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Stable isotopic investigation of *Porites* coral from the Minicoy Island

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Stable isotope analysis has been performed on a coral collected from the Minicoy Island to investigate its potential as a proxy for southwest monsoonal variability. The X-Ray picture of the *porites* coral collected revealed about 24 annual bands (1989-2013). The mean annual extension over this period is ca. 7.7mm/year. Stable carbon ($\delta^{13}C$) and oxygen isotope ($\delta^{18}O$) analysis of these bands reveal that the isotopic composition is controlled by kinetic fractionation. There is a drop of $\delta^{18}O$, ca 1‰ relative to the mean value during -1998 indicating anomalous warming of the sea surface warming.

[Key words: Coral *porites*, Minicoy Island, Stable isotope of O and C, Kinetic fractionation, SST, SSS**]**

Introduction

Corals are the most important component of the marine ecosystem that grows in the tropical oceans. Reef building corals are one of the best known archives that provide high quality records of ocean atmospheric variabilities on sub seasonal resolution spanning up to a few hundred years[1,2,3&,4]. Carbon and oxygen stable isotope ratio measurement of corals have been widely used to study the hydrological and meteorological conditions in tropical marine environment[5,6,7,8&9]. The isotopic and chemical tracers incorporated in the coral skeleton are known to provide useful information, such as, sea surface temperature (SST), sea surface salinity (SSS), upwelling intensity, oceanic circulation etc. Lakshadweep Islands and Maldives in the north Indian Ocean harbor various types of corals and some workers have studied them for paleoclimatic/paleo environmental reconstruction. It has been demonstrated that stable isotope analysis of corals from these regions are useful proxies for SST[10] and southwest monsoon rainfall over the Kerala coast[11]. Some workers have studied their morphology and distribution[12&13] for identification of new coral species, coral classification and abundance. Minicoy Island is strategically located in the northern Indian Ocean and falls in the pathway of the southwest monsoon circulation[14].Additionally the oceanographic characteristics of this region offer some added advantage for coral analysis. Thus investigation of stable isotope (C and O) characteristics of corals from this region could provide high resolution records of climate variability. The genus *Porites* is the most common species used for the paleoclimatic studies, because they provide fairly well defined annual density bands, which can be identified in an X-radiogram. Porites have relatively high growth rate (10-12 mm/yr) and have wide geographical distribution. Their oxygen isotope ratios have been related to SST variations [15, 16 &17]. To our knowledge, the stable isotopic studies of corals from the Minicoy Islands have not been reported earlier. Hence, to explore the potential of these corals from the Minicoy Island we collected a *Porites* spp. and analyzed the stable isotopic composition of the annual bands.

Study Area and Methodology

Minicoy Island is the southernmost atoll of the Lakshadweep archipelago (Figure 1). The atoll is 10 km in length, having a maximum breadth of about 6 km and the Island margin offers a platform for the growth of the different types of corals. Minicoy Island enjoys a tropical savanna type climate (Koppen's classification 1960) maintaining warm temperatures throughout the year and receives dominantly the SW monsoon rains as suggested by Mannadiar 1977[18] and also collected from the Climate-data.org.

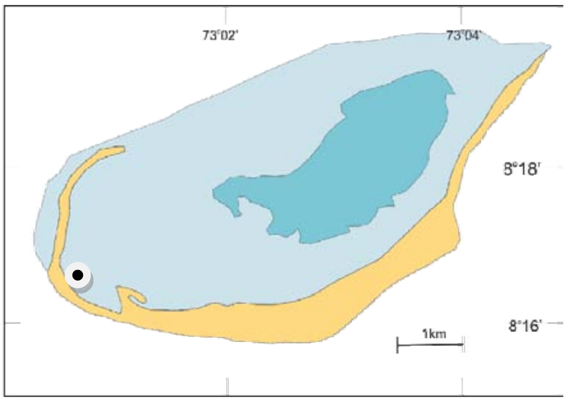

Fig .1- The Minicoy Island (yellow) surrounded by the atoll in the north and Indian Ocean in the south.

The annual average precipitation is 1266 mm/yr. Figure 2 shows the climatological variations of the mean monthly precipitation in Minicoy.

