Harrow & Hillingdon Geological Society Overseas Field Trips

Belgium

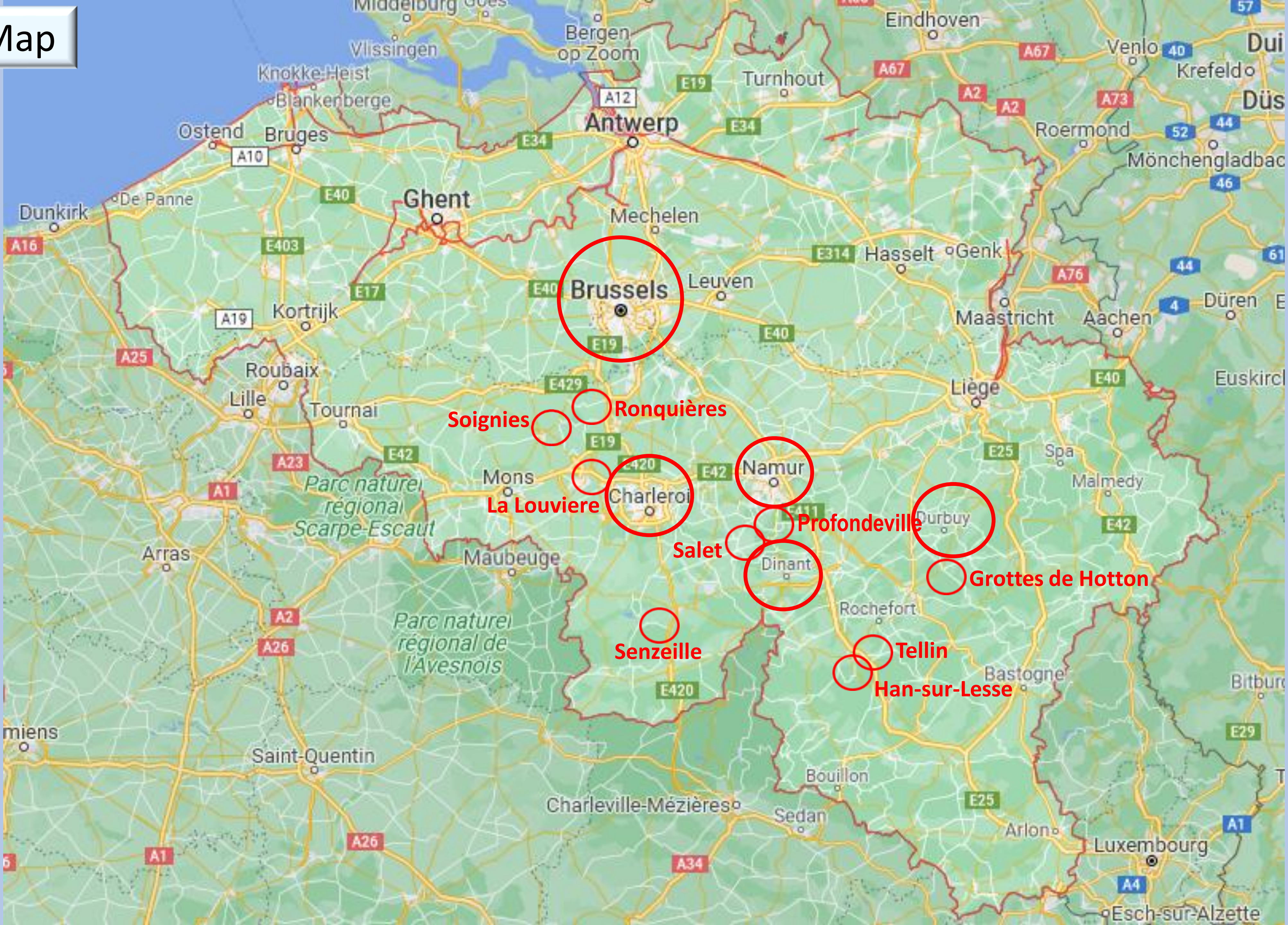
Spring 2018


We visited localities in
Wallonia …
… finishing in Brussels

Based in Namur, we visited the areas below to localities in Palaeozoic rocks:

- The central industrial belt, which, with coal, limestone and iron ore resources, fuelled an industrial revolution parallel to our own.
- The Condroz and the Famenne, between the industrial belt and the Ardenne to the south.
- The northern Ardenne.
- Finishing at the Museum of Natural Sciences in Brussels.

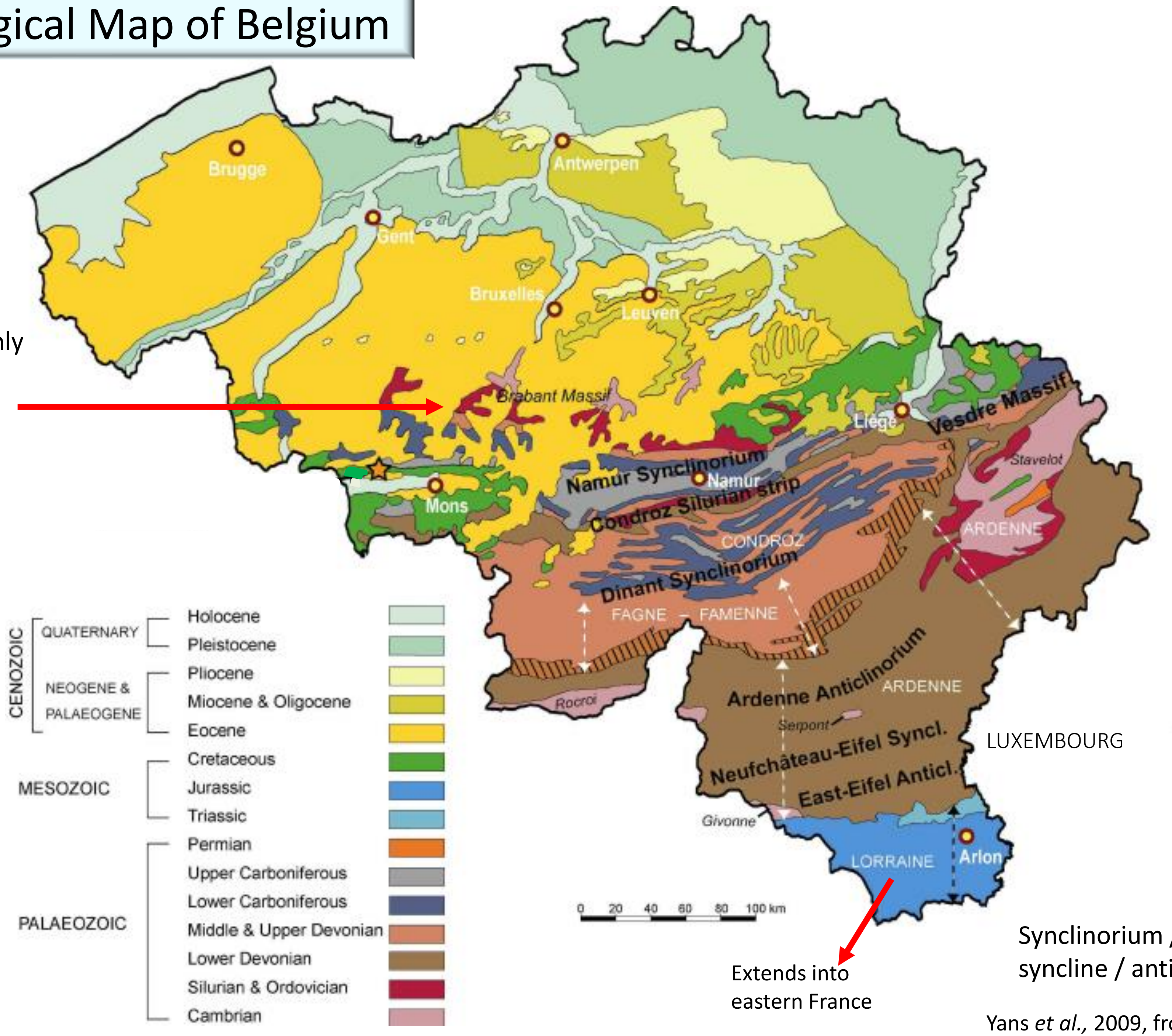
Locality Map



Google maps

Simplified Geological Map of Belgium

The Brabant Massif of mainly lower Palaeozoic rocks continues into England and Wales under East Anglia, London and the Midlands.



LUXEMBOURG

Extends into eastern France

Synclinorium / anticlinorium = a regional syncline / anticline with secondary folds

Yans *et al.*, 2009, from the Geological Survey of Belgium

Key geological features of Belgium (with emphasis on the Palaeozoic of Wallonia)

- Belgium's geology ranges from Lower Palaeozoic to Holocene within its 30,500 km^2 area.
- Excepting the Quaternary cover, the outcrops can be divided into two large areas:
  - The northern part with mostly Cenozoic deposits (<66 Ma) – mainly marine and unconsolidated sediments
  - The southern part with mostly Palaeozoic (>252 Ma) sedimentary rocks, strongly deformed in the latest Carboniferous by the Variscan orogeny.
- In the southern part, younger rocks occur around Mons (Mesozoic and Cenozoic), Liège (Cretaceous) and Arlon in the far south (Jurassic and Triassic). However, only the Palaeozoic geology within the scope of this presentation is summarised below.

- **Lower Palaeozoic** rocks (Cambrian-Silurian) occur in:
  - The Stavelot, Rocroi, Serpont and Givonne inliers in the Ardenne
  - The Condroz inlier just south of Namur
  - Valley bottoms in the Brabant Massif.
- These rocks were deformed in the Avalonia*-Baltica-Laurentia collisions of late Ordovician to early Devonian time, causing the Caledonian orogenic phases. Igneous rocks (some volcanic) occur in parts of the Brabant massif and to a lesser extent in the other inliers. Thrust sheets and folds occur in the Ardenne inliers, but the Brabant Massif appears to have been detached and moved a short distance and its rocks highly folded.

- **Upper Palaeozoic** rocks (Devonian, Carboniferous and Permian) rest unconformably on the Lower Palaeozoic basement.
- They feature several structural units caused by the Variscan orogeny. The northern border of the Variscan belt (i.e., the Front) runs through Belgium, where the affected rocks form the Rhenohercynian fold-and-thrust Zone (RHZ). North of the Variscan front, the Brabant Massif (part of the 'Old Red Sandstone continent') was unaffected. The RHZ encompasses mainly marine or coastal sediments deposited in the Rhenohercynian sea beyond which lay the Variscan belts of central Europe.

Continued

*Belgium belonged to Avalonia (as does the S. British Isles) which separated and drifted away from the southern hemisphere continent of Gondwana in the Ordovician. Avalonia collided with Baltica (Fennoscandinavia, European Russia) and both collided with Laurentia (N. America) leading respectively to the Ardenne and Brabant phases of the Caledonian orogeny in Belgium.

Key geological features of Belgium (with emphasis on the Palaeozoic of Wallonia)

- **Upper Palaeozoic** (continued). In the *Lower Devonian*, sandstones, shales and conglomerates were deposited in the Rheic Ocean from the Old Red Sandstone (ORS) continent. They occur in the High Ardenne, with some of the shales altered to slates.
- The *Middle Devonian* saw a rise in sea level with the coast receding to the Brabant Massif. There was a dramatic increase in carbonate deposition on a vast platform which grew off the coast of the ORS continent, which itself continued to supply increasing volumes of detritus. Carbonate deposition was probably related to a warmer climate with the area now between the equator and the southern Tropic.
- The *Upper Devonian* saw a further rise in sea level and the growth of another carbonate platform north of the previous one. Carbonate mounds grew as build-ups of initially limestone with sponges, then becoming enriched with crinoids and corals and finally in calcified sponges and cyanobacteria. A fall in sea level in the latest Devonian resulted in the ORS continent coastline readvancing and the burial of the limestones in detrital sandstones and shales.
- The *Carboniferous* in Belgium is traditionally subdivided into the Dinantian, Namurian and Westphalian. Carbonates, detrital sediments, and mixed detrital sediments and coal dominate these series, respectively. The Rheic Ocean, located near the Equator, was closing, as evidenced by the forthcoming collision of Gondwana and Laurussia (i.e., the ORS Continent). This major tectonic event gave rise to the Variscan mountain belt and to the formation of the supercontinent Pangaea.
- Following the coastal plain environment of the latest Devonian, the *Dinantian* marks a return to fully marine conditions. A dramatic decrease in detrital sediment supply led to the resumption of a 'carbonate factory' on a very large carbonate shelf. Again, mound development took place. The main areas of the Dinantian are the Condroz and Hainaut.
- The *Namurian* series broadly comprises black shale with subordinate limestones, followed by shales, sandstones and conglomerates. Small beds of coal announce the future development of the great equatorial coal forest.
- The *Westphalian* saw the bulk of the coal measures formed. The uplift of the Variscan mountains led to general retreat of the seas, giving way to an extended marsh and lagoon environment. Huge amounts of sediment coming from the Variscan mountains accumulated in subsiding areas, covering even the Brabant Massif. The sediments exhibit cyclicity i.e., sandstone (coastal/fluvial/soil), coal (equatorial forest) and shales (floodplain and lake sediment). Occasional marine incursions occurred.

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Palaeogeography of the Lower Palaeozoic

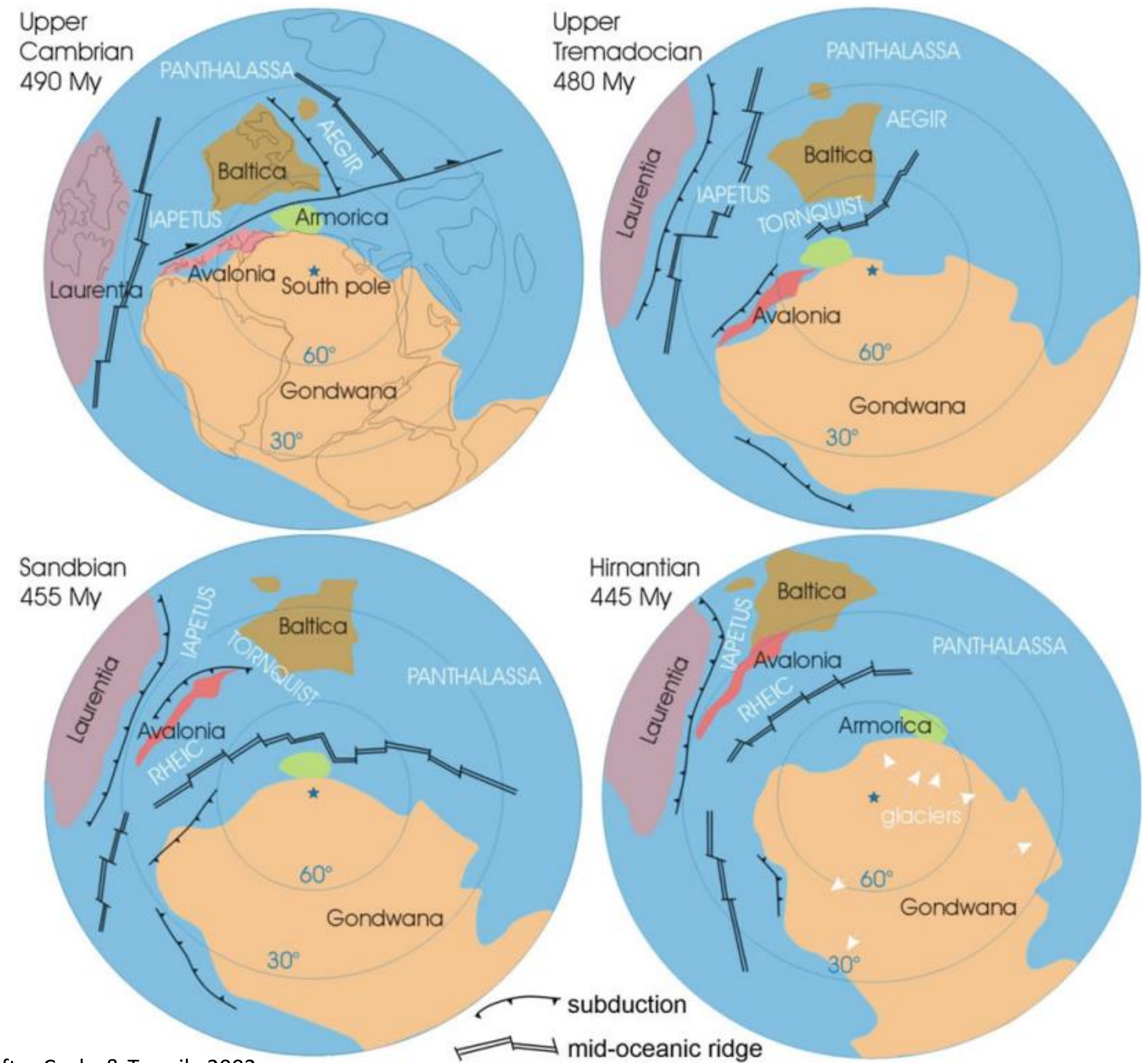
White arrows indicate ice movement.

