On the intriguing relationship between seawater salinity and $\delta^{18}O$ of *Globigerina bulloides* at higher latitudes

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**ABSTRACT**

The $\delta^{18}O$ variation in planktic foraminifera *Globigerina bulloides* from nineteen surface sediment samples, collected onboard ORV *Sagar Kanya* between 1.92°S and 55.01°S latitude in the Indian Ocean sector of Southern Ocean, have been analyzed to understand the relationship between oxygen isotopic fractionation and near surface seawater salinity. The initial intriguing results indicate that up to ~31°S latitude, salinity may influence the oxygen isotopic composition of the foraminiferal tests. However, beyond 31°S (further south) latitude, salinity does not appear to influence the *G. bulloides* oxygen isotopic composition significantly.

**INTRODUCTION**

The monitoring of the impact of various physico-chemical processes on the stable isotopic composition of different water masses in the ocean is significant (Mackensen 2001). Different isotopic signatures of the water masses have the potential to be differentiated in fossil carbonates as well (Mackensen et al., 1996). Major isotopic fractionation in foraminiferal shells is caused by equilibrium/kinetic effects associated with the hydrologic cycle (freezing, evaporation, precipitation). These effects in turn also change the seawater salinity. Therefore, $\delta^{18}O$ variations of foraminiferal tests could possibly be an important tool to understand salinity-linked variation in different water masses in modern marine environment.

An oceanic transect from low latitude to higher latitude encompasses a variety of regimes, each having its own distinct water mass characteristics (Orsi, Whitworth & Nowlin 1995). One among such significant hydrographical boundaries is Sub Tropical Convergence (STC) or Sub Tropical Front (STF) (Deacon 1933, 1937; Clifford 1983; Hofmann 1985). The adjoining region of this STF witnesses a number of oceanic frontal systems having their own physical properties (currents, salinity, temperature, density, nutrient contents etc). Having realized the significance of the above-mentioned region, the Indian pilot expedition to Southern Ocean (PESO) was launched in January 2004 with an aim to understand various oceanographic processes in different water regime and their effects and changes both in space and time. Accordingly a number of surface and sub surface sediment samples were collected along a north-south transect between 80° E and 40° E longitude.

In order to assess the intriguing relationship between isotopic composition of planktic foraminifera and the changes that occur across this transect in the gradient of sea surface salinity, we particularly explore the trends in the latitudinal distribution of $\delta^{18}O$ *Globigerina bulloides* and near sea surface salinity.

**MATERIALS AND METHODS**

A total of nineteen surface sediment samples were collected onboard ORV *Sagar Kanya* between 1.92°N and 55.01° S latitude in the Indian Ocean sector of Southern Ocean (Fig.1). Since, all the sediment samples were collected from above the calcium carbonate compensation depth (CCD) and foraminiferal lysocline (4,400-4,700 m water depth; Banakar et al., 1998), therefore, the dissolution effect on the samples may be ruled out. Immediately all the sediment samples [top 1 cm of the sediment core/grab] were stained with Rose Bengal and preserved in 10% formalin to differentiate living specimens of benthic foraminifera. The presence of living benthic foraminiferal specimen at all the stations indicates presence and recovery of surface sediment samples. Accordingly the surface hydrographic properties were considered for inter-comparison assuming that the surface sediment samples are the representative of the modern time. All the sediment samples were processed as per standard procedure. An appropriate
amount of sediment from each sample was dried overnight at 45°C. The sediments were sieved through 63µm sieve. Plus 63µm fraction was dried and transferred to plastic vials. From the dried >63µm fraction, a representative aliquot was taken by quartering and coning, to pick 10-12 mature specimens of *G. bulloides* for stable isotopic (oxygen) analyses. *G. bulloides* species was selected for the isotopic analysis because of its ubiquitous presence in all the samples. To determine oxygen isotope ratios of *G. bulloides*, the properly cleaned specimen were analysed through a Finnigan MAT 251 isotope ratio gas mass spectrometer coupled to an automatic carbonate preparation device (Kiel I) and calibrated via NBS 19 to the PDB scale at the Alfred Wegener Institute for Polar and Marine Research, Germany. The values are given in d-notation versus VPDB (Vienna Pee Dee Belemnite). Precision of oxygen measurements based on repeated analyses of a laboratory standard over a one-year-period was better than 0.09‰ for oxygen. Since planktic foraminifera in recent sediment in general have $^{18}O$/$^{16}O$ ratios consistent with growth in isotopic equilibrium with sea water at or near the sea surface (Woodruff, Savin & Douglas 1980; Curry & Mathews 1981), the near sea surface salinity was measured using CTD all along the transect at designated station for inter comparison. The correlation coefficient of these two parameters in different latitudinal zones was calculated and plotted using Excel software.

