



Geologica Acta: an international earth  
science journal

ISSN: 1695-6133

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Geologica Acta: an international earth science journal, vol. 14, núm. 3, septiembre, 2016,  
pp. 195-217

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# An updated biostratigraphy for the late Aragonian and Vallesian of the Vallès-Penedès Basin (Catalonia)

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## ABSTRACT

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The Vallès-Penedès Basin (Catalonia, Spain) is a classical area for the study of the Miocene land mammal faunas and includes one of the densest and most continuous records in Eurasia. Furthermore, it is the type area for the Vallesian European land mammal age. After decades of study a huge amount of bio- and magnetostratigraphic data have been collected, allowing an unprecedented dating accuracy. Here we provide an updated local biostratigraphy for the late Aragonian, Vallesian and Turolian of the Vallès-Penedès Basin. This new biostratigraphic scheme is almost exclusively based on fossil rodents, which are the most abundant and one of the best known mammal orders in the area. Our proposal represents a significant refinement compared to previous attempts and provides a formal diagnosis and description of each zone, as well as clear definition of boundaries and a reference locality and section. The chronology of zone boundaries and main bioevents is based on detailed magnetostratigraphic data. The defined biozones allow for the correlation of the sites without associated magnetostratigraphical data. Finally, the correlation of the Vallès-Penedès local zones with other detailed local biostratigraphies, such as those of the Calatayud-Montalbán and Teruel basins (east-central Spain) is discussed. The sequence and chronology of the main bioevents is roughly comparable, although the rodent succession and the structure of the assemblage show important differences between these areas.

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### KEYWORDS

Miocene. Biostratigraphy. Magnetostratigraphy. Rodents. Iberian Peninsula.

## INTRODUCTION

The Vallès-Penedès Basin (Catalonia, Spain) is a reference area for the study of Miocene land mammal faunas of Europe. The earliest fossil finds date back to the late 19<sup>th</sup> century and the area has been sampled systematically ever since. Most of the older key contributions to the knowledge of the fossil faunas of this basin were by the team led by Miquel Crusafont Pairó between the 1940s and the 1970s. These comprised the discovery of numerous new sites, the description of many new taxa and the first attempts to place the Vallès-Penedès mammal succession in a detailed stratigraphical framework (for a more detailed review see Casanovas-Vilar *et al.*, 2011a). Crusafont and co-workers soon noted that most of the late Miocene mammal assemblages from the Vallès-Penedès Basin differed from those of the purportedly coeval European sites known at the time, such as Pikermi in Greece. The Vallès-Penedès assemblages were characterized by the coexistence of the three-toed hipparionin horses with faunal elements that were characteristic of the middle Miocene, such as certain rhinos, cervids, suoids and chalicotheres. At that time, hipparionin horses were thought to be one of the defining elements of the so-called Pikermian faunas, which characteristically include a high diversity of open country herbivores, such as bovids and giraffids, whereas forest herbivores, such as cervids and certain rhinos, are very rare. The Pikermian faunas represent a rather uniform mammal community that later during the Turolian extended its range into Western Europe (Eronen *et al.*, 2009). Then, typical Pikermian faunas were known from the sites of Piera in the Vallès-Penedès Basin (Villalta Comella and Crusafont Pairó, 1946; Crusafont Pairó, 1950), but apparently some ‘Pikermian’ taxa such as the hipparionin equids had dispersed earlier. Furthermore, Crusafont Pairó (1950) already noted that *Hipotherium catalaunicum*, the species present at the Vallès-Penedès sites, is more archaic than any of the hipparionin species present at Pikermi (see Bernor *et al.*, 1996). On the other hand, *Cremohipparion mediterraneum*, one of the species described from Pikermi, might be present at the Piera sites (Pirlot, 1956; but see Bernor *et al.*, 1996 for a different opinion). Therefore, the Vallès-Penedès assemblages clearly represented a transition between the forest faunas of the middle Miocene and the open-country, savannah-like faunas of the late Miocene.

At the time Crusafont and co-workers were surveying the basin, the Eastern Paratethys marine stages were often informally used for the correlation of the mammalian faunas. Pikermi was correlated to the late Pontian, whereas older European sites, such as La Grive (France), were correlated to the Sarmatian. The late Miocene Vallès-Penedès sites represented an intermediate stage, and were informally correlated to

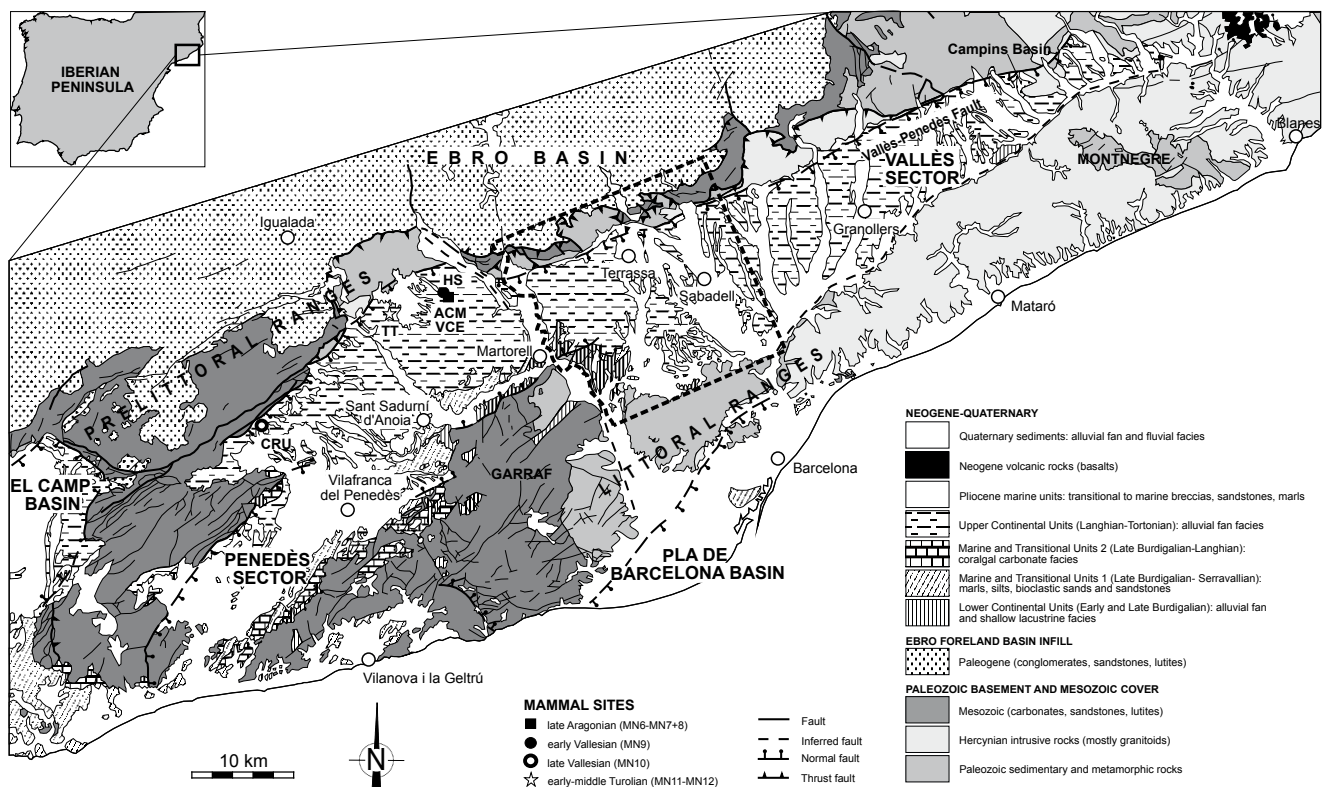
the Meotian, which is placed between the Sarmatian and the Pontian (Crusafont Pairó, 1950; Crusafont Pairó and Villalta Comella, 1947). The term “Spanish Meotian” was used for some time in the literature, until Crusafont formally proposed the Vallesian mammal stage for the late Miocene mammal assemblages of the Vallès-Penedès Basin (Crusafont Pairó, 1950). Now we know that the Meotian is indeed younger than the Vallesian (Hilgen *et al.*, 2012). In later works (*e.g.* Crusafont Pairó and Truyols Santonja, 1960), the team better characterized the Vallesian succession in its type area and discussed further the correlation of the newly introduced mammal stage. The Vallesian was soon accepted in Eurasia because of the simple criterion used to define its lower boundary: the dispersal of hipparionin horses. These horses originated in North America and crossed the Bering Strait at a time of global sea-level lowering near to the middle/late Miocene transition (Bernor *et al.*, 1996; Woodburne *et al.*, 1981, 1995). A considerable effort has been devoted to firmly date the first appearance of these horses in the Old World, with ages ranging from 11.2 to 10.3Ma in different regions (Barry and Flynn, 1990; Barry *et al.*, 1982, 2002; Bernor *et al.*, 1988, 1996; Flynn *et al.*, 2013; Garcés *et al.*, 1996, 1997, 2003; Kappelman *et al.*, 2003; Van Dam *et al.*, 2014).

As far as the subdivision of the Vallesian is concerned, Crusafont Pairó and Truyols Santonja (1960) already noticed that this stage may be subdivided in its type area into the early and late Vallesian. The early Vallesian would include sites such as Can Poncic and Can Llobateres 1, whereas the late Vallesian would include the sites near the towns of Terrassa and Viladecavalls (Sant Miquel de Toudell, Can Purull, La Tarumba and others). The forest elements of middle Miocene origin are rarer during the late Vallesian, coinciding with the first record of new eastern immigrants. With the introduction of the MN (Mammal Neogene) zonation as a standard correlation scheme for the European Neogene faunas (Mein, 1975), the early and late Vallesian were equated to zones MN9 and MN10, respectively. This implied the extension to other European regions, not only of this mammal stage but also of its major subdivisions. Later studies of the Vallesian in its type area further subdivided it in a number of local zones mostly on the basis of the composition of the rodent faunas (Agustí, 1981, 1982; Agustí and Moyà-Solà, 1991). Finally, a magnetostratigraphic study of the Vallès sector of the basin undertaken during the 1990s allowed the correlation of several sites and fossiliferous sections to the Geomagnetic Polarity Time Scale (GPTS), thus enabling a well-supported chronology for the local zones and main bioevents (Agustí *et al.*, 1997; Garcés *et al.*, 1996). Later work in the Penedès sector of the basin provided further

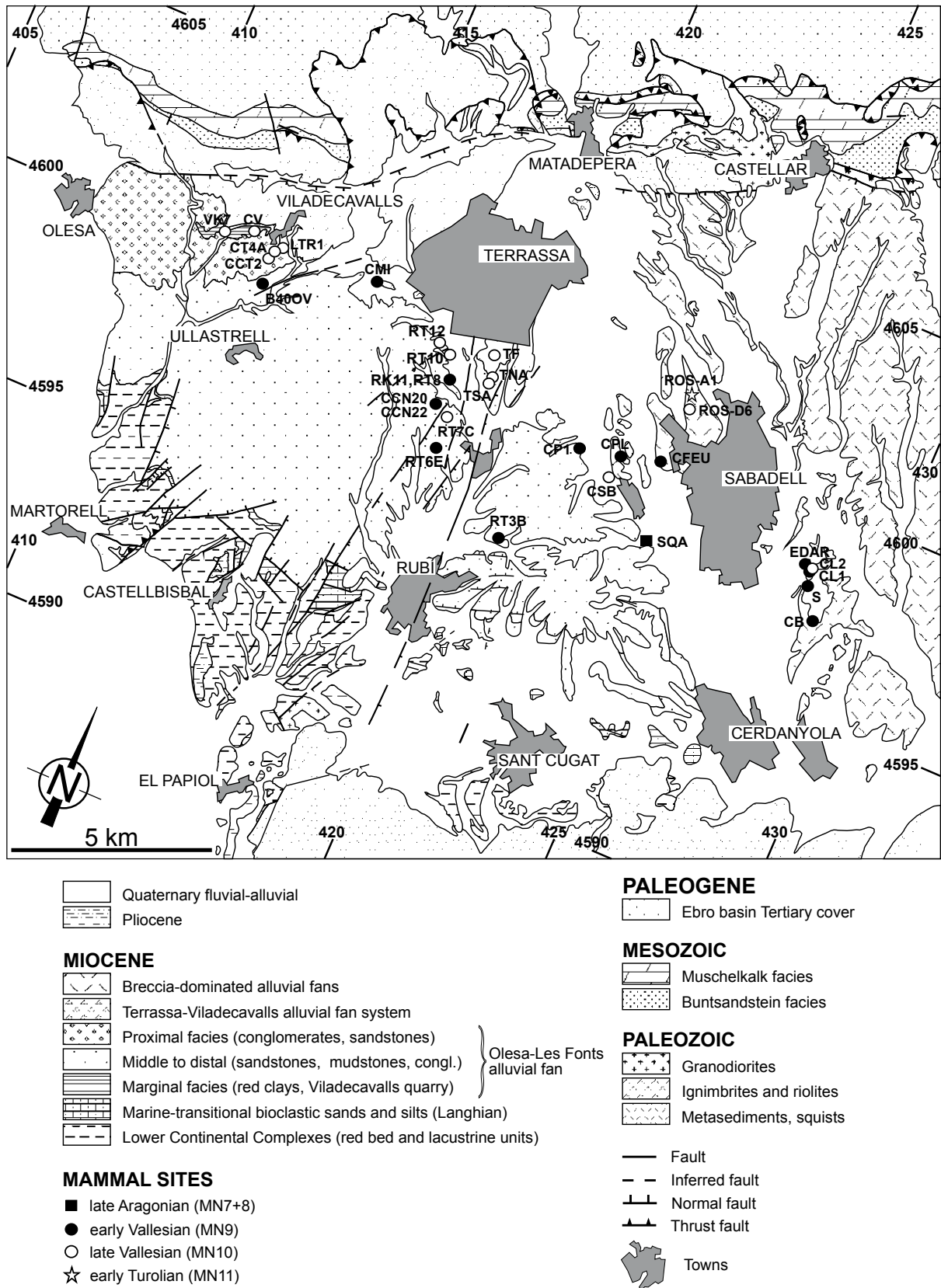
extension of the bio-magnetostratigraphic framework down into the late Aragonian and its transition with the Vallesian (Casanovas-Vilar *et al.*, 2011b; Moyà-Solà *et al.*, 2009). A preliminary new zonation ranging from the late Aragonian to the Vallesian was given in Casanovas-Vilar (2007), later updated in Casanovas-Vilar *et al.* (2011b). These zonations, however, lacked formal definitions and precise zone boundaries. Furthermore, at that time only test samples were available for most of the late Aragonian sites of the basin. Here we provide an updated biostratigraphy of the late Aragonian and the Vallesian in the Vallès-Penedès Basin that is based on rodents, arguably the most abundant and one of the best studied mammal orders. Additionally, we also propose a preliminary biostratigraphy of the Turolian based on the limited information currently available in the basin. We have reviewed the microfauna of all the Vallesian sites and included all the newly-discovered late Aragonian sites from the area of els Hostalets de Pierola (Alba *et al.*, 2006, 2011), in the Penedès sector of the basin. Unambiguous zone definitions and dated boundaries are provided. Finally, the chronology of the main bioevents and correlation of the proposed zonation with other Spanish and French records are discussed.

## GEOLOGICAL SETTING

The Vallès-Penedès Basin (Figs. 1;2) is part of a widespread system of NE-SW and NNE-SSW oriented horst and half-grabens that were formed as a result of the opening of the northwestern Mediterranean during the latest Oligocene and the Miocene (Bartrina *et al.*, 1992; Cabrera and Calvet, 1996; Cabrera *et al.*, 2004; Roca and Guimerà, 1992; Roca *et al.*, 1999). It is an elongated half-graben (100km long by 12-14km wide) parallel to the Catalan coastline and bounded by the pre-littoral range to the NW and the littoral range to the SE (Garraf-Montnegre horst). The Vallès-Penedès master fault defines its northwestern margin, and its basement dips gently towards this margin, where it attains up to 4,000m in depth (Bartrina *et al.*, 1992; Roca *et al.*, 1999). The sedimentary filling of the Vallès-Penedès Basin started in the early Miocene (Ramblan/early Burdigalian; Cabrera, 1981a, b; Cabrera *et al.*, 1991, 2004; de Gibert and Casanovas-Vilar, 2011) and ended in the late Miocene (Turolian/Messinian). Major features of the stratigraphic record in the Vallès-Penedès half-graben were closely controlled by the tectonic activity of its main bounding faults and the sea level changes in the western



**FIGURE 1.** Simplified geological map of the Vallès-Penedès Basin with major Miocene mammal sites (modified from Institut Cartogràfic i Geològic de Catalunya, 2015). The area enclosed by the dashed perimeter is shown in detail in Figure 2. ACM: Abocador de Can Mata; CRU: Can Cruset; HS: Hostalets Superior; TT: Torrentet de Traginers; VCE: Variant de la Carretera de l'Ecoparc.



**FIGURE 2.** Detailed geological map of the western Vallès sector (see Fig. 1) showing the position of the main mammal sites (modified after Garcés *et al.*, 1996). For locality acronyms see Electronic Appendix I, available at [www.geologica-acta.com](http://www.geologica-acta.com).

Mediterranean (Bartrina *et al.*, 1992; Cabrera and Calvet, 1996; Cabrera *et al.*, 2004; Roca *et al.*, 1999).

