Glacial-interglacial changes in the surface water characteristics of the Andaman Sea: Evidence from stable isotopic ratios of planktonic foraminifera

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Stable carbon and oxygen isotopic analyses of the planktonic foraminifera (*Globigerinoides ruber*) from a deep sea sediment core (GC-1) in the Andaman Sea show high glacial-to-Holocene $\delta^{18}O$ amplitude of 2.1‰ which is consistent with previously published records from this marginal basin and suggest increased salinity and/or decreased temperature in the glacial surface waters of this region.

A pulse of ^{18}O enrichment during the last deglaciation can be attributed to a Younger Dryas cooling event and/or to a sudden decrease of fresh water influx from the Irrawady and Salween rivers into the Andaman Sea. High $\delta^{13}C$ values observed during the isotopic stages 2 and 4 are probably due to the enhanced productivity during glacial times in the Andaman Sea.

1. Introduction

Extensive studies in the north Atlantic showed that the deglacial warming proceeded in two steps (Termination 1a and Termination 1b), separated by a near glacial cooling event that occurred between 11,000 and 10,000 years B.P. (Broecker *et al* 1988; Overpeck *et al* 1989). This strong cooling is also observed on the European continent and is referred to as Younger Dryas. Subsequent high resolution oxygen isotopic investigations in the foraminiferal shells from radiocarbon dated cores from Sulu Sea and northwest Pacific suggested the global nature of the Younger Dryas cooling (Kallel *et al* 1988a; Kudrass *et al* 1991). Recent high precision ^{10}Be measurements in the Lake Moraine from western North America provided additional evidence that the Younger Dryas was at least hemispheric, if not a global phenomenon (Gosse *et al* 1995).

The initial studies on the Younger Dryas in north Atlantic and surrounding regions led researchers to conclude that its origin was due to a perturbation of physical conditions in the north Atlantic Ocean, such as the sudden diversion of melt water from Mississippi to St. Lawrence drainage, a rapid variation in temperature of north Atlantic atmosphere or a rapid change in sea ice cover. However stable isotopic records from deep sea sediment cores, ice cores and numerous radiocarbon dated glacial deposits have led several authors to suggest a change in the global atmospheric-oceanic mixing as the cause for the Younger Dryas cooling event (Kudrass *et al* 1991; Alley *et al* 1993; Gosse *et al* 1995).

The Andaman Sea is a marginal oceanic basin with a maximum water depth of ~4.4 km. Excessive runoff from major rivers like Irrawady and Salween results in low surface salinity which is reflected in the $\delta^{18}O$ distribution pattern of Holocene planktonic foraminifers (Duplessy 1982). Thus any change in the freshwater riverine input into this basin can significantly alter the $\delta^{18}O$ values of the surface dwelling planktonic foraminifera. Irrawady and Salween rivers are also characterised by modest dissolved nutrient levels resulting in the low primary productivity (Naqvi *et al* 1994).

Keywords. Stable isotopes; Younger Dryas; deglaciation; holocene, last glacial maximum (LGM).

Carbon and oxygen isotopic ratios in the planktonic and benthic foraminifera from several deep sea cores of the northeast Indian Ocean have indicated significant changes in the chemical characteristics of the surface and deep waters of this region since the last glaciation (Duplessy 1982; Kallel *et al* 1988b; Sarkar *et al* 1990; Ahmad and Labeyrie 1994; Naqvi *et al* 1994). However, not much information is available on the surface and deep-water characteristics of the Andaman Sea because of the scarcity of high sedimentation rate cores from this region. In this paper we present high-resolution stable isotopic records from a new deep-sea core of the Andaman Sea.

2. Methodology and stratigraphy

Gravity core (GC-1) was collected from the Andaman Sea (9°N and 94° 17′E; water-depth 2909 m; core length 4.2 m; figure 1). The core was sub-sampled at 1 cm interval in the top 20 cm and alternatively 1–2 cm interval for the rest of the core. Sub-samples separated at 10–20 cm intervals were selected for this study. Samples were washed through a 150 μm sieve and subsequently dried at 60°C. About 40–80 specimens of *Globigerinoides ruber* (white) in the size range of 250–315 μm were picked for the stable isotopic measurements. The CO_2 was extracted by reaction with 100% phosphoric acid and isotopic ratios were measured using a VG Micromass 903 mass spectrometer at NGRI, Hyderabad. The precision based on replicate measurements of the international standard (NBS-19) and inhouse standard (CRS) was better than ±0.10‰ and ±0.15‰ for carbon and oxygen respectively. The results are summarized in table 1.

