

# Indirect biostratigraphy in condensed successions: a case history from the Bajocian of Normandy (NW France)

Giulio PAVIA and Luca MARTIRE

Dipartimento di Scienze della Terra, via Valperga Caluso 35, 1015 Torino, Italy;  
e-mail: giulio.pavia@unito.it, luca.martire@unito.it

**Key-words:** taphonomy, condensation, biostratigraphy, ammonites, Middle Jurassic, Normandy.

**ABSTRACT:** The fossil assemblages of the Bajocian of Normandy are affected by taphonomic condensation, and the use of these assemblages for biostratigraphy must be carried out with great care because of the taphonomic reworking (reelaboration) of most of them. Nevertheless such beautiful fossils, ammonites in particular, retain their value at least as taxonomic references if their relative stratigraphic position is recognized. Such a goal has been achieved in the Bretteville section, where the “*Oolithe Ferrugineuse de Bayeux*” Formation (*OFB*), consisting of 14 beds contained within 170 cm of strata, is exposed. Each bed contains a condensed ammonite assemblage in which the overall chronologic interval represented by fossils is longer than the time of sedimentation of the bed, and no ammonites can be defined as contemporaneous with the enclosing matrix, except for the topmost two beds. The timing of biologic and sedimentary events in this Fe-oolitic succession must thus be established in an indirect way, through a stratigraphy of fossils based on their taphonomically delayed first occurrence. In particular, we can only define the maximum age of each layer, constrained by the youngest recorded fossil. On the basis of this approach, the lower part of the *OFB* is shown to fall within the middle to upper part of the Bajocian Stage (Humphriesianum to Parkinsoni chrons), whereas the uppermost *OFB* can be referred to as the uppermost Bajocian (latest Parkinsoni Chron). We conclude that, at Bretteville and in general for the Fe-oolites of Normandy, fossiliferous horizons with condensed assemblages have no value for definition of the biostratigraphic standard scale, and that indirect biostratigraphy is useful to assign minimal chronologic values to taxa when (1) their stratigraphical range has not yet been established in expanded successions, (2) they are new taxa, and (3) they are present only in a condensed succession that suffered from the same taphonomic constraints as the Bajocian of Normandy.

## INTRODUCTION

The Bajocian succession of the Bayeux area in western Normandy (Fig. 1) has been intensively studied since the mid-nineteenth century because of its rich fossil content. In particular, the famous French author d’Orbigny, in classic monographs (1842-51, 1849-52, 1850-52), described many fossils

and the lithostratigraphy of the *Oolithe Ferrugineuse* Formation outcropping around Bayeux from which the name *Bajocien* was derived, first used in 1849 (1849-52, p. 157) and formally defined in 1850 (d’Orbigny 1842-51, p. 606). Much later, Rioult (1964) proposed the section of Sainte-Honorine on the English Channel coast as the stratotype of the Bajocian Stage. However, many

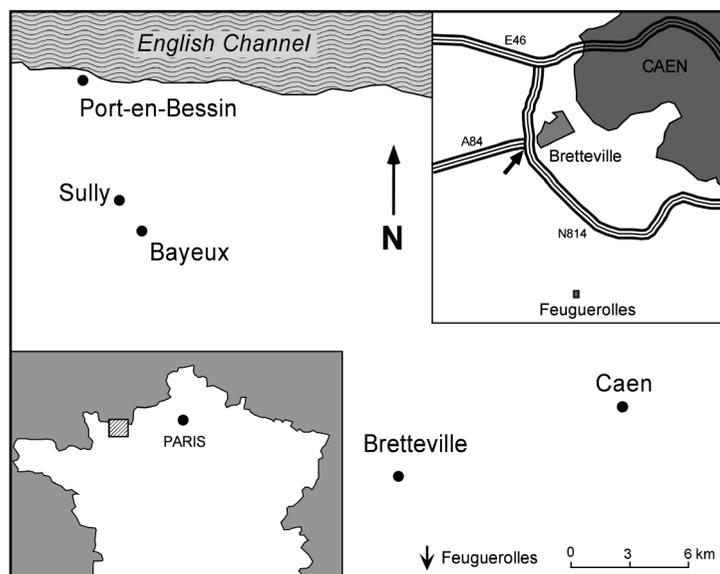


Fig. 1. Location of the study area; the arrow in the top right insert refers to the Bretteville section.

authors (Gabilly and Rioult 1971; Fürsich 1971; Rioult *et al.* 1991) recognized that discontinuities are present through the *OFB* succession and some fossil assemblages are condensed. In addition to that, more recently Pavia (1994) discussed the stratigraphic condensation (*sensu* Gómez and Fernández-López 1994) of the sections around Bayeux, where the *OFB* is reduced to a few decimetres, and demonstrated that their rich ammonite assemblages show high taphonomic condensation (see also Martire and Pavia 1996) so that they are of no use in defining biostratigraphic subdivisions. Nevertheless, fossils, particularly ammonites, from the Bajocian of Normandy are extremely important in taxonomic studies for systematics and phylogenetic interpretation. Consequently, thicker and less condensed sections would be very useful.

