

## ITALIAN PLIO-PLEISTOCENE MAMMAL BIOCHRONOLOGY AND CORRELATION WITH MARINE SEQUENCES: THREE CASE STUDIES

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### SUMMARY

The use of the biochronological units, based on the occurrence and evolutionary degree of the mammals, in the correlation between marine and continental sequences, in some cases enables a more detailed definition of the age of the sequences, but in other cases shows a more complex framework. In this paper three case studies will be pointed out: Mandriola (Sardinia, Early Pliocene-Middle Pliocene boundary), Lower Valdarno (Tuscany – Plio-Pleistocene boundary) and Tiberino River Basin (Umbria - Pliocene Pleistocene boundary).

Biochronological criteria can be considered a very useful tool to infer age determination in the case of Mandriola fossiliferous site. The interpretation of the marine and non marine fossil record of Lower Valdarno and Tiber River Basin lead to two different scenarios: 1) the Italian peninsula can be considered as a *refugium* area for the Pliocene taxa, which survived until the earliest Pleistocene; 2) the age of deposits previously referred to Early Pleistocene has to be considered older (Late Pliocene).

### RIASSUNTO

Le unità biocronologiche, basate sulla comparsa e sul grado evolutivo delle diverse associazioni a mammiferi, rappresentano un importante strumento per la correlazione tra le sequenze marine e quelle continentali. In alcuni casi questa metodologia di lavoro porta a una maggiore definizione dell'età del deposito e della sequenza stratigrafica; in altri, invece, le unità biocronologiche mettono in evidenza un quadro più complesso. In questo lavoro vengono presi in considerazione tre casi di studio: Mandriola (Sardegna - passaggio Pliocene inferiore-medio), il Valdarno Inferiore (Toscana – passaggio Plio-Pleistocene) e il Bacino Tiberino (Umbria – passaggio Plio-Pleistocene).

I criteri biocronologici si sono rivelati uno strumento assai utile per definire con maggior dettaglio l'età di un deposito fossilifero nel caso del sito di Mandriola. L'interpretazione dei ritrovamenti paleontologici provenienti dalle successioni marine e continentali del Valdarno inferiore e del Bacino Tiberino conducono alla definizione di due scenari: 1) la penisola Italiana come area rifugio per taxa pliocenici, qui sopravvissuti sino alle prime fasi del Pleistocene; 2) l'età di depositi in precedenza attribuiti al Pleistocene Inferiore deve essere considerata più antica (Pliocene Superiore).

Keywords: Biochronology, marine/continental correlation, fossil vertebrates, Plio-Pleistocene

Parole chiave: : Biocronologia, correlazioni marino-continentale, vertebrati fossili, Plio-Pleistocene

### INTRODUCTION

In 1997 Gliozzi *et al.* published an integrated biochronological framework based mainly on mammal faunal assemblages and their evolutionary degree.

Such a biochronological framework for Pliocene and Pleistocene can be considered a first step for correlating continental and marine sequences. The comparison between biochronological and biostratigraphical data enables in some cases a more detailed correlation of the sequences, while in other cases such a correlation does not seem to fit perfectly. In this paper three case studies will be presented, illustrating those two situations.

#### **1) Inferring age constraints to marine successions by means of continental fossil vertebrates: the Mandriola fossiliferous site case study**

Age determination of the various formations outcropping in the Sinis Peninsula (western Sardinia, Italy)

and their stratigraphical correlations have been for a long time a matter of debate.

Actually, each formation outcrops in a very limited area, most of the time they show no visible stratigraphical continuity or heteropy with other formations, and usually lacks significant fossils.

Nonetheless, a revision of the lagomorph and rodent content of the Mandriola fossiliferous site (southern coast of the Capo Mannu Peninsula, northern portion of the Sinis Peninsula; Fig. 1) fixed a constraint to the age of the enclosing formations.

