

Evolution of Miocene calcareous nannofossil assemblages as a response to paleoceanographic changes in the northern South China Sea

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The South China Sea (SCS) is the largest marginal sea in the western Pacific, and is located in the west Pacific warm pool (WPWP) and in a key region of global thermohaline circulation. The thick sedimentary sequence in the SCS represents a complete and continuous record of tectonic, paleoclimatic, and paleoceanographic changes, and therefore makes the SCS an important area for studying Cenozoic paleoenvironments. Here we selected the continuous sediment archives obtained from International Ocean Discovery Program (IODP) Site U1501 in the northern margin of the SCS, for biostratigraphic and paleoceanographic studies. A quantitative analysis of the calcareous nannofossil assemblages was performed, in combination with CaCO_3 (wt%) measurements, to investigate the paleoceanographic changes in the SCS during 15 to 5 Ma.

A total of 117 species of 32 genera of calcareous nannofossils were identified in the 217 samples from IODP Site U1501. The common taxa include *Reticulofenestra* (*R. minuta*, *R. minutula*, *R. haqii*, *R. pseudoumbilicus*), *Florisphaera profunda*, *Cyclicargolithus floridanus*, *Discoaster* (*D. berggrenii*, *D. brouweri*, *D. pentaradiatus*, *D. quinqueramus*, *D. variabilis*), *Helicosphaera carteri*, *Calcidiscus leptoporus*, *Coccolithus pelagicus*, *Sphenolithus* (*S. abies*, *S. moriformis*, *S. heteromorphus*), *Umbilicosphaera* (*U. jafari*, *U. rotula*). Small *Reticulofenestra* spp. are predominant in the assemblages throughout the middle Miocene, indicating high marine productivity during the middle Miocene. The abundances of *Umbilicosphaera*, *Discoaster*, and large *Reticulofenestra* spp. (*R. pseudoumbilicus*, *R. perplexa*), whose high abundances may be related to low-fertility conditions, show a rapidly increasing trend from the middle to late Miocene. Meanwhile, CaCO_3 (wt%) and total shield index decreased during this interval, reflecting the decrease of marine productivity and the enhancement of carbonate dissolution, which coincided with the Carbonate Crash. Subsequently, the abundance of small *Reticulofenestra* spp. gradually increased and CaCO_3 (wt%) increased synchronously, indicating that marine productivity gradually recovered and carbonate preservation improved.

The evolution of the calcareous nannofossil assemblages mentioned above reflects the paleoceanographic changes that occurred from the middle Miocene to early Pliocene in the SCS. During the middle Miocene, the

Indonesia Seaway was not completely closed, and therefore the thermocline was shallow and the surface mixing was strong, which may have provided sufficient nutrients to maintain a high marine productivity. Then, at the middle to late Miocene boundary, the proto-WPWP was formed due to the constriction of the Indonesian Seaway, which deepened the thermocline, weakened the surface mixing and reduced the nutrient supply from the deep sea, thereby reducing productivity and biogenic carbonic production, leading to the Carbonate Crash event. Subsequently, enhanced monsoon circulation and continental weathering led to an increase in the nutrient supply, which increased the marine productivity from the late Miocene to the Pliocene, and led to the biogenic bloom event in the SCS. This work was jointly funded by the National Natural Science Foundation of China (No. 41976045, 41888101) and the Southern Ocean Science and Engineering Guangdong Laboratory (Zhuhai) Innovation Team Construction Project (No. 311021002).