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# Paleoclimatic correlations between Western european continental and marine areas Contribution of big villafranchian fauna

**Marie-Françoise Bonifay**

Laboratoire de géologie du Quaternaire, CNRS - Luminy Case 907, 13288 - Marseille Cedex 9, France.

## ABSTRACT

Key-words: Paleoclimatic correlations; Villafranchian fauna; marine isotopic records.

It is very difficult to make paleoclimatic correlations between continental and marine areas, but it is possible with biostratigraphic data. Reliable correlations can be made only between broad periods: between 3.5 and 3 Ma, around 2.4 Ma, until 1.6 Ma and after 1.6 Ma. The arid Mediterranean phases led to the disappearance of the European Villafranchian fauna (1.0 Ma).

## INTRODUCTION

As the history of large continental fauna is dominated by phenomena of inertia and the one of paleotemperatures in marine environments by sensitivity, correlations between those two can rarely be made and then, only during major events. The goal of the present work is to continue the search for such correlations (Bonifay, 1980-1990).

The succession of large European Plio-Pleistocene faunas is relatively simple and has long been established by paleontologists; between 3 and 2.4 Ma Pliocene faunas disappeared in favor of Villafranchian faunas.

## THE LAST PLIOCENE FAUNA

In France, the first changes affecting Pliocene faunas occurred in the Vialette fauna (Haute-Loire). In addition to Pliocene forms such as the two mastodonts, *Zygolophodon borsoni* and *Anancus arvernensis*, the perissodactyl *Tapirus arvernensis* and the carnivore *Agriotherium insigne* (Ballesio *et al.*, 1973; Heintz *et al.*, 1974), we note the presence of new species of Artiodactyls: *Cervus cusanus*, *Croizetoceros ramosus*, *Croizetoceros pardinensis*, *Arvernoceros ardei* for the cervids, *Dicerorhinus jeanvireti* for the perissodactyls, *Ursus etruscus*, *Felis issiodorensis* for the Carnivores and the genus *Pliotragus* for the bovids. This assemblage corresponds to the lower part of the Villanyan which is characterized by the appearance of *Kislangia* in the micromammals.

Changes also occured in the flora of that period. During the lower Pliocene, the vegetation is one of mediterranean type, which indicates well marked seasons with dry summers. Around 3.2 Ma the existing flora requires a cooler climate and more humid conditions (Bertoldi *et al.*, 1989). The palynologists describe the Vialette flora as an arborescent vegetation with pines, Cupressaceae and birch-trees still associated with *Taxodiaceae* (Meon *et al.*, 1980).

A number of radiometric dates obtained at the Vialette site show discrepancies: 3.8 Ma according to Savage & Curtis (1970), 3.3 Ma by Bandet *et al.* (1978), which appears more accurate, and between 2.92 and 2.48 Ma (Fouris *et al.*, 1991). According to Alberdi and Bonnadonna (1987), who based their conclusion on the age of Italian deposits (Triversa) — between 3 and 3.17 Ma — and on Spanish deposits (Las Higuernelas), the age of these three sites which contain similar faunas is probably greater than 3 Ma.

It is accepted that a major cooling in the earth's climate occured when the Arctic ice cap expanded beginning at around 3.1 Ma (Raymo, 1989). This event is well marked in the oxygen isotopic record of the marine environment at the beginning of the Gauss period (Shackleton & Opdyke, 1976) which also reflects an expansion of the Antarctic glacier ice-cap. It is obvious that these first cold waves led to the changes observed in the Vialette-type fauna, which, as mentionned above, is slightly older than 3 Ma.

The age comparison is even better if we consider the 5 to 7% age change calculated by Shackleton *et al.* (1990) who in their recent studies place the Gauss-Matuyama event at 2.6 Ma. This climatic degradation however, cannot sufficiently explain the installation of the large Villafranchian fauna *sensu stricto*. The Triversa assemblage in Italy and that of Vialette in France are considered, either as being close to those in the Ruscinian from the Perpignan Pliocene by Italian paleontologists, or as a distinct sub-zone of MN 16 (Mein, 1990).

## THE FIRST VILLAFRANCHIAN FAUNA

Within the following continental association, represented in France by the Perrier sites (Puy de Dôme) from the upper part of the MN 16 zone, there were also a large number of forest species where *Cervidae* were dominant. Presence of *Acinonyx, Homotherium, Euryboas* and *Leptobos* is noted, just as in Triversa faunas (Azzaroli *et al.*, 1982); other migrant species, such as *Gazella borbonica* and *Dicerorhinus etruscus* appear for the first time. They become rapidly associated in our west-european regions with *Equus* species which, however, have not reached the indo-pakistanese area (Tobien, 1979).

