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CRICETIDAE (RODENTIA, MAMMALIA) FROM THE EARLY MIOCENE SITE OF ELS CASOTS (VALLÈS-PENEDÈS BASIN, CATALONIA)

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Abstract: Els Casots is an extremely rich early Miocene site located in the Vallès-Penedès Basin (Catalonia, Spain) that has provided both micro- and macrovertebrates. However, the small mammals have been poorly studied. In this work we describe the cricetid fauna from els Casots and provide further insights into the chronology of the site. The cricetids are very common and include the species *Megacricetodon primitivus* and *Democricetodon hispanicus*. A second, larger-sized *Democricetodon* species is also represented by just one molar. The presence of *M. primitivus* together with the eomyid *Ligerimys ellipticus* indicates a correlation to zone MN 4 and to the local zone C of the Calatayud-Montalbán Basin (Aragón, east-central Spain), the type area of the Aragonian mammal age. This is further supported by the presence of two different *Democricetodon* species. A correlation to the local subzones of that area is attempted, but unfortunately the cricetid succession is not the same in both basins. However, the fact that *L. ellipticus* is the only eomyid species present at els Casots would indicate that this site is somewhat younger than other MN 4 localities from the Vallès-Penedès, where this species coexists with its ancestor *Ligerimys florancei*.

Key words: Cricetidae, Rodentia, *Megacricetodon*, *Democricetodon*, biostratigraphy, early Miocene, Catalonia, Iberian Peninsula

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Introduction

The Vallès-Penedès Basin (Catalonia, Spain) is a reference area for the study of the Miocene terrestrial vertebrate faunas of Western Europe. Earliest findings date back to the late 19th century, starting with the discovery of a few mammal remains in the lignite mines of la Fontsanta, in the town of Subirats (Almera 1898, Crusafont et al. 1955). In the following century, especially after the 1940s, the Miocene outcrops of this basin were systematically surveyed, resulting in the discovery of hundreds of new sites and the collection of tens of thousands of specimens (for a historical review see Casanovas-Vilar et al. 2016a). Eventually, even a land mammal age, the Vallesian, was defined on the basis of the late Miocene record of the Vallès-Penedès Basin and was successfully applied to other areas of the Old World (Crusafont Pairó 1950). Recently, the middle and late Miocene records of the basin have been intensively studied and most of the major sites have been correlated to detailed local magnetostratigraphical sections that allow for a high-resolution chronology (Casanovas-Vilar et al. 2016a, b). In comparison, the early Miocene part of the record has been studied very little. In the Vallès-Penedès Basin the early Miocene is represented by about 20 sites that comprise the Ramblian (MN 3) and early Aragonian ages (MN 4; Casanovas-Vilar et al. 2011a, 2016a). Many of these sites were already reported by Crusafont et al. (1955) in a lengthy monograph on the early Miocene successions of the area and their mammal fauna. The early Miocene sites, particularly the older ones, are very poor in comparison with the younger ones from the same basin. In addition, their correlation is based entirely on biostratigraphy (Agustí et al. 1985, Casanovas-Vilar et al. 2011a, 2016a).

In the recent years there has been a renewed interest in this part of the record, with the sampling of some of the classical sites and ongoing magnetostratigraphical studies. However, these new field campaigns have confirmed that early Miocene sites of the Vallès-Penedès are indeed poor. Els Casots site, discovered in 1989, is an exception to this pattern. It is located in the town of Subirats (Alt Penedès, Barcelona), just a few hundred meters away from the now abandoned lignite mines that provided the first vertebrate findings in the late 19th century. After five field campaigns during the 1990s more than a thousand remains were

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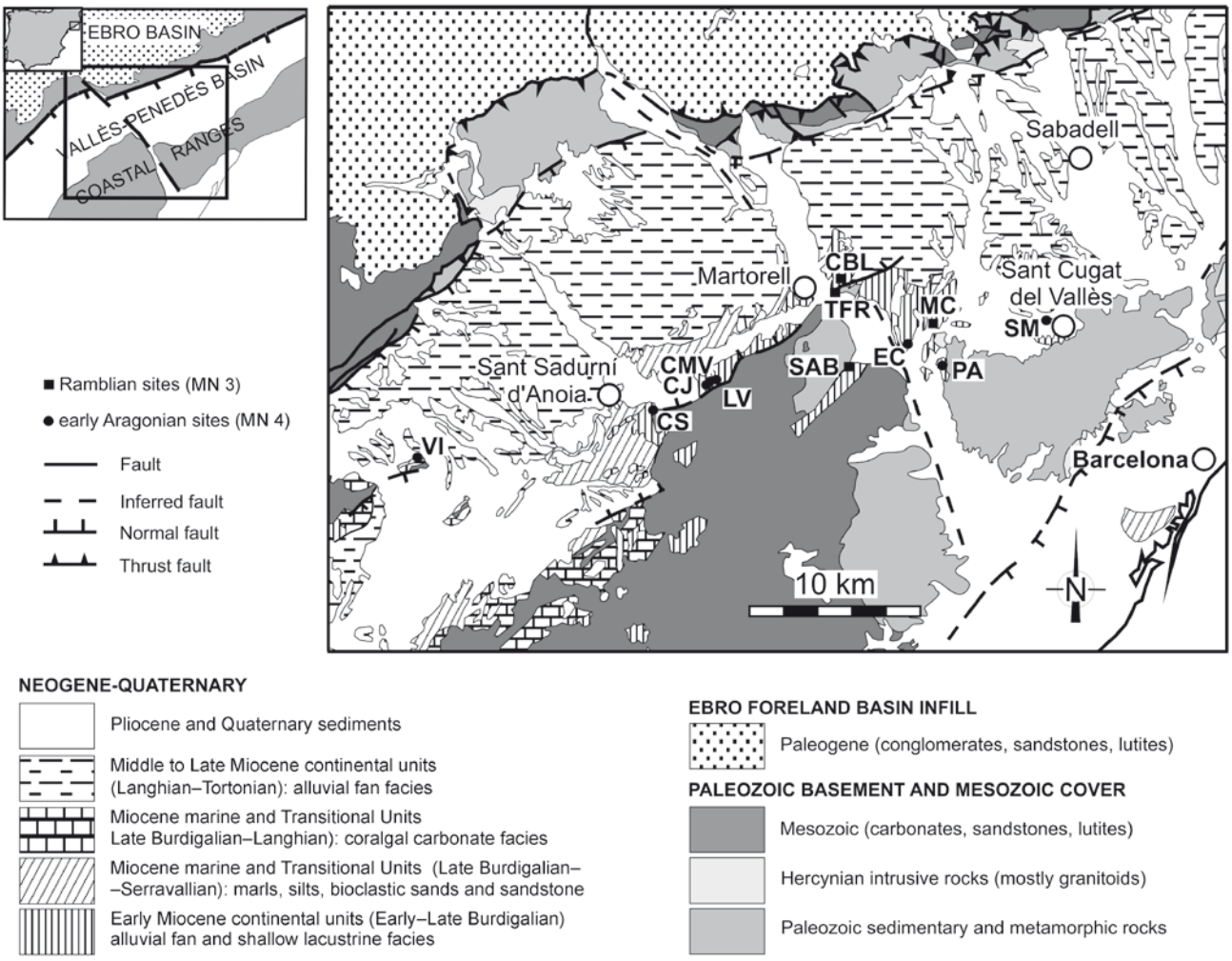


