

Brachiopod assemblages in the Devonian of Ferques (Boulonnais, France). Relations to palaeoenvironments and global eustatic curves

Denise Brice

Faculté Libre des Sciences, 13 rue de Toul, 59046 Lille-CEDEX, France. E-mail: denise.brice@fls.fupl.asso.fr

Abstract. Twelve brachiopod assemblages of the Devonian of Ferques (4 in the Givetian, 8 in the Frasnian), some of them previously briefly described (Brice 1986), are reviewed and analysed with respect to their diversity, dominance, preservation, palaeoenvironment and associated benthic fauna. They are classified according to Boucot (1975). Stratigraphic and biostratigraphic positions relative to conodont standard biozonation are defined or discussed. A correlation between the positions and the characteristics of twelve assemblages and three global sea-level curves of Depophase II (Transgression-Regression of Johnson et al. 1985), Ila, I Ib, I Ic, is proposed and discussed.

Key words: Brachiopod assemblages, Givetian, Frasnian, Boulonnais, palaeoenvironment, eustatic curves

Résumé

Douze Assemblages de brachiopodes du Dévonien de Ferques (4 dans le Givétien, 8 dans le Frasnien), certains précédemment brièvement décrits (Brice, 1986), sont révisés, analysés (diversité, dominance, conservation, paléoenvironnement, faunes benthiques associées, etc.). Ils sont classés d'après Boucot (1975). Pour chaque assemblage les positions stratigraphique et biostratigraphique dans la zonation standard des conodontes sont précisées ou discutées. Un essai de corrélation entre dix de ces assemblages (position, caractéristiques) et les variations globales du niveau marin de la Depophase II (cycles Transgression-Regression de Johnson et al. 1985), Ila, I Ib, I Ic, est tenté et discuté.

Introduction

This work contains a review of twelve brachiopod assemblages recognized in the Devonian of Ferques: four in the Givetian, eight in the Frasnian. Observations consist of occurrence, abundance, proportion, size, stages of growth, preservation, and relation to sedimentation reflecting the ancient environment. A correlation is proposed between these observations from the Boulonnais region and global eustatic cycles along the Old Red Continent margin.

Middle and Upper Devonian sediments of the classic Ferques inlier area (Boulonnais, northern France) show (Brice et al. 1979a) an alternation of clastics (Caffiers, Beaulieu, Hydrequent and Sainte Godeleine Formations) and carbonate rocks including bioherms and biostromes (Blacourt and Ferques Formations). These deposits are rich in brachiopod faunas. The present state of systematic study of brachiopods offers a suitable background for palaeoecology and others investigations. According to Ager (1967) "fossil brachiopods seem to be more suitable than any other for the study of the effect of palaeoecological factors on the course of evolution".

Since the classic works of Rigaux (1872, 1892, 1908), many papers on the Devonian of Boulonnais, mainly the collaborative memoir edited by Brice (1988a), have been published (Mistiaen et al. 2002b, Brice et al. 2002). Detailed stratigraphy and biostratigraphy (Brice and Meats 1972, Brice 1988a–c, Brice et al. 1976, 1979a, b, 1981, 1989, Brice and Loones 2002, Brice and Mistiaen 1988, Chamley 1988, Mistiaen 1988a, b, Mistiaen et al. 2002a, Pelhate and Poncet 1988, Racheboeuf 1988) allow the exact occurrences of brachiopod fauna and their environment to be investigated.

Taking into account the newly collected fossils and new data in stratigraphy, our previous analysis of brachiopod benthic assemblages (Brice 1986) is updated and reviewed in relation to paleoenvironments and in correlation with global transgressive-regressive cycles. The material (about 16000 specimens) is housed in the collections of the "Faculté Libre des Sciences, 13, rue de Toul. F - 59046 Lille CEDEX". The term assemblage is applied instead of community because a strict autochthoneity cannot often be demonstrated. The classification elaborated by Boucot (1975) was adopted for these benthic assemblages.

Givetian stage

The late Middle Devonian stage (Givetian) is represented in the Ferques area by the Blacourt Formation, which consists of the Griset, Couderousse and Bastien Members and the lowermost level ("La Cédule limestone", term a of the Cambresèque Member), the lower part of the Beaulieu Formation.

Assemblage 1 (Tab. 1, Fig. 1)

This assemblage was identified in the upper part of term b of the Griset Member in the lower part of the Blacourt Formation (Fig. A). The assemblage is exposed in the Griset

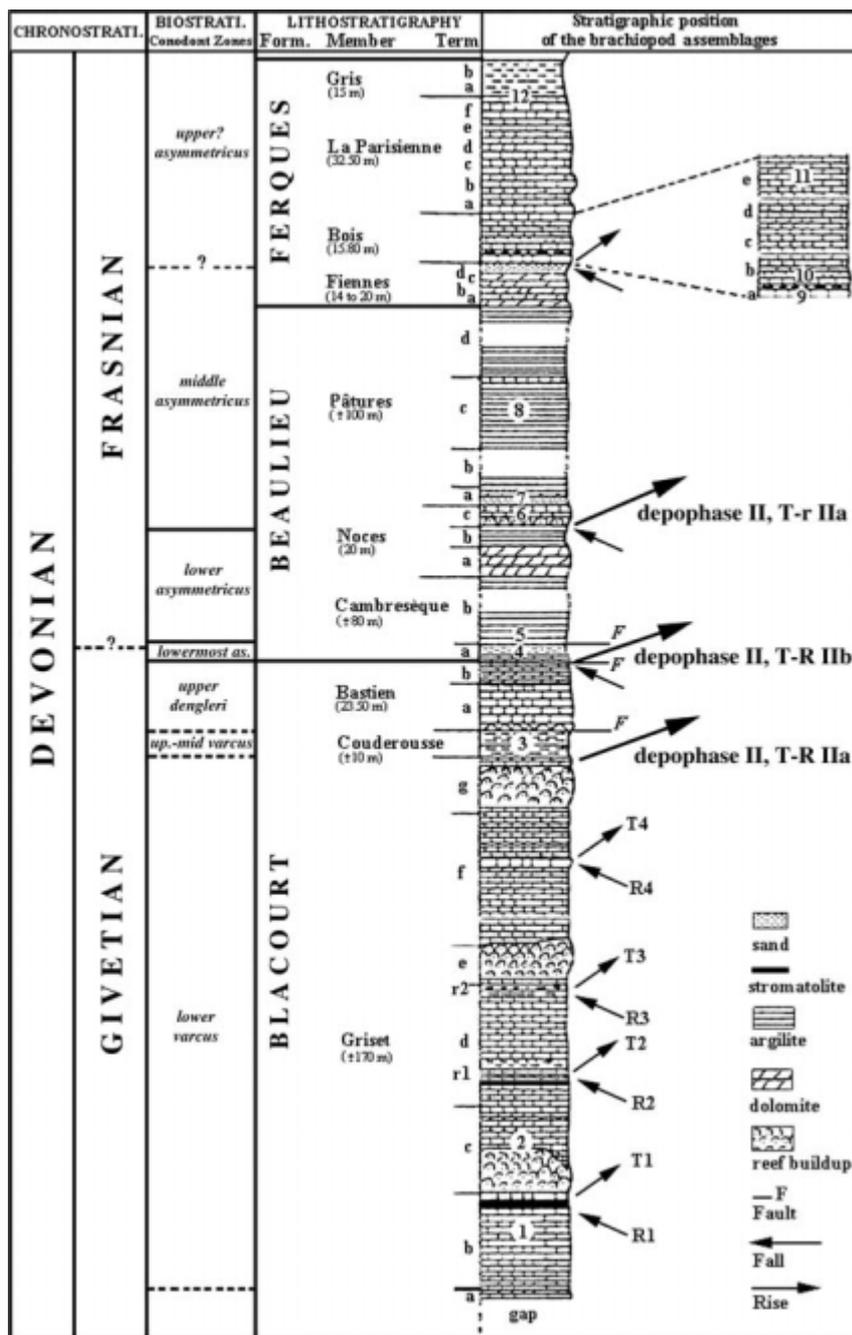


Fig. A. Simplified logs of the Blacourt, Beaulieu and Ferques Formations, Devonian of Ferques, Boulonnais, after Brice et al. (1979a, 1989) modified. Thicknesses are adapted; R1 and R2 correspond to "1er repère schisteux" and "2ème repère schisteux" (Magne 1964).

and Banc Noir quarries in the Ferques inlier area and is situated about 21 m above the base of the formation (Brice 1988b, Brice et al. 1979a, Brice and Mistiaen 1988).

This level, which is about 3 m thick, is characteristic of the Early Givetian (lower *varcus* Zone). In the absence of any index form, the base of the lower *varcus* Zone is set (in dotted) at the entry of *Icriodus* gr. *eslaensis-brevis* Van Adrichen Boogaert 1967-Stauffer 1940 (Bultynck in Brice et al. 1979b), the lower part of term b.