In this respect, it is worth remembering the note by Gabilly and Rioult (1971; see also Parsons 1974) who briefly described the classic outcrop at May-sur-Orne quarry, south of Caen (Fig. 1). Although that study was focussed on the stratigraphic relationships of beds and ammonite assemblages at the Lower-Middle Jurassic boundary, it demonstrated that the *OFB* could be considerably thicker at May-sur-Orne than on the Bessin coast (Fig. 1). The May-sur-Orne section was not analysed further; by now, the quarry is out of work and it is impossible to get any detail on its ammonite succession. Later on, Rioult, attempting to get a complete picture of the inland *OFB* succession,

coordinated the analysis of the section at Feugueroles, some 8 km south of Caen, where the *OFB* totals 3 meters (Gauthier *et al.* 1996). These authors described a seemingly continuous biostratigraphic sequence from the middle to the upper part of the Bajocian Stage. However, the rocks are superficially altered by Pleistocene ice weathering, so that textural features could not be observed and taphonomic analyses was not undertaken. In this respect, we note that the latter is essential in reduced successions such as those of the Normandy Bajocian (Pavia and Martire 1997).

In 1995, during the excavation of the highway around Caen, a new section was exposed at Bretteville. The succession, intermediate in distance between Sully and Feugueroles, is similar though a bit thinner than that of the latter locality.

The fine state of preservation of the abundant fossils, mainly ammonites, and the absence of any superficial alteration of rocks have produced information that, integrated with that coming from Feugueroles (Gauthier *et al.* 1996), enables a better understanding of the *OFB* in Normandy. In particular, the Bretteville section assumes importance to (1) verifying the biostratigraphic potential of the fossil assemblages which, though not useful for Standard Zone purposes, at least could spell out the rhythm of the sedimentary events recorded in the *Oolithe Ferrugineuse de Bayeux* Formation, (2) assigning a more precise biochronologic significance to the ammonites which would constitute references of Middle Jurassic taxonomic studies and phylogenetic interpretation.

In this paper we summarize the results of the taphonomic analyses carried out on the section at Bretteville and the implications for the biostratigraphic interpretation of the fossil assemblages of this condensed succession. No attempt is made either to carefully describe the taphonomic characteristics or to list the entire ammonite contents, which will be detailed in a separate paper.

#### THE BAJOCIAN SUCCESSION OF NORMANDY AND THE BRETTEVILLE SECTION

The current knowledge of the Middle Jurassic stratigraphy of Normandy is essentially based on a few sections, some close to the English Channel

coast (Sully, St. Honorine-des-Pertes near Port-en-Bessin: Fig. 1) and two others inland south of Caen, May-sur-Orne and Feuguerolles (Fig. 1). The Bajocian succession comprises three formations (Riout 1964; Gabilly and Riout 1971; Riout *et al.* 1991; Pavia 1994): from base to top the *Malière*, the *Oolithe Ferrugineuse de Bayeux*, and the *Calcaires à Spongiaires*.

The *Malière* Formation is represented by grey cherty limestones consisting of biomicrites with sponge spicules and glauconite grains. The base contains ammonites of the Early Aalenian. For the Bajocian, the *Discites* and *Laeviuscula* European Standard Zones are documented (Gabilly and Riout 1971; Parsons 1974).

At the very top of the *Malière* Formation, thin and discontinuous sediments have been considered a distinct member and given the name *Couche Verte* after their greenish colour. It consists of a floatstone rich in commonly phosphatized and bored lithoclasts eroded from the underlying cherty limestones. Glauconite is abundant both as grains in the matrix and coatings of the lithoclasts. At Feugue-

rolles the *Couche Verte* is represented by a 10 cm thick bed, whereas in the other sections it fills the dense network of partially truncated firm ground burrows that occur at the top of the *Malière* Formation. This layer was assigned to the Sauzei Zone by Parsons (1974). Although all the fossils contained in the *Couche Verte* are taphonomically reworked (reelaborated *sensu* Fernández-López 1985, 1991), the absence of any ammonite referable to the Humphriesianum Chron of the Early Bajocian leads to the confirmation of Parsons's dating to the Sauzei Zone.

Above, the *Oolithe Ferrugineuse de Bayeux* (*OFB*) consists of the well known and most characteristic facies of the Bajocian of Normandy. The *OFB* consists of grey to yellow limestones rich in ferruginous or phyllitic ooids. Ooids range in size from 0.3 to 2 mm and may be variably abundant in different beds, but they never give rise to a supporting framework. The intergranular matrix is represented by wackestones to packstones containing bivalve and echinoderm fragments, benthic foraminifera, peloids, and scattered

