The Sparnacian deposits of the Paris Basin: A lithostratigraphic classification

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ABSTRACT: As the result of a study integrating lithostratigraphy and biostratigraphy of the Upper Paleocene (Thanetian) and Lower Eocene (Sparnacian-Ypresian) of the Paris Basin, a new lithostratigraphic unit, the Mont Bernon Group, can be formally recognized. The group includes four formational units: the Mortemer (Mortemer Limestone), the Vaugirard (Plastic Clay), the Soissonnais (Lignitic Clay of Soissons) and Epernay (Lignitic Clay of Epernay) formations and associated members. An integration of charophyte, dinoflagellate cyst and, to a lesser extent, calcareous nannoplankton biostratigraphy allows us to place the succession in an approximate, integrated biostratigraphic framework.

Our introduction of a formal lithostratigraphic framework for the Upper Paleocene-Lower Eocene succession in the Paris Basin contributes to emphasize the distinctiveness of the Sparnacian deposits as an independent stratigraphic unit.

INTRODUCTION

During the last century, when stratigraphic classification lay at the center of the geologic sciences, a number of continental to brackish deposits that outcrop in the Paris Basin, commonly referred to as "Sparnacian Stage" or "Sparnacian facies", acquired the distinction of providing elements that proved fundamental to lower Paleogene chronostratigraphy. First and foremost, the Lignites et Grés du Soissonnais yielded a flora distinct enough from those of the Upper Cretaceous and the Eocene London Clay (Ypresian) and Calcaire grossier (Lutetian) as to justify the introduction of a Paleocene Epoch (Schimper 1874). Second, the body of shallow marine to continental deposits with particular facies and faunas, sandwiched, in the Paris Basin, between the marine Thanetian and Cuisian sands was considered sufficiently distinctive as to warrant the erection of a new stage, the Sparnacian Stage (Dollfus 1880; from the Town of Epernay = *Sparnacum* in Latin). Third, the Conglomérat de Meudon discovered by d'Orbigny in 1836 contains an exceptional vertebrate fauna that still serves as a reference for many studies concerned with mammal evolution around the Paleocene/Eocene boundary.

Whereas the chronostratigraphic connotation of the "Sparnacian Stage" erected by Dollfus (1880) has been controversial because of its predominantly non-marine facies (e.g., Berggren 1971), recent studies on the Upper Paleocene-Lower Eocene stratigraphic interval worldwide have revealed that its deposits (those assigned to it by definition [Dollfus 1880], not those that constitute the stratotype [Dollfus 1905]) are actually associated with a remarkable episode in the Cenozoic history of the Earth system. Yet, these deposits are among the poorest documented of the Paleogene record of northwestern Europe. This undoubtedly reflects the diversity and lateral variation of facies (together resulting in restricted biostratigraphic correlation potential) and the insufficient number of extensive outcrop sections now available. However, it is also likely that the confusion that has arisen regarding the correlation of these deposits with those in adjacent basins of northwestern Europe has hampered their comprehensive regional description. On many occasions, circular reasoning involving biostratigraphic assignments based on presumed lithostratigraphic correlations and lithostratigraphic correlations based on presumed chronostratigraphic assignments have resulted in inextricable situations and difficulty in "objective" use of published data. Thus, whereas placement in a global stratigraphic and chronologic framework of the "Sparnacian" unit taken as a whole has been achieved (Berggren et al. 1985; Berggren and Aubry 1996), regional stratigraphic interpretation of the "Sparnacian deposits" lags considerably compared to the interpretation of the Lambeth Group in England (Ellison et al. 1994, and references therein) and of the lower Ieper Group in Belgium (Steurbaut 1998 and references therein).

In the Paris Basin the Upper Paleocene-Lower Eocene succession comprises three distinct lithologies. These consist of two well delineated sand units, until now broadly referred to as Sables de Bracheux (Paleocene) and Sables de Cuise (Eocene), bracketing a poorly understood lithologic complex of continental and brackish clays, limestones, sands and lignites, most of which contain organic matter, broadly referred to as Argiles à Lignites. With regard to this lithologic complex Lemoine (1937, p. 286) wrote "Le Sparnacien montre dans le Vexin, comme partout ailleurs, de grandes variations de faciès dont on n'entrevoit pas les lois et aussi d'importantes variations d'épaisseur qui paraissent liées aux situations anticlinales et synclinales comme si les dépôts lagunaires sparnaciens avaient rempli des dépressions préexistantes." [The Sparnacian shows in the Vexin area, as elsewhere, ample facies variations whose laws remain obscure and also important variations in thickness that would appear to be related to the anticlinal and synclinal locations as if the Sparnacian brackish deposits had filled preexisting depressions].

TABLE 1
Simplified lithostratigraphic framework for the Upper Paleocene-Lower Eocene deposits of the Paris Basin.

PARIS BASIN	
MONTAGNE DE LAON GROUP	Laon Fm.
	Cuise Fm.
	Mont-Notre-Dame Fm.
MONT BERNON GROUP	Epernay Fm.
	Soissonnais Fm.
	Vaugirard Fm.
	Mortemer Fm.
VESLES GROUP	Bracheux Fm.
	Châlons-sur-Vesles Fm.
	Moulin Compensé Fm.
VIGNY GROUP	no formation defined

The indicated formations, with their members, correspond to classic lithologic units as follows: *Moulin Compensé Formation:* Tuffeaux du Moulin Compensé; *Châlons-sur-Vesles Formation:* Sables de Châlons-sur-Vesles; *Bracheux Formation:* Sables de Bracheux; *Mortemer Formation:* Calcaire de Mortemer; *Vaugirard Formation:* Argiles Plastiques de Vaugirard, including *Meudon Member:* Conglomerat de Meudon, *Limay Member:* Argiles Plastiques de Limay, and *Provins Member:* Argiles Plastiques de Provins; *Soissonnais Formation:* Argiles à Lignites de Soissonnais, including *Vauxbuin Member:* Sables de Vauxbuin, *Vexin Member:* Fausses Glaises de Vexin, *Ailly Member:* Sables et Argiles à Ostracodes et Mollusques, and *Craquelins Member:* Argiles Glaucionieuses des Craquelins; *Epernay Formatiom:* Argiles à Lignites de Epernay, including *Paris Member:* Fausses Glaises de Paris; *Mont-Notre-Dame Formation:* Sables de Laon, Tuffeau de Mont-Notre-Dame; *Cuise Formation:* Sables de Cuise; *Laon Formation:* Argile de Laon.

As a result of our extensive field work (Thiry 1981; Dupuis and Steurbaut 1987; Thiry, Aubry and Cavelier, unpublished data) we formalize here a lithostratigraphic framework for this lithologic complex which we define as the Mont Bernon Group. For a uniform lithostratigraphic treatment of the whole Upper Paleocene-Lower Eocene succession of the Paris Basin, we also introduce a formal lithostratigraphic framework for the sandy units that bracket the Mont Bernon Group, and thus define the Vesles Group (below) and the Montagne de Laon Group (above; Table 1). In addition, we informally introduce the Lower Paleocene Vigny Group.

Our lithostratigraphic formalization clearly departs from earlier approaches by French stratigraphers for whom the "stage" was of paramount importance, resulting in the neglect of formal lithostratigraphic (and biostratigraphic) procedures. This has led to a situation in which the numerous lithologies designated by the names of the localities of occurrences merely correspond to the lateral and vertical lithologic variations that are expected within a formation or its members. Yet, no attempt at grouping these local lithologies into a regional framework has been systematically undertaken until now. We believe that our introduction of formal groups, formations and members will help clarify the early Paleogene sedimentary history in the Paris Basin, and facilitate stratigraphic correlations within northwestern Europe and with the North sea area.

THE VIGNY, VESLES AND MONTAGNE DE LAON GROUPS

The Vigny group

We introduce informally this group to unite the Lower Paleocene calcareous deposits of the Paris Basin (text-fig. 1). These form a well defined unconformity-bounded stratigraphic package that was deposited between two major erosional events (Montenat et al. 2002). The group includes the Calcaire de Vigny, Calcaire de Montainville, Calcaire de Meudon, Calcaire de Vertus, Calcaire de Laversines and Marnes de Meudon (e.g., Pomerol 1981; Montenat et al. 2002). The marine, reefal limestones are biocalcarenites that have been collectively, but improperly, referred to as "Calcaire Pisolitique". The limestones (calcaires) are marine; the marls (marnes), rich in gastropods, are continental. The Vigny group rests unconformably on the Campanian Chalk.

The Vesles Group

We introduce the Vesles Group, named after the Vesles River Valley where the group is well represented, to describe essentially marine glauconitic sandy units that extend broadly north of Paris from Dieppe to Reims (text-fig. 2) (Rouvillois 1960; Feugueur 1963; Mégnien 1980; Pomerol 1981). It comprises the Moulin Compensé, Châlons-sur-Vesles and Bracheux formations (Table 1).

The lower and upper boundaries of the Vesles Group are clearly marked by the lithologic contrast between its marine sands and the bracketing carbonate lithologies. It rests either on the Vigny Group or the Upper Cretaceous Chalk and is overlain by the essentially non-arenitic basal beds of the Mont Bernon Group.

Moulin Compensé Formation

Name: After the so-called Moulin Compensé Quarry, in the east of Châlons-sur-Vesles (Marne), ~10km NNW of Reims (Marne).

Type section: The section is that of the so-called Moulin Compensé Quarry, near Châlons-sur-Vesles, and described in Janin and Bignot (1993).

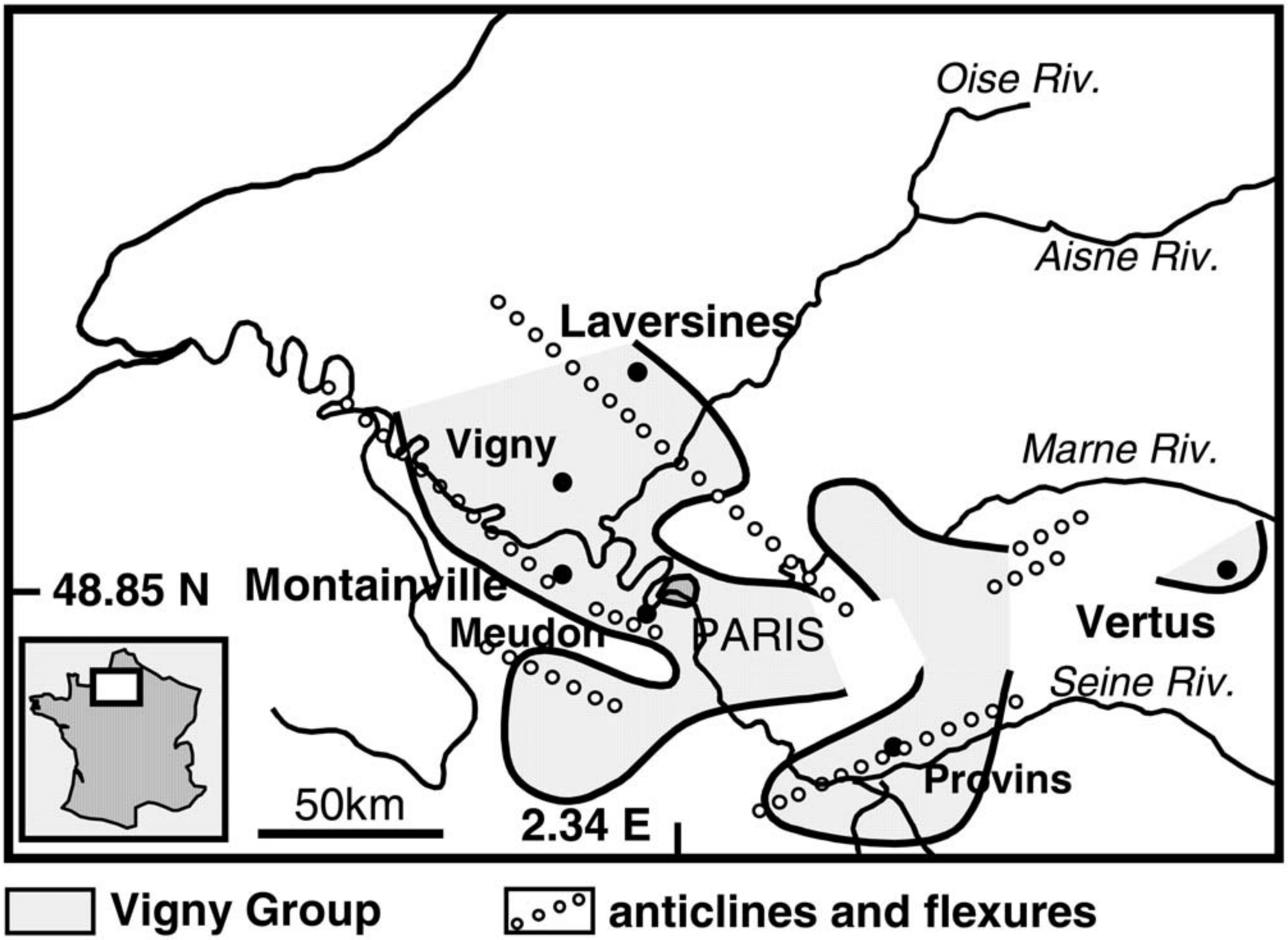
Lithology: Fine, glauconitic, clayey, calcareous, silts or sands often with small flint pebbles, occasionally phosphate-bearing.

Boundaries: The Moulin Compensé Formation rests unconformably on the Upper Cretaceous Chalk. In the type area near Châlons-sur-Vesles, the Châlons-sur-Vesles Formation rests conformably on the Moulin Compensé Formation.

Thickness: 6 to 7m in the type area. The clay content is highly variable, as reflected by the numerous local names (Argile de Vaux-sous-Laon [a sandy and glauconitic clay], the Tuffeau de la Fère [a partly indurated, glauconitic and phosphatic sand] and the Argile de Clary) that are in use.

Regional correlation: "Tuffeaux" and related facies (i.e., soft, chalky, porous limestones) outcrop between Reims and Cambrai, along a 15 to 30km wide area, and then pass laterally into the Argile de Louvil in Belgium (Dupuis 1979).

Biostratigraphical characterization and age: The formation yields molluscan assemblage characterized by *Pholadomya*



TEXT-FIGURE 1
Geographic extension of the Vigny Group.

oblitterata (Munier-Chalmas and de Lapparent 1893; Pomerol 1981). It belongs to (calcareous nannofossil) Zone NP6 and NP7 (Janin and Bignot 1993; Steurbaut 1998; Aubry, Thiry and Cavelier, unpublished).

Age: Thanetian, Late Paleocene

Genetic interpretation: This formation was deposited in a shallow marine environment immediately above the eroded chalk. Cretaceous coccoliths contribute significantly to the sedimentary matrix, and rounded flint pebbles result from the erosion of the chalk.

Châlons-sur-Vesles Formation

Name: After the town of Châlons-sur-Vesles (Marne)

Type section: Quarry at the entrance of Châlons-sur-Vesles. The section was first described by Melleville (1861).

Lithology: White and yellow, fine, glauconitic sands with cross bedding, burrows, and graded sand-filled channels. Abundant, molluscan shells aligned with the cross bedding.

Boundaries: The boundary with the underlying Moulin Compensé Formation is transitional. The upper boundary is the contact with the Bracheux Formation.

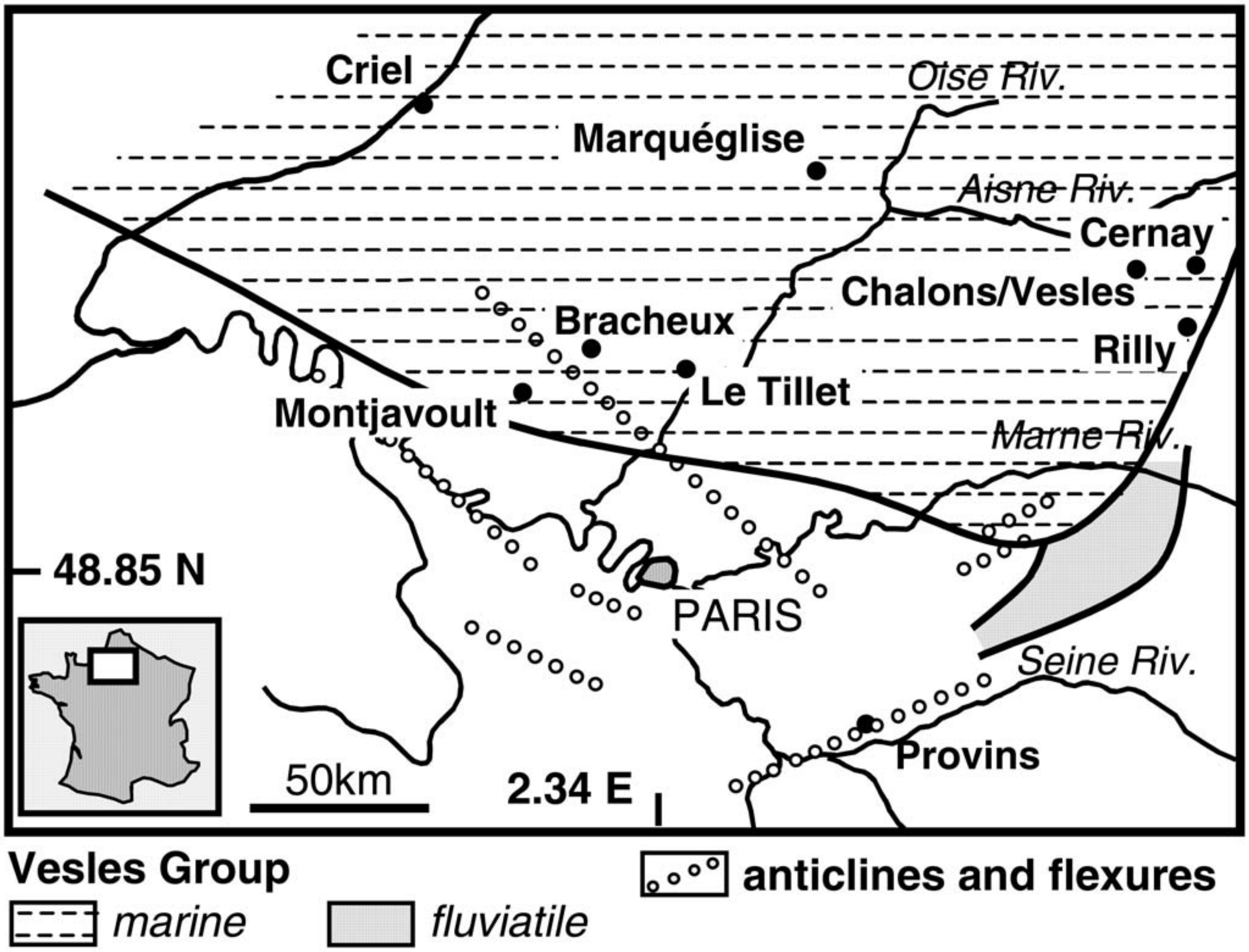
Thickness and distribution: 6m in the type area.

Regional correlation: We assign the Sables de Dieppe (Seine maritime), de Montjavoult (Oise) and de Le Tillet (Oise) to the Châlons-sur-Vesles Formation.

On the eastern side of the Paris Basin the marine sands of the Vesles Group pass laterally into continental marls (e.g., Marnes de Montchenot, Marnes de Chenay, Marne de Breuil-sur-Vesles, Marne de Saint-Thierry, i.al.), lacustrine limestones (e.g., Calcaire de Rilly), fluviatile sands (Sables de Rilly), and mammal-bearing conglomerates (e.g., Conglomérat de Cernay). However the relation within the Vesles Group between continental deposits and marine formations is poorly understood.

Biostratigraphical characterization: Molluscan assemblages characterized by *i. al.*, *Turritella circumdata*, *T. compta, Cythereae proxima, C. veneriformis, Pectunculus terebratularis, Nemocardium edwardsi, Ostrea eversa* (Pomerol 1981). The formation belongs to (Calcareous nannofossil) Zone NP8 (Aubry 1983, 1986; Dupuis and Steurbaut 1987; Steurbaut 1998; Aubry, Thiry and Cavelier, unpublished data). The continental marls belong to the Charophyte *Sphaerochara edda* Zone (Riveline 1984, 1986; see Appendix 1).

Age: Thanetian, Late Paleocene



TEXT-FIGURE 2
Geographic extension of the main formations of the Vesles Group.

Genetic interpretation: The Châlons-sur-Vesles Formation corresponds to an upward coarsening sequence of marine sands that reflects a transition from lower shoreface to backshore. In the east, characteristic features such as, *i. al.,* sigmoidal bedding, current ripples, herring-bone stratification (opposite current patterns), abundant truncations and crossbeds preserved in shallow troughs, are indicative of nearshore deposition in high energy conditions and under tidal influence. Deposition of these sands, often of different grain size in successive laminae, was associated with a regressive barrier that migrated northwards. In the west, deposition occurred in slightly deeper conditions as indicated by fine, strongly bioturbated lithologies.

The Bracheux Formation

Name: From the town of Bracheux, near Beauvais (Oise).

Type-section: The Butte de la Justice, 5km east of Beauvais, was renowned for its mollusc-rich Sables de Bracheux, for which it constituted a reference section (Hébert 1848). This exposure is no longer accessible. We thus propose the cliff section at Criel (Seine-maritime) as the type-section of the Bracheux Formation.