Brachiopod fauna of this assemblage is moderately diverse and commonly small in size. *Atrythyris betencourti*

(*athyrid*) is dominant in abundance, followed in decreasing order by *Crurithyris inflata* (ambocoeliid), *Productella subaculeata* (productellid), rhynchonellid Trigonirhynchidae, diverse but uncommon, often disarticulated and broken spiriferids (*Tenticospirifer plicatula*, *Undispirifer rigauxi*, *Cyrtina sauvagei*), *Stringocephalus burtini* (terebratulid), and *Spinatrypa* sp. G. (atrypid). Other elements present in the benthic fauna are frequent fragments of ramose tabulate corals (*Alveolites*, *Thamnopora* sometimes in life position), different sizes of bryozoan columnals (some of them with diameter about one centimetre), rare small remains of stromatoporoids, massive rugose corals (*Cyathophyllum* e.g. *briceae* Rohart 1988 etc.), rostroconchs (*Conocardium*), gastropods, orthocone, cyrticone cephalopods, trilobites and fish remains.

The lithology of Assemblage 1 consists of greenish or dark pyritic micritic limestone (mudstone-wackestone) with a variable but generally high proportion of terrigenous material (sand, silt, clay and carbonaceous material) in the upper part.

According to Pelhate and Poncet (1988), carbonate beds of the Griset Member in the Blacourt Formation are ordered in four transgressive-regressive sequence deposits in the infratidal zone. For these authors, the non-recognition of internal and external platforms suggests a block-faulting morphology for the depositional area. Moreover, the decrease in the ratio of regressive phase thickness to transgressive phase thickness from the base to the top of the Griset Member may indicate a tendency for this area to stay in the infratidal zone with regards to a progressive opening of the sedimentary basin (extensive tectonics) during the Givetian, in front of the Caledonides.

The first assemblage (the third Benthic Assemblage in Boucot's classification) is situated in the upper part of the first regressive sequence (Pelhate and Poncet 1988), typified by an oolitic bed, gullyng, and reworking which reflects a high-energy environment. However, the presence of several tabulate corals in life position indicates that a part of this assemblage was in a low-energy, shallow environment near a barrier-protected area.

The top of this regressive sequence corresponds to stromatolite level deposits in the intertidal zone.

Tab. 1. Brachiopod taxa of Assemblage 1

<i>Productella subaculeata</i> (Murchison 1840)	Ps
Trigonirhynchiidae	Tr
<i>Spinatrypa</i> sp. G	Sp
<i>Atrythyris betencourti</i> (Rigaux 1892)	Ab
<i>Crurithyris inflata</i> (Schnur 1853) & Ambocoeliidae	Am
<i>Tenticospirifer plicatula</i> (Paeckelmann 1942)	Tp
<i>Undispirifer rigauxi</i> Brice 2002	Ur
<i>Cyrtina sauvagei</i> Rigaux 1908	Cs
<i>Stringocephalus burtini</i> (Defrance 1825)	Sb
Number of specimens = 631	

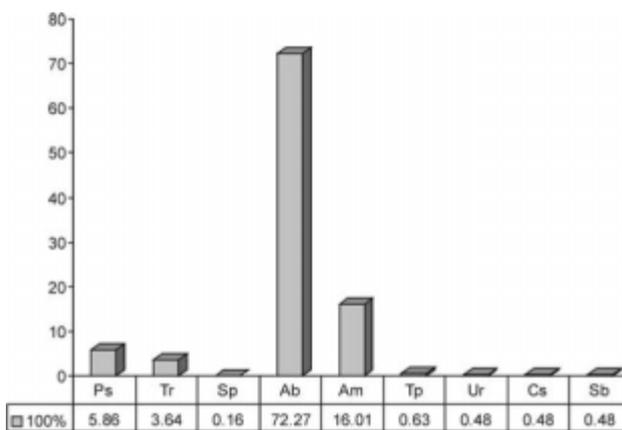


Fig. 1. Histogram of Assemblage 1.

Assemblage 2 (Tab. 2, Fig. 2)

This assemblage occurs about fifteen metres above Assemblage 1, in term c of the Griset Member in the Blacourt Formation (Fig. A). It is 5–6 m thick around and above the first biostrome (Brice and Mistiaen 1988).

Similar to the previous assemblage, Assemblage 2 is characteristic of the Early Givetian (lower *varcus* Zone cf. ante).

Benthic fauna of Assemblage 2 is important and well diversified. Brachiopods form only a part of these faunas. Of the twelve taxa present, eight were also present in the first assemblage, but in different proportions. In this one, commonly disarticulated spiriferids *Tenticospirifer plicatula* and *Undispirifer rigauxi* are dominant in abundance, followed by *Crurithyris inflata* and *Cyrtina sauvagei*. Other brachiopods are, in decreasing order: *Atrythyris betencourti*, *Athyris kaisini* (athyrids), *Spinatrypa* sp. G. (atrypid), cf. *Ripidiorhynchus*, *Schnurella?* sp. (rhychnellids), *Dagnachonetes* cf. *gibbosus* (chonetid), *Productella subaculeata* (productellid) and *Stringocephalus burtini* (terebratulid). The associated faunas are mainly stromatoporoid fragments, solitary or phaceloid rugose corals, tabulate corals (*Alveolites*, ramose *Thamnopora*), ramose bryozoans, rare bivalves, gastropods, cyrticone cephalopods, crinoid ossicles, and trilobite remains (Morzadec 1988).

Tab. 2. Brachiopod taxa of Assemblage 2

<i>Dagnachonetes</i> cf. <i>supragibbosus</i> (Sobolev 1909)	Ds
<i>Productella subaculeata</i> (Murchison 1840)	Ps
cf. <i>Ripidiorhynchus</i> sp.	Ri
<i>Schnurella?</i> sp.	Sc
<i>Spinatrypa</i> sp. G.	Sp
<i>Atrythyris betencourti</i> (Rigaux 1892)	Ab
<i>Athyris kaisini</i> Rigaux 1908	Ak
<i>Tenticospirifer plicatula</i> (Paeckelmann 1942)	Tp
<i>Undispirifer rigauxi</i> Brice 2002	Ur
<i>Crurithyris inflata</i> (Schnur 1853)	Ci
<i>Cyrtina sauvagei</i> Rigaux 1908	Cs
<i>Stringocephalus burtini</i> (Defrance 1825)	Sb
Number of specimens = 851	

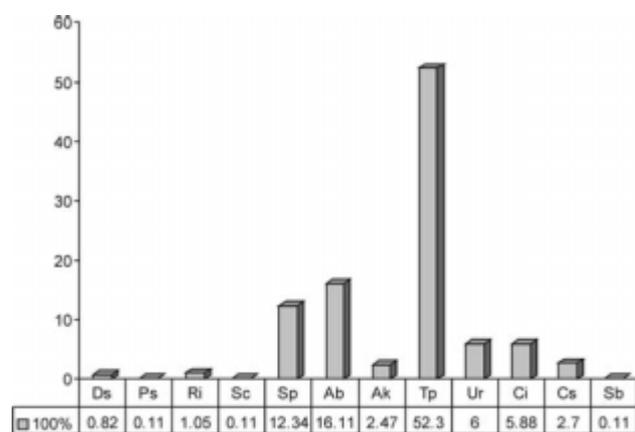


Fig. 2. Histogram of Assemblage 2.

The sediment is represented by bioclastic biomicritic limestone (packstone, wackestone, mudstone) with a fair proportion of clay- and silt-sized material. Spines of productellids, palechinids, bioclasts and encrustations by lamellar stromatoporoids, tabulate corals, auloporids, serpulids, and bryozoans are frequent.

According to Pelhate and Poncet (1988), these deposits belong to the second transgressive sequence deposits in the infratidal zone of the Griset Member. Sediment composition with abundant and highly diverse fragments of benthic fauna suggests a high-energy, shallow-water environment on the reef periphery, favourable for a rich development of different benthic groups (the third Benthic Assemblage in Boucot's classification).

Others terms of the Griset Member (d–g) are relatively poor in brachiopods which are represented by ambo-coeliids, rare reticulariids, athyrids and *Stringocephalus burtini* (terebratulid). However, benthic faunas are abundant and very diversified, consisting of diverse builders such as sponges, algae and stromatolites. Additionally, they are sometimes associated with worms in small bioherms (Mistiaen and Poncet 1983a, b). Stromatoporoids (Mistiaen 1988a), tabulate corals (Mistiaen 1988b) and rugose corals (Rohart 1988) are mainly found in three reef

buildups (bioherm or biostrome) that developed nearshore platforms in a warm open shallow sea. According to Chamley (1988), the nature of average clay assemblages in the Griset Member of the Blacourt Formation suggests an unstable context and the presence of a well-sloped relief.