Tremadocian – earliest Ordovician
Sandbian – early late Ordovician
Hinantian – latest Ordovician
These are International stage names. The latter two are equivalent to part of the British Caradoc and Ashgill stages respectively.

At top left, the Palaeozoic continents are shown indicating the outlines of the present-day continents.

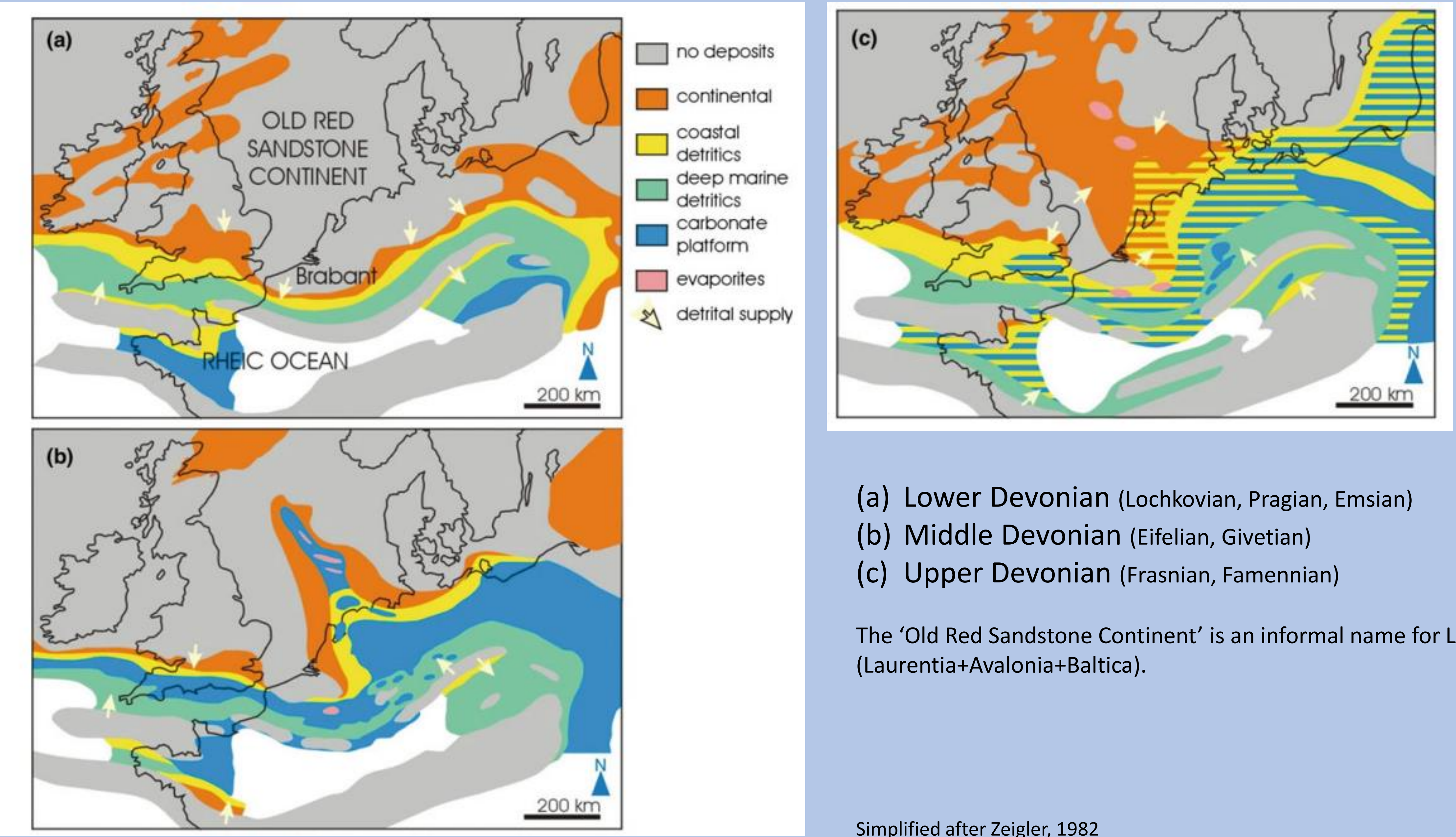
The microcontinent Avalonia, of which southern Britain and Belgium form part, originated as a volcanic island arc in the latest Precambrian (c. 750-550 Ma) due to subduction beneath the Gondwana margin.

Avalonia accreted to Laurentia c. 400 Ma joining ‘England’ to ‘Scotland’.



After Cocks & Torsvik, 2002

Maps of NW Europe in the Devonian

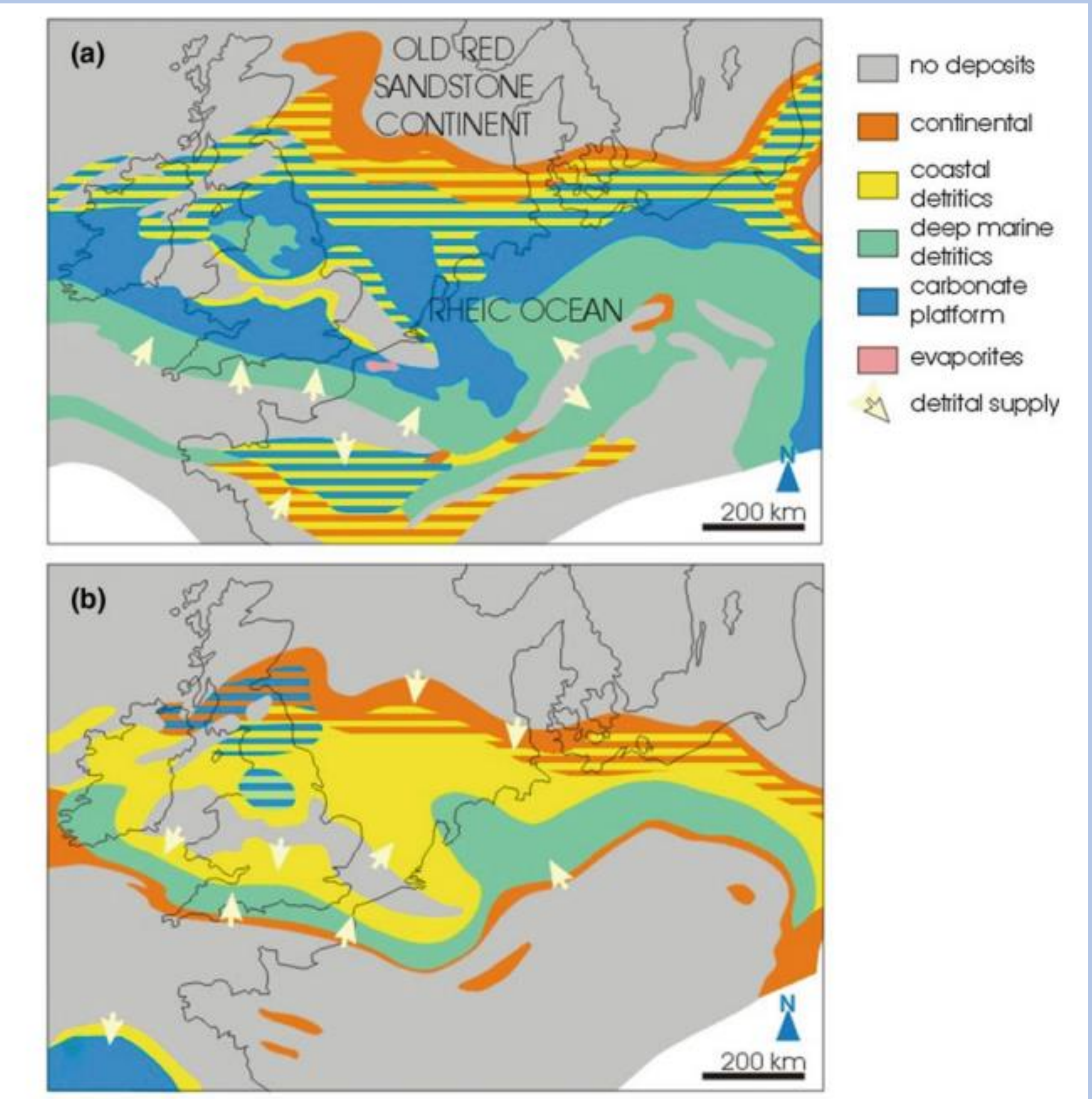


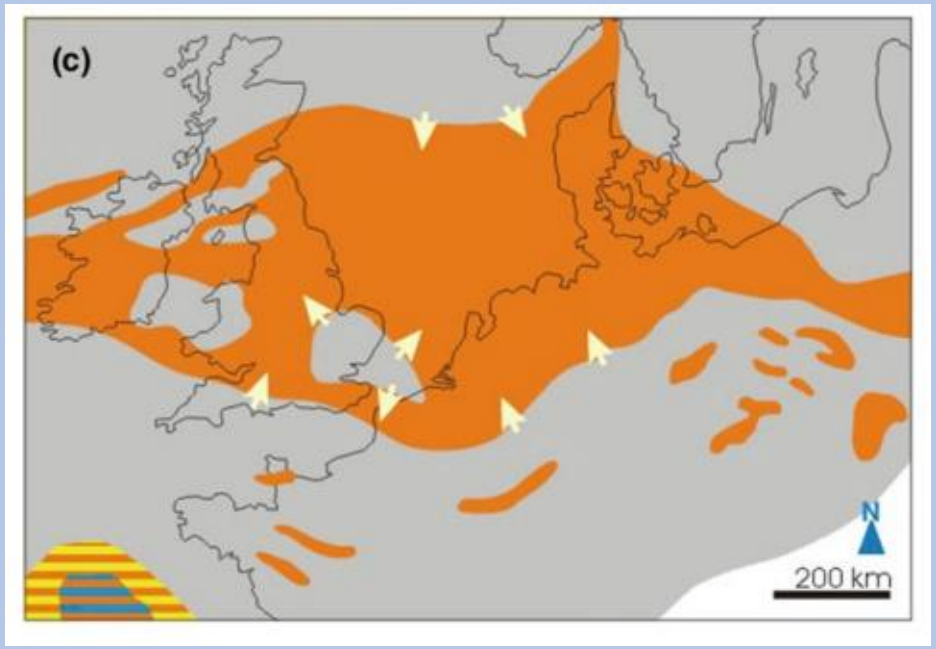
(a) Lower Devonian (Lochkovian, Pragian, Emsian)
(b) Middle Devonian (Eifelian, Givetian)
(c) Upper Devonian (Frasnian, Famennian)

The 'Old Red Sandstone Continent' is an informal name for Laurussia (Laurentia+Avalonia+Baltica).

Simplified after Zeigler, 1982

Maps of NW Europe in the Carboniferous



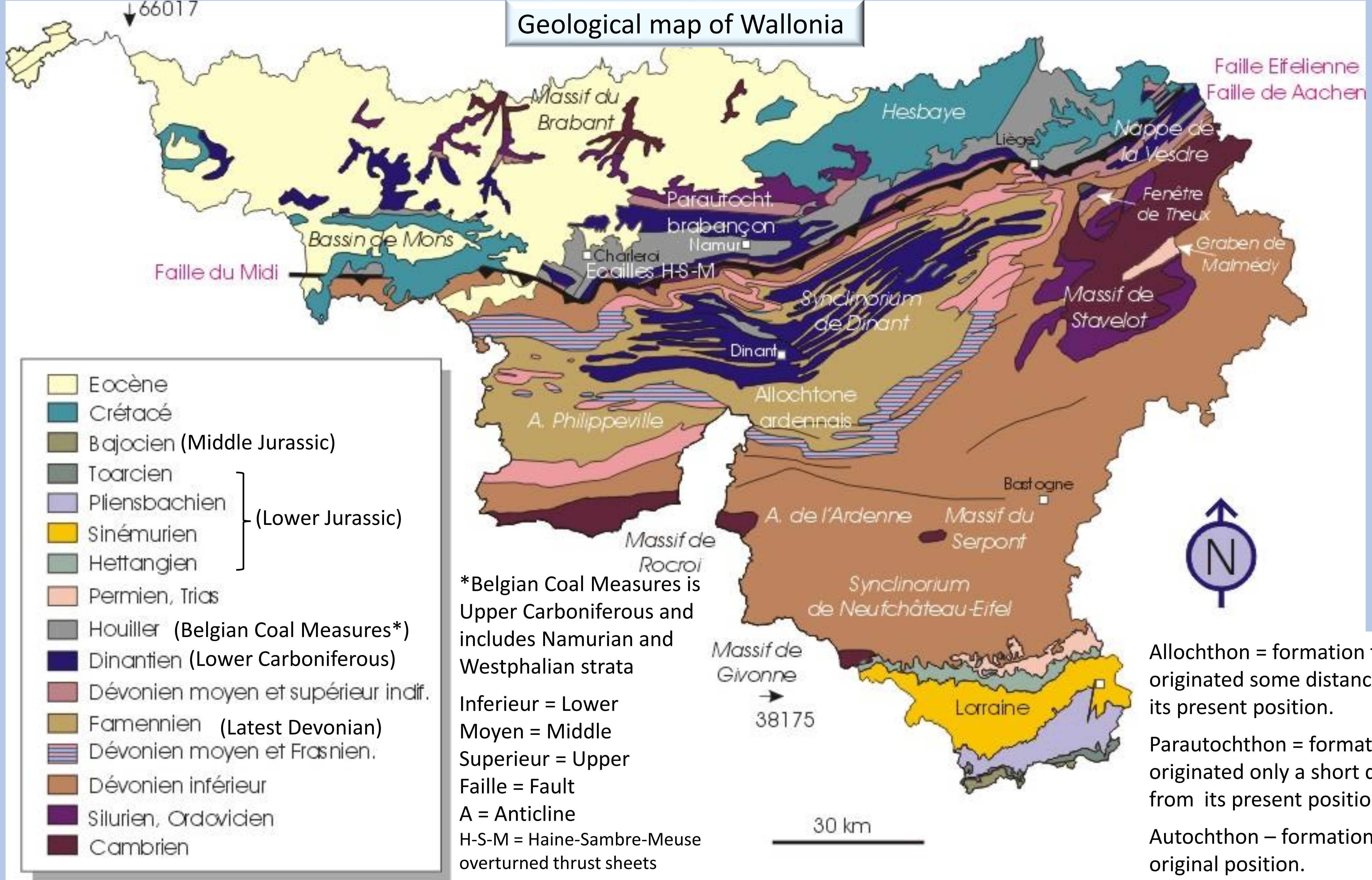


(a) Dinantian
(b) Namurian
(c) Westphalian

The ‘Old Red Sandstone Continent’ is an informal name for Laurussia (Laurentia+Avalonia+Baltica).

