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New dinosaurs from Denmark

Nouveaux dinosaures du Danemark

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Abstract

Only the Baltic island of Bornholm is likely ever to produce Danish dinosaurs, not the western mainland Denmark. The Mesozoic of Bornholm spans Late Triassic to Late Cretaceous, with some potentially dinosaur producing deposits from Early Jurassic to Early Cretaceous being continental, lagoon, littoral or marginal marine. So far the only dinosaurs have been found in 2000 and 2002 in the basal Jydegaard Fm., carrying a 'Purbeck-Wealden fauna' of the Earliest Cretaceous (Late Berriasian or Ryazanian) at Robbedale. Both are single tooth crowns; the first find, a 21-mm crown, is a dromaeosaurine, *Dromaeosauroides bornholmensis* Christiansen & Bonde 2003, possibly the only true dromaeosaur from the Lower Cretaceous of Europe. Estimated length of the animal is over 3 m. The second find is a somewhat unusual sauropod, most likely titanosaurian, the crown being only ca 15 mm high, with an unusual wear facet. Both teeth were derived from the lowermost 2-3 metres of the formation. Future expectations from this deposit are small ornithopods - and possibly mammals. ***To cite this article: N. Bonde, P. Christiansen, C. R. Palevol 2 (2003) 13–26.***

Résumé

C'est seulement sur l'île de Bornholm, dans la mer Baltique, que l'on peut trouver des restes de dinosaures au Danemark, et non dans la partie occidentale du pays. Le Mésozoïque de Bornholm s'étale du Trias supérieur au Crétacé supérieur, avec des dépôts allant du Jurassique inférieur au Crétacé inférieur, de type continental, lagunaire, littoral ou de bordure de mer, susceptibles de renfermer des dinosaures. Jusqu'à maintenant, on a seulement trouvé des dinosaures en 2000 et 2002, dans la partie basale de la formation de Jydegaard, qui comporte une faune de type « Purbeck-Wealden » du Crétacé inférieur (Berriasien supérieur ou Ryazanien) à Robbedale. Dans les deux cas, il s'agit de dents uniques : la première est une couronne de 21 mm, appartenant à un dromæosaurien, *Dromaeosauroides bornholmensis* Christiansen & Bonde 2003, peut-être le seul dromæosaure du Crétacé inférieur européen. La longueur estimée de l'animal est supérieure à 3 m. La seconde est une dent de sauropode, probablement un titanosaure ; la couronne a une hauteur d'environ 15 mm, avec une facette d'usage assez particulière. Les deux

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dents proviennent des 2-3 mètres de base de la formation. Dans cette formation sont attendus de petits ornithopodes - et, peut-être, des mammifères. ***Pour citer cet article : N. Bonde, P. Christiansen, C. R. Palevol 2 (2003) 13–26.***

Keywords: Dromaeosaurine; sauropod; teeth; Early Cretaceous; Bornholm; Denmark

Mots clés : Dromaeosaurinae ; Sauropoda ; dents ; Crétacé inférieur ; Bornholm ; Danemark

1. Introduction

Denmark is a rather unlikely region for major finds of (non-avian) dinosaurs, because in the mainland of western Denmark the exposed Mesozoic sediments are exclusively the marine Maastrichtian chalk (in Danish ‘skrivekridt’ = writing chalk) deposited some distance offshore. Easternmost Denmark is the small Baltic island Bornholm (about 20 × 30 km), where Mesozoic sediments of pre-Maastrichtian age are exposed along the western and southern near coastal area [12, 38]. Some of these sediments, spanning Late Triassic to Late Cretaceous, are in fact continental, littoral or marginal marine, thus potentially capable of yielding dinosaur remains. So far only two teeth of dinosaurs have been found very recently in basal Cretaceous sediments of a ‘Purbeck-Wealden’ aspect [4] in a single locality, a gravel pit at Robbedale, a few kilometres east of the main town, Rønne.

One of these teeth is a dromaeosaurid, possibly the only European dromaeosaur from Early Cretaceous, and it has recently been dubbed *Dromaeosauroides bornholmensis* [8]. The second tooth appears to be from an herbivorous dinosaur, a sauropod. Both are briefly described below, and the geological and faunal background is summarized.

2. Danish Mesozoic sediments

The Maastrichtian Chalk of western Denmark has yielded no dinosaurs, but a few fragments of marine reptiles. One rather recent find comprises a few postcranial bones and scutes of a crocodile from Stevns Klint (= cliff) about 50 km south of Copenhagen, and from the same few metres of chalk along the cliff, the older collection holds a few crocodilian teeth, traditionally referred to *Thoracosaurus* (also known from the Danian [Early Palaeocene] limestones in the Faxe Quarry, some 25 km to the west, and as a complete skull from the Danian of the Limhamn Quarry south of Malmö in SW Scania, Sweden [40]). An occipital fragment of a crocodile was found in the 1990s in the chalk at Stevns Klint, and both that fossil and the above skeletal parts were evaluated as ‘Danekræ’ (literally ‘Danish creature’, a concept introduced in 1990 to secure important fossils) owing to the rarity of such discoveries in Denmark. Accordingly, they were purchased by the state collection (Geological Museum, see [15]).

Mosasaurs are slightly more abundant finds in the chalk, a few fairly to very small teeth have been found at Stevns Klint. A large tooth crown, approximately 4 cm in total height, in the Rørdal Quarry in Ålborg, N-Jutland, appears to represent *Mosasaurus hoffmanni*, while a couple of medium-sized teeth from the Dania Quarry at Assens, 25 km north of Randers, E-Jutland, and from Stevns, must be referred to another, presently undetermined genus. Accordingly, there appear to be at least three species among these mosasaur finds [3]. A fragmentary vertebral centrum has also been found. These chalk mosasaurs are not nearly as diverse as the slightly older mosasaurs from Scania, as noted below.

The Danish pre-Maastrichtian sediments are treated below under Bornholm.