Assemblage 3 (Tab. 3, Fig. 3)

This assemblage, 5–6 m thick, occurs in the lower part of the Couderousse Member of the Blacourt Formation (Fig. A), and is exposed in the Banc Noir Quarry and in the Caffiers–Ferques railcut.

This member yielded conodont Fauna V with *Polygnathus denisbriceae* Bultynck 1979b (Bultynck in Brice et al. 1979b). In the Ardenne, *Polygnathus denisbriceae* was found in the lower part (with the exception of the base) of the lower member of the Fromelennes Formation (Bultynck 1975). Moreover, Bultynck (write com. 1986) placed the base of the Upper *dengleri* Zone at the entry of *Icriodus subterminus* Youngquist 1945, that was found in samples 6 to 26 from the Bastien Member of the upper Blacourt Formation. Therefore, the Couderousse Member nearly belongs to the Middle–Upper *varcus* Zones. In addition, Milhau (1983) has identified the same ostracod assemblage both at the top of the Griset Member, 3 m below

Tab. 3. Brachiopod taxa of Assemblage 3

<i>Aulacella</i> sp.	Au
<i>Dagnachonetes</i> cf. <i>supragibbosus</i> (Sobolev 1909)	Ds
Trigonirhynchiidae	Tr
<i>Desquamatia</i> (<i>Independatrypa</i>) <i>sola</i> Godefroid 1986	Is
<i>Spinatrypa</i> sp.	Sp
<i>Athyris</i> sp.	At
<i>Cyrtospirifer verneuiliiformis</i> (Paeckelmann 1942)	Cv
<i>Undispirifer undiferus</i> Roemer 1844	Uu
<i>Undispirifer?</i> <i>gerolsteinensis grandis</i> Brice 2002	Ug
<i>Cyrtina</i> sp.	Cy
<i>Stringocephalus burtini</i> (Defrance 1825)	Sb
<i>Stringocephalus</i> sp.	St
Number of specimens = 1015	

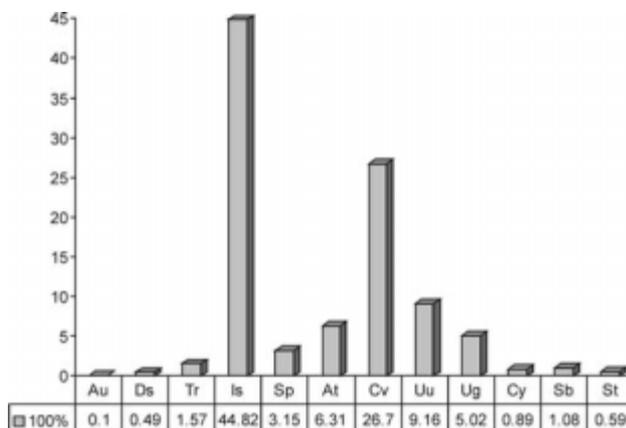


Fig. 3. Histogram of Assemblage 3.

the base of the Couderousse Member, and about 1 m below the base of the Fromelennes Formation in the Ardenne.

Brachiopods of this assemblage are more abundant and more diversified than in both previous assemblages. *Desquamatia* (*Independatrypa*) *sola* and *Spinatrypa* sp. (atrypids) are the most abundant (Godefroid 1988), followed by *Cyrtospirifer verneuiliiformis*, *Undispirifer undiferus*, *U.?* *gerolsteinensis grandis*, and the rare *Cyrtina* sp. (spiriferids). Other elements are *Athyris* sp. (athyrid), rhynchonellids Trigonirhynchiidae, *Stringocephalus burtini*, *Stringocephalus* sp. (terebratulids), *Dagnachonetes* cf. *supragibbosus* (chonetid), and *Aulacella* sp. (orthid). These brachiopods are associated with very abundant and varied bryozoans. According to Bigey (1987, 1988), fistuliporids (*Fistulipora pavementum* Bigey 1988) and rhabdomesids (*Acantoclema distilus* Bigey 1988) dominate in number over fenestellid fragments. Other fossils include disarticulated crinoid columnals, tentaculites, *Spirorbis*, rare solitary rugose corals, bivalves, gastropods, orthocone, cyrtocone cephalopods and trilobite remains (Morzadec 1988).

The sediments are represented by indurated bioclastic crinoidal pyrite-rich limestone with nodular aspects alternating with grey calcareous micaceous claystone. The microfacies consists of packstone–wackestone, reworked biomicrite, and natural bioclasts of different sizes. The lower beds are rich in large shells of sometimes disarticulated brachiopods suggesting a high-energy environment followed by a lower-energy environment in the upper beds. These may correspond to transgressive offshore deposits (the third Benthic Assemblage in Boucot's classification).

Depophase II, T-R cycle IIa

The Late Middle Devonian was a time of general transgression in Euramerica during the Taghanic onlap (House 1985, Johnson et al. 1985, 1986, Johnson and Sandberg 1989). Most authors consider that IIa, the first T-R cycle of Depophase II, was initiated at the base of the Middle *varcus* Zone in conodont standard zonation. This level corresponds to the base of the Fromelennes Formation (Bultynck 1975) in Belgium and with the base of the Couderousse Member of the Blacourt Formation in Boulonnais (Bultynck in Brice et al. 1979b). The reefal middle member of the Fromelennes Formation in the Ardenne is not recognized in the Ferques area, but this absence may be due to an important fault located between the Couderousse and Bastien Members (Mistiaen 1988a). Faunal response to the regression phase was weak or none (Johnson and Sandberg 1989). In the Boulonnais, brachiopods and other faunas are rare or absent in the Bastien Member of the Blacourt Formation.

Assemblage 4 (Tab. 4, Fig. 4)

This assemblage occurs in term a (= "La Cédoule Limestone"), 10–15 m thick, which is the lowermost part of

the Cambresèque Member of the Beaulieu Formation (Fig. A). The exact total thickness is unknown because of faults.

Conodont fauna VII with *Ancyrodella binodosa* Uyeno 1967 (Bultynck in Brice et al. 1979b) found at these levels is characteristic of the Lowermost *asymmetricus* Zone (Bultynck 1982a, b), which, in modern taxonomy, is the early and lower part of the Upper *Mesotaxis falsovalis* Zone (Ziegler and Sandberg 1990), latest Givetian in age.

Benthic faunas are extremely diverse and brachiopods are abundant. In this assemblage, the presence of small well-preserved *Comiotoechia barroisi* (rhynchonellids) is dominant in several beds (Brice and Meats 1972). Other elements, in decreasing order of abundance, are: *Douvillina cedulae* and *D. sp.* (strophomenids), *Rhyssochonetes douvillei* (chonetid), often disarticulated, deformed and broken *Apousiella dordodoti*, *Cyrtospirifer cf. verneuili*, *C. syringothyridiformis*, *Cyrtina aff. douvillei*, *Uchtospirifer sp.* (spiriferids), *Schizophoria striatula* (orthid), atrypids and athyrids. Crinoid ossicles and bryozoans are abundant and diversified. The former belong mainly to *Laudonomphalus gr. regularis-ornatus*, large in size and dominant in abundance (Le Menn 1988), followed by *Pentagonistipes? diversiformis* Le Menn 1988 and *Tantalocrinus scutellus* Le Menn 1985. Bryozoans are represented by three species: *Fistuliramus pachycystis* Bigey 1988, *Petalotrypa brevicamerata* Bigey 1988 and *Leptotrypella radiata* Bigey 1988. Other elements in the assemblage are “*Plexituba*” *briceae* Mistiaen 1988b (auloporid tabulate coral), *Disphyllum pashiense* (Soshkina 1939); (phaceloid rugose coral), *Michelinoceras anguliferum* (orthocone cephalopod), tentaculites and vertebrate remains.

Term a (= La Cédule Limestone) overlies a fault found in a brecciated limestone bed (0.50 m thick) located on top of the Bastien Member (Brice and Mistiaen 1988) in the upper part of the Blacourt Formation. The sediments are represented by hard fossiliferous, bioclastic crinoidal yellowish-grey limestone alternating with dark blue marls with silt. The reddish-brown upper part is more argillaceous. The lower beds are rich in large shells of sometimes disarticulated brachiopods suggesting a high-energy environment followed by a lower-energy environment in the upper part (the third Benthic Assemblage in Boucot’s classification).

Depophase II, T-R cycle IIb

As the previous one, this term corresponds to the transgressive deposits in a similar environment as that of IIa. In Belgium, “significant transgressive pulses occurred at the base of the Frasnian Group at the entry of *Ancyrodella binodosa* in the upper part of the Lowermost *asymmetricus* Zone” (Bultynck in Johnson et al. 1985) and also in the Boulonnais at the base of “La Cédule” limestone, the lowermost bed of the Beaulieu Formation that has yielded *Ancyrodella binodosa* Bultynck (Bultynck in Brice et al. 1979b, Bultynck 1982a, b).

