

Ostracodes; witnesses of the Plio-Quaternary boundary in the North Eastern Atlantic Preliminary results

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ABSTRACT

Key words: Ostracodes; Morphological variability; Seasonal contrasts; Climatic change; Plio-Pleistocene.

The 2,4 MY crisis is an important event for the upper Neogene of North Atlantic. A new climatic system occur and widespread during the Quaternary and is characterized by glacial and interglacial alternance. To follow the different steps of this crisis, we have choosen a borehole situated in the Cotentin peninsula (Normandy, France) and used ostracodes such as markers. The interpretation of quantitative and qualitative data from the ostracode fauna analysis shows that bathymetry was around 40 and 60 meters with slight fluctuations, excepted during Praetiglian event where the zone was out of water. The morphological variability analysis of four species (the best represented in the core), show a low variability between the basement and 80 meters. Beyond this limit and after 10 meters, characterized by very low values, the variability increases to very high values to the top of the core. Present data; Abe et Choe, 1988; Peypouquet et al, 1988; Carbonel *et al.*, 1990 a, 1990 b; show that there is a close link between seasonal contrast intensity and ostracode intraspecific morphological variations. The carbonates balance at the interface water / sediment, were ostracodes live and moult, is related and reflects the intensity of the seasonal contrast. After the Praetiglian event, an increase of the seasonal contrast occurs during the Tiglian A and the lower Tiglian B.

INTRODUCTION

The recognition of climatic changes affecting the northern hemisphere during the upper Pliocene, to drive the "present day" kind of climate, is an interesting problem. A few questions still remain: when did the first "quaternary type" climatic change occurs? Was it a sudden cooling event or a succession of climatic degradations? What kind of cyclicity is affected?

According to Zagwijn, 1963; Zagwijn and Suc, 1983; Suc and Zagwijn, 1984; (Fig. 1) a first glacial event occurs at 3.2 My (Reuverian glaciation) followed by a second big one at 2.4 My, the Praetiglian glaciation, associated with a low stand stage. During the glacial epoch, the autors have demonstrated that the polar front was situated approximately in front of Ireland. After the Praetiglian event, the climate of the North hemisphere becomes contrasted with a succession of cool and warm episodes. This is one of the main characteristics of the Quaternary climate. We have good synthesis for North sea area; Zagwijn, 1963; and for Mediteranea sea; Suc, 1984; nevertheless, no reconstitutions

were available for the North Atlantic and Channel area. Marchesieux borehole is located in Normandy, at the Atlantic ocean / Channel crossing and with a Plio-Pleistocene stratigraphical range. This site is situated in the sway area of the polar front and associated with low bathymetry deposits. The geographical characteristics allow recognition of the paleoclimatic and paleohydrological changes.

In order to evaluate paleoclimatic and paleohydrologic changes, we propose to analyse quantitative and qualitative responses of ostracode faunas to paleoenvironmental changes and compares with both calcimetry data and sedimentology.

THE BASIN OF NORMANDY

Geographic and Paleogeographic data

Marchesieux core is localised in Normandy (North East of France) in the sedimentary basin of Carentan (Fig. 2 a). This area is surrounded in the north, by Paleozoic eruptive