Simplified after Zeigler, 1982

Geological map of Wallonia



*Belgian Coal Measures is Upper Carboniferous and includes Namurian and Westphalian strata

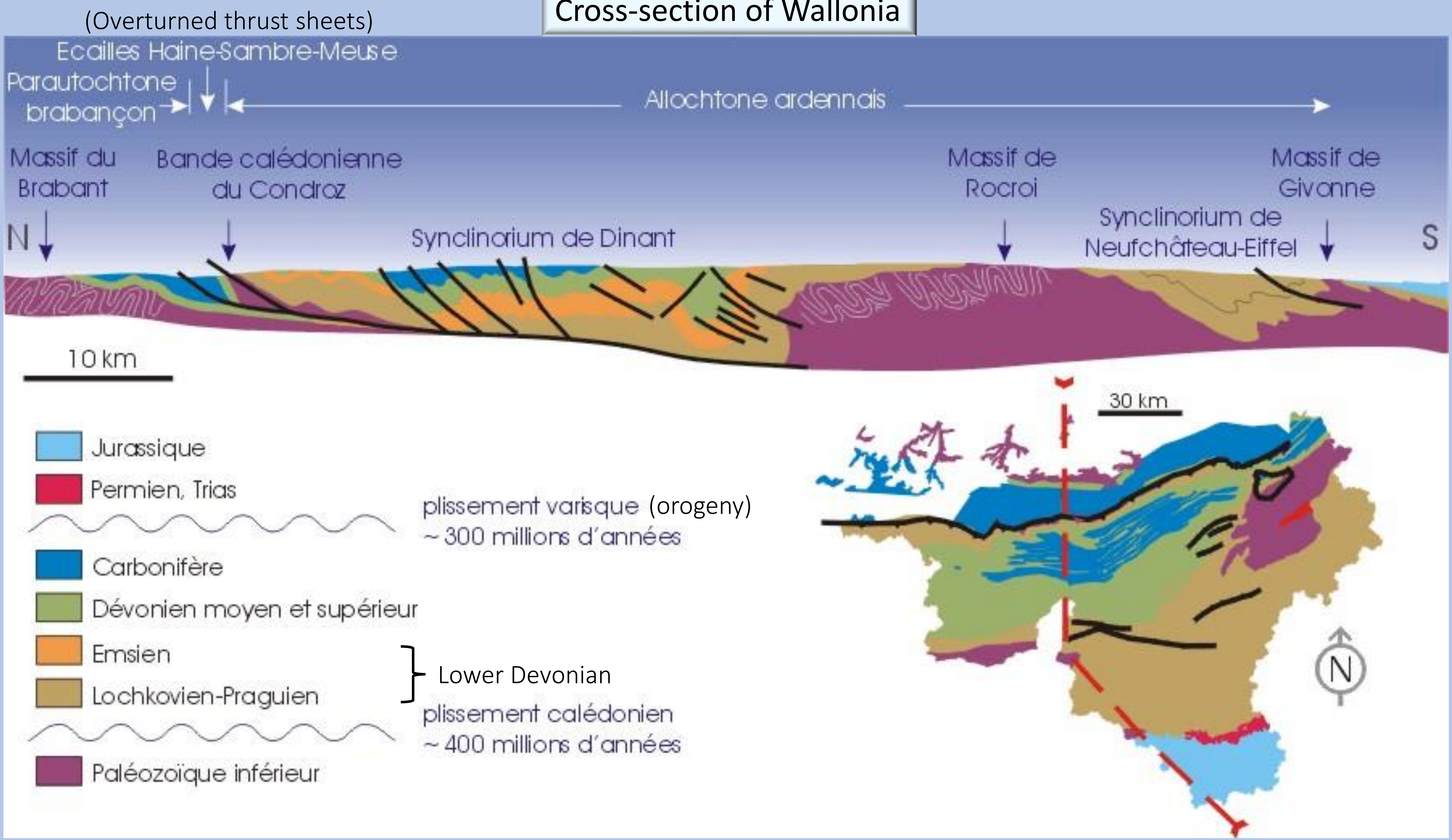
Inferieur = Lower
Moyen = Middle
Superieur = Upper
Faille = Fault
A = Anticline
H-S-M = Haine-Sambre-Meuse overturned thrust sheets

Allochthon = formation that originated some distance from its present position.

Parautochthon = formation that originated only a short distance from its present position.

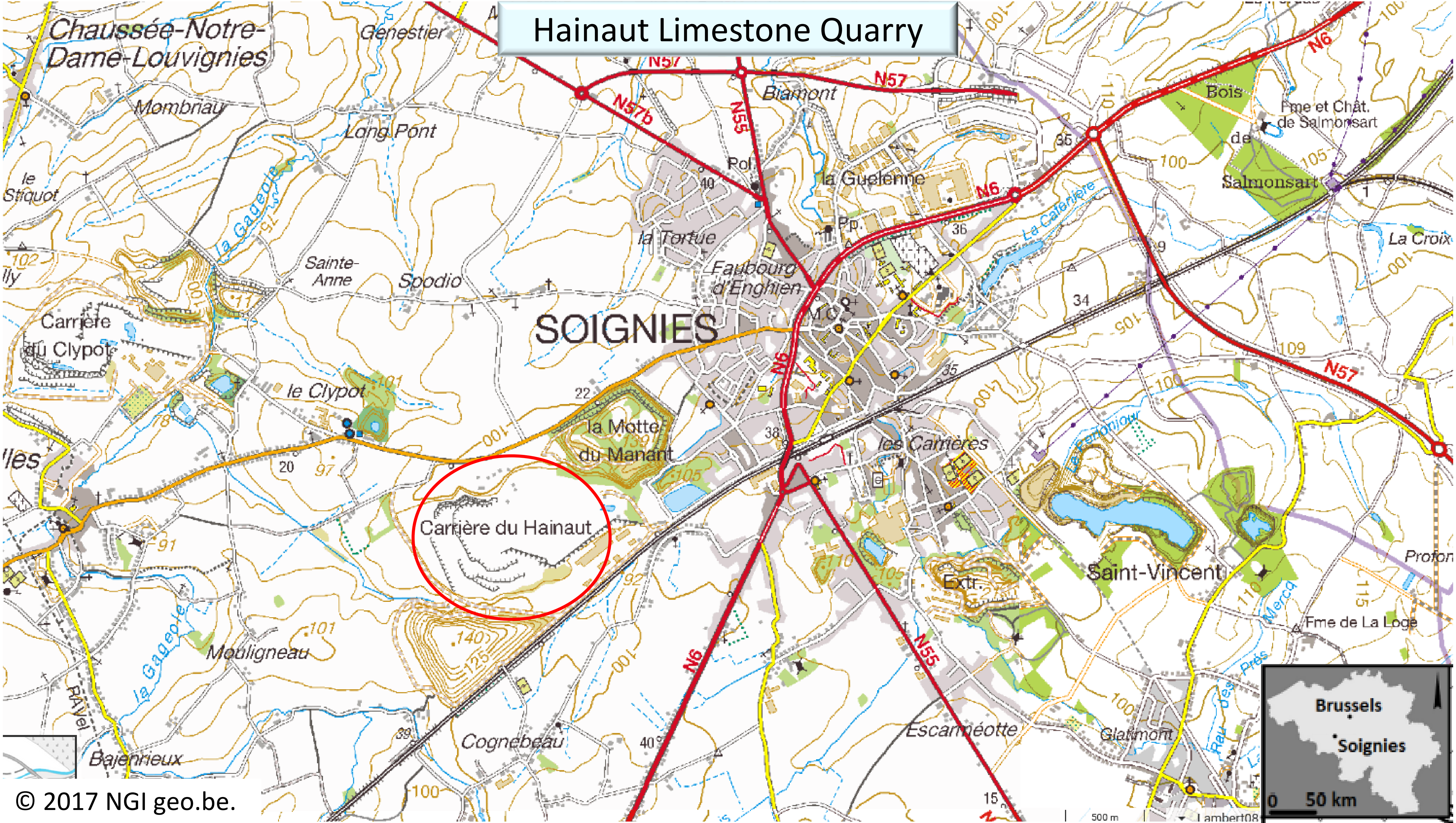
Autochthon – formation in its original position.

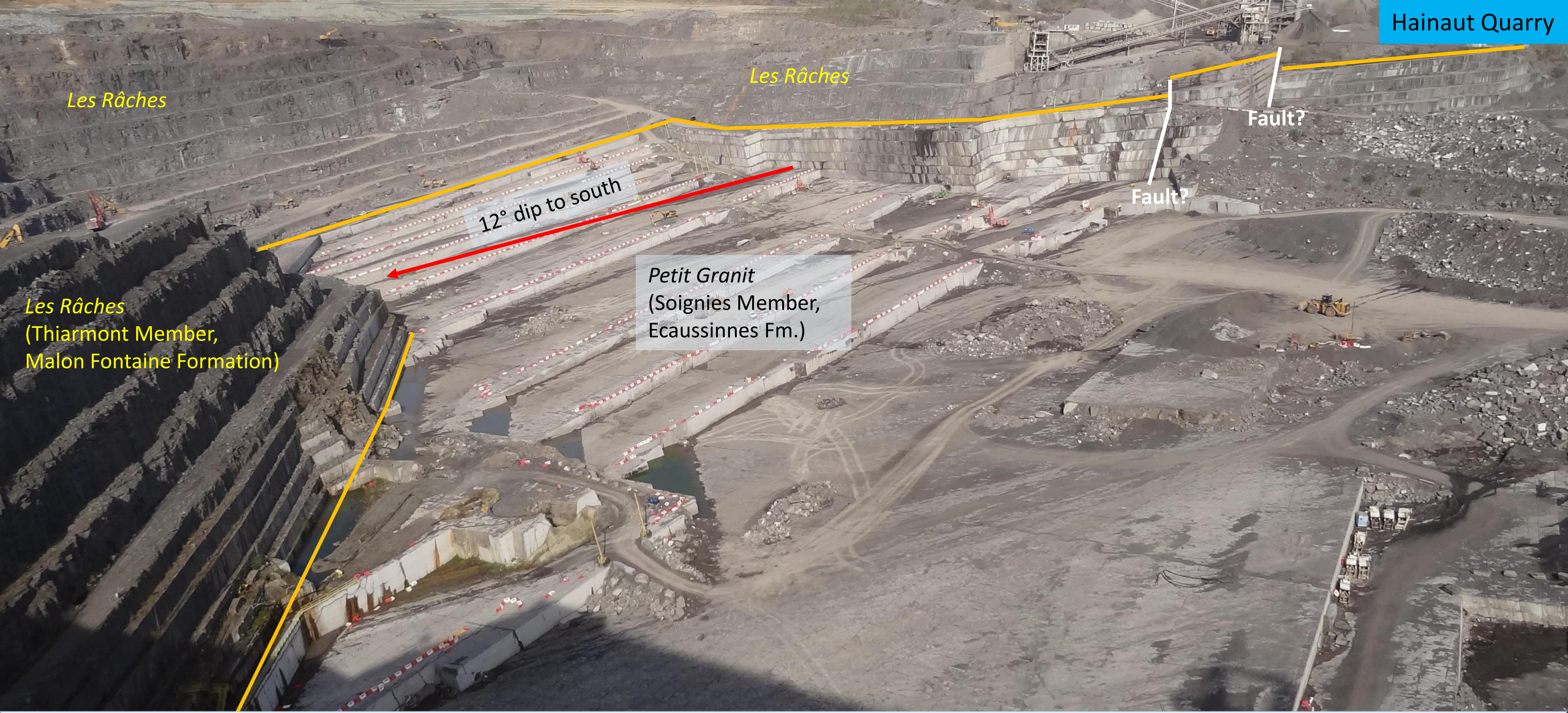
Cross-section of Wallonia



Boulvain & Vandenburghe, 2017

Hainaut Limestone Quarry





Hainaut Quarry, begun 1888 and one of Europe's largest, is in limestone dating from the upper Tournaisian of the Lower Carboniferous (c.350-340 Ma). Here, it is overlain unconformably by thin Cenozoic strata, below which up to 50m of *'Les Raches'* rests on 45m of *'Petit Granit'* – both quarrymen's terms. The Carboniferous limestone in Belgium was deposited in tropical conditions on a vast marine shelf where differential subsidence occurred forming six sedimentation areas, one of which is Hainaut. The latitude of the area was then about 15°S. The limestones dip away from the older rocks of the Brabant Massif to the north (then land). This massif extends into England as the London Platform.

The best quality stone is called *Petit Granit* because when polished it does take on a granitic appearance owing to its calcite crystals shining in a dark blue-grey matrix. It is a very hard, almost impervious, limestone, full of crinoids and corals fragments. It is worked for dimension stone that has trade names such as *Pierre Bleue* and *Bleue Belge*; it has many uses from flooring, paving and wall tiling to sculpture and building stone. The darker, rubbly limestone (*Les Râches,* left and top), is worked by partner companies for aggregate…


… as seen here. Both limestones are micrites (recrystallised lime mud)
Hainaut Quarry
The aggregate is produced by a partner company working the rubbly limestone overburden.
Râches
(Thiarmont Member,
Malon Fontaine Formation)
Petit Granit
(Soignies Member,
Ecaussinnes Formation)
The good quality stone is up to 75m below the surface and dips towards the south.

The quality stone is extracted by sawing out blocks weighing up to 100 tonnes.
The crawler cutting machines (ringed) are employed after a long bench cut parallel to the face has been made.
Hainaut Quarry
Loose block being split
Bench

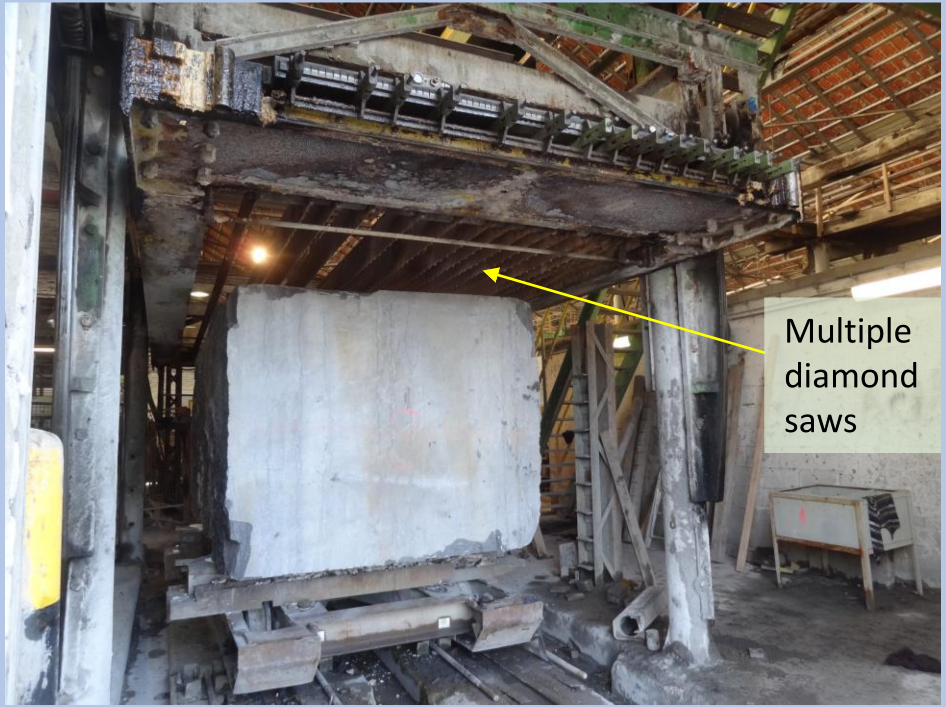

Hainaut Quarry
The extracted blocks are stored here to the right of the area just shown to await transport to the processing works. There they will be sawn into slabs and smaller blocks. Some of the production will be polished or cut into bespoke shapes or receive various finishes.

Transporting the blocks for processing

A block can weigh over 6 tonnes.

Another method is to use a straddle carrier

Hainaut Quarry



Upper L: Blocks to be sawn into slabs.
Lower L: Block in place for sawing.
Above: Sawing completed (takes about 1.5 hours)

The water-cooled* saws move back and forth; their spacing can be adjusted for the slab thickness required. This machine, one of several, has 68 saw blades.

*Recycled water is used in sawing, which is groundwater encountered in quarrying operations. The water is pumped to storage tanks. Used water is recycled again.

The limestone is an important aquifer, so most of the groundwater released during operations is stored in a reservoir to supply 40,000 homes in the area.

Hainaut Quarry

A: Slabs for processing.

B: Polishing machine.

C: Feeding paving slabs into another polishing machine.

D: Polished surface showing coral and crinoid fragments, and calcite crystals (10c coin is 20mm across).

Hainaut Quarry


A


B

A, B: Stonemasons at work.

