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Large mammal biochronology framework in Europe at Jaramillo: The Epivillafranchian as a formal biochron

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ABSTRACT

European large mammal assemblages in the 1.2–0.9 Ma timespan included Villafranchian taxa together with newcomers, mostly from Asia, persisting in the Middle Pleistocene. A number of biochronological schemes have been suggested to define these "transitional" faunas. The term Epivillafranchian, originally proposed by Bourdier in 1961 and reconsidered as a biochron by Kahlke in the 1990s, is at present widely introduced in the literature. This contribution, after selecting the most representative European large mammal assemblages within this chronological interval, provides a new definition proposal for the Epivillafranchian as a biochron included within the *Praemegaceros verticornis* FO/*Bison menneri* FO, and *Crocuta crocuta* FO.

1. Historical background

The Villafranchian Mammal Age corresponds, in the International Stratigraphic Scale, to a timespan from Late Pliocene to most of the Early Pleistocene. Within these limits, the Villafranchian is comprised between 3.5 Ma and 1.1–1.0 Ma (Pillans and Gibbard, 2012). The Late Villafranchian–Galerian transition also occurs within the Matuyama magnetochron, between the K and Jaramillo subchrons around 1.1 Ma, within the late Early Pleistocene (Berggren et al., 1995; Napoleone et al., 2003). A recent revision of the Villafranchian (Rook and Martínez-Navarro, 2010) points out that the transition from Villafranchian to Galerian Mammal Ages deserves a wider re-evaluation, representing a major episode in mammalian fauna reorganization. Furthermore the 1.2–0.9 Ma time span represents the final phase of the interval dominated, in the global climatic record, by 41 ky periodicity. This period is characterized by significant fluctuations in $\delta^{18}O$ values, in contrast to those recorded during the earlier part of the Matuyama magnetochron (Lisiecki and Raymo, 2005). The increased climatic instability of this time interval created a significant climatic variability in subtropical Africa (De Menocal, 2004), and the ecological preconditions for faunal turnover in Europe. The mammal faunal communities of this time span primarily include survivors from the latest Villafranchian, as well as more evolved taxa characteristic of the beginning Middle Pleistocene (Kahlke, 2007; Rook and Martinez Navarro, 2010).

New terms (intended as sub-biochron, or more or less "informal" biochron) have been proposed to define such faunal assemblages, calibrated directly below the Jaramillo submagnetochron: Protogalerian (Caloi and Palombo, 1996); Epivillafranchian (Kahlke, 2001, 2006, 2007, 2009); "latest Villafranchian" (Koufos, 2001) and "Final Villafranchian" (Spassov, 2003). Although not formalized yet, the term Epivillafranchian seems to have been more widely introduced in the literature (Rook and Martinez Navarro, 2010). The latter name should be preferred also in term of nomenclature priority. The term Epivillafranchian (*Epi-Villafranchien* in the original paper) was introduced by Bourdier (1961) on the basis of the scheme proposed by Viret (1954) who subdivided the Villafranchian, considering large mammal bioevents, in: 1) *Villafranchien ancien*; 2) *Villafranchien normal inférieur*; 3) *Villafranchien normal supérieur* and 4) *Villafranchien supérieur*.

Bourdier (1961) proposed a revision of this scheme characterised by: i) *Proto – Villafranchien* between the Pliocene and the Quaternary, ii) *Villafranchien inférieur*; iii) *Villafranchien moyen*; iv) *Villafranchien supérieur* and v) "*Epi-Villafranchien*". According to Bourdier (1961), the latter is characterized by a "more evolved fauna that the Villafranchian one: Elephant teeth with more tight lamellae, occurrence of forms already similar to *Equus caballus* and, specifically, of the occurrence of the bison." The same author

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recognised within the Rhône Basin (France) a "warm" *Epi-Villafranchien* for the Durfort site (around 900 ka according Kahlke et al., 2011) and a "cold" *Epi-Villafranchien* for the site of Saint-Cosme. Bourdier (1961) considered the former as corresponding to the Günz-Mindel and the latter to the Mindel. The reason this term was not introduced or recognized by later authors is probably because Bourdier itself (1961) defined his scheme "very hypothetic" and "provisional". Moreover the same author did not mention in an explicit way the name *Epi-Villafranchien* in the figured scheme of his work, where the fauna and flora from Durfort was identified as "*Post-Villafranchien inférieur*" (characterized by the occurrence of *Elephant meridionalis* var. *cromerensis* and *Bos* cf. *Bison*) and the fauna and flora from Saint-Cosme was identified as "*Post-Villafranchien supérieur*" (characterized by *Equus stenonis*, *Rangifer tarandus*? and semi-archaic mollusk).

