



New insight into the Pleistocene deposits of Monte delle Piche, Rome, and remarks on the biochronology of *Hippopotamus* (Mammalia, Hippopotamidae) and *Stephanorhinus etruscus* (Mammalia, Rhinocerotidae) in Italy

Nuevo enfoque sobre los depósitos del Pleistoceno de Monte delle Piche, Roma, y observaciones sobre la biocronología de Hippopotamus (Mammalia, Hippopotamidae) y Stephanorhinus etruscus (Mammalia, Rhinocerotidae) en Italia

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ABSTRACT

Several large mammal assemblages have been collected in the Roman basin since the XIX century, but they usually lack any stratigraphic datum or details about the fossiliferous localities. In this work, the stratigraphic provenance of large mammal remains discovered at Monte delle Piche (Rome) is investigated. The systematic revision of these specimens allows the recording of the presence of *Hippopotamus* sp., *Stephanorhinus* sp. and *Stephanorhinus etruscus*. On the basis of micropalaeontological analysis performed on sediment sampled from the studied specimens and considering the stratigraphy of the area, two fossiliferous levels are recognised at Monte delle Piche.

The remain of the hippopotamus was collected in fluvial gravels and sand deposits, in which the presence of *Cypripideis* is also recorded. This deposit is chronologically related to the latest Early-early Middle Pleistocene. *Hippopotamus* was present in Italy and Western Europe from the latest Villafranchian to MIS 4/3. The mandible of *S. etruscus* was collected in marine deposits along with abundant foraminifera and ostracods, which correlate with the late Early Pleistocene. *Stephanorhinus etruscus* occurred in Western Europe at the beginning of the Villafranchian, and it was documented until the end of the Villafranchian in Italy and until the Early-Middle Pleistocene transition in the Iberian Peninsula.

Keywords: *Hippopotamus*; *Stephanorhinus etruscus*; Biochronology; Early Pleistocene; Monte delle Piche; Italy.

RESUMEN

Desde el siglo XIX varias colecciones de mamíferos han sido recolectadas en la cuenca de Roma, aunque normalmente existen carencias en los datos estratigráficos o en la localización de los yacimientos. En este trabajo, se ha estudiado la posición estratigráfica de grandes mamíferos descubiertos en el Monte delle Piche (Roma). La

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revisión sistemática de estas especies permite identificar la presencia de *Hippopotamus* sp., *Stephanorhinus* sp. y *Stephanorhinus etruscus*. Considerando el área estratigráfica y teniendo en cuenta el análisis micropaleontológico realizado y el muestreo de los especímenes estudiados, se han reconocido dos niveles fosilíferos en el Monte delle Piche.

El resto de *Hippopotamus* fue extraídos en gravas fluviales y depósitos de arena, en los cuales la presencia de *Cyprideis* fue también identificada. Este depósito está relacionado cronológicamente con la parte tardía del comienzo del Pleistoceno medio. *Hippopotamus* estuvo presente desde el Villafranchense tardío hasta MIS 4/3 en Italia y en el oeste de Europa. La mandíbula de *S. etruscus* fue recogida en depósitos marinos con abundante fauna de foraminíferos y ostrácodos, que se correlaciona con el Pleistoceno inferior. *Stephanorhinus etruscus* estuvo presente en el oeste de Europa a principio del Villafranchense, y fue documentado hasta el final de Villafranchense en Italia y hasta el final de la transición del Pleistoceno inferior-medio en la Península Ibérica.

Palabras clave: *Hippopotamus*; *Stephanorhinus etruscus*; Biocronología; Pleistoceno inferior; Monte delle Piche; Italia.

Introduction

The area of the Roman Basin (Rome, Central Italy) have been object of several investigations by Volcanologists, Geologists and Palaeontologists because the peculiarity of its rocks and the richness of late Early and Middle Pleistocene fossil assemblages (Ponzi, 1878; Meli, 1896; Portis, 1896; Conato *et al.*, 1980; Esu, 1982; Caloi & Palombo, 1986, 1994; Kotsakis *et al.*, 1992; De Rita *et al.*, 1995; Marra & Rosa, 1995; Marra *et al.*, 1995, 1998; Milli, 1997; Caloi *et al.*, 1998; Capasso Barbatto *et al.*, 1998; Di Stefano *et al.*, 1998; Petronio & Sardella, 1999; Karner *et al.*, 2001; Milli & Palombo, 2005; Cosentino *et al.*, 2009; Sottili *et al.*, 2010 and references therein; Petronio *et al.*, 2011 and references therein). This area is the result of several geological processes and is characterised by Plio-Pleistocene depositional sequences usually covered by volcanoclastic deposits (Conato *et al.*, 1980; Marra *et al.*, 1995; Caloi *et al.*, 1998; Karner *et al.*, 2001). Due to the intense urbanization since the XIX century, several large mammal remains have been collected from the sedimentary successions outcropping in the Roman area, but the specimens usually lack any stratigraphic datum or details about the fossiliferous localities (Caloi *et al.*, 1980; Petronio, 1988; Di Stefano *et al.*, 1998; Petronio & Sardella, 1999; Kotsakis & Barisone, 2008; Rozzi *et al.*, 2011; Pandolfi *et al.*, 2013a, b).

The aim of this paper is the systematic revision of the Pleistocene mammals collected in the fossiliferous deposit of Monte delle Piche (Rome) at the beginning of the second half of the XIX century. Ponzi (1858) described shortly the Monte delle Piche sequence, which was characterised, from the bottom

to the top, by “Sub-Apennine Marne” (=?Monte Vaticano Formation), sands with some lignite beds at the base (in which mammal remains have been collected according to the author), alluvial gravels and volcanic tuff (Fig. 1). On the basis of the results of micropalaeontological analysis performed on a relatively small amount of sediment sampled from the studied specimens, the revised biochronology of large mammals and considering the stratigraphy of the area, the relative chronological position of the specimens is investigated.

Material and Methods

The considered mammal remains are housed at Museo di Paleontologia, “Sapienza” University of Rome (MPUR) and have never been studied in detail. The specimens have been collected at the foot of Monte delle Piche during the construction of the Rome-Civitavecchia railway between 1856 and 1858 (Ponzi, 1858) (Fig. 1).

The mammal remains from Monte delle Piche are represented by two fragmentary mandibles of Rhinocerotidae (MPUR 1515; MPUR 1516) and a femur of a large-sized Hippopotamidae (MPUR 999). A third reworked hemimandible of a rhinocerotid (MPUR 138), collected from the same locality, was described by Pandolfi *et al.* (2013b) and referred to *Acerorhinus* sp.