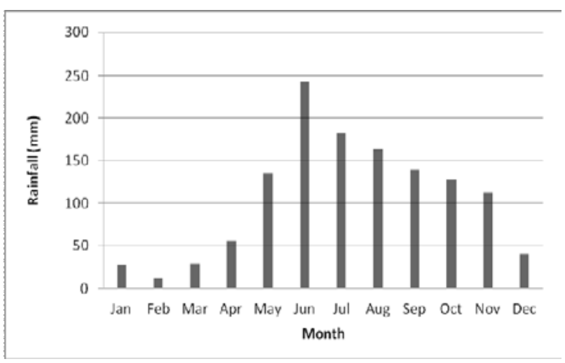

Fig.2- Climatological variations of monthly precipitation at the Minicoy Island for the year 2000 to 2013 excepting 2003 when rainfall data was not available for most of the time. The data was provided by the National Data Center, India Meteorological Department, Pune.

A live coral sample (*Porites spp.*) was collected from the Minicoy Lagoon at a shallow water depth during low tide from the southern end of the island (Figure 1) on 21/October/2013, (8°16'55.2" N, 73°03'16.8"E, and 13ft msl). The sample was thoroughly cleaned and then air dried. The sample was sliced, polished and a thin stripe (about 1 cm thick) was made along the growth axis. This stripe was X-rayed using the standard technique of Chakraborty (1992)[19] to reveal the annual bands. The maker of the X-ray machine is Collimes X-Ray and the model is DX300. Single exposure intensity of 70kv and time 12ms were used to get a good picture. About 24 bands were found (Figure. 3).

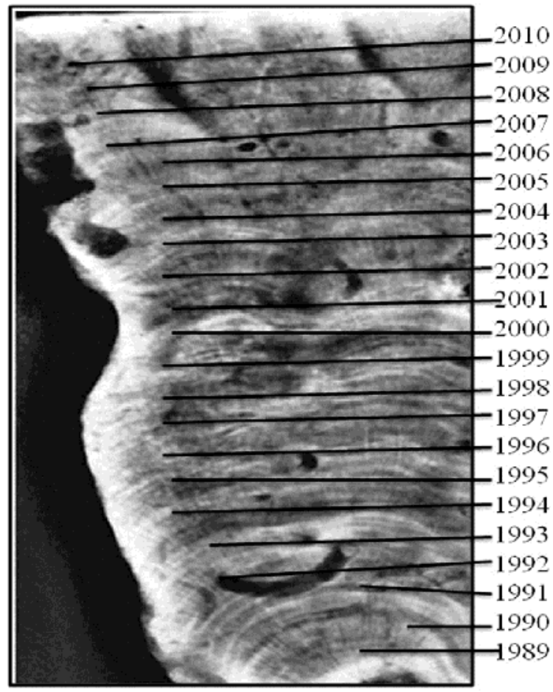

Fig. 3- X-ray positive picture of the *Porites* coral with annular bands.

The top most band represents the year of collection i.e. 2013 based on which the chronology of the other bands have been fixed. In this context it may be mentioned that the top two bands showed anomalously high $\delta^{18}O$ values and hence these two years (2012-2013) isotopic data have been discarded. The coral had an average growth rate of 7.7 mm/year. For stable isotope measurement, 100-200µg of coral powder was extracted along a vertical growth axis transect using low powered hand held drilling equipment (Minicraft make drill machine Model-MB150 Hobby torque drill machine; drill bit size: 0.1 mm to 1 mm diameter). The samples were then treated with 100% H_3PO_4 using an online extraction system interfaced with a Thermo Scientific Delta V Plus Isotope Ratio Mass Spectrometer under continuous flow configuration at IITM, Pune The analytical precision was 0.1‰ for both $\delta^{13}C$ and $\delta^{18}O$ measurement and the stable isotope ratios were reported in permil relative to VPDB. In order to study the behavior of coral $\delta^{18}O$ with respect to climatic parameters, such as Indian monsoon rainfall we have used the rainfall index 'TISM' as proposed by Xavier et al., (2007)[20]. This is based on the tropospheric temperature (TT) difference which is defined as the mean air temperature between the levels 600 and

200hPa. According to this concept the monsoon onset and withdrawal is based on the reversal of TT between a northern box (40-100°E, 5-35°N) and a southern box (40-100°E, 15-5°N), denoted as □TT. The monsoon onset is defined as the date when □TT changes sign from negative to positive, and the withdrawal date is defined as the date when □TT changes sign from positive to negative (see Figure 2 in Xavier et al., 2007)[20]. The NCEP/NCAR reanalysis data[21] has been used to calculate the TT. LRS is the 'length of rainy season' defined as the number of days between onset and withdrawal of monsoon while TISM is the integral of □TT during LRS.

