

## Influence of monsoon upwelling on the planktonic foraminifera off Oman during Late Quaternary

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Planktonic foraminifer abundances, fluxes, test sizes, and coiling properties are influenced in various ways by the south-west monsoon winds and associated upwelling in the western Arabian Sea. The influence of monsoon driven upwelling on the planktonic foraminifer species abundances, coiling directions of *Globigerinoides bulloides* and *Neogloboquadrina pachyderma* and size variations of selected planktonic foraminifer species and carbon isotopic composition of *Globigerina bulloides* is summarized here.

[**Key words:** Indian Ocean, Arabian Sea, Oman margin, monsoon, upwelling, planktonic foraminifera]

### Introduction

During the Northern Hemisphere summer strong south-westerly monsoon winds blow across the Arabian Sea, which cause offshore Ekman transport and intense seasonal upwelling along the Oman and Somalia margins, and the southwest coast of India<sup>1-4</sup>. The upwelling process brings cold, nutrient-rich waters from a few hundred meters' depth to the surface and increases the biological productivity in the euphotic zone. These SW monsoon winds and associated upwelling process are the reasons why the Arabian Sea is one of the highest productivity regions in the world oceans<sup>5</sup>. During winter the north-east monsoon winds invoke onshore Ekman transport of surface waters, which suppresses upwelling and lowers the productivity along the continental margin of the western Indian Ocean. Thus, the south-westerly and north-easterly winds produce a striking seasonal contrast in primary productivity<sup>6</sup> and seasonally dominant biogenic and lithogenic fluxes<sup>7</sup> in the Arabian Sea. Distinctive plankton fauna and flora thrive in the upwelling waters and are eventually incorporated into the sediments on the sea floor after the death of the organisms, forming a geological record of upwelling there. The sedimentary record in the Arabian Sea, influenced by this upwelling system, is thus linked to the structure and intensity of the monsoon. Therefore, these sediments provide an integrated information of the upwelling process and Asian monsoon strengths over geological time.

The monsoon system is one of the Earth's most dynamic features, which interacts with global

atmospheric circulation that controls the heat budget in the Arabian Sea. Hence changes in the monsoon system may play an essential role on global climate. The southwest (SW) monsoon system in the Arabian Sea exerts a strong influence upon the climatic conditions in south and southeast Asia, and the strength of the SW monsoon is varied through time in response to solar insolation, albedo of the Tibet Plateau and ocean circulation and chemistry<sup>8</sup>.

This communication summarises the influence of upwelling on the planktonic foraminifer species mass accumulation rates (flux), coiling direction, test size and isotopic values primarily based on the results from the Ocean Drilling Program (ODP) Site 723A (18°03N, 57°37E, water depth 808m) from the Oman Margin, Arabian Sea.

### Monsoon upwelling variation

Based on three indices of upwelling, namely fluxes of total planktonic foraminifera and *Globigerina bulloides*, and relative abundance of *Globigerina bulloides* upwelling variability was reconstructed<sup>9</sup> at this site covering a time span of 20 kyr. These studies inferred that the strength of the SW monsoon and the related upwelling were weaker during the last glacial period. Upwelling started to increase from 12 Kyr and reached maximum intensity between 9 and 6 kyr. Values of the upwelling indices started to decrease at 5 kyr BP, which reflects a weakening of the SW monsoon. The lowest upwelling indices in the Holocene are recorded between 3.5 and 1 kyr BP,

suggesting that upwelling decreased and the SW monsoon became weaker during this period. These inferences are strongly supported by the lake level records from Africa, Arabia, and India<sup>10</sup>, paleohydrological data from western Tibet<sup>11</sup>, and pollen records from northwest India<sup>12</sup> and eastern Arabian Sea<sup>13</sup>. Taking this information on the monsoon upwelling variability as a phase value the upwelling influence on the planktonic foraminifera is discussed here.

### Influence of monsoon upwelling on the fluxes of various planktonic foraminifer species

Thirty-three recent planktonic foraminifer species were identified at ODP Site 723A. The relative abundances of few individual species show greater values during intense upwelling period. This may be due to the fact that if one dominating species increases greatly in relative abundance, the other species can not do so because the sum of relative abundance by definition equals<sup>9</sup> 100. Therefore, changes of fluxes on planktonic foraminifer species are discussed here.

Abundant planktonic foraminifera species such as *Globigerinita*, *glutinata*, *Globigerinoides ruber*, *Neogloboquadrina dutertrei*, *Globigerina flaconensis*, *Globigerinoides. sacculifer* and *Globorotalia menardii* show high and low fluxes during strong and weak upwelling periods respectively (Fig. 1). Greater fluxes of *Globigerina bulloides* in the intervals of stronger upwelling (19 to 15.9 and 12 to 5 kyr BP) compared to the sediment trap fluxes<sup>9</sup> indicate that the SW monsoon was stronger during those periods compared to modern day. On the other hand, *Globigerina bulloides* exhibits lower fluxes in the sediment record during intervals of weak upwelling (15 to 12 and from 5 kyr BP) compared to the sediment-traps, which suggests that these periods are marked by a weaker SW monsoon compared to the present day.

