

Late Oligocene micromammal teeth (MP28/29) from the Lower Freshwater Molasse (USM) of Chrummorge (Lägern, N-Switzerland)

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Abstract The small sandpit “Chrummorge” on the Lägern hill (N-Switzerland) was searched for small mammal fossils. Bone fragments and about 100 teeth were retrieved while screen-washing of about 300 kg of Late Oligocene river channel-sands. Sedimentology indicates a probably meandering stream type, which likely followed a more erosional environment with tropical karsts and the formation of bolus-clay and iron ore. Even though, most of the micromammal teeth were rolled due to river transport before sedimentation, it was still possible to identify teeth of biostratigraphical importance, dating this new mammal assemblage to MP28/29 (about 24.6 ± 0.2 Ma). These Late Oligocene river channel sands are the oldest molasse sediments in the Lägern area, and they are in direct contact with Late Jurassic limestone. Thus they add important information for the reconstruction of the regional geological history.

Keywords Micromammal teeth · Rodentia · Lower freshwater Molasse · Oligocene · Taxinomy · Biostratigraphy

Zusammenfassung Die kleine Sandgrube „Chrummorge“ an der Lägern im östlichsten Faltenjura wurde auf Kleinsäugerreste beprobt. Die meisten Zähne und Knochenstücke konnten durch das Sieben von rund 300 kg

Sediment gewonnen werden. Etwa 100 mehr oder weniger gut bestimmbare Zähne wurden ausgelesen. Die meisten Knochen und viele Zahnteile waren durch Flusstransport stark gerollt. Die Datierung in MP 28/29 (rund 24.6 ± 0.2 Ma) dieser Kleinsäuger-Vergesellschaftung ist speziell interessant, weil diese Rinnensande direkt über Oberjurakalken folgen und daher die ältesten Molassesedimente der Region darstellen und somit zu neuen Details der regionalen geologischen Geschichte beitragen. Die sedimentologischen Gegebenheiten deuten auf Ablagerung in einem mäandrierenden Strom hin, welcher auf ein mehr erosives Regime mit tropischer Verkarstung und Bildungen von Boluslehm und Bohnerz folgte.

Abbreviation

PIMUZ Paleontological Institute and Museum of the University of Zurich, Switzerland

1 Introduction

In 2006, the author explored the ancient sand pit Chrummorge previous to an excursion planned for the adult evening classes (*Volkshochschule*) of Zurich. After finding some tiny rolled bone fragments, a sample of about 20 kg of sediment was taken for screenwashing. Out of these, a few teeth and fragments were extracted. Two more major sampling trips followed later, recovering another 300–400 kg of sediment, that have yielded a total of about 100 micromammal teeth. These teeth are sufficiently diverse and well preserved for a closer identification, providing an opportunity for an adequate biostratigraphical calibration of the Chrummorge outcrop, which may later be

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important for palaeogeographical reconstructions. The small sand pit of the locality Chrummorge only served as a very local source of sand, either like the mica-rich sands of the Upper Freshwater Molasse as additive for the production of tiles, or as moulding sand for the use in a foundry, probably some 100–200 years ago (Kündig et al. 1997).

2 Geographical and geological setting

The locality “Chrummorge” is located on the parrish area of Wettingen AG (LK 1:25'000, Nr. 1070, national grid 668'650/258'720, 595 m above sea level), about 20 km NW of Zurich, N-Switzerland (Fig. 1). It is situated in the easternmost Folded Jura mountains on the southern slope of the western Lägern anticline system. The top of this anticline is formed by Late Jurassic limestones, locally covered with bolus clay (a red iron rich sediment of Eocene or younger age that is considered as a corrosional residue) and overlain by Oligocene molasse sediments (mostly alluvial sands and marls). In the sand pit Chrummorge, fine to middle grained quartz- and mica-rich unconsolidated sands and sandstones crop out. Hard sandstone-nodules and patches (so called “Knauers”) of a length of up to 2 m (Fig. 2) were possibly formed due to carbonate-rich waters circulating in sands with variable porosity during early diagenesis. The sands were most probably formed by the erosion of granitic material either derived from the western Alps or from the north (Black Forest), but no analysis considering the origin of the sediment particles has been done here. Berger et al. (2005a) show an axial fluvial system, the so called “Genfersee-Schüttung” draining the Molasse basin from west to east during the Late Oligocene, which was drawn after Schlanke et al. (1978), indicating that the sand could have been derived mostly from the western Alps. Reworked tiny Jurassic Limestone pieces

and fragments of silicified Jurassic fossils of up to over 1 cm in size were frequently found within the outcropping sands and sandstones. They indicate erosion of a nearby Late Jurassic outcrop at the time of deposition. Cross-bedding in the sands is widespread and suggests a meandering to braided stream environment. Ferruginous pisoliths reworked from Eocene to Early Oligocene bolus clays were also occasionally found. In consequence, Eocene–Oligocene bolus clays and Late Jurassic limestones must have been locally eroded or reworked. Only a few 100 m east of the sand pit, Late Jurassic limestone and Eocene–Oligocene bolus clays are cropping out today. Immediately west of, the sand pit, beds with Late Jurassic limestone are locally cropping out. A piece of an alpine Permian “Verrucano” found in the same bed is from glacial activity of the ice age. Therefore this Jurassic limestone debris bed is either talus material or debris from a local moraine of one of the last glaciations.

3 Preparation and storage

Some of the sediment was pre-screened under dry condition on place. All the same, the screenwashing effort was important as a considerable portion of the sandy sediment was still present after 1–2 washing cycles. In consequence, a treatment with buffered formic acid followed, in order to further reduce the amount of sediment. The 0.8 mm fraction had the highest fossil contents with respect to the remaining sediment, but the picking of the micromammal fossils was still a time-consuming effort. The work in searching the fossil remnants with the binocular microscope remained all the same a long lasting effort. The fractions smaller than 0.5 mm were too poor in fossil remains and were therefore not picked.

In the residue, micromammal teeth were rare, and they were carefully extracted with tweezers and treated from the root-side with water-diluted white glue. Some of the recovered tooth fragments were even identified as belonging together and were glued under the binocular. Secured teeth were mounted in small polystyrol boxes with some sort of soft sealant allowing easy occasional removal for research purposes.

Measurements were done with an ocular containing a measurement line and a calibration scale, but also electronically with a digital microscope, both leading to the same results.

The figured specimens are all deposited in the Paleontological Institute and Museum of Zurich University under the numbers PIMUZ A/V 4810 to PIMUZ A/V 4835. The not figured material is so far kept in the private collection of the author. It is available for study on request and will be deposited in a publicly available collection at a later time.

