MUSÉUM NATIONAL D'HISTOIRE NATURELLE

Publication trimestrielle. Vol. XXI — N° 1-2 1979

Omaggio dell'autore

POLLEN
et
SPORES

E.P.H.E.
LABORATOIRE de PALYNOLOGIE

EXTRAIT

PARIS
61, Rue de Buffon
—
1979

PUBLIÉ AVEC LE CONCOURS DU CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE

PALYNOLOGY AND STRATIGRAPHY OF THE PLIO-PLEISTOCENE SEQUENCE OF THE STIRONE RIVER (NORTHERN ITALY)

BY

D. BERTOLANI MARCHETTI (*), C. A. ACCORSI (*), G. PELOSIO (**) and S. RAFFI (**).

((*) *Institute of Botany, Bologna University,*
(**) *Institute of Geology, Parma University*).

SOMMAIRE. — Une succession plio-pleistocène du Torrent Stirone près de Parme (Italie septentrionale) a été étudiée au point de vue stratigraphique et palynologique avec l'appui de quelques données paléomagnétiques. Dans le diagramme on a distingué le comportement de deux types de Taxodiacées (que l'on a exclus du nombre des médiocratiques typiques) : le type *Sciadopytis* disparaît à la limite conventionnelle plio-pléistocène, vraisemblablement à cause d'un dessèchement du climat, tandis que le type *Sequoia-Taxodium* a des oscillations apparemment liées à l'évolution de la ligne de côte. La courbe climatique montre une période fraîche, au milieu de laquelle on remarque la première apparition de *Arctica islandica,* suivie d'un réchauffement en deux vagues successives qui engendrent la prédominance de *Quercus, Carya, Carpinus* etc... Des problèmes de corrélations ont été discutés.

Introduction.

The present study is a part of the interdisciplinary research programme on the Plio-Pleistocene sequence of the Stirone River (PELOSIO and RAFFI, 1974). The new palynological data are therefore enclosed in a stratigraphical framework supported by numerous paleontological, paleoecological and paleomagnetic data, most of which have not been yet published.

The Stirone River is a left bank tributary of the Taro River and a long stretch of it marks the boundary between the Provinces of Parma and Piacenza. In its middle course the river erodes and exposes to view the Plio-Pleistocene sedimentary sequence underlying the old and recent *alluvia.* It was first illustrated and described by PAPANI and PELOSIO (1962). The sequence outcrops in the river bed almost continuously for 5 km, from Scipione Ponte to

FIG. 1. — On the left of the graph the local paleoenvironmental variations throughout the sequence are represented. On the right of the lithologic column the mediocrats curve is reported. The percentages of *Sequoia/Taxodium*, which form the coastal damp forest, and those of *Sciadopytis*, signifying cool mountain and very rainy climate are marked out. Small percentages of *Eucommia/Celtis* (E-C) and *Ephedra* (O) are represented. On the right side of the graph there is the climate curve.

The graph is divided in 7 sections, for which the mean percentages of the main *taxa* are given.

a) Cold or wet-cold climate. Air-bladdered pollens 47.2 %. *Sciadopytis* 16.8, *Seq./Tax.* 19.3, *Pinus* t. *haploxylon* 27.2, *Pinus* t. *dipl.* 8.6, *Tsuga* 5.6, *Cedrus* 4.0, *Picea* 3.4, *Abies, Fagus, Alnus, Quercus, Carya, Pterocarya, Platycarya, Castanea, Aesculus, Ulmus, Eucommia* 0.3, *Acer, Nyssa, Zelkova, Myrica, Morus, Maclura, Viburnum, Buxus, Palmae, Rhamnus, Myrtales, Ephedra* 0.3, *Gnetum, Ericales,* Cupressaceae, *Taxus, Salix.*

b) Dry-cold, then from temperate cool to cool climate. Air bladdered pollens 59.3 %. *Pinus hapl.* 20.3, *Pinus dipl.* 20.0, *Abies* 2.2, *Cedrus* 4.4, *Tsuga* 3.3, *Sciadopytis* 2.3, *Seq./Tax.* 6.6, Cupressaceae, *Fagus, Betula, Alnus, Carya, Pterocarya, Corylus, Carpinus, Ulmus, Zelkova, Quercus, Platycarya, Juglans, Castanea, Ostrya, Fraxinus, Celtis* 0.7, *Eucommia* 1.2, *Nyssa, Myrica,* cf. *Grewia, Morus, Ilex, Viburnum, Buxus, Rhamnus, Ephedra* 0.4, *Gnetum,* Ericales, *Pistacia.*

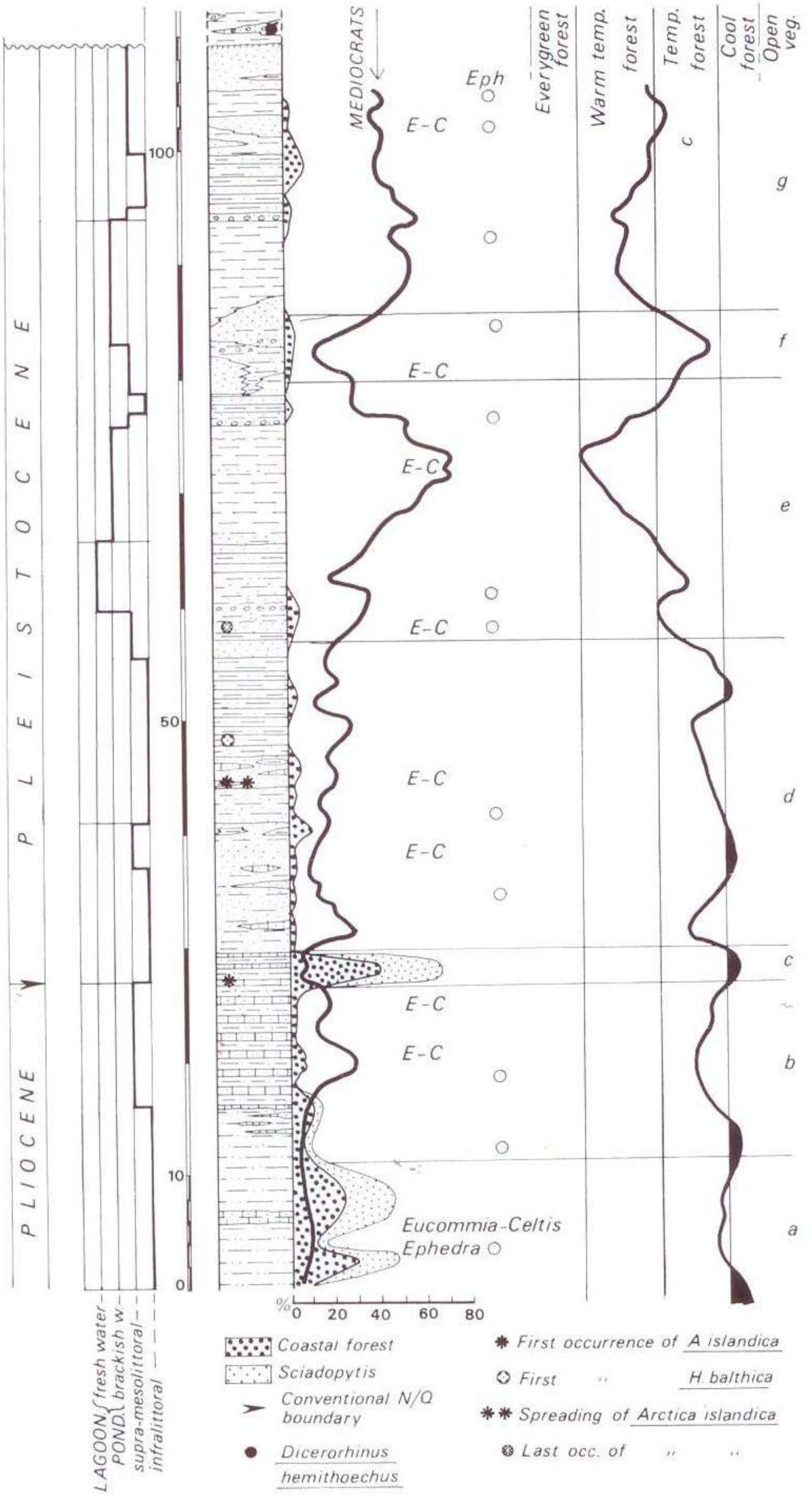
c) Wet-cold climate. Air-bladdered pollens 24.0 %. *Sciadopytis* 29.0, *Seq./Tax.* 41.4, *Pinus hapl.* 15.5, *Pinus dipl.* 3.7, *Cedrus* 1.3, *Tsuga* 4.2, Cupressaceae, *Fagus, Betula, Alnus, Salix, Pterocarya, Castanea, Aesculus, Corylus, Ostrya, Carpinus, Nyssa, Ilex, Laurus, Rhamnus, Ephedra,* Ericales.

