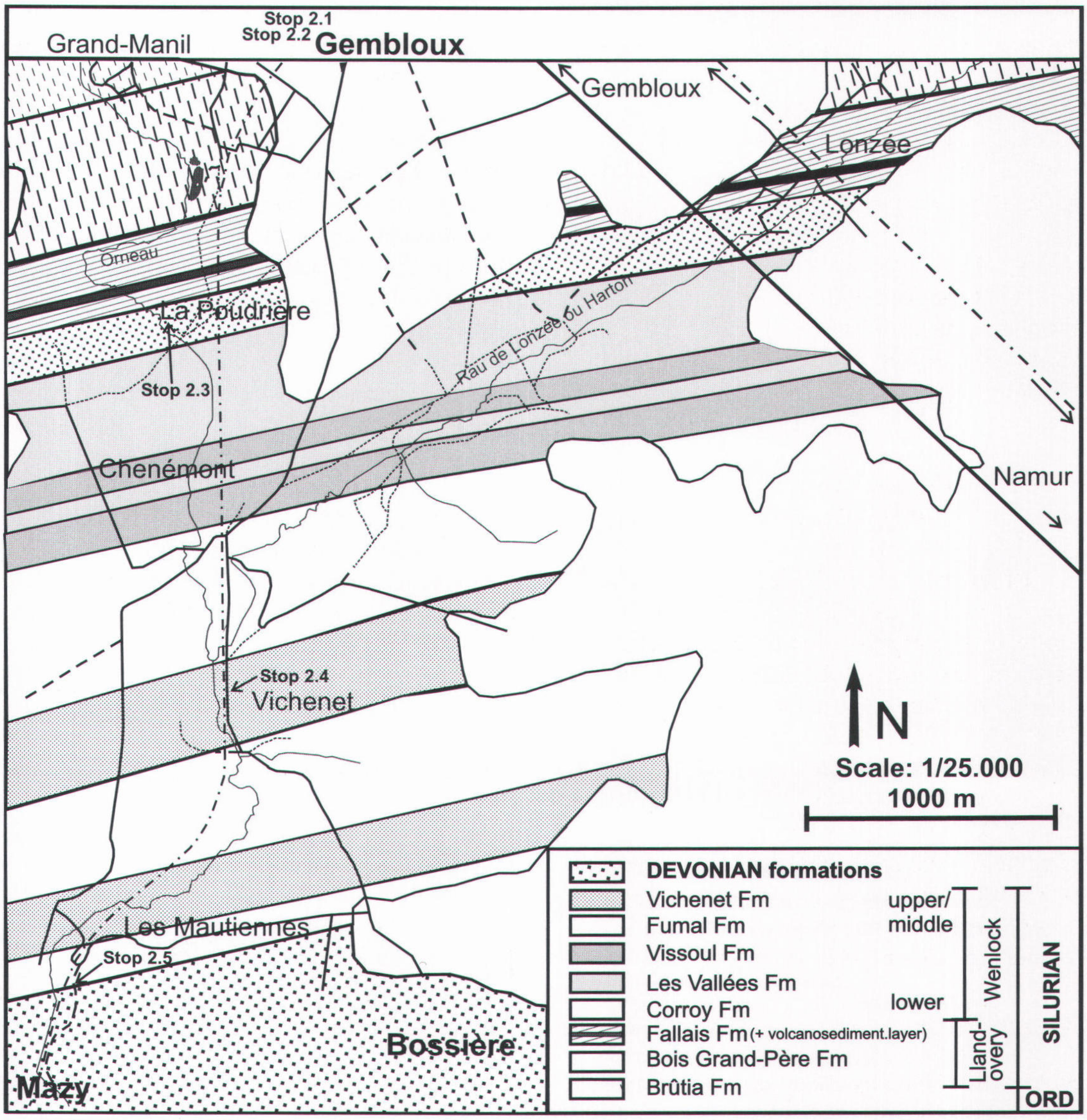

Figure 19. Geological map of the Orneau Valley after De Schepper (2000).

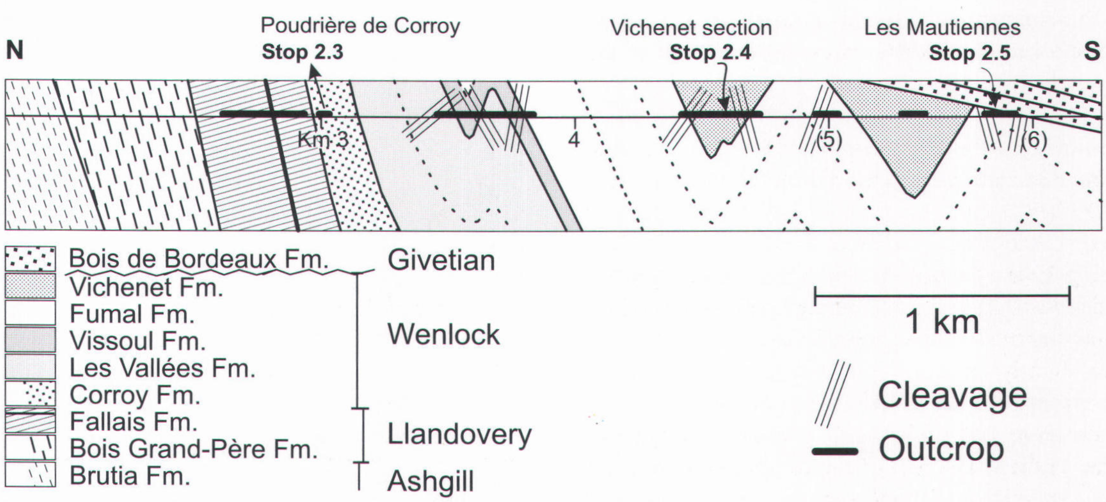

Figure 20. N-S cross-section of the Orneau valley south of Gembloux, after De Schepper (2000), Belmans (2000) and Debacker (2001) (vertical exageration not to scale).

gin, mostly without laminated hemipelagite. In the Mehaigne area six members occur with a 26 m thick volcanic layer near the top, the volcano-sedimentary layer of Pitet. In the Orneau Valley along the railway cut at km 2.809 a similar volcano-sedimentary rock is present, only a few meters thick and located at about 20 m below the top of the formation.

Sedimentology. The unit contains typical Bouma-type turbidites, with mostly distal Tde and more rarely Tcde divisions and no laminated hemipelagite present. A turbiditic basin is hence deduced. The unit is relatively thick in the Mehaigne area (estimated at 600 m) for a relatively short period of time.

Thickness. Difficult to measure in the Orneau Valley but estimated at 300-400 m (Delcambre *et al.*, 2002).

Age. Undated in the Orneau Valley. Telychian, late Llandovery, based on acritarchs in the Sennette Valley (Martin, 1969a). The chitinozoans from the Mehaigne area indicate for the lower half of the formation the *Angochitina longicollis* global Biozone which is calibrated versus the graptolite biozonation from the post-*Monoclimacis griestoniensis* to the pre-*Cyrtograptus insectus* Biozones. The *Margachitina margaritana* global Biozone is observed in the upper half. According to the calibration by Mullins (1998) the upper half corresponds to the *Cyrtograptus insectus* graptolite Biozone, the uppermost biozone of the Telychian, late Llandovery (Verniers *et al.*, 2001).

5.5. Corroy Formation

The formation as defined by Malaise (1900) and later by Legrand (1961) is restricted by Verniers (1982), Verniers & Van Grootel (1991) and Verniers *et al.* (2001) to its lower third part. The type locality is situated in the abandoned quarry *La Poudrière de Corroy*, near the Orneau river, 150 m west of km 3.050 of the railway (stop 2.3).