Results and Discussion

Figure 4 and 5 shows the time profile of $\delta^{18}O$ and $\delta^{13}C$ of the coral sample which spans from 1990 to 2013.

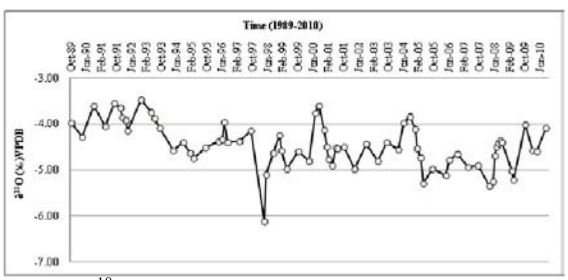

Fig. 4- $\delta^{18}O$ record of the coral *Porites* sample for the period of (1989-2010).

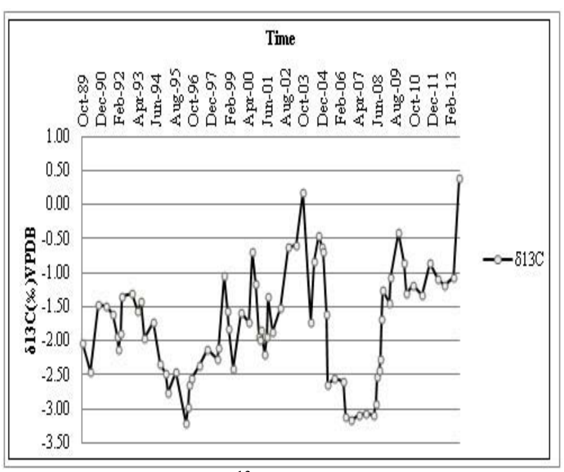

Fig. 5- Shows $\delta^{13}C$ values based on time.

The $\delta^{18}O$ has a range of about -3.5 to nearly -5.0‰, yielding average amplitude of 1.5‰. Though the range of $\delta^{18}O$ variability is somewhat similar but the amplitude is relatively higher than that of *Porites* of the Kavaratti Island, which show average $\delta^{18}O$ amplitude in the order of 1‰[22&10]. We studied the local SST and SSS (a proxy for sea water $\delta^{18}O$) pattern to understand the cause of high $\delta^{18}O$ amplitude as coral oxygen isotope composition is mainly controlled by SST and sea water oxygen isotopic composition[15]. The daily data of SST and SSS was downloaded from the Global Ocean Data Assimilation System Link (GODAS) http://www.esrl.noaa.gov/psd/data/gridded/data.godas.html) and the climatological monthly means were calculated for the past 24 years (1989-2013) over a 1.5X1.5 gird box (8.0N-9.0N, 72.5E-73.5E). The annual variations of these two parameters are presented in figure 6.

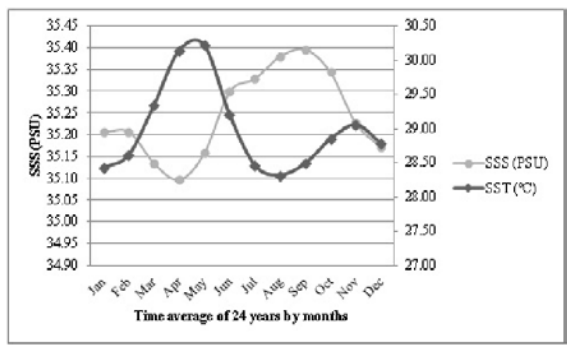

Fig. 6- Mean annual climatological (1989-2013) variations of sea surface temperature (black) and sea surface salinity (gray) around the Minicoy Island (8.0N-9.0N, 72.5E-73.5E). Data source: GODAS

The monthly variations of and SSS in Figure 6 clearly show that SST and SSS are almost out of phase. Since $\delta^{18}O$ is inversely correlated with SST and positively related to SSS, the effect of changes in these two parameters is additive, resulting in an enhanced $\delta^{18}O$ isotopic signal. But it is to be noted that the mean amplitude of SSS is only 0.2 g/kg while SST has amplitude of about 2°C, so the effect of salinity variation is small compared to the temperature variation. Corals growing in this kind of environment are better suited for SST reconstruction. The data shows that during April-May SST increases when SSS and $\delta^{18}O$ show lower values (Figure 7).

