ESTRATTO DALLA

PALAEONTOGRAPHIA ITALICA

RACCOLTA DI MONOGRAFIE PALEONTOLOGICHE

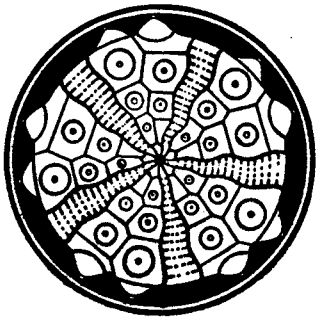
FONDATA DA MARIO CANAVARI

CONTINUATA E ACCRESCIUTA DA GIUSEPPE STEFANINI

Vol. LXVI - (n. ser. Vol. XXXVI) - Anno 1970

A. AZZAROLI - A. BERZI - On an upper Villafranchian fauna at Imola, northern Italy, and its correlation with the marine pleistocene sequence of the Po plain

(pagg. 1-12 - tavv. I-III e 2 figure)



PISA
Industrie Grafiche V. Lischi & Figli
1970

ABSTRACT

In the Santterno valley a marine sequence is exposed ranging from the Miocene to the Lower Pleistocene. Remains of continental Mammals have been found in the uppermost beds; they suggest a late Villafranchian, precromerian age.

This fauna occurs in the sand with temperate marine fauna which Gignoux referred to the latest Calabrian; on it Gignoux based his correlation: Calabrian = Villafranchian.

The fauna however represents only a part of the Upper Villafranchian, and comes from strata situated more than 1000 m above the Plio-Pleistocene boundary determined by Selli, well above the strata with cold marine fauna.

RIASSUNTO

Nella Valle del Santerno si riscontra una sequenza marina cronologicamente compresa fra il Miocene ed il Pleistocene inf. Dai terreni stratigraficamente superiori provengono numerosi resti di mammiferi continentali che suggeriscono un Villafranchino molto alto, e comunque precromeriano.

La fauna proviene dalla sabbia a fauna marina di clima temperato, attribuita al Calabriano alto da Gignoux. Su questa fauna Gignoux basò la sua nota correlazione: Calabriano=Villafranchiano. In realtà la fauna rappresenta solo una parte del Villafranchiano superiore, ed è situata oltre 1000 m sopra il limite Plio-Pleistocene, determinato da Selli, e sopra i livelli a fauna marina fredda.

A. AZZAROLI - A. BERZI

ON AN UPPER VILLAFRANCHIAN FAUNA AT IMOLA, NORTHERN ITALY, AND ITS CORRELATION WITH THE MARINE PLEISTOCENE SEQUENCE OF THE PO PLAIN [1]

(with 3 plates and 2 tex-figures)

INTRODUCTION

In 1914 GIGNOUX published a description of the Pliocene formations of the Adriatic border of the Italian Peninsula and of the Southern margin of the Po plain. In this and in later papers GIGNOUX divided the Pliocene into three stages, namely: Plaisancian, Astian and Calabrian. The section dealing with the surroundings of Imola, a little town on the Santerno river to the SE of Bologna, is of particular interest for correlations between marine and terrestrial faunas.

The marine sequence of the Santerno valley dips gently towards the Po plain and ends with yellow sands of littoral facies. Their molluscan fauna, according to GIGNOUX, is typical of the upper part of the Calabrian: «elle appartient au *Calabrien*, et même, probablement, à une zone assez élevée de cet étage». The same sands have yielded also remains of terrestrial mammals, among which GIGNOUX quoted «une molaire typique d'*Elephas meridionalis* Nesti». This was considered a typical Villafranchian species: hence GIGNOUX concluded for his well-known correlation: Calabrian = Villafranchian: «Ainsi la *faune marine calabrienne* se montre *contemporaine de la faune continentale villafranchienne*».

As stated above, GIGNOUX placed the Calabrian at the top of the Pliocene. In contrast with his partitions, HAUG placed the Calabrian, and with it the Villafranchian, in the Lower Pleistocene. When, in 1948, the International Geological Congress in London made a recommendation in favour of HAUG's views, the Calabrian and the Villafranchian gere generally accepted as representing the marine and the continental facies of the Lower Pleistocene, respectively.

It is now realized, however, that the Villafranchian covers a long time interval, ranging from the Upper Pliocene to the Lower Pleistocene (see AZZAROLI 1970). In particular, the fluvio-lacustrine deposits of the type area of the Villafranchian, as defined by PARETO (1865), i. e. the area between Villafranca d'Asti, Dusino and S. Paolo della Valle (Asti province, Piedmont) belong to the Upper Pliocene (HÜRZELER 1967, SAVAGE & CURTIS 1967, AZZAROLI 1970). AZZAROLI proposed to divide the Villafranchian into four substages: Lower Villafranchian, Middle Villafranchian, Upper Villafranchian *a*, Upper Villafranchian *b*.

A direct correlation between a Lower Villafranchian fauna and an Upper Pliocene marine fauna has been made at Montopoli, Lower Valdarno (Tuscany): see AZZAROLI 1963. No direct correlations have been made, however, between Middle and Upper Villafranchian

[1] The present work was supported by a grant by the «Consiglio Nazionale delle Ricerche, Gruppo di Lavoro per la Paleontologia, Sezione di Firenze».

faunas and marine sequences in the Mediterranean area. AZZAROLI provisionally assumed that the lowermost Pleistocene Red Crag of East Anglia belongs to the Middle Villafranchian, but its mammalian fauna is too poor to settle the matter conclusively.