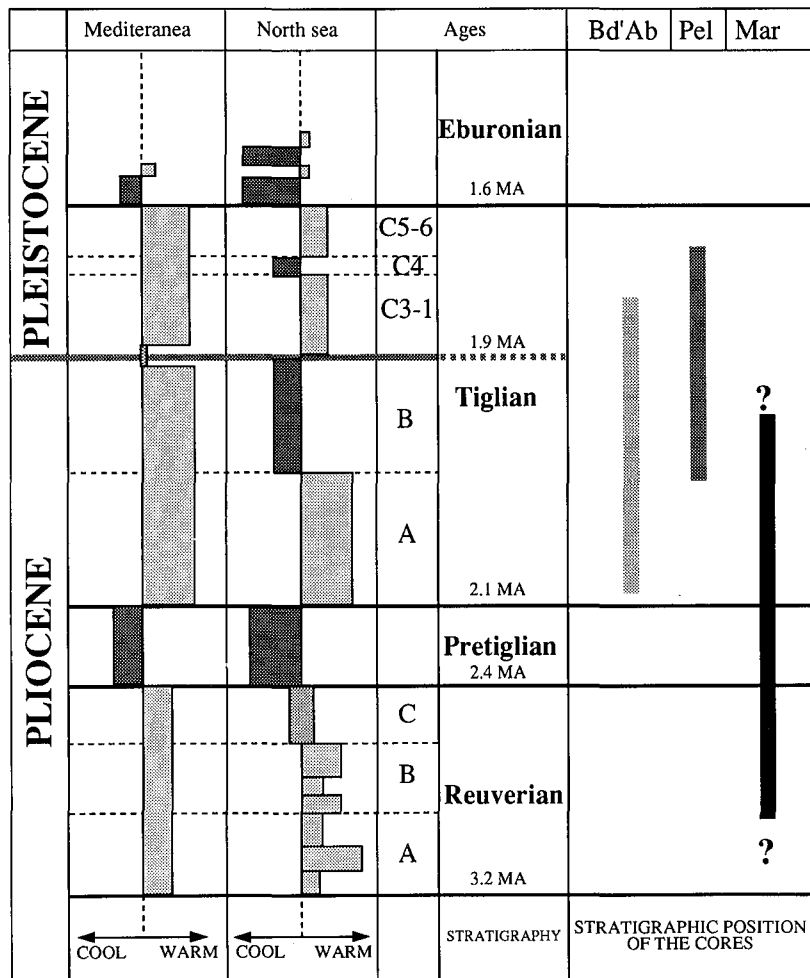


Fig. 1 — Correlations between North Sea and Mediterranean (after Zagwijn & Suc, 1984). Stratigraphic position of the cores.

rocks (North Cotentin) and in the South by Mesozoic sedimentary formations (Coutançais). Normandy Pliocene sediments are deposited in two basins, the Saint Sauveur le Vicomte Basin in the north and the Carentan Basin in the South. These basins are separated by a horst, due to very active tectonic and development of pull apart structures affecting this area during the Pleistocene. A paleogeographic reconstruction based on ostracodes data was proposed for Carentan basin by Braccini, 1987 and Carbonel *et al.*, 1990. This basin is a low bathymetry bay which may not exceed 70 meters. The insulation from the open sea is due to the horst structure development. There is an opposition with Saint Sauveur le Vicomte Basin characteristics which is more open and deeper. Giresse, 1969; has shown that continental supplies are due mainly to solifluxion than to rivers. For Carentan Basin, the main paleoenvironment characteristic is the great development of phytal activity in the infralittoral zone; Kasimi, 1986; Braccini, 1987; Carbonel *et al.*, 1990.

Lithological description

160 meters have been drilled in the Pliocene where we collected samples every meter (Fig. 2 b). The base (160 m)

of the core is characterized by an unconformity with Permian red clay in contact with Pliocene grey clay. Grey fine sandy clay occurs from 152 m to 88 m. At 88 m a second unconformity with erosion surface had been interpreted such as a sedimentary hiatus; (Barrier, unpublished). The sediment is more and more sandy with bioclastic deposits frequent from 88 to 32 meters and very abundant from 32 to 5 meters. The top of the core is characterized by green clay and vegetal soil (5 meter to the surface). Correlations with other cores in this area has not been possible because of a very active tectonic (pull apart structures), which have affected this zone during the Pleistocene.

Stratigraphical interpretation

Stratigraphical interpretations based on planktonic foraminifers and nannofossils are not possible because of the low bathymetry deposits and the closed character of the bay. For the stratigraphical evaluation, we have correlated the calcimetry curve from the core and data from Shackleton, 1984.

It is possible to display three shifts which may represent paleoclimatic events and interpreted such as stratigraphical

