Geologica Acta, 15, Nº 2, June 2017, 121-134
DOI: 10.1344/GeologicaActa2017.15.2.4

geologica acta

Micromammal biostratigraphy of the Alcoi Basin (eastern Spain): remarks on the Pliocene record of the Iberian Peninsula

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ABSTRACT

The study of 13 micromammal localities in the southern section of the Gormaget ravine (Alcoi Basin, SE Spain) and another 4 localities in the northern section has allowed us to define four local biozones in the dawn of the Pliocene, possibly recording the Mio-Pliocene boundary. The great density of localities close to the Mio-Pliocene boundary has enabled us to achieve a great resolution in the biozonation of the earliest Pliocene, only comparable in the Iberian Peninsula to the record of the Teruel Basin (NE Spain). We interpret these biozones in the light of the Neogene Mammal units and the European Land Mammal Ages, and correlate them with other local biozones defined for the same time span in the Iberian Peninsula.

KEYWORDS **Micromammal. Biostratigraphy. Alcoy Basin. Spain. Early Pliocene.**

INTRODUCTION

A great number of vertebrate localities have been described in the Alcoi Basin (SE Spain) among which only the classic locality of Alcoi-Mina, known since the 19th century (Montoya *et al.*, 2006), has yielded macromammal remains. In this work, we summarize the data from 13 micromammal localities of the southern section of the Gormaget ravine and another 4 sites of the northern section (Figs. 1; 2; 3, Tables 1; 2) in order to give, for the first time, a biozonation for Alcoi Basin. Other micromammal localities described in the area are Alcoi-Barranc (Thaler *et al.*, 1965; Adrover, 1969), Alcoi-N (López Martínez, 1989), Alcoi-4B (Freudenthal *et al.*, 1998), Alcoi-2 (Esteban Aenlle and Lacomba, 1988) and Alcoi Cotes Altes-2 (Mansino *et al.*, 2009). Among these, Alcoi-Barranc and Alcoi-N are lost localities, since the former lies under a dwelling and the location of the latter is not clear, while

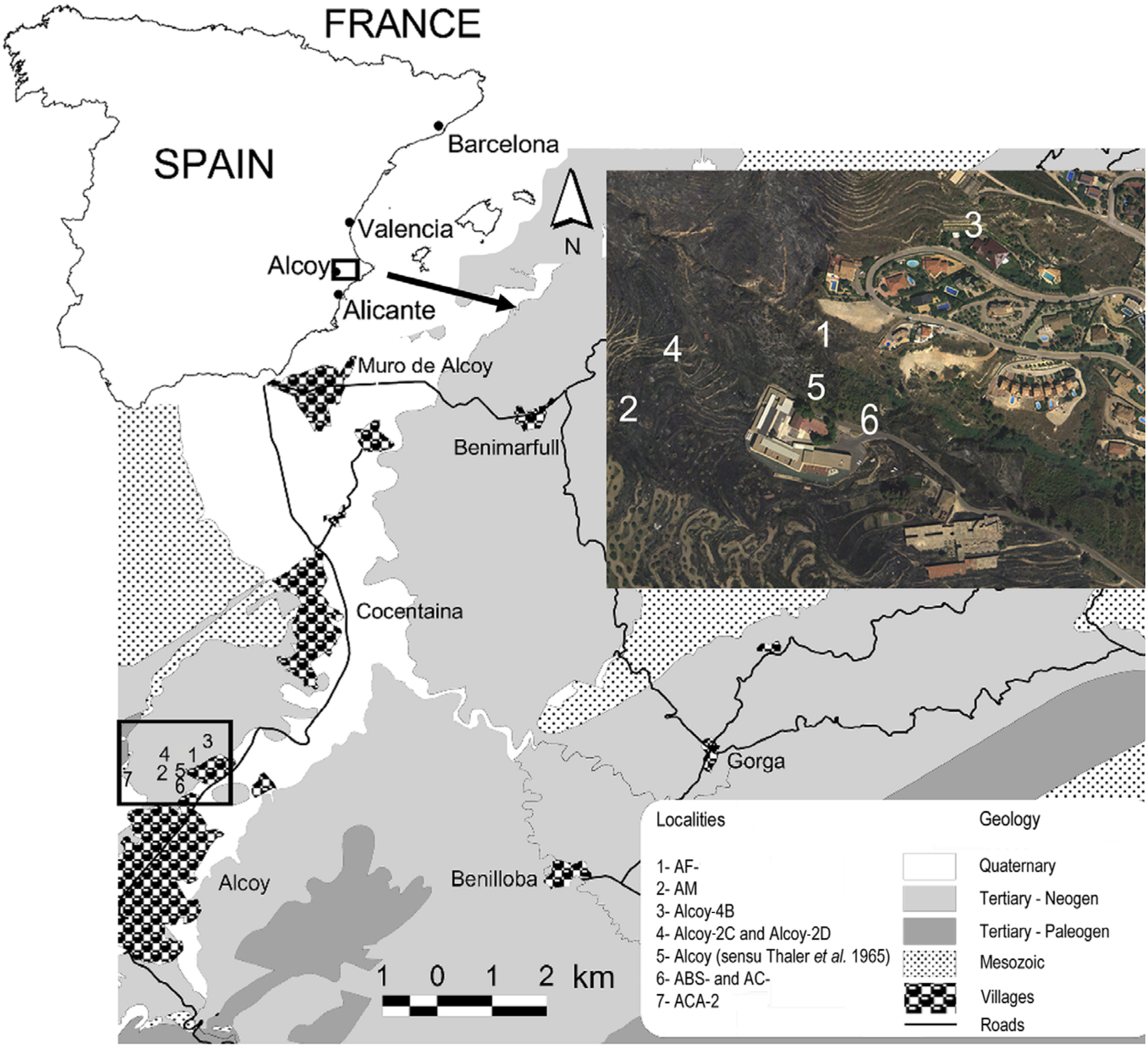

FIGURE 1. Geographic and geological setting of the Alcoi Basin, showing the location of the outcrops of the Gormaget ravine. The location of other fossil localities studied previously is also shown: Alcoi (Thaler *et al.*, 1965), Alcoi-4B (Freudenthal *et al.*, 1998), AM (Alcoi-Mina, Montoya *et al.*, 2006), ACA-2 (Alcoi Cotes Altes 2, Mansino *et al.*, 2009).

Alcoi-2 and Alcoi-4B have just been recently relocated. The age of the studied localities ranges, probably, from the latest Turolian (Ventian, sensu Morales *et al.*, 2013) to the Early Pliocene. The great number of sites covering a relatively narrow time span has allowed us to describe the biozonation of MN14 of the Alcoi Basin with a great degree of resolution, defining four different biozones, and to compare it with other Iberian basins.

Other relevant works dealing with the latest Miocene and/or earliest Pliocene of Spain are those of van de Weerd (1976), Mein *et al.* (1990) and van Dam *et al.* (2001) in the Teruel Daroca-Calatayud and Teruel basins, Agustí *et al.* (1983, 1999, 2006) and Garcés *et al.* (1998, 2001) in the Fortuna Basin, Martín Suárez and Freudenthal (1998) in the Crevillente outcrops of the Bajo Segura Basin, García-Alix *et al.* (2008a) in the Granada Basin and Minwer-Barakat *et al.* (2012a) in the Guadix Basin.

STRATIGRAPHIC RECORD AND INTERPRETATION

Geological context of fossil sites

The Betic cordillera can be subdivided into several major tectonic domains: the External Betics (separated in Prebetic

FIGURE 2. Detailed lithostratigraphic log of the South and North sections of the Gormaget ravine (Alcoi Basin), showing the position of the localities ABS-1 to 10, AC-0C, 0B and 0, AL2-C and D. The dashed lines connect the ABS section with the supposed stratigraphic position of Alcoi Forn (AF) deposits. Scale in metres.

