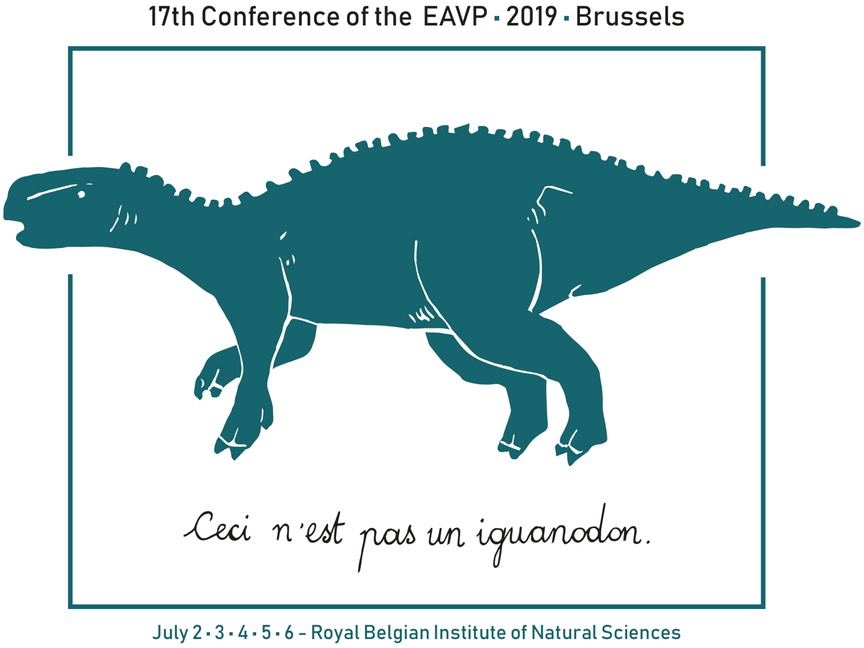

Bernissart workshop and field trip in La Malogne underground quarry

1st of July, 2019

XVII Conference of the EAVP – Brussels, Belgium
2 – 6 July 2019

Schedule

8:50	Departure from the Museum ; in front of the Iguanodon statue
10:15	Arrival at the Iguanodon Museum in Bernissart. Coffee break
10:30	Bernissart talks
12:15	Lunch
13:30	Visit of the Iguanodon Museum
15:00	Visit of La Malogne underground quarry
18h00	Arrival at Brussels

Table of contents

An introduction to the geology of the Mons Basin and the Bernissart Sinkhole, Belgium

JEAN-MARC BAELE, PASCAL GODEFROIT, PAUL SPAGNA,
AND CHRISTIAN DUPUIS

Abstract

Bernissart is located in the northern part of the Mons Basin, which consists of a 300 m-thick pile of Meso-Cenozoic sediments that accumulated in a small but actively subsiding area. Sedimentation initiated in the Lower Cretaceous with continental siliciclastics, from which the Iguanodons were recovered at Bernissart, and continued under marine conditions during the Cretaceous and more changing environments during the Tertiary. Subsidence in the Mons Basin was mainly controlled by intrastratal dissolution of deep evaporite beds in the Mississipian basement. Localized collapse structures, i.e. sinkholes or 'natural pits', developed throughout the basin and trapped the Barremian lacustrine clay with dinosaurs and other taxa at Bernissart.

Introduction

Bernissart is located in the northwestern part of the Mons Basin, western Belgium, just next to the French border. The Mons Basin is a small, but peculiar subsiding zone predominantly originating from deep karstification processes. In this paper we provide the essentials of the geological context and processes in the Bernissart area for understanding the geological environment of the deposits that have yielded the *Iguanodon* skeletons.

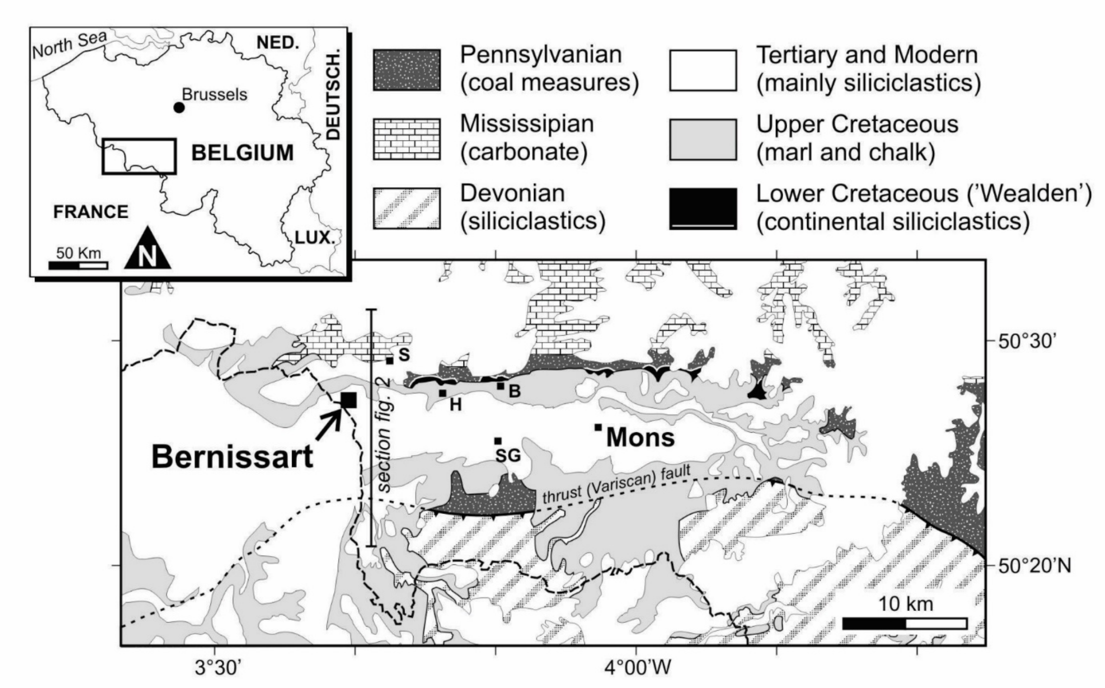

Fig. 1 – Location of Bernissart and other localities of interest within the simplified general framework of the Mons Basin

General structure of the Mons Basin

The Mons Basin is traditionally defined by the extension area of Meso-Cenozoic, mainly Cretaceous, sediments that accumulated within an EW-elongate subsiding zone in Southwestern Belgium (Marlière, 1970; Fig. 1). The basin developed uncomfortably on Pennsylvanian coal measures and is bounded by Mississipian carbonate in the north and by overthrusted Devonian siliciclastics in the south (Fig. 2). The subsiding area is rather small, less than 40 x 15 km in dimension, and the maximum depth of the basin is only 300 m. However, the Mons Basin attracted many geologists, because its sedimentary record is significantly different from that in other nearby basins such as the Paris Basin, to which it is connected westwards. In addition, the structure of the basin is uncommon: the maximum thickness for each sedimentary unit is observed in different region of the basin (Cornet 1921a). There is therefore no single perennial depocentre for the basin but several depocentres that moved over time (Fig. 3.2). A sigmoid or clinoform-like sedimentary architecture developed, especially in the northern part of the basin. However, this is not the result of sediment progradation, as it is the case for actual clinoforms, but of a southward migration of the depocentres through time.

