Biostratigraphy of the Continental Upper Miocene of Crevillente (Alicante, SE Spain)
Biostratigraphie du Miocène supérieur continental de Crevillente (Alicante Espagne sudorientale)

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BIOSTRATIGRAPHY OF THE CONTINENTAL UPPER MIOCENE OF CREVILLENTE (ALICANTE, SE SPAIN)

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ABSTRACT - The sequence of mammal localities of Crevillente is analyzed biostratigraphically and chronostratigraphically. A detailed biozonation on the basis of rodents is proposed. The localities are attributed to the Turolian or, in marine terms, to the Tortonian and the Messinian. The correlation of the Tortonian/Messinian boundary with the mammal sequence may be carried out with high precision.

KEYWORDS: UPPER MIOCENE, BIOSTRATIGRAPHY, RODENTIA, SE SPAIN.

RÉSUMÉ - La biostratigraphie et la chronostratigraphie de la séquence de gisements de mammifères de Crevillente sont analysées, donnant comme résultat une zonation détaillée à base de rongeurs. Les gisements sont attribués au Turolien, ou, en terminologie de stratigraphie marine, au Tortonien et Messinien. La corrélation de la limite Tortonien/Messinien avec la séquence de gisements à faunes de rongeurs peut être effectuée avec grande précision.

MOTS-CLÉS: MIOCÈNE SUPÉRIEUR, BIOSTRATIGRAPHIE, RODENTIA, ESPAGNE SUDORIENTALE.

INTRODUCTION

The area studied is located between the villages of Crevillente, Elche and Aspe (province of Alicante), topographical map Elche (28-35). It is accessed by road N-330 between Crevillente and Aspe. The localities are situated on either side of the road between kilometer 15 and 19 (Fig. 1).

The sedimentary sequence under study lies unconformably on the Mesozoic substratum. Towards the North it is slightly inclined, and towards the South it is folded with inclinations of up to 60° SSE. It consists of alternating continental and marine beds, and sometimes it is difficult to decide whether a specific fossiliferous bed is of continental or marine origin, since most mammal-bearing beds do contain marine fossils too (see Freudenthal et al. 1991a). In this context it is relevant to note, that there are no signs of roundness or sphericity of the vertebrate fossil remains: the state of preservation is excellent; the fragile roots of the teeth are frequently preserved, and incus, malleus and vertebrae often have intact apophysis. For that reason we think that the specimens have undergone little transportation, at least after the decomposition of the cadaver. On the other hand the marine microfossils are often reworked (pers. comm. J. Usera, J. Civis). Consequently, our conclusion is, that the beds with concentrations of mammal remains are continental deposits.

The good quality of exposure of the sediments and the large number of good fossiliferous localities have allowed us to study - in direct lithostratigraphical superposition - the vertical distribution of the rodent associations (Fig. 2). Probably Crevillente is one of the best sequences known for the fossil mammal record of the Late Miocene.

LOCALITIES

Nearly all studied localities (CR2, CR4B, CR5, CR7, CR8, CR15, CR17, CR18 and CR22) are geographically close together. Only CR14 and CR31 are farther away. With the exception of CR14, all localities can be correlated lithostratigraphically, due to the good exposure, and the presence of hard marker beds, that stand out in the field and are easy to recognize and follow from a distance. We will first give a short description of the localities, their UTM co-ordinates, and their equivalence - if possible - with the levels studied by de Bruijn et al. (1975). They are placed in numerical order, corresponding to the order in which they were found during the prospection. In the figures they are arranged chronologically.

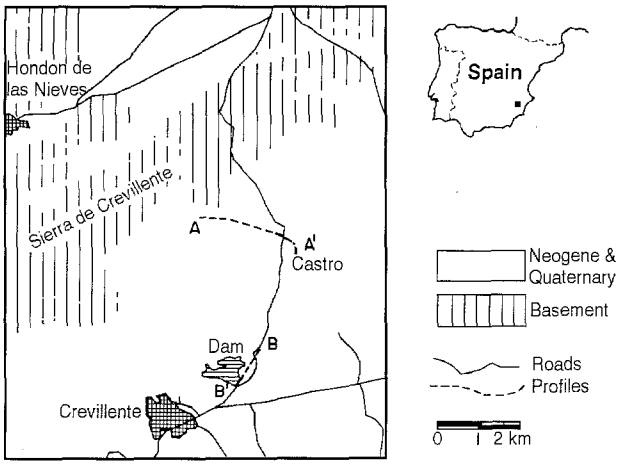

FIGURE 1 - Geographical situation of the localities and principal roads of access. Position of the section represented in Fig. 2. *Situation géographique des localités et routes principales. Position de la section de la Fig. 2.*