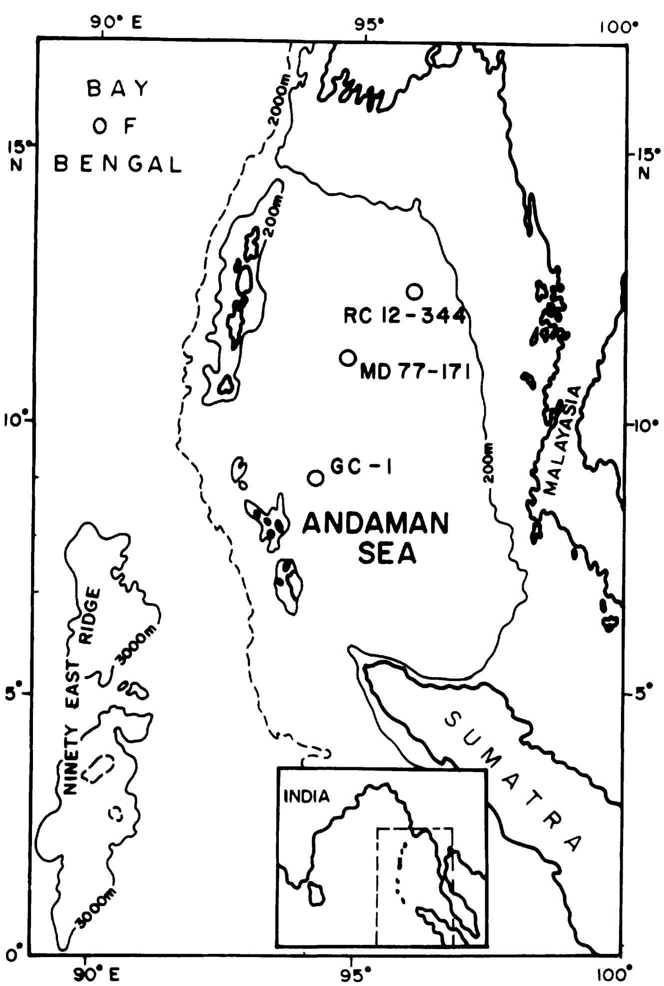

Figure 1. Location map of sediment cores.

Table 1. *Carbon and oxygen isotopic data represented in per mil vs. PDB in the planktonic foraminifera (Globigerinoides ruber).*

Sub-bottom depth (cm)	$\delta^{18}O$	$\delta^{13}C$
0	−3.2	1.11
20	−3.02	1.37
30	−3.09	1.23
40	−2.89	1.53
50	−3.44	1.21
60	−3.08	1.26
70	−2.83	1.21
80	−2.94	1.06
90	−2.56	1.09
100	−1.59	1.25
110	−1.78	1.17
120	−1.9	1.29
130	−1.82	1.19
140	−2.21	0.96
150	−1.19	1.63
160	−0.97	1.59
180	−1.16	1.53
200	−1.72	1.08
220	−1.63	1.27
240	−1.7	1.26
260	−1.72	1.49
280	−1.86	1.4
300	−1.82	1.59
330	−1.71	1.6
340	−1.85	1.61
350	−1.49	1.66
380	−1.56	1.61
400	−1.94	1.6
410	−1.89	1.32
420	−1.94	1.38

Age determination and correlation of cores are based on the planktonic oxygen isotopic stratigraphy by tuning the data of GC-1 core with the SPECMAP $\delta^{18}O$ stack record of Imbrie *et al* (1984). We have also determined ^{14}C date in one sediment sample from GC-1 core corresponding to the timing of $\delta^{18}O$ shift during the deglaciation. This sample showed an age of 10,900± 1000 years B.P. (figure 2). The sedimentation rate during the last glacial period is considerably high (8.3 cm/kyr) compared to the average rate (5.3 cm/kyr) of this core.

3. Discussion

The $\delta^{18}O$ variations measured in the foraminiferal shells reflect both the global variations of the ocean water $\delta^{18}O$ due to ice volume change and isotopic fractionation between calcium carbonate and water (Emiliani 1955). Oxygen isotopic fractionation between $CaCO_3$ and water increases by ~0.2‰ for each degree water is cooled (Shackleton 1974), whereas a 1‰ increase in salinity causes a ~0.3‰ enrichment in $\delta^{18}O$ (Craig and Gordon 1965).

Glacial-to-Holocene $\delta^{18}O$ amplitude in GC-1 is considerably higher (2.1‰) compared to the ice-volume change of 1.2‰ reported for this transition (Labeyrie *et al* 1987). Subtracting this value from the total G/H amplitude of GC-1, a difference of 0.9‰ was obtained which could arise either due to the cooling of surface water by ~ 4°C, or, alternatively, by an increase in salinity (~3‰) or a combination of both.

