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NEW BIOSTRATIGRAPHIC AND CHRONOSTRATIGRAPHIC DATA FROM THE SAUTOU FORMATION AND ADJACENT STRATA (CAMBRIAN, GIVONNE INLIER, REVIN GROUP, NORTHERN FRANCE) AND SOME LITHOSTRATIGRAPHIC AND TECTONIC IMPLICATIONS

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(8 figures, 3 plates)

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ABSTRACT. In the western part of the Givonne Inlier, the “Falizette” and the “Claire-Terne de la Borne” rivers exhibit sections described as belonging, in ascending order, to the La Chapelle (Rv2), Illy (Rv3) and Sautou (Rv4) Formations. The “Falizette” section yielded acritarchs of zone 4 (locally 4b) similar to assemblages observed earlier (Vanguestaine, 1978) in the “Givonne” and “ Hatrelle” valleys of the Givonne Inlier. In the “Terne de la Borne” section, the strata described as belonging to the Illy Formation and most part of the Sautou Formation, the latter in its type locality, provided acritarchs of zone 2 (and possibly 1) and do not correlate therefore with the Rv3 and the Rv4 of the Rocroi Inlier but with Rv2 (and possibly Rv1) of the same area. This correlation is reinforced by the observation in the sequence of a roofing slate seam, previously undescribed, a possible equivalent of the Peureux Member, characterizing the upper part of Rv1 in the Rocroi Inlier.
Besides specimens pointing to an acritarch biozone 2 assemblage, the richest sample of the Sautou Formation also yielded rare examples of acritarch species which have not previously been recorded in Belgium or the surrounding areas. They are *Adara alea, Celtiberium geminum,* possibly *Eliasum llaniscum, Multiplicisphaeridium martae* and *Retisphaeridium postae.* The probable metazoan *Ceratophyton vernicosum* has also been observed. Compared to the well dated Newfoundland Cambrian succession, acritarch biozones 2 assemblages indicates a mid Middle Cambrian age. This new chronostratigraphic result not only allows a better calibration of the Belgian acritarch zonation with respect to the acritarch and trilobite international zonations but also confirms our interpretation of the lithostratigraphic succession.

KEYWORDS. Acritarchs, Revin Group, Givonne Inlier, northern France, Middle-Upper Cambrian, lithostratigraphy, chronostratigraphy

1. Introduction

Palynological researches in the Givonne Inlier have been totally negative in the eastern part, the Muno metamorphic area, and positive in the less metamorphic (deep anchizone to epizone) central part and western part (Vanguestaine, 1973, 1978). It is assumed that the deep epizonal metamorphism (Beugnies, 1987) in the eastern part destroyed all acritarch organic matter during the Devonian and Carboniferous sedimentation phase and/or the Hercynian orogeny. In the central and western parts, decreasing metamorphism led to the preservation of organic matter and the recognition of acritarch biozones 3 and 4b (Vanguestaine, 1978). The fossiliferous lithological units, the La Chapelle Formation (also called Rv2) and the lower part of the Illy Formation (= Rv3) have revealed a comparable biostratigraphical signature to their lithostratigraphic equivalents in the Rocroi and Stavelot Inliers, despite diachronism between the three areas and a possible gap in the Rocroi Inlier (Vanguestaine, 1992).

Other unpublished observations in strata described as belonging to the upper part of the Illy Formation (Rv3) and in the Sautou Formation (RV4) in the Terne de la Borne river section, at the western end of the Inlier, with too little identifiable specimens, were left uninterpreted (samples Givonne-4,-5,-6,-7 and –8 *in* Vanguestaine, 1973).

The aim of the present paper is to restudy the Claire-Terne de la Borne sections based on new sampling in an area with discontinous outcrops and on a new lithostratigraphy which was not dated yet palaeontologically. The Terne de la Borne section is the type locality of the Sautou Formation (Rv4) (Beugnies, 1960b). A nearby section in the Falizette river valley has also been sampled as it exhibits an easily recognizable sequence of slates immediately below and above the Olly Member, a roofing slate seam, in-between the La Chapelle (Rv2) and the Illy (Rv3) Formations. The study of the La Falizette section will serve not only to evaluate its biostratigraphic position with respect to the succession in the Claire-Terne de la Borne valleys but also to compare with coeval strata in the median part of the Inlier, in the Givonne and Hatrelle river areas (Vanguestaine, 1978). The studies described herein were preliminary presented by Léonard & Vanguestaine (2004).

2. Geological framework

The Givonne Inlier is the most southern of the six lower Palaeozoic outcrops in Belgium and surrounding countries (Fig. 1). It forms the core of a Hercynian anticlinal fold, the Givonne anticline, has a Prídolí-Lochkovian cover to the North (the Fepin conglomerate of the Neufchâteau-Eifel Synclinorium) and is concealed by Jurassic sediments of the Paris Basin to the South.

According to Beugnies (1960b), the structure of the Givonne Inlier is characterized by a Caledonian anticlinal, the Bosséval anticlinal, of which the axis coincides with the Hercynian Givonne anticlinal. This apparently simple structure is extraordinarily complicated by secondary, nearly isoclinal folds and a strong slaty cleavage while outcrops are very discontinuous. Therefore a lithostratigraphic study cannot result in an accurate stratigraphical column.

The siliciclastic sediments, mainly grey or blue grey quartzites and dark grey slates, form a comprehensive series in which nevertheless four formations are distinguished on the relative abundances of the two lithotypes. They are from oldest to youngest: the La Chapelle (Rv2a), Illy (Rv3),

Figure 1: Location of the Givonne Inlier within the Lower Palaeozoic areas of Belgium and the surrounding countries.

Sautou (Rv4) and Pourru-aux-Bois (Rv5) Formations. A roofing slate horizon, the Olly Member (Rv2b), is defined at the top of the La Chapelle Formation (Beugnies, 1960b). We refer to Verniers *et al.* (2001) for their lithological description and acronyms to be used on the geological maps (respectively LCH, ILL, SAU and PAB). These formations are correlated in Fig. 2 with their supposed lithostratigraphic equivalents in the Rocroi Inlier (Beugnies, 1960a). Note that no Rv1 is mentioned in the Givonne Inlier equivalent to the lowermost part of the Revin Group in the Rocroi Inlier, the Rocher de l'Uf Formation (Rv1a) and its uppermost part, the roofing slate Peureux Member (Rv1b).

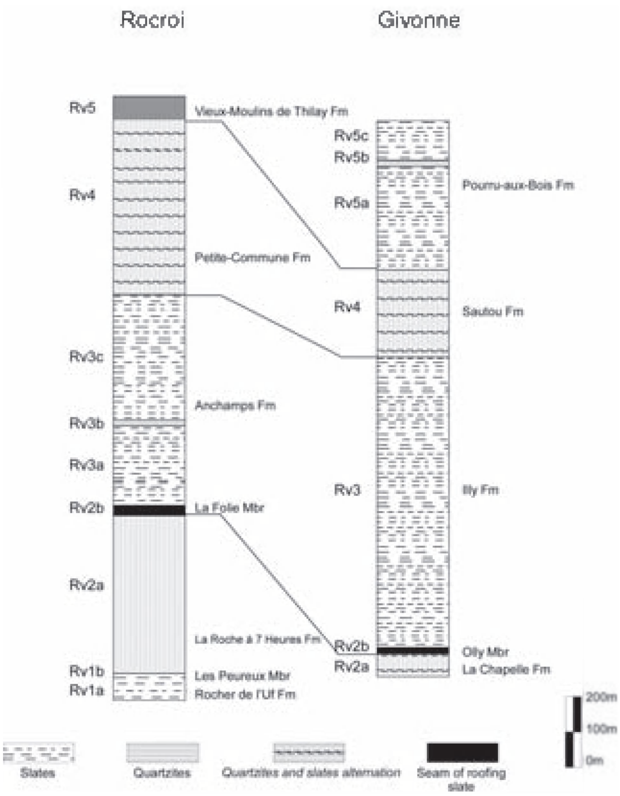

Figure 2: Comparison between the lithostratigraphy of the Rocroi and Givonne Inliers (Beugnies, 1960b, Verniers *et al.*, 2001). Lithostratigraphic correlations according to Beugnies (1960b).

3. Studied sections, sample locations and palynological techniques.

3.1. The Claire-Terne de la Borne river sections

The Terne de la Borne is a river flowing north – south, west of the Sautou castle. It is a tributary of La Claire river located east of Bosséval and Briancourt village, north of Sedan, Département des Ardennes, France. The official geological map (Geological Map 69 Charleville – Mèzières 1/50.000, B.R.G.M., 1973) is based on the observations by Beugnies (1960b, 1962) in the Givonne Inlier (Fig. 3). It indicates an anticlinal structure with a La Chapelle Formation (=Rv2) core. The study outcrops extend discontinously from the core of the fold towards the North, at the western side of the Claire-Terne de la Borne river valleys, where they belong to the anticlinal recumbent flank. A first outcrop, in the Claire river valley, lies 250 metres North of the bridge over the Claire, near a disused factory called "Moulin Chicot". It exposes a few metres of alternating quartzites and slates. Two fossiliferous samples previously studied (Vanguestaine, 1978) come from this outcrop. They belong to the acritarch biozone 3. After a gap of about 700 metres, a more or less continuous section exposes, for about 500 metres, the upper part of the Illy Formation (=Rv3) and the major part of the Sautou Formation (=Rv4) according to the lithostratigraphy of Beugnies (1960b, 1962). In the field, the distinction between the two units can be made as follows. The Illy Formation is dominantly slaty while the Sautou Formation is more quartzitic. The base of the Sautou Formation is marked by the presence of some metric quartzitic beds, but upwards these quartzitic beds tend to be thinner and never exceed 60 centimetres. Our observation does not match with the one by Beugnies (1960b) when he mentions quartzitic beds of 5 to 10 metres thickness. The uppermost part of the Sautou Formation, moreover, is poorly known as a new observation gap of about 300 metres separates the preceeding outcrops from an isolated small quarry located near the crossroads to Les Hazelles. According to the geological map (Fig. 3), this outcrop lies just below the Devonian cover and would belong to the upper part, but not necessarily the top, of the Sautou Formation. It has to be noted that 108 metres South of the mentioned Illy-Sautou boundary, a slaty horizon of about 8-10 metres thick has been observed. This roofing slate seam is not mentioned by Beugnies (1960b, 1962).

