996; Montuire et al. 1997) has also been applied, and although the results thus obtained should be accepted with caution, they seem to indicate that the deposits were formed under rather cold conditions.

By measuring of the SDQ index on the *Arvicola terrestris* teeth, it has been established that the values of this index in Layers 2 and 4 from Baranica are similar to those from the last glacial localities in Central Europe, with absolute ages of about 30,000–35,000 B.P. The absolute dating gives the age of 23,520 ± 110 B.P. for Layer 2 and 35,780 ± 320 B.P. for Layer 4, which is rather consistent with the estimates obtained by measuring of the SDQ index.

These results should be seen as preliminary. Other faunal elements also need to be studied and so we will get a more complete picture of the composition of the fauna and paleoecological conditions in the Late Pleistocene in this region. In this way, correlations with the faunas from neighbouring countries will be enabled, as well as the study of the evolution and migration of small mammals in this interesting and dynamic part of Europe.

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