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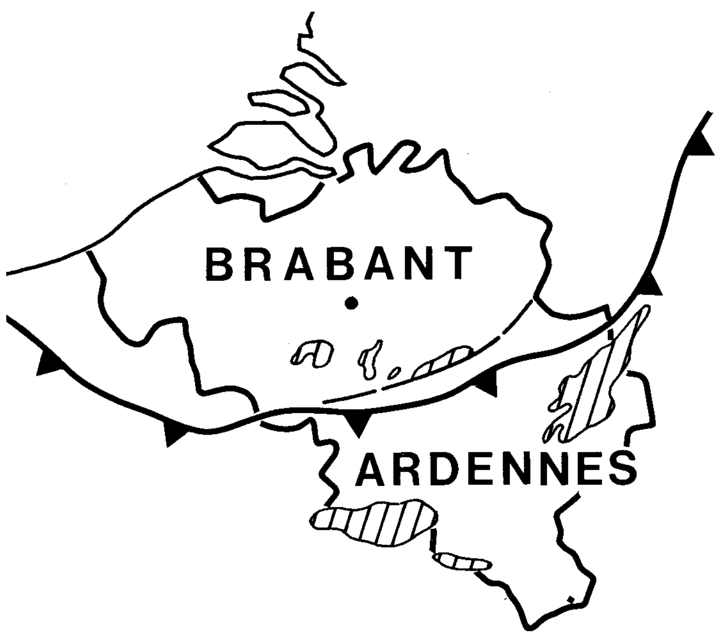

INTERNATIONAL MEETING ON THE CALEDONIDES OF THE MIDLANDS AND THE BRABANT MASSIF
EXCURSION GUIDEBOOK

Liège, 7, place du Vingt-Août, Belgique

Décembre 1991

GUIDEBOOK TO THE EXCURSION ON THE STRATIGRAPHY AND MAGMATIC ROCKS OF THE BRABANT MASSIF, BELGIUM

Editors: L. ANDRE, A. HERBOSCH, M. VANGUESTAINE & J. VERNIERS

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GUIDEBOOK TO THE EXCURSION ON THE STRATIGRAPHY AND MAGMATIC ROCKS OF THE BRABANT MASSIF, BELGIUM

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(47 figures)

1. LOWER PALAEOZOIC STRATIGRAPHY AND SEDIMENTOLOGY IN THE THYLE AND SENNETTE VALLEYS (BRABANT MASSIF)

DAY 1: Friday 22 September 1989

(A. HERBOSCH, S. LOUWYE, T. SERVAIS, G. VAN GROOTEL, M. VANGUESTAINE & J. VERNIERS)

1.1. GENERAL INTRODUCTION

The first excursion day aims to give an overall view of the stratigraphy, petrography and sedimentology of the Lower Palaeozoic sediments of the Brabant Massif, especially in recently studied outcrops.

The Brabant Massif is the most important in size of the six Caledonian Massifs in Belgium and surrounding area (Fig. 1). The general structure is an anticlinorium directed NNW-SSE, with a Cambrian core with Ordovician and Silurian margins (Fig. 2). The Massif is limited to the NE, E, S and SW by a gently dipping Devonian-Carboniferous cover. The Caledonian fold belt continues however under this Upper Palaeozoic cover.

In most parts the Brabant Massif is covered by Mesozoic and Cenozoic sediments, and only discontinuous outcrops are present in the major river valleys at its southern border. The Thyle (tributary of the Dyle river) and the Sennette (tributary of the Senne river) will be visited during this excursion.

The rocks of the Brabant Massif are nearly all of a sedimentary origin and characterized by a very monotonous almost purely clastic rock sequence. Their thickness is estimated to be more than 7000 m. The age of some important formations is still unknown due to the scarcity of macrofossils and unfavourable facies or poor conservation for microfossils. Their study is further complicated by the shortening of the Lower Palaeozoic during the Caledonian orogeny. Whether or not the sequence include Precambrian rocks is still a matter of speculation (Fig. 6).

1.2. OVERALL PALAEOGEOGRAPHY (after Pickering *et al.*, 1988)

Pickering *et al.*, 1988 present a hypothetical scheme for the plate reconstruction for the Ordovician to Devonian times in NW Europe.

In the Tremadoc, Avalonia (part of the Late Precambrian Cadomian arc comprising a.o. England, Wales, Southern Ireland, south of the Southern Uplands of Scotland and Belgium) rifted off Gondwana with a trench which progressively consumed the Tornquist's Ocean.

By the Late Ordovician (Caradoc-Ashgill) the Tornquist's Ocean closed, between Baltica and Avalonia. At the same time, the Rheic Ocean, between Gondwana and Avalonia developed. This is supported by faunal evidence in recent papers (Lesperance and Sheehan, 1988; Sheehan, 1988) (Fig. 4).

By the early Silurian, the lapetus Ocean, separating Laurentia from eastern Avalonia and Baltica, was closed (Fig. 5).

By the late Silurian and early Devonian times, collision had occured between North American and European plates resulting in the final stages of the Caledonian orogeny.

1. Royal Museum for Central Africa, Tervuren. 2. Université Libre de Bruxelles, Laboratoires associés de Géologie, Pétrologie, Géochronologie.

3. Rijksuniversiteit Gent, Laboratorium voor Paleontologie.

4. Université de Liège, Services associés de Paléontologie.

5. Geologische Dienst van België/Vrije Universiteit Brussel.Research Associate N.F.S.R. (Belgium).

6. Grant-holder, I.R.S.I.A.

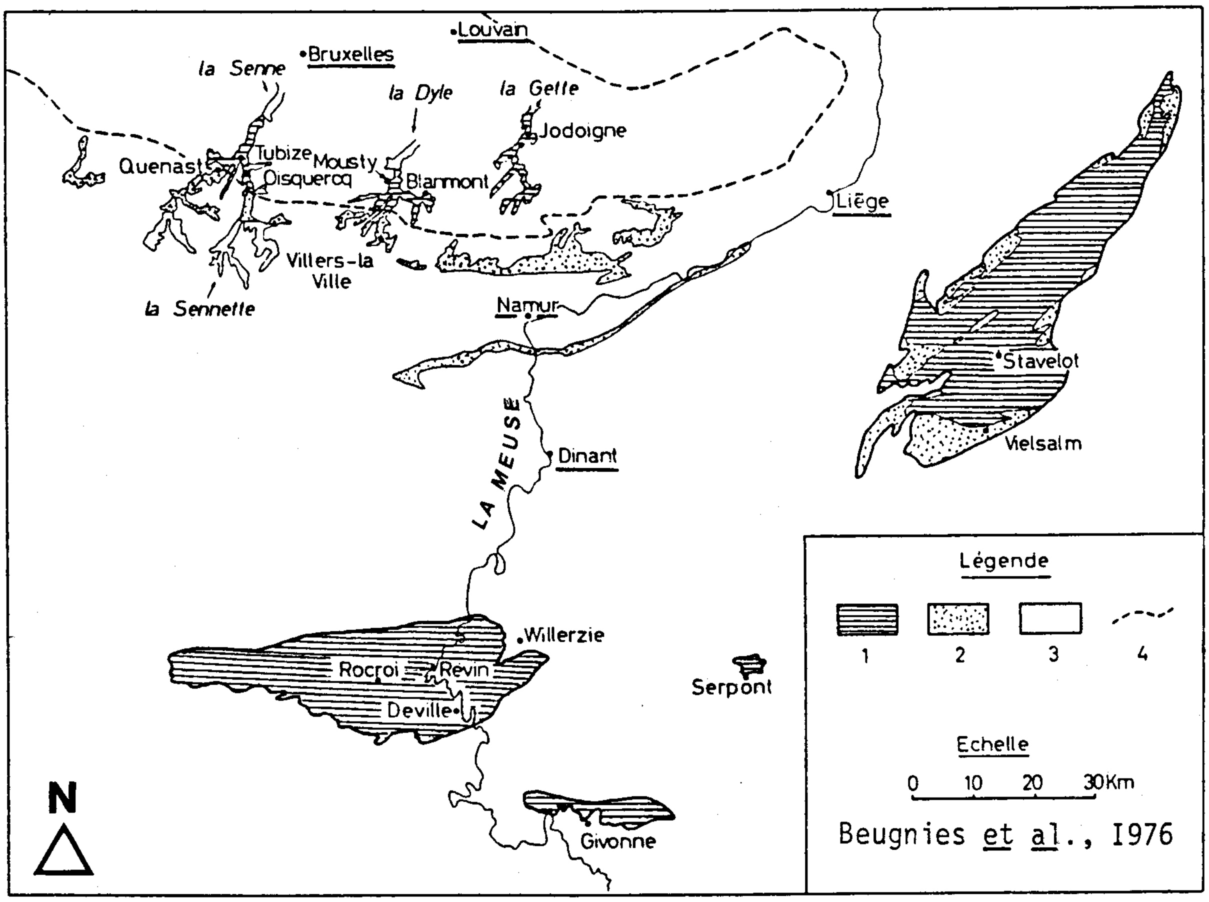


Fig. 1: The Lower Paleozoic Massifs in Brabant, Condroz and the Ardenne, Belgium and northern France (Beugnies *et al.*, 1976). 1: Cambrian; 2: Ordovician and Silurian; 3: post Silurian; 4: confines of the Cambrian in the Brabant Massif at the surface or under Meso- and Cenozoic Cover. Note that Ordovician rocks are now demonstrated to crop out on the eastern border of the Rocroi Massif near the locality Willerzie (Geukens, 1981; Roche *et al.*, 1986).

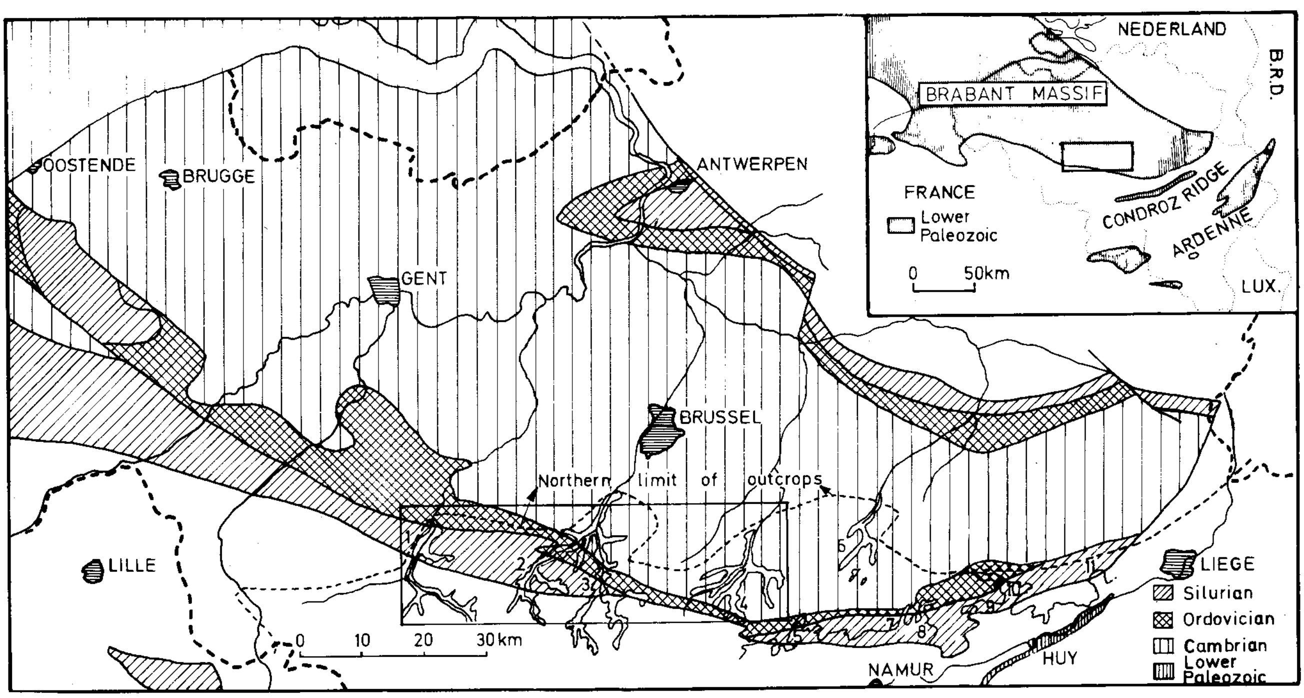


Fig. 2: General geological map of the Brabant Massif after LEGRAND, 1968. The inset shows Lower Palaeozoic Massifs in Belgium. The rectangle marks the excursion area. The numbers mark the outcrop areas (in between brackets the visited localities). (1) Dender valley (Lessines), (2) Senne valley , (3) Sennette valley (Rogissart, Asquempont, Quenast, Fauqué, Ronquières), (4) Thyle valley (Chevlipont, Abbey of Villers-la-Ville, Tri Botte, Rigenée).

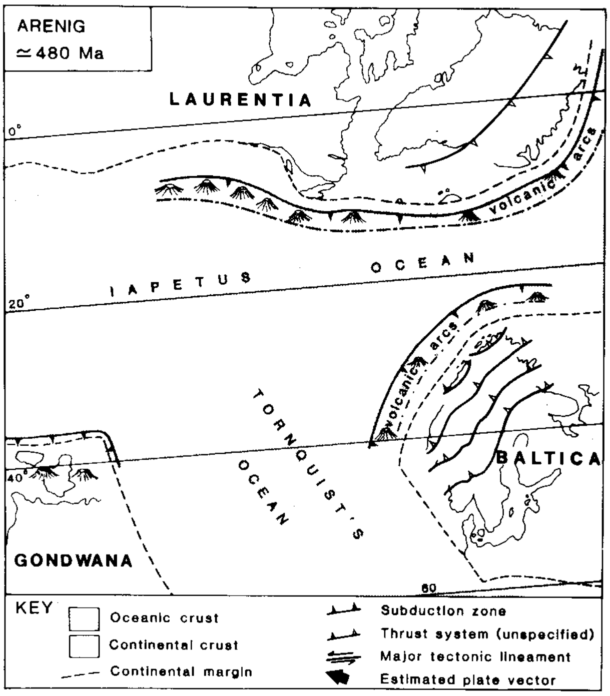


Fig. 3: Plate reconstruction of the Iapetus Ocean in the Arenig (from Pichering *et al.* 1989).

Fig. 3, 4, 5: Reproduced by permission of the Royal Society of Edinburgh and Dr. K.T. Pickering from Transaction of the Royal Society of Edinburgh, Earth Sciences, volume 79: 361-382 and volume 80: 69.

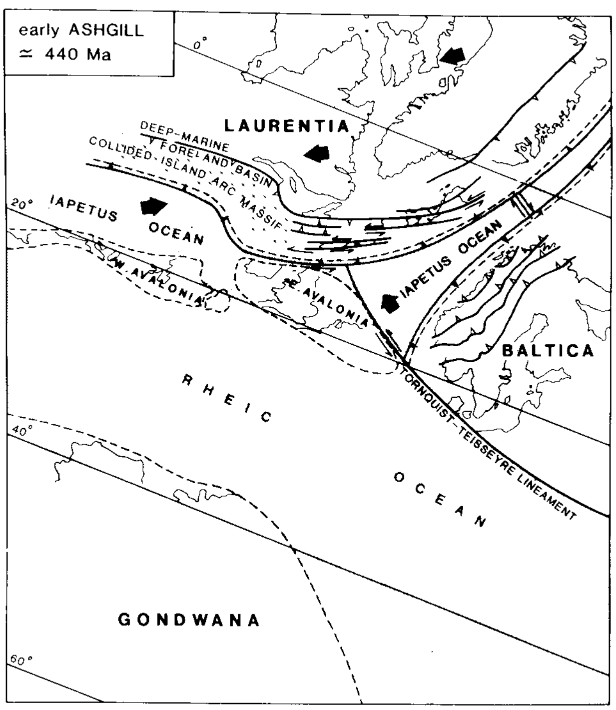


Fig. 4: Plate reconstruction of the Iapetus Ocean in the early Ashgill (from Pickering *et al.* 1988).

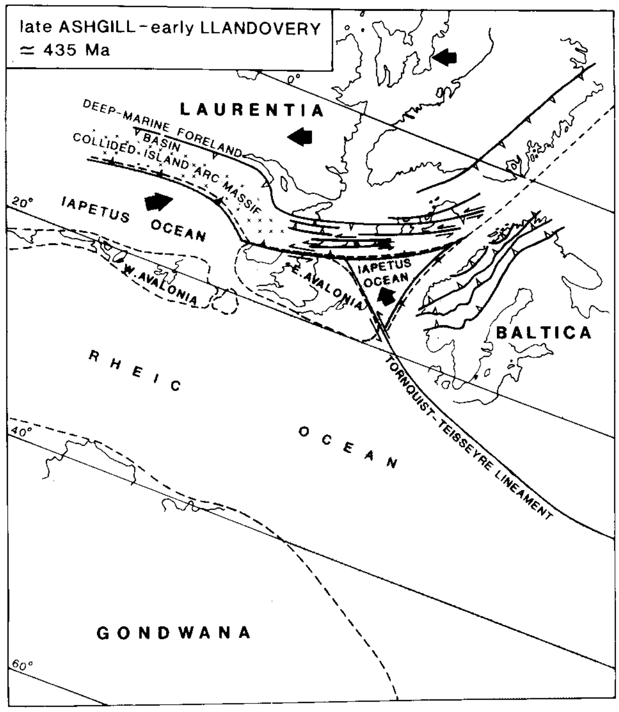


Fig. 5: Plate reconstruction of the Iapetus Ocean in the Late Ashgill to early Llandovery (from Pickering *et al.* 1988).

1.3. STRATIGRAPHY

A general lithostratigraphical scheme for the Lower Palaeozoic in the Brabant and the Ardenne Massifs is given in Fig. 6.

1.3.1. ORDOVICIAN OF THE DYLE BASIN

The Dyle river and its tributaries (Fig. 2), e.g. the Thyle river, which will be visited on this excursion, expose outcrops between Wavre and Sart-Dames-Avelines with ages from the Cambrian (Assise de Blanmont, Fig. 6) to the Middle Ordovician (Assise de Rigenée, Fig. 6).

The oldest beds (Cambrian) will not be shown as their study has not yet been updated. They will be observed in the Sennette valley. The outcrops visited in the Thyle valley belong to the Lower and Middle Ordovician. The geologic mapping (Fig. 7) is based on a new lithostratigraphic scale comprising five formations which are stratigraphically above the "Assise de Mousty" (thought to be Cambrian). In stratigraphic order (Fig. 8):

- **"X" formation** (*sensu nov.*) shows dark grey to black, bedded (rubannés) shales with graptolites and grey shales with siltstone laminae to the top. These shales are locally manganiferous (garnet, Mn ilmenite, Mn chlorite, Fig. 12). Not yet named,

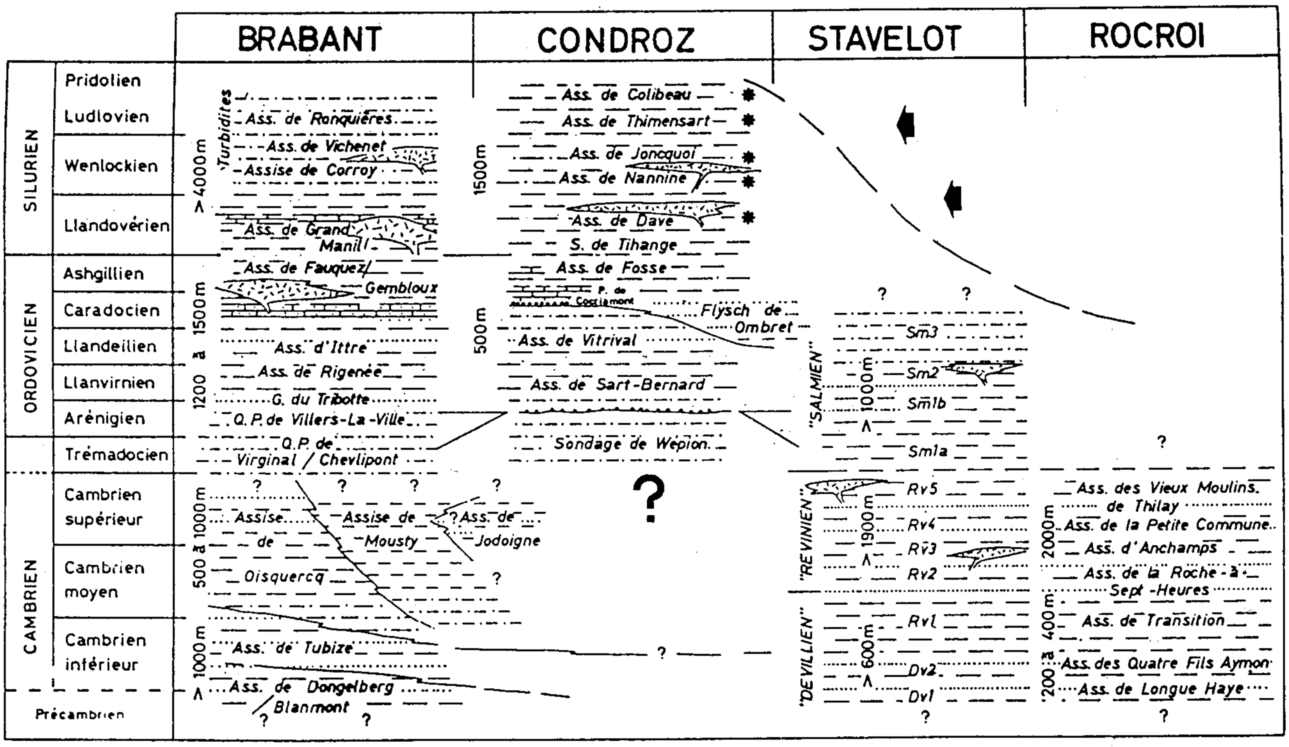


Fig. 6: Lower Paleozoic lithostratigraphy in Belgium from Robaszynski & Dupuis (1983, adapted from Walter (1980) with data from André, Beugnies, P. Michot, Verniers). Note that since the «Assise» of Oisquercq was proven to be older than the «Assise» of Mousty (Vanguestaine, 1989, 1991, Herbosch *et al.*, 1991, and the «Assise» of Vieux Moulins de Thilay in its type locality is not equivalent of the Rv5 of the Stavelot Massif but contemporaneous with the top of the «Salmian» (Sm3) (Roche *et al.*, 1986).

this formation has often been erroneously assigned to the upper part of the Assise de Mousty. The transition to the overlying formation is progressive with an increase in thickness and frequency of silty laminae. The transition with the Mousty shales is not visible.

- **Chevlipont formation** (*sensu* Anthoine, 1943) shows the typical "quartzophyllade" facies described by the earlier belgian authors (Malaise, 1910; de la Vallée Poussin, 1931; Legrand, 1968). It is a bedded to laminated siltstone with wavy to lenticular bedding formed by mm to cm alternation of light coloured silty beds or laminae and dark clay-silt laminae. The silty beds often display ripples with unidirectional cross laminations. Millimetric-sized horizontal bioturbation are observed in the clay-silt laminae.

- **Abbey of Villers-la-Ville** formation (*sensu* Anthoine, 1943) is constituted by sandy to argillaceous siltstones, roughly laminated with greyish to blackish colours. The parallel stratification is strongly disturbed by horizontal bioturbation, more rarely vertical. The boundary with the overlying formation is progressive with an increase in silty-sandy beds and the disappearance of the very characteristic dark colour.

- **Tri Botte formation** (*sensu* Michot, 1978) is characterized by fine sandstones, more or less argillaceous, strongly bioturbated, with grey-green to grey-brown colours. The lower half of the formation is characterized by "psammites" (belgian term for micaceous sandstones) in decimetric beds with a minor argillaceous matrix and by the appearance of potassic feldspar. Higher in the formation, the rock becomes darker due to the increasing amount of matrix and/or argillaceous layers. Vertical and oblique bioturbation is very pronounced. Outcrops are absent, however, in most of this very thick formation.

- **Rigenée formation** (*sensu* Malaise, 1910): the transition to characteristic grey-black mudstones-siltstones of this formation is extremely rapid. Horizontal bioturbation (mm) and fine silty laminae are still visible at the base. The upper part of the formation has not yet been studied in detail.

The table of Fig. 9 shows the correlation between the proposed succession and the previous nomenclature.