Text-fig. 1. Geographical location and simplified geological map of the Vallès-Penedès Basin indicating the main early Miocene mammal localities (modified from Casanovas-Vilar et al. 2016a). Locality acronyms are as follows: CBL = La Costablanca; CJ = Can Julià; CMV = Can Martí Vell; CS = els Casots; EC = El Canyet; LV = Les Cases de la Valenciana; MC = Molí de Can Calopa; PA = Escletxes del Papiol; SAB = Sant Andreu de la Barca; SM = Sant Mamet; TFR = Turó de les Forques; VI = Vilobí del Penedès.

collected, thus this site is comparable to other "classical" sites of the basin, such as Can Llobateres (Moyà-Solà and Rius Font 1993). The recovered material includes fishes, reptiles, birds and micro- and macromammals (Moyà-Solà and Rius Font 1993, Casanovas-Vilar et al. 2011b). To date, only a small part of the fossils has been prepared and studied in detail, particularly the artiodactyls (Pickford and Moyà-Solà 1994, 1995, Duranthon et al. 1995, Van der Made 1997, Orliac 2006, Alba et al. 2014), but resulting in the description of two new species, the suid *Eurolistriodon adelli* Pickford et Moyà-Solà, 1995 and the palaeomerycid *Ampelomeryx ginsburgi* Duranthon, Moyà-Solà et Köhler, 1995. More recently, the equid *Anchitherium* von Meyer, 1844 was first reported from the site (Rotgers and Alba 2011) and the cranial remains of the small crocodilian *Diplocynodon ratelii* Pomel, 1847, which is particularly abundant, were described (Díaz Aráez et al. 2017). The rest of the large mammal fauna, which amongst others includes several carnivores (amphycionids, felids, hyaenids), and at least two species of rhinocerotids and proboscideans (gomphotheres and deinotheres) has been the subject of only preliminary reports (Moyà-Solà and Rius Font 1993, Casanovas-Vilar et al. 2011a). As far as small mammals are concerned, Aldana Carrasco (1992) described the sciurid rodents and Agustí and Llenas (1993) provided a brief account of the remaining rodent fauna with succinct descriptions but no figures. The updated faunal list (Casanovas-Vilar et al. 2011b) shows a very diverse rodent fauna that includes two species of sciurids (*Atlantoxerus idubedensis* Cuenca Bescós, 1988, *Heteroxerus rubricati* Crusafont, Villalta et Truyols, 1955); eight glirids (*Glirudinus modestus* (Dehm, 1950), *Microdyromys* sp., *Muscardinus* sp., *Peridyromys murinus* (Pomel, 1853), *Pseudodryomys ibericus* De Bruijn, 1966, *Simplomys julii* (Daams, 1989), *Simplomys simplicidens* (De Bruijn, 1966), *Bransatoglis* sp.); the eomyid *Ligerimys ellipticus* Daams, 1976; and three cricetids (*Democricetodon hispanicus* Freudenthal, 1967, *Democricetodon* sp. 2, *Megacricetodon primitivus* (Freudenthal, 1963)). Els Casots has been correlated to the MN 4 (early Aragonian; Agustí and Llenas 1993, Casanovas-Vilar et al. 2011a, b, 2016a) because of the presence of the cricetids *Megacricetodon* and *Democricetodon*. The occurrence of the tragulid

Dorcatherium Kaup, 1833 and the bovid *Eotragus* Pilgrim, 1939, which were first recorded within this zone in Western Europe (Agustí et al. 2001), further supports this correlation. In addition, the coexistence of *Megacricetodon primitivus*, *Democricetodon hispanicus* and *Ligerimys ellipticus* (although very rare) is characteristic of local biozone C of the Calatayud-Montalbán Basin (see Daams et al. 1999, Van der Meulen et al. 2012), thus els Casots has been also tentatively correlated to this zone (Casanovas-Vilar et al. 2011a, b, 2016a, Jovells-Vaqué et al. in press).

Cricetid rodents are of the uttermost importance for the correlation of Miocene sites, being the basis for regional and local biostratigraphical scales. In this work, we describe the dental material of the cricetids from els Casots and further provide some new insights into its age. In addition, two partial skulls of the cricetid *Democricetodon hispanicus* and associated postcranial material have been recovered in this site. This material has been preliminarily described in Jovells-Vaqué et al. (2017) and will not be discussed here.

Geological setting

The Vallès-Penedès Basin is an elongated half-graben parallel to the coastline and extending between the Catalan Littoral Ranges (Text-fig. 1). It originated during the latest Oligocene and the Miocene as a result of the opening of the northwestern Mediterranean (Cabrera and Calvet 1996, Roca et al. 1999, Cabrera et al. 2004). The basin is limited by normal faults with a vertical slip greater than 1000 m. Most of the record consists of continental alluvial fan sediments sourced from the limiting reliefs except for at least three episodes of marine transgression during the late Burdigalian, Langhian and early Serravallian which mostly affected the southwestern half of the basin (Cabrera et al. 1991, 2004, Cabrera and Calvet 1996, Roca et al. 1999, De Gibert and Casanovas-Vilar 2011, Casanovas-Vilar et al. 2016a). The early Miocene sediments correspond to the Ramblian and early Aragonian (MN 3–MN 4) and generally crop out near the southeastern margin of the basin (Text-fig. 1). They mostly consist of small-ranging alluvial fan deposits made of intense red mudstones, sandstones and conglomerates (Cabrera 1981, Cabrera et al. 1991, 2004, De Gibert and Casanovas-Vilar 2011, Casanovas-Vilar et al. 2016a). The main vertebrate sites are located in the mudstone-dominated distal areas of the fan systems. In certain areas small lacustrine systems developed, such as in la Costablanca (Castellbisbal), el Molí de Can Calopa (Rubí) or Subirats. Els Casots is placed in the Subirats lacustrine unit, which also includes other remarkable mammal sites such as Can Julià (Crusafont et al. 1955), Les Cases de la Valenciana (Crusafont et al. 1955, Jovells-Vaqué et al. in press) and Can Martí Vell (Agustí 1981, 1983). This unit is predominantly made of grayish to yellowish lutites interbedded with relatively thin layers of carbonates and lignites. The latter were extracted from the long-abandoned coal mines of la Fontsanta, next to the site of els Casots. The site itself corresponds to a small lake of about 5 km^2 surrounded by small reliefs made of Mesozoic carbonates. The two-meter-thick stratigraphic series of the site includes massive limestones corresponding to the center of the lake and mudstone deposits corresponding to more marginal shallow areas (Moyà-Solà and Rius Font 1993, Casanovas-Vilar et al. 2011b). Mudstone deposits vary from gray to yellow and black and are particularly rich in gastropod and plant remains. Vertebrate remains have been recovered throughout the series, including the carbonates, but are more abundant in the black mudstones which have even produced partial skeletons (Moyà-Solà and Rius Font 1993, Casanovas-Vilar et al. 2011b). In addition, three of these black layers, termed els Casots 72, 73 and 74, were screen-washed and provided a rich collection of microvertebrate remains, including the material described in this work.