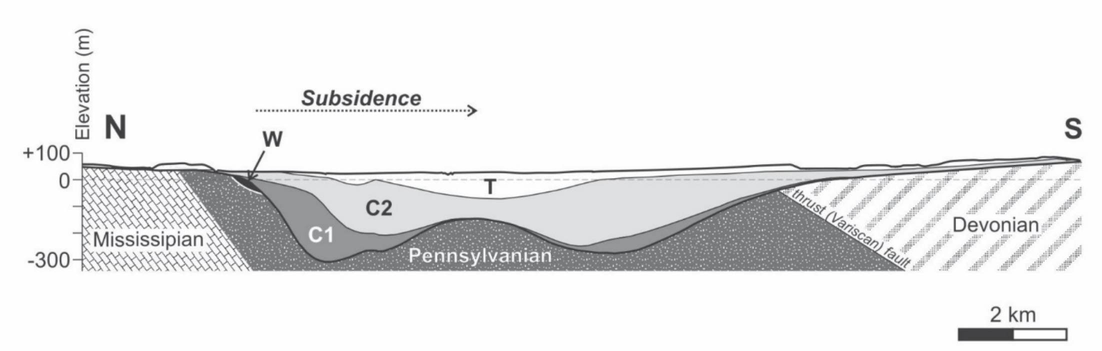

Fig. 2 – Geological cross-section of the Mons Basin in the Bernissart area. The arrow shows the direction of depocenter migration in the northern part of the basin since the Bareemian. W: Barremian (Wealden); C1: Albian-Cenomanian ; C2: Turonian-Campanian; T: Tertiary and Quaternary.

Sedimentary record

Sediment accumulation in the Mons Basin started in Early Cretaceous times (Fig. 3). The Wealden facies (including the Sainte-Barbe Clays Formation, the Baudour Clays Formation, and the Hautrage Clays Formation), as defined by Allen (1955), appears principally as the first sediments trapped and conserved in the Mons Basin. They outcrop exclusively on the northern border of this structure, trapped either in plurikilometrical deposits (Marlière, 1946), including the Hautrage Clays Formation and the Baudour Clays Formation or in filling of sinkholes, known as resulting from deep dissolution processes. Successive depocentre migration and erosion account for the unusual location of these oldest sediments, which would be otherwise expected lying deeply buried in the middle of the basin. In the whole Mons Basin, the Wealden facies is clearly diachronous (Fig. 3), with ages extending from middle (to upper) Barremian in the western part of the basin to upper Turonian in its eastern part (Yans et al., 2006; Yans, 2007; Dejax et al., 2007; Dejax et al., 2008). The Baudour Clays Formation and Hautrage Clays Formation consist of lignitic clays and sands that deposited in fluviatile, deltaic and lacustrine environment (Yans, 2007).

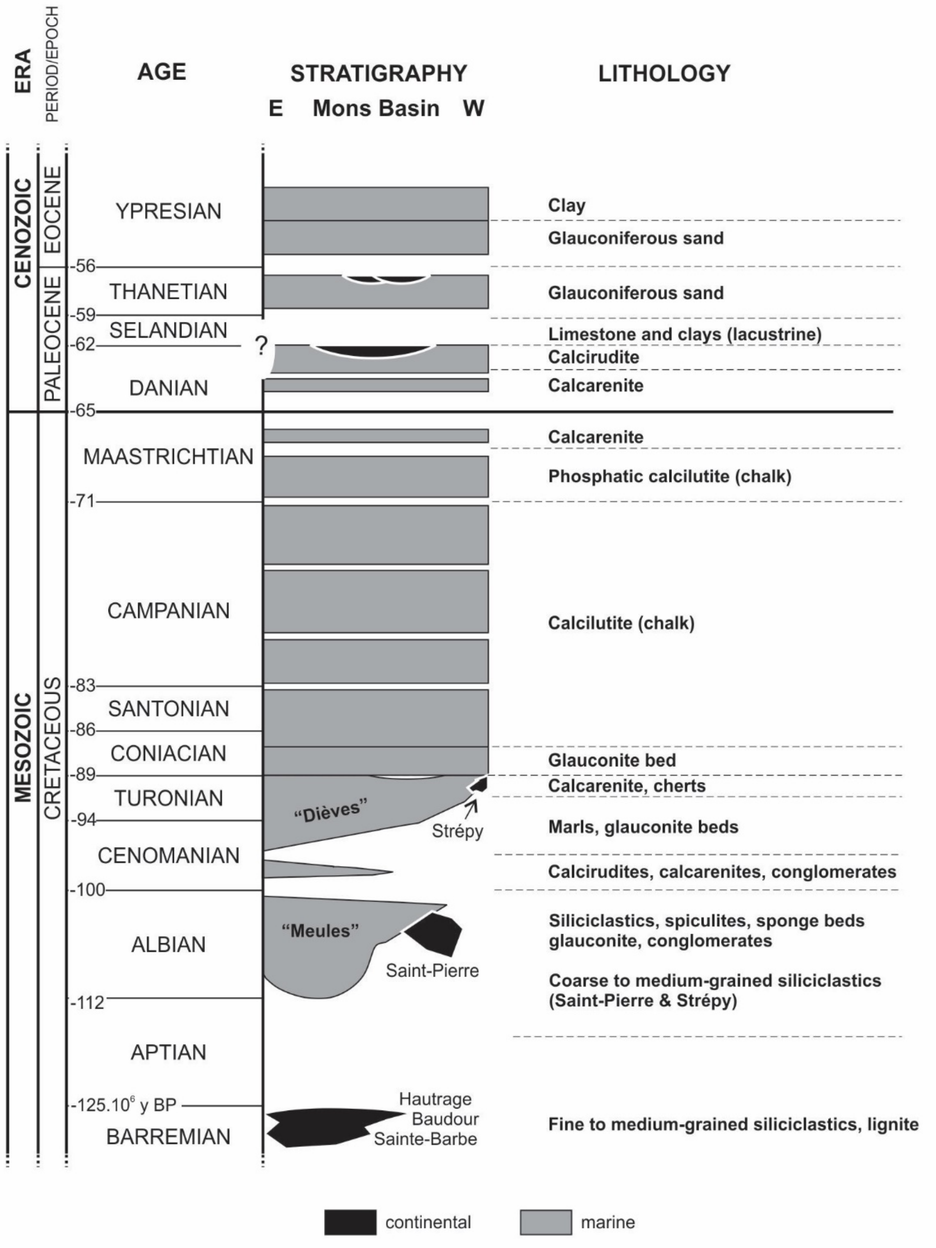

Fig. 3 - Cretaceous lithostratigraphic scale of the Mons Basin (modified after Marlière, 1970 and Robaszynski et al., 2001).

Eustatic transgressive pulses during the Albian and Cenomanian left mixed siliciclastics-carbonate formations ("meule") that, again, are found mainly in the north of the basin but extend deeper and farther southward than the 'Wealden' formations. Maximum flooding of the basin was initiated with the Turonian transgression during which marls 'dièves') deposited. After a short sea-level fall an important transgressive phase onset and carbonate calcilutite (chalk) accumulated during the Coniacian, Santonian, and Campanian. Receding sea then resulted in an increase in detrital and phosphate input in the Maastrichitian chalk as well as a sedimentary hiatus that lasted until the Early Paleogene. Various shallow marine to continental environments were subsequently induced throughout the Tertiary by a multitude of transgressive-regressive phases. Sustained lowland conditions with frequent swamp environment, occurrence of decametric-thick Quaternary peat beds and microseismic activity in the Mons area suggest that subsidence was active in recent times and is still active today.

Subsidence in the Mons Basin: heritage from deep evaporite

The main control of the subsidence in the Mons Basin was not satisfactorily unraveled until deep anhydrite layers were discovered by drilling exploration in the 1970's (Delmer, 1972). The Saint-Ghislain borehole revealed massive anhydrite layers and associated brecciated / karstified horizons producing large quantities of sulfate-rich geothermal water (see Quinif and Licour, Chapter 5 of this book). Progressive dissolution of deep (>1500 m) evaporite in underlying Mississipian carbonate is now considered as a major subsidence process in the Mons Basin although tectonic activity may have also played a significant role (Dupuis and Vandycke, 1989). As a result of intrastratal karstification, collapse structures developed at different scales depending on factors that are not well understood yet. The highly irregular surface contact between the Palaezoic basement and overlying Cretaceous formations, formerly interpreted as a fluvial erosional surface by Cornet (1921b), now receives a better explanation through karstic-induced deformations. Among the karstic-induced collapse structures produced by deep evaporite dissolution, sinkholes, or 'natural pits', are the smallest in horizontal extension but perhaps the most spectacular as they can reach more than 1000 m in vertical extension. The term ‘sinkhole’ will be used in the following although it is usually restricted to the collapse structure that form at the surface. Sinkholes in the Mons Basin consist in decametric to hectometric-wide pipes filled with downdropped and often brecciated geological formations that may originate from more than 150 m above (Delmer, 2004; Fig. 5). Mining records have reported a large number of these sinkholes in the Mons area (Delmer and Van Wichelen, 1980). They are often found concentrated within larger-scale subsiding regions (Bernissart area, for example; Fig. 4). In these areas, geological formations are heavily fractured in decametric-wide corridors, termed ‘brouillages’ by miners. These corridors often radiate from the sinkholes and may represent the boundaries of large blocks that have collapsed.