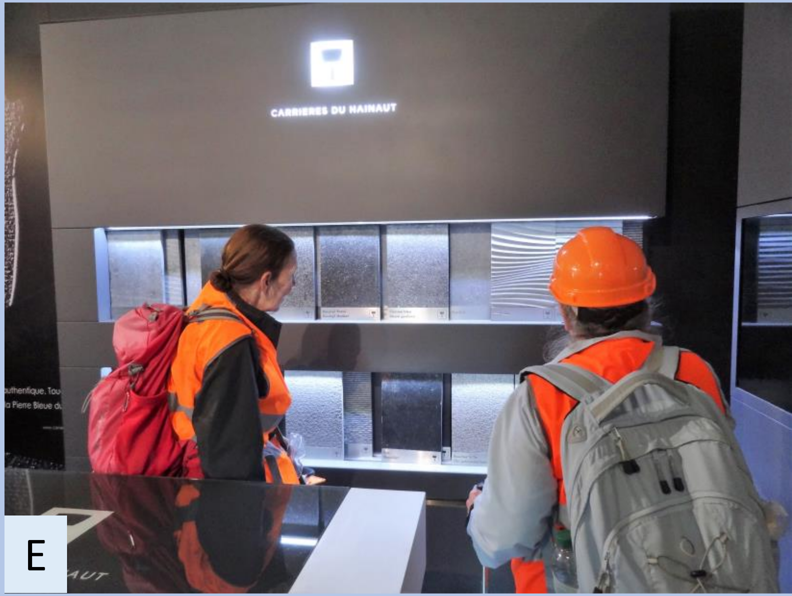
C: Shaped & carved blocks.

D: Building with offices, showroom and weighbridge.

E: Display of samples.


C


D



E

Video of extraction to finished article at the quarry (17min) (Scroll down when clicked)

A


B


C

D

Pierre Bleue Documentation Centre in Soignies

The Centre houses a historical archive of the local stone industry, and it includes a museum of the local geology and the industry.

A: Limestone plaque at the entrance.
B: Sculpture in *Pierre Bleue*. It illustrates the difference in colour between the unpolished (A) and polished stone.
C: Display of stone working tools including squares shown here, with saws in the background. Extraction hook on the shelf below.
D: Museum geology gallery.

Bois-du-Luc colliery

A

B

C

Bois-du-Luc colliery

Coal Measures form an E-W belt across central Belgium (Liège-Mons) extending into northern France and ultimately into east Kent. They are of Upper Carboniferous (Pennsylvanian/Westphalian) age, c. 320-310 Ma. Deposition was on tropical forest-covered alluvial plains.

Bois-du-Luc is now one of four Walloon mining sites listed by UNESCO as World Heritage Sites and is on the European Route of Industrial Heritage (ERIH). The 19thC pit-head buildings (A) stand on the site of one of the oldest coal mines in Belgium, the Fosse St-Emmanuel, with recorded activity dating back to 1685. At closure in 1959, the pit was 558m deep. The company ceased mining in 1973.

Bois-du-Luc is particularly known its preserved company town Bosquetville, which was created for the colliery and includes workers' housing begun in 1838 (B). Comprehensive social amenities were provided. The colliery has ornate gateways, one to the pit-head and the other (C) to the manager’s office and workshops. Steel guillotine gates were installed after the general strike of 1893.

Bois-du-Luc

A

B

C

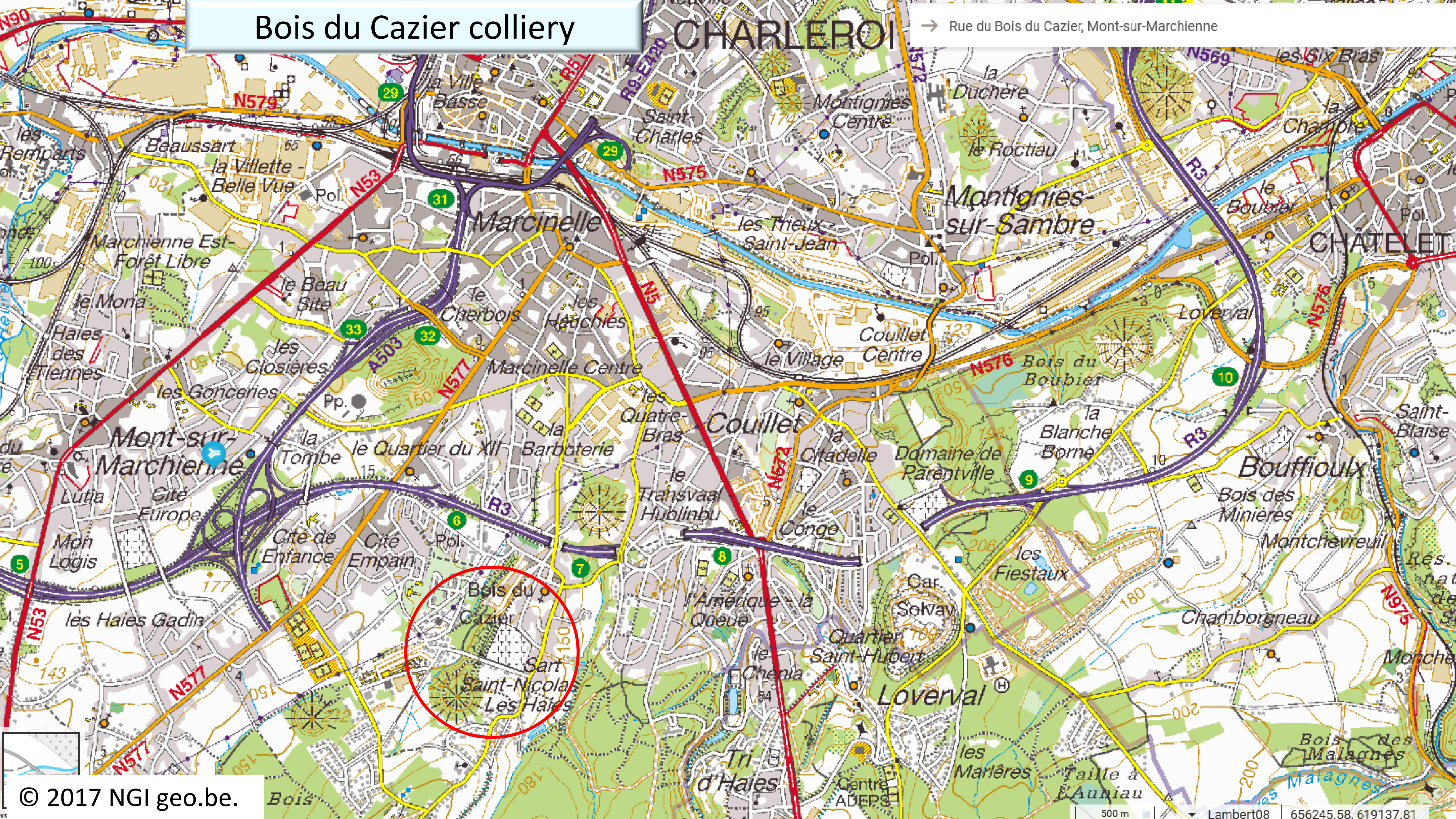
D

A: The mine office.
B: In the winding house.
C: Pumping machinery.
D: Workshop.

The mining village comprised all the essential elements for the comfort and well-being of the workers in order that they worked hard in return, the concept known as paternalism. Shops, schools, a church, a park, a hospital, a brewery and a hospice were provided, and each house has a rear garden.

The site became a museum in 1983 covering not only mining but other industry too.

Bois du Cazier colliery



Bois du Cazier colliery

Bois du Cazier was a coal mine in Marcinelle, near Charleroi. It is best known as the location of Belgium's worst ever mining disaster that occurred on 8 August 1956 in which 262 men, including 136 Italians, were killed. Aside from memorials to the disaster, the site features a small park (incorporating three slag heaps), preserved headframes and buildings, as well as an Industrial Museum and Glass Museum. The museum, which opened in 2002, features on the European Route of Industrial Heritage and is one of the four Walloon mining sites listed by UNESCO as a World Heritage Site in 2012.

The Bois-du-Cazier mining company was formed in 1899 as a subsidiary of Charbonnage d'Amercœur S.A. However, despite reaching peak annual production in the 1950s*, both were by then experiencing difficulties and the Bois-du-Cazier company went into liquidation in 1961, the year after a winding tower had been built (demolished 2004). The mine closed in 1967.

*170,000 t. in 1955

Bois-du-Cazier

The mining disaster 975m below ground was caused by a wagon, about to be taken up the shaft, which tore out a girder severing a high-pressure oil pipe, telephone wires, a high-pressure air pipe supplying pneumatic tools and a high-tension cable causing arcing. Details on the next slide. This started a fire which rapidly spread through the mine. Many of the miners died of smoke inhalation. The majority were guestworkers (such as the Italians) under a policy Belgium was operating at the time.

A: Memorial to the miners (in Carrara marble).

B: Part of mural in the pit bank.

C: Memorial plaques beneath the pit bank

D: 60th anniversary plaque to the Italian miners.

E: 50th anniversary plaque to Greek miners.

A

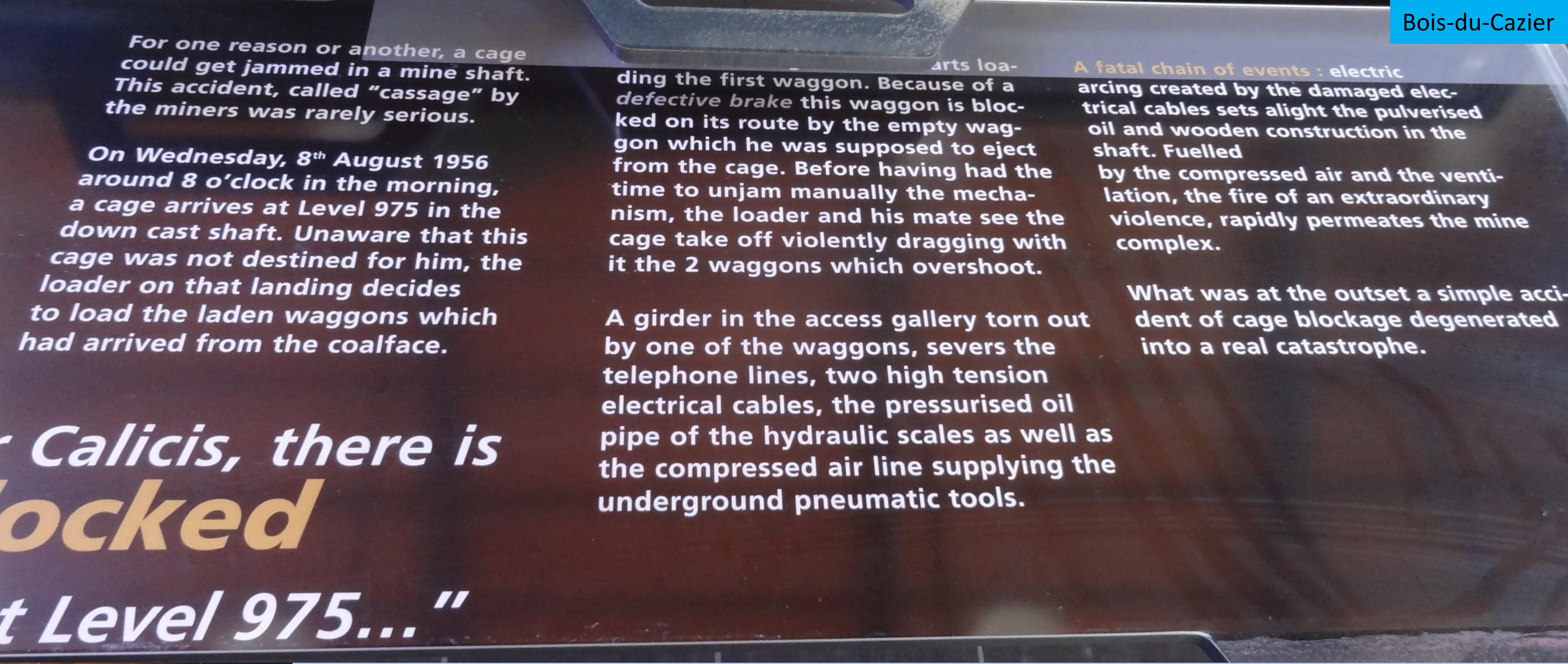
B

C

D

E

Bois-du-Cazier

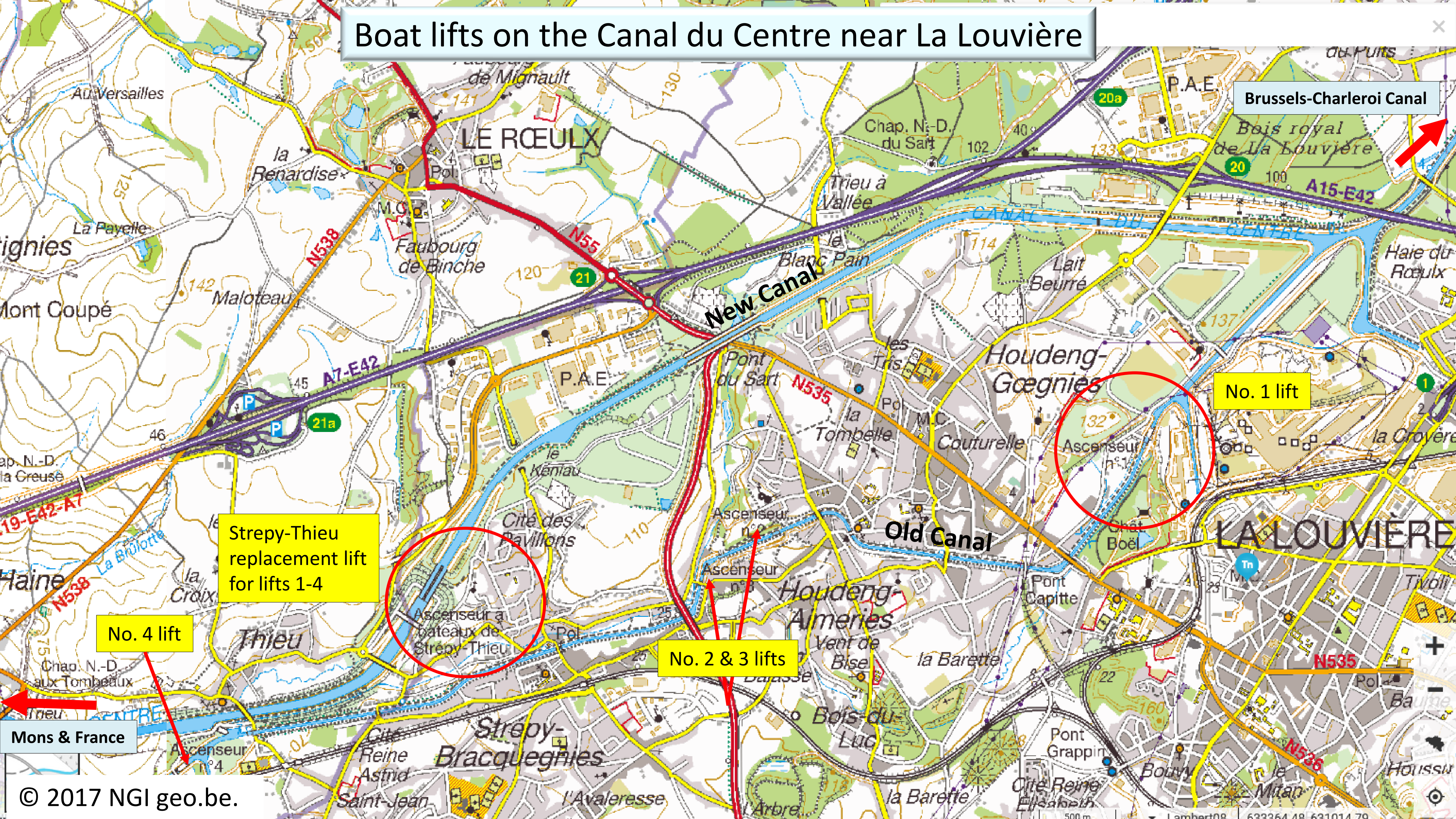


This clock shows when the fire started.

Cause of the disaster

(In the exhibition of the disaster in the winding house)

Boat lifts on the Canal du Centre near La Louvière



Canal boat lifts

Hydraulic boat lift No. 1 (1888), Canal du Centre, La Louvière.

The Canal du Centre runs E from Mons to the Brussels-Charleroi Canal near La Louvière. It takes traffic passing between NE France/W Belgium and the Scheldt/Meuse rivers. The 22km canal climbs out of the Cretaceous Mons Basin onto Paleogene strata. The Mons-Thieu section has six locks and the Thieu to Houdeng-Gœgnies section climbs 66m over 7 km – considered too steep for locks. Instead, four hydraulic boat lifts, built 1888-1917, were provided (now UNESCO listed). They were designed by British engineer Edwin Clark, designer of the Anderton Lift in Cheshire (between the R. Weaver and the adjacent Trent & Mersey Canal).