The term Villafranchian was proposed by Pareto (1865) as a continental stage referring to fluvial and lacustrine sediments in the surroundings of Villafranca d'Asti (Piedmont, Northern Italy) that contained mammal fauna remains. The same author also included within the Villafranchian definition mammalian faunas from Upper and Lower Valdarno basins, in Tuscany. On the other hand, the identification of mammal faunas referable to Middle Pleistocene in Italian peninsula occurred one century later thanks to the finding in 1960s of the mammal fauna from the area of Ponte Galeria (Rome) (Ambrosetti, 1967). Albeit well before both Tuccimei (1891, 1898) at Campo di Merlo (Rome) and De Alessandri (1903) at Cortiglione Monferrato (Asti, Piedmont) recovered "large size deer", but they did not recognized the biostratigraphic importance as "post-villafranchian" elements. Around Rome, non-marine Middle Pleistocene sections were extensively studied by Blanc and co-authors in 1950s (Blanc et al., 1953, 1955a,b), who correlated the sediments with periods of Alpine glaciations. In particular, Blanc (1957) described "five glacial periods" in Latium: I, Acquatraversan; II, Cassian; III, Flaminian; IV, Nomentanan; V, Pontinian. Blanc (1957) also proposed to correlate these with the Alpine glaciations: Acquatraversan with Donau; Cassian with Günz, or Mindel I; Flaminian with Mindel II, and pre-Riss; Nomentanan with Riss; and finally Pontinian with Würm. Moreover Blanc (1957) attributed sedimentary sequences bearing fossil remains to each of glacial cycles. Ambrosetti and Bonadonna (1967) and Ambrosetti et al. (1972) continued this approach by developing a continental type section for the Middle Pleistocene. The term Galerian was introduced by Ambrosetti et al. (1972) to indicate the sediments deposited between the erosive phases Cassia and Flaminia (between ~1 Ma and ~820 ka), very well represented in the area of Ponte Galeria (Rome). According to the original definition, the Galerian is characterized by the occurrence of *Bos primigenius*, *Elephas antiquus*, *E.* cf. *trogontherii*, *Megaceros verticornis*, *Mimomys savini*, *Cervus acoronatus* and *Hippopotamus amphibius*. Galerian has been used to define the Italian faunas previously attributed to Cromerian (Ambrosetti, 1967; Ambrosetti and Bonadonna, 1967; Azzaroli and Ambrosetti, 1970) and was then used as a Mammal Age (Azzaroli et al., 1982, 1988; Gliozzi et al., 1997; Sardella, 2007). To describe the faunal turnover at the Villafranchian/Galerian transition Azzaroli et al. (1988) defined the so-called "end-Villafranchian event" occurring at around 1 Ma, and these authors put in evidence that this transition "did not take place at once".

In the literature, the vertebrate faunas referable to the early Middle Pleistocene and having a similar composition to the Galerian fauna were often referred to as Cromerian or Tiraspolian but, as stated by Azzaroli et al. (1988), the first term "defines a stage based on pollen and of much shorter duration than Galerian", whereas the second one, based on a faunal complex from Moldova and used for Russian and other Eastern Europe deposits, "has to be restricted to the younger part of the Galerian".

Gliozzi et al. (1997) revised the Italian biochronological framework and indicate that the beginning of the Galerian is marked by the appearance of "*Praemegaceros*" (=*Megaceroides*) *verticornis*, which is first recorded in Italian peninsula at the Colle Curti (the locality also names a Faunal Unit), a site dated to the late Early Pleistocene, and magnetostratigraphically characterised as placed at the base of the Jaramillo Subchron (Coltorti et al., 1998). This fauna (Ficcarelli and Silvestrini, 1991; Rook and Martinez Navarro, 2010), in addition of recording the first finds of the megalocerine *Praemegaceros verticornis*, is characterised by the dominant occurrence of *Hippopotamus*, and by the occurrence of *Bison* (*Bison*).

