

# Biometric analysis of the Maastrichtian *Arkhangelskiella* group in the Indian Ocean (ODP Hole 762C): Taxonomy and evolution

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The Late Cretaceous genus *Arkhangelskiella* has been the object of numerous biometric studies due to its large variation in size and rim width throughout its stratigraphic range. Coincident with becoming a more significant component of the nannofossil assemblage in the late Campanian of the North Atlantic, the genus significantly increased in size. While some authors advocated against the presence of several morphotypes of the unique species *Arkhangelskiella cymbiformis*, others have identified three variants of this species in the North Sea (var. NT, var. N, and var. W), based on the thickness of the rim and suggested dominance of these variants in distinct stratigraphic intervals of the Campanian–Maastrichtian. The definition of these variants was later emended based on variation in the length of the coccolith, and they were elevated to species: *A. cymbiformis* sensu lato (var. NT), *A. confuse* (var. N), and *A. maastrichtiensis* (var. W). In the Danish Basin, these morphotypes strongly overlap across all measured biometric parameters. The different variants have been valued in terms of stratigraphy in the Danish Basin with var. N rising to dominance in the early Maastrichtian and var. W dominant in the late Maastrichtian. It was also deemed necessary to introduce a fourth variant (var. SW) of average size and relatively thick rim that constitutes a transitional Maastrichtian form between var. N and var. W. Variant NT was then considered a separate ancestor lineage, dominant in the Campanian.

In our study, morphological variations in *A. cymbiformis* were studied across the Maastrichtian within sedimentary deposits of Ocean Drilling Program (ODP) Hole 762C (Indian Ocean), which has excellent stratigraphic constraints. We measured coccolith length and width, rim width, and central area length and width on 1876 specimens from 32 samples. Coccolith length ranges from 7  $\mu\text{m}$  to a staggering maximum of 18  $\mu\text{m}$ . The results confirm that the length, rim width, and central area opening are primary parameters for distinguishing between *Arkhangelskiella* variants. The study confirms the presence of four overlapping variants with distinct stratigraphic occurrences: var. N, a small variant of <10  $\mu\text{m}$  with relatively thick rim that is dominant in the early Maastrichtian; var. W, a large variant of >12  $\mu\text{m}$  that is dominant in the late Maastrichtian; and var. NT, of 8–14  $\mu\text{m}$ , which bears a thin rim and wide-open central area and is present throughout the Maastrichtian. The transitional *A. cymbiformis* var. SW is needed to explain the overall stratigraphic evolution of these forms. While this evolutionary pattern and the upper limits in rim width and central opening size are similar to those found in the Danish Basin, the upper limits in coccolith length are significantly larger by +2  $\mu\text{m}$ , highlighting the difficulty in defining clear globally applied rules for the distinction of morphospecies. Comparison between the percentage of the four variants and global climatic trends suggests that while the rise in dominance of the small (var. N) and very large (var. W) variants were favored during the early and late Maastrichtian cooling episodes, the transitional var. SW dominated during the mid-Maastrichtian and late Maastrichtian warm episodes.