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Evolution of organic debris and palynomorph preservation in two late middle Frasnian sections, southern Dinant Synclinorium border, Belgium

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ABSTRACT – The palynofacies content of two successive calcareous shaly units [Boussu-en-Fagne Member (= Boussu) and Neuville Formation] of late middle Frasnian age has been investigated in two coeval Belgian localities at the southern margin of the Dinant Synclinorium (La Boverie and Lion quarries, 60 km apart). The two units are differentiated by an abrupt increase in calcareous nodule concentration, which marks a sequence boundary between a transgressive and a high stand systems tract. Despite difficulties associated with differential thermal alteration, the organic matter in both areas shows very similar trends.

At both localities, the Boussu Member contains higher concentrations of organic debris and sporomorphs than the Neuville Formation, while the relative proportion of black (oxidized) debris compared with brown damaged fragments progressively increases upsection in both the investigated sections. Moreover, the shale which is grey and pyritic at the base, becomes grey-green, nodular, and bioturbated towards the top. Therefore, the relative increase of opaque debris (which is considered the fraction most resistant to oxidation processes) suggests a change in the preservation of organic matter during the Boussu-Neuville interval. This alteration affects mainly the degraded and infested organic debris and, more or less equally, the most abundant microfossils (acritarchs and spores). Concurrently, acritarch concentration decreases while the number of broken specimens increases. The possibility of differential alteration of acritarch taxa is considered but is not confirmed by a concomitant relative increase in other palynomorphs. Moreover, the acritarch and prasinophycean assemblage succession, combined with the Shannon diversity index data, suggest similarities with Staplin's distribution model. If so, significant differential alteration of acritarchs and prasinophytes is unlikely and the observed assemblage successions are probably due to changes in water depth that have induced variations in the reefal environment.

RIASSUNTO – [Evoluzione del detrito organico e preservazione dei palinomorfi in due sezioni della parte alta del Frasniano medio, margine meridionale del Sinclinorio di Dinant, Belgio] – *Le palinofacies di due successive unitá calcareo argillose [Membro Boussu-en-Fagne (= Boussu) e Formazione Neuville] della parte alta del Frasniano medio sono state studiate in due localitá coeve sul margine meridionale del Sinclinorio di Dinant (Cava La Boverie e Cava Lion, distanti 60 km). Le due unitá si distinguono per un improvviso aumento nella concentrazione di noduli calcari, che segna un limite di sequenza tra un* "transgressive systems tract" *e un* "high stand systems tract". *Nonostante problemi associati a una alterazione termica differenziale, la sostanza organica delle due unitá mostra tendenze molti simili nelle localitá studiate. In ambedue le localitá il Membro Boussu contiene concentrazioni di detrito organico e di sporomorfi piú alte di quelle della Formazione Neuville, mentre la proporzione relativa di detrito nero (ossidato) rispetto ai frammenti bruni ("damaged fragments") cresce progressivamente dalla base fino alla sommitá della successione studiata. Inoltre, le argilliti sono grige e ricche in pirite alla base e divengono grigio-verdi, nodulari e bioturbate verso il tetto. Pertanto, la crescita relativa del detrito opaco, che è considerata essere le frazione piú resistente ai processi ossidativi, suggerisce un cambiamento nella preservazione della materia organica durante l'intervallo Boussu-Neuville; l'alterazione interessa soprattutto il detrito organico degradato* ("degraded and infested organic debris") *ed in modo praticamente uguale i piú comuni microfossili (acritarchi e spore). Nello stesso tempo, l'abbondanza degli acritarchi diminuisce mentre aumenta il numero degli esemplari rotti. Viene pertanto presa in considerazione anche la possibilitá di una alterazione differenziale dei taxa di acritarchi. Tale possibilitá non è peró confermata da un concomitante relativo aumento degli altri palinomorfi. Inoltre, la successione delle associazioni ad acritarchi e prasinofite, combinata con i dati dell'indice di diversitá di Shannon, suggeriscono somiglianze con il modello di distribuzione di Staplin. Se questo è vero, non è probabile una importante alterazione differenziale di acritarchi e prasinofite e la successione delle associazioni osservate è probabilmente dovuta a cambiamenti nella profonditá del mare che hanno indotto variazione nell'ambiente recifale.*

INTRODUCTION

A knowledge of problems related to sedimentation, alteration, and burial of organic matter is prerequisite to understanding the distribution of organic-walled microfossils in ancient environments and to apply the distribution-data in predictive palaeoecological models.

This paper focuses mainly on problems of alteration when organic matter passes from anoxic or dysaerobic to more oxidizing conditions. The palynofacies of two coeval sections of mid-Frasnian age, each presenting a succession of such depositional conditions, have been studied. Their stratigraphy and sedimentology are well-known and so they can serve as a case of organic matter taphocoenosis.

LOCATION OF SECTIONS AND THEIR STRATIGRAPHIC SETTING

The two analyzed sections are part of the southern margin of the Dinant Synclinorium (Text-fig. 1). The La Boverie section (Boulvain & Coen-Aubert, in prep.) belongs to a succession in a large active quarry where early-middle Frasnian strata are very well exposed. The Lion section lies at the southwest border of the well-known Lion Quarry, type locality of the Lion Member mud mound. The exposed strata have been described by several authors, most recently by Boulvain & Coen-Aubert (1992) and Coen-Aubert (1994).

STRATIGRAPHY

Frasnian stratigraphy of Belgium has been the subject of many publications; Bultynck *et al.* (1998) and Boulvain *et al.* (in press) constitute the most recent contributions. Lithostratigraphic classification into formations and members takes account of rapid vertical and lateral facies variations.

The present paper is concerned with two lithological units, which in ascending order are: the Boussu-en-Fagnes Member (here termed Boussu Member and constituting part of the Grand Breux Formation); and the Neuville Formation. The Boussu Member overlies the Lion Member mud mound, and is succeeded by the Neuville Formation (Text-figs. 2 and 3).

In the Lion Quarry, the Boussu Member is 43 m thick and begins with 4 m of grey nodular bioclastic shales. It passes abruptly upwards into green shales containing discrete calcareous nodules interbedded with calcareous layers. Temporary increase in bottom turbulence is evidenced by sporadic beds of tempestites. The Neuville Formation starts with 4.5 m of shales enclosing abundant, aggregated carbonate nodules and reddish mudstones. The following 8.5 m are characterized by alternating nodular limestones and nodular green shales. The position of the base of the Neuville Formation adopted here follows Coen-Aubert (1994), not Sandberg *et al.* (1992).

At La Boverie Quarry, the thickness of the Boussu Member is reduced to 16 m, partly due to faults. As in the Lion Quarry, the member starts with 4.5 metres of grey shales and limestones rich in corals and crinoids and its lower contact with the Lion Member is sharp. The base of the Neuville Formation is placed at the abrupt change in the abundance of nodules. This unit outcrops for less than 10 m and is represented by nodular limestones and shales. There is also a colour change, from grey to green.

