A Ruscinian mammalian microfauna from a fissure filling near Sondershausen (Thuringia, Central Germany)

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Abstract The mammalian microfauna from the karstic fissure fill site Sondershausen in Thuringia is presented. It is the first record of Pliocene micromammals in Central Germany and includes 621 identified specimens of 13 species, mostly isolated teeth and only a few jaw fragments. Nearly three quarters of the specimens belong to the dormouse *Glis minor*. The vespertilionid bats, represented by two *Myotis* species, make a contribution of ca. 20%. In terms of numbers of specimens, the remaining species are negligible. The micromammal assemblage probably derives from an accumulation of regurgitation pellets from an owl. The fauna correlates with the late Ruscinian Mammal unit MN 15, with the eomyid *Eomyops* and the flying squirrel *Blackia* as Miocene holdovers and the cricetids *Cseria*, *Baranomys* and *Bjornkurtenia* as Ruscinian newcomers. The sciurid, the eomyid and in particular, the stunning abundance of the dormouse *Glis minor* are strong indicators of a forest-dominated environment.

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Introduction

Fossil-bearing karst fissure deposits in Germany are mainly reported and described from Upper Jurassic limestones of Southern Germany (Schwäbisch-Fränkische Alb), and contain micromammals mostly of Eocene, Oligocene and Miocene age. In contrast, karst fissure fillings are very rare in Central Germany. An outstanding example is the fissure filling of Walbeck, which was found in the late 1930s in a quarry northwest of the city of Magdeburg (Saxony-Anhalt). Walbeck is particularly renowned for its enormous amount of Palaeocene arctocyonid jaws (Condylarthra) and isolated teeth of additional taxa (e.g. Weigelt 1939, 1942, 1960; Russell 1964; Mayr 2002, 2009). A former quarry on the Totenberg near Sondershausen in Thuringia (Central Germany) has long been known for fissure fillings which yielded iron ore pisoids, so-called bean ores. Von Freyberg (1962) and Böhme and Schulz (1986) reported on it in short notes, but to date no fossil remains have been published from it. In February 1995, a new fissure filling was recovered in the Lower Muschelkalk (mu 1, Wellenkalk/Schaumkalk) of a former quarry on the "Großer Totenberg" by M. Hellmund (Martin-Luther-University, Halle-Wittenberg, Saxony-Anhalt) and F. Schöpe (formerly TU Bergakademie Freiberg, Saxony). The site is located ca. 2 km south of the city of Sondershausen in Thuringia (Central Germany) (Fig. 1); see the geological survey map sheet no. 40 of H. Eck (dated 1864/1869) and sheet no. 4631 edited by the "Zentrales Geologisches Institut der DDR" in 1961 for details. The geographical coordinates are: r4425000, h5692000 (Gauß-Krüger-notation)¸ 51°21′28.11″N–10°55′18.29″E (longitude–latitude-notation), ca. 370 m height a.s.l.

The karst fissure is more or less vertically oriented with a maximum width of ca. 50 cm (Fig. 2). The fissure filling
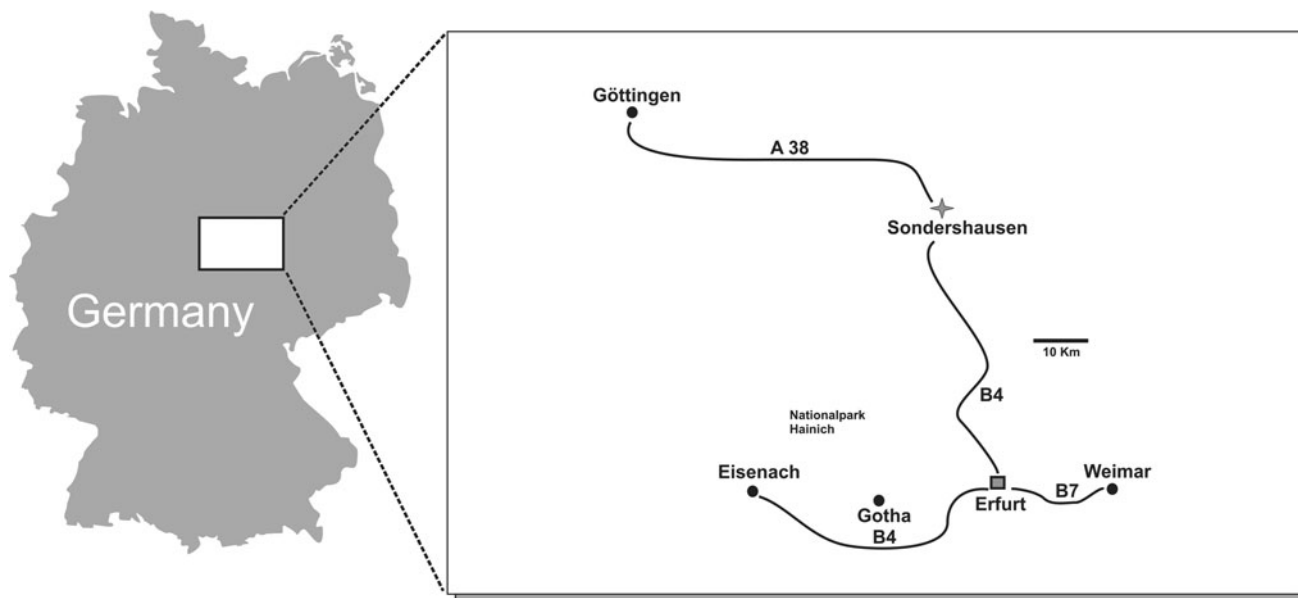
Fig. 1 Sketch map with the fissure fill site

Fig. 2 Photograph of the fissure, length of the hammer 32.5 cm

is a yellowish to brown, decalcified, in fresh state ductile lubricating clay. A cursory examination revealed bean ores and some scattered tiny bone fragments of micromammals, which prompted us to excavate the sediment. At 170 cm below the top, there was a largely calcified bed, several centimetres thick containing mainly rounded bean iron ore of different size (1–15 mm). A sample of ca. 300 kg from near the top down to a depth of 180 cm has been taken.

Methods

The sampled material was screen-washed with several sieves down to a mesh of 0.5 mm. The dried residue was screened for small vertebrates. Only teeth, some dentary fragments and broken postcranials of small mammals were identified. The teeth, the only taxonomically useful remains, were measured. All measurements are given in millimetres. If a taxon is represented by only few specimens, meristic measurements are presented under the caption "Materials and measurements," otherwise the sample statistics are presented in the tables.

Regarding the terminology of the teeth and the measurements we refer to Reumer (1984) for the soricids, to Sigé (1968) for the chiropterans, to Daams (1981) for the glirids, to Engesser (1990) for the eomyids, to Storch (1987) for the murids, and to Rabeder (1981) for the cricetids (arvicolids). In the Plates 1, 2, 3, 4, 5, 6 all specimens are figured as left ones and in cases where only right teeth are available, the mirror image is presented.

All specimens are kept in the Senckenberg Research Institute, Research Station of Quaternary Palaeontology,

Weimar, under the catalogue numbers IQW 2011/31394-32014 (Sondershausen-Totenberg 30566-31176).

Ruscinian small mammal assemblages in Germany

In contrast to the numerous Oligocene and Miocene small mammal assemblages, Pliocene small mammal faunas are comparatively rare in Germany. In the early 1930s, Heller (1936) studied various Pliocene faunas from the fissure fillings in the "Rosengartenbruch" and Gewerkschaftsbruch" quarries SW of Gundersheim, now County Alzey-Worms, in Rhineland Palatinate. The insectivore, bat, and rodent faunas described by him included Late Ruscinian and Villanyian faunal levels (Kretzoi 1962). Tobien (1980) explored, amongst other faunas, the Gundersheim fissure fillings to reveal their exact biostratigraphic correlation. One of them, Gundersheim 4, yielded a Ruscinian micromammalian assemblage, which was published in detail by Fejfar et al. (2006). The rodents of the other fissure filling, Gundersheim-Findling, were presented by Fejfar and Storch (1990) and the insectivores by Dahlmann and Storch (1996). Gundersheim 4 and Gundersheim-Findling correlate with the late Ruscinian mammal unit MN 15b. Another locality, Wölfersheim (County Wetterau, Hesse), yielded a faunal assemblage of fluvio-lacustrine origin, roughly coeval with Gundersheim-4 and Gundersheim-Findling. The complete micromammalian fauna was presented in a detailed study by Dahlmann (2001).

The two late Pliocene faunas from the Lower Rhine area are a bit younger. The rodents from the Reuver Clay of Hambach allow a correlation with the early Villanyian, MN 16a (Mörs 1998), and the insectivores and rodents from Reuver Series (Unit 11) of Frechen near Köln with MN 16b (Reumer 1995; Van Kolfschoten et al. 1998). This short overview shows that Pliocene micromammal faunas are very rare in Germany and so far restricted to its westernmost parts. Therefore, every micromammal assemblage is a welcome addition, increasing our understanding of this time period in the region.

For comparison, the classical localities of the Pliocene of Poland are relevant: i.e. Podlesice and Rębielice. The small mammals of these localities were made known by Kowalski (1956, 1962, 1963), Sulimski (1964) and Godawa (1993). The fossil arvicolids of some localities in the former Czechoslovakia, reviewed by Fejfar and Horacek (1990), are also relevant. The Hungarian Pliocene micromammal faunas, made known by many authors (e.g. Kormos 1934; Jánossy 1970, 1972; Kretzoi 1959, 1962), and the Bulgarian Pliocene fauna from Muselievo in Northern Bulgaria by Popov (2004), are also taken into account.