d) Oscillations from cold to cool or temperate-cool climate. Air bladdered pollens 49.4 %. *Pinus hapl.* 9.4, *Pinus dipl.* 13.7, *Picea* 13.1, *Abies* 5.6, *Cedrus* 5.8, *Tsuga* 7.5, *Sciadopytis, Seq./Tax.,* Cupressaceae, *Taxus, Fagus, Betula, Alnus, Salix, Carya, Pterocarya, Platycarya, Juglans, Castanea, Corylus, Carpinus, Fraxinus, Tilia, Ulmus, Zelkova, Celtis* 0.5, *Eucommia* 0.5, *Quercus* 3.8, *Ostrya, Morus, Myrica, Ilex, Viburnum, Liriodendron, Rhamnus,* Myrtales, *Engelhardtia,* Ericales, *Ephedra,* Palmae.

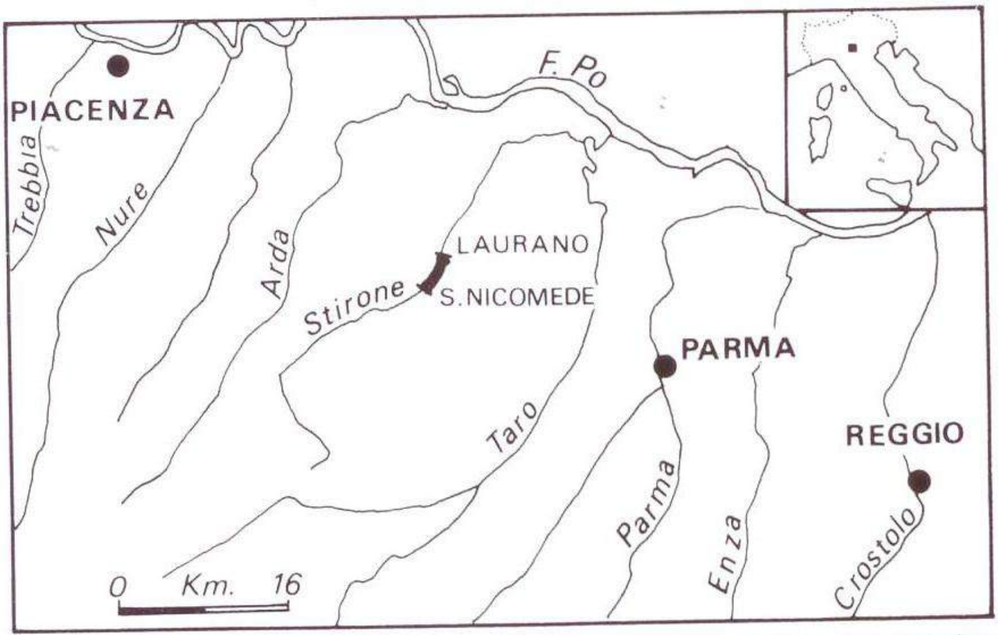
e) First mitigate-cool, then wet-warm climate ; the warmest with successive rise of *Quercus, Carpinus* and *Carya*. Air-bladdered pollens 43.4 %. *Pinus hapl.* 4.5, *Pinus dipl.* 11.6, *Picea* 7.6, *Abies* 4.7, *Podocarpus, Cedrus, Tsuga* 5.6, *Sciadopytis, Seq./Tax.,* Cupressaceae 3.0, *Fagus, Betula, Alnus* 8.5, *Carya* 6.7, *Pterocarya, Zelkova* 2.3, *Engelhardtia, Quercus* 12.0, *Carpinus* 11,2, *Corylus* 3.6, *Fraxinus, Tilia, Ulmus, Ostrya, Eucommia* 1.3, *Celtis* 0.6, *Myrica,* cf. *Grewia, Morus,* and many other thermophylous *taxa.*

f) Moderately cold climate. Air-bladdered pollens 56.1 %. *Pinus hapl.* 12.7, *Pinus dipl.* 26.8, *Picea* 7.4, *Abies* 6.2, *Tsuga* 10.3, *Seq./Tax.* 2.1, Cupressaceae, *Fagus, Betula, Cedrus, Carya* 6.8, *Platycarya, Zelkova* 3.6, *Quercus* 9.5, *Corylus, Carpinus, Ostrya, Tilia, Ulmus, Celtis* 0.3, *Eucommia* 0.6, *Juglans, Castanea, Myrica, Morus, Viburnum, Buxus,* Palmae, Myrtales, *Cornus, Ephedra* 1.8, Ericales.

g) Warm climate ; presence of hygrophytes. Air-bladdered pollens 19.9 %. *Pinus hapl.* 3.3, *Pinus dipl.* 10.2, *Picea, Abies* 3.0, *Cedrus, Tsuga* 16.5, *Seq./Tax.* 2.5, Cupressaceae, *Taxus, Fagus, Betula, Alnus* 3.1, *Salix, Zelkova, Carya* 26.2, *Pterocarya, Platycarya, Quercus* 6.0, *Carpinus,* 9.4, *Fraxinus, Tilia, Ulmus, Juglans, Castanea, Corylus* 2.2, *Celtis* 0.2, *Eucommia* 1.0, *Ostrya, Acer, Aesculus, Liriodendron, Myrica, Morus, Ilex, Viburnum, Rhamnus,* Ericales *Ephedra* 0.4, *Cornus,* Cistaceae, *Liquidambar, Laurus,* Palmae, *Pistacia* and many other thermophylous plants.


