Deutsche Stratigraphische Kommission

Exkursionsführer zum

Jahrestreffen der Subkommissionen für Karbonstratigraphie, Devonstratigraphie und Proterozoikum bis Silur

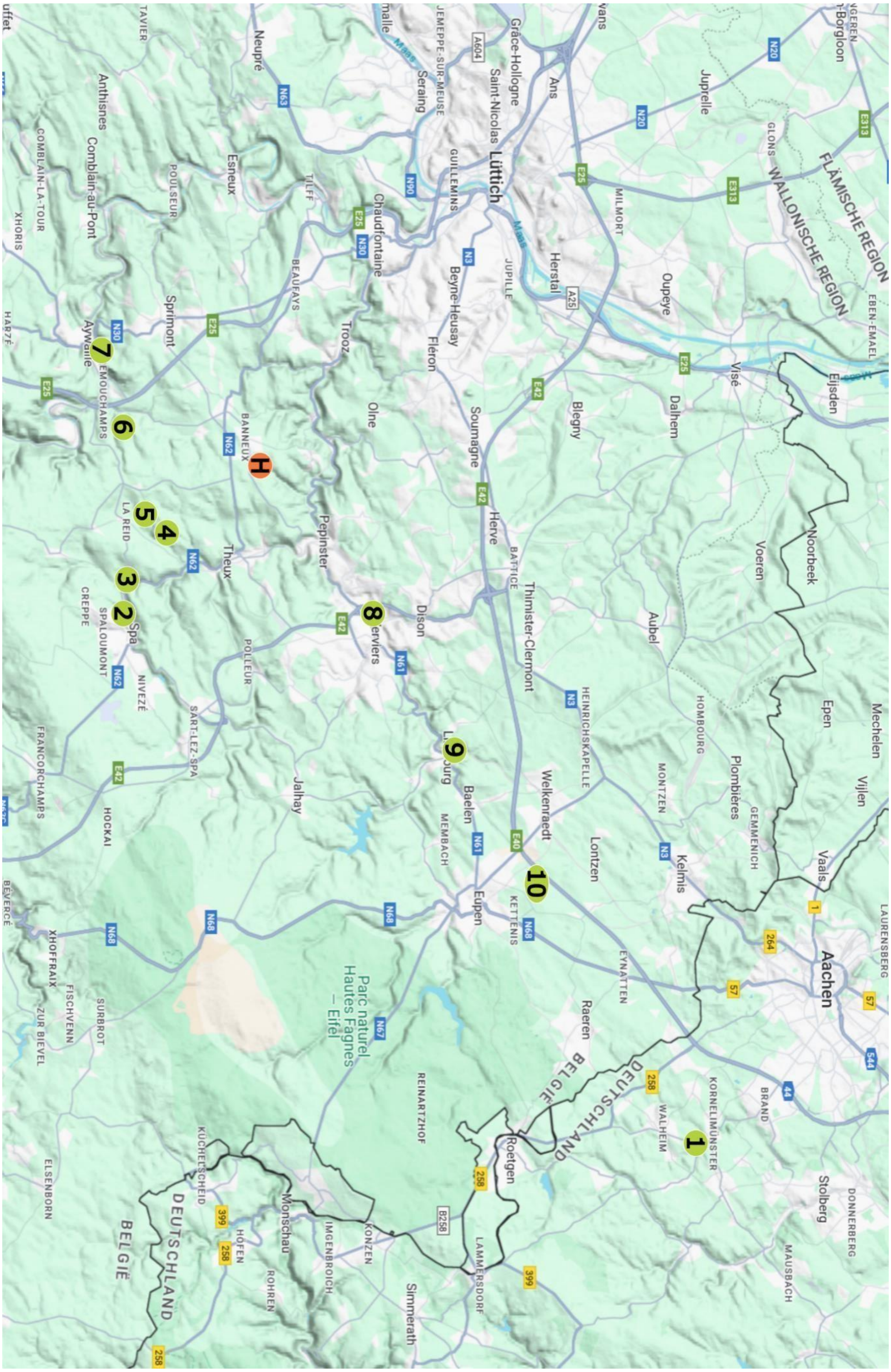
23. Mai bis 25. Mai 2025

Pepinster, Belgien östliche Wallonie und

Region Aachen

mit Beiträgen von : Julien Denayer, Jean-Marc Marion, Edouard Poty, Sven Hartenfels, Sarah Esteban Lopez & Sascha Sandmann

Geologischer Dienst NRW



[Stop localities, screenshot from maps.google.com]

Field trip itinerary

Friday, May 23rd 2025, Aachen region

Stop 1: Kornelimünster, cycle path along the former Vennbahn railway route

Saturday, May 24th 2025, eastern Wallonia

Stop 2: Spa – greetings, introduction and first point: Cambrian black shale of La Gleize Formation

Stop 3: Marteau – unconformity of the Pridoli-Lochkovian Fooz Formation on the Cambrian Jalhay Formation

Stop 4: La Heid de Fer at Theux – oolithic ironstone beds in Lower Famennian Hodimont Formation

Stop 5: Le Chaffour quarry at La Reid – Middle-Upper Frasnian Lustin and Aisemont Formation

Stop 6: Sécheval – Middle Devonian Pepinster Formation [time dependent]

Stop 7: La Heid des Gattes quarry – Lower to Upper Famennian transect (Marche-en-Famenne, Esneux, Souverain-Pré and Condroz formations)

Stop 8: Lambermont – Upper Frasnian Aisemont and Lambermont formations, Frasnian-Famennian Boundary

Stop 9: Dolhain section – uppermost Famennian Dolhain Formation, Devonian-Carboniferous Boundary, Tournaisian Hastière Formation

Sunday, May 25th 2025, eastern Wallonia

Stop 10: Carnol quarry at Eupen – continuous section from lower Tournaisian (Pont d'Arcole Formation) to Middle Visean (Lives Formation)

Stop 1: Kornelimünster, cycle path along the former Vennbahn railway route – a preliminary report

Fig. 1: Compiled photograph of the newly cleaned railway cut in early May 2025.

Introduction: The Devonian of the Rhenish Massif includes a wide range of small-sized biostromes to large biohermal reef complexes. They grew variably in times of reduced siliciclastic delivery from the Old Red Continent on the inner shelf (e.g. Wahlheim Reef Complex, Eifel, Bergisch Gladbach-Paffrath Syncline, Velbert Anticline, and Hagen-Balve Reef complexes) or at its margin (e.g. Attendorn and Brilon Reef complexes). In addition, reef grow occurred also on the top of volcanic seamounts within the outer shelf basin of the Rhenohercynian Ocean (e.g. Beringhauser Tunnel, Lahn-Dill Syncline). Most reefs are of Givetian age and drowned in the course of the global Taghanic Event or of lower/middle Frasnian transgressions (e.g. Frasnes, Timan, *semichatovae*, Middlesex events: Aboussalam and Becker 2016, Becker et al. 2016b, Hartenfels et al. 2016, Stichling et al. 2022, Becker and Aboussalam 2023). However, with the Upper Kellwasser Event, at the Frasnian/Famennian boundary, reef ecosystems collapsed on a global scale. Along with this devastating mass extinction event, a unique microbialitic reef with subordinate corals (Schlupkothen Member, Wülfrath Formation, Rohdenhaus North Quarry:
e.g. Becker et al. 2016a, Hartenfels et al. 2017) disappeared. Nowadays it represents the youngest known reef structure of the Rhenish Massif.

Globally, lager reef structures re-appeared after 65 million years during the Lower Permian leaving an enigmatic period, which is characterised by predominantly small buildups of low diversity (Copper 1989). Especially during the Famennian, the reef ecosystem was more or less unoccupied. Whereas microbial mounds occurred in the Canning Basin, Australia (e.g. Playford 1980) or Guilin area, province Guangxi, South China (e.g. Bao 1993), a deeper water microbial-crinoid-sponge mound was reported by Dreesen et al. (1985), among others, from the middle Famennian of eastern Belgium.

Middle Famennian, shallow-water stromatoporoid buildups are known from Alberta, Canada (Stearn et al. 1987) and a 1 m thick, stromatoporoid bearing sponge-microbe symbiont bed was reported from the upper Famennian Pinyon Peak Limestone, southwestern Utah, USA, by Stock and Sandberg (2019). Further uppermost Famennian (Strunian) stromatoporoid buildups can be found in the Krakow Upland, Poland (Berkowski 1994) and in western Europe (e.g. Conil 1964, Weber 2000a, Becker and Weber 2016). According to Herbig and Weber (1996), the occurrences in western Europe preserve the youngest stromatoporoid buildups of the world. These biostroms offer an excellent opportunity to study the recovery of the stromatoporoid reef ecosystem after one of the most dramatic extinction phases in earth history and followed almost immediately by its renewed collapse and complete disappearance from the geological record.

Thus, the succession at the railway cut of the former Vennbahn Tram (Figs. 1–2), which is nowadays one of the most beautiful long-distance cycle paths connecting the cities of Aachen and Troisvierges, Luxembourg, allows to investigate the re-blooming of stromatoporoid buildups in the short time interval of the Strunian.

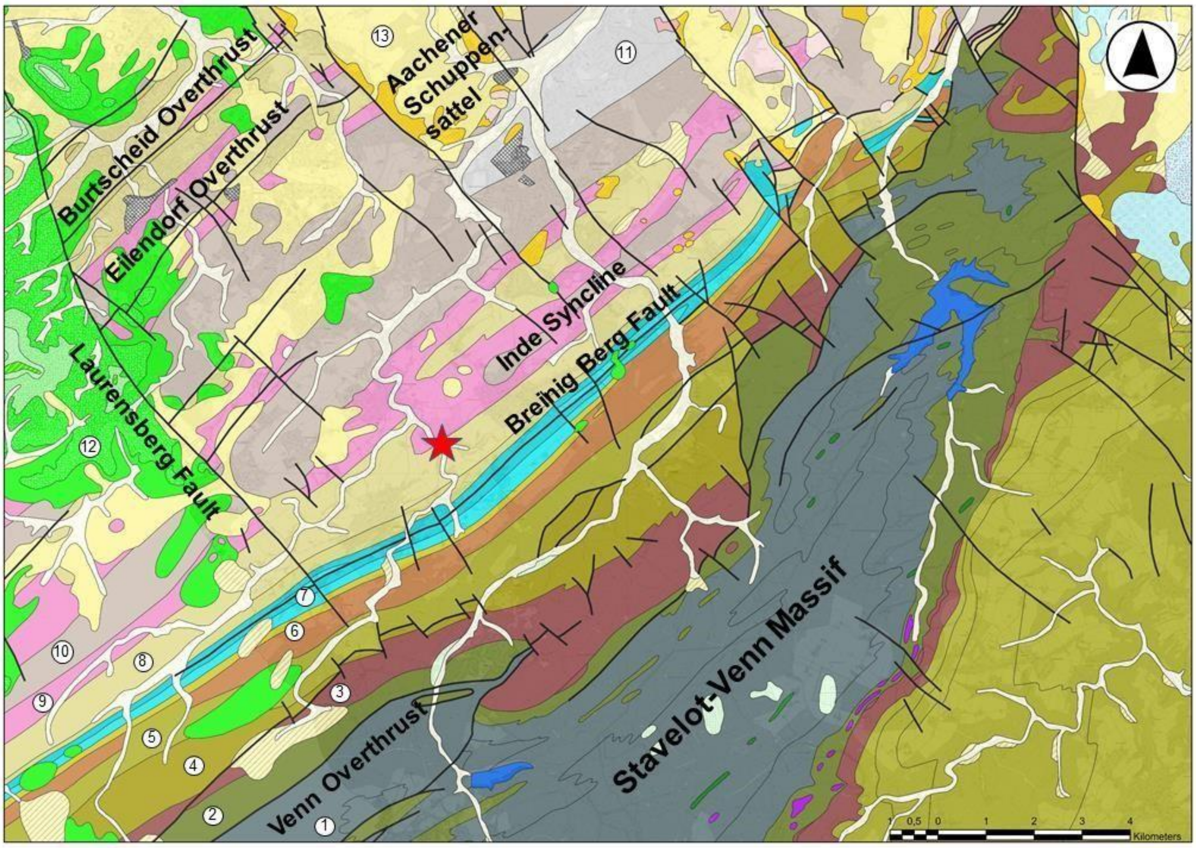


Fig. 2: Geological map of the Aachen region. **1** Revin Group, Middle to Upper Cambrian; **2** Salm Group, Lower to Middle Ordovician; **3** Gedinnian; **4** Siegenian; **5** Emsian; **6** Eifelian; **7** Givetian and Frasnian limestones; **8** Famennian; **9** Tournaisian and Viséan; **10** Namurian; **11** Westphalian; **12** Upper Cretaceous; **13** Quaternary. Red star = Kornelimünster – Vennbahn cycle path section.

Location: The section crops out in an NW-SE running former railway cut near the urban area of Kornelimünster, in the hillside SW of the Inde river and just W of the equestrian centre "Schlausermühle" (map sheet 5203 Stolberg, UTM32 301807 / 5622604, Fig. 2).

Access: Highway A44, Exit 3 Aachen-Brand, first Trierer Straße, then Napoleonsberg street in direction Kornelimünster, parking ground Korneliusstraße on the eastern outskirts of Kornelimünster. From there, one follows the Iternberg street and then turns E immediately after the Itertal Viaduct to reach the former railway line. After approximately 450 m to the SE, the top of the uppermost Famennian section is exposed along the track on the northeastern slope.

Previous studies: In contrast to the well-known, but rather overgrown, Kornelimünster road section, which is located about 200 m to the NE in the Inde Valley, the railway cut succession is almost unstudied. So far, there are only few entries in the core and outcrop database of the Geological Survey of North Rhine-Westphalia, which go back to the mapping activities of Wolfgang Schmidt (1951) and Martin Salamon (2007) as well as to building site investigations, carried out by the city of Aachen.

For this reason, reference is made to the previously published studies on the Kornelimünster road section.