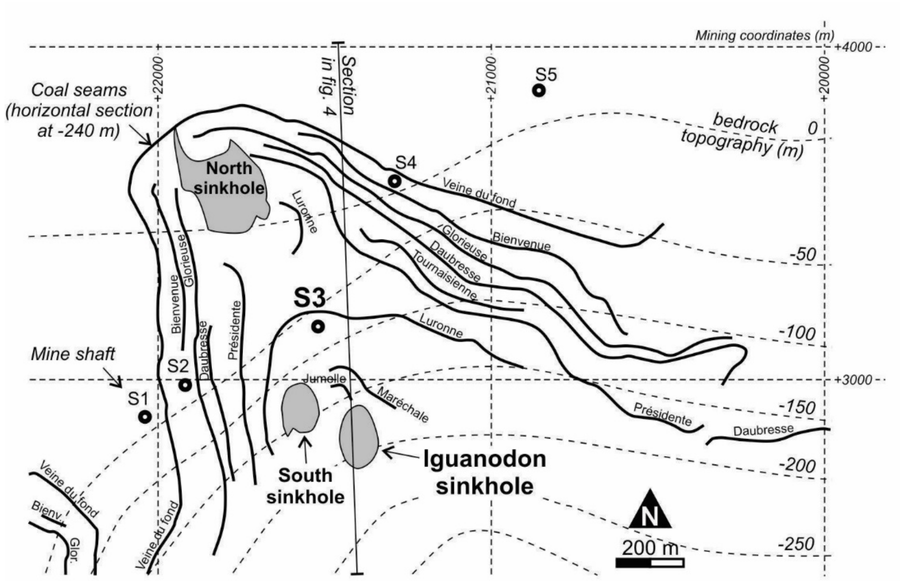

Fig. 4 - Plan view of the horizontal section at -240m in the Bernissart area showing the relation between the sinkhole distribution and the larger scale subsiding zone revealed by the coal seam deformation pattern (modified from Delmer, 2000). S1, Négresse pit; S2, Moulin pit; S3, Sainte-Barbe pit; S4, Sainte-Catherine pit; S5, unnamed pit.

A closer look at Bernissart: the Iguanodon Sinkhole

Three sinkholes were recognized by coal miners in the Bernissart area (Fig. 4): the North, the South and the Iguanodon sinkholes. Wealden facies sediments were recognized in the North (at 160m) and in the Iguanodon sinkholes (Cornet and Schmitz, 1898; Cornet, 1927). The South Sinkhole was never explored. The main filling in the North Sinkhole consists of Pennsylvanian coal strata that have just downdropped with very little deformation (to the point that they were still mineable in the past).

Figure 5 is a N-S cross-section passing through the Iguanodon Sinkhole, adapted from Delmer and Van Wichelen (1980) and including the new data from the 2003 drilling program (Tshibangu et al., 2004; Yans et al., 2005). It shows south-dipping Cretaceous strata lying with slight unconformity on the Pennsylvanian basement.

Several observations indicate sustained but fading out karstic subsidence since Barremian times in the geological formation overlying the Iguanodon Sinkhole : (1) marine Cretaceous formations are downdropped and thicker than in surrounding areas, (2) Tertiary rocks also show this trend but to a lesser extent (Van den Broeck, 1899) and (3) today a small swampy circular area is noticeable at the surface right above the sinkhole (already mentioned by De Pauw, 1898).

Coring of the Ber3 borehole drilled in 2003 yielded about 50 m of Lower Cretaceous clay (Sainte-Barbe Formation) out of the Iguanodon Sinkhole (Fig. 5). A middle Barremian to earliest Aptian age was obtained by palynological dating (Yans et al., 2006). The environment at Bernissart was formerly interpreted as lacustrine based on grain size and varve-like laminar stratification (Van Den Broeck, 1898). This received confirmation by recent studies (Yans, 2007; Schnyder et al., 2009; Spagna, 2010).

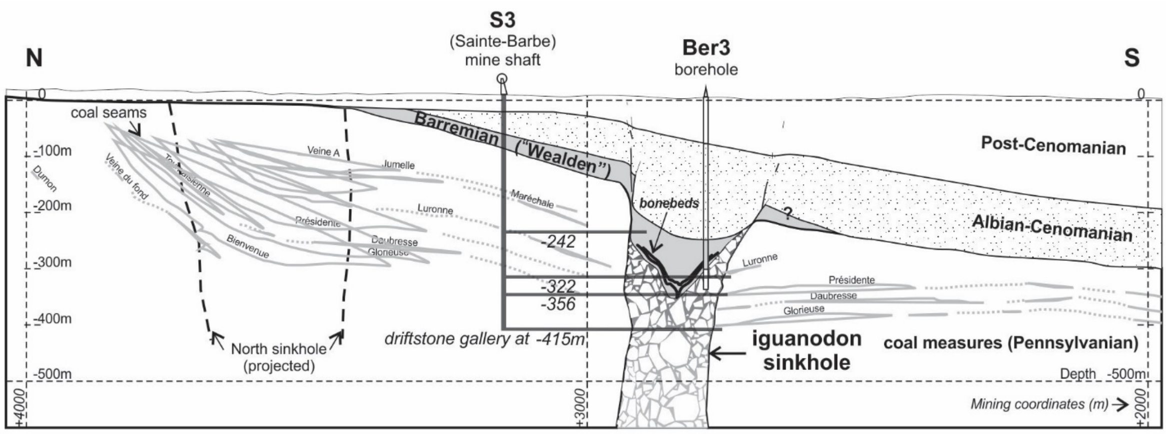

Fig. 5. - Cross-section in the Bernissart area showing the geological setting of the Iguanodon Sinkhole (adapted from Delmer and Van Wichelen, 1980). In this hypothesis, downwarping of the bonebed at -322 m would explain the fossils that were found at -356 m. Therefore the bonebeds in both galleries would be stratigraphically equivalent (see Fig. 14.4 in Chapter 14 in this book for a second hypothesis, based on the occurrence of additional, deeper bonebeds).

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140 years ago: the discovery of the Bernissart Iguanodons

PASCAL GODEFROIT

Abstract

The discovery, in 1878, of more than twenty complete skeletons of the ornithopod dinosaur *Iguanodon*, is one of the most important discoveries in the history of palaeontology. Here we shortly describe the discovery, the excavation, the preparation, the exhibition and the study of these extraordinary skeletons.

Introduction

Bernissart is a former coal-mining village in western Belgium, situated less than a km from the Franco-Belgian frontier. In 1878, the Sainte-Barbe Pit (Fig. 1) started to produce one of the greatest dinosaur discoveries of all times: more than 20 complete articulated skeletons and several incomplete specimens of *Iguanodon*. These were the first complete skeletons ever discovered and still remain one of the greatest accumulations of a single taxon of dinosaur. This discovery was a cornerstone in the history of palaeontology: for the first time, it was possible for the scientific community to realize how dinosaurs really looked like. Most of the specimens of *Iguanodon* are now on display in the renovated Janlet Wing of the Royal Belgian Institute of Naturals Sciences in Brussels. Nine of them are standing, mounted within an enormous glass cage. Many others have been left in their original position, lying on their sides as found entombed in the coal mine. This astonishing array of *Iguanodon* skeletons constitutes one of the most impressive displays of dinosaurs anywhere in the world.