Most of the Miocene record consists of continental sediments, predominantly alluvial red mudstones, sandstones and conglomerates, sourced from the surrounding reliefs. During the early Miocene (Ramblian-early Aragonian; MN3-MN4), alluvial fans were generally small and their catchments were mostly located at the littoral range (Cabrera, 1981a, b; Cabrera *et al.*, 1991, 2004; de Gibert and Casanovas-Vilar, 2011). Small lacustrine systems, which have yielded the richest mammal-bearing sites of this interval, developed in areas near the southeastern margin (Cabrera, 1981a, b; Cabrera *et al.*, 1991; Casanovas-Vilar *et al.*, 2011a, 2015). Subsequent deformation led to the partitioning of these older units into different fault-bounded blocks (Cabrera, 1981a, b; Cabrera and Calvet, 1996). Prominent sea-level highstands during the Mid-Miocene Climatic Optimum (Zachos *et al.*, 2001) favored a series of marine transgressions that affected the Vallès-Penedès. Three different marine transgressions are known: a late Burdigalian, a Langhian and an early Serravallian one (Cabrera and Calvet, 1996; Cabrera *et al.*, 1991; de Gibert and Casanovas-Vilar, 2011; Roca *et al.*, 1999). The Langhian transgression was the most widespread, with shallow marine environments extending as far as the Vallès sector of the basin. Continental sedimentation was fully re-established after the early Serravallian (late Aragonian), lasting until the Tortonian (middle Turolian). The Vallès-Penedès master fault remained active until the Tortonian, controlling the development of large alluvial fan systems, some attaining a radius of 10–15 km, sourced from the reliefs of the pre-littoral range (Cabrera and Calvet, 1996; Garcés *et al.*, 1996; Roca *et al.*, 1999; Casanovas-Vilar *et al.*, 2008; de Gibert and Casanovas-Vilar, 2011). Most of the vertebrate fossil sites are located in distal to terminal fan, mudstone-dominated facies (Fig. 2). At the end of the Miocene, the dramatic sea level fall of the late Messinian interrupted the sedimentation in the basin (Cabrera and Calvet, 1996). Miocene deposits are unconformably overlain by Pliocene alluvial-fluvial and shallow marine sediments and Pleistocene-Holocene alluvial-colluvial units.

## MATERIAL AND METHODS

### Magnetostratigraphy

Magnetostratigraphic studies in the Vallès-Penedès basin first aimed to provide an independent chronostratigraphic frame for the rich paleobiological record. Early works focused on the Vallesian successions (Garcés *et al.*, 1996; Agustí *et al.*, 1997), and later on extended down into the late Aragonian (Moyà-Solà *et al.*,

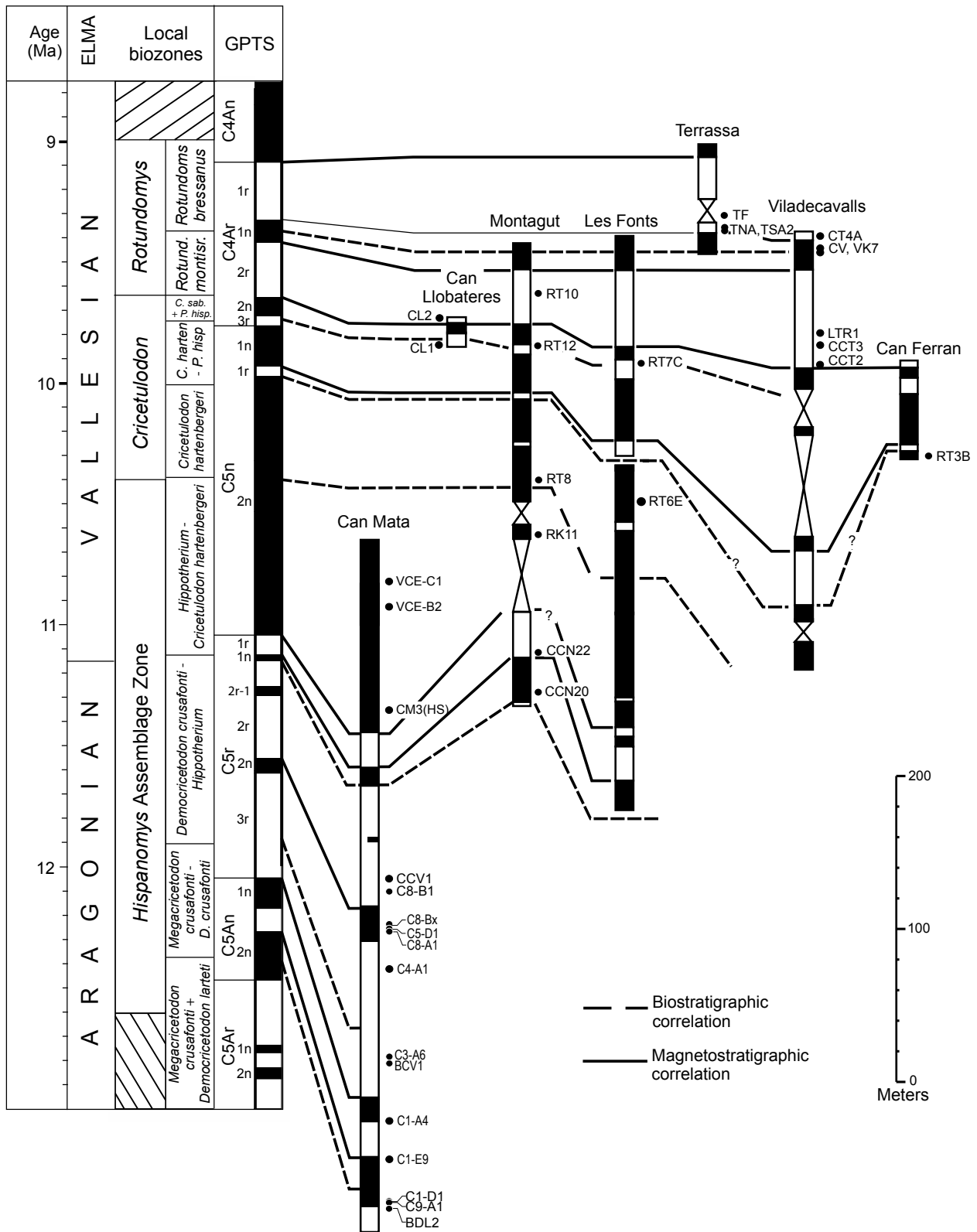
2009; Casanovas-Vilar *et al.*, 2011b, 2015). The sequences studied for magnetostratigraphy include four main composite sections: Abocador de Can Mata, Les Fonts, Montagut and Viladecavalls, plus a few shorter ones (Fig. 3). Despite the diversity of lithologies and grain-size, all the sequences contain abundant mudstone beds, which were sampled with a density of 1–2 m/site. The time resolution is approximately 10 kyr, which is sufficient to rely on the completeness of the magnetostratigraphic record at the scale of chrons and subchrons of the GPTS.

A correlation of the local magnetostratigraphy with the GPTS (Ogg, 2012) was feasible after the unambiguous identification of chron C5n, a distinctly long normal chron that characterizes the early Tortonian, in both the Vallès sector (Garcés *et al.*, 1996) and in the Abocador de Can Mata (ACM) sequence of els Hostalets de Pierola (Moyà-Solà *et al.*, 2009). The overall magnetostratigraphic sequence represents approximately 3.6 Myr, from 12.6 Ma to 9.0 Ma (Fig. 3). Here we summarize the magnetostratigraphic results of previous works (Garcés *et al.*, 1996; Agustí *et al.*, 1997; Moyà-Solà *et al.*, 2009; Casanovas-Vilar *et al.*, 2011b, 2015) and further update the results of the Abocador de Can Mata section with new magnetostratigraphical data from Ecoparc de Can Mata (Alba *et al.*, 2012; Casanovas-Vilar *et al.*, 2015), which extend the upper part of the section (Fig. 3)

### Biostratigraphy

The Vallès-Penedès record comprises slightly more than 200 micromammal sites ranging from the late Aragonian to the Turolian. However, the distribution of the sites is clearly uneven, with most sites (>130) correlated to the latest Aragonian and early Vallesian (Fig. 4). By contrast, the Turolian is represented by only two sites. 70% of the sites within the studied time interval have associated magnetostratigraphic data, with the proportion increasing to 95% for the late Aragonian, the best sampled part of the record (Fig. 4). Regarding the Vallesian part of the record, magnetostratigraphic data are available for the most of the sites. However, the correlation of a significant number of sites, including some important ones such as Can Poncic 1 or Castell de Barberà, is based on biostratigraphy. Finally, the two Turolian sites known to date have no associated magnetostratigraphic data and have delivered a relatively poor rodent fauna that only allows a gross biostratigraphical correlation.

Rodents define the basis for the proposed local biozonation. Most of the material was recovered using systematic screen-washing (see Daams and Freudenthal, 1988a), except for a small part of the old collections of a few sites (Can Llobateres 1, Sant Quirze, Hostalets Superior) that were surface collected. Similarly, a few of the remains



**FIGURE 3.** Correlation of the key local magnetostratigraphical sections of the Vallès-Penedès Basin to the Geomagnetic Polarity Time Scale (GPTS). The European Land Mammal Ages (ELMA) and local biozones of the Vallès-Penedès are also indicated. We have indicated some of the major sites in the Can Mata composite section. For locality acronyms see Electronic Appendix I. Neogene time scale and boundaries after Hilgen *et al.* (2012). GPTS after Ogg (2012).

of certain large-sized rodents, such as castorids and some sciurids, were recovered during the systematic excavation of a number of sites (particularly Sant Quirze, Castell de Barberà and Can Llobateres 1). In Electronic Appendix I (available at [www.geologica-acta.com](http://www.geologica-acta.com)) we provide a list of the sites included in this work, indicating their bio- and magnetostratigraphic correlation, and an updated faunal list of the rodent fauna. In most cases, the rodent fauna has not been studied in detail yet. In case systematic descriptions are available, the references are provided.

### Abbreviations

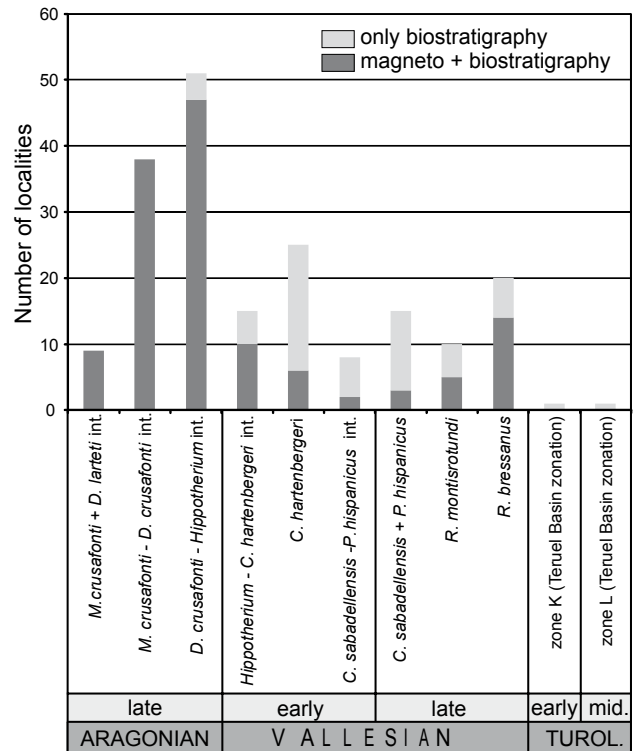
ELMA: European Land Mammal Age; FCO: First Common Occurrence; FHA: First Historical Appearance (see Walsh, 1998); FLO: First Local Occurrence; FO: First Occurrence; GPTS: Geomagnetic Polarity Time Scale; LLO: Last Local Occurrence; LO: Last Occurrence; MN: Mammal Neogene units.

### Locality acronyms

Locality names are mostly provided in full throughout this work, with a few exceptions: the composite stratigraphic section of Can Mata (Alba *et al.*, 2006, 2011), including both the ACM and the ECM; B40OV (Alba *et al.*, 2010); ROS; RT (Garcés *et al.*, 1996; Agustí *et al.*, 1997); and EDAR (Checa Soler and Rius Font, 2003). The abbreviations used are the following, ACM: local stratigraphic section of Abocador de Can Mata [Can Mata Landfill]; B40OV: Autovia Orbital de Barcelona [Orbital Highway of Barcelona], section Olesa de Montserrat-Viladecavalls; BCV: Barranc de Can Vila [Can Vila Ravine] (ACM sector); BDL: Bassa de Lixiviats [Settling Pond of Leachates] (ACM sector); C1–C9, Cells 1 to 9 (ACM sectors); ECM: local stratigraphic section of Ecoparc de Can Mata [Waste Treatment Plant of Can Mata]; EDAR: Estació Depuradora d'Aigües Residuals Sabadell-Ripoll [Wastewater Treatment Plant Sabadell-Ripoll River]; S5, sector 5 (B40OV sector); ROS: Ronda Oest de Sabadell [West Ring Road of Sabadell]; RT: Autopista de Rubí-Terrassa [Rubí-Terrassa Highway]; VCE: Variant de la Carretera de l'Ecoparc [Bypass of the Waste Treatment Plant Road].

### BIOSTRATIGRAPHY: LOCAL BIOZONES OF THE LATE ARAGONIAN TO THE TUROLIAN

Here we propose a new local biostratigraphy ranging from the late Aragonian to the middle Turolian. A new local biozonation is introduced for the late Aragonian and Vallesian. Although our proposal clearly follows those of Agustí *et al.* (1997) and Casanovas-Vilar *et al.* (2011b), more clear-cut definitions are provided here, together with



**FIGURE 4.** Number of rodent localities by local biozone. The number of localities with available bio- and magnetostratigraphical data is indicated with dark gray, localities dated only by biostratigraphy are indicated in light gray. Note the higher abundance of localities and greater dating accuracy for the late Aragonian (see text for details).

additional information on the small and large mammal fauna. Furthermore, the correlation of these biozones with other local zonations of Iberian basins is discussed. Concerning the Turolian, it is represented by too few sites to attempt a local biozonation. Therefore, the Turolian localities from the Vallès-Penedès are correlated to other biostratigraphical schemes.

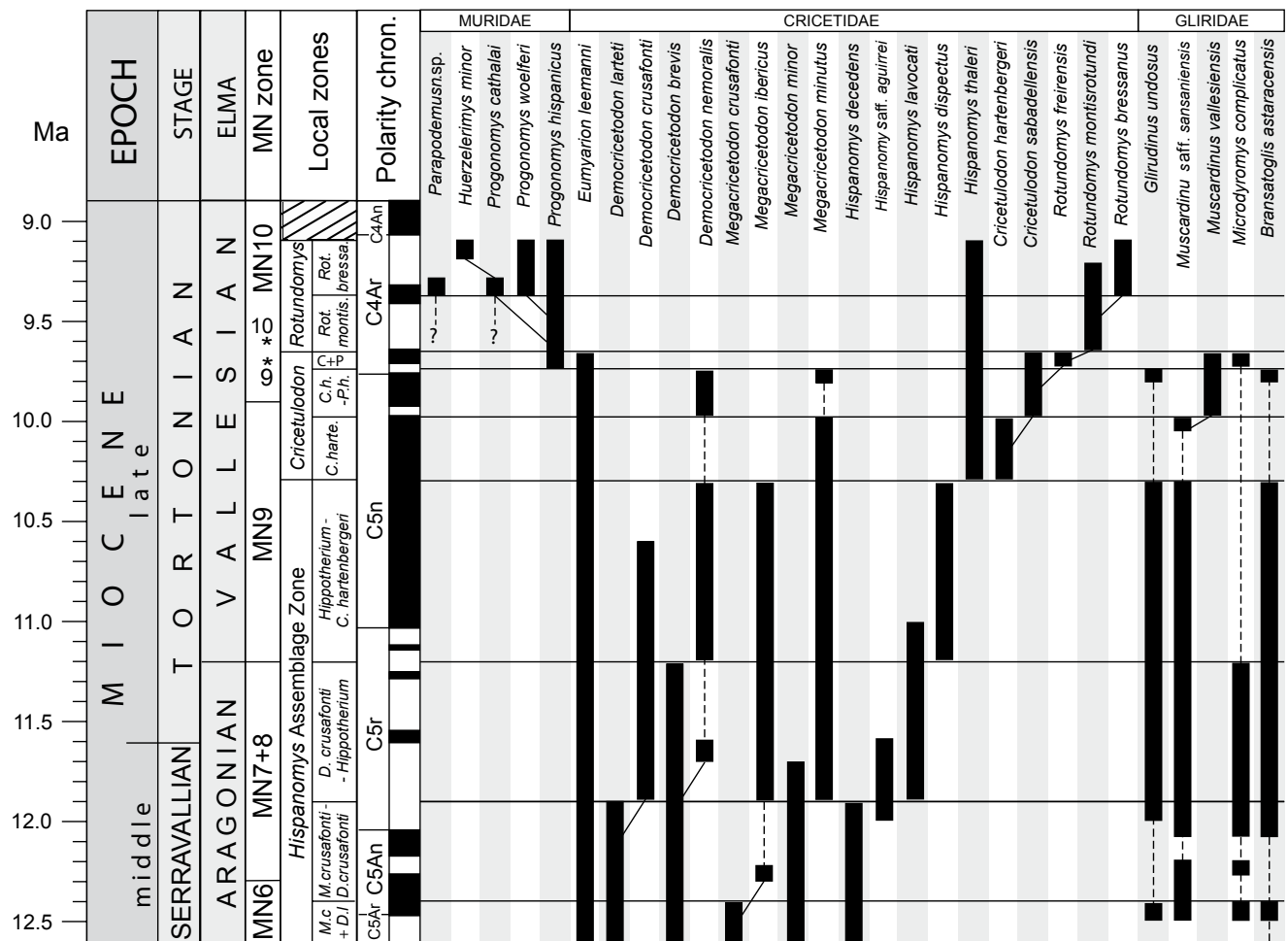
The biozonation is mainly based on the composition of the rodent fauna. Rodents stand out as one of the best known mammal groups in the study area. Their dense and continuous record comprises almost 200 localities and more than 18,000 remains. In addition, certain species (*e.g.* the members of the *Cricetulodon hartenbergeri* – *Rotundomys bressanus* lineage) show very short ranges, allowing for high resolution during particular time intervals. The fact that most of the known sites have only delivered small mammals argues against the definition of a biostratigraphical scheme based on large mammals. Also, certain macromammal groups, such as perissodactyls and artiodactyls, are in need of taxonomic revision. Therefore, we will just briefly mention the main bioevents (such as FLO and LLO) in the large mammal faunas, but, with the exception of the

FLO of the equid *Hippotherium*, they will not be used for the definition of the biozones.