Frech (1885): Study on Upper Devonian corals, partly based on Kornelimünster specimens. Dantz (1893): Description of outcrops in the vicinity of Kornelimünster.
Holzapfel (1910): Mentioning of the Kornelimünster road section as an excellent fossil site.
Richter and Richter (1933): Description of *Omegops cornelius* (as *Phacops cornelius*).
Flügel and Flügel-Kahler (1975): Description of "Strunian" stromatoporoids of the Aachen region. Weyer (1976): Description of the tabulate coral *Cleistopora struniana*, locus typicus: 300 N of Kornelimünster road section.
Poty (1984): Discussion of rugose corals at the Devonian-Carboniferous Boundary, partly based on Kornelimünster specimens.
Richter (1985): Geological field guide of the Aachen and northern Eifel region.
Herbig and Weber (1996): Microfacies development of stromatoporoid biostroms in the Strunian. Weber (2000a): Unpublished Ph.D. Thesis on the Strunian shallow-water facies of Europe containing a detailed section log of the Kornelimünster road section.
Weber (2000b): New topotype of *Omegops cornelius*.
Weber (2007): Section description.
Mösle and Becker (2016): Geological field guide of the Aachen region.
Becker and Weber (2016): Geological field guide of the Devonian-Carboniferous transition in the Aachen region.
Becker (2018): Geological field guide of the Aachen region. Description of the abandoned quarry at the base of the Kornelimünster road section with platy, mica-rich, partly carbonatic sandstones (Evieux Formation, upper portion of Condroz Sandstone).

Palaeogeographic setting: In middle Famennian to middle Viséan times the northern Eifel represented the northwestern prolongation of the shallow-marine Ardennes Shelf. Connections with neritic successions of the western Velbert Anticline were conscientiously discussed by Amler and Herbig (2006). However, drill core Krefeld, currently being driven by the Geological Survey of North RhineWestphalia, will certainly provide valuable new insights into this insufficiently investigated part of the subsurface of the Lower Rhine Embayment. The London-Brabant High to the NW may have been a source area of clastic shedding. The subsurface Campine Basin was located further in the N.

In the time interval from the middle Famennian to the middle Mississippian, the palaeoenvironment in the Aachen region underwent considerable changes. Starting with the siliciclastic Esneux Formation of the basal Condroz Group, it developed into a mixed clastic and biostromal platform (Etroeungt Formation) in the uppermost Famennian (Strunian). This trend continued into the Tournaisian and Viséan. As pointed out by Becker and Weber (2016), eustatic and regional sea-level falls on the one hand and the transgressive global Lower Alum Shale Event (Pont d'Arcole Formation) at the base of the middle Tournaisian on the other led to significant interruptions of the sedimentological record. A major unconformity marks the transition into the Viséan. In the active Hastenrath Quarry (map sheet 5203 Stolberg, UTM32 307947 / 5629732, approximately 8 km to the NE of Kornelimünster) it begins with the distinctive *Vaughanites* Oolite (Hastenrath Member, Terwange Formation, Fig. 3).

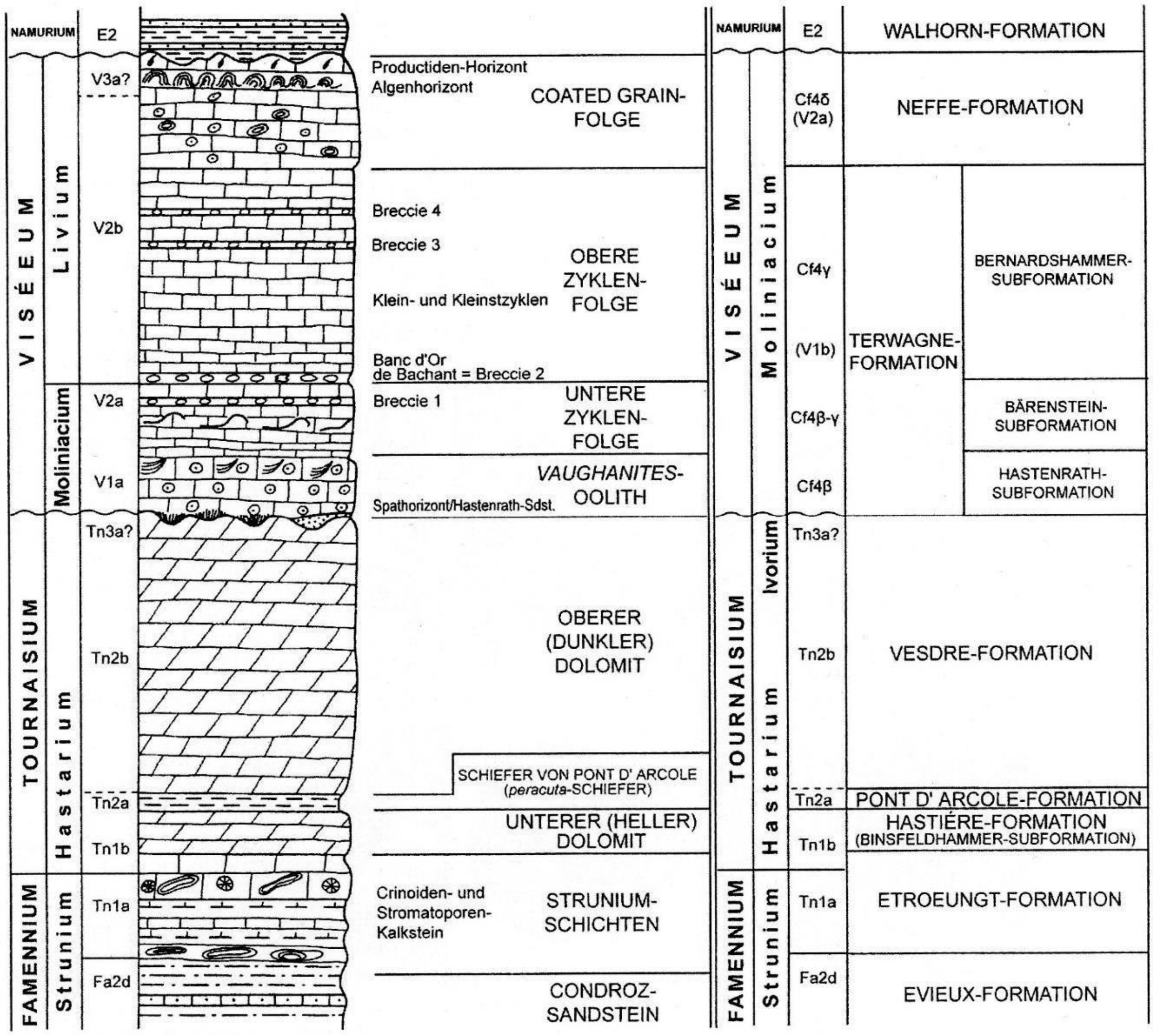


Fig. 3: Uppermost Famennian to Viséan chrono-, litho- and biostratigraphy of the Aachen region (Inde Syncline) representing both, the old (left) and new formation terminology (right, Amler and Herbig 2006).

Tectonic setting: The Venn Anticline represents the north-eastern part of the Stavelot-Venn Massif, which, as part of the central European Variscides, is situated at the northern edge of the Rhenohercynian Zone. Early Palaeozoic sedimentary rocks of the pre-Devonian basement, consisting of light to dark shales as well as quartzites of Cambrian and Ordovician age, are exposed in the core of the anticline.

Transgressive Devonian to Carboniferous deposits form an almost complete sedimentary succession, which was first systematically described by Holzapfel (1910), overlying the Cambrian-Ordovician sedimentary rocks with an angular unconformity. Therefore, the deposits of the Famennian to Tournaisian of the Aachen region are part of an outcrop belt along the Inde Syncline and the “Aachener Schuppensattel”, which are situated NW of the Venn Overthrust (Fig. 2).

The Kornelimünster sections belong to the NW dipping south-eastern flank of the Inde Syncline with Namurian deposits (Walhorn Formation) in its core.

Succession and facies development: The section “Kornelimünster – Vennbahn cycle path” belongs to the Famennian Condroz shelf. As mentioned by Paproth et al. (1986) as well as Herbig and Weber

(1996), this shallow-marine, mixed carbonate-siliciclastic facies developed adjacent to lowlands at the south-eastern margin of the Old Red Continent. Further to the E, it graded into turbiditic sandstones and siltstones, deeper marine shales, or cephalopod limestones of the Rhenish basin (compare e.g. Becker et al. 2021, Hartenfels et al. 2022, Korn et al. 2024).

The Strunian, which comprises the latest Devonian transgression in western Europe (e.g. Conil and Lys 1980, Conil et al. 1986, Streel et al. 2006), embraces the uppermost Famennian (compare Thorez et al. 2006) and can be interpreted as a separate (sub)stage. However, supraregionally, the Strunian transgression was diachronous and proceeded from a depocenter in northern France (Avesnois) and southern Belgium towards the E and from a depocenter in the region of the Velbert Anticline to the Aachen region and easternmost Belgium (Vesdre) towards the SW (Herbig and Weber 1996).

The Evieux Formation, the upper unit of the Condroz Group, crops out approximately 400 m to the SE of the main section (Fig. 2). Opposite of a small picnic area, yellowish-brown weathered, fine-grained sandstones can be found in the steep western slope of the former railway cut. In contrast to the wellknown Kornelimünster road section, the transition from the siliciclastic succession to the first nodular limestone beds of the Etroeungt Formation, which are poor in macrofauna, is not exposed.

Overall, our new bed-by-bed record shows a cyclic character and can be divided into three major stacked sequences of small-scaled transgressive cycles. According to Herbig and Weber (1996, Fig. 4), these ideally consist of four units (A–D) showing a transition from barren siltstones (Unit A) via intermediate units B (siltstone-marl/shale-limestone alteration) and C (nodular to thick-bedded limestones) to highly fossiliferous grainstones (Unit D). However, this ideal succession is rarely fully developed and usually only consists of individual parts. In the case of our studied section, the siltstones of Unit A are completely suppressed.

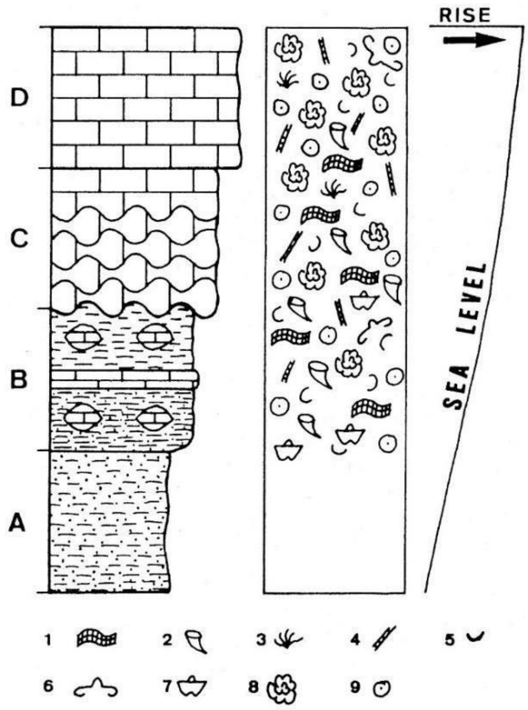


Fig. 4: Idealized Strunian transgressive cycle showing the transition from barren siltstones (Unit A) via intermediate units B (siltstone-marl/shale-limestone alteration) and C (nodular to thick-bedded limestones) to highly fossiliferous grainstones (Unit D). **1** stromatoporoids, **2** rugose corals, **3** syringoporoids, **4** calcareous algae, **5** ostracods, **6** trilobites, **7** brachiopods, **8** foraminifera, **9** echinoderms (Herbig and Weber 1996).

Cycle 1 has a total thickness of at least 950 cm and starts with an alteration of dark grey, slightly dolomitized, crinoidal nodular limestones (crinoidal grain- and rudstones) with grey, brownish weathered, silty shales (beds 1 to 40a) corresponding to Unit B (Figs. 4, 6). On its own, this interval has a thickness of 826 cm and yields a diverse and rich macrofauna. The assemblage consists of crinoid remains, solitary rugose corals, laminar and bulbous to domical stromatoporoids, gastropods, algae incrustations, and as a special feature a representative of the trilobite order Phacopida. Bed 9 possibly supplied one of the very rare specimens of *Omegops cornelius* (Figs. 5–6) and, therefore, this bed could correlate with the *Omegops* Bed of the Kornelimünster road section. The latter yielded *Omegops cornelius* in association with the rugose corals "*Palaeosmilia*" and *Campophyllum* as well as the conodont *Bispathodus spinulicostatus* Morphotype 1 (Weber 2000a, 2000b, Becker and Weber 2016). In the road section, it lies approximately 27,6 m above the base of the Etroeungt Formation. Future preparation work will hopefully allow a more precise taxonomic classification of the trilobite find. Starting from Bed 40b upwards to Bed 45, Cycle 1 culminates in a 124 cm thick succession of dark grey, slightly dolomitized, nodular to thick-bedded crinoidal limestones, mostly very rich in macrofossils. Besides the dominantly represented crinoid remains, abundant rugose corals as well as laminar and bulbous to domical stromatoporoids occur forming a stromatoporoid-coral buildup (units C and D, Fig. 4). However, since they are mostly isolated within the matrix, they did not form a rigid framework as in typical biostroms. Upsection, two further incomplete cycles follow, in which the siltstoneshalelimestone alteration (Unit B) in particular is less pronounced.

Fig. 5: Two views of the cephalon of a possible specimen of *Omegops cornelius* from Bed 9.

Cycle 2 enters with an approximately 120 cm thick interval of again alternating dark grey, slightly dolomitized, crinoidal nodular limestones with grey, brownish weathered, silty shales (Unit B, beds 46a to 53a, Figs. 4, 6). It is noticeable that the thickness of the individual silty shale beds decreases towards the top of the unit. Corresponding to Unit B of Cycle 1, the crinoidal grain- to rudstones yielded solitary rugose corals and stromatoporoids. A 189 cm thick package (beds 53b to 57) of macrofossil-rich nodular to thick-bedded, dark grey, slightly dolomitized, crinoidal limestones (units C and D) completes this second cycle. The macrofossil content equals that of the underlying cycle. Again, crinoid remains are the dominant faunal element. The assemblage is completed by rugose corals and stromatoporoids. The latter are represented by both, laminar and bulbous to domical forms and may reach a diameter of several tens of centimetres. Several cm-large nodules of red algae are a conspicuous element in Bed 56 (Figs. 7–8). Identical red algae were also described by Weber (2000a, his Bed 67) from the road section. Again, the stromatoporoids do not form a rigid framework.

