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Dry climate near the Western Pacific Warm Pool: Pleistocene caliches of the Nansha Islands, South China Sea

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Abstract

The Nansha (Spratly) Islands are located in the middle of the South China Sea (at about 10°N) near the northwestern margin of the Western Pacific Warm Pool (WPWP). A borehole was drilled at an atoll at Nansha, and cores were taken. The upper 165.4 m of the borehole consists entirely of limestone of reef facies and lagoon facies, which had been influenced by extensive meteoric diagenesis. Petrographic and geochemical studies have identified at least four subaerial exposure surfaces (SES) in the Pleistocene carbonate sequence. These SES are thought to have resulted from global sea-level changes and characterized by caliche formation.

When developed in limestone, caliches typically form in areas where annual precipitation ranges from 500 mm up to about 1200 mm, compared with 1800–2200 mm of annual rainfall of the present-day Nansha Islands. The Nansha caliche therefore indicates the existence of several dry climate episodes during Pleistocene sea-level lowstands. Lower rainfall and higher evaporation during such dry conditions may explain the higher sea-surface salinities reported elsewhere in the South China Sea. The Nansha caliche may also indicate reduced extent of the WPWP and southerly shift of the Intertropical Convergence Zone during major sea-level lowstands.

Keywords: Caliche; Palaeoclimate; Sea-level changes; Nansha Islands; South China Sea

1. Introduction

Scientists are divided as to the climates of western Pacific tropical seas during glacial periods. Determin-

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ing how cold it was has been the focal point of various investigations (see the review by De Deckker et al., 2002; Lea et al., 2002). In recent years, other aspects of the palaeoclimate, such as sea-surface salinity, precipitation, shift in the Intertropical Convergence Zone (ITCZ) and the amplitude of the East Asian Monsoon (EAM), have also attracted increasing attention. Some authors have proposed that significant lower precipitation and/or higher salinity developed in the vicinity of the South China Sea during glacial periods (Wang, 1999; van der Kaars et al., 2001; De Deckker et al., 2002; Wang et al., 2003; Wei et al., 2003). On the other hand, Hu et al. (2003) pointed out that there was no obvious climate change from the last glacial period to the early Holocene in the southern South China Sea based on their *n*-alkanes data.

In this paper, we present in situ field evidence of dry climates during the late Cenozoic sea-level lowstands at the Nansha (Spratly) Islands, located near northwestern margin of the WPWP. Our evidence is derived from the occurrence of a climate-sensitive soil that developed on an islet, and is therefore independent of assumptions about ice volume and the original chemical composition of seawater.

When marine carbonates emerge during sea-level falls, either of two types of subaerial exposure surface (SES) may develop: a karst surface or a caliche surface (Esteban and Klappa, 1983). Caliche typically formed in sub-arid to sub-humid climate (Esteban and Klappa, 1983; James and Choquette, 1990; Milnes, 1992). Four caliche zones have been identified in the late Neogene sequence of Nansha and provide important palaeoclimate signatures, which may shed some new light on the palaeoclimate reconstruction of the tropical West Pacific.

2. Regional setting

The Nansha (Spratly) Islands of South China Sea consists of numerous atolls, reefs and banks. In the time span from 1995 to 2003, the annual rainfalls of Nansha Islands are in the range of 1800~2200 mm and the average temperature is 27 °C, ranging from 30 °C in summer to 25 °C in winter according to the Central Weather Bureau, Taiwan.

The tectonic history of the Nansha Islands has been dominated by crustal extension and rifting since the

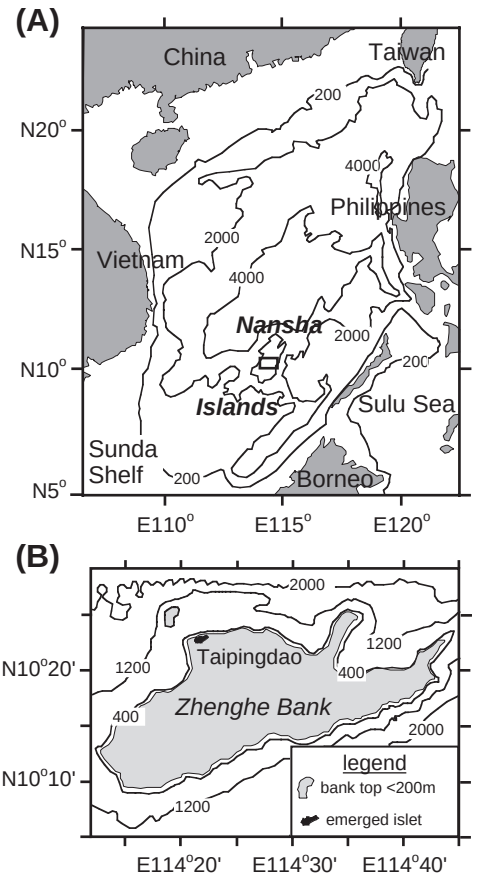

Fig. 1. (A) General geographic and bathymetric feature of the South China Sea. The rectangle in the center indicates the location of the Zhenghe Bank. (B) Simplified bathymetric feature of the Zhenghe Bank and location of Taipingdao. Based on the Hydrographic Data Bank System of South China Sea, Ministry of Transportation, ROC.

opening of the South China Sea in the Paleogene (Schulter et al., 1996). Block faulting ceased during the Middle to Late Miocene. Thermal subsidence has been the major tectonic component since then.

Taipingdao is the largest islet of Nansha Islands, and is located at 10°23′N and 114°22′E as part of the Zhenghe Bank (Fig. 1). It measures about 0.43 km^2 in area, covered by bioclastic sediments and guano deposits, and has a maximum elevation of 4 m.

3. Materials and methods

A fully cored borehole of 523.35 m in depth below the surface was drilled in 1981 at Taipingdao