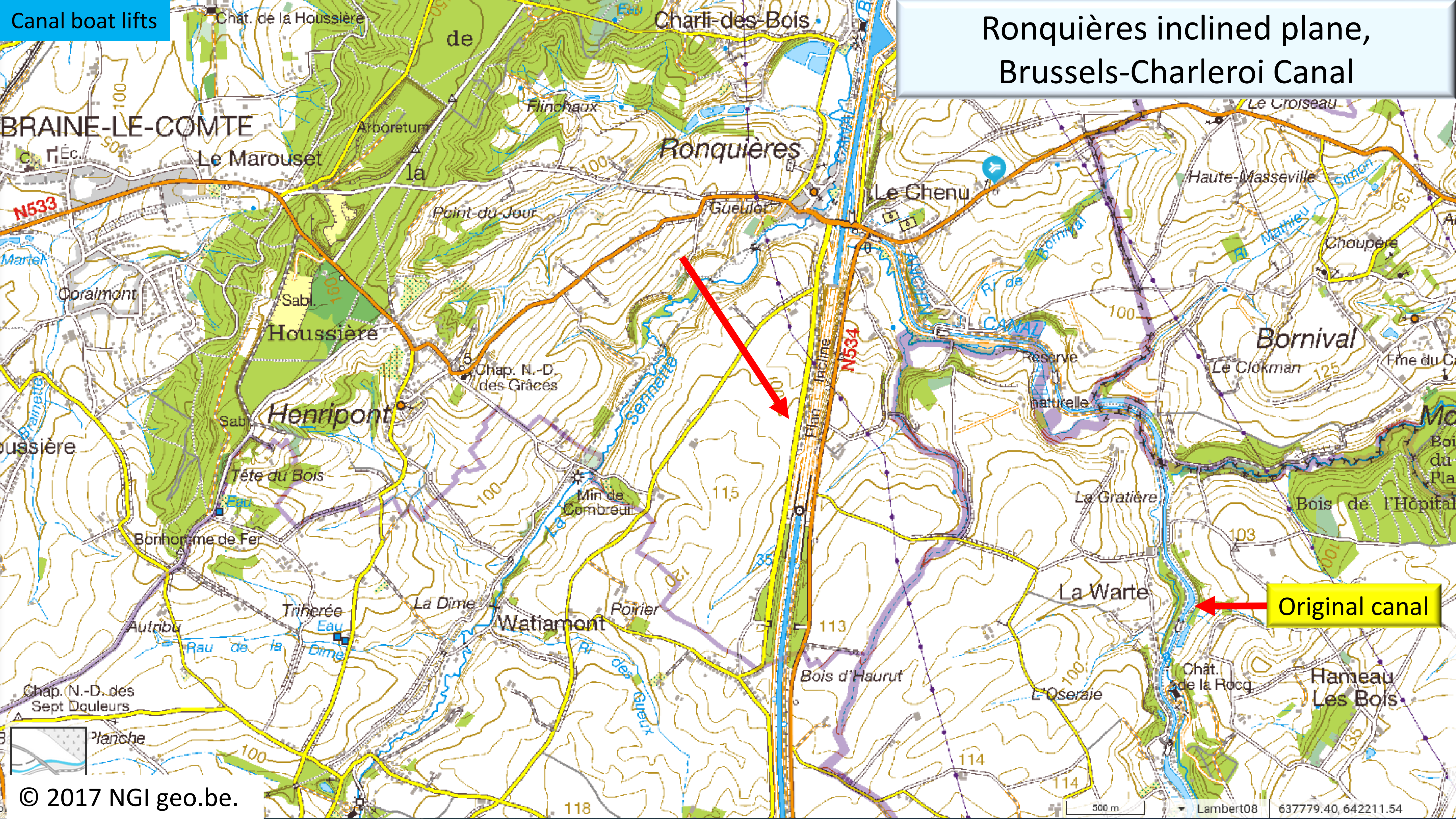
For commercial traffic this canal section has, since 2002, been replaced by an enlarged parallel canal with the single Strepy-Thieu boat lift. The old canal could take 300t boats whereas the new takes 1350t boats.

Canal boat lifts

The Strepy-Thieu boat lift

Constructed 1982-2002 to take barges of the new European standard of 1350t. The rise is 73.15m and has two electrically powered caissons (LH one shown above) each weighing up to 8400t with water. Each caisson is supported by 112 suspension cables (for counterbalance) and 32 control cables (for lifting and lowering) The lift takes seven minutes. The lift has increased traffic from 30kt to 200kt/month.

Ronquières inclined plane, Brussels-Charleroi Canal



Ronquières inclined plane, Brussels-Charleroi Canal

The inclined plane was built in 1962-68 on a new section of the canal replacing part of the 1832 route which had 14 locks ascending the valley of the Eau de Samme River. The inclined plane climbs an interfluve between the latter river and the River Sennette to the west. The higher ground (the divide between the Rivers Senne to the N. and Sambre to the S. at Charleroi) is capped with Paleogene strata. Locally these rest on Siluro-Devonian rocks of the Brabant Massif into which the rivers have cut down. Then canal is then level via the Canal du Centre to the Strepy-Thieu boat lift (for descent) and the route to Charleroi goes down through one lock.

The inclined plane is 1,432m long and ascends 68m. It consists of two large caissons each running on four rails, and each pulled by eight cables wound by winches at the top.

Each caisson measures 91m x 12m and can carry one boat of 1,350t or several smaller boats in up to 3.7m of water. Each caisson has a 5,300t counterweight running in the trough under the rails, which permits the caisson to be moved independently of the other. Running on 59 pairs of axles, each caisson travels the incline in 22 minutes. However, it takes 40 minutes in all for a boat to pass through the 1,800 metres of the entire structure, including the holding area at the top, entered through a rising gate.

The tower is 150m tall and houses a control and movements room with a view over the whole structure plus comprehensive camera coverage.
The gradient of the incline is 5% and the upper part is supported by concrete columns as shown at left. From the top, the canal is on a 4.5km-long embankment, up to 27m high, constructed from spoil excavated for the inclined plane.

The electro-mechanical machinery that controls the movement of the caissons and the maintenance and repair installations are housed in a reinforced concrete frame below the tower. Hydroelectric power is generated by turbines driven by water piped under pressure from the top of the incline.

In summary the Brussels-Charleroi Canal and the Canal du Centre connect the Scheldt and Meuse Basins, linking France and Germany through the central industrial belt of Belgium, to Brussels and finally the major port of Antwerp.

Namur Citadel

Upper Carboniferous

Namur Citadel – Upper Carboniferous – Namur type locality of NW European stage

Below is Namurian strata of the Andenne Formation (Belgian Coal Measures Group, age c.320 Ma). Unlike the British Coal Measures, the BCM Group includes the Namurian succession, which in this area has thin coal seams. These shales and sandstones were deposited in a foreland basin ahead of the Variscan [orogenic] front (the peak of the orogeny occurring at c.300 Ma). The orogeny transported the whole succession a short distance N. The section shown lies within the northern limb of the Namur Syncline which has been moderately deformed by N-directed Variscan forces. It overlooks the R. Meuse, and the same rocks occur on the other side of the river, which has cut down through them.

The section is called the Chemin de Ronde ('walkway'), showing small-scale folding. The folding is interpreted as mainly due to deformation caused by seismic activity while the sediments were still soft. The Variscan orogeny led to further folding by which time several km of sediments had accumulated. The degree of this folding was much less here than further south.

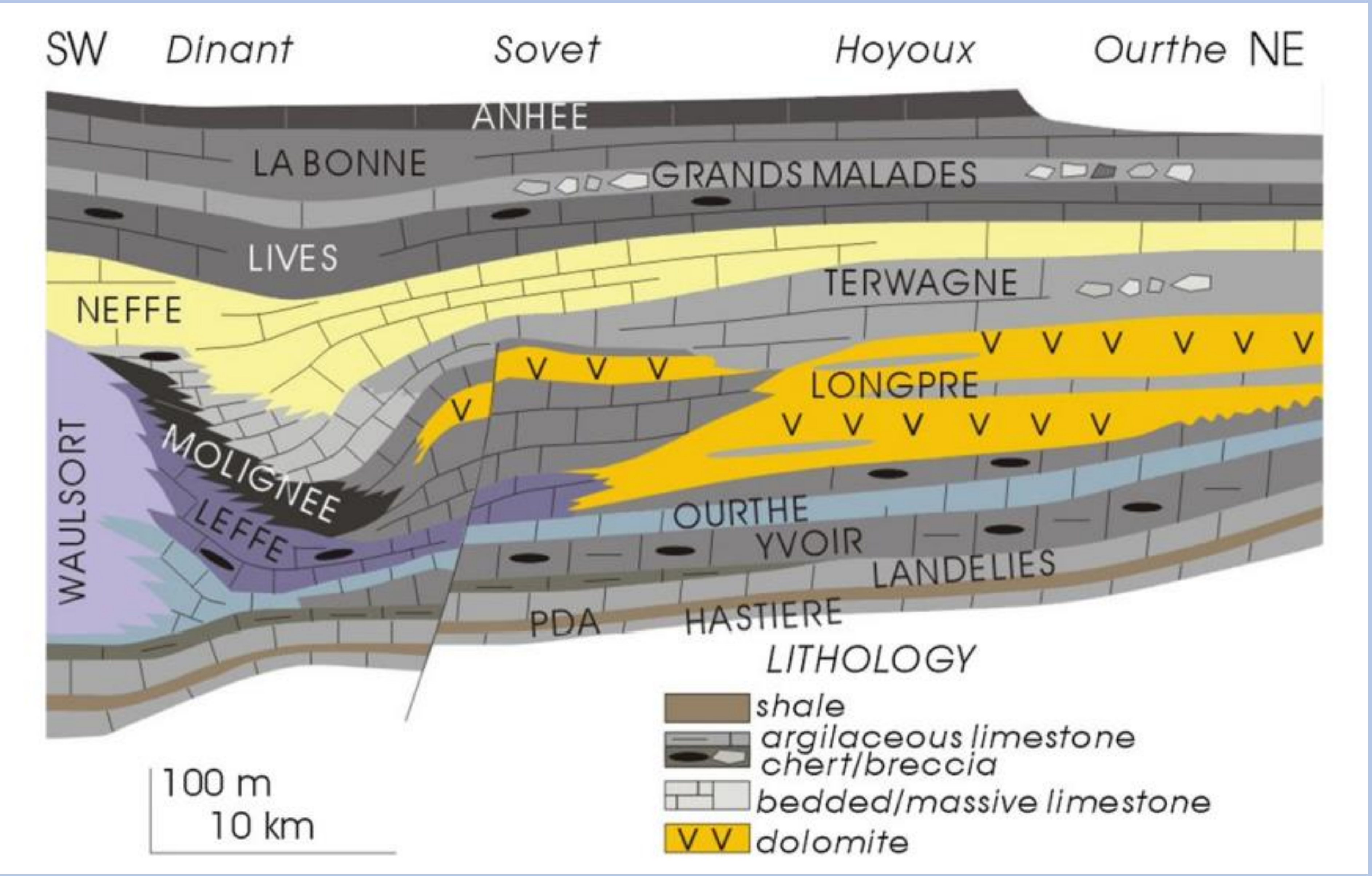
The R. Meuse and the Pont de Jambes. Beyond the alluvium island, the valley narrows as it passes through harder Lower Carboniferous and Devonian rocks.

Namur Citadel

The sediments are both marine and fluvial. The sea floor may have been steepened by earth movements, inducing massive gravitational instability leading to sliding. River-deposited muds appear to have been loaded by overriding sand bars distorting the mud with the sand bodies sinking into it. The section does show isolated sandstone blocks which appear to be 'floating' within the shales.

Spheroidally laminated honeycomb structures in silty shales (closer view right). These may be the result of previously-mentioned seismic activity shaking the still-soft sediments inducing liquefaction. This would lead to upward squeezing of mud beneath sandy sediments and loss of strength in the layer leading to the formation of sand balls.

Dinantian formations: Synthetic transect through the Dinant Syncline before the Variscan orogeny



Localities visited in relation to formations

Dinant (Lives Fm.)

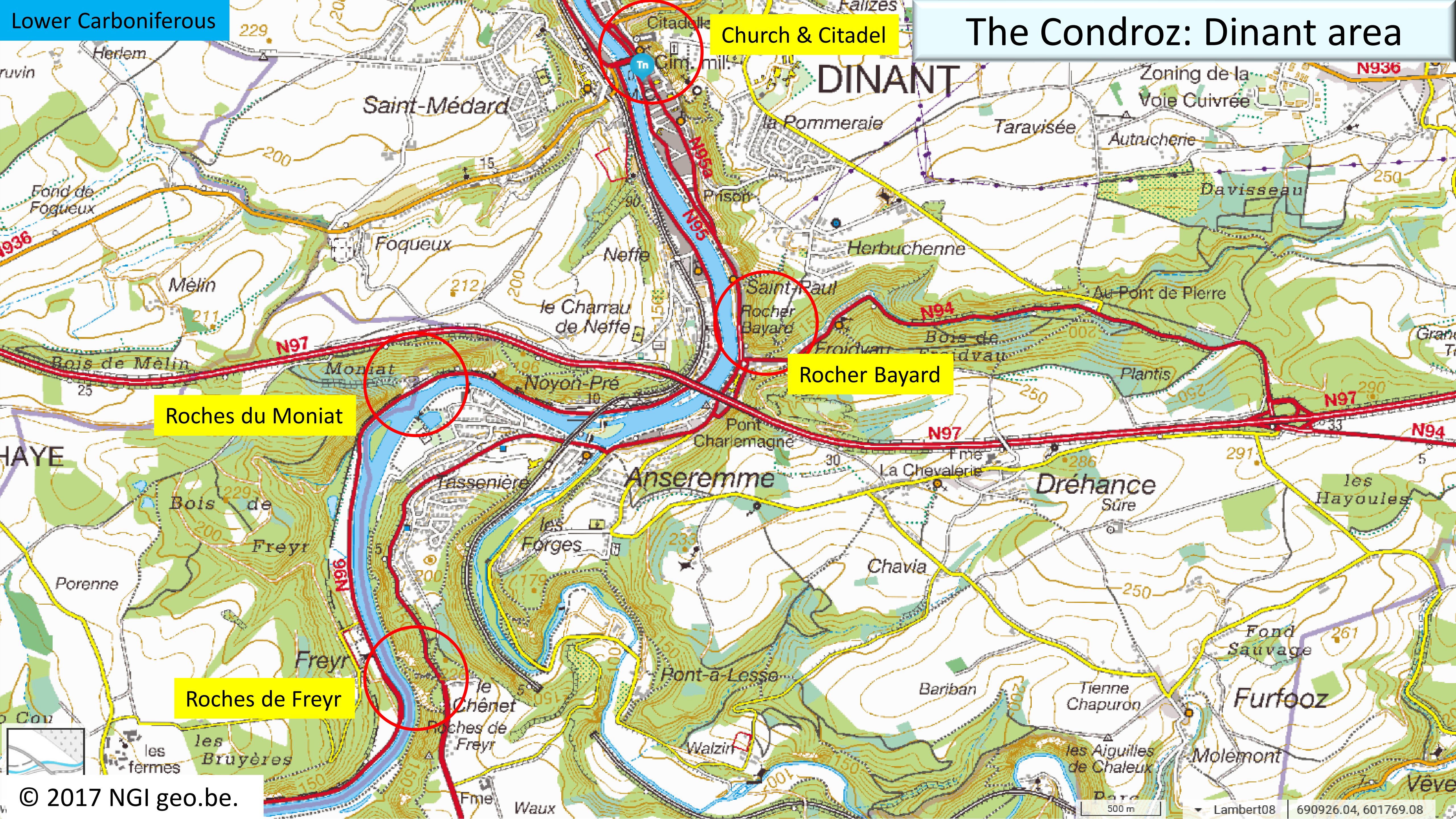
Dinant-Freyr river trip (Leffe, Molignée & Waulsort Fm's).

Salet road section (Molignée Fm.)

