Acta zool. cracov., **39**(1): 559-570, Kraków, 15 Aug., 1996

# Paleomagnetic calibration of Plio-Pleistocene mammal localities in central Italy

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Accepted for publication: 5 April, 1995

TORRE D., ALBIANELLI A., BERTINI A., FICCARELLI G., MASINI F., NAPOLEONE G. 1996. Paleomagnetic calibration of Plio-Pleistocene mammal localities in central Italy. Acta zool. cracov., **39**(1): 559-570.

Abstract. Paleomagnetic analyses have been carried out in the central Apennines. Sites studied include the Upper Valdarno and Colle Curti basins and the Oriolo site on the external margin of the belt. The oldest fossil fauna, belonging to the Triversa faunal unit (early Villafranchian), occurs in the first cycle of Upper Valdarno fluvio-lacustrine sediments, and a Gauss magnetic age, at the Kaena event, is assigned to it. The Matassino and Tasso local faunas (late Villafranchian) belong to the second Upper Valdarno sedimentary cycle and fit the upper short reversal of the Olduvai subchron and the lowermost part of the next magnetic chron, respectively. The assemblage from the Colle Curti basin is of earliest Galerian age and can be located to the beginning of the Jaramillo event. Palynological analyses have been carried out in both areas. The sediments from which the fauna of the Oriolo section comes cross either the Matuyama-Jaramillo or the Matuyama-Brunhes magnetic boundary.

Key words: Villafranchian, early Galerian, magnetostratigraphy, palynology, central Apennines, Italy.

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## I. INTRODUCTION

Mammal localities are widely represented in the Plio-Pleistocene basins along the Apennine belt of Italy. Most of them have been studied since antiquity and this has resulted in a detailed mammal biochronology. Geochronological dating of significant events was tentatively made by AZZAROLI (1977), AZZAROLI et al. (1986, 1988), DE GIULI et al. (1983), and TORRE (1987).

Two basins in the central Apennines have been selected as more amenable to a sharper definition of the mammal assemblages that characterize the onset of the early Villafranchian (Triversa faunal unit), late Villafranchian (Olivola and Tasso faunal unit), and Galerian mammal ages. The first is the Arno Valley basin, located upstream of Florence (the Upper Valdarno), and the second the Colle Curti basin, in the Colfiorito area of the Umbria-Marchean region (Fig. 1).

LINDSAY et al. (1980) carried out paleomagnetic investigations on sediments with an early Villafranchian fauna; the sampled site was at Fornace RDB quarry, on the Triversa stream, at

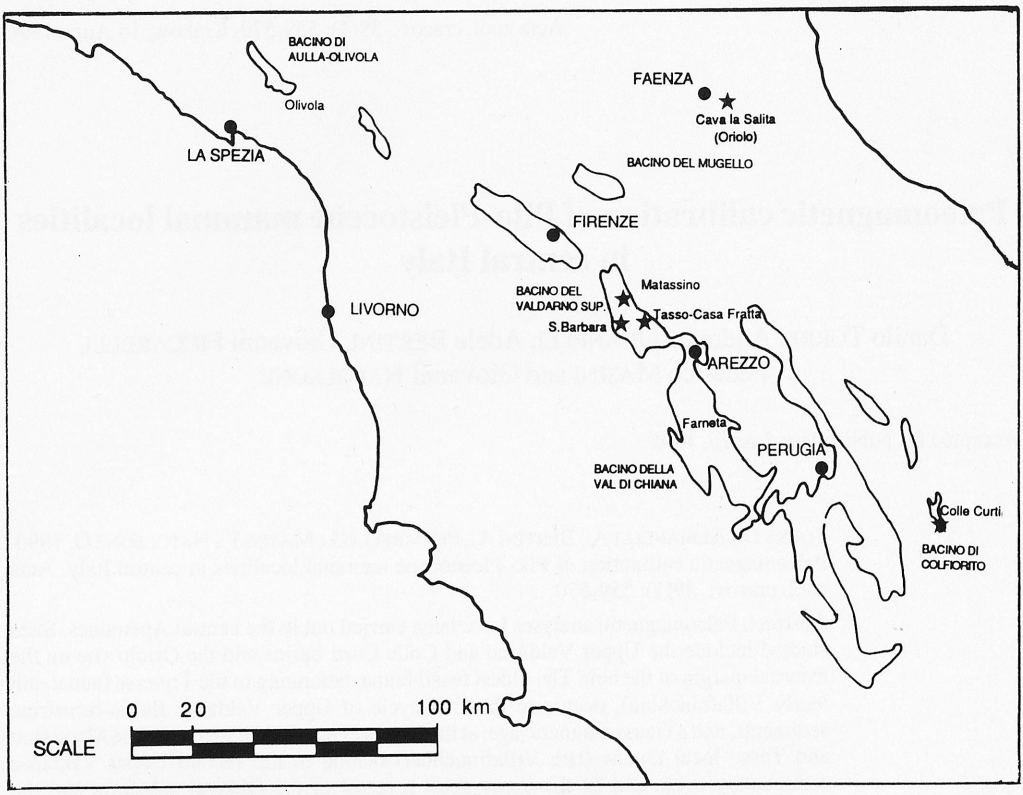


Fig. 1. Location of the surveyed areas.

Villafranca d'Asti (Piedmont). They demonstrated the presence of two intervals of reversed magnetic polarity, separated by a normal magnetozone, and interpreted the sequence to represent the middle of the Gauss magnetic chron, with a record of the Kaena and Mammoth events separated by a normal magnetozone. The short length of the sequence and the poor quality of the samples left the interpretation uncertain. At present, detailed paleomagnetic sampling has been performed in the S. Barbara quarry of Upper Valdarno, from which a fauna referred to the Triversa faunal unit has long been known. Results of these investigations (cf. ALBIANELLI et al. 1993) are reported here.