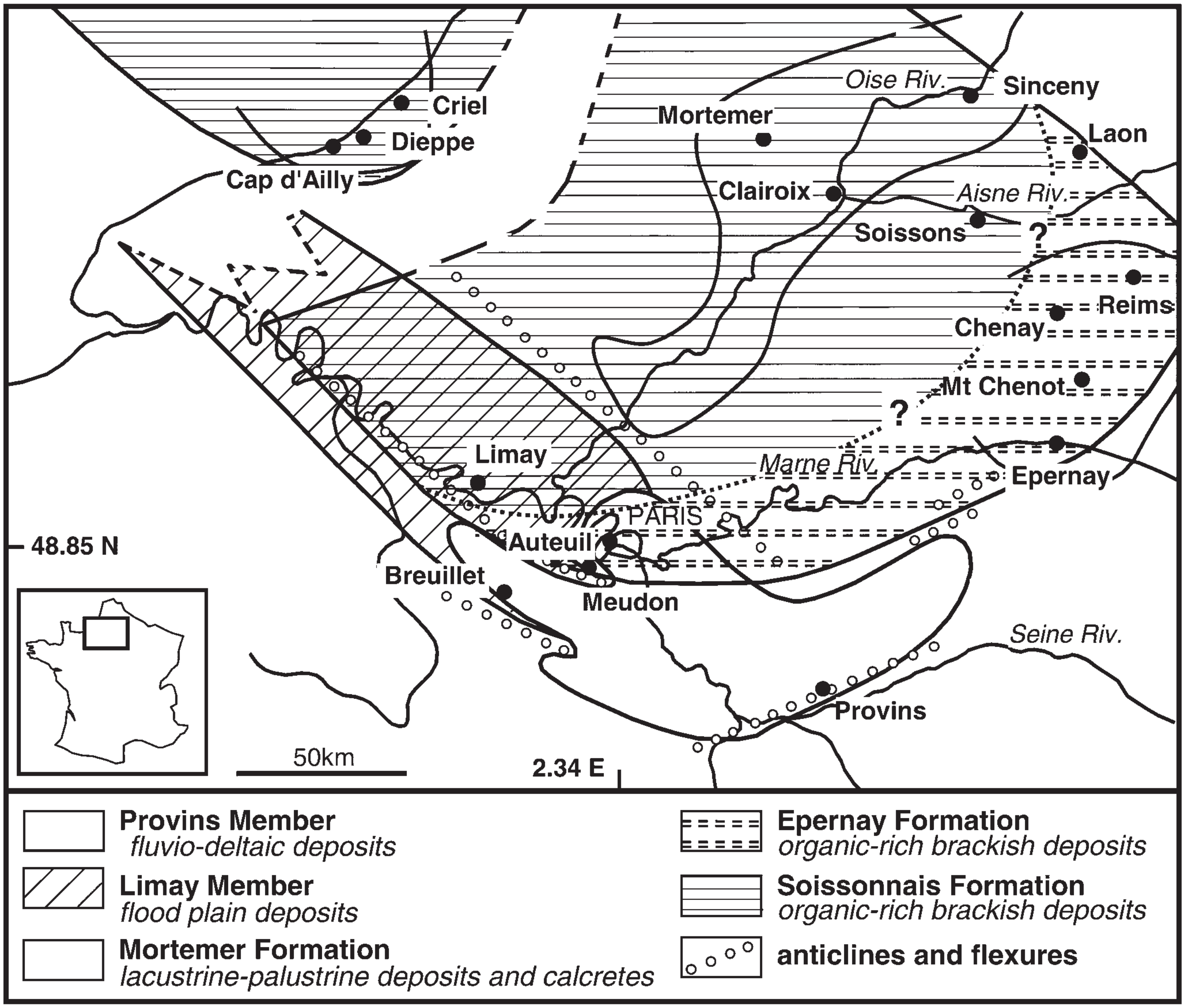
Lithology: Coarse, glauconitic and calcareous sands.

Boundaries: The Bracheux Formation is of similar lithology to the Châlons-sur-Vesles Formation, and the two units have not been previously distinguished. However in many localities a distinct shelly horizon with sparse flint gravels marks a regional erosional contact between the two formations. This horizon is particularly well exposed in the Lihons Quarry and the cliffs of Criel where the two formations outcrop (Dupuis et al. 1986; Dupuis and Steurbaut 1987).

Thickness: The formation is 30m thick in the Butte de la Justice. It is 4.5m at Criel.

Regional correlation: The Bracheux Formation includes the Sables de Bracheux at Bracheux, the Sables de Criel and Rosière, the Marnes de Marquéglise. As noted above, the geometric relations between the marine (Sables de Châlons-sur-Vesles, Sables de Bracheux and their respective correlative marine sands) and continental (e.g., Sables de Rilly, Marnes de Chenay) Thanetian deposits are unclear as yet.

Biostratigraphical characterization and age: Molluscan assemblages characterized by *Cyprina scutellaria, Cucullaea crassa-*



TEXT-FIGURE 3
Geographic extension of the main formations of the Mont Bernon Group. The Vaugirard Formation, which consists exclusively of continental deposits, is restricted to synclines of Variscan and Hercynian trends on the southern edge of the basin. It comprises the Limay Member and the Provins Member. It is onlapped by the brackish deposits of the Argiles à Lignites formations, that are restricted to the northern part of the basin. The Mortemer Formation extends to the south where it is represented by the Marnes à Rognons below the Limay Member.
Precise geographic location of localities from which cited lithologic terms are borrowed can be found in Feugueur (1963).

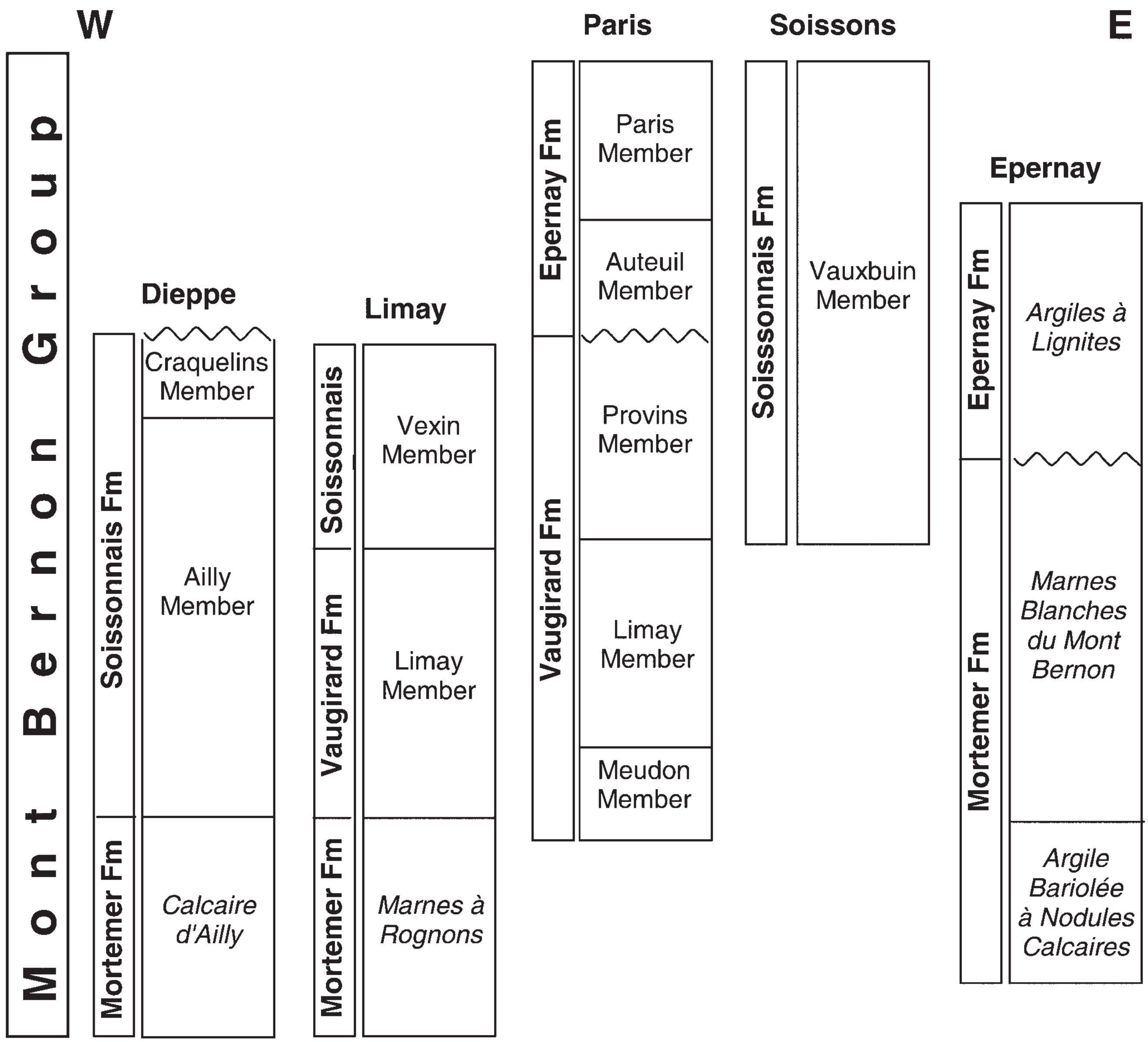
tina, Ostrea bellovacina, Cardita pectuncularis, Pectunculus terebratularis (Munier-Chalmas and de Lapparent 1893; Pomerol 1981). The Bracheux Formation belongs to Zone NP9 (Subzone NP9a; Aubry 1983, 1986; Dupuis and Steurbaut 1987; Bignot et al. 1994; Steurbaut 1998; Aubry, Thiry and Cavelier, unpublished).

The continental marls belong to the Charophyte *Sphaerochara edda* Zone (Riveline 1984, 1986; see Appendix 1).

Age: Thanetian, late Paleocene

(Note: Subzone NP9a [Aubry 1999] is the stratigraphic interval between the lowest occurrence of *Discoaster multiradiatus* and the highest occurrence of *Fasciculithus alanii*. The lower part of Subzone NP9b is further characterized by the [generally abundant] occurrences of *Rhomboaster* spp. and the short-lived *Discoaster araneus* [the so-called *Rhomboaster-Discoaster araneus*—or RD—assemblage; see Kahn and Aubry 2004]. The reported occurrence of *D. araneus* from the Thanetian sands of Criel [Steurbaut 1998] would imply that the Bracheux Formation extends into Subzone NP9b, thus straddling the carbon isotope excursion [CIE] that characterises the Paleocene/ Eocene boundary (Aubry et al. 2002). The illustrations given [op. cit., plate 1, figs. 3, 4) of *D. araneus* are in fact of *Discoaster falcatus*).

Genetic interpretation: These sands were deposited in shallow marine environments that supported a rich biocenosis indicative of a nordic marine influence (Farchad 1936) although it may well reflect a short cooling event at ~57 Ma (Zachos et al. 2001).



TEXT-FIGURE 4
Lithostratigraphic subdivisions of the Mont Bernon Group. The thicknesses of formations and members are not to scale.

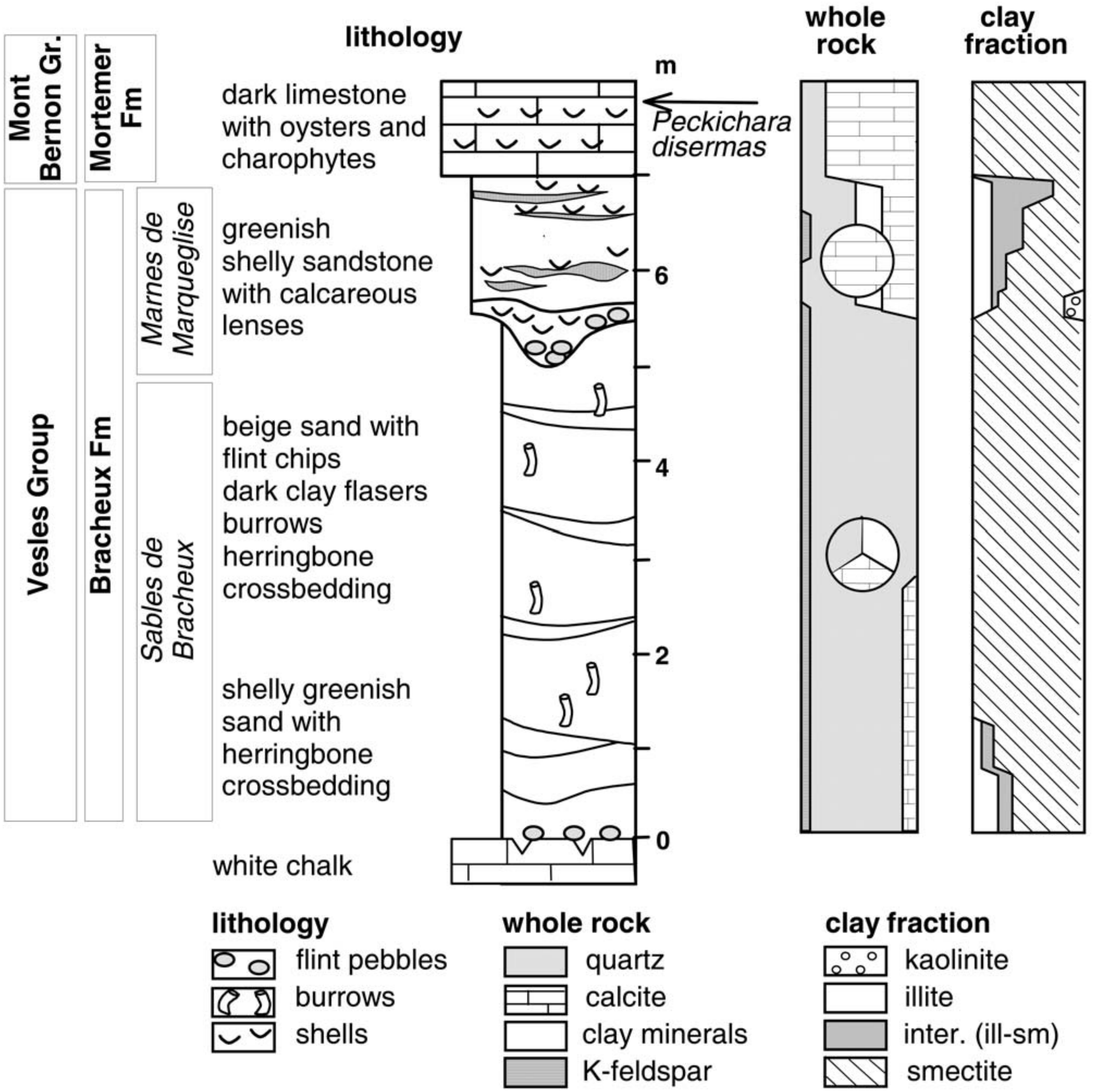
The Montagne de Laon Group

The Montagne de Laon Group, named after the town of Laon (Aisne), outcrops extensively in the Paris Basin. We informally distinguish three formations, Mont-Notre-Dame formation, Cuise formation and Laon formation (Table 1). We provisionally assign the Formation de Varengeville to the Montagne de Laon Group, although it consists dominantly of clays.

The main part of the Montagne de Laon Group consists of marine calcareous and glauconiferous sands. These sands are rich in microfossils, dominated by large benthic foraminifera with, i.al., *Nummulites planulatus* and *Alveolina oblonga*, that provide means to correlate geographically restricted lithologies (i.e., "Niveau d'Aizy, Niveau de Pierrefonds, Niveau d'Hérouval", Feugueur 1963; Mégnien 1980). We propose to unite these local lithologies under the term Sables de Cuise formation.

The base of the Montagne de Laon Group is clearly marked by an extensive, thick, almost non-calcareous bed informally termed the Tuffeau du Mont-Notre-Dame (Munier-Chalmas and Lapparent 1893) but commonly referred to as Sables de Laon following Chateauneuf and Gruas-Cavagnetto (1978). Because the same denomination cannot be used for a group and its subdivisions, we introduce the name Mont-Notre-Dame formation.

A clayey layer, known as Argile de Laon (Melleville 1860), forms the upper part of the group. Its upper contact with the overlying Glauconie Grossière of Lutetian Age is sharp, erosive, and marked by a pebble bed.



TEXT-FIGURE 5
Mortemer Formation at the type locality of Rollot. In several quarries along the Oise RiverValley hard limestones with slightly different lithologies overlie the glauconitic sands of the Vesles Group. These limestones are referred to the Mortemer Formation.

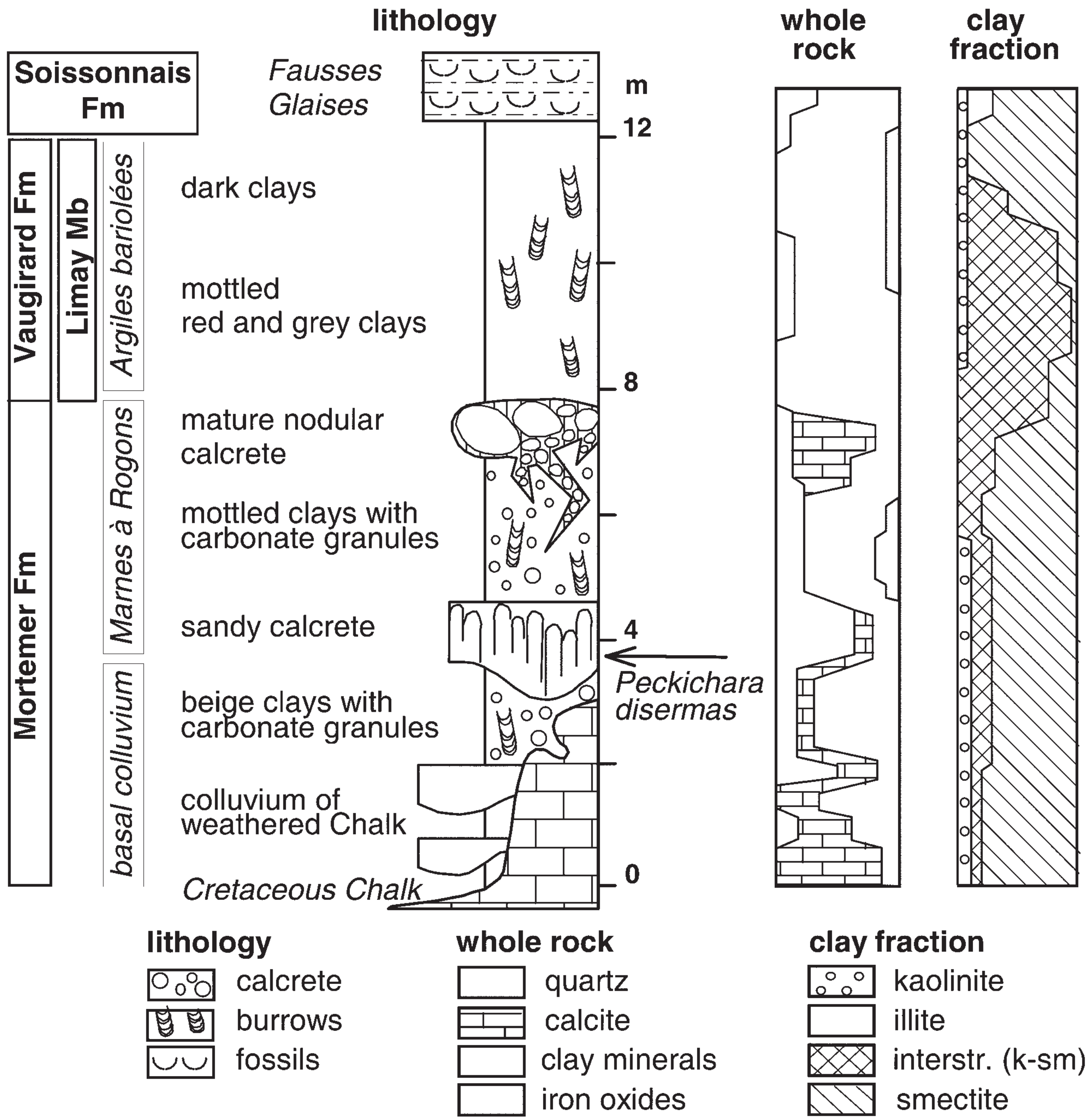
The marine deposits of the Montagne de Laon Group extend from the Reims-Laon region in the east to the Gisors area in the West. Towards the southeast, they pass laterally into the mammal-bearing, continental Sables à Unios et Térédines and into the Pisé de Sézanne (Leriche 1904; Lecomte 1994).

The Montagne de Laon Group is Lower Eocene; its base belongs to the (dinoflagellate) *Wetzeliella astra* Zone; its upper boundary lies in the *Kisselovia coleothrypta* Zone (Chateauneuf and Gruas-Cavagnetto 1978). The Formation de Varengeville (upper part) and the Sables d'Aizy belong to (calcareous nannofossil) Zone NP11. The Sables de Cuise probably belong to lower Zone NP12 (Aubry 1983, 1986).

