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Seasonal variation in skeletal silicification of *Neodenticula seminae*, a marine planktonic diatom: Sediment trap experiments in the NW Pacific Ocean (1997–2001)

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Abstract

Neodenticula seminae is an important component of pelagic diatom floras in the subarctic North Pacific and its adjacent seas. We conducted an SEM image analysis of four series of samples collected by sediment traps in the NW Pacific, in order to investigate the relations between its morphology, evolution, and environment. Seasonal variation in the skeletal morphology was common: lightly silicified morphs were dominant during spring blooms and in the summer (under oligotrophic conditions owing to surface water stratification and progressive nutrient limitation), whereas heavily silicified morphs became abundant in the fall and winter, subsequent to the onset of intensive vertical mixing. These observations suggest that the morphology of *N. seminae* is influenced by environmental factors including the nutrient availability as well as by its reproductive strategy.

Keywords: Diatom; Morphology; North Pacific Ocean; Oyashio; Sediment trap; Silicification

1. Introduction

Neodenticula seminae (Simonsen and Kanaya) Akiba and Yanagisawa (Fig. 1) is a pennate diatom which is widely distributed in the subarctic North Pacific and its high-latitude marginal seas, where it commonly accounts for >40% of the diatom associations in surface waters and bottom sediments (Fig. 2; Karohji, 1959; Kanaya and Koizumi, 1966; Sancetta, 1982; Sancetta and Silvestri, 1986; Takahashi, 1986; Onodera et al., 2003; Aizawa et al., 2005). The species appeared in the fossil record around 2.4 Ma in the North Pacific (Akiba and Yanagisawa, 1986; Yanagisawa and Akiba, 1990, 1998), and its fossil occurrences in the North Atlantic are limited to the mid-Pleistocene (Baldauf, 1987; Koç et al., 1999). It is believed to be limited in its distribution and mainly present in the Northern Hemisphere, although living *N. seminae* have been reported from subtropical gyres of the Indian Ocean and the North Atlantic. Those occurrences, however, are sporadic and episodic. For instance, Semina (1981) reported fewer than 100 specimens·L^{-1} in low-latitude waters of the North Atlantic (29° N, 71° W), in contrast to up to 3.3×10^7 specimens·L^{-1} in surface seawaters of the subarctic North Pacific and its marginal seas.

Primary productivity in the subarctic North Pacific and its marginal seas is among the highest in the world's

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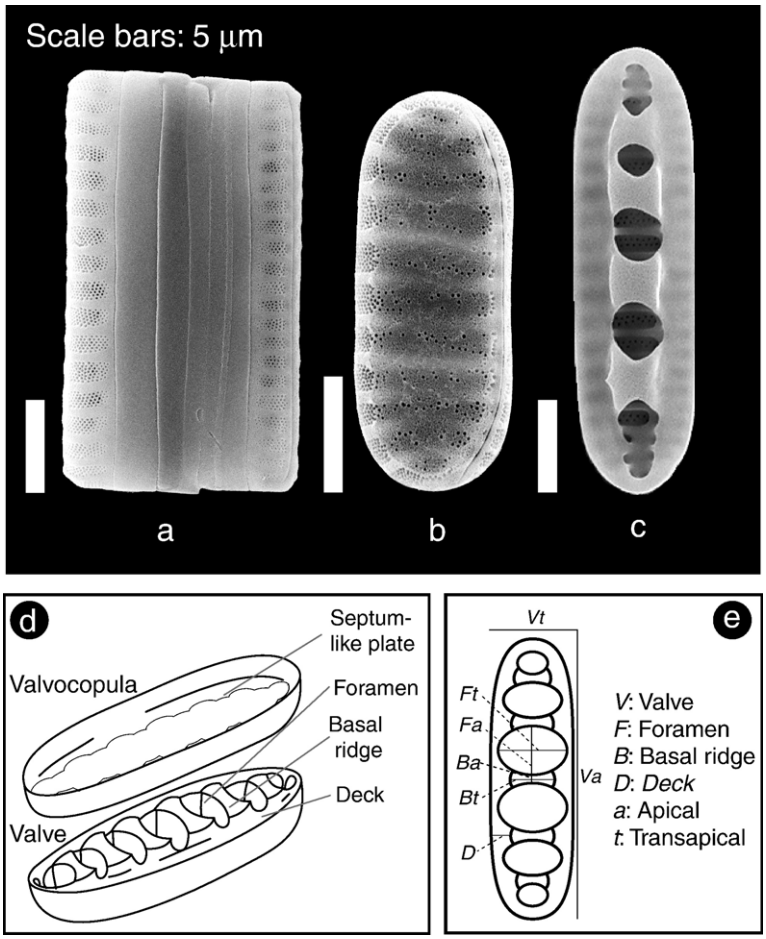

Fig. 1. Scanning electron micrographs of *Neodenticula seminae*. (a) Girdle view; (b) valvar view; and (c) internal valvar view of a frustule. (d) A schematic illustration of a part of theca and (e) morphometric dimensions measured in this study.

oceans. Phytoplankton serves as an efficient biological pump driving elemental cycles including the carbon cycle in the oceans (Honjo, 1997). Therefore the dominant diatoms in the highly productive regions of the oceans are likely to play a crucial role in ocean-scale ecosystem and biogeochemical dynamics. Nevertheless, basic information on *N. seminae* is limited because specimens are difficult to obtain owing to its pelagic habitat.

Kurihara and Takahashi (2002) used light microscope (LM) observations to report that the apical valve length in *N. seminae* fluctuates seasonally, with maximum values in spring, minimum values in fall, and a bimodal distribution in fall and winter. They argued that these fluctuations might be caused by the annual reproductive cycle, with asexual reproduction dominant during spring and summer when productivity is high, whereas sexual reproduction occurs in fall and winter when productivity is lower. Shimada et al. (2003) and Shimada and Tanimura (2006) used material from plankton net and surface seawater samples, and found marked intraspecific morphological variability in *N. seminae,* particularly in the appearance of the internal structure of the valve. They distinguished two biogeographic provinces: (1) the Oyashio (Current) region in the NW Pacific and (2) other regions of the North Pacific and the Bering Sea.

In this study, we analyze the morphological variability in *N. seminae* in time-series materials collected in the NW Pacific and compare our data on spatial morphological variability with data on variability in environmental factors, in order to explore the possible origin of such variability and to gain insight into the nature of the species. Such morphological information will give us a key for understanding past interactions between ecological and evolutionary strategies in the phytoplankton and regional climatic change and biogeochemical dynamics in the oceans.