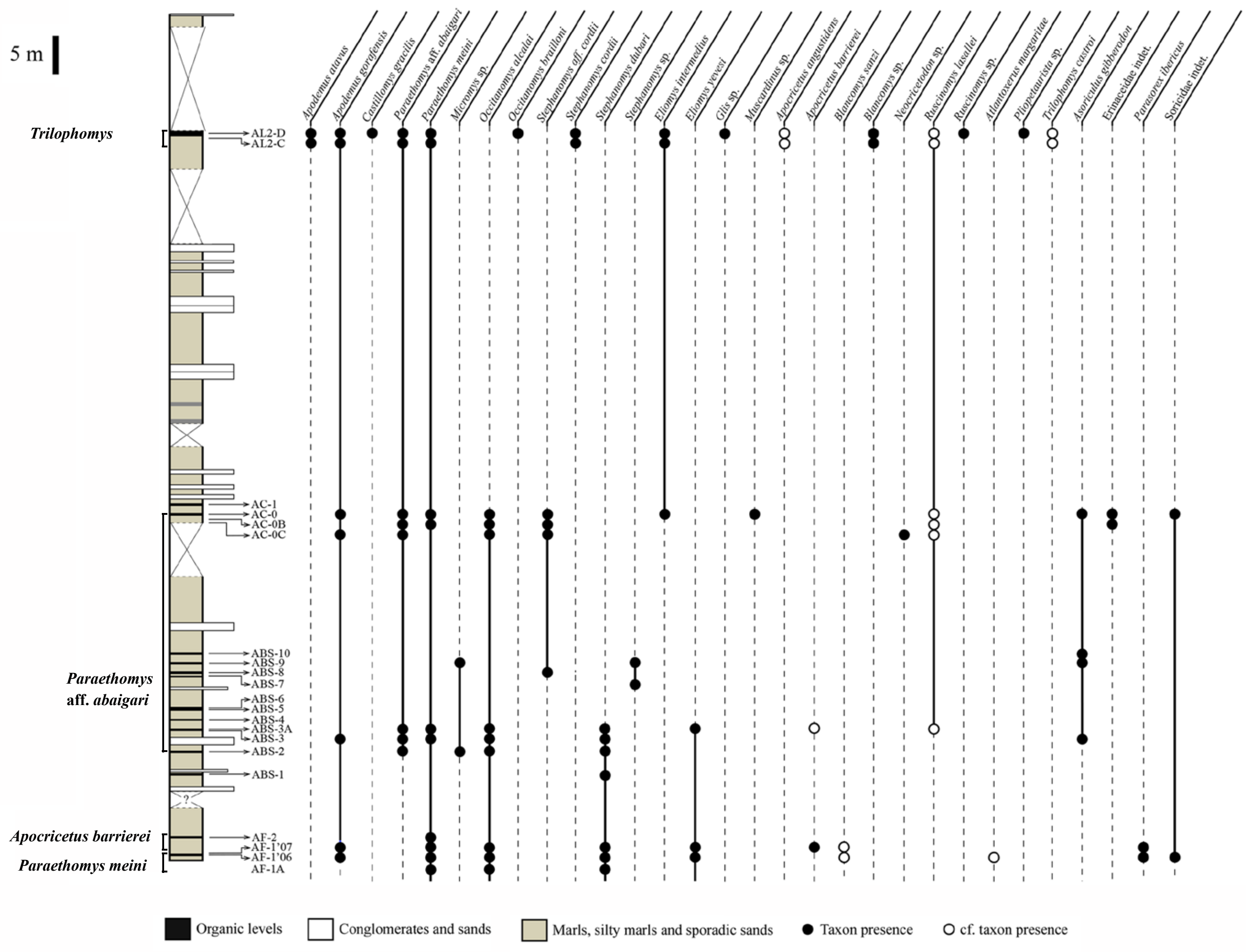

FIGURE 3. Synthetic stratigraphic log of the South and North sections of the Gormaget ravine (Alcoi Basin), showing the position and proposed biozonation of the localities ABS-1 to 10, AC-0C, 0B and 0, AL2-C and D, and AF-1'06, A, 1'07 and 2. The dashed lines connect the ABS section with the supposed stratigraphic position of AF deposits. Scale in metres.

and Subbetic), the Internal Betics (with differentiated metamorphic complexes), the Gibraltar Flysch units and the Neogene basins. Mesozoic rocks with neritic carbonates and detritic intercalations, form the substratum of the inner Prebetic in the studied area. A widespread detachment at the level of the Triassic evaporites caused the formation of thrusts and folds showing a ENE-WSW trend.

Previous geological studies of this area were carried out by Durand Delga *et al.* (1964), Montenat (1973: 1009-1014, fig. 153) and Aguirre *et al.* (1975), although one of the first studies on "Puntal de la Mina" section was performed in 1853 by Gervais. More recently, the Alcoi Basin has been studied by Pierson d'Autrey (1987).

In the context of the Betic Range, the stratigraphic record of Neogene postorogenic basins provides essential information for understanding the final evolution on the Atlantic-Mediterranean communication (Hüsing *et al.*, 2010; Corbí *et al.*, 2012; Minwer-Barakat *et al.*, 2012b). The closure of the seaway and the isolation of the basins are diachronic, so the marine to continental transition occurs at a different time depending on its geographical location (Krijgsman *et al.*, 2000).

In the geographical framework of Alcoi, the tectonic context of the Betic Range allowed the development of vast synclinal depressions oriented ENE-WSW and filled during the Miocene with the characteristic marine marls in tap facies (Pierson d'Autrey, 1987). The isolation from the sea in the North Prebetic basins of Alicante occurred very early (Tortonian), and marine sediments are only represented in the Unit I of Viseras *et al.* (2004). In this way, a marine basal Tortonian with carbonate facies and limited thickness (always less than 30m) was deposited over the tap facies in angular unconformity. Over these deposits lies continental facies, essentially constituted by lacustrine and fluvial sediments. These first continental deposits belong to Unit II of Viseras *et al.* (2004). They are represented by alluvial fan facies in the margin and fluvio-lacustrine facies in the centre. In this context, the Miocene-Pliocene transition took place in a continental environment (Aguirre *et al.*, 1975).

The central part of the Alcoi Basin forms a depression that disrupts the structural trend of the Betic mountain chain. This depression can be divided into several quadrangular grabens, one of them being the Almudaina Graben (Pierson d'Autrey, 1987), where the studied deposits are located.

Two sedimentary associations in continental facies are present over the marine lower Tortonian (Pierson d'Autrey, 1987): a white lacustrine sequence series and a red fluvial sequence that fills all the central part of the Alcoi Basin, covering the ancient sediments.

The deposits of the Alcoi Basin contain a great number of interesting fossil sites which are very important to understand the paleoenvironmental evolution of this area. Continental localities in lignite deposits (like Alcoi-Mina) belong to the fluvial conglomerates, silts and clays unit inside synthem V of Ballesteros *et al.* (2007), which covers different Paleogene and Miocene units in angular discordance.

The studied series of the Gormaget ravine are located SE of the Alcoi fault (030-050/55SE) (Pierson d'Autrey, 1987), which divides the Neogene record of the syncline in different sub-basins and, more recently, influenced the position of the studied stratigraphic record.

Stratigraphy and sedimentology of the studied deposits

In the studied area of the Gormaget ravine, it has been possible to obtain synthetic stratigraphic information of about 68 metres in the southern side of this ravine and about 4 metres in the northern side (Figs. 2; 3). This series includes materials located very close to the outcrop of Alcoi-Mina, like the Alcoi Cristian (AC), Alcoi Barranc Sud (ABS) and Alcoi-2 (AL2) sections, of which the faunal lists are summarized in Table 2.

The studied area is dominated by sandy-marl deposits with gray to brownish colours, which can be several metres thick. In these marls, there are frequent isolated pebbles as well as interbedded sandy to conglomerate alayers. Conglomerate beds are relatively common, reaching a thickness of a metre or more. The presence of organic levels of intense dark colour is also remarkable. In about 20m in the ABS section, we identify up to 11 of these organic levels (fossil levels ABS-1 to ABS-10, see Figs. 2; 3). Conglomeratic intercalations are frequent in this section, usually lacking internal structure, with a slightly erosive base and a yellow sandy matrix. In the middle to upper part of the sandy marls, organic levels are always present. Some of the conglomerates present in the ABS section are coarsening upwards, and some sandy intercalations show the existence of tractive sedimentary structures. In some organic and sandy marl levels, the remains of fresh-water gastropods are common. The ABS conglomerates differ from those at the top of the Gormaget ravine (stratigraphically higher), which have a reddish matrix, a larger average size of the pebbles and greater thickness of the strata.

