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CLAY MINERAL ASSOCIATIONS IN THE YPRESIAN FORMATIONS IN THE NW EUROPEAN BASIN TIME AND GEOGRAPHICAL VARIATIONS - INTERPRETATIONS

by

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(with 5 figures)

ABSTRACT

Clay minerals of Ypresian sediments are presented from five sites in the Belgian Basin, the North of France and the Isle of Wight. The detrital input strongly predominates. The following clay minerals have been encountered: chlorite, illite, irregular mixed-layer minerals (10 - 14_s) (14_c - 14_s), smectites, kaolinite and fibrous clay minerals (sepiolite).

The vertical evolution of the clay mineralogy in the Ypresian deposits is expressed by the succession of three mineralogical zones. We can also observe lateral changes of the clay mineralogy from east to west in the NW European basin.

The clay stratigraphical record depens on the complementary and sometimes antagonistic influences of the different terrigenous sources and marine currents, of which the intensity seems to be linked in particular to the opening of the North sea toward the Atlantic Ocean. The climate and paleogeographic conditions, the Ypresian transgression included, the tectonic activity in the old crystalline chains, and the reworking of thick paleosoil blankets also conditionned the clay stratigraphical record.

Key words: Clay minerals, Ypresian, NW European basin, climate, paleogeography, currents, detrital input, paleosoils.

SAMENVATTING

De klei-fractie van Ypresien sedimenten uit vijf vindplaatsen verspreid over het Belgische Bekken, Noord-Frankrijk en het Eiland Wight wordt voorgesteld. Deze fractie is voornamelijk detritisch en omvat de volgende kleimineralen: chloriet, illiet, onregelmatige intermediaire mineralen (10-14_s) - (14_c-14_s), smectieten, kaloliniet en fibreuze mineralen (sepioliet).

De verticale evolutie in de kleimineralogie van de Ypresien afzettingen wordt gekenmerkt door de opeenvolging van drie mineralogische zones. Bovendien worden er in het NW-Europees bekken, van E naar W, laterale veranderingen in deze kleimineralogie waargenomen.

De evolutie in de klei-fractie, zowel in ruimte als tijd, is het gevolg van complementaire of soms tegengestelde invloeden van de verschillende terrigene bronnen en van de mariene stromingen, waarvan de intensiteit vooral schijnt afhankelijk te zijn van de opening van de Noordzee naar de Atlantische Oceaan. De samenstelling van de klei-assemblages wordt bovendien bepaald door de klimatologische en paleogeografische condities tijdens de Ypresien transgressie, door de tektonische aanpassingen van de oude kristallijne massieven en door het herwerken van de dikke verweringslagen.

Sleutelwoorden: kleimineralen, Ypresien, NW-Europees Bekken, klimaat, paleogeografie, stromingen, herkomst, paleosols.

RESUME

La fraction argileuse des sédiments yprésiens est présentée à partir de cinq sites principaux répartis dans le bassin belge, le Nord de la France et l'Ile de Wight. Essentiellement détritique, elle comprend les minéraux argileux suivants: chlorite, illite, minéraux interstratifiés irréguliers en traces (10-14_s) - (14_c-14_s), smectites, kaolinite et minéraux fibreux (sépiolite).

L'évolution verticale de la composition argileuse des dépôts yprésiens est marquée par la succession de trois zones minéralogiques. On observe également des changements latéraux de la fraction argileuse d'E en W du bassin NW européen.

Les évolutions temporelle et spatiale des cortèges argileux résultent de l'influence complémentaire ou antagoniste des différentes sources terrigènes et des courants marins dont l'intensité paraît être liée notamment à l'ouverture de la Mer du Nord sur l'Atlantique. Les conditions climatiques et paléogéographiques, dont la transgression yprésienne, les réajustements tectoniques des vieux massifs cristallins et les remaniements des épaisses couvertures d'altération fossiles conditionnent également les assemblages argileux.

Mots-clés: Minéraux argileux, Yprésien, Bassin NW européen, climat, paléogéographie, courants, apport détritique, paléosols.