Boulvain & Vandenburghe, 2017

Lower Carboniferous

The Condroz: Dinant area



Lower Carboniferous

Dinant

Dinant gives its name to the *Dinantian*, an epoch of the Lower Carboniferous in NW Europe. It is subdivided into the *Tournaisian* (after Tournai) and *Viséan* (after Visé near Maastricht). The Dinantian equates to the lower two-thirds of the *Mississippian* in the international geological timescale.

The view is across the Meuse to the Collégiale Notre-Dame (14thC but with multiple rebuilds) and the Citadel atop a crag of Carboniferous limestone. This belongs to the Viséan *Lives Formation* (age c.340-335 Ma) which extends as far as the Boulonnais in France. Stromatolites and lime mudstones feature in the limestone seen here.

Further information on the town: dinant.be/patrimoine/sites (in French)

Dinant: Collegiale Notre-Dame and the Citadel

Below: Limestone columns and floor

Upper right: Floor of polished limestone; grey – fractures infilled with calcite and black – collective term *Noir Belge.* The latter is rich in bituminous organic matter.

Lower right: Corals and other fossils in limestone floor slabs in the Citadel.

Lower Carboniferous

Lower Carboniferous

Dinantian limestone exposures between Dinant and Freyr (1)

Both these features are in the Leffe Formation (late Tournaisian, c.350 Ma) and despite being a few km apart are in the same local development of the unit. Chert is common in the limestone, but macrofossils are not. The rock texture ranges from grain-supported (packstone) to mud-supported grains (wackestone). Rocher Bayard was cut through by Louis XIV's soldiers (later widened) creating the V-shaped gash. The bedding is vertical but in R. du Moniat the limestone is much more massive.

Rocher Bayard

Roches du Moniat

Dinantian limestone exposures between Dinant and Freyr (2)

Roches de Freyr

Looking downstream on the Meuse, the cliffs expose the the Leffe and Molignée Formations. The tree cover in the foreground conceals the Waulsort Formation (named after a village upstream). It is known for its Waulsortian mud mounds which are build-ups of lime mud produced by the precipitation of calcite induced by microbial action in tropical seas. They are also fossiliferous with crinoids, bryozoans etc.

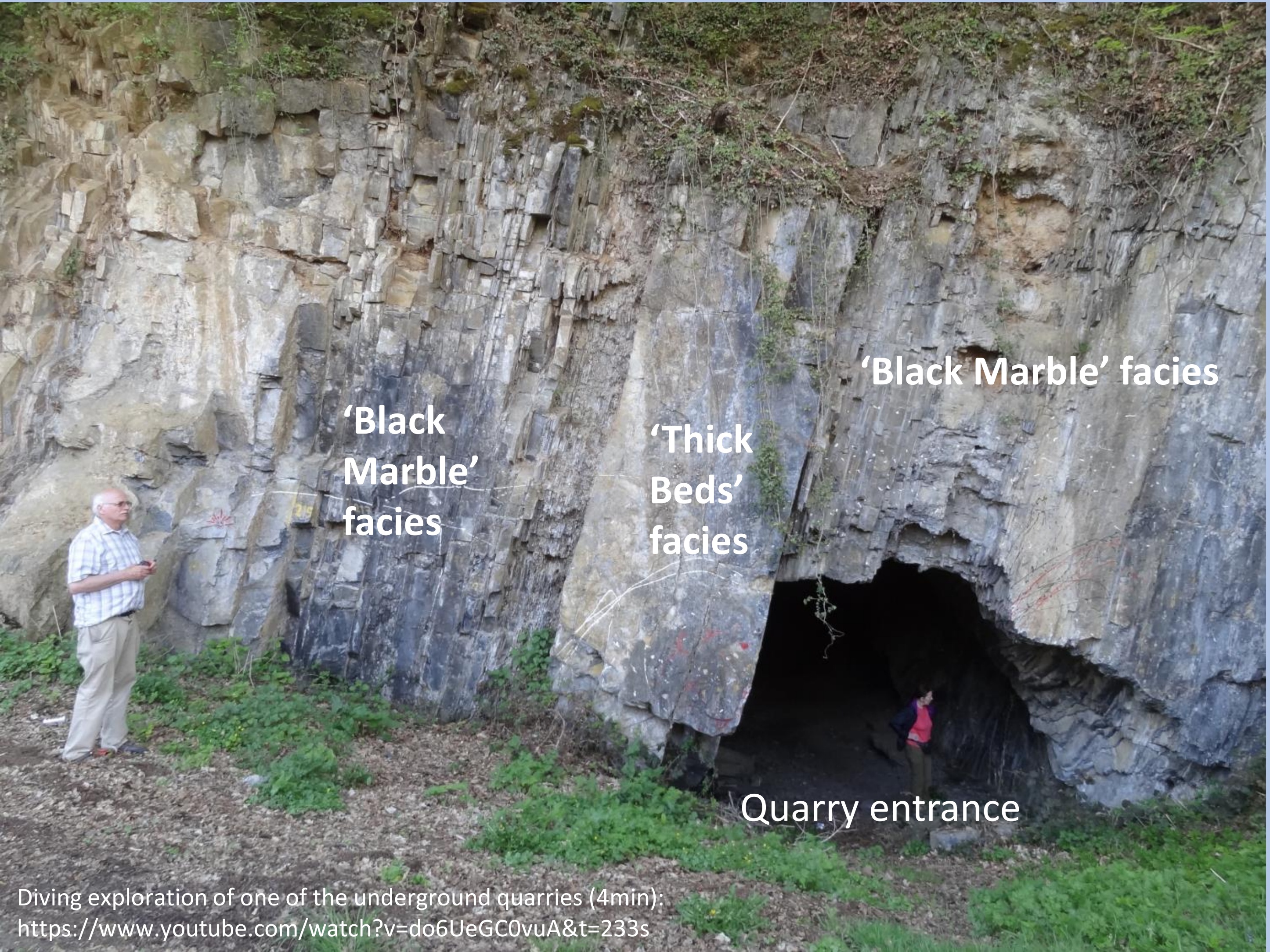
The nearest face is a fault plane in the Molignée Formation and the cliffs beyond are in the older Leffe Fm. The whole feature is an anticlinal structure.

Salet road section – Carboniferous limestone (Molignée Formation)

Salet road section – Carboniferous limestone (Molignée Formation)

The Molignée Fm. (c.345 Ma) is Visean in age and overlies the Tournaisian Leffe Fm. It is the type locality, the section being in the valley of the R. Molignée, a tributary of the R. Meuse. In this area, the formation includes the 'Denée Black Marble' which has been quarried underground here.

Most of the 'Black Marble' was exploited in this way in many quarries during the early 20thC, and Denée, 6km to the west, was the centre of the industry.



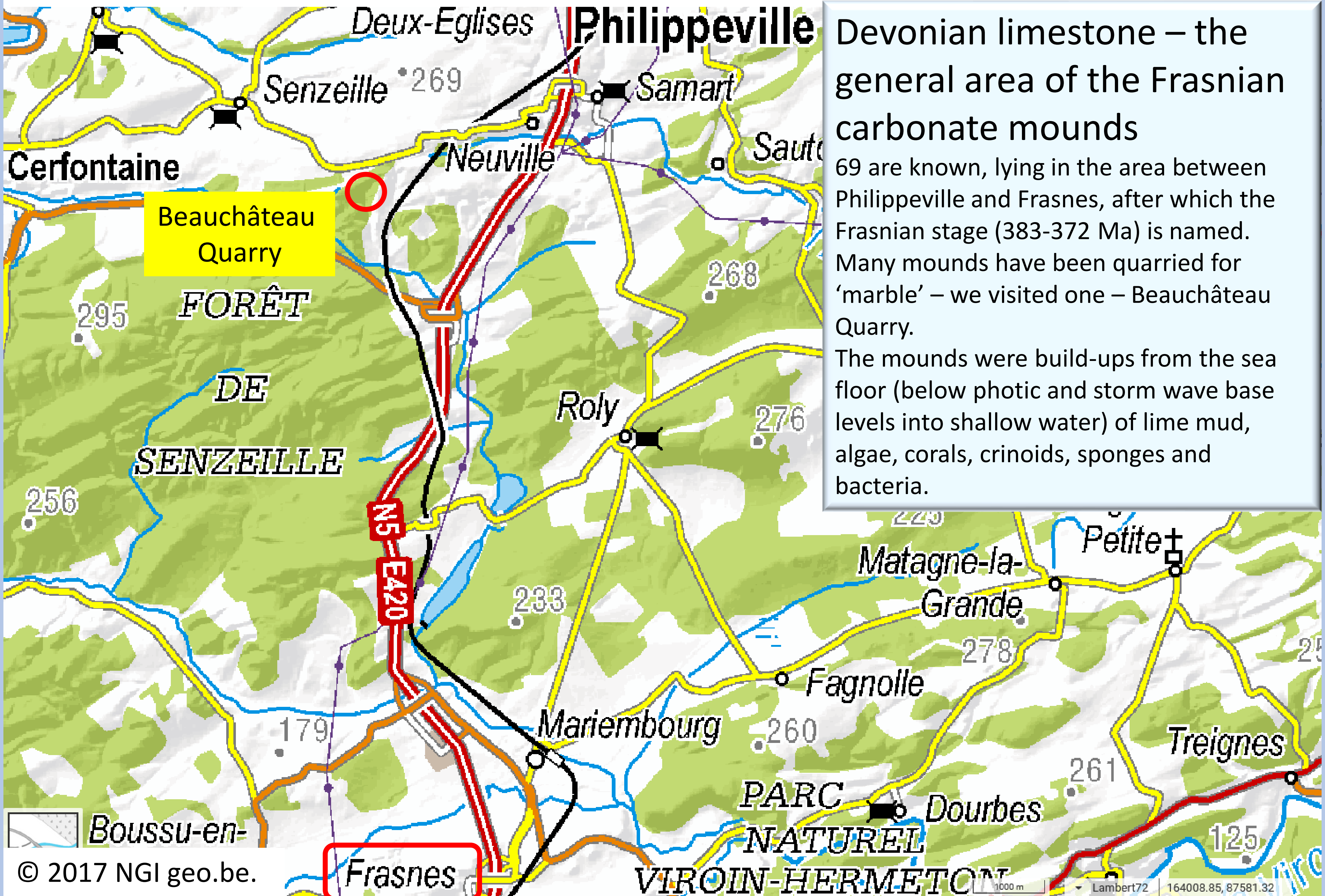
Diving exploration of one of the underground quarries (4min):
https://www.youtube.com/watch?v=do6UeGC0vuA&t=233s

Devonian limestone – the general area of the Frasnian carbonate mounds

69 are known, lying in the area between Philippeville and Frasnes, after which the Frasnian stage (383-372 Ma) is named.

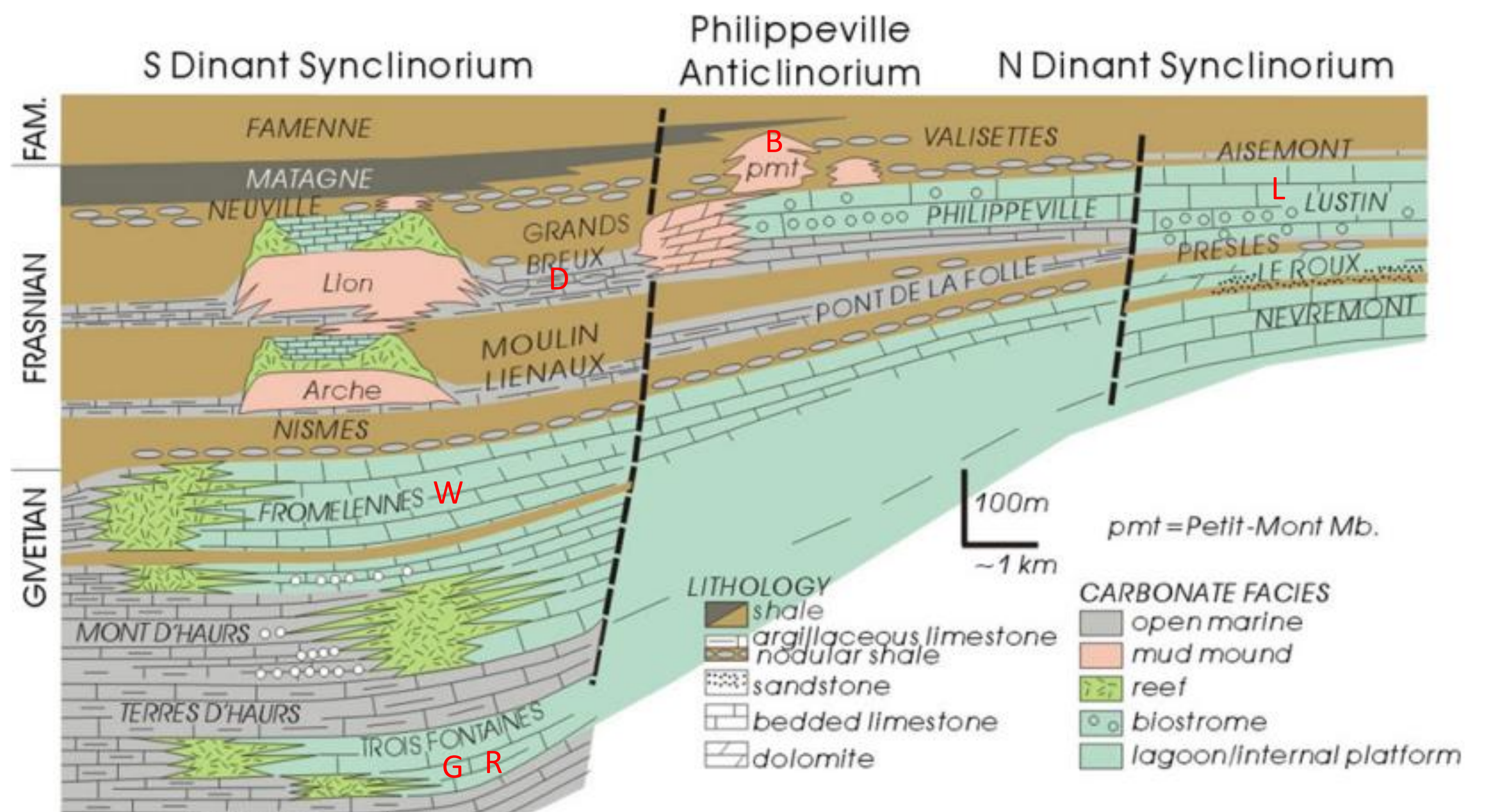
Many mounds have been quarried for 'marble' – we visited one – Beauchâteau Quarry.

The mounds were build-ups from the sea floor (below photic and storm wave base levels into shallow water) of lime mud, algae, corals, crinoids, sponges and bacteria.



Carbonate mounds in the Devonian Limestone of the Frasnes area

Of the various Palaeozoic carbonate mounds known throughout the world, the Frasnian carbonate mounds of Belgium are probably the earliest studied. This remarkable interest carried by generations of geologists derives from the number and quality of the outcrops: as mentioned, 69 carbonate mounds are known, and the fact that the majority were quarried has provided many square metres of sawn sections for examination.
In the Dinant Synclinorium, three stratigraphic levels bear Frasnian carbonate mounds (see right). These are, in stratigraphic order, the Arche, the Lion and the Petit-Mont Members. In the Philippeville Anticlinorium, only the upper level contains mounds (Petit-Mont Member). The other carbonate mound levels are replaced laterally by bedded limestone, locally with back-reef character. At the northern border of the Dinant Synclinorium and in the Namur Syncline, the entire Frasnian consists of bedded limestone and argillaceous strata.



Localities visited marked: B. Beauchâteau Quarry, D. Durbuy Anticline, G. Grotte de Hotton, L. Lustin Q., R. Resteigne Q., W. Wavrielle Anticline.

