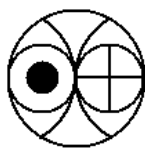


**QUATERNARY GEOCHRONOLOGY AND  
PALAEOCLIMATOLOGY OF THE INDIAN  
OCEAN**

**MANISH TIWARI**

**Ph.D. Thesis**

**February 2005**



**Physical Research Laboratory  
Ahmedabad – 380009, India**

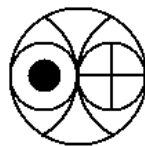
# **Quaternary Geochronology and Palaeoclimatology of the Indian Ocean**

Thesis submitted to  
**The Maharaja Sayajirao University of Baroda,**  
**Vadodara, India**

*For the degree of*  
**Doctor of Philosophy in Geology**

By  
**Manish Tiwari**

February 2005



Planetary & Geosciences Division  
Physical Research Laboratory  
Ahmedabad – 380009, India

# Contents

List of figures	(iv)
List of tables	(vii)

<b>Chapter 1</b>	<b>Introduction</b>	<b>1-17</b>
1.1	Monsoon and the associated oceanographic effects.....	3
1.1.1	Southwest (SW) Monsoon.....	3
1.1.2	Northeast (NE) Monsoon.....	4
1.2	A brief review of the earlier work on past monsoon.....	8
	variations	
1.2.1	Western/Northern Arabian Sea.....	8
1.2.2	Eastern Arabian Sea.....	11
1.2.3	Equatorial Arabian Sea.....	12
1.3	Aims of the present study.....	14
1.4	Thesis outline.....	16
 <b>Chapter 2</b>	 <b>Materials &amp; Experimental Techniques</b>	 <b>18-43</b>
2.1	Collection and locations of the sediment cores.....	19
2.2	Foraminifera and their separation procedure.....	21
2.2.1	Separation of foraminifera.....	22
2.3	Radiocarbon chronologies.....	23
2.4	Isotopic and chemical proxies employed in this study.....	26
2.4.1	Oxygen isotopes.....	26
2.4.2	Carbon isotopes.....	31
2.4.3	Nitrogen isotopes.....	33
2.4.4	Biogenic Proxies.....	34
2.5	Analytical scheme followed to measure various.....	35
	proxies, their precisions and accuracies	
2.5.1	$\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ measurements on foraminifera.....	35
2.5.2	Calcium Carbonate and Organic Carbon measurements.....	42
2.5.3	Nitrogen isotope measurements.....	43
 <b>Chapter 3</b>	 <b>Eastern Arabian Sea: High Resolution Monsoon</b>	 <b>44-</b>
<b>66</b>	 <b>Reconstruction for the Past ~2800 years</b>	
3.1	Introduction.....	45
3.2	Core location.....	46
3.3	Oceanographic conditions at the core site.....	46
3.4	Age-Depth Model.....	48
3.5	Precipitation Signals as Manifested by Oxygen Isotopes.....	49
3.6	Temporal variation in productivity.....	54
3.6.1	Productivity as manifested by $\text{CaCO}_3$ and $\text{C}_{\text{org}}$ content.....	54

3.6.2	Productivity as manifested by $\delta^{13}\text{C}$ .....	58
3.7	Temporal variation in the stable isotopes of nitrogen.....	60
3.8	The Solar connection.....	61
3.9	Spectral analysis.....	64
3.10	Inferences.....	65
<b>Chapter 4</b>	<b>Equatorial Arabian Sea: SW Monsoon, NE Monsoon and Intermonsoon Variations during the Past 35,000 years</b>	<b>67-97</b>
4.1	Introduction.....	68
4.2	Core Location.....	69
4.3	Oceanographic and Climatologic conditions at the core site...	70
4.4	Age-Depth Model.....	72
4.5	Oxygen isotope Analysis.....	73
4.5.1	SW Monsoon vs. NE Monsoon.....	73
4.5.2	Correlation with the high latitude temperature record.....	78
4.6	Temporal Variations in Productivity.....	84
4.6.1	Productivity as Exhibited by Calcium Carbonate Content.....	84
4.6.2	Regional climatic evolution: comparison..... with eastern Arabian Sea	87
4.6.3	Productivity as exhibited by Sedimentary Organic Matter.....	88
4.6.4	Productivity as exhibited by the $\delta^{15}\text{N}$ .....	90
4.6.5	Productivity as exhibited by the carbon isotopes.....	92
4.7	Spectral Analysis.....	93
4.8	Inferences.....	95
<b>Chapter 5</b>	<b>Western Arabian Sea: SW Monsoon History since the Last Glacial Maximum</b>	<b>98-121</b>
5.1	Introduction.....	99
5.2	Core location.....	99
5.3	Oceanographic conditions at the core site.....	100
5.4	Age – Depth model.....	103
5.4	Downcore productivity variations in the core SS 4018 G.....	104
5.4.1	Productivity as manifested by $\text{CaCO}_3$ and $\text{C}_{\text{org}}$ .....	104
5.4.2	Productivity as manifested by $\delta^{13}\text{C}$ .....	109
5.4.3	Productivity as manifested by $\delta^{15}\text{N}$ .....	110
5.5	Oxygen isotopic analysis.....	113
5.6	Spectral Analysis.....	116
5.7	Inferences.....	120

<b>Chapter 6</b>	<b>Conclusions</b>	<b>122-130</b>
<b>6.1</b>	Major Conclusions.....	123
<b>6.1.1</b>	Past variations in the SW monsoon intensity.....	123
<b>6.1.2</b>	NE monsoon intensification.....	124
<b>6.1.3</b>	Correlation between SW monsoon wind strength..... and SW monsoon precipitation	125
<b>6.1.4</b>	Correlation between SW monsoon precipitation..... and high latitude climate	125
<b>6.1.5</b>	Past variations in the IEW and the relatable SO index,..... SW monsoon, East African rains and El Nino frequency	126
<b>6.1.6</b>	Regional Climatic evolution.....	127
<b>6.1.7</b>	The solar influence.....	127
<b>6.1.8</b>	Limitations of Corg, $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$ at the..... equatorial core site	128
<b>6.2</b>	Recommendation for future studies.....	128
<b>References</b>		<b>131-161</b>