Recent paleomagnetic results have also been obtained at several sections covering the late Villafranchian local faunas of Matassino and Tasso (TORRE et al. 1993). New data for this interval have been collected, so that the full extent of the Upper Valdarno faunas is paleomagnetically calibrated.

In the other basin, at Colle Curti, the fauna recovered from recent collections is dated as terminal Early Pleistocene (FICCARELLI & MAZZA 1990; FICCARELLI & SILVESTRINI 1991). The paleomagnetic study has been intented to locate more precisely the basal early Galerian fossil layer within the magnetic time scale (COLTORTI et al. in press).

Moreover, in both areas palynological analyses have been carried out in order to match the recorded paleomagnetic data to the climatic changes occurring during these times.

At another site, La Salita quarry near Oriolo di Faenza, in the Apennine external margin, paleomagnetic reconnaissance has been carried out along a post-Villafranchian transitional sequence containing scattered mammal finds.

A c k n o w l e d g m e n t s. For kind assistance in sampling the Upper Valdarno section of the lignite quarry and collecting a core that has made it possible to complete the sequence throughout the lignite seam, deepest thanks are due to the management of ENEL national power plant at S. Barbara, and particularly to Dr. G. MIOTTO for making available their facilities and Mr. L. MURICCI and Mr. R. SALUSTI for their continuous assistance in field operations and core drilling. The measurements taken at the ETH magnetic laboratory have been made possible by Friederich HELLER's assistance and advice: to him our deepest thanks are due also for the freedom of the laboratory facilities and for useful discussions.

## II. UPPER VALDARNO BASIN

G e o l o g i c a l s e t t i n g. The basin is located southeast of Florence between the Chianti Hills and the Pratomagno Ridge. Its geological structure is a bench-mark in the main features of the intermontane basin alignment throughout the Apennines. Current research considers the Upper Valdarno basin to be an asymmetric half graben structure, bounded on the northeast by normal faults dipping southwest, along which major vertical displacements have occurred. On the southwest side smaller antithetic normal faults are present. Fluvio-lacustrine deposits averaging some 550 m in thickness have filled the basin during three Plio-Pleistocene main depositional phases (SAGRI et al. 1994).

The first depositional cycle developed during the early Villafranchian (Piacenzian) in the form of the fluvio-lacustrine deposits of Castelnuovo dei Sabbioni. Tectonic displacement produced a northeastward tilting that enlarged the basin to a shallow water lake. A second cycle followed in the latest Pliocene and produced the fan-delta and lacustrine-palustrine deposits of Montevarchi. At the end of the Early Pleistocene important vertical displacement produced the third sedimentary cycle, with coarse and alluvial-fan deposits that completely filled the basin. Both the second and third cycle sediments are horizontal. The details of the sedimentary features are shown in Fig. 2.

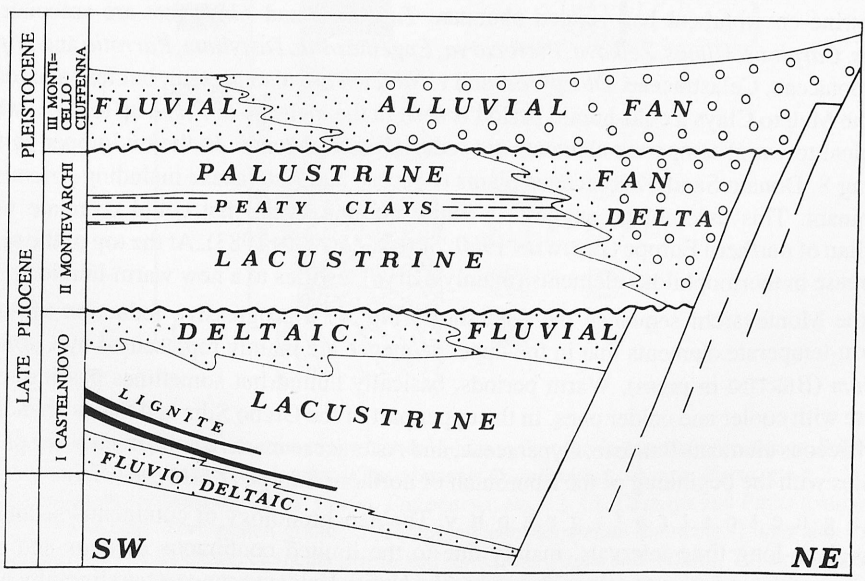


Fig. 2. Stratigraphic setting of the Upper Valdarno.

The mammal faunas. The biochronology of the sequence is based on mammalian faunas recovered from several levels and at different sites. The oldest associations are defined in the Castelnuovo dei Sabbioni deposits, on the left bank of the Arno river, over a distance of about 12 km. *Ursus minimus*, *Tapirus arvernensis*, *Dicerorhinus* sp., and *Leptobos* sp. were collected from the basal lignite seam and the silty beds just above it. In several other localities *Mammuthus borsoni* and *Anancus arvernensis* were also collected. Such fossils are not abundant, but are similar to the lower Villafranca d'Asti fauna (the Triversa faunal unit of AZZAROLI 1977) and thus indicative of an early Villafranchian assemblage.

