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Distribution and ecology of planktonic foraminifera from the seas around the Indonesian Archipelago

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Abstract

Planktonic foraminiferal assemblages in 50 core-top samples from the western and southern areas of the Indonesian Archipelago and 29 core tops retrieved northwest of Australia were grouped using cluster analysis. These assemblages make it possible to sub-divide the studied area in five provinces: 1/ the Banda/Java region (I); 2/ the Timor region (II); 3/ the Java upwelling region (III); 4/ the Indian monsoon Sumatra region (IV), and 5/ the NW Australia margin region (V). The foraminiferal assemblage groups reflect differences in sea-surface temperature, salinity, thermocline depth, and nutrient supply between these five provinces. These differences are related to surface circulation patterns. The carbonate dissolution is rather intense compared to that in other areas of the eastern Indian Ocean. Within the studied area, the strongest dissolution occurs in samples from the Java upwelling region, with the lysocline level rising above ~2800 m. The increase in abundance of *Globigerina bulloides* at 10–8 ka BP in core SHI-9034 (the Java upwelling region) corresponds to the decrease in core SHI-9006 (the Banda/Java region) which indicates an intensification of upwelling in relation to a strengthened southeastern monsoon over the studied area.

Keywords: Indonesian Archipelago; planktonic foraminifera; carbonate dissolution; cluster analysis; upwelling; southeastern monsoon

1. Introduction

The Indonesian Archipelago is a pathway for oceanic heat transfer between the Pacific and Indian oceans (Godfrey and Golding, 1981; Godfrey and Ridgway, 1985). Within this archipelago there are at least eight deep-sea basins connected through relatively shallow sills (Tomczak and Godfrey, 1994; Martinez et al., 1997). The surface circulation shows a strong seasonal variability related to monsoonal forcing. The Indonesian Archipelago, the only low-latitude connection between two major ocean basins, is a key area along the return branch of the Great Conveyor Belt which ultimately brings surface waters from the Pacific to the north Atlantic (Gordon, 1986; Hirst and Godfrey, 1993; Bray et al., 1996; Gordon and Fine, 1996; Müller and Opdyke, 2000).

The archipelago is situated within the Western Pacific Warm Pool (WPWP), and annual mean sea surface temperatures exceed 28 °C (Tomczak and Godfrey, 1994; Martinez et al., 1997). The WPWP not only supplies large amounts of water vapor and latent heat

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to the western Pacific atmosphere, but it represents a major contributor to global climate changes through the El Niño/Southern Oscillation system. The WPWP dynamics are intimately linked to current transport processes in the Indonesian Archipelago (Thunell et al., 1994; Ahmad et al., 1995; Linsley, 1996; Wang, 1998; Martinez et al., 1999; Wang et al., 1999b).

Thus, researches focused on surface circulation variability in the low-latitude Indian–western Pacific region are critical for a better understanding of the Asian monsoons, the dynamics of the WPWP, El Niño events and thermohaline circulation in the global ocean.

Several paleoceanographic studies have been conducted in the study area. Martinez et al. (1998, 1999) studied the late Pleistocene paleoceanography of the northern Australian margin and the eastern Indian Ocean including the Indonesian Archipelago. Gingele et al. (2002) analyzed the history of the South Java Current during the last 80 ka using the distribution of clay minerals. Hanebuth et al. (2000) studied late-glacial sea level changes across the Sunda shelf. Visser et al. (2003) found that SST of waters within the Indonesian Archipelago increased by 3.5–4.0 °C across the last two glacial–interglacial transitions, leading the Northern Hemisphere ice sheets melting by about 2000–3000 years. The tropical Pacific region possibly regulates the poleward flux of heat and water vapor, thus affecting global glacial–interglacial climate changes (Cane, 1998), similar to the mechanisms involved in El Niño/Southern Oscillation.

Much work remains to be done to unravel the history of this region, having an intricate geographic setting with numerous straits and basins, and affected by complex climatic mechanisms on various timescales (monsoon, El Niño/Southern Oscillation). Because the Indonesian Archipelago is located near the equator and has vast, shallow shelves and coasts, the glacial–interglacial and seasonal temperature differences are small, but changes in the amount of fresh water transported are large, making paleoclimatologic and paleoceanographic research in the region difficult. Many attempts have been made using single cores or single proxies to reconstruct specific aspects of local environmental changes. However, these attempts often lack a solid background based on modern sedimentary and faunal patterns. A comprehensive survey based on seafloor surface samples can provide us with a key to unravel the interrelation between modern sedimentation and ocean environment. Once this interrelation is revealed, we can reconstruct past current distribution and sediment transport patterns over longer time periods in the past. Therefore, this paper focuses on providing a more complete planktonic foraminifera database obtained from core-top material recently collected in the seas around the Indonesian Archipelago, correlating foraminiferal distribution with environmental variables and an attempt to apply the results to interpretation of down-core observations.

2. Modern hydrography and environments in the Indonesian region

2.1. Surface currents, throughflow and monsoon-related, seasonal changes

The wind stress between the Pacific and the Indian oceans maintains a sea level height difference between these two ocean basins (Bray et al., 1996), leading to a net inflow of water into the Indian Ocean (Hirst and Godfrey, 1993). The major components of the Indonesian throughflow (ITF) are the Mandanao Current waters that originate from the upper thermocline of the north Pacific and are transported into the Indonesia seas through the Makassar Strait (Gordon, 1986; Gordon and Fine, 1996) (Fig. 1). Halmahera Eddy water originates from the upper thermocline of the South Pacific and seeps into the lower thermocline of the Banda Sea, making up an important part of the Throughflow (Fig. 1). Only a small portion of the waters flowing through the Makassar Strait into the Indonesian seas directly enters the Indian Ocean through the Lombok Strait, between the islands of Bali and Lombok. The largest part of these waters turns eastward into the Banda Sea and Flores Sea before spreading into the Indian Ocean through the Timor Sea as parts of the west-flowing South Java Current, the South Equatorial Current, and the south-flowing Leeuwin Current that runs along the western Australian margin (Gordon and Fine, 1996; Siedler et al., 2001) (Fig. 1).

Temperature gradients between the ocean and adjacent continents (eastern Asia and Australia) result in monsoon winds blowing from the southeast during winter (August), and turning to the opposite direction during summer (February). Ocean currents in the area move according to the wind regime. During the summer monsoon (NW monsoon), the surface currents flow from the Java Sea into the Banda Sea. The high atmospheric temperatures in the region induce evaporation of oceanic water at the surface, low-pressure cells and rain. The overall balance is a gain of freshwater from precipitation at the sea surface. Consequently, SSTs are high and sea-surface salinities (SSSs) low (Martinez et al., 1998). Surface water masses of low salinity reach the Banda Sea. During the winter monsoon (SE monsoon), surface current flows from Arafura and Banda