TIME EQUIVALENCE OF STUDIED SECTIONS

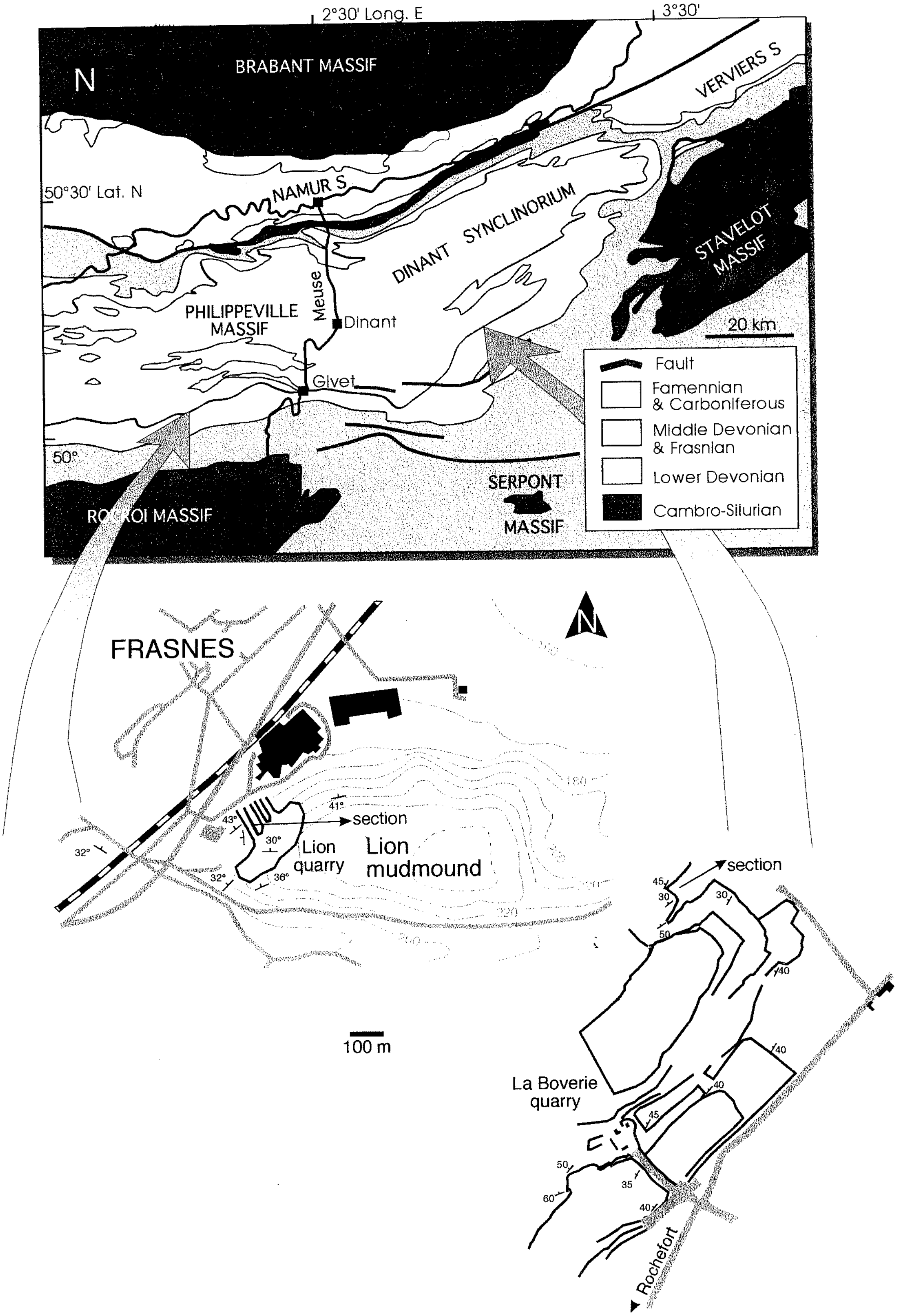
Very detailed conodont analysis of the Lion section was published by Sandberg *et al.* (1992) as part of their study of the Lion mud mound. According to these authors, the Boussu Member belongs to the upper part of the late *hassi* conodont Zone and to the *jamieae* conodont Zone; the boundary between the Boussu-Neuville units is approximately coincident with the *jamiae*-early *rhenana* conodont Zones; and the Neuville Formation covers the early and late *rhenana* conodont Zone. This biostratigraphy however is not confirmed by Bultynck *et al.* (1998) who considered that the Neuville Formation is entirely within the early *rhenana* condont Zone. As discussed by Bultynck *et al.* (1998, p. 61), these differing viewpoints are mainly due to incorrect taxonomic determinations by Sandberg *et al.* (1992) in the Lion Quarry. Moreover, the position of the base of the Neuville Formation adopted here does not follow Sandberg *et al.* (1992). It lies 10.5 m above (Coen-Aubert, 1994). Therefore, the upper part of the Boussu Member belongs to the early *rhenana* conodont Zone. Nevertheless, the conodont zonation gives us a time approximation of ±1 Ma for the studied sequences (Sandberg *et al.*,1992, text-fig. 21).

Conodonts have not been studied at La Boverie. Observations by one of us (M. Coen-Aubert, unpubl.) demonstrate that the lower parts of both studied sections contain the same rugose coral fauna. The relatively short distance between the sections (6O km) and the fact that they are localized within the same bathymetric belt lead us to accept, despite the absence of conclusive biostratigraphic control, that the two sections are approximately coeval.

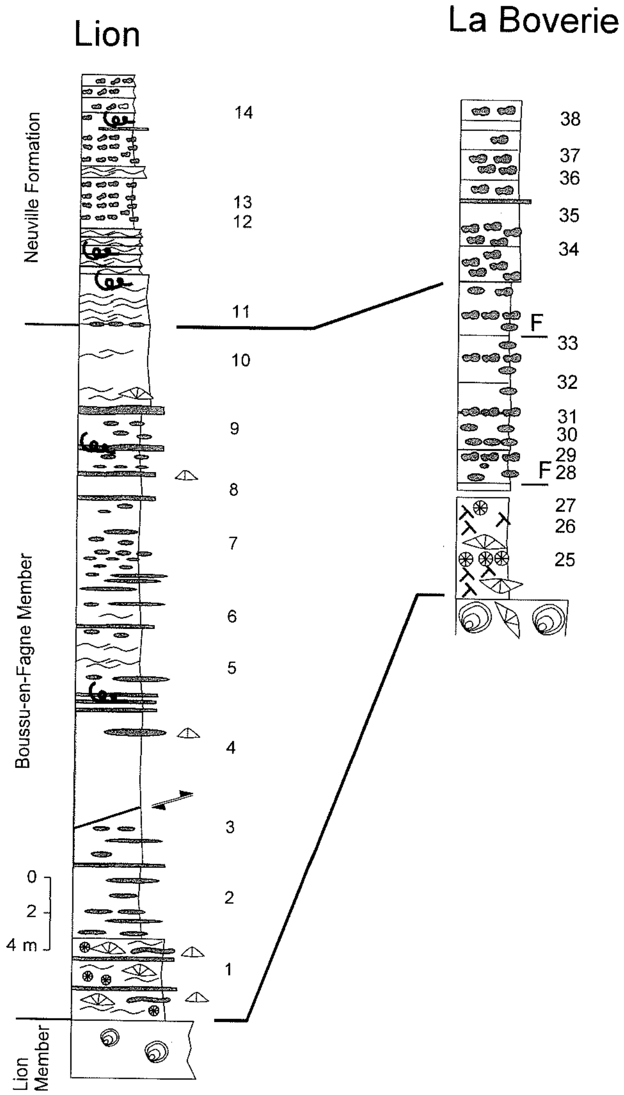
PREVIOUS STUDIES

Boulvain & Herbosch (1996) and Boulvain & Coen-Aubert (1998) investigated the sedimentology of bioherms within the upper part of the Frasnian succession and proposed a palaeogeographic evolution of the Frasnian platform in relation to eustacy. They interpreted the Boussu Member as an accumulation within a transgressive systems tract and the Neuville Formation in a highstand systems tract. At the very base of the Boussu Member, a rapid rise in sea level drowned the Lion reefal mud mound; during Neuville time, a highstand episode resulted in resumption of reefal activity in several parts of the basin.