Synthetic N-S transect through the Dinant Syncline before the Variscan orogeny showing the Givetian and Frasnian formations

Boulvain & Vandenburghe, 2017

Devonian

Beauchâteau 'Red Marble' Quarry

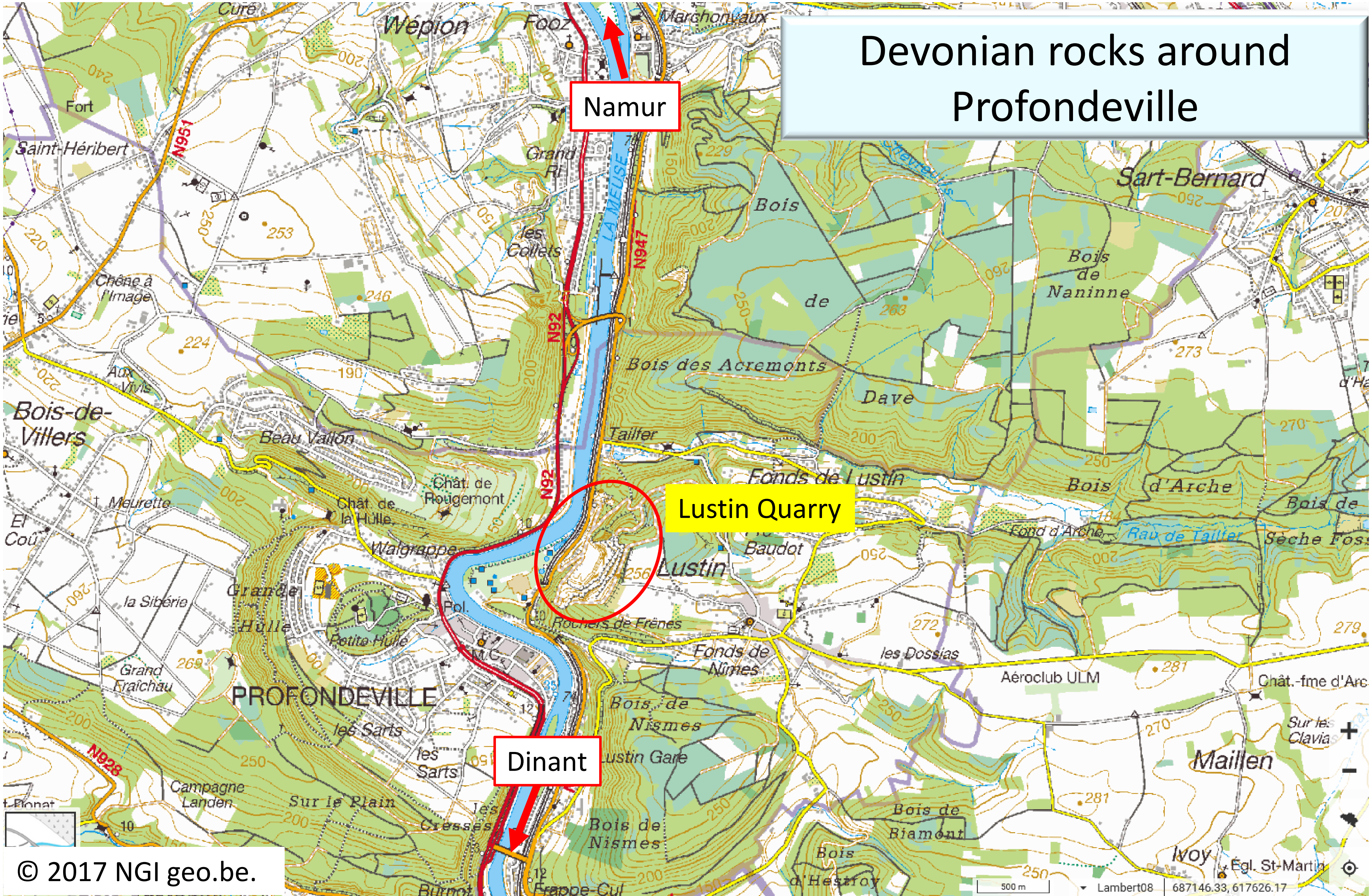
This abandoned marble quarry (worked 1874-1950) is the most spectacular outcrop of a Late Frasnian (c.375 Ma) carbonate mound in Belgium. It is one of the 69 mounds known between Phillippeville and Frasnes and are situated in the Phillippeville Anticline.

The mounds are 30-80 m thick and 100-250 m in diameter. They are embedded in the Neuville Formation, which consists of shales, nodular shales and muddy limestones.

Mound growth typically began below the photic and storm wave base zones and built up into shallow-water environments, some becoming atolls. The base is of of clayey limestone. On this accumulated limestone with calcite-filled cavities (stromatactis), possibly resulting from the dewatering of lime muds or from cavities forming beneath local cemented crusts on the sea floor. As the mound grew, limestone richer in crinoids and corals accumulated. Then the texture changed to that of rounded pellets (peloids) with sponges and cyanobacteria, then algal mats and corals. A core of algal and microbial limestone can occur within large mounds. The uppermost part of the mounds may show a repeat of lower facies.

The mound features large sawn sections exposing facies ranging from the middle part of the mound to its top. The upper central face shows interfingering between grey massive microbial facies and pink bedded bioclastic flank sediments. The red colouration is due to haematite derived from iron bacteria. The mound is flanked by crinoid-rich clayey limestone, seen upper left.

Devonian rocks around Profondeville



Devonian rocks around Profondeville

Profondeville lies 10km S of Namur on the R. Meuse and features the active sandstone and limestone quarry of Lustin.

Right: The Walgrappe Syncline in sandstones of the Ciney Fm. (Upper Devonian, Famennian; c.365 Ma)

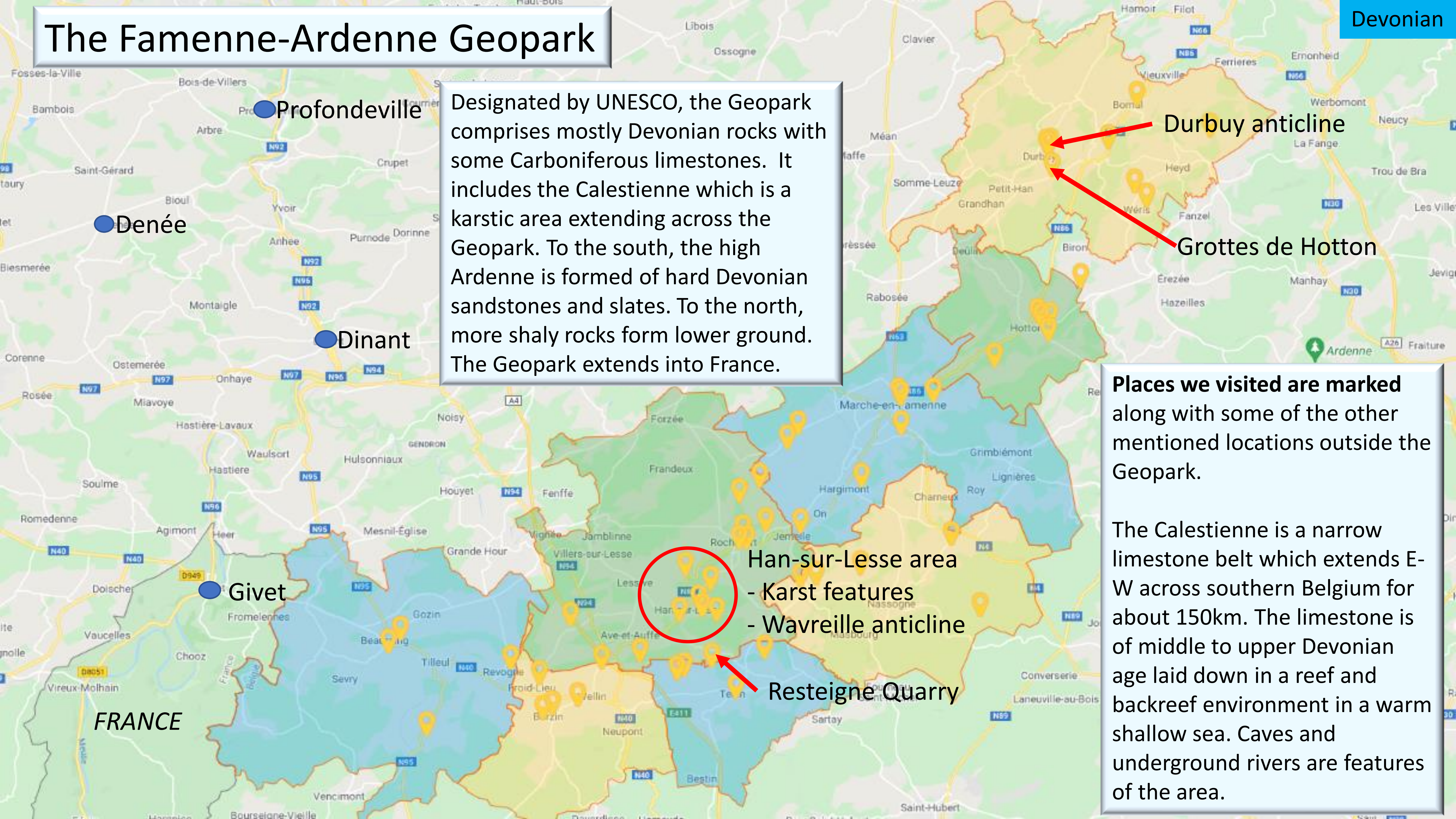
Below: Limestone of the Lustin Fm., (Upper Devonian, Frasnian; c.377 Ma), Walgrappe Syncline.

The quarry section (above) is in marine sandstone and was deposited some way offshore below tidal influence. The biscuit colour of the highest sandstone is due to iron-dolomite cementation. Subordinate limestone, some dolomitic, also occurs. Similar sandstones were also deposited in North Devon during this time when, due to plate tectonics, 'SW England' was close to what is now Belgium, before moving along the Bristol Channel-Bray Fault to its present position during the Variscan orogeny.

The limestone (left) is a well-bedded micritic limestone (= formed by the recrystallisation of lime mud). We are in the northern part of both the Dinant Synclinorium* and the Walgrappe Syncline (the latter a secondary fold of the former). The limestone equates to some of the limestones of South Devon. (*Synclinorium = large regional syncline with secondary folds.)

The Famenne-Ardenne Geopark

Designated by UNESCO, the Geopark comprises mostly Devonian rocks with some Carboniferous limestones. It includes the Calestienne which is a karstic area extending across the Geopark. To the south, the high Ardenne is formed of hard Devonian sandstones and slates. To the north, more shaly rocks form lower ground. The Geopark extends into France.



Places we visited are marked along with some of the other mentioned locations outside the Geopark.

The Calestienne is a narrow limestone belt which extends E-W across southern Belgium for about 150km. The limestone is of middle to upper Devonian age laid down in a reef and backreef environment in a warm shallow sea. Caves and underground rivers are features of the area.

Devonian

Resteigne Quarry near Tellin, Famenne-Ardenne Geopark
Devonian Limestones

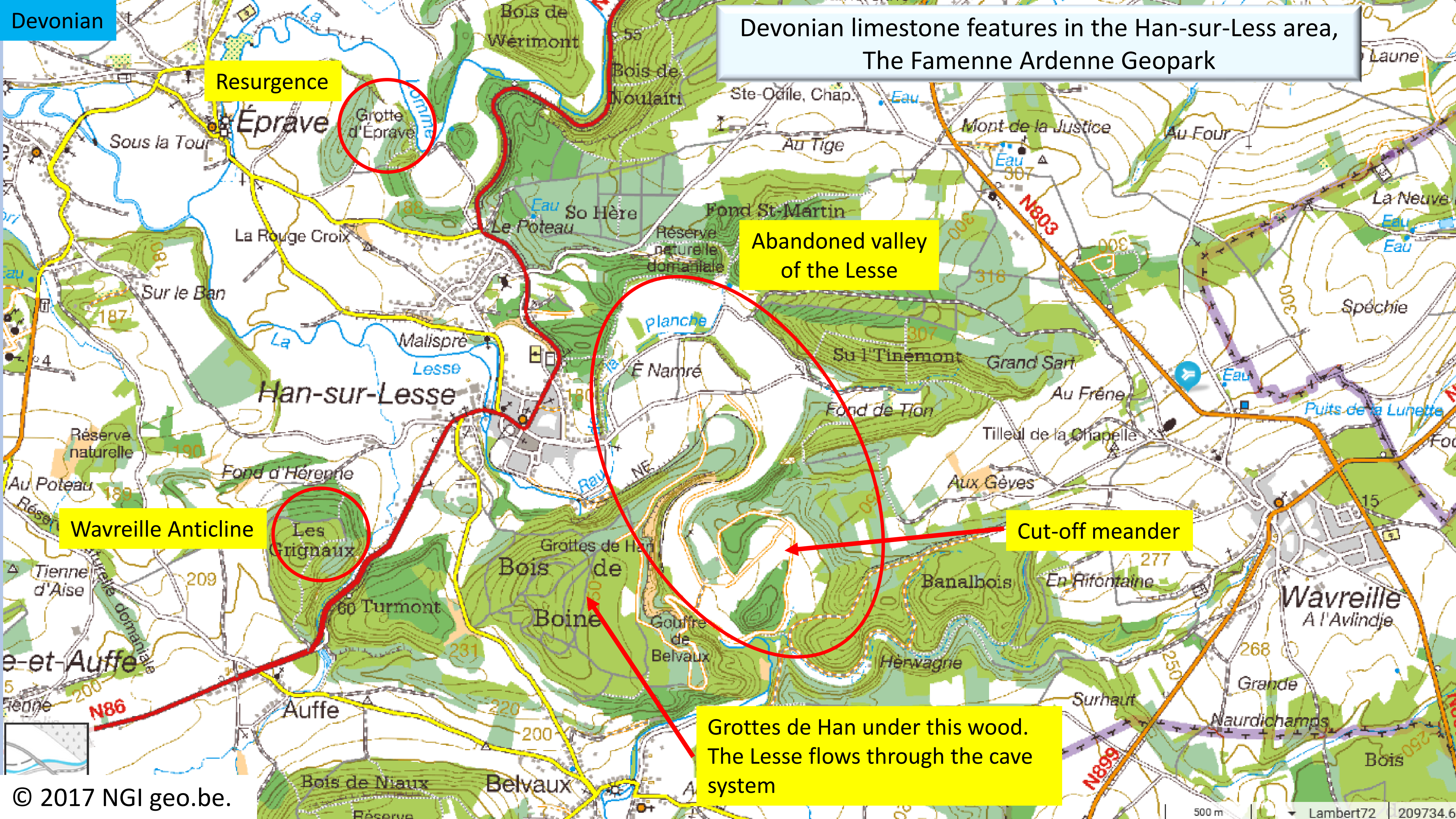
This limestone is middle Devonian (early Givetian*) in age, c.385 Ma. Belonging to the Trois-Fontaines Formation, it lies within the Dinant Synclinorium (a large syncline with superimposed smaller folds). In general, the Givetian limestones were deposited on a shelf giving warm shallow marine conditions with tidal flats and lagoons with local coral patch reefs and coral/algal banks. The two left-hand photos show inclined bedding, and the photo below shows solitary corals and shell fragments.

*Givetian – named after nearby Givet in France.

As generally with Devonian limestones in Belgium, there is some affinity with those in South Devon which outcrop around Torbay, Ashburton and Plymouth. This is due to the position of 'SW England' at this time.

Devonian

Devonian limestone features in the Han-sur-Less area, The Famenne Ardenne Geopark



Devonian

Wavrielle Anticline near Han-sur-Lesse

Formed by the earth movements of the Variscan orogeny, this anticline is within middle Devonian (Givetian) age limestone (Fromelennes Fm.).

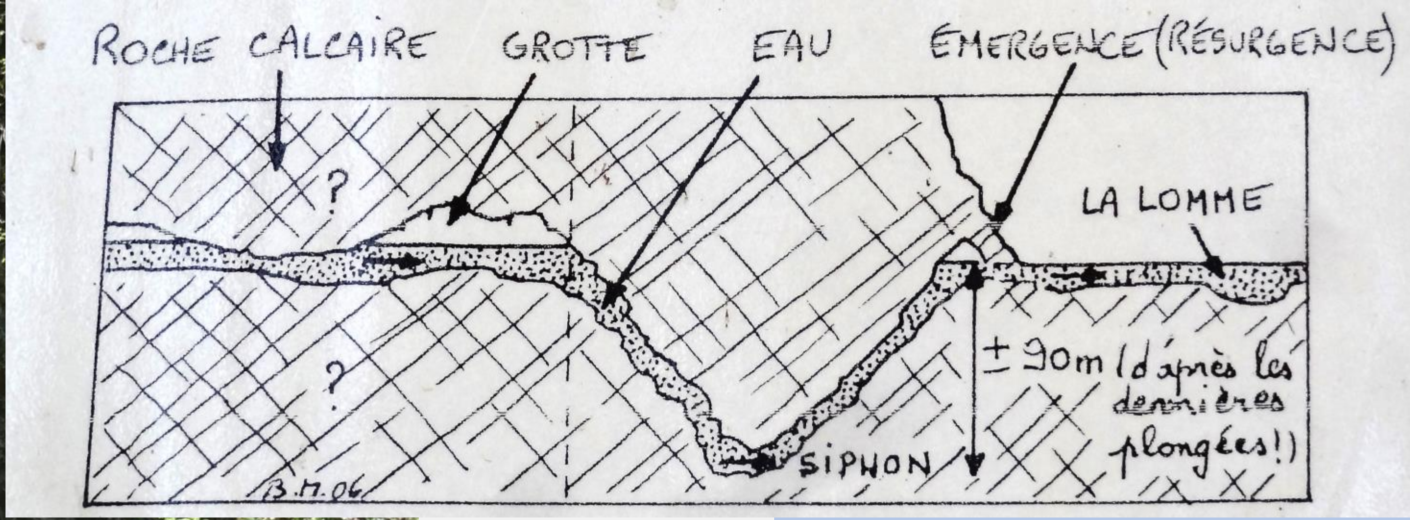
We are in the Calestienne, as already mentioned a narrow strip of Devonian limestone which crosses the Famenne Ardenne Geopark. It lies between the Condroz to the N and the Ardenne to the S and contains the most important karstic phenomena in Belgium.

