Danian ammonites: A discussion

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Possible ammonite survivors reported from the lowermost Danian deposits of Denmark (Stevns Klint) and The Netherlands (Curfs-Ankerpoort quarry) are questioned. Some of the specimens from Denmark are almost certainly reworked from the uppermost Maastrichtian deposits. As concerns the remainder of the reported material, reworking is also possible, at least theoretically. On the basis of Ockham's Razor, the hypothesis that all specimens are reworked from the Maastrichtian strata must be preferred until compelling evidence for Danian survivors is proven. Such evidence may be potentially provided by articulated ammonite aptychi located in Danian deposits or by aptychi revealing Danian isotopic signals.

Key words: K-Pg boundary, extinction, survival, ammonites, aptychi, reworking, hardgrounds, Danian, Maastrichtian, Denmark, Netherlands.

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Ammonites belong to the most frequently quoted victims of the end-Cretaceous biotic crisis, although the exact pattern of their extinction is difficult to recognize due to problems of interregional correlation. In Europe, 14 or 15 ammonite species may have extended to the very top of the Maastrichtian (Kennedy 1993). Recently, some authors have suggested that a few ammonites may have survived into the early Danian. Possible Danian ammonite survivors have been reported from Denmark by Surlyk & Nielsen (1999) and from The Netherlands by Smit & Brinkhuis (1996) and Jagt (1999). The problem is worth discussing in the context of controversy over the nature of the Cretaceous-Paleogene (K-Pg) turnover.

Denmark

Internal and external moulds of *Baculites vertebralis* and *Hoploscaphites constrictus* have been known for a long time from the Cerithium Limestone, exposed at Stevns Klint, south of Copenhagen (Rasmussen 1971, Birkelund 1979, 1993, Surlyk & Nielsen 1999). The Cerithium Limestone and the underlying Fish Clay, both of earliest Danian age, form infillings of small basins between the crests of the uppermost Maastrichtian bryozoan mounds. The Cerithium Limestone and the crests of the Maastrichtian mounds are truncated by a hardground, overlain by the lower Danian bryozoan limestone (Fig. 1a).

The ammonites from the Cerithium Limestone were regarded as being derived from the Maastrichtian chalk (Birkelund 1979, 1993), a view challenged by Surlyk & Nielsen (1999). They wrote: "The Maastrichtian chalk beneath the Fish Clay is unlithified even today. Only the crests of the Maastrichtian mounds became lithified in connection with erosion and hardground formation *after* deposition of the Cerithium Limestone. Ammonites could thus only be reworked before the dissolution of the aragonite shell, and reworking of ammonite casts or moulds could not have taken place *during* deposition of the Cerithium Limestone" (Surlyk & Nielsen 1999: 117). However, these doubts cannot be sustained, for the following reasons:

1) The Maastrichtian chalk must have become locally lithified *prior* to or *during* the deposition of the Fish Clay and the Cerithium Limestone. This is indicated by the occasional presence of angular clasts of Maastrichtian chalk and moulds of Maastrichtian bivalves in the Fish Clay (Christensen et al. 1973, Surlyk & Håkansson 1999, Heinberg 1999).
2) Many aragonitic shells of Maastrichtian fossils survived unchanged until the early Danian. This is clear from the presence of voids marking the posi-