P L I O C E N E
P L E I S T O C E N E
LAGOON{fresh water
POND.{brackish w.
supra-mesolittoral
infralittoral
0
10
50
100
MEDIOCRATS
Eph
E-C
Eucommia-Celtis
Ephedra
% 0 20 40 60 80
Evergreen forest
Warm temp. forest
Temp. forest
Cool forest
Open veg.
c
a
b
c
d
e
f
g
Coastal forest
Sciadopytis
Conventional N/Q boundary
Dicerorhinus hemithoechus
First occurrence of A islandica
First " H. balthica
Spreading of Arctica islandica
Last occ. of " "

the site of Laurano. The strata dip NNE with an inclination first increasing from 28° to 38°, then gradually decreasing towards the plain and nearly reaching a horizontal position. The lithology of the Plio-Pleistocene sedimentary cycle is mainly clayey in the lower and middle part, silty and sandy upwards with intercalations of calcarenite, biosparite and sporadic pebble beds and lenses. At the base of the sequence a few metres of cobbly conglomerates outcrop. Up to now this conglomerate has been interpreted as the base of the Pliocene transgression. A recent phase of erosion in the river has revealed very clearly the part of the sequence immediately above the conglomerate. Thus it was observed that above the conglomerate there was a succession of silt and sand layers about forty metres thick and containing fresh water molluscs and ostracods. Subsequently without any apparent discontinuity there can be found therefore a typical marine Lower Pliocene in deep-pelitic facies. The new local datum agrees with analogous situations which have already been observed in neighbouring areas. Further research regarding this topic is being carried out in the Institute of Geology of Parma (Iaccarino S. and Papani G.).



Map of the area surrounding the Plio-Pleistocene sequence of the Stirone river.

The whole Tabianian is characterised by a deep-pelitic facies ; afterwards a gradual regression began, probably also controlled by local tectonic factors. The upper part of the sequence, and in particular the 109 metres at the top, has been studied in detail, from a palynological, paleontological and paleoecological point of view. In fact this tract includes the conventional Plio-Pleistocene boundary (first appearance of *Arctica islandica* at 26.80 m of the sequence). The series of strata, which was investigated in detail (Fig. 1) presents moderate bathymetric oscillations within the infralittoral environments, with two brackish episodes and a fresh water one intercalated in the marine sequence. It is probable that after the beach episode of 37-41 m, just before the levels with *Venus multilamella* (LAMARCK), a sheltered environment with normal salinity set in. The brackish episodes between 65.50-76 m and 83-94 m give evidence of the subsequent physiographic evolution in a regressive trend.

Description of the sequence and paleoecological observations.

(P. and R.).

0.00 - 16.00 m : silt and fine sand, bioclastic lenses and irregularly cemented beds frequent near the top.

MACROFOSSIL CONTENT (molluscs, echinoderms, bryozoans, ...) :
— mixed fossil assemblages containing species with specimens in life position : *Astarte fusca* POLI, *Clavagella bacillum* (BROCCHI), *Thracia convexa* (WOOD), *Glans rhomboidea* (BROCCHI), *Clausinella fasciata* (DA COSTA) ;
+ species characteristic of sandy detrital bottom : *Gouldia minima* (MONTAGU), *Parvicardium minimum* (PHILIPPI), *Timoclea ovata* (PENNANT) ;
+ *Posidonia*-meadow species : *Jujubinus exasperatus* (PENNANT), *Alvania montagui* PAYRAUDEAU, *Alvania punctura* (MONTAGU),... ;
— transported fossil assemblage characterized by shell detrital accumulations dominated by *Chlamys opercularis* (LINNÉ), *Ditrupa cornea* (LINNÉ), *Corbula gibba* (OLIVI) (and much fewer specimens of the assemblages mentioned above).
The species of the assemblages, particularly those in life position, are not good indicators of bathymetry. A suggestion of the depth of the environment can be inferred from the sedimentary structures towards the top of the interval, indicating the influence of the wave motion on the bottom. Therefore the part of the sequence underlying them, can be attributed to the infralittoral with a gradual trend to regression.

16.00 - 26.80 m : beach deposits with frequent alternances of biosparite and sand beds ; coarse-grained clastics near the top, where scattered pebbles occur more frequently.

MACROFOSSIL CONTENT (molluscs, calcareous algae, ...) :
— transported fossil assemblages with *Pecten jacobaeus* (LINNÉ), *Glycymeris inflata* (BROCCHI), *Chlamys opercularis* (LINNÉ), *Lutraria lutraria* (LINNÉ), ... At 26.80 m first appearance of occasional specimens of *Arctica islandica* (LINNÉ).

26.80 - 37.00 m : silt and fine sand alternating with bioclastic beds and rare sandstones.

MACROFOSSIL CONTENT (molluscs, calcareous algae, ...) :

— mixed fossil assemblages with the same association characteristic as noticed in the preceding layers between 0.00-16.00 m ;

— transported fossil assemblages with *Chlamys opercularis* (LINNÉ), *Glycymeris violacescens* (LAMARCK), *Lutraria lutraria* (LINNÉ), *Panopea glycimeris* (BORN), *Acanthocardia tuberculata* (LINNÉ), *A. echinata mucronata* (POLI), *Venus multilamella* (LAMARCK), *Tellina corbis* (BRONN), *T. pulchella* (LAMARCK), *Mactra corallina* (LINNÉ), *Spisula subtruncata* (DA COSTA), ... At the base of this interval there was found *Pholadidea vibonensis* (PHILIPPI), considered to be a boreal immigrant in the Mediterranean Pleistocene. In this interval, however, there are still present and associated with very few specimens of *A. islandica,* both species of « Pliocene affinity » like *Amusium cristatum* (BRONN), *Pelecyora brocchi* (DESHAYES), *Cerithium varicosum* (BROCCHI), *Cymatium affine* (DESHAYES), and species of temperate-warm affinity, like *Mitra zonata* MARRYAT, *Charonia nodifera* (LAMARCK), *Schilderia achatidea* (SOWERBY), still living in the Mediterranean.

37.00 - 41.00 m : well sorted fine sand, silt and bioclastic lenses (beach deposits).

