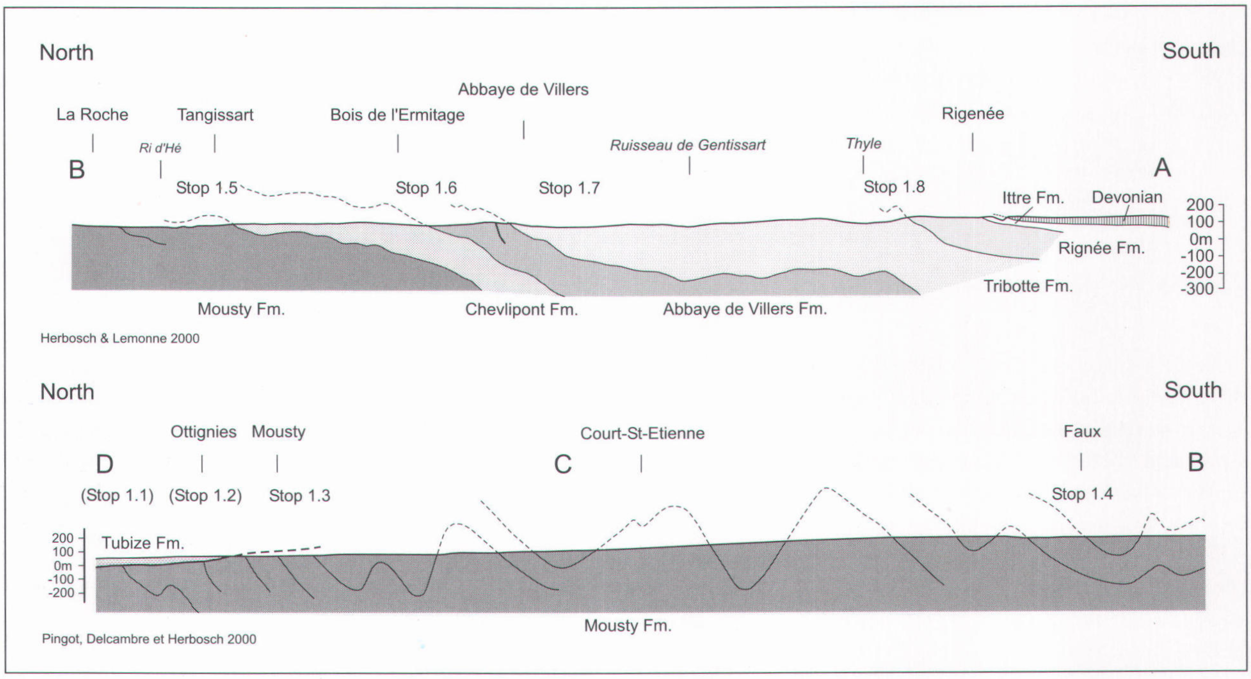


**Figure 7**. N-S cross-section in the central part of the geological map on Figure 6. The position of this ABCD section is shown on the structural map (Fig. 10). No vertical exaggeration. Stops between brackets are not situated in the cross section but projected

3.2.9. Ittre Formation (Beugnies, *in* Robaszynski & Dupuis, 1983; Servais, 1991a)

Description. Rhythmic alternation of light grey fine sandstone, grey siltstone and dark mudstone (slate) in decimetric beds. The sandstone and siltstone beds show parallel, oblique and convolute lamination, fining upward grading and load casts. All of these features are characteristic of Bouma-type sequences (Servais, 1991a, in the Sennette Valley). The base of this formation crops out with exactly the same facies in the Dyle basin (near Rigenée, Ri des Goutailles, Herbosch & Lemonne, 2000). The occurrence of a very large slump within the Ittre and the Bornival Formations has been suggested in the Sennette valley (Debacker, 2001; Debacker *et al*., 2001). Thin volcanic beds are observed in the basal part of the formation in the Sennette valley (Corin, 1963; Debacker, 2001; Debacker *et al*., 2001).

Sedimentology. This rhythmic sedimentation has been interpreted as Bouma-type distal turbidites (only the intervals c, d, and e are present, Servais, 1991a). Van Grootel *et al.* (1997) have recently shown that Unit II of the Lessines borehole also belonged to this formation. Herbosch *et al.* (1991) observed over 86 m rhythmic low density turbidite sequences (decimetric Piper sequences E1E2E3, Stow, 1986) which towards the top become high density distal turbidite sequences (c, d, and e intervals). The whole formation often shows slumps and microbreccias tens of centimetres in size. This is interpreted as a clastic deep marine environment which extends from the continental slope to the turbidite plains.

Thickness. More than about 180 m in the Sennette valley (Debacker, 2001; Debacker *et al*., 2001) and 86 m in the Lessines borehole (Herbosch *et al.,* 1991).

Age. Graptolites described by Martin and Rickards (1979) and Degardin (*in* Herbosch *et al.,* 1991) indicate a Caradoc age. These same graptolites later re-examined by Maletz and Servais (1998) indicate the *Nemagraptus gracilis* or '*Diplograptus multidens'* Biozone (Aurelucian or Burrellian), with a preference for the latter biozone (Fig. 8). The chitinozoans, moderately well preserved and diverse with the presence of *Belonechitina* cf. *robusta*, indicate a Burrellian age. Both fossil groups together indicate a Burrellian age (Caradoc) (Verniers *et al.*, 1999; Samuelsson & Verniers, 2000) (Figs. 8 & 9).

3.2.10. Upper Ordovician formations

In the Dyle basin, the highest visible formation is the Ittre Formation. The overlying rocks of the Upper Ordovician outcrop in the Senne and Orneau basins (Fig. 3) where they have been recently studied by the research team of J. Verniers (Van Grootel *et al.*, 1997, 1998; Verniers *et al.*, 1999, 2001, 2002a; Debacker, 2001) and recently mapped during the Wallonia map-