We shall now examine the problem of correlations on the basis of the fauna of the Imola hills.

THE MARINE SEQUENCE

The marine sequence of the Santerno valley, South of Imola, has been described by SELLI (1962), and more in detail by CREMONINI, ELMI & MONESI (1967). The marine Pleistocene overlies conformably the marine Upper Pliocene and is made of two formations. The lower formation is about 1090 mt. thick and is made of blue and gray clays and silty clays, often laminated, more rarely bedded. There are intercalations of fine sands and pebble lenses. The Plio-Pleistocene boundary is marked by the appearance of « cold » species, such as *Arctica islandica, Chlamys septemradiata, Panopaea norvegica*. The higher formation is made of yellow sands, often cross-bedded, with intercalations of clays and marls, and occasionally scattered pebbles and marine shells. The thickness is about 40 mt. This formation is said to overlie transgressively the lower one.

No mention is made of gravel lenses, which however occur at the base of the sands and have locally eroded the underlying clays.

We think however that the alleged unconformity between the blue clays and the yellow sands is only a local phenomenon, confined to restricted areas. Exposures are rather poor, the rocks being incompetent and rapidly eroded, and the whole area being cultivated; but near Bergullo the sands seem to overlie the clays without any trace of unconformity. Our impression is that the yellow sands are a littoral and partly deltaic deposit; erosion on the top of the clays may have been brought about by ordinary depositional processes, and does not necessarily imply a true transgression.

Age of the marine sequence

The blue and gray clays contain a rich fauna, mainly of molluscs, foraminifera and ostracods. Details were given by CREMONINI, ELMI & MONESI for the Plio-Pleistocene boundary and for the lower section of the clays, which do not concern us here. No details were given by these authors for the upper part of the sequence. They stated however that the faunas of the clays and sands give evidence for climatic fluctuations: the lower part of the clays has a « cold » fauna; this is followed by identical clays with a « temperate » fauna, where the species indicative of a cold climate disappear (no new « warm » elements seem however to appear in this section), and then again by similar clays with a « cold » fauna. The fauna of the sands is less rich, but is indicative of a temperate climate, like the fauna of the intermediate section of the clays.

More details about the fossil content of the yellow sands were given by TOLDO (1905) and by GIGNOUX (1916). TOLDO lists the following fossils, all from the yellow sands: *Ostrea edulis, Donax minutus, Solenocurtus strigilatus, Tellina pellucida, T. pulchella, T. nitida, Corbula gibba, Mactra subtrucata, Donax semistriatus, Dosinia lupinus, Cardium tuberculatum, C. paucicostatum, C. oblongum, Chlamys opercularis, Leda pella, Pectunculus violacescens, Dentalium entalis, D. alternans, Scalaria alternicostata, Nassa pygmaea, Aporrhais pespelecani,* foraminifera, silicified wood, fossil leaves. The sands at Casino Belvedere, where leaves were

found, contained also vertebrate bones, which TOLDO identified as follows: *Cervus (euryceros?), Ippopotamus* (sic), *Rhinoceros megarhinus, Elephas antiquus*, and several coprolites.

GIGNOUX gave an additional list of fossil species, the most significant of which he considered to be:

Chlamys septemradiata - A species of Northern affinities, always common in the Calabrian;

Tapes senescens var. aff. *caudata* - This is the only extinct species and is very common in the higher Calabrian beds, of littoral facies, at Monte Mario, Rome;

Turritella tricarinata - The species is represented by a variety (var. cf. *pliocaenicus*) which is dominant in the Calabrian.

Of the mammals quoted by TOLDO, GIGNOUX discussed only the elephant: « c'est une molaire typique d'*Elephas meridionalis*, determinée à tort *E. antiquus* ».

SELLI and his followers held different views. According to them, the age of the clays ranges over the Calabrian to the Emilian and the Sicilian. The yellow sands are referred to the « Milazzian », this term being used in the sense defined by SELLI (1962), which does not imply a time equivalence with the Milazzian of Capo Milazzo, Sicily.

How far such an arbitrary use of an old established, though admittedly ill-defined chronostratigraphic term is warranted, is debatable. Moreover, the use of the name Sicilian seems also to be out of place here. The age of the type Sicilian clays of Ficarazzi, Sicily, is now difficult to define, but in Central and Southern Italy the term Sicilian has been currently used to indicate a time unit that is definitely younger than the higher part of the clays of the Santerno valley. We feel that under present circumstances this loose use of old-established and ill-defined terms can lead only to confusion. In our case, the yellow sands of the Imola hills represent the upper part of the Calabrian for GIGNOUX, the Milazzian for SELLI and his followers.

Leaving aside the question of names, we may retain the fundamental facts:

1) the mammal-bearing, littoral sands overlie by more than 1000 mt. thickness the Plio-Pleistocene boundary; even assuming a high sedimentation rate — which seems very reasonable in our case — they are appreciably younger, in the geological time-scale, than this boundary;

2) The yellow sands represent a temperate climate, and there seems to be another temperate oscillation lower down sequence, between two colder phases, though the evidence for this is rather meagre in our opinion.