### Diversity of planktonic foraminifera

Diversity of planktonic foraminifera has been used in several quantitative paleoecological interpretations<sup>14</sup>. Usually, diversity increases from polar to equatorial regions, but in some areas extreme environmental conditions alter the global diversity pattern. Plankton-tow data from the Arabian Sea show lower values of the Shannon-Wiener diversity index in the upwelling regions than in the non-upwelling

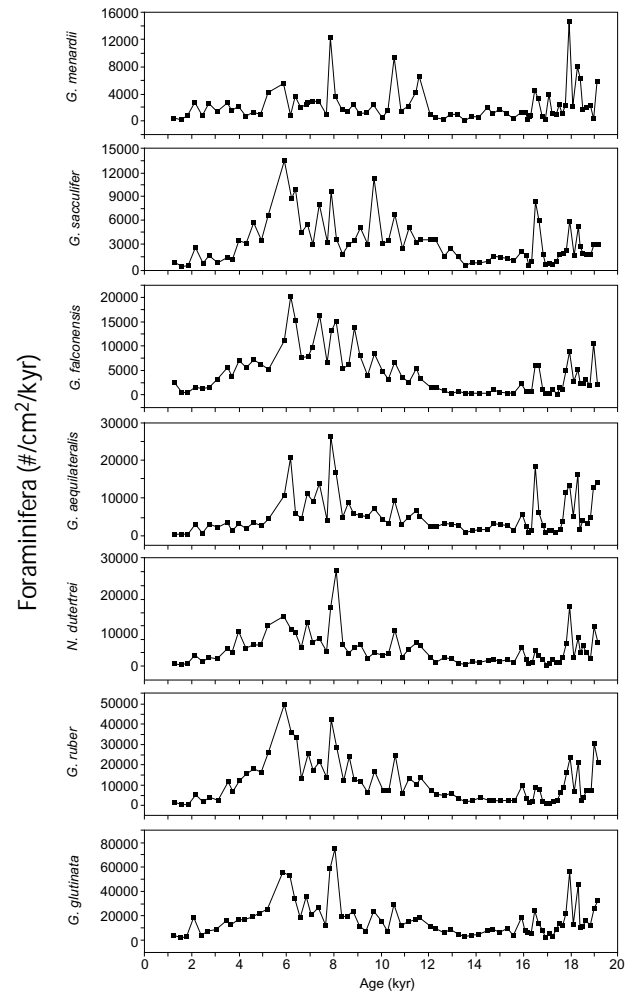


Fig. 1—Fluctuations in fluxes of *Globigerinita glutinata*, *Globigerinoides ruber*, *Neogloboquadrina dutertrei*, *Globigerinella aequilateralis*, *Globigerina flaconensis*, *Globigerinoides sacculifer* and *Globorotalia menardii* at the ODP Site 723A.

regions, whereas simple diversity (species richness) does not show such a difference<sup>15</sup>. In Site 723A the Shannon-Wiener index does not exactly mirror the upwelling indices. However, relatively high values are noticed between 19 to 9.5 kyr BP, whereas values are relatively low during the middle Holocene (Fig. 2). Student's t-test was used to determine the significance of the difference in the Shannon-Wiener index between the periods of strong upwelling (12 to 5 kyr BP) and weak upwelling (Last glacial period and late Holocene). The Shannon-Wiener index is not significantly different between these periods ( $t=1.18$ ;  $p>0.05$ ), indicating that diversity of planktonic foraminifera is not controlled by the intensity of upwelling. On the other hand, diversity differed

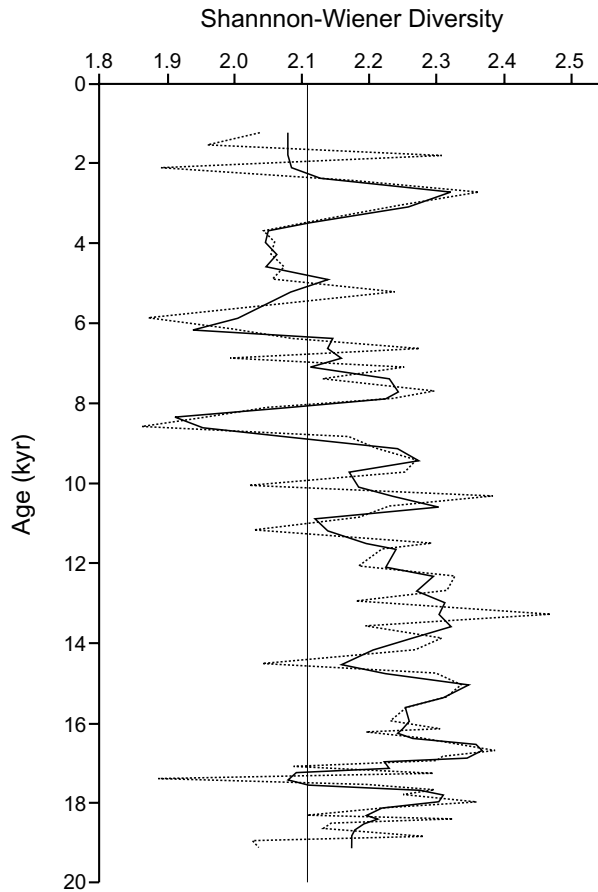


Fig. 2—Variability of diversity of planktonic foraminifera at the ODP Site 723A

between the Holocene and Last glacial period ( $t=2.98$ ;  $p<0.01$ ), which may be caused by environmental changes other than upwelling associated with global climatic changes during the Holocene and LGP.