The overlying sediments of the Montevarchi sequence contain a quite rich fauna extending throughout the Olivola and Tasso faunal units of the initial late Villafranchian (AZZAROLI 1977). The Olivola faunal unit is represented by the Matassino local fauna, which was retrieved from a single level and contains *Mammuthus (Archidiskodon) meridionalis, Equus stenonis, Leptobos etruscus, Pseudodama nestii, Eucladoceros dicranios, Sus strozzii, Canis etruscus,* and *Prolagus* sp. The Tasso faunal unit is younger and represented by some local faunas, of which the Casa Frata Local Fauna (BORSELLI et al. 1980; DE GIULI & MASINI 1986; MASINI 1989) contains *Mammuthus (Archidiskodon) meridionalis*, *Dicerorhinus etruscus*, *Equus stehlini*, *Leptobos* aff. *furtivus*, *Pseudodama nestii*, *Eucladoceros dicranios*, *Praeovibos* sp., *Ursus etruscus*, *Sus strozzii*, *Canis etruscus* (?), *Canis falconeri*, *Pachycrocuta brevirostris*, *Martes* sp., *Homotherium crenatidens*, *Lynx issiodorensis*, *Lepus etruscus*, and, with some reservation, *Acinonyx pardinensis.* Other faunas in the vicinity of Casa Frata and at the same stratigraphic level (Il Tasso, Casa Inferno) also contain *Equus stenonis*, *Leptobos etruscus* (advanced form), *Leptobos vallisarni*, *Hippopotamus antiquus*, *Sus strozzii*, *Canis arnensis*, *Canis falconeri*, *Megantereon cultridens*, *Macaca florentina*, *Hystrix etrusca*, *Mimomys savini*, *Lepus valdarnensis*, *Lepus etruscus*, and *Prolagus* gr. *michauxi-calpensi/savagei.*

Palynological data. In the first sedimentary cycle, palynological analyses still in progress have already produced evidence for different climatic phases. Five spectra are reported in Fig. 3. The taxa are clustered in 12 groups based on their ecological and climatic requirements. The lower part of the Meleto Clays records a subtropical to warm-temperate climate. A lacustrine environment has yielded abundant *Taxodium* and *Alnus* that are associated with *Quercus, Carpinus*, *Ulmus*, *Zelkova*, *Pterocarya*, *Engelhardtia*, *Distylium*, *Parrotia* and *Liquidambar*. Sapotaceae, Celastraceae, *Diospyros,* and t. *Nauclea* are also present, but less abundant. On top of the Meleto Clays a cold-humid period is seen in the increase of *Picea* up to 30%, while the subtropical to warm-temperate elements are reduced in abundance. In the mid-upper part of the overlying S. Donato Sands, herbaceous plants (Poaceae and Asteraceae including *Artemisia*) are predominant. This assemblage suggests a major cooling event that could correlate with the Praetiglian of northern Europe (ZAGWIJN 1960; SUC & ZAGWIJN 1983). At the top of the sequence the increase in thermophilous elements (mainly *Carya*) testifies to a new warm-humid episode.

In the Montevarchi sequence the data show (Fig. 4) a progressive reduction of subtropical/warm-temperate elements that in the upper sequence are mainly represented by *Cathaya* and *Taxodium* (BERTINI in press). Warm periods, basically humid but sometimes passing to dryer, alternate with cooler and colder ones. In the upper part of the Oreno Silts and Sands an increase in the herbaceous elements Poaceae, Cyperaceae, and Asteraceae marks a cold, mainly dry phase that correlates with the beginning of the Eburonian of northern Europe (ZAGWIJN 1974).

Magnetostratigraphy. The geochronology of continental sediments rarely involves long time intervals, mainly due to the limited continuous sections and difficult correlation with marine sequences. Therefore, the Upper Valdarno magnetostratigraphy has been reconstructed by means of a composite polarity sequence from several sections.

