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THE MIDDLE PLEISTOCENE DEPOSITS OF THE ROMAN BASIN (LATIUM, ITALY): AN INTEGRATED APPROACH OF MAMMAL BIOCHRONOLOGY AND SEQUENCE STRATIGRAPHY

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Abstract. The biochronological setting proposed for the Plio-Pleistocene large mammal faunas of the Italian peninsula is based on the definition of faunal units (FUs) and mammal ages (MAs). Many evidences suggest that a multidisciplinary approach could enable us to better understand the actual meaning of a given faunal assemblage taking into account sedimentological and physical stratigraphic studies of the sedimentary successions in which local mammal faunas occur. The Pleistocene deposits of the Roman Basin can be considered a significant model to test this integrated approach. The detailed study of this sedimentary succession, in terms of facies analysis and sequence stratigraphy, sets some physical and temporal constrains to the occurrence of faunal complexes because the allocyclic control (climate and eustatic variations) on both landscape and stratigraphical evolution can affect the association type of mammal faunas. A correlation scheme between the Roman Pleistocene sequence-stratigraphic units and the mammal biochrons has been proposed; this approach constitutes a first tentative to connect the mammal fauna remains to the sedimentary processes which are responsible of their transport, stock and potential preservation in the depositional environments and to collocate this fauna in the systems tracts of the fourth-order depositional sequences recognised in the local Roman Basin Pleistocene succession.

Riassunto. Gli schemi biocronologici proposti per le faune a grandi mammiferi del Plio-Pleistocene della penisola italiana si fondano sulla definizione di unità faunistiche (FUs) e di età a mammiferi (MAs), ma hanno raramente tenuto conto dei dati della sedimentologia e della stratigrafia fisica delle successioni in cui questi fossili sono stati rinvenuti. L'analisi che è stata condotta sui depositi del Pleistocene medio e superiore del Bacino Romano ha invece messo a confronto i dati dell'analisi di facies e stratigrafico-sequenziale con gli schemi biocronologici delle faune a mammiferi. Questo ha consentito di vincolare i limiti fisici e temporali dei complessi faunistici già attribuiti a diverse FUs e, allo stesso tempo, ha evidenziato come i fattori allociclici (per esempio, variazioni climatiche ed eustatiche) possano influenzare la costituzione dell'associazione faunistica. E' stato di conseguenza proposto uno schema di correlazione tra i biocroni di appartenenza delle associazioni e le unità stratigrafico-sequenziali riconosciute nella successione del Bacino Romano; in questo schema i resti di fauna fossile sono stati correlati con i processi sedimentari responsabili del loro trasporto, accumulo e preservazione potenziale nei diversi ambienti deposizionali, e collocati nell'ambito dei systems tracts riconosciuti nelle diverse sequenze deposizionali di quarto ordine che costituiscono l'impalcatura stratigrafica della successione pleistocenica romana.

Introduction

Fossil mammals mainly occur in fluvio-lacustrine deposits, fissures or isolated pockets frequently cropping out in caves, quarries or natural sections. Such recovery very limited in time and space makes it difficult to apply chronological time scale to continental faunas. More rarely mammal remains occur in marine sediments (e.g.deltaic and shoreface environments), after transport by river flood events. Continental successions are generally highly discontinuous, without stratigraphic control, chronological faunal sequences are generally based on the stage of evolution reached by selected, well defined mammal lineage and on the basis of first and last appearance bioevents. Accordingly, several problems arise in the define continental biochrons that could be used on an extensive scale, especially for large mammalian faunas (Azanza et al. 2003; Palombo et al. 2000-2002).

The biochronological setting recently proposed for the large Italian mammal faunas (Gliozzi et al. 1997)

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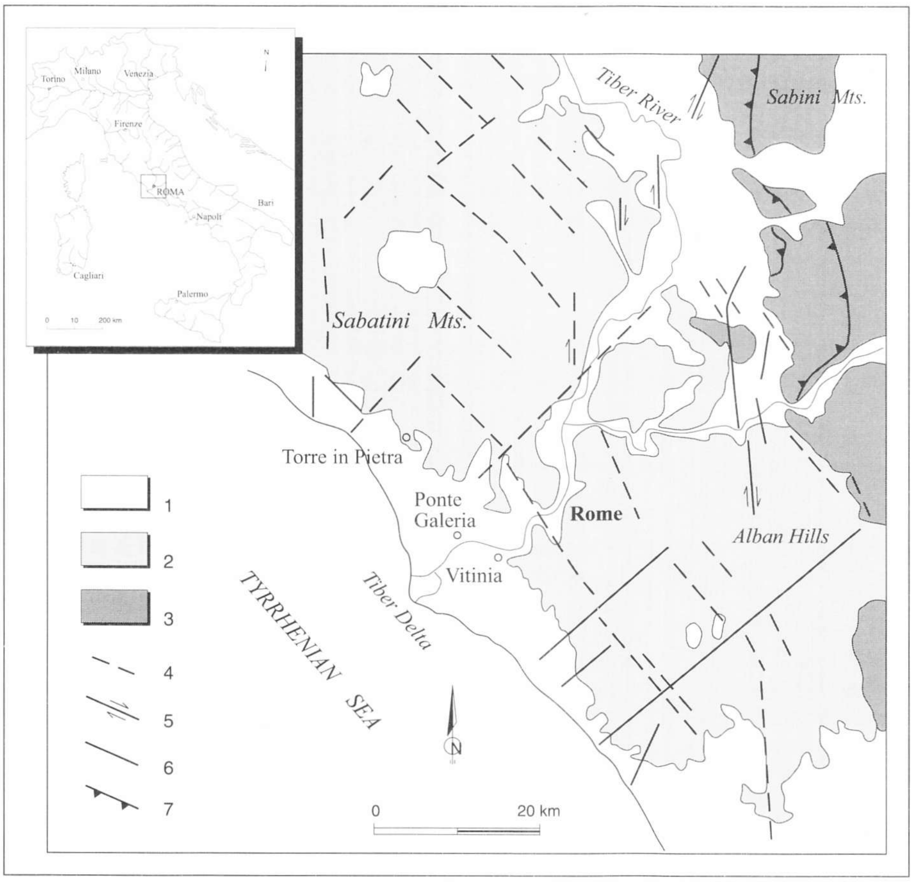