On the other hand during the month of August SST decreases, but SSS and $\delta^{18}O$ increase owing to the monsoon induced upwelling that occurs during this time[22 &10]. Coral $\delta^{18}O$ and $\delta^{13}C$ show a positive (r=0.5) correlation, (Figure 8).

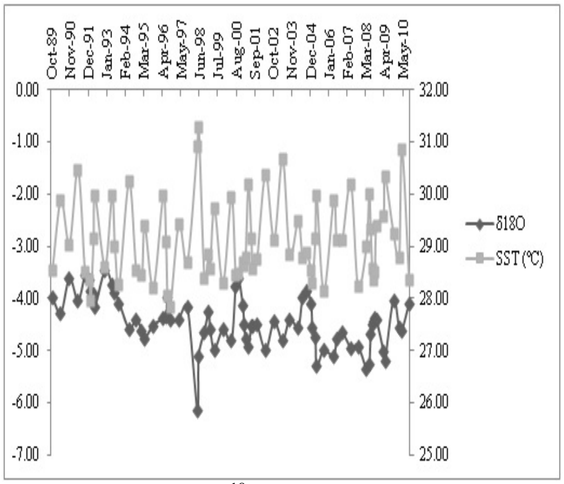

Fig. 7- Graph showing $\delta^{18}O$ (‰) and SST (°C) values versus time.

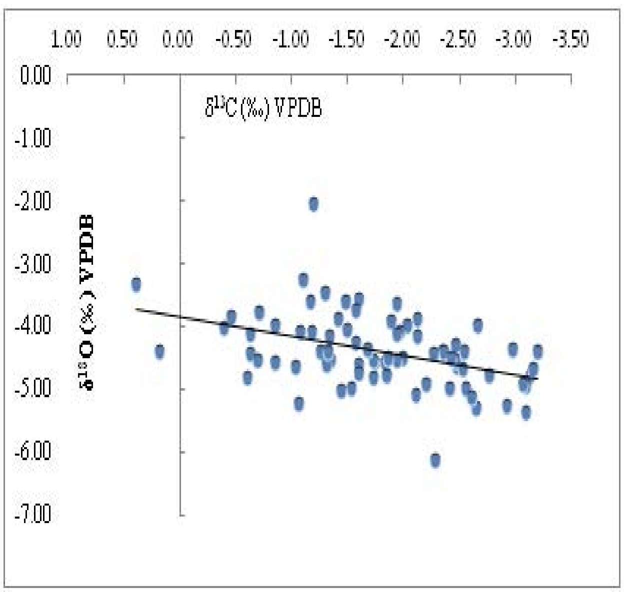

Fig.8- Graph showing ($\delta^{18}O$ versus $\delta^{13}C$ ‰) VPBD.

Which implies that coral calcification was kinetically controlled[19].

Coral $\delta^{18}O$ on the other hand show a negative correlation with the SST (r= -0.32, p< 0.002, n =77) (Figure 9). A sharp decrease in coral $\delta^{18}O$ in 1989 was probably due to anomalous warming of sea surface during that year. The relationships between coral $\delta^{18}O$ and Indian monsoon indices have also been examined. It has been found that coral $\delta^{18}O$ is weekly correlated (r=0.16) with the rainfall over the Peninsular India as well as with the all India rainfall index (r=0.12).

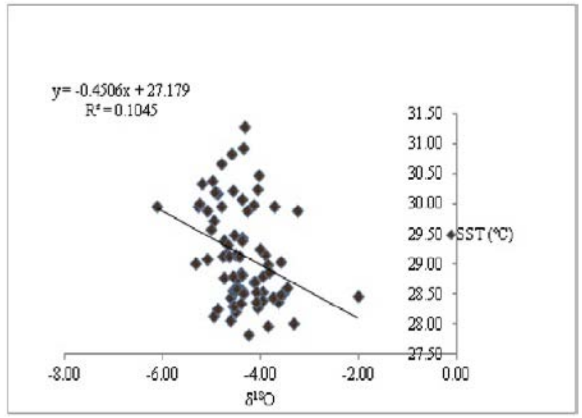

Fig.9- Graph showing the coral $\delta^{18}O$ and SST.

