Biochronological data inferred from the early Pleistocene Arvicolinae (Mammalia, Rodentia) of the El Chaparral site (Sierra del Chaparral, Cádiz, southwestern Spain)

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Rodents are one of the most stratigraphically significant groups of mammals in the European Pleistocene, because they have diversified more than other taxa over this relatively short geological time span. Arvicolines (voles) are particularly useful for biochronological correlation, because of the abundance of their remains and their rapid evolutionary rates. In addition, some voles undertook long-range and rapid migrations and may have had extensive geographical distributions, which enable interregional correlations (Minwer-Barakat et al., 2011). For these reasons, arvicolines have been used for the biostratigraphical subdivisions of the Quaternary (Chaline, 1972; van der Meulen 1973; Agustí, 1986; Sala and Masini, 2007; Cuenca-Bescós et al., 2010a; among many others).

The El Chaparral site is located in the western sector of the Betic Cordilleras mountain range, in an area known as Manga de Villaluenga del Rosario (Cádiz), forming part of the Grazalema Natural Park. It is a deposit of endokarstic origin located between 950 and 1080 m a.s.l., which forms part of the Jurassic limestone pavement of the Sierra del Chaparral (UTM coordinates: X286547, Y4062771; Fig. 1). In February 2009 a calcareous breccia was discovered that is rich in fossil bone remains. Once the state of conservation of the osseous remains and of the brecciated deposits had been evaluated, it was agreed that the site would be excavated.

The stratigraphic and sedimentological features of the site have been well established in previous studies (Giles Pacheco et al., 2011). As for paleontologic work, several fossil groups from the El Chaparral site have already been studied, including amphibians, squamate reptiles, insectivores, bats, carnivores and ungulates (Table 1). The rodents from the site have also been published as a faunal list (Table 1) (Giles Pacheco et al., 2011).

This work aims to provide a detailed study of the arvicoline (rodent) faunas from the El Chaparral site. Particularly interesting is the correlation of the El Chaparral site with the Sierra de Atapuerca, which contains one of the most complete stratigraphic sequences from the continental Pleistocene of Europe, with very abundant and diverse arvicoline rodents, in which the earliest record of *Homo* in western Europe has been documented (Cuenca-Bescós et al., 2010a; Carbonell et al., 2008, among many others). This study thus offers a good opportunity for adding to knowledge about the arvicoline rodent assemblages of the early Pleistocene.

GEOLOGICAL SETTING

Manga de Villaluenga, situated between the towns of Benaocaz and Grazalema in the southwest of the Sierra de Grazalema Natural Park, is a site of scenic interest made up of a long, narrow depression comprising abrupt walls and a flat base. Apart from a few torrents that drain towards the Abyss of Villaluenga, no fluvial course of any importance flows through it, due to the high degree of surface infiltration produced by the karstification of the Jurassic limestone (Santiago and Pedroche, 2000). The valley is positioned on a fan-shaped syncline, the nucleus of which features the silty marls of the Upper Cretaceous (red layers). The sides (Sierra del Caillo-Sierra del Chaparral) are made up of Jurassic limestone and dolomite with almost vertical inclination. The direction of the valley coincides with that of the syncline axis, having been excavated by erosion to the core, in favour of the softer Cretaceous materials which are now only present in small amounts at the lowest points of the sides and base of the valley (Gutiérrez et al., 1991). The Quaternary deposits in this sector are made up of calcium-deficient red clays (terra-rossa) over which flow temporary streams that run

underground through abysses and fractures upon reaching the limestone substrate, getting lost in the interior of the massif. El Chaparral is a karst fracture, an abyss silted with calcium-deficient terra-rossa, limestone blocks normal in Jurassic formations highly affected by the action of clays and speleothems (calcites) from the walls of the fracture.

The paleontologic deposit is found in the interior of the fracture and is partially brecciated in some parts (a conglomerate of fauna, highly altered limestone blocks and speleothems [calcites] covered in the terra-rossa matrix clay) whereas in others there are only non-brecciated remains in the same clays. It all seems to correspond to the same unit of red clays (terra-rossa).

