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The Ventian mammal age (Latest Miocene): present state

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ABSTRACT

The Ventian land mammal age includes most of the Spanish faunas assigned to the biochronologic unit MN 13. It is correlatable with the Messinian, although it may include, in its latest part, early Pliocene faunas. We propose that the Ventian begins with the first occurrence of the Muridae genus *Stephanomys* (7 Ma, paleomagnetic dating from El Bunker, Teruel basin), well recorded in Teruel basin, and ends with the appearance of *Promimomys* (ca. 5 Ma), also registered in the Teruel basin. We suggest a new reorganization of the Ventian. The first subdivision corresponds to the zone M (Dam *et al.*, 2001). The second, zone N, is proposed here for the first time, being equivalent to the zone with *Celadensia* (Mein *et al.*, 1990; Dam *et al.*, 2006) plus the part of the zone with two *Paraethomys* (Dam *et al.*, 2006) in which *Celadensia* has dissappeared and still does not register *Promimomys*. The Ventian is now accurately recognized with quite precise boundaries and divisions, so that it can be easily recognized

RESUMEN

La edad de mamíferos terrestres Ventiense incluye la mayoría de las faunas españolas de la unidad biocronológica MN 13. Se correlaciona con el Messiniense, aunque su parte final puede incluir faunas de edad Plioceno basal. El Ventiense comienza con la primera aparición del genero de Muridae *Stephanomys* (7 Ma; datación paleomagnética de El Bunker, cuenca de Teruel), y termina con la aparición de *Promimomys* (ca. 5 Ma), ambas registradas en la cuenca de Teruel. En este trabajo proponemos una nueva organización del Ventiense. Una primera división correspondiente a la zona M (Dam *et al.*, 2001), y una nueva zona denominada N, equivalente a la zona con *Celadensia* (Mein *et al.*, 1990; Dam *et al.*, 2001) más la parte de la zona con dos *Paraethomys* (Dam *et al.*, 2006) en la que *Celadensia* ha desaparecido y aún no se registra *Promimomys*. El Ventiense es ahora reconocido con límites y divisiones precisas, de forma que puede ser fácilmente reconocible en las cuencas continentales Ibéricas

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in the Iberian continental basins with Mio-Pliocene sediments allowing refined intra- and inter-basin correlations.

Keywords: Biochronology, Iberian Peninsula, continental basins, Messinian.

con sedimentos Mio-Pliocenos permitiendo unas correlaciones intra e inter cuenca detalladas.

Palabras clave: Biocronología, Península Ibérica, cuencas continentales, Messiniense.

1. INTRODUCTION

The end of the Miocene in the Mediterranean domain was marked by major geological events that were of critical importance in the evolution of the continental environments, and which reached its climax during the "Mediterranean Salinity Crisis" (MSC) caused by the closure of the Atlantic-Mediterranean connection, with a subsequent isolation and desiccation of the Mediterranean Sea. It was a period marked by a general decline of the sea level, strong orogenic reactivation and the onset of the Late Miocene glaciation, which had a serious effect over the organic associations –see Aguirre (2003) for an excellent summary of this global crisis. In this scenario, the Mediterranean continental basin of the Iberian Peninsula has a relevant importance, being one of the few areas in which there is a significant fossil documentation, largely covering the time span between the end of the Miocene and the beginning of the Pliocene (ca. 7-5 Ma). The diversity and richness of the Spanish sites from this period led to the proposal a new Mammalian Age by Aguirre *et al*. (1976) named as "Ventian", choosing Venta del Moro (Valencia) as its reference locality, whose mammals record is one of the most important sources for the knowledge of the Mediterranean continental environments of the Miocene/Pliocene trasition (Montoya *et al*., 2006; Gibert *et al*., 2013). The aim of the present paper is to validate the Ventian land mammal age, specifying its subdivision in local zones. An important aspect of this work is the discussion of the mammalian faunas close to the Mio / Pliocene limit in the Iberian Peninsula, whose biostratigraphic position has been and still remains a subject of debate.

2. BACKGROUND OF THE VENTIAN MAMMAL AGE

The Ventian was proposed as "Continental Mammals Age" by Aguirre *et al*. (1976) during the Messinian Seminar # 2 (Gargano, Italy), with the following definition "*The 6.9 Ma date from Barqueros correlates to latest Turolian of pre-Librilla age (i.e. Crevillente V). We therefore propose to stablish a new mammal 'age': the Ventian (from Venta del Moro locality), to span the time from the first appearance of* Apodemus *to the first appearance of microtine in SW-European Faunas. The radiometric-based duration of the Ventian age spans from around 6.5 Ma to 4 Ma, or, in other words, the Messinian (latest Miocene) and the Zanclean (early Pliocene)*". Shortly after its definition, Alberdi *et al*. (1977) analyzed the mammalian faunas which were attributed to the Ventian, and, based on its composition, restricted the Ventian to the Late Miocene, biozone MN 13, thus strictly correlating it with the marine Messinian. Therefore, the Ventian would only correspond with the Uppermost Miocene faunal associations. This definition has prevailed in the literature, particularly in the southern Spanish basins, where the final Miocene is widely exposed (Ruiz Bustos, 2011). An exception to this interpretation may be found in Alberdi & Bonadonna (1988), who considered that the localities of Venta del Moro, Sahabi and Bacinello V3 represent particular faunal associations unassimilable neither to the Turolian nor the Ruscinian. Therefore, these localities would not represent a transition between the Miocene and the Pliocene, but would be related to the beginning of the Pliocene and correlated with the Zanclean. However, this view is in contradiction with recently available paleomagnetic age for Venta del Moro (Gibert *et al*., 2013) and other Ventian sites, still considered Miocene sites.