3.2. Location of samples in the Claire-Terne de la Borne section

In total, 19 samples have been collected in this section and 10 contain acritarchs. Their location is given in appendix.

3.3. The Falizette river section

The Falizette river is a tributary of the Meuse River, west of "Saint-Menge" (Fig. 3). It exhibits for about 400 metres slaty dominated strata in discontinous small outcrops along the eastern bank. A disused roofing slate quarry is a distinctive topographic feature. In there, the Olly Member is present (see Fig. 2). According to the geological map (Fig. 3), the section would be at the normal southern flank of the Bosséval anticlinal and would therefore expose from North to South the uppermost part of La Chapelle Formation (=Rv2a), the Olly Member (Rv2b) and the lowermost part the Illy Formation (=Rv3).

3.4. Location of samples in the Falizette section

Ten samples were studied and 7 samples are fossiliferous. Their location is given in appendix.

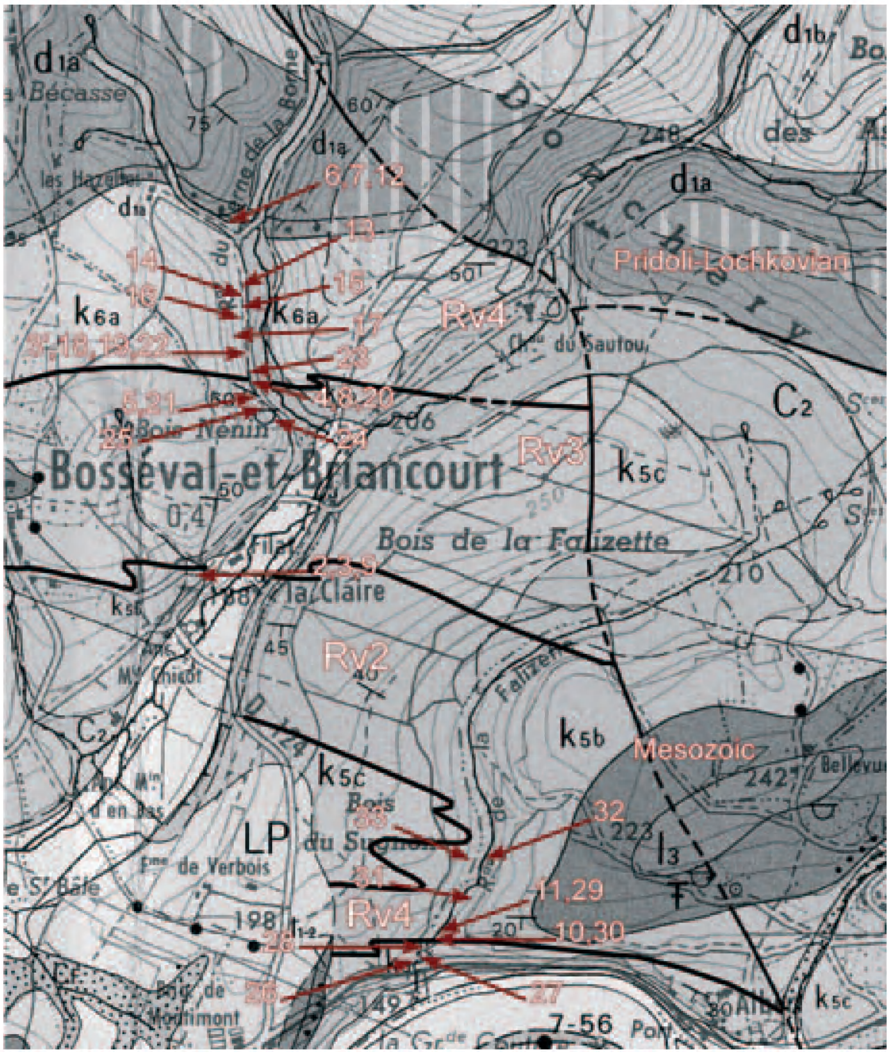

Figure 3: Geological map of the Bosséval area in the western part of the Givonne Inlier (BRGM, 1973). Localities of the studied samples in the Claire-Terne de la Borne and the Falizette river sections. The symbols K5b, K5c and K6a on the B.R.G.M. geological map correspond respectively to the notation Rv2, Rv3 and Rv4 of Beugnies (1960a and 1962). Samples 2, 3, 3', 4 and 5 in blue have been collected by the first author. Samples in black are from the second author.

3.5. Palynological techniques

Samples were treated with standard palynological methodology in use at the Palynological Laboratory of the Liege University (Léonard, 2004). The slides are housed in the collections of the Laboratory.

4. Palynological observations

In total, 17 samples (7 in the Falizette section, 10 in the Claire-Terne de la Borne section) are fossiliferous including 2 samples (Givonne –2 and –3) previously studied (Vanguestaine, 1978). Fourteen samples are barren. The organic matter is generally very poorly preserved. Sample Givonne –16, the richest and most diversified of all samples, revealed that about 20% of the recognizable organic walled microfossils are indeterminable, damaged specimens, about 70% are non-indicative sphaeromorphs and only 10% are differentiated, determinable specimens. Due to the relative richness of some samples however, enough specimens can be identified to enable a biostratigraphy (see below sections 6 and 7). Givonne –16 moreover yielded rare specimens not found previously in Belgium or surrounding areas (see section 4.2.). Because they are not yet involved in the local acritarch biozonation, their stratigraphic meaning is discussed in a separate section.

4.1. Species of local biostratigraphical value

The following species are observed:

-*Cristallinium cambriense* (Slavikova, 1968) Vanguestaine, 1978.

-*Dictyotidium hasletianum* Vanguestaine, 1974.

-*Heliosphaeridium lanceolatum* (Vanguestaine, 1974) Moczydlowska, 1998 (= *Micrhystridium lanceolatum in* Vanguestaine, 1974).

-*Leiosphaeridia fumiana* Vanguestaine, 1974.

-*Lophosphaeridium bacilliferum* Vanguestaine, 1974.

-*Lophosphaeridium ? kryptoradiatum* Vanguestaine, 1974.

-*Lophosphaeridium tentativum* Volkova, 1968.

-*Retisphaeridium brayense* (Gardiner & Vanguestaine, 1971) Moczydlowska, 1998 (= *Stictosphaeridium brayense* Gardiner & Vanguestaine, 1971 *in* Vanguestaine, 1978).

-*Stelliferidium*? sp. A in Brück & Vanguestaine, 2004 (= *Priscogalea*? sp A *in* Vanguestaine, 1978 and *Timofeevia* aff *lancarae in* Ribbert *et al.* 2002).

-*Synsphaeridium* sp. *in* Vanguestaine (1978). *Timofeevia pentagonalis* (Vanguestaine, 1974) Vanguestaine, 1978

.- *Timofeevia phosphoritica* Vanguestaine, 1978.

The stratigraphic distribution of these species is depicted in Figs 5 and 6 and their stratigraphic meaning is discussed in section 6.

4.2. Species of international value

These species were encountered in a single sample, Givonne –16 and have never previously been recorded in the Ardennes. Their chronostratigraphic significance is discussed in section 7.

They are:

-*Adara alea* Martin *in* Martin & Dean, 1981.
-*Celtiberium dedalinum* Fombella, 1978.
-*Multiplicisphaeridium martae* Cramer & Diez, 1972.
-*Retisphaeridium postae* (Jankauskas *in* Jankauskas & Postii, 1976) Vanguestaine *in* Brück & Vanguestaine, 2004.
-*Ceratophyton vernicosum* Kirjanov *in* Volkova *et al.*, 1979.
-The presence of *Eliasum llaniscum* Fombella, 1977 is suspected but can not be ascertained.

4.3. Palaeontological notes

Adara alea: the four specimens are pale coloured compared with the dark coloration of most observed acritarchs probably built with a thicker membrane than *Adara alea*. Membrane thickenings described as radiating around the different processes (Martin & Dean, 1981) are locally observed (Pl. III, Fig. 3). Sometimes the ridges are not typically disposed in a radiating pattern (Pl. III, Figs 4 & 5).

Ceratophyton vernicosum Kirjanov in Volkova *et al.*, 1979: only one single specimen is observed. It has the typical conical form. The "apex" is distinctly pointed and the "antapex" probably broken. The length is 185 μm. The ratio base width: length is about 1: 4. The holotype has a size of 180 μm and a ratio width to shell length of 1:3. In reflected light, the recorded specimen shows a sort of striation somewhat oblique to the longitudinal axis. A fiber wall structure is also noted in the original diagnosis. Volkova *et al.* (1979) have mentioned the species in the latest Precambrian to Lower Cambrian strata of Russia, Lithania, Latvia, Bielorus and Ukraine. Moczydlowska (1991) figured one specimen from Lower Cambrian strata in Southeastern Poland. Konzalova & Fatka (1992) figured one possible specimen from the Lower Cambrian of the Czech Republic. Fatka & Vavrdova (1998) noted *Ceratophyton* sp. in Moravia, and dated it as Lower Cambrian. It should be noted that *Ceratophyton vernicosum* is not classified in the Acritarcha Incertae Sedis Group but as a metazoan. It will be demonstrated (section 8) that the strata in which the species occurs are mid Middle Cambrian in age and constitutes so far its youngest record.

