

## NEW DATA ON THE LOWER PLEISTOCENE (GELASIAN) LIGNITE BEDS OF CASTEL SAN PIETRO (RIETI, CENTRAL ITALY)

LUCA PANDOLFI<sup>1\*</sup>, MARCO SPADI<sup>1</sup>, EDOARDO MARTINETTO<sup>2</sup>, TASSOS KOTSAKIS<sup>1</sup> & DANIELA ESU<sup>3</sup>

<sup>1\*</sup>Corresponding author. Dipartimento di Scienze, Università Roma Tre, Largo S. Leonardo Murialdo, 1-00146 Roma, Italy.  
E-mail: luca.pandolfi@uniroma3.it

<sup>2</sup>Dipartimento di Scienze della Terra, Università degli Studi di Torino, Via Valperga Caluso 35, I-10125 Torino, Italy.

<sup>3</sup>Dipartimento di Scienze della Terra, Sapienza Università di Roma, P.le A. Moro 5, 00185 Roma, Italy.

To cite this article: Pandolfi L., Spadi M., Martinetto E., Kotsakis T. & Esu D. (2017) - New data on the lower Pleistocene (Gelasian) lignite beds of Castel San Pietro (Rieti, Central Italy). *Riv. It. Paleontol. Strat.*, 123(2): 335-346.

**Keywords:** sedimentary basin; flora; ostracods; mollusks; mammals; paleoenvironment; biochronology; Villafranchian.

**Abstract.** A multiproxy study of the lignite-bearing lacustrine sequence cropping out at Castel San Pietro (CSP) (Rieti, central Italy) provides new insights on the paleoenvironmental evolution of an extensional basin, located on the Tyrrhenian side of the Apennine range. The CSP fossiliferous levels reflect deposition in a stable lacustrine environment. Mammal remains collected from this locality during the past centuries include *Stephanorhinus etruscus*, *Anancus arvernensis* and the beaver *Castor fiber*. The co-existence of the Etruscan rhinoceros and the mastodont suggests a middle Villafranchian age (Montopoli or Coste San Giacomo Faunal Unit) for the lignite beds of CSP. New paleoflora findings are in agreement with an attribution to the Piacenzian or Gelasian age for these deposits whilst the presence of the ostracod *Qinghaiocypris* cf. *Q. riojensis* suggests a time interval from Zanclean to Gelasian (between ~4.5 and ~1.8 Ma). Accordingly, the lignite beds of CSP most likely were deposited during the Gelasian (from ca. 2.5 to 1.8 Ma; from Montopoli to Coste San Giacomo FUs or possibly to Olivola FU) in forested area and warm and humid conditions.

### INTRODUCTION

During the Neogene-Quaternary transition climatic changes heavily affected flora and fauna in Eurasia. In correspondence of glacial-interglacial alternation linked to the onset of Northern Hemisphere Glaciation (NHG; ~2.7 Ma) (Salzmann et al. 2011; Dowsett et al. 2013; Haywood et al. 2013; Woodard et al. 2014), seasonality amplified and in Western Eurasia climates became generally drier and cooler (e.g., Joannin et al. 2007; Combourieu-Nebout et al. 2015). At the same time, Northern Europe was characterized by increasing aridity and more intense seasonality that caused a gradual replacement of the Neogene forests by tundra-like vegetation (Bredenkamp et al. 2002; Popescu et al. 2010). Also in northern Italy, this event corresponds to a local disappearance of woody plant taxa living in warm temperate and humid conditions (Martinetto et al. 2015). Paleoenvironments from central Italy allow us to assess the responses of flora and

fauna to climatic fluctuations in the central Mediterranean area (Petronio et al. 2011). Among other localities, the non-marine deposits of the Rieti Basin and middle Tiber valley of central Italy provide a notably preserved terrestrial record of continental and shallow marine conditions during the late Pliocene-Early Pleistocene (Mancini et al. 2007; Barisone et al. 2014). However, the chronological age (Gelasian or Calabrian) of these deposits is still debated among the researchers (see Cosentino & Fubelli 2008; Mancini et al. 2008) due to the absence of significant fossil records. Among the sites located along the middle Tiber valley, that of Castel San Pietro (CSP) is potentially very interesting for the presence of lignite beds containing large mammal remains and gastropods recorded during the end of the 1800's and the first half of the 1900's (Tuccimei 1889a, 1889b, 1891; Maxia 1949). CSP site corresponds to an old mine used for extraction of lignite beds in a thick clay succession located at 42°15'58"N, 12°43'04"E and 295 m a.s.l.

Accordingly, the CSP lignite beds are here investigated in order to:

Received: February 12, 2017; accepted: June 9, 2017

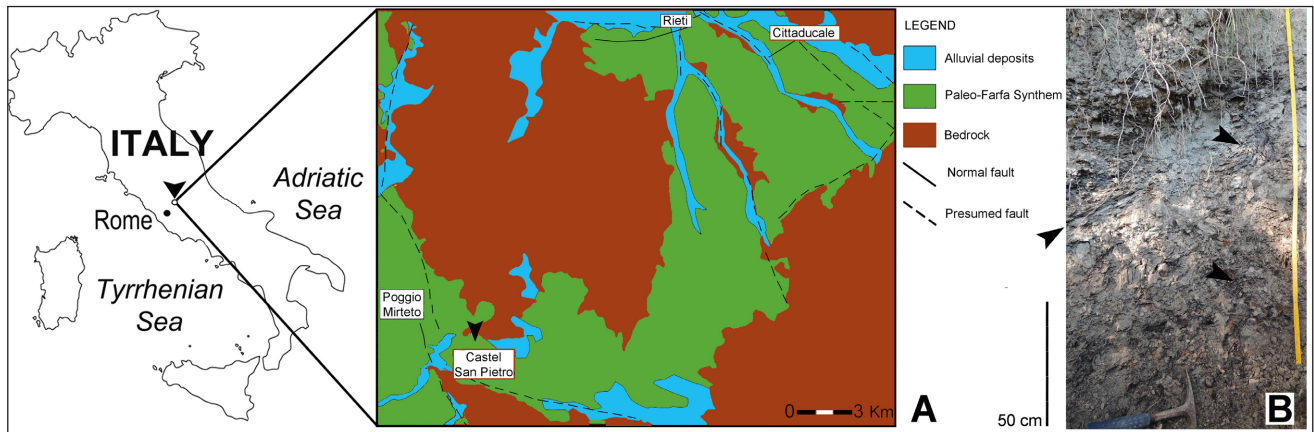


Fig. 1 - A) Location map of the Castel San Pietro lignite mine. B) Lignite beds (black arrows) cropping out at Castel San Pietro site.

(1) reevaluate the chronological position of the CSP deposits; (2) combine sedimentological data and the autecology of fauna and flora in order to reconstruct the paleoenvironment in the CSP area; (3) increase the knowledge of the Early Pleistocene of central Italy along the Tyrrhenian side of central Apennines.

## GEOLOGICAL SETTING AND STRATIGRAPHY

The fossiliferous deposits of CSP are located on the Tyrrhenian side of the central Apennines, 50 km NE of Rome, and are developed in a small area situated at the confluence of the middle valley of the Tiber River and the Rieti Basin (Fig. 1A). The latter is an extensional

tectono-sedimentary basin developed since the Pliocene and related to the extensional tectonics that affect the Apennine chain (Funciello & Parotto 1978; Faccenna et al. 1996). The final emplacement of these tectonic units was followed by regional uplift, that formed graben-type depressions generally parallel to the thrust fronts under prevailing NE-SE extensions (Cavinato & De Celles 1999).

