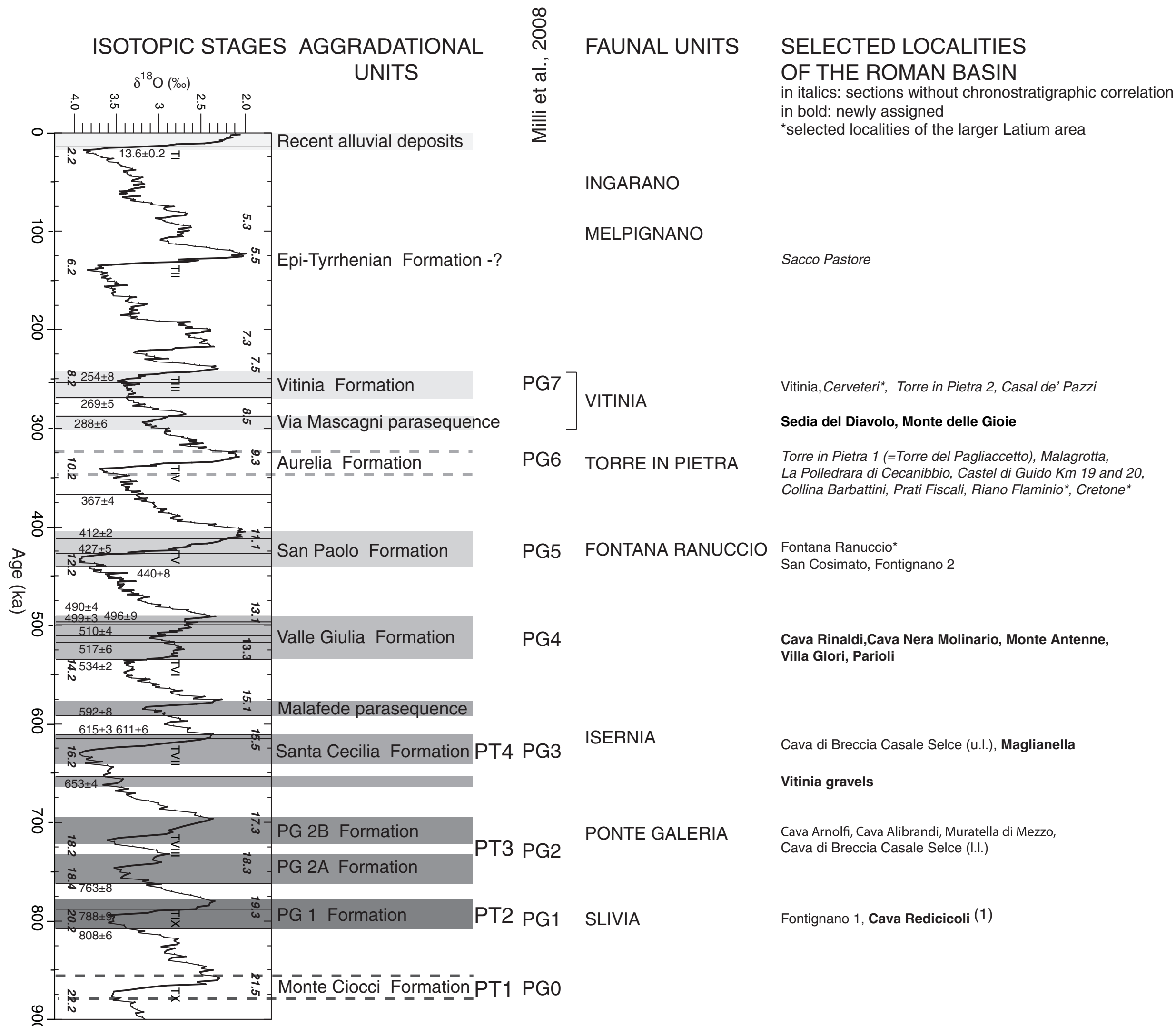

Fig. 3. Recognition of the stratigraphic position within the geochronologically constrained aggradational units of the fossiliferous localities of the Roman basin provides their correlation with the $\delta^{18}O$ isotopic record (Lisiecki and Raymo, 2005). Horizontal lines are the age constraints derived by the $^{40}Ar/^{39}Ar$ dating of the volcanic deposits intercalated within the aggradational units of the paleo-Tiber River shown in Fig. 2. Each shaded box individuates a period of sea-level rise that accounts for the deposition of the sedimentary successions in the coastal area of Rome. (1) The possible occurrence of a distinct, later faunal assemblage in the upper levels of Cava Redicicoli (Di Stefano et al., 1998) is discussed in the text (see also Fig. 4).

3. Eustatic forcing on the stratigraphic record

Several studies (Marra and Florindo, 2014 and references therein), have shown that glacio-eustatic forcing controlled deposition of sedimentary sections in the coastal plains of the paleo-Tiber River and in the alluvial plains of its tributaries near Rome. Using $^{40}Ar/^{39}Ar$ ages of tephra layers intercalated with the sedimentary deposits and paleomagnetic measurements on clay horizons it was demonstrated that the sedimentary sections were deposited during sea-level rises and associated marine ingressions following the glacial terminations (Karner and Marra, 1998; Karner and Renne, 1998; Marra et al., 1998; Florindo et al., 2007). The stratigraphic record of each complete glacially forced sea-level oscillation in a coastal area is represented by a basal erosive surface, progressively excavated as a consequence of lowering of sea level during glacial periods, overlain by a succession of clastic sediments and rapidly deposited during sea-level rise in response to deglaciation. The geochronologic constraints in the whole area of Rome spanning the Middle Pleistocene to the Holocene evidenced that the sedimentary transition from gravel to clay corresponds to a glacial termination and thus to the transition between an odd and an even isotopic stage. Therefore, in the text we will associate the sedimentary units to a pair of MIS (e.g., MIS 20–19).

Generally, the aggradational sections recognized in Ponte Galeria are fining-upward sequences, with coarse-grained gravel and sand, up to 10 m in thickness, overlying the erosional base of each section. The coarse-grained deposits are followed by a relatively thin (1–2 m) sand horizon, which grades upward into a several meters thick package of silt and clay. In the older sections, deposited during MIS 22–21 through MIS 16–15, these clay intervals have moderate thickness (<10 m), probably as a consequence of the lower amplitude sea-level oscillations associated to these early glacial cycles (Karner et al., 2001b). In contrast, a significant increase of the clay section is observed in the younger successions (e.g., San Paolo Formation, MIS 11; Karner and Marra, 1998), up to that of the modern Tiber River, which reaches 70 m in thickness within the present-day coastal plain (Marra et al., 2013).

Radiometric age constraints on the sedimentary record deposited within the valley and in the coastal plain of the modern Tiber River (Marra et al., 2008, 2013) demonstrate that the rapid accumulation of gravel marks a unique time in the depositional history of the river, occurring during an ~7 kyr interval between the end of the Last Glacial

Maximum (LGM; ~21 ka, Bard et al., 1990) and the last glacial termination (T-I; ~14 ka, Stanford et al., 2006). Indeed, the transportation by the Tiber River of gravel with diameters of the pebbles >5 cm required exceptional hydrologic conditions that have not been repeated during Holocene time. These conditions are possible only during a glacial termination due to the combination of several factors, such as increased sediment supply to the Tiber drainage basin, increased regional rainfall, low sea level causing a steeper gradient. These conditions would have worked in concert during the 21 ka–14 ka interval, until the accelerated rise in sea level during the glacial termination led to a rapid drop in competence of the Tiber River and, consequently, to the start of sandy clay deposition.

4. Materials and methods

4.1. The mammal remains from Ponte Galeria area

The studied material is presently housed in two collections, one in the Museum of Paleontology, Sapienza University of Rome (MPUR), the other in the Soprintendenza Archaeologica of Rome (SAR). Most of the paleontological specimens were collected from several quarries localized in the area since the beginning of the second half of the 20th century and were published by Blanc et al. (1951), Ambrosetti (1965, 1967), Caloi and Palombo (1978, 1980a,b, 1986), Caloi et al. (1980a,b,c, 1981), Capasso Barbato and Petronio (1981, 1983), Capasso Barbato et al. (1983), Petronio (1986), Di Stefano and Petronio (1993, 1997) and Petronio and Sardella (1998, 1999). Other considered specimens housed in the MPUR were collected during the end of the 19th century around and within the city of Rome; they were mostly published by Blanc, Clerici, De Angelis d'Ossat, Maxia, Meli, Ponzi, Portis and Tuccimei (for details see references in Kotsakis and Barisone, 2008). A few remains housed at MPUR have been never published in previous works on the area and are shortly described in the next chapter.

The revised Quaternary time scale (Gibbard et al., 2010) for chronostratigraphy and geochronology is followed in this paper. The biochronology of mammals follows schemes reported by Gliozzi et al. (1997) for Italy and later modified by Petronio and Sardella (1999) and Petronio et al. (2011).

4.2. Method of correlation of the faunal assemblages with the aggradational successions

Based on the abovementioned relationships between sedimentation and glacio-eustatic sea-level changes including erosional as well as depositional phases, it is inferred that a discontinuous stratigraphic record occurs in the Ponte Galeria area. This is represented by a succession of ten major aggradational units deposited during MIS 22–21 through MIS 2–1, plus several minor successions corresponding to the more pronounced sub-stages (e.g., Via Mascagni succession), representing the physical remnant of as many glacio-eustatic sea-level cycles in this time span (Fig. 3).

The modern Tiber River analog suggests that the basal coarse gravel sections in the ancient sedimentary succession of the paleo-Tiber River accumulated only since the end of a glacial maximum, and their deposition ceased during the glacial termination. Whereas a continuous transportation of coarse material is supposed to occur during the entire phase marking the passage from the previous highstand to the following lowstand, thickness of this material cannot increase much within the fluvial incision or within the coastal plain, as a consequence of the continued lowering of the sea level, causing its removal and re-deposition seaward.

Similarly, deposition of the clay section occurred only since the glacial termination, which formally coincides with the start of the new isotopic stage. Consistent with this assumption, cold fauna within the basal portion of some of these clay horizons (e.g., '*Helicella* Clay'; Conato et al., 1980; Kotsakis et al., 1992) should be considered as survivors of the lowstand period at the onset of the abrupt climatic change leading to a warmer climate and rise in sea level. The main portion of these clay sections was deposited during the high-stand, within lagoonal or coastal environments, as shown by the faunal assemblage of the '*Venerupis senescens* clay' (Conato et al., 1980) or the 'Santa Cecilia clay' (Karner and Marra, 1998), deposited during the high stands of MIS 17 and MIS 15, respectively. However, continental deposits associated to the transition between interglacial and glacial periods may occur in the near-coast area as a consequence of the regressive phases, in particular as eolian deposits and, to a lesser extent, as lacustrine–palustrine ones.

In the present work, we correlate the deposits in which the recognized faunal assemblages occur to the aggradational sections identified in the Ponte Galeria area. Based on this approach, any fossil that can be referred to an identified geochronologically constrained sedimentary unit can be assigned a discrete age, corresponding to that of the associated MIS (Fig. 3).

Identification of the glacio-eustatically forced sedimentary units can be achieved by:

(1) literature data: whenever the outcrop corresponds to published type sections;
(2) stratigraphic context: whenever the stratigraphic position of the outcrop with respect to other dated sections is determinable;
(3) recognition of pyroclastic deposits of known age within the outcrop;
(4) identification of the age of pyroclastic material occurring in the strata or conglobed in the fossil, by means of:
  (1) petrographic analysis of thin section, or
  (2) laboratory geochemical analysis (e.g., glass composition, trace element ratios), allowing at correlate the deposit with known, dated products;
  (3) direct radiometric dating ($^{40}Ar/^{39}Ar$).

5. The Ponte Galeria area

5.1. Stratigraphy of Ponte Galeria area

Three aggradational successions deposited in the time span between 800 and 600 ka have been identified in the Ponte Galeria area: PG1, PG2, and Santa Cecilia formations (Marra et al., 1998). These correspond only in part to the fourth-order sequences described by sequence-stratigraphic work in this area (e.g., Milli et al., 2008), as illustrated in this section.

In contrast to previous assumptions about the start of the sedimentation in this area with MIS 22 (Kotsakis et al., 1992), ages of pyroclastic layers intercalated within the sedimentary succession, combined with the reversed polarity of the clayey deposit of the first, oldest sequence, allowed Marra et al. (1998) to correlate the three older aggradational successions occurring in the Ponte Galeria area to MIS 20–19, MIS 18–17 and MIS 16–15 (Figs. 2, 3).

The oldest continental deposits of the paleo-Tiber River (Karner et al., 2001b), represented by the transgressive cycle of Monte Ciocci–Monte delle Piche Formation (Conato et al., 1980; Marra, 1993), lack direct radioisotopic data but are tentatively correlated to MIS 22–21. Gravel and sands of the Monte Ciocci Formation constitute a terraced deposit, presently between 55 and 70 m a.s.l., ca 10 km inland with respect to the Ponte Galeria area. Marine sediments deposited during highstand of this early glacio-eustatic cycle (Monte delle Piche Unit; Conato et al., 1980) constitute the substrate of the PG1 deposits in Ponte Galeria (Fig. 2).

The PG1 deposit has been correlated to MIS 20–19 based on the reversed geomagnetic polarity of its highstand deposits (*Helicella* Clay), and on the $^{40}Ar/^{39}Ar$ age of 763 ± 8 ka (Karner and Renne, 1998) (all the ages reported in this work are re-calculated according to the Fish Canyon sanidine standard age of 28.201 ka; Kuiper et al., 2008) for a volcanic ash horizon in the lowstand deposits of the subsequent aggradational section (PG2). The PG1 unit includes the "river pebble and cobble conglomerates" and the overlying "blue-gray *Helicella*-bearing clays" of Conato et al. (1980). The absence of any evidence of marine fauna and the sedimentary features of the lower gravel layer indicates its continental origin, whereas a transition from a limno-brackish to a littoral environment is evidenced by the faunal facies associations described by Conato et al. (1980) occurring in the upper clay section. The lower part of the deposit contains *Helicella ericetorum*, *Trichia hispida*, *Chondrula* (*Jamina*) *reversalis*, *Chondrina avenacea*, *Pupilla muscorum* and *Valonia pulchella*; the upper part is characterized instead by the occurrence of *Ammonia beccarii* and *Elphidium crispum*. These two members also constitute the fourth-order sequence PG1 defined by Milli et al. (2008) based on a sequence-stratigraphic approach.

Other studies (Florindo et al., 2007; Marra and Florindo, 2014) proposed a correlation of the PG1 sequence with the fluvial–lacustrine deposits of northern Rome, which have been investigated in boreholes (Fig. 4). Two tephra layers intercalated at the gravel–clay transition in the aggradational succession of the paleo-Tiber in Rome were dated 808 ± 6 and 788 ± 9 ka (Florindo et al., 2007), providing further evidence of its deposition during glacial termination X, between MIS 20 and MIS 19.

These tephra layers, along with that dated 763 ± 8 ka, represent the oldest dated volcanic products in this region and, based on their geochemical signature, have been correlated to the early Monti Sabatini activity. Emplacement of these early volcanic products follows the first pulse of ca. 45 m of regional uplift (Karner et al., 2001b), associated to magma injection along the Tyrrhenian Sea margin of Latium, linked with the birth of the volcanoes of the Roman Magmatic Province (Conticelli and Peccerillo, 1992). It is coincident with a climax of extensional tectonics, originating a NW–SE oriented graben in the area of Rome (paleo-Tiber graben; Marra and Rosa, 1995) and causing minor subsidence in the area of Ponte Galeria (Marra and Florindo, 2014).

The PG 2 Formation includes two aggradational successions that correlate with two distinct, consecutive peaks in the $\delta^{18}O$ record: MIS 18.3 and MIS 17.3, respectively (Fig. 3; Marra et al., 2008). The early PG2 aggradational unit (PG 2A) corresponds in part to the "beach conglomerates and bright yellow *A. islandica* sands", characterized by the presence of benthic foraminifera, that occur above the "*Helicella* clay" (Conato et al., 1980). The age of 763 ka yielded by the tephra layer intercalated in the lower "beach conglomerates" allowed Marra et al. (1998) to identify it as the deposit of the regressive phase following the highstand of MIS 19 (see Fig. 3) and heralding the sea-level rise associated to MIS 18.3. The deposition of the "middle clay" layer is associated with this highstand (Marra et al., 1998), characterized by the presence of benthic foraminifera and by a normal magnetic polarity. This clay layer was not recognized by Conato et al. (1980), nor in later sequence-stratigraphic studies performed in the Ponte Galeria area (e.g., Milli et al., 2008).

The second aggradational succession PG 2B comprises the "Pebble gravels and sands with frequent cross-laminations", in which the presence of *Ostrea*, *Pecten*, *Mytilus* and *Ammonia* evidences the permanence of a marine environment, even if conditioned by the proximity of a large deltaic system, and the "*V. senescens* clay" including large *Ammonia* and other Foraminifera of evident marine character, along with lagoonal and brackish Ostracoda and Foraminifera, as well as abundant *V. senescens* and *Cerastoderma edule* (Conato et al., 1980).

A major unconformity is placed on top of the "*Helicella* clay" of the PG1 sequence, marking the boundary with the following PG2 sequence of Milli et al. (2008) (Fig. 3). It is overlain by gravels and sandy-gravel barrier beach deposits, passing upwards to lagoonal mud, and corresponds to the "pebble gravels and sands with frequent cross-laminations" and the overlying "*V. senescens* clay" of Conato et al. (1980).