Tab. 4. Brachiopod taxa of Assemblage 4

<i>Schizophoria striatula</i> Schlotheim 1813	Ss
<i>Douvillina cedulae</i> (Rigaux 1872) & <i>Douvillina sp.</i>	Dc
<i>Rhyssochonetes douvillei</i> (Rigaux 1872)	Rd
<i>Comiotoechia barroisi</i> (Rigaux 1908)	Cb
Atrypid	Atr
<i>Athyris oehlerti</i> Rigaux 1908	Ao
<i>Athyris sp.</i>	At
<i>Cyrtospirifer syringothyridiformis</i> (Paeckelmann 1942)	Cs
<i>Cyrtospirifer cf. verneuili</i> (Murchison 1840)	Cv
<i>Uchtospirifer sp.</i>	Uc
<i>Apousiella dordodoti</i> (Rigaux 1908)	Ad
<i>Cyrtina aff. douvillei</i> Rigaux 1908	Cd
Number of specimens = 591	

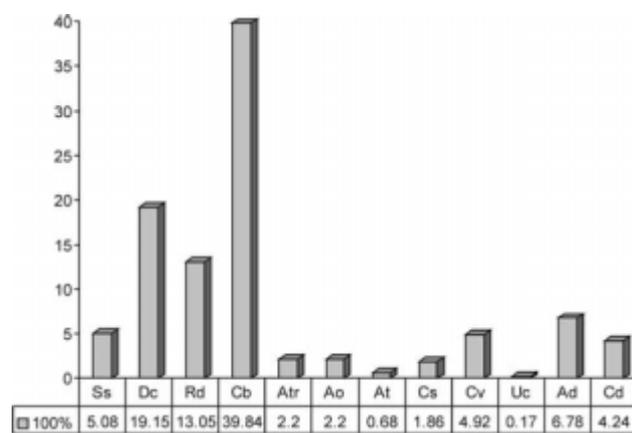


Fig. 4. Histogram of Assemblage 4.

Frasnian stage

The early Upper Devonian (Frasnian stage) is represented by three formations: 1) The Beaulieu Formation with the stratigraphic Cambresèque (p.p.), Noces and Pâtures Members, 2) The Ferques Formation with the Fiennes, Bois, Ferques and Gris Members, and 3) The Hydrequent Formation (p. p.) (Loboziak et al. 1983).

Assemblage 5 (Tab. 5, Fig. 5)

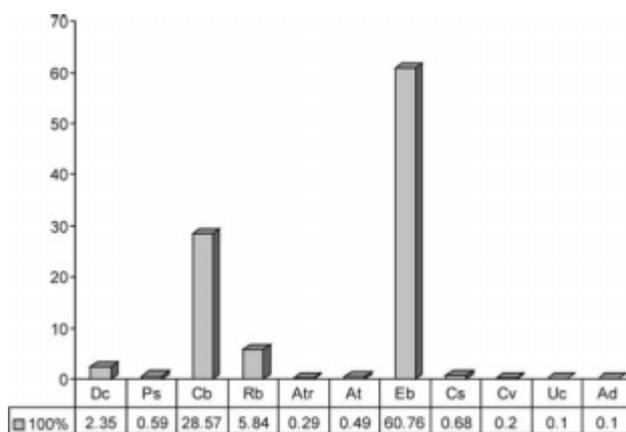
This brachiopod assemblage occurs in the lower part of the Cambresèque Member (about 10 m in the lower part of term b of the Beaulieu Formation (Fig. A).

Conodont fauna VIII with *Ancyrodella rotundiloba rotundiloba* (Bryant 1921) (Bultynck in Brice et al. 1979b) is found at this level and belongs to the Lower *asymmetricus* Zone, which is the upper part of the Late *Mesotaxis falsovalis* Zone and the *Palmatolepis transitans* Zone (Ziegler and Sandberg 1990) in modern taxonomy. Conodont fauna VIII is characteristic of the Early Frasnian.

Well-preserved *Eodmitria belliloci* (spiriferid), in the lower part of term b, is the most abundant element. Several

Tab. 5. Brachiopod taxa of Assemblage 5

<i>Douvillina cedulae</i> (Rigaux 1872)	Dc
<i>Productella subaculeata</i> (Murchison 1840)	Ps
<i>Comiotoechia barroisi</i> (Rigaux 1908)	Cb
<i>Ripidiorhynchus belliloci</i> Brice & Meats 1972	Rb
Atrypid	Atr
<i>Athyris</i> sp.	At
* <i>Eodmitria belliloci</i> Brice 1982	Eb
<i>Cyrtospirifer syringothyriiformis</i> (Paeckelmann 1942)	Cs
<i>Cyrtospirifer</i> cf. <i>verneuili</i> (Murchison 1840)	Cv
<i>Uchtospirifer</i> ? sp.	Uc
<i>Apousiella dorlodoti</i> (Rigaux 1908)	Ad
Number of specimens = 1022	



* *Eodmitria supradisjuncta belliloci* Brice 1982 type of the genus *Eodmitria* is emended in *Eodmitria belliloci*

Fig. 5. Histogram of Assemblage 5.

spiriferids are encrusted by one or several *Petrocrania* craniid brachiopods and *Spirorbis* worms (Brice and Mistiaen 1992). Other elements, commonly found above the base of term b, are in current alignments and in imbrication of disarticulated and broken shells. They include, in decreasing order of abundance: *Comiotoechia barroisi*, *Ripidiorhynchus belliloci* (rhynchonellids), *Douvillina cedulae* (strophomenid), *Productella subaculeata* (productellid), rare athyrids, atrypids, *Cyrtospirifer syringothyriiformis*, *C.* cf. *verneuili*, *Uchtospirifer*? sp., and *Apousiella dorlodoti* (other spiriferids).

The lower part of the assemblage is lithologically dominated by dark greyish-red or bluish-grey argillaceous deposits that are broken into small blocks and interbedded with silt-sized storm deposits (Lefrançois et al. 1993). The deposits are in current alignment and in imbrication of disarticulated and broken shells. The presence of argillaceous deposits and large well-preserved spiriferids suggests a low-energy environment interrupted by tempestites. The brachiopod fauna probably belongs to the second Benthic Assemblage in Boucot's classification.

Brachiopods and other faunas become rare in the upper part of the Cambresèque Member and in the lower part of the Noces Member (terms a–b), which are Frasnian in age.

The lowermost part of term a of the Noces Member corresponds to a reef buildup (biostrome or bioherm) where more or less dolomitized stromatoporoids appear as phantoms.

Assemblage 6 (Tab. 6, Fig. 6)

This assemblage occurs in the upper part of the Noces Member (term c, 5 m thick), in the middle part of the Beau-lieu Formation (Fig. A).

This term has yielded, in samples 34–35 of Bultynck (Bultynck in Brice et al 1979b), young forms doubtfully attributed to *Ancyrodella gigas* Youngquist 1947. Later, from the base of term c, this same level has yielded some true *Ancyrodella gigas* (Coen in Brice et al. 1981). According to Ziegler (1962), the entry of *Palmatolepis punctata* (Hinde 1879) with *Polygnathus asymmetricus* Bischoff and Ziegler 1957 marks the base of the Middle *asymmetricus* Zone, which is the *Palmatolepis punctata* Zone in modern taxonomy. In the absence of *Palmatolepis punctata* (Hinde 1879) in Boulonnais, the base of the Middle *asymmetricus* Zone is not precisely defined. However, Ziegler (1962 op. cit.) admits that *Ancyrodella gigas* appears at the same time as *Palmatolepis punctata*.

Brachiopod fauna of this assemblage is diverse but not abundant. *Metabolipa meatsi* (pentamerid) is the most abundant, being followed by *Schizophoria striatula* (orthid). Other taxa, in decreasing order of abundance, are: *Desquamatia* (*Seratrypa*) *belliloci*, *D.* (*Seratrypa*) sp. A, *Spinatrypa* cf. *explanata*, *Spinatrypa* sp. (atrypids), *Ladogioides ferquensis* (rhynchonellid), *Cyrtospirifer syringothyriiformis*, *C. conoideus*, *Adolfia sauvagei*, *Undispirifer belliloci*, *Cyrtina douvillei* (spiriferids), *Productella subaculeata* (productellid), *Cranaena rigauxi* (terebratulid), *Douvillina dutertrei* (strophomenid) and *Longispina maillieuxi* (chonetid). Rigaux (1892) pointed out the presence of *Goniatites retrorsus* von Buch, which Corsin (1928) considers as *Tornoceras*, at, or near, this level (cf. Becker 2002).

