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A Miocene pollen flora from the petroliferous deposits in the Bohai Bay Basin, North China, and its palaeoclimatic and stratigraphic significance

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Abstract

A Miocene oil-bearing sediment core (~879 m) from the Guantao Formation in the Bohai Sea area, North China, provides a new pollen sequence with rich and diverse composition. The predominant occurrence of Ulmaceae (*Ulmus*, *Zelkova*, and *Planera*) and amentiferous taxa, such as *Juglans*, *Quercus*, *Carya*, *Liquidambar*, *Corylus*, and *Betula*, in the pollen flora, suggests forest vegetation existed around the study area at that time. Associated with abundant *Pinus*, evergreen oaks and Rutaceae, the forest could be a mixed deciduous and evergreen broad-leaved type developing under a warm and humid climate. The flourishing of aquatics, mainly *Trapa*, *Ceratopteris*, and *Persicaria*, indicates the prevalence of humid habitats. By integrating the quantitative coexistence approach with the characteristics of the flora, this Miocene forest is assumed to sustain under a climatic pattern with probably higher winter temperature and less seasonal precipitation than at present. The pollen flora is assigned to the late Early Miocene in age based on a comparison with some established pollen sequences, dated contemporaneous floras, and some stratigraphically important aquatic taxa.

Keywords: Pollen flora; Vegetation; Miocene; Bohai Bay Basin; North China

1. Introduction

As one of the largest oil-gas reservoirs in eastern China, the Bohai Bay Basin, with an area of 200 000 km^2, is located in the northeastern part of North China. It was formed and controlled by active tectonic movements resulting in rifts, faults, and depressions from Paleogene. It consists of a number of sags and uplifts striking in NNE-NE direction (Qi et al., 1995; Guo et al., 2007; Tang et al., 2008; Zhang et al., 2010). The present-day Bohai Sea area is the main part of the basin and the centre of deposition and depression as well (Guo et al., 2007). Since the 1960s, this basin has received much attention from the oil companies for exploring a large number of thick oil-gas bearing beds (Gao and Zhu, 2000).

Pollen analysis as a necessary and effective method has been widely employed in the basin for stratigraphic division, correlation, and environmental reconstruction. With the accumulation of pollen data, Cenozoic pollen sequences and palynostratigraphic framework have been established since the late 1970s (RIPEDMPI and NIGPAS, 1978; Guan et al., 1989). However, these pollen data only showed the general characteristics of pollen floras from the specific sediment units and are generally presented by pollen assemblages with only a range of percentages for each taxon. Up to now, no detailed pollen diagram is available showing the variation of pollen taxa sample by sample. Thus, further studies are still needed to make more precise stratigraphic correlation and age assignment and to better reconstruct vegetation and climate.

Here we report a new, detailed pollen flora from the Miocene Guantao Formation in the core 12B 13-1 in the Bohai Sea area. We try to reconstruct the vegetation history and climate variability, and to improve age assignment by comprehensive correlations for the Guantao Formation. The palaeoclimate is quantitatively and preliminarily reconstructed by using the coexistence method.

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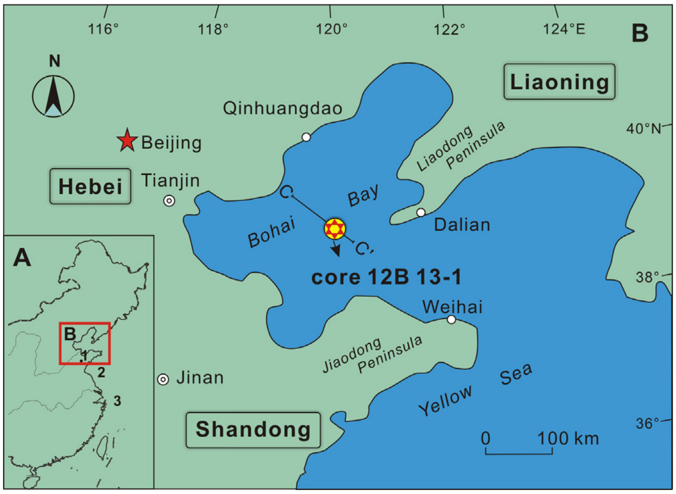

Fig. 1. Map showing the location of the core 12B 13-1 in the Bohai Sea area, North China, and a transect section C-C′ shown in Fig. 2.

