

# EARLY AND MIDDLE ORDOVICIAN ACRITARCHS OF THE SENNE-SENNETTE RIVER VALLEYS (BRABANT MASSIF, BELGIUM) AND THEIR STRATIGRAPHIC IMPLICATIONS

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(6 figures, 1 table, 2 plates)

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**ABSTRACT.** Early and Middle Ordovician strata from the Senne-Sennette river valleys, at the southern border of the Brabant Massif, have been intensively sampled for an acritarch study. Previous research, together with unpublished and new observations, are reported. Three sections are studied in the Sennette valley: along the Bruxelles-Charleroi canal south of Asquempont, in the Virginal railway trench and at La Tourette along the bief 29 of the old canal. Two other locations are also considered: a section along the Coeurq river and another along the railway and in the quarry at Quenast, in the Senne valley. An early Tremadocian assemblage is observed in the three localities of the Sennette valley within strata which biostratigraphical content allows their lithostratigraphical assignment to the Chevlipont Formation. Between the latter formation and the Rigenée Formation, rocks coeval to the Abbaye de Villers and Tribotte Formations of the Thyle valley, yielded two distinct assemblages. The *Frankea hamata*-*Striatotheca rarirrugulata* Acritarch Zone of the English Lake District, indicating a late Arenig age, is observed in sediments reported to the Abbaye de Villers Formation from the Virginal railway section. The lithostratigraphical assignment is confirmed as the same Zone is recorded from coeval strata from the Thyle section. A second assemblage, characterized by the co-occurrence of species such as *Arbusculidium filamentosum* and *Frankea sartbernardensis*, is recognized in an unnamed member attributed to the Abbaye de Villers Formation at Asquempont and in strata attributed to the Abbaye de Villers Formation in the Quenast railway section. In these two localities of Asquempont and Quenast, chitinozoans indicating respectively a middle and a late Arenig age are also described. According to acritarchs, the age of those strata would be late Arenig. Combined acritarch and chitinozoan results indicate a probable late Arenig age. Moreover, due to their acritarch content, the lithostratigraphical attribution of the Asquempont and Quenast strata is questioned. They are coeval with the Tribotte Formation or with a level at the boundary between the Tribotte and the Rigenée Formations of the Thyle river section. Other 'pre-Rigenée' localities could also belong to the *A. filamentosum*-*F. sartbernardensis* assemblage, based on the presence of *F. sartbernardensis* or *A. filamentosum*. One locality is situated at Asquempont and consists of the main part of the section studied by Martin & Rickards (1979) and another is located at La Tourette. Samples of the Rigenée Formation have not revealed the stratigraphical markers known in the type section of the Thyle valley despite the great number that were investigated in different localities from the Senne-Sennette valleys.

**KEYWORDS:** Acritarch biostratigraphy, chitinozoan biostratigraphy, Abbaye de Villers Formation, Chevlipont Formation.

## 1. Introduction

Previous acritarch studies in Lower and Middle Ordovician strata of the Thyle river section (Martin, 1977; André *et al.*, 1991; Servais, 1991; Vanguestaine & Léonard, 2005) allowed the recognition of three successive acritarch assemblages: 1. an early Tremadocian assemblage, in the Chevlipont Formation, characterized by the abundance of diacromorph species amongst which *Acanthodiacrodium angustum*, of galeate species assigned to the genera *Cymatiogalea* and *Stelliferidium* and of vulcanisphaerid species as *Vulcanisphaera flagellum*; 2. the late Arenig *Frankea hamata*-*Striatotheca rarirrugulata* Acritarch Zone in the middle and upper part of the Abbaye de Villers Formation and the lower part of the Tribotte Formation; 3. the successive appearance of *Frankea sartbernardensis*, *Striatotheca quieta*, *Arkonion virgata* and *Frankea*

*hamulata* from the upper part of the Tribotte Formation up to the middle part of the Rigenée Formation. The Arenig-Llanvirn boundary is probably to be found within this last sequence.

Coeval strata also exist in the Senne-Sennette river valleys, 30 km west of the Thyle valley. They are herein studied in three sections from the Sennette valley (the Bruxelles-Charleroi canal section, the Virginal railway section and the La Tourette section), in the Coeurq river valley and in the Senne valley (Quenast railway section and Quenast quarry). Their rocks have been assigned to the Lower and Middle Ordovician formations defined in the Thyle valley (Verniers *et al.*, 2002). From base to top, the succession is composed of the Chevlipont Formation (early Tremadocian), the Abbaye de Villers Formation (late Arenig), the Tribotte Formation (late Arenig-early Llanvirn) and the Rigenée Formation (late

Arenig-Llanvirn). The ages are according to Vanguetaine (this volume). In the studied area, the Asquempont fault forms the contact between Ordovician rocks and the Lower-Middle Cambrian Oisquerq Formation. Due to the tectonic complexity of the area (Debacker *et al.*, 2003), the stratigraphical order, the thickness estimation and the lithostratigraphical assignment of the Lower-Middle Ordovician rocks is problematical. Local names and informal units have therefore been used in the literature.

Leriche (1912) used the term “quartzophyllades de Virginal” and assigned them to the early Tremadocian, which revealed correct much later (Vanguetaine, 1978), for finely laminar siltstones (now the Chevliport Formation) in the Virginal railway section.

Legrand (1967) described the Lower-Middle Ordovician rocks along the Bruxelles-Charleroi canal south of Asquempont. From base to summit, he distinguished four lithological units: 1. black siliceous shales; 2. grey-green sandstones with trace of fossils; 3. laminar siltstones; 4. blackish shales with graptolites and inarticulated brachiopods. Units 1, 2 and 3 were considered as Arenig (now assigned to the Abbaye de Villers and Tribotte Formations); unit 4 as Llanvirn (now the Rigenée Formation). For the same succession along the Bruxelles-Charleroi canal south of Asquempont, Martin & Rickards (1979) used informal units (A-D) between km 40.079 and km 39.776, the last locality containing a graptolite level.

Beugnies in Waterlot *et al.* (1973) considered a black unit (now ‘unnamed member’ of the Abbaye de Villers Formation in Verniers *et al.*, 2002), immediately south to the Asquempont fault, as belonging to the Revin Group and used the term Rv2, inferring a Cambrian age. This unit is actually Middle Ordovician in age (Vanguetaine, 1978 and Samuelsson & Verniers, 2000). Its precise age will be discussed later (Section 4.3.). Moreover Beugnies in Waterlot *et al.* (1973) introduced a Quenast unit (‘Quartzophyllades zonaires de Quenast’) for laminar siltstones and sandstones in the railway section at Quenast. Lenoir (in Lenoir *et al.*, 1989 and in André *et al.*, 1991, fig. 16) also used this term and extended it to encompass all units comprised between the Chevliport Formation (= Virginal Formation in André *et al.*, 1991) and the Rigenée Formation (= La Tourette Formation in André *et al.*, 1991) in the studied area.

In the Virginal railway section, Vanguetaine (1978) reported the existence of two acritarch assemblages: an early Tremadocian in the ‘quartzophyllades de Virginal’ (now the Chevliport Formation) and a Middle Ordovician one (dated as Arenig-Llanvirn at the time) in the overlying strata (now the Abbaye de Villers Formation). He also recorded an Arenig-Llanvirn assemblage immediately south to the Asquempont fault in the canal section (in strata reported now to the unnamed member of the Abbaye de Villers Formation, Verniers *et al.*, 2002) and in the Quenast railway section. Middle Ordovician rocks of the Virginal railway section will be demonstrated to be older than the Middle Ordovician rocks of Asquempont and part at least of the rocks of Quenast (Sections 4.2. & 4.3.).

Martin & Rickards (1979), in their study of the Ordovician and Silurian rocks of the Bruxelles-Charleroi canal section, also examined some of the Middle Ordovician strata of concern in the present paper. They used, as already said, informal units (A, B, C, D, E, F) for the studied Ordovician rocks. Because units E and F are of late Ordovician age (Martin & Rickards, 1979, Verniers *et al.*, 2002), only the units A to D will be considered herein. However few acritarch species are identified by Martin & Rickards (1979) and taken as indicative of a broad ?late Arenig-Llanvirn age. This age is locally confirmed by the restudy of *Didymograptus artus* graptolite level in the unit D (Maletz & Servais, 1998). Stratigraphically important taxa as *Arbusculidium filamentosum*, *Frankea sartbernardensis*, *Vogtlandia multiradialis* were however determined and their meaning will be discussed (Section 4.3.).

Lenoir (1987 and in André *et al.*, 1991) examined new samples from several sections of the Senne-Sennette valleys. He completed the observations of Vanguetaine (1978) in finding the lower Tremadocian acritarch assemblage in two other localities (Asquempont and La Tourette) and the Middle Ordovician acritarch assemblage at La Tourette, in the Coeurq section and in the Quenast quarry. His unpublished work is incorporated in the present paper and modified according to the new stratigraphic progress made in the Thyle valley Vanguetaine (this volume) and the observations of new samples.

Samuelsson & Verniers (2000) described chitinozoans in three of the studied units: a mid Arenig assemblage in the unnamed member of the Abbaye de Villers Formation at Asquempont; a late Arenig assemblage in the Abbaye de Villers Formation in the Quenast railway section; a late Arenig-early Llanvirn assemblage in the Rigenée Formation from the canal section south of Asquempont.

Hennebert & Eggermont (2001) and Debacker *et al.* (2003) mapped the eastern part of the studied area (Sennette valley) and provided useful cross-sections for the present work.

The aim of the present paper is to review the different sections studied so far and their acritarch content in the Senne-Sennette valleys and to establish comparisons with coeval strata in the Thyle section and with the chitinozoan results.