Two lithofacies can be distinguished. The lower part is composed of a biostrome with abundant crinoid ossicles, *Disphyllum gradatum* Tsien 1970 (disphyllid phaceloid rugose corals), lamellar stromatoporoids, and tabulate auloporids. The biostrome is overlain by a hard, partly dolomitized pink crystalline limestone (calcilutite biomicrite) with crinoid ossicles, geodes, and ochre in the fissures. Brachiopods (mainly pentamerids) are often recrystallized. Thus, the environment may be interpreted to have been a shallow subtidal zone with flourishing phaceloid rugose corals (facies 1) covered by the third Benthic Assemblage of Boucot's classification (facies 2).

Dephase II, T-R cycle IIc

The T-R cycle IIc generally begins above the base of the Middle *asymmetricus* Zone and continues through the *Ag. triangularis* Zone. On the platform, it is characterized by a reef buildup, e.g., in Western Canada (Leduc Formation) and in Belgium (bioherms d, h in the Middle *asymmetricus*

Tab. 6. Brachiopod taxa of Assemblage 6

<i>Schizophoria striatula</i> Schlotheim 1813	Ss
<i>Douwillina dutertrei</i> Murchison 1840	Dd
<i>Longispina maillieuxi</i> (Rigaux 1908)	Lm
<i>Productella subaculeata</i> (Murchison 1840)	Ps
<i>Metabolipa meatsi</i> Brice 1988	Mm
<i>Ladogioides ferquensis</i> Brice 1981	Lf
<i>Desquamatia (Seratrypa) belliloci</i> (Rigaux 1908)	Sb
<i>Desquamatia (Seratrypa) sp. A</i>	DS
<i>Spinatrypa cf. explanata</i> (Schlotheim 1820)	Se
<i>Spinatrypa sp. N</i>	Sp
<i>Athyris davidsoni</i> Rigaux 1872	Ad
<i>Cyrtospirifer syringothyriiformis</i> (Paeckelmann 1942)	Cs
<i>Cyrtospirifer conoideus</i> (Roemer 1843)	Cc
<i>Adolfia sauvagei</i> (Rigaux 1872)	As
<i>Undispirifer belliloci</i> Brice 2002	Ub
<i>Cyrtina douvillei</i> Rigaux 1908	Cd
<i>Cranaena rigauxi</i> Brice 1988	Cr
Number of specimens = 703	

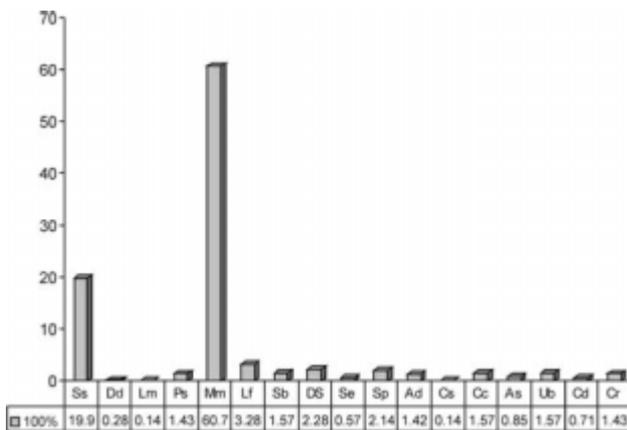


Fig. 6. Histogram of Assemblage 6.

Zone and bioherm j in the Upper *asymmetricus* Zone); (Bultynck in Johnson et al. 1985). According to Rohart (1988), phaceloid disphyllid originating from a biostrome developed at the base of term c of the Nocés Member in the Ferques area is identical at the phaceloid disphyllid from bioherm d in Belgium.

Assemblage 7 (Tab. 7, Fig. 7)

This assemblage occurs in the lowermost part (term a) of the Pâtures Member of the Beaulieu Formation (Fig. A). It is well exposed in the Caffiers-Ferques railcut section. It is 4–5 m thick and overlies Assemblage 6.

This level contains Fauna X with *Ancyrodella gigas* described by Bultynck (in Brice et al. 1979b). It is characteristic of the Middle *asymmetricus* Zone (cf. ante).

The brachiopod fauna is very different from that of the previous assemblage. In this case, the brachiopods are commonly small, abundant and much more diverse (Brice

Tab. 7. Brachiopod taxa of Assemblage 7

<i>Aulacella sp.</i>	Au
<i>Cariniferella mistiani</i> Brice 1981	Cm
<i>Monelasma deshayesi</i> (Rigaux 1872)	Md
<i>Schizophoria striatula</i> Schlotheim 1813	Ss
<i>Douwillina thomasi</i> (Rigaux 1908)	Dt
<i>Douwillina douxami</i> (Rigaux 1908)	Dd
<i>Douwillina ferquensis</i> (Rigaux 1872)	Df
<i>Douwillinaria fischeri</i> (Verneuil 1845)	Dof
<i>Gamphalosis gosseleti</i> (Rigaux 1872)	Gg
<i>Eoschuchertella bouchardi</i> (Rigaux 1872)	Eb
<i>Longispina rigauxi</i> Racheboeuf 1979	Lr
<i>Productella subaculeata</i> (Murchison 1840)	Ps
<i>Steinhagella? cf. membranacea</i> (Phillips 1841)	Sm
<i>Metabolipa meatsi</i> Brice 1988	Mm
<i>Coeloterorhynchus kayseri</i> (Rigaux 1908)	Ck
<i>Globulirhynchia lemesli</i> (Rigaux 1892)	Gl
<i>Desquamatia (Seratrypa) belliloci</i> (Rigaux 1908)	Sb
<i>Desquamatia (Neatrypa) legayi</i> (Rigaux 1908)	Nl
<i>Rigauxia acutosina</i> (Rigaux 1908)	Ra
<i>Apousiella belliloci</i> (Rigaux 1908)	Ab
Number of specimens = 4256	

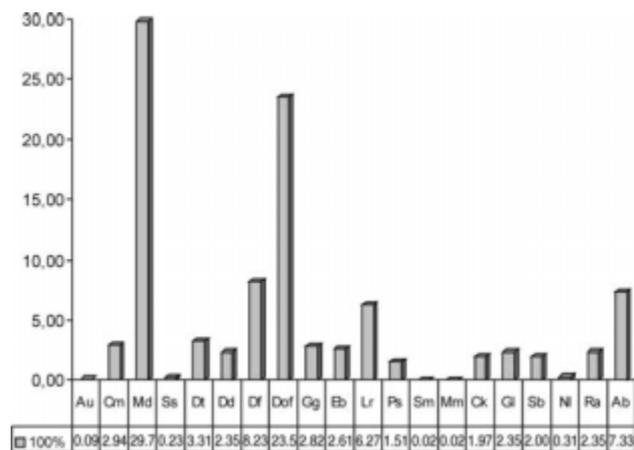


Fig. 7. Histogram of Assemblage 7.

1988b). Orthids are represented by four taxa (very small *Monelasma deshayesi*, *Schizophoria striatula*, *Cariniferella mistiaeni*, and *Aulacella sp.*). *Monelasma deshayesi* corresponds to about one-third of the brachiopod assemblage. The remainder of the population consists of six small and thin strophomenid taxa (in decreasing order of abundance): *Douwillinaria fischeri*, *Douwillina ferquensis*, *D. thomasi*, *Gamphalosis gosseleti*, *Eoschuchertella bouchardi*, *Douwillina douxami*, *Apousiella belliloci*, *Rigauxia acutosina* (spiriferids), *Longispina rigauxi* (chonetids), *Globulirhynchia lemesli*, *Coeloterorhynchus kayseri* (rhynchonellids which are often smooth or with few costae restricted to the anterior parts of valves), *Desquamatia (Seratrypa) belliloci*, *D. (Neatrypa) legayi* (atrypids), *Productella subaculeata*, *Steinhagella? cf. membranacea* (productellids) and rare *Metabolipa*