#### **Influence of upwelling on the coiling properties of *Neogloboquadrina pachyderma* and *Globigerina bulloides* in the Arabian Sea**

Fluctuations in coiling direction of planktonic foraminifer species, that is the direction in which the foraminifera add their chambers during growth, have been used in stratigraphy and paleoclimatology since the 1950's. Vasicek<sup>16</sup> was the first to point out that coiling direction of *Globorotalia scitula* could be correlated with environmental parameters. Ericson<sup>17</sup> and Bandy<sup>18</sup> showed that coiling proportion in *Neogloboquadrina pachyderma* is related to the sea-surface temperature. Coiling direction changes along various latitudinal gradients have been investigated in detail for *Neogloboquadrina pachyderma* and *Globorotalia truncatulinoides* and provided

summaries of coiling properties of planktonic foraminifera<sup>19-25</sup>. In most of the species that have been studied for coiling directions, it is generally agreed that sinistrally coiled specimens were adapted to cooler parts and dextral specimens to warmer parts of their distributional ranges.

The cause of the shifts in coiling direction in planktonic foraminifera remains an intriguing problem in the biology of foraminifera and marine micropaleontology. Coiling percentages in many species are obviously differentiated latitudinally, but it is not known yet whether they are controlled primarily by environmental factors or whether they reflect variation along latitudinal clines. For instance, coiling direction of *Neogloboquadrina pachyderma* can be correlated with variations in sea-surface temperature with change in coiling from dominantly sinistral to dextral occurs<sup>26</sup> at surface temperatures between 7 and 9°C. Alternatively, it has been recently suggested that coiling in *Neogloboquadrina pachyderma* is controlled by differences in food requirements and associated timing of reproduction between the sinistrally and dextrally coiled morphotypes<sup>27</sup>. Plankton-tow samples analyzed by these latter authors from the Walvis Bay upwelling region show that dextrally coiled *Neogloboquadrina pachyderma* are dominant prior to upwelling, whereas the sinistrally coiled morphotype predominates during the upwelling period. This suggests that upwelling influences the coiling ratios in *Neogloboquadrina pachyderma*. The same pattern has been observed in the Santa Barbara Basin<sup>28</sup>. Sediment cores from upwelling regions may provide insight into the relationship between food requirement and coiling direction in *Neogloboquadrina pachyderma* and *Globigerina bulloides* through late Quaternary time.

This section is aimed to address coiling patterns in *Neogloboquadrina pachyderma* and *Globigerina bulloides* in terms of fluxes of the sinistral and dextral varieties and through coiling ratios (proportions of sinistral specimens) in samples from Ocean Drilling Program (ODP) Site 723A from the Oman Margin, Arabian Sea.

#### *Neogloboquadrina pachyderma*

Fluctuations of the sinistral morphotype fluxes of *Neogloboquadrina pachyderma* follow closely the variation in the upwelling index in being higher (>600 specimens/cm<sup>2</sup>/ky) from 10 to 5 kyr and lower (<500 specimens/cm<sup>2</sup>/ky) during the late Holocene and last

