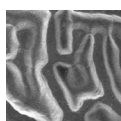


Micromammalian faunas from the Middle Miocene (Middle Aragonian) of the Tudela Formation (Ebro Basin, Spain)

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Two new fossil micromammal localities of Middle Miocene age (Pico del Fraile 2, PF2 and Sancho Abarca 5, SA5) from the Tudela Formation (northeastern Ebro Basin) are described. PF2 contains rodents and insectivores of Aragonian age (local zone Dc). The rodent assemblage from the locality SA5 is very scarce and probably of Middle Aragonian age, like PF2. The micromammal fauna from the locality PF2 is very similar to that from Valdemoros 3B (VA3B) (Calatayud-Daroca Basin), including *Microdyromys* cf. *remmertii*, a species until now only described from the Miocene of the Daroca-Villafeliche area. Among the fauna recorded in PF2, a form of *Democricetodon* is described. The sedimentary record of the Pico del Fraile and Sancho Abarca sections and the mammalian findings extend the stratigraphic and paleontological knowledge of this part of the Ebro Basin, and allow its study in a continuous stratigraphic context.

- Key words: rodents, insectivores, *Democricetodon*, magnetostratigraphy, biostratigraphy, Ebro Basin, Aragonian.

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The deposits of the Tudela Formation crop out in the central part of the Western sector of the Ebro Basin (Spain) in the so-called Bardenas Reales de Navarra. The sedimentological environment during the deposition of the Tudela Formation favours the presence of a great number of micro- and macromammal sites in the stratigraphic sequence of this formation. In the past two decades our team has performed an extensive paleontological and magnetostratigraphical investigation that has increased the paleontological knowledge and established a detailed chronology of the fossiliferous sites in the span between Late Agenian

and Late Ramblian (Murelaga 2000; Murelaga *et al.* 2002; Murelaga *et al.* 2004a, 2004b; Larrasoña *et al.* 2006; Ruiz-Sánchez *et al.* 2010a, 2010b; Ruiz-Sánchez *et al.* 2012a, 2012b, 2012c; Figs 1, 2). So far, the younger deposits of the Tudela Formation had not been studied. In this contribution we present a complete study of the rodent and insectivore faunas of two new sites found at the top of the Tudela Formation, which permit to increase the biostratigraphical data of the formation, and to compare this with the fossil contents of other areas of the Ebro Basin of similar age. PF2 contains three genera of cricetids (*Eumyarion*,

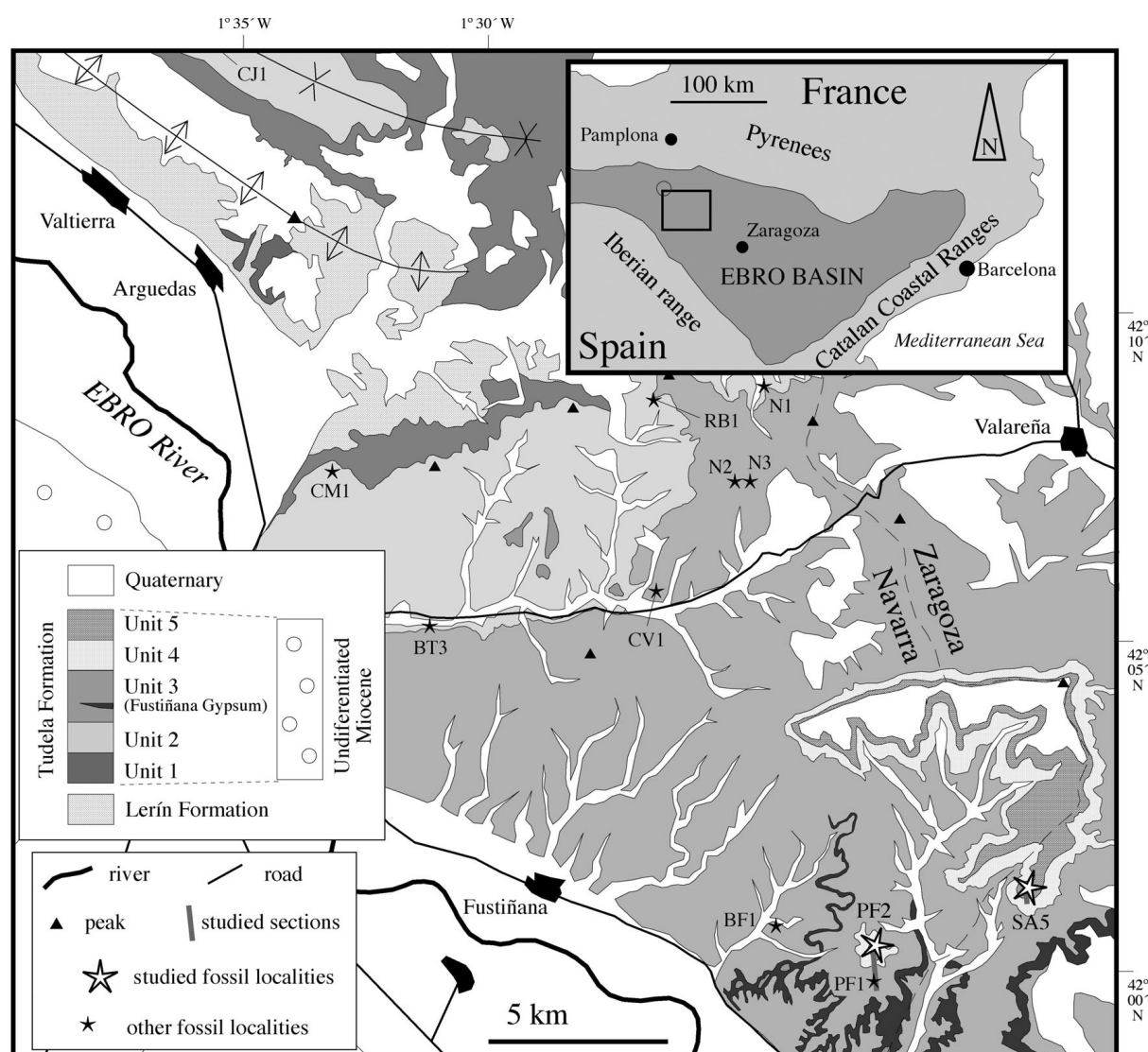


Figure 1. Geological map of the Tudela Formation in the Bardenas Reales of Navarra, with the situation of the localities presented in this work. PF2 – Pico de Fraile 2, SA5 – Sancho Abarca 5. The situation of other localities previously studied in the lower part of the Tudela Formation is shown as well (Murelaga 2000; Murelaga *et al.* 2004a, b).

Megacricetodon and *Democricetodon*), four glirids (two species of *Microdyromys*, *Pseudodyromys* and *Vasseuromys*), one sciurid (*Spermophilinus*) and three insectivores (*Galerix*, *Miosorex* and *Myxomygale*). SA5 contains two cricetids (*Megacricetodon* and *Democricetodon* or *Fahlbuschia*), one sciurid (*Spermophilinus*) and one glirid (*Vasseuromys*). Moreover, the biostratigraphical information is correlated with the existing magnetostratigraphic information in the area (Larrasoña *et al.* 2006).

Geological setting

The fossil localities PF2 and SA5 are located in the highest stratigraphic levels of the Pico del Fraile and Sancho

Abarca sections, respectively (Figs 1, 2). These sections include sediments of the upper part of the Tudela Formation, including the youngest sediments preserved in the western part of the Ebro Basin in the region of the Bardenas Reales de Navarra (Larrasoña *et al.* 2006). The Tudela Formation is divided into five lithostratigraphic units according to the predominance of distal alluvial (Units 1 and 4), palustrine (Unit 3), and lacustrine (Units 2 and 5) facies (Larrasoña *et al.* 2006). The Pico del Fraile section spans the uppermost part of Unit 3, Unit 4, and the lowermost part of Unit 5, whereas the Sancho Abarca spans the uppermost part of Unit 4 and the entire Unit 5 (Larrasoña *et al.* 2006; Fig. 2). Unit 5 is made up of grey and ochre mudstones and grey and beige limestones. The mudstone packages are massive and range from a few centimetres to several metres in thick-

ness. The limestone beds are up to 2 metres thick, often massive and bioturbated, and contain abundant gastropods, ostracods, charophytes, fish bones and other fossil fragments. The limestones indicate deposition in a stable fresh-water lacustrine system, whereas the mudstones were deposited under palustrine conditions. These facies are similar to those described from the Lower and Middle Miocene of the central part of the Ebro Basin, when the latter formed an endorheic depression at the foothills of the Pyrenees and the Iberian and Catalan Coastal ranges (Arenas & Pardo 1999, Alonso Zarza *et al.* 2002). Magnetostratigraphic data indicate that fossil localities PF2 and SA5 are located within chron C5Br of the Langhian (Middle Miocene – Larrasoña *et al.* 2006; Fig. 2) at an approximate age of 15.8 and 15.5 Ma, respectively, in the ATNTS2004 time scale (Lourens *et al.* 2004).

Material and methods

The fossils were collected during the campaigns of 2004 to 2010, and are deposited in the “Departamento de Estratigrafía y Paleontología de la Universidad del País Vasco” (UPV/EHU) and Museo Aragonés de Paleontología (Fundación Conjunto Paleontológico de Teruel). The nomenclature used in the description of the teeth and the measurement methods are taken from Mein & Freudenthal (1971) – Cricetidae, Freudenthal (2004) – Gliridae, Cuenca (1988) – Sciuridae, Prieto & Rummel (2009) and Prieto *et al.* (2010) – Erinaceidae, Reumer (1984) – Soricidae and Rümke (1985) – Talpidae. The measurements are given in units of 0.1 mm, and were taken on a binocular microscope Leica MZ7₅, by means of displacement of a mechanical stage, connected to a Sony Magnescale measuring equipment.

Lower teeth are coded as d4, p4, m1, m2, m3, upper teeth as P4, M1, M2 and M3.

We use the MN units (European Neogene land mammal units) or the local zones defined by Daams & Freudenthal (1988), Daams *et al.* (1999) and/or Van der Meulen *et al.* (2012).

Abbreviations. – BU – Buñol; CMVI – Can Martí Vell I; PF2 – Pico del Fraile 2; SA5 – Sancho Abarca 5; VA3B – Valdemoros 3B; VL2A – Villafeliche 2A; L – Length; W – Width; UPV/EHU – Universidad del País Vasco/Euskal Herriko Unibertsitatea; SCSIE (UV) – Servei Central de Suport a l’Investigació Experimental de la Universitat de València.

Systematic palaeontology

Order Rodentia Bowdich, 1821
Family Cricetidae Fischer, 1814

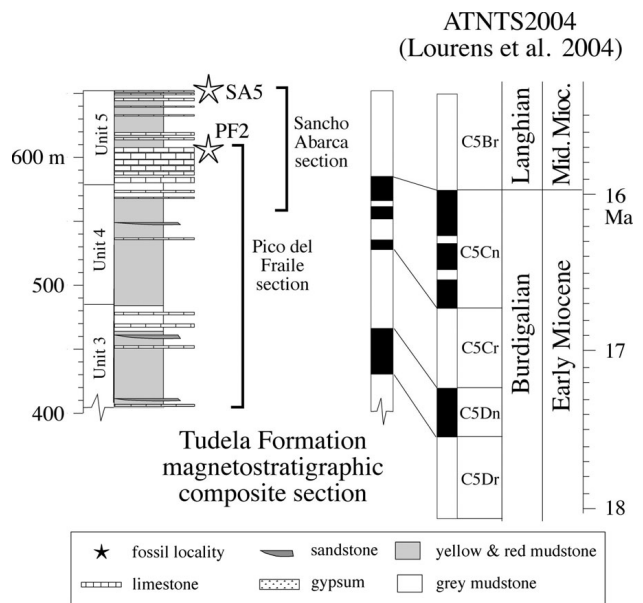


Figure 2. Stratigraphy of the Tudela Formation in the studied sections, with the localities presented in this work, and with the paleomagnetic sequence of the section of Pico de Fraile and of the section of Sancho Abarca (see Larrasoña *et al.* 2006), correlated with the ATNTS time scale of Lourens *et al.* (2004).