THE OCCURRENCE OF MAMMALS

The occurrence of mammalian fossils in the Imola hills has been known for a long time. In 1846 SCARABELLI gave a first list of fossils. Several of these were said to come from the yellow sands with marine shells; an upper molar of *Hippopotamus* was said to come from the top of the blue marls underlying the sands, and a fragment of a deer antler was found in the talweg of the Santerno river. In 1851 SCARABELLI (1852) gave a more detailed description of the surroundings of Imola, particularly of the valley of the « Rio Pradella », a little tributary to the right of the Santerno, South of the town. The name « Rio Pradella », sometimes spelt « Rio Pratella », is no longer in use: the little stream is now called Rio Rosetta; La Pradella is a farm house on its left (western) bank.

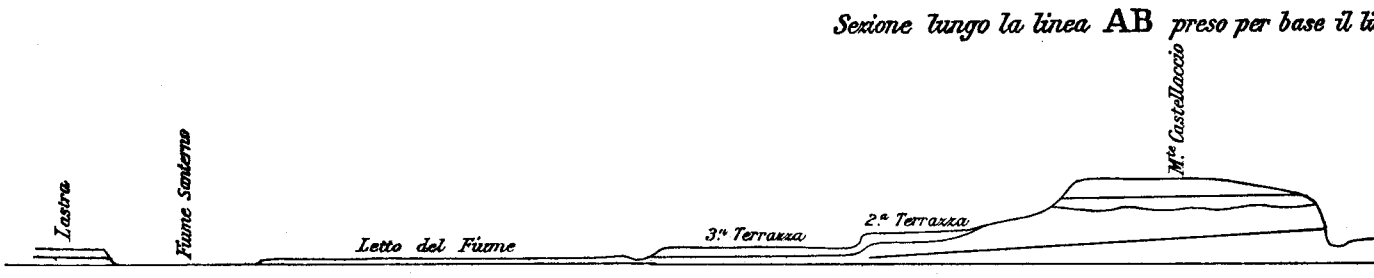


FIG. 1. — Geological section of Monte Castellaccio and neighbourhoods, near Imola (

From this second description by SCARBELLI the stratigraphy appears to be more complicated than previously stated. SCARABELLI gave a detailed section of the Southern slope of the Castellaccio Hill, 500 mt. North-West of la Pradella (farm-house), where he distinguished three formations:

polygenic gravel
mud (Lehm)
fluviatile gravel

The Castellaccio Hill is a part of the system of Pleistocene terraces fringing the foothills of the Po plain; it is also famous for the remains of a Neolithic settlement found at its top, and excavated later by Scarabelli.

The section of the right bank of the stream, South of La Pradella and about 3/4 km. away from the Castellaccio Hill, is different. SCARABELLI gave the following succession:

yellow sand with marine shells
sandy clay
blue clay with shells

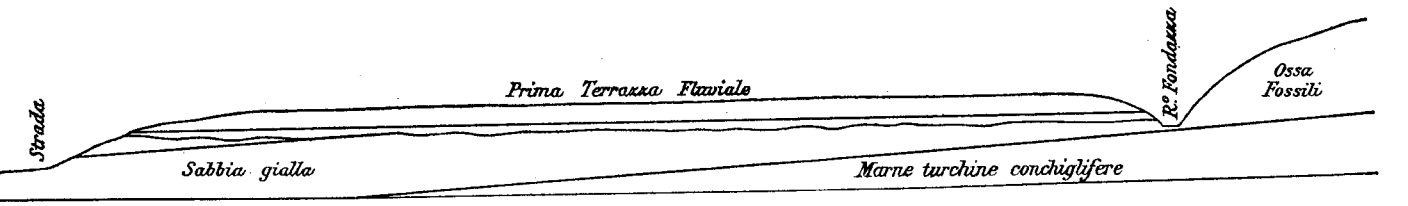
This sequence was said to be Pliocene. Still according to SCARABELLI, between the top of the sandy clay and the base of the yellow sand, the slope is cut by a terrace with the following section:

fluviatile marly sand
reddish sand
calcareous shelly gravel with bones

The place of this section is called « La Sganga ». Several bones of rhinoceros were said to come from this Pleistocene terrace at La Sganga: if so, they should be considerably younger than the yellow littoral sands.

SCARABELLI seems however to have changed his mind later. In 1881 he published a colour map of the area, at the scale of 1:5000, with a section running from La Sganga (though this name does not appear on the map) northwards to La Pradella and Castellaccio, and then to the NW towards the Santerno river. The place of fossil bones is clearly indicated at the Southern end of the section (La Sganga) but they are indicated to come from the yellow sands with marine shells. There are no river terraces at La Sganga, but only on the opposite bank of the Rio Pradella (see figs. 1-2).