The hippopotamus remain is morphologically compared with the specimens housed at the MPUR, Museo di San Giuliano (L’Aquila) (MSG), Museo di Storia Naturale, Accademia dei Fisiocritici, Siena (MSNAF) and Museo di Anatomia Comparata, “Sapienza” University of Rome (MACUR) as well as with the specimens published by Leonardi (1948),

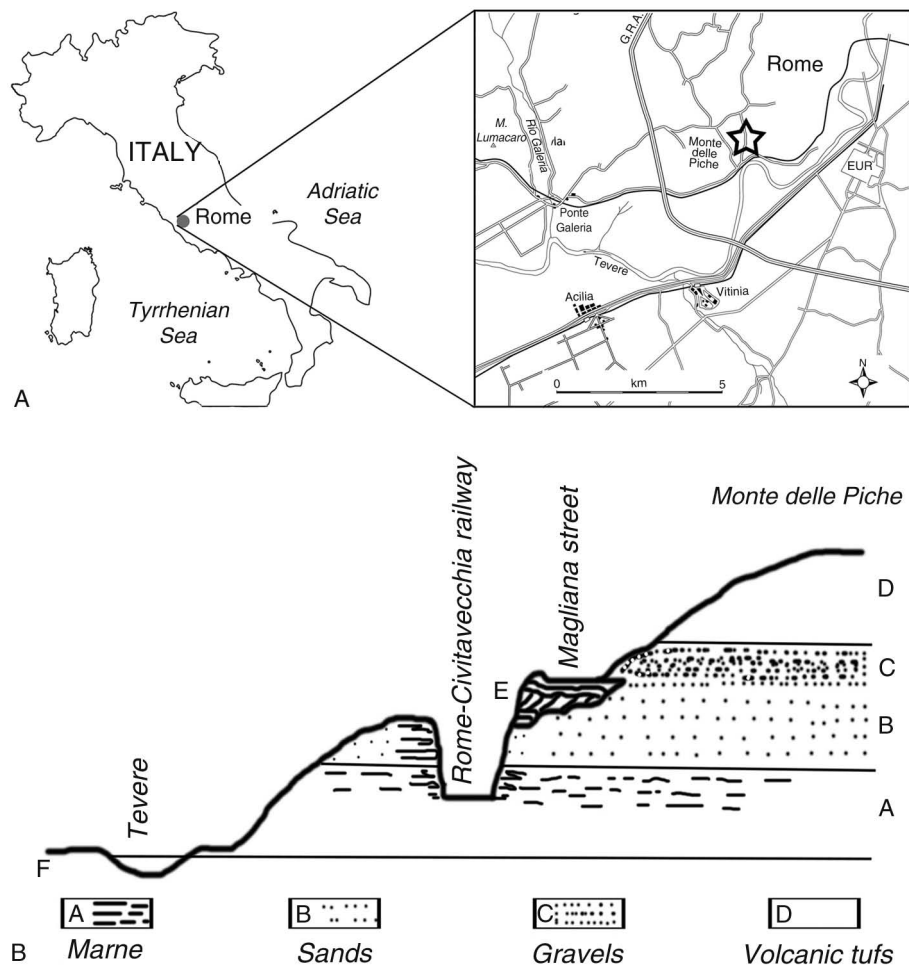


Fig. 1.—A, location of Monte delle Piche (Rome, Central Italy). B, stratigraphic sequence of Monte delle Piche redrawn from Ponzi (1858).

Blandamura & Azzaroli (1977), Caloi *et al.* (1980), Kahlke (2001a) and Mazza & Bertini (2013).

The remains of rhinoceros are morphologically compared with several Pliocene and Early-early Middle Pleistocene specimens from a number of European localities. The comparisons are based on the material housed at the Naturhistorisches Museum, Basel (NMB), Museo Nacional de Ciencias Naturales, Madrid (MNCN), Museum für Naturkunde, Berlin (MfN), Naturhistorisches Museum, Wien (NHMW), Hungarian Natural History Museum, Budapest (HNHM), MSNAF, Museo di Storia Naturale, sezione di Geologia e Paleontologia, Florence (IGF), Museo Geologico Capellini, Bologna (MGC), Museo di Geologia e Paleontologia, University of Padua, Padua (MGPP), Museo di Paleontologia “L. Boldrini”,

Pietrafitta (Perugia) (MPLBP), Museo Paleontologico Parmense, University of Parma, Parma (MPP), Museo di Scienze della Terra, University of Bari, Bari (MSTB) and MPUR as well as on the specimens published by Azzaroli (1962), Guérin (1972, 1980), Mazza *et al.* (1993), Sala & Fortelius (1993), Lacombat (2006) and Pandolfi (2013).

The dental nomenclature follows Guérin (1980) and Lacombat (2005); the morphometric data of the Monte delle Piche specimens were obtained following Guérin (1980) and Lacombat (2005) and are reported in Table 1. Ratio diagram was made using data on extant *Diceros bicornis* (data from Guérin, 1980) as standard.

Micropalaeontological content of sediment samples collected from the studied specimens was

Table 1.—Comparative dimensions (in mm) of the specimen MPUR 1516 and the species *D. megarhinus*, *S. jeanvireti*, *S. etruscus* and *S. hundsheimensis* (= *D. etruscus brachycephalus* in Guérin, 1980 but excluding the type species).

Tooth Measurements	MPUR 1516	<i>D. megarhinus</i> ¹	<i>S. jeanvireti</i> ¹	<i>S. etruscus</i> ¹	<i>S. hundsheimensis</i> ¹	<i>S. etruscus</i> ²	<i>S. hundsheimensis</i> ²	
P/2	L	31.8	29.5–43	27–28.5	25–33	27–39	25.7–27.26	27.41–32.29
	W	20.6	16.5–25	16.5–19	16–21.5	16–33	17.43–17.8	18.88–22.93
P/3	L	36.39	35–44	33–38	31.5–37	33–42.5	31.29–38.65	31.22–37.50
	W	30.17	22–31.5	23–27	21.5–29	21–37	25–28.68	22–29.07
P/4	L	36.03	37.5–48	37–40.5	35–39.5	33–45	35.05–34.4	33.96–40.23
	W	30.67	27.5–38	24–31	24–31	24–35	29.3–30.68	21.20–32.65
M/1	L	43.6	38.5–53	42–47	37–43	37–57	40.8–45.03	38.28–48
	W	30.36	29–40	28–34	26.5–33	25–37	25.46–30.46	25.58–38.64
M/2	L	46.29	43–57.5	43–50	40.5–47.5	42–57.5	41.6–43.18	40.19–50.14
	W	29.27	31–39	27–33	27–33.5	23.5–35	28.45–29.52	26.04–36.60
M/3	L	45.62	48–62	43.5–51	41–50	44–59	42.64–43.18	40.80–51.60
	W	27.72	29.5–37	26–33	26–33	25–33	27.57–28.74	26.49–31.30
Tooth row	LP	ca 105	101–136	98–106	87–108	99–116	96–96.4	107.18
	LM	ca 135	134–165	127–138	121–143	119–163.5	122.09–122.7	129.50–143
	Ltot	ca 240	228–293	234–242	210–251.5	228–263.5	218–222	231.67

1=data from Guérin (1980); 2=data from Lacomat (2005, 2006). L=maximal length; W=maximal width; LP=length of the premolars; LM=length of the molars; Ltot=maximal length of the tooth row.

analysed in order to add some palaeoenvironmental and biostratigraphic information or to corroborate existing data. The analyses on ostracods and foraminifera were performed on all the samples, which were disaggregated in 5% H₂O₂ solution, washed using a 0.125 mm mesh sieve and dried. From the whole dried sieved sediments, ostracods and foraminifera was handpicked and analysed under the stereomicroscope. On the whole, ostracod valves were medium preserved, while foraminifera show a preservation spanning between bad to good.