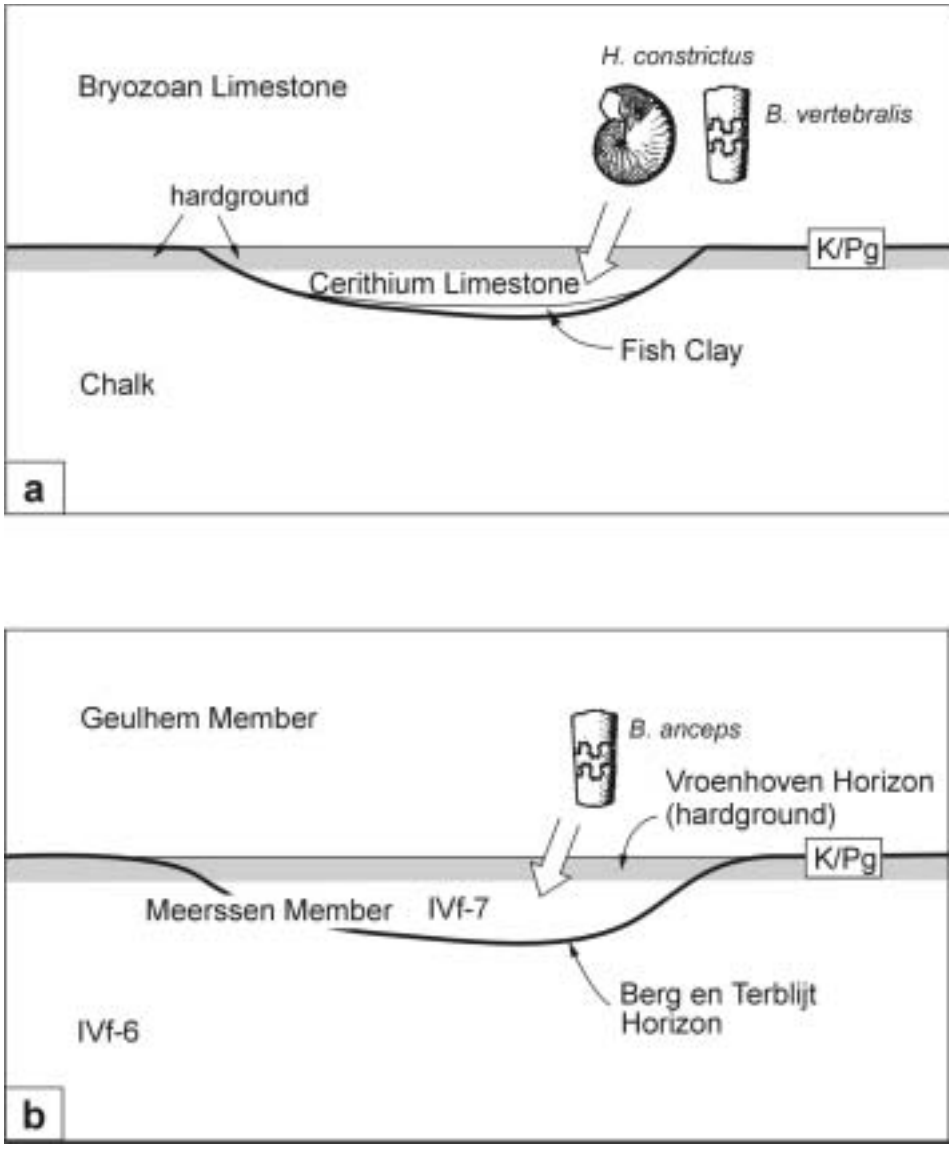

Fig. 1. Geologic situation of the Danian ammonite-bearing units in Denmark (a) and in The Netherlands (b); a is based on Heinberg (1999); b is based on Herngreen et al. (1998). K/Pg – Cretaceous/Paleogene boundary. For further explanation see text.

tion of the original aragonite shell in ammonite, bivalve and gastropod moulds collected in those parts of the Maastrichtian chalk which were incorporated into the Danian hardground (Birkelund 1993, Heinberg 1999).

Some ammonite specimens from the Cerithium Limestone represent slightly worn and phosphatized internal moulds (Birkelund 1993, Surlyk & Nielsen 1999). It is likely that they were already devoid of their shells at the time of burial. In view of point 1 above, they most probably represent *remanié* moulds derived from the indurated parts of the Maastrichtian chalk. Other specimens differ in preservation, being imprints of ammonite shell fragments (personal observations in collections of Geological Museum, Copenhagen). With regard to point 2 above, such specimens may either represent fragments of original ammonite shells derived from the soft Maastrichtian chalk or remnants of indigenous Danian ammonites, crushed on the seabottom prior to burial.

Another suggested Danian ammonite survivor from Denmark is represented by a pair of aptychi, probably of *Hoploscaphites constrictus*, found near Boesdal quarry on Stevns Klint (Surlyk & Nielsen 1999). Aptychi are paired calcitic coverings on the outer surface of ammonite lower jaws, serving additionally as opercula, and connected originally by an elastic conchiolin band (Lehmann & Kulicki 1990, Seilacher 1993). The aptychi reported by Surlyk & Nielsen (1999) are situated close to each other, but not articulated, and are preserved as imprints in a flint nodule. Although the specimen was found loose on the beach, Surlyk & Nielsen (1999) argued for its Danian age, based on its red-brown col-

our, typical of Danian flints, and its occurrence at a location where no Maastrichtian strata were exposed. They indicated the Lower Danian bryozoan limestone as a possible source of the flint. Moreover, they excluded its reworking from the Maastrichtian chalk as: "…reworked flint nodules are not known from the Maastrichtian-Danian of Denmark" (Surlyk & Nielsen 1999: 117). This may be true, but a marine crocodile found in Danian strata at Limhamn, Sweden, not far from Stevns Klint, had Cretaceous flint gastrolites preserved in its stomach region (Troedsson 1923). So, there is a possibility that the aptychus-bearing flint was derived from Maastrichtian strata.

