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Cañada: a new micromammal succession from the lower Vallesian and Turolian of the Daroca area (Calatayud-Montalbán basin, Spain)

Cañada: Una nueva sucesión de micromamíferos del Vallesiense inferior y Turoliense del área de Daroca (Cuenca de Calatayud-Montalbán, España)

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ABSTRACT

A new section including nine stratigraphically superposed microvertebrate fossil localities from the Calatayud-Montalbán basin (Spain) is presented. The Cañada localities and the small mammal assemblages are described, allowing a biostratigraphical correlation with the lower Vallesian from the nearby section of Nombrevilla. The results of this work are important because they help to improve the time resolution of the lower Vallesian faunal record from the Daroca area and to precise their relative biostratigraphical position. In addition, the upper part of the Cañada section includes two Turolian faunas, increasing the poor record from this age in the Calatayud-Montalbán basin.

Key words: Taxonomy, Biostratigraphy, Late Miocene, lower Vallesian, Turolian

RESUMEN

Se da a conocer una nueva sección que incluye nueve yacimientos de microvertebrados en superposición estratigráfica en la Cuenca de Calatayud-Montalbán (España). Se describen las localidades de la sección de la Cañada y sus faunas de micromamíferos, lo que posibilita su correlación con el Vallesiense inferior de la cercana sección de Nombrevilla. Los resultados obtenidos en este trabajo son importantes debido a que ayudan a mejorar la resolución temporal del registro faunístico del Vallesiense inferior del área de Daroca, y a precisar su posición bioestratigráfica relativa. Por otra parte, el tramo superior de la sección de la Cañada incluye dos faunas del Turoliense que incrementan el escaso conocimiento del registro de esta edad en la Cuenca de Calatayud-Montalbán.

Palabras clave: Taxonomía, Bioestratigrafía, Mioceno superior, Vallesiense inferior, Turoliense

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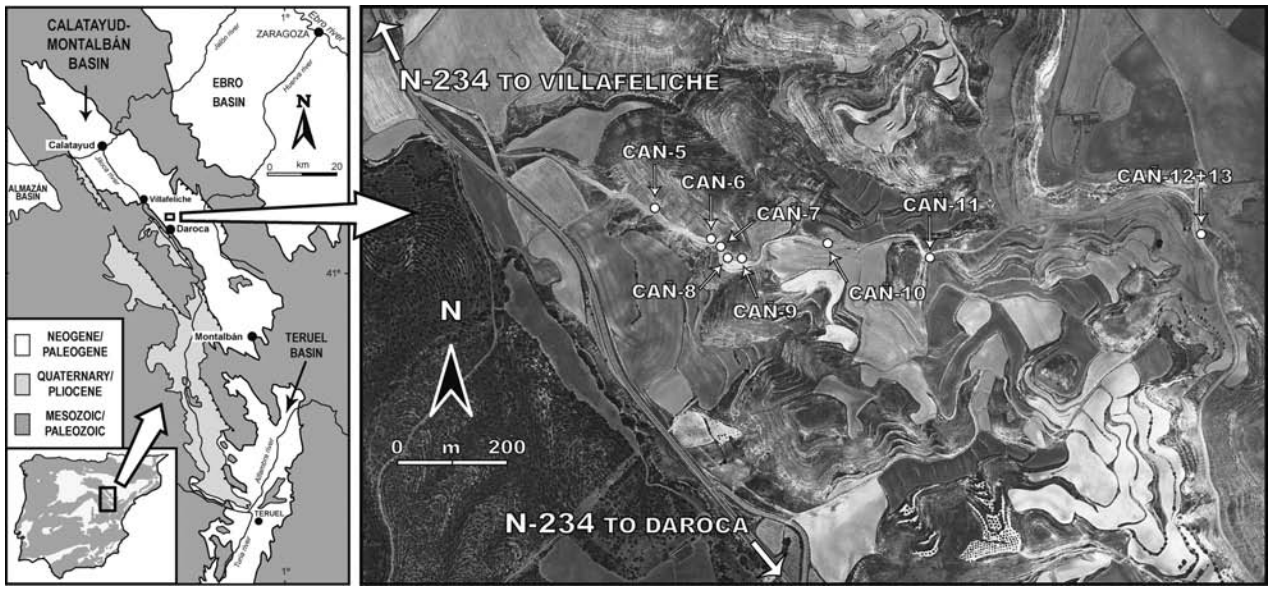

Fig. 1.—Location and synthetic geology of the Calatayud-Montalbán basin, Spain (modified after García-Paredes et al., 2010). The orthophotograph shows the location of the Cañada section area and localities. Abbreviations: CAÑ = Cañada.