## 2. Section locations, studied samples and palynological techniques

Five sections have been sampled, three in the Sennette valley, one in the Coeurq and the fifth one in the Senne valley (Fig. 1).

### 2.1. Sections in the Sennette valley

The three studied sections are the canal section south of Asquempont, the Virginal railway section and the La Tourette section along the bief 29 of the old canal.

### 2.1.1. The Bruxelles-Charleroi canal section south of Asquempont

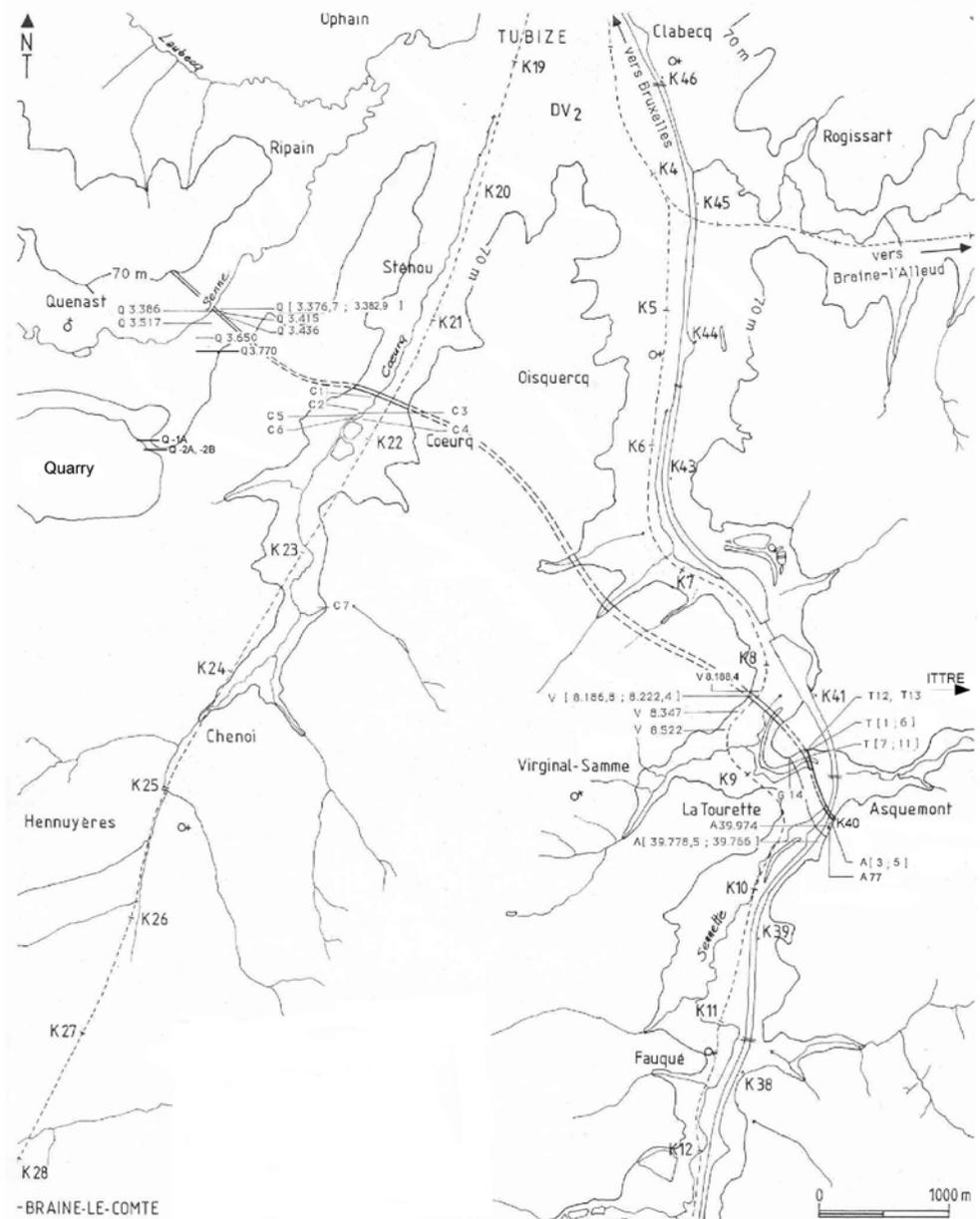
The digging of the new Bruxelles-Charleroi canal has created important outcrops amongst which the one south of Asquempont. On the eastern side of the canal, the fault contact between Lower and Middle Ordovician rocks and Lower to lower Middle Cambrian rocks of the Oisquercq Formation is observable (Legrand, 1967; Hennebert & Eggermont, 2002; Debacker *et al.*, 2003).

Several faults rendered the local structures very complicated (Debacker, 2001; Hennebert & Eggermont, 2002). The Asquempont fault has been thoroughly studied and redefined by Debacker *et al.* (2003) who distinguished pre-cleavage (the redefined Asquempont fault) and post-cleavage faults (amongst which the Asquempont fault sensu Legrand, 1967) associated to the Nieuwpoort-Asquempont fault zone (De Vos *et al.*, 1993). Legrand (1967) reported the discovery of a graptolite level in a shaly unit, now assigned to the Rigenée Formation and

identified the lower Llanvirn *Didymograptus artus* graptolite Zone, confirmed by Martin & Rickards (1979) and Maletz & Servais (1998). Except for a few meters of Tremadocian rocks crushed by the Asquempont fault found by Lenoir (1987), Legrand (1967) postulated the existence of a complete Middle Ordovician succession comprising from base to top four units: 1. black siliceous shales; 2. grey-green sandstones with traces of fossils; 3. laminar siltstones; 4. blackish shales (see Table 1).

The unnamed member of the Abbaye de Villers Formation of Verniers *et al.*, (2002) corresponds to the lower part of the unit 1 of Legrand (1967). Units A, B, C and D of Martin & Rickards (1979) corresponds to the units 1 to 4 (except the unnamed member) of Legrand (1967).

The succession, very briefly described by Beugnies in Wartelot *et al.* (1973) at Asquempont, comprised the unnamed member taken as a unit belonging to the Revin Group (Rv2). The overlying units either have



**Figure 1:** Sample location in the Lower and Middle Ordovician strata of the Coeurq, Senne-Sennette river valleys. A = Asquempont, C = Coeurq, Q = Quenast, T = La Tourette, V = Virginal. The Asquempont fault (sensu Debacker *et al.*, 2003) is according to the mapping of Lenoir (1987) and indicated by a double line.

Thyle Lithostratigraphy (Verniers <i>et al.</i> , 2002)	Bruxelles-Charleroi Canal section (south of Asquempont)	Virginal railway trench	La Tourette section	Coeurcq river section	Quenast quarry and railway sections
Rigenée Formation	- Unit 4 (Legrand, 1967) - Unit D (Martin and Rickards, 1979) - Rigenée Formation (Verniers <i>et al.</i> 2002) - La Tourette Formation (Lenoir, 1987; André <i>et al.</i> , 1991; Servais <i>et al.</i> , 1993)	⇒	←	⇒	←
Tribotte Formation	- Units 1-3 (Legrand, 1967) - Units A-B-C (Martin and Rickards, 1979) - Unnamed member of the Abbaye de Villers Fm (Verniers <i>et al.</i> , 2002) + Formation des phyllades et quartzites noirs (Waterlot <i>et al.</i> , 1979)			←	⇒
Abbaye de Villers Formation	Abbaye de Villers and Tribotte Fm (Hennebert and Eggermont, 2002) Abbaye de Villers/Tribotte Formation (Debacker <i>et al.</i> , 2004)	Abbaye de Villers Fm (Debacker <i>et al.</i> , 2004)		Quenast Formation (Lenoir, 1987; André <i>et al.</i> , 1991; Servais <i>et al.</i> , 1993)	- Formation des schists et phyllades gréseux gris noirs (S1 1a in Waterlot <i>et al.</i> , 1979) - Quartzophyllades zonaires à <i>Dictyonema flabelliforme</i> (Sm2 in Waterlot <i>et al.</i> , 1979) - Formation de phyllades verts (=Sm1) in Waterlot <i>et al.</i> , 1979)
Chevlipont Formation		Quartzophyllades de Virginal (Leriche, 1912) Formation de Virginal (Lenoir, 1987; André <i>et al.</i> , 1991; Servais <i>et al.</i> , 1993)	⇒		- Formation des phyllades et quartzites noirs (Rv2 in Waterlot <i>et al.</i> , 1979)  Abbaye de Villers Fm (Samuelsson and Verniers, 2002)

never been observed by later workers (his Sm 1, green, shale formation) or are not clearly characterized (his Sm 2 = the Quenast formation, and S11a, a formation described as composed of grey green shales and sandy slates). However his Llanvirn S11b unit is recognized later and corresponds to the Rigenée Formation.

Hennebert & Eggermont (2002) assigned to the Abbaye de Villers Formation, most of the rocks comprised between the Asquempont fault to the north and the Rigenée Formation to the south, except some faulted Tribotte strata at mid distance. Mapping of Debacker *et al.* (2003) in the Asquempont area did not distinguished the Abbaye de Villers from the Tribotte Formations and they are grouped in one unit.

It will be demonstrated (Section 5.1.) that most of the rocks comprised between the Chevlipont and the Rigenée Formation are coeval with the Tribotte Formation or with strata at the boundary between the Tribotte and Rigenée Formations.

Thirteen samples are taken in this section (location in Appendix 1).

### 2.1.2. The Virginal railway section

The section, localized about 1 km west of the Asquempont section, has been recently restudied in detail by Debacker *et al.* (2003). From north to south, the section exhibits the Asquempont Member of the Oisquercq Formation, at km

8.185 of the old railway the Asquempont fault, between km 8.185 and 8.235 the Chevlipont Formation, from km 8.235 to 8.380 the Abbaye de Villers Formation and between km 8.380 and 8.575 the Rigenée Formation. Ten samples have been studied (location in Appendix 1).