Crevillente 2 (CR2, 30SXH401944) - This is the oldest one of the localities studied, and it is identical to the one published by de Bruijn et al., (1975) under the same name. It is located at about 100 m west of the road, at km post 15. Faunal list (macromammal list after Montoya (1994), modified by P. Mein for this paper): *Indarctos atticus* (WEITHOFER, 1888), *Promephitis* sp., Viverridae indet., *Plioviverrops guerini* VILLALTA & CRUSAFONT, 1948, *Adcrocuta eximia* (ROTH & WAGNER, 1854), *Paramachairodus ogygia* (KAUP, 1832), *Machairodus aphanistus* (KAUP, 1833), *Microstonyx major* (GERVAIS, 1848), *Dorcatherium naui* KAUP, 1833, *Lucentia iberica* Azanza & MONTOYA, 1995, Muntiacinae indet., *Birgerbohlinia schaubi* CRUSAFONT, 1952, *Tragoportax gaudryi* (KRETZOI, 1941), *Hipparion mediterraneum* (ROTH & WAGNER, 1855), *Dicerorhinus schleiermacheri* (KAUP, 1832), *Deinotherium giganteum* KAUP, 1829, *Tetralophodon longirostris* (KAUP, 1832), *Postpalerinaceus* cf. *vireti* CRUSAFONT & VILLALTA, 1947, *Galerix iberica* MEIN & MARTIN-SUAREZ, 1993, *Desmanella* sp., *Prolagus crusafonti* LOPEZ MARTINEZ, 1975, *Hystrix parvae* (KRETZOI, 1951), *Heteroxerus grivensis* (FORSYTH MAJOR, 1893), Aff. *Aragoxerus* sp., *Eliomys truci* MEIN & MICHAUX, 1970, *Muscardinus* sp., *Hispanomys peralensis* VAN DE WEERD, 1976, *Neocricetodon occidentalis* AGUILAR, 1982, *Cricetulodon bugesiensis* FREUDENTHAL, MEIN & MARTIN-SUAREZ, 1998, *Apodemus lugdunensis* (SCHAUB, 1938), *Apodemus* sp., *Huerzelerimys vireti* (SCHAUB, 1938), *Occitanomys sondaari* VAN DE WEERD, 1976.

Crevillente 4B (CR4B, 30SXH396939) - This locality is found in a dug out shelter, about 600 m west of the road, and may be accessed by a dirt road, that begins just opposite Castro Hill.

Faunal list: Soricidae gen. indet., sp. indet., *Archaeodesmana* sp., *Galerix iberica, Prolagus crusafonti, Heteroxerus grivensis, Eliomys truci, Muscardinus* sp., *Hispanomys peralensis, Neocricetodon occidentalis, Apodemus lugdunensis, Huerzelerimys vireti, Occitanomys sondaari.*

Crevillente 5A (CR5A, 30SXH398945) - Located east of road N-330, and a few metres above it, at its crossing with the small road that ascends Castro Hill.

Faunal list: *Prolagus crusafonti, Atlantoxerus* sp., *Eliomys truci, Apocricetus plinii* (FREUDENTHAL, LACOMBA & MARTIN-SUAREZ, 1991), *Apodemus barbarae* (VAN DE WEERD, 1976), *Huerzelerimys turoliensis* (MICHAUX, 1969), *Occitanomys adroveri* (THALER, 1966).

Crevillente 6 (CR6) - The locality denominated Crevillente 6 by de Bruijn et al. (1975) could not be recovered, since it has disappeared under the dam of Crevillente. We did find several poorly fossiliferous sites, that are probably equivalent to Crevillente 6, but that are so poor, that we have not been able to make significant collections. The faunal list here after is based on the Utrecht collection which we restudied.

Faunal list: *Eliomys truci, Muscardinus* sp., *Hispanomys* sp., *Apocricetus alberti* FREUDENTHAL, MEIN & MARTIN-SUAREZ, 1998, *Occitanomys alcalai* ADROVER, MEIN & MOISSENET, 1988, *Stephanomys ramblensis* VAN DE WEERD, 1976, *Apodemus gudrunae* VAN DE WEERD, 1976, *Paraethomys meini* (MICHAUX, 1969).

N.B. *Apocricetus alberti* will be described as a new species to replace *Cricetus* cf. *kormosi* SCHAUB, 1930 (Freudenthal, Mein & Martín Suárez, in press).

Crevillente 7 (CR7, 30SXH396946) - East of the main road, in the hill south of Castro, at the level of the pass separating the two hills. Access is easiest from the TV-antenna on Castro Hill, descending southward into the pass and following the west side of the hill horizontally about 100 m.

Faunal list: Soricidae gen. indet., sp. indet., *Galerix iberica, Heteroxerus* sp., *Eliomys truci, Apodemus meini* (MARTIN-SUAREZ & FREUDENTHAL, 1993), *Occitanomys adroveri.*

Crevillente 8 (CR8, 30SXH404951) - This locality lies next to the dust road that begins at the foot of Castro Hill and reaches Elche passing through the "Alto de la Peña"; one has to follow this trail about 600 m, to find this lens of dark clay, embedded in limestones, 50 m after crossing a ford. Along the same trail we sampled the localities CR9, CR10, CR11, CR12, CR13, CR25, CR26,

