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Unstable Holocene climate in the northeastern East Sea (Sea of Japan): evidence from a diatom record

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Abstract

A total of 45 and 42 sediment subsamples from gravity cores GH98-1223 and GH98-1227, respectively, were obtained in the northeastern East Sea (Sea of Japan) and analyzed for diatom abundance. A ^{14}C date for sediment organic carbon (GH98-1223) along with probable and plausible correlation to the well-established timeframe constrains the age to the Mid-to-Late Holocene. Abundances of most species including *Neodenticulopsis seminae* (Simonsen and Kanaya) Simonsen and *Fragilariopsis doliolus* (Wallich) Grunow were less than 20% in average, relative to the most dominant species, *Thalassionema nitzschioides* (Grunow) Hustedt, which ranged from 29% to 59% (for core GH98-1223) and between 23% and 46% (for core GH98-1227). Frequencies of cold-water species were generally higher than those of warm-water species because of the high-latitude cold-water occupying dominantly in the basin. The vertical distribution of cold-water species was largely opposite to that of warm-water species. For example, the frequency of a cold-water species, *N. seminae*, was inversely related to that of a warm-water species, *F. doliolus*. We conclude that changes in abundance of *F. doliolus* and diatom temperature index (T_d value) represent quasi-periodic fluctuations, demonstrating that the Tsushima Warm Current and its branch of the Soya Warm Current play a significant role in the transportation of diatom cells and heat. The pulse-like oscillations of this indicator species, which are observed in basin-wide and regional scales, reflect that the strength or intensity of the dominant current is governed by a globally induced unstable climatic system during the Holocene period.

Keywords: Diatom; Tsushima Warm Current; Soya Warm Current; Paleoclimate; East Sea; Sea of Japan; Holocene

1. Introduction

During the last two decades, high-resolution paleoclimatic oscillations have been recognized mainly from ice cores (GRIP, GISP2, Vostok; Johnsen

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et al., 1997; Petit et al., 1999) and North Atlantic regions (Hughen et al., 1996; Bond et al., 1999). Among the millennial-scale climate shifts widely accepted as occurring during the last glacial, the most pervasive paleoclimatic signals are irregular Dansgaard–Oescher (D–O) cyclicity and associated Heinrich events. The existing paleoclimatic record suggests abrupt changes from one stable mode to another. For example, rapid climate oscillations recognized from the North Atlantic region at higher latitudes are closely related with the sudden reorganization of the North Atlantic thermohaline circulation (e.g., Broecker et al., 1990).

In general, Holocene (<11,500 yr B.P. after Roberts, 1998) records in deep-sea environments have been generally considered to be of little significance, compared to those during the last glacial period. The Holocene period, characterized as an extremely stable climate, is defined in the GISP2 ice core as beginning at the termination of the Younger Dryas (YD) event ~11,600 yr B.P. GISP2 $\delta^{18}O$ values show relatively minor Holocene variation compared to 4‰ to 5‰ millennial oscillations during the last glacial period (Dansgaard et al., 1993). Although the Holocene may be described as comparatively stable, there is a growing body of evidence indicating that climate has varied significantly and rapidly over the last 10,000 years (Pielou, 1991; Mosley-Thompson, 1996; Khim et al., 2002). Distinct climatic intervals recognized during the Holocene include the Neoglaciation, which followed a Mid-Holocene period of warmer climate (the Hypsithermal).

Since the development of empirical orthogonal function (EOF) that has been calculated from GISP2 atmospheric chemical proxies (O'Brien et al., 1995), more pervasive high-resolution cycles have been recently reported from marine sediments (Bond et al., 1999). Many paleoclimatic indicators show a quasi-periodic continuation, in spite of much less pronounced intensity, of this variability throughout the Holocene. These climatic fluctuations vary on several hundreds to thousands of years time frames, resulting in a broad variety of possible forcing mechanisms. So far, several kinds of effects are clearly suggested, including astronomically induced variations (~900 yr; Loutre et al., 1992), internally forced oscillations of the ocean-atmosphere system (~1.5 kyr; Bond et al., 1999), and changes in solar activity (~2.5 ky; Stuiver and Reimer, 1993). Of particular interest was the discovery in the southern part of the East Sea (Sea of Japan) of sediments that Koizumi (1989) reported as showing a similar periodic occurrence of Tsushima Warm Current intensification during the Holocene, based on the diatom abundances as preliminarily confirmed by Shin et al. (2000) in the northern part of the East Sea (Sea of Japan).

Diatoms are the most abundant microfossils found in the sediments of the northwestern Pacific (Jouse, 1962; Kanaya and Koizumi, 1966; Kozlova and Mukhina, 1967; Sancetta, 1979; Tanimura, 1999) and the Sea of Okhotsk (Sancetta, 1981, 1982; Shiga and Koizumi, 2000; Shimada et al., 2000; Koizumi et al., 2003). Although these phytoplanktons are restricted to the surface mixed layer, the wide distribution of diverse species and their physiology and ecology are far better understood than any other microfossil group. Furthermore, diatom species in the sediments are reasonably diverse, and the distributions of various species reflect regional water mass variation, providing interpretative tools for understanding paleoceanographic conditions. A number of previous studies on surface sediment assemblages of diatoms and their relationships to surface water conditions in the North Pacific and adjacent marginal seas have been carried out within the last few decades (Venrick, 1971; Sancetta, 1979; Tanimura, 1981, 1999). These studies generally have focused on species and distribution, taxonomic and morphologic problems, oceanographic and ecological significance in the marine environment. However, fewer studies have addressed the usefulness of past environmental reconstruction.

The primary purpose of this study is to document the changes in abundance of various diatom species within the Mid-to-Late Holocene and to correlate their distribution with the climatic regimes associated with Tsushima Warm Current, from which infer Holocene paleoclimatic fluctuations in the East Sea (Sea of Japan).

2. Modern oceanography and paleoceanographic setting

The East Sea (Sea of Japan) is a semi-isolated marginal basin of the northwestern Pacific Ocean