Moreover, the proposal of the Alfambrian "continental stage" by Mein *et al*. (1990), based on the micromammal composition of the sedimentary sections of Teruel Basin, has introduced some confusion when including Miocene faunas into the MN 14, traditionally placed within the Pliocene. According to these authors the term Alfambrian is used for "*designer le periode qui debute avec l'entrée de* Celadensia *et s'achève avec celle des* Mimomys *à cément. Sont contenu et ses limites se fondent sur l'évolution des arvicolidés et des trilophomyidés. L'Alfabrien correspondrait aux zones 14 et 15 de l'échelle des mammifères*". Finally, in this historical review, the definition of the Ventian continental stage with the proposal of a stratotype carried out by Ruiz Bustos (1997) has to be pointed out; it includes the section of lacustrine sediments dated next to the highway A-9, between km 244 (Pulianas, Granada) and km 249 (localities of Alfacar and Jun, Granada), that ranges from the Late Turolian (MN 12) up to the end of the Ventian. Currently, although our knowledge of the taxonomy of the Spanish fauna is incomplete and requires a sound revision for some mammal groups, the progress in both geology and palaeontology has been remarkable. In this regard, the basins of Teruel, Cabriel, Segura, Fortuna, Guadix-Baza and Granada have been particularly important. They represent continuous stratigraphic series with abundant micromammal localities, permitting a more precise assessment of the continental biostratigraphy along the Mio-Pliocene boundary (Fig. 1).