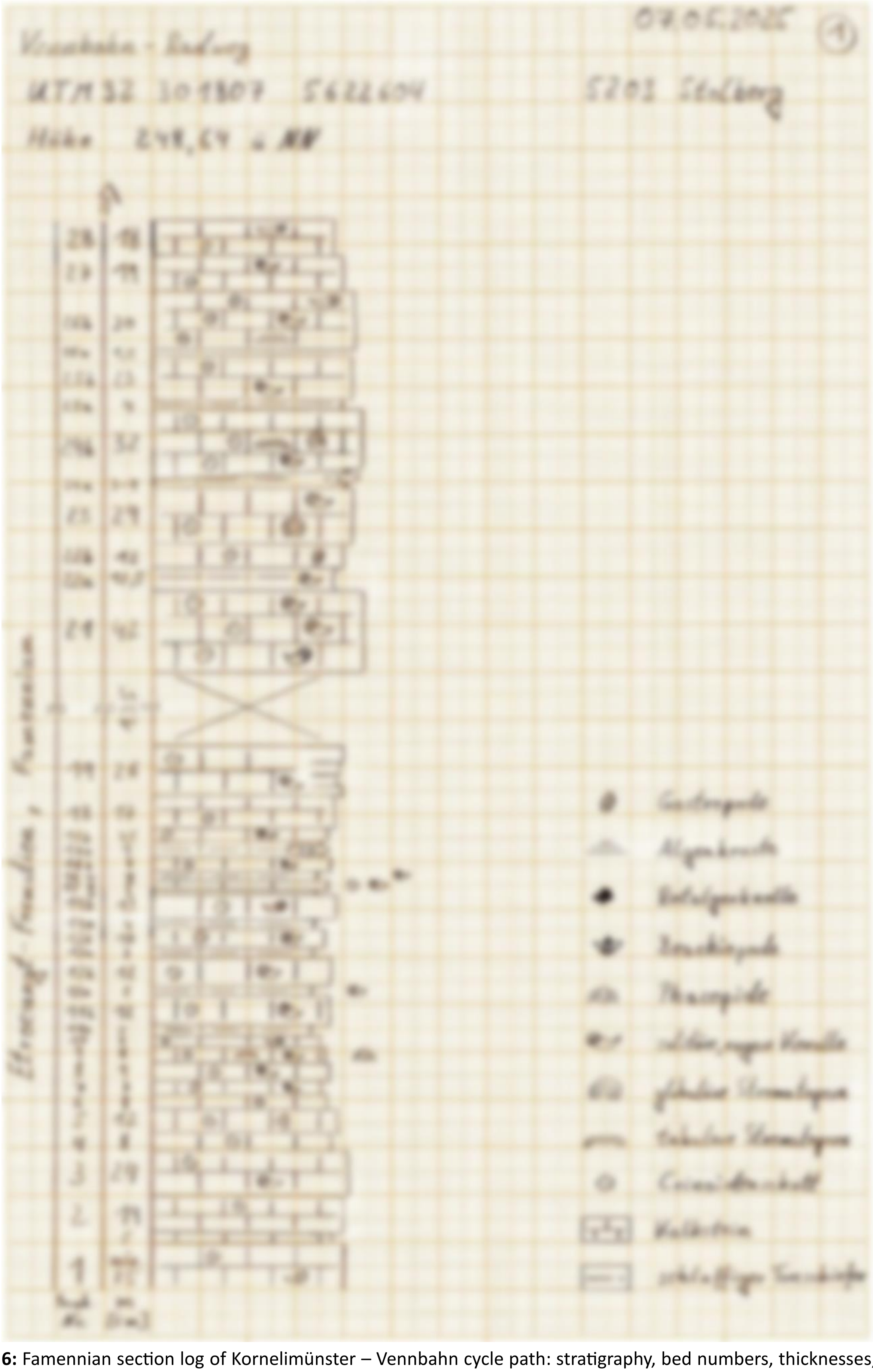


Fig. 6: Famennian section log of Kornelimünster – Vennbahn cycle path: stratigraphy, bed numbers, thicknesses, and fossil content.

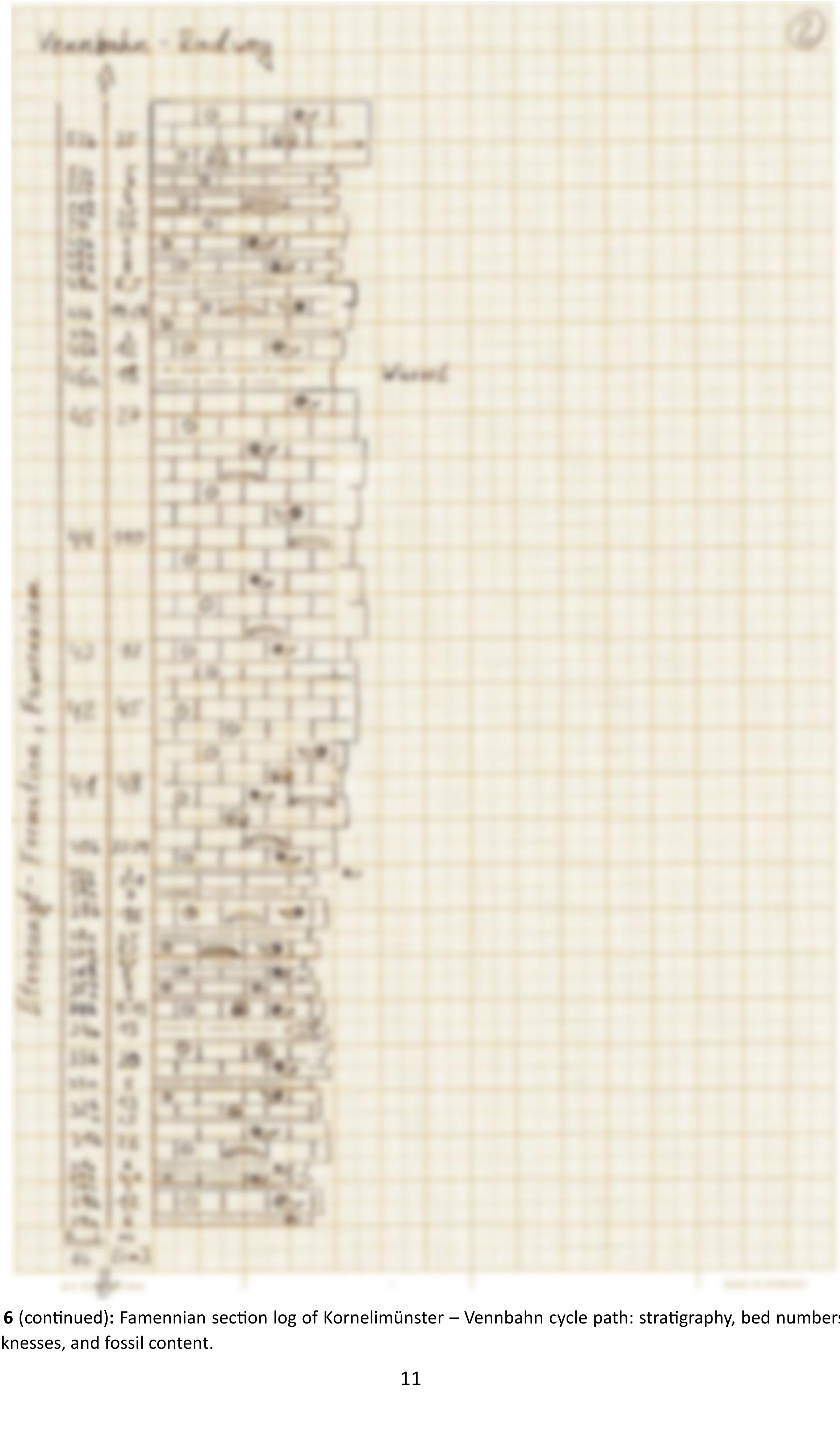


Fig. 6 (continued)**:** Famennian section log of Kornelimünster – Vennbahn cycle path: stratigraphy, bed numbers, thicknesses, and fossil content.

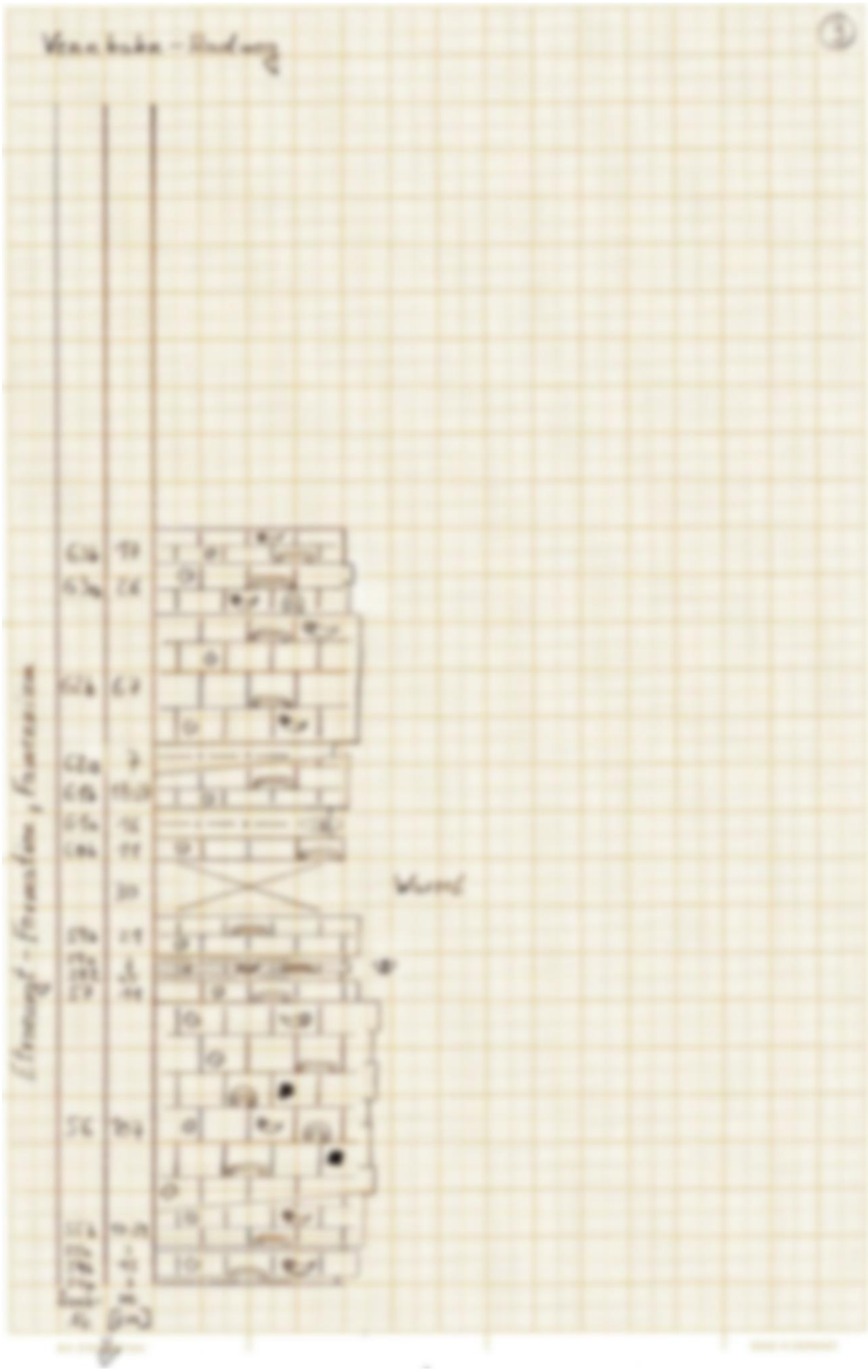


Fig. 6 (continued)**:** Famennian section log of Kornelimünster – Vennbahn cycle path: stratigraphy, bed numbers, thicknesses, and fossil content.

Cycle 3 resembles the previous cycles and starts again with an at least 113 cm thick crinoidal nodular limestone-silty shale alteration (Unit B, beds 58a to 62a, Fig. 9) and is followed by macrofossil rich, slightly dolomitized crinoidal nodular to thick-bedded limestones (units C to D, beds 62b to 63b, Figs. 4, 6). The latter has a thickness of 110 cm and consists of crinoid remains, solitary rugose corals and laminar grown stromatoporoids. In contrast to the underlying cycles, bulbous to domical forms are lacking, so far. In the topmost part of Unit B of Cycle 3 (beds 61a to 62a) a large, laminar stromatoporoid occurs that reaches a diameter of more than 100 cm.

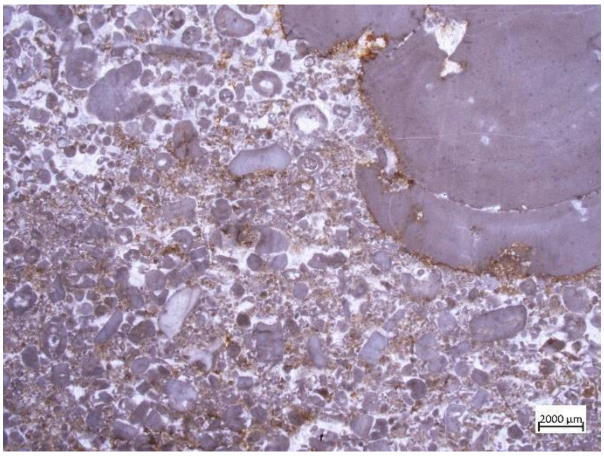


Fig. 7: Crinoidal grainstone yielding nodules of red algae, Bed 56, thin-section, figure width ca. 2,6 mm.

Fig. 8: Crinoid remains and cross section of a rugose coral, Bed 56.

Fig. 9: Laminar stromatoporoid from Bed 58 b.