From a chronostratigraphical point of view the graptolites and/or the acritarchs confirm the adopted order of succession and give the following ages:

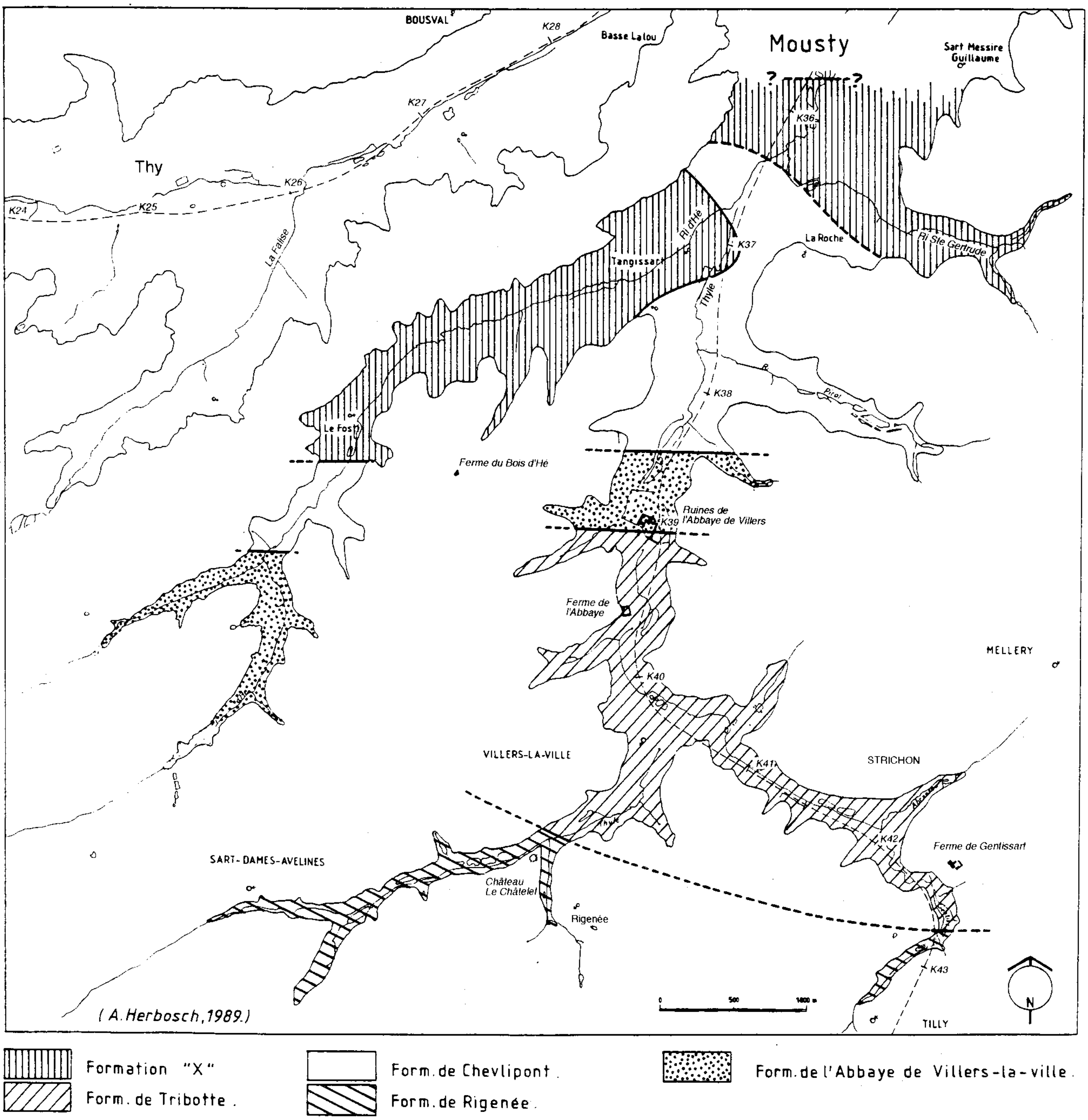


Fig. 7: Geological map of the Thyle Valley (Herbosch, unpublished data).

- **Lower Tremadoc**: *Rhabdinopora (Dictyonema) flabelliforme sociale* and *typica* varieties in the "X" formation.

  Lower (?) Tremadoc: acritarchs in the Chevlipont formation at Chevlipont.

- **Arenig-Llanvirn**: acritarchs from the Abbey of Villers-la-Ville formation.

- **Arenig-Llandeilo**: acritarchs from the Rigenée formation.

The new mapping (Herbosch, unpublished data) confirms the simple monoclinal structure rehabilitated and defined more precisely by P. Michot (1978). But contrary to the last author we do not necessitate a fault (Fig. 11) because we observed a continuous transition between the Tri Botte and the Rigenée formations in both the Thyle and the Gentissart valleys (Fig. 7).

The presence of garnet porphyroblasts, of manganiferous ilmenite, of rutile and of abundant illite-chlorite sandwiches indicates a degree of metamorphic evolution of at least the anchizone (Fig. 12). Figure 13 gives chemical analysis of the rocks of these formations.

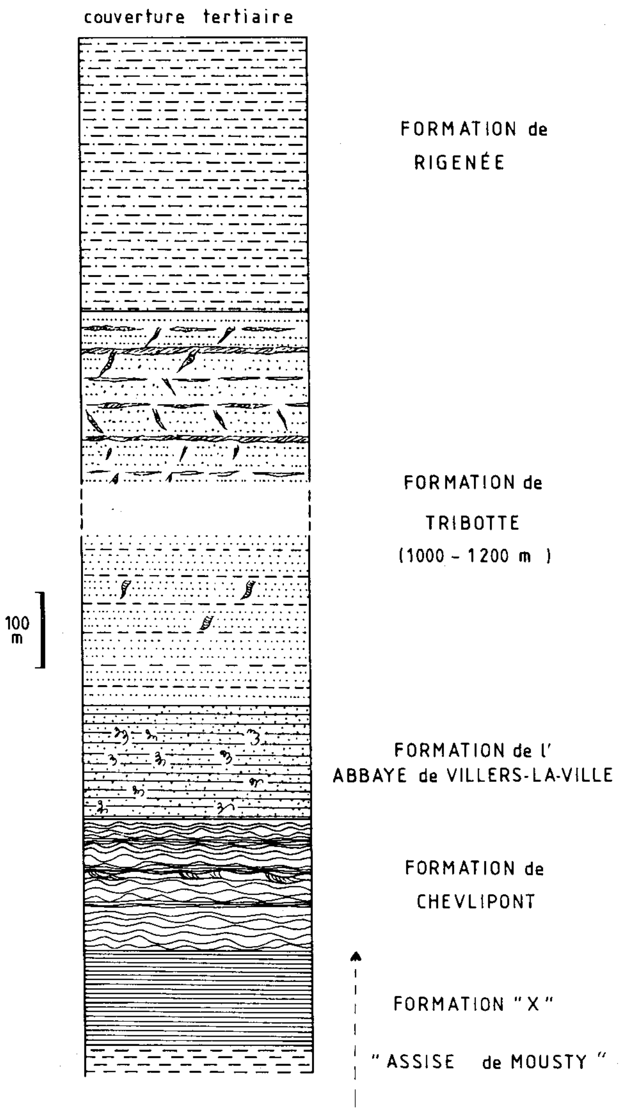


Fig. 8: Lithostratigraphy of the Thyle Valley (Herbosch, unpublished data).

1.3.2. LOWER PALAEOZOIC OF THE SENNE BASIN

A discontinuous section of the Cambrian and Ordovician is observable in the Sennette valley between Halle and Fauqué (Fig. 14). This section connects to the North with that of the Silurian at Ronquières (Fig. 2 and section 1.3.3). The broadening of the canal Brussels-Charleroi (1962-1967) produced several large outcrops, studied by Legrand (1967)(Fig. 15).

1.3.2.1 CAMBRIAN

1.3.2.1.1 **"Assise de Tubize"**: green slates and feldspathic sandstones. Presence of *Oldhamia*, ichnofossil in the form of a star, found for the first time in the Bray Group of Ireland. This trace fossil is also known in the Devillian of the Ardennes Massifs at Rocroi and Stavelot. Thus the oldest rocks of the Brabant Massif are also considered to be Cambrian (Fig. 6). Vander Auwera and André (1985) subdivide this «assise» into 3 distinct units:

- **Rogissart Unit** is constituted of sandstones, feldspathic sandstones, arkoses and graded greywackes in alternation with silty pelitic shales as well as schists with magnetite porphyroblasts.

- **Fabelta Unit** is made up of sandstones, of magnetite bearing siltstones with intercalations of thin chloritic layers and decimetric beds of feldspathic sandstones with cross-bedding in which one observes layers of heavy minerals.

- **Forges Unit** contains black siltstones with fine intercalations of green siltstones.

1.3.2.1.2 **"Assise d'Oisquercq"**: an essentially pelitic lithologic unit.

It is subdivided from base to top into:

- **Unnamed formation**: blue, green or grey slates and quartzites.

- **the Oisquercq formation** (*sensu nov.*): purplish massive claystones.

- **the Ripain formation** (*sensu nov.)*: with the same lithology as the Oisquercq Formation but with colours grading upwards over a dozen meters from purple to greyish-greenish. The silt content increases in the upper part of the formation.

1.3.2.2 ORDOVICIAN

A fault contact, the Asquempont fault (Fig. 14), is present in the sections of the new and old canal. In other sections, e.g. the railway sections at Virginal and Quenast, the following Ordovician formations lay apparently concordant over the Ripain formation of supposedly Cambrian age (Fig. 16):

- **Virginal formation** (*sensu* Mortelmans, 1955): constituted of laminar greyish siltstones ("quartzophyllades") displaying typical wavy to lenticular bedding. It was dated with acritarchs as Tremadoc (Vanguestaine, 1977).

- **Quenast formation** (*sensu* Beugnies, 1973): at its base dark sandy to clayey burrowed laminar siltstones, overlain by heavily burrowed laminar greenish clayey sandstones alternating with "psammites" and mudstones, and finally roughly

UNITES LITHOSTRATIGRAPHIQUES (selon R. et P. ANTHOINE, 1942-43) (R)		(Michot, 1978) (N)			(Ce travail, 1989) (N)
Assise de Gembloux		Assise de Rigenée *Llandeilien (sup ?)*			Formation de Rigenée *Arénigien sup-Llanvirnien à Llandeilien*
ASSISE DE VILLERS -LA- VILLE *Arénigien*	Grès et psammite de Strichon Psammite de Tri Botte	FORMATION DE VILLERS -LA- VILLE	Assise du Tri Botte *Llandeilien*		Formation de Tri Botte
	Quartzophyllade siliceux de Villers		Assise de Laroche	Couches de l'Abbaye *Llanvirnien-Arénigien*	Formation de l'Abbaye de Villers-la-Ville *Arénigien sup-Llanvirnien*
ASSISE DE MOUSTY *Llandeilien*	Quartzophyllade de Chevlipont			Couches de Chevlipont *Trémadocien*	Formation de Chevlipont *Trémadocien*
	Grès et schiste manganésifère	ASSISE DE MOUSTY	Micacites grenatifères		Formation non nommée *Trémadocien*
	Schiste noir de Faux Schiste noir zoné de Glory				" assise " de Mousty
(N) et (R) signifient que les auteurs considèrent une succession des dépôts normale ou renversée.					

Fig. 9.: Comparison between the previously published litho- and chronostratigraphy and the new proposal in this study (Herbosch, Vanguestaine, unpublished data). The chronostratigraphy proposed herein is based on Lecompte, 1949, Martin, 1976, Servais, 1991a and Vanguestaine *et al.*, 1989.

laminar clayey to sandy siltstones. It was also dated with acritarchs as Arenig-Llanvirn (Vanguestaine (1977), Martin & Rickards, 1979).

- **La Tourette formation** (*sensu* nov.): constituted of dark coloured graptolitic mudstones-siltstones. Dated by graptolites as very probably early Llanvirn.

From a lithostratigraphic point of view the correlations with the Ordovician of the Thyle are fairly evident (Chevlipont- "Abbaye de Villers-la-Ville" - Tri Botte - Rigenée, Fig. 17, Herbosch, 1989).

However from a biostratigraphical view point the position of the Quenast formation is not yet clearly established.

The succession in the upper part of the Ordovician presents still difficulties. The simple syncline proposed by Martin and Rickards (1979) for the section situated south of the Asquempont bridge (Fig. 18) is contradicted by Servais (1991b). The latter observes turbidites in Unit E of Martin and Rickards (1979), for which the polarity indicates an inversion of the beds. The syncline is thus a synform.

1.3.3. THE SILURIAN IN THE SENNETTE VALLEY: THE RONQUIERES AREA

An extensive review on the Silurian is given by VERNIERS & VAN GROOTEL (1991). The different lithostratigraphic units of the Silurian in the Brabant Massif are resumed in Fig. 19. Its thickness in measured sections or boreholes is more than 2850 m from its base to the top of the early Ludlow.

The Ronquières area was chosen in this excursion because it shows two of the major outcrops of the Silurian in the Brabant Massif: the "Plan Incliné" section and the Mont Godart sections (near the bridge of Ronquières). The two outcrops contain respectively 206 m and 180 m of sediments and are separated by about 140 m of unexposed strata. They are the type locality of the Ronquières formation (Gorstian, Ludlow) *sensu* MICHOT, 1954 and LEGRAND, 1967; and redescribed in detail by LOUWYE, VAN GROOTEL & VERNIERS, in prep.) (Fig. 19).

At the first stop, a panoramic view of the "Plan Incliné", the Caledonian (or Acadian) angular unconformity (early Ludlow/ Middle Devonian) and the

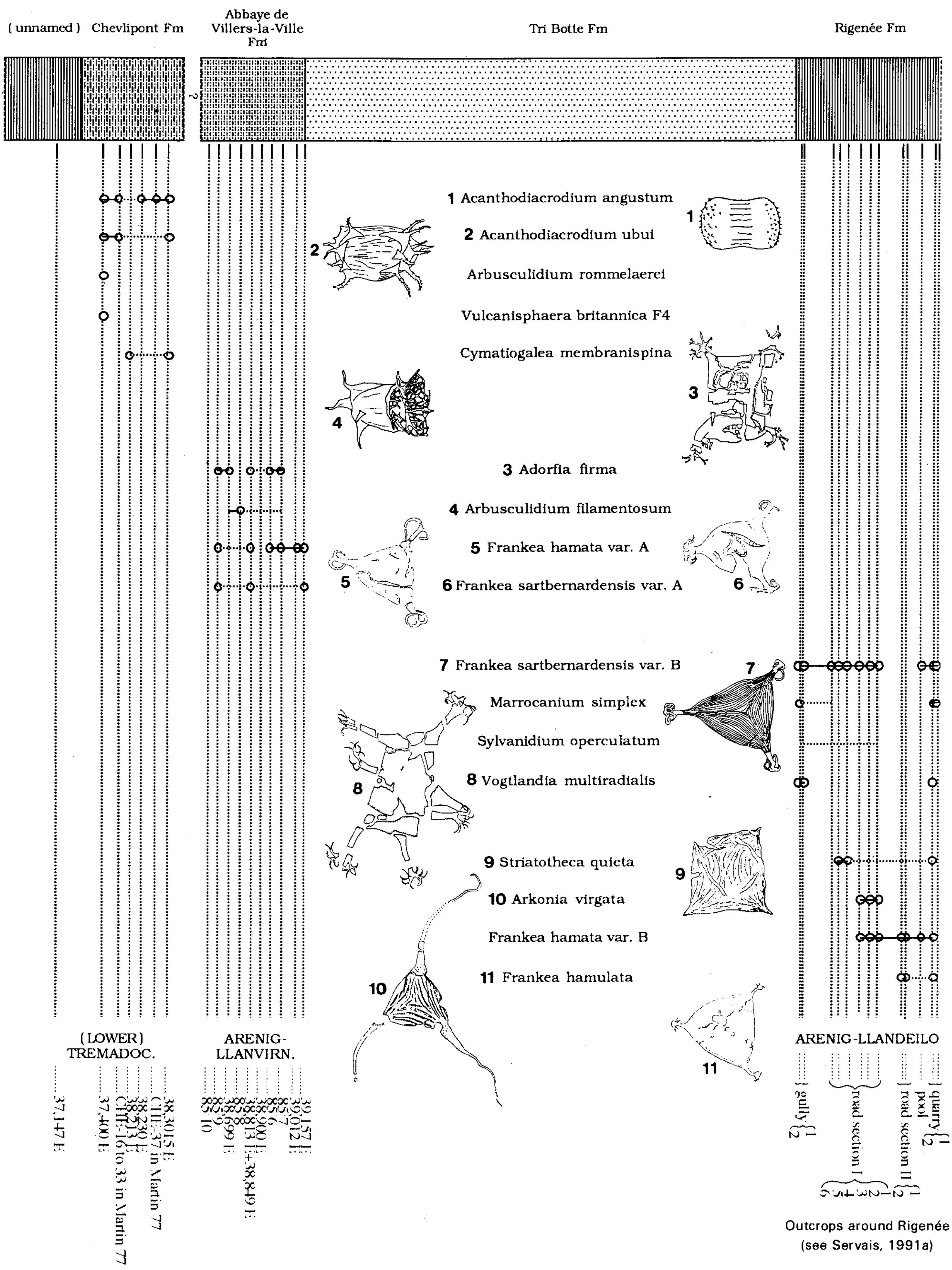


Fig. 10: Occurrences of acritarchs in the lower and middle Ordovician lithostratigraphic units of the Thyle Valley. The location of the samples is given in Figs. 11, 26 and in Servais (1991a). The samples of the «Abbaye de Villrs-la-Ville» formation come from the following localities: 85/9 and 85/10: west side section along the road to Court-Saint-Etienne, km 30.783; 85/8: idem km 30.928; 85/6 and 85/7: northern part of the outcrops in the quarry behind «Café de la Forêt», close to the ruins of the abbey. The drawings of acritarchs are from other specimens than those found in the samples studied (Vanguestaine, unpublished data; Servais, 1991a).

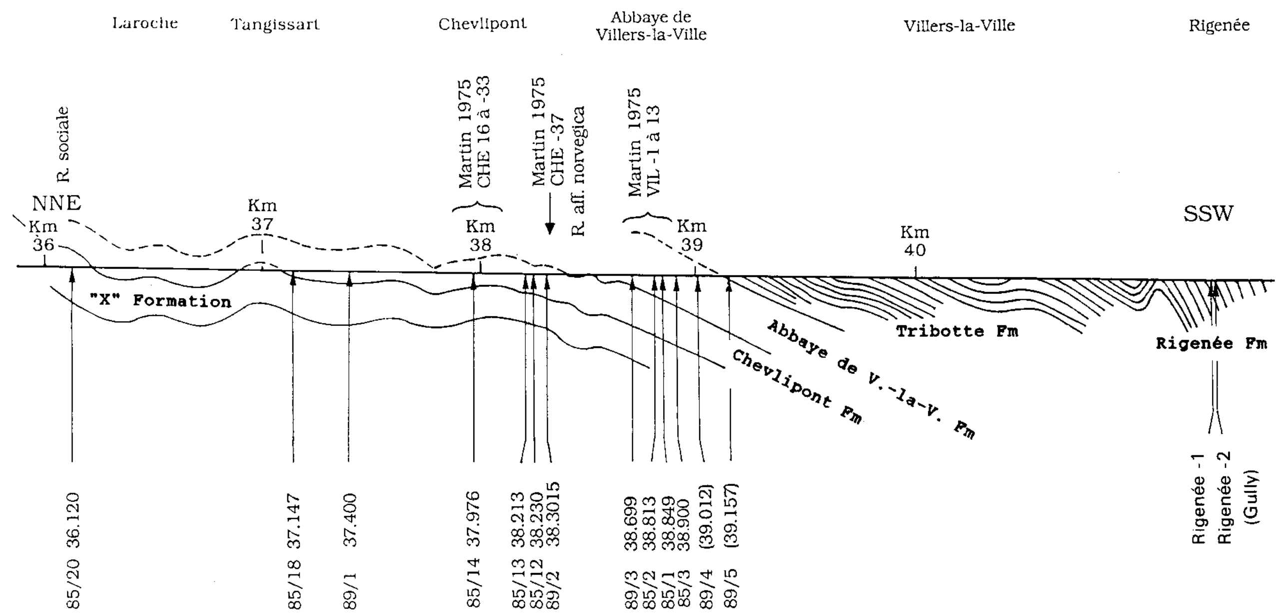


Fig. 11: Cross section along the Thyle Valley, modified after Michot (1978), with location of the palynological samples (Vanguestaine, 1989).

Formation	Illite-chlorite sandwiches	Rutile	Mn-Ilmenite	Mn-Garnet	Andalousite
Rigenée	+	+			
Tribotte	+	(+)			
Abbaye de Villers-la-Ville	+	+			
Chevlipont	+	+			
"X"	+	+	+	+	+

Distribution of metamorphic minerals

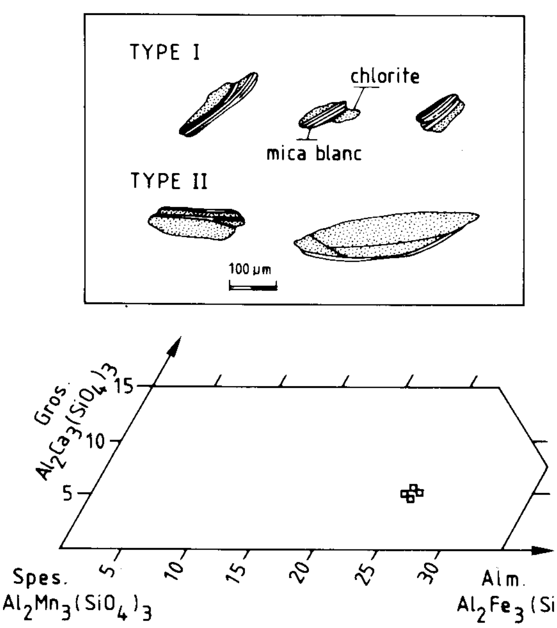


Fig. 12: Metamorphism in the Ordovician rocks of the Thyle Valley, with indication of metamorphic minerals, the morphology of the illite-chlorite sandwiches after Dandois (ms 1985) and microprobe analysis of garnets in the "X" formation (Jodard, 1986).

general structures of the Silurian can clearly be observed. Lateral variation within the turbidites will be shown and the Late Caledonian tectonic history can here be demonstrated.

In the second stop at the Mont Godart (near the bridge of Ronquières) the turbiditic, hemipelagic and bentonitic sedimentation can be observed in the outcrops of the road section, as is the litho- and biostratigraphy (graptolites & Chitinozoa) and the megacyclical (vertical) variations.

The palaeoenvironment of the sedimentary basin was a apparent northward directed turbiditic fan system. Superimposed on the vertical megacyclicity produced by the own dynamics of the fan system (sidewards moving lobes causing alternating overbank or gully deposition creating a megacyclical variation), one has to take into account the influences of changing water depths by local, regional and eustatic factors. The regional deepening-shallowing cycle observed in the Elton Beds in the Welsh Borderland, can also be recognized here in the Ronquières formation of the same age. Higher energy sediments evidenced by more complete turbidite sequences and sandier composition reveals overall shallower conditions in the Mont Godart formation (chapel section, Mont Godart) at the bottom of the section and in unit V and W in the top of the Ronquières formation. Deeper conditions prevailed in between. It is supposed that all smaller (metric and decametric) megacyclities are the result of local influences or of the own dynamics of the turbiditic fan system.

N° Ech.	Sed. 1/1	Sed. 1/3	Sed. 1/5	Sed. 1/7	Sed. 1/9	Sed. 1/10	Sed. 1/11	Sed. 1/12	Sed. 1/13	Sed. 1/14	Sed. 2/1	Sed. 2/2	Sed. 2/3	Sed. 2/4	Sed. 2/5
Nature	Sch.	Sch.	Ps.	P-Q.	P-Q.	Ps.	Ps.	Ps.	P-Q.	Sch.	Sch.	Q.	Ph.	Sch.	Sch.
SiO_2	57.65	54.53	60.33	76.55	69.44	55.30	58.47	61.04	67.45	57.61	58.25	78.58	58.22	61.04	61.67
Al_2O_3	23.00	24.10	20.19	11.46	14.96	22.10	20.88	19.80	17.64	19.62	21.87	7.51	20.77	20.05	16.79
Fe_2O_3	3.15	3.14	3.16	1.37	1.72	2.32	3.01	2.22	2.74	4.72	2.50	2.63	2.47	2.05	4.54
FeO	3.73	4.71	4.03	1.31	3.33	5.49	4.03	4.22	2.54	1.71	3.75	4.32	4.98	3.70	0.11
MnO	0.06	0.09	0.06	0.02	0.04	0.10	0.08	0.17	0.07	5.18	0.55	0.14	0.21	0.13	0.02
MgO	1.63	2.06	2.15	0.81	0.74	2.46	2.20	2.03	0.71	1.14	2.01	2.13	2.33	1.80	0.49
CaO	0.39	0.22	0.30	0.18	0.08	0.42	0.21	0.22	0.04	0.79	0.13	0.12	0.18	0.16	0.18
Na_2O	1.25	1.19	1.03	1.11	1.41	0.54	0.81	1.11	1.07	0.08	0.38	0.08	0.46	0.32	0.19
K_2O	3.47	3.42	3.15	2.56	2.80	4.57	4.01	3.87	3.54	3.32	4.33	0.76	4.49	4.42	3.30
TiO_2	1.10	1.05	0.97	0.97	0.95	1.02	1.02	0.91	0.88	0.95	1.03	0.65	1.01	1.04	0.93
P_2O_5	0.29	0.14	0.18	0.09	0.07	0.30	0.07	0.11	0.09	0.01	0.01	0.04	0.08	0.02	0.04
Perte au feu	5.27	5.77	4.86	2.46	3.82	5.74	5.10	4.43	3.49	4.87	4.84	3.12	4.77	4.44	4.22
Total	100.99	100.42	100.41	98.89	99.36	100.26	99.89	99.63	100.26	100.00	99.65	100.08	99.97	99.16	99.48

Sch.: schiste ; Ps.: psammite; P-Q.: psammo-quartzite; Q.: quartzite; Ph.: phyllade; Perte au feu = lost during heating.