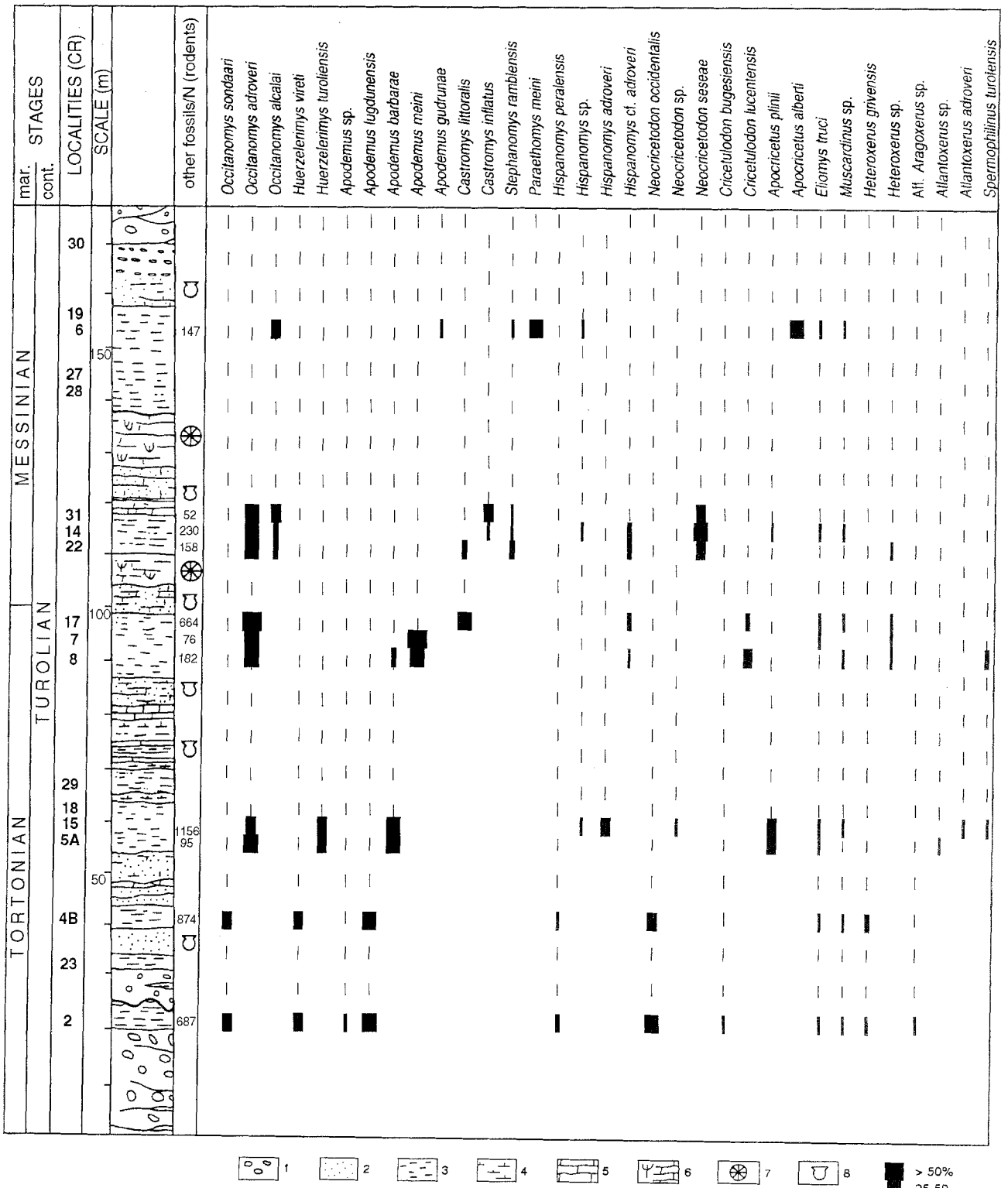

FIGURE 2 - Vertical distribution and abundance of the species of rodents in the stratigraphic column, composed from the sections A-A' and B-B' studied in Crevillente (modified after Freudenthal et al., 1991). Symbols: **1:** conglomerates, **2:** sandstones, **3:** marls, **4:** marly limestones, **5:** limestones, **6:** reef limestones, **7:** reefs, **8:** oysters and other bivalves. *Distribution verticale et fréquence des espèces de rongeurs dans la colonne stratigraphique composée des sections A-A' et B-B' étudiées à Crevillente (modifiée d'après Freudenthal et al., 1991). Symboles: **1:** conglomérats, **2:** grès, **3:** marnes, **4:** calcaires marneuses, **5:** calcaires, **6:** calcaires récifales, **7:** récifs, **8:** huîtres et autres bivalves.*

CR27 and CR28, which are all very poor, and were not sampled at a large scale.

Faunal list: Soricidae gen. indet., sp. indet., *Galerix iberica, Prolagus crusafonti, Heteroxerus* sp., *Spermophilinus turolensis* DE BRUIJN & MEIN, 1968, *Muscardinus* sp., *Hispanomys* aff. *adroveri* AGUSTI, 1986, *Cricetulodon lucentensis* (FREUDENTHAL, LACOMBA & MARTIN-SUAREZ, 1991), *Apodemus barbarae, Apodemus meini, Occitanomys adroveri.*

Crevillente 14 (CR14, 30SXH371923) - W of road N-330, in the Barranco de la Garganta, alongside a little macadam road, that begins at km stone 18 and ends in the village of Crevillente.