Sandberg *et al.* (1992) made a quantitative conodont analysis of the Lion mud mound and adjacent strata based on several samples collected in the Lion section (the same section studied herein). These authors identified variations in the conodont biofacies, from polygnathid or polygnathid-icriodid (Boussu Member) to polygnathid-icriodid or palmatolepid-polygnathid (Neuville Formation), in response to a general, though fluctuating, deepening. However data presented herein (see also Boulvain & Herbosh, 1996) indicate that the Neuville Formation probably does not represent a deeper facies than the Boussu Member.



Text-fig. 1 - Location of the sections studied at the southern border of the Dinant Synclinorium, Belgium.



Text-fig. 2 - Sample positions and lithostratigraphic correlation between the two sections investigated.

Helsen (1992) presented a map depicting conodont colour alteration indices (C.A.I.) of the Frasnian rocks of the Dinant Synclinorium. The sections studied in the present work are included in the same isograd, between 3.0 and 4.0 C.A.I., which corresponds to burial temperatures of 120-190°C.

Observations in the Lion section formed part of the results reported in the Praha CIMP Symposium by Vanguestaine *et al.* (1997). Three assemblages were distinguished:

1) Assemblage exhibiting dominance of thin-spined acritarchs (*Micrhystridium* Deflandre, 1937, *Solisphaeridium* Staplin, Jansonius & Pocock, 1965, *Veryhachium* Deunff, 1954 *ex* Downie, 1959, and ?*Villosacapsula* Loeblich et Tappan, 1976) associated with a peri-reefal environment.

2) Assemblage characterized by abundance of thick-spined acritarchs (*Baltisphaeridium* Eisenack, 1958 *ex* Eisenack, 1959, *Hercyniana* Burmann, 1976, *Multiplicisphaeridium* Staplin, 1961, and ?*Visbysphaera* Lister, 1970) representing an off-reef environment.

3) Assemblage comprising poorly preserved acritarchs with a higher proportion of sphaeromorphs, spores, chitinozoans, and scolecodonts. The significance of this assemblage is still unclear.

ANALYTICAL METHOD AND RESULTS

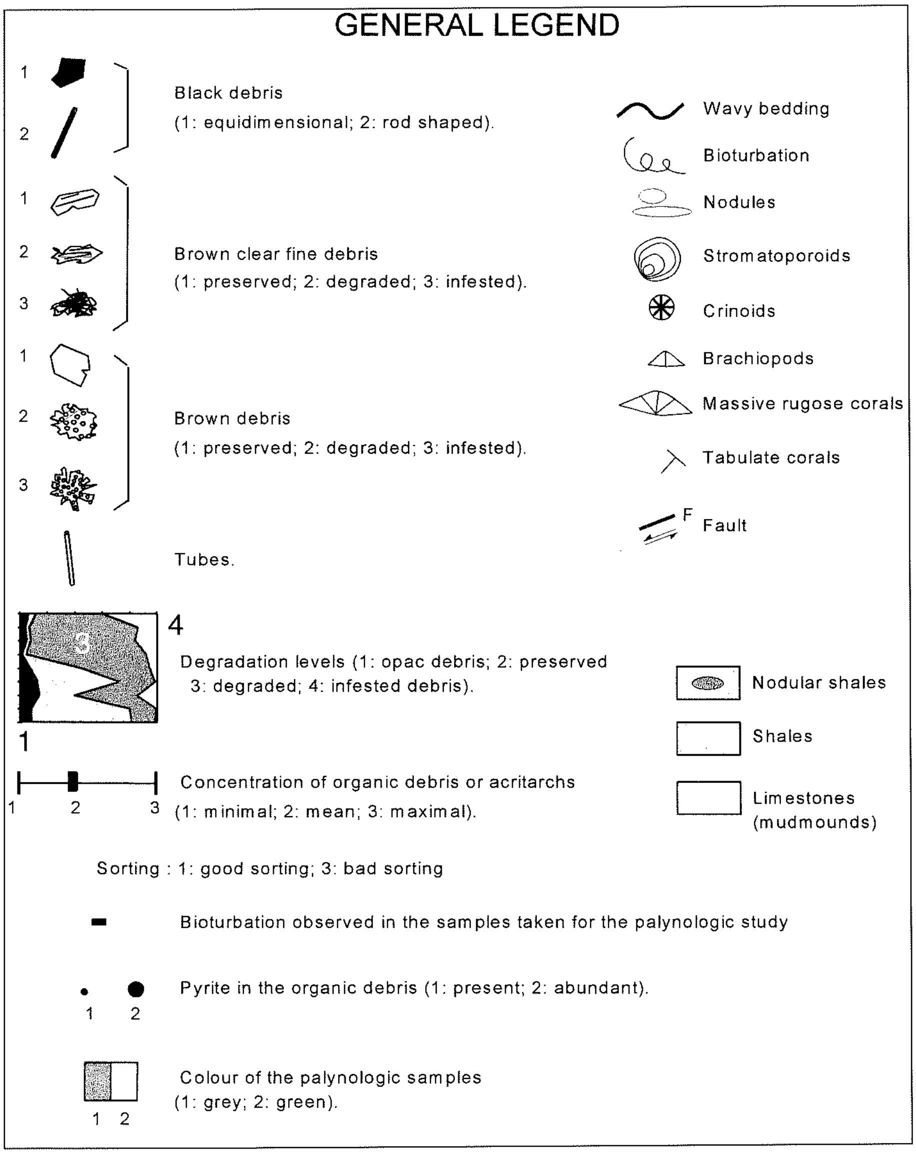
Each sample was prepared using the Liège University technique (Streel, 1965). A known quantity of exotic spores (*Lycopodium*) was added as a standard to be compared with the autochtonous material, according to the method described by Stockmarr (1971). The first stage of the microscopic organic matter study consisted of identifying the different kinds of components present in the samples and establishing a system of classification, using a transmitted-reflected light microscope. This type of analysis enabled observation of the variation in biodegradation of the organic matter, a feature discussed by several authors (Hart, 1986; Gorin & Steffen, 1991) and applicable to interpretation of changes in sedimentary conditions. It is a direct function of the time passed by the organic matter in the superficial environments, i.e. aerobic sedimentary bottoms where fungi, bacteria and burrowing animals are the main degrading factors. Consequently, organic matter biodegradation is directly related to sedimentation rate and oxygen content (Hart, 1986). For this reason, the present work attempts to estabish an organic matter classification system with emphasis on degradation of the different kinds of fragments, even if some of these are of unknown biological origin.

THERMAL ALTERATION INDEX

Thermal alteration index (TAI), based on miospore colouration in the entire range of spore types, has been evaluated in the two areas utilizing five samples selected from both lithological units. Results clearly demonstrate differences in burial state, not indicated by conodonts (Helsen, 1992). The La Boverie area was more deeply buried (mean TAI 4, according to the scale of Traverse, 1988, p. 416) than the Lion region (mean TAI 3-3+). Organic matter is slightly darker in the first section than in the second. Thus, among the dark rounded palynomorphs recorded at La Boverie, it often proved difficult to distinguish spores from sphaeromorphs.