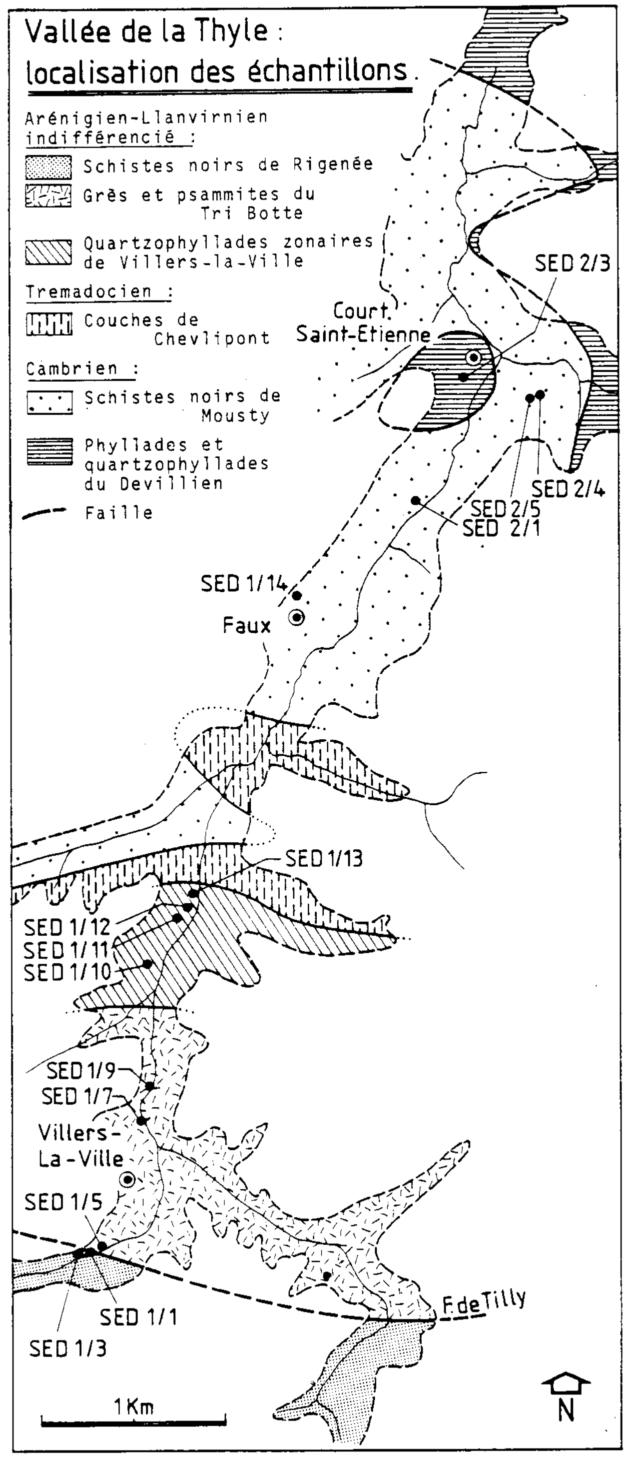


Fig. 13: Chemical composition of the Cambrian-Ordovician rocks in the Thyle Valley (according to André, ms 1983), and location of the samples on a map. Abbreviations: N° Ech.: Number of sample; Sch.: shale; Ps. psammite; P-Q: psammo-quartzite; Q: quartzite; Ph: slate.

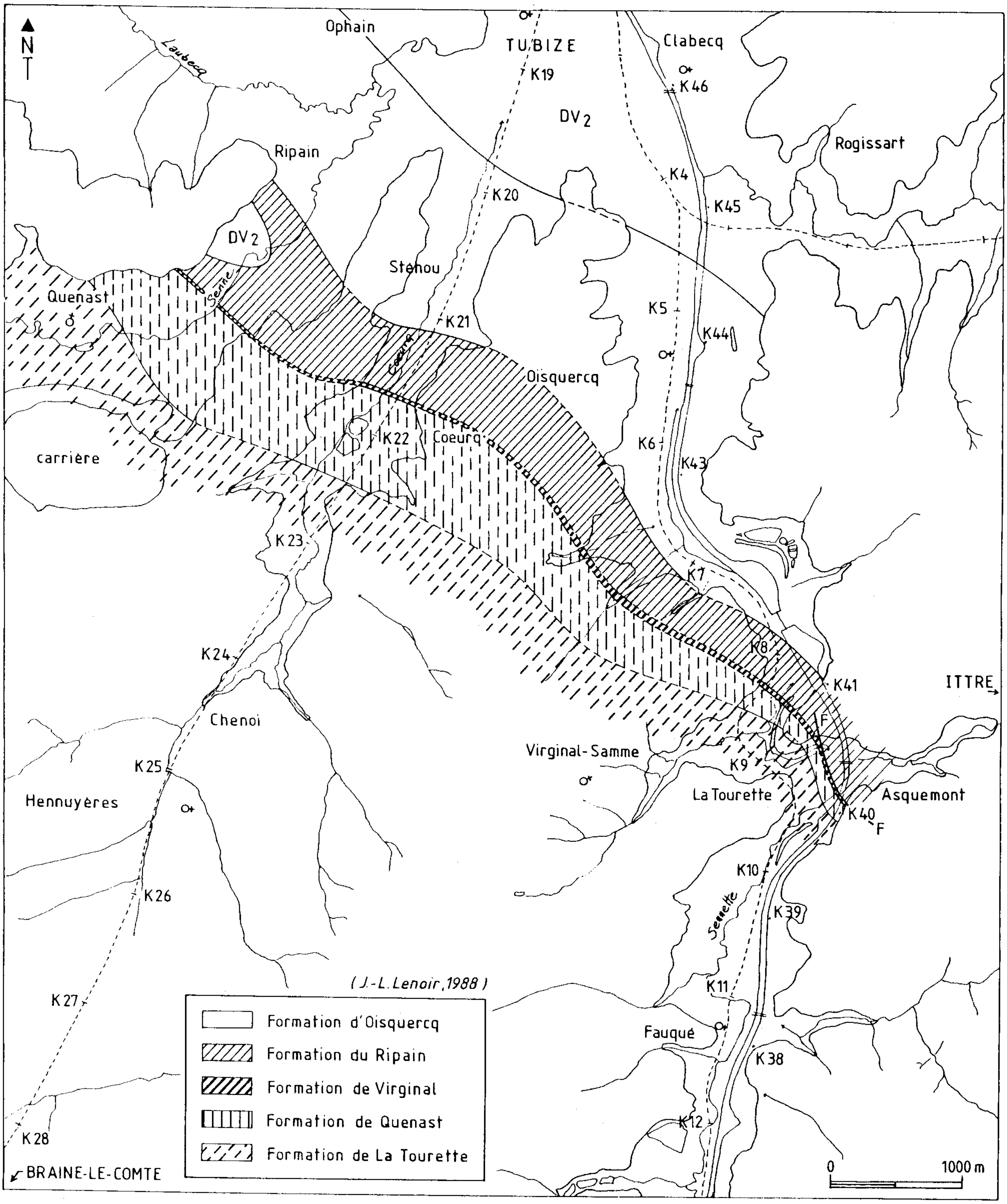


Fig. 14: Geological map of the Senne Basin between Quenast and Asquempont according to Lenoir (ms 1987).
(Asquemont on the map = Asquempont; Fauqué = Fauquez)

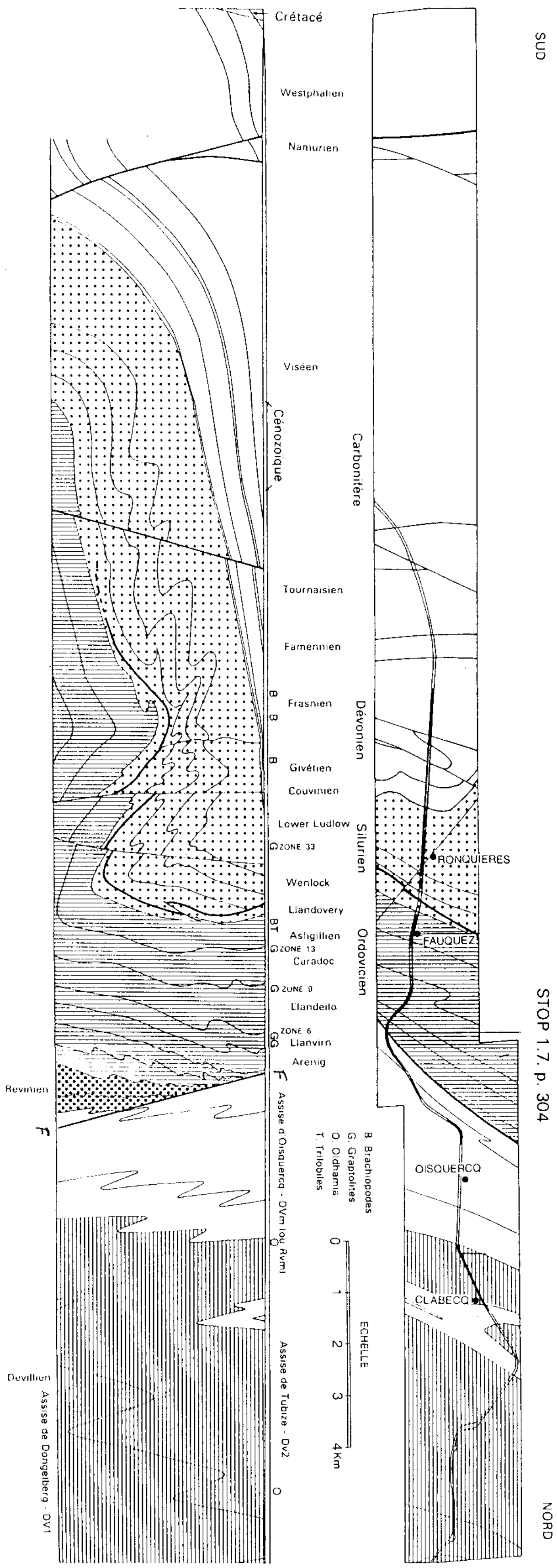


Fig. 15: Map and cross section along the Senne/ Sennette Valley from Halle to La Louvière, according to Legrand (1967).

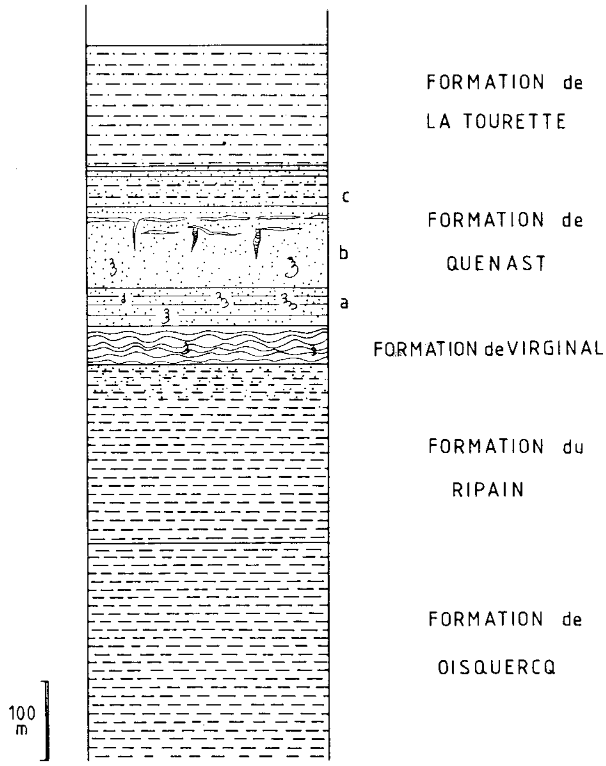


Fig. 16: Part of the Cambrian and Ordovician lithostratigraphy in the Senne Basin (Lenoir, ms 1987).

DESCRIPTION OF EXCURSION STOPS

STOP 1.1: CHARLEROI OTTIGNIES RAILWAY SECTION AT CHEVLIPONT.

Location: railway crossing at Chevlipont km 37,9 - 37,750

General structure: The 160m long (Fig. 21) outcroup shows regular bedding ("Bois de l'Hermitage dome" of Michot, 1978, Fig. 11), gently dipping to the N (N 30°-60° W).

Lithostratigraphy: Chevlipont formation (*sensu* Anthoine, 1943).

Biostratigraphy: Tremadoc, probably Lower Tremadoc. Acritarchs: Martin (1977) and Vanguestaine (1989); graptolites have been found higher in this formation by Lecompte (1949).

Lithology: bedded to laminated siltstone with wavy to lenticular bedding formed by mm to cm alternation of light coloured silty beds or laminae and dark clay-silt laminae. The silty beds often display unidirectional

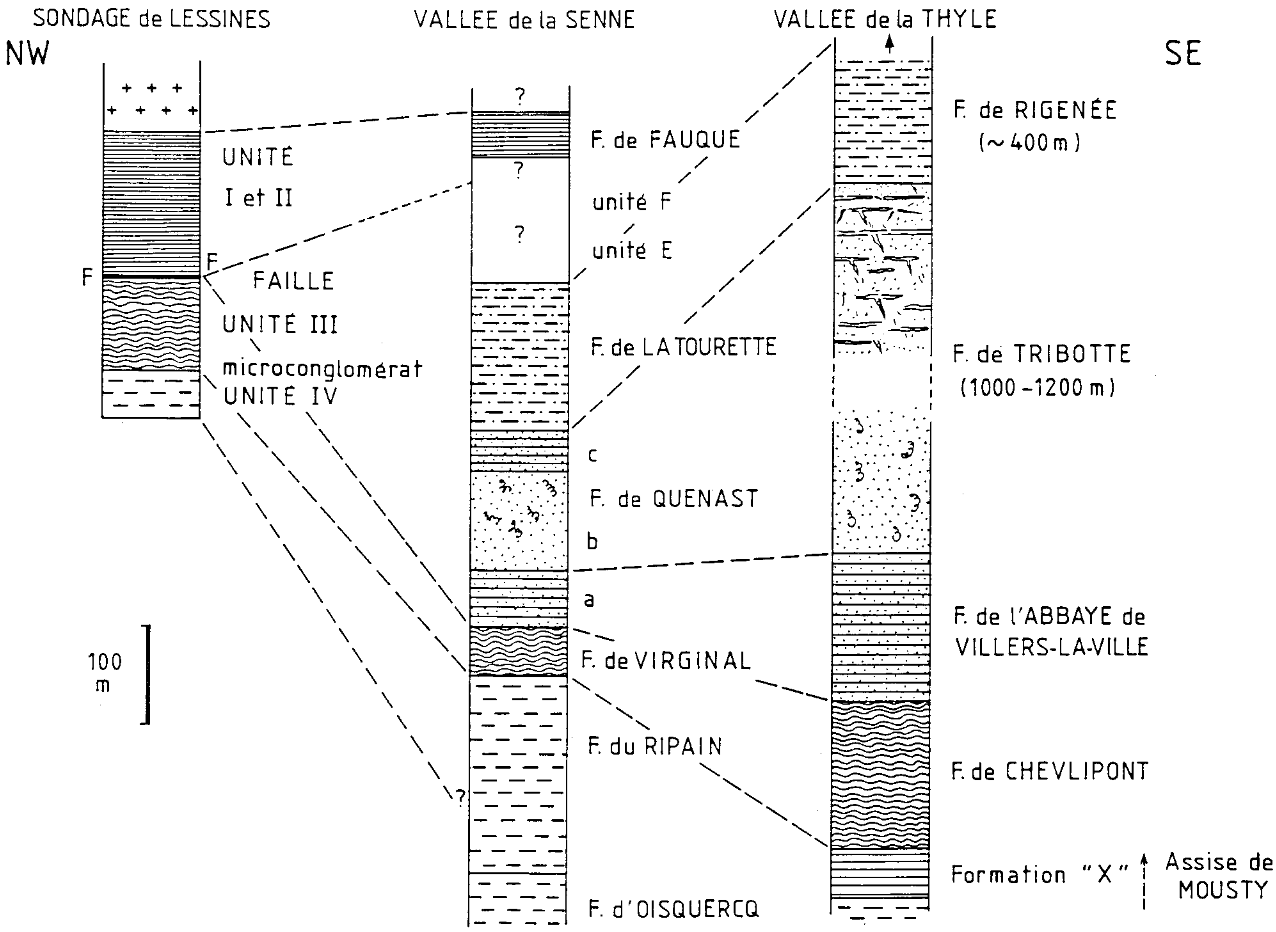


Fig. 17: Correlation of the Ordovician lithostratigraphy in three valleys of the outcrop area in the Brabant Massif (Herbosch, 1989).

ripples with cross laminations. Millimetric sized horizontal bioturbation is present especially in the clayey beds. This is the typical "quartzophyllade" facies previously described by Malaise (1910), de la Vallée Poussin (1931), Legrand (1968). One can commonly observe beds of very fine sandstone, cm to dm, homogeneous and laterally continuous. The only visible structure of these beds are fluid escape structures, plane parallel and convolute structures, and flat bases and summits.

Thickness: 150 to 200 m without important facies variation. The boundary with the underlying black shales of "X" formation is progressive and is marked by the increase in number and size of the silty laminae. The transition to the Abbey of Villers-la-Ville formation is not visible.

Sedimentology: The alternation of silty-argillaceous beds with reticulate structure and clayey-silty beds with embedded structure indicate a sedimentation of alternating periods of agitation with traction currents and quiet periods with deposition of fine particle (essentially clays). Episodic thin (1-10 cm), massive and continuous sandy beds are interpreted by Geukens (in Martin, 1977, fig. 21) as high density turbidites. However, they lack the characteristic structures and organization of the Bouma model. This formation is interpreted (Herbosh *et al.,* 1991) as a fine grained turbidite sequence on a depositional slope, according to the model of Stow (1986). If this proves to be correct than the massive sandy beds are definitely high density distal turbidites and the underlying "X formation" could be pelagic or hemipelagic deposits.

Correlation: Virginal formation (Senne basin); Unit III, Lessines borehole (also Fig. 17).

STOP 1.2: CHARLEROI-OTTIGNIES RAILWAY SECTION: ABBEY CUT

Location: Railway section, km 38,700-38,900; NE of the ruins of the Abbey of Villers-la-Ville.

General structure: the E flank of the railway cut shows approximately 250 m of continuous section in the Abbey dome (Michot, 1978, Fig. 11). A series of subvertical faults (two of which are clearly visible at km 38,750 km and 38,810) cut the outcrops into tilted sections. Until km 38,765 the beds are horizontal, then change to a regular dip of 25-30° S (strike N 80° E), which continues till the town of Villers-la-Ville (Fig. 22).

Lithostratigraphy: Abbey of Villers-la-Ville formation (*sensu* Anthoine, 1943).

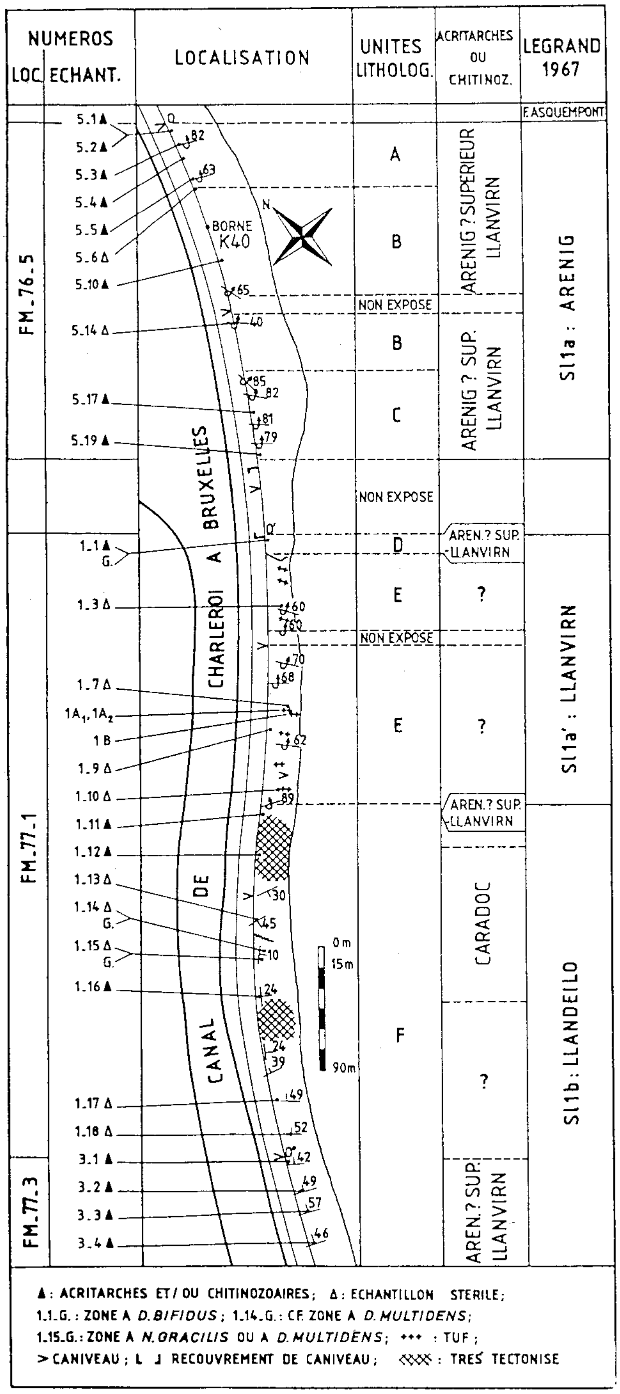


Fig. 18: Location of outcrops, lithological units, fossil and palynological sampling localities and different chronostratigraphical datation of the large section along the canal Brussels-Charleroi, south of Asquempont (from Martin & Rickards, 1979).

Biostratigraphy: Arenig-Llanvirn, more probably Llanvirn by acritarchs (Martin, 1977). There is a stratigraphic lacuna between the Chevlipont formation (Lower Tremadoc) and the Abbey de Villers-la-Ville formation (Arenig-Llanvirn).

Lithology: argillaceous to sandy siltstone, roughly laminar or bedded, greyish or blackish. The plane-parallel stratification is frequently disturbed by a strong horizontal and more rarely vertical bioturbation (mm). One can observe lenticular decimetric beds. At km 38,842 a meter scale structure (Fig. 23) may be interpreted as a channel with cross bedding. Pyrite is abundant. Locally one can observe a siltstone with siderite cement. Towards the top of this formation lighter coloured decimetric beds of psammites become more frequent.

Thickness: maximum 150 m. The transition to the psammites at the base of the Tri Botte formation is progressive and the exact boundary is not easily put in the field.

Sedimentology: A depositional environment of greater agitation than in the underlying formation is suggested by the poorer segregation of the argillaceous and quartzose fractions, the increase of grain size (average is always greater than 60 microns), the abundance of quartz and the importance of bioturbation. The presence of pyrite and of organic material (and siderite) implies a reducing environment.

A shelf environment is attributed to this unit, probably above the wave base and below the intertidal level in contrast to the Tri Botte facies.

Correlation: lower part of the Quenast formation ? (only based on lithostratigraphy).

STOP 1.3: RAILWAY SECTION AND OLD TRI BOTTE QUARRY (OVERVIEW FROM THE BUS)

Location: Railway section (km 39.160), south of the ruins of the Abbey, and Tri Botte (km 39.8 of the Charleroi-Ottignies railway).

General structure: the quarry, now blocked by a wall, cuts a prominent rocky cliff. The decimetric to metric beds dip regularly south (20-30° S) with an approximately E-W strike. This strike and dip can be observed from km 38,8 and continues till km 47 if the Holé dome (Michot, 1978, Fig. 11), no longer visible, is not taken into account.

Lithostratigraphy: Tri Botte formation (*sensu* Michot, 1978).