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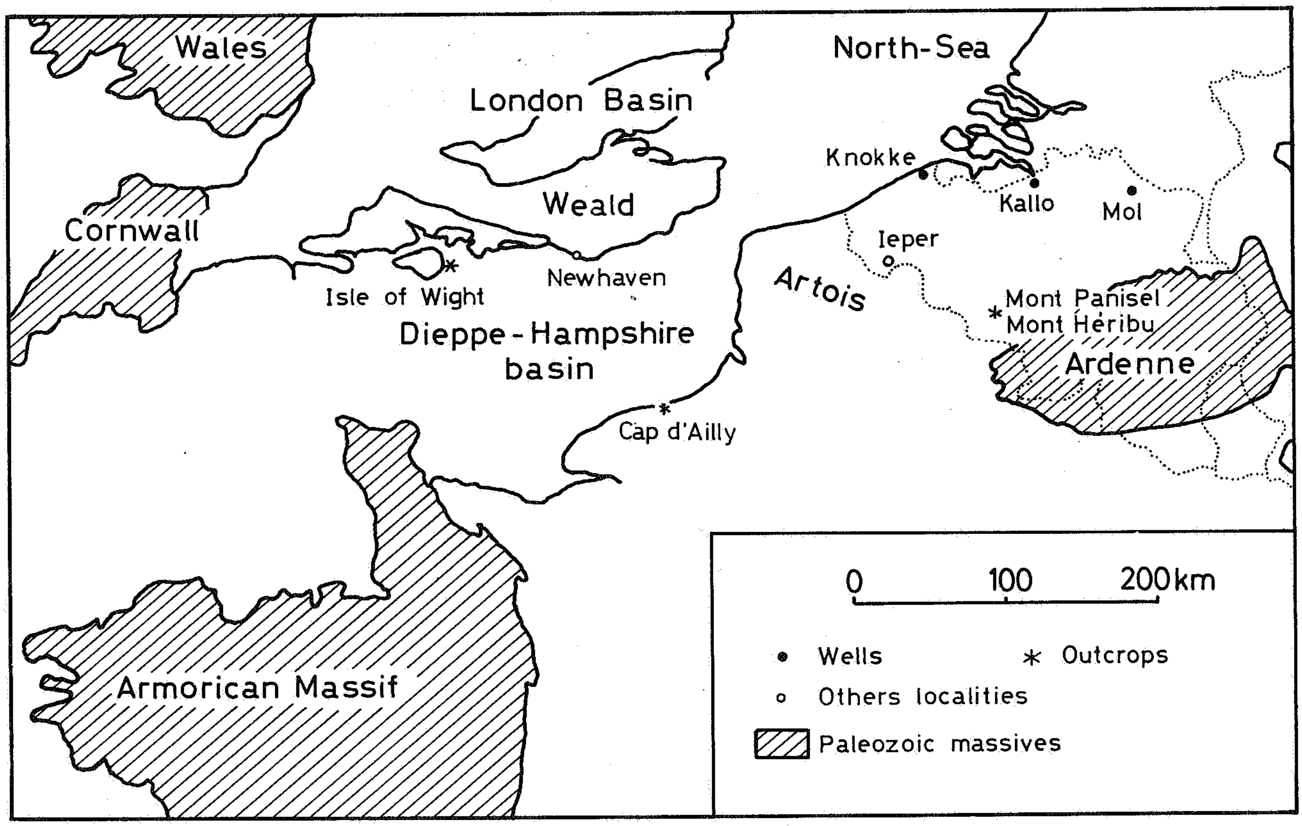

Fig. 1.- Location map of the main studied sections bordering the NW European Palaeozoic massives.

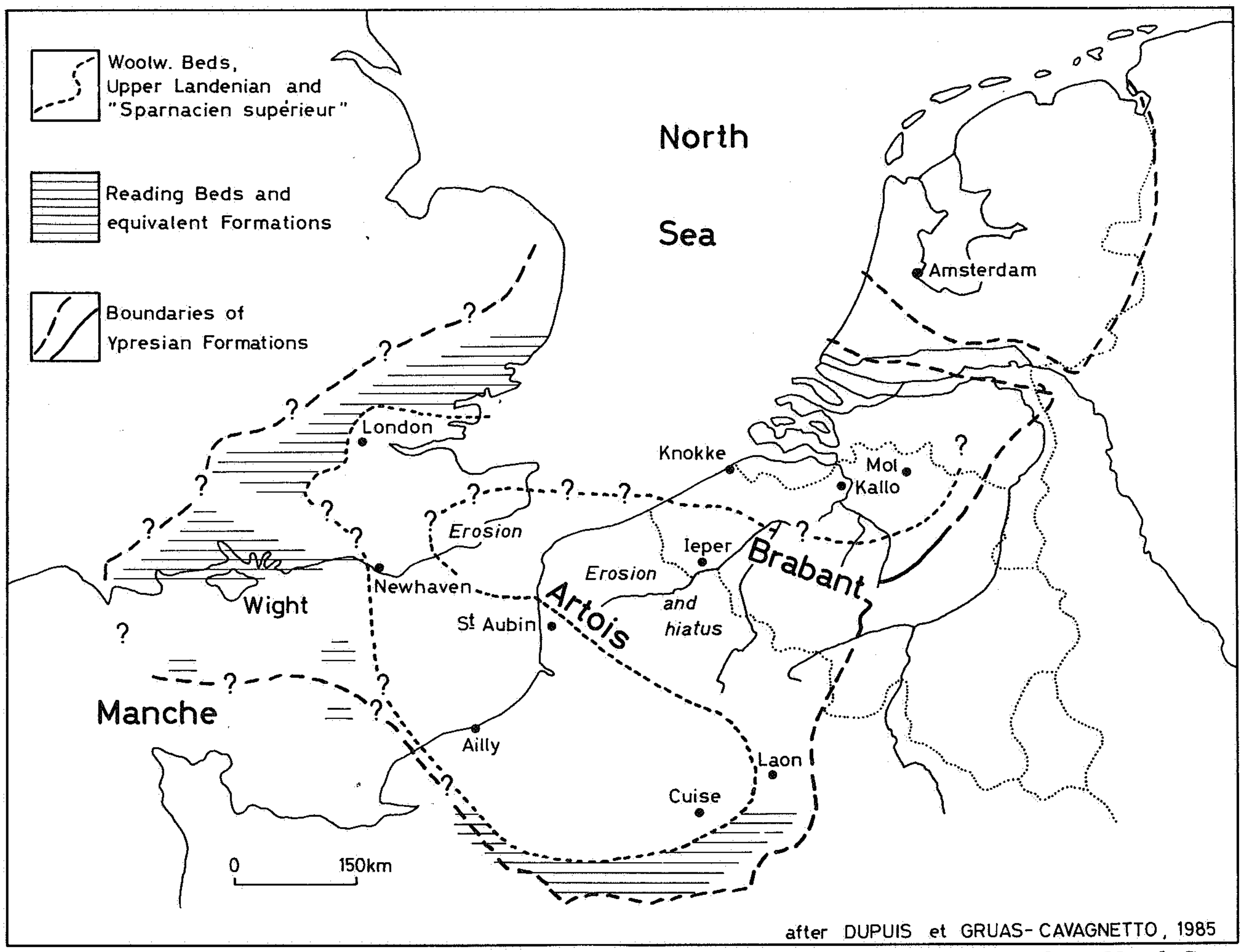

Fig. 2.- Palaeogeography at the beginning of the «Ypresian transgression» in the Southern North Sea and Dieppe-Hampshire basin. Modified after DUPUIS & GRUAS-CAVAGNETTO, 1985.