TABLE 1. Abbreviations and coordinates of the fossiliferous sections of the Alcoi Basin and the sites of La Bullana in the Cabriel Basin

Abbreviation	Name	X	Y
ABS-	Alcoi Barranc Sud	-0,4701	38,7187
AC-	Alcoi Cristian	-0,4700	38,7187
AF-	Alcoi Forn	-0,4708	38,7195
AL2-	Alcoi 2	-0,4726	38,7194
LB2B	La Bullana 2B	-1,3829	39,4568
LB3	La Bullana 3	-1,3829	39,4568

Overlying the ABS section, and after a covered stretch of about seven metres, we described a section named AC (Mansino *et al.*, 2015b). The facies association has some differences with that of the ABS section. The organic levels of AC are situated in the middle or upper part of sandy marls, which are arranged above each conglomeratic intercalation or just in contact with the top of conglomerates. The AC section shows evidence of pedological structures in marl levels, and irregular precipitation of carbonates. The level AC-0 is possibly similar in age to the classic (and lost) locality of Alcoi Barranc (Adrover, 1969) (Mansino *et al.*, 2015b).

The uppermost organic layer of the sections here described corresponds to the fossil site of Alcoi-2D (AL2-D), although other organic levels are presented above the AC deposits, like Alcoi-Mina inferior, being of little importance and without fossil remains. The levels AL2-C and AL2-D are considered equivalent to the fossiliferous levels of the classic locality of Alcoi-Mina (Mansino *et al.*, 2013). AL2-D has a thickness of more than 60cm, only visible in a small outcrop. At first sight, we can find abundant gastropod shell fragments. In the lower part of AL2-D there is a fine clay level with intense ochre colour (AL2-C). In addition, in the middle and lower part of the organic layer we detect two light coloured marly limestone levels. AL2-D seems to be a palaeosoil, formed in "organic soil material" (Soil Group of the Histosols; Food and Agriculture Organization of the United Nations, FAO).

TABLE 2. Faunal lists and proposed biozonation of the localities of the Gormaget ravine (Alcoi Basin). Abbreviations, Mio: Miocene; Plio: Pliocene; Ru: Ruscinian; Tu: Turolian

Epoch	ELMA	MN	Locality	Faunal list
Pliocene	Ruscinian	MN14	AL2-D	*Apodemus atavus, Apodemus gorafensis, Castillomys gracilis, Paraethomys meini, Paraethomys* aff. *abaigari, Occitanomys brailloni, Stephanomys cordii, Apocricetus* cf. *angustidens, Ruscinomys* cf. *lasallei, Ruscinomys* sp.*, Blancomys* sp.*, Trilophomys* cf. *castroi, Eliomys intermedius, Glis* sp.*, Pliopetaurista* sp.
			AL2-C	*Apodemus atavus, Apodemus gorafensis, Paraethomys meini, Paraethomys* aff. *abaigari, Stephanomys cordii, Apocricetus* cf. *angustidens, Ruscinomys* cf. *lasallei, Blancomys* sp.*, Trilophomys* cf. *castroi, Eliomys intermedius*
			AC-0	*Apodemus gorafensis, Paraethomys meini, Paraethomys* aff. *abaigari, Occitanomys alcalai, Stephanomys* aff. *cordii, Ruscinomys* cf. *lasallei, Eliomys intermedius, Muscardinus* sp.*, Asoriculus gibberodon, Erinaceidae indet., Soricidae* indet.
			AC-0B	*Paraethomys meini, Paraethomys* aff. *abaigari, Occitanomys alcalai, Stephanomys* aff. *cordii, Ruscinomys* cf. *lasallei, Erinaceidae indet.*
			AC-0C	*Apodemus gorafensis, Paraethomys* aff. *abaigari, Stephanomys cordii, Neocricetodon* sp.*, Occitanomys alcalai, Ruscinomys* cf. *lasallei*
			ABS-10	*Asoriculus gibberodon*
			ABS-9	*Micromys* sp.*, Asoriculus gibberodon, Stephanomys* sp.
			ABS-8	*Stephanomys* aff. *cordii,*
			ABS-7	*Stephanomys* sp.
			ABS-3A	*Paraethomys meini, Paraethomys* aff. *abaigari, Occitanomys alcalai, Stephanomys dubari, Apocricetus* cf. *barrierei, Ruscinomys* cf. *lasallei, Eliomys yevesi*
			ABS-3	*Apodemus gorafensis, Paraethomys meini, Paraethomys* aff. *abaigari, Occitanomys alcalai, Stephanomys dubari, Asoriculus gibberodon*
			ABS-2	*Paraethomys* aff. *abaigari, Occitanomys alcalai, Stephanomys dubari*
			ABS-1	*Stephanomys dubari*
			AF-2	*Paraethomys meini*
			AF-1'07	*Apodemus gorafensis, Paraethomys meini, Stephanomys dubari, Occitanomys alcalai, Eliomys yevesi, Apocricetus barrierei, Blancomys* cf. *sanzi, Parasorex ibericus*
Mio/Plio	Ru/Tu	MN13? MN14?	AF-1A	*Paraethomys meini, Stephanomys dubari, Occitanomys alcalai*
			AF-1'06	*Apodemus gorafensis, Paraethomys meini, Stephanomys dubari, Occitanomys alcalai, Eliomys yevesi, Atlantoxerus* cf. *margaritae, Blancomys* cf. *sanzi, Parasorex ibericus, Soricidae* indet.

The Alcoi Forn (AF) section cannot be correlated with the rest of the sections presented in this paper. However, the materials are very similar to those described above, and their faunal content suggests a slightly older age (Mansino *et al.*, 2015a).

Sedimentological interpretation

The Gormaget ravine section includes fluvial sediments overlying the lacustrine facies developed in the center of the basin, arranged at the foot of the southern slopes of the Benicadell and Mariola ranges and the northern slopes of the Menechaor range (Pierson d'Autrey, 1987). The studied sediments consist of characteristic facies of alluvial systems with interbedded sandy marls with organic layers, floodplain deposits and intercalations of lacustrine sediments. Upwards, reddish colours are predominant, and conglomerates take more importance in both thickness and grain size, while organic marls are absent (Mansino *et al.*, 2013; Mansino *et al.*, 2015a, b).

The alluvial systems are the result of a complex interaction of climate and tectonics. In this sense, the sediments presented in the fluvial stream also depends on the topography, geology and hydrology of the basin (de Pedraza, 1996). The studied stratigraphic section is organized in a progradational trend, showing a gradual transition from a lower unit of organic marls with sporadic conglomerates to an upper, more proximal, conglomerate unit. This is a context in which sediment supply surpasses subsidence.

The Upper Miocene continental deposits of the Alcoi Basin show the existence of a large lake surrounded by the mountain ranges of Benicadell to the north, Cantauco to the south and west and Mariola to the west (Fig. 1) (Pierson d'Autrey, 1987). These reliefs provided abundant detrital sediment that filled the lacustrine basin. Surrounding river floodplain environments were developed, containing frequent organic levels with vertebrate remains. The upper red sediments (Pierson d'Autrey, 1987) are related to the evolution of the sedimentary and climatic context.

Alluvial facies like those present in the fossiliferous sites are located in the margins of the basin. Conglomeratic bodies were interpreted as meandering channels, more or less anastomosed, within a marly to silty floodplain (Pierson d'Autrey, 1987). The uppermost massive conglomerates have been interpreted as subaerial deposits, formed by gravitational mass or debris flows (Santisteban *et al.*, 1997).

The sedimentary sequence with vertebrate outcrops represents a fluvial environment in which floodplain deposits are dominant. They are deposited over lacustrine environments, showing the progradation of a fluvial system. Thick red conglomeratic banks are developed on the upper part of the series, showing the progressive influence of the contributions in the filling of the basin.