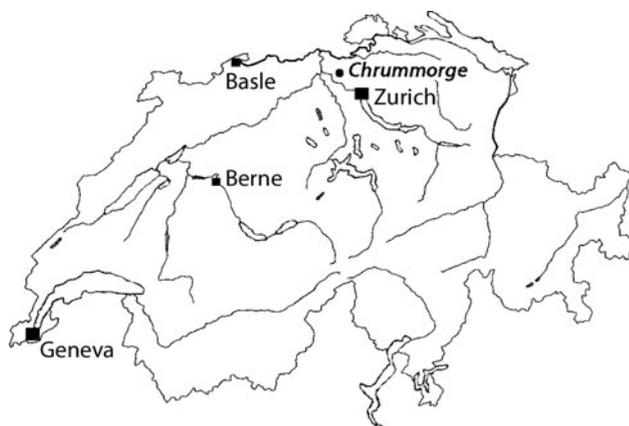


Fig. 1 Localisation of the ancient sand pit “Chrummorge”

Fig. 2 The outcrop “Chrummorge” with sandstone nodules (Knauer) and sampling bags



4 Systematic palaeontology

4.1 Reworked Late Jurassic invertebrate fossils

Silicified invertebrates were reworked from the Late Jurassic limestones. Most abundant are remains of echinoids, especially cidarids (spines and fragments of the “body”). Other silicified fossils recovered include brachiopods, serpulids and especially bryozoans.

4.2 Molasse invertebrate fossils

These include some poorly preserved aragonitic shell-fragments of unidentified molluscs and some calcite body-shells of slugs, and at least one fragment of a calcite operculum from another landsnail (Pomatiasidae). Further, a few coal remains and four charophyte oogonias were also found. These charophytes are heavily corroded due to the acid treatment of the sediment and could therefore not be identified any closer. All these fossils are interpreted as being of molasse origin and thus more or less synchronous with the recovered micromammal teeth.

4.3 Molasse lower vertebrates (fishes, reptiles, birds)

More than 50 pharyngeal teeth of fishes were found. Most, if not all can be assigned to *Tarsichthys* sp. After Gaudant et al. (2002) this taxon is typical for cyprinid pharyngeal teeth assemblages in the lower freshwater Molasse from MP27 on.

Reptiles are represented by three fragmented teeth of smaller crocodylians, more than twenty pieces of ophisaurid osteoderms, two jaw-fragments of iguanid lizards and one fragment of a snake vertebra. Two reptilian jaw fragments

cold as yet not be closer identified. Birds are represented with a few very tiny fragments of egg shells.

4.4 Molasse micromammal teeth

4.4.1 *Artiodactyla, Cainotheriidae* indet

Material. One mandible, four incisors, six premolars and several tooth fragments

Measurements. Mand. dext. (m1–m3): m1, 4.1 mm × 3.4 mm. m2, 4.8 mm × 3.6 mm. m3, 6.8 mm × 3.4 mm. P4 sup. dext., 3.50 mm × 4.75 mm (PIMUZ A/V 4810, Fig. 3a).

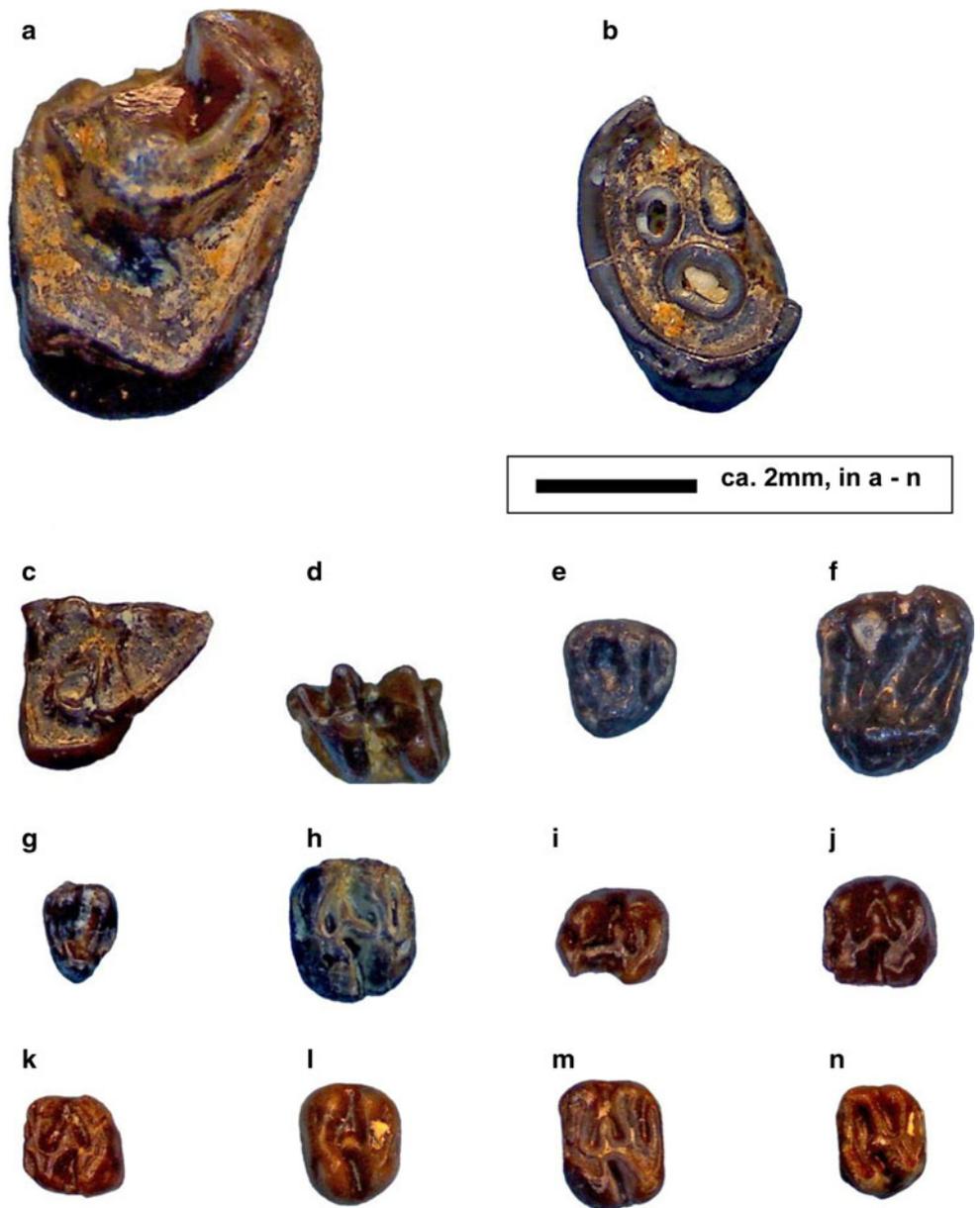
Discussion. This is largest mammal found so far at Chrummorge. Within European Late Oligocene faunal assemblages, three genera of Cainotheriidae are recorded: *Cainotherium*, *Caenomeryx* and *Plesiomeryx* (Erfurt & Métais 2007). These animals all were roughly of the size of an actual rabbit and were abundant all over Europe. At Gaimersheim in Germany occurs *Caenomeryx filholi* and the slightly smaller *Plesiomeryx huerzeleri*. But *Caenomeryx procommunist*, *Plesiomeryx cadurcensis* and *Cainotherium commune* will have to be considered as well. For the time being the cainotheriid remains can not be identified at genus or species level.

