

## **Did the fossil diatom resting spore diversification enhance the evolution of other organisms across the E/O Boundary?**

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Abstract:

The fossils of diatom resting spores can be preserved as significant constituents in fossil marine diatom assemblages, which provide useful information for reconstructing paleoproductivity and paleoenvironmental changes. Although the taxonomy of resting spores is less well understood, recently, a firm taxonomic basis for the classification of fossil resting spores in biostratigraphic and paleoceanographic research, using Eocene through the Recent DSDP and ODP samples. As the result, distinct resting spore event (*Chaetoceros* Explosion Event, CEE), including abrupt changes in their species richness, abundance increasing and their half reducing of average valve sizes was documented within a ~6 myr time interval across the Eocene/Oligocene boundary. Based on evaluation of the ecologic differences between *Chaetoceros* and cyst-forming dinoflagellates, the CEE event indicated that i) the role of main primary producer might have switched from dinoflagellate in the Eocene to diatom, especially *Chaetoceros*, in the Oligocene; ii) the oceanic conditions changed from stable with annual nutrient supply provided by upwelling in winter in the Eocene, to unstable with a sporadic supply of nutrients by increased vertical mixing after the development of ACC leading enhanced nutrient supply to the surface waters. The CEE event might occur in all over the world oceans. Moreover, the evolution of the Mysticeti (baleen whales), which consumes a lot of copepods mainly eating diatoms, from the Archaeoceti (paleowhale) across the E/O boundary, coincides with CEE. Consequently, CEE is likely to have enhanced the evolution of whales (*Chaetoceros*-baleen whale co-evolution hypothesis). In order to testify the hypothesis, we need to study core samples containing fossils of *Chaetoceros* resting spores collected from the high latitude, near-shore upwelling regions where baleen whales are feeding before breeding in low latitudes. For this study, we need samples from the continuous marine sedimentary succession with *Chaetoceros* resting spores from the Eocene to the Oligocene with little gaps.

## Did the fossil diatom resting spore diversification enhance the evolution of other organisms across the E/O Boundary?

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### 1) Importance of *Chaetoceros* resting spore studies

The marine diatom genus *Chaetoceros* is one of the most important taxa in present oceans, especially coastal upwelling regions (Hasle & Syvertsen, 1996) and their contribution accounts for 20-25% of total marine primary production (Werner, 1977). Under nutrient-rich conditions, most *Chaetoceros* species reproduce rapidly and form long chains of thin-walled cells, just like normal vegetative diatoms, but their valves are not preserved as fossil due to dissolution (Fig. 1; Itakura, 2000). On the other hand, as nutrient supplies are depleted, most of them form thick-walled resting spores which sink to the sea floor, where they await the return of favorable conditions that nutrients are provided again by upwelling (McQuoid & Hobson, 1996). The heavily silicified resting spore valves are preserved in sediment as fossils and abundantly occurred from near-shore sediments in association with other fossil diatom valves. **The fossil resting spores can be preserved as significant constituents in fossil marine diatom assemblages, which provide useful information for reconstructing paleoproductivity and paleoenvironmental changes.**

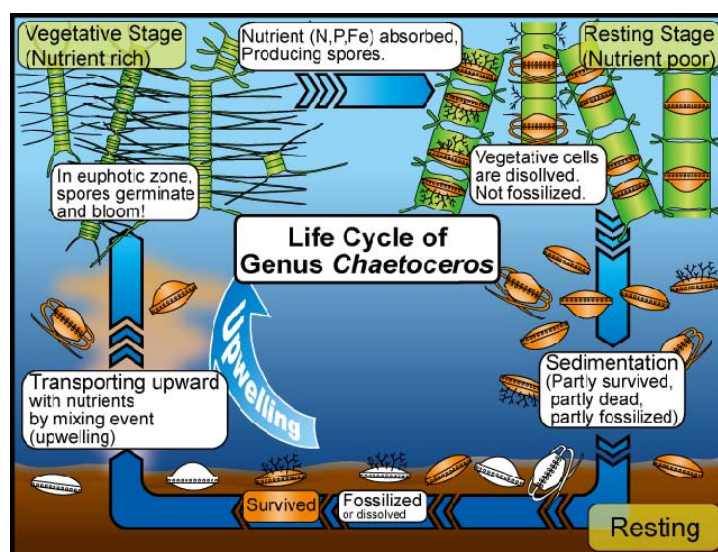


Fig 1. Life cycle of marine diatom genus *Chaetoceros*.