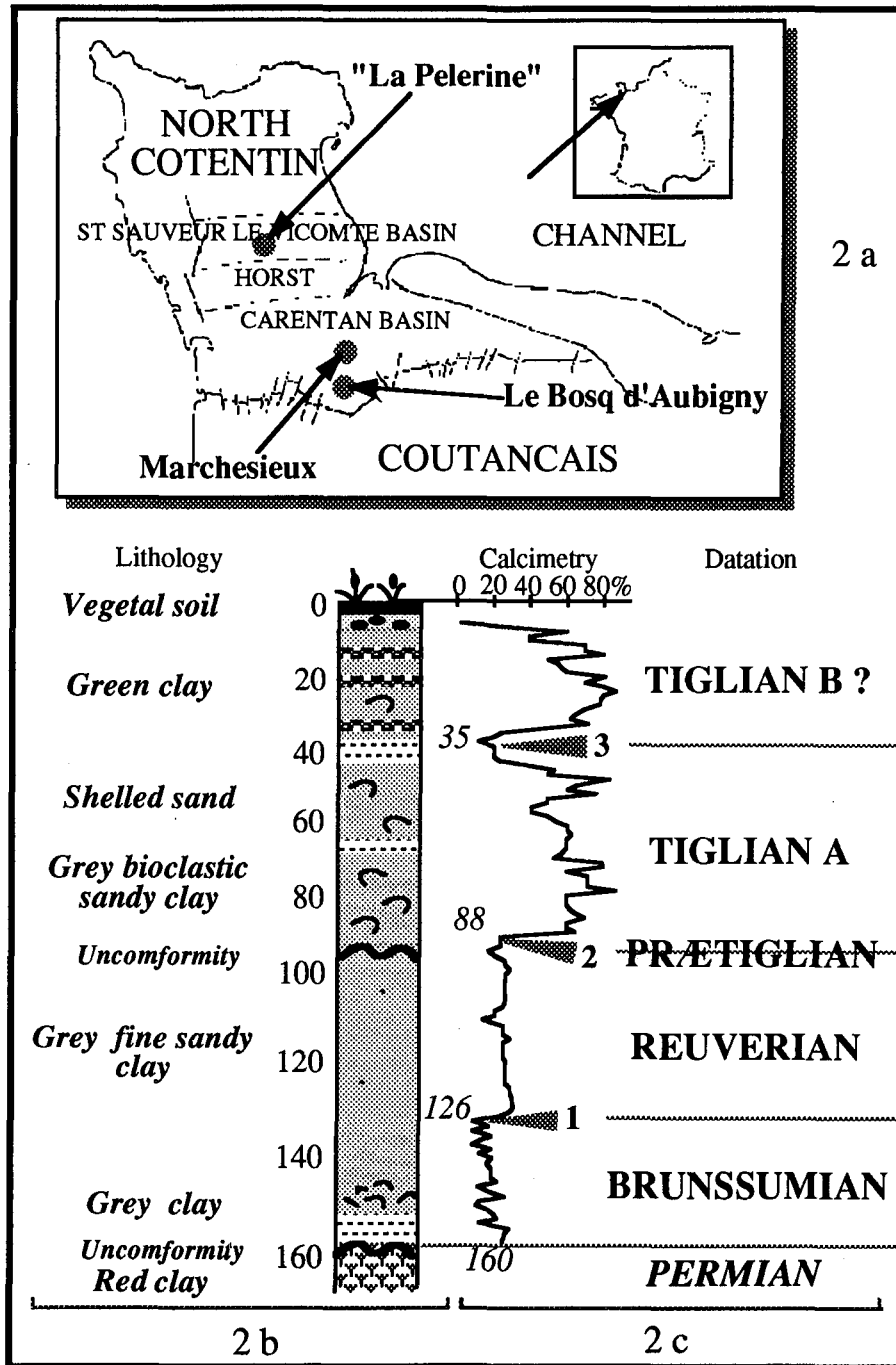


Fig. 2 — 2a - Localisation of the borehole; 2b - borehole and lithological description; 2c - calcimetry and datation.

breaks (Fig. 2 c). The first positive shift (1/126 m) might be correlable with the 3.2 My boundary. The second positive shift (2/88 m) associated with a sedimentary hiatus, might be in relation with the Praetiglian event (2.4 my). In fact, due to the Praetiglian glaciation, a great low stand stage, Haq et al., 1987; has affected the North of Europe and a lot of coastal bays have been out of water during at least 0.3 My. It is the case of marginal basins from Normandy. The third negative shift (3/35 m) would be probably interpreted such as the Tiglian A/B boundary.

OSTRACODE FAUNAS QUANTITATIVE DATA

Density of the ostracodes

The density represents the number of shells by ponderal unity of sediment, in this study, the number of individuals for 50 grammes. This value could be linked with the trophic level and the oxygenation at the water/sediment interface. High values of density are interpreted as a good trophic level and sufficient oxygenation and vice versa (Fig. 3 a).