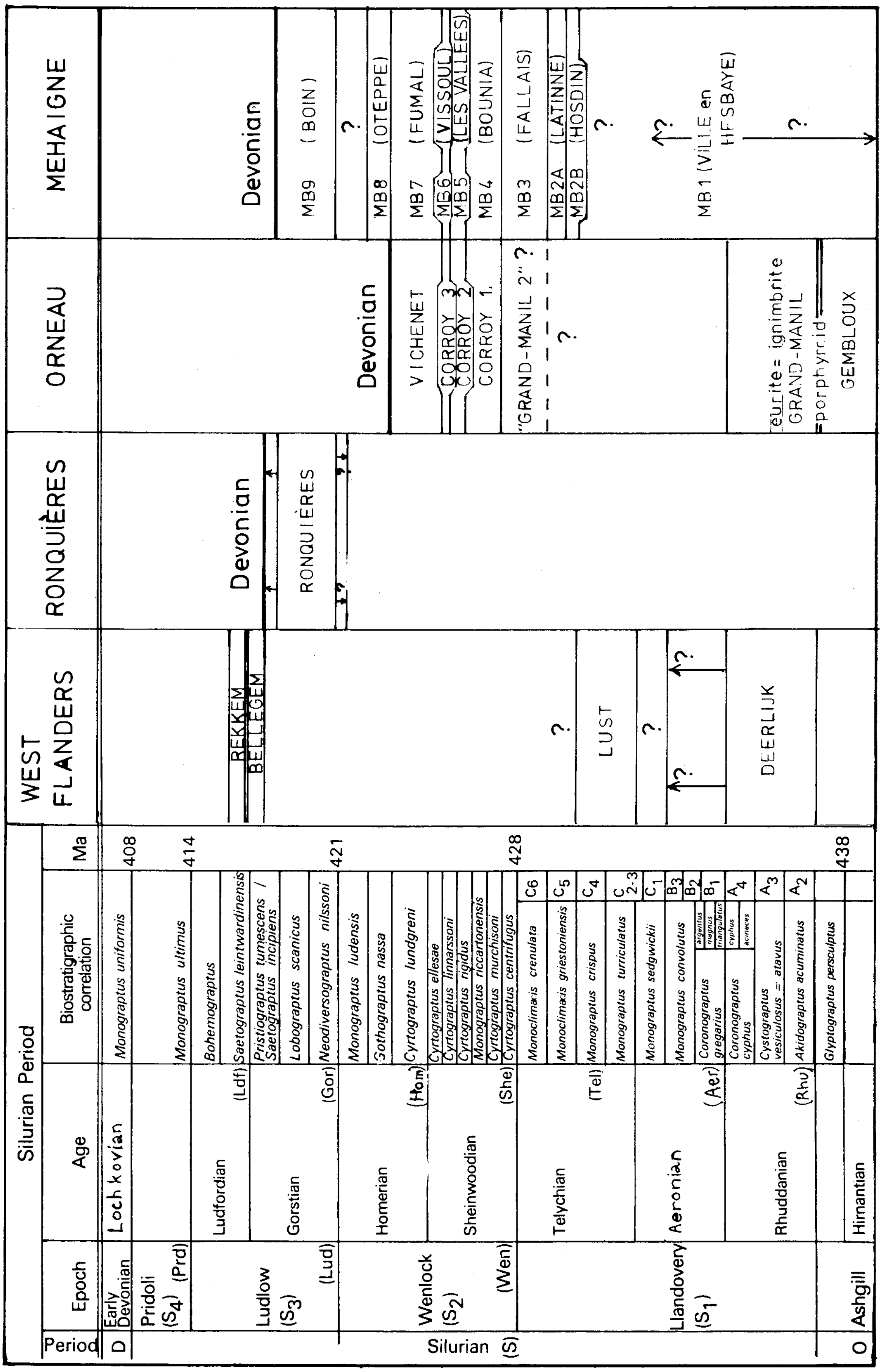


Fig. 19: Stratigraphical position of the Silurian formations of the Brabant Massif. For an updated version see Verniers & Van Grootel, this volume, Fig. 3 & 4.

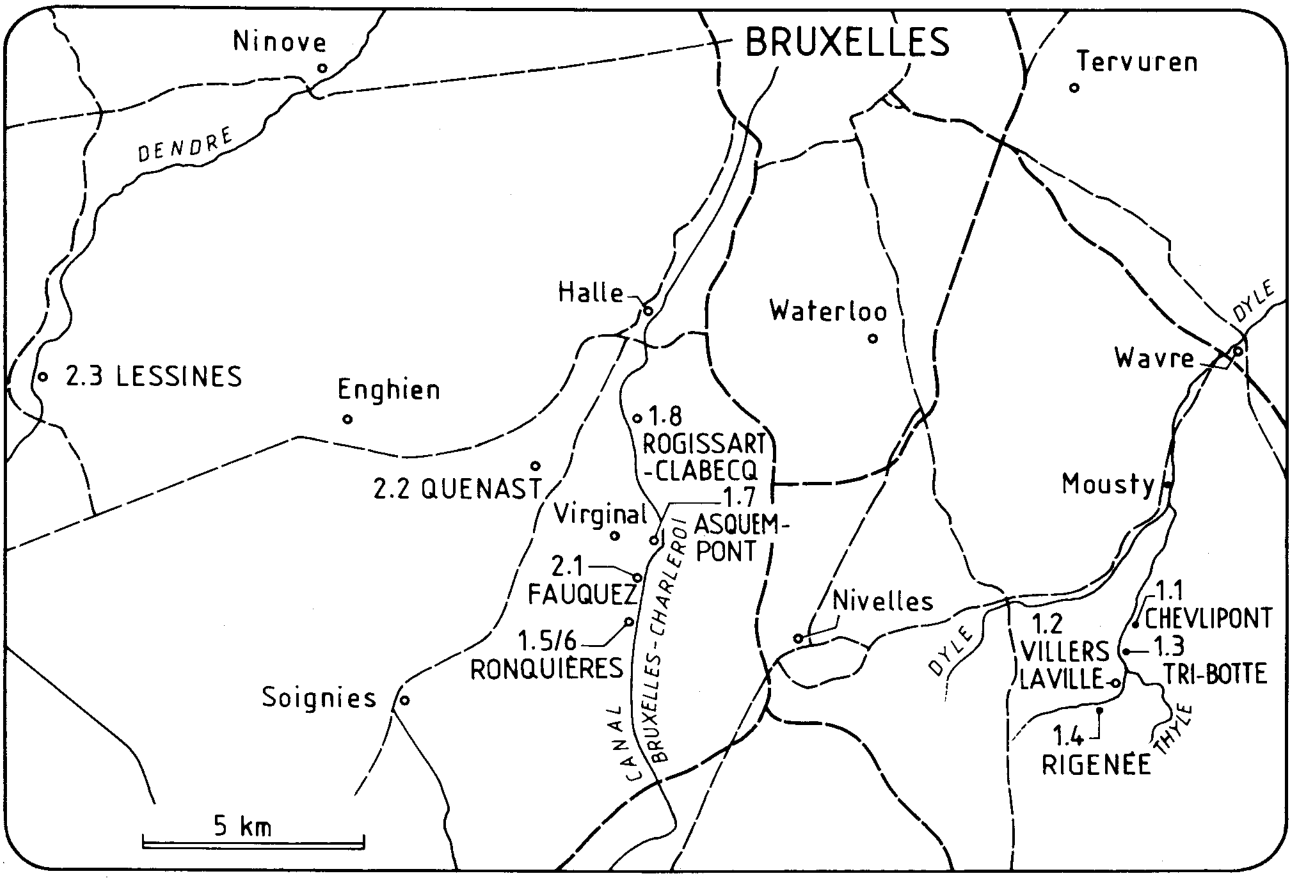


Fig. 20: General road map of the excursion area

Biostratigraphy: no stratigraphic meaningful fossil groups, but numerous ichnofossils: fucoids (Malaise, 1910; de la Vallée Poussin, 1931) and bilobites (Legrand, 1967). By deduction (age of under- and above lying formations) Arenig to Llanvirn.

Lithology: on the whole this very thick formation is characterized by fine grained sandstones locally more argillaceous (matrix and/or beds) more strongly bioturbated, primarily vertically, and much lighter in colour (grey green to grey brown), than the Villers-la-Ville formation. The outcrops are very discontinuous and often strongly altered.

The lower half of the formation is characterized by "psammites" in decimetric beds where one can sometimes discern cross-bedding (Tri Botte quarry). Microscopically the structure is reticulate to quartzitic; the increase in grain-size of quartz (average grain size 70 to 90 microns) is accompanied by poorer sorting (Fig. 24); and finally the albite content increases remarkably (5 to 11 %) and is accompanied by the appearance of potassic feldspar (orthoclase). Certain beds contain up to 18 % feldspar which is close to that of an arkose (Fig. 25).

The upper half of the formation becomes darker, due to the increase in the argillaceous matrix and argillaceous beds and the vertical and oblique bioturbation is yet again more intense. Very beautiful burrows, several centimetres long, with internal layering ("spreiten") are frequently observed.

Thickness: about 1000 to 1200 m. The transition to the Rigenée formation, seen in two valleys (Fig. 7), is very rapid which has led many authors (Anthoine, 1943; Michot, 1978) to invoke a fault contact. In our opinion, despite the rapidity of lithologic change field observations do not allow to postulate a fault between the two formations. Fourmarier (1921) and de la Vallée Poussin (1931) also observed a normal sedimentary contact.

Sedimentology: Subtidal to intertidal: the more argillaceous and bioturbated facies of the upper part are typical of intertidal sediments (mud flats). These facies are well exposed in the building stones of the church of Villers-la-Ville.

Correlation: Upper and middle part of the Quenast formation (Senne Valley) purely on lithostratigraphic grounds. No biostratigraphic correlations available.

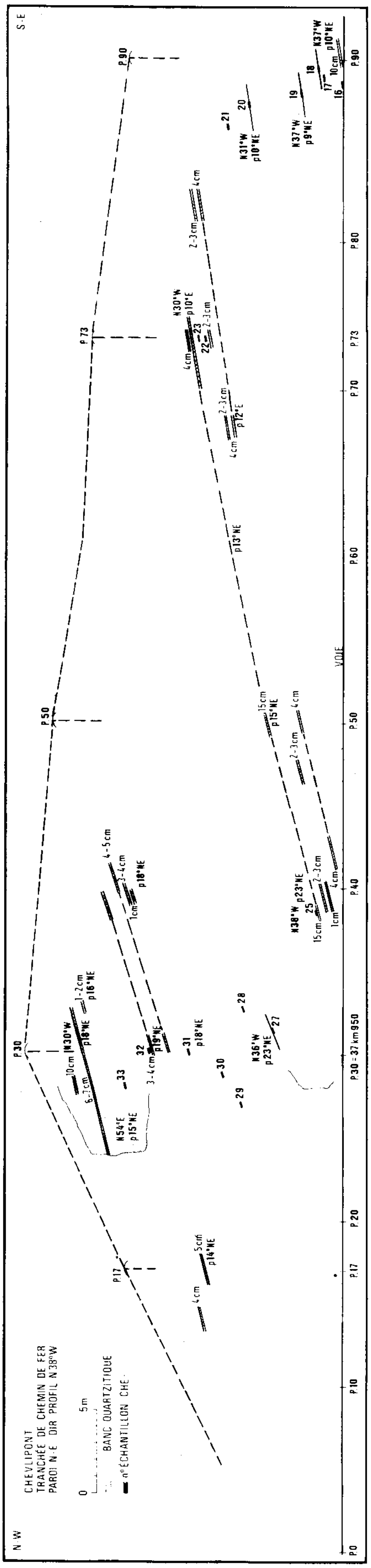


Fig. 21: Sketch by Martin (1976) of the railway section close to the Chevlipont railway crossing on the Leuven-Charleroi railway.

STOP 1.4: CHATELET FARM (RIGENÉE, THYLE VALLEY)

Locality: Rigenée in front of Châtelet farm; road cut along the north side of the road Villers-la-Ville to Sart-Dames-Avelines.

General structure: a 200 m long continuous profile shows toward the W regularly dipping beds (25-40° S) interrupted by a cascading fold, and toward the E a completely disturbed zone (Fig. 26).

Lithostratigraphy: Rigenée formation (*sensu* Malaise, 1910).

Biostratigraphy: Upper Arenig to Llanvirn (acritarchs) in the lower part ("chemin creux" du Châtelet). Llanvirn acritarchs species were found in the "Châtelet farm" section. The upper part is at least of late Llanvirn age (Servais, 1991a).

Thickness: approximately 400 m, upper part disappears under Tertiary cover.

Lithology: grey to black mudstones. At the base some siltstone laminae are present and the bioturbation is important. The upper part has not yet been studied in detail.

Sedimentology: Current analysis is still underway but the palaeoenvironment is interpreted as definitely deeper than the Tri Botte formation.

STOP 1.5: RONQUIERES PLAN INCLINÉ (PANORAMIC VIEW)

Location: Large cutting of the inclined ship lift on the canal Brussels-Charleroi, 500-1650 m SSE of the church of Ronquières (Fig. 27; 29).

Access: Car park, west of the road, 900 m south of the bridge; panoramic walk along the (public) upper footpath at the edge of the large cutting; stop in front of the fifth lighting pole.

Stratigraphy:

Above the Caledonian unconformity: Bois de Bordeaux Formation, Mautiennes Member (previously abbreviated as Coa and Cob), Alvaux Member (Gva),

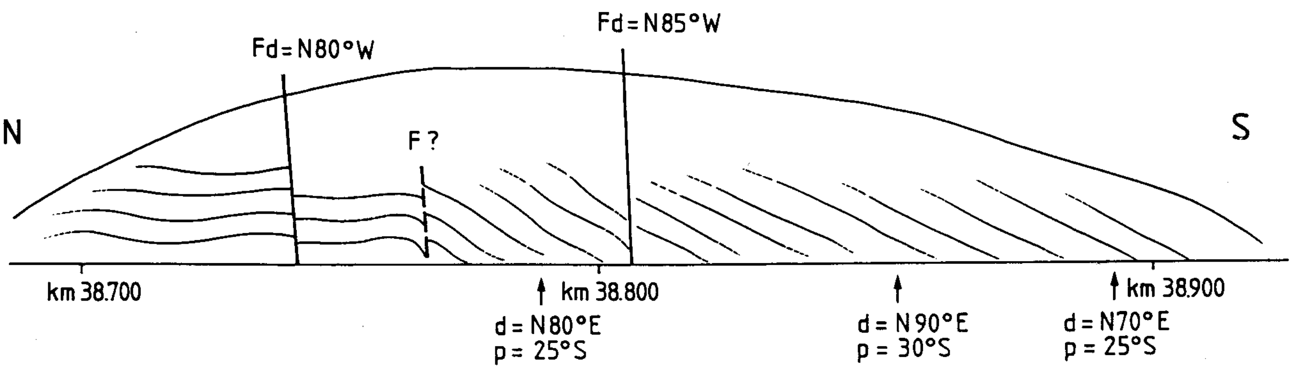


Fig. 22: Sketch by Jodard (ms 1986) of the eastern side of the railway section, north of the ruins of the Villers-la-Ville Abbey, showing the Abbey of Villers-la-Ville formation.

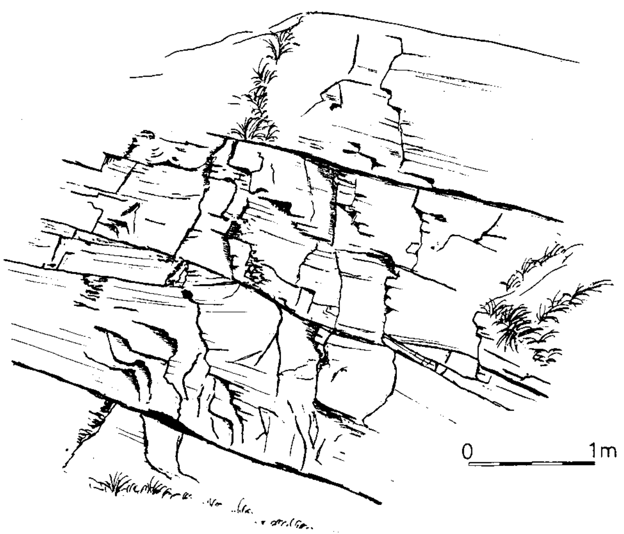
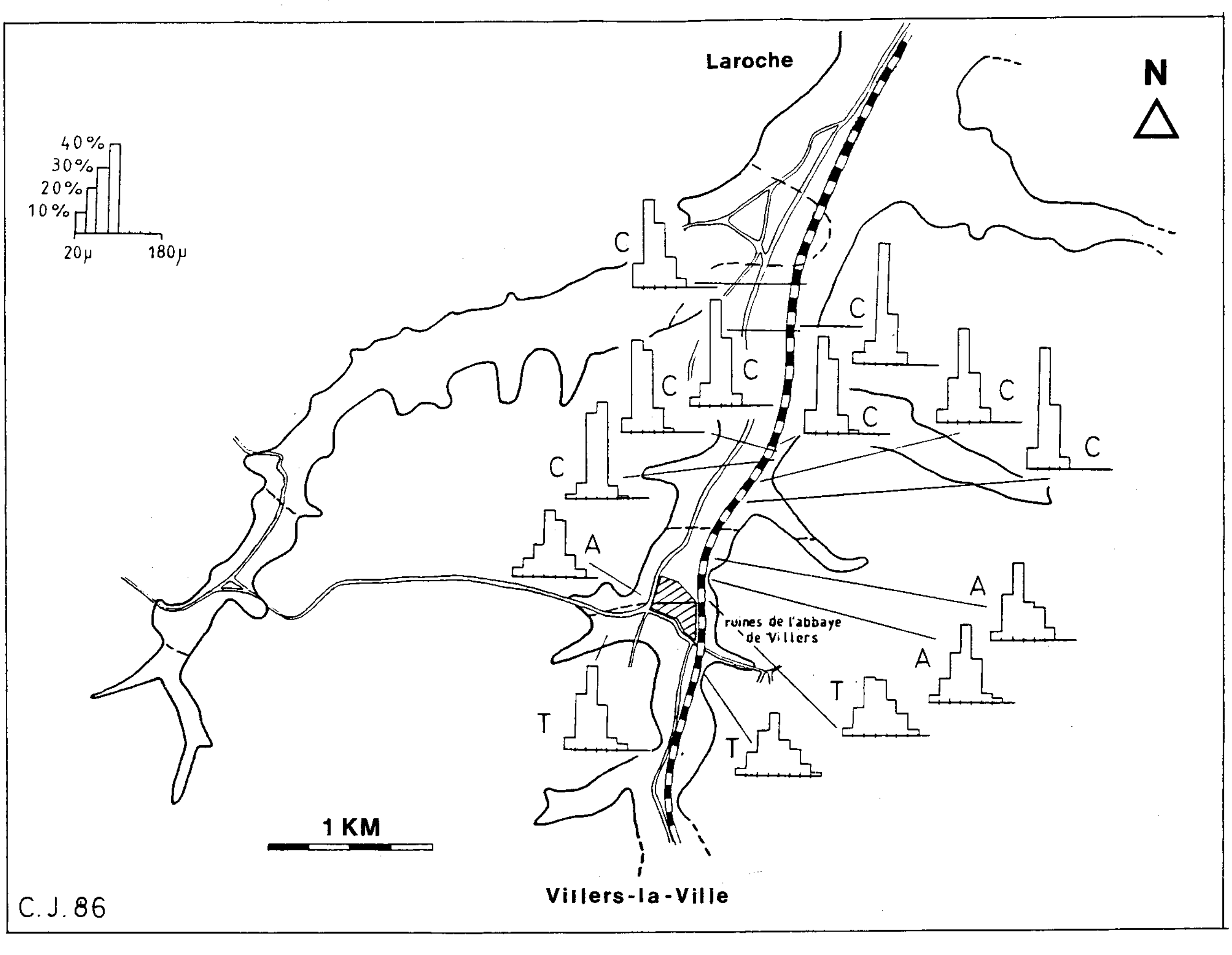


Fig. 23: Drawing of a channel structure in the deposits of the Abbey of Villers-la-Ville formation at km 38.842 of the railway Leuven-Charleroi north of the ruins of the Abbey of Villers-la-Ville (Herbosch, unpublished data).

Fig. 24: The quartz granulometry in the Thyle Valley. Abbreviations: C: Chevlipont formation; A: Abbey of Villers-la-Ville formation; T: Tri Botte formation (C. Jodard, ms 1986).



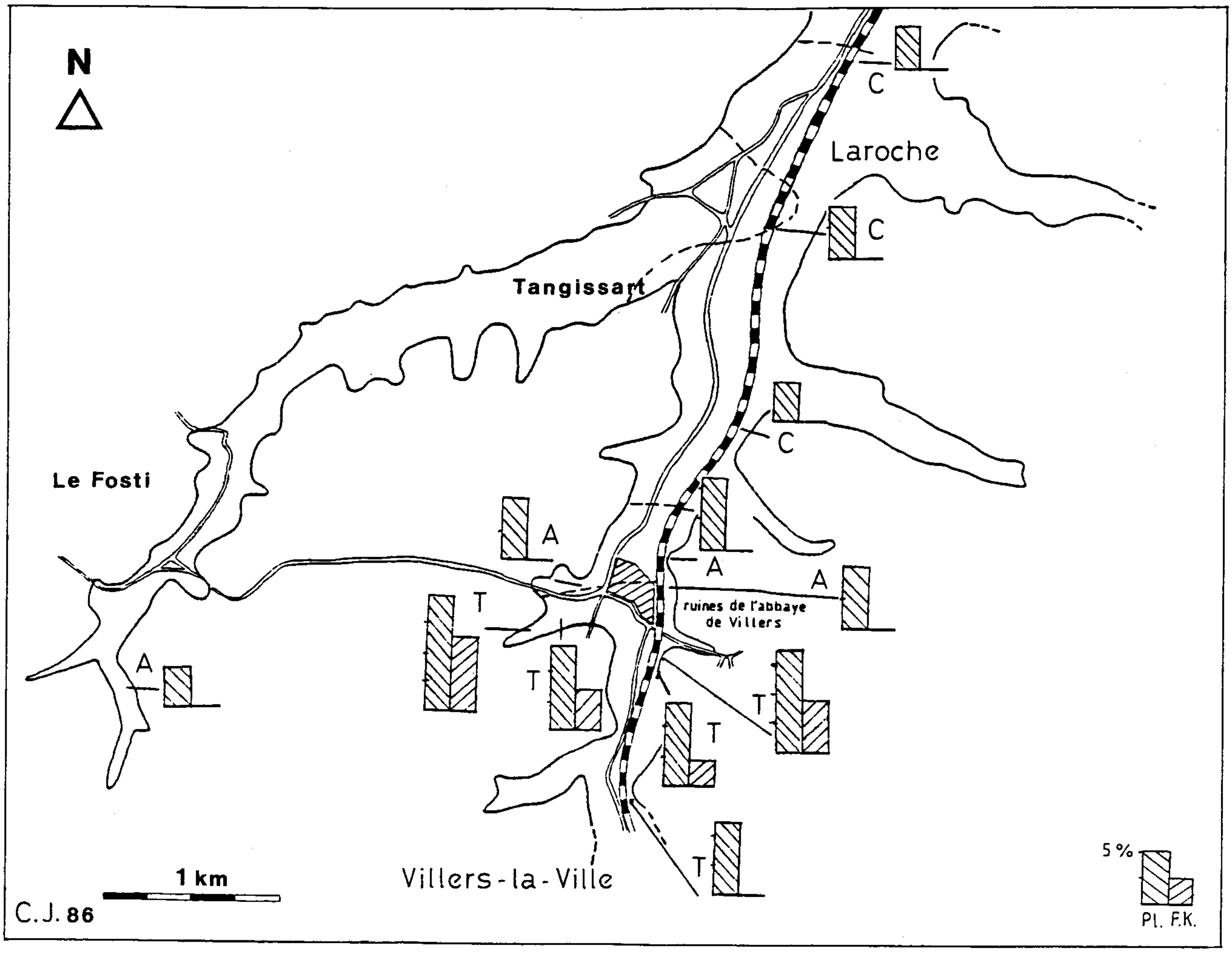


Fig. 25: The distribution of feldspar in the Thyle Valley. Abbreviations: C: Chevlipont formation; A: Abbey of Villers-la-Ville formation; T: Tri Botte formation; Pl.: plagioclase; F.K.: potassic feldspars (orthoclase)(C. Jodard, ms 1986).

and Mazy Member (Gvb), Devonian system, Givetian stage. Below the Caledonian unconformity: the Ronquières formation, different units; Silurian system; Ludlow series, Gorstian stage; *N. nilssoni* and *L. scanicus* graptolite zones (Fig. 28).

General structure:

To the right the Devonian strata, inclining 5-10° S, are clearly visible, above the sixth lighting pole, by their reddish colour; the northern tip of the Devonian starts exactly at the northern edge of the iron railing of the "belvedere" (=eastern panoramic view); the upper few meters of the Silurian sediments are coloured in red by the Lower and/or Middle Devonian palaeosol development. Figure 28 gives a table of the Palaeozoic stratigraphical units in and around this section.

To the left there is a large syncline (south dipping axial plane) passing through the lower lock doors named the "Porte Avale" Syncline. In the front left a large anticline occurs (inclined to the north) exactly at the fourth lighting pole, called the middle anticline, and in front right a gentle open syncline exists between the fifth and the sixth lighting pole, called the "Belvedere Syncline". The three fold axes dip westward 5-10°. South of the "Belvedere" railing (to the far right), under the Devonian unconformity, the Silurian is structurally suddenly complex with many folds and faults.

Legrand (1967) has pointed to the fan-shaped slaty cleavage in the three folds. He deduced from this cutting a first folding phase, followed by slaty cleavage formation and afterwards a second folding phase producing the fan-shaped slaty cleavage. Both phases are Caledonian because they are cut by the slightly inclined Devonian cover. Earlier authors as Mortelmans (1954), thought before the ship lift cutting of Ronquières was opened, that the second folding phase was Variscan. Fig. 30 hypothesizes the geological and tectonic history of the area.

Thickness: A maximum of 206 m of sediments were measured between the Porte Avale and the Central Anticline (east side). All other outcrops in the cutting are estimated to duplicate this section via folds and faults. The stratigraphy in the tectonized zone under the Devonian was not studied due to the many deformation and changes in sediment thickness across the fold (pointing to an early deformation stage).

Lateral Variation: Fig. 29 resumes the observations on lateral variations in the Silurian sediments of the Ronquières area. There is a lateral N-S variation in the higher energy turbidites (shallower conditions) with decrease of thickness and energy towards the north. In E-W direction variation is unclear. In the sediments all current direction point northwards. In the lower energy turbidites and deeper sediments (lamellated hemipelagites) lateral variation is less in either E-W or N-S direction.