In 1968 we visited the exposures along the right bank of the Rio Rosetta (Rio Pradella) and had the impression that SCARABELLI's map of 1881 gives a very accurate representation



gna, Italy). Redrawn from the orignal of Scarabelli (1881). Approximate scale 1:5.000.

of facts. The sandy clays (top of the lower marine formation) are locally eroded and overlain by lensing gravels with flat river pebbles, passing upwards into sandy clays, thin silty clay beds and finally yellow, massive or cross-bedded sands with occasional marine shells. This seems to be a littoral and partly deltaic deposit, but there are no river terraces on the right bank of the stream. We think therefore that the rhinoceros bones came from the yellow sands with marine shells, as shown in the cross-section of SCARABELLI (1881).

The above discussion concerns only the rhinoceros specimen from La Sganga, which is not of primary interest for the determination of the age of the mammalian fauna. All the other specimens undoubtedly came from the yellow sands. This can be inferred from informations given by SCARABELLI and in some labels of the collection, from the matrix when preserved, and from an examination of the fossiliferous localities, as we carried out in 1968.

The mammalian fauna

Thanks to the kindness of the Director of the Museum of Imola, we were able to carry out a thorough study of the mammalian fauna. We give here a list of the specimens, together with the results of our observations.

Elephas aff. meridionalis NESTI

The elephant is represented by the following specimens:

1) A molar tooth, much rolled, from the Santerno. - 2) Portion of a tusk; « Rio Pradella, 1825 ». - 3) Portion of a tusk; « Rio Pradella, 1885 ». - 4) Fragment of a molar; « Rio Pradella, 1840 ». - 5) Fragment of a molar; « Imola Hills, below La Gonza » - 6) Fragment of a pelvis, « Rio Pradella , near La Sganga ». - 7) Third left upper and lower molars, apparently of the same individual, « Rio Pradella, 1840 » (Pl. I, Figs. 2, 2a, 3, 3a). - 8) Several fragments of a skeleton, « from Bergullo, presented by Cerchiari, 1843 »: parts of a tibia, a rotula, left astragalus and navicular, several other bones of the foot, poorly preserved. This specimen was said to come from the yellow sands with marine shells (SCARABELLI, 1846).

Of all these fossils, only those listed under N° 7 are of stratigraphic significance. They are labelled « *Elephas antiquus* » and there is little doubt that one of these is the tooth referred to by GIGNOUX. In our opinion they do not belong to *Elephas antiquus*, but GIGNOUX's statement that this is a typical *meridionalis* is equally unwarranted. The teeth are not very much worn and belong to an individual who still had his second molars in use. They show the broad crown of the *Elephas meridionalis* lineage, but are definitely more advanced than the typical specimens from the Upper Valdarno. The laminar frequency is 6 in the upper molar