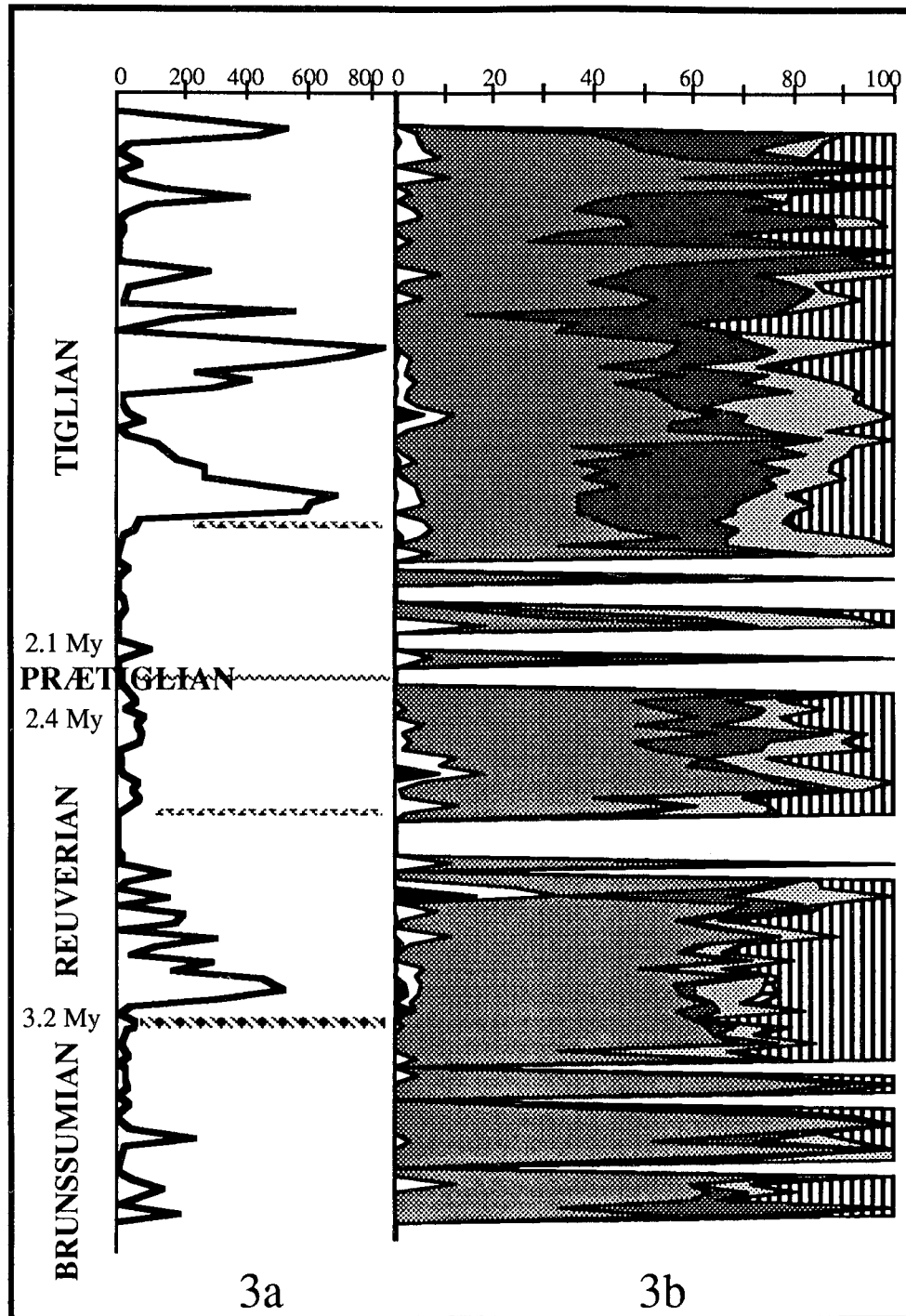


Fig. 3 — 3a - Number of valves per 50 grammes; 3b - Ostracode fauna assemblage; ■ - Cool; □ - Coastal; ▨ - Ubiquist; ▩ - Phytal; ▪ - Inner-shelf; ▫ - Outer-shelf; ▬ - Epibathyal.

Four stages have been recognized and so by the alternating of increase and decrease phases. Stages one and two are characterized by a range of values from 200 to 0 for the first and 600 to zero for the second. The stage three is characterized by low values (70 to 0). The fourth stage is characterized by very fluctuating values from high to nil ones (700 to 0). The fluctuating density values of this last stage might be correlated with the fluctuation of the oxygen isotopes values.

There are differences of density values between the stages. Stages one and two show medium to low values which could be related to a medium trophic level and a fluctuating oxygenation. During stage three, paleoenvironmental conditions become more drastic for oxygenation and trophic level. This could be in relation with the Praetiglian unconformity occurring at 88 meters. The situation improves better during stage four, with high fluctuating values of the density which could be correlatable to high fluctuating trophic level and good oxygenation. This last observation substantiates stage four as a Tiglian epoch.

Assemblage of the ostracodes

The assemblage of the ostracodes show few differences from the bottom to the top of the core (Fig. 3 b). Phytal ostracodes are dominant during stages one and a bit less during stage two. The assemblage is present during the other stages but in lesser extent. More particularly this assemblage is characterized by *Aurila convexa*, *Leptocythere* sp., *Cnestocythere* sp. and *Paradoxostoma* sp. We interpretate the bathymetry of the site around 40 to 60 meters with a very developed phytal activity. Stage three represent a transition stage with both a decrease of the phytal assemblage and an increase of inner-shelf fauna with, *Quadracythere* sp., *Bythocythere* sp., *Hermanites* sp., *Falunia* sp., *Cytheretta* sp.. Nevertheless, the ostracode fauna is not very developed. The stage four is characterized by an increase of the outer-shelf fauna with *Pterygocythereis* sp., and *Echinocythereis* sp. and the persistence of the inner-shelf fauna. This last assemblage could be in relation with Tiglian high stand stage and / or with paleohydrological changes such as low thermic water stratifications. It is interesting to note that an epibathyal assemblage with *Argilloecia* sp., *Bensonocythere* sp. and *Cytheropteron* sp. are present in some levels during the stage 2 and the stage 4. Coastal assemblage is present in all the stages, with values of around 5 to 15 %, and is made mainly of *Cytheridea* sp.

Marchesieux site is dominated by phytal activity with a low bathymetry around 40 to 60 meters (Fig. 3 c). There is a difference between stage one and stage two for density value and ostracodes assemblage. This could be in relation with the Brunsumian/Reuverian boundary occurring around 130 meters (3.2 My). The Praetiglian event (2.4 to 2.1 My) is marked by a sedimentary hiatus and by a decrease of the

density of the ostracodes from low to nil values around the event (110 to 70 meters). After, Tiglian stages are very favorable for benthic life and more particularly for ostracodes, with a great trophic level and a good oxygenation.

