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Ammonite taphonomy and stratigraphy of the Bajocian at Maizet, south of Caen (Calvados, NW France)

Taphonomie et stratigraphie des associations à ammonites du Bajocien de Maizet, au sud de Caen (Calvados, NO France)

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ABSTRACT

A study of the ammonite assemblages from the "Oolithe ferrugineuse de Bayeux" Formation of Bajocian age is presented herein. The section at the locality of Maizet shows a high level of stratigraphic condensation, and taphonomic reworking is common within the sequence. All the ammonites being studied are classified herein as having been reworked, transported or displaced on the sea-floor prior to burial, and as such, are determined taphonomically as being resedimented or reelaborated fossil elements. Seven evidences of reelaboration within the sequence under investigation are detailed here. The palaeontological units, so-called taphorecords, characterized by distinctive taphonomic features, are used to directly or indirectly assign beds to biochronostratigraphic units. In addition, identification of taphorecord relationships regarding successive or contemporaneous deposition allows their registratic succession and order of depositional events to be inferred. The latter may be deduced on the basis of bed succession or by reference to stratigraphical intervals that now are only represented in the stratigraphic column by fossils. Deposition by tractional currents and winnowing is indicated by sharp bed-base and by reworked fossil elements. Biochronostratigraphic correlation with other sections of the inland Bajocian successions in the Calvados area (Bretteville, Feuguerolles) highlights a common depositional evolution that may be related to an eastward-deepening carbonate ramp.

Mots clés :
Ammonites
Bajocien
Calvados
Tapho-enregistrements
Biochronologie
Succession enregistrée

RÉSUMÉ

L'étude traite des assemblages d'ammonites bajociennes de la formation dite « Oolithe ferrugineuse de Bayeux ». La coupe de Maizet illustre une section condensée, avec un remaniement taphonomique omniprésent. Toutes les ammonites sont des éléments remaniés qui ont été transportés ou remobilisés avant l'enfouissement. Sur la base de paramètres taphonomiques, on peut distinguer les éléments resédimentés de ceux réélaborés, ces derniers sur la base de sept critères de réélaboration. Les fossiles ont été regroupés dans des tapho-enregistrements montrant une conservation distinctive ; par conséquent, il a été possible d'attribuer directement ou indirectement tous les niveaux

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de Maizet à des unités biochronostratigraphiques. La relation de succession temporelle entre tapho-enregistrements permet de reconstituer leur succession enregistrée et l'ordre chronologique des événements sédimentaires. Ces derniers sont, soit matérialisés par les niveaux successifs de la coupe, soit rapportés à des intervalles stratigraphiques qui ne sont plus représentés dans la colonne stratigraphique, si ce n'est que par les fossiles. Les surfaces irrégulières en base de banc et les éléments remaniés suggèrent que ces dépôts carbonatés ont été affectés par l'action de courants de traction. La comparaison biochronostratigraphique avec d'autres coupes du Bajocien affleurant au sud de Caen (Bretteville, Feuguerolles) permet de retracer une évolution commune des dépôts, qui peuvent être attribués à une rampe carbonatée s'approfondissant vers l'est.

1. Introduction

The well-known formation "Oolithe ferrugineuse de Bayeux" in the Calvados area (NW France) has been the focus of a variety of palaeontological and stratigraphic studies since the mid-19th century. The richness and diverse nature of the fossil record of this formation provided data that lead to the establishment of the Bajocian stage, as it was named in 1849 (d'Orbigny, 1849–1852, p. 157). The latter was more precisely defined in 1850 on the basis of the ammonite record (d'Orbigny, 1842–1851, p. 606), and the succession described in detail in 1852 from the section of Les Hachettes near Sainte-Honorine-des-Pertes (d'Orbigny, 1850–1852, p. 477). More than one century later, Rioult (1964, 1980; see also Fürsich, 1971; Parsons, 1974) stated that this section should be regarded as the stratotype of the Bajocian Stage. Although the I.U.G.S selected the stratotype (the Bajocian GSSP) at the locality of Cabo Mondego in Portugal (Pavia and Enay, 1997), the Les Hachettes section still retains its historical value.

Besides Sainte-Honorine, d'Orbigny (1842–1851, 1850–1852; see also Rioult, 1964) referred to other localities near Bayeux and in the area south of Caen (Fig. 1). Among the former, worthy of mention are the sites at Saint-Vigor and, above all, at Sully which was previously mentioned by de Caumont (1824), and further described by Brasil (1895; see also Haug, 1910, p. 1008) and Bigot (1928). As to localities in the area south of Caen, the inland succession at Moutiers-en-Cinglais (Dufrénoy and de Beaumont, 1848) was recognized by d'Orbigny (1850–1852) as being thicker than on the coast. Over the last 40 years many localities have been investigated: Pavia (1994; see also Martire and Pavia, 1996) correlated the succession of Sully to those of Les Hachettes and Saint-Côme-de-Fresné; Gabilly and Rioult (1974) briefly described the Lower Bajocian succession in the May-sur-Orne quarry; Gauthier et al. (1996) studied the fossiliferous outcrop of the Feuguerolles-sur-Orne quarry; Pavia and Martire (2010; see also Martire and Torta, 2000) gave a detailed account of the biochronostratigraphical subdivision of the Bretteville-sur-Odon section.

The successions occurring in the coastal sector north of Bayeux and those south of Caen differ significantly, depending on the degree of their stratigraphic condensation (sensu Gómez and Fernández-López, 1994). The former are extremely condensed, typified by successions at the localities of Les Hachettes and Sully, whereas thelatter are more expanded as may be observed at the localities of Feuguerolles-sur-Orne and Bretteville-sur-Odon, as well as at the Évrecy section (refer to Pavia, 1994). Thus, description of further sections is considered to be of great importance in order to update current knowledge of the Bajocian successions in the Calvados area.

The present paper is a report of field studies carried out in September 2010 at the Maizet locality, where an almost complete section of the "Oolithe ferrugineuse de Bayeux" Formation was sampled. In particular, the stratigraphy of the fossiliferous deposits is discussed in detail, because the condensed fossil-assemblages recorded show a high degree of taphonomic reworking. The latter conclusion is supported by the biochronological data and is based on correlation with the sections mentioned above, deemed as being useful for tracing the Fe-oolithic succession within the inland Bajocian outcrops in the area of Calvados.