The foraminiferal content found in the sediment was collected and classified. The taxonomy of planktonic foraminifera is according to Kennett & Srinivasan (1983), Hemleben *et al.* (1989) and Iaccarino *et al.* (2007), whereas the identification of benthic foraminifera was based on Loeblich & Tappan (1987), Cimerman & Langer (1991), Sgarrella & Moncharmont-Zei (1993) and Fiorini & Vaiani (2001).

The revised Quaternary time scale (Gibbard *et al.*, 2010) for chronological references is used in this text; the Pleistocene spans approximately between 2.6 and 0.001 Ma. The biostratigraphic scheme adopted here is that of Iaccarino *et al.* (2007).

Systematic palaeontology

Class MAMMALIA Linnaeus, 1758
 Order ARTIODACTYLA Owen, 1848
 Family HIPPOPOTAMIDAE Gray, 1821
 Genus *Hippopotamus* Linnaeus, 1758
Hippopotamus sp.

Material: MPUR 999, a fragmentary femur.

Description: The femur lacks of the distal epiphysis and the proximal articular head, which was supported by a relatively elongated neck (Fig. 2). The trochanter is massive and the diaphysis has a sub-circular section.

Remarks: Elongated neck is evident in *H. antiquus* according to Caloi *et al.* (1980) and can be noticed in some specimens from L'Aquila Basin (L'Aquila) (MSG 385 and 403) and S. Oreste (Rome) (MPUR/V 1950) referred to this species. Nevertheless, this character is also observable in some specimens referred to *H. amphibius* (Caloi *et al.*, 1980). The breadth of the diaphysis (TDd=70.7 mm) is smaller than those measured on the femurs of *H. antiquus* from S. Oreste (= *H. ex gr. H. antiquus* according to Mazza & Bertini, 2013) given by Caloi *et al.* (1980) (TDd=80 and 76 mm) and from Valdarno



Fig. 2.—Femur of *Hippopotamus* sp. from Monte delle Piche (MPUR 999) in dorsal view. Scale bar equals 5 cm.

(TDd=79–92 mm) and Colle Curti (TDd=84–90 mm) given by Mazza & Bertini (2013). The value obtained on the specimen from Monte delle Piche is close to those of *H. ex gr. H. antiquus* (TDd=69–79 mm) and *H. amphibius* (TDd=46–80 mm) given by Mazza & Bertini (2013). However, due to the conservation status of the remain and the wide morphological variability of *Hippopotamus* (Caloi *et al.*, 1980; Petronio, 1995), a sure specific attribution of the studied specimen is excluded.

Order PERISSODACTYLA Owen, 1848
Family RHINOCEROTIDAE Gray, 1821
Genus *Stephanorhinus* Kretzoi, 1942
Stephanorhinus sp.

Material: MPUR 1515, a fragment of hemimandible.

Description: The specimen MPUR 1515 consists only of a partial horizontal ramus with D/3, D/4 and M/1 (Fig. 3A). Labial cingula are absent; D/4 and M/1 display a relatively marked and deep vestibular grooves; M/1 has a long and narrow paralophid. D/3 is relatively worn and the paralophid is short and broad. The anterior lingual valley in D/3 has a narrow V-shaped morphology. The posterior valley in D/4 and M/1 has a broad V-shaped morphology. Other morphological characters cannot be observed because the specimen is covered by a thick and hard crust of sediment.

Remarks: Marked and deep vestibular grooves and V-shaped lingual valleys are recognised in D/4 and M/1 of *S. etruscus* from Pirro Nord (MPUR no code) and Barberino (MGC 7602) (Fig. 3) as well as in the specimens of *S. etruscus* reported by Lacombe (2006). In D/3 from Monte delle Piche the vestibular groove is open and shallow as in D/3 of *S. etruscus* from Castel San Pietro (MPUR no code) (Fig. 3B) while it is closed in the specimen from Pirro Nord and some specimens from Senèze (e.g., NMB Se1682). In the D/3 from Barberino a weak mesial cingulum

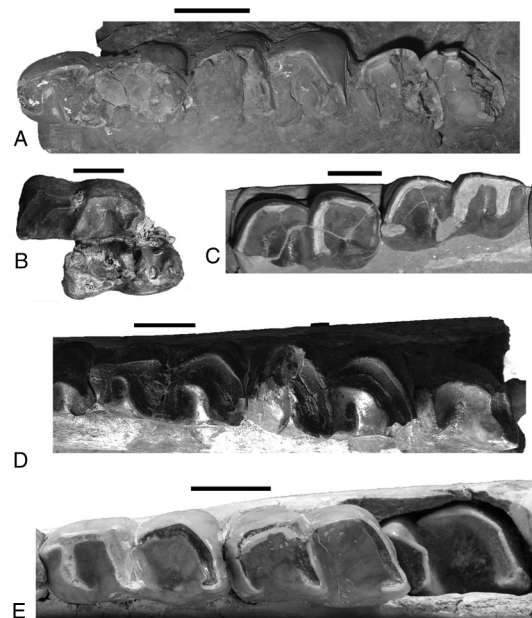


Fig. 3.—A, fragmentary hemimandible from Monte delle Piche (MPUR 1515) with D/3-D/4 and M/1, occlusal view; B, D/3 of *S. etruscus* from Castel San Pietro (MPUR no code), occlusal view; C, D/3-D/4 of *S. etruscus* from Barberino (MGC 7602), occlusal view; D, D/3-D/4 of *S. hundsheimensis* from Mosbach (MfN 26224); E, D/3-D/4 and erupting M/1 of *D. megarhinus* from Montpellier (NMB MP921). Scale bar equals 2 cm.

is also present. V-shaped lingual valleys and marked vestibular groove are evident in D/4 and M/1 of two hemi-mandibles of *S. etruscus* from Navezze di Gussago (MGPP 31406 and 31406a). In the latter specimens, D/3 displays the same morphological characteristics than that from Monte delle Piche, while M/1 has a mesial cingulum. The specimen from Monte delle Piche differs from *S. hundsheimensis* from Mosbach (MfN 26224, 26225) in which the vestibular wall of the trigonid in D/3 is slightly concave (Fig. 3D) and D/4 has an U-shaped posterior lingual valley and a deep vestibular groove (MfN 26224, 26225, 26227). Two D/4 of *S. hundsheimensis* from Contrada Monticelli (MSTB 30600 and 30600a) display a more obtuse and shallow vestibular groove; this feature is also present in the specimens of *S. hundsheimensis* reported by Lacomat (2006). In *Dihoplus megarhinus* (NMB MP921), D/3 has a relatively more marked and deep vestibular groove than in the Monte delle Piche specimen (Fig. 3E); moreover D/3 and D/4 display distal and mesial cingula. In D/3 of *Dihoplus megarhinus* from Montepellier, a marked vestibular groove occurs between the protoconid and the paraconid (Fig. 3E). This groove appears very shallow in *S. etruscus* and *S. hundsheimensis*. Unfortunately, only three deciduous teeth of *S. jeanvireti* are known and they do not show distinctive morphological and morphometric features (Guérin, 1972, 1980).