Introduction

The Calatayud–Montalbán basin (northeastern Spain; Figure 1) has yielded one of the richest and best known micromammal fossil records for the European Miocene. The basin contains several well-exposed sections with superposed vertebrate fossil sites, which served as stratotypes for two continental stages, the Aragonian (Daams *et al*., 1977) and the Ramblian (Daams *et al*., 1987). The Aragonian type section and its directly adjacent areas have by far the most detailed micromammal faunal succession. Since the overview of Daams *et al*. (1999), new taxonomical information and stratigraphical distributions of early and middle Aragonian faunas have become available and are summarized in Van der Meulen *et al*. (2011, 2012). However, the distribution of mammal faunas in the Calatayud-Montalbán basin is not homogeneous. The density of faunal assemblages from the upper Aragonian and lower Vallesian is relatively low in comparison with the number of faunas and the temporal resolution of the lower and middle Aragonian (Álvarez-Sierra *et al*., 2003; Daams *et al*., 1999).

In order to increase the available information on the upper Aragonian and lower Vallesian faunas, several prospections were carried out. The aim of those fieldworks was to find new stratigraphic sections with superposed fossil sites that could complete the gaps on our knowledge of the paleontological record of the Miocene deposits of the Daroca area (Zaragoza, Spain). Prospection of this area, which was particularly promoted by the late Remmert Daams, has yielded successful results in several stratigraphic sections close to the Nombrevilla village, covering the uppermost Aragonian and lower Vallesian (Álvarez Sierra *et al*., 2003; Garcés *et al*. 2003), and the new Cañada section, covering the lower Vallesian, presented here for the first time.

The increase of fossil information will improve the time resolution and help to answer important questions on the strong mammal turnover observed around the Aragonian-Vallesian boundary and throughout the lower Vallesian. The lack of information from this interval led to the idea of a strong and rapid turnover. The results from the Nombrevilla sections indicated that the different micro and macromammal events were not synchronous around the Aragonian-Vallesian boundary (Álvarez-Sierra *et al*., 2003).

Despite the abundant paleontological information from the latter sections, important gaps of information exist between the successive Nombrevilla faunas, especially concerning lower Vallesian sediments. The study of the Cañada section intends to fill some of those gaps with new faunal information. This section is stratigraphically above the Car-

rilanga fossil site and covers most part of the lower Vallesian. The new information will also be important to establish more precisely the relative biostratigraphic position of Nombrevilla 1 and Carrilanga since several options have been proposed before (Daams *et al*.,1999; Van Dam *et al*., 2006).

In this paper we introduce the new section and present the preliminary results on the taxonomy of the different faunal assemblages from the stratigraphicaly superposed localities. Full analysis of the rodents is part of the PhD thesis of PL-G, and a joint publication on the taxonomy of the insectivores is currently being prepared as well.

Geological setting

The Calatayud-Montalbán basin, a narrow depression oriented NW-SE, is situated in northeastern Spain (Figure 1), delimited by Paleozoic and Mesozoic reliefs and filled by continental deposits ranging in age from Late Paleogene to Early Pliocene (Alcalá *et al*., 2000; Sanz-Rubio, 1999; Sanz-Rubio *et al*., 2003). The basin is filled by alluvial sediments along their margins and lacustrine (carbonates and evaporites) in the middle of the basin.

The sedimentary record in the Calatayud-Montalbán basin constitutes of three units named by Sanz Rubio (1999) as Lower, Intermediate and Upper Unit, respectively. They are bounded by sedimentary discontinuities.

The Lower Unit, of Oligocene? - Middle Miocene (middle Aragonian) age, has a thickness of 500 m of which 100-150 m outcrop. In the marginal areas this unit consists of coarse-detritic deposits which progressively grade into silts and clays, and anhydritic and halitic facies towards the center of the basin.

The Intermediate Unit covers the Middle and Late Miocene (middle and late Aragonian and Vallesian), has a thickness ranging from 30 m to 120 m (Alcalá *et al*., 2000). In the marginal areas the deposits of this unit are interpreted as alluvial deposits passing to carbonates and lamellate gypsum towards the center of the basin.

The Upper Unit, of Late Miocene- Early Pliocene age, is divided in three subunits: the lowest consists of detritic deposits, the intermediate of tufaceous limestones, and the upper one of lacustrine carbonate facies (Alcalá *et al*., 2000).

In the central part of the Calatayud basin, where our micromammal sites were found, detritic and carbonate deposits from the Intermediate and Upper Unit crop out; sediments from the Lower Unit are not present (Anadón *et al*., 2004).

In the Daroca-Nombrevilla area the Vallesian deposits consist of red silts alternating with lacustrine limestones, locally interfingering with gravel and sand lenses. These facies are typical for distal alluvial fans alternating with shallow carbonate lake facies with abundant signs of subaerial exposure (Alcalá *et al*., 2000; Garcés *et al*., 2003). Most of the small mammal fossil sites from the Nombrevilla area have been found in dark silty marls, analogous to those of the Cañada section. These facies are interpreted as ponds in paludal environments, although some sites, some sites could be related to seasonal swamps in alluvial fan environments (Alcalá *et al*., 2000).

