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# Study of a Sauropod Dinosaur Vertebra Found in the Kimmeridgian of Cricquebœuf (Normandy, France)

157-152 miljoner år gamla sauropodfossil från  
Cricquebœuf (Normandie, Frankrike)

Charlotte André

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The work for this thesis was carried in cooperation with Paléospace Museum

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# Abstract

## Study of a Sauropod Dinosaur Vertebra Found in the Kimmeridgian of Cricquebœuf (Normandy, France).

Charlotte André

In 1999 a Kimmeridgian age vertebra of a sauropod dinosaur was discovered directly in a layer of clays from Cricquebœuf in Normandy, France. The vertebra is now located at the Paleospace museum and was part of an inventory in 2015 as well as the subject of this Master thesis. Two shells of the oyster *Deltoideum delta* typical of the upper Jurassic, sits on the vertebra making it easy to identify the original stratigraphic position of the vertebra. The origin of the vertebra, found *in situ* in a bed of clays, and the presence of these oysters assure that the vertebra belongs to the Kimmeridgian (between  $157,3 \pm 1$  and  $152,1 \pm 0.9$  millions of years). No reworking is possible in this environment of low energy and with a such weight (2,430 kg). The position of the vertebra in the skeleton of a sauropoda has been ascertained in this study. It belongs to the caudal part of the skeleton, but the position in the tail was more difficult to find. Fortunately, with some literary review, the vertebra is identified as a middle caudal vertebra essentially based on its dimension and based on the presence of the articulation facets for a typical bone in the tail, the chevron. The goal of this study was also to find a clade of dinosaur to which we can link this vertebra. Based on its morphology, the base of the neural arch is located on the anterior two thirds of the centrum; this is a particularity of the Titanosauriform dinosaurs. After reviewing the sauropod fauna present during the Kimmeridgian in Europe, the two titanosauriforms to which this vertebra can be referred are *Europasaurus holgeri* from Germany and *Lusotitan atalaiensis* from Portugal. Arguments are established to compare with these two taxa. Cricquebœuf's vertebra seems to have some morphological characteristics of *Lusotitan atalaiensis*. It should be considered that the comparisons could have been done with closest fauna like sauropods of England but unfortunately, they stay very poorly known. The paleogeography of the Kimmeridgian indicates that France was composed of few European islands and lithology confirms that Cricquebœuf was located underwater (200 m maximum). Finding a sauropod vertebra in marine sediments indicates drifting after death and taphonomy is also discussed in this article. The vertebra may have come to the Armorican massif (western France) because it is the closest island to Normandy in the Kimmeridgian. Because European and Norman sauropods are not well known, and a lot of fossils are in private collection without no description, only future discoveries and studies may allow us to confirm or reject this hypothesis that the vertebra of Cricquebœuf could be a vertebra of *Lusotitan atalaiensis*. In the future it will be necessary to clarify the faunal relations between the different European islands of the Kimmeridgian.

**Keywords:** Sauropoda, Dinosaurs, Vertebra, Kimmeridgian, Normandy, France

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# Populärvetenskaplig sammanfattning

## 157-152 miljoner år gamla sauropodfossil från Cricquebœuf (Normandie, Frankrike)

Charlotte André

Under andra världskriget förstördes många paleontologiska samlingar och mycket få lämningar av sauropoder, stora växtätande, fyrfota dinosaurier från juratiden (för ungefär 208 till 146 miljoner år sedan), har bevarats i Frankrike. Ett fynd från Normandie, Frankrike av en trolig fossil ryggradsdel, donerat till Paleospace museum av fru och herr Hurtrelle, verkar vara det enda exemplaret av en sauropod som finns bevarad i offentliga samlingar.

Målet med denna studie är att uppskatta ålder på den fossila skelettdelen, bestämma dess position i dinosauriens kropp, undersöka vilken gren av familjen Dinosauria som den tillhör och slutligen försöka bestämma dess möjliga geografiska levnadsplats.

Kotan är täckt av två typiska ostron, *Deltoideum delta*, från den övre juratiden. Tack vare detta var det lätt att bestämma dess ursprungliga stratigrafiska läge. Ostronen visar att fossillet tillhör Kimmeridgian (mellan  $157,3 \pm 1$  och  $152,1 \pm 0,9$  miljoner år). Denna studie visar att fossillet ursprungligen är en del av svansen av en sauropod. Dess exakta placering inom svansen var svårare att bestämma men jämförande litteraturstudier visar att kotan förmodligen tillhör mittregionen av svansen. Detta baseras i huvudsak på kotans dimensioner och förekomsten av specifika morfologiska element som är typiska för ben på svansens undersida. En ryggkota består av ett centrum, neuralbågen och de artikulära ytorna för chevronbenet. Baserat på dess morfologi ligger basen av neuralbågen på de främre två tredjedelarna av centrumdelen. Detta är en särprägel hos Titanosaurier. Granskning av den sauropoda faunan under Kimmeridgian i Europa visar att dessa karaktäristiska drag hos ryggkotan indikerar att den kommer från titanosauriformen *Lusotitan atalaiensis* från Portugal.

Den paleogeografiska rekonstruktionen under Kimmeridgian visar att fyndplatsen låg under vatten och Frankrike bestod av ett fåtal öar. I dagsläget vet vi väldigt lite vad gäller fördelningen av fauna mellan dessa olika öar, mycket på grund av avsaknaden av fossil till följd av förstörelsen under andra världskriget. Vi kan inte vara helt säkra på att kotan som studeras här kommer från *Lusotitan atalaiensis* men vi kan inte utesluta att det kunde ha levt på Armorican massivet, ön närmast fyndplatsen under Kimmeridgian. Dock kan olika migrationsvägar vara möjliga. Möjligen kan sauropoder ha vandrat eller simmat över de laguner som separerat öarna. Att hitta ett sauropodfossil i marina sediment indikerar transport efter djurets död. Denna tafonomi (processer som förekommer mellan död och fossilisering av en organism) har också diskuterats i denna artikel. Fynd av sauropoder från Europa är få, men speciellt avsaknaden av fossil från Normandie gör att forskningen fortfarande är i startgroparna. Endast framtida upptäckter och studier gör det möjligt för oss att bekräfta eller förkasta att den beskrivna fossila kotan från Cricquebœuf kommer från en *Lusotitan atalaiensis*.

**Nyckelord:** Sauropod, dinosaurie, ryggkota, Kimmeridgian, Normandie, Frankrike

Examensarbete E1 i Geovetenskap, IGV025, 30 hp

Handledare: Eric Buffetaut, Laurent Picot och Sebastian Willman

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# 1. Introduction

Dinosaurs have been well known since the 19<sup>th</sup> century and they still fascinate today because of their gigantic size. The word “Dinosauria” was erected in 1842 by Richard Owen based on two Greek words: “deinos” (fearfully great) and “sauros” (lizard or reptile). Dinosaurs are subsequently referred to as “terrible lizards” but they were neither terrible nor lizards (Brett-Surman *et al.*, 2012).

In France, several dinosaurs have been discovered in the Normandy region, but unfortunately, many French paleontological materials found during the 19<sup>th</sup> century were destroyed during the bombings by the Allied forces of the Second World War. These Norman collections disappeared before being described and illustrated (Buffetaut, 2011).

Since the Second World War new discoveries of dinosaurs in Normandy are limited to a partial skeleton of the stegosaurian *Lexovisaurus* from Callovian, some remains of *Streptospondylus* and *Poekilopleuron* from Kimmeridgian and a partial skeleton of the megalosaurian *Dubreuillosaurus* from Bathonian (Buffetaut, 2011; Allain, 2005) and a partial skeleton of the sauropod *Normanniasaurus* from Albian (Le Loeuff *et al.*, 2013).

Sauropods are the biggest group of dinosaurs having walked on earth (Curry Rogers & Wilson, 2005). They were quadrupedal, herbivorous and present in all continents except Antarctica (Weishampel *et al.*, 2004).

1999 was the first time that a bony element of a sauropod was found *in situ* from the Kimmeridgian of Normandy, more specifically in Cricquebœuf. Because of the limited availability of fossil remains, each new discovery is important even if it is some isolated bones like the vertebra described here.

The Kimmeridgian of Cricquebœuf is well-known for its fossils contents: ammonites (many species such as *Pictonia* including *Pictonia baylei*), nautiloids, some bivalves, gastropods, and elements of various fishes. Some tetrapod remains have also been found, such as sauropterygian bones, dinosaur and ichthyosaur vertebrae, bones and teeth of crocodylians in the upper part of the shelly limestones, as well as some indeterminate bones (Lepage, 2014).

This study of this isolated vertebra proves that sauropods were present in the Normandy region, which was unknown before this discovery, and gives us a better understanding of Normandy dinosaurs.

## 2. Aims

This specimen of a sauropod vertebra is interesting because of the rarity of dinosaurs from the Norman Kimmeridgian. The aim of this project is to estimate the age and stratigraphic position of the vertebra, determine its precise position in the tail, determine which family of Sauropoda it belongs to, and, if possible, which species it belongs to and finally trying to discuss the environmental constraints on the dinosaur to which the vertebra belonged.

## 3. Background

### 3.1. Historical context and review of dinosaurs from Normandy

Normandy is one of the regions of France where remains of dinosaurs have been reported from the beginning of the nineteenth century. Even if the concept of “dinosaur” was not formulated, Georges Cuvier realized that the fossils he studied were different from living crocodiles. Ten years after Cuvier’s death, the definition of Dinosauria was formulated by the British paleontologist Richard Owen in 1842 (Buffetaut, 2011).

New fossil discoveries continued throughout the nineteenth in Norman quarries and cliffs. Many natural history museums were created all over Europe; the one in Rouen was founded in 1828 and, in 1845, an office of natural history was created in Le Havre by Charles-Alexandre Lesueur, a researcher in charge of the collections of the office. He acquired fossils of vertebrates from the Jurassic and Cretaceous by donation of collections, including his own collection.

Buffetaut (1995, 2011) explains that in 1842, Charles-Alexandre Lesueur presented stratigraphic interpretations and illustrations of fossils from each layer of Cap de la Hève. Even though the vertebrae *Streptospondylus* is present in stratigraphic interpretations, there is no explanation as to what animal the vertebrae belong to.