Leiosphaeridia fumania: the distinction with *Lophosphaeridium latviense* Volkova 1974, another weakly ornamented species, is unclear (see also Brück & Vanguestaine, 2004, p. 209).

Lophosphaeridium bacilliferum: the relatively long (about 2 μm), rodlike, densely distributed, apparently solid processes of this species are comparable with those of *Asteridium lanatum* (Volkova, 1969) Moczydlowska 1991. But the vesicle diameter of the latter is smaller (7-14 μm *in* Moczydlowska 1998) than in *L. bacilliferum* (20.5-30 μm). The processes of *Asteridium spinosum* Moczydlowska 1998 are described as thorn-like.

Lophosphaeridium ? kryptoradiatum: the striae described as linking the granulae (Vanguestaine, 1974) are not observed herein.

Polygonium martinae in Moczydlowska & Crimes (1995): the recorded specimens are quite similar to the Irish specimens illustrated in Moczydlowska & Crimes (*ibid.*). The large conical bases of the processes are well developed in the specimen shown in Plate II, Fig. 17. The Late Cambrian type population from Canada (Martin, 1992), chosen by Moczydlowka & Crimes (1995) as type material of *P. martinae*, differs both from the Irish specimens illustrated by Moczydlowska & Crimes (1995) and the French material

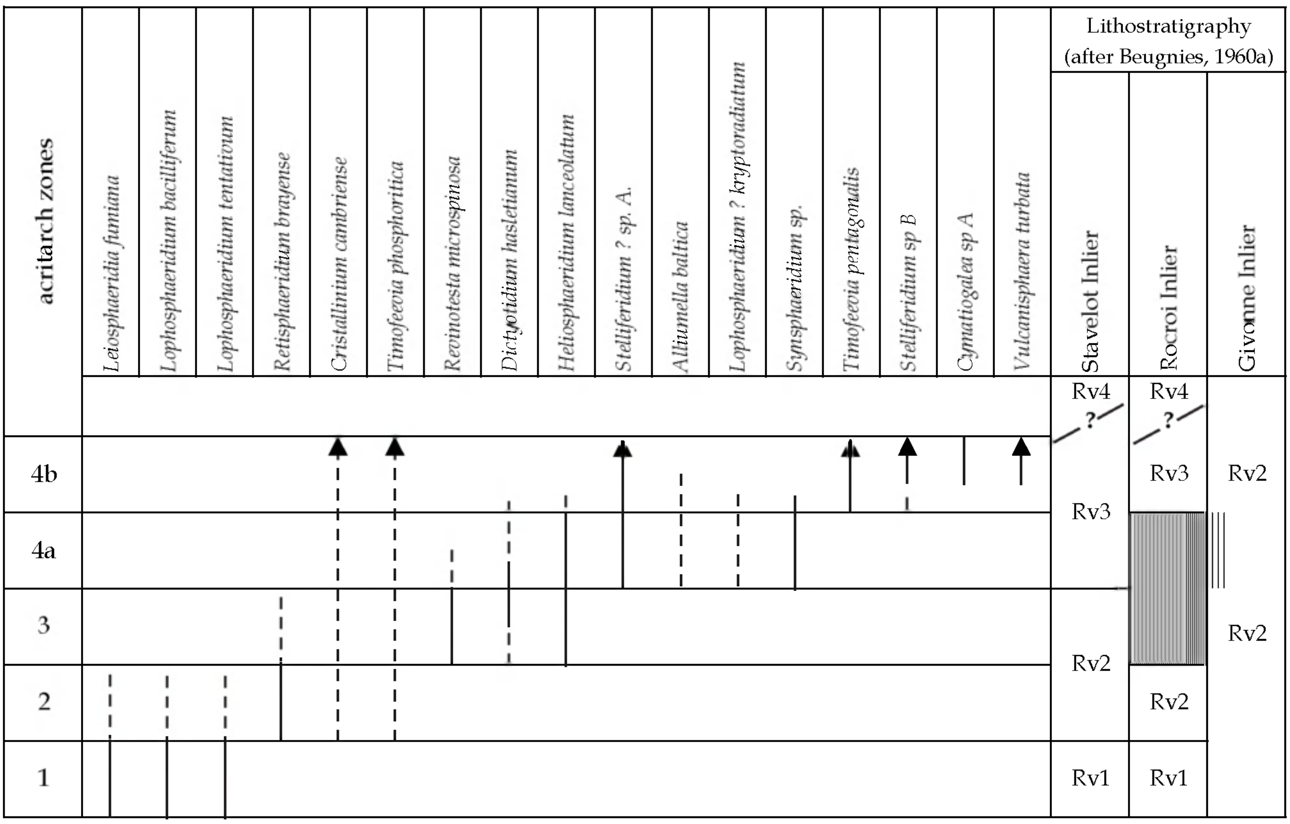

Figure 4: Acritarch biozonation for the lower part of the Revin Group in the Belgian Ardennes and surrounding areas (after Vanguestaine *in* Ribbert *et al.*., 2002)

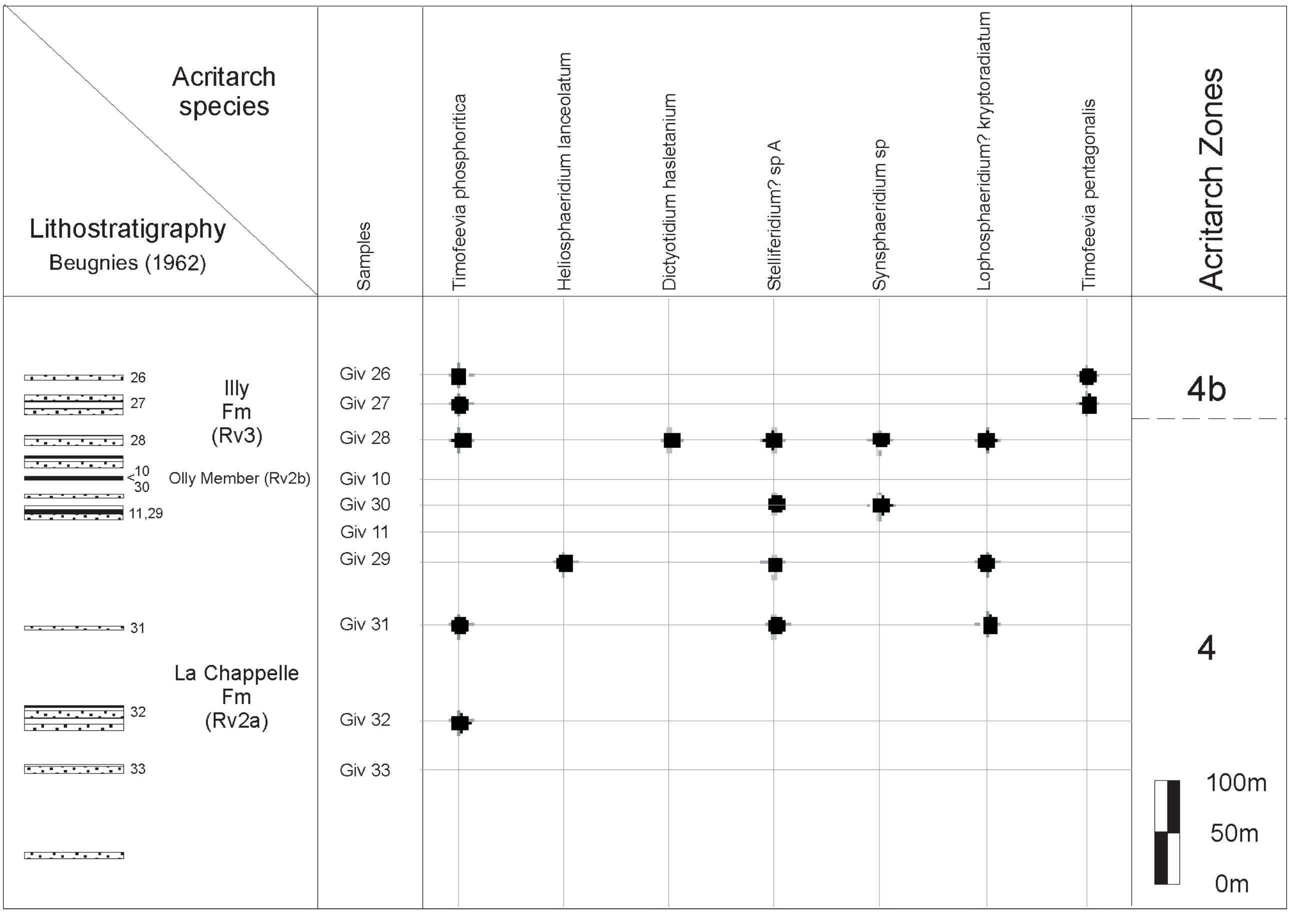

Figure 5: Falizette section : left : stratigraphical column and sample location ; right : acritarch distribution and biozonation. Note that the lithological succession is not a log but a objective representation of the different lithologies along the profile independently of the strata dip and folding. Lithology as in Figure 2

reported herein, in having a variable number of processes of variable base width. In our opinion moreover, the Irish Booley Bay Formation hosting the so-called *P. martinae*, is misdated as Late Cambrian by Moczydlowska & Crimes (1995). Taking these discrepancies into opinions, the presence of this species is not used herein for stratigraphic purposes (section 8).

Timofeevia phosphoritica: several tens of this species have been observed always with truncated processes. The differences between *Timofeevia lancarae* (Cramer & Diez, 1972) Vanguestaine, 1978 and *T. phosphoritica* mainly rest on the length of the processes and the density of their distal ramification. Because they are always broken in the observed material, these features are unknown. The holotype of *T. phosphoritica* (Grand-Halleux borehole 2922 metres, acritarch zone 4a) is quite comparable with the present specimens and comes from coeval strata. *T. lancarae* is observed in the informal zone 4c (see Ribbert *et al.*, 2002). The present material is therefore referred to *T. phosphoritica*.

