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A Short Introduction to the Geology of the Mons Basin and the Iguanodon Sinkhole, Belgium

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Jean-Marc Baele*, Pascal Godefroit, Paul Spagna, and Christian Dupuis

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 Mississippian basement. Localized collapse structures, such as 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. Here 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.

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 east–west elongate subsiding zone in southwestern Belgium (Marlière, 1970; Fig. 3.1). The basin developed uncomfortably on Pennsylvanian coal measures and is bounded by Mississippian carbonate in the north and by overthrusted Devonian siliciclastics in the south (Fig. 3.2). The subsiding area is rather small, less than 40 by 15 km in dimension, and the maximum depth of the basin is only 300 m. However, the Mons Basin has attracted many geologists because its sedimentary record is significantly different from that of other nearby basins, such as the Paris Basin, to which it is connected westward. 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 depocenter for the basin but rather several depocenters 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

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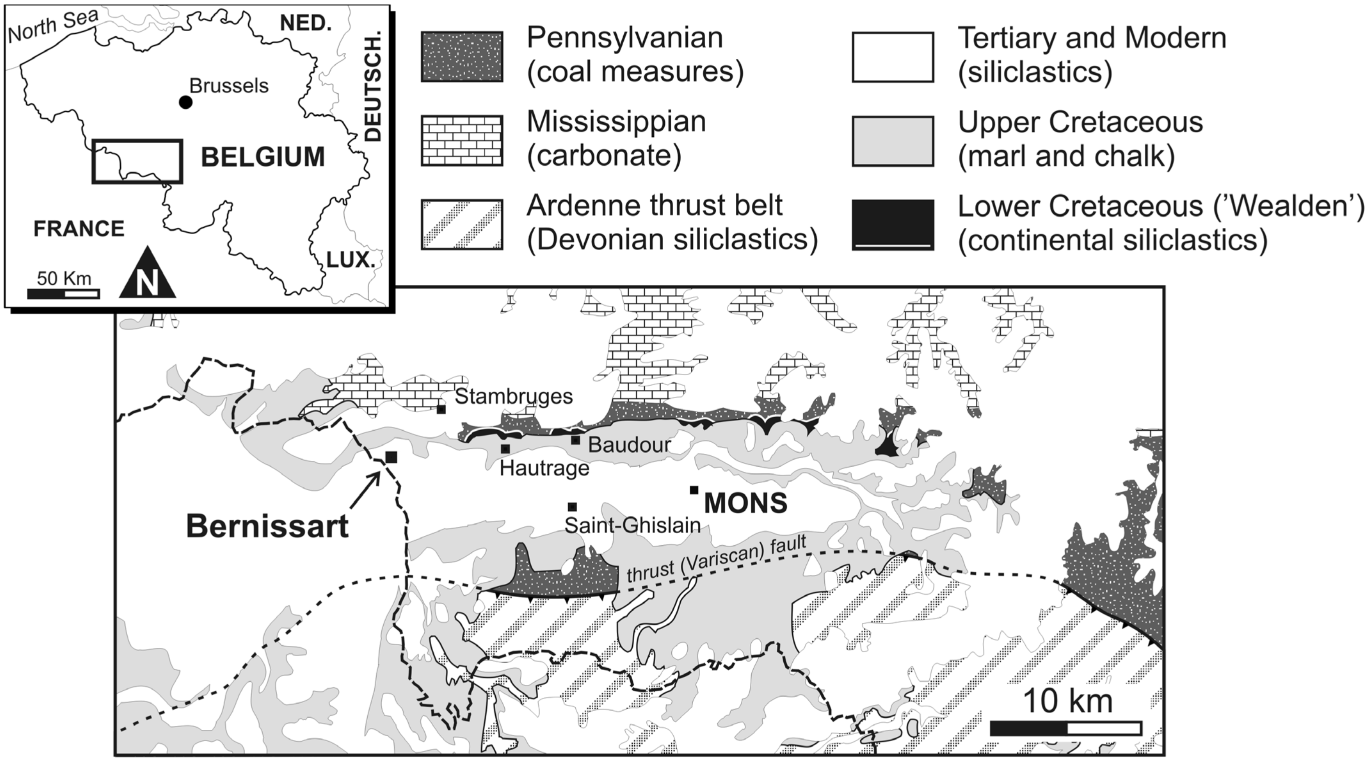