The maximal length of the D/3 from Monte delle Piche (L=41.5 mm) is close to the minimal values of *D. megarhinus* (L=41.5–51 mm) and *S. jeanvireti* (L=40–47 mm) and to the maximal value *S. etruscus* (L=38–42 mm) given by Guérin (1980). Moreover it falls into the dimensional range of *S. hundsheimensis* from Untermassfeld (L=39–44 mm) given by Kahlke (2001a) and it is longer than the specimens of *S. hundsheimensis* from Vallonnet (L=28.50–32.87 mm) given by Lacomat (2006).

In conclusion, the specimen MPUR 1515 from Monte delle Piche displays morphological similarities with *S. etruscus* but it is not compared with *S. jeanvireti* because of the scarcity of data. Therefore, a sure attribution to *S. etruscus* cannot be confirmed.

Genus *Stephanorhinus* Kretzoi, 1942

Stephanorhinus etruscus (Falconer, 1868)

Material: MPUR 1516, an almost complete mandible.

Description: The rhino mandible MPUR 1516 (Fig. 4A) lacks of fragments of the vertical rami, part of the incisor corpus and the left P/2. The specimen is covered by a black, hard and relatively thick sediment. The lower border of the mandible is convex and the height of the horizontal ramus decreases below the premolars. The vestibular groove is marked and deep in M/3, while it is less deep in the other teeth. Labial cingula are absent. M/2 has a mesial cingulum and P/2 has a weak mesial cingulum. The lingual valleys have a V-shaped morphology in all the teeth.

Remarks: The mandible from Monte delle Piche differs from those of *D. megarhinus* from Montpelier (NMB MP1, MP1031, MP94, MP858, MP822) in which the lower border of the mandible below the molar portion is linear and an inflexion point is present at the level of M/1 (Fig. 4). The vestibular groove in *D. megarhinus* is broader and shallower than in the specimen from Monte delle Piche; vestibular, mesial and distal cingula can be also observed on the teeth of *D. megarhinus*. Furthermore, the lingual valleys in *D. megarhinus* have usually a U-shaped morphology (Guérin, 1980). In *S. jeanvireti* from Monte San Pietro (MGC 9354), Capannoli (IGF 1449v) and Vialette (NMB Vt621 and Vt627), the lower border of the mandible appears less convex than in the specimen from Monte delle Piche (Fig. 4). Moreover, weak vestibular cingula can be recognised in the teeth of *S. jeanvireti* from Capannoli, Monte Pulgnasco (MGC 9352) and Vialette. In *S. etruscus* from Upper Valdarno and Olivola mesial cingula occur in M/2 and M/3, while vestibular cingula are generally absent or are represented by a more or less marked extension of the mesial cingulum. In *S. etruscus* from Upper Valdarno, the lower border of the mandible is regularly convex as well as in the specimen from Monte delle Piche (Fig. 4). The horizontal rami of three mandibles from Pietrafitta (MPLBP no code, probably n°583, n°584 and n°585 in Mazza *et al.*, 1993) display a convex lower border. The mandibles of the Etruscan rhino differ from those of *S. hundsheimensis* from Isernia la Pineta (MPI 33083), Contrada Monticelli (MSTB no code), Torrente Stirone (MPP no code) and Hundsheim (NHMW 2013/0282/0001) which display a more slender mandible with a straight ventral border (Fig. 4). The lingual valleys in the molars of *S. hundsheimensis*