? *Skiagia sp*: some specimens with an external surface bearing coarse dispersed granulae of about 1-2 μm width are questionably assigned to the genus *Skiagia* in the supposition that the characteristic processes are broken as observed in Brück & Vanguestaine (2004, Figs 5 & 11) for *Skiagia ciliosa* specimens.

5. Acritarch biozonation in the Lower Palaeozoic of the Ardennes (Belgium, northern France and western Germany)

The palynological study (Vanguestaine, 1973) of most representative sections of the Lower Palaeozoic of the Ardennes led to an informal acritarch biozonation (Vanguestaine, 1974) refined in subsequent papers (Vanguestaine, 1978; Ribecai & Vanguestaine, 1992; Ribbert *et al.*, 2002). Fig. 4 reproduces part of the biozonation, i.e. with biozones 1 – 4b, which were encountered in the present study. The ranges of selected species involved in the biostratigraphic scheme are indicated.

Other Cambrian acritarch biozonations were proposed for other areas in the world. In Eastern Newfoundland, Martin & Dean (1988) proposed 7 acritarch biozones relatively well constrained in relation to the trilobite biozonation. Volkova (1990) proposed a succession of 8 acritarch biozones for coeval strata in Russia. Other schemes exist for Lower-lower Middle Cambrian rocks, for example Volkova *et al.* (1979), Moczydlowska (1991). Moczydlowska (1999) has discussed how to detect the Lower-Middle Cambrian boundary by means of acritarchs. Her results have been applied in Vanguestaine *et al.*, 2002, in Brück & Vanguestaine (2004) and Brück & Vanguestaine (in press) to date Lower Palaeozoic successions in Southeastern Ireland. Ribecai & Vanguestaine (1993) used the biozonations of Martin & Dean (1988) and of Volkova (1990) to better constrain in age the upper part of the Revin Group (acritarch biozones 4b to 6) in relation to the trilobite succession. They demonstrate that the zone 4b corresponds to an interval of time near the Middle-Upper Cambrian boundary and that zones 5 and 6 are defined on the basis of taxa (as *Trunculumarium revinium* and *Acanthodiacrodium golubii*) also well known in Upper Cambrian strata of Eastern Newfoundland and/or Russia.

In contrast, acritarch zones 1–4b of the lower part of the Revin Group are much less constrained. The three

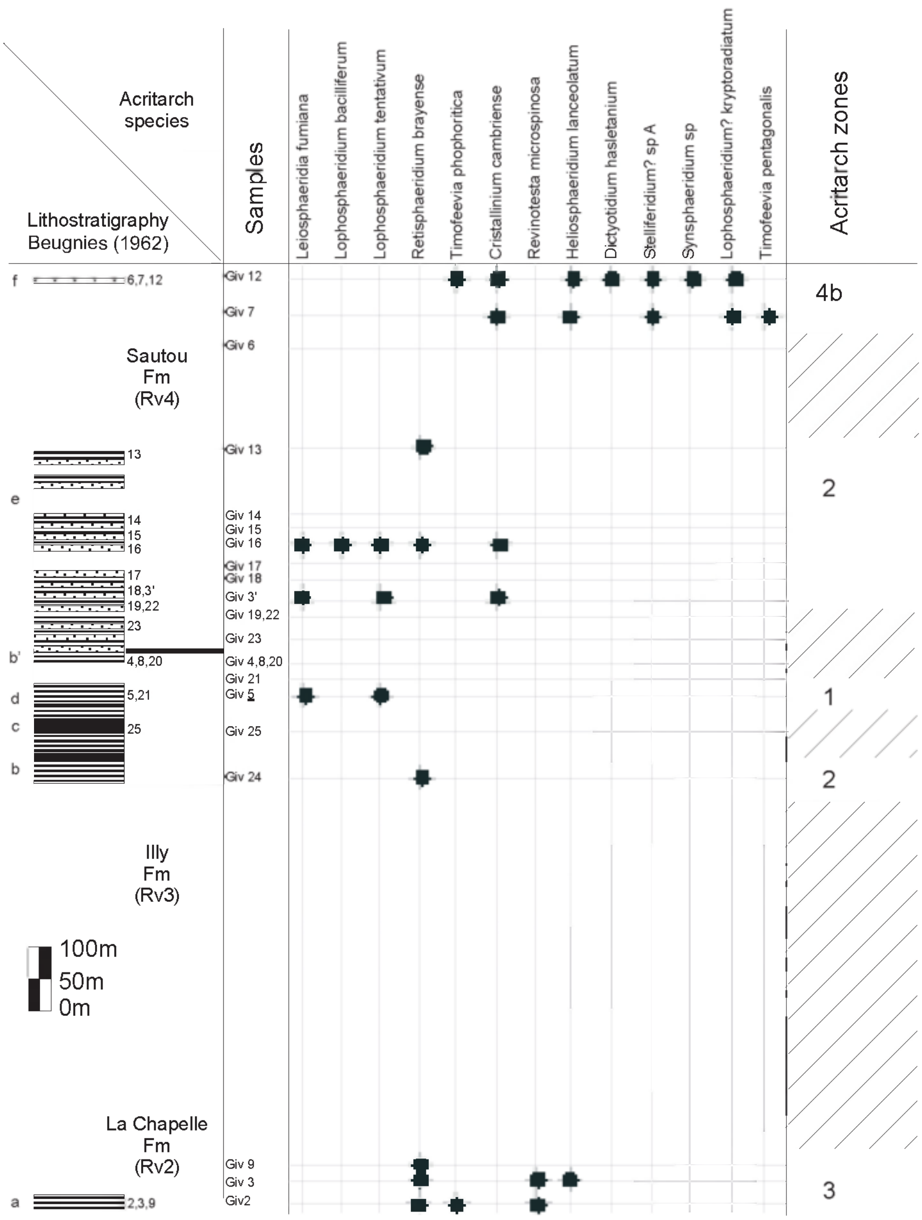

Figure 6: Claire-Terne de la Borne acritarch distribution and biozonation. Underline samples are from Vanguestaine's collections.

species characterizing zone 1 are forms with reduced ornamentation. Their comparison with assemblages observed elsewhere is difficult. *Leiosphaeridia fumiana* and *Lophosphaeridium bacilliferum* display however similarities respectively with *Lophosphaeridium latviense* (Volkova, 1974), Moczydlowska, 1998 (see Brück & Vanguestaine, 2004, p.209) and *Asteridium lanatum* (Volkova, 1969) Moczydlowska 1991. The first one is known in lower Middle Cambrian rocks (Volkova, 1974); the second in the Lower Cambrian (Moczydlowska, 1991). Due to the size of the ornamentation and the quality of the illustration, exact relationships between the different species can not be ascertained. Zone 2 comprises two of the species used to define the Lower-Middle Cambrian boundary: *Cristallinium cambriense* and *Timofeevia phosphoritica*. According to Moczydlowska (1999) both would appear above the boundary. Therefore their presence in acritarch zone 2 would indicate the Middle Cambrian. But it is up to now unknown to which part of the Middle Cambrian the acritarch biozone 2 would belong. In this respect, the new observation of the species up to now unknown in the Ardennes considerably narrows down the stratigraphical position of the biozone 2 (see section 8 below). Zone 3 and zone 4a are characterized by species poorly known elsewhere (see however Brück & Vanguestaine, 2004, for *Heliosphaeridium lanceolatum* and *Stelliferidium*? sp A). Despite difficulties in accurately correlating the acritarch biozonation used in the present paper with acritarch biozonations observed elsewhere, there is no doubt however that the rock succession in the Ardennes, yielding the different acritarch biozones, are in the right stratigraphical order. The appearance of *Timofeevia phosphoritica* and *Cristallinium cambriense* in zone 2 precedes the appearance of *Timofeevia pentagonalis* (zone 4b) in the Ardennes (Vanguestaine, 1978) and elsewhere (Martin & Dean, 1988; Moczydlowska, 1998, 1999; Volkova, 1990).

6. Biostratigraphy of the Falizette and Claire-Terne de la Borne river sections

The different species observed in the 17 fossiliferous samples are shown in Figs 5 & 6. The newly recorded taxa of sample Givonne –16 are not taken in account as they are observed for the first time in Ardennes.

