The Cretaceous of the Boulonnais (France) and a comparison with the Cretaceous of Kent (United Kingdom)

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ROBASZYNSKI, F. & F. AMÉDRO. 1986. The Cretaceous of the Boulonnais (France) and a comparison with the Cretaceous of Kent (United Kingdom). *Proc. Geol. Ass.* **97** (2), 171–208. The distribution, structure and stratigraphy of the Boulonnais Cretaceous is summarised, followed by a more detailed discussion of representative sections of the Wealden, Aptian, Albian and Chalk. Comparisons and correlations are made with the Kent successions. The facies variations and palaeogeographic changes result from a combination of eustatic sea-level changes and vertical tectonic movements of blocks.

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1. GENERAL DESCRIPTION OF THE BOULONNAIS (F.R.)

(a) Geography

In a physiographic sense, the Boulonnais is the eastern part of an exhumed and eroded horst, the western part of which occupies the Weald. Being 25 km from east to west and 30 km from north to south, the Boulonnais is bounded by Artois to the east, Picardy to the south, the maritime plain to the north and the Straits of Dover to the west (Fig. 1). The Bas-Boulonnais and Haut-Boulonnais are distinctive areas, both geologically and geographically.

The two areas also have distinctive soil types and varied land use: cereal farming on the Haut-Boulonnais; grass-lands, forests and stone quarries on the Bas-Boulonnais, these differences being related to the various lithologies represented by the bedrock (Fig. 2).

The Haut-Boulonnais forms a semi-circular cuesta from the Mont de Couple at the north to Dannes in the south, following a nearly NW–SE direction passing Landrethun, Hardinghen, Nabringhen and Lottinghen and then a NE–SW direction via Desvres and Samer. The substrate, essentially chalky, includes marly chalks, chalks without flints, and chalk with flints. This is of Cenomanian, Turonian, Coniacian and early Santonian age. When conditions of observation are sufficiently good, at the base of the cuesta it is possible to find outcrops of Albian clays, Aptian marls or sands, and clays and sands of 'Wealden' facies.

The Bas-Boulonnais, more humid and grassy, is formed on Middle to Upper Jurassic limestones, clays, marls and sandstones which surround the Palaeozoic Ferques Massif, the western extension of the northern limb of the Namurian Synclinorium.

(b) Structure

The Boulonnais is a rare area in northern France where the Palaeozoic basement and the Mesozoic cover outcrop side by side.

Palaeozoic formations are on the north side of the Namur Synclinorium and were overthrust by the Dinant Synclinorium at the end of Westphalian times. The main overthrust fault named 'Faille du Midi', has an estimated horizontal displacement of 30 to 40 km and is accompanied by some other faults such as the Hydrequent overthrust.

Mesozoic marine and epicontinental formations were affected by sub-vertical faults oriented N 100°–N 110° (longitudinal faults) or N 20°–50° (transverse faults).

The boundaries of the Boulonnais, as well as the rivers and the hills probably all have the same structural origin. A set of N 110°–N 30° faults defines tectonic blocks, which have moved relative to each other, thus setting up the complex horst of the Weald–Boulonnais which was later divided by the transverse graben of Pas de Calais.

The main tectonic events recorded in the Boulonnais are as follows (from the older to the younger, after Colbeaux *in* Robaszynski *et al.*, 1982):

- The Variscan orogeny ended in the folding of Palaeozoic strata and in overthrusts (late Westphalian) of Armorican direction.
- By late Variscan times, longitudinal faults cut up the Palaeozoic massif into large bands oriented WNW–ESE.
- At the end of the Jurassic and at the beginning of the Cretaceous, tectonic instability is manifested in coarse detrital facies at the top of the Portlandian and by the emersion of the area in 'Purbeckian'–'Wealden' times. Longitudinal faults were reactivated and their horizontal displacement were expressed by second order anticlinal and synclinal folding. Upper Cretaceous formations rest with angular discordance on the underlying strata, an angle of 5° to 10° being measured on seismic reflexion profiles at sea (Auffret & Colbeaux, 1977); on land, a mappable discordance is identifiable on the whole of the area covered by the 1:50,000 Marquise sheet.
- During the end of Cretaceous–Eocene times,

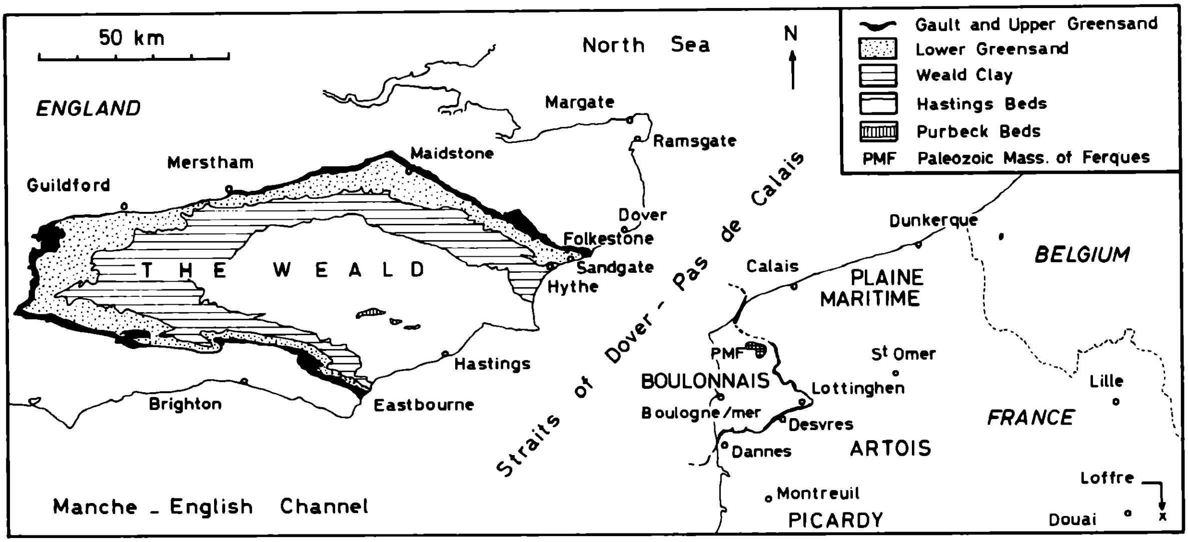

Fig. 1. Geographical situation of the Boulonnais and the Weald.

longitudinal faults continued to form lines of weakness which allowed the uplift of the Weald–Artois horst, this structure being rejuvenated during the Miocene.

- Finally, at the end of the Lower Pleistocene, a transverse fault zone, the 'Zone Faillée du Pas de Calais', reactivated a graben structure which was initiated still Lower Cretaceous times (see chapter 4). This zone linked the English Channel with the North Sea. The erosion of the Boulonnais and the Weald continued until the middle of Mid-Pleistocene and, during the second part of the Mid-Pleistocene, the present-day shore-line began to develop.

(c) Palaeogeographical summary

In the Boulonnais, the older sediments lying on the Variscan peneplain are continental sandy shales, Liassic in age, preserved in hollows in the eroded Palaeozoic surface. The Mesozoic transgression began in the Middle Jurassic and continued during the Upper Jurassic.

The post-Jurassic regression marked the beginning of a long period of emersion during which deposition of continental sands and clays of Wealden type took place.

The oldest marine Cretaceous sediments are Lower Aptian and represent the first transgressive pulse in this part of Western Europe. A second marine transgression occurred in late Aptian times and after several advances and retreats during the Albian, which deposited the Greensand and Gault facies, the Chalk sea covered the whole area.

(d) Previous work

After the initial works of Rozet (1828), Gaudry (1860) and Rigaux (1866), it was Chellonneix (1872a) who, under the influence of Barrois, produced the first detailed description of the 'assises crétacées du Cap'. It should be pointed out, however, that Phillips (1819) had already provided an appendix to his study of the cliffs of Kent 'containing some account of the Chalk Cliffs of the Coast of France, opposite to Dover'. He recognized there the main divisions of the Dover Chalk, but only on 'mineralogical' criteria. Some years after the publication of Chellonneix's observations, studies were carried out on the French coast by Potier & De Lapparent (1875) in connection with the first Channel Tunnel project which was to cross the Straits in the Lower Cenomanian strata. This project provided the stimulus for numerous studies which gave a better knowledge of the Cretaceous between 1870 and 1880, e.g. Barrois (1873, 1874, 1875, 1879), Hébert (1874), De Mercey (1876).

At the beginning of the 20th Century, the Lower Cretaceous was the subject of detailed studies by Parent (1903), Briquet (1903, 1906), Rigaux (1903) and Dutertre (1921 to 1938). Later on, Destombes & Destombes (1938, 1943, 1958, 1962, 1965, 1969) improved the understanding of the Albian of Wissant using ammonites. Microfossils were next to extend the understanding of Cretaceous stratigraphy, especially after the Second World War, with Marie (1941, 1960), Magné & Polvêche (1961), Andreieff (1964) and Baccaert (1973) working on foraminifera, Davey & Verdier (1969, 1970), Verdier (1975), Foucher & Taugourdeau (1975) and Fauconnier (1975) working

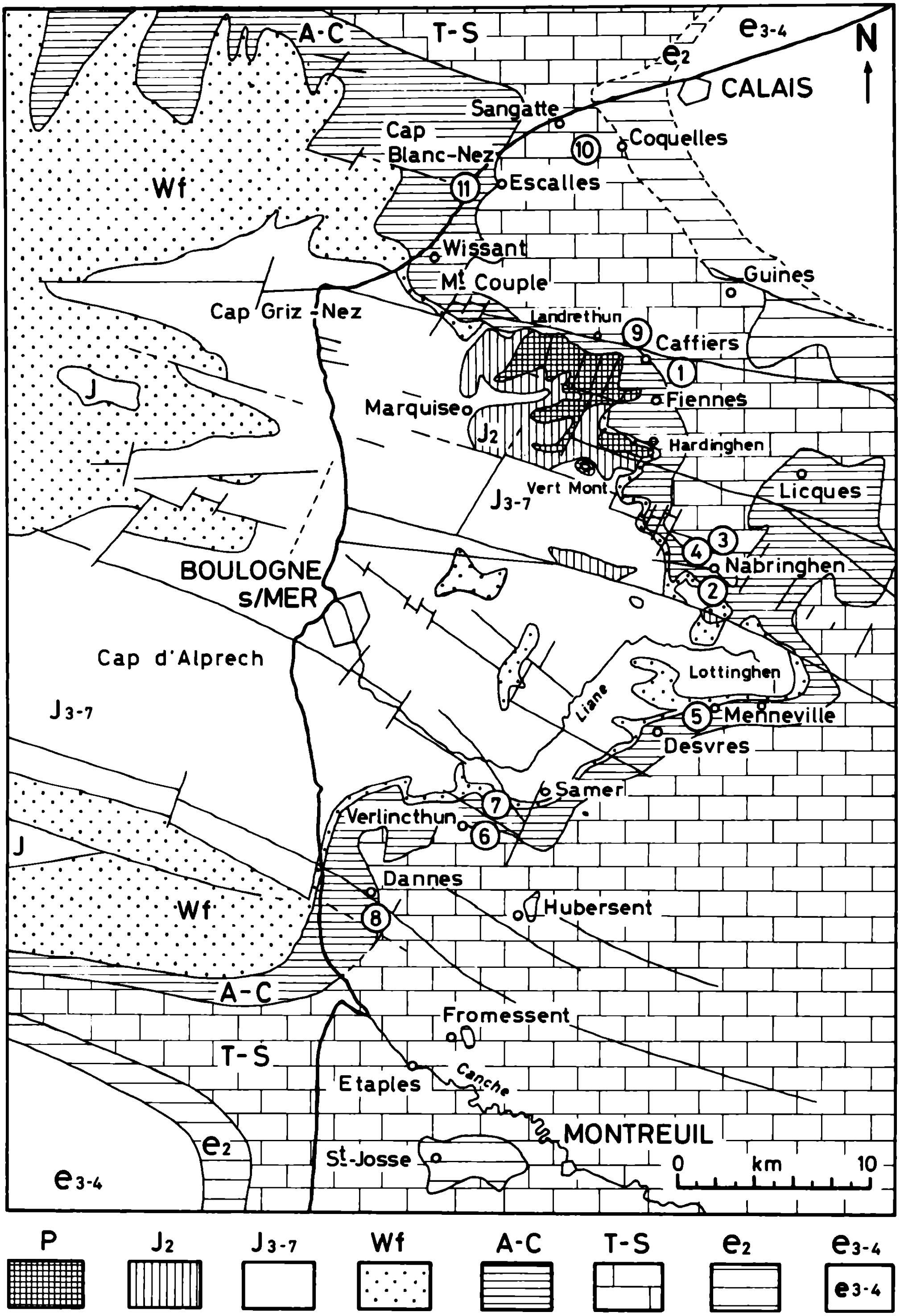

Fig. 2. Geological sketch-map of the Boulonnais area with location of exposures visited (P = Palaeozoic basement rocks of the Ferques Massif – J2: Dogger – J3–7: Upper Jurassic – Wf: Wealden facies – A–C: Aptian, Albian and Cenomanian – T.S.: Turonian, Coniacian and basal Santonian – e2: Landenian or Thanetian – e3–4: Ypresian).

on dinoflagellates, and Herngreen (1971) studying spores and pollens of the continental Cretaceous of 'Wealden' facies.

A second Channel Tunnel project during the 1960's initiated new geological exploration. Some results were published but do not reflect the full extent of information obtained (Bruckshaw *et al.*, 1961; Carter & Destombes, 1972; Destombes & Shephard-Thorn, 1972).

Since 1975, new lithological studies combined with accurate bed-by-bed palaeontological collecting led to the development of multistratigraphic charts for the Cretaceous, showing the vertical distribution of ammonites, echinoderms, brachiopods, inoceramids and of other macrofossils, and of foraminifera, calcareous nannoplankton and dinoflagellates (Robaszynski & Amédro edit. *et al.*, 1980; Amédro & Magniez-Jannin, 1982).

(e) Subdivisions of the Cretaceous

Although the term 'Mesocrétacé' (Albian, Cenomanian and Turonian) was introduced as early as 1907 by Jacob, then used by Haug (1911), and has recently provided the title of the 'Mid-Cretaceous Events' project led by R. Reyment (1982), the Subcommission on Cretaceous Stratigraphy recommends the use of a two-fold division for the Cretaceous, with a lower and an upper sub-systems, the boundary between the two parts being placed between the Albian and Cenomanian stages (Birkelund *et al.*, 1984). This subdivision will be followed here.

(f) Cretaceous outcrops in the Boulonnais

With the closing of local clay, sand, marl and chalk pits, the number of available outcrops of the Cretaceous in the Boulonnais is continually being reduced; for example, since 1975 the closing, sometimes followed by the infilling, of the Lottinghen, Desvres, Nesles and Burets quarries, or the progressive overgrowing of the Menty and Verlincthun quarries, and of the Vert-Mont roadcutting or the Caffiers railway cutting. Only the natural section of Cap Blanc-Nez, from Wissant to Sangatte, is assured of a certain permanence. This section has provided much of the biostratigraphical data for the Cretaceous in northern France. Figure 3 tries to place in a general stratigraphic framework—in which are shown the main sedimentary or erosional gaps—the whole of the studied outcrops, except for the Hardinghen section which has been re-interpreted from Olry's data (1904).

2. THE LOWER CRETACEOUS (F.A.)

The Boulonnais is an important area for the study of Lower Cretaceous rocks because elsewhere in northern France beds of this age do not outcrop and are known only from wells and boreholes. The pottery and ceramic industries have extensively exploited the Wealden and Albian clays (Desvres). In recent times the Albian clays were worked for use as silicate additive in the cement industry (Nesles, Lottinghen). At present (1984), all these quarries have been abandoned and, if the unfavourable economic situation persists, the Lower Cretaceous outcrops will continue to deteriorate.

The Lower Cretaceous of the Boulonnais presents contrasting facies: the continental facies, essentially of white sands and mottled reddish clay; and the transgressive marine facies of the Aptian–Albian, characterised by detrital sedimentation (coarse sands, clays, marls) with glauconite often present and sometimes abundant.

(a) Wealden facies of the Boulonnais

Several publications have been devoted to the Wealden facies of the Boulonnais, notably by Parent (1893, 1903), Rigaux (1903), Dutertre (1925), Bonte (1965, 1977), and Bonte & Godfriaux (1958a, 1958b). Despite these studies, the complete lithostratigraphic sequence remains unknown due to the lack of continuous sections between the Portlandian and the Aptian. Moreover, much of the research on the Wealden of the Boulonnais has concentrated on the stratigraphic position of glauconitic sandstones capping several hills around Boulogne-sur-Mer (Wimille Sands, Saint-Etienne-au-Mont Sands). In fact, these sands are now considered to be the result of decalcification of Upper Portlandian sandstones (Bonte & Godfriaux, 1958b).

(i) *Past and present sections*

In 1976, an unconformity representing the Jurassic–Cretaceous boundary was visible to the north and south of Boulogne-sur-Mer, in the Terlincthun bypass and on the Equihen plateau. Here, grey clays of Wealden facies occurred in pockets on the Upper Portlandian (glauconitic sandstone with *Trigonia gibbosa*). Similar pockets are formed on the top of the cliffs of La Crèche, to the south of Wimereux, but here the grey–black lignitic clays rest on limestones of Purbeckian facies.

As for the rest of the succession, descriptions of the old quarries at Neuville and Pelincthum, near Nesles (Rigaux, 1903), indicate the presence of mottled reddish clays covered by grey–white argillaceous sands in the south of the Boulonnais. A similar lithological succession can be seen today in the quarries at Longueville and Nabringhen in the east of the Bas-Boulonnais. Three sections taken in these quarries clearly show dramatic variations in the thickness of the lithostratigraphic units within a few hundred metres (Fig. 4). Because of the scarcity of information, it is unfortunately not yet possible to

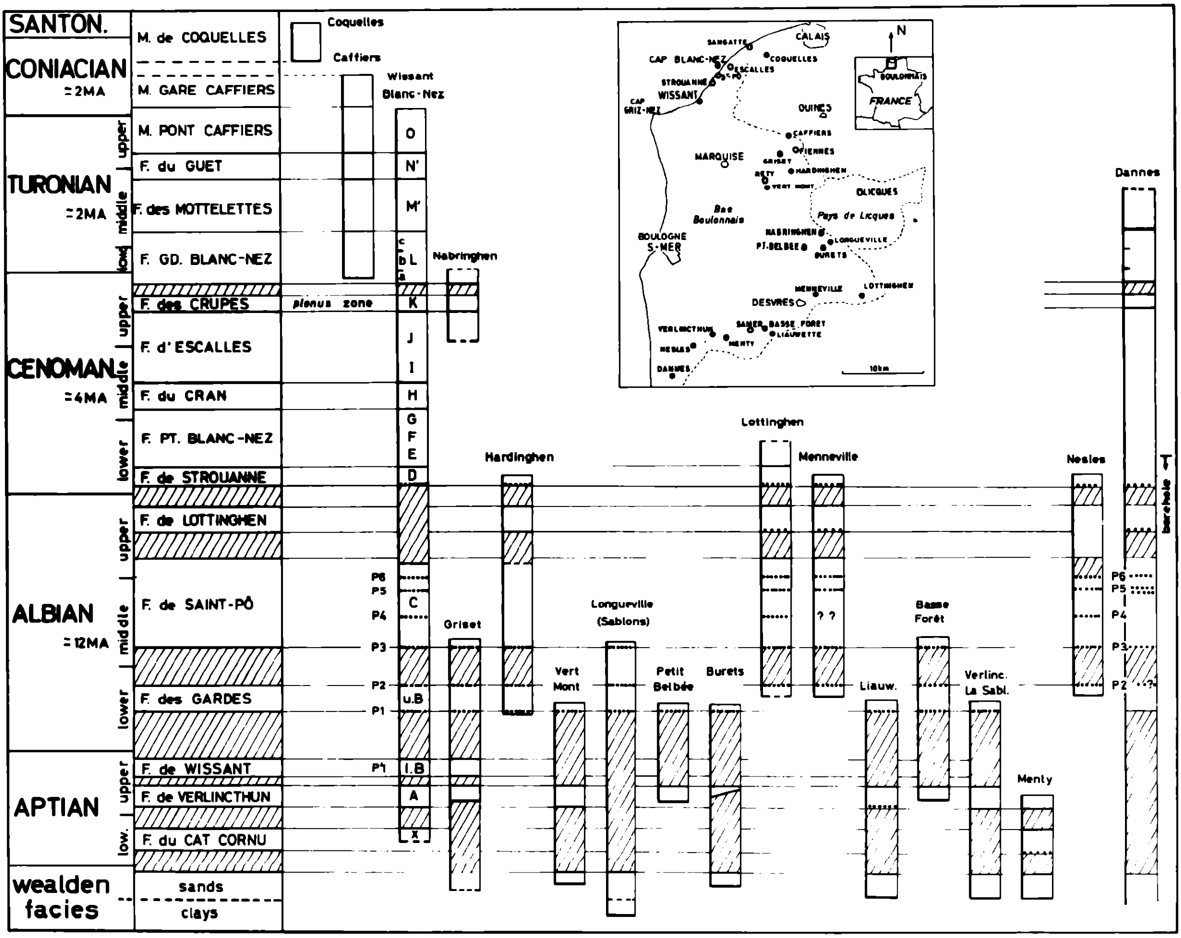

Fig. 3. Stratigraphical position of Cretaceous outcrops of the Boulonnais.

establish lithological correlations between the Wealden formations of the Boulonnais. In the same way, the scarcity of fossils makes the determination of their precise stratigraphical position difficult. However, spores were recently recorded at Longueville (Herngreen, 1971). The associations recognized indicate, for this horizon at least, an age between the late Barremian and early Aptian (abundance of *Parvisaccites radiatus* Couper, presence of *Equisetosporites ovatus* (Pierce), *E. albertensis* Singh, *Trilobosporites bernissartensis* (Delcourt & Sprumont).