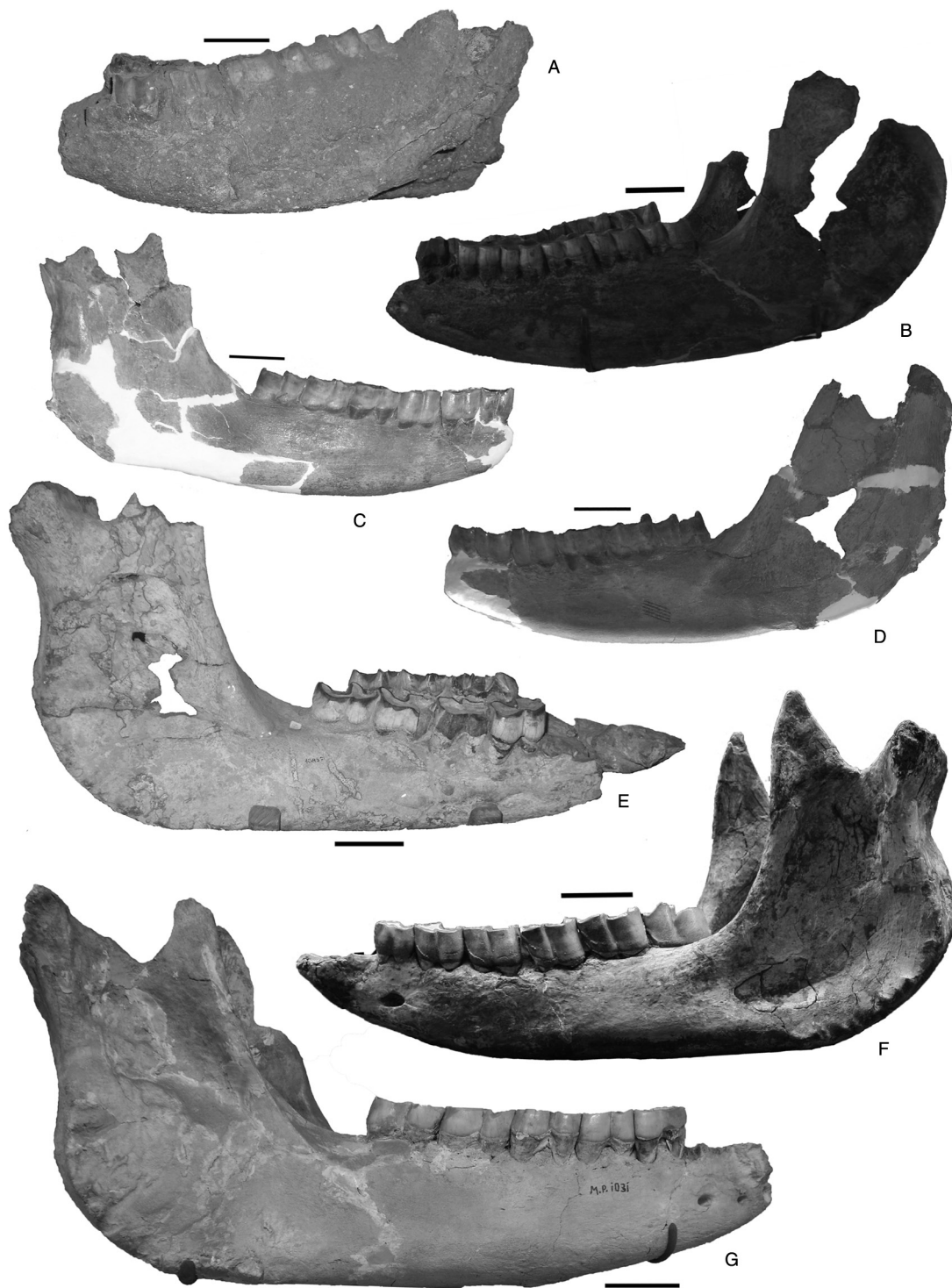


Fig. 4.—A, mandible from Monte delle Piche (MPUR 1516) in lateral view; B, mandible of *S. etruscus* from Upper Valdarno (IGF 755); C, right hemimandible of *S. etruscus* from Pietrafitta (MPLBP no code, most probably n°583 in Mazza *et al.*, 1993); D, left hemimandible of *S. etruscus* from Pietrafitta (MPLBP no code, most probably n°584 in Mazza *et al.*, 1993); E, mandible of *S. jeanvireti* from Monte San Pietro (MGC 9354); F, mandible of *S. hundsheimensis* from Torrente Stirone (MPP no code); G, mandible of *D. megarhinus* from Montpellier (NMB MP1031). Scale bar equals 5 cm.

from Contrada Monticelli (MSTB 30600, 30600a, no code) are broader than in those from Monte delle Piche, and the vestibular groove in M/1 appears more marked. The lower molars from Hundsheim displays mesio-vestibular and distal cingula; moreover, lingual cingula characterised by small cuspules are also present. Mazza & Varola (1999) didn't reported the presence of lingual cingula on the specimens from Contrada Monticelli, but a small lingual cingulum can be observed on a M/1 (MSTB 30600).

The dimensional characters of the teeth and the tooth row of the specimen from Monte delle Piche are not conclusive for an attribution to *S. etruscus* because they fall into the dimensional ranges of the four considered species (Table 1). The ratio diagram of the dental measurements reveals that the Monte delle Piche specimen is proportionally quite different from *D. megarhinus*, *S. jeanvireti* and *S. hundsheimensis* considering the mean values given by Guérin (1980) (Fig. 5). It resembles the mean of *S. etruscus* given by Guérin (1980) in the proportion of the tooth row and the mean of *S. hundsheimensis*

given by Lacombat (2005, 2006) in the proportion of the teeth (with the exception of P/2 and M/1). The proportion of the specimen from Monte delle Piche is partially close to that of the maximal values of *S. etruscus* given by Guérin (1980); a similarity with the mean of *S. etruscus* from Senèze can be also noticed (Fig. 5).

Micropalaeontological analyses

Micropalaeontological analyses revealed the presence of some ostracod valves and foraminiferal tests in the sediment that covers the vertebrate remains.

The MPUR 999 covering deposits yielded few valves of *Cyprideis* instars (Fig. 6), in agree with very shallow (optimum of *Cyprideis* <10 meters, Neale, 1988) and oligohaline waters. The hard blackish crusts of sediment on the MPUR 1515 and MPUR 1516 mandibles provided few valves of *Loxoconcha* sp. (MPUR 1515) and instars of *Krithe* sp. and *Bairdopilata* sp. (MPUR 1516) (Fig. 6),

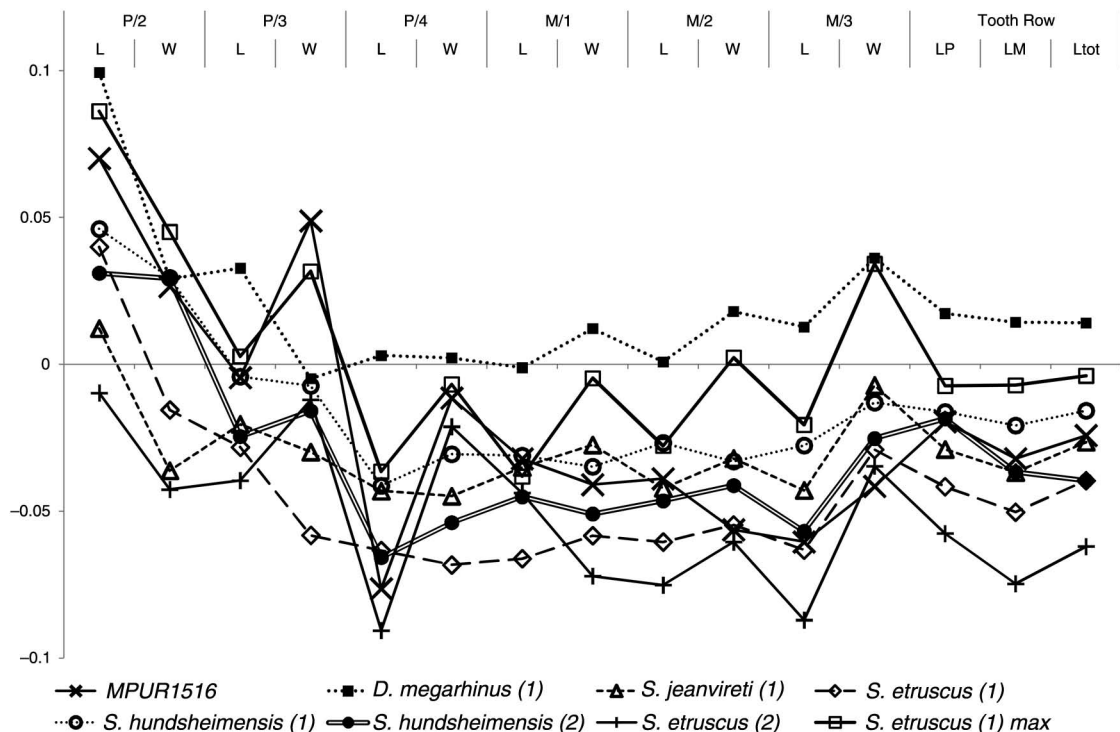


Fig. 5.—Ratio diagram for the lower teeth and tooth row from Monte delle Piche compared with those of *D. megarhinus*, *S. jeanvireti*, *S. etruscus* and *S. hundsheimensis*. Standard is *Diceros bicornis* (data from Guérin, 1980). 1= data from Guérin (1980); 2= data from Lacombat (2005, 2006). Abbreviations are reported in Table 1.