Contemporary flora is dominated by trees (poplar, alder, birch-tree, oak) associated with Mediterranean species, such as, evergreen-oak, pomegranate, box-wood and jujube-tree. Pliocene species have disappeared, excepted the *Pinus haploxylon* and some rare *Carya* and *Taxodium* (Méon *et al.*, 1980)

From this moment on, the whole Villafranchian assemblage can be considered as established. The Etouaires site is dated between the beginning of the trachyandesitic eruptions of the Mont Dore at around 2.47 Ma and the aerian trachytic pumices at 2.35 Ma (Poidevin *et al.*, 1985). In Italy, the Montopoli site is close to the Gauss/Matuyama reversal (2.47 Ma) and the Rincon fauna in Spain is contemporaneous to the second cold period recorded in the Mediterranean oxygen isotopic curves (2.6 - 2.5 Ma) (Thunell, 1979).

In the perimediterranean flora, the abundance of the Taxodiaceae will progressively decrease up to 2.03 Ma (isotopic stage 82), which according to Combourieu-Nebout and Vergnaud-Grazzini (1991) reflects a temperature decrease and probably an hygrometric one as well. The increase of *Artemisia* in the flora of the central mediterranean zone, and that of *Gazella* in the Perrier-Roccaneyra large fauna, between 2.35 and 2 Ma., support this hypothesis.

In the marine environment, the critical threshold for North Atlantic ice cap growth was crossed circa 2.57 Ma (Jansen & Sjoholm, 1991). A number of deep-sea cores taken from the North Atlantic have revealed the maximum extension of the cold front, which corresponds to the gradual accumulation of the ice cap at around 2.4 Ma (Shackleton *et al.*, 1984; Zimmerman *et al.*, 1984). If for the period previous to 2.4 Ma, the values of the $\delta^{18}O$ are slightly inferior to the present, due to the absence of a Greenland ice-cap, later on the amplitude of the variations of the $\delta^{18}O$ increased, and there was an extension of the cold front. Isotopic stages 100 (2.4 Ma) to 96 (2.3 Ma) and 82 (2.05 Ma) represent ice growth equal to 80 meters above water-level and the ice cap at this period is estimated to be equal to half of that existing 18 000 years ago (Raymo *et al*,. 1989). In order to better visualize these differences, and knowing that a change of 0,6‰ in $^{18}O$ values does not only reflect temperature variations (Raymo *et al*, 1989), I tryed to emphazise the importance of the climatic variations by distinguishing $\delta^{18}O$ values lower than 3,5 ‰ (increase of temperature) and those higher than 4‰ (decrease of temperature (Figs. 1). The climatic deterioration slightly after 2.4 Ma becomes more evident.

A study of DSDP site 552A (Hooper & Funell, 1986) clearly shows a cooling shortly after 2.4 Ma which lasted approximately 100 000 years when sea-water temperatures were similar to those found during the Pleistocene glacial period: 8° in summer and 2° in winter. During an interglacial period, these temperatures reached 9° in winter and 16° in summer. It is obvious that the western European continent was affected by this surrounding mass of cold water.

At this time, northern immigrants appeared in the mediterranean region (foraminifera such as *Hyalinea baltica* or mollusk such as *Arctica islandica*). It is during this period that Villafranchian associations *sensu stricto* are formed in our european regions.

This period is marked by important exchanges both within the Eurasian continent and between the European and African continents: *Homotherium* or *Euryboas* move through the African continent (Aguirre & Morales, 1980). *Archidiskodon gromovi* which is probably of african origin arrives in Italy (Montopoli). Between 2.3 and 2.5 Ma. in tropical zones, a severe dryness increases and the hygrometry decreases. These results are based on the importance of eolian deposits coming from North Africa in low latitudes atlantic cores (Pokras *et al.*, 1989; Ruddiman *et al.*,1989) This would explain why the carnivores have taken advantage of the marine regression to spread out to the South and not the Artiodactyls, in particular the Cervids, which are associated to an important vegetal cover; on the contrary the expansion of the arbustive flora in middle Europe would have been used by Elephants to invade our regions. The dispersion of the genus *Equus (E. stenonis)* which is a particular important immigrant, also shows the relations between the American and European continents at that time: the *Equus simplicidens* of the

Hagerman — Palako fauna (3.3 Ma) is considered to be the direct ancestor of the European stenonians, seen for the first time in Rincon (Spain) around 2.5 Ma (Lindsay *et al.*, 1980); an hypothesis supported by mitochondrial DNA data (Forsten, 1992).