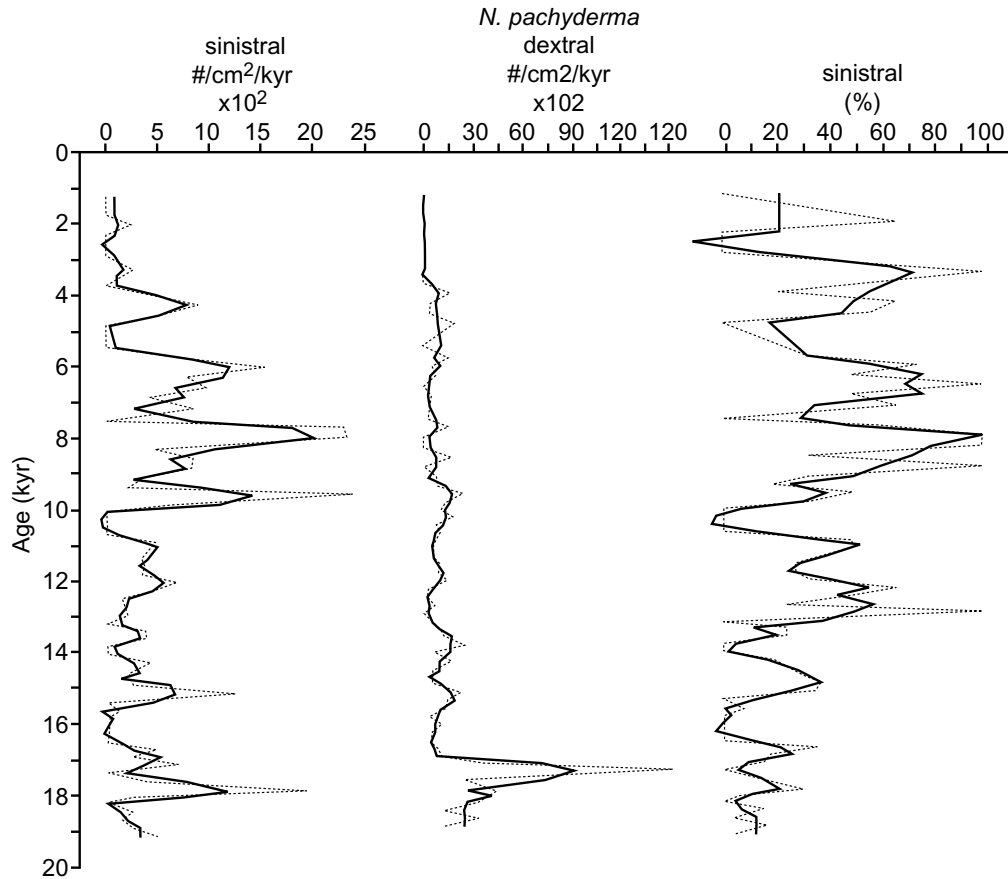


Fig. 3—Mass accumulation rates of the sinistral and dextral morphotypes of *Neogloboquadrina pachyderma* and proportions of the sinistral morphotype of *Neogloboquadrina pachyderma*. Open circles represent original data and solid circles represent five-point moving averages.

glacial period (Fig. 3). Even if fluxes of the dextral morphotype of *Neogloboquadrina pachyderma* were greater than those of the sinistral morphotype, the fluxes of the dextral morphotype does not show a similar relationship to the upwelling index. Rather, it shows a significant peak at 18 ka and then remains relatively uniform but from 17 kyr through the present day (Fig. 3).

If coiling is expressed in terms of coiling proportions a pattern emerges that is consistent with the fluctuations of the sinistral morphotype flux (Fig. 3). In the weak upwelling period (19-12 kyr) sinistral proportions ranged between 0 and 50%. During the interval of intense upwelling (10-5 kyr) sinistral forms generally constitute more than 50% of the faunas and with maximum proportions of up to 80%. Through the interval of weaker upwelling during the last 5 kyr sinistral proportions again decreased to less than 40%.

#### *Globigerina bulloides*

At Site 723A both the sinistral and dextral morphotypes of *Globigerina bulloides* show relatively low flux (< 20,000 specimens/cm<sup>2</sup>/ky.) from 19 to 12 kyr when upwelling was weak, and higher values (>20,000 specimens/cm<sup>2</sup>/ky.) between 11-5 kyr during the time of stronger upwelling (Fig. 4). Beginning at 5 kyr, both morphotypes show descending trends. Throughout the section studied, the sinistral morphotype is more abundant than the dextral morphotype. Proportions of the sinistral morphotype of *Globigerina bulloides* also parallel with upwelling changes and show generally lower values (<65%) between 19-12 kyr during the period of weaker upwelling, and highest values (>65%) during the interval of intense upwelling between 11 to 5 kyr.

Recent observations of variation in coiling pattern in upwelling regions suggest that, irrespective of surface-water temperature, the sinistrally coiled

