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Pollen–spore distribution in the surface sediments of the western Bohai Sea, China

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ABSTRACT

Eighty-six seafloor surface sediment samples from the western Bohai Sea were analyzed palynologically to understand the distribution pattern and transport paths of pollen and spores. The results reveal that the pollen assemblages are dominated by arboreal pollen, which accounts for an average of 52% and mainly includes *Pinus*, deciduous *Quercus*, *Carpinus*, *Betula*, *Nitraria*, *Castanea*, and *Ulmus*. The pollen percentages of herbaceous taxa reach an average of 25%, mostly represented by Chenopodiaceae, *Artemisia*, Gramineae, Liliaceae, *Polygonum*, *Typha*, and Cyperaceae. The fern spores are mostly *Selaginella*, *Osmunda*, Triletes, and Monoletes. The distribution characteristic of pollen and spores implies that the pollen assemblages correspond well with the watershed vegetation. Variation in the pollen assemblages in different parts of the marine area could reflect differences in local vegetation, especially the vegetation along the inflowing rivers. The spatial distribution of pollen assemblages further suggests that the discharge from the Yellow River and Luanhe River has a great contribution to the pollen inputs into the western Bohai Sea. Pollen concentrations are lower in the nearshore sea area (water depth < 20 m) due to the combined effects of dynamic sedimentary environment and inflowing rivers. By contrast, pollen concentrations show higher values in the deeper waters of fine sediments near estuaries of Yellow River and Luanhe River and the sea area north of 39.5°N, reaching a maximum concentration of 7000 grains/g. Based on the distribution characteristics of pollen and spores, the PCA analysis results of the distribution of the dominant pollen taxa confirm that pollen grains and spores deposition into the western Bohai Sea was primarily affected by the hydrodynamic condition or water sorted effect (including river flows and ocean currents), and secondarily through aeolian transportation. Non-arboreal pollen were mainly carried by fluvial input and deposited in the nearshore shallow water area. Arboreal pollen dominated by *Pinus* were mainly transported by winds and ocean currents, and fern spores mainly by river flows and ocean currents. The latter two types were mostly concentrated in relatively deeper water area.

1. Introduction

Pollen grains in marine sediments are derived from terrestrial vegetation. Therefore, they can provide not only vegetation information of a pericontinental area, but also direct evidence for marine–terrestrial environmental change. However, pollen sources in marine sediments are very complex, and accurate interpretation of the palynological information relies on a sound understanding of the distribution patterns and transport mechanisms of pollen grains and spores in marine sediments (Stanley, 1966; Heusser, 1988; Kershaw, 1994; van der Kaars, 2001; Dupont and Wyputta, 2003). Theoretically, pollen source areas can be quantitatively traced based on pollen assemblage changes, but multiple factors can complicate reconstruction attempts, such as pollen production, transmission mode, transport distance, and depositional environments (Xu et al., 2012). Hence, an adequate knowledge of the

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dispersal mechanisms of pollen from land to ocean and pollen provenance is a prerequisite for fossil pollen data interpretation.

An understanding of the modern processes of pollen dispersal is vital for Quaternary palaeovegetation, palaeoclimatic and palaeoenvironmental reconstruction. Due to limited knowledge about pollen–spore sedimentary process, past changes in the research area were mostly reconstructed through palynological study on the core sediments (e.g. Meng and Wang, 1987; Chen et al., 2012). Therefore studies on the modern processes of marine pollen–spore dispersal are necessary, especially in the Bohai Sea, where only a few studies on marine pollen–spore distribution and dispersal are available, and only with a low spatial resolution (Cheng, 1978; Jin, 1984; Xu and Sun, 1988; Wang, 1993). In this paper, we present the results of pollen–spore analysis of the surface sediments from the western part of the Bohai Sea, aiming to determine the distribution patterns of pollen grains and spores as well as their transport mechanisms and provenance.

2. Study area

The Bohai Sea, a shallow, low-gradient and semi-enclosed continental shelf area off the coast of northeastern China, is connected with the Yellow Sea through the narrow Bohai Strait (Fig. 1). Covering an area of about 78,000 km^2, it can be geographically divided into five parts: the Liaodong Bay in the northeast, the Bohai Bay in the west, the Laizhou Bay in the south, the Bohai Basin in the center, and the Bohai Strait in the east (Qin et al., 1990). The water depth is mostly less than 30 m throughout the Bohai Sea with an average depth of ~18 m and maximum depth of 84 m toward the northern Bohai Strait (Chen and Zhao, 1985; Chen et al., 2013). The huge amounts of terrigenous sediments in the Bohai Sea are mostly carried by the coastal rivers, including the Yellow River, the Luanhe River, the Haihe River, and the Liaohe River (Fig. 1). The surface sediments in Bohai Sea are mainly soft clay mud, fine silt mud, coarse silt, and fine sand (Fig. 2).