The stratigraphy of the site is based on the sedimentary units which mainly form the deposits called C1 and C2. Level C1, reaching from 10 to 15 cm, is composed of an edaphic sublevel of terra-rossa integrated with red clay sediments with organic elements and characterized by a high rate of bioturbation, mainly by vegetation. It contains some macro and microfauna remains. Level C2, reaching from 50 to 60 cm, is made up of an extremely homogenous, multi-coloured, compact terra-rossa. It does not show signs of significant bioturbation. The coarser elements of the deposit are predominantly limestone rock, completely smoothed on the surface by the slow erosive action of the terra-rossa and of angular calcite fragments. These contain the highest concentration of macro and microfauna (Giles Pacheco et al., 2011) (Fig. 1).

MATERIAL AND METHODS

During the excavation of the El Chaparral site sediments for each different level were screen-washed in order to obtain the small-vertebrate fossil remains. Most of the

material, except for a few molars, comes from level C2. The specimens described were sorted in the Institut de Paleoecologia Humana i Evolució Social (IPHES, Tarragona, Spain). The El Chaparral assemblage includes a total of 68 identified arvicoline teeth corresponding to a minimum number of 33 individuals, representing at least 5 taxa: *Allophaiomys lavocati*, *Victoriamys chalinei*, *Iberomys huescarensis*, *Pliomys episcopalis* and *Terricola* cf. *arvalidens*.

The nomenclature used in the descriptions of the arvicoline teeth (only first lower molars are considered) is that of van der Meulen (1973) and Martin (1987). Length, width and parameters a, b, c, d and e (Fig. 2) are those proposed by van der Meulen (1973), and parameters Li and La are those proposed by Cuenca-Bescós et al. (1995) (Fig. 2). Index A/L is the ratio between parameter a and length; B/W and C/W are the ratios between parameters b and c and width; and La/Li is the ratio between the parameters Li and La.

Institutional Abbreviations—**VR-CHP**, Villaluenga del Rosario-Chaparral.

Anatomical Abbreviations—**ACC**, anteroconid complex; **AC**, anterior cap; **BRA**, buccal re-entrant angle; **BSA**, buccal salient angle; **L**, length; **La**, mean width of T4; **Li**, mean width of T5; **LRA**, lingual re-entrant angle; **LSA**, lingual salient angle; **PL**, posterior lobe; **TTC**, trigonid-talonid complex, **T1–T7**, triangles 1–7; **W**, width.

SYSTEMATIC PALEONTOLOGY

Family CRICETIDAE Fischer, 1817.

Subfamily ARVICOLINAE Gray, 1821

Genus *ALLOPHAIOMYS* Kormos, 1932

ALLOPHAIOMYS LAVOCATI Laplana and Cuenca-Bescós, 2000

(Fig. 3A–C)

Occurrence and Material—Level C1: one complete (VR-CHP09/C1/J15/158-167) m1. Level C2: one partial and three complete (VR-CHP09/C5/J15/192-200) m1; one complete (VR-CHP09/C2/K16/135-187) m1; eight complete (VR-CHP/C3/J15/176-184) m1; two partial and seven complete (VR-CHP09/C4/J15/184-192) m1; one partial (VR-CHP09/C2/J15/168-176) m1; two partial and three complete (VR-CHP09/C6/J15/200-208) m1; one partial and two complete (VR-CHP09/C6/J15/208-210) m1; one complete (VR-CHP09/C4/K15/198-204) m1.

Measurements—See Table 2.

Description—The complete teeth present a posterior lobe, three closed triangles and the anteroconid complex (ACC). The enamel is thinner in the trailing edges than the leading edges in m1 (positive or *Microtus*-like). The synclines are filled with cement. T4 and T5 are broadly confluent and connect with AC by a relatively narrow neck. The buccal border of AC is rounded, and no distinct T6 is observed. On the anterolingual side, there is a clearly distinct, pointed T7, delimited by a very deep LRA4 and a shallower, but clear LRA5.