6.1. Falizette section

In the Falizette section, the presence of 3 of the 4 species

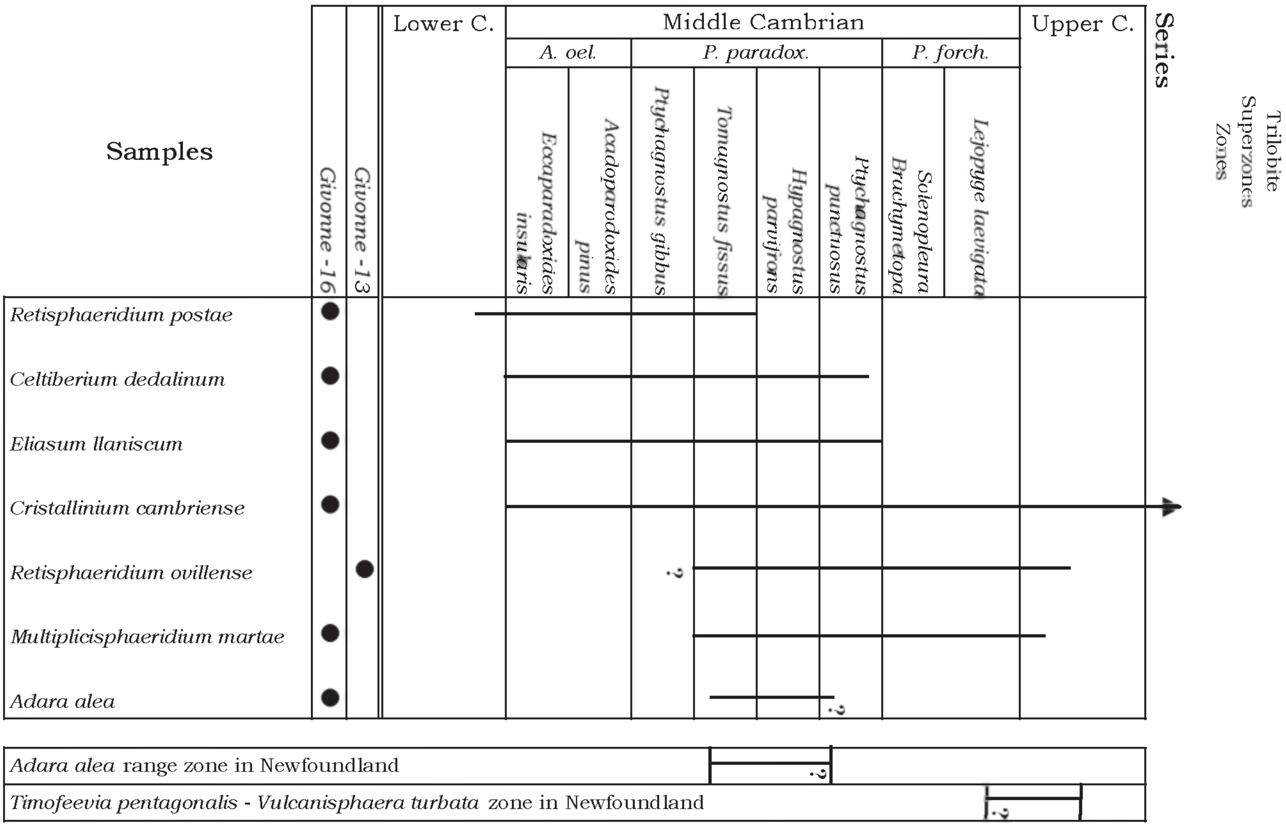

Figure 7: Know stratigraphical ranges of selected acritarch species from two samples, Givonne –13 and Givonne –16, in the Terne de la Borne river section.
Lower C and Upper C for Lower and Upper Cambrian. *Acadoparadoxides oelandicus*, *Paradoxides paradoxissimus*, *Paradoxides forchhammeri* are names of trilobite Superzones. *Eccaparadoxides insularis*, *Acadoparodoxides pinus*, *Ptychognostus gibbus*, *Tomagnostus fissus*, *Hypagnostus parvifrons*, *Ptychagnostus punctuosus*, *Solenopleura brachymetopa*, *Lejopyge laevigata* are trilobites Zones.

characterizing zone 4 is noted within the Olly Member, above and below it (Fig. 5). Samples Givonne –27 and –26 supposed to be the youngest contain *Timofeevia pentagonalis*. Its first appearance datum marks the base of the 4b biozone. Normally, the strata below Givonne –27 without the species would have to be placed in the 4a biozone. Taking into account the poor preservation of the organic matter, the position of the boundary between the bioznes 4a – 4b can not be fixed herein. In fact, previous observations in the Givonne and Hatrelle river sections, in the median part of the Givonne Inlier, led to the identification of the acritarch biozone 4b in the strata immediately below and above the Olly Member (Vanguestaine, 1978). The present observations partly confirm the previous ones. It can be assumed that regionally the base of the 4b acritarch biozone is situated below the Olly Member.

6.2. Claire-Terne de la Borne section

In the Claire-Terne de la Borne section, at least three, maybe four acritarch assemblages are encountered (Fig. 6). The Sautou Formation yields in its major part (e in Fig. 6), the acritarch biozone 2, characterized by the abundance of *Retisphaeridium brayense* and the presence of *Cristallinium cambriense*. The acritarch biozone 4b is present in its uppermost part (f in Fig. 6). Compared to the assemblage recorded in the Falizette section both assemblages of biozone 4b are indentical. Below the base of the Sautou Formation, biostratigraphical results are much more scattered. Sample Givonne –5, in the sequence noted as d in Fig. 6 yields two species known in biozones 1 and 2 but without *Retisphaeridium brayense* which characterizes the base of biozone 2. This sample could belong to acritarch biozone 1. Sample 24, in the sequence noted b, yielded a single species *Retisphaeridium brayense* and could only tentatively be interpreted as belonging to acritarch biozone 2. The outcrop near the "Moulin Chicot" (noted a) has been attributed to acritarch biozone 3 as it contains several specimens of *Revinotesta microspinosa* and *Heliophaeridium lanceolatum* and as the markers of acritarch biozone 4 are absent (Vanguestaine, 1978). New taken samples from this outcrop were barren except for Givonne –9 in which one of the species known in biozone 3 (*Retisphaeridium brayense*) is observed.

7. Biostratigraphical implications

The palynological observations reported above would place the Falizette strata (RV2 – RV3; acritarch biozone 4, locally 4b) stratigraphically above most part of the Claire – Terne de la Borne strata (Rv3 – Rv4 according to Beugnies, 1962; acritarch biozones 1?, 2 and 3) if we exclude the northernmost outcrop (acritarch biozone 4b). This is in contradiction with the lithostratigraphic succession of Beugnies (1960a, 1962) (see Fig. 2).

The Falizette section is biostratigraphically comparable to the Givonne and La Hatrelle rivers sections previously studied (Vanguestaine, 1978). Acritarch biozone 4b is identified in the latter area of the middle part of the Givonne Inlier where it is associated with strata immediately below and above the Olly Member. It is here assumed that this slaty horizon is a reliable stratigraphic marker at least within the Givonne Inlier.

Therefore, the stratigraphic problem herein encountered concerns the Terne de la Borne section and not the Falizette section.

The so-called RV4 (Sautou Formation) of the Terne de la Borne section yield the acritarch biozone 2 in its major part (unit e in Fig. 6) and a 4b biozone in its uppermost accessible part (unit f in Fig. 6), both parts being separated by an observation hiatus corresponding to about 300 metres without any outcrops. Despite similarities of facies, these two parts probably do not belong to the same stratigraphic unit as suggested by Beugnies (1960a). The uppermost part, unit f, acritarch biozone 4b, certainly corresponds either to a part of Rv2 or a part of Rv3, somewhere near the Olly Member. Compared to the succession of the Rocroi Inlier (Vanguestaine, 1978; Figs 2 & 3 herein) the main part (unit e of Fig. 6) of the Sautou Formation would better correlate with RV2 (Roche à 7 heures Formation) than with RV4 (Petite Commune Formation, Fig. 2) as suggested by Beugnies (1960a). From a lithostratigraphical point of view, the newly proposed correlation would appear to be accurate as both RV2 and RV4 are quartzitic dominated formations in the Rocroi Inlier (Beugnies 1960b; see Fig. 2).

South of the so-called RV3 – RV4 boundary according to Beugnies (1960a, 1962) in the Terne de la Borne section, a slaty horizon (unit c in Fig. 6) associated with possibly an acritarch zone 1 assemblage is observed. This roofing slate seam could be interpreted as a lithostratigraphic equivalent of the "veine ardoisière des Peureux" (Peureux Member) in the Rocroi Inlier. If this interpretation is correct, then the so-called RV3 of Beugnies (1962) in the Terne de la Borne would partly correspond to the RV1 (Rocher de l'Uf Formation) of the Rocroi Inlier.

The southernmost outcrop near Moulin Chicot has been previously determined (Vanguestaine, 1978) as containing to acritarch biozone 3.

8. Newly discovered species and their chronostratigraphical significance

Among the samples studied in the Sautou Formation, the Terne de la Borne section, one sample, Givonne –16 (see location in Figs 3 & 6), is much richer than the others and has been the object of special attention. Besides specimens of the acritarch biozone 2, this sample has yielded rare specimens of species never recorded before in the Lower Palaeozoic of the Ardennes. They are 4 specimens of *Adara alea*, 1 of *Celtiberium dedalinum*, 10 specimens of *Multiplicisphaeridium martae*, about 10 specimens of *Polygonium martinae in* Moczydlowska & Crimes (1995), 2 specimens of *Retisphaeridium postae* and about 5 specimens of possible *Eliasum llaniscum*. Except for *P. martinae* of which the determination is problematic (see Palaeontological notes - section 4.3.), the known stratigraphic range of the latter species is shown in Fig. 7. The range of *Cristallinium cambriense* and that of *Cristallinium ovillense*, observed in Givonne –13, are also taken into consideration. Examination