2. Large mammal biochronology framework in Europe around Jaramillo

The Villafranchian/Galerian transition can be considered one of the most controversial issues in the European biochronological framework. At the Jaramillo Subchron a marked faunal turnover was caused by the shift of the climate from 41 ky obliquity orbital cycles to a highly non-linear system dominated by 100 ky periodicity with asymmetric glacial/interglacial cycles (Clark et al., 2006).

Caloi and Palombo (1996) reconsidered the question of the Villafranchian/Galerian boundary and proposed four hypotheses (A, B, C and D) to subdivide the Italian mammal faunas of the late Early Pleistocene. The "A" hypothesis was to extend the Villafranchian up to the Early/Middle Pleistocene limit. In this hypothesis the Italian Galerian faunas is characterised by the occurrence of *Ursus deningeri*, *Palaeoloxodon antiquus*, *Mammuthus* "*trogontherii*", *Sus scrofa*, *Cervus elaphus acoronatus* and *Bison schoetensacki*. As underlined by Caloi and Palombo (1996), many of these taxa already occurred in Western Europe localities near to Jaramillo Subchron. The "B" hypothesis was to extend the Galerian into the late Early Pleistocene, possibly close to Jaramillo. In this case the Galerian would be characterised by the disappearance of some Villafranchian elements such as *Lynx issiodorensis*, *Megantereon cultridens*, *Sus strozzii* and *Bison (Eobison) degiulii*. In the "C" hypothesis the term Protogalerian was introduced as "a biochron whose lower limit coincides with the first appearance of Galerian forms, persisting into the early Middle Pleistocene". Finally, in the hypothesis "D" a different meaning for the "Protogalerian" was proposed, based on the "appearance and persistence of *M.* (*Allophaiomys*) [Biharian (partim) mammal age]; *M. savini* – *M. pusillus* and *M. savini* (partim) zones, sensu Fejfar and Heinrich (1990)". None of these hypotheses was further developed.

In the Italian biochronological scheme defined by Gliozzi et al. (1997), the early Galerian is "characterised by the occurrence of *Megaceroides verticornis* and by the persistence of forms with Villafranchian affinities such as *Pachycrocuta brevirostris*, *Homotherium* ex gr. *crenatidens-latidens*, *Mammuthus (Archidiskodon) meridionalis*, a small sized *Stephanorhinus* and an advanced forms of *Pseudodama*." Moreover the presence of two species of Arvicolids at Colle Curti site (Italy), *Pliomys lenki* (first occurrence in Italy) and *Microtus* (*Allophaiomys*) sp. "confirms the innovative character of this faunal assemblage" (Gliozzi et al., 1997).

Koufos (2001) proposed an updated biochronological scheme for the Plio-Pleistocene mammalian faunas of Greece. The author introduced the "Latest Villafranchian" and, according to his scheme, it corresponds to MNQ zones 19 and 20 (sensu Guérin, 1990). The Latest Villafranchian is marked by the appearance of the arvicolid *Mimomys savini* and of the megacerine *Praemegaceros* and by the last appearance of the bovid *Gazella*, as recorded in the site of Kaiafas. In his framework, the site of Volos and Megalopolis are referred to the Galerian.

Spassov (2003) indicates the "Final Villafranchian" to define the "mass Megafauna dispersal events" occurring at around 1 Ma. In his

view, the Greek site of Apollonia 1 "represents the latest S–E European Villafranchian association" and could be referred to Pirro FU sensu Gliozzi et al. (1997).

3. The Epivillafranchian as a formal biochron

In recent decades, authors that have discussed the biochronological significance of the Villafranchian/Galerian transition agree that this temporal interval (corresponding to 1.2–0.9 Ma) is characterised by the appearance of taxa typical of the Middle Pleistocene large mammal assemblages – i.e. the megacerine *Praemegaceros verticornis*, *Bison* (*Bison*) spp. and *Sus scrofa* – together with Villafranchian species (Sardella, 2007; Kahlke et al., 2011). To achieve a formal definition of the "Villafranchian/Galerian transition", we take into account two alternative schemes that, up to the present, have been adopted to formally define this biochronological issue:

A) the Gliozzi et al. (1997) proposal in which the beginning of the Galerian is conventionally marked by the appearance of *Praemegaceros verticornis*;

Table 1
Large mammal composition of selected European Epivillafranchian localities. Solid circle indicates specific attribution, whereas open circle indicates the generic attribution (presence of lithic artefacts in the *Homo* row).