We offer this article as a tribute to Burkart Engesser, whom we appreciate for his many outstanding contributions to mammalian palaeontology and biostratigraphy.

Systematic palaeontology

Order Soricomorpha Gregory, 1910
Family Soricidae Fischer, 1814

Sorex Linnaeus, 1758

Type species: *Sorex araneus* Linnaeus, 1758

Sorex cf. *polonicus* Rzebik-Kowalska, 1991
Pl. 1, fig. 1

Material (measurements see Table 1)
IQW 2011/31394-31409
Left dentary fragment with broken i, a3, p4–m3; right dentary fragment with m3, 15 isolated teeth (partly fragments).
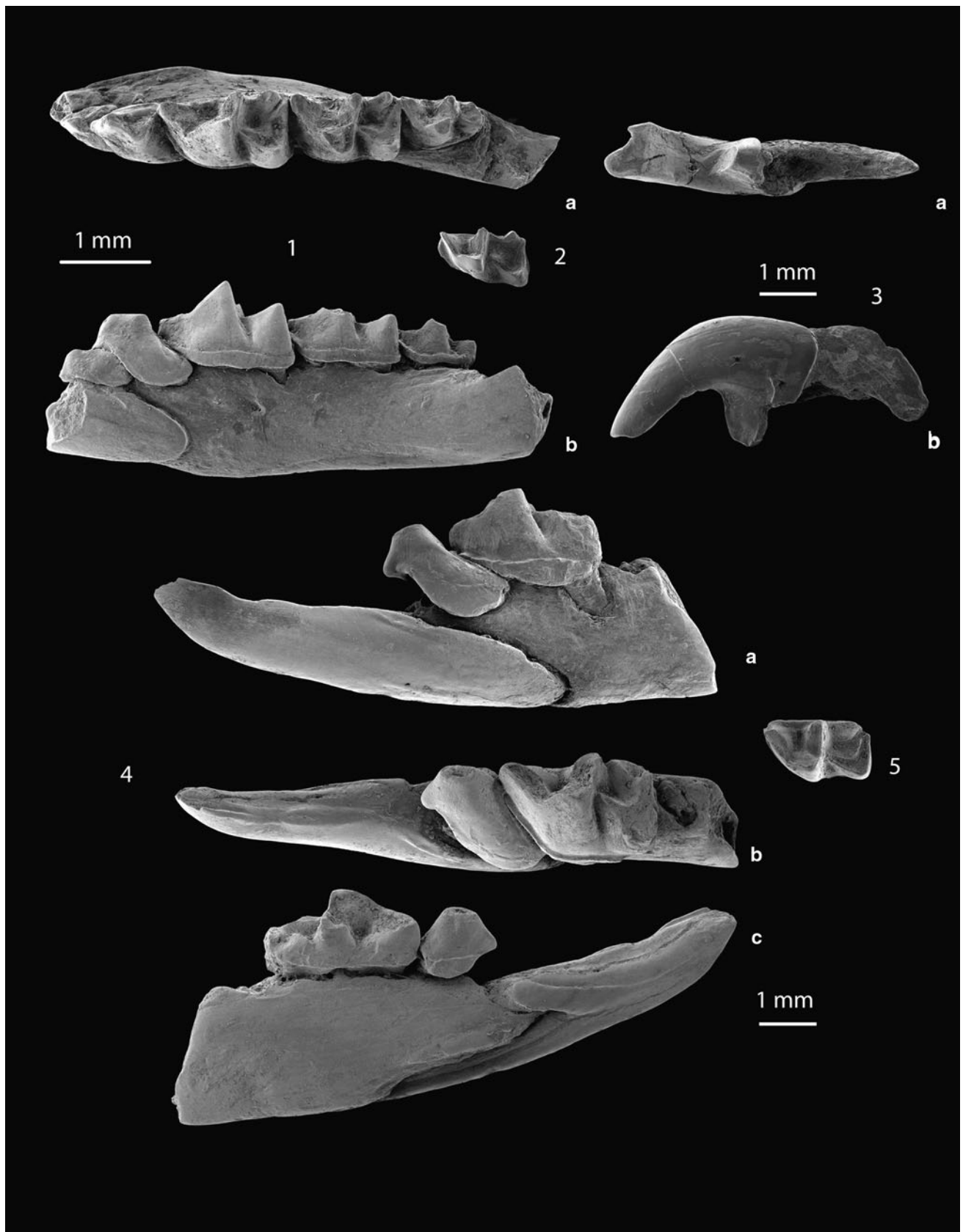
Description

The left dentary preserves the horizontal ramus, p4–m3 and the antemolar directly anterior to p4. The mental foramen is situated below the re-entrant valley of m1.

All teeth have reddish apices. The lower incisor fragments show an upturned apex. They are tricuspulate and are provided with a narrow cingulid along the posterior margin. The upper incisors are not fissident. The remaining teeth show the typical *Sorex* morphology.

Remarks

The size of the dentary is within the range of the extant *Sorex araneus* of Central Europe, *S. coronatus* Millet, 1882 of Switzerland and *Sorex subaraneus* Heller, 1958 from Tarkö (Hungary). It is larger than in most samples of *S. runtonensis* Hinton, 1911, but fits with the largest dentary of the type locality West Runton (see compilation of ranges of lm1–m3 of some samples in Maul 2001, tab. 9). It also fits the length of m1–m3 of the smallest dentaries of *S. subaraneus* from the type locality Erpfingen, but the dentary is higher (cf. Heller 1958, p. 18), and it is distinctly larger than in *S. casimiri* Rzebik-Kowalska, 1991 from Rębielice Królewskie 1A (cf. Rzebik-Kowalska 1991, tab. 11). The Sondershausen dentary is only slightly smaller than *S. polonicus* Rzebik-Kowalska, 1991 from Rębielice Królewskie 1A.

In the posterior position of the mental foramen the dentary from Sondershausen differs from all known species. Usually in *Sorex* the mental foramen is located either under p4, below the trigonid of m1, or in between (see

Table 1 Measurements (mm) of the teeth of *Sorex* cf. *polonicus*

IQW-no	Object	L	Wa	Wp
2011/31394	Left dentary			
	p4	1.11	0.73	
	m1	1.57	0.85	0.94
	m2	1.41	0.81	0.79
	m3	1.04	0.59	
	Lp4–m3	4.50		
	Lm1–m3	3.80		
	H below m1, lingually	1.51		
	H below m2, lingually	1.45		
2011/31395	right dentary m3	1.01	0.55	
2011/31396	right p4	1.07	0.73	
2011/31397	right m1	1.58	0.76	0.86
2011/31398	right m2	1.43	0.73	0.73
2011/31399	right m2	1.35	0.66	0.71

IQW-no	Object	Llab	LT	H
2011/31400	right I sup.	2.26	1.17	1.25

IQW-no	Object	L	W
2011/31401	left A sup.	0.73	0.75

L length, *lab* labial, *H* height, *T* talonid, *Wa* width anterior, *Wp* width posterior

compilation of data in Zaitsev and Rzebik-Kowalska 2003, tab. 1). Due to stratigraphic and geographic proximity the specimen is provisionally assigned to *Sorex* cf. *polonicus*.

Sorex minutus Linnaeus, 1766
Pl. 1, fig. 2

Material and measurements:
IQW 2011/31410 Left p4 (0.87*0.58)
IQW 2011/31411 Left m1 (1.08*0.59*0.63)

The small p4 and m1 from Sondershausen are indistinguishable from *Sorex minutus*. The m1 is smaller than the two m1 from Wölfersheim (cf. Dahlmann 2001, p. 11), but it is within the range of the m1 of *S. minutus* from Osztramos 7 (cf. Reumer 1984, tab. 3) and from some Pliocene faunas from Poland (cf. Rzebik-Kowalska 1991, tab. 3).

Beremendia Kormos, 1934

Type species: *Crossopus fissidens* Petényi 1864

Beremendia fissidens (Petényi 1864)
Pl. 1, fig. 3

Material and measurements:
IQW 2011/31412 Right Isup. 3.34*1.50*2.22 (Llab*LT* Hlab)

The soricid sample includes one robust fissident upper incisor with a red apex and large talon. It is in the size range of the upper incisors of *Beremendia fissidens* from Węże and Rębielice Królewskie 1A, but smaller than in the early Pleistocene samples from Poland (cf. Rzebik-Kowalska 1976, tab. 2).

Blarinoides Sulimski, 1959

Type species: *Blarinoides mariae* Sulimski, 1959

Blarinoides mariae Sulimski, 1959
Pl. 1, figs. 4–5

Material and measurements:
IQW 2011/31413 Left dentary fragment with **i**, p4, m1
Llab i 7.17; p4 2.05*1.43; m1 2.55*1.49* > 1.42; h dentary below m1 lingually 2.55
IQW 2011/31414 Right m2 1.87*1.09*c.1.03

The preserved part of the horizontal ramus of the dentary shows a small mental foramen slightly in front of the posterior root of m1. It is located in a shallow depression and still blocked by sediment. There are two alveoli for two single-rooted antemolars. The symphysis is a deep sulcus extending to below the trigonid of m1. All teeth have red apices.

The incisor has an undulating upper margin indicating worn cusps. The single-rooted p4 has no posterior crest and no posterolingual sulcus. m1 and m2 have a broad labial cingulid and a hypolophid not joining the entoconid, but leaving a postentoconid-valley between hypolophid and entoconid in m1 or a narrow notch in m2.