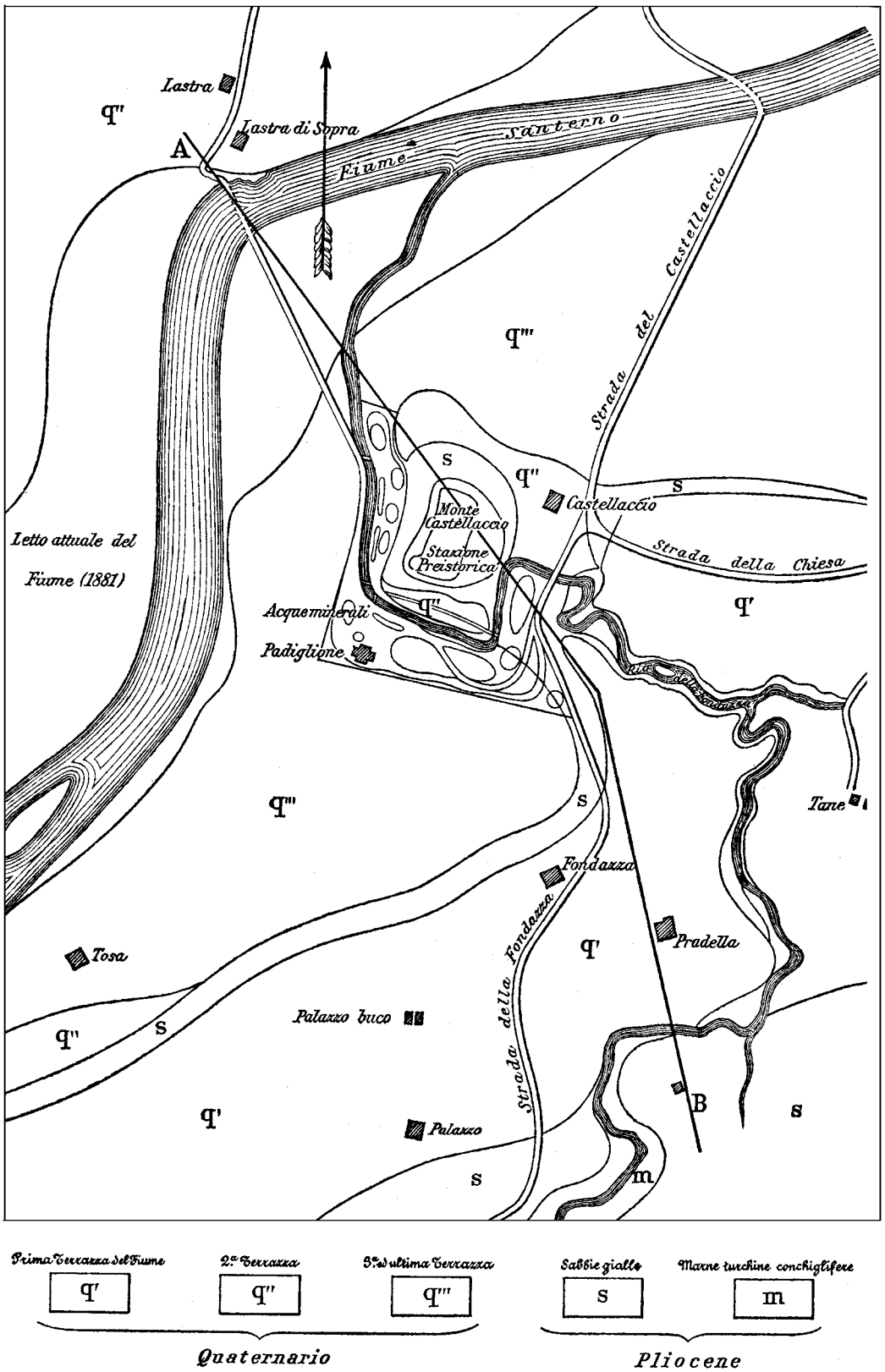


FIG. 2. — Geological map of Monte Castellaccio and neighbourhoods, near Imola (Bologna, Italy). Redrawn from Scarabelli (1881). Approximate scale 1:10.000.

and about 6.5 in the lower one; both teeth, moreover, are very high-crowned, so much so that the upper molar, as seen from the profile, equals the shape of *Elephas antiquus*. The lamellae meet the grinding surface at a sharp angle, and the outer ends of the nine lamellae not yet affected by wear slope very steeply upwards; the hight of the crown is much greater than its length. The lower molar is also hypsodont, though to a lesser degree. The laminar frequency of these two molars corresponds to that of *Elephas meridionalis cromerensis* Dép. & Mayet.

Equus stenonis (?) COCCHI

1) Two upper cheek teeth and other fragments of teeth; « Rio Pradella, presented by Cerchiari, 1859 » (Pl. III, Figs. 4, 5). - 2) Fragment of a metacarpal, « from the Imola Hills ».

Two complete teeth — seemingly a molar and a praemolar of the right tooth row — are of the size of *Equus stenonis* and show the short protocone typical of this species. Teeth of this kind are not known from post-Villafranchian deposits.

Dicerorhinus cf. etruscus FALCONER

1) Two upper dental rows; « Rio Pradella at Casa Belvedere (La Sganga), presented by Cerchiari, 1842 » (Pl. II, Fig. 3). 2) Part of a skeleton, consisting of: atlas (Pl. I, figs. 1, 1a), two cervical vertebrae (undetermined), seventh cervical vertebra, six dorsal vertebrae, fifteen poorly preserved vertebrae (undetermined), two caudal vertebrae, fragments of neurapophyses of vertebrae, fragment of ischion, fragment of humerus, several fragments or ribs, two bones of the pes. These specimens were found by Mr. Cerchiari in the same place as the upper tooth rows of 1842, and SCARABELLI states that « with no doubt they belong to the same individual ».

The rhinoceros comes from the place which SCARABELLI interpreted as a river terrace in 1851. The place was visited also by Sir Hugh Falconer in May 1861, with Scarabelli, Capellini and Cerchiari. FALCONER recognized the series described by SCARABELLI, but quoted *Cardium edule* from the sands (lehm of SCARABELLI), which hardly fits with the idea of a river terrace. FALCONER relates further that Mr. Cerchiari, the owner of the estate, used to reward his farmers for every fossil they collected for him. This resulted in the collection of many fossils, but was disastrous for the rhinoceros: the tooth rows found in 1842 belonged to a superb skull, and the farmers broke it to pieces to get a separate reward for each fragment. This is the more regrettable as the rhinoceros is the most puzzling animal in the fauna.

Besides the skeleton quoted under 1 and 2, other specimens were found:

3) Two mandibular rami, « Rio Pratella at Casa Belvedere » (Pl. II, figs. 1, 1a). - 4) Fragment of a lower jaw, « Rio Gange 1827). - 5) Fragment of a lower jaw, « Bergullo 1841 ». - 6) Another fragment of a lower jaw, « Rio Pratella at Casa Belvedere, Cerchiari 1852 ». - 7) Some isolated molars, from: « Rio Pratella »; « near Palazzo del Buco, Rio Pratella »; « monticino Scarabelli».

FALCONER (1868) described in detail the tooth rows, which he referred to *Rhinoceros leptorhinus* CUVIER (= *Dicerorhinus megarhinus* De Christol). He stressed the differences between the Imola specimens and *Rhinoceros (Dicerorhinus) etruscus* from the Upper Valdarno: a well-developed *cingulum* in the upper molars, a tubercle at the posterior end of the third upper molar, the shape of the *crochet*.

