THE EARLY PLIOCENE MAMMAL ASSEMBLAGE OF VAL DI PUGNA (TUSCANY, ITALY) IN THE LIGHT OF CALCAREOUS PLANKTON BIOSTRATIGRAPHICAL DATA AND PALEOECOLOGICAL OBSERVATIONS

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Riassunto. Viene condotta un'indagine stratigrafica sui depositi argillosi e sabbiosi affioranti in Val di Pugna, nota località vicino a Siena (Toscana, Italia) che ha restituito in passato significativi resti di mammiferi fossili. Lo scopo del lavoro è la datazione e l'interpretazione dell'ambiente deposizionale dei sedimenti che contengono i resti di vertebrati raccolti in questa località di cui è nota con precisione la provenienza. Sono state studiate in dettaglio due sezioni stratigrafiche, ubicate nei pressi degli abitati di Ruffolo e di Case il Poggio, da cui provengono resti di mammiferi sia marini che terrestri. L'analisi biostratigrafica integrata di foraminiferi planctonici e nannoplancton calcareo ha permesso di riconoscere che i depositi analizzati abbracciano il limite delle Zone a foraminiferi planctonici MPL3 e MPL4, corrispondente alla zona a nannofossili calcarei a *Reticulofenestra pseudoumbilicus* (MNN 14-15). Le caratteristiche sedimentologiche ed il contenuto faunistico indicano un ambiente deposizionale marino in progressivo approfondimento con passaggio da depositi di shoreface superiore fino a depositi di lower shoreface-offshore. La fauna a vertebrati considerata è rappresentata, tra i mammiferi marini, da un cetaceo (*Tusciziphius crispus*) e un sirenide (*Metaxytherium gervaisi*) e, tra i mammiferi continentali, da un rinoceronte (*Stephanorhinus jeanvireti*) e un bovide (*Alephis lyrix*). I resti di sirenidi sono probabilmente i soli autoctoni perché l'ambiente di sedimentazione è compatibile con il loro habitat naturale. L'accumulo degli altri reperti fossili viene invece interpretato come dovuto al trasporto per galleggiamento e alla successiva deposizione sul fondo di parti scheletriche da carcasse in decomposizione. L'inquadramento biostratigrafico dei siti di ritrovamento permette di precisare l'età dei reperti esaminati. Di particolare importanza risultano l'invecchiamento di *Stephanorhinus jeanvireti* dalla zona MN16 alla zona MN14 e quello di *Alephis lyrix* dalla zona MN15 alla zona MN14.

Abstract. The stratigraphy of clayey and sandy beds outcropping in Val di Pugna locality near Siena (Tuscany, Italy) celebrated for the past finds of fossil mammalian remains, is studied here. The research is aimed to date and define the depositional environment of the sediments that yielded fossil bones of known provenance.

Two sequences have been studied in detail; they are located near the hamlets of Ruffolo and Case il Poggio, where both marine and land mammal remains had been found. The integrated biostratigraphic analysis of the planktonic foraminifers and calcareous nannoplankton indicates that the deposits straddle the transition from the Zone MPL3 to MPL4 of the planktonic foraminifer biostratigraphic scale, which is correlated with the *Reticulofenestra pseudoumbilicus* Zone (MNN14-15 Zone) of the calcareous nannoplankton scale.

The sedimentary characters and the faunal content are suggestive of a progressively deepening marine environment, with a transition from upper shoreface deposits to lower shoreface-offshore deposits. The vertebrates include a cetacean (*Tusciziphius crispus*) and a sirenid (*Metaxyterium gervaisi*) amongst the marine mammals, while the land mammals are represented by a rhino (*Stephanorhinus jeanvireti*) and a bovid (*Alephis lyrix*). The sirenid remains are likely the only autochthonous elements because of their ecologic consistency with the depositional environment of the embedding sediments. The other fossil specimens are interpreted here as parts of decaying and floating carcasses that deposited their bones as they drifted away, inflated by decomposition gasses.

The biostratigraphy of the sites permits to date the fossil bones. Noteworthy occurrences are those of *Stephanorhinus jeanvireti* and *Alephis lyrix* in levels correlated with Zone MN14, since they are usually reported in Zone MN16 and Zone MN15 assemblages, respectively.

Introduction.

Fossil marine mammals are relatively frequently encountered in Pliocene sediments of Italy. Many important sites located in Tuscany, such as those of Orciano Pisano, Volterra, and Siena hills, have yielded wealthy amounts of their remains. In contrast to marine vertebrates sites, Pliocene land mammal localities are very few and bones there were collected in past times without rigorous stratigraphic control. Val di Pugna, in the outskirts of Siena, is one of the few celebrated sources of Pliocene invertebrate and vertebrate specimens in Italy. It yielded both marine and land vertebrate remains, which enjoyed the consideration of researchers at least since the second half of the 19th century, the

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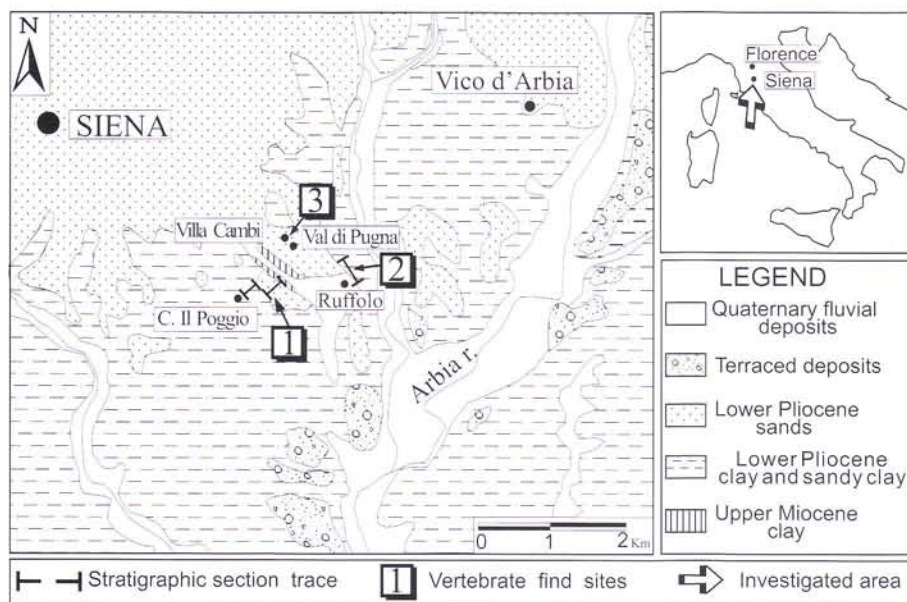
most significant contributions being those by Capellini (1872, 1885).

A detailed stratigraphic analysis of two sections of Val di Pugna, Case il Poggio, and Ruffolo, was the occasion for a revision of the vertebrates from this area. The present study is meant to define the stratigraphic position of the Val di Pugna vertebrates and the depositional environment of the fossil-bearing sediments.

Material and methods.

The mammal fossils examined are housed in the Museum of the Accademia dei Fisiocritici di Siena and in the Museo di Storia Naturale, Sezione di Geologia e Paleontologia of the University of Florence (IGF). Part of these fossils were collected in the nineteenth century and others in more recent times from Pliocene sediments outcropping in the Val di Pugna area, about 4 km southeast of Siena (Fig. 1). In particular the present study focuses on the fossil specimens from three sections located near Case il Poggio, Ruffolo, and Villa Cambi (site 1, 2, 3, respectively in Fig. 1). Other remains, reported geographically from Val Pugna, but actually without a more appropriate stratigraphic record, were discarded. Fifty-eight samples, twenty-five from Ruffolo, twenty-three from Case il Poggio, and ten from Villa Cambi, were collected for calcareous plankton biostratigraphy. The samples were washed on a 63 μ sieve for foraminifer analysis. The dried residues were split into two fractions and the fraction over 125 μ was analyzed. The preservation and abundance of the planktonic foraminifer assemblages were qualitatively and semi-quantitatively assessed (Fig. 2, 3).

