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A new Oligocene (MP 24) mammal fauna (Dürrenberg, Canton Jura, NW Switzerland) from the eastern slope of the "Rauracian depression"

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Abstract A new molasse outcrop at Dürrenberg (Canton Jura, NW Switzerland) yielded 53 micromammal teeth. The coexistence of the rodent taxa *Blainvillimys* cf. *helmeri* Vianey-Liaud, 1972, *Theridomys* cf. *lembronicus* Bravard, in Gervais, 1848–52, *Toeniodus curvistriatus* Pomel, 1853, and *Issiodoromys minor* var. 1 Filhol, 1876 enables a correlation with the European MP 24 reference level. Compared with the Delémont basin, the Oligocene sedimentation started remarkably later in the Dürrenberg area, because it is situated on the eastern slope of the "Rauracian depression". Therefore the new site is important for the reconstruction of the dimension and geometry of this structure that connected the alpine foreland basin with the southern Rhine Graben during the Late Rupelian and Chattian.

Keywords Mammalia · Rodentia · Theridomyidae · Oligocene · Switzerland

Zusammenfassung Ein neuer Molasseaufschluss bei Dürrenberg (Kanton Jura, NW-Schweiz) lieferte 53 Kleinsäugerzähne. Die Vergesellschaftung der Taxa *Blainvillimys* cf. *helmeri* Vianey-Liaud, 1972, *Theridomys* cf. *lembronicus* Bravard, in Gervais, 1848–52, *Toeniodus curvistriatus* Pomel, 1853 und *Issiodoromys minor* var. 1 Filhol, 1876 ermöglicht die Einstufung in die europäische Säugetierzone MP 24. Zu dieser Zeit erfolgte im weiter westlich gelegenen Delsberger Becken bereits die Ablagerung von alpinen fluviatilen Sanden der Molasse alsacienne, währenddessen bei Dürrenberg erst im obersten Teil des Profils der Einfluss von alpinen Schüttungen feststellbar ist. Das Profil Dürrenberg lag seinerzeit auf der östlichen Grabenschulter der "Raurachischen Senke", die das Gebiet des heutigen Juras querte und während des späten Rupeliums und Chattiums das alpine Vorlandbecken mit dem Oberrheintalgraben verband.

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Abbreviations

NMB Natural History Museum Basel, Basel, Switzerland
NMS Naturmuseum Solothurn, Solothurn, Switzerland

1 Introduction

During a mapping campaign in 2005, Dr. H.R. Bläsi (Bern) discovered a new outcrop near Dürrenberg (Mervelier, Canton Jura, Switzerland, Fig. 1), which shows the contact between altered Mesozoic limestones of the Late Jurassic Reuchenette Formation with overlying Cenozoic molasse sediments. The outcrop was uncovered by a small landslide, which exposed a 9 m thick section (Figs. 2, 3). The geological map of Koch et al. (1936) showed no molasse deposits at this location. Therefore the lithostratigraphic classification and the age of these deposits were unknown. In June 2009, the author took a first test sample, which contained one tooth of *Blainvillimys* sp. For biostratigraphical purposes, approximately 600 kg of sediment was subsequently excavated, screen washed and picked for micromammal teeth.

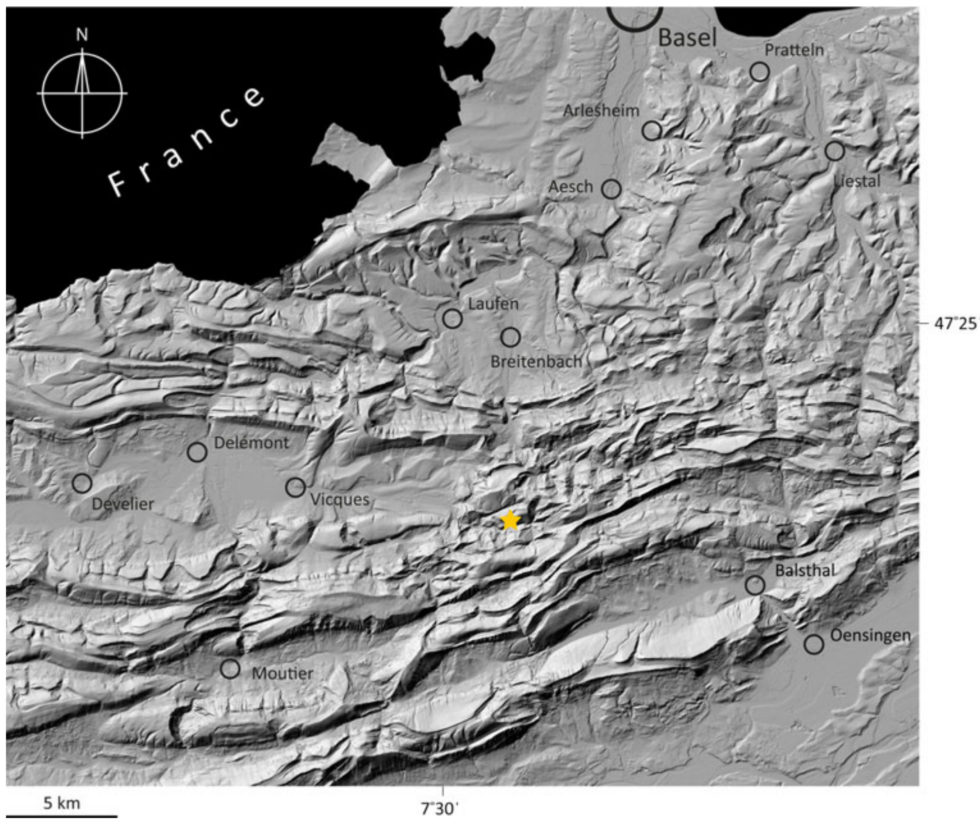


Fig. 1 Geographical setting. Topographical map showing the position of the Dürrenberg section (marked with the *yellow asterisk*), located on the area of Mervelier (Canton Jura), about 15 km to the east of Delémont

The Dürrenberg locality lies within the Folded and Thrusted Jura Mountains, on the southern flank of the Dürrenberg anticline close to the Scheltenpass and about 15 km to the east of Delémont (Fig. 1). Bedding is steeply inclined and dipping towards the southeast (Fig. 2).

After the screen washing process, the largest amount of remaining residue consisted mainly of slightly rounded Mesozoic limestone pebbles, some of them silicified, with a diameter up to 10 cm. The residue <2 mm consisted mainly of quartz sand and reworked ferruginous pisoliths ("Bohnerzkügelchen") of the Eocene "Sidérolithique", which is a product of soil formation and terrestrial weathering of Jurassic and possibly Cretaceous formations. Besides, bone fragments, teeth of mammals and reptilians, as well as debris of terrestrial gastropods have been found. No alpine detritus could be ascertained within the residue.