After Lesueur’s death, the office of natural history was headed by Gustave Lennier, a naturalist who specialized in geology and paleontology. In 1870, Gustave Lennier indicated the presence of a *Streptospondylus* in the Kimmeridgian of Le Havre following illustrations of Lesueur (Lennier, 1870). These vertebrae were for a long time confused with vertebrae of crocodylians, but in fact, *Streptospondylus* is a theropod dinosaur described on the basis of some specimens from the Callovian of Vaches Noires cliffs. Gustave Lennier had a limited knowledge of dinosaurs, and among the remains he described, there was a pleurocoels

vertebra (cavities on lateral sides of the vertebra) belonging to a sauropod identified later by American and German paleontologists. Gustave Lennier campaigned for the transfer of Le Havre collections to a better place; in 1881, the Natural History Museum of Le Havre was created comprising ichthyosaurus, plesiosaurus, crocodilians and dinosaurs, even if identifications were uncertain. The museum of Le Havre became one of the biggest natural history museums of France (Buffetaut, 2011).

In the university collection of Caen, Alexandre Bigot worked on crocodilians, ichthyosaurs, pliosaurs, chelonians and fishes. He continued the work of his predecessors, Jacques-Amand and his son Eugène Eudes-Deslongchamps, on invertebrates remains and made some studies of reptils fossils after their death. As a result, the collections of Caen (gathered by Jacques-Amand & Eugène Eudes-Deslongchamps and Alexandre Bigot) acquired a worldwide reputation (Buffetaut, 2011).

The presence of Sauropoda has been known since the visit to the museums in Normandy by the famous Othniel Charles Marsh in 1897, during his travel in Europe. He wrote a short note about his studies of European dinosaurs, especially Norman Sauropoda from the Kimmeridgian, and the remains of *Poekilopleuron* (identical to *Megalosaurus* from Buckland), and some bony elements of *Pleurocoelus* from Caen and bigger remains than *Pleurocoelus* that resembled to *Morosaurus* (*Morosaurus* Marsh is apparently a synonym of *Camarasaurus* Cope) from Le Havre (Marsh, 1897). The fossils did belong to the Kimmeridgian but *Pleurocoelus* is known from the Lower Cretaceous in North America. Alexandre Bigot used deductions from O. C. Marsh in a short note in 1897 (Bigot, 1897); many vertebrae, bony limbs, teeth and pieces of jaws are mentioned but never described or illustrated. Only some casts remain in the Peabody museum in Yale University (USA) (Buffetaut, 2011).

Franz Nopcsa, a baron impassioned by paleontology, visited Le Havre's collection in 1911 and made descriptions of the remains (crocodilians skull and a relatively complete stegosaurian named *Omosaurus lennieri* (Nopcsa, 1911)) from Émile Salvalle, a local researcher and Gustave Lennier (Buffetaut, 2011).

After the First World War, a decline in interest for sciences occurred. The museums and universities kept acquiring new paleontological remains in their collections, but nobody described them. Bigot took care of the collections of Caen, but paleontology of vertebrates was not his favorite subject, so he published only short notes on them (Buffetaut, 1983).

A few years later, Friedrich von Huene, a German paleontologist, described briefly a scapula and a coracoid of a sauropod called *Pelorosaurus* based on a picture by his friend F.

Nopcsa. Obviously, F. Nopcsa took many pictures of Le Havre collections and made a photography inventory. He mentioned sauropods of Le Havre in passing in his article (von Huene, 1927). Only the drawing of the scapulocoracoid from Huene in 1927 subsisted today (Buffetaut, 2011).

Unfortunately, during the Second World War in 1944, all the paleontological collections of the natural history museums and universities at Caen and Le Havre were destroyed by Allied air raids. All of the collections of Jacques-Amand & Eugène Eudes-Deslongchamps, Alexandre Bigot, and Gustave Lennier disappeared before having been fully described and illustrated, as well as scientific libraries that have been burned along with universities, museums, and private properties. Alexandre Bigot talks of “a lost paradise” (Buffetaut, 2011).

Some new collections were established at the end of the World War II with the help of André Maury in Le Havre to buy collections and to make exhibitions based on objects that had not been destroyed. In Caen, the museum was a part of the university and collections were not open to public. After the death of Alexandre Bigot in 1953, a general lack of paleontology professionals encouraged amateurs like Roger Brun to search for fossils themselves. This passionate collector of natural history gathered a big collection that he placed in a building near his farm named “Museum of Natural History of Normandy”. In this collection, remains of dinosaur from the quarry of Fresnes d’Argences of Callovian were exposed after their discoveries in 1955 (Buffetaut, 2011).

The post-war reconstructions encouraged exploitation of quarries and allowed the discovery of fossils, but mechanization made it difficult for quarry workers to discover and extract fossil bones because fossils are easily destroyed in the process. During the last thirty years, beautiful discoveries have been made in Normandy, such as a partial skeleton of the stegosaurian *Lexovisaurus* from the Roger Brun collection, a partial skeleton of Dinosaurian from Triassic of Airel, a skull of ichthyosaur from Albian of Pays de Caux, a snout of crocodylians from Kimmeridgian of Cricquebœuf (Buffetaut, 1983) and a partial skeleton of the megalosaur *Dubreuillosaurus valesdunensis* (Allain, 2005).

The identifications of Gustave Lennier, Othniel Charles Marsh, Alexandre Bigot and Friedrich von Huene seem to be very doubtful. G. Lennier had a limited knowledge of dinosaurs and within the vertebrae that he attributed of *Streptospondylus*, there is a that clearly vertebra belongs to a sauropod *Pleurocoelus*. O. C. Marsh identified *Pleurocoelus* and *Morosaurus* based on Norman remains, but these two species were sauropods from North-America. *Pleurocoelus* was described from lower Cretaceous of United States but fossils seen by O. C. Marsh come from Kimmeridgian of Caen. A. Bigot reused identification of

*Pleurocoelus* by O. C. Marsh without any more research or verification. This is the same problem with the scapulacoracoid from Kimmeridgien described and identified by F. von Huene as *Pelorosaurus* sp. *Pelorosaurus* is a sauropod from lower Cretaceous in England and Portugal but the scapulacoracoid comes from Kimmeridgian of Octeville-sur-mer (Buffetaut, 1983, 2011 and *personal communication*, 2018).

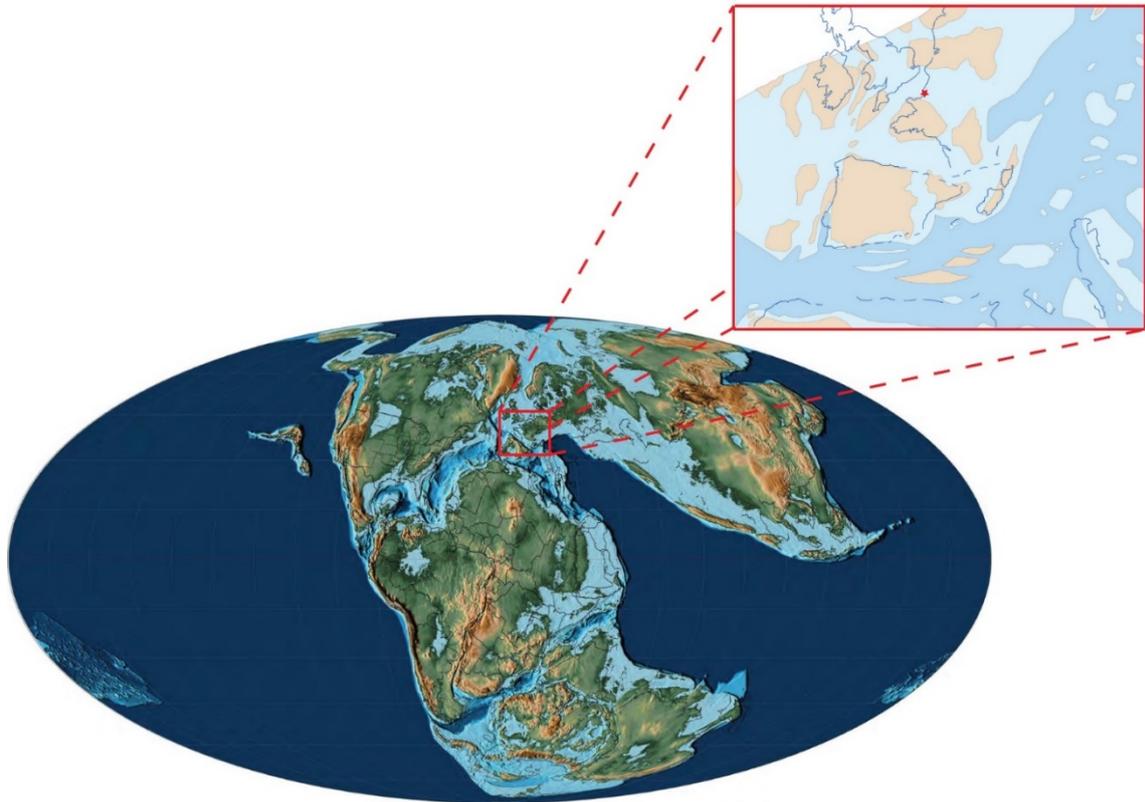
Many Norman dinosaur fossils (a fibula and a tibia, for example) are present in private collections of amateur paleontologists or collectors but have never been described and published. Since the Second World War, no caudal vertebra of sauropod from Jurassic have been discovered. Consequently, the Sauropoda vertebra studied here seems to be the only sauropod specimen from the Kimmeridgian of Normandy preserved in a public collection through the donation of Mrs. and Mr. Hurtrelle to the Paleospace museum.

### **3.2. Paleogeography of the Kimmeridgian**

Dinosaurs appeared at the end of the Triassic and got extinct at the end of the Cretaceous (Klein *et al.*, 2011). The paleogeography at this time was completely different from today.

The splitting of the supercontinent Pangea started in the Late Triassic and continued during the Jurassic, with the separation of three continents (North-America, Eur-Asia and Gondwana) (Moore *et al.*, 1992) and the emergence of the South Atlantic Ocean as a rift (Pomerol, 1975).

In the Jurassic, Western Europe was covered by shallow epicontinental seas surrounding carbonaceous platforms. During the Kimmeridgian, Europe was situated around latitude 30°N and the only islands in France were the Armorican massif, the central massif, the Montagne Noire and the Ardennes massif (Figure 1) (Lefort, 2011). The Armorican massif and the southwestern England were the two major islands near Normandy.