The fossiliferous layer consists in a lens (3 m thick in its central part and approximately 10 m long) of silt and sands accumulated in a coastal lagoon (Esu, 1986). The lens lies at the base of the Capo Mannu Fm., consisting of various sand complexes of aeolian origin (Pecorini *et al.*, 1974; Carboni & Lecca, 1995). The Capo Mannu Fm. overlies the shallow water marine limestones of the Calcari di Mandriola Fm. (Fig. 1), whose depositional facies becomes shallower from bot-

tom to top. All the complex represents a transition from a marine littoral environment to a continental aeolian one (Carboni & Lecca, 1995).

The non-marine molluscs found in the deposit unfortunately cover too wide a stratigraphical range (Pliocene; Esu, 1986) to be useful for age determination.

Fossil vertebrates of the lagoonal sediments were at first illustrated in a preliminary note by Pecorini *et al.* (1974), who inferred an Early Pliocene age (Ruscinian, MN14; for a synoptic MN Zones - Mammal Ages - chronostratigraphic chart, see Esu, 1999) for the deposit due to the presence of the murid *Rhagapodemus hautimagnensis*. This opinion was in later years reconsidered by other palaeontological studies (López Martínez & Thaler, 1975; Esu & Kotsakis, 1985).

On the other hand, regional stratigraphy data assigned the Mandriola fossiliferous site to Middle Pliocene (Carboni & Lecca, 1995).

The new systematic attribution of one faunal element (the murid *Rhagapodemus azzarolii*; Angelone & Kotsakis, 2001) has been one of the factors that led to the reconsideration of the age of the deposit. *R. azzarolii* underwent only slight morphological and morphometric modifications if compared with its continental ancestor (*R. ballesioi* Mein & Michaux, 1970): that may demonstrate that its colonisation of Sardinia occurred a short time before the deposition of the lagoonal sediments (for a synthesis on insular environment induced modifications on vertebrates see Azzaroli, 1982). The temporal distribution of *R. ballesioi* in central and western Europe covers part of MN14 to early MN15 (Middle-Upper Zanclean), fixing a lower age boundary for its arrival on the island.

An upper limit could be established by the presence of *Prolagus* aff. *P. depereti*, derived from *P. depereti* López, 1975, only known in late Ruscinian assemblages (MN15, late Early Pliocene – earliest Middle Pliocene).

For these reasons, the arrival of these faunal elements in Sardinia and the age of the Mandriola fossiliferous site is considered to be the Zanclean-Piacenzian boundary (Angelone & Kotsakis, 2001).

The difficulty in using a common biochronological tool (such as evolutionary degree of faunal elements) to compare continental faunas and insular ones, in this case has fortunately been avoided.

## 2) New perspectives in Lower Valdarno stratigraphy by means of mammal faunas

In Lower Valdarno area (Tuscany, Italy) sediments spanning from Early Pliocene to Late Pleistocene – Holocene outcrop. The marine Pliocene cycle deposits are represented by the “Sabbie Gialle” Fm outcropping either on the left and on the right-hand side of the Arno (Fig. 2). The end of this cycle is commonly considered to be Middle Pliocene in age, as attested by the micro-paleontological content of the deposits on the left-hand side of the Arno river (Bossio *et al.*, 1981). In this area the transgressive overlying sediments of the “Sabbie e Argille ad *Arctica islandica*” Fm are discordant over the Sabbie Gialle Fm. and represent the Early Pleistocene marine incursion.

Another interpretation is suggested by the recent study of Casa Sgherri (Santa Croce sull’Arno, Pisa) mammal fauna and of the findings at Vinci, in the surroundings of Fucecchio (Firenze), on the right-hand side