The organic marls represent lacustrine deposits that may be interpreted as expansive periods of a lake or small isolated ponds between river branches, at the margins of alluvial plains or in an area between two fans. They must have developed in a flooded area of low energy. The lenticular shape of some of the organic levels in the studied area is probably related to the existence of depressions of limited extension in which a poor drainage occurred. In this sense, organic deposits could accumulate vertebrate remains representing different palaeoenvironments around them.

BIOZONATION OF THE LATE TUROLIAN-EARLY RUSCINIAN OF THE ALCOI BASIN

The study of the taxa present in the Alcoi Basin has allowed us to distinguish four biozones in the Early Ruscinian and, probably, in the Late Turolian (Ventian, sensu Morales *et al.*, 2013). The locality ABS-1 is not included in this scheme because of its uncertain stratigraphic position and poor fossil assemblage.

As recommended by the International Stratigraphic Guide, we have used widespread taxa when defining a biozone (Salvador, 1994). Minwer-Barakat *et al.* (2012a) suggested that the preferable definition for a biozone when dealing with fossil mammals is the assemblage zone, arguing that it would be difficult to know the stratigraphical position of a locality where the first or last occurrence of the taxa that marks the boundaries of a certain biozone are absent. However, because of the relatively short span of time studied, the faunal lists of some localities of the Gormaget ravine placed in different biozones greatly overlap, being the main difference the addition or disappearance of a single taxon. For this reason, we have used the interval zone when defining a biozone. Following García-Alix *et al.* (2008a) and Minwer-Barakat *et al.* (2012a), we have also included a reference locality as well as a section for each defined biozone.

The different evolutionary stages of some of the taxa used to discriminate between different biozones are shown in Figure 4. According to these criteria, we have defined the following biozones:

Paraethomys meini interval zone

Definition. Interval zone corresponding to the interval between the FAD of *Paraethomys meini* below and the FAD of *Apocricetus barrierei* above.

Reference section and locality. Section of Alcoi Forn, locality AF-1'06.

Other localities. AF-1A.

Biostratigraphical correlations. The FAD of *Paraethomys meini* in the Iberian Peninsula has been recorded in the Librilla section, in the region of Murcia (SE Spain, Garcés *et al.*, 1998; Agustí *et al.*, 2006) with an estimated age of 6.2Ma, and in the Late Miocene locality of Venta del Moro, in the Cabriel Basin (SE Spain), with an age of 6.23Ma (Gibert *et al.*, 2013. See a discussion on this topic in García-Alix *et al.*, 2016). This biozone can be correlated with the upper part of the *Paraethomys meini* zone in the Granada Basin (García-Alix *et al.*, 2008a; Fig. 5 of this work), in which the localities close to the Mio-Pliocene boundary have yielded remains of *Stephanomys dubari* and/or *Apodemus gorafensis*, like MNA-2 and 4, CLR-3, DHS-15B, 14, 16 (reference locality), 1 and 4, BRA-5B, CAC-5 and 11, AGU-1C and PUR-3 (García-Alix *et al.*, 2008a, b).

The *Paraethomys meini* zone of the Granada Basin has been partly correlated with the *Apodemus gudrunae* zone of the Guadix Basin (Minwer-Barakat *et al.*, 2012a) (Fig. 5). However, in the Alcoi Basin the *P. meini* zone comprises just

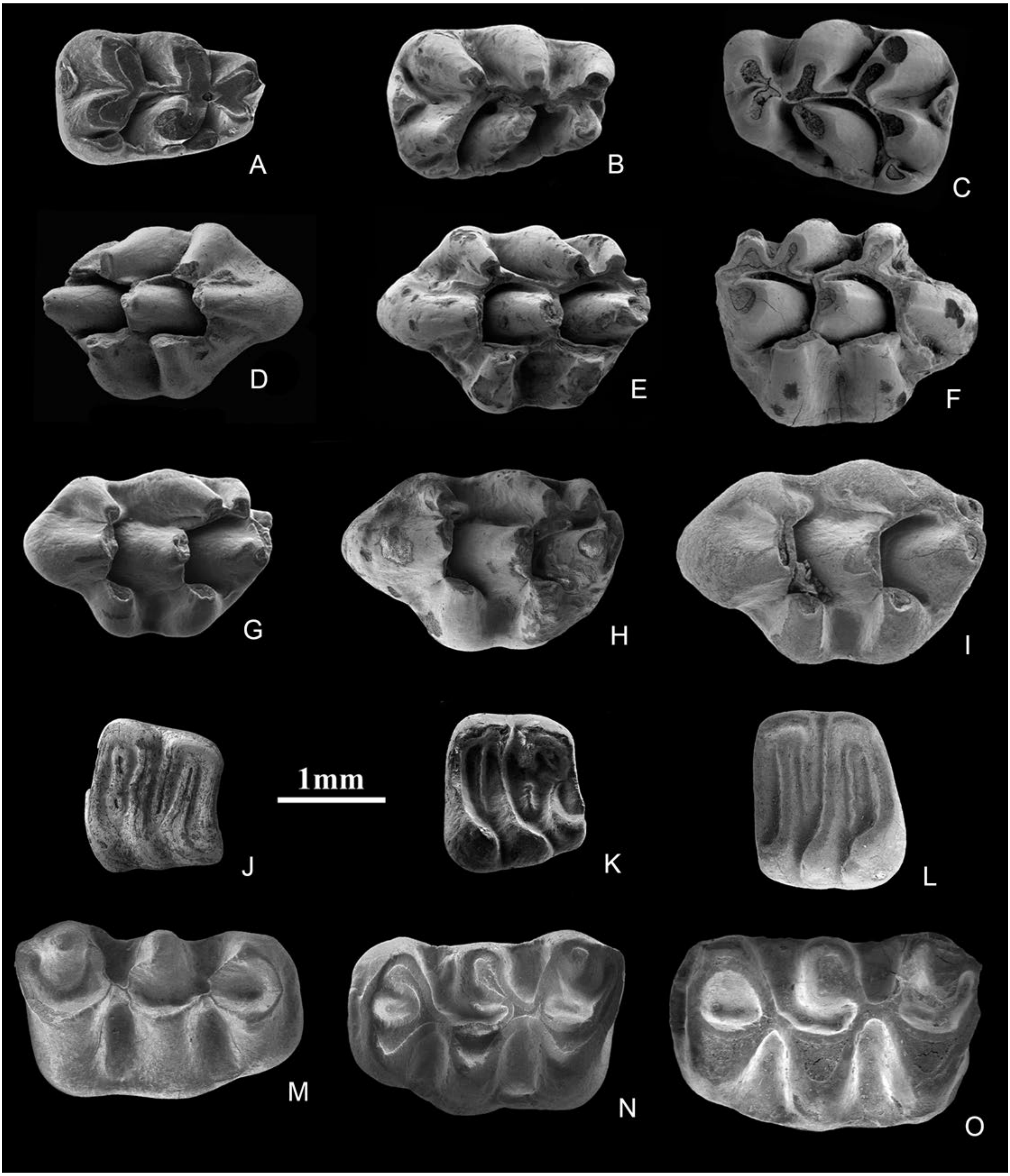

FIGURE 4. Evolutionary stages of some of the genera present in the localities from the Alcoi Basin studied in this work: *Stephanomys dubari*: A= right m1, AF1'06-12; D= right M1, ABS2-34. *Stephanomys* aff. *cordii*: B= right m1, ACO-1; E= left M1, ACO-12. *Stephanomys cordii*: C= left m1, AL2D-7; F= right M1, AL2D-98. *Paraethomys meini*: G= left M1, AF1'06-72. *Paraethomys aff. abaigari*: H= right M1, ACO-43; I= left M1, AL2D-101. *Eliomys yevesi*: J= AF1'06-190, right m1, 2; K= ABS3A-38, right m1, 2. *Eliomys intermedius*: L= AL2D-290, left m1, 2. *Apocricetus barrierei*: M= right M1, AF1'07-34; N= left M1, ABS3A-37; *Apocricetus cf. angustidens*: O= left M1, AL2D-259. Scale= 1mm.

two localities, both very close to the Mio-Pliocene boundary, and younger than the localities from other basins. In localities such as NGR-1 and RCH-3 (Guadix Basin, *Apodemus gudrunae* zone, Minwer-Barakat *et al.*, 2012a), *A. gudrunae* is present instead of *A. gorafensis*, while in Celadas-2 and Arquillo-4 (Teruel Basin, Adrover *et al.*, 1993) *Stephanomys ramblensis* is present instead of *S. dubari*, and in Crevillente 6 (*Paraethomys* zone, Martín-Suárez and Freudenthal, 1998) are present both *S. ramblensis* and *A. gudrunae*. These differences suggest an older age for these sites (see Fig. 5). In addition, the localities of Zorreras-2B and 3A (Sorbas Basin, Martín-Suárez *et al.*, 2000), of latest Turolian age, with the joint presence in Zorreras 3A of *S. dubari*, *P. meini*, *O. alcalai* and *A.* cf. *gorafensis*, may be correlated with this biozone (Fig. 5).