Faunal list: *Prolagus crusafonti, Eliomys truci, Muscardinus* sp., *Hispanomys* sp., *Hispanomys* aff. *adroveri, Neocricetodon seseae* AGUILAR, CALVET & MICHAUX, 1995, *Apocricetus plinii, Occitanomys adroveri, Occitanomys alcalai, Castromys inflatus* (MEIN, MOISSENET & ADROVER, 1990), *Stephanomys ramblensis.*

Crevillente 15 (CR15, 30SXH389945) - East of, and a few metres above road N-330, at km 16.5. It is a bed of white marl with gypsum, several metres thick, part of which is very rich in mammal remains.

Faunal list, Macromammals after Montoya & Alberdi (1995): *Paramachairodus* sp., *Microstonyx major,* Cervidae gen. indet., sp. indet., *Tragoportax gaudryi,* cf. *Hispanodorcas* sp., *Hipparion concudense* cf. *aguirrei* SONDAAR, 1961, *Dicerorhinus schleiermacheri, Deinotherium* cf. *giganteum,* Gomphotheriidae indet. Soricidae gen. indet., sp. indet., *Galerix iberica,* Talpidae gen. indet., sp. indet., *Prolagus crusafonti, Atlantoxerus adroveri* (DE BRUIJN & MEIN, 1968), *Spermophilinus turolensis, Eliomys truci, Muscardinus* sp., *Hispanomys adroveri, Hispanomys* sp., *Apocricetus plinii, Neocricetodon* sp., *Apodemus barbarae, Huerzelerimys turoliensis, Occitanomys adroveri.*

Crevillente 17 (CR17, 30SXH401949) - Along the road ascending Castro Hill, below the surface of the road, about 20 m before the first strong curve to the right. It probably corresponds with the locality Crevillente 5 by de Bruijn et al. (1975), which was sampled before the construction of the road. It is a black clay, rich in gastropods.

Faunal list: Chiroptera gen. indet., sp. indet., Soricidae gen. indet., sp. indet., Soricidae gen. indet., sp. 2, Desmaninae gen. indet., sp. indet., *Galerix iberica, Prolagus crusafonti, Heteroxerus* sp., *Eliomys truci, Muscardinus* sp., *Hispanomys* aff. *adroveri, Cricetulodon lucentensis, Occitanomys adroveri, Castromys littoralis* MARTIN SUAREZ & FREUDENTHAL, 1994.

Crevillente 22 (CR22, 30SXH399951) - On the right of the road ascending Castro Hill, about 100