I. INTRODUCTION

1. Paleoclimatologic and paleogeographic information gained from the clay mineralogy in sedimentary deposits.

When they have been incorporated in the sediments, clay minerals permit to reconstruct climatic, tectonic and hydrodynamic events which conditioned their formation on the continental margins and their sedimentation in the basin.

For example, studies of clay minerals in deposits in the Atlantic Ocean, allow to deduce the main events which constitute the ocean's history and in particular the principal phases of its opening since Jurassic times (CHAMLEY and DEBRABANT, 1984).

Works about clay minerals of tertiary sediments in the Belgian basin and its adjacent basins show that these minerals are principally derived from the continental margins (MERCIER-CASTIAUX, 1986).

2. Studies of clay mineralogy in the Ypresian deposits of the Belgian basin.

Studies of clay mineral associations in the Ypresian deposits of the Belgian basin have been carried out by the first author since 1982. Some of the results were already published in QUINIF et *al.*, 1983, MERCIER et DUPUIS (in press) and MERCIER-CASTIAUX, CHAMLEY et DUPUIS, 1988.

In the Belgian basin and other parts of the NW European basin several previous investigations were done (see the report n° 4 of the I.G.C.P. project 124: The Northwest European Tertiary Basin and SELLWOOD and SLADEN, 1981).

3. Present information.

The present information allows us to describe the lateral changes of the clay mineralogy from east to west in the Ypresian deposits of the NW European basin, and their vertical evolution, which is expressed, at least in Belgium, by the succession of three mineralogical zones.

3.1. General configuration of the basin.

The NW European basin under investigation (Belgian basin, NW part of the Paris basin, Hampshire basin) is bordered by the following Paleozoic massives: the Ardenno-rhenan massif in the SE, the Armoricain massif in the SW and Cornwall in the W (fig. 1).

3.2. The Ieper Formation in the NW European basin.

Concerning more especially the Ieper Formation in the NW European basin, the studied samples come from three boreholes in Belgium and from three outcrops located respectively in Belgium, in northern Normandy and in the Isle of Wight (fig. 1). With regard to the Belgian basin, we will use the section of the Knokke borehole as the reference because it gives the most precise indications about the clay mineral evolution. The sections of the Kallo and Mol boreholes will be used to follow the evolution of the clay minerals to the E of the basin. The Ailly outcrop in the Dieppe basin to the W of the Paris basin, and the Isle of Wight outcrops belonging to the Dieppe-Hampshire basin, will allow to see the evolution towards the western part of the NW European basin.

4. Lithostratigraphy.

During the last decades various lithostratigraphic classification and correlation schemes have been proposed for the late Palaeocene (="Sparnacien" of French authors and "Upper Landenian" of Belgian authors) and Ypresian of the NW European Tertiary basins.

The Ypresian stratigraphy of Belgium and northwestern France was revised by STEURBAUT & NOLF (1986). These authors also gave a good summary of previous investigations in this basin. The conclusions and proposals of STEURBAUT & NOLF are followed in the present study. Among other works which have been consulted are:

(1) CURRY and *al.*, (1978) for the correlation of tertiary rocks in the British Isles.

(2) KING (1981) for the stratigraphical study of the London Clay.

(3) DUPUIS and *al.*, (1984) for the correlations of the basal Ypresian deposits in the different basins.

(4) DUPUIS and GRUAS-CAVAGNETTO, (1985) for the datation of the Woolwich Marine Beds compared to the Sables de Bracheux.

5. Successive paleogeographic configurations during Late Palaeocene-Early Eocene times.

Figure 2 shows the extension of the Sparnacian and Ypresian deposits.

a) Late Palaeocene

In the N of France, the Sparnacian deposits were formed during the Late Palaeocene regression and the beginning of the Ypresian (or "londinian") transgression. The shallow basin-shaped morphology of the Paris basin explains the large extension of these deposits.

A thorough study allowed to show their diachronism in different points of the basin. The diachronism of the Sparnacian deposits was already discussed by DUPUIS and GRUAS-CAVAGNETTO, 1985.

Studying the Tertiary of Newhaven, these authors demonstrated that the Woolwhich Beds, of which the only remnant in the Hampshire basin is found at Newhaven, are younger than the Sables de Bracheux. They also found that the first appearance of mangrove is earlier in the Dieppe-Hampshire and Paris basins (where it is considered to have occurred more or less synchronously at the beginning of the Ypresian) than in the Belgian basin (earliest appearance in the Early Ypresian *Dracodinium simile* zone). In the same way, KING