**Figure 1.** Paleomap of world and zoom on Europe during the Kimmeridgian (from Scotese, 2014 for world scale map and from Christ & Romeuf, 2018). Red star: Place where the vertebrae was found. Pink: continental islands, light blue: platform, dark blue: basins. Blue lines: actual coastlines.

### **3.3. Paleoecology of the Kimmeridgian**

The climate of the Kimmeridgian in Europe fluctuated from tropical (Lefort, 2011) and warm conditions, due to intense volcanism and ongoing orogenesis (Pomerol, 1975), to semi-arid conditions similar to a Mediterranean-type seasonal climate. Furthermore, it was dominated by a monsoonal circulation patterns (Noto & Grossman, 2010). Noto and Grossman (2010) also suggest that a semiarid climate probably had the greatest diversity of herbivorous dinosaurs. In fact, a semiarid climate indicates a high ground-cover of plants, so the fauna living there included small, intermediate, and tall herbivorous dinosaurs.

Pteridospermatophyta and gymnosperms are present and abundant on continental islands as in Asia (Pomerol, 1975), a continent with more or less the same climate as Europe (Noto & Grossman, 2010), so the presence of these spores reinforces the idea of a semiarid climate in Europe.

## 4. Materials

The fossil described in this study bears the number 2013.1.196 and is deposited at the Paleospace museum of Villers-sur-Mer in France. It was discovered by Françoise and Jacques Hurtrelle, on January 31<sup>th</sup>, 1999 and has remained undescribed until now. The vertebra was found as is, and no preparation was therefore necessary. First thought to be the remains of a marine reptile, it was later identified as a caudal vertebra of a sauropod (by Eric Buffetaut, unpublished).

The Hurtrelle collection bears the name of its collectors. Françoise and Jacques Hurtrelle prospected regularly between 1998 and 2012 on the small beach of Cricquebœuf at low tide. Their regular excavations allowed them to build a collection of 840 fossils belonging to the Late Jurassic and Cretaceous (Couture, 2015) including invertebrate fossils but also some rare vertebrate fossils such as sauropterygian bones, dinosaur and ichthyosaur vertebrae, bones and teeth of crocodylians, elements of various fishes, and indeterminate bones (Lepage, 2014). The Hurtrelle family wished to preserve the collection in order for it to be studied. As the Paleospace museum received the label “Musée de France” in 2015 “, the Hurtrelle collection was donated to it in 2015 (Couture, 2015).

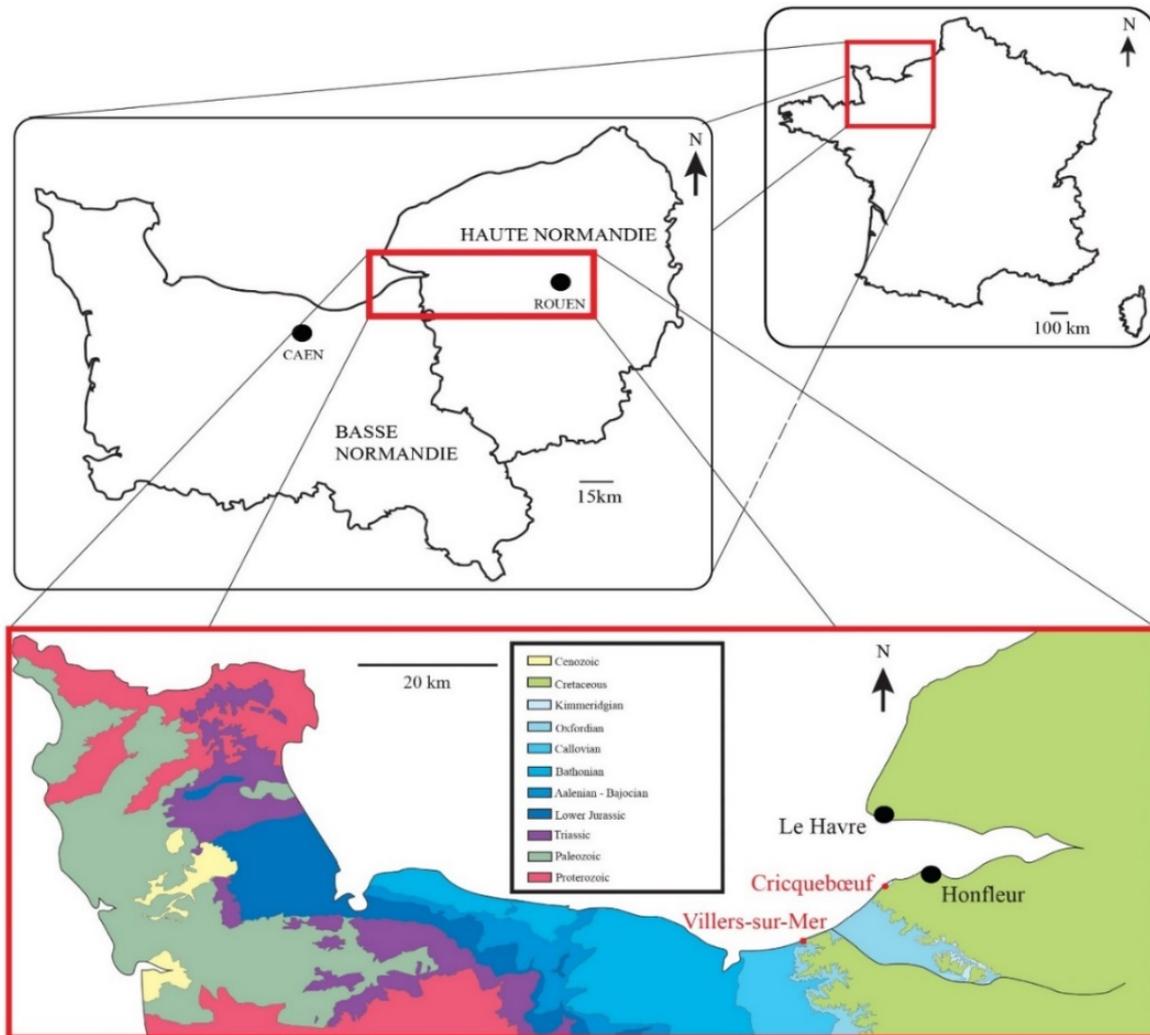
## 5. Geological settings

The vertebra from the Hurtrelle collection was found at the base of the *Deltoideum delta* clay (formerly called *Liostrea delta* (Samson *et al.*, 1996)), just above the shelly limestone (Kimmeridgian) directly in the outcrops on the beach of Cricquebœuf in Normandy, France (Yves Lepage, *personal communication*, 2018) (Figure 2).

The Kimmeridgian, which is the last stage of the Jurassic period, crops out poorly in the Basse Normandie region. The Kimmeridgian is visible on both sides of the Seine estuary. On the North side, it appears as scattered exposures (Gallois, 2005a) and is present under the irregular cliffs (around 8-10 m) from Cap de la Hève to Cauville via Octeville-sur-Mer. On the South side of the estuary, the Kimmeridgian crops out only in the small towns of Villerville and Cricquebœuf.

On the beach of Cricquebœuf, these outcrops belonging to the Oxfordian and Kimmeridgian stages are on the foreshore. They have been covered by a solifluction process and affected by perturbations of landslides relating to limestones beds (Lepage, 2014).

Locally, a shifting of the sand allows a better exposure. Stratigraphic studies of the area of Cricquebœuf by Guyader and Hurtrelle (Yves Lepage, *personal communication*, 2018) have resulted in the description of a stratigraphic section of Cricquebœuf (Figure 3).



**Figure 2.** Location of Normandy (France) and simplified geological map of Normandy. Red dot: Place where the vertebrae was found (Cricquebœuf). Red square: Location of Paleospace museum (Villers-sur-Mer).

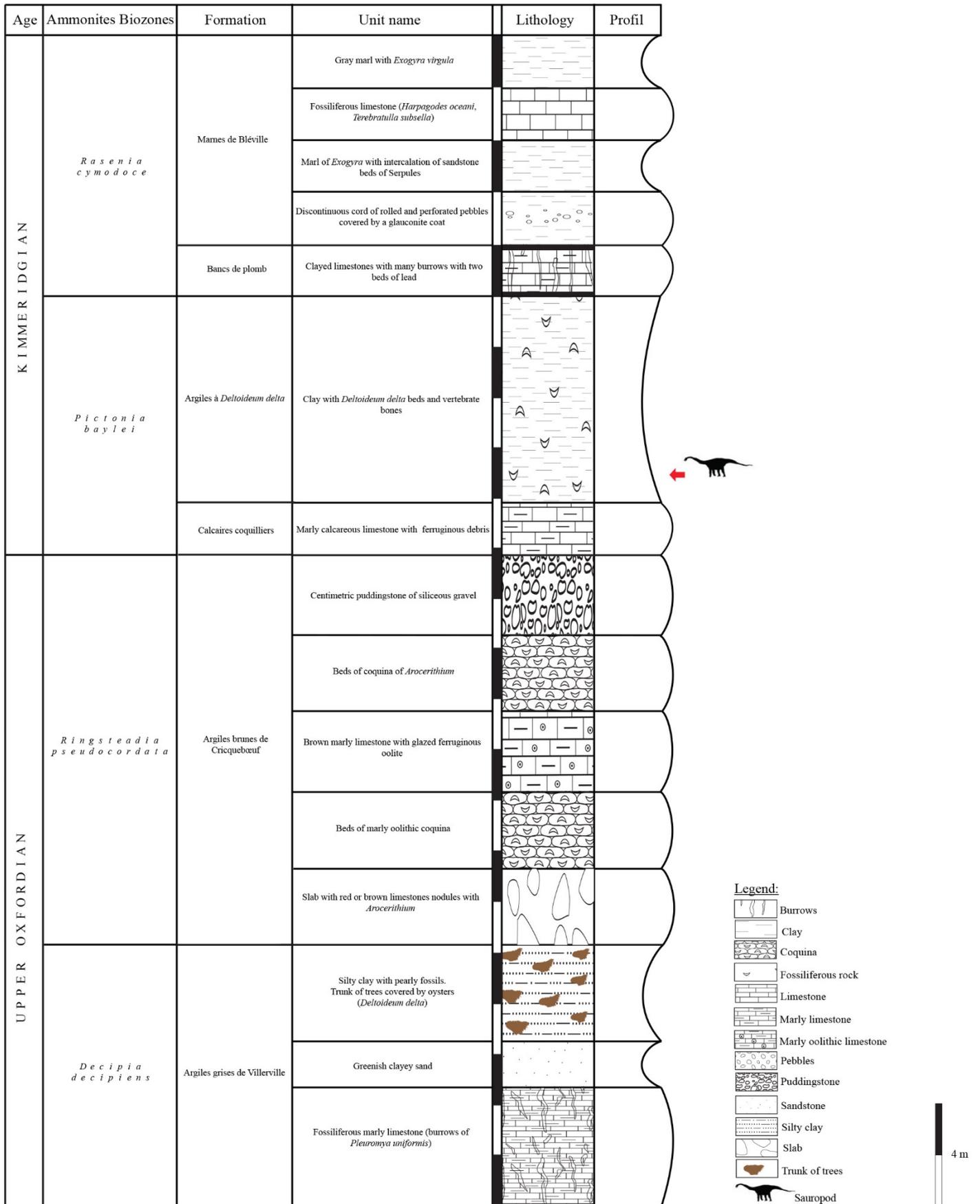
The boundary between the Kimmeridgian and the Oxfordian is located between the base of *Pictonia*-rich limestones and the top of *Ringsteadia frequens*-rich centimetric puddingstone with siliceous gravel (on the beach of Cricquebœuf) (Figure 3). On the ground, the boundary is characterized by scraps of shelly limestone of ferruginous grains. Some “beds of lead” as the name suggests, contain lead and punctuate the base of the Kimmeridgian (Figure 3). The Kimmeridgian succession consists of alternating clays, limestones and marls. The Kimmeridgian clay is composed mainly of illite, along with some chlorite and some kaolinite. The bottom part consists of a layer of limestones with ferruginous grains and with ammonites