4.4.2 *Marsupialia, Didelphida: Amphiperatherium exile* (Gervais 1848)

Material. One tooth

Measurements. M1 sup., 2.20 mm × 1.90 mm (PIMUZ A/V 4811, Fig. 3c).

Fig. 3 Cainotheriid, Rhizospalacid, Marsupial, Insectivor, Sciurid, Glirid and Eomyid teeth from “Chrummorge”, Wettingen AG (all teeth figured as left teeth). **a** Cainotheriidae indet., P4 sup. dext. (inverse), PIMUZ A/V 4810. **b** *Rhizospalax poirrieri*, P4 sup. sin. Fragm., PIMUZ A/V 4816. **c** *Amphiperatherium exile*, M1 sup. dext. (inverse), PIMUZ A/V 4811. **d** *Paratalpa* cf. *micheli*, m1 inf. dext. (inverse), PIMUZ A/V 4812. **e** *Heteroxerus* cf. *lavocati*, P4 sup. sin., PIMUZ A/V 4814. **f** *Heteroxerus* cf. *lavocati*, M1/2 sup. sin., PIMUZ A/V 4813. **g** *Gliravus* sp., P4 sup. dext. fragm. (inverse), PIMUZ A/V 4815. **h** *Eomys* cf. *major*, P4/M1 sup. sin., PIMUZ A/V 4817. **i** *Eomys* cf. *ebnatensis* P4 inf. sin., PIMUZ A/V 4818. **j** *Eomys* cf. *ebnatensis* m2 inf. sin., PIMUZ A/V 4819. **k** *Eomys* cf. *ebnatensis* m2 inf. sin., PIMUZ A/V 4820. **l** *Eomys* cf. *ebnatensis* P4 sup. sin., PIMUZ A/V 4821. **m** *Eomys* cf. *ebnatensis*, M1 sup. sin., PIMUZ A/V 4822. **n** *Eomys* cf. *ebnatensis*, M2 sup. sin., PIMUZ A/V 4823



Discussion. One strongly worn upper molar with the typical marsupial shape was found. It is significantly smaller than upper molars of *Peratherium antiquum*, the other known marsupial-lineage from the Late Oligocene of Europe. Comparisons with von Koenigswald (1970, figs. 25 and 47) show a best correlation with the teeth of *A. exile* from Gaimersheim considering their general shape and size. According to Ziegler (1990a), this species from Gaimersheim, which was named *Amphiperatherium frequens* ssp. *gaimersheimensis* by von Koenigswald (1970), is synonym with *A. exile*, and this is also followed here.

4.4.3 *Eulipotyphla, Talpidae: Paratalpa* cf. *micheli* (Lavocat 1951)

Material. One complete and one half tooth.

Measurements. M1/2 inf. dext., 1.85 mm × 1.30 mm × 1.75 mm, (PIMUZ A/V 4812, Fig. 3d).

Discussion. The shape and the typical anterior and posterior cingulae of this tooth are typical for a talpid insectivore. According to Ziegler (1990b) the genera *Desmanella* and *Myxomygale* can be excluded, as lower molars of those are significantly smaller than the tooth

present here. The tooth fits best with *Paratalpa* cf. *micheli* and is in size very close to those of similar molars from the Herrlingen-region in Germany, but it is also within the size-range of teeth from Coderet in France (Ziegler 1998). *Geotrypus jungi* has slightly larger teeth (Ziegler 1990b).

Thus, the tooth from Chrummorgen is referred here to *Paratalpa* cf. *micheli* to which it fits well in size and shape. According to Ziegler (1991) both in Herrlingen and in Coderet *Paratalpa* cf. *micheli* and *Geotrypus* cf. *jungi* are present, thus these two species seem to be widespread in the Late Oligocene of Europe.

4.4.4 Rodentia, Sciuridae: *Heteroxerus* cf. *lavocati* (Hugueney 1969)

Material. Two teeth, two fragmented teeth.

Measurements. P4 sup. sin., 1.40 mm × 1.35 mm (PIMUZ A/V 4814, Fig. 3e).

M1/2 sup. sin., 1.80 mm × 2.05 mm (PIMUZ A/V 4813, Fig. 3f).

M3 sup. sin. fragm., ? mm × 1.75 mm.

m1/2 inf. sin. fragm., 1.55 mm × 1.50 mm.

Discussion. These teeth of squirrels may be best compared with *Heteroxerus*. Particularly the upper molar (M1/2) shows an enamel morphology of the occlusal surface that is different from *Palaeosciurus*, especially in the character and position of protoconus and hypoconus (Kristkoiz 1992, fig. 13). The M1/2 sup. dext. of the Sciurinae sp. 1 from Ehrenstein in Germany, supposedly belonging to a *Palaeosciurus*, however, is also close in shape and size (Werner 1994), but is lacking the typical isolated mesostyle of *Heteroxerus lavocati*. The M1/2 sup. from Chrummorge shows quite primitive features, similar as in the upper molars of *H. costatus* from Vivel del Rio in Teruel, Spain (Hugueney et al. 1987, pl. 1 fig. 35). In both species the metacone-arm is partially connected with the hypocone which in younger and higher developed species of *Heteroxerus* is no longer the case. Both in *Heteroxerus costatus* and in *H. lavocati* the upper molars have an isolated mesostyle. The teeth of *H. costatus* pictured by Kristkoiz (1992, p. 27) are congruent in this feature. The upper M1/2 from Chrummorgen is somewhat bigger than are those from Gaimersheim and Vivel del Rio. The other teeth from Chrummorge are within the uppermost size range of *H. costatus* from Gaimersheim and fit better within the size of *H. lavocati* from Coderet (Hugueney 1969; Werner 1994). Therefore the two teeth from Chrummorge are referred to *Heteroxerus* cf. *lavocati*, still showing some slight resemblance to *H. costatus*. More and better preserved material is required for a closer identification.

4.4.5 Rodentia, Gliridae: *Gliravus* sp.

Material. Two partially damaged teeth.

Measurements. P4 sup. dext. fragm., 0.88 mm × 1.05 mm (PIMUZ A/V 4815, Fig. 3g)

m1 inf. sin., 1.25 mm × 1.15 mm, enamel mostly badly eroded.

Discussion. The fairly reduced, slightly damaged upper premolar shows no anteroloph, but two lingually fused middle crests (protoloph and metaloph) and a somewhat damaged posteroloph. Freudenthal (2004) diagnosis *Gliravus* (*G. majori*, type-species) as follows: “The shape of P4 is a rectangle, with a very reduced, or absent anteroloph. Lingual and labial lengths are very similar, and the exit of the sinus lies in the middle of the tooth”. An almost symmetrical arrangement of protoloph and metaloph is typical for *Gliravus* (emended diagnosis for *Gliravus* in Berger 2008). Vianey-Liaud (1989) figured two upper P4 of *Gliravus majori* from Quercy, France, but they are slightly smaller. Hugueney (1969) stated in the original diagnosis of *G. bruijni* from Coderet that the upper P4 is quite molariform, which is not the case in the tooth from Chrummorge. Vollmayr (1966) describes *Gliravus* from the folded lower freshwater Molasse of Southern Germany and refers two upper premolars (p. 82) to *Gliravus* nov. spec. aff. *majori*. In size and morphology these two upper premolars seem to be very similar to the P4 sup. from Chrummorge. The upper P4 from Chrummorge also fits well in the range of *G. bruijni* (Hugueney 1969), but this author stated that there is little difference in size to *G. majori*. Unfortunately, the lower m1 from Chrummorge is lacking enamel and its structural details cannot be studied. Thus, the two teeth are yet left without an identification at species level, but they show affinities to *G. majori* and *G. bruijni*.