The third glacio-eustatically forced aggradational succession in the Ponte Galeria area is represented by a layer of littoral to lagoonal clay (Santa Cecilia Formation; SCF) associated to beach and fluvial gravels and sands, at the base, and to continental (dune bar) sands (Eolian Salmon Sand, Conato et al., 1980) at the top. The fluvial–sandy gravel deposits correspond to the PG 3 fourth-order sequence that Milli et al. (2008) correlate to MIS 15. The lagoonal deposit of the SCF, containing abundant *C. edule* along with rare *Ammonia* (Marra et al., 1998), was not previously identified by Conato et al. (1980), who probably did not recognize the unconformable contact between this upper clay deposit and the underlying equivalent represented by the "*V. senescens* clay" (Karner and Marra, 1998). However, two tephra horizons within the lagoon clay and the continental sand of the Santa Cecilia Formation, the $^{40}Ar/^{39}Ar$ ages of which are 615 ± 3 ka and 611 ± 6 ka (Marra et al., 2014), respectively, univocally tie this deposit to MIS 15 (Figs. 2, 3), ruling out also its correlation with MIS 13, as proposed in Milli et al. (2008). Indeed, the correlation proposed in Milli et al. (2008) for the PG4 sequence, represented by sandy fluvial deposits at the base passing upward to lagoonal and palustrine–lacustrine muds, with MIS 13 should

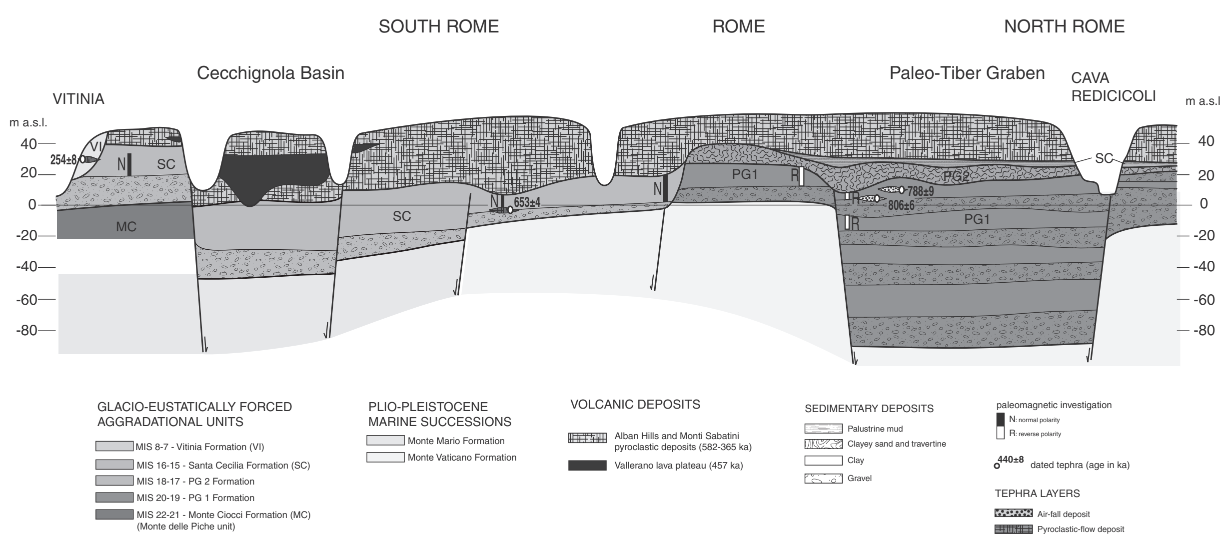

Fig. 4. N–S geologic section through the area of Rome (horizontal not to scale) showing the lithostratigraphic features of the aggradational deposits of the paleo-Tiber River and the position of dated volcanic layers and of the paleomagnetically investigated clay sections used for correlation with the $\delta^{18}O$ isotopic record (modified after Marra and Florindo, 2014). The stratigraphic position of the fossiliferous localities described in the text is also shown. Location of the section is shown in Fig. 1.

be considered superseded by the geochronologic evidence provided by the interbedded tephra layers, as well as by the fact that the deposit of PG4 in Ponte Galeria underlies the "Pisolitic tuffs", representing the first large explosive eruption at the Colli Albani Volcanic District occurred 565 ± 2 ka (Tufo Pisolitico di Trigoria; Karner et al., 2001a; Marra et al., 2009), and is therefore much older than 500 ka.

The lagoon deposit of the SCF in Ponte Galeria represents the highstand deposit of a complete aggradational cycle whose basal, coarse-grained portion is found in southern Rome (Marra et al., 1998; Marra and Florindo, 2014). There fluvial–lacustrine deposits have been correlated to glacial termination VIII occurring at the transition between MIS 16 and MIS 15, based on the $^{40}Ar/^{39}Ar$ age of 653 ± 4 ka of a tephra layer on top of the basal gravel and based on the normal polarity of the overlying clay section (Florindo et al., 2007). However, this age pre-dates the glacial termination of ca. 25 ka (Fig. 3), suggesting that an early aggradation, occurring since the previous isotopic substage, characterized the sedimentary succession correlated to MIS 16–15 (Marra and Florindo, 2014).

The systematic pre-dating of the ages of early glacial terminations (IX through VII) provided by tephra layers intercalated at the top of the gravel beds of the aggradational succession of the paleo-Tiber, as evidenced in Fig. 3, has been thoroughly discussed in other work (Florindo et al., 2007; Marra et al., 2008; Marra and Florindo, 2014). However, whether this may be the result of an incorrect calibration of the isotopes curve or of the standard used in the $^{40}Ar/^{39}Ar$ dating method (see Channell et al., 2010, for discussion), as well as of an early aggradation of some gravel beds, it doesn't challenge the evidence that full aggradation of the sedimentary successions of the paleo-Tiber River, marked by deposition of a thick package of clay sediment, occurred in response to the sea-level rise associated to each glacial termination, as provided by geochronologic constraints spanning the whole Middle Pleistocene (Fig. 3).

The four aggradational successions deposited by the paleo-Tiber River before the start of the climactic explosive phase of volcanic activity around 600 ka, correlated to MIS 22–21 through MIS 16–15, which are characterized by similar geometry of the depositional units due to the common paleogeographic conditions, have been designated as paleo-Tiber Units 1–4 (Florindo et al., 2007; Marra and Florindo, 2014). A dramatic paleogeographic change occurred in the paleo-Tiber delta around 600 ka, after the deposition of the Santa Cecilia Formation and before that of the subsequent aggradational succession, the Valle Giulia Formation. At this time, marine to littoral sedimentation within the coastal plain was replaced by fresh-water sedimentation within narrow, deeply incised fluvial valleys (see Fig. 2). This abrupt facies change has been correlated to a second pulse of uplift of ca. 30 m (Karner et al., 2001b), concurrent with the start of the major explosive activity of the Monti Sabatini and Alban Hills volcanic districts, whose first large ignimbrites erupted at 565 ± 2 ka (Karner et al., 2001a).

A large number of plinian and sub-plinian eruptions characterized the activity of these volcanoes in the time span 560–250 ka (Karner and Renne, 1998; Karner et al., 2001a; Marra et al., 2003, 2009; Sottili et al., 2004, 2010). In particular, the Monti Sabatini erupted a large number of air-fall deposits that emplaced in the Ponte Galeria area as a consequence of the eastward and southeastward direction of the regional winds, whereas only a few, distal pyroclastic flows erupted by the Alban Hills reached this area.

The sedimentary deposits of the eustatic cycles corresponding to MIS 14–13 through MIS 8–7 have been identified partly revising the correlations provided by previous authors (Conato et al., 1980: Kotsakis et al., 1992; Milli, 1997), thanks to several age constraints achieved by $^{40}Ar/^{39}Ar$ dating of intercalated tephra layers (Karner and Marra, 1998; Karner and Renne, 1998). The deposits of all these cycles are represented by remnants of the sedimentary fill of the valleys incised during the corresponding lowstands, and occur on the flanks of the valleys excavated during the last glacial maximum. In particular, the principal outcrops are located along the Fosso Galeria Valley, at the confluences of its major tributaries, in Cava Rinaldi, Pantano di Grano, Malagrotta, and San Cosimato (1, 2, 3, and 4 in Fig. 2). These outcrops display typical transgressive series, with coarse-grained deposits at the base, passing gradually to finer sediments towards the top (Conato et al., 1980). However, the basal portions of these successions are scarcely exposed and most of the outcropping sediments represent the upper part of the succession, deposited since the glacial termination. For this reason, the deposits of these agggradational successions in Ponte Galeria are generally correlated to the odd MIS (e.g., Conato et al., 1980; Karner and Marra, 1998).

The sedimentary cycles correlated to MIS 13 and MIS 11, which were previously included in the San Cosimato Formation (Conato et al., 1980), have been named Valle Giulia and San Paolo Formation, respectively (Marra and Rosa, 1995; Karner and Marra, 1998). Deposits of the Valle Giulia Formation are widespread along the Tiber Valley in Rome (Marra and Rosa, 1995) where they overly the Tufo del Palatino pyroclastic-flow deposit (534 ± 2 ka; Marra et al., 2009). These are represented by sandy clay and sand with frequent travertine layers, in which fresh-water gastropods occur. In contrast, in the Ponte Galeria area sediments of the Valle Giulia Formation have been identified only at the locality of Cava Rinaldi, were robust correlation to MIS 13 is provided by ages of four intercalated volcanic layers (Karner and Marra, 1998; Marra et al., 2014). Here, well-stratified white calcareous muds with abundant fresh-water gastropods are topped by few meters of lagoonal clay with *Ammonia* and frequent *C. edule*. Probably due to its limited exposure, the deposit correlated to MIS 13 is not included in the sequence-stratigraphic schemes for this area, which attribute to this isotopic stage the older deposit of the SCF (PG4, Milli et al., 2008).

The two younger cycles correlating with MIS 9 and MIS 7 have been designated in the literature as Aurelia and Vitinia Formations (Conato et al., 1980).

The sedimentary facies of the deposits of the San Paolo (=San Cosimato Formation), Aurelia and Vitinia formations are described in detail in Conato et al. (1980) and are consistently correlated to MIS 11, 9 and 7 by sequence-stratigraphic studies (Milli et al., 2008), which identify them as three fourth-order sequences (PG5, PG6, PG7), and by the geochronologically constrained aggradational sections described here (Fig. 3). All these successions show a progressive vertical passage from a fluvio-lacustrine to a brackish littoral ecosystem (Conato et al., 1980).

The deposits of MIS 9 (Aurelia Formation) are poorly exposed and lack of volcanic markers that would allow for direct geochronologic dating (dashed border lines in Fig. 3), and for this reason they are not readily distinguished from the younger ones of the Vitinia Formation. The only exception is represented by an outcrop east of Malagrotta (site #3 in Fig. 2) described in Karner and Marra (1998), where two distinct aggradational sections occur with an unconformable contact above a distal deposit of the Tufo Lionato pyroclastic-flow (367 ± 4 ka; Marra et al., 2009). Indeed, most of the deposits occurring in Ponte Galeria ascribed in Conato et al. (1980) to the Aurelia Formation (e.g., those in Pantano di Grano and Via della Pisana), correlate with MIS 7 cycle of the Vitinia Formation, as evidenced by the ages of the intercalated volcanic products (Karner and Marra, 1998).

The occurrence of a sub-sequence within the deposit ascribed to the Aurelia Formation was recognized in an outcrop in north Rome (Via Mascagni) (Marra and Rosa, 1995; Palombo et al., 2004). Geochronological constraints (Karner et al., 2001a) allowed at correlate this aggradational unit to MIS 8.5 (Marra, 2004). Indeed, the presence of gravel at the base of this sub-sequence, which unconformably overlies lacustrine deposits of the Aurelia Formation, which in turn erosionally overlie the pyroclastic-flow deposit of Tufo Lionato (367 ± 4 ka), evidences the occurrence of a transgressive interval of a complete sea-level oscillation. The age of the Via Mascagni sub-sequence, constrained at the top by the Tufo Giallo di Sacrofano pumice-flow deposit (288 ± 2 ka, Karner et al., 2001a), matches that of MIS 8.6–8.5 (Fig. 3).

Closely spaced in time with respect to the two preceding aggradational cycles of the Aurelia Formation and Via Mascagni sub-sequence, the early aggradation of clay sediments of the Vitinia Formation, correlated to MIS 7.5, is evidenced in Pantano di Grano by the age of an intercalated pumice layer dated 269 ± 5 ka (Karner and Marra, 1998). A second step of aggradation occurred around 254 ± 8 ka, in agreement with the age of MIS 7.5 (Fig. 3), as evidenced by the age of a tephra layer intercalated in the deposits at the type locality of Vitinia (Karner and Marra, 1998). The early aggradation of the Vitinia Formation is consistent with the occurrence of a sea-level rise at 270 ka (Grant et al., in press).

A series of marine terraces at 40 m of elevation along the Tyrrhenian coast is correlated to the fluvial–lacustrine deposits of MIS 7 (Sorgi, 1994; Karner et al., 2001b) (Fig. 2). A second suite of terraces at 20–25 m a.s.l. correlates with the Tyrrhenian Formation (MIS 5e; Conato et al., 1980; Hearty and Dai-Pra, 1986; Bordoni and Valensise, 1998), whose equivalent continental deposits (Epi-Tyrrhenian Formation) are not recorded in the studied area, with the possible exception of a travertine deposit unconformably overlying the Vitinia Formation in Pantano di Grano (#2 in Fig. 2). This travertine deposit displays a progradational structure and may be related to the occurrence of the third, most recent pulse of uplift of ca. 50 m since 250 ka, estimated based on the elevation of the terraces along the coast (Karner et al., 2001b; Ferranti et al., 2006).

5.2. The mammal assemblages from Ponte Galeria area: synthesis and new data

The Ponte Galeria area recently provided several faunal assemblages, reason for which it is at the origin of the Galerian LMA name. These faunal assemblages have been correlated with six different biostratigraphic zones (from the latest Early Pleistocene to the late Middle Pleistocene), corresponding to the Faunal Units (FUs) of Colle Curti/Slivia, Ponte Galeria, Isernia, Fontana Ranuccio, Torre in Pietra, and Vitinia (Gliozzi et al., 1997; Petronio and Sardella, 1999; Petronio et al., 2011).

The earliest assemblage was discovered at Fontignano in the blue-gray clays (Conato et al., 1980) with *Helicella ericetorum*. It is represented by two taxa of rodents only: *Prolagurus pannonicus* and a rodent morphologically close to *Predicrostonyx* (Kotsakis et al., 1992). This small assemblage was referred to Colle Curti or Slivia FUs (Kotsakis et al., 1992; Gliozzi et al., 1997).

During the last decades, a slightly younger faunal assemblage has been collected in the pebble gravels and sands with frequent cross laminations below the lagoonal mud with *Venerupis senescens* (about 0.75 Ma) (Conato et al., 1980) (Fig. 2); it represents the classic Ponte Galeria fauna *Auctorum*.

In particular, from Cava Arnolfi (Fig. 1) fossil remains of *Hippopotamus antiquus*, *P. verticornis* (= *P. verticornis dendroceros* in Ambrosetti, 1967; Abbazzi, 2004; Croitor, 2006a), *Axis eurygonos* (= *Dama* sp. in Ambrosetti, 1967), *Bison* sp. (= *Bos primigenius* in Ambrosetti, 1967), *Palaeoloxodon* (= *Elephas* in Ambrosetti, 1967) cf. *antiquus,* and *Mammuthus trogontherii* were found (Ambrosetti, 1967; Petronio and Sardella, 1999; Petronio et al., 2011) (Figs. 5, 6).

From the locality Muratella di Mezzo, some remains of *P. antiquus*, *Hippopotamus* sp., *P. verticornis*, and *Megaloceros savini* were collected (Caloi and Palombo, 1980a).

Fragmentary remains of *M. savini* and *P. verticornis* were also collected in the levels of gravels and sands of undefined localities of Ponte Galeria. *M. savini* is represented by a fragment of antler with the burr, part of the first tine and of the beam (Fig. 5) while *P. verticornis* is represented by a juvenilis fragment of antlers with the second tine and a not developed first tine, and by three fragments of mandible with teeth characterized by pachyostosis (Fig. 5).

From pebble graves and sands (upper part of the gravel unit) in the quarry Cava Alibrandi remains of *A. eurygonos* and *E. altidens* were discovered (Capasso Barbato and Petronio, 1983; Petronio and Sardella, 1999).

Other fossil remains, such as *M. trogontherii*, *A. eurygonos* and *E. altidens*, were found in the lower levels of the Ponte Galeria Formation in Cava di Breccia 1 of Casal Selce, approximately at km 14 of the Via Aurelia (Fig. 5); a fragmentary skull of *Hemibos galerianus* comes from the same deposit of this locality (Petronio and Sardella, 1999; Martinez-Navarro and Palombo, 2004, 2007) (Fig. 6). *A. eurygonos* is well-documented by three fragmentary antlers recently recovered in the lower levels of Ponte Galeria and characterized by a largely obtuse angle between the first tine and the beam and by the burr very close to the first tine (Fig. 5). Among the Cervidae remains collected from the abovementioned deposit, a fragment of horn of *Capreolus* sp. has been recently identified (Fig. 5).

At Cava di Breccia di Casal Selce a faunal assemblage collected from the salmon sand deposit (Fig. 2) was referred to the Isernia FU in particular for the occurrence of *Arvicola cantianus* (Petronio and Sardella, 2001). The faunal list includes many remains of amphibians, reptiles, birds and especially of mammals (still under study). Among the other taxa: *Perdix palaeoperdix*, *Gyps melitensis*, *Palaeocryptonyx* sp., *Allocricetus bursae*, *A. cantianus*, *Macaca sylvanus*, *Lynx pardina spelaea*, *Meles meles*, *Stephanorhinus* sp., *E. altidens*, *E. sussenbornensis*, *Sus scrofa priscus*, *H. antiquus*, *A. eurygonos*, *C. elaphus acoronatus*, and *Bison* cf. *B. schoetensacki* are present (Petronio and Sardella, 2001; Bedetti, 2003; Kotsakis and Barisone, 2008; Mancini et al., 2008).

The following assemblages of Via Portuense and Maglianella, and from Vitinia, whose attribution has been revised in the present work were also referred to the Galerian LMA.

Remains of *H. antiquus* come from lacustrine deposits of the Ponte Galeria Formation outcropping at Via Portuense (Rome) (Bonadonna, 1965; Caloi et al., 1980a; Petronio, 1995; Petronio and Sardella, 1999). Moreover, *H. antiquus* was also recorded in lacustrine deposits at Maglianella, Via Aurelia (Ambrosetti et al., 1972; Caloi et al., 1980a; Petronio, 1995).