Herbig and Weber (1996) provided a facies model for the Strunian shallow-marine, dynamic, mixed carbonate-siliciclastic ramp system (Fig. 10).

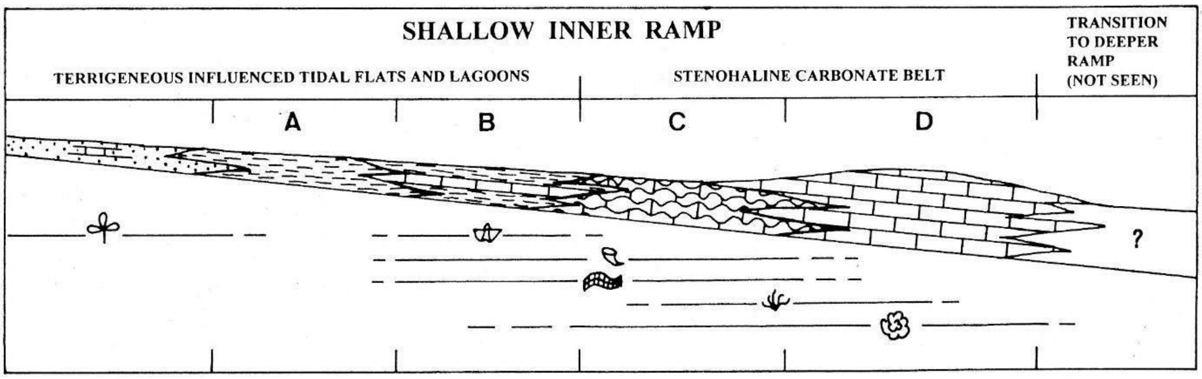


Fig. 10: Facies model for lithofacies and lateral organism ranges of the Etroeungt Formation. **A** barren siltstone, **B** siltstone-marl/shale-limestone alteration, **C** nodular to thick-bedded limestones, **D** highly fossiliferous grainstones (Herbig and Weber 1996).

The present fieldtrip aims at presenting representative lithostratigraphic successions at the crossing of three tectonostratigraphic units of south-eastern Belgium, namely the Vesdre area (or Massif, or Nappe, depending on tectonic conceptions), the Theux Tectonic Window (Parautocthon) and the northeastern part of the Dinant Synclinorium (Ardenne Allochthon) (Fig. 11).

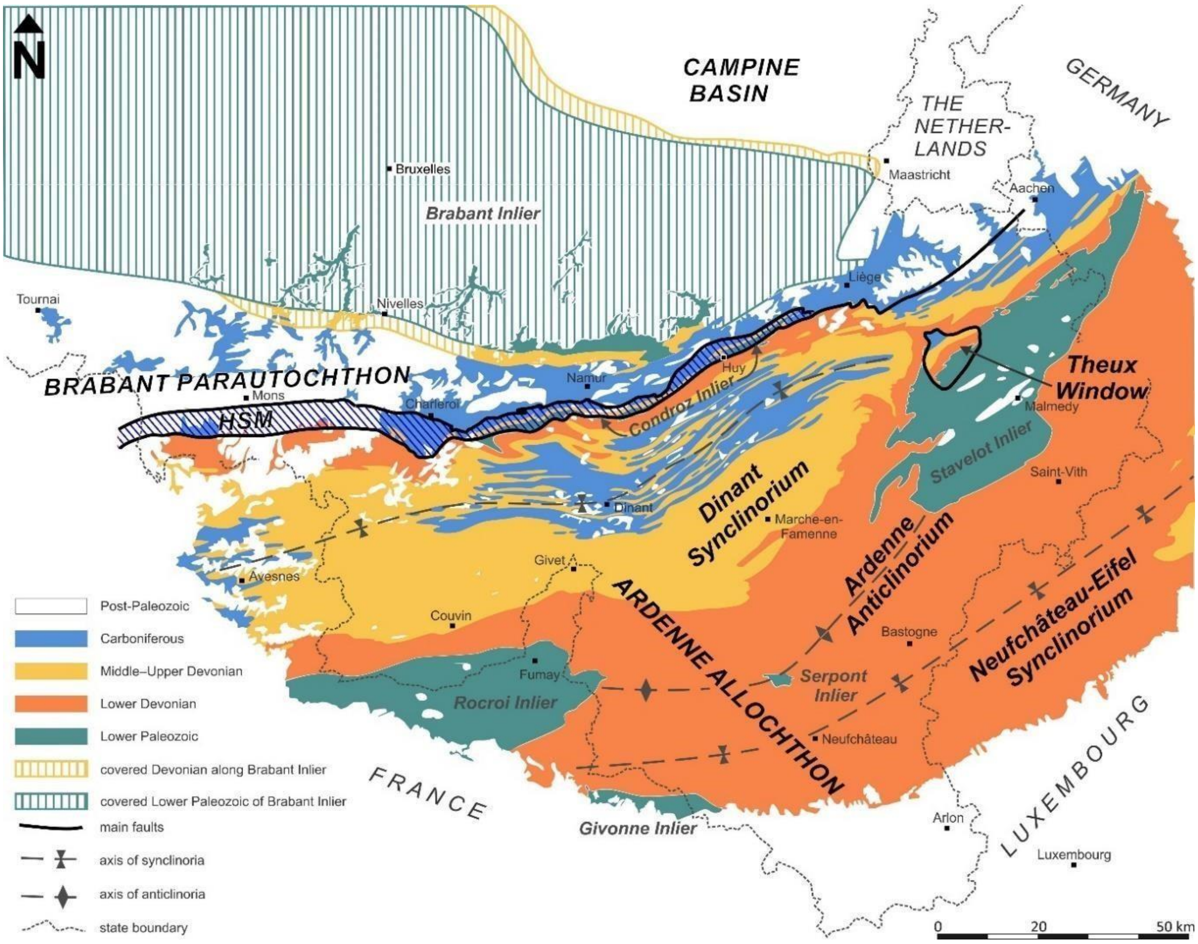


Fig. 11: Simplified geological map of southern Belgium and neighbouring areas (after Mottequin & Denayer, 2024).

Very condensed geological settings

The Devonian and Carboniferous strata crop out in several Variscan structural units, such as the Dinant Synclinorium, the Haine-Sambre-Meuse overturned trust sheets (former 'southern limb of the Namur Synclinorium), the Brabant Parautochthon (former 'northern limb of the Namur Synclinorium', continuing westwards to the Boulonnais area of northern France), the Theux Tectonic Window and the Vesdre area (Fig. 11).

As soon as the Early Devonian, the Dinant-Namur Basin functioned as a shelf divided in several sedimentation areas corresponding to several blocks that display distinct characters of subsidence and accommodation. The Early Devonian is largely dominated by siliciclastic facies of the 'Old Red Sandstone' witnessing the weathering and erosion of the Caledonian Chain located to the north. In the more distal part of the basin, marine conditions are established as soon as the Pridoli but carbonates are anecdotical, the succession being largely dominated by fine coarse-grained siliciclastics (Lochkovian and Emsian) or fine-grained siliciclastics (mostly Praguian) (Fig. 12). Each transgression pushed the coastline northwards as the littoral facies reached the northern part of the Dinant Synclinorium during the (Pridoli-Lochkovian) but reached the Namur area only by the GivetianFrasnian.

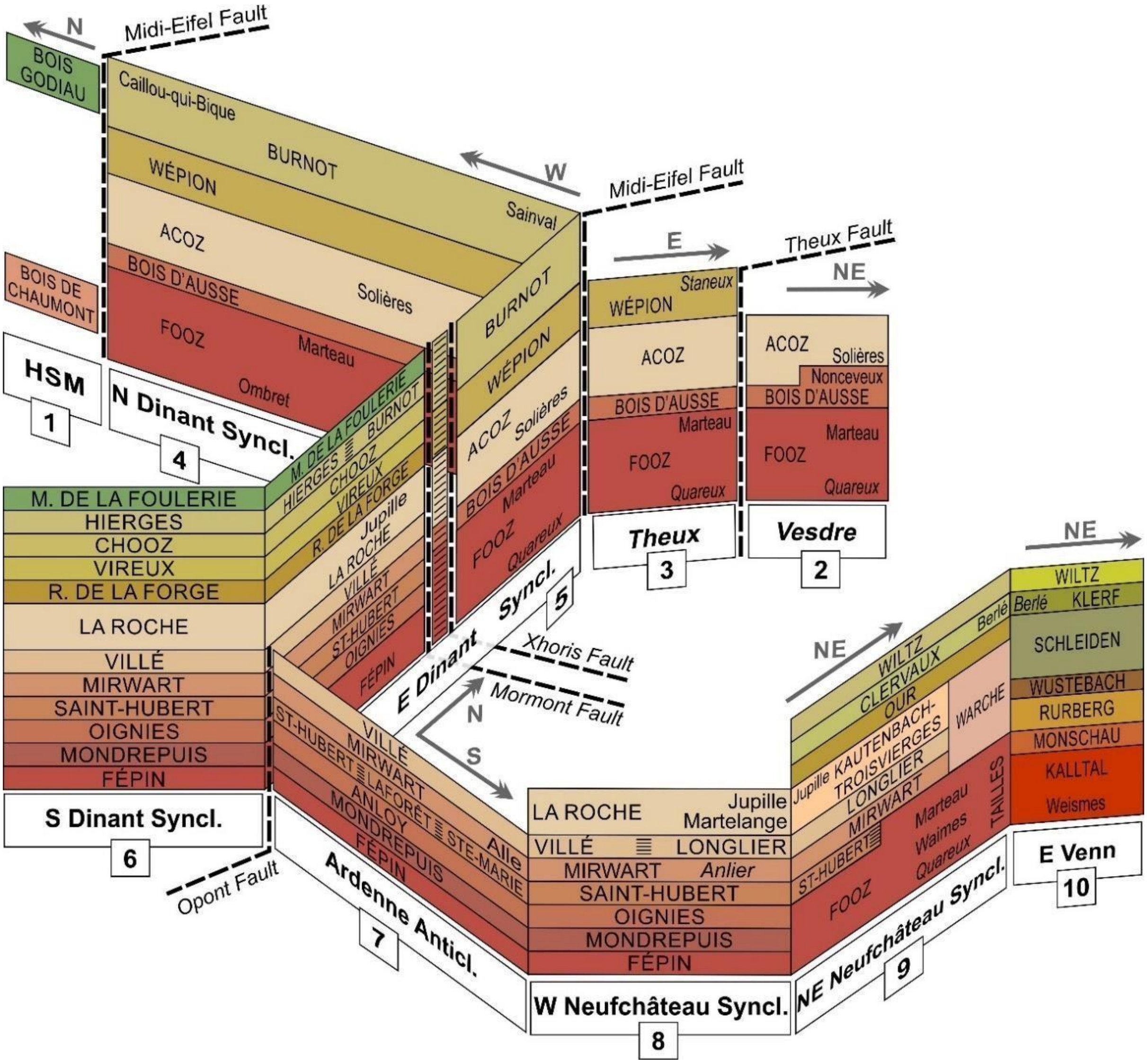


Fig. 12: Schematic vertical and lateral relationships of the Lower Devonian units of Belgium. Formations are indicated in capital letters, members in regular letters whereas remarkable beds and facies are indicated in italics. Abbreviations: Anticl., Anticlinorium; HSM, Haine–Sambre–Meuse Overturned Thrust sheets; M. DE LA FOULERIE, Moulin de la Foulerie Formation; R. DE LA FORGE, Ruisseau de la Forge Formation; Syncl., Synclinorium. 1, Haine–Sambre–Meuse Overturned Thrust sheets; 2, Vesdre area; 3, Theux Window; 4, Northern limb of the Dinant Synclinorium; 5, Eastern limb of the Dinant Synclinorium; 6, Southern limb of the Dinant Synclinorium; 7, Ardenne Anticlinorium; 8, Western part of the Neufchâteau–Eifel Synclinorium; 9, North-eastern part of the Neufchâteau–Eifel Synclinorium; 10, German Venn area. After Denayer & Mottequin (2024).

The Middle Devonian Period recorded the onset of the 'carbonate factory' and the development of many metazoan and microbialite reefs, among which large Eifelian bioherms and extensive Givetian stromatoporoid and tabulate coral biostromes. In the proximal areas, the marine character is not fully established before the Givetian, during the Eifelian, the Old Red Sandstone facies still dominate.

The Frasnian succession (Upper Devonian) reflects a ramp setting with several breaks of slope. The distal part of the Namur–Dinant Basin recorded the development of several carbonate mound levels separated by argillaceous episodes (Fig. 13). The Famennian strata witnesses of a large-scale regression. This change is marked by a transition to thick argillaceous deposition during the Late Frasnian and Early Famennian. During the rest of the Famennian, alluvial to offshore siliciclastics dominated.