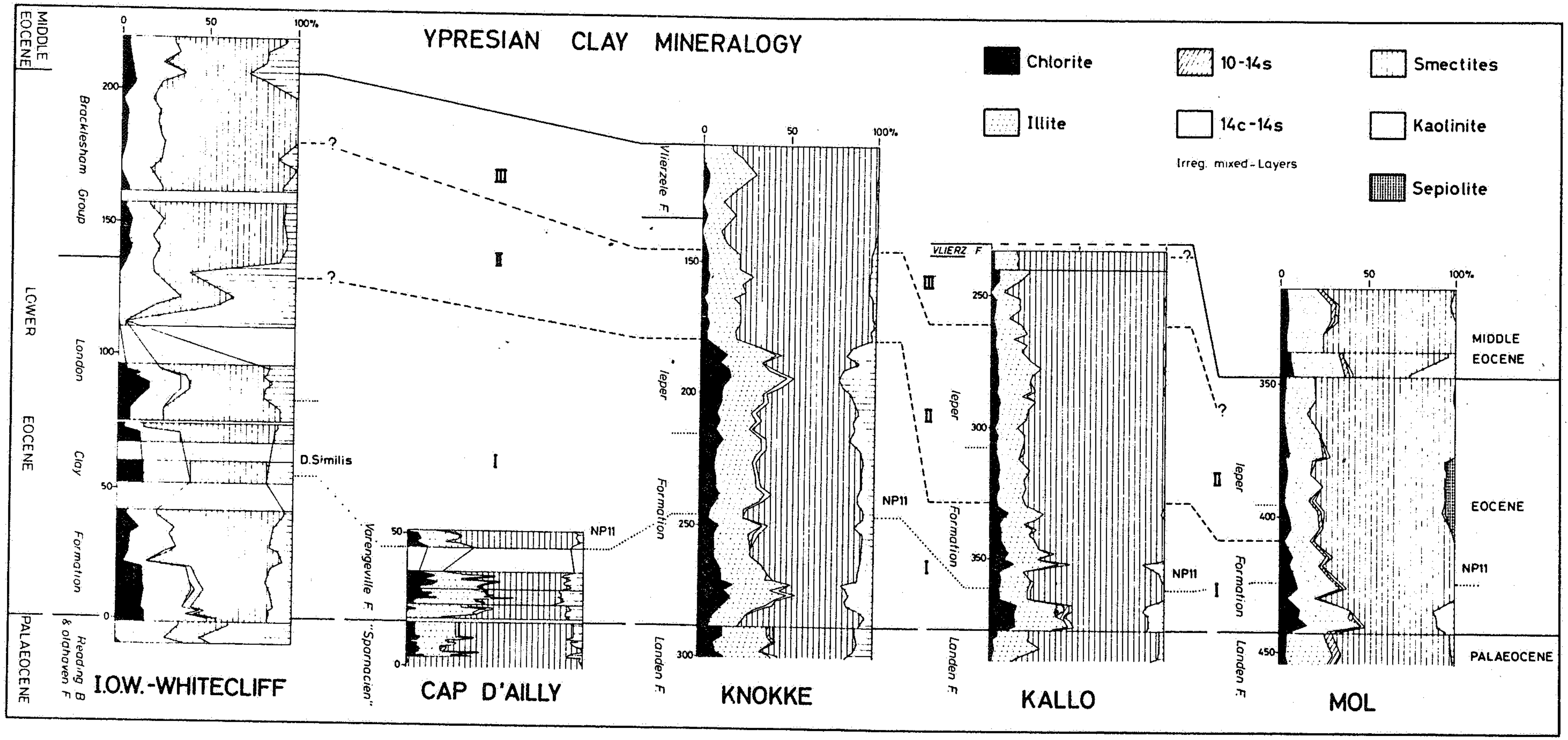

Fig. 3

Clay mineral composition and tentative mineralogical zonation of the main studied sections. Nannoplankton zone NP 11 is indicated on the Cap d'Ailly, Knokke, Kallo and Mol sections. The major part of this zone can be correlated with the Dracodinium similis *zone in the White cliff Bay section (Isle of Wight).*

(1981) showed the diachronism of the londinian transgression through both the London and Hampshire basins.

b) Ypresian-Cuisian

Since FEUGUEUR (1963), it was generally admitted that the "Artois Axis" was already separating the London and Belgian basins from the Paris basin in Early Ypresian. Nevertheless, DUPUIS and *al* (1984) minimize the paleogeographic influence of the "ARTOIS AXIS" at that time and demonstrate the intervention of the transversal Bray-Artois high. During the Lower Ypresian, the sea flooded the Paris basin.

At that time the sea in the NW European basin attained its maximal transgression of the Tertiary times. Nevertheless, this transgression was not a regular one. Indeed, STEURBAUT and NOLF (1986) recognize three transgressive phases. The first one, situated at the beginning of the stage, is the most important and corresponds to the maximum extension of the Ypresian sea, with the deposition of the Argile d'Orchies.

A slight regression, accompagnied by an emersion in the southeastern part of the Belgian basin, appears before a second transgression which is sporadic and of minor importance. It is followed by a regression, probably due to eustatic sea level changes. In the Late Upper Ypresian, the sea transgresses again depositing the "Vlierzele Formation", the top of which, the Aalterbrugge lignitic horizon indicates a new regressive phase, marking the end of the Ypresian in the Belgian basin.

II. METHODOLOGY

The mineralogical analysis of the clay fraction in all the samples was done by X-ray diffraction of orientated-pasts of decarbonated fraction (< 2μm), HOLTZAPFFEL, 1985). When samples were not rich enough in clay fraction (=very little argillaceous sands), the X-ray diffraction was performed on orientated aggregates. The determination is based on the analysis, in routine, of natural, glycolated and heated samples and also on complementary tests for better identification of kaolinite compared with chlorite, the different types of smectites and vermiculite (MERCIER-CASTIAUX, 1986) (using a Kristalloflex 4 Siemens, at the Mons Polytechnic). The associated methods comprise the optical microscopy for the study of sedimentary smears, the granulometry, the X-ray diffraction on total sediment (powder diagrams), the transmission electronic microscopy (< 2μm fraction), the differential thermal analysis of the clay fraction, the classical analytical chemistry and atomic absorption spectrometry (major and trace elements chemistry, total rock) the results of which are not exclusively reported here.