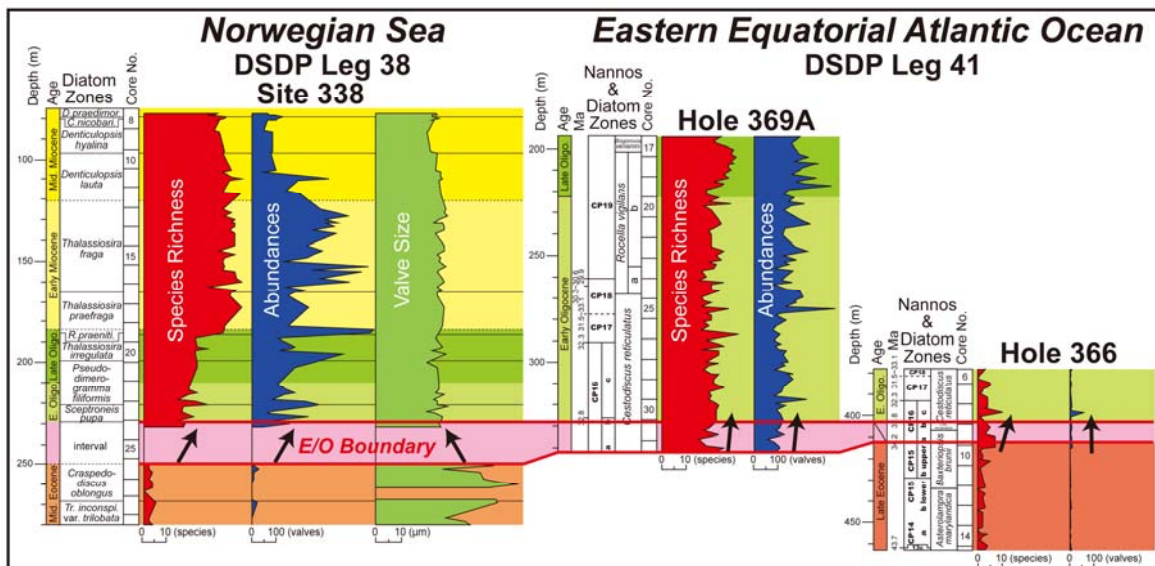
### 2) *Chaetoceros* Explosion Event across the Eocene/Oligocene boundary

The taxonomy of resting spores is less well understood because their corresponding vegetative frustules are rarely preserved along with the resting spores and their valve structures are simple. No attention, therefore, has been paid to the significance of resting spores from a geological point of view, which contrast well with that the taxonomy and biostratigraphy of fossil diatoms from Cenozoic sediments have been studied intensively in several oceans by using marine sedimentary successions collected by the DSDP, ODP and IODP (e.g. Yanagisawa & Akiba, 1998).

Recently, a firm taxonomic basis from the classification of fossil resting spores in

biostratigraphic and paleoceanographic research, using Eocene through the Recent samples from DSDP Site 338 in the Norwegian Sea, Site 436 and Holes 438A and B in north-western Pacific and several on-land sections (e.g. Suto, 2006). As the result, **distinct resting spore event (*Chaetoceros* Explosion Event, CEE)**, including abrupt changes in their species richness (explosive 10-fold increasing), abundance (abruptly increasing) and their average valve sizes (half reducing) was documented from the DSDP Site 338 within a ~6 myr time interval across the Eocene/Oligocene boundary (Fig. 2; Suto, 2006).

Based on evaluation of the ecologic differences between *Chaetoceros* and cyst-forming dinoflagellates, Suto (2006) indicated that **i) the role of main primary producer might have switched from dinoflagellate in the Eocene to diatom, especially *Chaetoceros*, in the Oligocene; ii) the conditions in the Norwegian Sea changed from stable with a constant (annual) nutrient supply provided by upwelling in winter in the Eocene, to unstable with a sporadic supply of nutrients by increased vertical mixing in the Ocean after the development of Antarctic Circumpolar Current leading enhanced nutrient supply to the surface waters (Falkowski et al., 2004).**



