Palaeogeography, Palaeoclimatology, Palaeoecology xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Palaeogeography, Palaeoclimatology, Palaeoecology

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

Sediment provenance in the western Pacific warm pool from the last glacial maximum to the early Holocene: Implications for ocean circulation and climatic change

Jianguo Liu[a,b,*,1], Wen Yan[a,c,**,1], Weihai Xu[a], Lifeng Zhong[a,d]

[a] Key Laboratory of Ocean and Marginal Sea Geology, South China Sea Institute of Oceanology, Chinese Academy of Sciences, Guangzhou 510301, PR China
[b] Laboratory for Marine Geology, Qingdao National Laboratory for Marine Science and Technology, Qingdao, 266061, PR China
[c] University of Chinese Academy of Sciences, Beijing 100049, PR China
[d] School of Marine Sciences, Sun Yat-Sen University, Guangzhou 510006, PR China

ARTICLE INFO

Keywords:
Rare earth elements
Clay minerals
Sediment transport
Climatic events
Frequency analysis
Solar insolation

ABSTRACT

Sedimentary records including clay minerals, major elements, rare earth elements (REE) and ^{14}C ages, were analyzed in one core from the western Pacific warm pool (WPWP), in order to identify the sources of sediments in the warm pool region from the last glacial maximum (LGM) to the early Holocene. The results showed that the sedimentation rate at the studied core site has decreased continuously since the LGM. Both major elements and clay minerals experienced staged changes in the study area. In the studied core, most major elemental concentrations decreased prior to 22 kyr BP but increased gradually after 13 kyr BP. Sediment provenance based on clay minerals and REEs further revealed that sediments were likely a mixture of dominant New Guinea sediments and Asian dust. The South Equatorial Current was the main force transporting New Guinea particles, while the East Asian winter monsoon and the correlated North Equatorial Countercurrent might have loaded the Asian dust into the study area. Moreover, Heinrich events were well imprinted in the western Pacific, and another cold climatic event that occurred at approximately 21 kyr BP was also recorded in the study area. These events were similarly documented in ice from Greenland but were undistinguished in ice from the Antarctic and stalagmites from the Hulu Cave, China. A frequency analysis of multi-proxies confirmed that sun irradiance essentially controlled the variation in sedimentary records in the western Pacific from the LGM to the early Holocene.

1. Introduction

The modern western Pacific warm pool (WPWP) receives large amount of solar radiation in the earth and as a result has the highest sea surface temperature (SST, Webster et al., 1996). Previous studies have suggested that the tropical Pacific may play a significant role in controlling global climate change (e.g., Koutavas et al., 2002; Visser et al., 2003; DiNezio and Tierney, 2013), in addition to the polar ice sheets (e.g. Clark et al., 1999; Rohling et al., 2014). However, until now, the mechanisms behind the connection between tropical and middle-high latitude regions remain unidentified. Additionally, the phase relationship between tropical SST and ice-volume change is still elusive.

Currently, the WPWP region is dominated by abundant rainfall and warm climate conditions throughout the year. In the South and East Asia, the annual terrigenous sediment discharged to the ocean accounts for approximately 70% of the total world input (Milliman and Farnsworth, 2011). Even though New Guinea, shown in Fig. 1, covers an area of only 8×10^5 km^2, its annual fluvial discharge is approximately 1.7×10^9 tons, comparable to the discharge from all of North America (Milliman and Farnsworth, 2011). Such heavy precipitation and high terrigenous input make the WPWP another significant area for the study of land-sea interactions. However, the temporal variation in terrigenous material sedimentation in the WPWP is poorly understood. In deep waters > 2000 m in depth, limited work has been conducted to explore the depositional environment of the western Pacific since the last glacial period, mainly due to low sedimentation rate (normally < 10 cm/kyr) in this open and deep ocean.