OSTRACODE FAUNAS QUALITATIVE DATA

Repartition of the "polymorph" species

To complete this study, we have chosen four species for their distribution in the core (20 to 60 % of the total population) and for the quality of their morphological variability (Fig. 4a):

Echinocythereis sp.: well represented in all the stages and characterized by reticulate and spinosity variability.

Hermanites sp.: represented in stage 4 with reticulate and spinosity variability.

Sagmatocythere sp.: sporadic in stages 1/2/3 with reticulate variability.

Quadracythere sp.: sporadic in stages 1/2/3 and very well represented in stage 4 with reticulate and costate variability.

Detritical supplies

To evaluate detritical supplies and its impact we have analysed firstly the repartition of *Cytheridea* sp. (Fig. 4 b), a coastal species which repartition is linked with detritical supplies. The repartition curve of this species has been plotted with a granulometrical chart (Fig. 4 d) and the repartition of *Echinocythereis* sp. spinosed morph and *Hermanites* sp. (Fig. 4 c) spinosed morph. It has been demonstrated that spinosity of ostracodes is generally related to thin detritical supplies like silts, clay or thin sands; Keyser, 1983; Peypouquet *et al.*, 1985; Mourguiart, 1987; Abe, 1988; Braccini, 1992; and/or degradation bacterial velum, Tölderer-Farmer, 1985. Spine structures are protecting pore canals and mecano-sensorial organs against obstruction. The level of spinosity might be linked to the intensity of detritical supplies.

The granulometry chart shows that stages 1 and 2 are mainly characterized by thin elements from 200 to 40 μ . The increase of *Cytheridea* frequency might be linked with the increase of >200 μ fraction occurring in the stage 2 and 3. Spinosed morphs seem more linked with 200 - 125 μ fraction. Praetiglian event is characterized by a peak of coarse detrital and the disappearing of most of the ostracodes. For stage 4, *Cytheridea* sp. and spinosed morphs seem linked with <200 μ for *Cytheridea* sp. and with >200 μ for spinosed morphs.

During stage 4, there is a drop for the 200 and 125 μ elements and an increase of thin elements. It may correspond to event 3 (calcimetry curve) and might be linked to the Praetiglian event.