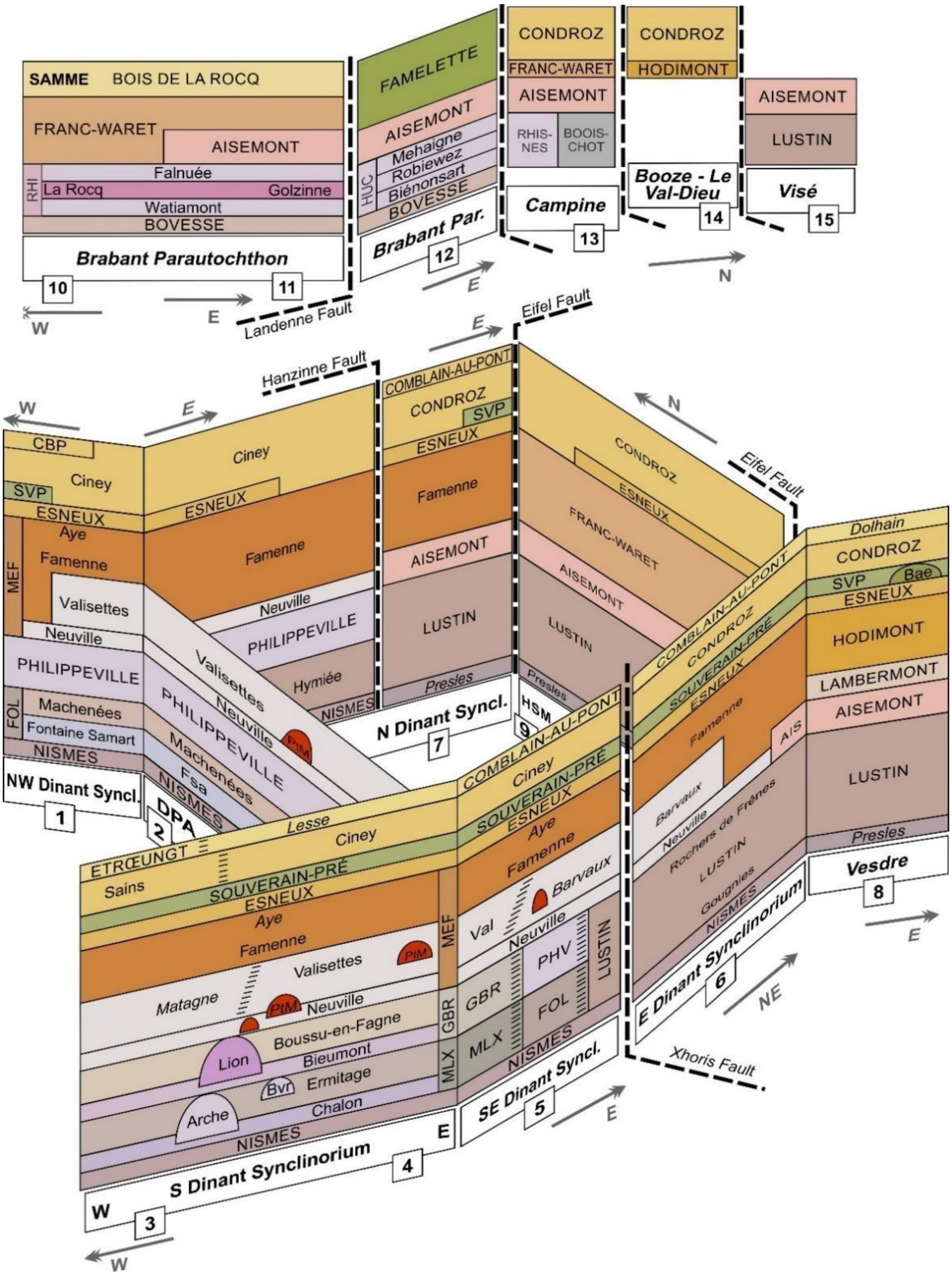


Fig. 13: Schematic vertical and relationships of the Upper Devonian of Belgium. Formations are in capital letters, members are in regular letters, names in italics are remarkable horizons and facies. The stratigraphic hiatuses shown in Figure 3 are not represented here. Abbreviations: AIS, Aisemont Formation; Bae, Baelen; Bvr, Boverie Member; CBP, Comblain-au-Pont Formation; DPA, Durbuy–Philippeville Anticlinorium; FOL, Pont de la Folle Formation; Fsa; Fontaine Samart Member; GBR, Grands Breux Formation; HSM, Haine–Sambre–Meuse Overturned Thrust sheets; HUC, Huccorgne Formation; MEF, Marche-en-Famenne Formation; MLX, Moulin Liénaux Formation; Par., Parautochthon; PHV, Philippeville Formation; PtM, Petit-Mont Member; RHI, Rhisnes Formation; SVP, Souverain Pré Formation; Syncl., Synclinorium; Val, Valisettes Member. 1: NW limb of the Dinant Synclinorium, Durbuy-Philippeville Anticlinorium, 3: western part of the southern limb of the Dinant Synclinorium, 4: eastern part of the southern limb of the Dinant Synclinorium, 5: south-eastern limb of the Dinant Synclinorium, 6: eastern limb of the Dinant Synclinorium, 7: northern limb of the Dinant Synclinorium, 8: Vesdre area, 9: Haine-Sambre-Meuse overturned thrusted sheets, 10: western part of the Brabant Parautochthon, 11: central part of the Brabant Parautochthon, 12: eastern part of the Brabant Parautochthon, 13: Campine Basin (only known from boreholes), 14: Booze-Le-Val-Dieu Ridge, 15: Visé area. After Mottequin et al. (2024).

The Devonian-Carboniferous transition is characterised by the re-installation of carbonate facies that suggest a change in regional climate, from cold to hot.

The Tournaisian is typically dominated by crinoidal limestone forming thick and widely extended units on the shelf. In the deeper part of the Namur-Dinant Basin (*Auge dinantaise* in the old literature, Dinant Sedimentation area, Fig. 14), large accumulation of mud-dominated Waulsortian mounds and banks strongly influenced the topography. At least three generations of mounds are superimposed on top of each other and separated by fine-grained, often cherty, limestone grouped under the term 'periWaulsortian facies'. In the beginning of the Viséan, the depositional settings changed again, with the filling of the depressions between the inner shelf and the Waulsortian mounds and the final smoothing of the relief. The platform displays an increasing restricted character during the Viséan, culminating with the deposition of stromatolitic limestone and evaporites. The upper Viséan however displays several biologically induced constructions, including the mounds of the Visé stratotype as well as isolated zones of marine influence surrounded by very-shallow platform where stromatolites continued to form. In the NE regions, the sedimentation displays more restricted facies with abundant depositional gaps culminating in the middle Visean. Following the Visean-Serpukhovian sea-level drop that ended the Visean carbonate factory, the Namurian to Westaphalian siliciclastics reflect the forthcoming Variscan orogeny.

General information can be found in recent revision of the Devonian lithostratigraphic scale of Belgium (Mottequin & Denayer, 2024) and in published field guidebooks for the lower Carboniferous (Denayer et al., 2019).

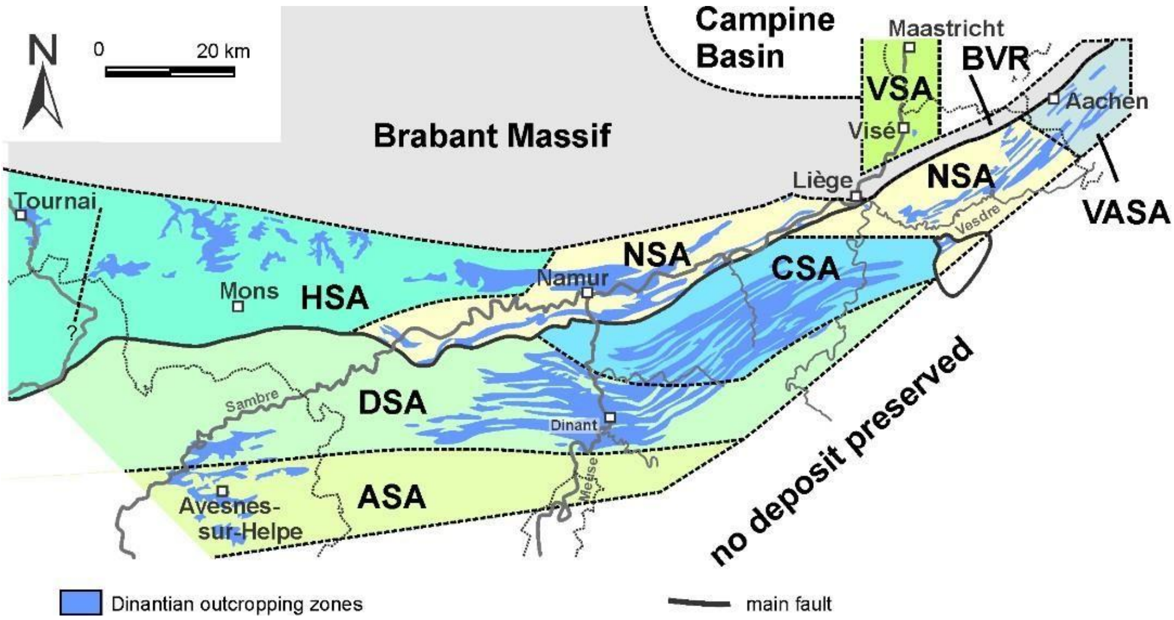


Fig. 14: Schematic map of sedimentation areas and lithostratigraphic successions in the lower Carboniferous. Abbreviations: ASA: Avesnois Sedimentation Area, CSA: Condroz Sedimentation Area, DSA: Dinant Sedimentation Area, HSA: Hainaut Sedimentation Area, NSA: Namur Sedimentation Area, VSA: Visé Sedimentation Area, VASA: Vesdre-Aachen Sedimentation Area, BVR: Booze-Le Val Dieu Ridge. After Poty (2016).

Stop 2: Spa (bottle plant) road section

Location: Chemin des Boteresse, 4900 Spa

References: Vanguestaine (1974), Geukens (1999).

Lithostratigraphy and biostratigraphy: La Gleize Formation, Late Cambrian, based on acritarchs (Vanguestaine, 1974).

Description: The outcrop exposes graphitic shale/slate, rich in pyrite and enclosing flattened nodules and lenses of coarser rocks than might be strongly weathered volcanoclastic material. Recumbent folds and horizontal thrusts make the succession difficult to see.

Stop 3: Marteau section

Location: Rue Marteau, 4900 Spa

References: Hance et al. (1992), Dejonghe et al. (1994), Goemaere et al. (2012).

Lithostratigraphy and biostratigraphy: Spa Member of the Jalhay Formation, Lower Ordovician, based on acritarchs and graptolites (Vanguestaine, 1974); unconformably overlain with the PridoliLochkhovian Fooz Formation (Quareux, Weismes and Marteau Members). The age of the Fooz Formation is mostly based on miospores from the Marteau siltstone, indicating the Lochkovian R to Mα zones (Steemans, 1989). However, south-east of the Stavelot–Venn Inlier, the Waimes Member, overlying the basal conglomerate yielded brachiopods (e.g. *Quadrifarius dumontianus, Shaleria rigida*) indicative of the Pridoli (Boucot, 1960).

Description: The Ordovician Spa Member is dominantly a slightly micaceous brownish slaty siltstone with some sandy lenses. Below the erosive surface, the siltstone is rubified, possibly through pedogenetisation (1-2 on Fig. 15A) previous to the deposition of the Fooz Formation. The latter exposes here a few lenticular conglomeratic-coarse sandstone beds, where pebbles are not abundant (Quareux Member, 3 on Fig. 15A) and a bed of coarse-grained lithic sandstone ("arkose") corresponding to a very reduced equivalent of the Waismes Member (150 m in the type locality 20 km south-eastwards, 4 on Fig. 15). Upwards is developed a thick unit of red siltstone and fine-grained sandstone with variegated shales and some horizons with dissolved carbonate nodules (reworked calcrete). The latter is typically the facies of the Marteau Member of the Fooz Formation (5 on Fig. 15A).

This succession displays the typical transgressive pulse, with fluviatile/deltaic deposits on an eroded Lower Paleozoic massif, passing to coastal marine deposits (Waimes Member) then return to a floodplain environment.

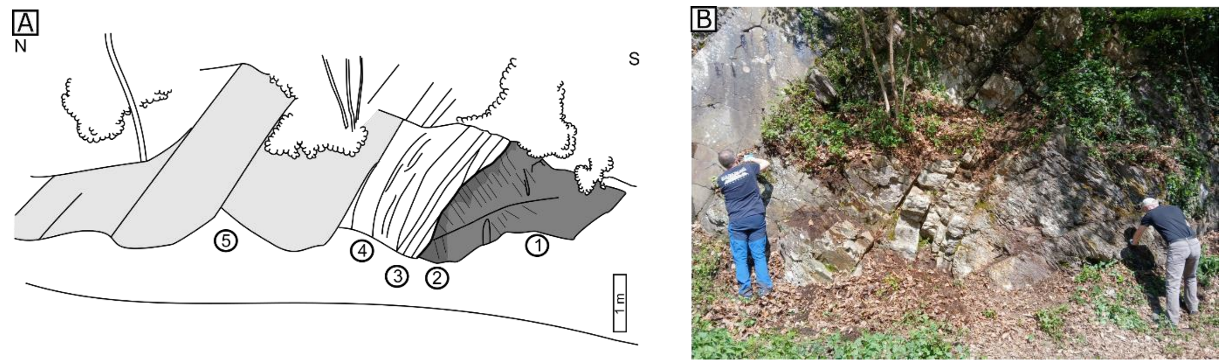


Fig. 15 A: Sketch and picture of the Marteau section showing the relationships of the Ordovician and Devonian strata. 1: Spa Member of the Jalhay Formation (Ordovician), note that bedding is subvertical, 2: rubified to of the Spa Member, 3: conglomeratic lenticular beds of the Quareux Member overlying the unconformity, 4: “arkosic” coarse-grained lithic sandstone of the Waisme Member, 5: red siltstone of the Marteau Member. **B:** Picture of the section. German geologists for scale.

Stop 4: La Heid de Fer at La Reid

Location: Chemin des Deux Chênes, 4910 Theux

References: Dreesen (1982a, 1982b, 1984, 1989a, 1989b).

Lithostratigraphy and biostratigraphy: Hodimont Formation, of earliest to middle Famennian. Conodonts of the basal part of the Formation belong the *triangularis* Zone (Mouravieff, 1970), whereas those recovered from the oolitic ironstone horizons clearly indicate that the latter correspond to condensation horizons (Dreesen, 1984, 1989a): horizon I (*triangularis–crepida* conodont zones), IIIa (*crepida* conodont Zone). The ammonoid *Cheiloceras* is known from the horizon IIIa (Dreesen, 1989b) but the ammonoids of horizon I remains undescribed (Fig. 16B). The first post-Kellwasser rugose corals (*Cheilaxonia cf. hoffmanni*) are known from the layers directly overlying the ironstone horizon I (Denayer et al., 2012) (Fig. 16C).