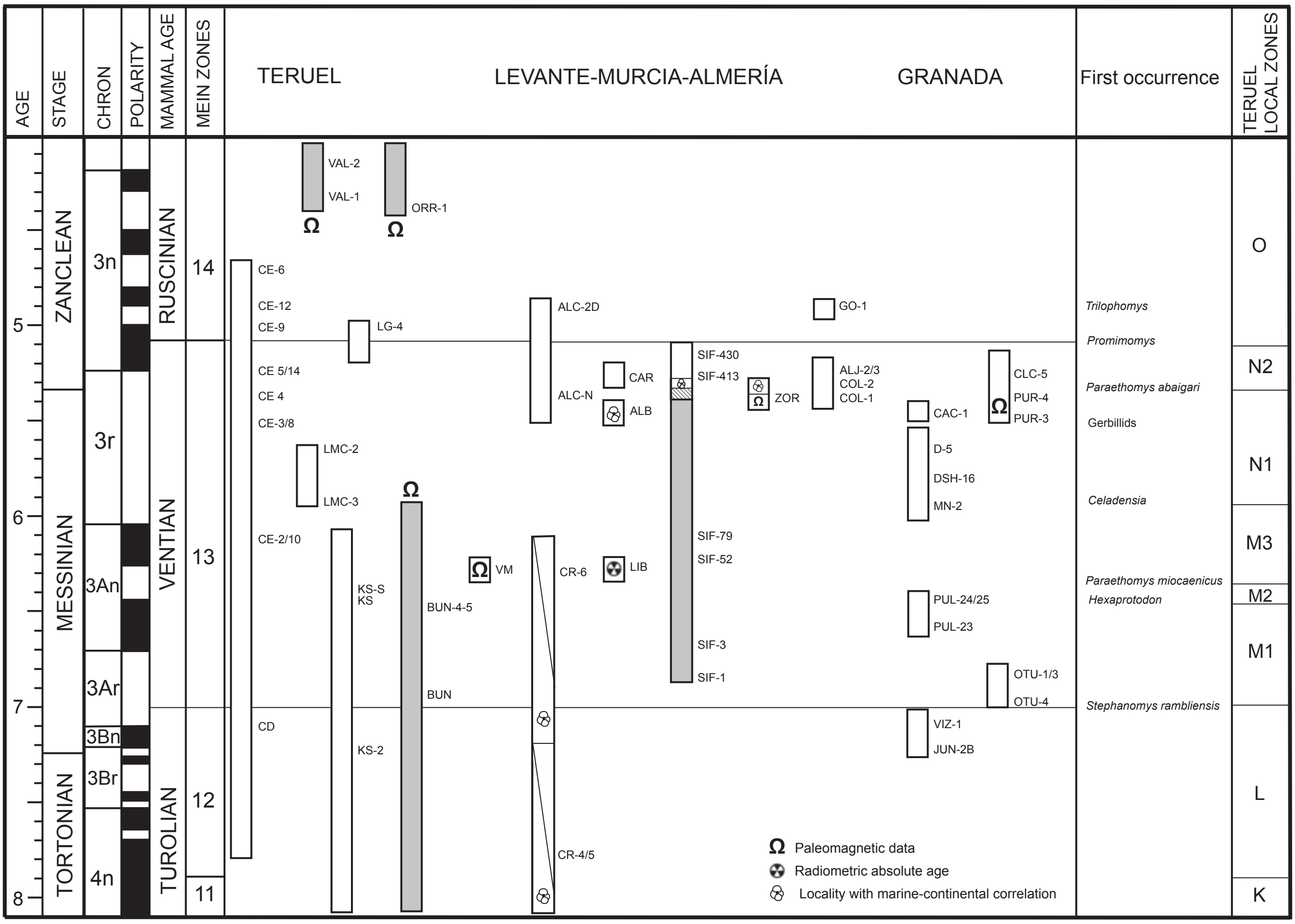

Figure 1. Biostratigraphy of selected Ventian Mammal localities. Teruel local zones after Dam *et al.* (2006) and in this work. Bars indicates that the localities are placed in the same stratigraphical section. Grey bars, section with paleomagnetic data. Primary information about localities ages in: Mein *et al*., 1973, 1990; Weerd, 1976; Boné *et al.*, 1978; Ruiz Bustos *et al*., 1984, 1992a, 1992b; Adrover, 1986; López Martínez, 1989; Sesé, 1989; Guerra Merchán & Ruiz Bustos, 1991; Guerra Merchán *et al*., 1991; Adrover *et al*., 1993; Martín Suárez & Freudenthal, 1998; Martín Suárez *et al*., 1998; Dam *et al*., 2001, 2006; Agustí *et al*., 2006; Montoya *et al*., 2006; García Alix *et al*., 2008; Mansino *et al*., 2009; Minwer-Barakat *et al*., 2009, 2012; Ruiz Bustos, 2011.
Localities (Left to right) CE= Celadas; CD= Concud; VAL=Villalba Alta; LMC= Loma de Casares; LG= La Gloria; KS= Las Casiones; ORR= Orrios; BUN= El Bunker; VM= Venta del Moro; ALC= Alcoy; CR= Crevillente; CAR= Caravaca; ALB= La Alberca; LIB= Librilla; SIF= Sifón; ZOR= Zorreras; GO= Gorafe; ALJ= Aljive; COL= Colorado; CAC= Cacín; D and DSH= La Dehesa; MN= La Mina; PUL= Pulianas; VIZ= Viznar; JUN= Jun; CLC= Calicasas; PUR= Purcal; OUT= Otura.

3. VENTIAN DEFINITION

The Ventian land mammal age includes most of the Spanish faunas of the MN 13 biozone (Mein, 1976, 1990; Bruijn *et al*., 1992; Daams *et al*., 1998). *Grosso modo*, it is correlatable with the Messinian, although its later assemblages may correlate with the early Pliocene faunas. The Ventian covers the time span comprised between 7 Ma (paleomagnetic age from El Bunker, in Teruel basin) and the entry of *Promimomys*, dated in Greece around 5.3 Ma by Hordijk & Bruijn (2009). The occurrence of this genus in the Teruel basin is not dated directly, but it could be close to 5 Ma (Dam *et al*., 2006). The Ventian begins with the first occurrence of the Muridae genus *Stephanomys* well recorded in Teruel basin (Dam *et al*., 2001, 2006) and ends with the first occurrence of *Promimomys*, also registered in the same basin (Mein *et al*., 1990). Although this deffinition does not differ from that proposed by Aguirre *et al*. (1976), it implies a significant shorter duration as the first occurrence of arvicolids in SW Europe was dated younger at that time, close to 4 Ma (Fig. 2).