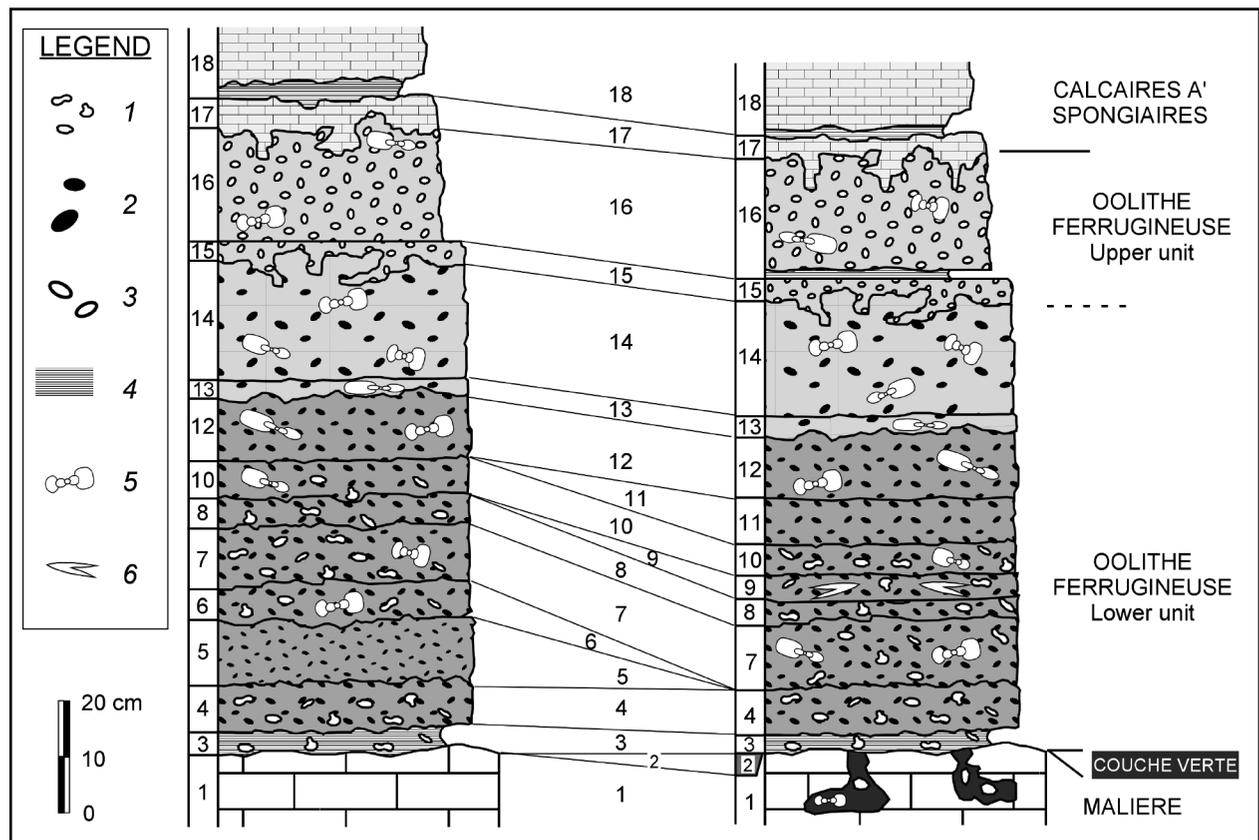


Fig. 2. Correlation of two sections, a few tens of metres apart, of the *Malière* to *Calcaires à Spongiaires* Bajocian succession at Bretteville. Legend: 1 – lithoclasts; 2 – Fe-ooids; 3 – phyllitic ooids; 4 – clay; 5 – ammonites; 6 – belemnites.

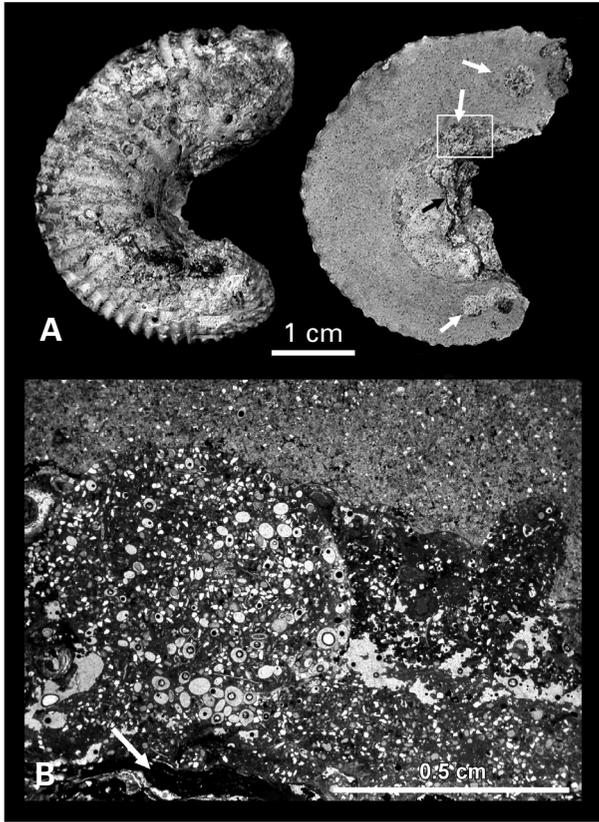


Fig. 3. *Otoites contractus*. A – Coupled lateral view and polished slab of the equatorial section of the mould. Several bivalve borings (white arrows), the erosion of the mould in correspondence of the inner whorls, and a thin Fe-oxide crust on this erosional surface (black arrow) are recognizable. The different composition of the outer and inner whorls and of the filling of the bivalve boring are evident. Note also the thin Fe-oxide crust (white arrow) (taphorecord 6). B – Photomicrograph of the squared area in Fig. 3 A.

detrital quartz grains. Ammonite moulds are very common. In the classical sections close to the English Channel coast (Sully, Port-en-Bessin; Fig. 1) the *OFB* shows at the very base a thin (0-30 cm) and discontinuous bed, containing cm-sized lithoclasts coated by oncoidal Fe-oxide crusts, that has been named *Conglomérat de Bayeux*. The *OFB* may be subdivided in two parts with a boundary marked by a burrowed omission surface. The lower part contains brown ferruginous ooids whereas the upper part is characterized by white phyllitic ooids and a more abundant mud fraction in the matrix (Rioult *et al.* 1991). The main lateral changes of the *OFB* concern the total thickness and number of beds distinguishable. According to Pavia (1994) on the coast the *OFB* does not exceed 40 cm and can be divided into 2 beds, whereas in the Feuguerolles section the thickness reaches about 350 cm and at least 7 layers have been described (Gauthier *et al.* 1996).

