Stuck in the middle. A geographical appraisal of the oldest insectivores – and a marsupial – from the Vallès-Penedès Basin (early Miocene, Catalonia, Spain)

Lars W. VAN DEN HOEK OSTENDE, Isaac CASANOVAS-VILAR & Marc FURIÓ

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Lars W. VAN DEN HOEK OSTENDE
Naturalis Biodiversity Center, Darwinweg 2, 2333CR Leiden (The Netherlands)
lars.vandenhoekostende@naturalis.nl

Isaac CASANOVAS-VILAR
Institut Català de Paleontologia Miquel Crusafont. Edifici Z, c/ de les Columnes, Campus de la UAB, 08193 Cerdanyola del Vallès, Barcelona (Spain)
isaac.casanovas@icp.cat

Marc FURIÓ
Institut Català de Paleontologia Miquel Crusafont. Edifici Z, c/ de les Columnes, Campus de la UAB, 08193 Cerdanyola del Vallès, Barcelona (Spain)
and Departament de Geologia, Universitat Autònoma de Barcelona (08193), Cerdanyola del Vallès, Barcelona (Spain)
marc.furio@uab.cat
marc.furio@icp.cat
(corresponding author)

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ABSTRACT

The Vallès-Penedès Basin in Catalonia (NE Spain) forms a biogeographically important connection between central Europe and the Iberian Peninsula. Whereas this is well documented for the late middle and early late Miocene, the early Miocene sequence has received far less attention. New excavations yielded micromammal assemblages from the Ramblian and early Aragonian. Among the euliphotyhplans and metatherian studied, we recognize seven non-soricid species (*Amphiperatherium frequens* von Meyer, 1846, *Galerix symeonidisi* Doukas, 1986 and *Galerix remmerti* van den Hoek Ostende, 2003, *Desmanodon daamsi* van den Hoek Ostende, 1997, *Heterosorex neumayrianus* Schlosser, 1887, *Chainodus* sp., *Plesiodimylus* sp.) and six species of shrews (*Paenelimnoecus* sp., *Miosorex* sp., cf. *Clapasorex*, cf. *Oligosorex*, cf. *Florinia* sp. and Soricinae indet.). They confirm the intermediate position of the Vallès-Penedès also at the time of the older faunas, but show that differences with the Iberian inland were less pronounced. These differences can be explained by higher humidity in the coastal region, as indicated by the presence of dimylids. The differences between this coastal area and inland basin confirm the potential of coastal regions as migration corridors.

RÉSUMÉ

Coincé au milieu. Bilan géographique des plus anciens insectivores – et d'un marsupial – du bassin de Vallès-Penedès (Miocène inférieur, Catalogne, Espagne).
Le bassin Catalan de Vallès-Penedès (Nord-Est de l'Espagne) constitue une importante connexion biogéographique entre l'Europe centrale et la Péninsule Ibérique. Bien que la fin du Miocène moyen et le début du Miocène tardif soient abondamment documentés, la séquence du Miocène inférieur a en revanche reçu une attention moindre. Des fouilles récentes ont permis de mettre à jour de nouveaux assemblages de micromammifères provenant du Ramblien et de l'Aragonien inférieur. Parmi les euliphotyhplans et métathériens étudiés, on reconnaît sept espèces de non soricidés (*Amphiperatherium frequens* von Meyer, 1846, *Galerix symeonidisi* Doukas, 1986 et *Galerix remmerti* van den Hoek Ostende, 2003, *Desmanodon daamsi* van den Hoek Ostende, 1997, *Heterosorex neumayrianus* Schlosser, 1887, *Chainodus* sp., *Plesiodimylus* sp.) ainsi que six espèces de musaraignes (*Paenelimnoecus* sp., *Miosorex* sp., cf. *Clapasorex*, cf. *Oligosorex*, cf. *Florinia* sp. et Soricinae indet.). Ces assemblages confirment la position intermédiaire de Vallès-Penedès même pour les faunes plus anciennes, bien que les différences avec l'arrière-pays eussent été moins marquées. Ce contraste peut être expliqué par le taux d'humidité plus important le long de la région côtière, comme le suggère la présence de Dimylidae. Cette hétérogénéité faunique entre la zone côtière et les bassins intérieurs confirme le potentiel des régions côtières en tant que couloir migratoire.

INTRODUCTION

At the end of the early Miocene, a remarkable transition takes place in the micromammal fauna of western Europe, when cricetid rodents, after a period of almost complete absence, enter the continent, ending the reign of the glirid/eomyid dominated faunas (Daams & Freudenthal 1990). This change in the rodent faunas is well documented in Spain as well as other parts of Europe and marks the transition between MN Units 3 and 4 (see Material and methods section), coinciding with the boundary between the Ramblian and Aragonian European land mammal ages.

In contrast to the rodents, the history of the Spanish insectivores around this important transition is poorly known. The eulipotyphlans of this period in central Europe have, for instance, been extensively studied from fissure fillings in the Frankonische Alb, such as Stubersheim 3, Wintershof-West, Petersbuch 2, Erkertshofen 1 and 2 (Doben-Florin 1964; Müller 1967; Ziegler 1989, 1990a, b, 1994) and, more recently, Petersbuch 28 (Klietmann *et al.* 2013a, b, 2014a, b, c, 2015a, b). In Spain, the insectivores of the Ramblian type sections were described by Van den Hoek Ostende (2003). Murelaga *et al.* (2004) and Ruiz-Sánchez *et al.* (2012b) published eulipotyphlans from the Ebro Basin and those from the Rubielos de Mora Basin were included in Van den Hoek Ostende *et al.* (2017). The published early Aragonian record of the order is, however, far more scattered. Finds from the Aragonian type area were included in papers on the talpid *Desmanodon* (Van den Hoek Ostende 1997) and the gymnure *Galerix symeonidisi* Doukas, 1986 (Van den Hoek Ostende & Doukas 2003). Hordijk *et al.* (2015) included descriptions of the insectivores in their paper on the locality of Montalvos 2 and Crespo-Roures *et al.* (2018) published *Plesiodimylus* finds from Mas d'Antolino B-5, and the other dimylid finds from the Ribesalbes-Alcora Basin were, in combination with the Talpidae of these localities, published by Crespo-Roures *et al.*

(2019). Finally, Van der Meulen *et al.* (2012) gave ranges for insectivore species for the early and middle Aragonian in the type area, without, however, giving any descriptions.

Due to its geographic position, the Vallès-Penedès Basin forms a transitional palaeobiogeographic area between the central European and the Iberian bioprovinces (e.g. Agustí 1990; Madern & Van den Hoek Ostende 2015; Casanovas-Vilar *et al.* 2005, 2008, 2016; Furió & Agustí 2017; Furió *et al.* 2011a, 2018; García-Alix *et al.* 2011; Madern *et al.* 2018). The basin is mainly known for its faunas from the late middle (Aragonian) and early late Miocene (Vallesian). However, it also yielded a series of continental localities from the late early Miocene. Although most of them were already known since the middle of the last century (Crusafont *et al.* 1955) these older sites received far less attention. However, renewed interest in the early Miocene sequence of the Vallès-Penedès is rapidly changing that situation. Here, we describe the Ramblian and early Aragonian eulipotyphlans from the Vallès-Penedès Basin in Catalonia (northeastern Spain), and in addition discuss the presumably insectivorous metatherian *Amphiperatherium*.

Some surveys carried out in the last decades by J. Agustí had resulted in the recovery of several representative small mammal assemblages from these early Miocene localities, including a few insectivore elements. However, most of the material described in this paper was recently collected by a team from the Institut Català de Paleontologia led by one of us (ICV), surveying both old and new sites in the oldest sections of the Vallès-Penedès with support of Generalitat de Catalunya and National Geographic. This campaign resulted in a collection of thousands of fossils of micromammals. As usual, the vast majority belonged to rodents and lagomorphs. The preliminary study of the rodent assemblages from these localities revealed that they can be correlated to the late Ramblian (MN 3) and early Aragonian (MN 4) (Casanovas-Vilar *et al.* 2011, 2016), or to local zones A and C, respectively,

faunas from the intermediate zone B still missing. Table 1 gives the stratigraphical sequence of the studied sites. The study of the rodents is in progress and some new micromammal assemblages have been recently described (Jovells-Vaqué *et al.* 2017; Jovells-Vaqué & Casanovas-Vilar 2018).

Insectivores, being far less abundant than rodents and lagomorphs in all these sites, needed a broader compilation of localities to show their real diversity in the Ramblian and Aragonian of the Vallès-Penedès. After the huge effort of sampling all these early Miocene localities, a large collection of fossils of insectivores is ready to be described in the present work. In studying the new material, we aim to answer three questions: 1) Are there any indications for environmental differences between the Vallès-Penedès and the inner zones of the Iberian Peninsula during the early Miocene? 2) To what extent were the insectivore assemblages from this basin already transitional between Spain and the rest of Europe at that moment? and 3) Are there any palaeoenvironmental changes that can account for the faunal turnover at the Ramblian/Aragonian boundary?

GEOLOGICAL SETTING AND BIOSTRATIGRAPHY

The Vallès-Penedès Basin is an elongated half-graben parallel to the Catalan coastline. The sedimentary infill is mostly defined by continental sediments deposited in the context of alluvial fans sourced from the bounding reliefs (Cabrera *et al.* 1991, 2004; Casanovas-Vilar *et al.* 2016). After almost a century of continued study the Vallès-Penedès Basin has become a reference area to understand the evolution of Miocene terrestrial faunas in Europe. Although better known for being the type area for the late Miocene Vallesian mammal age (Crusafont Pairó 1950), its long continental successions span almost the entire Miocene, with only the earlier and latest part of this epoch missing (see Casanovas-Vilar *et al.* 2016 for an updated review).

The early Miocene deposits crop out in a relatively restricted area near the south-western margin of the basin (Fig. 1). In general they are located in the mudstone-dominated distal facies of small-ranging alluvial fans and occasionally in lacustrine deposits (Cabrera 1981; Cabrera *et al.* 1991, 2004; Casanovas-Vilar *et al.* 2016). Early Miocene alluvial fan facies are characterized by their intensely red colors and poor fossil content. Nevertheless, some sites, such as Molí de Can Calopa or Escletxes del Papiol, have delivered relatively good samples. Lacustrine deposits developed in the context of shallow carbonate and evaporitic lake systems that existed at different times in certain depressed areas. These lake facies are cyclically alternating with distal facies of alluvial fan systems made of predominantly grayish to yellowish lutites. The major early Miocene mammal sites, such as la Costablanca or els Casots, are located in these lutitic facies and have delivered both small and large mammals (Agustí *et al.* 1985; Casanovas-Vilar *et al.* 2016). In addition, the lacustrine facies of la Costablanca have also delivered a rich macrofloral assemblage (Sanz de Síria 1981). Recent biostratigraphical studies have provided a preliminary chronology of the early Miocene record of the Vallès-Penedès Basin (Casanovas-Vilar

et al. 2016; Jovells-Vaqué *et al.* 2017, 2018). Interestingly, and in contrast to younger deposits in the basin, the same local biozonation used in the nearby Calatayud-Montalbán Basin, the type area for the Aragonian mammal age (see Daams *et al.* 1999; Van der Meulen *et al.* 2012), can be roughly applied to the Vallès-Penedès Basin (Jovells-Vaqué *et al.* 2017, 2018). This may suggest that environmental differences within the Iberian Peninsula were less pronounced in early Miocene times. However, some environmental differences between coastal and central areas in the Iberian Peninsula during the early Miocene have been detected according to their faunal content (Ruiz-Sánchez *et al.* 2012a; Freudenthal *et al.* 2014; Van den Hoek Ostende *et al.* 2017; Crespo-Roures *et al.* 2018, 2019). Ongoing magnetostratigraphical works are set to refine the chronology of the main sites and bioevents and improve correlations.

The early Miocene record of the Vallès-Penedès Basin covers the late Ramblian and early Aragonian, that is the latest part of unit MN 3 and MN 4 (Agustí *et al.* 1985; Casanovas-Vilar *et al.* 2016). The Ramblian is represented by very few sites, mostly associated to ancient lake systems (Fig. 2). These include Sant Andreu de la Barca, la Costablanca and Molí de Can Calopa. These sites have delivered both micro- and macromammals, including the first occurrences of gomphothere proboscideans and the equid *Anchitherium* von Meyer, 1834 in the area (Casanovas-Vilar *et al.* 2016). The site of Turó de les Forques is located in the basal breccia deposits just immediately discordant over the Paleozoic substrate, and is considered one of the oldest in the Vallès-Penedès Basin (Casanovas-Vilar *et al.* 2016). Ramblian sites are characterized by a high diversity of glirids and the absence of cricetids other than *Melissiodon* Schaub, 1920, a peculiar genus characterized by a unique "honeycomb" molar morphology (Jovells-Vaqué & Casanovas-Vilar 2018). Therefore, these sites are correlated to local zone A, which corresponds to the "cricetid vacuum" (Daams & Freudenthal 1990). The presence of the eomyid *Ligerimys antiquus* Fahlbusch, 1970 reinforces this correlation (see Daams *et al.* 1999; Van der Meulen *et al.* 2012).