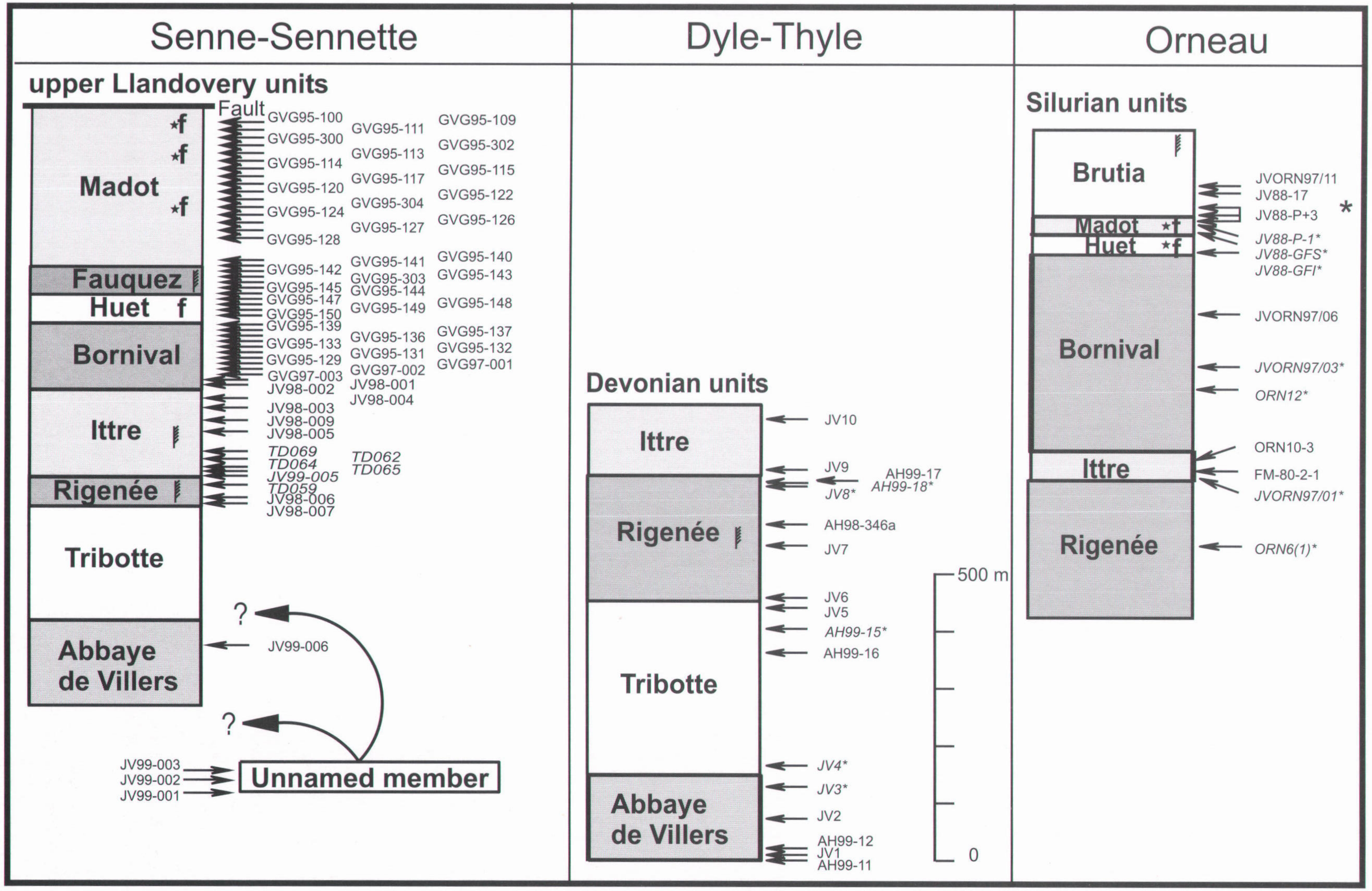


**Figure 8**. Schematic Ordovician lithostratigraphy in the three valleys of the outcrop area in the Brabant Massif with approximate thickness of the formations and location of the horizons sampled for chitinozoans in Samuelsson & Verniers (2000). Sample numbers in italics are barren. The star (*) indicates the location of the barren samples JV88-P+7 to JV88-P+15, and sample JV88-P+16 which yielded a single chitinozoan (see Fig. 9). The five-pointed stars indicate that macrofossils such as bryozoans, brachiopods, cystoids and trilobites are recovered in these units. The stylised graptolites denote levels with graptolites. Chitinozoans from the Bornival (upper members), Huet, Fauquez and Madot formations from the Sennette valley were studied by Van Grootel *et al.* (1997) and Van Grootel & Verniers (1998).

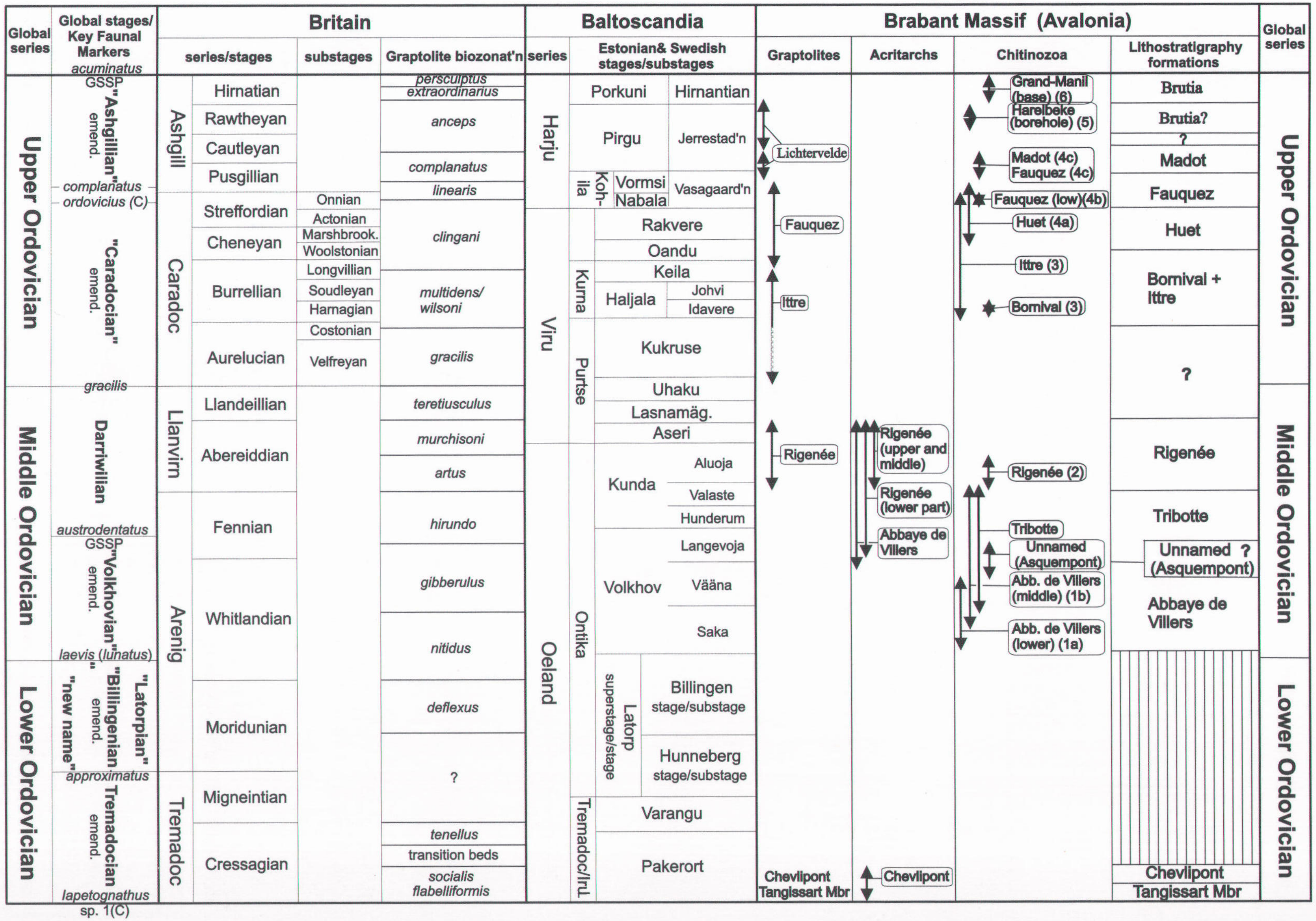


**Figure 9**. Schematic correlation of the Ordovician Brabant Massif formations with chitinozoan, acritarch and graptolite biozonations and the global, British and Baltoscandian chronostratigraphy and British graptolite biozonation (after Fortey *et al.*, 1995; Webby, 1998). Vertical hatching indicates hiatus, non-deposition, erosion or faulted contact. Arrows in biostratigraphy column indicate the range of the biozones versus the chronostratigraphy on the left. The number between brackets in the chitinozoan column is the number of the local biozonation. The Tangissart member is now considered the top part of the Mousty Formation (after Samuelsson & Verniers, 2000).

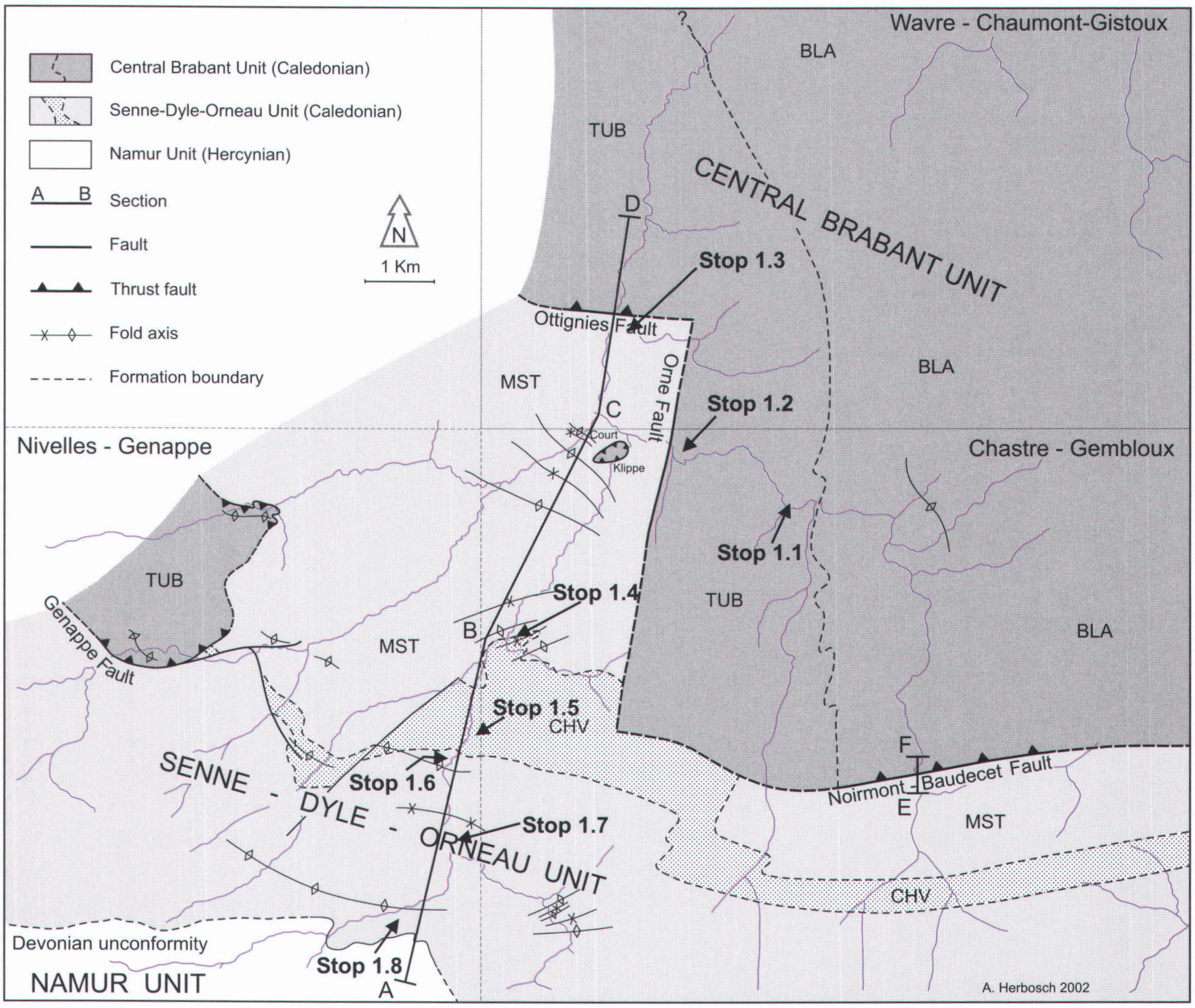


**Figure 10**. Structural map of the Dyle basin. BLA = Blanmont Fm.; TUB = Tubize Fm.; MST = Mousty Fm.; CHV = Chevlipont Fm. ABCD cross-section of Fig. 7 and EF cross-section of Fig. 11.