Ammonites are commonly reelaborated both in the coast sections (Pavia 1994) and at Feuguerolles (Pavia, pers. data). The age of the *OFB* is therefore not easy to state with precision although it is on the whole bracketed between the Humphriesianum Chron of the Early Bajocian and the Parkinsoni Chron of the Late Bajocian.

The top of the Bajocian is made of the *Calcaires à Spongiaires*, siliceous limestones with dm-sized sponge remains. At Sully the boundary with the underlying *OFB* is transitional, whereas the present outcrops of Feuguerolles quarry do not reach this upper unit.

The outcrop at Bretteville has been already cited in literature by Gabilly and Rioult (1971) and by Gauthier *et al.* (2000). The section was briefly described by Martire and Torta (2000) within the study of unusual structures called “pseudoborings”. The Bretteville section (Fig. 2) shares some features with both Sully and Feuguerolles. The *Couche Verte* is only preserved as burrow fills in the top of the *Malière*. The total thickness of the *OFB* is about 170 cm and 14 different beds were distinguished. The *OFB* may be subdivided into two lithozones, bounded by an omission surface with firm-ground burrows, on the basis of colour and composition of the ooids. The lower lithozone, in turn, shows a top part (beds 13-14) with larger but less densely packed Fe ooids than the lower part. The lower part, moreover, contains cm-sized lithoclasts of marly limestones. This tract of section (beds 3-10) could correspond to the *Conglomérat de Bayeux* although no oncoidal Fe-oxide crusts occur which are locally characteristic of the coast sections. Some clay-rich beds may be recognized at different strati-

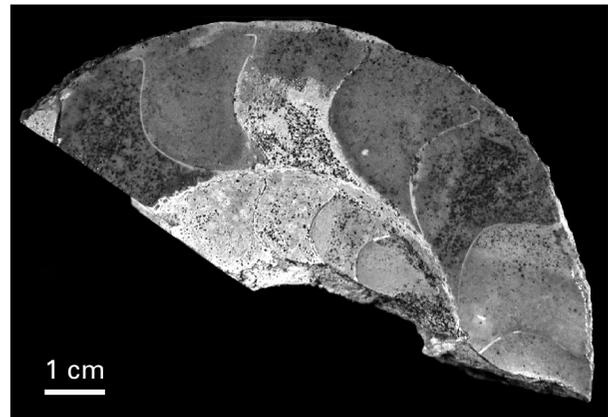


Fig. 4. *Stephanoceras* sp. Polished slab of the equatorial section of the mould. Note the dark, Fe-oxide staining of most of the chamber fills (taphorecord 5).

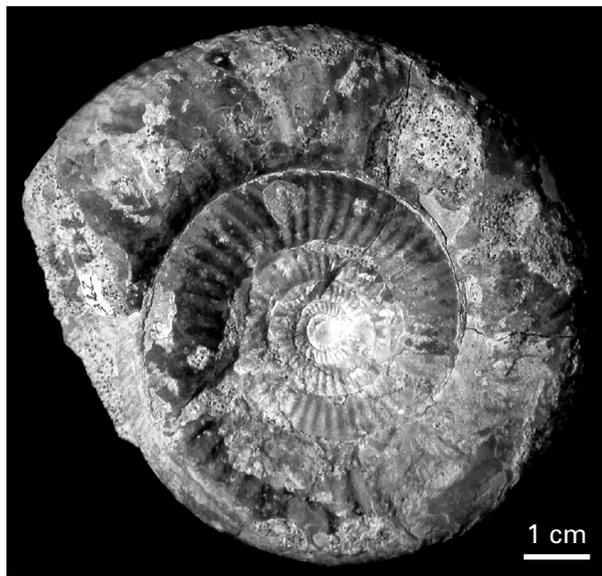


Fig. 5. *Prorsisphinctes* aff. *martiusi*; note the external Fe oxide crusts on the shell (taphorecord 4).

graphic levels (beds 3 and base of bed 16). The topmost beds, 17-18, show the typical litho-facies of the *Calcaires à Spongiaires*, and are separated from the uppermost *OFB* by a distinct burrowed omission surface.

Actually, two different sections, a few tens of metres apart, were measured, sampled and described during the highway excavation works. Correlation between the two sections is easy even though some beds of the lower unit (*e.g.* beds 6, 9 and 11) are lenticular and pinch out laterally. Ammonites are common in all beds but show different states of preservation so that a mixing of fossils pertaining to subsequent chrons appears evident in each bed. Biostratigraphic dating of the *OFB* at Bretteville thus requires careful taphonomic analysis.