Three different zones are recognized, which are further divided into several subzones. This is a major difference with previous works (Agustí et al., 1997; Casanovas-Vilar et al., 2011b), which did not consider such a hierarchy. This scheme is introduced for practical purposes, since the main zones allow a rough local correlation even if sample size is very limited (less than 15–20 specimens). On the other hand, the subzones provide a finer local correlation, although a greater sample size is usually required to identify the species that characterize each subzone. FLO and LLO data are used to characterize the different zones. Following Murphy and Salvador (1999), the zones are named after

their diagnostic taxa. Their full name (including the kind of biostratigraphical unit) is given the first time they are introduced, whereas an abridged version is used afterwards. For a graphical summary of the local zonation and the main bioevents, see Figure 5. A comparison with previously proposed local zonations is provided in Figure 6.

In this section we also propose correlations with the records of the Calatayud-Montalbán and Teruel basins (Daams et al., 1999; Álvarez-Sierra et al., 2003; Van Dam et al., 2001, 2014; García-Paredes et al., in press). These correlations are only introduced here and they are more thoroughly discussed in the next section. Finally, a correlation with the MN zones is also provided. Currently, two different concepts of the MN-zonation coexist (Van



**FIGURE 5.** Local biozonation of the Vallès-Penedès Basin for the late Aragonian to Vallesian. The ranges of biostratigraphically important rodent taxa are indicated as well as the putative phylogenetic relationships of some lineages. Dashed lines indicate discontinuities in the ranges of those taxa. See main text for details. In the case of the MN (Mammal Neogene) zones, we indicated their boundaries as defined on the basis of selected appearance events (see Hilgen et al., 2012) as well as the chronological position of their reference sites (“faunal concept” of MN zones after De Bruijn et al., 1992; see text for details). Reference sites are: Sansan (France) for MN6, La Grive M (France) for MN7+8, Can Llobateres 1 (Spain) for MN9 and Masía del Barbo (Spain) for MN10. The estimated age of Sansan and La Grive is older than their respective MN zones so that they do not appear in the figure. These reference sites are indicated by an \*. The age of the MN zone boundaries are after Hilgen et al. (2012) except for the MN6/MN7+8 boundary which is re-defined in this work (see text for details). Miocene time scale and boundaries after Hilgen et al. (2012). GPTS after Ogg (2012).

Dam *et al.*, 2001; Van Dam, 2003; Hilgen *et al.*, 2012). On the one hand MN zones can be defined using a strict biostratigraphic approach based on the FO of one or a few selected taxa (*e.g.* Steininger, 1999; Agustí *et al.*, 2001; Hilgen *et al.*, 2012). Alternatively, a more “faunal” approach can be used, defining the zones after the complete faunas of selected localities (De Bruijn *et al.*, 1992). In this latter concept, the MN zones are viewed as an ordered sequence of reference localities. Note that this has important implications, since the reference localities for two MN zones may be very close in age (as for MN9 and MN10; see Figs. 5; 7), which may not be desirable. Even worse, the use of different concepts can lead to puzzling situations in which the reference locality for a given MN zone is

correlated to a different MN zone as biostratigraphically defined. For example, Can Llobateres 1 (see Figs. 5; 7), the reference locality for MN9, has an estimated age of 9.76Ma (see Electronic Appendix I) which would imply a correlation with the MN10 as defined by the FCO of the murid *Progonomys* at 9.98Ma (Hilgen *et al.*, 2012; Van Dam *et al.*, 2014). Here we apply the biostratigraphical concept of the MN-zonation based on FHA events (in Europe; Hilgen *et al.*, 2012), the ages of which may or may not correspond with the ages of first appearance events of Agustí *et al.* (2001) as defined in selected ‘boundary sections’. We acknowledge that first occurrences may be regionally diachronic (see Van der Meulen *et al.*, 2011, 2012). Therefore, a MN zone boundary age as defined by

EPOCH	ELMA	MN zone	Agustí (1981, 1982)	Agustí and Moyà-Solà (1991)	Agustí <i>et al.</i> (1997)	Casanovas Vilar <i>et al.</i> (2011)	This work			
MIOCENE	late	TUROLIAN	MN12	<i>Parapodemus barbarae</i>				Zone L (Teruel Basin zonation)		
			MN11	<i>Parapodemus lugdunensis</i>	<i>Parapodemus lugdunensis</i>	<i>Occitanomys</i> sp. A	<i>Occitanomys</i> sp. A	Zone K (Teruel Basin zonation)		
		VALLESIAN	MN10	<i>Progonomys hispanicus</i>	<i>Progonomys</i>	<i>Rotundomys bressanus</i>	<i>Rotundomys bressanus</i>	<i>Rotundomys</i>	<i>Rotundomys bressanus</i>	
			MN9	<i>Cricetulodon</i>	<i>Cricetulodon</i> (MN9b)	<i>Cricetulodon</i>	<i>Cricetulodon sabadellensis</i>		<i>Cricetulodon</i>	<i>Rotundomys montisrotundi</i>
	ARAGONIAN	MN7+8	<i>Fahlbuschia crusafonti</i>	<i>Megacricetodon ibericus</i> + <i>Hipparion</i> (MN9a)	<i>Megacricetodon ibericus</i> + <i>Hipparion</i>	<i>Megacricetodon ibericus</i> + <i>Hipparion</i> s.l.	<i>Hispanomys assemblage</i>	<i>Cricetulodon sabadellensis</i> + <i>Progonomys hispanicus</i>		
		MN6		<i>Megacricetodon ibericus</i> (MN8)	<i>Megacricetodon ibericus</i> (MN8)	<i>Megacricetodon ibericus</i> + <i>Democricetodon crusafonti</i>		<i>Cricetulodon hartenbergeri</i> – <i>Progonomys hispanicus</i> interval		
	middle	ARAGONIAN	MN7		<i>Megacricetodon crusafonti</i> (MN7)		<i>Megacricetodon ibericus</i> + <i>Democricetodon larteti</i>	<i>Cricetulodon hartenbergeri</i>		
			MN8		<i>Megacricetodon gersii</i>			<i>Hippotherium</i> – <i>Cricetulodon hartenbergeri</i> interval		
								<i>Democricetodon crusafonti</i> – <i>Hippotherium</i> interval		
								<i>Megacricetodon crusafonti</i> – <i>Democricetodon crusafonti</i> interval		
							<i>Megacricetodon crusafonti</i> + <i>Democricetodon larteti</i>			

FIGURE 6. Comparison of the local biozones defined in this work with previous biozonations for the Vallès-Penedès Basin.

a FHA event in one region may not automatically apply to other regions across Europe. However, in Figures 5; 7 we have also indicated the position of the reference sites for the different MN zones.

### ***Hispanomys* assemblage zone**

**Definition:** The Cricetodontinae *Democricetodon*, *Megacricetodon* and *Hispanomys* are always present and stand out as the most common rodents in most of the sites. *Democricetodon* and *Megacricetodon* are usually represented in the sites by two coexisting species which differ markedly in size and morphology. *Hispanomys* is represented by different species with rather short ranges. The lower boundary would correspond to the FLO of the genus *Hispanomys*, whereas the upper boundary corresponds to the decrease in diversity and abundance of the Cricetodontinae that coincided with the FLO of the Cricetinae *Cricetulodon*.

**Boundaries:** The lower boundary is not recorded, but the genus *Hispanomys* is already present in the lowermost part of the ACM composite section, within chron C5Ar.1r. This would yield an estimated age of at least 12.6Ma for the lower boundary. The upper boundary would be placed at half-way within chron C5n.2n, with an estimated age of 10.3Ma.

**Correlations:** MN6 (late part) or MN7+8 – MN9 (early part).

**Subzones:** Four different subzones can be recognized on the basis of the coexistence of the different species of the cricetodontines *Megacricetodon* and *Democricetodon* as well as on the occurrence of the first hipparionin equids of the genus *Hippotherium*.

### ***Megacricetodon crusafonti* + *Democricetodon larteti* concurrent range subzone**

**Definition:** The basis is defined by the FLO of *Megacricetodon crusafonti*. The top is defined by the LLO of *Megacricetodon crusafonti*.

**Synonyms:** *Megacricetodon crusafonti* + *Megacricetodon gersii* zone in Alba *et al.* (2006) and Casanovas-Vilar (2007).

**Boundaries:** The age for the lower boundary is not known, the upper boundary is placed within chron C5An.2n, with an estimated age of 12.39Ma.

**Reference locality:** ACM/C9-A1.

**Reference section:** ACM composite section (Moyà-Solà *et al.*, 2009).

**Additional mammal data:** Among the cricetids, FLO of *Hispanomys decedens*, which becomes a major component of the rodent assemblages. *Eumyarion* is relatively rare, whereas other cricetids, such as *Megacricetodon minor* and *Democricetodon brevis*, may be common in certain sites. Among the eomyids, FLO of *Keramidomys*. The glirids are relatively diverse, although they are scarce and their record is sparse. FLO of *Paraglrirulus werenfelsi* and *Myomimus* (cf.) *dehmi*.

**Other remarkable localities:** ACM/BDL2, ACM/C1-D1.

**Correlations:** Because of the presence of *Megacricetodon crusafonti*, this unit can be correlated to MN6 sensu Mein (1999) and Agustí *et al.* (2001) or to MN7+8 sensu Hilgen *et al.* (2012). It is time-equivalent to the lowermost part of zone G3 of the Calatayud-Montalbán Basin (Daams *et al.*, 1999; Álvarez-Sierra *et al.*, 2003; Van Dam *et al.*, 2014; García-Paredes *et al.*, in press), although the defining criterion (presence of *Megacricetodon crusafonti*) fits better with the diagnosis of zone G2 (Daams *et al.*, 1999; see discussion below).

### ***Megacricetodon crusafonti* – *Democricetodon crusafonti* interval subzone**

**Definition:** The base is defined by the LLO of *Megacricetodon crusafonti*, the top is marked by the FLO of *Democricetodon crusafonti*.

**Synonyms:** *Megacricetodon ibericus* + *Democricetodon larteti* concurrent range zone in Alba *et al.* (2006), Casanovas-Vilar (2007) and Casanovas-Vilar *et al.* (2011b).

**Boundaries:** The lower boundary is placed within chron C5An.2n, with an estimated age of 12.39Ma. The upper boundary is placed within chron C5r.3r, with an estimated age of 11.88Ma.

**Reference locality:** ACM/BCV1.

**Reference section:** ACM composite section (Moyà-Solà *et al.*, 2009).

**Additional mammal data:** Amongst the cricetids, FLO of *Megacricetodon ibericus*, LLO of *Hispanomys decedens*, and FLO of *Hispanomys* aff. *aguirrei*. *Democricetodon larteti* and *Eumyarion leemanni* are the most common elements of rodent assemblages. *Hispanomys* may also be a common component. Amongst the eomyids, FLO of *Eomyops*. The glirid faunas are diverse, although they never constitute a major part of the rodent assemblage. FLO of castorids in the Vallès-Penedès (*Chalicomys batalleri*).

Other remarkable localities: ACM/C1-A4, ACM/C1-E9, ACM/C3-A6.

Correlations: This unit may covers the lower part of the MN7+8 (Mein, 1999; Agustí *et al.*, 2001; Hilgen *et al.*, 2012). It could be equivalent to the MN7 sensu Mein and Ginsburg (2002). It would also be equivalent to the middle part of zone G3 of the Calatayud-Montalbán Basin (Daams *et al.*, 1999; Álvarez Sierra *et al.*, 2003; Van Dam *et al.*, 2014; García-Paredes *et al.* in press).

#### ***Democricetodon crusafonti* – *Hippotherium* interval subzone**

Definition: The base is defined by the FLO of *Democricetodon crusafonti*, the top is defined by the FLO of the equid *Hippotherium*.

Synonyms: *Megacricetodon ibericus* + *Democricetodon crusafonti* concurrent range zone in Alba *et al.* (2006), Casanovas-Vilar (2007) and Casanovas-Vilar *et al.* (2011b).

Boundaries: The lower boundary is placed within chron C5r.3r, with an estimated age of 11.88Ma. The upper boundary is placed within chron C5r.1n, with an estimated age of 11.18Ma.

Reference locality: ACM/C5-D1.

Reference section: ACM composite section (Moyà-Solà *et al.*, 2009).

Additional mammal data: Among the cricetids, FLO of *Hispanomys lavocati*, *Megacricetodon minutus* and *Democricetodon nemoralis*. *Hispanomys* is a major component of the rodent faunas together with *Democricetodon crusafonti*. *Eumyarion leemanni* may be very common. On the contrary, *Megacricetodon ibericus* is generally rare. FLO of *Anomalomys gaudryi*. A diverse glirid fauna is present, although the overall abundance of the family is low. FLO of *Glirulus lissiensis*. Similarly, the sciurids are diverse and include an important number of genera belonging to the Xerinae (*Spermophilinus*, *Heteroxerus*, *Tamias*) and the Sciurinae (*Miopetaurista*, *Albanensia*, *Neopetes*). FLO of the castorid Euroxenomys.

Other remarkable localities: ACM/C4-A1, ACM/C8-A1, ACM/C8-Bx, ACM/C8-B1, Sant Quirze A.

Correlations: This unit covers the upper part of the MN7+8 (Mein, 1999; Agustí *et al.*, 2001; Hilgen *et al.*, 2012) and may be equivalent to the MN8 sensu Mein and Ginsburg (2002). It can also be correlated to the upper part of zone G3 of the Calatayud-Montalbán Basin (Daams

*et al.*, 1999; Álvarez-Sierra *et al.*, 2003; Van Dam *et al.*, 2014; García-Paredes *et al.*, in press).

#### ***Hippotherium* – *Cricetulodon hartenbergeri* interval subzone**

Definition: The base is defined by the FLO of the equid *Hippotherium*, the top is defined by the FLO of *Cricetulodon hartenbergeri*.

Synonymies: *Megacricetodon ibericus* + *Hipparion* zone in Agustí *et al.* (1997). *Megacricetodon ibericus* + *Hipparion* s.l. concurrent range zone in Casanovas-Vilar (2007) and Casanovas-Vilar *et al.* (2011b).

Boundaries: The lower boundary is placed within chron C5r.1n, with an estimated age of 11.18Ma. The upper boundary is located at half-way within chron C5n.2n, with an estimated age of 10.3Ma.

Reference locality: Creu Conill 20.

Reference section: Montagut composite section (Garcés *et al.*, 1996).

Additional mammal data: The rodent fauna contains the same components as the previous biozone except for a few new occurrences. *Megacricetodon ibericus* is extremely common in certain sites. *Eumyarion leemanni* and different *Hispanomys* species may also be locally common. The cricetodontines record an important number of LLOs: *Megacricetodon ibericus*, *Democricetodon crusafonti*, *Hispanomys lavocati* and *Hispanomys dispectus*. Amongst the insectivores, FLO of the anourosoricine *Crusafontina endemica*. Regarding the macromammals, the FLO of *Hippotherium* at Creu Conill 20 (11.18Ma) is the most outstanding event. FLO of giraffids.

Other remarkable localities: Creu Conill 22, Hostalets de Pierola Superior (upper, Vallesian levels of els Hostalets de Pierola), ECM/VCE-C1 and, most likely, Can Missert and Castell de Barberà.

Correlations: This unit correlates to the lower part of the MN9 (Mein, 1999; Agustí *et al.*, 2001; Hilgen *et al.*, 2012). It is also time-equivalent to zone H of the Calatayud-Montalbán Basin (Daams *et al.* 1999; Álvarez-Sierra *et al.*, 2003; Van Dam *et al.*, 2014; García-Paredes *et al.*, in press). Initially, Daams and Freudenthal (1988a) defined zone H by the presence of *Megacricetodon ibericus* in the Calatayud-Montalbán Basin, which occurs much later there than in the Vallès-Penedès Basin (see discussion). Currently the FLO of *Hispanomys nombrevillae*, which has an estimated age of 11.20 (López-Guerrero *et al.*, 2014), is used to define the lower boundary of zone H (Van Dam *et al.*, 2014; García-Paredes *et al.*, in press).

***Cricetulodon* range zone**

**Definition:** *Cricetulodon* is the dominant rodent in all sites. The lower boundary is defined by the FLO of this genus and the upper boundary by its LLO.

**Boundaries:** The lower boundary is placed at half-way within chron C5n.2n, with an estimated age of 10.3Ma. The upper boundary is placed near the base of chron C4Ar.2r, with an estimated age of 9.65Ma.

**Correlations:** MN9 (late part) – MN10 (early part).

**Subzones:** Three different subzones can be recognized on the basis of the species of the genus *Cricetulodon* present and the occurrence of the earliest murids of the genus *Progonomys*.

***Cricetulodon hartenbergeri* range subzone**

**Definition:** The base is defined by the FLO of *Cricetulodon hartenbergeri* and the top by its LLO.

**Boundaries:** The lower boundary is located at half-way within chron C5n.2n, with an estimated age of 10.3Ma. The upper boundary is placed near the base of chron C5n.1r (9.98Ma).

**Reference locality:** Can Poncic 1.

**Reference section:** Montagut composite section (Garcés *et al.*, 1996).

**Additional mammal data:** The cricetid fauna is markedly less diverse than in the previous biozone. *Cricetulodon hartenbergeri* is the most abundant rodent. FLO of *Hispanomys thaleri* and *Anomalomys gaillardi*. Regarding the macromammals, LLO of *Anchitherium* at the locality of Can Poncic 1, where *Hippotherium* is also recorded (a co-occurrence of both equids is also observed in other sites from central Europe).

**Other remarkable localities:** B400V/S5C, Santiga, EDAR-2, EDAR-6.

**Correlations:** This unit correlates to the upper part of the MN9 (Mein, 1999; Agustí *et al.*, 2001; Hilgen *et al.*, 2012). It would also cover all or part of zone I of the Calatayud-Montalbán and Teruel basins (Daams *et al.*, 1999; Álvarez-Sierra *et al.*, 2003; Van Dam *et al.*, 2001, 2006, 2014).