The basin-fill succession unconformably overlying the bedrock has been recently described within a project of the Italian National Institute for Environmental Protection and Research (ISPRA); the unit was grouped into three synthems: Paleo-Farfa Synthem (late Pliocene-Gelasian), Rieti Basin Supersynthem and Farfa River Supersynthem (Middle Pleistocene-Late

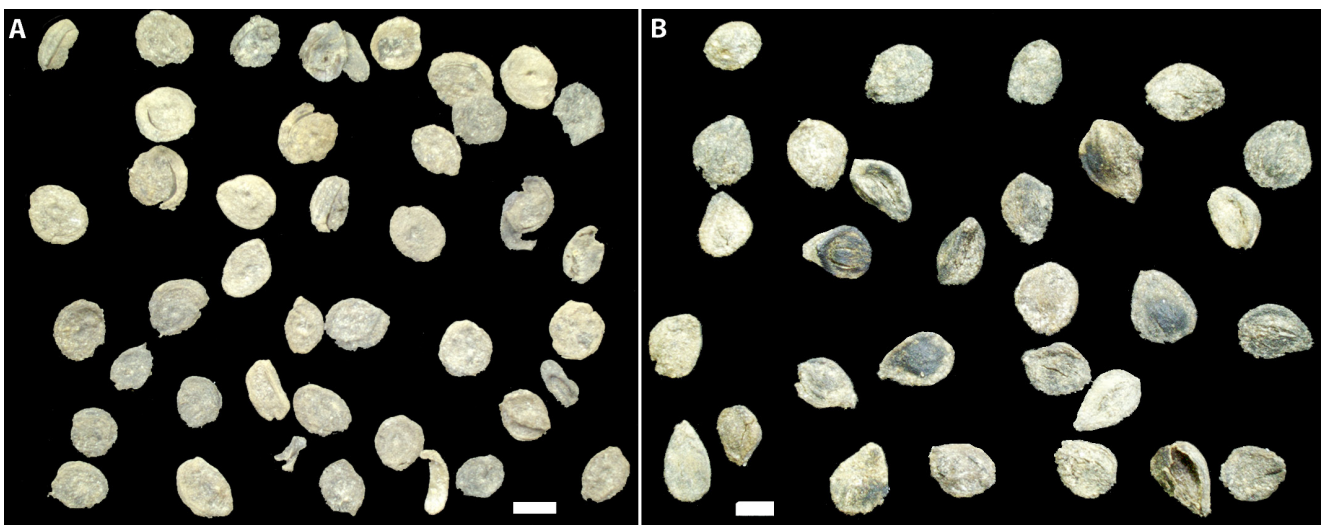
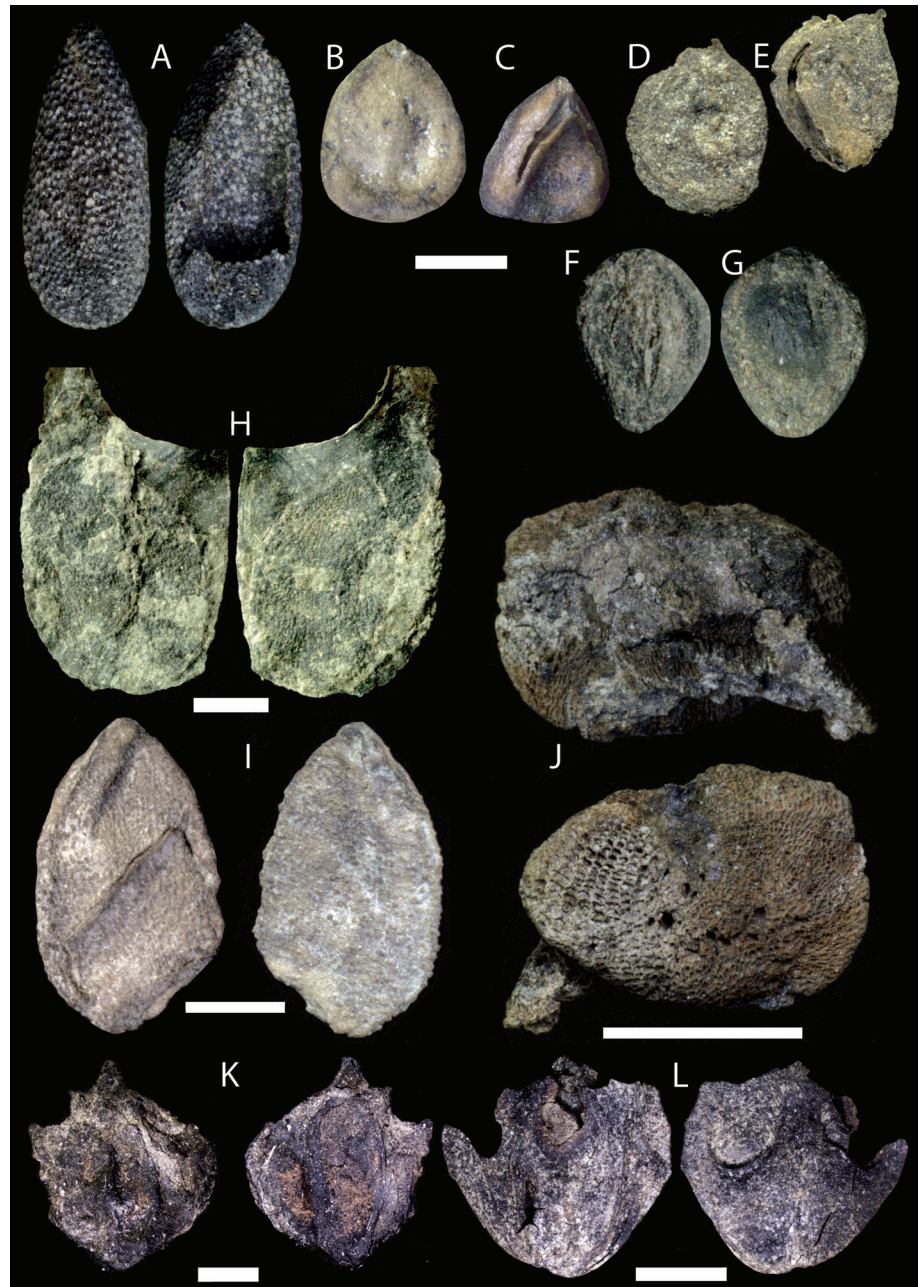


Fig. 2 - Fruit assemblages from CSP site, UMS, Italy, showing shape and size variation. A) *Potamogeton* cf. *P. polymorphus*, MGPT-PU105148. B) *Schoenoplectus isolepioides*, MGPT-PU105151. Scale bars = 0.5 mm.

Fig. 3 - Carpological remains from CSP site, UMS, Italy. A) *Actinidia faveolata*, damaged seed seen from both sides, MGPT-PU105154. B, C) *Decodon globosus* seeds, MGPT-PU105155, MGPT-PU105156. D, E) *Potamogeton* cf. *polymorphus*, endocarps, MGPT-PU105149, MGPT-PU105150. F, G) *Schoenoplectus isolepoides*, achenes, MGPT-PU105152, MGPT-PU105153. H) *Liriodendron geminata*, compressed fruit base with the pair of seeds well visible inside, seen from both sides, MGPT-PU105157. I) *Liriodendron geminata* seed from both sides, MGPT-PU105158. J) cf. *Eurya* seed with attached organic material and fragments of another seed, seen from both sides, MGPT-PU105159. K) *Pterocarya limburgensis*, split endocarp (damaged) seen from the external and internal side, MGPT-PU105160. L) *Pterocarya limburgensis* complete endocarp seen from both the flattened external sides, MGPT-PU105161. Scale bars, A-G = 0.5 mm, H-J = 1 mm, K-L = 2 mm.



Pleistocene) (Cosentino et al. 2014). The Paleofarfa Synthem is composed of several lithostratigraphic units mainly linked to a fluvial environment and its related settings. These units are, from the oldest to the youngest, Fosso Canalicchio Unit, Cenciara Unit, and Montasola Unit linked to slope and pedemontain areas; Ornaro Basso Unit and Monteleone Sabino Unit (UMS) related to a distal part of a fluvial area; and Torre Baccelli Unit connected to a marginal marine environment (Cosentino et al. 2014).