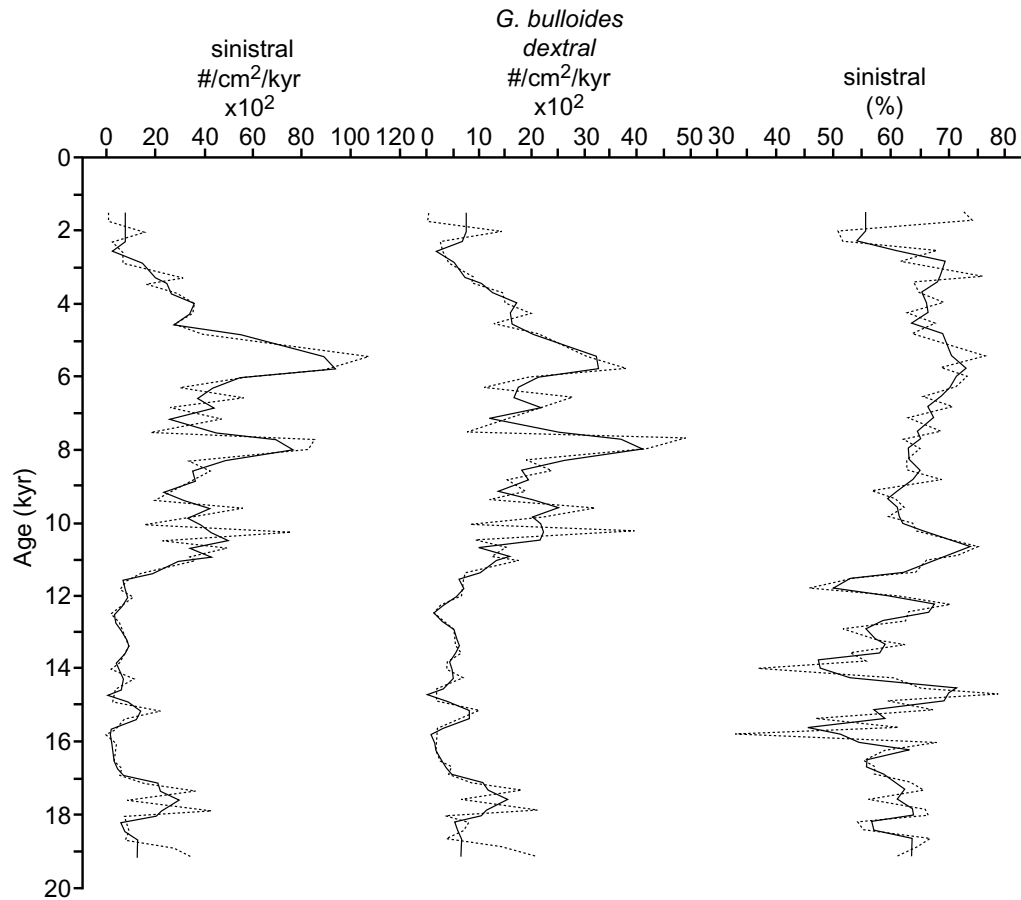


Fig. 4—Mass accumulation rates of the sinistral and dextral morphotypes of *Globigerina bulloides* and proportions of the sinistral morphotype of *Globigerina bulloides*. Open circle represent original data and solid circles represent five-point moving averages.

variety of *Neogloboquadrina pachyderma* is more abundant in high-productivity, upwelled surface waters<sup>27-29</sup>. Temperature control on the coiling properties of *Neogloboquadrina pachyderma* is negligible in the Arabian Sea due to the fact that the summer and winter mean sea-surface temperatures are 26-29°C and 26-28°C, respectively, in this area<sup>30</sup>. Thus, these temperatures are much higher than the earlier reported temperature interval at which the coiling dominance in *Neogloboquadrina pachyderma* changes from dextral to sinistral (7-9°C). This indicates that upwelling and associated increase in nutrient-rich waters trigger the greater productivity of the sinistral morphotype of *Neogloboquadrina pachyderma*. Therefore, the down-core data from the tropical upwelling region of the Arabian Sea also support the contention that coiling properties of *Neogloboquadrina pachyderma* are controlled by the availability of nutrients. Therefore, coiling direction in *Neogloboquadrina pachyderma* cannot always be

used to monitor changes in surface-water temperature, but in upwelling regions it may instead shed light on the productivity of the surface waters.

Under open-ocean conditions *Globigerina bulloides* is most abundant in optimally adapted to subpolar waters<sup>21</sup>. However, its abundance is also greatly increased in areas influenced by upwelling processes away from the subpolar water mass such as the Arabian Sea<sup>31</sup> and the Cariaco Basin<sup>32</sup>. Even if the flux of both the sinistral and dextral morphotypes of *Globigerina bulloides* increased during the interval of intense upwelling (11-5 kyr) at this site, it is clear that the sinistral morphotype increases relatively more than the dextral morphotype, which is manifested by the greater proportions of sinistrally coiled specimens (Fig. 4).

It has been earlier shown that percentage of sinistral *Globigerina bulloides* increased towards polar regions in a linear relationship with surface-water temperatures in the southern Indian Ocean<sup>33</sup> and

the southwestern Atlantic Ocean<sup>34</sup>. Therefore, one would expect a greater proportion of the dextral morphotype at our tropical study site in the Oman Margin, Arabian Sea. Instead, we observe that the flux and proportions of the sinistral morphotype are higher than those of the dextral morphotype throughout the interval. Therefore, it is suggested that the greater abundance of the sinistral morphotype of *Globigerina bulloides* in this study area may be due to an enhanced survival rate of this morphotype in more fertile, upwelled surface waters.

### Influence of monsoon upwelling on the test sizes of planktonic foraminifera

The mean test sizes of *Globigerinoides ruber*, *Globigerinita glutinata*, *Globigerina bulloides*, and *Neogloboquadrina dutertrei* were smaller during the last glacial period and larger between 11 and 5 kyr (Fig. 5). The oscillations in mean test sizes of these species agree closely with those in the upwelling index (Fig. 5). The maximum mean sizes correspond with the intense upwelling period (12-5 kyr) and smaller means coincide with weaker upwelling during the last glacial and late Holocene. However, detailed examination of the mean test size records indicate that they differ in amplitude and slightly offset the upwelling indices curves during some intervals. In any event, the mean size variations exhibit significant positive rank correlations with variation in mass accumulation rate of *Globigerina bulloides*, which we interpret to represent an upwelling index<sup>35</sup>. This indicates that the mean test size of *Globigerinoides ruber*, *Globigerinita glutinata*, *Globigerina bulloides* and *Neogloboquadrina dutertrei* are related to upwelling and associated productivity changes in the Arabian Sea.