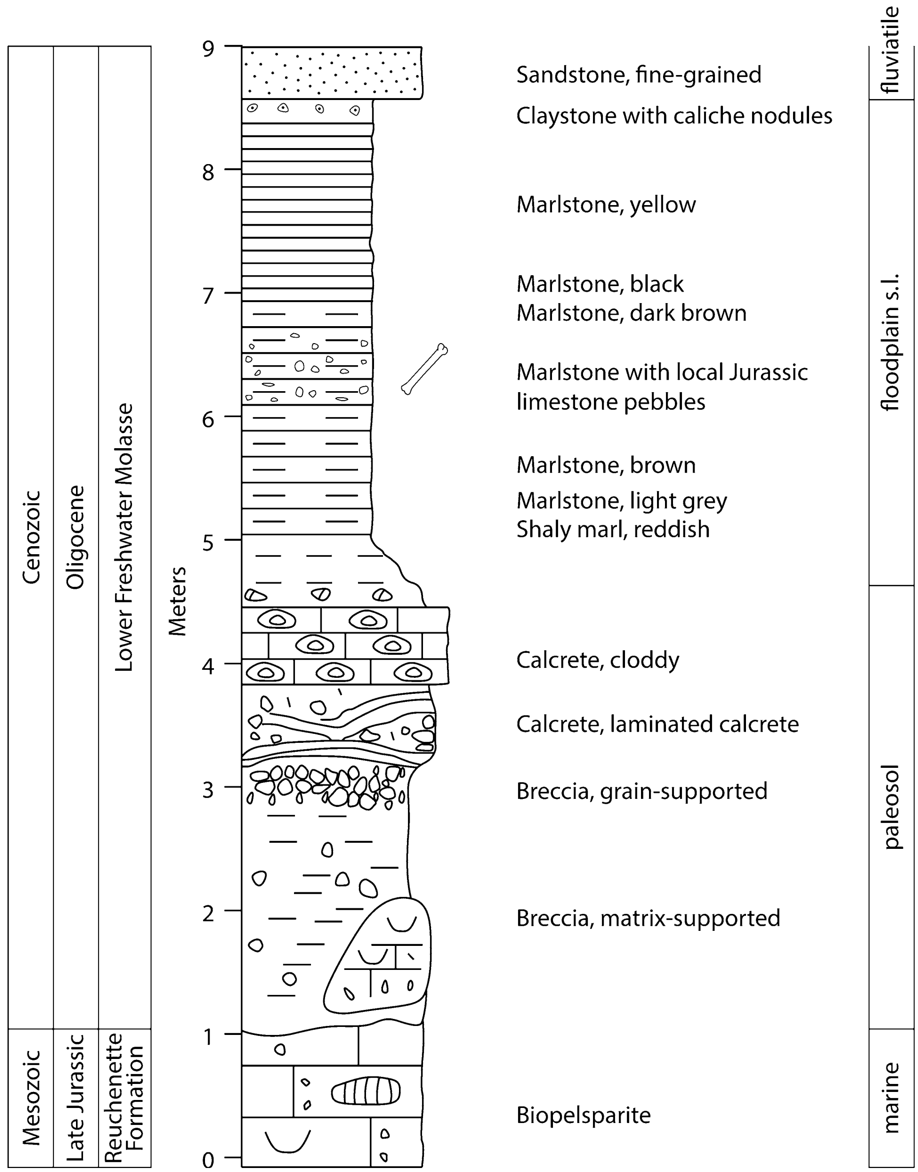
Fig. 2 At the Dürrenberg outcrop (federal coordinates 607.485/242.915, 820 m) bedding is steeply inclined and dipping to the southeast. *A* marks the characteristic massive calcrete beds (between 3–4.5 m in the section of Fig. 3), *B* marks the fossiliferous layer, which has yielded the studied mammal teeth. The top of the Late Jurassic Reuchenette Formation is not visible, but is located 1 m to the left

2 Material and methods

The Dürrenberg material consists of 53 teeth of small mammals. The preservation of the teeth is generally of rather poor quality. Out of approximately 50 teeth only 20 were well preserved. The most important taxa are described and figured in the systematic part. All measurements are given in millimetres, and conventional size measurements were taken with an Olympus binocular.

Cricetid and glirid teeth are relatively easy to measure by measuring the entire crown length and width, the width perpendicular to the length (Fig. 4). In contrast, as stated

Fig. 3 Dürrenberg section, slightly modified from Wanner (2010). The uppermost layer (fine-grained sandstone) most probably records the onset of the Molasse alsacienne sedimentation



by Freudenthal (1997) "theridomyid teeth are difficult to measure, due to their shape, their hypsodonty, and their (relatively) large size". Vianey-Liaud (1972) proposed to measure the wear surface, and not the entire crown length and width. Her measuring method implies the definition of wear stages. In this study, theridomyid teeth were measured according to Vianey-Liaud (1972, Fig. 2), the height of lower molars of *Issiodoromys* according to Schmidt-Kittler and Vianey-Liaud (1987, see also Fig. 4). Dental terminology for the Theridomyidae is given in Fig. 5.

All specimens from the Dürrenberg locality and all figured specimens with the prefix "NMB" are stored at the Natural History Museum Basel. Specimens with the prefix "NMS" [material from a new excavation at the locality Balm (MP 22) in 2012] are stored at the Naturmuseum Solothurn.

3 Systematic palaeontology

Family Theridomyidae Alston, 1876
Subfamily Theridomyinae Alston, 1876
Genus *Theridomys* Jourdan, 1837

Theridomys cf. *lembronicus* Bravard, in Gervais, 1848–52 (Figs. 6a, b)

Type locality. Saint-Germain-Lembron, France, MP 25

Material. 2 $M^{1/2}$, ? × 2.16 mm, ? × 2.52 mm

Description. The locality Dürrenberg yielded two slightly fragmentary upper molars of a large Theridomyidae. Regarding its size and its more or less regular enamel

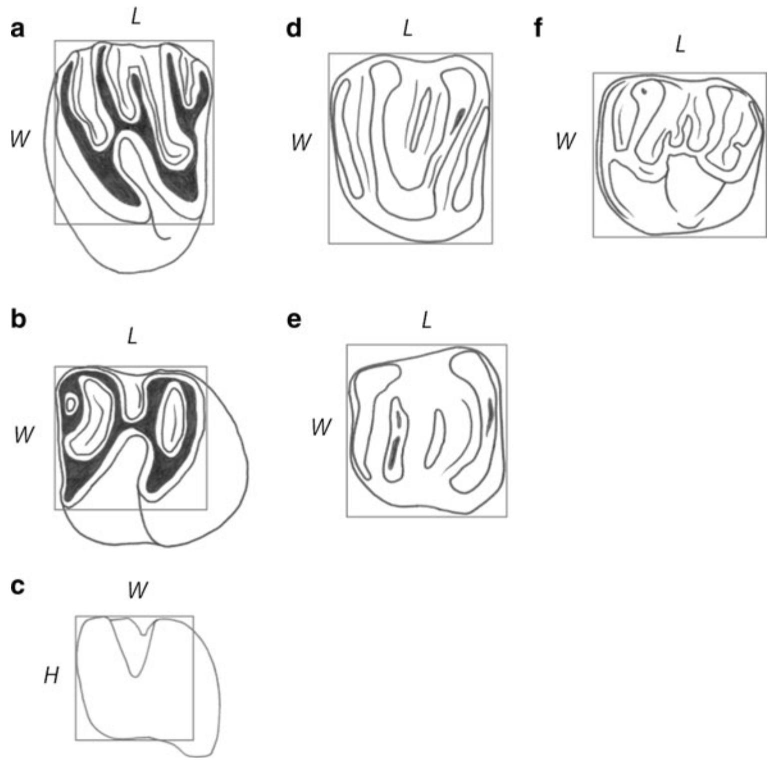


Fig. 4 General measurements of teeth. **a** Upper molar of a theridomyidae (*Theridomys*). **b** Lower molar of a theridomyidae (*Blainvillimys*). **c** Lower molar of *Issiodoromys*, *labial view*. **d** Upper molar of glirid. **e** Lower molar of a glirid. **f** Upper molar of a cricetid. *L* length, *W* width, *H* Height