The calcareous nannofossil assemblages were studied from "smear slides" prepared following the standard procedure. Qualitative and semiquantitative analyses were carried out to determine the preservation and abundance of the nannofossil assemblages (Fig. 2, 3). Quantitative methods have been adopted to investigate the occurrences of some index species (Backman & Shackleton 1983; Rio et al. 1990). Quantitative data were obtained by:

1 - Counting the index species relative to a fixed number of taxonomically related forms. A counting of 100 reticulofenestrids >4 microns was performed to evaluate the abundance of *Reticulofenestra pseudoumbilicus*;

2 - Counting the index species per unit area of the slides. This method was applied to assess the abundance of rare or very rare taxa,

such as *Discoaster asymmetricus*, *D. tamales*, and *Sphenolithus* spp. The counting was performed by scanning an area of 16 mm2.

The biostratigraphic schemes adopted here are those proposed for the Mediterranean area by Cita (1973, 1975) and emended by Rio et al. (1984) and Sprovieri (1992) for the planktonic foraminifers, and that by Rio et al. (1990) for the calcareous nannofossils. The integrated biostratigraphic schemes of Figs. 2 and 3 are based on those of Berggren et al. (1995), Rio et al. (1990), and Sprovieri (1993). The magnetostratigraphic polarity time scale is after Cande & Kent (1995).

The washing residues and the smear slides studied are housed in the Earth Sciences Department of the Pisa University.

Geological and stratigraphical setting.

Val di Pugna is located in the northwestern portion of the Siena basin, the latter was formed by the extensional processes that affected the whole Tyrrhenian margin since the Late Tortonian (Elter et al. 1975; Malinverno & Ryan 1986; Patacca et al. 1990). The basin is filled with marine and continental sediments accumulated from the Late Miocene to the Quaternary (Bossio et al. 1993). Pliocene deposits outcrop extensively in the basin and reach a thickness of over 1000 m (Costantini et al. 1982; Gandin & Sandrelli 1992). They are mainly represented by clays, clayey-sands (both indicated as "Pa" on the *Foglio 120 Siena*; Signorini 1967) and sands ("Ps" on the same map), recording the Lower-Middle Pliocene resumption of marine deposition in the area (Gandin 1967, 1982), following the Upper Miocene continental sedimentation (Bossio et al. 1993).

The sections analyzed are located about 4 km southeast of Siena, in the outskirts of Val di Pugna, near the hamlets of Case il Poggio and Ruffolo (sites 1 and 2 in Fig. 1). A detailed section of the sands outcropping near the hamlet of Villa Cambi (site 3 in Fig. 1) is not shown here because it is easily correlatable, with the lower portion of Case il Poggio section. The lateral stratigraphic relationship between the deposits of Case

Il Poggio and Ruffolo are established on the same basis. The Case il Poggio sedimentary succession (Fig. 2) is about 36 m thick, lies directly on top of the Upper Messinian brackish clays and displays a generally fining-upwards tendency.

The 22 m thick basal section, which corresponds to Capellini's (1885) "Fangonero" section, is represented by massive bioturbated fine-grained yellow sands. Fossiliferous beds are present and yield *Peliciora gigas* and *Panopea glicimeris* specimens still preserved in life position. *Teredolites* traces were found in tree remains. Five lenticular (few cm-thick) intercalations of feldspar litharenites occur some 9 m from the base of the outcropping section. They are formed by shale slabs, fossiliferous mudstone-wackestone, low-grade metamorphic rocks and chert. Mudstone-wackestone lithoclasts derive from lower Paleogene units, as attested by the presence of *Acarinina bullbrooki* and *Planorotalites* sp.. Angular fragments of quartz are also abundant and are associated with different amounts of feldspar. Centimetric well-rounded clay chips are frequent in the basal part of the section. Clast-supported polygenic conglomerates, few tens of cm thick, are also present. They are characterised by an erosive base and display a metric lenticular geometry. Embrication is common. From a compositional point of view, the conglomerate elements include light-grey and grey-green mudstone and wackstone containing early Tertiary planctonic foraminifers, silicified fine to medium-grained bioclastic packstone, chert, polycrystalline quartz, low-grade methamorphic rocks, and subordinate micaceous dark grey siltstones to fine grained sandstones. Granules and pebbles, scattered within sand matrix, have been observed up to 16.5 m from the bottom of the section.

This basal interval is characterised by scanty and poorly diversified microfossil assemblages, mainly represented by shallow-water benthonic foraminifers, among which *Ammonia beccarii* and *Elphidium crispum*, represented by large specimens, are the dominant taxa. Autochthonous planktonic foraminifers are absent or very rare (Plankton/Benthos ratio= $P/P+B^*100=0$-0.5) (Fig. 2). The same faunal assemblage and lithostratigraphic features characterise the sands outcropping on the other side of the valley, at Villa Cambi. This faunal association is suggestive of the shallower part of an inner neritic environment (bathymetric zonation after Wright 1978). From 22 to 24.5 m from the bottom there is a gradual transition to grey clayey-silty sands. Grain size further decreases from 24.5 m to the top of the section. This upper interval consists of massive, intensely bioturbated grey silty clay. The two latter intervals record a gradual increase in the abundance of foraminifers. The diversification of the benthonic assemblages increases upwards, with a progressive replacement of littoral taxa by deep-water marine dwellers. A consistently increasing percentage of plank-

tonic forams is also observed. In particular samples from the clayey-silty sand interval (BMS 84 and BMS 34 in Fig. 2) show a slightly more diversified benthic association in respect to the underlying interval. Benthic assemblages are characterised by abundant littoral taxa (*Ammonia beccarii, Florilus boueanum, Elphidium complanatum, E. aculeatum, Cribroelphidium decipiens, Rosalina globularis, Asterigerinata planorbis, Cibicides lobatulus, Planorbulina mediterranensis*), along with rare specimens of deeper dwelling benthic taxa (*Bigenerina nodosaria, Dorothia gibbosa, Sphaeroidina bulloides, Cibicidoides pseudoungerianus, Cassidulina neocarinata, Melonis soldanii, Pullenia bulloides, Uvigerina peregrina, Sigmoilopsis celata, Siphonina planoconvexa*). The $P/P+B^*100$ ratio ranges from 1 to 10 and from the sample BMS34 upwards in the sequence reworked planktonic taxa have no longer been encountered. The inner neritic environment suggested by these samples is deeper than that documented in the underlying interval.

Relatively rich and diversified benthonic foraminiferal assemblages were found in the samples collected from the silty-clay interval (BMS35 to BMS38 in Fig. 2). *Cassidulina neocarinata, Cassidulinoides* sp., *Sphaeroidina bulloides, Bigenerina nodosaria, Dorothia gibbosa, Textularia* spp., *Valvulineria bradyana, Lenticulina* spp., *Hanzawaya boueana, Pullenia bulloides, Uvigerina peregrina, Cibicidoides pseudoungerianus, C. ungerianus, Melonis soldanii, M. padanum, Gyroidinoides neosoldanii, Oridorsalis umbonatus, Praeglobobulimina ovata, Bulimina* spp., *Bolivina* spp., *Nodosaria* spp., *Marginulina costata*, and *Sigmoilopsis celata* are common. The planktonic foraminifer content shows a further increase in this interval ($10<P/P+B^*100<25$). These data are indicative of the shallower portion of an outer neritic environment.