Apocricetus barrierei interval zone

Definition. Interval zone corresponding to the interval between the FAD of *A. barrierei* below and the FAD of *Paraethomys* aff. *abaigari* above.

Reference section and locality. Section of Alcoi Forn, locality AF-1'07.

Other localities. AF-2.

Biostratigraphical correlations. *Apocricetus barrierei* has been considered an Early Ruscinian indicator (MN14) by a number of authors (Mein *et al.*, 1990; Freudenthal *et al.*, 1998; Kälin, 1999; García-Alix *et al.*, 2008a, b, c). This biozone can be correlated with the *Apocricetus barrierei* zone of the Granada Basin, in which the reference locality, PUR-4, has in common with AF-1'07 *Apodemus gorafensis*, *Occitanomys alcalai*, *Stephanomys dubari*, *Paraethomys meini*, *Apocricetus barrierei* and *Eliomys yevesi* (García-Alix *et al.*, 2008a, b; Mansino *et al.*, 2015a, c), while taxa like *Stephanomys cordii* and *Trilophomys*, indicators of the end of the Early Ruscinian, are absent.

Although the faunal composition of this biozone and the *P. meini* biozone are very similar, *Apocricetus* represents over 10% of the specimens of AF-1'07 (4 out of 38), while it is absent in the much more abundant assemblage of AF-1'06 (139 specimens). For this reason, we have chosen to include these localities in different biozones. The *Apocricetus barrierei* biozone of the Alcoi and Granada basins can be correlated with the *Celadensia* zone in the Teruel Basin (Fig. 5), of which the reference locality is Peralejos E (Mein *et al.*, 1990). This latter biozone is characterized by the presence of the microtoid cricetid *Celadensia nicolae*, very abundant in the localities of the Teruel Basin (Mein *et al.*, 1990), which is absent in other Iberian basins such as the Granada Basin (García-Alix *et al.*, 2008b), the Guadix Basin (Minwer-Barakat *et al.*, 2012a) and the Alcoi Basin. The faunal list of Peralejos E. includes several taxa present in AF-1'07 and PUR-4, like *Apocricetus barrierei*, *Occitanomys alcalai*, *Paraethomys*

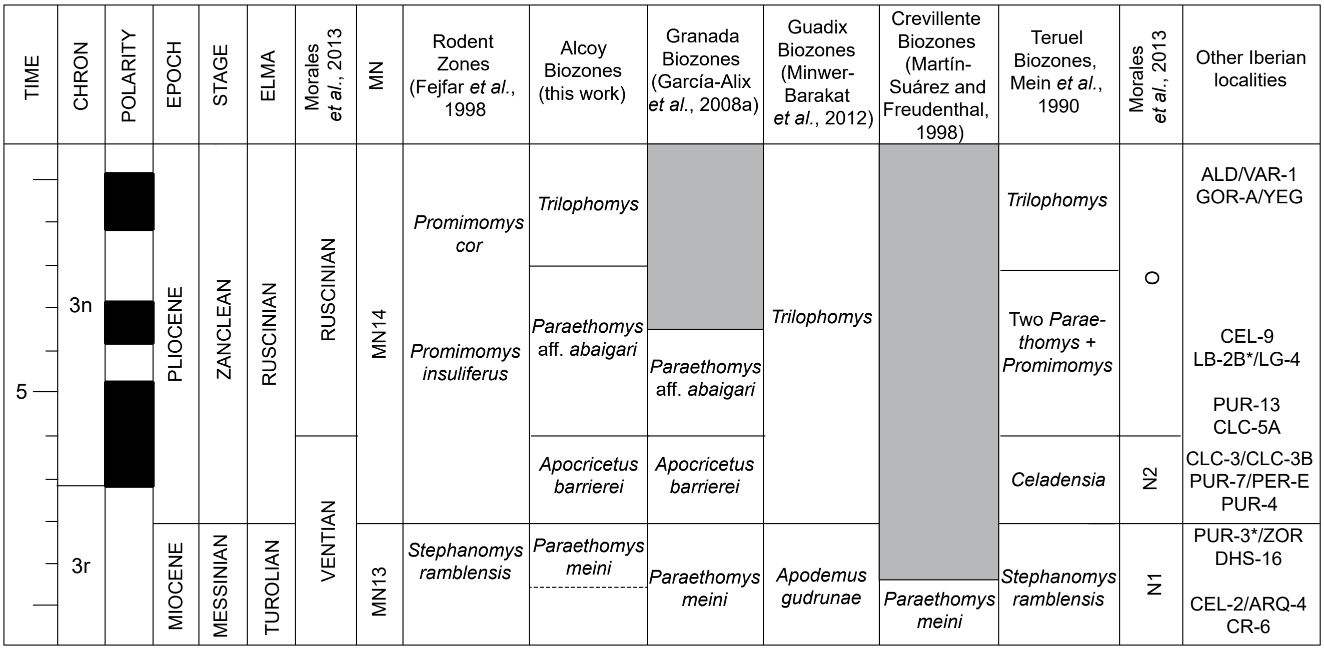

FIGURE 5. Correlation between the biozones defined in this work for the Alcoi Basin and the local biozonations of other Spanish basins, the Rodent zones of Fejfar *et al.* (1998), and other contemporaneous Iberian localities. Abbreviations, ALD: Aldehuela; ARQ: Arquillo; CEL: Celadas; CLC: Calicasas; CR: Crevillente; DHS: Dehesas; ELMA: European Land Mammal Age; GOR: Gorafe; LB2B: La Bullana 2B, PER: Peralejos; POLAR: polarity; PUR: Purcal; VAR: Villalba Alta Río; YEG: Yeguas; ZOR: Zorreras. The asterisk indicates the localities from which palaeomagnetic data are available.

anomalus (synonymized with *P. meini* by several authors, see García-Alix *et al.*, 2008b for a complete list) and *Apodemus gorafensis*. It also includes *Stephanomys medius*, synonym of *S. cordii* (García-Alix *et al.*, 2008b), which is present in younger localities. However, the material of *Stephanomy*s from Peralejos E. is reviewed in García-Alix *et al.* (2008b), who consider that it should be ascribed to *S. dubari* rather than to *S. cordii*.

Paraethomys aff. *abaigari* interval zone

Definition. Interval zone defined by the interval between the FAD of *Paraethomys* aff. *abaigari* and FAD of *Trilophomys*.

Reference section and locality. Section of Alcoi Cristian, locality AC-0.

Other localities. ABS-2, ABS-3, ABS-3A, ABS-7, ABS-8, ABS-9, ABS-10, AC-0C, AC-0B.

Biostratigraphical correlations. The lower part of the section, ranging from ABS-2 to ABS-7, can be correlated with the *Paraethomys* aff. *abaigari* zone of the Granada Basin, which includes the localities PUR-13 and CLC-5A, in which *Stephanomys dubari* is present (García-Alix *et al.*, 2008b). In the upper part of the section, from ABS-8 to AC-0, the *Stephanomys* present is *S.* aff. *cordii*, which suggests a younger age for these localities with respect to those of the *Paraethomys* aff. *abaigari* zone of the Granada Basin. In the Teruel Basin, the presence of two distinguishable species of *Paraethomys* is accompanied by the appearance of the arvicolid *Promimomys* (Mein *et al.*, 1990), absent in the Granada (García-Alix *et al.*, 2008b), Guadix (Minwer-Barakat *et al.*, 2012a) and Alcoi basins. However, the general resemblance of the faunas from this latter zone makes it possible to correlate with the *Paraethomys* aff. *abaigari* zone of the Alcoi Basin (Fig. 5).