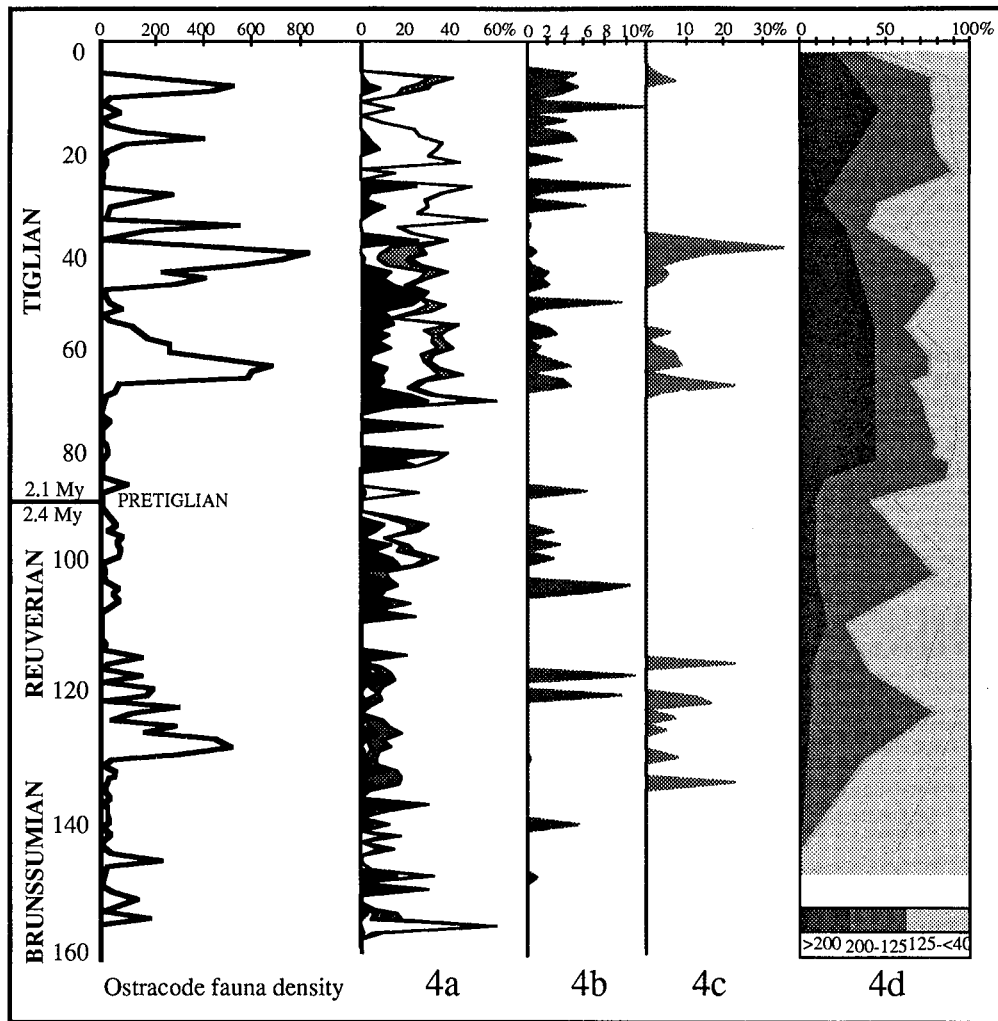


Fig. 4 — 4a - Repartition of the polymorph species; *Echinocythereis* sp. ■; *Quadracythere* sp. □; *Hermanites* sp. ▨; *Sagmatocythere* sp. ▩; 4b - repartition of *Cytheridea* sp.; 4c - repartition of spinosed morphs; 4d - granulometry chart.

Intensity of the morphological variability

Due to many works, relation between the intraspecific variability of the ostracodes and environmental parameters are well known ; Peypouquet *et al.*, 1985; Mourguiart, 1987; Peypouquet *et al.*, 1988; Abe, 1988; Ikeya & Ueda, 1988; Carbonel, 1990; Carbonel *et al.*, 1990; Braccini, 1992. In fact, it has been demonstrated that there are very close relations between the intensity of the intraspecific variability and the seasonal contrast. When the seasonal contrast is important, the morphological variability is high and on the opposite, when a low seasonal contrast occurs, morphological variability is weak. For the four above described species, we have added the number of the morphs with no distinguished quality and polarity of the variability (Fig. 5 a).

Stages 1, 2 and 3 are characterized by low to medium values, with a drop during the Praetiglian event (stage 3). The maximum of intraspecific variability occurs during stage 4 with more 8 to 12 morphs (for 4 species) and a peak at 40 meters with 16 species. The four considered species are equally affected by intraspecific variability.

Stage 1 is characterized by a low seasonal contrast and might be considered as the main component of the Brunsumian climate in this area. After, it occurs an increase of the seasonal contrast at the stage 1/2 boundary. Highest values during stage 2 might be in relation with an increase of the seasonal contrast during the Reuverian. The maximum of seasonal contrast occurs at stage 4, interpreted as the Tiglian epoch. In fact we can separate two phases, a first one from 88 to 35 meters, which represents the Tiglian A, and a second one from 34 to 5 meters, probably associated to the lower Tiglian B.

Polarity of the morphological variability

According to Peypouquet *et al.*, 1988; there are relations between carbonate balance at water / sediment interface and the level of bioprecipitation of the ostracode shells. If the carbonate balance trend to dissolving conditions, the test will be degraded (*sensu* Peypouquet), on the contrary, if the carbonate balance trend to precipitating conditions, the ostracode test will be equilibrated to a graded. This chemical mechanism is controlled by oxygenation in relation with primary productivity due to continental