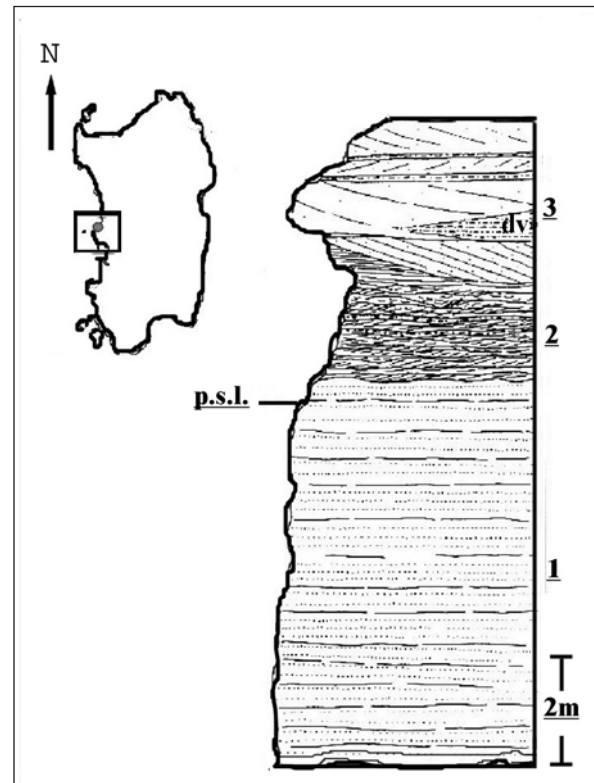


Fig. 1 - Location of the Mandriola fossiliferous site and lithological section of the outcrop. 1. Calcari di Mandriola Fm. limestones, deeper water facies; 2. Calcari di Mandriola Fm. limestones, shallower water facies; 3. first dunar complex of the Capo Mannu Fm.; p.s.l.: present sea level; dv: vertebrate deposit (not in scale) (from Carboni & Lecca, 1995, modified).

of the Arno, in continental sediments correlated to the post-Pliocene marine cycle of the left-hand side (Fig. 2). *Germanomys* sp. (*Arvicolidae*, *Rodentia*) has been found in the “Conglomerati di Vinci”. It is related to Middle to early Late Pliocene (MN15b-16b) (Fejfar, 2001). Together with *Germanomys*, remains of *E. ex gr. E. stenonis-senezensis* have been recovered. Such a finding, even if without a specific attribution, reduces the time span to Late Pliocene (Costa San Giacomo-Olivola F.U.), since either *E. stenonis* Cocchi and *E. senezensis* Prat are widespread in western Europe in sites correlated with Late Pliocene and earliest Pleistocene (Alberdi *et al.*, 1998).

A few km westward in the sediments of the Massarella Unit, related to those of Vinci, the Casa Sgherri local fauna has been found (Marcolini *et al.*, 2000; Marcolini, 2001, Marcolini, in press). Large and small mammals have been recovered and the assemblage seems to be related to the Late Pliocene. As to large mammals, the contemporary presence of *Enhydriactis ardea* (Bravard), *Acinonyx pardinensis* (Croizet & Jobert), *Sus strozzi* Meneghini and *Macaca sylvana florentina* (Cocchi) has important biochronological meanings since such an assemblage indicates a time lapse comprised between the Costa S. Giacomo F.U. and the Olivola F.U. As to small mammals, *Mimomys ostramosensis* Janossy & Meulen and

*Mimomys pitymyoides* Janossy & Meulen are associated in several Late Villanyian faunas (see discussion in: Marcolini, 2001) while all the three species *M. ostramosensis*, *M. pitymyoides* and *M. pusillus* (Méhély) have been recently recovered together in some Late Villanyian localities (i.e. Przymilowice 3, Poland) (Nadachowski, 2001). If we consider this piece of information, together with large mammals biochronological information the assemblage can be correlated with the Costa S. Giacomo to Olivola F.U., Late Pliocene in age (Marcolini, in press).

On the basis of the fossil content, the basal portion of the Massarella unit and the "Conglomerati di Vinci" must be attributed to the Late Pliocene (Marcolini, 2001; in press), in accordance to the recent interpretation of the Lower Valdarno area suggested by Zanchetta *et al.* (1995), Zanchetta & Mazza (1996) and Marcolini *et al.* (2000). These authors suggest that the post-Middle

Pliocene cycle in the Lower Valdarno is not entirely attributable to the Early Pleistocene but it could be antedated to the Late Pliocene.