The fossiliferous CSP succession consists of a clay deposit with lignite beds within UMS (Fig. 1B). In particular, UMS is composed of sub-

horizontal beds of well-rounded, clast-supported conglomerates, with coarse to medium calcareous pebbles in a sandy matrix. Beds are up to 10 m thick and are characterized by trough and planar cross-bedding. There are also sandy-silty and clay levels including lignite lenses. The UMS belongs to a gravel-bed braided fluvial system, deposited in an unstable environment. This environment was most likely dominated by alluvial plain with presence of stable lakes and ephemeral ponds (Cosentino et al. 2014; Barisone et al. 2014). In this study, we report a new single section of about 1 meter thick clay with lignite lenses cropping out along stream-cuts near Castel San Pietro village.

Taxon	Part	Substrate water	Growth form	MAT indicat.	Moisture indicat.	Ex/n	Nr. Samples	Total abundance
<i>Actinidia faveolata</i>	seed	m	climber	>0.7 <24	MO	ex	2	2
<i>Alisma</i> sp.	fruit	h	herb	u		n	1	1
<i>Alnus glutinosa</i> -type	fruit	h	tree, broad-leaved	u		n	3	6
<i>Carex pendula</i> -type	fruit	h	herb	u		n	5	14
<i>Carex</i> subgen. <i>Vignea</i>	fruit	h	herb	u		n	1	1
cf. <i>Eurya</i>	seed	m	shrub?	u		ex	1	1
cf. <i>Viscum</i>	fruit bract	m	epiphyte	u		n	1	1
<i>Cladium</i> cf. <i>paleomariscus</i>	fruit	h	tall herb	u		n	3	8
<i>Decodon globosus</i>	seed	h	herb	u		ex	3	10
<i>Liriodendron geminata</i>	seed	m	tree, broad-leaved	>4 <22	MO	ex	3	3
<i>Pilea</i> sp.	fruit	m/h	herb	>1.8		ex	1	1
Pinaceae indet.	seed	m	tree	u		n	1	1
<i>Potamogeton</i> cf. <i>polymorphus</i>	fruit	a	herb	u		n	2	66
<i>Potamogeton</i> sp. 2	fruit	a	herb	u		n	2	3
<i>Potentilla pliocenica</i>	fruit	m/h	herb	u		n	1	1
<i>Pterocarya limburgensis</i>	endocarp	m/h	tree, broad-leaved	>3.1 <22	mo	ex	2	4
<i>Rubus</i> cf. <i>microspermus</i>	endocarp	m/h	herb/shrub/climber	u		n	1	1
<i>Schoenoplectus isolepioides</i>	fruit	h	herb	u		n	2	34
<i>Solanum</i> cf. <i>dulcamara</i>	seed	m/h	climber	u		n	1	1
<i>Tilia</i> sp.	fruit	m	tree, broad-leaved	u		n	1	1

Tab. 1 - List of the taxa recorded from paleocarpological analyses. Substrate water requirement: a) aquatic, h) hygrophilous, m) mesic. MAT (Mean Annual Temperature) indicators were obtained from Irace et al. (2017) and Martinetto et al. (2017), and synthetically expressed by the boundary values, e.g.: >13 = distribution of Nearest Living Relatives (NLRs) mainly in areas where the MAT is > 13°C; <14 = distribution of NLRs mainly in areas where the MAT is < 14°C; u) uncertain. Moisture indicators include: MO) typical elements of “moist” climate, not tolerating a Mean Annual Precipitation < 1000 mm/y; mo: elements of “moist” climate, also tolerating a Mean Annual Precipitation < 1000 mm/y; elements of “dry” climate are absent. Additional information about the modern distribution of the NLRs for each taxon is reported in the column “ex/n”, where “ex” means “exotic” (extra-European), “n” native.

## MATERIAL AND METHODS

Several samples were collected from the CSP site and were analysed for paleontological content. Unfortunately, the lignite mine was abandoned during the beginning of the second half of the 1900's; accordingly, the new samples were collected from the cropping out lignite beds; these may not be the same levels which yielded the large mammal remains. We considered all samples as collected from the same clay level. In total, more than 15 kg of sediment were soaked in a H<sub>2</sub>O<sub>2</sub> 5% solution for 24 hours, sieved with a 0.125 mm-mesh sieve and dried. Paleontological remains were handpicked under stereomicroscope and identified using the Nikon SMZ-U microscope. Ostracod, mollusk and carpological remains were recognized. In addition, valves of adult ostracods were studied using the Scanning Electron Microscope in LIME laboratories of Università di Roma TRE. The ostracod material and gastropod shells are stored at the Gliozzi Ostracod Collection (GOC), Department of Science, Università degli Studi di Roma Tre, mounts M354, M366 and M382. The carpological remains are stored in the Department of Earth Science, Università degli Studi di Torino (MGPT-PU). Mammal remains from the CSP lignite mine, have been collected during the first half of 1900's; the specimens mentioned by Maxia (1949) are currently housed at the Museo di Paleontologia, Sapienza, Università di Roma (MPUR).

## RESULTS

### Carpological remains

Mummified fruits and seeds were isolated from five sediment samples (Figs 2, 3). The carpological assemblage is quantitatively dominated

by aquatic (*Potamogeton*: Fig. 2A) and/or emergent aquatic/hygrophilous (*Carex pendula*-type, *Cladium*, *Decodon*, *Schoenoplectus*: Fig. 2B) plants. These indicate a waterlogged environment with shallow freshwater, mostly covered by dense vegetation (as also indicated by lignite accumulation). The woody plant component is documented by the possibly autochthonous (due to complete delicate infructescences found in four out of five samples) hygrophilous tree *Alnus* and by a few wind-transported (*Liriodendron*, *Pterocarya*, *Tilia*) or animal-transported (*Actinidia*, cf. *Eurya*, *Rubus*) disseminules originating from mesophytic environments (Fig. 3; Tab. 1).

### Mollusks

Tuccimei (1889a) reports a list of fourteen species of mollusks (eleven gastropods and three bivalves) collected in CSP lignite mine: “*Helix* (*Macularia*) *vermicularia*, *Helix* (*Tachea*) *sabina*, *Carychium* *minimum*, *Ancylus* (*Velletia*) *lacustris*, *Lymnaea* (*Gulnaria*) *auricularia*, *Planorbis* (*Spirodiscus*) *corneus* [= *Planorbarius* *corneus*], *Planorbis* (*Gyraulus*) *rossmaessleri* [= *Gyraulus* *rossmaessleri*], *Bythinia* *tentaculata*, *Vivipara* *ampullacea*, *Valvata* *piscinalis*, *Valvata* *bronni*, *Unio* *batavus*, *Anodonta* cfr. *bronni*, *Pisidium* *amnicum*”. In a second publication of the same year Tuccimei

Fig. 4 - Mollusks from CSP site, UMS, Italy. A) *Planorbis planorbis* M382/1/3. B) *Carychium tridentatum*, M382/3/2. C) *Platyla* sp., M382/1/2. D) *Bithynia* sp. operculum, M382/2/2. E) *Viviparus* sp., M382/3/1. F) *Acanthinula aculeata*, M382/1/1. G) *Vitrea* sp., M382/2/3. Scale bar = 1 mm.