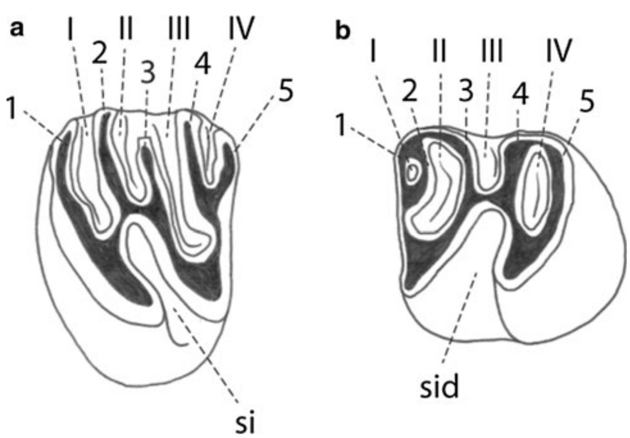


Fig. 5 Dental terminology for the Theridomyidae Alston, 1876. **a** Upper left molar of a theridomyidae (*Theridomys*). **b** Lower left molar of a theridomyidae (*Blainvillimys*). *1–5* anticlines, *I–IV* synclines, *si* sinus, *sid* sinusid

thickness it can be attributed to the genus *Theridomys* (Vianey-Liaud 1972, p. 300, 325). The most conspicuous feature in one specimen is an isolated second anticline, i.e. the first and second synclines are fused. Both teeth show a long and narrow sinus. In both teeth the third syncline is the longest. With its long and narrow sinus the specimens from Dürrenberg clearly differ from most other *Theridomys* species like *T. crusafonti* Thaler, 1969, *T. perrealensis* Vianey-Liaud, 1977, *T. ludensis* Vianey-Liaud, 1985, *T. calafensis* Vianey-Liaud & Hartenberger, 1987, *T. brachydens* Gad, 1987, *T. bumbachensis* Mayo, 1987, and *T. margaritae* Vianey-Liaud, 1989. *T. octogesensis* Arbiol, Agusti & Hugueney, 1997 also shows a long and narrow sinus, but the latter species shows a more complex dental pattern. The most striking differences to *T. lembronicus* (type and figured specimens in Vianey-Liaud 1972) are the more transverse synclines and anticlines (especially syncline III and anticline IV). Regarding this feature, the specimens from Chaptuzat, France (Stehlin and Schaub 1951, p. 37) are very similar to those from Dürrenberg, and for that reason the specimens from Dürrenberg are assigned to *T.* cf. *lembronicus*.

Vianey-Liaud (1972) reports the presence of *Theridomys lembronicus* from the French localities Saint-Germain-Lembron (MP 25), Perrier (MP 25), ?Cournon (MP 28–29?), "La Sauvetat" (MP 25), Antoingt (MP 25), Aubenas-les-Alpes (MP 25), St-Vincent-de-Barbeyragues (MP 25) and Les Matelles (MP 25). Hugueney (1997) added the localities Authezat (MP 25), Chaptuzat (MP 25?),) St. Yvoine (MP 25), and Solignat (MP 25?).

Genus *Toeniodus* Pomel, 1853

Toeniodus curvistriatus Pomel, 1853 (Fig. 6e)

Type locality. La Sauvetat, France, MP 25

Material. 2 $m_{1/2}$, 1.78 × 1.66, 1.96 × 1.66 mm

Description. Both lower molars show a for the genus *Toeniodus* characteristic transverse fusion of synclinid IV and sinusid that crosses the entire tooth.

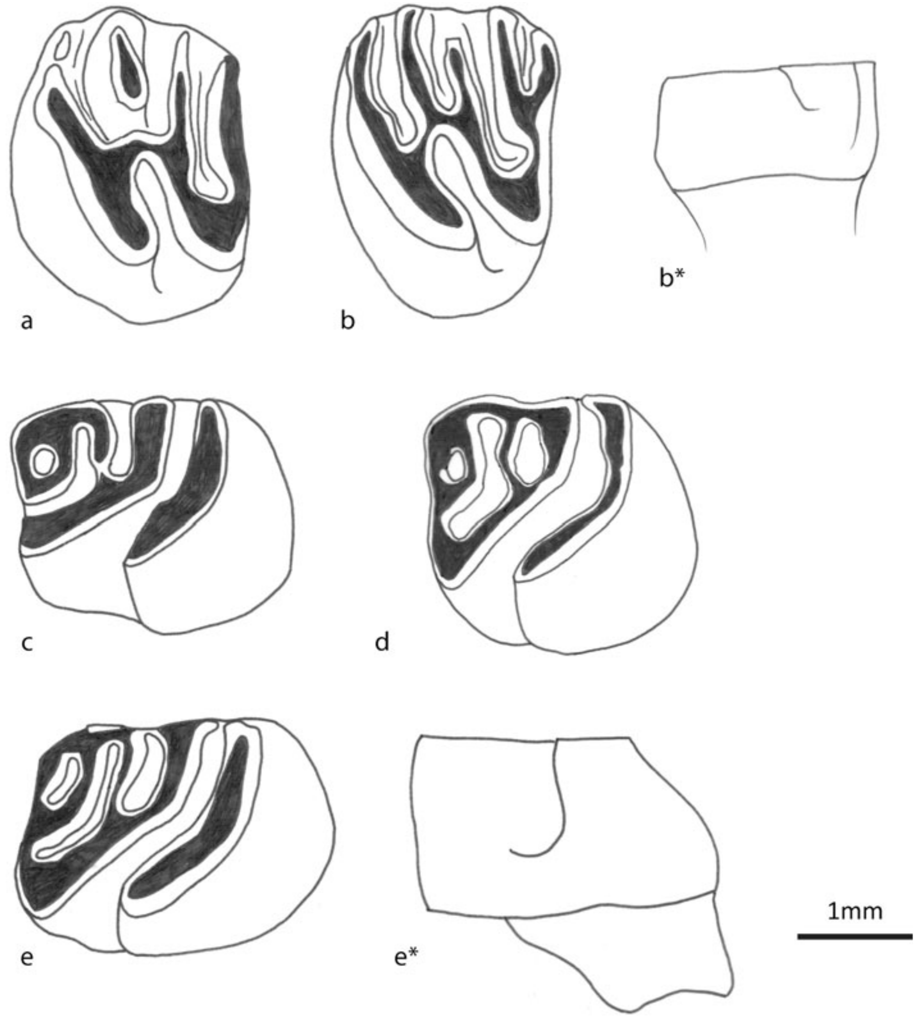


Fig. 6 *Theridomys* cf. *lembronicus* Bravard, in Gervais, 1848–52 from Dürrenberg. **a** $M^{1/2}$ dext. (inversed) NMB Dü.4. **b** $M^{1/2}$ dext. (inversed) NMB Dü.5. **a**, **b** occlusal view, **b*** labial view. **c** *Toeniodus ernii* Mayo, 1987 from Balm. m_1 sin. NMB Blm 218. Redrawn from Mayo (1987). **d** *Toeniodus curvistriatus* Pomel, 1854 from Court 1. $m_{1/2}$ sin. NMB Crt.1. **e** *Toeniodus curvistriatus* Pomel, 1854 from Dürrenberg. $m_{1/2}$ sin. NMB Dü.6. **e** occlusal view, **e*** labial view. All specimens were figured as left ones. If no left teeth were available, right teeth were drawn and mirrored, indicated here with "inversed"