Indeed, Zanchetta & Mazza (1996), on the basis of the finding of *Anancus arvernensis* (Croizet & Jobert) in sediments disconformably overlying the Sabbie Gialle Fm. and laterally continuous with the Sabbie e Argille ad *Arctica islandica* Fm., suggest that the lowermost part of this new cycle may be older than the base of the Early Pleistocene. The authors suggested two scenarios to justify this finding: the first hypothesis is that *Anancus arvernensis*, whose LAD in Italy is in the Costa San Giacomo F.U., survived until the Pleistocene Olivola F.U. (now correlated with Late Pliocene; Torre *et al.*, 1996). The second one is that the base of the Sabbie e Argille ad *Arctica* cycle is older than previously believed, i.e. Late Pliocene. The authors saw the second scenario as the most acceptable.

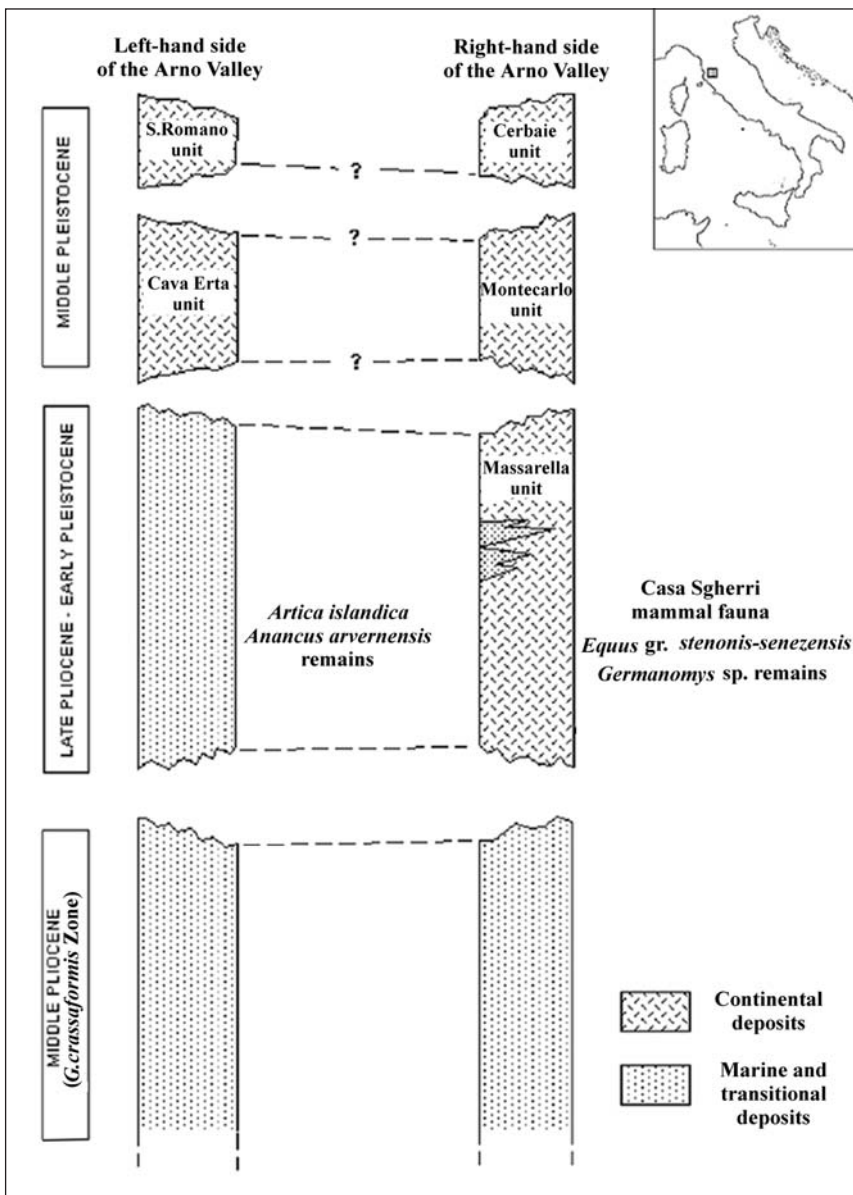


Fig. 2 - Location of the Lower Valdarno fossiliferous sites and schematic sketch of the relationships of the left-hand and right-hand Plio-Pleistocene deposits.