It is still very difficult to judge the thickness of Wealden beds in the Boulonnais since no continuous sections are accessible. However, according to Olry (1904) a borehole at Wissant went through 66.50 m of clays and sands of Wealden facies.

(*ii*) *Comparison with the Weald*

Formations of Wealden facies are much thicker in southeast England than in the Boulonnais. In Kent, for example, the combined thicknesses of the Hastings Beds and Weald Clay can reach over 800 metres. The sedimentary environment of the Wealden facies of the Weald has been studied in detail by Allen (1965, 1967, 1976). However, because of rapid lateral facies variations, it is impossible to establish a lithological correlation with the Wealden facies in the Boulonnais. It is only possible to consider a comparison based on stratigraphic age. In as much as the English formations cover the period from uppermost Ryazanian to late Barremian (Casey, 1961; Rawson *et al.*, 1978) it seems, from our present state of knowledge, that the Wealden facies of the Boulonnais correlates only with the upper part of the Weald Clay of the Weald (i.e. similar to East Kent; see Worssam, 1963).

(b) Aptian of the Boulonnais

The sections described by Gaudry (1860), Le Hon (1864), Rigaux (1903), Briquet (1903, 1906), Dutertre

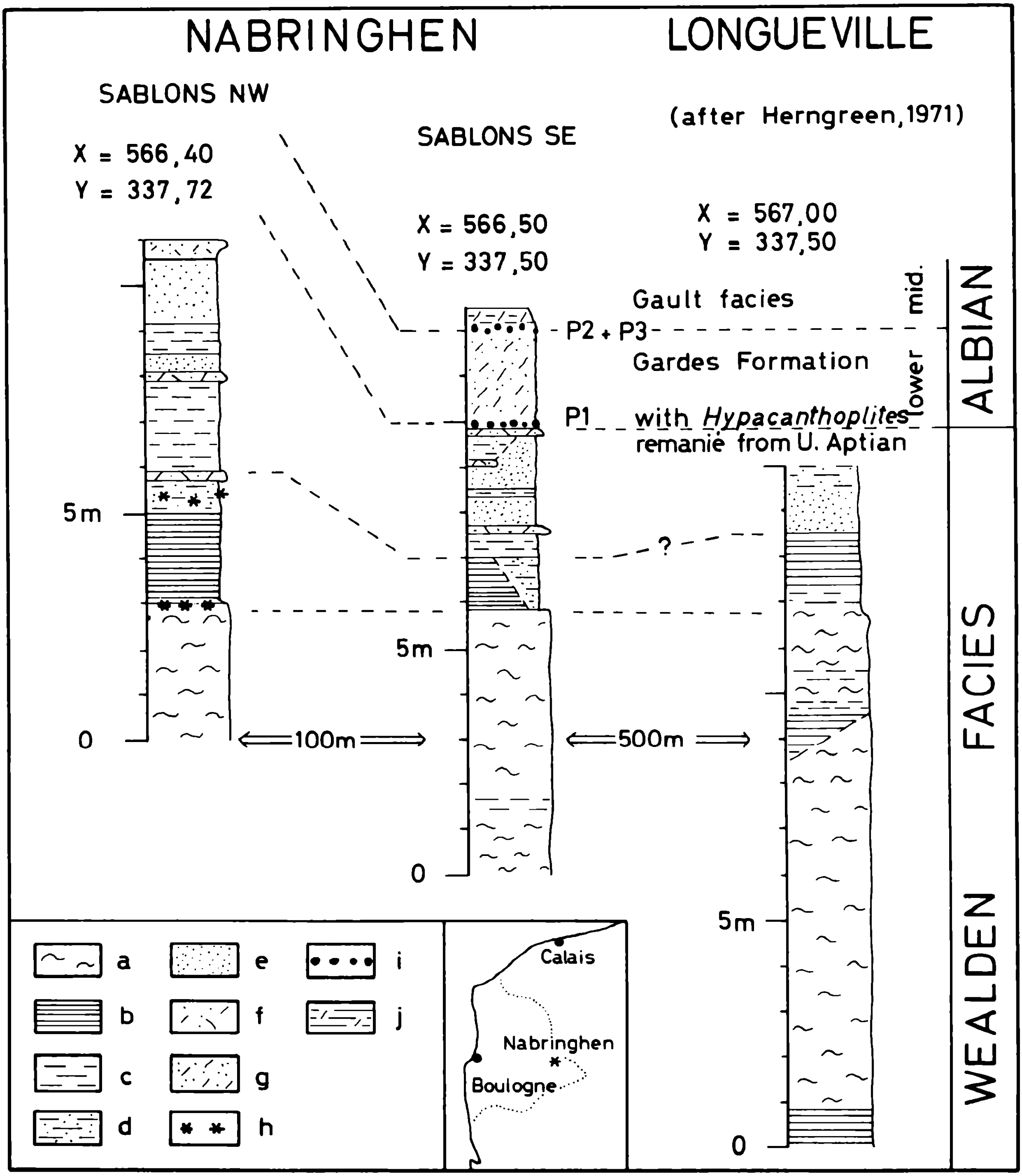

Fig. 4. Lithological sections of Wealden facies at Nabringhen and Longueville (a: mottled reddish clay – b: black clay – c: grey to white sandy clay – d: grey, clayey sand – e: white sand – f: white sand with limonite – g: glauconitic, coarse sand – h: pyrite – i: phosphatic nodules and quartz gravel – j: glauconitic clay of Gault facies).

(1923, 1925, 1936, 1938), Bonte & Broquet (1962), Amédro & Mania (1976), Bonte (1977) and Robaszynski & Amédro edit. *et al.* (1980) give a precise picture of the Aptian of the Boulonnais. Three formations were established by Amédro & Mania (1976): in ascending order the Cat-Cornu Formation, the Verlincthun Formation and the Wissant Formation.

(*i*) *Representative sections of the Aptian*

The composite reference section for the Aptian of the Boulonnais comprises two localities, namely the Cat-Cornu quarry in Menty, and the outcrops of the bay of Wissant.

At Menty the Cat-Cornu Formation and the largest part of the Verlincthun Formation outcrop in this old disused quarry (Fig. 5). In ascending order the succession is:

Wealden facies

a– White, fine siliceous unfossiliferous sands, 2 metres seen. In the southern part of the quarry, overlain by a bed of grey argillaceous sand, 1 metre thick, with its upper part full of burrows infilled with glauconitic sand from beds c or d.

Cat-Cornu Formation (*Lower Aptian*)

b– 0.02 m. Bed of brownish, ferruginous, sandy-phosphatic nodules of 3 mm to 5 cm in diameter. The nodules have been rounded by reworking.

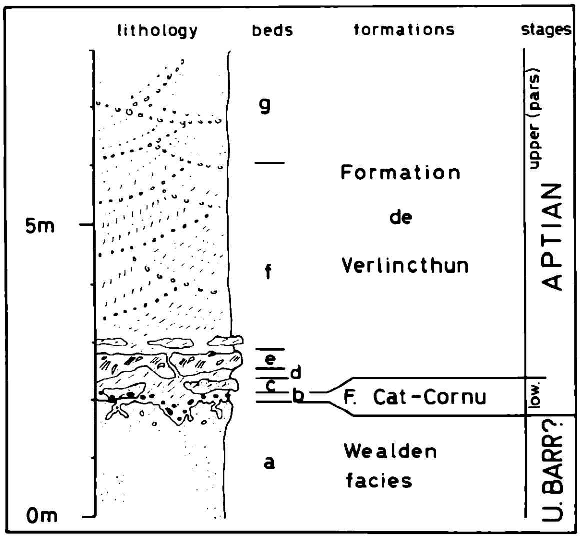

Fig. 5. The contact between Wealden facies beds and Aptian at the Cat Cornu quarry at Menty (lithology; a: white, fine sands – b: ferruginous, sandy phosphatic nodules, strongly rolled – c: glauconitic sand, more or less indurated into a grey-brown sandstone – d: argillaceous glauconitic sand – e: brownish red sandstone – f: cross-bedded, glauconitic sands – g: yellowish, cross-bedded sands).

The nodules have yielded a rich fauna including bivalves: *Gervillella* sp., *Panopea* sp.; brachiopods: *Sulcirhynchia hythensis* Owen; and especially ammonites: *Cheloniceras* (*Cheloniceras*) *cornuelianum* (d'Orbigny), *Ch.* (*Ch.*) *crassum* Spath, *Ch.* (*Ch.*) cf. *meyendorffi* (d'Orbigny), *Deshayesites* cf. *grandis* Spath, *Dufrenoya* cf. *furcata* (J. de C. Sowerby), *Lithancylus grandis* (J. de C. Sowerby), *L. fustis* Casey, *Epancylus* sp., *Tropaeum* cf. *hillsi* (J. de C. Sowerby), *Tropaeum* sp. (The determinations of the brachiopods and of the ammonites were checked by Drs. E. F. Owen and R. Casey respectively.) This association suggests a condensation of the Zones of *Deshayesites deshayesi* (Subzone of *D. grandis*) and of *Tropaeum bowerbanki* defined by Casey (1961) corresponding to the top of the Lower Aptian.

Verlincthun Formation (*Upper Aptian pars*)

c– 0 to 0.20 m. Glauconitic sand, more or less cemented into a grey-brown, friable sandstone. Wooden fragments a few centimetres across are abundant, as well as the external moulds of the bivalves *Pterotrigonia mantelli* Casey and *Thetis minor* (J. de C. Sowerby). This bed has a layer of rolled pebbles from bed b at its base.

d– 0.10 m to 0.30 m Greenish, argillaceous glauconitic sand with lenticles of glauconite.

e– 0.10 m to 0.50 m. Large concretionary masses of brownish red sandstone which enclose wood fragments and external moulds and bivalves (e.g. *P. mantelli*).

f– 3.50 m. Green glauconitic coarse grained cross-bedded sands with band of impersistent quartz sandstone at the bottom. Towards the top, glauconite poor beds pass up into lighter coloured beds.

g– Approximately 2 m. Yellowish, coarse-grained, cross-bedded sands.

In the bay of Wissant the Aptian formations cannot be seen in the cliffs and are exposed only on the beach between Wissant and the hamlet of Strouanne. Sand and shingle often obscure the outcrops. However, depending on the exposure at low tide, most parts of the Verlincthun Formation and of the Wissant Formation can be examined. In ascending order, the observed beds (or inferred in the case of the Cat-Cornu Formation) are as follows (Fig. 6).

Cat-Cornu Formation (*Lower Aptian*)

Marked with 'x' on Fig. 6. Although no outcrop of the Cat-Cornu Formation could be observed in the bay of Wissant, its existence is inferred following the collection on the beach of an internal mould of *Cheloniceras* (*Cheloniceras*) *crassum* preserved in a greyish–green glauconitic calcareous sandstone.

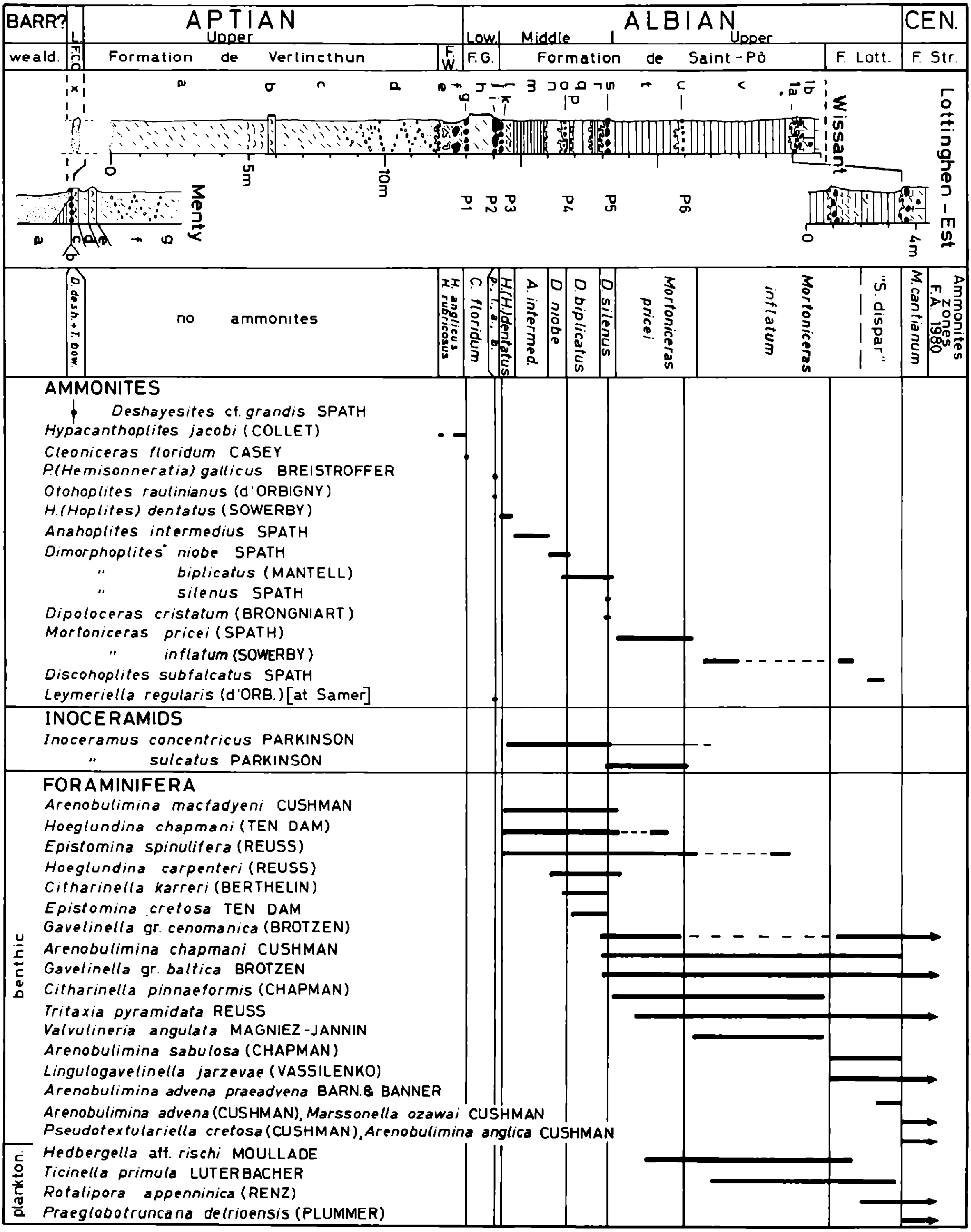

Fig. 6. Vertical distribution of the main biostratigraphical elements in the Aptian–Albian of the Boulonnais.

Verlincthun Formation (*Upper Aptian pars*)

a– Approximately 6.60 m seen. Very dark green, burrowed glauconitic clay. Crystals of authigenic pyrite a few millimetres across are disseminated throughout. Five beds of oysters have been recognized in the uppermost metre. Each bed, about 5 cm thick, consists of an enormous quantity of large shells (10 cm to 20 cm) of *Ostrea* (*Liostrea*) *leymerii* Leymerie, *Aetostreon latissimum* (Lamarck), *Rastellum* cf. *macropterum* (J. de C. Sowerby).

b– 0.25 m. Dark green glauconitic sand, in many places indurated into concretions of glauconitic calcareous sandstone.

c– 3 m (estimated thickness). Dark-green burrowed glauconitic clay, similar to bed a, but without oysters.

d– 3 m (estimated thickness). White, cross-bedded sand, passing down to underlying bed c.

Wissant Formation (*Upper Aptian pars*)

e– 0.50 m. Greyish-green, argillaceous glauconitic sand, characterized by a very closely spaced network of burrows (*Thalassinoides paradoxica*). The boundary with the lower white sands (bed d) is emphasised by an irregular omission surface. Rare, greyish phosphatic nodules, a few centimetres in diameter, one of which collected at the bottom of the bed yielded a good example of *Hypacanthoplites jacobi* (Collet).

f– 0.50 m. Grey argillaceous glauconitic sands, similar to the previous ones, but lacking evidence of bioturbation. Many black phosphatic nodules, 1 to 12 cm in diameter. In the lower half of the bed there is a level of brownish, sandy phosphatic concretions, 10 to 15 cm in diameter. Most of them reveal the existence of aggregates of fossils embedded in each other. Among them, fragments of wood, with ammonites: *Hypacanthoplites jacobi, H. anglicus* Casey, *H. hanovrensis* (Collet), *H. sarasini* (Collet), *H. clavatus* (Fritel), *H. elegans* (Fritel), *H. spathi* (Dutertre), *H. rubricosus* Casey, *H.* cf. *simmsi* (Forbes), *H. corrugatus* Casey, *H. milletioides* Casey and *H.* cf *trivialis* Breistroffer (the last two species are very rare); bivalves: *Pterotrigonia mantelli, Thetis minor*; brachiopods: *Cyclothyris deluci* (Pictet); echinoids: *Phyllobrissus* cf. *gresslyi* Agassiz and arthropods: *Hoploparia longimana* (G. B. Sowerby). This association is typical of the Zone of *Hypacanthoplites jacobi* of Breistroffer (1947) (= Subzone of *H. rubricosus* + Subzone of *H. anglicus* of Casey 1961).

Gardes Formation (*Lower Albian*)

g– 0.03 m. Phosphatic nodule bed P1 with *Beudanticeras newtoni* Casey, *Douvilleiceras mammillatum* (Schlotheim), *Cleoniceras floridum* Casey.

(*ii*) *Correlation of the Aptian of the Boulonnais*

The correlation of the outcrops in the bay of Wissant and the Cat-Cornu quarry makes it possible to establish a chronology of the Aptian formations in the Boulonnais. Lateral facies variations prevent the development of a standard section for the Boulonnais from those localities. To obtain a general impression of the Aptian of the Boulonnais, it is necessary to use a set of correlated outcrops. The lithological and facies correlations for the Aptian formations of the Boulonnais are shown in Fig. 7.

The Cat-Cornu Formation is only exposed in the western part of the present Bas-Boulonnais. To the north in the bay of Wissant, it appears as a calcareous glauconitic sandstone with *Cheloniceras* (*Cheloniceras*) *crassum*. From the lithologic description of the borehole at Wissant by Olry (1904), it seems that the formation is 11 m thick.

In the south, in the Cat-Cornu quarry, the formation was completely removed by a period of intra-Aptian erosion, and is represented only by a thin bed of remanié pebbles of phosphatic sandstone at the bottom of the Verlincthun Formation

The Verlincthun Formation has a wider areal extent than the Cat-Cornu Formation, being visible in the eastern part of the Boulonnais, but then thinning and wedging out (Burets quarry).

In the southern part of Boulonnais, the Verlincthun Formation comprises two lithostratigraphic units that have been described in the Cat-Cornu quarry:

- lower unit (2 to 4 m): green glauconitic sand, indurated at the bottom;
- upper unit (4 to 6 m): white sands, in places cross-bedded.

A similar lithological sequence could be observed in 1977 in the road-cutting of Vert-Mont at Réty, in the north-east of the Bas-Boulonnais. There, the white sands were covered by one metre of black clay of continental facies sediments. In the north, there are the same lithostratigraphical units as in the Cat-Cornu quarry, but there are lateral variations of facies in the lower units. In Wissant, glauconitic sands pass up to a glauconitic clay containing several beds of oysters ('Argile à *Ostrea leymerii*' of Gaudry, 1860) approximately 10 m thick, while in the Griset quarry the bottom of the formation is condensed and indurated as a ferruginous microconglomerate rich in oysters (0.40 m thick). A shoal must have existed on the Palaeozoic Ferques Massif.