Description: The Hodimont Formation is dominantly shaly-silty and contains three bundles of oolithic ironstone horizons: one near the base (horizon I of Dreesen, 1982a), one in the upper third (horizon II) and one at the top (horizon IIIa) marking the boundary with the overlying Esneux Formation (not exposed here). These remarkable horizons are made of 2-8 beds of haematitic oolithes, pisolithes and pseudo-oolithes (coated grains and haematitised bioclasts) cemented with various proportion of calcitic, haematitic or limonitic cement and alternating with “normal” micaceous siltstone and shale beds. These haematitic beds are usually rich in bioclasts and fossils (cephalopods, rugose corals, brachiopods, bivalves) and quartz grains (“fossil ore” sensu Dreesen, 1982). Other beds are made of pure haematitic oolithe with haematitic cement (“flax seed ore” sensu Dreesen, 1982). Some beds are carbonate-dominated and consist of bioclastic wackestone to grainstone with few oolithes, occasionally nodular. Though they are relatively thin (a few centimetres to 40 cm), they can be traced over tens of kilometres.

Here, the haematitic beds correspond to Horizon I and is composed of 6 beds varying from 2 to 40 cm in thickness, and of various carbonate proportion (Fig. 16A).

Dreesen (1982a, 1982b, 1989a) demonstrated that these beds consist of at least one, but usually several concentration, omission and erosion events. The deposition took place during times of reduced to null siliciclastic input and the origin of the iron is to be searched volcaniclastics. Chloritized angular benthonic relicts, vermicular extraclasts, weathered fragments of volcanic glass and idiomorphic zircon crystals are rather frequent in these horizons, which suggest a relation to volcanic ashes. Moreover, they correlate basinwards to bathyal deposits that incorporate numerous metabentonites (volcanic tuffs, “Rotschieferfazies”) in the Rhenish Massif. The presence of within-bed erosive surfaces, microstromatolithic hardground and ferruginized allochems points to erosion and transportation of material from proximal areas during stroms (or tsunamis) during lowstands.

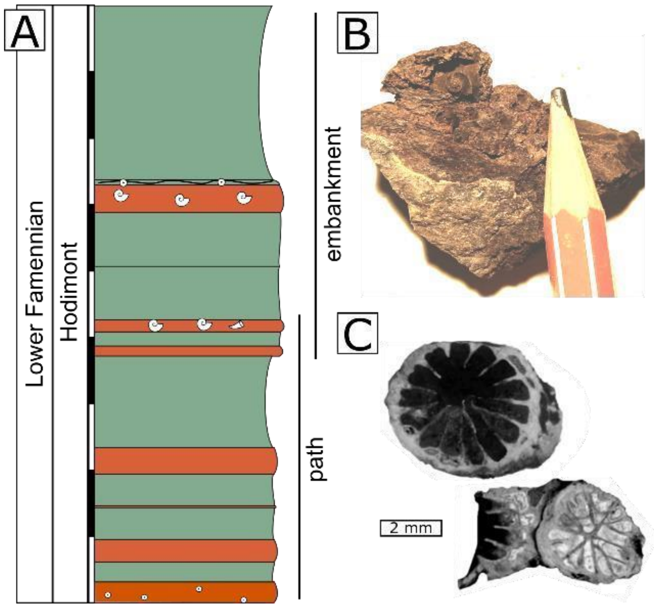


Fig. 16 A: Schematic log of the Heid de Fer section and its oolithic ironstone beds. **B:** a very small ammonoid preserved as external mould in a decalcified bed. **C:** rugose coral *Cheilaxonia cf. hoffmanni* (=fig. 7E-F in Denayer et al., 2012).

Stop 5: Le Chaffour quarry at La Reid

Location: Rue du Chenal, 4910 Theux

References: Coen et al. (1977), Coen-Aubert & Lacroix (1979), Poty & Chevalier (2007).

Lithostratigraphy and biostratigraphy: Rochers de Frênes Member of the Lustin Formation (middle Frasnian) and Tchafornis Member of the Aisemont Formation (upper Frasnian). Although poor in conodonts the Lustin Formation spans the interval of the *punctata* to the lower *rhenana* conodont zones according to Gouwy & Bultynck (2000). The rugose corals *Wapitiphyllum vesiculosum, Argutastrea konincki* (Fig. 17C) and *A. lecomptei* are typical of the Rochers de Frênes Member. The Tchafornis Member belongs to the lower *rhenana* conodont zones (Bultynck & Dejonghe, 2002). Coen et al. (1977) reported from that member a rugose coral association named "faune 1", dominated by *Frechastraea limitata, F. coeni, Potyphyllum ananas* and *Hankaxis insignis*.

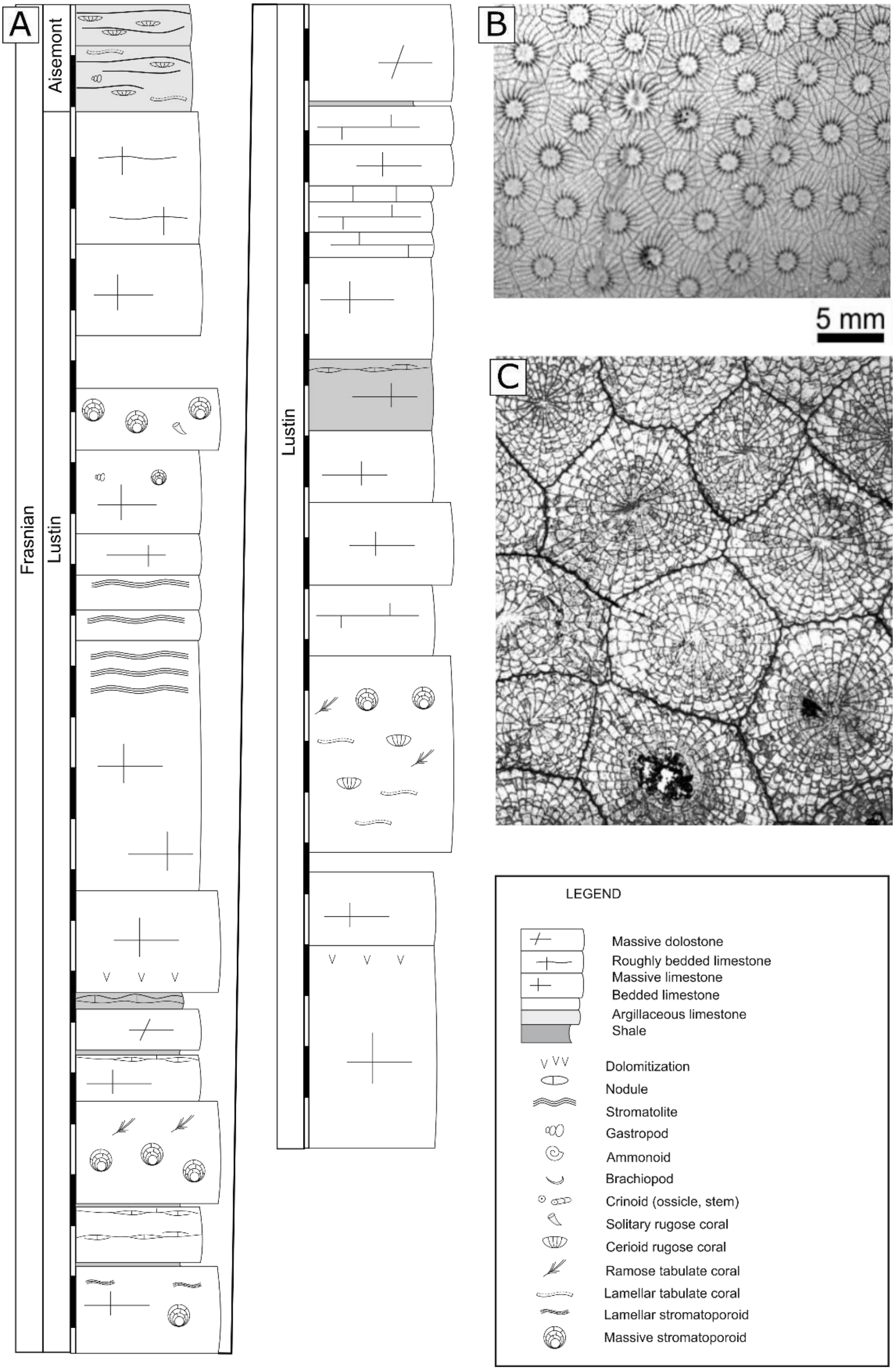


Fig. 17 A: Simplified log of the Chaffour quarry. **B:** *Frechastraea coeni*, a rugose coral typical of the base of the upper Frasnian. **C:** *Argutastraea konincki*, a rugose coral typical of the middle Frasnian.

Description: Here, the Rochers de Frênes Member displays its typical "lagoonal" facies, i.e. alternation of stromatoporoid-coral matrix-supported parabiostromes and beds of fine-grained mudstonewackestone either laminated (stromatolites) or with bird-eyes. In fact, these facies are arranged in shallowing-upwards sequences starting with the coarse-grained bioclastic limestone, passing upwards to finer-grained material capped by stromatolitic mudstone and/or microbreccia of pedogenetic origin (calcretes). These sequences are 1.5-4 m thick (Fig. 17A).

The top of the Lustin Formation is marked by an erosive sub-aerial surface that corresponds to a sequence boundary caused by emersion. On top is deposited the slightly argillaceous fine-grained bioclastic limestone of the Aisemont Formation which is rich in platy colonies of *Frechastraea* (Fig. 7B) and *Potyphyllum*. The basal bed is rich in siliceous sponge spicules. A major faunal turnover is associated with the boundary between the Lustin and Aisemont Formation. It is, in fact, the first step of the Late Frasnian Crisis.

Stop 6: Sècheval quarry

Location: Sècheval, 4920 Remouchamps

References: Liégeois (1956), Hance et al (1996).

Lithostratigraphy and biostratigraphy: Pepinster Formation. In Remouchamps, the basal part of the formation yielded *Icriodus corniger* and *I. retrodepressus* that both indicate the *partitus* conodont Zone, i.e. the lower part of the Eifelian. The occurrence of stringocephalid brachiopods and the rugose coral *Argutastrea tenuiseptata*, c. 10 m below the top of the Formation confirms that the upper part of the Pepinster Formation is Givetian in age, in the *timorensis* conodont Zone characterising the top of the lower Givetian (Gouwy & Bultynck, 2003a). This unit is an equivalent to the German FriesenratherSchichten (Kasig & Reissner, 2008).

Description: The Pepinster Formation is divided into three units. The lower one, starting on top of the last conglomeratic bed of the Burnot Formation is an alternation of reddish and greenish sandstone and siltstone with dissolved carbonate nodules. The middle one includes carbonate sandstone with decalcified fossils (crinoids, brachiopods, tentaculites) interstratified with wine-red siltstone and shale. The upper unit is made of wine-red micaceous sandy siltstone with decalcified nodules and sandstone with numerous palaeosols with root traces (Fig. 18A). In the Sècheval quarry, bed surface with ripple marks and impact of raindrops are frequent (Fig. 18B).

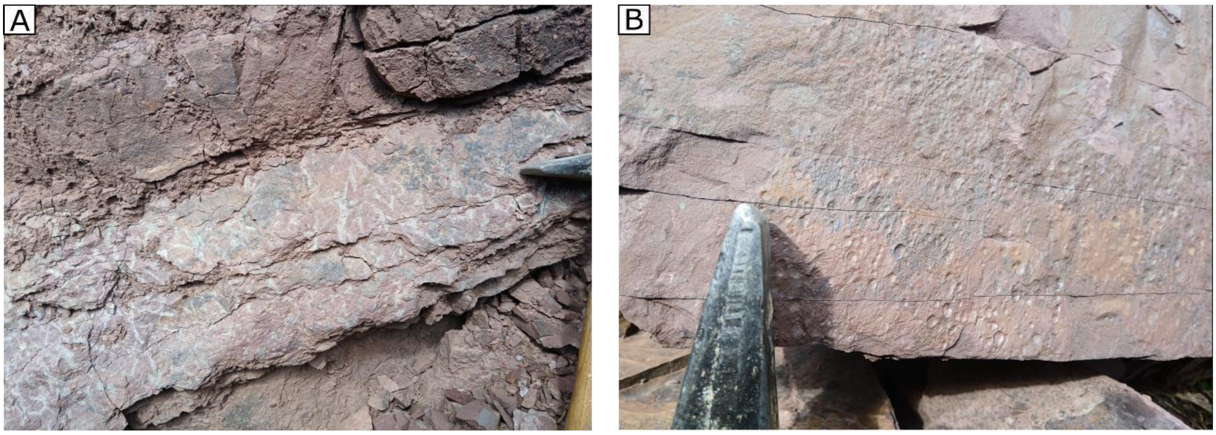


Fig. 18: Pepinster Formation in the Sècheval quarry. **A:** Palaeosol horizon with reticulated root traces. **B:** Bedding plain with impact of raindrop demonstrating that Belgium was a rainy country for 380 million years!

Stop 7: La Falize quarry at Remouchamps

Location: Rue Trotinfosse, 4920 Remouchamps

References: Macar (1948), Thorez et al. (2006), Mottequin et al. (2024).

Lithostratigraphy and biostratigraphy: Marche-en-Famenne, Esneux, Souverain-Pré and Condroz Formation, covering almost the entire Famennian stage (Fig. 19).

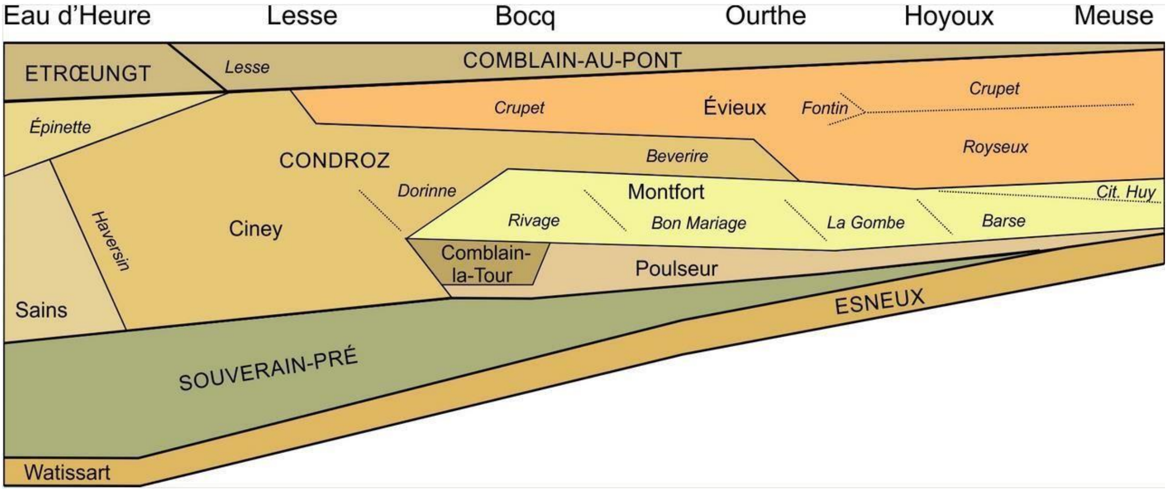


Fig. 19: Middle–uppermost Famennian formations within the Dinant Synclinorium and the Haine–Sambre– Meuse Overturned Thrust sheets (origin of data: see main text). Formations are in capital letters, members in regular letters, and facies in italics. Cit. Huy, Citadelle de Huy. After Mottequin et al. (2024).