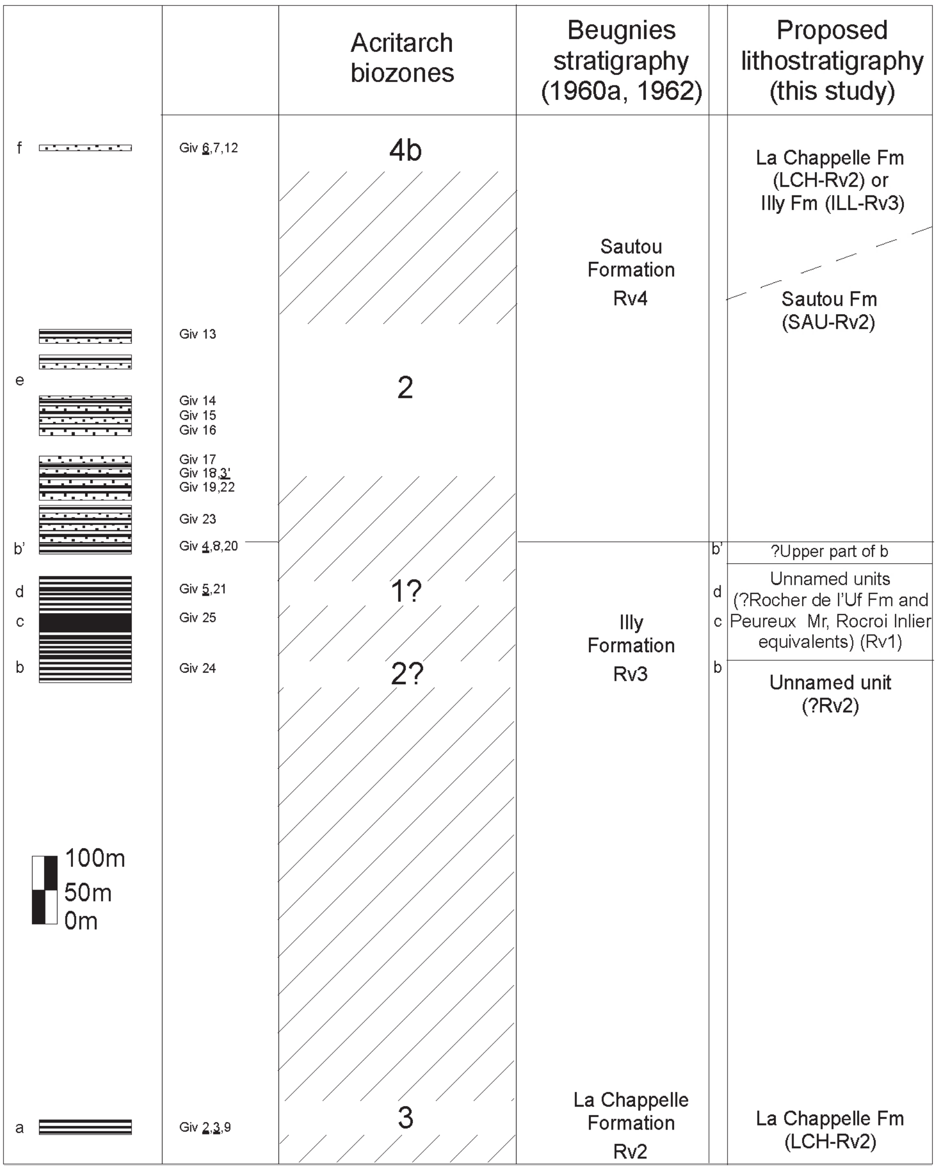

Figure 8: Compared Acritarch biozones, Beugnies stratigraphy and proposed lithostratigraphy of the Claire-Terne de la Borne river section. Oldest unit and anticlinal core would be sequence d. In the supposed northern flank of the anticlinal, the gap between units d and b' would comprise the succession c b, b being partly represented in b'.

of Fig. 7 shows that the recorded species indicate an age corresponding to that of the range biozone of *Adara alea*, i.e. mid Middle Cambrian. *Adara alea* is known in the Cambrian of different areas (Canada, Czech Republic, Spain, Sweden, Turkey, Tunisia, Wales, Poland - see Moczydlowska, 1998) but is only precisely dated by trilobites in Newfoundland (Martin & Dean, 1981, 1988).

9. Geological implications

9.1. Lithostratigraphical succession in the Claire-Terne de la Borne section

The first implication of our biostratigraphic and chronostratigraphic results concerns the lithostratigraphic succession as proposed by Beugnies (1960b, 1962). Acritarch biozone 2 (and perhaps also 1) observed in the so-called Rv3-Rv4 succession in the Terne de la Borne section does not match with acritarch biozone 4 (locally 4b) in the Rv2-Rv3 succession in the Falizette river. It has been suggested (section 7) that the Sautou Formation is not an equivalent of Rv4 in the Rocroi Inlier but an equivalent of Rv2 of the same area. Therefore, the geological succession observed in the Claire-Terne de la Borne section from South to North would be:

- a part of La Chapelle Formation (=Rv2) comprising the acritarch biozone 3 in the Claire section;
- a possible unnamed equivalent of Rv1 of the Rocroi Inlier with locally ? acritarch zone 1 and a roofing slate seam corresponding to the “Veine des Peureux” (Peureux Member) passing up into some metres (see Fig. 6) of an unnamed slaty unit possibly containing the acritarch zone 2;
- a Rv2 equivalent of the Rocroi Inlier with acritarch zone 2 in the main part of the so- called Rv4 (Sautou Formation);
- finally, a Rv2 or Rv3 sequence with acritarch 4b biozone at the northernmost outcrop previously placed in an upper part of the Sautou Formation (Fig. 8). This lithostratigraphic readjustment is not only based on the local acritarch biozonation but is also supported by newly discovered species (section 8). Fig. 7 indicates that, in Newfoundland, *Adara alea* range, is older than *Timofeevia pentagonalis* appearance. In the Givonne Inlier, *Adara alea* is recorded in strata attributed to a formation, the Sautou Formation, described as younger than the La Chapelle or Illy Formations (Beugnies, 1960a) in which *Timofeevia pentagonalis* is observed.

9.2. Localisation of the Bosséval anticlinal axis in the Terne de la Borne

Taking in account these results, the geology of the western part of the Civonne Inlier, while still interpreted as having an anticlinal structure, would have not its main axis near the Moulin Chicot in the Claire river as suggested by Beugnies (1960b) but about 1 kilometer to the North near the place where the roofing slate seam is outcropping.

9.3. The Sautou Formation in the Givonne Inlier

Another implication of our results deals with the lithostratigraphic significance of the Sautou Formation. Taken as a stratigraphical equivalent of the Rv4 of the Rocroi Inlier (see Fig. 2) by Beugnies (1960a), it now appears as an equivalent of Rv2 of the same area. On the one hand, Rv2 in the Givonne Inlier is defined as being the La Chapelle Formation and , on the other hand, the study outcrop is the type locality of the Sautou Formation. Up to now, the La Chapelle Formation has yielded either acritarch zone 3 or acritarch zone 4, generally 4b, (Vanguestaine 1978 and herein). Therefore, the Sautou Formation in the Terne de la Borne river with its zone 2-4b acritarch biozones is older than the La Chapelle Formation in its main part, possibly coeval with the uppermost part of this formation. It is herein suggested to provisionaly restrict the acceptance of the Sautou Formation as defined above. It means that both the Sautou Formation in its type locality and the La Chapelle Formation are parts of Rv2. As the Sautou Formation was mapped in all the Givonne Inlier by Beugnies (1960b) particularly in the eastern part where an Rv5 formation (Pourru-aux-Bois Formation) is defined (see Fig. 2 and Beugnies 1960b), the lithostratigraphic meaning of the Sautou Formation elsewhere than in the Terne de la Borne section is problematic.

9.4. The so-called Illy Formation in the Terne de la Borne section

In its type locality (see Vanguestaine, 1978, Fig. 7b, p. 257), the Illy Formation has yielded the acritarch biozone 4b in its lower part. A similar result is obtained in the Falizette section studied herein (see section 6.1.). The palynological results in the upper part of the so-called Illy Formation in the Terne de la Borne section, as interpreted by Beugnies (1962) do not match with previous ones. It has to be noted nevertheless that palynological data are rather limited in the Terne de la Borne section (see Fig. 6) to two samples yielding 3 taxa altogether. Field observations of a slaty seam and acritarch biostratigraphy are however in full accordance with the succession observed in the Rocroi Inlier (Vanguestaine, 1978) where an Rv1, with an acritarch biozone 1 and the Peureux Member at its top is followed by an Rv2 with an acritarch biozone 2. It is herein tentatively suggested that the slaty dominated strata previously attributed to the Illy Formation are in fact a succession comprising from base to top an unnamed Rv1 equivalent, a roofing slate seam, an unnamed slaty dominated sequence lying just below the base of the Sautou Formation (Fig. 8).

10. Conclusions

10.1. The application of the biostratigraphic scheme developed elsewhere in the Lower Palaeozoic of the Ardennes (southern Belgium, northern France and western Germany) questioned the lithostratigraphic succession in the western part of the Givonne Inlier. In the Terne de la Borne river section of this area, the succession from oldest to youngest can no longer be La Chapelle, Illy, Sautou, because most part of the Sautou Formation, in its type locality, has now been revealed to be older than the La Chapelle Formation. This affirmation is supported by a relatively good acritarch record and biozonation.

10.2. It appears moreover that in the same section, the acritarch content of what is attributed to the Illy Formation does not match with the Illy Formation in its type locality. The so-called Illy Formation comprises presumably unnamed units older than the Sautou Formation as redefined above. This conclusion is less well constrained than the first one but supported nevertheless by the finding of a roofing slate seam possibly equivalent to the Peureux Member (“Veine ardoisière des Peureux”) in the Rocroi Inlier.

10.3. If conclusion 2 is correct, then an equivalent unit of the Rocher de l’Uf Formation (Rv1), the oldest part of the Revin Group, would be recognized for the first time in the Givonne Inlier.

10.4. As a consequence of conclusion 2 also, the Bosséval anticlinal axis would not be located South of Bosséval-et-Briancourt, near Moulin Chicot, but about 1 kilometer North of it.

10.5. As the Sautou Formation has been mapped in all parts of the Givonne Inlier, the question arises with regard to its stratigraphic meaning in other areas than that of this study.

10.6. In addition to species of acritarch biozone 2, species never recorded before in the Ardennes in a sample from the Sautou Formation indicate a correlation with the *Adara alea* range zone of Newfoundland giving a relatively precise mid Middle Cambrian age.

10.7. The same sample yielded also a single specimen of *Ceratophyton vernicosum*, a probable metazoan, usually found in late Precambrian to Lower Cambrian rocks elsewhere. The present paper proves its extension up to the mid Middle Cambrian.