THE MONT BERNON GROUP

The Mont Bernon Group includes clays and lignite bearing-clays with intercalated lacustrine limestones, marls and shallow marine sands. Whereas the clays and lignite-bearing clays constitute distinct regional lithologic units, the sands and limestones are local units that are difficult to correlate among themselves. As a result, a multitude of informal "formations" have been named without clear content and too often confusion has been introduced between litho- and chronostratigraphy.

The Mont Bernon Group is named after the Mont Bernon, a hill located in the southern outskirts of Epernay (text-fig. 3). The

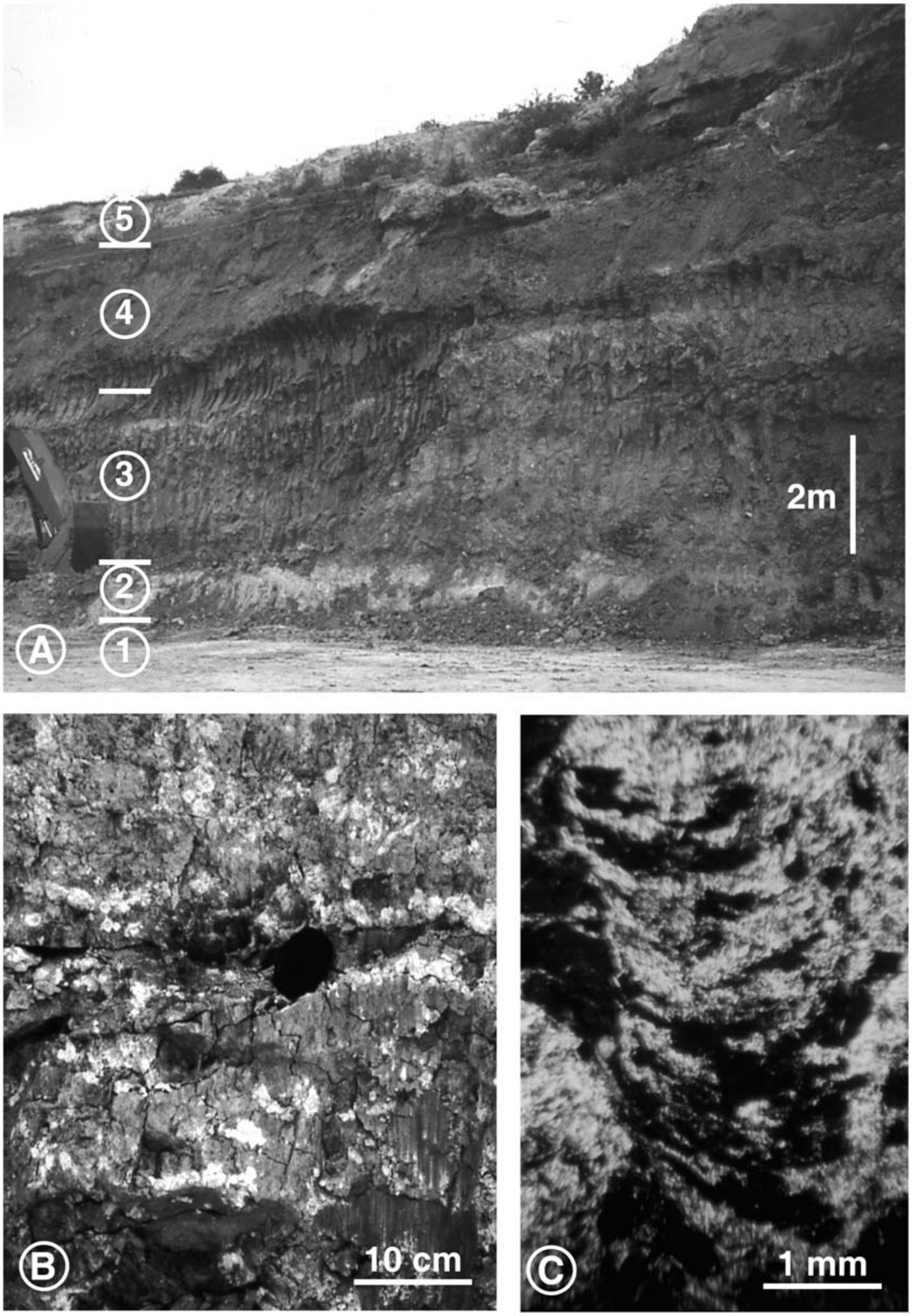


TEXT-FIGURE 6
Limay Member: Type section at Limay (Yvelines). The Limay Member consists of homogeneous, carbonate-free, mottled clays. Clay minerals are dominantly smectitic. It overlies the Marnes à Rognons of the Mortemer Formation and underlies the Vexin Member. The stratigraphic occurrence of the charophyte marker species *Peckichara disermas* is shown.

20m-deep Mont Bernon Corehole drilled from the bottom of the Fosses-Parisis and the Champagne Roederer quarries constitutes a 31m-thick partial reference section for the group (see below; see also diagrammatic section in Bignot 1980, fig. 4). The lower part of the group was recovered in the Mont Bernon Corehole; its upper part outcrops in the nearby Champagne Roederer Quarry (Laurain et al. 1983).

The group overlies the marine sands of the Vesles Group in the western and northern parts of the Paris Basin; on its southern and eastern edges the group rests directly on the Upper Cretaceous Chalk. It is overlain by the marine sands of the Montagne de Laon Group everywhere except in the south of the basin where it underlies Middle Eocene (Lutetian) lacustrine marls.

The Group is largely Lower Eocene, but straddles the Paleocene/Eocene boundary (Thiry et al., unpublished manuscript). It comprises four formations: (1) the Mortemer Formation, (2) the Vaugirard Formation, (3) the Soissonnais Formation, and (4) the Epernay Formation (text-figs. 3, 4). The latter two formations extend mainly over the central and northern parts of the basin. The Mortemer Formation occurs throughout the basin



TEXT-FIGURE 7
Limay Quarry : Type section of the Limay Member. (photographs: M. Thiry)
(A) Overview of the section : (1) chalk forming the quarry floor, (2) basal colluvium, (3) Marnes à Rognons : carbonate nodules-bearing variegated clays, (4) upper mottled clay without obvious stratification, (5) Fausse Glaises.
Lithologies (2) and (3) represent the Mortemer Formation. Lithology (4) is the Limay Member. Lithology (5) is the Vexin Member.
(B) Pedogenetic carbonate granules scattered throughout the variegated clays (Mortemer Formation). Detail of interval (3).
(C) Striotubules in the Limay Member. The striotubulues are not compacted, and result from burrowing in a relatively dry clayey sediment, suggesting oxic deposition. Detail of interval (4).

whereas the Vaugirard Formation is restricted to its southern edge.

As discussed by Feugueur (1963), it is extremely difficult to correlate the carbonate-rich continental strata that occur around the Paleocene/Eocene boundary in the Paris Basin on the basis of lithology alone. Some stratigraphic units (e.g., Calcaire de Montchenot, Marnes de Rilly, Marnes de Chenay *p.p.*) are correlative with the Châlons-sur-Vesles and Bracheux formations. They belong to the (charophyte) *Sphaerochara edda* Zone and the Upper Paleocene (Thanetian) Vesles Group. Other stratigraphic units (e.g., Marnes de Dormans *p.p.*; Calcaire de Clairoix, Marnes de Sinceny) are Sparnacian and belong to the (charophyte) *Peckichara disermas* Zone. However, the lithostratigraphic differentiation between the Thanetian and Sparnacian lacustrine limestones and marls is based not on biostratigraphy, but because of the difference in geographic distribution. The Thanetian marls and limestones of the Vesles Group occur only in the easternmost part of the Paris Basin, whereas the Mortemer Formation extends throughout the basin. In addition, sections described by late 19th Century authors (e.g., Hebert 1853, 1854, 1862; Munier-Chalmas and de Lapparent 1893), but no longer exposed, clearly show a lower marly unit, characterized by *Paludina aspersa* and resting on marine Thanetian sands, and an upper marly unit locally separated from the lower marly unit by a mammal-bone-rich conglomerate.

This is the first time that the Argiles à Lignites have been divided into two formations. Lignite-bearing clays occur throughout the Paris Basin West, North and East of Paris. Although forming an apparently single complex of recurrent lithologies (alternating clays, sands and lignites) formed in predominantly brackish environments, these lignitic clays have been shown through biostratigraphy to consist of two unconformable units, a fact that is also supported by field evidence (see discussion below). Thus, despite the similarity in facies that makes distinction almost impossible based on lithology alone, we describe two formations, the older Soissonnais Formation and the younger Epernay Formation.

The Mortemer Formation

A multitude of carbonate-rich continental deposits are scattered over the Paris Basin between the marine Thanetian sands and/or the Upper Cretaceous chalk, below, and the Argiles Plastiques de Vaugirard or the Argiles à Lignites, above.

Name: From the town of Mortemer (in the Oise Valley). The term Calcaire de Mortemer was introduced by Graves (1847).

Type-section: A sand pit in the locality of Rollot, near Mortemer (Somme; Pomerol and Riveline 1975; text-fig. 5) is proposed as the type-section.

Lithology: In its type locality (near Rollot), the Mortemer Formation consists of a 3m-thick, ostracode- and charophyte-rich, microcrystalline limestone, overlying an oyster coquina (text-fig. 5).

Dupuis et al. (1986) differentiated three regional units correlative with the stratotypic Calcaire de Mortemer:

1) The Calcaire d'Ailly unit, which occurs in the Dieppe area and consists of lacustrine to paludal marls and sandy limestones that seal broad sand-filled channels cut into the chalk, and terminates with a 1 m-thick lignitic bed (L1). This unit rests either on the Sables et Grés du Pays de Caux or on the Chalk.

2) The "Marnes à Rognons" that underlie the Limay Member on the southwestern edge of the basin between Rouen and Paris (see below) and the Marnes blanches du Mont Bernon in the Epernay area. These include calcareous nodule-bearing sandy and clayey units with calcareous nodules. They have also been referred to as "marnettes".

3) The Marnes Blanches unit of the Mont Bernon Corehole, which comprises marls interbedded with nodular and lacustrine limestones that are rich in *Microcodium* fragments and reworked Upper Cretaceous foraminifera and calcareous nannofossils. The coarse calcarenites exposed in the Quarries of Saran (Marne) and Rosnay (Aisne) are lateral correlatives of the Marnes Blanches of the Mont Bernon Corehole unit. They consist mainly of calcareous nannofossils (coccoliths) massively reworked from the Upper Cretaceous chalk. Massively reworked calcareous nannofossils also occur in the carbonate-rich units of the western part of the Paris Basin (e.g. in the Calcaire de Clairoix, MPA-MT, unpublished) although not as extensively as in the east (Laurain and Meyer 1986).

Boundaries: At Rollot, the Mortemer Formation rests with a sharp discontinuity on the greenish shelly sandstones and marls of the Marnes de Marquéglise (upper part of the Bracheux Formation = Vesles Group). Locally, the Mortemer Formation rests unconformably on the Upper Cretaceous Chalk (e.g., in the Limay Quarry, text-figs. 6, 7). The upper boundary is not exposed in the type-section. It can be seen in the nearby locality of Ressons-sur-Matz (Oise) where the contact with the overlying Soissonnais Formation is sharp. On the southern edge of the basin, the upper boundary with the Limay Member is also sharp (e.g., in the Limay Quarry) and marked by a mature nodular calcrete (text-figs. 6, 7; see below). In the eastern part of the basin, the Mortemer Formation directly underlies the Epernay Formation.

Thickness and distribution: The Mortemer Formation varies greatly in thickness, from >3m at the type locality to ~5m at Limay, 8m at Bougival, 12m at Sarans, and 15m at Mont Bernon.

Regional correlation: Carbonate-rich continental deposits extend from Cap d'Ailly in the West to the Reims area in the East, and from the Aisne River Valley in the north to the Seine River Valley in the south. The northernmost outcrop of the Mortemer Formation is the poorly documented locality of Vertain, where a *Coryphodon* was discovered (Malaquin 1888, 1899; Dupuis et al. 1986).

In the west, the Calcaire d'Ailly (Dupuis et al. 1986) correlates with the Calcaire de Mortemer.

In the East the Marnes Blanches recovered from the Mont Bernon Corehole (Laurain et al. 1983), the Marnes de Chenay *p.p.* (Lemoine 1880) and the Marnes de Dormans *p.p.* (Feugueur 1963) belong to the Mortemer Formation.

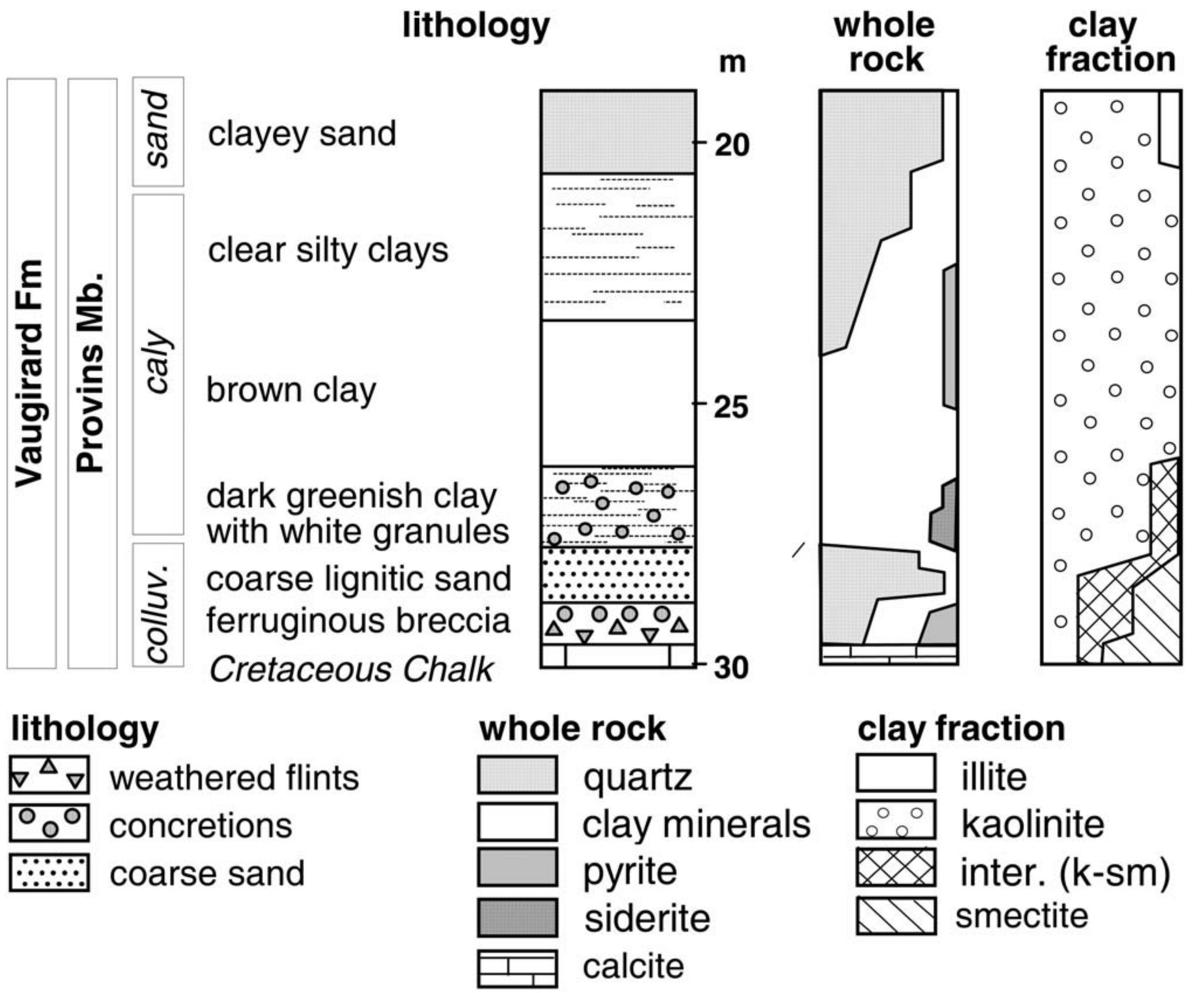
We assign the nodular carbonates that occur on the southern edge of the Paris Basin below the Limay Member, often referred to as "Marnes à Rognons" in the literature, to the Mortemer Formation. We interpret these latter as pedogenic calcretes (Thiry 1981) formed during a time of widespread carbonate deposition.

Biostratigraphic characterization and age: A freshwater molluscan fauna has been recovered from the Calcaire de Mortemer (Bignot 1965). The formation has yielded charophytes typical

TABLE 2
Biostratigraphic content of the Mont Bernon Group. Unit 1 and 2 as defined in the text. Mammal zonation from Hooker 1996; Charophyte zonation from Riveline 1983. 1984; Subdivisions SEb, PDa, DPb, PDc and PPa correspond to the biostratigraphic intervals distinguished as the *Sphaerochara edda* (SE), *Peckichara disermas* (PD) and *Peckichara piveteaui* (PP) Zones by Riveline (1986); Dinoflagellate cyst zonation of Powell (1992).

LOCALITY	FORMATION (this paper)	LITHOLOGIC UNIT	BIOSTRATIGRAPHY			POLARITY
			Charophytes	Dinocysts	Mammals	
Mutigny	Epernay Fm.	near top of Argiles à Lignites d' Epernay	Zone PP		Zone PEIV	
Epernay, Mont Bernon Corehole	Epernay Fm.	"Argiles et lignites du Soissonnais"	(?) Zone PP(1)			
Epernay, Carrière Fosse-Parisis	Epernay Fm.	in marly clay, 5 m below Sables à Unios et Térédines	(?) Zone PP(2) (+ P. torulosa)			
Saran	Epernay Fm.	Argiles d'Epernay, lower 5 m above contact with Marnes de Dormans	Zone PPa(a)			
Sainte-Marguerite (Ailly)	Soissonnais Fm.	in clays and lignites immediately overlying the Calcaire d'Ailly	Subzone PDb(b)	Apectodinium acme		
Guitrancourt	Soissonnais Fm	Fausses Glaises		Apectodinium acme		
Soissons	Soissonnais Fm.	Argiles à Lignites du Soissonnais			Zone PEII	
Soissons	Soissonnais Fm.	Argiles à huitres et Cyrènes with Cyrena cuneiformis	Zone PDb+c (+ H. sparnaciensis and H. leptocera(c)	Apectodinium acme		
Sinceny	Soissonnais Fm.	Sables de Sinceny	PDc (e)	Apectodinium acme	Zone PE II	
Meudon	Vaugiirard Fm.	Conglomérat de Meudon	-	-	Reference level MP7(d); Zone PEII	R(f)
Banthelu	Mortemer Fm. mmm		PD			
Epernay 1, Mont Bernon Corehole	Mortemer Fm.	Marnes Blanches at 11.00 m	Subzone PDb			
Epernay 1, Mont Bernon Corehole	Mortemer Fm.	in marnes à rognons between 18 and 11.50 m	Subzone PDa	Apectodinium acme		
Guitrancourt	Mortemer Fm.	sandy clay below the Argiles bariolées;	Subzone PDa (+Peckichara microcarpa)			
Rollot	Mortemer Fm.	both the Marnes de Marquéglise and the Calcaire de Mortemer;	Subzone PDa (+Grovesichara boureaui and P. microcarpa)	Apectodinium acme		
Saint-Thierry	?? Mortemer Fm.	marls regarded equivalent to the Marnes de Chenay;	Zone SEb (+M. berruensis)			
Saran	Mortemer Fm.	Marnes de Dormans,	Zone Pdb-c(a)			
Try	Mortemer Fm.	Marnes Blanches de Dormans			Zone PE I	

Charophytes zonal assignment from Riveline (1986) unless specified - (1) Indirect zonal assignment, based on presumed lithologic correlations - (2) Zonal assignment, based on secondary markers - (a) in Lecomte, 1994 - (b) Dupuis and Riveline (unpublished data) - (c) from Bignot *et al.* 1981 - (d) Schmidt-Kittler, 1987 - (e) as determined in the locality of Vauxbuin - Magnetostratigraphy: (f) from Russell *et al.* (1993).