It has been shown earlier that mean test size of *Globigerina bulloides* increased toward the south in the southern Indian Ocean as a result of decreasing surface-water temperature<sup>33</sup>, and that mean size in this species is highly correlated with late quaternary climatic fluctuations in the southern Indian Ocean<sup>33</sup>. The present study shows that mean size in *Globigerina bulloides* may also be influenced by other environmental factors, such as upwelling, besides the water temperature, or that productivity in the surface waters may be the primary controlling factor of test size in this species. Mean size of *Globigerinoides ruber* changes along geographic gradients in the Atlantic Ocean and may be related to

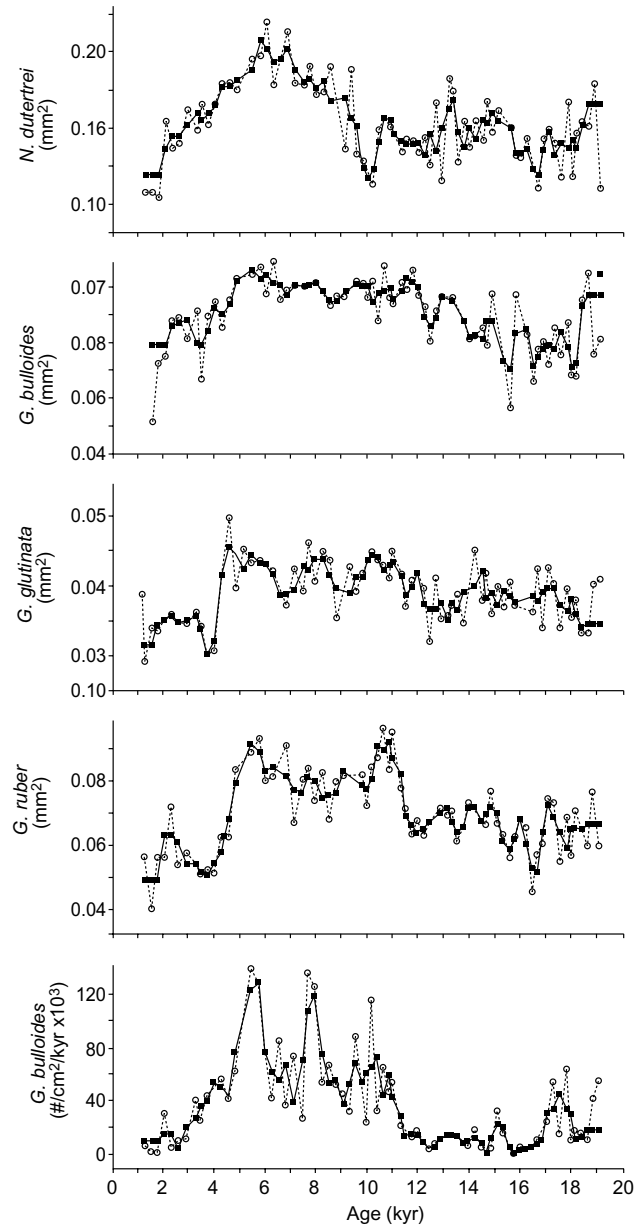


Fig. 5—Relationship between changes in upwelling estimated by upwelling indices (flux of *Globigerina bulloides* and test size variations of *Globigerinoides ruber*, *Globigerinita glutinata*, *Globigerina bulloides* and *Neogloboquadrina dutertrei*). Dashed lines represent raw data and solid line represents five point moving averages.

the temperature and salinity<sup>36, 37</sup>. Results of this study show that the mean size of *Globigerinoides ruber* is related to upwelling changes in the Arabian Sea back through the latest Quaternary.

Under normal circumstances weaker upwelling during the last glacial period would lead to higher sea surface temperatures (SST), whereas stronger

upwelling during the Holocene would result in lower SSTs in the upwelling regions of the Arabian Sea. In contrast, the SSTs derived from the isotope records of planktonic foraminifera<sup>38</sup> and long-chain alkenones (UK-37)<sup>39</sup> show that SSTs were at least 2 to 3°C cooler during the weak upwelling last glacial period than during the intense upwelling Holocene period. This cooling of Arabian Sea during last glacial period is in phase with the global cooling during that time. Independently of whether the monsoon upwelling and SSTs are related or not, the mean test sizes of *Globigerinoides ruber*, *Globigerinita glutinata*, *Globigerina bulloides*, and *Neogloboquadrina dutertrei* are correlated with the monsoon upwelling index based on flux of *Globigerina bulloides*, which suggests that the mean size variations of these species are mainly controlled by the upwelling process.