The early Aragonian is better represented than the Ramblian. In particular the Subirats lacustrine unit has provided several rich sites (les Cases de la Valenciana, Can Julià, Can Martí Vell and els Casots) that include both large and small mammals (Casanovas-Vilar *et al.* 2016). The Aragonian boundary is marked by the first common occurrence of modern-looking cricetids of the genus *Democricetodon* Fahlbusch, 1964. In the Aragonian type area, *Democricetodon hispanicus* Freudenthal, 1967 is the first and only species to be recorded, being restricted to local zone B (see Daams *et al.* 1999; Van der Meulen *et al.* 2012). The appearance of additional *Democricetodon* species as well as that of the cricetid genera *Megacricetodon* Fahlbusch, 1964 and *Eumyarion* Thaler, 1966 characterizes local zone C. In the Vallès-Penedès Basin, the genera *Democricetodon* (first represented by *D. hispanicus*), *Megacricetodon* and *Eumyarion* are all first recorded simultaneously at sites from the Subirats lacustrine unit, thus indicating that local zone B is entirely missing in the Vallès-Penedès (Jovells-Vaqué *et al.* 2017, 2018). Zone C is further subdivided into subzones Ca and Cb in the
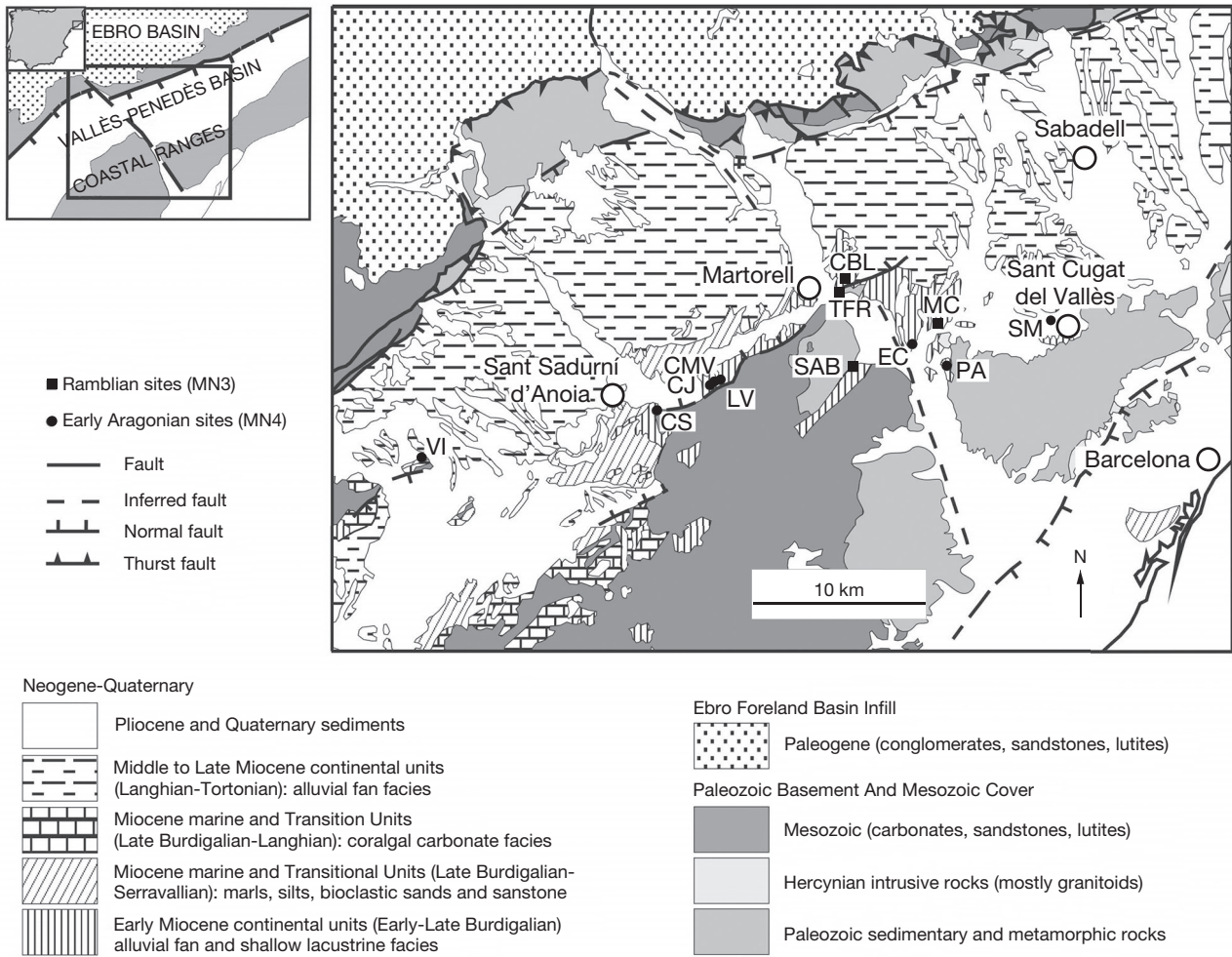
FIG. 1. — Geographical location and simplified geological map of the Vallès-Penedès Basin indicating the main early Miocene mammal localities (modified from Casanovas-Vilar et al. 2016). Locality acronyms are as follows: **CBL**, La Costablanca (levels 1 and 2); **CJ**, Can Julià; **CMV**, Can Martí Vell (levels 1-3); **CS**, Els Casots; **EC**, El Canyet; **LV**, Les Cases de la Valenciana; **MC**, Molí de Can Calopa; **PA**, Les Escletxes del Papiol; **SAB**, Sant Andreu de la Barca (levels 1 and 3); **SM**, Sant Mamet; **TFR**, Turó de les Forques 1; **VI**, Vilobí del Penedès.

type area, which are distinguished (amongst other criteria) because the former includes the eomyid species *Ligerimys florancei* Stehlin & Schaub, 1951 and *Ligerimys ellipticus* Daams, 1976, while in subzone Cb only *L. ellipticus* is recorded (Van der Meulen *et al.* 2012). In the Vallès-Penedès, both *Ligerimys* species are only recorded at Can Martí Vell and les Cases de la Valenciana, whereas in all other early Aragonian sites only *L. ellipticus* is present. Furthermore, additional *Democricetodon* species are recorded in some of these sites (els Casots, Vilobí del Penedès, Sant Mamet, el Papiol), which also may support a younger age (Casanovas-Vilar *et al.* 2016; Jovells-Vaqué *et al.* 2018). However, our preliminary data indicate that the cricetid succession in Calatayud-Daroca and the Vallès-Penedès is not the same; for example, *D. hispanicus* persists for a longer time in the Catalan basin (Jovells-Vaqué *et al.* 2017, 2018), so the subdivision of zone C into subzones Ca and Cb in this area should be taken with caution.

During the latest early Miocene and the middle Miocene (17-15 Ma), at least three sea-level transgressions took place during the late Burdigalian, the Langhian and the

early Serravallian. Since the southwestern margin of the basin is open to the sea, a shallow sea flooded a large part of the basin (Cabrera *et al.* 1991; Cabrera & Calvet 1996; Roca *et al.* 1999; Domènech *et al.* 2011; Casanovas-Vilar *et al.* 2016). The sequences deposited at this time make up the so-called Marine and Transitional Units and consist of coralgal platform carbonates as well as marine bay and transitional fan-delta siliciclastic facies. These separate the early Miocene continental units from the middle and late Miocene ones. A few early Aragonian sites appear associated with marine or transitional deposits. Vilobí del Penedès is located in bay deposits slightly above gypsum deposits corresponding to coastal sabkhas associated to the late Burdigalian transgression (Agustí *et al.* 1990; Cabrera *et al.* 1991). Sant Mamet and les Escletxes del Papiol are located in distal alluvial fan facies situated just a few meters below marine Langhian deposits (Agustí *et al.* 1985; Cabrera *et al.* 1991; Casanovas-Vilar *et al.* 2016). These sites have delivered two *Democricetodon* species and only one eomyid, *L. ellipticus*, which agrees with their younger age. Finally, we note that

Ma	Age/Stage	MN	Stratigraphy scheme				Local zone	Locality acronym
			BAIX PENEDÈS	ALT PENEDÈS	BAIX LLOBREGAT	VALLÈS OCCIDENTAL		
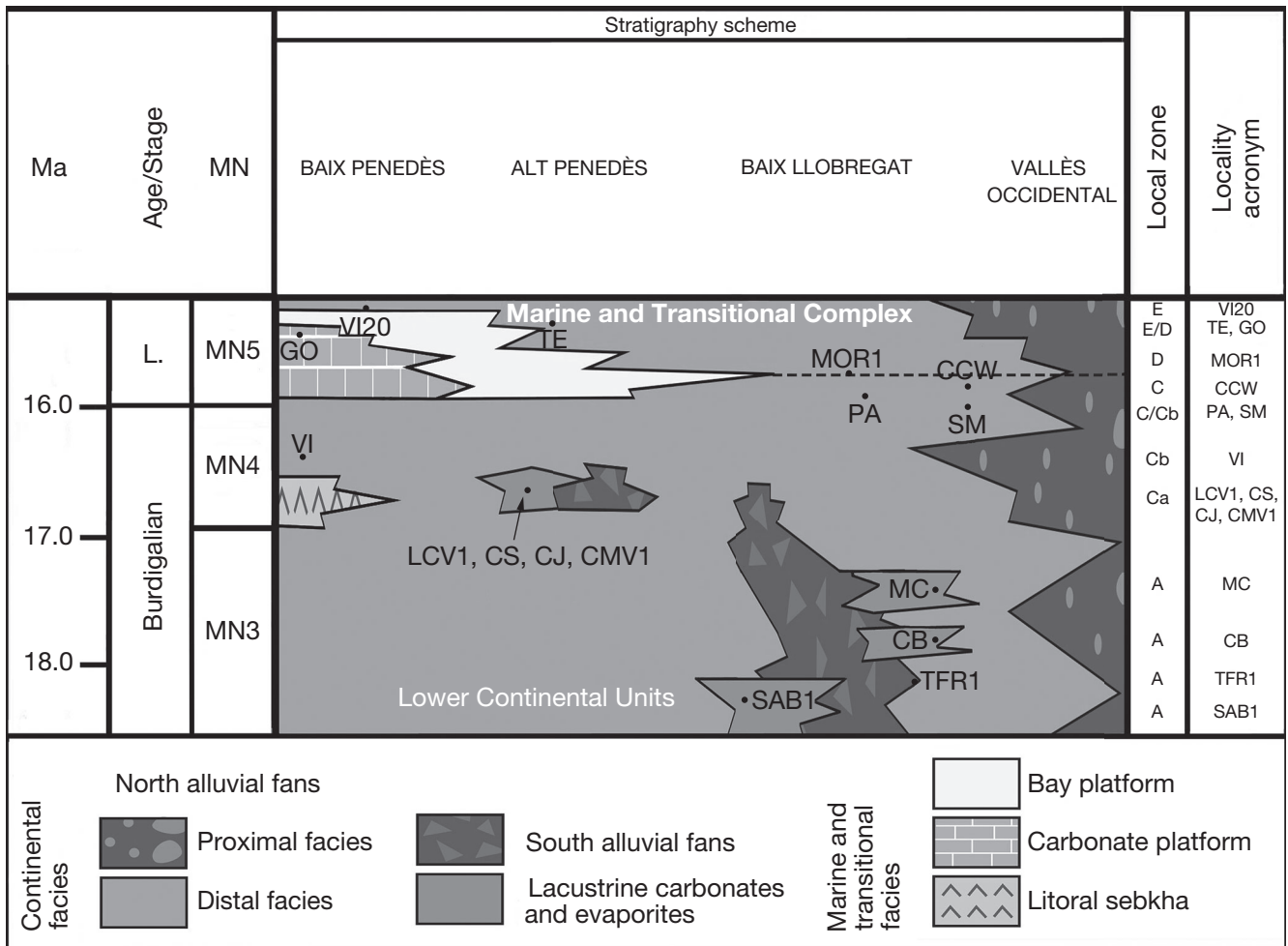
Fig. 2. — Generalized stratigraphic framework of the early to early middle Miocene sedimentary record of the Vallès-Penedès Basin showing the main lithostratigraphic units and their relationships (modified after Cabrera et al. 1991 and De Gibert & Casanovas-Vilar 2011). Note the different early Miocene lacustrine systems (including most localities) as well as the marine deposits associated to the Langhian transgression. See Figure 1 for locality acronyms.

the stratigraphical position and correlation of a few sites (El Canyet, El Palau 3B and la Vinya Vella) is controversial, although they have been generally correlated to the MN4 (Agustí *et al.* 1985).

MATERIAL AND METHODS

The teeth were measured using a Nikon Measuroscope 10 connected to a Nikon SC-112 counter. The orientation of the teeth for measuring and the dental terminology follows Klietmann *et al.* (2014a) for *Amphiperatherium*, De Jong (1988) for the Erinaceidae, Van den Hoek Ostende (1989) for the Talpidae, Klietmann *et al.* (2014b) for the Dimylidae, Reumer (1984) for the Soricidae and Furió *et al.* (2015) for the Heterosoricidae. All measurements are in millimeters. SEM photographs were taken at the Servei de Microscopia de la Universitat Autònoma de Barcelona. The material is stored at the Institut Català de Paleontologia Miquel Crusafont (ICP). The definition and boundaries of the MN (Mammal Neogene zones) follow Hilgen *et al.* (2012).

SYSTEMATIC PALEONTOLOGY

Infraclass METATHERIA Huxley, 1880
Family HERPETOTHERIIDAE Trouessart, 1879
Genus *Amphiperatherium* Filhol, 1879

Amphiperatherium frequens (von Meyer, 1846)
(Fig. 3A-G)

MATERIAL AND MEASUREMENTS (in cm). — **Spain**. El Canyet, IPS19361, mandible with m1-m4, partially encaged in sediment; El Palau 3B, 1 m2 sin., IPS86230, 2.17 × 1.17 × 1.26; 1 m3 dext., IPS86231, 2.11 × 1.18 × 1.12; Can Martí Vell II, M3 dext., IPS102010, LvK 2.16 × WvK 2.36; LCr 2.12 × WCr 2.75; 1 m1 sin., IPS86262, 2.00 × 1.00 × 1.12; 1 m3 dext., IPS86260, 2.16 × 1.18 × 1.14; Can Martí Vell I, 1 M4 dext., IPS86243, 1.10 × 2.30; Les Cases de la Valenciana 1, 1 M3 sin., IPS86622, – × –, 2 fragmented upper molars, IPS86615, IPS86623; Turó de les Forques, 1 M2 dext., IPS86822, – × –; p2? dext., IPS86823, – × 0.75, m3 sin., IPS85484, 2.19 × 1.22 × 1.16; Sant Andreu de la Barca 1, dP3 dext., IPS86180, LvK 1.63 × WvK 1.36; LCr 1.37 × WCr 1.68.