	Untermassfeld	Het Gat	Le Vallonet	Saint Prest	Durfort	Colle Curti	Redicicoli	Madonna della Strada	Trinchera Elefante	Fuente Nueva-3	Barranco Leon-5	Vallparadís Estació	Megapolis-Marathousa
Artiodactyla													
Bison menneri	●	●											
Bison schoetensacki			●	●	●		●						
Bison sp. aff. *B. degiulii*							●	○					
Hemitragus sp.			●						●	●			
Capreolus cusanoides	●												
Cervalces (=*Alces*) *carnutorum*	●			●									
Alces latifrons		●											
"*Pseudodama*" *nestii vallonnetensis*	●		●			●						●	
Pseudodama rhenanus perolensis					●		○						
Axis eurygonos								●					
Praemegaceros cf. obscurus										●	●		
Praemegaceros verticornis group		●	●	●		●				●	●		●
Megaloceros savini		●										●	
Eucladoceros giulii/ *Arvernoceros giulii*	●							●	●				
Sus scrofa priscus	●											○	
Hippopotamus antiquus	●	●		●	●	●	●	●		●	●	●	●
Perissodactyla													
Stephanorhinus etruscus		●						●	●				
Stephanorhinus hundsheimensis	●		●	●	●	●	●			●	●	●	
Equus suessenbornensis		●	●										
Equus altidens			●	●			●					●	○
Proboscidata													
Mammuthus meridionalis	●	●	●	●	●	●	●	●			●		
Carnivora													
Meles meles	●		●										
Baranogale antiqua									●				
Mustela cf. *palerminea*									●				
Pannonictis cf. *nestii*									●				
Vulpes praeglacialis			●						○			●	
Canis mosbachensis/Canis aff. *arnensis*	●					●			●			●	
Lycaon lycaonoides	●		●			●						●	
Lynx cf. issiodorensis	●								●				
Lynx pardina spelaea			●									○	
Acinonyx pardinensis	●		●										
Puma pardoides	●											●	
Panthera pardus			●										
Panthera ex gr. *P. gombaszoegensis*	●		●						●			●	
Megantereon whitei/M. cultridens adroveri	●										●	●	
Pachycrocuta brevirostris	●		●	●									
Homotherium latidens	●	●	●									●	
Ursus cf. *dolinensis*	●								●				
Ursus deningeri			●			○				○	○		
Primates													
Macaca sylvanus florentinus	●		●						●			●	
Homo antecessor lithic artifacts			○				○		●	○	●		

B) the "Epivillafranchian" sensu Kahlke (2001, 2006, 2007, 2009).

Gliozzi et al. (1997) stated that "the early Galerian assemblage is characterized by the presence of *Megaceroides verticornis* and by the persistence of forms with Villafranchian affinities such as *Pachycrocuta brevirostris*, *Homotherium* ex gr. *crenatidens-latidens*, *Mammuthus* (*Archidiskondon*) *meridionalis*, a small sized *Stephanorhinus* and an advanced form of "*Pseudodama*". Moreover Palombo and Sardella (2007) indicate that both the Pirro Nord (latest Villafranchian) and Colle Curti Italian local faunas show a relatively high similarity coefficient due to the presence of several common taxa (carnivores, rhinoceros, hippopotamuses) at both localities. In their opinion the early Galerian faunal units seem more closely related to those of the Villafranchian than to the ensuing true Galerian ones, despite the appearance of *Praemegaceros verticornis*, as well as the innovative characteristics demonstrated by the arvicolids from Colle Curti. For all these reasons, the biochronological scheme proposed by Gliozzi et al. (1997) did not sufficiently take into account the "transitional character" of these faunas.