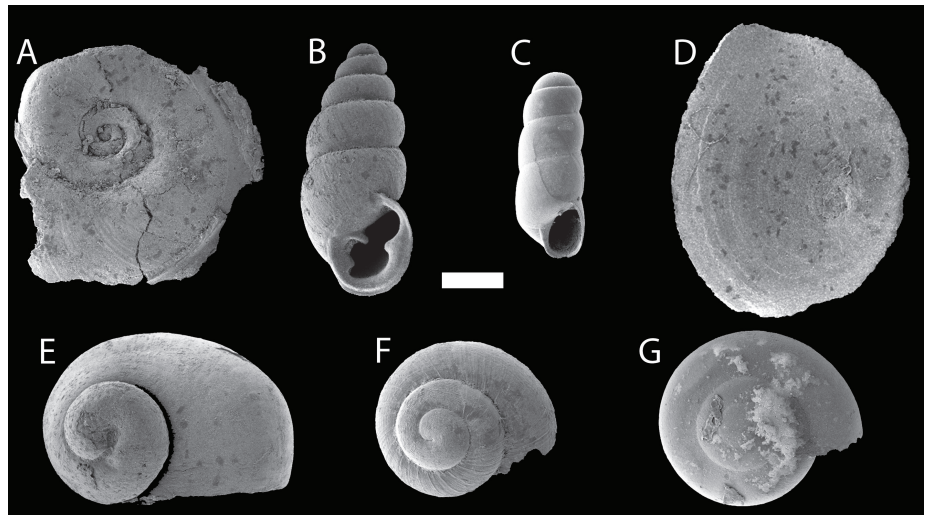
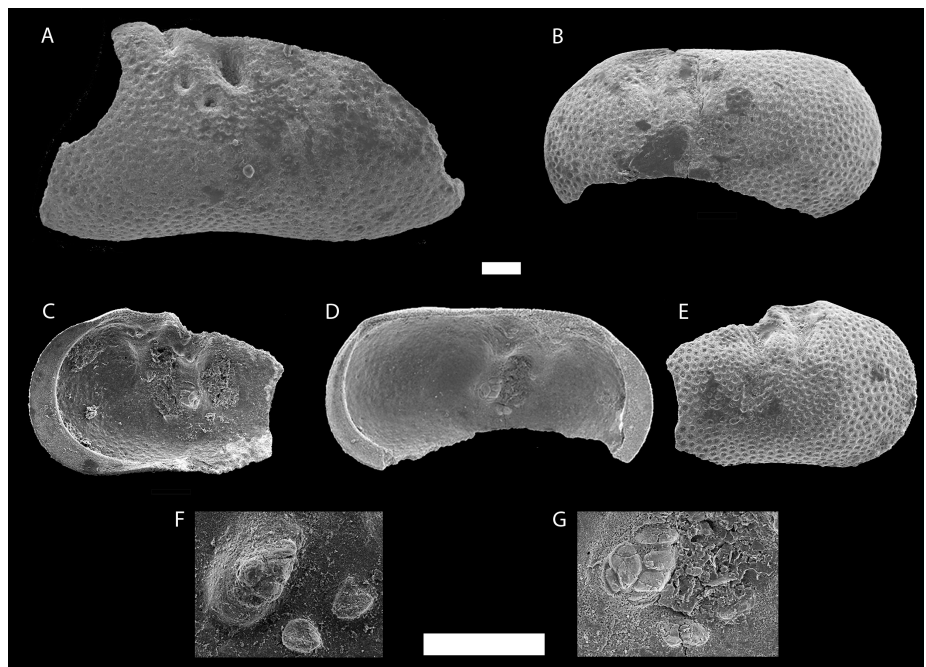


Fig. 5 - Ostracods from CSP, UMS, Italy. A-G) *Qinghaicypris* cf. *Q. riojensis*. A - Lateral view of a left female valve, M366/1/1. B - Lateral view of a left juvenile female valve, M366/1/3. C - Lateral inner view of a right juvenile female valve, M366/1/2. D - Lateral inner view of a left juvenile female valve, M366/1/3, illustrated in B. E - Lateral external view of a right juvenile female valve, M366/1/2, illustrated in C. F - Detail of central muscle scars in inner view of a left female valve, M366/1/1, illustrated in A. G - Detail of central muscle scars in inner view of a left juvenile female valve, M366/1/3, illustrated in B. Scale bars = 100  $\mu$ m, upper one for A-E and lower one for F-G.



(1889b), mentioned the presence in the same site of another gastropod species "*Glandina lunensis*". Following Esu & Girotti (1975), the freshwater gastropod *Planorbarius cornu heriacensis* is present at CSP (specimen of the coll. Tuccimei, MPUR, Museo di Paleontologia Università Sapienza di Roma); however, the bad preservation of the single available specimen does not allow a specific attribution.

A poor non-marine mollusk assemblage, mainly composed of fragmentary specimens, has been recovered from the new samples collected at CSP succession (Fig. 4). The poor preservation of the shells prevented the identification to the species level for many specimens. Eight taxa of freshwater and terrestrial gastropods have been recognized: *Viviparus* sp. (apex), opercula of *Bithynia* sp., *Ancylus*

*fluviatilis*, *Planorbis planorbis*, *Carychium* cf. *tridentatum*, *Platyla* sp., *Acanthinula aculeata* and *Vitrea* sp. (Fig. 4). Among the taxa reported by Tuccimei (1889a, b), only four genera *Viviparus*, *Bithynia*, *Ancylus* and *Carychium* (but not the same species) have been recorded from the studied fossiliferous layers.

### Ostracods

Ostracods are scarce and fragmentary in the material from CSP site (Fig. 5). The entire ostracod association is composed by fragmented valves of Ilyocyprididae and few valves of Candoninae juveniles. Ilyocyprididae species present all characters of the genus *Qinghaicypris*, revised by Yang et al. (2004) and by Rodríguez-Lázaro & Martín-Rubio (2005) (Fig. 5). Species assignment is difficult due to the

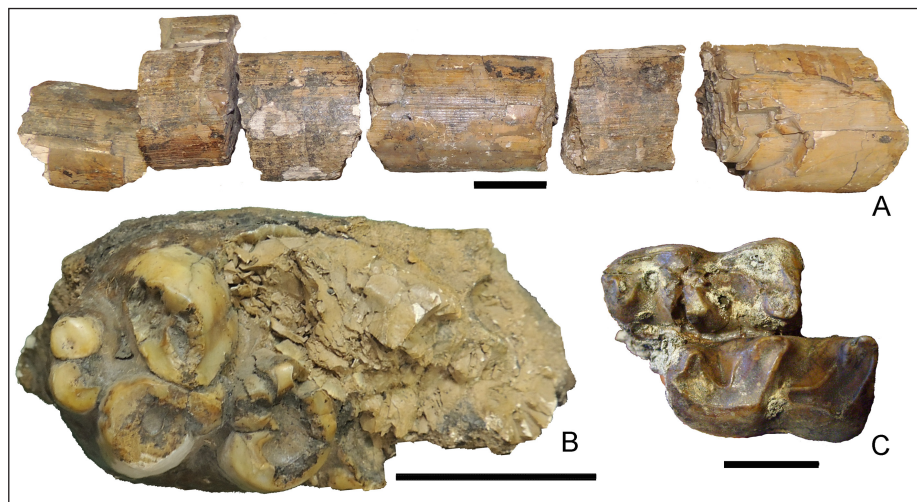


Fig. 6 - Mammal remains collected at Castel San Pietro lignite mine housed at MPUR; historical collection. A) Fragmentary tusk of *Anancus arvernensis*. B) Damaged lower molar of *Anancus arvernensis*. C) Fragmentary mandible with dp3s of juvenile *Stephanorhinus etruscus*. Scale bar = 5 cm for A-B; 2 cm for C.

scarcity of material but the comparisons permitted to assign the ostracod material to *Qinghaicypris* cf. *Q. riojensis* (Fig. 5). Its presence in the CSP site represents the first record of this species in Italy.