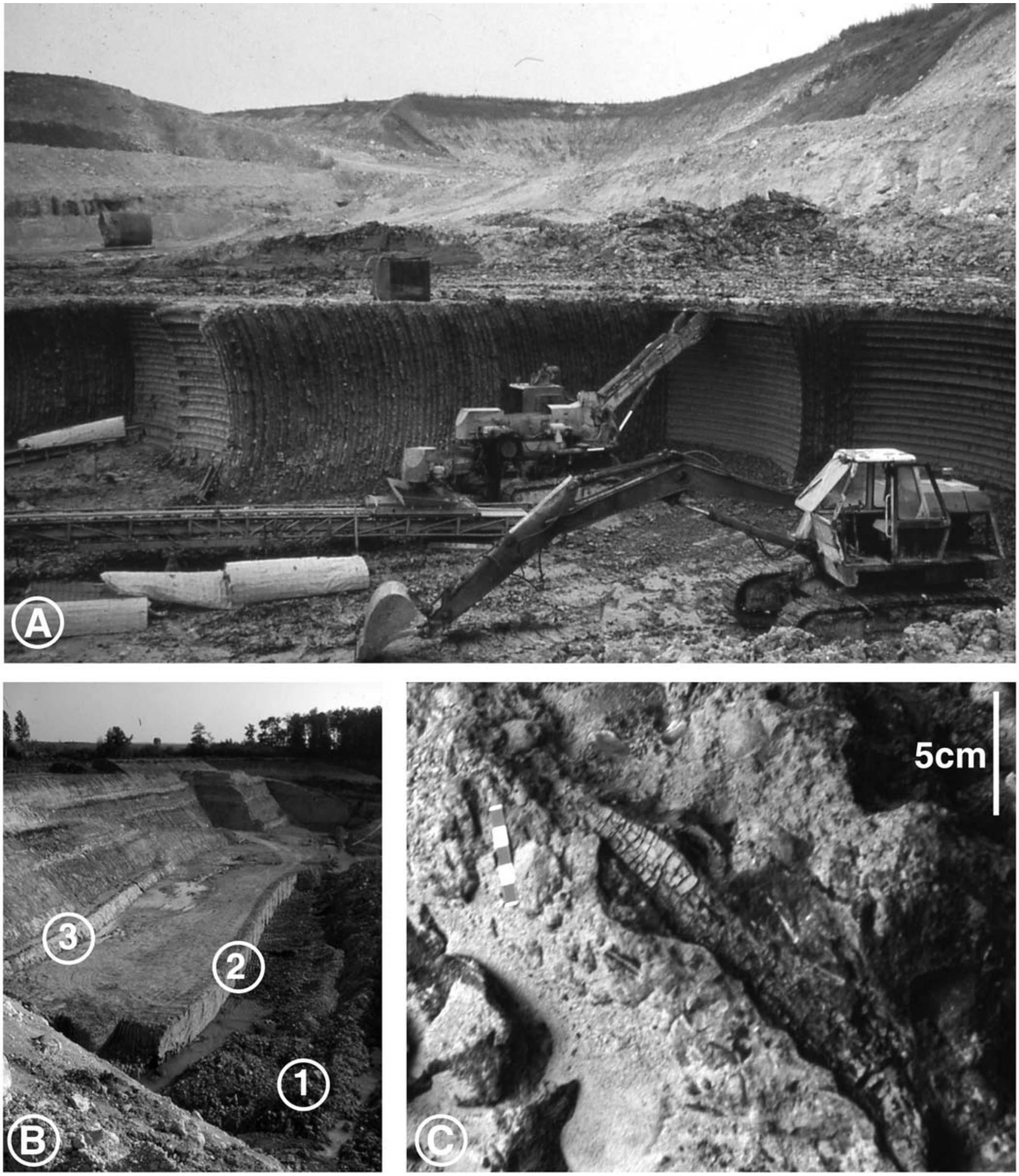
TEXT-FIGURE 8
Provins Member: Corehole type section, Chalautre (Seine-et-Marne). The Provins Member comprises, in stratigraphic order: first, a colluvium resting on the Chalk, second, a dark-colored, massive, clay unit, and third, a light-colored, clayey sandstone. The basal colluvium, formed of products resulting from the weathering of the Chalk, is dominantly composed of smectitic clay minerals (similar to the Limay Member). In contrast, only kaolinite is present in the overlying lithologies.

of the lower Sparnacian *Peckichara disermas* Zone (Grambast 1972a, b, 1977; Laurain et al. 1983; Riveline 1984; Lecomte 1994, Riveline and Dupuis, unpublished; see Table 1 and Appendix 1). At Dormans, a conglomerate within the marls have yielded the remains of a (Sparnacian) *Coryphodon* (Hébert 1862) and has been related to the Conglomérat de Meudon.

The "Marnes à Rognons" below the Limay Member in the Vexin (Limay area) have yielded a few ostracodes and charophytes. The latter characterize the *Peckichara disermas* Zone (Riveline 1986, Table 2, Appendix 1).

Genetic interpretation: Despite its lithologic diversity (lacustrine and palustrine limestones, pedogenic calcretes, *in situ* and reworked *Microcodium* and reworked Cretaceous coccoliths) the Mortemer Formation constitutes a striking feature of the Sparnacian of the Paris Basin, indicative of a short interval of time during which carbonate sedimentation prevailed throughout the basin (Laurain and Meyer 1986). Following the withdrawal of the Thanetian sea, lacustrine and paludal environments and even hydromorphic soils were established over a flat landscape left by the sea. However a shallow topographic gradient resulted in highlands that remained emergent during the late Thanetian towards the south where calcareous paleosols developed, and low areas in the north where lakes formed.

In the west, clay deposition on a flood plain was followed between floods by weathering and paleosol formation, resulting in calcrete and more or less hydromorphic vertisols and gley soils (Thiry 1981). This ultimately produced the Marnes à Rognons facies characteristic of the western edge of the Paris Basin. The occurrence of carbonate nodules in vertical and oblique joints



TEXT-FIGURE 9
The Provins Member. (photographs: M. Thiry).
(A) Bouchy-Saint-Genest Quarry, located between Provins and Sezanne, showing the 4.5m-thick exploited kaolinitic unit.
(B) Bois-du-Roy Quarry, North of Sezanne: (1) basal bed with lignitic seams rich in plant remains, (2) main kaolinitic unit (80% kaolinite, 20% silts), 3m thick, dark colored, and without visible bedding, (3) light colored upper sands. The member is capped by Middle and Upper Eocene limestones.
(C) Montpothier, South of Sezanne. Detail of the basal bed. Ferruginized wood is embedded in coarse sand with pebbles of flint.

and petrographic features such as illuviation cutans, clearly indicate that the calcrete horizons were formed in a soil under the influence of percolating water.

The Vaugirard Formation

The Vaugirard Formation designates the Argiles Plastiques described by Cuvier et Brongniart (1811).

Name: from Vaugirard, a southwest borough of Paris.

Type section: Reference to the quarries of Vaugirard, where the clays were exploited, seems to have first been made by de Roys (1854). Some quarries were still active after the second world war (Soyer 1953). During the last decades, typical sections through this formation have been drilled in relation to geotechnical surveys, in particular the La Defense project and subway extensions.

Lithology: Clay is the dominant lithology. It is mottled in the western part of the basin due to pedogenetic processes. Reducing conditions in lacustrine environments prevailed in the east, where sandy facies dominate at the top of the formation, with sand-filled channels incised throughout the clay. Both oxidized and reduced facies interfinger in the Paris area.

Boundaries: The Vaugirard Formation overlies unconformably the Cretaceous Chalk, the Calcaire de Vigny Group (Calcaire Pisolithique; Bignot et al. 1980) or the Mortemer Formation. We infer through biostratigraphic dating that the Vaugirard Formation is overlain conformably by the Soissonnais Formation and unconformably by the Epernay Formation.

Thickness and distribution: The formation is restricted to synclines of Variscan and Hercynian tectonic trends (text-fig. 3). The thickness averages 15m.

Biostratigraphic characterization and age: The formation belongs to the (charophyte) *Peckichara disermas* Zone (Riveline 1986; see Table 2, Appendix 1). It includes the important mammal locality of Meudon that represents Reference Level MP7 (Schmidt-Kittler 1987) and Zone PE II (Hooker 1996).

Genetic interpretation: Until Hébert (1854), stratigraphers who studied the Argiles Plastiques de Vaugirard believed them (like gypsum) to result from geyser activity because of their extreme chemical purity and the absence of biological indices.

The oxidized facies of the Vaugirard Formation that prevail on the southwest margin of the Paris Basin result from deposition in a flood plain with sandy channels and paleosols. The dark organic-rich clays that prevail on the southeast margin of the basin are of lacustrine origin.

Subdivision: The Vaugirard Formation includes three members, the Limay Member in the west, the Provins Member in the east (Thiry 1981) and the Meudon Member restricted to a southwestern suburb of Paris (text-figs. 3, 4).

*The **Limay Member***

Name: After the town of Limay (Yvelines), about 40km WNW of Paris.

Type section: Limay Quarry section. The Limay Member has been quarried for the manufacture of cement. The quarry provided extensive outcrops for many years. Several sections have been described by Thiry (1981).

Lithology: The Limay Member (described as Argiles plastiques bariolées by Thiry 1981), consists of smectitic (montmorillonite-beidellite and interstratified kaolinite/smectite) clays of oxidised red-mottled facies. In the type-section of Limay, the Limay Member is sandwiched between the Marnes à Rognons of the Mortemer Formation, below, and the Vexin Member of the Soissonnais Formation, above (text-figs. 6, 7; Thiry 1981). The section exhibits, in stratigraphic order:

1) A basal colluvium of mottled clay with relicts of weathering products (e.g. corroded flints, weathered Chalk breccia, sandy lenses mainly composed of flint chips).

2) A middle unit of carbonate nodule-bearing variegated clays. These have generally been referred to as Marnes à Rognons. The clays exhibit small striotubules, 1.5 to 2mm in diameter, which intersect ferruginous patches. The striotubules are not compacted and appear to reflect burrowing into a relatively dry clayey sediment, suggesting a subaerial, oxic depositional environment. Pedogenetic carbonate granules are scattered throughout the mottled clays. Nodules genetically related to calcrete crust occur in horizontal lenses, up to 1m thick, but some have penetrated into the underlying clay along vertical and oblique joints.

The basal colluvium and nodule-bearing variegated clays belong to the Mortemer Formation.

3) Upper mottled clays without obvious stratification, extensively burrowed with small striotubules similar to those in the underlying variegated clays. Bleaching along vertical and horizontal joints is indicative of hydromorphic paleosols. This upper unit constitutes the Limay Member.

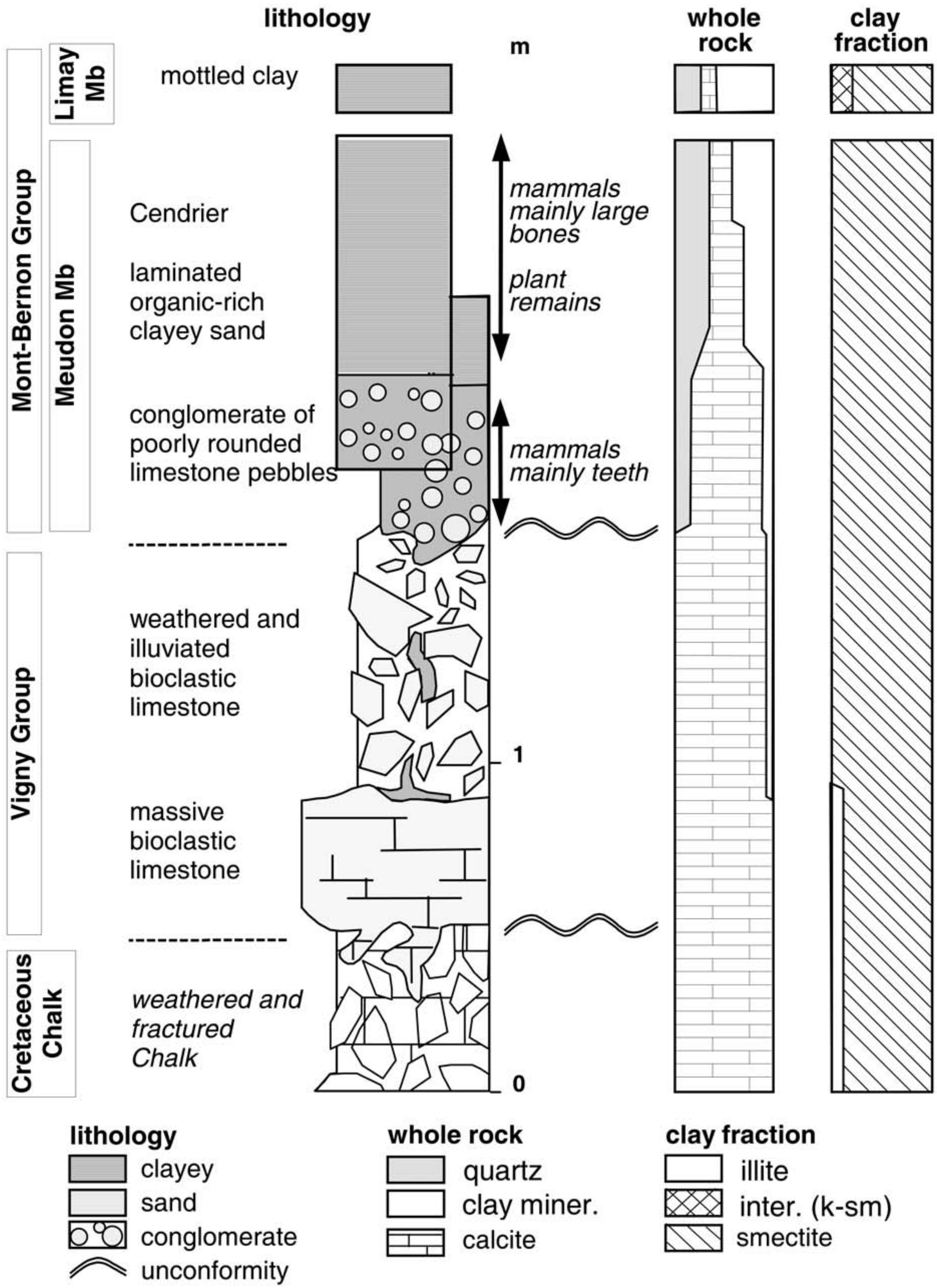
Boundaries: The Limay Member overlies the Mortemer Formation, as seen in several coreholes from the western part of the Paris Basin (Thiry 1981). West of Paris, the top of the member is sharp, well marked by the contact between the mottled clays and the finely laminated organic and shell-rich silty clays of the Vexin Member. In the Paris area, the Limay Member is overlain by the Auteuil Member. In the southern suburbs of Paris the contact between the Limay Member and the Provins Member is transitional.

Thickness and Distribution: The Limay Member occurs west and south of Paris. It is restricted to the Seine syncline, delineated by the Bray anticline in the north and the Seine, Remarde and Meudon anticlines in the south. The thickness of this member averages 10 to 15m, and a maximum thickness of 27m has been observed in the Bougival Corehole (Thiry et al. 1998) taken in this western suburb of Paris.

Regional correlations: The Limay Member correlates with the Provins Member on the southeastern edge of the basin.

Biostratigraphic characterization and age: The mottled clays of the Limay Member are barren.

Genetic interpretation: This sedimentary unit was formed in a flood plain at the foot of two anticlinal ridges (text-fig. 3). Clayey sediments were deposited during floods. Weathering occurred and paleosols developed between floods, resulting in more or less hydromorphic vertisols and gley soils formation (Thiry 1981). The flood plain extended northwest towards southern England, where the Reading Formation (Ellison et al.



TEXT-FIGURE 10
Composite section of the Meudon Member, Meudon (Yvelines). The Conglomérat de Meudon corresponds to the filling of a fluviatile channel on the flank of an anticline. Mammal teeth are especially abundant in the lower conglomeratic unit. The finer, upper unit (= Cendrier), rich in plant leaves, has yielded the bones of large mammals.

1994) displays similar paleosol features and burrows (Buurmann 1980).

The Provins Member

Name: From the town of Provins (Seine-et-Marne), where the kaolinitic Argiles Plastiques de Provins have been quarried for over 100 years over a 1000km^2 area.

Type section: The type is the Chalautre Corehole (Thiry 1981; text-figs. 8, 9). The Chalautre Quarry (near Provins) constitutes a good reference section through this member and reveals sedimentological relationships between the lacustrine clay units and the incised sand channels.

Lithology: The Argiles Plastiques de Provins (described as Argiles plastiques kaoliniques by Thiry 1981) are kaolinitic and of anoxic facies. The clays are brown and grey at the base, becoming light tan upwards (text-fig. 9). In the stratotypic section, the member includes three lithologies (text-fig. 8), in stratigraphic order:

1) A basal colluvium of reworked chalk and flint pebbles in a matrix of clays, coarse sands and lignites. It fills the depressions of the erosional surface of the Cretaceous Chalk. Siderite granules are frequent and the clay minerals include kaolinite, smectite and interstratified kaolinite/smectite. This facies has been previously (erroneously) correlated with the Cendrier of the Conglomérat de Meudon (Feugueur 1963).

2) A middle clay unit 1 to 5m in thickness, essentially structureless. The lower part of the clay is pure kaolinite, without quartz and with only minor amounts of pyrite and organic matter. Its upper part consists of large lenticular beds of silty kaolinitic clay.

3) An upper light colored clayey sands. The transition with the underlying clay is generally gradual, but in places the contact is erosional and the sands fill shallow troughs coated by dark organic-rich clay and mud. Occasional red ferruginous mottles and silcrete pans top these clayey sands.

Boundaries: The Provins Member overlies unconformably the Cretaceous Chalk. This lower contact is everywhere sharply defined, forming a slightly undulose discontinuity with a basal lag or thicker unit of residual weathering products of the Chalk. South of Paris, the Limay Member passes transitionally to the Provins Member. The upper limit is also unconformable and shows rapid variations on a kilometric scale; the top of the Provins Member is sometimes silicified (pedogenic silcrete) and occasionally overlain by Middle Eocene marl and lacustrine limestone or by Upper Eocene lacustrine limestone (Calcaire de Champigny) (Thiry et al. 2003).

Thickness and distribution: The maximum thickness of this member is 25m, with an average of 10m.

Regional correlations: In the Remarde Anticline area the Argiles Plastiques de Provins are of ferruginous facies and capped by coarse sands referred to as Arkose de Breuillet (Janet 1903), which may correlate with the Auteuil Member (but see below).

Biostratigraphic characterization and age: The Argiles de Provins are generally barren. However, pollen grains characteristic of lower Sparnacian Zone 2 of Chateauneuf and Gruas-Cavagnetto (1968) have been recovered (J.J. Chateauneuf, personal communication to MT, 1978).

Genetic interpretation: The Argiles Plastiques de Provins were deposited in deltas that prograded into an anoxic lake (Thiry 1981). The sands were deposited in distributary channels, whereas the kaolinitic clays collected in the lake. The silty clays represent mudflows on the delta front resulting from the collapse of natural levees along the channel banks. Laterally, oxydized facies formed on the margin of the basin and on the anticlinal crest (Remarde Anticline). The ferruginous and mottled facies are paleosol horizons with iron oxide nodules, root traces and mud cracks, indicating episodes of emersion during which primary pyrite was oxydized.

The Meudon Member

Name: From the town of Meudon (Hauts de Seine) where the mammal-bearing conglomerate was first described (d'Orbigny 1836).

Type-section: A type-section is preserved behind a window in an underground parking, 6 rue Albert-Julien Lanen in Meudon (Russell et al. 1993; text-fig. 10).

Lithology: The conglomerate comprises two units: (1) a coarse conglomerate with pebbles of limestone that are 1 to 15cm in diameter and embedded in a brown sandy matrix, and (2) a brown, finely laminated, sandy clay, known as "Cendrier", rich in plant remains.

Boundaries: In the literature, the conglomerate is described as sandwiched between the Lower Paleocene marine limestones (= Calcaire Pisolithique = Vigny Group) and the Limay Member (d'Orbigny 1836; Planté 1869, Russell et al. 1989). Carbon isotope stratigraphy (Thiry et al. 1998) indicates that a stratigraphic gap corresponding to the Mortemer Formation (i.e., Marnes à Rognons) occurs at Meudon. This is easily explained by the location of Meudon on an anticlinal crest.

Thickness and distribution: The mammal-bearing Conglomérat de Meudon (d'Orbigny 1836) is known only from a few underground quarries and outcrops distributed over a few square kilometers in the town of Meudon, a southern suburb of Paris. It is 0.30 to 0.80m thick.

Biostratigraphic characterization and age: The conglomeratic unit has yielded numerous small mammal teeth, and bones of large mammals have been retrieved from the Cendrier. Early descriptions of the faunas recovered from the Conglomérat de Meudon are fragmentary and the conglomerate has remained inaccessible for about 100 years. The discovery of two sections in the late 1980s (Russell et al. 1989; Russell et al. 1993) has considerably increased our inventory of Neustrian mammals from northwestern Europe (Russell et al. 1988). Of particular stratigraphic significance are the occurrences of *Coryphodon* and *Hyracotherium* (see discussion in Lucas 1998). Recent definition of a Global Standard Stratotype-section and Point (GSSP) for the base of the Eocene (Aubry et al. 2002) implies that the Conglomérat de Meudon is Lower Eocene. Its mammal fauna characterizes Reference level MP7 (Schmidt-Kittler 1987) and Zone PE II (Hooker 1996).

Genetic interpretation: Both the basal conglomeratic unit and the "Cendrier" constitute the filling of a fluviatile channel carved in a weathered Calcaire Pisolithique (Vigny Group; text-fig. 10).

The Soissonnais Formation

Name: From the area surrounding the town of Soissons (Marne). The Argiles à Lignites du Soissonnais were originally described by Brongniart (1829).

Type section: The lower boundary stratotype is designated at Vauxbuin, Carrière des Cailloux, where the contact between the formation and the underlying Thanetian sands is exposed. The upper boundary stratotype is at "Les Craquelins" in the western cliffs at Cap d'Ailly. The upper boundary is the contact between the Craquelins Member and the Mont-Notre-Dame Formation (= base of the "Sables Fauves" as locally known) at the base of the Montagne de Laon Group.

Lithology: The Soissonnais Formation includes a diversity of lithologies, the most typical ones being well bedded, dark clays, silts, sands, shell layers (coquina) and lignites. Beds are centimetre to decimetre-thick, burrows are frequent and paleosols with well delineated root traces are common (below the lignitic layers).