**3) The south-western branch of the Tiber River Basin (Umbria): an open air lab for correlating continental to marine deposits**

The Tiber River Basin is the largest intramontane basin of the Apennine, in which non marine sedimentation took place from Pliocene up to Holocene. Modern studies give an updated picture of stratigraphy and palaeontology of its south-western branch, where the sedimentary successions widely crop out. Stratigraphy was depicted, among others, by Conti & Girotti (1978), Ambrosetti *et al.* (1989, 1995a, 1995b), Basilici (1995, 1997), Abbazzi *et al.* (1997).

The Pliocene and Early Pleistocene deposits considered in these studies are referable to three lithostratigraphic units (Fig. 3):

1. The "Fosso Bianco" Formation, a lacustrine unit, Middle Pliocene – Late Pliocene in age.
2. The "S. Maria di Ciciliano" Formation, which unconformably lies above the "Fosso Bianco" Formation. It consists of sediments laid down in a fluvial environment characterised by different facies: meandering channel deposits with trough cross stratification, lake and swamp deposits, and paleosols. This formation has been referred to the Early Pleistocene but, as discussed in this work, the palaeontological data suggest the occurrence of Late Pliocene elements.
2. The "Chiani-Tevere Formation", a marine unit widely outcropping along the Middle Tiber Valley and bordering on the "S. Maria di



Ciciliano" Formation by means of the interfingering of their sediments. The "Chiani-Tevere" Formation is mostly Early Pleistocene, with only in a few sites a Gelasian age. The total thickness exceeds 300 m and the heteropy to the "S. Maria di Ciciliano" Formation occurs where its strata are Santernian in age (Mancini *et al.*, in press).

Up to 15 years ago the only important large mammal finding in the south-western branch of the Tiber River Basin was the almost complete skeleton of *Stephanorhinus etruscus* (Falconer) coming from Capitone (Ambrosetti, 1972). In the following years a new research campaign enabled a more detailed definition of the stratigraphy of continental deposits outcropping in the area as well as the discovery of many vertebrate sites.

In the area near Terni and Montecastrilli the "S. Maria di Ciciliano" Formation outcrop (Basilici, 1995; 1997). This formation is heteropic to the marine Chiani-Tevere Formation, which is mostly of Santernian age (Mancini *et al.* in press), thus it has traditionally be referred to Early Pleistocene. Recent discoveries in the Terni area suggest the occurrence of more fossiliferous levels different in composition and age.

In the fluvial deposits exposed in this area three mammal faunal assemblages have been collected until now.

The older one comes from Torre Picchio and includes a great number of vertebrates, coprolites, freshwater molluscs, ostracods and plants (woods, fruits and seeds) (Girotti *et al.*, in press).

Vertebrates are represented by large and small mammals, rare birds, reptiles, amphibians and some fishes. Among the mammals *Prolagus* sp. *Oryctolagus lacosti* (Pomel), *Mimomys medasensis* Michaux, *?Mammuthus meridionalis* (Nesti), *Stephanorhinus* cf. *S. etruscus* (Falconer), *Equus stenonis* Cocchi, *Sus strozii* Meneghini, *Eucladoceros dicranios* (Nesti) vel *ctenoides* (Nesti), *Axis nestii* (Major), Bovoidea

(*?Gallogoral* sp.), *Leptobos vallisarni* Merla vel *L. etruscus* (Falconer), Mustelidae indet. (*?Baranogale* sp.), *Canis* cf. *C. arnensis* Del Campana, *?Homotherium creatidens* (Fabrini) have been found. This faunal assemblage shows transitional features between Costa S. Giacomo F.U. and Olivola F.U., with the contemporary occurrence of *Mimomys medasensis* (recorded herein for the first time outside Spain), *?Baranogale* sp. (similar in size with the middle Villafranchian European specimens), *?Gallogoral* sp., *Axis nestii* and *Leptobos etruscus*.