***Cricetulodon hartenbergeri* – *Progonomys hispanicus* interval subzone**

**Definition:** The base is defined by the LLO of *Cricetulodon hartenbergeri*, while the top is defined by the FLO of *Progonomys hispanicus*.

**Synonymies:** *Cricetulodon sabadellensis* range zone in Casanovas-Vilar *et al.* (2011b).

**Boundaries:** The lower boundary is placed near the base of chron C5n.1r (9.98Ma) and the upper boundary is placed at half-way of chron C4Ar.3r, with an estimated age of 9.73Ma.

**Reference locality:** Can Llobateres 1.

**Reference section:** Montagut composite section (Garcés *et al.*, 1996).

**Additional mammal data:** The cricetine *Cricetulodon sabadellensis* overwhelmingly dominates the rodent assemblages. *Hispanomys thaleri* may be relatively common in certain sites, although all other cricetodontines are very rare. Furthermore, this biozone records the LLO of the genera *Megacricetodon* (*M. minutus*) and *Democricetodon* (*D. nemoralis*), which had characterized the middle Miocene rodent faunas. *Eumyarion leemanni* may be common in certain sites. The glirid fauna is very diverse, although this family represents a small percentage of the rodent assemblages. Certain glirid genera show their LLO, notably *Glirudinus* and *Bransatoglis*. FLO of *Muscardinus vallesiensis*. Amongst the eomyids, FLO of *Keramidomys pertesunatoi*, which is restricted to this biozone.

**Other remarkable localities:** Can Feu 2, Can Pallars de Llobateres.

**Correlations:** Because of the absence of *Progonomys*, this unit should be correlated to the upper-most part of the MN9 (Mein, 1999; Agustí *et al.*, 2001; Hilgen *et al.*, 2012). However, it is time-equivalent to the earliest MN10 (Hilgen *et al.*, 2012) because *Progonomys* is already recorded as a common element in the Calatayud-Montalbán Basin at 10.0–9.9Ma, while in the Vallès-Penedès Basin it does not occur until the following biozone (see discussion below). The *C. hartenbergeri* – *P. hispanicus* interval subzone would be approximately time-equivalent to subzone J1 in the Teruel (Van Dam *et al.*, 2001, 2006) and Calatayud-Montalbán basins (Van Dam *et al.*, 2006, 2014; García-Paredes *et al.*, in press).

***Cricetulodon sabadellensis* + *Progonomys hispanicus* concurrent range subzone**

**Definition:** The base is defined by the FLO of *Progonomys hispanicus*, while the top is defined by the LLO of *Cricetulodon sabadellensis*.

**Boundaries:** The lower boundary is placed within chron C4Ar.3r, with an estimated age of 9.73Ma. The upper

boundary is placed near the base of chron C4Ar.2r, with an estimated age of 9.65Ma.

Reference locality: Trinxera de Can Llobateres 1.

Reference section: Montagut composite section (Garcés *et al.*, 1996).

Additional mammal data: *Cricetulodon sabadellensis* overwhelmingly dominates the rodent faunas in certain sites. However, in a few localities this species is replaced by its putative descendant, *Rotundomys freirensis*, which also becomes the most abundant element in the rodent assemblages. *Rotundomys freirensis* is confined to this biozone. *Eumyarion leemanni* is very rare and its highest record is at the base of this biozone. The murids first appear at the base of this biozone and are represented by just one species, *Progonomys hispanicus*, which is moderately common in all sites. The glirid fauna is still diverse, although *Microdyromys complicatus*, *Muscardinus hispanicus* and *Muscardinus vallesiensis* have their last records within this biozone. The castorids and sciurids are rare, the latter family being represented solely by *Spermophilinus bredai* in most sites.

Other remarkable localities: Can Llobateres 2, Trinxera de Can Llobateres 0, RT- 11, RT-7C.

Correlations: This unit correlates to the early part of the MN10 (Mein, 1999; Agustí *et al.*, 2001; Hilgen *et al.*, 2012). It would also be time-equivalent to the lowermost part of subzone J2 of the Teruel Basin (Van Dam *et al.*, 2001, 2006, in preparation). However, *Progonomys hispanicus* is the only taxon in common between both areas (see discussion).

#### **Rotundomys abundance zone**

Definition: *Rotundomys* is the dominant rodent in all sites. The lower boundary is defined by the FLO of *Rotundomys montisrotundi*, the upper boundary is defined by the LLO of *Rotundomys bressanus*.

Boundaries: The lower boundary is placed near the base of chron C4Ar.2r, with an estimated age of 9.65Ma. The upper boundary is poorly constrained at the Vallès-Penedès, but the uppermost record of *Rotundomys bressanus* is placed within chron C4Ar.1r, with an estimated age of 9.1Ma.

Correlations: MN10 (late part).

Subzones: Two different subzones can be recognized on the basis of the species of the genus *Rotundomys* present.

#### **Rotundomys montisrotundi lineage subzone**

Definition: The base is defined by the FLO of *Rotundomys montisrotundi*, the top is defined by the FLO of its putative descendant *Rotundomys bressanus*.

Boundaries: The lower boundary is placed near the base of chron C4Ar.2r (9.65Ma), the upper boundary is located half-way within chron C4Ar.1n, with an estimated age of 9.36Ma.

Reference locality: Camí de Can Tarumbot 2.

Reference section: Viladecavalls composite section (Garcés *et al.*, 1996).

Additional mammal data: The rodent faunas are not well known. The cricetine *Rotundomys montisrotundi* is present at most sites, being one of the most common rodents. *Progonomys hispanicus* is the only murid species present.

Other remarkable localities: Can Casablanca, La Tarumba 1, Ceràmiques Viladecavalls, Sant Miquel de Toudell.

Correlations: This unit correlates to the early part of the MN10 (Mein, 1999; Agustí *et al.*, 2001; Hilgen *et al.*, 2012). It is also approximately time-equivalent to a large part of subzone J2 of the Teruel Basin (Van Dam *et al.*, 2001, 2006. Nevertheless, *Progonomys hispanicus* is the only species in common between both areas, the genus *Rotundomys* not being recorded in the Teruel Basin (see discussion).

#### **Rotundomys bressanus lineage subzone**

Definition: The base is defined by the FLO of *Rotundomys bressanus*, and the top by the LLO of this taxon.

Boundaries: The lower boundary half-way within chron C4Ar.1n, with an estimated age of 9.36Ma. The upper boundary of this subzone is poorly constrained, but the uppermost occurrence of *Rotundomys bressanus* is within chron C4Ar.1r, which yields an estimated age of at least 9.1Ma. However, the upper boundary of this biozone is extended to the Vallesian/Turolian boundary for convenience. The age of such boundary is estimated at 8.9Ma (Hilgen *et al.*, 2012).

Reference locality: Trinxera Nord Autopista.

Reference section: Terrassa composite section (Garcés *et al.*, 1996).

Additional mammal data: *Rotundomys bressanus* is usually the major component of the rodent assemblages.

*Rotundomys montisrotundi* may be present at some sites, but it is very rare. Among the murids, FLO of *Progonomys cathaloi*, *Progonomys woelferi*, *Huerzelerimys minor* and *Parapodemus* sp. nov. The eomyids, glirids, sciurids and castorids are rare. FLO of the glirid *Muscardinus heintzi*. A number of extinctions affecting the latter families appear to have taken place within this biozone, but this may reflect the lack of an adequate record in successive zones rather than a real pattern. FLO of the equid *Cremohipparion mediterraneum*.

Other remarkable localities: ROS-D6? (it may belong to the previous biozone), Trinxera Sud Autopista 2, Torrent de Febulines 3, Torrent de Febulines [classical site], Can Cruset. The fauna of the sites around Terrassa (Trinxera Nord Autopista, Trinxera Sud Autopista, Torrent de Febulines) is sometimes considered altogether in the literature and referred to as ‘Terrassa’ (Agustí *et al.*, 1984; Morales *et al.*, 1999).

Correlations: This unit correlates to the late part of the MN10 (Mein, 1999; Agustí *et al.*, 2001; Hilgen *et al.*, 2012). It is approximately time-equivalent to subzone J3 of the Teruel Basin (Van Dam *et al.*, 2001, 2006). A biostratigraphical correlation with the Teruel zonation is not feasible because the genus *Rotundomys* is not recorded in this basin (see discussion).

#### ***Huerzelerimys vireti* range zone (zone K of Teruel Basin)**

The site ROS-A1 is correlated to the *Huerzelerimys vireti* range zone (zone K), defined in the Teruel Basin as the interval between the FLO and the LLO of the murid *H. vireti* (Van Dam *et al.*, 2006). Zone K combined with zone J4 (Van Dam *et al.*, 2006) correlate to the MN11 as stratigraphically defined (Mein, 1999; Agustí *et al.*, 2001; Hilgen *et al.*, 2012).

The faunas of this zone are insufficiently known and just include one site (ROS-A1) in the Vallès-Penedès Basin. The estimated age of ROS-A1 would then be between 8.8 and 7.6Ma (Agustí *et al.*, 2001; Van Dam *et al.*, 2006; Hilgen *et al.*, 2012). The murid *Huerzelerimys vireti* is common. It records the FLO of the cricetine *Kowalskia fahlbuschi*, which is a major component of the rodent assemblages. The large mammal fauna is insufficiently known. There is a significant impoverishment of many groups, and the bovids and hipparionin equids dominate the herbivore assemblage.

#### ***Parapodemus barbarae* – *Stephanomys ramblensis* interval zone (zone L of Teruel Basin)**

The site Torrentet de Traginers, in the town of Piera, is tentatively correlated to *Parapodemus barbarae* –

*Stephanomys ramblensis* interval zone (zone L) of the Teruel Basin (Van Dam *et al.*, 2001, 2006), which would yield an estimated age between 7.6Ma and 7.4–6.8Ma (Agustí *et al.*, 2001, 2006; Van Dam *et al.*, 2001, 2006; Hilgen *et al.*, 2012). This zone is considered to be equivalent to MN12 as stratigraphically defined (Mein, 1999; Agustí *et al.*, 2001; Hilgen *et al.*, 2012). Zone L is defined in the Teruel Basin as the interval between the first appearance of *P. barbarae* and that of *S. ramblensis*, but also covers the total range of the murids *Occitanomys adroveri* and *Huerzelerimys turolensis* (Van Dam *et al.*, 2001). The only known microfauna from the Vallès-Penedès Basin (Torrentet dels Traginers) includes just one taxon, *Occitanomys adroveri*, which justifies the proposed correlation. However, this micromammal sample is scarce, comprising just 20 specimens, and clearly more data are needed.

The classical macromammal sites of Piera (Plana del Castell, Torrent del Gall Mullat, Finca Llopart, Teuleria de les Flandes) would also belong to this zone. The fauna of all these sites is usually considered altogether with that of Torrentet de Traginers and referred to in the literature as ‘Piera’ (see for example Agustí *et al.*, 1985, 1997; Morales *et al.*, 1999). As far as macromammals are concerned, this zone would record the FLO of the boselaphin bovid *Tragoptax* aff. *gaudryi*. The giraffid *Birgerbohinia*, the suid *Microstonyx* and the equid *Cremohipparion* are very abundant. On the contrary, rhinocerotids and cervids are scarce and markedly less diverse than in preceding zones.

## **DISCUSSION AND CORRELATION WITH OTHER RECORDS**

The proposed local biozonation differs from earlier attempts in providing a formal diagnosis and description of each zone, as well as clear boundaries and a reference locality and section. However, slightly modified concepts of previous biostratigraphic schemes are retained (see Fig. 6). In this section we compare our zonation with earlier works and further discuss its correlation with other records.

Regarding the late Aragonian, the proposed zonation is similar to that of Alba *et al.* (2006), Casanovas-Vilar (2007) and Casanovas-Vilar *et al.* (2011b). Alba *et al.* (2006) were the first to recognize that the sites of the lowermost part of the ACM series belonged to a distinct biozone and tentatively correlated it to part of the MN6. These authors introduced the *Megacricetodon crusafonti* + *Megacricetodon gersii* zone for this part of the record. However, this conclusion was precipitate because the micromammal sample at that time was very limited and even the attribution of the *Megacricetodon* remains to a particular species could be questioned. Subsequent studies concluded that those sites belonged to a distinct biozone

that might be correlated to part of the MN6, but admitted that the material recovered was too scarce to adequately characterize it (Casanovas-Vilar, 2007; Casanovas-Vilar et al., 2011b). Additional sampling of the lower part of the ACM series has provided good samples for some sites (ACM/C9-A1, ACM/BDL2), allowing an unambiguous identification of the characteristic species. As a result, we propose the *Megacricetodon crusafonti* + *Democricetodon larteti* concurrent range subzone, which would be equivalent to the *M. crusafonti* + *M. gersii* zone of Alba et al. (2006). *Megacricetodon gersii* does not occur in the studied assemblages, since earlier citations correspond to small-sized specimens of *M. crusafonti*. The cricetid *M. crusafonti* was considered to be the more characteristic element of the MN6, but Aguilar (1980) showed that the material from the reference locality (Sansan, France) belonged to a different species, *M. gersii*, whereas *M. crusafonti* was apparently restricted to the Spanish sites. Daams and Freudenthal (1988b) and Daams et al. (1999) showed that, in the Calatayud-Montalbán Basin (north-central Spain), *M. gersii* occurred in older levels than *M. crusafonti*. Therefore, Agustí et al. (2001) proposed a subdivision of the MN6 into MN6a and MN6b in Western Europe, each subunit being characterized by a different *Megacricetodon* species. This subdivision roughly corresponds to zones G1 and G2 of the Calatayud-Montalbán Basin (Daams et al., 1999). However, Hilgen et al. (2012) recently evaluated the boundaries of the MN zones and proposed to define the lower boundary of MN6 by the FHA of *M. gersii* and the lower boundary of MN7+8 by the FHA of *M. crusafonti*. In accordance, zone G1, which solely includes *M. gersii*, would be correlated to the MN6, whereas zone G2, characterized by the presence of *M. crusafonti*, would be correlated to lower part of MN7+8. Therefore, the *M. crusafonti* + *D. larteti* subzone could either be correlated to the MN7+8 sensu Hilgen et al. (2012) or to the MN6b sensu Agustí et al. (2001). In any case, our magnetostratigraphic correlations (Figs. 3; 5; 7) indicate that the *M. crusafonti* + *D. larteti* zone of the Vallès-Penedès is time-equivalent to the lower-most part zone G3 of the Calatayud-Montalbán Basin. Zone G3 of the Calatayud-Montalbán Basin is defined by the presence of transitional assemblages between *M. crusafonti* and *M. ibericus* (Daams and Freudenthal, 1988b; Daams et al., 1999), with the latter unambiguously present in the youngest sites of this zone (Álvarez-Sierra et al., 2003; Van Dam et al., 2014). Therefore, zone G3 covers most of the MN7+8 in that area.

These *M. crusafonti* – *M. ibericus* transitional assemblages are not recognized in the Vallès-Penedès Basin. The medium-sized *Megacricetodon*, which is quite abundant in the lowermost part of the ACM series, perfectly fits the diagnosis of *M. crusafonti*. *Megacricetodon ibericus* is present (although sporadically) in the next biozone (*M.*

*crusafonti* – *D. crusafonti* interval subzone; see below), whereas no transitional forms are recorded between the LLO of *M. crusafonti* and the FLO of *M. ibericus*. The definition of the Vallès-Penedès *M. crusafonti* + *D. larteti* subzone would fit better with that of zone G2 of the Calatayud-Montalbán Basin, even though it is time-equivalent to the lower part of zone G3. Therefore, we conclude that *M. crusafonti* persisted for a slightly longer time in the Vallès-Penedès.

Interestingly, the genus *Hispanomys* is already present in the lowermost levels of the *M. crusafonti* + *D. larteti* subzone, with an estimated age of ca. 12.6Ma. This age is near to that of the first record of this genus in the Calatayud-Montalbán Basin which is at 12.4Ma (López-Guerrero et al., 2014). Nevertheless, *Hispanomys* is represented by different species in these areas. In Calatayud-Montalbán, the oldest *Hispanomys* species present is *Hispanomys* cf. *aguirrei* (López-Guerrero et al., 2014) whereas in the Vallès-Penedès it is *Hispanomys decedens*, the same species that occurs in La Grive M, L5 and L7, France (López-Antoñanzas and Mein, 2011). An as yet undescribed form closely related to *H. aguirrei* occurs in younger late Aragonian sites in the Vallès-Penedès. The various *Hispanomys* species have proven their biostratigraphic value in the Calatayud-Montalbán Basin, where they could well serve as the basis for the subdivision of the long local zone G3 into shorter intervals (see López-Guerrero et al., 2014). In the Vallès-Penedès *Hispanomys* species could also be of great use in refining the diagnoses for some zones and their boundaries. However, this would first require a detailed taxonomic revision of the genus in this area. The rest of the late Aragonian is covered by the *Megacricetodon crusafonti* – *Democricetodon crusafonti* and the *Democricetodon crusafonti* – *Hippotherium* interval subzones. These are equivalent to previous zonations that prominently considered the occurrence of *Megacricetodon ibericus* as a defining criterion (Alba et al., 2006; Casanovas-Vilar, 2007; Casanovas-Vilar et al., 2011b). Thus, the late Aragonian of the ACM series was divided into two zones taking into account the coexistence of *M. ibericus* with two different large-sized *Democricetodon* species, *D. larteti* in the older sites and *D. crusafonti* in the younger ones (Fig. 6). The choice of *M. ibericus* as a diagnostic criterion was influenced by previous zonations (Agustí and Moyà-Solà, 1991; Agustí et al., 1997) and by the local biostratigraphy of the relatively closely situated Calatayud-Montalbán Basin, where medium-sized species of *Megacricetodon* are the major components of the late Aragonian and earliest Vallesian rodent assemblages (Daams and Freudenthal, 1988a, b; Daams et al., 1999). This is not the case in most of the Vallès-Penedès sites, where these cricetids may be rare or even absent, particularly in the well-sampled ACM series. Therefore, the zones proposed here are based on the

FLO and LLO of abundant taxa (*D. larteti*, *D. crusafonti*, *Hippotherium*). The *M. crusafonti* - *D. crusafonti* and *D. crusafonti* - *Hippotherium* interval subzones are time-equivalent to zone G3 of the Calatayud-Montalbán Basin (Daams *et al.*, 1999). Nevertheless, in zone G3 *D. larteti* only occurs in the oldest sites of zone G3, its last record being around 12.6Ma (Van Dam *et al.*, 2014), much earlier than in the Vallès-Penedès Basin (11.9). For most of zone G3, *D. crusafonti* is the only large-sized *Democricetodon* species present in the Calatayud-Montalbán Basin. On the other hand, during the first half of zone G3 transitional assemblages between *M. crusafonti* and *M. ibericus* occur in the Calatayud-Montalbán Basin, *M. ibericus* not being recorded until 11.9Ma (Van Dam *et al.*, 2014), *i.e.* 0.4Myr later than in the Vallès-Penedès. Both local zonations do not match because of this diachrony in the FLOs and LLOs of the defining taxa, even though gaps in the record of the Calatayud-Montalbán Basin would allow for somewhat older ages for the FLO of *M. ibericus*. On the other hand, the proposed zonation for the late Aragonian can probably be extended to France, particularly to the fissure fillings of La Grive (for an updated review of the La Grive fauna, see Mein and Ginsburg, 2002). Some fissures, such as La Grive M, would correlate to the *M. crusafonti* - *D. crusafonti* interval subzone or even to the earlier *M. crusafonti* + *D. larteti* subzone, being characterized by the presence of *D. larteti* and *Hispanomys decedens*, as well as by the absence of some faunal elements typical of the subsequent zone such as *D. crusafonti* and *M. ibericus*. Other fissure fillings, such as La Grive L3 and L5 would correlate to the *D. crusafonti* - *Hippotherium* interval subzone (Casanovas-Vilar, 2007; Casanovas-Vilar *et al.*, 2008, 2011b).