Fossil localities

The Cañada section is located between the kilometers 225 and 226 on a dirt road on the east side of the road N-234 from Daroca to Calatayud (Figure 1). The track starts from an abandoned bend of the old road outline and runs to the east-southeast up to the "El Plano" plateau. The first fossil site of the section (Cañada 5) is situated approximately 350 meters from the beginning of the track. The section is located along west and south sides of La Dehesa and before Calerón ravine. It includes a succession of nine microvertebrates sampled sites, which are distributed across approximately 60 m of stratigraphic series. The linear distance between the first and last fossil localities (Cañada 12 and 13) is approximately 1 km and the altitude ranges from 890 m to 950 m. All the prospected levels are superposed stratigraphically and the numbers of the localities reflects their order (higher number represents upper position in the section).

The fossil remains were collected by screen washing with a smallest mesh size of 0.7 mm. The survey was conducted looking for dark levels representing reducing environments, and specially those with abundant remains of fossil gastropods or plants. These kinds of facies are the more favorable for obtaining microvertebrate fossil remains and have been evaluated taking a test sample of about 100 kg of sediment. Depending on the results of the test sample, we collected larger amount of sediment from different localities.

Cañada 5

The first site of the section is situated at 350 m distance from the beginning of the track, at the left border and an altitude of about 890 m. It is a poorly-consolidated marl level below a thick tabular limestone (1 m approximately). The layer shows a brown colour at the bottom that quickly changes to dark green. It contains gastropod remains and carbonate nodules. The top of the level shows signs of strong oxidation and root remains are abundantly present. A test sample of approximately 100 kg was collected.

Cañada 6

It is situated approximately 120 m from the previous site, on the same side of the track. Cañada 6 and the nearest sites Cañada 7, 8 and 9 are situated between 900 m and 910 m altitude. Cañada 6 is a green level of marly silts between light-coloured, strongly indurate carbonatic beds, which contains complete remains of large and small gastropods. The level disappears laterally. A test sample of approximately 100 kg was collected.

Cañada 7

It is situated about 20 m from Cañada 6 at the north side of the track. The level is grey-brown and silty and contains many gastropod remains. It is situated below a level of nodular limestone. A test sample of approximately 100 kg was collected.

Cañada 8

It is less than 30 m from Cañada 7, following the north side of the track. It is a level of about 20 cm of variable composition. The grain size decreases upwards. The lower part of the layer is a black silt that progressively changes upwards to brown silt with higher clay content and to gray clay at the top. There is a brown-orange level below of higher carbonate content. The transition between these two layers has also been sampled. There are gastropod remains in all levels but more abundant in the brown silts. After the test sample of 100 kg we collected about 1400 kg in total.

Cañada 9

It is approximately three meters higher than the previous site, at the same side of the track, but up in the slope. It is a thick gray-green clayey level with many large gastropod remains (both broken and complete). The level lies between layers of nodular limestone. We collected the upper 30-40 cm of this level. A test sample of 100 kg and a production sample of 2000 kg were collected.

Cañada 10

Following same side of the dirt road 190 m away from Cañada 9, at about 930 m of altitude, we found a clayey level, 20 cm thick, with gastropod remains. It is brown at the base but turns to black towards the top. A test sample of 100 kg and a production sample of 2000 kg were collected from the darkest part.

Cañada 11

It is located 210 m away from the previous site, in the slope of a pathway on the south side of the dirt road in front of an electric pylon; the altitude is slightly higher than 930 m. It is a black marly level that irregularly passes laterally into a dark brown marl with abundant carbonate nodules. The darkest part has sparse small gastropod remains and carbonates. A test sample of 100 kg was collected.

Cañada 12 and Cañada 13

The upper sites of the section are situated approximately 1600 m away from the N-234 road, just after the junction of the dirt road with the one running south to Pedregueras. Cañada 12 is a small light gray sandy channel, in the slope below the plateau, containing macro-vertebrate remains, clay balls and small nodules of carbonate. Cañada 13 is a variegated clayey layer just above Cañada 12. It is red, orange, gray and green, and also contains some small remains of vertebrates. Test samples of 100 kg from each site were collected.

Paleontology

Cañada 5

Vertebrate remains are scarce. Identifiable elements include Ochotonidae incisors, osteoderms and vertebrae of reptiles. The micromammal faunal list is as follows:

— Erinaceinae indet.
— *Prolagus* sp.

Cañada 6

Vertebrate remains are scarce. Identifiable elements include postcranial bones of micromammals, Ochotonidae incisors, osteoderms and vertebrae of reptiles and fish. The small mammal faunal list is as follows:

— Erinaceinae indet.
— Soricidae indet.
— *Prolagus* sp.
— *Myomimus dehmi*
— *Hispanomys* sp.