4.4.6 Rodentia, Rhizospalacidae: *Rhizospalax poirrieri* (Miller & Gidley 1919)

Material. Two tooth fragments.

Measurements. P4 sup. sin. fragm., ? mm × 3.20 mm (PIMUZ A/V 4816, Fig. 3b).

fragm. dent. indet. with an “enamel-island”.

Discussion. These two fragments proof the presence of hypsodont teeth with isolated, closed enamel-islands and in general with thick enamel. At a first glance these fragmented teeth resemble somewhat of teeth from a small beaver (*Steneofiber*). However, the completely closed enamel-islands of *Rhizospalax* are typical of this genus, although Hugueney (1969) notes many similarities between *Rhizospalax* and *Steneofiber*. Miller and Gidley (1919, fig. 2) figured a P4 sup.

sin. in a palate from Peu Blanc (Sorbier, Allier, France) and Hugueney (1969, pl. 5) one in a skull fragment from Coderet, France, and both are very similar to the fragment of the slightly damaged P4 from Chrummorge. The size range given by Hugueney (1969) fits also well. As there is no other species described so far, the material from Chrummorge can be referred to *R. poirrieri*.

4.4.7 Rodentia, Eomyidae: *Eomys cf. major* (Freudenberg 1941)

Material. One tooth, two tooth-fragments.

Measurements. 1P4/M1 sup. sin., 1.40 × 1.60 mm (PIMUZ A/V 4817, Fig. 3h)

1 Fragm. M2 sup. dext., 1.30 mm × ? mm.

1 Fragm. M1/M2 sup. sin., ? mm × 1.40 mm.

Discussion. The mesoloph of the two upper molars is of medium length, like in the type maxilla from Gaimersheim (Engesser 1990, p. 34, fig. 16e). The height of the crown of the three teeth from Chrummorge is moderate. *Eomys huerzeleri*, which is very similar in size, may also be considered, but its crown is supposedly higher (Engesser 1982, 1990). The size of the teeth from Chrummorge fits well within the upper range of *Eomys major*, to which species these teeth from Chrummorge are tentatively referred to.

4.4.8 Rodentia, Eomyidae: *Eomys ebnatensis* (Engesser 1987)

Material. 31 teeth.

Measurements. d inf. sin., 1.12 mm × 0.78 mm.

p4 inf. sin., 1.38 mm × 1.05 mm (PIMUZ A/V 4818, Fig. 3i), 1.05 mm × 0.98 mm.

p4 inf. dext., 1.08 mm × 1.03 mm.

m1 inf. sin., 1.38 mm × 1.18 mm.

m2 inf. sin. 1.30 mm × 1.23 mm (PIMUZ A/V 4819, Fig. 3j), 1.13 mm × 1.10 mm, 1.13 mm × 1.15 mm (PIMUZ A/V 4820, Fig. 3k).

m2 inf. dext., 1.05 mm × 1.03 mm.

m3 inf. sin., 1.23 mm × 1.00 mm, 1.00 mm × 0.95 mm, 1.20 mm × 0.95 mm, 1.00 mm × 0.93 mm,

1.15 mm × 0.95 mm, 1.13 mm × 0.95 mm.

m3 inf. dext., 1.13 mm × 1.05 mm, 1.13 mm × 1.00 mm.

P4 sup. sin., 1.15 mm × 1.33 mm (PIMUZ A/V 4821, Fig. 3l), 1.05 mm × 1.08 mm, 1.25 mm × 1.28 mm, 1.03 mm × 1.00 mm.

M1 sup. sin., 1.20 mm × 1.40 mm (PIMUZ A/V 4822, Fig. 3m), 1.13 mm × 1.30 mm.

M1 sup. dext., 1.13 mm × 1.15 mm, 1.20 mm × 1.28 mm.

M2 sup. sin., 1.05 mm × 1.25 mm (PIMUZ A/V 4823, Fig. 3n).

M2 sup. dext., 1.03 mm × 1.25 mm.

M3 sup. sin., 0.83 mm × 1.00 mm.

M3 sup. dext., 0.83 mm × 0.98 mm, 0.93 mm × 1.15 mm, 0.75 mm × 0.93 mm.

Discussion. The teeth of this second and smaller eomyid from Chrummorge are not easy to determine as they show quite a wide variety in enamel patterns. The P4 sup. mostly has a short mesoloph (three out of four). The M1 sup. mostly has a half-long mesoloph (three out of four). The mesoloph of M2 is long and is labially fused with the paraconus in both teeth. In one upper M2 (PIMUZ A7V 4823) the longitudinal crest is interrupted, like in *Rhodanomys hugueneyae* from Küttigen (Engesser 1987). The M3 sup. are quite reduced. Regarding these features, the present teeth resemble *E. ebnatensis* from Fornant 6 (Engesser 1990). All lower molars mostly have half-long mesolophids and clearly show an anterolophid that is centrally fused with the metalophid; only one m1 inf. shows a long mesolophid. Three out of four m2 inf. are lacking a 4th syncline. In size, the teeth are within the ranges of *E. ebnatensis* and *R. hugueneyae*. The smaller eomyid from Chrummorge fits fairly well into size and morphology of *Eomys ebnatensis*, although some teeth, especially two p4 inf. and three m2 inf. could also likely be identified as *R. hugueneyae*, whereas a few other teeth resemble *Eomys molassicus*. This either shows the presence of more than one species or an evolutionary stage with a wide individual morphological variation. An evolution from *Eomys* to *Rhodanomys* and further to *Ritteneria* seems plausible in any case (Engesser 1990). Difficulties with the determination of isolated teeth, for instance with *Eomys zitteli*, were also reported by Fahlbusch (1970). Most of the material from Chrummorge fits rather well into the range of *E. ebnatensis*, especially when compared with the description from Fornant 6 (still identified as *E. zitteli* in Engesser & Hugueney 1982), and the one from Ebnat-Kappel (Frei 1979; Engesser 1990). Therefore, the Chrummorge-teeth are referred to *E. ebnatensis*.

4.4.9 Rodentia, Dipodidae: *Plesiosminthus cf. promyarion* (Schaub 1930)

Material. Two teeth.

