

## The Eocene Arctic *Azolla* phenomenon: species composition, temporal range and geographic extent.

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*Azolla* is one of the world's fastest growing aquatic macrophytes renowned for its rapid vegetative spread and invasive biology. Using samples from IODP cores from the Lomonosov Ridge (Arctic) and from outcrops in Denmark (Collinson et al 2009 a,b *Review Palaeobotany and Palynology* 155,1-14; & doi:10.1016/j.revpalbo.2009.12.001) we have shown that two species of this freshwater floating plant bloomed and reproduced in enormous numbers in the latest Early to earliest Middle Eocene of the Arctic Ocean and in the area of present day Denmark. To expand our knowledge of the spatial distribution of these species we have now completed a study of samples from 15 additional sites. The sites range from the Sub-Arctic (Northern Alaska and Canadian Beaufort Mackenzie Basin) to the Nordic Seas (Norwegian-Greenland Sea and North Sea Basin) and the material comes from ODP cores and commercial exploration wells. The study included palynological slides and mesofossils.

The new data show that the *Azolla* phenomenon involved five species, in some sites more than one species co-existed. Species can be distinguished from one another by characters of the megaspore apparatus (e.g. megaspore wall, floats, filosum) and the microspore massulae (e.g. glochidia hairs and fluke tips). The attachment to one another and the co-occurrence of megaspore apparatus and microspore massulae, combined with evidence that these spores were shed at the fully mature stage of their life cycle, shows that the *Azolla* remains were not transported over long distances, a fact which could not be inferred from isolated massula fragments or glochidia alone. However, glochidia characters are particularly useful as they provide the future potential to identify the different species when only palynological preparations are available. Our evidence shows that the *Azolla* phenomenon affected the area from the western Arctic, through the North Sea and south as far as Denmark for a maximum duration of 1.2 million years (from c. 49.3 to c. 48.1 Ma). In some areas the *Azolla* grew on the ocean surfaces and in others on adjacent land. Apparently, co-incident with the termination of the EECO, Northern Hemisphere middle and high latitude environmental conditions were suitable for simultaneous widespread proliferation of several *Azolla* species. High precipitation conditions invoked (e.g. by climate models) for the EECO might have aided in the onset of massive *Azolla* proliferation in the Northern Hemisphere. The *Azolla* phenomenon is an unexpected and unpredictable consequence of Paleogene warm climate conditions.