TOTAL ORGANIC MATTER CONCENTRATION

The total organic matter concentration (Text-fig. 4; Text-fig. 3 for legend) is the sum of the amount of



Text-fig. 3 - Explanation of conventional symbols used in this paper.

palynomorphs and organic debris. As stated earlier, concentrations have been estimated by the marker grains method (Stockmarr, 1971).

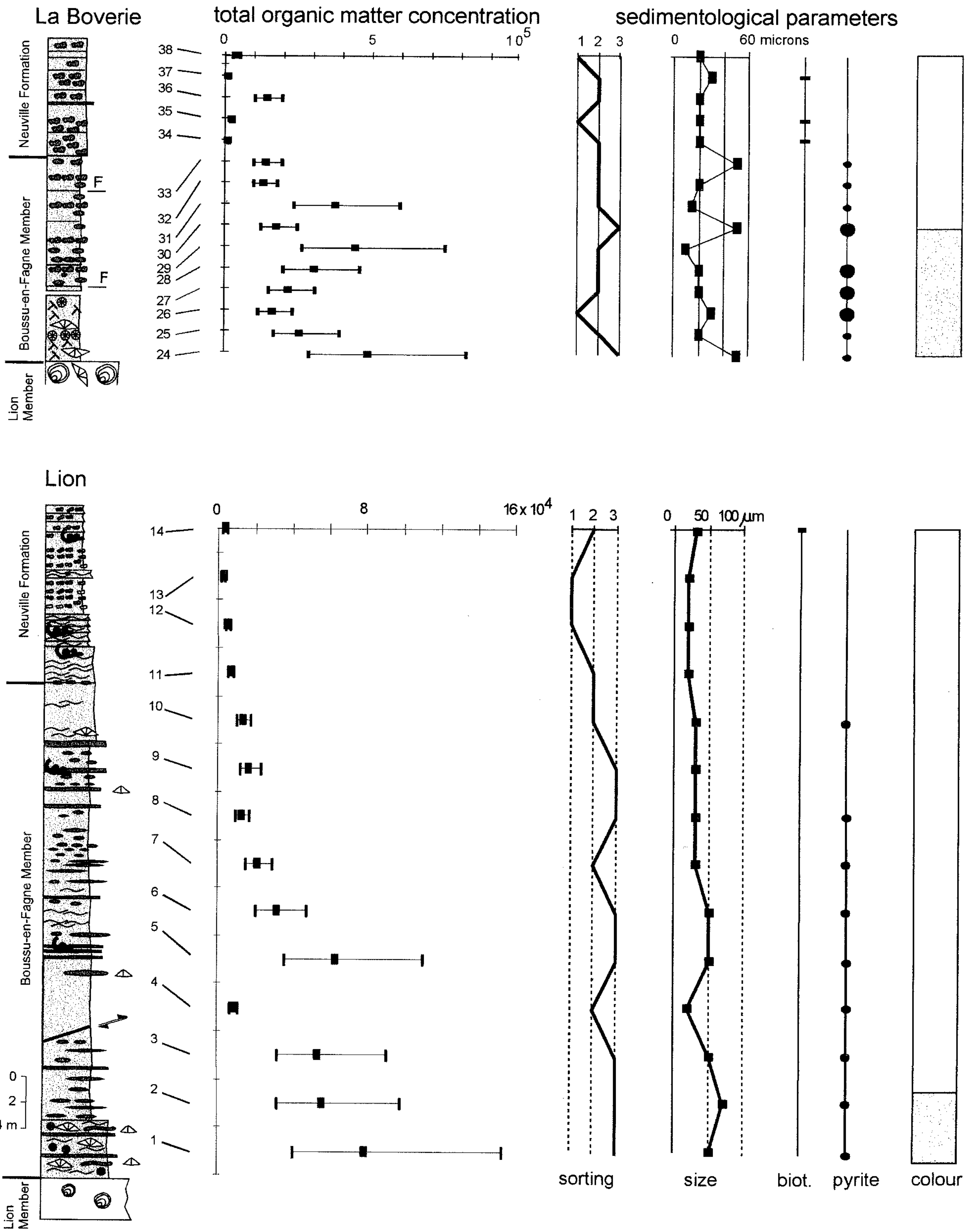
The curves clearly show a pronounced upsection decrease in the values recorded at both localities. The mean values calculated for the Boussu Member and the Neuville Formation are respectively 26,800 and 5,200 specimens per gram of rock at La Boverie, and 35,700 and 4,000 at Lion.

As shown in Text-fig. 4, a clear correlation exists between the highest organic concentrations, grey colour of the rocks, and pyritization of the organic membranes. Another correlation also occurs between the lowest organic densities, the green rock colouration, and absence of pyrite. Also observed was more bioturbation in the Neuville Formation than in the Boussu Member, while bioturbation is more prevalent in the La Boverie than the Lion section.

Several explanations for the decrease in organic matter in the upper part of the profiles may be proposed:

1) *Differences of compaction rate between Boussu and Neuville units* – The former, composed of more shaly strata, underwent higher compaction and hence higher organic matter concentration than the latter in which the consolidation of the limy nodules preceded compaction.

2) *Palaeogeographic change* – The contact between Boussu and Neuville units represents a significant change in palaeogeography of the Frasnian basin, involving variations in current circulation patterns, organic matter productivity, and sedimentation. This is supported by sequence stratigraphic analysis



Text-fig. 4 - Total organic matter concentration and sedimentological parameters. Note that total organic matter concentration is not expressed at the same scale in both profiles (see Text-fig. 3 for legend).

(Boulvain & Herbosch, 1996; Muchez *et al.*, 1996) in which the contact between these units, recognizable throughout the southern part of the Dinant basin, has been chosen as a systems tract boundary. Moreover, the contact also corresponds to major faunal extinctions as exemplified among rugose corals by replacement of the *"Hexagonaria"* fauna by the *"Phillipsastrea"* fauna (Coen-Aubert, 1994).

3) *Preservation* – Amount of organic content may not be a function of sedimentation (thanatocoenosis) but of preservation (taphocoenosis). Boulvain & Coen-Aubert (1992, p. 38) recorded in the Lion section carbonate concentrations of 42% in the first 4 m (where sample 1 had been collected), fluctuating between 6% and 10% through the remaining Boussu Member. Boulvain (unpubl.) has measured at least 20% carbonate in the Neuville Formation. However, the samples in this study are uniformly mudstones aside from the previously mentioned differences in colour, pyrite, bioturbation, and compaction rates.

As stated by Tyson (1995, p. 131), an inverse relation links bioturbation and resulting organic content: highly bioturbated sediments exhibit low total organic matter, while non-bioturbated sediments feature high contents of organic residues. Bioturbated mudstones in the Neuville Formation display a lower amount of organic matter. Tyson (1995) showed that, in carbonate facies, there is a positive correlation between bioturbation and the carbonate content. Bioturbated shales in the Neuville Formation are richer in carbonate. Bioturbation can also explain size decrease and better sorting of black debris observed in the Lion section (Text-fig. 4).