Description. Mudslate, mudstone, siltstone and fine sandstone, alternating in thin beds, decimetric to a few cm thick. The sandstone is light-coloured, obliquely stratified, sometimes convolute bedding, with often undulating base and bounce and other current marks. Interbedded are dark grey laminated hemipelagite layers containing most of the graptolite levels. Some of the beds are slightly calcareous. The mudslate is greenish grey in the lower part of the formation, indicating its softer, chloritic composition. The colour changes to dark grey in the upper part of the formation, indicating a more quartzic or illitic composition. The lower boundary occurs via a gradual transition from the Fallais Formation and is marked by the lowest presence of at least three, decimetric, sandstone beds per meter of sediment. The upper boundary is marked by the highest sandstone bed of more than 5 cm thickness.

Sedimentology. Typical Bouma-type turbidites, with mostly Tde sequences, frequent to very frequent T(b)cde sequences, generally twice as thick as the average Tde sequence, with sandstone Tc-divisions in thickness between 2 and 12 cm. The turbidites alternate with laminated hemipelagites indicating an autochthonous sedimentation in the basin. Throughout the outcrop area of the Brabant Massif there is an overall tendency in this formation to thinner turbidite sequences from east to west (Verniers *et al.*, 2001). The sudden increase of energetic turbidites in the formation in relation to the under- and overlying formation indicates a more shallow period which is also observed on the Baltica platform as e.g. in Gotland (Laufeld, 1979). No eustatic sea-level low is observed at this time (see Johnson *et al.*, 1985; Kaljo *et al.* 1995), and hence the shallowing event is probably caused by a tectonic event affecting

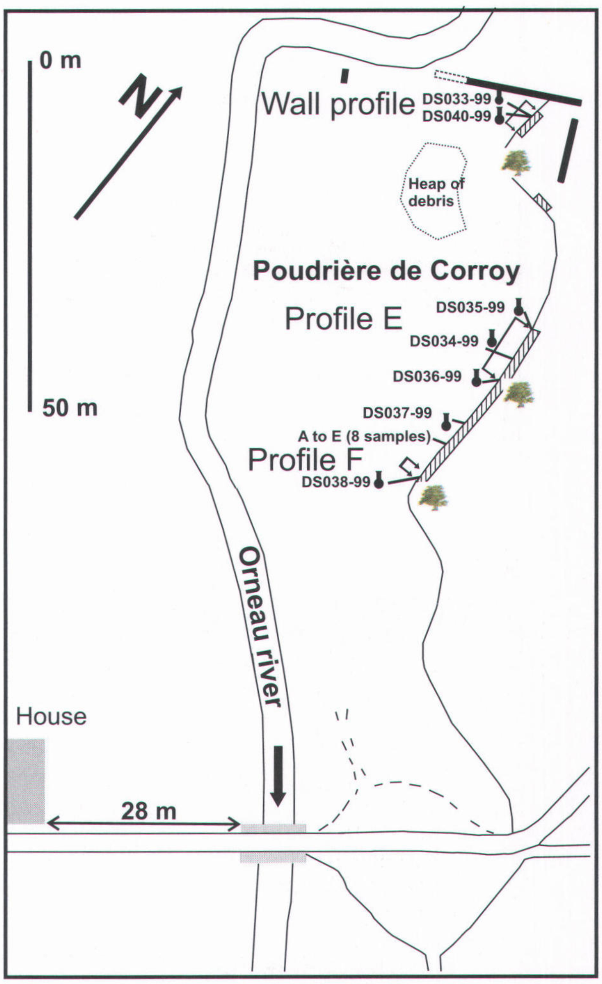

Figure 21. Location map of the samples for chitinozoan studies in the Poudrière de Corroy, type locality of the Corroy Formation, after De Schepper (2000).

Formations	Orneau	*Ancyrochitina ancyrea*	*Ancyrochitina* spp.	*Angochitina longicollis*	*Bursachitina* sp. A in Sutherland (1994)	*Cingulochitina burdinalensis*	*Cingulochitina cingulata*	*Cingulochitina dreyensis*	*Cingulochitina ithoniensis*	*Cingulochitina pitetensis*	*Cingulochitina* spp.	*Conochitina acuminata*	*Conochitina claviformis*	*Conochitina fortis*	*Conochitina proboscifera*	*Conochitina subcyatha*	*Conochitina truncata*	*Conochitina tuba*	*Conochitina tuba?* in Paris (1981)	*Conochitina visbyensis*	*Conochitina* spp.	*Desmochitina opaca*	*Desmochitina* spp.	*Eisenackitina anulifera*	*Eisenackitina causiata*	*Eisenackitina* spp.	*Margachitina margaritana*	*Salopochitina bella*	*Sphaerochitina jaegeri*	*Sphaerochitina serpaglii*	*Sphaerochitina* sp. B in Verniers (1982)	*Sphaerochitina* spp.	*Conochitina spp. cf. Vitreachitina* sp. 2	Chitinozoa spp.	Total number of chitinozoans	N° of specimens determined to genus level	N° specimens determined to species level	Weight of dissolved rock (g)	Number of chitinozoans per gram of rock	Acritarchs
Vichenet	Sect. B: DS-027-99	3?			3		9				1		3	1?		1		5			6		1			2			2	4				4	41	10	27	66.31	0.56	>400
	Sect B: DS-026-99												1	3				2			10													1	17	10	6	27.15	0.59	>100
	Sect. A: DS-025-99													1																				1	2	0	1	25.91	0.04	>7
	Sect. A: L9 base						1							1?							2					2								1	6	6	2	31.04	0.23	x
	Sect. A: LHP 8/9													2		1		2																0	5	3	5	29.9	0.17	x
	Sect. A: L8 top																																		0	0	0	29.92	0.00	x
	Sect. A: DS-024-99																																		0	0	0	35.27	0.00	0
	Sect. C: DS-029-99																																	5	5	0	0	13.19	0.00	?
	Sect. C: DS-028-99																																	1	1	0	0	14.25	0.00	>5
	Sect. D: DS-031-99																																		0	0	0	12.95	0.00	0
	Sect. D: DS-032-99																																		0	0	0	14.21	0.00	>100
Fumal	DS-052-99																				1														1	1	0	12.83	0.08	>100
	DS-054-99																																		0	0	0	12.54	0.00	10
Vissoul	DS-051-99		1				1							2							1													3	8	2	3	12.16	0.41	>15
	DS-055-99						13							3																				3	19	0	16	12.97	1.23	>100
Les Vallées	DS-050-99																																		0	0	0	12.22	0.00	>250
Corroy	DS-038-99					9									1		1				1				2			1				1		4	20	2	14	11.78	1.36	x
	E Te (01-0814)					3						2									2				1				3					4	15	9	11	12.42	1.29	x
	E Tc (01-0815)	1																			3			1										2	7	2	5	12.41	0.56	x
	D Td (01-0813)	2				4															2				2									5	15	7	10	11.72	1.37	x
	C Te (01-0816)			2		4		2				5					2				10			6	9			1	2			1		7	51	34	44	19.06	2.83	x
	C Tc (01-0817)	1		3		1			1						1		11				26	7		5	9									4	69	39	65	19.91	7.03	x
	B Te (01-0812)					5						10									8			2	2		1							2	30	20	28	22.6	1.50	x
	B LHP (01-0806)		4			2						2												3										0	11	7	11	23.43	0.30	x
	A Te (01-0805)					2															3													1	6	2	5	22	0.27	x
	DS-037-99	1?		8		2		4		1		6			3		2		1		23			3	3				2			2		5	65	25	35	52.88	1.13	>200
	DS-036-99							2				2									3	1?	1	1	3		2							3	17	4	10	12.35	1.13	>500
	DS-034-99							1													3													0	4	3	1	12.13	0.33	16
	DS-035-99			2				2				5			2						5					1						1		4	22	7	11	12.41	1.45	3
	DS-033-99		2	8		6		19		4		27			17		8	17		2	11			2	8							1		51	183	14	118	52.69	2.51	>100
	DS-040-99																																	0	0	0	0	12.19	0.00	0
Fallais	DS-039-99																																		0	0	0	11.94	0.00	0
Bois Grand-Père	DS-046-99																																		0	0	0	12.68	0.00	0
	DS-042-99																				1					1					1	1	2		6	3	3	54.36	0.11	>350
	DS-041-99																																		0	0	0	13.2	0.00	0
	DS-049-99																																		0	0	0	12.81	0.00	0
Brutia	DS-048-99																																	1	1	0	0	12.58	0.00	0
	Total	4	7	23	3	38	24	30	1	5	1	59	4	11	24	2	24	26	1	2	121	7	2	23	39	6	3	2	9	4	1	7	2	112	627	210	431	790.37	0.79	

Figure 22. Composition of chitinozoan assemblages and concentrations in samples of the Silurian of the Orneau valley after De Schepper (2000).

both areas and linked with the Scandian orogeny. During the excursion M.P. Dabard (Rennes) and A. Loi (Cagliari) criticised the turbiditic nature of this formation and indicated features suggesting a tempestite sedimentation. A detailed sedimentological study of the outcrop is hence needed.

