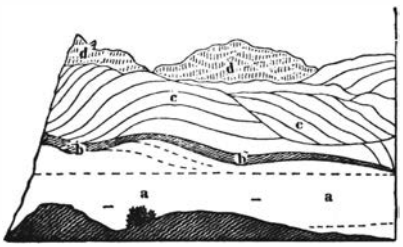

A DANISH HISTORICAL VIEW OF THE BOUNDARY

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The classical question in drawing the boundary between the Mesozoic and the Cenozoic is whether it should be drawn at the base of the Danian stage or at the top. This question, and matters connected with it, have been under debate for more than 150 years, if we admit Forchhammer's paper from 1825 to be the starting point of the discussion. A thorough historical survey of this largely biological problem is given by Berggren (1964) in English; readers of Danish will find supplementary information in Ravn (1903), Milthers (1908), Ødum (1926), Hintze (1937), and Garboe (1959, 1961).

Among the earliest writers describing localities with Maastrichtian and/or Danian strata one might mention Dyssel (1757), Abildgaard (1759, 1781), Pontoppidan (1763, 1767), Steffens (1810), Bedemar (1820), and Bredsdorff (1824a,b).

The first thorough descriptions of Stevns Klint and Møns Klint are found in Abildgaard's works from 1759 and 1781, respectively (see cover of the book).

In Forchhammer's paper (1825) "Om de geognostiske Forhold i en Deel af Sjælland og Naboeõerne", the strata in Stevns Klint were given their first clear description, as follows (from top to bottom):

Forchhammer 1825	Present interpretation
Kalksteen-Conglomerat	Quaternary breccia of lower Danian bryozoan limestone
Corallit-Kalksteen	Bryozoan limestone (lower Danian)

(cont.)

Forchhammer 1825	Present interpretation
Leer og Ceritkalksteen	Cerithium limestone (lower Danian) Fish clay (basal bed of the Danian) Indurated white chalk (Upper Maastrichtian)
Kridt med Flint	Upper Maastrichtian white chalk

From his "Ceritkalksteen" Forchhammer cited the following fossils: "En Trochus. Trochus niloticæformis Slotheim, To Cerithier, En Ampullaria(?), En Cypræa, En Buccinum (?), En Patella, En Arca, En Mytilus, En Pecten, En Turbinolia, En Dentalium, En Echinit". On the basis of these fossils and the fact that his "Ceritkalksteen" bed rests on white chalk, Forchhammer considered the "Ceritkalksteen" as an equivalent of the (Tertiary) "calcaire grossier" in France. The clay bed he saw as an analogy to the (also Tertiary) "Argile plastique" and London Clay in France and England. From the fossil fauna known to Forchhammer from the (middle Danian) limestone in Fakse ("Faxöe"), he concluded that there is such similarity between that and the fauna of his "Ceritkalksteen" in Stevns Klint that these limestones must be considered identical. This correlation was accepted for many years afterwards and consequently the "Ceritkalksteen" came to be known by the name of "Faxe-laget" (i.e. "the Fakse bed").

In the same paper Forchhammer (1825) concluded that the white chalk of Møns Klint (Maastrichtian), owing to its being sandwiched with Quaternary clays, belongs to the great pebble formation ("den store Rullesteens Samdanning" or Geschiebe), and was therefore, likewise, of Tertiary age. He supported this with fossil evidence, noting "*Ananchytes ovata*, *Ostrea vesicularis*, en *Gryphæa*, *Belemnites muscronatus*, to *Flustra* Arter" in common with the bryozoan limestone of Stevns Klint. His views were soon after repeated in English (1828) and in German (1829).