### Mammals

Mammal remains from the lignite mine of CSP have been collected since the end of the 1800's. Tuccimei (1889a, 1889b, 1898) reported the presence of *Rhinoceros etruscus* (recte *Stephanorhinus etruscus*, see Pandolfi et al. 2015), *Cervus* sp. (= Cervidae indet., Petronio et al. 2002), *Bos* sp. (= *Leptobos* sp., Petronio et al. 2002) and *Castor fiber*. Unfortunately, a lot of the specimens recorded by Tuccimei (1889a, 1889b) were stored at the Istituto Tecnico di Poggio Mirteto and were destroyed during World War II (A. Banchelli, pers. comm. December 2015), whilst remains of *C. fiber* were housed at Istituto Sant'Apollinare at Rome, but have never been revised. Barisone et al. (2006) assigned the beaver specimens figured by Tuccimei (1891: Pl. V, fig. 2-3) to *Castor fiber plicidens*, but this assignment is doubtful. According to Tuccimei (1898), some remains of cervids, and probably also bovids and rhinoceroses were stored at the Istituto Sant'Apollinare in Rome (Tuccimei 1898), but they seem to be currently inaccessible (visit by T.K and L.P.). Scant and fragmentary remains of *Hippopotamus* from the surroundings of Castel San Pietro have been cited by Meli (1882), and later reported by Tuccimei (1891). It is unclear if they have been collected from the lignite mine. The location of these remains is currently unknown and they have been probably lost. With respect to other specimens (except *C. fiber*), only two teeth (lower molars) of rhinoceros were figured in occlusal view

by Tuccimei (1891: Pl. IX, figs. 3-4). Accordingly, these remains cannot be evaluated for an accurate taxonomic identification. Maxia (1949) recorded the occurrence of *Anancus arvernensis* and *S. etruscus* from the lignite beds of CSP. The specimens collected by Maxia (1949) are housed at MPUR and include a fragmentary mandible, part of a lower molar and fragments of tusk of a mastodon (Fig. 6A-B) and a fragment of a rhinoceros mandible with two deciduous teeth (Fig. 6C; Pandolfi et al. 2015: fig. 3B). A fragmentary mandible of *Tapirus arvernensis* housed at MPUR was usually supposed to derive from CSP suggesting a Pliocene age for the locality of the discovery (Azzaroli 1980; Kotsakis 1986). A careful analysis of the fossil records of tapir in Italy and the cross check of several bibliographic sources revealed that this tapir specimen was instead discovered at Spoleto (Pandolfi & Kotsakis 2017).

## DISCUSSION

### Biochronology

According to Pandolfi and Marra (2015) and Pandolfi et al. (2016), the first occurrence of *Stephanorhinus etruscus* in Italy is at the Pliocene-Pleistocene transition, during the Montopoli FU (= Faunal Unit). This species occurred in Italy during the whole of the Early Pleistocene (Pandolfi & Marra 2015; Pandolfi et al. 2016; Pandolfi & Erten, 2017). The mastodon *Anancus arvernensis* is recorded during the Pliocene and the Early Pleistocene in Italy. The species is documented at Villafranca d'Asti, Montopoli, Coste San Giacomo and several other localities (among others Sismonda 1851; Tuccimei 1891;

Capellini 1907; Gliozzi et al. 1997; Petronio et al. 2011; Bellucci et al. 2012), spanning from Triversa to Coste San Giacomo FUs. Fossil evidence suggests that *A. arvernensis* became extinct at the beginning of the late Villafranchian, Olivola FU (Palombo et al. 2002; Palombo & Ferretti 2005; Rook & Martínez-Navarro 2010). However, Zanchetta & Mazza (1996) reported a fragmentary skeleton of *A. arvernensis* at Monte Castello (Lower Valdarno, Pisa), suggesting an age close to the Gelasian-Calabrian transition and Rook et al. (2013) did not exclude the presence of the mastodon in the Olivola FU based on uncertain stratigraphic provenance of some fossils collected in the Upper Valdarno Basin. The importance given by Tuccimei (1899a, 1891) to the beaver as a biochronological marker is now discarded (Barisone et al. 2006). Remains of Bovidae, Cervidae and ?Hippopotamidae from CSP (Meli 1882; Tuccimei 1889a, 1889b, 1891, 1898) were not figured or described and it is impossible to give a precise systematic attribution for these taxa.

Accordingly, the coexistence of *A. arvernensis* and *S. etruscus* at Castel San Pietro suggests an age for this site spanning from Montopoli to Coste San Giacomo FUs (Early Pleistocene), although a slightly younger age (Olivola FU) cannot be ruled out.

The same age is suggested by the carpological remains. From the biochronological point of view, the relevant occurrences are those of several Neogene taxa that got extinct in Europe during the Pliocene and Pleistocene: *Actinidia faveolata*, *Decodon globosus*, cf. *Eurya*, *Liriodendron geminata*, *Potentilla pliocenica*, *Pterocarya limburgensis*, and *Schoenoplectus isolepioides*. Among these, *Schoenoplectus isolepioides* has so far been detected only in the Piacenzian (Irace et al. 2017), whereas *Actinidia faveolata* is rarely reported also in the Gelasian (Tiglian), even in central Europe. An important finding is represented by cf. *Eurya*, a seed type similar to *Eurya stigmosa*. This species is common in the Zanclean, and rare in the Piacenzian, and the last occurrence is represented by a single seed in a layer (AD3) of the Arda section (Emilia-Romagna, northern Italy; Martinetto et al. 2015). This layer was assigned to the Gelasian (Martinetto et al. 2015), even if recent studies suggest an attribution to the Calabrian (Crippa et al. 2016; Monesi et al. 2016). The seed found in CSP is surely related to *Eurya* but the cell pattern looks different from that of *Eurya stigmosa*, and further research is

needed to clarify the possible relations to other genera of the Pentaphragmaceae (*Visnea*?), a family that was very common in Europe during the Eocene-Miocene, but got extinct in the late Cenozoic, with a single species (*Visnea mocanera*) persisting on the Canary Islands (Weitzman et al. 2004).

At the present state, when considering that central Italy was certainly a refuge area for humid thermophilous plants in the Pliocene-Pleistocene (Martinetto 2001; Martinetto et al. 2017), the indications of the CSP paleoflora are for a Piacenzian or Gelasian age.

These data are in agreement with palynomorphs found in a section 500 meters southwest of the Torre Baccelli power plant (~ 1 km southwestern of CSP), consisting of silts and clayey silts comprised in UMS. These palynomorphs consist of several elements that persist in central Italy until the Gelasian (Barisone et al. 2014), in particular *Symplocos*, *Nyssa* and tricolpate Hamamelidaceae (*Hamamelis*, *Distylium*). Fruit findings would be required to assess if the type of *Symplocos* documented by pollen may belong to *Symplocos* sect. *Lodhra*, a member of the “humid thermophilous plant taxa of East Asian affinity” group defined by Martinetto et al. (2017), which is otherwise missing in the CSP deposits. This group is characteristic of the Zanclean-Piacenzian in northern Italy and the rest of Europe, whereas it is reported after the Northern Hemisphere Glaciation starting (~2.7 Ma) only in central Italy, where it probably found a humid and mild refuge to overcome the cooling and precipitation decrease occurred during this event. Actually, the presence of several Neogene taxa (*Actinidia faveolata*, cf. *Eurya*, *Potentilla pliocenica*, *Schoenoplectus isolepioides*) in central Italy is a typical feature of Piacenzian and Gelasian sites (see Martinetto 2001; Martinetto et al. 2014).

The ostracod genus *Qinghaicypris* is distributed from the early Messinian of Baccinello-Cinigiano Basin (Tuscany, central Italy) (Ligios 2009; Ligios et al. 2012) to the Early Pleistocene (Gelasian) of southern Europe and China (Rodríguez-Lázaro & Martín-Rubio, 2005). In particular *Q. riojensis* is surely described from Pliocene (Piacenzian) deposits of the Ebro Basin (northern Spain) (Rodríguez-Lázaro & Martín-Rubio 2005) and Paludonian Beds (Lower and post-Paludonian Beds) of Serbia (Krstić 2006). Recent revision of Neogene and Quaternary deposits of Lake Slavonia (mainly Croatia

and Serbia) permits to define that Lower to post-Paludinic beds to Cernikian corresponding to a time interval from Zanclean to Gelasian (between ~4.5 and ~1.8 Ma) (Mandic et al. 2015). Accordingly, the presence of ostracod species related to *Qinghaicypris* cf. *Q. riojensis* in the CSP points to a maximum age deposition within the Gelasian (Rodríguez-Lázaro & Martín-Rubio 2005).

All the recorded mollusk species are wide ranging during the Quaternary in Europe, including Italy. At present, they are still extant in Europe reaching West Asia, and, except for *P. planorbis*, North Africa (Ložek 1964; Welter-Schultes 2012).