In this study, we analyzed one box core (DY12) and several referenced surface (0–2 cm) samples (DY11 and Y3-6), which were collected from the central part of the WPWP during the same cruise. Clay mineral

* Correspondence to: J. Liu, Laboratory for Marine Geology, Qingdao National Laboratory for Marine Science and Technology, Qingdao 266061, PR China.
** Correspondence to: W. Yan, University of Chinese Academy of Sciences, Beijing 100049, PR China.
E-mail addresses: jgliu@scsio.ac.cn (J. Liu), wyan@scsio.ac.cn (W. Yan).
[1] Contributed equally to this study.

https://doi.org/10.1016/j.palaeo.2017.12.040
Received 25 August 2017; Received in revised form 29 December 2017; Accepted 30 December 2017

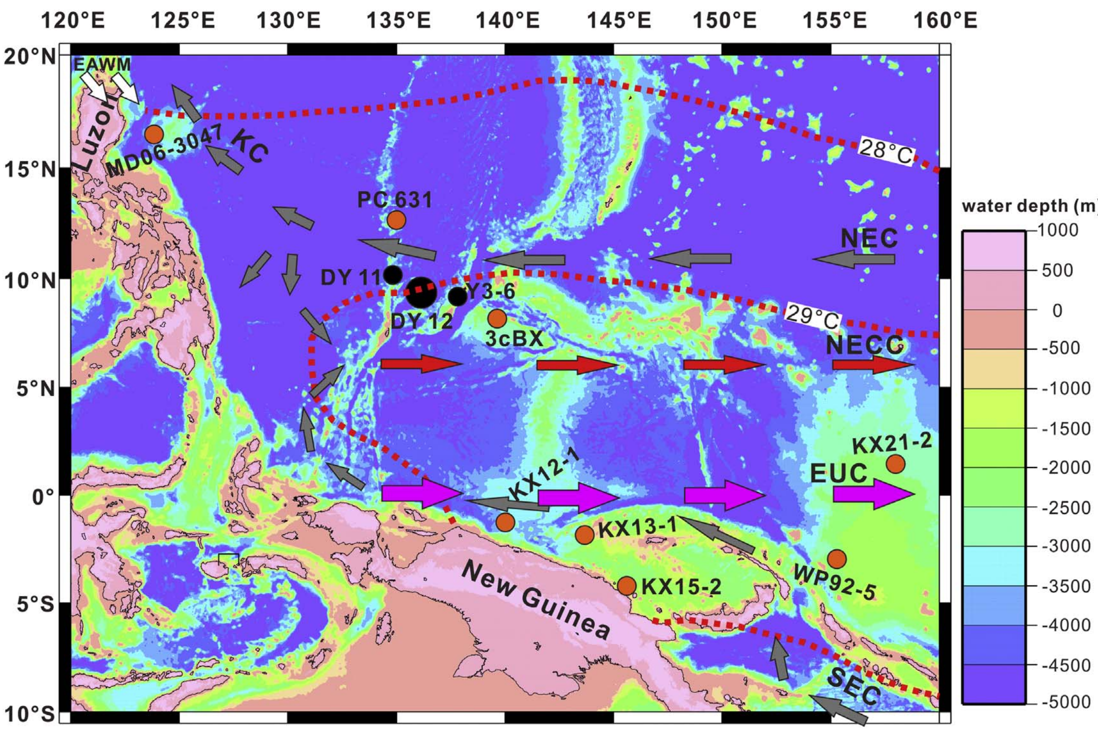

Fig. 1. Location of Core DY12 and referenced samples in the western Pacific. Abbreviations are as follows: NEC, North Equatorial Current; NECC, North Equatorial Countercurrent; SEC, South Equatorial Current; EUC, Equatorial Undercurrent; KC, Kuroshio Current; and EAWM, East Asian winter monsoon.

assemblages, major elements and rare earth element (REE) compositions, together with six accelerator mass spectrometry (AMS) ^{14}C dating measurements of the core sediment samples, are used to study variability history of sediment sources from ~26 kyr BP to 10 kyr BP and its circulation and climatic implications in the warm pool region.