ping program (Chastre-Gembloux map, Delcambre *et al.*, 2002 and Braine-le-Comte-Feluy map, Hennebert & Eggermont, 2002). A brief description of these formations which we will not see is given below:

a) Bornival Formation: centimetric alternation of dark grey siltstone and dark grey to blackish mudstone with very fine sandstone beds (with plane or oblique laminations); same chitinozoan assemblage and age as the Ittre Formation.

b) Huet Formation: greenish to grey siltstone and fine sandstone, with characteristic brown to orange alveoli of decalcified fossil fragments; late Caradoc (Verniers *et al.*, 2001; Samuelsson & Verniers, 2000) (Figs. 8 & 9).

c) Fauquez Formation: a black shale facies which shows fine centimetric alternation of dark grey silty slate with black slate showing abundant pyrite and graptolites. The rhythmic sequences and grading point to a low density turbiditic environment (Lessines borehole, Herbosch *et al.*, 1991); latest Caradoc to earliest Ashgill (Verniers *et al.*, 2001; Samuelsson & Verniers, 2000) (Figs. 8 & 9).

d) Madot Formation: unit containing many volcanic and volcano-sedimentary rocks (André *in* André *et al.*, 1991; Van Grootel *et al.*, 1997) interbedded with dark shale and siltstone as well as siltstone rich in macrofossils (bryozoans, brachiopods, crinoids, trilobites, rugosa corals, etc.); early or middle Ashgill (Verniers *et al.*, 2001; Samuelsson & Verniers, 2000) (Figs. 8 & 9).

e) Brutia Formation: compact dark grey mudstone and slate with a very characteristic level of bioturbated mudstone. Upper part composed of about 40 m of volcanic rocks (eurite of Grand-Manil Member or Nivelles Member, Corin, 1965; Herbosch & Lemonne, 2000). Age: middle Ashgill to early Llandovery (Verniers *et al.*, 2001) (Figs. 8 & 9).

### *3.3. Cartography and general tectonics*

3.3.1. New geological maps

The geological map given in Figure 6 is a schematic synthesis of three new geological maps (scale 1/25,000) recently surveyed for the Ministry of the Walloon Region. These new maps are: Nivelles-Genappe (Herbosch & Lemonne, 2000), Chastre-Gembloux (Delcambre *et al.*, 2002) and Wavre-Chaumont-Gistoux (Herbosch *et al.*, in prep. a). They cover all the Lower Palaeozoic and the Devonian outcrops of the Dyle basin and only the northern part (the Ordovician) of the Orneau valley.

As has been seen previously (see 3.2; Fig. 5) the stratigraphic column encompasses the lowest Lower Cambrian (Blanmont Formation) to the Upper Ordovician (Ittre Formation, Bornival Formation only visible at Gembloux) and the best sections occur in the Middle-Upper Cambrian (Mousty Formation) and in the Lower to Middle Ordovician (Chevlipont to Ittre formations). This new mapping definitively demonstrates the absence of the Oisquercq Formation in the Dyle basin (Figs. 5 & 4). Previously it had been confused (Anthoine & Anthoine, 1943) with a non-magnetite bearing facies of the Tubize Formation which is very similar. The Silurian is absent in the Dyle basin, hidden below a Middle Devonian cover to the south. However, it is present in large outcrops in the Orneau valley, just SE of the edge of the map (south of Gembloux, Fig. 6), a site which will be visited (see 1.3.2). Palaeozoic rocks are covered for the most part by Eocene formations (in white on the map, Fig. 6).

The cross-section of the Thyle Valley between Rigenée and La Roche (Fig. 7, cross-section AB) is the only section that is well constrained due to the relative quality and continuity of the outcrops (Michot, 1978). In this NNE-SSW cross-section we observe two large (km scale) low amplitude gentle anticlinal antiforms (Bois de l'Ermitage and Rigenée) separated by a large (km scale) low amplitude gentle synclinal synform (from Abbaye de Villers to Thyle river). The southern limbs of the two anticlines appear relatively short with inclinations of 30-35°, whereas their northern limbs are long, undulating and close to horizontal. The asymmetry of these folds is barely perceptible because of their large interlimb angles. The cross-section BCD, which continues to the north in the direction of Ottignies (Fig. 7), is much less well constrained because of the scarcity of outcrops and the almost complete absence of marker beds in the Mousty Formation. The only clear observation is that one moves from the large (km scale) gentle folds observed in the south (section AB) into a series of smaller (hm scale) open to close folds in the north, and that one progressively proceeds down series, as a lydite marker bed is encountered in the vicinity of Mousty (Franquenies Member). The Tubize Formation occurs in the extreme northern part of the cross-section in fault-contact (nowhere visible in outcrop) with the Mousty Formation (cf. 3.3.2).

3.3.2. Structural Implications

The structural map can be found in Figure 10. It can be observed that the Caledonian basement (Brabant Massif) covers most of the mapped area except to the SW where the Devonian of the Namur Synclinorium unconformably overlies this basement. The Devonian unconformity which separates these two major units is marked by a basal conglomerate (Bois de Bordeaux Formation).

Two structural units can clearly be defined in the Caledonian basement (Fig. 10):
– the Central Brabant Unit, formed by the oldest rocks of the Blanmont and Tubize formations (and probably also the Jodoigne Formation present to the NE), crops out poorly and shows a general NNW-SSE direction with folds characterised by frequent steep plunges, variable trends and a north dipping cleavage (Lembeek type cleavage-fold relationship, Sintubin *et al.*, 1998). However, sub-horizontal to gently plunging folds have also been observed (Wavre-Chaumont-Gistoux map sheet, Herbosch *et al.,* in prep. a).
– the Senne-Dyle-Orneau Unit, formed by all the younger formations (from Mousty to the Silurian formations), shows E-W to NW-SE fold axes and open upright folds with a steeply N-dipping axial planar cleavage (Fauquez type cleavage-fold relationship, Sintubin, 1997a).

The tectonic break between these two domains has been described repeatedly since Fourmarier (1921) and is clearly visible on the aeromagnetic map (Chacksfield *et al.,* 1993; Sintubin, 1999; Everaerts, 2000).

The contact between these two units is always faulted (Genappe, Ottignies, Orne and Noirmont-Baudecet faults, Fig. 10). The Tubize Formation typically overlies the Mousty Formation but can also be found overlying the Abbaye de Villers or Chevlipont Formations (Fig. 6). At Court-St-Etienne (centre north, Figs. 6 & 10), a small zone with Tubize Formation is completely surrounded by the Mousty Formation suggesting a klippe (Anthoine & Anthoine, 1943). However, these faults have never been observed in the field due to the scarcity of outcrops, and thus only geophysical measurements (magnetism), trenches or boreholes have allowed us to deduce their presence and the position of their trace:
– at Baurieux, a magnetic ground survey allowed de

Magnée and Raynaud (1944) to prove the existence of the Orne Fault, as well as its trace under the Cenozoic cover (Fig. 14);
– at Noirmont (Figs. 10 & 11, section E-F), several boreholes and an old quarry along a N-S profile indicate the presence of an E-W trending fault, the Noirmont-Baudecet Fault. Other boreholes scattered to the east allow us to show its continuation until Baudecet (N of Gembloux). This fault could corresponds with an E-W magnetic lineament recognised by Sintubin (1997b);
– at Ottignies, the Ottignies Fault (Herbosch & Blockmans, in press a) is less well constrained but nevertheless its existence is proven along several hundred metres by trenching (Van Tassel, 1986);
– the trace of the Genappe Fault and its prolongation towards the NE (Cala valley) is poorly constrained in outcrop, but can be clearly seen on aeromagnetic maps (Herbosch & Lemonne, 2000).

As a consequence, we believe that in the Dyle-Thyle area all the Lower Cambrian of the Central Brabant Unit was thrusted onto the Cambrian-Silurian foreland. According to this hypothesis, the Tubize Formation outcrop at Court-St-Etienne is a klippe, the Ottignies and Noirmont-Baudecet faults are a part of a single unique thrust fault and the Orne Fault, more vertical could be interpreted as a tear fault (Herbosch & Blockmans, in press a).