Before Bernissart

Around 1822, Mary Ann Mantell discovered large fossilized teeth while strolling in the Sussex countryside in England. Her husband, the physician Dr. Gideon Mantell, was very intrigued by these fossils. He described them and named them *Iguanodon* ('Iguana tooth'), because of their superficial resemblance to those of living iguanas (Mantell, 1825). *Iguanodon*, the second representative of the group after *Megalosaurus* (Buckland, 1824), was one the few chart members of the 'Dinosauria', named by Richard Owen in 1842.

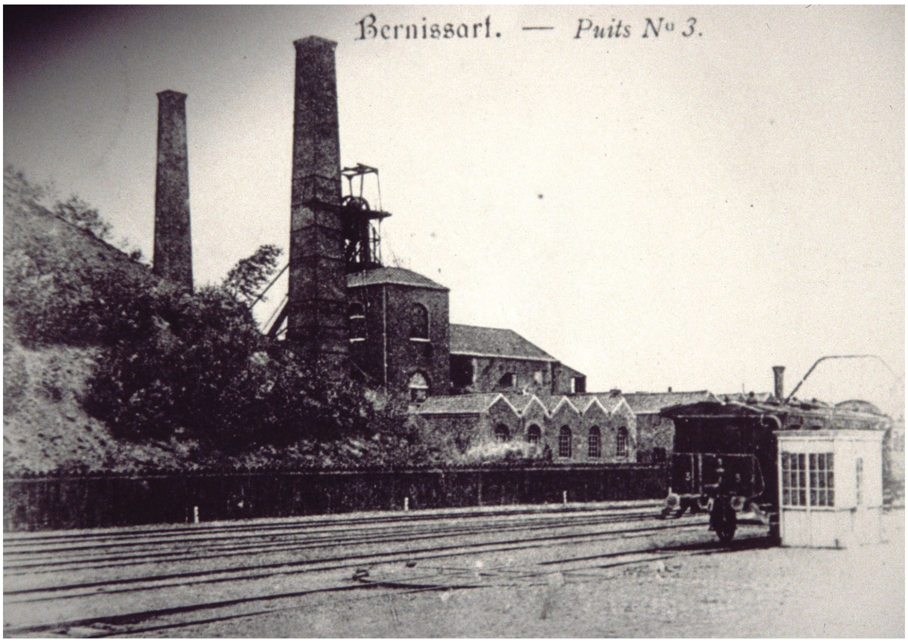

Fig. 1 - The Sainte-Barbe pit and mine buildings at the end of the 19th Century, at the time when the Bernissart Iguanodons were discovered.

For 56 years, very little was known about *Iguanodon* and other dinosaurs. Mantell imagined these antediluvian animals to be some kind of giant lizards with elongated bodies and sprawling limbs. In 1854, the sculptor Waterhouse Hawkins erected a full-size reconstruction of *Iguanodon* for the Crystal Palace exhibition centre in London as a rhinoceros-like heavy quadruped with a large spike on its nose.

The first partial dinosaur skeleton, named *Hadrosaurus foulki* Leidy, 1858, was discovered in 1857 in New Jersey. This skeleton was reconstructed in a bipedal gait at the Academy of Natural Sciences of Philadelphia, but many questions were still left unanswered about the general appearance of dinosaurs.

The discovery of the Bernissart Iguanodons

In 1878, miners working in the the Sainte-Barbe Pit at Bernissart reported that the Luronne seam was cut out, at 322 m depth, by what they called a 'cran', a local name for pits formed by natural collapse through the coal seams and filled with Lower Cretaceous clayey deposits normally located above the Coal Measures. The miners had to traverse this 'cran' as quickly as possible in order to rejoin the Luronne seam.

On February 28, two miners, J. Créteur and A Blanchard, found in the clays of the 'Cran' what they believed to be a tree trunk filled with gold. Many other specimens were collected by the miners in March. On April 2, the local doctor L'Hoir and the mine manager G. Fagès concluded, that these strange objects were in fact fossil bones filled with pyrite, the 'fool's gold'. They rapidly sent fragments of fossil bones to several Belgian specialists. P.J. Van Beneden, a zoologist from Leuven University, was the first to recognize among the collected specimens teeth of the dinosaur *Iguanodon* (Van Beneden, 1878). On April 12, the management of the colliery sent a telegram to E. Dupont, director of the Royal Museum of Natural History in Brussels, asking for the services of L. De Pauw, a technician highly experienced in the restoration of fossils.

The excavation of the Bernissart Iguanodons

During three years, L. De Pauw and his team, composed by one museum warder, one moulder and nine miners, actively excavated the 'Iguanodon Cran' at Bernissart. In August 1878, an important earthquake blocked the excavation team during two hours in the gallery 322 m below ground level. This gallery was subsequently flooded in autumn, forcing the team to abandon their researches during several months. The excavations restarted from May 1879 onwards. They were extended horizontally for 50m at the 322 m level. The miners also encountered fossiliferous clays at a depth of 356 m, but the diameter of the 'cran' was reduced at only 9m at this level and the skeletons were consequently completely dislocated (De Pauw, 1902).

It was the first time that palaeontologist had the opportunity to collect such a wealth of fossils within a single locality. More than twenty more or less complete skeletons of *Iguanodon* were found lying as they had fallen, little disturbed by their burial (Fig. 2). Besides these dinosaurs, hundreds of fragments of plants, hundreds of fishes, several crocodiles and tortoises, one amphibian, one fragment of insect, and one carnivorous dinosaur phalanx were also discovered.

The excavation method elaborated by L. De Pauw was so efficient that it is still used at the present time during palaeontological excavations. Each *Iguanodon* skeleton was split into pieces that were coated with plaster of Paris. After being sketched and catalogued, the blocks were carried to the surface. After three years of excavations, about six hundred blocks, totalling more than 130 tonnes, were transported to Brussels in furniture removal vans.

The excavations were stopped in 1881, because the expenses involved by this enterprise were considered too high by the Belgian government. Members of the Parliament suggested that an Iguanodon skeleton should be sold abroad in order to collect supplementary subsidies, but public outcry prevented this transaction. From 1915, the German forces of occupation, under the initiative of the palaeontologist Otto Jaekel, planned to start new excavations at Bernissart in order to send new *Iguanodon* skeletons in German natural history museums. But the preliminary researches were interrupted in 1918 by the end of the First World War (Roolf, 2004). After the war, further initiatives to start new excavations at Bernissart were immediately stopped because of the absence of wish from the Belgian government to put up the money for such researches.