Cañada 7

The vertebrate remains from this test sample are more abundant than from previous sites. Apart from the bone fragments, the identifiable elements include postcranial bones of micromammals, one fragment of a insectivore mandible, and one fragment of a rodent mandible, Ochotonidae incisors, osteoderms and vertebrae of reptiles, and vertebrae of fishes occur as well. The micromammal faunal list is as follows:

— *Parasorex* sp.
— Soricidae indet.
— Ochotonidae indet.
— *Myomimus dehmi*

Cañada 8

The sample includes numerous vertebrate remains. Apart from the bone fragments, the identifiable elements also include vertebrae of fishes, a high proportion (and diversity) of amphibian and reptiles (fragments of mandibles, vertebrae and osteoderms), postcranial bones of micromammals, and Ochotonidae and Rodentia incisors. The micromammal faunal list is as follows:

— *Parasorex* sp.
— Erinaceinae indet.
— *Miosorex grivensis*
— Soricidae indet.
— *Prolagus* sp.
— Castoridae indet.
— *Democricetodon crusafonti*
— *Megacricetodon minor-debruijni*
— *Hispanomys* cf. *nombrevillae*

Cañada 9

The sample of 2000 kg includes numerous vertebrate remains. Apart from the bone fragments, the identifiable elements include vertebrae of fishes, a high proportion (and diversity) of amphibian and reptiles (fragments of mandibles, vertebrae and osteoderms), postcraneal bones of micromammals, and Ochotonidae and Rodentia incisors. The micromammal faunal list is as follows:

— *Parasorex* sp.
— Soricidae indet.
— *Prolagus* sp.
— Castoridae indet.
— *Myomimus dehmi*
— *Muscardinus hispanicus*
— *Democricetodon crusafonti*
— *Megacricetodon minor - M. debruijni*
— *Megacricetodon ibericus*
— *Hispanomys* cf. *nombrevillae*

Cañada 10

The sample of 2000 kg includes numerous vertebrate remains, but most of them are unidentifiable bone fragments (preservation worse than those from Cañada 8 and 9). The micromammal faunal list is as follows:

— Erinaceinae indet.
— *Parasorex* sp.
— *Desmanella* sp.
— *Turiasorex pierremeini*
— *Prolagus* sp.
— Castoridae indet.
— *Myomimus dehmi*
— *Muscardinus hispanicus*
— *Ramys multicrestatus*
— *Megacricetodon minor - M. debruijni*
— *Hispanomys nombrevillae*

Cañada 11

A small number of vertebrate remains from the test sample were found. The identifiable elements include one osteoderm of a reptile. The micromammal faunal list is as follows:

— Ochotonidae indet.
— Castoridae indet.
— *Hispanomys* cf. *nombrevillae*

Cañada 12

The 100 kg test sample contains abundant vertebrate remains. It includes numerous Ochotonidae and Rodentia incisors and teeth fragments. The level also contains macrovertebrate remains (cf. *Tetralophodon*). The micromammal faunal list is as follows:

— cf. *Postpalerinaceus*
— *Parasorex* sp.
— *Desmanella* cf. *crusafonti*
— *Talpa* sp.
— *Paenelimnoecus* sp.
— cf. *Dinosorex*
— *Prolagus* sp.
— Castoridae indet.
— cf. *Atlantoxerus*
— cf. *Democricetodon sulcatus*
— *Ruscinomys schaubi*
— *Huerzelerimys turoliensis*
— *Occitanomys adroveri*
— cf. *Parapodemus barbarae*

Cañada 13

It is a rich locality (but not as rich as Cañada 12) with abundant vertebrate remains from the 100 kg test sample. It includes Ochotonidae and Rodentia incisors and jugal teeth fragments. The micromammal faunal list is as follows:

— *Parasorex* sp.
— Soricidae indet.
— *Prolagus* sp.
— Castoridae indet.
— cf. *Atlantoxerus*
— *Ruscinomys schaubi*
— *Huerzelerimys turoliensis*
— *Occitanomys adroveri*

Discussion

The faunal composition of the studied localities in the Cañada section indicates that it is stratigraphically equivalent to upper part of the Nombrevilla section that includes Nombrevilla 9 and younger localities such as the classic locality Nombrevilla 1 (Álvarez-Sierra *et al.*, 2003). The relative position