whose test is still intact. The upper zones can be identified because of the presence of abundant *Exogyra* oysters in the poor clayey outcrops of the slopes (Guyader *et al.*, 1970).

Although it can be difficult to assess the thickness of each layer as they have been dilated by many landslides, Bourgeois (1997) and Dugué *et al.* (1998) estimated that the thickness should be around 20 meters for the Kimmeridgian and around 25 meters for the upper Oxfordian.

The Kimmeridgian is the last stages of the Jurassic that crops out in this area. It is followed by a gap: the Portlandian (Tithonian) and a large part of the lower Cretaceous are missing due to a long period of post-Jurassic emersion followed by continental erosion (Aubry & Gigot, 2017). It is not represented on the section because no layers of Tithonian or Lower Cretaceous crops out in Cricquebœuf. The Kimmeridgian sedimentation illustrates a connection between tectonism and eustasy and especially the big regression at the end of the Jurassic (Gallois, 2005b).

The subject of this study, the vertebra of a sauropod, was collected on the beach of Cricquebœuf and more precisely in the *Pictonia baylei* zone. This zone consists of a marly limestone with ferruginous debris called “Calcaires coquilliers” and a bed of clay with some bones and an abundance of *Deltoideum delta*, giving its name to the bed “Argiles à *Deltoideum delta*” (Guyader *et al.*, 1970). This bed includes two bands of coquina of *Deltoideum delta* (one at the top and one at the bottom). Clays can be more or less pyritic and consist of illite and kaolinite. At the bottom of this bed, water-worn vertebrate bones are common. Pyritic internal molds of gastropods and bivalves are known in the whole bed. In the upper part, some rolled lime-green grains of glauconite can be observed. These clays were deposited in low energy conditions, certainly on the protected seafloor of the shallow water. The sediments were rich in organic matter and the endofauna was prolific, which favored the formation of pyrite and the dissolution of calcareous tests (Mégnyen, 1980).



**Figure 3.** Stratigraphic section of Oxfordian and Kimmeridgian recording in Villerville, modified from Guyader, 1968 with Jacques Hurtrelle and Yves Lepage (personal communication).

## 6. Systematic paleontology

Reptilia Linné, 1758

Dinosauria Owen, 1842

Saurischia Seeley, 1888

Sauropodomorpha von Huene, 1932

Sauropoda Marsh, 1878

Eusauropoda Upchurch, 1995

Neosauropoda Bonaparte, 1986

Macronaria Wilson & Sereno, 1998

Titanosauriforms Salgado, Coria & Calvo, 1997

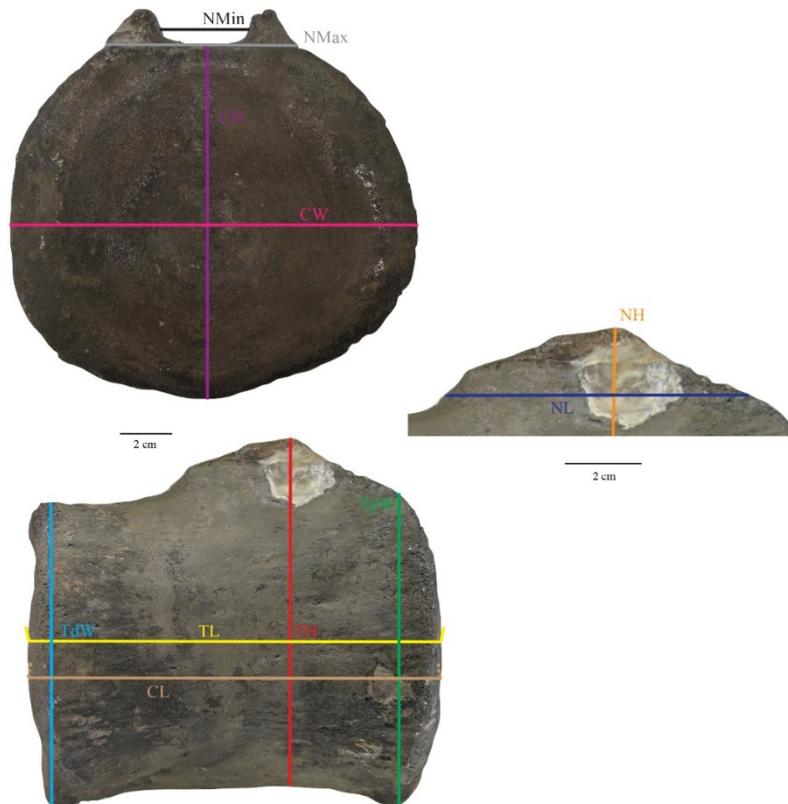
## 7. Description

All the anatomical words used in this report follow the nomenclature of Wilson, 1999, revised by Wilson *et al.*, 2011. The preservation of the vertebra is relatively good, except for the proximal and distal borders that seem to be slightly eroded. Unfortunately, the neural arch is missing; only its base is present.

The vertebra was previously identified as a marine reptile by Yves Lepage. During the 11<sup>th</sup> Annual Meeting of EAVP (European Association of Vertebrate Paleontologists) in Villers-sur-Mer, it was displayed alongside other bones of marine reptiles and there it was recognized as belonging to a sauropod dinosaur (Couture, 2015) due to its robust spool-shape (Eric Buffetaut, *personal communication*, 2018). The fossil called 2013.1.196 is a distinctive caudal vertebra with circular proximal and distal articular faces and an elongate-spool-shaped centrum (Figure 5). The preserved base of the neural arch is located closer to the proximal border. The centrum is amphicœlous, with concave anterior (14 mm) and posterior (10 mm) articular faces, and slightly longer than broad. The ventral surface of the vertebra is mostly flat but becomes slightly transversely concave at the anterior and posterior ends, between the articular eminences for the chevron. Chevron facets are weakly present on the posterior margin of the ventral surface of the centrum, but not on the anterior margin. The average Elongation Index (aEI = anteroposterior length of the centrum divided by the average height and width of the posterior articular surface) is 0.93.

Table 1. Measurements (in mm) of 2013.1.196

Measurements		Vertebra 2013.1.196
Total	Height (with neural arch) (TH)	121
	Proximal width (TpW)	117
	Distal width (TdW)	115
	Length (without cotyles) (TL)	126
Centrum	Height (CH)	102
	Width (CW)	117
	Length (with cotyles) (CL)	102
Neural arch	Height (at the proximal border) (NH)	19
	Length (NL)	54
	Minimal width (inside) (NMin)	28
	Maximal width (outside; at the base of the neural arch) (Nmax)	60
Weight (in kg)		2.430



**Figure 4.** Figure showing measurements. At the top: proximal view. At the bottom: left lateral view. At the right: zoom on the neural arch. Abbreviations in Table 1. Scale bar: 2cm.



**Figure 5.** Caudal vertebra of sauropod dinosaur (2013.1.196). Pictures on the left and computer drawings on the right. From top to bottom: dorsal, right lateral, proximal and ventral views. Hatches represent the eroded parts. Scale bar: 2 cm

## 8. Review of dinosaurs from England

Remains of English sauropods have been known since the 19<sup>th</sup> century and many of them are considered as *nomina dubia* due to the lack of better complete skeletons. All British sauropods belong to Eusauropoda, except *Camelotia borealis* (considered as a melanorosaurid) (Martill & Naish, 2007).

The first named sauropod is *Cetiosaurus*, studied by Owen (1841), but it was confused with a crocodylian. *Cetiosaurus* is considered as “bin” taxon for a large quantity of sauropod remains from around the world (Upchurch & Martin, 2003). 13 species of Jurassic and Cretaceous were recently linked to this genus. The probable type species *Cetiosaurus oxoniensis*, 7 species are *nomina nuda* or *nomina dubia*, 3 species are valid taxa and different to the type species (*Cetiosaurus glymptonensis*, *Cetiosaurus humerocristatus* and *Cetiosaurus brevis*) and 2 remains are isolated bones identified as Eusauropoda indet (the remain named *Cetiosaurus* by Reynolds and a tooth of *Cardiodon rugulosus* by Owen) (Martill & Naish, 2007). If all of these remains belong truly to *Cetiosaurus*, the range of this genus would extend from the Bajocian to the Barremian; but, in reality, most of these remains are fragmentary and indeterminate (Upchurch & Martin, 2003). Nowadays, *Cetiosaurus* is known from UK in Oxfordshire, Buckinghamshire, Northamptonshire, Rutland, Gloucestershire, Yorkshire, the Isle of Wight, Skye, and Morocco (Upchurch & Martin, 2003).