Remarks—The measurements of the specimens of *A. lavocati* from the El Chaparral site fall within the size ranges of the population from the type locality of the species in the Sima del Elefante Lower Red Unit (Laplana and Cuenca-Bescós, 2000), and from Cal Guardiola Layer D3 (Minwer-Barakat et al., 2011). The length, width and the values of A/L and C/W are very close to the mean values from Sima del Elefante and Cal Guardiola. This species differs from the other European early Pleistocene species of *Allophaiomys*, such as *A. pliocaenicus*, *A. burgondiae*, *A. nutiensis* and *A. chalinei*, from Guadix Baza basin, Betfia 2, Monte Peglia, Valerots, Cueva Victoria or TD3-TD4 (Atapuerca), in the general morphology and size of the m1 (see discussion in

García-Alix et al., 2009; van der Meulen, 1973; Laplana et al., 2000, Alcalde et al., 1981; Minwer-Barakat et al., 2011).

Moreover, *A. aff. lavocati* has been cited in Barranco León D in the Guadix-Baza basin, though a definitive species assignment has not been made (Agustí et al., 2010). In fact, other authors have referred this material to *A. cf. pliocaenicus* (Gibert et al., 2007). These three localities (Sima del Elefante Lower Red Unit, Cal Guardiola Layer D3 and Barranco León D) have all been assigned to an early Pleistocene age (1.2 Ma).

Genus *VICTORIAMYS* Martin, 2012

VICTORIAMYS CHALINEI (Alcalde, Agustí and Villalta, 1981)

(Fig. 3D–H)

Occurrence and Material—Level C1: one complete (VR-CHP09/C1/K18/143-150) m1. Level C2: one partial and two complete (VR-CHP09/C5/J15/192-200) m1; one complete (VR-CHP09/C3/J15/176-184) m1; four complete (VR-CHP09/C4/J15/184-192) m1; one partial and one complete (VR-CHP09/C2/J15/168-176) m1; four complete (VR-CHP09/C6/200-208) m1; one partial and nine complete (VR-CHP09/C6/K15/196-204) m1; one partial and eight complete (VR-CHP09/C6/J15/208-210) m1; two complete (VR-CHP09/C4/K15/180-188) m1; two complete (VR-CHP09/C5/K15/188-196) m1; one complete (VR-CHP09/C7/J15/202-210) m1.

Measurements—See Table 2.

Description—The recovered molars present a posterior lobe, three closed triangles and the anteroconid complex (ACC). T4 and T5 are broadly confluent and connect with the anterior cap (AC). The AC is very short and broad; it is mesiodistally

compressed. The enamel is undifferentiated. The amount of cement in the re-entrant folds is variable.

Remarks—The size of the specimens of *V. chalinei* from El Chaparral falls within the range of those from the type locality of the species, Cueva Victoria (Alcalde et al., 1981), TD3-TD4 of Gran Dolina (Atapuerca) (Cuenca-Bescós et al., 1995) and Cal Guardiola Layer D5 (Minwer-Barakat et al., 2011). The *V. chalinei* specimens from El Chaparral are generally larger than the *A. lavocati* specimens (Fig. 4). *Victoriamyschalinei* has been identified in several early Pleistocene sites, such as Cueva Victoria (Alcalde et al., 1981), Almenara-Casablanca 3 (Agustí & Galobart, 1986), Huetor Tájar 1 and 8 and Tojaire-1 (García-Alix et al., 2009) and TD3 to TD6 of Gran Dolina (Cuenca-Bescós et al., 1995), with an estimated age of 0.9 -0.85 Ma.

Genus *IBEROMYS* Chaline, 1972

IBEROMYS HUESCARENSIS (Ruiz Bustos, 1988)

(Fig. 3I, J)

Occurrence and Material—Level C2: one complete (VR-CHP09/C5/J15/192-200) m1; one complete (VR-CHP09/C2/K16/135-187) m1; three complete (VR-CHP09/C4/J15/184-192) m1; two complete (VR-CHP09/C5/K15/188-196) m1.

Measurements—See Table 2.

Description—The teeth are characterized by bucco-lingual asymmetry; the buccal triangles are much smaller than the lingual ones (Table 2; Fig. 4). Cement is abundant in the synclines. The enamel differentiation is positive or *Microtus*-like. The posterior lobe, T1, T2 and T3 are isolated. T4 and T5 are confluent in all specimens. The AC is short and triangular, separated from T4–T5 by a very narrow neck. LRA5 and T7 are well developed. BRA4 is absent, so T6 is hardly differentiated from the AC.