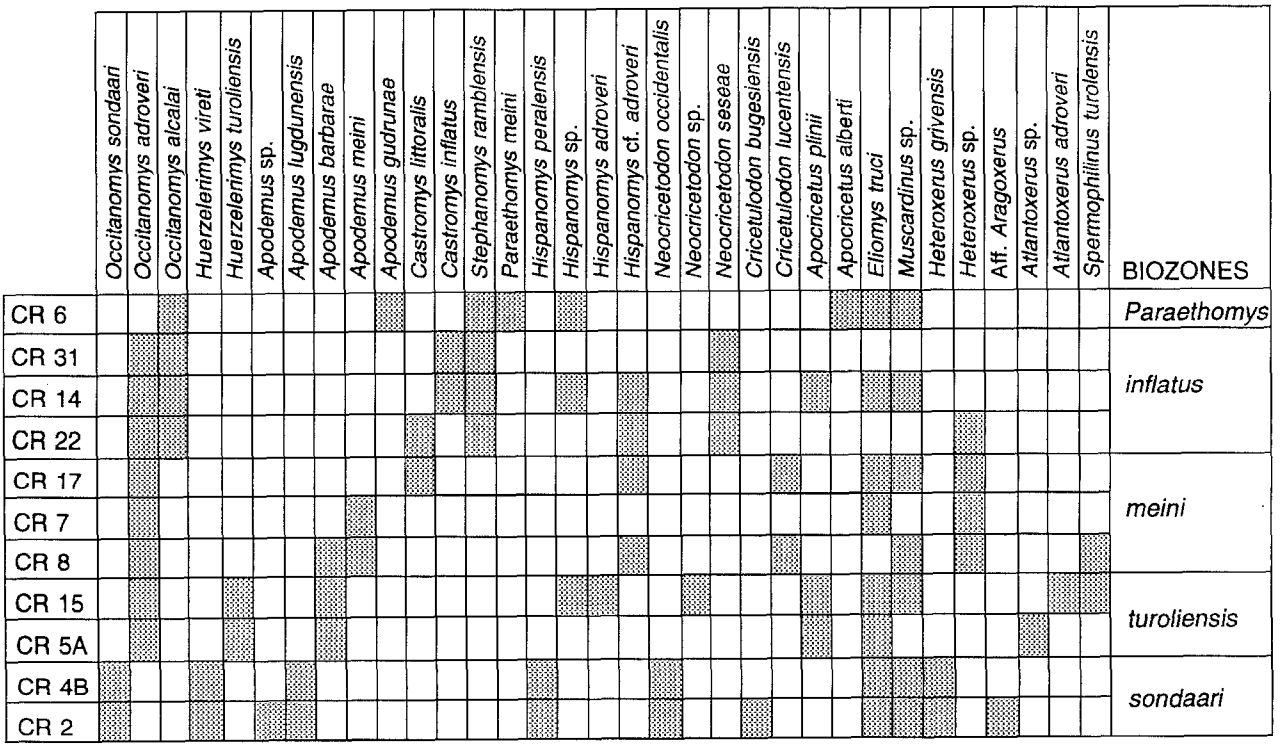

FIGURE 3 - Distribution of the species of rodents and biozonation. *Distribution des espèces de rongeurs et biozonation.*

m beyond Crevillente 17; it is a grey clay, about 1 m thick, with scarce gastropods.

Faunal list: *Galerix iberica, Blarinella* sp., Soricidae indet., *Prolagus crusafonti, Heteroxerus* sp., *Hispanomys* aff. *adroveri, Neocricetodon seseae, Occitanomys adroveri, Occitanomys alcalai, Castromys littoralis, Stephanomys ramblensis.*

Crevillente 31 (CR31, 30SXH372939) - On the eastern border of road N-330, about 50 m N of the bridge over the Barranco de la Garganta. It is a marly lens, about 30 cm thick, embedded in a limestone sequence.

Faunal list: *Prolagus crusafonti, Neocricetodon seseae, Occitanomys adroveri, Occitanomys alcalai, Castromys inflatus, Stephanomys ramblensis.*

BIOSTRATIGRAPHY

On the basis of the vertical distribution of the rodent species we propose a Biozonation of the Turolian of the area of Crevillente (Fig. 3). The paleontological data have been published by de Bruijn et al (1975), Freudenthal et al. (1991a, 1991b), and Martín Suárez & Freudenthal (1993, 1994). New data on the Cricetidae will be published in a revision of Late Miocene and Pliocene Cricetinae (Freudenthal, Mein & Martín Suárez in press).

The biozonation is based upon the distribution and the associations of the species of Muridae, that are dominant in our samples. In all localities there are at least two species of Muridae, which generally have a restricted vertical distribution. For the definition of the biozones we have taken into account the possibilities of correlation with other continental basins; in this respect the Muridae are the most appropriate, since the Cricetinae, that are abundant in Crevillente, are scarce in the stratotype of the Turolian, and therefore less suitable for correlations.

The alternation of marine and continental deposits implies the existence of mammal-barren intervals, both within and between biozones. According to chapter 7, C, 8 of the International Stratigraphic Guide (1994) this does not affect the continuity of the zonation. We distinguish five biozones, which are defined, from old to young, as follows:

- ***sondaari* Zone**. Concurrent-range Zone defined by the simultaneous occurrence of *Apodemus lugdunensis* and *Occitanomys sondaari*. The descendants of these two species, *Apodemus barbarae* and *Occitanomys adroveri* appear in the next Zone.

The lower limit of this Biozone coincides with the FAD of *Occitanomys sondaari* and *Huerzelerimys vireti*. The upper limit of the Biozone coincides with the FAD of *Occitanomys adroveri, Huerzelerimys turoliensis* and *Apodemus barbarae.*

The reference section is situated in the sequence of Castro Hill. For practical reasons its lower limit is the bottom of the locality CR2, because the underlying conglomerates do not contain any fossiliferous locality; its upper limit is the top of the locality CR4B. Thus, the reference section includes a marine deposit (barren interval) with abundant bivalves and foraminifera.

In Crevillente the distribution ranges of the two name-giving species of the biozone are restricted to the mentioned reference section, which includes the localities CR2, CR3, CR4, and CR23. CR4B is a lateral equivalent of the reference section. Both species are easily identified and together they comprise about 40% of the available specimens (Martín Suárez & Freudenthal 1993).

As may be seen in Fig. 3, the range of distribution of *Huerzelerimys vireti* is also restricted to this Biozone, but we did not choose that species for the definition of the zone, because it is less frequent. Among the Cricetidae *Hispanomys peralensis, Neocricetodon occidentalis* and *Cricetulodon bugesiensis* are restricted to (part of) this Biozone. The Sciuridae *Heteroxerus grivensis* and *Aff. Aragoxerus* have only been found in this Biozone.

- ***turoliensis* Zone**. Concurrent-range Zone defined by the presence of *Huerzelerimys turoliensis* and *Apodemus barbarae.* Its lower limit coincides with the upper limit of the previous Zone, and is the FAD of the two name-giving species and of *Occitanomys adroveri*. Its upper limit is the FAD of *Apodemus meini* and the LAD of *Huerzelerimys turoliensis.* The range of distribution of *H. turoliensis* is restricted to this Zone. On the other hand, *Apodemus barbarae* is found in younger levels too.