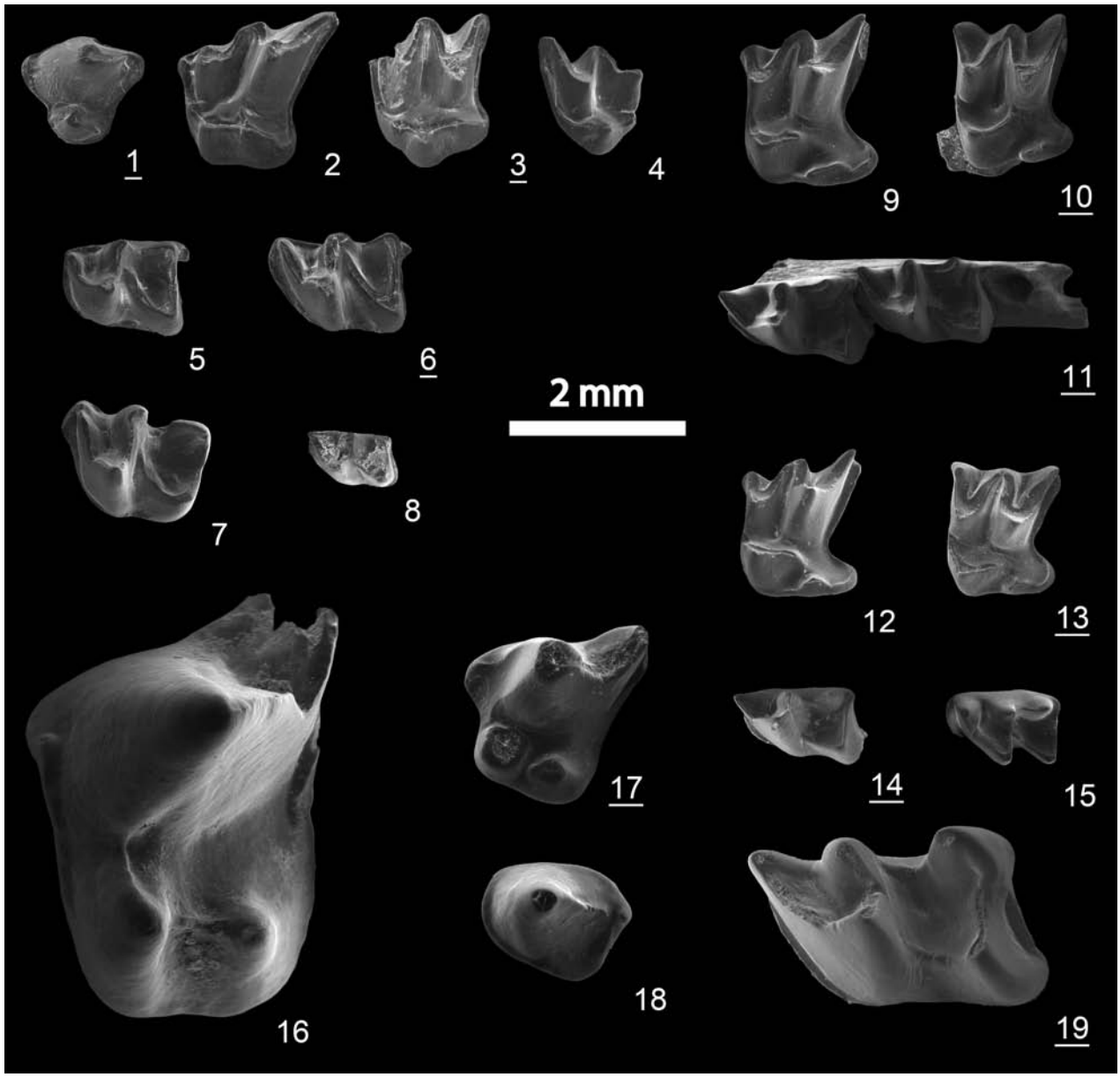

Fig. 2.—Insectivores from the Cañada section. *Desmanella* sp. from Cañada 10: **1**. P4 dext. (CAÑ 10-26); **2**. M1 sin. (CAÑ 10-27); **3**. M2 dext. (CAÑ 10-28); **4**. M3 sin. (CAÑ 10-30); **5**. m1 sin. (CAÑ 10-20); **6**. m2 dext. (CAÑ 10-25); *Talpa* sp. from Cañada 12: **7**. m3 sin. (CAÑ 12-88); *Paenelimnoecus* sp. from Cañada 12: **8**. m2 sin. (CAÑ 12-86); *Miosorex* sp. from Cañada 8: **9**. M1 sin. (CAÑ 8-101); **10**. M2 dext. (CAÑ 8-109); **11**. mandible with m1, m2 dext. (CAÑ 8-106); Soricidae indet. from Cañada 8: **12**. M1 sin. (CAÑ 8-108); **13**. M2 dext. (CAÑ 8-124); **14**. m1 dext. (CAÑ 8-103); **15**. m2 sin. (CAÑ 8-104); cf. *Postpalerinaceus* from Cañada 12: **16**. P4 sin. (CAÑ 12-100); *Parasorex* sp. from Cañada 8: **17**. P3 dext. (CAÑ 8-100); Erinaceinae indet. from Cañada 6: **18**. p2 sin. (CAÑ 6-41); *Parasorex* sp. from Cañada 12: **19**. m1 dext. (CAÑ 12-90); All specimens are figured as belonging to the left side to facilitate comparison; the numbers of the mirror images are underlined.