MACROFOSSIL CONTENT (molluscs, ...) :

— transported fossil assemblage with *Chamelea gallina* (LINNÉ), *Glycymeris violacescens* (LAMARCK), *Mactra corallina* (LINNÉ), *Spisula subtruncata* (DA COSTA), *Acanthocardia tuberculata* (LINNÉ), *Solen marginatus* PENNANT, *Ensis ensis* (LINNÉ), *Donax venustus* POLI, *Tellina pulchella* LAMARCK, *Sphaeronassa mutabilis* (LINNÉ), *Neverita josephinia* RISSO, ... (typical species to-day of the « Biocoenosis of fine well-sorted sand ») and *Posidonia*-meadow species (*Bittium reticulatum* (DA COSTA), *Jujubinus exasperatus* (PENNANT), *Alvania* spp., ...).

In this tract of the sequence there are found the last specimens of *Diloma patula* (BROCCHI), a species which seems to have become extinct in the Lower Pleistocene. Rare valve of *A. islandica* are present in the necrocoenosis.

41.00 - 44.00 m : silty clay.

MACROFOSSIL CONTENT (molluscs, echinoids, ...) :

— residual fossil community with *Venus multilamella* (LAMARCK), *Glossus humanus* (LINNÉ), *Acanthocardia paucicostata* (SOWERBY), *Nucula placentina* LAMARCK, *Haustator tricarinatus pliorecens* (MONTEROSATO), *Amyclina semistriata* (BROCCHI), ... This interval may be considered to have been deposited in shallow water, most probably in a sheltered environment. At the top of this bed there has been recently found the new species *Portlandia impressa* PERRI, which may be regarded as a boreal immigrant (PERRI, 1975).

44.00 - 48.00 m : sand, silty sand, with sandstone and bioclastic lenses.

MACROFOSSIL CONTENT (molluscs, echinoids, ...) :

— transported fossil assemblages with *Arctica islandica* (LINNÉ), *Spisula subtruncata* (DA COSTA), *Pitar rudis* (POLI), *Parvicardium papillosum* (POLI), *P. minimum* (PHILIPPI), *Venerupis senescens cuneiformis* PELOSIO and RAFFI, ...

— residual fossil community with *Schizaster canaliferus* (LAMARCK), *Haustator tricarinatus pliorecens* (MONTEROSATO), *Panopea glycimeris* (BORN), *Cardium hians* BROCCHI, *Glossus humanus* (LINNÉ), ... This assemblage may be related to a facies of the present-day adriatic zoocoenosis « *Schizaster canaliferus* - *Amphiura chiajei* ».

The base of this interval is characterized by the spreading of *A. islandica* which remains very frequent upwards in the sequence.

48.00 - 55.50 m : bioclastic-sand alternating with silty clay.

MACROFOSSIL CONTENT (molluscs, echinoderms, ...) :

— residual fossil community (in the clay-silty intercalations) with *Arctica islandica* (LINNÉ), *Venerupis senescens cuneiformis* PELOSIO and RAFFI, *Spisula subtruncata* (DA COSTA), ... *Astropecten irregularis* PENNANT, *Echinocardium cordatum* (PENNANT), *Ophiura* sp.

— transported fossil assemblage with *Chamelea gallina* (LINNÉ), *Venus multilamella* (LAMARCK), *Ditrupa cornea* (LINNÉ) and species of the residual fossil community.

At the base the first appearance of *Hyalinea balthica* (SCHROETER) is recorded.

55.50 - 59.60 m : sand and coarse sand, thin pebble lenses (beach deposits).

MACROFOSSIL CONTENT (molluscs) :

— transported fossil assemblage with *Chamelea gallina* (LINNÉ), *Glycymeris violacescens* (LAMARCK), *Mactra corallina* (LINNÉ), *Ensis ensis* (LINNÉ), *Venus multilamella* (LAMARCK),...

Last occurence of *A. islandica* at 58.00 m.

59.60 - 65.60 m : silt and sand, thin green clay beds ; at the base a cobbly bed (lacustrine deposits).

MACROFOSSIL CONTENT (fresh water molluscs) :

— residual fossil community with *Dreissena polimorpha* PALLAS, *Theodoxus isseli* (CLERICI), *Melanopsis hastata* NEUMAYR, *Hydrobia* spp., *Unio* sp.

65.60 - 75.80 m : silty clay, with occasional fine sand beds (brackish water deposits).

MACROFOSSIL CONTENT (brackish water molluscs) :

— residual fossil community with *Cerastoderma lamarcki* (REEVE), *Venerupis senescens senescens* (DODERLEIN), *Cerithium*

vulgatum Bruguiere, *Hinia reticulata nitida* (Jeffreys), *Abra ovata* (Philippi), ...
Apart from the one exception of *Venerupis senescens* (extinct) these assemblages correspond to the present-day brackish water lagoon biocoenosis of the Mediterranean Sea.

75.80 - 78.50 m : silty clay alternating with sand ; at the base a cobbly bed (shallow water deposits).

Macrofossil content (molluscs) :

— residual fossil community with *Glycymeris violacescens* (Lamarck), *Chamelea gallina* (Linné), *Sphaeronassa mutabilis* (Linné), *Mactra corallina* (Linné),...

78.50 - 83.00 m : sand changing laterally into silt lenses ; upwards abundant plant remains, gravel lenses, red sand lenses : symptoms of possible short emergence.

Macrofossil content (molluscs) :

— transported fossil assemblage with the prevalent elements of the preceding residual fossil community.

83.00 - 93.80 m : sand at the base, silt near the top (brackish water deposits).

Macrofossil content (brackish water molluscs) :

— residual fossil community with the same species of the brackish water deposits of the interval between 65.60-75.80 m.

93.80 - 100.00 m : sands and silt intercalations ; at the base a cobbly bed (shallow water deposits).

Macrofossil content (molluscs) :

— residual fossil community with *Chamelea gallina* (Linné), *Ensis ensis* (Linné), *Lentidium mediterraneum* (Costa), ...

100.00 - 109,00 m : coarse sand, pebble and fossil reworked lenses.

Macrofossil content (molluscs) :

— transported fossil assemblage with prevalent elements of the underlying residual fossil community.
This interval represents locally the final regression of the Plio-Pleistocene marine cycle. At the top is present a surface of erosion.

Continental environment sediments (fluvio-lacustrine pebbles, sand and silt) with vertebrate faunas and fresh water molluscs are unconformable on this marine sequence. At 110 metres a complete skull of *Dicerorhinus hemitoechus* (Falconer) was discovered (Cigala Fulgosi, 1976). About 20 m above the base of the fluvio-lacustrine sequence, Bucha *et alii* (1975) have identified the Matuyama/Brunhes boundary (0.69 m.y.B.P.).