Genus *Eumyarion* Thaler, 1966

Type species. – *Eumyarion medius* (Lartet, 1851).

Eumyarion cf. weinfurteri (Schaub & Zapfe, 1953)

Figure 3A

Locality. – Pico del Fraile 2 (PF2).

Material and measurements (L × W). – 1 m1 (PF2-1) (> 17.7 × 11.5); 1 m2 (PF2-13) (> 15.2 × 12.1).

Description. –

m1. The broken tooth does not conserve the anteroconid. On the lingual side the metaconid extends forward to the anteroconid. The anterolophulid is short, interrupted and connected to the protoconid. Metalophulid double, with a long anterior branch connected to the anterolophulid and a posterior very short branch that runs towards the lingual part of the protoconid, but ends freely. Posterior arm of the metaconid connected to the mesolophid. The mesolophid is long and double. The ectomesolophid reaches the labial border of tooth. The hypolophulid is transverse and connected to the ectolophid, just in front of the hypoconid. The sinusid is transverse. There is a long oblique hypoconid hind arm, connected to the posterolophid.

m2. The mesolophid is long and connected to the posterior arm of the metaconid. The ectomesolophid is short. The

hypolophulid is transverse and connected to the anterior part of the hypoconid.

Discussion. – The sizes of m1 and m2 of *Eumyarion* cf. *weinfurteri* from PF2 are less than in the corresponding elements of *E. valencianum* and *E. medius* and within the upper range of *E. weinfurteri* from Bézian and La Romieu (France) (Daams & Freudenthal 1974, Bulot 1979, Wu 1982). The metalophulid with the anterior arm connected to the anterolophulid and the posterior arm very short and not connected to any ridge or cusp, the large, double mesolophid, connected to the posterior arm of the metaconid and the development of the ectomesolophid and the hypoconid hind arm, connected to the posterolophid, are typical of the populations of *Eumyarion weinfurteri* from Bézian and La Romieu.

Agustí (1983) described a small *E. weinfurteri* population from CMVI (lower part of unit MN4). This material differs from our elements in the absence of anterolophulid and ectomesolophid, the presence of a mesolophid of medium length, and a posterior arm of the hypoconid not connected to the posterolophid.

The presence in *E. cf. weinfurteri* from PF2 of a double metalophulid with the posterior arm very short and a large mesolophid in the m2 are very similar to what has been described in the populations of *E. weinfurteri* from European localities of an age posterior to MN4. In Wu (1982; fig. 14, 38) the m2 of *E. bifidus* from Puttenhausen (MN5) has a mesolophid of medium size, that does not reach the lingual border of the tooth.

Genus *Megacricetodon* Fahlbusch, 1964

Type species. – *Megacricetodon gregarius* (Schaub, 1925).

Megacricetodon aff. *primitivus* (Freudenthal, 1963)

Figure 3B–H

Locality. – Pico del Fraile 2 (PF2).

Material. – 3 m1 (PF2-11, PF2-139, PF2-41); 5 m2 (PF2-14, PF2-15, PF2-42, PF2-140, PF2-141); 1 m3 (PF2-24); 1 M1 (PF2-6); 1 M2 (PF2-17); 1 M3 (PF2-25).

Measurements. – Table 1.

Description. –

m1. The anteroconid is simple and rounded. The anterosinusid and protosinusid are bordered by a low ridge. The anterolophulid is complete. The metalophulid and hypolophulid are transverse and short. The mesolophid is short (1) or of medium length (1). The ectomesolophid is absent. The posterolophid descends to the base of the entoconid.

m2. The lingual anterolophid is long, not reaching the lingual border. A short and very narrow anterosinusid is present. The labial anterolophid is long and descends towards the base of the protoconid. The mesolophid is short. The ectolophid is continuous. The ectomesolophid is absent. The posterolophid is connected to the entoconid.

m3. The lingual anterolophid is of medium size. Anterosinusid small. The labial anterolophid is short and descends towards the base of the protoconid. The metalophulid is short and complete. A short mesolophid is present. The sinusid is narrow and transverse. The posterosinusid is relatively large. The metaconid, entoconid and posterolophid form a continuous lingual wall along the lingual border.

M1. The anterocone displays a shallow split. The labial portion of the anterocone is bigger than the lingual part. Anterior platform of the anterocone absent. The protolophule is short and posterior. A very short spur on the posterior wall of the paracone is present. The mesoloph is of medium size. The mesoloph and the posterior spur of the paracone are not connected. A small and low cusp is present at the antero-lingual base of the hypocone. The metalophule is short and posterior. Posterossinus small and narrow.

M2. The protolophule is simple and forward directed, and it is connected to the anterior part of the protocone. The posterior wall of the paracone does not have a spur. The mesoloph is of medium size. The sinus is transverse. The metalophule is simple, transversal and connected to the hypocone. The posteroloph is connected to the posterior part of the metacone. Posterossinus long and large.

M3. The lingual anteroloph and protosinus are absent. The labial anteroloph is long, connected to the paracone, enclosing a long and relatively wide anterosinus. The protolophule is transverse and connected to the anterior part of the

Figure 3. Rodents from the localities Pico de Fraile 2 and Sancho Abarca 5 (Ebro Basin, Spain). • A – *Eumyarion* cf. *weinfurteri*, left m1, PF2-1. B–H – *Megacricetodon* aff. *primitivus*; B – right m1, PF2-11.; C – right m2, PF2-140; D – right m2, PF2-14; E – left m3, PF2-24; F – left M1, PF2-6; G – right M2, PF2-17; H – left M3, PF2-25. • I–N – *Democricetodon* aff. *hispanicus*; I – left m1, PF2-7; J – left m1, PF2-8; K – right m2, PF2-143; L – left m3, PF2-21; M – left M1, PF2-2; N – right M2, PF2-155. • O–S – *Spermophilinus besana*; O – right d4, PF2-33; P – right m1,2, PF2-39; Q – right m1,2, PF2-36; R – right m3, PF2-40; S – right M1,2, PF2-26. • T, U – *Microdyromys* cf. *remmertii*; T – left p4, PF2-102; U – right M3, PF2-75. • V–X – *Microdyromys* cf. *koenigswaldi*; V – right m1, PF2-83; W – right m1, PF2-88; X – left M1,2, PF2-112. • Y–B* – *Vasseuromys* aff. *cristinae*; Y – left M1, SA5-16; Z – left m1, SA5-6; A* – left m3, SA5-11; B* – right m3, SA5-9. • C* – *Pseudodryomys* cf. *ibericus*; left m2, PF2-96. Scale: 1 mm.

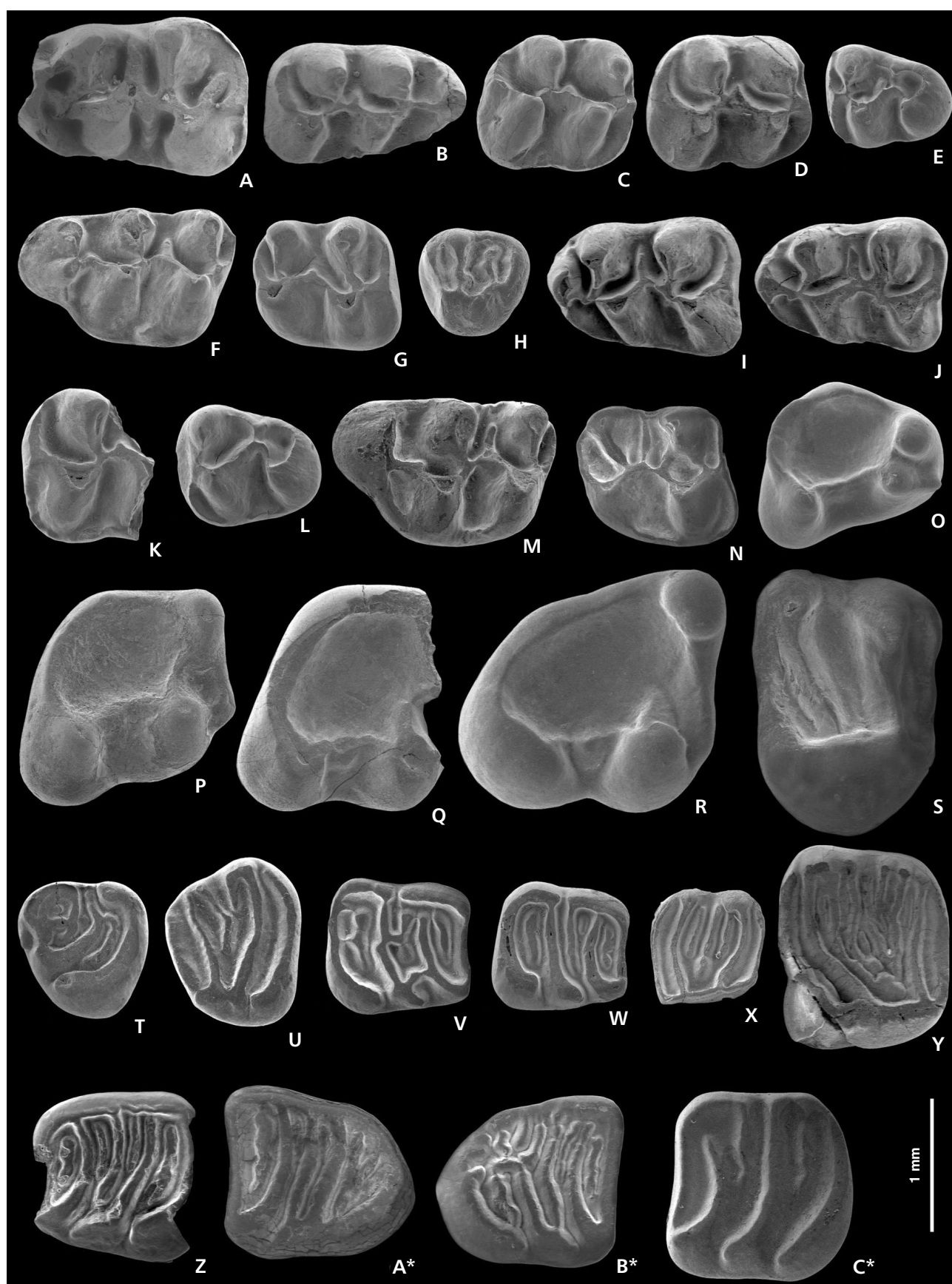


Table 1. Measurements in tenth of millimetres of the teeth of *Megacricetodon* aff. *primitivus* from PF2. L = length; W = width; p4 = fourth premolar; m1 = first lower molar; m2 = second lower molar; m3 = third lower molar; M1 = first upper molar; M2 = second upper molar; M3 = third upper molar.

Element	Parameter	n	min.	mean	max
m1	L	2	14.0	14.3	14.6
	W	2	8.7	8.8	8.9
m2	L	3	11.3	11.7	11.9
	W	3	9.6	10.0	10.3
m3	L	1		9.6	
	W	1		7.6	
M1	L	1		15.4	
	W	1		9.9	
M2	L	1		10.6	
	W	1		9.7	
M3	L	1		8.1	
	W	1		7.8	

protocone. The sinus is very shallow. Neo-entoloph high and connected to protocone and hypocone. Axioleph short. Centroloph long. The posteroloph is long and curved, forming a labial wall with the metacone and the posterior wall of the paracone.