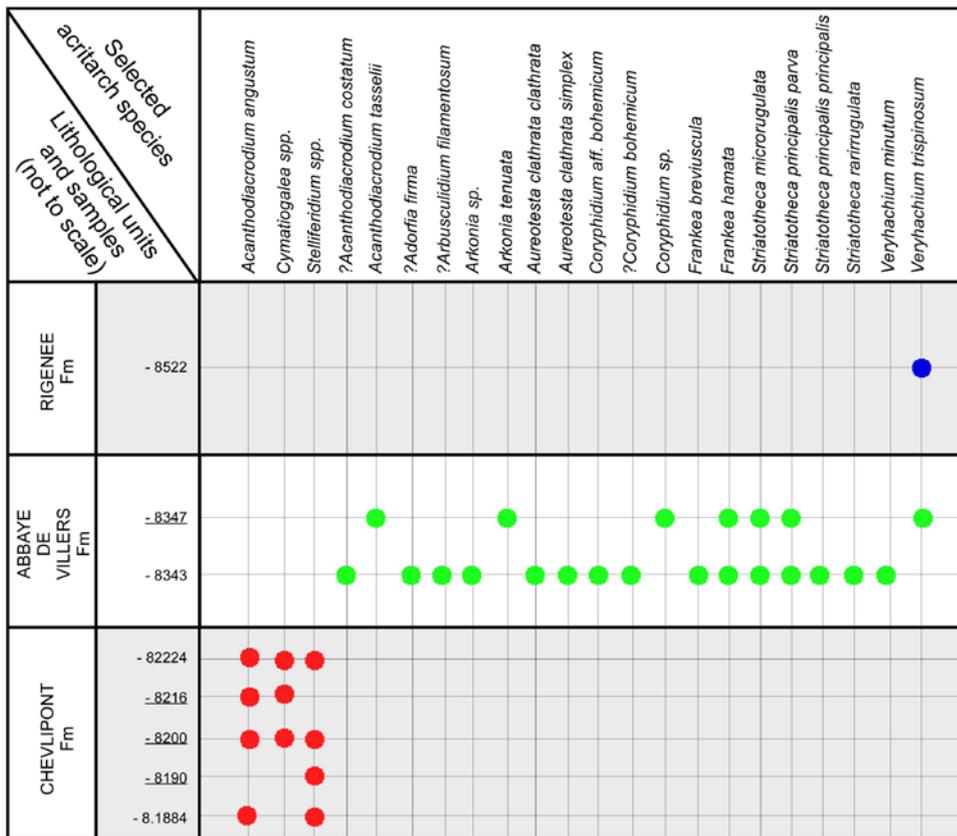
### 2.1.3. The La Tourette section

The section lies at the northern side of an arm of the old canal, called “bief 29”, in the garden of the house with number 11. It is accessible by the road along the new canal. From east to west, it exhibits several small outcrops belonging to the Oisquercq, Chevlipont and the unnamed member of the Abbaye de Villers Formation (Lenoir, 1987). A slaty breccia between the outcrops of the Oisquercq and the Chevlipont Formation is a striking feature probably corresponding to the Asquempont fault. A galena dyke and a quartz vein are also observable in an outcrop within the property of the house with number 13. Eleven samples were taken (location in Appendix 1).

## 2.2. The Coeurcq river valley section

Dispersed outcrops of laminar siltstones and slates are observable along the Coeurcq river just north of the Coeurcq village. They have been mapped by Beugnies in Waterlot *et al.* (1973) as belonging to the “Quenast quartzophyllades” and by Lenoir (1987) in his Quenast formation but will be referred in the present work to an undefined formation. An





**Figure 3:** Acritarch species distribution in the Lower and Middle Ordovician of the Virginal railway section. Underlined samples are from Vanguestaine (1978). Virginal -8.343 is a newly studied sample.

Their identification and stratigraphical distribution in each section is presented in Figures 2 to 6. Although many other species are present, only a few selected taxa are reported in the figures. Studies of Martin (1977), Servais (1991) and Vanguestaine & Léonard (2005) in the Thyle section describe and illustrate most of the species discussed herein. Two plates illustrate the main taxa encountered in the Senne-Sennette valley. The identification of Vanguestaine (1978) have generally been controlled by us except for two samples of the Quenast railway section in which some key species as *Frankea sartbernardensis* could not be found again. Their identification in those samples remains therefore unsure.

### 3.1. Acritarch species distribution in the studied sections

#### 3.1.1. Asquemont section (Fig. 2)

Palynological results demonstrate a clear distinction between samples Asq-3 and Asq-5 on one hand and the other samples on the other hand. The transition from one assemblage to the other is observed between sample Asq-5 to Asq-5,5, i.e. within half a meter. This observation matches very well with the profile provided in Debacker *et al.* (2003) where the boundary between the Chevlipont Formation and the unnamed member is located about 5 m south of our point O, the quartz veins (see Appendix 1). The best diversified samples (Asq-7 and Asq-11) are in the unnamed member. They are much better than samples higher in the sequence in units A, B and in the Rigenée Formation which yielded very few identifiable specimens as also mentioned in Martin & Rickards (1979).

#### 3.1.2. Virginal railway section (Fig. 3)

Once again the difference in composition, already emphasized in Vanguestaine (1978), between the lower samples from the Chevlipont Formation and from overlying strata is particularly clear. Sample 8.343, newly studied, has yielded a very diversified assemblage.

#### 3.1.3. La Tourette section (Fig. 4)

Here again, the same clear distinction into two assemblages is evident. The transition from one assemblage (sample -6) to the completely different assemblage (sample -7) was observed within a few decimeters lacking any notable tectonic disturbance. However, it should be noted that one acritarch species, *Acanthodiacrodium angustum* (Pl. I, Fig. 3), commonly found in the lower assemblage (La Tourette -1 to -6) is also found as a single specimen in La Tourette -7 (Pl. I, Fig. 2) where it is mixed to species of the second assemblage. Debacker *et al.* (2003) did not mention any fault in this section at the contact between their mapped units Chevlipont and Abbaye de Villers - Tribotte.

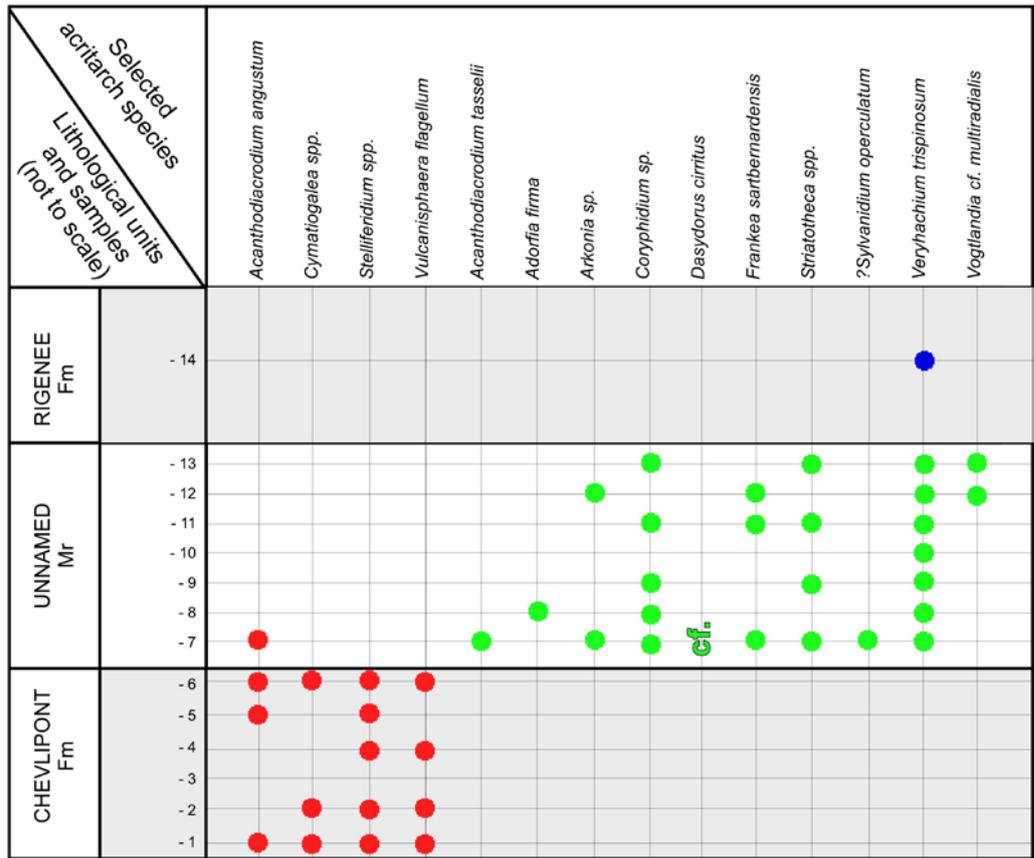
#### 3.1.4. Coeurq river section (Fig. 5)

Very few results were obtained from samples of this section. They indicate however a post-early Tremadocian age and therefore a correlation of the undefined formation with the Abbaye de Villers or Tribotte Formations of the Thyle river valley.