Based on the CLIMAP (1981) results, the high G/H $\delta^{18}O$ amplitude of the previously published data from the northeast Indian Ocean cores was explained in terms of salinity variations only, as the temperature change from the LGM and to the Holocene was considered very small (Duplessy 1982; Sarkar *et al* 1990; Ahmad 1995). However, this assumption may not be valid today in the light of recent oxygen isotopic and alkenones data which clearly demonstrate a significant decrease (2–4°C) in the sea surface temperature (SST) of the Indian Ocean and other low-latitude regions of the world during the LGM (Rostek *et al* 1993; Norton *et al* 1997). Therefore a net 0.9‰ change in $\delta^{18}O$ between the LGM and Holocene in the surface waters of the Andaman Sea may be due to the combination of both decreased temperature and increased salinity during the LGM.

The $\delta^{18}O$ values in this core decreases from a maximum glacial value of −0.97‰ to minimum Holocene value of −3.44‰ (table 1). This shift from glacial to interglacial conditions is clearly interrupted by a return to near glacial value. Though the timing of this $\delta^{18}O$ shift approximately corresponds to the Younger Dryas cooling event it could also be due to the decreased discharge of fresh water from the Irrawady and Salween rivers into the Andaman Sea.

Examination of the $\delta^{18}O$ record of the planktonic foraminifera (*G. ruber*) from two other cores of the Andaman Sea (RC 12–344 and MD 77–171) also indicates the presence of similar $\delta^{18}O$ oscillation during the last deglaciation (Fontugne and Duplessy 1986). The magnitude of the $\delta^{18}O$ shift in all these three cores varies from 0.4‰ to 0.7‰, which is very close to the global Younger Dryas shift of 0.6‰.

The $\delta^{13}C$ values in GC-1 core varies considerably from 1.0 to 1.7‰ with higher values generally coinciding to glacial stages 2 and 4 (mean $\delta^{13}C = 1.58‰$) compared to the Holocene (mean $\delta^{13}C = 1.23‰$). Because planktonic $\delta^{13}C$ depends on the $\delta^{13}C$ of total dissolved carbon in the upper water column which is controlled by biological productivity, the relatively high glacial $\delta^{13}C$ values could be due to the increased productivity. The intensification of the northeast monsoon during the last glacial period might have increased biological production resulting in the preferential incorporation of lighter isotope ^{12}C relative to the ^{13}C from the water column (Duplessy 1982; Sarkar *et al* 1990). Similar enriched $\delta^{13}C$ values have also been reported earlier from the glacial foraminifera of MD 77–169 core of the Andaman Sea (Fontugne and Duplessy 1986).

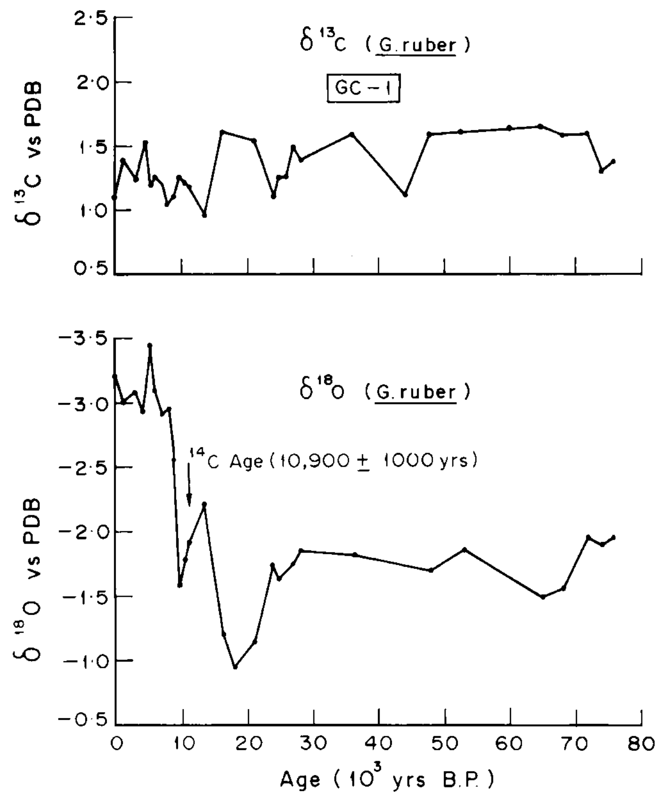

Figure 2. Carbon and oxygen isotopic composition of the planktonic foraminifera (*Globigerinoides ruber*) from GC-1 core plotted against age.

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