The glauconitic clayey sands with *Hypacanthoplites* which comprise the Wissant Formation attain their maximum thickness (1 metre) in the type-locality. Towards the southeast, the formation thins (0.35 m in the Griset quarry) and in the Burets quarry and at Nabringhen is represented only by a bed of phosphatic

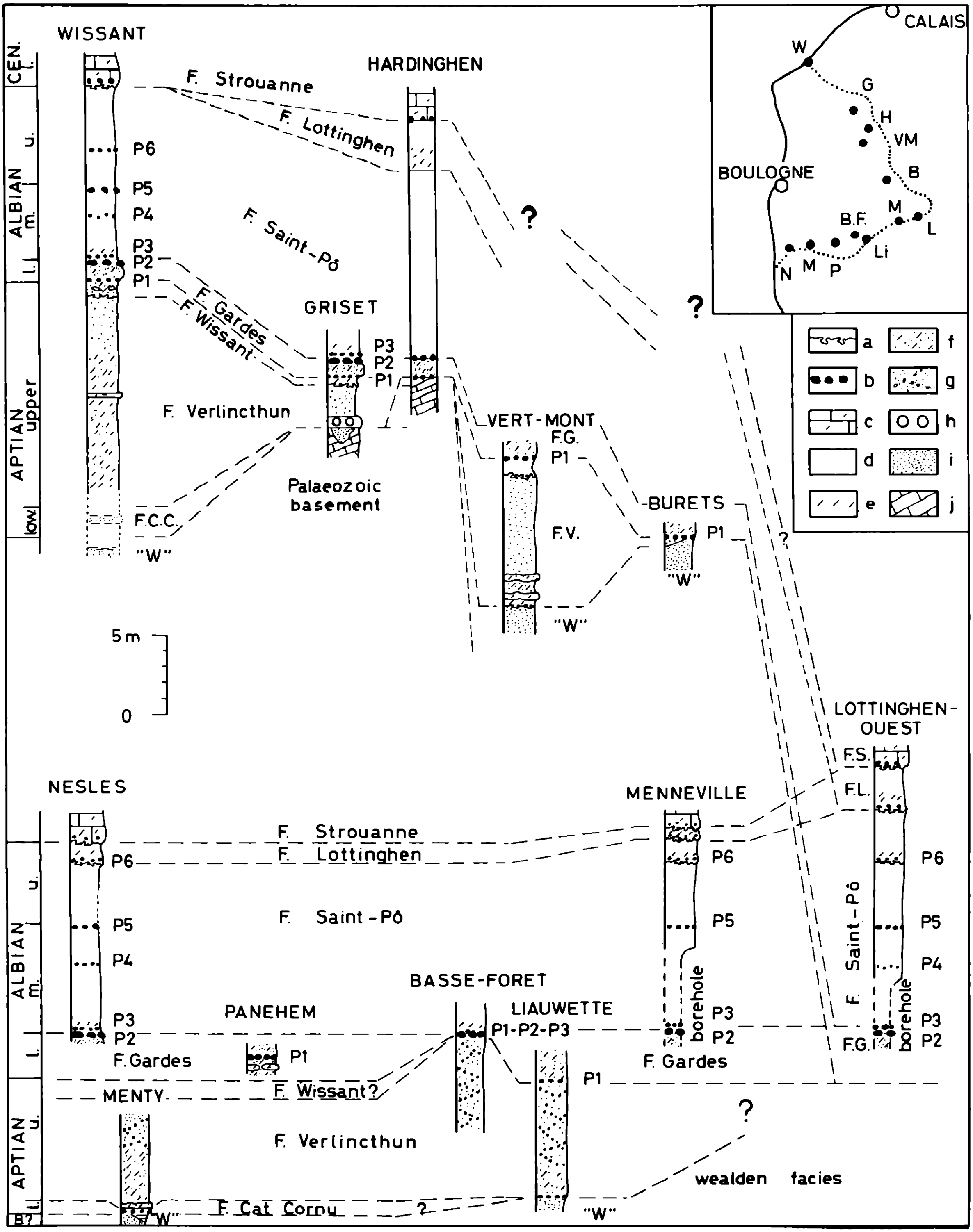

Fig. 7. Correlation of Aptian–Albian sections in the Boulonnais (a: burrowed surface – b: phosphate nodule bed – c: glauconitic chalk – d: Gault clay – e: glauconite – f: glauconitic sand – g: cross-bedded sands – h: conglomerate – i: Wealden facies sands – j: Palaeozoic limestones).

nodules, elements of which are included in the basal Albian bed as a remanié (Dutertre, 1938). The Wissant Formation is not exposed in the southern part of the Boulonnais.

(iii) Comparison with the Aptian of Kent
The syntheses written by Kirkaldy (1939), Casey (1960–1978, 1961) and Middlemiss (1976) give us a precise understanding of the Aptian beds in Kent. The currently accepted litho- and biostratigraphic correlations between the Aptian formations of Kent and Boulonnais are summarized in Figures 10 and 11. The most interesting point is a dramatic reduction of thickness of the Aptian formations from Kent to the Boulonnais. In ascending order, correlated formations are as following:

From the associations of the ammonites collected in the Cat-Cornu quarry at Menty, the Cat-Cornu Formation is the equivalent of a large part of the Hythe Beds. As the oldest ammonite subzone known in the Aptian of Boulonnais is the Subzone of *Deshayesites grandis,* it seems probable that there is no marine sediment equivalent to Atherfield Clay or to the lowest Hythe Beds in the Boulonnais.

As there are no cephalopods, it is impossible to correlate the Verlincthun Formation with the English sequence on palaeontological evidence. The facies characteristics (glauconitic sands overlain by cross-bedded white sands) suggest equivalence with the Sandgate Beds. However, in the Boulonnais, there is no evidence of the *Ch. martinioides* phosphatic nodule bed present in East Kent at the base of the Sandgate Beds. This suggests that the lower part of the Verlincthun Formation may be younger than the lowest Sandgate Beds, possibly of the same age, or slightly younger than the Zone of *Parahoplites nutfieldensis.*

The glauconitic sandy clays with *Hypacanthoplites rubricosus* and *H. jacobi* of the Wissant Formation exactly correspond to the basement bed (bed 1) of the Folkestone Beds, observed in 1961 by Casey at East Wear Bay near Folkestone. Interestingly, the Wissant Formation represents the only sedimentary sequence in the Boulonnais that is condensed in Kent.

In fact, although the beds are in general thinner in the Boulonnais than in Kent, the same phases of sedimentation and the same facies exist in both regions.

This indicates a similar palaeogeographical evolution for both regions in the Aptian stage. The fact that the transgressive phases occurred slightly later in the Boulonnais and that the beds there are thinner suggests, however, that the region occupied a more marginal position in the sedimentary basin.

(c) Albian of the Boulonnais

The Albian of the Boulonnais has been famous since the recognition in 1842 by d'Orbigny of the 'Sables verts' and of the 'Gault' at Wissant in the type-sections, thereby enabling the establishment of the Albian stage. Many stratigraphical and palaeontological studies of the Albian outcrops of the bay of Wissant have been made, notably by Barrois (1873, 1878), Destombes & Destombes (1938, 1965), Marie (1941, 1965), Owen (1971), Baccaert (1973), Verdier (1975), Price & Jorden (1977), Van der Wiel (1978) and Amédro & Destombes (1978). Synthesis of the definitions of formations and a summary of the data on ammonites, inoceramids, ostracods, planktonic and benthic foraminifera, calcareous nannoplankton and dinoflagellates have recently been published by Robaszynski & Amédro edit. *et al.* (1980), Amédro, Damotte, Magniez-Jannin & Manivit (1981).

The recent discovery in the south Boulonnais of the uppermost Albian, absent in the Wissant section, makes it possible to complete the stratigraphical results already obtained (Robaszynski & Amédro edit. *et al.*, 1980; Amédro *et al.*, 1981; Amédro & Magniez-Jannin, 1982).

(i) Representative sections of the Albian
The Albian formations of the Boulonnais comprise two sections: the outcrops of the bay of Wissant and the Lottinghen quarry (Figs. 6 & 7).

In the bay of Wissant the Gardes Formation and the Saint-Pô Formation occur in a series of scattered outcrops in the cliffs and foreshore over 3 km between Strouanne and the Cran d'Escalles.

In ascending order, the sequence is as follows, with the main macrofaunal markers:

Gardes Formation (*Lower Albian*) (Fig. 12, point 2)

g– 0.03 m. Phosphatic bed P1. Black phosphatic nodules, 2 to 5 cm in diameter, containing remanié *Hypacanthoplites* from bed f as well as an indigenous fauna including inoceramids: *Inoceramus salomoni* d'Orbigny; brachiopods: *Burrirhynchia leightonensis* (Walker) and many ammonites: *Leymeriella* (*Neoleymeriella*) sp., *Beudanticeras newtoni, B. dupinianum* (d'Orbigny), *Douvilleiceras mammillatum, D. orbignyi* Hyatt, *Anadesmoceras* cf. *baylei* (Jacob), *Cleoniceras floridum* and *Sonneratia flava* (Casey).

h– 1.00 m. Coarse green glauconitic sands, commonly cemented to form sandstones. Rare macrofauna: *B. newtoni, D. mammillatum, Sonneratia dutempleana* (d'Orbigny).

i– 0.08 m. Phosphatic bed P2. Grey or brown nodules 1 to 15 cm, commonly flattened, commonly with an argillaceous glauconitic cement and burrows. The whole bed has the appearance of a hardground: *I. salomoni, Beudanticeras newtoni, B. dupinianum, B. arduennense* Breistroffer, *Douvilleiceras mammillatum, D. orbignyi, D. scabrosum* Casey, *D. monile* (J. Sowerby), *Cleoniceras cleon* (d'Orbigny), *Sonneratia dutempleana*, *Pseudosonneratia* aff. *occidentalis* Casey, *Protohoplites* (*Hemisonneratia*) *puzosianus* (d'Orbigny), *P.* (*H.*) *gallicus* (Breistroffer), *P.* (*Protohoplites*) *archiacianus* (d'Orbigny), *P.* (*P.*) *michelinianus* (d'Orbigny), *Otohoplites* aff. *guersanti* (d'Orbigny), *O. raulinianus* (d'Orbigny), *O. auritiformis* (Spath), *O. elegans* (Spath), *O. waltoni* Casey, *O. glyptus* Casey, *O. destombesi* Casey, *Tegoceras gladiator* (Bayle), *Protanisoceras raulinianum* (d'Orbigny).

j– 0.01 m. Yellow, well crystallized pyrite, encrusting phosphatic nodules of beds P2 and P3.

Saint-Pô Formation (*Middle and Upper Albian pars*) (Fig. 12, between points 2 and 3–4)

k– 0.05 m. Phosphatic bed P3. Grey or black rolled nodules of 3 to 5 cm. The macrofauna consists almost entirely of internal moulds of ammonites: *Hoplites* (*Hoplites*) *dentatus* (J. Sowerby), *H.* (*H.*) *spathi* Breistroffer, *H.* (*H.*) *rudis* Parona & Bonarelli, *H.* (*H.*) *escragnollensis* Spath, *H.* (*H.*) *persulcatus* Spath, *H.* (*H.*) *similis* Spath, *H.* (*H.*) *canavarii* Parona & Bonarelli, *Oxytropidoceras* aff. *roissyanum* (d'Orbigny) and *Hamites* sp.

l– 0.60 m. Black glauconitic clay passing up to less glauconitic clay. Abundant crushed argillaceous fossils: *I. concentricus*, *Hoplites* spp. (similar to the ones found in bed k).

m– 1.40 m. Black clay, containing scattered nodules of sedimentary baryte: *I. concentricus*, *Anahoplites intermedius* Spath, *A. mantelli* Spath, *A. praecox* Spath, *A. planus* (Mantell), *Euhoplites microceras* Spath, *E. loricatus* Spath, *E. aspasia* Spath, *Falciferella milbournei* Casey (abundant at the top of the bed), *Hamites* sp.

n– 0.60 m. Light-grey clay, piped into the top of bed m in burrows. *I. concentricus*, *Anahoplites planus*, *Dimorphoplites niobe* Spath, *Euhoplites* spp. (similar to the ones found in bed m), *Hamites* sp. This bed is characterized by the small spatangoid echinoid: *Hemiaster* cf. *bailyi* (Forbes) Woodward.

o– 0.03 m. Phosphatic bed P4. Small, black rolled or broken nodules situated in the base of bed p with: *I. concentricus*, *A. planus*, *Dimorphoplites niobe*, *D. pinax* Spath, *D. doris* Spath, *D. biplicatus* (Mantell), *Euhoplites loricatus* (with var. *meandrinus* Spath), *E. truncatus* Spath, *E. lautus* (Parkinson), *Mojsisovicsia subdelaruei* (Spath), *Eubrancoceras* sp., *Hamites attenuatus* (J. Sowerby). Frequent decapod crustaceans: *Notopocorystes stokesii* (Mantell), *N.* (*Cretacoianina*) *broderipii* (Mantell), *Necrocarcinus labeschii* (Deslongchamps), *Xanthosia similis* (Bell).

p– 0.30 m. Dark grey clay. Burrows can be seen at the bottom and top of this bed. *I. concentricus*, *Anahoplites planus*, *Dimorphoplites glaber* Spath, *D. chloris* Spath, *S. biplicatus*, *Euhoplites lautus*, *E. truncatus*, *E. nitidus* Spath, *E. armatus* Spath, *Hamites gibbosus* (J. Sowerby), *H. attenuatus*.

q– 0.70 m. Light grey clay. A few small burrows can be seen at the top. Same fauna as in bed p.

r– 0.50 m. Dark grey clay. Abundant burrows in the top 20 cm (*Thalassinoides*, *Chondrites*). At the boundary with bed q, a layer of internal moulds of ammonites with pyritic phragmocone and phosphatic body-chamber contains a macrofauna similar to the one found in bed p or q. In the middle of bed r, other taxa present are: *Anahoplites* aff. *mangyschlakensis* Saveliev and *Semenovites* sp. gr. *litschkovi* Saveliev (det. H. G. Owen). In the upper 20 cm there are also several argillaceous or pyritic internal moulds of *Inoceramus subsulcatus* Wiltshire, *Dipoloceras cristatum* (Brongniart) and *D. bouchardianum* (d'Orbigny).

s– 0.08 m. Phosphatic bed P5. Very abundant black nacreous nodules. *I. concentricus*, *I. subsulcatus*, *I. sulcatus* Parkinson, *Beudanticeras beudanti* (Brongniart), *B. subparandieri* Spath, *Anahoplites planus*, *Dimorphoplites glaber*, *D. chloris*, *D. biplicatus*, *D. silenus* Spath, *Metaclavites compressus* (Parona & Bonarelli), *M. trifidus* (Spath), *Euhoplites truncatus*, *E. armatus*, *E. trapezoidalis* Spath, *E. serotinus* (Spath), *E. ochetonotus* (Seeley), *Neophlycticeras boloniense* (Destombes), *Dipoloceras cristatum*, *D. fredericksburgense* Scott, *D. pseudaon* Spath, *Hysteroceras capricornu* Spath, *H. simplicicosta* Spath, *Hamites gibbosus*.

t– 2.50 m. Grey marly clay, including abundant scattered *Inoceramus sulcatus* (argillaceous, crushed), and pyritic internal moulds of *Hysteroceras orbignyi* (Spath). There is a bed of phosphatic nodules, several centimetres in diameter, at 0.50 m above the basement. In the middle of bed t, there is a level with abundant pyritic phragmocones of *Beudanticeras beudanti*. Other taxa present are: *Anahoplites picteti* Spath, *Metaclavites compressus*, *M. trifidus*, *Epihoplites gibbosus* Spath, *Euhoplites subcrenatus* Spath, *E. inornatus* Spath, *E. serotinus*, *Mortoniceras* (*Mortoniceras*) *pricei* Spath, *M.* (*Deiradoceras*) *cunningtoni* Spath, *M.* (*D.*) *albense* Spath, *Prohysteroceras* (*Goodhallites*) *goodhalli* (J. Sowerby), *Hysteroceras varicosum* (J. de C. Sowerby), *H. carinatum* Spath, *Idiohamites tuberculatus* J. Sowerby.

u– 0.03 m. Phosphatic bed P6. Grey to brown nodules, 2 to 4 cm in diameter. The macrofauna is the same as in bed t, but with in addition: *Semenovites gracilis* (Spath), *S. iphitus* (Spath), *Epihoplites denarius* (J. de C. Sowerby), *E. deluci*

(Brongniart), *E. gibbosus* (Spath), *Euhoplites alphalautus* Spath. There is also frequent occurrence of the bivalve *Plicatula radiola* Lamarck.

v– 4.00 m. Grey, marly clay. A level of large *Mortoniceras* (*Deiradoceras*) and *Prohystoceras* (*Goodhallites*) in clay preservation overlies P6. In the lower 0.40 m of bed v, evidence of a few *Semenovites, Epihoplites gibbosus, Inoceramus* cf. *concentricus* and of a brachiopod which is characteristic of this level: *Moutonithyris dutempleana* (d'Orbigny), but *Inoceramus sulcatus* has disappeared. In the upper 3.60 m, only a few *Euhoplites alphalautus* and *Mortoniceras* (*Mortoniceras*) gr. *inflatum* have been collected, as well as a very large population of a comatulid described by Rasmussen (1971): *Glenotremites loveni* (Carpenter).

Strouanne Formation (*Lower Cenomanian pars*) (Fig. 12, point 4)
Beds 1 and 2: 1.80 m. Glauconitic conglomeratic chalk containing *Mantelliceras, Schloenbachia* and *Neostlingoceras,* resting on a bed (1a) consisting of clay and remanié phosphates, which are burrowed down into the Saint-Pô Formation. The remanié nodules of the Albian have yielded ammonites: *Dipoloceras* cf. *bouchardianum, Mortoniceras* (*Deiradoceras*) sp. and *Mortoniceras* (*M.*) sp.

About 130 species of ammonites have been recognized in the Albian of Wissant. If, in addition to this, we count the whole assemblage of taxa belonging to other fossil groups (macro-, micro-, nannofossils), we come to a total quantity of over 500 species. The vertical distribution of the significant species of each group is indicated on Fig. 6.

The zones of ammonites used here are those defined in 1980 by Amédro *in* Robaszynski & Amédro edit. *et al.* and Amédro (1981) because, in fact, several points of the 'standard' zonation—i.e. a synthesis of the schemes of Spath (1923–1941), Breistroffer (1947), Casey (1961) and Owen (1958, 1975)—are not quite satisfactory (Fig. 9):

The limits of the index fossils are different from limits of the zones to which they relate. For example, *Mortoniceras* (*Mortoniceras*) *inflatum,* which is the index fossil of a zone in U.K. occurs only in the Subzone of *Callihoplites auritus*. *Leymeriella* (*Leymeriella*) *tardefurcata* is limited to the Subzone of *L.* (*Neoleymeriella*) *regularis.* On the other hand, *Euhoplites lautus* extends above its zone into the overlying zone of *M.* (*M.*) *inflatum* of Spath.

The same ambiguity can be found in certain subzones. *Hysteroceras orbignyi* and *H. varicosum* represents two different Subzones although both occur in these two Subzones. *Euhoplites nitidus* is a subzonal index but its range is the same as that of *E. lautus* which is a zonal index!

Certain index fossils are rare e.g. *Mojsisovicsia* represents only 4 per cent of the fauna in the Subzone of *M. subdelaruei* is too imprecise, this species only occurs here because the communication between the Anglo-Paris Basin and the Tethyan realm became accidentally wider.

Inversion of the subzones. Casey (1961) defined a Subzone of *Otohoplites raulinianus* overlain by a Subzone of *Protohoplites* (*Hemisonneratia*) *puzosianus* based on collections made from phosphatised horizons at the top of the Lower Greensand in southeast England. But Destombes (1979), found the inverse of this sequence in the argillaceous facies in Aube and Pays-de-Bray in France.

The subzonal indices belong to different and unrelated families: Parahoplitidae, Leymeriellidae, Hoplitidae, Lyelliceratidae, Brancoceratidae. Those continually changing criteria render the definition of limits of zones and subzones highly suspect (see Owen, 1984). Different species do not appear at the same time in the different families. For example, the Subzone of *Leylliceras lyelli* is presently defined (Destombes & Destombes, 1965; Owen, 1971; Destombes, 1979) as the interval between the occurrence of an association of *Lyelliceras*: *L. pseudolyelli* (Parona & Bonarelli), *L. huberianum* (Pictet), *L. hirsutum* (Parona & Bonarelli) (Lyelliceratidae) and the extinction of *Hoplites* (*Hoplites*) *benettianus* (Hoplitidae). It should be noted that the range of *Lyelliceras lyelli* is not even used to define the limit of the Subzone of *L. lyelli.*

Finally, incorporating all the ammonite bioevents observable in the field into a single zonal scheme leads to an unnecessary and impractical increase in the number of subzones.