of Carrilanga with respect to Nombrevilla 1 is controversial. Since the inclusion of Carrilanga in the biostratigraphic scale of the Calatayud-Montalbán basin (Daams *et al*., 1987, 1999; Daams & Freudenthal, 1988) it has been considered younger than the classic Nombrevilla fauna. Van Dam *et al*. (2006) offer a different ranking for the lower Vallesian localities included in Zone H, proposing that Carrilanga is older than Nombrevilla 1. The new stratigraphic and paleontological information supports the latter conclusion. The levels containing the Carrilanga fauna are stratigraphically lower than those

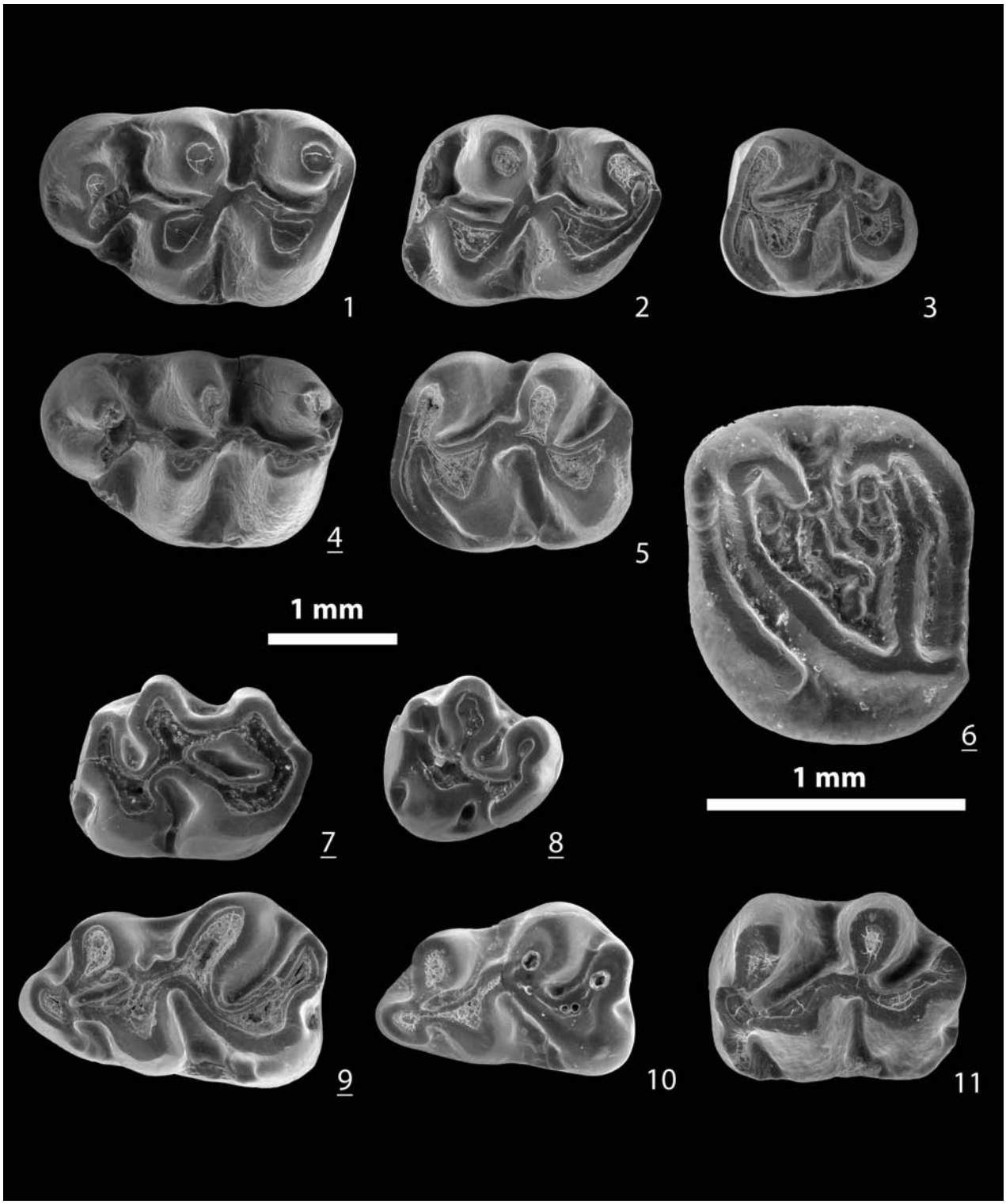

Fig. 3.—Rodents from the Cañada section. *Democricetodon crusafonti*: 1. M1 sin. (CAÑ 8-2) from Cañada 8; 2. M2 sin. (CAÑ 8-4) from Cañada 8; 3. m3 sin. (CAÑ 8-7) from Cañada 8; 4. M1 dext. (CAÑ 8-2) from Cañada 8; 5. m2 sin. (CAÑ 9-5) from Cañada 9; *Ramys multicrestatus*: 6. M1-2 dext. (CAÑ 10-10) from Cañada 10; *Hispanomys nombrevillae*: 7. M2 dext. (CAÑ 10-3) from Cañada 10; 8. M3 dext. (CAÑ 10-5) from Cañada 10; 9. m1 dext. (CAÑ 9-2) from Cañada 9; 10. m1 sin. (CAÑ 10-2) from Cañada 10; *Hispanomys* cf. *nombrevillae*: 11. m2 sin. (CAÑ 8-22) from Cañada 8. All specimens are figured as belonging to the left side to facilitate comparison; the numbers of the mirror images are underlined.

from the Cañada section. Moreover, the faunal compositions indicate that the Cañada localities are younger than that of Carrilanga. This is mainly based on the evolutionary stage of *Hispanomys*, which is closer to that in Nombrevilla 9, 10 and 1 (López Guerrero *et al*, 2009).