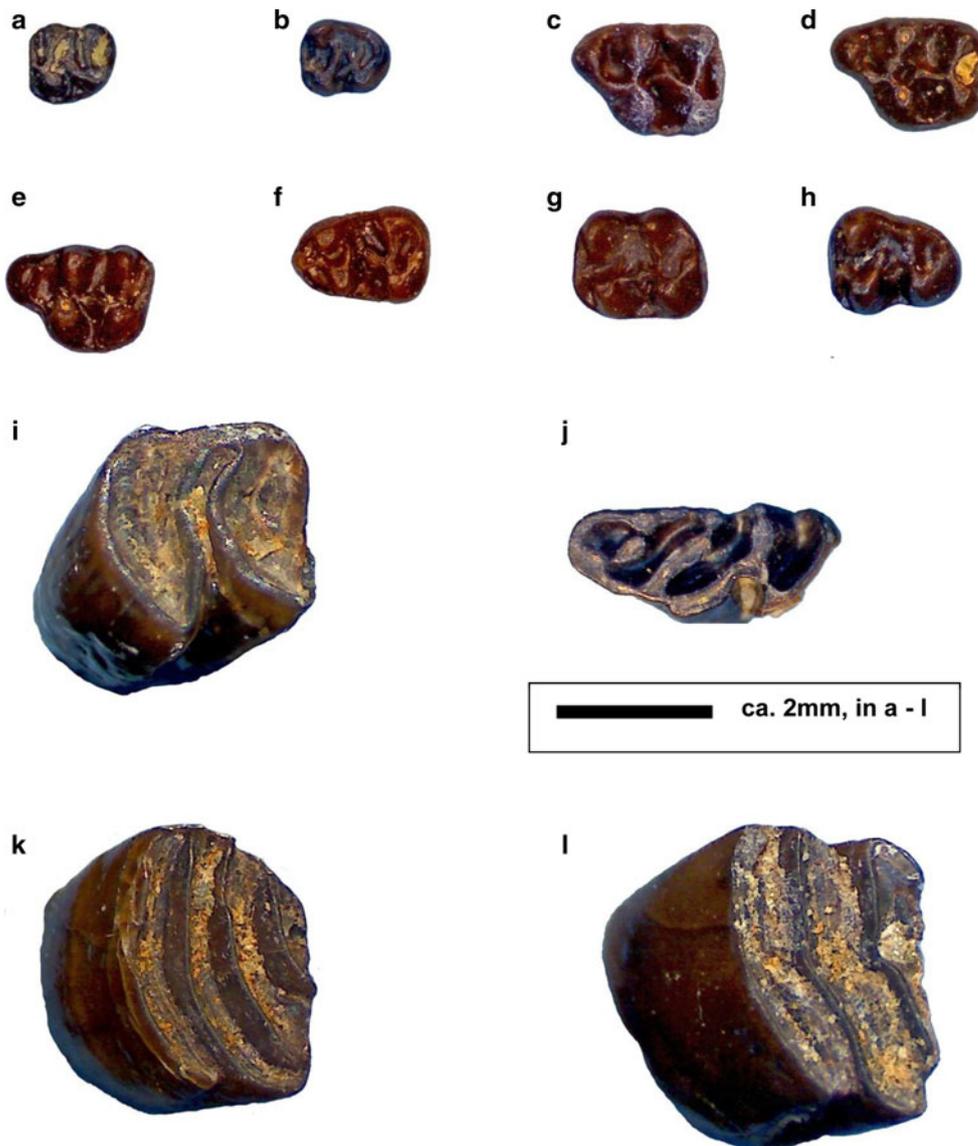
Measurements. M2 sup. sin. 1.00 mm × 0.88 mm (PIMUZ A/V 4824, Fig. 4a).

M3 inf. sin., 1.10 mm × 0.88 mm (PIMUZ A/V 4825, Fig. 4b).

Discussion. The upper M2 has an interrupted longitudinal crest or entoloph but otherwise shows no further

Fig. 4 Dipodid, Cricetid and Theridomorpha teeth from “Chrummorge”, Wettingen AG (all teeth figured as left teeth)

a *Plesiosminthus* cf. *promyarion*, M2 sup. sin., PIMUZ A/V 4824.
b *Plesiosminthus* cf. *promyarion*, M3 inf. sin., PIMUZ A/V 4825.
c *Adelomyarion vireti*, M1 sup. sin., PIMUZ A/V 4826.
d *Adelomyarion vireti*, M1 sup. sin., PIMUZ A/V 4827.
e *Eucricetodon* cf. *dubius*, M1 sup. dext. (inverse), PIMUZ A/V 4828. **f** *Eucricetodon* cf. *dubius*, M1 inf. sin., PIMUZ A/V 4829. **g** *Eucricetodon* cf. *dubius*, m2 inf. sin., PIMUZ A/V 4830. **h** *Eucricetodon* cf. *dubius*, m3 inf. sin., PIMUZ A/V 4831. **i** *Issiodoromys* sp., m1/2 inf. sin. (sw 5), PIMUZ A/V 4832. **j** *Issiodoromys* sp., d4 inf. dext. (inverse), PIMUZ A/V 4833. **k** *Archaeomys* sp., M2 sup. dext. (inverse), PIMUZ A/V 4834. **l** *Archaeomys* sp., M1/2 inf. dext. (inverse), PIMUZ A/V 4835



reductions. There is a cingulum around the protoconus and a small crest entering the labial syncline. The upper M2 from Chrummorge falls within the lower part of the size range of the equivalent teeth from Ruisseau du Bey (*P. promyarion*), Gaimersheim (*P. promyarion*), Pech du Fraysse (*P. promyarion*) and Fornant 11 (*P. myarion*), whereas the M2 from Coderet (*P. schaubi*) are larger in size (Hugueney 1969; Kristkoiz 1992; Ziegler & Werner 1994). The second upper molar from *Plesiosminthus promyarion* from the Spanish locality Hinojosa de Jarque (Cuenca & Canudo 1994) also fits very well regarding size and morphology. The upper M2 from Chrummorge fits well into *P. promyarion*.

Somewhat doubtful is a lower m3 from Chrummorge. The ectolophid of this tooth is slightly interrupted towards the protoconid. The posterior arm of the protoconid has a connection with the metaconid. The

entoconid is low and not prominent. Otherwise the m3 shows no reduction.

This lower m3 from Chrummorge is unusually long for *Plesiosminthus* and even exceeds the length of the teeth from Coderet, but remains smaller than the much younger *P. winstoerferi* (Engesser 1987). This m3 from Chrummorge remains questionable and may even belong to a very small cricetid like *Heterocricetodon* or *Pseudocricetodon*, but this can as yet not be further corroborated.

4.4.10 Rodentia, Cricetidae: *Adelomyarion vireti* (Hugueney 1969)

Material. 11 teeth, of which two damaged.

Measurements. M1 sup. sin., 1.75 mm × 1.25 mm (PIMUZ A/V 4826, Fig. 4c), 1.78 mm × 1.25 mm (PIMUZ A/V 4827, Fig. 4d), ? mm × 1.08 mm.

M1 sup. dext., 1.73 mm × 1.20 mm, 1.88 mm × 1.33 mm, 1.90 mm × 1.28 mm, 1.75 mm × 1.33 mm.
 M2 sup. sin., 1.53 mm × 1.38 mm.
 M3 sup. dext., 1.25 mm × 1.15 mm.
 m1 inf. dext. fragm., ? mm × 0.98 mm.
 m2 inf. sin., 1.53 mm × 1.18 mm.