11. Acknowledgements

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Appendix: sample localities

(a) acritarch present; (o) acritarch absent

A1. Claire and Terne de la Borne river sections

A1.1. Claire section

Outcrop 250 metres north of the bridge on the Claire, at the crossroads of D24 and the path to Les Hazelles: La Chapelle Formation (Rv2) (Beugnies, 1962)

Givonne-1(o),-2(a) and –3(a) in Vanguestaine (1973, 1978); Givonne-9(a). Two other samples (o) not numbered herein were also taken from the same locality. From this outcrop to the gate (point o) of the Terne de la Borne section, a distance of 650 metres is measured.

A1.2. Terne de la Borne section

Samples are located with respect to 8 electricity poles along the path bordering the Terne de la Borne. The distance of the poles 8, 5, 4, 3, 2, and 1 measured from a gate (point 0) in the entrance of the path is respectively 744, 455, 350, 258, 173 and 103 metres. Lithostratigraphy according Beugnies (1960b and 1962). From North to South:

A1.2.1. Sautou Formation

Givonne-6(o), -7(a) and –12(a) are all three in the most septentrional outcrop at the crossroad to Les Hazelles, 50 metres north of pole 8.
Givonne-13 (a): in front of pole 5
Givonne-14 (o): 33 m south of pole 5
Givonne-15 (o): 55m south of pole 5
Givonne-16 (a): 10 m north of pole 4
Givonne-17 (o): 40m south of pole 4
Givonne-18 (o): 75m south of pole 4
Givonne-3' (a): 15m north of pole 3
Givonne-19 (o): and –22(o) : in front of pole 3
Givonne-23 (o): 20 m south of pole 3

A.1.2.2. Illy Formation

Givonne-8 (o): 20 m north of pole 2
Givonne-20 (o): 13 m north of pole 2
Givonne-4 (o): 11 m north of pole 2
Givonne-21 (o): 5 m north of pole 1
Givonne-5 (a): 6 m south of pole 1
Givonne-25 (o): 18 m south of pole 1
Givonne-24 (a): 62 m south of pole 1

A.2 Falizette river section

Samples are measured with respect to the N5 road distance (point 0). To help their location, a gate and a well are respectively marked at 20 and 120 metres north of point 0. The roofing slate seam (Olly Member) is just behind this well. Lithostratigraphy is after Beugnies (1960b, 1962). From north to south, with respect to point o:

A.2.1. Illy Formation:

Givonne-33(o) : 435m; -32 (a):375m; -31(a): 285m; -11(o) and 29(a): 150m

A.2.2. Olly Member :

Givonne-10(o)and 30(a): 120m

A.2.3. La Chapelle Formation

Givonne-28(a):85m; -27(a) : 50m; -26(a): 30m.

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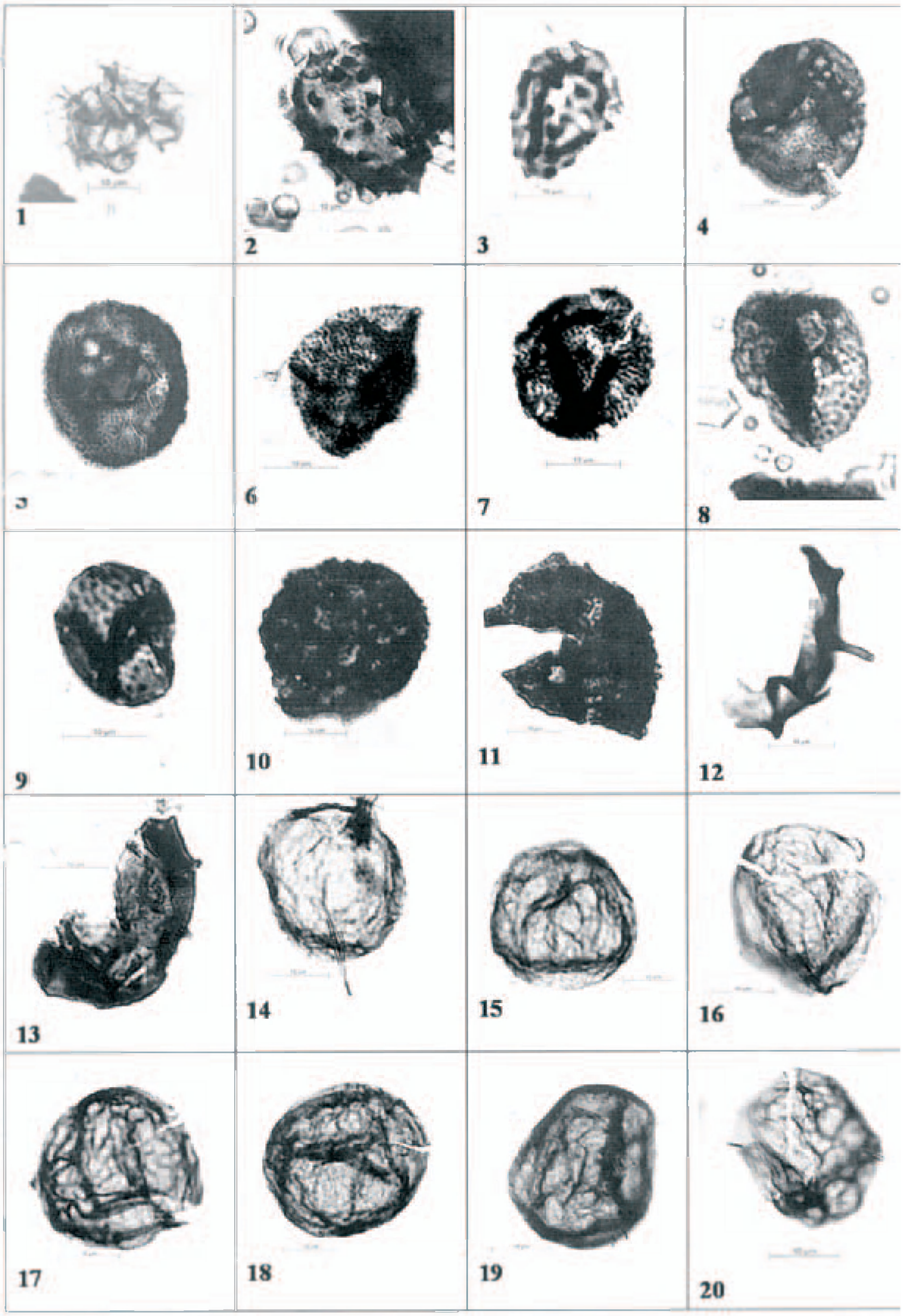

Plate I

Fig. 1. *Cristallinium cambriense* (Slavikova, 1968) Vanguestaine, 1978: Givonne –3, 59636, N43. Distinctly granulated wall surface.
Figs 2 and 3. *Heliosphaeridium lanceolatum* (Vanguestaine, 1974) Moczydlowska, 1998. – (2): Givonne –7, 60103, H32/2. Coarse granulated wall surface; – (3) Givonne –29, 60827, M49/2. – Figs 4 and 5. *Leisphaeridia fumiana* Vanguestaine, 1974. – (4): Givonne –3, 59629, T32/1; – (5) Givonne –3, 59636, N54/1. – Figs 6 and 7. *Lophosphaeridium bacilliferum* Vanguestaine, 1974. – (6): Givonne –16, 60218, M32/1-3; – (7) Givonne –16, 60218 (034/4-P34/2). – Figs 8 and 9. *Lophosphaeridium? kryptoradiatum* Vanguestaine, 1974. – (8): Givonne –7, 60103, R41/3; – (9): Givonne –29, 60809, K49/2 – K50/1. – Figs 10 and 11. *Lophosphaeridium tentativum* Volkova, 1968. – (10): Givonne –3, 59636, S46/4; – (11) Givonne –5, 59640, H44, 3-4. – Figs 12 and 13. *Stelliferidium* ? sp A *in* Brück & Vanguestaine (2004). – (12) Givonne –12, 60207, X42/1-2; – (13): Givonne –29, 60809, S43/4. – The typical stelliferid ornamentation of the wall surface does not appear on the microphotographs.
Figs 14 – 20 *Retisphaeridium brayense* (Gardiner & Vanguestaine, 1971) Moczydlowska, 1998: (14) Givonne –13, 60209, P33/1; – (15) Givonne –13, 60209, V33; – (16) Givonne –13, 60209, E39; – (17) Givonne –13, 60209, L40/1; – (18) Givonne –13, 60209, E41; – (19) Givonne – 24, 60331, H53; – (20) Givonne –16, 60218, V55/2.

