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Middle–Late Ordovician organic-walled phytoplankton from Sweden: diversity and early radiation

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The Borenshult-1 core, drilled in the vicinity of Motala, east of Lake Vättern in south central Sweden, comprises a well-dated and nearly complete succession of marine marly carbonates deposited relatively close to land. The 34 core samples analyzed for palynology encompass the upper part of the Darriwilian (Furudal Limestone), the entire Sandbian (Dalby Limestone, the Kinnekulle K-bentonite and the lower Skagen Limestone) and the lower part of the Katian (Skagen Limestone). The age of this interval is well-constrained to the late Darriwilian (Stage slice Dw3)–early Katian (Stage slice Ka1), based on conodonts and 206Pb/238U dating of volcanic ash deposits.

The samples yielded predominantly marine organic-walled phytoplankton, mainly acritarchs, with subordinate chitinozoans, scolecodonts and fragments of graptolites. Sparse terrestrial palynomorphs, represented by cryptospores and trilete spores, were also found in 23 of the samples.

A total of 154 acritarch species corresponding to 53 genera were identified, as well as low percentages of abnormal forms (teratological forms) of acritarch species at some levels. The stratigraphic distribution of genera and species allowed for three palynological assemblages to be distinguished: Assemblage A of a late Darriwilian age, Assemblage B of a Sandbian age (further subdivided into sub-assemblages B1 and B2), and Assemblage C dated as Katian.

Genera such as *Baltisphaeridium*, *Ordovicidium*, *Pachysphaeridium* and *Orthosphaeridum*, which are common in Middle Ordovician phytoplankton assemblages from Baltica, are well represented, with several species, mainly in Assemblage A and sub-assemblage B1, up to the lower Sandbian. However, the presence of a majority of taxa with worldwide distribution supports the cosmopolitanism of the studied assemblages, already proposed to begin near the Darriwilian–Sandbian transition.

Notably, phytoplankton taxa with Silurian affinities, previously known from the Hirnantian, appear for the first time in the late Darriwilian part of the Borenshult-1 drillcore (Dw3). Important taxa occurring are *Tylotopalla* and *Metaleiofusa*, which is definitively established from the beginning of the Sandbian (early Late Ordovician), together with the first appearance of the genus *Visbysphaera*. These occurrences question the relationship between the appearance of pioneering phytoplankton morphotypes and the Hirnantian glaciation.

Other taxa with no pre-Silurian records such as *Visbysphaera pirifera* subsp. *minor*, *Petaloferidium cazurrum* and *Dorsennidium* cf. *D. estrellitae* are here present in the Sandbian, where bentonite beds are intercalated.

The genus *Frankea* is recorded for the first time from the Ordovician of Sweden, suggesting a high to middle latitudinal distribution instead of a peri-Gondwanan distribution.

The highest diversity corresponds to the Darriwilian and partly to the Sandbian assemblages, followed by a significant decline in the Katian. The main changes are observed in the Sandbian, with a significant drop in diversity, which is probably related to intense volcanic activity represented by the bentonite beds. Diversity as well as origination and turnover rates are the lowest in the interval bearing the suite of K-bentonites, particularly near the thickest of them. The marked drop in diversity in the Katian part of the succession, visible in both low originations and abundance, is possibly related to a regression at the onset of the GICE (Guttenberg isotope carbon excursion), with less favorable environmental and climatic conditions.

Changes in phytoplankton assemblages together with the onset of innovative morphologies of acritarchs were previously interpreted as a consequence of environmental and climatic perturbations related to the Ordovician glaciation. Here we show that the first appearances of these advanced taxa already occurred ca 15 Ma earlier, suggesting that a possible combination of factors such as sea level changes and volcanism triggered these changes, instead of a major event such as the Hirnantian glaciation. Additionally, these new findings challenge previous models of evolution and radiation of the Ordovician phytoplankton and set up Baltica as a new key area for paleogeographical research.

ABSTRACT

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