## THE EXPANSION OF THE VILLAFRANCHIAN FAUNA

Afterwards, the expansion of large Villafranchian fauna increased regularly in Europe. We can follow the history of Saint-Vallier rich faunas, which correspond to the upper Villanyan and the Biharian of the micromammals zonations, excepted in Italy where a massive erosion period — the Acquatraversa — takes place (Azzaroli *et al.*, 1986). In France we can cite the Chilhac and the La Rochelambert deposits (around 2.0 Ma), the Coupet (2.12 Ma).

In the marine environment, a detailed study at ODP Site 607 in the North Atlantic (Ruddiman *et al*, 1989) shows that during this period, isotopic oscillations are short and of low amplitude until isotopic stage 58 (1.55 Ma). This relative stability is due, according to the authors, to the dominance of cycles of 41 000 years in relation with the rythm of orbital obliquity.

## THE LAST VILLAFRANCHIAN FAUNA

As early as 1.6 Ma ago, it appears that climatic conditions in the northern hemisphere were sufficiently harsh to push cold Northern species towards the south and an arid belt occured in the Mediterranean basin. The cold intervals in northern Europe corresponded to dry periods in Mediterranean regions. This is certainly one of the reasons why large Villafranchian fauna proliferated either in middle-altitude mountain areas during this period, where most of the southern European faunas are found, or further north (England, Holland). These faunas exhibit an imbalance, illustrated by the proliferation of the genus *Canis* in southern Europe (Sénèze in France, Olivola, Leffe and upper Val d'Arno in Italy: "Wolf event" of Azzarolli, 1983). It should be emphasized, however, that upper Villafranchian faunas always contain the same Cervidae species, which