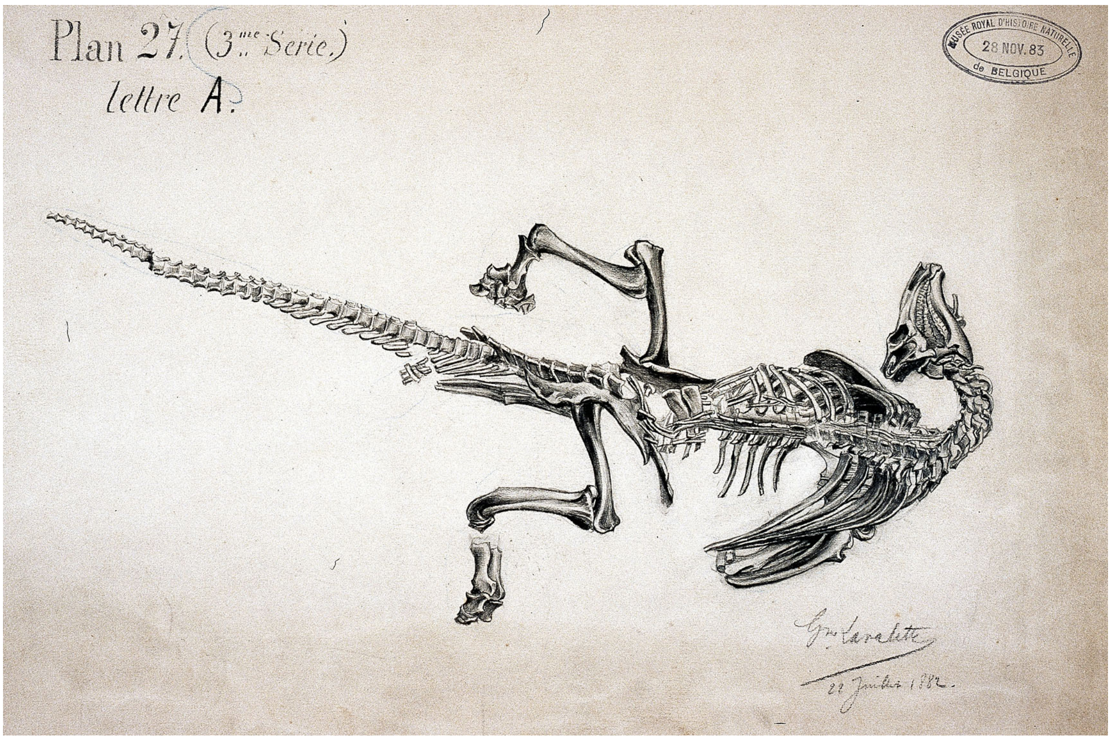

Fig. 2 - Drawing by G. Lavalette of a specimen of *Iguanodon bernissartensis* as discovered in the Sainte-Barbe pit at Bernissart.

Preparation and mounting of the Iguanodon skeletons

After death, the Iguanodon carcasses were covered by clayey sediments and their decomposition therefore developed in anoxic environment. In such conditions, sulphate-reducing bacteria were highly involved in the putrefaction processes. The hydrogen sulphide, produced during the hydrolysis of the organic matter by these bacteria, combined with the iron from the sediments and from the degradation of haemoglobin to form pyrite, which was deposited in cavities within the bones. In contact with damp air, the pyrite oxidised to form a salt, iron sulphate, or an iron oxide, limonite. Decomposition of both led to the disintegration of bone containing them (Leduc, 2012). For that reason, the *Iguanodon* bones became extremely fragile when they were extracted from the Bernissart pit.

Once they were arrived in Brussels, the *Iguanodon* blocks were stored in the Museum workshop, housed in the St George Chapel of the Nassau Palace, now preserved as an exhibition hall in the Albert I Royal Library. Between 1878 and 1905, the bones were impregnated with a carpenter's glue-based gelatine and the pyrite was systematically curetted from the bones. Some vertebrae contained more than 1 kg of pyrite. The remaining cavities were filled with 'carton-pierre', a stable mixture of paper, glue and talc (De Pauw, 1902).

It was decided to mount the best preserved *Iguanodon* specimens in a lifelike gait. In 1882, the first specimen was assembled and mounted by L. De Pauw and his team in the St. George Chapel. The bones were suspended from scaffolding by ropes that could be adjusted so as to obtain the most lifelike position for the complete skeleton, which was then supported by an iron framework (Fig. 3). This first mounted specimen was publicly exhibited in 1883 in a glass cage constructed in the interior court of the Nassau Palace. But the Nassau Palace Chapel quickly became too small for the storage, preparation, mounting and exhibition of these numerous and bulky skeletons. In 1891, the Iguanodons and the Royal Museum of Natural History were transported to a new home in the Leopold Park. In 1899, five specimens were mounted in a glass cage close to the entrance of the museum. From 1902 onwards, the whole Bernissart exhibition was permanently installed in the newly-constructed Janlet Wing of the Royal Museum of Natural History (Fig. 4).

Between 1933 and 1937, the Iguanodon skeletons were dismantled and treated, because thirty years of changes in temperature and humidity had produced important damages. The bones were soaked in a mixture of alcohol and shellac, a natural lacquer secreted by coccid insects. The specimens were installed into two large glass cages, in order to stabilize the temperature and humidity of their environment.

From 2004 till 2007, the Janlet Wing of the Royal Belgian Institute of Natural Sciences was entirely renovated. At this occasion, the Iguanodon skeletons were completely restored again. All the bones were reinforced by a solution in acetone and alcohol of synthetic polyvinyl acetate ('Mowilith'). New glass cages were constructed to protect the skeletons.

Fig. 3 - Mounting of the first *Iguanodon* specimen in the St. George Chapel of the Nassau Palace. Note, close to the *Iguanodon*'s leg, the cassowary and wallaby skeletons used for comparison.

The study of the Bernissart Iguanodons

Just after the discovery of the Bernissart Iguanodons, E. Dupont, then director of the Royal Museum of Natural History, asked the young naturalist G. A. Boulenger to study these specimens. In 1881, Boulenger presented his first results to the Belgian Academy of Sciences, Letters and Fine Arts: he described the anatomy of the pelvis of these dinosaurs and proposed that the greater number of sacral vertebrae (six) in the Bernissart form, as opposed to the five sacral vertebrae in the English species *I. mantelli*, merited the establishment of a new species that he named *Iguanodon bernissartensis*. Unfortunately, this paper was refused publication, although a brief highly critical review of Boulenger's paper was published by Van Beneden (1881). The latter claimed that the Bernissart Iguanodons belonged to *Iguanodon mantelli*, already described from disarticulated specimens discovered in England. Shortly afterwards, in 1881, Boulenger accepted a post at the British Museum (Natural History) and in 1882 study of the Bernissart Iguanodons was entrusted to L. Dollo. Between 1882 and 1923, Dollo published many preliminary notes on the Bernissart fauna and, especially, on *Iguanodon* (see bibliographical list in Norman, 1980). He distinguished two species at Bernissart: most of the specimens belong to the larger form *I. bernissartensis*, the new species named by Boulenger, although a single complete individual represents the smaller and slender *I. mantelli*. While studying in detail several parts of the *Iguanodon* skeleton, Dollo was adopting a forensic approach to understanding these fossils. He developed a new style of palaeontology that became known as palaeobiology: palaeontology can be expanded to investigate the biology, and by implication the ecology and the behaviour of extinct creatures. Dollo's final contribution to the *Iguanodon* story was published in 1923 as a synthetic study, to honour the centenary of Mantell's original paper. He identified *Iguanodon* as an ecological equivalent of the giraffe. Its kangaroo-like posture enabled it to reach high into the trees to gather its fodder, which it was able to draw into its mouth by using a long, muscular tongue. The sharp beak was used to nip off tough stems, while the teeth served to pulp the food before it was swallowed. This image of *Iguanodon* as a gigantic kangaroo-style creature, as depicted by Dollo, has become iconic during more than 60 years and was reinforced by the distribution of full-sized replicas of mounted skeletons of *Iguanodon* from Brussels to many of the great museums around the world (Norman, 2005).

In 1980, the British palaeontologist D. Norman published a monographic study of *Iguanodon bernissartensis*. Functional analysis of the skeleton indicated that the vertebral column, stiffened by a network of ossified tendons, was held more or less horizontal while the animal was walking or running. Norman also believed that *I. bernissartensis* was mainly a quadrupedal animal. The structure of the pectoral girdle, the ratios of the fore-and hindlimb lengths, the strongly fused carpal bones, and the presence of hoof-like unguals on the middle three digits of the hand suggest that the adult of *I. bernissartensis* spent most of its time in a quadrupedal posture, though juveniles had a predominantly bipedal mode of life.

In 1986, Norman concluded that the small species from Bernissart belongs to *Iguanodon atherfieldensis* Hooley, 1925, a species previously described from the Wealden Beds of the Isle of Wight. This species is now included within its own genus, *Mantellisaurus* (Paul, 2007).