Thickness. About 100 m (Verniers *et al.*, 2001), with at least 53 m present in the quarry *Poudrière de Corroy* representing the upper part of the formation but probably not its top (De Schepper, 2000).

Age. Graptolites from the *Poudrière de Corroy* belong to the *Cyrtograptus murchisoni* and *Monograptus riccartonensis* Biozones (Malaise, 1900; Legrand, 1961); graptolites in the Mehaigne area indicate the presence of the *Cyrtograptus centrifugus* and *Cyrtograptus murchisoni* Biozones in the lower part of the formation, and the upper part of the *Monograptus riccartonensis* Biozone and the middle Wenlock *Monograptus flexilis* Biozones (now *Monograptus dubius* Biozone) in the upper part of the formation: lower to middle Sheinwoodian (lower and basal middle Wenlock) (Verniers & Rickards, 1979).

The results of the recent chitinozoan study in the *Poudrière de Corroy* by De Schepper (2000) on fourteen samples are shown on Fig. 23 &24. The chitinozoans for this part of the formation were described as belonging to subzone C3 (Verniers, 1981, 1982), to the *Margachitina margaritana* global Biozone of Verniers *et al.* (1995) and to the *Cingulochitina burdinalensis* local biozone of Verniers (1999). The *Margachitina margaritana* global Biozone starts in the uppermost Telychian in the *Cyrtograptus insectus* graptolite Biozone (Mullins, 1998). The former chitinozoan biozone spans the Wenlock-Llandovery boundary and hence this boundary cannot be located exactly with chitinozoans. The presence of Wenlock graptolites close to the base of the formation however suggests that the base of the Wenlock coincides or lies close to the base of the Corroy Formation.

5.6. Les Vallées Formation

The formation is defined in the Mehaigne and Burdinale valleys by Verniers (1976), Verniers & Van Grootel (1991) and Verniers *et al.* (2001) where mostly the lower part is visible, while the upper part of the formation is visible in the northern part of the railway section of the Orneau Valley, 350-500 m east and northeast of the "Ferme de Chenémont" (parastratotype section). The unit was considered earlier as the middle part of the Corroy Formation (Legrand, 1961; Verniers, 1983b). It is not visited during the excursion.

Description. Grey mudslate, mudstone, siltstone and fine sandstone with non-calcareous quartzic pelite in the Te-divisions in 10 to 40 cm thick Bouma-sequences.

Sedimentology. More energetic but still distal turbidites, alternating with thin-bedded laminated hemipelagites.

Thickness. Estimated at more than 225 m.

Age. middle Wenlock, based on the relative position of the formation: above the formation which at its top contains graptolites of a middle Wenlock post-*Monograptus riccartonensis* Biozone and chitinozoans of the middle Wenlock and below a formation with middle Wenlock graptolites (Verniers, 1982, 1999).

5.7. Vissoul Formation

The unit was considered as the upper part of the Corroy Formation by Malaise (1910) and Legrand (1961). The very different sedimentology in comparison with the Corroy Formation in its type locality, the *Poudrière de Corroy*, was the reason why this new unit was defined by Verniers (1976, 1983a, b) (see Verniers & Van Grootel, 1991; Verniers *et al.*, 2001).

Description. Grey mudslate, mudstone, siltstone and fine sandstone with non-calcareous quartzic pelite in the Te-division.

Sedimentology. Distal to slightly proximal turbidites alternating with thin-bedded laminated hemipelagites; the Tde sequences are medium thick and the T(b)cde sequences are frequent (about 15% of all sequences) and normally about 50% thicker than the average Tde sequences; the Tc-divisions are thin (2-8 cm). This formation forms a clearly different sedimentology from the adjacent units Les Vallées and Fumal formations.

Thickness. Estimated at more than 30 m.

Age. Graptolites from the Burdinale Valley are not characteristic for one particular biozone but the assemblage indicates a range from the *Pristiograptus dubius* to the *Cyrtograptus lundgreni* biozones, middle Sheinwoodian to early Homerian (middle to late Wenlock) (Verniers & Rickards, 1979; Zalasiewicz *et al.*, 1998); the chitinozoans belong to subzone D1 (Verniers, 1982) and to the *Cingulochitina cingulata* global Biozone or possibly the *Conochitina pachycephala* global Biozone of Verniers *et al.* (1995), spanning the same interval as indicated by the graptolites.

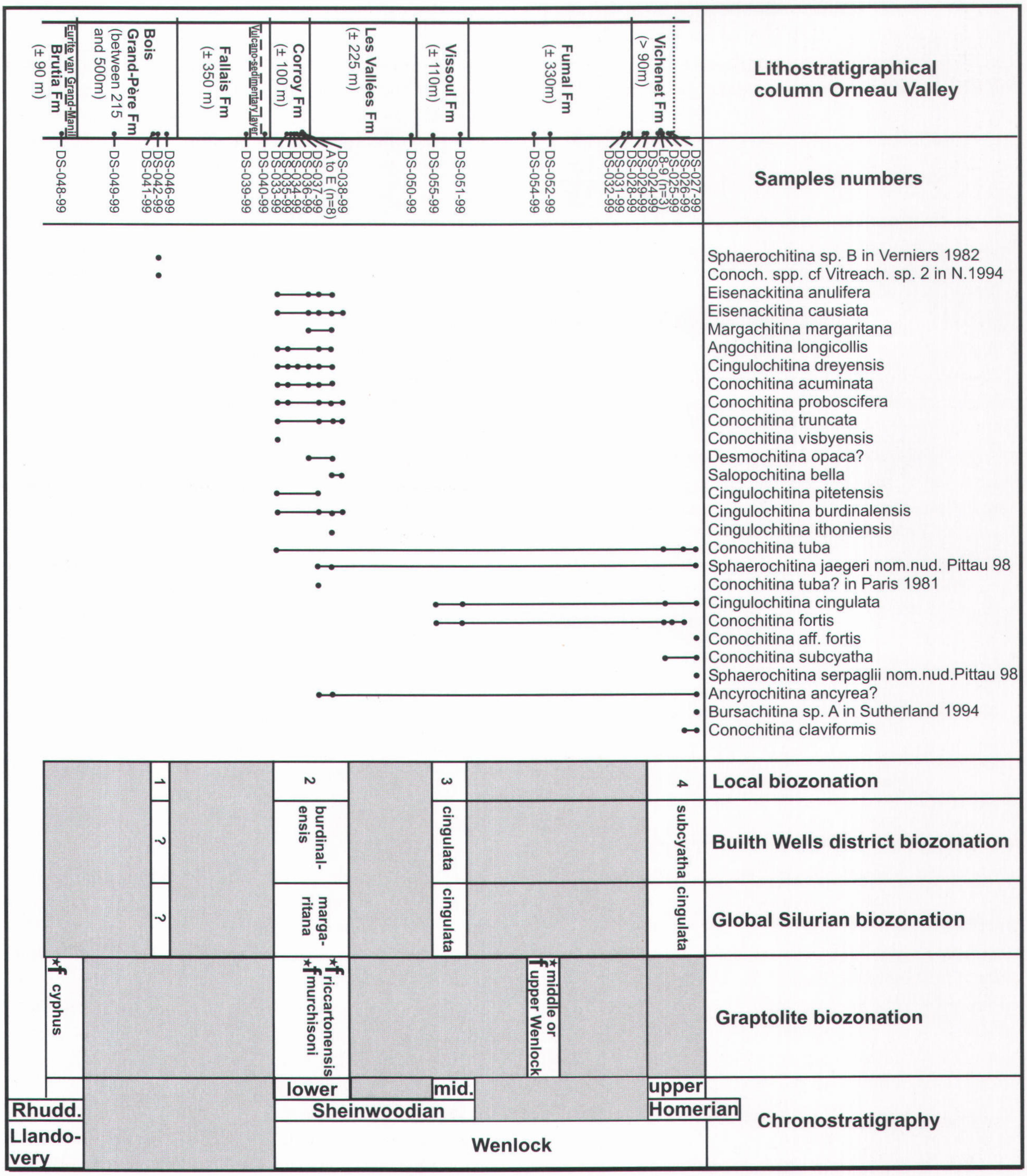

Figure 23. Ranges of selected chitinozoan species in the Silurian of the Orneau valley after De Schepper (2000), with local biozonation, correlation with the Builth Wells district (Verniers, 1999), with the global Silurian biozonation (Verniers *et al.* 1995), with the graptolite biozonation (see text) and with the deduced chronostratigraphy.