The size of the teeth lies in the range of *B. mariae* from Węże (Sulimski 1959, tab. 5; cf. Rzebik-Kowalska 1976, tab. 8) and from Osztramos 7 (Reumer 1984, tab.), but they are slightly larger than in *B.* cf. *mariae* from Wölfersheim (cf. Dahlmann 2001, tab. 6).

Order Chiroptera Blumenbach, 1799

The chiropterans are represented solely by isolated teeth and one maxillary fragment with P4–M1, all consistent with verspertilionids. For identification to species level, better-preserved material including dentaries and maxillary fragments with anterior dentition is necessary. Hence the determination of the Sondershausen chiropterans can only be approximate.

Family Vespertilionidae Gray, 1821

Myotis Kaup, 1829

Type species: *Vespertilio myotis* Borkhausen, 1797

Myotis sp. I
Pl. 2

Material (measurements see Table 2):
IQW 2011/31415-31467

52 isolated teeth, right maxillary fragment with P4–M1 (P4 1.17*1.02, M1 1.23*1.45, may represent a separate species; it is not included in the sample statistics).
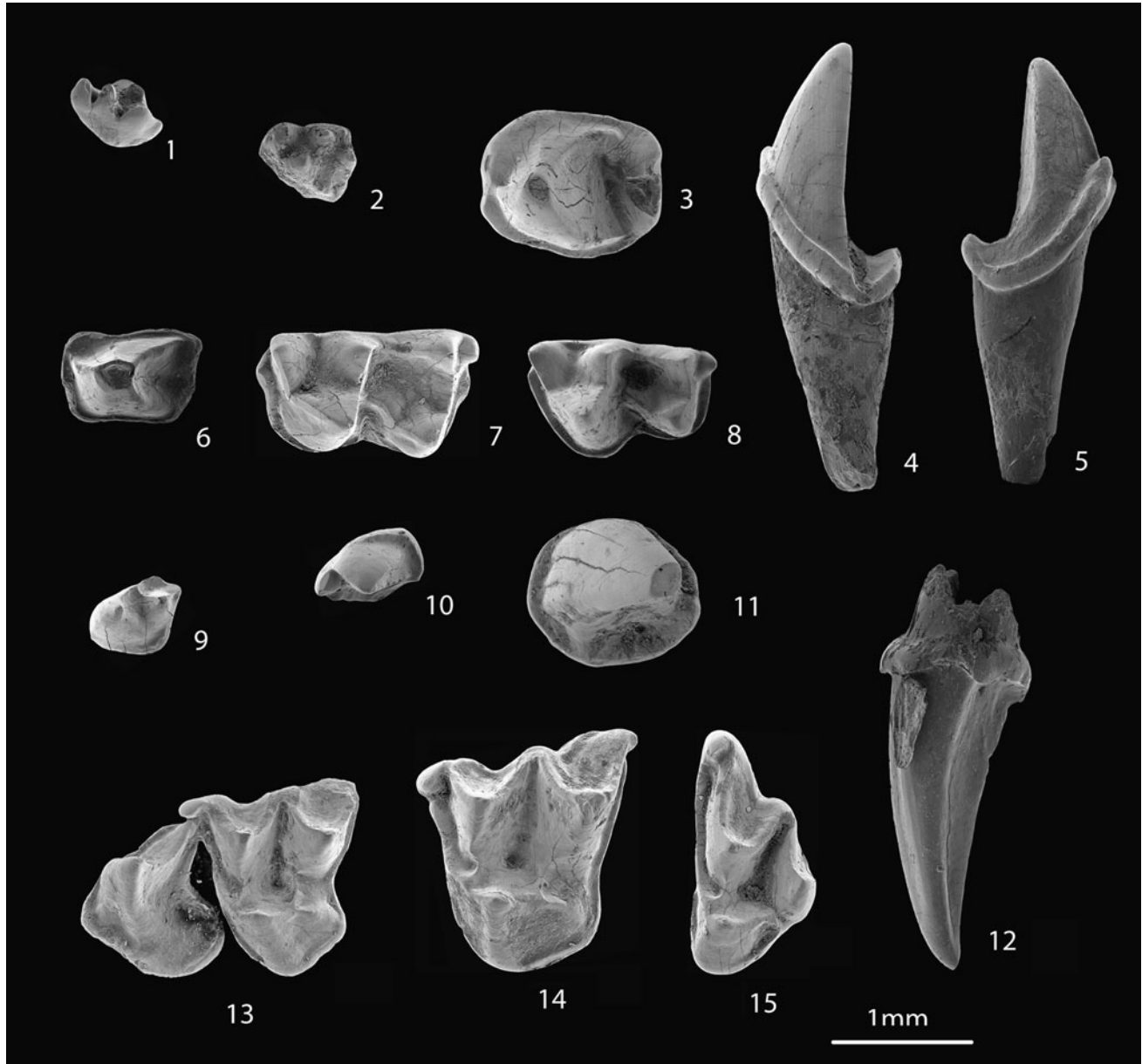

Plate 2 Myotis sp. I. **1** Right i2, occlusal view; IQW 2011/31459 A6, **2** left i3, occlusal view; IQW 2011/31460 B7, **3** I, right c1, occlusal view; IQW 2011/31419 B1, **4** left ci, labial view; IQW 2011/31415 A1, **5** left ci, lingual view; IQW 2011/31416 A2, **6** left p4, occlusal view; IQW 2011/31424 C2, **7** left m1/2, occlusal view; IQW 2011/31427 D1, **8** left m3, occlusal view; IQW 2011/314132 E1, **9** left I1, occlusal view; IQW 2011/31463 C6, **10** left I2, occlusal view; IQW 2011/31467 D6, **11** left Cs, occlusal view; IQW 2011/31435 F1, **12** right Cs, lingual view; IQW 2011/31438 F4, **13** right maxillary fragment with P4–M1, occlusal view; IQW 2011/31440 G4 (possibly *Myotis* sp. II or a separate species), **14** left M1, occlusal view; IQW 2011/31443 G2, **15** left M3, occlusal view; IQW 2011/31450 I4. All figures ×20

Table 2 Sample statistics of *Myotis* sp. I

Tooth	Meas	n	Min–max	Mean	SD
ci	L	8	1.23–1.39	1.30	0.050
	W	8	0.94–1.09	1.03	0.052
	H_{labial}	6	1.69–2.02	1.85	0.130
p4	L	4	1.01–1.16	1.09	0.076
	W	3	0.73–0.80	0.77	
m1/2	L	3	1.61–1.64	1.63	
	Wa	5	0.91–1.00	0.96	0.032
	Wd	5	0.99–1.07	1.03	0.030
m3	L	3	1.39–1.46	1.43	
	Wa	3	0.93–0.96	0.94	
	Wp	3	0.71–0.76	0.73	
Cs	L	4	1.20–1.27	1.23	
	W	3	1.10–1.16	1.13	
	H_{ling}	2	2.12–2.38	2.25	
M1	L	2	1.45–1.62	1.54	
	W	2	1.76–1.78	1.77	
M2	L	1		1.53	
	W	1		2.03	
M3	L	5	0.86–0.97	0.92	0.042
	W	5	1.79–1.93	1.86	0.058

L length, *H* height, *Wa* width anterior, *Wd* width distal, *Wp* width posterior (small maxillary fragment not included)

Description

Incisors—the larger incisors are attributed to *Myotis* I. The i2 has three labial cusps and a disto-labial accessory cuspule in line, and a low but voluminous disto-lingual accessory cusp. There is no vestige of a cingulid.

The i3 has two labial cusps, a disto-labial accessory cuspule, and two lower disto-lingual cusps. The labial cingulid is faint.

The I1 has a dagger-like anterior cusp and a small posterior one, as well as a labial cingulum.

The I2 has a main cusp flanked lingually by one to two accessory cuspules and labially by a marked cingulum.

Remaining dentition—all isolated p2/3 and P2/3, which are assigned to *Myotis* sp. I due to size matching, are single-rooted. The p4 is elongate with a strong labial cingulid bent upwards below the protoconid. m1 and m2 are indistinguishable. They are myotodont and have an angulated paralophid. The talonid is slightly wider than the trigonid in all specimens, and the metaconid is situated disto-lingually from the protoconid. In the m3 the trigonid is distinctly wider than the talonid. Both the M1 and M2 have a paraconule, a metaconule, a faint paraloph and metaloph. The proprotocrista joins the parastyle; the postprotocrista tapers distally. In the M1 the labial margin is

more oblique than in the M2. The M3 has also a paraconule and a paraloph.

The only P4 is from the maxillary fragment with P4–M1, which does neither fit in size *Myotis* sp. I nor *Myotis* sp. II. It is surrounded by a cingulum with a mesio-lingual cuspule and is devoid of a projecting cuspidate parastyle. This P4 is distinctly larger than in Myotis II. But the M1 is smaller than in Myotis I and II. Possibly it represents separate species.

Myotis sp. II
Pl. 3

Material (measurements see Table 3):
IQW 2011/31468-31540 73 isolated teeth

Myotis sp. II differs from *Myotis* sp. I only in being distinctly smaller. The maxillary fragment with P4–M1 may belong to this species or to a third verspertilionid.