Materials and methods

The described material is housed in the Institut Català de Paleontologia Miquel Crusafont at Sabadell (Barcelona, Spain). Collection numbers are given in the main text and for the figured specimens. Dental terminology and measurement methods for cricetid cheek teeth follow Oliver and Peláez-Campomanes (2013) and Freudenthal and Daams (1988). All measurements are in millimeters. Summary statistics are presented for our largest sample (els Casots 74) rather than reporting all the measurements. The material from the three fossiliferous levels (els Casots 72, 73, 74) is described together in the systematic section.

Abbreviations

IPS – Institut Català de Paleontologia Miquel Crusafont collection number;

L – mesio-distal length; M/m – molars, upper case letters indicate upper molars and lower case lower ones; Max. – maximum; Min. – minimum; MN – Neogene Mammal Zones (after Mein 1975, 1999; age boundaries follow Hilgen et al. 2012); S.D. – standard deviation; W – bucco-lingual width.

Systematic palaeontology

Order Rodentia Bowdich, 1821
Family Cricetidae Fischer [de Waldheim], 1817

Genus *Democricetodon* Fahlbusch, 1964

***Democricetodon hispanicus* Freudenthal, 1967**
Pl. 1, Figs 1–5

1993 *Democricetodon* aff. *hispanicus*; Agustí and Llenas, p. 70.
1993 *Fahlbuschia* sp.; Agustí and Llenas, p. 70 (? partim).

Material from els Casots level 72.3 M3 (IPS 45092, IPS 45093, IPS 94650); 1 m1 (IPS 19522).

Material from els Casots level 73.1 M3 (IPS 19503); 8 m1 (IPS 19517, IPS 45051, IPS 45053 – IPS 45058); 7 m3 (IPS 19519, IPS 94653, IPS 94698, IPS 94700, IPS 94701, IPS 94637, IPS 94638).

Material from els Casots level 74.10 M1 (IPS 19491, IPS 45000 – IPS 45008); 15 M2 (IPS 19491, IPS 45006 – IPS 45008, IPS 19475, IPS 45019 – IPS 45027, IPS 19490); 5 M3 (IPS 45006, IPS 45008, IPS 45027, IPS

94602, IPS 94652); 12 m1 (IPS19481, IPS 45040 – IPS 45050); 15 m2 (IPS 19474, IPS 45059 – IPS 45071, IPS 94609); 8 m3 (IPS 45069, IPS 19473, IPS 45082 – IPS 45087).

Measurements. See Tables 1–3.

Description. M1. The M1 have three roots. The most mesial of them is cylindrical and located below the anterocone, a second one is positioned at the postero-labial corner of the molar and the last one is flattened and occupies the lingual part of the tooth. All studied specimens have a simple anterocone, except one in which this cusp is slightly subdivided (IPS 45001). The arms of the anteroph are well developed, and enclose the anterior valleys. The anterophule is simple and placed somewhat lingually. The protosinus is relatively reduced. The protolophule consists of a single posterior arm that joins the entoloph behind the protocone. IPS 45000 exhibits a double protolophule with a very low anterior arm. A vestigial anterior arm is also present in IPS 45008 (Pl. 1, Fig. 1), but it is interrupted before reaching the paracone. In some specimens, there is a short ectoloph on the paracone. The mesoloph is of medium length in six out of nine specimens; in the remaining ones it is short. The metalophule consists of a posterior arm only that connects the metacone with the posteroloph just behind the hypocone. The sinus is always wide and transverse. The posterosinus is highly reduced and closed by the posteroloph. The sinus is closed by well-developed cingulum.

M2. The M2 have two roots (mesial and distal) which are flattened. The anteroloph shows a long and high labial arm that encloses the narrow anterosinus. The protosinus is vestigial and is also closed by a much lower lingual arm of the anteroloph. In six out of 13 specimens, the protolophule consists of an anterior arm and a posterior one, which is connected to the entoloph posteriorly to the protocone. In the other nine specimens, the posterior arm of the protolophule is incomplete (for example in IPS 45008; Pl. 1, Fig. 1), being interrupted before merging with the paracone. In nine out of 15 specimens, the mesoloph is long, while it is of medium length in five, and short in only one. When long, the labial end of the mesoloph may end in a small mesostyle at the edge of the mesosinus or it may curve distally to contact the anterior wall of the metacone. The sinus is transverse and closed by a cingulum. The metalophule is short and simple, being transverse in half of the specimens and anterior to the hypocone in the remaining ones. The posteroloph closes the posterosinus, while the mesosinus is closed by a low cingulum.

M3. The M3 have two cylindrical roots. These molars show a characteristic button shape and a reduced distal half. The anterosinus is almost closed by the well-developed labial arm of the anteroloph. As in the M2, the protosinus is highly reduced and is closed by a low lingual arm of the anteroloph. The hypocone is rotated antero-labially and connects with the protocone by means of a neo-entoloph. The protolophule consists of a single anterior arm in all specimens. The metacone cannot be clearly distinguished and it connects with the hypocone through a short metalophule. The mesosinus is closed by a cingulum which is continuous with the posteroloph. The posterosinus is reduced to a tiny circular valley.

Table 1. Measurements (in mm) of *Democricetodon hispanicus* from els Casots level 72. Only complete specimens were measured.

