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# Late Quaternary record of pteropod preservation from the Andaman Sea

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ABSTRACT

In order to understand the glacial to interglacial fluctuations in pteropod preservation and productivity during the late Quaternary (~54 ka BP to present), we investigated pteropod, organic carbon ($C_{org}$) and *Globigerina bulloides* abundance in a deep sea core from the western Andaman Sea. Pteropod abundance and preservation is similar to the “Indo-Pacific carbonate preservation type”, showing better preservation during glacial and poor preservation during interglacial periods. The core site appears to have remained below the aragonite compensation depth (ACD) throughout the Holocene, indicated by the total absence of pteropods. Maximum abundance and good preservation of pteropods was observed during stadials such as Younger Dryas (YD), Heinrich Events (HEs) and Last Glacial Maxima (LGM) indicating weaker oxygen minimum zone (OMZ) and deeper ACD. Furthermore, the high relative abundance of mesopelagic pteropods over epipelagic forms suggests a well ventilated water column with weak OMZ particularly during LGM, apparently driven by intense winter monsoon. Increased monsoon-driven productivity was observed during 45–40 ka, of early Marine Isotope Stage 2 (MIS 2, 24–22 ka), Bølling/Allerød (B/A; 15–13.5 ka), YD and late Holocene as evidenced by $C_{org}$ content and *G. bulloides*. Enhanced pteropod preservation of H1 associated with low $C_{org}$ content and *G. bulloides* suggests that reduced monsoonal driven productivity might have influenced pteropod preservation. Deglacial preservation spike in the Andaman Sea is consistent with other northern Indian Ocean records and elsewhere outside the Indian Ocean implying the event is global in nature, marked by deepening of ACD probably driven by enhancement of winter monsoon on local and changes in intermediate water circulation on regional scale.



## 1. Introduction

Carbonate production, accumulation and dissolution in the pelagic environments play vital role in global carbon cycling. Besides, planktic foraminifera and coccoliths, pteropods represent an important constituent of oceanic plankton, which play dominant role in oceanic $CO_2$ system (Berner and Honjo, 1981). Pteropods are marine gastropods known as “sea butterflies”, common members of calcareous zooplankton communities in the upper ocean (Bè and Gilmer, 1977; Almogi-Labin et al., 1998). The preservation and accumulation of pteropods on the seafloor is related to the changes in water masses and their properties (e.g. Klöcker et al., 2006). Their shells are composed of aragonite, a metastable polymorph of $CaCO_3$ which is more susceptible to dissolution than calcite in sea water (Mucci, 1983; Millero, 1996; Morse and Arvidson, 2002). Therefore, the aragonite lysocline and aragonite compensation depth (ACD) are much shallower than the carbonate compensation depth (CCD). Of the total $CaCO_3$ produced in oceans, pteropods contribute about ~10–12% (Berner and Honjo, 1981; Fabry, 1990; Fabry and Deuser, 1991, 1992), occasionally reaching >50% in some areas (Lalli and Gilmer, 1989). Bè and Gilmer (1977) were the first to report a detailed zoogeographic and taxonomic review of pteropods from the world oceans. Berger (1978) investigated pteropods in marine sediments and published a global map, showing the ACD and optimum depth limits of pteropod preservation and thus facilitating their use as bathymetric indicators (Herman and Rosenberg, 1969). Pteropods exhibit two important life strategies, i.e., epipelagic [non migratory species that live in the mixed layer (0–100 m)] and mesopelagic [migratory species that inhabit the intermediate water mass and migrate diurnally]. The latter are, because of their migrations sensitive to changes in water column stratification and OMZ intensity.

Generally, high abundance of pteropods are restricted to shallow and subtropical seas such as Arabian Sea (Herman and Rosenberg, 1969; Singh, 1998), Red Sea and Mediterranean Sea (Almogi-Labin and Reiss, 1977; Reiss et al., 1980; Almogi-Labin, 1982; Almogi-Labin et al., 1986, 1991; Wang et al., 1997). The preservation of aragonite along the Pakistan continental margin was investigated by Berger (1977, 1978); Reichart et al. (1998, 2002); von Rad et al. (1999) and Klöcker and Henrich (2006) and off Somalia Margin by Ivanova (2000) and Klöcker et al. (2006), Murray Ridge by Reichart et al. (1998), Gulf of Aden by Almogi-Labin et al. (2000) and the northern

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Arabian Sea by Böning and Bard (2009). All these studies carried out so far in the northern Indian Ocean are confined to the western part. Aragonite preservation in the eastern part of the northern Indian Ocean, Bay of Bengal (BOB) and the Andaman Sea, and changes therein through time, are virtually unknown.

The world's highest physical and chemical erosion rates are found in the Himalayan Rivers. The Himalayan Rivers contribute enormous quantities of sediments to the BOB and Andaman Sea, thus providing a record of climate variability. Sediments of the Andaman Sea are largely derived from Ayeyarwady, Salween and Sittang rivers (Rodolfo, 1969). Moderate to high sedimentation rates in this basin allow the construction of paleo records with a high temporal resolution. The present day ACD of Andaman Sea lies at about 1200 m depth (Bhattacharjee and Bandyopadhyay, 2002), ACD fluctuations with time however are not known. Because the depth of the ACD provides important constraints on Andaman Sea circulation, an attempt is made here to understand the late Quaternary (last 54 ka) record of pteropod preservation.