3. Southern Scandinavia, including Scania

Apart from Denmark, Mesozoic sediments in Scandinavia are mainly exposed in southern Sweden (i.e. Scania), and the Late Cretaceous is represented by marine limestones of Santonian to Early Maastrichtian age. Most exposures are of Campanian age [37], the largest ones situated in NE-Scania, the former kaolin pit on the island Ivö in Lake Ivö, possibly most famous for its many plesiosaurian bones, referred to *Scanisaurus* by Persson [27]. This species of plesiosaur also occurs in another large quarry some 40 km to the west at Ignaberga, where several mosasaurs also have been found (some also on Ivöe), and abundant, especially small mosasaurian teeth, have been discovered in the former kaolin quarryat Åsen, on the coast of Lake Ivö. These localities and some other in this region have yielded a few large vertebrae of very long necked elasmosaurian plesiosaurs and very short necked polycotylids [27]. J. Lindgren from Lund is currently studying the mosasaurian diversity, amounting to five or six species in the Campanian (Johan Lindgren, pers. comm., 2001). There are also turtle fragments and a crocodilian skull, *Aigialosuchus* [27].

Persson [27] also described a tooth of a large carnivorous dinosaur from Ivö, probably a tyrannosaurid, and lately two small ornithopod teeth have been found at Åsen (currently being studied by Rees, Siversson and Lindgren from Lund; pers. comm. by Rees 2002).

Rees, in his thesis [32], described Early-Cretaceous sharks, e.g., from Vitebäck Clay, in southern Scania, Early Berriasian, but also tetrapods like albanerpetontid amphibians and crocodilian teeth like? *Theriosuchus* - this is a faunal setting in which dinosaurs could be expected.

No tetrapods have been found in the Jurassic rocks of Scania, but there is an outlier of Late (?)-Jurassic sediments on the western Norwegian island of Lofoten, from which vertebra of ichthyosaurs have been described, and recently a Danish North Sea drilling hit a Jurassic, marine reptilian bone, and such have also been reported from erratic boulders in North Jutland (derived from the bottom of Skagerrak with ammonites etc. - all, as yet, undescribed).

The Late-Triassic rocks, however, formerly coal producing, of the Hälsingborg region in NW-Scania, have yielded a large specimen of the extremely dorsoventrally compressed plagiosaurid stegocephalian, *Gerrothorax* [24], and several hundred footprints of small theropod dinosaurs, along with a trackway of a larger (?) ornithopod [5]. A few articulated vertebrae of a medium-sized dinosaur have also been found [6].

4. The Baltic island of Bornholm

The island of Bornholm (Fig. 1A) has a geology more reminiscent of that of Scania than of western Denmark, and Mesozoic rocks spanning a period from Late Triassic to Late Cretaceous (pre-Maastrichtian) are found in rather limited to very small exposures along the western and southern coasts surrounding the horst of Precambrian igneous rocks [12, 38]. All the lithostratigraphic units of the Bornholmian Mesozoic (apart from the marine Late Cretaceous) were described and many defined and named by Gravesen et al. [14] and the sedimentary log is a mixture of continental to littoral, lagoon and near-coastal marine deposits, with many hiatuses wedged in between. The semi-popular geological guide to Bornholm by Gravesen [13] also reviewed the Mesozoic and many localities and their fossils, and the vertebrates have been briefly summarized by Bonde 1993 [2] and more fully in 2003 [4].

Tetrapods have only been found in Lower Jurassic and Lower Cretaceous rocks, the former a marine near coastal coarse sandstone, Hasle Sandstone, of Pliensbachian age from the west coast [13, 14]. Apart from shark teeth and spines [30] and chimaeroid tooth plates, this deposit has produced many teeth, vertebrae, ribs, gastralia and limb bones of plesiosaurs, amounting to three (possibly four) species, as judged from the morphology of the teeth [33]. Most common is *Attenborosaurus*, but two teeth appear to be from *Plesiosaurus* (s. s.), and a third species has much larger teeth. Further two plesiosaurian bones, a dentary and a small proximal limb bone, are from exposures on the south coast [20], and both of these were valuated as 'danekræ'. Surprisingly, no bones of ichthyosaurs have been identified (and only one fragment of an actinopterygian) in these sandstones. No other Jurassic deposits have produced vertebrates, despite having been quarried for a century for ceramic clay, and although the Lowermost and Middle Jurassic paralic to fluviatile sediments comprising clays and coal could potentially preserve tetrapod foot prints.

The Lower Cretaceous deposits are comprised in the Nyker Group of Berriasian to Valanginian age ([14]; presently being scrutinized for vertebrates by Rees, see also his preliminary results in his thesis 2001). The Nyker Group comprises three formations, the Rabekke, Robbedale and Jydegaard Formations (Fig. 2). The Rabekke Formation is of approximately equivalent age to the Vitabäck Clay, i.e., Berriasian, containing fluviatile and lacustrine to marginal marine clays and sand; it has yielded plants and ostracods, but no vertebrates. The overlying Robbedale Formation contains shallow marine quartzose sand with galleries of trace fossils [23], some supposed to be feeding traces of rays. The entire formation is correlated with