Within a gravel horizon cropping out in Vitinia below the younger deposits of the Vitinia Formation, Caloi et al. (1981) recorded the occurrence of *C. elaphus* ssp., *Dicerorhinus* cf. *hemitoechus*, *Megaceros verticornis* (= *P. verticornis*), *Equus* sp., *Dama* sp. and *B. primigenius* (Caloi et al., 1981; Petronio and Sardella, 1999). However, the *Cervus* remain, represented by a fragment of pedicle with the burr, can be only ascribed at genus level. The distal epiphysis of metatarsus ascribed to *Dama* sp. by Caloi et al. (1981) is smaller than *D. clactoniana* and shows a distal constriction between the distal epiphysis and the diaphysis typical of the genus *Axis*. The proximal articular surface of third metacarpus of rhinoceros is less developed antero-posteriorly than *S. hemitoechus* and the proximal epiphysis is smaller; it can be ascribed to *S. hundsheimensis*. The remains ascribed to *B. primigenius* by Caloi et al. (1981) appear indeterminable at genus level; only the distal fragment of a metatarsus shows some morphological affinities with the genus *Bison*. In particular, the distal end of the metatarsus follows with the natural prolongation of the line of the diaphysis.

Thus the faunal assemblage from the lower levels of Vitinia includes *Cervus* sp., *Axis* sp., *P. verticornis*, cf. *Bison* sp., Bovidae indet., *Equus* sp. and *S. hundsheimensis*. The assemblage can be correlated with the latest Early Pleistocene — first half of the Middle Pleistocene, but it cannot be included in a well-defined chronological zone.

Moreover, a mandible of *S. hundsheimensis* was also collected at Cava di Breccia (Petronio, 1988; Petronio and Sardella, 1999; Pandolfi et al., 2013).

An unpublished horn core of *B. primigenius* and an antler of *C. elaphus eostephanoceros* occurring within pyroclastic deposits referred to the San Cosimato Formation outcropping at Fontignano (Di Stefano and Petronio, 1993), and a few unpublished remains of mammals collected in volcaniclastic deposits at Via Pisana ascribed to *E. ferus* and *B. primigenius* were referred to the later Fontana Ranuccio FU (Fig. 5).

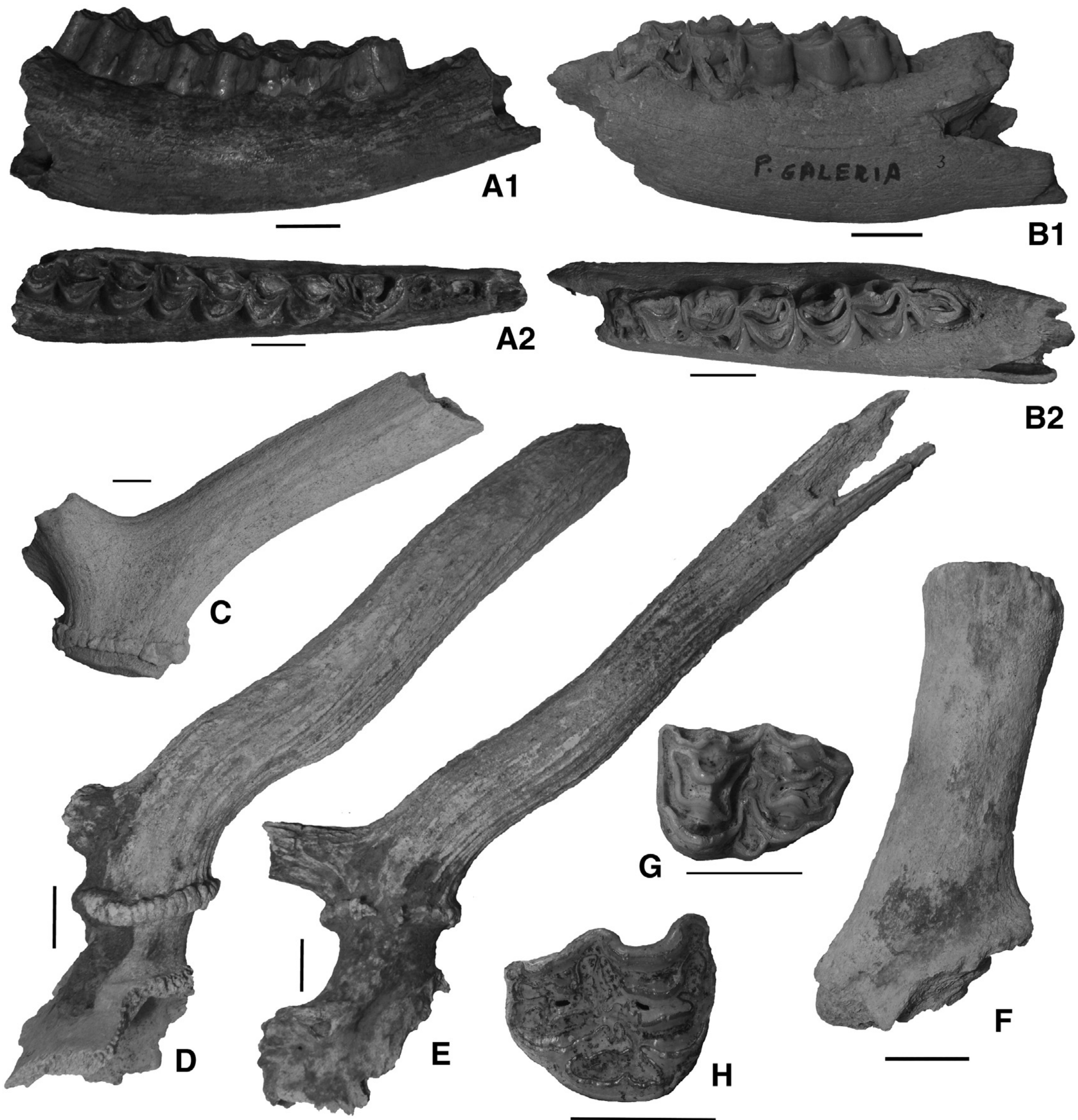

Fig. 5. Large mammal remains from the Ponte Galeria area. A: *Praemegaceros verticornis* fragmentary mandible from Cava Arnolfi (MPUR V897), 1 in buccal view, 2 in occlusal view, B: *Praemegaceros verticornis* fragmentary mandible from Ponte Galeria (MPUR n3), 1 in buccal view, 2 in occlusal view, C: *Megaloceros savini* fragment of antler from Ponte Galeria in lateral view (MPUR NS84.12), D: *Axis eurygonos* fragment of antler and pedicle from Casal Selce lower level in lateral view (MPUR sn), E: *Axis eurygonos* fragment of antler and pedicle from Casal Selce lower level in lateral view (MPUR sn), F: *Capreolus* sp. fragment of horn from Casal Selce lower level (MPUR sn), G: *Bos primigenius* upper molar from Via Pisana in occlusal view (MPUR sn), H: *Equus ferus* upper premolar from Via Pisana in occlusal view (MPUR sn). Scale bar is 2 cm.

Different faunal assemblages referred to Aurelian LMA are recorded in the Ponte Galeria area. Among the other localities, Malagrotta, Cava Rinaldi, Torre in Pietra, and Polledrara must be mentioned (Caloi and Palombo, 1978, 1980a,b; Palombo et al., 2004; Petronio et al., 2011; Anzidei et al., 2012). The faunal assemblages are characterized by the dominance of *B. primigenius*, *P. antiquus* and *C. elaphus* ssp. In the site of Torre in Pietra, two different faunal assemblages have been recorded; the older one is referred to the Torre in Pietra FU (late Middle Pleistocene) and the younger one to the Vitinia FU (sensu Gliozzi et al., 1997). Among the other taxa, the older assemblage includes *Ursus* cf. *spelaeus*, *Canis lupus*, *Vulpes vulpes*, *Panthera spelaea*, *E. ferus*, *S. hemitoechus,* and *S. scrofa*. The younger one is represented by *Microtus arvalis-agrestis*, *Arvicola terrestris-amphibius*, *Martes* cf. *foina*, *C. crocuta*, *C. lupus*, *V. vulpes*, *S. hemitoechus*, *H. amphibius*, *D. dama* ssp., *C. elaphus* ssp., and *C. capreolus*. At Malagrotta, among the other species, *C. lupus*, *Dama* cf. *clactoniana* and *B. primigenius* are recorded. At La Polledrara, the fauna assemblage is also characterized by the presence of *Bubalus murrensis*, *C. lupus*, *V. vulpes*, and *M. sylvanus*.

6. Discussion

6.1. Chronostratigraphic and biostratigraphic review of the mammal assemblages from Ponte Galeria and correlation with other Italian fossiliferous localities

Between approximately 3.3 and 0.01 Ma (Late Pliocene–Holocene), wherein the modern faunas were formed, three Mammal Ages have been defined (Gliozzi et al., 1997; Petronio et al., 2011):

(1) Villafranchian — from ca. 3.3 to ca. 1.1 Ma (Late Pliocene and part of the Early Pleistocene), which includes, in chronological order, the Faunal Units of Triversa, Montopoli, Saint Vallier, Costa San Giacomo, Olivola, Tasso, Farneta, and Pirro;
(2) Galerian — from ca. 1.1 to ca. 0.35 Ma (part of the Early Pleistocene–late Middle Pleistocene), which includes the Faunal Units of Colle Curti, Slivia, Ponte Galeria, Isernia, and Fontana Ranuccio;

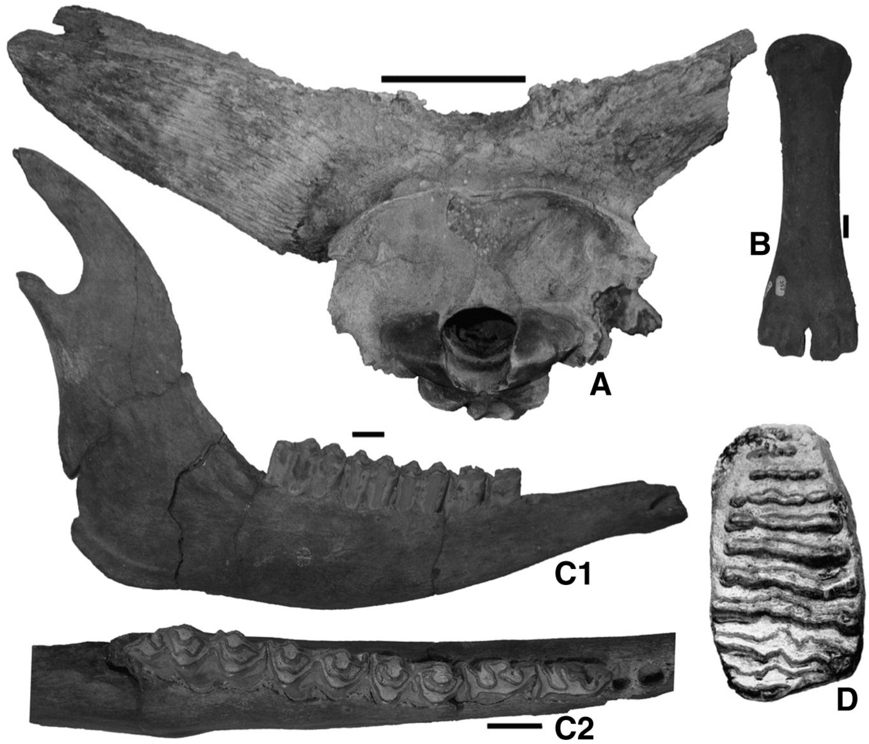

Fig. 6. Large mammal remains from Ponte Galeria area. A: *Hemibos galerianus* fragmentary skull (ASR sn) from Cava di Breccia lower level in occipital view (photo C. Petronio), B: *Bison* sp. metacarpus from Cava Arnolfi in anterior view (MPUR V357), C: *Bison* sp. mandible from Cava Arnolfi (MPUR 358), 1 in buccal view, 2 occlusal view of the tooth row, D: *Mammuthus trogontherii* upper molar from Cava Arnolfi in occlusal view (from Ambrosetti, 1967; no scale reported). Scale bar for B and C is 2 cm; for A 10 cm.

(3) Aurelian — from ca. 0.35 to ca. 0.01 Ma (late Middle Pleistocene–Late Pleistocene), which includes the Faunal Units of Torre in Pietra, Vitinia, Melpignano, and Ingarano.

Conato et al. (1980) correlated the "*Helicella* clay" with the termination X of the isotopic scale, at the transition from MIS 22 to MIS 21, based on its reversed magnetic polarity. However, the stratigraphic scheme of Fig. 2 evidences its correlation with the following glacial termination IX, at the transition MIS 20–19. Thus, according to Marra et al. (1998), the earliest assemblage from Fontignano with *P. pannonicus* and a rodent close to *Predicrostonyx* has to be related to the Slivia FU (sensu Gliozzi et al., 1997) and in particular to MIS 20–21 (Fig. 3; Table 1). The peculiar small assemblage from Fontignano is chronologically close to those from Monte Tenda (in which *Microtus* is present together with *Terricola*) and Slivia (in which *Microtus* is present together with *Dinaromys*) (Pasa, 1947; Ambrosetti et al., 1979; Gliozzi et al., 1997; Kotsakis et al., 2003; Sala and Masini, 2007) (Fig. 6). Slightly younger than Fontignano is the small mammal assemblage from the Sant'Arcangelo basin, chronologically correlated with the early Brunhes chron (Masini et al., 2005).

The "fluvial gravel with clay layers" occurring below the early explosive volcanic products once cropping out in Cava Redicicoli, at the Bufalotta locality north of Rome, from which a rich mammalian fauna was discovered and described by Blanc (1955), and whose chronological attribution has been the subject of debate (Di Stefano et al., 1998; Palombo et al., 2004; Milli and Palombo, 2005) are also to be correlated to the PG 1 Formation and MIS 20–21.

Indeed, the reconstruction of the sub-surface stratigraphy in the larger area of Rome provided in Florindo et al. (2007) has shown that the alternating gravel and clay deposits underlying the early Alban Hills explosive products in the area north of Rome are those of the Paleotiber 2 unit, which includes the PG1 and the Rome deposits, correlated to MIS 20–19 based on ages of two tephra layers dated 802 and 788 ka (Florindo et al., 2007). Therefore the faunal assemblage described there, also considering the taxa recognized, should be included in the Slivia FU. The taxa collected from Cava Redicicoli include *M. meridionalis*, *Bison* aff. *B. degiulii*, *Bison* sp. aff. *B. schoetensacki*, *E. altidens*, *H. antiquus*, *S. hundsheimensis* and Megacerini indet. (Caloi et al., 1979; Caloi and Palombo, 1995; Di Stefano et al., 1998; Milli and Palombo, 2005; Petronio and Pandolfi, 2011). Palombo et al. (2002) and Milli and Palombo (2005) cited an unpublished manuscript of Blanc according to which the mammal assemblage came from a single fossiliferous level. This assemblage suggests a latest Early Pleistocene age for the deposits in which the remains were collected and a correlation with the Colle Curti FU has been proposed by Milli and Palombo (2005). Nevertheless, several taxa from Cava Redicicoli are also recorded during the Middle Galerian (*E. altidens*, *H. antiquus*, *S. hundsheimensis*). The first occurrence of bison related with *B. schoetensacki* is recorded in Italy in the Slivia FU (Gliozzi et al., 1997) while small-sized bison referred to *B. degiulii* is also recorded during the Early Galerian at Ellera in association with *P. verticornis* (Cherin et al., 2012). *M. meridionalis* is surely recorded within the Colle Curti FU while it is not present in the Slivia FU and in the Ponte Galeria LF where *M. trogontherii* occurs. However, in the LF of Slivia the herbivores are represented by few remains and their identification is doubtful (Palombo et al., 2002). Based on this evidence and that carnivores and micromammals from Ponte Galeria are scantily known, Palombo et al. (2002) did not exclude the possibility that the Slivia and Ponte Galeria assemblages belong to the same FU. The new data on the stratigraphy of the Roman basin allow confirming that Slivia and Ponte Galeria FUs belong to two different time spans. Moreover, the LF of Cava Redicicoli, chronologically related with Slivia FU, allows adding new data about the occurrence of taxa during the MIS 20–19 in Italy. The latter time span is therefore characterized by the persistence of *M. meridionalis*, and the presence of two bisontine forms, a large one (related with *B. schoetensacki*, confirming the occurrence of this species during the Slivia FU) and a smaller one (related with *B. degiulii*, recently recorded also in other Early Galerian assemblages) (Fig. 6).

Nevertheless, the occurrence of two distinct faunal assemblages in the Cava Redicicoli record, as suggested by Di Stefano et al. (1998),

Table 1
List of selected fossiliferous localities that yielded mammal remains in the Ponte Galeria area and correlations with the Italian Mammal Zones, Stratigraphic Units, Marine Isotopic Stages, and radiometric ages.