Fig. 1 - Geological sketch of the Central Italy Tyrrhenian margin. Legend: 1: Messinian to Holocene sedimentary deposits; 2: Pliocene-Pleistocene lavas and volcaniclastic deposits; 3: Mesozoic-Cenozoic sedimentary deposits; 4: main buried faults; 5: strike-slip faults; 6: normal faults; 7: major thrust.

is based on the definition of faunal units (FUs) (Azzaroli 1977). The FU is defined as a faunal complex, arranged on the basis of local faunal assemblages. It differs from the previous, and the subsequent faunal complexes by typical associations and first/last appearances of one or more taxa. Since the first introduction of these biochrons, Italian palaeontologists have proposed some new FUs and/or new mammal ages (MAs) (e.g. Caloi & Palombo 1987; Gliozzi et al. 1997; Petronio & Sardella 1998) based on local bioevents, whose recognition depends on the acquisition of new data and on the discovery of new fossiliferous assemblages. The biochronological scheme proposed thus gives a very detailed resolution for the Italian continental fauna, but it is less useful in the comparison with the European ones (Azanza et al. 2003). The complex physiography of Italian Peninsula and the remarkable latitudinal extension (in comparison with the longitudinal one), provides a particular opportunity to detect single bioevents, which can be regarded as markers of faunal renewal. Such a biochronological scheme, however, does not take into account the sedimentological and physical stratigraphic context of the sedimentary successions containing mammal faunas. A multidisciplinary approach could enable us to better understand the actual meaning of a given local faunal assemblage. Accordingly, the attribution to a given FU or the introduction of new FUs should consider the analysis of the sedimentary environments in which fossil remains occur, as well as the taphonomic analysis.

The Pleistocene deposits of the Roman Basin provide a good opportunity to test this integrated approach. Facies analysis and use of sequence stratigraphy concepts (Milli 1997) enable of us to test: *i*) the validity of the biochronological sequence of mammal faunas proposed for the studied area; and *ii*) to evaluate the variations of the mammal paleocommunities in function of paleoenvironmental changes. This approach sets the spatial and temporal limits of the fossil record and clarifies how the sedimentary processes acting in the depositional environments (autocyclic factors) and climatic and eustatic sea-level changes (allocyclic factors) have affected the taxonomical composition of each mammal assemblage. Following these principles a correlation scheme between the Roman Pleistocene sequence-stratigraphy subdivisions and the mammal biochrons recognized in this area is here proposed. In particular we emphasise the following problems: *i*) the relationships between faunal changes and the sequences stratigraphic framework of the Pleistocene successions; *ii*) the need that the attribution of a new faunal assemblage to a given FU takes into account the general preservation of fossil bones in relation to processes acting in the sedimentary environments; *iii*) the relationship among depositional sequences, faunal complexes and geochronology.