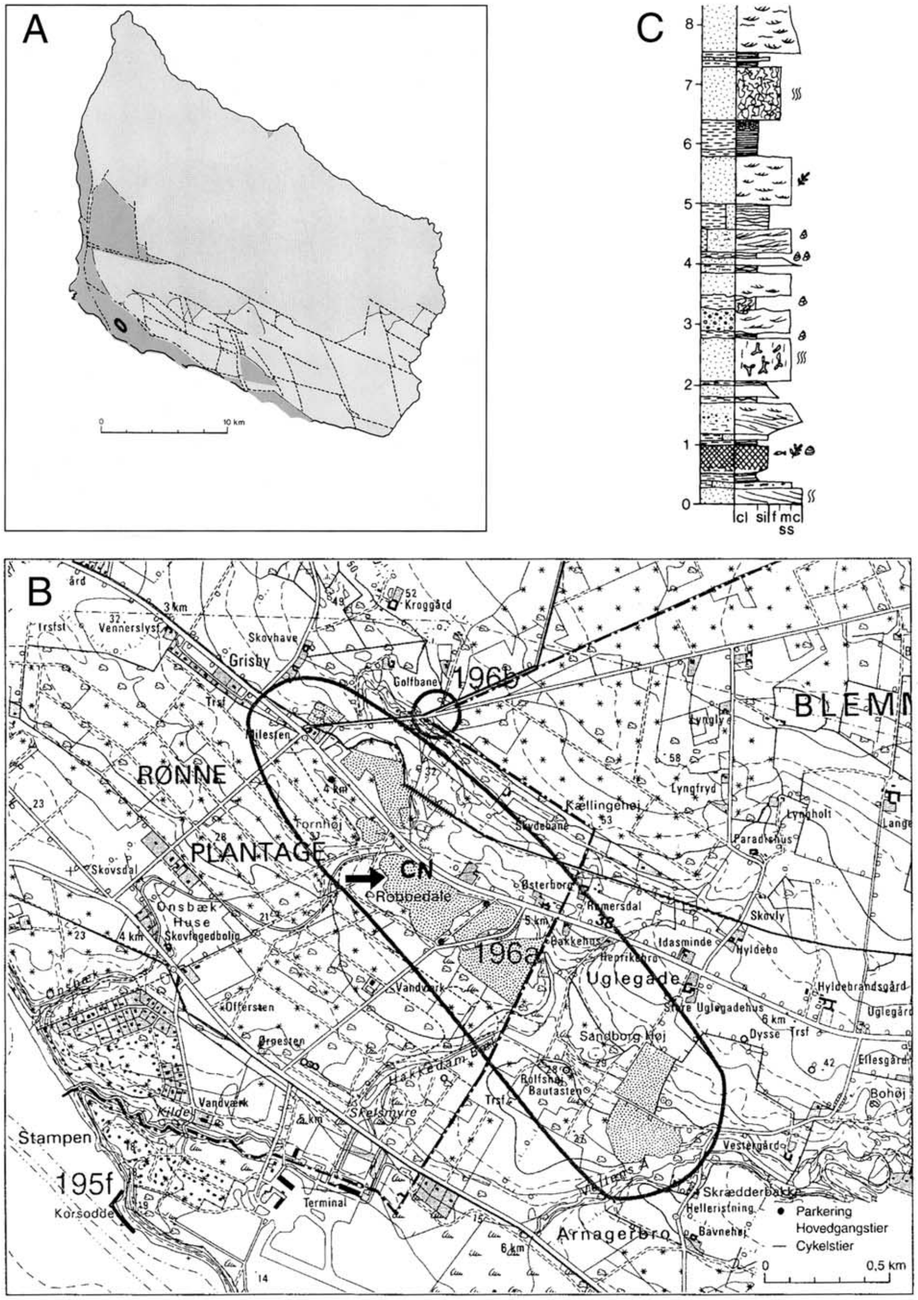

Fig. 1. (**A**) Isle of Bornholm with Robbedale region indicated; (**B**) detailed map of Carl Nielsen's sandpit (CN, stippled; modified from [14]); (**C**) sedimentological log of the basal Jydegaard Formation with bivalves, plants and small fish indicated at the *Neomiodon* bed (cross hatched), and snails, plants and bivalves above. All fossils are probably derived from the lower 2-3 metres (modified from [39]).

Fig. 1. (**A**) Île de Bornholm, avec indication de la région de Robbedale ; (**B**) sablière de Carl Nielsen (CN, en pointillé, d'après [14], modifié) ; (**C**) sédiments de la partie basale de la formation de Jydegaard, avec bivalves, plantes et petits poissons indiqués dans la couche de *Neomiodon* (hachures) et au-dessus des escargots, plantes et bivalves. Tous les fossiles proviennent probablement des 2 à 3 mètres inférieurs (d'après [39], modifié).

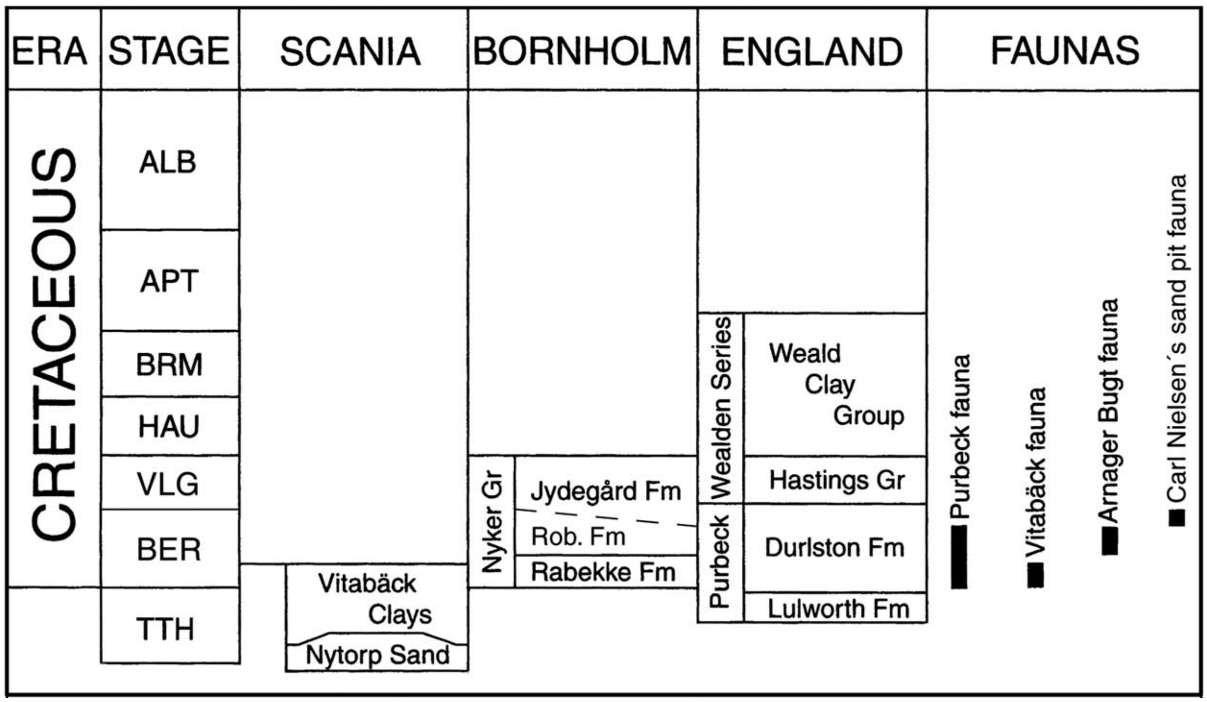

Fig. 2. Stratigraphy and age of the Robbedale fauna, and associated faunas described in the text, from the Early Cretaceous of Bornholm, Scania and England (modified from [32]).