Concerning the correlation of the late Aragonian zones of the Vallès-Penedès with the MN system, we follow the taxonomic choices of Agustí *et al.* (2001) for the definition of the boundaries of MN6 and MN7+8, because it allows for higher-resolution correlations for this time interval. We therefore propose to define the lower boundary of MN7+8 by the FHA of *M. ibericus* rather than based on the FHA of *M. crusafonti* (as proposed by Hilgen *et al.*, 2012). As a consequence, our *M. crusafonti* + *D. larteti* subzone would correlate to MN6. The first record of *M. ibericus* occurs within chron C5An.2n in the ACM series, yielding an estimated age of around 12.3Ma. This would imply a slightly younger age for the MN6/MN7+8 boundary than previous estimates (between 13.1 and 12.5Ma, Agustí *et al.*, 2001; Hilgen *et al.*, 2012). The proposed age for the MN6/MN7+8 boundary is only slightly younger than the lower boundary for our *M. crusafonti* - *D. crusafonti* interval subzone (12.39Ma). Note that this definition of the MN7+8 can only be applied to southwestern Europe, where *M. ibericus* is present. The boundaries in other regions, such as the North Alpine Foreland Basin,

are based on other taxa and place the MN6/MN7+8 boundary at considerably older ages, around 13.9Ma (Kälin and Kempf, 2009).

The beginning of the Vallesian is marked by the dispersal of the equid *Hippotherium*, but as far as the small mammal faunas are concerned, the earliest Vallesian assemblages do not differ from the latest Aragonian ones. In other words, the small mammal assemblages of the *D. crusafonti* - *Hippotherium* subzone cannot be distinguished from those of the earliest Vallesian. This had been already noted by previous authors, who introduced the *M. ibericus* + *Hipparion* (*sensu lato*) zone for the first half of the early Vallesian (Agustí and Moyà-Solà, 1991; Agustí *et al.*, 1997; Casanovas-Vilar *et al.*, 2011b). Later early Vallesian faunas are clearly distinguished by the presence of the cricetine genus *Cricetulodon*, which dominates the small mammal assemblages. In this work we define the *Hippotherium* - *Cricetulodon hartenbergeri* interval subzone for the earliest Vallesian, which would be equivalent to the *M. ibericus* + *Hipparion* zone. While *Megacricetodon ibericus* may be very common at certain early Vallesian sites (such as Creu Conill 22) it is extremely rare in others (such as in the ECM series), to the point that there is not enough material to confidently identify the species. Therefore, we decided to base the new local zonation on two taxa that are very common after their FLO: *Hippotherium* and *Cricetulodon*. This new definition implies that when only small mammals have been recovered we cannot distinguish the *D. crusafonti* - *Hippotherium* subzone from the *Hippotherium* - *C. hartenbergeri* subzone. Nevertheless, if the locality has associated high-quality magnetostratigraphical data, such as in the case of the ECM series, the sites can be confidently correlated to one of the subzones on the basis of the characteristic pattern of polarity reversals (Fig. 3). Although *Hippotherium* may be rare or even absent (as in the ECM sites), it is present in most of the sites that have delivered macromammals. In the Vallès-Penedès, *Hippotherium* is first recorded within chron C5r.1n (Creu Conill 20), with an estimated age of 11.18Ma (Garcés *et al.*, 1996, 1997; dates recalculated taking into account the latest version of the GPTS after Ogg, 2012). This age is consistent with the record of the Calatayud-Montalbán Basin, where its first appearance could be placed between 11.2 and 10.8Ma (Garcés *et al.*, 2003; Van Dam *et al.*, 2014). It is also congruent with the data from Central Europe (Bernor *et al.*, 1988; Woodburne, 2009), but it is somewhat older than age estimates for this event in other areas (Sinap Formation, Siwaliks), which range from 10.8 to 10.3Ma (Barry and Flynn, 1990; Barry *et al.*, 1982, 1985, 2002; Bernor *et al.*, 1996; Flynn *et al.*, 2013; Kappelman *et al.*, 2003). These age differences may reflect a slight diachrony in the dispersal of this taxon or may be due to a sampling effect; *Hippotherium*

may have been initially very rare or linked to particular paleoenvironments that became more widespread after its first dispersal.

The correlation of Castell de Barberà and Can Missert sites with the early Vallesian is more controversial. The first accounts on these sites (Crusafont-Pairó and Golpe-Posse, 1974a, b) reported the presence of *Hippotherium*. Nevertheless, in subsequent publications (see Agustí *et al.*, 1997, 2005; Casanovas-Vilar, 2007; Casanovas-Vilar *et al.*, 2011b), these sites were correlated to the late Aragonian, because (at least in the case of Castell de Barberà), the scarce hipparionin material (see Rotgers and Alba, 2011) would have been collected from a younger level (although very close, less than ten meters higher stratigraphically). On the other hand, the stratigraphical proximity of this site to Can Llobateres 1 (see Crusafont Pairó and Truyols Santonja, 1951) certainly would argue against a late Aragonian age for Castell de Barberà. Here we assume that Castell de Barberà may well belong to the earliest Vallesian. Unfortunately, the small mammal faunas are of no help to solve this question. In the case of Can Missert, Crusafont-Pairó and Golpe-Posse (1974b) reported *Hippotherium*, although the presence of such material was not confirmed afterwards, resulting in a correlation to the latest Aragonian (see Agustí *et al.*, 1997; 2005). However, Robles *et al.* (2011) reported a *Hippotherium* incisor from Can Poal, a nearby site that would be stratigraphically positioned below Can Missert. Therefore, we also favor a correlation of Can Missert to the early Vallesian.

The appearance of the cricetine *Cricetulodon* is also a remarkable Vallesian bioevent. This genus is first recorded in Turkey by the end of the middle Miocene (MN7+8; Ünay and de Bruijn, 1984; Koufos, 2003; de Bruijn *et al.*, 2013) and dispersed into the Iberian Peninsula during the early Vallesian. The oldest European species known, *C. hartenbergeri*, is recorded within chron C5n.2n in the Vallès-Penedès Basin (RT8 site), yielding an estimated age of 10.3Ma. In the Calatayud-Montalbán Basin its first occurrence is also in chron C5n.2n in the Pedregueras section (Van Dam *et al.*, 2014), with a proposed age of 10.6Ma (Pedregueras 2A site). In the Vallès-Penedès Basin, *Cricetulodon* is not recorded in the well-sampled sites of the ECM series, which range between 10.9 and 10.6Ma (Alba *et al.*, 2012). On the other hand, the absolute chronology of the Pedregueras section is not direct, but largely depends on its lithostratigraphic correlation with the Nombrevilla section, for which magnetostratigraphic dating is available (Garcés *et al.*, 2003; Van Dam *et al.*, 2014). Thus, although *Cricetulodon* may occur earlier in the Calatayud-Montalbán Basin than in the Vallès-Penedès Basin, the uncertainty associated to this date allows for slightly younger ages than reported in the Calatayud-Montalbán record.

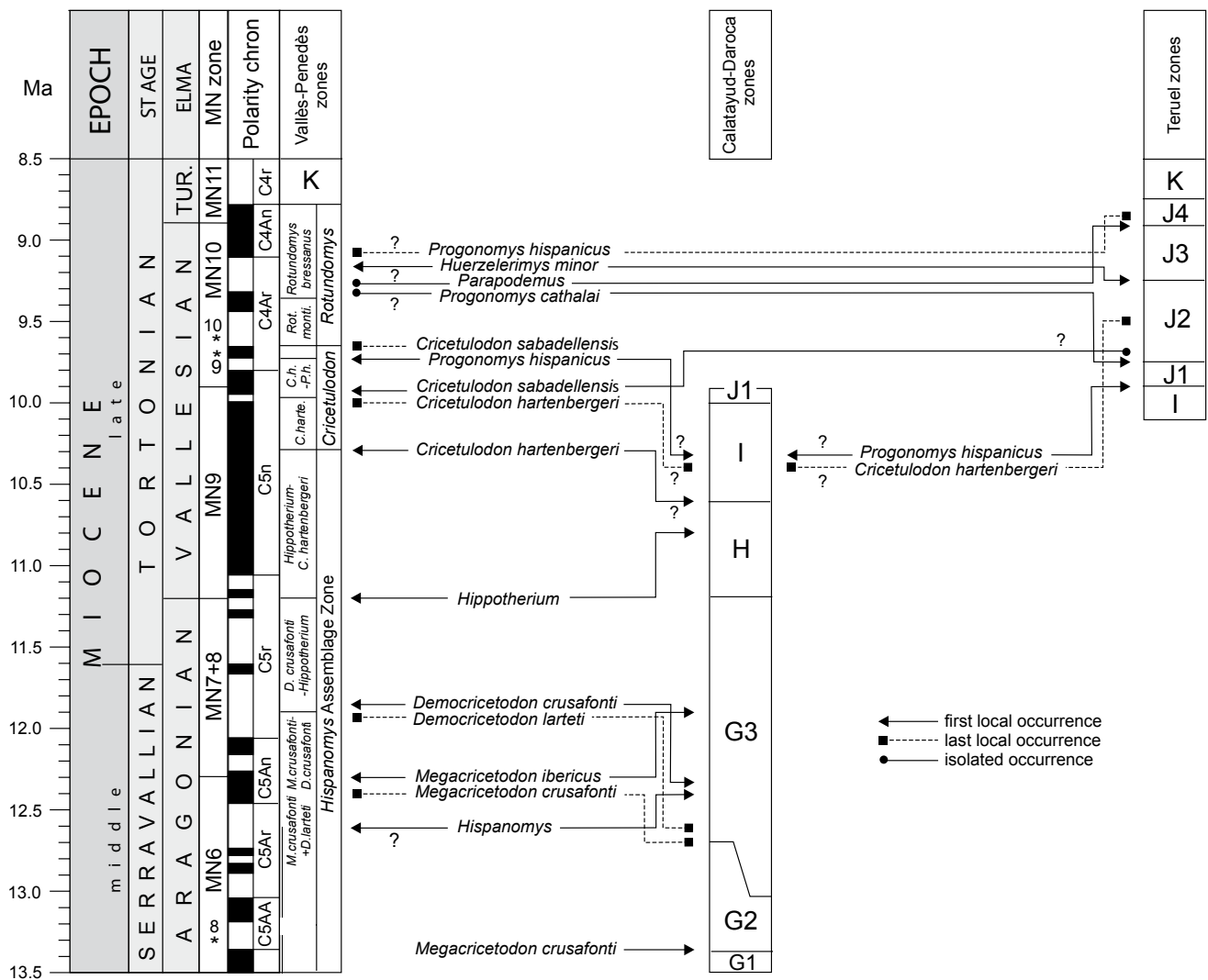
The different subzones of the *Cricetulodon* and *Rotundomys* zones are slightly modified versions of the ones introduced by Casanovas-Vilar *et al.* (2011b) and provide a high resolution for the dating of the Vallesian sites. These zones consider the evolution of the *C. hartenbergeri* - *R. bressanus* lineage together with the appearance of certain murid taxa. *Progonomys hispanicus* is the earliest murid in the Vallès-Penedès, being recorded in RT-11 and RT-7C, which are correlated to the uppermost part of chron C4Ar.3r with an estimated age of 9.7Ma. The early evolution of the Muridae is well documented in the middle Miocene of Pakistan (Jacobs, 1977), where the genus *Progonomys* first appeared at around 12Ma (Barry and Flynn, 1990; Barry *et al.*, 1982, 2002; Flynn *et al.*, 1995, 2013; Wessels, 2009). Updated stratigraphic correlations attained in the Calatayud-Montalbán and Teruel basins (Van Dam *et al.*, 2014) show a very rare presence of *Progonomys* during the early Vallesian, at 10.4Ma and a common occurrence of this form after 10.0-9.9Ma. In Turkey, its first record is at 10.1 Ma (Kappelman *et al.*, 2003). In the Vallès-Penedès, Hartenberger and Thaler (1963) and Michaux (1971) reported a couple of murid molars from Can Llobateres 1 (kept at the University of Montpellier) which resemble the first *Progonomys* morphotypes in the Teruel Basin (assigned to Muridae incertae sedis by Mein *et al.*, 1993). This would indicate a slightly older age for this bioevent in the Vallès-Penedès, closer to 9.8Ma. Similarly, Agustí (1981) reported a single molar of a small-sized *Rotundomys* (which we assign to *R. montisrotundi*) from that site. The FLO of the genus *Rotundomys* (*R. freirensis* from RT-11 and RT-7B) coincides with that of *Progonomys*, whereas *R. montisrotundi* occurs slightly later (at around 9.65Ma). After the collection of thousands of small mammal remains in the successive campaigns undertaken at Can Llobateres 1 during the 1990s and 2010–2013, no further *Rotundomys* or murid remains have been recovered. This may indicate that the old collections include material from the upper levels of the Can Llobateres section, which are correlated to the late Vallesian, or from other sites of the basin.

Previous zonations for the late Vallesian (Agustí and Moyà-Solà, 1991; Agustí *et al.*, 1997; Casanovas-Vilar *et al.*, 2011b) were constructed in relation to the concept of the 'Vallesian Crisis'. Therefore, the oldest zone of the late Vallesian was not only characterized by the concurrent range of *Progonomys* and *Cricetulodon*, but also by the abrupt extinction of a number of mammal taxa that presumably preferred humid and forested environments. Regarding the macromammals, the suids *Listriodon* and *Parachleuastochoerus*, the bovid *Miotragocerus*, amphicyonid and barbourfelid carnivorans and finally, hominids disappeared. Certainly, a number of extinctions

seem to have affected the rodents, particularly the cricetids (*Democricetodon*, *Megacricetodon*, *Eumyarion*) and glirids (*Glirudinus*, *Bransatoglis*, *Microdyromys*). However, other alleged extinctions may in fact reflect a smaller sample size as compared to the early Vallesian, which is insufficient to record certain rare taxa (Casanovas-Vilar et al., 2014). Indeed, the above-mentioned taxa would ultimately disappear, but probably during a longer time interval comprising the whole late Vallesian and part of the Turolian (Casanovas-Vilar et al., 2014).

The biostratigraphic correlation of the Vallesian zones with other local biostratigraphic schemes is even less straightforward than in the case of the late Aragonian,

given the little faunal overlap between the Vallès-Penedès and the Calatayud-Montalbán and Teruel basins during this time interval (Fig. 7). The *Hippotherium* – *C. hartenbergeri* zone is time-equivalent to zone H of the Calatayud-Montalbán Basin, which is defined by the FLO of *Hispanomys nombrevillae* in that area (Van Dam et al., 2014; García-Paredes et al., in press). On the other hand, the *C. hartenbergeri* subzone would cover zone I from the same area, even though in the Calatayud-Montalbán Basin, *C. hartenbergeri* is probably recorded in somewhat older sites (ranging from 10.6 to 10.4Ma) than in the Vallès-Penedès Basin (Van Dam et al., 2014). *Cricetulodon sabadellensis* characterizes the rest of the early Vallesian and the beginning of the late Vallesian



**FIGURE 7.** Comparison of the Vallès-Penedès local zonation with the local biostratigraphical schemes of the Calatayud-Montalbán and Teruel basins (east-central Spain). Hatching indicates hiatuses or insufficiently known faunas. The local zonation of the Calatayud-Daroca basin is taken from Daams et al. (1999), Álvarez-Sierra et al. (2003), Van Dam et al. (2014) and García-Paredes et al. (2016) whereas that of the Teruel basin from Van Dam et al. (2001, 2006). The first and last local occurrences are indicated for biostratigraphically important taxa, note important diachronies. Isolated occurrences indicate that the taxon has only been recovered from one site in that area. Question marks next to occurrence data indicate poorly constrained ages. For further details see text and Figure 5.

(from 9.98 to 9.65Ma). On the other hand, successive species of *Rotundomys* are the basis for the definition of the late Vallesian local biozones of the Vallès-Penedès. In the Teruel Basin, *C. hartenbergeri* has a longer record than in the Calatayud-Montalbán Basin, extending into the late Vallesian to around 9.5Ma (subzone J2; Van Dam *et al.*, 2001, 2006). Interestingly, one specimen resembling *C. sabadellensis* was recently identified in Puente Minero 2 (estimated age 9.73Ma; Van Dam *et al.*, unpublished data), suggesting the presence of this taxon in the late Vallesian of the Teruel Basin as well. The Vallès-Penedès zonation for the early Vallesian can also be recognized in the Seu d'Urgell Basin in the Catalan Pyrenees (Casanovas-Vilar *et al.*, 2011b).