## 2. Oceanographic setting

The Andaman Sea (AS) is a marginal sea, in the eastern part of the north East Indian Ocean situated between the east of Andaman Nicobar Ridge (ANR) and west of Malayan Peninsula, with a maximum water depth of 4400 m. It is interconnected with the BOB by the Deep Prepares Channel, Ten Degree Channel and the Great Channel. The oceanographic processes in these seas are however comparable only up to a depth of about 1000 m, as the deep water exchange between these two region (AS and BOB) is hampered by several sills (Fig. 1a). Similar to the Arabian Sea, the Andaman Sea experiences a seasonal reversal in surface circulation, driven by the Indian monsoon. Biological productivity in offshore region is ~0.8–1.0 $mgC/m^2$/day which is higher than the <0.6 $mgC/m^2$/day observed in coastal areas of the Andaman Sea (Janekarn and Hylleberg, 1989). Surface water salinities range between 31.8 and 33.4‰ (Sarma and Narvekar, 2001) (Fig. 1b), due to the large fresh water discharges from the Ayeyarwady–Salween river system (Janekarn and Hylleberg,

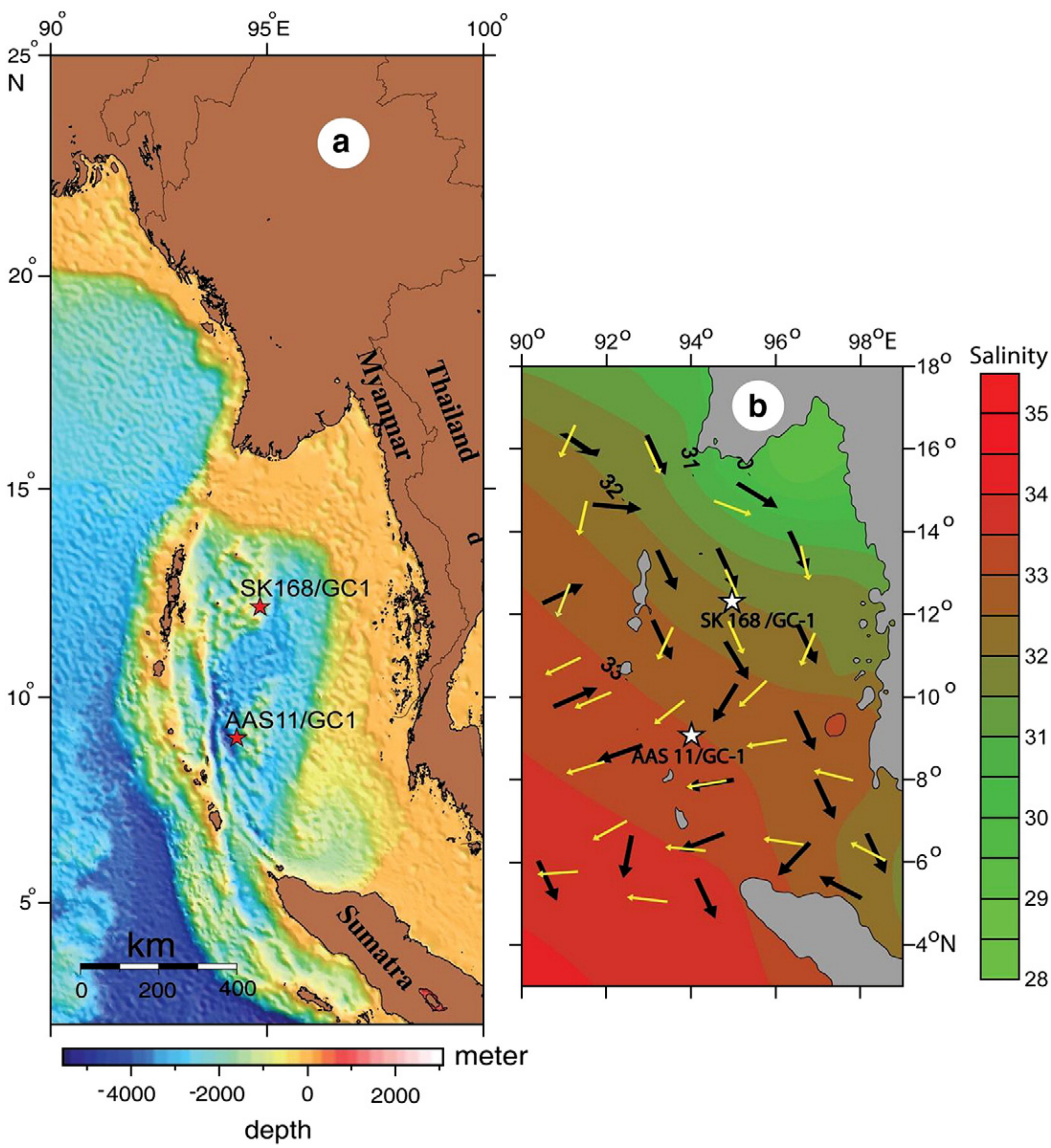


**Fig. 1.** Location of core SK 168/GC 1, Andaman Sea, with an additional site under discussion (AAS 11/GC 1) in the Eastern Indian Ocean (modified from Kamesh Raju et al., 2004): a) bathymetry of Andaman Sea along with core locations; b) salinity (annual salinity at the surface, World ocean atlas, 2009, www.nodc.noaa.gov) and monsoon currents in Andaman Sea black arrow—summer monsoon, yellow arrow—winter monsoon, (modified from Brown, 2007 reference therein).