Boundaries: See above (type section)

Thickness and distribution: In the cliffs at Varengeville, where two of its members are seen in superposition, the formation is ~10m thick. The Soissonnais Formation is 10m thick in its stratotype, but according to Bignot et al. (1981) may vary between 8.5 and 11.7m in the stratotypic area.

Regional correlation: Regional correlation of the Soissonnais Formation is extremely difficult based on lithology alone. Until Laurain et al. (1983) discovered that the lignite-bearing clays in the Epernay area were substantially younger than the lignite-bearing clays in the Soissons area, these two deposits, regarded as coeval although their age may differ by up to 2 m.y., were united under the single name of Argiles à Lignites and interpreted as evidence of temporary widespread brackish/lacustrine conditions in the Paris Basin. Our recognition of two distinct formations should encourage a systematic integrated lithologic-sedimentologic-biostratigraphic and chemostratigraphic study of all lignite-bearing clays in order to unravel their stratigraphic relationships.

Biostratigraphic characterization and age: The Soissonnais Formation belongs to the (dinoflagellate) Zone W1 of Chateauneuf and Gruas-Cavagnetto (1978; and may belong in part to Zone Aau of Powell 1992; Table 2, Appendix 2) and to the (charophyte) *Peckichara disermas* Zone (Table 2, Appendix 1).

Genetic interpretation: The finely bedded silts and clays with ripple marks are tidal flat deposits. Cross stratification and coquina-filled incised channels are indicative of tidal erosion. The molluscan fauna (*Ostrea, Corbicula* [the "*Cyrena*" of earlier authors], *Tympanotonos, Melanopsis*, i.al.; see Feugueur 1963) indicates environments of highly variable salinity.

Subdivision: We differentiate three members in the Soissonnais Formation. Their common character is the presence of lignites that may be a major (e.g., Vexin Member) or minor (e.g., Ailly Member) lithologic component.

The Vauxbuin Member

*Name:*From the town of Vauxbuin, near Soissons (Aisne).

Type section: Bignot et al. (1981) described five sections—two quarries, one road trench and two local outcrops—for which they gave a short historical background. We designate the road trench section (at the "les Cailloux" Locality) as type locality of the Vauxbuin Member.

Lithology: The Vauxbuin Member consists of a succession of 1) sands and lignite-bearing clays, 2) shelly sands, and 3) clays rich in "*Cyrena*" and oyster shells (Bignot et al. 1981).

Boundaries: In the type area the sands and lignite-bearing clays rest directly on Thanetian sands. The upper surface of the decalcified Thanetian sands are penetrated by roots, indicating a period of emersion. The upper boundary, unknown at Vauxbuin, is the contact with the base of the Mont-Notre-Dame Formation (= known as Sables de Laon regionally) of the Montagne de Laon Group.

Thickness and distribution: Known to vary between 8.5 and 11.7m around Soissons (= the stratotypic area).

Regional correlation: (see discussion above)

Biostratigraphic characterization and age: This member has yielded plant remains upon which Schimper (1874) based the introduction of the Paleocene Epoch. A few levels of this member have yielded scarce, uncharacteristic charophyte assemblages. However the *Peckichara disermas* Zone was identified at Vauxbuin (Bignot et al. 1981; Riveline 1984, 1986; see Table 2 and Appendix 1). Chateauneuf and Gruas-Cavagnetto (1978) assigned the Argiles à Lignites du Soissonnais to their Zone W1 and remarked on the high abundance of *Apectodinium* spp. in them. Based on this, the Argiles à Lignites du Soissonnais may belong to Zone Aau of Powell 1992 (see discussion below, Table 2 and Appendix 2). Consequently, the Argiles à Lignites du Soissonnais Member is lowermost Eocene.

Genetic interpretation: Lacustrine and swamp conditions are inferred for the basal part of the member. Sediments above reflect increasingly brackish conditions (Bignot et al. 1981).

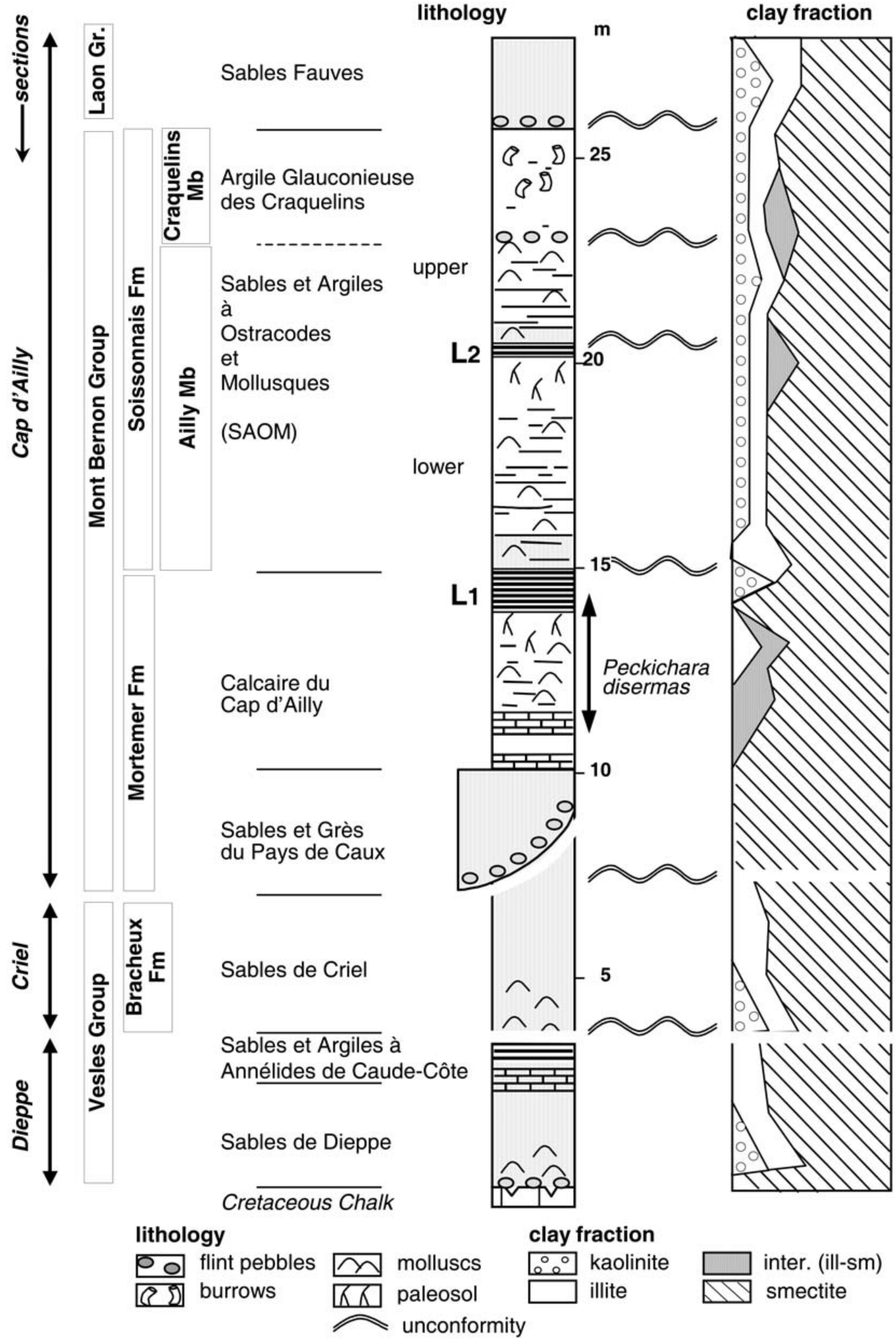
The Vexin Member

In the western part of the basin, along the Seine River Valley and over the Vexin Plateau (between the Bray Anticline and the Seine River), a deposit generally referred to as Fausses Glaises lies directly above the Limay Member. As this deposit has never been recorded lying above sands similar to the Sables d'Auteuil, we believe that this unit is distinct from the Fausses Glaises de Paris. We designate it as the Vexin Member.

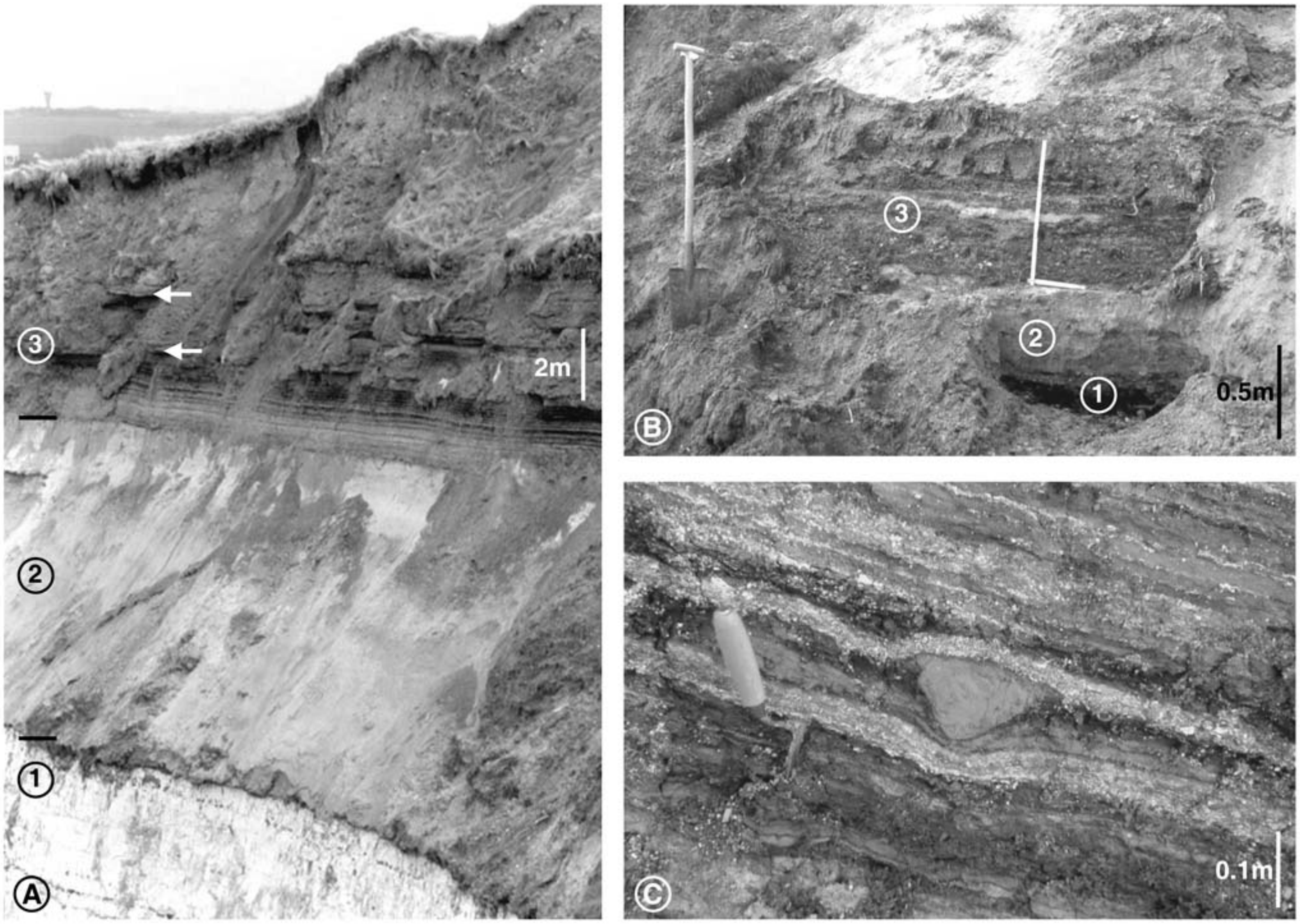
Name: From the region of Vexin français, between the Oise and Seine river valleys.

Type section: Quarry section at Limay (Yvelines), where the Vexin Member overlies the Limay Member (text-figs. 6, 7). This geometry is also seen in neighbouring quarries at Guitrancourt and Porcheville (Thiry 1981).

Lithology: The Vexin Member consists typically in alternating centimeter thick layers of clay, sands and lignites. Clays and sands are often rich in brittle, partly decalcified, mollusc shells and nodules of pyrite. A few, 20-50cm thick, clayey and silty layers also occur, displaying flaser-beddings. Numerous paleosols with root traces occur.



TEXT-FIGURE 11
Composite section of the Mont Bernon Group, Cap d'Ailly (Seine Maritime). Assigned to the lower part of the Mortemer Formation, the Sables et Grès du Pays de Caux rest on the sands of the Vesles Group from which they are separated by an erosional surface. Above, the Calcaire du Cap d'Ailly, the Ailly Member and the Craquelins Member form successive packages separated by erosional surfaces. Note that in these brackish units, as in other correlative brackish deposits of the Mont Bernon Group, the clay fraction is dominated by abundant smectite and interstratified illite/smectite. In contrast, the clay fraction in the correlative continental deposits consists of kaolinite and smectite (compare with text-fig. 5).



TEXT-FIGURE 12
The Ailly Member (photographs: C. Dupuis; scales in figures B and C given by a shovel and a folding measuring stick [figure B] and a trowel [figure C])

(A) Cliff outcrop at Criel. The Ailly Member (3) overlies two units of glauconitic sand. The upper unit forms the Sables de Criel (2) (= Bracheux Formation, Vesles Group) themselves unconformable with the Campanian Chalk (1). The clear bedding of the Ailly Member results from the cyclical alternation of thin layers of coquina (whitish) and clays and silts. The two, prominent, 1m-thick beds (arrows) are indurated oyster coquinas. A prominent stromatolithic bed marks the base of the member.

(B) Cliff outcrop at Varengeville. (1) Lignite L1 underlying the Ailly Member. (2) sands; (3) coquinas with interbedded sands and clays.

(C) Cliff outcrop at Varengeville. Detail view of the Ailly Member showing the cyclical alternation of centimeter-thick layers of coquina, clays and silts. Note the occurrence of a small, compaction-derived, silty channel.

Boundaries: The Vexin Member rests on the Limay Member. The contact is sharp with occasional burrows. This lower boundary is readily delineated in drilling logs by the marked contrast in lithology and color between the two members. The upper boundary of the Vexin Member is always strongly erosive.

Thickness and distribution: The Fausses Glaises du Vexin have often been eroded away during the Lutetian tansgression, and often less than 5m of the original deposit is preserved. However, the member is 12.5m-thick in a corehole at Evecquemont near Meulan (Yvelines) and as much as 18m thick in a corehole in Pontoise (Feugueur 1963) and at Ennery (Lemoine 1937) near Pontoise (Yvelines).

Regional correlation: The Vexin Member is probably a lateral correlative of the Vauxbuin Member.

Biostratigraphic characterization and age: The Vexin Member (recovered from the Montjavoult and Le Tillet Coreholes) belongs to the *Apectodinium hyperacanthum* or *A. homomorphum* (Chateauneuf and Gruas-Cavagnetto 1978). The high abundance of *Apectodinium* spp. (Gruas-Cavagnetto 1968; Table 2, Appendix 1) may indicate Zone Aau of Powell (1992). The macrofauna includes species indicative of brackish conditions, such as the bivalves *Corbula arnouldi, Corbicula* (*Cyrena*) *cuneiformis, C. tellinella, Ostrea sparnacensis, O. bellovacina, Melania inquinata, Tympanotonos funatus, Melanopsis buccinoides* and the fish *Lepidosteus suessoniensis*. Microfossils, as recovered at Guitrancourt, include a few ostracodes (*Vetustocytheridea*) and shallow water benthic foraminifera (*Cibicides*)

Genetic interpretation: The Vexin Member was deposited in marine marshes, partly under tidal influence. It includes true tidal flat deposits as well as tidal channel deposits. The landscape was very low relief. Numerous, extensive paleosols with root traces indicate that large areas were episodically emergent, and transformed into salt marshes. High values of the pollen to dinoflagellate cysts ratio indicates a dominant continental influence and the quasi-monospecific *Apectodinium* assemblages indicate a lagoonal setting with restricted marine influences (Aubry and Chateauneuf 1980).

The Ailly Member

The Sables et Argiles à Ostracodes et Mollusques (SAOM) were described from the Cap d'Ailly section by Bignot (1965). They are described here as the Ailly Member.

Name: From the cliffs at Cap d'Ailly (near Dieppe, Seine maritime).

Type section: Cliffs section at the Cap d'Ailly.

Lithology: The Ailly Member consists of finely laminated clays and large lenses of sands that are extremely rich in molluscs. Dupuis and Steurbaut (1987) and Dupuis (2000) delineated two units separated by a lignitic bed (L2 in text-fig. 11) resting on a 1m-thick matured paleosol (text-figs. 11, 12). The two units are very similar, but the upper one is rich in oysters whereas the lower one yields no or few oysters. The upper unit, decalcified in its uppermost part, consists of green sub-mottled clays with a few beds of oyster-rich limestone. A striking layer of sideritic concretions occurs 1m below its top. In addition stromatolithic encrustings occur. Such encrustings are notably common in the lower part of the upper unit in sections without unit 1 (Dupuis et al. 1998a). Strong lateral variations in thickness and lithology remain poorly documented (Bignot 1965; Destombes et al. 1977). In the section below the Cap d'Ailly lighthouse the base of the lower unit includes sandy tidal bars. In the cliffs at Les Craquelins the Ailly Member exhibit meter-thick sand bars consisting of non disarticulated shells (dominantly *Corbula*).

Boundaries: The Ailly Member overlies the Calcaire d'Ailly (Mortemer Formation) and underlies the Craquelins Member (former argiles glauconieuses inférieures of Bignot 1965). The contact between the Calcaire d'Ailly and the Ailly Member is erosional. Locally Lignitic Bed L1, and eventually the upper part of the Calcaire d'Ailly, were eroded prior to deposition of the Sables et Argiles à Ostracodes et Mollusques. The contact between units 1 and 2 of the member is also an erosion surface.

Thickness and distribution: The Ailly Member extends from the English Channel (outliers of Eu, Saint-Valéry-sur-Somme, Montreuil and Fromessent) to the northeastern part of the Paris Basin (Laon, Holnon and Lihons). Deposits reminiscent of the Sables et Argiles à Ostracodes et Mollusques have been recovered from coreholes in northern Belgium where they are referred to as "Landénien supérieur continental" underlying the Ypresian succession, as in the Ostende Corehole (Feugueur 1963) and the more recent Knokke and Kallo wells (Dupuis et al. 1990). The Sables et Argiles à Ostracodes et Mollusques facies extends also to the Hampshire Basin and has been described from the Newhaven section (Dupuis and Gruas-Cavagnetto 1985).

Regional correlation: The upper part of the Ailly Member may correlate, in part, with the Harwich Formation (Dupuis et al. 1998a) as suggested by the short range of *Nematosphaeropsis* sp. cf. *N. lattivitatus* in both (De Coninck in Dupuis et al. 1998a; Jolley and Spinner 1989).

Biostratigraphic characterization and age: The Ailly Member belongs to (dinoflagellate cyst) Zone W1 (and possibly to part of Zone Aau of Powell 1992) (Gruas- Cavagnetto 1966. 1970; Table 2, Appendix 2).

Genetic interpretation: The Ailly Member is a very shallow lagoonal deposit that records tidal influences.

The Craquelins Member

The argile glauconieuse inférieure of Bignot (1965) and Bignot and Masson (1968) that outcrops at Cap d'Ailly has been described by Dupuis (2000) as the Argile Glauconieuse des Craquelins. It is formally described here as the Craquelins Member.

Name: From the name "Les Craquelins" given to the western part of the cliffs at Cap d'Ailly (near Varengeville, Seine Martitime).

Type section: Outcrops in the cliffs at "les Craquelins" near the Cap d'Ailly lighthouse.

Lithology: The lower part of this non-calcareous member consists of a 1m-thick, dark, reddish clay rich in coarse, dark green, glauconitic grains. Its upper part is a glauconite-free bioturbated sand. It is likely that this deposit is decalcified as C. King (personal communication 1990) has found in it a single, probably apatitic, brachiopod shell. In addition, unidentifiable molds of invertebrate shells are not uncommon.

Boundaries: The Craquelins Member is separated from the underlying Ailly Member by a lag deposit with angular flint flakes and shark teeth, and from the overlying Sables Fauves of the Varengeville Formation by a sharp erosional contact. Locally, the base of the Sables Fauves contains small centimetric well rounded flint pebbles. Such pebbles, known as "galets avellanaires" [hazelnut-like pebbles], occur all over Normandie (e.g., Galets de Saint-Saëns, Fortin in Dollfus 1898), Picardie (Galets de Picardie, Leriche 1909) and far east into the Paris Basin (Galets de Sinceny; Feugueur 1963).

Thickness and distribution: The Craquelins Member is no more than 10m thick. It is known only from the Cliffs at Varengeville. Towards the east, the Sables Fauves (= Mont-Notre-Dame Formation) lie directly on the Ailly Member, the lithologic contact being sharp and erosional. The absence of the Craquelins Member may reflect a major erosional event prior to the deposition of the sands.

Regional correlation: No correlative beds are known from the Paris Basin.