The genus *Toeniodus* has been recorded from the localities Balm (MP 22), Grenchen-1 (MP 24), St. Yvoine (MP 25), ?Cournon (MP 28–29?), Coulou (MP 23), "La Sauvetat" (MP 25), Gas (MP 24), Maintenon (MP 24), St. Martin de Castillon (MP 23/MP 24), Heimersheim (MP 24) and Court 1 (MP 24, Fig. 6d).

The Dürrenberg specimens are clearly larger than the smallest known specimens from Balm (MP 22), which have been interpreted by Mayo (1987) as the stratigraphically oldest and most primitive species (*Toeniodus ernii*).

Vianey-Liaud (1998) proposed a single lineage from a primitive *Toeniodus curvistriatus* (=? *T. ernii* Mayo, 1987) in MP 22 to a more evolved *T. curvistriatus* and then possibly to *T. hexalophodus* Bahlo, 1975 in MP 24. According to Hugueney (1997), *Toeniodus curvistriatus* is recorded from the MP 24 and MP 25 levels.

Genus *Blainvillimys* Bravard, in Gervais, 1848–1852

Blainvillimys cf. *helmeri* Vianey-Liaud, 1972 (Fig. 7a, b, d)

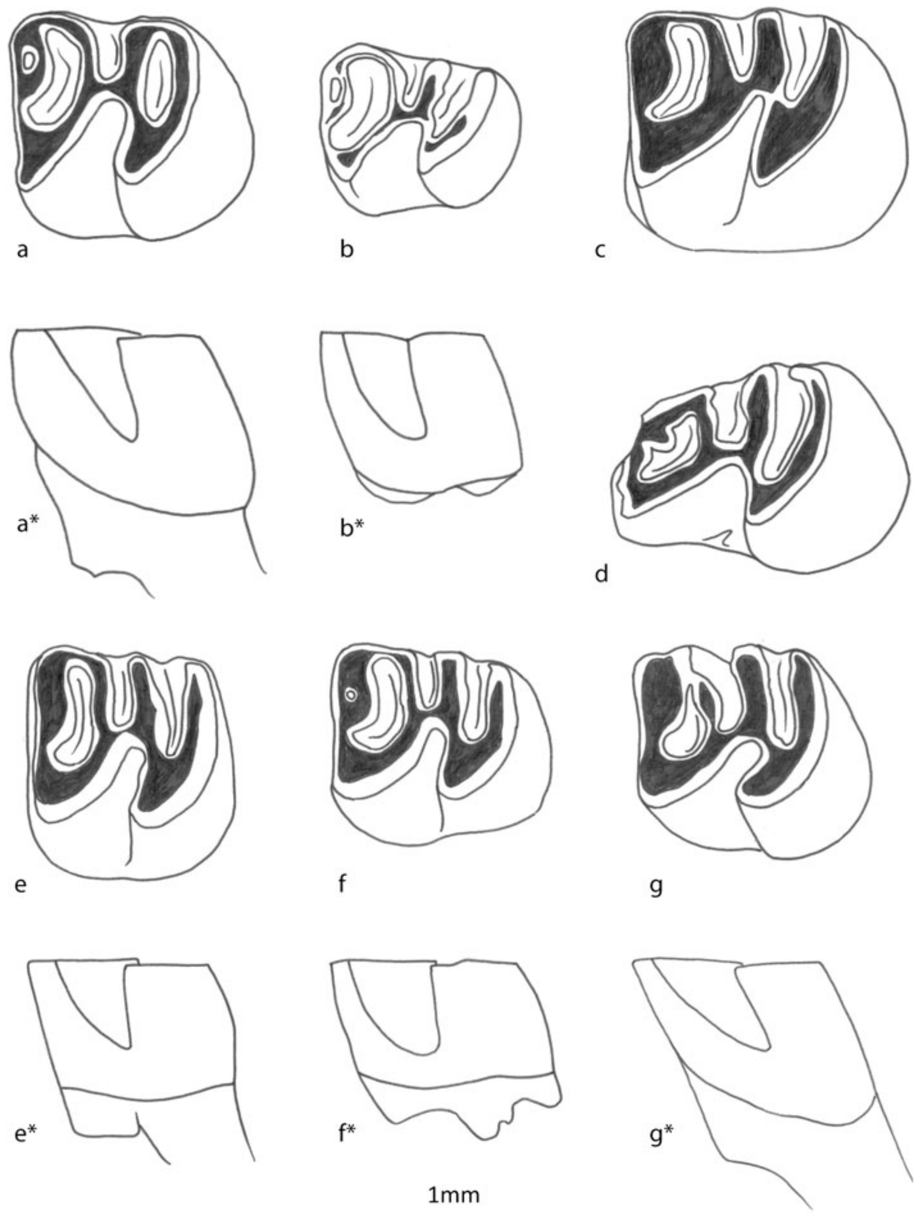
Type locality. Les Chapelins, France, MP 23

Material. 3 $m_{1/2}$, 2 m_3, 1 p_4, several fragments and corroded teeth. $m_{1/2}$: 1.72 × 1.66, 1.82 × 1.64 mm; m_3: 1.62 × 1.28 mm; p4: ? × 1.50 mm

Description. The genus *Blainvillimys* is characterized by a reduction of the enamel thickness on the anterior side of the anticlinids and the posterior side of the anticlines (Vianey-Liaud 1972, p. 300, p. 325). The taxonomy of the genus is essentially based on morphologic characteristics that evolved through time. General phylogenetic trends within the genus *Blainvillimys* are (1) increase in hypsodonty, (2) transversal deepening of sinus and sinusid, (3) more backwards directed sinusid in lower molars, (4) higher frequency of synclinid I in lower molars, and (5) increase of taeniodonty.