Discussion. The first upper molars have a characteristic anteroconus that is smoothly pointed. The protoconus is often slightly lingually prominent as is the paraconus labially.

The morphological reductions are stronger than in *Adelomyarion* sp. from Vivel del Rio (Hugueney et al. 1987). Regarding size, the tooth from Vivel del Rio fits into the population of *A. vireti* from Coderet (Hugueney 1969). All teeth of *Adelomyarion* from Chrummorge especially M1 sup. und M2 sup. Resemble those from Coderet (Hugueney 1969), both morphologically and regarding their size. *Adelomyarion* from Wintersberg/Trempel in Frei (1979) is slightly smaller and shows more reductions. All the same, this author referred the M1 sup. (fig. 6, pl. V, p. 217) to *A. vireti*. *A. vireti* from Hinojosa de Jarque (Cuenca & Canudo 1994) is similar to the type material from Coderet. The *Adelomyarion* from Ebnat-Kappel discussed in Frei (1979) seems peculiar and it is even doubtful that it belongs to that genus. *Adelomyarion alberti* from Spin (Daams 1989) is not considered here. However, the material from Chrummorge can be referred to *A. vireti*, without any doubts.

4.4.11 Rodentia, Cricetidae: *Eucricetodon* aff. *dubius* (Schaub 1925)

Material. 12 teeth.

Measurements. M1 sup. sin. fragm., ? mm × 1.33 mm.
 M1 sup. dext., 1.88 mm × 1.25 mm (PIMUZ A/V 4828, Fig. 4e), 1.78 mm × 1.18 mm.
 M2 sup. dext., 1.45 mm × 1.33 mm.
 M3 sup. dext., 0.83 mm × 0.98 mm.
 M1 inf. sin., 1.65 mm × 1.10 mm (PIMUZ A/V 4829, Fig. 4f).
 m2 inf. sin., 1.50 mm × 1.13 mm, 1.55 mm × 1.20 mm (PIMUZ A/V 4830, Fig. 4g).
 m2 inf. Dext., 1.53 mm × 1.25 mm.
 m3 inf. sin., 1.53 mm × 1.23 mm (PIMUZ A/V 4831, Fig. 4h), 1.45 mm × 1.23 mm.
 m3 inf. dext., 1.35 mm × 1.15 mm.

Discussion. All lower m2 show a short posterior arm of the protoconid and a mesolophid. The presence of a labial ectomesolophid and a free hypoconid posterior arm is indicated. The upper M1 are quite simple with mostly short to medium-sized mesolophids. *Eucricetodon collatus* from Coderet (Hugueney 1969) is larger than the species from Chrummorge which fit in the lower size-range of

Eucricetodon dubius from Gaimersheim and other German localities (Dienemann 1987). *Pseudocricetodon moguntiacus* from Burgmagerbein, Germany (Dienemann 1987), is only slightly smaller than the Chrummorge teeth, but its enamel structure is more delicate and complex. *Pseudocricetodon thaleri* from Ehrenstein 4 is much smaller (Dienemann 1987). *Eucricetodon longidens* (even the ones from Küttigen) and *Eucricetodon haslachensis* in Werner (1994) are larger than the Chrummorge teeth. The lineage *Eucricetodon hochheimensis*—*Eucricetodon haslachensis* has over all much larger teeth (Werner 1994). In Dienemann (1987) this lineage is derived from *E. dubius*. The lineage *E. dubius*—*E. collatus*—*E. longidens* was already suggested by Engesser (1985). *Eucricetodon incertus* from Ehrenstein 7 (Dienemann 1987) fits almost in size with the teeth of Chrummorge. But there are significant morphological differences, especially in m2 inf. *E. incertus* was placed in the genus *Allocricetodon* by Freudenthal (1994). Another species, *Eucricetodon atavus*, is similar in size too, but the M1 sup. differs significantly as the anteroconus has a crest pointing caudally, a feature only observed in this species. This species was placed in the new genus *Atavocricetodon* by Freudenthal (1996). Thus, the *Eucricetodon* teeth from Chrummorge show typical features of three different species, they are within the size-ranges of *Atavocricetodon atavus*, *Allocricetodon incertus* and *E. dubius*. The morphology of lower molars shows some similarities to that from *A. atavus* but the morphology of the upper teeth is congruent to that from *E. dubius*. Because the teeth from Chrummorge are closest to *E. dubius*, they are determined here as *Eucricetodon* aff. *dubius*.

The *Eucricetodon* teeth from Chrummorge seem to be morphologically consistent with exception of a m3 inf. and the only M3 sup. found. The phylogenetic relationship between the many *Eucricetodon* species given by Dienemann (1987) is very questionable and probably much more complex. It is doubtful that it can be resolved based on tooth morphology only.

4.4.12 Rodentia, Cricetidae: *Melissiodon* sp

Material. One molar fragment.

Measurements. m2 inf. dext., preserving entoconid and posterolophid.

Discussion. This fragment can be easily positioned and identified within fig. 54 of *Melissiodon* in Kristkoiz (1992). *Melissiodon* is very characteristic because of its steep and thin enamel walls. In the Late Oligocene of Europe, two species are well known: *Melissiodon chatticus* and *Melissiodon quercyi*. Additionally, three more species (*M. emmerichi*, *M. schalki* and *M. schroederi*) are mentioned to be present in Late Oligocene European faunas (Mödden

1999; Kristkoiz 1992). It is not possible to determine the tooth fragment to species level.

4.4.13 Rodentia, Theridomorpha: *Issiodoromys* sp

Material. Two teeth, four tooth fragments.

Measurements. M2 sup. dext., 2.30 mm × 1.62 mm (stage of wear level 5) and labially eroded.

m1/2 inf. sin., 2.50 mm × 2.38 mm stage of wear level 5) (PIMUZ A/V 4832, Fig. 4i).

d inf. dext., 2.95 mm × 1.25 mm (PIMUZ A/V 4833, Fig. 4j).

Discussion. Both teeth show a stage of wear level 5 after Mayo (1987). The enamel pattern and the very high crown are typical for *Issiodoromys*. Mayo (1987) described two new species from the Swiss molasse, *Issiodoromys oppligeri* from Fornant 6 and *Issiodoromys rickenbachensis* from Rickenbach, which both fit in shape and size with the material from Chrummorge. Mödden (1994) referred the material from Rickenbach to *Issiodoromys pseudanoema* and the material from Fornant 6 to *Issiodoromys limognensis*, which was followed by Engesser and Mödden (1997). The doubtful *Issiodoromys terminus* is considered as synonymous to *I. pseudanoema* by Thaler (1966). A lower milkmolar from Chrummorge is very similar to the two lower milkmolars of *Issiodoromys minor* from the Late Oligocene Pareja locality in Spain, figured in Daams et al. (1989). A third synclinid is missing and the lingual succession of the sinuid is interrupted. The first synclinid is lingually closed. All these features are exhibited by the Chrummorge milkmolar tooth, which is, however, significantly larger in size. Although the Chrummorge teeth are closest to *I. pseudanoema*, they are identified as *Issiodoromys* sp. for the time being.