The reference locality for the *Promimomys* and *Paraethomys* zone in Teruel is La Gloria 4 (Mein *et al.*, 1990). The faunal list of this locality is similar to those of the sites of the *Paraethomys* aff. *abaigari* zone of the Alcoi Basin (see Table 2; Fig. 3), with remains of *Episoriculus (Assoriculus) gibberodon*, *Apocricetus barrierei*, *Occitanomys alcalai*, *Paraethomys meini* and *P.* aff. *abaigari*, *Apodemus gorafensis*, *Eliomys intermedius* and *Stephanomys medius* (= *cordii*). García-Alix *et al.* (2008b) noted that the *Stephanomys* present in La Gloria 4 and Celadas 9 is *S. dubari*, like in the lower part of the section from Alcoi, but the presence of *Eliomys intermedius* in La Gloria 4 instead of *E. yevesi* like in ABS-3A suggests a slightly younger age. The locality of LB2B, in the Cabriel Basin (Mansino *et al.*, 2015d) belongs to the *Paraethomys* aff. *abaigari* biozone (Fig. 5). Neither this biozone nor the next one can be correlated with the Rodent Zones of Fejfar *et al.* (1998), who distinguish two zones in the Ruscinian corresponding to the range of two species of *Promimomys*.

Trilophomys Assemblage zone

Definition. Assemblage zone defined by the association of *Apocricetus barrierei*, *Stephanomys cordii*, *Castillomys gracilis*, *Apodemus gorafensis*, *Paraethomys meini*, *Paraethomys* aff. *abaigari* and *Trilophomys*.

Reference section and locality. Section of Alcoi-2, locality AL2-D.

Other localities. AL2-C.

Biostratigraphical correlations. This biozone can be correlated with the *Trilophomys* assemblage zone of the Guadix Basin (Minwer-Barakat *et al.*, 2012a), where the joint presence of *Trilophomys*, *Stephanomys cordii* and *Apocricetus barrierei*, considered MN14 indicators, has been recorded in the localities of Yeguas, Gorafe A and Gorafe 4 (Ruiz Bustos *et al.*, 1984; Martín-Suárez, 1988; Minwer-Barakat *et al.*, 2012a). However, according to these authors the lower boundary of this biozone coincides with the MN13-MN14 boundary. The presence in the Alcoi Basin of several mammal localities recording a relatively short span of time has allowed us to distinguish three biozones in MN14 (*Apocricetus barrierei* interval zone, *Paraethomys* aff. *abaigari* interval zone and *Trilophomys* assemblage zone), of which *Trilophomys* appears in the upper part, and therefore this biozone can be correlated with the upper part of the *Trilophomys* assemblage zone of the Guadix Basin (Fig. 5).

In addition, the *Trilophomys* zone of the Teruel Basin, in which usually appears *Blancomys*, can be correlated with the biozone of the same name from Alcoi (Fig. 5). The presence of *Stephanomys margaritae* in the reference locality of Villalba Alta Río 1, as well as in Orrios 1, Lomas de Casares 1 and Aldehuela suggest a younger age for these localities (Mein *et al.*, 1990).

REMARKS ABOUT THE EARLIEST PLIOCENE

The age of the Mio-Pliocene limit has been estimated at 5.33Ma (Gradstein *et al.*, 2004, 2012), and it likely coincides with the Turolian-Ruscinian boundary (Hernández-Fernández *et al.*, 2004; García-Alix *et al.*, 2008a). The base of the MN14 was defined by Mein *et al.* (1990) as the entry of the microtid *Celadensia* in the Teruel Basin. However, the occurrence of *Celadensia* in the MN13 locality of Baccinello (Rook and Torre, 1995) led Agustí *et al.* (2001) to consider the FAD of *Promimomys* as the lower boundary of MN14. On the other hand, as we have seen, *Promimomys* is absent in localities in the lower part of MN14 of the southernmost Iberian basins, such as Guadix, Granada and Alcoi; therefore, it is difficult to establish correlations among different basins. So, Agustí *et al.* (2001) considered that in the absence of arvicolids the distinction between MN13 and MN14 is mainly based on the evolutionary stages of the genera *Apodemus*, *Stephanomys*, *Paraethomys*, *Ruscinomys* and *Apocricetus*, which may also lead to some uncertainties.

Morales *et al.* (2013) proposed a redefinition of the Ventian Mammal age including most of the Spanish faunas of MN13, but also some localities traditionally placed in the Ruscinian. These authors divided the Ventian in the zones M (ranging from the FAD of *Stephanomys ramblensis* to the FAD of *Celadensia*) and N (subdivided in N1, corresponding to the range zone of *Celadensia*, and N2, ranging from the appearance of a big sized *Paraethomys*, *P. abaigari* or aff. *abaigari*, to the appearance of *Promimomys*, which marks the beginning of the Ruscinian). They also considered that the appearance of a large sized *Paraethomys* besides the smaller *P. meini* signals the beginning of the N2. However, it is not clear if the big sized *Paraethomys* was an immigrant, or the product of a speciation event (García-Alix *et al.*, 2008b). These latter authors also suggest that two different lineages of *Paraethomys* may be represented in the locality of PUR-4, because the population of *P. meini* shows a great variability in size, although they regard the presence of two distinct species unlikely.

The same scenario occurring in PUR-4 has been described in AF-1’06 in the Alcoi Basin (Mansino *et al.*, 2015a), in which two different species of *Paraethomys* cannot be recognized yet, but there is a continuum distribution ranging from small to big specimens. In younger localities, like those from ABS and AC, the difference between both species is greater and two groups of *Paraethomys* may be recognized. However, since the large sized lineage seems to be more similar to *P. meini* as we get closer to the Mio-Pliocene boundary, to detect the appearance of *P.* (aff.) *abaigari* may be difficult beyond a certain point. This makes troublesome to recognize the lower boundary of the subzone N2, casting doubts on the validity of this subdivision. In addition, Morales *et al.* (2013) explain that the zone N2, which has two *Paraethomys*, is only supported by stratigraphic criteria, and that it may be Pliocene indeed, but further evidence is needed to solve this question. Therefore, and based on the data of the Alcoi and Granada basins, we think it is more consistent to consider the subzone N2 proposed by Morales *et al.* (2013) as Early Ruscinian.

CONCLUSIONS

The study of the micromammal localities of the southern and northern sides of the Gormaget ravine in the Alcoi Basin has allowed us to define four biozones in the earliest Pliocene and possibly the latest Miocene: *Paraethomys meini* interval zone, corresponding to the interval between the FAD of *Paraethomys* below and the FAD of *Apocricetus barrierei* above, which comprises the localities AF-1’06 and AF-1A; *Apocricetus barrierei* interval zone, corresponding to the interval between the FAD of *A. barrierei* below and the FAD of *Paraethomys* aff. *abaigari* above, comprising the localities AF-1’07 and AF-2; *Paraethomys* aff. *abaigari* interval zone, defined by the interval between the FAD of *Paraethomys* aff. *abaigari* and FAD of *Trilophomys*, comprising the localities ABS-2, ABS-3, ABS-3A, ABS-7, ABS-8, ABS-9, ABS-10, AC-0, AC-0C and AC-0B, and *Trilophomys* Assemblage zone, defined by the association of *Apocricetus barrierei*, *Stephanomys cordii*, *Castillomys gracilis*, *Apodemus gorafensis*, *Paraethomys meini*, *Paraethomys* aff. *abaigari* and *Trilophomys*, which comprises the localities AL2-C and AL2-D.

The resolution achieved in the biozonation of the Alcoi Basin in the earliest Pliocene and Mio-Pliocene boundary can only be compared in the Iberian Peninsula to that of the Teruel Basin (Mein *et al.*, 1990). The local biozonation proposed for the Alcoi Basin can be correlated with other local biozonations dealing with the Late Miocene and Early Pliocene of the Iberian Peninsula, like the Teruel, Granada, Crevillente and Guadix basins.