Fossiliferous locality	Mammal assemblage	Mammal age	Faunal unit	Stratigraphic level	MIS	Radiometric age (Ma)	Formation
Fontignano 1	*Prolagurus pannonicus*, ?*Predicrostonyx*	Galerian	Slivia	Blue-gray clays with *Helicella ericetorum*	20		PG 1
Cava Redicicoli	*Mammuthus meridionalis*, *Bison* aff. *B. degiulii*, *Bison* sp. aff. *B. schoetensacki*, *Equus altidens*, *Hippopotamus antiquus*, *Stephanorhinus hundsheimensis*, Megacerini indet.	Galerian	Slivia	Gravel and clays	20/19	0.808–0.788	PG 1
Cava Arnolfi	*Hippopotamus antiquus*, *Praemegaceros verticornis*, *Axis eurygonos*, *Bison* sp., *Palaeoloxodon* cf. *antiquus*, *Mammuthus trogontherii*	Galerian	Ponte Galeria	Gravels and sands underlying the *Venerupis senescens* clays	18.2/17.3		PG 2B
Muratella di Mezzo	*Palaeoloxodon antiquus*, *Hippopotamus* sp., *Praemegaceros verticornis*, *Megaloceros savini*	Galerian	Ponte Galeria	Gravels and sands underlying the *Venerupis senescens* clays	18.2/17.3		PG 2B
Ponte Galeria undefined locality	*Megaloceros savini*, *Praemegaceros verticornis*	Galerian	Ponte Galeria	Gravels and sands underlying the *Venerupis senescens* clays	18.2/17.3		PG 2B
Cava Alibrandi	*Axis eurygonos*, *Equus altidens*	Galerian	Ponte Galeria	Gravels and sands	18.2/17.3		PG 2B
Cava di Breccia 1, Casal Selce	*Mammuthus trogontherii*, *Axis eurygonos*, *Equus altidens*, *Hemibos galerianus*, *Capreolus* sp., *Stephanorhinus hundsheimensis*	Galerian	Ponte Galeria	Gravels and sands underlying the *Venerupis senescens* clays	18.2/17.3		PG 2B
Vitinia	*Cervus* sp., *Axis* sp., *Praemegaceros verticornis*, cf. *Bison* sp., Bovidae indet., *Equus* sp., *Stephanorhinus hundsheimensis*	Galerian	Ponte Galeria	Gravels and sands	16	0.653	
Cava di Breccia 2, Casal Selce	*Perdix palaeoperdix*, *Gyps melitensis*, *Palaeocryptonyx* sp., *Allocricetus bursae*, *Arvicola cantianus*, *Macaca sylvanus*, *Lynx pardina spelaea*, *Meles meles*, *Stephanorhinus* sp., *Equus altidens*, *Equus sussenbornensis*, *Sus scrofa priscus*, *Hippopotamus antiquus*, *Axis eurygonos*, *Cervus elaphus acoronatus*, *Bison* cf. *B. schoetensacki*	Galerian	Isernia	Salmon sand deposit	15	0.615–0.611	Santa Cecilia
Via Portuense	*Hippopotamus antiquus*	Galerian	Isernia	Lacustrine deposits	15		Santa Cecilia
Maglianella	*Hippopotamus antiquus*	Galerian	Isernia	Lacustrine deposits	15		Santa Cecilia
Via Pisana	*Bos primigenius*, *Equus ferus*	Galerian	Fontana Ranuccio	Volcanoclastic deposits	13	0.517–0.499	Valle Giulia
Cava Rinaldi	*Palaeoloxodon antiquus*, *Ursus* sp., *Cervus elaphus* ssp., *Bos primigenius*, *Castor fiber*	Galerian	Fontana Ranuccio	Lacustrine deposits	13	0.517–0.499	Valle Giulia
Fontignano 2	*Bos primigenius*, *Cervus elaphus eostephanoceros*	Galerian	Fontana Ranuccio	Pyroclastic deposits	12.2–11.1	0.44–0.412	San Paolo

cannot be excluded also based on the detailed stratigraphic reconstruction of this area. Calcareous mud deposits correlated to MIS 17, as well as brown sandy silt deposits correlated to MIS 15 occurs between the fluvial clay and gravel layers and the overlying volcanic deposits in the area north of Rome (Fig. 4), and it is possible that the quarry where the vertebrate remains described by Blanc were discovered exposed the entire suite of these sedimentary sequences, which may have contained three faunal assemblages attributable to the Slivia, the Ponte Galeria and the Isernia FUs. Even in the latter hypothesis, the presence of a faunal assemblage related with the latest Villafranchian (as proposed by Caloi et al., 1979) or the Colle Curti FU (as proposed by Palombo et al., 2002; Milli and Palombo, 2005) can be excluded and the biostratigraphic considerations previously exposed for *Mammuthus* and the bisons can be confirmed.

Many fossil bones have been found during the last decades in the upper part of "pebble gravels and sand with frequent cross laminations" of the Ponte Galeria Formation that correlates with the end of MIS 18.2 lowstand (Fig. 3).

The LF of Ponte Galeria was initially referred to the Isernia FU by Gliozzi et al. (1997). The LF of Isernia La Pineta includes some taxa, such as *Praemegaceros solilhacus* and *Arvicola cantianus*, which do not occur in the fauna assemblages collected from the gravels and sands of the Ponte Galeria Formation. Moreover, *A. cantianus* was widespread in Western Europe from approximately 0.6 Ma (Koenigswald and Van Kolfschoten, 1996; Maul et al., 2000). Based on these reasons, Petronio and Sardella (1999) named the Ponte Galeria FU, considered as intermediate between Slivia FU and Isernia FU. According to Petronio and Sardella (1999), the Ponte Galeria FU is characterized by the first occurrence of *M. savini* and *H. galerianus*, and the faunal assemblage includes *P. antiquus*, *M. trogontherii*, *S. hundsheimensis*, *E. altidens*, *H. antiquus*, *P. verticornis*, *A. eurygonos*, *C. elaphus acoronatus* and *Bison* sp. This faunal assemblage was magnetostratigraphically dated between 763 ± 8 and ca. 700 ka (age of the tephra layer at the base of the PG 2 gravels and of the MIS 17.3 highstand, respectively; Figs. 2, 3) (Marra et al., 1998; Petronio and Sardella, 1999; Milli et al., 2004). The site of Isernia La Pineta is well-known for the occurrence of archeological tools; the faunal assemblage is particularly rich in remains of *B. schoetensacki* and *S. hundsheimensis* (Sala, 1987; Sala and Fortelius, 1993; Coltorti et al., 2005, 2011; Thun Hohenstein et al., 2009 and references therein). The age of this site was for many years matter of debate among researchers. The K/Ar age of 736 ka, provided by Coltorti et al. (1982), was considered too old for being in accordance with the paleontological evidences (e.g., the occurrence of *A. cantianus*) (Kolfschoten and Koenigswald, 1996; Petronio and Sardella, 1999). The new $^{40}Ar/^{39}Ar$ data provided by Coltorti et al. (2005) assessed the age of the archeological stratum at 610–606 ka, confirming the value of the biochronological framework pointed out for Italy. Coeval or slightly younger fossiliferous localities than Isernia La Pineta are Venosa–Notarchirico and Valdemino (Caloi and Palombo, 1986; Gliozzi et al., 1997; Nocchi and Sala, 1997; Cassoli et al., 1999; Petronio et al., 2011). In the Ponte Galeria area, the LF of Casal Selce 2 could be chronologically related with the Isernia FU. The layers of the salmon sands in which the mammal fauna was collected correspond to the Eolian salmon sand deposits of Conato et al. (1980) and correlate with the Santa Cecilia Formation (SCF; Karner and Marra, 1998). In particular, the upper sand horizon of the SCF has very tight age constraints, represented by a lower boundary age of 615 ± 3 ka and an upper boundary age of 565 ± 2 ka (Fig. 2). Moreover, a pumice fall intercalated within the sand deposit yielded an age of 611 ± 6 ka (Karner and Marra, 1998; age re-calculated in this work). The second faunal assemblage from Cava di Breccia di Casal Selce displays different character with respect to that occurring in the overlying horizon of the PG2 Formation, and is referable without doubts to the middle part of the Galerian.

The mammal assemblage discovered in the sandy gravel deposits at the locality of Vitinia was previously included in the Ponte Galeria FU, in particular because of *P. verticornis* occurrence (Caloi et al., 1981; Petronio and Sardella, 1999). According to our chronostratigraphic revision, instead, it must be attributed to an age slightly older than the LF of Isernia La Pineta. Based on the age constraints provided by Florindo et al. (2007), deposition of these gravels occurred shortly before 653 ± 4 ka, largely predating the glacial termination and the associated sea-level rise during MIS 15 causing the deposition of the highstand sediments of the Santa Cecilia Formation, within which the Cava di Breccia faunal assemblage attributed to the Isernia FU was collected (Fig. 4). This datum suggests that the last occurrence of *P. verticornis* in Italy is approximately between MIS 16 and MIS 15. To the lower level of Vitinia can be correlated the faunal assemblages of Pagliare di Sassa (L'Aquila basin, Central Italy) and Fornaci Fondo–Pagano (Mercure basin, Southern Italy) (Cavinato et al., 2001; Sardella et al., 2006; Palombo et al., 2010; Mancini et al., 2012) where the presence of *P. verticornis* and the occurrence of the genus *Dama* with distal palmations on the antlers (*Dama* s.s. to distinguish from the species included in the genus *Dama* but lacking the distal palmations on the antlers here indicated as *Dama* s.l. and referred to the genus *Axis* by Di Stefano and Petronio, 1993, 1997) has also been recorded (Cavinato et al., 2001; Mancini et al., 2012). This confirms the presence in Italy of LFs intermediate in age between the FUs of Ponte Galeria and Isernia, characterized by the persistence of *P. verticornis* and the first occurrence of the genus *Dama* s.s.

The lacustrine deposits outcropping in Maglianella, at km 11 of the Via Aurelia, are likely correlated to the SCF and the high stand of MIS 15; therefore, the remains of *H. antiquus* recovered in there (Caloi et al., 1980a; Petronio, 1995; Petronio and Sardella, 1999) should be included in the Isernia FU (Table 1).

Remarkably, the sedimentary deposits in which the three distinct faunal assemblages recognized in Ponte Galeria occur (referred to Slivia, Ponte Galeria, and Isernia FUs) represent three aggradational successions, linked to the three consecutive MIS 20–19, MIS 18–17 and MIS 16–15 intervals (Fig. 3).

The only outcropping deposits of the Valle Giulia Formation in the Ponte Galeria area occur in Cava Rinaldi (Karner and Marra, 1998). Vertebrate remains attributed to the Early Aurelian (Ambrosetti, 1965; Caloi et al., 1998) and correlated to MIS 10–9, were discovered in this location. However, the ages of three volcanic layers interbedded within the Cava Rinaldi lacustrine succession evidence a correlation with MIS 13 (Figs. 2, 3; Table 1), to which also the recovered faunal assemblage has to be referred. This assemblage includes *P. antiquus*, *Ursus* sp., *C. elaphus* ssp., *B. primigenius,* and *Castor fiber* (Ambrosetti, 1965). In the Ponte Galeria area, the small LF of Via Pisana (in which *B. primigenius* is present) is coeval in age with Cava Rinaldi. Moreover, the LFs of GRA km 2 could be of the same age. In this locality, the occurrence of *Hyaena prisca* is also documented (Caloi and Palombo, 1986).

The deposits occurring in the northern urban area of Rome (Monte Antenne, Villa Glori, Val Melaina, Parioli; Marra and Rosa, 1995) previously ascribed to the "Parioliano" (Ambrosetti and Bonadonna, 1967; Ambrosetti et al., 1972; Caloi and Palombo, 1988) and included in the Galerian FU, in which remains of *P. antiquus*, *Stephanorhinus* sp., *Hippopotamus* sp., and *B. primigenius* occur are also correlated to the Valle Giulia Formation.

The occurrence of *C. elaphus eostephanoceros* at Fontignano in the San Cosimato Formation was considered the earliest record of the subspecies in Italy by Di Stefano and Petronio (1993). The San Cosimato Formation corresponds indeed to the San Paolo Formation and correlates with MIS 11 (440–410 ka, Fig. 3), in good agreement with the attribution of the faunal assemblage to the Fontana Ranuccio FU (based on the LF of Fontana Ranuccio, which has a lower boundary at 458 ka; Cassoli and Segre Naldini, 1993; Palombo et al., 2002; Segre Naldini et al., 2009 and references therein).

More recently, the age of the Fontana Ranuccio LF has been revised based on the identification of the Pozzolane Nere pyroclastic-flow deposit (Biagio Giaccio, personal communication), which has a $^{40}Ar/^{39}Ar$ age of 409 ± 2 ka (Marra et al., 2009), coincident with MIS 11 (Fig. 3).

The faunal assemblage from Cava Nera Molinario, which includes *P. antiquus*, *Hippopotamus* sp., and *C. e. eostephanoceros* (Blanc et al., 1955; Di Stefano and Petronio, 1993; Di Stefano et al., 1998) was also attributed to the Fontana Ranuccio FU.

The stratigraphic scheme of this site reported by Blanc et al. (1955), however, shows that the vertebrate remains underlie the Tufo Rosso a Scorie Nere pyroclastic-flow deposit (452 ± 2 ka, Karner et al., 2001a) and are intercalated within the "Tufi Stratificati Varicolori di Sacrofano" *Auctorum*, which correspond in part to the Tufo Giallo di Prima Porta and Grottarossa Pyroclastic Sequence pyroclastic-flow deposits, dated 514 ka (Karner et al., 2001a). These age constraints clearly indicate that the fossils are associated to lacustrine deposits of the Valle Giulia Formation, correlating with MIS 13 (ca. 500 ka), and should be considered slightly older than the Fontana Ranuccio LF, which in turn correlates with MIS 12–11 (ca. 450–400 ka). Nevertheless, they can be included in the Fontana Ranuccio FU due to the similarities in faunal compositions, as opposite to those referred to the older Isernia FU. Based on these considerations, the occurrence of *C. elaphus eostephanoceros* in Italy can be pre-dated. Chronologically related with Cava Nera Molinario is a mammal assemblage recently discovered in the northern area of Rome, near Palombara Sabina (Manni et al., 2000). The faunal list includes *P. antiquus*, *B. primigenius*, Cervidae indet. and some lithic tools collected in a pedogenetic level dated at approximately 0.5 Ma (Manni et al., 2000). Moreover, a fragmentary skull of *S. hemitoechus* collected in the north-western area of the Roman Basin was dated at ca. 0.5 Ma based on the petrography and geochemistry of the volcanoclastic sediments containing the rhinoceros skull (Pandolfi et al., 2013).

The beginning of the Aurelian LMA was conventionally placed in correspondence to MIS 9 (Gliozzi et al., 1997; Palombo, 2004; Palombo et al., 2004; Petronio et al., 2011). During the Aurelian, the occurrence of the taxa that represent the core of the present-day mammal fauna is recorded. The mammal communities become more and more similar to the modern ones, with the diminishing of large-sized forms and the increase of medium- and small-sized ones. Two distinct FUs, Torre in Pietra and Vitinia, were recorded within two unconformably stacked sedimentary deposits at the type section of Torre del Pagliaccetto (Malatesta, 1978), which were referred to the Aurelia (MIS 9) and Vitinia Formations (MIS 7) (Caloi and Palombo, 1978, 1990, 1995; Gliozzi et al., 1997; Caloi et al., 1998).

In the Early Aurelian, Torre in Pietra FU (referred to MIS 9 by Gliozzi et al., 1997), *C. lupus*, *U. spelaeus*, *M. giganteus*, *P. spelaea*, *B. murrensis*, and *V. vulpes* appear for the first time in Italy. Together with these species, different local subspecies of *C. elaphus* are present; they show endemic features, witnessed by the particular archaic structure of the antlers. In the deposits of the Roman area referable to this period, *P. antiquus* and *B. primigenius* are constantly present; they are the most abundant species, followed by rhinos, horses, deer, hippos, and scarce carnivores (Caloi and Palombo, 1995; Palombo, 2004; Palombo et al., 2004; Petronio et al., 2011 and references therein). In the assemblages of the Middle Aurelian, referable to the Vitinia FU, an archaic subspecies of the modern fallow deer, *D. dama tiberina* and *E. hydruntinus* appear.

The distinction of an Early and a Middle Aurelian, including the Torre in Pietra and the Vitinia FUs, has been questioned based on the revised attribution of sediments hosting the faunal assemblages of Sedia del Diavolo and Monte delle Gioie, previously attributed to the Vitinia Formation (Caloi et al., 1998), to the Aurelia Formation (Milli et al., 2004; Palombo et al., 2004). However, a more detailed study showed that these sections are coeval with the Via Mascagni sub-sequence (Marra and Rosa, 1995), which correlates with MIS 8.5 (Marra, 2004; Fig. 3). Therefore, they represent an intermediate aggradational unit with respect to the Aurelia and the Vitinia formations, which is separated from these two successions by two lowstand periods. Therefore, at least from a chronological point of view, the distinction of a Middle Aurelian (Vitinia FU) corresponding to the MIS 8.5 and MIS 7, as opposed to an Early Aurelian (Torre in Pietra FU) corresponding to MIS 9, is justified. The distinctive feature of the Vitinia FU would be represented by the appearance of *D. dama tiberina* and *E. hydruntinus*. These two species were never found in the fossiliferous localities related to the Torre in Pietra FU where a larger species of fallow deer (*D. clactoniana*) and *E. ferus* were instead recorded.

However, we remark that the type-section of Torre del Pagliaccetto lacks of geochronological constraints supporting the correlation of the Torre in Pietra FU and the Early Aurelian LMA with MIS 9. Similarly, none of the other localities of the Roman area referred to the early Aurelian (Castel di Guido, Malagrotta, La Polledrara di Cecanibbio, Collina Barbattini, Riano Flaminio, Cretone, Prati Fiscali; Caloi et al., 1998; Anzidei et al., 2001, 2012; Petronio et al., 2011) is radiometrically tied to MIS 9, whereas in other cases (e.g., Pantano di Grano) geochronological constraints have shown correlation with MIS 7 (Karner and Marra, 1998). A sure attribution to the early MIS 10 can be made only for the cervid remains from the “Tufo Lionato” pyroclastic flow of Sedia del Diavolo (Caloi et al., 1980b; Di Stefano et al., 1998), dated at 367 ± 4 ka (Marra et al., 2009). This age represents the lower limit of the Torre in Pietra FU.

The difficulty to date the deposits of MIS 9 is basically due to the scarcity of volcanic activity occurring in the corresponding interval. Indeed, the Alban Hills have typical recurrence times of ca. 45 ka (Marra et al., 2004) and were characterized by a nearly absolute dormancy after the Villa Senni eruption cycle (367 ± 4 ka) and the start of the successive Monte delle Faete phase (280 ± 2 ka) (Marra et al., 2009). The Monti Sabatini district also experienced an even longer period of relative dormancy, from 410 to 310 ka (Sottili et al., 2010).

In contrast, the faunal assemblage of Vitinia is tied to MIS 7 by the occurrence of a pyroclastic layer dated 254 ± 8 ka (Karner and Marra, 1998) within the deposit of this depositional unit at the type-section, whereas the other LFs of Torre in Pietra 2, Casal de' Pazzi and Cerveteri (Caloi et al., 1998; Palombo et al., 2002) lack of geochronological constraints.

The only faunal assemblage discovered within deposits correlated to MIS 5 in the whole Roman area is that described by Blanc (1939, 1948) at the Saccopastore quarry, in the Aniene River valley, where two human skulls attributed to archaic Neanderthalian individuals were also discovered. The deposits constitute an alluvial terrace of the Epi-Tyrrhenian Formation and, along with the terraced deposits along the modern coast, represent the only remnant of this aggradational cycle, which elsewhere in this area was probably eroded during the sea-level lowstand associated with the Last Glacial maximum.