3.3.3. Stratigraphic implications

The hypothesis that the Lower Cambrian of the Central Brabant Unit was thrusted onto its foreland also has implications for an old stratigraphic problem that has not yet received an entirely satisfactory resolution. The problem is the following: how can the absence of the Mousty Formation in the Senne basin be explained when it is present in the Dyle basin whereas, on the contrary, the Oisquercq Formation is present in the Senne basin but absent in the Dyle? The schematic drawing in Figure 12 illustrates this problem.

The most widely accepted explanation (Vanguestaine, 1978) was that there were lateral variations in the facies between the two regions, implying that these two formations had the same age (not well known at the time). This simple solution which did not satisfy everyone (Legrand, 1967, 1968), can no longer be considered since Vanguestaine (1991, 1992; Herbosch *et al.*, 1991) demonstrated, using micropalaeontology, that the Oisquercq Formation is upper Lower to Middle Cambrian in age and thus underlies the Mousty Formation which is Middle Cambrian to earliest Tremadocian in age (Fig. 4).

Now that almost all of the outcrop areas of the Brabant Massif have been mapped the following explanation can be proposed:
– let us begin with the Senne basin. Mapping of the Ittre-Rebecq region (Herbosch *et al.*, in prep. b) demonstrates that the Asquempont Fault, as Beugnies (*in* Waterlot *et al.*, 1973, Figs. 48 & 49) has clearly shown, runs from the Sennette valley through the Senne valley and then continues to the NNW. This important fault causes the disappearance of the upper part of the Oisquercq Formation, all of the Mousty Formation and

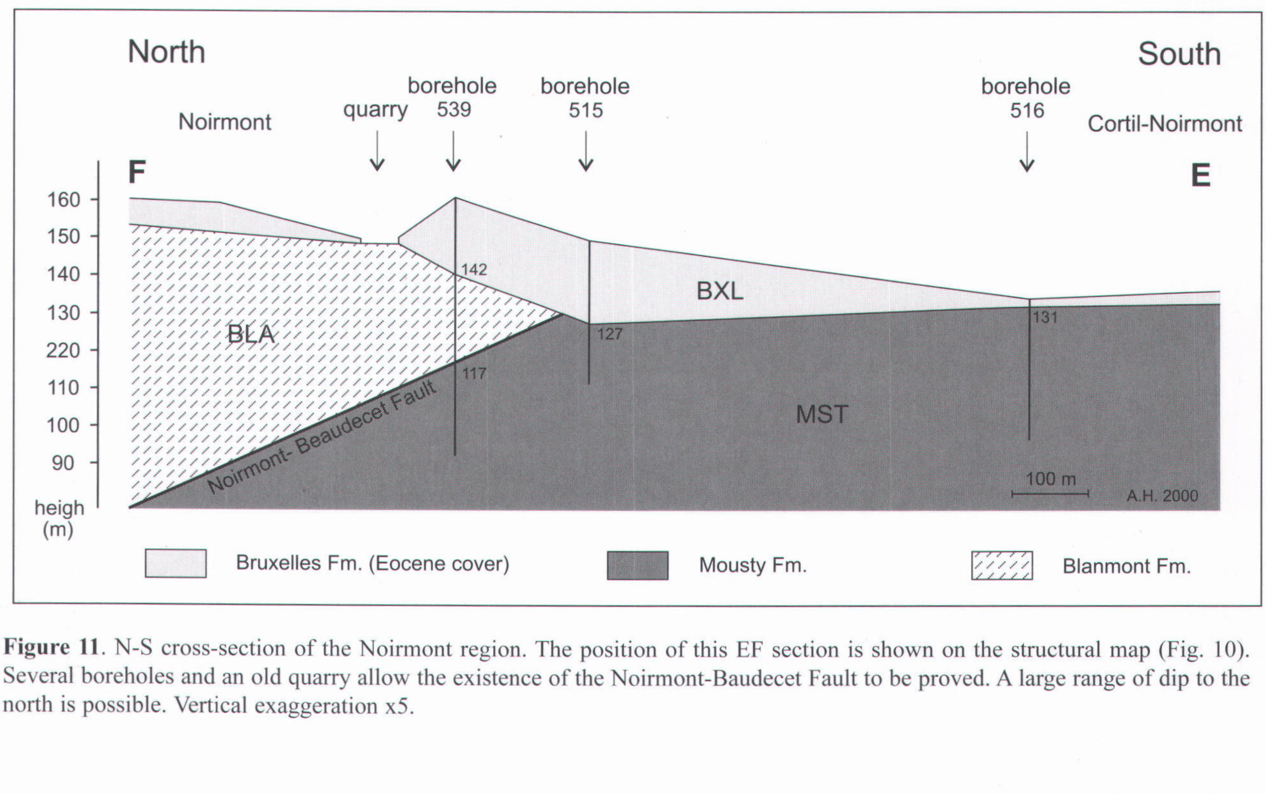


**Figure 11**. N-S cross-section of the Noirmont region. The position of this EF section is shown on the structural map (Fig. 10). Several boreholes and an old quarry allow the existence of the Noirmont-Baudecet Fault to be proved. A large range of dip to the north is possible. Vertical exaggeration x5.

almost all of the Chevlipont Formation. Indeed, the work done by Vanguestaine (1978, *in* André *et al.*, 1991) and by Lenoir (1987) shows that there remain several or at the most ten metres of the Chevlipont Formation in the four sections where the Asquempont Fault is observed (Fig. 12). This situation is identical to that of the Lessines borehole (Herbosch *et al.*, 1991).

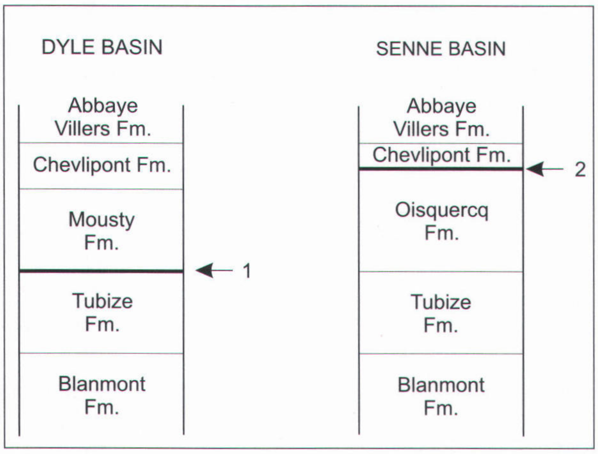


**Figure 12**. Stratigraphical succession in the Senne and Dyle basins (not to scale). 1=thrust fault contact 2=Asquempont Fault.

The interpretation by these authors of the contact between the Oisquercq Formation (Unit IV of the borehole) and the Chevlipont Formation (Unit III of the borehole) must now be revised. What was previously interpreted as a basal conglomerate is more likely to be a fault breccia (Debacker, 2001 and Debacker & Herbosch, unpublished data);

– in the Dyle basin, if we accept the hypothesis of a thrust fault, which is suggested by the complex and lobed aspect of the thrust front as well as the presence of a klippe, one could suppose that the Oisquercq Formation as well as a basal part of the Mousty Formation have been hidden underneath the thrust sheet.

## 4. Description of excursion stops DAY 1

### *Stop 1.1. Church of Mont-Saint-Guibert*

Location. Escarpment at the southern base of the church.

General structure. The bedding attitude is approximately N-S (strike N10°-20°E, dip 80°W) while the cleavage attitude in the argillaceous beds is: strike N45°E, dip 82°W. This implies a steeply WNW-plunging cleavage-bedding intersection. This peculiar geometry has already been described in the Senne basin by Sintubin *et al.* (1998). It is often observed in the structural unit forming the central part of the Brabant Massif (Central Brabant Unit of Fig. 10, also see introduction 3.3.2).

Lithostratigraphy. Lower part of the Tubize Formation; the Blanmont Formation crops out about 400 m to the east (Figs. 5 & 6).

Lithology. Rhythmic sequences of sandstone, siltstone and mudstone (slate). Beds show graded bedding, plane and convolute lamination. Here in the lower part of the formation the sandstone has a high mica content but does not contain any rock debris or feldspars, as opposed to the Rogissart Member (Senne basin, middle part of the Tubize Formation).

Sedimentology. A detailed study of this 5 meter-long section (Fig. 13) shows sedimentological features supporting a turbiditic origin of this rhythmic sequence. This sequence can be described in terms of the classical Bouma division. Incomplete Tab and Tae sequences, with a mean thickness ranging from 10 cm to 1 m, are most frequent. While load casts and graded bedding are frequently observed, flute casts are scarce. Only one complete Tabcde sequence, with rip-up clasts, has been recognised. All bedding polarity criteria indicate a younging of the sequence towards the WNW.

Biostratigraphy. An Early Cambrian age is proposed as the only fossil present is the trace fossil *Oldhamia* (Malaise, 1883), a genus from the Lower to Middle Cambrian, and which does not occur below the Cambrian-Precambrian boundary (Crimes, 1992; Verniers & De Vos, 1995). According to new observations by A. Seilacher (pers. comm., 1998) *Oldhamia* sp. is more restricted in time and only present in the Tommotian or Nemakit-Daldynian (early Early Cambrian), age proposed for this formation.