## TAPHONOMIC ANALYSIS

Taphonomic analyses have been undertaken only on beds 4 to 14, *i.e.* on the lower part of the formation, which is the best known in the literature; the results are summarized below. Data on the uppermost *OFB* is only preliminary; information is given, with biochronologic comments, for beds 15-16.

The main criteria for documenting the state of taphonomical alteration of ammonites from beds 4-14 are as follows:

1. Textural and/or compositional difference between the internal mould and the encasing

sediment (matrix). Typical examples are: occurrence of glauconite grains in the mould that are absent in the matrix; phosphatization of the mould;

2. Textural and/or compositional difference among different parts of the internal mould (*e.g.* the innermost whorls of the phragmocone, the outer part of it, and the body chamber) (Fig. 3);
3. Boring, mainly ascribed to bivalves, of the internal mould (Fig. 3);
4. Coating of the shell by crusts of ochre to brown-Fe oxides; less commonly glauconite may replace Fe oxides;
5. Ochre-coloured, Fe-oxide staining of some parts of the internal mould; this effect may be restricted to some chamber fills or even to a part of a single chamber fill, the remaining being similar to the matrix (Fig. 4); again, less commonly green glauconite may replace Fe oxides;
6. Bioencrustation of the mould or of the Fe encrusted shell by epizoans such as bryozoans and cirripeds;
7. Discontinuity, commonly highlighted by a thin yellow Fe-oxide staining, between the matrix and the fill of the last chamber.

More than one of these features may be, and indeed are, recognized in a single specimen. The combination of two or more such features allows distinction of 6 groups of fossils based uniquely on their taphonomical characteristics (taphorecords in Fernández-López 1987). The decreasing index number labelling these taphorecords refers to less and less evident reelaboration.

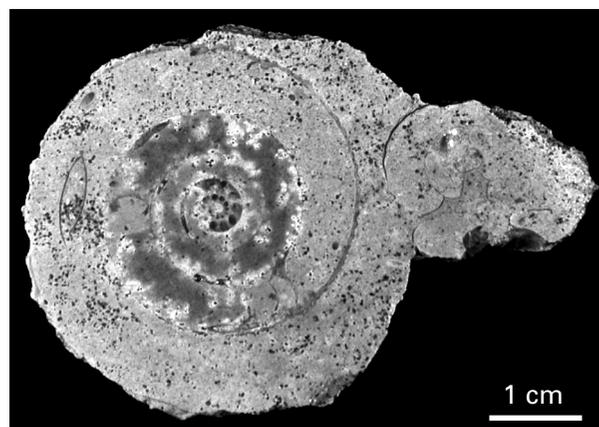


Fig. 6. *Chondroceras* sp.; the inner and darker part of the mould is phosphatized (taphorecord 3).

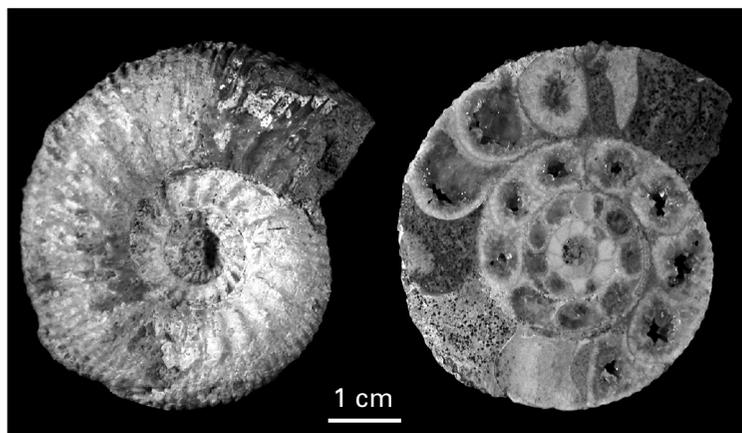


Fig. 7. *Stephanoceras umbilicum*. Innermost whorls are stained green by glauconite, whereas other external chamber fillings are stained dark yellow by Fe oxides. Note also the absence of any external coating by authigenic minerals (taphorecord 2).

The main diagnostic feature of each taphorecord (TR) may be resumed as follows.

TR 6: bored and abraded molds with neither shell nor septal remains (Figs. 3A, B). Moulds are composed of phosphatized sediment in the external whorls and of glauconite-rich one in the internal whorls. Fe oxides encrust the outer part of the mould.

TR 5: moulds with neomorphic shells coated with Fe oxides. Thin laminae of Fe oxides also occur within the shell usually at the boundary between structurally different layers. The mould of most chambers is stained dark yellow by Fe oxides (Fig. 4).

TR4: moulds with neomorphic shells coated with Fe oxides (Fig. 5). Differently from TR5, the mould is not stained.

TR3: partly phosphatized moulds with a thin external glauconite coating. The shell has been leached and replaced partly by sediment and partly by a sparry calcite cement. Septa are only partially preserved (Fig. 6).

TR2: in contrast to all the previous taphorecords, TR2 lacks any external coating by authigenic minerals. On the contrary the internal mould is very complex with texturally different fillings depending on the chambers; some of them are partly phosphatized, others are stained dark yellow by Fe oxides or green by glauconite (Fig. 7). The shell is neomorphic and shows thin laminae of Fe oxides within it.

TR1: no mould staining nor external crusts of authigenic minerals occur in this taphorecord. Thin laminae of Fe oxides however are recognizable within the shell (Fig. 8).

