Marine Geology 368 (2015) 58–65

Contents lists available at ScienceDirect

Marine Geology

journal homepage: www.elsevier.com/locate/margeo

Deposition pattern and sources of palynomorphs on the continental margin off Hokkaido Island, northwest Pacific

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ARTICLE INFO

Article history:
Received 11 July 2014
Received in revised form 17 June 2015
Accepted 18 June 2015
Available online 25 June 2015

Keywords:
Palynomorphs
Silt–clay
Deposition
Source
Hokkaido

ABSTRACT

Hokkaido Island in northern Japan is located in a cool temperate to boreal climate zone influenced by summer monsoons and typhoons during summer–autumn, while its eastern area is influenced by the subarctic Oyashio Current. Palynomorph (pollen and spores) distribution was investigated in surface sediments from the shelf and slope (40–2300 m water depth) in the offshore area of Tokachi Plain, central-eastern Hokkaido Island. The objective of this study was to examine the source, transportation, and deposition of palynomorphs in marine environments. The majority of palynomorphs were transported from the Tokachi coastal plain by both strong local winds from the mountain areas during the spring–summer and the floods caused by heavy monsoon and typhoon rainfall. Approximately 10% of all palynomorphs were transported from both southwest and west areas by the wind. Palynomorph transportation by the Oyashio Current could not be discriminated because the same vegetation is present in Hokkaido and the islands in upper streams of the Oyashio Current. The total grain abundance was dependent on water depth. High concentrations were observed at depths of 700–1500 m, which is a region associated with high levels of fine silt and clay, suggesting that the transportation and deposition of palynomorphs are controlled by their grain sizes. This study supported a strong correlation between the distribution of sediments and the concentration of palynomorphs.

1. Introduction

Marine cores can provide longer, more continuous paleo-environmental records than terrestrial cores. Palynological studies using the marine cores have been performed in many sea areas of the world to reconstruct vegetation and climate in adjacent land (e.g., Dupont et al., 1998; Heusser, 1988; Igarashi and Oba, 2006; Sánchez Goñi et al., 1999, 2008).

In these studies, it is important to ensure that marine palynomorph records correctly reflect the adjacent terrestrial vegetation. In addition, it is important to determine how and from where the palynomorphs were transported into marine sediments. To understand these processes, detailed studies have been performed in the Gulf of California (Cross et al., 1966), Western Iberia (Naughton et al., 2007), the Mediterranean region (Sánchez Goñi et al., 2002), the South China Sea (Luo et al., 2013; Chuanxiu et al., 2014), the Chile margin (Montade et al., 2011), and in NW Africa (Hooghiemstra et al., 2006), and similarity between marine pollen assemblages and vegetation in nearby lands was confirmed.

In the northwestern Pacific, several marine cores obtained from adjacent seas to Japan were analyzed palynologically, and climatic changes were reconstructed (Heusser, 1989; Heusser and Morley, 1985a,b, 1990, 1997; Morley and Heusser, 1997). In these series of studies in the NW Pacific, Heusser and Morley (1985a) classified marine pollen assemblages obtained from the NW Pacific into three dominant pollen assemblages. The sources of these pollen assemblages were specified with vegetation in Japan, Sakhalin, and the maritime province of Siberia. However, detailed comparison between the vegetation of Japan and marine pollen assemblages off Japan has not yet been performed.

In this report, we palynologically studied the surface sediments on the continental shelf and slope of the central-eastern Hokkaido, northern Japan, in the NW Pacific. To establish the distribution pattern of palynomorph in the shelf and slope we correlated it with the distribution pattern of sediments in the study sea area (Noda and TuZino, 2010). We discuss the sources of marine palynomorphs, deposition patterns of each taxon on the sea bottom, long distance transportation with winds, the influence of the Oyashio Current flowing nearby the coast of central-eastern Hokkaido, and post-depositional degradation. The palynomorph assemblages collected from the adjacent land of the study area were used to examine correlations between land and sea. Pollen trap records obtained from west of the study area over 5 years

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http://dx.doi.org/10.1016/j.margeo.2015.06.008
0025-3227/

(Igarashi, 1979, 1987) were also used for discussion on transportation of palynomorphs by the wind.

2. Regional settings

2.1. Topography of the study area

The study area (Fig. 1) was the continental shelf and slope off the Tokachi Plain, central-eastern Hokkaido Island, which is located in the area from 42°N to 42°45′ N and 143°25′ E to 144°45′ E (76 km wide and 123 km long). The area has water depths of 40–2300 m and is bound by the Kushiro Submarine Canyon (Fig. 2) to the northeast and NW–SE trending ridges to the southwest (Sakurai et al., 1975). The Tokachi Plain has a flat topography, which is less than 100 m above sea level (a. s. l.), and is surrounded by the Hidaka Mountains in the west, the Ishikari Mountains in the north, and a series of hills in the east (Fig. 2).

The continental shelf along the Tokachi Plain is approximately 25 km wide, and the continental slope (depths of 150–2000 m) slopes gently at an average of 1.0–1.5°, with isobaths running parallel to the shoreline (Fig. 2; Noda and TuZino, 2010). Ten rivers flow into the Pacific Ocean in this region: of these, the Tokachi River is the largest (Fig. 2) with a mean discharge of 256 m^3/s, and peaks at 300–450 m^3/s between April and June due to snowmelt. The discharge of the Tokachi River increases significantly during extreme flooding events associated with typhoons (Noda and TuZino, 2010; Water Information System maintained by the Ministry of Land, Infrastructure and Transport, Japan).