The Bohai Sea circulation is composed of the predominant extension of the Yellow Sea Warm Current (YSWC), the Liaonan Coastal Current (LNCC), and the southern Bohai Sea Coastal Current (BSCC) (Guan, 1994; Fang et al., 2000). In winter, the YSWC is driven by the incursion of a branch of the Kuroshio subsurface water onto the shelf, extends northward, and can reach the Bohai Sea. The current moves westward along the central part of the sea and splits into two branches: one moving toward the northeast to form a clockwise gyre (Liaoxi Coastal Current (LXCC)) and another moving southward and then turning eastward along the southern coast to form a counterclockwise gyre (Lubei Coastal Current (LBCC); Fig. 1) (Guan, 1994; Su, 1998). In summer, the YSWC disappears in the Bohai Sea, and the eddies produced by the Bohai Sea itself are stronger than in winter and the central eddy is missing, while the eddy in the Laizhou Bay is more pronounced, and a coastal current along the southern and western coastlines of the Bohai Sea is established (Su and Weng, 1994). The coastal current flows southward in winter and northward in summer, reflecting the prevailing wind direction (Guan, 1994; Fang et al., 2000). The hydrological conditions of Bohai Sea are not only affected by the open sea, but are also controlled by the configuration of the coastline, coastal river runoff variations, submarine topography, and atmospheric circulation (Department of Marine Geology, Institute of

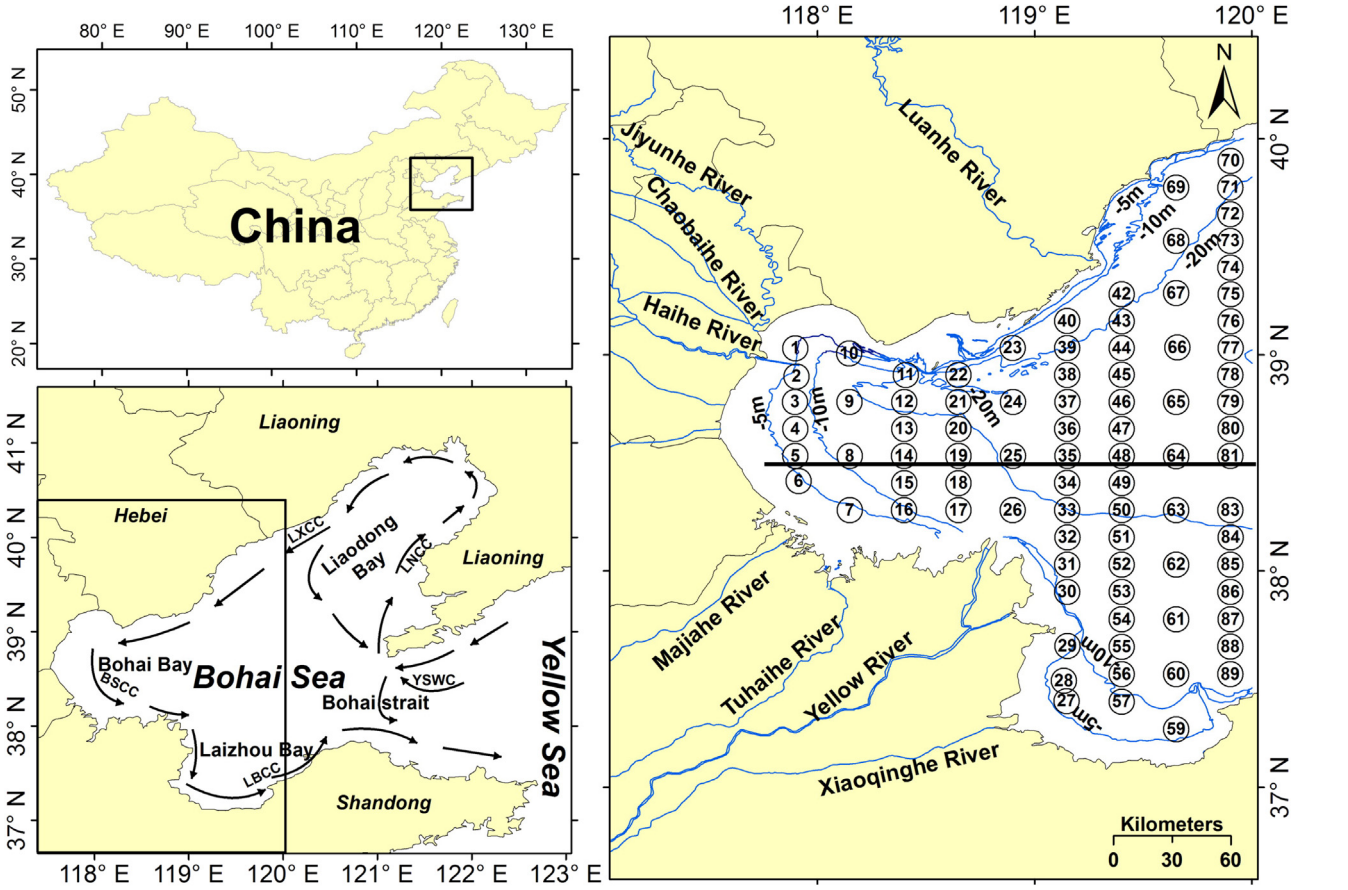

Fig. 1. Current circulation in the Bohai Sea in the summer (arrows indicate circulation direction) (Zhu et al., 2007), surface sediment sample, locations in the western Bohai, Sea and the location of the selected transect (thick black line).