Tab. 8. Brachiopod taxa of Assemblage 8 and their proportions in percent

<i>Aulacella</i> sp.	Au	0.03
<i>Monelasmia deshayesi</i> (Rigaux 1872)	Md	0.22
<i>Schizophoria striatula</i> Schlotheim 1813	Ss	14.8
<i>Douvillina dutertrei</i> Murchison 1840	Dd	2.84
<i>Douvillina thomasi</i> Rigaux 1908	Dt	0.09
<i>Douvillina ferquensis</i> (Rigaux 1872)	Df	0.09
<i>Eoschuchertella bouchardi</i> (Rigaux 1872)	Eb	0.19
<i>Eoschuchertella? elegans</i> (Rigaux 1872)	Ee	25.08
<i>Longispina maillieuxi</i> (Rigaux 1908)	Lm	7.29
<i>Productella subaculeata</i> (Murchison 1840)	Ps	0.25
<i>Whidbornella productoides</i> (Murchison 1840)	Wp	0.03
<i>Metabolipa meatsi</i> Brice 1988	Mm	2.15
<i>Ripidiorhynchus ferquensis</i> (Gosselet 1887)	Rf	0.06
<i>Ripidiorhynchus boloniensis</i> (Orbigny 1850)	Rb	0.25
<i>Platyterorhynchus gosseleti</i> (Rigaux 1908)	Pg	1.96
<i>Coeloterorhynchus kayseri</i> (Rigaux 1908)	Ck	2.68
<i>Globulirhynchia lemesli</i> (Rigaux 1892)	Gl	0.03
<i>Desquamatia (Seratrypa) belliloci</i> (Rigaux 1908)	Sb	5.74
<i>Spinatrypina pratorum</i> Godefroid 1988	Sp	0.26
<i>Athyris oehlerti</i> Rigaux 1908	Ao	0.13
<i>Cyrtospirifer syringothyriiformis</i> (Paeckelmann 1942)	Cs	24.92
<i>Cyrtospirifer loonesi</i> Brice 2002	Cl	0.44
<i>Rigauxia acutosina</i> (Rigaux 1908)	Ra	0.57
<i>Eleutherokomma barroisi</i> (Rigaux 1892)	Eb	4.89
<i>Eleutherokomma legayi</i> (Rigaux 1872)	El	1.45
<i>Adolfia sauvagei</i> (Rigaux 1872)	As	0.19
<i>Cyrtina bouchardi</i> Brice 1988	Cb	1.26
<i>Cranaena rigauxi</i> Brice 1988	Cr	2.11
Number of specimens = 3170		100 %

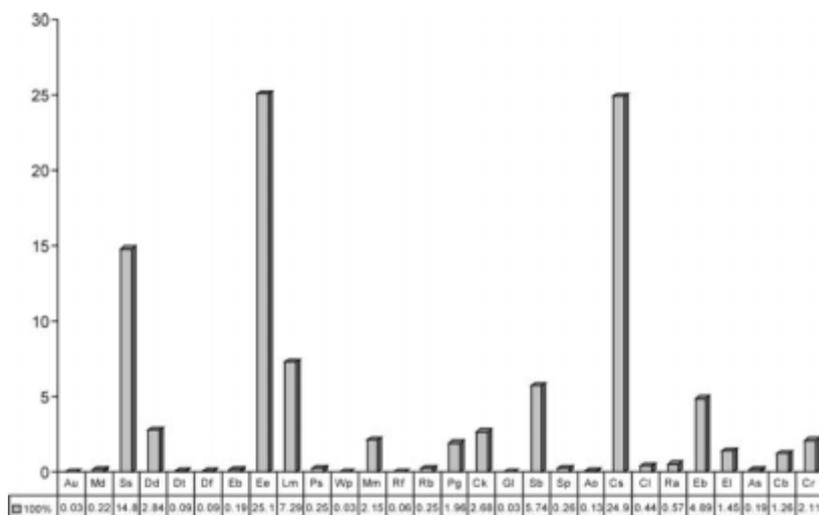


Fig. 8. Histogram of Assemblage 8.

meatsi (pentamerid). The associated fauna consists sometimes of crinoidal fragments in connection, bryozoans, delicately branched auloporid tabulate corals, gastropods, and abundant tentaculites represented by four families, six genera and eleven species (Farsan 1983).

Sediments are represented by greenish-grey carbonate muds and marls, yellowish by alteration, and several calcareous (wackestone–packstone) nodules. This assemblage and the characteristics of its sediments reflect a low-energy environment with a soft muddy bottom in subtidal zone. The fourth or fifth Benthic Assemblage in Boucot's classification may be inferred.

Assemblage 8 (Tab. 8, Fig. 8)

Assemblage 8 occurs in the upper part (term c) of the Pâtures Member of the Beau-lieu Formation (Fig. A) which corresponds to the upper part of units 3, 4, and 5 and the lower part of unit 6. It is 10–12 m thick (Mistiaen et al. 2002a) and has been exposed by a temporary trench north of the La Parisienne quarry.

According to Dégardin (in Mistiaen et al. 2002a), the conodont assemblage of unit 3 and the base of unit 4 is similar to fauna X with *Ancyrodella gigas* (Bultynck in Brice et al. 1979b). It is characteristic of the Middle *asymmetricus* Zone (cf. ante).

Brachiopods are abundant, dominating the benthic fauna (Brice in Mistiaen et al. 2002a). They have a higher taxonomic diversity than in previous assemblages. *Eoschuchertella? elegans* (strophomenid) and large *Cyrtospirifer syringothyriiformis* (spiriferids) are the most abundant, and are often well preserved. Other abundant fauna includes *Schizophoria striatula* (orthid), *Longispina maillieuxi* (chonetid), *Desquamatia (Seratrypa) belliloci* (atrypid), small *Eleutherokomma barroisi*, *E. legayi*, and *Cyrtina bouchardi* (spiriferids). There are also several moderately represented taxa, such as *Douvillina dutertrei*, *D. douxami* (strophomenids), *Coeloterorhynchus kayseri*, *Globulirhynchia lemesli* (rhynchonellids), *Metabolipa meatsi* (pentamerid), *Cyrtospirifer loonesi*, *Rigauxia acutosina* (spiriferids), rare *Monelasmia deshayesi*, *Aulacella* sp. (orthids), *Douvillina ferquensis*, *D. thomasi*, *Eoschuchertella bouchardi* (strophomenids), *Ripidiorhynchus ferquensis*, *R. boloniensis* (rhynchonellids), *Spinatrypina pratorum* (atrypid), *Athyris oehlerti* (athyrid) and *Productella subaculeata*, and *Whidbornella productoides* (productellids). The associated fauna is abundant, consisting of crinoid ossicles, bryozoans, and vertebrates remains of unit 4. Lamellar stromatoporoids, lamellar or encrusting (alveolitids, auloporids) and massive (*Thecostegites*) tabulate corals, and

solitary and phaceloid rugose corals are frequent in the upper part of unit 5 and the lower part of unit 6.

The sediments are represented by dark clays with rare calcareous quartziferous biomicritic nodules. These are overlain by black clays with more abundant calcareous nodules and disarticulated brachiopods, and crinoid columnals, some of which are reworked. Above, yellowish clays with grey calcareous nodules are present. The limestone of the upper bed is rich in builders (cf. ante). The associated fossil shells are common: large, articulated, and well preserved, with mucronate spiriferids pointing to autochthony for at least a part of the brachiopod assemblage or to deposition after a short-distance transport. In Boucot's classification, this assemblage falls in the third Benthic Assemblage.

Assemblage 9 (Tab. 9, Fig. 9)

This assemblage occurs in the thin basal bed (about 0.6 m thick) of term a of the Bois Member of the Ferques Formation (Fig. A).

Conodonts are generally not common in the Ferques Formation. In the basal bed of the Bois Member, Magne (1964) noted the presence of *Ancyrodella curvata* (Branson and Mehl 1934) in his sample RF 934, which was collected at the base of the Bois Member in the Bois quarry. Ziegler and Sandberg (1990, p. 18) stated that "The Early *hassi* Zone corresponds to all of the former Upper *asymmetricus* Zone and possibly a slightly younger, previously unzoned interval. The Early *hassi* Zone is characterized by the joint occurrence of the early form of *Ancyrodella curvata* having only a moderate lateral lobe". In the absence of this information, assignment of this level to the Upper *asymmetricus* Zone is uncertain.

The brachiopod fauna is abundant and moderately diversified. *Athyris oehlerti* and *Cyrtospirifer archiaci* comprise about 80 % of the sample, with all growth stages being present. These taxa are associated with *Schizophoria* sp. (orthid), *Douvillina* sp. (strophomenid), *Productella* sp. (productellid), *Ripidiorhynchus* sp., *Platyterorhynchus* sp. (rhychonellids), *Atryparia (Costatrypa)* sp., *Spinatrypa* (atrypids), rare *Longispina* sp. (chonetid) and *Cranaena rigauxi* (terebratulid). Other groups include rugose corals represented by four species of solitary corals (*Tabulophyllum*, *Thamnophyllum*), one of phaceloid coral (*Disphyllum*), and one of a massive coral (*Hexagonaria*) (Rohart 1988), six species of lamellar or encrusting forms of *Actinostroma*, *Clathrocoilon*, *Stictostroma*, *Habrostoma*, *Stachyodes* (stromatoporoids) (Mistiaen 1988a), lamellar and encrusting *Alveolites*, *Thamnopora*, *Syringopora*, *Aulopora*, *Plexituba* (tabulate corals) (Mistiaen 1988b). Encrusting bryozoans, gastropods, bivalves, trilobite remains (Morzadec 1988) and rare tentaculites are also present.