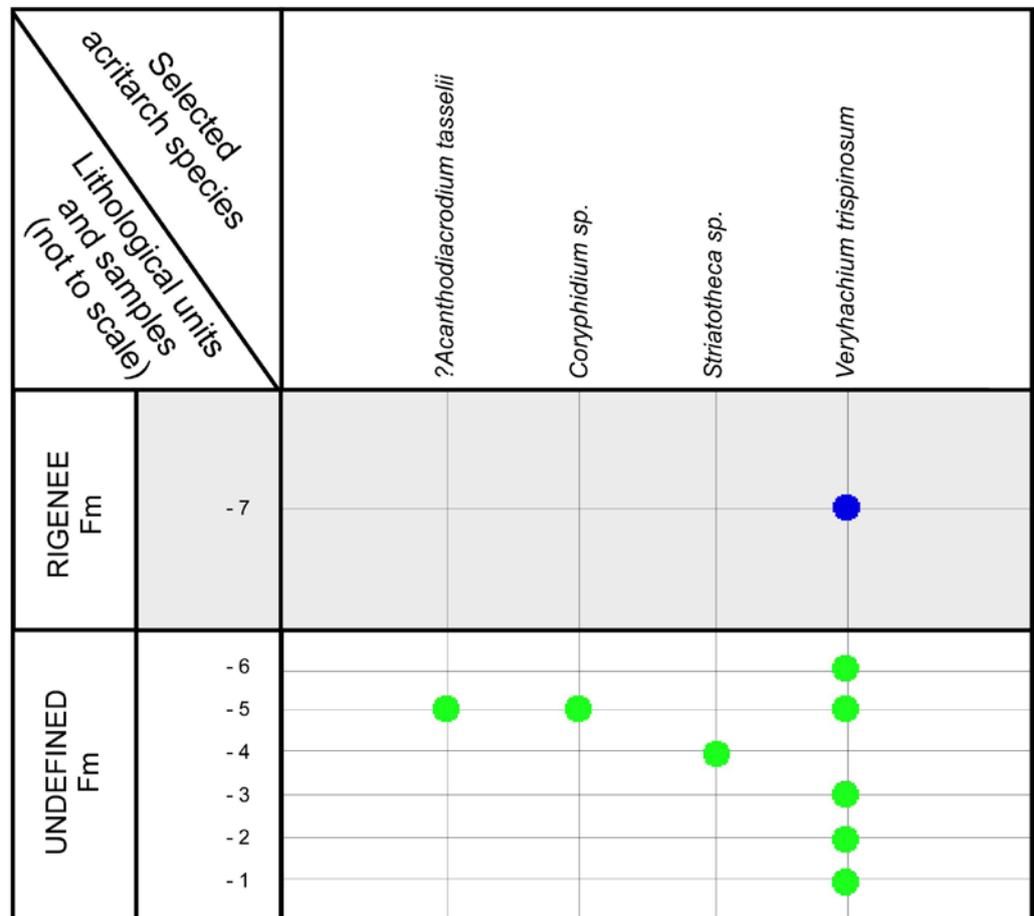
#### 3.1.5. Quenast railway and quarry section (Fig. 6)

The so-called Transitional Zone is nearly completely

**Figure 4:** Acritarch species distribution in the Lower and Middle Ordovician from La Tourette section.



**Figure 5:** Acritarch species distribution in the Lower and Middle Ordovician from the Coeurq river section.





the species in the Asquempont canal section according Martin & Rickards (1979) and its stratigraphic meaning with respect to the Arenig-Llanvirn boundary.

Occurrence: Unnamed member in the Asquempont canal section (Asquempont – 7); quartzophyllades zonation de Quenast (Quenast – 3.700); ?Abbaye de Villers Formation at Virginal (Virginal – 8.343).

Genus *Arkonia* Burmann, 1970  
*Arkonia virgata* Burmann, 1970  
 Pl. II Fig. 3

- 1970 *Arkonia virgata* n. sp. in Burmann, p. 298, pl. 7, fig. 6  
 non 1977 *Arkonia virgata* Burmann, 1970 in Martin, p. 12  
 1991 *Arkonia virgata* Burmann, 1970 in Servais, p. 240-241, pl. 1, fig. 22  
 1991 *Arkonia virgata* Burmann, 1970 in André *et al.*, p. 290  
 1992 *Arkonia virgata* Burmann, 1970 in Servais & Maletz, p. 270, pl. 3, fig 12  
 1993 *Arkonia virgata* Burmann, 1970 in Maletz & Servais, p. 140, 142, fig 4:18

Remarks:

1. The distinction between two of the commonest species of the genus, *Arkonia tenuata* and *Arkonia virgata* lies in the number and the thickness of the ribs orning the external surface of the central triangular body. According to Burmann (1970), *A. tenuata* is covered with fine ribs, 10-12 in number (including the calked ribs) parallel to the adjacent sides. *A. virgata* bears relatively thick ribs, about 7 in number (including the calked ribs) parallel to the adjacent sides.
2. The specimen figured Pl. II, Fig. 3 is clearly an *Arkonia virgata* as the ribs are widely spaced. Specimen of Pl. II, Fig. 4 seems more densely striated and would be better placed in a transitional position between *virgata* and *tenuata*.
3. Martin (1977, p.12) cited the species in the Abbaye de Villers Formation of the Brabant Massif. No illustration was however provided. Its identification is problematic because it was not observed afterwards (Vanguetaine, this volume).
4. According to Servais (1997), the species is unknown in proven Arenig rocks.

Occurrence: Unnamed member of the Asquempont canal section (Asquempont – 7).

Genus *Coryphidium* Vavrdová, 1972  
*Coryphidium* spp.  
 Pl. II, Fig. 7

Remark: Due to the poor state of preservation, distinction at the specific level is very difficult and is generally not achieved, except in sample Virginal –8.343 where

*Coryphidium* aff. *bohemicum* sensu Molyneux and Leader (1997) is clearly recognized. See Vanguetaine (this volume) for identification of the latter species.

Occurrence: Ubiquitous.

Genus *Dasydorus* Playford & Martin, 1984  
*Dasydorus* sp. cf. *Dasydorus cirritus*  
 Playford & Martin, 1984  
 Pl. II, Fig. 8

- 1984 *Dasydorus cirritus* sp. nov. in Playford & Martin p. 198, fig. 6A-C  
 1988 *Dasydorus cirritus* Playford & Martin in Arriagha e Cunha & Vanguetaine, p. 72-73; pl. I, figs 12, 13; pl. II, figs 1-4

Description: elliptical vesicles with a granular like ornamentation of *Lophosphaeridium* aspect except that a smooth polar zone can be evidenced on some specimens. Ornaments of  $\frac{1}{2}$  -  $\frac{3}{4}$   $\mu\text{m}$  in diameter.

Remarks:

1. *D. cirritus* bears baculum-like projections, 1-3.8  $\mu\text{m}$  long. Whether or not the herein observed specimens have shorter ornaments than *D. cirritus* or that they are truncated projections is unknown and justifies their description in open nomenclature.
2. The species is described in the Goldwyer Formation of Western Australia of poorly constrained age: late Arenig - ?early Caradoc (Playford & Martin, 1988). It is also well illustrated in the “Xistas com *Phyllodocites*” Formation, Southeast Portugal dated as late Arenig (*Didymograptus hirundo*) by graptolite. (Arriagha e Cunha & Vanguetaine, 1988). The acrotarch content (?*Arkonia virgata*, *Striatotheca quieta*, *Stellechinatum* cf. *celestum*) could however be in favour of an early Llanvirn age.

Occurrence: Unnamed member in the Latourette section.

Genus *Frankea* Burmann, 1970  
*Frankea sartbernardensis* (Martin, 1966) Colbath, 1986  
 Pl. II, Figs 9 and 10

- non 1977 *Frankea sartbernardensis* (Martin, 1965) Burmann, 1970, in Martin, pl. 5, fig. 7  
 1978 *Frankea sartbernardensis* Martin, 1966 in Vanguetaine, p. 194-196 (pro parte)  
 non 1991 *Frankea sartbernardensis* var. A in André *et al.*, p. 290  
 1991 *Frankea sartbernardensis* var. B in André *et al.*, p. 290  
 1991 *Frankea sartbernardensis* in Servais, figs 17, 21, 23

Remarks:

1. Servais (1993) provided measurements of 50 specimens of *F. sartbernardensis* from Sart-Bernard, lower

Llanvirn, Belgium. The process length against central body diameter ratio is about 1:5 to 1:6. This confirms Martin's (1969) and Vecoli *et al.* (1999) ratio of 1/5. It is interesting to note that Martin (1969) observed that Ordovician specimens (comprising the holotype of Sart-Bernard) have a ratio process length against central body side length smaller than reworked Silurian specimens (pl. V, fig. 220, pl. VI, fig. 263 in Martin 1969). The latter specimen was transferred into *F. breviscula* by Servais (1993).

2. *Frankea sartbernardensis* in Martin (1977) is clearly a *Frankea hamata*.
3. *Frankea sartbernardensis* var. A in André *et al.* (1991) are in fact *F. breviscula* (see Vanguetstaine, this volume).
4. The specimens observed have very short processes (ratio about 1/5) and generally fine striation on the central body resembling the striation known in *Arkonia tenuata*.
5. Identification of specimens observed by Vanguetstaine (1978) is confirmed for the Asquempont section. The specimens of the Quenast railway section (Quenast – 3.386 and –3.650) could not be reinvestigated. Their identification is still to be confirmed. The species is however clearly recognized in the newly studied sample Quenast –3.770.

Occurrence: Unnamed member of the Asquempont canal and La Tourette sections; unit A (Martin and Rickards, 1979) of the Asquempont canal section; quartzophyllades de Quenast.

