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Paleoenvironmental changes in the northern South China Sea over the past 28,000 years: A study of TEX_{86}-derived sea surface temperatures and terrestrial biomarkers

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ABSTRACT

We have generated a record of TEX_{86} (TEX^{H}_{86})-derived sea surface temperatures (SSTs) over the last 28 ka for core MD97-2146 from the northern South China Sea (SCS). The TEX^{H}_{86}-derived temperature of a core-top sample corresponds to the SSTs in warmer seasons. The SST record shows a drop during the Oldest Dryas period, an abrupt rise at the onset of the Bølling–Allerød period, a plateau across the Younger Dryas period, and an abrupt rise at the beginning of the Holocene. The glacial–interglacial contrast in TEX^{H}_{86}-derived temperature is almost the same as that in foraminiferal Mg/Ca ratio-derived temperature, but it is larger than those in $U^{K'}_{37}$ and transfer function-derived temperatures. Possible interpretations are: (1) the seasonal shift of glycerol dialkyl glycerol tetraether (GDGT) production, (2) the overestimation of temperature change by TEX^{H}_{86}, and (3) the underestimation of temperature change by $U^{K'}_{37}$ and transfer function approaches. The similar variation in TEX^{H}_{86}-derived temperature at the study site and Chinese stalagmite $\delta^{18}O$ during the last deglaciation suggests that changes in TEX^{H}_{86}-derived temperature in this period reflected atmospheric and oceanic reorganization on a millennial timescale. The long-chain *n*-alkanes are mainly of higher plant origin before ~14 ka and a mixture of higher plant and lithic origins after ~14 ka; the abundance ratio of long-chain to short-chain *n*-fatty acids decreases at ~15 ka, suggesting a drastic change in sediment sources at ~14–15 ka. We attribute the higher content of fresh higher plant *n*-alkanes and long-chain *n*-fatty acids before ~14–15 ka to enhanced aeolian transportation and/or arid environments. Increased precipitation likely due to intensified summer monsoon after ~14–15 ka enhanced the erosion of sedimentary rocks and increased the contribution of lithic *n*-alkanes.

1. Introduction

Numerous paleoceanographic studies of sea surface temperature (SST) have been undertaken in the South China Sea (SCS). Wang and Wang (1990) and Wang et al. (1995) generated summer and winter SST records for the SCS, based on foraminifer assemblages, and found that during the last glacial maximum (LGM) the SCS experienced larger seasonal SST differences and a steeper latitudinal SST gradient than it does presently. Similar phenomena were reported using foraminifer- and alkenone-based SST records for the northern SCS (Huang et al., 1997a,b; Chen and Huang, 1998; Pelejero et al., 1999a; Chen et al., 2003). Kienast et al. (2001) identified a millennium-scale temperature variation that mimics Greenland ice core records. Recently, Oppo and Sun (2005) and Zhao et al. (2006) reported millennium-scale temperature records from the northern and southern SCS, respectively, for the time since the penultimate glacial interval. The glacial–interglacial changes of SST in the SCS have been attributed either to the inflow of cold water from the North Pacific (e.g., Wang and Wang, 1990; Wang et al., 1995) or to changes in winter monsoon intensity (e.g., Huang et al., 1997a,b). Disagreements of paleotemperatures in the SCS among different proxies such as alkenone $U^{K'}_{37}$, the foraminiferal Mg/Ca ratio, and transfer function are potentially attributable to differences in the season and depth that each proxy reflects (e.g., Steinke et al., 2008). Alternative approaches are useful for better understanding paleotemperature changes in the SCS.

TEX_{86} is a recently developed paleotemperature proxy (Schouten et al., 2002), which is based on glycerol dialkyl glycerol tetraethers (GDGTs). The TEX_{86} paleothermometer has the advantage that it does not seem to be influenced by changes in salinity (Wuchter et al., 2004) and is more sensitive to temperature changes in tropical waters (Kim et al., 2010). However, caution is

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still required when applying TEX_{86} because a water-column study suggested that TEX_{86} recorded not only temperature changes, but also changes in archaeal ecology, nutrient concentrations, and possibly oceanographic conditions (Turich et al., 2007). More case studies are necessary to test the reliability of this proxy. Furthermore, TEX_{86} has not been previously applied to SCS sediments.

Changes in terrestrial vegetation and sediment transport pathways have also been investigated from the perspective of monsoon variation. Sun and Li (1999) reported a transition from a herb-dominated cool and dry climate during the last glacial to a warm and humid climate in the Holocene in South China, as shown by pollen and spore assemblages in the SONNE 17940 core from the northern SCS. Wang et al. (1999a) attributed the increase in clay content observed at ~14.5 ka in core 17940 to an increase in fluvial supply from the Pearl River due to the intensification of the summer monsoon. Pelejero (2003) revealed the parallel glacial–interglacial variability of terrestrial *n*-alkane concentration in four different cores retrieved from the northern, western and southern SCS, taking values linearly inversely correlated to the $U^{K'}_{37}$-derived SST, with higher concentrations during glacials. This oscillation was attributed to the emergence and flooding of the shelves caused by sea level variations, together with SCS SSTs, have a clear dependency on the Northern Hemisphere climate evolution. Terrestrial biomarkers such as long-chain *n*-alkanes and long-chain *n*-fatty acids are useful for understanding the contribution and provenance of terrestrial material (e.g., Pelejero et al., 1999b; Pelejero, 2003; Yamamoto and Polyak, 2009).