Remarks—The morphology of the specimens recovered in El Chaparral is very similar to that of the few specimens of *I. huescarensis* from Huescar-1, the type locality (see Ruiz-Bustos, 1988). The measurements obtained for our specimens fall within the range of those from the type locality, Huescar-1 (Mazo et al., 1985), levels TD3–TD4 and TD6 from Gran Dolina, Atapuerca (Cuenca-Bescós et al., 1995; 1999), and Cal Guardiola Layer D5 and Vallparadís Layer EVT7 (Minwer-Barakat et al., 2011). The conjunction of the great asymmetry between buccal and lingual triangles and the short, subtriangular AC distinguishes *I. huescarensis* from the early Pleistocene species *Steneocranius gregaloides*, *Microtus arvalidens* and *Microtus sesae*. Apart from the Italian locality of Rifreddo (Masini et al., 2005), *I. huescarensis* has only been identified in Spain, where it is a common element of the early Pleistocene mammal assemblages.

Genus *PLIOMYS* Méhely, 1914

PLIOMYS EPISCOPALIS Méhely, 1914

(Fig. 3K, 5)

Occurrence, Material and Measurements—Layer C2: one complete m1 (VR-CHP09/C5/J15/192-200, L: 2.73 mm; W: 0.93 mm; a: 1.41 mm; b: 0.12 mm; c: 0.07 mm; La: 0.39 mm; Li: 0.53 mm; A/L: 51.65; B/W: 12.9; C/W: 7.52; La/Li: 73.58).

Description—The tooth recovered is rooted, without cement in the re-entrant angles, and the triangles of the TTC are semi-closed. In the ACC, T4-T5 are semi-open, with a wide neck separating the triangle of the ACC from a well-developed T6 and a non-existent T7 hardly confluent with the AC. The ACC seems to be leaning toward the labial side.

Remarks—The tooth recovered in El Chaparral layer C2 is morphologically quite similar to the specimens ascribed to *P. episcopalis* from TD3-TD4 and TD6 of Gran Dolina, Atapuerca (Cuenca-Bescós et al., 1995; 1999). The measurements of the tooth fall within the range of those from TD3 and TD4 of Gran Dolina, Atapuerca (Cuenca-Bescós et al., 1995). According to Chaline (1987), the reduction of T7 and the ACC that seems to be leaning toward the labial side are unique characters of *P. episcopalis* and separate it from the closely related species *P. lenki*.

Genus *MICROTUS* Schrank, 1798

Subgenus *TERRICOLA* Fatio, 1867

MICROTUS (TERRICOLA) ARVALIDENS (Kretzoi, 1958)

(Fig. 3L)

Occurrence, Material and Measurements—one complete m1 (VR-CHP09/C1/J15/158-167, w: 0.80 mm; a: 1.26 mm; b: 0.04 mm; c: 0.19 mm; d: 0.28 mm; e: 0.75 mm; La: 0.38 mm; Li: 0.39 mm).

Description—The enamel differentiation is positive or *Microtus*-like. The posterior lobe, T1, T2 and T3 are closed. In the ACC, T4 and T5 are broadly confluent, forming the so-called “*Pitymys*-rhombus”, separated from the AC by a long, narrow neck. The asymmetry between buccal and lingual triangles is not very accentuated. BRA3 and LRA4 are opposed. T6 and T7 are well developed and connect broadly with the AC.

Remarks—The tooth recovered from El Chaparral falls within the range of the specimens of *Microtus (Terricola) arvalidens* from TD3 and TD4a of Gran Dolina, Atapuerca, but is slightly smaller than the specimens of the same species from TD4b

and TD6 of Gran Dolina, Atapuerca (Cuenca-Bescós et al., 1995; 1999) and the specimens from Cal Guardiola Layer D5 and Vallparadís Layer EVT3 (Minwer-Barakat et al., 2011). The morphology of the occlusal surface of the tooth is very similar to that of *M. arvalidens* from Atapuerca (Cuenca-Bescós et al., 1995; 1999), Cal Guardiola and Vallparadís (Minwer-Barakat et al., 2011), Monte Peglia (van der Meulen, 1973), Rifreddo (Masini et al., 2005) and West Runton (Maul and Parfitt, 2010). The broad confluence of T4-T5, the unmarked asymmetry of buccal and lingual triangles and the development of T6 distinguish *M. (T.) arvalidens* from other closely related early Pleistocene voles such as *Steneocranius gregaloides* and *Iberomys huescarensis*. *M. (T.) arvalidens* is common in European early Pleistocene assemblages, but also documented in the middle Pleistocene (Markova, 2006, among others).