The reference section is exposed at the crossroads of the N-330 with the little road that ascends Castro Hill. It consists of a sequence of 10 m of grey-white marls with abundant gypsum, overlying a massive conglomerate/sandstone bed, and overlain by marine beds rich in oysters, algal mats, etc. The limits of the reference section coincide with the limits of the marl body. Mammal localities are CR5A, CR15, and CR18.

The lower limit of this Biozone coincides with an important faunal renovation. Besides the appearance of both name-giving species, we see the first occurrences of *Occitanomys adroveri* and *Apocricetus plinii. Hispanomys adroveri, Atlantoxerus adroveri* and *Spermophilinus turolensis* are restricted to this Biozone (CR15).

- *meini* Zone. Interval Zone between the FAD of *Apodemus meini* and the FAD of *Stephanomys ramblensis*. Its lower limit is the upper limit of the previous Zone. The upper limit of this Biozone is the FAD of *Occitanomys alcalai* + *Stephanomys ramblensis*. *Cricetulodon lucentensis* is restricted to this biozone.

The reference section is situated in the Castro Hill sequence, and includes the localities CR8, CR7 and CR17; it is formed by a set of dark marls and lutites (about 13 m), between two bodies of sandstones with abundant oysters. These sandstones form clearly recognizable marker beds in the field. The limits of the reference section are the lower and upper contact of the marls, or, in other words, the bottom of the locality CR8 and the top of locality CR17.

In the lower part of this Biozone (CR8) we find the last record of *Apodemus barbarae*, and the first record of the cricetids *Cricetulodon lucentensis* and *Hispanomys* cf. *adroveri*. These Cricetidae are found in younger levels too, but they are absent in part of the Biozone (CR7). This absence, in our opinion, is due to ecological conditions that will be analyzed in a forthcoming paper on paleoecology (Martín Suárez & Freudenthal, in prep.).

This Biozone contains a Biohorizon, defined by the LAD of *Apodemus meini* and the FAD of its descendent *Castromys littoralis*.

- *inflatus* Zone. Interval Zone between the FAD of *Stephanomys ramblensis* and the FAD of *Paraethomys meini*. Its lower limit is the upper limit of the *meini* Zone and its upper limit coincides with the disappearance of *Castromys inflatus*. This species is chosen as the name-giving taxon of this Interval Zone, because it is an easily identifiable murid of big size, though not used in the definition of the zone limits (see International Stratigraphic Guide ed. 1994, p. 61).

The reference section is composed of a lower part exposed in the Castro Hill, and an upper part exposed in the Crevillente-dam section (eastern border of the road Crevillente-Aspe). It consists of a set of marls and marly limestones overlying a reef. On top there are sandstones with abundant oysters overlain by a second reef. It includes the localities CR22, CR14 and CR31.

The locality CR22 contains the first record of *Occitanomys alcalai* (though in very low numbers), coexisting with *Occitanomys adroveri*. *Stephanomys ramblensis* is an important index fossil, but unfortunately in Crevillente it is extremely scarce (less than 5%), and only useful in rich localities. As for the Cricetidae, in this Biozone we have the last record of *Hispanomys* cf. *adroveri* and *Apocricetus plinii; Neocricetodon seseae* is restricted to this Biozone.

- *paraethomys* Zone. Concurrent-range Zone, defined by the simultaneous occurrence of *Paraethomys meini* and *Apodemus gudrunae*. In our section its lower limit coincides with the upper limit of the *inflatus* Zone (FAD of *Paraethomys meini*). The upper limit can not be defined in the area of Crevillente, since no younger fossiliferous localities are present.

Its reference section is exposed in the outcrop of Crevillente-dam, and located in a thick body of marls and lutites (20 m), unconformably overlying a reef limestone. The lower limit coincides with this unconformity, and the upper limit is the top

Localities Crevillente	BIOZONES CREVILLENTE	Thaler 1972	van de Weerd 1976	Mein 1990	van Dam 1997	Other localities	Stage mar.	Stage cont.	Series
CR6 CR28 CR19	*Paraethomys*	zone Seynes	*Stephanomys*	MN13	M3	Masada del Valle 7 Rambla de Valdecebro 6 Arquillo, La Fontana	MESS	TUROLIAN	MIOCENE
CR31 CR14 CR22	*inflatus*	souszone Alcoy	*ramblensis*		M1	Rambla de Valdecebro 3 La Gloria 6			
CR17 CR7 CR8	*meini*	zone Teruel	*Parapodemus*			Jun 2B, 2C	TORTONIAN		
CR18 CR15 CR5A	*turoliensis*	souszone	*barbarae*	MN12	L	Los Mansuetos, Aljezar B, Casa del Acero, Concud Masada del Valle 2			
CR4B CR23 CR2	*sondaari*	Teruel	*Parapodemus lugdunensis*	MN11	K	Tortajada A, Amberieu 3 Vivero del Pino, Mollon Aguanaces, Puente Minero			

FIGURE 4 - Bio- and chronostratigraphic correlations. *Corrélations bio- et chronostratigraphiques.*

of the marls, which are unconformably overlain by sandstones with bivalves and the conglomerates (Pliocene?), that form the top of the section. The marls are supposed to contain the locality CR6 (De Bruijn et al., 1975), that is no longer accessible. In the same level we have sampled the localities CR19, CR27 and CR28, which are unfortunately very poor, and did not yield significant collections; they do, however, contain the same species as CR6, and therefore permit a correlation.