Discussion. – In several morphological features, the morphology of *Megacricetodon* from PF2 is very similar to what has been described in Valtorres, type locality of *Megacricetodon primitivus*. This species has been described with a wide range of morphological variation (Daams & Freudenthal 1988, Oliver-Pérez *et al.* 2008). This causes a confusing situation that has led several authors to consider the possible existence of more than one species in the populations ascribed to this taxon (Ruiz-Sánchez 1999, Ruiz-Sánchez *et al.* 2003, Oliver-Pérez *et al.* 2008).

Some of the morphological features that have been described as typical of *M. primitivus* are present in the *Megacricetodon* of PF2. The presence of a simple anteroconid in the m1, a mesolophid in the m3 and a single and anterior protolophule without posterior spur in the M2, are very similar to what has been described in the type population of *M. primitivus*. However, the material from PF2 shows some important differences. The most significant is the better development of the mesoloph/ids in PF2.

On the other hand, the *Megacricetodon* from PF2 is clearly distinguishable from *M. collongensis*, characteristic species from the Middle Aragonian of the Iberian Peninsula (Daams & Freudenthal 1988, Daams *et al.* 1999, Ruiz-Sánchez 1999, Ruiz-Sánchez *et al.* 2003). In this latter species, a high percentage of m1 has a divided anteroconid, the mesolophid of the m3 is practically absent and the M2 usually has double protolophules with a posterior spur on the paracone.

The material of *Megacricetodon* from PF2 differs from *M. primitivus* and *M. collongensis* and coincides greatly with the description by Ruiz-Sánchez (1999) of *Megacricetodon* nov. sp. 3 from Morteral 22. Therefore, and until more material is available in PF2, we classify this assemblage as *Megacricetodon* aff. *primitivus*.

Megacricetodon sp.

Locality. – Sancho Abarca 5 (SA5).

Material and measurements ($L \times W$). – 1 m1 (SA5-1) ($> 12.8 \times 9.5$); 1 m2 (SA5-3) ($- \times 9.9$); 1 M3 (SA5-4) (8.1×8.4).

Description. –

m1. An incomplete specimen is available, preserving only the posterior part. The protosinusid is bordered by a low ridge. The mesolophid is of medium length. The ectomesolophid is absent. The hypolophulid is short and transverse. The posterolophid descends reaching the base of the entoconid.

m2. An incomplete specimen is available. Only the most posterior part of the tooth is preserved. The posterolophid descends and nearly reaches the entoconid base.

M3. The lingual anteroloph is much reduced. The labial anteroloph is long and is connected to the paracone. A short and relatively wide anterosinus is present. The protosinus is absent. The protolophule is a slightly oblique, connected to the anterior part of the protocone. The paracone does not have a posterior spur and the mesosinus is open to the labial side. The lingual portion of the mesosinus is nearly open to the lingual side. The sinus is relatively narrow. The neo-entoloph is very low and connected protocone and hypocone. The axioleph is long and low. The centroloph is of medium size. The metalophule is long, and is connected to hypocone and metacone. The posteroloph descends along the posterior border of the tooth, connecting to the metacone. The posterosinus is narrow and deep.

Discussion. – Some of the striking morphological characters of this material are the medium-sized mesolophid of m1, the height of the neo-entoloph and the opening of the mesosinus to the labial side of the M3. The medium-sized mesolophid is very common in populations of *Megacricetodon* in the time span between the Early and Middle Miocene (MN4 and MN5, local zones C and D).

On the other hand, the M3 is a very interesting element in the taxonomy of cricetids (Freudenthal & Daams 1988). According to several authors (Freudenthal & Daams 1988, Ruiz-Sánchez 1999), some of the characters of the M3, as the height of the neo-entoloph and the size of the sinus,

would permit the distinction among the species of the genus *Megacricetodon*. According to Freudenthal & Daams (1988), there seems to exist an evolutionary tendency to the closing of the neo-entoloph and reduction of the sinus. Based on these criteria, the only M3 from SA5 would correspond to an old representative of the genus *Megacricetodon*. However, the material is too poor and, until more material is available, we classify it as *Megacricetodon* sp.

Genus *Democricetodon* Fahlbusch, 1964

Type species. – *Democricetodon crassus* Freudenthal, 1969.

Democricetodon aff. *hispanicus* Freudenthal, 1967

Figures 3I–N, 4A

Locality. – Pico de Fraile 2 (PF2).

Material. – 5 m1 (PF2-7, PF2-8, PF2-9, PF2-10, PF2-142); 1 m2 (PF2-143); 4 m3 (PF2-19, PF2-21, PF2-22, PF2-23); 4 M1 (PF2-2, PF2-3, PF2-4, PF2-5); 2 M2 (PF2-16, PF2-155).

Measurements. – Table 2.

Description. –

m1. The length/width ratio varies between 1.45 and 1.51, with a mean of 1.49. The anteroconid is small and triangular. From the anteroconid, an anterolophid descends along the border of the molar, sometimes reaching the protoconid base. A small lingual cingulum ridge from the anteroconid towards the metaconid base is present (2) or not (2). The metalophulid is transverse or slightly directed forward (3) or anterior (1). In the former specimens the metalophulid connects to the posterior end of the anterolophulid near the protoconid. In the other specimen the metalophulid connects to the middle of the anterolophulid. Anterosinusid wide (3) (Fig. 3J) or narrow (1) (Fig. 3I). The protosinusid is large. A small posterior fold of the metaconid is present (3), running towards the mesolophid without reaching it. The mesolophid is long, but does not reach the edge of the molars. A very short ectomesolophid is present in 3 out of 4 specimens (Fig. 3J). The sinusid points obliquely forward. The hypolophulid is very short and slightly curved and it points forward. A posterior fold of the hypolophulid is present in 2 out of 4 specimens, either of medium length (1) or large (1), connected to the posterolophid in the latter case (Fig. 4A). The posterolophid closes the posterosinusid.

m2. A small labial cingulum ridge is present. Mesolophid of medium length or long. The posterolophid closes the posterosinusid.

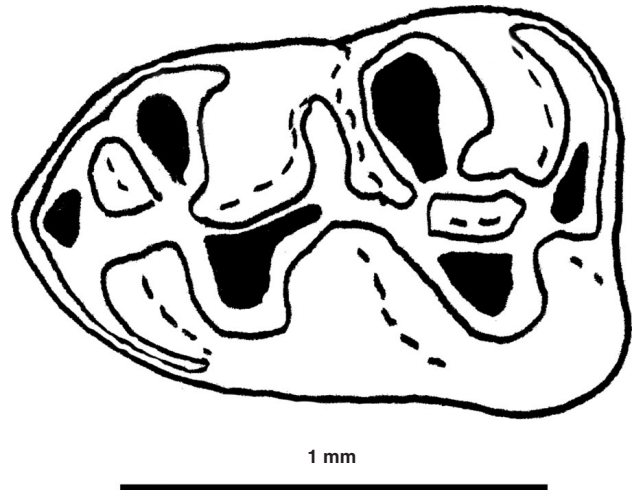


Figure 4. *Democricetodon* aff. *hispanicus* from Pico de Fraile 2 (PF2). A – m1 sin. (PF2-9). Scale: 1 mm.

Table 2. Measurements in tenth of millimetres of the teeth of *Democricetodon* aff. *hispanicus* from PF2. L = length; W = width; m1 = first lower molar; m3 = third lower molar; M1 = first upper molar; M2 = second upper molar.

Element	Parameter	n	min.	mean	max.
m1	L	3	14.0	14.4	14.7
	W	3	9.2	9.7	10.1
m3	L	3	10.3	10.6	10.8
	W	3	8.6	9.0	9.5
M1	L	4	16.6	16.5	17.5
	W	4	10.1	11.0	11.8
M2	L	2	10.8	11.3	11.9
	W	2	10.3	10.4	10.5

m3. The lingual anterolophid is very short or absent. The labial anterolophid reaches the base of the protoconid. The mesolophid is absent. The sinusid is transverse and shallow. The hypolophulid is short. The posterolophid closes a posterosinusid that is smaller than the mesosinusid.

M1. The anterocone is a broad transverse ridge. A labial spur of the anterolophule is present in most specimens. In 3 out of 4 specimens it is directed towards the base of the paracone, forming an anterior protolophule. So, 3 out of 4 specimens have a double protolophule. The mesoloph is of medium length to long, not reaching the labial border. The sinus is transverse. A small and low cusp is present at the antero-lingual base of the hypocone. The metalophule is single and posterior, connected to the posteroloph. The posterosinus is narrow and relatively long, closed by the connection posteroloph-metacone. Anterosinus and mesosinus are closed by a low ridge that runs along the labial side.

M2. The protolophule is double with the anterior branch interrupted. The mesoloph is long, reaching the border of the tooth. The sinus is transverse. A small and low cusp is present at the antero-lingual base of the hypocone. The metalophule is transverse. The posteroloph connects to the metacone. The posterosinus is relatively large.

Discussion. – Van der Meulen *et al.* (2004) revised the material of medium-sized Cricetidae from the Miocene of the Daroca-Villafeliche area. In that paper they synonymized *Fahlbuschia*, *Pseudofahlbuschia* and *Renzimys* with *Democricetodon*, as well as some species of these genera. In a subsequent paper, Freudenthal (2005) discussed this work and ratified the original status of these cricetid genera. This question is still open to discussion and until it is resolved, we prefer to use the cricetid systematics from before 2004. Nevertheless, some data of the former paper are of great interest for our present work.

Figure 6 shows the measurement values of several populations of the genera *Democricetodon* and *Fahlbuschia* from the local zones B and C (MN4) and D (MN5) of the Aragonian (Iberian Peninsula) and from Erkertshofen (Eichstätt i. B., Germany, type locality of *Democricetodon franconicus*). The size of the *Democricetodon* from PF2 is clearly smaller than the species *F. koenigswaldi* (Freudenthal, 1963), *P. jordensi* Daams & Freudenthal, 1988, *D. moralesi* Van der Meulen *et al.*, 2004 and *D. cf. affinis sensu* Freudenthal (2005) from Valdemoros 3B (VA3B); it is smaller or coincides with the lower range of *F. sacedoniensis* Freudenthal, 2005 and *F. decipiens* Freudenthal & Daams, 1988; it coincides with the mean values of *D. franconicus sensu* Van der Meulen *et al.* (2004) and of true *D. franconicus* Fahlbusch, 1966 from Erkertshofen; lastly, the upper molars coincide with the lower range, and the lower molars with the upper range of *D. hispanicus sensu* Freudenthal & Daams (1988).

Morphologically, the *Democricetodon* from PF2 is very different from *Fahlbuschia sacedoniensis* and *F. decipiens*. The poor development of the mesolophids of m1,2 and the absence of an anterior protolophule in the M1 of *F. sacedoniensis* is very different from what we have described in the population of *Democricetodon* from PF2. The degree of development of mesolophs and mesolophids in the two first molars and of double protolophules in the M1,2 of *F. decipiens* is similar to that of *Democricetodon* from PF2, though slightly less in *F. decipiens*. However, there are significant differences between the material of these species, like the development of the posterior branch of the hypolophulid, only present in PF2.