The different faunal localities can be correlated biostratigraphically with the nearby sections of Nombrevilla. The lower levels of the Cañada section (Cañada 6 to Cañada 9) correlate to the intermediate levels of Nombrevilla section, represented by Nombrevilla 9, 10, 1, 13 and 14 (Álvarez Sierra *et al*., 2003; López-Guerrero *et al*., 2009), based on the presence of *Hispanomys nombrevillae*, *Democricetodon crusafonti*, *Megacricetodon ibericus* and *Megacricetodon* belonging to the lineage *M. minor-M. debruijni*. All those localities show a typical Zone H composition (Daams & Freudenthal, 1988) with a high proportion of insectivores (Figure 2), lagomorphs, cricetid rodents and, in lower numbers, glirids. It is also important to point out the almost constant presence of castorids in the Cañada section. Castorids are also recorded in the Nombrevilla section and represent a re-entry in the Calatayud-Montalbán basin after an absence of 7 Myr (Álvarez-Sierra *et al*., 2003; López Guerrero *et al*., 2007).

The intermediate part of the Cañada section (Cañada 10 and 11) shows a faunal combination that is recorded neither in the Nombrevilla nor in the Pedregueras sections. The faunal particularity is the co-ocurrence of *Ramys multicrestatus*, a taxon characteristic of Zone I, and *Hispanomys nombrevillae*, typical for Zone H (Figure 3), instead of *H. aragonensis,* typical for Zone I. Therefore, it represents a new combination of taxa intermediate between the previously known upper levels of zone H, such as Nombrevilla 13 and 14, and the Pedregueras levels belonging to Zone I. Based on the presence of a characteristic taxon of the Zone H (*H. nombrevillae*) and despite of the presence of *Ramys,* we place Cañada 10 and 11 in the upper part of Zone H. The scarcity of the material does not allow establishing with certitude that the last occurrence of *M. ibericus* predates the first occurrence of *Ramys* in the basin nor that the latter is previous to the first occurrence of *Cricetulodon*. The new data indicate that the first occurrence of *Hispanomys aragonensis* is posterior to that of *Ramys*.

Finally, the upper part of the Cañada section includes a canalized structure which sediments contain two superposed Turolian faunas. The faunal composition of Cañada 12 and 13 can be correlated with the Biozone L of Van Dam *et al*. (2001) based on the presence of the murids *Huerzelerimys turolensis*, *Occitanomys adroveri* and *Parapodemus barbarae* (Figure 4). Faunas from this period are rare in the Calatayud-Montalbán basin. Is noticeable the presence of a cricetid rodent like cf. Democricetodon sulcatus. In the northern part, near Calatayud, various small Turolian faunas were found (Sesé, 2003; Van Dam & Sanz-Rubio, 2003). The Cañada 12 and 13 assemblages are the first Turolian faunas recorded in the Villafeliche-Daroca area. This new finding implies a gap in the faunal information of approximately 2 Myr in this area, including the Zones J1, J2, J3, J4, and K.

Conclusions

The results obtained during prospection and excavation of the new Cañada section provide a better knowledge on the lower Vallesian record of the Daroca area. The faunal assemblages of the Cañada localities allow for a straightforward biostratigraphical correlation to the near sections of Nombrevilla. The new stratigraphic and paleontological information has improved the time resolution of the lower Vallesian faunas and has constrained more precisely the relative biostratigraphic position of Nombrevilla 1 and Carrilanga, supporting the older age of the Carrilanga fauna. The intermediate part of the Cañada section contains a new faunal combination stratigraphically intermediate between the previously known associations of zone H and Zone I, and it is assigned here to zone H (top). In addition, the two superposed Turolian faunas from the Cañada section represent the first evidence of this age in the Villafeliche-Daroca area, being among the few Turolian localities found in the Calatayud-Montalbán basin. Thus, the results of this work, and the more detailed analysis of these micromammal faunas in progress, will further complete the gaps on our knowledge of the paleontological record from the Miocene deposits of this basin.