On the occasion of the mounting of an *Iguanodon bernissartensis* cast in a quadrupedal position at the RBINS in 1992, Bultynck discussed in a short paper the posture and gait of this species. Recent investigations about the Bernissart Iguanodons include a study of their neurocranial anatomy (Lauters et al., 2012), about the diagenesis of their fossil bones (Leduc, 2012), and about the intraspecific variation of their skeletal anatomy (Verdu et al., 2017).

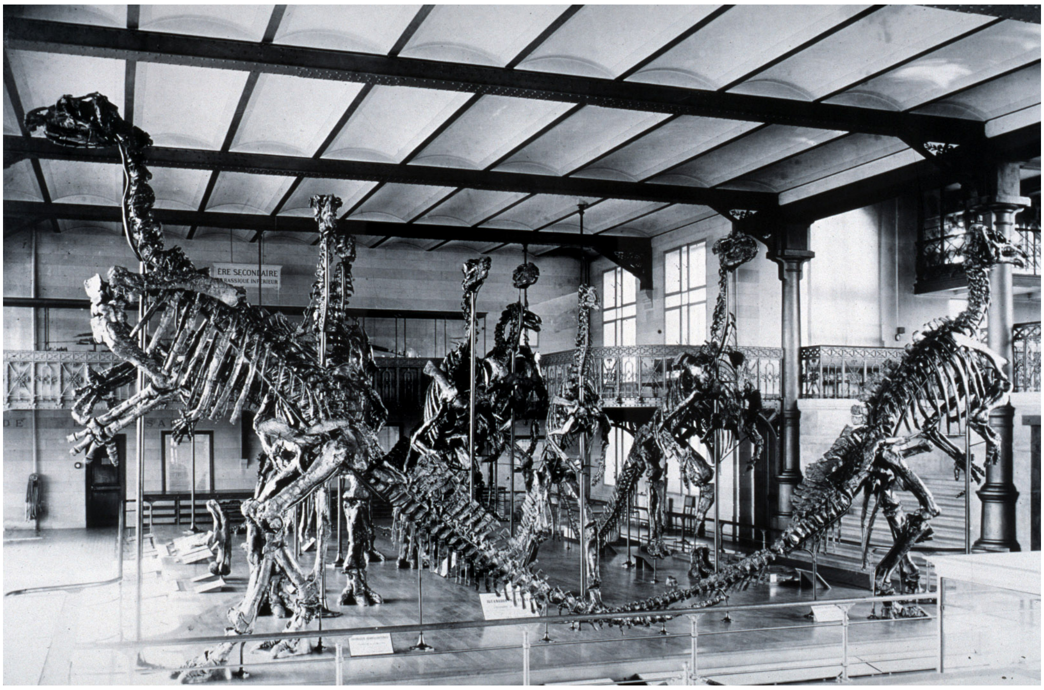

Fig 4 - Exhibition, at the beginning of the 20th Century, of the mounted *Iguanodon* specimens in the Janlet Wing of the Royal Museum of Natural History.

New boreholes within the Iguanodon Sinkhole

In 2002-2003, three new boreholes were drilled within and around the Iguanodon Sinkhole at Bernissart. Initially, the aim of this drilling program was to evaluate the chances of finding more fossils, to understand the genesis of the Iguanodon Sinkhole, and to test a seismic geophysical technique for ground imaging (Tshibangu et al., 2004a and b). In October 2002 the drilling program started with a completely cored well (named BER 3) using the PQ wireline technique. BER 3 reached 349.95 meters of Thanetian, Late Cretaceous, Early Cretaceous and Westphalian sediments (Yans et al., 2005; Yans, 2007). During the operations, different parameters were recorded: rate of penetration, core recovery and a brief core description (Tshibangu et al., 2004a and b). BER 3 provided exceptional material to improve our knowledge of the Iguanodons-bearing Wealden facies, with a multidisciplinary research funded by FRS-FNRS, whose results are e.g. summarized in a book published by Godefroit (ed., 2012). Another borehole (BER 2) also cut Wealden facies (Spagna and Van Itterbeeck, 2006).

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La Malogne underground quarry (Cuesmes)

ASBL Malogne

The Malogne underground quarry is located in the central part of the Mons Basin, slightly off to the south. The excavating galleries spread over kilometres in the Maastrichtian phosphatic "chalk" (Ciply-Malogne Fm; Figs 1,2), which has been actively mined between the 19th to mid-20th century, mainly for feeding the fertilizer industry (average production: 200-250 kt/ year).

The Ciply-Malogne Fm is overlying the Spiennes Fm, which may be observed in a few places at the floor when it is not covered with waste dumps. The fossiliferous Cuesmes Conglomerate is found intercalated between these two formations. The thickness of Ciply-Malogne Fm. grades from a few meters at the outcrop to 50 m in its deeper parts to the north. Phosphate occurs as dark-brown carbonate-apatite grains, mostly <1mm in diameter. Average phosphate content is ca. 10% P_2O_5 but post-Thanetian cryptokarstification locally induced a secondary enrichment in phosphate. Regression during the Maastrichtian probably created favorable restricted conditions for phosphate accumulation.

Flints are virtually absent in the Ciply-Malogne Fm of the Malogne Quarry but they are abundant northward in the nearby Ronveaux Quarry (Mesvin).

A thick hardground caps the Ciply Fomation. It is intensely burrowed and covered with a fossiliferous phosphatic conglomerate (Poudingue de la Malogne). This hardground plays an important role in maintaining the stability of the galleries, which have here a square cross section. Laterally, its thickness may be considerably reduced and cemented zones no longer continuous but nodular (firmground). Then the cross section of the galleries must have an ogival profile in order to be self-supporting as it is the case in other nearby underground quarries.

Fossils are abundant and besides the great diversity in invertebrates, the Ciply-Malogne Fm yielded spectacular vertebrates such as large reptiles (*Hainausaurus bernardi* Dollo, 15 m long, excavated from a nearby open pit quarry, mosasaurs, chelonids, etc.). The first mosasaur was discovered near Maastricht in 1766. In the Mons Basin seven species of mosasaurs have been discovered: *Plioplatecarpus houzeaui*, *Halisaurus ortliebi*, *Mosasaurus lemonnieri*, *Prognathodon solvayi*, *Prognathodon giganteus*, *Globidens dakotensis* and in

1885 the first description, given by Louis Dollo, of the hainosaur (17 m), a Mosasaur discovered in February 1885 in an open pit quarry exploited by Léopold Bernard in Mesvin-Ciply. Louis Dollo described the Hainosaur and concluded: « the Mesvin-Ciply Mosasaur therefore represents a new genus. Following the instructions of the Museum board, I shall name *Hainosaurus bernardi* ». The first term means "saurian from de Haine river" and mirrors the term "*Mosasaurus*" or "saurian from the Meuse", both being found in cretaceous deposits, one of the Limburg and the other in the Hainaut rocks. The epithet "*bernardi*" is a reminder of Mr. Bernard, an industrialist from Mesvin-Ciply who owned the quarry where the Hainosaur was discovered (Fig. 3).

Paleogene fossils are also abundant, but reworked, in the La Malogne Conglomerate (Danian), which is found topping the hardground.

The formations overlying the Ciply-Malogne Fm are the Saint-Symphorien (Maastrichtian, not visible here) and Ciply calcarenites (Danian). The Ciply calcarenite with its flint band is exposed along the entrance gallery and where the roof collapsed. No K/T boundary is observable because the Uppermost Maastrichtian and lowermost Danian are missing.

Glauconitic sand of Thanetian age (Hannut Fm) can be observed in places where the gallery cuts cryptokarsts.

The Mons Basin has recorded a multistage tectonic history, which can be observed in La Malogne underground quarry (Fig. 2).