TABLE 1. — Localities studied with their corresponding stage and zone and their relative position (when possible). Abbreviations: **srm**, stratigraphic refinement method used to determine the relative position; **L**, lithostratigraphy; **M**, magnetostratigraphy; **B**, biostratigraphy.

Localities	Stage and zone	Relative position	Srm
La Vinya Vella	MN4	very high in succession	B+L
El Palau 3B	MN4?	–	B
El Canyet	MN4?	–	B
Les Escletxes del Papiol	Aragonian zone C	subzone Cb? younger than Vilobí	B+L
Sant Mamet	Aragonian zone C	subzone Cb? younger than Vilobí	B+L+M
Vilobí del Penedès	Aragonian zone C	subzone Cb? younger than Els Casots	B+L
Els Casots	Aragonian zone C	subzone Cb?	B+L
Can Julià	Aragonian zone C	–	B+L
Can Martí Vell 1-3	Aragonian zone C	subzone Ca?	B+L
Les Cases de la Valenciana	Aragonian zone C	subzone Ca?	B+L
El Molí de Can Calopa	Ramblian zone A	younger than Costablanca	B+L
La Costablanca 1-2	Ramblian zone A	–	B+L
Turó de les Forques	Ramblian zone A	below Costablanca	B+L
Sant Andreu de la Barca 1-3	Ramblian zone A	–	B

DESCRIPTION

dP3
The occlusal outline is triangular. The parastylar region is broken in the only sufficiently complete specimen. The metaconus is the highest cusp. The paraconus is somewhat lower than the metaconus. The antimetaconus is almost as high as the paraconus, whereas the antiparaconus is reduced to a tiny elongated bulge between both. The protoconulus (= "paraconule" *in* Furió *et al.* 2012) is discernible as a small elevation of the preprotocrista. The preprotocrista connects with the base of the paraconus by means of a faint ridge. The protoconus is the most lingual cusp of the tooth, and the highest of the lingual lobe. The postprotocrista descends irregularly, so the most posterior inflexion can be interpreted as a weak metaconulus. The metaconulus is separated from the base of the metaconus by a notch. There is no cingulum surrounding the base of the tooth.

M2
The only specimen found is incomplete, as the metaconus complex is missing. The parastyle is partially fragmented, but is clearly reduced. The paraconus is the highest cusp. The protoconus is much lower. The preprotocrista does not reach the base of the paraconus, as it is interrupted by a well-marked notch. The protoconulus and metaconulus are rather inconspicuous. The preserved part of the postpotocrista is a continuous ridge at the posterolingual margin of the tooth.

M3
The metaconus is the highest cusp. The protoconus is clearly lower than the metaconus and only somewhat lower than the paraconus. The parastyle is formed by a hardly protruding, triangular area. The metaconulus is very small. The antiparaconus is pronounced; the antimetaconus is tiny, only represented by a small pimple placed close to an occlusal inflexion of the labial margin. The labial margin is concave.

M4
The occlusal outline is triangular, and about twice as long in the labio-lingual than in the meso-distal direction. The paraconus is a sharp elevated cusp in a central position with two crests at an angle of 90º. One of the crests is completely parallel to the anterior margin, thus connecting with the parastyle. The other one is completely perpendicular to the anterior margin thus reaching the posterior corner and the purported metaconus. The protoconus is placed at the lingual corner. The basal cingulum covers the anterior margin, running from the protoconus to the base of the parastyle. The postprotocrista makes a soft 'S' curvature ending in a faint and slightly elevated metaconulus.

Mandible
The specimen from El Canyet only preserves the horizontal ramus. The lingual side is strongly dissolved and the labial one is covered by a hard sedimentary crust, so no significant mandibular character can be observed.

p2 (?)
The only specimen is damaged, lacking the posterior extension. This tooth is monocuspid and two-rooted. The two roots are very close to each other. The main cusp is trifaced. In lingual view, the crown is triangular. The lingual face is flat. The labial face is convex. In labial view, the anterior part of the base elevates in anterior direction reaching half of the total height of the main cuspid.

m1
The trigonid has an elongated aspect, with a paralophid clearly longer than the protolophid. The protoconid is the highest cusp. The metaconid is somewhat lower, and the paraconid is lower than the metaconid. The talonid is clearly wider and shorter than the trigonid. The hypoconid is very large. The oblique cristid ends just lingually of the base of the protoconid; the hypolophid is curved and separated from the entoconid by a wide post-entoconid valley. The entoconid is small; the entocristid slopes down steeply. The anterior cingulid is strong; the posterior cingulum is well developed. A small portion of labial cingulid borders the re-entrant valley.

m2
The relative height of the trigonid cuspids is the same as in m1. However, the proportion between length and width is

different, with a paralophid only slightly longer than the pro-tolophid. The talonid and trigonid have similar lengths and widths. The hypoconid is the highest cuspid of the talonid. The entoconid is well developed, but it is shorter than the hypoconid. The hypoconulid is tilted distally, thus providing a 'twisted' aspect to the postcristid. The hypoconulid and the entoconid are separated by a wide notch. There is a well-developed cingulid below the paralophid. The oblique cristid ends more labially than lingually, at about one third of the protolophid length.

m3
The talonid is shorter and somewhat narrower than the trigonid. The hypoconulid stands out less than in m2. The rest of the characters are quite the same as in m2.

REMARKS
Occurrences of the herpetotheriid metatherian *Amphiperatherium* are quite frequent in the early Miocene of central Europe (von Koenigswald 1970; Ziegler & Fahlbusch 1986; Ziegler 1990a, 1999; Klietmann *et al.* 2014a). By contrast, this genus is rather rare in Spain, though its presence in the Iberian Peninsula was noted in Buñol (Robles *et al.* 1991), Mas d'Antolino and Barranc de Campisano (Furió *et al.* 2012) and Montalvos 2 (Hordijk *et al.* 2015). Moreover, fossils were found in the Ramblian and early Aragonian sections of the Calatayud-Montalban basin (LHO, pers. obs.), but these collections are currently lost. The material from Las Cases de Valenciana was already described by Jovells-Vaqué *et al.* (2018).

Species identification based on isolated molars is difficult, but the only European marsupial known from the Miocene is *Amphiperatherium frequens* von Meyer, 1846. As the material generally fits this species both metrically and morphologically, its identification on the species level seems to be safe. Our material is too limited to venture assigning it to one of the subspecies as defined in central Europe.

Infraclass EUTHERIA Huxley, 1880
Order EULIPOTYPHLA
Waddell, Okada, Hasegawa, 1999
Family ERINACEIDAE Fischer, 1814
Genus *Galerix* Pomel, 1848

Galerix remmerti Van den Hoek Ostende, 2003
(Fig. 3H-J)

MATERIAL AND MEASUREMENTS (in cm). — **Spain.** Turó de les Forques, 1 M2 dext. damaged, IPS85480, – × 3.06; 1 M3 sin., IPS85486, 1.36 × 2.24; 1 m2 dext., IPS85482, 2.98 × 2.06; Sant Andreu de la Barca 3, 1 P4 sin. damaged, IPS86202; Sant Andreu de la Barca 1, 1 p1, IPS86194, 1.45 × 0.69.

DESCRIPTION
P4
The specimen from Sant Andreu de la Barca 3 is heavily damaged, lacking the posterolabial part of the premolar, having the protocone restored and being abraded around the parastyle.

The overall appearance of the tooth is quite sturdy. The conical protocone is about twice the height and size of the hypocone. The two lingual cusps stand well isolated from each other.

M2
The specimen of Turó de les Forques shows a very strong protocone-metaconule connection. From this, a faint ridge runs in the direction of the hypocone, which stands more or less isolated. The metaconule is atypical in not having a true crescent shape, but short and blunt anterior and posterior arms. The posterior cingulum is continuous.

M3
The three main cusps are connected by sharp ridges, the most prominent one being the ridge that connects protocone and paracone. In front of the paracone lies a well-developed parastyle, which connects to the base of the paracone by a short ridge.

p1
The premolar is much longer than wide; the occlusal outline is sub-oval. The tip of the main cusp lies in front of the middle of the tooth. There is a tiny anterior flattening and a much larger posterior one. The tooth has one root that is directed obliquely backwards.

m2
The cusps have a sturdy appearance, with relatively straight flanks. The talonid is of the same length and width as the trigonid. The blade-like paralophid is slightly hooked. There is a very small metacristid. The posterior cingulid slopes up to just below the centre of the hypolophid. The anterior cingulid seems rather narrow and tapers out against the paraconid.

Galerix symeonidisi Doukas, 1986
(Fig. 3K-M)

MATERIAL AND MEASUREMENTS (in cm). — **Spain.** El Canyet, 1 mandible sin. with broken m2 and slightly damaged m3, IPS20978, – × –; 1.67 × 1.19; Can Julià, 1 m3 dext., IPS86238, 1.78 × 1.16; Can Martí Vell I: 1 P2 sin., IPS96863, 1.67 × 0.86; 1 mandible dext. with m1 and m2, IPS96861, 2.75 × 1.81; 2.32 × 1.72; 1 labial half of P4 dext., IPS96862, 2.27 × –; Can Martí Vell III, 1 M2 dext., IPS90033, 1.75 × 2.29; 2 M2 sin., IPS90034-35, 1.75 × 2.42; 1.79 × 2.48; Les Cases de la Valenciana 1, 1 M2 sin., IPS86824, 1.86 × 2.47; 1 M3 sin., IPS86596, 1.11 × –; 1 p1 sin., IPS86598, 1.11 × 0.60; 1 p2 dext., IPS86597, 1.14 × 0.56; 1 m3 sin., IPS86825, 1.90 × 1.21; Vilobí de Penedès, 1 P3 lingual fragment, IPS86856; 2 damaged M1 dext., IPS86858, 86860; 1 p4 sin., IPS86852, 1.91 × 1.12; La Vinya Vella, 1 M1 dext., IPS106596, 2.33 × 3.05; Sant Mamet 1, 1 M1 sin., IPS105162, +1.94 × +2.60; 1 p4 dext., IPS105166, 1.70 × 0.97; 1 m2 sin., IPS105164, 2.36 × 1.48; 1 m2 dext., IPS105165, 2.41 × –.

DESCRIPTION
P2
The outline is elliptical and mesiodistally elongated. The two roots of this tooth are divergent and the main cusp is a bit anterior to the centre of the premolar.

P4

Only the labial side is preserved in the single available specimen. The parastyle is somewhat protruding. The preserved part of the posterior margin is covered by a thin but well-defined cingulum.

M1

The two available specimens from VdP are damaged. Only the specimen from La Vinya Vella is completely preserved. The anterior width is quite similar to the lingual length. The posterolabial corner is elongated. The protocone-hypocone connection is stronger than the protocone-metaconule connection. The latter is even missing on one of the specimens. The posterior arm of the metaconule is short and it does not reach the posterior cingulum in any specimen.

M2

The protocone-hypocone connection is strong. Two out of three M2 from Can Martí Vell III lack the protocone-metaconule connection. The posterior cingulum is continuous in the two specimens in which this character can be ascertained.

M3

Even though the anterolabial part of the only available specimen is damaged, the last upper molar is triangular in occlusal view, in spite of the broken anterolabial part. The central basin is closed, except for a small notch near the paracone, thus partially interrupting the anterior crest.

Mandible

The only fragment from El Canyet is very damaged. It is a posterior fragment of the horizontal ramus with no significant characters other than a rather high mandibular corpus. The position of the mental foramen is unknown.

p1

The outline of the occlusal surface is slightly ovoid. The tip of the unicuspid lies in the anterior part of the tooth; there is a small flattening behind it. The p1 is one-rooted.

p2

In contrast to the p1, the p2 is double rooted. The outline is elliptical and the tip more centrally placed. There is no posterior flattening.

p4

The premolar consists of a trigonid with a very short posterior flattening. The metaconid is well developed. In our hardly worn specimen, the paraconid is formed like a sharp ridge. The paralophid is interrupted by a clear notch between the paraconid and the protoconid. The posterior flattening is bordered by a low posterior ridge.

m1 and m2

These elements show the invariable aspect typical of the genus, being the m1 larger than the m2 and having a more pointed paraconid, which is rounded in m2. Other than that, the only remarkable trait on these elements is the posterior cingulid, which rises obliquely the distal margin of the tooth, but it does not reach the postcristid.

m3

Specimens have been found in Les Cases de la Valenciana 1, El Canyet and Can Julià. The element from El Canyet is not complete, thus hampering comparisons. The element from Can Julià only differs from that of Les Cases de la Valenciana described in Jovells-Vaqué *et al.* (2018) in having a slightly smaller talonid.

Remarks

Galerix is a very common element in the Miocene faunas of the late and middle Miocene of Europe. The genus probably originated in Anatolia (Van den Hoek Ostende 1992). The earliest representatives in Europe are known from MN 3 onwards. In Spain, the oldest *Galerix* known hitherto is *G. remmerti* Van den Hoek Ostende, 2003 a large-sized species which seems closely related to the central European *G. aurelianensis* (Van den Hoek Ostende 2003). In addition, Van den Hoek Ostende (2003) noted the presence of a very large *Galerix* in some Ramblian assemblages, known from a couple of elements only. At the start of the Aragonian, *G. remmerti* is replaced by the much smaller-sized *G. symeonidisi* in the Daroca-Calamocha basin (Van den Hoek Ostende & Doukas 2003). A similar situation occurs in central Europe, but here *G. symeonidisi* gradually replaces *G. aurelianensis*. *Galerix symeonidisi* is in its turn replaced by *G. exilis*. Initially, this replacement was considered a matter of gradual evolution (Ziegler & Fahlbusch 1986) but according to the cladistic analysis of Borrani *et al.* (2018), *G. symeonidisi* and *G. exilis* are not closely related species. Based on the large overall variation in some *Galerix* assemblage of the Daroca-Calamocha area, Van den Hoek Ostende and Doukas (2003) showed that in fact the two species must have occurred together. This discussion clearly demonstrated the difficulties of interpreting *Galerix* assemblages if more than one species could be present. In the case of the material from the Vallès-Penedès, identifications are hampered by the scarce material and the absence of characteristic elements (P3, p4) in most assemblages.