Element	Collection number	L	W
M3	IPS 45092	0.69	0.75
M3	IPS 45093	0.94	0.97
M3	IPS 94650	0.93	0.95
m1	IPS 19522	1.41	1.11

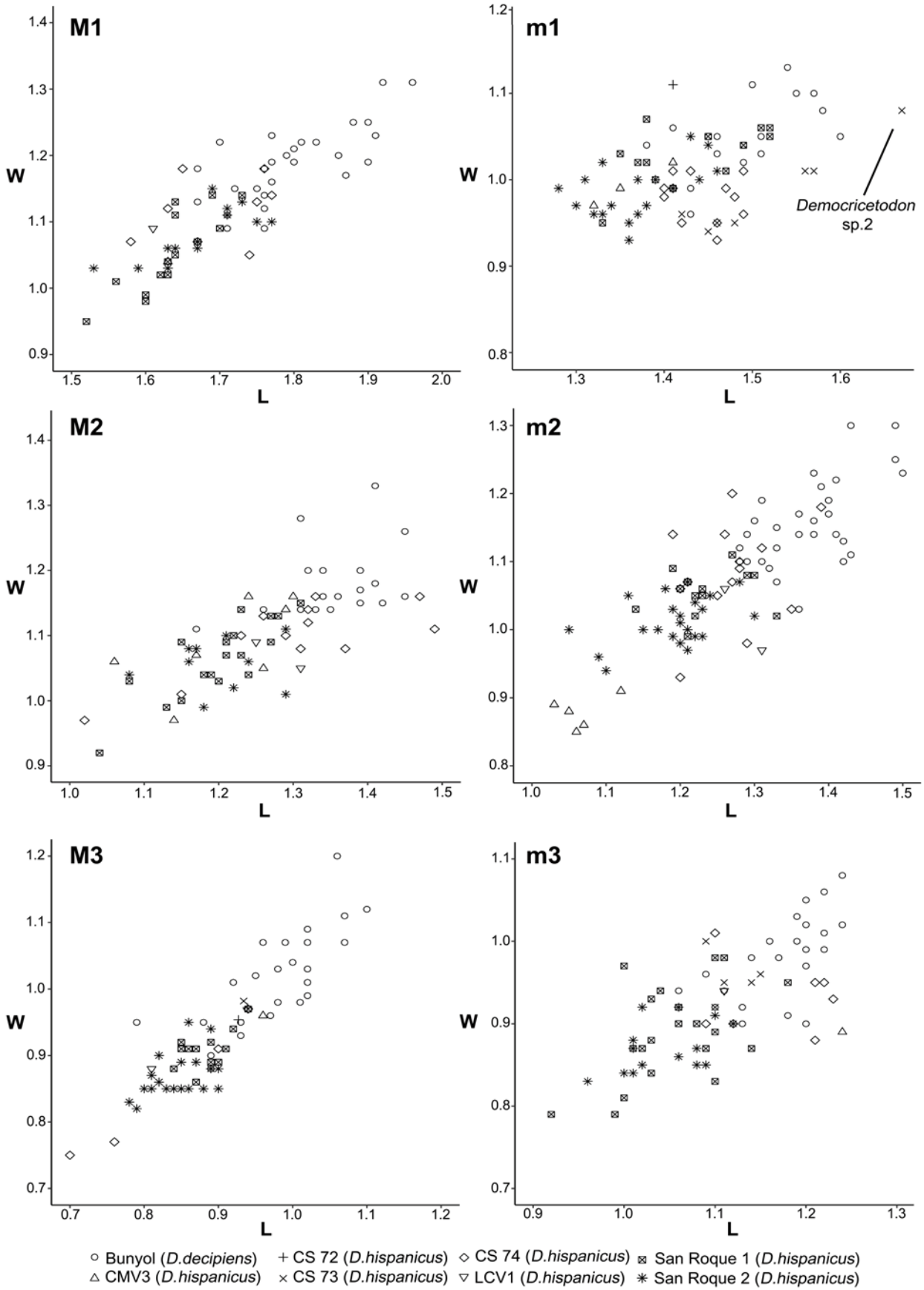
Table 2. Measurements (in mm) of *Democricetodon hispanicus* from els Casots level 73. Only complete specimens were measured.

Element	Collection number	L	W
M3	IPS 19503	0.93	0.98
m1	IPS 19517	1.56	1.01
m1	IPS 45051	1.42	0.96
m1	IPS 45054	1.45	0.94
m1	IPS 45055	1.48	0.95
m1	IPS 45056	1.46	0.95
m1	IPS 45057	1.57	1.01
m1	IPS 45058	1.45	0.94
m3	IPS 19519	1.12	0.90
m3	IPS 94653	1.14	0.94
m3	IPS 94698	1.09	0.92
m3	IPS 94700	1.09	0.99
m3	IPS 94637	1.11	0.95

m1. They have two cylindrical roots, one located below the anteroconid and the other one below the posterior part of the teeth. The anteroconid is simple and rounded. The mesolophid is variable in length, being short in six out of 21 specimens, of medium length in 12 and long in the remaining ones. The anterior valleys are closed by the arms of the anterolophid, which are quite low. The sinusid is wide and mostly points forwards, although it may be transverse in a few specimens. This valley and the mesosinusid are closed by a low cingulid. The hypolophulid is very short and merges with the entolophid anteriorly to the hypoconid. The metalophulid, is absent in IPS 19481 (Pl. 1, Fig. 2) and in IPS 45055 it is interrupted before reaching the protoconid. In the other specimens, the metalophulid is very short and anterior to the protoconid. The posterolophid closes the posterosinusid, reaching the posterior wall of the entoconid.

m2. These teeth have two cylindrical roots (mesial and distal). The lingual anterolophid and the anterosinusid are reduced. The protosinusid is closed by the labial arm of the anterolophid. The mesolophid is short in nine out of 15 specimens and absent in two, while in the remaining four it is of medium length. The remaining morphological features replicate those of the m1.

m3. The specimens present two cylindrical roots (mesial and distal). The anterior valleys are relatively reduced and they appear to be closed by the arms of the anterolophid which are quite low. The metaconid is prominent and connects with the anterolophid by means of an extremely



Text-fig. 2. Length/width scatter plot for the molars of *Democricetodon hispanicus* and *D. decipiens* from different Spanish sites. Locality acronyms are as follows: BU = Bunyol; CMV3 = Can Martí Vell 3; CS72 = els Casots level 72; CS73 = els Casots level 73; CS74 = els Casots level 74; LCV1 = Les Cases de la Valenciana 1; SR1 = San Roque 1; SR2 = San Roque 2. Data for SR1 and SR2 taken from Freudenthal and Daams (1988), data for BU taken from Daams and Freudenthal (1974).

Table 3. Summary measurements (in mm) for *Democricetodon hispanicus* from els Casots level 74. Only complete specimens were measured.