**RESULTS AND DISCUSSION**

Fig.2a shows that the minimum value of $\delta^{18}O$ is -1.53 ‰, recorded at station SK 199C/14, whereas it reaches to the maximum (3.138 ‰) at station SK 200/33. Similarly the minimum near sea surface salinity recorded in this transect is 33.7 (at station SK200/21) whereas maximum salinity (35.7) was recorded at station SK200/14 [Fig.2 b]. It is also evident from figs. 2 a-b that both these parameters are apparently showing peculiar trends in two distinct latitudinal regime which has been categorized here as Zone- A (between 1.02° S and 31.00° S latitude) and Zone- B

![Figure 1. Locations of grab and Piston corer samples.](image)
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**Figure 2.** Latitudinal changes of δ¹⁸O in *Globigerina bulloides* (A), and salinity of near sea surface water (B). The horizontal dotted line marks the zones A and B with different relationship between salinity and δ¹⁸O in *Globigerina bulloides*.

**Figure 3.** Graph shows the relationship between seawater oxygen isotopic composition and salinity in the southwestern Indian Ocean. Figure 3A shows the direct relationship between δ¹⁸O and near sea surface salinity (R = +0.73) in Zone- A, whereas Figure 3B shows the inverse relationship between δ¹⁸O and near sea surface salinity (R = -0.82) in Zone- B.
they do not necessarily change the oceanographic conditions of higher latitude regions, processes affect the sea surface salinity and other ice formation and melting? It appears that while these changes in seawater characteristics as a result of sea foraminifera (Craig & Gordon 1965; Matsumoto, Lynch & Anderson 2001) as much as evaporation and precipitation (Craig & Gordon 1965).

Gordon 1965; Matsumoto, Lynch & Anderson 2001). Due to a brines and increases salinity of the water. Due to a very small isotopic fractionation between water and ice no depletion of water $\delta^{18}$O accompanies the salinity increase. This results in an essentially zero slope in $\delta^{18}$O versus salinity plot [Craig & Gordon 1965]. Probably a combination of such peculiar processes leads to the change in relationship between salinity and $\delta^{18}$O G. bulloides towards higher southern latitudes in the study area.

Based on the data discussed here, it appears that perhaps salinity does not play a direct and governing role in influencing the $\delta^{18}$O of G. bulloides tests in higher latitude regions. The preliminary inferences drawn in this study are at tandem with the findings of earlier studies which pointed out that the $\delta^{18}$O of foraminiferal calcite near the Antarctica is not related to density in a straight forward way, as it is in the warm waters of the world ocean (Lynch-Stieglitz, Curry & Slowey 1999).

**CONCLUSIONS**

Based on this study carried out to understand the relationship between near-surface seawater salinity and $\delta^{18}$O G. bulloides it is observed that in the southwestern Indian Ocean, upto around 31° S latitude $\delta^{18}$O G. bulloides becomes progressively heavier with increasing salinity of the ambient water mass, whereas beyond 31° S (further south) latitude, G. bulloides oxygen isotopic composition becomes heavier with decrease in seawater salinity. However, to further understand the intriguing interrelationship of oxygen isotopic fractionation and sea salinity in higher latitudes and to augment this study further, a number of transects in and around the study area (different sector of Southern Ocean) are proposed for similar investigations. In order to further augment our inferences it is proposed to calculate seawater salinity from the G. bulloides oxygen isotopic ratio and sea water temperature and compare the estimated values with the physical data of salinity.

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