Systematic Palaeontology

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)

Giulio Pavia\textsuperscript{a,***}, Aldo Defaveri\textsuperscript{b}, Lionel Maerten\textsuperscript{c}, Marco Pavia\textsuperscript{a}, Marta Zunino\textsuperscript{a}

\textsuperscript{a} Dipartimento di Scienze della Terra, via Valperga Caluso 35, 10125 Torino, Italy
\textsuperscript{b} via Pilipari 4/b, 15004 Valmaddonna (AL), Italy
\textsuperscript{c} 3, impasse du Moulin, 14114 Ver-sur-Mer (Calvados), France

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\textbf{A B S T R A C T}

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 biochrononstratigraphic units. In addition, identification of taphorecord relationships regarding successive or contemporaneous deposition allows their registrafic 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. Biochrononstratigraphic 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.

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\textbf{R É S U M É}

L’étude traite des assemblages d’ammonites bagoïennes de la formation dite «Oolithe ferrugineuse de Bayeux». La coupe de Maizet illustre une section condensée, avec un remaniement taphonome 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 réelaborés, 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

\textsuperscript{***} Corresponding author.
E-mail address: giulio.pavia@unito.it (G. Pavia).

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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 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 biochronostatigraphical subdivision of the Breteville-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 the latter are more expanded as may be observed at the localities of Feuguerolles-sur-Orne and Breteville-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.

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. Malière Formation (Aalenian to Lower Bajocian in age)

The thickness varies up to a few metres. The Malière Fm is represented by grey cherty bioclastic containing sponges and glauconite grains. The topmost thin layer consists of glauconitic floatstone rich in phosphatised bioclastic material; lithoclasts derived from the underlying bioclastic layer correspond to the "Couche verte" Member Auct., and is separated from the typical Malière Fm (Malière 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 m² 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.
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) reeolaborated fossils that derive from previous sedimentary units 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 “reeolaboration” assumes a different meaning when referred to within a stratigraphical or taphononomical context; hence the terms “reeolaboration” and “reeolaborated” are not synonyms (Fernández-López, 2011a; Zunino et al., 2012). Unlike the common use of the term “reeolaboration” in sedimentology and its chronostratigraphical meaning in geology (Jackson, 1997), the term “reeolaboration” 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;
- reeolaboration, 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 body chamber and to the most external whorls of the phragmocone; inner whorls are usually lacking (hollow ammonites) except where the shell shows breakages due to biotstratonomic processes.

The reeolaboration 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 reeolaborated 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-assembly 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 biotstratonomic 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-assembly 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 regressive 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 biotstratigraphic and biochronostratigraphic classifications and units, that proposed by Riout 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 biotstratigraphic assignment of the Maizet Fe-ooolithic beds, though seemingly favoured by the rich fossil record, is made difficult by the recurrent reeolaboration processes affecting the ammonite assemblages. The time interval of a condensed fossil-assembly is longer than the sedimentation time of the encasing bed. For this reason, herein the practice of “indirect biotstratigraphy” as generically presented by Fernández-López (1997, fig. 3) and applied by Pavia and Martire (2010) to fossil-assemblages composed only of reeolaborated 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-ooolithic sedimentary events recorded at Maizet (maximum age of each bed), whenever it cannot precisely be defined by the resedimented fossils.

The Fe-ooolithic 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 (Rioul 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 Malière 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 Malière 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 reeleraborated (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, sonniidss (Wichellia spp.) and early stephanoceratids ( _Mollistepphanus cf. mollis_ ) allow assignment to the late Laeviuscula Chron;
- RL-1/1 [features [1], [3b], [6]]: the phosphatized internal moulds of sonniids, such as Shirbuinia trigonals 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 Malière 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 Malière Fm. Fossils are abundant. The internal moulds of infraunal bivalves are resedimented elements, whereas all ammonites are reeleraborated:

- 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 _Sonniidae_ 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 Malière Fm, Fe-oolithic intraclasts and reeleraborated 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 _Sonniina_ spp., _Papilliceras_ sp., Bradfordia prae radiata, Emileia–Otoites group, _Kumatostephanus perjurundus_ 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 reeleraboration 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 chron.

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.evolve cens_ and _C.gervilli_ are the most common together with _Dorsetensia_ spp., _Poecilocymorphus cladoi des_, _Toxamblytes 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 reeleraborated 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 reeleraboration 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. 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 biomircrite 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 Caumontispincthes nodatus and Infracarkinssonia 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, Lokuciteras), Leptostpincthes 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.

Biochronostatigraphy: 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-oooids. The bed contains scattered centimetre-sized Fe-oolithic lithoclasts coated by oncoidal Fe-oxide crusts. The rich ammonite assemblage contains fossils of four reeleraborated 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 reeleraboration of those two taphorecords;
- RL-8/9 (features [3a], [4a]): mostly entire, Fe-oxide coated shells or stained internal moulds of the dimorphic couples Caumontispincthes-Infracarkinssonia 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.

Biochronostatigraphy: 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-oooids, 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 reeleraborated 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 reeleraboration 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 Leptostpincthes-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 Bajocischinctes 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 Odontolites–Pseudogarantiana refer to the upper Garantiana Chron.

Biochronostatigraphy: 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-oooids, 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 Durotrigienia–Parkaninosa. Two reeleraboted taphorecords may be distinguished:

- RL-11/14: specimens of Odontolites–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 Odontolites-Pseudogarantiana and Durotrigienia-Parkaninosa, with Fe-oxide coated shells and internal moulds formed of fine and tightly packed Fe-oid biomicrite, refer the bed to the earliest Parkinsoni Chron.

Biochronostatigraphy: 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. 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 stéphanoceratid 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 néomorphe. Le spécimen conserve la ligne de suture (B), dont la morphologie est similaire, excepté le lobe omblical non rétracté, à celle du genre Phaulostephanus, le stéphanocéradé 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*, *Prorsispinctes 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.

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
lithostratigraphic succession and the fossil-assemblages show evidence of stratigraphic and taphonomic condensation, indicated respectively by recurrent sedimentary discontinuities and reeleraboration 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-ooidal 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-ooidal succession (Fig. 7A, centre).

The first phase of this procedure is the drafting of the registraric 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 reeleraborated 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 registraric succession displays the chronologic order of each resedimented or reeleraborated 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 registraric 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 registraric 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 reeleraborated ammonites that reflect the depositional events documented by the concretionary internal moulds. Note that this registraric succession does not list the taphorecords deriving from further reeleraboration 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 reeleraborated, 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 parallels between the successions (Fig. 7B).

Equivalence of the layers of the Malière Fm may be noted at the three sites, particularly regarding the “Couche verte” Member. The reeleraborated 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-Dorsetena assemblage, as has also been observed at the Feuguerolles locality (bed 1a2). On the contrary, the
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-oolithic limestones and ammonites encompass the biochronographic 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, Évrepy 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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