Several specimens of typical *Dicerorhinus etruscus* were collected from the Upper Valdarno and Oivola after FALCONER's studies, and the range of variation of the species appears now to be wider than FALCONER had assumed. There is often a well-developed *cingulum* and the other characters are equally variable. The only significant difference we can find between the two upper tooth rows of the skull destroyed in 1842 and the typical specimens of *Dicerorhinus etruscus* from the Upper Valdarno and Olivola is the size. The total length of the tooth rows from «La Pradella» is 260 mm., while in the other specimens the average is 230 mm., with very small variations. The two tooth rows were restored by Scarabelli; his work was very accurate, and though it may have caused some alteration of proportions, the difference in length seems to be too large to be accounted for by a deformation caused during the restoration.

Le lower jaws are of the same size as the typical *Dicerorhinus etruscus*: the total length of the lower tooth row (only the specimen collected in 1852 is complete, the others lack the P_2) is about 220 mm.

Of the other bones, only the atlas and the humerus are significant. The articular surfaces of the atlas indicate an animal of the size of *D. etruscus*, but the lateral apophyses are broader than in the specimens of the Upper Valdarno (3 specimens in all) we have examined. The humerus, though badly damaged, is of the size of a medium sized *D. etruscus*; the shaft is slender and the width of the trochlea (damaged) was little more than 75 mm. The bone is smaller than the largest specimen of *D. etruscus* from the Upper Valdarno and definitely smaller than the humerus of *D. megarhinus*.

In conclusion, the rhinoceros from La Sganga is not *D. megarhinus* («*Rhinoceros*» *leptorhinus* is a synonim of the latter); it is definitely closer to *D. etruscus*, but shows some differences, the significance of which is not easily explained. The characters of the dentition and the size of the humerus rule out any possibility to identify it with known post-Villafranchian species, e.g. *D. hemitoechus* or *D. kirchbergensis*.

Hippopotamus amphibius (?) L.

1) Fragment of a lower jaw, «Rio Sganga». - 2) Fragment of a lower canine, «Rio Sganga, 1844». - 3) Fragment of a lower canine, «Rio Gonze» (this seems to be another way of spelling the name «Rio Gange»). - 4) Large portion of a pelvis; no locality; «presented by Cerchiari».

There is not much to say about the characters of the hippopotamus. The species is interesting for the simple fact of its occurrence. It makes its first appearance in Italy in the Upper Villafranchian (very probably Upper Villafranchian *b*) and reappears several times during the Middle and Upper Pleistocene. Its occurrence in the Imola assemblage points to the Upper Villafranchian *b*.

Leptobos (?) sp.

1) Fragment of a metatarsal; «Rio Pradella, 1844». - 2) First phalanx of a foot, «Imola Hills». - 3) Second phalanx of a foot, «Rio Pratella». - 4) Some fragments of molars, «Rio Sganga».

These specimens seem to indicate the Villafranchian, but are of minor interest for the stratigraphy.

Cervus (Eucladoceros) cf. dicranios NESTI

1) Large portion of a right antler, with the pedicle and part of the frontal; « Rio Pradella, presented by Cerchiari » (Pl. III. figs. 2, 2a). - 2) Fragment of the upper portion of an antler; « Rio Pradella, presented by Cerchiari » (Pl. III, fig. 3). - 3) Right metacarpal; « Bergullo, presented by Cerchiari, 1852 » (Pl. III, fig. 1). - 4) Portion of a left metatarsal, « Bergullo ». - 5) Portion of a right metatarsal, « Imola Hills ». - 6) Left calcaneus, « Rio Pratella ». - 7) Fragment of antler, « washed in the Santerno river, 1838 ». - 8) Fragment of a left lower jaw, « Rio Pratella, presented by Cerchiari, 1896 » (Pl. II, figs. 2, 2a). - 9) Several fragments of antlers and pedicles, « Imola Hills ».

The most significant specimen is the antler N° 1. It recalls the type of *Cervus dicranios* and other specimens from the Upper Valdarno for the strong backward bend of the larger (trez) tine and for the shape of the beam, but the position of the tines is different. The trez is directed somewhat more outwards than in the type; this however might be due to a slight displacement, when the anter was broken between the burr and the brow tine and was subsequently restored. The brow tine is broken at its base; it is not very large and is inserted on the inner side of the beam, while in the specimens from Tuscany it faces forwards, or slightly outwards. This gives a rather abnormal appearance to the antler, but it should be recalled that individual variations in *Cervus dicranios*, and in all species of the subgenus *Eucladoceros*, are very great.

The fragment of lower jaw (N° 8) has an unusually thick and massive ramus, reminiscent of *Megaceros verticornis*, but the only tooth preserved is smaller than in this species.

The metacarpal (N° 4) is 315 mm. long and differs from the metacarpals of megacerids by its more slender shape; so do also the fragments of metatarsals.

Cervus sp.

A small species, of the size of a fallow-deer.

1) Fragment of a radius, « Imola Hills ». - 2) Fragment of a humerus, « Castel Bolognese » (a little town SW of Imola).

Deer of this size are very common in the Middle and Upper Villafranchian.

The age of the fauna

The fossils are unfortunately so fragmentary that very accurate identifications are almost impossible. This makes the definition of the age of the fauna more difficult.