The Netherlands

Internal and external moulds of *Baculites anceps* have been reported from the top of unit IVf-7 of the Meerssen Member of the Maastricht Formation, as exposed in the Curfs-Ankerpoort quarry in the Maastrichtian type area near Maastricht (Jagt 1999). This unit, composed of biocalcarenite with clay and fossil hash intercalations, was for a long time regarded as the top of the Maastrichtian Stage. Recently, it was dated as early Danian, and proposed to be the correlative of the Cerithium Limestone of Denmark (see the results of investigations of the Curfs-Ankerpoort and the Geulhemmerberg sections in Smit & Brinkhuis 1996, Herngreen et al. 1998, Jagt 1996, 1999). The IVf-7 unit occurs locally, filling the palaeodepressions in uppermost Maastrichtian sediments (Fig. 1b), much like the Cerithium Limestone. However, the two units are not coeval: the unit IVf-7 corresponds exclusively to the planktic foraminifer P0 Zone (Smit & Zachariasse 1996) whereas the Cerithium Limestone ranges at least to P1b Zone (Schmitz et al. 1992).

The baculitid ammonites from the unit IVf-7 have been considered to be potential Danian survivors in view of their very good preservation (Jagt 1999). There are even numerous specimens with their aperture intact (John W.M. Jagt, personal communication). They were clearly buried with their aragonitic shell still present. Regarding their origin, they may represent indigenous Danian survivors or reworked Maastrichtian shells. Although in this case there is no clear evidence that aragonite survived the K-Pg boundary, this may be taken for granted in view of the age of the IVf-unit, the deposition of which was completed within a few hundreds of years after the presumed K-Pg event (Smit & Brinkhuis 1996).

At first sight, the reworking scenario has difficulties in respect of the potential source of the specimens. The base of the unit IVf-7, from which the shells are most likely derived, comprises the Berg en Terblijt Horizon, which is regarded as a hardground by Smit & Brinkhuis (1996). Hardgrounds are submarine discontinuities which were lithified before their final burial (Goldring & Kaźmierczak 1974). Erosion of the intact shells from a cemented substrate would be improbable. However, the most convincing evidence for submarine lithification of the sea-floor are borings and/or encrusters (Goldring & Kaźmierczak 1974, Bromley 1975). These are missing in the Berg en Terblijt Horizon. In contrast, burrows are present, occasionally descending from within the IVf-7 unit (personal observations at the Geulhemmerberg section). This means that the surface of the Berg en Terblijt Horizon was soft enough to be penetrated by burrowers, even some time after its final burial (post-omission suite *sensu* Bromley 1975). Thus, the Berg en Terblijt horizon is not a true hardground, and erosion of ammonite shells from it was possible.

Final remarks

In view of the above discussion, the supposed Danian ammonite survivors from Denmark and the Netherlands may all be reworked. This is almost certainly the case of phosphatised and worn moulds in the Cerithium Limestone, but is also possible for the remainder of the material. Except for the aptychi-bearing flint from the Boesdal beach, all the supposed Danian ammonites come from the Cerithium Limestone and unit IVf-7. Both units have been deposited in palaeodepressions, naturally predisposed to accumulation of material derived from the intervening palaeohighs (compare Text-figs 1a and 1b). Moreover, evidently redeposited Maastrichtian macro- and microfossils do occur in the Cerithium Limestone and in the unit IVf-7 (Jagt 1996, Surlyk & Nielsen 1999).

According to Ockham's Razor, one should accept the simplest and least unusual explanation for a given fact or observation. The hypothesis that all the ammonites under discussion are reworked is clearly the simplest and least unusual one. Thus, it is preferrable to the hypothesis that some finds represent ammonite survivors in the Danian until compelling evidence emerges in favour to the latter. Such evidence remains in doubt, but may be potentially gleaned from ammonite aptychi.

Organic bands connecting aptychi certainly disintegrated rapidly after the death of their owner. Thus, the reworking of articulated aptychi was virtually impossible. Articulated aptychi in the Danian deposits, either occurring in ammonite body chambers or isolated in a "butterfly position" (Seilacher 1993), would

provide convincing evidence that ammonites survived into the Danian.

Also single aptychi may be used as potential proof of Danian ammonite survivors. They may preserve isotopic signals of the sea inhabited by their owners. The carbon, oxygen and strontium isotopic signals from the Cretaceous and Paleogene intervals are significantly different (e.g. Corfield 1994). Using isotopic criteria, Barrera & Keller (1990) demonstrated that certain foraminifers in the lowest Danian strata are survivors rather than reworked Maastrichtian specimens. The same method may be applied to the aptychi. If a Maastrichtian aptychus in the Danian sediments is reworked, it should possess Maastrichtian isotopic signals. If its owner lived during the earliest Danian, it should have Danian signals.

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