4.4.14 Rodentia, Archaeomyidae: *Archaeomys* sp

Material. 2 teeth, several tooth fragments.

Measurements. M2 sup. dext., 2.2 mm × 3.0 mm (PIMUZ A/V 4834, Fig. 4k).

m1/2 inf. sin., 2.2 mm × 3.0 mm (PIMUZ A/V 4835, Fig. 4l).

Discussion. After Mayo (1983) and Mödden (1993) the dental positions can be identified. The morphological nomenclature of Mödden (1993) is followed, even though it is considered somewhat problematic. *Archaeomys quercyi* always shows an isolated synclinal II on the upper molars, which is an important feature in considering an early evolutionary stage of *Archaeomys*. However, this is not the case in the M2 sup. from Chrummorge. Thus, morphologically and in size the upper molar falls within the ranges of

the younger and higher developed *Archaeomys*-species *A. limognensis*, *A. helveticus*, *Archaeomys arvernensis* and *Archaeomys laurillardi*. These are all closely related to each other and some are probably even synonymous. *A. laurillardi* is distinguished from *A. arvernensis* only in shape and size of the upper premolar (P4) according to Mödden (1993). Thaler (1966) considered *A. arvernensis* as a synonym of *A. laurillardi*, due to their very close resemblance. The M2 sup. from Chrummorge perfectly fits the teeth from Rickenbach and Coderet figured in Mödden (1993, fig. 38 and 30). *Archaeomys kaelini* was described by Mayo (1987) from Fornant 6. It is considered as synonymous with *A. helveticus* in Mödden (1993) and in Engesser and Mödden (1997). The upper molars of *A. helveticus* from the Molasse of western Switzerland (Engesser et al. 1984) seem to be similar, but eventually a bit wider than the one from Chrummorge. The material from Chrummorge is related to the *Archaeomys limognensis-helveticus-arvernensis-laurillardi*-complex. A possible relationship within Archaeomyini is outlined in Mödden and Vianey-Liaud (1997). A closer examination and more material will eventually permit a better identification.

5 Discussion

The recovered mammal teeth are all from small mammals, the tallest of which were small hare-sized ruminants. A sorting due to river transport seems evident, because no larger, pebbles or larger bones were found. Totally about fourteen mammal species were distinguished, but only nine are referred to species level. The compiled faunal list of mammals from the Chrummorge locality is:

Cainotheriidae indet.

Amphiperatherium exile (Gervais 1848)

Paratalpa cf. *micheli* Lavocat 1951

Heteroxerus cf. *lavocati* (Hugueney 1969)

Gliravus sp.

Rhizospalax poirrieri (Miller & Gidley 1919)

Eomys cf. *major* (Freudentberg 1941)

Eomys cf. *ebnatensis* (Engesser 1987)

Plesiosminthus cf. *promyarion* (Schaub 1930)

Adelomyarion vireti (Hugueney 1969)

Eucricetodon aff. *dubius* (Schaub 1925)

Melissiodon sp.

Issiodoromys sp.

Archaeomys sp.

5.1 Comparison with other related Swiss mammal faunas

As a lot of research was already carried out on Late Oligocene mammal faunas from Switzerland, it is possible to

Locality	MP (MN)	Cainotheriidae	Amphiperatherium exile	Heteroxerus	Glirivus	Eomys major	Eomys ebnatensis	Eomys huerzeleri	Rhodanomys hugueneyae	Rhodanomys transiens	Rhodanomys schlosseri	Eomyodon volkeri	Eucrietodon dubius	Eucrietodon praecursor	Eucrietodon hochheimensis	Eucrietodon collatus	Eucrietodon longidens	Eucrietodon sp.	Pseudocricetodon thaleri	Allocricetodon incertus	Adelomyarion sp.	Adelomyarion vireti	Melissiodon	Plesiosminthus promyaron	Plesiosminthus winistoerferi	Plesiosminthus myaron	Issiodoromys quercyi	Issiodoromys limognensis	Issiodoromys pseudanoema	Archaeomys arvernensis	Archaeomys helveticus	Archaeomys laurillardi	Rhizospalax poirrieri	Steneoiber dehmi	Amphiliagus antiquus	Piezodus tomerdingensis		
Fornant 11	MN1	X	X								X						X								X										?	X		
Boudry 2	MN1	X								X						X																						X
Brochene Fluh 53	30		?		X			aff				X				X		X				X	X		X										sp	?	X	
Küttigen	30		X	X	x				X							X						X		?	?								X	X	X	X	X	
Brochene Fluh 19/20	29	X	X	x	x			X	X			X			cf	X			cf			X	X					X			aff	sp	?					
Rickenbach	29	X	X	x	x			cf	X						cf	X						X	X	X	X			X	X	X			X	X	X	X		
CHRUMMORGE	28/29	x	x	x	x	cf	cf								aff							x	x	cf			?	?	?	?			x					
Fornant 6	28	X				X	X					X	X					cf				cf	X	X			X				X					X		
Fornant 7	28				X	X							X					cf	X				X	X			X											
Boningen 1	27		cf			X						X							X	X		X	X			X												
Wynau 1	27	X			X	aff	X											cf	X	X		X	X			X												

legend: directly compared faunas first appearance distribution (expected if without x) last occurrence

Fig. 5 Important faunal elements, their occurrence in the faunula “Chrummorge”. and in related Swiss molasse reference faunas. Compiled after Engesser and Mödden (1997). ? Indicates an uncertain proof of the occurrence due to incomplete preservation of teeth

compare the Chrummorge fauna to some of these faunas. Ebnat-Kappel (Frei 1979), Boudry-La-Fabrique (Mojon et al. 1985), Fornant 6, Rickenbach, Brochne Fluh 19/20, Küttigen (Engesser & Mödden 1997) are all superficially similar. Of these, Fornant 6 and Rickenbach share the most taxa with Chrummorge. The caenotheriids, *A. exile* and *Paratalpa cf. micheli* are common taxa in Late Oligocene faunas, but not very significant. *Heteroxerus cf. lavocati* shows primitive characters, but in many faunas the genus *Heteroxerus* is absent. *Glirivus* has its last occurrence in the latest Oligocene. *Rhizospalax* is characteristic and only occurs in Rickenbach, Brochne Fluh 19/20 and Küttigen. *Eomys cf. major* of Chrummorge is large but seems not yet belong to *E. huerzeleri*. *E. major* is present in Fornant 6, whereas in Brochne Fluh 19/20 *E. huerzeleri* appears. *Eomys cf. ebnatensis* is comparable to *Eomys* from Ebnat-Kappel, Fornant 6 and Rickenbach. *P. promyaron* was found in Fornant 6 and Rickenbach, *A. vireti* in Küttigen, Brochne Fluh 19/20 and Rickenbach, whereas in Fornant 6 a similar form occurs. *Eucrietodon* (aff.) *dubius* is a relatively small species of *Eucrietodon*, and is known from Fornant 6 and a similar species from Rickenbach. *Melissiodon* and the Archaeomyini *Issiodoromys* sp. and *Archaeomys* sp. are not yet sufficiently identified at Chrummorge. From Rickenbach *Archaeomys helveticus* and *Archaeomys arvernensis* are reported, at Fornant 6 only *Archaeomys helveticus*. At Brochne Fluh 19/20 and Küttigen *A. laurillardi* is reported. From Fornant 6 *I. limognensis* is listed, from Rickenbach and Brochne Fluh 19/20 *Issiodoromys pseudanoema*. In Küttigen, no *Issiodoromys* was found. If we compare all these faunas and the occurrences of faunal elements according to the faunal lists

given in Engesser & Mödden (1997), Chrummorge is best placed somewhere between Fornant 6 and Rickenbach (Fig. 5).