Fig. 2. Stratigraphie et âge de la faune de Robbedale et faunes associées (mentionnées dans le texte), provenant du Crétacé inférieur de Bornholm, de Scanie et d'Angleterre (d'après [32], modifié).

the lower part of the German 'Wealden' (W1-W2) according to Allen & Wimbledon [1]. The upper member, the Langebjerg Mb. (= 'Robbedale Gravel'), is exposed on the south coast in Arnager Bay, where Rees [32] has identified two hybodonts, one *Parvodus* ('*Lissodus*') *rugianus* known from northern Germany, UK, Scania [35], and perhaps also from the Jydegaard Fm. (see below), the other a new species also recognized from the latter formation. The Robbedale Fm. interfingers with the overlying and uppermost formation, the Jydegaard Formation, described in next section. The remaining Cretaceous strata are all marine, of Albian to Santonian age; they have yielded poor, undescribed shark faunas and one acanthopterygian teleost [2], but so far no tetrapods.

5. The Early Cretaceous (Late Berriasian/Ryazanian) at Robbedale

The final, regressive stage of the Nyker Group is the Jydegaard Formation, with its largest exposures, especially of the lower part of the formation, in sand and gravel pits ca 5 km east of Rønne, the larger being 'Carl Nielsen's pit' at Robbedale (Fig. 1B). A small part of this pit, the western corner, is now a geological conservation site. In this pit the exposure comprises the top part of the Robbedale Fm. overlain conformably by the lower 8-10 m of the Jydegaard Fm. (definitions in [14], see [4, 13]), and only the conservation site is well exposed today. Most of the other walls of the now abandoned and partly water infilled industrial sandpit are overgrown with vegetation.

The vertebrate fauna has been collected from the basal 2-3 m of the Jydegaard Fm. (Fig. 3), the base of which is the first thin clay layer above the 'Robbedale Gravel'. A few decimetres with alternating thin sands and clay are succeed by the thickest clay layer (0.5-1 m) of the formation, the sideritic *Neomiodon* bed (Fig. 1C), thus named for the mass mortality layers of this very abundant bivalve. Succeeding this are coarse sand layers with a few thin clays, and approximately 2 m above the *Neomiodon* bed is a 10-20-cm indurated

Fig. 3. Section of the basal Jydegaard Formation in Carl Nielsen's Pit, cleaned by the 'Fossil Project'. Dark layers are rusty sands and clay. The uppermost one, approximately 2 metres above the *Neomiodon* bed, is packed with the snail *Viviparus*. The *Neomiodon* bed itself is concealed 20-30 cm below the ground level.

Fig. 3. Coupe de la base de la formation de Jydegaard, à la sablière de Carl Nielsen, nettoyée par les soins du « Projet Fossiles ». Les niveaux sombres sont des sables et argiles rouille. Le niveau le plus élevé dans la coupe, près de 2 m au-dessus de la couche à *Neomiodon*, est riche en escargots *Viviparus*. La couche à *Neomiodon* est enfouie à 20–30 cm sous le sol.

clay bed, packed with the freshwater snail *Viviparus*. The remaining 6-7 m are alternating sand and clay layers, some with snails and plants [4 (fig. 2), 39].

The *Neomiodon* clay bed is indurated as a clay-iron stone for most of its thickness, but the lower and upper few centimetres still consist of soft clay. All of the vertebrate fossils have been collected from the *Neomiodon* bed, or the sand layer approximately 2 m above it (not immediately below the *Neomiodon* bed, as claimed by Rees [31 (fig. 2)], because those layers have not been well exposed for years). Several layers in the *Neomiodon* bed are completely covered by this extremely abundant bivalve, mostly with both valves preserved together. Additionally, plants, teeth, scales and other vertebrate fragments are often found in this bed, and also in the soft clay. Surprisingly, not until 2002 were the first small complete fish fossils discovered in the *Neomiodon* bed. These are small stem-teleosteans, e.g., *Pleuropholis* [4]. Prior to 2002, only isolated fragments had been found. Other vertebrate fragments are found by washing and sieving the sands from the overlying 2 m; a few may have fallen down from the sand a little higher up in the section, and those collected on top of the *Neomiodon* bed were summarized by Bonde [2].

Since the late 1990s the main part of the collecting has been organized by the 'Fossil Project', a group of unemployed young people, taking care of this and several other important geological localities on Bornholm. This has, among others, resulted in the Robbedale pit now having a clean, well-exposed section of the basal Jydegaard Formation, from which they sieve large amounts of sand (Fig. 3). This is done also in co-operation with the new exhibition centre 'Natur-Bornholm'. At this facility the discovered fossils are often exhibited in the section concerning the geological history of Bornholm.

The age of the lower Jydegaard Formation corresponds to the German 'Wealden', especially its middle part (Middle Bückeberg Fm. = W 3–W 4) according to Piasecki [28] and in agreement with [1], equivalent to the Durlston Beds, Upper Purbeck, as well as to the lower Ashdown Fm., which is the base of the Hasting Beds of the type Wealden in UK. This is why Bonde [4] calls it a 'Purbeck–Wealden' fauna. So the age is Upper Berriasian or Ryazanian, about 140 million years, while the upper parts of the 60-100-m thick Jydegaard Fm. may well cover most of the Valanginian [14].

Jan Rees' ongoing project comprises collecting from all of the Nyker Group localities and sections through the Berriasian and Valanginian.

6. The fauna and environment

The fauna from the pit at Robbedale is reviewed by Bonde [4], and it comprises a few hybodont sharks (teeth, finspines and 'hooks' from the head), amioids (only scales), *Lepidotes* (jaws with tritoral teeth, scales, very common), pycnodonts (vomerine and 'splenial' toothplates and ?scales), *Pleuropholis* and two other small, nearly complete stemgroup teleostean, teleostean scales and fragments, turtles (fragments of carapaces), lacertilians (a lower jaw, see [31]), crocodiles (e.g., teeth of *Pholidosaurus* [2] - perhaps also coprolites with fish fragments, ribs, ?scutes), a few very thin bone fragments (?birds or pterosaurs), and finally two dinosaurian teeth (also [8]).