3.1. Location of Bernissart and other localities of interest within the simplified geological framework of the Mons Basin. *Abbreviations:* B, Baudour; S, Stambruges, H, Hautrage; SG, Saint-Ghislain.

progradation, as it is the case for actual clinoforms, but of a southward migration of the depocenters through time.

Sedimentary Record

Sediment accumulation in the Mons Basin started in Early Cretaceous times (Fig. 3.3). 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 kilomter-wide deposits (Marlière, 1946), including the Hautrage Clays Formation and the Baudour Clays Formation or infilling of sinkholes, known as resulting from deep dissolution processes (see Quinif and Licour, Chapter 5 in this book). Successive depocenter migration and erosion account for the unusual location of these oldest sediments, which would be otherwise expected to lie deeply buried in the middle of the basin. In the whole Mons Basin, the Wealden facies is clearly diachronous (Fig. 3.3), 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, 2008). The Baudour Clays Formation and the Hautrage Clays Formation consist of lignitic clays and sands that deposited in fluvial, deltaic, and lacustrine environments (Yans, 2007; Spagna et al., Chapter 9 in this book; Godefroit et al., Chapter 13 in this book).

Eustatic transgressive pulses during the Albian and Cenomanian left mixed siliciclastic–carbonate formations known as *meule* that again are found mainly in the north of the basin but that extend deeper and farther southward than the Wealden formations. Maximum flooding of the basin was initiated with the Turonian transgression, during which marls (or

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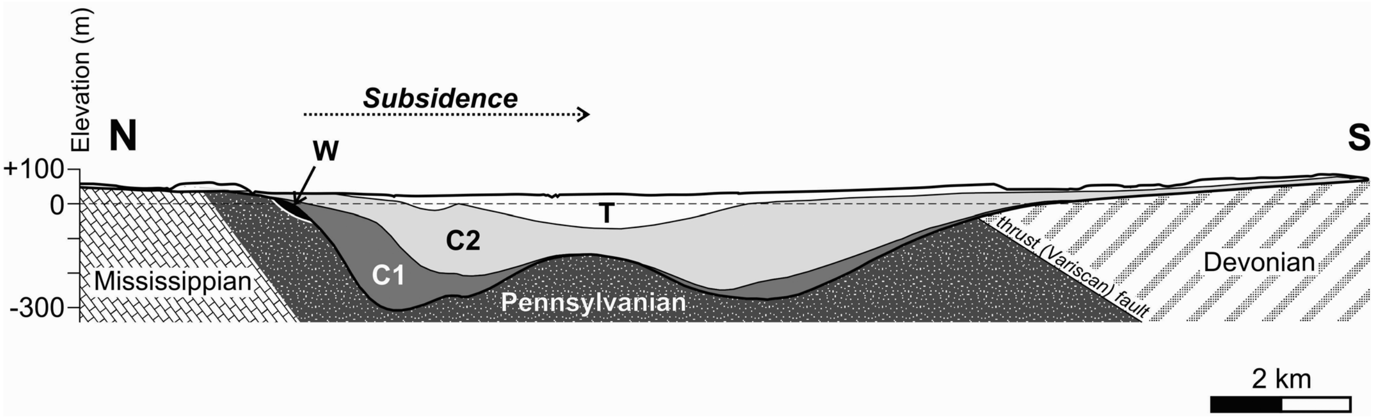