This level overlies a dolomitic sand bed (the top of the Fiennes Member). It consists of red or grey, partly dolomitized limestone rich in diverse bioclastic fragments. Brachiopod fauna is commonly small in size and is sometimes encrusted by epizoans (*Spirorbis*). *Cyrtospiriferids*

Tab. 9. Brachiopod taxa of Assemblage 9

<i>Schizophoria striatula</i> Schlotheim 1813	Ss
<i>Douvillina dutertrei</i> Murchison 1840	Dd
<i>Longispina rigauxi</i> Racheboeuf 1979	Lr
<i>Productella subaculeata</i> (Murchison 1840)	Ps
<i>Ripidiorhynchus ferquensis</i> (Gosselet 1887)	Rf
<i>Platyterorhynchus gosseleti</i> (Rigaux 1908)	Pg
<i>Spinatrypa silvae</i> Godefroid 1988	Ssi
<i>Atryparia (Costatrypa)</i> sp. B	AC
<i>Athyris oehlerti</i> Rigaux 1908	Ao
<i>Cyrtospirifer archiaci</i> (Murchison 1840)	Ca
<i>Cyrtospirifer verneuili</i> (Murchison 1840)	Cv
<i>Adolfia sauvagei</i> (Rigaux 1872)	As
<i>Cranaena rigauxi</i> Brice 1988	Cr
Number of specimens = 893	

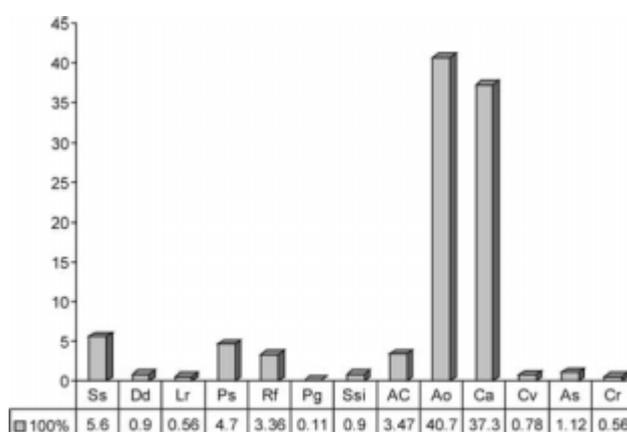


Fig. 9. Histogram of Assemblage 9.

are generally favourably preserved which argues against any extensive transport. This assemblage suggests that the fauna lived and accumulated in waters of shallow to moderate depth below wave base, but the presence of some broken and disarticulated brachiopod shells probably reflects a mixed assemblage. It can be most readily assigned to the transition between Boucot's third and fourth Benthic Assemblages. Wallace (1969a, b) early considered this association as a true life assemblage, but later (Wallace 1978) as a hurricane deposit.

Assemblage 10 (Tab. 10, Fig. 10)

This assemblage occurs about 4 m above the previous one, in term b (0.6 m thick) of the Bois Member (Fig. A).

According to Coen (in Brice et al. 1981), this level has only yielded *Polygnathus*; its position in the conodont zonation is uncertain and probably the same as for the previous one.

Brachiopods are extremely abundant but fauna is not very diverse (6 small taxa). *Cyrtospirifer verneuili* and *Productella subaculeata* are the most abundant. Both species are generally articulated, well preserved, and represent about 90 % of the benthic assemblage where young forms

Tab. 10. Brachiopod taxa of Assemblage 10

<i>Longispina rigauxi</i> Racheboeuf 1979	Lr
<i>Productella subaculeata</i> (Murchison 1840)	Ps
<i>Ripidiorhynchus ferquensis</i> (Gosselet 1887)	Rf
<i>Spinatrypa silvae</i> Godefroid 1988	Ssi
<i>Athyris oehlerti</i> Rigaux 1908	Ao
<i>Cyrtospirifer verneuili</i> (Murchison 1840)	Cv
Number of specimens = 1463	

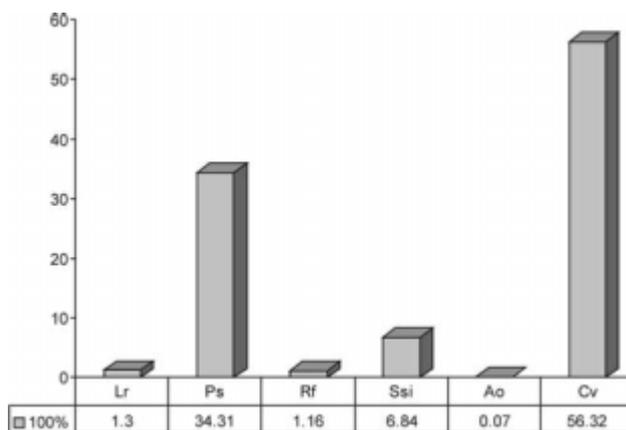


Fig. 10. Histogram of Assemblage 10.

are generally absent. Other elements present (in decreasing order of abundance) are *Spinatrypa silvae* (atrypid), *Longispina rigauxi* (chonetid), *Ripidiorhynchus ferquensis* (rhynchonellid), and *Athyris oehlerti* (athyrid). The almost uniform size and the absence of disarticulated cyrtospiriferids evidence environment protected by argillaceous matrix and formed by an accumulation (thanatocoenose) from a short-distance transport.

This level overlies a biostrome. It consists of argillaceous limestone and marls. In the upper part of the bed, fossils lie in all positions and close to one another, with only little matrix between them. In Boucot's classification, this brachiopod assemblage corresponds to the third Benthic Assemblage.

Assemblage 11 (Tab. 11, Fig. 11)

The assemblage occurs in the upper part of the Bois Member, in term e, and is about 6 m thick (Fig. A).

As with the previous assemblage, its position in the conodont zonation is uncertain, and probably the same as for Assemblage 10.

Brachiopod assemblage is much less fossiliferous than in other assemblages. Most of the specimens are extremely small. The only common brachiopods are *Longispina rigauxi*, a few *Retichonetes armata* (chonetids) followed by less abundant *Cyrtospirifer verneuili* (spiriferid), *Productella subaculeata* (productellid), *Douvillina dutertrei*, and *Nervostrophia* sp. (strophomenids). Other brachiopods are even rarer (*Ripidiorhynchus ferquensis*, *Adolfia sauvagei*, *Spinatrypa silvae*, *Eoschuchertella*

Tab. 11. Brachiopod taxa of Assemblage 11

<i>Douvillina dutertrei</i> Murchison 1840	Dd
<i>Nervostrophia</i> sp.	Ne
<i>Eoschuchertella ferquensis</i> Brice 1988	Ef
<i>Longispina rigauxi</i> Racheboeuf 1979	Lr
<i>Retichonetes armata</i> (Bouchard 1845)	Ra
<i>Productella subaculeata</i> (Murchison 1840)	Ps
<i>Ripidiorhynchus ferquensis</i> (Gosselet 1887)	Rf
<i>Spinatrypa silvae</i> Godefroid 1988	Ssi
<i>Athyris bayeti</i> Rigaux 1908	Ab
<i>Cyrtospirifer verneuili</i> Rigaux 1908	Cv
<i>Adolfia sauvagei</i> (Rigaux 1872)	As
Number of specimens = 860	

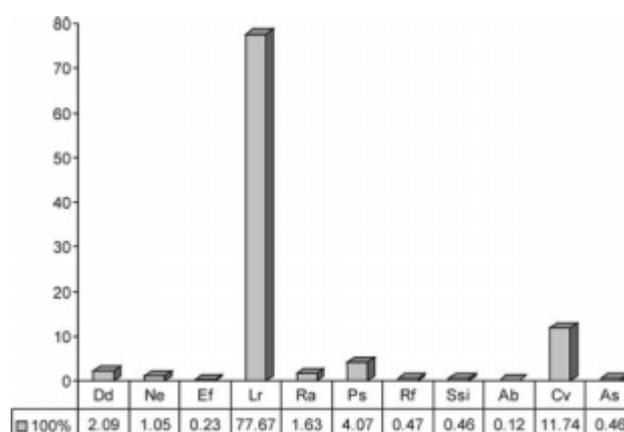


Fig. 11. Histogram of Assemblage 11.

ferquensis, and *Athyris bayeti*). Associated fauna includes tentaculites, crinoid ossicles, and fenestellid bryozoans.

The lithology consists of yellow and white-weathering plate-like argillaceous limestone. Articulated chonetids are very common on the surface of some thin beds. There are no apparent traces of any significant transport and the assemblage may be regarded as autochthonous. The character of sediments reflects a stable, low-energy environment in a subtidal zone. The fourth Benthic Assemblage of Boucot's classification may be inferred.