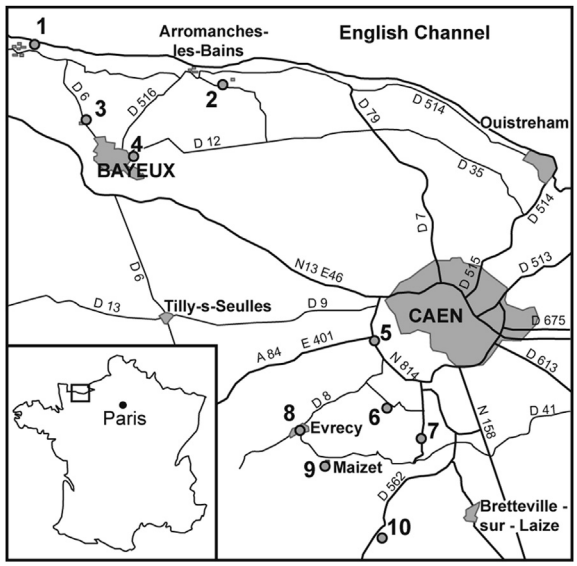


Fig. 1. Geographical location of the cited Bajocian outcrops in Calvados. 1. Sainte-Honorine-des-Pertes. 2. Saint-Côme-de-Fresné. 3. Sully. 4. Saint-Vigor. 5. Bretteville-sur-Odon. 6. Feuguerolles-sur-Orne. 7. May-sur-Orne. 8. Évrecy. 9. Maizet. 10. Moutiers-en-Cinglais.
Fig. 1. Localisation géographique des gîtes du Bajocien cités dans l'article. 1. Sainte-Honorine-des-Pertes. 2. Saint-Côme-de-Fresné. 3. Sully. 4. Saint-Vigor. 5. Bretteville-sur-Odon. 6. Feuguerolles-sur-Orne. 7. May-sur-Orne. 8. Évrecy. 9. Maizet. 10. Moutiers-en-Cinglais.

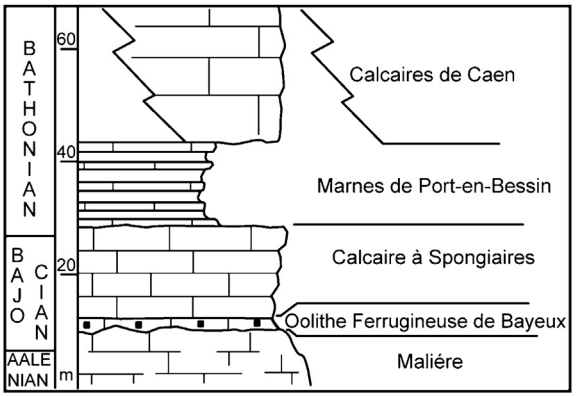


Fig. 2. Upper Aalenian to Middle Bathonian succession of the Bayeux and Caen areas.
Fig. 2. Succession de l'Aalénien supérieur au Bathonien moyen des environs de Bayeux et Caen.
Modified after Rioult et al., 1991.

2. Material and methods

Throughout the Calvados area, the Bajocian succession comprises three formations (Rioult, 1964; Rioult et al., 1991), whose general features from bottom up are as follows (Fig. 2).

2.1. Maliére Formation (Aalenian to Lower Bajocian in age)

The thickness varies up to a few metres. The Maliére Fm is represented by grey cherty biomicrite containing sponges and glauconite grains. The topmost thin layer consists of glauconitic floatstone rich in phosphatised bio- and lithoclasts derived from the underlying biomicrite; it corresponds to the "Couche verte" Member Auctt., and is separated from the typical Maliére Fm (Maliére s.s. on Fig. 3).

2.2. "Oolithe ferrugineuse de Bayeux" Formation (Lower and Upper Bajocian)

The thickness ranges from 20 cm at Les Hachettes to 3 m at Feuguerolles. The "Oolithe ferrugineuse de Bayeux" Fm consists of grey or yellow bioclastic wackestone to packstone, rich in ferruginous or phyllitic ooids. In the lower part of the coastal "Oolithe ferrugineuse de Bayeux" Fm, a basal 10–30 cm-thick layer is known as the "Conglomérat de Bayeux" Member with ellipsoidal Fe-oncoids within a yellow calcareous matrix; this member is separated from the typical "Oolithe ferrugineuse de Bayeux" Fm (Oolithe Ferrugineuse s.s. on Fig. 3).

2.3. "Calcaires à spongiaires" Formation (uppermost Bajocian)

The siliceous limestones rich in sponge remains may be up to 12 m in thickness in the coastal successions.

The studied section is located within the administrative district of Maizet (coordinates 49°04′42″ N and 0°27′58″ E). Study of the site was made possible due to a scientific agreement with the Municipality of Maizet. The field studies were carried out by a 16-member team over a two-week period in mid-September 2010. Exposure of a surface of approximately 40 m^2 of the "Oolithe ferrugineuse de Bayeux" Fm was done using an excavator. Unfortunately, due to the effects of Pleistocene ice-weathering, the rock structure beneath the soil had been altered; a complex network of microfractures had developed, and a microcrystalline alabaster crust had been deposited on the fossils. As a result of this diagenetic action, evidence regarding bedding planes was difficult to ascertain, so they could only be recognized on the basis of the textural changes of overlapping rock-bodies and the taphonomic features of fossils.

The section at Maizet was carefully sampled for fossils, mainly ammonites, which were collected bed by bed in the interval comprising the top "Couche verte" Member and the "Oolithe ferrugineuse de Bayeux" Fm. On the whole, more than three thousand ammonites were collected and these are presently housed for study purposes in the "Museo di Geologia e di Paleontologia di Torino" (MGPT). As far as fossil-diagenetic features are concerned, preservation as internal moulds with neomorphic or pseudomorphic shells is the rule.

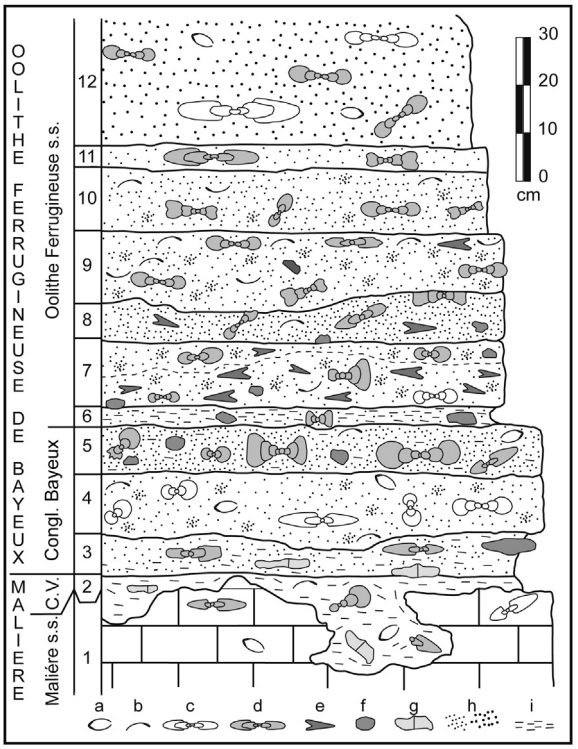


Fig. 3. The Bajocian lithostratigraphic succession at the Maizet locality. The density of fossils is indicative.
C.V.: "Couche verte" Member. Congl. Bayeux: "Conglomérat de Bayeux" Member. Textures: a: articulated bivalve; b: disarticulated bivalve; c: resedimented ammonite; d: reelaborated ammonite; e: belemnite rostrum; f: lithoclast and oncoid stained by Fe-oxides; g: phosphatized intraclast; h: ferruginous ooids; i: marly matrix.
Fig. 3. La succession lithostratigraphique du Bajocien à Maizet. La densité des fossiles est indicative.