Among the geologists who read Forchhammer's papers with scepticism was Charles Lyell, who came to Scandinavia in 1834 and used the occasion to travel together with Forchhammer to Stevns Klint, Fakse and Møn. When seeing the cliffs of Møn, Lyell had to accept the fact that the white chalk lies intermingled with and in many places also lies on top of sands and boulder clay, but he was of the opinion that this mixing of deposits had taken place after the deposition of the chalk in an era of "comparatively modern date" (1837). There was thus no proof of all the beds having been formed at the same time, and Forchhammer's arguments for a Tertiary age of the Møn chalk were to be discarded. Lyell's views were published in a number of papers (e.g. 1837). His views on Stevns Klint and Fakse largely corresponded with Forchhammer's as far as the series of strata is concerned, and he

accepted Forchhammer's theory of the identity between the "Ceritkalksteen" and the limestone in Fakse Quarry. For the whole series of limestones in Stevns Klint, however, he assumed a Cretaceous age.

His arguments for a Cretaceous age of the "Ceritkalksteen" (which he called "Faxoe bed") include the occurrence of "*Baculites faujasi*", "*Belemnites mucronatus*", and an "Ammonite". These fossils clearly derived from those parts of the basal Danian hardground that involve Maastrichtian host sediment, so Lyell's belief that the whole of this complex bed was Cretaceous is easily understandable.

It is less easy to give a plausible explanation of Lyell's statement that "*Belemnites mucronatus*" also occurs in the "Faxoe bed". Belemnites (*Belemnitella junior* and *Belemnella casimirovensis*) do occur in the Upper Maastrichtian white chalk of Stevns Klint, but they are very rare. There is little chance that Lyell himself actually found a belemnite *in situ* in the "Faxoe bed". It has been suggested that Lyell may have purchased a belemnite from workmen at Fakse quarry, where belemnites occur not uncommonly in the Quaternary deposits overlying the Danian limestone (Johnstrup, 1876).

In "Danmarks geognostiske Forhold ..." (1835) Forchhammer admitted his rashness in comparing his clay bed in Stevns Klint with the Argile plastique and his "Ceritkalksteen" with the Calcaire grossier. He now also referred the "Ceritkalksteen" (or "Faxöe-Kalk") to the Cretaceous, and there can be little doubt that this change of opinion was induced by Lyell's views. The logotype to this article reproduces Forchhammer's (1835) view of the Stevns Klint succession.

In the same book Forchhammer outlined the "Kridtformation" (Cretaceous formation) in Denmark and Scania as follows (from top to bottom):

4. Faxøekalk, Blegekridt (more or less indurated, white Danian limestone) and Limsteen (Danian bryozoan limestone)

3. Skrivekridt (white chalk)

2. Saltholms-Kalk (fine-grained, hardened limestone of Danian age)

1. Grønsand (greensand) and Gråkridt (grey chalk) in Bornholm and Scania

Although Forchhammer thus listed the Saltholm limestone as being older than the (Maastrichtian) white chalk, on another page he mentioned the possibility of its being younger (1835, p. 84). The proper age of the Saltholmskalk was only correctly established about a decade later.

In 1846 Desor coined the term "terrain danien" for the sequence of limestones resting upon the white chalk in Denmark and at the same time also indicated that some limestones in the Paris basin were to be seen as parallels of the "terrain danien" in Denmark. In Desor's opinion, this new stage evidently belonged to the Cretaceous as its fauna comprised fossils like "les Ananchytes (i.e. *Echinocorys*), les Holaster et les Micraster". For the "terrain danien" Forchhammer (at a meeting in 1847) proposed the Danish name "Det nyere Kridt" (i.e. "Newer Chalk").

In his paper from 1849 Forchhammer mentioned the fact that borings near Copenhagen had shown the "Saltholms-Kalk" to lie on top of the white chalk, thus showing the younger age of the former.