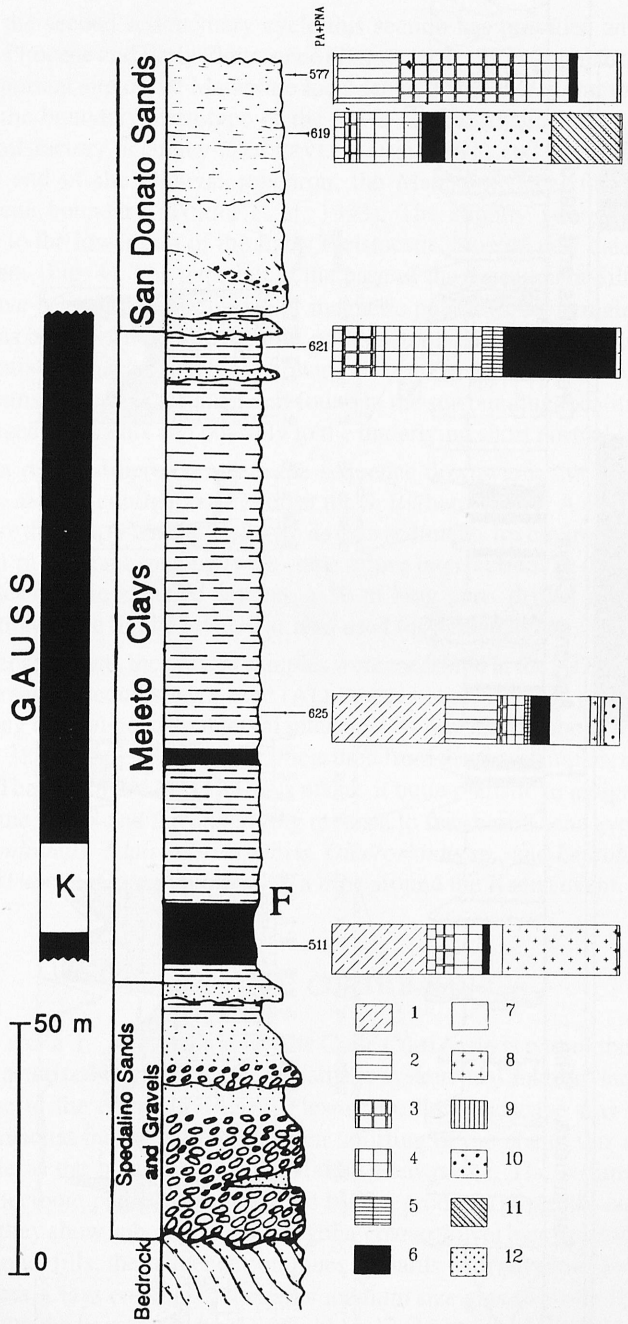


Fig. 3. Composite stratigraphic section of the Upper Valdarno first fluvio-lacustrine sequence. Pollen groups: 1. Subtropical/warm-temperate elements (Taxodiaceae, *Engelhardtia, Myrica, Nyssa*, etc.); 2. Warm-temperate/temperate elements (*Quercus*, *Carya, Pterocarya*, etc.); 3. Cf. *Cathaya* and *Pinus* t. *haploxylon*; 4. *Pinus* and Pinaceae worn pollen grains; 5. Temperate/cool-temperate elements (*Tsuga* and *Cedrus*); 6. Cold-temperate and mountain elements (*Picea* and *Abies* plus *Fagus* and *Betula*); 7. Taxa not climatically significant but often indicative of local edaphic conditions; 8. *Salix* and *Alnus*; 9. Mediterranean evergreen (*Olea*, *Phillyrea*, etc); 10. Herbs; 11. *Artemisia* and *Ephedra*; 12. Hydrophilous plants.

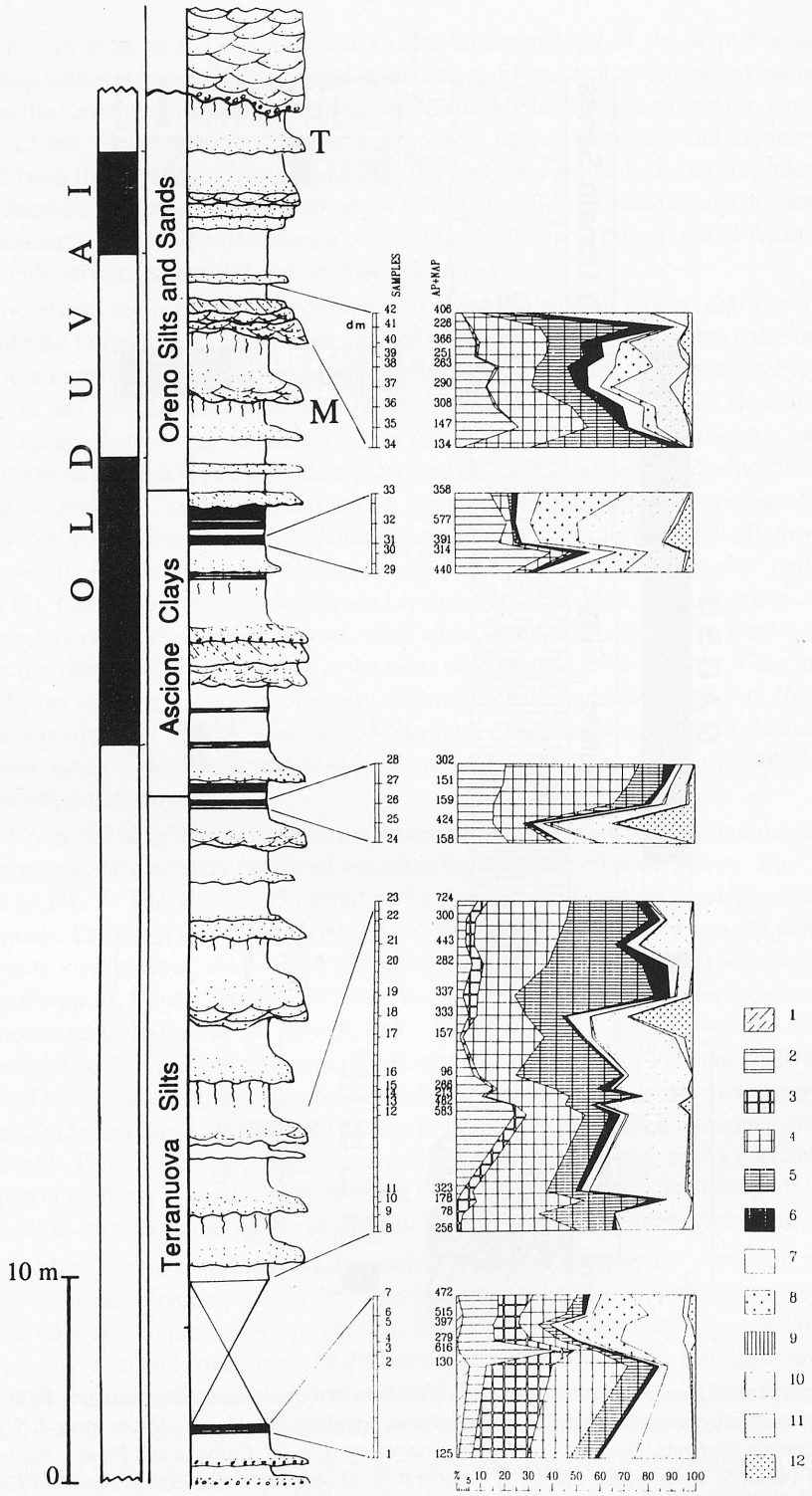


Fig. 4. Composite stratigraphic section of the Upper Valdarno second fluvio-lacustrine sequence. Pollen groups as in Fig. 3. Synthetic pollen diagram scale in decimeters.