Since 1980, following the idea proposed by Thomel (1973a, 1973b) for the Cenomanian, Amédro *in* Robaszynski & Amédro edit. *et al.* (1980) has recommended the use of a phyletic biozonation in the Albian of the Anglo-Paris Basin. The advantage of such a scheme is that the limits between the different intervals are precise, since they are defined on phyletic criteria. The proposition we agreed on is a sequence of Assemblage-Zones, the meaning of which is close to that generally accorded to Interval-Zones defined by the appearance of a species.

The evolution of the Hoplitidae—which are present in large numbers in the Anglo-Paris Basin—is used to provide the zonal framework for the largest part of the Lower Albian and of the Middle Albian. The sudden proliferation of the Brancoceratidae, and their wide areal extent make them more suitable for the subdivision of the Upper Albian. A comparison

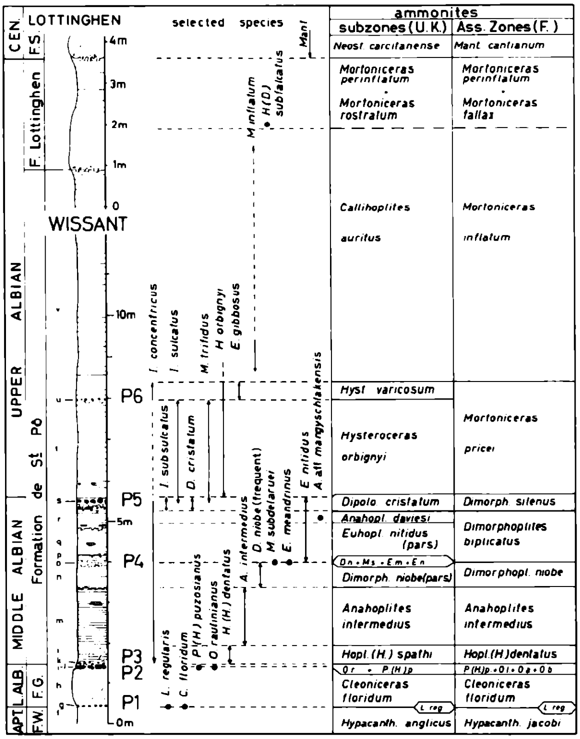

Fig. 8. Vertical distribution of index ammonites and inoceramids in the Albian of the Boulonnais. Comparison of 'standard' zonation and tentative phyletic zonation with ammonites.

between this phyletic zonation and the standard zonation appears in Figs. 8 and 9.

The Lottinghen-Est quarry

An old clay quarry that is now filled with water previously showed the top of the Saint-Pô Formation, the Lottinghen Formation and the base of the Strouanne Formation. In ascending order, the succession is as follows (measurements are taken from the water-level in July 1976):

Saint-Pô Formation (*Middle and Upper Albian pars*)
0 to 0.80 m. Grey blue clay with rare macrofauna.

Lottinghen Formation (*uppermost Albian*)
0.80 to 1.20 m. Coherent green glauconite, piped down in burrows into the top of the underlying Saint-Pô Formation. Rounded phosphatic nodules few centimetres in diameter occur at the base: *Gryphaeostrea canaliculata* (J. Sowerby).

1.20 m to 2.40 m. Glauconitic coherent green marl. *G. canaliculata*, *Mortoniceras* (*Mortoniceras*) *inflatum* (J. Sowerby) at 1.50 m; *Hyphoplites* (*Discohoplites*) *subfalcatus* Spath at 2.00 m; appearance of the planktonic foraminiferal species *Rotalipora appenninica* (Renz) at 2.20 m.

2.40 m to 3.70 m. Dark blue clay. *G. canaliculata*.

Strouanne Formation (*Lower Cenomanian pars*)
3.70 m to 5.00 m. Glauconitic, bioturbated chalk, containing small scattered phosphatic nodules. Many burrows at the base; *Mantelliceras mantelli* (J. Sowerby), *Schloenbachia varians* (J. Sowerby).

The main macro- and micropalaeontological markers collected in the Lottinghen Formation, (which does not exist in Wissant) are indicated in Fig. 6.

N.B.: Another quarry—Lottinghen Ouest—situated 50 m away from the quarry we describe, showed a larger part of the Saint-Pô Formation, but with a sequence similar to the one recognized in Wissant.

(*ii*) *Correlations of the Albian of the Boulonnais*

As for the Aptian, a series of outcrops of the Albian of Boulonnais are correlated from Wissant to Nesles on lithological and palaeontological criteria (Fig. 7).

The Gardes Formation (Lower Albian) exhibits an almost constant lithology throughout the Boulonnais; the type-section is at Wissant. Generally speaking, the formation comprises 1 to 2 metres of coarse, green glauconitic sands, intercalated between the phosphatic beds P1 and P2. However, at two localities, the lithological sequence is different.

At Panehem, in the Samer area, at least 1.5 m of green glauconitic sands could be seen in 1975 under the phosphatic bed P1 (Fig. 7). These sands, which are quite different from the sands occurring in the Wissant Formation in the Upper Aptian, were slightly indurated in their medial part, forming an incoherent sandstone with several internal moulds of molluscs, including two ammonites: *Leymeriella* sp., and *L.* (*Neoleymeriella*) *regularis* (d'Orbigny). This section exposes the only non-condensed sequence of the Assemblage-Zone of *L.* (*N.*) *regularis* known in the Boulonnais at the present time.

Secondly, in the Basse-Forêt de Desvres quarry, local intra-Albian erosion has removed the glauconitic sands of the Gardes Formation. In this case, the Saint-Pô Formation (Middle and Upper Albian) directly overlies the Verlincthun Formation (Upper Aptian).

If we compare the different sections of the Saint-Pô Formation (M. and U. Albian pars) we realize that the phosphatic beds P3, P4, P5 and P6 are similar throughout the Boulonnais. This comparison also shows that the lower part of the Saint-Pô Formation has the same lithological characteristics from Wissant to Nesles. However, a lateral facies variation occurs in

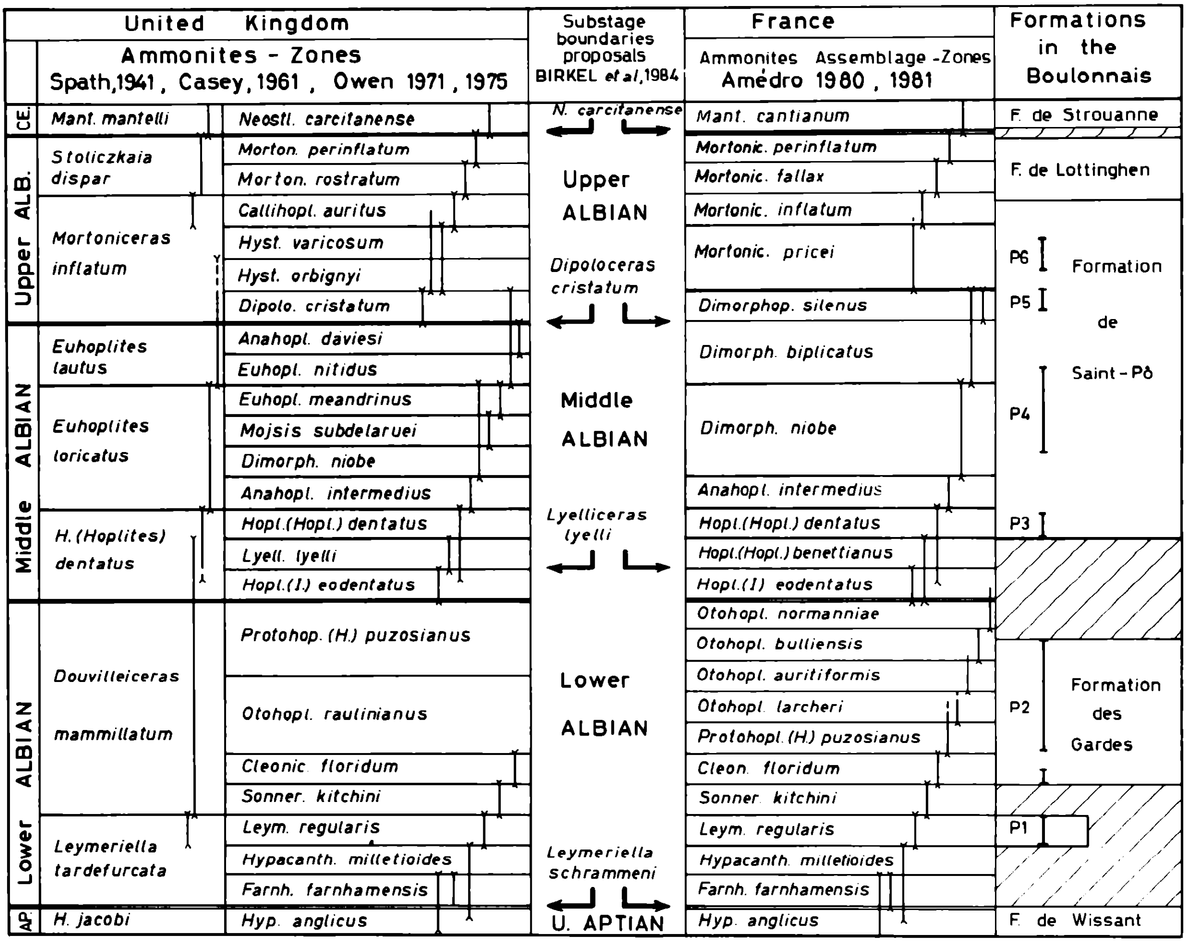

Fig. 9. Comparison of ammonite zonations of the Albian stage in the Boulonnais and the Weald.

the southern Boulonnais in the upper part of the formation: glauconite occurs in Menneville and in Lottinghen quarries in the 40 cm of clay that overlie P6. Finally, it should be noted that in Nesles, the top of the Saint-Pô Formation corresponding to the *Mortoniceras* (*M.*) *inflatum* Assemblage-Zone is missing (erosion down to P6).

Until recently, the Lottinghen Formation, with its characteristic lithological features (glauconitite and glauconitic clay, defined at its base by a bed of phosphatic nodules) had only been recognized in the southern Boulonnais at Lottinghen, Menneville and Nesles (Amédro & Magniez-Jannin, 1982). However, the description by Olry (1904) of the succession penetrated by a coal mine-shaft near the village of Hardinghen, in the Boulonnais coal basin, suggests that the Lottinghen Formation also exists in the northern part of the Boulonnais. In ascending order the lithologies described by Olry, and the present interpretation, are as follows:

Olry 1904	*present interpretation*
0 – level of the ground (O.D. + 120 m) 0 to 2.85 m. Vegetal earth including flints, then yellowish and reddish clay with flints.	Quaternary and Tertiary (?) formations 2.85 m.

2.85 m to 12.00 m. Very argillaceous grey marl. 12.00 m to 13.00 m. Less grey, crumbly marl. 13.00 m to 15.00 m. Aquiferous white chalk, in large pieces. 15.00 m to 17.20 m. Yellowish 'rusty' chalk with *Inoceramus labiatus* (sic) at the base.	Petit Blanc-Nez Formation (Lower Cenomanian) seen for 14.35 m.
17.20 m to 18.70 m. Hard grey glauconitic chalk ('Tourtia gris').	Strouanne Formation (Lower Cenomanian *pars*) 1.50 m.
18.70 m to 20.50 m. Grey clay with Gault facies. 20.50 m to 21.85 m. Dark green clay, very glauconitic.	Lottinghen Formation (Upper Albian *pars*) 3.15 m.
21.85 m to 31.00 m. Greyish-blue clay including *Belemnites minimus*, *Inoceramus sulcatus* and '*Ammonites spendens*.'	Saint-Pô Formation (Middle and Upper Albian *pars*) 11.35 m.
31.00 m to 33.20 m. Plastic clay at first grey, then blackish. 33.20 m to 33.55 m. Phosphatic nodules. 33.55 m to 34.20 m. Green blackish sand. 34.20 m. Coal-bearing strata.	Gardes Formation (Lower Albian) 1 m.

Consequently, contrary to the opinion of Marie (1941) and Destombes & Destombes (1965), the uppermost Albian ('Vraconnian') does in fact exist in the Boulonnais. Moreover, it occurs continuously, from the north to the east and the south of this area; the section of Wissant appears to be an exception. The absence of the Lottinghen Formation at Wissant is probably simply the result of local structural influences leading to erosion. This interpretation is substantiated by the occurrence of several remanié Upper Albian ammonites in the Strouanne Formation of the Lower Cenomanian.

(*iii*) *Comparison with the Albian of Kent*

The main data on the Folkestone sections are from Barrois (1875), Spath (1923), Casey (1961, 1966), Owen (1958, 1971, 1975) and Hart (1973). These result in the definition of a detailed lithological sequence which is completed by the charts of the vertical ranges of ammonites, inoceramids, foraminifera and ostracods. The correlation between the Albian of the Boulonnais and of East Kent is shown in Figs. 10 and 11. As with the Aptian, a dramatic contraction of the sequence occurs in the Boulonnais, where the Albian formations are only about 18 m thick in Lottinghen and 11 m in Wissant, whereas they are about 58 m thick at Folkestone.

Because of its facies of glauconitic sands, the Gardes Formation (='Sables verts' *auct.*) corresponds to the Folkestone Beds in Kent, (upper part of the Lower Greensand). But this equivalence has to be considered in connection with the biostratigraphical data. On one hand, the base of the Folkestone Beds is Upper Aptian and is consequently correlated with the Wissant Formation. On the other hand, the main mass of Folkestone Beds is dated from the Subzones of *Hypacanthoplites milletioides*, *Leymeriella* (*Neoleymeriella*) *regularis* and *Sonneratia kitchini*. These subzones are lacking in Wissant as well as in the main part of the Boulonnais (except at Panehem in the case of the *regularis* Subzone). Consequently, most outcrops of the Gardes Formation, characterized by the occurrence of *Cleoniceras floridum*, *Protohoplites* (*Hemisonneratia*) *puzosianus*, *Otohoplites raulinianus* equate only with the terminal 1.20 m of the 18 m thick Folkestone Beds, i.e. the section including the

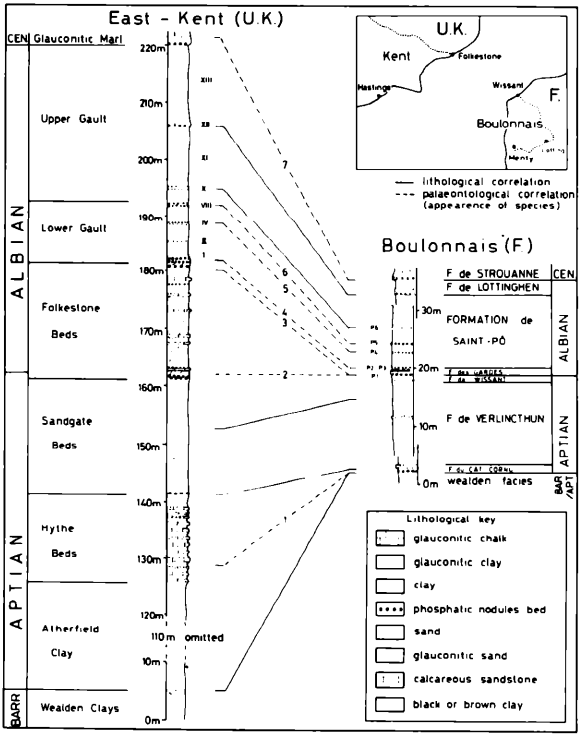

Fig. 10. Tentative correlation of Aptian–Albian sequences in the Boulonnais and East Kent. Palaeontological datum lines: appearance, of 1: *Tropaeum* cf. *hillsi* – 2.: *Leymeriella* (*Neoleymeriella*) *regularis* – 3: *Cleoniceras floridum* – 4: *Hoplites* (*Hoplites*) *dentatus* – 5: *Mojsisovicsia subdelaruei* – 6: *Dipoloceras cristatum* – 7: *Schloenbachia varians*.

EAST KENT (U.K.)

stages	Ammonites - Zones OWEN, 1975 CASEY, 1961		Formations	
CEN	*Neostlingoc. carcitanense*		Glauconitic Marl	
Upper ALB.	*S. dispar*	*M. perinflatum*	U. Gault	XIII
		M. rostratum		XII
	M. inflatum	*C. auritus*		XI
		H. varicosum		X
		H. orbignyi		IX
		D. cristatum	Lower Gault	VIII
Middle ALBIAN	*E. lautus*	*A. daviesi*		VII
		E. nitidus		V-VI
	E. loricatus	*E. meandrinus*		IV
		M. subdelaruei		
		D. niobe		III
		A. intermedius		II
	H. (H.) dentatus	*H. (H.) spathi*		I
		L. lyelli		
		H. (I.) eodentatus		
Lower ALBIAN	*Douvilleic. mammill.*	*Protohoplites puzosianus*	Folkestone Beds	sulphur band
		Otohoplites raulinianus		*Mammillatum* Bed.
		C. floridum		
		S. kitchini		main mass
	Leymeri. tardef.	*L. regularis*		
		H. milletioides		
		F. farnhamensis		
Upper APTIAN	*Hypacant. jacobi*	*H. anglicus*		nodule beds
		H. rubricosus		
		N. nolani	Sandgate Beds	main mass
	Parahopl. nutfield.	*P. cunningtoni*		
		T. subarcticum		
	Chelonic. martin.	*C. buxtorfi*		nodule bed
		C. gracile		
		C. debile		
Lower APTIAN	*Tropaeum bowerb.*	*C. meyendorffi*	Hythe Beds	
		D. transitoria		
	Deshay. deshay.	*D. grandis*		
		C. parinodum		
	Deshay. forbesi	*D. callidiscus*	Atherfield Clay	
		D. kiliani		
		D. fittoni		
	Prodesh. fissicost.	*P. obsoletus*		
		P. bodei		

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Neo. carc.
U. ALB.
Dipol. cristatum
M. ALB.
L. lyelli
L. ALB.
Leym. schramm.
APT.

BOULONNAIS (F.)

Formations		Ammonites - Zones AMEDRO, 1980 CASEY, 1961		stages
F. de Strouanne		*Neostlingoc. carcitanense*		CEN
F. de Lottinghen		*Mortonic. perinflatum*		Upper ALB.
		Mortonic. fallax		
Formation de Saint-Pô		*Mortonic. inflatum*		
	P6	*Mortonic. pricei*		
	P5	*Dimorphopl. silenus*		Middle ALBIAN
		Dimorphopl. biplicatus		
	P4	*Dimorphoplites niobe*		
		Anahoplites intermedius		
	P3	*H. (H.) dentatus*		
		H. (H.) benettianus		
		H. (I.) eodentatus		
Form. des Gardes	sulphur band	*Otohopl. normanniae*		Lower ALBIAN
	P2	*Otohopl. bulliensis*		
		Otohopl. auritiformis		
		Otohopl. larcheri		
		Protohopl. puzosianus		
	main mass P1	*Cleoniceras floridum*		
		Sonneratia kitchini		
	P1	*Leymeriella regularis*		
		Hypacant. milletioides		
		Farnham. farnhamensis		
Formation de Wissant		*Hypacant. jacobi*	*H. anglicus*	Upper APTIAN
			H. rubricosus	
Formation de Verlincthun			*N. nolani*	
		Parahopl. nutfield.	*P. cunningtoni*	
			T. subarticum	
?		*Chelonic. martin.*	*C. buxtorfi*	
			C. gracile	
			C. debile	
Formation du Cat Cornu		*Tropaeum bowerb.*	*C. meyendorffi*	Lower APTIAN
			D. transitoria	
		Deshay. deshay.	*D. grandis*	
			C. parinodum	
		Deshay. forbesi	*D. callidiscus*	
			D. kiliani	
			D. fittoni	
		Prodesh. fissicost.	*P. obsoletus*	
			P. bodei	

Fig. 11. Comparison of lithological formations and ammonite zones of the Aptian–Albian of the Boulonnais and East Kent (beds I to XIII according to Jukes-Browne, 1900).

'Main Mammillatum Bed' and the 'Sulphur Band' at East Cliff, Folkestone.

Precise correlations between the 'Gault clays of Wissant', (=Saint-Pô Formation), and the Gault of Folkestone have already been established by Destombes & Destombes (1938) and by Owen (1971).