6.2. Biochronological, paleobiogeographic and paleoenvironmental implications for selected taxa from Ponte Galeria: comparison with European data

P. pannonicus and *Predicrostonyx* suggest dry and cold climatic conditions in Central Italy during MIS 20. These conditions are also documented in the pollen diagrams of Colle Curti and Cesi (Bertini, 2000), which show a significant increase of herbaceous forms (Chenopodiaceae and *Artemisia*), testifying to the progressive increase in aridity and progressive decrease in temperature from approximately 1 Ma to 0.6–0.7 Ma (Bertini, 2000).

The age of the earliest assemblages of Ponte Galeria is in agreement with the presence of *P. pannonicus* in Europe. Indeed, the species occurs before the Jaramillo subchrone in Central Europe and at the Jaramillo subchrone in Eastern Europe (Maul and Markova, 2007) and it was present until the Matuyama–Brunhes reversal (Markova, 1998; Kolfschoten and Markova, 2005; Maul and Markova, 2007). *Predicrostonyx* is unknown in Eastern Europe (Maul and Markova, 2007) while in Western Europe it is related with an Early Pleistocene age (Maul and Markova, 2007). The last occurrence of the genus was probably during the end of the Early Pleistocene. However, *P. antiquitatis* from the latest Early Pleistocene of Les Valerots (chronologically related with the Italian localities of Slivia and Monte Tenda) was included in the genus *Dicrostonyx* and made synonymous of *P. compitalis* (Chaline, 1972; Kowalski, 1995, 2001; Sesé and Villa, 2008). *Prolagurus* and *Predicrostonyx* probably migrated into Central Italy from Central Europe together with the new grazer *B. schoetensacki*, during the Slivia FU. The latter taxon occurred in Europe approximately at 1 Ma at Vallonnet (Moullé et al., 2006) while a large bison is recorded during the late Early Pleistocene at Venta Micena (Martínez-Navarro et al., 2011) and the species *B. menneri* occurred at Untermassfeld (Sher, 1997; Kahlke, 2001). The presence of a small-sized bison related with *B. degiulii* during the Slivia FU (Cava Redicicoli LF) may probably be explained with the persistence of Late Villafranchian populations due to optimum in climatic conditions or delay in dispersal of competitive species. According to Croitor and Brugal (2007), *B. degiulii* may be a close relative of *B. tamanensis* of which it might be an endemic subspecies.

The persistence of *M. meridionalis* during the Slivia FU (Cava Redicioli LF; Fig. 6) is in agreement with the latest records of this species in other European localities around the Early–Middle Pleistocene transition. Remains of *M. meridionalis* are reported at Dorst (Netherlands), Don-Dürkheim 3 and Voigtstedt (Germany), and West Runton (England) (Franzen et al., 2000; Lister et al., 2005; Lister and Stuart, 2010). Both the small-sized bison and *M. meridionalis* become extinct in Italy at the beginning of the Middle Pleistocene when new species such as *H. galerianus*, *M. trogontherii* and *P. antiquus* appeared.

The presence of the genus *Hemibos* in the Ponte Galeria LF (Ponte Galeria FU) was interpreted as a dispersal event from Asia towards Western Europe. Nevertheless the genus *Hemibos* was recently recorded in the late Early Pleistocene locality of Venta Micena, thus predating its first occurrence in the rest of Europe (Martínez-Navarro et al., 2011). The species from Ponte Galeria, collected in the deposits underlying the *V. senescens* clays, is larger than the other four known species of the genus (Martinez-Navarro and Palombo, 2004, 2007) and it is probably the last species of a European lineage.

In Europe, *M. trogontherii* is first recorded during the Matuyama–Brunhes transition and the record of Ponte Galeria is placed between the earliest occurrences of the species. Nevertheless, the species occurred in eastern Asia during the Early Pleistocene (Wei et al., 2003; Zhu et al., 2004; Tong, 2012). *M. trogontherii* represents an immigrant from Asia and the possibility of temporal overlap with *M. meridionalis* and even the hybridization between the two species has been raised by Lister and Sher (2001) and Lister et al. (2005).

P. verticornis is well documented at Ponte Galeria (Ambrosetti, 1967; Caloi and Palombo, 1980a; Petronio and Sardella, 1999; this work); the species occurs in Italy around the Jaramillo subchrone (Ficcarelli and Mazza, 1990; Coltorti et al., 1998; Abbazzi, 2004). Croitor and Kostopoulos (2004) and Croitor (2006a,b) recognized as a valid name the species *P. pliotarandoides* and ascribed some remains of Early Pleistocene large-sized deer to this species, including the specimen from Borgo Nuovo (Central Italy). However, other authors (Azzaroli, 1979; Geraads, 1986; Abbazzi, 2004) considered *P. pliotarandoides* as morphotype of *P. verticornis*.

P. verticornis occurs early in Spain, before the Jaramillo subchrone (Madurell-Malapeira et al., 2010), while it is present during the latest Early Pleistocene–early Middle Pleistocene in Germany (Kahlke, 1956, 1969), England (Azzaroli, 1953; Lister et al., 2010), France (Guérin et al., 2003; Moullé et al., 2006), and Moldova (Croitor, 2006b). During the early Middle Pleistocene in England and Italy, *P. verticornis* is sometimes recorded together with *M. savini* (Caloi and Palombo, 1980a,b; Lister et al., 2010; this work). Based on the calibration of the mammal assemblages previously discussed, *M. savini* occurs in Italy during a well-defined time span between MIS 18 and 16. The latter species is present in Spain during the early Middle Pleistocene (approximately MIS 19 to 14; Atapuerca TD inf.–Arenero Manuel Soto; Made and Tong, 2008); in Germany it is recorded at Voigtstedt and Süssenborn (approximately MIS 17–16) (Kahlke, 1965, 1969) while in England it is reported at Pakefield, Trimmingham, West Runton and Mundesley (approximately MIS 18 to 15) (Made and Tong, 2008; Lister et al., 2010). A giant deer with palmate brow tine ascribed to *M.* aff. *savini* is recorded at Libakos (Greece; ca 1.2 Ma) and is probably at the origin of *M. savini* in Western Europe (Made and Tong, 2008). Both *P. verticornis* and *M. savini* disappear from the Italian Peninsula before the Isernia FU, about in concomitance with the first occurrence of the genus *Dama* with distal palmations on the antlers.

The first occurrence of *Capreolus* was reported by Vislobokova et al. (1995) from the Early Villafranchian of Trans-Baikal area (Eastern Russia). The genus *Capreolus* occurs later in the Georgian locality of Diliska (Middle Villafranchian) (Vekua, 1991; Vekua and Lordkipanidze, 1998) while in Central Europe it is recorded first at Untermassfeld (Kahlke, 1997, 2001). At the end of the Early Pleistocene, the genus spread into the Levant (Evron; Tchernov et al., 1994; Porat and Ronen, 2002). The early occurrence of the genus in Italy is recorded at Isernia La Pineta and Valdemino LFs, both referred to the Isernia FU. Thus, the record of Ponte Galeria predated the diffusion of the roe deer in Italy.

Axis eurygonos is well represented at Ponte Galeria (ca. 0.75 Ma) by antlers, teeth and postcranial remains and appears to be a very long-lived species. It occurs at first during the Late Villafranchian (Farneta FU) and disappears after the Late Galerian (Fontara Ranuccio FU) (Di Stefano and Petronio, 1993; Di Stefano et al., 1995; Petronio et al., 2011). According to Di Stefano and Petronio (1993) the genus *Axis* seems in the beginning exclusively diffused in the Italian Peninsula and it spread into Continental Europe at the end of the Early Pleistocene (*Cervus nestii vallonnetensis* is synonymous of *A. eurygonos* according to Di Stefano and Petronio, 1993). The *Dama*-like cervids disappeared in Europe during the end of the Early Pleistocene (they are recorded at Vallonnet, Untermassfeld and in the lower levels of Atapuerca; de Lumley et al., 1988; Kahlke, 1997; Made, 1998, 2011; Croitor, 2006a; Moullé et al., 2006). The persistence of this taxon in Italy could be related with the presence of favorable climatic conditions and *refugia* for interglacial faunas.

The presence of several fossiliferous localities around 0.5 Ma, which show a different faunal composition than those referred to the Isernia FU, are recognized in this work. Among the other, Cava Nera Molinario, Cava Rinaldi, and Via della Pisana in the Roman area have well-defined geochronological constraints relating them to the Valle Giulia Formation. The LF of GRA km 2 (in which *H. prisca* was collected) and Palombara (the fossiliferous level was dated at approximately 0.5 Ma) can be chronologically correlated with the abovementioned localities. On the whole, the mammal assemblages are characterized by the presence of *H. prisca*, *P. antiquus*, *B. primigenius*, *C. elaphus eostephanoceros*, and *S. hemitoechus*. Due to the intermediate age between the LFs of Isernia La Pineta and Fontana Ranuccio and the different faunal compositions with respect to the Isernia FU, the above-mentioned localities are referred to the Fontana Ranuccio FU. Thus, the lower limit of this FU is correlated with MIS 14–13 (534 ± 2 ka).

B. primigenius appears early in Italy at Venosa–Notarchirico, at ca. 0.6 Ma (Cassoli et al., 1999; Lefèvre et al., 2010) and is recorded together with *B. schoetensacki*. The auroch is relatively rare at Notarchirico but it appears more frequently in the fossiliferous localities of the Roman area dated at ca. 0.5 Ma. The early aurochs are smaller and more slender than those from the late Middle Pleistocene (Pandolfi et al., 2011) and they probably originated from African species of the genus *Bos* (Martínez-Navarro et al., 2007, 2010; Martínez-Navarro and Rabinovich, 2011). A parallelism in the diffusion of the *Bos* and the Acheulean culture (Mode II tools) has been established by Martínez-Navarro et al. (2007, 2010).

Cervus elaphus eostephanoceros was considered as a typical Late Galerian taxon and a marker for the Fontana Ranuccio FU (Di Stefano and Petronio, 1993). Nevertheless, its records in the localities of Valle Giulia Formation pre-dated its first occurrence previously known. In Europe, the subspecies occurs at Hundsheim (MIS 15–13) where it is recorded together with *S. hundsheimensis* (Toula, 1902; Di Stefano and Petronio, 1993). The latter species disappears in Italy before ca. 0.5 Ma, when *S. hemitoechus* appears for the first time (Pandolfi et al., 2013). This species was widespread at first in Southern Europe (Italy, Southern France, Greece) and its diffusion can be related to the diffusion of the Mediterranean-type habitat during the interglacial periods, with the presence of abrasive herbaceous elements (Pandolfi et al., 2013).

During the Early Aurelian, in Central Italy the pollen diagrams shows predominance of open vegetation with relatively brief forestal phases (Follieri et al., 1988; Magri, 1999). At the same time, the European mammal record is characterized by the occurrence of the *Mammuthus*–*Coelodonta* Faunal Complex (Kahlke, 1999; Kahlke and Lacombat, 2008; Kahlke et al., 2011); the latter occurs in Italy only during the last glaciation (MIS 4) (Petronio et al., 2007; Pandolfi and Tagliacozzo, 2013). *B. murrensis* reached Central Italy during MIS 9 (Anzidei et al., 2012) probably from Central Europe where it occurred around MIS 11 (Berckhemer, 1927; Franzen and Koenigswald, 1979; van Dam et al., 1997). *Megaloceros giganteus*, *C. lupus,* and *U. spelaeus* are also recorded for the first time in Italy only during MIS 9. These three species are recorded slightly earlier in the rest of Europe around MIS 11–10. In France, the earliest occurrence of *C. lupus* is at Lunel–Viel together with *E. hydruntinus* (around 0.38 Ma; Bonifay, 1971, 1981, 1991; Burke et al., 2003; Boudadi-Maligne, 2010; Kahlke et al., 2011) while in Spain it is recorded at Atapuerca TG10 (around MIS 10; Made et al., 2003) (Kahlke et al., 2011 and references therein). *Ursus spelaeus* and *M. giganteus* appears both in England during MIS 11 together with *E. hydruntinus* (i.e., Swanscombe; Schreve, 2001; Schreve and Bridgland, 2002); during the same time span, the giant deer also occurred at Steinheim/Murr (Adam et al., 1995). *Equus hydruntinus* is recorded later in Italy, during MIS 8.5–7 (Caloi et al., 1980c; Conti et al., 2010; this work) together with the occurrence of *D. dama tiberina* (Di Stefano and Petronio, 1997); during MIS 7 another subspecies of fallow deer, *D. d. geiselana*, occurred in Central Europe (Pfeiffer, 1997). The latter subspecies is also recorded during MIS 5 in the Iberian Peninsula (Álvarez-Lao et al., 2013).

7. Conclusions

The high resolution of the Ponte Galeria record is an exceptional case in Europe and represents a crucial archive to study and understand the faunal turnover and dispersal of taxa during the Middle Pleistocene.

In the Ponte Galeria area, several mammal assemblages were collected in fossiliferous deposits that are calibrated on the basis of radiometric ages and the glacio-eustatically forced aggradational sedimentary successions. Six biochronological units covering a time span of about 0.6 Myr, including MIS 20–19 through 8–7 (ca. 0.8 Ma to 0.2 Ma) are recognized in the studied area.

The study of the mammal assemblages from Ponte Galeria and the very high stratigraphic resolution of the fossiliferous levels allow to compare the new data with the Italian and European records and to reconstruct in great detail the faunal turnover in Italy during the Middle Pleistocene.

In this paper, a new biochronological framework is obtained for the Italian Peninsula (Fig. 7) with the following interesting novelties:

(1) The cold small mammal assemblage from Fontignano and the large mammal assemblage from Cava Redicicoli are referred to the Slivia FU and correlated to MIS 20–19 (about 0.8 Ma).
(2) The last occurrence of *M. meridionalis* in Italy is recorded during this time span in agreement with the European records. Moreover, the persistence of small Villafranchian bovids (*Bison* aff. *degiulii*, ?endemic, not recorded in the rest of Europe) and the delay in dispersal of large-sized bison (*B. schoetensacki*, recorded in Europe around 1.2–1 Ma) are also testified.
(3) The FUs of Slivia and Ponte Galeria represent two different biochronological intervals and can be distinguished by faunal compositions. Among other taxa, the occurrence of *H. galerianus* and *M. savini* and the disappearance of *M. meridionalis* and the small bisontine forms in the Ponte Galeria FU are recorded.
(4) At the beginning of the Ponte Galeria FU (0.75–0.7 Ma), the first occurrence of the genus *Capreolus* and the persistence of the Villafranchian *Axis* (not present in the rest of Europe later than ca. 0.9 Ma) are recorded. The latter taxon is represented by very abundant and diagnostic remains.
(5) The presence of faunal assemblages intermediate in age between Ponte Galeria and Isernia LFs (e.g., lower Vitinia gravels) are confirmed and calibrated. These assemblages (dated around 0.65 Ma) are characterized by the last occurrences of *P. verticornis* and *M. savini* and by the first occurrence of the genus *Dama*. They can be included in the Ponte Galeria FU and are slightly older than the Isernia FU. The local faunas of Ponte Galeria belonging to the Isernia FU are placed at around 0.6 Ma on the basis of geochronological constraints presented in this paper. This age is in agreement with that of the Isernia LF (Coltorti et al., 2005).
(6) Several large mammal assemblages from the Roman area usually ascribed to Fontana Ranuccio (e.g., Cava Nera Molinario) or Torre in Pietra FUs (e.g., Cava Rinaldi) are re-calibrated and radiometrically dated at around 0.5 Ma. During this period, the first occurrences of *S. hemitoechus*, *C. elaphus eostephanoceros*, and *H. prisca* together with abundant remains of *B. primigenius* are recorded. These biochronological events allow us to predate the beginning of the Fontana Ranuccio FU.
(7) *S. hemitoechus* and *B. primigenius* occur at first in Italy and later were widespread in Europe while the first occurrence of *C. elaphus eostephanoceros* seems to be coeval in both Italy and Central Europe .
(8) The Torre in Pietra and Vitinia FUs represent two different biochronological intervals and can be distinguished on the basis of stratigraphy (different depositional levels) and faunal composition (occurrences of *E. hydruntinus* and *Dama dama* in the Vitinia FU).
(9) The beginning of the Aurelian LMA can be placed in correspondence with the MIS 10–9 transition (around 0.33 Ma), since during this time span occurs the deposition of the Aurelia Formation (Fig. 3), which is correlated with the sedimentary section of Torre del Pagliaccetto, hosting the faunal assemblage of the Aurelia FU (Gliozzi et al., 1997). This period is characterized in Europe by the appearance of the *Mammuthus–Coelodonta* Faunal Complex (Kahlke, 1999; Kahlke and Lacombat, 2008; Kahlke et al., 2011) that occurs in Italy only during the last glaciation (MIS 4) (Petronio et al., 2007; Pandolfi and Tagliacozzo, 2013). Moreover, typical Aurelian taxa such as *C. lupus*, *U. spelaeus,* and *M. giganteus* occur in Italy later (during MIS 9) than in other European localities (during MIS 11). Finally, the dispersal event of *E. hydruntinus* is recorded in Italy only during MIS 8.5–7 (Vitinia FU), spanning 0.29–0.25 Ma, while the species occurs in the rest of Europe during MIS 11.
(10) Villafranchian taxa persist in Italy at least until the second half of the Galerian; they are long-lived in Italy with respect to the rest of Europe. This can be explained by the presence of more favorable climatic conditions, as well as by-o the role of "cul de sac" played by the Italian Peninsula.
(11) The faunal turnover between Villafranchian and Galerian taxa is completed in Italy around 0.5 Ma (proposed lower limit of the