Belgium’s largest show cave, the Grottes de Han, is in this area.

Devonian

Abandoned valley of the River Lesse which flows underground through the Grottes de Han, which has 14km of passages. Direction of flow is towards us from the top right, and it joins the R. Meuse near Dinant.

Devonian



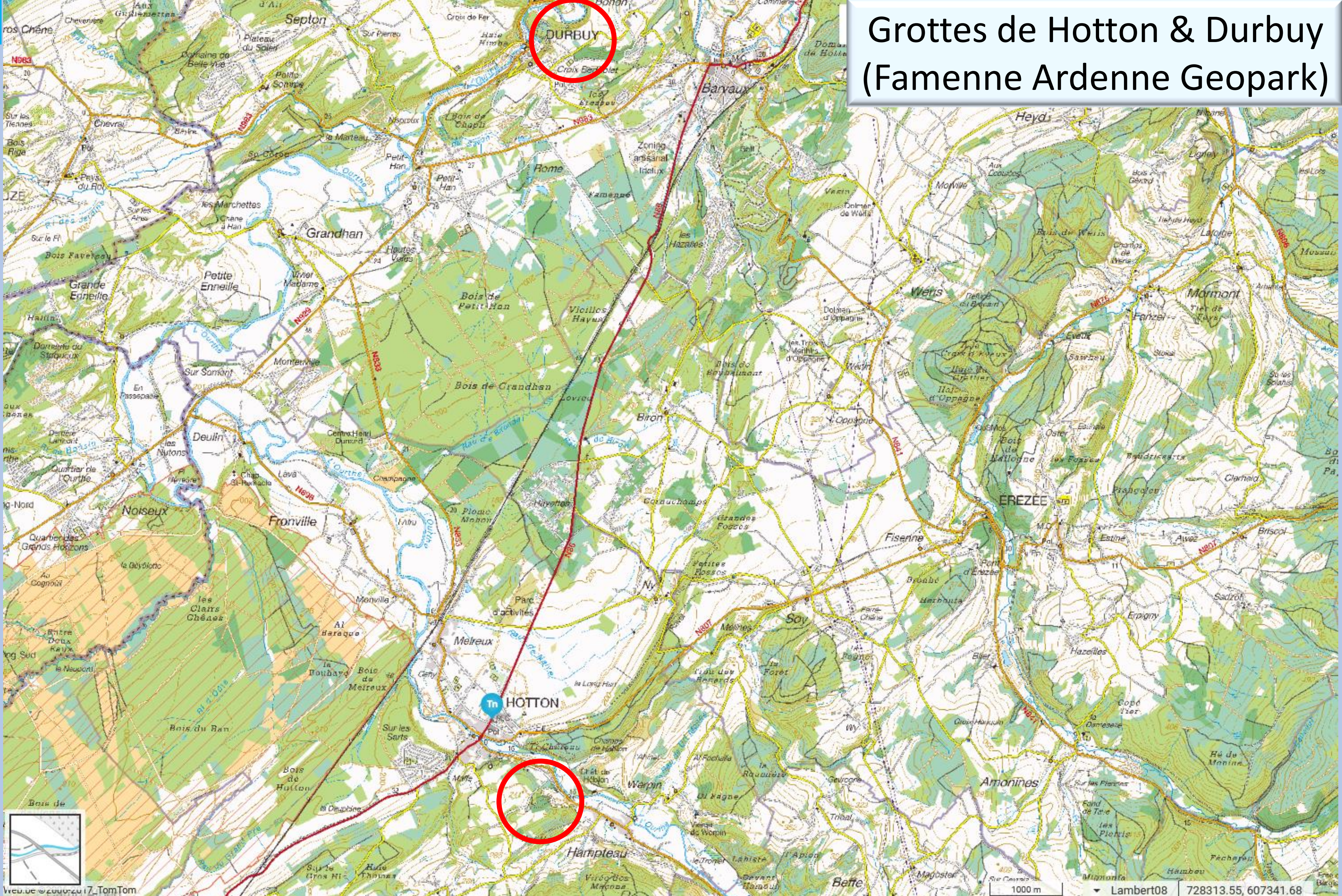
Information panel

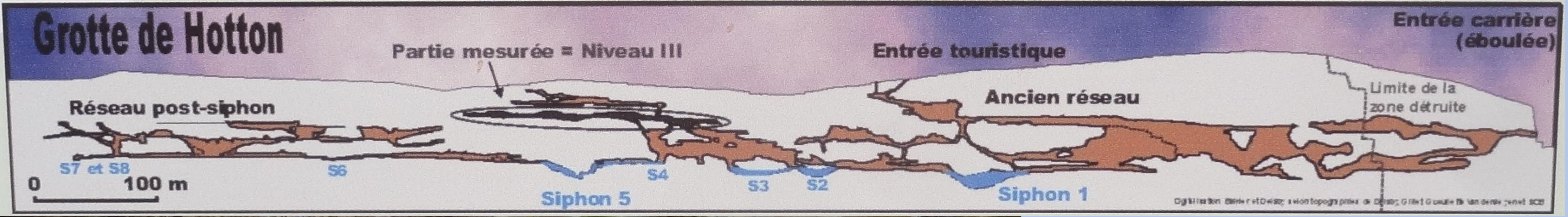
Resurgence of the underground R. Lomme entering the surface river near Éprave. The Lomme is a tributary of the R. Lesse.

The siphon has been dived to its depth of 90m below surface river level. The other end of the cave was once open to the public.

Devonian

Grottes de Hotton & Durbuy (Famenne Ardenne Geopark)





From the display panel on-site

Grotte de Hotton (the Calestienne, Famenne-Ardenne Geopark) - 1

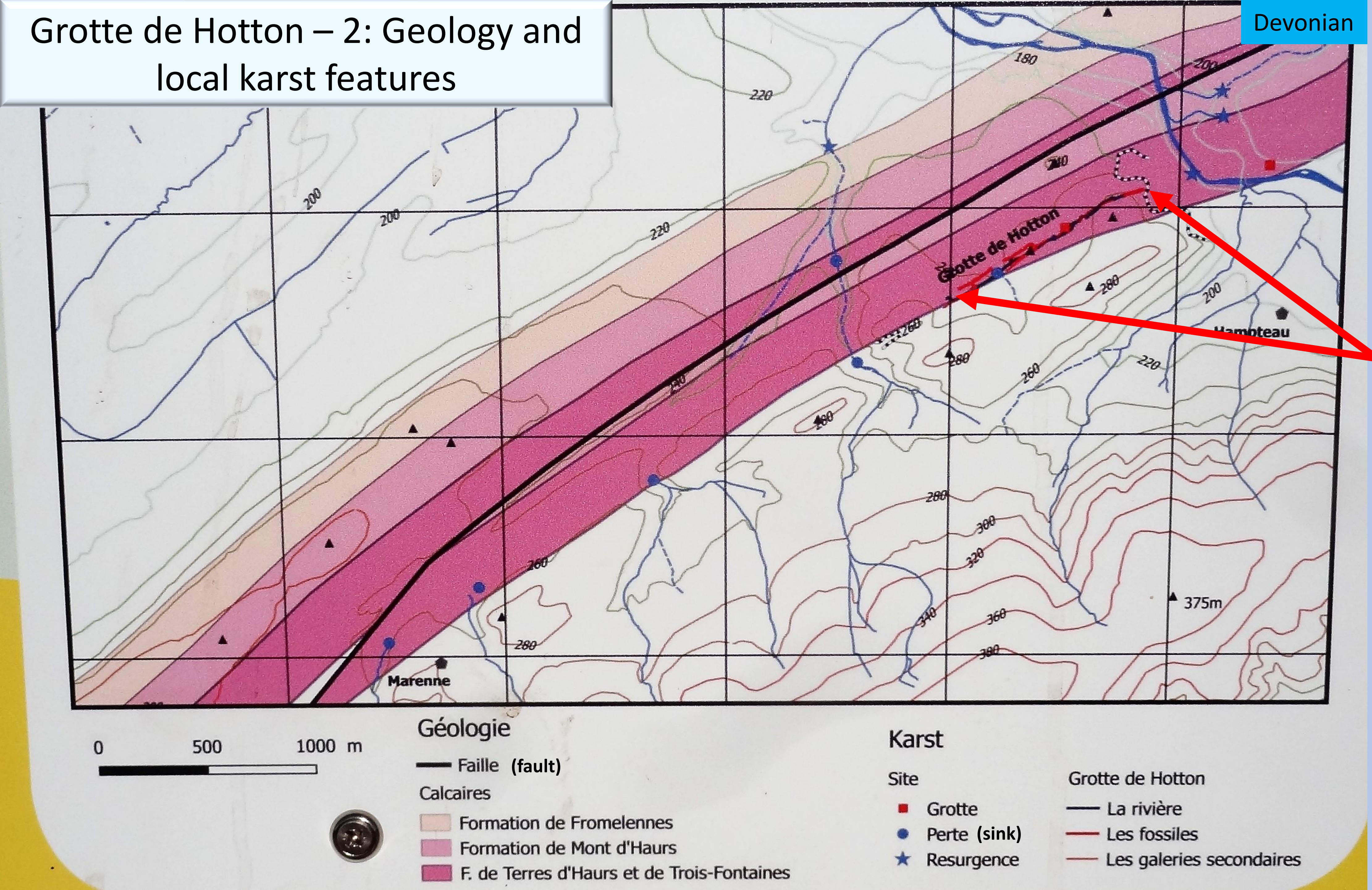
One of Belgium’s many show caves, this system is close to the R. Ourthe just outside the village of Hotton. The river that formed the caves flows from the Ardenne and sinks below ground when it encounters the limestone. It flows underground for about 1 km and reappears as a resurgence, draining into the Ourthe. This differs from the Lesse, which, in draining through the Grottes de Han, cut off a meander (slide 55), now abandoned.

The Grotte de Hotton was discovered in 1958 during quarrying (far right, above). As shown in the section, the river has abandoned the upper levels, but they exhibit superb decorations (speleothems) as at left. The limestone is Givetian in age (middle Devonian).

Grotte de Hotton – 2: Geology and local karst features

Devonian

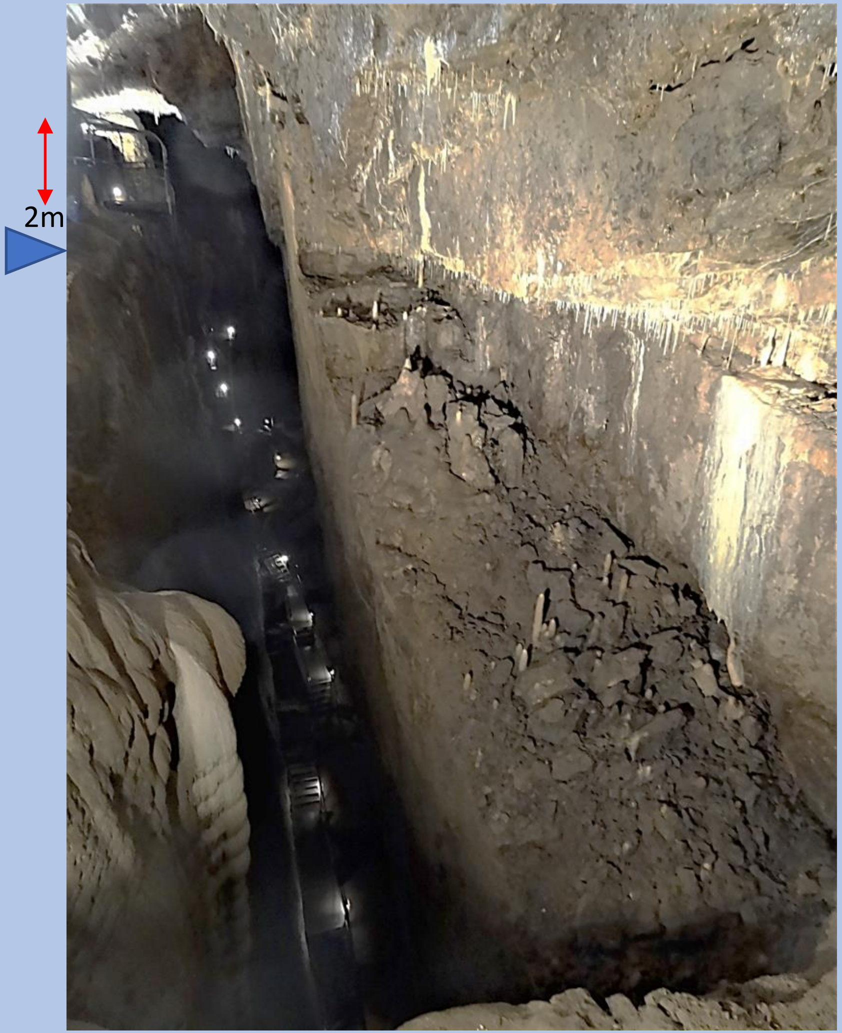
From the display panel on-site



The cave system formed along bedding planes, nearly vertical in this area.

Grotte de Hotton - 3

(Left) A chamber in the upper level of the system. It is about 10m across and 5m high.



(Right) This 60m high passage has developed along a bedding plane. The lights are on a staircase leading up to a walkway at the top left corner for which a scale is shown. The walkway leads to the chamber shown above by following it towards the camera and leaving the large passage. This highly decorated chamber is one of several.

Devonian

The Durbuy Anticline (Famenne-Ardenne Geopark)

This anticline is known as *Homalius' Rock* or the *Roche à la Falize* and is like the Wavreille anticline seen earlier. The limestone belongs to the Devonian (Frasnian) Grand-Breux Formation (age c. 375 Ma). The anticline was formed at c. 300 Ma by earth movements during the Variscan orogeny. It overlooks the R. Ourthe.

Museum of Natural Sciences, Brussels - 1

The museum is part of the Royal Belgian Institute of Natural Sciences. Its most important objects are 30 Iguanodon skeletons, discovered in 1878 in Bernissart, W of Mons and near the French border. Cretaceous in age, they were discovered at 332m depth during the sinking of a colliery shaft.

Museum of Natural Sciences, Brussels - 2

Left: **Eocene tree stump** from eastern Flanders. Dissolved silica from the Middle Thanetian beds allowed for groundwater silcrete formation, notably silicifying the overlying Hoegaarden swamp cypress forest. This very early Eocene saw marked climatic changes (Paleocene-Eocene Temperature Maximum) and uplift of the Bray-Artois and Brabant blocks, resulting in a variety of continental and coastal deposits. These overlie a major erosive unconformity and form the Tiernen Formation which accumulated over just 0.5 Myr.

Mammoth from Lier, near Antwerp, found 1860 in Quaternary deposits at 10m depth by road workers. It is one of three disarticulated skeletons found at the site, and this one was reassembled.

Cotham Marble is a variety of Rhaetian (latest Triassic) stromatolitic limestone from the Penarth Group, found in south Wales and around Bristol, possibly extending to the south coast in east Devon. It is named after Cotham House in Cotham, Bristol. This limestone was used for ornamental purposes, particularly during the Victorian era. On cut and polished faces, the stone has the appearance of a landscape, complete with ploughed fields, trees, and hedges.