Oba<sup>40</sup> documented a direct relationship between variation in mean size and relative abundance in populations of *Globorotalia menardii*, *Neogloboquadrina dutertrei*, and *Neogloboquadrina pachyderma* in Indian Ocean cores. Similar correlations have been demonstrated between mean size and relative abundance of *Globigerina bulloides* in surface sediments from the Indian Ocean<sup>33</sup>. On the contrary, *Orbulina universa* shows an inverse relationship between relative abundance and test size in the Indian Ocean<sup>41</sup>. Mean sizes of *Globigerinoides ruber* and *Globigerina bulloides* are weakly, but statistically significant, positively correlated with their relative abundances at this site<sup>35</sup>. Mean size of *Globigerinita glutinata* show a significant negative correlation with relative abundances, whereas no such correlation exists in *Neogloboquadrina dutertrei*.

Relative abundance data of planktonic foraminifera would not be an optimum measure of the productivity and optimum environmental conditions for individual species<sup>33, 38, 40</sup>, because the relative abundance of any one species is affected by the relative abundance of other species and the sedimentation rate. In view of this, we used the mass accumulations rates (fluxes), which provide a more optimal measure of the productivity of various species, for comparisons with their mean size variations to assess whether mean size is controlled by productivity or not. Test sizes and fluxes of *Globigerinoides ruber*, *Globigerinita glutinata*, *Globigerina bulloides* and *Neogloboquadrina dutertrei* show positive correlation<sup>33</sup>, which implies that productivity of individual species and test size are directly related and thus that

maximum growth occurs in areas of optimum environmental conditions. The strong positive relationships between the mean test sizes of all four species and the upwelling index at this site through the last 19 kyr suggest that the productivity of these species was enhanced and that they grow larger in cool, nutrient-rich upwelling waters. This relationship between mean sizes and upwelling intensity suggests that mean size variations in *Globigerinoides ruber*, *Globigerinita glutinata*, *Globigerina bulloides* and *Neogloboquadrina dutertrei* can be used as another micropaleontological tool to trace the upwelling strength.

#### Carbon isotopic ratios of *Globigerina bulloides*

Earlier stable isotope studies have shown that *Globigerina bulloides* secretes its shell out of equilibrium with respect to both carbon and oxygen<sup>42, 43</sup>. There are some contradictions regarding whether *Globigerina bulloides* calcifies its tests with isotopic equilibrium of ambient seawater or not. Curry & Mathews<sup>44</sup> reported that *Globigerina bulloides* is at isotopic equilibrium with ambient seawater and is recording extremely valuable paleoceanographic information over a wide range of sea surface conditions. Similarly, several researchers have used the oxygen and carbon isotopic ratios of *Globigerina bulloides* to infer the paleoceanographic conditions in different oceans<sup>45</sup>. However, Spero & Lea<sup>46</sup> demonstrated that *Globigerina bulloides* does not calcify at the isotopic equilibrium, but with correction factor the isotopic data of *Globigerina bulloides* can be used to derive the paleoceanographic conditions. Although several researchers have used  $\delta^{18}\text{O}$  data of *Globigerina bulloides* but most of them have not discussed about the  $\delta^{13}\text{C}$  values for unknown reasons.

It is well documented that *Globigerina bulloides* production increases during upwelling season, thus this species abundance in the sediments measures the upwelling strength in the Arabian Sea<sup>9, 31, 47</sup>. If *Globigerina bulloides* tests calcify in the upwelling waters one would expect lighter  $\delta^{13}\text{C}$  because upwelling brings nutrient rich and depleted  $\delta^{13}\text{C}$  waters to the surface. Strikingly, the  $\delta^{13}\text{C}$  values of *Globigerina bulloides* are about 1‰ lighter than that of benthic foraminifera (*U. excellens*) (Fig. 6). Two possibilities might explain the anomalous  $\delta^{13}\text{C}$  values of *Globigerina bulloides*: 1) Regeneration of nutrients in the surface waters should be higher than in the bottom waters, and 2) Vital effect induced isotopic