### *Stop 1.2. Beaurieux, Orne Valley*

Location. Western side of a small valley, northern tributary of the Orne, situated 150 m west of the motorway bridge which cuts across the Orne Valley (Fig. 14).

General structure. A series of small outcrops each several meters in size, dispersed across the wooded hillside. The bedding which is often poorly visible is subvertical (>80°W, more rarely E) and cuts across the hillside following an approximately N-S direction (strike N350° to 020°E). The cleavage, relatively rough, is vertical and runs in an E-W direction (N090° to 110°E, 65°-75°N), which is the common cleavage direction of the Dyle basin.

Lithostratigraphy. Lower part of the Tubize Formation (Fig. 5).

Lithology. The facies is homogeneous (no visible stratification or lamination) and is composed of grey-green siltstone (slate) with numerous millimetric crystals of magnetite.

Sedimentology. In view of the presence of sandy episodes which have been interpreted as turbidites, we consider these silty and argillaceous sequences to be deep-sea pelagic to hemipelagic deposits (for more details see 3.2.2).

Age. Cf. stop 1.1.

Magnetic survey and the Orne Fault. A magnetic survey of the Beaurieux area has been published by de Magnée & Raynaud (1944) with the intention to verify the hypothesis that the Orne Fault is a thrust fault (Anthoine & Anthoine, 1943). This work (Fig. 14) shows that there are several magnetic horizons (stripes in Fig. 14) oriented in a NNE to NNW direction which are abruptly interrupted towards the west where a negative anomaly occurs corresponding to the Mousty Formation. Thus the Orne Fault must surely dip to the east and must run close to and east of the interruption of the magnetic horizons. The Orne Fault has been traced essentially on the basis of this magnetic survey; its prolongation to the NW is only based on a few outcrops (Figs. 6 & 10).

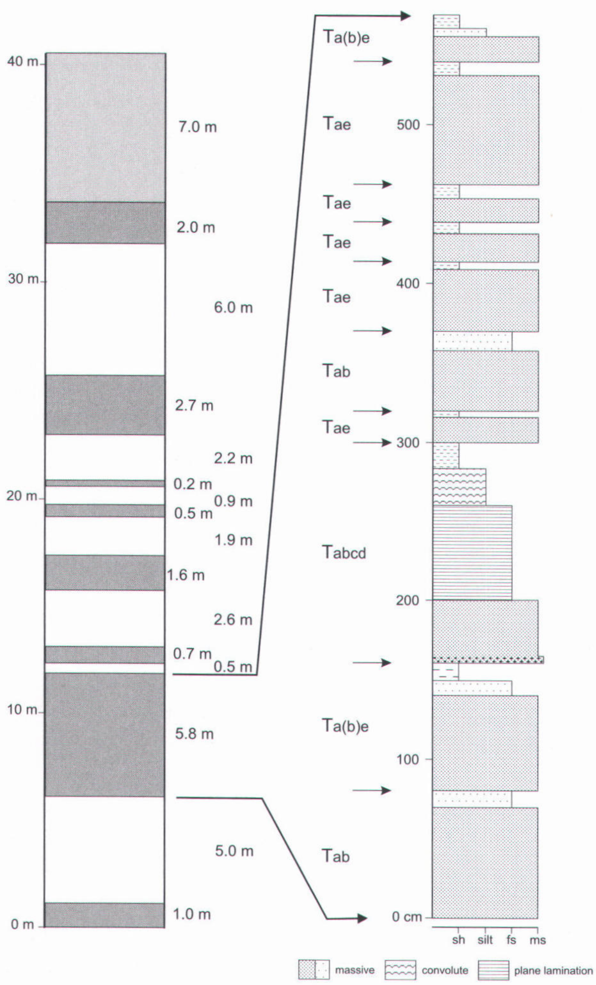


**Figure 13**. Left: general stratigraphical section of all the outcrop present below and south of the church of Mont-Saint-Guibert (lower part of Tubize Formation, lower Lower Cambrian); grey: in outcrop, white: present, but not outcropping; right: detailed lithological log of part of the section. Tab = type of Bouma turbidite sequence; Sh = shale; fs = fine sandstone; ms = medium sandstone.

### *Stop 1.3. Former Franquenies quarry*

Location. Private property situated at the Franquenies locality, SE of Céroux-Mousty, on the northern slope of the Angon brook, about 200 m west of the Brussels-Namur railway line.

General structure. The wall of this old quarry, 25 m long and 5-6 m high, cuts into the wooded flank of the valley. Bedding is clearly visible (strike N040°-050°W, dip 50°-60°E) as well as cleavage parallel to the wall; the strike is approximately E-W and the dip is sub-vertical (N or S). The unconformity with the Cenozoic cover (Brussels Formation, Eocene) is marked by a thin basal conglomerate which can be seen several dozen meters to the north.

Lithostratigraphy. Franquenies Member, lower visible part of the Mousty Formation.

Lithology. Black shale (slate) massive or laminated, grey to grey-black in colour, locally grey-brown (in the yard of the house). The organic material has been transformed into graphite by metamorphism and when touched the rocks leave traces on the fingers. The pyrite is not visible any more due to the alteration in this old quarry, but it was noted in older descriptions. Silicified zones can also be seen, in particular in the centre and towards the top of the wall (inaccessible overhanging zone) which forms extremely black and hard concretionary masses with botryoidal structures. Several blocks that have fallen to the foot of the wall can be observed. These are lydite essentially formed of quartz which has been completely obscured by a finely dispersed black graphitic pigment and sometimes a bit of pyrite. Certain samples, in thin section, show numerous transparent objects formed by microcrystalline silica without any graphitic pigment which are embedded in a completely opaque matrix (finely dispersed graphite). These objects are about 150 to 200 microns in size, are oblong and elongated along the bedding (compaction). These objects strongly suggest radiolarian phantoms and in certain exceptional cases we have been able to observe very poorly preserved radioles. Unfortunately,

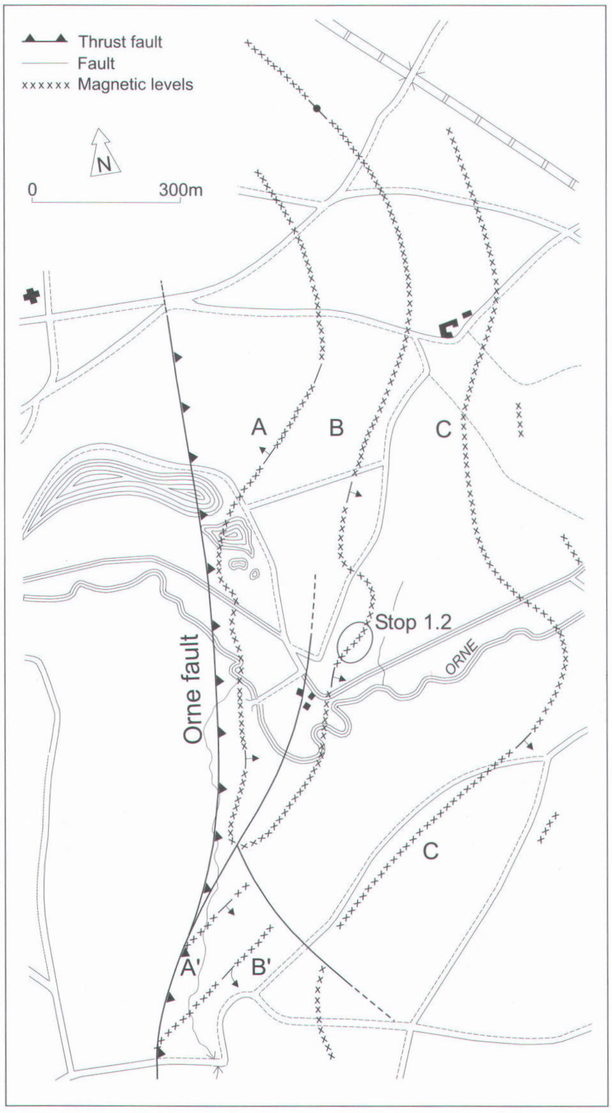


**Figure 14**. Geological interpretation of the field magnetic survey done by de Magnée and Raynaud (1944). Location of stop 1.2. (A. Herbosch modified after de Magnée & Raynaud, 1944).

M. Caridroit (University of Lille I) has not been able to confirm our hypothesis through acid extractions.

Sedimentology. Pelagic or hemipelagic shales deposited in a deep-sea anoxic environment as substantiated by the abundance of organic material, pyrite (only seen in boreholes) and manganese (in the form of garnet, see 3.2.4). The presence of lydites (radiolarians?) is also in agreement with this type of environment.

Biostratigraphy. Despite numerous attempts, no acritarchs have yet been obtained on samples coming from outcrops in the Dyle basin (Vanguestaine, pers. comm.). This is probably due to the strong surface alteration affecting these pyritic shales. The same facies in boreholes contains acritarchs giving ages between the Middle and Late Cambrian (Vanguestaine, 1992).