2. Study area

2.1. Modern climate and vegetation

The Bohai Bay is a typical semi-enclosed sea lying in eastern North China (Fig. 1A, B). A continental warm temperate climate prevails in its surrounding mainland including the North China Plain in the west, the Liaodong Peninsula in the northeast, and the Jiaodong Peninsula in the southeast (Fig. 1B). The study area is located in the northern margin of the Asian monsoon region and is sensitive to pronounced seasonal changes. The mean annual temperature ranges from 8 °C to 14 °C, and monthly temperature averages from −3 °C to −22 °C in January and 24 °C to 28 °C in July. The climate features wet summer with a mean annual precipitation of 500–1000 mm, 60–70% of which falls in summer (ECVC, 1980).

Modern vegetation of the area is characterized by the zonal warm temperate forest dominated by *Pinus-Quercus*. Deciduous oaks are the dominant trees in the forest such as *Quercus wutaishanica*, *Q. acutissima*, *Q. variabilis*, and *Q. mongolica*. Pine is diverse in species and its forests are widely distributed. *P. densiflora* is dominant in the eastern coastal peninsulas whereas *P. tabuliformis* is mainly in the west inland. Common arboreal components mixed in the pine-oak forest include Betulaceae, Salixaceae, Juglandaceae, Ulmaceae, and Aceraceae. Subalpine dark coniferous forest on the highlands consists of *Abies*, *Picea*, and *Larix*. The lowland broad-leaved deciduous forest has been extensively disturbed by humans for agriculture and urbanization for a long time (ECVC, 1980).

2.2. Geological setting

Stratigraphically, Neogene sediments are well developed. They are unconformable with the underlying Paleogene deposits, spreading from west to east in the Bohai Sea area (Fig. 2). Neogene sequence in the basin includes two units, that is, the lower Guantao Formation and the upper Minghuazhen Formation as revealed in the core 12B 13-1 (Fig. 2).

Located at the Bodong sag in the eastern part of the Bohai Basin (Fig. 2), the core 12B 13-1, drilled during 1979–1980 by the Offshore Petroleum Exploration Bureau of Bohai, is 4119.73 m long in total. The Guantao Formation is 879 m in thickness ranging from 2008 m to 2887 m in the core (Guo and Wang, 1980) (Fig. 3). Lithologically, the formation is subdivided into two parts: the upper part (2008.0–2455.5 m) is characterized by the alternating gray to grayish-green mudstone, grayish-white sandstone and gravel; the lower part (2455.5–2887.0 m) is the oil-bearing beds composed of grayish to brown grayish oil-patched sandstone, oil-soaked sandstone, muddy siltstone and grayish mudstone interbedded with gravels (Guo and Wang, 1980) (Fig. 3).

3. Material and methods

Sixteen samples were collected from the study core with an interval of 40 m or 60 m, among which 15 samples are from the Guantao Formation (Fig. 3) and one sample from the lowermost part of the overlying Minghuazhen Formation. The Minghuazhen sample here is taken as a reference for pollen comparison with the Guantao samples. The pollen samples are selected mostly from the organic sediments and thus contain rich fossil palynomorphs. Detailed sampling layers are indicated in Fig. 3.

Laboratory pollen preparation generally followed the standard preparation method (Faegri and Iversen, 1989): successive treatments with NaOH (10%) to remove humic acids and oil, HF (40%) treatment to digest silicates, and acetolysis treatment to remove unwanted organic matter. After chemical treatment, the remains were concentrated through a 7-μm-mesh nylon cloth and then the residue was stored in a mixture of glycerol and balata. All of the prepared samples are stored in Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences.

Palynomorphs were identified and counted using a Zeiss AX10 light microscope, usually at 400× magnification (630× when necessary) with the aid of references on modern and fossil pollen and spores (e.g., Wang et al., 1995; Song et al., 1999), as well as modern pollen keys kept in the Nanjing Institute. When possible, palynomorphs were mostly referred to natural classification at the genus or family level; alternatively, some limited types were designated to morphotaxa. Following the summation routine in the previous palynological studies, a minimum of 300 grains including pollen, spores, and algae were counted for each sample as the pollen sum to permit pollen percentage calculation for each taxon. The pollen diagram was prepared with Tilia 2.0 and the associated TGView 2.0 (Grimm, 1991–1993) and was modified with the CorelDraw X6 when necessary.

To quantitatively explore the climate significance of pollen flora, the coexistence approach (CA) (Mosbrugger and Utescher, 1997) was used. The CA, following the principle of the classic Nearest Living Relative (NLR) method (Mosbrugger, 1999), is based on the assumption that the climatic tolerance of fossil species is similar to those of their NLRs (e.g., Mosbrugger and Utescher, 1997; Utescher et al., 2007; Bruch et al., 2011). It reconstructs the terrestrial palaeoclimatic parameters for a given fossil flora by using climatic intervals in which all of the NLRs of