In all out of five lower $m_{1/2}$ and m_3, the synclinid I is always present. Concerning the frequency of synclinid I, the specimens from Dürrenberg clearly differ from those of the older species *B. langei* Vianey-Liaud, 1972 and *B. gregarius* (Schlosser, 1884). Vianey-Liaud and Schmid (2009) give a frequency of the synclinid I for *B. langei* of 1–10 %, 15–25 % for *B. gregarius*, and >50 % for

Fig. 7 *Blainvillimys* cf. *helmeri* Vianey-Liaud, 1972 from Dürrenberg. **a** $m_{1/2}$ dext. (inversed) NMB Dü.1. **b** m_3 sin. NMB Dü.2. **a**, **b** occlusal view, **a***, **b*** labial view. **c** *Blainvillimys* cf. *blainvillei* Gervais, 1848–52 from Grenchen 1. $m_{1/2}$ sin. NMB UM 3242. **d** *Blainvillimys* cf. *helmeri* Vianey-Liaud, 1972. p_4 sin. from Dürrenberg. NMB Dü.3. *Blainvillimys helmeri* Vianey-Liaud, 1972 from Lovagny (niv. 14). **e** $m_{1/2}$ sin. NMB Lvy.11, **f** $m_{1/2}$ sin. NMB Lvy.12, **g** $m_{1/2}$ dext. (inversed) NMB Lvy. 13. **e**–**g** occlusal view, **e**–**g*** labial view



B. helmeri. The sinusid is directed slightly backwards and reaches slightly more lingually than in *B. helmeri*. On the other side, the synclinid III is longer than in *B. blainvillei*. There is some resemblance with *B. gemellus* Vianey-Liaud, 1989, and ? *Blainvillimys avus* (Stehlin and Schaub 1951). *B. gemellus* shows a shorter sinusid, a distinctly longer synclinid III and is distinctly larger. ?*Blainvillimys avus* was first described by Stehlin and Schaub (1951) as *Pararchaeomys avus* and later transferred with some doubt to the genus *Blainvillimys* by Vianey-Liaud (1998). However, the specimens from Dürrenberg show no tendency of a fusion of sinusid and synclinid IV typical for ?*B. avus*.

Vianey-Liaud (1998) proposes two different evolutionary lineages for the genus *Blainvillimys*, one leading from *Blainvillimys langei* Vianey-Liaud, 1972—*B. gregarius* (Schlosser, 1884)—*B. helmeri* Vianey-Liaud, 1972,—*B.* n. sp. from St. Martin de Castillon to ?*B. avus* (Stehlin and Schaub, 1951), the other leading from *B. gemellus* Vianey-Liaud, 1989—*B. blainvillei* (Gervais, 1848–1852) to *B. stehlini* (Mayo 1987). The specimens from Dürrenberg are intermediate between *B. helmeri* (typical for MP 23), and *B. blainvillei* (typical for MP 25), but distinctly closer to *B. helmeri* (see also Fig. 7). For that reason the specimens from Dürrenberg are assigned to *B.* cf. *helmeri*.

Genus *Issiodoromys* Croizet, in Blainville, 1840

Issiodoromys minor Filhol, 1876 (Figs. 8d, 9b)

Type locality. not defined, see Mödden (1994)

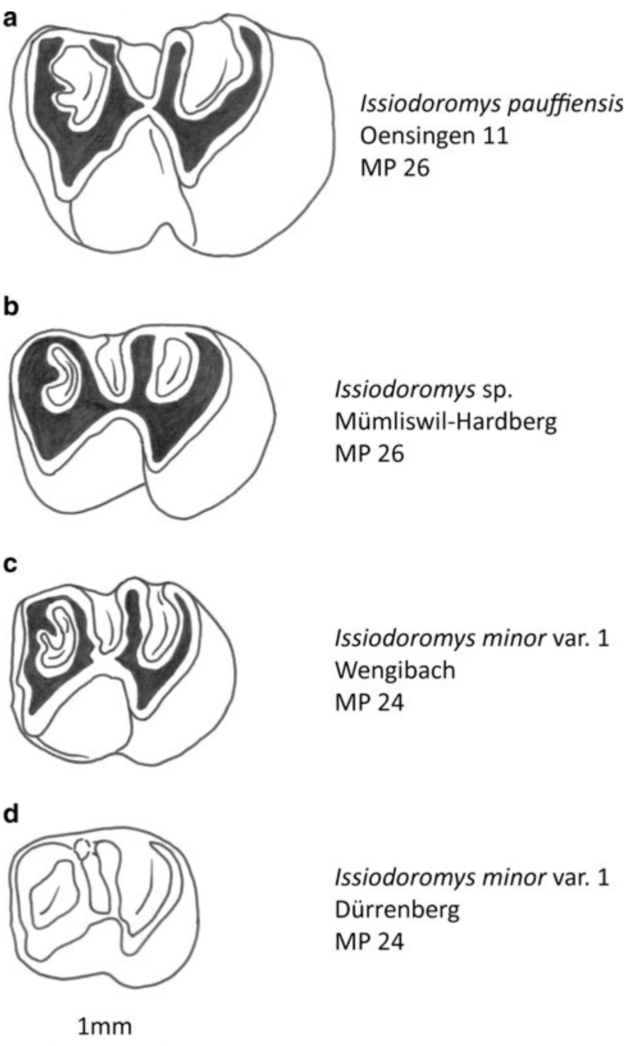


Fig. 8 Lower molars ($m_{1/2}$) of different *Issiodoromys* species showing increasing size (all teeth in occlusal view) **a** *Issiodoromys pauffiensis* Vianey-Liaud, 1976 from Oensingen. $m_{1/2}$ sin. NMB U.M. 7214. **b** *Issiodoromys* sp. from Mümliswil-Hardberg, $m_{1/2}$. NMB Mü.72. **c** *Issiodoromys minor* var. 1 Filhol, 1876 from Wengibach. $m_{1/2}$. NMB Wb.1. **d** *Issiodoromys minor* var. 1 Filhol, 1876 from Dürrenberg. $m_{1/2}$ sin. NMB Dü.7

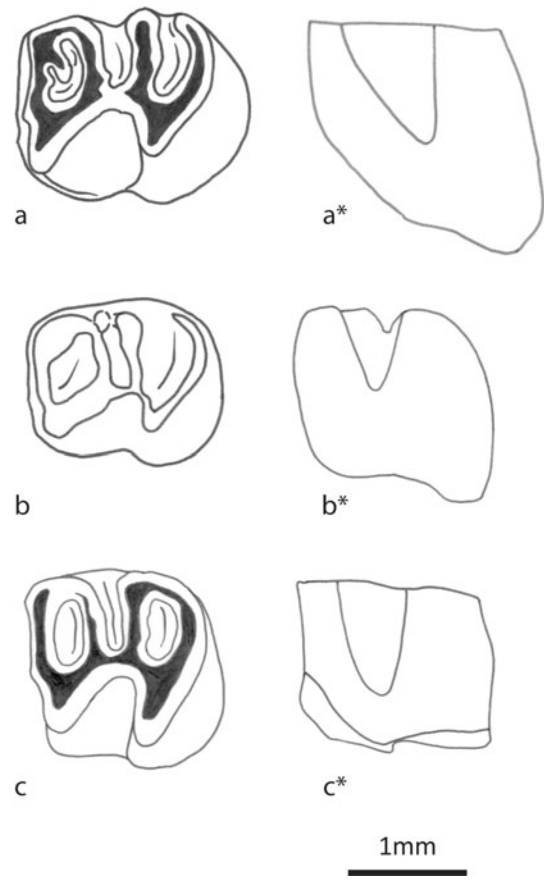


Fig. 9 Lower molars ($m_{1/2}$) of different *Issiodoromys* species showing increasing hypsodonty (all teeth in occlusal and labial view). **a** *Issiodoromys minor* var. 1 Filhol, 1876 from Wengibach. $m_{1/2}$. NMB Wb.1. **b** *Issiodoromys minor* var. 1 Filhol, 1876 from Dürrenberg. $m_{1/2}$ sin NMB Dü.7. **c** *Issiodoromys balmensis* (Mayo, 1987) from Balm. $m_{1/2}$ dext. (invers) NMS 40896. *Left side* occlusal view, *right side* (marked with *asterisk*) labial view

Material. 1 $m_{1/2}$, 1.48 × 1.02 mm, H = 1,54 mm, H/L = 1.04

Description. The genus *Issiodoromys* is represented by one tooth, a well-preserved slightly worn $m_{1/2}$. The stage of wear is 0–1, according to Vianey-Liaud (1979). There is no trace of an antesinusid. The tooth is longer than wide, and the sinusid is directed slightly backwards.