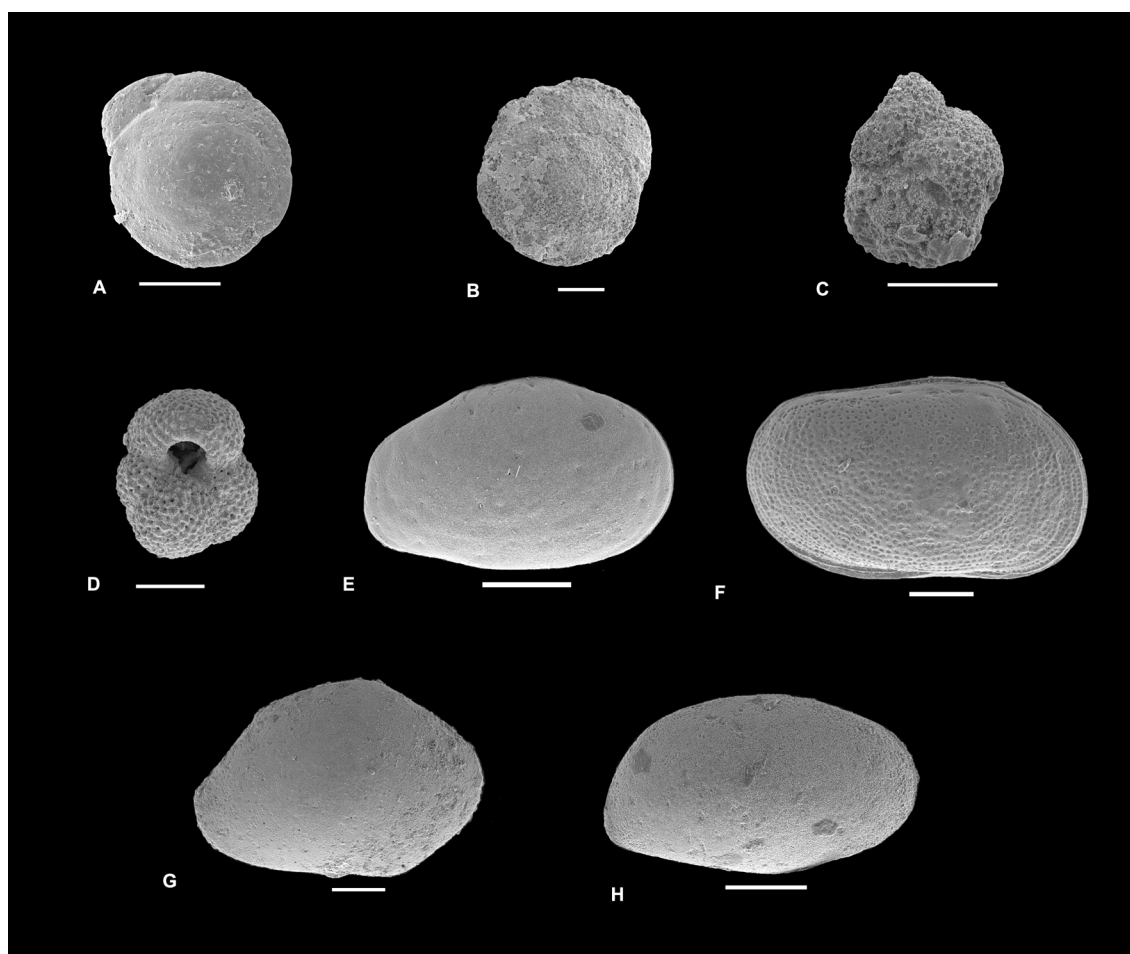


Fig. 6.—Ostracods and foraminifera collected from the specimens MPUR 1515 and MPUR 1516 from Monte delle Piche. A, *Cibicides dutemplei*, spiral view (MPUR 1516); B, *Globorotalia miozea*, spiral view (MPUR 1516); C, *Neogloboquadrina pachyderma*, spiral view (MPUR 1516); D, *Globoturborotalita woodi*, umbilical view (MPUR 1515); E, *Cyprideis* sp. juv. (MPUR 999); F, *Loxoconcha* sp. (MPUR 1515); G, *Bairdoppilata* sp. juv. (MPUR 1516); H, *Krithe* sp. juv. (MPUR 1516). Scale bar 100 μ m.

testifying a marine environment from infralittoral (MPUR 1515) to circalittoral (MPUR 1516).

The MPUR 999 is barren of foraminifera, whereas in the MPUR 1515, just one test, referable to the planktonic species *Globoturborotalita woodi*, was found.

In the MPUR 1516, 18 tests of foraminifera (10 planktonic and 8 benthic specimens) were collected and classified (Fig. 6). Seven foraminifera show poor preserved tests. This group comprises benthic taxa typical of circalittoral environments as *Bulimina* spp. and *Cibicides dutemplei* (Van Morkhoven *et al.*, 1986; Sgarrella & Moncharmont Zei, 1993) and the planktonic species *Globorotalia miozea*. Among the well preserved foraminifera

there is *Ammonia tepida* that is a benthic foraminifer typical of brackish-waters and marine infralittoral zones (Frezza & Carboni, 2009). Nevertheless, planktonic species are more frequent and are represented by *Globigerinita glutinata*, *Globigerinita parkerae*, *Neogloboquadrina pachyderma* sinistral coiling and *Turborotalita quinqueloba* (Fig. 6).

Biochronology of Pleistocene *Hippopotamus* in Italy

The first occurrence of the Pleistocene *Hippopotamus* in Italy is controversial. Until the end of the last century it was in the Early Pleistocene sites in the Upper Valdarno, approximately referred to the

end of the Olduvai subchrone (Tasso Faunal Unit according to Gliozzi *et al.*, 1997). However, according to Napoleone *et al.* (2003), the Upper Valdarno specimens are probably younger and they ascribe them to the latest Early Pleistocene. During this time span, *Hippopotamus* is recorded at Montecastrilli (Terni), as well as at Redicicoli (Rome), Madonna della Strada (L'Aquila), Colle Curti (Macerata), Il Crostolo (Reggio Emilia) and in the Mugello Basin (Tuscany) (Ambrosetti & Cremaschi, 1976; Ficarelli & Mazza, 1990; Abbazzi *et al.*, 1995; Coltorti *et al.*, 1998; Girotti *et al.*, 2003; Petronio *et al.*, 2003; Magri *et al.*, 2010; Petronio & Pandolfi, 2011; Petronio *et al.*, 2011; Mancini *et al.*, 2012; Kotsakis & Pandolfi, 2012).

Recently, Bellucci *et al.* (2011) reported the presence of an incisor fragment of hippopotamus in the Middle Villafranchian assemblage of Costa San Giacomo (Anagni Basin). According to these authors, the remain was found “in the field where most of the Costa San Giacomo FU bones were previously collected” (Bellucci *et al.*, 2011, p. 8) and they pre-dated the occurrence of hippopotamus at approximately 2.0 Ma.

Hippopotamus was surely present in Italy until MIS 4/3 (Gliozzi *et al.*, 1997; Palombo, 2004; Petronio *et al.*, 2007, 2011).