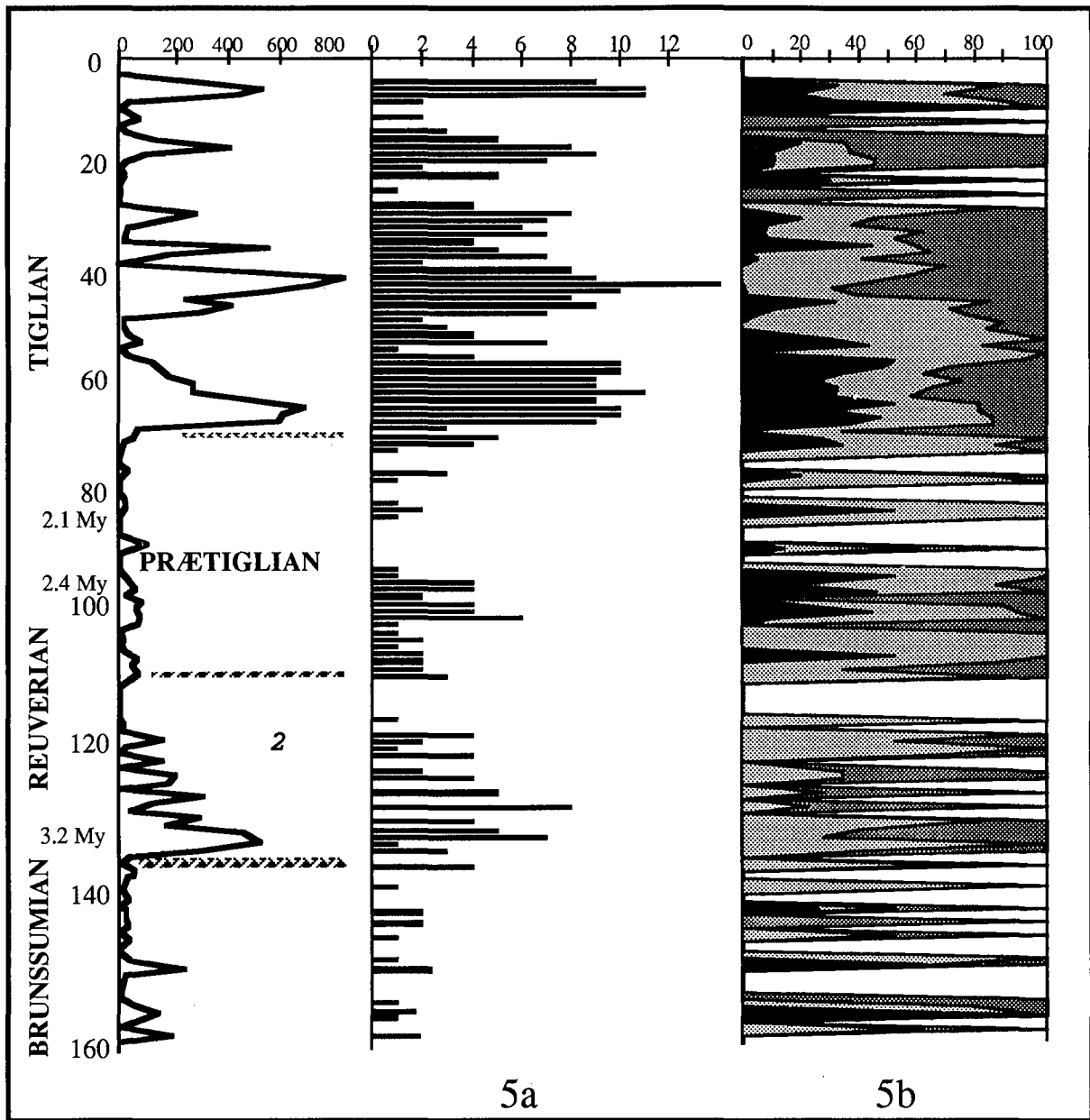


Fig. 5 — 5a - Intensity of the architectural variability. 5b - Ostracode architectural variability; aggraded morphs ; equilibrated morphs ; degraded morphs .

supplies, phytal activity; Mourguiart, 1987; Carbonel *et al.*, 1990; or upwellings; Tolderer-Farmer, 1985; Peyrouquet *et al.*, 1988; Braccini, 1992. Analysing the relative proportion of the polymorphs could be summarised as an evaluation of the bioprecipitation tendency and could be translated as paleoclimatological expression (Fig. 5 b).

Stage 1 is characterized by equilibrated and aggraded morphs accrediting correct bioprecipitation of the dissolved carbonates. During stage 2, ratio of degraded morphs is the highest, in relation with, an increase of the dissolving conditions of the carbonate. Before and after the Praetiglian event, bioprecipitation conditions seem more favorable, according to a great aggraded and equilibrium

morphs ratio. Stage 4 could be separate into two parts: a first one from 66 to 50 meters, with an equal proportion of aggraded, equilibrated and degraded morphs; a second, characterized by a progressive increase of the degraded morphs, a stability of the aggraded morphs and the decrease of the equilibrium morphs. Bioprecipitation of the carbonate seems more difficult in the second part than in the first one. Difference in polarity of the architectural variability between the two parts could be explained by differences in paleoclimatic component and is accrediting a probably Tiglian B from 35 meters to the top of the core. The separation into two parts of stage 4, based on the polarity of the polymorphism, is correlatable with an increase of the variability of the ^{13}C and ^{18}O .

SYNTHESIS AND PROSPECTIVE (Fig. 6)

If Normandy area paleogeography was well known, due to preceding works from Clet-Pelerin, 1983; Pareyn, 1984; Kasimi, 1986; Braccini, 1987; Carbonel *et al.*, 1990; we had to answer other basic questions:

- What was the stratigraphy of the borehole ?
- What was the signification of the variability of the ostracode faunas (inter and intraspecific)
- According to ostracodes data, what kind of factors have controlled Marchesieux paleoenvironment ?
- Is it possible to correlate these results with data from other areas?

We have proposed a stratigraphy by correlating the calcimetry curve from Marchesieux borehole and the

DSDP site 552; Shackleton, 1984. We have shown that the stratigraphical range was upper Brunsumian (3.0 My) to probably Tiglian B (1.8 My). According to the sedimentary hiatus (level 88) and due to the great low stand stage occurring at 2.4 My, we demonstrated that Praetiglian deposits did not exist. This stratigraphical interpretation had been controlled both by benthic foraminiferals; Toumarkine, unpublished; and ostracode faunas. We have replaced the position of the core in the Carentan basin with a bathymetry around 40 to 60 meters and associated with a phytal environment. This site is more open on the Atlantic sea than the Bosq d' Aubigny site; Carbonel *et al.*, 1990. In this area, the main part of the inputs are due to solifluxion supplies from continent on contrary, detrital inputs are weak; Giresse, 1969 and desalination indices are not recorded from ostracode assemblages. According to ostracode faunas quantitative and qualitative data, we have separated four stages with every stage corresponding to a