Geologic and stratigraphic setting

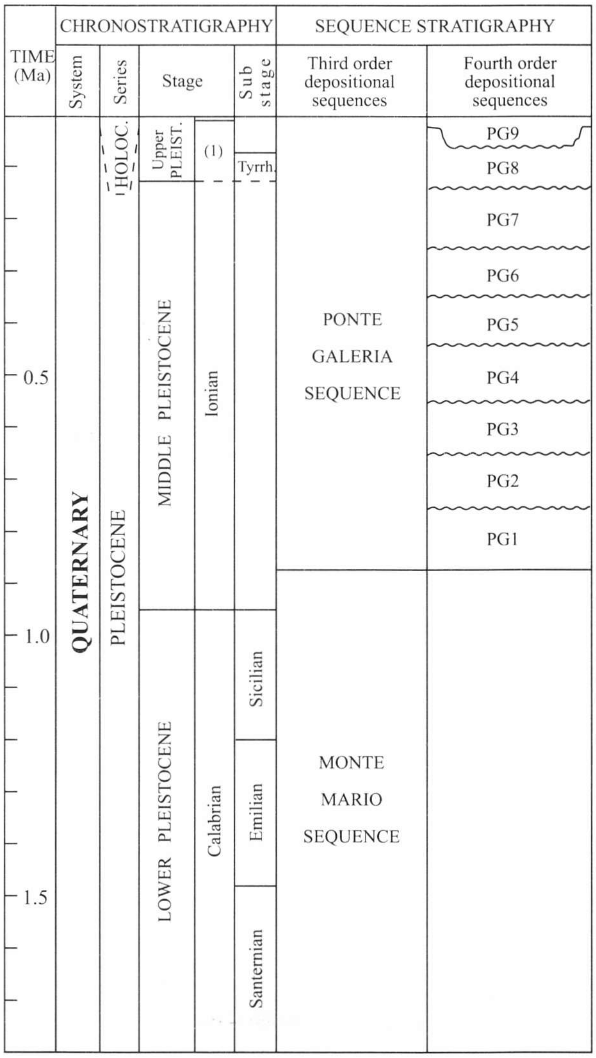
The investigated area (Fig. 1) is located along the Latium Tyrrhenian margin that underwent extensional tectonic processes since the Late Miocene during the opening of the Tyrrhenian Sea. Extension was coeval with compression in the Apennine chain, which migrated eastwards, towards the Padan-Adriatic-Ionian foreland (Boccaletti et al. 1990a,b; Patacca et al. 1990; Doglioni et al. 1998; Argnani & Ricci Lucchi 2001; Patacca & Scandone 2001). In the Latium area, extensional tectonics was coeval with an intense volcanic activity beginning in the Late Pliocene (De Rita et al. 1997) and reaching a climax in the Middle-Late Pleistocene, when the volcanic complexes of the Magmatic Roman Province developed (Locardi et al. 1976; Fornaseri 1985; Cioni et al. 1993; De Rita et al. 1993; 1995; Karner et al. 2001).

In the recent years Plio-Pleistocene geologic and stratigraphic setting of the Rome area has been investigated by several authors that underlined the interaction among glacio-eustatic sea-level fluctuations, volcanic activity and tectonic uplift of the Latium Tyrrhenian margin (Conato et al. 1980; Milli 1992, 1994, 1997; Bellotti et al. 1993; De Rita et al. 1991, 1994; Cavinato et al. 1992; Marra & Rosa 1995; Alvarez et al. 1996; Karner & Marra 1998; Karner & Renne 1998; Marra et al. 1998; Karner et al. 2001). Conato et al. (1980), revised the stratigraphy of the Rome urban area and of surrounding zones (i.e. the Ponte Galeria area) and subdivided the Pleistocene succession into informal lithostratigraphic units named, from the older to the younger: Monte Mario Formation (Lower Pleistocene), Ponte Galeria Formation, S.Cosimato Formation, Aurelia Formation and Vitinia Formation (Middle-Late Pleistocene). More recently Milli (1992, 1997) refined the stratigraphy of this area by using a sequence-stratigraphic approach. Sequence-stratigraphic subdivisions are based on detailed facies analysis of the Quaternary sedimentary succession of the Roman Basin. Such a chrostratigraphic framework is used herein to constrain the biochronological scheme of the Latium mammal faunas.

Sequence stratigraphy

The subdivision of the Roman Pleistocene deposits in third- and fourth-order depositional sequences is based on facies analysis and correlation of several stratigraphic-sedimentological sections and wells drilled for water research and civil engineering purposes. A petrographic composition and a qualitative micro- and macrofaunistic analysis of several samples were also carried out. Radiometric ages of sedimentary and volcaniclastic deposits (Milli 1997) were used to estimate the age of the unconformities bounding the depositional sequences. Sequence boundaries ages were refined further through correlation with the oxygen isotope record (Shackleton 1995). The Pleistocene chronostratigraphic scheme used in this study was developed by Berggren et al. (1995a, b) with the resolution proposed by the Quaternary Working Group of the Italian Commission on Stratigraphy (Cita & Castradori 1995), that considered the base of the Middle Pleistocene as being close to the upper Jaramillo reversal, to isotopic stage 25, and to the *Gephyrocapsa/Pseudoemiliania lacunosa* nannofossil zonal boundary.

The two recognised third order sequences were named Monte Mario Sequence (MMS) and Ponte Galeria Sequence (PGS) (Milli 1992) respectively (Fig. 2). These sequences span a time interval corresponding approximately to the Early Pleistocene (1.795-0.87 Ma) and to the Middle-Late Pleistocene to Holocene (0.87 Ma to Present), and are bounded at the base by type-1 unconformities (Vail et al. 1984; Van Wagoner et al. 1988). Both sequences are composite because they contain higher-frequency (fourth order) sequences (Mitchum & Van Wagoner 1991).



(1) unnamed (Tarentian)

Fig. 2 - Chronostratigraphy and sequence stratigraphy of the Roman Pleistocene deposits (modified after Milli 1997).

Within the depositional sequences, each parasequence shows different facies associations in relation to depositional environments. As visible on the stratigraphic cross-sections (Pl. 1), the flooding surfaces bounding the parasequences are traceable in different environments. Each parasequence may contain facies associations belonging to coeval fluvial, lacustrine-lagoonal and beach environments. Depending upon where it is observed each parasequence can be constituted by a vertical facies succession related to a single depositional environment or by a vertical facies succession related to different depositional environments.

In the studied area the Lower Pleistocene deposits of the Monte Mario Sequence (MMS) crop out with limited extension and are interpreted as the expression of two coeval coastal and transition-shelf depositional systems which migrated landward and seaward, during the transgressive and the highstand phases respectively (Milli 1992). The fossil record consisting of a late Villafranchian mammal fauna is very poor. Abundant mammal fauna is instead preserved in the overlying PGS.