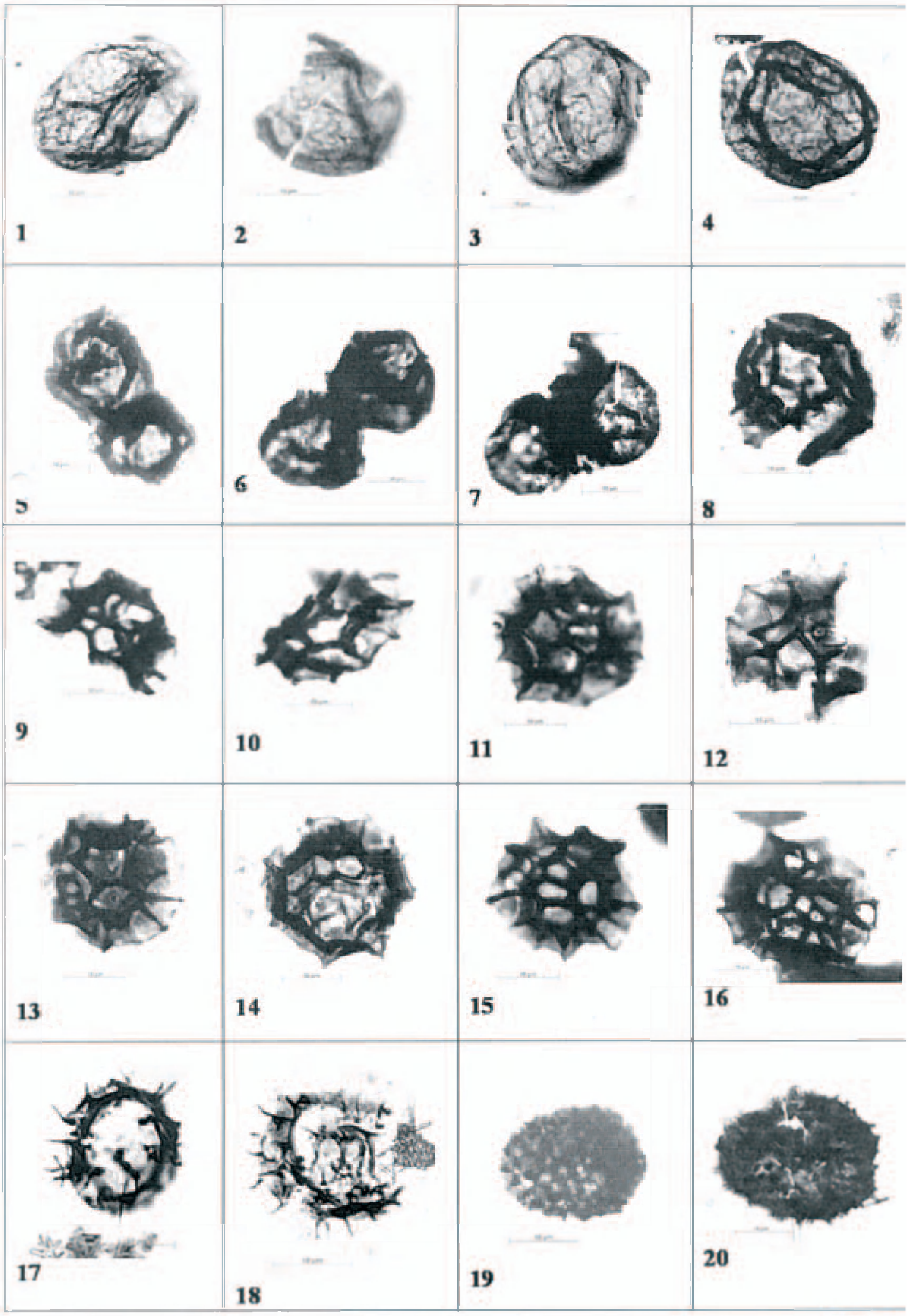

Plate II

Figs 1-4. *Retisphaeridium brayense* (Gardiner & Vanguestaine, 1971) – Moczydlowska 1998: (1) Givonne –13, 60209, T35/2; (2) Givonne –13, 60209, M38/4; – (3) Givonne –13, 60209, R38/3; – (4) Givonne –16, 60218, O30. – Figs 5-7. *Synsphaeridium* sp. *in* Vanguestaine (1978) – (5) Givonne –12, 60207, J55/2; – (6) Givonne –12, 60207, H50/2-4; – (7) Givonne –28, 60826, R35/1

Fig. 8. *Timofeevia pentagonalis* (Vanguestaine, 1974) Vanguestaine 1978: Givonne –26, 60824, O46-O47.

Figs 9-16. *Timofeevia phosphoritica* Vanguestaine, 1978: (9) Givonne –28, 60826, H30/1; – (10) Givonne –28, 60826, O36/3; – (11) Givonne –27, 60807, W40/2; – (12) Givonne –27, 60825, W33/3; – (13) Givonne –27, 60807, M42/3; – (14) Givonne –27, 60225, K30/3; – (15) Givonne –27, 60825, M41/2-4; – (16) Givonne –28, 60826, R5/4.

Figs 17 and 18. *Polygonium martinae in* Moczydlowska & Crimes (1995): (17) Givonne –16, 60218, P30; – (18) Givonne –16, 60218, S41/4

Fig. 19. *Retisphaeridium ovillense* (Cramer & Diez, 1972) Vanguestaine, 2002: Givonne –13, 60209, F42.

Fig. 20. *?Skiagia* sp: Givonne –3', 59629, E43/1: The coarsely granulate wall surface may well represent truncated processes of which only the proximal portion is preserved.

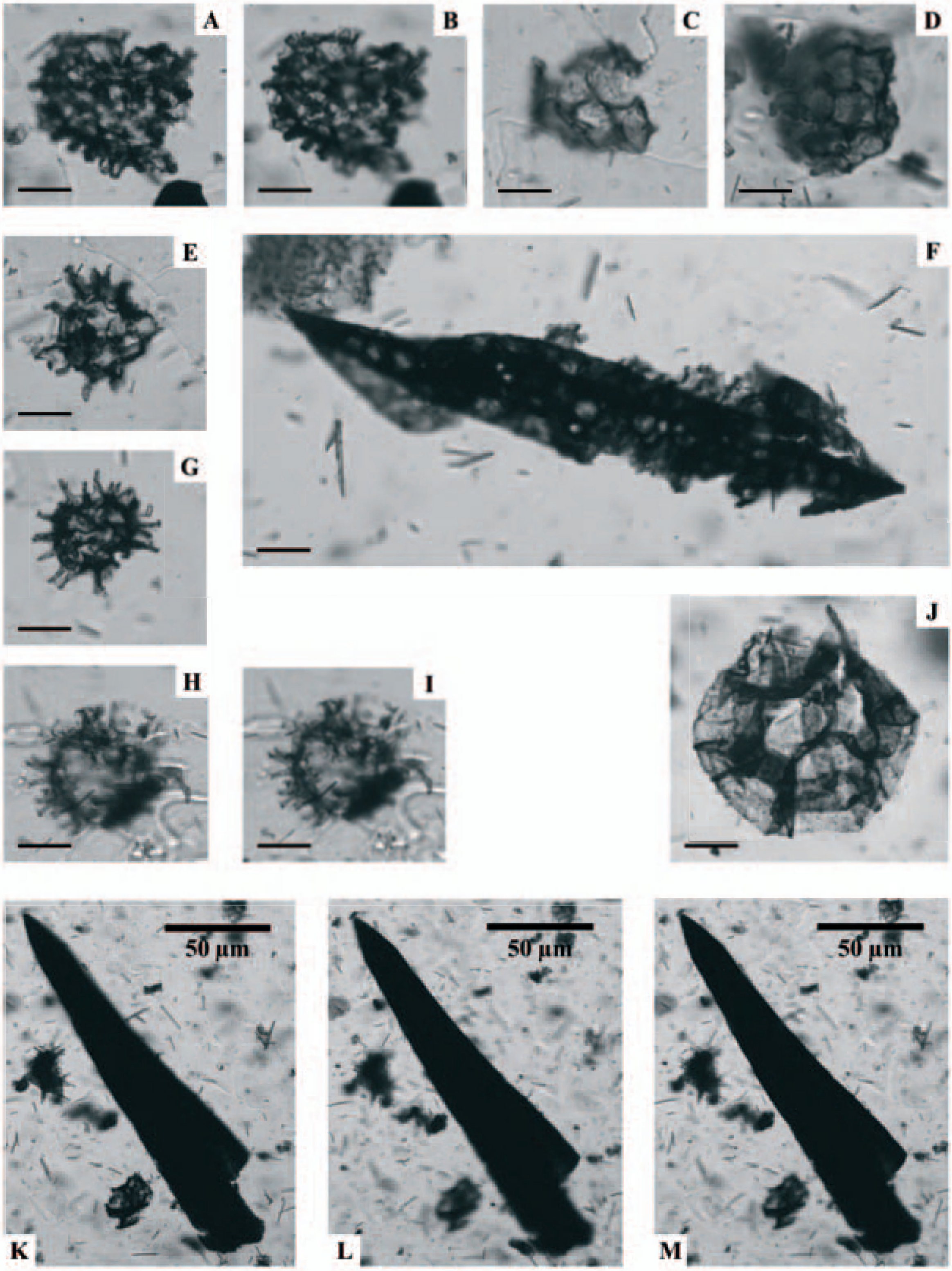

Plate III (All specimens at approximately 1000x, except K, L, M at 400x)

Figs 1-5. *Adara alea* Martin *in* Martin & Dean (1981):(1) and (2) Givonne –16, 60220, H46/2-4: vesicle diameter 29μm; hollow rounded protuberances; – (3) Givonne –16, 60220, U52: fragmented specimen showing in the lower right corner the typical radially arranged wrinkles; (4) and (5) Givonne –16, 60219, P42: specimen exhibiting an apparent polygonal pattern probably due to diagenetically induced folding of the membrane between the protuberances; surface membrane wrinkled but apparently the striae are not radially arranged. Diameter 27μm.

Fig. 6. *Celtiberium geminum* Fombella 1977: Givonne –16, 60219, Q30/2. Diameter 17 μm.

Fig. 7. *Cristallinium cambriense* (Slavikova, 1968) Vanguestaine, 1978: Givonne –16, 61462, R53.

Figs 8-11. *Multiplicisphaeridium martae* Cramer & Diez, 1972: (8) Givonne –16, 60220, V41: vesicle diameter 18 μm; processes up to 6 μm; – (10) Givonne –16, 61462, H43/4: vesicle diameter 20μm; – (11) Givonne –16, 60219, T35: vesicle diameter 19μm; processes up to 5 μm.

Fig. 12. ? *Eliasum llaniscum* Fombella 1977: Givonne –16, 60218, W55/1: 118μm long specimen with folded pattern but pointed, not rounded, extremities.

Fig. 13. *Retisphaeridium postae* (Jankauskas, 1976) Vanguestaine *in* Brück & Vanguestaine (2004): Givonne –16, 60219,Y40/4. Diameter 41 μm.

Figs 14-16. *Ceratophyton vernicosum* Kirjanov *in* Volkova *et al.* (1979): Givonne –16, 60219, Y37/1-2: conical object of 185 μm with pointed apex and damaged antapical end.