### Paleoenvironmental and paleoecological observations

Generally, woody plant taxa living in warm temperate and humid conditions persisted in central Italy until the end of the Gelasian (~1.8 Ma). Only extreme glacial peaks affected central Italy with development of steppe-like conditions, as suggested by pollen data (Pontini & Bertini 2000; Russo Ermolli et al. 2010; Petronio et al. 2011). During the Early Pleistocene, high Mean Annual Temperature (MAT) and Mean Annual Precipitation (MAP), similar to those recorded during the Zanclean, characterized the interglacial cycles in central Italy, whilst during the glacial phases the MAT and MAP were close to modern values (Bertini 2000; Szabó et al. 2017).

Monteleone Sabino Unit (UMS) deposits represent the upper part of Paleo-Farfa Synthem along the Rieti Basin and its junction with the middle Tiber valley. The main lithology of this unit is related to fluvial deposition. Cosentino et al. (2014) accurately described the facies variation within UMS and devised a general southern drainage. The Paleo-Farfa river flowed in the opposite direction compared to the current one, principally in a braided plain dominated by coarse transport. CSP lignite and fine-grained deposits can be associated to lateral variations of this general setting.

Sedimentological analysis of the UMS shows deposition on a floodplain separated by swamp and lacustrine areas (Cosentino et al. 2014); the CSP sequence was deposited in an environment similar to the latter. Due to the presence of ostracods (*Q.* cf. *Q. riojensis*), mollusks (*Viviparus* sp., *Bithynia* sp. [opercula], *A. fluviatilis*, *P. planorbis*), and freshwater macrophyte flora (*Potamogeton*,

*Cladium*, *Decodon*, *Schoenoplectus*), we conclude that the CSP site was occupied by a freshwater lake or pond where lignite deposition was enhanced.

The occurrence in more than one sample of *Liriodendron*, *Pterocarya* and *Actinidia* suggests that these mesic to meso-hygrophilous plants grew not far from the waterlogged sedimentary environment: it also rules out an hypothetical reworking of their remains from older deposits. Conversely, the ten taxa represented by single remains could represent: 1) allochthonous plants the fruits/seeds of which reached the lake due to episodic events; 2) rare autochthonous plants; 3) autochthonous plants producing a few fruits/seeds.

Carpological remains suggest that the lignite beds of the CSP section were deposited during a humid and warm temperate climate interval, while ostracod and mollusk remains suggest that the lignite beds most probably were deposited in a lacustrine-swampy environment characterized by flowing waters. Among the mollusks, the freshwater *A. fluviatilis* lives in flowing waters and occasionally on rocks in the marginal wash-zone of lakes, requiring clear waters; *Viviparus* sp. and *P. planorbis* inhabit all kinds of well-vegetated aquatic habitats of lowland, such as slow rivers, lakes, and closed ponds. *P. planorbis*, which is the most abundant in the assemblage, prefers swampy environment liable to dry up periodically (Kerney 1999; Welter-Schultes 2012). The terrestrial *C. tridentatum*, *A. aculeata* and *Vitrea* sp. are characteristic of woods and damp grasslands or moderately moist places, requiring permanent humid conditions (Kerney & Cameron 1979; Welter-Schultes 2012).

The occurrence of the opercula only - without shells - of the slow-moving freshwater *Bithynia* sp. points to a transport of the material.

The autoecological characteristics of *Q. riojensis* inferred by Rodríguez-Lázaro & Martín-Rubio (2005) and by Krstić (2006) indicate that the fossil ostracod assemblage recovered in CSP represents a thanatocoenosis in a stable lacustrine environment.

The presence of *A. arvernensis* provides information supporting a humid climate with woodlands. Indeed, bunodont dentition of *A. arvernensis* suggests a browser feeding (leaves, fruits and twigs) (Kahlke et al. 2011). In addition, mastodon walking-adaptation on soft soil implies a moist forest habitat for this species (Rivals et al. 2015).



According to Guérin (1980), *S. etruscus* was related to humid climates and its hypsodonty was rather similar to those of the extant *Dicerorhinus sumatrensis* and *Rhinoceros sondaicus* suggesting a similar diet. According to Fortelius et al. (1993), *S. etruscus* was a long-limbed rhinoceros browsing on vegetation of intermediate height in predominantly open habitats. The paleoecology of these mammal species is in agreement with the paleoenvironment inferred by the paleoflora.

## CONCLUSIONS

The Pliocene-Lower Pleistocene of middle Tiber valley and Rieti Basin deposits have been the subject of several studies to determine their age which is still under debate (see Mancini et al. 2007, 2008; Cosentino & Fubelli 2008).

New paleontological findings from the CSP site, coupled with the previously reported and re-studied mammalian fauna, point to an age referable to the Gelasian (from Montopoli to Coste San Giacomo FUs or possibly Olivola FU).

Fossil flora and fauna suggest deposition of the CSP fossiliferous layers on a plain, which was crossed by a low-energy channel system disjointed by lacustrine and swampy areas in a general coarse-deposition fluvial system. The deciduous and humidity-requiring woody plant taxa (*Actinidia*, *Alnus*, *Liriodendron*, *Pterocarya*) of the CSP site show that the Early Pleistocene (Gelasian) paleoenvironment in central Italy was dominated by a humid climate with forested areas as also testified by records from other localities (see Martinetto 2001; Martinetto et al. 2014).

The macroflora includes five definitely extinct species plus three possibly extinct species, exclusively reported from Europe, and only three uncertainly identified species (*Alnus glutinosa*-type, *Carex pendula*-type, *Solanum* cf. *dulcamara*) that may still grow today in the studied area. East Asia is the only territory where the nearest living relatives of all five extinct species still persist.

Paleoclimate and paleoenvironmental conditions inferred from the CSP during the Early Pleistocene confirm that the the climate at the onset of NHG in the central Mediterranean was more humid and temperate than in other parts of Europe.

*Acknowledgements.* We thank J. Kovar-Eder, an anonymous reviewer and the editor I. Mazzini for their suggestions.

We thank M.R. Palombo, Director of the MPUR, for granting us access to the studied mammal material, C. Petronio (Sapienza, Università di Roma) and A. Banchelli (geologist, Poggio Mirteto) for useful information. The microphotography of plant remains has been carried out with the help of the Vertebrate Palaeontology group of the Turin University, and we thank particularly A. Villa. LP thanks the European Commission's Research Infrastructure Action, EU-SYNTHESYS project AT-TAF-2550, DE-TAF-3049, GB-TAF-2825, HU-TAF-3593, ES-TAF-2997; part of this research received support from the SYNTHESYS Project <http://www.synthesys.info/> which is financed by European Community Research Infrastructure Action under the FP7 "Capacities" Program.

## REFERENCES

- Azzaroli A. (1980) - I mammiferi fossili del Pliocene. In: AA.VV. I vertebrati fossili italiani, Catalogo della Mostra, Verona, 195-198.
- Barisone G., Argenti P. & Kotsakis T. (2006) - Plio-Pleistocene evolution of the genus *Castor* (Rodentia, Mammalia) in Europe: *C. fiber pligidens* of Pietrafitta (Perugia, Central Italy). *Geobios*, 39: 757-770.
- Barisone G., Esu D., Gliozzi E., Kotsakis T. & Pontini M.R. (2014) - Inquadramento biocronologico e paleoambientale dei depositi plio-pleistocenici. In: Cosentino et al. (Eds) - Note illustrative della Carta Geologica d'Italia alla scala 1:50.000, Foglio 357 - Cittaducale: 109-117, ISPRA-Servizio Geologico d'Italia.
- Bellucci L., Mazzini I., Scardia G., Bruni L., Parenti F., Segre A. G. & Naldini E. S. (2012) - The site of Coste San Giacomo (Early Pleistocene, central Italy): Paleoenvironmental analysis and biochronological overview. *Quaternary Intern.*, 267: 30-39.
- Bertini A. (2000) - Pollen record from Colle Curti and Cesi: early and middle Pleistocene mammal sites in the Umbro-Marchean Apennine mountains (central Italy). *J. Quaternary Sci.*, 15: 825-840.
- Bredenkamp G.J., Spada F. & Kazmierczak E. (2002) - On the origin of northern and southern hemisphere grasslands. *Plant Ecol.*, 163: 209-229.
- Capellini G. (1907) - Mastodonti del Museo Geologico di Bologna. *Mem. R. Accad. Sci. Ist. Bologna*, ser. 6, 4: 63-81.
- Cavinato G. P. & De Celles P.G. (1999) - Extensional basins in the tectonically bimodal central Apennines fold-thrust belt, Italy: response to corner flow above a subducting slab in retrograde motion. *Geology*, 27: 955-958.
- Combourieu-Nebout N., Bertini A., Russo-Ermolli E., Peyron O., Klotz S., Montade V., Fauquette S., Allen J.R.M., Fusco F., Goring S., Huntley B., Joannin S., Lebreton V., Magri D., Martinetto E., Orain R. & Sadori L. (2015) - Climate changes in the central Mediterranean and Italian vegetation dynamics since the Pliocene. *Rev. Palaeobot. Palynol.*, 218: 127-147.
- Cosentino D. & Fubelli G. (2008) - Comment on: "Geomorphological, paleontological and <sup>87</sup>Sr/<sup>86</sup>Sr isotope analyses of early Pleistocene paleoshorelines to define the