**Fig 2.** *Chaetoceros* Explosion Event across the Eocene/Oligocene Boundary

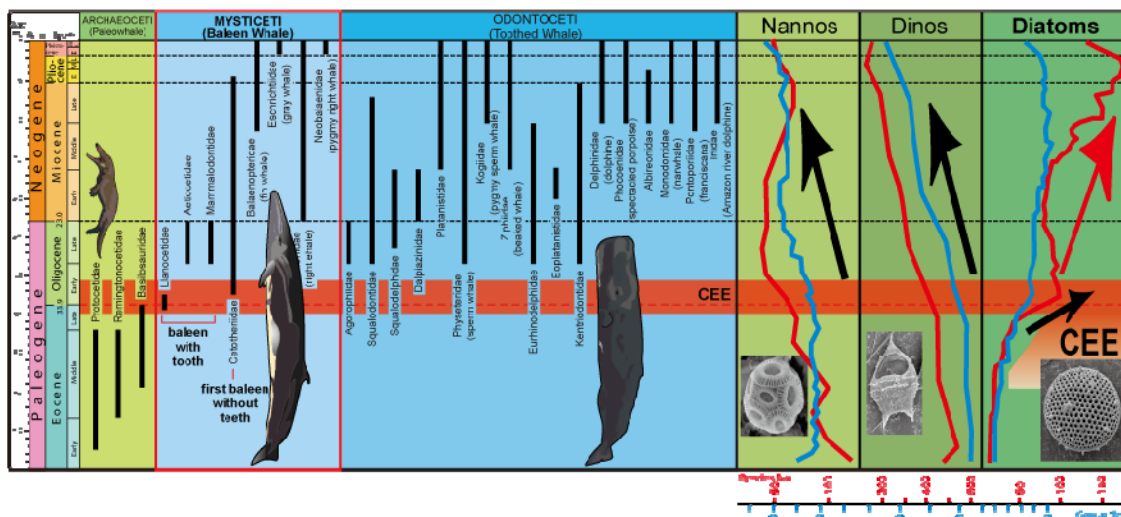
The CEE event was also recognized in the DSDP Holes 366 and 369A, eastern equatorial Atlantic Ocean (Suto, in prep.), the event, therefore, might occur in all over the world oceans. Moreover, the evolution of the Mysticeti (baleen whales), which consumes a lot of copepods mainly eating diatoms, from the Archaeoceti (paleowhale) across the Eocene/Oligocene boundary, coincides with CEE. Consequently, **CEE is likely to have enhanced the evolution of whales (*Chaetoceros*-baleen whale co-evolution hypothesis)**(Suto presented in AGU, 2007; Fig. 3).

### 3) Proposed locations for coring

In order to testify the CEE hypothesis, **we need to study core samples containing fossils of *Chaetoceros* resting spores collected from the high latitude, near-shore upwelling regions where baleen whales are feeding (e.g Southern and North Pacific Oceans) before breeding in low latitudes.**

For this study, we need samples from the continuous marine sedimentary succession with *Chaetoceros* resting spores from the Eocene to the Oligocene with little gaps. But

there are limited core samples covering E/O boundary because the upper Eocene sediments have been eroded in many marine cores and there is a hiatus at that boundary (e.g. DSDP Sites 274 and 338, ODP Site 908). Moreover, the information on changes in abundance of resting spore in association with those of normal fossil diatom valves cores is very limited. Furthermore, it is difficult to know the occurrence of resting spores from the previously published literatures, because they have been out of the scope of investigations for most of diatom researchers.



**Fig 3.** Comparison of chronologic ranges of cetacean families worldwide, with eukaryotic phytoplankton diversity curve.

If we can collect core samples from Eocene to Oligocene sedimentary successions without any gap from the upwelling region in the Southern Ocean, we will achieved not only **to reconstruct the paleoproductivity and paleoenvironmental changes in the ocean and to clarify the causes, process, and effect of CEE and the evolution of baleen whale enhanced by diatoms**, but also **to establish and refine an Eocene through Oligocene normal diatom zonation which will increase reliability of diatom biostratigraphy.**

### References:

- Falkowski, P.G., Katz, M.E., Knoll, A.H., Quigg, A., Raven, J.A., Schofield, O. & Taylor, F.J.R. (2004). The evolution of modern eukaryotic phytoplankton. *Science*, **305**, 354-360.
- Hasle, G.R. & Syvertsen, E.E. (1996). Marine diatoms. In: Tomas, C.R. (Ed.), *Identifying Marine Diatoms and Dinoflagellates*, 5-385. Academic Press, San Diego.
- Itakura, S. (2000). Physiological Ecology of the resting stage cells of coastal planktonic diatoms. *Bulletin of Fisheries and Environment of Inland Sea*, **2**, 67-130 (in Japanese with English abstract).
- McQuoid, M.R. & Hobson, L.A. (1996). Diatom resting stages. *J. Phycology* **32**, 889-902.
- Suto, I. (2006). The explosive diversification of the diatom genus *Chaetoceros* across the Eocene/Oligocene and Oligocene/Miocene boundaries in the Norwegian Sea. *Marine Micropaleontology*, **58**, 259-269.
- Yanagisawa, Y. & Akiba, F. (1998). Refined Neogene diatom biostratigraphy for the north-west Pacific around Japan, with an introduction of code numbers for selected diatom biohorizons. *Journal of the Geological Society of Japan*, **104**, 395-414.