With respect to the biostratigraphical frame proposed by Morales *et al.* (2013), we consider the subzone N2 of the Ventian as problematic since its lower limit, marked by the presence of two *Paraethomys*, is difficult to recognize in localities close to the Mio-Pliocene boundary; besides *Promimomys*, which marks its upper limit, is absent in other Iberian basins. Therefore, we think that the subzone N2 (Morales *et al.*, 2013) must belong to Early Ruscinian.

ACKNOWLEDGMENTS

This study was supported by the project CGL2011-25754 of the Spanish Ministry of Economy and Competitiveness and GV06/304 of the Valencian government. This investigation was carried out thanks to the Prometeo Project of the Secretariat for Higher Education, Science, Technology and Innovation from Ecuador. We want to thank the Paleontological association “Isurus”, from Alcoi, as well as all the students at the Universitat de València that have taken part in the field work. We would like to thank Dr. Jordi Agustí, Dr. Antonio García-Alix and Journal Manager Laura Rincón for their useful comments and criticism.

REFERENCES

Adrover, R., 1969. Los micromamíferos del Plioceno inferior de los lignitos de Alcoy. I. *Ruscinomys*. Boletín de la Real Sociedad Española de Historia Natural (Sección Geológica), 67, 245-272.

Adrover, R., Mein, P., Moissenet E., 1993. Roedores de la transición Mio-Pliocena de la región de Teruel. Paleontologia i Evolució, 26-27, 47-84.

Aguirre, E., Hoyos, M., Morales, J., 1975. Alcoy: observaciones preliminares sobre la secuencia Neógeno- Cuaternaria del Serpis. Acta Geológica Hispánica, 10(2), 75-77.

Agustí, J., Moyà-Solà, S., Gibert, J., Guillén, J., Labrador, M., 1983. Nuevos datos sobre la bioestratigrafía del Neógeno continental de Murcia. Paleontologia i Evolució, 18, 83-94.

Agustí, J., Garcés, M., Krijgsman, W., 1999. Investigaciones bioestratigráficas y magnetoestratigráficas en la Cuenca de Fortuna (Murcia) y sus implicaciones para la evolución de la cuenca mediterránea durante el Messiniense (Mioceno superior). Memorias de arqueología, 14, 27-36.

Agustí, J., Cabrera, L., Garcés, M., Krijgsman, W., Oms, O., Parés, J.M., 2001. A calibrated mammal scale for the Neogene of Western Europe. State of the art. Earth-Science Reviews, 52, 247-260.

Agustí, J., Garcés, M., Krijgsman, W., 2006. Evidence for African-Iberian exchanges during the Messinian in the Spanish mammalian record. Palaeogeography, Palaeoclimatology, Palaeoecology, 238, 5-14. DOI: 10.1016/j.palaeo.2006.03.013

Corbí, H., Lancis, C., García-García, F., Pina, J.A., Soria, J.M., Tent-Manclús, J.E., Viseras, C., 2012. Updating the marine biostratigraphy of the Granada Basin (central Betic Cordillera). Insight for the Late Miocene palaeogeographic evolution of the Atlantic – Mediterranean seaway. Geobios, 45, 245-263. DOI: http://dx.doi.org/10.1016/j.geobios.2011.10.006

Ballesteros Navarro, B.J., Rodríguez Hernández, L., Hernández Bravo, J.A., López Gutiérrez, J.L., Fernández Mejuto, M., García Menéndez, O., Domínguez Sánchez, J.A., Díaz Losada, E., Castillo Pérez, E., Padilla Benítez, A., Vela Mayorga, A., Muñoz Alonso, J., Gómez Fontalva, J., 2007. Actualización y mejora del conocimiento hidrogeológico y funcionamiento de los acuíferos de Alicante. Caracterización hidrogeológica de la U.H. 08.40 (Sierra Mariola). Alicante, Instituto Geológico y Minero de España, 118pp.

Dam, J.A. van, Alcalá, L., Alonso Zarza, A., Calvo, J.P., Garcés, M., Krijgsman, W., 2001. The Upper Miocene mammal record from the Teruel-Alfambra region (Spain). The MN system and continental stage/age concepts discussed. Journal of Vertebrate Paleontology, 21, 367-385.

Durand Delga, M., García Rodrigo, B., Magne, J., Polveche, J., 1964. À propos du Miocène de la région d'Alcoy (province d'Alicante, Espagne). Cursillos y Conferencias, 9, 213-217.

Esteban Aenlle, J., Lacomba, J.I., 1988. El yacimiento de Alcoy-2. Nuevo nivel con micromamíferos del Plioceno inferior (MN15) en el área de Alcoy. In: Alcalá, L., Roca, A., Paricio, J., Agustí, J., Checa, L. (eds.). Comunicacions. Col·loqui Homenatge a R. Adrover "Bioeventos y sucesiones faunísticas en el Terciario continental ibérico", Sabadell, 17.

Fejfar, O., Heinrich, W.D., Lindsay, E.H., 1998. Updating the Neogene rodent biochronology in Europe. Mededelingen Nederlands Instituut voor Toegepaste Geowetenschappen TNO, 60, 533-554.

Freudenthal, M., Mein, P., Martín Suárez, E., 1998. Revision of Late Miocene and Pliocene Cricetinae from Spain and France. Treballs del Museu de Geologia de Barcelona, 7, 11-94.

Garcés, M., Krijgsman, W., Agustí, J., 1998. Chronology of the late Turolian deposits of the Fortuna basin (SE Spain): implications for the Messinian evolution of the eastern Betics. Earth and Planetary Science Letters, 163, 69-81.

Garcés, M., Krijgsman, W., Agustí, J., 2001. Chronostratigraphic framework and evolution of the Fortuna basin (Eastern Betics) since the Late Miocene. Basin Research, 13, 199-216.

García-Alix, A., Minwer-Barakat, R., Martín, J.M., Martín Suárez, E., Freudenthal, M., 2008a. Biostratigraphy and sedimentary evolution of late Miocene and Pliocene continental deposits of the Granada basin (southern Spain). Lethaia, 41, 431-446. DOI: 10.1111/j.1502-3931.2008.00097.x

García-Alix, A., Minwer-Barakat, R., Martín-Suárez, E., Freudenthal, M., 2008b. Muridae (Rodentia, Mammalia) from the Mio-Pliocene boundary in the Granada basin (southern Spain). Biostratrigraphic and phylogenetic implications. Neues Jahrbuch für Geologie und Paläontologie Abhandlungen, 248, 183-215. DOI: 10.1127/0077-7749/2008/0248-0183

García-Alix, A. Minwer-Barakat, R., Martín-Suárez, E., Freudenthal, M., 2008c. Cricetidae and Gliridae (Rodentia, Mammalia) from the Miocene and Pliocene of southern Spain. Scripta Geologica, 136, 1-37.

García-Alix, A., Minwer-Barakat, R., Martín-Suárez, E., Freudenthal, M., Aguirre, J., Kaya, F., 2016. Updating the Europe-Africa small mammal exchange during the late Messinian. Journal of Biogeography, 43(7), 1336-1348. DOI: 10.1111/jbi.12732

Gervais, P., 1853. Description des ossements fossiles de mammifères rapports d'Espagne par MM. de Verneuil, Collomb et de Lorière. Bulletin de la Société géologique de France 2e série 10, 147-168, pls 3-6.

Gibert, L., Scott, G.R., Montoya, P., Ruiz-Sánchez, F.J., Morales, J., Luque, L., Abella, J., Lería, M., 2013. Evidence for an African-Iberian mammal dispersal during the pre-evaporitic Messinian. Geology, 41, 691-694. DOI: 10.1130/G34164.1

Gradstein, F., Ogg, J., Smith, A. (eds.), 2004. A Geologic Time Scale. Cambridge, Cambridge University Press, 589pp.

Gradstein, F.M., Ogg, J.G., Schmitz, M.D., Ogg, G.M. (eds.), 2012. The Geologic Time Scale 2012. Elsevier, 2 volumes plus chart, 1176pp.