Another faunal assemblage comes from Villa S. Faustino and Colle S. Andrea, near Massa Martana (Ambrosetti *et al.*, 1995a) and it is referable to the late Villafranchian.

At Villa S. Faustino the fossil mammals mainly come from the sandy deposits (Ambrosetti *et al.*, 1995; Sardella *et al.*, 1995) and include: *Castor* sp., Elephantidae indet., *Stephanorhinus etruscus*, *Equus stenonis*, *Sus strozii*, *Axis nestii*, Cervidae indet., *Leptobos* sp. (*vallisarni* vel *etruscus*), *Megantereon cultridens* (Cuvier, *partim*). At Colle S. Andrea *Pachycrocuta* cf. *P. brevisrostris* (Aymard) Cervidae indet., *Leptobos* cf. *L. vallisarni*, *Castor* sp. occur.

The paleontological analysis of these sites suggests they are coeval and to refer the faunas to the Tasso F.U.

The third assemblage comes from Colle S. Umano and includes large mammals referable to the late Villafranchian-earliest Galerian (Early Pleistocene). The faunal list includes a large sized equid referable to *Equus* ex gr. *E. bressanus-suessenbornensis*, a bovid with bisontine features (*Bison* vel *Leptobos*), *Hippopotamus antiquus* Desmarest and *Axis eurygonos* (Azzaroli).

The presence of different mammal faunas in the south-western branch of the Tiber River Basin suggests a more complex framework for the stratigraphy of the "S. Maria di Ciciliano" Formation. The faunal assemblage coming from Torre Picchio shows more "archaic" features (*Mimomys medasensis*, *Axis nestii*, the possible