This does not necessarily imply that both units as deposited had more or less the same mineral and organic content and are now lithologically differentiated by subsequent diagenetic processes. The importance and effects of facies shifts on the initial mineral and organic (biocoenosis) particle content are unknown. However, the experience of the Liège palynology laboratory is that pure limestone beds of the Middle and Late Devonian and Dinantian Belgian formations are nearly always devoid of organic matter. This absence of organic material is linked to the absence of terrigenous muds, the alkalinity of the palaeoenvironment (Dorning & Bell, 1987, p. 272; Traverse, 1988, p. 34), or to more oxidizing conditions.

4) *A combination of mechanisms* – For example, the carbonatation and bioturbation (3) induce less compaction (1) and dissolution of organic residues either by alkalinisation or by oxidation (3). As anoxic or dysaerobic conditions are related to deep sea phases, the hypothesis (3) is in agreement with highstand conditions in Neuville Formation (2) implying a progressive decrease of water depth and a more aerobic environment (3).

Observations of organic debris allow verification of hypothesis (3) and how dissolution of organic matter would proceed.

Organic debris percentages

Nine classes of organic debris were formulated: opaque equidimensional and opaque elongated (rods) debris; translucent tubes; clear brown and dark brown equidimensional debris (Text-fig. 5.) in which three additional categories were constructed: preserved, damaged and infested, depending of the state of preservation, following Hart's (1986) classification.

Text-fig. 6 shows the relative percentage of the values of these nine classes for both localities. Two diagrams are shown: on the left, classes by classes; on the right, all types grouped in four categories: opaque, well-preserved, degraded, and infested debris. At both localities, relative increases in opaque debris and decreases in degraded and infested debris are observed, but not assessed statistically.

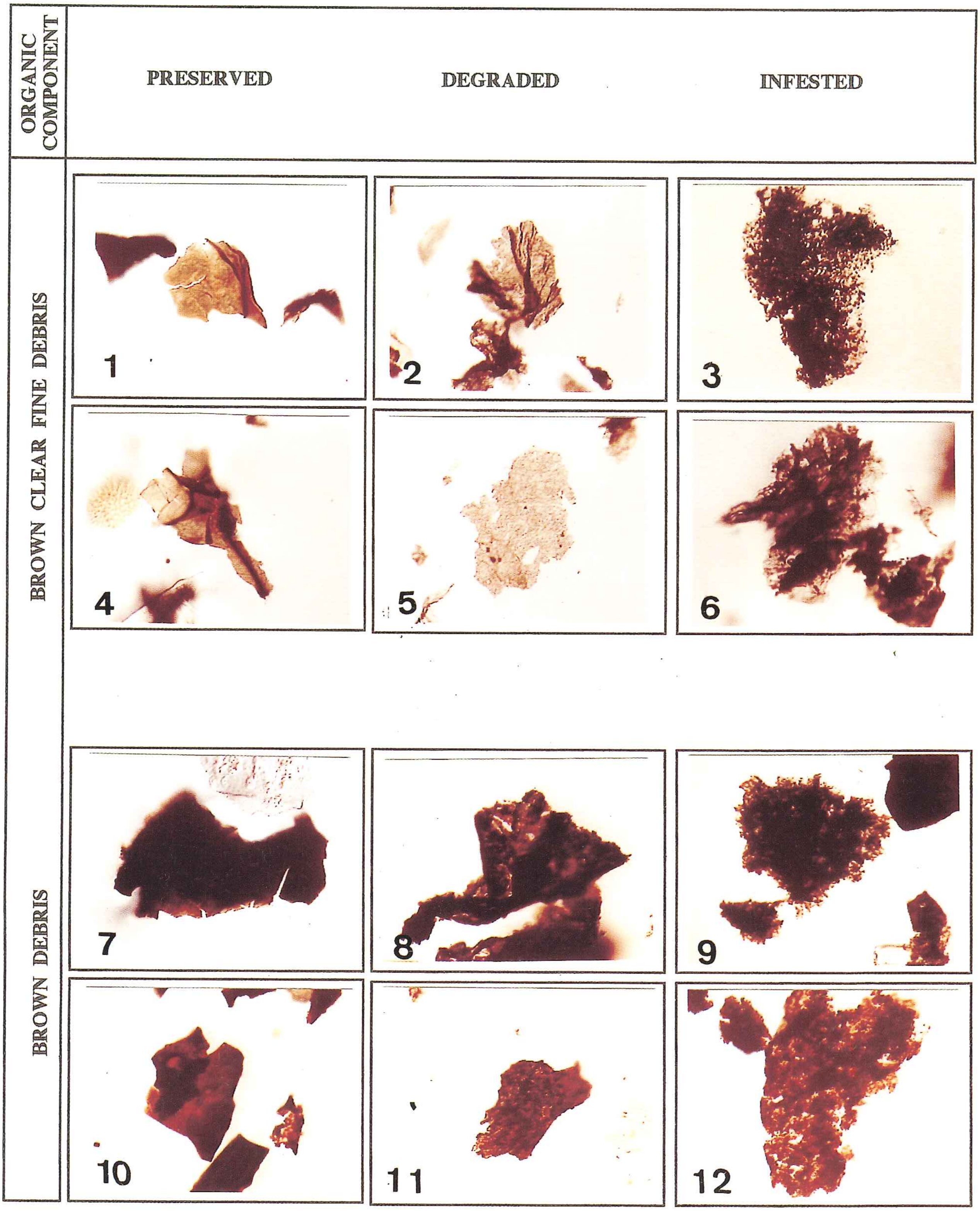
Facies changes could explain such shifts in relative proportions of organic debris. Oxygen availability also seems pertinent when considering the relative rise of opaque debris versus degraded-infested debris, parallel to the decrease in total concentration of the organic matter. Opaque organic debris is most resistant to the oxidation process. Degraded and infested debris were either less resistant to oxidation or were preserved during inital stages of alteration. Sample 36 (Text-figs. 4, 6) presents a higher total concentration and a lower opaque versus degraded-infested ratio; this supports the former hypothesis.

These observations suggest that part of the organic matter is altered when passing from anoxic or dysaerobic conditions in the lower part of the sequence to more oxidizing environment in the upper part of the studied sections. The other explanation (change in the physical environment) could be checked by examining the palynomorph content.