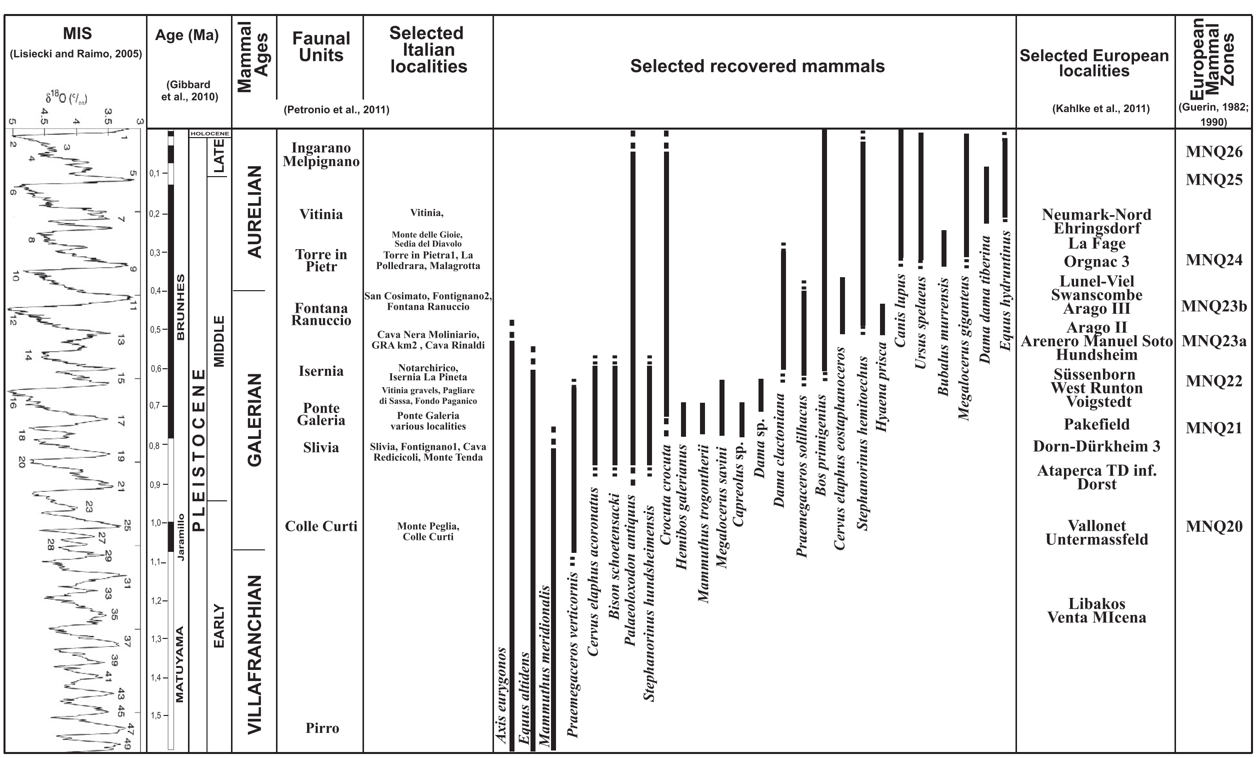

Fig. 7. New biochronological scheme for the Middle Pleistocene of Italy and correlation with selected European localities and the European Mammal Zones (after Guerin, 1982; 1990).

Fontana Ranuccio FU) while the faunal turnover between the Galerian and the Aurelian taxa occurs later in Italy than in Central and Western Europe. Taxa related with temperate-cold (e.g., *P. pannonicus*, *B. schoetensacki*, *U. spelaeus*, *M. giganteus*) or cold (*Mammuthus primigenius*, *Coelodonta antiquitatis*) climate conditions spread in Italy later than in the rest of Europe. This could be explained by the presence of geographic barriers such as the Alps that limited the diffusion of species coming from north-western Asia into the Peninsula. In addition, species related with more temperate-warm climate and coming from Africa via the Middle East or Western Asia (e.g., *B. primigenius*, *S. hemitoechus*) seem to appear at first in the Peninsula.

Probably, the delay or advance in dispersal events of taxa in Italy could be related to the fluctuations of the biomes during the Quaternary and with the geographic position of the Peninsula that is placed in the southern extremity of Europe.

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References

Abbazzi, L., 2004. Remarks on the validity of the generic name *Praemegaceros* Portis 1920, and an overview on *Praemegaceros* species in Italy. 15. Rend. Fis. Acc. Lincei, pp. 115–132.

Adam, K.D., Bloos, G., Ziegler, R., 1995. Steinheim/Murr, N of Stuttgart — locality of *Homo steinheimensis*. In: Schirmer, W. (Ed.), Quaternary Field Trips in Central EuropeField Trips on Special Topics. vol. 2. Verlag Dr. Friedrich Pfeil, München, pp. 726–728.

Alonso-Garcia, M., Sierro, F.J., Kucera, M., Flores, J.A., Cacho, I., Andersen, N., 2011. Ocean circulation, ice sheet growth and inter-hemispheric coupling of millennial climate variability during the mid-Pleistocene (ca 800–400 ka). Quat. Sci. Rev. 30, 3234–3247.

Álvarez-Lao, D.J., de Arsuaga, J.L., Baquedano, E., Pérez-González, A., 2013. Last Interglacial (MIS 5) ungulate assemblage from the Central Iberian Peninsula: the Camino Cave (Pinilla del Valle, Madrid, Spain). Palaeogeogr. Palaeoclimatol. Palaeoecol. 374, 327–337.

Ambrosetti, P., 1965. Segnalazione di una fauna con *Elephas antiquus* rinvenuta nella zona di Ponte Galeria (Roma). Boll. Soc. Geol. Ital. 84, 15–22.

Ambrosetti, P., 1967. Cromerian fauna of the Rome area. Quaternaria 9, 267–283.

Ambrosetti, P., Bonadonna, F.P., 1967. Revisione dei dati sul Plio-Pleistocene di Roma. Atti Soc. Gioenia Sc. Nat. Catania 18, 33–72.

Ambrosetti, P., Azzaroli, A., Bonadonna, F.P., Follieri, M., 1972. A scheme of Pleistocene chronology for the Tyrrhenian side of central Italy. Boll. Soc. Geol. Ital. 91, 169–184.

Ambrosetti, P., Bartolomei, G., De Giuli, C., Ficcarelli, G., Torre, D., 1979. La breccia ossifera di Slivia (Aurisina-Sistiana) nel Carso di Trieste. Boll. Soc. Paleontol. Ital. 18, 207–220.

Anzidei, A.P., Arnoldus-Huyzendveld, A., Palombo, M.R., 2001. La Polledrara di Cecanibbio site. In: Sardella, R. (Ed.), Galerian and Aurelian Fossiliferous Localities in the Rome Area. EUROMAM 2001, Firenze, Perugia, Roma, pp. 30–35.

Anzidei, A.P., Bulgarelli, G.M., Catalano, P., Cerilli, E., Gallotti, R., Lemorini, C., Milli, S., Palombo, M.R., Pantano, W., Santucci, E., 2012. Ongoing research at the Late Middle Pleistocene site of La Polledrara di Cecanibbio (Central Italy), with emphasis on human-elephant relationships. Quat. Int. 255, 171–187.

Azzaroli, A., 1953. The deer of Weybourn Crag and forest bed of Norfolk. Bull. Brit. Mus. Nat. Hist. Geol. 2, 1–96.

Azzaroli, A., 1979. Critical remarks on some giant deer (genus *Megaceros* Owen) from the Pleistocene of Europe. Palaeontogr. Ital. 71, 5–16.

Azzaroli, A., De Giuli, C., Ficcarelli, G., Torre, D., 1982. Table of the stratigraphic distribution of terrestrial mammalian faunas in Italy from the Pliocene to the early middle Pleistocene. Geogr. Fis. Dinam. Quat. 5, 55–58.

Azzaroli, A., De Giuli, C., Ficcarelli, G., Torre, D., 1988. Late Pliocene to early Mid-Pleistocene mammals in Eurasia: faunal succession and dispersal events. Palaeogeogr. Palaeoclimatol. Palaeoecol. 66, 77–100.

Bard, B., Hamelin, E., Fairbanks, R., 1990. U–Th ages obtained by mass spectrometry in corals from Barbados: sea level during the past 130,000 years. Nature 346, 456–458.

Bedetti, C., 2003. Le avifaune fossili del Plio-Pleistocene italiano: sistematica, paleoecologia ed elementi di biocronologia(PhD Diss.) Univ. Roma, Italy.

Berckhemer, F., 1927. *Buffelus murrensis* n. sp. Ein diluvialer Buffelschadel von Steinheim a. d. Murr. Jahresh. Ver. Naturk. Wurttemb. 83, 146–158.

Berger, W.H., Jansen, E., 1994. Mid-Pleistocene climate shift: the Nansen connection. In: Johannessen, et al. (Eds.), The Polar Oceans and Their Role in Shaping the Global Environment. AGU Geophysical Monograph. 85, pp. 295–311.

Bertini, A., 2000. Pollen record from Colle Curti and Cesi: Early and Middle Pleistocene mammal sites in the Umbro and Marchean Apennine Mountains (Central Italy). J. Quat. Sci. 15, 825–840.

Bertini, A., 2010. Pliocene to Pleistocene palynoflora and vegetation in Italy: state of the art. Quat. Int. 225, 5–24.

Blanc, A.C., 1939. Il giacimento musteriano di Saccopastore nel quadro del Pleistocene Laziale. Riv. Antropol. 32, 223–234.

Blanc, A.C., 1948. Notizie sui ritrovamenti e sul giacimento di Saccopastore e sulla sua posizione nel Pleistocene laziale. Palaeontogr. Ital. 47, 3–23.

Blanc, A.C., 1955. Ricerche sul Quaternario Laziale, III. Avifauna artica, crioturbazioni e testimonianze di soliflussi nel Pleistocene medio-superiore di Roma e di Torre in Pietra. Il periodo glaciale Nomentano, nel quadro della serie di glaciazioni riconosciute nel Lazio. Quaternaria 2, 187–200.

Blanc, G.A., Tongiorgi, E., Trevisan, L., 1951. Giacimento di fauna ad ippopotamo nel Quaternario antico della Maglianella presso Roma. Soc. Ital. Progr Sc. XLII Riun, Roma.

Blanc, A.C., Lona, F., Settepassi, F., 1955. Ricerche sul Quaternario Laziale, I. Una torba ad *Abies*, malacofauna montana e criosedimenti nel Pleistocene inferiore di Roma. Il periodo glaciale Cassio. Quaternaria 2, 151–158.

Bonadonna, F.P., 1965. Resti di *Hippopotamus amphibius* Linné nei sedimenti del Pleistocene medio-inferiore della Via Portuense (Roma). Boll. Soc. Geol. Ital. 84, 21–37.

Bonifay, M.F., 1971. Carnivores quaternaires du Sud-Est de la France. Mem. Mus. Hist. Nat. Paris 21, 1–377.

Bonifay, M.F., 1981. Les *Praemegaceros* du Pléistocène moyen de la grotte de l'Escale à Saint-Estève-Janson (Bouches-du-Rhône). Leur intérêt dans le contexte biostratigraphique européen. Bull. Ass. Fr Étude Quaternaire 3, 109–120.

Bonifay, M.F., 1991. *Equus hydruntinus* Regalia *minor* n.ssp. from the caves of Lunel-Viel (Herault, France). In: Meadow, R.H., Uerpmann, H.P. (Eds.), Equids in the ancient world. vol. II. L.R. Verlag, Wiesbaden, pp. 178–216.

Bordoni, P., Valensise, G., 1998. Deformation of the 125 ka marine terrace in Italy: tectonic implications. In: Stewart, I.S. (Ed.), Coastal Tectonics. Geol. Soc. Spec. Pub. 146, pp. 71–110.

Boudadi-Maligne, M., 2010. Les *Canis* pléistocènes du Sud de la France : approche biosystématique, évolutive et biochronologique(Thèse de Doctorat) Université Bordeaux 1.

Burke, A., Eisenmann, V., Ambler, G., 2003. The systematic position of *Equus hydruntinus*, an extinct species of Pleistocene equid. Quat. Res. 59, 459–469.

Caloi, L., Palombo, M.R., 1978. Anfibi, rettili e mammiferi di Torre del Pagliaccetto (Torre in Pietra, Roma). In: Malatesta, A. (Ed.), Torre in Pietra, Roma. Quaternaria. 20, pp. 315–428.

Caloi, L., Palombo, M.R., 1980a. *Megaceros savini* e *Megaceros* cf. *verticornis* (Cervidae) del Pleistocene medio-inferiore di Ponte Galeria (Roma). Geol. Romana 19, 121–130.

Caloi, L., Palombo, M.R., 1980b. Resti di mammiferi del Pleistocene medio di Malagrotta (Roma). Boll. Serv. Geol. Ital. 100, 141–188.

Caloi, L., Palombo, M.R., 1986. Resti di mammiferi in livelli del Pleistocene medio inferiore affioranti al Km 2 del G.R.A. (Roma). Boll. Serv. Geol. Ital. 104, 141–156.

Caloi, L., Palombo, M.R., 1988. Le mammalofaune plio-pleistoceniche dell'area laziale: problemi biostratigrafici ed implicazioni paleoclimatiche. Mem. Soc. Geol. Ital. 35, 99–126.

Caloi, L., Palombo, M.R., 1990. Osservazioni sugli equidi italiani del Pleistocene medio inferiore. Geol. Romana 26, 187–221.

Caloi, L., Palombo, M.R., 1995. Biostratigrafia e Paleoecologia delle mammalofaune del Pleistocene medio dell'Italia Centrale. Stud. Geol. Camerti B 503–514.

Caloi, L., Palombo, M.R., Petronio, C., 1979. Cenni preliminari sulla fauna di Cava Redicicoli (Roma). Boll. Serv. Geol. Ital. 100, 189–198.

Caloi, L., Palombo, M.R., Petronio, C., 1980a. Resti cranici di *Hippopotamus antiquus* (= *H. major*) e *Hippopotamus amphibius* conservati nel Museo di Paleontologia dell'Università di Roma. Geol. Romana 19, 91–119.

Caloi, L., Palombo, M.R., Petronio, C., 1980b. Le principali mammalofaune del Pleistocene della Campagna Romana. Paleont. Str. Evol. 1, 73–79.

Caloi, L., Palombo, M.R., Petronio, C., 1980c. La fauna quaternaria di Sedia del Diavolo (Roma). Quaternaria 22, 177–209.

Caloi, L., Cuggiani, M.C., Palmarelli, A., Palombo, M.R., 1981. La fauna a Vertebrati del Pleistocene medio e superiore di Vitinia (Roma). Boll. Serv. Geol. Ital. 102, 41–76.

Caloi, L., Palombo, M.R., Zarlenga, F., 1998. Late Middle Pleistocene mammals faunas of Latium. Stratigraphy and environment. Quat. Int. 47/48, 77–86.

Capasso Barbato, L., Petronio, C., 1981. La mammalofauna pleistocenica di Castel di Guido (Roma). Boll. Serv. Geol. Ital. 102, 95–108.

Capasso Barbato, L., Petronio, C., 1983. Nuovi resti di mammiferi del Pleistocene medio-inferiore di Ponte Galeria (Roma). Boll. Serv. Geol. Ital. 104, 157–176.

Capasso Barbato, L., Palmarelli, A., Petronio, C., 1983. La mammalofauna pleistocenica di Cerveteri (Roma). Boll. Serv. Geol. Ital. 102, 77–94.

Cassoli, P.F., Segre Naldini, E., 1993. Le faune di Costa S. Giacomo e Fontana Ranuccio. In: Gatti, S. (Ed.), Dives Anagnia. Archeologia nella Valle del Sacco, L'Erma, Roma, pp. 30–38.

Cassoli, P.F., Di Stefano, G., Tagliacozzo, A., 1999. I vertebrati dei livelli superiori (A e Alfa) della serie stratigrafica di Notarchirico. In: Piperno, M. (Ed.), Notarchirico. Un sito del Pleistocene medio-iniziale nel bacino di Venosa (Basilicata). Osanna, Venosa. I, pp. 361–438.

Cavinato, G.P., Petronio, C., Sardella, R., 2001. The Mercure River Basin (Southern Italy): Quaternary stratigraphy and large mammal biochronology. The world of elephants, Proceedings of the 1st International Congress, Rome, pp. 187–190.

Chaline, J., 1972. Les rongeur du Pléistocène moyen et supérieur de France. Cah. Paléontol. 1–410 (Editions du CNRS).

Channell, J.E.T., Hodell, D.A., Singer, B.S., Xuan, C., 2010. Reconciling astrochronological and $^{40}Ar/^{39}Ar$ ages for the Matuyama–Burunhes boundary and late Matuyama Chron. Geochem. Geophys. Geosyst. 11, Q0AA12. http://dx.doi.org/10.1029/2010GC003203.

Cherin, M., Bizzarri, R., Buratti, N., Caponi, T., Grossi, F., Kotsakis, T., Pandolfi, L., Pazzaglia, F., Barchi, M.R., 2012. Multidisciplinary study of a new Quaternary mammal-bearing site from Ellera di Corciano (central Umbria, Italy): preliminary data. Rend. Soc. Geol. Ital. 21, 1075–1077.

Coltorti, M., Cremaschi, M., Delitala, M.C., Esu, D., Fornaseri, M., McPherron, A., Nicoletti, M., Otterloo, R. Van, Peretto, C., Sala, B., Schmidt, V., Sevink, J., 1982. Reversed magnetic polarity at an early Lower Palaeolithic site in Central Italy. Nature 300, 173–176.

Coltorti, M., Albianelli, A., Bertini, A., Ficcarelli, G., Laurenzi, M.A., Napoleone, G., Torre, D., 1998. The Colle Curti mammal site in the Colfiorito area (Umbria-Marchean Apennine, Italy): geomorphology, stratigraphy, paleomagnetism and palynology. Quat. Int. 47/48, 107–116.

Coltorti, M., Feraud, G., Marzoli, A., Peretto, C., Ton-That, Y., Voinchet, P., Bahain, J.J., Minelli, A., Thun Hohenstein, U., 2005. New $^{40}Ar/^{39}Ar$, stratigraphic and palaeoclimatic data on the Isernia La Pineta Lower Palaeolithic site, Molise, Italy. Quat. Int. 131, 11–22.