A macroscopic taphonomic study was carried out on the collected material based on the recognition of a variety of mechanisms of taphonomic alteration of fossils (refer to Fernández-López, 1991, 2007, 2011a,b). All the Bajocian ammonites from the locality at Maizet are considered to represent reworked elements; they are either (1) resedimented fossils that had been elements displaced on the sea-floor, after accumulation by taphogenic production and prior to burial (sensu Fernández-López, 1991), and are coeval with the encasing sediment in which they are buried, or (2) reelaborated fossils that derive from previous sediments and, subsequent to exposure on the sea-bottom, were incorporated within a new, younger sediment (Pavia and Martire, 1997, 2010). It is worth noting here that the word "reworking" assumes a different meaning when referred to within a stratigraphical or taphonomical context; hence the terms "reworked" and "reelaborated" are not synonyms (Fernández-López, 2011a; Zunino et al., 2012). Unlike the common use of the term "reworking" in sedimentology and its chronostratigraphic meaning in geology (Jackson, 1997), the term "reworking" in taphonomy refers to the particular processes that taphonomic elements have been subjected to during their permanence on the substrate prior to final burial. Investigation of taphonomic reworking aims to characterize the relationships between fossils and their sedimentary matrix; it includes two processes, as outlined previously:

- resedimentation, which refers to any displacement of the taphonomic elements on the sea-floor prior to burial;
- reelaboration, which indicates exhumation and displacement of previously buried taphonomic elements on the substrate before their further burial.

The resedimented ammonites from the Maizet locality are preserved as entire or fragmented shells with concretionary internal moulds with the same textural composition as the encasing matrix. The sedimentary infilling is limited to the bodychamber and to the most external whorls of the phragmocone; inner whorls are usually lacking (hollow ammonites) except where the shell shows breakages due to biostratinomic processes.

The reelaboration features observed on fossils from the Maizet locality are very similar to those described from the localities at Sully and Bretteville-sur-Odon (Pavia, 1994; Pavia and Martire, 2010). The macroscopic criteria used herein for the recognition of the taphonomic alteration of the Maizet ammonites are in accordance with those proposed by Fernández-López (1986, 2011b). The reelaborated ammonites from Maizet may be classified by distinctive features:

1 lithological and/or textural differences and discontinuity between the sedimentary filling of the internal mould and the encasing matrix, possibly highlighted by mineral staining;
2 different phases of sedimentary infilling;
3 shell coated by (a) Fe-oxide or (b) glauconite crusts;
4 Fe-oxide (a) or glauconite (b) staining of the internal mould;
5 epizoan encrustation on moulds or on stained shells;
6 mould disarticulation at a septal surface;
7 abrasion surfaces on the internal mould.

In this study, the distinction of taphorecords has also been taken into consideration (Fernández-López, 1987, 1991; Pavia and Martire, 1997; Zunino et al., 2012). Taphorecords are palaeontological units composed of fossils showing distinctive taphonomic features. The fossil-assemblage of a bed may be composed of elements belonging to one or more taphorecords, anyone of which has diagnostic characters related to a peculiar set of biostratinomic or fossil-diagenetic processes. As the taphorecord is a palaeontological unit devoid of any stratigraphic, taxonomic or chronologic meaning, it may occur in different overlying beds. The identification of diverse taphorecords within the condensed fossil-assemblage of a particular bed allows heterochronies to be detected among fossils. The taphorecords may be arranged in a topological (relative, temporal) order of younger and older sets of taphonomically equivalent elements, i.e. in a succession of distinctive palaeontological units. In a stratigraphic section, this kind of sequence is the registratic succession (Fernández-López, 1986, 1991, 1995, 1997; Fernández-López and Gómez, 1990). The latter provides a temporal distribution of the taphonomic processes (i.e. the taphorecords) and relates them to the depositional events of each successive bed within the section.

As to the scheme of biostratigraphic and biochronostratigraphic classifications and units, that proposed by Rioult et al. (1997) is referred to herein as it is accepted by most workers (see Pavia and Zunino, 2012, and references therein). The ammonite Standard Zones, into which the Bajocian Stage of the West Tethyan Realm is divided, are as follows, from bottom up: Discites, Laeviuscula, Propinquans and Humphriesianum zones for Lower Bajocian; Niortense, Garantiana and Parkinsoni zones for Upper Bajocian: the detailed biochronostratigraphic scheme with subzones is given below under the section "Remarks and discussion". It is worth noting that any precise biostratigraphic assignment of the Maizet Fe-oolithic beds, though seemingly favoured by the rich fossil record, is made difficult by the recurrent reelaboration processes affecting the ammonite assemblages. The time interval of a condensed fossil-assemblage is longer than the sedimentation time of the encasing bed. For this reason, herein the practice of "indirect biostratigraphy" as generically presented by Fernández-López (1997, fig. 3) and applied by Pavia and Martire (2010) to fossil-assemblages composed only of reelaborated elements, such as those from some beds of the condensed section of Bretteville, has been utilized: the youngest among the recorded fossils constrains the timing of the Fe-oolithic sedimentary events recorded at Maizet (maximum age of each bed), whenever it cannot precisely be defined by the resedimented fossils.

The Fe-oolithic facies and the stratigraphic condensation of the Bajocian succession in the Calvados area are comparable with those of the coeval successions at localities in Dorset, that are well known from English literature (see Callomon and Cope, 1995). Regarding the Aalenian and Bajocian stages, Callomon and Chandler (1990)

proposed a documented sequence of biohorizons based on ammonite assemblages that might constitute a useful reference for palaeontological studies on the Middle Jurassic Fe-oolithic formations of the so-called Anglo-Paris Basin (Rioult et al., 1991). However, the Bajocian succession in Dorset is composed of beds in which taphonomic condensation apparently does not occur, so that it is difficult to compare it with the sets of beds and fossil-assemblages from the Calvados area where taphonomic condensation is the rule (Pavia, 1994; Pavia and Martire, 2010). As may be observed in the following description, only a few beds sampled at the Maizet locality actually correspond to the biohorizons put forward by Callomon and Chandler (1990).

3. The stratigraphic succession at Maizet

The section exposed during excavation of the Maizet site includes a total of 130 cm from the top Maliére Fm to the upper "Oolithe ferrugineuse de Bayeux" Fm (Fig. 3). Twelve beds have been distinguished on the basis of textural features, taphonomic criteria and sedimentary discontinuities. Beds 1–2 represent the topmost Maliére Fm, whereas beds 3–12 pertain to the "Oolithe ferrugineuse de Bayeux" Fm. In particular, beds 3–5 may be referred to the "Conglomérat de Bayeux" Member, though its organisation in beds is atypical compared with that of the coastal outcrops (Pavia, 1994; Pavia and Martire, 2010). Beds 6–12 correspond to the middle part of the "Oolithe ferrugineuse de Bayeux" Fm, whereas the so-called white-oolithic layer, regularly encountered at the top of formation, is missing due to Quaternary erosion. The following description includes the lithological characteristics of beds, specifies the taphonomic features [1] to [7] as listed above, taphorecord by taphorecord within each condensed fossil-assemblage, and refers to ammonites with significant biochronostratigraphic meaning. In the following description, taphorecords are quoted with an acronym specifying resedimented (RS) or reelaborated (RL) units, the bed pertinence and a progressive number.