Schmidt-Kittler et al. (1997) propose a single evolutionary lineage leading from *Issiodoromys medius* Vianey-Liaud, 1976 in MP 22—*I. minor* var. 1 Filhol, 1876—*I. minor* var. 2 Filhol, 1876—*I. minor* var. 3 Filhol, 1876 to *I. pauffiensis* Vianey-Liaud, 1976 in MP 26. This evolutionary lineage that extends up to MP 30 is very useful for biostratigraphical purposes. According to Mayo (1987), the small *Issiodoromys* species from Balm (MP 22, *I. balmensis*) probably represents the ancestral species of *Issiodoromys medius* Vianey-Liaud, 1976. The specimen from Dürrenberg best fits *with Issiodoromys minor* var. 1 (sensu Schmidt-Kittler et al. 1997) in size and morphology. Size, morphology and hypsodonty are intermediate between *I. medius* and *I. pauffiensis* (see Figs. 8, 9).

Family Gliridae Thomas, 1897

A considerable part (about 30 %) of the Dürrenberg material consists of glirids. All teeth belong to the subfamily Gliravinae Schaub, 1958. Among the material at least two species of two genera may be distinguished. Berger (2008, p. 18) correctly stated that determination of Gliravinae based on the recent contradictory publications of Daams and de Bruijn (1995), Vianey-Liaud (1994, 2003), and Freudenthal (2004) is difficult and often subjective. For that reason he introduced an emended diagnosis for the Genus *Gliravus* and a differential diagnosis to the genera *Glamys* and *Schizogliravus*, which is followed in this study. *Schizogliravus* may be considered as a junior synonym of *Butseloglis* Vianey-Liaud, 2004 (Freudenthal and Martín-Suárez 2007, p. 258).

Genus *Gliravus* Stehlin and Schaub, 1951 (Fig. 10d, e)

Material. 1 $M^{1/2}$, 1.12 × 1.30 mm. 1 m_1, 1.06 × 1.16 mm, 1 m_2, 1.10 × 1.22 mm

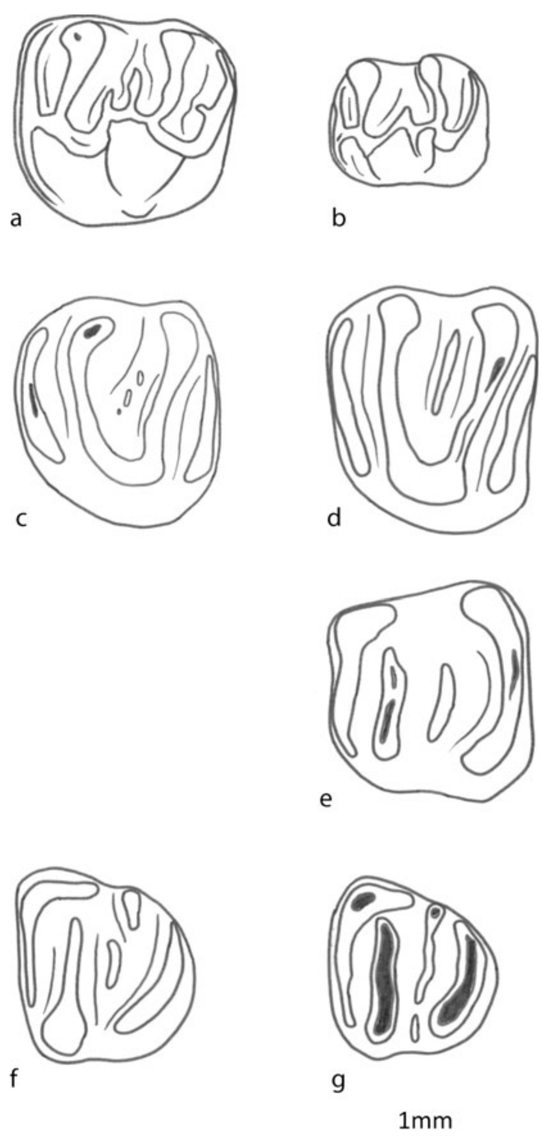


Fig. 10 **a** *Pseudocricetodon ?moguntiacus* (Bahlo, 1975) from Dürrenberg. M^2 sin. NMB Dü.8. **b** *Pseudocricetodon* cf. *philippi* Hugueney, 1971 from Dürrenberg. m_2 sin. NMB Dü.9. **c** *Gliravus majori* Stehlin & Schaub, 1951 from Balm. $M^{1/2}$ sin. NMS 40895. **d–e** *Gliravus* sp. from Dürrenberg. $M^{1/2}$ sin. NMB Dü.10, $m_{1/2}$ sin. NMB Dü.11. **f–g** *Schizogliravus tenuis* (Bahlo, 1975) from Dürrenberg. m_3 sin. NMB Dü.12. m_3 sin. NMB Dü.13

Description. One single $M^{1/2}$ with a rectangle shape shows a simple morphology with a more U than V shaped trigon. The occlusal surface is strongly concave. Antero- and posteroloph are long, isolated, not connected with the protoconus. There is no tendency towards a union of anteroloph and posteroloph along the lingual border. The (post)centroloph is well developed and long. Labially, there is a distinct indentation. With this dental pattern the specimen fits (with the exception of the missing tendency towards a union of anteroloph and posteroloph) pretty good the emended genus diagnosis of *Gliravus* (Berger 2008). In size, this upper molar is in the lower size variability of *Gliravus bruijni*, in the uppermost size variability of *Schizogliravus tenuis,* and fits well in size with *Gliravus majori*. The Dürrenberg specimen is distinctly larger than the specimens from Balm (MP 22, Fig. 10), but smaller than the *Gliravus* species from Mümliswil-Hardberg (MP 26, *Gliravus* cf. *majori* in Engesser and Mödden 1997).

The m_1 is trapezoidal, the tooth is wider than it is long. The metalophid shows no contact with the metaconid, it ends at the base of the metaconid. The mesolophid is short, it shows no contact with the entoconid. Additional crests are missing.

The m_2 is rectangular, distinctly wider than long. Meta- and mesolophid are parallel to the anterolophid and not directed backwards. Neither the metalophid nor the mesolophid is connected with the metaconid or metaconid. There are no additional crests. Both lower molars show a distinctly concave occlusal surface. With only one available $M^{1/2}$ and two lower molars it is not possible to give a reliable determination on the species level.