Radon anomaly. Tondeur *et al.* (1994) have shown that the towns of Villers-la-Ville and Court-St-Etienne are areas where there is a risk of high levels of radon in the houses. These risk areas coincide perfectly with the outcrop zones of the Mousty Formation (Tondeur *et al.*, 2001). Black shales are well known in the geochemical literature for their enrichment in uranium (average shale U content = 2 to 4 ppm; average black shale U content = 8 ppm but the variability is very high, up to 189 ppm in Swedish alum shale).

### *Stop 1.4. Charleroi-Ottignies railway section: La Roche - Faux cut*

Location. Railway section, km 36.2-36.1, 500 m to the north of the La Roche station.
General structure. Very discontinuous outcrops on the eastern side of the track. This cut has been described in detail by Van Tassel (1986) at a time when the outcrop was in much better condition (Fig. 15). The bedding, of variable direction, is cut by numerous almost vertical faults that run approximately E-W.
Lithostratigraphy. Tangissart Member, uppermost part of the Mousty Formation. This member is a maximum of 100 m thick and marks the transition between the Mousty and the Chevlipont formations.

Lithology. Black shales alternating with dark shales with lighter siltstone laminae. The number and the size of these laminae vary considerably from sample to sample. The thickest are rarely greater than 0.5 cm. Horizontal bioturbation is also observed (*Planolites*).

Sedimentology. The silty laminae which appear episodically, and higher up more and more frequently within the black shales are interpreted as very distal low density turbidites (mud turbidites, Fig. 16). This interpretation is only possible within the extended framework of the sedimentological study of the Chevlipont Formation (cf. stop 1.5 and see sedimentological introduction 3.2.5) and the gradual transition from the Mousty to Chevlipont formations. As a result, the depositional environment is interpreted as an anoxic deep marine environment. However, instead of having a purely pelagic sedimentation a terrigenous component, typical of hemipelagic sedimentation, appears progressively. This is interpreted as the beginning of a regression which continued into the overlying formation.

Biostratigraphy. It is within this section and in the talus of the Faux-La Roche road (now hidden by a wall) that Lecompte (1948) described *Rhabdinopora flabelliforme* which proves the early Tremadocian age of the

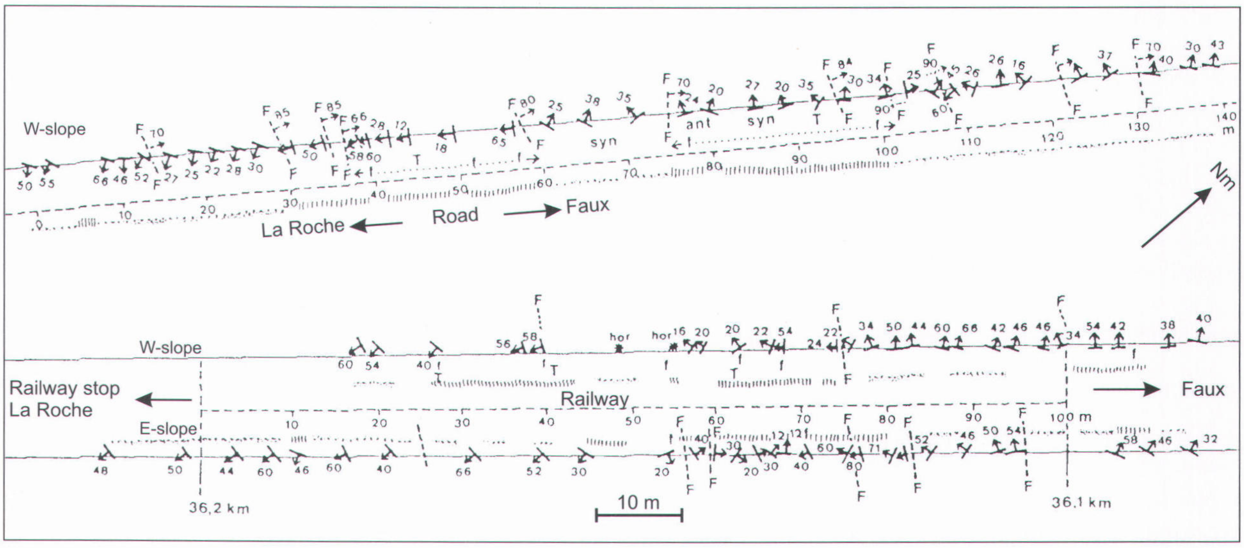


**Figure 15**. Location map by Van Tassel (1986) of the road and Charleroi-Ottignies railway sections N of La Roche station (stop 1.4). Tangissart Member, uppermost part of Mousty Fm. Stippling = silty laminated shales. Hatching = black shales. f = graptolite. T = trilobite. F = fault.

member (see also Van Tassel, 1986). However, Vanguestaine (*in* André *et al.*, 1991) has only found rare and poorly preserved acritarchs.

### *Stop 1.5. Charleroi-Ottignies railway section at Chevlipont*

Location. Railway crossing to the NE of Chevlipont (old water mill along the Thyle river). NE side, km 37.93-38.08.

General structure. This quite continuous 160 m long outcrop shows regular bedding gently dipping to the N (strike N30°-40°W, dip 20°N). The north dipping beds correspond to the N limb of a low amplitude (hm scale) gentle antiform ("Bois de l'Hermitage dôme", Michot, 1978). This gentle antiform is part of the long undulating N limb of the larger (km scale) Bois de l'Hermitage anticline, which extends from La Roche to the Bois de l'Hermitage (Fig. 7).

Lithostratigraphy. Middle part of Chevlipont Formation (Fig. 5).

Lithology. Grey siltstone with characteristic wavy bedding consisting of rhythmic alternations (mm to cm) of light grey siltstone laminae and dark grey clayey siltstone to mudstone laminae. Each of these centimetric rhythmic sequences is graded. Silty laminae occur frequently in small lenses a few cm long and a few mm thick with oblique lamination and load structures. These wavy silty laminae occur at the base of the most complete sequences. Millimetre-size horizontal bioturbation (*Planolites*) is frequently observed in the clayey laminae at the tops of the sequences. This facies is regularly interrupted by cm to dm fine sandstone beds which are either massive or present plane parallel bedding or convolute structures.

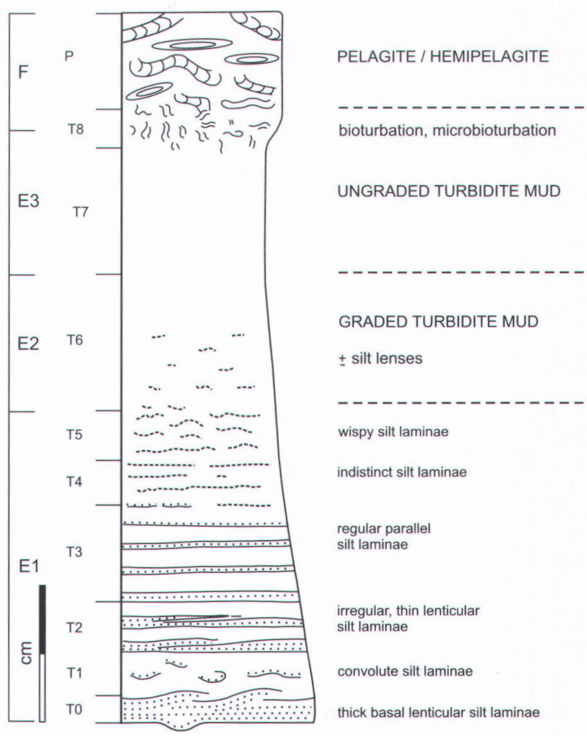


**Figure 16**. Low density turbidite facies model. Structural division E1 to F redrawn after Piper (1978), T0 to P redrawn after Stow & Shanmugam (1980).

Sedimentology. Study of the outcrops and boreholes allows the interpretation of this facies as low density turbidite sedimentation typical of "mud turbidites"

(Stow & Shanmugam, 1980; Stow, 1986). This laminar siltstone is the result of the repetition of incomplete Stow's sequence model (Fig. 16) whose lower intervals (T0 to T4), and in particular the silty basal lamination with ripples (T0), are well developed in comparison to the upper argillaceous intervals (T7 is almost always absent). These top-cut-out type of sequences are transitional to silt turbidite facies (Stow & Piper, 1984). Repetition of these truncated sequences with minor variations led to the development of a distinctive facies, thin parallel to wavy silt-laminated mud, in which individual turbidite units may not be readily distinguished.

Several other arguments support this interpretation: frequent presence in boreholes of slumps and intraformational breccias; occurrence of thin sandy beds interpreted as high density distal turbiditic episodes; lateral variation to high density turbidites; sedimentary continuity with the pelagic shales of the Mousty Formation. The depositional environment is always deep, relatively reducing (pyrite and organic matter), with a slightly increased slope (slumps), certainly closer to the continental slope than the depositional environment of the Mousty, although we can not be any more precise.