Starting with the second sedimentary cycle this section has provided an almost continuous record of the Late Pliocene and Early Pleistocene (TORRE et al. 1993). A polarity change was found just below the important site of the Matassino local fauna, in the lower Oreno Silts and Sands. In accordance with the boundary stratotype of the Vrica marine section, which has recently been calibrated with satisfactory accuracy (ZIJDERVELD et al. 1991) and placed in a short reversed interval near the end of the Olduvai subchron, the Matassino local fauna lies close to the Pliocene-Pleistocene boundary (TORRE et al. 1993). The slightly younger Tasso faunal unit therefore belongs to the lower part of the Early Pleistocene. Several new data can now be added to the previous ones (Fig. 4). The gaps left at the base of the Terranuova Silts and on top of the Ascione Clays have been filled. The series of magnetic polarities has remained unchanged, but their continuity has been defined. The dubious polarity found near the top of the Oreno Silts and Sands has been satisfactorily resolved as showing the end of the Olduvai followed by reversed polarity. The remains of the Tasso faunal unit found in the surrounding localities belongs to these reversely magnetized sediments and possibly to the underlying short normal level.

The other data reported here complete the sequence downward: the Meleto Clays outcrop almost completely along a continuous section at the S. Barbara quarry. A section of nearly 130 m was sampled before the quarry was refilled with its own sediments for environmental reasons. Hand samples at about 1 m constant spacing (with some minor interruptions in the upper portion) have been collected. Besides the sampled section, a 50 m long core, drilled in order to control the stratigraphic position of the lignite level, was also used for paleomagnetic measurements.

As for the upper sequence, the present samples were measured at the ETH Magnetic Laboratory in Zürich and normal procedures were used (ALBIANELLI et al. 1993, in press). The results have demonstrated a long normal polarity interval interrupted a few meters above the lignite level by a reversed one (Fig. 3). The base of the lignite, measured from the core samples, is in another normal polarity interval. The age of the Meleto Clays makes it quite realistic to assign the long normal a late Gauss age in the GPTS and the underlying reversal to the short Kaena event (Chron 2An.1r). Therefore, *Ursus minimus, Tapirus arvernensis, Dicerorhinus* sp., and *Leptobos* sp., found in the lignite seam or just above it, are pinpointed to a time around the Kaena event.

## III. COLLE CURTI BASIN

G e o l o g i c a l  s e t t i n g. The Colle Curti basin is part of the larger basinal area of Colfiorito, characterized by the filling of a drainage system in a "mature" landscape (COLTORTI et al. 1991). Close to the end of the Early Pleistocene this landscape was fragmented by the activation of extensional faults that produced an uplifting of the chain; this activity reached its greatest magnitude at the beginning of the Middle Pleistocene. The sediment deposition that accompanied the tectonic phases is represented by the products presently outcropping at Colle Curti. At the base they show sub-angular and angular coarse gravel bars more than one meter thick and rare small channel fills; the sequence continues upwards with silts and sands, in beds of a few decimeters thickness. Clays containing lenses of medium size gravels cover the previous interval and, at meter 45 from the base, a mammal assemblage has been found (BORSELLI et al. 1988). The clays, extending a further 14 meters, are followed by more than 30 m of gravel bars interbedded with sand, silt, clay and peat layers. All these are strongly weathered (COLTORTI et al. in press).

T h e  m a m m a l  f a u n a s. Until recently, only scarse mammal finds were reported from the Colle Curti area but lately, after specific campains (BORSELLI et al. 1988; FICCARELLI & MAZZA 1990; FICCARELLI et al. 1990; FICCARELLI & SILVESTRINI 1991), a significant faunal assemblage has been recovered. This assemblage includes *Hippopotamus antiquus*, *Stephanorhinus* cf. *hundsheimensis*, *"Elephas"* sp., *Pseudodama farnetensis*, *Megace-*

*roides verticornis*, *Canis arnensis*, *Canis* (*Xenocyon*) *falconeri*, *Ursus* sp., an undetermined hyaenid, and a form of *Microtus* (*Allophaiomys*) with more derived features than *M.* (*A.*) *ruffoi* and *M.* (*A.*) *pliocaenicus*.

The bulk of the material is represented by well to excellently preserved hippotamus. The presence of *Megaceroides verticornis* and *Microtus* (*Allophaiomys*) indicates an earliest Galerian mammal age (upper part of the early Biharian). This conclusion is also supported by specimens of *Pseudodama* that display characters of the most derived morphotypes of the genus. The faunal assemblage is the most modern among the local faunas that, maintaining some Villafranchian characters, record in Italy the migratory and evolutionary events remarking the great faunal turnover that occurred in the Middle Pleistocene.

The environment indicated by the assemblage is a wet climate with mild winters.

P a l y n o l o g i c a l d a t a. The evolution of the climate in the investigated sequence has been inferred through palynological analysis of 40 sampled levels starting just above the fossiliferous mammal layer (COLTORTI et al. in press). Only 28 of these showed a high pollen concentration that allowed us to identify 70 taxa and group them according to their ecological and