The basal portion of Case il Poggio section is interpreted as a shallow-marine upper-shoreface deposit. The presence of *Panopea glicimeris* in life position is consistently suggestive of a subtidal environment. Conglomerate supplies and abundant plant remains are also consistent with a fairly close fluvio-deltaic environment. In the middle and upper part of the section, the characteristics of the lithofacies and the faunal content indicate a general deepening of the depositional environment to a lower shoreface-offshore zone.

Ruffolo section (Fig. 3) displays an overall thickness of about 25 meters. It is formed by a monotonous, intensely bioturbated massive grey silty clay with rare flat centimetric intercalations of sandy clay. The abundant foraminiferal content shows some differences between the lower and the upper portion of the section. The benthic foraminifer assemblages from the lower portion (samples BMS 39 to BMS 51 in Fig. 3) are mainly represented by typical inner neritic taxa (*Florilus boueanum, Ammonia* sp., *Cibicides lobatulus, C. refulgens, Cancris auriculus, Elphidium* sp., *E. complanatum,*
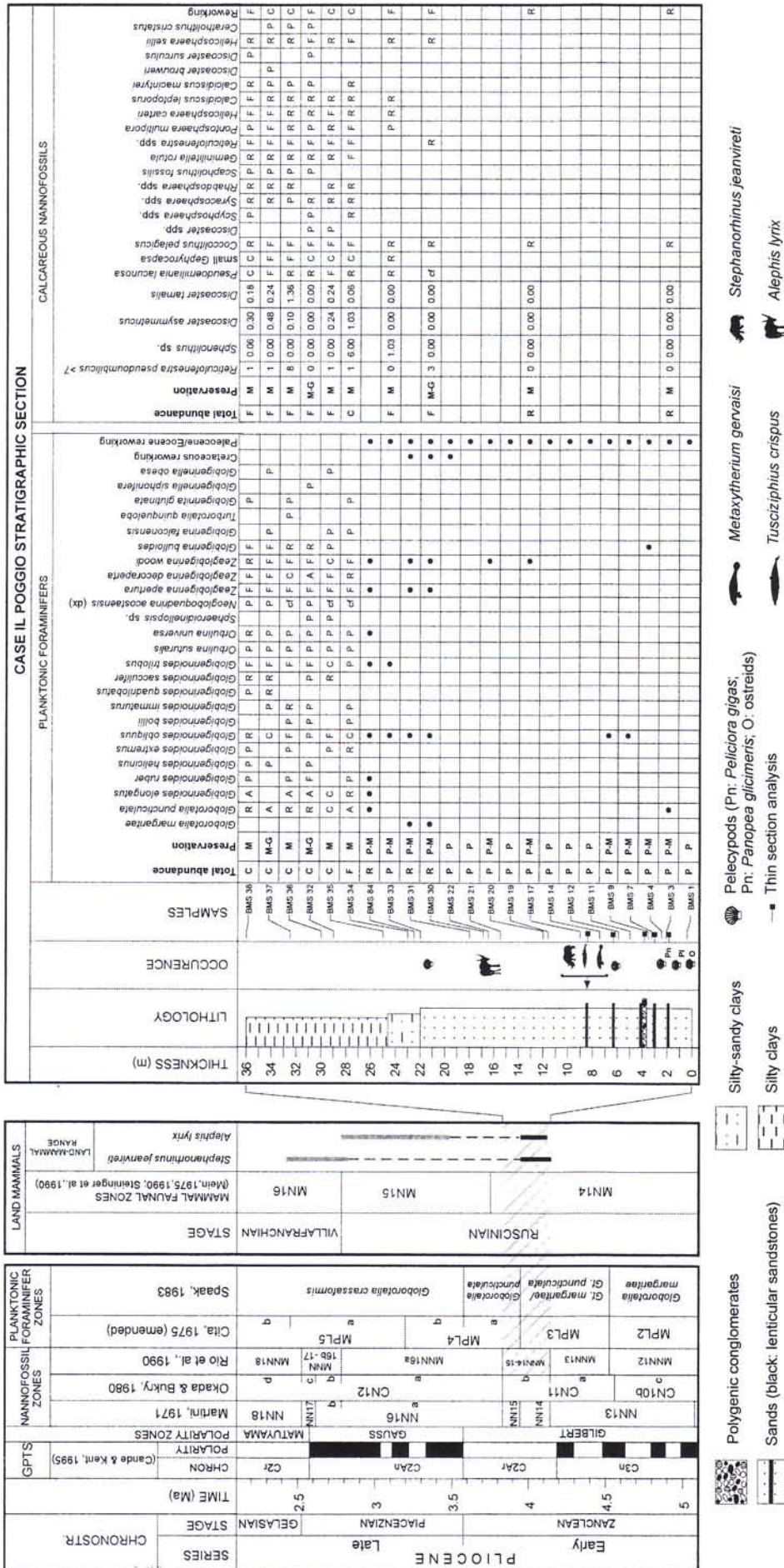
Fig. 2 - Calcareous plankton biostratigraphy of the Case il Poggio section. Integrated biostratigraphic scheme according to: Berggren et al. (1995), Rio et al. (1990) and Sprovieri (1993). Magnetostratigraphic polarity time scale is after Cande & Kent (1995). The stratigraphic position of the mammal remains is based on Capellini (1872, 1885) and Cuscani Politi (1977). Correlation between land mammal faunal zones and marine faunal zones is after Mein (1975, 1990) and Steininger et al. (1990). Age distribution of *Alephis lyrix* and *Stephanorhinus jeanvireti* according to: Guérin (1972, 1980) (grey bars), this paper (black bars).

Abundance and preservation codes of the planktonic foraminifers:

Total abundance (planktonic foraminifers/planktonic foraminifers + benthonic foraminifers): A (abundant): >30%; C (common): 10-30%; F (few): 3-10%; R (rare): 3-1%; B (barren): no specimens.

Relative abundance (single planktonic taxon/total abundance): A (abundant): >30%; C (common): 10-30%; F (few): 3-10%; R (rare): 3-1%; P (presence): <1%; B (barren): no specimens; • : occurrence, without estimation of the relative abundance (just in case of total abundance <3%).

Preservation state: G (good): little or no fragmentation, overgrowth and/or dissolution (>90% of intact specimens); M (moderate): some signs of fragmentation, overgrowth and/or dissolution (30%-90% of intact specimens); P (poor): severe fragmentation, heavy overgrowth and/or dissolution (<30% of intact specimens).

Abundance and preservation codes of the calcareous nannofossils:

Total abundance (at a magnification of 1250x): A (abundant): >30 spec.s per view. C (common): 10 to 30 spec.s per view. F (few): 1 to 10 spec.s per view. R (rare): 0.1 to 1 spec.s per view. P (presence): < 0.1 spec.s per view. B (barren): no specimens.

Relative abundance of the single taxa (at a magnification of 1250x): A (abundant): >1 spec. per view. C (common): 1 spec. per view. F (few): 1 spec. per 2-10 views. R (rare): 1 spec. per 10-100 views. P (presence): 1 spec. per 100-600 views.

Preservation state: G (good): little or no evidence of dissolution and/or secondary overgrowth; fully preserved diagnostic characters. M (moderate): dissolution and/or secondary overgrowth; partially altered primary morphological characteristics; nearly all specimens can be identified at the species level. P (poor): severe dissolution, fragmentation and/or secondary overgrowth; largely destroyed primary features; many specimens cannot be identified at the species and/or at generic level.