3.1. Bed 1 (min 20 cm)

Grey to bluish biomicritic limestone with sponge spicules and glauconitic grains; the topmost layer is slightly clayey and contains phosphatized lithoclasts. The upper surface is erosional and carved by deep holes due to enlargements of *Thalassinoides*-type burrows (Fürsich, 1971). Two taphorecords have been distinguished:

- RS-1/1: resedimented fossils; among the ammonites, sonniniids (*Witchellia* spp.) and early stephanoceratids (*Mollistephanus* cf. *mollis*) allow assignment to the late Laeviuscula Chron;
- RL-1/1 (features [1], [3b], [6]): the phosphatized internal moulds of sonniniids, such as *Shirbuirnia trigonalis* and *Fissilobiceras* spp., indicate the middle Laeviuscula Chron.

Biochronostratigraphy: the resedimented ammonites characterize the upper Laeviuscula Zone.

3.2. Bed 2 (5–20 cm)

The thin bed and the sedimentary filling of holes and burrows at the top Maliére Fm pertain to the "Couche verte" Member. The sediment is a whitish to greenish, largely matrix-supported floatstone containing phosphatized, glauconitized and bored pebbles reworked from the Maliére Fm. Fossils are abundant. The internal moulds of infaunal bivalves are resedimented elements, whereas all ammonites are reelaborated:

- RS-2/2: the resedimented bivalves represent the post-depositional colonization of the soft muddy sediment;
- RL-2/2 (features [1], [2], [4b], [7]): *Fissilobiceras fissilobatum* and *Witchellia* spp. refer it to the Laeviuscula Chron;
- RL-2/3 (features [1], [4b], [6]): internal moulds of Sonniniidae and Otoitidae of the Propinquans Chron.

Biochronostratigraphy: indirect reference to the upper Propinquans Zone.

3.3. Bed 3 (5–10 cm)

The red-brown clayey layer contains lithoclasts of the Maliére Fm, Fe-oolithic intraclasts and reelaborated fragmentary moulds. The boundary upon bed 2 appears transitional, possibly due to sediment charge and bioturbation:

- RL-3/4 (features [1], [3a], [4a], [4b], [6], [7]): specimens of *Sonninia* spp., *Papilliceras* sp., *Bradfordia praeradiata*, *Emileia–Otoites* group, *Kumatostephanus perjucundus* refer to the Propinquans Chron. The taxonomic composition of RL-3/4 is complementary to that of RL-2/3; actually, RL-3/4 may be regarded as due to a further reelaboration of fossils RL-2/3 that produced additional Fe-oxide crusts and abrasion surfaces of the internal moulds;
- RL-3/5 (features [1], [3a], [4a], [6]): the fragmentary moulds of *Dorsetensia* sp. and *"Teloceras" labrum* indicate the passage between the Propinquans and Humphriesianum chrons.

Biochronostratigraphy: indirect reference to the lowermost Humphriesianum Zone.

3.4. Bed 4 (13 cm)

Pink–brown wackestone to packstone with randomly dispersed fine Fe-ooids. The rich fossil record includes resedimented specimens:

- RS-4/3: among ammonites, the dimorphic species *C. evolvescens* and *C. gervillii* are the most common together with *Dorsetensia* spp., *Poecilomorphus cycloides*, *Toxamblyites densicostatum*, *Stephanoceras plagium*, "*Teloceras blagdeni* (sensu d'Orbigny)".

Biochronostratigraphy: upper part of the lower Humphriesianum Zone. The ammonite assemblage of

bed 4 may be correlated with the English Biohorizon Bj-14b of Callomon and Chandler (1990).

3.5. Bed 5 (10 cm)

Red–brown packstone with homogeneously distributed fine- to medium-sized Fe-ooids; some centimetre-sized Fe-oolithic intraclasts are present and coated by Fe-oxide crusts. The fossil-assemblage is extremely rich in reelaborated ammonites lying in varied positions, also subvertical. Ammonites show similar taphonomic features within a single reelaborated taphorecord, whereas bivalves are identified as resedimented elements:

- RS-5/4: bivalves represent a taphorecord of resedimented elements reflecting the post-depositional colonization of the soft ground;
- RL-5/6 (features [1], [2], [3a], [4a], [5], [6], [7]): the ammonite taxa are referable to four different biochrons: *Lissoceras semicostulatum* (5/6a: Propinquans Chron; possible further reelaboration of RL-2/3); *Dorsetensia* spp., *Poecilomorphus cycloides*, *Toxamblyites densicostatum*, *Stephanoceras brodiaei*, *Chondroceras* spp. (5/6b: early Humphriesianum Chron); *Oppelia subradiata*, *Stephanoceras bigoti*, *S. humphriesianum*, *S. mutabile*, *Itinsaites* spp. (5/6c: middle Humphriesianum Chron); *Lokuticeras tenuicostatum*, *Teloceras* (*T.*) *acuticostatum*, *T.* (*Paviceras*) *hoffmanni*, *Normannites* spp. (5/6d: late Humphriesianum Chron).

Biochronostratigraphy: indirect reference to the uppermost Humphriesianum Zone.