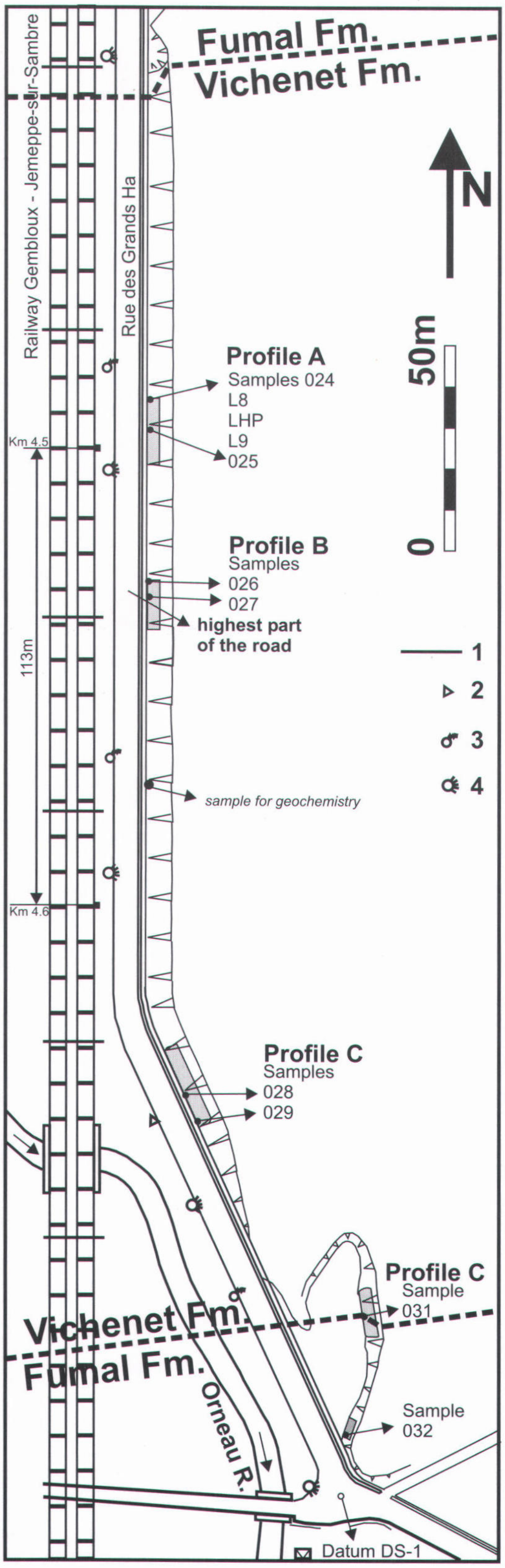

Figure 24. Location map of the Vichenet section, type locality of the Vichenet Formation and of the samples for chitinozoan studies after De Schepper (2000); compare with section in Fig. 25; 1: road sign, 2: electricity pole, 3: pole for street lighting.

5.8. Fumal Formation

The formation resembles much the Les Vallées Formation and can only be distinguished by its relation towards the neighbouring formations. The name was informally proposed by Michot (1957), Verniers (1976, 1983a) and Verniers & Van Grootel (1991) and formalised in Verniers *et al.* (2001).

Description. Grey mudslate, mudstone, siltstone and fine sandstone with quartzic pelite in the Te-divisions.

Sedimentology. Three types of sequential patterns occur: (a) thick Tde sequences (average between 24 and 28 cm) with absent or very rare T(b)cde sequences; (b) medium thick to thick Tde sequences (average between 17 and 25 cm) with rarely present to very frequent T(b)cde sequences (6 to 30% of all sequences) of about the same thickness as the Tde sequences; the c-divisions are either thicker or thinner than 10 cm but there is a higher frequency (80%) of c-divisions thinner than 10 cm; (c) medium thick to thick Tde sequences (average between 14 and 18 cm) and no T(b)cde sequences. Lower and upper boundaries are not observed in the Mehaigne area: the upper boundary is situated in an observation gap of ± 20 m between this formation and the Vichenet Formation.

Stratotype. Stratotype sections south-east of the church of Fumal; parastratotype in the outcrops just south to south-west of the church of Fumal in the Mehaigne Valley.

Thickness. Estimated in the Mehaigne area: 330 m (Verniers, 1983a).

Age. Middle Wenlock to early Homerian. The chitinozoans, the only fossils found in this formation in the Mehaigne area, belong to the *Cingulochitina cingulata* global Biozone and possibly the *Conochitina pachycephala* global Biozone of Verniers *et al.* (1995), middle Sheinwoodian to lower Homerian (middle to late Wenlock). In the Mehaigne area most of the upper two thirds of the formation can be assigned to the Welsh *Conochitina subcyatha* local biozone, lower Homerian (late Wenlock), and the uppermost part of the formation to the lower or middle part of the Homerian (late Wenlock) (Verniers, 1999).

5.9. Vichenet Formation

Unit created by Malaise (1910) with type locality in a 350 m long road section north of the abandoned railway station of Vichenet-Bossière, east of the castle of Vichenet in the Orneau Valley. It was meant to represent the Ludlow in the Brabant Massif. A graptolite locality described by him, could not be located, nor could the fossils of his collection. Michot (1954) proposed the name Ronquières Formation for the Ludlow and abandoned the term "Assise de Vichenet". The unit was informally reinstalled by Verniers (1976, 1983a), Verniers & Van Grootel (1991) and formally by Verniers *et al.* (2001). The section exposes only the lower part of the formation while the higher parts seem to be missing in this valley.

Description. Grey mudslate, mudstone, siltstone and rare fine sandstone with often calcareous quartzic-chloritic pelite in the thick Te-divisions. Characteristic are the very thick Te or Tde turbidite sequences and very rare or absent Tcde sequences, the grey to greenish colour, its sometimes calcareous content up to 5%, alternating with laminated hemipelagite beds. De Schepper (2000) placed the lower limit of the formation in the type section above the highest sandstone bed of a Tcde sequence.

Sedimentology. Alternating distal thick-bedded turbidites with thin-bedded laminated hemipelagites.

Thickness. Measured in the type locality at about 90 m for the basal part of the formation by De Schepper (2000); in the Mehaigne area estimated at more than 210 m (Verniers, 1983a) and in the Landenne outcrop area at more than 350 m (De Winter, 1998).

Age. Until recently no fossils were found in the Orneau Valley and the age was estimated middle to upper Wenlock, based on its relative position in relation to a fossil locality below the unit (Rickards, pers comm. *in* Verniers, 1983b). Chitinozoans studied by De Schepper (2000) presented here (Figs. 23 & 24) indicate a lower to middle part of the Homerian (late Wenlock). In the Mehaigne area only chitinozoans are found and limited to the middle part of the formation. The assemblage belongs to the *Sphaerochitina lycoperdoides* global Biozone of Verniers *et al.* (1995), lower to middle part of the Homerian (upper Wenlock) (Verniers, 1982, 1999). In the Landenne area the chitinozoans belong to the same biozone for most of the formation and for the lower part of the formation to the *Cingulochitina cingulata* local biozone, middle of the Sheinwoodian (middle Wenlock) to the middle Homerian, late Wenlock (De Winter, 1998).