The Ponte Galeria Sequence (PGS)

The thickness of this sequence ranges from 10 m to 110 m, between Rome and the Tyrrhenian coast (Pl. 1). In this sector, the PGS strata include of a variety of depositional systems, ranging from fluvial and fluvio-lacustrine to coastal barrier-lagoonal and transition-shelf. These systems are organised in lowstand (LST), transgressive (TST) and highstand systems tracts (HST). Volcaniclastic deposits belonging to the Albani and Sabatini volcanic complexes are interbedded essentially within the sediments of the TST.

The basal unconformity of the PGS is an erosional surface, truncating TST/HST coastal and shelf deposits belonging to the Monte Mario Sequence. The PGS sequence boundary can be followed for as far as to the 10 km NW and 20 km to the SE. This unconformity on the basis of biostratigraphic and geochronological data was dated 0.87 Ma and correlated with oxygen isotope stage (OIS) 22. The climatic event related to this unconformity formation has been also recognised in the Pianura Padana area and interpreted as related to the beginning of the alpine glaciations (Muttoni et al. 2003). The upper boundary of the PGS coincides with the position of the present sea-level. As such, the PGS constitutes an incomplete third-order depositional sequence, whose HST began to develop about 5,000 years B.P. (when the sea-level reached its present position).

The PGS is a composite depositional sequence consisting of nine fourth-order depositional sequences named PG1 to PG9, from the oldest to the youngest (Milli 1997), with a period of ca. 100,000 years (Fig. 2). In the PGS the stack of the first three fourth-order depositional sequences (PG1 to PG3) forms the LST and in particular the prograding lowstand wedge (PLW). The subsequent sequences, from PG4 to part of PG9, are ascribed to the TST, whereas the HST sediments were deposited during the last 5,000 years.

The stacking pattern of the high-frequency depositional sequences

The boundaries of the nine fourth-order depositional sequences are expressed by sharp erosional surfaces recording a basin- and downward facies shift, associated with subaerial exposure and paleosols development in the interfluve areas. These sequences show an internal parasequence progradation and retrogradational stacking pattern which defines the systems tracts. Their thickness varies between 5 m and 80 m, mainly depending on the intensity of the erosional phases connected with lowering of sea-level.

These sequences fill half-graben basins, formed by extensional tectonics along the coastal margin of Latium. Structural features with dominantly NW-SE, NE-SW and N-S directions developed in different times, conditioned the orientation of the incised valleys, which were filled with fluvial, lacustrine and marshy-lagoon deposits belonging to the TST and partially to the HST of most fourth-order sequences. The lowstand systems tracts of these sequences constitute the Latium submerged continental margin (Chiocci & Normark 1992; Chiocci & Milli 1994).

The stratigraphic organization of these deposits (Pl. 1) is characterized by a seaward stack of the fourth-order depositional sequences. This trend indicates that this sedimentary succession was not primarily controlled only by glacio-eustasy. In such a case the equilibrium point of each fourth-order sequences should have migrated landward, as visible on the global eustatic curve of Haq et al. (1988) and Hardenbol et al. (1998). For this reason, the present stack of the fourth-order sequences that define the third-order Ponte Galeria composite sequence is considered to be the result of the interaction of two factors: *i*) the high-frequency glacio-eustatic sea-level fluctuations and *ii*) the tectonic uplift that affected the Tyrrhenian margin of the Latium coast during the Middle-Late Pleistocene. This last process would have forced the seaward migration of the fourth-order sequence equilibrium points contributing to define the recognised stacking pattern (Milli 1997).

Biochronological framework

Late Villafranchian

During the Pliocene and Early Pleistocene the present sector of the Rome area (Campagna Romana) was chiefly characterised by coastal to shelf sedimentation (Conato et al. 1980; Milli 1992; Bergamin et al.