In the P4 from SAB3, protocone and hypocone are separated, a condition also found in one specimen of *G. remmerti* from San Roque 4A (Van den Hoek Ostende 2003). The M1 from Sant Mamet 1 and the M2 from Turó de les Forques are peculiar, as their metaconules do not have the crescent-shape that is considered typical for the Galericini (Van den Hoek Ostende 2001). However, this morphotype is also known from Petersbuch 28 (Klietmann *et al.* 2014a) and from Zone B localities in the Daroca-Calamocha area (LHO, pers. obs.). The molar somewhat exceeds the largest specimen of *Galerix remmerti* from the inland localities, as do the m2 and M3 from the same locality. Also the p1 from Sant Andreu de la Barca 1 is remarkably large. The molars do fall in the size range of *G. aurelianensis* Ziegler, 1990, a central European species that mainly differs from *G. remmerti* in size and presumably
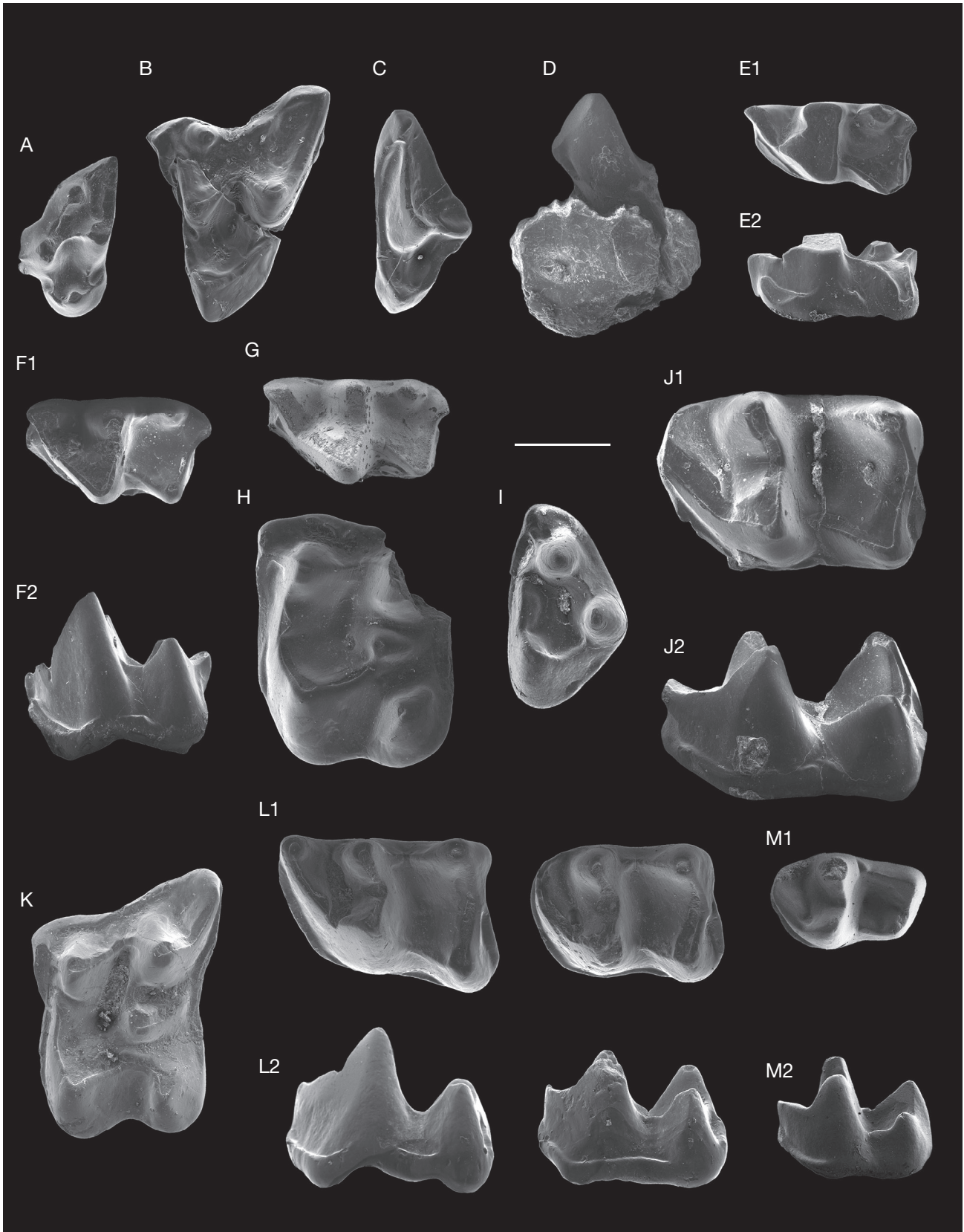
FIG. 3. — Marsupial and galericines from the early Miocene of the Vallès-Penedès: *Amphiperatherium frequens* von Meyer, 1846 (**A-G**). **A**, IPS86180. dP3 dext. (rev) SAB1. **B**, IPS102010. M3 dext. (rev) CMV-II. **C**, IPS86243. M4 dext. (rev). CMV-I. **D**, IPS86823. p2? dext. (rev). TFR. **E**, IPS86262. m1 sin. CMV-II. (E1-ocl; E2-lab). **F**, IPS86230. m2 sin. Palau 3B. (F1-ocl; F2-lab). **G**, IPS86260. m3 dext. CMV-II. *Galerix remmerti* Van den Hoek Ostende, 2003 (**H-J**). **H**, IPS85480. M2 dext. (rev). TFR. **I**, IPS85486. M3 sin. TFR. **J**, IPS85482. m2 dext. (rev). TFR. (J1-ocl; J2-lab). *Galerix symeonidisi* Doukas, 1986 (**K-M**). **K**, IPS106596. M1 dext. (rev). LVV. **L**, IPS96861. m1+m2 dext. (rev). CMV-I. (L1-ocl; L2-lab). **M**, IPS86238. m3 dext. (rev). CJ. (M1-ocl; M2-lab). Scale bar: 1 mm.

was part of the same migration event at the beginning of the Ramblian. Actually, the distinction between *G. aurelianensis* and *G. remmerti* is not always easy without a large sample. For instance, Klietmann *et al.* (2014a) suggested that the form present in the French localities of Beaulieu and Bouzigues (Aguilar *et al.* 2003; Sigé *et al.* 1997) was likely *G. remmerti*. Would it be the case, the presence of *G. aurelianensis* in the Vallès-Penedès basin would create a biogeographic problem of difficult interpretation. Even the possibility that these two forms were conspecific and the differences observed are only a matter of latitudinal variation cannot be discarded. In the absence of further elements to judge, a conservative taxonomic solution is herein preferred, noting that these questions must deserve attention in future works.

The younger material of *Galerix* from the MN 4 localities in our study clearly belongs to a smaller species. Jovells-Vaqué *et al.* (2018) already identified the galericine from Cases de la Valenciana as *Galerix* cf. *symeonidisi* based on the size and the absence of a protocone-metaconule connections in two of the three upper molars. Their identification is now confirmed by a lingual fragment of a P3 from Vilobí del Penedès which clearly shows a hypocone, one of the main characteristics of *G. symeonidisi*. Of the two damaged M1 from this locality, one misses the protocone-metaconule connection. The complete M1 from La Vinya Vella (the only insectivore fossil found in this site) is tentatively ascribed to the same species due to the strong similarities with the material from Vilobí del Penedès. However, because of its somewhat larger size it could even belong to *G. exilis*, which is known to co-occur and ultimately replace *G. symeonidisi* in the Daroca-Calamocha area in Zone C (Van den Hoek Ostende & Doukas 2003). This would be in line with La Vinya Vella being one of the youngest localities in this study. The material from LVV is, however, too limited and we thus refrain from ascribing it to a different species.

In short, the localities of the Vallès-Penedès seem to fit the pattern observed in the inland basins, in which the large-sized *G. remmerti* is replaced by *G. symeonidisi* around the Ramblian-Aragonian boundary. Moreover, the large size of the larger species fits with that of the central European *G. aurelianensis*, suggesting a near continuous distribution between the northern species and *G. remmerti*. As yet, the material is limited and some caution must be observed in these conclusions, but they fit in nicely with the current ideas about early Miocene galericine distribution patterns.

Family TALPIDAE Fischer, 1814 *incertae sedis*
Genus *Desmanodon* Engesser, 1980

Desmanodon daamsi Van den Hoek Ostende, 1997
(Fig. 4A-F)

MATERIAL AND MEASUREMENTS (in cm). — **Spain.** El Palau 3B, 1 m2 dext., IPS86232, – × –; Can Martí Vell III, 1 m3 sin., IPS86278, 1.24 × 0.78; Sant Andreu de la Barca 3, 1 M3 sin., IPS86203, 1.12 × 1.67; Sant Andreu de la Barca 1, 1 P? dext., IPS86195, 1.45 × 0.69; 2 P4 dext., IPS86192-93, 1.43 × 1.17; – × –; 2 M1 sin., IPS86183-84, – × –; 1.62 × 1.50; 1 M2 dext., IPS86181, 1.77 × 2.25; Turó

de les Forques, 1 P4 dext., IPS85483, 1.36 × 1.24; 1 damaged M1 dext., IPS85488, – × –; 1 M1 sin., IPS86816, 1.73 × 2.32; 1 M2 sin., IPS86817, 1.74 × 1.97; 1 M2 dext., IPS86818, 1.76 × 2.13; Costablanca, 1 M2 sin., IPS19372, 1.91 × 1.84.

DESCRIPTION
P?
One premolar from Sant Andreu de la Barca 1 is tentatively assigned to *Desmanodon* based on its high tip. The occlusal outline is teardrop-shaped, with the point directed backwards. The tip of this unicuspid lies in the front part of the premolar at about two thirds its length. It bears a sharp posterocrista and has a round anterior face. A narrow cingulum surrounds the tooth, being interrupted at the anterolabial flank of the paracone only. The cingulum is a bit thicker at the posterior end of the premolar. There are two plank-shaped roots of about equal size, which stand parallel to one another.

P4
The outline of the occlusal surface is triangular; the premolar is somewhat longer than wide. Both parastyle and protocone are small, the posterocrista is S-curved (Morphotype C sensu Van den Hoek Ostende 1989). The paracone is high and its posterocrista is curved just behind its tip. The narrow cingulum is continuous on the lingual side, interrupted at the base of the paracone on the labial side.

M1
The labial cusps, and particularly the metacone, are very high. The occlusal surface is irregularly quadrangular, with a long lingual side. The posterior arm of the paracone is relatively straight. The posterior arm of the metacone is just somewhat longer than the anterior arm. The mesostyle is incompletely divided. There is a small, slightly protruding parastyle in the anterolabial corner of the molar. The low protocone lies in the anterolingual corner of the molar. Its short anterior arm ends against the base of the paracone. The posterior arm follows the contours of the outline lingually, and continues as the well-developed posterior cingulum. In one of the two specimens from Turó de les Forques, a slight thickening in the posterior arm reveals the position of the hypocone. There is no protoconule. In one of the two specimens, there is a very short portion of lingual cingulum just behind the protocone.

M2
It is slightly asymmetrical due to the anterior position of the protocone and the small hypocone. There is no protoconule. The high labial cusps occupy about two thirds of the occlusal surface. The mesostyle is poorly divided. The small parastyle is slightly protruding; the metastyle is more developed as a labial thickening of the posterior cingulum. There are short stretches of cingulum along the anterior flank of the paracone and the posterior flank of the metacone, respectively.

M3
It has an incompletely divided mesostyle, with the two cusplets clearly separated in the unworn specimen from Sant Andreu
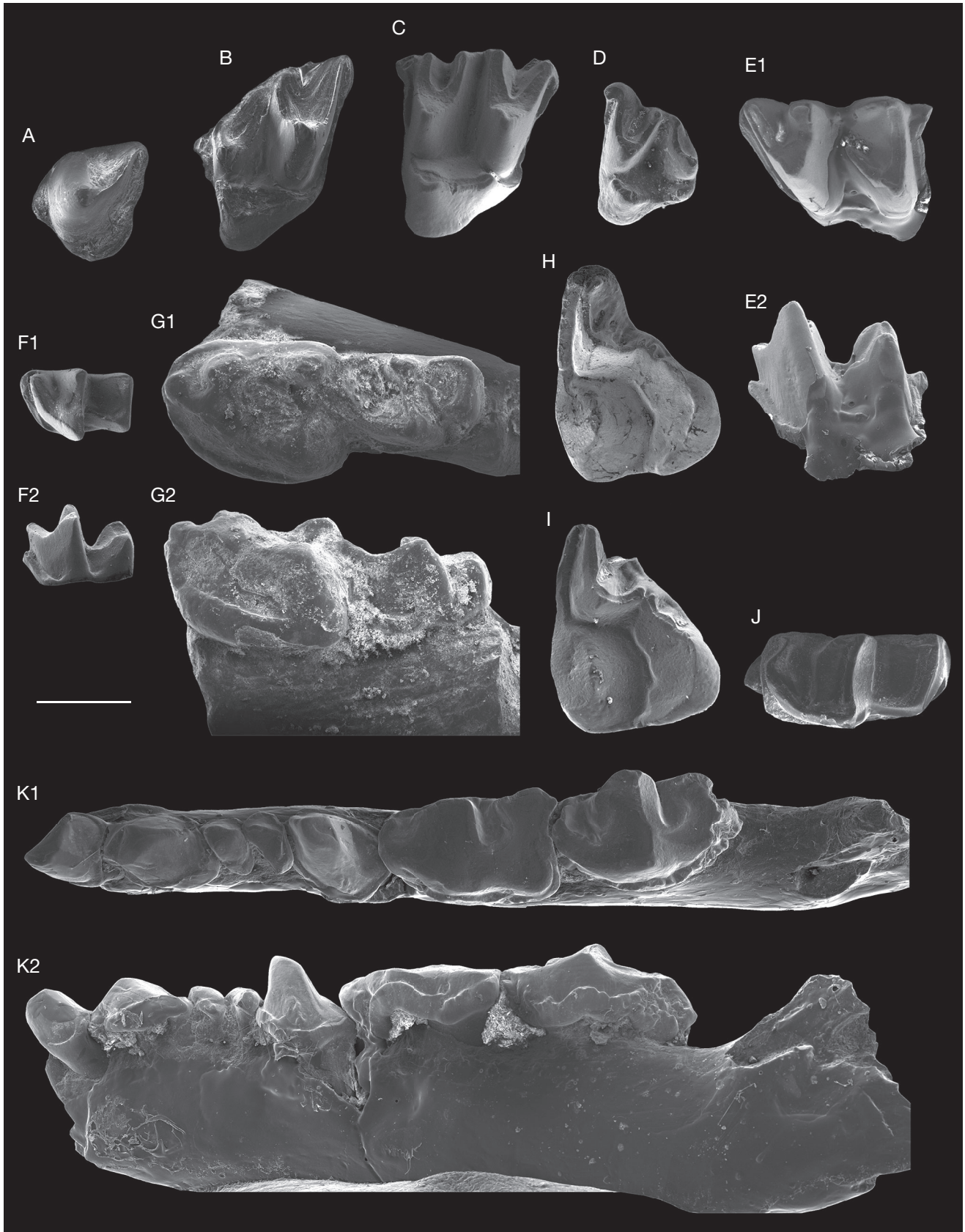
Fɪɢ. 4. — Talpid and dimylids from the early Miocene of the Vallès-Penedès. *Desmanodon daamsi* Van den Hoek Ostende, 1997 (**A-F**). **A**, IPS106596. P4 dext. (rev). TFR. **B**, IPS86816. M1 sin. TFR. **C**, IPS86818. M2 dext. (rev). TFR. **D**, IPS86203. M3 sin. SAB-3. **E**, IPS86232. m2 dext. (rev). Palau 3B. (E1-ocl; E2-lab). **F**, IPS86278. m3 sin. CMV-III. (F1-ocl; F2-lab). *Chainodus* sp. (**G**). **G**, IPS116324. m1+m2 dext. (rev). CB2. (G1-ocl; G2-lab). *Plesiodimylus* sp. (**H-K**). **H**, IPS86256. M2 dext. (rev). CMV-II. **I**, IPS85481. M2 dext. (rev). TFR. **J**, IPS85668. m2 sin. CB2. (ocl). **K**, IPS86185. mand. with c-m2 sin. SAB1. (K1-ocl; K2-lab). Scale bar: 1 mm.