III. RESULTS

1. General features of clay mineralogy (fig. 3).

Only few cristalline species have been encountered: the primary minerals (chlorite-illite), irregular interstratified minerals (10-14), (14_c-14_s), smectites, kaolinite and fibrous clay minerals. The respective percentages of these minerals largely vary with time and in lesser proportions from a borehole to another for corresponding levels. As a general rule, primary minerals and kaolinite have a tendency to decrease in favour of smectites from the bottom to the top of the Ieper Formation. The interstratified minerals are only present as traces. Fibrous minerals (sepiolite) appear in notable proportions (5 %) only in the Mol borehole, in the E of the basin, and in the Héribu Member at the Mont Héribu near Mons.

The minerals associated with the clay minerals in the clayey fraction are almost always quartz and feldspar, sometimes goethite, hematite, opal C.T., and clinoptilolite.

2. Diagenetic features.

Post-depositional modifications of the Ypresian clay mineral associations seem insignificant or are even absent, as shown by the irregular decrease of illite and chlorite quantities toward the bottom of the boreholes; both clay minerals usually develop with depth under the effects of increasing temperatures and pressures (KISCH, 1983). The absence of this thermodynamic evolution is also attested by the rapid or progressive variations of clay mineral associations which happen regardless of the burying level, by the increasing proportions of smectites with depth, and by the illite crystallinity (MERCIER-CASTIAUX, 1986). The absence of this kind of diagenesis is due to the relatively weak thickness of the tertiary deposits (maximal thickness: 600m), associated with moderate tectonic constraints and to a banal geothermal gradient: in such conditions, the clay mineral modifications linked to burying clearly appear only beyond 2000m of sedimentary overloading (DUNOYER DE SEGONZAC, 1969).

Some diagenetic features can be observed in relation with the lithology. For example, in the Isle of Wight the kaolinite proportions increase abruptly when passing from the London Clay to the Bagshot Sands (fig. 3, at about 110 and 130m). This mineral, which reaches then 90 % of the clay fraction was formed in a weakly cemented and very permeable lithofacies, and constitutes characteristic stocks of small and automorph hexagonal tablets (electron microscopic observations) which, in the Bagshot Sands have secondarily developed as a result of acid water circulation through the porous sandstone (MILLOT, 1964). However, it can be noted that the clayey levels intercalated in this sandstone at 120 mare much richer in kaolinite too than the enclosing formations: this suggests that diagenetic kaolinisation is only a complementary phenomenon.

An early diagenesis of silica of biological origin can be detected by the presence of opal C.T. (cristobalite-tridymite) and zeolite (clinoptilolite) especially at Palaeocene times. Increases of the proportions of primary minerals (chlorite-illite) and/or the presence of kaolinite seem unfavourable to this phenomenon.