Legend:
Pelecypods (Pn: *Peliciora gigas*; Pn: *Panopea glicimeris*; O: ostreids)
Metaxytherium gervaisi
Stephanorhinus jeanvireti
Tusciziphius crispus
Alephis lyrix
■ Thin section analysis
Silty-sandy clays
Silty clays
Polygenic conglomerates
Sands (black: lenticular sandstones)

Fig. 3 - Calcareous plankton biostratigraphy of the Ruffolo section. Adopted integrated biostratigraphic scheme, abundance and preservation codes of the planktonic foraminifers and calcareous nannofossils as in Fig. 2. The stratigraphic position of the *M. gervaisi* remains is based on Canocchi (1987).

Quinqueloculina sp., *Triloculina* sp., *Planorbulina mediterranensis, Asterigerinata planorbis, Rosalina globularis,* and *Reussella spinulosa*) associated with rare specimens of several deeper dwelling taxa (*Dorothia gibbosa, Bigenerina nodosaria, Lenticulina* spp., *Melonis padanum, M. soldanii, Cassidulina neocarinata, Sphaeroidina bulloides, Cibicidoides ungerianus, C. pseudoungerianus, Uvigerina peregrina, Pullenia bulloides, Sigmoilopsis celata, Planulina ariminensis, Marginulina costata, Bolivina* spp., and *Bulimina* spp.). Planktonic forams range from 5% to 10%. Upward in the section benthonic taxa typical of deeper settings increase in abundance gradually replacing taxa typical of shallower depths. The planktonic foraminiferal content increases consistently (10<P/P+B*100<30). Foraminiferal assemblages from the upper portion of the Ruffolo section are very similar to those of the upper part (silty-clay interval) of the Case il Poggio section.

These data suggest a shift of the depositional environment from an inner neritic zone (lower portion of the section) to the shallower portion of an outer neritic zone (upper part of the section). The characters of the lithofacies and of the faunal assemblage permit to refer the Ruffolo deposits to a lower shoreface-offshore accumulation area.

Biostratigraphy.

An integrated biostratigraphic study, based on plankton foraminifers and calcareous nannofossils, was performed. The distribution of the calcareous plankton taxa of Case il Poggio and Ruffolo is plotted in Fig. 2 and 3, respectively. The main taxa of planktonic foraminifers and calcareous nannofossils are shown in Pl. 1 and 2.

The biostratigraphy of the sections studied here is the following:

· **Ruffolo section.** - The planktonic foraminiferal assemblages are characterized by the co-occurrence of *Globorotalia puncticulata* (Pl. 1: figs. 3a-c) and *Globorotalia margaritae* (Pl. 1: figs. 1a-c) in the lower portion of the section. *Globorotalia margaritae* disappears abruptly between the samples BMS 50 and BMS 51, while *Globorotalia puncticulata* is constantly present to the top of the section (Fig. 3). The calcareous nannofossils assemblages are characterized by the presence of *Reticulofenestra pseudoumbilicus, Pseudoemiliana lacunosa,* small *Gephyrocapsa* specimens, and scattered specimens of *Discoaster asymmetricus* and *Discoaster tamalis* (Pl. 2: figs. 6, 7-8, 4-5b, 2, 1). The accumulated information suggests that the deposition of the Ruffolo section occurred in a short time lapse (not exceeding 300 kyr.) confined between the upper portion of the MPL3 Zone and the basal part of the MPL4 Zone, corresponding to the *Reticulofenestra pseudoumbilica* Zone (MNN 14-15 Zone in Fig. 3).
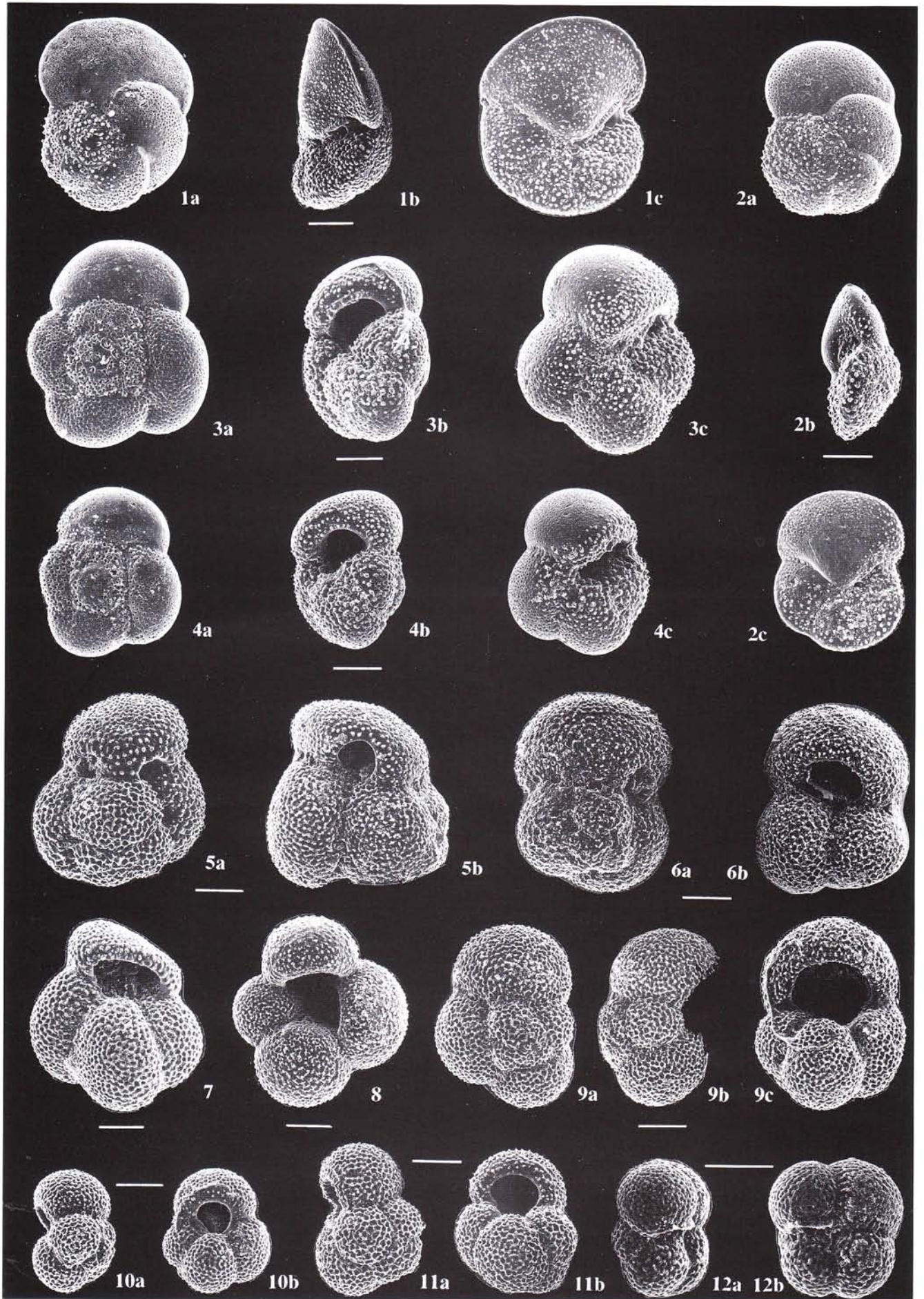
Case il Poggio section. - The planktonic foraminiferal record from the sandy lower portion of the sequence is extremely poor and affected by Paleocene-Eeocene and Cretaceous reworked taxa. Nevertheless, *Globorotalia puncticulata* and *Globorotalia margaritae* (Pl. 1: figs. 2a-c) are occasionally recorded. The deposit is therefore assigned to the MPL3 concurrent range Zone. The silty-clayey upper portion of the section is characterized by the presence of *Globorotalia puncticulata* (Pl. 1: figs. 4a-c) and the absence of *Globorotalia margaritae*. This interval was thus deposited in the MPL4a Subzone.