The environment, as envisaged by Noe-Nygaard et al. [26], is a back barrier coastal strip (the sands) with wash-over fans (layered sand with snails and bivalves) facing a lagoon (deepest parts with clay and *Neomiodon* mass mortality), and drying freshwater pools on the beach (*Viviparus* mass mortalities), the barrier protecting the fresh to brackish lagoon from the sea, and the sand being transported from nearby rivers. They imagine a narrow half-peninsula protecting the lagoon [25]. A setting somewhat like that of the Florida Keys, with a mixture of marine, lagoonal, brackish, freshwater and land fauna. The mass mortalities of *Neomiodon* were probably caused by toxins from blooms of dinoflagellates, of which one species is totally dominating in the basal Jydegaard Fm. Additionally, the small fish may have been poisoned [4].

Because there are both plants and small land animals (the lacertilian - and rare mammals could be expected) on the barrier, the size of which we do not know, dinosaurs may well have been feeding here, and theropods may have hunted along the shoreline.

7. The dinosaurs

Dinosaur remains from Scandinavia are scarce. Persson [27] described a tooth of a large carnivorous dinosaur from Ivö, possibly a tyrannosaurid, and lately two small ornithopod teeth have been found at Åsen (currently being studied by Rees, Siversson and Lindgreen from Lund; pers. comm. by Rees 2002). Significantly, a few avian fragments have been found on Ivö, e.g., a vertebra named *Parascaniornis stensioei* by Lambrect [17] and supposed to be a flamingo relative confamilial with *Scaniornis*, earlier described from the Danian in Limhamn. Ella Hoch recognized the holotype in Geological Museum, Copenhagen, as a hesperornithiform, and later Rees & Lindgren [34] presented four fragmentary limb bones from the Swedish collections, two of which they refer to *Hesperornis* and Baptornitidae.

Two dinosaur teeth have been recovered in Carl Nielsen's Pit at Robbedale, the first, discovered in 2000, being a tooth from a theropod (see [8]) and the other representing a recent find from 2002, described here for the first time. Both of the teeth have been found in the sand and clay at or just above the *Neomiodon* bed dug away by the 'Fossil project'.

The first tooth in September 2000 in fact collected by hand in the sand piles by a young student who was participating in a palaeontological field course taught by the authors, and very appropriately called 'The hunt

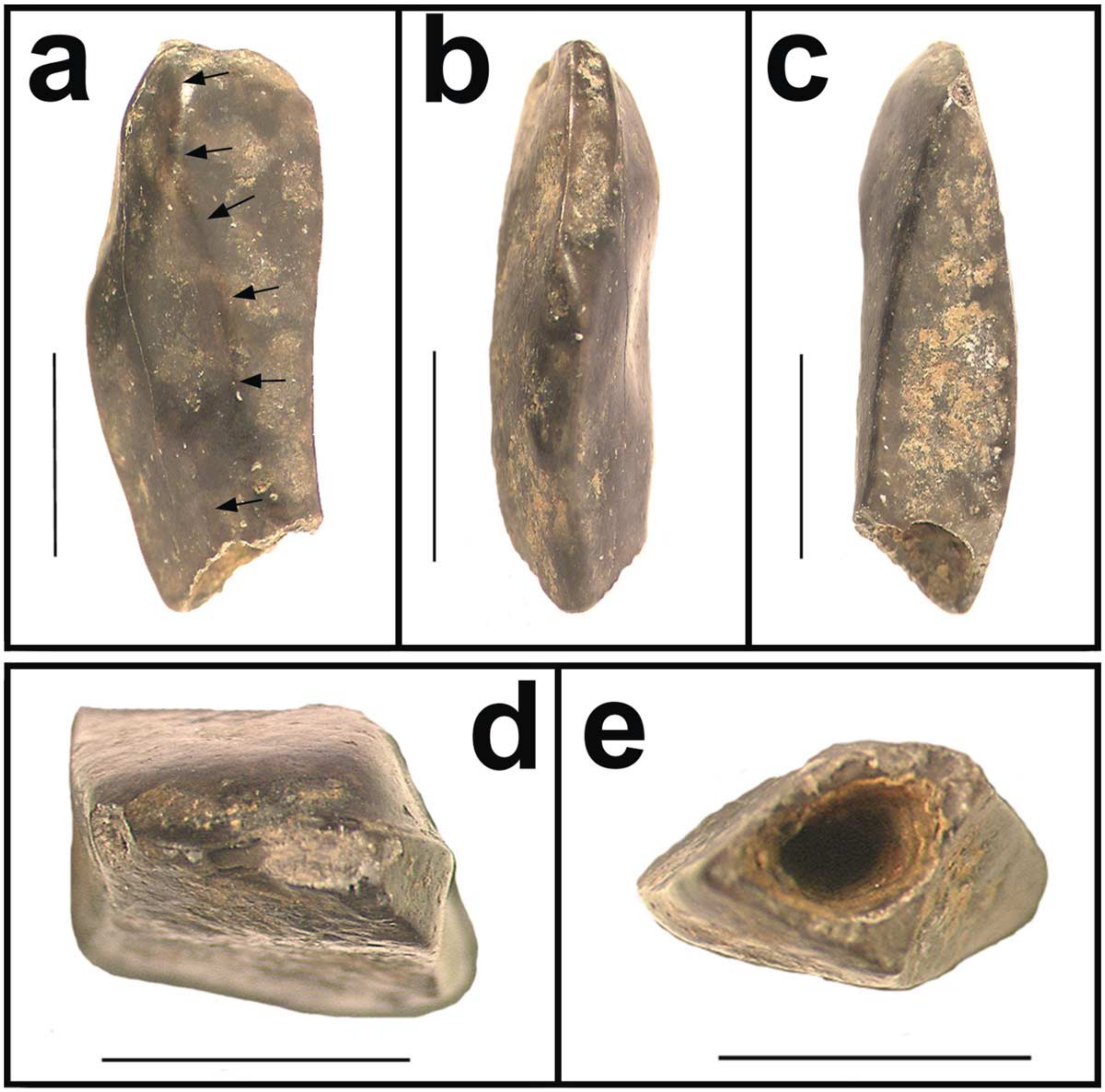

Fig. 4. Sauropod tooth crown in (**a**), labial view, displaying blunt, curved ridge (arrows); (**b**), mesial view with distinct wear facet from opposing tooth; (**c**), distal view with extensive wear facet from opposing tooth; (**d**), top view showing medial wear facet and distinct eroded areas; (**e**), view of the extensive pulp cavity, indicating root resorption. All scale bars: 5 mm. Borrowed from the 'Fossil Project', Robbedale, Bornholm.
Fig. 4. Couronne d'une dent de sauropode ; (**a**) vue labiale, montrant une crête émoussée et courbée (flèches) ; (**b**) vue mésiale, avec facette distincte d'usure d'une dent opposée ; (**c**) vue distale, avec une facette d'usure très marquée d'une dent opposée ; (**d**) vue du haut d'une facette d'usure mésiale et des zones distinctes érodées ; (**e**) vue de la cavité pulpaire importante, indiquant une résorption de la racine. Échelle : 5 mm. Prêt du « Fossil Projektet » Robbedale, Bornholm.

for Danish dinosaurs' - local television happened to be filming the course at that very moment. The second tooth was found by members of the 'Fossil project' in the summer 2002.