The probable type species *Cetiosaurus oxoniensis* comes from the Bajocian– Bathonian and is based on remains from Oxfordshire, Northamptonshire and Buckinghamshire included Owen's original type material of *Cetiosaurus medius*. It is based on several remains: 11 caudal centra, sacral ribs and a metatarsal, a metacarpal, an ungual and part of a dorsal centrum (Upchurch & Martin, 2003). In 1968, the discovery of remains that were ascribed to *Cetiosaurus* from the Bajocian of Rutland allowed for a better understanding of this sauropod, even if the Rutland cetiosaur is referred to as *Cetiosaurus oxoniensis*. In the Bathonian of Oxford, an isolated braincase has also been related to *Cetiosaurus* (Martill & Naish, 2007).

Another species found in Oxfordshire is *Cetiosaurus glymptonensis* based on nine caudal vertebrae. It belongs to the Bathonian and is considered the oldest diplodocid (clade within Diplodocoidea including *Diplodocus* and *Apatosaurus*) according to the proportional elongate size of the vertebrae and the presence of lateral ridges on the centrum (Martill & Naish, 2007).

“*Cetiosaurus*” *humerocristatus* is known by a partial left humerus, a phalanx and some parts of the right pubis, but the identification of this species seems doubtful because

“*Cetiosaurus*” *humero cristatus* was only defined on a gracile humerus based on its degree of elongation (1500 mm when complete) and the distal prolongation of its deltopectoral crest (Hulke, 1874; Lydekker, 1888; Martill & Naish, 2007).

Another bone (a left humerus) was found in 1868, from the Kimmeridge Clay by John Clavell Mansel-Pleydell, a Dorset antiquary with an interest in geology, botany and ornithology. This bony element was described by Hulke in 1869 and Lydekker, 1888 as *Ornithopsis manseli* (West, 2017). For the moment, *Ornithopsis manseli* is only known by its left humerus; so, it is considered as a *nomen dubium*. If this left humerus had been more complete, it could have been possible to link *Ornithopsis manseli* to “*Cetiosaurus*” *humero cristatus* because it appears to have been similar to “*Cetiosaurus*” *humero cristatus* (Martill & Naish, 2007). Both seem to represent the first Brachiosauridae in Europe (Martill *et al.*, 2006)

In the Callovian of Peterborough, “*Ornithopsis*” *leedsii*, a vertebrae, rib, and pelvic fragments of a sauropod discovered in 1887 are referred to as Brachiosauridae (Upchurch & Martin, 2003).

A second specimen (dorsal, sacral and caudal vertebrae, a scapulocoracoid and forelimb, a partial ilium, a left hindlimb, and chevrons) was also found in Peterborough and from the Oxford Clay Formation and referred to as “*Ornithopsis*” *leedsii*, (*Cetiosauriscus* von Huene, 1927), but it was incorrect (Martill & Naish, 2007). This second specimen was renamed *Cetiosauriscus stewarti* by Charig in 1980. A distal tail segment referred to *Cetiosauriscus stewarti* cannot be associated with the taxon, and some authors (Rauhut *et al.*, 2005) place it as part of a clade between two Middle or Upper Jurassic Chinese taxa (*Mamenchisaurus* and *Omeisaurus*) (Martill & Naish, 2007).

Some remains discovered in 1868, on the shores of Portland Harbour, were studied by Robert Damon, a famous geologist who tried to gather natural history specimens in Weymouth in 1884. Robert Damon identified these remains as *Gigantosaurus megalonyx* (West, 2017). Later, a few paleontologists re-described these remains and attributed them to the genus *Ornithopsis*, a Brachosauridae (Delair, 1959). It is also called *Ornithopsis humero cristatus* or *Pelorosaurus humero cristatus* (Martill *et al.* 2006), but, in fact, it cannot be identified beyond Sauropoda (Martill & Naish, 2007).

Caudal vertebrae of “*Cetiosaurus*” *brevis* found in Wealden (Barremian) were close to the remains (humerus) of *Pelorosaurus conybeari*. This humerus was firstly identified as “*Cetiosaurus*” *conybeari*, but *Pelorosaurus conybeari* differs from “*Cetiosaurus*” *brevis* by a less prominent deltopectoral crest (Martill & Naish, 2007).

Other robust bony elements (humerus, radius and ulna, and associated skin impressions) refer to *Pelorosaurus*, “*Pelorosaurus becklesii*” from Wealden and indicate that it belongs to a titanosaur (Martill & Naish, 2007).

Three sauropods present on the Isle of Wight (*Oplosaurus armatus*, “*Pleurocoelus*” *valdensis* and *Rebbachisauridae indet.*) had been identified based on tooth morphologies (Martill & Naish, 2007).

Many English remains are *nomen dubium*. This is the case of the several dorsal and sacral vertebrae of *Bothriospondylus suffossus* from the Kimmeridge Clay of Wiltshire. These remains are identified beyond Neosauropoda (Martill & Naish, 2007).

*Bothriospondylus robustus* from the Bajocian–Bathonian Forest Marble Formation of Wiltshire could be a new genus but is a *nomen dubium* based on the characteristics of ventral centrum of a macronarian (Upchurch, 1993).

A caudal vertebra found in Wealden (Barremian) were identified by Owen (1842) in “*Cetiosaurus*” *brevis*. These vertebrae resemble the vertebrae of a titanosaur by the absence of a hyposphenal ridge. Therefore, these materials are named as Titanosauriforms *incertae sedis* (Martill & Naish, 2007).

*Dinodocus mackesoni* was firstly described as a pliosaur but it is a Titanosauriforms indet. from the Aptian–Albian of Hythe, Kent (Martill & Naish, 2007). On the Isle of Wight, some discoveries have been made. Remains (tooth and vertebral centra) had concluded at 9 sauropod genera and 11 species with an unnamed diplodocoid. 2 (*Oplosaurus armatus* and *Ornithopsis hulkei*) need to be associated to a *nomina dubia* (Martill & Naish, 2007).

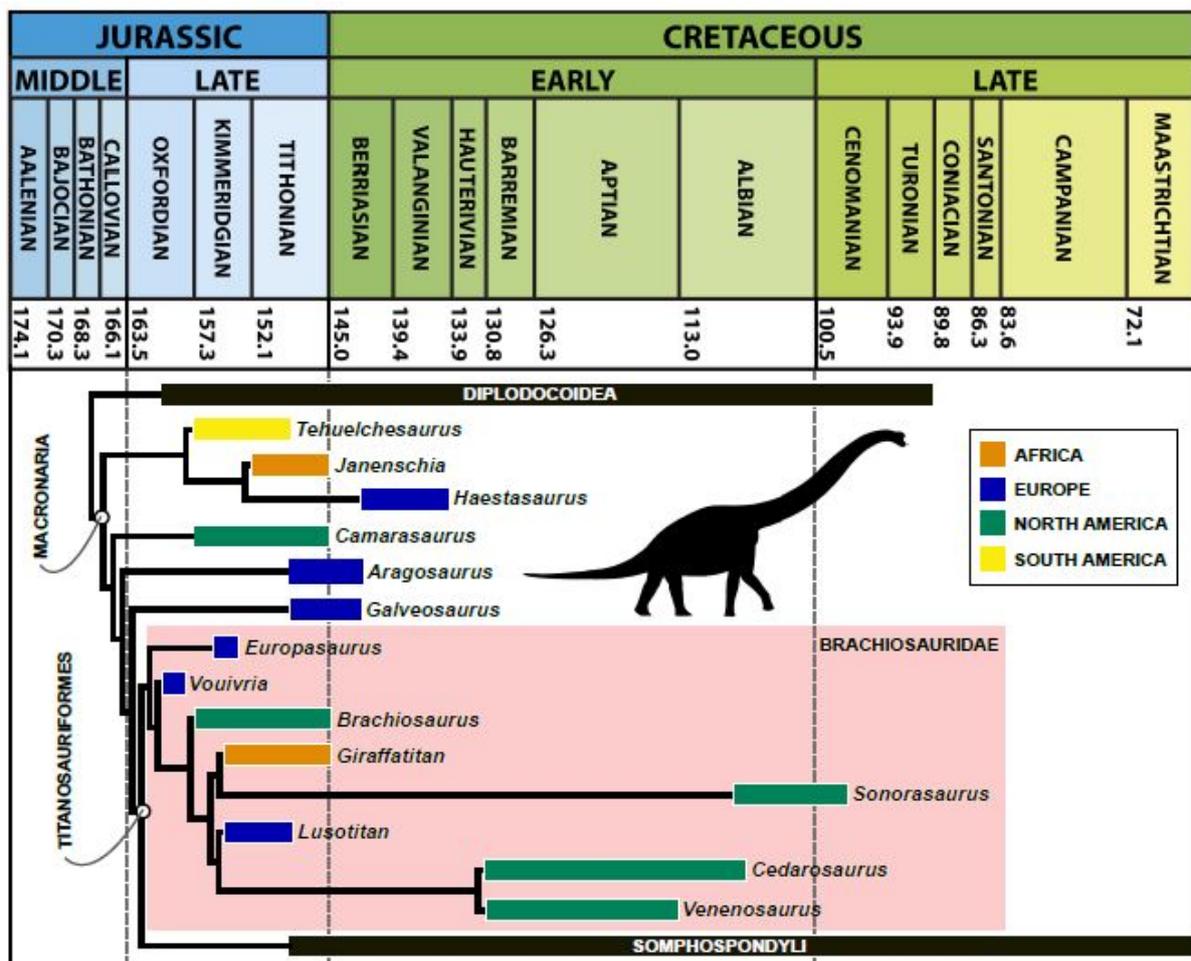
*Macrurosaurus semnus* is the youngest British sauropod from the Cenomanian of Cambridgeshire. Based on its 25 caudal vertebrae it cannot be identified beyond Titanosauria indet. so, it is a *nomen dubium* too (Martill & Naish, 2007).

In summary, most of these identifications are doubtful at species level since they are isolated elements.

## 9. Comparisons

Because of the destruction of all Norman paleontological collections found in the 19<sup>th</sup> century due to the Second World War, 2013.1.196 can only be compared with specimens from areas outside Normandy, such as European sauropods.

