**NETWORK PROJECT 'COLDCASE: RE-OPENING OF THE BERNISSART IGUANODON CRIME SCENE**

**Summary of the final report**

**Context:**

From 1878 until 1881, an exceptional series (37-38 specimens) of sub-complete and articulated skeletons of iguanodontid dinosaurs were unearthed from a single Lower Cretaceous locality at Bernissart (Belgium), revealing for the first time the anatomy of dinosaurs; following this discovery, considerable advances were made possible about the biology of these fantastic animals. **T**he Bernissart Iguanodons constitute a unique fossil assemblage of worldwide reputation that represents an integral part of the Belgian cultural and scientific heritage. However, the causes of the mass-accumulation of fully-articulated iguanodon skeletons and other vertebrates in the Iguanodon Sinkhole 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.

**Objectives:**

The aim of the Coldcase project is to shed light on the processes that led to this unique accumulation of dinosaur bones some 125 million years ago and to propose an integrated formation-model for the *Iguanodon*-rich deposit of Bernissart. A series of taphonomic elements ('indices'), collected from different sources (fossils, iconographic documents, drilling and core data), are investigated to reconstruct the circumstances of the Bernissart Iguanodon demise:

- **The analysis of the 'crime scene'**, including the distribution of the skeletons within the sinkhole and an analysis of the Bernissart palaeoenvironment.
- **The forensic analysis of the victims**, including a better knowledge of the Iguanodontia family, an assessement of the intraspecific variability, of the age profile, and of the health of the Bernissart Iguanodon population, and a better consideration of the collateral victims.
- **Cross-checking the witness testimonies,** to detect any changes in the lacustrine palaeoenvironments, input of clastic material by short flood events, presence of soot, redox conditions, etc. that could be related to either proposed death-scenario for the Bernissart palaeofauna. It also aims at clarifying a number of palaeoenvironmental aspects, in particular the relationships between the formation of the so-called Bernissart Palaeolake, the accumulation of iguanodontids along with other taxa and the deep sinkhole beneath.

**Methodologies:**

In the Coldcase project, we planned to use non-invasive advanced technologies to produce an integrated formation-model for the world-class iguanodon deposit of Bernissart:

- **Computed 3D mapping** of the 1878-1881 excavation plans and drawings to replace each individual skeleton in its precise environmental and stratigraphic framework, in order to check whether the skeleton concentration results from cyclic catastrophic events, as suggested by previous studies, or from attrition processes.

- **Core logger** at large scale and **microXRF** at higher resolution for key intervals on the core drilled through the Bernissart Wealden deposits, for assessing palaeoenvironmental changes through sedimentology, composition of the sediment and evolution of the type and concentrations in organic matter.

- **Palaeohistological, molecular palaeontology, and biogeochemical studies** of the *Iguanodon* bones and teeth will be important for reconstructing the age structure, palaeoenvironments, dietary adaptations, and interactions with the environment of the *Iguanodon* population at Bernissart.

**Main results:**

- The Iguanodon Sinkhole is not purely cylindrical but button-hole shaped and it is clearly widening upward. Intense deformation of the geological strata kilometers around the sinkhole shows that in fact all the area was subjected to intense collapse. The existence of open fractures and faults may have created a communication between the surface and the deep geothermal, sulphate-rich reservoir.
- The Bernissart palaeoflora can be subdivided into four assemblages: algae" in the water column of the lake; a vegetation composed of *Weichselia* and *Phlebopteris* closest to the lake margin; *Hausmannia*, *Onychiopsis* and the other ferns further away from the margin; and Matoniaceae indet., conifers and aff. *Taeniopteris* even further away from the depositional site. In general, the plant assemblage at Bernissart consists of an open vegetation, which probably belonged to an early successional stage that was burnt frequently by wildfires.
- Our study confirms the presence of two taxa in the Bernissart Iguanodon assemblage: *Iguanodon bernissartensis*, represented by at least 33 individuals, and *Mantellisaurus atherfieldensis*, represented by two or three individuals. Our phylogenetic analysis suggests that those species are sister-taxa, forming the family Iguanodontidae at the base of the clade Iguanodontoidea.
- Individual variation in the postcranial skeleton of *Iguanodon bernissartensis* is more important than previously stated. No direct evidence of sexual dimorphism has been found in the postcranial skeleton of *I. bernissartensis*, even though some characters have a bimodal distribution.
- Palaeohistological analyses reveal the presence of mature bone tissues in all Bernissart Iguanodon individuals. However, most of them were still actively growing upon their death. Both *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 *M. atherfieldensis*, justifying their taxonomic distinction and considerable size differences. No juveniles are known in the Bernissart Iguanodon fossil population. It means that they died in the prime of their lives, which is not compatible with an attritional mortality scenario.

- Most Bernissart Iguanodons were apparently in good physical condition when they died. The total number of palaeopathologies in the Bernissart Iguanodon population is lower than in other ornithopod populations studied so far.
- The reduced taxic diversity for the abundant actinopterygian fish fauna found at Bernissart confirms the lacustrine to swampy environment for the Bernissart 'Lake'.
- During the Early Cretaceous, the Iguanodon sinkhole growth processes first created a small but steep-walled basin, which gradually evolved into a wider lake basin by successive sliding and stepping back of the margins. The formation of the Bernissart deposit may have been much shorter than previously thought. A close analogue in dimension, including the depth of the initial deep-seated collapse that caused subsidence exists in Louisiana (Bayou Corne sinkhole), and it took less than 10 years for the lake basin to reach maturity.

**General conclusions:**

Our study in the frame of the Coldcase Project shows that sinkhole formation processes may have played an active role in the trapping of Iguanodon herds along with other taxa. The lower half clay section, which is fossiliferous, exhibits a clay texture which is more disorientated than the nonfossiliferous 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.

**Keywords:** Bernissart Iguanodons, dinosaurs, Lower Cretaceous, taphonomy, mass-deaths.