Biostratigraphy. Tremadocian, probably Lower Tremadocian. This is based on the presence of abundant and well preserved acritarchs (Martin, 1976; Vanguestaine *in* André *et al.*, 1991; Vanguestaine, 1992; Herbosch *et al.,* 1991), as well as the presence of rare graptolites (Lecompte, 1949).

***Stop 1.6. La Roche - Abbaye de Villers road, km 30.75***

Location. West slope of the Thyle Valley, on the road from the Villers Abbey to La Roche at about km 30.75 (outcrop just above a stone wall).

General structure. An almost continuous outcrop over 60-70 m. A succession of three antiforms (meter to decameter scale) with step fold geometry can be observed. Further north the beds remain sub-horizontal to gently S dipping with an approximately E-W strike. On the AB cross-section of Figure 7, this outcrop is situated in the fold hinge zone of the northern km scale antiform (Bois de l'Hermitage). Although the folds are considered to be tectonic they may well have formed along a previous soft deformation structure (Debacker, 2001). Michot (1978) has previously described slump structures not far from this outcrop in the same formation.

Lithostratigraphy. Lower third of the Abbaye de Villers Formation (Fig. 5).

Lithology. Grey to dark grey argillaceous to sandy siltstone, roughly laminar to bedded. This laminar structure is marked either by set of numerous mm thick silty laminations or by lighter coloured silty/sandy beds which interrupt the argillaceous sedimentation. The abundance of mm sized micas (illite-chlorite stacks in thin section) is also very characteristic. The stratification is frequently disturbed by a strong horizontal or more rarely vertical bioturbation (plurimillimetric to centimetric). Unfortunately, this outcrop does not show the oblique laminated bedsets that are frequently observed elsewhere in this formation (for example in the Abbaye de Villers railway trench).

Sedimentology. The alternation of silty-sandstone beds and clay beds implies significant periodic variations in the energy of the depositional environment, conditions that are characteristic of continental shelves. The dominantly argillaceous character demonstrates that the depositional environment is certainly below the fair weather wave base. This depth which corresponds to the middle shelf is compatible with the observed strong bioturbation in an essentially horizontal direction, with the strong tendency towards dysoxic conditions (dark colour, pyrite) and finally with the presence of submarine dunes (?) with oblique stratification (Fig. 17).

A significant sedimentological gap is observed between the Chevlipont and Abbaye de Villers Formations as we move directly from a deep marine environment probably situated close to turbidite plains to a relatively shallow continental shelf environment.

Biostratigraphy. No macrofossils are found. Chitinozoans in the lower third of the formation in the Dyle basin contain *Eremochitina brevis* (Samuelsson & Verniers, 2000). The same assemblage occurs in the Grès Armoricain Formation in Brittany, and indicates a middle Arenig, Whitlandian (*pro parte*), or possibly late Arenig age (Paris, 1981). Acritarchs in the middle and upper part of the formation indicate a late Arenig or post-Arenig age according to Martin (1976) and Vanguestaine (*in* André *et al.*, 1991), which is corroborated by the chitinozoans (Samuelsson & Verniers, 2000) (Figs. 8 & 9). One of the acritarch genera present, *Frankea,* does not appear below the uppermost Whitlandian, top middle Arenig, in levels of the upper part of the *Isograptus gibberulus* graptolite Biozone, according to Servais (1993) and Brocke *et al.* (1995) or of the *Expansograptus hirundo* graptolite Biozones, upper Arenig.

An important time gap is thus present between the Chevlipont and the Abbaye de Villers formations (Figs. 4 & 8).

### *Stop 1.7. Bois Pinchet pond, 500 m S of Abbaye de Villers*

Location. East slope of the Thyle Valley to the NE of the Bois Pinchet pond. Corresponds with km 40.5 of the Charleroi-Ottignies railway line.

General structure. Numerous small outcrops dispersed over about a hundred metres in a general N-S direction

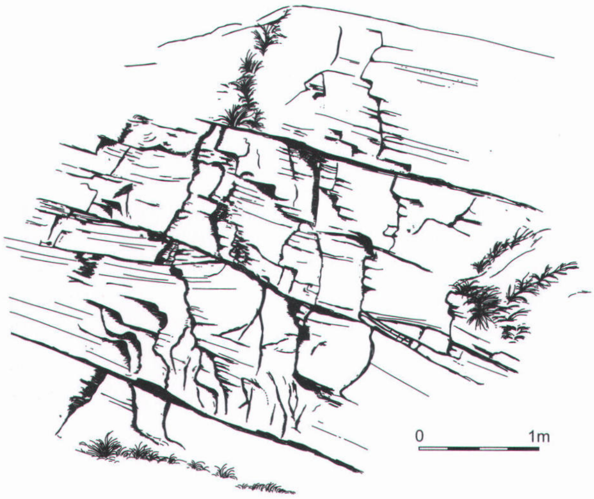


**Figure 17**. Set of oblique stratifications (sand ridge?) in the Abbaye de Villers Formation; km 38.842 of the railway cut just east of the ruin of the Abbaye de Villers (drawing F. Boulvain).

on the Bois Pinchet slope. The beds have a WNW-ESE strike and are slightly dipping to the south (strike N60°W, dip 15°-20°S). On the AB cross-section (Fig. 7) this outcrop is situated in the northern descending limb of the large km scale syncline which extends from Abbaye de Villers to the Thyle river.

Lithostratigraphy. Lower third of the Tribotte Formation.

Lithology. This lower part contains brownish grey, clayey sandstone and siltstone, with coarse laminations and strong bioturbation (mainly horizontal). The transition is progressive and is marked by an increase in grain size (average 70 to 90 microns), an increase in the quartz content and the disappearance of the dark colouring. Thin section examination shows abundant potassic feldspar (up to 18%) and plagioclase in the sandstone from the base of the formation (Jodard, 1986; Herbosch *in* André *et al.,* 1991).

Sedimentology. At the base of this formation there is a progressive evolution from a shelf environment situated under the wave base, the depositional environment of the Abbaye de Villers Formation, towards a more agitated (sand) and oxygenated (lighter coloured rocks) environment, probably situated close to the wave base (clays are still present). The arkosic episode at the base of this zone has not yet been explained sedimentologically or geodynamically.

Biostratigraphy. Neither macrofossils nor acritarchs have been observed but numerous ichnofossils: 'Fucoids' (Malaise, 1911; de la Vallée Poussin, 1930), bilobites (Legrand, 1967). A poor chitinozoan assemblage however, in the uppermost part of the formation, containing *Euconochitina vulgaris* indicates a middle Arenig to early Llanvirn age (Verniers *et al.*, 1999; Samuelsson & Verniers, 2000) (Figs. 8 & 9).

### *Stop 1.8. "Chemin creux de Rigenée", NW of Rigenée, Thyle Valley*

Location. Along a dirt road going to the village of Rigenée, east of the bridge over the Thyle, which leads to the old castle Le Chatelet.

General structure. Discontinuous outcrops in the road and on its south side. They begin about 60 m from the bridge and continue until the road curves to the S and becomes sunken. The bedding attitude is WNW-ESE with a moderate dip (strike N70°-80°W, dip 55°-60°S). This moderate dip corresponds to the southern limb of a small scale (hm) anticline which is situated in the fold hinge zone of the southernmost large scale anticline (Rigenée, Figs. 6 & 7). The cleavage can be clearly seen in the argillaceous rocks and is always in an E-W direction and sub-vertical (dipping to the N, occasionally to the S).

Lithostratigraphy. Top of the Tribotte Formation and base of the Rigenée Formation (Fig. 5).

Lithology. Dark grey to bluish grey laminated siltstone and mudstone. The siltstone has often experienced bioturbation. The lower boundary of the unit marks a rapid upward change (over about 10 metres, Servais, 1991b; Herbosch & Lemonne, 2000) from light clayey siltstone (upper part of Tribotte Formation) to dark finely laminated argillaceous siltstone to mudstone.

Sedimentology. The sedimentology has not yet been systematically studied. The extremely rapid passage from the light coloured silto-argillaceous rocks of the Tribotte Formation into the dark laminar siltstone of the lower part of Rigenée Formation can only be explained by a rapid increase in water depth. Indeed, we move from an intertidal environment to an environment situated at least beneath the wave action zone (if not deeper).

The overlying Ittre Formation can clearly be interpreted as a turbidite environment. Thus it can be deduced that the monotonous mudstone of the middle and upper part of the Rigenée Formation probably resulted from a relatively rapid event marking the transition from a shallow shelf environment to a deeper environment close to the continental slope (probable depositional environment of the Ittre Formation).

Biostratigraphy. According to Martin (1969a), acritarchs indicate an (early) Llanvirn age. Acritarchs studied by Servais (1993) indicate that for the base of the formation (this outcrop) a late Arenig or younger age cannot be excluded. Higher levels of the formation seem to be (at least) late Llanvirn in age if not younger as indicated by the presence of *Frankea hamulata*, a species not found in rocks older than late Llanvirn. A poor assemblage of chitinozoans with *Lagenochitina obeligis* and *Cyathochitina calix* indicates the same extended age bracket (Verniers *et al.,* 1999; Samuelsson & Verniers, 2000) (Figs. 8 & 9).