The calcareous nannofossil association consists only of Paleogene and Cretaceous reworked taxa in the lower sandy portion of the sequence. Samples from the silty clayey upper portion of the sequence display the same associations observed in the Ruffolo section and are therefore assigned to the *Reticulofenestra pseudoumbilica* Zone (MNN 14-15 Zone).

The integrated nannofossils and planktonic foraminifer data from the Case il Poggio section are therefore suggestive of an age of deposition ranging from the MPL3 Zone to the lower portion of the MPL4a Subzone (Fig. 2).

PLATE 1 (planktonic foraminifers)

Fig. 1   - *Globorotalia margaritae* Bolli & Bermudez, 1965. Ruffolo section, sample BMS48. a: spiral view; b: side view; c: umbilical view.
Fig. 2   - *Globorotalia margaritae* Bolli & Bermudez, 1965. Case il Poggio section, sample BMS30. a: spiral view; b: side view; c: umbilical view.
Fig. 3   - *Globorotalia puncticulata* (Deshayes, 1832). Ruffolo section, sample BMS45. a: spiral view; b: side view; c: umbilical view.
Fig. 4   - *Globorotalia puncticulata* (Deshayes, 1832). Case il Poggio section, sample BMS32. a: spiral view; b: side view; c: umbilical view.
Fig. 5   - *Globigerinoides elongatus* (d'Orbigny, 1826). Case il Poggio section, sample BMS38. a: spiral view; b: umbilical view.
Fig. 6   - *Globigerinoides ruber* (d'Orbigny, 1839). Ruffolo section, sample BMS61. a: spiral view; b: umbilical view.
Fig. 7   - *Globigerinoides extremus* Bolli &Bermudez, 1965. Ruffolo section, sample BMS53. Umbilical view.
Fig. 8   - *Globigerina bulloides* d'Orbigny, 1826. Ruffolo section, sample BMS52. Umbilical view.
Fig. 9   - *Zeaglobigerina apertura* (Cushman, 1918). Ruffolo section, sample BMS45. a: spiral view; b: side view; c: umbilical view.
Fig. 10   - *Zeaglobigerina woodi* (Jenkins, 1960). Case il Poggio section, sample BMS37. a: side view; b: umbilical view.
Fig. 11   - *Zeaglobigerina decoraperta* (Takayanagi & Saito, 1962). Ruffolo section, sample BMS49. a: side view; b: umbilical view.
Fig. 12   - *Neogloboquadrina acostaensis* (Blow, 1959). Ruffolo section, sample BMS61. a: side view; b: umbilical view.
           (Scale bars: 100 µm)
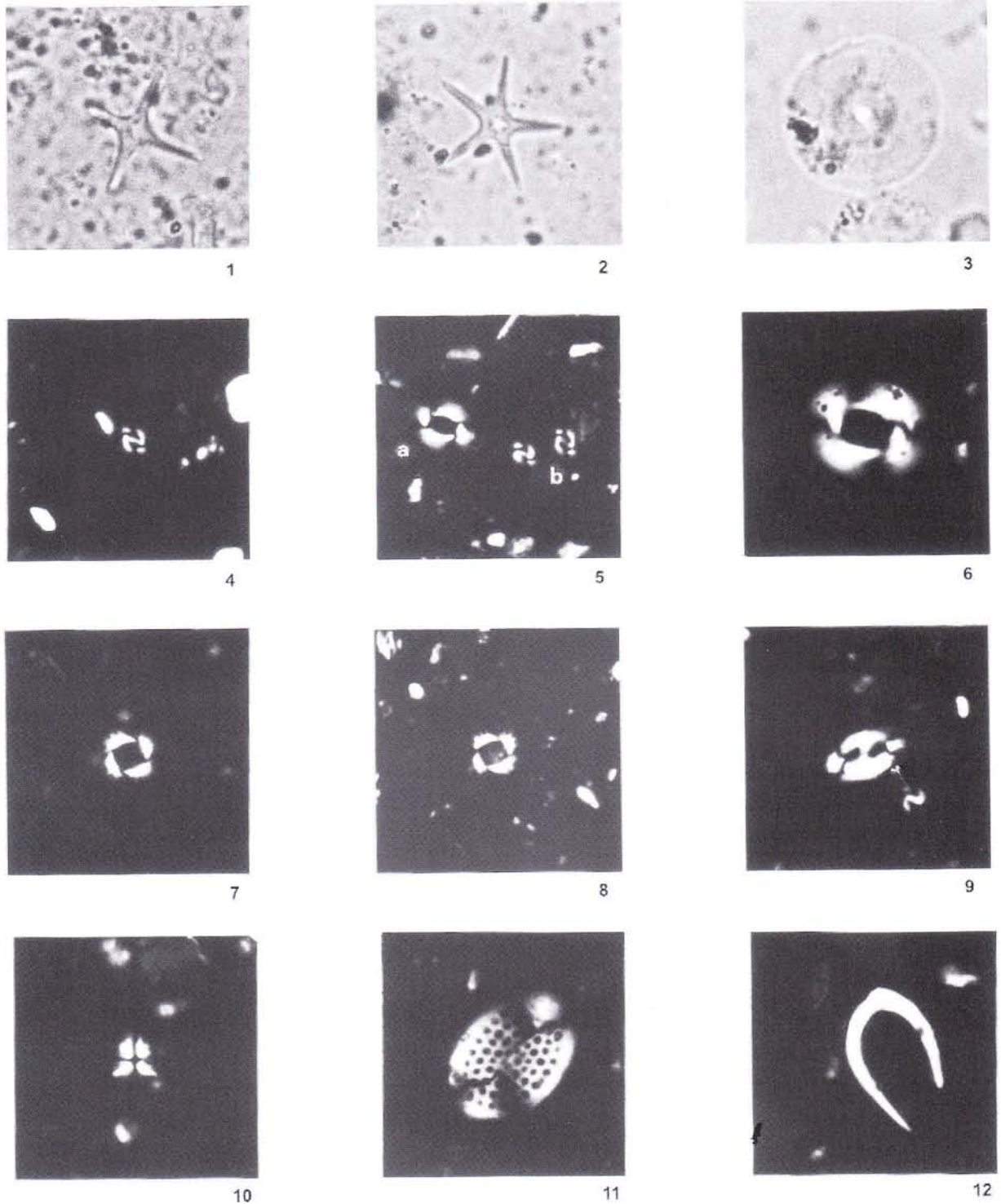
PLATE 2 (calcareous nannofossils)

Fig. 1   - *Discoaster tamalis* Kamptner (1967). Case il Poggio section, sample BMS36.

Fig. 2   - *Discoaster asymmetricus* Gartner (1969). Ruffolo section, sample BMS41.

Fig. 3   - *Calcidiscus macintyrei* (Bukry & Bramlette, 1969) Loeblich & Tappan (1978). Ruffolo section, sample BMS43.

Fig. 4   - small *Gephyrocapsa* (Rio, 1982). Ruffolo section, sample BMS43.

Fig. 5   - *Reticulophenestra* sp. (a), small Gephyrocapsa (b). Case il Poggio section, sample BMS34.

Fig. 6   - *Reticulofenestra pseudoumbilicus* (Gartner, 1967) Gartner (1969). Ruffolo section, sample BMS41.