A major step forward was taken with Johnstrup's paper "Om Grønsandet i Sjælland" (1876) in which he published the results of 6 borings in the Lellinge area. In 1842 a greensand formation had been found in the area that was originally believed to correspond in age to the Upper Cretaceous greensand in the island of Bornholm (i.e. the Cenomanian Arnager Greensand and the Santonian Bavnodde Greensand). Johnstrup's borings at Lellinge showed the following sequence (from top to bottom):

4. Quaternary
3. Greensand
2. Saltholmskalk
1. Limsten (bryozoan limestone of the Danian).

Consequently the greensand at Lellinge was clearly younger than the Saltholmskalk, and Johnstrup referred the greensand to the "Nyere Kridt" as its youngest member. From the adjoined fauna lists by Mørch (also 1876) from the Arnager Limestone and greensands in Bornholm and from the Lellinge Greensand, respectively, Johnstrup concluded that the differences in fauna were so great that these greensands could not possibly be contemporaneous. Furthermore, Johnstrup stressed that whereas ammonites and belemnites occur in the white chalk, they are not found in the Fakse limestone at Fakse, nor are they found in the Limsten, Saltholmskalk, Blegekridt or (Lellinge) greensand. The fact that ammonites and belemnites are found in the "Faxelaget" ("Faxe bed") in Stevns Klint should not, according to Johnstrup, lead to the erroneous assumption that they are found in "Det nyere Kridt" proper. (His explanation of Lyell's belemnite from the "Faxoe limestone" has been commented upon already).

Johnstrup summed up the Upper Cretaceous and Danian deposits in Denmark as follows:

	Greensand	
	Saltholmskalk	Lellinge
"Nyere Kridt"	Limsten	
(=Danian)		
without	Faxekalk and limsten	
Belemn.mucronata	Faxelaget	Stevns and Fakse
	Fiskeler	
Younger Senonian		
Formation with	Skrivekridt	
Belemn.mucronata	(=white chalk)	
Older Senonian	Arnagerkalk	Bornholm
Formation with	Grønsandsten	
Belemn.westfalicus		

Von Koenen's work "Über eine Paleocäne Fauna von Kopenhagen" (1885) was a major palaeontological contribution through which the Selandian (Paleocene) fauna of Eastern Denmark was first really thoroughly described. Whereas Johnstrup had placed the Lellinge Greensand within the Danian, von Koenen the year after (1886) clearly stated that on palaeontological grounds the Lellinge Greensand ("Glaukonitsand-Formation") belonged to the Paleocene and not to the Cretaceous.

At the Naturalists' Meeting in Stockholm in 1898 K.A. Grönwall (see Grönwall, 1899), introduced the Zone of *Crania tuberculata*. This characteristic brachiopod is frequent in certain facies of the upper Danian and is also very abundant as a redeposited fossil in the basal conglomerate of the Selandian. In his Zone of *Crania tuberculata* Grönwall included not only the upper Danian, but also the basal conglomerate of the Selandian, maintaining that one should place the Cretaceous/Tertiary boundary on top of the latter, i.e. between his "Crania limestone" and the Lellinge Greensand.

In his paper on the "Yngra Krita" (=Danian) of Scandinavia, Hennig (1899) concluded on the basis of the fauna as a whole that the Danian fauna is transitional between the Cretaceous fauna of the white chalk and the "Eocene" fauna of the "tuffeau de Ciply", but still retaining a distinctly Cretaceous character (p. 156).

Ussing (1899) stated, in his description of the Danian in "Danmarks Geologi ...", that the "Ceritkalk" in Stevns Klint (=the Cerithium limestone) is not an equivalent to the limestone in Fakse.