There is lithological continuity on both sides of the Channel between the Saint-Pô Formation and beds I to XI of the Gault of Folkestone. Evidence for this is found in the similar position of the phosphatic beds, omission-surfaces and the changes in colour of the clays in the different sequences. However, it should be noted that in England the phosphatic beds are generally divided, so that every phosphatic horizon of the Boulonnais is represented by two phosphatic horizons in Kent, and that between Boulonnais and Kent all the beds get thicker.

The lithological continuity is completed by the range in both areas of several peculiar palaeontological horizons, the characteristics of which are as follows: abundance of the small ammonite *Falciferella milbournei* at the top of the *Anahoplites intermedius* A.-Z. (Assemblage-Zone), frequent occurence of the echinoid *Hemiaster* cf. *bailyi* in he *Dimorphoplites niobe* A.-Z., as well as the occurrence of the brachiopod *Moutonithyris dutempleana* at the top of the *Mortoniceras* (*M.*) *pricei* A.-Z.

Finally, the phosphatic bed P3 of the Boulonnais contains a unique fauna of *Hoplites* from the *H.* (*H.*) *dentatus* A.-Z. But Bed Ia of Folkestone shows a succession of three phosphatic nodule beds with successively *H.* (*Isohoplites*) *eodentatus, Lyelliceras lyelli* and *H.* (*H.*) *dentatus,* which indicates the condensation of the *H.* (*I.*) *eodentatus* A.-Z., the *L. lyelli* A.-Z. and the *H.* (*H.*) *dentatus* A.-Z. Consequently, the base of the clays with Gault facies is somewhat younger in the Boulonnais than in Kent, even though, in both regions, a gap marks the boundary between Lower and Middle Albian.

From its litho- and biostratigraphical characteristics, the Lottinghen Formation is seen to be the part equivalent of beds XII and XIII of Folkestone.

Finally, during the Albian and previously the Aptian times, the both Boulonnais and Kent appear to behave as a single palaeogeographical unit. The fact that the beds always get thicker from France to England, and that the transgressive phases took place earlier in Kent, suggests that southeast England was subsiding more at that time than the Boulonnais. On the other hand, the lacunae recognized in the Upper Albian in Wissant and in Nesles point to a certain tectonic instability in the Boulonnais at that time.

3. THE UPPER CRETACEOUS (F.R.)

In the Boreal realm of Europe, the Upper Cretaceous sees the beginning of chalk sedimentation which, in contrast to the terrigenous sedimentation of the Lower Cretaceous, is a carbonate bio-accumulation facies, almost entirely composed of coccoliths and foraminiferal tests. From the Cenomanian the transgression of the Chalk Sea continued until a very wide area from the Irish to the Russian Platform was covered. Chalk is well represented in the Boulonnais and is of Cenomanian, Turonian, Coniacian and basal Santonian ages. The whole Santonian and the Campanian are exposed in other parts of the Paris Basin, for example in Normandy, Champagne and Sénonais, whereas the Maastrichtian is preserved only in the Mons Basin (Belgium), in some outcrops of the Cotentin (*Baculites* Limestone) and in the Reims area.

In chalk facies, the most useful stratigraphical marker horizons to establish correlations between close or distant sections are of a lithological or palaeontological nature.

The most commonly used *lithostratigraphical marker horizons* are:

- marl-bands (from several cm to one dm thick, grey to green coloured, often of a wide geographical extent because probably related to anoxic events in the whole of basin; *cf.* Hart & Bigg, 1981);
- hardgrounds (from one to several dm or one m thick, yellowish, with a nodular aspect, composed of hardened, carbonate cemented chalk, with a glauconitic coating and sometimes burrowed surface, of a regional to local scale);
- flint levels (siliceous nodules, burrow-form or kidney-shaped; flint appearance, coalescence of several layers or peculiar form of certain flints may be used as local or regional reference-level).

As for the *bioevents,* levels of appearance or extinction of index macrofossils (ammonites, inoceramids, echinoids, brachiopods) or index microfossils (foraminifera, calcareous nannoplankton, dinoflagellates, ostracods) are most important. The integration of bioevents with a lithostratigraphical framework based on marker horizons gives high confidence correlations. Using this method it has been possible to correlate sections throughout the Boulonnais and with the Dover area.

The biostratigraphical study of the Upper Cretaceous of the Boulonnais led us to establish a set of formations, most of them being defined in the Cap Blanc-Nez cliffs which constitute a regional reference section for the Cenomanian-Turonian (Figs. 12 & 13). This section was completed with the detailed analysis of the Caffiers railway cutting (Turonian-Coniacian *pars*) and of the Coquelles old quarry (Coniacian *pars*—basal Santonian).

(a) The Cenomanian chalk of the Boulonnais

In 1872, Chellonneix published the first description of the 'assises crétacées du Cap', giving the fossil content of Cenomanian strata supplemented by a section of the cliff, seen from the beach. Later on, with the

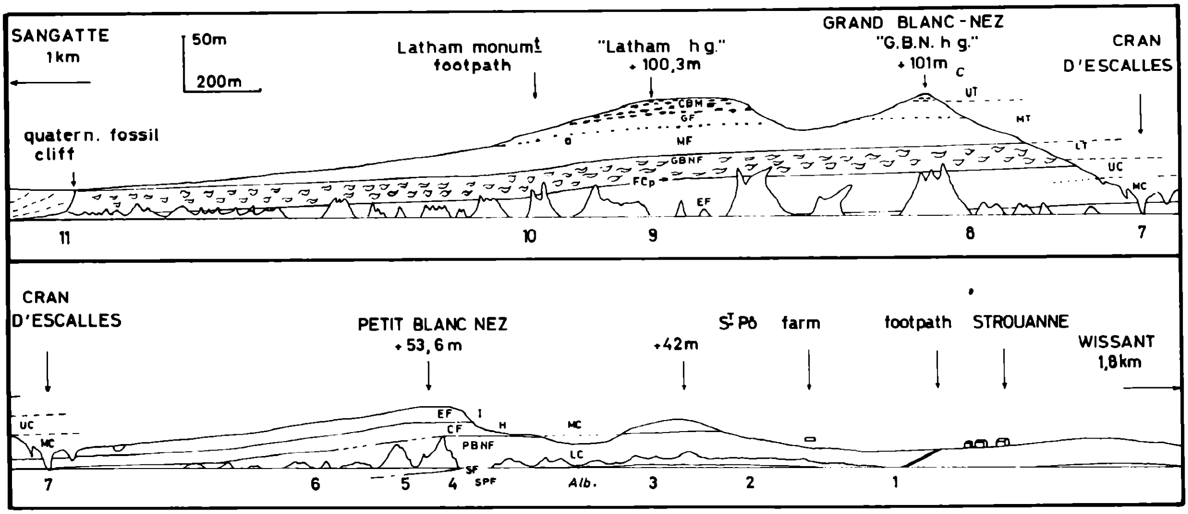

Fig. 12. The Cretaceous cliffs of the Cap Blanc-Nez, view from the beach. (Alb = Albian; LC–MC–UC: Lower, Middle, Upper Cenomanian; LT–MT–UT: Lower, Middle, Upper Turonian; C: Coniacian; SPF: St Pô Formation; SF: Strouanne Formation; PBF: Petit Blanc-Nez Formation; CF: Cran Formation; EF: Escalles Formation; CpF: Crupes Formation = Plenus Marls, GBNF: Grand Blanc-Nez Formation; MF: Mottelettes Formation; GF: Guet Formation; CBM: Caffiers Bridge Member; 1 to 11: location of points of observation. 1: Lower Cenomanian, glauconitic chalk; 2: Lower Albian, P1, glauconitic sands, P2; 3: Middle and Upper Albian, P3, dark clay, P4, dark grey clay, P5, grey clay, P6, marly clay; 4: Lower Cenomanian, glauconitic chalk at the base of the Petit Blanc-Nez headland, metric rhythms of grey bluish chalk and marl; 5: Boundary between Upper Albian clays and Lower Cenomanian glauconitic chalk exposed on the beach; 6: small faults in the Lower Cenomanian; 7: Lower part of the Middle Cenomanian at the Cran d'Escalles, chalk with incipient hardgrounds; 8 and 9: views on the Middle Cenomanian to Upper Turonian section of the Grand Blanc-Nez-cliffs; 10: Plenus Marls = Crupes Formation, exposed at the top of the fall; 11: Quaternary fossil cliff.

succeeding Channel Tunnel projects considering routes in both impervious and resistant strata, detailed geological and geotechnical surveys were undertaken on the Cenomanian succession (Potier & De Lapparent, 1875; Bruckshaw *et al.* 1961; Carter & Destombes, 1972; Destombes & Shephard-Thorn, 1972). Other studies that have improved the biostratigraphical knowledge on the Cenomanian are those of Barrois (1873, 1875), Leriche (1905), Magné & Polvêche (1961), Jefferies (1963), Andreieff (1964), and more recently Amédro *et al.* (1976, 1978), Elewaut & Robaszynski (1977), and Robaszynski & Amédro edit. *et al.* (1980). Moreover, the structure of the post-Palaeozoic cover was examined by Briquet (1924), Pruvost (1925), Destombes & Destombes (1963), Colbeaux & Mania (1976), Auffret & Colbeaux (1977) and Colbeaux *et al.* (1980).

(*i*) *Representative sections of the Cenomanian*

At Wissant and Sangatte Cenomanian chalk is well exposed and accessible between the Petit Blanc-Nez headland (south of the Cran d'Escalles) and the Grand Blanc-Nez headland (north of the Cran d'Escalles). This gives the possibility of following without break the whole lithological sequence. Moreover, when the beach is not covered by sand, the low dip of the strata to the NE provides good and richly fossiliferous outcrops.

In general terms, the Cenomanian begins with a greenish glauconitic chalk, followed by a succession of metre-scale grey chalk cycles beginning with grey-green marls, and culminating with thick layers of white-grey chalk topped by the '*Actinocamax plenus* marls'. Several formations were named along the cliff section (Robaszynski & Amédro edit. *et al.*, 1980) and will be briefly described in ascending order, as follows.

The Strouanne Formation (Lower Cenomanian *pars*) comprises 2 m of glauconitic chalk (named 'Tourtia' by coal miners in northern France). At the base of the Petit Blanc-Nez headland, the formation is made of two beds (Fig. 12, point 4); when the foot of the cliff is cleared by tidal currents, the burrowed contact with the Albian marl is visible. The base of the formation is strongly glauconitic, dark green and yields a lot of small phosphatized pebbles. The glauconite content progressively decreases towards the top which becomes more calcareous and contains large sponges known as '*Plocoscyphia*' *labrosa*. The formation is also accessible at the Strouanne beach footpath (Fig. 12, point 1).

Ammonites: *Neostlingoceras carcitanense* (Mathe-

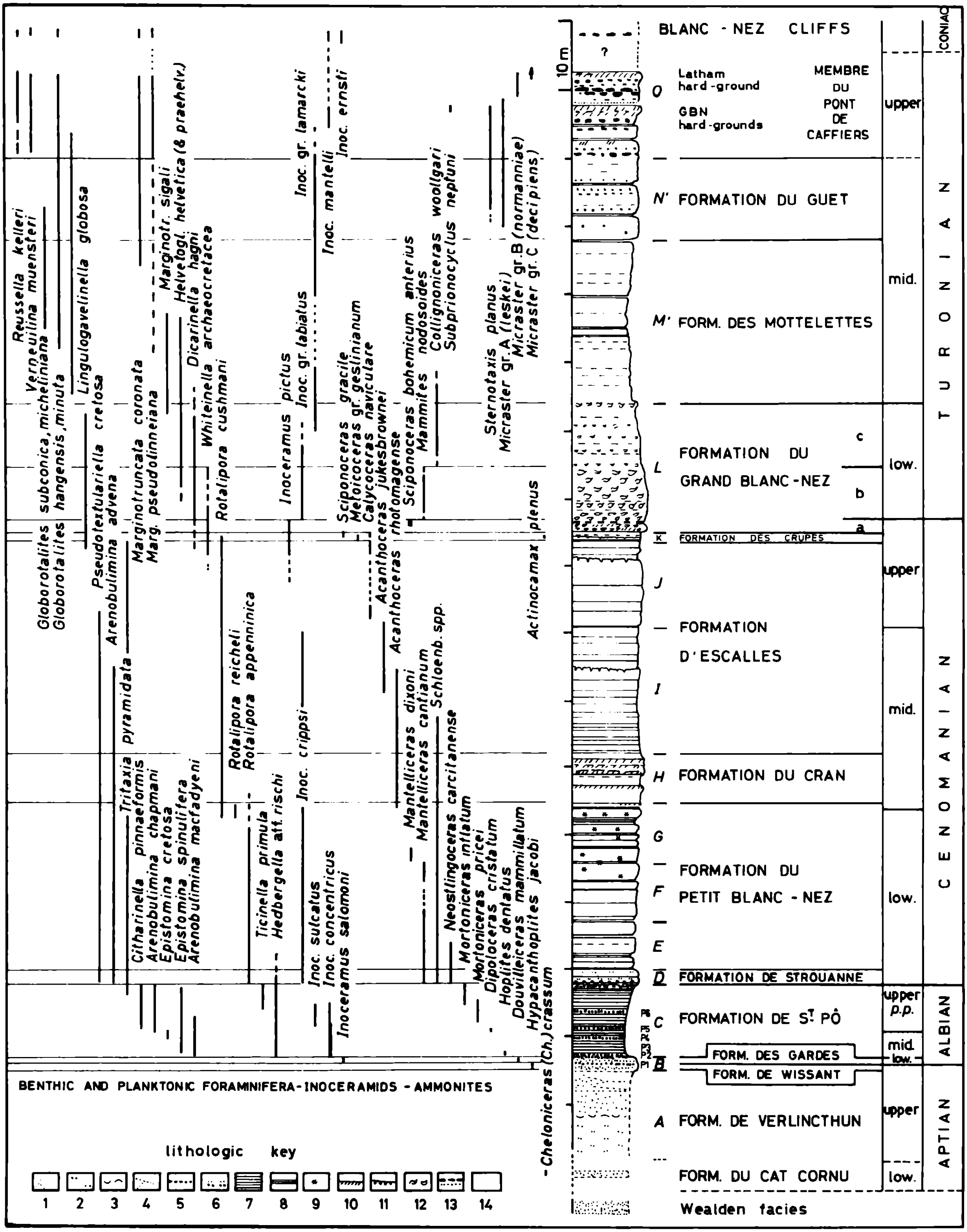

Fig. 13. The Cretaceous formations at the Cap Blanc-Nez: lithological succession and vertical distribution of main fossils (1: sand – 2: glauconitic sand – 3: Oysters – 4: cross-bedded sands – 5: phosphate nodule bed – 6: basal conglomerate ('Tourtia') – 7: Gault clay – 8: marl band – 9: pyrite – 10: hardground – 11: burrowed surface – 12: nodular chalk – 13: flint level – 14: chalk).

ron), *Schloenbachia varians* (J. Sowerby), *Mantelliceras mantelli* (J. Sowerby), *Eutrephoceras* sp. (nautiloid). Inoceramids: '*Inoceramus*' *crippsi* Mantell. Echinoids: *Holaster trecensis* Leymerie. Brachiopods: *Moutonithyris dutempleana* (d'Orbigny). Planktonic foraminifera: *Rotalipora appenninica* (Renz), *Praeglobotruncana delrioensis* (Plummer). Benthic foraminifera: *Tritaxia pyramidata* (Reuss), *Arenobulimina advena* (Cushman), *Pseudotextulariella cretosa* (Cushman), *Gavelinella cenomanica* Brotzen, *G. baltica* Brotzen, *Lingulogavelinella jarzevae* (Vassilenko), *Marssonella ozawai* Cushman.

The detailed vertical distribution of macro- and micro-fossils are given *in* Amédro *et al.* (1978), Robaszynski & Amédro edit. *et al.* (1980) and Amédro (in press); see Fig. 14.

The Petit Blanc-Nez Formation (Lower Cenomanian *pars* and extreme base of Middle Cenomanian) consists of 25 m of chalk-marl cycles. From the Petit Blanc-Nez headland towards the Cran d'Escalles at the north, a succession of about 20 beds is exposed, 1 to 2 m thick, bluish in color, the middle beds being light coloured. Each bed is a cycle beginning with a blue-greenish marl and progressively passing to light grey marl chalk, the top of which is commonly marked by the presence of sponges ('*Plocoscyphia*' *labrosa*). Generally, marls are fully burrowed by small trace fossils such as *Chondrites*. Upper beds commonly contain radiate pyrite nodules and their marly dark base make visible some minor faults (Fig. 12, point 6). On the south side of the Cran d'Escalles, the top of the formation is marked by a spring-line. The Channel Tunnel would have to be bored in this formation because of the impervious character of the sequence.

Ammonites: *Hypoturrilites gravesianus* (d'Orbigny), *Schloenbachia varians, Mantelliceras mantelli, M. cantianum* Spath, *M. saxbii* (Sharpe), *Acompsoceras sarthense* (Guéranger). Inoceramids: '*Inoceramus*' *crippsi, I. virgatus* Schlüter. Echinoids: *Holaster trecensis, Cidaris vesiculosa* Dolfuss, Brachiopods: *Cyclothyris* cf *polygona* (d'Orbigny). Planktonic foraminifera: *Praeglobotruncana delrioensis*, appearance of *P. stephani* (Gandolfi), development and extinction of *Rotalipora appenninica*, presence of *Rotalipora reicheli* (Mornod) only at the top, appearance of *Rotalipora montsalvensis* (Mornod). Benthic foraminifera: some fifty species, most of them being present in the Strouanne Formation, extinction of *L. jarzevae* and *M. ozawai* above the basal beds.

All these fossils belong to the Lower Cenomanian, but the highest bed of the formation contains *Turrilites costatus* Lamarck and *Acanthoceras rhotomagense* (Brongniart) and is Middle Cenomanian.

The Cran Formation (Middle Cenomanian *pars*) is 7.5 m thick and consists of more or less granular chalk, with hardgrounds. The formation is completely exposed on the northern side of the Cran (Fig. 12, point 7) and its top is visible at the foot of the south side of the large Grand Blanc-Nez fall (Fig. 12, point 8). 2.5 m above the base of the formation, the chalk is hardened and yields small rhynchonellids: *Grasirhynchia martini* (Mantell). The next bed contains abundant small rhynchonellids: *Orbirhynchia mantelliana* (J. de C. Sowerby) forming the '*mantelliana* band' of Kent (Kennedy, 1969). Above this bed follows 2 m of hardened chalk with several incipient hardgrounds, capped by a true hardground which is related to a sedimentary break detectable practically all over the Western Europe: this is the 'Mid-Cenomanian non-sequence' of Carter & Hart (1977).

Ammonites: numerous *Acanthoceras rhotomagense, Turrilites costatus*, some *Schloenbachia* sp., *Euomphaloceras cunningtoni* (Sharpe), hundreds of specimens of *Sciponoceras baculoide* (Mantell) in the '*mantelliana* band'. Inoceramids: '*Inoceramus*' *crippsi, I. virgatus*. Echinoids: *Holaster subglobosus* (Leske). Planktonic foraminifera: extinction of *Rotalipora reicheli* at the base of the Formation, development and extinction of *Rotalipora montsalvensis*, appearance of *Rotalipora cushmani* (Morrow). Benthic foraminifera: the same as below with appearance of *Flourensina intermedia* Ten Dam.

The Escalles Formation (Middle Cenomanian *pars* and Upper Cenomanian *pars*) is 31 m of grey chalk with thin rhythms in the lower part, massive whitish-grey chalk in the upper part. It is accessible on the south side of the large Grand Blanc-Nez fall (Fig. 12, point 8) and on the beach, from the Grand Blanc-Nez headland to Sangatte.

In the lower half the rhythms begin with a thin marly bluish horizon passing rapidly upwards into a several dm thick chalk bed. About 12 m above the base, a phosphatized hardground cuts the regular sequence. Fossils give a Middle Cenomanian age for this lower half.

Ammonites: *Acanthoceras rhotomagense* at the base, *A. jukesbrownei* (Spath) at the top. Inoceramids: '*Inoceramus*' *crippsi*. Echinoids: *Holaster subglobosus*. Planktonic foraminifera: *Rotalipora cushmani*, appearance of *Rotalipora greenhornensis* (Morrow) at the top. Benthic foraminifera: the same as below.

In the upper half some rare and thin marly horizons underline massive whitish-grey chalk beds with rare Upper Cenomanian fossils.

Ammonites: rare *Calycoceras naviculare* (Mantell). Inoceramids: rare *Inoceramus pictus* Sowerby. Echinoids: *Holaster nodulosus* Goldfuss. Planktonic foraminifera: *Rotalipora cushmani, R. greenhornensis*, appearance of *Whiteinella archaeocretacea* Pessagno towards the top ('grosses globigérines'). Benthic foraminifera: the same as below, but rare; appearance of *Lingulogavellinella globosa* (Brotzen).