5.10. Structural geology of the Silurian in the Orneau Valley

Like the southern Sennette Valley (cf. Legrand, 1967), also the Silurian in the southern Orneau Valley shows folds with a pronounced convergent cleavage fanning (Fourmarier, 1921; Kaisin, 1933; Mortelmans, 1954). Mortelmans (1954; cf. Kaisin, 1933) interpreted these fans as the result of two deformations: a first-phase Caledonian deformation, responsible for folding and cleavage development, followed by a Variscan overprint, causing a post-cleavage fold amplification accompanied by a passive rotation of the cleavage in the fold limbs, hence resulting in convergent cleavage fans. However, following the construction of the inclined ship lift at Ronquières, Legrand (1967) demonstrated that, at least in the Sennette Valley, this hypothesis is highly questionable, since the Silurian-Devonian unconformity can be seen truncating the convergent cleavage fans. Instead, Legrand put forward a two-phase Caledonian origin for the convergent cleavage fans. More recently, partly in accordance with Legrand (1967), the convergent cleavage fans in the Ronquières area were explained by means of a single-phase progressive deformation, consisting of a continued fold amplification after cleavage development (Debacker *et al.*, 1999). However, although Legrand (1967) questioned the influence of the Variscan deformation in the southern rim of the Brabant Massif, a Variscan origin for the convergent cleavage fans and kink bands was still advocated in the Orneau Valley by Vandenven (1967).

The origin of the convergent cleavage fans in the southern Orneau Valley, was studied structurally in an unpublished M.Sc. thesis by Belmans (2000).

5.10.1. Les Mautiennes

The outcrop shows a steeply inclined, gently W-plunging antiform with a slightly N-verging asymmetry and a well-developed convergent cleavage fan, truncated by the Middle Devonian angular unconformity (Fig. 20). The angular unconformity is sharp and straight. Detailed observations show that, in contrast to the opinion of Kaisin (1933), there is no evidence of slip along the unconformity. In this respect, the observations of Belmans (2000) in the Orneau Valley point to a similar situation as in Ronquières (cf. Legrand, 1967) and, contradicting the models of Kaisin (1933), Mortelmans (1954) and Vandenven (1967), they point to a pre-Givetian origin of the convergent cleavage fans.

5.10.2. Vichenet

This outcrop is the most accessible and one of the longest outcrops of the Orneau Valley. It contains a large open upright, gently W-plunging synform, comprising several smaller folds, which are cross-cut by small faults. All the folds show a convergent cleavage fanning. However the cleavage fan angle does not seem to be related to the fold interlimb angle: tighter folds may have a less developed convergent cleavage fan than more open folds (Fig. 25; cf. Fig. 20).

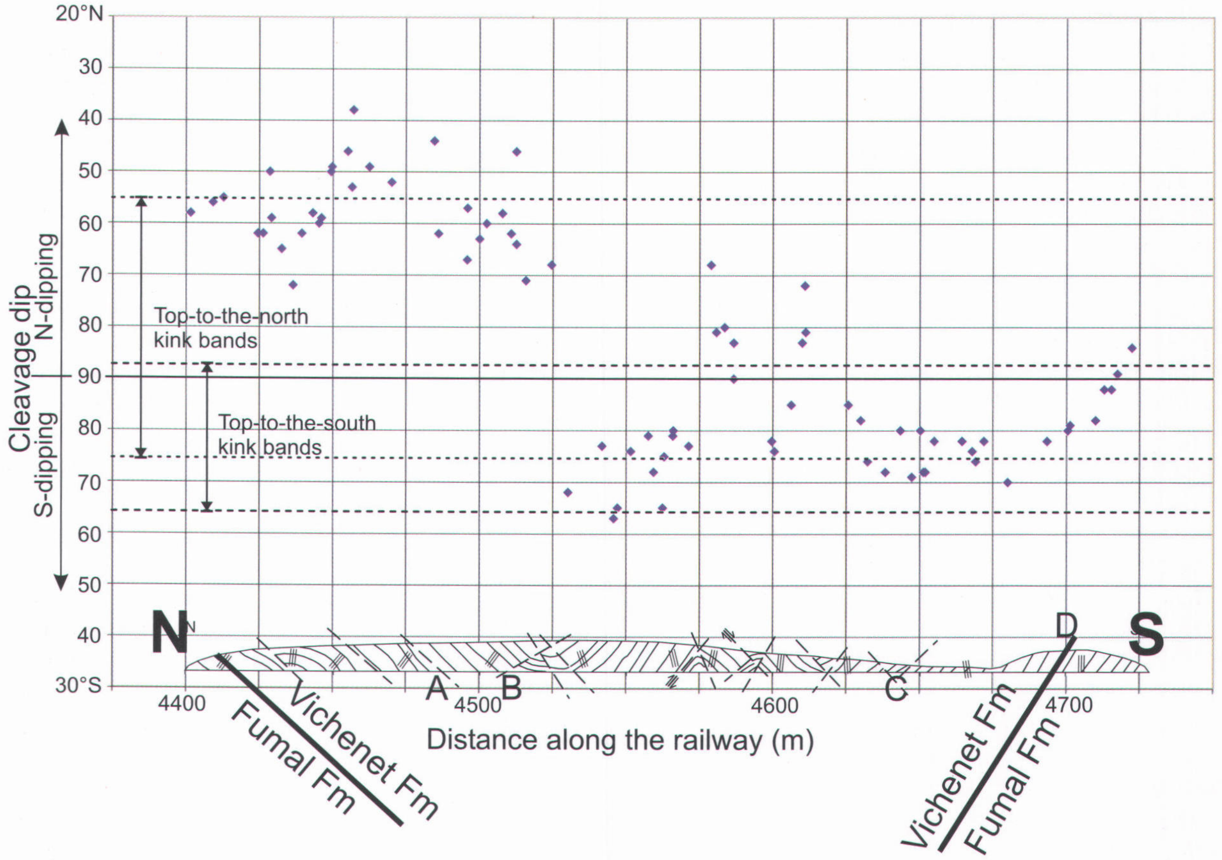

Figure 25. Graph showing the change in cleavage dip along the Vichenet section. Below a cross-section along the Vichenet section, oriented parallel to the railway, is added for better orientation. Cleavage data and the cross-section are taken from Belmans (2000). Note the change in cleavage dip across the folds, reflecting a pronounced convergent cleavage fanning. Also shown are the cleavage dip intervals in which top-to-the-north and top-to-the-south kink bands are encountered. Conjugate sets are expected, and occasionally encountered, in the zone of overlap, between cleavage dips 87°N and 64°S. A, B and C: visited places in the outcrops (figure after Debacker, 2001).