3.6. Bed 6 (5 cm)

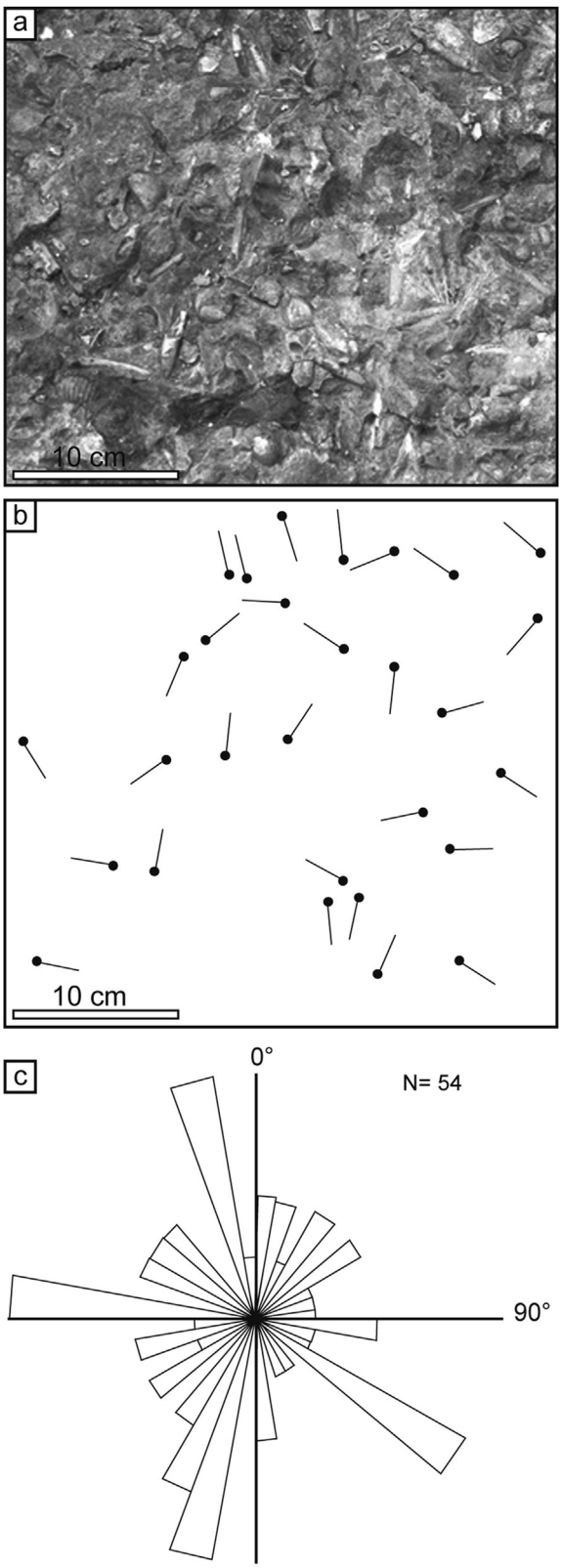
It constitutes a layer that may be correlated through the whole sector from Maizet to Bretteville-sur-Odon. The bed rests on the topmost erosional surface of bed 5, and consists of dark grey to brown clays with frequent cm-sized Fe-oolithic intraclasts eroded from the underlying bed. Fossils are common with abundant stephanoceratids:

- (RL-6/6): the fossils show the same preservational features of RL-5/6 with additional Fe-oxide crusts and abrasion surfaces of the internal moulds.

Biochronostratigraphy: indirect reference to uppermost Humphriesianum or lowermost Niortense zone.

3.7. Bed 7 (12–15 cm)

The lower boundary is undefined due to sediment compaction. The lithofacies is a grey to light-brown biomicrite with scattered Fe-stained lithoclasts and clusters of small Fe-ooids. The matrix allows distinction of two parts, depending on the clay content, being reduced in the upper one with most regular Fe-ooid distribution. The lower sublayer is "rostral supported" due to the high concentration of belemnite rostra (Fig. 4). The condensed fossil-assemblage is composed of three taphorecords:



- RS-7/5: resedimented specimens of the dimorphic couple *Caumontisphinctes nodatus* and *Infraparkinsonia debilis*, typical of the upper part of the early Niortense Chron (Nodatus Biohorizon in Pavia and Zunino, 2012);
- RL-7/7 (features [1], [2], [4a], [6], [7]): fragmentary to entire stephanoceratid moulds (*Teloceras, Lokuticeras*), *Leptosphinctes festonensis* and *Subcollina ochotorenai* of the latest Humphriesianum Chron (Fig. 5);
- RL-7/8 (features [1], [4a], [6], [7]): mostly entire, often laterally truncated internal moulds of ammonites such as *Teloceras* (*T.*) *banksi* of the early Niortense Chron.

Biochronostratigraphy: upper part of the lower Niortense Zone. The ammonite assemblage of bed 7 may be correlated with the English Biohorizon Bj-21 of Callomon and Chandler (1990).

3.8. Bed 8 (7–14 cm)

The lower boundary is sharp. The lithofacies is a brown biomicrite with fine, uniformly distributed Fe-ooids. The bed contains scattered centimetre-sized Fe-oolithic lithoclasts coated by oncoidal Fe-oxide crusts. The rich ammonite assemblage contains fossils of four reelaborated taphorecords:

- RL-8/7 and RL-8/8: fragmentary, occasionally subvertical specimens of stephanoceratids showing the same taphonomic features as RL-7/7 and RL-7/8, respectively, with supplementary abrasion surfaces of the internal moulds that testify to further reelaboration of those two taphorecords;
- RL-8/9 (features [3a], [4a]): mostly entire, Fe-oxide coated shells or stained internal moulds of the dimorphic couples *Caumontisphinctes-Infraparkinsonia* and *Orthogarantiana–Strenoceras* referable to the middle Niortense Chron;
- RL-8/10 (features [4a], [5]): internal moulds of *Spiroceras* spp. of the late Niortense Chron.

Biochronostratigraphy: indirect reference to the upper Niortense Zone.

3.9. Beds 9–10 (30 cm)

Bed 9 rests on the erosive surface delimiting the top of bed 8, whereas a horizontal bedding plane separates it from bed 10. The lithofacies of both beds is a light-brown biomicrite containing medium-sized, sub-millimetre Fe-ooids, partly distributed in clusters due to bioturbation, and scattered centimetre-sized Fe-oolithic lithoclasts coated by oncoidal Fe-oxide crusts. The fossil record includes abundant reelaborated ammonites:

- RL-9/11 (features [1], [2], [4a], [6], [7]): scattered badly preserved stephanoceratids referable to the latest Humphriesianum or to the earliest Niortense chrons. The taxonomic composition is the same as that of RL-7/7; the additional Fe-oxide crusts and abrasion surfaces of the internal moulds testify to possible reelaboration of fossils from RL-7/7;
- RL-9/12 (features [3a], [4a], [6], [7]): mostly entire, Fe-oxide coated shells or stained internal moulds of *Cadomites homalogaster*, uncoiled *Spiroceras orbignyi* and the dimorphic couples *Orthogarantiana-Strenoceras* and *Leptosphinctes-Cleistosphinctes* typical of the late Niortense Chron. Fossils are almost the same of those of RL-8/10 with additional Fe-oxide crusts on the shell and supplementary abrasion surfaces of the internal moulds;
- RL-9/13 (features [4a], [6]): the record mostly refers to Fe-oxide stained internal moulds of the dimorphic couple *Garantiana–Pseudogarantiana* and *Bajocisphinctes mouterdei* [M + m] of the Garantiana Chron;
- RL-10/13: the record shows taphonomic features corresponding to those of RL-9/13 with supplementary abrasion surfaces of the internal moulds;
- RL-10/14 (features [4a]): the Fe-oxide stained moulds of the dimorphic couple *Odontolkites–Pseudogarantiana* refer to the upper Garantiana Chron.

Biochronostratigraphy: indirect reference to the middle–upper Garantiana Zone for bed 9, and to the upper Garantiana Zone for bed 10.