Element	L				W				N
	Min.	Mean	Max.	S. D.	Min.	Mean	Max.	S. D.	
M1	1.58	1.69	1.77	0.07	1.05	1.12	1.19	0.05	8
M2	0.93	1.25	1.49	0.16	0.84	1.07	1.16	0.09	14
M3	0.73	0.91	1.33	0.23	0.77	0.83	0.96	0.09	5
m1	1.40	1.44	1.49	0.03	0.93	0.98	1.01	0.03	12
m2	1.19	1.26	1.39	0.06	0.93	1.08	1.20	0.07	15
m3	1.09	1.17	1.23	0.06	0.88	0.94	1.01	0.04	8

short metalophulid. The mesolophid is absent in all the specimens. The entoconid is greatly reduced and is integrated into the hypolophulid, which is well developed and wide. The sinusid is generally open and points backwards. The posterosinusid is reduced and completely closed by the posterolophid which is very high. The mesosinusid is also closed by a high ridge that departs from the posterior wall of the metaconid.

Discussion. The specimens from els Casots fit within the size range of *Democricetodon hispanicus* (Text-fig. 2; see also Van der Meulen et al. 2003). However, a few somewhat larger dental elements (M2, and some m1, m2 and m3) previously led Agustí and Llenas (1993) to ascribe the material to *D.* aff. *hispanicus*. Nevertheless, the described material perfectly corresponds in morphology with *D. hispanicus* and only very few specimens are slightly above the upper size range of the species. *Democricetodon hispanicus* is distinguished from chronologically and geographically close species such as *D. decipiens* Freudenthal et Daams, 1988, *D. franconicus* Fahlbusch, 1966 and *D. koenigswaldi* (Freudenthal, 1963) by its smaller size (Van der Meulen et al. 2003). It further differs from *D. decipiens* by its longer mesolophids and from *D. koenigswaldi* by the predominance of transverse or anterior metalophules in the M2 (Van der Meulen et al. 2003). In els Casots material, the mesolophs are predominantly of medium length or long in the M1 and M2. In the lower molars, the mesolophid is predominantly long in the m1 and short in the m2. The protolophule is predominantly posterior in the M1 and double in the M2, with a generally better-developed anterior arm. The metalophule is always posterior to the hypocone in the M1 and anterior to the hypocone or transverse in the M2. All these characters fit with *D. hispanicus*, although long mesolophs/ids are somewhat more frequent in the material from other localities (see Freudenthal and Daams 1988, Van der Meulen et al. 2003). *Democricetodon decipiens* is distinguished from the material of els Casots by the presence of predominantly short mesolophids in the lower molars, a situation that in the described material only occurs in the m2. *Democricetodon hispanicus* occurs in other sites of the Vallès-Penedès Basin such as Les Cases de la Valenciana (Jovells-Vaqué et al. in press) and Can Martí Vell 1 and 2 (Agustí 1981, 1983), which are also included in the Subirats lacustrine unit. The material of all these sites is very similar in size and morphology, which could presumably be due to their similar age.

***Democricetodon* sp. 2**

Pl. 1, Fig. 6

1993 *Fahlbuschia* sp.; Agustí and Llenas, p. 70 (partim).

Material. 1 m1 (IPS 45052) (Pl. 1, Fig. 6) from els Casots level 73.

Measurements. L = 1.67, W = 1.08.

Description. m1. This specimen has two roots: a cylindrical one located under the anteroconid and distal one which is flattened. The anteroconid is simple and rounded. The anterior valleys are narrow, specially the anterosinusid, and closed by the well-developed arms of the anterolophulid. The metalophulid is short and reaches the longitudinal ridge anteriorly to the protoconid. The mesolophid is long and reaches the lingual margin of the teeth. The mesosinusid is closed by a low cingulid. The sinusid points markedly forwards and is closed by a low cingulid which emerges from the base of the protoconid and reaches the hypoconid. The hypolophulid is simple and merges with the hypoconid anteriorly. Finally, the posterolophid is thick and reaches the base of the entoconid, thus enclosing the posterosinusid.

Discussion. Agustí and Llenas (1993: 70) reported a few larger-sized lower molars from els Casots 73 that they tentatively attributed to a "primitive form of *Fahlbuschia* of small dimensions". Amongst the studied specimens, only the described m1 appears to be above the size range of *Democricetodon hispanicus* (Text-fig. 2), being slightly larger than the type material of *Fahlbuschia decipiens* from Bunyol (Valencia; Daams and Freudenthal 1974, Freudenthal and Daams 1988). Van der Meulen et al. (2003) consider *Fahlbuschia* Mein et Freudenthal, 1971 a junior synonym of *Democricetodon* (but see Freudenthal (2006) for a different taxonomic opinion) and propose emended diagnoses for several species of this genus. Their emended diagnosis for *D. decipiens* stresses its larger size as compared to *D. hispanicus* and predominantly short mesolophs and mesolophids (Van der Meulen et al. 2003: 429). The described m1 shows a long mesolophid comparable to that of *D. hispanicus* specimens from the same site and is slightly larger than *D. decipiens*, being closer in size to *D. moralesi* Van der Meulen, Peláez-Campomanes et Daams, 2003 or *D. koenigswaldi* (Van der Meulen et al. 2003). However, in these species the mesolophid is generally even more reduced than in *D. decipiens*. Unfortunately, the diagnosis of *Democricetodon* species requires of sufficient material in

order to evaluate the variation in features such as the length of the mesoloph/id or the morphology of the protolophule/metalophule in the upper molars (see Maridet 2003, Van der Meulen et al. 2003). Clearly the material from els Casots 73 does not allow for such assessment, so it is therefore ascribed to a second, larger-sized *Democricetodon* species. Further material could clarify its taxonomical attribution and provide valuable biostratigraphic information.

Genus *Megacricetodon* Fahlbusch, 1964

Megacricetodon primitivus (Freudenthal, 1963)

Pl. 1, Figs 7–11

1993 *Megacricetodon minor primitivus*; Agustí and Llenas, p. 70.

Material from els Casots level 72. 2 M1 (IPS 45094, IPS 94649); 2 M2 (IPS 45094, IPS 45089); 2 M3 (IPS 45094, IPS 45089); 3 m1 (IPS 44995, IPS 44996, IPS 19514); 3 m2 (IPS 19515, IPS 44997, IPS 19523).

Material from els Casots level 73. 7 M1 (IPS 44963 – IPS 44968, IPS 94641); 1 M3 (IPS 94639); 6 m1 (IPS 44969 – IPS 44974); 1 m3 (IPS 94640).