2. Regional setting

The studied core is located in the WPWP, which has a mean annual SST of approximately 29 °C (Fig. 1). Surface conditions in the WPWP are characterized by warm and nutrient-poor water associated with an SST ≥ 28 °C (Pflaumann and Jian, 1999). The annual average sea-surface salinity for a 1 × 1° grid box centered on 155.5°E and 3.5°S is 34.47 p.s.u. (Schlitzer, 2007). The inter-annual variability of the WPWP is mostly affected by the El Niño-Southern Oscillation. During El Niño periods, warm surface water shifts eastward, driven by weakened trade winds, resulting in a small SST drop and reduced precipitation at the nearby Core 3cBX (8°1.2′N,139°38.4′E, water depth 2829 m) in the WPWP (Dai and Wigley, 2000; Sagawa et al., 2012).

The study area is directly impacted by the North Equatorial Current. The most significant oceanographic characteristics of the North Equatorial Current are annual and seasonal changes in the latitudinal position of its bifurcation, which are influenced by monsoon and El Niño-Southern Oscillation activities (Qiu et al., 2014). At the same time, the North Equatorial Current provides noteworthy pathways for zonal heat and water mass exchange across the Pacific Ocean. This current is separated into two branches (Fig. 1) after approaching the western boundary along the Philippine coast (Toole et al., 1990). Previous studies have suggested that the North Equatorial Current bifurcation shifts more southward and send more water mass into the Kuroshio Current in the summer (June to August) and shifts more northward and send less water mass into the Kuroshio Current in winter (Qu and Lukas, 2003; Kim et al., 2004; Qu et al., 2004).

In the present tropical western Pacific, seasonal precipitation variability is controlled by both El Niño-Southern Oscillation change and migration of the Intertropical Convergence Zone. Evaporation/precipitation ratios related to local insolation and water vapor advection dynamics dominate rainfall types in this area. The South Equatorial Current, which exhibits relatively low salinity resulting from abundant precipitation, is a westward-flowing current located between 8°S and 3°N and is mostly localized to the upper water column from 0 to 300 m (Reverdin et al., 1994). This current is characterized by high dissolved oxygen and low nutrient concentrations in warm surface waters (Anderson and Ravelo, 1997). Beneath the South Equatorial Current, the Equatorial Undercurrent flows from west to east below the thermocline (Fine et al., 1994) and supplies nutrients to the South Equatorial Current (Li et al., 2011).

3. Materials and methods

Core DY12 (9°11.94′N, 136°8.40′E) was retrieved from a water depth of 4566 m during "the western Pacific seamounts cruise" in winter 2014 by *RV Science No 1*, which belongs to the Institute of Oceanology, Chinese Academy of Sciences (Fig. 1). Core DY12, which has a length of 55 cm, exhibits uniform lithology and contains gray silt and sandy silt but is mixed with several silty sand layers. These coarse-grained components (> 63 μm) almost consist of several types of radiolarian without foraminifera. The core was subsampled at 1-cm intervals in the laboratory for further clay minerals, major elements and REEs analyse.

Due to lack of foraminifera in core sediments, we chose bulk carbon as an alternative measured material for dating. > 8.0 g of bulk sediment samples from six horizons among the above subsampled sediments were measured for dating at the AMS Laboratory Beta Analytic (Table 1). All AMS ^{14}C ages were converted to calendar years using the CALIB 7.1 software program with the MARINE 13 calibration data set (Reimer et al., 2013) after a global 400-year reservoir age correction was applied (Fairbanks et al., 2005).

Major minerals and REEs of the unwashed bulk sediment samples were analyzed by inductively coupled plasma-atomic emission spectrometry and inductively coupled plasma-mass spectrometry, respectively, at the Institute of Geophysical and Geochemical Exploration,