The vertebra described here can be compared to other Macronaria (including Titanosauriforms) because it seems to share characteristics with this group. Moreover, some of them belong to Titanosauriforms, but they are Titanosauriforms indet. and it would be complicated to compare our vertebra with uncertain materials. Reviewed in Figure 6, the only macronarian sauropods found in Europe during the late Jurassic period were *Vouivria damparisensis* (France, Oxfordian), *Europasaurus holgeri* (Germany, Kimmeridgian), *Lusotitan atalaiensis* (Portugal, Kimmeridgian), *Galveosaurus herreroi* (Spain, Tithonian), and *Aragosaurus ischiaticus* (Spain, Tithonian) (Mannion *et al.*, 2017).



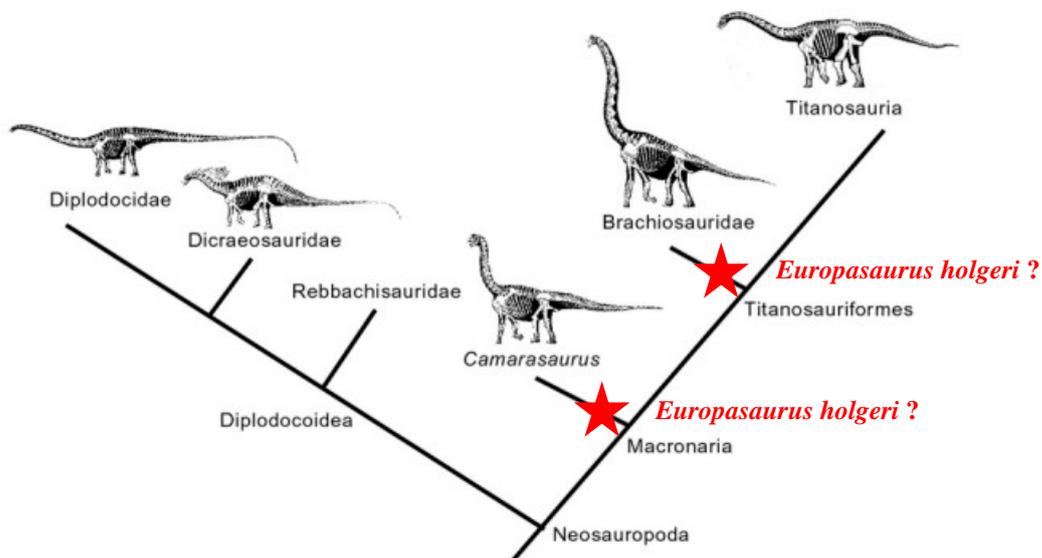
**Figure 6.** Phylogenetic tree showing geographic distribution of basal Macronaria (modified from Mannion *et al.*, 2017).

The comparisons will be focused on Titanosauriforms found in Europe during the Kimmeridgian. Based on figure 6, only *Europasaurus holgeri* and *Lusotitan atalaiensis* were found in this period so the comparisons will focus on these two taxa.

All these following deductions are hypothetical because some missing parts, essentially the neural arch, makes identifications uncertain.

*Europasaurus holgeri* is a sauropod found in northern Germany in 2006. Its discovery is relatively recent, and it is a little enigmatic because the size suggests that it was a dwarf sauropod (Sander *et al.*, 2006).

The phylogenetic position of *Europasaurus* is still debated today (Figure 7). *Europasaurus* belongs to the first camarasauromorphs of the late Jurassic (middle Kimmeridgian) but is less derived than *Brachiosaurus* (Carballido & Sander, 2014), and it was recently reclassified as Titanosauriform (Mannion *et al.*, 2017), so we can compare our vertebra with this Titanosauriforms.



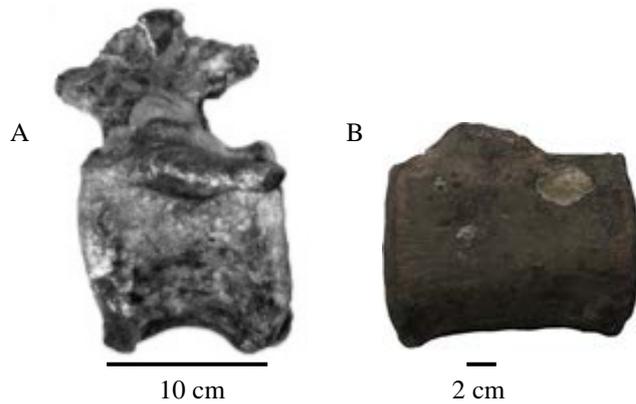
**Figure 7.** Cladogram of Neosauropoda, Schachner, 2004.

here are two major differences between the vertebrae of *Europasaurus holgeri* and that of 2013.1.196 (Figure 8). Firstly, the bottom of the vertebra is concave for *Europasaurus* but relatively flat for the vertebra of Cricquebœuf. Secondly, the size of the vertebra of *Europasaurus* are around 5 cm but the size for the vertebra of Cricquebœuf is around 12 cm. Thirdly, the transverse processes are directly fixed on the lateral sides of the centrum for the anterior (DFMMh/FV 866) and middle (DFMMh/FV 553.1) vertebrae of *Europasaurus holgeri*, which is absent on the vertebra described herein.



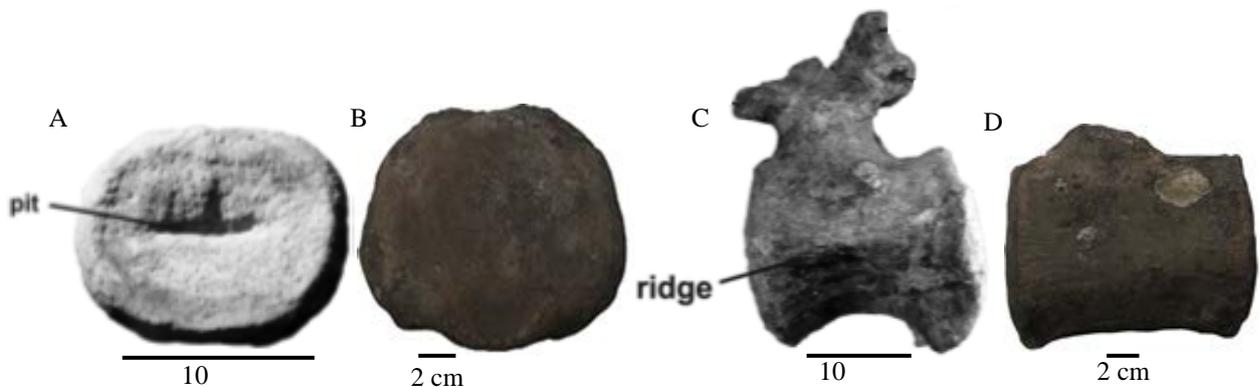
**Figure 8.** In left: 2013.1.196 in left lateral view. In right: middle caudal vertebra of *Europasaurus holgeri* in left lateral view, (DFMMh/FV 553.1 C, left view (Carballido & Sander, 2014))

*Lusotitan atalaiensis* is a well-known sauropod from Portugal. Lapparent and Zbyszewski described it in 1957 as a brachiosaur, which they called *Brachiosaurus atalaiensis* because it was found in Atalaia region. Many remains of ribs, pectoral girdle, fore and hind limb, pelvic girdle and vertebrae have been found. The 19 caudal vertebrae have been re-studied in 2013 by Mannion *et al.*, and they have been named Cd-A to Cd-S (Cd is an abbreviation of “caudal”). Each vertebra has been described in brief detail. Our vertebra is therefore also compared with these 19 vertebrae. 2013.1.196 seems to be close in morphology to those of Cd-C (MG 4985 4) to Cd-H (MG 4958 9). In fact, Cd-C is the first vertebra in this series with the chevrons preserved. The posterior chevrons facets are visible in Cd-C, and they are separated to the median line. It could be suggesting that the chevrons were unbridged, obviously it is the case for all chevrons facets all along the tail. Moreover, the neural arch is situated on the two thirds of the centrum of 2013.1.196; this is a particularity of the titanosauriforms. Cd-D and Cd-E had some kind of shallow triangular concavity along the posterior portion of the ventral surface, created in part by very subtle ridges that support the widely separated posterior chevron facets. As a result of the erosion of 2013.1.196, the ridges are flat, but they are visible in the posterior part of the ventral view (Figure 9).



**Figure 9.** A. Photography of anterior caudal vertebra of *Lusotitan atalaiensis* Cd-D in right lateral view (Mannion et al. 2013). B. 2013.1.196 in right lateral view. Cd- means caudal.

Cd-F had a lateral crest on the lateral side of the centrum and a depression on the distal surface of the centrum, so it is different from 2013.1.196. Cd-G to Cd-H had neither lateral crest nor depression on the posterior surface of the centrum, exactly like 2013.1.196. Mocho *et al.* (2016) reinforced the study of this series of caudal vertebrae and indicated that the Cd-H could be the first middle caudal vertebra around the fifteenth position in the tail (Figure 10).