Fig. 7   - *Pseudoemiliania lacunosa* (Kamptner, 1963) Gartner (1969). Ruffolo section, sample BMS41.

Fig. 8   - *Pseudoemiliania lacunosa* (Kamptner, 1963) Gartner (1969). Case il Poggio section, sample BMS36.

Fig 9   - *Helicosphaera sellii* Bukry & Bramlette (1969). Case il Poggio section, sample BMS32.

Fig. 10   - *Sphenolithus* sp. Deflandre in Grassé (1952). Ruffolo section, sample BMS40.

Fig. 11   - *Pontosphaera multipora* (Kamptner, 1948) Roth (1970). Case il Poggio section, sample BMS34.

Fig. 12   - *Ceratolithus cristatus* Kamptner (1950). Ruffolo section, sample BMS47.
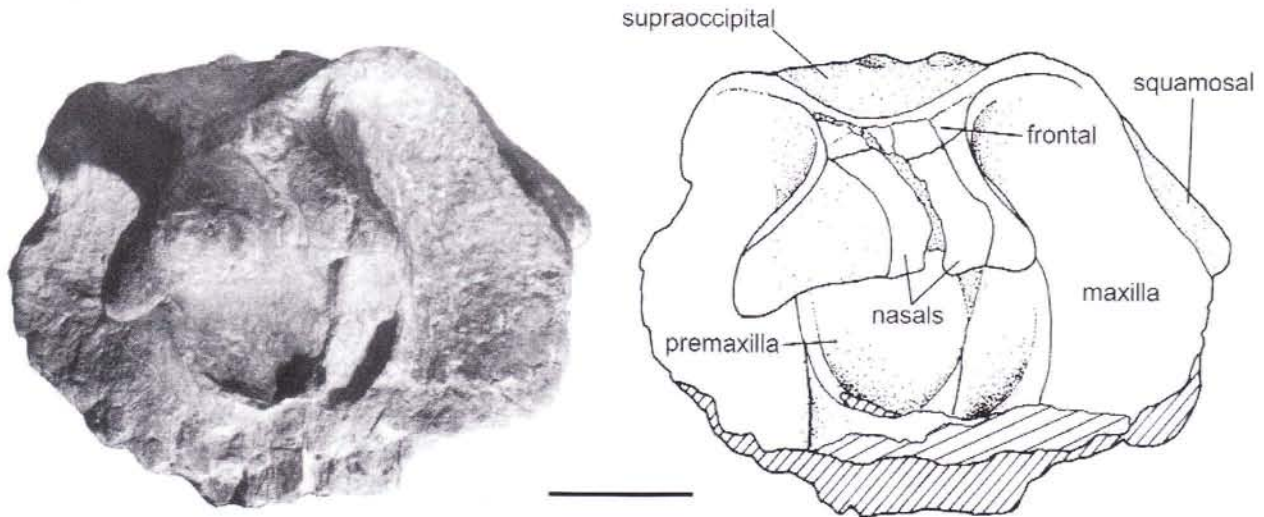   (All specimens x 2150)

Fig. 4 - *Tusciziphius crispus* Bianucci, 1997, holotype, Fangonero, Val di Pugna (province of Siena, Tuscany). Skull lacking of rostrum in dorsal view (IGF 1576V). Scale bar = 10 cm.

Marine mammals.

Bones of one cetacean individual (Fig.1, site 1) and of two sirenians (Fig.1, sites 1 and 2) represent the only ascertained marine mammal finds from Val di Pugna. Despite their small number, the specimens are significant and representative; two of them are holotypes.

The cetacean fossil was recovered in the sands of Case il Poggio section (Fig. 1, site 1). The specimen consists of an incomplete skull (IGF 1594V), a fragmental hyoid (IGF 1534V), some incomplete vertebrae and ribs (IGF 1536V, IGF 1537V, IGF 1569V, IGF 1570V, IGF 1572V). The fossil was originally described and assigned to *Choneziphius planirostris* by Capellini (1885) because of the presumed affinities to a ziphiid from the Miocene sediments of Antwerp (Belgium). Recently Bianucci (1997) described this find as the holotype of *Tusciziphius crispus*. The skull of *Tusciziphius* (Fig. 4) shows close affinities to the skulls of the present-day *Ziphius*, *Mesoplodon* and *Hyperoodon*.

The two sirenian specimens are referred to the extinct dugongid genus *Metaxytherium* (Fig. 5). The most ancient find is a fragmentary skull and mandible found in 1863 in the same stratigraphic level that yielded the cetacean remains (Fig. 1, site 1). This specimen, now housed in the Museo dell'Accademia dei Fisiocritici at Siena (number catalogue 496), was described by Capellini (1872) as the holotype of *Felsinotherium* (=*Metaxytherium*) *gervaisi*. Capellini also claimed that some ribs were successively recovered in the same locality where the holotype of *M. gervaisi* had been found; he consequently attributed the new finds to the same individual. The current location of the ribs in the Museum is now unknown and they thus could not be examined. The second significant sirenian specimen (IGF 1374799) is a complete skull found in the 1969 at Ruf-

folo (Fig. 1, site 2). This fossil was described in detail by Canocchi (1987) and referred to the same species as the Case il Poggio find. The skull from Ruffolo provided new information on the distinctive characters of *M. gervaisi*, a species that according to Canocchi (1987) is morphologically intermediate between *M. serresi* and *M. subapenninum* (=*M. forestii* = *M. gastaldii*) from the Pliocene of the Mediterranean Basin.

Land Mammals.

The fauna examined was recovered in sites 1 and 3 of Fig. 1, and was previously studied by Capellini (1872, 1885) and by Cuscani Politi (1963, 1977, 1979). The results of the present revision, however, delineate a
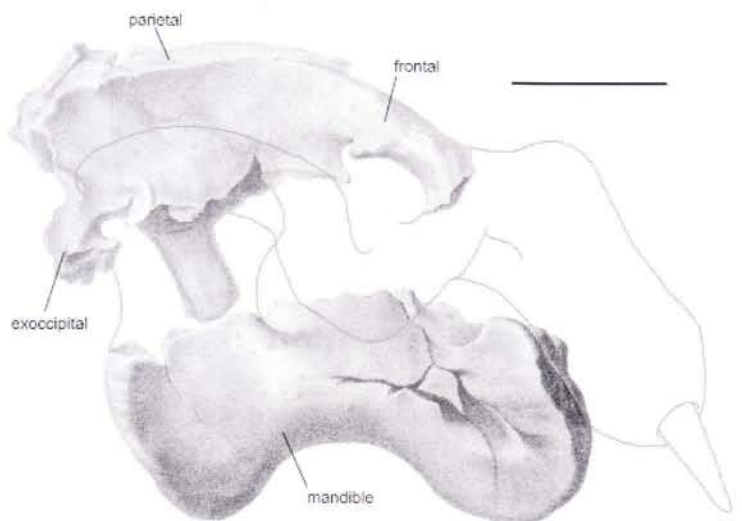

Fig. 5 - *Metaxytherium gervaisi* (Capellini, 1872), holotype, Fangonero, Val di Pugna (province of Siena, Tuscany). Incomplete skull and mandible in lateral view (MAFS, not catalogued) (after Capellini, 1872, pl. 7). Scale bar = 10 cm.

slightly different picture.