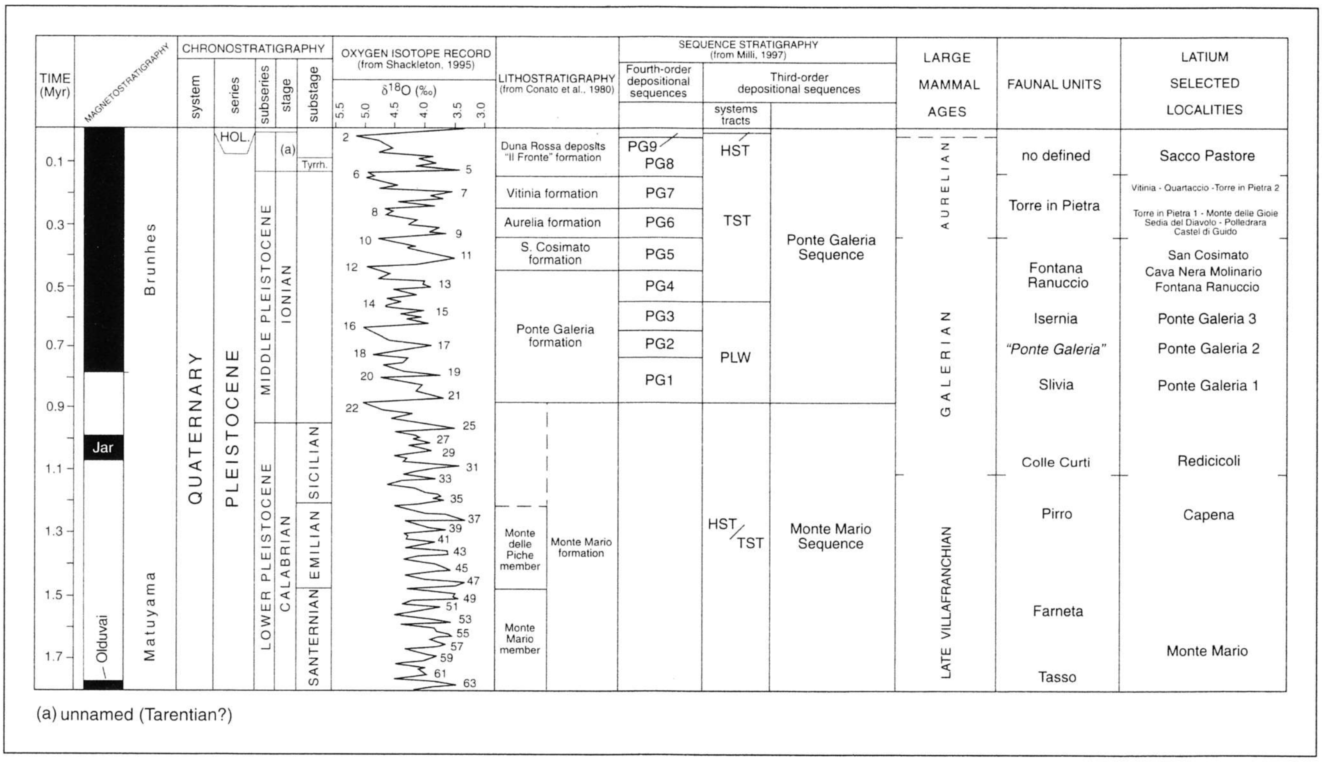


Fig. 3 - Comparison among litostratigraphy units, sequence stratigraphy subdivison and recognised faunal units in the Roman Pleistocene deposits.

2000). Consequently the fossil record related to the Late Villafranchian mammal fauna is very poor. In the Rome urban area a molar tooth of *Mammuthus meridionalis* (= *Elephas antiquus* after Ponzi 1878), whose morphology and biometrical characters should refer it to late Villafranchian faunal complexes (?Farneta FU) (Fig. 3,) was found in the marine sands of the Monte Mario Formation (Lower Pleistocene).

Early Galerian

The latest Early Pleistocene paleoclimatic variations, (early Galerian Mammal Age, sensu Gliozzi et al. 1997), caused a considerable faunal renewal although many Villafranchian taxa surviving also during the Galerian (*Mammuthus meridionalis*, and *Bison* cf. *B.* (*Eobison*) *degiulii*, *Equus altidens*, *Hippopotamus* ex gr. *antiquus*, *Axis eurygonos* (see Di Stefano & Petronio 2000-2002), *Stephanorhinus hundsheimensis*, *Bison* sp. aff. *B. schoetensacki*, Megacerini indet.). The bioevent, which marks the beginning of the Galerian Mammal Age (MA), is the first appearance of *"Praemegaceros" verticornis*. In Italy the lowest occurrence of this taxon is recorded in the Colle Curti (Marche) deposits, calibrated at the bottom of Jaramillo submagnetochronozone (Coltorti et al. 1998). In the Latium a coeval fauna was firstly reported by Blanc (1955) at Redicicoli (Roma) (Palombo et al. 2000-2002).

Middle Galerian

In the Campagna Romana, as well as in other Italian faunas, mammal assemblages found in the early Middle Pleistocene deposits record both the local evolution of pre-existing taxa and the arrival of immigrant species from Asia or central Europe. The successive appearance of pachyderms (*Elephas antiquus, Mammuthus trogontherii, Stephanorhinus kirchbergensis, Stephanorhinus hemitoechus*), cervids (small-sized *Capreolus capreolus*, medium-sized *Cervus elaphus acoronatus, Cervus elaphus eostephanoceros* and *Dama clactoniana*, large-sized *"Praemegaceros" solilhacus* and *Megaloceros savini*), large-sized bovids (*"Bos" galerianus* and then *Bos primigenius*), and carnivores (Hyaenidae, *Ursus deningeri, Panthera leo fossilis*) took place while the "Villafranchian" survivals progressively disappeared (e.g. the large carnivores as *Pachycrocuta brevirostris*, and *Homotherium latidens*; pachyderms as *Mammuthus meridionalis* and *Hippopotamus* ex gr. *antiquus*; cervids of *Axys* group). Basing on this fauna three different FUs have been proposed for the middle Galerian, mammals faunas (Gliozzi et al. 1997; Petronio & Sardella 1999): Slivia (on the basis of the Slivia fauna, "Carso Triestino", North Italy, found in karst deposits), Ponte Galeria (on the basis of the faunal evidence from the Ponte Galeria area) and Isernia FUs (on the basis of rich faunal assemblage from Isernia La Pineta, Central Italy).

They differ essentially for the persistence of *Mimomys savini*, *P. brevirostris* and *P. gombaszoegensis*, for the exclusive occurrence of "*Bos*" *galerianus* and for the appearance of *Bos primigenius* respectively (see also Palombo in press).