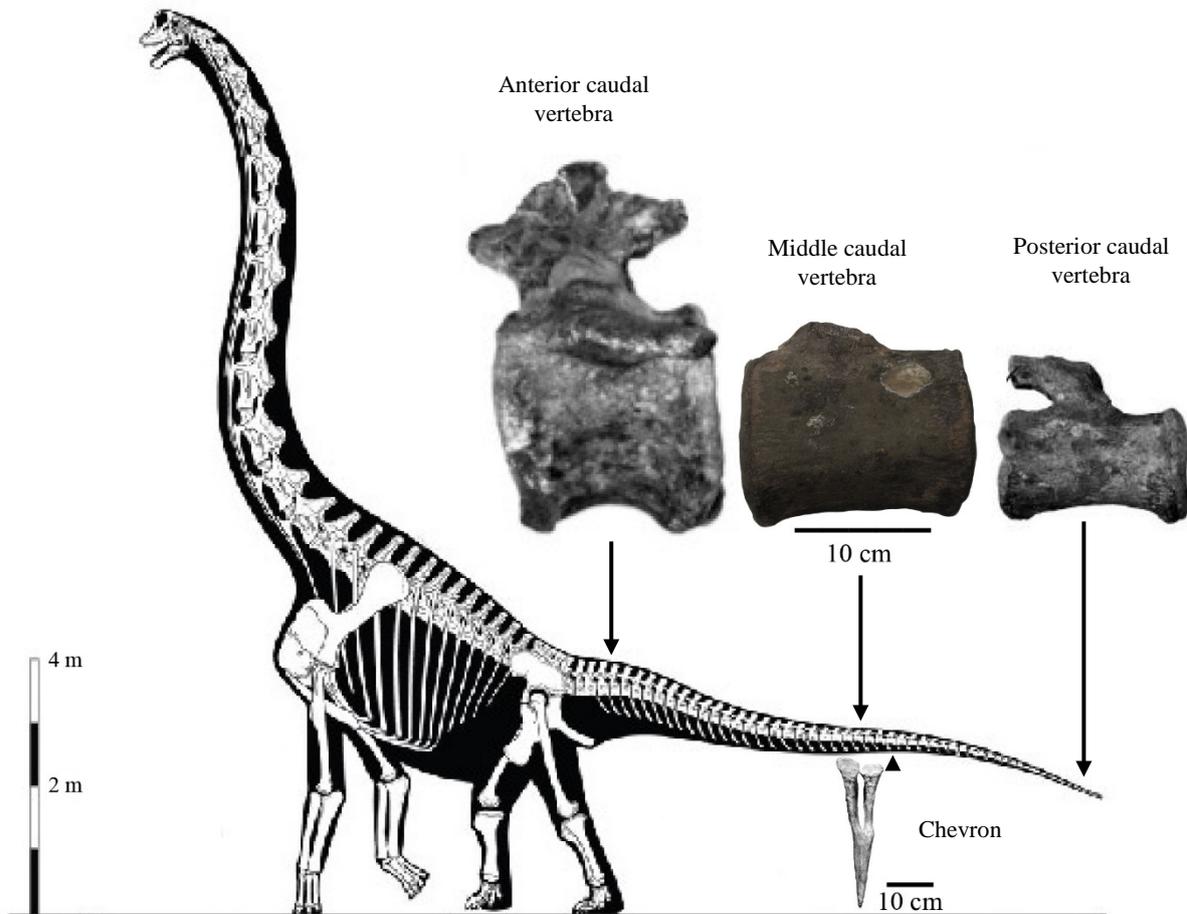


**Figure 10.** A. Photography of posterior caudal vertebra of *Lusotitan atalaiensis* Cd-M in posterior view (Mannion et al. 2013). B. 2013.1.196 in posterior view. C. Photography of posterior caudal vertebra of *Lusotitan atalaiensis* Cd-F in right lateral side

## Interpretation

According to Weishampel *et al.* (2004), generally, the width of proximal caudal vertebrae is relatively short, like a disc. The caudal vertebrae become progressively longer at the middle of the tail. The distal caudal vertebrae are a bit flat and elongate, like a stick (from more than twice its length to five or six times its length) (Figure 11) (Weishampel *et al.*, 2004).

Unlike the distal vertebrae, the width of 2013.1.196 is less than twice its length; the only vertebrae whose length is more or less equal to their diameter are the middle caudal vertebrae. Chevron facets are present on the posterior margin like shallow triangular concavity on our vertebra. Chevrons are bone present after the first or the second caudal vertebra but are missing at the end of the tail (Weishampel *et al.*, 2004; Brusatte, 2012). That suggests that 2013.1.196 could be a middle caudal vertebra.



**Figure 11.** Shape of *Lusotitan atalaiensis* to explain morphological differences between the vertebrae of the tail. Silhouette from Deviant art based on Sander *et al.*, 2006. Posterior caudal, anterior caudal vertebra and chevron from Mannion *et al.*, 2013. Middle caudal vertebra: 2013.1.196.

Furthermore, the base of the neural arch is located on the anterior two thirds of the centrum; this is a specific character of the titanosauriforms. Titanosauriforms belongs to Macronaria (Neosauropoda) (Curry Rogers & Wilson, 2005). So, according to the presence of the articular facets for the chevron bone and the measurements, the vertebra seems to belong to the middle region of the tail. Even if the neural arch is missing, we can see at the base that the neural arch is completely fused with the centrum, and no neurocentral sutures are visible.

If it were a juvenile, the neural arch would be unfused (Brett-Surman *et al.*, 2012; De Souza *et al.*, 2014; Wedel, 2003; Weishampel *et al.*, 2004). It indicates that we have a vertebra of an adult sauropoda.

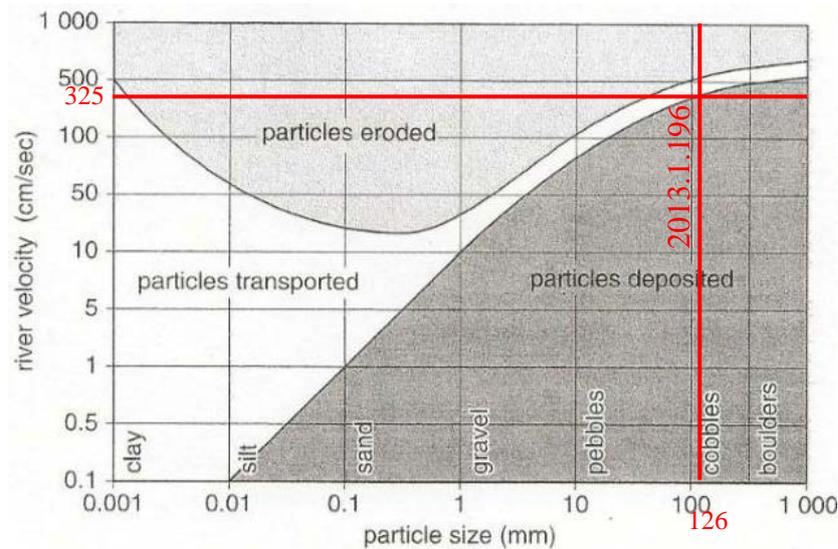
2013.1.196 seems to be closer to *Lusotitan atalaiensis* from Portugal than other European species, so the only remaining hypothesis is that 2013.1.196 could belong to *Lusotitan atalaiensis*, from Cd-D to Cd-H, excluding again Cd-F. As explained in the section “Review of sauropods from England”, English sauropods are represented by less complete remains than those from Portugal, which complicates comparisons. If English sauropods were better known, perhaps the similarities would be stronger than with the Portuguese species. In all cases, the paleobiogeography is consistent with the place of Normandy in the Kimmeridgian and the location of Portugal island. Globally, sauropods from Normandy are poorly known, so all of these hypotheses are theoretically possible.

## 10. Discussion

### 10.1. Reworking

Reworking of fossils are due to a removing or displacing from its original deposition and incorporated to a younger formation by natural agents (Graw-Hill, 2003). Reworking of dinosaurs remains can be explain by phenomena that have high energy, as attested by the works of Lofgren *et al.*, 1990 and Buck *et al.*, 2004 in the case where these remains were fossilized in a fluvial system or alluvial fan, a system of high energy.

The vertebra studied here weighs 2.430 kg and measures ~12 cm long, so, according to Figure 12, the diagram shows that the vertebra can be compared to cobbles (~100 mm) and it will require also a river velocity around 325cm/sec to be reworked in younger deposits. On the contrary, the vertebra 2013.1.196 was found in clays deposits, very fine-grained sediments, synonym of environment of lower energy (settling clays). In this way, reworking an “object” so heavy in a bed of lower energy can be ruled out. So, this discovery *in situ* of this vertebra shows that the vertebra is contemporary with the sediments that enclose it.



**Figure 12.** Hjulstrom curve graph, Diaz, 2012.

## 10.2. Age

Two shells of the oyster *Deltoideum delta* are attached to the left lateral side and right lateral side on the base of the neural arch of the vertebra (Figure 13). *Deltoideum delta* is also known as *Liostrea delta* or *Ostrea subdeltoidea* (Samson *et al.*, 1996; Fischer, 2000). They were oysters which had valves with subtriangular outline and a height that would be equal to 15 cm and around 10 to 15 cm long. They belong to the family Gryphaeidae (Fischer, 2000). The border of the valves shows a lamellar structure (sheet of calcite) characteristic of oyster shells. These oysters were gregarious animals and formed coquina (Aubry & Gigot, 2017). This species appeared in the middle of Jurassic (Callovian) and is known essentially in the Oxfordian and in the Lower Kimmeridgian at different localities such as northern France (Pas-de-Calais (Boulonnais)), eastern France (Meuse), north-western France (Seine-Maritime and Calvados) and in Great Britain. As the vertebra was found directly in the outcrops on the beach of Cricquebœuf and the stratigraphy of the region indicates that the Kimmeridgian crops out in Cricquebœuf, the only link between the presence of these oysters on the vertebra and our vertebra is that they were living during the Kimmeridgian when the vertebra was on the seabed (see paragraph on Taphonomy). Thanks to that, 2013.1.196 can be dated to Kimmeridgian (between  $157,3 \pm 1$  and  $152,1 \pm 0.9$  millions of years) (Fan & Hou, 2013-2016).



**Figure 13.** Dorsal view of 2013.1.196 with the two *Liostrea delta*. **1.** *Liostrea delta* in left lateral. **2.** *Liostrea delta* at the base of the neural arch.