Genus *Striatotheca* Burmann, 1970

*Striatotheca quieta* (Martin, 1969) Rauscher, 1974

Pl. II, Figs 11 and 12

1969 *Veryhachium quietum* n. sp. in Martin, p. 100-101, pl. V, fig. 226; pl. VI, fig. 290, text-fig. 48

1991 *Striatotheca quieta* (Martin, 1969) Rauscher in André *et al.*, p. 290

1991 *Striatotheca quieta* (Martin, 1969), Rauscher 1974 in Servais, pl. 1, fig. 8

1997 *Striatotheca frequens* Burmann, 1970 in Servais p. 62

Remarks:

1. *S. quieta* with its short conical processes is easily differentiated from *S. frequens* Burmann, 1970 which bears longer cylindrical, very gradually tapering processes with obtuse terminations.
2. Servais (1997, p. 62) mentioned few similar specimens to *S. frequens* found in the Rigenée Formation. He probably means *S. quieta* effectively found in that formation (Servais, 1991).
3. The holotype (Martin, 1969) is probably a reworked Ordovician specimen in Silurian strata. The drawing provided by Martin exhibits a densely striated membrane surface. The recorded specimens are on the contrary ornamented with widely spaced ribs.

4. First appearance of the species is unclear (Servais, 1997; Cooper *et al.*, in press). In Belgium, the species is unknown in the Abbaye de Villers Formation and the Tribotte Formation but currently recorded in the Rigenée Formation of the Brabant Massif (Servais, 1991) and in the Huy Formation of the Bande de Sambre-et-Meuse (Martin, 1969, Servais & Maletz, 1992).
5. Two specimens with a similar striation on the central body have been observed of which one is reported as *?S. quieta* due to the fact that the processes could be broken.

Occurrence: Unnamed member of the Asquempont canal section; Rigenée Formation in the Quenast quarry.

*Striatotheca* spp.

Remark:

Due to the poor state of preservation, the distinction between some species as *S. principalis parva* and *S. rarirrugulata* are in general difficult to discriminate. This remark does not apply to the sample Virginal –8.343.

Genus *Sylvanidium* Loeblich, 1970

*?Sylvanidium operculatum* Vavrdová, 1978

Pl. II, Fig. 13

1978 *Sylvanidium operculatum* n. sp. in Vavrdová, p. 68; pl. 11, fig. 4; pl. 12, figs 1-2; pl. 14, fig. 9; text-figs 2t-v

1982 *Sylvanidium operculatum* in Vavrdová, p.149, pl. 3, figs 6, 7

1989 *Sylvanidium operculatum* in Vanguetstaine *et al.*, p. 45

1991 *Sylvanidium operculatum* in André *et al.*, p. 240

?1989 *Acanthodiacrodium* cf. *simplex* Combaz, 1968 in Rushton & Molyneux, p.272, fig. 4A

Remarks:

1. *Sylvanidium operculatum* is described by Vavrdová (1978) in Llanvirn strata of Bohemia as a kind of *Leiofusa* with elliptical central body and relatively long processes, one at each pole, slightly offset away from the long axis of the vesicle. The presence of a median excystment aperture is an additional specific feature.
2. Rushton & Molyneux (1989) figured similar specimens cited as *Acanthodiacrodium* cf. *simplex* Combaz, 1968 in the upper Arenig of the English Lake District (Black Combe Inlier). No excystment structure is mentioned but dimension are similar to the ones of *Sylvanidium operculatum* except the process length.
3. Specimens, cited as *?Sylvanidium operculatum* are mentioned in Vanguetstaine *et al.* (1989) and André *et al.* (1991). They come from the lowermost part of the Rigenée Formation (sample Rigenée, chemin creux – 2) in strata in which *Dicrodiacrodium normale*, *Frankea sartbernardensis* and *Striatotheca quieta* are

also observed (André *et al.*, 1991, Servais, 1991 and Vanguetaine, unpublished). No excystment structure is visible.

4. The figured specimen (Pl. II, Fig 13) comes from La Tourette –7 sample. Dimensions of the figured specimens lies between the dimensions of *Sylvanidium operculatum* and *Acanthodiacrodium* aff. *simplex*. No excystment structure is clearly observed.

Occurrence: Unnamed member of the La Tourette section.

Genus *Vogtlandia* Burmann, 1970  
*Vogtlandia multiradialis* Burmann, 1970  
 Pl. II, Fig. 14

- 1970 *Vogtlandia multiradialis* n. sp. in Burmann, pl. IV, fig. 1  
 1979 *Vogtlandia multiradialis* Burmann, 1970 in Martin & Rickards, p. 191, fig. 2, p. 193  
 1989 *Vogtlandia multiradialis* in Vanguetaine *et al.*, p. 45  
 1991 *Vogtlandia multiradialis* in André *et al.*, p. 290  
 1991 *Vogtlandia* cf. *multiradialis* in Servais, p. 240-241, pl. 1, fig. 14

Remark:

Burmann (1970) created 4 species assigned to a new genus *Vogtlandia*. They are distinguished on the base of process number and length. *V. imperfecta* and *V. tenuata* (3 processes), *V. ramifacata* (4-5 processes), *V. multiradialis* (7 processes). The generally poor preservation of the recorded specimens does not allow the distinction between the different species. *Vogtlandia multiradialis* is however clearly recorded in some samples, as Asq-11m.

Occurrence: Unnamed member of the Asquempont canal and La Tourette sections; questionable presence in the “quartzophyllades de Quenast”.

## 4. Stratigraphic interpretation

Based on their acritarch content, the different studied samples are grouped into four distinct assemblages. The comparison with the Thyle section enable a stratigraphic interpretation.

### 4.1. *Acanthodiacrodium angustum* assemblage

The easily recognizable species *Acanthodiacrodium angustum* is identified in 9 samples from the Asquempont, Virginal and La Tourette sections. *Acanthodiacrodium* spp., *Cymatiogalea* spp. and *Stelliferidium* spp. are commonly found in this assemblage. *Acanthodiacrodium ubuii* Martin, 1969 is probably recorded (Pl. I, Figs 4-6) but left in open nomenclature due to the poor preservation. Moreover, the La Tourette section exhibits *Vulcanisphaera flagellum* specimens (Pl. I, Figs 11 and 12). This assemblage is similar to the assemblage found in the Chevlipont Formation at the Thyle river section (Martin,

1977, André *et al.*, 1991). In Belgium, it has also been met in other places such as the Lessines borehole (Herbosch *et al.*, 1991), the Wépion borehole (Martin, 1969) and the Jalhay Formation in the Stavelot Inlier (Vanguetaine, 1974, 1986), always in the same stratigraphical context. Index species of the late Tremadocian *Stelliferidium trifidum* – *Cymatiogalea messaoudensis* assemblage of the Lierneux Member (Stavelot Inlier, Breuer and Vanguetaine, 2004) are not encountered. Therefore, an early Tremadocian age is much probable. Full determination of *Acanthodiacrodium ubuii* would be interesting as the species is restricted to the lower part of the Tremadoc (Rasul and Downie, 1974).

### 4.2. *Frankea hamata*-*Striatotheca rarirrugulata* assemblage

Sample Virginal –8.343 and, and in a lesser extent sample –8.347, yielded an assemblage very similar to the one observed in the middle and upper parts of the Abbaye de Villers Formation and the lower part of the Tribotte Formation of the Thyle river section. It is characterized by the co-occurrence of *Frankea hamata*, *Frankea breviscula* and *Striatotheca rarirrugulata*. *Adorfia firma* and *Arbusculidium filamentosum* are also typical species of this assemblage. This assemblage is dated as late Arenig, (late Fennian, early Darriwilian) in the English Lake District (Cooper *et al.*, in press). The lithostratigraphic attribution to the Abbaye de Villers Formation (Debacker *et al.*, 2003) of the rocks yielding this assemblage in the Virginal section is in accordance with acritarch biostratigraphy though the Abbaye de Villers Formation and the lower part of the Tribotte Formation in the Thyle river section could not be discriminated based on their acritarch content.

### 4.3. *Arbusculidium filamentosum*-*Frankea sartbernardensis* assemblage

A particular assemblage, unknown so far in the Thyle river section, combines elements of assemblages recorded separately in that area. *Adorfia firma* and *Arbusculidium filamentosum* appear restricted to the middle and upper part of the Abbaye de Villers Formation and the lower part of the Tribotte Formation. While, *Acanthodiacrodium tassellii*, *Arkonion virgata*, *Frankea sartbernardensis*, *Striatotheca quieta*, *?Sylvanidium operculatum*, *Vogtlandia multiradialis* are species recorded in the upper part of the Tribotte Formation and/or in the lower part of the Rigenée Formation.

This particular assemblage is observed:

- (i) in the unnamed member of the Asquempont canal section (*?Adorfia firma*, *Arbusculidium filamentosum* together with *Arkonion virgata*, *Frankea sartbernardensis*, *Striatotheca quieta* and *Vogtlandia multiradialis*).  
 (ii) in one sample at least of the Quenast section (sample 3.770) (*Adorfia firma*, *Arbusculidium filamentosum* together with *Frankea sartbernardensis*, *Vogtlandia* sp.).  
 The specimens observed in the unnamed member at La Tourette (*Frankea sartbernardensis*, *?Sylvanidium*

*operculatum* and *Vogtlandia* sp.), are supposed to belong to the same assemblage even if *Adorfia firma* and *Arbusculidium filamentosum* are not recorded.

Based on acritarch evidence, this particular assemblage belongs to strata which could not correspond to the Abbaye de Villers, the lower part of the Tribotte and most part of the Rigenée formation. It has to be correlated to the middle part of the Tribotte Formation (where acritarchs are unknown) or with the upper part of the same Formation where *Frankea sartbernardensis* and *?Vogtlandia multiradialis* are recorded. The turbiditic like facies of the unnamed member points rather to a lithostratigraphic position at the boundary between the Tribotte (shelf facies) and the Rigenée (deep environment close to the continental slope). The presence of *Frankea sartbernardensis* indicates an age not older than late Arenig (Cooper *et al.*, in press; Vanguestaine, this volume).