Age: A K-Ar radioisotopic age of 54 Ma has been measured on glauconite (Yans and Dupuis, unpublished).

Genetic interpretation: The clay yields a very diversified dinocyst assemblage indicative of open marine deposition (De Coninck, personal communication 1995), consistent with the richness in glauconite of the clay.

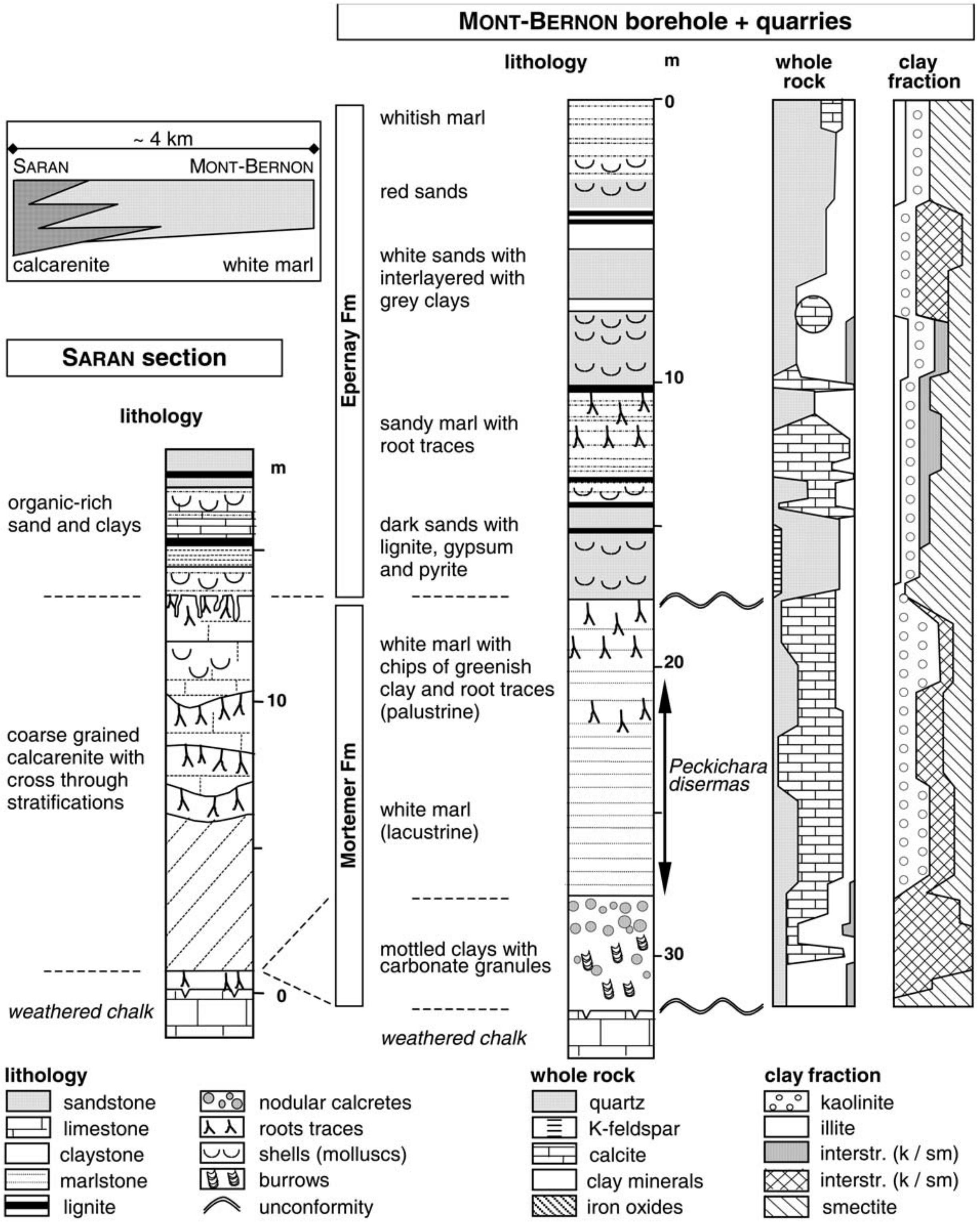
The Epernay Formation

The Epernay Formation is lithologically very similar to the Soissonnais Formation. However, the two formations belong to different biozones and are separated by a ~2 m.y.-long hiatus.

The Argiles à Lignite d'Epernay of Ducreux et al. (1984) is here formalized as the Epernay Formation.

Name: From the town of Epernay (Marne).

Type section: This formation is well exposed at Mont Bernon on the eastern side of the town of Epernay.



TEXT-FIGURE 13
Composite section of the Mont Bernon Group, Mont Bernon (Marne). The Epernay Formation rests on the Mortemer Formation. The contact is sharp and disconformable in the section at Saran (Marne) where a paleosol directly overlies the calcarenites of the Mortemer Formation and where the uppermost calcarenites show karst-related dissolution features and are penetrated by burrows. The clay fraction of the basal mottled clays and the white marls in the corehole consists of abundant interstratified kaolinite-smectite minerals, a characteristic of the Sparnacian paleosols and flood plain deposits of the Paris Basin. The Epernay Formation consists of illite and interstratified illite-smectite, an assemblage that is characteristic of the Sparnacian brackish deposits. The interstratified kaolinite-smectite association in the white sands that occur between 5 and 6.50m in the Epernay Formation is indicative of direct inheritance from proximal continental materials. The Saron section shows the rapid lateral facies variations in the Eastern border of the basin, as illustrated by the multitude of informal "formations" that have been named in this area.

Lithology: The Epernay Formation consists of alternating clays, sands and lignites, often rich in molluscs, interlayered with paleosols with root traces. The thickness of discrete layers varies from 0.1 to 1.0m.

Boundaries: In the Mont Bernon Corehole (Laurain et al. 1983), the contact between the Epernay Formation and the underlying Marnes Blanches du Mont Bernon (Calcaire de Mortemer Formation) is sharp. In the nearby outcrop of Saran the contact is an indurated and bioturbed horizon indicative of a discontinuity (text-fig. 13).

The Epernay Formation is unconformably overlain by the Sables à Unios et Térédines. These are coarse fluviatile sands, with cross-bedding, forming a regressive sequence whose chronostratigraphic position is poorly established.

Thickness and distribution: The thickness reaches over 20m.

Regional correlation: Based on dinoflagellate stratigraphy, the Argiles à Lignites d'Epernay are, at least in part, correlative with the Fausses Glaises that occur in the Paris area (La Défense Corehole, Pont de Puteaux Corehole) in association with the Sables d'Auteuil (see below). Chateauneuf and Gruas-Cavagnetto (1978) have assigned the Fausses Glaises recovered from the Pont de Puteaux Corehole to the *Wetzeliella meckelfeldensis* Zone and noted the presence of *Dracodinium varielongitudis* in the La Défense Corehole. We describe the Sables d'Auteuil and the Fausses Glaises de Paris which constitute a characteristic lithologic succession in the Paris area as members of the Epernay Formation.

Biostratigraphic characterization and age: The Epernay Formation belongs to the (charophyte) *Peckichara piveteaui* Zone and the (dinoflagellate) *Wetzeliella meckelfeldensis* Zone (Laurain et al. 1983; Riveline 1984, 1986; Lecomte 1994; Gruas-Cavagnetto 1968, 1976a; See Table 2, Appendices 1, 2). The formation includes several well known mammal-bearing localities, in particular those of Avenay and Mutigny, the latter assigned to Zone P/E IV (Hooker 1996; see Table 2).

The Argiles à Lignites d'Epernay at Mont Bernon were designated as stratotype of the Sparnacian Stage (Dollfus 1905). In fact the Argiles à Lignites d'Epernay are younger than any other deposit of the Mont Bernon Group, and belong to the Ypresian Stage *s.s.* (see Aubry et al. 2003).

Genetic interpretation: The Epernay Formation was deposited under brackish conditions in maritime marshes and tidal flat environments. It result from the stacking of microsequences that comprise marginal marine deposits (coquinas) at their base and becoming increasingly more brackish upwards (as shown by the succession of charophyte-bearing limestones and lignites). In the upper part of the formation, the microsequences are topped by paleosols indicating mangrove conditions (with *Nipa* palms). The sedimentary environment was changing from maritime marshes, to bogs and swamps, to wandering fluviatile channels fringed with ripparian forests. The paleolandscape was very flat, and even tiny changes in sea-level would have affected landscapes far inland, resulting in the alternation of sequences more marine in facies with sequences more continental in facies.

Subdivisions: In the Paris area, two members can be differentiated within the Epernay Formation (text-fig. 3). Their common character is the presence of lignites that may be a major (Paris Member) or minor (Auteuil Member) lithologic component.

The Auteuil Member

Name: From the town of Auteuil in the suburbs of Paris (Seine). The Sables d'Auteuil were first mentioned by Hébert (1854) and their lithostratigraphic position specified by Planté (1869). They are well described in Feugueur (1963).

Type section: Auteuil, a suburb of Paris (Seine). The Auteuil Member outcrops in the southwestern part of Paris, where numerous sections were described in the late 19th and early 20th centuries.

Lithology: The member consists of black, coarse, plant remains-rich sands, with nodules of pyrite.

Boundaries: The Auteuil Member is known only from coreholes in the Paris area. It is always intercalated between the Vaugirard Formation and the Paris Member.

Thickness and distribution: The thickness of this member varies between 0.5 and 10m (Soyer 1953).

Regional correlation: The Auteuil Member was thought to correlate with the fluviatile coarse sands of the Arkose de Breuillet to the south and the Argiles à Lignites du Soissonnais to the north (Soyer 1953, Feugueur 1963). However, Chateauneuf and Gruas-Cavagnetto (1978) have shown them to correlate broadly with the lithologic units that we assign here to the Montagne de Laon Group.

Biostratigraphic characterization and age: Shallow marine faunas were first reported by Cayeux (1905) and Combes (1905) and have been reinvestigated several times since. These include *Cyrena cuneiformis, Potamides* sp., *Melasia*, sp., *Teredina oweni*, *Ditrupa* and *Membranipora*. Plant remains also occur, notably *Sequoia langdorfi* Heer. Chateauneuf and Gruas-Cavagnetto (1978) reported the occurrence of *Dracodinium varielongitudis* in the Sables d'Auteuil.

Genetic interpretation: The Sables d'Auteuil are brackish deposits. They were most probably deposited in an estuary that was fed by rivers flowing in the basin from the south.

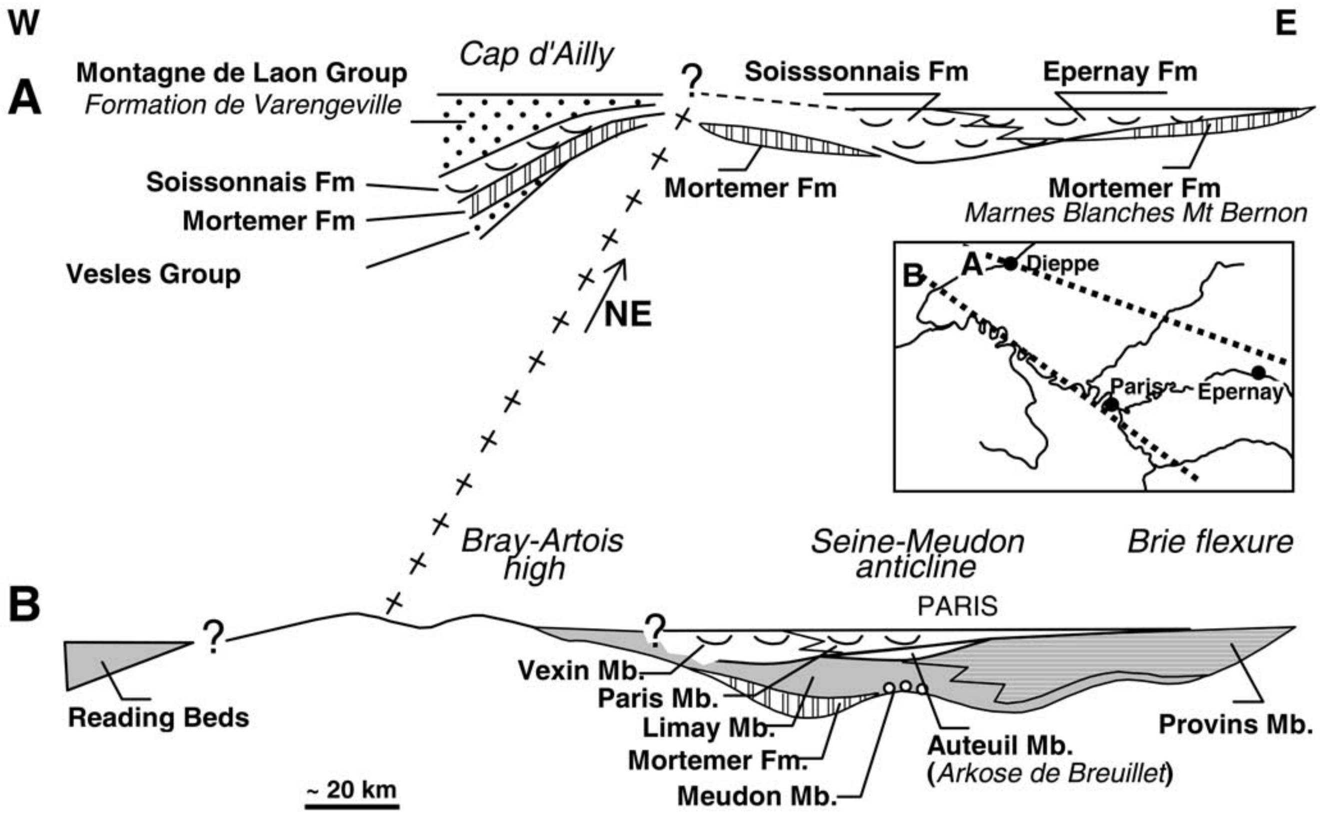
The Paris Member

Cuvier and Brongniart (1811) introduced the term Fausses Glaises for organic-rich, fossil-bearing sandy clays that, in the Paris area (e.g., Faubourg de Vaugirard Quarry and numerous coreholes in Paris and its suburbs), occur in succession with a sandy layer (here attributed to the Auteuil Member, see above) and the Vaugirard Formation. The term 'Fausses Glaises' has been correctly used to designate the lignitic deposits that overlie the Auteuil Member, in particular in the La Défense Corehole (Chateauneuf and Gruas-Cavagnetto 1978).

Name: From the city of Paris.

Type section: The Paris Member has been well described during the 19th century when the clays were excavated from numerous quarries for brickwork, and in particular from the Quarry of the Faubourg de Vaugirard, in the southern part of the city.

Lithology: The Paris Member consists of alternating grey clays, sands and lignites, with coquina beds.



TEXT-FIGURE 14
Upper Paleocene-Lower Eocene lithostratigraphic succession in the Paris Basin. The geometric relationships between the main formations of the Mont Bernon Group are best established in the Paris area. As seen in coreholes and outcrop exposures the mammal-bearing Meudon Member underlies the Limay Member, itself overlain by the Provins Member. Westward of Paris the Vexin Member overlies the Limay Member, itself overlying the Mortemer Formation. In Paris, the Auteuil Member is intercalated between the Provins Member and the Paris Member. In the west, in the Cap d'Ailly area, the marine glauconitic sands of Dieppe and Criel (Vesles Group, Châlons-sur-Vesles Formation and Bracheux Formation, respectively) underlie the fluviatile sands, marls and lacustrine limestones of the Mortemer Formation, itself overlain by the Ailly Member. In the east, the Marnes Blanches du Mont Bernon (= Mortemer Formation) underlie the Epernay Member. The Bray-Artois high thus separates two depositional provinces (Dupuis 1979). One is centered over Dieppe in the west, the other is stretched between Paris and Epernay in the east.

Boundaries: The lower boundary is conformable, and corresponds to a gradual transition from the Auteuil Member to the Paris Member. The upper boundary is generally well defined and erosive. The Paris Member is overlain either by sands from the Montagne de Laon Group or by the Glauconie Grossière of Lutetian Age (middle Eocene).

Thickness and distribution: The member averages 4 to 5m in thickness. However, it reaches a thickness of 10 to 12m in several coreholes drilled in Paris (Soyer 1953).

Regional correlation: Finely laminated, clayey deposits interlayered with fine sands and lignites are widespread in the Paris Basin, and such lithologies constitute also the bulk of the (older) Soissonnais Formation. The lateral correlations of the member are thus difficult to establish confidently, unless in stratigraphic succession with the Auteuil Member.

Biostratigraphic characterization and age: The Paris Member, well dated in the La Défense and Pont de Puteaux coreholes, belongs to (dinoflagellate) Zone W3 (Gruas-Cavagnetto 1976a, Chateauneuf and Gruas-Cavagnetto 1978) (Table 2, Appendix 2).

Genetic interpretation: The Paris Member is a brackish deposit. The clays, finely laminated with flaser, represent tidal flat deposits. The coarser sands, rich in brackish molluscs, were deposited in tidal channels. Lignites, up to 1m-thick, are associated with levels rich in root traces, corresponding to poorly evolved paleosols.

RELATIONSHIPS BETWEEN THE FOUR FORMATIONS OF THE MONT BERNON GROUP

The geometric relationships between the formations and members described above are not yet satisfactorily elucidated. This is because of the limited vertical extent of the Mont Bernon Group outcrops and the sharp lateral facies variations, problems that have plagued stratigraphy in the Paris Basin since its inception (Cuvier and Brongniart 1822; Brongniart 1929; Prévost 1832; Hébert 1854; Dollfus 1880; Leriche 1904; Feugueur 1963; Broekman 1978; Bignot et al. 1980; Ducreux et al. 1984; Dupuis et al. 1986; Dupuis and Steurbaut 1987; Cavelier 1987). Indeed, the distinction by Dollfus (1880) of a stratigraphic unit (the Sparnacian) sandwiched between the Thanetian and Cuisian deposits was contested by Leriche (1904, 1905) who saw in the "Sparnacian" deposits no more than lateral equivalents of the Cuisian deposits (based on the principle of sedimentary cycle). An important aspect of Dollfus's work is that, together with Prestwich (1850, 1852, 1854) in England, he recognized the importance of erosional surfaces separating onlapping sedimentary packages (the now familiar 'sequence'; see Aubry 2000).

The most complete accessible lithostratigraphic succession through the Mont Bernon Group is in the outcrops of the Cap d'Ailly and Dieppe (text-figs. 11, 12), where its contacts with the Vesles Group (in the cliffs along the English Channel at Dieppe and Criel) and Montagne de Laon Group (in the cliff at Cap d'Ailly) occur, and in the Mont Bernon Corehole-outcrop composite section (text-fig. 13) which comprises a corehole drilled on the occasion of the 26th International Geological Congress in Paris (1980) and a rehabilitated complementary outcrop section (Laurain et al. 1983).

The Cap d'Ailly section

The Mortemer Formation, corresponding to the Calcaire d'Ailly, is overlain by the Soissonnais Formation represented by the Ailly Member and the Craquelins Member. The upper part (above lignitic bed **L2)** of the Ailly Member may be correlative with the Vexin Member.

The multiple outcrops of the Cap d'Ailly section allow us to distinguish four depositional sequences in this lithostratigraphic succession (Dupuis et al. 1998a; Dupuis 2000) (text-fig. 11). The lowest sequence comprises the Sables et Grès du Pays de Caux and the Calcaire d'Ailly of the Mortemer Formation, and ends with lignitic Bed **L1**. The Ailly Member comprises two sequences separated by lignitic Bed **L2** at the top of the lowest sequence. The Craquelins Member is clearly unconformable with the Sables Fauves (= lower part of the Formation de Varengeville [Leriche 1939]) of the Montagne de Laon Group). Its upper surface is erosional and the base of the Sables Fauves Formation is characterized by an occurrence of rounded pebbles (the so-called "galets avellanaires", =hazelnut-like pebbles).

The Mont Bernon composite section

The lower part of the Mont Bernon Corehole consists of about 3m of red and ochre mottled clay with calcrete nodules equivalent to the Marnes à Rognons and thus assignable to the Mortemer Formation (text-fig. 13). This clay is overlain by a 10m-thick lacustrine to brackish, white and greenish, charophyte-bearing marl which comprises several layers with burrows and root traces. This is typical of the Mortemer Formation. It is overlain by 15m of organic-rich sands, clays, lignites and marls of the Epernay Formation. Paleosols are frequent. Shelly sands and marls indicate deposition in a brackish to shallow marine environment.

Geometric relationships through the basin

The numerous sections and coreholes that we have examined over the years (Thiry 1981; Dupuis and Steurbaut 1987; Thiry and Dupuis 1998) are the basis for the stratigraphic relationships that we propose here between formations and members (text-fig. 14). Several lateral deposits, mainly fluviatile but also brackish, estuarine and deltaic sands, are omitted from it. In particular, we do not show the stratigraphic position of the Falun de Pourcy and Sables à *Unio* et Térédines (Dollfus 1903) that are local deposits in the eastern part of the basin, or that of the relatively extensive Sables et Argiles de Sarron (Hébert 1855) and Sables de Sinceny (Dollfus 1877) that occupy the area between the Oise and Marne River valleys. This is essentially because their lateral correlations with any particular member within the Argiles à Lignites formations remain equivocal.