Coltorti, M., Boraso, R., Mantovani, F., Morsilli, M., Fiorentini, G., Riva, A., Rusciadelli, G., Tassinari, R., Tomei, C., Di Carlo, G., Chubakov, V., 2011. U and Th content in the Central Apennines continental crust: a contribution to the determination of the geo-neutrinos flux at LNGS. Geochim. Cosmochim. Acta 75, 2271–2294.

Conato, V., Esu, D., Malatesta, A., Zarlenga, F., 1980. New data on Pleistocene of Rome. Quaternaria 22, 131–176.

Conti, N., Petronio, C., Salari, L., 2010. The equids of the Late Pleistocene of "Tana delle Iene" (Ceglie Messapica, Brindisi, Southern Italy). Boll. Soc. Paleontol. Ital. 49, 227–236.

Conticelli, S., Peccerillo, A., 1992. Petrology and geochemistry of potassic and ultrapotassic volcanism in central Italy: petrogenesis and inferences on the evolution of the mantle source. Lithos 28, 221–240.

Croitor, R., 2006a. Early Pleistocene small-sized deer of Europe. Hell. J. Geosci. 41, 89–117.

Croitor, R., 2006b. Taxonomy and systematics of large-sized deer of the genus *Praemegaceros*Portis, 1920 (Cervidae, Mammalia). Cour. Forsch.-Inst. Senckenberg 256, 91–116.

Croitor, R., Brugal, J.P., 2007. New insights concerning Early Pleistocene cervids and bovids in Europe: dispersal and correlation. In: Kahlke, R.D., Maul, L.C., Mazza, P.P.A. (Eds.), Late Neogene and Quaternary Biodiversity and Evolution: Regional Developments and Interregional Correlations, Vol. II. Courier Forsch.-Institut Senckenberg. 256, pp. 91–116.

Croitor, R., Kostopoulos, D.S., 2004. On the systematic position of the large-sized deer from Apollonia, Early Pleistocene, Greece. Paläontol. Z. 78, 137–159.

Crundwell, M., Scott, G., Naish, T., Carter, L., 2008. Glacial–interglacial ocean climate variability from planktonic foraminifera during the Mid-Pleistocene transition in the temperate Southwest Pacific, ODP Site 1123. Palaeogeogr. Palaeoclimatol. Palaeoecol. 260, 202–229.

De Lumley, H., Kahlke, H.D., Moigne, A.M., Moullé, P.E., 1988. Les faunes de grands mammifères de la grotte du Vallonnet Roquebrune-Cap-Martin, Alpes-Maritimes. Anthropologie 92, 465–496.

Di Stefano, G., Petronio, C., 1993. A new *Cervus elaphus* of Middle Pleistocene age. N. Jb. Geol. Paläont. (Abh.) 190, 1–18.

Di Stefano, G., Petronio, C., 1997. Origin and evolution of the European fallow deer (*Dama*, Pleistocene). N. Jb. Geol. Paläont. (Abh.) 203, 57–75.

Di Stefano, G., Petronio, C., Sardella, R., 1995. The Villafranchian faunas from the Tiber River Basin. Il. Quaternario 8, 509–514.

Di Stefano, G., Petronio, C., Sardella, R., 1998. Biochronology of the Pleistocene mammal faunas from Rome urban area. Il Quaternario 11, 191–199.

Ferranti, L., Antonioli, F., Mauzc, B., Amorosi, A., Dai Pra, G., Mastronuzzi, G., Monaco, C., Orrù, P., Pappalardo, M., Radtke, U., Renda, P., Romano, P., Sansò, P., Verrubbi, V., 2006. Markers of the last interglacial sea-level high stand along the coast of Italy: tectonic implications. Quat. Int. 145/146, 30–54.

Ficcarelli, G., Mazza, P., 1990. New fossil foundings from the Colfiorito basin (Umbro-Marchean Apennine). Boll. Soc. Paleontol. Ital. 29, 245–247.

Florindo, F., Karner, D.B., Marra, F., Renne, P.R., Roberts, A.P., Weaver, R., 2007. Radioisotopic age constraints for Glacial Terminations IX and VII from aggradational sections of the Tiber River delta in Rome, Italy. Earth Planet. Sci. Lett. 256, 61–80.

Follieri, M., Magri, D., Sadori, L., 1988. 250,000-year pollen record from Valle di Castiglione (Roma). Pollen Spores 30, 329–356.

Franzen, J.L., von Koenigswald, W., 1979. Erste Funde vom Wasser-büffel (*Bubalus murrensis*) aus pleistozänen Schottern des nördlichen Oberrhein–Grabens. Senckenb. Lethaea 60, 253–263.

Franzen, J.L., Gliozzi, E., Jellinek, T., Scholger, R., Weidenfeller, M., 2000. Die spätaltpleistozäne Fossillagerstätte Dorn-Dürkheim 3 und ihre Bedeutung für die Rekonstruktion der Entwicklung des rheinischen Flußsystems. Senckenb. Lethaea 80, 305–353.

Geraads, D., 1986. Les ruminants du Pléistocène d'Oubeidiyeh (Israel). In: Tchernov, E. (Ed.), Les Mammifères du Pléistocène inférieur de la vallée du Jourdain a Oubeidiyeh. Mém. et Trav. du Centre de Recherche Française de Jérusalem. 5, pp. 143–181.

Gibbard, P.L., Head, M.J., Walker, M.J.C., The Subcommission on Quaternary Stratigraphy, 2010. Formal ratification of the Quaternary System/Period and the Pleistocene Series/Epoch with a base at 2.58 Ma. J. Quat. Sci. 25, 96–102.

Gliozzi, E., Abbazzi, L., Ambrosetti, P.G., Argenti, P., Azzaroli, A., Caloi, L., Capasso Barbato, L., Di Stefano, G., Ficcarelli, G., Kotsakis, T., Masini, F., Mazza, P., Mezzabotta, C., Palombo, M.R., Petronio, C., Rook, L., Sala, B., Sardella, R., Zanalda, E., Torre, D., 1997. Biochronology of selected mammals, molluscs and ostracods from the Middle Pliocene to the Late Pleistocene in Italy. The state of the art. Riv. Ital. Paleontol. Stratigr. 103, 369–388.

Grant, K.M., Rohling, E.J., Bronk Ramsey, C., Cheng, H., Edwards, R.L., Florindo, F., Heslop, D., Marra, F., Roberts, A.P., Tamisiea, M.E., Williams, F., 2014. Sea-level variability over five glacial cycles. Nat. Commun. (in press).

Guérin, C., 1982. Première biozonation du Pléistocène européen, principal résultat biostratigraphique de l'étude des Rhinocerotidae (Mammalia, Perissodactyla) du Miocène terminal au pléistocène supérieur de l'Europe occidentale. Geobios 15 (4), 593–598.

Guérin, C., 1990. Biozones or mammal units? Methods and limits in biochronology. In: Lindsay, E.H., Fahlbush, V., Mein, P. (Eds.), European Neogene Mammal Chronology. Plenum Press, New York, pp. 119–130.

Guérin, C., Dewolf, Y., Lautridou, J.P., 2003. Révision d'un site paléontologique célèbre: Saint-Prest (Chartres, France). Geobios 36, 55–82.

Head, M.J., Gibbard, P.L., 2005. Early–Middle Pleistocene transitions: an overview and recommendation for the defining boundary. In: Head, M.J., Gibbard, P.L. (Eds.), Early–Middle Pleistocene Transitions: The Land–Ocean Evidence. Geological Society of London, Special Publication. 247, pp. 1–18.

Hearty, P.J., Dai-Pra, G., 1986. Aminostratigraphy of Quaternary marine deposits in the Lazio region of central Italy. In: Ozer, A., Vita-Finzi, C. (Eds.), Dating Mediterranean Shorelines. Zeitschrift fuer Geomorphologie, Supplementband. 62, pp. 131–140.

Joannin, S., Bassinot, F., Nebout, N.C., Peyron, O., Beaudouin, C., 2011. Vegetation response to obliquity and precession forcing during the Mid-Pleistocene transition in Western Mediterranean region (ODP site 976). Quat. Sci. Rev. 30, 280–297.

Kahlke, H.D., 1956. Die Cerviden reste aus den Altpleistozanen Ilmkiesen von Sussenborn bei Weimar. Akad.Verlag, Berlin.

Kahlke, H.D., 1965. Die Cerviden-Reste aus den Tonen von Voigstedt in Thüringen. Paläont. Abh. Abt. A. 2, 381–426.

Kahlke, H.D., 1969. Die Cerviden-Reste aus den Kiesen von Sussenborn bei Weimar. Paläont. Abh. Abt. A. 3, 547–609.

Kahlke, H.D., 1997. Die Cerviden-Reste aus dem Unterpleistozän von Untermassfeld. In: Kahlke, R.D. (Ed.), Das Pleistozän von Untermassfeld bei Meiningen (Thürngen) Teil 1. Monographien des Römisch-Germanischen Zentralmuseums Mainz. 40, pp. 181–275.

Kahlke, R.D., 1999. The History of the Origin, Evolution and Dispersal of the Late Pleistocene Mammuthus–Coelodonta Faunal Complex in Eurasia (Large Mammals). Fenske Companies, Rapid City.

Kahlke, H.D., 2001. Neufunde von Cerviden-Reste aus dem Unterpleistozän von Untermassfeld. In: Kahlke, R.D. (Ed.), Das Pleistozän von Untermassfeld bei Meiningen (Thürngen) Teil 2. Monographien des Römisch-Germanischen Zentralmuseums Mainz. 40, pp. 461–482.

Kahlke, R.D., Lacombat, F., 2008. The earliest immigration of woolly rhinoceros (*Coelodonta lologoijensis*, Rhinocerotidae, Mammalia) into Europe and its adaptative evolution in Palaearctic cold stage mammal faunas. Quat. Sci. Rev. 27, 1951–1961.

Kahlke, R.D., Garcia, N., Kostopoulos, D.S., Lacombat, F., Lister, A.M., Mazza, P., Spassov, N., Titov, V.V., 2011. Western Palaearctic palaeoenvironmental conditions during the Early and early Middle Pleistocene inferred from large mammal communities, and implications for hominin dispersal in Europe. Quat. Sci. Rev. 30 (11–12), 1368–1395.

Karner, D.B., Marra, F., 1998. Correlation of fluviodeltaic aggradational sections with glacial climate history: a revision of the classical Pleistocene stratigraphy of Rome. Geol. Soc. Am. Bull. 110, 748–758.

Karner, D.B., Renne, P.R., 1998. $^{40}Ar/^{39}Ar$ geochronology of Roman volcanic province tephra in the Tiber River valley: age calibration of Middle Pleistocene sea-level changes. Geol. Soc. Am. Bull. 110, 740–747.

Karner, D.B., Marra, F., Renne, P.R., 2001a. The history of the Monti Sabatini and Alban Hills volcanoes: groundwork for assessing volcanic–tectonic hazards for Rome. J. Volcanol. Geoth. Res. 107, 185–215.

Karner, D.B., Marra, F., Florindo, F., Boschi, E., 2001b. Pulsed uplift estimated from terrace elevations in the coast of Rome: evidence for a new phase of volcanic activity? Earth Planet. Sci. Lett. 188, 135–148.

Kotsakis, T., Barisone, G., 2008. I vertebrati fossili continentali del Plio-Pleistocene dell'area romana. In: Funiciello, R., Praturlon, A., Giordano, G. (Eds.), La Geologia di Roma. Mem. Descr. Carta Geol. d'Italia. 80, pp. 115–143.

Kotsakis, T., Esu, D., Girotti, O., 1992. A post-Villafranchian cold event in Central Italy testified by continental molluscs and rodents. Boll. Soc. Geol. Ital. 111, 335–340.

Kotsakis, T., Abbazzi, L., Angelone, C., Argenti, P., Barisone, G., Fanfani, F., Marcolini, F., Masini, F., 2003. Plio-Pleistocene biogeography of Italian mainland micromammals. Deinsea 10, 313–342.

Kowalski, K., 1995. Lemmings (Mammalia, Rodentia) as indicator of temperature and humidity in the European Quaternary. Acta Zool. Cracov. 38, 85–94.

Kowalski, K., 2001. Pleistocene rodents of Europe. Folia Quaternaria 72, 3–389.

Kuiper, K.F., Deino, A., Hilgen, F.J., Krijgsman, W., Renne, P.R., Wijbrans, J.R., 2008. Synchronizing rock clocks of Earth history. Science 320, 500–505.

Lefèvre, D., Raynal, J.P., Vernet, G., Kieffer, G., Piperno, M., 2010. Tephro-stratigraphy and the age of ancient southern Italian Acheulean settlements: the sites of Loreto and Notarchirico (Venosa, Basilicata, Italy). Quat. Int. 223, 360–368.

Leroy, S.A.G., 2007. Progress in palynology of the Gelasian–Calabrian Stages in Europe: ten messages. Rev. Micropaleontol. 50, 293–308.

Leroy, S.A.G., Arpe, K., Mikolajewicz, U., 2011. Vegetation context and climatic limits of the Early Pleistocene hominin dispersal in Europe. Quat. Sci. Rev. 30, 1448–1463.

Lisiecki, L.E., Raymo, M.E., 2005. A Pliocene–Pleistocene stack of 57 globally distributed benthic δ18O record. Paleoceanography 20. http://dx.doi.org/10.1029/2004PA001071 (PA 1003).

Lister, A.M., Sher, A.V., 2001. The origin and evolution of the woolly mammoth. Science 294, 1094–1097.

Lister, A.M., Stuart, A.J., 2010. The West Runton mammoth (*Mammuthus trogontherii*) and its evolutionary significance. Quat. Int. 228, 180–209.

Lister, A.M., Sher, A.V., Essen, H., van Wei, G., 2005. The pattern and process of mammoth evolution in Eurasia. Quat. Int. 126/128, 49–64.

Lister, A.M., Parfitt, S.A., Owen, F.J., Collinge, S., Breda, M., 2010. Metric analysis of ungulate mammals in the early Middle Pleistocene of Britain, in relation to taxonomy and biostratigraphy. II: Cervidae, Equidae and Suidae. Quat. Int. 228, 157–179.

Maasch, K.A., 1988. Statistical detection of the mid-Pleistocene transition. Clim. Dyn. 2, 133–143.

Made, J. van der, 1998. A preliminary note on the cervids from Bilzingsleben. Praehistoria Thuringica 2, 108–122.

Made, J. van der, 2011. Biogeography and climatic change as a context to human dispersal out of Africa and within Eurasia. In: Carrion, J.S., Rose, J., Stringer, C. (Eds.), Ecological Scenarios for Human Evolution During the Early and Middle Pleistocene in the Western Palearctic. Quat. Sci. Rev. 30, pp. 1353–1367

Made, J. van der, Tong, H.W., 2008. Phylogeny of the giant deer with palmate brow tines *Megaloceros* from west and *Sinomegaceros* from east Eurasia. Quat. Int. 179, 135–162.

Made, J. van der, Aguirre, E., Bastir, M., Fernández Jalvo, Y., Huguet, R., Laplana, C., Márquez, B., Martínez, C., Martinón, M., Rosas, A., Rodríguez, J., Sánchez, A., Sarmiento, S., Bermúdez de Castro, J.M., 2003. El registro paleontológico y arqueológico de los yacimientos de la Trinchera del Ferrocarril en la Sierra de Atapuerca. Coloquios de Paleontología 1, 345–372.

Madurell-Malapeira, J., Minwer-Barakat, R., Alba, D.M., Garces, M., Gomez, M., Aurell-Garrido, J., Ros-Montoya, S., Moya-Sola, S., Berastegui, X., 2010. The Vallparadís section (Terrassa, Iberian Peninsula) and the latest Villafranchian faunas of Europe. Quat. Sci. Rev. 29, 3972–3982.

Magri, D., 1999. Late-Quaternary vegetation history at Lagaccione near Lago di Bolsena (central Italy). Rev. Palaeobot. Palynol. 106, 171–208.

Magri, D., Palombo, M.R., 2013. Early to Middle Pleistocene dynamics of plant and mammal communities in South West Europe. Quat. Int. 288, 63–72.

Malatesta, A., 1978. La serie di Torre in Pietra nel quadro del Pleistocene Romano. In: Malatesta, A. (Ed.), Torre in Pietra, Roma. Quaternaria. 20, pp. 537–577.

Mancini, M., Bellucci, L., Petronio, C., 2008. Il Pleistocene inferiore e medio di Nettuno (Lazio) stratigrafia e mammalofauna. Geol. Romana 41, 71–85.

Mancini, M., Cavuoto, G., Pandolfi, L., Petronio, C., Salari, L., Sardella, R., 2012. Coupling basin infill history and mammal biochronology in a Pleistocene intramontane basin: the case of western L'Aquila Basin (central Apennines, Italy). Quat. Int. 267, 62–77.

Manni, R., Margottini, S., Palombo, M.R., Palladino, D.M., Zarattini, A., 2000. Scavo e recupero di resti di *Elephas* (*Palaeoloxodon*) *antiquus* Falconer & Cautley nei pressi di Palombara Sabina (Roma). Atti 2° Conv. Naz. Archeozoologia. Abaco, Forlì, pp. 99–106.

Marino, M., Maiorano, P., Lirer, F., 2008. Changes in calcareous nannofossil assemblages during the Mid-Pleistocene Revolution. Mar. Micropaleontol. 69, 70–90.

Markova, A.K., 1998. Early Pleistocene small mammal faunas of Eastern Europe. 60. Mededelingen Nederlands Institut voor Toegepaste Geowetenschappen, TNO, pp. 313–326.

Marra, F., 1993. Stratigrafia ed assetto geologico-strutturale dell'area romana compresa tra il Tevere ed il Rio Galeria. Geol. Romana 29, 515–535.

Marra, F., 2004. Commento a: Giordano G., Esposito A., De Rita D., Fabbri M., Mazzini I., Trigari A., Rosa C., Funiciello R., 2003 — The sedimentation along the Roman coast between Middle and Upper Pleistocene: the interplay of eustatism, tectonics and volcanism — new data and review. Il Quaternario 16 (1bis), 121–129 Il Quaternario, 17, 2/2, 643–645.

Marra, F., Florindo, F., 2014. The subsurface geology of Rome: sedimentary processes, sea-level changes and astronomical forcing. Earth Sci. Rev. http://dx.doi.org/10.1016/j.earscirev.2014.05.001.