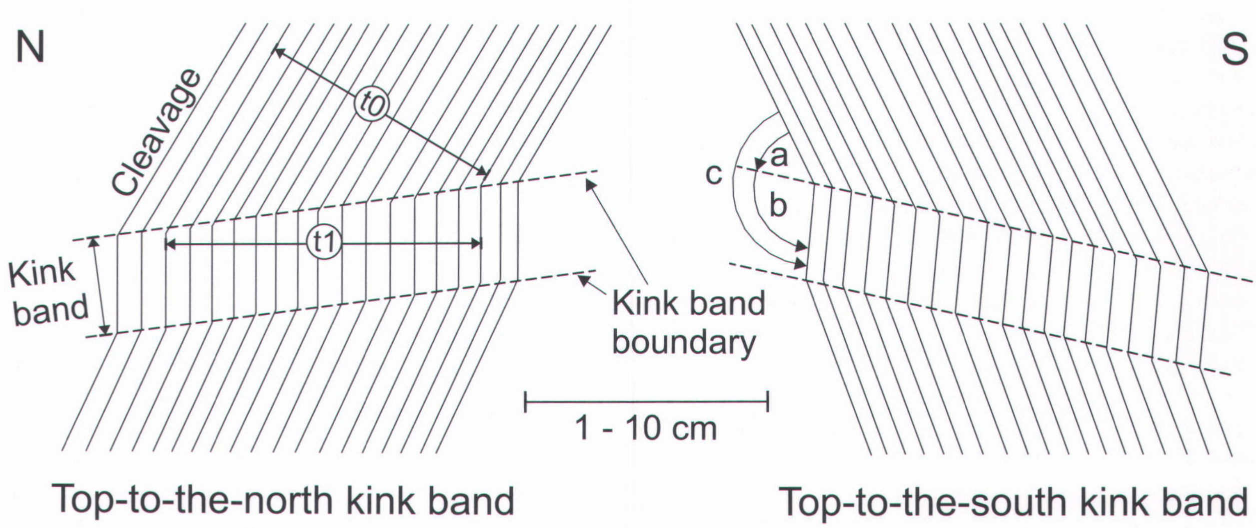

Figure 26. Top-to-the-south and top-to-the-north contractional kink bands from the Vichenet section. The internal geometry of most of the kink bands points to a volume increase inside the kink band (compare thickness t0 with thickness t1), which can be calculated by means of the formula (sin b/sin a) – 1. Figure after Debacker (2001).

The fold train is cross-cut by numerous faults, post-dating the cleavage. The faults have their highest concentration in this outcrop. Due to the scarcity of fault striations and other kinematic indicators and the rather homogeneous lithology and the resulting lack of marker horizons, the sense and amount of fault displacement is difficult to determine. Nevertheless, it appears that both S- and N-dipping, normal and reverse E-W-trending faults occur, some apparently forming conjugate sets. The faults usually occur in the hinge zones of the smaller folds, possibly indicating a relationship between fold geometry and faulting (Fig. 25). A zone of turbidite sequences with cross-bedded c-divisions (De Schepper, 2000) was used by Belmans (2000) to correlate both limbs of the large-scale synform in the section. From this analysis, it follows that the net result of the normal and reverse faults is hardly reflected across the synform. Hence, there is no evidence for important faults.

Like for the faults, the highest concentration of kink bands is also found in this outcrop. The kink bands have sub-horizontal to gently, occasionally moderately dipping kink band boundaries, and sub-horizontal to gently plunging, E-W-trending kink axes. As previously noted by Vandenven (1967), kink bands with a top-to-the-south-geometry as well as kink bands with a top-to-the-north-geometry, occur. Vandenven (1967) argued that the former type of kink bands only occur in zones with a S-dipping cleavage, whereas the latter are restricted to zones with a N-dipping cleavage. He concluded that the kink bands were formed during fanning of the cleavage. Inspired by Mortelmans (1954), he attributed both the fanning and the kink bands to a second deformation phase of Variscan origin. However, although most kink bands are compatible with the generalisation of Vandenven (1967), Belmans (2000) also observed top-to-the-south kink bands in zones with sub-vertical to steeply N-dipping cleavage and top-to-the-north kink bands in zones with a sub-vertical to steeply S-dipping cleavage (respectively termed top-to-the-south, B and top-to-the-north, B by Debacker, 2001). As such, based on kink band geometry and position, Belmans (2000) was able to distinguish four different types of kink bands, two with a top-to-the-south geometry (called top-to-the-south, A and top-to-the-south, B by Debacker, 2001) and two with a top-to-the-north geometry (called top-to-the-north, A and top-to-the-north, B by Debacker, 2001). Locally, conjugate sets may be observed (e.g. top-to-the-south, A kink band and top-to-the-north, B kink band in zone of steeply S-dipping cleavage). All the kink bands are of a contractional kind and reflect development under the influence of a steeply plunging shortening with a N-S-directed extension. Because of the seemingly preferred orientation of the top-to-the-south and top-to-the-north kink bands with respect to cleavage dip, these structures formed after development of the convergent cleavage fans (Fig. 25). Conjugate kink bands develop where the shortening is parallel to the anisotropy (e.g. Price & Cosgrove, 1990). As shown on Figure 25, top-to-the-south and top-to-the-north kink bands (and occasional conjugate set), both occur in zones of sub-vertical to steeply S-dipping cleavage. Hence it is suggested that the kink bands in the southern Orneau Valley formed after development of the convergent cleavage fans, under the influence of a sub-vertical to steeply S-plunging shortening. The preferential orientation of the different types of kink bands may partly be attributed to the orientation of the cleavage within the convergent cleavage fans and partly to a change in local strain or stress orientation under the influence of bedding orientation and fault tip zones.

5.10.3. Discussion and conclusion

The truncation of the folds and the well-developed convergent cleavage fans by the angular unconformity questions a Variscan origin for the convergent cleavage fans. Instead, as previously put forward by Legrand (1967) in the southern Sennette Valley, the convergent cleavage fans may be attributed to a pre-Givetian, "Caledonian" deformation. However, as in the Ronquières area, also the rocks in the southern Orneau Valley only show evidence for one single deformation phase (Belmans, 2000). Hence, following the hypothesis of Debacker *et al.* (1999), Belmans (2000) explained the convergent cleavage fans in the Silurian of the Orneau Valley as the result of continued fold amplification after cleavage development.

The apparent preferred position of the faults in the fold hinge zones, in combination with the small displacements, the parallelism of the fault trend with the cleavage trend and the fold hinge lines, and the frequently occurring apparent conjugate sets of reverse faults suggest a genetic relationship between folding and fault development. Possibly the small reverse faults formed as accommodation structures during folding. Several of the normal faults initially may have developed in the fold hinge zones or may reflect reactivated reverse faults (Belmans, 2000; Debacker, 2001; cf. Legrand, 1967).

As argued by Vandenven (1967), the thick overburden necessary for kink band development cannot be attributed to the Middle Devonian to Carboniferous deposits considered to have been previously overlying the Brabant Massif (cf. Patijn, 1963; Van den haute & Vercoutere, 1990). Instead, Vandenven (1967) suggested that the convergent cleavage fans were formed by an accentuation of the pre-existing "Caledonian" folds during Variscan thrusting and that this was accompanied by simultaneous kink band development due to the weight of the hypothetical thrust sheet. However, several objections can be made. Firstly, from a kinematic point of view, the shortening necessary for forming the convergent cleavage fans (sub-horizontal, N-S-directed) is at high angles to the shortening responsible for kink band development (sub-vertical). As such, a contemporaneous development of both the kink bands and the convergent cleavage fans seems unlikely (Belmans, 2000). Secondly, there is no evidence for a post-Givetian deformation in the southern Orneau Valley (Belmans, 2000) and the cleavage fanning can entirely be explained by means of a Caledonian single-phase progressive deformation (Belmans, 2000; cf. Debacker *et al.*, 1999). Thirdly, in order to explain the well-developed cleavage and the anchizonal degree of metamorphism in the Silurian deposits of the Orneau Valley (cf. Geerkens & Laduron, 1996), a significant overburden can be inferred, which was eroded prior to deposition of the Givetian continental sediments, which do not have a cleavage and only reflect diagenetic burial conditions. The load, necessary for kink band development, may have been caused by the now eroded post-Wenlock to pre-Givetian deposits previously overlying the Silurian deposits in the southern Orneau Valley.

In our opinion (Belmans, 2000; Debacker, 2001), the deformation of the southern Orneau Valley can be depicted as follows. Roughly N-S-directed shortening led to folding and cleavage development which eventually resulted in the presence of convergent cleavage fans. During shortening, small reverse faults likely developed in the fold hinge zones as fold accommodation structures. As shortening progressed a gradual change in stress pattern occurred. The initial, approximately sub-horizontal, N-S-directed maximum compressive stress gradually changed orientation and became steeply plunging during the final stages of shortening. The steep maximum compressive stress was responsible for kink band development and normal faulting. The orientation and geometry of the kink bands may partly be attributed to the orientation of the cleavage and partly to a change in local strain or stress orientation under the influence of bedding orientation and nearby fault tip zones. During the last stages of shortening and after shortening, the overburden was removed by erosion. The last erosion products are represented by the Givetian conglomerates.