The oldest mammal remains in the Ponte Galeria area (Ponte Galeria 1, Fig. 3) are represented by two arvicolids (*Prolagurus pannonicus* and *Predicrostonyx* sp.) collected at Fontignano (Kotsakis et al. 1992), in the lacustrine-lagoon deposits (*Helicella* bearing clay of Conato et al. 1980) of the PG1 Sequence (Milli 1997).

The "classical" Galerian fauna (Ponte Galeria 2, Fig. 3) comes from the beach sand and gravel deposits underlying the lagoonal *Venerupis senescens* clays (HST of PG2 sequence, Milli 1997) and includes *Crocuta crocuta*, "*Praemegaceros*" *verticornis*, *Megaloceros savini*, *Axis eurygonos*, *Mammuthus trogontherii* and "*Bos*" *galerianus* (Petronio & Sardella 1998; Petronio et al. 2000). The third fauna assemblage (Ponte Galeria 3, Fig. 3) comes from the HST lacustrine and beach deposits of the PG3 sequence (Milli 1997) and includes cervids, bovids, *Allocricetus bursae*, birds, reptiles, amphibians and very scarce remains of *Hyaena prisca* (Petronio et al. 2000; Palombo et al. 2000-2002). For these characters such Authors have compared this fauna to those from Isernia-La Pineta and Venosa Notarchirico (Isernia FU, sensu Gliozzi et al. 1997).

Late Galerian

In Italy, last Galerian taxa have been recorded in the Fontana Ranuccio FU where *Ursus deningeri*, stenonoid horses, megalocerines of the *Megaceroides verticornis* group were still present, whereas *Hippopotamus* ex gr. *amphibius* firstly appeared together with *Panthera leo spelaea*. Moreover, a new advanced subspecies of red deer, *Cervus elaphus eostephanoceros*, substituted the previous *Cervus elaphus acoronatus*. In the Ponte Galeria area only few remains belonging to *Stephanorhinus* sp. and *Bos primigenius* have been found in the deposits of PG5 sequence, whereas taxa typical of Fontana Ranuccio FU lack; *C. e. eostephanoceros* has been reported at Cava Nera Molinario (Roma) (Di Stefano & Petronio 1993). Accordingly, in the Ponte Galeria area a quite good biochronological framework can be proposed for the (middle Galerian) faunas (deposits from PG1 to PG3 sequences) whereas so far few data are available for the late Galerian ones (deposits of PG4 and PG5 sequences).

Aurelian

Mammal faunas referred to the early and middle Aurelian MA (late Middle Pleistocene) (sensu Gliozzi et al. 1997) have been known for a long time from Latium, especially from the "Bassa Campagna Romana". These faunal complexes characterised by the appearance, of *Ursus spelaeus*, *Canis lupus*, a large horse with advanced morphology, *Megaloceros giganteus* and *Dama dama*, have been originally referred to Torre in Pietra and Vitinia FUs (Caloi et al. 1998; see also discussion in Palombo et al. 2003). The latter has been distinct on the basis of the abundance of a primitive fallow deer (*Dama dama tiberina*) and by the appearance of *Cervus elaphus* with features similar to those of modern forms of red deer.

The most representative sites occurring in the Aurelia Formation (Conato et al. 1980) or PG6 sequence (Milli 1997) are those of Torre in Pietra, Malagrotta, Cava Rinaldi (upper levels), Castel di Guido, La Polledrara di Cecanibbio and Collina Barbattini (Palombo et al. 2000-2002). The association of *Elephas* (*Palaeoloxodon*) *antiquus* with large *Bos primigenius*, accompanied by cervids, generally characterised these mammalian assemblages. The cervids are represented by the yet persistent Galerian form *Dama clactoniana*, by the an archaic form of modern red deer, *Cervus elaphus rianensis*, as well as by the giant deer and roe deer, that are less frequent. Horse as well as rhinoceroses (*Stephanorhinus hemitoechus*, *S. hundsheimensis* and *S. kirchbergensis*), *Hippopotamus*, wild boar and small carnivores are frequently present, while the big carnivores (bears, lions and leopards) are poorly documented. Faunas differ by taxonomy and ecological structure and this has been mainly ascribed to local microclimatic factors; recent studies indicate instead that these differences can be related to the taphonomic factors as well as to the processes acting in sedimentary environment conditioning the time average of bones accumulation.

The main part of large mammals occurring in the Vitinia Formation (Conato et al. 1980) or PG7 sequence (Milli 1997) are the same than in the previous one, even if *Elephas* (*Palaeoloxodon*) *antiquus* shows relatively more evolved dental features and red deer seems to be more closely related to the modern form. Moreover, *Dama dama tiberina* is usually abundant) and *Equus hydruntinus* sporadically occurs.

In the Roman Basin mammal fauna related to late Aurelian has been found in fluvio-lacustrine deposits of the PG8 sequence in the Rome urban area (Saccopastore). This fauna has been found in deposits respectively underlying and overlying the clays bearing the famous two archaic neanderthalian skulls (Segre 1984) and has been referred to the OIS5 (Palombo in press).