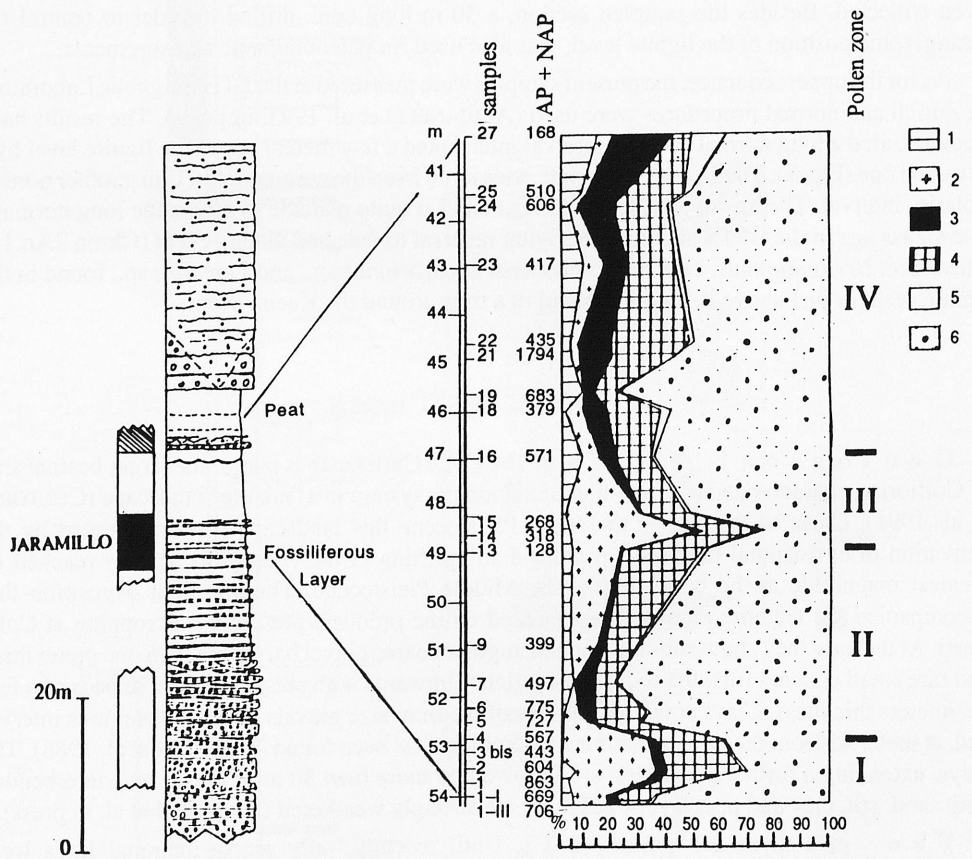


Fig. 5. Colle Curti section. Pollen groups: 1. Deciduous elements (*Quercus, Carpinus*, etc.); 2. *Tsuga* and *Cedrus*; 3. *Abies* and *Picea*; 4. *Pinus* plus Pinaceae poorly preserved pollen grains; 5. Other arboreal pollen plants; 6. Non arboreal pollen plants. Synthetic pollen diagram scale in meters.

climatic significance. The synthetic pollen diagram of Fig. 5 shows the percentage of characteristic taxa in which the arboreal and non arboreal pollen abundances are based on the total pollen content.

Four main zones extend through the section and mark a sharp alternation of high pollen percentages between open vegetation and high altitude coniferous forest. The open vegetation, represented by Asteraceae (Cichorioideae), Poaceae, and Cyperaceae, indicates dry and probably cool/cold climate conditions. Phases II and IV reflect the presence of an altitudinal steppe with cold winters and dry summers. The high altitude coniferous forest is mainly represented by *Tsuga* and *Cedrus* (first and third pollen zones). *Tsuga* indicates cool temperatures and high atmospheric humidity. The first and third pollen zones could therefore represent either interglacials in an altitudinal site or interstadial intervals.

M a g n e t o s t r a t i g r a p h y. Two parts of the sequence were sampled: 15 meters in the sandy silts of the gravel unit (with 9 sampling sites) and about 20 meters of the overlying clays (more closely spaced in the fossil layer). Samples of about one inch to a side were prepared for the measurements, which were carried out at the ETH magnetic laboratory of Zurich with the common procedures to detect the fossil vector values. Under the thermal treatments the samples across the fossiliferous levels showed relatively strong magnetization and good characteristic directions defining a normal polarity interval within two reversed ones that continue upward and downward in the section.

Since the mammal age assigned to the fauna is earliest Galerian, the normal polarity interval bracketing the site level must be related to the Jaramillo event (Chron C1r.1n) in the GPTS.

## IV. ORIOLO SECTION

This 20 m long section outcrops in the La Salita quarry, near Oriolo di Faenza in the Romagna region, through a transitional sequence belonging to the "Sabbie Gialle" (yellow sands) stratigraphic unit overlying the marine "Argille Azzurre" (blue clays) of the Early Pleistocene. The bulk complex has been divided by MARABINI et al. (1987a, b) and COLALONGO et al. (1982) into two distinct sedimentary cycles, the first representing the regressive closure of the marine blue clays and the second an unconformable minor cycle with shoreface to foreshore sedimentary structures. This latter occupies the greater thickness of the yellow sands and from it the mammalian fossils were retrieved.

The finds are scarce but scattered throughout the entire section and include remains of hippopotamus, rhinoceros, horse, bison, and elephant. Most representative are a skull of *Bison* cf. *schoetensacki* at the bottom and a skull of *Mammuthus meridionalis vestinus* close to the top (Fig. 6). In the opinion of the authors cited such a second cycle possibly belongs to the "Milazzian" age (Middle Pleistocene). On the other hand, the presence of southern elephant and bison would place these sediments close to the Jaramillo magnetic event (terminal early Pleistocene).

The paleomagnetic investigation has involved a reconnaissance survey of the possible sites within the sandy Oriolo sequence. The results show a transition from reversed to normal polarity at the 9.5 m level (Fig. 6) which does not permit resolution of the problem of its position at either the Jaramillo or the Brunhes magnetic chrons. A further sample, taken from the sediments overlying the Sabbie Gialle (the Olmatello Formation), has a normal polarity magnetization but is also unhelpful since this latter formation is separated from the yellow sands by a remarkable unconformity.

The same polarity pattern was found during a geological survey directed by prof. G. B. VAI (personal communication).