Kahlke (2006, 2007, 2009) reconsidered the term Epivillafranchian as a biochron sensu Lindsay (1990). In his opinion, the European late Early Pleistocene faunas are not simply a "mixture" of Villafranchian and Galerian elements. Kahlke (2006) considered the large mammal assemblage from Untermassfeld as the "principal reference material for the large mammal fauna of the Epivillafranchian" and supported the idea of "a separate chronostratigraphical unit wedged between the Villafranchian and the Galerian biochrons". The large mammal assemblage is composed by the following taxa (Table 1): *Bison menneri*, *Capreolus cusanoides*, *Cervalces* (=*Alces*) *carnutorum*, *Dama* (=*Cervus* s.l. =*Pseudodama*) *nestii vallonnetensis*, *Eucladoceros giulii*, *Hippopotamus antiquus* (=*H. amphibius antiquus* =*H. major*), *Stephanorhinus hundsheimensis*, *Panthera onca gombaszoegensis* (=*Panthera gombaszoegensis*), *Acinonyx pardinensis pleistocaenicus*, *Puma pardoides* (=*Panthera schaubi* =*Viretailurus schaubi*), *Megantereon cultridens adroveri* (=*Megantereon whitei*), *Homotherium crenatidens*, *Pachycrocuta brevirostris*, *Ursus* cf. *dolinensis* (=*U. rodei*), *Lycaon* [*Canis* (*Xenocyon*)] *lycaonoides* and *Canis mosbachensis* (Kahlke, 1997, 2001; Hemmer, 2001; Sotnikova, 2001). As finally summarised by the same author, the Epivillafranchian can be considered the "*Bison menneri* – *Eucladoceros giulii* assemblage chron", and is comprised between 1.2 and 0.9 Ma, i.e. late Early Pleistocene – early Middle Pleistocene (Kahlke et al., 2011).

Although the Epivillafranchian sensu Kahlke has a great regional significance, its use as a Mammal Age at a European scale should be integrated with data from other European sites to better define the faunal turnover occurred at the end of the Jaramillo Subchron. The occurrence of the long legged *Bison menneri* is reported from Untermassfeld and from other northwestern European sites of the North Sea region, e.g. Het Gat (Post et al., 2001; Mol et al., 2003; Drees, 2005). Moreover, the occurrence of the large sized cervid *Eucladoceros giulii* or closely related forms is reported only in a few sites (see Table 1). Finally, the taxonomy of this cervid is also discussed in the literature. Croitor and Kostopoulos (2004) ascribe it to the genus *Arvernoceros*, and Mancini et al. (2012) refer to *Arvernoceros* aff. *Arvernoceros giulii* the large cervid remains from the Scoppito-Madonna della Strada site (L'Aquila, central Italy).

In addition, the diverse vertebrate assemblage at Valparadís Estació (Spain) provides further evidence of an Epivillafranchian fauna in Western Europe (Madurell at al., 2010; Madurell et al., 2014). In particular, from this site the earliest occurrence of the straight tusked elephant *Elephas* (*Palaeoloxodon*) *antiquus* (a very significant bioevent at a European scale) is documented together with *Sus* sp. and other large mammal taxa (Madurell at al., 2010). A recent revision of the Villafranchian from the Iberian peninsula (Madurell et al., 2014) indicates that the only megacerine deer documented at the Epivillafranchian assemblages at Valparadís Estació is *Megaloceros savini* (Table 1).

As a result, to evaluate the validity of the term in a wider biochornological framework, the most representative "Epivillafranchian" large mammal assemblages have been considered: Untermassfeld (Germany); Het Gat (The Netherlands); Le Vallonet, Saint-Prest and Durfort (France); Colle Curti, Redicicoli, Scoppito and Slivia (Italy); Trinchera Elefante, Fuente Nueva-3, Barranco Leon-5 and Vallparadís Estació (Spain); Megapolis-Marathousa (Greece) (Fig. 1). Table 1 lists the large mammal composition for each site. Is it possible, therefore, to find palaeobiological events with a wide territorial significance, and, consequently, on the co-occurrences of typical taxa that characterize the "Epivillafranchian" large mammal assemblages?

To compare these faunas, it is noteworthy to consider: (1) some disagreements regarding the taxonomical approach among the authors; (2) the incomplete continental stratigraphic record; (3) the physiographical barriers, climatic changes and vegetation cover shift that influenced the mammalian dispersal; (4) the diachroneity in mammal dispersal.