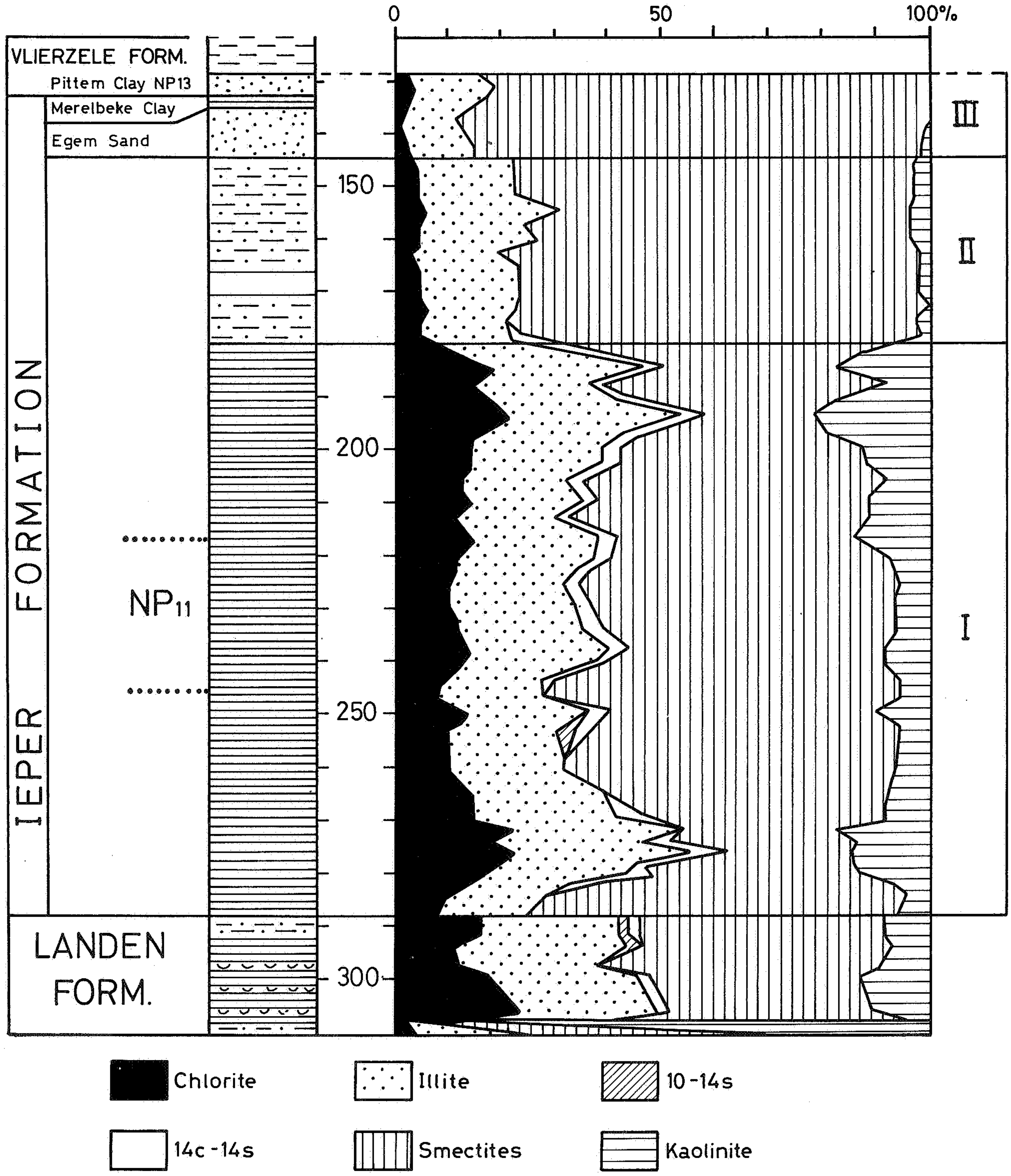

Fig. 4.- Clay mineralogy of the reference section of Knokke.

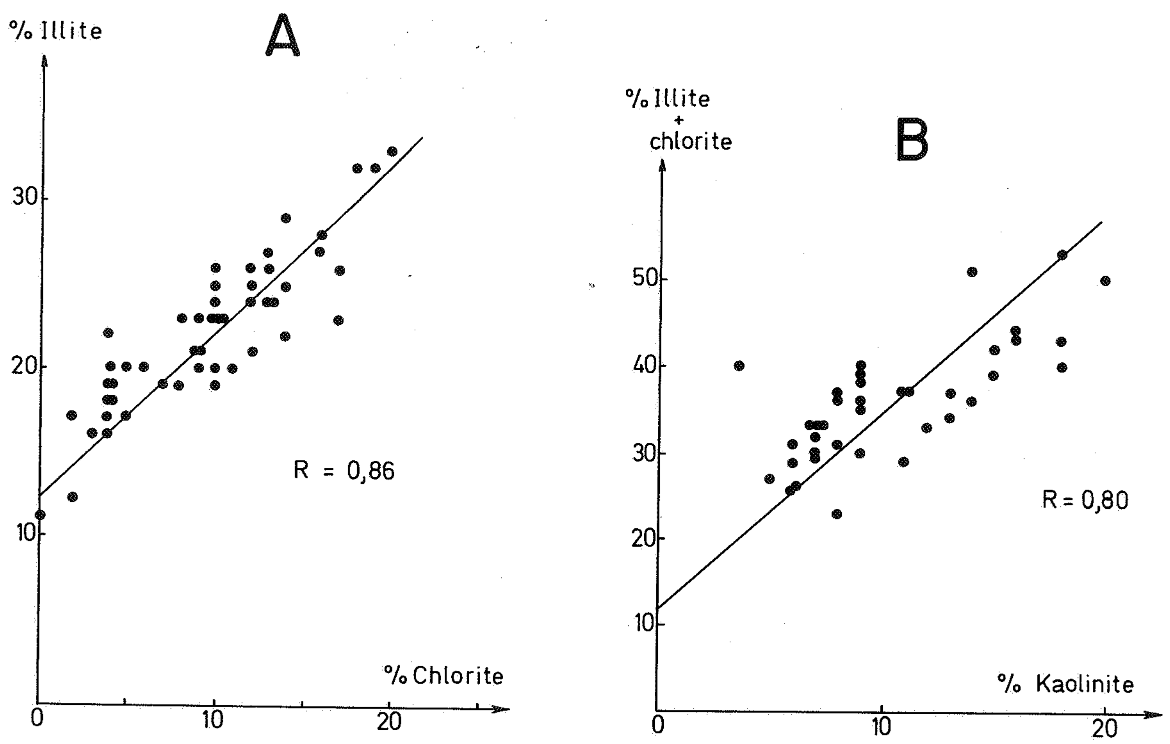

Fig. 5.- Linear relationsships between chlorite and illite and chlorite + illite and kaolinite percentages.

Observations made by transmission electron microscopy show the presence of lathed smectites which result from diagenetic recrystallisation of detrital smectites. This phenomenon is favoured when the sediments micro-permeability is reduced, when the chemical exchanges between the clay particles and the interstitial solutions are easy but restricted to the near environment (abundant smectites) and when the sedimentation rate is low to medium (HOLTZAPFFEL and CHAMLEY, 1986). For example, lathed smectites reach 20% of the total smectites in the Ypresian sediments of the Mol borehole.

The formation of these singular minerals, associated or not with glauconite, seems hindered by the presence of opal CT and clinoptilolite and by the abundance of simple clay minerals (illite, chlorite, kaolinite). Lathed smectites developed without any noticeable modification of the proportions of the clay minerals in the associations. With an almost constant chemical composition, it is assumed that the lathed smectites do not disturb the environmental signal given by the detrical clay minerals (HOLTZAPFFEL, 1986, a). This agrees with the observations of HOLTZAPFFEL (1986, b) and HOLTZAPFFEL and CHAMLEY (1986) applied to the Atlantic area.