3.2. Geological cross section of the Mons basin in the Bernissart area. The arrow shows the direction of depocenter migration in the northern part of the basin since the Barremian. *Abbreviations:* W, Barremian (Wealden); C1, Albian–Cenomanian; C2, Turonian–Campanian; T, Tertiary and Quaternary.

dièves) were deposited. After a short fall in the sea level, an important transgressive phase began, 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 Maastrichtian 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 1970s (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 in this book). Progressive dissolution of deep (>1,500 m) evaporite in underlying Mississippian 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; Vandycke and Spagna, Chapter 6 in this book). As a result of intrastratal karstification, collapse structures developed at different scales depending on factors that are not yet well understood. The highly irregular surface contact between the Paleozoic 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 1,000 m in vertical extension (see Quinif and Licour, Chapter 5 in this book). The term *sinkhole* will be used in the following, although it is usually restricted to collapse structures 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. 3.5). Mining

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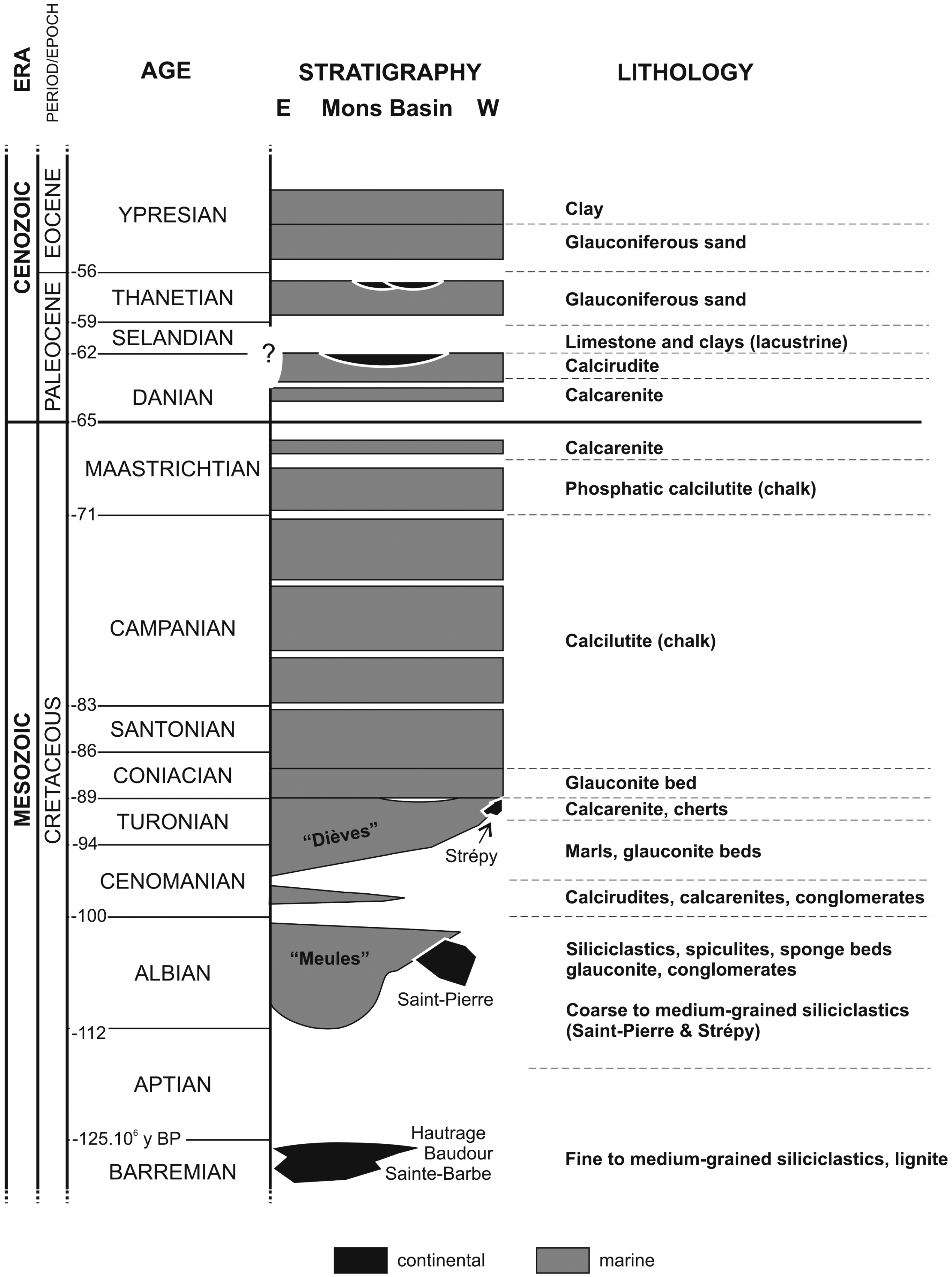