de la Barca 3. The anterior arm of the protocone is only slightly longer than the posterior arm, and bends sharply at its end to form a protruding parastyle. There is a short stretch of cingulum between the parastyle and the anterior flank of the paracone. The hypocone is a small but distinct cusp, well isolated from the metacone.

m2

The specimen from El Palau 3B has been restored after breakage. The trigonid is somewhat narrower and clearly shorter than the talonid. The cuspids are very high. The oblique cristid ends against the posterior wall of the trigonid, just labially to the metaconid. The entocristid is high, and quickly slopes down. The cingulid is well developed on the anterior and posterior sides. The lingual cingulid cannot be assessed properly because of the damage, but is certainly narrower than the anterior and posterior cingulids. The entostylid protrudes sharply.

m3

It has a talonid which is only slightly reduced and somewhat shorter and narrower than the trigonid. The two arms of the protoconid form a narrow V-shape. The oblique cristid ends halfway the posterior wall of the trigonid. The entocristid is well developed. The anterior cingulid is narrow but distinct and rounds the paraconid, ending below the trigonid valley.

Remarks

The early history of the genus *Desmanodon* mirrors that of *Galerix*. This talpid also had its oldest known records in Anatolia and it purportedly dispersed into Europe around the MN2/MN3 transition (Van den Hoek Ostende 1997; Van den Hoek Ostende *et al.* 2016). The only species known so far from the Iberian Peninsula is *D. daamsi*, which is characterized by an incompletely divided mesostyle in the upper molars and poor hypocone development on the M1 and M2. In these characters, as well as in size, the material from the Vallès-Penedès fits well with the earlier described assemblages from the basins of Calatayud-Teruel, Rubielos de Mora, and Ribesalbes-Alcora (Van den Hoek Ostende 1997, 2003; Hordijk *et al.* 2015; Van den Hoek Ostende *et al.* 2017; Crespo-Roures *et al.* 2019). The most characteristic feature of the Iberian talpid, its relatively slender humerus, could not be ascertained for in the Vallès-Penedès assemblages as to date no humeri have been found.

Family DIMYLIDAE Schlosser, 1887
Genus *Chainodus* Ziegler, 1990

Chainodus sp.
(Fig. 4G)

MATERIAL AND MEASUREMENTS (in cm). — **Spain**.

Material from Turó de les Forques, 1 m1 dext., IPS85453, 2.16 × 1.74.

Material from Costablanca 2, 2 mandibles bearing m1 and m2: sin. IPS116323, m1 2.04 × 1.75, m2 1.68 × 1.20; dext. IPS116324 m1 2.07 × 1.72, m2 1.79 × 1.21.

DESCRIPTION
M1

The molar is strongly amblyodont. The trigonid is only slightly higher than the talonid. The protoconid, paraconid and metaconid are regularly spaced, bordering a shallow but open trigonid basin. The hypoconid is massive. The oblique cristid ends against the base of the protoconid, the hypolophid connects to the entoconid. The posterior cingulid slopes up to just below the point where hypoconid and entoconid meet. A thick entocristid borders the shallow talonid basin on the lingual side. The labial cingulid is very strong at the base of the protoconid, but tapers out in both directions against the base of the hypoconid and the base of the paraconid, respectively. There is a stretch of bulbous lingual cingulid at the base of the trigonid.

m2

The trigonid is clearly longer and somewhat wider than the talonid. Because of the long, regularly curved paralophid, the trigonid basin is very open. The metaconid lies somewhat anterolingually of the protoconid. The talonid cusps are very reduced and incorporated in a low ridges surrounding the shallow talonid basin.

REMARKS

The genus *Chainodus* is a rare occurrence in the Iberian faunas. Its presence was first noted by Gibert (1975) as *Cordylodon* (= *Chainodus*) *intercedens* from Rubielos de Mora 2. The observation by Furió *et al.* (2011a) that *Chainodus* was present in lower Miocene strata of the Vallès-Penedès was based on the material that is described here. Recently, Van den Hoek Ostende *et al.* (2017) confirmed the presence of *Chainodus* in other assemblages from the Rubielos de Mora Basin. However, the species was not *C. intercedens*, a taxon which is very common in central Europe in the later part of the early Miocene (e.g. Müller 1967; Ziegler 1990a; Klietmann *et al.* 2014b). Instead, the authors identified the dimylid from Alto de Ballester as *C. sulcatus*, based on the loose symphysis of the lower jaw. As this character cannot be observed in our material, we leave the identification at the genus level.

Genus *Plesiodimylus* Gaillard, 1897

Plesiodimylus sp.
(Fig. 4H-K)

MATERIAL AND MEASUREMENTS (in cm). — **Spain**. Can Julià, 1 m2 sin., IPS86237, 2.53 × 1.36; Sant Andreu de la Barca 1, 1 mandible with c-m2 sin., IPS86185, c – × –; p1 1.29 × 0.81; p2 0.66 × 0.66; p3 0.67 × 0.71; p4 1.33 × 0.92; m1 2.12 × 1.32; m2 2.24 × 1.27; Turó de les Forques, 1 M2 dext., IPS85481, 1.80 × 2.35; Costablanca 2, 1 m2 sin., IPS85668, 2.51 × 1.34; Can Martí Vell II, 1 M2 dext., IPS86256, 2.05 × 2.49; 1 m1 sin., IPS86258, 2.31 × 1.45.

DESCRIPTION
M2

The second upper molar from Turó de les Forques is hardly worn and slightly damaged in the parastylar region. The specimen from Can Martí Vell II is rather complete. The outline of the occlusal surface is triangular. The massive protocone has a faint crest

between its tip and the base of the paracone. The two arms of the paracone stand at nearly a right angle; the anterior arm is not strongly elongated. The separate cusps of the mesostyle are still discernible in the specimen from Turó de les Forques, but would merge already at an early wear stage as they are in the element from Can Martí Vell II. The metacone is large and shaped as a curved ridge. Its arm is thickened just in front of the tip. The anterior face of the metacone slopes gently towards the protocone, the posterior side is much steeper.

Mandible
Only the horizontal ramus is preserved. The ventral margin is rather straight but there is a slight constraint under the p4 and m1. The mental foramen is covered by sediment, but it makes a shallow concavity under the trigonid of the m1. The symphyseal area covers the lingual side from the c to the anterior tip.

c
The only specimen is damaged, missing part of the anterolingual region. The preserved part shows a relatively narrow cingulum, which slopes up at the back of the tooth.

p1
The outline is subtriangular, with convex lingual and labial sides. The main cusp is massive and has its tip in the front part of the premolar. The cingulid is thickest along the posterior side and tapers out along the lingual and labial sides. It is missing at the very front of the premolars.

p2 + p3
The second and third lower premolar are similar in morphology, the p2 being slightly larger. The premolars are much wider than long, with a subelliptical outline. The central cusp is low. The cingulid appears widest at the posterior sides. In the p3, it surrounds the tooth; in the p2, it appears to be missing on the anterior side.

p4
The last premolar is set obliquely in the mandible. Its occlusal outline is elliptical. The tip lies far to the front of the premolars; the centrocristid is blunt. The p4 is surrounded by a cingulid that is of the same thickness throughout, but appears to be missing at the very front of the tooth.

m1
The only available specimen is heavily worn, obliterating all the details of the cusps. The trigonid is clearly longer than the talonid, but of the same width. The anterior side of the molar is rounded. The cingulid is well developed on the labial side. It tapers out halfway the posterior side and is missing along the anterior side of the molar.

m2
The second lower molar shows a slight degree of amblyodonty, but the ridges are relatively sharp. The talonid is somewhat shorter and narrower than the trigonid. The trigonid valley has its deepest point just behind the paraconid. The paralophid is curved and incorporates the paraconid completely. It reaches its farthest point about halfway the width of the molar, after which it curves back and becomes quickly lower. The posterior arm of the protoconid curves slightly backward before reaching the metaconid. The latter bears a very short metacristid. The talonid basin is very shallow, and is surrounded by a ridge, in which only the entoconid stands out a bit. The molar has a very strong anterior cingulid, which rapidly grows thinner near the base of the protoconid, but it still is well developed on the labial side, and ends halfway the posterior face of the talonid.

Remarks
In contrast to *Chainodus*, *Plesiodimylus* is a relatively unspecialised dimylid. Its ability to deal with a wider range of environments may explain why this genus had the largest stratigraphic and geographic distribution in its family (Furió *et al.* 2011a; Crespo-Roures *et al.* 2018). *Plesiodimylus* is known from Germany (Müller 1967; Stephan-Hartl 1972; Schötz 1985; Ziegler & Fahlbusch 1986; Ziegler & Mörs 2000; Ziegler 1990a, 2005; Klietmann *et al.* 2014b), Austria (Ziegler 2006a, b), Slowakia (Fejfar & Sabol 2009), Czech Republic (Van den Hoek Ostende & Fejfar 2015), Switzerland (Bolliger 1992; Kälin & Engesser 2001), Poland (Rzebik-Kowalska 1996), Greece (Doukas 1986) and Turkey (Engesser 1980). In Spain, *Plesiodimylus* is a quite common element in the late middle Miocene and early late Miocene faunas of the Vallès-Penedès (Furió *et al.* 2011a, b; Van den Hoek Ostende *et al.* 2016), but had not been recognized from the early Miocene until recently, when Crespo-Roures *et al.* (2018) described a new species, *P. ilercavonicus*. Hitherto, the occurrences of this species are restricted to the type locality of Mas d'Antolino B-5 (early Aragonian) and the nearby sites of Barranc de Campisano 1 and Mas d'Antolino B 11 (Crespo-Roures *et al.* 2019). Metrically, the Vallès-Penedès material is smaller than this species and comparable in size to *P.* aff. *chantrei* from Petersbuch 28 (Klietmann *et al.* 2014b). Notably, there appear some differences particularly in the anterior dentition, such as the relatively shorter p1, the p2 > p3 and the obliquely set p4. Given the limited material, these elements are for the moment best classified as *Plesiodimylus* sp.

Family HETEROSORICIDAE Viret & Zapfe, 1952
Heterosorex Gaillard, 1915

Heterosorex neumayrianus (Schlosser, 1887)
(Fig. 5A-G)

MATERIAL AND MEASUREMENTS (in cm) — **Spain.** Can Julià, 1 M1 sin., IPS21034, 1.65 × –; 1 M2 dext., IPS86235, 1.49 × –; 1 M2 sin., IPS86236, 1.48 × –; Can Martí Vell III, 1 i1 dext. fragmented, IPS90036; Can Martí Vell II, 1 P4 dext., IPS21023, 1.52 × 1.45; 1 M1 sin., IPS86257, 1.60 × 1.86; 1 m1 dext., IPS86259, 1.95 × 1.29; Can Martí Vell I, 1 Ax sin., IPS86252, 1.10 × 0.89; 1 maxillary with M1 + M2 dext., IPS21025, 1.60 × 1.79, 1.38 × 1.71; 1 maxillary with M2 + M3 sin., IPS86241, 1.45 × 1.82, 0.83 × 1.27; 2 ax dext., IPS86249-50, 1.26 × 1.01; 1.19 × 0.92; 1 ax sin., IPS86251, 1.25 × 1.01; 1 i1 sin., IPS86254, > 4.75; 1 i1 dext (IPS86255, > 5.06), 2 mandibles with m1-m3 sin. (IPS86244-45, 2.08 × 1.30, 1.68 × 1.21, 1.30 × 0.98; 2.15 × 1.18, 1.74 × 1.15, 1.36 × 0.97; 1 mandible with

m2, m3 dext., IPS86246, 1.63 × 1.28, 1.29 × 0.96; Cases de la Valenciana 1, 1 M1 dext., IPS86826, 1.67 × 1.93; ax, IPS86600, 1.22 × 1.00; Costablanca 2, 1 maxillary with M1 + M2 sin., IPS85666, 1.64 × 1.84; 1.54 × −; 1 M3 sin., IPS85667, 0.88 × −.