Biochronology of *Stephanorhinus etruscus* in Italy

Stephanorhinus etruscus occurred in Italy during the latest Pliocene in the site of Villafranca d'Asti and during the earliest Pleistocene at Montopoli (MN16) (Guérin, 1980; Pandolfi, 2013), but it was more common during the second half of the Early Pleistocene, in particular in the Upper Valdarno, Olivola and in the Tiberino Basin (Falconer, 1868; Mazza, 1988; Petronio *et al.*, 2003, 2011; Pandolfi, 2013). Fortelius *et al.* (1993) also reported the first occurrence of the Etruscan rhino in the localities of Palaia (Lower Valdarno, Tuscany) and Città della Pieve (Perugia). Nevertheless, the remains from Palaia (a fragmentary nasal bone IGF 5566v and an almost complete mandible IGF 13091) display morphological and morphometric features close to *D. megarhinus* (Azzaroli, 1962; Guérin, 1980; Pandolfi, 2013). Unfortunately, the attribution of the

specimen from Città della Pieve cannot be confirmed because it is part of a no-defined Private Collection (Fortelius *et al.*, 1993, p. 67), it was not figured by the authors and information about the stratigraphic level was not reported.

The earliest occurrence of *S. etruscus* in Europe is that from Piedrabuena (Spain) which is dated to an age earlier than 3.0 Ma (MN15-MN16 transition) (Mazo & Torres, 1991; Mazo, 1999).

The last occurrence of *S. etruscus* is relatively controversial. Several small sized remains from the latest Early Pleistocene of Europe were usually ascribed to *S. etruscus*, *S. cf. S. hundsheimensis* or to *S. hundsheimensis*. According to Pandolfi & Petronio (2011) the latest Villafranchian Italian rhinoceroses from Pirro Nord (ca. 1.5 Ma), Madonna della Strada (ca. 1.3 Ma) and Imola basin (latest Villafranchian) can be ascribed to *S. etruscus*. The remains from Pietrafitta (latest Early Pleistocene, Farneta FU) were ascribed to *S. cf. S. hundsheimensis* by Mazza *et al.* (1993) and were related to *S. etruscus* by Van der Made (2010) and Pandolfi & Petronio (2011). However, the specimens from Pietrafitta are morphologically and morphometrically closer to *S. etruscus* than to *S. hundsheimensis* and can be ascribed to the Etruscan rhino despite the dental proportions are quite different (see Mazza *et al.*, 1993). The hemi-mandibles from Pietrafitta display a more slightly convex lower border of the horizontal rami than in *S. hundsheimensis* and the height below the first molar is shorter than in the Toula's species.

Therefore, the presence of *S. hundsheimensis* or related forms during the latest Villafranchian in Italy is not supported by clear evidence and the last occurrence of *S. etruscus* can be placed at the end of the Villafranchian. Nevertheless, *S. etruscus* was reported during the early Galerian in Spain where it seems to be a long-lived species (Cerdeño, 1993; Van der Made, 2010). The presence of the Etruscan rhino can be confirmed at Huescar (around 0.9 Ma) (Cerdeño, 1993; Van der Made, 2010) and at Atapuerca TD4, TD6 and TD8 (Brunhes-Matuyama transition) (Van der Made, 1998, 1999, 2010). The earliest Italian record of *S. hundsheimensis* is coeval with those from other European localities such as Vallonnet (France) and Untermassfeld (Germany), while at Vallparadís (Spain) *S. hundsheimensis* was also recorded in the ancient levels of the fossiliferous

section dated around 1.5 Ma (Kahlke, 2001b; Moullé *et al.*, 2006; Madurell-Malapeira *et al.*, 2010).

Stratigraphy of Monte delle Piche and stratigraphic position of the fossil mammal remains

Micropalaeontological analysis suggests that the specimens from Monte delle Piche were deposited in two different levels that were characterised by two different sedimentary environments: specimen MPUR 999 in the continental deposits and specimens MPUR 1516 and MPUR 1515 in marine sediments.

In agreement with the absence of foraminifera and the presence of *Cyprideis* sp. as well as the conglomerates and sand found on the bone, the specimen MPUR 999 (femur of hippopotamus) was deposited in fluvial sediments which underlies the volcanic tufs in the stratigraphic succession of Monte delle Piche (Fig. 1). The fluvial sediments in which the hippopotamus was collected could be correlated with the fluvial deposits of the “Paleo Tiber” described by Marra & Rosa (1995) in the adjacent areas of Monte delle Piche and in the Ponte Galeria Formation (>0.9 Ma) (Fig. 7). Carboni & Iorio (1997) found Pleistocene continental

deposits (fluvial-marsh silt) that overlap Gelasian marine sediments in the boreholes from the Portuense district near the Monte delle Piche site (Fig. 7). Ultimately, according to Fig. 1, as reported by Ponzi (1858), fluvial conglomerates are deposited below the volcanic levels in the Monte delle Piche succession, which suggests an age earlier than approximately 0.6 Ma. Indeed, volcanoclastic elements are extensively present in all of the stratigraphic successions of the area from ca. 0.6 Ma (cfr. Karner *et al.*, 2001; Sottili *et al.*, 2010). Based on these observations, the fossiliferous level with the hippopotamus could be chronologically related to a time span between 0.9 and 0.6 Ma. This age is in agreement with the presence of the hippopotamus in Italy represented by the species *H. antiquus* (Fig. 7; Petronio *et al.*, 2011).

Marine ostracods and foraminifera (from infralittoral to circalittoral zones) are documented in the sediments collected from specimens MPUR 1516 and MPUR 1515. They suggest that these vertebrate remains were deposited in a marine environment. Marine deposits were reported by Ponzi (1858) at the bottom of the succession of Monte delle Piche (Fig. 1). The marine sediments, in which the specimens MPUR 1515 and MPUR 1516 were