8. A herbivorous dinosaur

The tooth (Figs. 4 and 5) is represented by a somewhat worn and eroded crown, rendering positive iden-

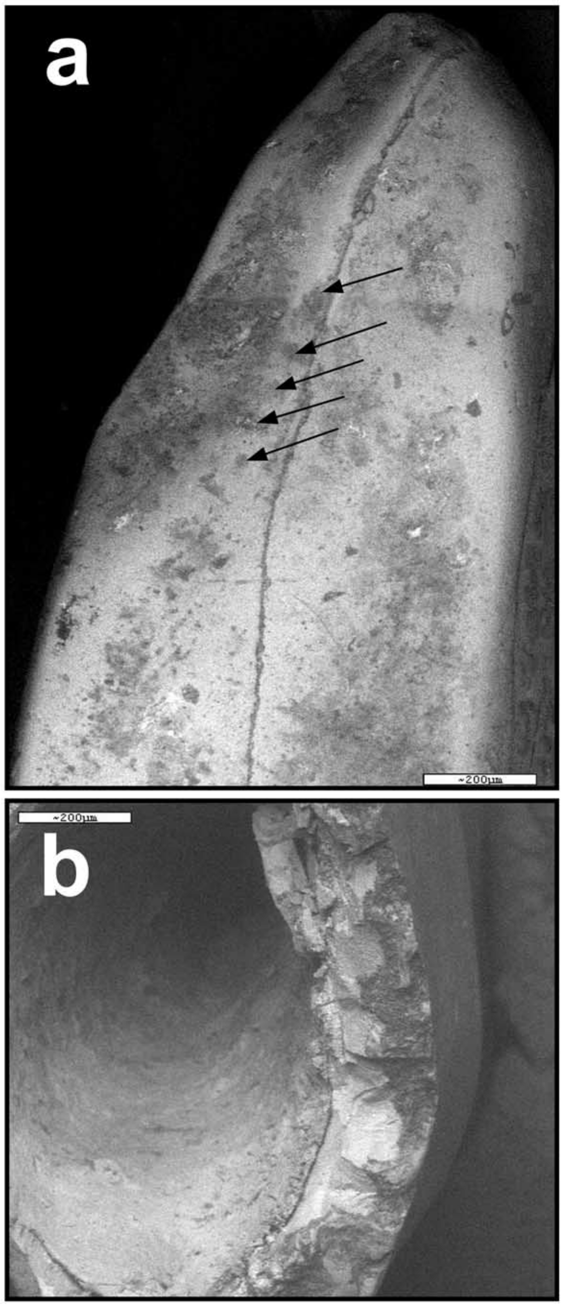

Fig. 5. Sauropod tooth (SEM photos): (**a**) mesio-labial view, with heavily worn denticle cores (arrows); (**b**) broken edge of the base of the tooth, showing enamel, approximately 200 γm thick. Scale bars: 200 µm.

Fig. 5. Dent de sauropode (photos au MEB) : (**a**) vue mésio-labiale, avec cœurs de denticules très émoussés (flèches) ; (**b**) bordure cassée de la couronne, montrant l'émail, d'épaisseur 0,2 mm environ. Échelle : 0,2 mm.

tification difficult. The tooth does, however, bear distinct resemblance to worn sauropod teeth, being overall elongate, slender and somewhat subrectangular in cross-section. The enamel is shiny black and smooth without any wrinkles, albeit with some faint lines on the lingual face. The labial face (Fig. 4a) is generally convex, whereas the lingual face is near planar. Slight erosion is present on the lingual face, probably post-mortem. Total crown height as preserved is 14.5 mm, and the lower margins are irregularly broken, so that nothing of the root is preserved. The tip of the crown is constricted into a rounded, chisel-like end, which is slightly eroded both at the distal and medial edges. At what is here interpreted as the mesial face of the tooth, the crown tip bears a dorsoventrally elongate wear facet (Fig. 4b), 6.7 mm in length and approximately 1.3 mm in width, forming a shallow trough with faint, but distinct and sharply raised edges. At the very tip of the crown (Fig. 4d) is a distinctive erosion scar, clearly of a taphonomic nature, resulting in an area completely lacking defined edges, and with a very rough, pitted structure.

Along the labial edge of the wear facet a faint ridge is running in a sinusoid curve towards the root, but failing to reach the root (Fig. 4a). Significantly, approximately at the 2/3 level of the wear facet the ridge bears 5–6 small, heavily eroded serration denticles (Fig. 5a), indicating the presence of a serrated carina in unworn teeth. Adjacent to this faint ridge is a distinct line, running nearly straight along the entire length of the crown. This represents a zone where a thin layer of enamel has disappeared from the line towards the medial edge of the tooth.

The opposite face, interpreted as the distal face, is heavily worn, but this is clearly not taphonomic erosion. A long, triangular wear facet extends from the root almost to the crown tip, being 10.8 mm in longitudinal outline (Fig. 4c). The facet is smooth, with numerous small pits and faint scratch marks, but the edges are raised, which is particularly distinct at the labial side near the root, indicating that the facet was formed by an object sliding repeatedly up along the distal edge of the crown. This object was evidently slightly narrower than the crown and is here interpreted as being the crown tip of an opposing tooth.

The crown is sub-trapezoidal in cross-section around the middle, with edges 4.5–6.5 mm long. The labial face bears a distinct ridge, forming the fourth 'angle' of the trapezoidal section. The ridge is low and blunt, extending along the entire length of the tooth, bending in a sinusoid curve along a rather wide, shallow depression, oval in outline, at the mesial side of the ridge. The ridge terminates at midsection near the root. The depression appears to be part of the natural morphology of the tooth and not owing to wear, potentially providing an easily recognisable feature.