STOP 1.6: MONT GODART SECTIONS (AT THE BRIDGE OF RONQUIERES)

Location: Sections along the canal lock, along the road Ronquières-Fauqué, along the climbing road to the old chapel, and along the road NW of the old chapel; 200-500 m west of the Church of Ronquières (Fig. 32).

Access: Leave cars along the east side of the road Ronquières-Fauqué close to the bridge or along the same road 220 m north of the bridge at the turnoff of the small climbing road to the old chapel.

General structure: The structure is quite constant over the whole Mont Godart; stratification in the road section: strike: N63°W & dip: 68-73°S; in the chapel section: N57°W & 65°S; and the slaty cleavage is quite constant too with the same strike and a dip of about 70° N (Fig. 32).

Stratigraphy: Mont Godart and Ronquières formations; Silurian system; ? Wenlock series, ? Homerian stage, ? top of *M. ludensis* graptolite zone; Ludlow series, Gorstian stage, *N. nilssoni* and *L. scanicus* graptolite zones (Fig. 33, 35 & 37).

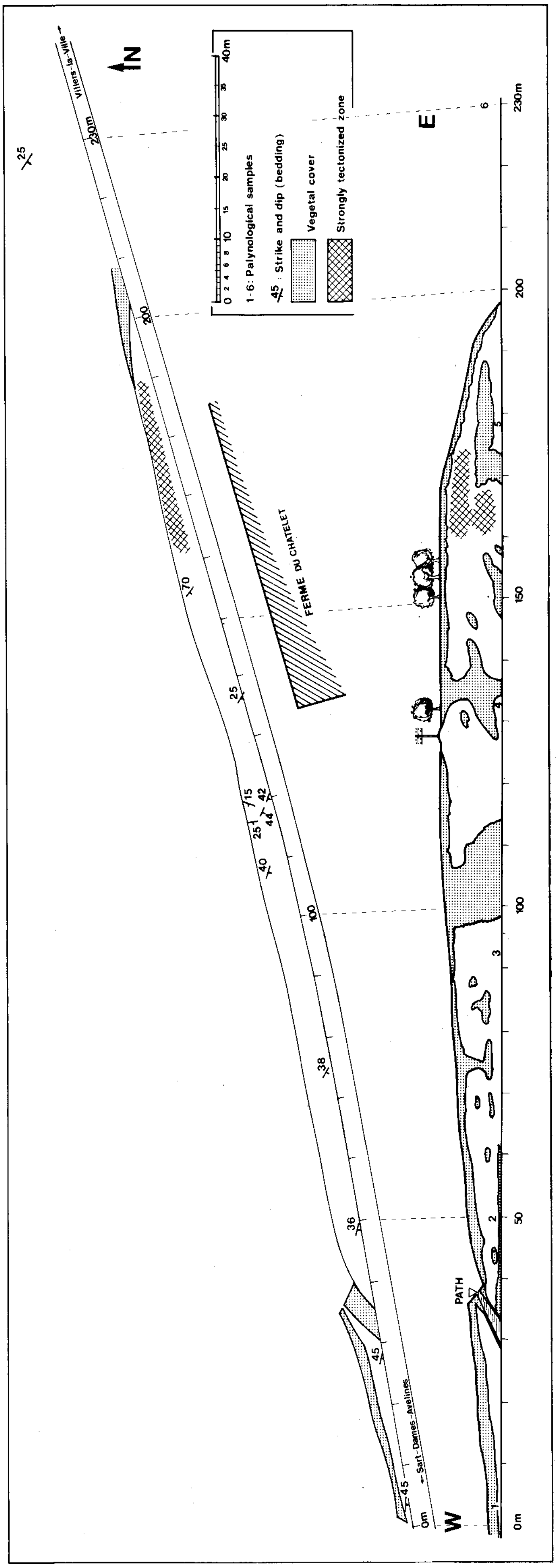


Fig. 26: Sketch by Servais (1991a) of the road sections exposing the Rigenée formation, close to the Châtelet Farm, west of Rigenée, in the Thyle Valley. Abbreviations: A to R: palynological samples; O: topographic markers in the form of the iron covers of the canalization in the tarmac; ⊥ strike and dip of stratification with the dip value.

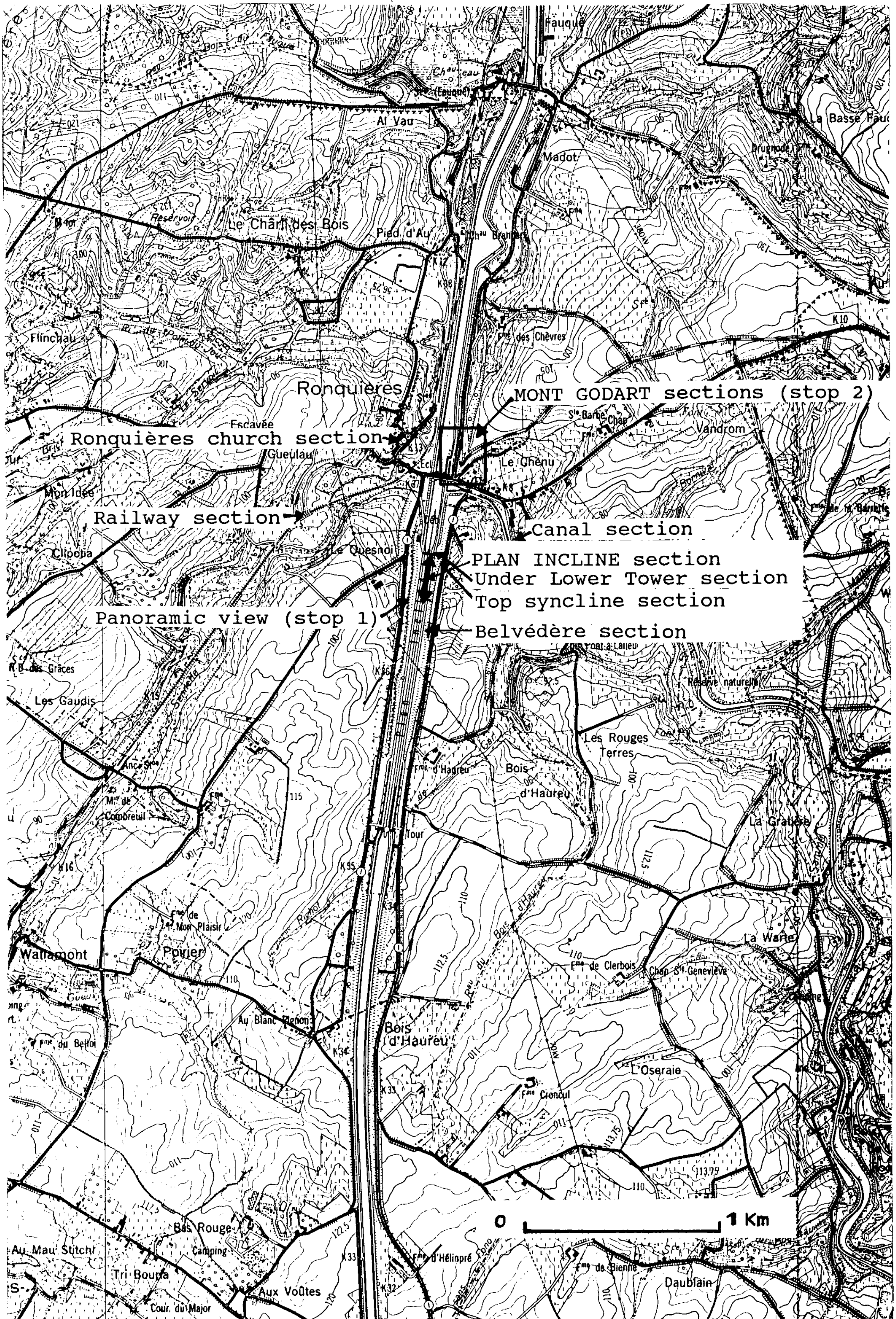


Fig. 27: Topographic map of the Ronquières area, with names of outcrops and visited places

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DEVONIAN SYSTEM
Givetian series (LEGRAND, 1967)
                    Palaeosol
                    Erosion
                    Gv b: 18m Red silts and sands, with 3
                    conglomerates in the upper half
                    (= Mazy Formation)
                    Gv a: 17m Grey clays; grey sands at the
                    bottom and at the top; fossil plants
                    (=stems) in the top sands.
                    (= Alvaux Limestone Formation)

Eifelian (=Couvinian) series (LEGRAND, 1967)
                    Palaeosol
                    Co b: 10m Conglomerates (fluvial/torrential)
                    in three layers with some red silts & grey
                    sandstones.
                    (=? Naninne Formation)
                    Co a: 15m Red silts with one conglomerate
                    bed and soils
                    (= ?Rouillon Formation)
                    Palaeosol (red colour of Silurian slates, up
                    to 10 m depth)

Caledonian angular unconformity

SILURIAN SYSTEM

Ludlow series
 Gorstian stage (=early Ludlow)
  (N. nilssoni and L. scanicus graptolite zones)
    Ronquières Formation (>526m)
    units A (pars),B to W
Wenlock? series
 Homerian? stage (=late Wenlock)
    Mont Godart Formation
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Fig. 28: Table with formation names of the Palaeozoic in the Ronquières area. The Devonian ages are according to Legrand (1967) and are all put into the Givetian by Verniers & Van Grootel (1991).

Lithostratigraphy: On Fig. 33 the general stratigraphy of the Mont Godart and the Ronquières formations is given with the position of graptolite levels, Chitinozoa samples and the resulting biostratigraphy. Fig. 34 gives for each of the six units a representative part of the log.

Biostratigraphy: Graptolites, collected in the road section at the Mont Godart, were determined by B. Rickards (1985 pers. comm.). *Bohemograptus bohemicus* (Barrande), *Lobograptus scanicus* (Tullberg) s.l., *Pristiograptus dubius* (Suess), *Saetograptus varians, Saetograptus chimaera* s.l., and *Saetograptus colonus* s.l. (Barrande) are present and clearly belong to the *N. nilssoni* and *L. scanicus* zones (Gorstian, lower Ludlow) without being able to distinguish in between the two.

Fig. 35 shows the distribution of Chitinozoa in the Ronquières area. Assemblages are dominated by two species *Cingulochitina convexa* and *C. serrata*. This assemblage can be correlated with the lower half of the Hemse Beds (Gotland) and the Elton Beds (Wales), confirming the graptolite age. The additional Chitinozoa species allow the subdivision in three subzones. Subzone 1 has species showing a Wenlock affinity and possibly age (lack of accurate comparative material in the type-areas in UK or Baltic Sea prohibit to be more affirmative). Subzone 2 characterizes the remaining Mont Godart section and lowest Plan Incline section. Subzone 3 is specific for most of the Plan Incliné section.

Sedimentology: Fig. 36 shows the different sedimentological types present in the Ronquières formation.

Vertical variation: Megacyclical variation is clearly visible throughout the Mont Godart sections (Figs. 34 and 37). The Mont Godart formation has many Tbcde (with a relative thick Tb division) and Tcde sequences (35%) and are the most energetic turbidites in the Mont Godart section. They pass gradually into the less energetic Unit B of the Ronquières formation with rare Tbcde or Tcde sequences (6%). On its turn lamellated hemipelagite (LHP) beds come into the column, they increase in thickness and rapidly dominate the turbidites (Unit C). In Unit D, while the LHP rapidly disappear, only two Tbcde sequences occur over a total of 65 sequences (3%), in Unit E 10 on 92 (11%), in the lower part of Unit F 17 on 74 (23%) and in the upper part 29 on 66 sequences (44%). The unit C contains most graptolite levels and is poor in Chitinozoa. The latter seem thus to be brought into the area only by turbidity currents while graptolites can either be brought into the deposition area by turbidites, when they are found in the Tb, Tc and Td divisions, or deposit there autochthonously when found in the LHP.

The meaning of megacyclicity in the Silurian of the Brabant Massif is still under debate (turbidite fan dynamics, local, regional or eustatic water depth changes). But there are some arguments (see 1.3.3) to postulate a large deepening-shallowing-deepening cycle as a regional (possibly eustatic) cycle, with minor metric and decametric oscillations caused by local influences or by the fan system dynamics.

STOP 1.7: BRUSSELS-CHARLEROI CANAL SECTION (SENNETTE VALLEY)

Locality: Asquempont, E flank N of km 40 (Fig. 14, 15)

General structure: in the absence of any stratification in these massive shales the geometrical disposition cannot be determined. During the digging of the canal folds have been observed (Mortelmans, comm. pers.). The more or less well developed slaty cleavage is probably parallel to the stratification (km 40,196: d = N35°W, p = 75°NE). At km 40,133.: beginning of the brecciated zone corresponding to the Asquempont fault.

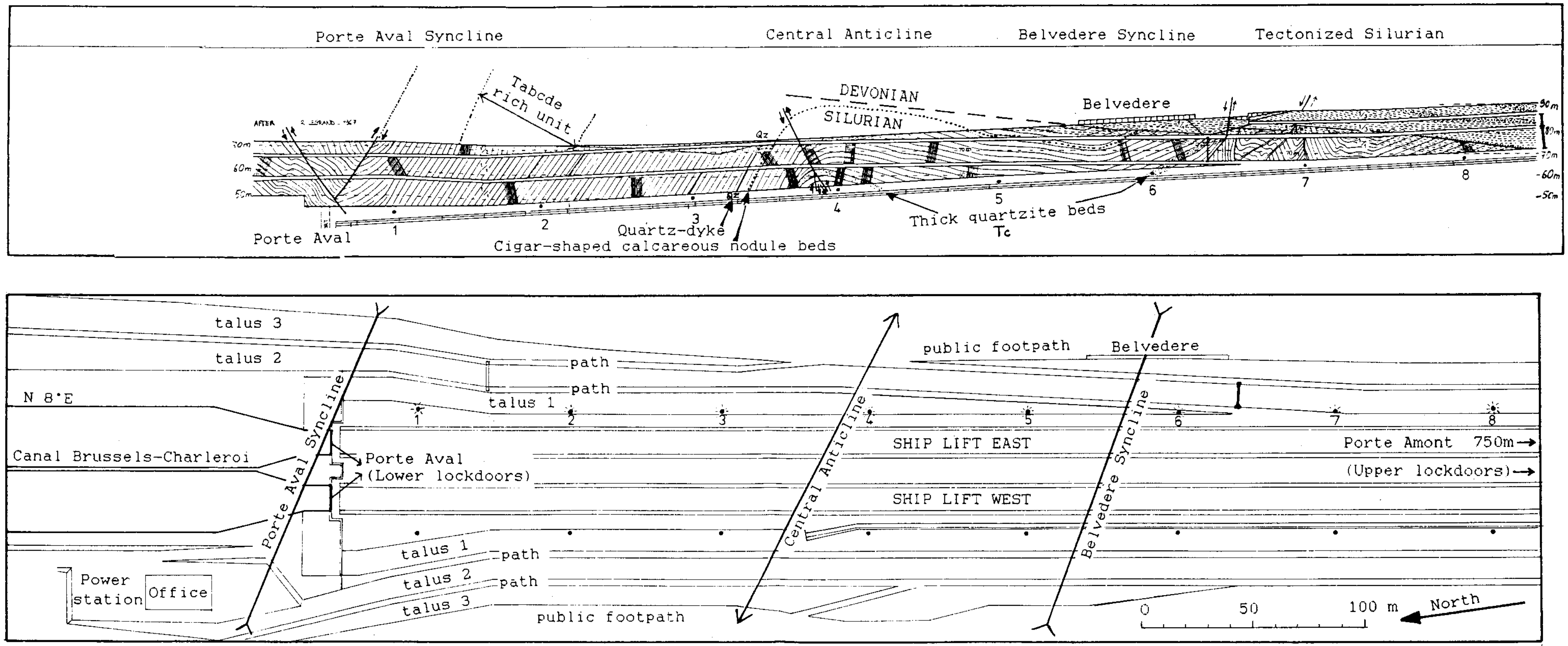


Fig. 29: Map (below) & section of the eastern flank (above) of the Plan incliné of Ronquières (section changed after LEGRAND, 1967).

MESOZOICUM — ? Faulting in new or reactivated faults during the Late Kimmerian uplift of the Brabant Massif (latest Jurassic/ Early Cretaceous) VAN DEN HAUTE & VERCOUTERE (1988).

PALAEOZOICUM — Perm-Carboniferous-Devonian (Famennian-Frasnian)Variscan faulting in new or reactivated faults (LEGRAND,1967)

Frasnian/Givetian limit:
°shearing (mylonites) in Bierghes quarry, 16 km NW, on geochronology (ANDRé & DEUTSCH, 1985); possibly contemporaneous with the Gv b deposition, faults through Eifelian/Givetian formations and Late Givetian erosion phase.

Givetian
°Palaeosol development. Legrand, 1967
°Erosion phase.
°Deposition of the Gv b (red silts and sands with 3 conglomerates at the top, Mazy Formation).
°Deposition of the Gv a (grey clays and sands, Alvaux Formation).

Eifelian
°Palaeosol development. Legrand, 1967
°deposition of middle and upper conglomerate (Cob).
°faulting of lower conglomerate (1-2m throw).
°deposition of lower conglomerate (Co b).
°deposition of red silts (Co a).

Emsian/ Praguian/ Lochkovian
°Palaeosol development and reddening (=rubefaction) of the Silurian slaty shales(LEGRAND, 1967).
°Erosion, peneplanation (N-S valleys morphology).
°Compression phase with south-dipping faults through the centers of the synclines and anticlines with south pushed over north.
°Intrusion of the quartz-calcite dyke.
°Second folding phase; fan-shape of slaty cleavage (LEGRAND, 1967).
°(re)formation of calcareous nodules in bread form in the Ronquières Formation, unit B (Mont Godart section).
°Slaty cleavage formation (LEGRAND, 1967).
°First folding phase (LEGRAND, 1967).

Early Lochkovian

Silurian
Pridoli
°continuous sedimentation during Ludfordian (=Late Ludlow), Pridoli, and Early Lochkovian (STEEMANS,1989), all eroded during the Early Devonian.

Ludlow
°Formation of the calcareous nodules in the form of cigars during early diagenesis.
°Turbiditic & hemipelagic sedimentation: Gorstian (=Early Ludlow) part preserved.

Fig. 30: Geological and tectonic history of the Ronquières area. The tectonic event in the Lower Devonian might need revision (J. Soper, pers. comm. 1989).

Facies types & location	Lateral variation E-W	N-S
-higher energy turbidites		
Plan Incliné, thick sandstone beds	no	yes
Plan Incliné, turbidites	no	yes
-lower energy turbidites		
Plan Incliné	no	no
Mont Godart sections	no	-
(Mehaigne area, MB7 Formation)	no	-
-laminated hemi-pelagites		
Plan Incliné	-	no
-cigar-shaped calcareous nodule beds		
Plan Incliné	no	yes

Fig. 31: Lateral variation in the Silurian of the Ronquières area.

Lithostratigraphy: Ripain formation (*sensu nov.* Lenoir, 1987). Upper part of the "Assise de Oisquercq" *sensu* Legrand (1967).

Biostratigraphy: no fossils in this section, however Vanguestaine (1989) has recently found acritarchs in a similar facies of the Lessines (Unit IV) and Oudenaarde boreholes, giving an age close to the boundary between Lower and Middle Cambrian.

Thickness: inferred thickness of 250-300 m (?) (Lenoir, 1987). Transition with the underlying Oisquercq formation is gradual over a dozen meters and is indicated only by an important change of colour (from green to purple).

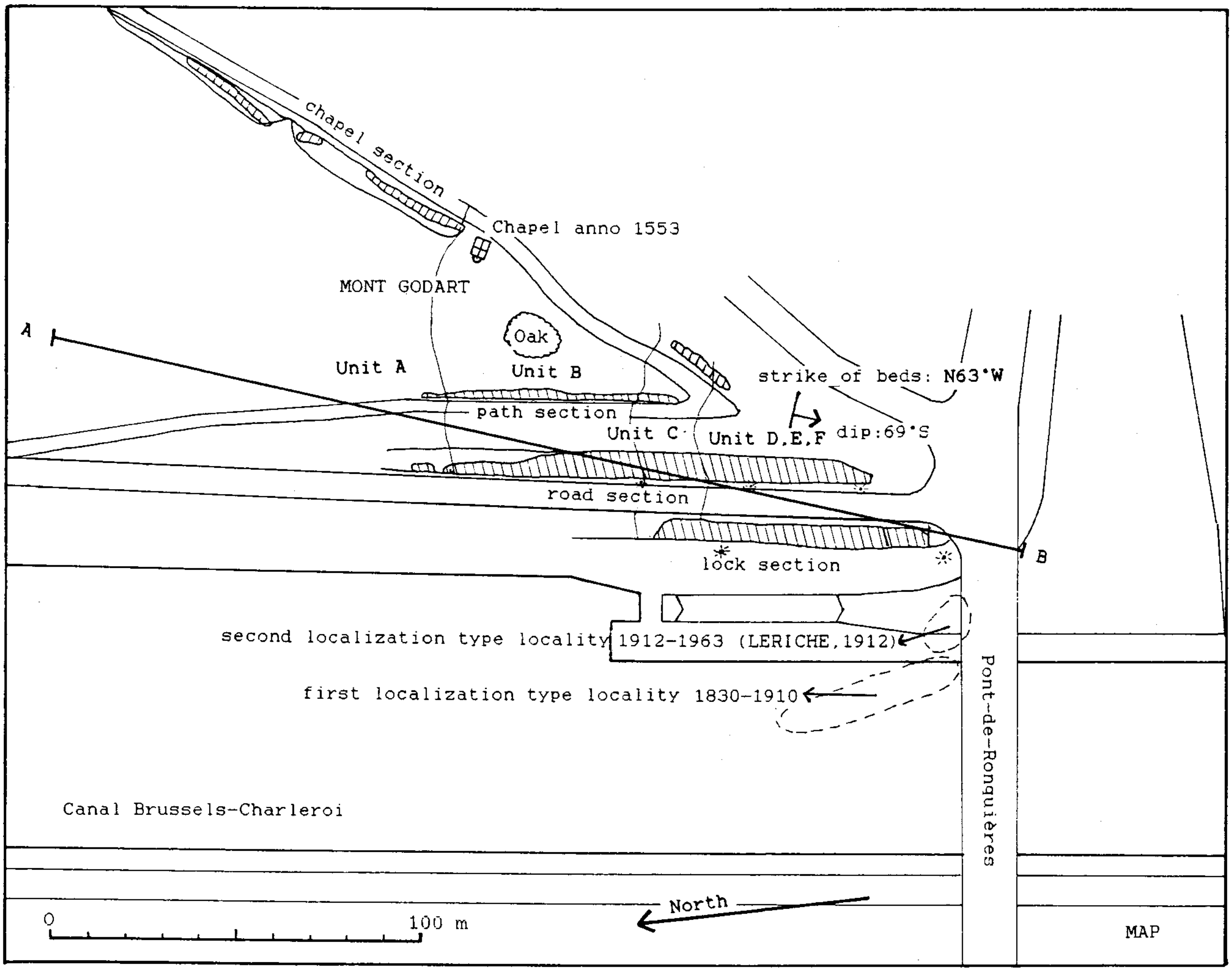
Lithology: greyish to greenish coloured massive claystones. The silt content increases in the upper part (to the S of the Asquempont bridge).

STOP 1.8: THE «ASSISE» OF TUBIZE (LOWER CAMBRIAN) OF ROGISSART-CLABECQ

If times permits, we will visit the Rogissart Unit of the «Assise» of Tubize, undated yet, but thought to be Early Cambrian in age or latest Precambrian. Occurrence of the ichnofossil *Oldhamia* (Vanguestaine, unpublished). This section has been described in detail by Vander Auwera & André (1985).

The Rogissart Unit is constituted of sandstones, feldspathic sandstones, arkoses and graded greywackes in alternation with silty pelitic shales as well as schists with magnetite porphyroblasts.

On the large outcrop the sedimentology and the lithology can be observed.



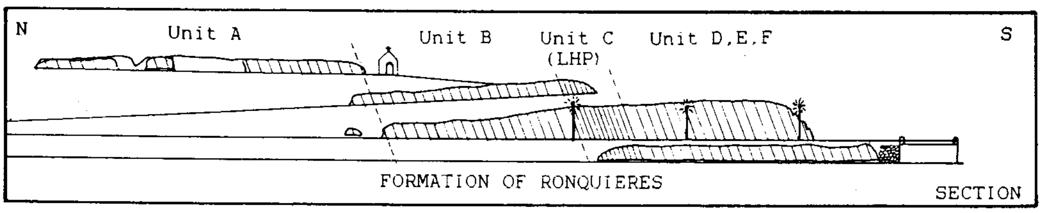


Fig. 32: Map of the Mont Godart sections, near the bridge of Ronquières with names of the four sections and probable location of the previous type localities. Below: geological section through the Mont Godart, normal to the strike.