DESCRIPTION
A
The occlusal outline looks like an irregular pentagon. The labial, the posterior and the lingual margins are sub-equal in length, the anterolabial and anterolingual sides being somewhat shorter. The labial margin is parallel to the lingual side, but it occupies a more posterior position. The main cusp occupies an advanced (anterior) position but at similar distance to both lingual and labial sides. A central ridge runs from the anterior tip of the tooth to the central point of the posterior cingulum. The posterior margin is oblique to the central crest and its base is occupied by a cingulum which extends further to both labial and lingual margins. There is a faint connection between the main cusp and the anterolingual corner.

P4
The occlusal outline is not completely triangular because the base of the protocone, at the anterolingual part, protrudes a little bit and makes it more squared. The paracone is the highest cusp and it bears an undulated posterior crest in occlusal view. The posterior margin is rather straight, with no emargination, and covered by a broad cingulum which extends lingually till the protocone. The protocone is only discernible as a small bulge. The hypocone is absent.

M1
The occlusal outline is square. The ectoloph is asymmetric, the anterior part (related to paracone) being shorter than the posterior one (related to the metacone). The mesostyle is only faintly divided. The posterior margin is bordered by a continuous ridge extended from the metastyle to the hypocone. The hypocone is only discernible as a small but sharp elevation in the posterior part of the endoloph. The protocone is placed at the anterolingual corner of the tooth. The anterior arm of the protocone is completely straight in labiolingual direction and connects with the base of the paracone. The posterior arm of the protocone forms the endoloph, running almost parallel to the lingual border, connecting with the hypocone. The metaloph is indicated as a very weak side branch, running towards, the base of the metaconid.

M2
The occlusal outline is less squared than the M1, with a posterior margin shorter than the anterior one. Paradoxically, the ectoloph is more symmetrical than in M1. The mesostyle is also faintly divided. However, this character is already not discernible in specimens with just worn ectoloph. The endoloph is more regular and continuous than in M1. The endoloph is a single element from the base of the paracone which elevates at the protocone and descends regularly with smooth curves down to the hypoconal flange, where it becomes a posterior cingulum ending at the posterolabial corner. There is no evidence of a metaloph connecting the protocone and the base of the metacone.

M3
The occlusal outline is rather triangular, but the posterior corner is rounded. The ectoloph is reduced to a 'V-shaped' crest. The mesostyle is divided, so this crest related to the paracone is separated from the posterolingual 'U-shaped' crest connecting the protocone and the purported metacone. There is no crest connecting the base of the paracone with the protocone.

i1
The labial and occlusal surfaces connect in an undulated crest with two cuspules. The apex is pointed. The enamel is somewhat wrinkled at the posterior part of the labial face.

a
The occlusal outline is heart-shaped with a slight asymmetry, the labial side being a bit longer than the lingual one. The two lateral (labial and lingual) margins are convex, whereas the posterior face is concave. The main cusp occupies an anterior position. An anterior crest descends abruptly to the anterior tip of the tooth. The two posterior arms connect with the posterolingual and the posterolabial corners respectively, thus delimiting a postero-occlusal concave surface, purportedly for the accommodation of the base of the posterior tooth in a 'piggy-back' disposal. In Can Martí Vell I, the specimen IPS86250 is similar in size to IPS86251 but smaller than IPS86249.

m1
The trigonid is longer but narrower than the talonid. The protocone is the highest cusp. The paralophid is straight in occlusal view but concave in labial view, and so is the protolophid. However, the paralophid is longer than the protolophid. The metaconid is a bit lower than the protoconid and it connects with the entocristid by means of a metacristid. Thus, the talonid valley is closed, whereas the trigonid valley is completely open at its lingual side. Entoconid and entostylid are fused, and only a faint notch separating both is discernible. The oblique cristid ends anteriorly at the center of the posterior face of the trigonid. However, the reentrant valley is covered by a labial flange so the basal cingulid is quite straight from the paraconid to the posterolabial corner. There is no cingulid covering the base of the lingual margin of the tooth.

m2
The trigonid and the talonid are similar in both length and width, with a subrectangular occlusal outline. In this case, both paralophid and protolophid are subequal in length. Other than that, the morphological pattern of the m2 follows that of the m1.

m3
The trigonid is much longer and wider than the talonid. Contrary to m1 and m2, the metaconid does not bear a metacristid. Nor is there a well-developed entocristid. The talonid is quite reduced, although it still preserves an inner basin. In the talonid the hypoconid is the only discernible cuspid as such. The basal
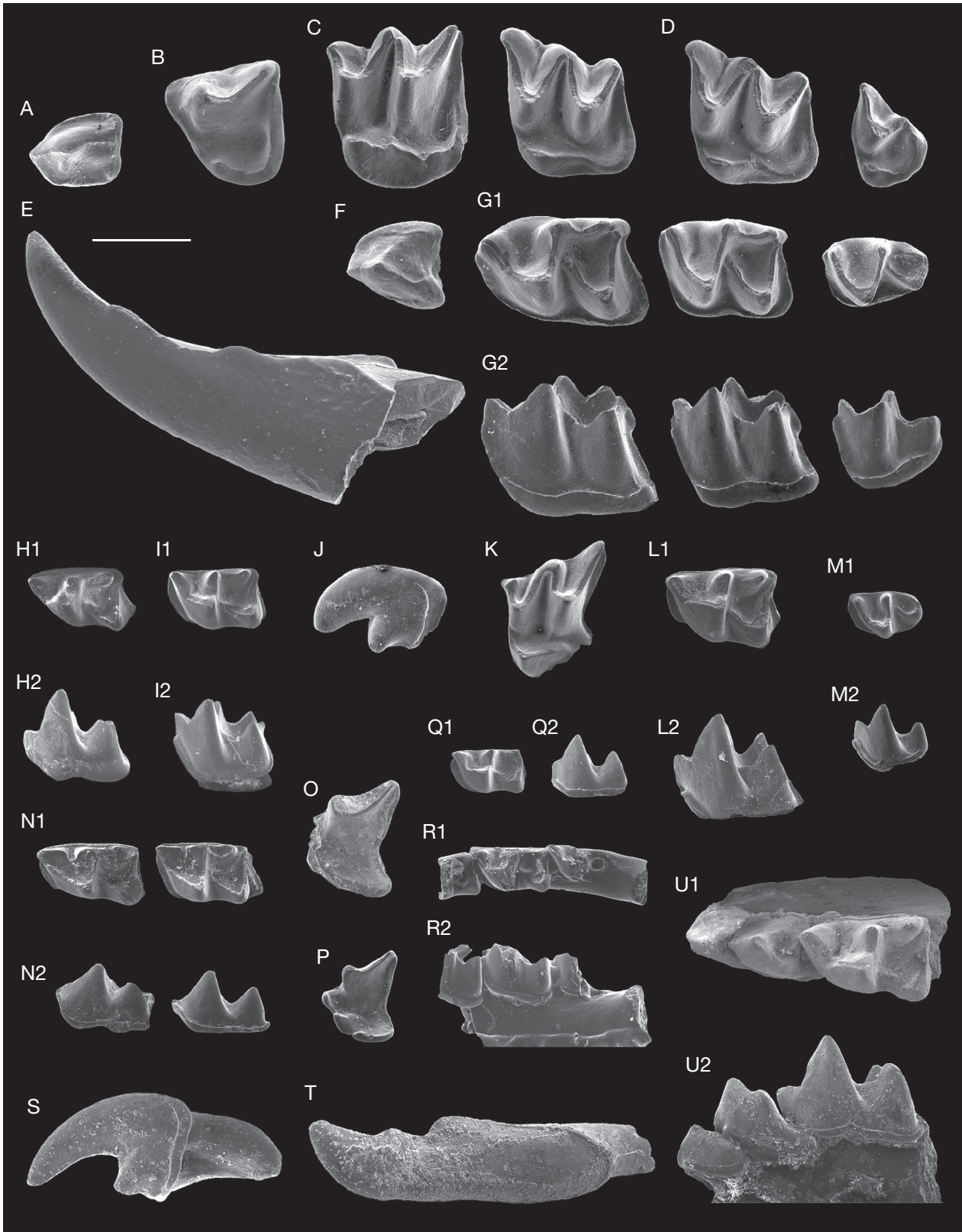
Fig. 5. — Heterosoricid and soricids from the early Miocene of the Vallès-Penedès: *Heterosorex neumayrianus* Schlosser, 1887 (**A**-**G**). **A**, IPS86252. Ax sin. CMV-I. **B**, IPS21023. P4 dext. (rev). CMV-II. **C**, IPS21025. M1+M2 dext. (rev). CMV-I. **D**, IPS86241. M2+M3 sin. CMV-I. **E**, IPS86251. ax sin. CMV-I. (ocl). **F**, IPS86254. i1 sin. CMV-I. (lab). **G**, IPS86244. m1-m3 sin. CMV-I. (G1-ocl; G2-lab). cf. *Clapasorex alvarezae* (**H**). **H**, IPS86819. m1 dext. (rev). TFR. (H1-ocl; H2-lab). cf. *Oligosorex thauensis* (**I**). **I**, IPS86866. m2 sin. VdP. (a-ocl; b-lab). *Miosorex* sp. (**J**-**M**). **J**, IPS86865. I1 sin. VdP. (lab). **K**, IPS86242. M1 sin. CMV-I. **L**, IPS86263. m1 sin. CMV-II. (L1-ocl; L2-lab). **M**, IPS90090. m3 sin. CMV-III. (M1-ocl; M2-lab). cf. *Florinia* (**N**-**O**). **N**, IPS86186. m1+m2 dext. (rev). SAB1. (N1-ocl; N2-lab). **O**, IPS85665. P4 dext. (rev) CB2. *Paenelimnoecus* (**P**-**R**). **P**, IPS86422. P4 sin. EPapiol. **Q**, IPS86425. m1 sin. EPapiol. (Q1-ocl; Q2-lab). **R**, IPS86242. m2 dext. (rev). EPapiol. (R1-ocl; R2-lab). Soricinae indet. (**S**-**U**). **S**, IPS85553. I1 sin. EC. (lab). **T**, IPS85554. i1 sin. EC. (lab). **U**, IPS85551. mand a1-m1 sin. EC. (U1-ocl; U2-lab). Scale bar: 1 mm.

cingulid covers the labial side of the tooth from the paraconid to the base of the hypoconid.

Remarks

Jovells-Vaqué *et al.* (2018) already noted the presence of *Heterosorex neumayrianus* Schlosser, 1887 in the early Aragonian locality of Las Cases de la Valenciana. As it turns out, this heterosoricid is a quite common element in the early Miocene insectivore faunas of the Vallès-Penedès, particularly in the Aragonian part of the sections.

Whereas the genus *Heterosorex* is a very common element in central European assemblages (Doben-Florin 1964; Ziegler & Fahlbusch 1986; Ziegler 1989; Klietmann *et al.* 2014c), its occurrence in the Iberian Peninsula is far more restricted. It appears near the start of the Ramblian in the localities of Cetina de Aragon (Van den Hoek Ostende & Furió 2005), Navarrete de Rio (Adrover 1972, 1975) and Ramblar 1 (Van den Hoek Ostende 2003). It is also present in the Ramblian localities of Alto de Ballester (Van den Hoek Ostende *et al.* 2017). In the Aragonian, scattered occurrences have been reported from O'Donell (Van den Hoek Ostende & Furió 2005), Buñol (Robles *et al.* 1991), Mas Antolino (Agustí *et al.* 1988), and Montalvos 2 (Hordijk *et al.* 2015). The most notable occurrences, however, are in the Daroca Calamocha area, where *Heterosorex* appears in a series of localities as a transient species during zone C (Van der Meulen *et al.* 2012; Van den Hoek Ostende *et al.* 2016). Most finds from the Vallès-Penedès coincide with this interval, so they could be part of the same '*Heterosorex*-event'. However, even with the limited record we have, the genus is also found in the Ramblian site of Costablanca 2. Therefore, also considering the occurrences in Buñol and Mas Antolino, it seems more plausible that the heterosoricids found more suitable habitats in the coastal region and only ventured inland during optimal conditions.

Family SORICIDAE Fischer, 1814
Subfamily CROCIDOSORICINAE Reumer, 1987
Genus *Clapasorex* Crochet, 1975

cf. *Clapasorex alvarezae* Van den Hoek Ostende, 2003
(Fig. 5H)

MATERIAL AND MEASUREMENTS (in cm). — **Spain.** Turó de les Forques, 1 m1 dext. in ramus, IPS86819, 1.17 × 0.69 × 0.70; 1 m1 dext., IPS86820, 1.20 × 0.67 × 0.73.

Genus *Oligosorex* Kretzoi, 1959

cf. *Oligosorex thauensis* (Crochet, 1975)
(Fig. 5I)

MATERIAL AND MEASUREMENTS (in cm). — **Spain.** Can Martí Vell III, 1 m1 sin., IPS90097, 1.11 × 0.67 × 0.69; Vilobí de Penedès, 1 m2 sin., IPS86866, 1.15 × 0.66 × 0.68.

cf. *Clapasorex alvarezae* vel cf. *Oligosorex thauensis*

MATERIAL EXAMINED. — **Spain.** Sant Andreu de la Barca 1, 1 m2 sin. trigonid in ramus, IPS86187.

Description

m1

In the m1 from Turó de les Forques, the trigonid and talonid are of similar length; the trigonid is only slightly narrower. The protoconid is rather massive; the metaconid lies close to the protoconid. The oblique cristid ends just lingually to the base of the protoconid. The hypolophid curves at just its lingual end, behind the entoconid, with little or no space for a post-entoconid valley. The entocristid slopes down before levelling, ending against the posterior flank of the metaconid. There is a well-developed cingulid on the anterior and posterior sides; the cingulum on the labial and lingual sides is narrow but continuous. The m1 from Can Martí Vell III has more slender cusps, the protoconid and metaconid further apart and a more open trigonid basin. Between the hypolophid and the entoconid, there is a narrow post-entoconid valley.

m2

The trigonid is just slightly narrower than the talonid and of similar length. The oblique cristid ends just a bit more lingually to the centre of the posterior wall of the trigonid. The hypolophid is relatively straight, with just a slight curve at the lingual end, rounding the entoconid and connecting to the lingual cingulum. The entocristid extends to the base of the metaconid. The cingulum is best developed on the anterior side, somewhat less on the labial and posterior sides and weak on the lingual side.