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records have reported a large number of these sinkholes in the Mons area (Delmer and Van Wichelen, 1980). They are often found concentrated within larger-scale subsiding regions (Bernissart area, for example; Fig. 3.4). In these areas, geological formations 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.

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

A Closer Look at Bernissart: The Iguanodon Sinkhole

Three sinkholes were recognized by coal miners in the Bernissart area (Fig. 3.4): the North, the South, and the Iguanodon sinkholes. Wealden facies sediments were recognized in the North Sinkhole (at –160 m) and in the Iguanodon Sinkhole (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 3.5 is a north–south cross section passing through the Iguanodon Sinkhole, adapted from Delmer and Van Wichelen (1980) and including 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 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, although 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 BER 3 borehole drilled in 2003 yielded about 50 m of Lower Cretaceous clay (Sainte-Barbe Formation) out of the Iguanodon Sinkhole (Fig. 3.5). A middle Barremian to earliest Aptian age was obtained by palynologic dating (Yans et al., 2006; Yans et al., Chapter 8 in this book). The environment at Bernissart was formerly interpreted as lacustrine on the basis of grain size and varvelike laminar stratification (Van Den Broeck, 1898). This was confirmed by recent studies (Yans, 2007; Schnyder et al., 2009; Spagna, 2010; Spagna et al., Chapter 9 in this book).

Conclusions and Further Developments

The Bernissart iguanodons were discovered in a unique and particularly complex geological context. In this chapter, we have only presented basic information about the geology of the Mons Basin and of the Iguanodon Sinkhole. Further aspects of the geology and paleontology of the Mons Basin and of the Wealden facies at and around Bernissart will be developed in the following chapters in this book:

- Information about the geometry of the Iguanodon Sinkhole and its integration in a 3D model of the top surface of the Paleozoic basement of the Mons Basin are presented in Chapter 4.