The Crupes Formation (Upper Cenomanian *pars*) is 1.30 m thick and is equivalent to the '*Actinocamax*

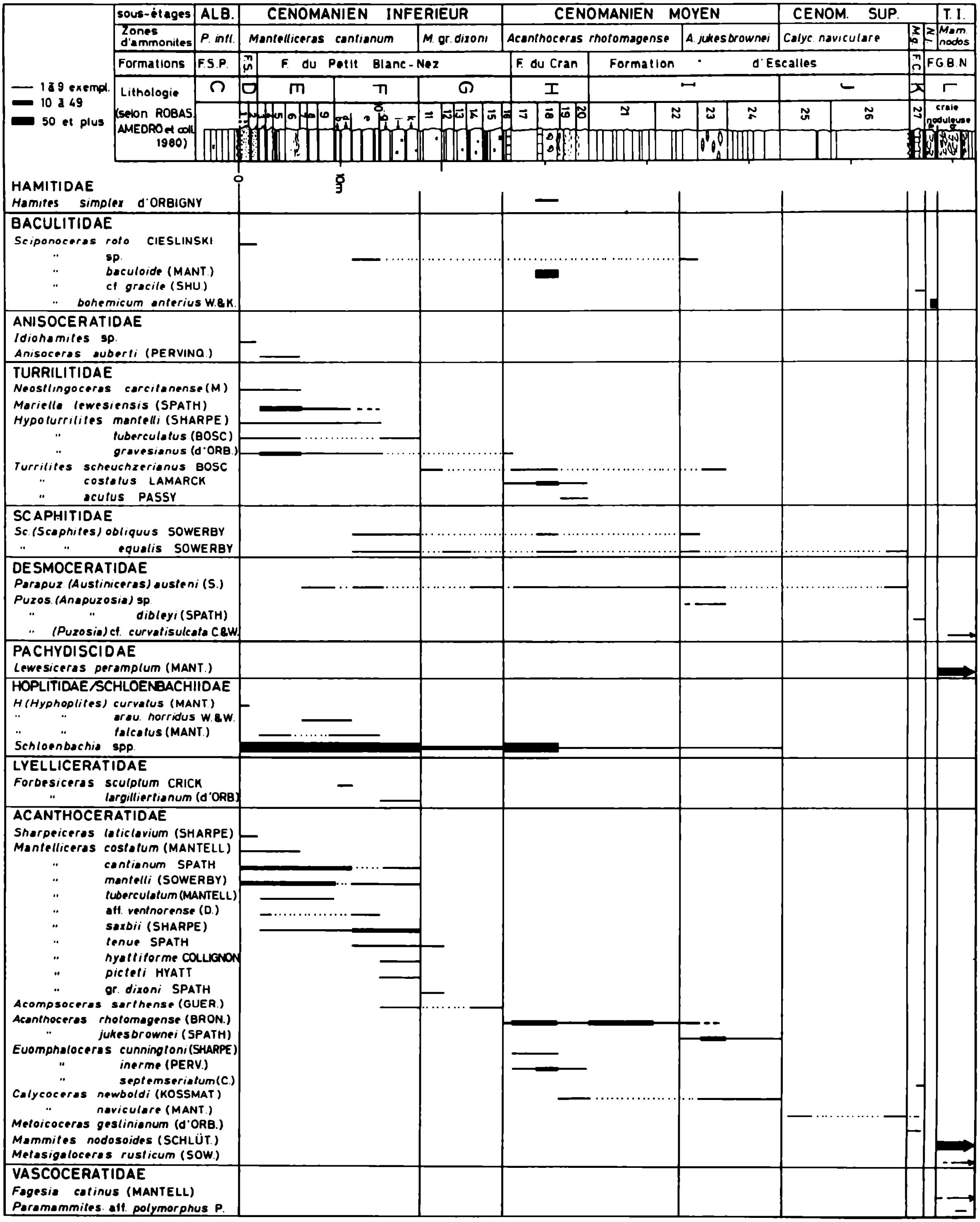

Fig. 14. Vertical distribution of ammonites and some other macrofossils in the Cenomanian of the Cap Blanc-Nez section (data from Amédro, in press).

plenus level' or 'Plenus marls'. The full succession of marly and chalky beds of this level exactly corresponds to the eight beds defined at Merstham by Jefferies (1963). This level is accessible at the top of the Grand Blanc-Nez fall (Fig. 12, point 8) and of another fall (Fig. 12, point 10). It forms a notch easily visible along the cliff and outcrops on the beach at about 1 km from Sangatte, in front of the Quaternary fossil cliff (Chellonneix, 1872, b; Dubois, 1925). The fossil association indicates high Upper Cenomanian (Fig. 15). The 'Plenus Marls' represent a global anoxic event related to an eustatic change of sea-level, with concomitant formation of hardgrounds.

Ammonites: *Sciponoceras* cf. *gracile* (Shumard), *Calycoceras naviculare, Metoicoceras geslinianum* (d'Orbigny), *Euomphaloceras* (*Kanabiceras*) *septemseriatum* (Cragin). Belemnites: *Actinocamax plenus* (Blainville). Inoceramids: *Inoceramus pictus.* Planktonic foraminifera: global extinction of *Rotalipora cushmani* and *R. greenhornensis,* appearance of *Dicarinella* gr. *hagni* (Scheibnerova), presence of *Whiteinella archaeocretacea.* Benthic Foraminifera: disappearance of numerous species, development of *Lingulogavelinella globosa*.

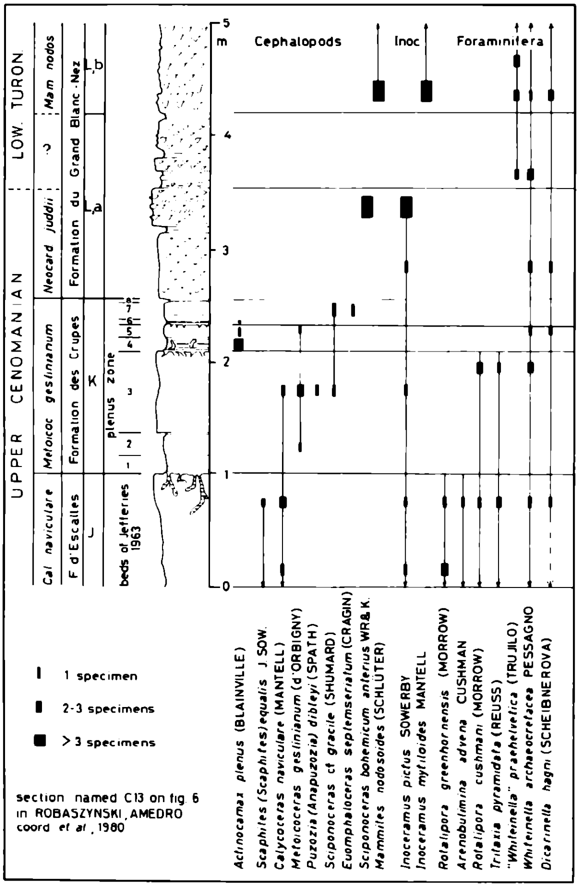

Fig. 15. The 'plenus' zone (=Crupes Formation) at the Cap Blanc-Nez cliffs: vertical distribution of index fossils (data for macrofossils from Amédro, in press).

Level 'a' of Grand Blanc-Nez Formation (uppermost Cenomanian) is 1.50 m thick and forms the basal part of the nodular chalk. In the lower part 'nodules' of yellowish hardened and compact chalk are coated or surrounded with thin greenish marls. The sequence includes several hardgrounds and terminates in a more marly horizon. Fossils are uncommon except *Sciponoceras bohemicum anterius* Wright & Kennedy and *Inoceramus pictus* indicating a terminal Cenomanian age. In other areas, the ammonite *Neocardioceras juddii* (Barrois & Guerne) was found at this level.

In the upper part are similar 'nodules' of yellowish hardened chalk as below; rare planktonic foraminifera such as *Whiteinella archaeocretacea* evolving towards '*Whiteinella*' *praehelvetica* (Trujillo). It is possible that this upper part of the level 'a' belongs to the lowest Turonian *Watinoceras coloradoense* zone.

There are several other sections of the Cenomanian in the Boulonnais. Cenomanian chalk generally forms the base of the cuesta which surrounds the Boulonnais. At Nabringhen for example, on the north part of the cuesta, the lay-out of a new road cuts the Escalles Formation (its upper part, with *Calycoceras* sp.), the Crupes Formation and the base of the Grand Blanc-Nez Formation (nodular chalk with *Inoceramus* gr. *labiatus*.

On the eastern part of the Boulonnais, there are no more good outcrops of Cenomanian chalk since the closing and infilling of the cement works of Desvres and Lottinghen. In the latter locality, the quarry cut through about ten metres of Cenomanian chalk (Escalles Formation), the 'Plenus Marls' (Crupes Formation) and nodular chalk (Grand Blanc-Nez Formation).

Now, at the SW of the cuesta, only the cement works of Dannes are exploiting chalk from the Escalles Formation (Upper Cenomanian) to the Mottelettes Formation (middle part of the Turonian). In this quarry were collected several *Calycoceras* in the Escalles Formation and *Metoicoceras geslinianum* in the Crupes Formation. As *Euomphaloceras septemseriatum* and *Actinocamax plenus* in an outcrop at about 500 m east of the quarry.

(*ii*) *Comparison with the Cenomanian of Kent*

Figure 16 illustrates a tentative correlation between the Cenomanian sequences on both sides of the Channel. Data related to the Cap Blanc-Nez sequence come from Amédro *et al.* (1978b) and Robaszynski & Amédro edit. *et al.* (1980). Data related to the Cenomanian from Folkestone to Dover come from Jefferies (1963), Kennedy (1969), Carter & Hart

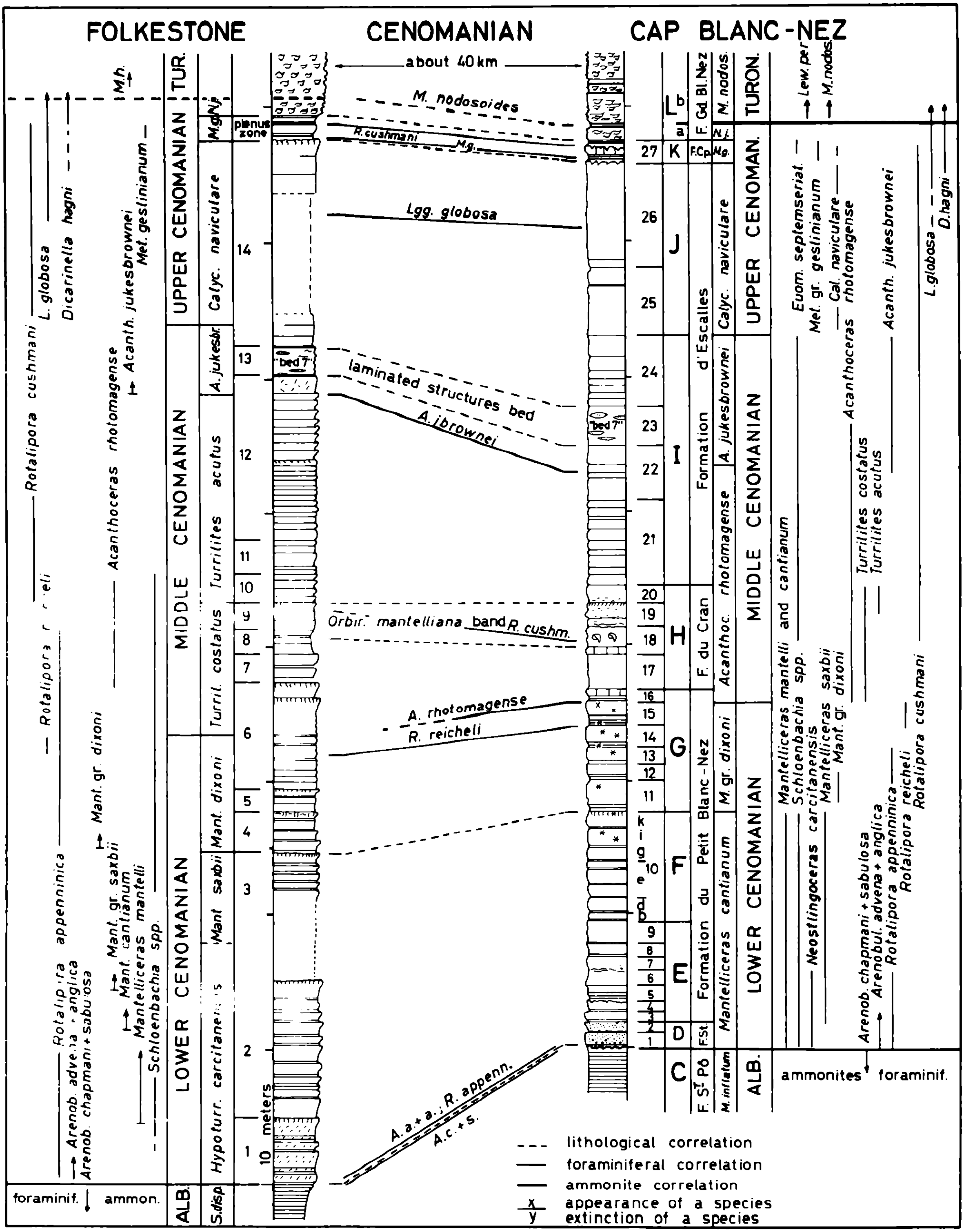

Fig. 16. Tentative correlation of Cenomanian successions on opposite parts of the Channel (lithology as in Fig. 13).

(1977), Wright & Kennedy (1981), Hart *et al.* (*in* Jenkins & Murray edit., 1981). Except a small difference in the thicknesses—68.5 m at Cap Blanc-Nez and about 80 m between Folkestone and Dover—the lithological successions are quite equivalent. To make comparisons, several beds form marker horizons as, for example, the basal glauconitic chalk, the *Orbirhynchia mantelliana* band, the laminated structures band or bed 7 of Jukes-Browne & Hill (1903) and the 'Plenus Marls'. The appearance or extinction of several species of index ammonites or index foraminifera support this attempt of correlation.

(b) The Turonian chalk of the Boulonnais

As in the case of the Cenomanian, it was Chellonneix (1872b) who gave the first description of the beds and zones of the Turonian at the Grand Blanc-Nez. Important complementary studies include the papers by Potier & De Lapparent (1875), Barrois (1878, 1879), Gosselet (1881), Parent (1892), Pruvost & Pringle (1924) and Destombes & Sornay (1958). More recently, detailed study of the formations of the headland was carried out by Amédro *et al.* (1976, 1978a), and those of the Caffiers railway cutting by Amédro & Robaszynski (1977), Amédro *et al.* (1979), Robaszynski & Amédro edit. *et al.* (1980).

(*i*) *Representative sections of the Turonian*

At Cap Grand Blanc-Nez practically the complete Turonian chalk sequence is exposed in the cliff between the headland and Sangatte, but access is difficult without ropes and rope ladders. Using these means a detailed description of 66 m of the sequence was made (Fig. 12, points 9 & 10).

The upper part of the level 'a' of the Grand Blanc-Nez Formation (possibly lowest Turonian) consists of 0.60 m of nodular chalk. The 'nodules' are of yellowish hardened chalk, surrounded by greenish marls. Marly horizons are intercalated towards the base and a marly horizon occurs at the top. No macrofossils are present (Fig. 15).

Level 'b' of the Grand Blanc-Nez Formation (Lower Turonian) comprises 9.5 m of nodular chalk. The bed is thick, yellowish in colour, slightly prominent, of 'curly' aspect and is easy to locate all along the cliffs towards Sangatte and just above the notch formed by the 'Plenus Marls'. The fossils of this level can be collected from large blocks which have fallen from the cliff.

Ammonites: *Mammites nodosoides* (Schlotheim), *M. wingi* Morrow, large *Lewesiceras peramplum* (Mantell) of 30 to 80 cm in diameter, rare *Metasigaloceras rusticum* (J. Sowerby), *Fagesia catinus* (Mantell) and *Paramammites* aff. *polymorphus* (Pervinquière). Inoceramids: *Inoceramus labiatus* Schlotheim, *I. hercynicus* Petraschek, *I. mytiloides* Mantell, *I. schoendorfi* Heinz. Echinoids: *Dorocidaris granulostriata* (Desor), *Discoidea minima* Agassiz, *Conulus subrotundus* Mantell. Brachiopods: *Orbirhynchia cuvieri* (d'Orbigny), *Gibbithyris grandis* Sahni. Planktonic foraminifera: *Dicarinella algeriana* (Caron), *D. imbricata* (Mornod), *D. hagni*, *Whiteinella archaeocretacea*, appearance of true *Helvetoglobotruncana praehelvetica* (Trujillo) and then of *H. helvetica* (Bolli). Benthic foraminifera: *Lingulogavelinella globosa*, appearance of *Arenobulimina preslii* (Reuss).

Level 'c' of the Grand Blanc-Nez Formation (base of the Middle Turonian) is 8 m of subnodular chalk. The hardened nodules are enclosed in a chalky matrix with thin greenish seams arranged in a flaser structure (Kennedy & Garrison, 1975). The lithology becomes progressively closer to a true chalk upwards.

Ammonites: rare *Lewesiceras peramplum*, appearance of *Collignoniceras woollgari* (Mantell). Inoceramids: *Inoceramus labiatus*, *I. mytiloides*, *I. hercynicus*, first *I. lamarcki* Parkinson and *I. brongniarti* Mantell. Echinoids: *Conulus subrotundus*. Brachiopods: last *Orbirhynchia cuvieri*, presence of *Gibbithyris grandis*. Planktonic foraminifera as in level 'b'. Benthic foraminifera: appearance of *Globorotalites hangensis* Vassilenko, *G. minuta* Goel, *G. subconica* (Morrow).

The Mottelettes Formation (Middle Turonian *pars*) is 24 m of marly chalk. The granular grey to white chalk contains numerous greenish thin seams of marl, several centimetres thick marl-bands and yellowish nodular horizons. At the top, the chalk becomes whiter. The macrofauna is sparse.

Ammonites: rare *Collignoniceras woollgari* at the base. Inoceramids: *Inoceramus lamarcki*. Echinoids: *Discoidea minima*, *Conulus subrotundus*. Brachiopods: '*Terebratulina gracilis* d'Orbigny' (surely '*Terebratulina gracilis*' Schlotheim, var. *lata* Etheridge), *Gibbithyris semiglobosa* (J. Sowerby), *G. subrotunda* (J. Sowerby). Planktonic foraminifera: extinction of *Helvetoglobotruncana helvetica*, presence of *Marginotruncana sigali* (Reichel), appearance of *M. pseudolinneiana* Pessagno, *M. marginata* (Reuss), *M. coronata* (Bolli). Benthic foraminifera: *Arenobulimina preslii*, *Globorotalites* spp., '*Coscinophragma*' *irregularis* (d'Orbigny).

The Guet Formation (Middle Turonian *pars*) is 12 m of chalk with few flints. The chalk is granular, white, with thin greenish marly seams, sparse digitate burrow-form flints towards the base. Two marl-bands each several cm thick are valuable lithological marker horizons. The macrofauna is sparse.

Ammonites: *Sciponoceras bohemicum bohemicum* (Fritsch). Inoceramids: *Inoceramus lamarcki*, appearance of *I. securiformis* Heinz and *I. vancouverensis frechi* Flegel. Echinoids: *Conulus subrotundus*, *Sternotaxis planus*, appearance of *Micraster corbovis* Forbes and *M. leskei* Des Moulins. Planktonic foraminifera: *Marginotruncana* *pseudolinneiana, M. marginata, M. coronata.* Benthic foraminifera: *Globorotalites multisepta* (Brotzen).

The Caffiers Bridge Member (Middle Turonian *pars*, Upper Turonian and Coniacian *pars*) is about 18 m thick. Granular white chalk, with numerous beds of black and nodular flints, and two marl-bands occur in the lower part. At the top of the Grand Blanc-Nez cliff, a small outcrop exposes a succession of four very fossiliferous hardgrounds containing Upper Turonian echinoids and ammonites. Higher up, above 10 m of succession covered by grass, a hollow in the chalk has yielded *Micraster decipiens* indicating a Coniacian age. Consequently, the Turonian–Coniacian boundary lies somewhere between these two points and the total thickness of the Turonian at Cap Blanc-Nez is between 66 m and 72 m. The hardground complex at the top of the cliff contains: Ammonites: *Subprionocyclus neptuni* (Geinitz), *Lewesiceras mantelli* Wright & Wright, *Scaphites geinitzii* d'Orbigny, *Hyphantoceras reussianum* (d'Orbigny). Inoceramids: *Inoceramus waltersdorfensis* Andert, *I. schloenbachi* Böhm, *I. inconstans* Woods, first *I. mantelli* De Mercey. Echinoids: *Micraster leskei, M. normanniae* Bucaille (or Rowe's '*praecursor*' form), and some forms announcing *M. decipiens* (Bayle). Brachiopods: *Gibbithyris subrotunda.* Planktonic foraminifera: *Marginotruncana pseudolinneiana.* Benthic foraminifera: appearance of the first *Reussella kelleri* Vassilenko and presence of *Verneuilina muensteri* Reuss.