In Ravn's (1902-1903) classical works on the Mollusca of the Danish "Cretaceous" (i.e. Cretaceous and Danian) the Danian and "Younger Senonian" are outlined in like way:

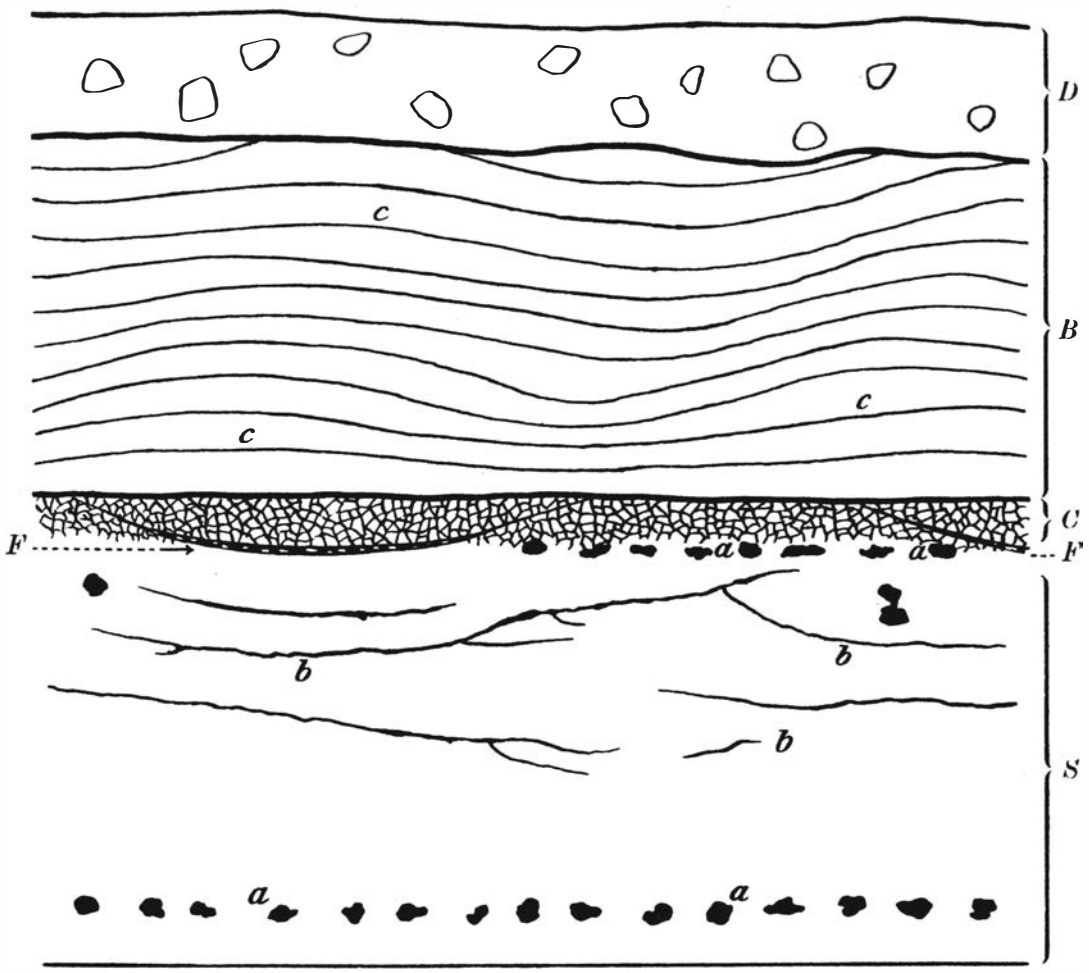
Danien.	**Craniakalk.**	*Crania tuberculata* NILSS.
	Saltholmskalk, Blegekridt, Bryozokalk, Koralkalk.	*Ananchytes sulcata* GOLDF. *Dromiopsis rugosa* v. SCHLOTH. sp.
	Lakune.	
Yngre Senon.	**Cerithiumkalk.**	*Ananchytes ovata* LESKE. *Scaphites constrictus* SOW. sp. *Belemnitella mucronata* v. SCHLOTH. sp.
	Fiskeler.	
	Skrivekridt.	