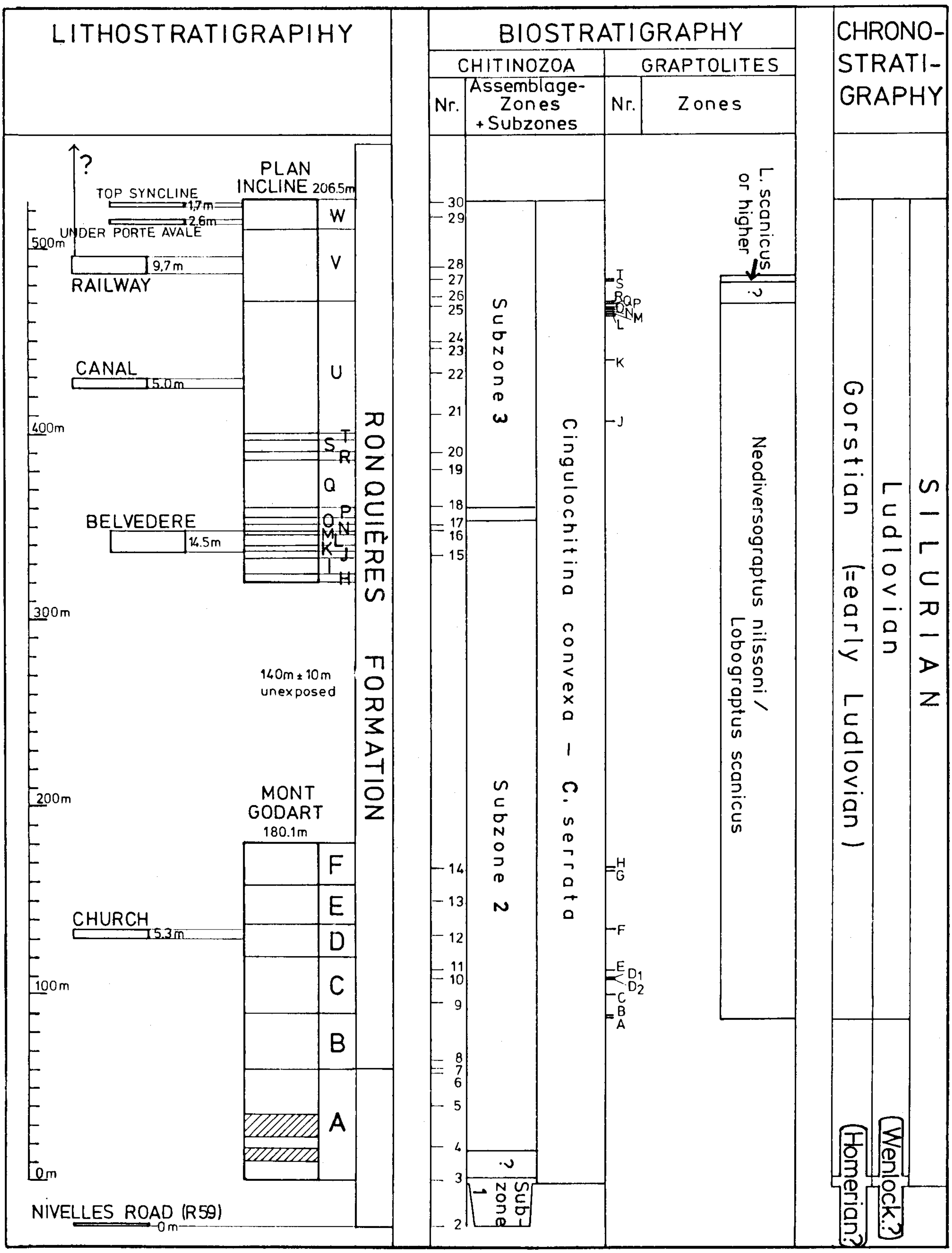
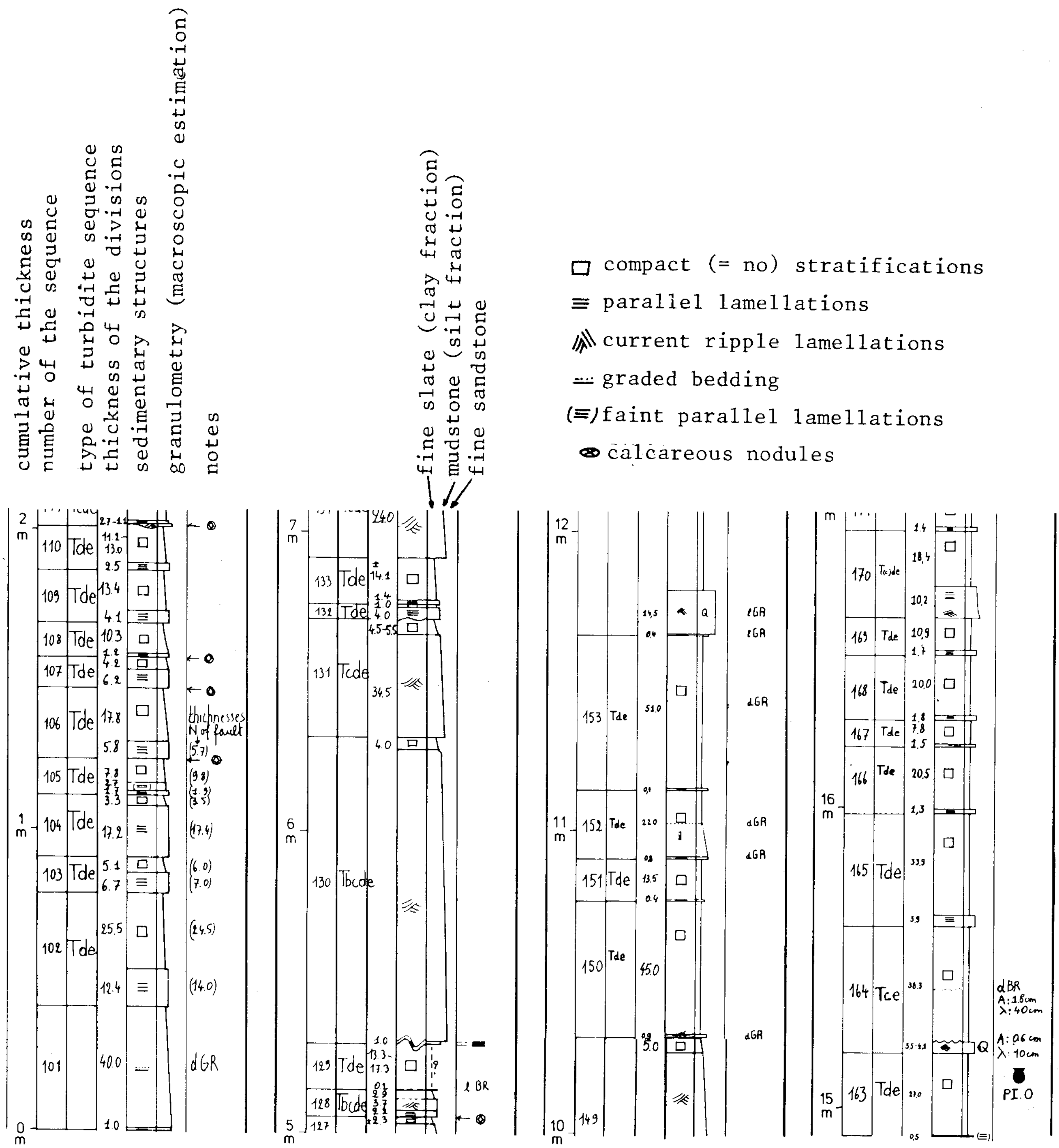


Fig. 33: General litho-, bio- and chronostratigraphy of the Silurian of the Ronquières area.
Unit A in the Mont Godart section corresponds with the Mont Godart formation.



NOTES

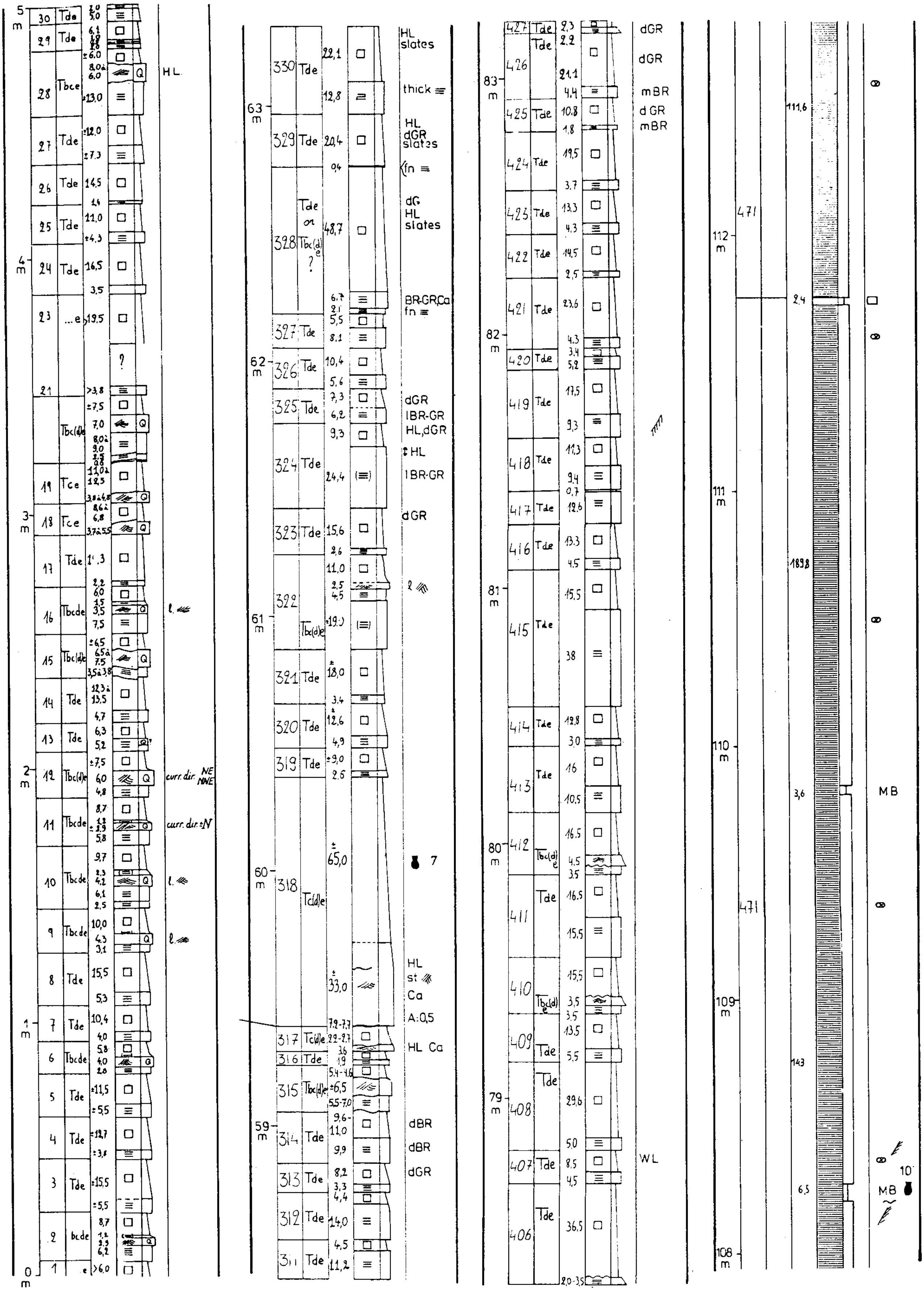
GN green
GR gray
BR brown
YE yellow
RS rusty coloured
l light
m medium
d dark

ABBREVIATIONS

A amplitude of ripple marks
λ wave lenght of ripple marks
MB metabentoniet ?
Ca calcitic cement
curr. dir. direction of current deduced from current ripples
HL hard layer
Mn manganese oxide impregnation

◎ pyritosphere level
chitinozoa sample
◇ pyrite level
graptolite level
〜 wavy bedding plane
sample place

Fig. 34A: Legend to the logs.



Unit A Transition A/B Unit B Unit C

Fig. 34: Examples of logs of the Mont Godart formation (Unit A) and of different units (B to F2) in the Ronquières formation at the Mont Godart sections, showing the sedimentological aspects of each unit and the variation between them.

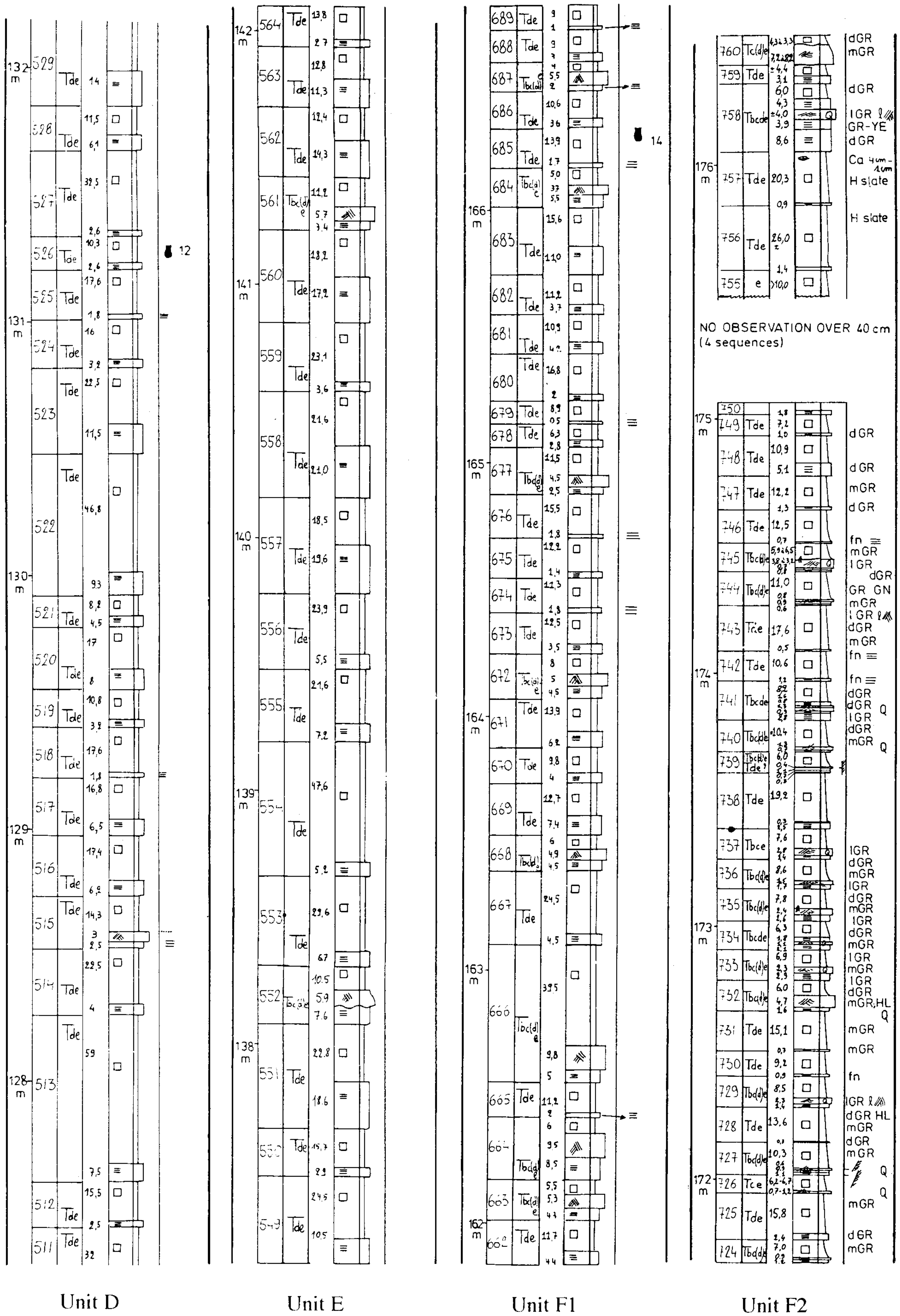

NO OBSERVATION OVER 40 cm
(4 sequences)
Unit D
Unit E
Unit F1
Unit F2

Fig. 34:

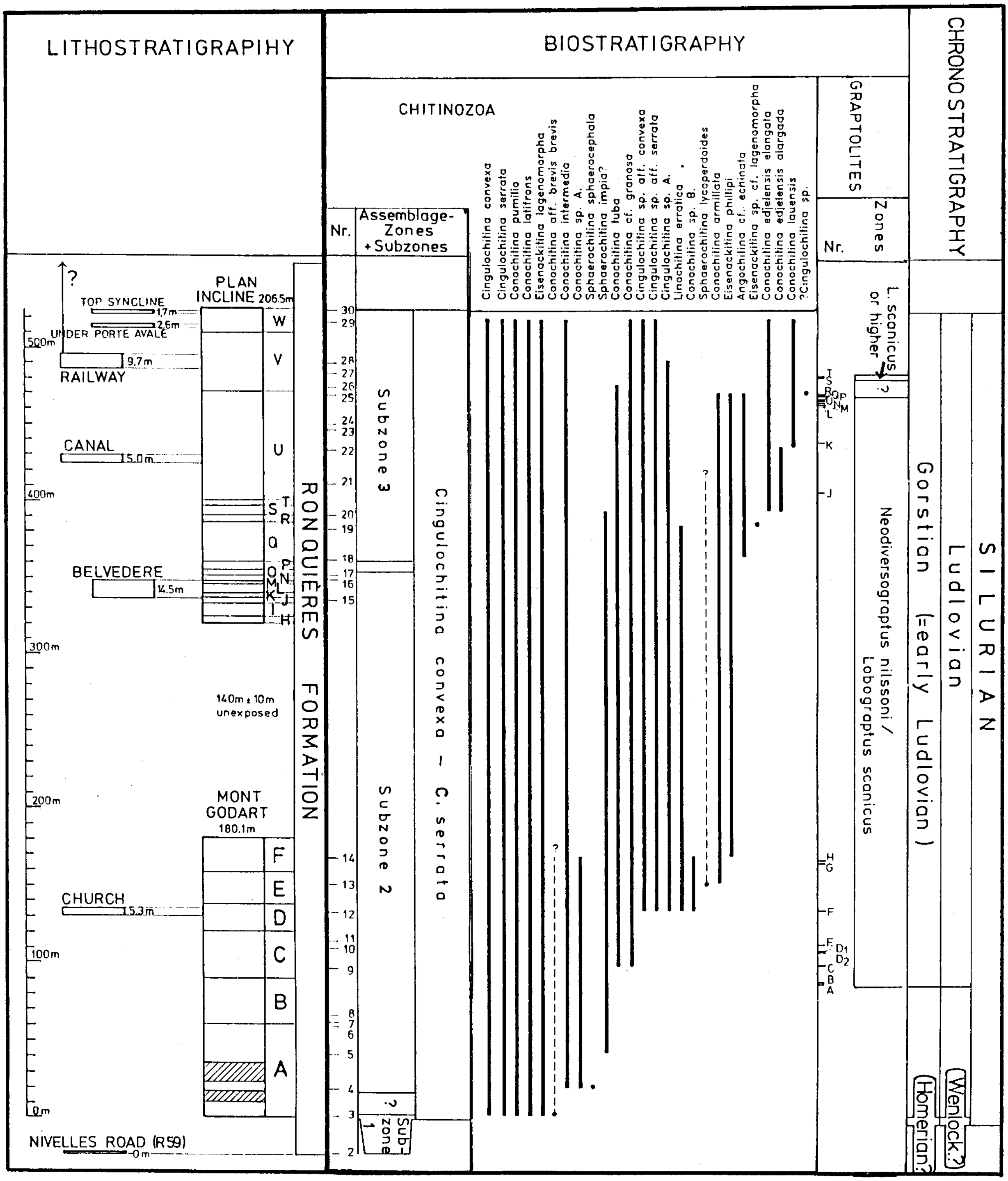


Fig. 35: Biostratigraphy with Chitinozoa of the Silurian of the Ronquières area.
Unit A in the Mont Godart section is the Mont Godart formation.

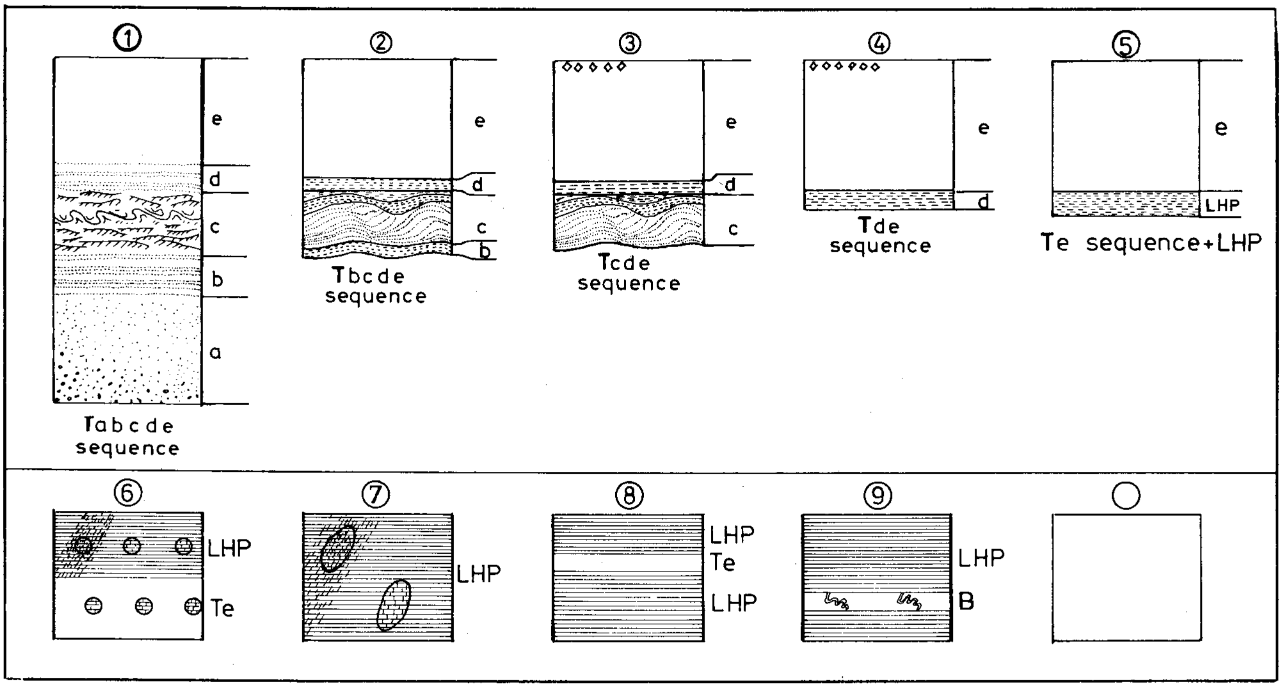


Fig. 36: The different sedimentological types in the Silurian of the Ronquières area. (1) to (5) turbiditic Bouma sequence: (1) Tabcde, (2) Tbcde, (3) Tcde, (4) Tde, (5) Te + LHP (lamellated hemipelagites); in the top 5 mm of a Te division or in the bottom of a Td division pyritospheres can occur. (5) to (9): lamellated hemipelagites (LHP); (6) cigar-shaped calcareous nodules, above in LHP, below in a Te division, (1-3 cm Ø x 10-20 cm L); the slaty cleavage is folded around the nodules; (7) bread-shaped calcareous nodules in LHP (15-25 cm Ø x 5-15 cm H); the slaty cleavage is passing undisturbed through the nodules; (8) minor Te turbiditic incursion in the LHP; (9) cream-coloured, very fine grained beds (1-6.5 cm thick) with a floor of coarser grains (B: meta-bentonites) in LHP; contorted quartz-veins present.

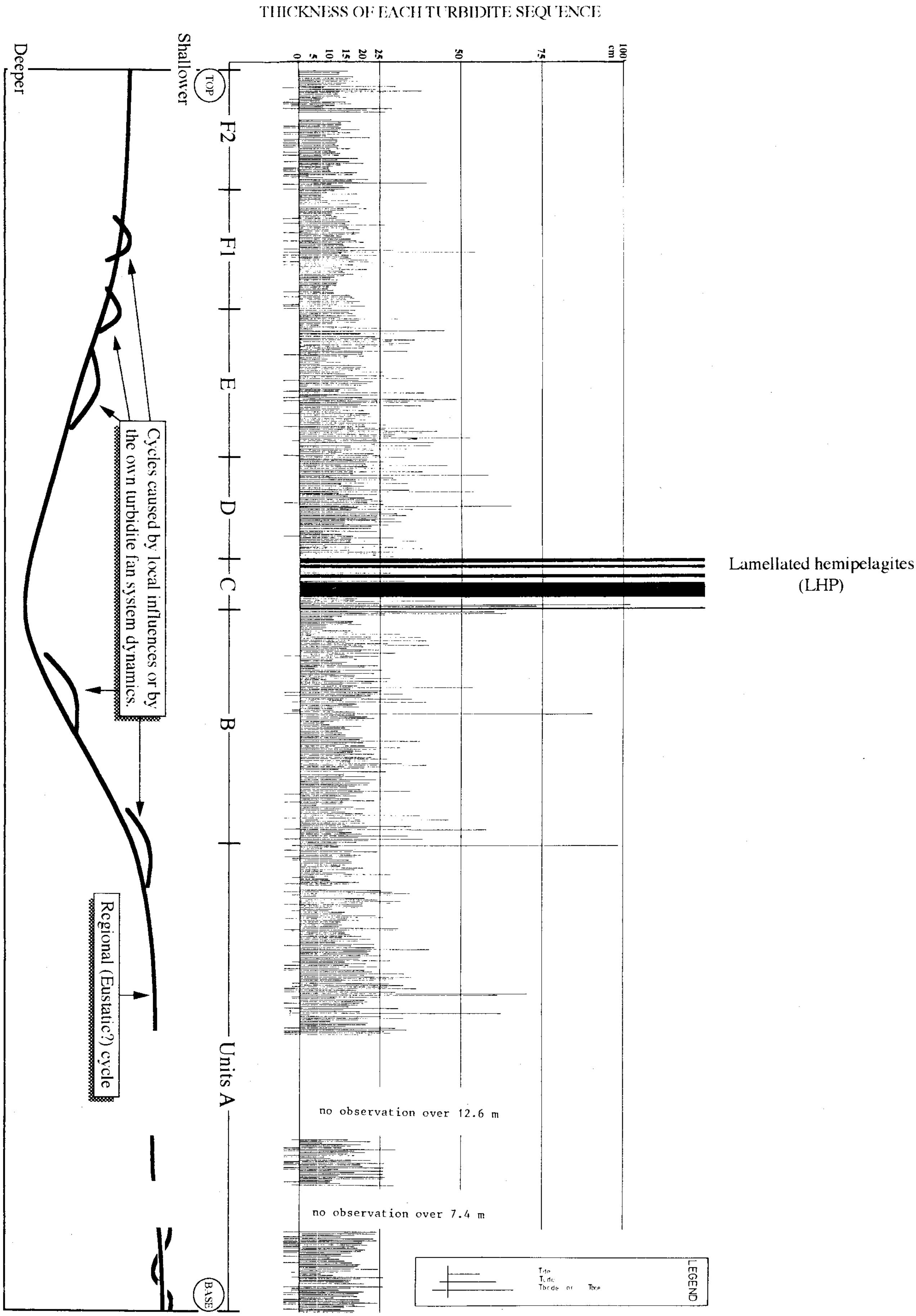


Fig. 37: Elements of the megacyclical variation in the Mont Godart sections, of the Ronquières formation; local, regional and eustatic influences. Unit A is the Mont Godart formation.