5.2 Biostratigraphy

There is a number of Late Oligocene mammal faunas described in the literature from Central Europe. The Swiss localities have been correlated by Mojon et al. (1985), Engesser and Mayo (1987), Brunet and Vianey-Liaud (1987), Engesser 1990, Engesser and Mödden (1997). As shown in the previous chapter, the fauna of Chrummorge is related to Fornant 6 and Rickenbach. We can now compare the faunal characteristics of the MP units to which Rickenbach and Fornant 6 are referred to and also compare with those of one MP unit higher and lower respectively. These faunal characterizations in the MP units are taken from Brunet and Vianey-Liaud (1987), L egendre and L ev eque (1997), Huguene (1997):

MP30, Coderet F (CH: K uttigen, Brochene Fluh 53; D: Fleursheim, Ehrenstein 4).

Last records. *Rhizospalax*, *Glirivus*, *Eomys*, *Archaeomys*, *Issiodoromys* and *Adelomyarion*

First record. *Rhodanomys transiens*

Typical record. *Plesiosminthus winistoerferi*, *Plesiosminthus schaubi*, *E. collatus*, *R. hugueneyae*

Clearly, Chrummorge does not belong here.

MP 29, Rickenbach CH (CH: Brochene Fluh 19/20; D: Herrlingen 4).

Last record. *E. dubius*

First records. *Rhizospalax*, *A. vireti*

Typical. *R. hugueneyae*, *Pseudotheridomys rolfoi*, *I. pseudanoema*, *E. huerzeleri*, *Eucricetodon praecursor*
Chrummorge has many elements in common, but the Eomyidae and Cricetidae of Chrummorge are less developed and the fauna of Chrummorge must therefore be slightly older.

MP 28, Pech du Fraysse F (CH: Fornant 6, Fornant 7; D: Gaimersheim 1).

Last records. *P. promyarion*, *Eomys zitteli*

First record. *Dremotherium quercyi*

Typical. *Archaeomys intermedius*, *A. quercyi*, *I. limog-nensis*, *E. major*

Chrummorge has many elements in common, but the Archaeomyini seem to be more evolved, *Rhizospalax* is not present in MP 28, but is so in Chrummorge, and thus, the fauna of Chrummorge must be slightly younger.

MP 27 Boningen CH(CH: Wynau 1)

Last record. *Allocricetodon incertus*

First records. *P. antiquum*, *E. dubius*

Typical. *Archaeomys robustus*, *Archaeomys ehrensteini*, *Issiodoromys quercyi*

There are few elements in common, the Theridomorpha at Chrummorge are clearly more evolved.

In general, *H. lavocati* is known from MP29 and younger. *Gliravus* occurs only up to MP30. *E. major* is only known from MP 27 and MP 28. *E. ebnatensis* and *E. dubius* both range from MP 27 to MP 29. *A. vireti* is known from MP 28 to MP 30. The first “modern” *Issiodoromys* (*I. limog-nensis*) appears in MP 28 and vanishes in MP 29 or latest in MP 30 (*I. pseudanoema*): The first “modern” *Archaeomys* (*A. helveticus*, *A. arvernensis*, *A. laurillardii*) appear in MP 28 and disappear in MP 30. *R. poirrieri* is only known from MP29 and MP 30.

Widespread and not significant are *Amphiperatherium exile*, *Paratalpa micheli* and

Melissiodon Thus, we end up with the fauna from Chrummorge somewhere between MP 28 and MP 29, which on a Swiss reference level is between Fornant 6 and Rickenbach. Regarding absolute age data, Schmidt-Kittler et al. (1997) indicate 25.3 million years for Boningen (MP27), 24.7 million years for Pech du Fraysse (MP28), 24.3 million years for Rickenbach (MP29) and 23.8 million years for Coderet (MP30). In Berger (1998) and in Berger et al. (2005b) a time-range of approximately 24–25.2 million years is indicated for the time period of the two zones MP 28 and MP 29. According to Schlunegger et al. (1996) and Kempf et al. (1997), 24.2–24.6 million years are given for the time period between Rickenbach and Fornant 6. Legendre and L  v  que (1997) and Kempf et al. (1997) correlate to the same geomagnetic chrons, Coderet being 6CN (24.1–23.15 Ma), Rickenbach 6CR

(24.8–24.15 Ma), Pech du Fraysse 7N + 7AB (25.75–24.8 Ma), Fornant 6 7N (25.3–24.8 Ma) and Boningen 7R (25.6–25.3 Ma). Kempf et al. precise these dates for Rickenbach to 24.5–24.2 Ma, and to 25.1–24.7 Ma for Fornant 6 and Fornant 7.

Based on faunal comparisons, the Chrummorge locality is somewhere between Fornant 6 and Rickenbach, and accordingly its absolute age is around 24.6 ± 0.2 Ma.

6 Conclusion and outlook

The fauna of Chrummorge can be placed at the transition between MP 28 and MP 29, giving an age of approximately 24.6 million years. This corresponds to the local datum for the beginning of the molasse-sedimentation at the L  gern-anticline near Wettingen (Canton AG), and thus may give an important input for later palaeogeographic reconstructions.

At the easternmost L  gern-anticline near Dielsdorf (Canton ZH) fissure-fillings with mammal remains give youngest ages of around MP18-20 (Rosselet 1991). This means a Late Eocene pre-Grand Coupure age (around 34 Ma years) for the Dielsdorf faunas. However, oldest suggested ages of parts of the Dielsdorf faunas are MP13 (around 44 Million years) according to Rosselet (1991). The Dielsdorf faunas may consist of separate fissures of different ages or there were older clays of fissure infills reworked and mixed with younger fossils. However, that would mean that during these 10 millions of years the outcropping surface of Late Jurassic limestone was more or less exposed to corrosion. Later, there were changes in tectonic movements and/or in sedimentation and erosion without creating further fissure fillings, that means from Earliest Oligocene times on the previously opened carst was largely filled and blocked. The undated bolus clay and “Bohnerz” (terrigenous iron ore formation) that often cover the uppermost Late Jurassic limestone surface provide evidence for a further strong weathering under tropical conditions during the ten million years that were between the last fissure fillings (yellow clays) and the first molasses sediments described here. It is not possible to estimate how much from the top of the Jurassic limestone sequence was eroded. At least in the study area, there is no evidence for any sedimentary remains dating from the Cretaceous.

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