Material from els Casots level 74. 6 M1 (IPS 44936 – IPS 44941); 2 M2 (IPS 44961, IPS 44984); 1 M3 (IPS 19479); 17 m1 (IPS 44942 – IPS 44958); 15 m2 (IPS44948 – IPS 44951, IPS 44959, IPS 44960, IPS 44962, IPS 44981 – IPS 44983, IPS 44985, IPS 94255, IPS 94256, IPS 94587, IPS 94588); 5 m3 (IPS 44949, IPS 44991 – IPS 44994).

Measurements. See Tables 4–6.

Description. M1. All the specimens have three roots. The most mesial root is cylindrical and located under the anterocone; there is a flattened root at the lingual half side and a cylindrical one at the postero-labial corner of the molar. The anterocone is deeply split with the labial cusp conspicuously larger than the lingual one. A few specimens show a faint anterior cingulum at the base of the anterocone, but in most specimens the anterior wall of the anterocone is smooth. The anterolophule connects the protocone with the lingual cusp of the anterocone. There is no labial spur on the anterophule. The protolophule consists of a posterior arm that connects the paracone with the entoloph posteriorly to the protocone. However, four out of 15 M1 show a vestigial extremely short anterior arm of the protolophule that does not reach the paracone. There is a short posterior ectoloph in the paracone spur in three specimens, while this character is absent in the remaining ones. The mesoloph varies from long to absent. It is long in three out of 15 specimens, of medium length in six (for example in IPS 44939; Pl. 1, Fig. 7), short in four and absent in the remaining two. The metalophule consists of a single arm that curves distally and joins the metacone with the posteroloph in a somewhat labial position. This implies that the posterosinus is highly reduced. The posteroloph is thin and partially closes this valley. The sinus is transverse. All the main valleys are closed by cingula, which are more pronounced on the lingual side. However, there is no lingual mesocingulum.

Table 4. Measurements (in mm) of *Megacricetodon primitivus* from els Casots level 72. Only complete specimens were measured.

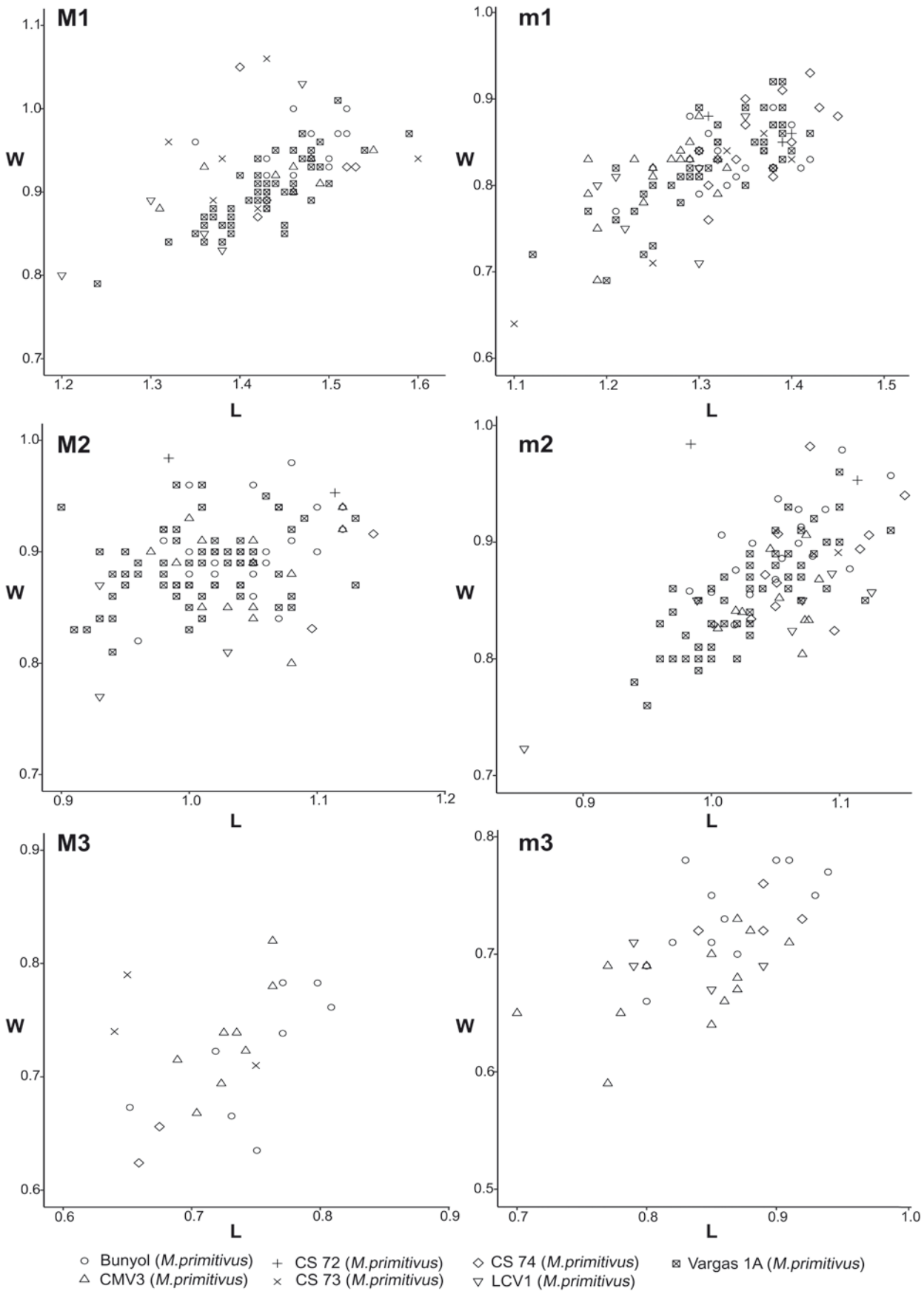
Element	Collection number	L	W
M2	IPS 45094	0.98	0.98
M2	IPS 45089	1.11	0.95
M3	IPS 45094	0.64	0.74
M3	IPS 45089	0.65	0.79
m1	IPS 44995	1.39	0.85
m1	IPS 44996	1.31	0.87
m1	IPS 19514	1.36	0.85
m2	IPS 19515	1.01	0.83
m2	IPS 44997	1.03	0.80
m2	IPS 19523	1.13	0.87

Table 5. Measurements (in mm) of *Megacricetodon primitivus* from els Casots level 73. Only complete specimens were measured.