It should be stressed first that the fauna is chronologically homogeneous and comes from the littoral and estuarine sands at the top of the marine sequence. SCARABELLI's description of La Sganga of 1852 seems to indicate a younger age for the rhinoceros skeleton as compared to the rest of the fauna, but geological evidence is not in favour of this interpretation, nor does the fossil give any evidence for a younger geological age. We pointed out above, moreover, that some years later SCARABELLI drew a map and a cross-section more in accordance with the interpretation we have adopted here.

We shall now consider separately the factors setting a lower and an upper limit to the age of the fauna.

The occurrence of hippopotamus rules out both Lower and Middle Villafranchian, and seems to rule out also the lower part of the Upper Villafranchian. This seems to be in accordance with the elephant, which is frankly more advanced than the type specimens of the Upper Valdarno. Generally speaking, we consider it unsafe to base geological datings on supposedly « primitive » or « advanced » features, because a correct reasoning should go the other way round: nevertheless, the evolutionary sequence of the *Elephas meridionalis* stock from the Upper Pliocene to the Lower Pleistocene in Italy is now fairly well known, and we may safey say that the specimen from Rio Pradella belongs to a species, or subspecies that does not occur either in the Upper Valdarno or in older beds. This does not necessarily imply that the Rio Pradella elephant is post-Villafranchian.

An upper limit to the age of the fauna is set by the horse, rhinoceros and deer.

The horse is a *stenonis*-like animal; hores of this kind have never been recorded from Cromerian or younger beds.

The rhinoceros, though not a typical *Dicerorhinus etruscus*, still has some primitive features, as a cingulum in the upper molars, and cannot be post-Villafranchian.

The larger deer is a representative of the *Eucladoceros* stock and has nothing to do with the Cromerian giant deer.

The remains of the smaller deer and of *Leptobos*, though scanty and difficult to determine, also speak for a Villafranchian age.

In conclusion, it may be assumed that the fauna of the yellow sands of the Imola Hills represents the highest part of the Upper Villafranchian, which, according to one of us (AZZAROLI 1970), is roughly the equivalent of the Pastonian of East Anglia (1).

FINAL REMARKS

Although the greatest change in the continental faunas of Europe took place between the close of the Villafranchian and the beginning of the Cromerian (Lower-Middle Pleistocene boundary), the Plio-Pleistocene boundary as defined in marine sequences is considerably older than the uppermost Villafranchian. In recent years there has been much debate on the age of the Plio-Pleistocene boundary, which some authors place at 1.8 m.y. (the « Olduvai event »), and others at about 2.7 m.y. or more.

Correlations between the Olduvai bed I fauna and European faunas are by no means easy, but SAVAGE & CURTIS (1967) have given an interesting datum for a solifluction deposit at Mt. Coupet, Southern France: 1.9 m.y. The fauna seems to be an Upper Villafranchian one (AZZAROLI 1970).

There seems to be little doubt that the Olduvai event corresponds to a climatic crisis, but in our opinion this is a crisis within the Villafranchian. Also in East Anglia there are conspicuous traces of cryoturbated soils underneath the Cromerian (WEST & GAY WILSON 1966).

The Plio-Pleistocene boundary, as evidenced by the sequence of the Santerno valley, represents an older and smaller climatic crisis, and may possibly represent the boundary be-

(1) A fine skull from the Forest Med at Bacton, now in the British Museum, may be refered to *Elephas meridionalis cromerensis* Dêp. & Mayet. Pollen from its matrix indicates a probably Pastonian age (G. WEST, private information). Note added in proof (A.A.).

tween the Lower and the Middle Villafranchian, which is also marked by a significant change in continental faunas.

SAVAGE & CURTIS (1967) give an age of 3.4 m.y. for a Lower Villafranchian fauna at Les Etouaires, Perrier Hills, Southern France; 2.5 m.y. for the Middle Villafranchian fauna of Roca Neyra, still in the Perrier Hills, and approximately 2.7 m.y. as a possible age for the Plio-Pleistocene boundary, which is in accordance with the conclusions of this paper.

A closer correlation of the sequence of the Santerno valley with the Lower Pleistocene sequence elaborated by British geologists for East Anglia does not seem possible at the moment. Three negative and positive fluctuations of the climate have been evidenced in East Anglia by pollen analysis, whereas the fluctuations in the Santerno sequence seem to be only two. This may be due to differences in climate at different latitudes, or to a different response to temperature fluctuations in marine faunas and in continental vegetations.

REFERENCES

AZZAROLI A. (1963) — *Rinoceronti pliocenici del Valdarno inferiore*. Palaeontogr. Ital., *57*: 11-20, pl. 6-15, Pisa.

AZZAROLI A. (1970) — *Villafranchian carrelations based on large mammals*. Giorn. di Geologia (2) *35*, (1967) Fasc. 1°. Committee on Mediterranean Neogene Stratigraphy. Proceedings of the fourth session in Bologna (Italy) 19-30 sept. 1967. Bologna.

CREMONINI G., ELMI C., MONESI A. (1967) — *La serie del F. Santerno (Imola)*. Guida alle escursioni - IV Congresso del Neogene Mediterraneo, Bologna 19-30. IX.67: 98-102. Bologna 1967.

FALCONER H. (1868) — Paleontological memoirs and notes. Vol. II. London 1868.