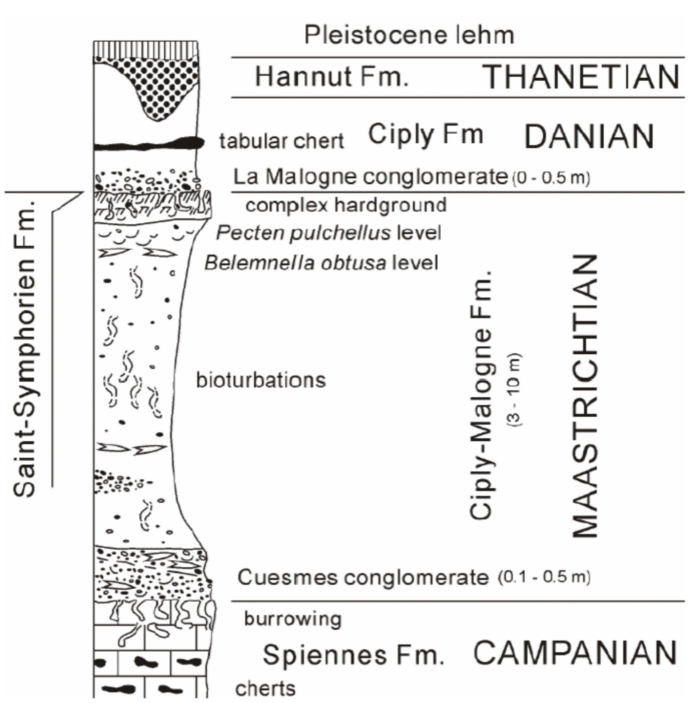

Figure 1: Stratigraphical section in La Malogne underground quarry

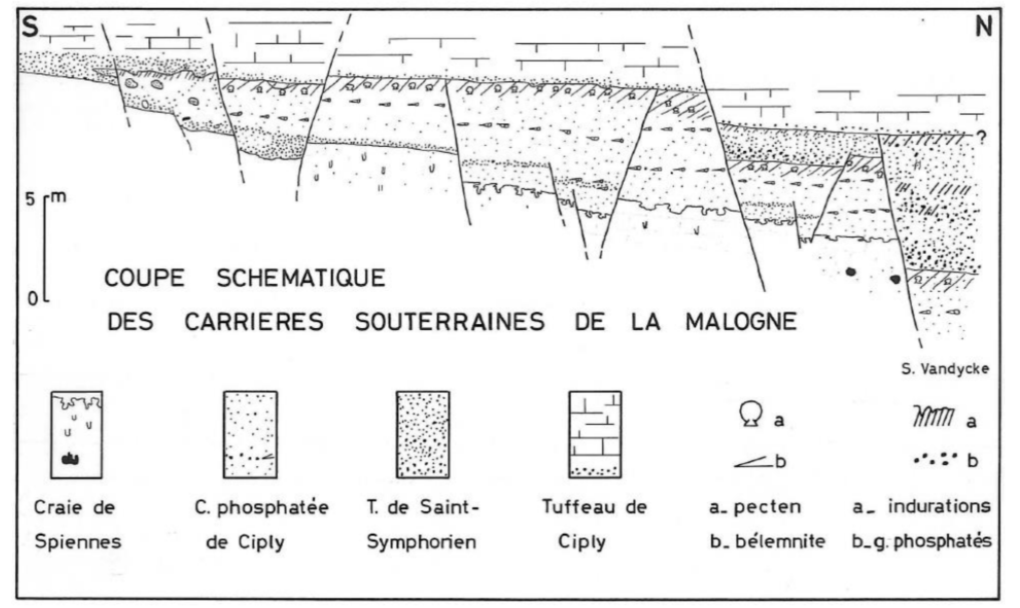

Figure 2: Typical fault pattern in La Malogne underground quarry

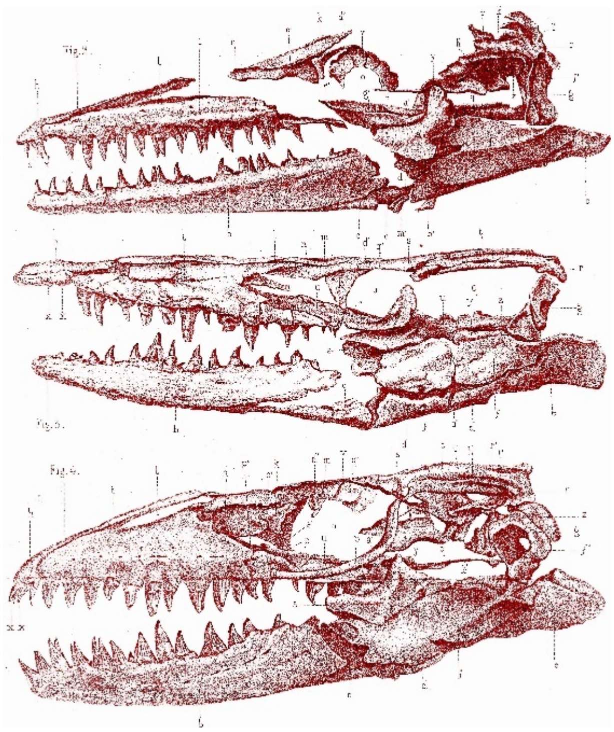

Figure 3: Mosasaur skulls described by Louis Dollo. From top to bottom, *Mosasaurus lemonnieri* (length of 0.53m), *Hainosaurus bernardi* (length of 1.55m) and *Prognathodon solvayi* (length of 0.58m)

THE LOWER CRETACEOUS BERNISSART SINKHOLES : DEADLY TRAPS OR PASSIVE GRAVEDIGGERS?

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Keywords*: Bernissart, deadly trap, iguanodon, margin sliding, sinkhole.*

The causes of the mass-accumulation of fully-articulated iguanodon skeletons and other vertebrates in the Lower Cretaceous, world-class fossiliferous deposit of Bernissart, Belgium, are still obscure. Most of the hypotheses consider the karstic collapse structure (sinkhole) from which the fossils have been unearthed as a simple receptacle for the carcasses. Our study in the frame of the ColdCase Project shows that sinkhole formation processes may also have played an active role in the trapping of iguanodon herds along with other taxa. LIBS (Laser-Induced Breakdown Spectroscopy) analysis of the 50 m-thick Sainte-Barbe clay Formation in the Ber3 borehole showed unexpected results that can be explained as changes in clay texture, drawing our attention to the sedimentary processes in relation to sinkhole dynamics. The lower half clay section, which is fossiliferous, exhibits a clay texture which is more disorientated than the non-fossiliferous upper half. Together with other data, this provides evidence that the Sainte-Barbe Fm. records a depositional sequence evolving upwards from proximal debris flows to distal “turbidites”. Sediment input in the Bernissart lake thus originated from the sinkhole margins, which repeatedly failed and slided. The fossiliferous layers would then coincide with maximum deepening of the sinkhole, when sliding hazard was greatest. The iguanodons may have triggered slidings due to their weight, which would explain the monospecificity of the assemblage of large vertebrates. This scenario also provides a mechanism for the liberation of H_2S initially stored in the lake bottom, increasing the number of iguanodon deaths by drowning and possibly affecting aquatic animals.

CRETACEOUS DISEASES: A PALAEOPATHOLOGICAL SURVEY OF THE *IGUANODON* SPECIMENS FROM BERNISSART (BELGIUM)

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Keywords: *Cretaceous, Ornithischia, Ornithopoda, Osteopathy*

The fossil deposit of Bernissart (Belgium) has yielded one of the largest dinosaur collections in Europe. Between 1878 and 1881, at least 43 specimens of *Iguanodon* were found in what is known today as the *Iguanodon* Sinkhole. Thanks to these skeletons, *Iguanodon* is one of the most famous dinosaur taxa, however some aspects of its biology remain enigmatic. Although new studies are covering topics like metabolism, growth, locomotion and intraspecific variability, the possible presence of palaeopathologies has yet to be established. Here, we present a survey of fossilised maladies recognised in the Bernissart specimens, which comprises traumas, infections, spondyloarthropathies and developmental anomalies. The pathologies have been subdivided by body region, with particular occurrences in dorsal vertebrae, the distal region of the tail, ribs, and pes. Some of these "lesions" are considered pseudopathologies because Bernissart *Iguanodon* specimens suffer from pyrite oxidation, which results in deformation and/or cavities resembling pathological conditions. The total number of palaeopathologies in Bernissart *Iguanodon* is lower than in other ornithopods, but this apparent "good health" of the population should be examined under the lens of the osteological paradox. It is possible that these dinosaur populations were comprised of healthy individuals and others suffering from severe diseases which gave no time for their bodies to react and start the healing process. In the future, the data collected from the Bernissart specimens will be included in a complete list of ornithopod palaeopathologies to analyse any phylogenetic and/or ecological influences on the occurrence of traumas and diseases in the clade.