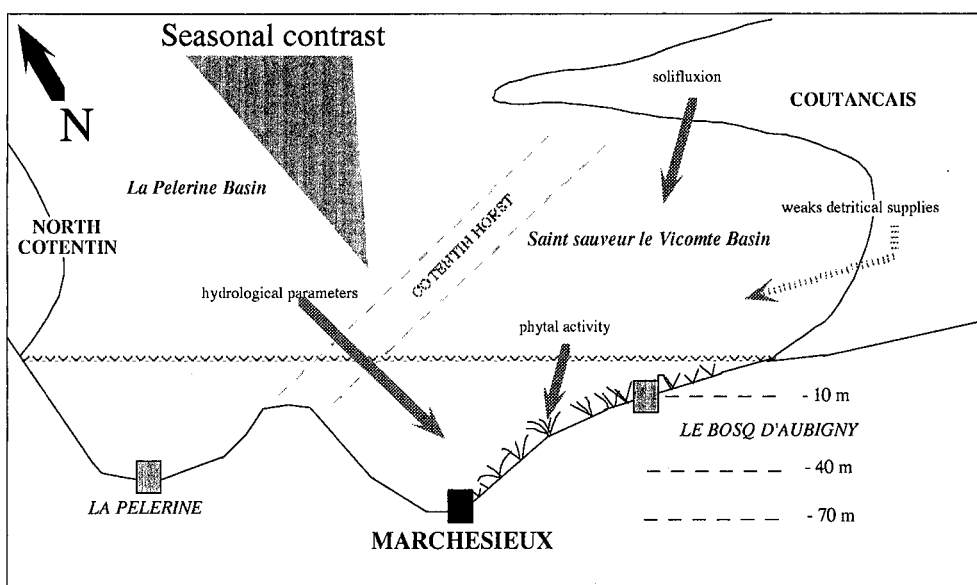


Fig. 6 — Factors controlling Marchesieux environment.

paleoenvironmental unit. Stage one corresponds to the upper Brunsumian and is characterized by a low seasonal contrast with possibly a low phytal activity and a weak primary productivity. This stage, could represent the last "witness" of the uniform Pliocene climate occurring in the north of Europe, as it is shown by Zagwijn, 1963; in the North Sea. We can correlate the "Late Brunsumian event", characterized by a cooling trend in the northern hemisphere (3.2 My), with a decrease of the ostracode fauna density and by a trending to dissolving conditions for carbonates. Stage two represents a part of Reuverian and is characterized, according to ostracode faunas data, by an increase of the seasonal contrast and a great fluctuation of the carbonate balance. We agree with Suc and Zagwijn, 1984; who pointed out in the North sea, a first climatic degradation (increase of seasonal contrast) occurring during

the Brunsumian. Stage three represents the Reuverian/Tiglian boundary but without the Praetiglian event (2.4 My). In fact this stage is characterized by few ostracodes and great detrital supplies. Life conditions in bottom waters, was not good for benthic organisms. The stage four could represent the Tiglian (first interglacial) and is characterized by a very high seasonal contrast. In the same way, we have shown that bathymetry was more elevated. This could be due both to the high stand stage occurring after the Praetiglian event and to a hydrological change in the basin (low thermic stratifications, best communication with opened sea). We have separated the stage four into two sub-stages which could be linked with Tiglian A and probable the basal Tiglian B. In fact, we have interpreted the difference between Tig. A and Tig. B such as a cooling trend and an increase of the solifluxion supplies. This

result agree with Zagwijn's interpretation of the Tiglian in the North Sea. The Tiglian A/B boundary is marked by a drop of the calcimetry curve and by a change in the variability of the isotopes of oxygen and carbon. The top of the borehole is characterized by the return of a warmest trend.

If we compare our paleoclimatic interpretation with Zagwijn's data from the North Sea, we showed that Marchesieux was controlled by a same climate tendency but, according to its latitudinal position and local conditions, the climate variability was more temperate in this area than in the North Sea. This could be a consequence of a privileged opening of the basin on the Atlantic ocean.

About the "Quaternary climate type" (characterized by seasonal contrast), we showed that the Reuverian still possesses this kind of climate. This result raises the question

of the position of what the Plio / Pleistocene boundary is. According to climatic data, the boundary would be at 2.4 My, which represents the first great glaciation for the Northern hemisphere.

Next steps of this work will consist first in better datations, using isotopes data of oxygen and carbon but unfortunately, a lot of problems are still unsolved. A second way will be to propose to analyse the morphological variability of the species that we described in this paper. To complete this, we suggest to use the shape computer analysis for a better evaluation of the ostracode morphological changes. The last step would be a close link between the ostracode fauna changes and the paleoclimatic and paleohydrological components of the paleoenvironment.

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