Genus *Schizogliravus* Freudenthal, 2004

Schizogliravus tenuis. (Bahlo, 1975) (Fig. 10f, g)

Type locality. Heimersheim, Germany, MP 24

Material. 2 m_3, 0.86 × 0.96 mm, 0.94 × 1.04 mm

Description. The Dürrenberg locality has delivered two m_3 of a glirid species that is distinctly smaller than the abovementioned *Gliravus* species. One specimen (Fig. 10f) is nearly identical with the m_3 of *Schizogliravus tenuis* figured by Bahlo (1975, Fig. 32).

The metalophid ends free, does not reach the metaconid. The mesolophid is long in one specimen, only slightly interrupted on the labial side and reaches the lingual side of the tooth. In the other specimen, the mesolophid is interrupted and forms two small crests. There are no accessory crests. The occlusal surface is distinctly less concave than in the specimens from *Gliravus* sp. from Dürrenberg.

Family Cricetidae Fisher von Walheim, 1817

Genus *Pseudocricetodon*. Thaler, 1969

Pseudocricetodon philippi Hugueney, 1971 (Fig. 10b)

Type locality. St. Martin de Castillon C, France, MP 24

Material. 2 m_2, 0.90 × 0.78 mm, 0.84 × 0.72 mm

Description. Pseudocricetodon philippi has been described by Hugueney (1971) from the French locality St. Martin de Castillon C (MP 24). It differs from all other known *Pseudocricetodon* species (*P. montalbanensis* (Thaler, 1969), *P. thaleri* (Hugueney, 1969), *P. moguntiacus* (Bahlo, 1975), *P. simplex* Freudenthal et al. 1994 and *P. adroveri* Freudenthal et al. 1994 by its considerably smaller size and its extremely simple morphology. The Dürrenberg locality yielded two very small m_2 of this species. Both teeth show a simple backward directed and short mesolophid and a semi-long ectomesolophid. The sinusid is open. According to Freudenthal et al. (1994) *P. philippi* seems to be a rare species. Besides its type locality, *P. philippi* is known from Heimersheim, St Henri, Pech-du-Fraysse, Pech Desse, Terrenoire, and Mirambueno 4C (Freudenthal et al. 1994).

Pseudocricetodon cf. *moguntiacus* (Bahlo, 1975) (Fig. 10a)

Type locality. Heimersheim, Germany, MP 24

Material. 1 M^2, 1.16 × 1.12 mm

Description. The only available M^2 shows a double, short mesoloph, the second mesoloph being longer than the first. There is a small relic of an accessory crest on the anterior side of the posteroloph. In size, the specimen from Dürrenberg fits well with *Pseudocricetodon moguntiacus* (Bahlo, 1975) from Heimersheim. It is distinctly smaller than *P. montalbanensis* (Thaler, 1969), *P. thaleri* (Hugueney, 1969), *P. simplex* Freudenthal et al. (1994) and *P. adroveri* Freudenthal et al. 1994. It is also distinctly smaller than *Atavocricetodon atavus* (Misonne, 1975), see measurements in Freudenthal (1988). Freudenthal et al. (1992) express their doubts about the homogeneity of Bahlo's *moguntiacus* collection and suppose that it belongs to two different species. Nevertheless, the M^2 from Dürrenberg is morphologically very close to the specimen from Heimersheim figured by Bahlo (1975, Fig. 22b). Therefore, the determination as *Pseudocricetodon* cf. *moguntiacus* (Bahlo, 1975) is preferred here.

4 Biostratigraphy

The Dürrenberg locality yielded approximately 50 micro-mammal teeth,which could be assigned to 10 different taxa (47 % Theridomyidae, 13 % Cricetidae, 30 % Gliridae, 10 % Insectivora, no eomyids). The resulting faunal list for the Dürrenberg locality is:

Didelphidae indet.
Lipotyphla indet.
Blainvillimys cf. *helmeri* Vianey-Liaud, 1972
Theridomys cf. *lembronicus* Bravard, in Gervais, 1848–52
Toeniodus curvistriatus Pomel, 1853
Issiodoromys minor var. 1 Filhol, 1876
Pseudocricetodon cf. *moguntiacus* (Bahlo, 1975)
Pseudocricetodon philippi Hugueney, 1971
Gliravus sp.

Schizogliravus tenuis (Bahlo, 1975)

The genus *Toeniodus* is known from MP 22–MP 25 (Hugueney 1997). *Issiodoromys minor* is known from MP 24–MP 25 (Schmidt-Kittler et al. 1997). The most primitive representatives of *I. minor* (*Issiodoromys minor* var. 1) are listed by Schmidt-Kittler et al. (1997) in MP 24. *Theridomys lembronicus* is recorded from MP 24–MP 25 (Hugueney 1997). According to Uhlig (2001) *Schizogliravus tenuis* is restricted to MP 22–MP 24. *Blainvillimys* cf. *helmeri* from Dürrenberg is more evolved than *B. helmeri* from the type locality Les Chapelins (MP 23), but distinctly less evolved than *B. blainvillei* typical for MP 25. For this reason, the Dürrenberg fauna is attributed to the European MP 24 reference level (reference locality for MP 24 is Heimersheim). Most probably it correlates to the lower part of MP 24 (Late Rupelian). All other species do not contradict this calibration. In contrary, the type localities of *Pseudocricetodon philippi* (St. Martin de Castillon C, France), *Pseudocricetodon moguntiacus* and *Schizogliravus tenuis* (both Heimersheim, Germany) are placed within MP 24.

Until now, the small fauna of Grenchen 1 (Stehlin 1914; Buxtorf and Troesch 1917; Engesser and Mödden 1997) was the only representative of the MP 24 reference level within the Swiss Molasse Basin. During the past 10 years, several important new mammal sites from the Lower Freshwater Molasse of Switzerland have been reported. Among these, 6 faunas were attributed to the MP 24 reference level: Stirzelwälder, Wengibach, Court 1, La Beuchille (Becker et al. 2004), Poillat (Becker et al. 2013) and Dürrenberg (Fig. 11). Stirzelwälder and Wengibach are localities situated within the subalpine molasse of central and eastern Switzerland. Court 1, La Beuchille, Poillat and Dürrenberg are localities from the molasse within or on the eastern slope of the "Rauracian depression" of the Jura Mountains. Only two of these six faunas are rather well documented: Stirzelwälder yielded until now approximately 200 teeth, Wengibach approx. 120 teeth. These 2 localities, and especially Stirzelwälder, offer the possibility for further sampling, while Court 1, La

Beuchille and Poillat are no longer accessible. Although the locality Dürrenberg remains accessible and its sediment is easily washable, its potential is hampered because of the poor preservation quality and the great effort to pick the large amount of residue.