6. Description of excursion stops DAY 2 (morning)

Stop 2.1. Outcrop below the Saracens Tower, Gembloux

Location. Outcrops along the Rue de Moulin, between houses N°44 and 42, below the walls of the *Faculté universitaire des Sciences Agronomiques de Gembloux*, close to the *Tour d' enceinte des Sarrasins* (dated AD 1156).

General structure. Bedding difficult to observe; steeply bedded strata (S0: N090/65-75°S: S1: N090/70-80°S). Some folds and faults are visible.

Lithostratigraphy. Rigenée Formation.

Lithology. Fine silty dark grey shale with dispersed pyrite and very rare centimetric sandstone or siltstone beds, with weak oblique bedding.

Sedimentology. See stop 1.8.

Biostratigraphy. No graptolites were found, nor chitinozoans in this outcrop (Samuelsson & Verniers, 2000); acritarchs were studied by Martin (*in* Verniers, 1983b) and by Servais (1991). The latter discovered here a rich assemblage characterised by *Arkonia virgata*, *Frankea sartbernardensis, F. hamata and F. hamulata*. The latter species indicates a late Llanvirn or younger age. With this assemblage this outcrop can be correlated with the middle to upper part of the Rigenée Formation in the Thyle Valley at stop 1.8.

Stop 2.2. Gembloux city centre, Place de l'Orneau and Grand-Manil, Try à la Vigne (flying stops)

Location: Below the restaurant (in 1980) of the school St-Guibert on the Place the l'Orneau and until recently in the school yard one could observe clearly the turbiditic Ittre Formation, dated elsewhere with graptolites and chitinozoans as Burrellian (low-middle Caradoc).

Further to the south between the city centre and the neighbourhood Grand-Manil several temporary outcrops indicated the monoclinal Upper Ordovician succession of the Bornival, Huet and Madot formations. The Fauquez Formation normally situated in between the latter two formations is not observed here. The Huet and the Madot formations contain rather rich macrofossil bearing levels with brachiopods, bryozoans, crinoids, trilobites, pelmatozoans, etc. studied by Lespérance and Sheehan (1987). The fauna of both levels was referred to in the literature as the "*grauwacke* *fossilifère de Grand-Manil*". It is now estimated that the lower level is late Caradoc and the second early Ashgill. Outcrops in both beds at present are very small or temporary. We will visit a similar but slightly younger facies in stops 2.8 and 2.9.

Stop 2.3. "La Poudrière de Corroy", abandoned quarry near the Orneau river, Gembloux

Location. Old abandoned quarry, used in the 18th century for the construction of a powder factory within the quarry. It was destroyed in the 19th century. It is located on the left bank of the Orneau river, 200 m west of km 3 of the railway line (map see Fig. 21).

General structure. The outcrop is now about 55 m long and 3-6 m high; strike of the bedding N074°/66-86°S, cleavage nearly parallel to the bedding.

Lithostratigraphy. Type locality of the Corroy Formation in its old and new definition.

Lithology. Centi- to decimetric shale/siltstone/sandstone alternations, with obliquely bedded, undulating sandstone beds with laminated siltstone and shale beds and interlayered centimetric laminated hemipelagites, in which graptolites can be found.

Sedimentology. Laminated hemipelagites are deposited in a deep-sea anoxic environment and alternate with the Bouma-type turbidites.

Biostratigraphy. The outcrops in the quarry are dated with graptolites and chitinozoans as early Wenlock (see Chapter 5.5).

Remarks. This turbidite facies shows that the foreland basin, started in the underlying Fallais Formation, is fully developing in the Brabant Massif. This is a clearly different facies than in the Condroz Inlier where a deep shelf sedimentation occurs in the same time interval.

Stop 2.4. Vichenet section, Gembloux

Location. A 300 m long outcrop along the road "Chemin du Grand Ha", close to the old railway station Vichenet-Bossière (see detailed map on Fig. 24 and section on Fig. 25).

General structure. A general synclinal or synclinorial structure with a series of folds with an E-W fold axes (see Chapter 5.10).

Lithostratigraphy. Type locality of the Vichenet Formation. De Schepper (2000) suggested that only the lower part of the formation is present in the type locality. The lower contact with the underlying Fumal Formation can be seen in the north and the south of the section (see Fig. 25).

Lithology and sedimentology. Thick-bedded silty shale in beds of 10 to 100 cm thick, interpreted as distal turbidites, alternating with dark grey centimetric laminated hemipelagites.

Biostratigraphy. Chitinozoans (this study) are the first fossils discovered in this formation in its type locality and indicate that the limit between the Sheinwoodian-Homerian (middle-late Wenlock) boundary runs in this long outcrop somewhere close to section A (see fig. 23).

Remarks. This stop, together with stops 2.3 and 2.5, illustrate the variation in the turbiditic sedimentation during the foreland basin development.

Stop 2.5. Les Mautiennes, Acadian ("Late Caledonian") unconformity, Gembloux

Location. Outcrop, along a dirt road, east of the railway and 57 m south of the middle of the railway bridge, where the "rue de Mautienne" crosses the railway line.

General structure. The outcrop shows the Fumal Formation with 10-20 cm thick distal Bouma-type turbidites in a medium grey silty shale, siltstone and some fine sandstone. A closed fold is clearly visible showing a cleavage fanning. This is cut by the Middle Devonian (Givetian) conglomerate and sandstone beds, dipping 10-14°S. It clearly shows the Caledonian folding and cleavage formation prior to the Givetian.

Lithostratigraphy. Fumal Formation and Les Mautiennes Member (Bois de Bordeaux Formation).

Biostratigraphy. No chitinozoans were recovered from the Fumal Formation in this outcrop, but elsewhere the unit is dated middle Wenlock (Sheinwoodian). The Devonian is dated by the presence of the brachiopod *Stringocephalus burtini*, an index fossil of the Givetian, in the basal conglomerate of a borehole in the vicinity (Bultynck *et al.*, 1991).

7. The Lower Palaeozoic of the Condroz Inlier in the Fosses area

7.1. Introduction

The Fosses area (Fig. 27), is the western termination of the Condroz Inlier around and west of the city of Fosses-la-Ville and consists structurally of two tectonic units: the central part of the Condroz Inlier in the north, and the Puagne Inlier in the west and south. Both contain Ordovician and Silurian strata, unconformably covered by Lochkovian (Lower Devonian) strata. Both are Variscan tectonic wedges situated in the Variscan Deformation Front. The northern tectonic unit underwent no or little metamorphism (diagenetic zone), while the Puagne Inlier underwent anchizonal metamorphism as deduced from the degree of carbonisation of the organic material and from the illite crystallinity (Steemans, 1994). It is interpreted that both sedimentation areas were originally more distant from one another (a few to a few tens of kilometre) and were thrusted northwards with different throws and became adjacent to each other during the Variscan shortening and thrusting in the Late Carboniferous. The Puagne area is more metamorphosed because it is interpreted to have derived from a more southern and deeper structural level than the central part of the Condroz Inlier.

In the Condroz Inlier Ordovician and Silurian sediments are deposited in a different environment than in the Brabant Massif, except for the Lower and Middle Ordovician, but which will not be visited nor discussed. The Upper Ordovician and Silurian sediments are mostly fine siliciclastics and interpreted as deposited on a deep shelf. As a rule units are thinner than in the Brabant Massif and turbidites are not found, except in the Ombret area, in the north-east of the Condroz Inlier. The Fosses area is the type area for several units, such as the Vitrival-Bruyère, Basse-aux-Canes, Fosses, Génicot and Thimensart formations, the Bois de Presles Member and the Cocriamont conglomerate bed (Figs. 4 & 28).