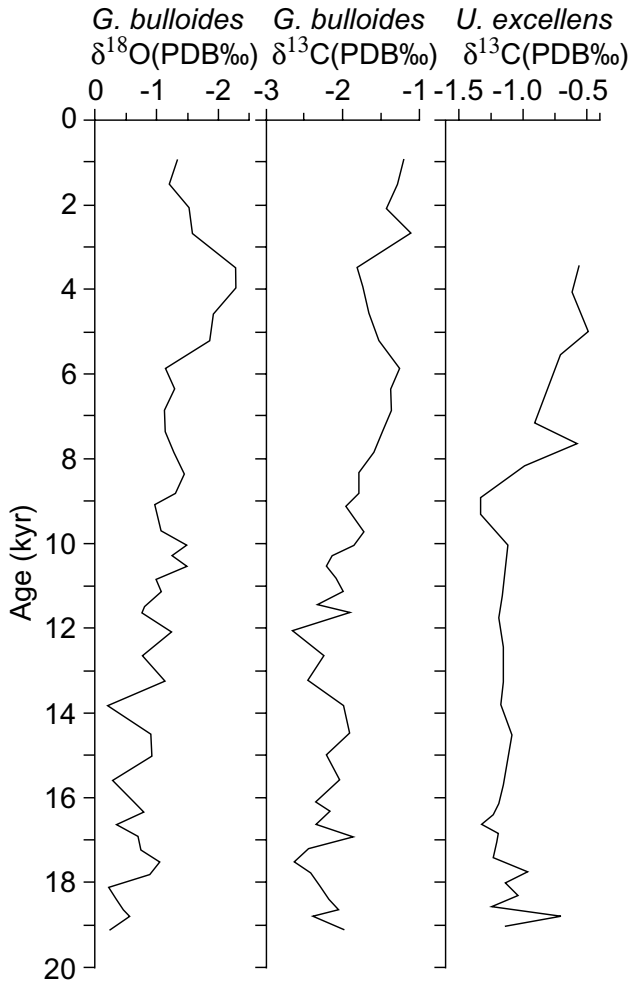


Fig. 6— $\delta^{18}\text{O}$  and  $\delta^{13}\text{C}$  records of planktonic foraminifera *Globigerina bulloides* and benthic foraminifera *Uvigerina excellens*.

fractionation. Former possibility is very unlikely because the other planktonic foraminifer species *Pulleniatina obliquiloculata*  $\delta^{13}\text{C}$  values were heavier than benthic foraminifera<sup>48</sup> hence the first possibility is ruled out. Another likely possibility is the vital effect induced fractionation. Earlier culturing experimental studies on the isotopic composition of *Globigerina bulloides* showed that 8-15% of  $\delta^{13}\text{C}$  signal is due to fractionation mechanism involving the incorporation of metabolic  $\text{CO}_2$  during calcification<sup>46</sup>. Despite vital effects, *Globigerina bulloides* showed higher  $\delta^{13}\text{C}$  (0.69‰) during Holocene compared to the last glacial period which agrees with the global  $\delta^{13}\text{C}$  trend in the world oceans. This points out that the vital effect for  $\delta^{13}\text{C}$  in *Globigerina bulloides* remain constant through time irrespective of upwelling in the Arabian Sea.

Earlier it has been shown that the mean test size of *Globigerina bulloides* is related to nutrient availability<sup>35</sup>. During strong upwelling Holocene period *Globigerina bulloides* would have calcified faster because of high nutrient availability. Higher calcification rates in foraminifera would require higher respiration<sup>49</sup>, which involves more respired  $\text{CO}_2$  and respired  $\text{CO}_2$  accounts for nearly 10% of the shell carbon in *Globigerina bulloides*<sup>50</sup> and higher calcification rates could produce more negative  $\delta^{13}\text{C}$  values<sup>46</sup>. Therefore, combination of higher calcification of *Globigerina bulloides* in the nutrient rich waters and involvement of respired  $\text{CO}_2$  would lead the more negative  $\delta^{13}\text{C}$  compared to benthic foraminifera. This process would have nullified the upwelling signature in  $\delta^{13}\text{C}$  values of *Globigerina bulloides*. The nature of the upwelling system might also be expected to influence the  $\delta^{13}\text{C}$  values of *Globigerina bulloides*.

### Conclusion

The flux of several planktonic foraminifer species (*Globigerina bulloides*, *Globigerinita glutinata*, *Globigerinoides ruber*, *Globigerinella aequilateralis*, *Neogloboquadrina dutertrei* and *Globigerina falconensis*) and mean test sizes of some abundant planktonic foraminifer species (*Globigerinoides ruber*, *Globigerinita glutinata*, *Globigerina bulloides* and *Neogloboquadrina dutertrei*) are directly proportional to the upwelling strength. It is evident from the present study that the flux of the sinistral morphotypes of *Neogloboquadrina pachyderma* and *Globigerina bulloides* also respond positively to upwelling strength. Therefore, the flux of several planktonic foraminifer species, coiling directions of *Neogloboquadrina pachyderma* and *Globigerina bulloides* and test size variations in some of the more abundant planktonic foraminifer species are all greatly influenced by the monsoon upwelling in the Arabian Sea.

*Globigerina bulloides* records an anomalous  $\delta^{13}\text{C}$  values, strikingly this species show an order of 1‰ depleted  $\delta^{13}\text{C}$  compared to benthic foraminifera (*Uvigerina excellens*), which suggests that the influence of vital effects on the  $\delta^{13}\text{C}$  data of *Globigerina bulloides*. In spite of vital effects *Globigerina bulloides* shows heavier and lighter  $\delta^{13}\text{C}$  values during Holocene and last glacial period respectively, which is in agreement with the global  $\delta^{13}\text{C}$  trend. This reveals that vital effects in



*Globigerina bulloides* were consistent through time irrespective of upwelling changes in the Arabian Sea.

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