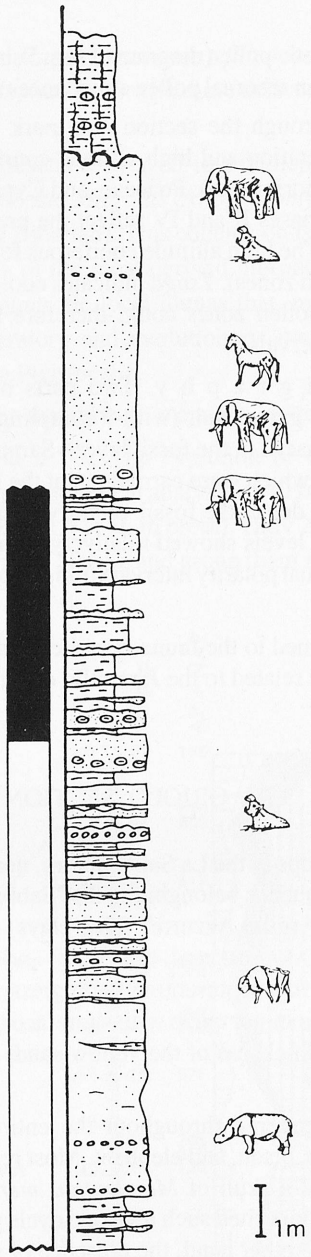


Fig. 6. Paleomagnetic data and stratigraphic section of Oriolo.

## V. CONCLUSIONS

1. The oldest mammal fauna, recovered from the lower beds of the first fluvio-lacustrine sequence in the Upper Valdarno basin, and correlated with the Triversa faunal unit of the early Villafranchian, is positioned across the Kaena magnetic event (chron C2An.1r) of the Gauss Epoch,

i. e., at about 3.17-3.10 Ma in the revised magnetic time scale (BAKSI 1993). The pollen flora and the faunal data demonstrate the presence of subtropical to warm temperate climatic conditions.

2. The Olivola faunal unit, the earliest faunal unit of the late Villafranchian, is represented by the Matassino local fauna recovered from the lower portion of the Oreno Silts and Sands in the second sedimentary sequence. Paleomagnetism places this local fauna in the short reversed interval of the upper Olduvai subchron (C2n). At Vrica, the stratotype of the Plio-Pleistocene boundary is placed in the same short interval and therefore the Matassino local fauna is assigned an age of about 1.8 Ma. The palynological data indicate that during the reversed interval the climate was warm-temperate passing to a dry and cold one (increasing amount of herbaceous plants). This transition likely marks the beginning of the Eburonian pollen phase of the Netherlands.

3. The immediately following Tasso faunal unit of the late Villafranchian correlates with the reverse polarity just above the Olduvai subchron and possibly with the uppermost part of the latter. According to BAKSI (1993) the age of the upper boundary of the Olduvai is 1.78 Ma. The palynological data suggest that a dry and cold climate began shortly before the time of the Tasso fauna.

4. The mammal fauna recovered in the Colle Curti basin is assigned to the beginning of the Galerian. The magnetic signature of the fossiliferous layer belongs to the earliest Jaramillo magnetic event (C1r.1n), at 1.0 Ma. Just above this layer the palynological data indicate the presence of significant amounts of *Tsuga* and *Cedrus*, implying a cool-humid climate. This is followed by two colder and dryer phases, as shown by the increase in herbaceous plants, separated by a new cool-humid one. Such climatic changes could correspond to the Bavelian phase of the pollen sequence in Holland (ZAGWIJN & DE JONG 1984).

5. The sparse mammal finds from the Oriolo section, in the Romagnan external Apennines could belong to the latest Early or Middle Pleistocene. The poor fossil record does not allow a firmer time definition. The magnetic signature in mid-section shows a polarity change from reversed to normal, which does not permit identification of the magnetic event. If future research assigns the normal polarity part to the Jaramillo, it would be proved that a bison of the *schoetensacki* group appeared in Italy before that event. On the other hand, if the normal polarity is attributed to the Brunhes it would testify to the survival of the southern elephant at least until that time.

## REFERENCES

ALBIANELLI A., BERTINI A., MAGI M., NAPOLEONE G., SAGRI M. in press. Il bacino Plio-Pleistocenico del Valdarno Superiore: eventi sedimentari, paleomagnetici e paleoclimatici. Il Quaternario.

ALBIANELLI A., NAPOLEONE G., POMPEO R. 1993. Il ruolo dei solfuri nella magnetizzazione residua di sedimenti continentali e sedimenti marini. Transactions of the XII Congress of GNGTS, Rome 24-26 nov. **1993**: 873-884.

AZZAROLI A. 1977. The Villafranchian stage in Italy and the Plio-Pleistocene boundary. Giornale di Geologia, **41**: 61-79.

AZZAROLI A., DE GIULI C., FICCARELLI G., TORRE D. 1986. Mammal succession of the Plio-Pleistocene of Italy. Memorie della Società Geologica Italiana, **31**: 213-218.

AZZAROLI A., DE GIULI C., FICCARELLI G., TORRE D. 1988. Late Pliocene to early mid-Pleistocene mammals in Eurasia: faunal succession and dispersal events. Palaeogeography Palaeoclimatology Palaeoecology, **66**: 77-100.

BAKSI A. K. 1993. A Geomagnetic Polarity Time Scale for the period 0-17 Ma, based on $^{40}Ar/^{39}Ar$ plateau ages for selected field reversals. Geophysical Research Letters, **20**: 1607-1610.

BERTINI A. in press. Palynological investigations on Upper Neogene and Lower Pleistocene sections in Central and Northern Italy. Memorie della Società Geologica Italiana.