Recently Billiaert (2000) studied in some detail two of the type localities: Vitrival-Bruyère and Basse-aux-Canes. Two other units, the Fosses and Génicot formations have the Fosses area as their type area, but no type section has yet been defined. B. Delcambre and J.-L. Pingot (pers. comm., 1999) suggested after their extensive mapping in the area, that the *Parc de Sart-Eustache* section and the area around the *Étang du Diable* might be a good candidate for a type section, being the most complete section in the area. The results of the study of this section are presented here. Michot (1931) was the first to postulate in the Puagne area (Fig. 27& 29) the presence of the Cocriamont conglomerate at the base of the Fosses Formation, overlying an unconformity, in the locality Gazelle. In the *Parc de Sart-Eustache* section, 2.5 km west of Gazelle, one cannot observe the base of the formation. The contact with the underlying units is located below the pond of the *Étang du Diable*, where probably a fault contact or an unconformity occurs. In the long *Parc de Sart-Eustache* section, however, it became evident that the Cocriamont conglomerate is not situated at the base of the formation, but much higher and according to the new definition of the Fosses Formation (Delcambre & Pingot, in press; Verniers *et al.*, 2001) not even in that formation but in the overlying Génicot Formation. In an 11 m thick interval, a lower 2.2 m interval with two thick sandstone beds occurs with the possible presence of small siltstone

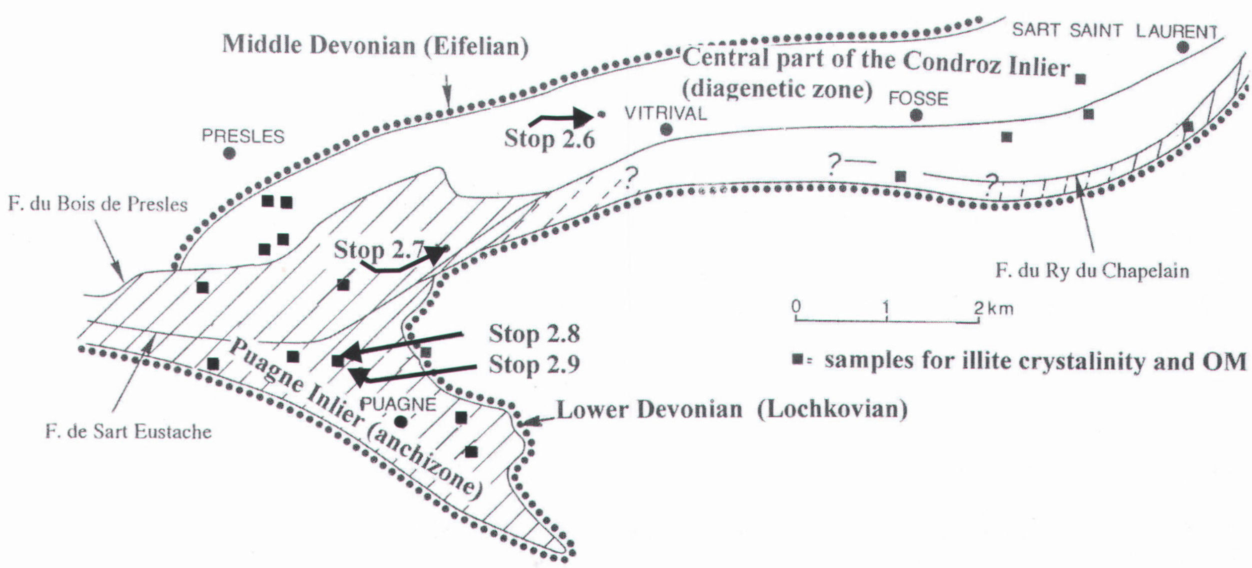

Figure 27. General sketch map of the western extremity of the Condroz Inlier, around Fosses (Fosse-la-Ville), after Steemans (1994). The hatched area corresponds to the area where a cleavage is observed after Michot (1934). Metamorphism data of Steemans (1994) are added and indicate that the area with cleavage corresponds to a higher metamorphic zone. The affinity of the area between the Bois de Presles Fault and the Sart-Eustache Fault to either the central part of the Condroz Inlier or to the Puagne Inlier has still to be established.

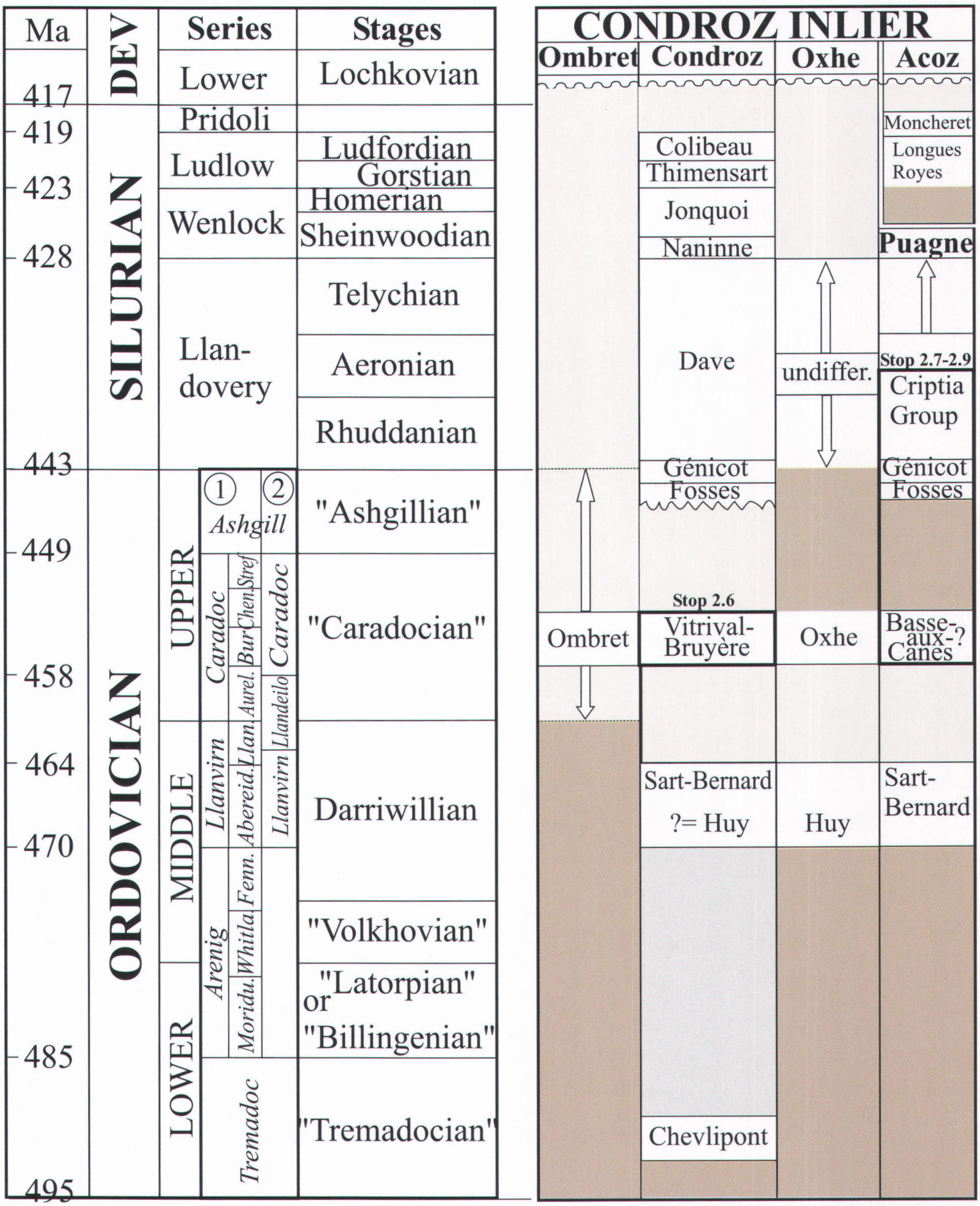

Figure 28. Chronostratigraphical position of the Lower Palaeozoic lithostratigraphic units in the Condroz inlier (detail of fig. 4) (after Verniers *et al.* 2001).

Figure 29. Detailed topographic map (1/25,000) of the Fosses area. The line indicates the limit of the Devonian cover. The location of the visited outcrops is indicated.