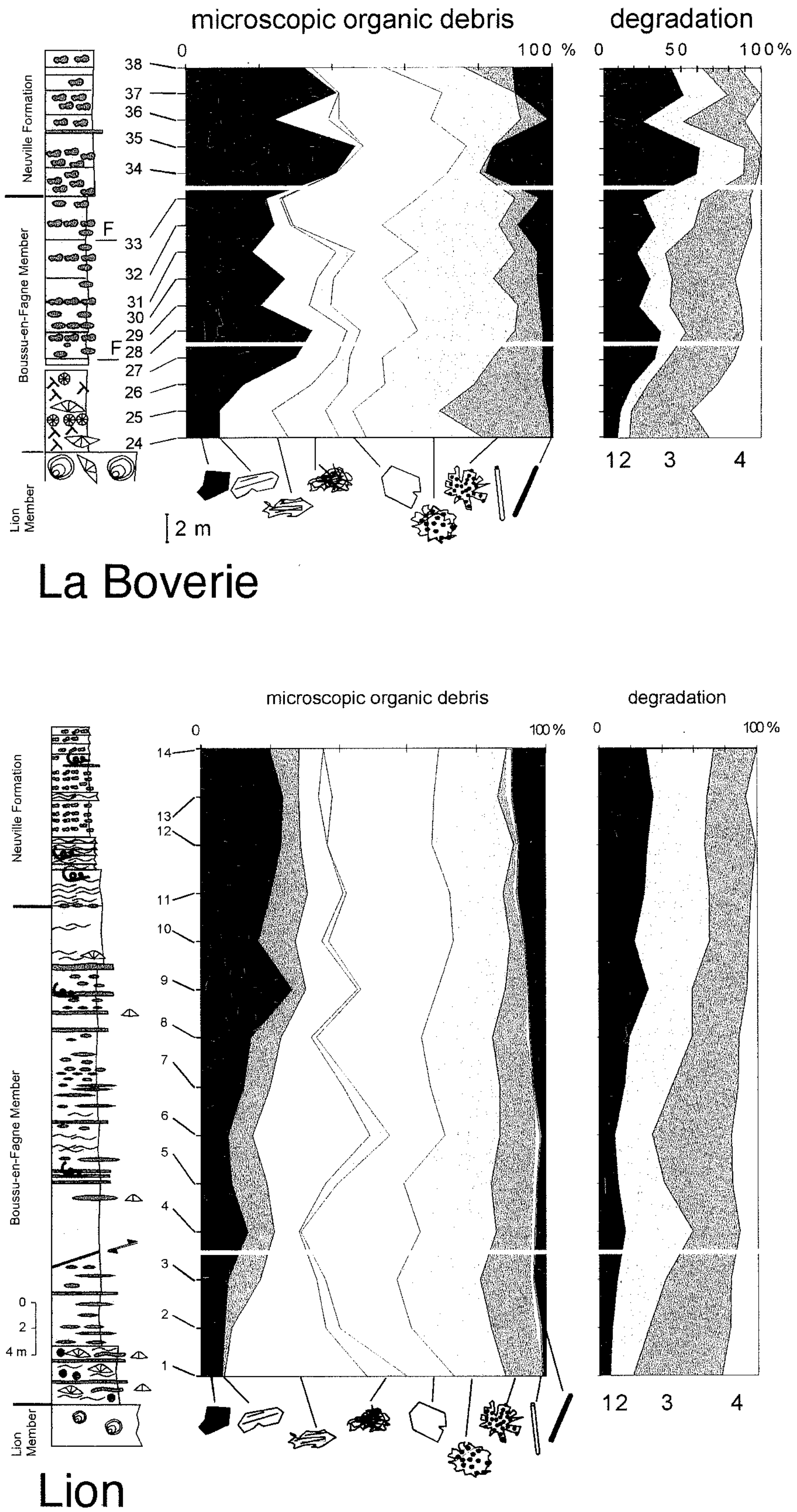
Palynomorph concentrations and percentages

The following microfossils have been counted: acritarchs and prasinophytes, spores, scolecodonts, Chitinozoa, and undetermined spherical particles (spores or sphaeromorphs).

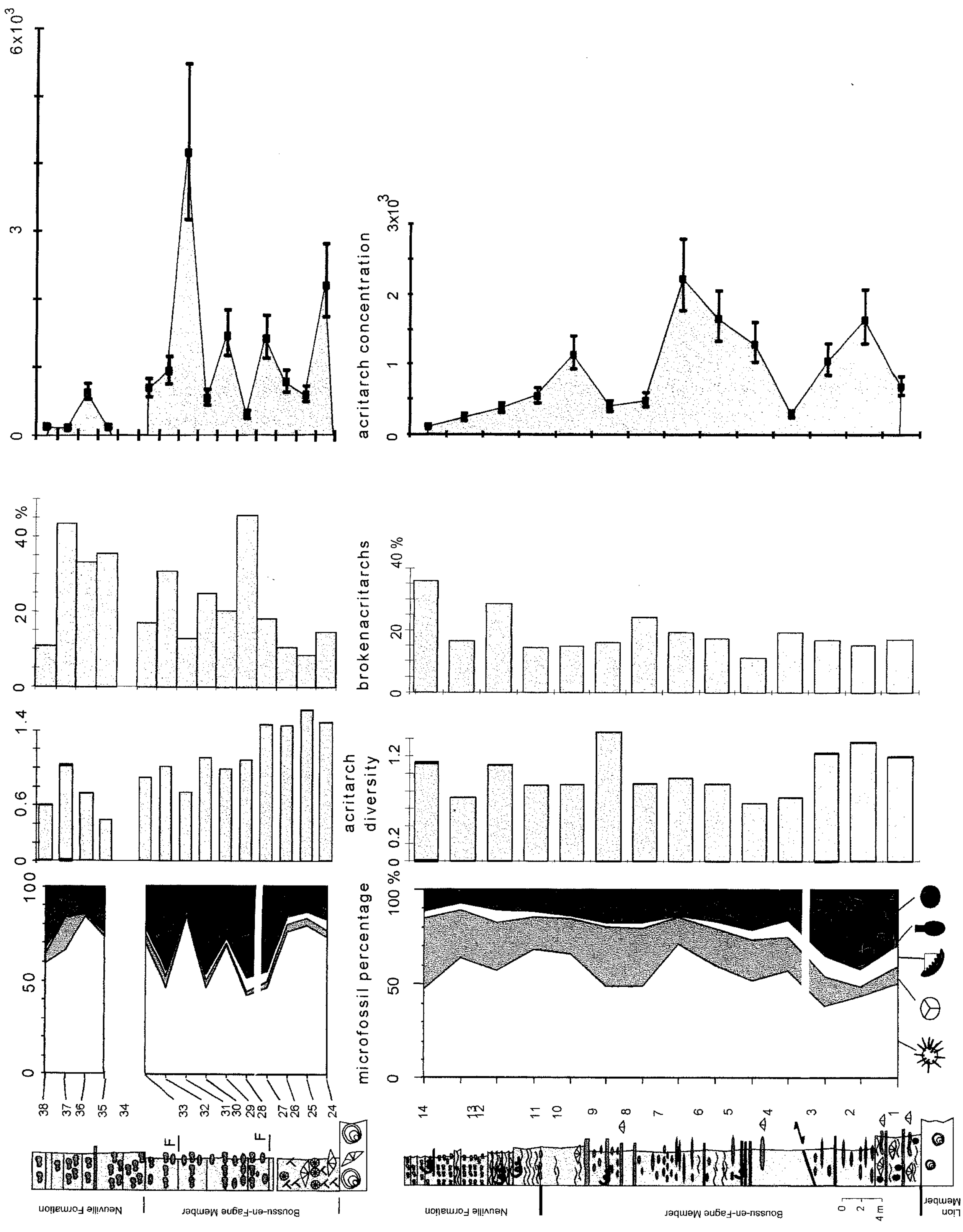
The curves of concentrations (Pardo-Trujillo, 1997) show the general decrease already displayed in the preceding diagrams. Particularly interesting are the results expressed as percentages (Text-fig. 7). Spore to acritarch ratios have been used by several authors (Streel & Vanguestaine, 1989; Wicander & Wood, 1997) to evaluate distance from the shoreline or position of an assemblage in an inshore-offshore transect. Distinct changes in the sedimentary facies would affect the relative percentages of the various palynomorph groups. The curves of the percentage variations (acritarchs vs. other microfossils) are relatively stable implying no appreciable facies variation. This observation supports the indirect preservation/concentration relationship hypothesis, and alteration would be more or less equivalent for the different microfossil categories.



Text-fig. 5 - Examples of translucent debris and their different states of preservation (modified from Hart, 1986). Each photomicrograph is 150 μm wide.