The paleoenvironmental evolution of the Stirone sequence is well recorded by the necrocoenosis of molluscs which, in agreement with the other paleontological data, characterize the bathymetric oscillations (Fig. 1) recognized on a sedimentological basis.

The most significant paleoclimatic event — in a conventional way — is represented by the first occurrence of *Arctica islandica,* which is found at 26.80 m. The frequency of the species is very low up to 41.00 m. In this interval there are still present both species of « Pliocene affinity », extinct today, and species of temperate-warm affinity, still living in the Mediterranean.

Between 41.00-59.60 metres the highest frequency of *A. islandica* and a remarkable impoverishment of faunal elements of « Pliocene affinity » and of temperate-warm affinity are recorded. In the following part of the sequence *A. islandica* does not occur. The environmental factors could justify the absence of the species at least up to 94 metres.

The decrease in the gradients of the taxonomic diversity of molluscs may be considered a common fact in the marine Plio-Pleistocene series of the Mediterranean Basin. This, however, is difficult to analyse in the single sequences (at least in those of Western Emilia) owing to a constant environmental control. It follows that molluscs do not allow a detailed examination of cyclic climatic oscillations like those indicated by pollen analyses. The following climatic oscillations bring about a reduction in the number of the species, but the disappearance of the species could depend also on local environmental variations and therefore such events are difficult to interpret in each single case.

Climatic vegetational remarks on the basis of palynological research.

(B. M. and A.).

The present study constitutes a further contribution to the pollen knowledge of the Stirone River sequence (LONA and BERTOLDI, 1973 ; BECKER-PLATEN *et alii,* 1975) ; as already observed it is a part of a vast interdisciplinary project comprehensive of paleontological, paleoecological and paleomagnetic studies.

Our research will be published later with very detailed graphs and tables and with an accurate description of the vegetational features which occurred. For the moment in the summarizing graph of the stratigraphic and paleoecological data (Fig. 1) only the climatic curve derived from that of the mediocrats is represented and it is based on the vegetational context of each sector. The graph of the Taxodiaceae was drawn separately without adding their percentage to that of the mediocrats ; moreover, the *Sequoia/Taxodium* type was distinguished from the *Sciadopytis* type.

A more detailed analysis of the different vegetational belts which rose and fell in consequence of climatic oscillations will be given in our final paper. Here a cool forest, a temperate forest and a warm-temperate forest, belonging to superposed vegetational belts, were only distinguished. In the considered tract of the sequence the « evergreen forest » and the « open vegetation » do not appear to have been represented.

Seven sections can be distinguished in the diagram, these being indicated from the bottom to the top with the letters *a* to *g*. In the lower part of the graph (in *a* and *c*) it is possible to see that the Taxodiaceae (of the type *Sciadopytis* and of the type *Taxodium/Sequoia*) reach notable values. However, they decline notably in *b* and still more in *d*, where *Sciadopytis* disappears definitively. The type *Sequoia/Taxodium* reappears along the graph, reaching the upper part, in such a way that it seems to follow quite faithfully the evolution of the coastal line.

The more critical parts for climatic-vegetational inferences are in the *a* and *c* sections of the diagram. Very often Taxodiaceae were included in the thermophylous plants ; however in the past one of us raised some doubts about this concept ; in the climatic curve of Villafranca d'Asti (FRANCAVILLA *et alii*, 1969, 1970) typical mediocrats only such as *Carya, Pterocarya, Zelkova, Quercus, Tilia* and so on are considered.

We have therefore attempted to make a precise examination of the Taxodiaceae-type components, with the aim of clarifying the situation. In the *Sequoia/Taxodium* group it has not been possible to make a generic distinction because very often the characteristic processus which allows a precise determination of the genus has not been identifiable ; obviously this was not problem with the *Sciadopytis* pollen grains identification.

Concerning the meaning and the ecology of the different taxa of this group, we can observe that the genus *Sequoia* include taxa of different ecological environments. *Sequoia sempervirens* lives either on North-American river-banks or in a coastal forest sometimes associated with *Taxodium distichum*, or on low mountain slopes, in conditions of high air humidity. On the other hand, while needing wet conditions, *Sequoia gigantea* also requires a temperate-cool climate with very snowy winters ; in fact it can be found nowadays in the American Sierra Nevada at 1500-2400 meters a.s.l. *Taxodium mucronatum* tolerates drier conditions : it lives at 1500-2400 meters a.s.l. on the Mexican mountains.

We have little information about *Sciadopytis*. It lives to-day in Japan (Hondo and Sukkok Isles) at 1700 metres a.s.l., but sometimes single trees live as high up as 2300 metres a.s.l. To-day it is cultivated on the Oceanic mountains at 1500-1700 metres a.s.l. It needs a cold winter, hot summer (monthly mean over 20°C) and high yearly rains (monthly mean over 500 mm) (TOMASELLI, *in litteris*, 31.5.1977).

Therefore we cannot consider totally the percentage of Taxodiaceae pollen grains as a unique group, because it includes assemblages with two different meanings. It must be emphasized that some authors propose to put *Sciadopytis* in a different family from that of Taxodiaceae.

Concerning the lower levels of the Stirone palynological sequence where it is possible to find the higher peaks of Taxodiaceae, we can suggest the presence of two different pollen assemblages of diverse vegetational belts. The first one would be a mountain vegetational group in which *Sciadopytis* prevails ; it should be favoured by very intense rainy seasons, and perhaps by the clayey substratum of the large extension of the Apennine « Argille scagliose » formation. The second represents a forest situated in a coastal environment, which might well have been constituted almost exclusively by the *Sequoia/Taxodium* type.

The higher *Sciadopytis* percentages are in connection with the maxima of the Taxodiaceae curve (see graph, section *a* and *c*). These percentages decrease with the diminishing of the general amount, and they are totally lacking in the upper part of the graph.

The features of a coastal forest are evident in the whole of the diagram where Taxodiaceae are present. These coastal formations with Taxodiaceae seem to depend on the paleogeographic evolution. They disappear in the upper part of the sequence in correspondence to the brackish water episodes and they reappear at the time of the re-establishing of a marine environment. This rhythmical evolution would seem to exclude the hypothesis of an eventual reworking.

In our opinion it is impossible to consider Taxodiaceae as a characteristic index of a warm climate and therefore they cannot be included in the typical mediocrats group. They may occur in a cool-temperate mountain, in a temperate or, at most, subtropical climate, or in a coastal assemblage. This particular environment is only partially influenced by climatic conditions, therefore the plants are partially independent of thermic oscillations. For example the sharp peak of Taxodiaceae in the *c* part of the graph corresponds to a scarcity of thermophylous plants and to a remarkable percentage of typical terminocrats.

The climatic curve of the Stirone River shows quite a cool period in the lower part ; in the upper part however an appreciable improvement can be noticed. This is characterized by two peaks of warm temperature (perhaps drier warm temperature) which promote the development of oak forest and subsequently of *Carya-Pterocarya* woods.