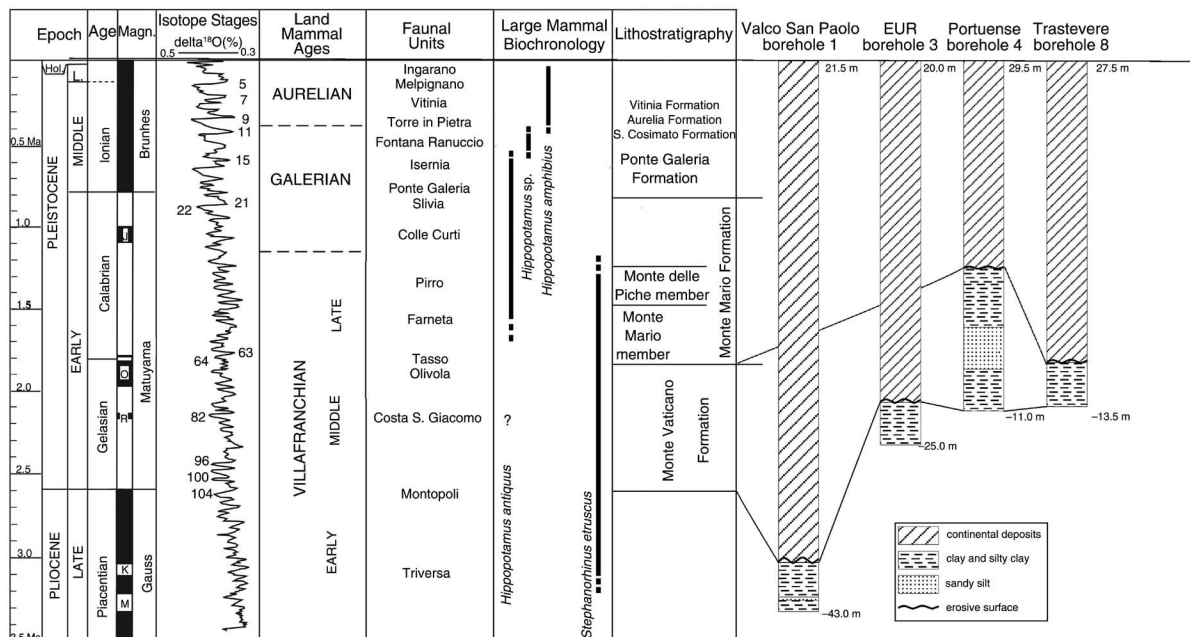


Fig. 7.—Correlation among chronology, large mammal biochronology, lithostratigraphy and the boreholes from Valco San Paolo, EUR, Portuense and Trastevere (redrawn from Carboni & Iorio, 1997; Petronio *et al.*, 2011).

collected, are represented by black and red silty deposits. A depositional level with the same chromatic and sedimentological characteristics as the sediment covering the rhino mandibles was recognised by Carboni & Iorio (1997) in the boreholes from Trastevere and Portuense districts, which was located on the Tiber River right bank near the Monte delle Piche (Fig. 7). Based on the presence of *Globigerinita umbilicata* and *Globorotalia oscitans*, these sediments were assigned to the Gelasian stage (Carboni & Iorio, 1997) (Fig. 7). On the contrary, boreholes located on the Tiber River left bank (Valco San Paolo and EUR districts) revealed marine sediments containing *Globorotalia aemiliana* that were ascribed to the Piacenzian stage (Carboni & Iorio, 1997). Consequently, Carboni & Iorio (1997) have identified the Piacenzian in the boreholes of the Tiber River left bank and the Gelasian in the deposits from the right bank. Both of these deposits as well as the deposits at Monte delle Piche are covered by continental sediments, indicating the presence of an erosive phase (Carboni & Iorio, 1997).

In the sediments sampled from MPUR 1516, *Neogloboquadrina pachyderma* sinistral coiling was found. In the Mediterranean area, the first occurrence of *N. pachyderma* is dated to the Upper Gelasian (Iaccarino *et al.*, 2007). Consequently, it is possible to assign these deposits to an age close to or younger than the Gelasian, thus agreeing with the data of Carboni & Iorio (1997) for the Trastevere and Portuense adjacent areas. In addition, in the boreholes carried out in the surrounding areas, marine sediments from ages after the Gelasian are completely lacking (Carboni & Iorio, 1997); in contrast, an erosion surface is present (Carboni & Iorio, 1997). The presence of *Globoturborotalia woodi* (the last occurrence was during the upper Tortonian) in the sample MPUR 1515 and of *Globorotalia miozea* (the last occurrence was in the lower Tortonian) in the sample MPUR 1516 together with the presence of a hemimandible of *Acerorhinus* sp. (Pandolfi *et al.*, 2013b), indicates a reworking of Miocene elements. On the other hand, Carboni & Iorio (1997) also found reworked Mio-Pliocene foraminifera in the boreholes drilled in the Portuense, Trastevere, Valco San Paolo and EUR districts. Based on the collected samples, the marine

deposit of Monte delle Piche would correlates with the Gelasian. Nevertheless, the Monte delle Piche Member, which correlates the first half of the Calabrian, was established by Conato *et al.* (1980) on marine sediment outcropping in this locality. A late Early Pleistocene is therefore suggested for the sediment in which the rhinoceros specimens were collected. This is in agreement with the occurrences of *S. etruscus* in Italy. The length of M/1 and M/2 of the specimen MPUR 1516, as well as the dimensions of P/2 and P/3, are close to the maximal values of the species given by Guérin (1980) (Table 1) and would suggest a correlation with the first evolutionary stage of the species (Early-Middle Villafranchian, approximately correlated with the Late Piacenzian-Gelasian, Fig. 7); nevertheless, the proportion of the teeth resembles that of *S. hundsheimensis* given by Lacombat (2006) and of *S. etruscus* from Senèze (Fig. 5).

Conclusions

Several mammal remains have been collected in the area of Rome since the beginning of the XIX century. They are housed in the collections of the MPUR, but they usually lack any stratigraphic data.

In the present work, the mammalian remains collected at Monte delle Piche are revisited in order to define their stratigraphic provenance and chronological position.

Micropalaeontological analysis and stratigraphy suggest that there are two fossiliferous levels at Monte delle Piche:

- The younger level, in which *Hippopotamus* sp. and ostracods are recorded, is attributed to a time interval between approximately 0.9 and 0.6 Ma. This time span is represented by fluvial conglomerates and sands attributed to the Ponte Galeria Formation. *Hippopotamus* was present in Italy from the end of the Villafranchian to MIS 4/3.
- The older level, in which *S. etruscus* is recorded, is attributed to the second half of the Early Pleistocene; this age is supported by foraminiferal data (*Neogloboquadrina pachyderma* sinistral coiling) and by the biochronology of the Etruscan rhino. The latter species occurred in

Italy during the beginning of the Villafranchian, but it was more common during the late Villafranchian. It has never been reported in the Roman Basin where typical Villafranchian taxa are very rare (Caloi *et al.*, 1998; Di Stefano *et al.*, 1998). Indeed, only an isolated molar of *Mammuthus meridionalis* (recorded in Italy until the early Galerian; Gliozzi *et al.*, 1997; Petronio *et al.*, 2011) was previously reported in the Roman Basin, in a coastal marine deposit at Monte Mario (late Early Pleistocene) (Ponzi, 1878; Di Stefano *et al.*, 1998; Milli & Palombo, 2005; Kotsakis & Barisone, 2008; Cosentino *et al.*, 2009). Instead, typical Villafranchian taxa were collected around the Roman Basin in the lignite beds outcropping at Castel San Pietro (Rieti, Middle Villafranchian) and in a lacustrine deposit at Capena (about 40 km north of Rome, latest Villafranchian) (Tuccimei, 1891, 1893, 1898; Petronio, 1979; Kotsakis, 1988; Kotsakis & Barisone, 2008; Petronio *et al.*, 2011). The finding of rhinoceroses in the marine deposits at Monte delle Picche could be explained with a transportation from nearby land. The preserved status of the mandible of MPUR 1516 suggests a rapid and complete burial of the specimen; the bathymetric data given by ostracods and foraminifera indicate that the mandible was deposited far from the coast. Deposition in a marine environment followed by a rapid burial of the mandible of MPUR 1516 can be confirmed by the characteristics of the sediment encompassing the mandible. It appears as a hard crust that was only disaggregated in acetic acid, revealing an early diagenesis. This process can be attributed to a localised alkaline condition generated by decaying organic matter (i.e., the rhinoceros), which permitted the calcite precipitation and consequent cementation of the sediment (Bathurst, 1975).

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