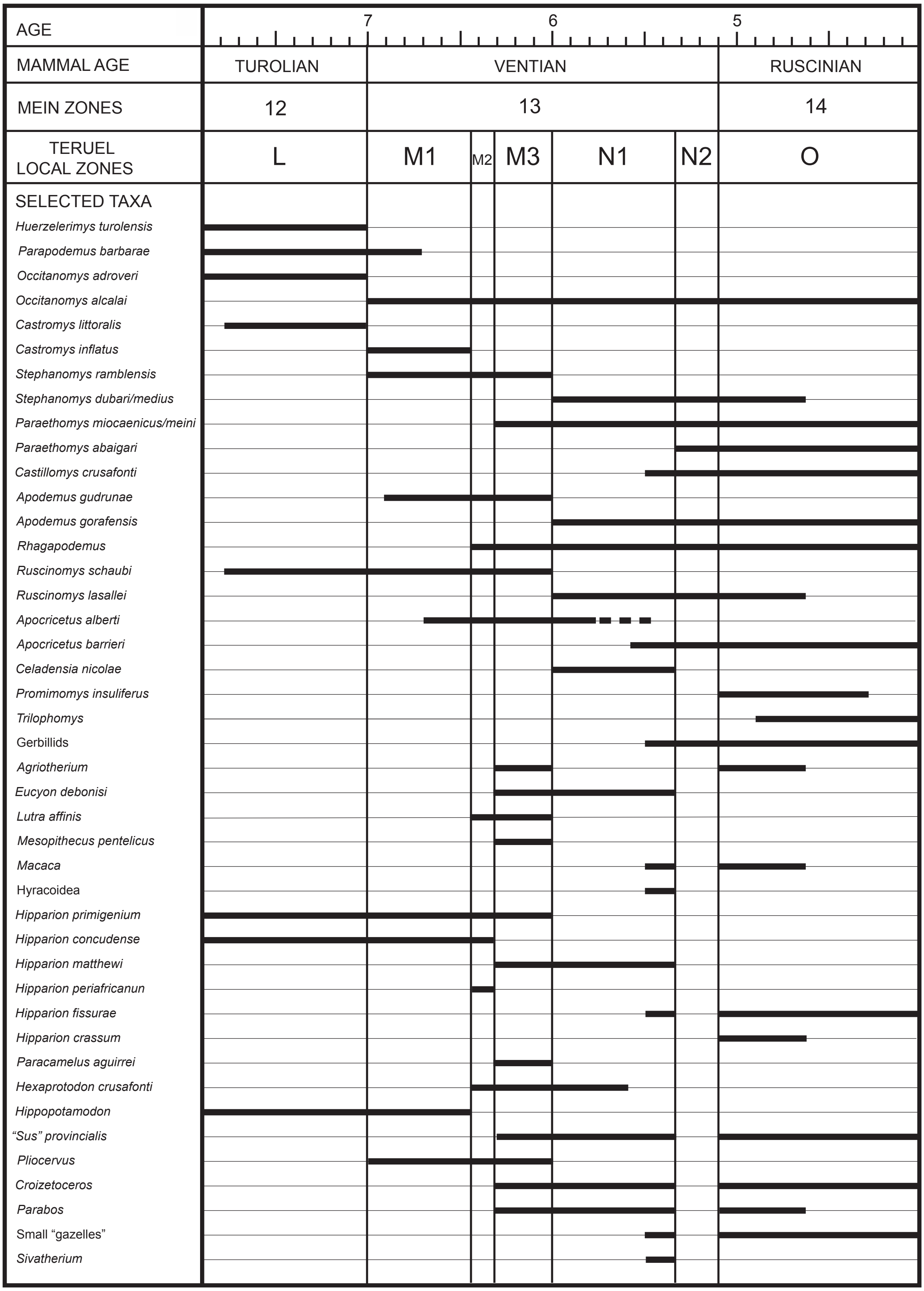

Figure 2. Range chart of selected Ventian taxa. Data source the same as figure 1, plus Thaler *et al.*, 1965; Bruijn *et al.*, 1975, 1992; Alberdi *et al.*, 1981; Aguilar *et al.*, 1984; Lacomba *et al.*, 1986; Alcala, 1994; Pickford *et al.*, 1997; Daams *et al.*, 1998; Kohler *et al.*, 2000; Alcalá & Morales, 2006; Montoya *et al.*, 2009; Agustí *et al.*, 2010; Ruiz Sánchez *et al.*, 2011.

4. CHRONOLOGY OF VENTIAN FAUNAS

4.1. The Teruel late Miocene local biozonation

Previous works (Weerd, 1976; Adrover, 1986; Mein *et al.*, 1990; Adrover *et al.*, 1993; Dam *et al.*, 2001, 2006) established a highly consistent time frame for the Mio-Pliocene transition in the Teruel Basin. In order to untangle the succession of the terminal Miocene mammalian localities, we propose the application of the biozone letter system –used extensively in central Iberian basins– for the late Miocene and early Pliocene biozones of the Teruel basins. Zones with *Celadensia* (Ce), two *Paraethomys* (2P), two *Paraethomys* plus *Trilophomys* (2P + Tr) and *Trilophomys* (Tr) (Dam *et al.*, 2006).