Samuelsson & Verniers (2002) recorded chitinozoans in three of the localities discussed herein:

(i) at Asquemont, in the unnamed member, where three samples (JV99-001, JV99-002, JV99-003) yielded an assemblage containing *Desmochitina ornensis* and *Conochitina pseudocarinata* indicating a mid Arenig age.

(ii) at Quenast (sample JV99-066, km 3.777 of the railway), co-occurrence of *Lagenochitina obelgis* and *Cyathochitina cf. dispar* provides evidence for a late Arenig age,

(iii) in the Thyle valley, the uppermost part of the Tribotte Formation contains *Euconochitina vulgaris* broadly indicative of a middle Arenig to early Llanvirn age.

If the three localities are more or less coeval, as suggested by acritarchs, combined acritarchs and chitinozoans results would indicate a late Arenig age.

#### 4.4. Rigenée Formation acritarchs

Ten samples of the Rigenée Formation were tested in the studied area. The results are very thin:

- *Arkonion tenuata* (Asquemont –39.7785, Quenast –2B)
- *Stelliferidium striatulum* (Asquemont –39.7785)
- *Striatotheca quieta* (Quenast –2B)
- *Striatotheca* spp (Quenast –2B)
- *Veryhachium trispinosum* (La Tourette –14, Asquemont –39.7785, –39.766, Quenast –2B, Queurcq –7)
- *Vogtlandia* sp (Quenast –2B)

At Asquemont, in their unit D, Martin & Rickards (1979), recorded *Frankea sartbernardensis* and *Striatotheca principalis*.

Compared with the Rigenée Formation at Rigenée (Servais, 1991), acritarch diversity in the Senne-Sennette sections is very low. A typical species as *Frankea hamulata* known in the middle and upper part of the Rigenée Formation at Rigenée and Gembloux (Servais, 1991), is not observed in the Senne-Sennette.

This situation could be explained by a slight lateral facies variation rendering the depositional sites in the Senne-Sennette somewhat more reducing and/or in a more distal position in the basin lowering acritarch

specimen number. Moreover, it should be noted that the only place where graptolites are found in the Rigenée Formation is in the Sennette valley. At Rigenée, graptolites were never discovered and only trilobites are known (Servais, 1988, p. 21).

## 5. Stratigraphical considerations

### 5.1. The Asquemont section

The Lower and Middle Ordovician rocks are discontinuously exposed at the southeastern trench of the new canal Bruxelles-Charleroi on a distance of about 350 m. Five lithological units are recognized from north to south, the Chevlipont Formation, an unnamed member (Verniers *et al.*, 2002) and units A, B, C and D of Martin & Rickards (1979). The *Acanthodiacrodiium angustum* and *Arbusculidium filamentosum*-*Frankea sartbernardensis* assemblages are recorded respectively in the Chevlipont and the unnamed member. Unit B of Martin & Rickards (1979) lithologically resembles (Lenoir, 1987) the rocks of the Virginal railway section in which the *Frankea hamata*-*Striatotheca rarirrugulata* assemblage was observed but neither Martin & Rickards (1979) samples in this unit or Asquemont –39.974 (Fig. 2) sample revealed typical species of that assemblage. Unit A of Martin & Rickards (1979) yielded *Frankea sartbernardensis* in two samples. One specimen is figured (pl. I fig. 16). *Vogtlandia multiradialis* is also noted. Both species are unknown in the Abbaye de Villers and lower part of Tribotte Formation of the Thyle section but are found together (as *?Vogtlandia multiradialis*) in the uppermost part of the Tribotte Formation (Vanguestaine, this volume) and in the Rigenée Formation (André *et al.*, 1991; Servais, 1991). Therefore a correlation between Unit A of Martin & Rickards and parts of the Tribotte or the Rigenée Formations is possible. Unit C of Martin & Rickards (1979) presents specimens normally excluding each other in the Thyle section but found together however in the same places of the Senne-Sennette sections, notably in the unnamed member (Section 4.3.). They are *Arbusculidium filamentosum* (Abbaye de Villers Formation) on one hand and *Acanthodiacrodiium tassellii* and *Vogtlandia multiradialis* (Rigenée Formation, see Vanguestaine, this volume; André *et al.*, 1991; Servais, 1991) on the other hand. The record of such an assemblage could imply a correlation with strata of the Thyle section at the boundary between the Tribotte and the Rigenée Formations.

In conclusion, if the inferred stratigraphic comparisons with the Thyle section are correct, the succession at the south-eastern trench of the canal could be from north to south : the Chevlipont Formation, the unnamed member of Verniers *et al.* (2002) (possibly equivalent to the upper part of the Tribotte Formation), unit A of Martin & Rickards (1979) (possibly equivalent to the upper part of the Tribotte Formation), unit B (unknown stratigraphical equivalent), unit C (possibly equivalent to the upper part of the Tribotte Formation),

unit D (= Rigenée). These correlations postulate that no diachronism exist between the Tribotte-Rigenée boundary in the Thyle section compared to the Tribotte (or Tribotte equivalent) –Rigenée in the Senne-Sennette valleys.

The succession, if correctly interpreted, is mainly composed of rocks younger than the Abbaye de Villers Formation except unit B of Martin & Rickards (1978).

Hennebert & Eggermont (2002) attributed the here described succession mainly to the Abbaye de Villers Formation and partly to the Tribotte Formation. Our results are in contradiction with their interpretation.

### 5.2. The Quenast railway section (Senne river valley)

According to Beugnies, in Waterlot *et al.* (1973), the succession along the railway trench, north of Quenast, between km 3.3 and 4.0, is composed from base to top of: a green slate formation, assigned to the Lower Tremadocian (= the Asquempont Member of the Oisquercq Formation), a transition zone of a few meters and the laminar siltstones of Quenast. This is the section studied in the present study. In fact, Beugnies mapped a southern unit, defined as composed of grey black shales and sandy slates and dated as Arenig, intercalated between the Quenast unit and the Rigenée Formation in all the Senne-Sennette valleys. This unit, at Quenast, was not studied for palynology. According to Herbosch (pers. comm.) it corresponds to the Tribotte Formation of the Thyle section. Outcrops of this unit exist at the northwest flank of the Senne valley in the “Bois du Chenoix”.

The transitional zone observed between km 3.378 and 3.386 and described as a green slate with centimetric layers of dark grey to black slate (Vanguestaine, 1978) has lithological features recalling the Lower Tremadocian Chevlipont Formation of the Thyle section. It was densely sampled by Vanguestaine (1978) and Lenoir (1987) (see Appendix 1). All samples are however barren or with useless stratigraphic specimens (Quenast –3.3785). This transitional zone could in fact correspond to a breccia linked to the Asquempont fault (sensu Debacker *et al.*, 2003) separating the Cambrian Oisquercq Formation from the Ordovician rocks.

According to Hennebert & Eggermont (2002), the overlying “Quartzophyllades zonaires de Quenast” sensu Beugnies in Waterlot *et al.* (1973) would be the equivalent of the Abbaye de Villers Formation. Six samples in these laminar siltstones yielded microfossils. Five samples were already studied in Vanguestaine (1978). A sixth one (Quenast –3.770) is new. The acritarch composition of this last sample (*Arbusculidium filamentosum*-*Frankea sartbernardensis* assemblage) suggests a correlation with the upper part of the Tribotte or a level at the boundary between Tribotte and the Rigenée Formation (Section 4.3.). In any case, it is comparable with assemblages recorded in the Abbaye de Villers Formation of the Thyle section (Vanguestaine, this volume). *Frankea sartbernardensis* was identified in two other samples (km 3.368 and 3.650, Vanguestaine, 1978). The stratigraphic meaning of this species is important as it was never recorded below the uppermost part of the

Tribotte Formation. But despite new observations in the original slides, the identification of *F. sartbernardensis* could not be confirmed. These lithostratigraphic considerations therefore concern only one part of the unit called “Quartzophyllades zonaires de Quenast” in its type locality.

Based on chitinozoans, Samuelsson & Verniers (2000) dated as late Arenig a sample from the Quenast railway section (JV99-066, km 3.777). The lithological unit containing the sampled strata was considered as the Abbaye de Villers Formation. Acritarch results in a very nearby sample (km 3.770) agree with the late Arenig age, but does not support the lithostratigraphical attribution.

The lithostratigraphical confusion here described for the Senne valley confirmed other confusions already mentioned (Section 5.1.) in the Asquempont section where rocks mainly assigned to the Abbaye de Villers Formation (Hennebert & Eggermont, 2002) yielded acritarchs indicating rather the Tribotte Formation. The present considerations questioned the Middle Ordovician lithostratigraphy as presently applied in the Senne-Sennette river valleys.

### 5.3 Asquempont-La Tourette-Virginal section relationships

The three sections sampled in the Sennette valley are located relatively close to each others: the distance between the Asquempont and La Tourette section is 500 m ; between La Tourette and Virginal sections, about 580 m are measured along the Asquempont fault (sensu Debacker *et al.*, 2003). Despite their proximity, the stratigraphical content of these sections is quite different. Above the Chevlipont Formation observed in the three sections, the unnamed member of Verniers *et al.* (2002) is found at Asquempont and La Tourette whereas the Abbaye de Villers Formation is observed at Virginal (Debacker *et al.* 2003).

On a biostratigraphical point of view, the Middle Ordovician unnamed member yielded at Asquempont the *Arbusculidium filamentosum*-*Frankea sartbernardensis* acritarch assemblage (Section 4.3.). A similar, but not identical, assemblage is found at La Tourette in the rocks reported to the same unit (Lenoir, 1987). This unit contains *Frankea sartbernardensis*. Absence of *Arbusculidium filamentosum* could be related either to the poor preservation or to some stratigraphic differences. According to the geological map of Debacker *et al.* (2003), the Asquempont and La Tourette sections belong to two different tectonic units separated by a normal fault called F7. Therefore, the two different sections do not necessary present coeval sequences of the unnamed member.