Some of the features described in the *Democricetodon* from PF2 are rare or unknown in any of the populations of this genus. Especially, the presence of a posterior fold of the metaconid or a double metalophulid of the m1 is absent

in the “lineage” *D. hispanicus* – *D. lacombai* (*sensu* Van der Meulen *et al.* 2004) and is rare in the “lineage” *D. franconicus* – *D. crusafonti*. It was mentioned by Fahlbusch (1966) for *D. franconicus* from Erkertshofen and it may be observed in at least one specimen of “*D. franconicus*” from La Col-D (see Van der Meulen *et al.* 2004, pl. 2, fig. 3). Some of our specimens present an ectomesolophid, which is absent (or at least not mentioned by Van der Meulen *et al.* 2004) in both *D. hispanicus* and “*D. franconicus*” from the Daroca-Villafeliche area, and occasionally present in true *D. franconicus* from Erkertshofen (Fahlbusch 1966). Even more important is the difference in the morphology of what we might call double hypolophulid of the m1 in the *Democricetodon* from PF2. In 2 of the 4 specimens of the *Democricetodon* from PF2 there is a posterior hypolophulid in the posterosinusid which may almost connect (1) or connect (1) to the posterolophid. The development of a complete double hypolophulid has not been described in any of the populations of the genus *Democricetodon*. However, Freudenthal & Daams (1988, pl. 4, fig. 8) figured a m1, of what those authors called *Democricetodon cf. affinis* from the locality VA3B, in which the entoconid extends into the posterosinusid without connecting to the posterolophid. That morphology is similar to some m1 from PF2. Apart from that, the general morphology of the *Democricetodon* from VA3B is very similar to the material from PF2: long mesoloph(id)s, protolophule of the M1,2 double, *etc.*

Fahlbusch (1966) mentioned that the only difference between *D. hispanicus* and *D. franconicus* is the longer mesoloph(id)s in the latter. Van der Meulen *et al.* (2004) add, as a second difference, between these species, the presence of up to 20% of M1 with a double protolophule in *D. franconicus* from Erkertshofen. However, in *D. hispanicus* from the localities of the Daroca-Villafeliche area, Van der Meulen *et al.* (2004; table 16) cited the presence of a double protolophule of the M1 of: 5% in San Roque 1 (SR1), 21% in San Marcos (SAM), 16% in San Roque 2 (SR2), 25% in San Roque 5 (SR5) and 26% in Villafeliche 2A (VL2A). So, for this feature, there is no difference between *D. franconicus* from Erkertshofen and *D. hispanicus* from the localities of the Daroca-Villafeliche area. On the other hand, the *Democricetodon* from PF2 presents a double protolophule in 3 of the 4 M1 and the single M1 from VA3B has a double protolophule too. Though our material is poor, the double protolophule in the M1 from PF2 seems to be dominant, contrary to the situation in *D. hispanicus* and *D. franconicus*.

We think our material represents a new species, but refrain from naming it because the material is poor, and call it provisionally *Democricetodon* aff. *hispanicus*. Maybe it would have been better to call it *D. aff. franconicus*, but unfortunately that may create confusion: Freudenthal (2005) argued that Van der Meulen *et al.* (2004) incorrectly

assigned the material from VA3B to *D. franconicus*. What they called *D. franconicus* is different from the type population from Erkertshofen, the material from VA3B should be excluded from it because it is too big, and the supposed lineages are not supported by the data. Our material shows some similarities with *D. franconicus sensu* Fahlbusch, 1966, but calling it *D. aff. franconicus* might lead to confusion with *D. franconicus sensu* Van der Meulen et al. (2004). It may be related to the *Democricetodon* from VA3B, but not identical, because the latter is larger.

***Democricetodon* sp. or *Fahlbuschia* sp.**

Locality. – Sancho Abarca 5 (SA5).

Material and measurements ($L \times W$). – 1 m2 (SA5-2) ($- \times 11.7$).

Description. –

m2. The specimen is broken. Only the posterior side of the tooth can be observed. A broken and not measurable mesolophid is present. The sinus is transverse. The posterolophid is curved and connected to the posterior side of the metacone. The posterosinus is narrow, long and curved.

Discussion. – The general morphology of the specimen agrees with both *Democricetodon* and *Fahlbuschia*. On the basis of this damaged specimen, its affinity cannot be determined any closer.

Family Gliridae Muirhead, 1819

Genus *Microdyromys* De Bruijn, 1966

Type species. – *Microdyromys koenigswaldi* De Bruijn, 1966.

***Microdyromys* cf. *koenigswaldi* De Bruijn, 1966**

Figure 3V–X

Locality. – Pico de Fraile 2 (PF2).

Material and measurements ($L \times W$). – 1 d4 (PF2-105) (7.5×6.6); 2 m1 (PF2-83, PF2-88) (10.2×9.5 ; 9.4×9.0); 1 M1,2 (PF2-112) ($8.1 \times > 8.0$).

Description. –

d4. Anterior part narrower than posterior. Anterior valley closed, with two small crests that are connected at its lingual border. The posterior valley is closed, without posterotropid. From the center of the mesolophid a small spur extends into the posterior valley.

m1. Anterolophid continuous and fused to the metalophid. Anterotropid long. Metalophid fused to the metaconid or not. In one of the two specimens, a spur connects the labial part of the metalophid with the mesolophid. Centrolophid long and continuous or not connected to the metaconid. In the latter specimen the centrolophid sends a longitudinal spur to the mesolophid. In one of the two specimens there is a short accessory crest between metalophid and centrolophid. Mesolophid long and continuous. The posterior valley has a long posterotropid, which in one of the specimens presents two longitudinal spurs that are connected to the posterolophid. Endolophid continuous, only interrupted at the the central valley.

M1,2. Endoloph continuous. Anteroloph connected to the paracone. Precentroloph longer than the postcentroloph. Prototrope long. The postcentroloph joins the metacone at a low level. Metaloph and posteroloph continuous. The posteroloph fused to the metacone. The prototrope is the only accessory crest.

Discussion. – The morphology and the size of the material assigned to *Microdyromys* cf. *koenigswaldi* are very similar to those described for that species. However, the presence of a small accessory crest between the metalophid and the centrolophid has not been described in *M. koenigswaldi*, but is found in one of the two m1 from PF2. That morphology appears in other species of the genus, like *M. complicatus* De Bruijn, 1966, and *M. remmerti* García-Paredes et al., 2010. The difference between the material from PF2 and that of *M. complicatus* is that in the latter there are always well-developed accessory crests outside the trigone in the upper molars (García-Paredes et al. 2010), whereas the single M1,2 of *M. cf. koenigswaldi* from PF2 does not present that morphology. On the other hand, *M. cf. koenigswaldi* from PF2 is smaller and has a simpler pattern of accessory crests than *M. remmerti*. Apart from *M. cf. koenigswaldi* we describe in this paper some specimens that by size and morphology are reminiscent of *M. remmerti*. García-Paredes et al. (2010, p. 1607) conclude that in the Miocene of Spain the species *M. remmerti* and *M. koenigswaldi* always occur together.

***Microdyromys* cf. *remmerti* García-Paredes, Peláez-Campomanes & Álvarez-Sierra, 2010**

Figure 3T, U

Locality. – Pico de Fraile 2 (PF2).

Material and measurements ($L \times W$). – 1 p4 (PF2-102) (10.5×9.4); 1 M3 (PF2-75) (10.2×12.3).

Description. –

p4. Suboval tooth with concave occlusal surface. Main

crests thicker than the accessory crests. There is a small accessory crest in the anterior valley. Mesolophid long, labially connected to the complex of anterior crests and lingually not connected to the posterolophid. Between the mesolophid and the complex of crests in the anterior valley there is a very small accessory crest. Posterolophid crescent-shaped. Between the posterolophid and the mesolophid there is a long posterotropid, connected at its ends to the mesolophid.

M3. Contour of a “Spanish fan”. Endoloph continuous, partially interrupted at the lingual border of the posterior valley. Labial border rounded and of greater length than the lingual border. Anteroloph not connected to the paracone. Precentroloph connected at medium height with the labial end of the protoloph. Postcentroloph connected to the metacone. Precentroloph of medium length, longer than the postcentroloph. Precentroloph and postcentroloph form a Y; the postcentroloph is interrupted. Posteroloph connected at medium height to the metacone. There are no accessory crests, neither inside nor outside the trigone.

Discussion. – The general morphology and the size of the two specimens is within the range of *M. remmerti*. The morphology of the p4 from PF2 is very similar to that of the oldest populations of the species found in the type area of the Aragonian, near Daroca-Villafeliche. One of the diagnostic characters of this material is the number of accessory crests. The single p4 from Pico de Fraile 2 (PF2-102) has 6 crests, in *M. remmerti* the number of crests varies between 6 and 8 (García-Paredes *et al.* 2010). The morphology of the M3 of *M. cf. remmerti* from PF2 is somewhat simpler than in the populations of *M. remmerti* from the type area. Whereas the M3 of *M. remmerti* has between 7 and 12 crests, the specimen from PF2 has 6 crests, without accessory crests inside or outside the trigone. In spite of that difference, the size, thickness of the crests and the presence of up to three accessory crests in the p4 from PF2 lead us to classify this material as *M. cf. remmerti*.

Genus *Pseudodryomys* De Bruijn, 1966

Type species. – *Pseudodryomys ibericus* De Bruijn, 1966.

Pseudodryomys cf. ibericus De Bruijn, 1966

Figure 3C*

Locality. – Pico de Fraile 2 (PF2).

Material and measurements ($L \times W$). – 1 m2 (PF2-96) (13.5 × 13.9).

Description. –

m2. Subquadrangular outline. Anterolophid not connected

to the protoconid. Metalophid moderately curved and not connected to the metaconid. Centrolophid long, connected at low level to the posterior part of the metalophid. Mesolophid and posterolophid long and continuous, connected to the entoconid. Posterotropid of medium length. Anterior valley open towards anterior. Central and posterior valleys labially open.

Discussion. – The morphology of the m2 is very similar to morphotype L (Daams 1974) of the m1,2 of the genus *Pseudodryomys*. The presence of a long centrolophid, of a single accessory crest in the posterior valley and of a metalophid that is little curved and not connected to the metaconid characterize this morphotype. The m2 from PF2 is clearly smaller than *P. granatensis* Agustí, 1993, in Martín-Suárez *et al.* 1993 from the locality of Murchas (MN5, Martín-Suárez *et al.* 1993) and *P. rex* García-Moreno, 1986, in Álvarez-Sierra & García-Moreno, 1986 from Torremormojón 6b (MN5-MN7/8, Álvarez-Sierra & García-Moreno 1986), and similar in size to the populations of *P. ibericus*. Morphologically it is very similar to *P. ibericus* and clearly different from *P. granatensis* and *P. rex*. Whereas in the m2 from PF2 there is only one accessory crest in the posterior valley, in *P. granatensis* there are no accessory crests (Martín-Suárez *et al.* 1993) and in *P. rex* there are two, one in the posterior valley and another one between metalophid and centrolophid (Álvarez-Sierra & García-Moreno 1986). We classify this specimen as *P. cf. ibericus*.

Genus *Vasseuromys* Baudelot & de Bonis, 1966

Type species. – *Vasseuromys rugosus* Baudelot & de Bonis, 1966.

Vasseuromys cristinae Ruiz-Sánchez *et al.*, 2012a

Locality. – Pico de Fraile 2 (PF2).

Material and measurements ($L \times W$). – See Ruiz-Sánchez *et al.* (2012a).

Diagnosis. – (From Ruiz-Sánchez *et al.* 2012a.) Medium-sized *Vasseuromys*. Lower molars with four extra ridges: anterotropid, extra ridge between metalophid and centrolophid, second centrolophid and posterotropid; metalophid mostly connected to the metaconid and mesolophid to entoconid; posterotropid connected to posterolophid; M1,2 with incomplete endoloph. M1,2 without extra ridges outside the trigone and three inside (prototrope, metatrope and medium-sized and elongated mesostyle between pre- and postcentroloph).

Ruiz-Sánchez *et al.* (2012a) described the population of

Vasseuromys from Pico de Fraile 2. Here we will describe the material from Sancho Abarca 5 (SA5).