One of the most outstanding Pliocene taxa from the Val di Pugna area is a large-sized rhinoceros, identified as *Rhinoceros megarhinus* or *R. leptorhinus* by Capellini (1872, 1885) and as *Rhinoceros megarhinus* by Cuscani Politi (1963, 1977), but which is actually referable to *Stephanorhinus jeanvireti* in the writer's (PM) opinion. The species is represented by several specimens, but the attribution to *S. jeanvireti* is mainly based on a mandible (Pl. 3, fig. 2), part of the blade of a right scapula, and a right radius, which were recovered in the same sand bed of Case il Poggio section that provided also cetacean and sirenian remains (Capellini 1885) (Fig. 1, site 1). The mandible includes both horizontal rami, although fragmentary, and the symphysis. The right ramus still retains its P_2- P_4 row and part of the right M_1. The two rami are long, depressed and slender, with a straight ventral profile, which lifts up abruptly at the symphysis. The latter is also slender and shows two fairly wide alveoli for the second incisors, the right one of which is still retained in form of gem. The cheek teeth are brachyodont with a hardly marked cingulum on the buccal side of the premolars and on the lingual side of P_3. The preserved portion of M_1 bears no cingulum. The enamel is smooth all over; cementum is absent. Compared with the known mandibles of *S. megarhinus*, the horizontal rami of the Val di Pugna specimen are less massive dorso-ventrally. Moreover, the incisive corpus bears only two anterior alveoli instead of the four normally present on the megarhinus mandibles. These characters are all suggestive of *S. jeanvireti*. The size and proportions of the cheek teeth (Tab. 1) also fall in the range of variability of *S. jeanvireti*. The fragmentary right scapula blade still bears attached to it part of the embedding sediment, a yellow bivalve-bearing sand. The supraspinous fossa is broad and deep and the wall of the blade is thin. The infraspinous fossa is broad as well, but quite deeper and the bone wall is much thicker. The spine margin is bent caudalwards to some extent. The radius is only represented by its distal half (measures in Tab. 1). The distal epiphysis is somewhat more compressed dorso-palmarly and enlarged latero-medially compared to *S. megarhinus*, and has also a deeper trough for the radial extensor.

Another interesting Pliocene faunal component from the Val di Pugna area is a large-sized bovid. It is represented by a partial skull (Pl. 3, fig. 1), the fragments of two isolated third lower molars, a right and a left one, a thoracic vertebra, the corpus of perhaps another thoracic vertebra, and the diaphysis of a left femur (measures of some of these specimens are in Tab. 1). The most outstanding specimen, found at Villa Cambi (Fig. 1, site 3), is the skull, originally described by Cuscani Politi (1979). The specimen lacks the rostral part of the muzzle (the fracture passed through the M^1-M^2 commissure, both right and left M^2 and M^3 being retained), the entire nasal bones and the occiput. The basal half of both horncores is still preserved. The latter are fairly straight in sagittal view, bend gently backwards in lateral view, have a triangular cross-section, show two marked ridges, an antero-inner and a poster-external one, and form an angle of about 80°-85° from one another. They are implanted to the skull farther back from the orbits than they generally are in antelopes. The skull has a fairly broad forehead. The molars are hypsodont with prominent styles, especially the parastyle and metastyle, protruding paracone ribs and comparatively less developed metacone ribs, and robust and pointed entostyles. Cuscani Politi (1979) referred this specimen to *Parabos boodon*. Gromolard & Guérin (1980) revised the species *Parabos cordieri* and Gromolard (1980) revisited the Pliocene large-size bovid material of Europe, originally attributed to *Parabos*. Gromolard (1980) elected *P. cordieri* type-species of the genus, attributed the Roussillon (France) large-sized bovid to the new genus and new species *Alephis lyrix*, but was undecided as to the generical attribution of the scanty boodon material from Alcoy (Spain), concluding that it can be provisionally accommodated into the open genus *?Parabos*, waiting for the possible discovery of new specimens that can hopefully clear the systematic position of this bovid. *?Parabos boodon* is larger and more robust than Alephis lyrix, which in turn is larger than *Parabos cordieri*. The skull from Val di Pugna recalls *Alephis lyrix* in its morphologic traits, but is much smaller. All the bovid material from Val di Pugna is indicative of an animal intermediate in size between *P. cordieri* and *Alephis lyrix*.

These large-sized Pliocene bovids are still imperfectly known. The relatively small size of the Val di Pugna *A. lyrix* bovid might be either the result of an adaptation to local circumstances or due to dimorphism or even to subspecific difference.

Discussion and conclusion.

The fortunate co-existence of continental and marine vertebrate remains in marine sediments enables to reliably determine the biostratigraphical position of the finds and to reconstruct the depositional environment in the two sections analysed here.

Gandin (1967, 1982) referred the sediments of the north-western part of the Siena basin, which include the two studied sections, to the *Globorotalia puncticulata* zone of Iaccarino (1963). This zone is defined by the range of distribution of the index marker. It approximately embraces Spaak's (1983) *Globorotalia puncticulata/Globorotalia margaritae* zone and *Globorotalia puncticulata* zone (MPL3 Zone and MPL4a Subzone of Cita, 1975, emended), which is the zonal scheme adopted here (Figs. 2 and 3). The integrated analysis of the planktonic foraminifers and calcareous nannofossils
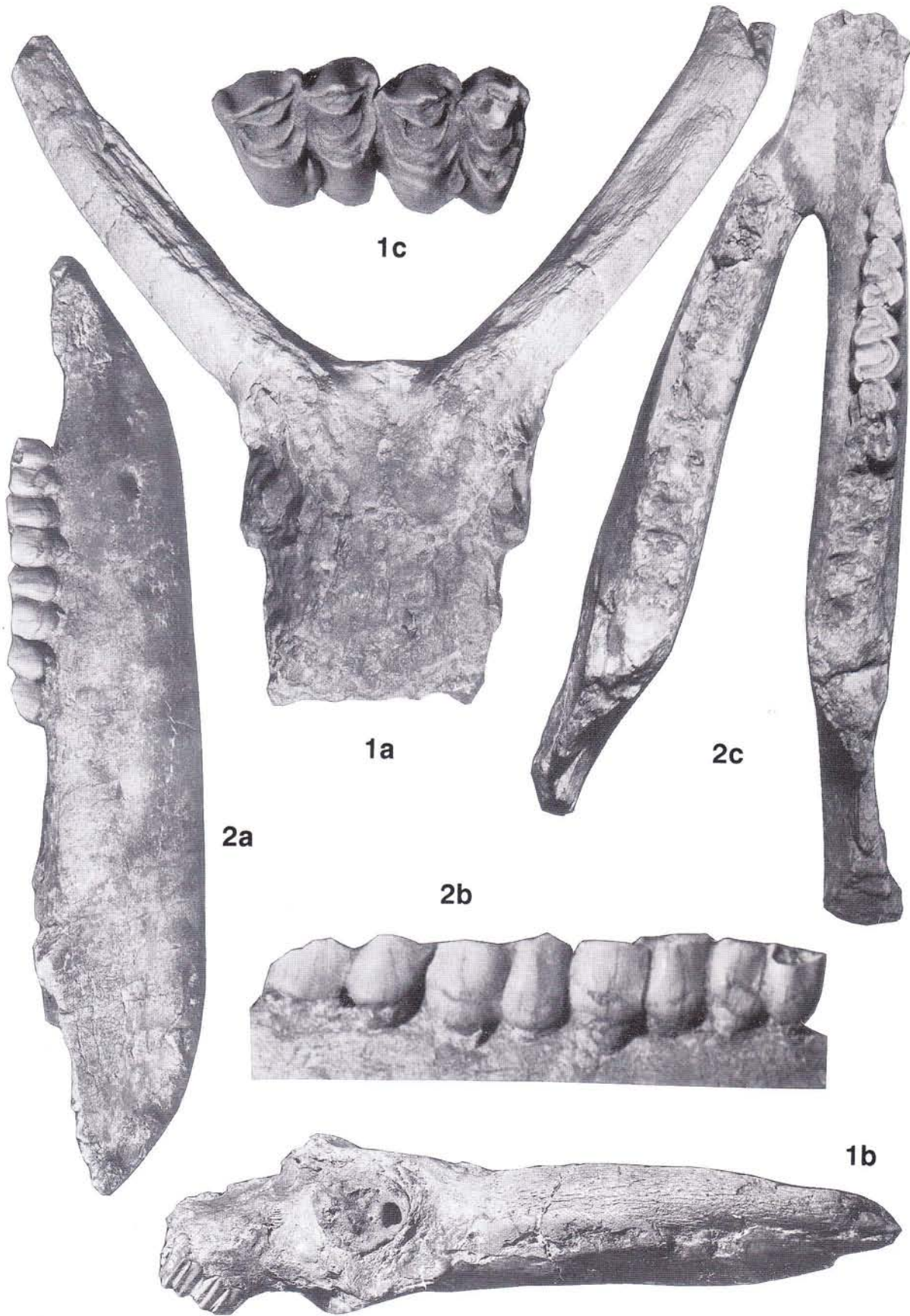
PLATE 3 (land mammals)