Description: Above the shale and siltstone of the Famenne Member (lower Famennian) exposed in the path, the thinly-bedded micaceous silty sandstone ("psammites stratoïdes") of the Esneux Formation marks the beginning of the coastal sedimentation dominated by sandstone in the Famennian. This very monotonous unit is overlain with siltstone with nodules of bioclastic sandy limestone that form locally continuous beds of the marine Souverain-Pré Formation. The nodules are typically dissolved in the outcrops, making this formation very easy to spot. Above comes a unit rather similar to the Esneux Formation but forming more regular thin beds and usually slightly carbonate (calcareous or dolomitic) and containing shaly interbeds (Poulseur Member of the Condroz Formation)

The quarry is mostly opened in the typical "Grès du Condroz", (Fig. 20A) that are in fact, genuine arkose or arkosic micaceous sandstone, with a lot of siltstone beds arranged in sequences (deepeningupwards at the base, shallowing-upwards in the upper part) of the Montfort Member of the Condroz Formation. The base of this unit is typically placed at a remarkable horizon of ball-and-pillows that reach here several metres in diameter (called "calamanes" by the quarrymen, Fig. 20D). They are interpreted as seismically-induced load casts.

Thorez et al. (1977) divided the Montfort Member into three units that are here re-interpreted as facies by Mottequin et al. (2024), from the base to the top: (1) a package of rhythmic shallowingupwards deposits of arkosic sandstone, bioturbated or with planar laminations, siltstone (dominant) and shale (Bon-Mariage Facies); (2) quartzitic and arkosic sandstone arranged in metre-thick beds displaying a systematic coarsening upward grading either massive or with planar and oblique laminations, megaripples, often bioturbated (Gombe Facies) (Fig. 20B); (3) greyish to blueish quartzitic and arkosic sandstone with massive texture or marked by (mega-)ripples intercalated with sandy and micaceous primary dolomite beds with abundant sedimentary structures such as channels, ripples, mud-cracks, flat pebbles and pseudomorphs of anhydrite clasts (Barse Facies) (Fig. 20C).

The development of red beds (in fact micaceous sandstone and arkosic sandstone where the quartz grains are coated with haematite) marks the base of the Evieux Member, a unit showing a shallowingupwards sequence culminating with fluviatile floodplain facies (channels, palaeosols, with plant fossils, etc.). The latter is exposed in the upper part of the quarry but is hardly accessible.

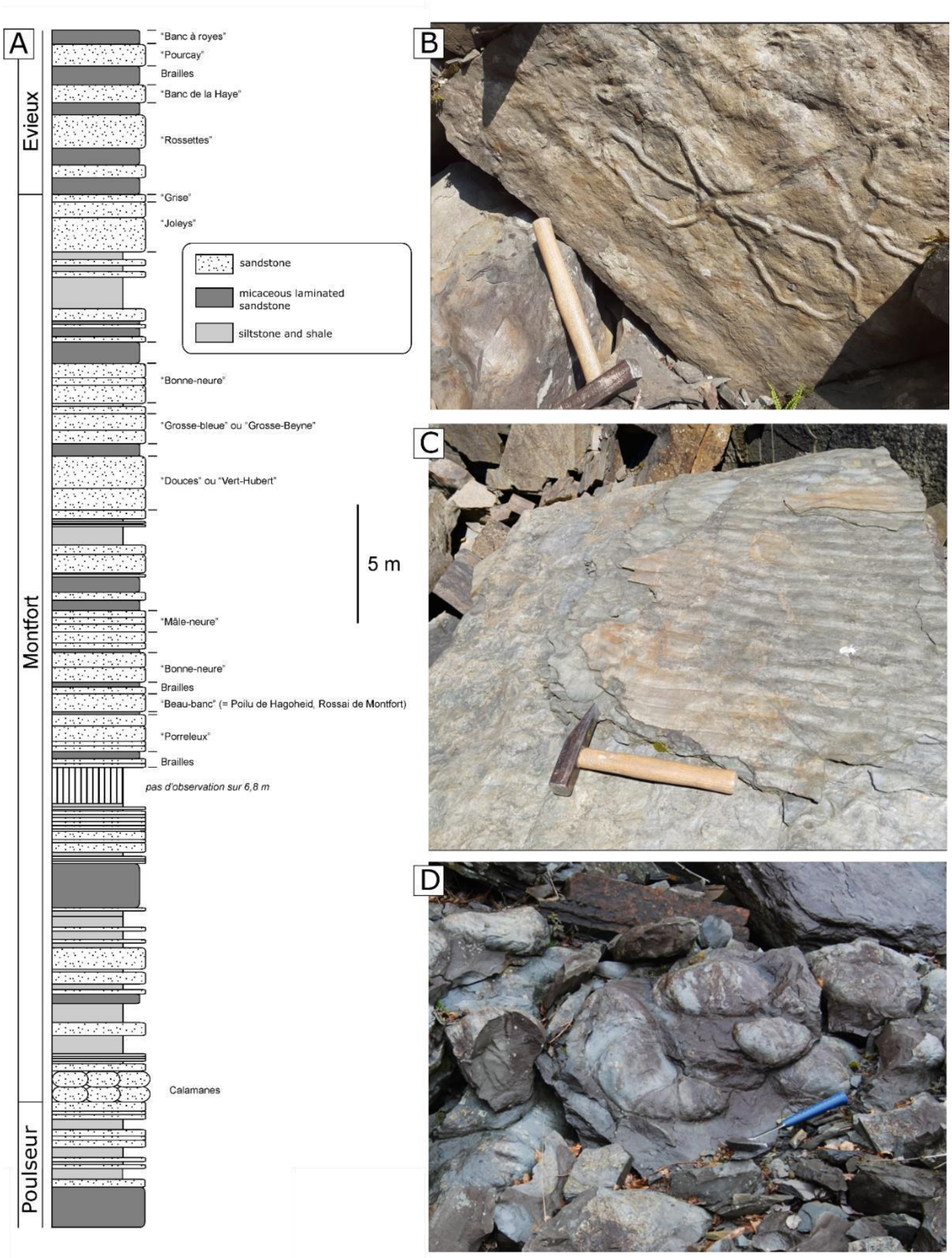


Fig. 20 A: log of the quarried beds of sandstone extracted from the Falize quarry at Remouchamps, with commercial names, after Corin (1933), drawing courtesy of B. Mottequin. **B:** The ichnofossils Psammichnites implexus in the Montfort Member. **C:** Ripple marks on a bed surface in Montfort Member. **D:** "calamanes", large ball-and-pillows near the base of the Montfort Member.

Stop 8: Lambermont section

Location: Rue des Combattants, 4800 Verviers

References: Coen-Aubert (1974), Vanbrabant et al. (2003), Schmidt (1994), Mottequin (2005).

Lithostratigraphy and biostratigraphy: Fond des Cris Member of the Aisemont Formation, Lambermont Formation (including Verviers Member, Matagne Facies and Hony Horizon), Hodimont Formation

Description: This section, though relatively tectonised, gives a good idea of the upper Frasnian succession of the area (Fig. 21A). It starts with the Fond des Cris Member of the Aisemont Formation ("second biostrome" or "membre superieur" in the literature) which is a massive limestone unit with oncoids and numerous corals (*Potyphyllum, Frechastratea, Macgeea, Alveolites*) capped by an emersion surface. The stained aspect of this limestone comes from de-dolomitisation process affecting the surface of the beds or more pervasively the limestone (Denayer & Poty, 2010). The erosive surface at the top (Fig. 21C) marks the sequence boundary between middle and upper Frasnian units and can be traced on hundreds of kilometres.

The Lambermont Formation starts with 6 m of green and grey shale with scarce calcareous nodules; they are rich in atrypide and spiriferide brachiopods (lower shaly member). It is followed by the Verviers Member, a c. 10 m thick unit starting with an argillaceous limestone bed rich in colonial rugose corals (*Frechastraea, Potyphyllum* and *Iowaphyllum,* Fig. 21D) known as the "troisième biostrome à *Phillipsastrea*" of Coen et al. (1977) and overlain by reddish to greenish argillaceous, nodular limestone and nodular shale with colonial rugose corals. This coral bed marks a renewal of fauna but the diversity stays nevertheless relatively low. The overlying shaly unit consist of a first 10 m thick package of green shale and nodular limestone alternations, with and a second package c. 10 m thick, of dark grey shale (Matagne Facies) with few lingulids and flat bivalves ("paper pectens"). Just above the dark shale is a 1 m thick set of c. 10 thin layers of coquina bed limestone alternating with shale (Hony Horizon, Fig. 11E) overlain with c. 3 m of black shale corresponding to the upper Kellwasser Event. The Hony Horizon was interpreted by Sandberg et al. (1988) as being related to a eustatic fall, but it reflects a series of at least seven tsunamites after and Mottequin & Poty (2016). This Horizon yielded the last Frasnian conodonts indicative of the *linguiformis* zone. The base of the Famennian stage is placed at the top of these beds (Fig. 21B).

Above the Hony Horizon is a 4-6 m package of purplish or green shale marks the base of the Hodimont Formation which is mostly distinguished by the presence of oolithic ironstone beds (see Heid de Fer section). This part is poorly exposed nowadays in the Lambermont section.

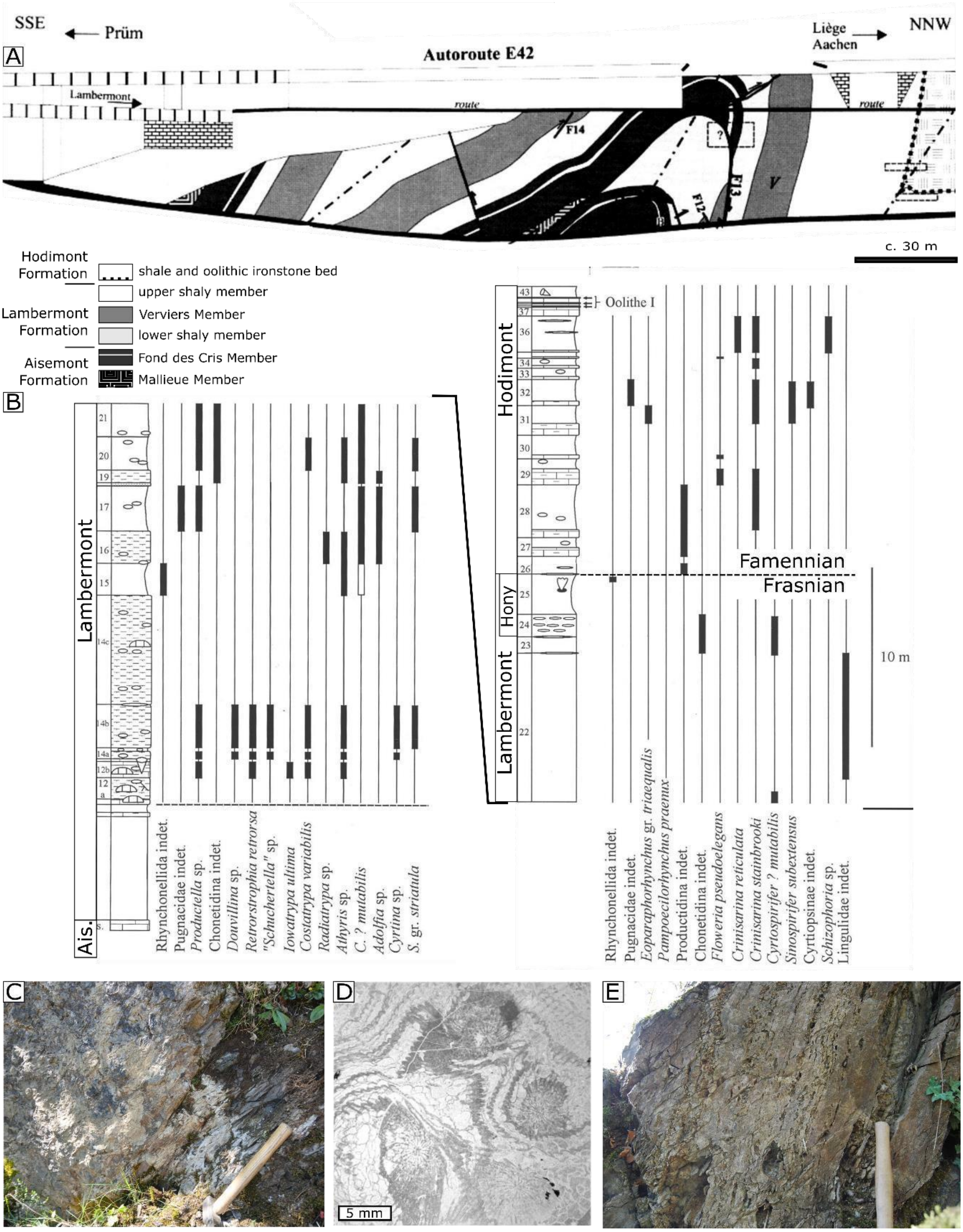


Fig. 21 A: Schematic sketch of the Lambermont section (after Vanbrabant et al., 2003). **B:** Log of the Lambermont section with distribution of brachiopod genera (modified after Mottequin, 2005). **C:** Contact between the limestone of the Fond des Cris Member and the shale of the Lambermont Formation. **D:** *Iowaphyllum mutabile*, a rugose coral typical of the Verviers Member. **E:** Dissolved coquina beds that correspond to tsunamites forming the Hony Horizon.