Discussion

The most diverse Pliocene chiropteran assemblage so far known is from Gundersheim, which was collected by Heller from various sites within the Gundersheim quarries and published by him (Heller 1936). He identified eight different *Myotis* species by means of their lower dentition. According to Kretzoi (1962), the rodent assemblage of Gundersheim includes species from two different stratigraphic levels: a late Ruscinian one, corresponding to the Csarnotian in Kretzoi′s subdivision, and a Villanyian one. Tobien (1980) reported in a preliminary communication on the fissure fillings of Gundersheim on 22 fissure fillings from three different quarries. One of these was labelled Gundersheim 4 by Tobien. The non-chiropteran micromammals of this locality were published in detail by Fejfar et al. (2006). They also listed the bat species, which were identified by Topál (1985). For comparison we relied on Heller (1936) and on publications on the bats from the Pliocene of Poland and Hungary (Kowalski 1956, 1962; Godawa 1993), which provide some measurements of the lower dentition. In most publications on Pliocene to early Pleistocene bats the upper dentition is neglected. Topál (1985) study on the Pliocene species of *Myotis* from Hungary does not include any measurements at all. Hence it is not relevant for comparisons.

Myotis sp. I is slightly smaller than the extant *Myotis bechsteini*, e.g. from Bulgaria (Popov 2004, tab. 5). Amongst the Pliocene bats it comes closest to *M. kormosi* Heller, 1936 from Osztramos 9 and 13, in which the lengths of p1, m1 and m2 compare well, but the m3 is larger (Godawa 1993, Tab. III). However, it cannot reasonably be referred to any of the known Pliocene species.
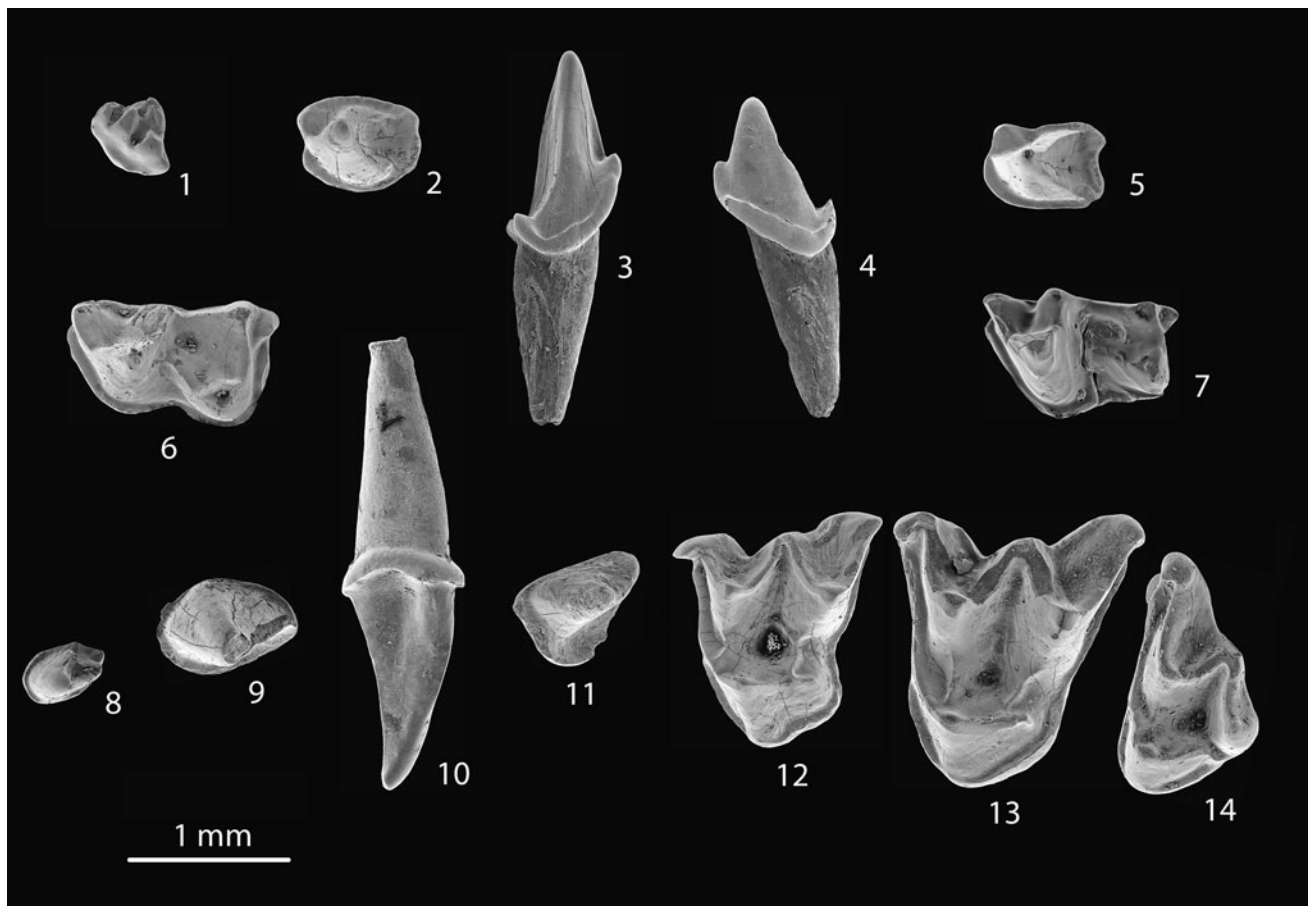
Plate 3 *Myotis* sp. II. **1** left i2, occlusal view; IQW 2011/31517 B7, **2** left c1, occlusal view; IQW 2011/31468 A1, **3** right c1, lingual view; IQW 2011/31471 B1, **4** right c1, labial view; IQW 2011/31472 B2, **5** left p4, occlusal view; IQW 2011/31475 C1, **6** left m1/2, occlusal view; IQW 2011/31481 D1, **7** left m3, occlusal view; IQW 2011/31497 G3, **8** left I1, occlusal view; IQW 2011/31519 C7, **9** left Cs, occlusal view; IQW 2011/31502 H1, **10** right Cs, lingual view; IQW 2011/31503/H2, **11** left P4, occlusal view; IQW 2011/31505/K6, **12** left M1, occlusal view; IQW 2011/31507/I2, **13** left M2, occlusal view; IQW 2011/31509/K1, **14** left M3, occlusal view; IQW 2011/31511/L1. All figures ×20

The same is true for the smaller bat species from Sondershausen, which coincides in size of the lower dentition with *M. danutae* Kowalski, 1956, *M. exilis* Heller, 1936 and with *M. helleri* Kowalski, 1962. The poor preservation of the Sondershausen sample allows no decision to which, if any, of these three species it can be referred.

Order Rodentia Bowdich, 1821
Family Sciuridae Fischer, 1817
Blackia Mein, 1970

Type species: *Blackia miocaenica* Mein, 1970

Blackia miocaenica Mein, 1970
Pl. 4, fig. 1

Material and measurements: IQW 2011/31541 Left M1/2 1.26*1.57

Description

The enamel of the small M1/2 is hardly ornamented, mainly due to advanced wear. Cones and lophs are low. All four lophs run subparallel to each other. Anteroloph and protoloph enclose a narrow basin. The mesostyle is crested and attached to the posterior crest of the paracone.

Remarks

Blackia miocaenica has a long stratigraphic range, spanning the entire Miocene and Ruscinian (i.e. MN 1–MN 15). The early Miocene species *B. ulmensis* Werner, 1994 from Ulm-Westtangente (MN 2), the Pliocene species *B. polonica* Black & Kowalski, 1974 from Podlesice (MN 14) and Rębielice Królowskie 1A (MN 16) and *B. wölfersheimensis* Mein, 1970 from Wölfersheim (MN 15) are synonyms of

Table 3 Sample statistics of *Myotis* sp. II

Tooth	Meas	n	Min–max	Mean	SD
ci	L	5	0.79–0.89	0.83	0.040
	W	6	0.65–0.70	0.67	0.016
	H_{labial}	4	0.87–1.66	1.07	0.194
p4	L	6	0.77–0.85	0.80	0.028
	W	6	0.50–0.65	0.57	0.054
m1/2	L	13	1.21–1.40	1.31	0.048
	Wa	13	0.69–0.79	0.73	0.031
	Wp	13	0.73–0.87	0.80	0.043
m3	L	6	1.08–1.28	1.20	0.076
	Wa	6	0.68–0.79	0.74	0.039
	Wp	6	0.61–0.75	0.66	0.054
Cs	L	3	0.89–1.04	0.94	
	W	3	0.66–0.81	0.73	
	H_{ling}	3	1.40–1.60	1.52	
P4	L	1		0.85	
	W	1		0.70	
M1	L	2	1.30–1.33	1.32	
	W	2	1.48–1.60	1.54	
M2	L	2	1.33–1.43	1.38	
	W	1		1.76	
M3	L	5	0.78–0.86	0.81	0.032
	W	5	1.54–1.75	1.62	0.088

L length, *H* height, *Wa* width anterior, *Wd* width distal, *Wp* width posterior

the type species (de Bruijn 1998; Dahlmann 2001). The M1/2 from Sondershausen is in the lowermost part of the range of the sample from Ulm-Westtangente (cf. Werner 1994, fig. 115), within the range of the samples from Oberdorf in Austria (cf. de Bruijn 1998, p. 106) and from Wölfersheim (cf. Dahlmann 2001, tab. 18), and slightly larger than the M1/2 from Podlesice, the type locality of *B. polonica* (cf. Black & Kowalski 1974), and from the Late Miocene Austrian sites Richardhof-Golfplatz, Richardhof-Wald and Schernham (Daxner-Höck 2004).