***Vasseuromys* aff. *cristinae* Ruiz-Sánchez et al., 2012a**

Figure 3Y–B*

Locality. – Sancho Abarca 5 (SA5).

Material. – 2 m1 (SA5-6, SA5-7); 1 m2 (SA5-8); 7 m3 (SA5-9, SA5-10, SA5-11, SA5-12, SA5-13, SA5-14, SA5-15); 2 M1 (SA5-17, SA5-18); 1 M2 (SA5-16).

Measurements. – Table 3.

Description. –

m1. Anterolophid and metalophid connected to the protoconid and to the metaconid, respectively. Centrolophid long and connected to the mesoconid. Mesolophid connected to the entoconid. Posterolophid long and prolonged towards the mesoconid. Four accessory crests: an anterotrid, one between metalophid and centrolophid, one between centrolophid and mesolophid, and a posterotrid. The accessory crests in the anterior and posterior valleys are long, the others of medium length. The posterotrid is simple. Endolophid continuous.

m3. Anterolophid connected to the protoconid. Metalophid connected at low level to the metaconid (3) or not connected (3). Centrolophid long and connected to the mesoconid. Mesolophid continuous (3) or interrupted (3) and connected to the entoconid. Posterolophid long and curved, prolonged forward and connected with the mesoconid. There are four accessory crests, an anterotrid, one between metalophid and centrolophid, another one between centrolophid and mesolophid, and a posterotrid. One of the six specimens has three accessory crests, because the one between centrolophid and mesolophid is absent. In 2 of the 6 specimens, the posterotrid is forked in two or three branches, connected to the entoconid and/or to the posterolophid. Endolophid continuous.

M1. Anteroloph long and continuous, connected at medium height to the protocone. Pre- and postcentroloph long (the anterior one being the longest) and interconnected. There are five accessory crests inside the trigone: a prototrope, one between prototrope and protoloph, one between pre- and postcentroloph and a double metatrope. Outside the trigone there are no accessory crests.

M2. Anteroloph connected to the protocone forming a continuous endoloph. Paracone slightly divided into two cusps. Pre- and postcentroloph long, the precentroloph longer than the postcentroloph. Up to six accessory crests in-

Table 3. Measurements in tenth of millimetres of the teeth of *Vasseuromys* aff. *cristinae* from SA5. L = length; W = width; m1 = first lower molar; m3 = third lower molar; M1 = first upper molar; M2 = second upper molar.

Element	Parameter	n	min.	mean	max.
m1	W	1		12.4	
m3	L	5	11.3	12.6	13.9
	W	6	11.1	12.0	12.5
M1	L	1		11.3	
	W	1		14.5	
M2	L	1		13.0	
	W	1		14.8	

side the trigone: a long prototrope, connected to the base of the metaloph, two small crests, one at each side of the prototrope, one between pre- and postcentroloph, a long metatrope, connected to the prolongation of the prototrope and two small crests on either side of the prototrope. Outside the trigone there is a short anterotrope, linked to the anteroloph. Metaloph transverse and connected to paracone and protocone. Posteroloph high and connected to protocone and metacone.

Discussion. – The genus *Vasseuromys* was originally described by Baudelot & de Bonis (1966) in the Lower Miocene French localities Laugnac and Moissac 1, to distinguish glirids of medium size with strong concavity of the occlusal surface and with tendency to form longitudinal walls. At present there are nine species formally described: *V. rugosus* Baudelot and de Bonis, 1966, *V. priscus* de Bonis, 1973, *V. pannonicus* (Kretzoi, 1978), *V. autolensis* (Cuenca, 1985), *V. bacchius* (Martínez-Salanova, 1987), *V. elegans* Wu, 1993, *V. duplex* Ünay, 1994, *V. cristinae* Ruiz-Sánchez et al., 2012a and *V. ramblensis* Ruiz-Sánchez et al., 2012b. Apart from *V. cristinae* (MN5) and *V. pannonicus* (MN11), these species have been described from Lower Miocene localities (MN1–MN3). In the interval MN4–MN5 various authors have described material of the genus *Vasseuromys* without specific designation (Wu 1993, Aguilar & Lazzari 2006, Agustí et al. 2011). In the Upper Oligocene locality Bergasa (Ebro Basin), Lacombe (1988) cited *Ebromys* (*Vasseuromys*) *bergasensis*. So, the stratigraphic range of the genus is Upper Oligocene (MP30) to Upper Miocene (MN11).

Several genera of dormice from the Lower Miocene have been synonymized with *Vasseuromys*, among them *Ebromys* Cuenca, 1985 (see Álvarez-Sierra et al. 1991) and *Nievela* Daams, 1976 (see Agustí 1981). The presence of new forms of the genus *Vasseuromys* in the interval MN4–MN5 may indicate, according to some authors (Agustí et al. 2011), that other genera are synonyms too, like e.g. *Ramys* (Álvarez-Sierra & García-Moreno 1986). The general dental pattern of these new forms and that of

Table 4. Measurements in tenth of millimetres of the teeth of *Spermophilinus besana* from PF2. L = length; W = width; dp4 = fourth lower premolar-decidual; p4 = fourth lower premolar; m1,2 = first or second lower molar; m3 = third lower molar; P4 = fourth upper premolar; M1,2 = first or second upper molar.

Element	Parameter	n	min.	mean	max.
d4	L	3	11.8	13.2	14.3
	W	3	10.0	11.5	12.4
p4	L	1		16.4	
	W	2	13.9	14.3	14.8
m1,2	L	0	–	–	–
	W	2	14.2	15.7	17.3
m3	L	2	18.6	19.9	21.2
	W	2	17.9	18.1	18.3
P4	L	0	–	–	–
	W	1		12.1	
M1,2	L	4	13.0	14.7	15.6
	W	4	16.9	18.6	20.0

Ramys, seem to confirm the hypothesis pointed at by Agustí *et al.* (2011).

By size and morphology, the material from SA5 is very similar to the material described by Agustí *et al.* (2011) from SC 109 as *V. aff. multicrestatus*. The presence of a continuous endoloph in the M2 and almost continuous (the anteroloph connects at medium height with the protocone) in the M1, as well as a continuous lingual endolophid in the m1, 3 of the *Vasseuromys* from SA5 are very similar to the material from SC 109. The presence of a more developed lingual endolophid (complete) in the lower molars from SA5 and of a continuous endoloph in the M1,2, are differences as compared with the material of *V. cristinae* from its type locality, Pico de Fraile 2. Therefore, and hoping to obtain more material from this locality, we classify it as *V. aff. cristinae*.

Family Sciuridae Fischer, 1814

Genus *Spermophilinus* De Bruijn & Mein, 1968

Type species. – *Sciurus bredai* Von Meyer, 1848

Spermophilinus besana Cuenca, 1988

Figure 3O–S

Locality. – Pico de Fraile 2 (PF2).

Material. – 3 d4 (PF2-32, PF2-33, PF2-34); 1 p4 (PF2-35); 4 m1,2 (PF2-36, PF2-37, PF2-38, PF2-39); 2 m3 (PF2-40, PF2-144); 1 P4 (PF2-29); 5 M1,2 (PF2-26, PF2-27, PF2-28, PF2-30, PF2-31).

Measurements. – Table 4.

Remarks. – Several authors changed *besana* to *besanus* thinking it is an adjective. However, it is a Spanish substantive (*besana* = furrow) used by Cuenca (1988) in apposition and therefore *besana* is the correct form.

Kretzoi & Fejfar (2004) considered *Spermophilinus* to be a junior synonym of *Csakvaromys* Kretzoi, 1951. De Bruijn & Bosma (2012) preferred *Spermophilinus* for the sake of nomenclatorial stability. We refrain from taking a decision on this question, which is not fundamental in the context of this paper.

Description. –

d4. Outline triangular-cuneiforme. The posterior part is clearly broader than the anterior part. Protoconid, metaconid and hypoconid well developed and prominent. The entoconid does not stand out in the posterolophid (2), or it is nothing but a mere bulge (1). Anteroconulid visible and connected by a small crest to the protoconid. Of the transverse crests the posterolophid is the major one. The metalophid is reduced because protoconid and metaconid are very close. Ectolophid low. Sinusid very reduced.

p4. Outline subtrapezoidal. Posterior part broader than the anterior part. Protoconid, metaconid and hypoconid are the best developed and prominent cuspids. The entoconid is a slight thickening of the posterolophid. Metalophid short, connecting protoconid and metaconid. Ectolophid somewhat higher than in the d4, bordering a sinusid that is deeper than in the d4. Mesoconid absent. Posterolophid high and complete.

m1,2. Outline rhomboidal, with a rounded posterolingual corner. Protoconid, metaconid and hypoconid are the best developed and most prominent cuspids. Entoconid not thickened. Metalophid complete (2) or interrupted near the base of the metaconid (1). Ectolophid of medium height, with a rounded, not much developed, mesoconid. Posterolophid high and complete.

m3. Narrowed posteriorly. Protoconid, metaconid and hypoconid are the best developed and most prominent cuspids. The entoconid is a weak thickening of the posterolophid. Anteroconulid very small (1) and connected to the base of the protoconid, or absent (1). The anterolophid is straight, connected to the base of the protoconid. Metalophid short. Ectolophid of medium height, with a very obvious mesoconid that delimits a shallow, forked sinusid. Posterolophid high and complete.

P4. Outline subtriangular-subrounded. Anteroloph short and isolated, not connected to the protocone. Protocone, paracone and metacone are the only cusps. Protoloph

slightly oblique, metaloph and posteroloph strongly oblique. The degree of wear impedes to observe more details.

M1,2. Outline subrectangular. There are three main cusps: protocone, paracone and metacone. There are no conules, except for one specimen in which the end of the metaloph is inflated. The four transverse crests (anteroloph, protoloph, metaloph and posteroloph) are continuous. Anteroloph and posteroloph are low; the anteroloph lower than the posteroloph. Anteroloph low connected (2) or at medium height (1) to the base of the protocone. Protoloph slightly anterior and oblique. Metaloph oblique. In one of the specimens there is a small mesostyle.

Spermophilinus sp.

Locality. – Sancho Abarca 5 (SA5).

Material. – 1 lower molar (SA5-22).

Description. –

Lower molar. Only the central part is preserved. The central valley is formed by a big basin surrounded by continuous walls. In spite of being only a fragment, the protoconid, metaconid and hypoconid may be observed. The entoconid is not more than a reduced thickening of the posterolophid. Ectolophid high.

Discussion. – The genus *Spermophilinus* contains four species: *S. besana* Cuenca, 1988, *S. bredai* (von Meyer, 1848), *S. giganteus* De Bruijn et al., 1970 and *S. turolensis* De Bruijn & Mein, 1968. The first two species are known from the Lower and Middle Miocene (*S. besana* in MN4 and the lower part of MN5 and *S. bredai* from the upper part of MN5 to MN8) (Cuenca 1988); the other two are found in the Upper Miocene (De Bruijn 1999). The distinction between the two Aragonian species (*S. besana* and *S. bredai*) is difficult, and is linked to the size and to small morphological differences (Cuenca 1988).

The similarities and differences between *S. besana* and *S. bredai* were listed by Cuenca (1988, p. 86). Ziegler (2005) has shown that these morphological differences are difficult to use. Comparing with Cuenca (1988), by size and morphology, the material from PF2, resembles mostly Cuenca's *S. besana*, especially in the development of the mesoconid in the lower teeth. Whereas the mesoconid in all lower teeth of *S. bredai* is more or less thick and delimits a forked sinusid, in *S. besana* from PF2, some elements (p4) do not have a mesoconid, and in others (m1,2) the development of that accessory cusp is less than in *S. bredai* from the Miocene of Calatayud-Montalbán. However, the presence of an anteroloph, which is connected, either low or at medium height, to the protocone in the M1,2, is a morphol-

ogy that is characteristic of *S. bredai* according to Cuenca (1988).