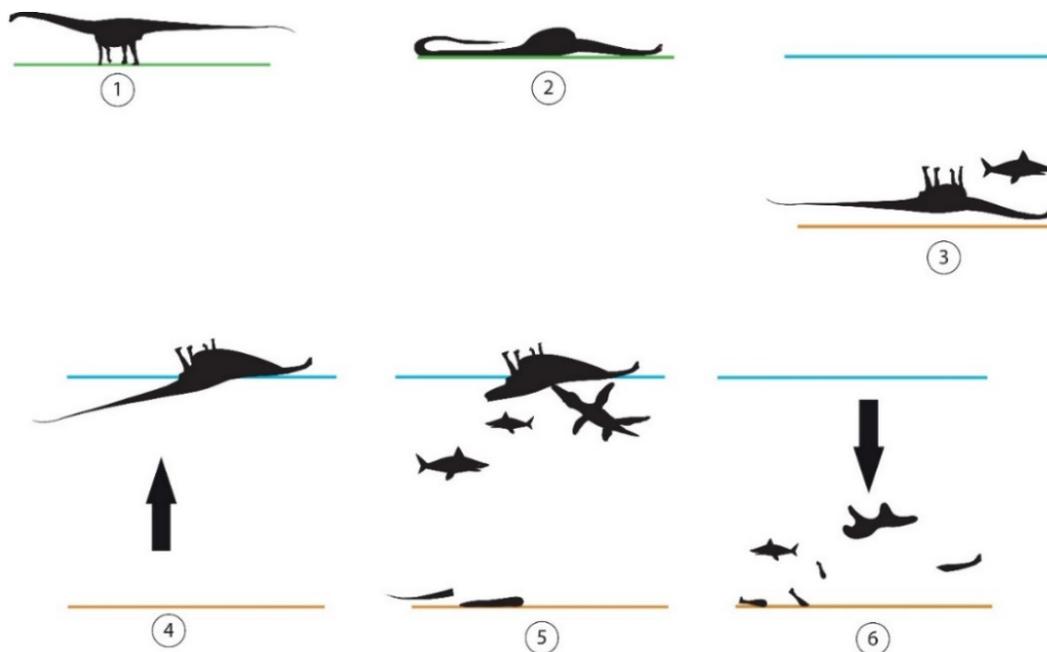
### 10.3. Taphonomy of dinosaurs

One remaining question about the vertebra is: how could a skeletal element of a terrestrial dinosaur be buried in marine deposits? Dinosaurs were exclusively terrestrial animals, and this is why a discovery of dinosaur remains in a marine context can be surprising. On the other hand, dinosaurs could surely walk on beaches because we have found many trackways made on coastal mudflats. The only explanation to how the vertebrae ended up in marine deposits involves a transport after death (Buffetaut, 1994) explained in Figure 14. Schäfer (1962) studied the decay of mammal carcasses and showed that a carcass can float and drift for more than one month due to the putrefaction gases inside the body. These gases inflate the carcass and allow it to float but particularly to be transported over hundreds or thousands of kilometers by marine currents as explained by Martill (1988). During the drifting, the carcass of the animal can lose some portions of the skeleton or isolated bones such as the lower jaw, which is one of the first bony elements to separate from the dead body, if one believes the study of Weigelt, 1927. Furthermore, during the floating, some scavengers or necrophagous organisms are able to intervene during the decay and cause some kind of dispersion on a

relatively complete skeleton. Once the seabed is reached, sessile organisms (like oysters) take advantage of a new "substrate" to cling to it (Buffetaut, 1994).

The *Deltoideum delta* oysters on 2013.1.196 are less than 3 cm in diameter, indicating that they are juveniles. It could indicate that the vertebra did not stay very long on the seabed before being buried in the sediment since we would expect the oysters to be more developed otherwise.

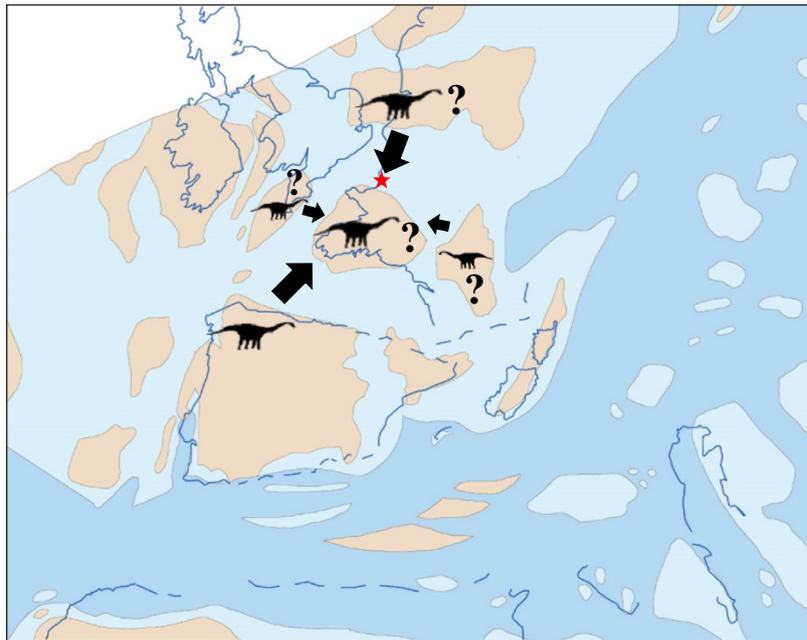
Theropods represents less than 10% of dinosaur faunas worldwide but dominate French assemblages (in Normandy and Franche-Comté). On the other side of Channel Basin, Martill (1988) mentions a more diverse assemblage (without any dominant taxa) in England in the Oxford clay and in the Kimmeridge clay Formation (Plasse, 2014). Furthermore, theropod remains seems to always be found in the East on emerged European land. Perhaps it is possible that a paleo-current was present from West to East coming from Channel Basin, and it could explain why French assemblages are less diverse than English assemblages (Plasse, 2014). The most likely hypothesis is that dinosaur assemblages present in marine sediments reflect only the relative abundance at a given time and some species appear to have been more abundant than others on continental areas, but the record could be biased (Buffetaut, 1994).



**Figure 14.** Taphonomy of a sauropod. **1.** Sauropod is a terrestrial animal living on islands. **2.** It dies near a coastline or a river. **3.** The body of the sauropod sinks to the seabed. **4.** The carcass can float and drift for more than one month due to the putrefaction gases inside the body. **5.** The carcass of the animal can lose some portions of the skeletons or isolated bones and some scavengers cause some kind of dispersion on a relatively complete skeleton. **6.** The seabed is reached.

#### 10.4. Migrations patterns

According to our comparisons, the vertebra seems to be closest to *Lusotitan atalaiensis* from Portugal. Different migrations could be possible, and, perhaps, it may even be that sauropods could cross or swim in the lagoons from island to island (Figure 15).

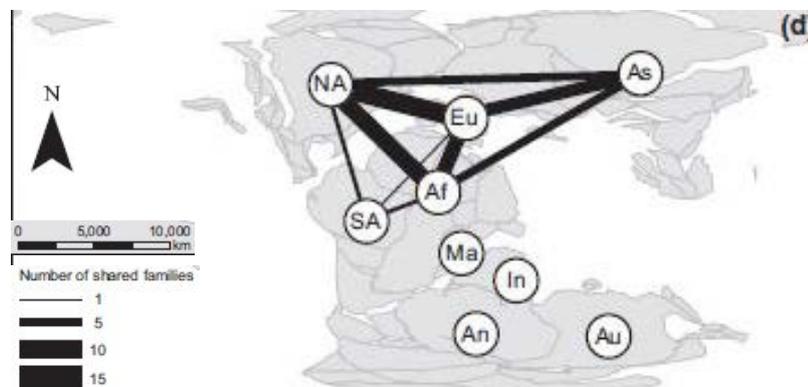


**Figure 15.** Paleomap of Europe during the Kimmeridgian (modified from Christ & Romeuf, 2018). Red star: Place where the vertebrae was found. Arrows: possible migrations. Dinosaur: *Lusotitan atalaiensis*. Pink: continental islands, light blue: platform, dark blue: basins. Blue lines: actual coastlines.

Fricke *et al.* (2011) showed that sauropods could walk several hundred kilometers from lowland to upland environments during seasonal migrations. These authors focused on oxygen isotope ratios present in tooth-enamel carbonate from *Camarasaurus* in deposits of Morrison basin (West of United States). They show that  $\delta^{18}\text{O}$  of water incorporated in tooth-enamel carbonate of *Camarasaurus* come from water located over 300 kilometers lowland and they could have migrated toward the place where they died. Migrations could have appeared from floodplain lowland to upland in arid season, during the summer, and returned to it during humid season, probably autumn or winter (Fricke *et al.*, 2011). The problem here

is that we don't know the wildlife relations between these different European islands, but this question was approached by Dunhill's team in their recent article (Dunhill *et al.*, 2016).

The goal of the study of Dunhill *et al.*, 2016 was to model biogeographic and geographic networks through the Mesozoic era based on points that are interconnected by lines. Points represent continents and they tested how continental splitting up affected dinosaur biogeographical and geographical structure and evolutionary (Dunhill *et al.*, 2016). The result of these networks shows that Dinosaurs may have moved on continents, and between islands, thanks to the formation of temporary land bridges, which could have been formed due to the sea levels changes during the Cretaceous (Figure 16) (Dunhill *et al.*, 2016).



**Figure 16.** First-step biogeographical network models for all dinosaur taxa in late Jurassic (modified from Dunhill *et al.*, 2016). Thickness of lines represents number of families shared between landmasses.

Dunhill's team separate dinosaurs by species, and sauropods tend to be less nomadic, less liable to swim, and less likely to be going across sea waves than other smaller dinosaurs like theropods. Trying to find some migrations models was complicated due to a lack of fossils (scattered discoveries) and some biases of the fossil record, so no satisfactory results were discussed. (Dunhill *et al.*, 2016). The phenomenon of mass migrations is supported by Hallam, 1981. He explains that transgression during the Oxfordian would have accentuated the isolation of the continental masses and restricted intercontinental migration of terrestrial organisms.

To summarize, these two articles (Dunhill *et al.*, 2016 and Hallam, 1981) explain us that it is possible that species from Portugal such as *Lusotitan atalaiensis* were able to migrate in Europe and especially on the Armorican massif where they could live there. These European migrations are still only hypothetical and need to be clarified in the future.

## 11. Conclusion

2013.1.196 is a vertebra found by Mrs. and Mr. Hurtrelle in 1999. It comes from the Kimmeridgian (between  $157,3 \pm 1$  and  $152,1 \pm 0.9$  millions of years) in the upper Jurassic period. The initial identification as a caudal vertebra of a Sauropoda turned out to be correct but more particularly, this vertebra is a middle caudal - it had a median position in the tail of the sauropods - because of the presence of the articulation surfaces for the chevron bone and its proportions.

Comparisons with previously reported sauropod remains from the Kimmeridgian of Normandy were made impossible due to the destruction of all Normandy's paleontological collections during World War II. Comparisons could, however, be made with other geographically close areas in Europe, and it is concluded that this bony element belongs to the Macronaria clade and more specially to a Titanosauriforms close to taxa from Portugal. It resembles middle caudal vertebrae of *Lusotitan atalaiensis* and may belong to this sauropod species. Some vital parts, such as the neural arch, are missing so identification to species level is still uncertain. Based on this hypothesis, this vertebra from Normandy seems to be closer to sauropods from Portugal than to German or English sauropods even though we need to keep in mind that English Kimmeridgian sauropods are poorly known.

The presence of terrestrial animals in marine deposits is explained as a result of a transport during decay. Indeed, carcasses of animals can be floating and drifting during many weeks before settling to the sea bottom.

Because European and Norman sauropods are not well known, and a lot of fossils are in private collection without no description, only future discoveries may allow us to confirm or reject this hypothesis. In the future, it will be necessary to clarify the faunal relations between the different European islands of the Kimmeridgian.

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