Discussion

Mammal assemblages and sequence stratigraphy in the Roman Basin

The Pleistocene sequence stratigraphic framework of the Roma Basin enables us to place the mammal fossil assemblages in the fourth-order sequences (from PG1 to PG7) (Fig. 3) constraining also their age both with the magnetostratigraphy and oxygen isotope scales.

In the PLW deposits of the PG1 sequence the scanty micromammal remains of cold climate, found in the *Helicella* clays (Fontignano area) can be attributed to Slivia FU basing on paleomagnetic data which indicate for these sediments a their deposition during a reverse period (Matuyama chron) (Kotsakis et al. 1992; Marra et al. 1998) (radiometric ages older than 0.75 Ma). On the basis of the *Mimomys savini* occurrence and of the survival of some Villafranchian carnivores, Slivia local fauna was generally considered as representative of the oldest Middle Galerian FU (sensu Gliozzi et al. 1997). Nevertheless, taking into account the doubtful identification of main herbivores coming from Slivia local fauna, as well as the scanty knowledge about carnivores and micromammals belonging to Ponte Galeria FU (sensu Petronio & Sardella 1999), the possibility that Slivia and Ponte Galeria assemblages belong to the same FU cannot be ruled out (Palombo in press).

The classic Ponte Galeria fauna, comes from beach deposit belonging to the HST of the PG2 sequence, correlated with the OIS 17. An age older than those of the Isernia-La Pineta local fauna has been hypothesised by Petronio & Sardella (1999) on the basis of the persistence of *Axys eurygonos* and the presence of both *Megaloceros savini* and *"Praemegaceros" verticornis* as well as and the exclusive occurrence of *"Bos" galerianus* at Ponte Galeria. Moreover, in the following beach deposit of PG3 sequence, correlated to OIS 15 (data also confirmed by radiometric ages reported in Karner & Renne 1998), the mammal assemblage shows more affinities with the Isernia-La Pineta fauna.

During the passage from Galerian (Early-Middle Pleistocene) to Aurelian mammal ages (Middle-Late Pleistocene) a faunal turnover occurred in Italy with a variation in the structure of large mammal assemblages (Palombo & Mussi 2001; Palombo in press). This faunal renewal was probably related to climatic changes, that in the Mediterranean area determined an expansion of the forest cover before to OIS 11 (Vergnaud-Grazzini et al. 1990). The renewed Late Middle Pleistocene faunas, previously ascribed to Torre in Pietra and Vitinia FUs, show quite similar composition and have recently been referred to a single FU, named Torre in Pietra. Moreover at Ponte Galeria area, in the case of isolated findings, it is quite difficult to individuate at which FU the mammal remains belong to, especially when the stratigraphic data do not clarify their occurrence in deposits of the PG6 or of PG7 sequences.

On the basis of sedimentological-stratigraphical data and mammal fossil record it seems possible to distinguish in the Ponte Galeria area two major faunal complexes: the Galerian complex and the Aurelian complex. The Galerian complex includes the faunal assemblages, already ascribed to Slivia, Ponte Galeria, Isernia and Fontana Ranuccio FUs, which have been essentially found in coastal-barrier lagoon deposits (sequences from PG1 to PG3) and subordinately in fluvio-lacustrine deposits (P4 to PG5 sequences). The complex is characterised by the occurrence of *Mammuthus "trogontherii"*, *"Praemegaceros" verticornis*, *Megaloceros savini*, *Axis eurygonos*, *Cervus elaphus* (archaic form), *"Bos" galerianus*, *Bison schoetensacki*.

The Aurelian complex includes the faunal assemblages found in fluvial and fluvio-palustrine deposits (sequences from PG6 to PG8), ascribed to Torre in Pietra FU (sensu Palombo et al. 2003). It is characterised, among the others, by the occurrence of *Ursus spelaeus*, *Canis lupus*, *Megaloceros giganteus*, *Cervus elaphus* (advanced form) and *Dama dama*.

Within these two complexes it is possible to distinguish faunal assemblages possibly belonging to biochrons of minor rank, whose actual biochronological value and significance can be clarified analysing the local environmental parameters.

The mammal fossil record significance in the systems tracts

The previous discussed stratigraphic and paleontological data suggest that the mammal fauna renewal occurred in relation to the main Pleistocene climatic changes that determined a diversification of the fauna in response to environmental opportunities and pressure. Climate and the related glacio-eustatic sea-level changes conditioned (allocyclic control) the stratigraphic organization of the sedimentary successions in which mammal faunas occur producing unconformities and transgressive surfaces (sequence boundaries and flooding surfaces) and progradational and retrogradational depositional systems in which the boundaries between biofacies are diachronous surfaces (see also Armentrout 1987). The biofacies term, here utilised to indicate "an association of organisms representing a particular depositional environment" should not be confused either with the "faunal unit" one, or the "paleocommunity" one. The abundance of mammal remains can suggest either one or more episodes of mass mortality or the fossil accumulation over substantial period of time (Liebig et al. 2003). Consequently a mammal assemblage not necessarily can be found in the deposits representative of the sedimentary environments in which these organisms lived. In the successions here analysed the mammal fossil assemblages are essentially found in highstand coastal-barrier lagoon deposits (HST) and in transgressive fluvial and fluvio-palustrine deposits (TST).