In this area, the Ventian includes two zones. The first corresponds to the zone M, being its diagnosis "*Stephanomys ramblensis*-*Celadensia* interval zone, from the entry of *Stephanomys ramblensis* to entry of the cricetid *Celadensia*" (Mein *et al.*, 1990; Dam *et al.*, 2001). The second zone N, newly proposed here, is diagnosed as "*Celadensia*-*Promimomys* interval zone, from the entry of *Celadensia* to entry of the arvicolid *Promimomys*". In turn, biozone N is subdivided into two subzones: N1 (= zone with *Celadensia*) corresponding to the range zone (total range) of *Celadensia* (Mein *et al.* 1990; Dam *et al.*, 2006) from the entry of *Celadensia* to the entry of *Paraethomys abaigari*, and N2 (= subzone with two *Paraethomys*) corresponding to the entry of *Paraethomys abaigari* to the entry of *Promimomys* (Dam *et al.*, 2006) where *Celadensia* has dissappeared and *Promimomys* is not recorded yet. N2 is represented by the localities Celadas 5 to 14 (Mein *et al.*, 1990). These two sites from the Celadas section (5 and 14) were included by Mein *et al.* (1990, p. 125) in the *Celadensia* zone. However, it is probably a mistake, as in figure 2 from the same paper, the sites are included in the zone with the two *Paraethomys* and *Promimomys* but before the first occurrence of *Promimomys*. This agrees with the view of Dam *et al.* (2006) who included Celadas 5 and 14 in the zone with two *Paraethomys* along with the site Celadas 9, which is placed a few meter above and records the entrance of *Promimomys*. In our opinion, Celadas 9 and La Gloria 4, both with *Promimomys,* represent a different faunal assemblage marked by the presence of this arvicolid, and, therefore, the beginning of a different zone. In conclusion, the N2 subzone is defined by the entry of a second *Paraethomys*, larger than *Paraethomys meini* and extends until the entry of *Promimomys* (see Dam *et al.*, 2006 supplementary notes). We propose for the early Ruscinian (MN14) a new Zone O, defined by the entrance of *Promimomys* and extend to the first occurrence of *Mimomys*, in which one of the most characteristic genera is *Trilophomys* (Fig. 2).

4.2. The Ventian in the Iberian continental basins

The early part of the Ventian (zone M), featuring *Stephanomys ramblensis*, has been widely recognized in the Iberian continental basins. It has been generally regarded as equivalent to the MN 13 and, although poses some correlation problems, the early Ventian is recognized without major complications in the basins of Teruel, Cabriel, Júcar, Fortuna and Granada (Weerd, 1976; Adrover, 1986; Lacomba *et al.*, 1986; Dam, 1997; Dam *et al.*, 2001; Agustí *et al.*, 2006; Montoya *et al.*, 2006; García-Alix *et al.*, 2008; Ruiz Sánchez *et al.*, 2011). On the contrary, the late Ventian, now zone N (N1 + N2), has important correlation problems –most of them due to the consideration of *Celadensia* as a typical Pliocene taxa– that shall be discussed below. In the Iberian Basins out of Teruel, *Celadensia* is only present at the site of Dehesa 5 (D5) (Boné *et al.*, 1978; Aguilar *et al.*, 1984; Mein & Agustí, 1990). After Ruiz Bustos (2011), the faunas of La Mina (M5 and M12), Dehesa (D4 and D5) and Calerico F5 would be located within the same intra-zone (SI 13-3), which would correspond to the subzone M3 in Teruel. However, the presence of *Stephanomys medius* (= *S. dubari*) in these faunas, well represented in lower levels such as La Dehesa 16 (DHS-16) (García-Alix, 2006; García-Alix *et al.*, 2008), would mark a clear separation with the faunas of the M zone, characterized by the presence of *S. ramblensis*. Therefore, in this section the separation among the subzones M3 and N1 at least would be placed below the site Dehesa D5 where *Celadensia* appears in the fossil record of this basin, and probably the rest of the series should be included in the same subzone. Another site with *Celadensia*, Castillejo de Robledo (Segovia), has recently been found in the Duero basin (Luengo *et al.*, 2009). At this site, *Celadensia*, among other species, is associated with *Stephanomys medius* and *Apocricetus alberti*. The association of these two species may indicate that Castillejo de Robledo is older than Peralejos E, and the other sites with *Celadensia*, in which this taxon is associated with *Apocricetus barrieri*. In these circumstances it is difficult to establish a clear limit between the M and N zones. Without more precise dates, this long lapse of time corresponding to the Chron 3r could mostly belong to this subzone N1. The upper limit of this subzone is recognized in the Celadas section by the appearance of a large-sized *Paraethomys*, *P. abaigari*, along with the moderate size species present since the beginning of the M3. Localities with two *Paraethomys*, without *Promimomys* or *Trilophomys*, now included in the subzone N2 in Teruel Basin, are found in Southern Iberian basins, even in sites with rather poor faunal associations such as Aljibe 2 and 3 in Guadix-Baza (Guerra Merchán *et al.*, 1991), the stratigraphic sections of Purcal and Calicasas in the Granada basin (Martín-Suarez *et al.*, 1998; Minwer Barakat *et al.*, 2012) and localities in the Alvalade basin (Antunes & Mein, 1989, 1995). Unfortunately, only in the Teruel basin a stratigraphic succession in which *Promimomys* clearly appears above localities with two *Paraethomys* is available. So there is an apparent lack of fossil record above this subzone in the rest of the basins, which has hindered correct inter-basin correlations. Since the association of two *Paraethomys* is constant in numerous localities of the MN 15, the presence of two *Paraethomys* to determine the subzone N2 is only supported by stratigraphic criteria. The possibility that this subzone N2 is correlatable with the Pliocene is real, while further evidence is needed to solve this question. In the current state of knowledge, the entrance of *Promimomys* would mark the end of the Ventian, and therefore the beginning of Ruscinian. Its dating in Teruel ca. 5 Ma is indirect, being somewhat more recent than that in Greece (Hordijk & Bruijn, 2009).

The subzone N1 can be correlated with the faunas of Guadix-Baza included by Minwer Barakat *et al.* (2012) in the local zone of *Apodemus gudrunae*, as well as other sites such as Colorado 1 (Guerra Merchán *et al.*, 1991). Regarding the Sorbas basin, the site of Zorreras, situated below the marine Pliocene and with inverse polarity, can be correlated with the end of the N1, providing a minimum age of ca. 5.3 Ma for the top of the subzone N1 (Martín Suárez *et al.*, 2000; Riding *et al.*, 2000). In Segura basin, the locality of La Alberca may also be included in the subzone N1. This locality is correlated with the Late Messinian (Bruijn *et al.*, 1975), confirming that at least part of the subzone still belongs to the Latest Miocene. The entry of the Gerbillidae in the Iberian Peninsula can be dated in these the faunas, being present, among other sites, in Zorreras and Negratín-1 (Agustí & Casanovas-Vilar, 2003). Salobreña (Málaga) and Almenara M (Castellón) are karst sites that share very similar faunal associations, with various genera of Gerbillids, *Castillomys* and other common species from the Ventian *sensu lato* (Aguilar *et al.*, 1984; Agusti *et al.*, 2010). The presence of gerbillids and the occurrence of *Castillomys* is widely detected in the subzone N1, which may include both localities.

In the Fortuna basin, although with several very complete stratigraphic sequences, the taxonomic information is very limited. The biozone M is recognized without problems, particularly in the Sifón section. Above the localities belonging to the M3 there is a gap coincident with a wide erosive phase. The following registered faunas (Sifón 413, 430 and Molina de Segura 10) have been correlated with the beginning of the Pliocene (Agustí *et al.*, 2006), but do not possess any element which clearly distinguishes them from similar associations present in the subzone N1; with no mention of the presence of a second *Paraethomys* or microtoid cricetids faunistic correlation with the Teruel subzones it is not feasible.

5. VENTIAN LARGE MAMMALS

The Ventian macromammal record is scant at the beginning of the biozone M but very well represented in the subzone M2 with sites such as Milagros, El Arquillo-1 and Las Casiones, where the first occurrence of *Hexaprotodon* is recorded (Alcala, 1994). The M3 subzone is represented by Venta del Moro from Cabriel basin (Morales, 1984; Montoya *et al.*, 2006; Gibert *et al.*, 2013) and Librilla in Fortuna basin, both with *Paracamelus* and *Parabos* (Alberdi *et al.,* 1981). As a whole, the known faunas of the zone M represent a dramatic change compared to Late Turolian ones (Fig. 2). The diversification of the genus *Hipparion*, with the appearance of small sized species such as *H. periafricanum*, the strong predominance of the Boselaphini over the rest of ruminants, and the appearance of *Hexaprotodon* and *Pliocervus* characterize the subzone M2. In Venta del Moro the predominance of *Hipparion* and the Boselaphini is similar to those of the M2, but faunal renewal is greater, with the appearance of the first camels of the Eurasian fossil record (Morales *et al.*, 1980; Pickford *et al.*, 1995), the first Bovini of Western Europe (Morales, 1984), the occurrence of *Mesopithecus* (Montoya *et al.*, 2006) and by genera that will persist in later faunas, as *Croizetocerus*, *Propotamochoerus*, *Agriotherium*, *Eucyon* and *Lutra* (Montoya *et al.*, 2006, 2009, 2011). The large mammals assemblage of Venta del Moro hardly resembles those of the Late Turolian, marking a major faunal turnover that foretell the Pliocene faunas. The large mammal faunas of the zone N, except for a small sample obtained in La Alberca (Mein *et al.*, 1973), are barely registered in the Iberian basins. A new faunal association, recently found in the Puerto de la Cadena, Murcia, currently under study, may provide valuable information on macromammal as it is equivalent in age to La Alberca. Probably Arenas del Rey, Granada Basin, with an association of *Hexaprotodon* and *Parabos* (Morales, 1984) indicates the persistence of *Hexaprotodon* in the N1 subzone. At the site of Almenara M the first occurrence of *Macaca* sp. is recorded (Kohler *et al.*, 2000) together with the hyracoid *Pliohyrax graecus* (Pickford *et al.*, 1997). Both species could be related to the expansion of the meridional faunas occurred during the Late Miocene (Pickford & Morales, 1994; Made *et al.*, 2006). We know nothing about the large mammals of the N2. Ruscinian localities such as La Gloria 4 which overlies the N2, register a drastically different association of large mammals, different from the one present in the Ventian M zone. Characterized by the almost total disappearance of the Boselaphini, and the predominance of Antilopinae (Alcalá & Morales, 2006). The emergence of modern carnivores as *Pliohyaena*, *Ursus* and *Nyctereutes*, common and characteristic Pliocene genera, highlights the dissimilarity with the Ventian faunas (Alcalá, 1994).