Text-fig. 6 - Changes in percentages of organic debris in the La Boverie and Lion sections. On the left by class; on the right, all classes grouped in four categories.



Text-fig.7 - Percentage distributions of microfossils in the two sections studied; and concentration, preservation, and diversity of acritarchs (using Shannon diversity index). Above, La Boverie profile; below, Lion profile. Note that miospores seem more abundant at Lion; at La Boverie, they could be confused with unidentified black spherical objects.

The same conclusion arises when considering Text-fig. 8 which depicts the mean rates of decrease of some types of organic debris and microfossil concentrations, when passing from one unit to another. Acritarchs and spores have a decrease rate comparable to black rods and opaque debris. The clear brown thin debris is the most affected, having a decrease rate of 89%. This indicates that there is no important differential decrease of one type of microfossil compared to another.

ACRITARCH CONCENTRATION, PRESERVATION, AND DIVERSITY

Text-fig. 7 shows evolution of acritarch concentration values. The lowest values are observed upwards as for other organic particles. Preservational change based on the number of broken specimens typically increases upwards at La Boverie and is less evident at Lion. Bioturbation could well be responsible for this change. Broken acritarchs could also result from greater turbulence, but organic particle size does not increase in higher parts of the sections (Text-fig. 4). Therefore, bioturbation would be the causal agent here.

The diversity has been calculated by the Shannon index. The 16 categories, listed in the next section, form the basic quantified material. At La Boverie, the values show a decrease, but are roughly similar at Lion. No abrupt change is observed at the Boussu/Neuville boundary; this would be expected if important environment change was effective at this level. The decrease in diversity at La Boverie can be interpreted either as related to preservational deficiencies due to bioturbation or as slight facies variation, implying changes in the biocoenosis. However, the extent to which alteration affected acritarchs at the specific/generic level also needs to be considered. It is tempting to attribute the diversity decrease, in the La Boverie profile, to differential dissolution of some acritachs, for example, of those with thin membranes. This possibility is supported by Zonnefeld *et al.* (1997), who have demonstrated that dissolution can differentially affect Pleistocene dinoflagellates.

PERCENTAGES OF SOME ACRITARCH AND PRASINOPHYTE CATEGORIES

Current results are based on 16 categories of taxa or groups of taxa:

1 - (Prasinophyte-like): *Cymatiosphaera* O. Wetzel, 1933 *ex* Deflandre, 1954, *Duvernaysphaera* Staplin, 1961, *Maranhites* Brito, 1965, and *Pterospermella* Eisenack, 1972.

2 - (Thin ornamented spheres): *Gorgonisphaeridium* Staplin, Jansonius & Pocock, 1965 with minute ornamentation, *Elektoriskos* Loeblich, 1970, and *Lophosphaeridium* Timofeev, 1959 *ex* Downie, 1963.

3 - Sphaeromorphs with smooth surface.

4 - *Gorgonisphaeridium* with true processes.

5 - *Visbysphaera*? *fecunda* Vanguestaine, Declairfayt, Rouhart & Smeesters, 1983.

6 - (Thin spined acanthomorphs): *Micrhystridium*, *Solisphaeridium*, and *Unellium* Rauscher, 1969.

7 - *Multiplicisphaeridium*.

8 - *Veryhachium*.

9 - *Villosacapsula*? *ceratioides* (Stockmans & Willière, 1962) Loeblich & Tappan, 1976.

10 - *Daillydium*.

11 - *Hercyniana sprucegrovensis* (Staplin, 1961) Vanguestaine *in* Kimpe *et al.*, 1978.

12 - *Polyedryxium* Deunff, 1954.

13 - *Stellinium* Jardiné, Combaz, Magloire, Peniguel & Vachey, 1972.

14 - *Baltisphaeridium* sp. aff. *B. longispinosum in* Vanguestaine *et al.*, 1983.

15 - Undetermined.

16 - Other sporadic genera; e.g., *Navifusa* Combaz, Lange & Pansart, 1967, *Tunisphaeridium* Deunff & Evitt, 1968.

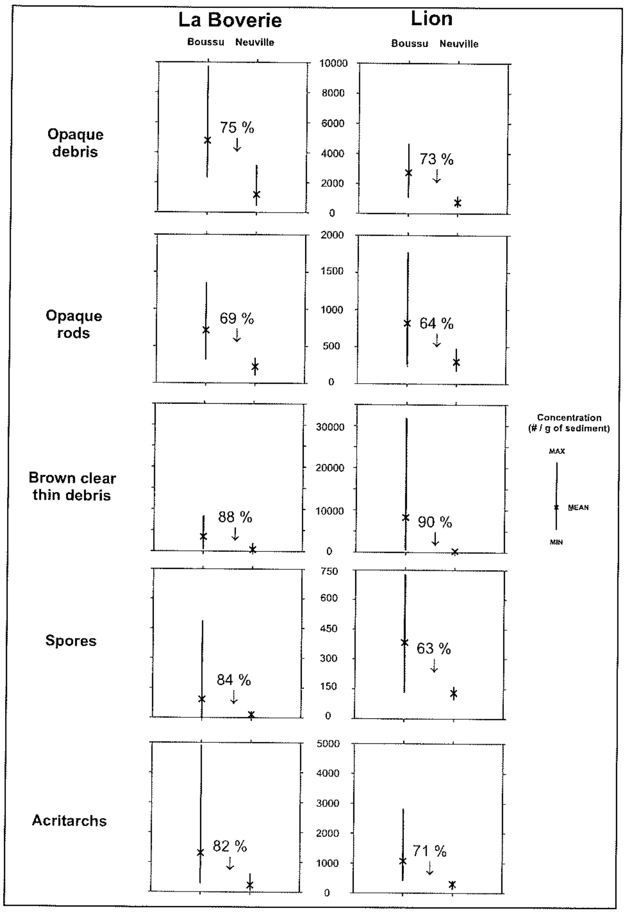
Concentration curves (Pardo-Trujillo, 1997) are not reproduced here. Text-fig. 9 focuses on percentage curves, which clearly show similar variations at both localities: decrease from base to top of the prasinophytes (*Cymatiosphaera, Duvernaysphaera, Maranhites, Pterospermella*); decrease of the group of finely ornamented acritarchs (small *Gorgonisphaeridium, Elektoriskos, Lophosphaeridium*); concomitant increase in thin-spined forms (*Micrhystridium, Solisphaeridium, Unellium*). Enrichment in *Visbysphaera*? *fecunda* is observed in the Boussu Member. An important peak of *Villosacapsula*? *ceratioides* is clearly evident in the uppermost part of both profiles. The significance of additional variation in taxonomic diversity is unclear.

Diversity expressed in Text-fig. 7 is also indicated in the number of categories encountered (Text-fig. 9). The lower portion of the La Boverie section is more diverse taxonomically than the equivalent part at Lion while the facies in both areas is similar (anoxic or dysaerobic). This does not support an hypothesis of differential alteration of organic matter linked to decreased diversity. Differences in biocoenosis between the two localities seems to be a better explanation.

SEQUENCE-STRATIGRAPHIC INTERPRETATION

An interpretation of these variations with respect to water depth in the Frasnian basin (as per Boulvain & Herbosch, 1996) is proposed below:

1) At the very base of the Boussu Member, a rapid rise in sea level effectively drowned the Lion reefal mud mound. Highest values of finely ornamented spheres belonging to the *Elektoriskos/Gorgonisphaeridium/Lophosphaeridium* group (reaching up to 25% in some levels) and prasinophytes (*Cyma-*



Text-fig. 8 - Mean rates of concentration decrease of some types of organic debris and microfossils.

tiosphaera, Duvernaysphaera, Maranhites, Pterospermella) accompanied this first phase.