Family Eomyidae Déperet & Douxami, 1902
Eomyops Engesser, 1979

Type species: *Eomys catalaunicus* Hartenberger, 1966

Eomyops aff. *bodvanus* (Jánossy 1972)
Pl. 4, fig. 2

Material and measurements: IQW 2011/31542 Left m1/2 0.97*0.95

This small eomyid m1/2 has a marked anterolophid with a lingual and a labial arm subequal in length, a short mesolophid, and a short and weak posterophid. *Estramomys simplex* Jánossy, 1970, first described from the Pliocene of

Osztramos, can be ruled out on morphological grounds, e.g. by the complete absence of a mesolophid (cf. Jánossy 1970). The specimen under study differs from *E. catalaunicus* Hartenberger, 1966 in having a weaker posterolophid, which is an essential character of *E. bodvanus*. However, the Sondershausen m1 is markedly larger than *E. bodvanus* from the type locality Osztramos 1 in Hungary (cf. Jánossy 1972, p. 42), and is similar in size to the small m1/m2 of *E. catalaunicus* from Can Llobateres (cf. Engesser 1990, Abb. 105), Rudabánya (Daxner-Höck 2005, tab. 2) and from a couple of late Miocene Austrian localities (Daxner-Höck and Höck 2009). As morphology is more important than size, we identify the Sondershausen specimen as *Eomyops* aff. *bodvanus*. According to Engesser (1990, fig. 30.19) the known biochronologic range of *E. bodvanus* and of the closely related *E.* aff. *bodvanus* is the Ruscinian (MN 14–MN 15).

Family Gliridae Muirhead, 1819
Glis Brisson, 1762

Type species: *Sciurus glis* (Linnaeus, 1766)

Glis minor Kowalski, 1956
Pl. 4, figs. 9–18

Material (measurements see Table 4; Fig. 3)
IQW 2011/31543-31988

Left dentary fragment with m1–m2, right maxillary fragment with M1–M3, 446 isolated teeth.

Description

d4—In all specimens, the roots are broken off. The identification as deciduous teeth is based on the thin broken edge and on the small overall size. There are four main ridges: anterolophid, metalophid, mesolophid and posterolophid. In some d4 the crests are rather irregular, and small extra ridges may be present.

p4—All are single-rooted. Aside from the four main ridges, most specimens have a posterior extra ridge, and one has in addition an anterior extra ridge. Only five p4 of 51 are without any extra ridges.

m inf.—All are double-rooted and have four main ridges. All m1 and m2 have three extra ridges in between. Six m3 out of 48 have only two extra ridges. The m1 tapers slightly anteriorly, whereas in the m2 the posterior width is smaller than the anterior. The m3 is more variable in size than the other molars. The smallest specimen (1.20*1.31 mm) was excluded from the sample statistics.

D4—The upper deciduous molar is triangular in occlusal outline and has three thin-walled roots, which are broken off in most of the D4. Five ridges can be identified:
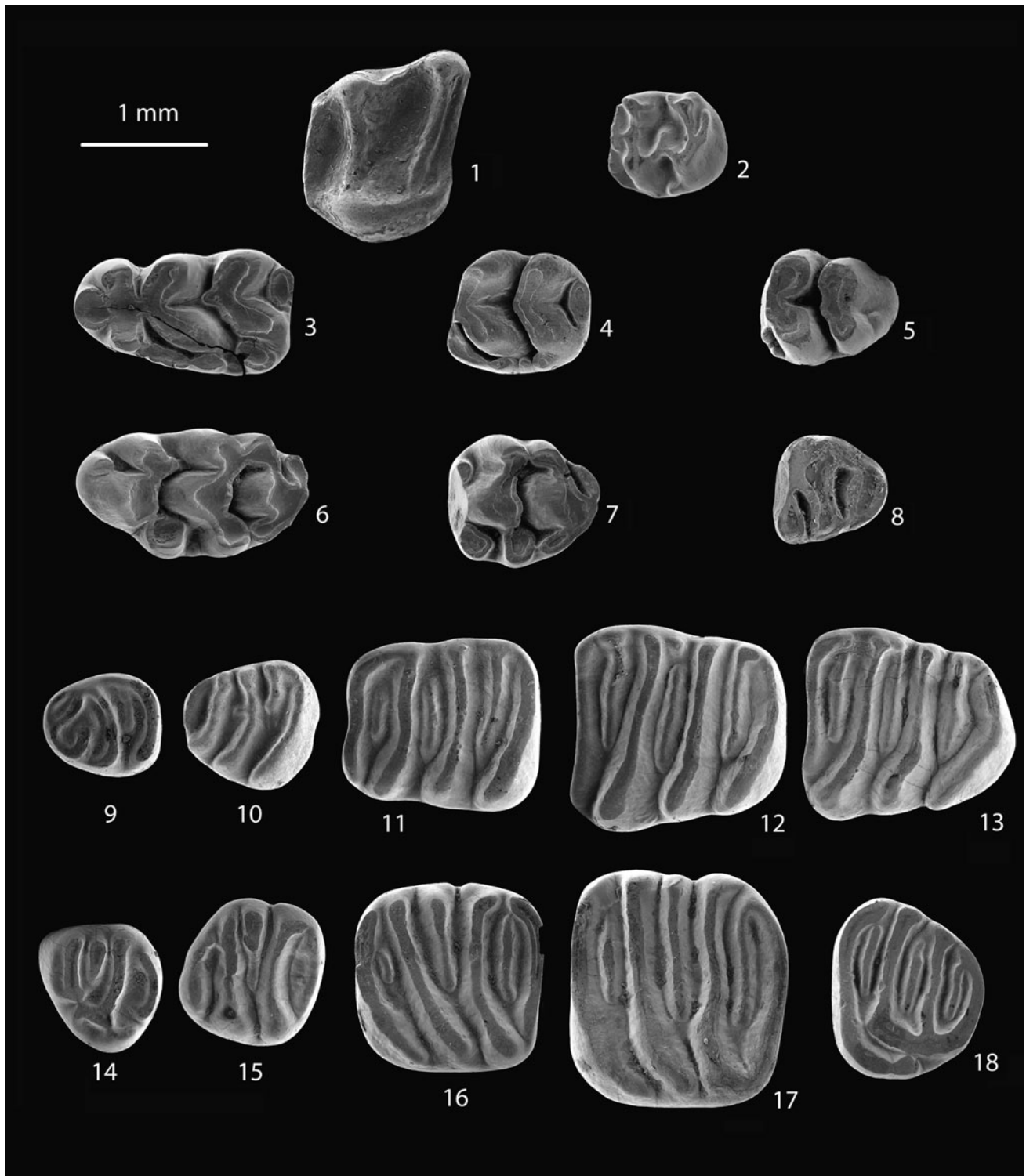
a residual anteroloph, protoloph, centroloph, metaloph and posteroloph.

P4—The P4 is more rounded in occlusal outline and double-rooted. The main ridges are the anteroloph, protoloph, metaloph and posteroloph. The centroloph is distinctly lower. Six P4 out of 56 have a weakly developed posterior extra ridge.

M1/2—The M1 and M2 have a broad internal root and two smaller rounded external roots. The four main crests, the shorter centroloph, and the anterior and posterior extra

Plate 4 1 *Blackia miocaenica*, left M1/2, occlusal view; IQW 2011/31541, **2** *Eomyops* aff. *bodvanus*, left m1/2, occlusal view; IQW 2011/31542, **3** *Apodemus atavus*, left m1, occlusal view; IQW 2011/31989/B1, **4** *Apodemus atavus*, right m2, occlusal view; IQW 2011/31992/D1, **5** *Apodemus atavus*, left m3, occlusal view; IQW 2011/31994/E1, **6** *Apodemus atavus*, left M1, occlusal view; IQW 2011/32001/G2, **7** *Apodemus atavus*, right M2, occlusal view; IQW 2011/32003/I1, **8** *Apodemus atavus*, left M3, occlusal view; IQW 2011/32004/K1, **9** *Glis minor*, left d4, occlusal view; IQW 2011/31598/F2, **10** *Glis minor*, left p4, occlusal view; IQW 2011/31545/A3, **11** *Glis minor*, left m1, occlusal view; IQW 2011/31686/B10, **12** *Glis minor*, left m2, occlusal view; IQW 2011/31695/D1, **13** *Glis minor*, left m3, occlusal view; IQW 2011/31781/A4, **14** *Glis minor*, left D4, occlusal view; IQW 2011/31605/G1, **15** *Glis minor*, left P4, occlusal view; IQW 2011/31623/H13, **16** *Glis minor*, left M1, occlusal view; IQW 2011/31836/B2, **17** *Glis minor*, left M2, occlusal view; IQW 2011/31856/D6, **18** *Glis minor*, left M3, occlusal view; IQW 2011/31948/A5. All figures ×20

Table 4 Sample statistics of *Glis minor*

Tooth	Meas	n	Min–max	Mean	SD
d4	L	8	0.95–0.99	0.97	0.014
	W	8	0.83–0.96	0.91	0.039
p4	L	53	1.02–1.24	1.12	0.054
	W	53	0.92–1.21	1.10	0.075
m1	L	63	1.54–1.80	1.69	0.063
	W	63	1.45–1.73	1.57	0.057
m2	L	49	1.52–1.83	1.68	0.068
	W	49	1.52–1.83	1.67	0.071
m3	L	46	1.37–1.71	1.52	0.081
	W	46	1.31–1.62	1.44	0.070
D4	L	6	0.80–1.02	0.90	0.086
	W	6	0.88–1.10	1.01	0.084
P4	L	56	1.01–1.23	1.11	0.058
	W	56	1.14–1.36	1.25	0.053
M1	L	51	1.41–1.73	1.58	0.067
	W	51	1.48–1.79	1.62	0.076
M2	L	68	1.42–1.72	1.56	0.067
	W	68	1.55–1.94	1.73	0.081
M3	L	45	1.08–1.32	1.21	0.065
	W	45	1.33–1.57	1.44	0.065

ridges are consistently present. The extra ridges are rather variable in length and development; the anterior one may be reduced to a vestige. There are no extra ridges between protoloph and centroloph and between centroloph and metaloph, respectively. In the M1 the anteroloph is more rounded than in the M2, the latter being wider and more quadratic.