Epoch	Stage	MP unit	Swiss reference localities	Faunas of the same age
Oligocene	Chattian	MP 26	Oensingen 11*	Talent 1, 8, 11, 16 Schwendibach
Oligocene	Chattian	MP 26	Mümliswil-Hardberg*	*Rigi 1*, Cuennet
Oligocene	Chattian / Rupelian	MP 25	Bumbach 1	Réchauvent-Cristallin, Talent 2, 13
Oligocene	Rupelian	MP 25	Talent 7	
Oligocene	Rupelian	MP 24	Grenchen 1	*Wengibach* *Stirzelwälder* *Dürrenberg, Court 1* *La Beuchille, Poillat*
Oligocene	Rupelian	MP 23	Lovagny	? Ruisseau des Comballes ? La Combe
Oligocene	Rupelian	MP 22	Balm	? Basel - St. Margarethen ? Dornachbrugg

Fig. 11 Biozonation of the lower part of the Lower Freshwater Molasse of Switzerland and Savoy on the basis of fossil mammals (mainly after Engesser and Mödden 1997). Localities not as yet known or considered by Engesser and Mödden (1997) are put in *italics*. *Asterisk* the Mümliswil reference fauna is considered here to be older than the Oensingen reference fauna. This is in concordance with Thaler (1965) and Vianey-Liaud (1977), but contradicts the classification of Baumberger (1927), Mayo (1980) and Engesser and Mödden (1997)

5 Paleogeography

During the Oligocene (Late Rupelian and Chattian), the Swiss Molasse Basin was connected with the Southern Rhine Graben (see palaeogeographic maps e.g. in Berger et al. 2005). This connection ("Rauracian depression", Baumberger 1927) enabled the transportation of alpine micaceous sands to the north and deposition in the marine Meletta beds and the mainly fluviatile Molasse alsacienne, as proved by the heavy mineral assemblage ("Genferseeschüttung", Füchtbauer 1964; Schlanke et al. 1978; Maurer 1983; Brianza et al. 1983). According to zircon and apatite fission-track ages of marine sandstones layers (Kuhlemann et al. 1999), the transportation started in the Late Rupelian (Meletta beds). Based on similarities in the fish fauna of the subalpine Lower Marine Molasse and the Southern Rhine Graben, Buxtorf and Fröhlicher (1933) and Fröhlicher and Weiler (1952) proposed the existence of a marine connection in the area of the future Central Swiss Jura Mountains. Since then the discussion on the location and duration of this possible former seaway went on. However, there is no evidence of unquestionable marine sediments south of the basins of Laufen and Delémont (Reichenbacher et al. 1996). A major progress was made with the discovery of interfingering marine and fluviatile sediments in the Delémont basin by Clement and Berger (1999). Roussé (2006) assumed therefore the development of an extensive deltaic system on the southern margin of the Upper Rhine Graben. Based on the distribution of abundant allochthonous planktonic foraminifera from the Late Rupelian to Early Chattian in Upper Rhine Graben deposits, Pirkenseer et al. (2011) ruled out the displacement of reworked material by marine currents because of unfavourable palaeotopographical and palaeogeographical

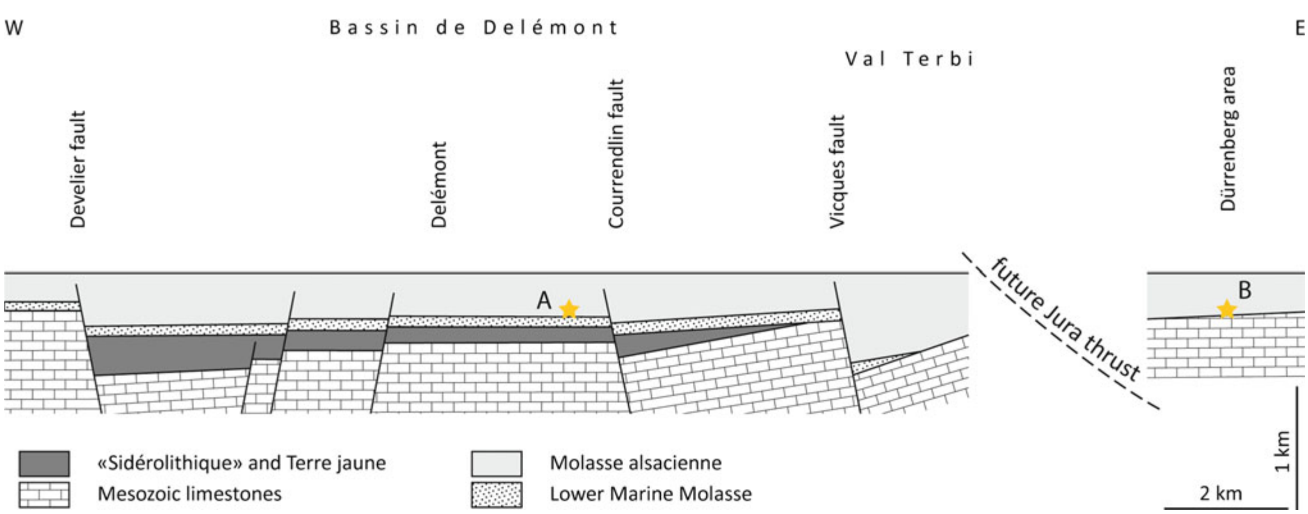


Fig. 12 Schematic W–E section from the Delémont basin to the Dürrenberg area during the latest Chattian (western part taken from Suter 1978). Because of the Jura thrust, the Dürrenberg area was originally situated a few kilometres further south. *A* La Beuchille locality (Delémont, Becker et al. 2004), *B* Dürrenberg locality

constraints. Unfortunately, the Dürrenberg locality does not add much new information to this discussion, as its position is on the eastern slope of the "Rauracian depression" and already outside the area of a possible marine transgression during the Rupelian (Fig. 12).

6 Conclusions

Because of the presence of reworked Eocene ferruginous pisoliths and of Oligocene micromammals, the Dürrenberg section can be attributed to the Lower Freshwater Molasse. It postdates the Siderolithic, but is slightly older than the local onset of the Molasse alsacienne sedimentation, because of the lack of any alpine detritus.

The Delémont basin is a southern prolongation of the Upper Rhine Graben and part of the "Rauracian depression". Rifting of this segment began in the Late Eocene. The central part of the Delémont basin contains a much thicker Eocene and Early Oligocene sedimentary record than the western and eastern part and the neighbouring graben shoulders (Liniger 1925; Suter 1978). The marine transgressions from the north (Upper Rhine Graben) during the Rupelian only affected the central part of the basin (Fig. 12). The eastern part of the Delémont basin (Val Terbi) contains no marine sediments of Rupelian age. In the central part of the Delémont basin fluviatile sedimentation of Molasse alsacienne started in MP 24 or earlier (localities La Beuchille and Poillat, Becker et al. 2004, 2013) on top of a thick Eocene ("Sidérolithique") and Early Oligocene ("Terre jaune") sedimentary record. At the same time 15 km to the east in the Dürrenberg area calcrete developed directly on top of altered Mesozoic limestones (Fig. 3). Later, fine-grained sediments were locally deposited, and in the uppermost part of the section alpine fluviatile sands were recorded. So the onset of Molasse alsacienne sedimentation started remarkably later in the Dürrenberg area than in the Delémont basin. Further to the west and the east, the Molasse alsacienne is thinning out. 30 km east of the Delémont basin, in the Brochene Fluh section (Waldenburg, Canton Baselland, Baumberger 1927; Picot 2002), the latest Oligocene Calcaires de Delémont directly overlay the Mesozoic limestones, with only a tiny intercalation of Molasse alsacienne. The Dürrenberg area is situated on the eastern slope of the "Rauracian depression" and is important for the reconstruction of the dimension and geometry of this structure (Fig. 12).

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