2. CALEDONIAN MAGMATISM

DAY 2: Saturday 23 September 1989

(L. ANDRE)

An overall account of the Caledonian magmatism is presented together with their geotectonic implications concerning the Early Palaeozoic plate tectonic reconstructions. Details for the areas visited are given in the beginning of the description of each localities.

2.1. MAIN FEATURES OF THE MAGMATISM

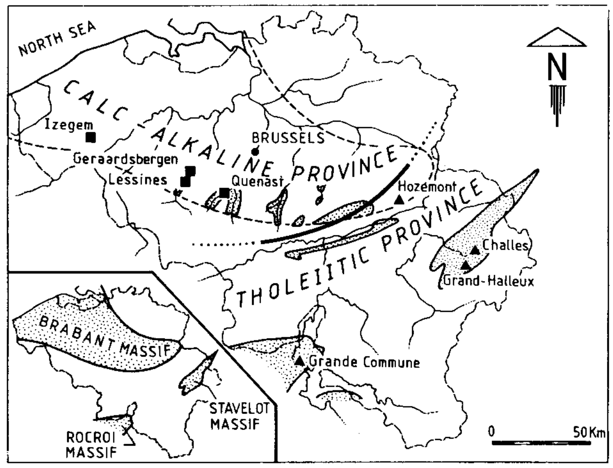


Fig. 38: Location of the two distinct Caledonian magmatic provinces.

In Belgium, the Caledonian (Ordovician-Silurian) magmatic activity extends to the four main Caledonian units: the Brabant Massif, the Sambre-Meuse belt (=Condroz Ridge), the Stavelot Massif and the Rocroi Massif. Two main provinces (Fig. 38) have been recognized (André *et al.*, 1986a) on the basis of the major elements (Fig. 39), trace elements (Fig. 40) and the Nd isotopic composition (Table 1):

- a north-western calc-alkaline province in the Brabant Massif;
- a south-eastern "back-arc" tholeiitic province that covers both the eastern part of the Brabant Massif and the "Ardennes" massifs.

In the Brabant Massif, the magmatic activity extends from the Upper Ordovician up to the Middle Silurian. It is concentrated along an arcuate belt that fits the southern margin of the Brabant Massif (Fig. 41). This magmatic belt is found to be associated with negative gravity anomalies that could indicate the presence of batholithic bodies (Legrand, 1968) at shallow depths (< 10 km) (De Meyer, 1983, 1984). Three major magmatic centres have been identified: a western, under the Flanders; a central, south of Brussels; an eastern, along the Meuse River.

The western centre is located around Deerlijk (Fig. 41). It is concealed under the Cenozoic cover and has been identified by numerous boreholes which encountered various rock types: lavas (Roeselare), breccias (Izegem, Kuurne); ash-flow tuffs (Deerlijk) and volcanoclastic deposits (Vichte, Pittem, Kuurne). The rock of the region are almost entirely Upper Ordovician (Ashgill) or Silurian in age and andesitic to rhyolitic in composition with a lack of basaltic members. All these rocks came out from similar calc-alkaline mantle sources, but they are not comagmatic because they derived from different parental magmas that evolved through different low-pressure crystal fractionation paths.

The central centre is located between Deftinge and Nivelles. Its activity culminated in the Caradoc-Llandovery time span. The rocks are made up of subvolcanic bodies (plugs, sills), lavas, tuffs and some volcanogenic sediments. They are mostly intermediate in composition (acid andesites and dacites) with a few scarce rhyolitic tuffs. The subvolcanic bodies contain a lot of cognate inclusions that appear to be coeval (André & Deutsch, 1984) and comagmatic to their host rocks. The calc-alkaline magmatic rocks derived from similar parental magmas through identical low-pressure crystal fractionation processes where plagioclase is the dominant separated mineral phase.

The eastern centre is located between Grand-Manil and Visé. It is partly concealed under the Upper Palaeozoic, Mesozoic and Cenozoic covers. The magmatic activity, essentially bimodal (basaltic and rhyolitic), culminated during the Silurian. The basaltic magmas tholeiitic in composition, crystallized as pillow lavas (Voroux-Goreux), but small intrusions of gabbros are also found. They probably represent high-level stocks crystallizing from the same magmas. The rhyolitic magmas generally erupted explosively and produces a lot of tuff deposits. These eruptions were however less gas-charged than those of the western centre since, up to now, no true ash-flow tuffs has been reported from this region. The genetic relationships between the basaltic and rhyolitic magmas have not yet been established.

Except the rare preservations of relict primary plagioclase, clinopyroxene and hornblende in several (chiefly hypabyssal) rocks, most original mineralogical features have been obliterated by greenschist facies recrystallizations related to the late magmatic hydrothermal activities (André & Deutsch, 1986), the early Lochkovian penetrative deformation (André, ms 1983) or the late Givetian stresses developed along the Oudenaarde-Bierghes fault zone (André & Deutsch, 1985).

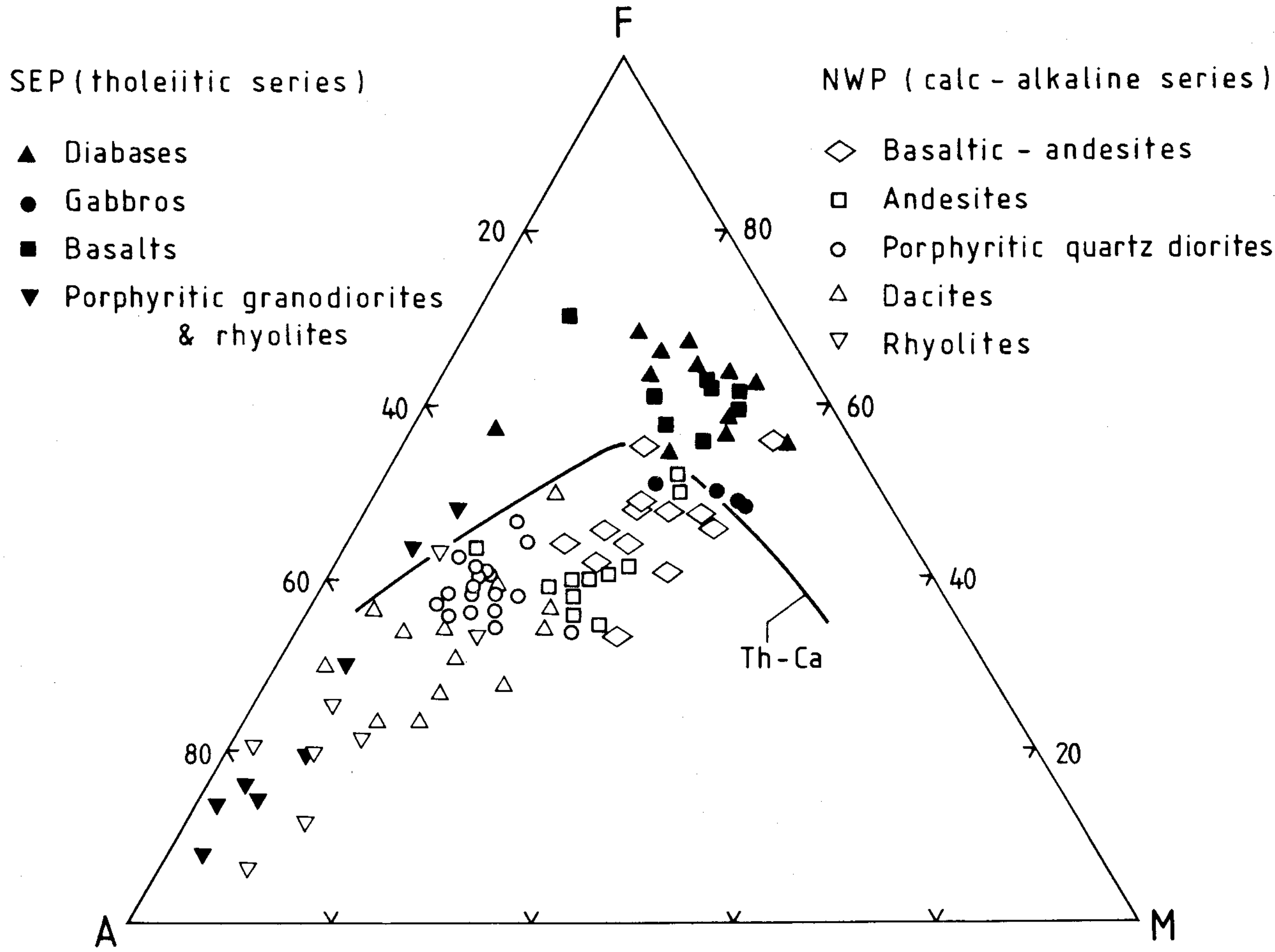


Fig. 39: AFM diagram of the igneous rocks from the northwestern and the southeastern provinces.

2.2. GEODYNAMIC INTERPRETATIONS

The juxtaposition of penecontemporaneous calc-alkaline and "back-arc" tholeiitic basic rocks indicates that the Ordovician-Silurian magmatism in the Brabant and Ardennes Massifs originated in a destructive plate margin environment. The spatial arrangement of the calc-alkalic and tholeiitic magmatic provinces (Fig. 38) argues for a SSE dipping benioff zone beneath the Midlands-Brabant craton. This subduction zone is proposed to mark the Ordovician-Silurian closure of the mid-european ocean (Fig. 42), the existence of which have been postulated on the basis of independent faunal and palaeomagnetic evidences (Whittington and Hughes, 1972; Cocks & Fortey, 1982; Perroud *et al.*, 1984).

This interpretation is strongly supported by the discovery of a juvenile late Precambrian volcanogenic source derivation for the early Cambrian sediments from the Brabant and Stavelot Massifs (André *et al.*, 1986; André, 1991). Indeed, since late Precambrian («Panafrican») volcanic activities are widespread over Gondwana but largely missing in Baltica (even in the Dalradian province from southern Norway), this is consistent with a provenance of these sediments from a predominantly southern source in Gondwana, before the drifting of the Midland-Brabant block from Gondwana to Baltica (Fig. 42).

2.3. KEY LOCALITIES

The aim of the excursion is to visit representative rock-types of each observed mode of emplacement. The field trip will focus on the intermediate (andesitic-dacitic) rocks from the central magmatic zone: a volcanic complex (the Fauqué complex); a plug (the Quenast plug) and a sill complex (the Lessines complex).

2.3.1. LOCALITY 1: THE FAUQUÉ VOLCANIC COMPLEX

2.3.1.1. Introduction

The Fauqué volcanic complex is made up of dacitic lavas, breccias and tuffs interbedded in the Upper Ordovician slates. The volcanic activity began by dacitic tuffs and mud-flow breccias composed of poorly sorted volcanic clasts supported within mudstones

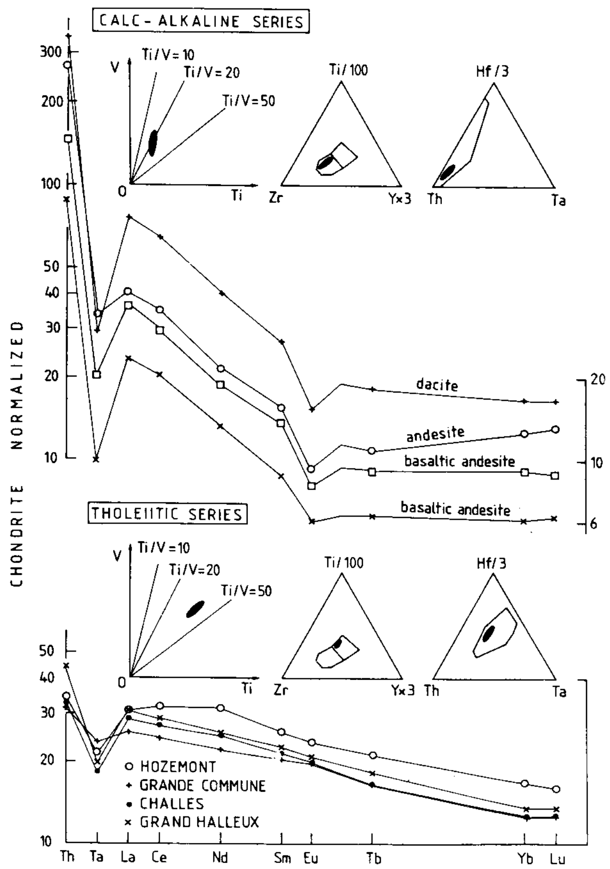


Fig. 40: Trace element characteristics of representative samples from calc-alkaline and tholeiitic series. insets show position of all analyzed basic to intermediate samples in Ti-V, Ti-Zr-Y, and Hf-Ta-Th discriminant diagrams.

matrices. These basal deposits are successively overlain by porphyritic dacitic lavas and graded-bedded coarse-grained tuffs. The activity virtually ended by a series of fine-grained tuff horizons interbedded above the volcanic complex in the Ordovician slates. Laterally, from N.W. to S.E. (Fig. 43), the complex gradually becomes thinner and the lithologies change from predominant lavas (point 2, Fig. 43), to predominant coarse-grained tuffs (point 1, Fig. 43). According to the geochemical data, the volcanic products are likely to derive from the Quenast vent located 4 km to the N.W. Therefore, these modifications in the lithology and the thickness of the complex are probably the consequence of the gradual increase of the distance from the eruption site.

2.3.1.2. Stop 2.1: Canal section (point 2, Fig. 43)

This outcrop exposes the eastern extension of the volcanic complex. This is a 20 m-thick volcanoclastic unit dipping S.E. The central part of the volcanic rock is made up of an unsorted tuff with lithic volcanic and shale fragments in a sandy matrix, the outer parts of white, strongly cleaved, fine-grained tuffs.

2.3.1.3. Stop 2.2: Bois des Rocs (point 1, Fig. 43)

The Fauqué brook has denuded a large section in the 100 m-thick dacitic lavas that characterizes the eastern part of the Fauqué complex; the rock is made up of various phenocrysts: plagioclase altered in albite, pyroxenes altered in chlorite and quartz. They are incorporated in a quartz-feldspathic sugary mesostasis or in a very fine-grained microlithic groundmass that locally exhibits a trachytic texture. The lava includes a lot of large slate xenoliths (up to 30 cm) and small (< 5 cm) comagmatic inclusions.

The trachytic texture has been used among other characteristic features (orientation of some breccia facies, inclination of the slates xenoliths) to determine the trend (N70°W) and the dip (40°N) of the lava flow. Two main facies have been distinguished:

- a foliated (N70°W 55°N) dacitic lava, to the north of the brook;
- a homogeneous dacitic lava to the south of the brook.

2.3.2. LOCALITY 2: THE QUENAST PLUG

2.3.2.1. Introduction

The Quenast quartz diorite forms a 2 km-wide elliptic plug-like body which is worked in a large quarry at 25 km to the SW of Brussels (Fig. 44). It outcrops amid the Upper Ordovician slates of the southern border of the Brabant Massif. Its northern limit is however followed by two subvertical zones of W.E. to N.W.-S.E stretching breccias and mylonites that have displaced the intrusion relatively to its metamorphic aureole. These fault zones are two western extension of the late Givetian Oudenaarde-Bierghes strike-slip mylonitic fault zone (André & Deutsch, 1985).

Before alteration, this hypabyssal intrusion consisted of homogeneous hornblende porphyritic quartz diorites made up of plagioclase (An:42-57), hornblende, quartz and ilmenite phenocrysts. The first two minerals are usually transformed into various low-temperature assemblages wherein they are sometimes preserved as very fine-grained inclusions (< 20 μm). Ilmenite, rimmed by sphene and rutile, is often partly unaltered.

In its upper part, the Quenast plug displays four concentric alteration zones whose secondary greenschist-facies parageneses were developed during a hydrothermal event at 438+/-28 Ma (Rb-Sr on whole rocks, André & Deutsch, 1986), shortly after the emplacement of the magma at 433+/-10 Ma (U-Pb on zircons, André & Deutsch, 1984). Each zone is defined by the nature of the minerals formed during the alteration of the phenocrysts (Fig. 44). From the border

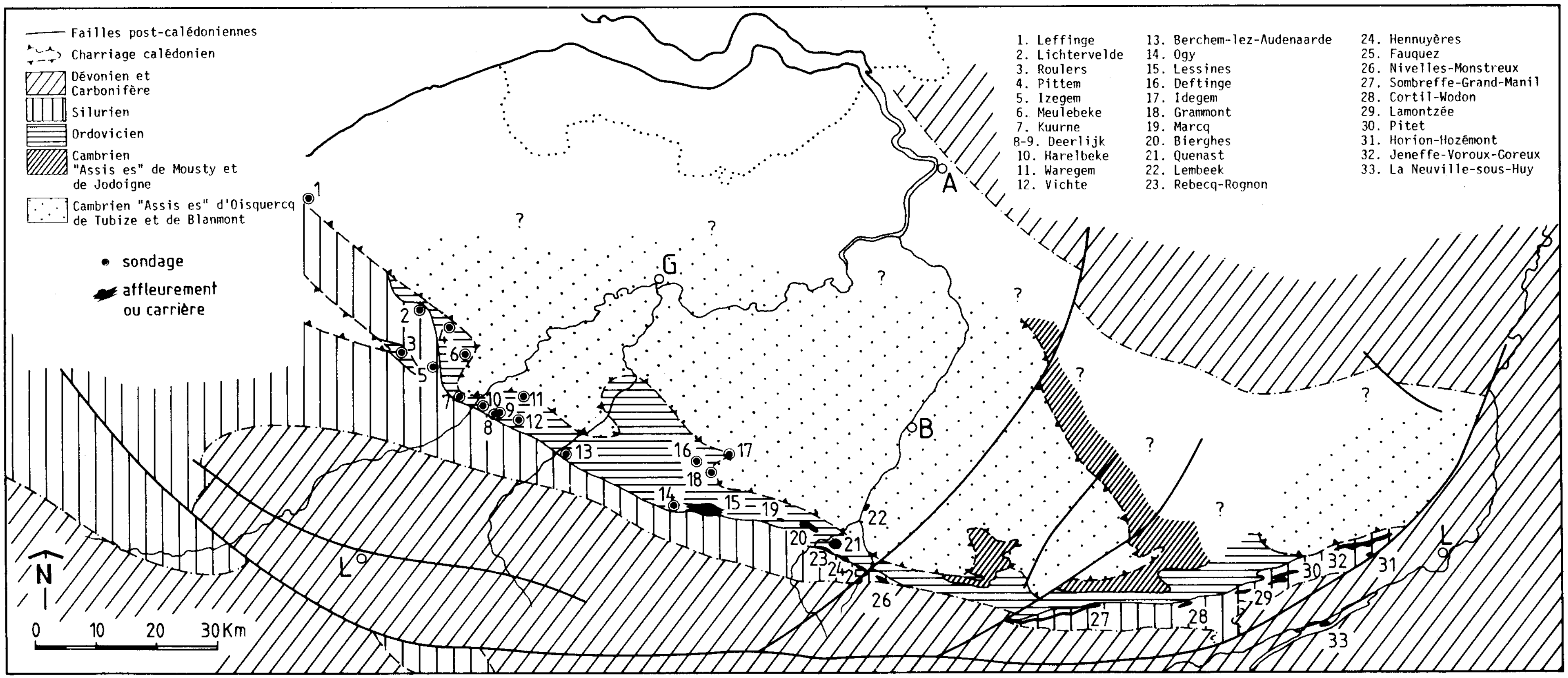


Fig. 41: Location of the magmatic rocks in the Brabant Massif.

to the centre of the plug, the plagioclase and hornblende phenocrysts are respectively transformed into: (1) albite + muscovite + calcite and muscovite + chlorite + calcite parageneses in the outer "calcite-muscovite-chlorite" (C.M.C.) zone; (2) albite + epidote and chlorite + biotite + epidote associations in the "zoned epidote" (Z.E.) zone; (3) albite + epidote and chlorite + epidote in the "epidote nodule" (E.N.) zone; (4) albite + chlorite + K-feldspar and chlorite + epidote mineral assemblages in the central "epidote-chlorite-K.feldspar" (E.C.K.) zone. With increasing depth in the quarry, the Z.E. and E.N. zones are replaced by a

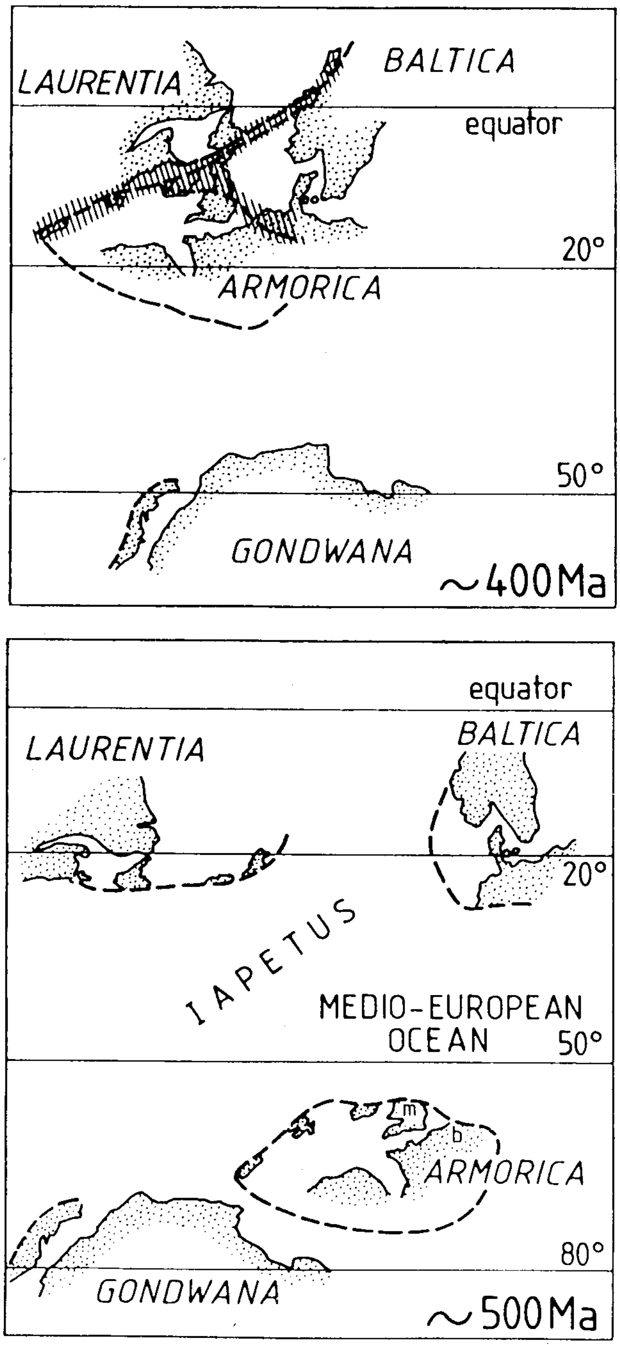


Fig. 42: Palaeogeographical reconstructions for the interval ±500 to ±400 Ma ago (after Perroud *et al.*, 1984; André *et al.*, 1986a). Abbreviations: m: Midlands Microcraton; b: Brabant craton.

biotite zone. The amphiboles are there entirely transformed into various types of biotites, but the plagioclases may be unaltered or partly converted to albite + K-feldspar + phengite.

The textural pattern of the matrix is variable from the outer to the inner zones of the plug. In the outer C.M.C. zone, the aplitic matrix is a saccharoidal equigranular mixture of fine-grained (0.1 mm) quartz and alkali feldspars with chlorite or biotite. In the central E.C.K. zone the aplitic texture is obliterated by the growth of a poikiloblastic K-feldspar which produces a ragged unequigranular perthitic groundmass.