M3—The M3 is triangular in occlusal view. It has three roots; two of them are fused in some specimens to an anterolingual or a posterolingual root. The configuration of ridges is as in M1 and M2. The ridges join lingually to an endoloph. Some internal ridges coalesce with one another in some specimens.

Discussion

Glis minor was described by Kowalski (1956) on the basis of material from the Pliocene of Podlesice and was upgraded to a species by Kretzoi (1959). de Bruijn (1998) added the subspecies *G. m. complicatus* from the early Miocene of Oberdorf in Austria. This subspecies is characterised by the consistent presence of an anterior and a posterior centroloph in all M1–M2 and most of the P4. This subspecies can be ruled out on morphological and metrical grounds. *Glis minor* is distinctly smaller than *Glis glis*, and is also smaller than *Glis sackdillingensis* (Heller, 1930). The latter species, which is closer to *G. minor* in size, has two additional extra ridges in the upper molars, one anterior to the centroloph and another behind it. Heller (1936) mentioned only the lower dentition and postcranial elements from the type locality, Sackdillingen cave, and emphasised the size difference compared to *Glis glis*. Kowalski (1963) differentiated *G. minor* from *G. glis* in his work on the Pliocene and Pleistocene dormice of Poland. The teeth from the Sondershausen sample are smaller than from *G. sackdillingensis* from Sackdillingen and match well with *G. minor* from Podlesice and Węże. The few teeth of *G. minor* from Wölfersheim are in the size range of the Sondershausen and Podlesice samples (cf. Dahlmann 2001, p. 70). *Glis minor* ranges from MN 14–MN 16.

Family Muridae Illiger, 1811
Apodemus Kaup, 1829

Type species: *Mus agrarius* Pallas, 1771

Apodemus atavus Heller, 1936
Pl. 4, figs. 3–8

Material (measurements, see Table 5):
IQW 2011/31989-32005 Left maxillary fragment with M1, 16 isolated teeth.

Description

Lower molars—all three m1 are moderately worn. The medial anteroconid and the lingual posterior cingulid are well developed. The anteroconid complex is connected to the protoconid-metaconid chevron. On the labial side there are three cingular cusps (c1–c3); the anterior one (c3) is crested. In the m2 the labial anteroconid is a strong cusp fused with the

c3 due to wear. c2 and c1 are small and are also fused due to wear. The posterior cingulid is a well-developed cusp. The entoconid-hypoconid chevron has neither a stephanodont anterior ridge nor a medial spur. Five of six m3 have a vestigial labial anteroconid, in one it is completely eliminated. The postcingulid is vestigial in two m3, and absent in another
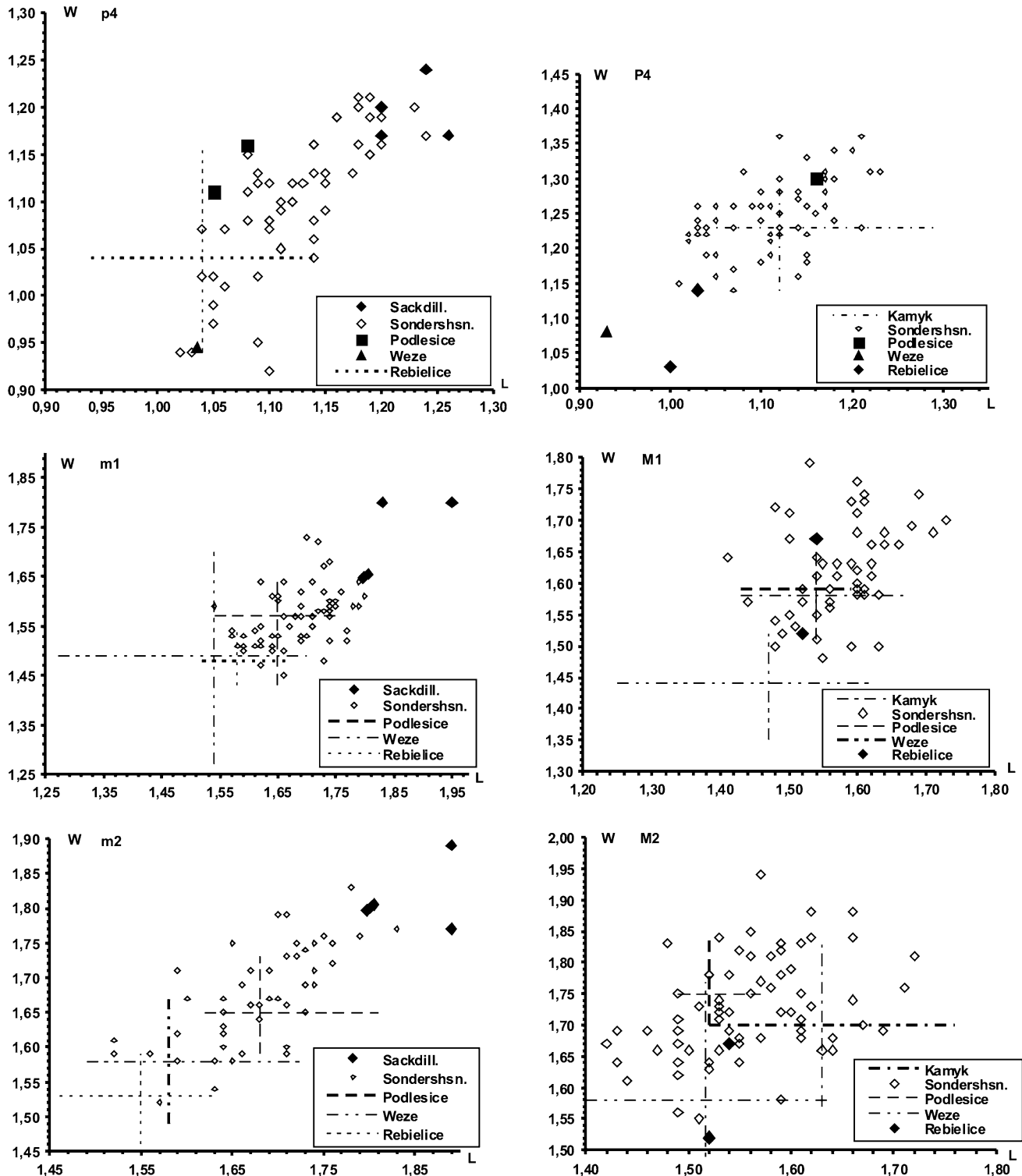

Fig. 3 *Glis minor* and *Glis sackdillingensis*, scatter diagram of the p4/P4, m1/M1 and m2/M2. Measurement of *G. sackdillingensis* from Sackdillingen (Heller 1936), *Glis minor* from Podlesice, Węże and Rębielice (Kowalski 1963)

Table 5 *Apodemus atavus*, meristic measurements (mm) of the teeth

IQW-no	Tooth	L	W
2011/31989	left m1	1.78	1.06
2011/31990	right m1	1.72	1.05
2011/31991	right m1	>1.6	>0.9
2011/31992	right m2	1.17	1.09
2011/31993	right m2		0.97
2011/31994	left m3	1.13	0.96
2011/31995	left m3	0.99	0.95
2011/31996	left m3		0.93
2011/31997	right m3	1.09	0.93
2011/31998	right m3	1.02	
2011/31999	right m3	0.93	0.97
2011/32000	left M1	1.89	1.23
2011/32001	left M1	1.86	1.14
2011/32002	right M1	1.93	1.17
2011/32003	right M2	1.23	1.08
2011/32004	left M3	0.93	0.92
2011/32005	right M3	0.86	0.80

L length, *W* width

two specimens. In one specimen, the posterior half is reduced to one cusp. Obviously the hypoconid is eliminated.

Upper molars—the M1 is triple-rooted. The two isolated specimens have a tiny root, centred between the others. In all three M1, t7 and t12 are well developed. The t3 has a free ending distal spur. t6 is fused with t9, and t1 with t2. There is neither a vestige of a t0 nor a connection between t1 and t5. The only M2 has four roots, marked t1 and t12, and a small t3. t4 and t8, and t6 and t9, respectively, are unfused in the only specimen showing moderate wear. The M3 are triple-rooted and triangular in occlusal outline. The t1 is well developed, the t3 vestigial. The posterior part of the tooth is reduced to one transversely elongated cusp, which includes t7, t8, possibly t9, and t12.

Discussion

Apodemus atavus was first described by Heller (1936) on the basis of a dentary fragment with m1–2, an edentulous dentary fragment and three isolated molars from karstic fissure fillings near Gundersheim. Fejfar and Storch (1990) presented a large sample of *A. atavus* from the late Ruscinian locality Gundersheim 4. *Apodemus atavus* from Sondershausen fits in morphology and dental measurements with the Gundersheim 4-sample, with the exception of the M3, which are slightly longer and narrower, and with *A.* cf. *atavus* from Frechen (Van Kolfschoten et al. 1998, Tab. 3). The Wölfersheim sample probably includes two species (Dahlmann 2001) and shows a wide range in dental measurements. *Apodemus atavus* from Sondershausen

covers the lower half of the Wölfersheim range. It is smaller than *A.* cf. *dominans* from Hambach (cf. Mörs 1998, p. 151).