At Caffiers about 12 km SE of the headland, a railway-cutting for the new private railway joining the 'Carrières du Boulonnais' to the national railway network, shows continuous good exposure of about 150 m of chalk (Fig. 17). Owing to a northerly dip caused by the proximity of the Landrethun fault, the whole Turonian sequence outcrops between the level-crossing and the Caffiers bridge. About 103–104 m were measured, i.e. nearly 35 m more than the Turonian thickness at Cap Blanc-Nez. All the formations detailed in the cliffs were found again in this section, with very similar litho- and biostratigraphical characteristics (Fig. 18) summarised below.

The Grand Blanc-Nez Formation, 'a', 'b', 'c', (uppermost Cenomanian, Lower Turonian and base of the Middle Turonian) comprises 16 m of nodular and subnodular chalks. The basal 2 m contains *Sciponoceras* sp. cf. *bohemicum anterius* and *Inoceramus pictus*, giving a terminal Cenomanian age. The succeeding 14 m yielded *Inoceramus labiatus, I. hercynicus, I. mytiloides* and *Orbirhynchia cuvieri* indicating the Lower to basal Middle Turonian.

The Mottelettes Formation (Middle Turonian *pars*) is 40 m of marly chalk. The white to grey chalk includes several marl-bands and hardgrounds. Very rare macrofauna: *Lewesiceras* sp., O. cuvieri,

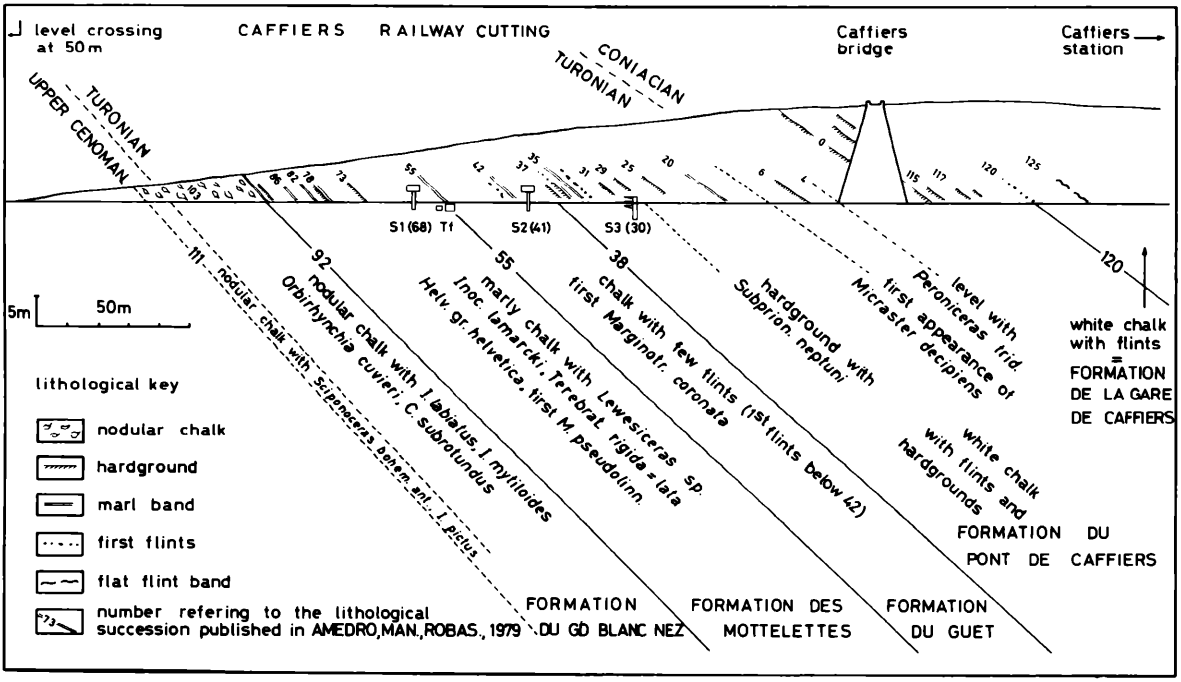

Fig. 17. The Cretaceous of the Caffiers railway cutting.

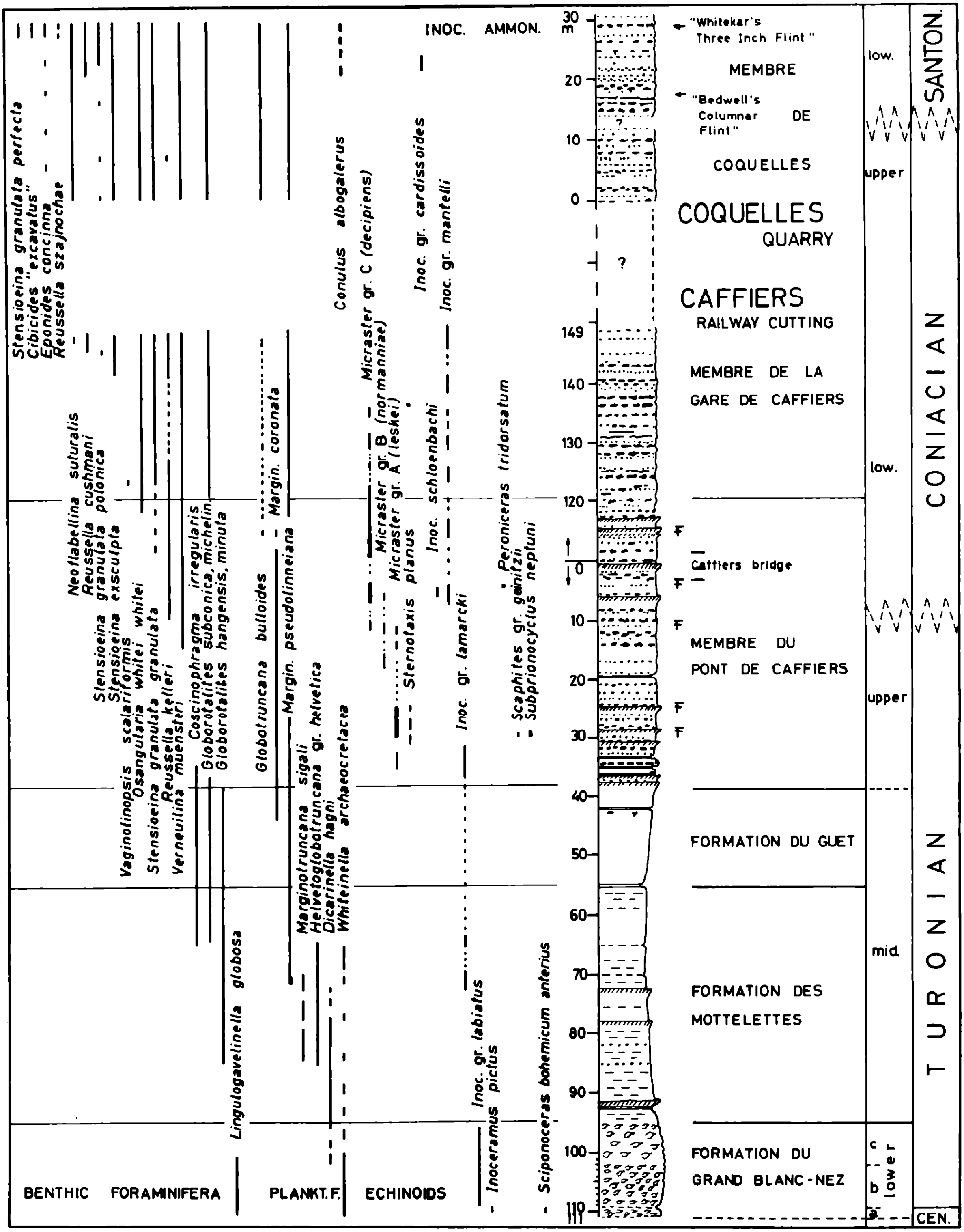

Fig. 18. The Turonian, Coniacian and Santonian succession at Caffiers and Coquelles: vertical distribution of the main biostratigraphical elements (lithology as in Fig. 13).

Terebratulina gracilis = lata, first *Inoceramus lamarcki* in the upper half.

The Guet Formation (Middle Turonian *pars*) is 17 m of chalk with few flints. The soft, white chalk is sometimes granular, with scarce small burrow-form flints appearing near the top, below a marl-band. Rare *Inoceramus lamarcki*.

The Caffiers Bridge Member, 47 m thick, of which 33 m are south of the bridge (Upper Turonian) and 14 m north (Coniacian *pars*) consists of white chalk with flint levels, marl-bands and hardgrounds. Macrofauna is abundant. For example, the hardground at level 29 (Figs. 17 and 18) yielded *Subprionocyclus neptuni, Lewesiceras mantelli, Scaphites geinitzii, Sternotaxis planus* and *Micraster leskei*, all Upper Turonian index fossils. Next to the south foot of the bridge (level 4) was found a specimen of *Peroniceras tridorsatum* (Schlüter), a Coniacian ammonite (Amédro & Robaszynski, 1978). About 11 m below, the chalk yielded *S. geinitzii* and *M. leskei* belonging to the Upper Turonian. Consequently, the Turonian–Coniacian boundary lies somewhere between these two points. Furthermore, in this interval was found the first *Micraster decipiens* which generally appears in the Paris Basin near this boundary.

The foraminiferal content of the Turonian–Coniacian chalks of the Caffiers railway-cutting was studied too. The results confirm these obtained on the Grand Blanc-Nez section (*cf.* Robaszynski, *in* Amédro *et al.*, 1979).

Before 1980, the Lottinghen cement-works showed a good section of the Grand Blanc-Nez Formation and the Mottelettes Formation. Today, only the Dannes cement-works are cutting these Lower and Middle Turonian formations in addition to the Upper Cenomanian ones.

(*ii*) *Correlation and comparison of the Turonian sections of the Boulonnais and Kent*

A tentative correlation between the Grand Blanc-Nez and Caffiers sections based on bioevents (extinction or appearance of macro- or microfaunal taxa) and lithostratigraphical marker horizons (hardgrounds, marl bands) is shown in Fig. 19. There is a significant thickness disparity; about 104 m at Caffiers compared with 70 m at Blanc-Nez. This difference can be explained by the thicker development of the upper part of the Turonian at Caffiers. In fact, if we accept that the appearance of *Micraster leskei* as well as the successive appearances of *Subprionocyclus neptuni* and *Reussella kelleri* are synchronous for these two closely spaced and lithofacially identical successions, it can be shown that there are 30 m between the appearance datum of *M. leskei* and that of *R. kelleri* at Caffiers as against 7 m at Blanc-Nez.

As a guide, the section of the Loffre borehole (near Douai; Robaszynski, 1978) is added to indicate the existence of a very different facies in the Lower Turonian. These sediments are green marls named 'Dièves' in northern France and a tentative correlation with chalky facies is shown using index foraminifera. Following a previous attempt by Hart (1983) to compare the Turonian sequence on both sides of the Channel, the same Fig. 19 proposes another tentative correlation based on some macro- and micropalaeontological datum levels as well as lithostratigraphical marker horizons. Data for the Dover section are taken from Hébert (1874), Jukes-Browne & Hill (1903), Smart *et al.* (1966), Stokes (1975, 1977), Gale & Woodroof (1981), Hart *et al.* (*in* Jenkyns & Murray, 1981), Hart & Bigg (1981), Hart (1983), Bailey *et al.* (1983), and from personal observations carried out on the Dover cliffs in the company of P. Woodroof and A. Gale.

If one accepts the synchroneity of the macro- and micropalaeontological datum-planes used, the comparison of the four Turonian sections calls for several comments.

At Dover, the nodular facies is developed throughout the succession whereas only the base of the Turonian presents this facies in the Boulonnais. In the same way, hardgrounds are more numerous and more marked on the English side.

Whilst the lower part of the Turonian on both sides of the Channel is entirely developed in nodular facies, the Loffre borehole shows a green marl facies about 30 m thick which extends into Belgium in the Mons Basin and towards the south in the Cambrai area.

The appearance of flint in the succession is successively younger from west to east. The first and generally branched burrow-form flints appear in the Kent in the middle part of the Turonian, but at the top of this middle part in the Boulonnais and seemingly still higher at Loffre.

At least, between Dover and the Boulonnais, some sets of beds can be used as very conspicuous levels on a regional scale. On both sides, the following lithological units in descending order are easily recognizable: the Top Rock, the Chalk Rock, the Basal Complex and the Four Foot Band (Stokes, 1977).

(c). The Coniacian–Santonian chalk of the Boulonnais

The presence of white chalk with flints containing *Micraster cortestudinarium* auct. (=*M. decipiens* Bayle) at the summit of the hills neighbouring the Grand Blanc-Nez was reported by Chellonneix (1872a) and Barrois (1873). Parent (1892) found the same chalk at Coquelles, and Dehée & Dubois (1927) interpreted a borehole that traversed the whole Cretaceous at this locality. More recently, Amédro & Robaszynski (1978), then Amédro, Manivit & Robaszynski (1979) and Robaszynski & Amédro edit.

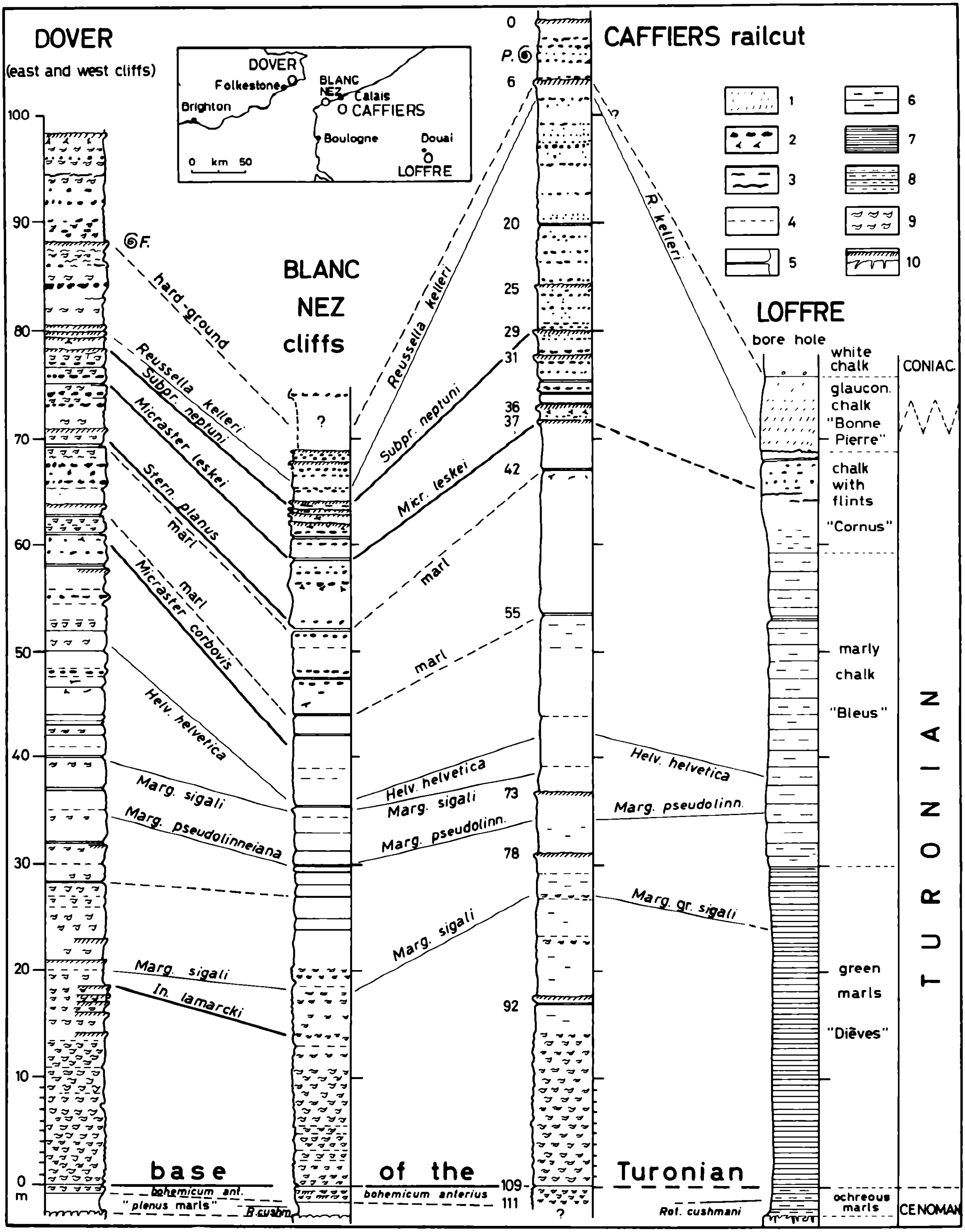

Fig. 19. Tentative correlation of Turonian successions in the north of France and on opposite sides of the Channel (1: glauconite – 2: flints – 3: tabular flint – 4: marl seam – 5: marl band – 6: marly chalk – 7: marl – 8: chalky marl – 9: nodular chalk – 10: above = hardground, below = burrowed surface – F: *Forresteria* (*Harleites*) *petrocoriensis* – P: *Peroniceras tridorsatum*; levels of appearances and extinctions as x and y in Fig. 16.

et al. (1980) documented the detailed lithology and macro- and micropalaeontological content of Turonian to Santonian chalks of Caffiers and Coquelles.

(*i*) *Representative sections of the Coniacian–Santonian*
To the north of Caffiers bridge, the widening of the old railway cutting has exposed several tens of metres of flinty chalk which macro- and micropalaeontological evidence indicate to be of Coniacian age (Fig. 18).

The upper part of the Caffiers Bridge Member (Coniacian *pars*) is 14 m thick and is white chalk with flints and hardgrounds. It outcrops on both sides of the Caffiers bridge and north of the same bridge. It is the typical white chalk, fine and soft, reinforced with beds of black and nodular flints and with incipient and true hardgrounds.

Ammonites: *Peroniceras tridorsatum* (Schlüter), very rare but a key biostratigraphical index fossil. Inoceramids: *Inoceramus schloenbachi, I. mantelli.* Echinoids: *Micraster decipiens.* Planktonic foraminifera: *Marginotruncana pseudolinneiana.* Benthic foraminifera: *Verneuilina muensteri, Reussella kelleri, Osangularia whitei* (Brotzen).

The Caffiers Station Member (Coniacian *pars*), 33 m thick, is white chalk with flints. It is without hardgrounds but contains several tabular flint levels. As the Landrethun fault is a little further away, the dip to the north is reduced to only a few degrees near the Caffiers station. Except some horizons full of *I. mantelli* remains, macrofossils are relatively rare: all that were found were fragments and several more or less crushed specimens of *Micraster decipiens* and *Echinocorys* sp. Benthic foraminifera: *Reussella kelleri, Verneuilina muensteri, Osangularia whitei, Vaginulinopsis scalariformis* Porthault at the base, appearance of *Gavelinella thalmanni* (Brotzen), *Stensioeina granulata granulata* (Olbertz) and towards the top of *Stensioeina exsculpta exsculpta* (Reuss), *Reussella cushmani* Brotzen and *Neoflabellina* gr. *suturalis* (Cushman).

In the old quarry of Coquelles is exposed the Coquelles Member, lower part ('Upper' Coniacian), which is about 10 m thick and consists of white chalk with flints. There are no exposure to provide a lithostratigraphical link between the Caffiers section and that of Coquelles 10 km away and it is probable that there is an approximately 20 m gap in the succession between them (*cf.* Amédro *et al.*, 1979 & Fig. 18). The Coquelles chalk is almost the same as that of Caffiers; white, fine, soft, with numerous beds of black and nodular flints. The lower beds contain very few fossils and provided only some incomplete or crushed specimens of *Inoceramus mantelli* and *Micraster* gr. *decipiens* (having some features of *M. coranguinum* (Leske). However, it is important to note just below the middle floor of the quarry, the presence of a fragment of *Inoceramus* (*Sphenoceramus*) *cardissoides* Goldfuss (det. J. Sornay; a form near from *I. undulatoplicatus* Roemer which appears at a higher horizon according to Seitz, 1961). Benthic foraminifera: progressive extinction of *Stensioeina granulata granulata* relayed by *Stensioeina granulata polonica* Witwicka, *S. exsculpta exsculpta* being always present.