Concerning the late Vallesian, the local zones of the Teruel Basin are based on the presence of different murid taxa that allow a subdivision of this time interval into subzones J1, J2 and J3 (Van Dam *et al.*, 2001, 2006). This family overwhelmingly dominates the rodent faunas of the Teruel Basin, but, in the Vallès-Penedès the most common taxa are the cricetines *Cricetulodon* and *Rotundomys*. This has been interpreted as an evidence for differing environmental conditions in the two regions (Casanovas-Vilar and Agustí, 2007). In any case, using murids in the zonation of the Vallès-Penedès Basin complicates the correlations because, in this basin, they are scarce and may not be recorded at all in a given site if sample size is small. Therefore, we decided to base our zonation in more common taxa. Nevertheless, the murid succession between both areas shows some coincidences. In subzone J1 of the Teruel Basin, *P. hispanicus* is the only murid present. Therefore, the *C. sabadellensis* + *P. hispanicus* and the *R. montisrotundi* subzones of the Vallès-Penedès would be biostratigraphically equivalent to this subzone, even though *P. hispanicus* is recorded much earlier in inner Spain. In subzone J2, the murid assemblage is enriched with *Progonomys cathalai*, whereas *Huerzelerimys minor* defines the lower boundary of subzone J3 (Van Dam *et al.*, 2001). In the Vallès-Penedès, *P. cathalai* is only recorded at ROS-D6, which also records a primitive *Parapodemus*. Interestingly, the first occurrence of the latter genus in the Vallès-Penedès is older than in Teruel, where *Parapodemus lugdunensis* is not recorded until subzone J4 (MN11, earliest Turolian; Van Dam *et al.* 2006). Concerning *Huerzelerimys minor*, in the Vallès-Penedès it is only recorded in Can Cruset and Can Cruset 4B, which are correlated to the *R. bressanus* subzone. There are no magnetostratigraphic data associated with any of these sites, so that their age is not well constrained. ROS-D6 includes scarce remains of the cricetid *R. montisrotundi*, thus suggesting a correlation with the *R. montisrotundi* subzone. However, *R. montisrotundi* also persists (although it is rare) in the *R. bressanus* subzone, and in ROS-D6 there are recorded a number of taxa

that are only known from the *R. bressanus* zone in the Vallès-Penedès, including *Neocricetodon ambarrensis* and *Muscardinus heintzi* (see Electronic Appendix I). Therefore, we favor a correlation of ROS-D6 with the *R. bressanus* zone, although an older correlation is also possible. However, we assume that the site is certainly older than Can Cruset and Can Cruset 4B so that the record of *P. cathalai* would precede that of its putative descendant *H. minor* in the Vallès-Penedès (Fig. 7).

The Turolian rodent record from the Vallès-Penedès is restricted to just two sites that have delivered markedly different faunas, ROS-A1 and Torrentet de Traginers, which can be tentatively correlated to the local zones K and L of the Teruel Basin, respectively (Van Dam *et al.*, 2001, 2006). A better sampling of the Turolian part of the record will confirm these tentative correlations or rather provide the basis for a local zonation for that age in the Vallès-Penedès.

## CONCLUSIONS

The detailed local biostratigraphy and magnetostratigraphy presented here allows an unprecedented dating accuracy for the late Aragonian and Vallesian of the Vallès-Penedès Basin. The rodent-based biozones permit the correlation of sites with no associated magnetostratigraphical data, even when the fossil sample size is very limited. On the other hand, a comparison with other records, such as those from the nearby Calatayud-Montalbán and Teruel basins, reveals that the order of the faunal events is roughly the same but that they are diachronic, with some events occurring earlier (*i.e.* first record of *Megacricetodon ibericus* and *Parapodemus*) or later (*i.e.* first record of *Cricetulodon* and *Progonomys*) in the Vallès-Penedès Basin. In addition, some taxa that are diagnostic of the Vallès-Penedès local zones, such as the various species of *Rotundomys*, are not recorded in these basins, thus hampering a direct biostratigraphic correlation. The faunal differences between the Vallès-Penedès Basin and those of east-central Spain are particularly strong during the late Vallesian, with markedly different rodent faunas occurring in both areas.

## ACKNOWLEDGEMENTS

This work has been supported by the Spanish Ministerio de Economía y Competitividad (CGL2014-54373-P and RYC-2013-12470 to ICV; CGL2014-55900-P), and the Agència de Gestió d'Ajuts Universitaris i de Recerca (2014 SGR 416) of the Generalitat de Catalunya. IG-P acknowledges a JAE-Doc contract (CSIC), co-funded by the European Social Fund, and the support of the Research group UCM-910607 "Evolution of

Cenozoic Mammals and Continental Paleoenvironments”. We acknowledge J. Agustí, L. Cabrera and M. Llenas for their help in the geographical and stratigraphical location of several sites that provided material kept in the collections of the ICP. We sincerely thank the insightful comments by the two reviewers of an earlier version of this manuscript, P. Peláez-Campomanes and F.J. Ruiz-Sánchez, which surely helped to improve the final result.

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**Manuscript received July 2015;**  
**revision accepted March 2016;**  
**published Online June 2016.**

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# ELECTRONIC APPENDIX I: DATABASE OF RODENT SITES MENTIONED IN THIS WORK

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## HOW TO USE THIS DATABASE

In this Appendix we provide an updated database of all the sites mentioned in the main text arranged in alphabetical order. Here the reader can find additional details regarding their location, age as well as an updated list of the rodent taxa. In case the rodent fauna has been described, the appropriate references are given, but this is rarely the case. When no references are given, the identifications of the rodent taxa should be taken as preliminary. 45 rodent sites from the Vallès-Penedès Basin ranging from the late Aragonian (MN7+8) to the middle Turolian (MN11) are included. The main criterion for their inclusion in this database is the richness of the rodent sample, which in almost all cases is well above 200 identifiable specimens. In addition, we have preferentially selected those sites with well constrained ages. The sites listed in this database comprise about one fourth of all the rodent sites known for this time interval. All the material is kept within the collections of the Institut Català de Paleontologia Miquel Crusafont (ICP) at Sabadell.

Many of these localities also include other macrovertebrates and microvertebrates besides rodents, but these have not been included in the faunal lists. For more complete, although not updated, faunal lists including all mammal orders the reader is referred to the synthetic papers by Agustí *et al.* (1985, 1997) and to the NOW database of fossil mammals (Fortelius, 2015).

For each record the information is arranged as follows:

Name of the locality [in bold]. In case of synonymy the name used in the collections of the ICP is given.

Acronym: Standard acronym used in maps, stratigraphical series, biostratigraphic charts and other figures.

Locality synonyms: Other names given to the locality, usually referring to older names used by some authors.

Municipality: Municipality to which the site belongs to.

Age: An absolute age can be estimated for the sites with associated magnetostratigraphical data using the methods of Barry *et al.* (2002). The calculations are based on the stratigraphic position of a given site in the local magnetostratigraphic series. The interpolation must be done between two points of known ages, namely polarity changes in the section that correspond to chron boundaries recorded in the same section. When one of the chron boundaries is not recorded in this section, then the absolute age (in Ma) can be calculated using the composite section which does record the chron boundaries.

Correlation to GPTS: Magnetostratigraphical correlation of the site to the Geomagnetic Polarity Time Scale. Ages for chron boundaries are after Ogg (2012).

Correlation to local biostratigraphy: Local subzone to which the site is correlated (see main text for details). Reference localities for these subzones are indicated.

Correlation to the MN zonation: MN zone to which the site is correlated. The diagnosis of MN zones used here is based in Mein (1999) and Agustí *et al.* (2001).

Faunal list: Rodent taxa present. Until formal descriptions of the specimens are published their identification should be considered preliminary.

Taxonomic references: Literature (including PhD thesis) where the rodent fauna of this site (or part of it) is described. In those works the reader can find further reference on the rest of the fauna recovered at a particular site.

Remarks: Additional remarks that usually refer to usual confusions or controversies regarding the name or the correlation of a particular site.

## LATE ARAGONIAN-TUROLIAN RODENT SITES FROM THE VALLÈS-PENEDÈS BASIN MENTIONED IN THIS WORK

### Abocador de Can Mata / Barranc de Can Vila 1

Acronym: ACM/BCV1

Locality synonyms: -

Municipality: els Hostalets de Pierola

Age: 11.97Ma

Correlation to GPTS: C5r.3r

Correlation to local biostratigraphy: *Megacricetodon crusafonti* – *Democricetodon crusafonti* Interval Subzone [reference locality]

Correlation to the MN zonation: MN7+8

Faunal list: *Spermophilinus bredai*, *Miopetaurista* cf. *crusafonti*, *Glirudinus undosus*, *Muscardinus* aff. *sansaniensis*, *Bransatoglis* cf. *astaracensis*, *Microdyromys complicatus*, *Eomyops* sp., *Eumyarion leemanni*, *Hispanomys* aff. *aguirrei*, *Megacricetodon minor*, *Democricetodon brevis*, *Democricetodon larteti*.

Taxonomic references: Casanovas-Vilar (2007); Casanovas-Vilar *et al.* (2010).

Remarks: -

### Abocador de Can Mata / Bassa de Lixiviats 2

Acronym: ACM/BDL2

Locality synonyms: -

Municipality: els Hostalets de Pierola

Age: 12.47Ma.

Correlation to GPTS: C5Ar.1r

Correlation to local biostratigraphy: *Megacricetodon crusafonti* + *Democricetodon larteti* Concurrent Range Subzone

Correlation to the MN zonation: MN6

Faunal list: *Spermophilinus bredai*, *Albanensia quiricensis*, *Myoglis* cf. *meini*, *Muscardinus* aff. *sansaniensis*, *Muscardinus* cf. *hispanicus*, *Bransatoglis astaracensis*, *Myomimus* cf. *dehmi*, *Eumyarion leemanni*, *Hispanomys decedens*, *Megacricetodon* cf. *minor*, *Democricetodon* cf. *brevis*, *Democricetodon larteti*.

Taxonomic references: -

Remarks: -

#### Abocador de Can Mata / Cel·la 1-A4

Acronym: ACM/C1-A4

Locality synonyms: -

Municipality: els Hostalets de Pierola

Age: 12.15Ma.

Correlation to GPTS: C5An.1n

Correlation to local biostratigraphy: *Megacricetodon crusafonti* + *Democricetodon crusafonti* Interval Subzone

Correlation to the MN zonation: MN7+8

Faunal list: *Spermophilinus bredai*, *Heteroxerus* cf. *rubricati*, *Miopetaurista* cf. *neogrivensis*, *Muscardinus thaleri*, *Eumyarion leemanni*, *Hispanomys decedens*, *Megacricetodon minor*, *Democricetodon* cf. *brevis*, *Democricetodon larteti*.

Taxonomic references: -

Remarks: -

#### Abocador de Can Mata / Cel·la 1-D1

Acronym: ACM/C1-D1

Locality synonyms: -

Municipality: els Hostalets de Pierola

Age: 12.45Ma.

Correlation to GPTS: C5An.2n

Correlation to local biostratigraphy: *Megacricetodon crusafonti* + *Democricetodon larteti* Concurrent Range Subzone

Correlation to the MN zonation: MN6

Faunal list: *Spermophilinus bredai*, *Glirudinus undosus*, *Muscardinus thaleri*, *Bransatoglis astaracensis*, *Microdyromys complicatus*, *Eumyarion leemanni*, *Hispanomys decedens*, *Megacricetodon crusafonti*, *Democricetodon* cf. *brevis*, *Democricetodon larteti*.

Taxonomic references: -

Remarks: -

#### Abocador de Can Mata / Cel·la 1-E9

Acronym: ACM/C1-E9

Locality synonyms: -

Municipality: els Hostalets de Pierola

Age: 12.30Ma.

Correlation to GPTS: C5An.2n

Correlation to local biostratigraphy: *Megacricetodon crusafonti* – *Democricetodon crusafonti* Interval Subzone

Correlation to the MN zonation: MN7+8

Faunal list: *Hispanomys* cf. *decedens*, *Megacricetodon ibericus*, *Megacricetodon* cf. *minor*, *Democricetodon* cf. *larteti*.

Taxonomic references: -

Remarks: -

#### Abocador de Can Mata / Cel·la 3-A6

Acronym: ACM/C3-A6

Locality synonyms: -

Municipality: els Hostalets de Pierola

Age: 11.95Ma.

Correlation to GPTS: C5r.3r

Correlation to local biostratigraphy: *Megacricetodon crusafonti* – *Democricetodon crusafonti* Interval Subzone

Correlation to the MN zonation: MN7+8

Faunal list: *Spermophilinus bredai*, *Heteroxerus grivensis*, *Muscardinus hispanicus*, *Microdyromys complicatus*, *Hispanomys decedens*, *Megacricetodon* cf. *ibericus*, *Megacricetodon minor*, *Democricetodon larteti*.

Taxonomic references: -

Remarks: -

#### Abocador de Can Mata / Cel·la 4-A1

Acronym: ACM/C4-A1

Locality synonyms: -

Municipality: els Hostalets de Pierola

Age: 11.72Ma.

Correlation to GPTS: C5r.3r

Correlation to local biostratigraphy: *Democricetodon crusafonti* – *Hippotherium* Interval Subzone

Correlation to the MN zonation: MN7+8

Faunal list: *Spermophilinus bredai*, cf. *Tamias* sp., *Albanensia quiricensis*, *Miopetaurista* cf. *neogrivensis*, *Neopetes* cf. *hoeckarum*, *Myoglis meini*, *Muscardinus* aff. *sansaniensis*, *Muscardinus hispanicus*, *Muscardinus thaleri*, *Bransatoglis astaracensis*, *Microdyromys complicatus*, *Eomyops* cf. *oppligeri*, *Keramidomys* cf. *carpathicus*, *Eumyarion leemanni*, *Hispanomys* aff. *aguirrei*, *Megacricetodon minor*, *Democricetodon* sp. (small size), *Democricetodon* cf.

*crusafonti*, *Anomalomys gaudryi*.

Taxonomic references: -

Remarks: -

#### Abocador de Can Mata / Cel-la 5-D1

Acronym: ACM/C5-D1

Locality synonyms: -

Municipality: els Hostalets de Pierola

Age: 11.64Ma.

Correlation to GPTS: C5r.2n

Correlation to local biostratigraphy: *Democricetodon crusafonti* – *Hippotherium* Interval Subzone [reference locality]

Correlation to the MN zonation: MN7+8

Faunal list: *Spermophilinus bredai*, *Albanensia quiricensis*, *Miopetaurista neogrivensis*, cf. *Neopetes* sp., *Muscardinus* aff. *sansaniensis*, *Muscardinus hispanicus*, *Bransatoglis astaracensis*, *Microdyromys complicatus*, *Paraglrulus werenfelsi*, *Myomimus dehmi*, *Eumyarion leemanni*, *Hispanomys* aff. *aguirrei*, *Megacricetodon* cf. *ibericus*, *Megacricetodon minor*, *Democricetodon brevis*, *Democricetodon crusafonti*, *Anomalomys gaudryi*.

Taxonomic references: -

Remarks: -

#### Abocador de Can Mata / Cel-la 8-A1

Acronym: ACM/C8-A1

Locality synonyms: -

Municipality: els Hostalets de Pierola

Age: 11.65Ma.

Correlation to GPTS: C5r.3r

Correlation to local biostratigraphy: *Democricetodon crusafonti* – *Hippotherium* Interval Subzone

Correlation to the MN zonation: MN7+8

Faunal list: *Spermophilinus bredai*, *Albanensia* cf. *quiricensis*, *Miopetaurista neogrivensis*, *Myoglis meini*, *Muscardinus hispanicus*, *Eomyops* cf. *oppligeri*, *Eumyarion leemanni*, *Hispanomys* aff. *aguirrei*, *Democricetodon* cf. *nemoralis*, *Democricetodon crusafonti*, *Anomalomys* cf. *gaudryi*.

Taxonomic references: -

Remarks: -

#### Abocador de Can Mata / Cel-la 8-B1

Acronym: ACM/C8-B1

Locality synonyms: -

Municipality: els Hostalets de Pierola

Age: 11.59Ma.

Correlation to GPTS: C5r.2r

Correlation to local biostratigraphy: *Democricetodon crusafonti* – *Hippotherium* Interval Subzone

Correlation to the MN zonation: MN7+8

Faunal list: *Spermophilinus bredai*, *Myomimus dehmi*,

*Hispanomys lavocati*, *Megacricetodon* cf. *minutus*,

*Democricetodon* cf. *brevis*, *Democricetodon crusafonti*.

Taxonomic references: -

Remarks: -

#### Abocador de Can Mata / Cel-la 8-Bx

Acronym: ACM/C8-Bx

Locality synonyms: -

Municipality: els Hostalets de Pierola

Age: 11.63Ma.

Correlation to GPTS: C5r.2n

Correlation to local biostratigraphy: *Democricetodon crusafonti* – *Hippotherium* Interval Subzone

Correlation to the MN zonation: MN7+8

Faunal list: *Spermophilinus bredai*, cf. *Tamias* sp., *Microdyromys* cf. *koenigswaldi*, cf. *Eliomys* sp., *Myomimus dehmi*, *Eumyarion leemanni*, *Hispanomys* aff. *aguirrei*, *Megacricetodon* cf. *ibericus*, *Megacricetodon minutus*, *Democricetodon crusafonti*, *Anomalomys gaudryi*.

Taxonomic references: -

Remarks: -

#### Abocador de Can Mata / Cel-la 9-A1

Acronym: ACM/C9-A1

Locality synonyms: -

Municipality: els Hostalets de Pierola

Age: 12.46Ma.