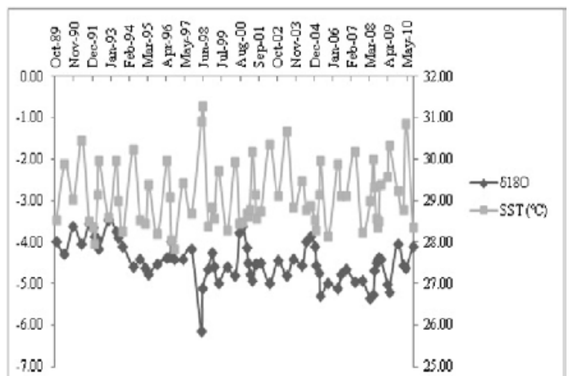

Fig.10- $\delta^{18}O$ (‰) and SST (°C) values versus time.

The carbon isotopic variations of coral carbonate, on the other hand, are believed to be controlled by the zooxanthellar activity (i.e. photosynthesis) mediated by light intensity and penetration[2]. But the interpretation of carbon isotopes in corals is rather complicated as the carbon pathways and their role in fractionating carbon isotopes are not fully understood. Long term $\delta^{13}C$ data from multiple sites are required for a meaningful interpretation of carbon isotopes. Figure 11 represents SST anomaly relative to the long term annual mean from 1989-2013 for Minicoy region.

Chakraborty et al., (2012)[23] demonstrated that $\delta^{18}O$ of corals are sensitive to the thermodynamic index of Indian summer monsoon rainfall (TISM, defined in Xavier et al., (2007)[20]. We have examined this relationship in case of Minicoy coral. TISM has been calculated for the period of 1989-2013 as described

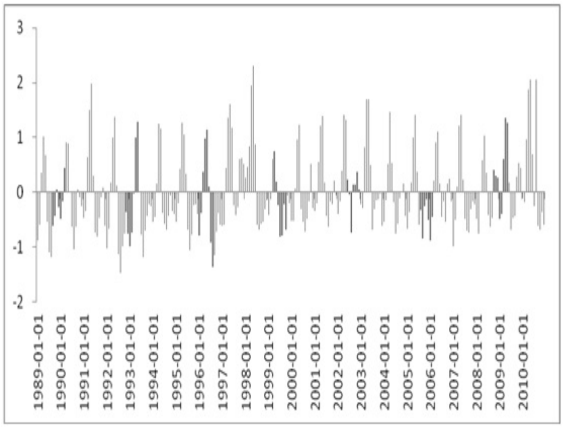

Fig.11- SST anomaly (deviation relative to the long term monthly mean of 1989-2013)

in the method section and then correlated with the mean annual values of coral $\delta^{18}O$ (r=0.23). Though the connections between coral $\delta^{18}O$ and monsoon indices are not very strong, however they are similar to that observed in case of other corals belonging to the Indian Ocean[23], indicating that the coral oxygen isotope in this region responds in the same manner as found in the equatorial Indian Ocean or Pacific Ocean region[23].

Conclusions

The present study reveals that the *Porites* coral from the Minicoy Island could be used as a proxy to study the climatic/environmental changes that are mostly driven by monsoon variabilities. The studied coral had about 24 annual rings had an average growth rate of 7.7mm/year. Higher values of $\delta^{13}C$ (0.18‰) is found in the coral sample during the months September to December, when photosynthetic activity within the coral polyps is strengthened which results systematic enrichment of the ambient seawater (in 13C) and hence in coral $CaCO^3$. Monsoonal activity retards the growth rate because of turbidity, sedimentation, sediment suspension and rainfall and hence sea surface temperature is reduced. Due to the upwelling SST drops result an increase in coral $\delta^{18}O$.The response of coral $\delta^{18}O$ to other climatic/environmental parameters are similar to other corals found in Indo-Pacific region.

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