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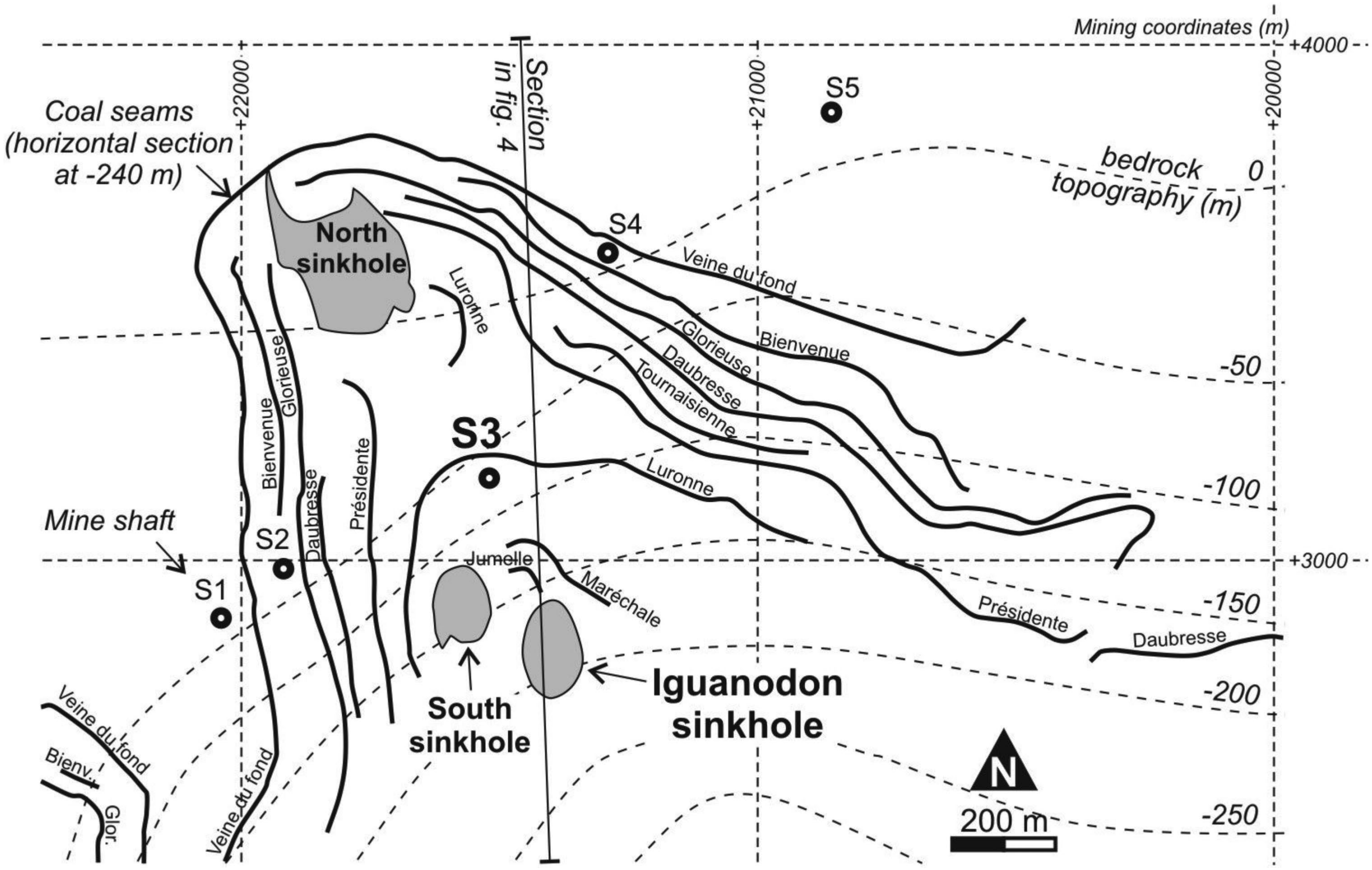

3.4. Plan view of the horizontal section at –240 m in the Bernissart area showing the relation between the sinkhole distribution and the larger-scale subsiding zone revealed by the coal seam deformation pattern (modified from Delmer, 2000). *Abbreviations:* S1, Négresse pit; S2, Moulin pit; S3, Sainte-Barbe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

- In Chapter 5, the sinkholes in the Mons Basin are considered from a karstologic point of view, and their genesis and evolution are discussed.
- The interactions between tectonic and karstic processes that contributed to the trapping and the conservation of the Wealden fossil-rich deposits on the northern part of the Mons Basin are described in Chapter 6.
- Chapter 7 focuses on the stratigraphy of the Cretaceous sediments overlying the dinosaur-bearing Wealden facies cut by the BER 3 borehole in the Bernissart Sinkhole.
- The age of the *Iguanodon*-bearing Wealden facies at Bernissart is refined in Chapter 8 according to recent works based on palynology and chemostratigraphy.
- In Chapter 9, Wealden facies at Bernissart and Hautrage are investigated following different sedimentological parameters, including lithofacies evolutions, mineralogical and granulometric data, and organic matter properties. A schematic east–west paleovalley map of the Mons Basin, integrating all the new paleoenvironmental results, is proposed.
- Mesofossil plant remains, sampled from the Hautrage Clays Formation and described in Chapter 10, provide important data for the reconstruction of the paleoenvironment of the Mons Basin during the Early Cretaceous.