All the ammonites present in the fossil assemblages sampled in the lower part of the *OFB* at Bretteville, are actually composed of reelaborated ammonites, which suffered erosion from older beds, possible transport into a new, younger place of sedimentation, and in any case exposure on the sea-bottom before final burial. These condensed fossil assemblages come from beds affected by taphonomic condensation, in which chronologically successive fossils were mixed (Pavia and Martire 1997; Gómez and Fernández-López 1994). As the overall chronologic interval represented by fossils in a condensed assemblage is longer than the time of sedimentation

of the containing stratigraphic layer; and no ammonites from beds 4 to 14 of Bretteville can be defined as contemporaneous of the encasing matrix, the timing of biologic and sedimentary events of this succession must thus be determined in an indirect way.

#### AMMONITE ASSEMBLAGES

For the aims of this study, we consider here only the ammonites of biochronologic significance. No attempt is made to record the entire ammonite content of each bed, which will be detailed in a separate paper. Taxa are listed according to the classification proposed by Donovan *et al.* (1980).

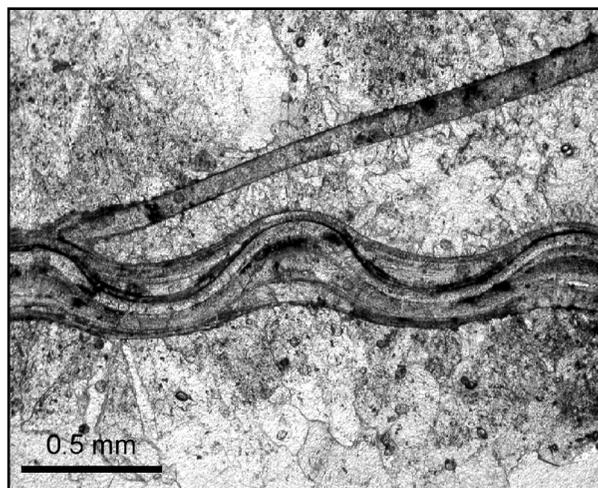


Fig. 8. Thin section of a specimen of *Garantiana* sp., showing thin laminae of Fe oxides within the shell (taphorecord 1).

### Beds 4-6

*Oppelia subradiata*, *Microtoxamblyites* sp., *Chondroceras evolvenscens*, *C. gervillii*, “*Stenmatoceras*” *blagdeni*, *Platystomites pinguis*.

Biochronology: the condensation of the late Sauzei Chron and the early to middle Humphriesianum Chron is typically documented. Bed 4 delivered also scattered specimens of *Emileia* sp. and *Otoites contractus* which possibly extend the biochronologic range of the ammonite assemblage to the early Sauzei Chron.

### Beds 7-8

*Dorsetensia romani*, *Stephanoceras bigoti*, *S. humphriesianum*, *S. mutabile*, *S. pyritosum*, *S. scalare*, *Lokuticeras rossbrunnense*, *L. tenuicostatum*, *Teloceras acuticostatum*, *T. (Paviceras) hoffmanni*, *T. (Paviceras) triptolemus*, *Chondroceras evolvenscens*, *C. gervillii*, *C. orbinyanum*, *C. ibericum*.

Biochronology: the fossil assemblage covers the entire Humphriesianum Chron with the mixing of several *Stephanoceras* of the early and middle part of this chron and some *Teloceras* of the early Blagdeni Subchron. The presence of *L. rossbrunnense* seems to extend the chronological range up to the earliest Niortense Chron.

### Bed 9

*Strigoceras septecarinatum*, *S. strigifer*, *Oppelia subcostata*, *Oecotraustes costiger*, *O. umbilicatus*, *Stephanoceras mutabile*, *S. umbilicatum*, *Teloceras multinodum*, *T. (Paviceras) triptolemus*, *Normannites fortis*, *N. immutans*, *N. orbigny*, *Caumontisphinctes aplous*, *C. polygyralis*, *Infraparkinsonia debilis*, *Stenoceras bigoti*, *S. latidorsatum*, *S. niortense*, *Orthogarrantiana haugi*, *O. densicostata*, *Leptosphinctes schmierereri*, *Cleistosphinctes interruptus*, *C. obsoletus*, *Bajocisphinctes curvatus*.

Biochronology: the interval covered by this condensed ammonite assemblage is long; it could virtually span from the Sauzei Chron (see *S. strigifer*) to the Parkinsoni one. Actually, we can be sure that the taphonomic condensation affects taxa of the Humphriesianum and the Niortense chrons. Younger levels can not be definitely proved as (1)

the *G. garantiana* Chron is represented only by *B. curvatus* whereas other taxa such as *Garantiana* gr. *garantiana* are not recorded, (2) the ranges of *S. truellei*, *O. subcostata* and *O. costiger* are usually listed from the Parkinsoni Zone, but their ranges seem to extend below into the Upper Bajocian (e.g. Pavia 1973).