BORSELLI V., DE GIULI C., FICCARELLI G., MAZZINI M. 1980. Casa Frata. Una località fossilifera del Villafranchiano Superiore presso Terranuova Bracciolini (Arezzo) nel Valdarno Superiore. Bollettino della Società Paleontologica Italiana, **19**: 245-258.

BORSELLI V., FICCARELLI G., LANDUCCI F., MAGNATTI M., NAPOLEONE G., PAMBIANCHI G. 1988. Segnalazione di mammiferi pleistocenici nell'area di Colfiorito e valutazione della potenzialità del giacimento con metodi geofisici. Bollettino della Società Paleontologica Italiana, **27**: 253-257.

COLALONGO M. L., RICCI LUCCHI F., GUARNIERI P., MANCINI E. 1982. Il Plio-Pleistocene del Santerno (Appennino romagnolo). [In:] G. CREMONINI, F. RICCI LUCCHI (eds.) – Guida alla geologia del margine appenninico padano. Guide Geol. Reg. S.G.I. Bologna, 161-166.

COLTORTI M., CONSOLI M., DRAMIS F., GENTILI B., PAMBIANCHI G. 1991. Evoluzione geomorfologica delle Marche centro-meridionali. Geografia Fisica e Dinamica Quaternaria, **14**: 73-86.

COLTORTI M., ALBIANELLI A., BERTINI A., FICCARELLI G., NAPOLEONE G., TORRE D. in press. The Collecurti Mammal Site in the Colfiorito area (Umbrian-Marchean Apennines): stratigraphy and palynological analysis. Quaternary Research.

DE GIULI C., FICCARELLI G., MAZZA P., TORRE D. 1983. Confronto tra successioni marine e continentali del Pliocene e Pleistocene inferiore in Italia e nell'area mediterranea. Bollettino della Società Paleontologica Italiana, **22**: 323-328.

DE GIULI C., MASINI F. 1986. Late Villafranchian faunas of Italy: The Casa Frata local fauna (Upper Valdarno, Tuscany). Paleontographia italica, **74**: 1-9.

FICCARELLI G., MAZZA P. 1990. New fossil findings from the Colfiorito basin. Bollettino della Società Paleontologica Italiana., **29**: 245-247.

FICCARELLI G., MAGNATTI M., MAZZA P. 1990. Occurrence of *Microtus* (*Allophaiomys*) gr. *pliocaenicus* in the Pleistocene lacustrine basin of Colfiorito (Umbria-Marchean Apennine, Central Italy). Bollettino della Società Paleontologica Italiana, **29**, 1: 89-90.

FICCARELLI G., SILVESTRINI M. 1991. Biochronologic remarks on the Local Fauna of Collecurti. Bollettino della Società Paleontologica Italiana, **30**: 197-200.

LINDSAY E. H., OPDYKE N. D., JOHNSON N. M. 1980. Pliocene dispersal of the horse *Equus* and late Cenozoic dispersal events. Nature, **287**: 135-138.

MARABINI S., LENAZ R., VAI G. B. 1987a. Pleistocene Superiore ed Olocene del margine pedeappenninico romagnolo: rapporto preliminare. Rendiconti della Società Geologica Italiana, **10**: 33-37.

MARABINI S., COSTA G. P., GIUSBERTI G., SAMI M., TAVIANI M., RICCI LUCCHI F., VAI G. B. 1987b. Rinvenimento di un cranio di *Elephas* nella parte alta delle "Sabbie Gialle" presso Faenza (Pleistocene). Rendiconti della Società Geologica Italiana, **10**: 55-58.

MASINI F. 1989. I bovini Villafranchiani dell'Italia. Tesi di dottorato di ricerca in Paleontologia. Università di Firenze.

SAGRI M., MARTINI I. P., BENVENUTI M., MAGI M. 1994. Basin fill architecture of the Neogene-Quaternary extensional basin in the northern Apennines. 15th IAS Regional Meeting, Ischia, Italy, 13-15 April, 1994. Field Guide, 31 pp.

SUC J.-P., ZAGWIJN W. H. 1983. Plio-Pleistocene correlations between the northwestern mediterranean region and northwestern Europe according to recent biostratigraphy and palaeoclimatic data. Boreas, **12**: 153-166.

TORRE D. 1987. Pliocene and Pleistocene marine-continental correlations. Annales Instituti Geologici Publici Hungarici, **70**: 71-78.

TORRE D., ALBIANELLI A., AZZAROLI A., FICCARELLI G., MAGI M., NAPOLEONE G., SAGRI M. 1993. Paleomagnetic calibration of late Villafranchian mammal faunas from the Upper Valdarno, central Italy. Memorie della Società Geologica Italiana, **49**: 335-344.

ZAGWIJN W. H. 1960. Aspects of the Pliocene and Early Pleistocene vegetation in the Netherlands. Mededelingen van de Geologische Stichting, CIII-I, **5**: 78 pp.

ZAGWIJN W. H. 1974. The Plio-Pleistocene boundary in western and southern Europe. Boreas, **3**: 75-97.

ZAGWIJN W. H, DE JONG 1984. Die Interglaziale von Bavel und Leerdam und ihre stratigraphische Stellung im niederlandischen Früh-Pleistozän. Mededelingen Rijks Geologische Dienst, **37**: 155-169.

ZIJDERVELD J. D. A., HILGEN F. J., LANGEREIS C. G., VERHALLEN P. J. J. M., ZACHARIASSE W. G. 1991. Integrated magnetostratigraphy and biostratigraphy of the upper Pliocene-lower Pleistocene from the Monte Singa and Crotone areas in Calabria, Italy. Earth and Planetary Science Letters, **107**: 697-714.