The broken edges in SEM photos indicate that the tooth has its enamel preserved about 0.2 mm thick (Figs. 4e and 5b). The dentine is, however, very thin and the pulp cavity is conspicuously large. Along with the fact that the specimen represents a worn tooth, this indicates distinct resorption of the root.

The tooth bears resemblance to the slender, apomorphic teeth of advanced sauropods, such as diplodocoids and titanosaurs. Diplodocoids have elongate, narrow, so-called pencil-like teeth, but the present tooth is precluded from belonging to this taxon, as it appears to have borne a serrated carina [41,43]. Rather, a titanosaurian (sensu lato) affinity seems more probable, also in accord with its age. Plesiomorphic titanosaurs have serrated carinae, and terminal wear facets on titanosaur teeth are usually produced by tooth-to-tooth contact [7, 36, 43]. The tooth from Bornholm appears to have just such a facet at the crown tip, although substantial crown to crown contact was present much further down the crown, as evidenced by the elongate wear facet along the distal edge. Thus, we refer this tooth to the Sauropoda, and provisionally to the Titanosauriformes.

In the English Wealden sauropod remains are taxonomically diverse and fairly common [18], and indeterminate sauropod teeth have been recovered [18 (plate 36)]. Overall, their chisel-like shape is not unlike the specimen from Bornholm, although they appear to be distinctly more elongate. Other sauropod teeth from the English Wealden (e.g., cf. *Pleurocoelus*) are distinctly less similar to the specimen from Bornholm. Unfortunately, taxon identification based on dental morphology in sauropod dinosaurs is still very tentative. A few of the named taxa from the Wealden are based on teeth, but these are not similar to the one from Bornholm.

9. The theropod tooth

In September 2000, a theropod tooth was recovered from the sand piles in Carl Nielsen's Pit. Diagnostic features used in identification of theropod teeth include size and proportions of the crown, crown curvature and denticle morphologyand number (e.g., [9, 11, 29, 44]). The tooth from Bornholm is identified as a dromaeosaurine dromaeosaur. The overall morphology of the crown, its fairly wide and less blade-like mediolateral cross sections and crown curvature (Fig. 6a and b) bears substantial resemblance to maxillary and dentary teeth of the Late Cretaceous *Dromaeosaurus* from North America (Fig. 5e), which remains the only well-known member of the more plesiomorphic Dromaeosaurinae subgroup of the Dromaeosauridae [9]. Significantly, both the mesial and distal carinae are turned slightly medially, characteristic of *Dromaeosaurus*, although the distal carina is less medially directed in the specimen from Bornholm.

The preserved crown height is 21.7 mm, the fore and aft basal length is 9.7 mm and the basal mediolateral width is 6.6 mm. This is roughly 25% larger than *Dromaeosaurus* (Fig. 6e), indicating an overall length of the animal of around 3 m. The tooth was old and worn when shed by the animal, as indicated by distinct wear facets towards the apex (Fig. 6a), which also extend somewhat proximally on the tooth crown, and indicated by wear of the denticles of the distal carina. Unfortunately taphonomic wear has subsequently damaged parts of the tooth surface, and small sand grains have frequently been pushed through the dark enamel. As this is a shed tooth and as the basis is irregular, this indicates that the crown height could have been slightly greater in life.

Both carinae are finely serrated (Fig. 6c and d). The mesial carina is worn and serration denticles are present only as dentine cores towards the apex (Fig. 6c), alternating with lighter areas between the denticles. The distal carina bears serration denticles all along the distal edge of the crown. The denticles are squarish and chisel-like in form and are rather labiolingually broad. Blood grooves are indistinct or absent. Denticle size scales with overall crown height in theropod teeth [10], and it is preferable to use a ratio index instead of absolute denticle number [29]. The tooth from Bornholm has very fine serrations per unit of scale. The apical part of the mesial carina bears 30.7 denticles per 5 mm (6.1/1 mm) and the distal carina (Fig. 6d) bears 30.1 denticles per 5 mm (6.05/1 mm). This results in an index of 1.01, nearly identical to *Dromaeosaurus*. The labiolingually wide, squarish