GIGNOUX M. (1916) — *L'étage calabrien (Pliocene supérieur marin) sur le versant Nord-Est de l'Apennin, entre le Monte Gargano et Plaisance*. Bull. Soc. Géol. France, (IV), *14*: 324-348, 5 Pl. (1914-16).

HAUG E. (1911) — Traité de Géologie. Vol. 2, Fasc. 3. Paris.

HÜRZELER J. (1967) — *Nouvelles découvertes de Mammifères dans les sédiments fluvio-lacustres de Villafranca d'Asti*. In: Problèmes actuels de Paléontologie (Evolution des Vertébrés), Colloques internationaux du C. N.R.S. Paris 6-11 juin 1966, n. 163: 633-636.

PARETO R. (1865) — *Note sur les subdivisions que l'on pourrait établir dans les terrains tertiaires de l'Apennin septentrional*. Bull. Soc. Géol. France (2) *22*: 210-277. Paris 1965.

SAVAGE D. E. & CURTIS G. H. (in press) — *The Villafrancian stage-age and its radiometric dating*. Proceedings of the Soc. of Econ. Pal. and Min., Res. Comm. Symp. on radiometric dating and paleontological correlation. Los Angeles 1967.

SCARABELLI G. (1846) — *Una parola sulle ossa fossili dell'Imolese*. N. Ann. Sc. Natur. (2) *4*: 81-84, Tab. 1. Tip. Sassi nelle Spaderie, Bologna.

SCARABELLI G. (1852) — *Sopra i depositi quaternari dell'Imolese. Rettifica di alcune opinioni intorno alla giacitura delle ossa fossili. Lettera del Sig. Scarabelli al Ch. Sig. Dott. Antonio Toschi*. Ann. Sc. Mat. e Fis., 11 pag., 3 Pl.

SCARABELLI G. (1881) — *Carta geologica del M. Castellaccio e dintorni, presso Imola*. Scala 1:5000. Tip. Teano e Virano, Roma.

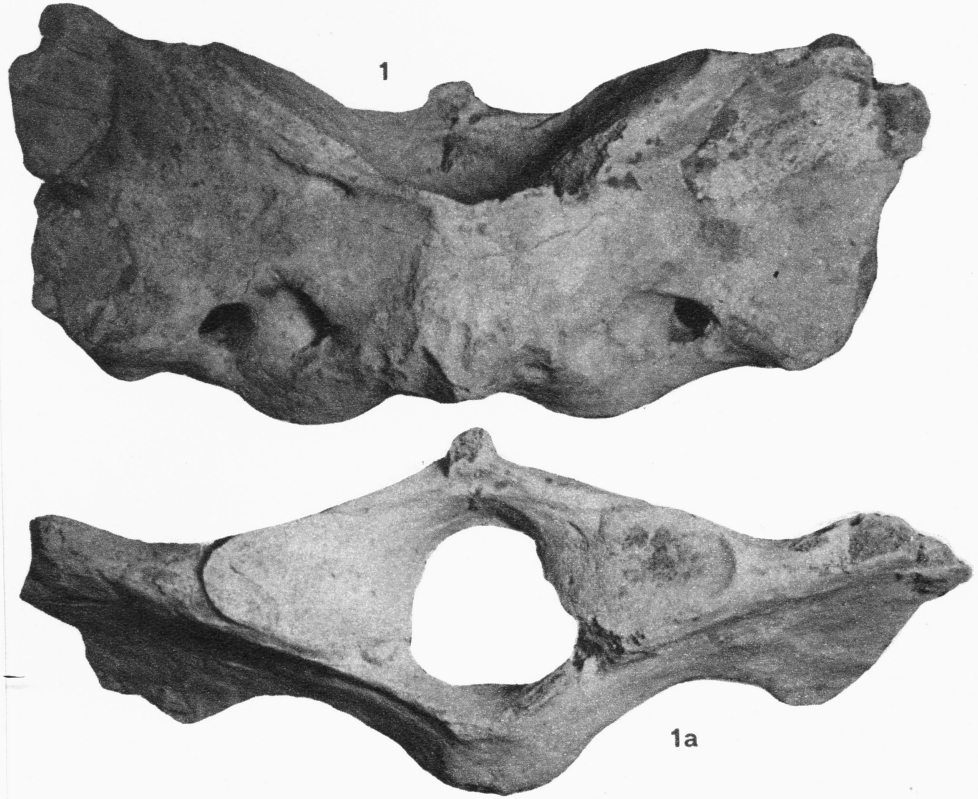
SELLI R. (1962) — *Le Quaternaire marin du versant Adriatique Jonien de la peninsule Italienne*. Quaternaria, *4*: 391-413, Pl. 1-4, geological map.

TOLDO G. (1905) — *Note preliminari sulle condizioni geologiche dei contrafforti appenninici compresi fra il Sillaro e il Lamone*. Boll. Soc. Geol. It., *24*: 343-386, 1 pl.

WEST R. G. & GAY WILSON D. (1966) *Cromer forest beded series*. Nature, *5022*: 497-498. London 1966.

Explanation of pl. I [I]

FIG. 1, 1*a* — *Dicerorhinus* cf. *etruscus:* atlas from Rio Pradella, La Sganga - pag. 7 1:2


1
1a