Apodemus atavus appeared in the late Ruscinian (MN 15) and vanished in the Villanyium (MN 16).

Family Cricetidae Fischer, 1817
Subfamily Arvicolinae Gray, 1821
Cseria Kretzoi, 1959

Type species: *Cseria gracilis* Kretzoi 1959

Cseria cf. *gracilis* Kretzoi 1959
Pl. 5, figs. 1–2

Material and measurements:
IQW 2011/32006 Left m1-fragment
IQW 2011/32007 Right m1-fragment
IQW 2011/32008 Left m2 (1.93*1.34 mm)

In one m1 only the anterior half is preserved, in the other the posterior one. Both are low-crowned and double-rooted with alternating re-entrants. The figured specimen is characterised by a salient angle (the *Mimomys*-fold) and the islet, both characters being typical of *Mimomys* and *Cseria*. The most conspicuous and most valuable character is the only slightly undulating, low linea sinuosa with its anterosinusid not extending to the occlusal surface, and the absence of cement in the re-entrants.

The two fragments are less evolved than *M. hassiacus* from Gundersheim and from Wölfersheim (cf. Fejfar and Storch 1990, figs. 18–26; Dahlmann 2001, figs. 21–36), and compare well with *Cseria gracilis* from Gundersheim-4 and from Wölfersheim (Fejfar and Repenning 1998, figs. 3, 4; Fejfar et al. 2006, fig. 7). Because of the poor preservation of the few specimens, identification as *Cseria* cf. *gracilis* seems reasonable. The biochronologic range of this species MN 15–MN 16.

Subfamily Baranomyinae Kretzoi, 1955
Baranomys Kormos, 1933

Type species: *Baranomys loczyi* Kormos, 1933

Baranomys cf. *longidens* (Kowalski, 1960)
Pl. 5, fig. 3

Material and measurements
IQW 2011/32009 Left m2 (1.21*0.84 mm)
IQW 2011/32010 Right m2 (partly damaged)

In both double-rooted m2 the triangles are confluent, the re-entrants are without cement and are slightly offset. The enamel is thinner than in *Bjornkurtenia*. The specimens compare well morphologically with *Baranomys longidens* and *Baranomys kowalskii* from Wölfersheim (see Fejfar and Repenning 1998, tex-fig. 6; Dahlmann 2001, fig. 20).
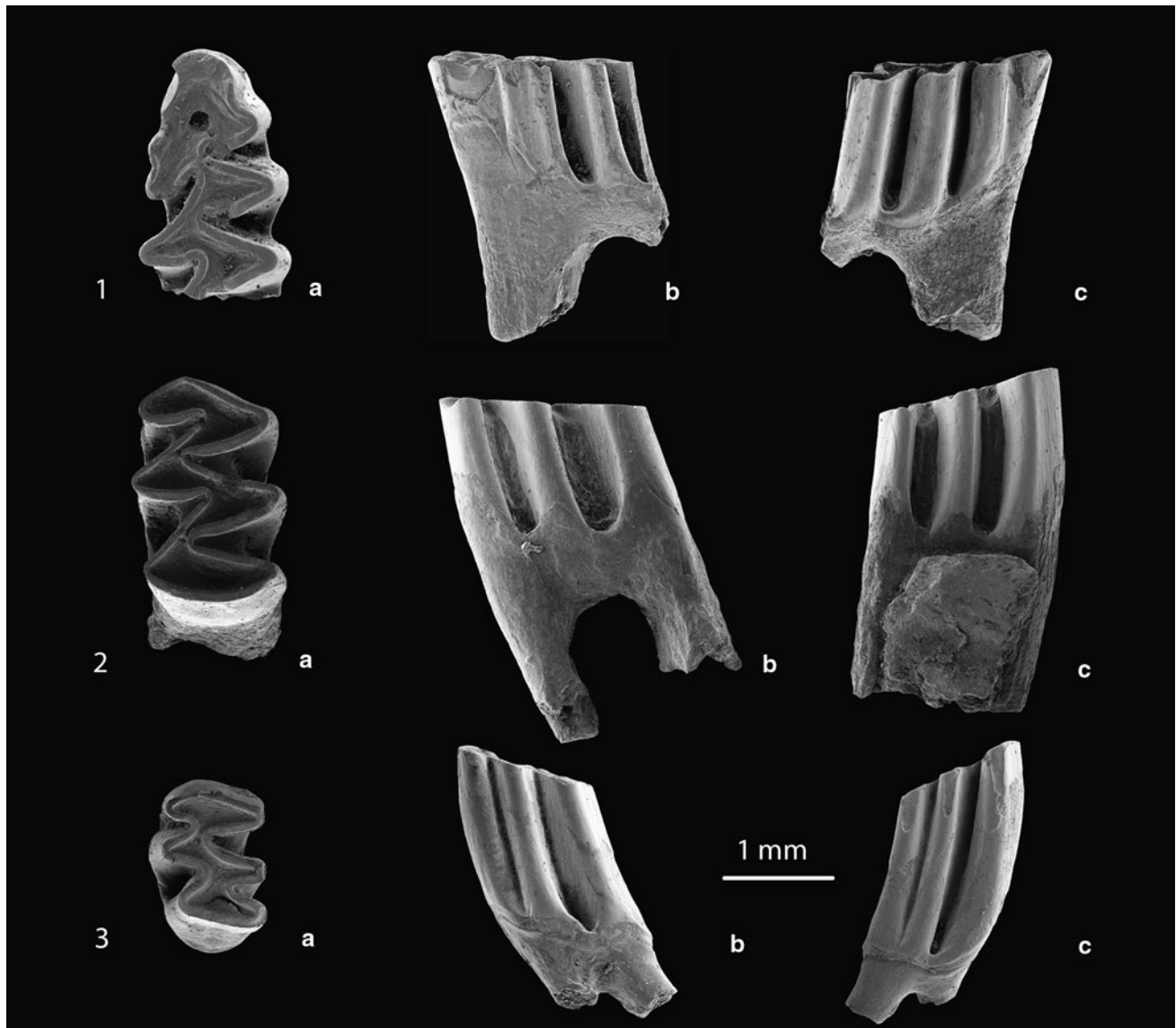
Plate 5 **1** *Cseria* cf. *gracilis*, right m1-fragment, *a* occlusal, *b* labial, *c* lingual views; IQW 2011/32007/1, **2** *Cseria* cf. *gracilis*, left m2, *a* occlusal, *b* labial, *c* lingual views; IQW 2011/32008/3, **3** *Baranomys* cf. *longidens*, left m2, *a* occlusal, *b* labial, *c* lingual views; IQW 2011/32009. All figures ×15

They are similar in size and morphology to *Baranomys longidens* from Węże and from Gundersheim 4 (Kowalski 1960, fig. 1; Sulimski 1964, Tab. 12, fig. 17; Fejfar et al. 2006, text.-fig. 2). As both species overlap in size and as the m2 are not adequate to differentiate the species, we identify the specimen with some caveat as *Baranomys* cf. *longidens*. *Baranomys kowalskii* is restricted to faunas correlating with the early Ruscinian (MN 14) and *B. longidens* to late Ruscinian (MN 15) faunas.

Bjornkurtenia Kowalski, 1992

Type species: *Trilophomys canterranensis* Michaux, 1976

Bjornkurtenia cf. *canterranensis* (Michaux, 1976)
Pl. 6

Material and measurements:
IQW 2011/32011 Left m2 (1.37*1.09 mm)
IQW 2011/32012 Left M1 (1.94*1.41 mm)
IQW 2011/32013 Left M2 (1.66*1.23 mm)
IQW 2011/32014 Right M2 (1.57*1.18 mm)

Description

All teeth are low-crowned, with only a slightly undulating linea sinuosa, a very thick enamel layer, and no cementum in the re-entrants.

m2—it has two mesio-distally flattened roots, both broken off, and no vestige of a third root between them. The two posterior re-entrants alternate, whereas the anterior ones exactly oppose one another. The two intermediate dentine-triangles are confluent.

M1—the first upper molar has a small lingual root between the large antero- and postero-labial roots, respectively. The two posterior re-entrants are in exact opposition, the anterior ones are slightly offset. The intermediate triangles are broadly confluent.

M2—the M2 has two antero-posteriorly flattened roots. The labial re-entrants are deeper than the lingual ones; all alternate. The posterior loop is confluent with the posterior triangle.