3.10. Beds 11 (5 cm)

Distinction of this bed is difficult as the lithofacies is similar to the preceding one, except for a rather wider diameter of the Fe-ooids, and the lower boundary is quite impossible to define due to Pleistocene weathering. However, the ammonite assemblage records the first occurrence of the dimorphic couple *Durotrigensia–Parkinsonia*. Two reelaborated taphorecords may be distinguished:

- RL-11/14: specimens of *Odontolkites–Pseudogarantiana* show the same taphonomic features as RL-10/13, with supplementary abrasion surfaces of the internal moulds;
- RL-11/15 (features [1], [3a], [5]): the two dimorphic couples *Odontolkites-Pseudogarantiana* and *Durotrigensia-Parkinsonia*, with Fe-oxide coated shells and internal moulds formed of fine and tightly packed Fe-ooid biomicrite, refer the bed to the earliest Parkinsoni Chron.

Biochronostratigraphy: indirect reference to the lower Parkinsoni Zone.

3.11. Beds 12 (min 25 cm)

The bed lies on a well-marked bedding plane and is made up of light-yellow packstone with millimetre-sized

Fig. 4. Top surface of the lower part of bed 7 at the Maizet locality: a: detail of the concentration of belemnite rostra on a surface of 1 m^2; b: distribution pattern of 24 rostra (dotted apex); c: rose diagram showing dispersion of 54 rostra with dip direction in 10 classes. The absence of any preferential orientation of rostra suggests deposition from loading currents generating outer-shelf storm deposits (Aigner, 1985).
Fig. 4. Surface sommitale de la partie inférieure de la couche 7 à Maizet : a : détail montrant la concentration des rostres de bélemnites sur une surface de 1 m^2 ; b : *pattern* de distribution de 24 rostres (apex pointu) ; c : diagramme montrant la dispersion de 54 rostres distribués en dix classes. L'absence d'orientation préférentielle des rostres indique un dépôt par des courants de tempête sur la partie externe de la plateforme (Aigner, 1985).

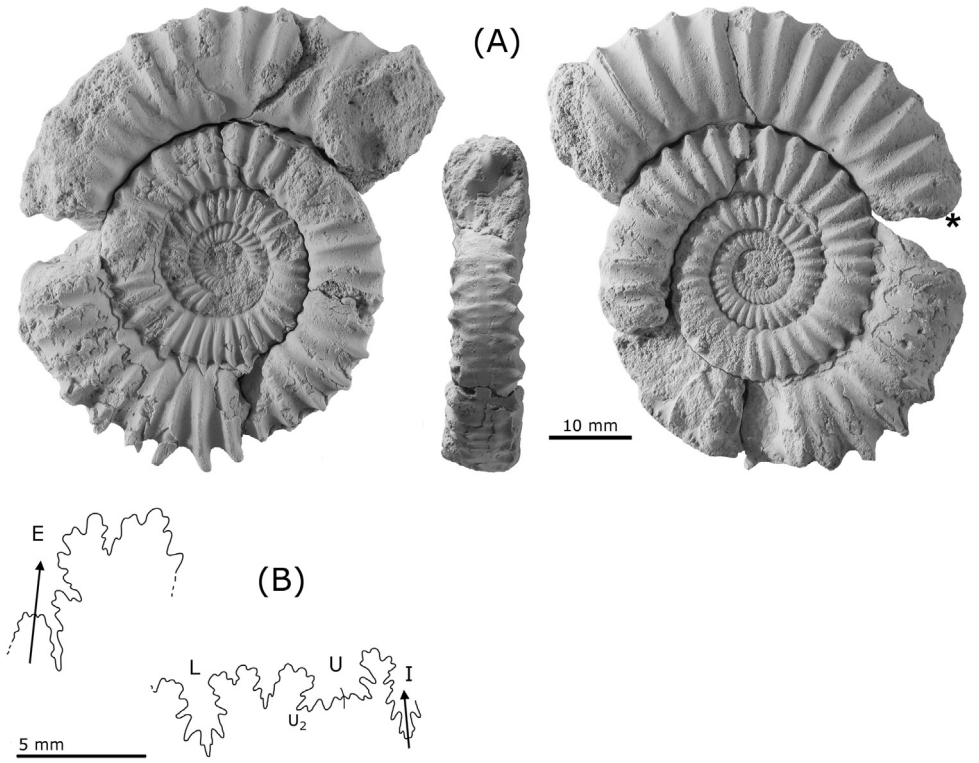


Fig. 5. An almost entire specimen (A) of *Subcollina ochotorenai* Pavia (MGPT-PU 112489), bed 7, at the Maizet locality. Note the high marginal spines on the neomorphic shell. The specimen preserves the suture-line (B) whose shape is similar, except for the un-retracted umbilical lobe, to that of *Phaulostephanus*, the stephanoceratid from which Sandoval and Westermann (1986) and Pavia (2000) supposed *Subcollina* to be derived. Actually, the taxon *Subcollina* is one of the ammonite stocks of East-Pacific origin dispersed into the Tethyan Realm via central Atlantic during the middle part of the Bajocian. Specimen MGPT-PU 112489 is stored in the palaeontological collections of the Museo di Geologia e Paleontologia of the Università degli Studi di Torino, Italy.
Fig. 5. Un exemplaire presque complet (A) de *Subcollina ochotorenai* Pavia (MGPT-PU 112489). Couche 7 à Maizet. Les hautes épines marginales sont préservées sur le test néomorphique. Le spécimen conserve la ligne de suture (B), dont la morphologie est similaire, excepté le lobe ombilical non rétracté, à celle du genre *Phaulostephanus*, le stéphanoceratidé que Sandoval et Westermann (1986) et Pavia (2000) ont supposé à l'origine du *Subcollina*. Il est intéressant de signaler que le taxon *Subcollina* est un représentant du groupe d'ammonites d'origine Est-Pacifique, dispersées dans la Téthys à travers l'Atlantique central pendant la partie moyenne du Bajocien. Le spécimen MGPT-PU 112489 est conservé dans les collections du musée de géologie et de paléontologie de l'université de Turin (Italie).

Fe-ooids, greater in size than those of the underlying beds and distributed in clouds. Ammonites are frequent and show pluridecimetric diameters (Fig. 6):