Element	Collection number	L	W
M1	IPS 44963	1.42	0.88
M1	IPS 44964	1.37	0.89
M1	IPS 44965	1.38	0.94
M1	IPS 44966	1.32	0.96
M1	IPS 44967	1.60	0.94
M1	IPS 44968	1.43	1.06
M1	IPS 94641	1.64	1.16
m1	IPS 44969	1.25	0.71
m1	IPS 44970	1.33	0.84
m1	IPS 44971	1.40	0.83
m1	IPS 44972	1.10	0.64
m1	IPS 44973	1.32	0.83
m1	IPS 44974	–	0.83
M3	IPS 94639	0.84	0.72
m3	IPS 94640	0.89	0.70

Table 6. Summary measurements (in mm) for *Megacricetodon primitivus* from els Casots level 74. Only complete specimens were measured.

Element	L				W				N
	Min.	Mean	Max.	S. D.	Min.	Mean	Max.	S. D.	
M1	1.40	1.46	1.53	0.06	0.87	0.93	1.05	0.07	5
M2	1.10	–	1.14	–	0.83	–	0.93	–	2
m1	1.30	1.37	1.45	0.05	0.76	0.85	0.93	0.04	15
m2	1.03	1.09	1.20	0.05	0.82	0.89	0.98	0.05	12
m3	0.84	0.92	1.08	0.09	0.72	0.73	0.76	0.02	5



Text-fig. 3. Length/width scatter plot for the molars of *Megacricetodon primitivus* from different Spanish sites. Locality acronyms are as follows: BU = Bunyol; CMV3 = Can Martí Vell 3; CS72 = els Casots level 72; CS73 = els Casots level 73; CS74 = els Casots level 74; LCV1 = Les Cases de la Valenciana 1; VR1 = Vargas 1. Data for VR1 taken from Daams and Freudenthal (1988), data for BU taken from Daams and Freudenthal (1974).

M2. The M2 have two flattened roots, mesial and distal. The anterior valleys are closed by the well-developed arms of the anterolophule. The labial arm is noticeably higher than the lingual one. The protosinus is very reduced, being vestigial in some specimens (for example in IPS 44961; Pl. 1, Fig. 8). The protolophule and the metalophule are simple, consisting in an anterior arm only. Two specimens (including IPS 44961; Pl. 1, Fig. 8) show a vestige of the posterior arm of the protolophule that can be recognized as a small protuberance posterior to the protocone. The mesoloph is always long, reaching the labial border of the molar although it becomes very low towards its end. In three specimens (for example IPS 44961; Pl. 1, Fig. 8), there is a short to medium-sized posterior ectoloph on the paracone, while it is absent in the remaining one. When present, the ectoloph approaches the mesoloph without contacting with it. The sinus is transverse. The posteroloph is well developed and reaches the base of the metacone, thus resulting in a closed posterosinus. The sinus and mesosinus are closed by relatively well-developed cingula.

M3. The M3 show a rounded outline and two cylindrical roots (labial and lingual). There is no trace of the protosinus and the lingual anteroloph. The anterosinus is narrow and partially closed by the well-developed labial arm of the anteroloph. The protolophule is simple and connects the paracone with the anteroloph in front of the protocone. The mesoloph and metalophule are highly variable. In one specimen, the mesoloph is long, ending in a prominent mesostyle and the metalophule is parallel to it and ends in a small metacone (IPS 45094). In a second one (IPS 19479; Pl. 1, Fig. 9), this ridge is shorter and isolated from the entoloph and the mesostyle but it shows a weak contact with the metalophule. A third specimen (IPS 45089) shows a peculiar morphology with an arched axioloph and a long, slightly posteriorly-directed mesoloph. The metacone is indistinguishable at the end of the metalophule, and the posterior and labial valleys are closed by a high ridge. The posteroloph is well developed and partially closes the very narrow posterosinus. The sinus is transverse and narrow, being closed by a low cingulum.

m1. The molars have two cylindrical roots, anterior and posterior. In slightly worn specimens, the anteroconid is simple and rounded. The anterior valleys are wide and closed by the arms of the anterolophid, which are low. The anterolophulid is very low and situated in a more or less central position. The anterolophulid shows a labial spur in six out of 26 specimens, it is generally short and low, but in a few instances, it reaches the labial anterolophid. The metalophulid and the hypolophulid are both simple, being defined by a very short anterior arm. The mesolophid is always present, being short in most specimens (20/26; see for example IPS 44950; Pl. 1, Fig. 10) and somewhat longer in a few others (6/26). The sinusid is wide and proverse. It is closed by a pronounced cingulid while the mesosinusid is open. The posterolophid is high and thick and closes a rather wide posterosinusid.

m2. The m2 have two cylindrical roots, mesial and distal. The anterior valleys are closed by the arms of the anterolophid. Unworn molars show a highly reduced to vestigial anterosinusid which quickly disappears because of wear (IPS 44950; Pl. 1, Fig. 10). The mesolophid is always present. Most specimens show a short mesolophid (15/18; see for example IPS 44950; Pl. 1, Fig. 10), although medium-length ones also occur (3/18) and one specimen (IPS 19515) shows a long mesolophid which is extremely low at its lingual end. The sinusid is wide and transverse to slightly proverse. This valley is closed by a cingulid in most specimens, although it is not as well developed as in m1. The remaining morphological features resemble those of the m1.

m3. The m3 are elongated and show two cylindrical roots. The anterior valleys are reduced, specially the anterosinusid, which is vestigial in some specimens. These valleys are closed by the arms of the anterolophid, which are low. The metalophulid is thick and short, joining the metaconid with the anterolophid in front of the protoconid. The mesolophid is absent in all the molars but one, (IPS 44994), which exhibits a vestige of this ridge just behind the protoconid. The sinusid is relatively wide and mostly retroverse. This valley is closed by a low cingulid as described for the m2. The hypolophulid is very thick and anterior to the hypoconid. The entoconid is reduced. The posterolophid is thick and short, but it closes the posterosinusid. The mesosinusid is closed by a high cingulid.