- uplift of Central Apennines (Italy)?" *Quaternary Res.*, 69: 163-164.
- Cosentino D., Miccadei E., Barberi R., Basilici G., Cipollari P., Parotto M. & Piacentini T. (2014) - Note illustrative della Carta Geologica d'Italia alla scala 1:50.000, Foglio 357-Cittaducale. ISPRA-Servizio Geologico d'Italia, 143 pp.
- Crippa G., Angiolini L., Bottini C., Erba E., Felletti F., Frigerio C., Hennissen J.A.I., Leng M.J., Petrizzo M.R., Raffi I., Raineri G. & Stephenson M.H. (2016) - Seasonality fluctuations recorded in fossil bivalves during the early Pleistocene: implications for climate change. *Palaeogeogr., Palaeoclimatol., Palaeoecol.*, 446: 234-251.
- Dowsett H.J., Foley K.M., Stoll D.K., Chandler M.A., Sohl L.E., Bentsen M., OttoBliesner B.L., Bragg F.J., Chan W.L., Contoux C., Dolan A.M., Haywood A.M., Jonas J.A., Jost A., Kamae Y., Lohmann G., Lunt D.J., Nisançioğlu K.H., AbeOuchi A., Ramstein G., Riesselman C.R., Robinson M.M., Rosenbloom N.A., Salzmann U., Stepanek C., Strother S.L., Ueda H., Yan Q. & Zhang Z.S. (2013) - Sea surface temperature of the mid-Piacenzian ocean: a data-model comparison. *Sci. Rep.*, 3(2013): 1-8.
- Esu D. & Girotti O. (1975) - La malacofauna continentale del Plio-Pleistocene dell'Italia centrale. I: Paleontologia. *Geol. Romana*, 13: 203-293.
- Faccenna C., Davy P., Brun J.-P., Funicicello R., Giardini D., Mattei M. & Nalpas T. (1996) - The dynamics of back-arc extension: an experimental approach to the opening of the Tyrhenian Sea. *Geophys. J. Int.*, 126: 781-795.
- Fortelius M., Mazza P. & Sala B. (1993) - *Stephanorhinus* (Mammalia: Rhinocerotidae) of the western European Pleistocene, with a revision of *S. etruscus* (Falconer, 1868). *Palaeontogr. Ital.*, 80: 63-155.
- Funicicello R. & Parotto M. (1978) - Il substrato sedimentario nell'area dei Colli Albani: considerazioni geodinamiche e paleogeografiche sul margine tirrenico dell'Appennino centrale. *Geol. Romana*, 17: 233-287.
- Gliozzi E., Abbazzi L., Argenti P., Azzaroli A., Caloi L., Cappasso Barbato L., Di Stefano G., Esu D., Ficarelli G., Girotti O., 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. It. Paleontol. Strat.*, 103: 369-388.
- Guérin C. (1980) - Les rhinocéros (Mammalia, Perissodactyla) du Miocène terminal au Pléistocène supérieur en Europe occidentale. *Docum. Lab. Géol. Univ. Lyon*, 79: 1-1185 (3 volumes).
- Haywood A.M., Hill D.J., Dolan A.M., Otto-Bliesner B.L., Bragg F., Chan W.L., Chandler M.A., Contoux C., Dowsett H.J., Jost A., Kamae Y., Lohmann G., Lunt D.J., Abe-Ouchi A., Pickering S.J., Ramstein G., Rosenbloom N.A., Salzmann U., Sohl L., Stepanek C., Ueda H., Yan Q. & Zhang Z. (2013) - Large-scale features of Pliocene climate: results from the Pliocene model intercomparison project. *Clim. Past.*, 9: 191-209.
- Irace A., Monegato G., Tema E., Martinetto E., Gianolla D., Vassio E., Bellino L., Violanti D. (2017) - Unconformity-bounded stratigraphy in the Plio-Pleistocene continental record: new insights from the Alessandria Basin (NW Italy). *Geol. J.*, 52: 177-206.
- Joannin S., Quillévéré F., Suc J.-P., Lécuyer C. & Martineau F. (2007) - Early Pleistocene climate changes in the central Mediterranean region as inferred from integrated pollen and planktonic foraminiferal stable isotope analyses. *Quaternary Res.*, 67: 264-274.
- Kahlke R.-D., García N., Kostopoulos D.S., Lacombe F., Lister A.M., Mazza P.P.A., 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. *Quaternary Sci. Rev.*, 30: 1368-1395.
- Kerney M. (1999) - Atlas of the land and freshwater molluscs of Britain and Ireland. Harley Books, Colchester, 272 pp.
- Kerney M.P. & Cameron R.A.D. (1979) - A field guide to the land snails of Britain and Northwest Europe. Collins, London, 288 pp.
- Kotsakis T. (1986) - Elementi di paleobiogeografia dei mammiferi terziari dell'Italia. *Hystrix*, 1: 25-68.
- Krstić N. (2006) - Pliocene ostracodes of the Paludonian beds in Pannonian Plain, Serbian part. *Glasn. Prirod. Mus. Beogradu*, Spec. Issue, 1: 1-509.
- Ligos S. (2009) - Studio sistematico delle ostracofaune dulcicole e salmastre dell'area mediterranea nel Miocene superiore pre-evaporitico: implicazioni biocronologiche e paleobiogeografiche. Unpublished PhD Thesis, Università degli Studi di Roma Tre, 255 pp.
- Ligos S., Anadón P., Castorina F., D'Amico C., Esu D., Gliozzi E., Gramigna P., Mola M. & Monegato G. (2012) - Ostracoda and Mollusca biodiversity and hydrochemical features of Late Miocene brackish basins of Italy. *Geobios*, 45: 351-367.
- Ložek V. (1964) - Quartärmollusken der Tschechoslowakei. *Rozpr. Ustr. Ust. Geol.*, 31: 1--368.
- Mai D.H. & Walther H. (1988) - Die pliozänen Floren von Thüringen, Deutsche Demokratische Republik. *Quartärpaläontologie*, 7: 55-297.
- Mancini M., D'Anastasio E., Barbieri M. & De Martini P. M. (2007) - Geomorphological, paleontological and <sup>87</sup>Sr/<sup>86</sup>Sr isotope analyses of early Pleistocene paleoshorelines to define the uplift of Central Apennines (Italy). *Quaternary Res.*, 67: 487-501.
- Mancini M., D'Anastasio E., Barbieri M. & De Martini P. M. (2008) - Invited reply to the Comment on: "Geomorphological, paleontological and <sup>87</sup>Sr/ <sup>86</sup>Sr isotope analyses on early Pleistocene paleoshorelines to define the uplift of Central Apennines (Italy)". *Quaternary Res.*, 69: 165-167.
- Mandic O., Kurecic T., Neubauer T.A. & Harzhauser M. (2015) - Stratigraphic and palaeogeographic significance of lacustrine molluscs from the Pliocene *Viviparus* beds in central Croatia. *Geol. Croat.*, 68: 179-207.