BIOCHRONOLOGICAL REMARKS

Small mammals, and particularly arvicolines, evolved rapidly during the Quaternary, so their record provides an important basis for the stratigraphic divisions and correlations between distant areas. In particular, the quick evolutionary radiation of the “*Microtus* group” (which includes forms ascribed to *Microtus*, *Allophaiomys*, *Stenocranius*, *Terricola*, *Iberomys* and *Pallasiinus*) constitute very useful tools for correlating European Pleistocene faunas.. The arvicoline assemblage from El Chaparral is composed of five extinct species (*A. lavocati*, *V.chalinei*, *I. huescarensis*, *P. episcopalis* and *M. (T.) arvalidens*). At the moment, *A. lavocati* is only represented in the Iberian Peninsula in the lower layers of the Sima del Elefante (TE7-14), Cal Guardiola Layer D3, and probably as *A. aff. lavocati* in Fuente Nueva 3 and Barranco León D (Cuenca-Bescós et al., 2010a; Minwer-Barakat et al., 2011; Agustí et al., 2010).

1 These localities have been estimated to be between 1.4 and 1.2 Ma in age in the
2 *Allophiomys lavocati* biozone, which may be included in the early Biharian of the
3 European mammal biozonation (Cuenca-Bescós et al., 2010). On the other hand, the
4 rest of the arvicoline association of El Chaparral (*V. chalinei*, *I. huescarensis*, *P.*
5 *episcopalis* and *M. (T.) arvalidens*) is represented in the lower layers of Gran Dolina
6 (TD3-TD6) in the Sierra de Atapuerca and in Cal Guardiola Layer D5 and Vallparadís
7 (EVT7) (Cuenca-Bescós et al., 2010; Minwer-Barakat et al., 2011). These layers are
8 situated in a Jaramillo-Matuyama-Brunhes chronology between 0.9–0.78 Ma in the *V.*
9 *chalinei* biozone (Cuenca-Bescós et al., 2010a), which may be included in the late
10 Biharian mammal age (Masini and Sala, 2007), correlated with the lower part of the
11 Galerian (cf. Cuenca-Bescós et al., 2010a). The presence of *A. lavocati* in our
12 assemblage, a species that seems to persist in the El Chaparral until recent times than
13 previously known, is probably related to the location of the site (a mountain range that
14 works as a refuge). This phenomenon can also be observed with other arvicoline species
15 in Iberia, such as *Chionomys nivalis*, at the beginning of the Holocene in the Pyrenean
16 mountain range (López-García et al., 2010) or *Pliomys lenki* during the late Pleistocene
17 in the Cantabrian range (Cuenca-Bescós et al., 2010b). Apart from *A. lavocati* the
18 absence from El Chaparral of the ancient forms of arvicoline species such as *A.*
19 *nutiensis*, *A. burgondiae* or *Ungaromys nanus* that appear in the lower layers of Sima del
20 Elefante (TE7-TE14), Atapuerca (Cuenca-Bescós et al., 2010), suggests that the age of
21 the site is close to that of the lower layers of Gran Dolina (TD3-TD6), Atapuerca
22 (Cuenca-Bescós et al., 2010), as well as Cal Guardiola Layer D5 and Vallparadís
23 (EVT7) in Barcelona (Minwer-Barakat et al., 2011), Cueva Victoria in Murcia (Agustí
24 et al., 2009), Huescar-1 in Granada (Mazo et al., 1985; Agustí et al. 2010), and Amenara
25 Casablanca 3 in Castellón (Agustí et al., 2011): i.e. between 0.9-0.78 Ma (Fig. 6). These

1 data can be corroborated with the large-mammal proxies, in which the presence of the
2 carnivores *Puma pardoides* and *Vulpes praeglacialis* and the ungulates *Hemitragus*
3 *bonali*, *Capreolus* sp. and *Stephanorhinus etruscus* brackets the age of the El Chaparral
4 site between the Jaramillo Subchron (1.07-0.99 Ma) and shortly after the Matuyama-
5 Brunhes transition at 0.78 Ma (Giles Pacheco et al., 2011).