Correlation to GPTS: C5An.2n

Correlation to local biostratigraphy: *Megacricetodon crusafonti* + *Democricetodon larteti* Concurrent Range Subzone [reference locality]

Correlation to the MN zonation: MN6

Faunal list: *Spermophilinus bredai*, *Albanensia* cf. *quiricensis*, cf. *Forsythia* sp., *Myoglis meini*, *Muscardinus* aff. *sansaniensis*, *Muscardinus thaleri*, *Bransatoglis astaracensis*, *Microdyromys complicatus*, *Paraglrulus werenfelsi*, *Eumyarion leemanni*, *Hispanomys decedens*, *Megacricetodon crusafonti*, *Megacricetodon minor*, *Democricetodon brevis*, *Democricetodon larteti*.

Taxonomic references: -

Remarks: -

#### Autopista de Rubí-Terrassa 3B

Acronym: RT3B

Locality synonyms: -

Municipality: Sant Quirze del Vallès

Age: 10.02Ma.

Correlation to GPTS: C5n.2n

Correlation to local biostratigraphy: *Cricetulodon hartenbergeri* Range Subzone

Correlation to the MN zonation: MN9

Faunal list: *Spermophilinus bredai*, *Euroxenomys minutus*, *Chalicomys jaegeri*, *Eumyarion leemanni*, *Megacricetodon* cf. *minutus*, *Cricetulodon hartenbergeri*, *Anomalomys gaillardi*.

Taxonomic references: -

Remarks: -

#### Autopista de Rubí-Terrassa 6E

Acronym: RT6E

Locality synonyms: -

Municipality: Rubí

Age: 10.09Ma

Correlation to GPTS: C5n.2n

Correlation to local biostratigraphy: *Cricetulodon hartenbergeri* Range Subzone

Correlation to the MN zonation: MN9

Faunal list: *Spermophilinus bredai*, *Muscardinus* aff. *sansaniensis*, *Myomimus dehmi*, *Eumyarion leemanni*, *Hispanomys* cf. *thaleri*, *Cricetulodon* cf. *hartenbergeri*.

Taxonomic references: -

Remarks: -

#### Autopista de Rubí-Terrassa 7C

Acronym: RT7C

Locality synonyms: -

Municipality: Terrassa

Age: 9.73Ma

Correlation to GPTS: C4Ar.3r

Correlation to local biostratigraphy: *Cricetulodon sabadellensis* + *Progonomys hispanicus* Concurrent Range Subzone

Correlation to the MN zonation: MN10

Faunal list: *Spermophilinus bredai*, *Albanensia* aff. *grimmi*, *Muscardinus hispanicus*, *Paraglrulus werenfelsi*, *Hispanomys* cf. *thaleri*, *Rotundomys freirensis*, *Progonomys hispanicus*.

Taxonomic references: -

Remarks: -

#### Autopista de Rubí-Terrassa 8

Acronym: RT8

Locality synonyms: -

Municipality: Terrassa

Age: 10.34Ma

Correlation to GPTS: C5n.2n

Correlation to local biostratigraphy: *Cricetulodon hartenbergeri* Range Subzone

Correlation to the MN zonation: MN9

Faunal list: *Muscardinus hispanicus*, *Eumyarion leemanni*, *Megacricetodon* cf. *minutus*, *Cricetulodon* cf. *hartenbergeri*.

Taxonomic references: -

Remarks: -

#### Autopista de Rubí-Terrassa 10

Acronym: RT10

Locality synonyms: -

Municipality: Terrassa

Age: 9.53Ma

Correlation to GPTS: C4Ar.2r

Correlation to local biostratigraphy: *Rotundomys montisrotundi* Lineage Subzone

Correlation to the MN zonation: MN10

Faunal list: *Rotundomys* cf. *montisrotundi*.

Taxonomic references: -

Remarks: -

#### Autopista de Rubí-Terrassa 11

Acronym: RT11

Locality synonyms: -

Municipality: Terrassa?

Age: -

Correlation to GPTS: -

Correlation to local biostratigraphy: *Cricetulodon sabadellensis* + *Progonomys hispanicus* Concurrent Range Subzone

Correlation to the MN zonation: MN10

Faunal list: *Spermophilinus bredai*, *Myoglis meini*, *Muscardinus hispanicus*, *Microdyromys complicatus*, *Glirulus lissiensis*, *Hispanomys thaleri*, *Rotundomys freirensis*, *Progonomys hispanicus*.

Taxonomic references: -

Remarks: The exact location of this site is unknown.

#### Autopista de Rubí-Terrassa 12

Acronym: RT12

Locality synonyms: -

Municipality: Terrassa

Age: 9.73Ma

Correlation to GPTS: C4Ar.3r

Correlation to local biostratigraphy: *Cricetulodon sabadellensis* + *Progonomys hispanicus* Concurrent Range Subzone

Correlation to the MN zonation: MN10

Faunal list: *Muscardinus hispanicus*, *Rotundomys* cf. *freirensis*.

Taxonomic references: -

Remarks: -

#### Autopista de Rubí-Terrassa km 11

Acronym: RK11

Locality synonyms: -

Municipality: Terrassa

Age: 10.98Ma

Correlation to GPTS: C5n.2n

Correlation to local biostratigraphy: *Hippotherium* – *Cricetulodon hartenbergeri* Interval Subzone  
 Correlation to the MN zonation: MN9  
 Faunal list: *Myomimus dehmi*, *Hispanomys* cf. *dispectus*, *Megacricetodon* cf. *ibericus*.  
 Taxonomic references: -  
 Remarks: -

#### Autovia Orbital de Barcelona, tram Olesa de Montserrat-Viladecavalls /Sector 5 locality C

Acronym: B40/S5C  
 Locality synonyms: -  
 Municipality: Viladecavalls  
 Age: -  
 Correlation to GPTS: -  
 Correlation to local biostratigraphy: *Cricetulodon hartenbergeri* Range Subzone  
 Correlation to the MN zonation: MN9  
 Faunal list: *Spermophilinus bredai*, *Myoglis* cf. *meini*, *Muscardinus hispanicus*, *Myomimus dehmi*, *Hispanomys thaleri*, *Megacricetodon* cf. *minutus*, *Cricetulodon hartenbergeri*.  
 Taxonomic references: Pineda-Muñoz *et al.* (2011).  
 Remarks: -

#### Cal Turu 4A

Acronym: CT4A  
 Locality synonyms: -  
 Municipality: Viladecavalls  
 Age: 9.11Ma  
 Correlation to GPTS: C4Ar.1r  
 Correlation to local biostratigraphy: *Rotundomys bressanus* Lineage Subzone  
 Correlation to the MN zonation: MN10  
 Faunal list: *Rotundomys bressanus*.  
 Taxonomic references: -  
 Remarks: -

#### Camí de Can Tarumbot 2

Acronym: CCT2  
 Locality synonyms: -  
 Municipality: Viladecavalls  
 Age: 9.64Ma  
 Correlation to GPTS: C4Ar.2r  
 Correlation to local biostratigraphy: *Rotundomys montisrotundi* Lineage Subzone [reference locality]  
 Correlation to the MN zonation: MN10  
 Faunal list: *Hispanomys* cf. *thaleri*, *Rotundomys montisrotundi*, *Progonomys hispanicus*.  
 Taxonomic references: -  
 Remarks: -

#### Camí de Can Tarumbot 3

Acronym: CCT3  
 Locality synonyms: -  
 Municipality: Viladecavalls  
 Age: 9.59Ma  
 Correlation to GPTS: C4Ar.2r  
 Correlation to local biostratigraphy: *Rotundomys montisrotundi* Lineage Subzone  
 Correlation to the MN zonation: MN10  
 Faunal list: *Rotundomys montisrotundi*, *Progonomys hispanicus*.  
 Taxonomic references: -  
 Remarks: -

#### Can Casablanca

Acronym: CSB  
 Locality synonyms: Can Casablanques  
 Municipality: Sant Quirze del Vallès  
 Age: -  
 Correlation to GPTS: -  
 Correlation to local biostratigraphy: *Rotundomys montisrotundi* Lineage Subzone  
 Correlation to the MN zonation: MN10  
 Faunal list: *Myoglis meini*, *Hispanomys thaleri*, *Rotundomys montisrotundi*, *Anomalomys* cf. *gaillardi*, *Progonomys* cf. *hispanicus*.  
 Taxonomic references: Agustí (1981a).  
 Remarks: -

#### Can Cruset

Acronym: CRU  
 Municipality: Torroelles de Foix  
 Locality synonyms: -  
 Age: -  
 Correlation to GPTS: -  
 Correlation to local biostratigraphy: *Rotundomys bressanus* Lineage Subzone  
 Correlation to the MN zonation: MN10  
 Faunal list: *Muscardinus* cf. *heintzi*, *Myomimus* cf. *dehmi*, *Rotundomys bressanus*, *Neocricetodon* cf. *ambarrensis*, *Progonomys hispanicus*, *Huerzelerimys minor*.  
 Taxonomic references: -  
 Remarks: This site is the only late Vallesian site known from the Penedès sector of the Basin and is located near the Vallès-Penedès master fault.

#### Can Feu 2

Acronym: CFE2  
 Municipality: Sant Quirze del Vallès  
 Locality synonyms: -

Age: -

Correlation to GPTS: -

Correlation to local biostratigraphy: *Cricetulodon hartenbergeri* – *Progonomys hispanicus* Interval Subzone

Correlation to the MN zonation: MN9

Faunal list: *Muscardinus hispanicus*, *Hispanomys* cf. *thaleri*, *Democricetodon* cf. *nemoralis*, *Cricetulodon sabadellensis*.

Taxonomic references: Casanovas-Vilar *et al.* (2012).

Remarks: -

### Can Llobateres 1

Acronym: CL1

Locality synonyms: Can Llobateres (classical site)

Municipality: Sabadell

Age: 9.76Ma

Correlation to GPTS: C4Ar.3r

Correlation to local biostratigraphy: *Cricetulodon hartenbergeri* – *Progonomys hispanicus* Interval Subzone [reference locality]

Correlation to the MN zonation: MN9 [reference locality]

Faunal list: *Spermophilinus bredai*, *Heteroxerus rubricati*, *Albanensia* aff. *grimmi*, *Miopetaurista neogrivensis*, *Miopetaurista crusafonti*, *Blackia miocaenica*, cf. *Pliopetaurista* sp., *Euroxenomys minutus*, *Chalicomys jaegeri*, *Glirudinus* cf. *undosus*, *Myoglis meini*, *Muscardinus vallesiensis*, *Muscardinus hispanicus*, *Bransatoglis astaracensis*, *Paraglrulus werenfelsi*, *Glirulus lissiensis*, *Eomyops catalaunicus*, *Keramidomys pertesunatoi*, *Eumyarion leemanni*, *Hispanomys thaleri*, *Megacricetodon* cf. *minutus*, *Democricetodon* cf. *nemoralis*, *Cricetulodon sabadellensis*, *Anomalomys gaillardi*.

Taxonomic references: Agustí (1981a); Aldana Carrasco (1991, 1992a, b, c); Casanovas-Vilar *et al.* (2015); Hartenberger (1965, 1966); Hartenberger and Thaler (1963); Mein (1970).

Remarks: The classic collection of this site includes a single molar of an undetermined murid (Hartenberger and Thaler, 1963; Michaux, 1971; Mein *et al.*, 1993) and two molars of *Rotundomys* cf. *montisrotundi* (Agustí, 1981a). No further material of these taxa has been found among the thousands of rodent specimens recovered after successive field campaigns at Can Llobateres 1 during the late 1980s, early 1990s and from 2010 on. Therefore, we consider that these specimens from the old collections were recovered from different levels of the Can Llobateres section or even from different site of the basin. Accordingly, we have excluded them from the updated faunal list presented here.

### Can Llobateres 2

Acronym: CL2

Locality synonyms: -

Municipality: Sabadell

Age: 9.62Ma

Correlation to GPTS: C4Ar.2r

Correlation to local biostratigraphy: *Cricetulodon sabadellensis* + *Progonomys hispanicus* Concurrent Range Subzone

Correlation to the MN zonation: MN10

Faunal list: *Spermophilinus bredai*, *Heteroxerus* cf. *grivensis*, *Muscardinus hispanicus*, *Paraglrulus werenfelsi*, *Hispanomys* cf. *thaleri*, *Cricetulodon sabadellensis*, *Progonomys hispanicus*.

Taxonomic references: Mein *et al.* (1993).

Remarks: Crusafont Pairó (1964) used the name 'Can Llobateres 2' for a small outcrop placed near the spring of Can Llobateres, on the side of the road opposite to Can Llobateres 1 and stratigraphically below it. Moyà-Solà and Köhler (1993, 1996) used the same name for a site closer to Can Llobateres 1 and located in the upper levels of the same section, which delivered a partial skeleton with cranium of the hominoid *Hispanopithecus laietanus*. The faunal list given here refers to the latter site and not to the one reported by Crusafont Pairó (1964) and includes the samples CL2C and CL2D. These samples presumably belong to very close stratigraphical levels.

### Can Missert

Acronym: CMI

Locality synonyms: -

Municipality: Terrassa

Age: -

Correlation to GPTS: -

Correlation to local biostratigraphy: *Hippotherium* – *Cricetulodon hartenbergeri* Interval Subzone

Correlation to the MN zonation: MN9

Faunal list: *Spermophilinus bredai*, *Muscardinus* aff. *sansaniensis*, *Muscardinus hispanicus*, *Paraglrulus werenfelsi*, *Eumyarion leemanni*, *Hispanomys daamsi*, *Megacricetodon* cf. *ibericus*, *Megacricetodon* cf. *minutus*, *Democricetodon nemoralis*, *Democricetodon* cf. *crusafonti*.

Taxonomic references: Agustí *et al.* (2005); Aldana Carrasco (1991, 1992a).

Remarks: This locality was previously correlated to the late Aragonian (MN 7+8; Agustí *et al.*, 1985, 1997, 2005). The correlation was based on scarce *Hippotherium* remains found in the nearby site of Can Poal, which is stratigraphically below Can Missert (Robles *et al.*, 2011).

**Can Pallars de Llobateres**

Acronym: CPL  
 Locality synonyms: -  
 Municipality: Sant Quirze del Vallès  
 Age: -  
 Correlation to GPTS: -  
 Correlation to local biostratigraphy: *Cricetulodon hartenbergeri* – *Progonomys hispanicus* Interval Subzone  
 Correlation to the MN zonation: MN9  
 Faunal list: *Spermophilinus* cf. *bredai*, *Heteroxerus* cf. *grivensis*, *Keramidomys pertesunatoi*, *Eumyarion leemanni*, *Hispanomys thaleri*, *Democricetodon* cf. *nemoralis*, *Cricetulodon sabadellensis*.  
 Taxonomic references: -  
 Remarks: -

**Can Poncic 1**

Acronym: CP1  
 Locality synonyms: Can Poncic, Can Ponsic, Can Ponsich  
 Municipality: Sant Quirze del Vallès  
 Age: -  
 Correlation to GPTS: -  
 Correlation to local biostratigraphy: *Cricetulodon hartenbergeri* Range Subzone [reference locality]  
 Correlation to the MN zonation: MN9  
 Faunal list: *Spermophilinus bredai*, *Heteroxerus rubricati*, *Albanensia* aff. *grimmi*, *Miopetaurista crusafonti*, *Euroxenomys minutus*, *Chalicomys jaegeri*, *Myoglis meini*, *Muscardinus hispanicus*, *Myomimus dehmi*, *Eomyops* cf. *catalaunicus*, *Hispanomys thaleri*, *Megacricetodon minutus*, *Cricetulodon hartenbergeri*.  
 Taxonomic references: Agustí (1981a, b); Aldana Carrasco (1991, 1992a, b, c); Hartenberger and Crusafont (1979).  
 Remarks: Golpe Posse (1974) introduced a second site near Can Poncic 1: Can Poncic 2. This site is approximately 6-10m below Can Poncic 1 in stratigraphic series and did not delivered *Hippotherium* or any giraffid remains, that according to Golpe Posse (1974) would indicate a late Aragonian age. However, given the short stratigraphic distance this correlation seems unlikely, and Can Poncic 2 would also have a Vallesian age. Unfortunately, the exact location of both sites is unknown, and detailed stratigraphical information is lacking.

**Castell de Barberà**

Acronym: CB  
 Locality synonyms: -

Municipality: Barberà del Vallès

Age: -  
 Correlation to GPTS: -  
 Correlation to local biostratigraphy: *Hippotherium* – *Cricetulodon hartenbergeri* Interval Subzone  
 Correlation to the MN zonation: MN9  
 Faunal list: *Spermophilinus bredai*, *Albanensia quiricensis*, *Miopetaurista neogrivensis*, *Euroxenomys minutus*, *Chalicomys jaegeri*, *Glirudinus undosus*, *Myoglis meini*, *Muscardinus* aff. *sansaniensis*, *Muscardinus hispanicus*, *Bransatoglis astaracensis*, *Paraglrulus werenfelsi*, *Myomimus dehmi*, *Eumyarion leemanni*, *Hispanomys daamsi*, *Megacricetodon minutus*, *Democricetodon nemoralis*  
 Taxonomic references: Aguilar *et al.* (1979); Agustí (1981a, b); Aldana Carrasco (1991, 1992a, b, c).  
 Remarks: Despite some controversy (De Bruijn *et al.*, 1992), this locality had been previously correlated to the late Aragonian (MN 7+8; Agustí *et al.*, 1985, 1997; Casanovas-Vilar *et al.*, 2011). This correlation was mostly based on scarce *Hippotherium* remains found few meters above the main fossiliferous horizon (Crusafont-Pairó and Golpe-Posse, 1974; Rotgers and Alba, 2011; see Alba and Moyà-Solà, 2012, for a more detailed discussion).

**Ceràmiques Viladecavalls**

Acronym: CV  
 Locality synonyms: -  
 Municipality: Viladecavalls  
 Age: 9.36Ma  
 Correlation to GPTS: C4Ar.1n  
 Correlation to local biostratigraphy: *Rotundomys montisrotundi* Lineage Subzone  
 Correlation to the MN zonation: MN10  
 Faunal list: *Hispanomys* cf. *thaleri*.  
 Taxonomic references: Agustí (1981a).  
 Remarks: The exact provenance of the material *Progonomys hispanicus* from Viladecavalls described by Schaub (1947b) is unknown, although it is generally assigned to this site.