Thus, Ravn placed the boundary between the Maastrichtian (=Younger Senonian") and Danian above the Cerithium limestone, not below the Fish clay and Cerithium limestone as Forchhammer and other geologists had done. Ravn's view of the boundary is further elucidated by his drawing of the strata in Stevns Klint (Fig. 1) from which it is completely clear that by his "Cerithiumkalk" he not only means the (Danian) Cerithium limestone proper (*sensu* Rosenkrantz, see below) above the Fish clay, but also the lithologically very similar part of indurated white chalk of Maastrichtian age. The fauna lists compiled by Ravn thus come to be composed of a mixture of Maastrichtian and Danian species. From his fauna lists Ravn concluded that the fauna was clearly a "Senonian" one, and therefore he interpreted the "Cerithiumkalk" horizon (and the Fish clay within it) as the top of the "Upper Senonian" in Denmark.

Fauna lists published by Brünnich Nielsen (1917a) from the "Cerithiumkalk" horizon seemed to vindicate Ravn's view of this horizon as containing a clearly Senonian fauna.

In his paper from 1919 Brünnich Nielsen presented a long discussion of the Cretaceous or Tertiary affinities of the Danian. On faunistic grounds he found the Tertiary character of the Danian fauna quite evident.

Further evidence in support of a Tertiary age of the Danian was presented by Rosenkrantz in his important paper on the "Craniakalk" from 1920. Rosenkrantz showed that there is a number of Paleocene species common to both the "Lower Craniakalk" (=upper Danian) and the "Upper Craniakalk" (=the basal conglomerate of the Selandian) such as *Pecten sericeus*, *Lima testis*, *Argiope scabricula*, *Trochocyathus? calcitrapa*, *Nucula densistria*, and *Leda ovoides*, species which also occur in the Lellinge Greensand itself.



Skematisk Profil af Stevns Klint. — *S.* Skrivekridt; *a*, Lag af Flintknolde; *b*, Flint udskilt i Sprækker. *F.* Fiskeler. — *C.* Cerithiumkalk. — *B.* Bryozokalk; *c*, Flint i sammenhængende Lag. — *D.* Diluvium.

Fig. 1. Diagrammatic section of Stevns Klint from Ravn (1903 p. 388). S: White chalk; a, horizon of flint nodules; b, flint in crevices. F: Fish clay. C: Cerithiumkalk. B: Bryozoan limestone; c, coherent horizons of flint. D: Quaternary.

In his two papers from 1924 and 1940 Rosenkrantz was able to show that what had hitherto been called "Cerithiumkalk" was really a mixture of two things: 1) hardened Upper Maastrichtian white chalk ("hærdnet Skrivekridt") below the Fish clay and 2) Brissopneusteslaget" ("the Brissopneustes bed") *sensu* Rosenkrantz, 1924 = Cerithium limestone s.str. (*sensu* Rosenkrantz, 1940) above the Fish clay. The two limestones were shown to contain widely different faunas, the fauna in the Cerithium limestone s.str. showing a strong affinity to the Danian whereas the

fauna of the hardened white chalk was found to be a typical Cretaceous fauna with ammonites, Cretaceous bivalves etc.

The importance of these two papers by Rosenkrantz can hardly be over-rated, because herein the complex nature of the Maastrichtian/Danian boundary in Stevns Klint is for the first time described in the way that geologists today agree to interpret it.

The controversy among early Danish geologists on the Cretaceous/Tertiary boundary was first and foremost concerned with the problem of where to place the boundary in the sequence, a discussion in which Mesozoic and Cenozoic faunal affinities were the main tool.

This discussion has now ebbed away. Left for the present generation is a thorough analysis of the changes in macro- and micro-fauna and in micro-flora around the generally accepted boundary between Maastrichtian and Danian, supplied with sedimentological and geochemical investigations. Continued studies will throw light on the size of the Maastrichtian/Danian hiatus in different parts of the country and may also provide background information of importance for the evaluation of hypotheses trying to describe the reasons for the changes in biota at the Cretaceous/Tertiary boundary.