Fig. 1   - *Alephis lyrix skull*: a: anterior view; b: left lateral view; c: right M2/ and M/3, occlusal view; a and b 1/4 nat. size; c 1/2 nat. size.

Fig. 2   - *Stephanorhinus jeanvireti*, mandible: a: right lateral view; b: particular of the right cheek toohrow; c: occlusal view; a and c: 1/4 nat. size; b: 1/2 nat. size.

Stephanorhinus jeanvireti		
Mandible 4747 (287)		
	length	breadth
P/2	31,24	19,58
P/3	38,8	26,4
P/4	42	29,56
M/1	44,6	-
Atlas 4756-4759 (277-279)		
	height of cranial articular surface	
	58	
Radius 4754 (276)		
	distal breadth	distal depth
	100	53,7
Caput femoris 4735 (281)		
	antero-posterior diameter	latero-medial diameter
	97,7	96,9
Alephis lyrix		
Skull 7136		
	length	breadth
M2/	30	28
M3/	32	29
M/3 (uncatalogued)	36,8?	16,66
Thoracic vertebra (uncatalogued)		
	length of the corpus	breadth of the corpus
	72,31	62,42
	height of the corpus	
	50,77	

Tab. 1 - Measurements of the Val di Pugna land mammal remains (in mm).

suggests that the two sections include that part of the plaktonic foraminiferal MPL3 Zone and MPL4a Subzone which is comprised in the calcareous nannoplankton *Reticulofenestra peseudoumbilicus* Zone. The sandy segment of Case il Poggio section is referable to the MPL3 Zone for the occurrence, albeit sporadic, of the two zone markers. The absence of biostratigraphically significant nannofossils prevents further detailed determination of the age of the section. Nonetheless, field observations suggest that the sands of this segment represent only the upper part of the MPL3 Zone, since they pass laterally into the clays of the lower part of the Ruffolo section, which can be confidently attributed to the uppermost part of this biozone.

The two sections record an upward deepening trend with the transition from an upper shoreface (lower portion of the Case il Poggio section) to a lower shoreface-offshore depositional environment. The fluvio-deltaic activity recorded in the lower portion of the Case il Poggio section is consistent with the presence of fairly abundant continental vertebrate remains. The lack of evidence of transport on the land mammal bones can possibly suggest that the latter derived from rotting carcasses floating and dispersing their elements alongshore. The same probably applies to the ziphiid remains. They too show no evidence of transport; they thus likely derived from a carcass drifting from the bathyal zone, the typical environment of this taxon, to the near-coast environment after death. The presence of pelagic bathyal cetaceans in neritic-littoral beds is not unusual (Bianucci 1996; Bianucci et al. 1998), beaked whale remains being occasionally found even in fluvial deposits (Mead 1975). On the other hand, the shoreface to shoreface-offshore transition recorded in the Ruffolo and Case il Poggio sections is consistent with the probable life habitat of the sirenids, which therefore likely represent the

only autochthonous mammalian remains in the Val di Pugna area.

The biostratigraphic framework (Fig. 2) prompts a more accurate dating of *Tusciziphius* (MPL3 Zone, not younger than 3.9 Ma). Its absence in the most recent marine sediments of the Mediterranean Basin could be interpreted with the 3-3.2 MA climatic deterioration (Raffi & Monegatti 1986), although such a conclusion is still speculative, given the rarity of significant ziphiid fossils.

The *Metaxytherium* bones from Ruffolo quarry described by Canocchi (1987) were collected from a bed referable to the base of MPL4a planktonic foraminiferal Subzone (Fig. 3), very close to the MPL3/MPL4 zonal boundary. The *Metaxytherium* remains described by Capellini (1872) are assigned to the MPL3 planktonic foraminiferal Zone and, tentatively, to the upper part of this zone (Fig. 2). The stratigraphic correlation of the two sections analysed stresses the slight age difference separating the *Metaxytherium*-bearing beds of the Case il Poggio section from those of the Ruffolo section.

The biostratigraphic setting of *Metaxytherium gervaisi* confirms the stratigraphic succession of the Mediterranean Pliocene *Metaxytherium* representatives suggested by Canocchi (1987). The earliest Pliocene *M. serresii* from France and Libya (Domning & Thomas 1987) is a small-sized species that dispersed again in the Mediterranean soon after the Messinian salinity crisis (Barnes et al. 1985). *M. gervaisi*, an apparently more advanced species that *M. serresii*, can be dated to about 3.9-4 MA on the basis of the new biostratigraphical information presented here. *M. subabbenninicum* (= *M. forestii* = *M. gastaldii*) is a large-sized species that characterizes the Upper Pliocene sands from peri-Adriatic areas (Canocchi 1987).

The occurrence of *Alephis lyrix* remains in sediments straddling the MPL3-MPL4 transition has very significant stratigraphical implications, in that it resumes, and possibly contributes to solve, a still open biochronologic question. *A. lyrix* is the typical bovid from Perpignan, in the Roussillon area. Mein (1990), and later De Bruijn et al. (1992), attributed the Perpignan site to the MN15 zone (Late Ruscinian), on the basis of micromammal evidence; an opinion shared also by Azanza et al. (1997), but on the basis of the results of a multivariate approach. The MN15 zone embraces a large part of the MPL4 zone and the MPL4-MPL5 transition of the planktonic foraminiferal zonation (Fig. 2). Bachelet (1990), however, and later on also Aguilar et al. (1991), again on micromammalian grounds, disagreed with Mein (1990), correlating Perpignan with the MN 14 zone (Early Ruscinian). The possibility that the Val di Pugna *A. lyrix* might corroborate this latter interpretation, with the additional support of micropaleontological evidence, cannot be thoroughly ruled out, although several other alternative explanations can be put forth,

one of which being that the Val di Pugna *A. lyrix* is a more primitive representative than that from Perpignan.

The presence of *Stephanorhinus jeanvireti* remains in deposits correlated with the MPL3-MPL4 transition, and therefore several hundred thousands of years before the ascertained time of occurrence of the species, which was hitherto known to be confined to the Lower Villafranchian (MN16) communities (Guérin 1972, 1980), is instead an absolute novelty. Nonetheless, *S. jeanvireti* is still an imperfectly known species, as are all the Early Pliocene European representatives of these perissodactyls.

The lines of evidence presented here have therefore shown that, despite their scantiness, the Val di Pugna land mammal finds contribute essential information for a sounder knowledge of the Early Pliocene mammalian faunas of Europe.

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