At this stage it is necessary to point out that the problem of Taxodiaceae decreasing is really divided into two distinct parts. The disappearance of this type of coastal forest may be in connection with the paleogeographic situation. A large increase of *Sciadopytis,* on the other hand, occurs in a very rainy period, obviously within given thermic boundaries, but not necessary in a very warm climate. So the disappearance of this species may only be due to a drying of the climate. If this interpretation is followed, some doubts may occur over the possibility of using the only fall of Taxodiaceae for a correlation of marine or continental series in different paleogeographic settings.

In the pollen diagram of the Stirone sequence there are always « *haploxylon* » and « *diploxylon* » Pines at all levels. A frequently present taxon is *Tsuga,* often associated with *Cedrus* in the cooler part of the sequence. In the *e* section, that is, the warmest one, *Cedrus* is very infrequent and probably *Tsuga* is a component of a warm-temperate forest, associated with *Quercus,* or *Carya* and so on. *Carya, Pterocarya, Zelkova* with other mediocrats are particularly abundant in the *e* and *g* complexes.

There are some very small percentages of *Eucommia* and more rarely of *Celtis* in the diagram. *Carpinus* is frequently represented and its curve rises together with that of *Quercetum* and *Caryetum*. *Carpinus* has not been indicated by the other authors. The plant is most frequent together with *Quercus* in section *e,* where the climate is obviously drier with respect to that in section *g,* where, in turn, *Tsuga* grows better. One must remember that in the graphs of the postglacial period of North America, *Carpinus* is found in the subboreal climatic phase, which is dry and hot.

In the reconstruction of these paleovegetational aspects one cannot exclude the possible and partial arrival of pollen from the Alpine region ; this hypothesis is suggested also by the mineralogical characteristics of the sediments, which are not limited to just an Apennine source (BELFIORE *et alii,* 1977).

In the graph the conventional Plio-Pleistocene boundary has been placed in correspondence with the first appearance of « cold immigrants » in the sequence. With regard to palynological data this boundary is included in a moderately cool and quite a long period.

As has already been mentioned, a real thermic rise has been observed in the upper part of the series. This climate change, that becomes drier but never too much so, appears in two subsequent waves at the *e* and *g* graph sections.

The vegetational history of the lower part of the Stirone sequence could be contemporary to that of the Vrica series, near Crotone, Calabria (SELLI *et alii*, 1977). Here also the proposed Plio-Pleistocene boundary, according to some pollen analysis, seems to be in a period with small climatic changes that were cool but not cold. At its top the Vrica section does not reach the warm period of the Stirone sequence. Further research may lead to interesting comparisons between the two sequences, which are placed in different latitudes, in different sea basins such as the Po paleogulf and Ionian Sea, and at the foot of mountains probably different in height and in vegetational belts.

Conclusions.

The Stirone River sequence has recently been investigated from a paleomagnetic point of view by BUCHA *et alii* of the Czechoslovakian Academy of Sciences, Prague (1975) and by J. KUKLA of the Lamont Observatory of Columbia University, New York (unpublished data). The two schools have independently recognised a normal event interpreted as Oldoway about 30 metres above the first appearance of the boreal immigrants in the sequence (*A. islandica, Ph. vibonensis*). KUKLA has also identified a further normal event in correspondence with the first appearance of *A. islandica,* which he interpreted as Reunion (personal communication). In the author's opinion (in AMBROSETTI *et alii*, 1975) *A. islandica* occurs in correspondence with this event in the Plio-Pleistocene sequences of Santerno and Pisa too (probably). Apart from this new datum, the paleomagnetic analysis seems to agree with the fact that *A. islandica* in the Stirone River sequence appears before the Oldoway event and so it is earlier than 1.8 m.y.B.P. In addition to agreeing with the Santerno data and perhaps also the Pisa data, this chronological datum is in general accord with the recent results of the Vrica section, presented by SELLI and Collaborators at the 10th INQUA Congress of Birmingham (1977), which suggest an age of about 2 m.y.B.P. on the basis of radiometric dating for the Plio-Pleistocene boundary.

BUCHA *et alii* (1975) have identified a normal event interpreted as Jaramillo at the top of the marine sequence of the Stirone River. If this interpretation was confirmed, this marine Pleistocene sequence would be equivalent to about a million years.

The appearance of the boreal immigrants constitutes the conventional means of indicating the beginning of the Pleistocene in the stratotype. However it is necessary to point out that the correlations cannot be based on boreal immigrants in that their presence is connected with particular ecological conditions (bathymetry, edaphic-trophic factors, etc.) tied to the evolution of the basins.

The Plio-Pleistocene boundary in the Stirone River sequence has been placed in correspondence with the first appearance of *A. islandica,* which seems to correlate, on the basis of paleomagnetic data, with those of Santerno and of Pisa, and with the N/Q boundary of the Vrica sequence, characterized by the appearance in bathial facies of the ostracod *Cytheropteron testudo*. With regards to the Stirone it would be necessary to emphasize that this chronostratigraphic reference is still only a working hypothesis for the moment.

The problem of a choice of a stratotype for the Lower Pleistocene is still present, if the discussion and disagreements resulting from the last INQUA Congress of Birmingham are considered. Taking into account the direct and the indirect dating (the latter through the oceanic biostratigraphic calibration) it is evident that at Le Castella and S. Maria di Catanzaro the marker beds of the stratotypes (RIO, 1974 ; HAQ, BERGREEN and VAN COUVERING, 1977) would be of an age correspondent to or more recent than 1.5-1.6 m.y.B.P., while in the Santerno and Vrica sequences they prove to be about 2 m.y.B.P. on the basis of paleomagnetic, radiometric and fission track data. If it is considered that at Vrica *Gephyrocapsa oceanica* appears about 30 metres above the level dated around 2 m.y.B.P. there already seems to be evidence of a discrepancy with the oceanic biostratigraphic calibration, that indicates a time of appearance at least later than Oldoway.

We think that the stratotype of the Lower Pleistocene should be selected (or possibly redefined) in a sequence which, in addition to holding the necessary requirements, is characterized by the earliest possible appearance of the boreal immigrants. Obviously this last consideration is beyond the criteria of the stratigraphic code, but it corresponds to the need of continuity with the concept expressed first of all by DE STEFANI, GIGNOUX and codified at the 18th International Geological Congress of London in 1948.