Assemblage 12 (Tab. 12, Fig. 12)

This assemblage occurs in the upper part of the Ferques Formation, in term f of La Parisienne Member and the Gris Member (Fig. A).

The Gris Member has yielded *Ancyrognathus triangularis euglypheus sensu* Coen 1973 (Coen in Brice et al. 1981). According to Klapper (1990), this conodont (not figured) may refer either to *Ag. tsiensi* Mouravieff or *Ag. coeni* Klapper which ranges from Zone 8 to the middle of Zone 11 in Montagne Noire. Currently, the age of the upper part of the Ferques Formation is uncertain.

Brachiopod fauna is abundant including a very high proportion of large individuals and epifaunal encrustation,

but the fauna is not very diverse. Four abundant species in decreasing order of frequency are: *Productella subaculeata* (productellid), *Athyris purchisoni* (athyrid), *Retichonetes armata* (chonetid), and *Cyrtospirifer verneuili* (spiriferid). Other uncommon species, in decreasing order of abundance, are *Douvillina dutertrei*, *Nervostrophia latissima*, *Eoschuchertella ferquensis* (strophomenids), *Ripidiorhynchus ferquensis* (rhynchonellid), *Schizophoria striatula* (orthid), *Athyris davidsoni* (athyrid), and *Spinatrypa longispina* (atrypid). Associated fauna comprises crinoid ossicles, lamellar and encrusting *Alveolites*, *Thamnopora*, auloporids (tabulate corals) (Mistiaen 1988b), solitary and massive rugose corals (Rohart 1988), encrusting bryozoans (Bigey 1988), gastropods, bivalves, and tentaculites.

The upper Ferques Formation consists of two lithofacies. The lower beds correspond to the top of the La Parisienne Member, term f (Brice et al. 1979a) and the lower part of the Gris Member (term a). The beds are formed by plate-like argillaceous limestone (biomicrite-packstone) deposit. The upper beds (term b of the Gris Member) are grey and noticeably richer in argillaceous material than the lower beds. This sedimentation on a stable platform and in a shallow, open sea suggests a low- or moderate-energy environment. The lithology passes progressively to shales (in the low-energy environment) and the sandstones of the Hydrequent Formation which has yielded few brachiopods. This assemblage and its environment may be attributed to the third Benthic Assemblage in Boucot's classification.

Conclusions

No relation can be proposed between the sedimentation and the fauna of the lowermost part of the Blacourt Formation, the Caffiers Formation, and global eustatic curves for two reasons. First, the contact between the two formations has never been observed; secondly, conodonts were not recognized in the sediments.

Only two brachiopod assemblages were identified, in the lower part of the Griset Member (Fig. A): Assemblage 1 in a regressive sequence, and assemblage 2 in a transgressive sequence, both deposited in an infratidal zone among four T-R sequences recognized by Pelhate and Poncet (1988). According to these authors and Chamley (1988), the carbonate sedimentation and the nature of average clay assemblages of the Griset Member, with numerous stromatolite levels, evaporite traces, cross bedding and numerous buildups, suggest deposition in a warm shallow water on a platform in an unstable area. This unstable area has a block-faulting morphology with the presence of a well-sloped relief. This morphology is favourable for reefal buildups (bioherms, biostromes) by different builders (algae, sponges, worms, stromatoporoids, rugose and tabulate corals). In these conditions, it is difficult to distinguish the influence of sea-level variations from the influence of tectonic movements in the observed depositional area of the Griset Member.

Tab. 12. Brachiopod taxa of Assemblage 12

<i>Schizophoria striatula</i> Schlotheim 1813	Ss
<i>Douvillina dutertrei</i> Murchison 1840	Dd
<i>Nervostrophia latissima</i> (Quenstedt 1871)	Nl
<i>Eoschuchertella ferquensis</i> Brice 1988	Ef
<i>Retichonetes armata</i> (Bouchard 1845)	Ra
<i>Productella subaculeata</i> (Murchison 1840)	Ps
<i>Ripidiorhynchus ferquensis</i> (Gosselet 1887)	Rf
<i>Spinatrypa longispina</i> (Rigaux 1872)	Sl
<i>Athyris davidsoni</i> Rigaux 1908	Ad
<i>Athyris purchisoni</i> Brice 1988	Am
<i>Cyrtospirifer verneuili</i> Rigaux 1908	Cv
<i>Adolfia sauvagei</i> (Rigaux 1872)	As
Number of specimens = 1545	

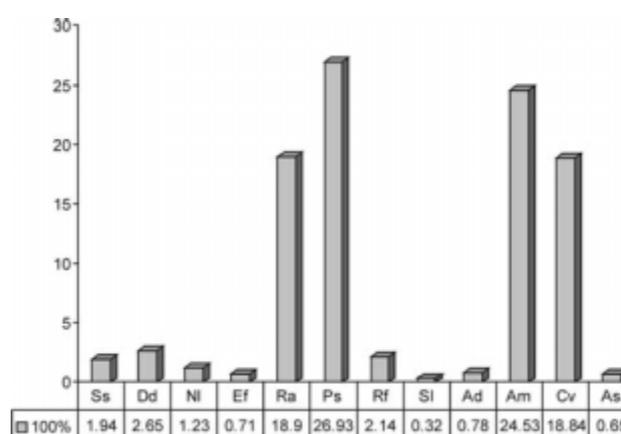


Fig. 12. Histogram of Assemblage 12.

In contrast, we found that the Middle *asymmetricus* Zone contains an important transgressive sequence over a vast region around the Old Red Continent, that is commonly considered the beginning of the first T-R Iia cycle of Depophase II. This transgressive sequence corresponds, in Boulonnais, to the Couderousse Member of the Blacourt Formation, which has yielded Assemblage 3, and to the lower part of the Fromelennes Formation in the Ardenne which is characterized by the entry of the first *Cyrtospirifer*.

In the lowermost *asymmetricus* Zone, we encountered the presence of another transgressive sequence which is commonly considered the beginning of the second T-R cycle IIb of Depophase I. This transgressive sequence corresponds, in Boulonnais, to the lowermost part of the Cambresèque Member of the Beaulieu Formation, which has yielded Assemblages 4–5. In the Ardenne, the sequence corresponds to the lower part of the Frasnés Group, which is characterized in the Ferques area by the entry of several species of *Cyrtospirifer* and the first *Apousiella* (mucrospiriferid) in Assemblage 4 of the topmost Givetian, and the entry of *Eodmitria* (spiriferid) in Assemblage 5 of the Early Frasnian.

We also encountered another transgressive sequence in the Middle *asymmetricus* Zone, which is commonly con-

sidered the beginning of the second T-R cycle IIc of Dephase I. This transgressive sequence begins, in Boulonnais, in the upper part of the Nocés Member of the Beaulieu Formation. It has yielded Assemblage 6 and continues with the Pâtures Member, which has yielded the most diversified Assemblages 7–8 and several remains of goniatites identified as *Carinoceras* cf. *galeatum* (Wedekind 1913), *Manticoceras* cf. *cordatum* (Sandberger & Sandberger 1850) by Becker (2002). The lowermost part of the Ferques Formation corresponds to a regressive sequence, where the mainly dolomitic Fiennes Member is in part built as a biostrome overlain by dark dolomite, clay and sand developed in very shallow water. Other Assemblages 9, 10, 11 were identified in the Bois Member in a transgressive sequence. Assemblage 12 was identified in the upper part of the La Parisienne Member and in the Gris Member. This last brachiopod assemblage includes abundant specimens and a very high proportion of large forms, but not very diverse. Conodonts are generally uncommon in the Ferques Formation and the conodont zones are still uncertain.

Brachiopods are neither abundant, diverse, nor well preserved in the Hydrequent Formation. Among these, *Ripidiorhynchus ferquensis* (rhynchonellid), which is Frasnian in age, is relatively abundant in a dolomitic ferruginous brecciated bed (1.8 m thick) lying ca. 23 m below the top of the formation. Conodonts have never been found in the Hydrequent Formation but rare goniatites were collected: “*Geyphyroceras*” *intumescens* by Corsin (1928), *Manticoceras* cf. *cordatum* by Wallace (1969b). However, the upper part of the Hydrequent Formation yielded spores and acritarchs which permitted a detailed palynological zonation (Loboziak and Streel in Brice et al. 1981, Loboziak et al. 1983, Streel et al. 1987). According to these authors, the Frasnian/Famennian boundary thus falls within the Hydrequent Shale between 0.5 and 2.5 m below the Sainte Godeleine Formation.

Psammites of the Sainte Godeleine Formation correspond to a large regressive sequence deposited in intertidal or supratidal zones or lacustrine zones (Lethiers 1982). They have yielded only endobiontic fauna, bivalves and gastropods. Its age is uncertain, so, the IId eustatic cycle has not been identified in Boulonnais.

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