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# Late Miocene development of the western Pacific warm pool: Planktonic foraminifer and oxygen isotopic evidence

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**Abstract**

The disappearance at ~10 Ma of the deep dwelling planktonic foraminifer *Globoquadrina dehiscens* from the western Pacific including the South China Sea was about 3 Myr earlier than its final extinction elsewhere. Accompanying this event at ~10 Ma was a series of faunal turnover characterized by increase in mixed layer, warm-water species and decrease to a minimum in deepwater species. Paleobiological and isotopic evidence indicates sea surface warming and a deepened local thermocline that we interpret as related to the development of an early western Pacific warm pool. The stepwise decline of *G. dehiscens* and other deep dwelling species from the NW and SW Pacific suggests more intensive warm water pileup than equatorial localities where surface bypass flow through the narrowing Indonesia seaway appears to remain efficient during the late Miocene. Planktonic $\delta^{18}$O values from the South China Sea consistently lighter than the tropical western Pacific during the Miocene also suggest, similar to today, more variable hydrologic conditions along the periphery than in the core of the warm pool. Stronger hydrologic variability affected mainly by monsoons and increased thermal gradient along the western margin of the late Miocene warm pool may have contributed to the decline of deep dwelling planktonic species including the early extinction of *G. dehiscens* from the South China Sea region. The late Miocene warm pool became influential and paleobiologically detectable from ~10 Ma, but the modern warm pool did not appear until about 4 Ma, in the middle Pliocene.


*Keywords:* Western Pacific Warm Pool (WPWP); South China Sea, ODP Leg 184; Indonesian seaway; Miocene; Planktonic foraminifers; Oxygen isotope

## 1. Introduction

Characterized by a thick layer of warm surface water with a deep thermocline down to ~170–300 m, the western Pacific warm pool (WPWP) occupies much of the tropical–subtropical region of the western Pacific and eastern Indian oceans (Yan et al., 1992). The WPWP is maintained by an intensified Equatorial Current and increased strength of trade winds that also help strengthen the Equatorial Countercurrent systems in the region. With average annual temperatures >28 °C, the WPWP acts as an important source of water vapor and latent heat for high latitudes. Relative stable sea surface temperature

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has been observed from within the core of the WPWP over the entire Pleistocene, implying little long-term change in the tropical net radiation budget (De Garidel-Thoron et al., 2005). Although the role of tropical heat transport in the late Cenozoic global climate change has been recently recognized (Lea et al., 2000; Koutavas et al., 2002; Visser et al., 2003), the early history of the WPWP remained little known. On the basis of planktonic foraminifer paleogeography, Kennett et al. (1985) suggested that the WPWP likely formed after the closure of the Indonesia seaway during the late Miocene, ~8 Ma. Srinivasan and Sinha (1998), however, indicated the final closing of the Indonesian seaway at ~5.2 Ma by referring also to planktonic foraminifer evidence.

In the Indo-western Pacific region, the late Miocene, from ~11.5 to 5.3 Ma, is not only marked by a progressive closing of the Indonesian seaway (Hall, 2002) but also by the onset of a final major episode of Himalayan–Tibetan uplift (Tapponnier et al., 2001). The tectonic-induced geomorphological changes helped transform regional paleoceanography and paleoclimate to near the modern patterns with strong trade winds and intense Equatorial countercurrents (Kennett et al., 1985; Ruddiman, 1997). A narrowing Indonesian seaway caused warm water pileup in the tropical western Pacific, and the existence of any early warm pool must have exerted a significant role similar to today in modulating the global climate (Kuhnt et al., 2004). Among the oceanographic characteristics associated with a warm pool are increased latitudinal and longitudinal temperature gradients that could be revealed by paleobiological and geochemical records. For example, the modern WPWP with its deep thermocline is supporting abundant mixed layer planktonic foraminifers such as *Globigerinoides* and fewer thermocline dwellers including *Globorotalia* and *Sphaerodinella* (Bé, 1977). If the present is any key

Table 1
Site localities and estimated age for the LO of *G. dehiscens* on the time scale of Berggren et al. (1995)

| Site | Latitude | Longitude | Water depth (m) | Zone | Age (Ma) | References |
|---|---|---|---|---|---|---|
| *W Pacific Ocean* | | | | | | |
| DSDP 206 | −32.013 | 165.452 | 3196 | N16 (mid) | 9.5 | Kennett, 1973 |
| DSDP 207 | −36.962 | 165.434 | 1389 | N16 (mid) | 9.5 | Kennett, 1973 |
| DSDP 289 | −0.499 | 158.512 | 2206 | N16 (base) | 9.8 | Keller, 1985 |
| DSDP 292 | 15.819 | 124.651 | 2943 | N16 (mid) | 9.5 | Keller, 1980 |
| DSDP 296 | 29.340 | 133.525 | 2920 | N15/N16 | 9.8 | Keller, 1980 |
| DSDP 586 | −0.497 | 158.498 | 2207 | N17/N18 | 6.0 | Jenkins and Srinivasan, 1986 |
| DSDP 588 | − 26.112 | 161.227 | 1533 | N16 (mid) | 9.5 | Jenkins and Srinivasan, 1986 |
| DSDP 590 | −31.167 | 163.358 | 1299 | | 9.5 | Spencer-Cervato et al., 1994 |
| DSDP 592 | −36.473 | 165.442 | 1088 | N16 (mid) | 9.5 | Jenkins and Srinivasan, 1986 |
| DSDP 593 | −40.508 | 167.674 | 1068 | | 9.8 | Spencer-Cervato et al., 1994 |
| ODP 806 | 0.320 | 159.360 | 2520 | N18 (base) | 5.6 | Chaisson and Leckie, 1993 |
| ODP 1143 | 9.362 | 113.285 | 2771 | N15 (top) | 9.8 | This study |
| ODP 1146 | 19.457 | 116.273 | 2091 | N16 (base) | 9.8 | This study |
| ODP 1148 | 18.837 | 116.565 | 3297 | N16 (base) | 9.8 | This study |
| *N Pacific Ocean* | | | | | | |
| DSDP 310 | 36.868 | 176.901 | 3516 | N16 (upper) | 9.0 | Keller, 1980 |
| *E Pacific Ocean* | | | | | | |
| DSDP 77 | 0.482 | −133.228 | 4291 | N17 (upper) | 6.0 | Keller, 1981 |
| DSDP 503 | 4.051 | −95.637 | 3672 | | 5.5 | Spencer-Cervato et al., 1994 |
| DSDP 573 | 0.498 | −133.310 | 4301 | | 5.5 | Spencer-Cervato et al., 1994 |
| ODP 846 | −3.095 | −90.818 | 3295 | N17 (upper) | 6.0 | Vincent and Toumarkine, 1995 |
| ODP 848 | −2.993 | −110.480 | 3867 | N17 (upper) | 6.0 | Vincent and Toumarkine, 1995 |
| *NE Indian Ocean* | | | | | | |
| DSDP 214 | −11.337 | 88.718 | 1655 | N17 (upper) | 6.0 | Srinivasan and Sinha, 1991 |
| ODP 758 | 5.384 | 90.361 | 2924 | N20 | 3.9 | Peirce et al., 1989 |
| ODP 761 | −16.738 | 115.535 | 2168 | N17/N18 | 5.8 | Zachariasse, 1992 |
| *W Atlantic Ocean* | | | | | | |
| DSDP 502 | 11.490 | −79.380 | 3051 | | 6.0 | Spencer-Cervato et al., 1994 |
| ODP 925 | 4.205 | −43.488 | 3040 | N17 (upper) | 6.0 | Chaisson and Pearson, 1997 |