The problems that have emerged from this study, although with a view to an analysis of the local situation, call for some observations of a more general nature, which up to now have hardly been touched upon in the reports on vegetational characteristics of the transitional strip from Pliocene and Pleistocene. The Tiberian boundary of LONA *et alii,* 1969) established at Pietrafitta near Perugia in the

Tiber basin, would be characterized by a sudden disappearance of the Taxodiaceae : « following a great peak of their fluctuating expansion and the consequent establishment of an impoverished vegetation indicating a particular period of climate deterioration (cold phases, continental-steppic and/or montane boreal phases) » (LONA and BERTOLDI, 1972, in the summary). This boundary was afterwards found by LONA and Collaborators even in the marine outcrops of Castell-Arquato and Stirone (Western Emilia) respectively about 10 metres below the spreading of *A. islandica*, and nearly in correspondence with the first occurrence of the species. BERTOLDI (1977) has discovered the boundary in the section of Le Castella, right at the marker bed. In the opinion of BECKER-PLATEN *et alii* (1977) in the sequence of Stirone a *Taxodium/Sciadopytis* maximum (Tiberian boundary, LONA, 1969) could be found 90 metres below the first appearance of *A. islandica*. The authors did not recognize however, as can be seen from their Fig. 1, the last great peak of Taxodiaceae and their subsequent abrupt decreasing, interpreted by LONA et BERTOLDI (1972) as the Tiberian boundary. The Tiberian phase and the subsequent abrupt decrease of the Taxodiaceae has been confirmed in the present study too, at 29 metres of our sequence. The Taxodiaceae peak bound by BECKER-PLATEN *et alii* 90 metres below the first appearance level of *A. islandica* does not therefore relate to LONA's Tiberian boundary, representing only an episode of the vegetational history of the Pliocene period.

On the basis of present-day vegetational data it has become evident that *Sciadopytis* and the other *Taxodiaceae* cannot be included in the sum of the mediocrats. *Sciadopytis*, as has already been mentioned, indicates a mountainous environment with cold winters and an extremely rainy climate. The Taxodiaceae — *Taxodium/Sequoia* type — should belong to the coastal vegetation, not strictly dependent on climatic oscillations. The disappearance of *Sciadopytis* in the Stirone River sequence could have followed a less rainy climate, which could have prevented the very slow reproduction (up to 14 months).

The coastal wood of Taxodiaceae, which is present at intervals up to the top of the sequence, could have been influenced by the paleogeographic evolution of the coast. It is important to note that Taxodiaceae — *Taxodium/Sequoia* type — are still present above the Tiberian boundary of LONA and BERTOLDI (1972), in correspondence to which, on the other hand, *Sciadopytis* disappears. Therefore it seems that, rather than marking the passage to a thermically deteriorated climate, the boundary of LONA and BERTOLDI indicates the transition from a uniform and abundantly rainy climate to a climate characterized at least by a dry period and therefore by more marked seasons.

According to ZAGWIJN (1975, p. 148) « It can be hardly doubted that the Tiberian as defined by LONA is time equivalent to the boundary between the Upper Pliocene (Reuverian) and the Pretiglian cold stage of the Netherlands ». In actual fact the Tiberian boundary of LONA in the Stirone sequence (in correspondence with the first appearance of *A. islandica*), even when not taking into account the paleomagnetic data of BUCHA and KUKLA, is much more recent, if one considers that it is localized at about 50-60 metres from the base of the zone with *Globorotalia inflata*, which begins in the Mediterranean Basin around 2.2 m.y.B.P. (CITA and RYAN, 1973). The level corresponding to the Tiberian boundary should not therefore be earlier than 2 m.y.B.P. In this way, using the data summarized in Fig. 8 of ZAGWIJN (the paleomagnetic data are of VAN MONTFRANS, 1971) the Tiberian boundary of LONA, at least with reference to the Stirone sequence, could be collocated in the Tiglian phase.

SUC (1975) has shown that in Languedoc the disappearance of the Taxodiaceae comes earlier than at least 2.5 m.y.B.P., and that it is earlier than their extinction in Holland. The author has also suggested that the extinction of the taxon is due to an important change of climate « caractérisé par l'installation d'un rythme à sécheresse estivale » (p. 251). In the discussion following the presentation of SUC's work, CHATEAUNEUF and JARDINÉ put forward the problem of the part that a paleogeographic variation can play, that is, how much influence it can have over the passage from a marine environment to a continental one on the pollen assemblage in general and in particular on the extinction of the Taxodiaceae. Although accepting the influence of this variation, SUC has maintained, however, his hypothesis of a climatic change, since he has observed that the replacement of the Taxodiaceae occurs even in environments which one could presume to be favourable to their development (for example the diatomites of Bernasso).

In conclusion the disappearance of the Taxodiaceae in The Netherlands roughly in correspondence to a time line of 2.5 m.y.B.P., in Italy in correspondence to a time line which has not yet been defined between 2 and 1.5 m.y.B.P. (or perhaps more recent), in Languedoc in correspondence to a time line earlier than 2.5 m.y.B.P., illustrates the irregular time transgressive characteristic of the phenomenon. These data seem sufficient in order to propose a more accurate evaluation of the significance of the Tiberian boundary, which does not appear to have a chronostratigraphic value, but it would seem to indicate climatic and ecologic changes which are not contemporary.

The local analysis of the Stirone River sequence would seem in fact to indicate a marked influence of the paleogeographic variations on the coastal wood with Taxodiaceae and the prevalently climatic dependence of *Sciadopytis*. One must admit that the circumstances of the disappearance of the Taxodiaceae in general constitute a problem which must be investigated in the single regions on the basis of the greatest number possible of parameters.

Summary.

A Plio-Pleistocene sequence from the River Stirone near Parma (northern Italy) has been studied stratigraphically and palynologically (some paleomagnetic data were used as well). The diagram shows two distinct types of Taxodiaceae (excluded from the typical mediocrats) : *Sciadopytis* type disappears at the time of the conventional Plio-Pleistocene boundary probably because of the drying up of the climate whereas the *Sequoia/Taxodium* type has oscillations apparently linked to the evolution of the coast-line. The climatic curve reveals a cool period in the middle of which appears for the first time *Arctica islandica,* followed by a warming up in two successive waves which gave rise to the dominance of *Quercus, Carya, Carpinus* etc... Correlations problems have been discussed.

BIBLIOGRAPHY.

AMBROSETTI, P. *et alii* (1975). — Guide book. Meeting of the INQUA Subcommission on Mediterranean and Black Sea shorelines, Pisa-Perugia-Tarquinia, March-April, 1975, 1-35.

AXELROD, D. I. (1964). — Problems of altitude of Tertiary Floras. Abstr. 10ᵉ Internat. Bot. Congr. Edimburg, 1-24.

BECKER-PLATEN, J. D., BENDA, L., CEPEK, P., DANIELS, C. H. v., MENGELING, H., MEYER, H. J., STEFFENS, P., STREIF, H., VINKEN, R. (1977). — Beiträge zur Plio-Pleistozän-Grenzziehung in Mittel-Italien. Proceed. of the 2nd Symposium on the Neogene-Quaternary Boundary, Bologna-Crotone, October 6-15, 1975, *Giornale di Geologia*, Ser. 2ª, 41 (1/2), 107-114.