Remarks

Van den Hoek Ostende (2003) commented on the difficulties in the taxonomy of the small shrews in the early Miocene and how these regularly led in literature to possible lumping of multiple species. In the material described in that paper, two of these small soricids were present as also testified by mandibles showing the alveoles of the antemolars. One of the species from the Ramblian type section was identified as *Clapasorex alvarezae*, the other as *Oligosorex thauensis*. Based on a change in the relative size of the m1 and m2, the younger assemblages of the latter were classified as *O.* aff. *thauensis*. Although the molar morphology of these two species, as indeed of most of the soricids of that period, is very close, Van den Hoek Ostende (2003) ventured to indicate some characters used to identify isolated molars. In the case of the lower molars, the cusps of *Clapasorex* had a more massive appearance, protoconid and metaconid of the m1 were situated close together and the hypolophid ran directly behind the entoconid without having a post-entoconid valley.

In the series from the early Miocene insectivore assemblages of the Vallès-Penedès, only a few isolated molars of small soricids have been found. Without the foreknowledge on the shrews from the Ramblian type section, these would almost certainly have been combined in one taxon. However, following the above-mentioned characteristics, both *Clapasorex alvarezae* and *Oligosorex* aff. *thauensis* appear to be represented in the Vallès-Penedès. Given the

Table 2. — Summary of the fossil occurrences of the taxa studied in this work. Question mark (?) indicates the occurrence of one or another similar taxon.

	Amphperatherium	Galerix remmerti	Galerix symeonidisi	Desmanodon daamsi	Chainodus sp.	Plesiodimylus sp.	Heterosorex neumayrianus	Miosorex sp.	Oligosorex cf. thauensis	cf. Clapasorex alvarezae	cf. Florinia	Paenelimnoecus sp.	Soricinae indet.
La Vinya Vella	–	–	×	–	–	–	–	–	–	–	–	–	–
El Palau 3B	×	–	–	×	–	–	–	–	–	–	–	–	–
El Canyet	×	–	×	–	–	–	–	–	–	–	–	–	×
Escletxes del Papiol	–	–	–	–	–	–	–	–	–	–	×	×	–
Sant Mamet 1	–	–	×	–	–	–	–	–	–	–	–	–	–
Vilobí del Penedès	–	–	×	–	–	–	–	×	×	–	–	–	–
Can Julià	–	–	×	–	–	×	×	–	–	–	–	–	–
Can Martí Vell 3	–	–	×	×	–	×	–	×	×	–	×	–	–
Can Martí Vell 2	×	–	–	–	–	×	×	×	–	–	–	–	–
Can Martí Vell 1	×	–	×	–	–	–	×	×	–	–	–	–	–
Les Cases de la Valenciana 1	×	–	×	–	–	–	×	–	–	–	–	–	–
Costablanca II	–	–	–	–	×	×	×	–	–	–	×	–	–
Costablanca	–	–	–	×	–	–	–	–	–	–	–	–	–
Turó de les Forques 1	×	×	–	×	×	×	–	–	–	×	–	–	–
Sant Andreu de la Barca 3	–	×	–	×	–	–	–	–	–	–	–	–	–
Sant Andreu de la Barca 1	×	×	–	×	–	×	–	–	?	?	×	–	–

difficulties in identifying these isolated molars, we do take some caution in assigning the material to one or the other taxon, hence presenting them as cf. *Clapasorex alvarezae* and cf. *Oligosorex thauensis*, respectively. Despite these reservations, it is notable that cf. *Clapasorex alvarezae* was identified from the oldest assemblage in our series, Turó de les Forques. In the Ramblian type area, *C. alvarezae* has only been identified from older localities (zone Z).

Genus *Miosorex* Kretzoi, 1959

Miosorex sp.
(Fig. 5J-M)

Material and measurements (in cm). — **Spain.** Can Martí Vell III, 1 m3 sin., IPS90090, 0.88 × 0.57; Can Martí Vell II, 1 m1 sin., IPS86263, 1.38 × 0.86 × 0.92; Can Martí Vell I, 1 M1 sin., IPS86242, 1.22 × –; Vilobí del Penedès, 1 I1 sin., IPS86865, 1.38 × 0.74 × 1.01.

Description
I1
The root is missing in the only specimen found. The dorsal margin is curved and the labial posterior side is covered by a marked cingulum. The apex and the talon extend ventrally to a similar extent.

M1
The hypoconal flange is missing in the only specimen found. The anterior margin is much shorter than the posterior one. The posterior emargination bears a marked cingulum which narrows at the point of maximum concavity. The posterior arm of the protocone does not reach the base of the metacone, but it is addressed to the hypocone.

Mandible
The specimen IPS86186 is preserved in a fragment of horizontal ramus, which shows that the mental foramen is placed below the protoconid of the m1.

m1
The trigonid and talonid of the m1's have a similar length, though the talonid is wider. The entoconid is much elevated, and it is separated from the entostylid by a prominent notch. There is a thin but well-defined cingulid covering all the posterior, labial and anterior base of the tooth.

m2
The m2 of this specimen shows similar traits as those of the m1, but the trigonid is less open (i.e., shorter paralophid), and the trigonid and talonid have similar widths.

m3
The trigonid resembles that of the m2. The talonid is reduced, with its various elements merged into a crest circling the talonid basin. The cingulid is well developed on the anterior and labial sides.

Genus *Florinia* Ziegler, 1989

cf. *Florinia*
(Fig. 5N-O)

Material and measurements (in cm). — **Spain.** Escletxes del Papiol, 1 P4 sin., IPS86423, 1.26 × 1.09; Can Martí Vell III, 1 m1 dext., IPS90052, 1.24 × 0.61 × 0.68; Sant Andreu de la Barca 1, 1 mandible with m1, m2 dext., IPS86186, 1.33 × 0.69 × 0.72, 1.21 × 0.73 × 0.73; Costablanca 2, 1 P4 dext., IPS85665, 1.18 × 1.22.

DESCRIPTION

P4

The premolar is about as long as it is wide, and has a slight posterior emargination. The paracone looks rather gracile, with a relatively short posterocrista; its tip lies just in front of the middle of the molar. The parastylar region is damaged in both available specimens, but, based on the P4 from Escletxes del Papiol, parastyle and protocone appear to be of the same size and height. The two cusps are connected by a low ridge. A low ridge following the lingual outline of the premolar starts at the basis of the protocone. At the position of the hypocone, this ridge is somewhat thickened.

m1

The outline of the occlusal surface is subtriangular. The trigonid is clearly narrower and much longer than the talonid. The paralophid is long and the metaconid is slightly lingual-posteriorly to the protoconid; the trigonid basin is widely open. The oblique cristid ends just lingually to the base of the protoconid. The entoconid is close to the metaconid, with a short entocristid. The hypolophid bends behind the entoconid and it is separated from that cusp by a wide postentoconid valley. The cingulum is well developed on the anterior and posterior sides, more narrow on the labial side.

m2

The m2 is far more rectangular than the m1. The trigonid is longer than the talonid; the trigonid basin is wide. In the other features it resembles the first lower molar.

REMARKS

The genus *Florinia*, including the species *F. stehlini*, is a regular occurrence in MN 3-MN 5 faunas in central Europe (Ziegler 1989, 2006b; Ziegler & Mörs 2000; Klietmann *et al.* 2014b). Here, the genus is for the first time described from Spain, although Van der Meulen *et al.* (2012) did list "*Florinia*" (their quotation marks) for a number of localities in the Aragonian type area, ranging from the uppermost Ramblian (San Roque 4A, Zone A, latest MN 3) to the middle Aragonian (Las Umbrias 10, Zone Dd, MN 5).

Tribe Paenelimnoecini Fejfar, Storch & Tobien, 2006
Genus *Paenelimnoecus* Baudelot, 1972

Paenelimnoecus sp.
(Fig. 5P-R)

MATERIAL AND MEASUREMENTS (in cm). — **Spain.** Escletxes del Papiol,1 P4 sin, IPS86422, 0.97 × 0.91; 2 m1 sin., IPS86425-26, 0.92 × 0.55; 0.95 × 0.51; 1 m2 dext. in ramus, IPS86424, 0.93 × 0.55.

DESCRIPTION

P4

The premolar is just somewhat longer than wide. The front part of the paracone is steep, leaving a wide space with the parastyle. The latter is somewhat larger than the protocone, which is situated lingually of the parastyle. A hypocone cannot be recognized. The lingual side stands at a low angle to the labial side; the cingulum of the posterior emargination covers the labial half but it is absent close to the lingual margin.

m1

The trigonid is clearly longer and slightly wider than the talonid. The metaconid lies posterolingually of the protoconid, shaping, in combination with the long paralophid, a very open trigonid basin. The oblique cristid ends labially to the middle of the posterior wall of the trigonid. The hypolophid is missing. The cusps of the talonid are damaged in one of the two specimens. In the other, the entoconid is missing but a very low barrier (?entocristid) borders the talonid basin lingually. The anterior cingulid is strong, the posterior cingulid is well developed. There is a narrow cingulid on the labial side, but the cingulum appears to be missing on the lingual side.

m2

The only available specimen is somewhat damaged. It closely resembles the m1, but the talonid and trigonid are of similar length and the trigonid basin is less open.

REMARKS

The most prominent character of the molars from Escletxes del Papiol is the reduced entoconid. This feature is characteristic for the genus *Paenelimnoecus*, many of the more advanced representatives of which even lose the entoconid altogether. A less reduced entoconid-entocristid complex is still present in the central European early Miocene species *P. micromorphus* (Doben-Florin 1964; Ziegler 1989; Klietmann *et al.* 2014c) and in *P. truyolsi*, a species known from the middle Miocene of the Calatayud-Montalban Basin (Van den Hoek Ostende *et al.* 2009). The two species are very close in morphology, mainly differing in the morphology of the p4, an element not found in the Vallès-Penedès assemblages. Comparison with the material of *P. truyolsi* from the inland localities shows that there are some small differences with that material. Notably, the Catalan molars are somewhat smaller than the sample from Aragón. The lower molars actually fit well with the *P. micromorphus* assemblage from the German fissure Petersbuch 28 (Klietmann *et al.* 2014c), but the P4 is smaller than that from the German locality. Notably, *Paenelimnoecus* has not been encountered in Ramblian deposits of the Daroca-Montalbán basin, even though the faunas of the Ramblian type section have been extensively studied (Van den Hoek Ostende 2003).

The classification of the genus *Paenelimnoecus* has been a bone of contention for mammal palaeontologists for many years (for discussion see Klietmann *et al.* 2014c). The solution we advocated *in* Van den Hoek Ostende *et al.* (2009), placing the genus in the Allosoricinae, seems now a poor choice. At that time, we already noted that the position of "*Sorex*" *gracilidens*, was one of the major issues to be resolved. In the meantime, Hugueney *et al.* (2012) erected a new genus, *Viretia*, within the Allosoricinae for that late early and middle Miocene species. Given the vast morphological differences between *Paenelimnoecus* and *Viretia*, placement within the

Allosoricinae for the former is indeed not tenable. Van den Hoek Ostende *et al.* (2009: 2003) already suggested: "Should [*Paenelimnoeucs* and *Allosorex*] be shown not to represent a single clade, the clear roots in the Crocidosoricinae would be better expressed by placing *Paenelimnoecus* in a separate tribe within that subfamily, rather than creating a monotypic subfamily for it." Although this classification as such is new, it is actually combing the views of Ziegler (1989) as Crocidosoricinae and Fejfar *et al.* (2006) as Paenelimnoecinae into one hierarchic solution. Notably, this solution would allow for a crocidosoricine stock that has a more advanced morphology of the p4 as the one currently considered typical for the subfamily, as was already advocated by Furió *et al.* (2007) for some genera.

Subfamily SORICINAE Fischer, 1814

SORICINAE gen. et sp. indet.
(Fig. 5S-U)

MATERIAL AND MEASUREMENTS (in cm). — **Spain.** El Canyet, 1 I1 sin., IPS85553, 1.81 × 075 × 1.30; 2 i1 dext., IPS85552, −, IPS85555, 3.20; 2 i1 sin., IPS85554, 3.60, IPS85556, − , > 2.94; 1 mandible with i1 and p4 sin., IPS85557, i1 3.35, p4 1.27 × 0.90); 1 mandible with i1 and m1 dext., IPS20979, i1 3.18, m1 1.55 × 0.88 × 0.98; 1 p4 sin., IPS85550, 1.20 × 0.82; 1 mandible with a1-m1 sin., IPS85551, 0.81 × 0.65, 1.10 × 0.79, 1.54 × 0.86 × 0.98.

DESCRIPTION
I1
The upper incisor is not fissident, but there is a medial cuspule visible in dorsal view. The dorsal margin is regularly curved. The talon is not much developed. There is a narrow cingulum covering the base of the tooth. The root is only somewhat shorter than the crown.

Mandible
The mandible shows that the mental foramen is placed below the reentrant valley of the m1. It is also noteworthy that the i1 extends back labially as much as below the paraconid of the m1.

i1
The lower incisor is bicuspulate. The anterior tip and the posterior cuspule have a similar height, whereas the intermediate one is a bit lower.

a1
The antemolar has a heart-shaped occlusal outline. It is smaller in size than its posterior counterpart, the p4. There is no posterolingual basin, but it has a tetrahedral morphology.

p4
The last antemolar has a heart-shaped occlusal outline and a 'paralophid-like' cristid, which defines a lingual valley.

m1
The most significant characters are the presence of a high entoconid and its corresponding cristid, the oblique cristid ending much labially and a continuous cingulid covering all the base of the tooth, also by the lingual side. The rest of the characters (or their 'absence') are detailed in the discussion about the taxonomic ascription.