BIOSTRATIGRAPHICAL CORRELATIONS

The quality of the exposures in the area has enabled us to construe a formal biozonation of the continental deposits of the Turolian of Crevillente. It is a very detailed local biozonation. One might object that the subdivision is excessively detailed, but in fact it only pretends to be useful in the area under study, whilst, on the other hand ,this extreme subdivision allows a detailed correlation with other continental basins.

We will try to correlate these Zones (Fig. 4) with the biozonations of van de Weerd (1976) and van Dam (1997), and make some remarks on the division by Thaler (1972). The revision of the "zonation" by Mein (1990) introduces, in comparison with earlier versions, a "reference fauna" from one single locality for each one of the subdivisions. Mein's "zonation" is not made up of Biostratigraphical Units or Biozones (which should be bodies of sediments); yet, it is widely used, and cannot be omitted in our comparisons. To a certain extent they might be considered as Oppel-Zones; however, the second edition of the International Stratigraphic Guide rejects the Oppel-Zone as a formal zone. Therefore, in this paper we refer to the "MN-zonation" with the informal denomination "MN units", with which we will compare, though not correlate, our Zones.

- *sondaari* Zone. The type-localities of the name-giving species (Tortajada A for *O. sondaari,* and Mollon for *H. vireti*) can be correlated with this Biozone. It is comparable to MN unit 11 (Mein, 1990).

In our biozonation the lower limit of the *sondaari* Zone is the FAD of *Occitanomys sondaari* and *Huerzelerimys vireti,* and this FAD coincides with an important faunal renovation that took place at the Vallesian/Turolian transition.

In the zonation by van de Weerd (1976) the upper limit of the *Progonomys hispanicus* Zone coincides with the lower limit of the *Parapodemus lugdunensis* Zone, and is based upon the first appearance of *P. lugdunensis*. After the publication of that zonation new localities have been discovered, like Dionay (Farjanel & Mein 1984), in which *Occitanomys hispanicus* and *Apodemus lugdunensis* coexist. Such localities should formally pertain to the *Parapodemus lugdunensis* Zone of van de Weerd's biozonation or to zone K of van Dam (1997). Accordingly, the limit between the mentioned biozones does not coincide with the Vallesian-Turolian faunal renovation.

- *turoliensis* Zone. This Biozone is restricted to the deposits where *Huerzelerimys turoliensis* and *Apodemus barbarae* are found associated. The type-locality of these two species is Los Mansuetos (Teruel, Spain). In Crevillente the species *Atlantoxerus adroveri* and *Spermophilinus turoliensis*, that are also considered good markers of the Turolian (Marks 1971), are restricted to this Biozone. So, it is well-correlated with Los Mansuetos, stratotype of the Turolian, and it may be compared with part of MN unit 12.

Van de Weerd defined the *Parapodemus gaudryi* barbarae Zone as "from the entry of *P. gaudryi barbarae* to the entry of *Stephanomys ramblensis*". This is also the definition of zone L by van Dam (1997). In Teruel the distribution ranges of these two species are contiguous, but in the area of Crevillente the situation is more complicated: between the disappearance of *Apodemus barbarae* and the appearance of *Stephanomys ramblensis* there is a sequence of about 20 m of sediments, containing several mammal localities (CR7, CR17), that did not yield any of the mentioned species.

- *meini* Zone. This biozone is formed by the deposits with only one species of *Occitanomys (O. adroveri)*, and without any *Huerzelerimys* species (see Fig. 3). The localities CR8 and CR7 contain *Apodemus meini*, which is unknown outside the area of Crevillente. CR17 contains *Castromys littoralis*, which is not known from Teruel, but does occur in Jun 2B, Jun 2C and Viznar 1 (Eastern sector of the Granada Basin, Martín Suárez & Freudenthal 1994). These localities may be placed in the upper part of the *meini* Interval Zone, above the *Castromys littoralis* FAD, or in the lower part of the *inflatus* Zone, because the absence of *Stephanomys* can not be considered decisive, in view of the small number of specimens available.

This Biozone shares with the *Parapodemus barbarae* Zone of van de Weerd (1976), and consequently with zone L of van Dam (1997), the definition of its upper limit (FAD of *S. ramblensis*). It is not comparable with any MN unit.

The complex of our first three Biozones (*sondaari, turoliensis* and *meini*), which form the lower part of the sequence, is comparable with the "Zone de Teruel, Sous-zone de Teruel" of Thaler (1972).