6 7 CONCLUSIONS

8
9 The El Chaparral site has yielded five arvicoline species: *A. lavocati*, *V. chalinei*,
10 *I. huescarensis*, *P. episcopalis* and *T. arvalidens*. The presence of the *A. lavocati* in our
11 assemblage shows that the species existed longer than previously known. The
12 association of the last four of these species together with the large-mammal assemblage
13 from El Chaparral allow us to include the site in the *Allophaiomys chalinei* biozone and
14 the late Biharian mammal age, suggesting a chronology for El Chaparral similar to Gran
15 Dolina (TD3-TD6) and Cal Guardiola Layer D5 and Vallparadís (EVT7), which are
16 placed between the top of the Jaramillo Subchron and the Matuyama-Brunhes
17 boundary (0.99-0.78 Ma).

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FIGURE CAPTIONS

FIGURE 1. **A**: location of the El Chaparral site. **B**: sketch cross-section of the El Chaparral site. (2/3 page width)

FIGURE 2. Nomenclature and measuring methods used for the first lower molars in the description of Arvicolinae. **Abbreviations**: **ACC**, anteroconid complex; **AC**, anterior cap; **BRA**, buccal re-entrant angle; **BSA**, buccal salient angle; **L**, length; **La**, mean width of T4; **Li**, mean width of T5; **LRA**, lingual re-entrant angle; **LSA**, lingual salient angle; **PL**, posterior lobe; **TTC**, trigonid-talonid complex, **T1–T7**, triangles 1–7; **W**, width. (2/3 page width)

FIGURE 3. Arvicolinae from El Chaparral. **A**, m1 left *Allophaiomys lavocati* (VR-CHP09/C3/J15/176-184); **B**, m1 right *A. lavocati* (VR-CHP09/C4/J15/184-192); **C**, m1 right *A. lavocati* (VR-CHP09/C6/J15/200-208); **D**, m1 left *Victoriamys chalinei* (VR-CHP09/C1/K18/143-150); **E**, m1 left *V. chalinei* (VR-CHP09/C4/J15/184-192); **F**, m1 left *V. chalinei* (VR-CHP09/C5/K15/188-192); **G**, m1 left *V. chalinei* (VR-CHP09/C6/K15/196-204); **H**, m1 right *A. chalinei* (VR-CHP09/C6/J15/200-208); **I**, m1 right *Iberomys huescarensis* (VR-CHP09/C2/K16/135-187); **J**, m1 left *I. huescarensis* (VR-CHP09/C5/K15/188-196); **K**, m1 left *Pliomys episcopalis* (VR-CHP09/C5/J15/192-200); **L**, m1 right *Terricola* cf. *arvalidens* (VR-CHP09/C1/J15/158-167). All the teeth are arranged in occlusal view. Scale 2 mm. (whole page width)

FIGURE 4. Distribution of the *Allophaiomys*, *Victoriamys* and *Iberomys* species from the El Chaparral site for variables A/L (vertical axis) and La/Li (horizontal axis). For abbreviations see Material and Methods. (2/3 page width)

FIGURE 5. First lower left molar (m1) *Pliomys episcopalis* (VR-CHP09/C5/J15/192-200). Left: occlusal view; right: buccal view. Scale 1 mm. (column width)

1 FIGURE 6. Correlation of the European chronology with the principal early Pleistocene
2 archaeo-paleontological sites in the Iberian Peninsula, placing the El Chaparral site in
3 its context. Atapuerca TE refers to Atapuerca Sima del Elefante levels TE7 to TE14;
4 Atapuerca TD refers to Gran Dolina levels TD3-TD6. C-B et al. 2010: Cuenca-Bescós
5 et al. 2010; M&S07: Masini and Sala 2007. (whole page width)