Besides the *Praemegaceros verticornis* earliest occurrence, other significant bioevents that characterize the Epivillafranchian faunal assemblages in Europe are also the first occurrence of *Megaloceros savini* (documented at Vallparadís Estació), and of the wild boar *Sus scrofa priscus* (recorded at Untermassfeld, and possibly at Vallparadís Estació). Together with these Asian newcomers, several Villafranchian taxa, mainly carnivores and equids, characterise this chronological interval. These include the giant hyaena *Pachycrocuta brevirostris*, the felids *Megantereon whitei*, *Acinonyx pardinensis*, *P. gombaszoegensis* and *Puma pardoides*, and the pack-hunting canid *Lycaon lycaonoides*. The equids *Equus altidens* and *Equus sussenbornensis* still survived.

The *Crocuta crocuta* bioevent (Martinez Navarro, 2010) represents a further renewal in European faunas, when most of the Villafranchian large carnivores became extinct. In the Italian fossil record, the large mammal assemblage of Slivia includes the latest occurrence of the giant hyena *Pachycrocuta brevirostris,* while the occurrence of *Crocuta crocuta* is documented at Casal Selce (Rome, around 0,7 Ma) (Sardella and Petrucci, 2012). This faunal

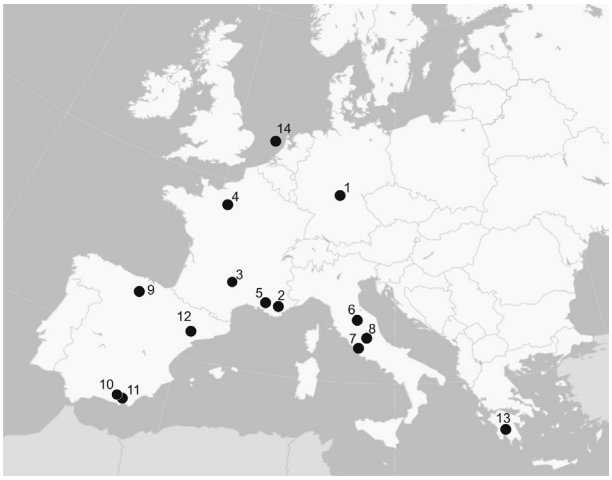

Fig. 1. Selected European Epivillafranchian localities: 1) Untermassfeld (Germany); 2) Le Vallonet, 3) Soleilhac, 4) Saint-Prest, 5) Durfort (France); 6) Colle Curti, 7) Redicicoli, 8) Scoppito/Madonna della Strada (Italy); 9) Trinchera Elefante, 10) Fuente Nueva-3, 11) Barranco Leon-5, 12) Vallparadís Estació (Spain); 13) Megapolis-Marathousa (Greece); 14) Het Gat (The Netherlands).

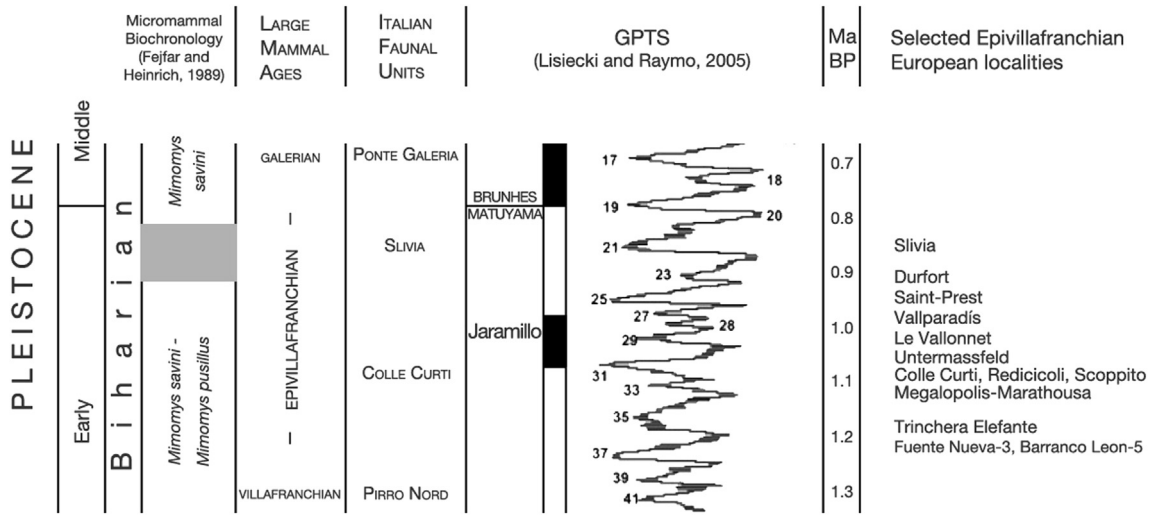

Fig. 2. Epivillafranchian biochronologic scheme.