This study presents records of TEX^{H}_{86}-derived SSTs and terrestrial biomarkers for the last 28,000 years from northern SCS core MD97-2146, located offshore from southern China. The objective of this work is to understand changes in SSTs derived from TEX^{H}_{86} as well as changes in sediment provenance. This is the first report of the application of TEX_{86} (TEX^{H}_{86}) paleothermometry in the SCS.

2. Oceanographic settings

The SCS is a marginal sea of the North Pacific with seven connections to surrounding seas and oceans (Fig. 1): the Taiwan Strait to the East China Sea (sill depth ~70 m), the Bashi Strait to the North Pacific (sill depth ~2500 m), the Mindoro and Balabac Straits to the Sulu Sea (sill depths ~450 and ~100 m, respectively), the Malacca Strait to the Indian Ocean (sill depth ~30 m), and the Gaspar and Karimata Straits (~40–50 m) to the Java Sea (Wyrtki, 1961). Surface circulation in the SCS is driven by large-scale, seasonally-reversed monsoon winds (Wyrtki, 1961). In the boreal summer, southwesterly winds drive an inflow of Indian Ocean water through the Sunda Shelf and a clockwise surface circulation in the SCS. In the boreal winter, northeasterly winds drive an inflow of North Pacific and East China Sea waters through the Bashi and Taiwan Straits, and surface circulation in the SCS is counterclockwise.

3. Materials and methods

3.1. Samples and age-depth model

During the IMAGES 1997 *Marion Dufresne* cruise, a giant piston core (MD97-2146; 38.69 m long) was collected from a water depth of 1720 m on the northern slope of the SCS at 20°07.08′N, 117°23.02′E (Fig. 1). The sediment retrieved consisted of dark gray nannofossil and foraminifer oozes with some radiolarians and diatoms (Chen et al., 1998).

An age model in calendar years was created from the AMS ^{14}C ages of seven samples of the planktonic foraminiferan *Globigerinoides sacculifer* (Lin et al., 2006) and six samples of mixed planktonic foraminifera *Globigerinoides ruber* and *G. sacculifer* (Shintani et al., 2008). The calendar age was converted using the CALIB5.0 program and marine04.14C dataset (Reimer et al., 2004) with a 400-year

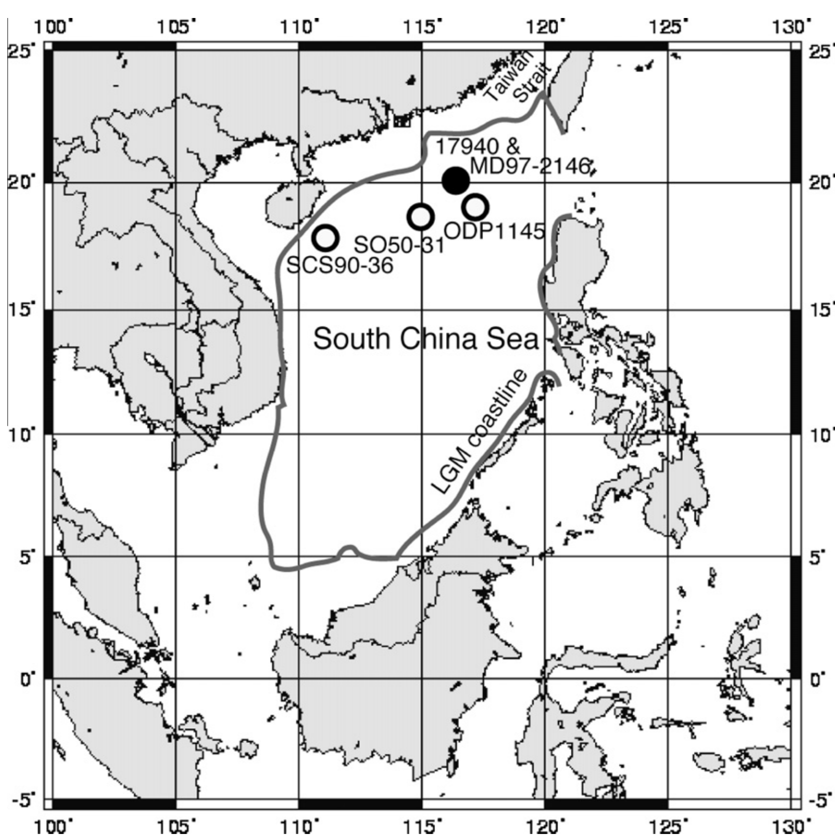

Fig. 1. Map showing the locations of core MD97-2146 and other cores referred to in this paper.