### Beds 10-12

*Strigoceras paronai*, *Oppelia flexa*, *O. subcostata*, *O. subtilicostata*, *Oecotraustes umbilicatus*, *Teloceras banksi*, *T. multinodum*, *Normannites quenstedti*, *Cadomites homalogaster*, *C. lissajousi*, *Sphaeroceras tenuicostatum*, *Caumontisphinctes bifurcus*, *Infraparkinsonia* spp., *Stenoceras bajocense*, *S. latidorsatum*, *S. niortense*, *Orthogarrantiana haugi*, *O. densicostata*, *O. inflata*, *Garantiana baculata*, *G. garantiana*, *G. plathyrrimum*, *Paragarantiana* spp., *Pseudogarrantiana* spp., *Spiroceras annulatum*, *S. laevigatum*, *S. orbigny*, *Leptosphinctes davidsoni*, *L. festonensis*, *L. schmierereri*, *Cleistosphinctes cleistus*, *C. interruptus*, *C. obsoletus*, *Bajocisphinctes bajocensis*, *B. curvatus*, *B. mousterdei*, *Microbajocisphinctes bigotitoides*, *M. robustus*, *Bigotites tuberculatus*, *Prorsisphinctes meseres*, *P. pseudomartinsi*, *P. stomphus*.

Biochronology: these three condensed ammonite assemblages are discussed together as their biochronologic range is the same, from the base of the Niortense to the Garantiana and also to the earliest Parkinsoni chrons. Nevertheless we could rule out the latter chron because of the absence of any *Parkinsonia*, the early representatives of which typically mark the beginning of the Parkinsoni Standard Zone. The only specification concerns Bed 10 in which we found a limited number of the stephanoceratids *Teloceras*, *Normannites*, *C. lissajousi*, and the dimorphic pair *Caumontisphinctes* – *Infraparkinsonia*; all these taxa pertain to the early part of the Niortense Chron and thus testify a taphonomic condensation a bit more extended than in beds 11 and 12 whose mixed ammonite assemblages do not contain anything from below the middle part of this chron.

### Beds 13-14

*Oppelia bajocensis*, *O. flexa*, *O. pleurifer*, *O. plicatella*, *Orycerites* cf. *aspidooides*, *Cado-*

*mites daubenyi*, *C. stegeus*, *Polyplectites bajoensis*, *P. dorni*, *P. rozycki*, *Garantiana dubia*, *G. garantiana*, *G. subgaranti*, *G. trauthi*, *Paragarantiana alticosta*, *P. pompecky*, *Paragarantiana longidoides*, *Pseudogarantiana minima*, *Pseudogarantiana* pl. spp., *Parkinsonia acris*, *P. arietis*, *P. parkinsoni*, *P. rarecostata*, *P. schloenbachi*, *Parkinsonia* sp., *Durotrigensia ferruginea*, *D. neuffensis*, *D. planulata*, *Durotrigensia* sp., *Microbajocisphinctes althoffi*, *Bigotites petri*, *B. lanquinei*, *B. thevenini*, *B. tuberculatus*, *Prorsisphinctes glyphus*, *P. meseres*, *P. pseudomartinsi*, *P. reparator*, *P. stomphus*.

Biochronology: the condensed ammonite assemblages of beds 13 and 14 are equivalent in terms of biochronologic range, despite some difference in taxonomic content. The occurrence of parkinsoniids (the dimorphic couple *Durotrigensia* and *Parkinsonia*) demonstrates reelaboration from sediments pertaining to the Parkinsoni Chron; other ammonites instead are restricted to (e.g. *Garantiana* spp., *P. stomphus*) or first appear in the Garantiana Standard Zone (e.g. *Paragarantiana* spp., *Pseudogarantiana* spp.). Furthermore, it is worth noting the absence of taxa typical of the upper Parkinsoni Standard Zone, such as *Parkinsonia bomfordi* and *Dimorphinites dimorphus*, which allows us to conclude that the reelaboration event took place before the late Parkinsoni Chron.

### Beds 15-16

The taxonomic content of these beds is identical to that described from the same layer on the coast and at Sully (Rioult 1964; Pavia 1994). From the taphonomic point of view, the fossils do not belong to any of the six taphorecords distinguished in beds 4-14. It is possible to group fossils in two taphorecords, provisionally labelled as TR-A and TR-B, the latter composed of resedimented fossils displaced on the sea-bottom before their burial (Fernández-López *et al.* 2006), and the former with reelaborated fossils. Nevertheless, the taxonomic record is the same for both taphorecords.

*Strigoceras truellei*, *Cadomoceras cadomense*, *Lissoceras ferrifex*, *L. haugi*, *L. psilodiscus inflatum*, *Microlissoceras* spp., *Cadomites* spp., *Polyplectites linguiferus*, *P. gracilis*, *Dimorphinites dimorphus*, *Vigoroceras defrancei*, *Parkin-*

*sonia* spp., *Durotrigensia* (?) *bomfordi*, *D. dorsetensis*, *Durotrigensia* sp., *Bigotites* spp., *Lobosphinctes costulatosus*, *Planisphinctes tenuissimus*.

Biochronology: the ammonite assemblages of beds 15 and 16 reflect taphonomic condensation due to the mixing of two fossil taphorecords. The age of these beds is indicated by the ammonites of the taphorecord TR-B, made up of resedimented fossils, which refer to the late Parkinsoni Chron, namely the Bomfordi Subchron. Nevertheless, as the taxonomic content of the two taphorecords is identical and the biochronologic meaning of their fossils is equivalent, the degree of taphonomic condensation (*i.e.* the mixing of fossils of different chronostratigraphic units) is almost insignificant.