assemblage has been proposed to define the Ponte Galeria Faunal Unit (Petronio and Sardella, 1999). The *Crocuta crocuta* bioevent is also documented in the lower unit TD 4/5 at Atapuerca (Spain) (García and Arsuaga, 2001).

Taking into account the data recorded from the European localities, a general formal framework for the "Epivillafranchian" biochron could be comprised between the *Praemegaceros verticornis* – *Bison menneri* FOs and the *Crocuta crocuta* FO bioevents. Together with the dispersal of *Praemegaceros verticornis* and *Bison menneri*, the beginning of the Epivillafranchian can be placed in correspondence of the diffusion of *Megaloceros savini* and *Sus scrofa priscus*.

The *Crocuta crocuta* bioevent marks the end of this biochron. Moreover, the extinction of large carnivores such as the felids *Megantereon* and *Puma* is of biochronological value even if these taxa are relatively rare (e.g. Hemmer et al., 2004). These events are quite well documented in the European faunal assemblages, having thus a wider biochonological value. In the Italian framework, the Epivillafranchian should include the Colle Curti and Slivia FUs. Therefore, the beginning of the Galerian Mammal Age could be placed in correspondence of the Ponte Galeria FU (sensu Petronio and Sardella, 1999).

4. Conclusions

During the 1.2–0.9 Ma time span, a progressive faunal renewal in Europe took place related to the final phase of the interval dominated by 41 ky periodicity in the global climatic record. The use of a distinct biochron, a new Mammal Age, is here supported to define this crucial episode in this transitional phase (Fig. 2). The approach adopted by Gliozzi et al. (1997) has been followed, but updated and considered at a European scale. In the last decade, the use of the term "Epivillafranchian" suggested by Kahlke (2001, 2006, 2007, 2009) for the Villafranchian/Galerian transitional faunas is here accepted with a new formal definition. As a consequence, the new scheme of the European land Mammal Biochronology (Fig. 2) requires a revision of the beginning of the Galerian Mammal Age. Therefore, the Epivillafranchian Mammal Age is defined by two main bioevents, recorded at European scale:

- *Praemegaceros verticornis* (the Galerian beginning event sensu Gliozzi et al., 1997) – *Bison menneri* FO (Kahlke, 2006, 2007, 2009);
- *Crocuta crocuta* FO (end of Epivillafranchian and beginning of the revised Galerian).

In Italy, the Epivillafranchian Mammal Age includes two Faunal units, Colle Curti and Slivia, whereas the Galerian includes three Faunal Units: Ponte Galeria (sensu Petronio and Sardella, 1999), Isernia and Fontana Ranuccio.

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Appendix

During recent decades, the taxonomical attribution of the taxa considered in this work has changed several times, and even nowadays there is no a general consensus on the taxonomy of some groups (e.g. megacerine deer). Therefore, we have preferred to report the original sentences to avoid misinterpretations. Dealing with the taxonomical questions is out of scope of this work. For its biochronological significance, it is worth clarifying the taxonomical attribution of *Praemegaceros verticornis* (Dawkins). This megacerine deer has been ascribed to several genera, e.g. *Megaloceros* (=*Megaceros*), *Orthogonoceros*, *Praemegaceros*, *Megaceroides* (Azzaroli, 1979). In this work, we follow Abbazzi (2004) who accepted the generic name *Praemegaceros* Portis, 1920.

Finally, the occurrence of *Elephas* (*Palaeoloxodon*) *antiquus* at Vallparadís Estació (Madurell et al., 2010) has been recently questioned (Madurell et al., 2014; Palombo, 2014). For this reason the *Elephas* (*Palaeoloxodon*) *antiquus* FO was not taken into account in our biochronological framework pending further taxonomical analysis of this taxon.

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