2.2. Sediments in the study area

In the study area, fine to very fine sand is distributed on the shelf (Fig. 2). Coarse silt is generally distributed on the upper slope between water depths of 200–700 m (Fig. 2). Fine silt and clay covers a wide area of middle slope depths from 700 to 1600 m, except for spurs draped by sand with a low mud content (Fig. 3). Sediments on the lower slope (1600–2000 m water depth) are slightly coarser than those on the middle slope (Fig. 2: Noda et al., 2003; Noda and TuZino, 2010).

2.3. Ocean currents

Hokkaido Island is surrounded by the Pacific Ocean, the Sea of Okhotsk, and the Sea of Japan (Fig. 1). In the Pacific Ocean, the Oyashio Current, which contains low-temperature, low-salinity, and nutrient-rich water, flows southwestward along the Kuril Arc and Hokkaido Island at a low velocity (0.2–0.4 m s^{-1}) (Isoguchi et al., 1997; Suzuki et al., 2003; Ohshima et al., 2005; Fig. 1). In the coastal area where the water partly originates from melting sea-ice in the Sea of Okhotsk, the current flows along the southeastern coast of Hokkaido in winter and spring (Kono et al., 2004). The Tsushima Current, which originates from the subtropical Kuroshio Current, flows westward along Honshu and Hokkaido Islands in the Sea of Japan (Fig. 1). One branch of the Tsushima Current flows out to the Pacific through the Tsugaru Strait (Fig. 1) between Honshu and Hokkaido. The other branch flows out to the Sea of Okhotsk through the Soya Strait (Fig. 1) between Sakhalin and Hokkaido, and then into the Pacific.

2.4. Meteorological data

The mid-latitude northwest Pacific region, Hokkaido Island, contains the subarctic boundary between the subtropical Kuroshio and subarctic Oyashio. The climate in winter is dominated by winter monsoon winds from the Siberian High. In summer and autumn, the summer monsoon originates in the Indian Ocean, and typhoons originating in the subtropical Pacific generate strong winds, heavy rain, and flooding.

The Tokachi River has a mean discharge of 256 m^3 s^{-1} with peaks at 300–450 m^3 s^{-1} between April and June due to snowmelt. During extreme flooding events, maximum discharge of the Tokachi River exceeds 5900 m^3 s^{-1} (Water Information System maintained by the Ministry of Land, Infrastructure and Transport, Japan).

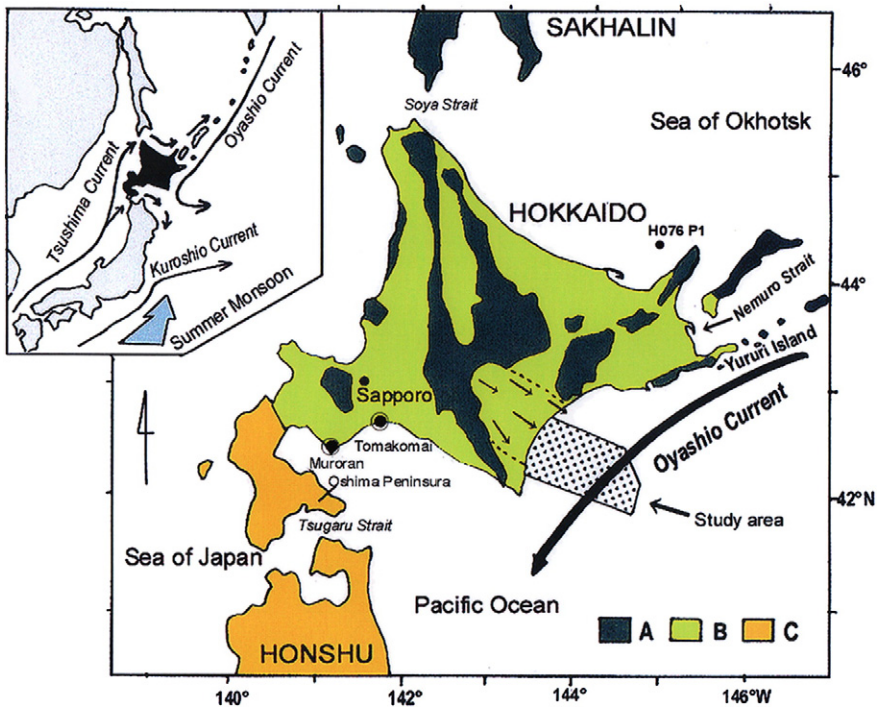

Fig. 1. Map showing of vegetation in Hokkaido Island, study sea area, Tokachi Plain (surrounded by dotted line), the directions of the Tokachi Winds (plural short arrows), direction of summer monsoon, sea currents and the localities cited in this paper. A: Boreal conifer forest and mixed forest of conifers and cool temperate broad-leaved trees, B: cool temperate broad-leaved forest except for *Fagus crenata*, C: *Fagus crenata* forest.
Compiled from Ito, 1982 and Ito et al., 1982.