MAGNETOBIOSTRATIGRAPHIC CORRELATIONS AND CHRONOSTRATIGRAPHIC FRAMEWORK

Correlations within the Mont Bernon Group are difficult even within distances of a few tens of kilometers not only because of abrupt lateral and vertical facies variations that render lithostratigraphic correlations difficult (see above), but because these abrupt changes in facies result in an uneven distribution of biostratigraphic markers. Until the late 1960s, correlations within the Mont Bernon Group were based mostly on lithologic similarities following the principle of sedimentary cycle, with some support from characteristic molluscan assemblages (Feugueur 1963). Although Broekman (1978) demonstrated that the concept of sedimentary cycle failed to explain the lateral and vertical succession of lower Paleogene deposits in the northern part of the Ile de France, and introduced the concept of succession of sedimentological sequences to interpret them, revision of the long-accepted lower Paleogene correlations (mainly based on Feugueur's work, 1963) was slow. Initiated through dinoflagellate cyst stratigraphy (Chateauneuf and Gruas-Cavagnetto 1978), the new correlation scheme has been progressively constructed based on incremental biostratigraphic findings that conflicted with the sedimentary cycle model. A detailed history of these findings is given in Cavelier (1987) and tentative correlations have been proposed for the sections exposed along the English Channel (Dupuis et al. 1998b).

The Mont Bernon Group cannot be described in terms of a biozonal succession, and indeed no biozonal boundaries seem to have been delineated in any of its formations due to the sporadic distribution of fossil groups in highly variable lithologies, reflecting deposition in unstable marginal environments. In many stratigraphic sections, disjunct intervals can be assigned to biozones based on unrelated paleontologic groups. Charophyte and dinoflagellate cyst stratigraphies provide reasonably tight constraints complemented by additional control from mammals. However, the multiplication of lithologic terms (long regarded of chronostratigraphic value) has created a confusing situation, greatly exacerbated until relatively recently by imprecise stratigraphic description of sections, insufficient reference to the exact level(s) in which paleontologic data were recorded and by the common use of indirect correlations, often involving circular reasoning, to reach (otherwise impossible) biozonal assignments. Thus despite relatively numerous paleontological studies, only a limited amount of data is useful for firm interpretation of stratigraphic sections and their correlations (Table II).

Charophytes

Charophytes have been successfully used for correlation between the eastern and western parts of the Paris Basin (Riveline 1984; 1986), based on a tripartite zonal subdivision (Riveline 1983; Riveline et al. 1996) apparently applicable to European Upper Paleocene-Lower Eocene (upper Thanetian to lower Ypresian) lacustrine and brackish deposits. The bulk of the charophyte-bearing deposits of the Mont Bernon Group belongs to the *Peckichara disermas* Interval Zone defined as the interval between the lowest occurrence (LO) of the latter species and the LO of *Peckichara piveteaui*. The Mortemer Formation (e.g., Marnes Blanches du Mont Bernon and Calcaire d'Ailly up to the lower part of Lignite **L1**; Marnes à Rognons below the Limay Member) belong to this zone (Appendix 1). The younger charophyte-bearing deposits in the group are the Epernay Formation (e.g., Mont Bernon and Saran sections) which belongs to the *Peckichara piveteaui* Zone.

As recognized by Riveline (1986), there are problems with the strict application of the Thanetian to Ypresian charophyte zonal definitions to the Paris Basin sedimentary record, and zonal characterization often requires the use of secondary markers. In particular, the ranges of *Peckichara disermas* and *P. piveteaui* are disjunct. Riveline (1986) has thus differentiated three biostratigraphic intervals in the *Peckichara disermas* Zone. The upper part of the zone is recognized by the occurrence of secondary markers (*Harrisichara leptocera, H. triquetra* and *Maedleriella lehmani*), whereas the occurrence of *Grovesichara boureaui* and/or *Peckichara microcarpa* are/is indicative of the lower part of the zone (Appendix 1). Both the Marnes Blanches in the Mont Bernon Corehole and the Calcaire d'Ailly appear to belong to the middle part of the *Peckichara disermas* Zone, which would indicate that these two members are correlative, thus supporting our assignment of both to the same formation. Also, this is in agreement with our assignment of the Marnes à Rognons which belong to the lower part of the *P. disermas* Zone (Banthelu, Guitrancourt, see Appendix 1), to the Mortemer Formation.

Dinoflagellate cysts

Dinoflagellate cyst stratigraphy has contributed decisive information for elucidating the correlations between the Thanetian to Ypresian deposits of the Paris Basin with those in other parts of northwestern Europe. Despite Chateauneuf and Gruas-Cavagnetto's landmark paper (1978), data published on dinoflagellate cyst occurrences in the Paleogene deposits of the Paris Basin are scattered in the literature, and emphasis is often placed on paleoenvironmental (landscape) reconstructions using dinoflagellate cysts and spores and pollen rather than on stratigraphic correlations. Chateauneuf and Gruas-Cavagnetto (1978) used three main biozones, previously defined by Costa and Downie (1976), to subdivide the Thanetian-lower Ypresian stratigraphic succession in the Paris Basin. These are the *Apectodinium homomorphum* Zone (W1; = interval from the lowest occurrence (LO) of *Apectodinium* spp. to the LO of *Wetzeliella astra*), the *Wetzeliella astra* Zone (W2; = from the LO of *W. astra* to the LO of *W. meckelfeldensis*) and the *W. meckelfeldensis* Zone (W3; from the LO of the nominate taxon to the LO of *Dracodinium simile*). These authors established that the bulk of the Sparnacian deposits, including the Sables de Sinceny, Argiles à Lignites du Soissonnais and Fausses Glaises du Vexin (= Soissonnais Formation) belong to Zone W1, but remarked that the Fausses Glaises de Paris (= Epernay Formation) overlying the Sables d'Auteuil in the Paris area belong to Zone W3 (and younger). This, to some extent, foretold the discovery that the (stratotypic) Argiles à Lignites d'Epernay in the eastern part of the Paris Basin also belong to that zone (Laurain et al. 1983).

While Zones W2 and W3 still serve as references, multiple biozonal schemes have been proposed to subdivide the *A. homomorphum* Zone (e.g., Costa and Manum 1988, Powell 1992; Bujak and Mudge 1994; Mudge and Bujak 1996) but no attempt has been made to refine correlations within the Sparnacian succession based on these revisions. Immediately at the Paleocene/Eocene boundary (as defined by the so-called "Carbon Isotope excursion (CIE)", Aubry et al. 2002), North Atlantic dinocysts assemblages are characterized by the sudden and oldest acme of *Apectodinium* spp. (Bujak and Brinkhuis 1998). This oldest acme was used by Powell (1992) to subdivide the *A. homomorphum* Zone *sensu* Chateauneuf and Gruas-Cavagnetto (1978) into 3 zones, respectively the Ahy, Aau and Gor Zones. The *Apectodinium augustum* (Aau) Zone, defined by the LO of the nominate taxon, is characterized by the acme of species of *Apectodinium* to which the nominate taxon is essentially restricted; this interval corresponds to Subzone P5b of Bujak and Mudge (1994) and Mudge and Bujak (1996) and Subzone D5a of Costa and Manum (1988). There are problems in delineating this zone in the Paris Basin. First, the nominate taxon has not been recorded at any level in the Paris Basin. Powell et al. (1996) explained its similar absence from the London Basin as reflecting the species restriction to offshore conditions. These authors proposed to use the beginning of the *Apectodinium* acme (in which the *Apectodinium* complex constitutes at least 34.5% of an assemblage) to delineate the base of the zone. Second, the *Apectodinium* acme is not unique to the Paleocene/Eocene boundary. Younger acmes occur in Chron C24 (Bujak and Brinkhuis 1998). Yet, an *Apectodinium* acme can serve to constrain the oldest possible age (i.e., Powell's Zone Aau) of a North Atlantic deposit in which it occurs (Bujak and Brinkhuis 1998). Third, dinoflagellate cyst counts are not available for all localities in the Paris Basin from which *Apectodium* species are reported (Appendix 2). However, cross references and comparisons between assemblages from different localities have proven very useful. Fourth, dinoflagellate cyst assemblages are often rare and little diversified in the shallowest marine deposits of the Mont Bernon Group. In such circumstances, it is not possible to characterize an acme, except by assuming that monospecificity of a scarce assemblage is a trademark of an acme.

The Soissonnais Formation has yielded dinocyst assemblages consisting of up to 80 to 90 % of *Apectodinium* species (Chateauneuf and Gruas-Cavagnetto 1978). Similarly, rich *Apectodinium* assemblages characterize the lignitic sands recovered from the Cuise-la-Motte Corehole, the Sables d'Auteuil from the La Défense Corehole, the Vexin Member in the Guitrancourt Quarry, the Sables de Sinceny and the Sables et Argiles à Ostracodes et Mollusques at Ailly (Appendix 2). The lignitic, silty clays recovered from the Hogues (between 23.50 and 22.50m) and the Tillet (between 141.85 and 155.95m) Coreholes (Chateauneuf and Gruas-Cavagnetto 1968; Chateauneuf 1971; Appendix 2) are also extremely rich in *Apectodinuim* spp. Indeed, Gruas-Cavagnetto (1974) remarked that the "blooming" of *Apectodinium homomorphum* is the mark of the Sparnacian. However, this characterization is misleading in as much as the *Apectodinium*-rich Sables d'Auteuil belong to the Ypresian Argiles à Lignites d'Epernay.

As noted above, *Apectodinium augustum* does not occur in the Anglo-Paris Basin. Where it occurs, *A. augustum* is part of a widespread acme of *Apectodinium* species, the oldest in a succession of earliest Eocene acmes (Bujak and Brinkhius 1998). Whereas, alone, an acme of *Apectodinium* may not characterize Zone Aau, it indicates, at least, that the Argiles du Soissonnais and other Sparnacian deposits with *Apectodinium* acmes cannot be older than Zone Aau.

We note that there is no evidence for dinocyst-bearing deposits assignable to the Gor Zone in the Paris Basin. There are no known records in this basin of the *Leiosphaeridia* spp. acme and of the *Deflandrea oebisfeldensis* abundance events documented from the Harwich Formation (Powell et al. 1996) and the North Sea (Bujak and Mudge 1994; Mudge and Bujak 1996). Dinoflagellate cysts are facies dependent and the absence of marker species may not have biostratigraphic significance. However, because the Early Eocene depositional environments in the Paris and London basins were similar, the absence of evidence for the Gor Zone may indicate a stratigraphic gap.

The Epernay Formation and the Paris Member belong to Zone W3. This formation is younger than the Sables de Laon (= Mont-Notre-Dame Formation herein) that belong to the *Wetzeliella astra* Zone (= W2; Chateauneuf and Gruas-Cavagnetto 1978).

Calcareous nannofossils

Calcareous nannofossils do not provide zonal assignments for the Mont Bernon Group, but they provide age constraints, particularly at its base. The youngest Thanetian marine sands in the western part of the Paris Basin below deposits of the Mont Bernon Group belong to Zone NP9. This zone has been identified in the Sables de Bracheux s.st. (i.e., from the locality of Bracheux; Aubry 1983, 1986), in the Sables de Criel at Criel (Dupuis and Steurbaut 1987) and in the Marnes de Marquéglise at Rollot (Bignot et al. 1994; Steurbaut 1998). In the eastern part of the basin, the youngest marine deposits datable by calcareous nannofossils belong to Zone NP8 (Janin and Bignot 1993; Aubry, Thiry and Cavelier, unpublished data). This implies that the Sables de Rilly (decalcified facies of the Sables de Châlons-sur-Vesles) probably do not correlate with the Sables de Bracheux s.s. (= Zone NP9), as has often been thought (see for instance Hooker 1996, text-fig. 3).

Direct correlations between dinoflagellate cyst and calcareous nannofossil stratigraphies (e.g., in the Formation de Varengeville: Chateauneuf and Gruas-Cavagnetto 1978 and Aubry 1985) indicate that the Argiles à Lignites d'Epernay Member is correlative with Zone NP11. They also indicate that the Sparnacian deposits s.s. (= Vaugirard Formation, Mortemer Formation and Soissonnais Formation) fall in the time interval of (calcareous nannofossil) Biochron NP9 (late part) to Biochron NP10 (although it may not represent it entirely).

Mammals

The Meudon Member is the best known lithostratigraphic unit of the Mont Bernon Group. It is assigned to Reference Level (RL) MP7 or RL MP7-8 by different authors (Schmidt-Kittler 1987; Hooker 1991; Lucas 1998). In an attempt to refine stratigraphic resolution in the interval of RL MP7 to MP8-9, Hooker (1996) subjected to parsimony analysis the faunas from the NW European localities assigned to these reference levels. This led him to establish 5 zones (PEI to PEV). The mammal faunas from the Mont Bernon Group fall into two zones. The faunas from Meudon (Meudon Member), Soissons (Soissonnais Formation) and possibly Sinceny (Sables de Sinceny = ?Auteuil Member) belong to Zone PEII, whereas the fauna from Pourcy (within the Epernay Formation) belongs to Zone PEIII.

Magnetostratigraphy

To date, magnetostratigraphic investigations have been restricted to three sections, the cliff section at the Phare d'Ailly near Varengeville in the western part of the Paris Basin, the underground outcrop in Meudon near Paris and a Thanetian through lower Ypresian section near Therdonne. While the "Sparnacian" interval at Therdonne has yielded no interpretable magnetic results (Ali 1989), reversed polarity (Chron C24r) characterizes the Conglomérat de Meudon Member (Russell et al. 1993).

Only the upper (17m) part of the Formation de Varengeville, equivalent to King's (1981) lithologic divisions A1b, A2, A3 and B1 have been investigated (Ali 1989; Ali et al. 1993). The formation is of reversed polarity (Chron C24r), except for a thin interval (represented by two sampled sites) with normal polarity at the base of the section (Division A1b). Flynn and Tauxe (1998) have raised the possibility that this normal polarity interval correlates with a thin normal polarity interval in the Wasatchian Bighorn Basin sequence (Tauxe et al. 1994).

Discussion

The Mont Bernon Group

The bewildering diversity of lithologies within the Mont Bernon Group contrasts sharply with its biostratigraphic uniformity. It is clear that the Mont Bernon Group consists of two main units. One unit corresponds to the Epernay Formation, belongs to the charophyte *Peckichara piveteaui* Zone, the dinoflagellate cyst *Wetzeliella meckelfeldensis* (W3) Zone and the Mammal Zone PE III, and correlates with (calcareous nannofossil) Zone NP11. The other unit comprises all the other lithologies assigned to the group. It belongs to the (charophyte) *Peckichara disermas* Zone, (dinoflagellate cyst) Zone W1 and (mammal) Zone PE II. It is characterized by assemblages extremely rich in *Apectodinium* spp., which indicates an age at least as young as the base of Powell's Zone Aau (=the oldest Eocene acme of *Apectodinium* spp.). This acme has been shown through indirect correlation (Crouch et al. 2000; Crouch et al. 2003) to be correlative with the upper part of (calcareous nannofossil) Zone NP9 (upper part; Subzone NP9b of Aubry 1999) and correlative with the CIE.

This age dichotomy is suggestive of a sedimentary discontinuity between the two units. There are several lines of evidence that support such a discontinuity. First, a lithologic boundary that is also a (multiple) biostratigraphic boundary is likely to correspond to a disconformable contact (see discussion in Aubry 1995). Second, the incomplete recovery of a zonal succession in the Paris Basin from Zone Aau to Zone W3 (see above) is suggestive of a stratigraphic gap. Such a gap is clearly expressed in the Saran section (text-fig. 13) by the indurated horizon at the top of the Marnes Blanches (see above). It is also expressed in the Mont Bernon composite section (text-fig. 13) by the sharp contact between the Marnes Blanches (Zone W1) and the Epernay Formation (Zone W3), as already suggested by Cavelier (1987). Third, sequence boundaries can be delineated between the two units. In the Dieppe area, a striking erosion surface clearly separates the Ailly and Craquelins members (= Soissonnais Formation) from the Formation de Varengeville (correlative with the Epernay Formation) (text-fig. 11). This erosion surface deeply incises the underlying Craquelins Member which is lacking eastward in the basin. In some places the onlap is marked by massive reworking, as in the Hogues Corehole (at ~22m; Chateauneuf 1971).

Relationship between the lower Mont Bernon Group and the Sparnacian Stage

Of the two units differentiated in the Mont Bernon Group, the younger (Epernay Formation) correlates with the Formation de Varengeville, part of the London Clay Formation and the Cuisian Sables d'Aizy (= Zone NP11, Aubry 1983, 1986). This upper unit is Ypresian in age. In contrast, the older, lower Mont Bernon Group is referred to as Thanetian in age in the literature, and it is directly correlatable with the Woolwich and Reading

TABLE 3
Lithostratigraphic correlations between the Upper Paleocene-Lower Eocene successions in the Paris, London and Belgium basins.
CIE= Carbon Isotopiqe Excursion, criterion for global correlation of the Paleocene/Eocene boundary. Location in the Paris Basin from Thiry et al. 1998; in the London Basin from Sinha (1997); in the Belgium Basin from Magioncalda (2004).

LITHO	PARIS BASIN		LONDON BASIN		BELGIUM BASIN		BIOSTRAT	STAGES
MONTAGNE DE LAON GROUP	ARGILE DE LAON Fm		THAMES GROUP	WITTHER Fm	IPPER GROUP			YPRESIAN
	CUISE Fm	EPERNAY Fm		LONDON CLAY Fm			W3 Pp NP 11	
	MONT NOTRE-DAME Fm						NP 10b	
MONT BERNON GROUP	SOISSONNAIS Fm	Craquelins Mb Ailly Mb Vexin Mb Vauxbuin Mb		HARWICH Fm		Zoult Silt Mb		SPARNACIAN
	VAUGIRARD Fm	Provins Mb Limay Mb Meudon Mb	LAMBETH GROUP	WOOLWICH - READING Fms	LANDEN GROUP	TIENEN Fm	Pd W1	
	MORTEMER Fm	← CIE		←		←		
VESLES GROUP	BRACHEUX Fm		THANET GROUP	UPNOR Fm		BOIS GILLES SAND Fm	NP 9	THANETIAN
	CHALONS-SUR-VESLES Fm			THANET SAND Fm		HANNUT Fm	NP 8	
	MOULIN COMPENSÉ Fm						NP 6-7	

formations, based on molluscan faunas, dinoflagellate cysts and charophytes. It corresponds exactly to the Sparnacian Stage as defined by Dollfus (1880).

Our introduction of the Mont Bernon Group recognizes the complexity of the facies changes during the late Thanetian and early Ypresian, when the Paris Basin was the setting of migrating marshes, lakes and shallow seas (Gruas-Cavagnetto et al. 1980; Thiry 1981; Laurain et al. 1983; Dupuis et al. 1982, 1984). It recognizes also their repetitiveness. The Argiles à Lignites facies are the best examples of such repetitiveness, not to mention the Argiles with *Ostrea bellovacina*, long thought to be restricted to the "Sparnacian" (pre-1983 concept) unit, but now recognized to occur in Ypresian levels as well. We stress here that there is no diachrony *per se* of the Argiles à Lignites facies in the Mont Bernon Group. The Epernay Formation belongs to a different relative sea level cycle than the Soissonnais Formation, from which it is separated by a main sequence boundary. A similar situation occurs with regard to the older carbonate-rich lithologies. In the Oise River Valley, carbonate-rich lithologies (= Mortemer Formation) overlie the youngest marine Thanetian (Marnes de Marquéglise, Zone NP 9) and are restricted to the (Charophyte) *Peckichara disermas* Zone. Instead in the Reims area, carbonate-rich deposits belong to both that zone and the *Sphaerochara edda* Zone (Thanetian). These carbonate-rich deposits belong to both the Vesles and the Mont Bernon groups. Carbonate deposition thus started earlier and lasted longer in the eastern part of the basin than elsewhere (Dupuis et al. 1986).

The Mont Bernon Group includes both the deposits that Dollfus (1880) included in his "Sparnacian" by definition and those that served to stratotypify it (Dollfus 1905). Multiple concepts have evolved behind the term "Sparnacian". Originally intended to describe a chronostratigraphic unit, the term acquired a second meaning as it served to designate a group of faunas of a particular age, in a fashion that is reminiscent of the "Land Mammal Ages" erected by American vertebrate paleontologists (e. g., Russell et al. 1982; Hooker 1996). As the Ypresian age of the stratotypic Argiles à Lignites d'Epernay was discovered, several authors used the term "Sparnacian" for facies designation. Authors who retained a chronostratigraphic meaning for the term offered several solutions, either extending it, restricting it to the "pre-Cuisian" deposits (Cavelier and Pomerol 1986), or to its stratotype (Hooker 1998). Based on the exceptionally strong and consistent definition that Dollfus had repeatedly given of his Sparnacian Stage, as well as on the clear correlations he established with the English succession (Woolwich-Reading Beds), Aubry (2000) questioned the significance given to Dollfus's stratotype (1905) and remarked that the restricted definition by Cavelier and Pomerol (1986) is that of Dollfus (1880). She thus proposed to respect Dollfus's (1880) original definition of this stage and to dismiss the Mont Bernon stratotype.