The morphological and biometrical analysis of the material of the Aragonian populations of the genus *Spermophilinus* seems to demonstrate gradual changes in the morphology and size of the two species (Cuenca 1988). Those changes are a general size increase, a reduction of the length of the crests in the upper molars (anteroloph and posteroloph) and an increase of the complexity of the dental pattern of the lower molars (mesoconid larger, forked sinusid, metalophid longer). The size of the material of *Spermophilinus* from PF2 allow us to tentatively assign the material to *S. besana*, although the development of the anteroloph in the upper molars and of the metalophid in the lower molars indicate a morphologically more derived population than those from the Lower Aragonian.

The specimen from SA5 is characterized by the presence of a big central basin with smooth surface, surrounded by a continuous wall. That distinguishes *Spermophilinus* from the other Sciuridae (Cuenca 1988), but this fragment cannot be classified more precisely.

Order Erinaceomorpha Gregory, 1910

Family Erinaceidae Fischer, 1814

Genus *Galerix* Pomel, 1848

Type species. – *Galerix exilis* (de Blainville, 1839).

Galerix cf. *exilis*

Figure 5A–D

Locality. – Pico del Fraile 2 (PF2).

Material and measurements ($L \times W1 \times W2$ for M1; $L \times W$ for the rest). – 1 p2 (PF2-46) (16.0 × 8.5); 1 p3 (PF2-47) (14.3 × 8.6); 2 M1 (PF2-43, PF2-44) (22.5 × 26.3 × 29.1; – × 26.8 × –).

Description. –

p2. The tooth is labiolingually compressed with a single central cusp. The occlusal outline is rather elliptical. There is no basal cingulum. Although only the crown is preserved, it is evident that the tooth was originally double-rooted. At the posterior extreme, there is a tiny elevation of the surface. There is no elevation at the anterior margin.

p3. The tooth is quite elliptical in occlusal view, except for the posterior margin, which is rather straight. The heel at this posterior side bears a tiny cusp. The main cusp occupies a central position. No roots are preserved.

M1. The tooth has a rather rectangular occlusal outline, but the posterolabial corner is somewhat elongated. The anterior, labial and posterior margins of the base are surrounded by a well-defined cingulum. The metacone, the paracone and the protocone have a similar height. In the less worn specimen (PF2-44) it is evident that these main cusps are quite elevated. There is a short postprotocresta connecting the protocone with the metaconule. The metaconule is not connected to the posterolabial corner, and consequently it does not interrupt the posterior basal cingulum. The anterior arm of the metaconule is connected to the anterior part of the metacone base. The protoconule is an elevation of the preprotocresta, separated from the paracone by a narrow notch. The lingual root is broad, with an oval section. The two labial roots have narrower circular sections.

Discussion. – The ascription of the material to the genus *Galerix* is based on the morphology of the M1, with a reduced transversal elongation and the posterior arm of the metaconule not reaching the posterolabial corner of the tooth (Van den Hoek Ostende 2001). The protocone connected to the metaconule adds some extra weight to the generic ascription. However, it must be noticed that some Miocene galericini combine this trait with an elongated paralophid of the p4, typical of *Parasorex* and *Schizogalerix* (Prieto *et al.* 2012), so this character is not always relevant. The p3 is shorter than p2, different to the condition found in *Parasorex*, *Schizogalerix* and *Deinogalerix* (Van den Hoek Ostende 2001), but similar to the equivalent elements of *Galerix* sp. from Petersbuch 68 (Prieto & Rummel 2009, fig. 2.E). However, this character does not seem to be so much recurrent in *Galerix*, as evidenced by *G. exilis* from Sansan (Engesser 2009, fig. 37a, b).

The ascription at species level is somewhat more complicated due to the high morphological variation within the genus *Galerix* (Van den Hoek Ostende 2003).

Unfortunately, most of the diagnostic elements (P3, M2, p4, m1 and m2) are missing in PF2. Thus, the specific identification of this material is only based on the two available M1's. The measurements indicate that the species present in PF2 is clearly smaller than *G. remmerti* from Ramblar 1 (Van den Hoek Ostende 2003) and *G. exilis* from most of the Aragonian localities of the Calatayud-Teruel Basin (De Jong 1988). Only Las Planas 5B has provided material of *G. exilis* of similar size in both length and width of the M1. According to Van den Hoek Ostende & Doukas (2003), *G. symeonidisi* is on average smaller than *G. exilis*. However, in this species often lacks the protocone-metaconule connection, a trait present in both M1's from PF2. Thus, we tentatively ascribe this material to *G. cf. exilis*. The presence of *G. symeonidisi* in this locality, however, cannot to be completely discarded.

Order Soricomorpha Gregory, 1910

Family Soricidae Fischer, 1814

Subfamily Crocidosoricinae Reumer, 1987

Tribe Myosoricini Kretzoi, 1965

Genus *Miosorex* Kretzoi, 1959

Type species. – *Miosorex grivensis* (Deperet, 1892).

Miosorex sp.

Figure 5E–I

Locality. – Pico del Fraile 2 (PF2).

Material and measurements. – 1 I1 (PF2-149) (L: 15.0; LT: 8.4; H: 9.7), 1 P4 (PF2-54) (W: 10.8; PE: 8.3; LL: 8.6; BL: 11.5), 1 M1 (PF2-150) (AW: 11.9; PE: 9.3; BL: 11.3), 1 i1 (PF2-51) (L: 29.0), 1 m2 (PF2-48) (L: 13.8; TRW: 7.0; TAW: 7.3).

Description. –

I1. The root is shorter than the crown. The apex is neither pointed nor fissident. The talon is well developed. The dorsal margin is rather curved. The posterior margin of the crown is not preserved in the only specimen available.

P4. The tooth has a mesio-distally compressed aspect. The paracone is the most prominent cusp of the tooth. The parastyle is connected to the protocone by means of a continuous ridge. The hypocone is not discernible as a single cusp, but there is a lingual ridge in its place connecting with the posterior cingulum. The posterior emargination is not much pronounced.

M1. The only available specimen is broken, and it lacks the posterolingual part. Thus, the size and the morphology of the hypoconal flange and the hypocone are unknown. The general aspect in occlusal view is rather quadrangular. The ectoloph is quite asymmetric. The metacone is higher than the paracone. The protocone is not connected to any other cusp. The anterior arm of the protocone vanishes immediately in front of the base of the paracone. The posterior arm of the protocone neither reaches the base of the metacone nor the hypocone. The labial half of the posterior margin is occupied by a well-defined cingulum.

i1. The lower incisor is tricuspluate. There is a thick curved cingulum at the base of the crown. The root is not preserved in the only specimen found. The crown is rather long.

m2. The trigonid and the talonid have a similar size. The protoconid is the highest cup. The metaconid is a slightly lower than the protoconid. There is a prominent buccal cingulum at the base of the paralophid. The lingual opening of

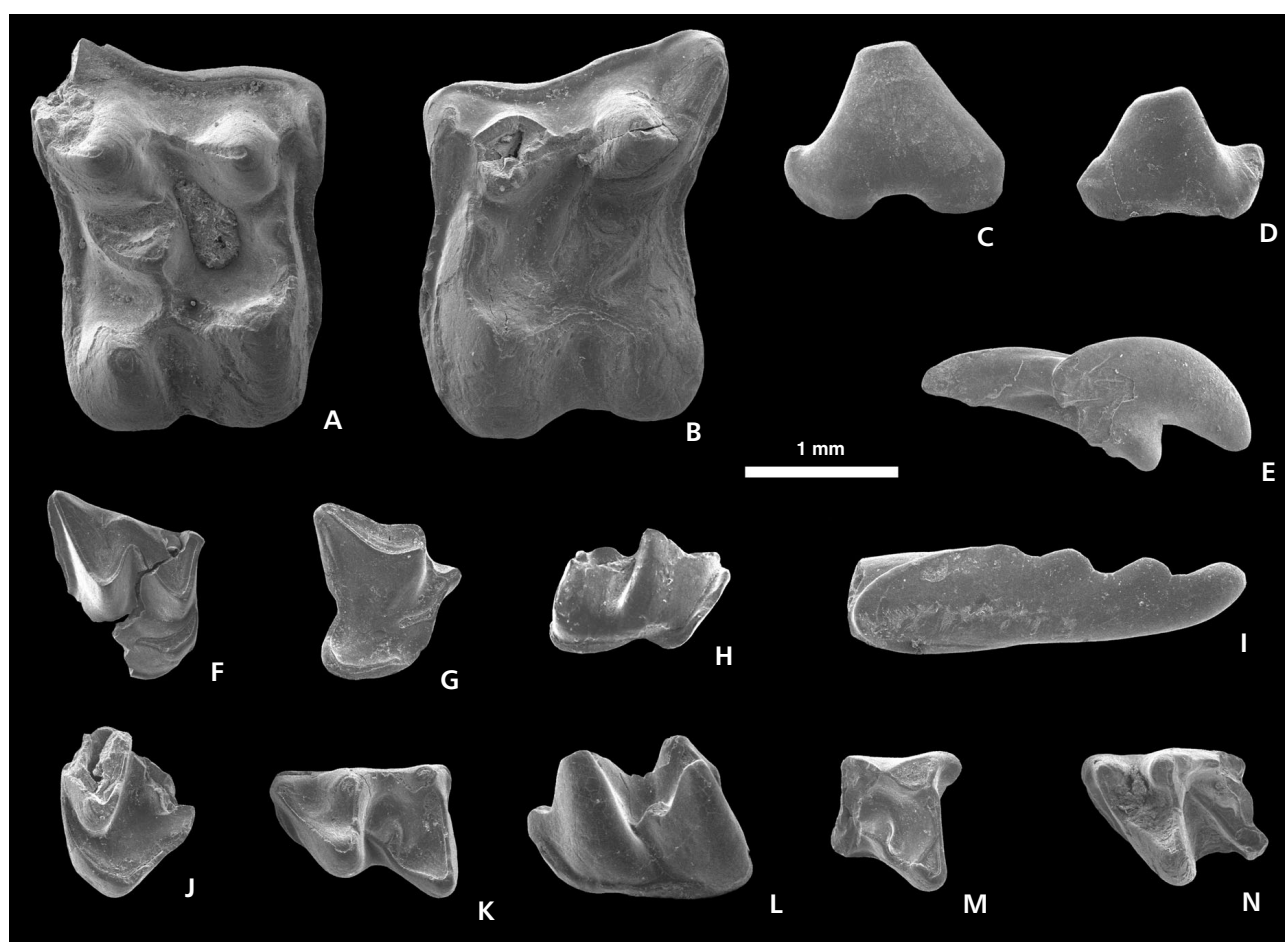


Figure 5. Insectivores from the locality Pico de Fraile 2 (Ebro Basin, Spain). • A–D –*Galerix* cf. *exilis*; A – right M1, PF2-44; B – left M1, PF2-43; C – right p2, PF2-46; D – left p3, PF2-47. • E–I –*Miosorex* sp.; E – right I1, PF2-149; F – right M1, PF2-150; G – right P4, PF2-54; H – right m2, PF2-48; I – right i1, PF2-51. • J–M –*Myxomygale* sp.; J – left M1, PF2-55; K – left m1 (occlusal), PF2-45; L – left m1 (labial), PF2-45; M – left talonid of m1, PF2-53; N – left m2, PF2-57. Scale: 1 mm.

the trigonid valley is not much developed. The entoconid is more developed than the entostylid. There is a small notch between the entoconid and the entostylid. The oblique cristid finishes right in the middle of the posterior face of the trigonid.

