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Evidence of increased rainfall prior to 3500 years BP as revealed by river borne terrigenous flux: A study from west coast of India

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ABSTRACT

The study has been conducted for insoluble residue and Calcium Carbonate content in a 4.80 m long shallow water (at 22 m water depth) sediment core (at 22 m water depth) off Central West Coast of India to reconstruct palaeo monsoonal precipitation linked with river discharge. The down core profile of carbonate content shows that it is generally less than 28% below ca. 3.00 m whereas, above 3.00 m it is generally more than 28% and this showing an general upward trend. On the contrary, the average insoluble residue is marked by higher value (>72%) below ca. 3.00 m while, above 3.00 m it is low (<72%) and showing a general downward trend. These trends ostensibly suggest an increased rainfall prior to around 3500 year BP which resulted in enhanced river discharge along with insoluble residue and diminution of calcium carbonate, (ascribed due to reduced productivity). Such a distinct response of Calcium Carbonate and insoluble residue at 3.00 m, corresponding to around 3500 years BP is congruous with the already established climatic changes of this core at ca. 3500 years BP linked with salinity changes due to alteration of rainfall pattern.

1. Introduction

It is a well known fact, that the global climate during the Holocene has displayed some noteworthy variations (Borzenkova et al., 2015). Recent palaeo climatic conjectures from lacustrine sediments, marine sediments and polar ice cores have suggested, that the Holocene might have been climatically more dynamic than the previously thought (O'brien et al., 1995; Bond et al., 1997; Campbell, 1998; Bianchi and Mccave, 1999; Korhola et al., 2000; Qian and Zhu, 2002; Wagner et al., 2004; Finkelstein and Davis, 2005; Liu et al., 2005; Mackay et al., 2005; Nicholas et al., 2012; Barnard et al., 2014). Similarly proxy records have revealed that significant climate variability occurred in this region, during the Holocene period (Clemens and Prell, 2003; Clemens et al., 2008, 1991; Sirocko et al., 1992; Neff et al., 2001; Burns et al., 2002; Fleitman et al., 2003, 2004).

In the recent years a surge of interest is generated on palaeo climatology or palaeo ceanography from the eastern Arabian Sea margin. (von Rad et al., 1999; Doose-Rolinoki et al., 2001; Lückge et al., 2001; