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 in the continental Iberian basins. The Ventian is now accurately recognized with quite precise boundaries and divisions, so that it can be easily recognized in the continental Iberian basins.

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 Ventienense comienza con la primera aparición del género de Muridae Stephanomys (7 Ma; datación paleomagnética de El Bunker, cuenca de Teruel), bien registrado en la 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 Ventienense. 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 Ventienense 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.

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

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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 the Miocene and the beginning of the Pliocene (ca. 7-5 Ma) 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 Ruscian. 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,

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 establish 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 Ruscian. 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.
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; Martin Suárez & Freudenthal, 1998; Martin 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=Dehesa; MN=Lina; 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; Bruin 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 & Brujin (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 definition 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).
| AGE  | MEIN ZONES | TERUEL LOCAL ZONES | SELECTED TAXA                      |
|------|------------|-------------------|-----------------------------------|
|      | 12         | L                 | Huerzelerimys turolensis          |
|      | 13         | M1                | Parapodemus barbaraee             |
|      |            | M2                | Occitanomys adroveri              |
|      |            | N3                | Castromys littoralis              |
|      |            | M1                | Castromys inflatus                |
|      |            | M2                | Stephanomys rambensis             |
|      |            | M3                | Stephanomys dubari/medius         |
|      |            | M3                | Paraeomys miocaenicus/meini       |
|      |            | N1                | Paraeomys abagari                 |
|      |            | N2                | Castilomyx crusafonti             |
|      |            | O                 | Apodemus gudrunae                 |
|      |            |                   | Apodemus goralensis               |
|      |            |                   | Rhagapodemus                      |
|      |            |                   | Ruscinomys schaubi                |
|      |            |                   | Ruscinomys lasaileri              |
|      |            |                   | Apocricetus alberti               |
|      |            |                   | Apocricetus barbari               |
|      |            |                   | Celadensia nicolae                |
|      |            |                   | Promimomys insuliferus            |
|      |            |                   | Trilophomys                       |
|      |            |                   | Gerbillids                        |
|      |            |                   | Agniatherium                      |
|      |            |                   | Eucyon debonisii                  |
|      |            |                   | Lutra affinis                     |
|      |            |                   | Mesopithecus pentelicus           |
|      |            |                   | Macaca                           |
|      |            |                   | Hyracidea                         |
|      |            |                   | Hippopanion primigenium           |
|      |            |                   | Hippopanion concinuense           |
|      |            |                   | Hippopanion mathewi              |
|      |            |                   | Hippopanion periatrificomun      |
|      |            |                   | Hippopanion fissurae              |
|      |            |                   | Hippopanion crassum              |
|      |            |                   | Paracamelus aguerei               |
|      |            |                   | Hexaprotodon crusafonti          |
|      |            |                   | Hippopotamodon                    |
|      |            |                   | "Sus" provincialis               |
|      |            |                   | Plococerus                        |
|      |            |                   | Croizetoceros                     |
|      |            |                   | Parabos                          |
|      |            |                   | Small "gazelles"                 |
|      |            |                   | Sivatherium                      |

**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; Lacombe 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 Miocene-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 abaiigari*, and N2 (= subzone with two *Paraethomys*) corresponding to the entry of *Paraethomys abaiigari* 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 Ruscian (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; Lacombe 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 & Agusti, 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 Peralaje 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. abaiigari*, 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 Ventic, and therefore the beginning of Ruscian. 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) in Zorreras and Negratín-1 (Agustí & Casanovas-Vilar, 2003). 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 Ventic 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 Gabriél basin (Moraes, 1984; Montoya et al., 2006; Gibert et al., 2013) and Librilla in Fortuna basin, both with Paracamélus 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. periafricamum, 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 from 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 (Moraes, 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 Plio hyrax graecus (Pickford et al., 1997). Both species could be related to the expansion of the meridional faunas occurred during the Teruel faunas (Pickford & Morales, 1994; Made et al., 2006). We know nothing about the large mammals of the N2. Ruscian 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 Ventic 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 Plio hyaena, Ursus and Nyctereutes, common and characteristic Pliocene genera, highlights the dissimilarity with the Ventic faunas (Alcalá, 1994).
6. THE VENCIAN 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 discussion 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

![Diagram showing geological and biotic events](chart)

**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 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 connexion, 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 immigration 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 Agustí et al. (2006) or third Afro-Iberian dispersal of Gibert et al. (2013) between 5.5-5.3 Ma. The Zanclean 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 Paraeothomys 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 Zanclean. 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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