6. THE VENTIAN SCENARIO

There is a general agreement that the late Miocene epoch (between 8-5 Ma) was a period of important ecological and climate changes. The possible causes (Fig. 3) of these changes are under disscusion with a controversy to separate causes from effect (Hay *et al.*, 2002; Molnar, 2005). Pickford & Morales (1994) have suggested that during the last 22.5 My there were at least four major faunal turnover in Spain and East Africa, also detected in other areas (Siwaliks and North American Great Plains), which show a strong correlation with the Alpine Neogene tectogenic phases. One of these turnover pulses occurred during the end of the Miocene and correlates well with Rhodanian tectogenic phase (Fig. 3). The timing of this episode (ca. 7.8-6.3 Ma) corresponds with the last Turolian faunas and the beginning of the Ventian Mammal Age. This period continues with the Messinian Salinity Crisis (MSC; 5.96-5.33 Ma) that probably favoured the faunistic exchanges in the peri-mediterranean area.

Therefore, the Venta del Moro fauna, now dated at 6.23 Ma (Gibert *et al.*, 2013), is pre-crisis and provides unique information about the early Ventian, equivalent to the zone M. During the last part of the Miocene there was

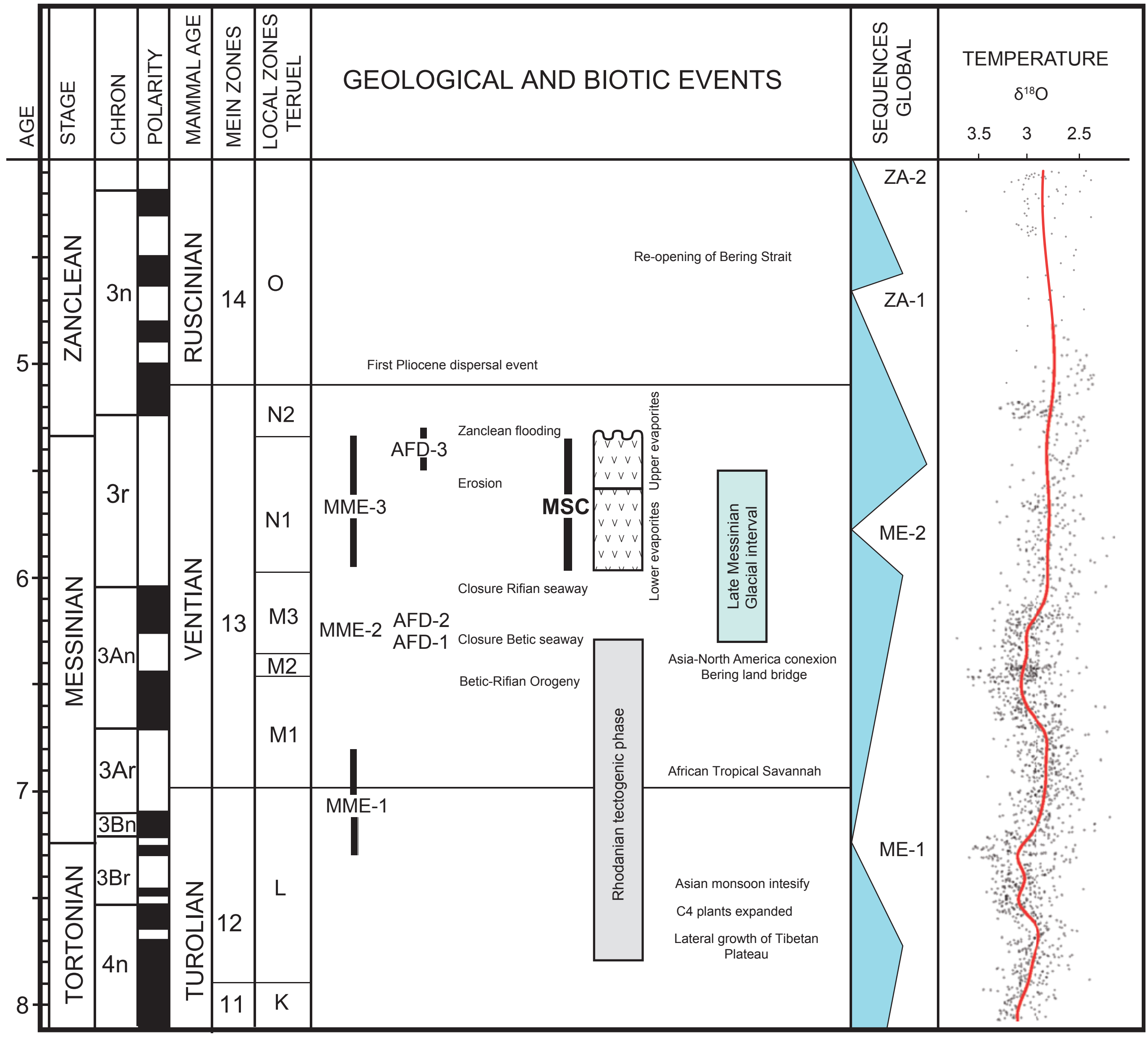

Figure 3. The Ventian scenario. Temperature curve from Zachos *et al.* (2008). Global sequences from Hardenbol *et al.* (1998). MME= Messinian Mammals Event after Agustí *et al.* (2006). AFD= African-Iberian Dispersal after Gibert *et al.* (2013). See also Pickford & Morales, 1994; Svitoch & Taldenkowa, 1994; Cerling *et al.*, 1998; Riding *et al.*, 2000; Pagani *et al.*, 2009; Gibert *et al.*, 2013.