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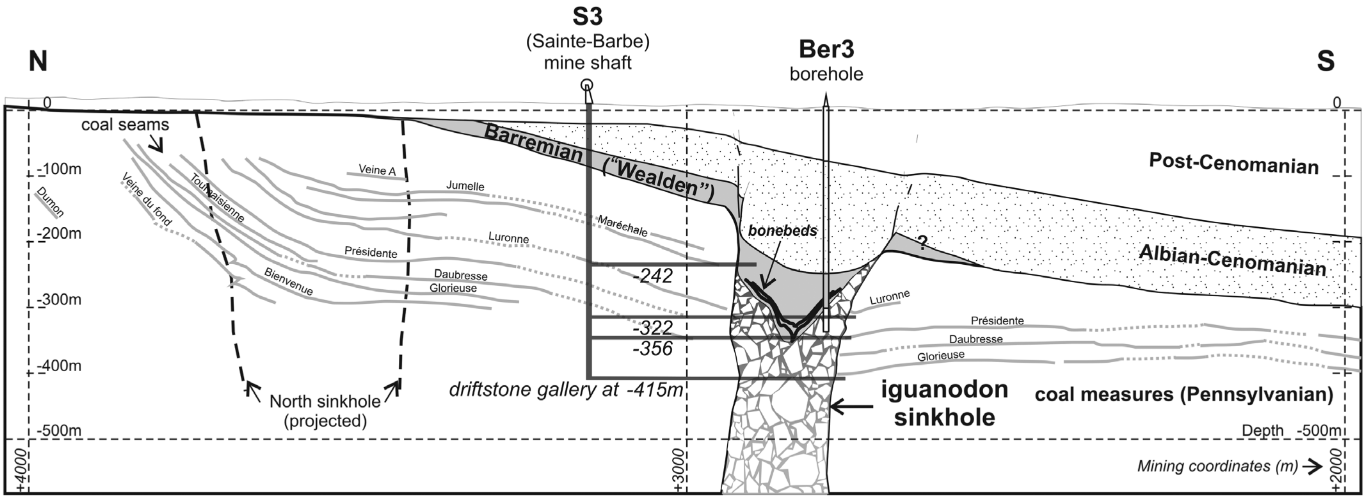

3.5. Cross section of the Bernissart area showing the geological setting of the Iguanodon Sinkhole (adapted from Delmer and Van Wichelen, 1980). In this hypothesis, downwarping of the bonebed at −322 m would explain the fossils that were found at −356 m. Therefore, the bonebeds in both galleries would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

- The bone diagenesis (postmortem modification of their chemical composition after their burial) of the *Iguanodon* skeletons discovered at Bernissart between 1878 and 1881 are investigated in Chapter 11.
- The bone fragments discovered at the occasion of the coring of the BER 3 borehole, drilled in 2003, are described and tentatively identified in Chapter 12. Comparison between "fresh" (from the borehole) and "old" (kept in the museum for more than 130 years under ordinary conditions) *Iguanodon* bones allowed researchers to check at the tissue level the degradation process experienced by pyritized bones.
- The rare dinosaur bones discovered in Wealden formations of the Mons Basin, outside the Iguanodon Sinkhole, are described in Chapter 13.
- As a synthesis, an integrated geological model is proposed in Chapter 14 to explain the exceptional mass accumulation of articulated skeletons in the Iguanodon Sinkhole. This model is then used as a framework for discussing different taphonomic scenarios. The role of site-specific geological factors, such as subsidence due to solution collapse deep underground and possible upwelling of sulfate-rich brines, is emphasized.

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