2) In mid-section, development of *Visbysphaera*? *fecunda* perhaps corresponds to the maximum flooding. In these middle strata, the assemblage is very similar to off-reef associations recorded elsewhere in the basin (Vanguestaine *et al.*, 1997);

3) In the upper part of the sequence, under highstand conditions, the *Micrhystidium* group is dominant (up to 80% of all acritarchs), representing an assemblage of peri-reefal type (Vanguestaine *et al.*, 1997). This is consistent with contemporaneous reefal activity observed at several localities distributed throughout the basin. Moreover, these upper strata at Lion record a bloom of *Villosacapsula*? *ceratioides* (up to 50%), immediately succeeding the conodont "*Palmatolepis semichatovae* event" (Sandberg *et al.*, 1992, p. 48), which is claimed to signify a transgression.

These observations are more indicative of ecological variations than the result of differential alteration. Taphonomic circumstances would, however, explain the generally observed decrease in organic matter (debris and palynomorphs) in the upper part of the profiles. This phenomenon is related to the passage from transgessive to highstand conditions, from anoxic or dysaerobic to more oxidizing environments.

Comparison with Staplin's model

According to the model suggested by Staplin (1961) in his study of Frasnian strata of Alberta, acritarch diversity and concentration ("hystrichospherid" abundance) increase with distance from the reef.

Observations presented herein do not contradict this model, because at the base of the analyzed sequence, in deep offshore conditions, diversified acritarch assemblages and high organic matter concentrations are observed. Towards the top of the succession, less diversified assemblages and reduced acritarch concentration, contemporenous with resurgent reefal activity, are recorded.

SUMMARY AND CONCLUSIONS

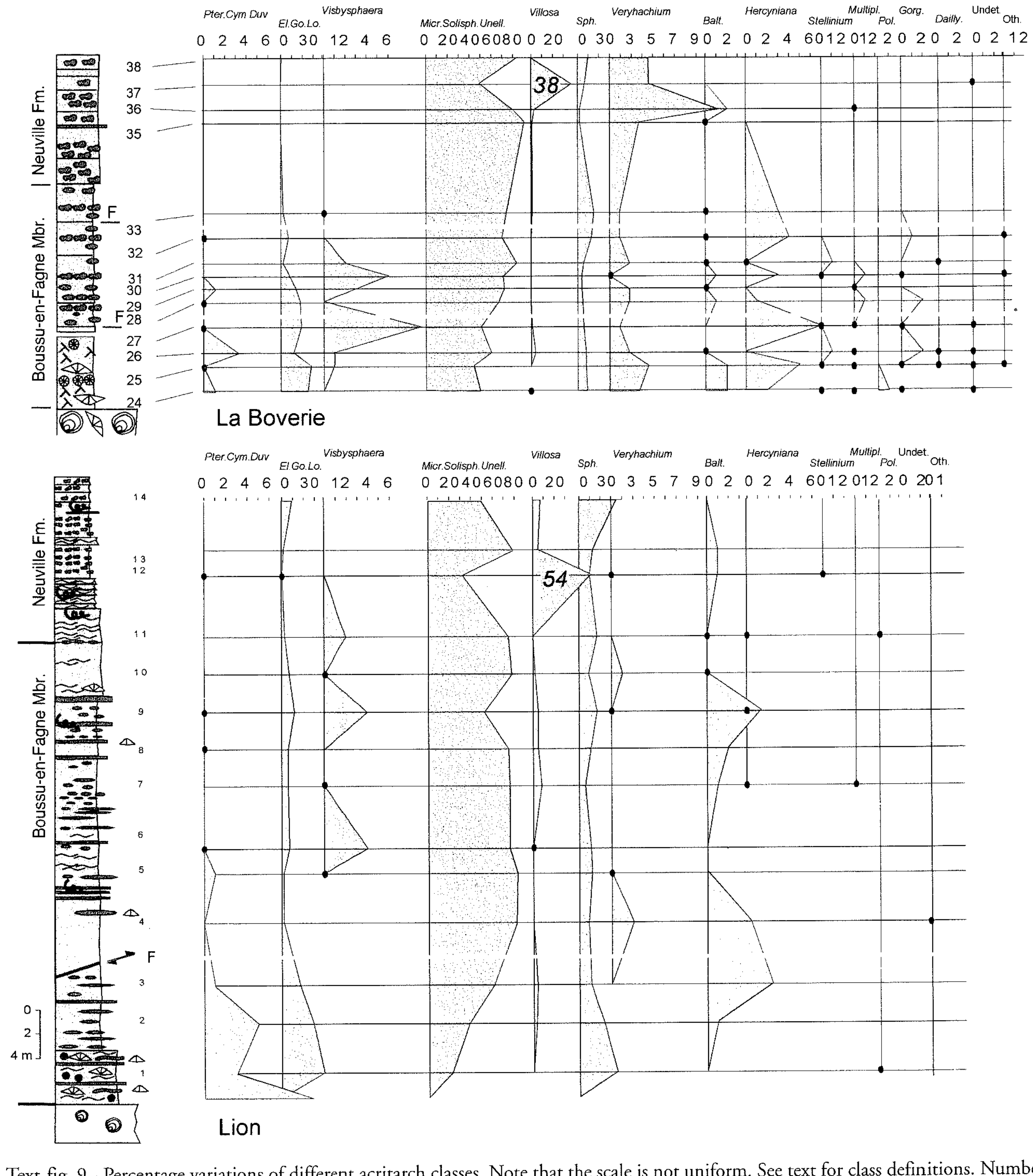
This research is concerned with organic matter taphonomy as a preliminary step to an acritarch distribution study with the goal to establish a predictable palaeoecological model. Two successive shaly units, studied from two discrete localities, represent a transition from an off-reef transgressive system to peri-reefal highstand conditions.

Differences in burial state of the sequences at the two localities have been noted. The distinct resulting colouration of the organic particles after thermal alteration has not been a major handicap for this study. However, estimation of spore quantities has been difficult in the La Boverie section as many miospores were probably confused with other black spherical objects.

At both localities, the two units show, after taphocoenosis, considerable differences in the total organic matter content. These differences are probably a consequence of minor facies changes, involving alteration of organic matter in alkaline and/or oxidizing conditions. Variation in oxygen availability is evidenced by changes in rock colour, in organic matter pyritisation, in observed sediment bioturbation, and the inferred effects of bioturbation (acritarch preservation, size and sorting of organic particles). Differential compaction rates could also be responsible for part of the concentration reduction.

This alteration differentially affected the organic debris: opaque organic matter is less altered than the damaged and infested particles. On the other hand, microfossils react like opaques.

Acritarchs and prasinophytes show relatively stable proportions indicating only slight changes in the shoreline position. Differences in preservation are noted, but no differential alteration is proven. A succession of assemblages is observed probably in response to slight changes in water depth, inducing variation with respect to the reefal environment.



Text-fig. 9 - Percentage variations of different acritarch classes. Note that the scale is not uniform. See text for class definitions. Numbers within the graphs of *Villosacapsula* refer to exceptional percentages of *V. ceratioides* at the same level in both sections.

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