a progressive global cooling and sea level fall (Zachos *et al.*, 2008), sea level was higher than today although during the Late Miocene glaciation (6.36-5.5 Ma) it shows relatively important obliquity forced eustatic fluctuations. Relatively high temperatures have been detected for that time (Fig. 3). The Iberian mammal faunas of the first part of the Ventian reflect this general mild climate, with high humidity (Dam, 2006), which favored the development of Asian-influenced associations. At the same time, the progressive closure of marine Betic corridors favored the arrival of immigrants from Africa. Nonetheless, this African faunal exchange was limited in both continental shores due to the existence of ephemeral geological or ecological barriers that acted as filters to dispersal (Gibert *et al.*, 2013). In contrast, the Northeast migrations were widely favored by the environmental conditions mentioned above, first moderately during the M1 and M2 subzones, and massively afterwards, during the the M3. Such is the case of Venta del Moro fauna (Montoya *et al.*, 2006), which witnessed the arrival of American mammals such as camels and dogs via the Bering conexion, new carnivores –*Lutra* and *Agriotherium*– and modern ruminants –e.g., *Parabos*, the oldest Bovini of Western Europe (Made *et al.*, 2006; Montoya *et al.*, 2006). Venta del Moro is certainly one of the most extraordinary faunal associations of the Late Miocene. This faunal climax, named by Agustí *et al.* (2006) the "Second Mammalian Messinian Event", stems from multiple inmigration events in which northern immigrants were predominant.

All these environmental conditions suddenly collapse after Venta del Moro age due to the development of a glacial period, whose peaks were detected during the glacial periods TG 20-22, coinciding with a significant drop in the Mediterranean sea level, within the MSC (Fig. 3). The mammalian faunas of this period, included in zone N (late Ventian), are very heterogeneous, probably in response to these strong environmental fluctuations. The appearance of the microtoid cricetid *Celadensia* could be related to this significant drop in temperature. Palinological data of The Arenas del Rey locality, correlated with N1 subzone, indicates the existence of relatively xeric and open vegetation but not a steppe landscape (Solé de Porta & Porta, 1977). This could confirm the climatic change between M/N biozones. Unfortunately, the faunal transition between these two zones is barely understood.

The closure of the Betic-Rifian corridor and the increase in the global temperature, favoured the return of African immigrant, but limited to a discrete number of taxa, which shows that the occidental connection between Europe and Northern Africa was never easy. The appearance of gerbillids, macaques and hyracoids mark this migration, which corresponds to the "Third Messinian Mammalian Event" of Agusti *et al.* (2006) or third Afro-Iberian dispersal of Gibert *et al.* (2013) between 5.5-5.3 Ma. The Zanclian transgression resets the open sea conditions in the Mediterranean and the end of the MSC. A series of Iberian localities, grouped in subzone N2, record the appearance of a new large-sized *Paraethomys* species. These sites lie stratigraphically above those with N1 faunas, but new data are needed to clarify their precise age. The absence of *Promimomys* –a genus that appears later during a new climate deterioration towards cooling and dry conditions– in the N2, is the clearest indication that they could still be included in the Ventian.

7. CONCLUSIONS

The Ventian land mammal age comprises the continental faunas dated between around 7 to 5 Ma, equivalent to the marine Messinian, although its latest part could correspond to the early Zanclian. The Ventian is divided into two zones: M (with three subzones), previously defined by Dam *et al.* (2001) and a new zone N, proposed here, with two subdivisions (N1 and N2). The subzone N1 is equivalent to the zone with *Celadensia* of Mein *et al.* (1990) and Dam *et al.* (2006), and the subzone N2 is restricted to the faunas with two *Paraethomys*, located below the sites with *Promimomys* (Teruel area), or above the sites of the N1, provided there are no hiatuses or significant breaks. The Ventian is clearly different from the Turolian, now restricted to the zones K and L and from the Ruscinian. A new zone is proposed for the Early Pliocene; Zone O, defined by the entrance of *Promimomys* and extend to the first appearance of *Mimomys*, in which one of the most characteristic genera is *Trilophomys*. The Ventian is now accurately recognized with quite precise boundaries and divisions and can be easily recognized in the Iberian continental basins with Mio-Pliocene sediments, allowing better intra- and inter-basin correlations.

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