Discussion. – Unlike the Plio-Pleistocene shrews, most of the soricids from the Late Oligocene to the Early-Middle Miocene show very similar molar patterns. Due to the conservative morphology of their posterior dentition, the main differences within this group are usually concentrated in the antemolars and incisors, and thus complete mandibles or maxillaries are needed for the identification of the species. In the assemblage from PF2, only a few disarticulated dental elements were recovered. Consequently, the number of upper and lower antemolars, one of the most diagnostic characters, is unknown. Although the soricid dental elements might indeed belong to more than one species, in the absence of repeated elements and their relative size, we

have decided to include them all under the same identification.

The morphology of the I1 is typical of the crocidorocines (Furió *et al.* 2007). The morphology of the P4, mesiodistally compressed and without hypocone, differentiates the genus *Miosorex* from *Lartetium* (Hugueney *et al.* 2012). In fact, the m2 recovered is very similar in size to that of *M. desnoyersianus* from Sansan (Baudelot 1972) and the i1 is also tricusculate, different from the bicusculate i1 of *Lartetium prevostianum*, according to Engesser (2009). However, the crown of the lower incisor from PF2 is longer than that of those species and its cusps are not tilted anteriorly as in *M. desnoyersianus*. Actually, this lower incisor is extremely similar in both length and morphology to that of *Miosorex* sp. 1 from Sandelzhausen (MN5) figured in Ziegler (2000, fig. 103). The morphology of the broken M1 does not provide much more information because the hypoconal flange is missing. Thus, the taxonomic identification is better left in open

nomenclature as *Miosorex* sp. pending further material from the nearby area.

Family Talpidae Fischer, 1814
Subfamily Talpinae Fischer, 1814
Tribe Urotrichini Dobson, 1883

Genus *Myxomygale* Filhol, 1890

Type species. – *Myxomygale antiqua* Filhol, 1890.

Myxomygale sp.

Figure 5J–M

Locality. – Pico del Fraile 2 (PF2).

Material and measurements. – 1 p2? (PF2-52), 2 m1 (PF2-45) ($13.9 \times 8.0 \times 9.7$) (PF2-53) ($- \times - \times 10.4$), 2 m2 (PF2-57) ($- \times 10.0 \times -$) (PF2-153), 2 M1? (PF2-55) (PF2-151), 1 M2? (PF2-154), 1 M3 (PF2-56).

Description. –

p2?. The tooth is labiolingually compressed. There is a central undulated cristid crossing the tooth from its anterior till its posterior extreme. The lingual face is concave whereas the labial one is convex. There is a strong cingulum forming the posterolingual base of the tooth. The tooth has two roots.

m1. There is only one complete m1 (PF2-45). The other specimen (PF2-53) preserves only the talonid. In the complete specimen, the talonid is much wider than the trigonid. The protoconid is the highest cusp. Paraconid, metaconid and entoconid are placed in a straight line at the lingual margin of the tooth. The hypolophid is also completely straight and perpendicular to the lingual face. The protoconid makes a slight inflexion, so the metaconid is somewhat less advanced than the protoconid. The re-entrant valley is not much pronounced. There is an intermediate cuspule at the oblique cristid with a small branch oriented towards the talonid basin. The oblique cristid is displaced labially with respect to the middle of the posterior face of the trigonid. There is a basal cingulum on the labial face, from beneath the paraconid until below the middle of the oblique cristid. The entostylid is less protruding in the complete specimen (PF2-45) than in the other one (PF2-53).

m2. Only two incomplete specimens have been found (PF2-57, PF2-153). The trigonid is mesiodistally compressed. The paraconid and the metaconid are closer to each other than they are to the protoconid. There is a metacristid, posterior to the metaconid. A small secondary ridge is dis-

cernible midway the oblique cristid, oriented towards the center of the talonid basin. The oblique cristid ends lingually, close to the base of the metaconid. The re-entrant labial valley is much pronounced. A well-defined labial cingulum forms the base of the tooth from below the paraconid till beneath the reentrant valley. The entostylid protrudes over the occlusal outline posteriorly to the entoconid.

M1?. There are no complete specimens, and only two lingual fragments (PF2-55, PF2-151) are preserved. The endoloph is asymmetric. The protocone is the highest lingual cusp. There is a small protoconule anteriorly to the protocone. Due to the wear of both specimens, no other lingual cusp is discernible. The anterior arm of the protoconule does not connect to the base of the paracone, but it extends until the anterior base of the tooth. Neither the mesostyle nor any other labial cusp is discernible in either specimen.

M2?. Only the lingual part is preserved in PF2-154. The protocone is the highest cusp. Apparently, there is no protoconule. The hypocone is discernible as a slight elevation of the endoloph posterior to the protocone.

M3. The only specimen available (PF2-56) lacks the anterolabial corner. The paracone is the highest cusp. The metacone is somewhat lower than the paracone, but higher than the protocone. The protocone is the only discernible lingual cusp. The endoloph extends from the basal midpoint of the anterior margin until the base of the metacone. The mesostyle is not divided.

Discussion. – The material of Talpidae from PF2 is certainly scanty. However, the similar and proportional size of different dental elements, and the presence of a repeated peculiar structure in the lower molars lead to assume that they all belong to the same species of talpid. The diversity of Early and Middle Miocene Talpidae in Spain is rather poor compared with countries like Germany or Austria (Ziegler 2006, Furió *et al.* 2011). Up to date, only five different genera of moles have been reported from the Ramblian and Aragonian (Early-Middle Miocene) sediments from Spain: *Desmanella*, *Desmanodon*, *Myxomygale*, *Proscapanus* and *Talpa* (Van den Hoek Ostende & Furió 2005). In the following lines we carry out a thorough analysis of the material from PF2 to elucidate which of these genera can be ruled out and which others cannot.

The most frequent talpid in the Early and early Middle Miocene in Spain is the genus *Desmanodon*, which has been found in several localities of the Daroca-Calamocha area (Van den Hoek Ostende 1997). The ascription of the material from PF2 to *Desmanodon* is discarded because in the latter genus the endolophs of the upper molars are connected to the base of the paracone, in contrast with the

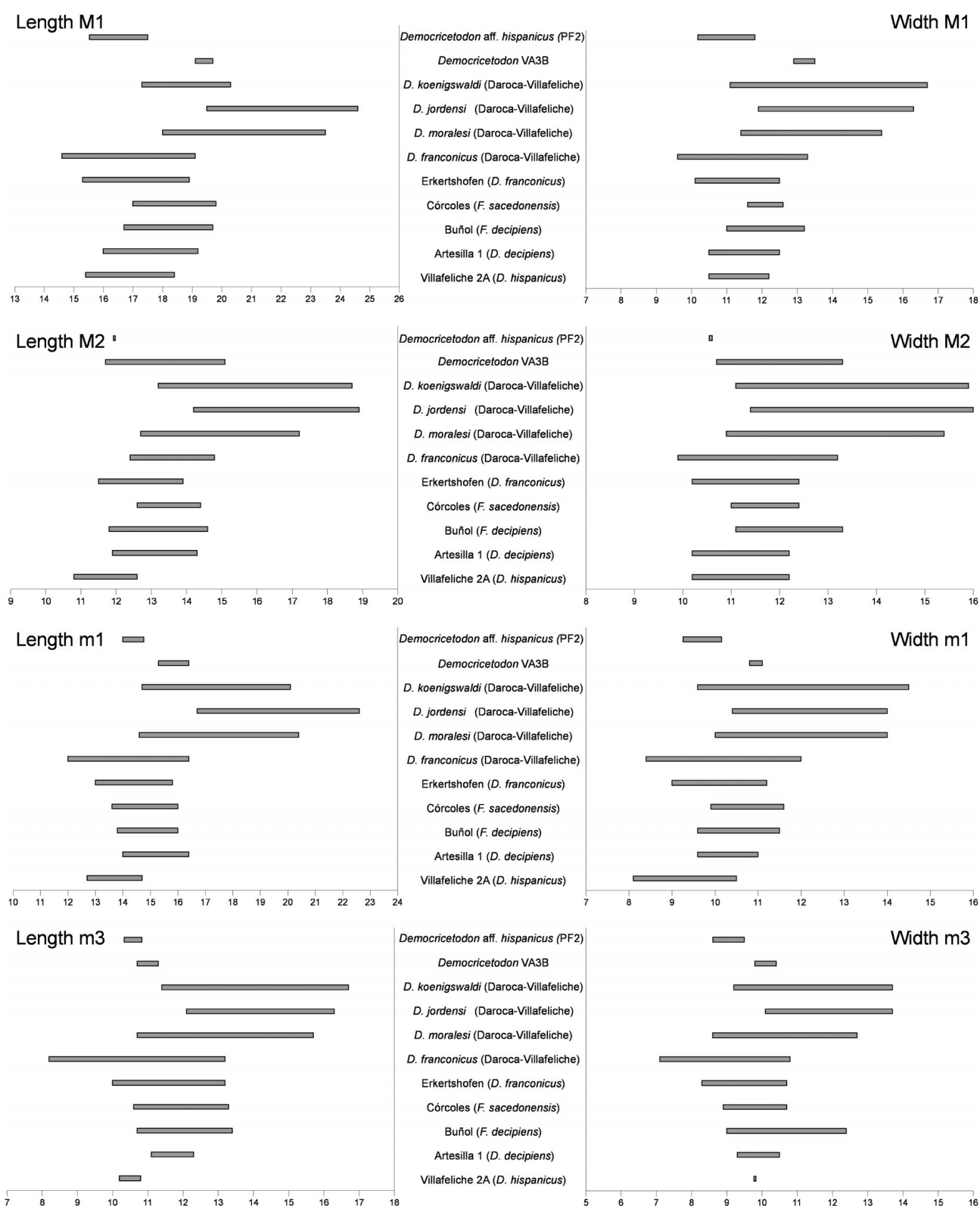


Figure 6. Ranges of variation of length and width (tenths of millimeters) of the lower (m1, m3) and upper molars (M1, M2) of *Democricetodon hispanicus* from VL2A and *Fahlbuschia decipiens* from BU *sensu* Freudenthal & Daams (1988), *Democricetodon franconicus* from Erkerthofen *sensu* Fahlbusch (1966), *Democricetodon franconicus-moralesi-jordensis-koenigswaldi* from Daroca-Villafeliche, *Democricetodon decipiens* from Artesilla 1 and *Democricetodon* from VA3B *sensu* Van der Meulen *et al.* (2004), *Fahlbuschia sacedoniensis* from Córcoles *sensu* Freudenthal (2005) and *Democricetodon aff. hispanicus* from PF2 (this paper).

condition observed in the material studied here, where this ridge extends till the midpoint of the anterior margin. Furthermore, the oblique cristid in *Desmanodon* is connected to the central point of the posterior face of the trigonid, whereas in the m2 from PF2 it reaches the metaconid. Similarly, *Desmanella* usually shows inflated lingual cusps in the upper molars and the re-entrant labial valley is less pronounced than it is in the material from PF2, so its presence in this locality is also rejected. The presence of a meta-cristid in the m2 pleads against its ascription to the genus *Talpa*. Finally, *Proscapanus* shows similar oblique cristids in its second lower molars, but not in its first lower ones, where this element extends lingually to join the metacristid (Ziegler 2003). Moreover, in its upper molars only the protocone is discernible, whereas in PF2, the labial fragments of the upper molars show more than one cusp. Finally, the m1 (the only measurable element found in PF2), is smaller than in any other species of *Proscapanus* known so far.