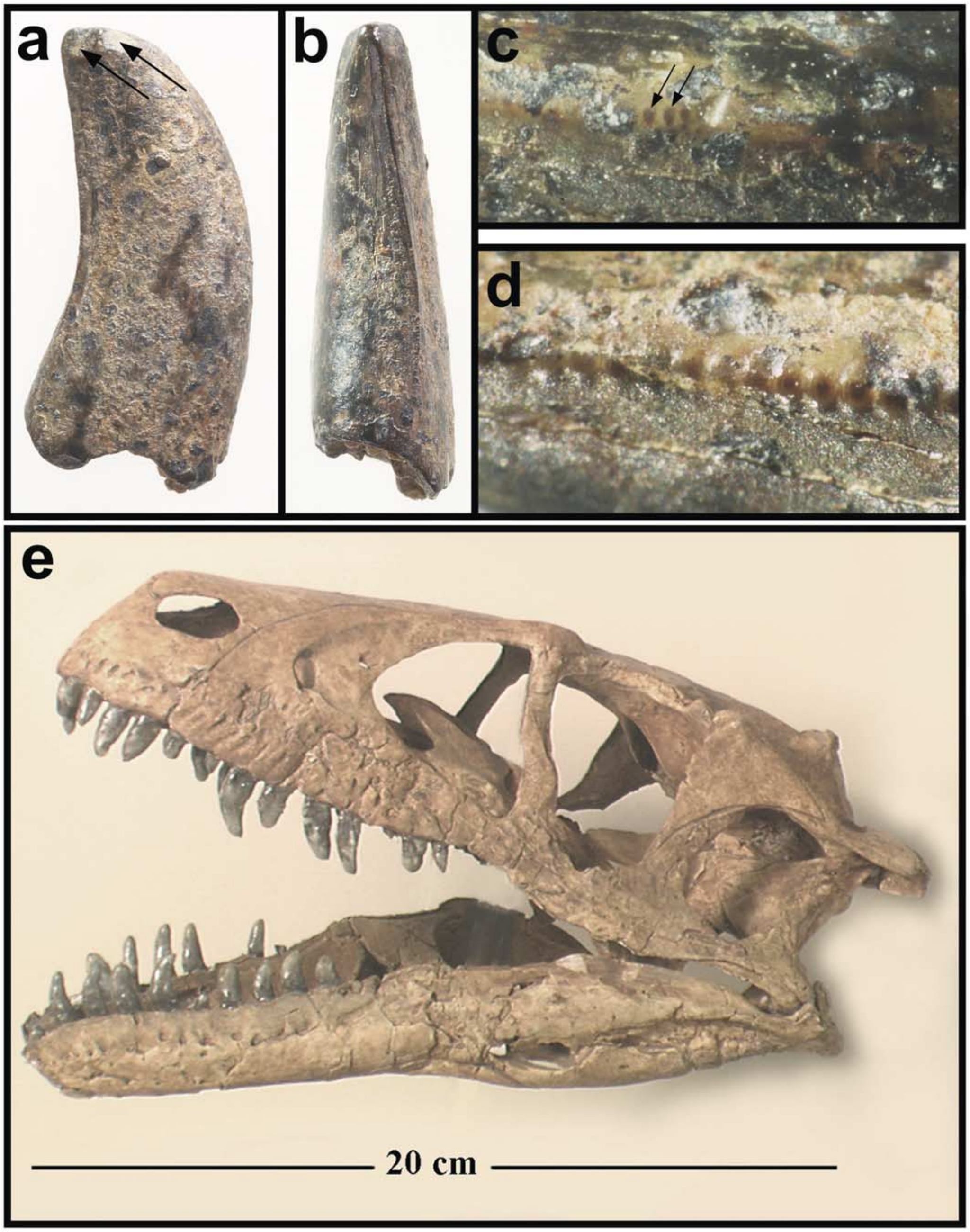

Fig. 6. Tooth of *Dromaesauroides bornholmensis* Christiansen & Bonde 2003 (MGUH DK No. 315): (**a**) lingual view, with wear facets (arrows); (**b**) distal view; (**c**), close-up of worn denticle cores on mesial carina (arrows); (**d**) close-up of serration denticles on distal carina; (e) cast of the skull of *Dromaeosaurus albertensis* (courtesy of Dr Philip J. Currie). Geological Museum, Copenhagen.

Fig. 6. Dent de *Dromaeosauroides bornholmensis* Christiansen & Bonde 2003 (MGUH DK n° 315) : (**a**) vue linguale avec facettes d'usure (flèches) ; (**b**) vue distale ; (**c**) agrandissement des cœurs des denticules usés sur la carène mésiale (flèches) ; (**d**) agrandissement des denticules de la carène distale ; (**e**) moulage du crâne de *Dromaeosaurus albertensis* (avec l'aimable autorisation du Dr Philip J. Currie). Musée de Géologie, Copenhague.

denticles with very faint or even absent bloodgrooves look very similar to those of *Dromaeosaurus*, in which bloodgrooves are usually confined to the bases of the teeth and are indistinct [9]. The condition in velociraptorine dromaeosaurs [9] looks very different.

Despite the close similarity to *Dromaeosaurus*, there are reasons to suppose that the specimen from Bornholm is not congeneric. One is the age, and Zinke's [44] referral of teeth from the Upper Jurassic of Portugal to *Dromaeosaurus* notwithstanding, it appears highly unlikely that the same genus should span more than 60 million years. Additionally, although the denticle index of the Bornholm specimen is near identical to *Dromaeosaurus*, the individual denticles are distinctly smaller, despite the larger size of the tooth. *Dromaeosaurus* only has 13-20 denticles/5 mm [29], not 30. Thus, the dromaeosaur from Bornholm most likely represents a new genus and species [8], called *Dromaeosauroides bornholmensis*.

The dromaeosaur from Bornholm is one of the oldest in the world, being surpassed in age only by some Late Jurassic teeth from Portugal [44], and possibly by teeth from the Middle Jurassic of England [19], although their dromaeosaurian affinities are a bit tentative. Jensen and Padian [16] referred postcranial remains from the Morrison Formation (Upper Jurassic) of Colorado to the dromeosaurs, but this is also tentative. Another possible dromaeosaur is Owen's *Nuthetes* (Owen 1879, a lower jaw with a few teeth initially identified as a lacertilian, later as a crocodilian) according to Milner [21, 22]. It is from the Durlston Fm. of the Purbeck Group - Middle Purbeck according to Weishampel [42], and therefore probably only a little older than the Robbedale tooth (correlating to Upper Durlston Fm. and Upper Purbeck - see discussion in [4]). We are, however, not entirely convinced, that *Nuthetes* can indeed be referred to the Dromaeosauridae s.s., as the teeth of this presumably juvenile form seem to lack autapomorphic features of the group [8]. The tooth from Bornholm should be regarded as the first undisputed Lower Cretaceous dromaeosaurid from Europe and one of the oldest occurrences of the Dromaeosauridae in the world.

10. Conclusion

Our initial expectations [see 2] were finding small herbivores as the first dinosaurian teeth, say hypsilophodonts or perhaps even *Iguanodon*, but to our surprise, the first one from 2000 turned out to be a rarity, like a dromaeosaur, which was completely unexpected, as dromaeosaurs were not known for sure in European Lower Cretaceous rocks. Finding teeth over 2 cm high from dromaeosaurs indicate rather big individuals of *Dromaeosauroides*, probably over 3 m long, so more resilient appendicular bones, e.g. claws could be expected also to be present in the lagoon sands.

Herbivorous dinosaurs were, as noted above, to be expected, but a sauropod tooth would not appear to be the first choice. One would tend to favour a smaller ornithopod, e.g., a dryosaurid or hypsilophodontid. The presence of sauropods could indicate the possibility of discovery of heavy limb bones and perhaps titanosaurian scutes, but it is worth remembering that industrial exploitation of the Robbedale Sand immediately below the *Neomiodon* bed has occurred for several decades, where also the lower Jydegaard Fm. above this bed was cleared away, and apparently no larger bones have ever been found. So perhaps (larger) dinosaurs are extremely rare in this deposit at this locality. We can only hope that the more systematic bulk sampling and washing by the 'Fossil project' will, despite the poor odds, turn up some more dinosaurs - or perhaps something as exciting as the first Danish Mesozoic mammal.

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