Discussion. The specimens from els Casots are similar in size to small *Megacricetodon* species such as *M. primitivus*, *M. minor* Lartet, 1851 and *M. collongensis* Mein, 1958 (Text-fig. 3; see also Daams and Freudenthal 1988, Oliver and Peláez-Campomanes 2014). However, a number of morphological features allow us to confidently ascribe the material from els Casots to *Megacricetodon primitivus.* The anterocone in the M1 is clearly divided and not predominantly simple or slightly split as in *M. minor. Megacricetodon collongensis* (Mein 1958) is similar in size, but shows a symmetrically split anterocone. In contrast, in *M. primitivus* and the specimens from els Casots, the labial cusp of the anterocone is generally larger than the lingual one (Oliver and Peláez-Campomanes 2014). The mesoloph in the M1 is variable, but is mostly of medium length, while in the M2 it is always long and low. Mesoloph development is similar in the type material from Valtorres (Freudenthal 1963) and in *M. primitivus* from other Spanish sites (Daams and Freudenthal 1988, Oliver Pérez et al. 2008, Oliver and Peláez-Campomanes 2014) but the mesoloph in the M2 is most commonly of medium length. The M2 protolophule is simple with only one anterior arm and in a few cases a vestigial posterior arm. Similarly, the protolophule is simple and posterior in the M1 with a vestige of the anterior protolophule occurring in a few specimens. Double protolophules are more common in other Spanish samples from the Calatayud-Montalbán Basin (Oliver Pérez et al. 2008, Oliver and Peláez-Campomanes 2014) as well as from Bunyol (Daams and Freudenthal 1974, Adrover et al. 1987) but not in other samples from the Vallès-Penedès Basin such as Can Martí Vell 1 and 2 (Agustí 1981, 1983) or Les Cases de la Valenciana 1 (Jovells-Vaqué et al. in press). Els Casots specimens perfectly agree in size and morphology with *M. primitivus* from these Vallès-Penedès sites although a few dental elements (particularly the lower molars) are slightly larger.

Biostratigraphic implications and conclusions

The cricetid fauna from els Casots comprises three different species: *Democricetodon hispanicus*, *Democricetodon* sp. 2 and *Megacricetodon primitivus*. The presence of *Megacricetodon primitivus* together with *Democricetodon* and *Ligerimys* Schaub, 1951 is indicative of an early Aragonian MN 4 age (Mein 1999, Agustí et al. 2001, Hilgen et al. 2012) as already proposed in previous publications (Agustí and Llenas 1993, Casanovas-Vilar et al. 2011a, b, 2016b). *Democricetodon* has already been recorded in the latest MN 3, although it is very rare (Daams et al. 1999, Hilgen et al. 2012, Van der Meulen et al. 2012), whereas the last occurrence of the eomyid *Ligerimys* marks the lower boundary of zone MN 5 (Daams et al. 1999, Agustí et al. 2001, Kälin and Kempf 2009, Hilgen et al. 2012, Van der Meulen et al. 2012). Zone MN 4 corresponds to local biozones B and C in the Calatayud-Montalbán Basin (east-central Spain), the type area of the Aragonian (see Daams et al. 1999, Van der Meulen et al. 2012). The first occurrence of *M. primitivus* marks the beginning of zone C, although this species persists in the area until zone Db (late MN 5; Van der Meulen et al. 2012, Oliver and Peláez-Campomanes 2014, García-Paredes et al. 2016). Zone C is further subdivided into subzones Ca and Cb on the basis of the species of *Democricetodon* present. While *D. decipiens* is restricted to zone Ca, its descendant *D. moralesi* characterizes zone Cb (Van der Meulen et al. 2003, 2012). *Democricetodon hispanicus*, which is the species co-occurring with *M. primitivus* at els Casots and all other Vallès-Penedès sites, is restricted to zones A and B (late Ramblian and earliest Aragonian) in the Calatayud-Montalbán Basin (Van der Meulen et al. 2012), thus arguing against a correlation of these sites with zone C. On the other hand, zone Ca also includes the replacement of the eomyid *Ligerimys florancei* Stehlin et Schaub, 1951 by its descendant *L. ellipticus* (Álvarez Sierra 1987), with the two species coexisting in a few sites (Van der Meulen et al. 2012). The latter species, the last member of the genus *Ligerimys*, disappears at the end of zone Cb. Both *Ligerimys* species are recorded in other sites of the Subirats lacustrine unit, such as Can Martí Vell 1 and 2 (Agustí 1981, 1983) and Les Cases de la Valenciana 1 (Jovells-Vaqué et al. in press), but only *L. ellipticus* is present at els Casots, being represented by just seven specimens out of more than 200 rodent teeth. This fact, together with the presence of a second, larger-sized *Democricetodon* species has been considered to indicate a younger age for els Casots when compared to the remaining sites (Agustí and Llenas 1993). Such an assumption seems reasonable, yet els Casots could either be correlated to the upper part of subzone Ca or to subzone Cb. The correlation attempt is further complicated by the presence of the cricetid *Eumyarion* Thaler, 1966 in Les Cases de la Valenciana 1, Can Martí Vell 1 and 2 and Sant Mamet but not in els Casots (Agustí 1981, 1983, Agustí et al. 1985, Jovells-Vaqué et al. 2017). This genus is not recorded in the Calatayud-Montalbán Basin until zone Cb, but has been recorded in Ca sites in the Teruel and Valencia area (Van der Meulen et al. 2012).

To sum up, we conclude that the presence of *Megacricetodon primitivus* and *Ligerimys ellipticus* at els Casots favors a correlation with zone C of the Calatayud-Montalbán Basin. This is further supported by the common occurrence of *Democricetodon* which is represented by two different species. *Democricetodon* serves as the basis for the subdivision of zone C into subzones Ca and Cb in that area, but unfortunately is represented by different species (*D. decipiens* and *D. moralesi*). The fact that *L. ellipticus* is the only eomyid present would favor a correlation to late zone Ca or to zone Cb, thus implying an age of about 16.4–15.9 Ma (ages after Van der Meulen et al. 2012), so that els Casots would indeed be slightly younger than other sites of the Subirats lacustrine unit (see Jovells-Vaqué et al. in press). The local zonation for the Aragonian in the type area could be roughly applied to the Vallès-Penedès Basin (as suggested by Casanovas-Vilar et al. 2011a, 2016a) but the cricetid succession shows some remarkable differences which hampers the use of detailed subzones. Concerning the genus *Democricetodon*, some characteristic species are not recorded in the Vallès-Penedès Basin, and apparently *D. hispanicus* persists for a longer time, thus coexisting with *M. primitivus* and *Eumyarion*. Hopefully, ongoing magneto- and biostratigraphical studies in the long-neglected early Miocene successions of this basin will shed new light on this issue.

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Explanations of the plate

PLATE 1

Scanning electron microscope (SEM) micrographs of the Cricetidae from els Casots.

Democricetodon hispanicus from els Casots 74

1. Right maxillary fragment with M1–M3 (reversed); IPS 45008.
2. Left m1; IPS 19481.
3. Right m2 (reversed); IPS 45059.
4. Left m3; IPS 19473.
5. Right m1 (reversed); IPS 45049.

Democricetodon sp. 2 from els Casots 73

6. Left m1; IPS 45052.

Megacricetodon primitivus from els Casots 74

7. Right M1 (reversed); IPS 44939.
8. Left M2; IPS 44961.
9. Left M3; IPS 19479.
10. Right m1 – m2 (reversed); IPS 44950.
11. Right m3 (reversed); IPS 44992.

PLATE 1