Graptolites in the lower or middle part of the formation in the Sennette Valley belong to the lower Llanvirn *Didymograptus artus* Biozone according to Martin and Rickards (1979). Additionally, following a new examination of the fauna by Maletz and Servais (1998) these graptolites have been attributed to the *Didymograptus artus* and the *Didymograptus murchisoni* Biozones, corresponding to the entire Abereiddian (lower Llanvirn) (Fig. 8).

## 5. Silurian of the Orneau Valley (DAY 2)

### *5.1. Introduction*

The Lower Palaeozoic sequence of the Brabant Massif can be well observed in the Dyle Valley for the Cambrian-Ordovician part. The small Orneau Valley passing thorough the city of Gembloux offers a good continuation upward of the sequence. Between Gembloux and the hamlet of Les Mautiennes, near Mazy (Fig. 18) this valley cuts through the Ordovician and Silurian sediments of the Brabant Massif, 20 to 45 m below the base of the Upper Eocene Bruxelles Formation, present in the upper parts of the valley (Fig. 19). The valley is oriented at right angles to the fold structures. The generally south dipping strata with some folds in the southern part allows the observation of a rather continuous succession with much of the Middle Ordovician to Silurian formations (Figs. 1 & 20). The series of long outcrops along the railway, roads and small quarries, known since long (Dumont, 1848), was chosen a century ago as the type area for the three-fold division of the Silurian in the Brabant Massif, with the "Assise de Grand-Manil" for the Llandovery, the "Assise de Corroy" for the Wenlock and the "Assise of Vichenet" for the Ludlow (Malaise 1900, 1910). Later stratigraphical studies corrected this division in other outcrop areas of the Brabant Massif as in Ronquières (Legrand, 1967) and in the Mehaigne area (Verniers, 1983a). It allowed to subdivide these too large and heterogeneous units in more than eight formations (Fig. 4). The units were well dated with graptolites, acritarchs and chitinozoans (see overview in Verniers & Van Grootel, 1991 and Verniers *et al.*, 2001, 2002b). In the stratigraphical revision of the Lower Palaeozoic formations of Belgium, four formations have their type locality in the Orneau Valley: the Brûtia, Bois Grand-Père, Corroy and Vichenet formations (Fig. 4) (Verniers *et al.*, 2001).

In an unpublished M.Sc. thesis by De Schepper (2000) the four type localities in the Orneau Valley were studied in some detail. Samples from all Silurian formations were taken for chitinozoan studies, but only from five formations the organic microfossils could be extracted. As usual in most of the Brabant Massif, the chitinozoans are dark to opaque and only moderately preserved. They have a concentration between 0.04 and 7.0 chitinozoans per gram of rock and a diversity of 1 to 12 species per sample (Fig. 22 & 23). The indicative and well preserved species are shown on Plates 1 to 5. Illite crystallinity studies in this area indicated that the metamorphism reached the low anchizone (Van Grootel *et al.*, 1997), which could have destroyed part of the microfossils. The assemblages of chitinozoans corroborated the age of the Corroy Formation, as deduced earlier by graptolites and they could date for the first time the Vichenet Formation (not Ludlow as assumed earlier but late middle to early late Wenlock). The lower limit of the latter formation in the type locality could be located (stop 2.4, see below).

The following Silurian formations are present in the Orneau Valley and are summarised from the stratigraphical revision by Verniers *et al.* (2001).

### *5.2. Brûtia Formation*

Defined during the geological mapping by Delcambre *et al.* (2002) the formation has its stratotype in Grand-Manil, between the localities Try-al-Vigne and Brûtia. It contains the lower part of the previous "Assise de Grand-Manil".

Description. The lower unit contains (greenish) medium to dark grey mudstone and slate, compactly bedded. At one third up in the unit, a mottled grey mudstone member occurs, a few meters thick, consisting of dark grey lenses (about 1-2 mm wide and 2-5 mm long) in a medi-

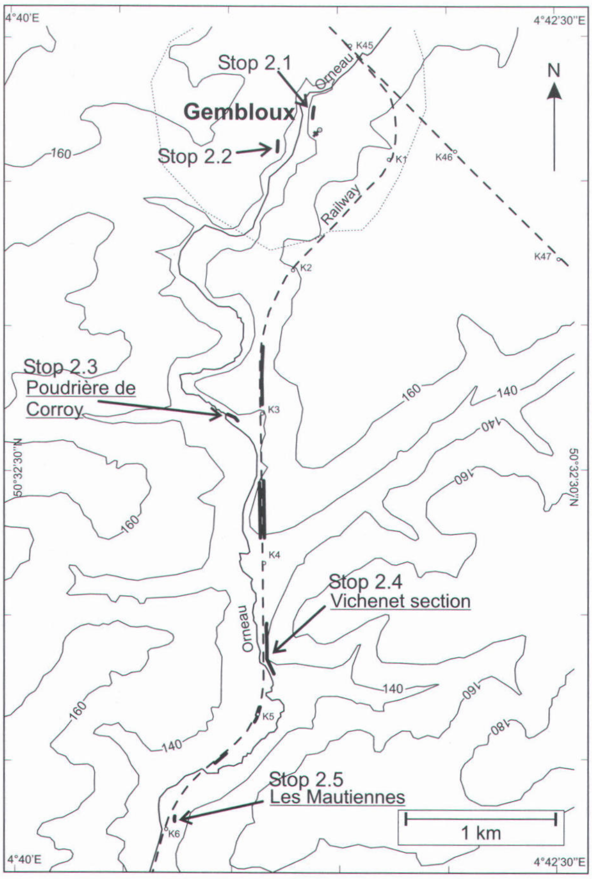


**Figure 18**. Simplified topographic map of the Orneau valley south of Gembloux, showing the position of the three visited outcrops. Also the position of other outcrops is shown (thick black lines).

um grey mudstone, interpreted as an ichnofossil (*Chondrites* sp.). The topmost part of the formation is a fine-grained quartzitic tuff, very hard and white, light pink or yellow in colour and is called the "Eurite of Grand-Manil Member". By weathering it was transformed into kaolinite and was locally exploited for the ceramic industry.

Sedimentology. The fine-grained sediments with occasional benthic fauna and bioturbation could indicate a deep shelf.

Thickness. In the Orneau Valley 40 m for the "Eurite" de Grand-Manil Member and between 80 and 100 m for the whole formation (Delcambre *et al*., 2002).

Age. Trilobites in the lower/middle part of the formation were described by Malaise (1903) without using them for dating. The chitinozoans from the mottled mudstone member are dominated by *Belonechitina* cf. *gamachiana*, indicating a middle or late Ashgill, possibly Hirnantian age (Samuelsson & Verniers, 1999, 2000). Graptolites described from the top of the formation in slates below the "Eurite of Grand-Manil member" in the Orneau Valley, belong to the *Coronograptus cyphus* Biozone (Elles *in* Maillieux, 1930a). Graptolite collections in the same levels mentioned in Gerlache (1956) and determined by Bulman (1950) as *Climacograptus scalaris* indicate the *Parakidograptus acuminatus* Biozone (the basal graptolite biozone of the Rhuddanian) or slightly above or below. A middle or late Ashgill to Rhuddanian age is proposed for the formation.

### *5.3. Bois Grand-Père Formation*

The formation was also created by Delcambre *et al.* (2002) and contains the middle part of the previous "Assise de Grand-Manil". Its stratotype is on private grounds in two small abandoned quarries and outcrops, a few hundred meters south of the Tri à la Vigne and Brûtia.

Description. Mostly medium to dark grey shale or slate unit, dark greenish grey at the base; at certain levels interbedding of many medium grey laminated siltstone beds and light coloured quartzitic very fine sandstone, a few to 20 cm thick. Some beds can be calcareous. The lower boundary is taken just above the "Eurite of the Grand-Manil member", with the upper boundary not observed.

Sedimentology. The sandstone beds show lamination or fine oblique stratification with undulating bedding planes; at least partly deposited as turbidites.

Thickness. About 200 m (Delcambre *et al.*, 2002); estimated between 375 and 500 m (Verniers *et al.*, 2001).

Age. Graptolites have been described from the *Coronograptus cyphus*, *Monograptus convolutus* and *Monograptus crispus* Biozones (Maillieux, 1930a, 1930b, 1933; Michot, 1930). A middle Rhuddanian to middle Telychian age is tentatively proposed (Verniers *et al.*, 2001). One of the three Chitinozoa samples contains only a few specimens, but amongst them *Conochitina* spp. cf. *Vitreachitina* sp. 2 Nestor, 1994 indicates a Telychian age (Nestor, 1994).

### *5.4. Fallais Formation*

The formation informally defined by Verniers (1976, 1983a) in the Mehaigne Valley, around the village of Fallais is poorly outcropping in the Orneau Valley.

Description. Light green, olive-greenish grey, or light grey chloritic mudslate and mudstone, with rare siltstone and fine sandstone beds from distal turbiditic ori-