- ***inflatus* Zone**. Deposits with *Stephanomys ramblensis* and any *Castromys* species pertain to this Biozone. In CR22 appears *Stephanomys ramblensis,* which has been considered a good guide fossil by various authors. In Crevillente it is very scarce as we have said before. Its presence permits a partial correlation with the *Stephanomys ramblensis* Zone in Teruel (van de Weerd, 1976), and with subzone M1 (van Dam, 1997). It is comparable to the oldest associations attributed to MN unit 13.

In CR14 and CR31 we find *Stephanomys ramblensis* and *Castromys inflatus*. The same association has also been encountered in some localities in the area of Teruel, like La Gloria 6 (type-locality of *Castromys inflatus*), La Gloria 1, Valdecebro 3, Velilla and Tramacastiel (Mein et al., 1990). These localities represent the upper part of the *inflatus* Zone, characterized by the presence of *Apodemus gudrunae.* In our area that species appears later, simultaneously with *Paraethomys meini*, in the next Zone. That later appearance is probably not real, but caused by a gap in the fossil record in the Crevillente area.

The lower limit of this Biozone, defined as the FAD of *Occitanomys alcalai* and *Stephanomys ramblensis,* corresponds to changes in the mammal fauna accompanying the Messinian/Tortonian boundary.

- ***paraethomys* Zone.** In the area of Crevillente we find the association of Muridae *Apodemus gudrunae, Stephanomys ramblensis, Paraethomys meini* and *Occitanomys alcalai*. It may be compared to the youngest localities attributed to MN unit 13. It may be correlated with subzone M3 of van Dam (1997).

The type-locality of *Apodemus gudrunae* and *Stephanomys ramblensis* is Rambla de Valdecebro 3, which is older than CR6 (*Paraethomys meini* is absent in Valdecebro 3, and present in CR6).

Van de Weerd (1976) defined the *Stephanomys ramblensis* Zone as "from the entry of *Stephanomys ramblensis* to the entry of *Castillomys crusafonti gracilis*". So this Zone contains the Miocene-Pliocene limit: *Castillomys gracilis* was considered a good marker for the beginning of the Pliocene, but Mein et al. (1990) report two sections in Teruel, Lomas de Casares and Celadas, with several localities dated as Pliocene on other grounds, in which *C. gracilis* is not yet present.

The lower limit of this Biozone coincides with the LAD of *Occitanomys adroveri* and *Castromys inflatus.* This limit represents an important faunal renovation that, in our opinion, coincides with the recuperation of wet climate conditions at the end of the Messinian.

Our Zones *inflatus* + *Paraethomys*, which form the upper part of the sequence, are comparable with the "Zone de Seynes, Sous-zone de Alcoy" (Thaler 1972).

CHRONOSTRATIGRAPHY

The sections studied in the area of Crevillente are Turolian, considered to be equivalent to the Upper Tortonian and Messinian (Fig. 4).

The stratotype of the Turolian is the section of Los Mansuetos (Crusafont 1965; for description see Marks 1971). The participants of the Reissensburg Congress (1988) agreed upon an equivalence of the Turolian with the units MN11, MN12 and MN13 of Mein (1975). During that congress each MN unit was assigned a "reference fauna" from an especially rich locality. Through this procedure we have a series of units with undefined limits, but with supposed chronological implications, which are difficult to conform with the recommendations of the International Subcommission of Stratigraphic Classification (ISSC). Nevertheless the MN units appear to be useful, especially in long distance correlations.

All the faunal associations found in the stratotype of the Turolian (Los Mansuetos) pertain to the *turoliensis* Zone. There are neither older nor younger faunas. In Crevillente we have records of the entire Turolian in direct lithostratigraphical superposition, unfortunately without any underlying or overlying mammal localities: the oldest (Neogene) sediments of the sequence are marine marls, overlain by about 50 m of conglomerates, on top of which lies the oldest mammal locality, CR2. The youngest locality discovered in the basin is CR6, and above it there is a level of marine sandstones, rich in oysters and other bivalves, gradually passing upwards to microconglomerates, and the sequence ends with some 25 m of typically continental conglomerates. So, although the Crevillente sequence represents the most complete Turolian section known, unfortunately both the lower and the upper boundary of the Turolian are missing.

On the other hand, the biostratigraphical and paleoecological analysis do allow to determine the limit Tortonian/Messinian in the Crevillente section: it is located in the marine limestones between CR17 and CR22.

CONCLUSIONS

The Late Miocene sediments in the area of Crevillente were deposited in a delta with alternating marine and continental conditions. The continental deposits are rich in fossil micromammal localities, and can de classified biostrati-

graphically in five local biozones: *sondaari, turoliensis, meini, inflatus* and *Paraethomys*; part of them can be correlated with the stratotype of the Turolian. The alternation with marine levels may take place within a biozone or between biozones. The marine deposits contain two reef phases, in the upper part of the sequence.

Chronostratigraphically, the deposits belong to the Turolian or, in marine terms, to the Upper Tortonian and Messinian. The limit between these two Stages coincides in Crevillente with the appearance of *Occitanomys alcalai* and *Stephanomys ramblensis* in the continental deposits, and must be located shortly above CR17.

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