Epidote is the most frequent secondary mineral. Its abundance increases from the outer rim of the Z.E. sector to the E.N. zone where this mineral composes up to 30 volume per cent (vol %) of the rock. In the E.N. zone, it is partly concentrated in large (1 to 15 cm

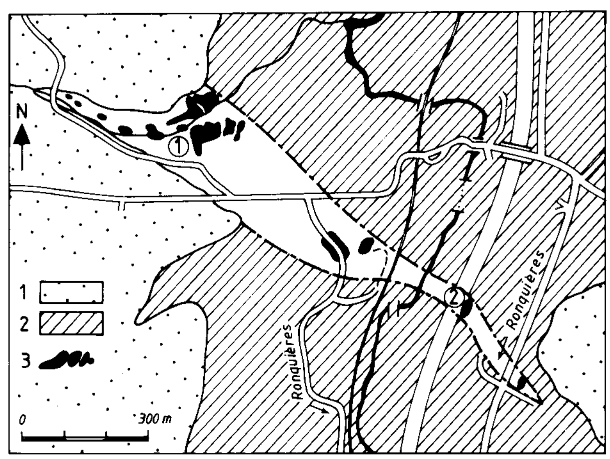


Fig. 43: Detailed geological map of the Fauqué volcanic complex. Abbreviations: 1: Cenozoic cover; 2: Ordovician slates; 3: outcrops of magmatic rocks.

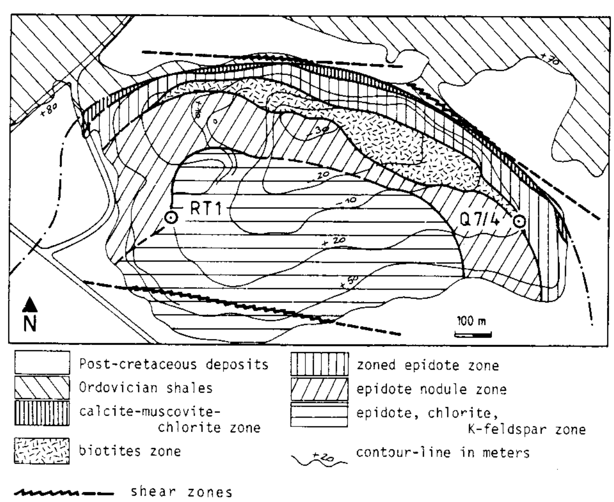


Fig. 44: Detailed geological map of the large active quarry in part of the Quenast plug, showing the distribution of the main hydrothermal alteration zones, with position of the two samples for isotopic studies.

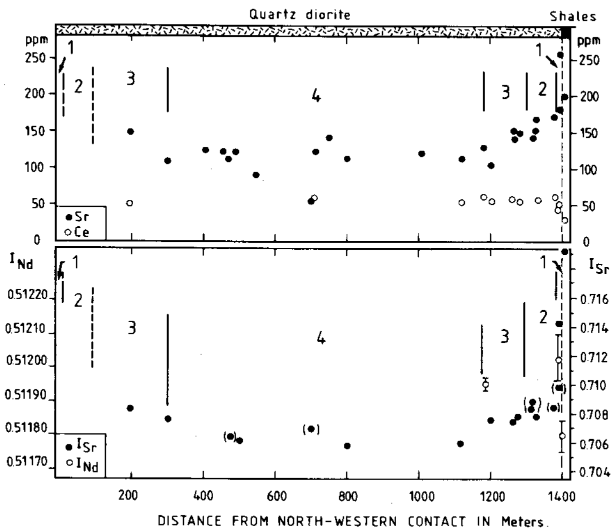


Fig. 45: Initial $^{87}Sr/^{86}Sr$, $^{143}Nd/^{144}Nd$, Sr and Ce data for the Quenast plug rocks as a function of the distance from the border of the intrusion (1= calcite + muscovite + chlorite zone; 2= zoned epidote zone; 3= epidote nodules zone; 4= epidote +chlorite + K-feldspar zone). The points between brackets correspond to samples collected outside the W.N.W.-E.S.E. section.

in diameter) subspheric nodules (70-90 vol % of epidote, 10-30 vol % of quartz) that line up in bands parallel to the margin of the plug. In contrast, in the E.C.K. zone, the epidote abundance quickly decreases to reach less than 5 vol % in the middle of the plug. A few scarce, widely spaced, calcite + adularia-rich and epidote-rich veins of a millimetre scale occur in the C.M.C. and Z.E. zones respectively. In the E.C.K. zone, the 1 mm-wide epidote-rich veins are often spaced by more than several tens of meters.

A Sr isotopic survey (Fig. 45) has shown that the hydrothermal alteration is due to the convective circulation of connate water. The E.N. zone is inferred to have evolved as a filter between two hydrothermal system: an outer widely open to the Sr coming from the country rocks and a central one relatively closed for Sr and transformed by connate water filtered for Sr.

The rock includes a lot of xenoliths and cognate inclusions. Most of them have been deeply transformed during the hydrothermal alteration of the quartz diorite. Four types of xenoliths have been identified: gneisses, basic metamorphic rocks, spotted slates and metasediments. The last two groups are distinctly the most frequent. Two main types of cognate inclusions have been encountered. The most frequent consist of black to greenish, small to large (1 cm to 3 m), microgranular inclusions ranging in texture from fine-grained diabasic rocks to plagioclase-rich porphyritic rocks. The other group of cognate inclusion is made up of a white plagioclase orthocumulate. These inclusions are coeval to the quartz diorite

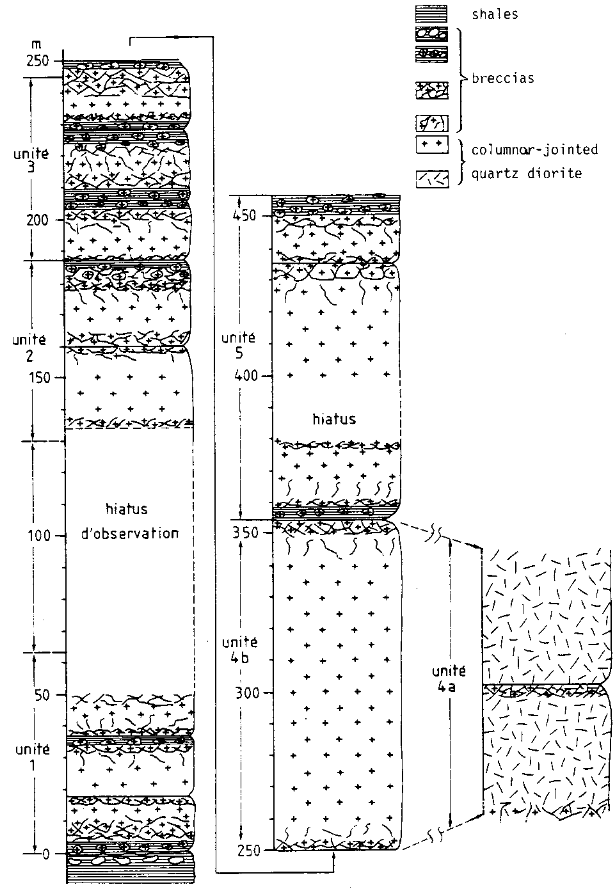


Fig. 46: Thickness and lithology of the various sills from the lower part of the Lessines complex.

(André & Deutsch, 1984). These microgranular inclusions represent the various generations of chilled margins formed in the successive stock-like intrusions wherein the parental magmas of the quartz diorite have passed along. They reveal a continuous record of the crystallization of the parental magmas of the quartz diorite. According to the geochemical data, the evolution of the liquid line of descent has been mainly controlled by the crystallization of plagioclase, in agreement with the presence of plagioclase cumulate inclusions. The geochemical modelling (André, ms 1983) has pointed out that the quartz diorite corresponds to the residual liquid of the separation of about 75 vol % of a mineral assemblage made up of plagioclase (70 %), clinopyroxene-amphibole (25 %) and Ti-Fe oxides (5%).

2.3.2.2. Stop 2.3: General view on the quarry

A general point of view on the Quenast quarry can be seen from the S.W. border of the pit where the following features can be observed:

- the pre-Cretaceous erosion surfaces;
- the Mesozoic-Cenozoic cover that conceals the porphyritic intrusion. The pre-Cretaceous erosion surface is characterized by a chaotic ball-type

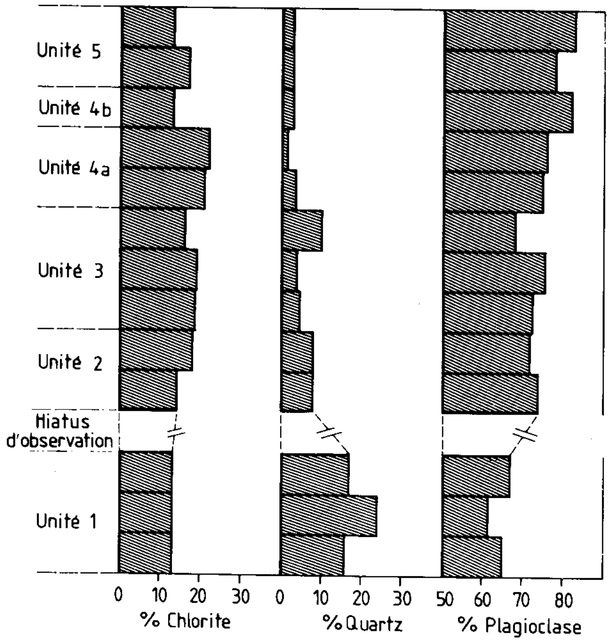


Fig. 47: Variations in the phenocrysts relative proportions for the Lessines sills.

arena alteration reworked by a marine transgression. From base to top the horizontal cover is made up of:

- discontinuous thin rosy Cretaceous chalk deposits; brown sandy clays of the Landen Formation (Upper Palaeocene, Thanetian);
- blue-grey clays of the Ieper Group (Early Eocene, Ypresian);
- Yellow-orange sands of the Brussels Formation (Middle Eocene, Lutetian);
- Quaternary sands & loams.

2.3.2.3. Stop 2.4: Visit of the second floor of the quarry

The second floor of the quarry exposes a very good section through the different hydrothermal alteration zones. The hydrothermal flow banding structures are very well exposed. They are locally planar and approximately parallel to the contact with the Ordovician slates, but in place they turn out to be highly contorted. The different sorts of inclusions will be described.

2.3.3. LOCALITY 3: THE LESSINES COMPLEX

2.3.3.1. Introduction

The Lessines porphyritic quartz diorite forms a 800 m-thick sill-like body dipping 25°-30° S.S.W. (Legrand & Mortelmans, 1948). According to an electric geophysical survey (Tavernier *et al.*, 1967), its lateral extension would exceed 10 km. The rock has been worked in about 25 quarries scattered around the town of Lessines. The contact between the magmatic rock and the Upper Ordovician black shales has been observed in an old quarry (Legrand & Mortelmans, 1948) and in various boreholes (a 435 m deep borehole implanted in 1987 in the "Carrières Unies" quarry encountered the surrounding shales at a deep of 145.5 m).

The sill complex is made up of a series of sills (11 in the first 450 m, Fig. 46). Their thickness is in the range: 20-100 m. Each sill is composed of a central homogeneous quartz diorite fringed upwards and downward by breccias made up of unsorted porphyritic blocks in a "mudstone" matrix. The central part of these sills are divided into prisms and irregular polygonal columns. The breccias and the columnar jointing are two different sorts of stress fractures related to the contraction due to cooling of the solidified magmas.

The primary mineral composition of the various sills are almost similar. All are characterized by quartz, plagioclase and ferromagnesian phenocrysts coated in a spherulitic or sugary quartz-feldspathic mesostasis. However, the relative proportion of the phenocrysts slightly changes from the base upwards (Fig. 10) showing that the composition of the magma moved from dacitic to acid andesitic compositions. Like the Quenast quartz diorite, this rock contains a lot of microgranular inclusions which reveal a nearly continuous record of crystallization of its parental magmas.

The Lessines complex has also been affected by a late-magmatic hydrothermal activity 414+/-16 Ma (Rb-Sr on whole rocks, André & Deutsch, 1984). This caused the development of a secondary mineral zonation parallel to the margin of the intrusion. From the border to the centre of the complex, the plagioclase and hornblende phenocrysts are respectively transformed into:

(1) albite + muscovite + calcite and muscovite + chlorite + calcite + pyrite parageneses in the outer "calcite-muscovite-chlorite" zone in the units 1, 2 and 3 (Fig. 46);

(2) albite + chlorite +/- K-feldspar and chlorite + epidote mineral assemblages in the central epidote-chlorite zone in units 4 and 5 (Fig. 46).

Finally, the intrusion has been cut by several networks of faults that have been reworked several times up to the Cretaceous.

2.3.3.2. Stop 2.5: Visit of the "Ermitage" quarry

A section along the northeastern part of the second floor of the quarry exposes the thicker unit 4b. This 100 m-thick sill, limited on its both sides by two faults, is characterized by a very regular development of the columnar jointing (dipping 70° to the N.N.E.).

The northern part of the section exposes a gradual transition between the columnar facies and the breccia facies.

BIBLIOGRAPHY

ANDRE, L., ms 1983. Origine et évolution des roches éruptives du massif du Brabant (Belgique). Unpubl. Ph.D. thesis, Université Libre de Bruxelles, Belgium, 422 p.

ANDRE, L., 1991. The concealed crystalline basement in Belgium and the «Brabantia» concept : constrains from the Caledonian magmatic and sedimentary rocks. *In:* L. André, A. Herbosch, M. Vanguestaine and J. Verniers (eds), Proceedings of the International Meeting on the Caledonides of the Midlands and the Brabant Massif, Brussels, 20 to 23 september 1989. Ann. Soc. géol. Belg., 114 (1): 117-139.

ANDRE, L. & DEUTSCH, S., 1984. Les porphyres de Quenast et de Lessines: géochronologie, géochimie isotopique et contribution au problème de l'âge du socle précambrien du massif du Brabant (Belgique). Bull. Soc. belge Géol., 93: 375-384.

ANDRE, L. & DEUTSCH, S., 1985. Very low-grade metamorphic Sr isotopic resettings of magmatic rocks and minerals: Evidence for a late Givetian strike-slip division of the Brabant massif (Belgium). Journ. Geol. Soc. London, 142: 911-923.

ANDRE, L. & DEUTSCH, S., 1986. Magmatic 87Sr/86Sr relicts in hydrothermally altered quartz diorites (Brabant massif, Belgium) and the role of epidote as a Sr filter. Contrib. Mineral. & Petrol., 92: 104-112.

ANDRE, L., HERTOGEN, J. & DEUTSCH, S., 1986a. Ordovocian-Silurian magmatic provinces in Belgium and the Caledonian orogeny in Middle Europe. Geology, 14: 879-882.

ANDRE, L., DEUTSCH, S. & HERTOGEN, J., 1986b. Trace-element and Nd isotopes in shales as indexes of provenance and crustal growth; the Early Paleozoic from the Brabant Massif (Belgium). Chemical Geol., 57: 101-115.

ANTOINE, R. & P., 1943. Les assises de Mousty et de Villers-la-Ville du bassin supérieur de la Dyle. Ann. Soc. Géol. Belg., 66: M53-170.

BEUGNIES, A., DUMONT, P., GEUKENS, F. MORTELMANS, G. & VANGUESTAINE, M., 1976. Essai de synthèse du Cambrien de l'Ardenne. Ann. Soc. Géol. Nord, 96: 263-273.

BEUGNIES, A., 1973. Le Cambro-Silurien brabançon et le Dévono-Carbonifère du flanc septentrional de Namur. Coupe de Tubize-Quenast-Fauquez-Feluy. *In:* Ardennes. Guides géologiques régionaux. Itinéraire 10, pp. 89-98. Paris : Masson.

COCKS, L.R.M. & FORTEY, R.A., 1982. Faunal evidence for oceanic separation in the Palaeozoic of Britain. Journal Geol. Soc. London, 139: 465-478.

DANDOIS, P., ms 1983. Le métamorphisme des terrains paléozoïques de la partie médio-occidentale de l'Ardenne: une approche de l' extension de la zone métamorphique par l' étude des minéraux phyllosilicates de la fraction argileuse des roches silico-alumineuses. Unpubl. Ph. D. thesis, Univ. Cath. Louvain, 1-194.

DE LA VALLEE-POUSSIN, J., 1931. Contribution à l'étude du Massif "Cambrien" dans les vallées de la Dyle et de la Gette. Mém. Inst. Géol. Louvain, 6 (3): 319-353.

DE MEYER, F., 1983. Gravity interpretation of the Western flank of the Brabant Massif. Konink. Meteorologish Inst. België, Publicaties, ser. A (111): 1-34.

DE MEYER, F., 1984. Two structural models for the Western flank of the Brabant Massif. Geophys. Prospect., 32: 37-50.

FOURMARIER, P., 1921. La tectonique du Brabant et des régions voisines. Mém. Acad. roy. Belgique, Cl. Sc., 2_ sér., 4: 41-50.

GEUKENS, F., 1981. Observations géologiques dans la région de Willerzie. Ann. Soc. Géol. Belg., 104: 67-73.

HERBOSCH, A., 1989. Comparison of Ordovician lithostratigraphic units, southern part of the Brabant Massif. Abstracts of the International Meeting on the Caledonides of the Midlands and the Brabant Massif, Brussels, 14.

HERBOSCH, A., VANGUESTAINE, M., DEGARDIN, J.M., DEJONGHE, L., FAGEL, N. & SERVAIS, T., 1991. Etude lithostratigraphique, biostratigraphique et sédimentologique du sondage de Lessines (bord méridional du Massif du Brabant, Belgique). *In:* L. André, A. Herbosch, M. Vanguestaine and J. Verniers (eds), Proceedings of the International Meeting on the Caledonides of the Midlands and the Brabant Massif, Brussels, 20 to 23 september 1989. Ann. Soc. géol. Belg., 114 (1): 193-211.

JODARD, C., ms 1986, Etude cartographique et pétrologique de l'Ordovicien inférieur de la Thyle. Unpubl. M. Sc. thesis, Université Libre Bruxelles, 1-145.

LECOMPTE, M., 1949. Découverte de nouveaux gîtes à Dictyonema dans le Trémadocien du Massif du Brabant. Bull. Inst. roy. Sci. nat. Belg., 25 (45): 1-8.

LEGRAND, R., 1967. Ronquières, documents géologiques. Serv. Géol. Belg., Mém., 6: 1-60.

LEGRAND, R., 1968. Le Massif du Brabant. Serv. Géol. Belg., Mém. 9, 1-148.

LEGRAND, R. & MORTELMANS, G., 1948. Un contact de la diorite quartzifère de Lessines et de l'Ordovicien. Bull. Soc. belge Géol., 57: 642-674.

LENOIR, J.L., ms 1987. Etude cartographique, pétrographique et palynologique de l'Ordovicien inférieure de la Senne. Unpubl. M. Sc. thesis, Université Libre Bruxelles, 1-119.

LESPERANCE, P.J. & SHEEHAN, P.M., 1988. Trilobites et brachiopodes ashgilliens (Ordovicien supérieur) de l'"Assise" de Fosse, Bande de Sambre-et-Meuse (Belgique). Bull. Inst. roy. Sc. nat. Belg., 57 (1987), 91-123.

MALAISE, C., 1911. Sur l'évolution de l'échelle stratigraphique du Siluro-cambrien de Belgique. Bull. Soc. belge Géol., Paléont., Hydrol., 24: 415-437.

MARTIN, F., 1969. Les acritarches de l'Ordovicien et du Silurien belge. Détermination et valeurs stratigraphique. Mém. Inst. roy. Sc. nat., 16O: 1-176.

MARTIN, F., 1976. Acritarches du Cambro-Ordovicien du Massif du Brabant, Belgique. Bull. Inst. roy. Sc. nat. Belg., 51 (1975): 1-33.

MARTIN, F. & RICKARDS, B., 1979. Acritarches, chitinozoaires et graptolithes ordoviciens et siluriens de la vallée de la Sennette. (Massif du Brabant, Belgique). Ann. Soc. géol. Belg., 1O2: 181-197.

MICHOT, P., 1954. Le Silurien in: Prodrôme d'une description géologique de la Belgique. 39-82.

MICHOT, P., 1978. L'Ordovicien de la vallée de la Thyle: structure tectonique, stratigraphie et lithologie. Ann. Soc. Géol. Belg., 100 (1977): 223-231.

MORTELMANS, G., 1955. Considération sur la structure tectonique et la stratigraphie du massif du Brabant. Bull. Soc. belge géol., 64: 179-218.

PERROUD, H., VAN DER VOO, R; & BONHOMMET, N., 1984. Paleozoic evolution of the Armorica plate on the basis of paleomagnetic data. Geology, 12: 579-582.

PICKERING, K.T., BASSETT, M.G. & SIVETER, D.J., 1988. Late Ordovician-early Silurian destruction of the Iapetus Ocean: Newfoundland, British Isles and Scandinavia - a discussion. Transact. Roy. Soc. Edinburgh: Earth Sciences, 79: 361-382.

PICKERING, K.T., BASSETT, M.G. & SIVETER, D.J., 1989. Erratum : Late Ordovician-early Silurian destruction of the Iapetus Ocean: Newfoundland, British Isles and Scandinavia - a discussion. Transact. Roy. Soc. Edinburgh : Earth Sciences, 80 : 69.

ROBASZYNSKI, F. & DUPUIS, C., 1983. Belgique. Guides Géologiques Régionaux, 204 p., Masson:Paris.

ROCHE, M., SABIR, M., STEEMANS, P., & VANGUESTAINE, M., 1986. Palynologie du sondage et de la région de Willerzie. Aardkundige Mededelingen, 3, 149-190.

SERVAIS, T., ms 1988. Litho- et biostratigraphie comparées d'Ordovicien des vallées de l'Orneau, de la Thyle, de la Sennette et du sondage de Lessines. Unpubl. M. Sc. thesis, Université de Liège.

SERVAIS, T., 1991a. Contribution to the stratigraphy of the Ordovician Rigenée formation (Brabant Massif, Belgium), with a preliminary study on acritarchs. *In:* L. André, A. Herbosch, M. Vanguestaine and J. Verniers (eds), Proceedings of the International Meeting on the Caledonides of the Midlands and the Brabant Massif, Brussels, 20 to 23 september 1989. Ann. Soc. géol. Belg., 114 (1): 233-245.

SERVAIS, T., 1991b. Discovery of turbiditical levels in the Late Ordovician of the Sennette Valley (Brabant Massif, Belgium). *In:* L. André, A. Herbosch, M. Vanguestaine and J. Verniers (eds), Proceedings of the International Meeting on the Caledonides of the Midlands and the Brabant Massif, Brussels, 20 to 23 september 1989. Ann. Soc. géol. Belg., 114 (1): 247-251.

SHEEHAN, P.M., 1988. Late Ordovicien (Ashgillian) brachiopods from the region of the Sambre and Meuse rivers, Belgium. Bull. Inst. roy. Sc. nat. Belg., 57 (1987), 5-81.

TAVERNIER, R., DE BREUCK, W. & DE MOOR, G., 1967. Geo-elektrisch onderzoek in de streek van Lessines. Meded. Koninkl. Vlaamse Academie Wetensch., Letteren en Schone Kunsten van België, 29: 1-63.

VANDER AUWERA, J. & ANDRE, L., 1985. Sur le milieu de dépôt, l'origine des matériaux et le faciès métamorphique de l'Assise de Tubize. Bull. Soc. belge Géol., 94 : 174-184.

VANGUESTAINE, M., 1977. Données palynologiques nouvelles dans l'Ordovicien inférieur du bassin de la Senne, Massif du Brabant, Belgique. Ann. Soc. géol. Belg., 100 : 193-198.

VANGUESTAINE, M., 1989. New palynological results from the Cambrian and Ordovician of the Brabant Massif. Abstracts Intern. Meet. Caledonides Midlands Brabant Massif, 15.

VANGUESTAINE, M., 1991. Datation par acritarches des couches cambro-trémadociennes les plus profondes du sondage de Lessines (bord méridional du Massif du Brabant, Belgique). *In:* L. André, A. Herbosch, M. Vanguestaine and J. Verniers (eds), Proceedings of the International Meeting on the Caledonides of the Midlands and the Brabant Massif, Brussels, 20 to 23 september 1989. Ann. Soc. géol. Belg., 114 (1): 213-231.

VERNIERS, J. & VAN GROOTEL, G., 1991. Review of the Silurian in the Brabant Massif, Belgium. *In:* L. André, A. Herbosch, M. Vanguestaine and J. Verniers (eds), Proceedings of the International Meeting on the Caledonides of the Midlands and the Brabant Massif, Brussels, 20 to 23 september 1989. Ann. Soc. géol. Belg., 114 (1): 163-192.

WALTER, R., 1980. Lower Paleozoic paleogeography of the Brabant Massif and its adjoining areas. Meded. Rijks Geol. Dienst, 32 (2), 14-25.

WHITTINGTON, H.B. & HUGHES, C.P., 1972. Ordovician geography and faunal provinces deduced from trilobite distribution. Roy. Soc. London Philosophical Trans., 263: 235-278.