At Virginal, the Abbaye de Villers Formation is found succeeding the Chevlipont Formation. It yields the *Frankea hamata*-*Striatotheca rarirrugulata* Acritarch Zone (Section 4.2.). It was demonstrated earlier (Section 4.3.) that the latter zone, also found in the Abbaye de Villers and lower part of the Tribotte Formations in the Thyle section, is older than the *Arbusculidium filamentosum*-*Frankea sartbernardensis* assemblage. This

assemblage, though not recorded in the Thyle section so far, is probably partly observed in the uppermost part of the Tribotte Formation and most probably corresponds to strata near the boundary between the Tribotte and the Rigenée Formations.

According to the geological map of Debacker *et al.* (2003), the contact between the Chevlipont Formation and the non differentiated Middle Ordovician Abbaye de Villers and Tribotte Formations, between La Tourette and Virginal, is not underlined by a fault. The Middle Ordovician is represented as containing coeval strata, which acritarch biostratigraphy demonstrated to be at least partly wrong.

The discrepancy underlined above could be related to the fact that the Asquemont fault at La Tourette could affect not only Tremadocian strata and underlying rocks (see Debacker *et al.*, 2003) but also overlying rocks, namely the Abbaye de Villers Formation. Other explanations could be found in unrecognized faults or in the outline of some recognized faults as the F10 fault between Virginal and La Tourette (see Debacker *et al.*, 2003).

A faulted contact at La Tourette between the Chevlipont Formation and the unnamed member is probable as a Tremadocian specimen (*Acanthodiacrodium angustum*, see Section 3.1.3.) was found together with Middle Ordovician acritarchs. This situation is presumably related to the brecciated state of the studied strata.

## 6. Conclusions

The Senne-Sennette river valleys offer the most complete succession of outcrops in the southern border of the Brabant Massif. However, due to their location in a highly tectonized zone and correlation difficulties with coeval strata in the Thyle river type section, Early and Middle Ordovician rock stratigraphy is relatively poorly known. The occurrence of a single graptolite horizon in one of the four described lithological units of the studied sequence rendered microfossil research even more important.

Lower Tremadocian assemblages are recognized in three places of the Sennette valley: the Virginal railway section, the Asquemont canal section and the La Tourette section along the right side of the old canal (Bief 29). All sections show the characteristic laminated facies of the Chevlipont Formation. Due to the fact that lower and/or upper contacts with adjacent strata are faulted, the exact thickness of the Formation in the Sennette area is unknown. Coeval strata in the Senne valley, Quenast railway section, are so far unknown.

A typical late Arenig acritarch assemblage belonging to the *Frankea hamata* – *Striatotheca rarrirugulata* Acritarch Zone of the English Lake District is newly identified in the Virginal railway section. It occurs in a lithological unit composed of decimetric grey-green sandstones in which plan parallel ichnofossils are developed. This unit was correctly assigned to the Abbaye de Villers Formation from the Thyle area in which the *Frankea hamata* – *Striatotheca rarrirugulata* Acritarch

Zone is also identified (Vanguestaine, this volume).

A third acritarch assemblage is recognized in the unnamed member of the Abbaye de Villers Formation of Verniers *et al.*, (2002) observable at Asquemont along the Bruxelles-Charleroi canal. This assemblage is characterized by the coexistence of *?Adorfia firma*, *Arbusculidium filamentosum* on one hand with *Acanthodiacrodium tassellii*, *Arkonion virgata*, *Frankea sartbernardensis*, *?Striatotheca frequens* and *Vogtlandia multiradialis* on the other hand, species currently occurring respectively either in the Abbaye de Villers Formation and the lower part of the Tribotte Formation or in the upper part of the Tribotte Formation and lower part of the Rigenée Formation in the Thyle section. A similar assemblage is also known from at least a part of the Quenast railway section which shows the coexistence of *Adorfia firma*, *Arbusculidium filamentosum* and *Frankea sartbernardensis*. Due to its stratigraphic position, it is also assumed that the La Tourette, Bief 29 section, with *Frankea sartbernardensis*, *?Sylvanidium operculatum* and *Vogtlandia cf. multiangularis* also belongs to the same third assemblage.

Chitinozoan associations are recorded in two of the three localities cited above, the Asquemont and Quenast sections. Chitinozoans and acritarchs both indicate a stratigraphical position above the middle part of the Abbaye de Villers Formation. But, whilst chitinozoans would indicate a middle or late Arenig age, acritarchs would point to a late Arenig or early Llanvirn age, due to the presence of *Frankea sartbernardensis* and *Arkonion virgata* which known first appearance are respectively late Arenig and early Llanvirn in age. Combined acritarch and chitinozoan results probably indicate a late Arenig age.

On a lithostratigraphical point of view, the unnamed member of the Asquemont canal section and of La Tourette would better be placed as an equivalent of the middle or upper part of the Tribotte Formation or at the boundary between the Tribotte and the Rigenée Formations than near the Abbaye de Villers – Tribotte boundary as previously suggested. Part at least of the “Quartzophyllades zonaires de Quenast” at Quenast occupies the same position. It is also suggested that most of the rocks occurring at Asquemont between the Chevlipont and the Rigenée Formations are coeval with the Tribotte Formation of the Thyle valley.

While in the type section of the Rigenée Formation, the Thyle river area, relatively good acritarch assemblages were observed, very few specimens are identified in coeval strata of the Senne-Sennette area, despite the number of samples tested.

The present paper emphasizes the importance of acritarch biostratigraphy to unravel the order of strata involved in strongly faulted tectonic structures. The succession in the time of the first apparition of the *Frankea* species *hamata*, *breviuscula* and *sartbernardensis* was particularly helpful. The described assemblages do not take in account all present species but only selected ones, with no incidence on our biostratigraphic conclusions. A better biostratigraphy could be obtained after a complete

description of all Lower and Middle assemblages is achieved.

## Appendix: Sample location

### 1. Asquemont canal section

The quartz veins (km 40.118 – 40.119 according Debacker *et al.*, 2003) associated to the Asquemont fault and/or the distance with respect to km 40 along the canal have been used to measure distances. At the time of sampling, the quartz veins were situated at km 40.133. The Km –post 40 in the meantime, has been moved and the distances given herein do not match that of the newly places km –post 40.

#### Chevlipont Formation

Asq –3, –5 (in Lenoir, 1987): 3 m and 5 m. south of the quartz veins.

#### Unnamed member of the Abbaye de Villers Formation

Asq –5 (sic), –28 (in Vanguetaine, 1978) and Asq –5,5, –11 in Lenoir (1987).

#### Unit A of Martin & Rickards (1979)

Asq –77 (= km 40.056) more or less corresponding to FM –76 –5.3.

#### Unit B of Martin & Rickards (1979)

Asq –39.974 (also called Asquemont 3): at the northern corner of the concrete plate n°15

Rigenée Formation (= Unit D of Martin & Rickards, 1979)

Asq –39.766 (also called Asquemont 2, northern corner of the outcrop) and –39.7785.

(Three other samples taken in the same formation are barren).

### 2. Virginal railway section

The samples are located according to the railway kilometers, all from the western side of the trench.

#### Chevlipont Formation

Virginal –8.1883, –8.1868, –8.1884 and –8.190 are four samples taken near the faulted contact with the Oisquercq Formation. They are taken from different height and therefore represent no more than about 2 meters of strata (for more details see Lenoir, 1987).

Virginal –8.200, –8.216 and –8.2224 are taken further to the south presumably in a higher stratigraphic position in the Formation.

#### Abbaye de Villers Formation

Two samples, at km 8.343 and 8.347, in a lithological unit composed of decimetric grey-green sandstones in which bedding plane parallel ichnofossils are developed. The lithostratigraphic attribution is from Debacker *et al.* (2003)

#### Rigenée Formation

Virginal –8.552.

Remark : The acritarch content of samples –8.200, –8.216 and –8.347 is also provided in Vanguetaine (1978). Sample 8.343 is a newly studied sample.

### 3. La Tourette section

Eleven samples are partly localized with respect to a stair, taken as point 0, in the garden of the property n°11. They are herein numbered according Lenoir (1987) but often named differently in the collections of Liège University (see synonymy).

#### Chevlipont Formation (in m. west of point 0)

La Tourette –1 (= La Tourette –6) and –2 (=P1): 13 m.

La Tourette –3 (= P2): 16,5 m.

La Tourette –4 (= P3): 25 m.

La Tourette –5 (= La Tourette –7) and –6 (= F1) at 29 m and 4 m east of a close.

#### Unnamed member of the Abbaye de Villers Formation

La Tourette –7 (= F2), –8 (= F3), –9 (= F4), –10 (= F5) and –11 (= P4) in a sequence comprised between 29 and 30,5 m from point 0. Sample La Tourette –11 is at 2,5 m east of the close.

La Tourette –12 (= La Tourette –5) and –13 in the outcrop bearing the galena dyke west of the close of the property n°11.

#### Rigenée Formation

La Tourette –14, about 15 m west of previous outcrops, from a sequence of homogeneous black slates.

### 4. Coeurq river section

#### Middle Ordovician laminar siltstones (no lithostratigraphical attribution)

Coeurq –1 in the northernmost outcrop, near a little concrete bridge.

Coeurq –2 in the Coeurq stream: black slate.

Coeurq –3, –5, –6: near the Coeurq fall.

Coeurq –4: along a road near the “Moulin du Coeurq”.

#### Rigenée Formation

Coeurq –7 : in an outcrop at the “Ferme des Aunois”, at 600 m northeast of the Hennuyères station.