A NEW LOOK AT THE BERNISART FLORA

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***Keywords**: Barremian, Belgium, plants, Wealden.*

In addition to the Iguanodons, the locality of Bernissart has, as well, yielded an abundant and diversified fossil plant assemblage. First reported by Dupont (1878), this flora was later studied in detail by Seward (1900). It appeared to be one of the most important Lower Cretaceous floras in Europe, with a very similar taxonomic composition to the English Wealden flora(s). Although, the Bernissart flora was never restudied after these early pioneer works, the Mons Basin Wealden facies have been subject to several studies focusing on plant macro- and mesofossils and on palynomorphs.

A comprehensive actualization of the taxonomy has been undertaken together with a paleoecological reconstruction based on the abundance, diversity and taphonomy of the extraordinarily large sample available. Although no new species have been identified, this revision has provided the first updated taxonomical list of the plants since their first description. The species diversity and taphonomical analysis provide an idea of the vegetation of the area, where four distinct assemblages have been identified. Dominated by *Weichselia reticulata*, the plant associations and the general environment of the Bernissart locality, but also of the whole Mons basin, will be discussed in detail.

We further demonstrate the necessity to update and revise floras that have been published in the past in order to obtain new information and depict a bigger picture of the paleoflora. Although historical collections are not always associated with information on the extraction of the material, some taphonomical and quantitative analyses are possible if the sampling is big enough and if biases are moderate. This work is part to a more comprehensive study of the Lower Cretaceous floras in Europe, where substantial palaeontological evidences have been recovered, some of which must be thoroughly revised and others must be studied for the first time.

THE *BOUILLABAISSE* OF BERNISSART

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Keywords: *actinopterygians, Barremian-Aptian, Bernissart, chondrosteans, ginglymodians.*

The Cretaceous (Barremian-Aptian) locality of Bernissart, Belgium, is well known for the *Iguanodon* remains it yielded but less for its actinopterygian assemblage. Alongside the dinosaur remains, about 3,000 actinopterygian specimens were also unearthed. These actinopterygians were studied by Traquair. The assemblage includes chondrosteans, pycnodontiforms, ginglymodians, halecomorphs and teleosts. They are nowadays the object of a revision, which has first dealt with the chondrosteans and ginglymodians.

Only one chondrostean taxon was discovered in Bernissart and described originally as "*Coccolepis*" *macroptera*. The family Coccolepididae is a group ranging from the Early Jurassic to the Early Cretaceous. Accordingly, the Bernissart species was among the last coccolepidids. Several anatomical differences, such as the insertion of the anal fin on the body, justified the erection of a new genus for the Bernissart coccolepidid: *Barbalepis macroptera*.

"Lepidotes" bernissartensis is a species of ginglymodian ray-finned fish described from Bernissart. A recent revision of its osteology led us to include this species in the genus *Scheenstia*, and to consider *L. brevifulcratus* and *L. arcuatus*, both from the same site, as synonymous of *S. bernissartensis*. This species is very close to *S. mantelli* from the Wealden of Europe. The performed cladistic analysis includes *Scheenstia* in the Lepidotidae, but the intrarelationships within this family are poorly supported.

The Bernissart actinopterygian assemblage is a typical Early Cretaceous actinopterygian assemblage containing as much non-teleostean actinopterygians as teleosts (in terms of taxon number). Later, teleosts override non-teleostean taxa in diversity, but during the Early Cretaceous both groups compete equally. In freshwater environments such as Bernissart, moreover, the proportion of 'ancient' taxa is generally more important than in marine environments (e.g. acipenseriformes and holosteans). In terms of number of individuals, teleosts are clearly overrepresented in the Bernissart assemblage. This abundance, together with the small size of most of these teleosteans fishes indicate that they were generalist in the Bernissart assemblage, as they were in most Jurassic and basal Cretaceous fish assemblages.

REASSESSMENT OF DOLLO'S CROCODYLOMORPHS FROM THE EARLY CRETACEOUS OF BERNISSART, BELGIUM

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Complete specimens of Early Cretaceous crocodylomorphs were discovered during excavations for dinosaurs in Wealden facies of the 'Cran aux iguanodons' (late Barremian – earliest Aptian) in the Sainte Barbe pit of the Belgian coal mine of Bernissart in 1879. Two skeletons of a goniopholidid (IRSNB R47 and IRSNB R290) and two skeletons of the small derived neosuchian *Bernissartia fagesii* (IRSNB R46 and IRSNB R118) were found at a depth of 322 m together with skeletons of *Iguanodon bernissartensis*. The two goniopholidid specimens were referred by Louis Dollo to *Goniopholis simus* but were never described.

In the framework of a long-term study of Cretaceous and Paleogene European crocodylomorphs, we reassessed Dollo's specimens and recently described and referred the Bernissart goniopholidid to *Anteophthalmosuchus hooleyi*. At this occasion, we also revised the unedited collections and discovered intriguing specimens. Among them is a large isolated caniniform tooth that reveals the presence of a goniopholidid of 1.5 times the size of IRSNB R47. The most astonishing discovery is a third partial specimen of a small individual and an isolated left ilium that we here refer to *Bernissartia*. A partial vertebral column with four dorsal vertebrae allows observations of the anterior and posterior views of the centrum and confirms the amphicoelous condition in *Bernissartia*. In addition, a small frontal bone indicates the presence of a third taxon similar to *Theriosuchus*. Finally, we correct a historical mistake by proving that Lavalette's drawing of "*Goniopholis simus*" corresponds in fact to specimen IRSNB R46 of *Bernissartia*.

HISTOLOGY AND GROWTH OF WEALDEN IGUANODONS FROM BELGIUM AND GERMANY

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Keywords: *Bernissart, bone diagenesis, bone histology, iguanodon, Nehden*

The genus *Iguanodon* comprises some of the earliest discovered dinosaur taxa. It acquired an iconic status when a large number of more or less complete skeletons was exhumed from a coal mine near Bernissart, Belgium. The skeletons represent the largest find of its kind in Europe, and their morphology has been studied extensively. However, these natural treasures are notably threatened by decay of the pyrite which is ubiquitously present in the skeletons, therefore continued action is needed to preserve them. Here we present results on the bone histology and preservation of *Iguanodon bernissartensis* and *Mantellisaurus atherfieldensis* from Bernissart (Belgium) and the contemporary bonebed locality of Nehden (Germany), from which hundreds of mostly disarticulated bones with similar preservation were uncovered. Our analytical approach (polarized light microscopy, µXRF, FTIR spectroscopy, carbon and oxygen stable isotope analysis) demonstrates the morphological preservation of bony tissues, and presence of metal sulfides on the boundary of the medullary cavity and cortex and silicate minerals in the core of the medullary cavity. Pyrite has thus not penetrated the bony tissues themselves, which allowed assessment of the growth of this iconic taxon. Our bone histological results indicate iguanodons *Iguanodon bernissartensis* and *Mantellisaurus atherfieldensis* generally grew fast, likely reaching adult size within a decade. However, a clear difference in growth trajectory can be seen between *I. bernissartensis* and *Mantellisaurus*, justifying their taxonomic distinction. Finally, it should be noted that though some variation in histological maturity exists, no juveniles are known from Bernissart, whereas younger individuals (<50% max size) are clearly present in the Nehden assemblage.