The whole diagenesis and neoformation phenomena, of limited extent, being identified, it is possible to use the clay mineral associations for the reconstitution of the successive continental and marine environments which developed in the Belgian basin and in its western approach during Ypresian times.

3. Outline of the clay mineral composition in the main sections and in the Knokke borehole reference section (fig. 3 and 4).

a) General remarks

The primary minerals reach high percentages (up to 50%, between 30 and 40% on average), during Palaeocene times and most of the Ypresian times. The linear correlation between chlorite and illite percentages is very good (fig. 5A). This indicates on one hand, the exceptional state of freshness of chlorite, a very fragile mineral which is very sensitive to continental alterations, and on the other hand, within crystalline or crystallophyllian rocks, the coincidence of their origin.

The primary minerals on the one hand, and kaolinite on the other hand vary also in parallel ways, as indicated by the value of the correlation coefficient which equals 0,80 (fig. 5b).

b) Zonation of the reference section of Knokke

The most striking fact, when considering the chronological evolution of clay minerals during the Ypresian times, is their distribution in three well defined zones which are characterised by decreasing percentages of primary minerals and of kaolinite from the bottom to the top of the Ypresian (fig. 4).

Two points can be underlined:

— the brutal nature of the changes when passing from one zone to another one;

— these mineralogical variations correspond to the lithological changes: the contents of primary minerals and of kaolinite decrease while the sediments become more sandy.

Zone I (288 m-180 m) shows contents which are similar to those observed in Palaeocene Beds. The average contents of clay minerals are $C = 12\,\%$, $I = 24\,\%$ $(10\text{-}14_S) = 0\,\%$, $(14_C\text{-}14_S) =$ traces, $S = 52\,\%$, $K = 10\,\%$. This zone corresponds to the "Orchies Clay".

Whithin this zone, we can see two sharp increases of primary minerals and of kaolinite situated respectively at the bottom and at the top of the zone.

In zone II (180 m-146 m), primary minerals and kaolinite contents decrease in an important way to the benefit of smectites. The average are: $C = 4\,\%$, $I = 19\,\%$, $(10\text{-}14_S) = 0\,\%$, $S = 74\,\%$, $K = 3\,\%$. This zone corresponds to silty clay.

In the zone III (146-130 m): primary minerals reach lower contents ($C =$ traces, $I = 11\,\%$). Kaolinite disappears and smectites content is high (88 %). This zone corresponds to the Egem Sand up to the Vlierzele Formation.

4. Kallo borehole N. Belgian Basin.

The clay mineral associations are similar to those of the Knokke borehole. Here again we can observe the three zones we have distinguished above. Nevertheless they are not as marked as in Knokke. Just like in the Knokke borehole, the primary minerals and kaolinite increase in an important way, within the more clayey zone I. In this zone, there are two other increases of the same minerals, but they are shorter. The "Sparnacian" facies of Late Landenian age is present and contains up to 35 % of kaolinite.

5. Mol borehole.

The distinction in zones is still possible but it is not as marked as at Kallo and, *a fortiori*, Knokke. Zone III cannot be distinguished. At the bottom of zone I, we notice again the sharp increase of the primary minerals and of kaolinite. The increases of primary minerals which we can observe higher at the levels 413 and 425,5 in zone I, correspond perhaps to those observed more distinctly at Kallo (351 and 332). Moreover, we can note the presence of fibrous minerals of sepiolite type in zone II. (Such minerals are present too in zone I, Héribu Member, at the "Mont Héribu"). Deposits with lagoonal facies of Late Landenian age are absent in the Mol borehole.

When comparing the Knokke, Kallo and Mol sections we see that, in general, toward the E of the basin the clay mineral associations show a decrease of primary minerals and of kaolinite and the apparition of fibrous minerals in zone II. The most constant feature is the marked increase of the primary minerals and kaolinite at the bottom of zone I of the Ypresian Beds.

6. Isle of Wight section (White cliff Bay).

The almost constant presence of kaolinite in percentages which nearly always lie between 10 and 15 %, is the major feature of the clay composition of Ypresian sediments in the Isle of Wight.

The exceptionnally high percentages of kaolinite observed in the Bagshot Sands, seem to be due, in part (as we have stated above) to neoformation of kaolinite in the porous sediments by the action of acid waters passing through. The primary minerals are also very abundant. The percentage average of primary minerals and kaolinite is superior to the same average in Knokke.

7. Cap d'Ailly section.

The deposition of the "Sparnacian" Beds (Ypresian transgression) corresponds to the arrival of primary minerals and kaolinite with percentages fluctuating respectively between 20 and 40 % and between 5 and 10 %. This composition contrasts with the one in the underlying continental beds in which the clayey fraction contains almost exclusively smectites. The sedimentation of sands and clays of the Formation de Varengeville of Cuisian age is accompagnied by a sharp increase of primary minerals and kaolinite, the percentages of which vary respectively between 30 and 50 % and between 5 and 15 %. These percentages decrease in the glauconiferous upper clays (NP 11).

As we have seen in the other boreholes of the Belgian basin, we can also note in this section the same increase of the primary minerals and kaolinite at the bottom of the Ypresian Beds.

IV. INTERPRETATION

1. Morphoclimatic interpretation.

The role of the climatic and geomorphologic factors is illustrated by the clay mineral associations.

The smectites, always and sometimes abundantly present in the studied formations, (e.g. in the Mol borehole), have the ferriferous beidellite composition according to chemical analysis on particles (MEB) and their thermic behaviour (HOLTZAPFFEL, 1985; MERCIER-CASTIAUX, 1986).