### 5. Quenast railway section and quarry

#### Transitional zone (Vanguetaine, 1978)

Six samples are localized according the railway kilometers. From north to south: Quenast -3.3767, -3.378, -3.3785, -3.3794, -3.3805 and -3.3829. Underlined samples are from Vanguetaine (1978). The others were collected by Lenoir (1987).

“Quartzophyllades zonaires de Quenast” according Beugnies in Waterlot *et al.* (1973)

Five samples in Vanguetaine (1978): Quenast -3.368, -3.415, -3.436, -3.517, -3.650. A sixth sample newly studied herein is located at km -3.770, opposite Bloc B2. A typographic error in Vanguetaine (1978) has altered the localization of the sample Quenast -7 which has to be red -3.750 instead of -3.650. The newly studied sample -3.750 is a topotype sample of Quenast -7 (Vanguetaine, 1978).

Rigenée Formation

Three samples, Quenast -1a, Quenast -2a, Quenast -2b are respectively taken in the Quenast quarry at the contact with the intrusive rocks (-1a) and at two places 10 m off the contact where a fault separates the shale from the intrusive rock itself (-2a, -2b).

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#### Plate I

(Acritarch specimens from the lower Tremadocian Chevliport Formation (1-12) and the Middle Ordovician unnamed member (13-15) in the Sennette valley sections)

(All microphotographs at 1000x)

Fig. 1 *Acanthodiacrodium achrasii* Martin, 1972  
Virginal -8.222, 21499, J53/4

Figs 2 and 3 *Acanthodiacrodium angustum* (Downie, 1958) Combaz, 1967  
2: La Tourette -7, 21629, S38/1  
3: La Tourette -6, 21635, H35/1

Figs 4, 5 and 6 *Acanthodiacrodium ubuii* Martin, 1969  
4: Virginal -8.222, 21499, N-039  
5: Asquempont -3, 21502, Q46-47  
6: Virginal -8.222, 21499, R51/3

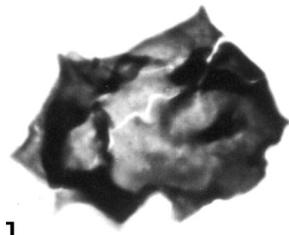
Fig. 7 *Cymatiogalea* sp.  
Virginal - 8.222, 21499, M54

Figs 8, 9 and 10 *Stelliferidium* spp.  
8: La Tourette -6, 21628, U47/1  
9: Virginal -8.222, 21499, F53  
10: Virginal -8.200, 6112, JK44

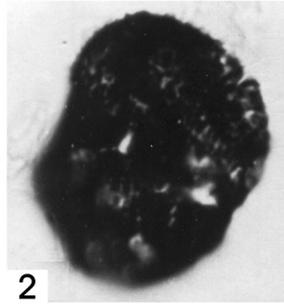
Figs 11 and 12 *Vulcanisphaera flagellum* Martin, 1977  
11: La Tourette -2, 21811, N46/4  
12: La Tourette -6, 21628, K52/2

Figs 13 and 14 *Acanthodiacrodium tassellii* Martin, 1969  
13: Asquempont -11 m, 21687, U42/4 : one of the poles exhibits well preserved processes.  
14: La Tourette -7 m, 21629, S49/2 : damaged specimen with broken processes.

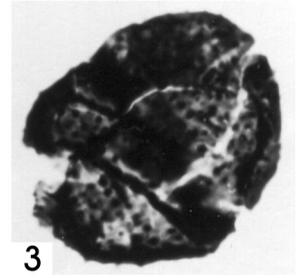
Figs 15 *?Adorfia firma* Burmann, 1970  
Asquempont -7 m, 21687, K44-K45: with unclear distal bulbous termination.



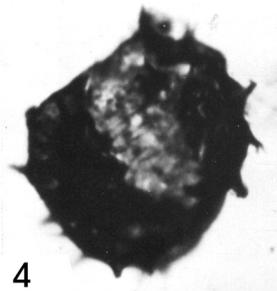
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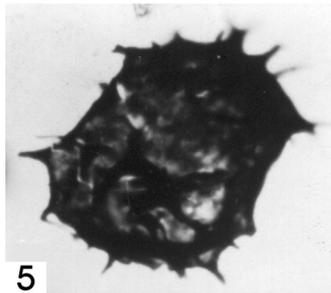
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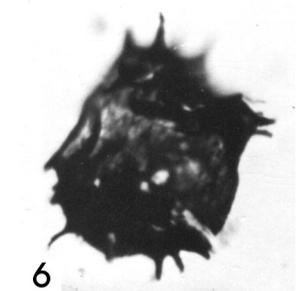
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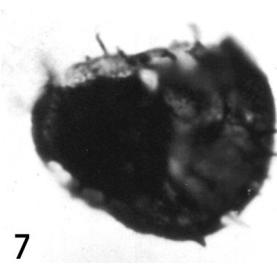
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5



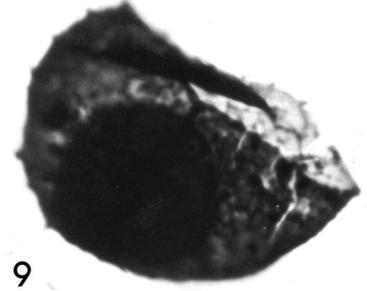
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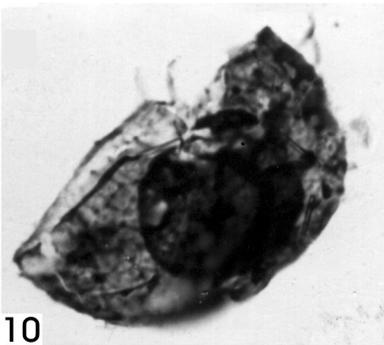
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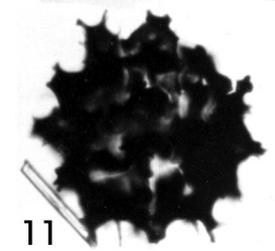
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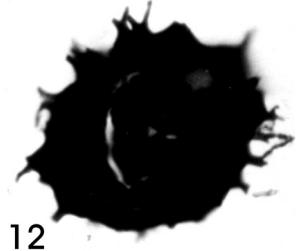
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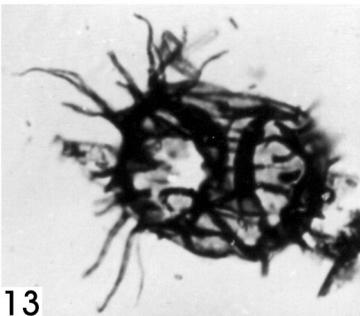
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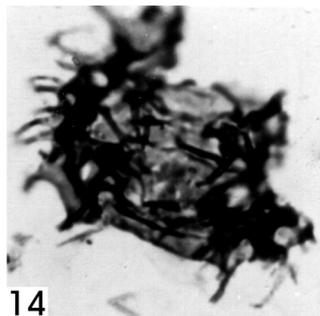
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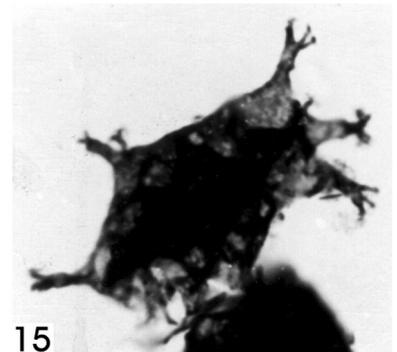
12



13



14



15

**Plate II**

(Acritarch specimens from Middle Ordovician strata of the Senne-Sennette river sections)

(All microphotographs at 1000x)

- Fig. 1 *?Adorfia firma* Burmann, 1970  
Asquemont -7 m, 21687, L55-56: unclear pedonculate balls in the ultimate pinnulae
- Fig. 2 *Arbusculidium filamentosum* (Vavrdová, 1965) Vavrdová, 1972  
Asquemont -7 m, 21676, P38/4 : distinct filamentous broken processes at one pole.
- Fig. 3 *Arkonion virgatum* Burmann, 1970  
Asquemont -7 m, 21685, M34/3
- Fig. 4 *Arkonion sp. cf. Arkonion virgatum* (Burmann, 1970)  
Asquemont -77m, 4586, P36/2
- Fig. 5 and 6 *Aureotesta clathrata simplex* (Cramer, Kanes, Diez and Christopher, 1974)  
Brocke, Fatka and Servais, 1977  
8: Asquemont -7 m, 21684, R48/3  
9: Asquemont -7 m, 21676, D42/1
- Fig. 7 *Coryphidium sp. cf. Coryphidium bohemicum* Vavrdová, 1972  
Asquemont -77 m, 4586, J38/1
- Fig. 8 *Dasydorus sp. cf. Dasydorus cirritus* Playford and Martin, 1984  
La Tourette -7, 21629, G56/3-4: one of the poles is distinctly smooth.
- Figs 9 and 10 *Frankea sartbernardensis* (Martin, 1966) Colbath, 1986  
12: La Tourette -7 m, 21636, D48/1  
13: Asquemont -7 m, 21685, T44/4
- Fig 11 *Striatotheca quieta* (Martin, 1969) Rauscher, 1974  
Quenast -2b, 21411, M49/3
- Fig. 12 *?Striatotheca quieta* (Martin, 1969) Rauscher, 1974  
Asquemont -7 m, 21684, O42 : possibly broken processes.
- Fig. 13 *?Sylvanidium operculatum* Vavrdová, 1978  
La Tourette -7 m, 21629, V44/4 : short (? broken) processes; ?lateral excystment structure.
- Fig. 14 *Vogtlandia multiradialis* Burmann, 1970  
Asquemont - 11 m, 21687, LM42: stellate specimen bearing at least 7 processes.