**Creu Conill 20**

Acronym: CCN20  
 Locality synonyms: -  
 Municipality: Terrassa  
 Age: 11.18Ma  
 Correlation to GPTS: C5r.1n  
 Correlation to local biostratigraphy: *Hippotherium* – *Cricetulodon hartenbergeri* Interval Subzone [reference locality]  
 Correlation to the MN zonation: MN9  
 Faunal list: *Euroxenomys minutus*, *Muscardinus hispanicus*, *Hispanomys dispectus*, *Megacricetodon ibericus*.

Taxonomic references: Casanovas-Vilar et al. (2006).  
 Remarks: The large mammals have not been described, but a faunal list is given in Agustí et al. (1997) and Casanovas-Vilar et al. (2006).

#### Creu Conill 22

Acronym: CCN22  
 Locality synonyms: -  
 Municipality: Terrassa  
 Age: 11.13Ma  
 Correlation to GPTS: C5r.1r  
 Correlation to local biostratigraphy: *Hippotherium* – *Cricetulodon hartenbergeri* Interval Subzone  
 Correlation to the MN zonation: MN9  
 Faunal list: *Spermophilinus bredai*, *Euroxenomys minutus*, *Myomimus dehmi*, *Hispanomys dispectus*, *Megacricetodon ibericus*, *Megacricetodon* cf. *minutus*, *Democricetodon* cf. *nemoralis*.  
 Taxonomic references: Casanovas-Vilar et al. (2006).  
 Remarks: See corrections on the rodent faunal list in Casanovas-Vilar et al. (2007, p.76).

#### Ecoparc de Can Mata / Variant de la Carretera de l'Ecoparc B2

Acronym: ECM/VCE-B2  
 Locality synonyms: -  
 Municipality: els Hostalets de Pierola  
 Age: 10.60Ma  
 Correlation to GPTS: C5n.2n  
 Correlation to local biostratigraphy: *Hippotherium* – *Cricetulodon hartenbergeri* Interval Subzone  
 Correlation to the MN zonation: MN9  
 Faunal list: *Spermophilinus bredai*, *Muscardinus hispanicus*, *Myomimus dehmi*, *Hispanomys aragonensis*, *Megacricetodon* cf. *ibericus*, *Democricetodon* cf. *nemoralis*, *Democricetodon* cf. *crusafonti*.  
 Taxonomic references: -  
 Remarks: -

#### Ecoparc de Can Mata / Variant de la Carretera de l'Ecoparc C1

Acronym: ECM/VCE-C1  
 Locality synonyms: -  
 Municipality: els Hostalets de Pierola  
 Age: 10.60Ma  
 Correlation to GPTS: C5n.2n  
 Correlation to local biostratigraphy: *Hippotherium* – *Cricetulodon hartenbergeri* Interval Subzone  
 Correlation to the MN zonation: MN9  
 Faunal list: *Spermophilinus bredai*, *Heteroxerus rubricati*, *Muscardinus hispanicus*, cf. *Eliomys* sp., *Myomimus dehmi*, *Hispanomys* cf. *aragonensis*, *Megacricetodon minutus*, *Democricetodon nemoralis*.

Taxonomic references: -  
 Remarks: -

#### Estació Depuradora d'Aigües Residuals Sabadell – Riu Ripoll 2

Acronym: EDAR2  
 Locality synonyms: -  
 Municipality: Sabadell  
 Age: -  
 Correlation to GPTS: -  
 Correlation to local biostratigraphy: *Cricetulodon hartenbergeri* Range Subzone  
 Correlation to the MN zonation: MN9  
 Faunal list: *Glirudinus undosus*, *Myoglis meini*, *Paraglrulus werenfelsi*, *Eomyops catalaunicus*, *Eumyarion leemanni*, *Hispanomys* cf. *thaleri*, *Cricetulodon hartenbergeri*, *Anomalomys* cf. *gaillardi*.  
 Taxonomic references: -  
 Remarks: -

#### Estació Depuradora d'Aigües Residuals Sabadell – Riu Ripoll 6

Acronym: EDAR6  
 Locality synonyms: -  
 Municipality: Sabadell  
 Age: -  
 Correlation to GPTS: -  
 Correlation to local biostratigraphy: *Cricetulodon hartenbergeri* Range Subzone  
 Correlation to the MN zonation: MN9  
 Faunal list: *Spermophilinus bredai*, *Chalicomys jaegeri*, *Paraglrulus werenfelsi*, *Cricetulodon hartenbergeri*.  
 Taxonomic references: -  
 Remarks: -

#### Hostalets Superior

Acronym: HS  
 Locality synonyms: see remarks.  
 Municipality: els Hostalets de Pierola  
 Age: -  
 Correlation to GPTS: -  
 Correlation to local biostratigraphy: *Hippotherium* – *Cricetulodon hartenbergeri* Interval Subzone  
 Correlation to the MN zonation: MN9  
 Faunal list: *Spermophilinus bredai*, *Heteroxerus rubricati*, *Heteroxerus* cf. *grivensis*, *Chalicomys* cf. *jaegeri*, *Myomimus dehmi*, *Eumyarion* cf. *leemanni*, *Hispanomys lavocati*, *Hispanomys dispectus*, *Megacricetodon ibericus*.  
 Taxonomic references: Agustí (1977a, 1980a, b, 1981a, b); Agustí and Gibert (1982a); Aldana Carrasco (1991, 1992a); Bataller Calatayud (1938); Hartenberger

(1967); Schaub (1944, 1947a).

Remarks: The classical collections of small vertebrates labeled as “Hostalets Superior” include material from different sites from the upper (Vallesian) levels of els Hostalets de Pierola. As far as the micromammals are concerned, these comprise Can Mata 3, “bloc de marga”, Can Flaquer and Barranc del Mastodont. Unfortunately, the provenance of the material is not always known, since most rodent specimens are just labeled as “Hostalets Superior”. Most of the specimens for which the locality is known come from “bloc de marga” (“the marl block”; also mentioned in the literature as “bloc de marne”, its French translation), a fallen marl block extremely rich in microvertebrate remains that is already mentioned by Schaub (1947a), which apparently came from Can Flaquer (Villalta in Agustí, 1981a: 22; Agustí et al., 1985). In accordance, most of the small vertebrate collections labeled as “Hostalets Superior” would belong to this site.

#### La Tarumba 1

Acronym: LTR1

Locality synonyms: -

Municipality: Viladecavalls

Age: 9.57Ma

Correlation to GPTS: C4Ar.2r

Correlation to local biostratigraphy: *Rotundomys montisrotundi* Lineage Subzone

Correlation to the MN zonation: MN10

Faunal list: *Spermophilinus bredai*, *Rotundomys montisrotundi*.

Taxonomic references: -

Remarks: -

#### Ronda Oest de Sabadell A1

Acronym: ROS-A1

Locality synonyms: -

Municipality: Sabadell

Age: -

Correlation to GPTS: -

Correlation to local biostratigraphy: *Huerzelerimys vireti* Range Zone (zone K of the Teruel Basin)

Correlation to the MN zonation: MN11

Faunal list: *Spermophilinus bredai*, *Hispanomys cf. peralensis*, *Neocricetodon fahlbuschi*, *Huerzelerimys vireti*.

Taxonomic references: -

Remarks: -

#### Ronda Oest de Sabadell D6

Acronym: ROS-D6

Locality synonyms: -

Municipality: Sabadell

Age: -

Correlation to GPTS: -

Correlation to local biostratigraphy: *Rotundomys bressanus* Lineage Subzone?

Correlation to the MN zonation: MN10

Faunal list: *Spermophilinus bredai*, *Muscardinus heintzi*, *Paraglrulus werenfelsi*, *Glirulus* aff. *lissiensis*, *Myomimus dehmi*, *Eomyops catalaunicus*, *Keramidomys mohleri*, *Rotundomys* cf. *montisrotundi*, *Neocricetodon ambarrensis*, *Progonomys cathalai*, *Parapodemus* n. sp.

Taxonomic references: -

Remarks: The rodent fauna from ROS-D6 is significantly different from that of other late Vallesian sites of the basin and includes a number of taxa that are only known from this site: *Keramidomys mohleri*, *Progonomys cathalai* and *Parapodemus* sp. interestingly, the fauna is dominated by murids. The genus *Rotundomys*, the usual major component, is so rare that even species identification is uncertain given that only two specimens have been recovered in a sample of 290 rodent cheek teeth. Finally, some rare taxa (*Muscardinus heintzi*, *Neocricetodon ambarrensis*, *Eomyops catalaunicus*) are relatively abundant in ROS-D6. The correlation to the *R. bressanus* subzone is uncertain because no remains of this taxon have been recovered, so that the locality may well belong to the previous *R. montisrotundi* subzone. However, the murid fauna is more diverse than in the *R. montisrotundi* subzone and the rodent assemblage includes *M. heintzi* and *N. ambarrensis*, which are only recorded in the *R. bressanus* subzone. Therefore, we favor this younger correlation.

#### Santiga

Acronym: SA

Locality synonyms: Santiga Provava

Municipality: Barberà del Vallès

Age: -

Correlation to GPTS: -

Correlation to local biostratigraphy: *Cricetulodon hartenbergeri* Range Subzone

Correlation to the MN zonation: MN9

Faunal list: *Spermophilinus* cf. *bredai*, *Euroxenomys minutus*, *Chalicomys jaegeri*, *Muscardinus hispanicus*, *Eomyops catalaunicus*, *Eumyarion leemanni*, *Cricetulodon hartenbergeri*.

Taxonomic references: Agustí (1981a); Aldana Carrasco (1991, 1992b).

Remarks: -

#### Sant Quirze A

Acronym: SQA

Locality synonyms: -

Municipality: Sant Quirze del Vallès

Age: -

Correlation to GPTS: -

Correlation to local biostratigraphy: *Democricetodon crusafonti* – *Hippotherium* Interval Subzone

Correlation to the MN zonation: MN7+8

Faunal list: *Spermophilinus bredai*, *Miopetaurista* cf. *crusafonti*, *Euroxenomys minutus*, *Chalicomys catalaunicus*, *Glirudinus undosus*, *Myoglis meini*, *Muscardinus* aff. *sansaniensis*, *Muscardinus hispanicus*, *Bransatoglis astaracensis*, *Microdyromys complicatus*, *Paraglrulus werenfelsi*, *Myomimus dehmi*, *Eomyops catalaunicus*, *Eumyarion leemanni*, *Hispanomys lavocati*, *Megacricetodon* cf. *ibericus*, *Megacricetodon minutus*, *Democricetodon brevis*, *Democricetodon crusafonti*.

Taxonomic references: -

Remarks: This locality is close but not equivalent to the classical site of Sant Quirze (also known as Trinxera del Ferrocarril - Sant Quirze). Descriptions of the rodent fauna of the classical site can be found in Schaub (1944, 1947a), Crusafont Pairó *et al.* (1948), Freudenthal (1966), Villalta Comella (1950), Mein (1970), Agustí (1977a, b, 1978, 1980a, 1981a, b) and Aldana Carrasco (1991, 1992a, 1992b).

#### Torrent de Febulines

Acronym: TF

Locality synonyms: Terrassa (pro parte, see remarks)

Municipality: Terrassa

Age: 9.10Ma

Correlation to GPTS: C4Ar.1r

Correlation to local biostratigraphy: *Rotundomys bressanus* Lineage Subzone

Correlation to the MN zonation: MN10

Faunal list: *Spermophilinus bredai*, *Chalicomys adroveri*, *Hispanomys thaleri*, *Rotundomys bressanus*, *Anomalomys gaillardi*, *Progonomys hispanicus*, *Progonomys woelferi*, Muridae sp. 3.

Taxonomic references: Agustí (1981a, b); Agustí and Gibert (1982b); Aldana Carrasco (1991, 1992a, b); Casanovas-Vilar and Alba (2011).

Remarks: This site is placed in the Can Jofresa section near Terrassa. In the NOW database (Fortelius, 2015) the site known as ‘Terrassa’ includes a composite faunal list of the various sites of the Can Jofresa section. Such list includes the faunas of Trinxera Nord Autopista, Trinxera Sud Autopista and Torrent de Febulines, among other sites. Such confusion probably stems from Agustí *et al.* (1984), who published a composite faunal list of these sites under the name ‘Terrassa’. Later on, Morales *et al.* (1999) followed this study and gave a composite faunal list for the macromammals. ‘Terrassa’ is not a single locality, but includes around ten different

sites from the Can Jofresa section, and therefore mixes material ranging from 9.3 to 9.1 Ma.

#### Torrent de Febulines 3

Acronym: TF3

Locality synonyms: Terrassa (pro parte, see remarks)

Municipality: Terrassa

Age: 9.10Ma

Correlation to GPTS: C4Ar.1r

Correlation to local biostratigraphy: *Rotundomys bressanus* Lineage Subzone

Correlation to the MN zonation: MN10

Faunal list: *Spermophilinus bredai*, *Myoglis meini*, *Muscardinus heintzi*, *Paraglrulus werenfelsi*, *Eomyops catalaunicus*, *Hispanomys thaleri*, *Rotundomys bressanus*, *Anomalomys gaillardi*, *Progonomys hispanicus*, *Progonomys woelferi*.

Taxonomic references: Agustí (1981a, b); Agustí and Gibert (1982b); Aldana Carrasco (1991, 1992a, b); Casanovas-Vilar and Alba (2011).

Remarks: See remarks for Torrent de Febulines.

#### Torrentet dels Traginers

Acronym: TT

Locality synonyms: Piera (*sensu lato*)

Municipality: Piera

Age: -

Correlation to GPTS: -

Correlation to local biostratigraphy: *Parapodemus barbarae* – *Stephanomys ramblensis* Interval Zone (zone L of the Teruel Basin)

Correlation to the MN zonation: MN12

Faunal list: *Occitanomys adroveri*.

Taxonomic references: -

Remarks: The fauna from the sites located in the town of Piera (Plana del Castell, Torrent del Gall Mullat, Finca Llopart, Teuleria de les Flandes and Torrentet dels Traginers) is usually considered altogether with that of Torrent de Traginers and referred to in the literature as ‘Piera’ (see for example Agustí *et al.*, 1985, 1997). Nevertheless, it is likely that these sites have slightly different ages.

#### Trinxera de Can Llobateres 0

Acronym: TCL0

Locality synonyms: -

Municipality: Sabadell

Age: -

Correlation to GPTS: -

Correlation to local biostratigraphy: *Cricetulodon sabadellensis* + *Progonomys hispanicus* Concurrent Range Subzone

Correlation to the MN zonation: MN10

Faunal list: *Heteroxerus* cf. *grivensis*, *Muscardinus vallesiensis*, *Muscardinus hispanicus*, *Microdyromys complicatus*, *Paraglitulus werenfelsi*, *Eumyarion leemanni*, *Hispanomys* cf. *thaleri*, *Cricetulodon sabadellensis*, *Rotundomys* cf. *freirensis*, *Progonomys hispanicus*.

Taxonomic references: -

Remarks: -

### Trinxera de Can Llobateres 1

Acronym: TCL1

Locality synonyms: -

Municipality: Sabadell

Age: -

Correlation to GPTS: -

Correlation to local biostratigraphy: *Cricetulodon sabadellensis* + *Progonomys hispanicus* Concurrent Range Subzone [reference locality]

Correlation to the MN zonation: MN10

Faunal list: *Spermophilinus bredai*, *Heteroxerus grivensis*, *Muscardinus vallesiensis*, *Muscardinus hispanicus*, *Microdyromys complicatus*, *Eomyops catalaunicus*, *Eumyarion leemanni*, *Hispanomys thaleri*, *Cricetulodon sabadellensis*, *Progonomys hispanicus*.

Taxonomic references: -

Remarks: -

### Trinxera Nord Autopista

Acronym: TNA

Locality synonyms: Trinxera Norte Autopista, Terrassa (pro parte, see remarks)

Municipality: Terrassa

Age: 9.30Ma

Correlation to GPTS: C4Ar.1r

Correlation to local biostratigraphy: *Rotundomys bressanus* Lineage Subzone [reference locality]

Correlation to the MN zonation: MN10

Faunal list: *Spermophilinus bredai*, *Muscardinus* cf. *heintzi*, *Hispanomys* cf. *thaleri*, *Rotundomys* cf. *montisrotundi*, *Rotundomys bressanus*, *Anomalomys gaillardi*, *Progonomys hispanicus*, *Progonomys woelferi*.

Taxonomic references: Agustí (1981a, b); Agustí and Gibert (1982b); Aldana Carrasco (1991, 1992a).

Remarks: See remarks in Torrent de Febulines.

### Trinxera Sud Autopista 2

Acronym: TSA2

Locality synonyms: Terrassa (pro parte, see remarks)

Municipality: Terrassa

Age: 9.30Ma

Correlation to GPTS: C4Ar.1r

Correlation to local biostratigraphy: *Rotundomys bressanus* Lineage Subzone

Correlation to the MN zonation: MN10

Faunal list: *Spermophilinus bredai*, *Heteroxerus grivensis*, *Hispanomys thaleri*, *Rotundomys* cf. *montisrotundi*, *Rotundomys bressanus*, *Anomalomys gaillardi*, *Progonomys hispanicus*, *Progonomys woelferi*.

Taxonomic references: Agustí (1981a, b); Agustí and Gibert (1982b); Aldana Carrasco (1991, 1992a).

Remarks: See remarks in Torrent de Febulines.

### Viladecavalls km 7

Acronym: VK7

Locality synonyms: Can Trullàs 7

Municipality: Viladecavalls

Age: 9.36Ma

Correlation to GPTS: C4Ar.1n

Correlation to local biostratigraphy: *Rotundomys montisrotundi* Lineage Subzone

Correlation to the MN zonation: MN10

Faunal list: *Rotundomys* cf. *montisrotundi*, *Progonomys* cf. *hispanicus*.

Taxonomic references: Agustí (1981a).

Remarks: -

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