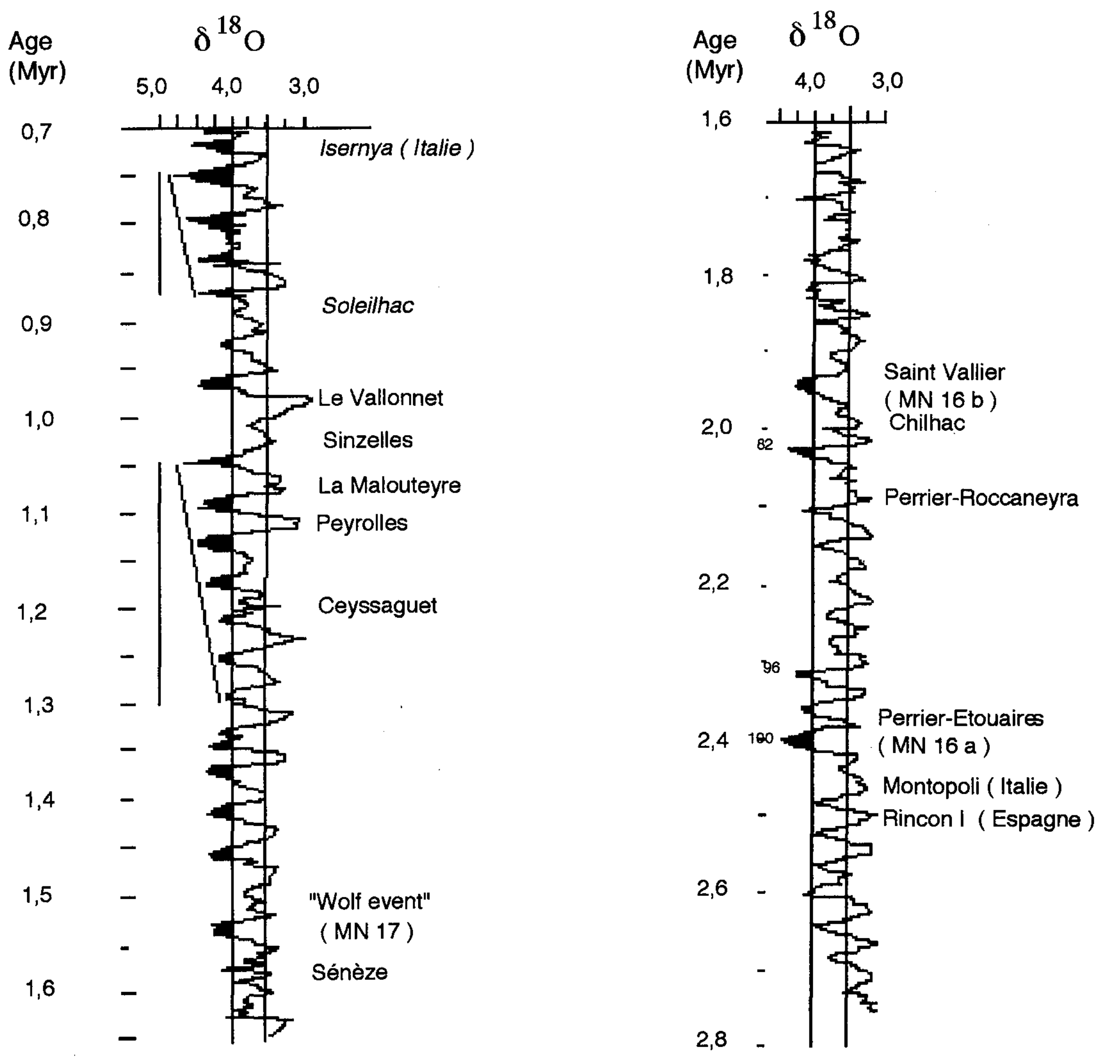


Fig. 1 — Marine paleoclimatic record between 0.7 and 2.8 Ma; main correlations with european big mammal faunas.

suggests that no major climatic change occurred until they disappeared. The cold isotopic stages, are underlined with an oblique line in figures 1 and 2 do not reach yet high Pleistocene values as $\delta^{18}O$ of 5‰.

The last Villafranchian fauna, e.g. Ceyssaguet dated at 1.2 Ma. and discovered in a loessic environment (Bonifay *et al.*, 1984), or Peyrolles or La Malouteyre (approximately 1.1 Ma) containing very few fossils, correspond to an advance of the polar front and to the immigration of cold forms into the Mediterranean area (isotopic stages 51-53). Destroyed by the cold and particularly by the drought in our European regions, Villafranchian species have entirely disappeared 950000 years ago (Soleihac deposit, Bonifay *et al.*, 1983).

## CONCLUSIONS

The history of large faunas appears to prove that the phenomenon of accumulation is in direct connection with the one of continuity. The Villafranchian fauna must have taken at least 500 000 years to get established, a period during which the oxygen isotopic curves in the marine records show well marked but brief cooling events. Its dissappearance, however, seem to have occurred much rapidly in about 100 or 200 000 years at the most. The isotopic curves show at first, important closely-spaced cold phases, followed by periods of extreme dryness evidenced by palynological data from the Mediterranean basin.

In conclusion, it appears that it is not possible to make detailed correlations between big continental faunas and marine data. It would thus be foolish to attempt a correspondance between distinct isotopic stages and faunal changes. Reliable correlations, however, can be made between broad periods:

— between 3.5 and 3 Ma: first installation of Villafranchian species in western Europe: first isotopic cold periods ; increase in hygrometry and less marked seasons recorded in the flora at circa 3.2 Ma;

— around 2,4 Ma: the Villafranchian fauna is established: pronounced cooling recorded in isotopic curves ; wide-spread intercontinental exchanges ;

— until 1,6 Ma: expansion of the Villafranchian assemblages ; stability in the isotopic record ;

— after 1,6 Ma: succession of disequilibria in the big Mammals assemblages mainly visible in southern Europe ; large fluctuations in isotopic records, then dry periods towards 1.6 and 1.3 Ma recorded in palynological data;

— 1,0 Ma = disappearance of Villafranchian fauna.

It is of special interest to note than when the intensity of the cold periods recorded in the isotopic curves do not reach that of the middle and upper Pleistocene, (i.e $\delta^{18}O$ values over 5‰) they are well withstood by the big faunas. The arid Mediterranean phases, however, detected by palynological data led to the disequilibrium, then the disappearance of the Villafranchian fauna in our western European regions.

After, a new temperate assemblage made up of more eurythermic elements came into existence, but, as opposed to what occurred previously, it could not withstand very cold phases and periodically, temporarily disappeared in favor of Arctic Mammals: paleontologic history is no longer the same.

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