Stop 9: 'Dolhain–Limbourg' section

Location: Rue Moulin en Rhuff, 4831 Limbourg

References: Conil (1968), Denayer et al. (2021), Mottequin et al. (2024).

Lithostratigraphy and biostratigraphy: Comblain-au-Pont Formation (Dolhain Facies), Hastière Formation (Binsfeldhammer Facies).

Description: This section starts with a few metres of micaceous siltstone and sandstone of the Condroz Formation and passes to mainly shaly beds with calcareous siltstone interbeds. A first horizon with corals and stromatoporoids Fig. 22C) is relatively sandy and shaly in its middle part. It then passes to an alternation of bioclastic calcareous shale and coarse crinoidal limestone. Conil's (1964) 'biostrome principal' is a 4.2 m thick biostrome composed of lamellar stromatoporoids in a sandy and argillaceous matrix with a nodular aspect due to stylonodularisation. It is overlain by 7 m of bioclastic limestone beds with few corals and stromatoporoids alternating with siliciclastic interbeds. The overlying unit is a massive crinoidal limestone, with poor microfauna and macrofauna that already represents Binsfeldhammer dolomitic Facies of the Hastière Formation (Amler & Herbig, 2006). The DevonianCarboniferous boundary is positioned at the top of bed no. 43 that yielded the last quasiendothyrids. Few evidence of the HSS Event is recorded as quartz grains and rare small intraclasts visible in thin section (Fig. 22B). The upper massive limestone could represent the middle member of the Hastière Fm as known from other localities ('lower dolomite' of Kasig, 1980) sections but without biostratigraphic evidence (Poty, 2016).

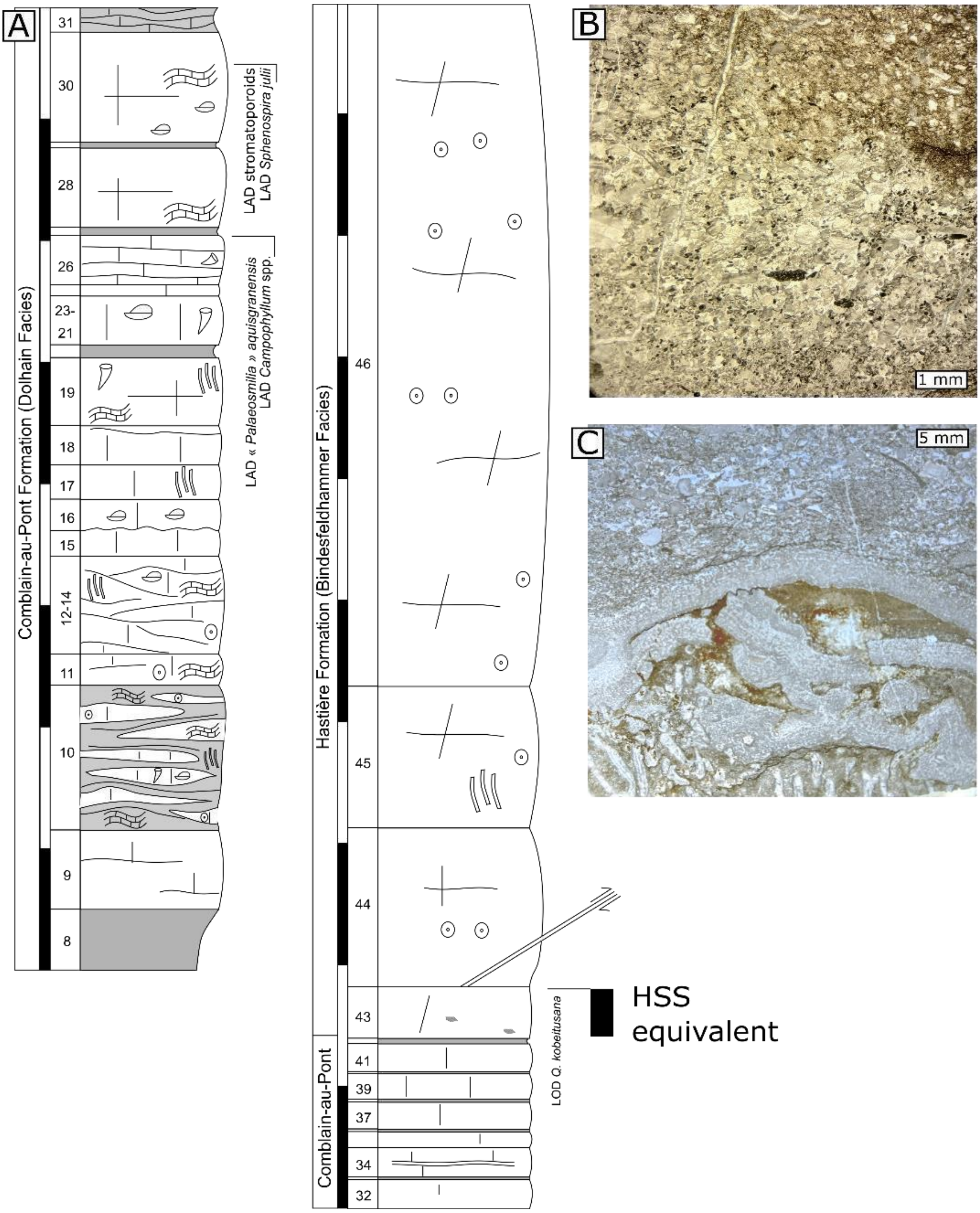


Fig. 22 A: Log of the Dolhain section. After Denayer et al. (2021). **B:** thin section at the base of bed 43 showing bioclastic grainstone with small intraclasts (dark grains) indicative of the Hangenberg Sandstone Event. **C:** thin section in stromatoporoid biostrome of bed 12-14.

Stop 10: Carnol quarry at Eupen

Location: Winweg 4701 Eupen

References: Poty (2016), Denayer et al. (2019).

Lithostratigraphy and biostratigraphy: Pont d'Arcole Fm, Vesdre Group (dolomitised Landelies, Yvoir, Ourthe and Longpré formations), lower to upper Viséan, Neffe and Lives formations, lower to middle Viséan.

Description: After Poty (2016), the section exposed in the Carnol quarry starts with < 6 m of dark shale poor in fossil (Pont d'Arcole Formation), followed by a thick succession of dolomitic limestone and dolostone forming the Vesdre Group (Fig. 23A). The lithological composition of the Vesdre Group is here slightly different from its westward expression (where it passes to the Engihoul Formation) Here, the Vesdre Group is thicker and its composition announces the lacunar succession known in the Aachen area. It comprises of: 37 m of crinoidal dolostone with syringoporids and *Siphonophyllia rivagensis* (corresponding to the dolomitised Landelies Formation); 44 m of decimetre- to pluridecimetre-thick beds of dolostone, cherty in its upper part (dolomitised Yvoir Formation); 13 m of dolostone and dolomitic limestone, with some cherts and numerous silicified *Cyathoclisia uralensis* in its lower part, becoming less dolomitic and poor in chert upwards, passing to an oolithic limestone with *Keyserlingophyllum obliquum, Uralinia* cf. *multiplex* and *Vaughanites flabelliformis* (Fig. 23D) in its upper part ("Vaughanites oolithe", correlated with the Hastenrath Member, a fossiliferous noncrinoidal equivalent of the Ourthe Formation); 8 m of laminated, dark dolostone, in decimetre- to pluridecimetre-thick beds, resting paraconformably upon the underlying unit (dolomitised upper member of the Martinrive Formation, Fig. 23E); 15 m of coarse-grained crinoidal dolostone in pluridecimetre-thick beds (dolomitised Flémalle Member of the Longpré Formation); 4 m of massive, coarse-grained, dolostone (dolomitised Avins Member of the Longpré Formation); after a c. 10 m-thick gap of observation (possibly corresponding to the Walhorn dolomitic breccia), 5 m of bedded dolostone and dolomitic breccia (dolomitised Belle Roche Breccia).

Above this dominantly dolomitic set of units, all included in the Vesdre Group, the southern part of the quarry exposes: 40 m of dark, fine-grained, limestone in pluridecimetre-thick beds of the upper part of the Terwagne Formation. An argillaceous palaeosol corresponding to the cinerite 'M' of Delcambre (1989) (Fig. 23C) and a horizon rich in *Dorlodotia briarti densa* respectively occur 10 m and 4 m below the top of the formation. Both levels can be traced along the northern margin of the basin. The overlying Neffe Formation is dominated by massive oolitic and bioclastic grainstone with *D. briarti briarti* (c. 10 m), and capped by 3-4 m of dark limestone with intraclasts, carbonaceous limestone and brachiopod coquina typical of the top of the Neffe Formation. The Haut-le-Wastia Member of the Lives Formation starts right on top of the argillaceous horizon of the Banc d'Or de Bachant, a pedogenetised cineritic bed (Fig. 23B). The first 30 m of limestone of the Haut-le-Wastia Member display parasequences dominated by stromatolitic facies. The youngest beds exposed in the quarry belong to the Corphalie Member (middle member of the Lives Formation), made of grey limestone rich in *Siphonodendron martini* and *Lithostrotion araneum*. As noted by Poty (2016), only the highstand system tracts are recorded in this area, lowstand system tract TST are lacking and transgressive system tracts are usually reduced in development, suggesting a proximal position of the area on the shelf with considerable non-deposition and/or erosion intervals.

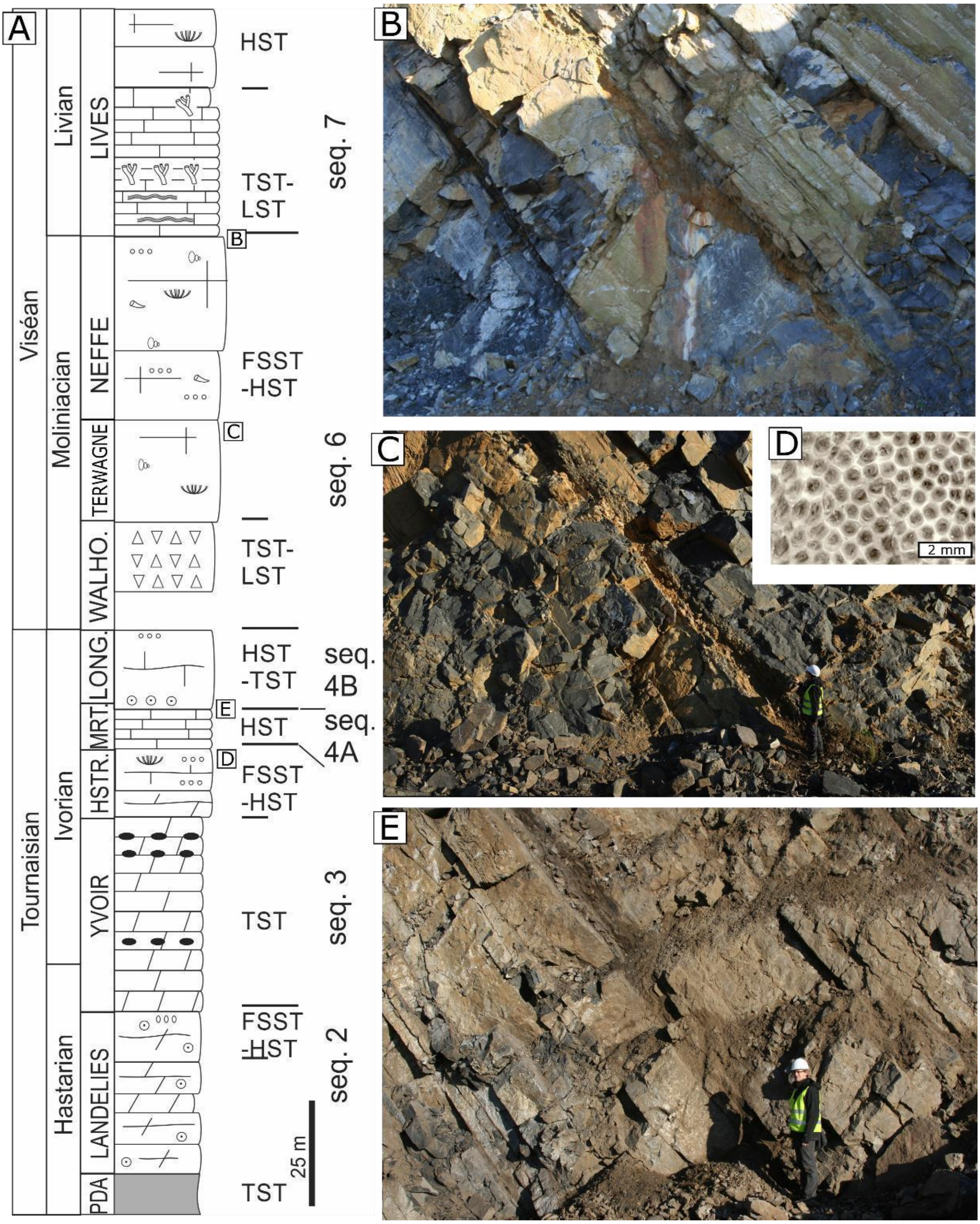


Fig. 23 A: Schematic log of the stratigraphical succession in the Eupen 'Carnol' quarry and sequential interpretation after Poty (2016). **B:** Banc d'Or de Bachant, marking the boundary between the Neffe and Lives Formations. **C:** Cineritic horizon 'M' in the upper part of the Terwagne Formation. **D:** *Vaughanites flabelliformis*, typical tabulate coral of the Hastenrath Member. **E:** boundary between the dolomitised Martinrive Formation and Flémalle Member. Belgian geologist for scale. Abbreviations: LST: lowstand system tract, TST: transgressive system tract, HST: highstand system tract, FSST: falling-stage system tract, seq.: third-order sequences HSTR.: Hastenrath Member, MRT.: Martinrive Formation, LONG.: Longpré Formation, PDA: Pont d'Arcole Formation, WALHO.: Walhorn Breccia. Legend of lithologies: see Fig. 17.

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