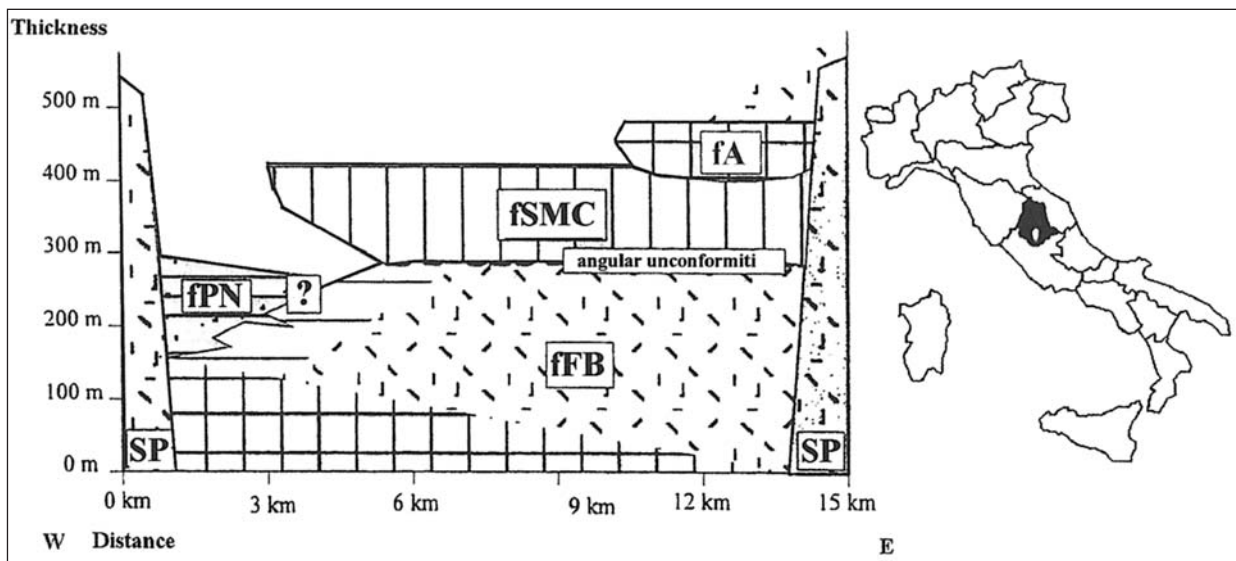


Fig. 3 - Location of the Tiber River basin and schematic sketch of the stratigraphy: fA - Acquasparta Formation (Early Pleistocene); fSMC - S. Maria di Ciciliano Formation (Early Pleistocene-?Late Pliocene); fPN - Ponte Naia Formation (Late Pliocene); fFB - Fosso Bianco Formation (Middle-Late Pliocene); PS - pre-Pliocene substratum.

occurrence of a middle sized bovid) compared to that from Colle S. Umano (*Axis eurygonos*, large bison-like bovid, etc...), with typical Early Pleistocene elements. Biochronological considerations suggest a wider time span for the continental succession of "S. Maria di Ciciliano" Formation (Late Pliocene-Early Pleistocene). The biochronology of this faunal assemblages and its significance in the stratigraphy of the Tiber River Basin is discussed in detail in Girotti *et al.* (in press), where two possibilities have been pointed out: to assign a Late Pliocene age to the fossiliferous deposit, with the first occurrence of species that will be very common during the Early Pleistocene times (e.g. *Axis nestii*, *Leptobos etruscus*) or to consider peninsular Italy as a *refugium* area, in which some vertebrates, molluscs and plants of Pliocene origin survived in the Early Pleistocene (see conclusions).

## CONCLUSIONS

The use of the biochronological units, based on the occurrence and evolutionary degree of mammals, for the correlation of marine and continental sequences, in some cases enables a more detailed definition of the age of the sequences, but in other cases shows a more complex framework.

The Mandriola fossiliferous site is an emblematic example of how biochronological criteria can be successfully used to infer age determination. Moreover, in this case it has been possible to apply continental European biochronological framework to the study of insular faunas.

The interpretation of the marine and non marine fossil record of Lower Valdarno and Tiber River Basin (related to the Plio-Pleistocene transition) lead to two different scenarios: 1) the Italian peninsula can be considered as a *refugium* area for the Pliocene *taxa*, which survived until the earliest Pleistocene; 2) the age of deposits previously referred to Early Pleistocene has to be considered older (Late Pliocene).

The latter interpretation fits well with the stratigraphy of the right-hand side of the Lower Valdarno and of the Upper Valdarno and also with the palaeomagnetic analyses of Ambrosetti *et al.* (1975) and Bedini *et al.* (1981) recognising the subchron Reunion (2-2.2 Ma) within the sediments of the "Sabbie e Argille ad *Arctica*" of the Colline Pisane. Moreover, this interpretation is confirmed by our recent findings of Vinci and Casa Sgherri that enable a correlation of the "Conglomerati di Vinci" and the Massarella Unit with the "Sabbie e Argille ad *Arctica*", since all of them bear mammals of the Costa San Giacomo-Olivola F.U.

The mammal faunas from the south-western branch of the Tiber River basin show differences in composition and can be referred to Costa S. Giacomo-Olivola F.U. (Torre Picchio), Tasso F.U. (Villa S. Faustino-Colle S. Andrea) and Farneta F.U. (Colle S. Umano) respectively. Such palaeontological data suggest a wider time span (Late Pliocene-Early Pleistocene) for the continental "S. Maria di Ciciliano" Formation. An age attribution for this formation other than Early Pleistocene is therefore problematic, both from a geologic and a stratigraphic point of view. From the geological point of view, the "S. Maria di Ciciliano" Formation is heteropic to the marine Chiani Tevere one,

which is prevailingly Santeranian in age and lies unconformably on the Middle Pliocene cycle: only in some areas of structural lowering it passes inferiorly and continuously to Late Pliocene strata, but before the heteropic episodes.

In order to find a solution to these still open problems a detailed analysis of the stratigraphy, of the local tectonics of the fossiliferous marine and non marine deposits, and the taphonomy of the mammal remains has to be considered.

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