The upper part ("Lower" Santonian) of the Coquelles Member is about 15 m thick and is white chalk with flints. The Santonian age is deduced from the occurrence of the benthic foraminiferal subspecies *Stensioeina granulata polonica* and the association of *Conulus albogalerus* Klein with 'high-zonal' forms of *Micraster decipiens* (=? Rowe's '*M. praecursor*' or *M. coranguinum* auct.; Rowe, 1899).

(*ii*) *Comparison with the Coniacian–Santonian of Kent*
In the well exposed sections of East Kent, Bailey *et al.* (1983) have defined several geographically widespread key lithostratigraphical and biostratigraphical marker horizons in the Coniacian to Campanian chalks. Some of these marker horizons were found at Coquelles.

One occurs 2 m above the middle floor of the quarry and lies at a level of flints some of which are conical; 1 m above comes a tabular flint and 2 m higher still a double flint level. From these beds the foraminiferal subspecies *Stensioeina granulata polonica* is present in its typical form and becomes abundant. The combination of the lithostratigraphical characteristics shows that this succession correlates with the 'Bedwell's Columnar Flint' as of the Kent cliffs, and which is situated a short distance above the Coniacian–Santonian boundary (Bailey *et al.*, 1984).

Another is found about 10 m above the conical flint bed, i.e. 2 m below the top of the quarry, and is a thick flint level. In the chalk just above appears the foraminiferal species *Cibicides excavatus* Brotzen (=*C.* gr. *beaumontianus* (d'Orbigny) of English authors). Once again the combination of lithostratigraphical and biostratigraphical characteristics indicates that this level can be correlated with 'Whitaker's Three Inch Flint' of the East Kent cliffs.

Between these two guide-levels, just as in East Kent, the chalk yields a macrofossil association that characterises the lower part of the Santonian in the Anglo–Paris Basin e.g. *Inoceramus* gr. *cardissoides, Conulus albogalerus, Echinocorys vulgaris* and *Micraster decipiens* trans to *M. coranguinum*.

4. PALAEOGEOGRAPHY AND TECTONICS (F.A. & F.R.)

(a) The structural lines

In the NW of the Paris Basin and especially in the Boulonnais, tectonic lines are distributed along two main directions, N 110° and N 30° (Fig. 20).

The 'Armorican' longitudinal faults form the major

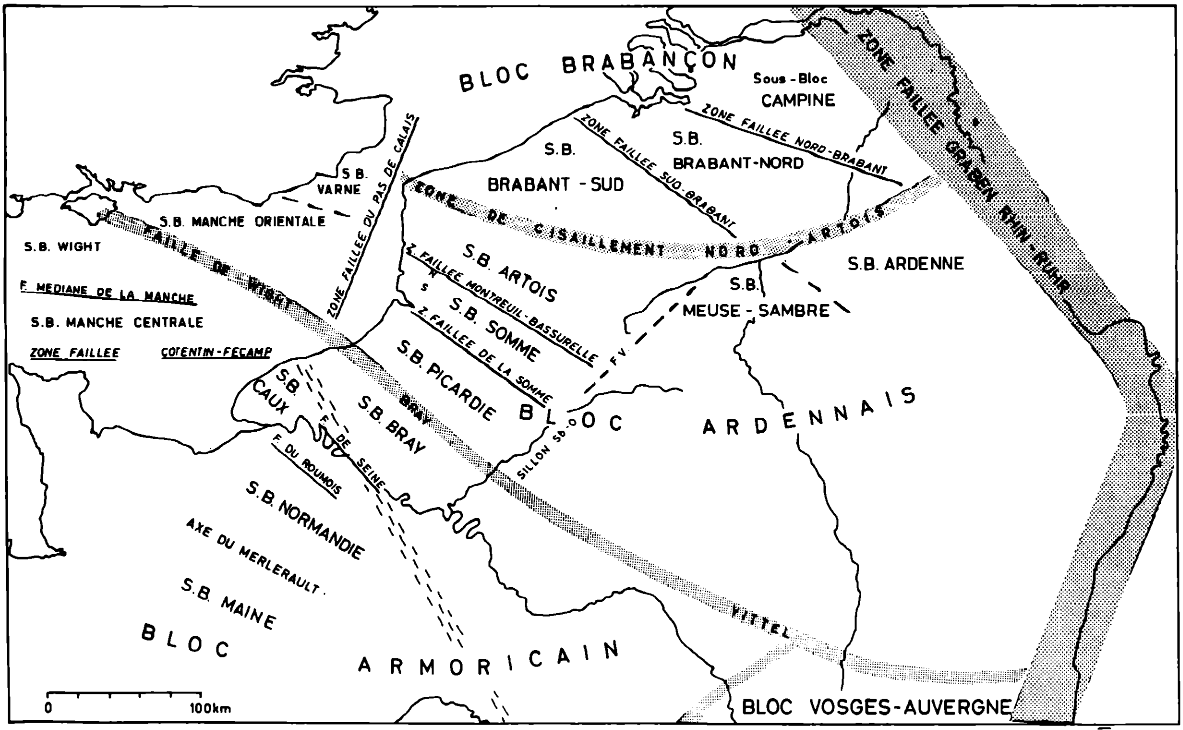

Fig. 20. Tectonic blocks in the NW of the Paris Basin (after Colbeaux *et al.*, 1980).

element of the structural network. Oriented N 110° to N 120°, they are post-Variscan and pre-Jurassic and have been intermittently re-activated right up to the present. They are dextral wrench faults which induced a longitudinal horst structure from Artois to Boulonnais and probably as far as the Weald.

The transverse faults are distributed about the direction N 30° and are probably inherited from Variscan tectonics. The existence of transverse lines in the Boulonnais is supported by several converging lines of evidence:

- faults oriented N 30° affect the Devonian and the Jurassic;
- joints oriented N 20°–N 50° are present in the Cretaceous chalks;
- present day morpho-structural units define a mosaic, the elements of which are bounded by N 100° and N 20–50° directions;
- the 'Purbeckian'–Portlandian boundary surface slopes downward to the sea in steps oriented N 10°–N 30°;
- a narrow offshore graben oriented N 30° is known in the Cretaceous SW of Calais, the Zone Faillée du Pas de Calais.

Thus, the Weald–Boulonnais–Artois longitudinal horst would be cut at right angles by a graben structure oriented N 30° and induced by the Zone Faillée du Pas de Calais. Movement of the latter would have led to the flooding of the Straits, connecting the English Channel and the North Sea since the end of the Lower Pleistocene (about 8–900,000 years B.P.).

Data related to the structure of the Boulonnais comes mainly from Briquet (1924), Pruvost (1925), Destombes & Destombes (1963), Colbeaux (1975, 1977), Auffret & Colbeaux (1977), Colbeaux *et al.* (1977, 1980), Robaszynski *et al.* (1982), and Colbeaux, Leplat, Paepe & Sommé (1979).

(b) The facies and the present geographical extent of Cretaceous deposits

During the last decade, a succession of publications has given much data on the thickness and geographical distribution of Cretaceous formations in the Boulonnais: Amédro & Mania (1976) for the Aptian; Amédro & Magniez-Jannin (1982), Amédro (1984) for the Albian; and Robaszynski (1981 & *in* Colbeaux *et al.*, 1980), Robaszynski & Amédro edit. *et al.* (1980) for the Upper Cretaceous.

The main structural directions, oriented N 110° and N 30°, define tectonic blocks (Colbeaux *et al.*, 1980) vertical movements of which must have at least controlled Cretaceous sedimentation. In fact, when a

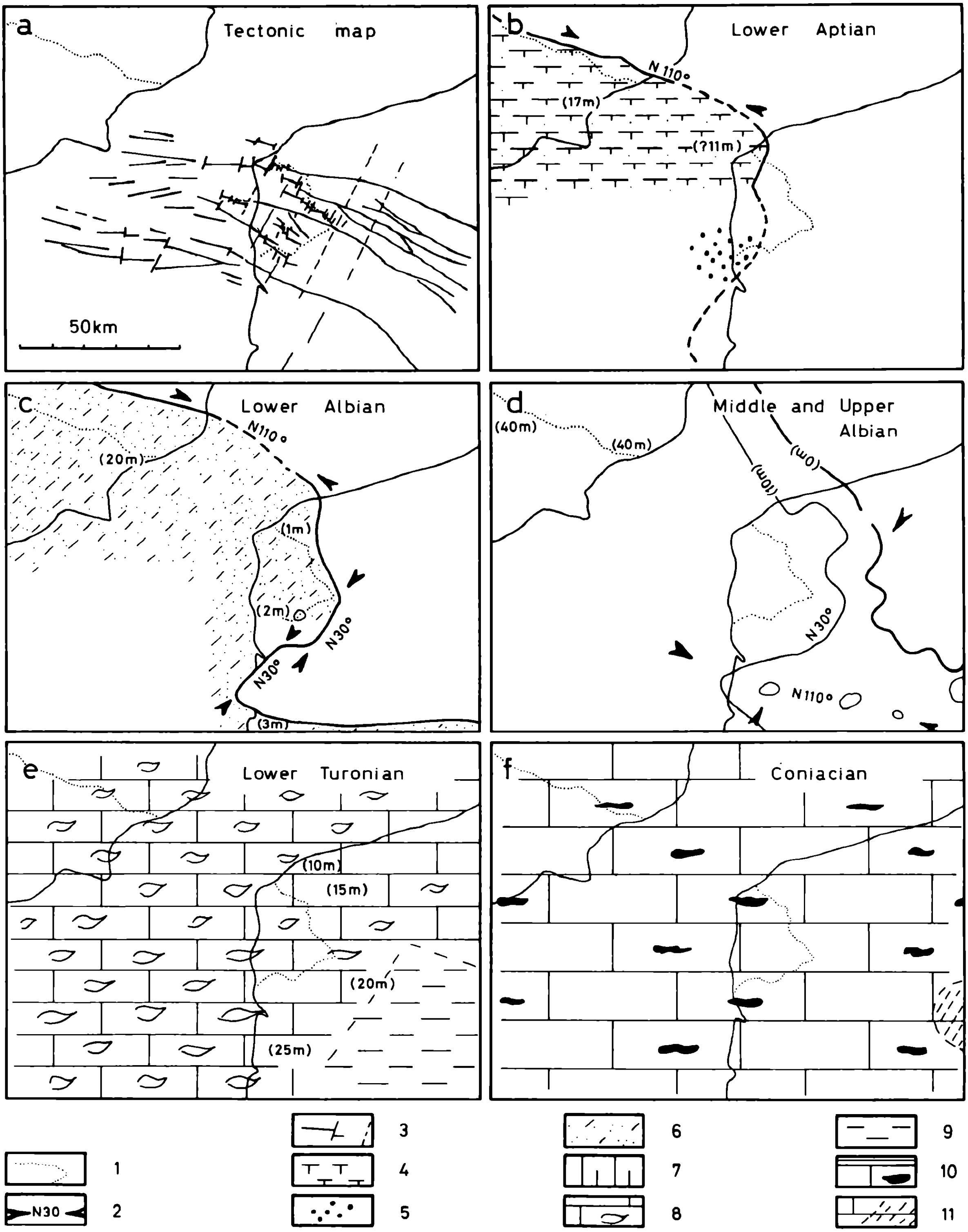

Fig. 21. Present-day limits of some Cretaceous facies in the Boulonnais (1: limits of the Boulonnais and eastern part of the Weald – 2: main directions – 3: faults – 4: calcareous sandstone – 5: phosphatic nodules – 6: glauconitic sands – 7: Gault clay – 8: nodular chalk – 9: green marl – 10: chalk with flints – 11: glauconitic chalk).

sector of the tectonic mosaic subsides more rapidly than its neighbours, it receives an extra-thickness of sediments and vice-versa. The present outcrop boundaries of the various Cretaceous formations generally follow the two alignments N 110° and N 30°. When either the isopachyte lines or the present facies boundaries are superimposed on these structural lineaments there is a strong indication that the sedimentation has been tectonically controlled, at least partly. This is tentatively illustrated in Fig. 21.

(*i*) *Lower Aptian*
After the long period of deposition of the continental Wealden facies, the sea reached the western Boulonnais at the end of the Lower Aptian, as testified by the fossil content—cephalopods and bivalves—of the Cat Cornu Formation. The present northern boundary of Aptian carbonate glauconitic sandy facies, which continues in the Weald as the Hythe Beds is oriented N 110°.

(*ii*) *Lower Albian*: *'Lower Greensand' facies = Gardes Formation*
A 'golfe boulonnais' (Leroux & Pruvost, 1935) formed at this time. Its present eastern boundary is approximate to the N 30° transverse direction, whereas towards the north edge of the basin the boundary follows an Armorican direction. The first advance of the Albian sea flooded the western Boulonnais during the *Leymeriella regularis* Assemblage Zone. After a short pause, the sea came back during the *Cleoniceras floridum* Assemblage Zone and submerged a greater part of the Boulonnais, but without extending beyond the present boundaries of the area. Following the inundation, the existence of the phosphatic horizon P2, in which four ammonite-zones are condensed, points to a period of instability of the western part of the Artois block, which ended with the hiatus between Lower and Middle Albian. This gap was probably the result of regional tectonically controlled sedimentation since elsewhere, as for example in the Aube area, there is no hiatus, Lower and Middle Albian sediments being in continuity.

(*iii*) *Middle and Upper Albian*: *'Gault' facies = St Pô Formation*
The Albian transgression completely covered the Artois, but the isopachyte map shows a greater relative subsidence of the tectonic units constituting the Boulonnais Gulf. The thickness of the Gault facies is generally more than ten metres throughout the Boulonnais, where in Artois it is of the order of 5 m or less (Caulier, 1974). A N 30° direction seems to separate this western part of the Artois Sub-block (the future Boulonnais) from the eastern part, which acted as a shoal and became the present Artois. Subsidence is further accentuated westwards, the Gault in Kent being about 40 m thick. In all probability part of the Weald at this time was lower than the Boulonnais, perhaps as a result of the activity of the Zone Faillée du Pas de Calais.

In this way, during the Aptian–Albian times, the Boulonnais seemed to be composed of small tectonic units, elongated in a N 30° direction and forming the western part of the Artois Sub-block. These units step downward progressively to form the southeastern side of the graben comprising the Zone Faillée du Pas de Calais. Such a structure, which might have been active since the Jurassic, would explain the tectonic instability of the Boulonnais, marked by events like the hiatus between the Lower and Middle Albian, the hiatus at the uppermost Albian and the presence of the phosphatic levels P1 to P6.

These events point to sedimentation being in part tectonically controlled (Amédro, 1984). In fact, Aptian–Albian sedimentation was primarily controlled by successive advances of the sea, caused by eustatic movements. This interpretation is supported by much more widespread events, such as the more and more easterly extent of Greensand and Gault facies (Fig. 22), the increase in carbonate content in the Upper Albian, the development of glauconitic facies in the uppermost Albian and the hiatus between the Albian and the Cenomanian (Fig. 23).

(*iv*) *Lower Turonian*: *'nodular chalk' = Grand Blanc-Nez Formation* (*and 'Dièves' facies*)
After the Upper Cenomanian, the nodular chalk facies spread over the whole area, except towards the SE in Artois, where there are deposits of green marls or 'Dièves' the boundaries of which seem to follow N 30° and N 100° directions.

(*v*)
From the Coniacian onwards the facies became uniform throughout the area with sedimentation of white chalk with flints. The lack of detailed data on the thickness of the various chalks prevents the recognition of movements of tectonic blocks (if, in fact, these movements actually took place at that time).

In conclusion, it appears that the flooding by Cretaceous seas of the northern margin of the Paris Basin did not occur progressively. Rather, it was the result of the combination of positive and negative eustatic variations of sea-level and of vertical movements of tectonic blocks, whose boundaries follow N 30° and N 110° structural directions. It is probable that such a partial tectonic control of Cretaceous sedimentation might have affected the Weald in the same manner as the north of France. So, we must return to the opinion previously expressed by Allen (1976) that 'The Weald is seen as a subsiding graben basin . . . , spasmodically open to the sea and margined by active horsts'.

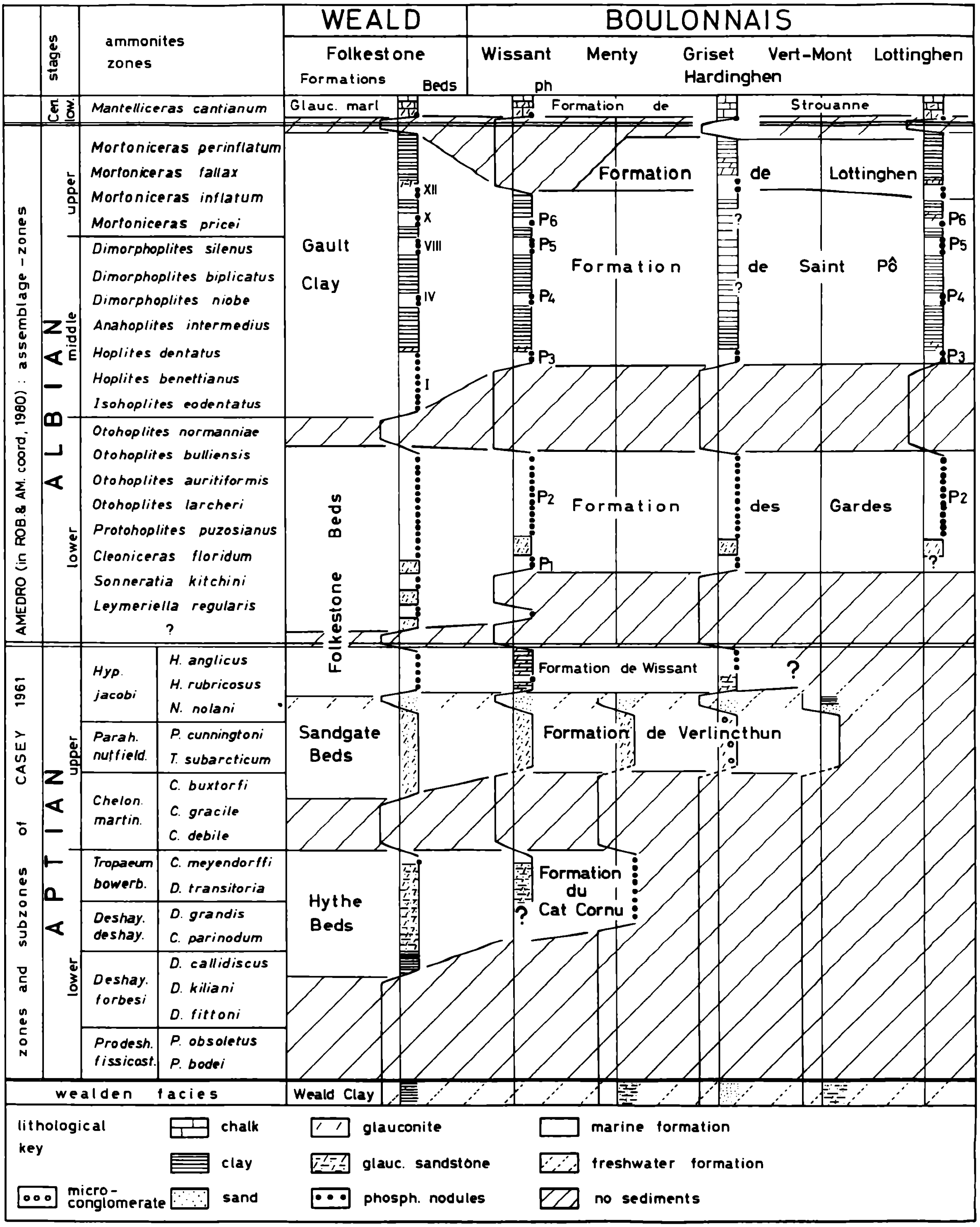

Fig. 22. Sedimentation phases during Aptian–Albian times in the Boulonnais.

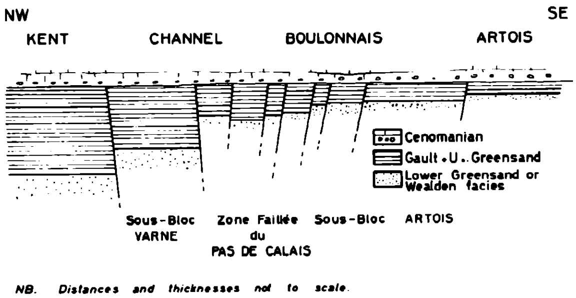

Fig. 23. Tentative interpretation of thickness variations of the Gault (=St Pô Formation) by tectonic control of sedimentation in the Boulonnais (about early Cenomanian times).

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