Discussion

The genus *Bjornkurtenia* was described by Kowalski (1992) with the type species *B. canterranensis* from La Jasse near Terrats (Pyrénées Orientales, France), which was originally assigned to *Trilophomys* Déperét, 1892 by Michaux (1976). Kowalski l. c. also provided evidence for the occurrence of *B. canterranensis* in the Pliocene fauna of Podlesice in Poland. Fejfar et al. (2006) recognised it in the fauna of Gundersheim 4, and Popov (2004) mentioned a right m1 from Muselievo (Bulgaria). Comparative measurements are only published from Terrats and from Podlesice. The m2 roughly correspond in size to Podlesice, but are a bit smaller than the two m2 from Terrats. The M1
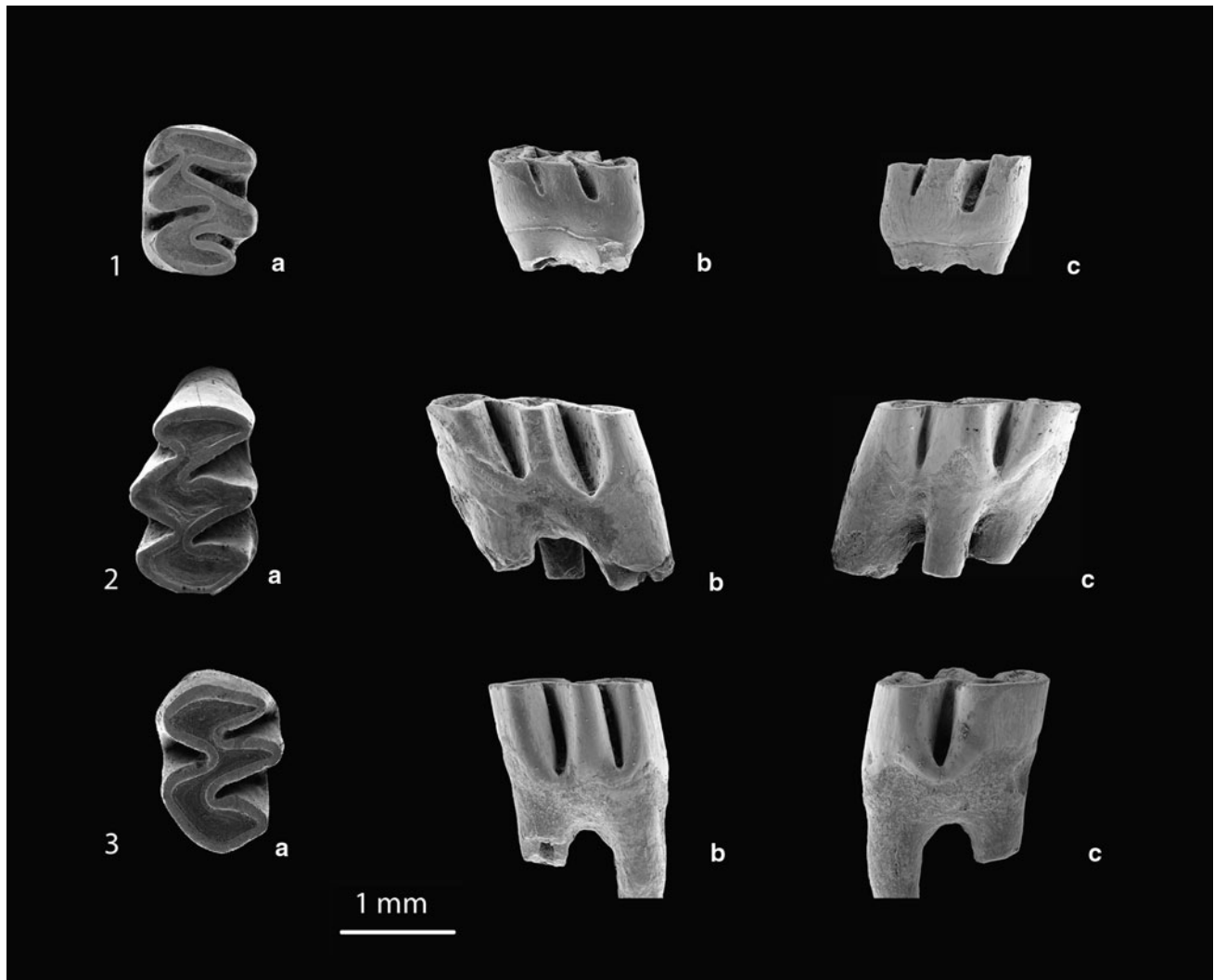

Plate 6 *Bjornkurtenia* cf. *canterranensis*. **1** left m2, *a* occlusal, *b* labial, *c* lingual views; IQW 2011/32011/1, **2** left M1, *a* occlusal, *b* labial, *c* lingual views; IQW 2011/32012/2, **3** Right M2, *a* occlusal, *b* labial, *c* lingual views; IQW 2011/32014/4. All figures ×15

is slightly larger than in Podlesice, and especially wider than in Terrats. The M2 are also larger than in the other localities. The biostratigraphic correlations of the known occurrences of *Bjornkurtenia* are: Terrats (MN 14), Podlesice (MN 14), Gundersheim 4 (MN 15b), Muselievo (MN 15b). Therefore the presence of *Bjornkurtenia* in a faunal assemblage clearly suggests a Ruscinian correlation.

Conclusions

Composition of the mammalian assemblage (Table 6)

The assemblage includes and 621 identifiable specimens belonging to 13 species consisting mostly of isolated teeth. It is clearly rodent-dominated with the dormouse *Glis minor* alone making up 73% of the sample. At 20%, the contribution of the verspertilionid bats to the total assemblage is also considerable. The soricid family and the murid *Apodemus atavus* each make up 3% of the fauna.

Table 6 Sondershausen, list of small mammals

Taxon	nisp
Soricomorpha	
Soricidae	
Sorex cf. *polonicus*	16
Sorex minutus	2
Beremendia fissidens	1
Blarinoides mariae	2
Chiroptera	
Vespertilionidae	
Myotis sp. I	53
Myotis sp. II	73
Rodentia	
Sciuridae	
Blackia miocaenica	1
Eomyidae	
Eomyops aff. *bodvanus*	1
Gliridae	
Glis minor	446
Muridae	
Apodemus atavus	17
Cricetidae	
Arvicolinae	
Cseria cf. *gracilis*	3
Baranomyinae	
Baranomys cf. *longidens*	2
Bjornkurtenia cf. *canterranensis*	4
Sum	621

nisp number of identified specimens

The remainder is quantitatively negligible. The number of species found is distinctly lower than in Wölfersheim (Dahlmann 2001) and also lower than in the Gundersheim fissure fillings (Heller 1936; Fejfar and Storch 1990; Dahlmann and Storch 1996; Fejfar et al. 2006). The rodent fauna from the Pliocene Reuver Clay of Hambach is more diverse as well (Mörs 1998). All in all, the Sondershausen fauna is quite unbalanced. Aside from the teeth, there are innumerable bone fragments. Only some metapodials are complete. All long-bones are broken to fragments which at longest are ca. 10 mm in length. The largest specimens are the rodent incisors, which are less susceptible to fragmentation. The whole sample appears somewhat size-graded.

There are two possibilities for small mammal remains to get into caves or fissures. Either they are part of the autochthonous fauna, as e.g. some bats, which sleep and roost in caves, or they are allochthonous. Predation is known as the major cause of small mammal bone accumulations, especially in caves and fissures (Andrews 1990). Micromammal assemblages are usually explained as accumulations of regurgitation pellets of birds of prey. Owls are probably the major contributors to fossil bone assemblages. The predator species differ in the skeletal element proportions expressed as proportions of numbers of bones in a sample. In the sample under study the bones are hardly identifiable due to breakage. Probably there was a resting place of an owl near the fissure, where an owl disgorged repeatedly its regurgitation pellets with the indigestible prey remains. However, before the final burial the pellets disintegrated and the bones might have been transported over some distance.

Biostratigraphic correlation

As to the stratigraphic resolution, the rarest species in the assemblage are the most significant ones.

The main reason for the assemblage to appear post-Miocene is the presence of arvicolids. The soricid *Sorex minutus* appeared in the Early Ruscinium (MN 14). *Beremendia fissidens* and *Blarinoides mariae* ranged from MN 14–MN 17. The vespertilionids are irrelevant for precise stratigraphic correlation.

The most common species in the Sondershausen assemblage, *Glis minor*, first appeared in the Early Vallesian (MN 9), as evinced by the records from Rudabanyà, Hungary (Daxner-Höck 2005), Bełchatów A, Poland (Kowalski 1997), Grytsiv, Ukraine (Nesin and Kowalski 1997). The Polish record from the type locality Podlesice, from Węże and Rębielice correlate with MN 14–MN 16. The Austrian occurrences range from MN 9–MN 11 (Daxner-Höck and Höck 2009). Hence the full range of this species is Early Vallesian to Early Villanyian (MN 9–MN 16).

The eomyid *Eomyops* and the flying squirrel *Blackia* are holdovers from the Miocene, when the eomyids and *Blackia* had their period of prosperity. *Eomyops bodvanus* is restricted to the Ruscinian (MN 14- possibly MN 15). *Blackia miocaenica*, spanning most of the Miocene, became extinct at the end of the Pliocene (MN 16), with its youngest occurrences recorded in Hambach (Mörs 1998) and Frechen (Van Kolfschoten et al. 1998) in the Lower Rhine Embayment.

The stratigraphic range of the arvicoline *Cseria gracilis* is MN 15–16. The genera *Baranomys* and *Bjornkurtenia* are restricted to the Ruscinian (MN 14–15).

Cseria is the only genus which only appears in the late Ruscinian. Hence, the assemblage should not be older. *Blackia*, *Eomyops bodvanus*, and the two barnomyines vanished by the end of the late Ruscinian. The fauna as a whole correlates with the late Ruscinian Unit MN 15.

Palaeoenvironment

Palaeoenvironmental conclusions based solely on the small mammal content of regurgitation pellets of owls can only be very general. The composition of the fossil assemblage obviously represents only a part of the former small mammal fauna, and it may be a mixture from different biotopes within the range of the predator. The association may also reflect the dietary preference of the predator. But usually birds of prey take what they can get and adapt their dietary requirements to a wide range of seasonal, climatic, ecological and regional variants. In the present sample there are no direct indicators for the proximity of standing or running water. There are no desmans or evidence from other species for an aquatic environment. The sciurid, a flying squirrel, the eomyid and the abundance of the glirid *Glis minor* are strong indicators for a forest-dominated environment. From the composition of the taphocoenosis, we can conclude that the environment within the range of the predator was mainly forested and that open grounds played at best only a minor role.

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