Consequently, we find in the genus *Myxomygale* the only candidate combining all the characters mentioned above: 1 – discernible lingual cusps in the upper molars; 2 – endoloph of the upper molars reaching the midpoint of the anterior margin; 3 – undivided mesostyle in M3; 4 – oblique cristid connected to the metacone in m2 but ending more labially in m1; 5 – presence of a metacristid in m2; 6 – small size. With respect to the last character, only the m1 is comparable, because no other talpid element from PF2 is complete. Unfortunately, no m1's of *M. engesseri* were recovered from the Greek locality of Aliveri (Doukas 1986), so this species cannot be compared with. Within the rest of Miocene species of *Myxomygale*, the m1 from PF2 is just a bit smaller than that of *M. gracilis* from Petersbuch 10 (Ziegler 2003) and those of *M. hutchisoni* from the German localities of Petersbuch 2 and Sandelzhausen (Ziegler 1985, 2000). However, the m1 from PF2 is extremely similar in size to *M. hutchisoni* from Oberdorf 4 (Ziegler 1998) and *M. minor* from Merkur-Nord (Van den Hoek Ostende & Fejfar 2006). It must be noticed that the first lower molars from PF2 resemble these two latter cases also in morphology by presenting a small ridge towards the talonid basin in their oblique cristids (Ziegler 1998, fig. 3.1; Van den Hoek Ostende & Fejfar 2006, fig. 5.4), a character never reported in any other talpid species as far as we know. The ascription to the species *M. minor* could get some more weight considering the possibly double-rooted p2, something hitherto only documented in this species within the genus (Van den Hoek Ostende & Fejfar 2006). The identification of this element from PF2, however, is premolar and the exact number of roots in lower premolars is actually unknown in several species of *Myxomygale*. Therefore, the identification has been left at the genus level because the sample is too small and the measurements are not enough for the specific discrimination.

Biostratigraphy

Figure 7 contains information on the stratigraphical distribution of the taxons described in the localities PF2 and SA5 and of related taxons. The locality PF2 contains *Eumyarion* cf. *weinfurteri*, *Megacricetodon* aff. *primitivus*, *Democricetodon* aff. *hispanicus*, *Microdyromys* cf. *koenigswaldi*, *Microdyromys* cf. *remmert*, *Pseudodryomys* cf. *ibericus*, *Spermophilinus besana*, *Galerix* cf. *exilis*, *Miosorex* sp. and *Myxomygale* sp. SA5 contains *Megacricetodon* sp., *Democricetodon* or *Fahlbuschia* sp., *Spermophilinus* sp. and *Vasseuromys* aff. *cristinae*.

The presence in both localities of a representative of the genus *Megacricetodon* permits to place them in the Aragonian or in the Lower Vallesian. The *Megacricetodon* from PF2 is similar to the one described by Ruiz-Sánchez (1999) from Morteral 22, of which the age has been established at the limit between units MN4 and MN5 (Ruiz-Sánchez *et al.* 2009).

The presence of *Megacricetodon* serves to consider grosso modo the age of the studied localities, and the presence of the accompanying taxons in PF2 permits a more detailed assignment. In this respect, the relevant taxons are *Spermophilinus besana* and especially *Microdyromys* cf. *remmert*.

By size and morphology the population of *Spermophilinus besana* from PF2 may be placed in the younger part of the time interval of that species. Cuenca (1988) described the presence of this taxon in the localities Villafeliche 2A (local zone B), Vargas 1A (local zone C), Olmo Redondo 5 (local zone C), Olmo Redondo 8 (local zone C) and Olmo Redondo 9 (local zone D), or, in other words, a range of distribution between the base of the Lower Aragonian (local zone B) and the middle part of the Middle Aragonian (local zone D). The biometrical and morphological details of the population from PF2 fit best with what Cuenca (1988) described in the populations from local zone D of the Middle Aragonian.

The presence of *Microdyromys* cf. *remmert* delimits the position of PF2 even more. *Microdyromys remmert* was described by García-Paredes *et al.* (2010) from the localities Villafeliche 4A, Villafeliche 4B, Valdemoros 3D, Valdemoros 3B, Vargas 7, Vargas 8B, Vargas 8C, Valdemoros 6A, Valdemoros 3E and Valdemoros 3F. The range of these localities comprises the local zones Dc and Dd. The morphology described by García-Paredes *et al.* (2010) in the material from the localities of the type area of the Aragonian presents a certain degree of variation that permits these authors to distinguish the age of the localities in question. The morphology of the p4 of *Microdyromys* cf. *remmert* from PF2, is very similar to that of the oldest populations of the species, and suggests that PF2 may be placed in the local zone Dc.

Regarding to the insectivores, in Spain, the latest part of MN4 and the beginning of MN5 is characterized by a gradual replacement of *G. symeonidisi* by *G. exilis* according to

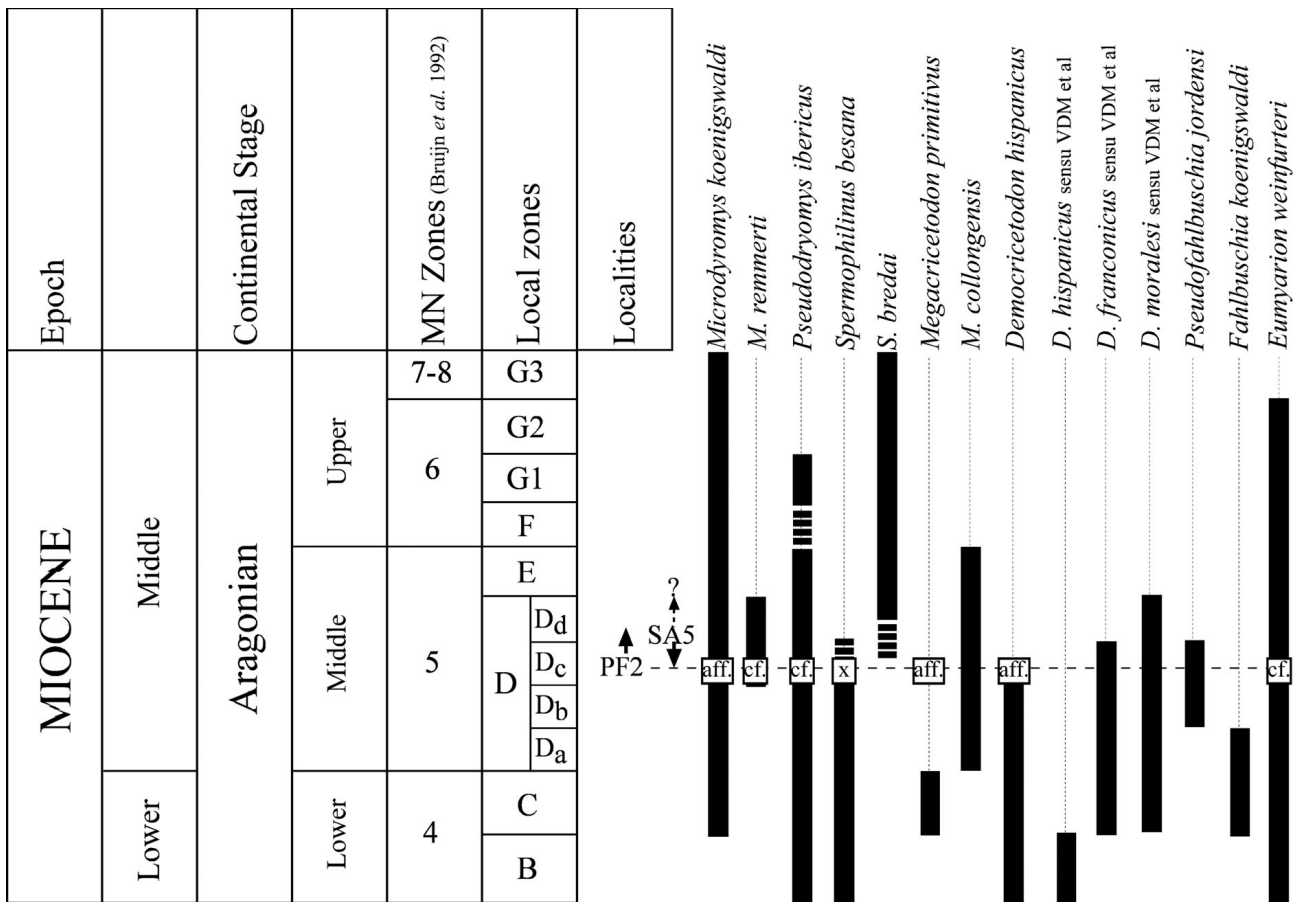


Figure 7. Distribution chart of the rodent studied in this paper and of related species according to the revision from Sesé (2006), and Cuenca (1988) and De Bruijn (1999) (*Sperophilinus*), Freudenthal & Daams (1988) (*Democricetodon*, *Fahlbuschia* and *Pseudofahlbuschia*), Daams & Freudenthal (1988) (*Megacricetodon*), Van der Meulen et al. (2004) (*Democricetodon hispanicus-franconicus-moralesi*) and Kálin (1999) (*Eumyarion*). *Sensu* VDM et al. – according to Van der Meulen et al. (2004).

Van den Hoek Ostende & Doukas (2003). The extinction of *G. symeonidisi* in the Daroca-Calamocha area seems to occur close to the Db-Dc (Van der Meulen et al. 2012) local zonation boundary (Van den Hoek Ostende & Doukas 2003), *G. exilis* thus being the only *Galerix* species present in the younger Aragonian small mammal assemblages. However, this genus is really scarce or nearly absent in the localities of the local zone Dc from Daroca-Calamocha, the interval represented in Pico del Fraile 2. Thus, the presence of *G. symeonidisi* in this locality cannot to be completely ruled out. At the genus level, the association of the erinaceid *Galerix* and the soricid *Miosorex* is very characteristic in the Middle Miocene small mammal assemblages from Spain, according to the data compiled by Van den Hoek Ostende & Furió (2005).

It is worth mentioning that the presence of the talpid *Myxomygale* in Spain had been reported only once before in the literature, from the MN3 locality of Ramblar 1 (Van den Hoek Ostende 2003). However, the occurrence in PF2 is much younger. In the German fossil record, *Myxomygale* has a rather continuous record (at least once occurrence per

MN Unit), ranging from MN 1 to MN 5 (Ziegler 2006). Therefore, the absence of *Myxomygale* in most of the Spanish localities in between is more likely indicative of a transient genus that only reached southern latitudes when environmental conditions were favourable.

The situation of SA5 is much more difficult to establish than PF2. However, on the basis of the stratigraphy and paleomagnetic data, SA5 is likely similar in age to PF2, being the record of *Vasseuromys* in line with correlation to zone Dc.

The location of the fossil localities PF2 and SA5 in the middle part of chron C5Br is entirely consistent with their biostratigraphic attribution to local zone Dc, keeping in mind the magnetobiostratigraphic correlation of the Aragonian in the Calatayud-Daroca Basin (Daams et al. 1999).

Conclusions

In the Unit 5 of the Tudela Formation two new localities (PF2 and SA5) have been located, whose fauna of rodents and insectivores permits an assignment to the Aragonian.

Regarding the rodents, in PF2 we found three representatives of the family Cricetidae, four of the Gliridae and one of the Sciuridae. Moreover, three species of insectivores are present, too. In SA5 we found two Cricetidae and one Sciuridae.

The *Megacricetodon* from PF2 presents morphology intermediate between the populations of the genus of the Lower and the Middle Aragonian.

The association of the erinaceid *Galerix* and the soricid *Miosorex* is characteristic from the Middle and early Late Miocene.

The presence of the genus *Myxomys* in the locality PF2 represents the first occurrence of this taxon in Aragonian deposits from Spain.

The presence, in PF2, of *Microdyromys* cf. *remmert* and *Spermophilinus besana* permits a detailed biostratigraphic assignment to local zone Dc; for SA5 this is more difficult, due to the poor material available.

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