This type of smectite preferably forms in soils of badly drained down-stream parts of continental margins, under a hot climate with contrasted seasonal humidity (PAQUET, 1970). Thus, the clay mineral associations of Ypresian sediments convey the erosion of soils formed on fairly flat continental margins and in a hot and humid climate.

The climatic information can be illustrated by some examples. In the Mol Borehole (NE Belgian basin) the arrival of fibrous clay minerals in the Ypresian sediments results from the erosion of half closed basins situated near the shore in a hot climate with very contrasted seasonal humidity, and of a transgressive sea. The results of palynologic studies confirm the climatic information deduced from the clay mineral associations.

The high kaolinite content in the Late Palaeocene Landenian brackisch deposits of the Kallo borehole seems to indicate for this period the presence of ferralitic soils in areas upstream the continental margins and a hot climate with a constant humidity during the entire year. Nevertheless, it is possible that kaolinite started to form earlier.

On the W of the Paris Basin, in the Ailly section, the Palaeocene lacustrine limestones containing 100 % of smectite in the clayey fraction, indicates continental alterations under a hot and humid climate too.

2. Influence of marine transgression.

The increases of content of primary minerals and kaolinite at the base of the Ypresian beds are linked to the marine transgression which marks the beginning of the Ypresian stage in Belgium. This transgression seems to be the most important of the stage because this mineralogical recorded evolution at the base of the Ieper Formation is the ampliest and the most generalized. Indeed, it can be observed in all the studied boreholes and sections in the Belgian basin and notably in the Mons Basin at the "Mont Héribu" (studies in progress). The first transgression which corresponds to the deposition of the Orchies Clay does not seem to be a continuous one; indeed, the other sharp increases of primary minerals and kaolinite observed at Knokke and Kallo and perhaps at Mol may correspond to pulses of the marine foreward movement.

It is possible that slight tectonical movements also favoured the continental erosion of the rocks and soils. Indeed, the effects of tectonical instability upon the clay mineral associations are the same as those of marine transgressions.

3. Influence of currents.

The variations of clay mineral associations with time, that is to say the decrease of primary minerals and kaolinite, parallel to the lithological evolution which we have well observed in Knokke, can be interpreted by current influences.

Then a changing pattern of currents would have had an increasing influence during the opening of the Channel toward the North Atlantic Ocean. This opening putting the southern part of the North Sea area in connection with the Atlantic Ocean is proved by the arrival of Nummulites of southern origin in the Belgian Basin where it corresponds, more or less, to the transition zone I - zone II in the Kallo borehole.

The decrease in primary minerals and kaolinite which is parallel to the increase in sand content of the deposits may be due to an increase of currents intensity towards the shore.

4. Diversity of the detrial supplies.

The increases of the primary minerals and kaolinite contents in the Ypresian beds towards the western part of the Belgian basin (Knokke borehole) suggest a western origin of the minerals. The most likely source, in this hypothesis, is Cornwall.

Indeed, the Artois Axis, at that time, is of minor paleogeographical importance. On the other hand, the higher contents in primary minerals and kaolinite in the contemporary London Clay of the Isle of Wight is an argument in favour of the existence of western supply zones: Cornwall in this case. Many works bring forward the existence of important ferralitic formations of Palaeocene age. Big quantities of kaolinite are further found in these ferralitic formations (ISAAC, 1981, 1983). In addition, kaolinite results from the hydrothermal alteration of granitic mas sives from the end of Carboniferous times (ANDERSON & OWEN, 1968).

To the W of the Paris Basin (in the Dieppe Basin at Ailly), the high contents of primary minerals and kaolinite in the Cuisian "Formation de Varengeville" probably come from th erosion of the SW uplifted Armorican Massif covered with kaolinite rich soils formed during Palaeocene times and even before (ESTEOULE-CHOUX, 1967). The WNW emerged Cornwall Massif, certainly contributed too in supplying the Dieppe-Hampshire Basin with terrigenous particles.

The important decrease of kaolinite toward the E of the Belgian Basin during Ypresian times does not mean that there were no ferralitic soils on the Ardennes at that time. On the contrary, such soils certainly existed because, first, this region is found at the same latitude as Cornwall and must have had almost the same climate and, secondly, the presence of kaolinite in the content of 35 % of the Landenian lagoonal sediments at Kallo proves their existences. This lateral mineralogical change is either due to:

- a better stability of the Ardenne Massif compared to more western massives like Cornwall;
- or a different vegetation having better soil fixative properties.

These two factors can add their effects.

A more important instability of the Cornwall and Armorican Massives compared to the Ardenne Massif could be explained by the Atlantic Ocean vicinity. Indeed, this ocean underwent an important phase of its history at the Palaeocene-Eocene boundary, with the separation of Greenland from the Rockall Plateau. This event had repercussions in the North Sea where it manifested itself as a series of volcanic eruptions.

V. CONCLUSIONS

To sum up, the clay minerals of the Ypresian sediments of the Belgian Basin, which are essentially inherited from the continental margins, give climatic informations confirmed by palynologic studies and informations about the morphology of continental margins. They also allow to show the currents influences which are linked to the opening of the Channel which probably happened almost at the time corresponding to the zone I-zone II boundary.

The clay mineral successions also suggest that the supply in terrigenous elements essentially came from the W, especially from Cornwall. This fact is perhaps due to a more important instability of this region which was more involved in the Atlantic Ocean history than the more eastern Ardenne.

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