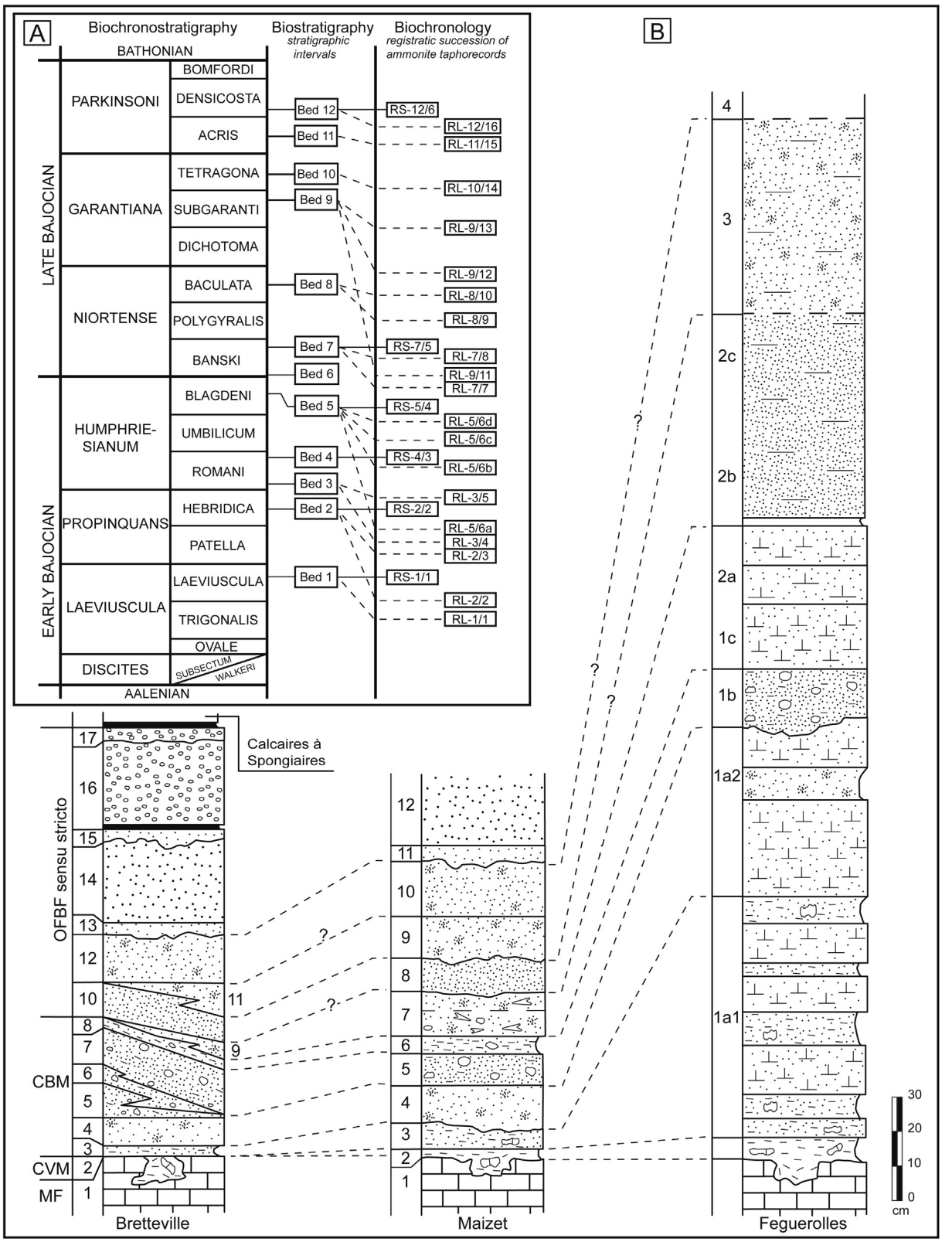
- RS-12/6: resedimented specimens of both bivalves and ammonites. Among ammonites, the parkinsoniids of the dimorphic couple *Durotrigensia–Parkinsonia* and large leptosphinctids (*Glyphosphinctes glyphus*, *Prorsisphinctes meseres*) dominate the fossil-assemblage, and indicate the early to middle Parkinsoni Chron;
- RL-12/16 (features [1], [6]): a second taphorecord groups reelaborated *Odontolkites-Pseudogarantiana* specimens of the early Parkinsoni Chron.

Biochronostratigraphy: early to middle Parkinsoni Zone.

Fig. 6. The condensed ammonite assemblage of bed 12 at the Maizet locality. Two resedimented specimens of the parkinsoniid *Durotrigensia* spp. (bottom), and a fragmentary, subvertical reelaborated specimen of the garantianid *Gonolkites* sp. (top).
Fig. 6. L'association condensée d'ammonites de la couche 12 à Maizet. Deux exemplaires resédimentés du parkinsoniidé *Durotrigensia* spp. dans la partie inférieure, et un exemplaire fragmenté, subvertical, réélaboré du garantianidé *Gonolkites* sp. dans la partie supérieure de la photo.

4. Remarks and discussion

Different aspects have been highlighted in this study regarding the ammonite record and the taphonomic characteristics recognized in the "Oolithe ferrugineuse de Bayeux" Fm from the excavation at the Maizet locality. The


A
Biochronostratigraphy
Biostratigraphy
stratigraphic intervals
Biochronology
registratic succession of ammonite taphorecords
BATHONIAN
LATE BAJOCIAN
EARLY BAJOCIAN
AALENIAN
PARKINSONI
GARANTIANA
NIORTENSE
HUMPHRIE-SIANUM
PROPINQUANS
LAEVIUSCULA
DISCITES
BOMFORDI
DENSICOSTA
ACRIS
TETRAGONA
SUBGARANTI
DICHOTOMA
BACULATA
POLYGYRALIS
BANSKI
BLAGDENI
UMBILICUM
ROMANI
HEBRIDICA
PATELLA
LAEVIUSCULA
TRIGONALIS
OVALE
SUBSECTUM
WALKERI
Bed 12
Bed 11
Bed 10
Bed 9
Bed 8
Bed 7
Bed 6
Bed 5
Bed 4
Bed 3
Bed 2
Bed 1
RS-12/6
RL-12/16
RL-11/15
RL-10/14
RL-9/13
RL-9/12
RL-8/10
RL-8/9
RS-7/5
RL-7/8
RL-9/11
RL-7/7
RS-5/4
RL-5/6d
RL-5/6c
RS-4/3
RL-5/6b
RL-3/5
RS-2/2
RL-5/6a
RL-3/4
RL-2/3
RS-1/1
RL-2/2
RL-1/1
B
Calcaires à Spongiaires
OFBF sensu stricto
CBM
CVM
MF
Bretteville
Maizet
Feguerolles
4
3
2c
2b
2a
1c
1b
1a2
1a1
30
20
10
0
cm

lithostratigraphic succession and the fossil-assemblages show evidence of stratigraphic and taphonomic condensation, indicated respectively by recurrent sedimentary discontinuities and reelaboration processes. In this respect, ammonites as sedimentary traps allow the reconstruction, at least partly, of the succession of sedimentary events that governed the deposition of the Bajocian Fe-oolithic beds. In general, the new data from Maizet allow a better definition of the inland stratigraphic architecture of the Bajocian succession.

4.1. Biochronology of the Bajocian ammonite assemblages from Maizet

The taphonomic analyses outlined in detail above may be converted into a biochronologic scheme (Fig. 7A, right), which takes into consideration the precise sequence of depositional events and marks the frequent discontinuities recognized within the Fe-oolitic succession (Fig. 7A, centre).