REMARKS
Surprisingly, this species does not show the typical characters of the Crocidosoricinae, which were the dominant shrews during the early Miocene. Instead, the elements recovered have typical derived Soricinae traits. This is something unusual in localities of this age, as red-toothed shrews become frequent in Eurasia at the end of the Miocene. Some anterior teeth are isolated elements which have been tentatively ascribed to this form because they all come from the same locality, and their general aspect fits well with those of the limited dental series recovered. The two specimens with m1 show that this element is larger than in the rest.

The most significant derived features are the presence of only two lower antemolars (including the p4), a mental foramen placed under the reentrant valley of m1 and a p4 with a posterolingual basin (instead of a two-branched protoconid). If not a soricine shrew in itself, this form could be also ascribed to one of those species purportedly leading to the Soricinae clade (according to Furió *et al.* 2007), like *Carposorex sylviae*. Actually, the dimensions of the m1 match perfectly with that species, according to the data provided by Crochet (1975). Moreover, the teeth have a massive aspect, the p4 has a labial branch more developed than the lingual one, and the m1 has a developed entoconid. However, the position of the mental foramen (under the reentrant valley of the m1; more advanced in crocidosoricines, also in *Carposorex*, in which it is placed under the p4), the absence of any connection between posterolabial crest of the protoconid and the labial cingulid, and the smooth enamel (instead of wrinkled as expected for the genus) discards such generic and specific allocation. In the other known species of the genus, *Carposorex burkarti* described by Hugueney *et al.* (2012), the differences are even more, because of the higher number of lower antemolars (at least three in *C. sylviae*) and the smaller size.

The oldest representative of the subfamily Soricinae in Europe is *Hemisorex robustus*. This species has been described in the French sites of Vieux-Collonges, Sansan and La Grive L3, L7 and M (Baudelot 1967; Engesser 1972, 2009; Hugueney *et al.* 2012). In fact, the measurements of the m1 in this form also fit quite well within the ranges provided by Engesser (2009) and Hugueney *et al.* (2012), with a length of about 1.50 mm and a width a bit less than 1.00 mm. The massive aspect, the bicuspulate i1, the p4 with a posterolingual basin and the position of the mental foramen would also support such ascription. However, the occlusal outline of the m1 (not as much rectangular as in *Hemisorex*) and the entoconid cristids (more developed than in *Hemisorex*), make a difference.

Paenesorex bicuspis from Petersbuch 31 described by Ziegler (2003) could be another possible candidate. However, it differs from the species found in El Canyet in the presence of a vestigial a2 between a1 and p4. Moreover, the overall size of teeth in *Paenesorex* is smaller than that of this undetermined soricid.

As there is hitherto no soricid species described in the early or middle Miocene matching all these characters, and in the absence of sufficient material we refrain from describing a new species, the most sensible option is leaving the identification of this form as Soricinae indet.

DISCUSSION

Even though quite diverse, overall, insectivores are not very abundant in the Ramblian and early Aragonian of the Vallès-Penedès. This mirrors the situation in other basins of the Iberian Peninsula. The proportion of insectivores relative to the rodents in the late Ramblian of the Daroca-Calamocha area does not surpass the 4 %. Obviously, having such limited material does not allow us to present a good overview of individual assemblages and in some cases also hampers identification. Nevertheless, looking at the record of the Vallès-Penedès as a whole (Table 2), some patterns arise, particularly when comparing it to the record from other areas.

The Ramblian

Combined, the Ramblian localities in the Vallès-Penedès (Sant Andreu de la Barca 1 and 3, Turó de les Forques and Costablanca I and II) yielded seven different insectivore taxa and, in addition, finds of the metathere *Amphiperatherium*. All localities were assigned to the late Ramblian (Zone A), as none of them yielded *Eucricetodon*. Comparing the insectivore alpha diversity, it is clear that the faunas in the Vallès-Penedès are more diverse than those of the late Ramblian of the Daroca-Calamocha area. In the latter basin, up to six different species have been reported, but these include a large and rare *Galerix* sp. from Moratilla and an early entrance of *G. symeonidisi* in the uppermost Ramblian of San Roque 4B (Van den Hoek Ostende 2003), a locality that also yielded the first rare occurrence of *Democricetodon* in that area (Van der Meulen *et al.* 2012). Of the remaining four species, two appear to be resident species for the Spanish Ramblian: *Galerix remmerti* and *Desmanodon daamsi* Van den Hoek Ostende, 1997, which appear in most of the assemblages, both in the Vallès-Penedès and in the Daroca-Calamocha area. The rare Soricidae gen. et sp. indet. from Bañón 5 and Moratilla 1 has some characteristics in common with cf. *Florinia* from the Vallès-Penedès (such as its size, an open trigonid and a wide postentoconid valley), but we consider it a separate taxon based on the clearly wider m1. As indicated before, far more complete material is needed to resolve the taxonomic issues of the early Miocene shrews. *Oligosorex* aff. *thauensis*, that is present in half of the late Ramblian assemblages of the Daroca-Calamocha area, has only a possible record in the Ramblian of the Vallès-Penedès in San Andreu de la Barca 1, but is also known from the early Aragonian of the area.

This leaves four species that are represented in the late Ramblian of the Vallès-Penedès, but not in coeval localities in Daroca-Calamocha. Notably, two of these, cf. *Clapasorex alvarezae* and the heterosoricid *Heterosorex*, are found in the early Ramblian of the inland basin. *Heterosorex* is only found in the lowermost localities, and appears, in contrast to its occurrences in the Vallès-Penedès, to be a transient species for the Daroca-Calamocha area (Van den Hoek Ostende 2003; Van den Hoek Ostende *et al.* 2016). The other two species are the dimylids *Chainodus* sp. and *Plesiodimylus* sp. *Chainodus* is a quite common element in central European faunas (e.g. Ziegler 1990a, 1994; Klietmann *et al.* 2014b; Van den Hoek Ostende & Fejfar 2015). In Spain, it was only found thus far in the Ramblian of the Rubielos de Mora Basin (Gibert 1975; Van den Hoek Ostende *et al.* 2017). *Plesiodimylus* is more common in central Europe, but it too has only been found rarely in Spain (Crespo-Roures *et al.* 2018, 2019). The finds from Turó de les Forques and Costablanca II are the only Ramblian occurrences of this dimylid in the Iberian Peninsula.

The early Aragonian

In contrast to the Ramblian insectivores, of which some descriptions have been published (Van den Hoek Ostende 2003; Van den Hoek Ostende *et al.* 2017), the Spanish early Aragonian record of the order is largely undescribed. However, the preliminary listing of the faunas of the Aragonian type section were given in Van den Hoek Ostende & Furió (2005) and an updated identification was provided in Van der Meulen *et al.* (2012).

Even though, because zone B is not yet recognized in the basin, there is a certain time gap between our Ramblian and Aragonian assemblages, and there are quite a few species that continue into zone C. Notably, the most common species remains the marsupial *Amphiperatherium*. Another resident taxon is *Desmanodon daamsi*, in line with finds from elsewhere in the Iberian Peninsula (Van den Hoek Ostende 1997). We know that the record of *Heterosorex* is discontinuous in the Daroca-Calamocha area, where it is present in the lowermost Ramblian as well as in zone Ca (Van den Hoek Ostende 2003; Van der Meulen *et al.* 2012; Van den Hoek Ostende *et al.* 2016). In that respect, we cannot be sure that it had a continuous presence in the Vallès-Penedès as the presence in the early Aragonian could be part of the same '*Heterosorex*-event'. However, the find in the late Ramblian certainly shows at the least a more continuous record and the overall higher diversity of the coastal basin makes likely that conditions would allow the heterosoricid to survive there. More humid conditions are partly indicated by the survival of one of the two dimylid taxa along the coast, *Plesiodimylus*. *Chainodus*, on the other hand, is restricted to the Ramblian in Spain.

The gymnure *Galerix* shows the familiar pattern in which *G. remmerti* is replaced by *G. symeonidisi* (Van den Hoek Ostende & Doukas 2003). The latter authors also demonstrated that during zone C a second, more gradual replacement took place, as *G. exilis* co-existed with *G. symeonidisi*. Individual molars are difficult to identify as one or the other species, and the scenario as proposed by Van den Hoek Ostende & Doukas (2003) was in part based on the overall size ranges, which were too big to account for a single species. Such a procedure is not possible for the rather scanty record of the Vallès-Penedès. Notably, almost all the specimens are rather small, better fitting with *G. symeonidisi*. The only possible

exception is the M1 from La Vinya Vella, one of the youngest localities in our series. The molar is somewhat larger and could represent *G. exilis*.

As for the true shrews, *Oligosorex*, known from the Ramblian of Daroca-Calamocha and with a possible record from Sant Andreu de la Barca 1 is a regular occurrence in the early Aragonian, as it is in the Aragonian type section. Also *Florinia* was mentioned from the type section, but, other than in the inland basin, is also known from the Ramblian in the Vallès-Penedès. *Miosorex* and *Paenelimnoecus* appear to be MN 4 immigrants, both in the Vallès-Penedès and in the inland basins. The most surprising find in our section is the Soricinae gen. et sp. indet. from El Canyet, which represents a taxon so far only known from this locality. The only shrew that is restricted to the Ramblian in the Vallès-Penedès series is *Clapasorex*, again in accordance with the inland basins, in which it seems to have extirpated a bit earlier.

*Palaeoenvironmental inferences
and biogeographical consequences*

The early Miocene insectivore fauna of the Vallès-Penedès consists of the gymnure *Galerix*, represented by various species, the talpid *Desmanodon remmerti*, the dimylids *Chainodus* (Ramblian only) and *Plesiodimylus*, the heterosoricid *Heterosorex neumayrianus* and the true shrews *Clapasorex* (Ramblian only), *Oligosorex*, cf. *Florinia, Paenelimnoecus, Miosorex*, and an indeterminate Soricine shrew, the latter three being known from the early Aragonian only. In addition, the insectivorous metatherian *Amphiperatherium* occurs frequently in our localities throughout the section. Because of the presence of the dimylids and the more continuous record of *Heterosorex*, this assemblage is more diverse than that from the inland basins of the Iberian Peninsula (Van den Hoek Ostende 2003; Van der Meulen *et al.* 2012). On the other hand, it is less diverse than the coeval central European eulipotyphlan faunas, particularly in the number of talpids and, to a lesser extent, the shrews. The difference with the central European record is in line with the suggestion of Furió *et al.* (2011a) that the diversity of insectivores is governed by a latitudinal humidity gradient across Europe. Of course, the Vallès-Penedès is at approximately the same latitude as the inland basins; here, the humidity gradient is governed by the vicinity to the coast. The more humid conditions in the Vallès-Penedès are clear from the presence of dimylids, which are considered strong indicators of humid environments (Furió *et al.* 2011a; Klietmann *et al.* 2015b). Notably, the dimylid *Plesiodimylus* has also been recorded in another coastal basin further south than any Vallès-Penedès locality (Crespo-Roures *et al.* 2018, 2019), whereas *Chainodus* is known from the Rubielos de Mora Basin (Van den Hoek Ostende *et al.* 2017). Palaeoenvironmental differences between the Vallès-Penedès and the inland basins already existed in the early Miocene but were far less outspoken than in later parts of the epoch (e.g. Madern *et al.* 2018). The observed differences do present a caveat. It is clear that the early Miocene zonation as defined in the Daroca-Calamocha area can be extended to the Vallès-Penedès. However, for instance the

boundary between Ramblian zones Z and A is indicated by the absence of *Eucricetodon* in the younger zone. Van den Hoek Ostende *et al.* (2017) already indicated that in the Rubielos de Mora Basin, the absence of *Eucricetodon* could also be environmentally controlled. As we noted in our Geological setting and Biostratigraphy section above, distinction between zone Ca and Cb is controversial in the Vallès-Penedès because of minor differences in the record. Thus, in correlating faunas, we must keep palaeoenvironmental differences between basins in mind.

Despite the absence of zone B in the Vallès-Penedès, there is a strong continuance of various taxa between the Ramblian and the Aragonian. *Miosorex* and *Paenelimnoecus* appear to be MN 4 immigrants, *Chainodus* and *Clapasorex* disappear during the Ramblian. The absence of a clear faunal turnover presumably indicates that there were sufficient forested conditions for insectivore taxa, as well as *Amphiperatherium* to survive, in line with forest-dwelling glirids and eomyids also continuing into the early Aragonian. However, it is clear that these more forested conditions were better represented in the coastal basins. This emphasizes the potential for coastal areas as dispersal corridors. In our study, this is best illustrated by *Heterosorex*, which presumably had a continuous presence in the Vallès-Penedès, which may have acted as a source area for more transient occurrences in the inland basins (Van der Meulen *et al.* 2012; Hordijk *et al.* 2015; Van den Hoek Ostende *et al.* 2016).

CONCLUSIONS

In line with its geographical position, the Vallès-Penedès yielded insectivore faunas from the late Ramblian and early Aragonian which are intermediate between the more diverse assemblages from central Europe and the somewhat poorer assemblages from the inland basins of the Iberian Peninsula. The main difference lies in the presence of the dimylids *Chainodus* (Ramblian only) and *Plesiodimylus*. Notably, these dimylids occur in the Iberian Peninsula only in the coastal basins. Other differences with the inland basins are the more continuous records of the insectivorous metatherian *Amphiperatherium* and the heterosoricid *Heterosorex*. The occurrences of the other eulipotyphlans largely mirror those from the Daroca-Calamocha area, with the exception of Soricinae gen. et sp. indet from el Canyet, which forms a unique and tantalizing early record of its subfamily.

The eulipotyphlan assemblages demonstrate that there were some palaeoenvironmental differences between the coastal and the inland basins, although at the time not as pronounced as they would become in the late middle and early late Miocene. These differences in environment suggest that some caution must be taken in correlating between coastal and inland basins, as the absence of stratigraphically important taxa may be in part environmentally controlled. In addition, our study emphasizes that the somewhat different ecology of coastal regions offers potential for them to serve as biogeographical corridors.

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