HST mammal assemblage

In this case mammal faunas have been found in progradational beach gravel and sandy-gravel deposits passing landwards to a lagoonal and fluvial deposits and seawards to a shelf deposits. The taphonomic context of fossil assemblages suggest a transport into a marine environment through fluvial floods as drowned still-living animals, as a part of a decaying carcass or as solitary bones. The variable concentration of bones in these beach sediments should be also caused by waves and currents actions as recognised in similar present environments (Liebig et al. 2003). Anyway, the presence of fossils remains belonging to terrestrial taxa in marine environments can be used to indicate the proximity of fluvial mouths; at the same time such kind of assemblages can be considered as the result of a rearrangement of remains belonging to one o more coeval communities, whose organisms lived in contiguous depositional systems.

TST mammal assemblage

In this case, mammal faunas have been found in fluvial and fluvio-palustrine deposits constituting part of incised valleys filling near to the coast. These incised valleys represented a by-passing zone during the deposition of the LSTs and were filled only during the deposition of the TSTs. These last ones show a general backstepping of the depositional systems (with fluvial deposits at its base passing upwards to lacustrine and lagoonal deposits) migrating landwards concomitantly with the rapid rises in sea-level. The sea-level changes determined a modification of the fluvial base-level and this produces a deposition of the most coarser sediment load upstream, in the montane zone. This suggests that the fluvial gravel and coarse sands filling the incised valleys near the coast essentially derived from erosion and short transport of the underlying and lateral sediments belonging to the previous depositional sequences. Consequently in these deposits the mammal assemblages are often represented by a mixing of bones derived by *i*) contemporary organisms living in same or in contiguous environments and by *ii*) mammal remains of different age, and possibly referable to distinct FUs, occurred in the pre-existing deposits. The major variety of bones types characterising the TST fluvial-palustrine deposits is the consequence of the terrestrial mammal skeletal construction, which are more resistant to decay as highlighted by Behrensmeyer (1978) and Behrensmeyer & Dechant Boaz (1980).

Biochronology and sequence stratigraphy

The need to recognise reworked fossils is a common problem in biostratigraphy as well in biochronology; such mechanism can be associated to erosion related to sedimentary processes acting in the depositional environment or could be associated with the erosion connected to the transgressive surfaces and/or sequence boundaries formation. Thus the presence of these fossil assemblages, might be used to identify discontinuity surfaces in the stratigraphic record or to confirm the interpretation of such surfaces in term of sequence stratigraphic approach (i.e. sequence boundary, flooding or maximum flooding surface; Sturrock 1996).

Such considerations highlight the operative problems related to the actual possibility to ascribe a mammal assemblage to a given FU, taking into account only the sequence stratigraphic framework of a sedimentary succession, especially when characteristic taxa are lacking. The same problem occurs when the new FUs are defined on the basis of the local appearance of a new taxon in an assemblage for which the characters of the sedimentary environment and the physical stratigraphic context have not defined yet.

Anyway, the chronological setting of a faunal assemblage can be inferred and supported by the sequence-stratigraphic framework even if the preservation of the depositional sequences is not complete owing to the erosion processes connect to sea-level falls. The widespread unconformity surfaces (sequence boundaries) bounding at the base and at the top these depositional units have in fact a time-stratigraphic or chronostratigraphic significance because, although all points on the sequence boundary do not represent the same duration of time, one instant of time is common to all points (Van Wagoner et al. 1990). This synchronicity is remarkable *i*) to define the temporal boundaries of the faunal assemblages; *ii*) to enable to better verify the problems connected to the non correspondence between fossil record and actual local lowest/highest occurrences of a given taxon and *iii*) to verify the relative chronology of a mammal assemblage, independently by their precise correlation with the geochronological scale.

Conclusions

The biochronological and sequence-stratigraphic scheme proposed for the Ponte Galeria area represents a valid tool to define and to correlate physical and biological events. This scheme also highlights as the sequence stratigraphy framework can constrain the possible chronological interval in which a bioevent, even if local, occurred. Nevertheless many problems remain to clarify before to consider definitive either the correlation between events and the geochronological framework, or the significance and the biochronological value of each assemblage. Crucial in this sense is the characterisation of the depositional and taphonomic context of the different fossiliferous levels, which can be solved only through a detailed facies and physical stratigraphic analysis of the studied succession. This is remarkable because can clarify the coeval or non coeval character and the actual structure of the recovery fauna, in relation to the different systems tracts in which the fossil remains occur.

In the Ponte Galeria area this methodological approach has highlighted as an integrated analysis being a necessary assumption in order to define biochrons which can be utilised on a large scale; at the same time this enable us to recognise two main faunal complexes that group faunal assemblages already ascribed to different FUs:

i) the Galerian complex, including the faunal remains referred to Slivia, Ponte Galeria, Isernia and Fontana Ranuccio FUs, found in essentially coastal-barrier lagoon depositional systems;

ii) the Aurelian complex including the faunal remains referred to Torre in Pietra and Vitinia FUs, founds in fluvial and fluvio-palustrine depositional systems.

The integrated mammal biochronology and sequence stratigraphy approach allowed to test how sequence stratigraphic subdivisions represent a valid support to establish a local chronostratigraphic framework in which faunal remains can be arranged. Also the definition at local scale temporal ranges can allow to better arrange the faunal complexes in a chronological framework, which take into account the climatic and sedimentary processes influencing the evolution of the depositional environments.

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