Marra, F., Rosa, C., 1995. Stratigrafia e assetto geologico dell'area romana. Mem. Descr. Carta Geol. d'Italia 50, 49–118.

Marra, F., Florindo, F., Karner, D.B., 1998. Paleomagnetism and geochronology of early Middle Pleistocene depositional sequences near Rome: comparison with the deep sea δ^{18}O climate record. Earth Planet. Sci. Lett. 159, 147–164.

Marra, F., Freda, C., Scarlato, P., Taddeucci, J., Karner, D.B., Renne, P.R., Gaeta, M., Palladino, D.M., Trigila, R., Cavarretta, G., 2003. Post-caldera activity in the Alban Hills Volcanic District (Italy): ^{40}Ar/^{39}Ar geochronology and insights into magma evolution. Bull. Volcanol. 65, 227–247.

Marra, F., Taddeucci, J., Freda, C., Marzocchi, W., Scarlato, P., 2004. Recurrence of volcanic activity along the Roman Comagmatic Province (Tyrrhenian margin of Italy) and its tectonic significance. Tectonics 23, TC4013. http://dx.doi.org/10.1029/2003TC001600, 2004.

Marra, F., Florindo, F., Boschi, E., 2008. The history of glacial terminations from the Tiber River (Rome): insights to glacial forcing mechanisms. Paleoceanography 23, PA2205. http://dx.doi.org/10.1029/2007PA001543.

Marra, F., Karner, D.B., Freda, C., Gaeta, M., Renne, P.R., 2009. Large mafic eruptions at the Alban Hills Volcanic District (Central Italy): chronostratigraphy, petrography and eruptive behavior. J. Volcanol. Geoth. Res. 179, 217–232. http://dx.doi.org/10.1016/j.jvolgeores.2008.11.009.

Marra, F., Bozzano, F., Cinti, F.R., 2013. Chronostratigraphic and lithologic features of the Tiber River sediments (Rome, Italy): implications on the Post-glacial sea-level rise and Holocene climate. Glob. Planet. Chang. http://dx.doi.org/10.1016/j.gloplacha.2013.05.002 (in print).

Marra, F., Sottili, G., Gaeta, M., Giaccio, B., Jicha, B., Masotta, M., Palladino, D.M., Deocampo, D., 2014. Major explosive activity in the Sabatini Volcanic District (central Italy) over the 800–390 ka interval: geochronological–geochemical overview and tephrostratigraphic implications. Quat. Sci. Rev. http://dx.doi.org/10.1016/j.quascirev.2014.04.010.

Martinez-Navarro, B., Palombo, M.R., 2004. Occurrence of the Indian genus *Hemibos* (Bovini, Bovidae, Mammalia) at the Early–Middle Pleistocene transition in Italy. Quat. Res. 61, 314–317.

Martinez-Navarro, B., Palombo, M.R., 2007. The horn-core of *Hemibos galerianus* from Ponte Milvio, Rome (Italy). Riv. Ital. Paleontol. Stratigr. 113, 531–534.

Martínez-Navarro, B., Rabinovich, R., 2011. The fossil Bovidae (Artiodactyla, Mammalia) from Gesher Benot Ya'aqov, Israel: out of Africa during the Early–Middle Pleistocene transition. J. Hum. Evol. 60, 375–386.

Martínez-Navarro, B., Pérez-Claros, J.A., Palombo, M.R., Rook, L., Palmqvist, P., 2007. The Olduvai buffalo *Pelorovis* and the origin of *Bos*. Quat. Res. 68, 220–226.

Martínez-Navarro, B., Belmaker, M., Bar-Yosef, O., 2009. The large carnivores from 'Ubeidiya' (early Pleistocene, Israel): biochronological and biogeographical implications. J. Hum. Evol. 56, 514–524.

Martínez-Navarro, B., Rook, L., Papini, M., Libsekal, Y., 2010. A new species of bull from the Early Pleistocene paleoanthropological site of Buia (Eritrea): parallelism on the dispersal of the genus *Bos* and the Acheulian culture. Quat. Int. 212, 169–175.

Martínez-Navarro, B., Ros-Montoya, S., Espigares, M.P., Palmqvist, P., 2011. Presence of the Asian Bovini *Hemibos* sp. aff. *H. Gracilis* and *Bison* sp. in the early Pleistocene site of Venta Micena (Orce, southern Spain). Quat. Int. 243, 54–60.

Masini, F., Giannini, T., Abbazzi, L., Fanfani, F., Delfino, M., Maul, L.C., Torre, D., 2005. A Latest Biharian small vertebrate fauna from the lacustrine succession of San Lorenzo (Santarcangelo basin, Basilicata, Italy). Quat. Int. 131, 79–94.

Maul, L., Markova, A., 2007. Similarity and regional differences in Quaternary arvicolid evolution in Central and Eastern Europe. Quat. Int. 160, 81–99.

Maul, L., Rekovets, L., Heinrich, W.-D., Keller, T., Storch, G., 2000. *Arvicola mosbachensis* (Schmidtgen 1911) of Mosbach 2: a basic sample for the early evolution of the genus and a reference for further biostratigraphical studies. Senckenb. Lethaea 80, 129–147.

McClymont, E.L., Sosdian, S.M., Rosell-Melé, A., Rosenthal, Y., 2013. Pleistocene sea-surface temperature evolution: early cooling, delayed glacial intensification, and implications for the mid-Pleistocene climate transition. Earth Sci. Rev. 123, 173–193.

Mildenhall, D.C., Hollis, C.J., Naish, T.M., 2004. Orbitally influenced vegetation record of the Mid-Pleistocene climate transition, offshore eastern New Zealand (ODP Site 1123, Leg 181). Mar. Geol. 205, 87–111.

Milli, S., 1997. Depositional setting and high-frequency sequence stratigraphy of the Middle–Upper Pleistocene to Holocene deposits of the Roman Basin. Geol. Romana 33, 99–136.

Milli, S., Palombo, M.R., 2005. The high-resolution sequence stratigraphy and the mammal fossil record: a test in the Middle-Upper Pleistocene deposits of the Roman Basin (Latium, Italy). Quat. Int. 126/128, 251–270.

Milli, S., Palombo, M.R., Petronio, C., Sardella, R., 2004. The Middle Pleistocene deposits of the Roman Basin (Latium, Italy). An integral approach of Mammal Biochronology and sequence Stratigraphy. Riv. Ital. Paleontol. Stratigr. 110, 559–565.

Milli, S., Moscatelli, M., Palombo, M.R., Parlagreco, L., Paciucci, M., 2008. Incised valleys, their filling and mammal fossil record. A case study from Middle–Upper Pleistocene deposits of the Roman Basin (Latium, Italy). In: Amorosi, A., Haq, B.U., Sabato, L. (Eds.), Advances in Application of Sequence Stratigraphy in Italy. GeoActa, Special Publication. 1, pp. 667–687.

Moullé, P.E., Echaussoux, A., Lacombat, F., 2006. Taxonomie du grand canidé de la grotte du Vallonnet (Roquebrune-Cap-Martin, Alpes-Maritimes). Anthropologie 110, 832–836.

Mudelsee, M., Schulz, M., 1997. The Mid-Pleistocene climate transition: onset of 100 ka cycles lags ice volume build-up by 280 ka. Earth Planet. Sci. Lett. 151, 117–123.

Nocchi, G., Sala, B., 1997. The fossil rabbit from Valdemino cave (Borgio Verezzi, Savona) in the context of western Europe Oryctolagini of Quaternary. Palaeovertebrata 26, 167–187.

Palombo, M.R., 2004. Biochronology of the Plio-Pleistocene mammalian faunas of Italian peninsula: knowledge, problems and perspective. Il. Quaternario 17, 565–582.

Palombo, M.R., Azanza, B., Alberdi, M.T., 2002. Italian mammal biochronology from Latest Miocene to Middle Pleistocene: a multivariate approach. Geol. Romana 36, 335–368.

Palombo, M.R., Milli, S., Rosa, C., 2004. Remarks on the late Middle Pleistocene biochronology on the mammalian faunal complexes of the Campagna Romana. Geol. Romana 37, 135–143.

Palombo, M.R., Mussi, M., Agostini, A., Barbieri, M., Di Canzio, E., Di Rita, F., Fiore, I., Iacumin, P., Magri, D., Speranza, F., Tagiacozzo, A., 2010. Human peopling of Italian intramontane basins: the early Middle Pleistocene site of Pagliare di Sassa (L'Aquila, central Italy). Quat. Int. 223/224, 170–178.

Pandolfi, L., Tagliacozzo, A., 2013. Earliest occurrence of Woolly Rhino (*Coelodonta antiquitatis*) in Italy (Late Pleistocene, Grotta Romanelli site). Riv. Ital. Paleontol. Stratigr. 119, 125–129.

Pandolfi, L., Petronio, C., Salari, L., 2011. *Bos primigenius* Bojanus, 1827 from the early Late Pleistocene deposit of Avetrana (Southern Italy) and the variation in size of the species in Southern Europe: preliminary report. J. Geol. Res. http://dx.doi.org/10.1155/2011/245408 (ID 245408).

Pandolfi, L., Gaeta, M., Petronio, C., 2013. The skull of *Stephanorhinus hemitoechus* (Mammalia, Rhinocerotidae) from the Middle Pleistocene of Campagna Romana (Rome, central Italy): biochronological and paleobiogeographic implications. Bull. Geosci. 88, 51–62.

Park, J., Maasch, K.A., 1993. Plio-Pleistocene time evolution of the 100-kyr cycle in marine palaeoclimate records. J. Geophys. Res. 98 (B1), 447–461.

Pasa, A., 1947. I mammiferi di alcune antiche brecce veronesi. Mem. Mus. Civ. St. Nat. Verona 1, 1–111.

Petronio, C., 1986. Nuovi resti di ippopotamo del Pleistocene medio-inferiore dei dintorni di Roma e problemi di tassonomia e filogenesi del gruppo. Geol. Romana 25, 63–72.

Petronio, C., 1988. Una mandibola di rinoceronte di Ponte Galeria (Roma). Atti Soc. It. Sci. Nat. — Mus. Civ. St. Nat. Milano 129, 173–178.

Petronio, C., 1995. Note on the taxonomy of Pleistocene hippopotamuses. Ibex J.M.E. 3, 53–55.
Petronio, C., Pandolfi, L., 2011. First occurrence of the genus *Arvernoceros* from the late Early Pleistocene in Italy. Riv. Ital. Paleontol. Stratigr. 117, 501–508.
Petronio, C., Sardella, R., 1998. *Bos galerianus* n. sp. (Bovidae, Mammalia) from the Ponte Galeria Frmation (Rome, Italy). N. Jb. Geol. Paläont. Mh. 5, 269–284.
Petronio, C., Sardella, R., 1999. Biochronology of the Pleistocene mammal fauna from Ponte Galeria (Rome) and remarks on the Middle Galerian faunas. Riv. Ital. Paleontol. Stratigr. 105, 155–164.
Petronio, C., Sardella, R., 2001. Mammal faunas from Ponte Galeria Formation. In: Sardella, R. (Ed.), Galerian and Aurelian fossiliferous localities in the Rome area. EUROMAM 2001, Firenze, Perugia, Roma, pp. 22–24.
Petronio, C., Di Canzio, E., Salari, L., 2007. The Late Pleistocene and Holocene mammals in Italy: new biochronological and paleoenvironmental data. Palaeontogr. Abt. A 279, 147–157.
Petronio, C., Bellucci, L., Martinetto, E., Pandolfi, L., Salari, L., 2011. Biochronology and Palaeoenvironmental changes from the Middle Pliocene to the Late Pleistocene in Central Italy. Geodiversitas 33, 485–517.
Pfeiffer, Th., 1997. *Dama* (*Pseudodama*) *reichenaiui* (Kahlke, 1996) (Artyodactyla, Cervidae, Cervini) aus den Mosbach Sanden (Wiesbaden-Biebrich). Mainz. Naturwiss. Arch. 35, 31–59.
Pisias, N.G., Mooore, T.C., 1981. The evolution of Pleistocene climate: a time series approach. Earth Planet 52, 450–458.
Porat, N., Ronen, A., 2002. Luminescence and ESR age determinations of the Lower Paleolithic site Evron Quarry, Israel. Adv. ESR Appl. 18, 123–130.
Sala, B., 1987. *Bison schoetensacki* Freud. from Isernia la Pineta (early Mid-Pleistocene — Italy) and revision of the European species of bison. Palaeontogr. Ital. 74, 113–170.
Sala, B., Fortelius, M., 1993. The rhinoceroses of Isernia la Pineta (early middle Pleistocene, Southern Italy). Palaeontogr. Ital. 80, 157–174.
Sala, B., Masini, F., 2007. The late Pliocene and Pleistocene small mammal chronology in the Italian peninsula. Quat. Int. 160, 4–16.
Saltzman, B., Verbitsky, M.Y., 1993. Multiple instabilities and modes of glacial rhythmicity in the Plio-Pleistocene: a general theory of late Cenozoic climatic change. Clim. Dyn. 9, 1–15.
Sardella, R., Palombo, M.R., Petronio, C., Bedetti, C., Pavia, M., 2006. The early Middle Pleistocene large mammal faunas of Italy: an overview. Quat. Int. 149, 104–109.
Schreve, D.C., 2001. Mammalian evidence from Middle Pleistocene fluvial sequences for complex environmental change at the oxygen isotope substage level. Quat. Int. 79, 65–74.
Schreve, D.C., Bridgland, D.R., 2002. Correlation of English and German Middle Pleistocene fluvial sequences based on mammalian biostratigraphy. Geol. Mijnbouw/Neth. J. Geosci. 81, 357–373.
Segre Naldini, E., Muttoni, G., Parenti, F., Scardia, G., Segre, A.G., 2009. Nouvelles recherches dans le bassin Plio-Pléistocène de Anagni (Latium méridional, Italie). Anthropologie 113, 66–77.
Sesé, C., Villa, P., 2008. Micromammals (rodents and insectivores) from the early Upper Pleistocene cave site of Bois Roche (Charente, France): systematics and paleoclimatology. Geobios 41, 399–414.
Sher, A.V., 1997. Late-Quaternary extinction of large mammals in northern Eurasia: a new look at the Siberian contribution. Glob. Environ. Chang. 47, 319–339.
Sorgi, C., 1994. La successione morfo-litostratigrafica in destra Tevere dell'ambito dell'evoluzione geologica quaternaria dell'area romana.Tesi di Laurea. Università degli Studi di Roma "La Sapienza".
Sottili, G., Palladino, D.M., Zanon, V., 2004. Plinian activity during the early eruptive history of the Sabatini Volcanic District, Central Italy. J. Volcanol. Geoth. Res. 135, 361–379.
Sottili, G., Palladino, D.M., Marra, F., Jicha, B., Karner, D.B., Renne, P., 2010. Geochronology of the most recent activity in the Sabatini Volcanic District, Roman Province, central Italy. J. Volcanol. Geoth. Res. 196, 20–30.
Stanford, J.D., Rohling, E.J., Hunter, S.H., Roberts, A.P., Rasmussen, S.O., Bard, E., McManus, J., Fairbanks, R.G., 2006. Timing of meltwater pulse 1a and climate responses to meltwater injections. Paleoceanography 21 (4), PA4103. http://dx.doi.org/10.1029/2006PA001340.
Tchernov, E., Horwitz, K., Ronen, A., Lister, A.I., 1994. The faunal remains from Evron Quarry in relation to other lower Paleolithic hominid sites in the southern Levant. Quat. Res. 42, 328–339.
Thun Hohenstein, U., Di Nucci, A., Moigne, A.M., 2009. Mode de vie à Isernia La Pineta (Molise, Italie). Stratégie d'exploitation du Bison schoetensacki par les groupes humains au Paléolithique inférieur. Anthropologie 113, 96–110.
Tong, V.C.H., 2012. Using asynchronous electronic surveys to help in-class revision: a case study. Br. J. Educ. Technol. 43, 465–473.
Toula, F., 1902. Das Nashorn von Hundsheim. *Rhinoceros* (*Ceratorhinus*) *hundsheimensis* nov. form. Abh. K.-Kg. Geol. Reichsanst. (Wien) 19, 1–223.
van Dam, I., Mol, D., de Vos, J., Reumer, J.W.F., 1997. De eerste vondst van de Europese waterbuffel, *Bubalus murrensis* (Berckhemer, 1927) in Nederland. Cranium 14, 49–54.
Van Kolfschoten, T., Markova, A.K., 2005. Response of the European mammalian fauna to the mid-Pleistocene transition. In: Head, M.J., Gibbard, P.L. (Eds.), Early–Middle Pleistocene Transitions: The Land–Ocean Evidence. Geological Society, London, Special Publications. 247, pp. 221–229.
Vekua, A.K., 1991. Istoriya zhivotnogo mira e pozvonochnye. In: Kiknadze, T.Z. (Ed.), Gruziya v antropogene. Sakartvelo, Tbilisi, pp. 308–381 (in Russian).
Vekua, A.K., Lordkipanidze, D., 1998. The Pleistocene palaeoenvironment of the Transcaucasus. Quaternaire 9, 261–266.
Vislobokova, I., Dmitrieva, E., Kalmykov, N., 1995. Artiodactyls from the Late Pliocene from Udunga, western Trans-Baikal, Russia. J. Vertebr. Paleontol. 15, 146–159.
Von Koenigswald, W., Van Kolfschoten, T., 1996. The *Mimomys–Arvicola* boundary and the enamel thickness quotient (SDQ) of *Arvicola* as stratigraphie markers in the Middle Pleistocene. In: Turner, A. (Ed.), The early Middle Pleistocene in Europe. Balkema, Rotterdam, pp. 211–226.
Wei, K.Y., Chiu, T.C., Chen, Y.G., 2003. Toward establishing a maritime proxy record of the East Asian summer monsoons for the late Quaternary. Mar. Geol. 201, 67–79.
Zhu, R.X., Potts, R., Xie, F., Hoffman, K.A., Deng, C.L., Shi, C.D., Pan, Y.X., Wang, H.Q., Shi, R.P., Wang, Y.C., Shi, G.H., Wu, N.Q., 2004. New evidence on the earliest human presence at high northern latitudes in northeast Asia. Nature 431, 559–562.