The first phase of this procedure is the drafting of the registratic succession (Fernández-López, 1986, 1991, 1995, 1997; Fernández-López and Gómez, 1990) of the whole stratigraphic section, as previously discussed. Basic information was derived from the diverse palaeontological units (taphorecords) recognized in each fossil-assemblage, which may be ordered in a chronologic sense according to the taphonomic modifications produced, ranging from the oldest to the youngest. Secondly, the fact that the internal moulds of reelaborated ammonites consist of sediments that record depositional events, even those not represented in the stratigraphic column, must be taken into consideration. These events may be positioned within the order of succession according to the biochronological meaning of the fossils. In other words, the registratic succession displays the chronologic order of each resedimented or reelaborated taphorecord that form the condensed fossil-assemblages of the stratigraphic section. Implementation of this practice may increase our knowledge of the sedimentary and biological evolution of the studied basin (Pavia and Martire, 1997).

The Bajocian registratic succession of the Maizet outcrop is represented on Fig. 7A (right). In particular, by comparing the stratigraphic succession of the twelve beds described at Maizet, it may be observed that the registratic units (taphorecords) considerably increase the geological record by adding up to at least 32 productive events: 12 are recognized on the basis of beds and related resedimented taphorecords; 20 are identified by taphorecords of reelaborated ammonites that reflect the depositional events documented by the concretionary internal moulds. Note that this registratic succession does not list the taphorecords deriving from further reelaboration of fossils of previously encountered taphorecords (RL-6/6, RL-8/7, RL-8/8, RL-10/13, RL-11/14). The result of such an ordering is that the very complex depositional evolution of the OFBF may be traced, which was mainly controlled by taphonomic reworking, erosion and omission phases. This genetic situation excludes other mechanisms such as extremely low rates of sediment accumulation leading to mixing on the same substrate of remains of organisms that lived in different times. In other words, it is a question of stratigraphic condensation (sensu Gómez and Fernández-López, 1994) not of sedimentary condensation as occasionally supposed (e.g., Rioult et al., 1991). The sharp, irregular base of beds and the normal grading of reworked elements indicate that these carbonate deposits were affected by tractional currents, scouring, and redeposition. Taphonomic data, such as the predominance of reelaborated, heterogeneous and incomplete, concretionary internal moulds (i.e. hollow ammonites), are indicative of a general low rate of sedimentation and an occasional high rate of sediment accumulation, due to sedimentary winnowing and bypassing interrupted by storm deposits, within shallow-water marine palaeoenvironments.

4.2. Comparison among Bajocian sections south of Caen

A high level of correspondence exists between the succession of the “Oolithe ferrugineuse de Bayeux” Fm, described at the Maizet locality, and the successions of the Feuguerolles-sur-Orne (Gauthier et al., 1996) and Bretteville-sur-Odon localities (Pavia and Martire, 2010). Some details may support the tracing of parallelisms between the successions (Fig. 7B).

Equivalence of the layers of the Maliére Fm may be noted at the three sites, particularly regarding the “Couche verte” Member. The reelaborated fossil content of the latter emphasizes an indirect reference to the middle–upper part of the Propinquans Zone, also in comparison with the same layer described from the coastal section of Les Hachettes (Pavia, 1994). A further correspondence exists with regard to beds 3 to 5 from the Maizet locality (equivalent to beds 3–7 at Bretteville). In particular, bed 4 allows precise assignment to the lower Humphriesianum Zone, Romani Subzone, on the basis of the rich *Chondroceras-Dorsetensia* assemblage, as has also been observed at the Feuguerolles locality (bed 1a2). On the contrary, the

Fig. 7. A. The biochronological and registratic succession of the Bajocian of Maizet. Each taphorecord corresponds to a depositional event arranged according to the biochronological meaning of its fossils and the indirect biochronostratigraphic evidence discussed in the text. The left column lists the geochronological divisions and the standard (sub)chronozones for the Bajocian Stage of the West Tethyan Subrealm. B. Biochronostratigraphic correlation of the “Oolithe ferrugineuse de Bayeux” Fm (OFBF) successions of the inland Bajocian in the Calvados area (for site location, see Fig. 1).
RS: resedimented taphorecord; RL: reelaborated taphorecord; MF: Maliére Fm; CVM: “Couche verte” Member; CBM: “Conglomérat de Bayeux” Member; OFBF sensu stricto: typical facies of the “Oolithe ferrugineuse de Bayeux” Fm. Bed numbering: for Bretteville, see Pavia and Martire (2010); for Maizet, see text; for Feuguerolles, see Gauthier et al. (1996).

Fig. 7. A. La succession biochronologique et enregistrée du Bajocien de Maizet. Chaque tapho-enregistrement correspond à un événement sédimentaire ordonné selon la signification biochronologique de ses fossiles et du critère de biostratigraphie indirect discuté dans le texte. La colonne de gauche énumère les divisions géochronologiques et les (sub)chronozones standard utilisées pour l'étage Bajocien du sous-domaine Ouest-Téthysien. B. Corrélation biochronostratigraphique entre les successions de la formation « Oolithe ferrugineuse de Bayeux » (OFBF), dans l'intérieur du Calvados (pour la localisation des gîtes, voir la Fig. 1).

reelaborated ammonites of bed 5 (identical to those of bed 7 at Bretteville and bed 1b at Feuguerolles) constrain reference to the uppermost Humphriesianum Zone, upper Blagdeni Subzone. The middle part of the "Oolithe ferrugineuse de Bayeux" Fm (beds 6 to 10 at the Maizet locality) does not demonstrate any precise parallelism with the sections at the localities at Bretteville (beds 8–12) or Feuguerolles (beds 2–3): on occasion, Fe-oolitic limestones and ammonites encompass the biochronostratigraphic interval ranging from the Niortense to the Garantiana zones. Nevertheless, it is worth noting here that correspondence between bed 7 at Maizet with bed 9 at Bretteville is recognized based on the high content of belemnite rostra. In addition, the exclusive record of large, resedimented specimens of *Teloceras* within beds 1c-2a at Feuguerolles should be highlighted, as these are absent at the localities Bretteville and Maizet. Finally, beds 11 and 12 at Maizet are recognized as being the same as beds 13 and 14 at Bretteville in terms of taphonomic evidence and biochronologic meaning; equivalent information may be obtained from bed 4 at Feuguerolles; however, the lack of taphonomic analysis here renders a direct comparison difficult.

In conclusion, the sections at Bretteville, Feuguerolles and Maizet demonstrate such a high level of reciprocal equivalence that a common depositional evolution may be indicated, presumed to be related to the deepening of the carbonate ramp (Préat et al., 2000) in the eastern sector of the Armorican Massif. However, the regional stratigraphic column outlined on Fig. 7B should be considered provisional, as taphonomic analyses have never been done at the locality at Feuguerolles, and the section at Bretteville needs revision in order to establish the chronological succession of the ammonite assemblages. The biochronological scheme outlined for the locality at Maizet (Fig. 7A, right) may be regarded as a starting point to which data from the localities at Bretteville-sur-Odon, Feuguerolles-sur-Orne and, maybe, in the future, Évrecy and Moutiers-en-Cinglais, can contribute in order to define a soundly-based general scenario for the inland Bajocian successions of the Calvados area.

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