Our introduction of the Mont Bernon Group, which includes both the unit on which Dollfus based the Sparnacian Stage and its stratigraphically disjunct stratotype, should help clarify the terminology for the Upper Paleocene-Lower Eocene stratigraphic record of the Paris Basin. It should also ease the controversy regarding the potential reintroduction of the Sparnacian Stage as the oldest stage of the Eocene Series (Aubry et al. 2003). We show here that Dollfus's Sparnacian Stage is the lower unit of the Mont Bernon Group (=lower Mont Bernon Group), bounded at the base and top by well marked unconformities (indeed, it forms a synthem), and is biostratigraphically well characterized.

Correlation of the Mont Bernon Group with the lithostratigraphic units in the Hampshire-London Basin and in Belgium

Formal lithostratigraphic frameworks for the Hampshire-London and Belgium basins have been recently revised (Ellison et al. 1994; Steurbaut 1998) to reflect the considerable amount of new information gathered in recent years on the geographic extent and biostratigraphic content of Upper Paleocene-Lower Eocene strata. Our current understanding of geometric relationships among Upper Paleocene-Lower Eocene stratigraphic units in the Paris Basin still needs further clarification, but confident correlations of the lithostratigraphic units of high rank (groups and formations) with those described in England and Belgium are possible (Table 3) and well supported by biostratigraphy.

The Vesles Group correlates with the Thanet Formation and the lower part of the Lambeth Group in England and with the lower part of the Landen Group in Belgium. The Thanetian Moulin Compensé and Châlons-sur-Vesles formations correlate with the Thanet Sand and Hannut formations, and the Bracheux Formation with the Upnor Formation and (broadly) with the Bois Gilles Sand Formation. The relationship between the marine formations and the Thanetian lacustrine deposits in the eastern part of the Paris Basin remains to be established.

The Woolwich and Reading formations in England and the Tienen Formation in Belgium correlate with the Mortemer, Vaugirard, and Soissonnais formations, and are thus correlative with the Sparnacian of Dollfus (1880). The similarity in facies between the Argiles plastiques bariolées of the Paris Basin and the Reading beds was already recognized by Dollfus (1880). As stated above, the geometric relationships between these formations of the Mont Bernon Group still need elucidation, and it is likely that their boundaries are diachronous.

The base of the Montagne de Laon Group is marked by an erosional contact that is recognizable throughout the Paris Basin, being also the erosional contact that separates the lower Mont Bernon Group from the Epernay Formation. In the west, two successive erosional contacts are preserved, one between the Craquelins Member and the Sables Fauves (= Sables du Mont-Notre-Dame Formation), the other between this member and the Ailly Member. The Craquelins Member belongs to a distinct, incomplete sequence which remains biostratigraphically uncharacterized, but which still belongs to the *Apectodinium hyperacantum* Zone (Zone W1). Chateauneuf and Gruas-Cavagnetto (1978) pointed out that the lowest occurrence (LO) of *Wetzeliella astra* (= base Zone W2) occurs slightly above the base of the Montagne de Laon Group. In the Cap d'Ailly section, this LO is located just above the barren Sables fauves (= Sables du Mont-Notre-Dame Formation). The LO of *W. astra* thus allows correlation of the base of the Montagne de Laon Group with the base of the Mont Héribu Clay Member of the Kortrijk Clay Formation and with the base of the London Clay Formation s.str. (see also Steurbaut 1998). If this is correct, the Craquelins Member may correlate with the Harwich Formation at the base of the Thames Group and the Zoute Silt Member of the Kortrijk Clay Formation. If this is confirmed, it may become suitable to transfer the Craquelins Member to the Montagne de Laon Group.

The upper part of the Mont Bernon Group correlates with the London Clay Formation and part of the Korttriijk Clay Formation (likely with the Orchies Clay Member).

CONCLUSIONS

For the first time, a formal lithostratigraphic framework is introduced for the Upper Paleocene-Lower Eocene stratigraphic succession in the Paris Basin. To establish this framework, we have selected lithologic terms that are associated with well known localities (e.g., Bracheux, Mortemer, Châlons-sur-Vesles, Epernay, Soissons, Ailly). We stress that whereas a number of formations and members are seen in stratigraphic superposition (as in the Mont Bernon Corehole and adjacent quarries, the cliffs at Cap d'Ailly) their lateral and vertical extents are poorly established. It is possible that some of the members we describe here may not be needed if they are shown to be lateral correlatives.

Our lithostratigraphic framework is critical in dissociating clearly, and for the first time, the Argiles à Lignites that outcrop in the Epernay area from those that outcrop in the Soissons area. Although their age difference was well known, their denomination under the same name led to considering them as a single sedimentary package. Their distinction results in the firm delineation of a regional erosional surface, surface that occurs throughout northwest Europe, and is most likely related to tectonic upheaval in the North Atlantic. This, in turn, leads us to show that the Sparnacian deposits form a lithologically heterogeneous but biostratigraphically homogenous lithostratigraphic unit (Lower Mont Bernon Group) that is bounded by regional unconformities. The Lower Mont Bernon Group forms an unambiguous distinct sedimentary package that has recorded a complex history of relative sea-level change (as seen, for instance in the Cap d'Ailly section), as well as some of the global changes (such as the Carbon Isotope excursion [CIE], Thiry et al. 1998) associated with the Paleocene/Eocene boundary. We hope that by providing a clear lithologic framework of reference, this contribution will facilitate the dialogue among scientists interested in the stratigraphy of northwestern Europe and its contribution to understanding the global changes associated with the Paleocene/Eocene boundary.

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APPENDIX 1
Charophyte biozonal assignments of selected localities/formations of the Paris Basin. Bold face: names of localities; Underlined: names of lithologic units as cited by author(s); In parentheses: our lithostratigraphic assignment. (1) Bignot et al. 1981; (2) Grambast 1972a; (3) Grambast 1972b; (4) Grambast 1977; (5) Laurain et al. 1983; (6) Riveline 1984; (7) Riveline 1986; (8) Riveline in Lecomte 1994; (9) Dupuis and Riveline (unpublished data).

BANTHELU (6, 7)

***Marnes à rognons* (Mortemer Formation)**
Peckichara disermas, *Peckichara* sp., *P. microcarpa*.
Peckichara disermas Zone (lower part)

BERRU (6)

***Marnes blanchâtres overlying the Conglomérat de Cernay* (Mortemer Formation)**
Peckichara disermas, Nitellopsis (*Campaniella*) *helicteres, Nitellopsis* (*Tectochara*) *dutemplei, Harrisichara leptocera,* i.al.
Peckichara disermas Zone

BREUIL-SUR-VESLES (6)

***Marnes à nodules calcaires* (= correlative with the Calcaire de Rilly; Châlons-sur-Vesles or Bracheux Formation)**
Nitellopsis (*Campaniella*) *helicteres, Harrisichara tougnetensis, Microchara berruensis*
Sphaerochara edda Zone

***Marnes vertes with operculums* (=Mortemer Formation)**
Peckichara disermas
Peckichara disermas Zone

CERNAY (3-5)

***Marnes* (Mortemer Formation)**

Nitellopsis (*Tectochara*) *dutemplei, Peckichara disermas, Harrisichara leptocera, Maedleriella cristellata:*
Peckichara disermas Zone.

EPERNAY 1: MONT BERNON BOREHOLE (6, 7)

***Marnes à rognons* (Mortemer Formation), between 18.35 and 11m**
Peckichara disermas, *Nitellopsis* (*Tectochara*) *dutemplei minor, Microchara* sp.
P. disermas Zone

***Base of the Argiles à Lignites* (Epernay Formation), between 5.9 and 6.0m**
Sphaerochara sp.

***Argiles à lignites* (Epernay Formation), between 1.1m and 1.5m**
Nitellopsis (*Campaniella*) *helicteres, Stephanochara sp.*

Epernay 2: Carrière Fosse Parisis (6, 7)

APPENDIX 1
continued.

***Top of the Argiles à Lignites* (Epernay Formation)**
P. torulosus.
P. piveteaui Zone

GUITRANCOURT (6, 7)

***Argiles bariolées* (Mortemer Formation)**
P. microcarpa, *Medleriella* sp.
Peckichara disermas Zone (?lower part).

LIHONS (6)

***Lignitic clays and marls* (Soissonnais Formation, (?) Ailly Member)**

Maedleriella lehmani, *Harrisichara triquetra, H. sparnaciensis, Nitellopsis* (*Campaniella*) *helicteres, Nitellopsis* (*Tectochara*) *dutemplei*

Assigned to the *P. piveteaui* Zone (3, see also Dupuis et al., 1986) based on the occurrence of secondary markers. However, the absence of *Harrisichara leptocera* is probably indicative of the *P. disermas* Zone (upper part; see Riveline, 1984, p. 113; species present in sample 71)

MONT BERNON SECTION (Fosse Parisis Corehole and Quarry) (2)

***Marnes blanches* (Mortemer Formation),** in the lower 7.6m, immediately above the contact with the argiles bariolées

Peckichara disermas, Nitellopsis (*Tectochara*) *dutemplei minor*, *Microchara* sp.
Peckichara disermas Zone (middle part)

***Argiles et sables argileux* (Epernay Formation)** at the base in the quarry)
Nitellopsis (*Campaniella*) *helicteres*, *Peckichara torulosa*.
Possibly *P. piveteaui* Zone.

MONTCHENOT (6)

***Marly clay* (= correlative with the Calcaire de Rilly; Châlons-sur-Vesles or Bracheux Formation)**
Harrisichara tougnetensis, Nitellopsis (*Campaniella*) *helicteres*, *Sphaerochara edda*, *Peckichara varians*
Sphaerochara edda Zone

MUTIGNY (6, 7)

***Sommet des Argiles à lignites* (Epernay Formation)**
P. torulosus, P. piveteaui, Nitellopsis (*Campaniella*) *helicteres, Maedleriella lehmani*
P. piveteaui Zone

PARIS 1, PASSY (corehole Sol-Essai) (6)
Argile calcaire (given as the "Cendrier", Meudon Member) and overlying Argiles grises (Provins Member)
Nitellopsis (*Campaniella*) *helicteres, Peckichara disermas*
Peckichara disermas Zone

PHARE D'AILLY (9)

***Upper part of the Sables et Grés du Pays de Caux, the Calcaire d'Ailly and Lignite L1* (Mortemer Formation)**
Peckichara disermas Zone (mid zone).

RILLY (6)

***Argiles et marnes* (Epernay Formation)**
Peckichara rillyensis, P. piveteaui, P. torulosa, *Maedleriella lehmani, Nitellopsis* (*Campaniella*) *helicteres*
Peckichara piveteaui Zone

ROLLOT (6, 7)

Calcaire de Mortemer (Mortemer Formation)
Grovesichara boureaui and *P. microcarpa*
P. disermas Zone

SAINT-THIERRY (6)

***Marnes de Chenay* (Châlons-sur-Vesles or Bracheux Formation)**
Nitellopsis (*Campaniella*) *helicteres, Harrisichara tougnetensis, Microchara berruensis*
Sphaerochara edda Zone

SARAN SECTION (8)

***Marnes blanches de Dormans* (Mortemer Formation)**, ~ 50cm below the contact marnes blanches/argiles à lignites
Harrisichara leptocera, *Maedleriella lehmani*, *N.* (*C*) *helicteres*
Peckichara disermas Zone (upper part)

***Argiles à lignites d'Epernay* (Epernay Formation)**, between ~ 3 and ~ 2.20m above the Marnes blanches/Argiles à Lignites contact
Peckichara piveteaui.
Peckichara piveteaui Zone.

SOISSONS (6, 7)

***Argiles à Cyrènes et à Huitres* (Soissonnais Formation, Vauxbuin Member)**
Nitellopsis (*Campaniella*) *helicteres, H. leptocera*
Peckichara disermas Zone

***Argiles et Lignites du Soissonnais* (Soissonnais Formation, Argiles Vauxbuin Member)**
Nitellopsis (*Tectochara*) *dutemplei minor, H. leptocera.*
Peckichara disermas Zone

VAUXBUIN (1, 6, 7)

***Correlative of the Sables de Sinceny (*Soissonnais Formation, Vauxbuin Member)**
Nitellopsis (*Campaniella*) *helicteres, H.arrisichara leptocera, Harrisichara sparnaciensis.* *Peckichara disermas* Zone.

APPENDIX 2
Dinoflagellate cyst assemblages in selected localities/formations of the Paris Basin. When a locality comprises several levels, these are arranged in stratigraphic order, the older one being at the bottom of the list and the younger one at the top. The genus name Wetzeliella used for Apectodinium in many publications has been modified appropriately. Bold face: names of localities; Underlined: names of lithologic units as cited by the author; In parenthesis: our lithostratigraphic assignment. Species lists as published. "Remarks" are ours. (1) Gruas-Cavagnetto 1976a; (2) Gruas-Cavagnetto 1976b; (3) Laurain et al. 1983; (4) Gruas-Cavagnetto 1968, (5) Bignot et al. 1981; (6) Gruas-Cavagnetto 1966; (7) Gruas-Cavagnetto 1970; (8) Gruas-Cavagnetto 1974.

CAP D'AILLY SECTION (6, 7)

"Argile du Phare d'Ailly" (Ailly Member): *Apectodinium homomorphum* (51%) with *Baltisphaeridium* sp. 1, *Baltisphaeridium* sp. 2,

Remarks: Gruas pointed to the similarity of the dinocyst assemblages in the Sables de Sinceny, the Sables à Cyrènes de Vieux Moulin and the "argile du phare d'Ailly" (ref. 7, p. 65; see also ref. 4, p. 22)

CUISE-LA-MOTTE COREHOLE (2)

Sparnacian: 85.70-96.90m

At 85.70m: Acme of *Apectodinium homomorpha* with few *Palaeocystodinium deflandrei, Diphyes colligerum, Apectodinium parvum, Baltisphaeridium* spp.;

At 88.50m: dominance of *Cyclonephelium pastielsi* with *Apectodinium* and *Paralecanellia indentata*;

89.85 to 96.60m: *Wetzeliella homomorpha* and *Baltisphaeridium*.

Remarks: The interval described above consists essentially in organic-rich, often glauconitic and clayey sands topped (85.40 to 88m) by organic rich clays alternating with shelly clays (Aubry, 1983). An acme of *Apectodinium* species occur at 86.70m, and in the interval between 88.50 and 96.60m (see Gruas Cavagnetto 1976, p. 22).

GUITRANCOURT (4)

Fausses Glaises (Vexin Member):

Sample 11 Argile supérieure (exact location and relation with faluns not given; presumably at top of the faluns): *Apectodinium* dominant; *P. deflandrei* absent.

Sample 8 (exact location of sample not given) *Palaeocystodinium deflandrei* (47-51%), *Apectodinium homomorphum*, *Baltisphaeridium* sp. 1 and (rare) *Epycephalopyxis indentata.*

Remarks: Gruas-Cavagnetto (1968) noted that the dinocyst assemblages in the coquina with *Cyrena* from Guitrancourt is similar to those in the coquina with *Cyrena* from the localities of Le Meux and Vieux Moulin. Whereas the abundance of dinocyts in the assemblages from Le Meux are not given, percentages are given for two levels at Vieux Moulin. In these, the dinocysts assemblages are dominated by *A. parva* (50% and 46% at level 20 and 21, respectively) and *A. homomorphum* (14% and 41% in levels 20 and 21, respectively).

LA DÉFENSE BOREHOLE (1)

Fausses Glaises (Paris Member, Epernay Formation): 22.50-25.20 m: same species as below, plus in the upper part of this interval: *Wetzeliella symmetrica, Hystricokolpoma rigaudae, Spiriniferites cingulatus, Cyclonephelium densebarbatum, Wetzeliella varielongitudina.*

Remarks: The occurrence of *W.* (*Vel Dracodinium*) *varielongitudina* and *Hystricokolpoma rigaudae* indicates Zone E2a of Bujak and Mudge (1994) and Mudge and Bujak (1996) = Zone W3 (*Wetzeliella meckelfedensis* Zone of Chateauneuf and Gruas Cavagnetto (1978).

Sables d'Auteuil (Auteuil Member, Epernay Formation): 30-32.50 m: Dinocysts are rare (7-15% of the microplankton assemblage). They include: *Apectodinum homomorphum, A. parvum*, and *Baltisphaeridium* with rare *Cyclonephelium pastielsi*, *C. exuberans*, *Cordosphaeridium inodes*, *Operculodinium centrocarpum*, *Lingulodinium machaerophorum, Paleocystodinium deflandrei, Dipyes colligerum.*

Remarks: Based on the comment by Gruas Cavagnetto (1976, p. 28) according to which L. Feugueur regarded these sands as correlative of the Sables de Sinceny, Costa and Manum (1988) assigned the latter to their Subzone D5a, characterized by the acme of *A. augustum*, *A. parvum* and/or *A. summissum.*

MONT BERNON (4)

Grey calcareous marls (Epernay Formation): *Apectodinium homomorphum* (6%), W. *homomorpha quinquelata* and *W. parva* (76%), *Hystrichokolpoma poculum*, *H. rigaudae, Baltisphaeridium* sp. 7.

Green clay (Epernay Formation): *Apectodinium homomorphum* (6%), W. *homomorpha quinquelata* and W. parva (90%), *Dyphies colligerum*, *Hystrichokolpoma rigaudae, Hystrichosphaera cf. furcata, Cyclonephelium sp., cf. Leptodinium sp.*

Remarks: Isolated samples were analyzed for dinocysts in this work, and the relationship between samples, taken in different quarries, are not known. However, the lithologies described in Gruas are difficult to relate to those described by Laurain et al. (1983). The occurrence of *H. rigaudae* would suggest assignment to = Zone E2a of Bujak and Mudge (1994) and Mudge and Bujak (1996) = ~ Zone W1 - ZoneW3.

MONT BERNON COREHOLE AND QUARRIES (3)

Argiles à Lignites (Epernay Formation): Dinocysts with low % except in the lower ~ 14m. Successive datums are: HO of *Apectodinium homomorphum tesselatum* and LO of *W. meckelfeldensis* at Level 16 (15.50-18.75m; i.e., immediately above the contact between the Argiles à Lignites and Marnes Blanches); LO of *Adnatosphaeridium robustum* at level 27 (22.55-22.80m).

Remarks: Based on the LO of *W. meckelfeldensis* at their base, the Argiles à Lignites belong to Zone W3 (Chateauneuf and Gruas Cavagnetto 1978).

Marnes Blanches (Mortemer Formation): dinocysts rare; essentially *Apectodinium* spp. and *Comasphaeridium*? *hispidum*

APPENDIX 2
continued.

MONT CHENOT (8)

Brown sand with clayey lenses (Mortemer Formation): *Palaeocystodinium deflandrei* (dominant) with *Apectodinium parvum* and *A. homomorphum.*

Remarks: This level at the base of the Marnes du Mont Chenot was placed by Gruas-Cavagnetto in the Sables de Rilly, regarded correlative with the Sables de Bracheux, and its dinocyst assemblage has been regarded characteristic of Zone D5. Hooker (1996) used this D5 zonal assignment for the top of the Sables de Rilly to constrain the stratigraphic position of the Cernay fauna. Zone D5 correlates largely with Zone NP9, which thus restricts the position of the Cernay fauna to this zone. However, no level younger than Zone NP8 has been delineated in the Sables de Rilly - Sables de Chalôns-sur-Vesles (Janin and Bignot, 1993; MPA, unpublished data). There is no known marine equivalent to the Sables de Bracheux *s. str.* in the eastern part of the Paris Basin. As pointed out by Gruas-Cavagnetto (8) the dinocyst assemblage recovered from the base of the Marnes de Mont Chenot is unusual for a Thanetian deposit, but expected for a Sparnacian level. Indeed, in this work, we assign the Marnes du Mont Chenot to the Calcaire de Mortemer Formation of the Mont Bernon Group.

SINCENY (4)

Falun supérieur à Ostrea : Apectodinium homomorphum (predominant) with *Baltisphaeridium* spp.

*Sables à Mollusques: Baltisphaeridium machaerophoru*m (predominant), *Apectodinium homomorphum* (abundant), *A. parvum* (abundant) with scarce *Cordosphaeridium tiara, Dyphies colligerum*, *Baltisphaeridium* sp. 3.

Remarks: Although percentages are not given in (4), Gruas-Cavagnetto (1966) remarked earlier on a similar abundance of *Apectodinium* sp. in the Sables de Sinceny as in the coquina with *Cyrena cuneiformis* at Vieux Moulin (see remarks on Guitrancourt, above).

SOISSONS (5)

Argiles à cyrènes et à huitres (Soissonnais Formation): *Apectodinium homomorphum, A. parvum* and *A. h. tesselatum* (up to 94%), *Glaphyrocysta* spp., *Dyphies colligerum.*

Faluns sableux (Soissonnais Formation): *Apectodinium homomorphum* and *A. h. tesselatum* (~ 15%), *Lingulodinium machaerophorum* (>40%), *Glaphyrocysta* spp. (10%), *Comasphaeridium hispidum* (at the top of the ~ 2m thick interval).

Remarks: The percentage of *Apectodinium* in the Argiles à Cyrènes et huîtres is highly variable between 88% to 3%. In addition, Gruas-Cavagnetto indicates that, as a rule, the frequency of *Lingulodinium machaerophorum* and that of *Apectodinium* spp. vary in opposition, these frequencies being directly linked to environmental conditions.