BELFIORE, A., MEZZADRI, G., VINCI, A. (1977). — Heavy minerals in the Pleistocene serie of the Stirone stream (Parma). Preprint X INQUA Congress, Birmingham, August, 15-24, 1977, 1-11.

BERTOLANI MARCHETTI, D. (1973). — Precedenti paleoclimatici, estensione cronologica e limiti del glaciale attuale. *L'Informatore Botanico Italiano,* 5, 71-75.

BERTOLANI MARCHETTI, D. (1975). — Preliminary palynological data on the proposed Plio-Pleistocene boundary type-section of Le Castella. *L'Ateneo Parmense, Acta Naturalia,* 11 (3), 467-485.

BERTOLANI MARCHETTI, D. (1978). — Possibile significato paleogeografico e paleobotanico delle Taxodiacee nei diagrammi pollinici del Pliocene terminale e dell'Eopleistocene. *Giornale Botanico Italiano,* 112, n° 4 : 296-297.

BERTOLANI MARCHETTI, D., ACCORSI, C. A. (1977). — Palynological research on the Plio-Pleistocene boundary in the Torrente Stirone (Parma, Northern Italy). Preprint X INQUA Congress, Birmingham, August, 15-24, 1977, 1-6.

BERTOLDI, R. (1977). — Studio palinologico della serie di Le Castella (Calabria). *Acc. Naz. Lincei, Rend. Cl. Sc. fis. matem., nat.*, Ser. VIII, 62 (4), 547-555.

BUCHA, V., HORACEK, J., KOCI, A., SIBRAVA, V., LOZEK, V. (1975). — Paleomagnetic correlations of Pleistocene sediments of Central Europe. I.G.C.P., Quaternary Glaciations in the Northern Hemisphere, Report No 2, Salzburg, September, 10-14, 1974, 9-36.

CIGALA FULGOSI, F. (1976). — *Dicerorhinus hemitoechus* (FALCONER) del post-Villafranchiano fluvio-lacustre del T. Stirone (Salsomaggiore, Parma). *Boll. Soc. Paleont. Ital.*, 15 (1), 59-72.

CITA, M. B., RYAN, W. B. F. (1973). — Time scale and general synthesis, in RYAN W. B. F. *et alii* : Initial reports of the Deep Sea Drilling Project, Vol. XIII, Washington, U.S. Government Printing Office, 1405-1415.

FRANCAVILLA, F., BERTOLANI MARCHETTI, D., TOMADIN, L. (1969). — Nouvelles données sur le Villafranchien type. Proc. VIII INQUA Congress, Paris, 1969.

FRANCAVILLA, F., BERTOLANI MARCHETTI, D., TOMADIN, L. (1970). — Ricerche stratigrafiche, sedimentologiche e palinologiche sul Villafranchiano tipo. *Giornale di Geologia*, Ser. 2ª, 36 (2), 701-741.

HAQ, B., BERGGREN, W. A., VAN COUVERING, J. A. (1977). — Corrected age of the Pliocene/Pleistocene Boundary : end of a controversy ? Preprint, X INQUA Congress, Birmingham, August, 15-24, 1977, 1-26.

LONA, F., BERTOLDI, R. (1972). — La storia del Plio-Pleistocene italiano in alcune sequenze vegetazionali lacustri e marine. *Acc. Naz. Lincei, Memorie Sc. fis., matem., nat.*, Ser. VIII, 11, Sez. III (1), 1-45.

LONA, F., BERTOLDI, R., RICCIARDI, E. (1969). — Plio-Pleistocene boundary in Italy based on the Leffian and Tiberian vegetational and climatological sequences. Coll. VIII INQUA Congress, Sect. Stratigraphy, Paris 1969, 573-574.

PAPANI, G., PELOSIO, G. (1963). — La serie plio-pleistocenica del T. Stirone (Parmense occidentale). *Boll. Soc. Geol. It.*, 81 (4), 293-335.

PELOSIO, G., RAFFI, S. (1974). — Osservazioni su *Arctica islandica* ed altri lamellibranchi del Calabriano dell'Emilia occidentale. *L'Ateneo Parmense, Acta Naturalia*, 10 (3), 347-367.

PERRI, M .C. (1975). — *Portlandia (Portlandia) impressa* n. sp. del Calabriano del T. Stirone (Parma). *Natura*, 66 (3/4), 174-182.

POLUNIN, N. (1967). — Eléments de Géographie Botanique. Gauthier-Villars, Paris.

RIO, D. (1974). — Remarks on Late Pliocene-Early Pleistocene calcareous nannofossils stratigraphy in Italy. *L'Ateneo Parmense. Acta Naturalia*, 10 (3), 409-449.

SCHNELL, R. (1970, 1971, 1977). — Introduction à la Phytogéographie des pays tropicaux. I) Les problèmes généraux — Les flores, les structures. II) Les problèmes généraux — Les milieux, les groupements végétaux. IV) La flore et la végétation de l'Afrique tropicale. Gauthier-Villars, Paris.

SELLI, R. *et alii* (1977). — The Vrica section (Calabria, Italy). A potential Neogene/Quaternary boundary stratotype. Preprint X INQUA Congress, Birmingham, August, 15-24, 1977, 1-8.

SELLI, R., ACCORSI, C. A., BANDINI MAZZANTI, M., BERTOLANI MARCHETTI, D., BIGAZZI, G., BONADONNA, F. P., BORSETTI, A. M., CATI, F., COLALONGO, M. L., D'ONOFRIO, S., LANDINI, W., MENESINI, E., MEZZETTI, R., PASINI, G., SAVELLI, C., TAMPIERI, R. (1977). — The Vrica section (Calabria, Italy). A potential Neogene/Quaternary boundary stratotype. *Giornale di Geologia* (2) 42 (1) T. 11 : 181-204.

SUC, J.-P. (1975). — Quelques taxons-guides dans l'étude paléoclimatique du Pliocène et du Pléistocène inférieur du Languedoc (France). *Revue de Micropaléontologie*, 18 (4), 246-255.

TOMASELLI, R. (1970). — Tipologia ecologico-strutturale della vegetazione del mondo. *Atti Ist. Botanico e Lab. Crittog. Università Pavia,* Ser. 6, 6, 1-232.

WALTER, H. (1960). — Einfürung in der Phytologie. III) Grundlagen der Pflanzenverbreitung. P.I., Standortslehre, 2 Ed., Stuttgart.

WALTER, H. (1971). — Ecology of tropical and subtropical vegetation. Oliver and Boyd, Edinburg.

ZAGWIJN, W. H. (1975). — Variations in climate as shown by pollen analysis, especially in the Lower Pleistocene of Europe. In : Ice Ages : Ancient and Modern. Ed. by A. E. Wright and F. Moseley, 137-152.

TABLE DES MATIÈRES.