- Martinetto E. (2001) - The role of central Italy as a centre of refuge for thermophilous plants in the late Cenozoic. *Acta Palaeobot.*, 41: 299-319.
- Martinetto E., Monegato G., Irace A., Vaiani S.C. & Vassio E. (2015) - Pliocene and Early Pleistocene carpological records of terrestrial plants from the southern border of the Po Plain (northern Italy). *Rev. Palaeobot. Palynol.*, 218: 148-166.
- Martinetto E., Momohara A., Bizzarri R., Baldanza A., Delfino M., Esu D. & Sardella R. (2017) - Late persistence and deterministic extinction of humid thermophilous plant taxa of East Asian affinity (HUTEA) in southern Europe. *Palaeogeogr., Palaeoclimatol., Palaeoecol.*, 467: 211-231.
- Maxia C. (1949) - Resti di Mammiferi rinvenuti nella miniera di lignite di San Pietro (Sabina). *Riv. Sci.*, 19: 346-347.
- Meli R. (1882) - Sulla zona dei fori lasciati dai litodomi pliocenici nella calcaria giurese di Fara Sabina. *Boll. R. Com. Geol. Ital.*, 13: 147-155.
- Monesi E., Muttoni G., Scardia G., Felletti F., Bona F., Sala B., Tremolada F., Francou C. & Raineri G. (2016) - Insights on the opening of the Galerian mammal migration pathway from magnetostratigraphy of the Pleistocene marine-continental transition in the Arda River section (northern Italy). *Quaternary Res.*, 86: 220-231.
- 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. & Ferretti M.P. (2005) - Elephant fossil record from Italy: knowledge, problems, and perspectives. *Quaternary Int.*, 126: 107-136.
- Pandolfi L., Grossi F. & Frezza V. (2015) - 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. *Estud. Geol.*, 71(1) e026: 1-16.
- Pandolfi L. & Marra F. (2015) - Rhinocerotidae (Mammalia, Perissodactyla) from the chrono-stratigraphically constrained Pleistocene deposits of the urban area of Rome (Central Italy). *Geobios*, 48: 147-167.
- Pandolfi L., Cerdeño E., Codrea V. & Kotsakis T. (2016) - Paleobiogeography and chronology of *Stephanorhinus etruscus* (Falconer, 1858) (Mammalia, Rhinocerotidae) in Eurasia. Abstr. XIV Ann. Meet. Europ. Assoc. Vertebr. Palaeontologists, Haarlem, p. 42.
- Pandolfi L. & Erten H. (2017) - *Stephanorhinus hundsheimensis* (Mammalia, Rhinocerotidae) from the late Early Pleistocene of the Denizli Basin (Anatolia). *Geobios*, 50(1): <http://dx.doi.org/10.1016/j.geobios.2016.10.002>
- Pandolfi L. & Kotsakis T. (2017) - A mandible of *Tapirus arvernensis* from Central Italy. *Ital. J. Geosci.*, 136: 131-133.
- Petronio C., Argenti P., Caloi L., Esu D., Girotti O. & Sardella R. (2002) - Updating Villafranchian mollusc and mammal faunas of Umbria and Latium (Central Italy). *Geol. Romana*, 36: 369-387.
- 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.
- Pontini M.R. & Bertini A. (2000) - Late Pliocene vegetation and climate in Central Italy: high-resolution pollen analysis from the Fosso Bianco succession (Tiberino Basin). *Geobios*, 33: 519-526.
- Popescu S.-M., Biltekin D., Winter H., Suc J.-P., Melinte-Dobrinescu M.-C., Klotz S., Rabineau M., Combourieu-Nebout N., Clauzon G. & Deaconu F. (2010) - Pliocene and Lower Pleistocene vegetation and climate changes at the European scale: long pollen records and climatostratigraphy. *Quaternary Int.*, 219: 152-167.
- Rivals F., Mol D., Lacombe F., Lister A.M. & Semprebon G.M. (2015) - Resource partitioning and niche separation between mammoths (*Mammuthus rumanus* and *Mammuthus meridionalis*) and gomphotheres (*Anancus arvernensis*) in the Early Pleistocene of Europe. *Quaternary Int.*, 379: 164-170.
- Rodríguez-Lázaro J. & Martín-Rubio M. (2005) - Pliocene Ilyocyprididae (Ostracoda) from the Ebro Basin (N. Spain). *Rev. Micropaleont.*, 48: 37-49.
- Rook L. & Martínez-Navarro B. (2010) - Villafranchian: The long story of a Plio-Pleistocene European large mammal biochronologic unit. *Quaternary Int.*, 219: 134-144.
- Rook L., Croitor R., Delfino M., Ferretti M.P., Gallai G. & Pavia M. (2013) - The Upper Valdarno Plio-Pleistocene vertebrate record - An historical overview, with notes on palaeobiology and stratigraphic significance of some important taxa. *Ital. J. Geosci.*, 132: 104-125.
- Russo Ermolli E., Sardella R., Di Maio G., Petronio C. & Santangelo N. (2010) - Pollen and mammals from the late Early Pleistocene site of Saticula (Sant'Agata de' Goti, Benevento, Italy). *Quaternary Int.*, 225: 128-137.
- Salzmann U., Williams M., Haywood A.M., Johnson A.L.A., Kender S. & Zalasiewicz J. (2011) - Climate and environment of a Pliocene warm world. *Palaeogeogr., Palaeoclimatol., Palaeoecol.*, 309: 1-8.
- Sismonda E. (1851) - Osteografia di un mastodonte angustidente. *Mem. R. Accad. Sci. Torino*, ser. 2, 12: 175-235.
- Szabó P., Kocsis L., Vennemann T., Pandolfi L., Kovács J., Martinetto E. & Demény A. (2017) - Pliocene--Early Pleistocene climatic trends in the Italian Peninsula based on stable oxygen and carbon isotope compositions of rhinoceros and gomphothere tooth enamel. *Quaternary Sci. Rev.*, 157: 52-65.
- Tuccimei G. (1889a) - Il Villafranchiano nelle valli sabine e i suoi fossili caratteristici. *Boll. Soc. Geol. Ital.*, 8: 95-131.
- Tuccimei G. (1889b) - Alcune recenti osservazioni sul Villafranchiano della Sabina. *Boll. Soc. Geol. Ital.*, 8: 566-568.
- Tuccimei G. (1891) - Alcuni mammiferi fossili delle provincie Umbra e Romana. *Mem. Pontif. Accad. N. Lincei*, 7: 89-152.
- Tuccimei G. (1898) - Sopra alcuni cervi pliocenici della Sabina e della Provincia di Roma. *Mem. Pontif. Accad. N. Lincei*, 14: 33-55.
- Velichkevich F.Y. & Zastawniak E. (2003) - The Pliocene flora of Kholmeh, south-eastern Belarus and its correlation with other Pliocene floras of Europe. *Acta Palaeobotanica* 43, 137-259.

- Weitzman A.L., Dressler S. & Stevens P.F. (2004) - Ternstroemiaceae. In: Kubitzki K. (Ed.) - The families and genera of vascular plants VI. Flowering plants. Dicotyledons. Celastrales, Oxalidales, Rosales, Cornales, Ericales: 450-460. Springer, Berlin, Heidelberg, New York.
- Welter-Schultes F.W. (2012) - European non-marine molluscs, a guide for species identification. Planet Poster Editions, Göttingen, 760 pp.
- Woodard S.C., Rosenthal Y., Miller K.G., Wright J.D., Chiu B.K. & Lawrence K.T. (2014) - Antarctic role in Northern Hemisphere glaciation. *Science*, 346: 847-51.
- Yang F., Sun Z., Qiao Z. & Zhang Y. (2004) - Revision of the diagnosis of the genus *Qinghaicypris* Huang, 1979 (Ostracoda) and the environmental significance of its type species. *Acta Micropal. Sin.*, 21: 367-381 [in Chinese with English abstract].
- Zanchetta G. & Mazza P. (1996) - *Anancus arvernensis* remains from the basal portion of the *Arctica islandica*-bearing marine deposits of Lower Valdarno. *Boll. Soc. Geol. Ital.*, 115: 105-113.