Hernández-Fernández, M., Azanza, B., Álvarez-Sierra, M.A., 2004. Iberian Plio-Pleistocene biochronology: micromammalian evidence for MNs and ELMAs calibration in southwestern Europe. Journal of Quaternary Science, 19, 605-616. DOI: 10.1002/jqs.862

Hüsing, S.K., Oms, O., Agustí, J., Garcés, M., Kouwenhoven, T.J., Krijgsman, W., Zachariasse, W.J., 2010. On the late Miocene closure of the Mediterranean-Atlantic gateway through the Guadix basin (southern Spain). Palaeogeography, Palaeoclimatology, Palaeocology, 291(3-4), 167-179.

Kälin, D., 1999. Tribe Cricetini. In: Rössner, G.E., Heissig, K. (eds.). The Miocene Land Mammals of Europe. München (Germany), Verlag Dr. Friedrich Pfeil, 373-388.

Krijgsman, W., Garcés, M., Agustí, J., Raffi, I., Taberner, C., Zachariasse, W.J., 2000. The Tortonian salinity crisis of the eastern Betics (Spain). Earth and Planetary Science Letters, 181(4), 497-511.

Kukal, Z., 1971. Geology of recent sediments. Prague, Central Geological Survey, 490pp.

López Martínez, N., 1989. Revisión sistemática y bioestratigráfica de los Lagomorpha (Mammalia) del Terciario y Cuaternario de España. Memorias del Museo Paleontológico de la Universidad de Zaragoza, 3(3), 1-350.

Mansino, S., Ruiz Sánchez, F.J., Montoya, P., 2009. Estudio preliminar de las faunas pliocenas de roedores del yacimiento Alcoi Cotes Altes 2 (ACA-2, Alicante, España). Paleolusitana, 1, 251-256.

Mansino, S., Fierro, I., Ruiz-Sánchez, F.J., Montoya, P., 2013. The fossil rodent faunas of the localities Alcoy 2C and 2D (Alcoy 1 Basin, Spain). Implications for dating the classical locality of 2 Alcoy-Mina. Journal of Iberian Geology, 39(2), 261-284. DOI: http://dx.doi.org/10.5209/rev_JIGE.2013.v39.n2.42501

Mansino, S., Fierro, I., Ruiz-Sánchez, F.J., Montoya, P., 2015a. Mio-Pliocene rodent assemblages from Alcoi Forn (Alcoy Basin, Eastern Spain). Biostratigraphical and palaeoclimatical inferences. Historical Biology, 28(8), 1050-1065. DOI: 10.1080/08912963.2015.1102238

Mansino, S., Fierro, I., Ruiz-Sánchez, F.J., Montoya, P., 2015b. Micromammal faunas from the Mio-Pliocene boundary in the Alcoy Basin (SE Spain): biostratigraphical and palaeoecological inferences. Bulletin of Geosciences, 90(3), 555-576. DOI: 10.3140/bull.geosci.1541

Mansino, S., García-Alix, A., Ruiz Sánchez, F.J., Montoya, P., 2015c. A new *Eliomys* from the Late Miocene of Spain, and its implications for the phylogeny of the genus. Acta Palaeontologica Polonica, 60(3), 577-588. DOI: http://dx.doi.org/10.4202/app.00014.2013

Mansino, S., Ruiz-Sánchez, F.J., Luque, L. de, Montoya, P., Gibert, L., Morales, J., Abella, J., Crespo, V.D., Scott, G.R., 2015d. First Early Pliocene micromammal faunas from the Venta del Moro area (Cabriel Basin, Spain): new data on the Messinian dispersal of *Debruijnimys*. Journal of Iberian Geology, 41(2), 273-293. DOI: http://dx.doi.org/10.5209/rev_JIGE.2015.v41.n2.46418

Martín-Suárez, E., 1988. Sucesiones de micromamíferos en la depresión Guadix-Baza. PhD. Thesis. Spain, Universidad de Granada, 241pp.

Martín Suárez, E., Freudenthal, M., 1998. Biostratigraphy of the continental Upper Miocene of Crevillente (Alicante, SE Spain). Geobios, 31, 839-847.

Martín Suárez, E., Freudenthal, M., Krijgsman, W., Rutger Fortuin, A., 2000. On the age of the continental deposits of the Zorreras Member (Sorbas Basin, SE Spain). Geobios, 33, 505-512.

Mein, P., Moissenet, E., Adrover, R., 1990. Biostratigraphie du Néogène Supérieur du bassin de Teruel. Paleontologia i Evolució, 23, 121-139.

Minwer-Barakat, R., García-Alix, A., Suárez, E.M., Freudenthal, M., Viseras, C., 2012a. Micromammal biostratigraphy of the Upper Miocene to lowest Pleistocene continental deposits of the Guadix basin, southern Spain. Lethaia, 45, 594-614. DOI: 10.1111/j.1502-3931.2012.00324.x

Minwer-Barakat, R., García-Alix, A., Martín-Suárez, E., Freudenthal, M., 2012b. The late Miocene continentalization of the Guadix Basin (southern Spain) reconsidered: A comment on Hüsing *et al.* (2010). Geobios, 45(6), 611-615. DOI: 10.1016/j.geobios.2012.05.001

Montenat, C., 1973. Les Formations néogènes et Quaternaires du Levant espagnol (Provinces d'Alicante et de Murcia). PhD. Thesis. France, Université de Orsay-Paris-Sud, 1170 pp.

Montoya, P., Ginsburg, L., Alberdi, M.T., Made, J. van der, Morales, J., Soria, M.D., 2006. Fossil large mammals from the early Pliocene locality of Alcoy (Spain) and their importance in biostratigraphy. Geodiversitas, 28(1), 137-173.

Morales, J., Peláez-Campomanes, P., Abella, J., Montoya, P., Gibert, L., Scott, G., Cantalapiedra, J.L., Sanisidro, O., 2013. The Ventian mammal age (Latest Miocene): present state. Spanish Journal of Palaeontology, 28(2), 149-160.

Pedraza Gilsanz, J. de, 1996. Geomorfología. Principios, métodos y aplicaciones. Madrid, Editorial Rueda, 414pp.

Pierson d'Autrey, L., 1987. Sédimentation et structuration synsédimentaire dans le bassin néogène d'Alcoy (Cordillères Bétiques externes Orientales Espagne). PhD. Thesis. Université de Paris, 315pp.

Santisteban, C. de, Montoya, P., Usera, J., Robles, F., 1997. El Terciario marino y continental de Alicante. In: Alcala, L., Alonso Zarza, A.M. (eds.). Itinerarios geológicos en el Terciario del centro y Este de la Península Ibérica. Museo Nacional de Ciencias Naturales (CSIC), Departamento de Petrología y Geoquímica UCM, 73-107.

Rook, L., Torre, D., 1995. *Celadensia grossetana* n. sp. (Cricetidae, Rodentia.) from the Late Turolian Baccinello-Cinigiano Basin (Italy). Geobios, 28(3), 379-382.

Ruiz Bustos, A., Sesé, C., Dabrio, C., Peña, J.A., Padial, J., 1984. Geología y fauna de micromamíferos del nuevo yacimiento del Plioceno inferior de Gorafe-A (Depresión de Guadix-Baza, Granada). Estudios Geológicos, 40, 231-241.

Salvador, A., 1994. International Stratigraphic Guide. A Guide to Stratigraphic Classification, Terminology, and Procedure. Boulder (Colorado), International Union of Geological Sciences and Geological Society of America, 2nd Edition, 214pp.

Thaler, L., Crusafont, M., Adrover, R., 1965. Les premiers micromammifères du Pliocène d'Espagne; précisions chronologiques et biogéographiques sur la faune d'Alcoy.

Comptes Rendus de l'Académie des Sciences de Paris, 260, 4024-4027.

Viseras, C., Soria, J.M., Fernández, J., 2004. Cuencas Neógenas Postorogénicas de la Cordillera Bética. In: Vera, J.A., (ed.). Geología de España. Madrid, Sociedad Geológica de España – Instituto Geológico y Minero de España (SGE-IGME), 576-581.

Weerd, A. van de, 1976. Rodent faunas of the Mio-Pliocene continental sediments of the Teruel-Alfambra region, Spain. Utrecht Micropaleontological Bulletins, 2 (Special Publication), 1-217.

Manuscript received December 2016;
revision accepted February 2017;