AKNOWLEDGEMENTS

With this paper we honor the great paleontologist Leonard Ginsburg. When we sampled the Cañada section, Leonard was there as part of the 'large mammal' team that was digging the nearby fossil site of Toril 3. Those of us that were there vividly remember the histories he shared with great enthusiasm with his

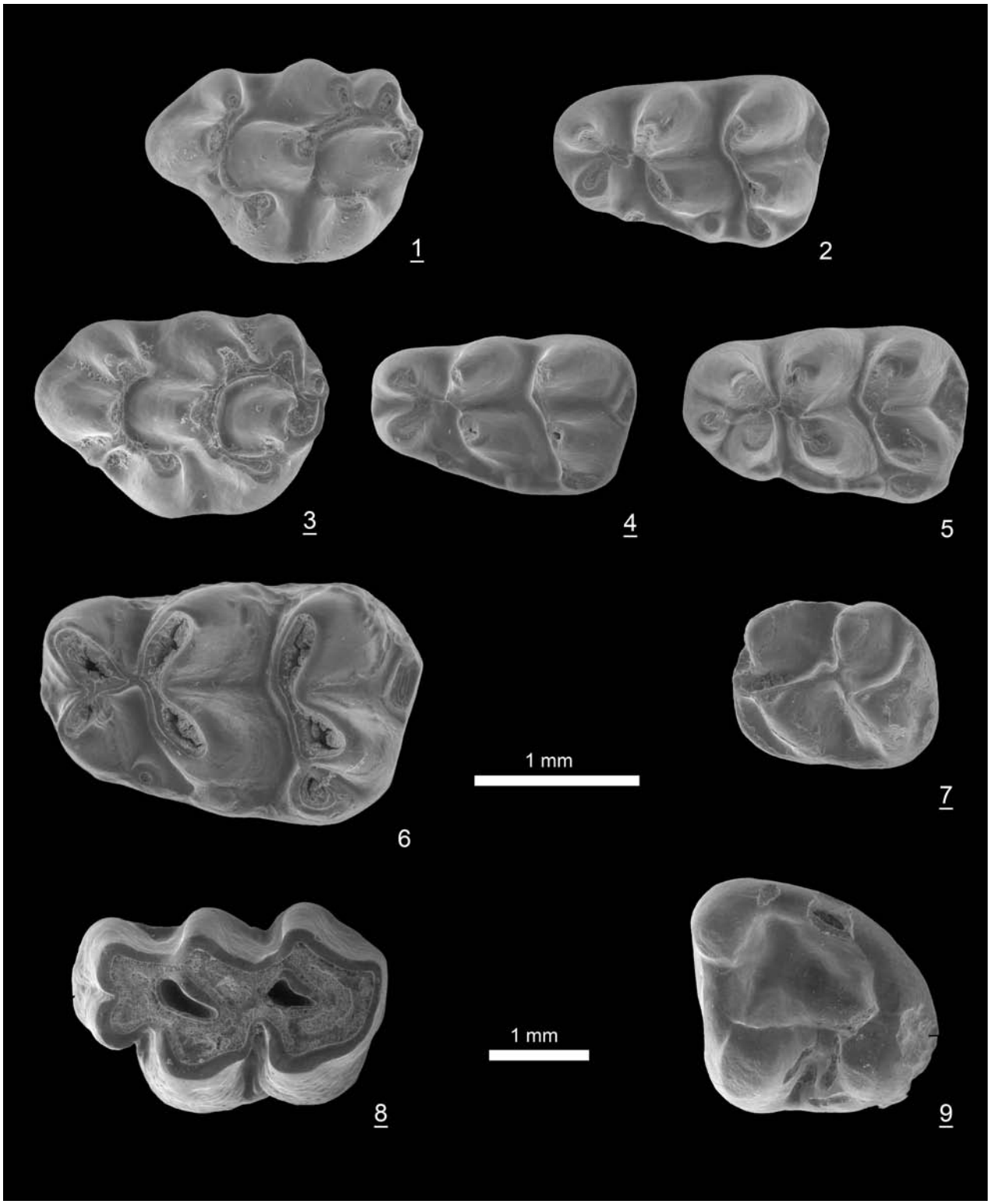

Fig. 4.—Rodents from the Cañada section. *Occitanomys adroveri* from Cañada 13: **1.** M1 dext. (CAÑ 13-26); **2**. m1 sin. (CAÑ 13-17); *Occitanomys adroveri* from Cañada 12: **3**. M1 dext. (CAÑ 12-40); **4**. m1 dext. (CAÑ 12-67); cf. *Parapodemus barbarae* from Cañada 12: **5**. m1 sin. (CAÑ 12-74); *Huerzelerimys turoliensis*: **6**. m1 sin. (CAÑ 12-26); cf. *Democricetodon sulcatus*: **7**. m2 dext. (CAÑ 12-30); *Ruscinomys schaubi* from Cañada 12: **8**. M1 dext. (CAÑ 12-4); cf. *Atlantoxerus*: **9**. m3 dext. (CAÑ 12-98). All specimens are figured as belonging to the left side to facilitate comparison; the numbers of the mirror images are underlined.

younger colleagues. Therefore, we cannot think of a subject more befitting a volume in his honour, than the results of the work we did in those days.

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