### BIOSTRATIGRAPHIC ARRANGEMENT

As said before, no direct biostratigraphic conclusions may be reached due to the taphonomic condensation affecting most beds, except for beds 15-16. In general, we could arrange a confident biostratigraphic evaluation by a process of exclusion (*ad escludendum*). When a bed lacks significant fossils, a time span may be indirectly bracketed by means of the youngest ammonite present in the bed below and the oldest ammonite present in the bed above, when both are not recorded in the bed in question. In the case of the Bretteville section, where all beds contain a rich although reelaborated fossil assemblage, for each bed or set of beds we could assume a relatively restricted biochronologic meaning that is encompassed by (1) a lower boundary established by its youngest ammonite, and (2) an upper boundary defined by the ammonites whose first appearance is only in the overlying layer. In other words, we can only define the maximum age of each layer by the youngest recorded fossil.

Bed 9 could be selected for clarifying such a procedure. The youngest ammonites are represented by reelaborated specimens of the dimorphic pair *Orthogarantiana* – *Strenoceras*, which are known to occur from the Polygyralis Subzone, that is in the middle and upper part of the Niortense Standard Zone. On the other hand, typical ammonites of the Garantiana Standard Zone are totally absent, and these in contrast occur in bed 10 (e.g. the dimorphic pair *Paragarantiana* – *Pseudogarantiana*). We may confidently

conclude that the deposition time of bed 9 has to fall within the middle to late Niortense Chron.

Similar arguments are valid for the other layers of the lower *OFB*. The time of deposition of beds 15-16, and the biostratigraphic meaning of their fossil assemblages are much clearer: they are dated by the resedimented, non reelaborated ammonites which belong to the upper part of the Parkinsoni Standard Zone. In summary, the following time-table can be assumed:

Beds 4-6: early to middle Humphriesianum Chron.

Beds 7-8: late Humphriesianum to early Niortense chrons.

Beds 9: middle to late Niortense Chron.

Beds 10-12: early to late Garantiana Chron.

Beds 13-14: early to middle Parkinsoni Chron.

Beds 15-16: late Parkinsoni Chron.

The occurrence of identical assemblages of fully reelaborated fossils in some successive beds hinders the constraint of the age of each bed. In these cases (beds 4-6, 7-8, 10-12, 13-14, 15-16) only the time interval in which deposition of a group of some beds took place may be defined on the whole. This, however, is the best we can do with condensed successions containing mainly reelaborated fossils such as those presented here.

## CONCLUDING REMARKS

In the Bajocian section of Bretteville, and in particular in the succession of the *Oolithe Ferrugineuse de Bayeux*, all the fossil assemblages are condensed; they mix temporally successive fossils deriving from the burial either of the taphonomic products of biota living in that environment, or of previously fossilized specimens (taphonomically reworked or reelaborated fossils) which suffered erosion from older beds and were later buried in a more recent sediment. The situation is quite different in the lower part of the *OFB* from that in the upper part (beds 15-16): all the ammonites from beds 4 to 14 are reelaborated and thus none is contemporaneous with the encasing matrix; on the contrary, some fossils from beds 15-16 are resedimented and thus allow direct dating of this layer. In such a situation, except for the topmost section, we cannot use the fossils for reconstruction of a standard biostratigraphic succession, but we are forced to make a stratigraphy of fossils based on their

taphonomically delayed first occurrence. The framework of the maximum biochronologic meaning of each bed or set of beds at Bretteville allows the reference of the lower subunit of the *OFB* to the middle to upper part of the Bajocian Stage (Humphriesianum to Parkinsoni chrons), whereas the uppermost *OFB* can be referred to as the uppermost Bajocian (latest Parkinsoni Chron).

The taphonomic approach to reelaborated fossils described represents an improvement in the study of condensed successions. It enables the use of data such as the biochronological meaning of reelaborated fossils that would be excluded by standard biostratigraphic analysis. Moreover it contributes to a more refined reconstruction of the chronological history of both sedimentary and paleobiological events. In particular for the Bretteville section:

- no direct biostratigraphy can be established from the sequence of ammonite assemblages;
- the fossiliferous horizons with condensed assemblages have no value for definition of biostratigraphic standard scale;
- the palaeontologic data permit only indirect chronologic evaluation of the succession by a process of exclusion (maximum age of beds): the conclusions assume a local value for description of the sedimentary evolution, mainly by means of depositional events which are no longer recorded in the succession but documented by reworked fossils or by lithoclasts (see chronoregistratic succession of Fernández-López 1991, *in* Pavia and Martire 1997);
- the definition of an indirect biostratigraphy, which can be achieved, assigns minimal chronologic values to taxa for which nothing has been defined when (1) their range has not been precisely defined in expanded successions, (2) they constitute new taxa, and (3) are present only in condensed successions that suffered from the same taphonomic constraints as that of the Bajocian of Normandy.

## Acknowledgements

The authors are indebted to Patrick Godefroy (Caen) for information about the works at Bretteville. Thanks also to Aldo Defaveri and Giuseppe Bartolotti (Alessandria) who gave a friendly help in sampling the outcrop. Critical reviews by T. Praszquier and N. Morton greatly

contributed to improve the manuscript. The research was funded by University of Torino grants.

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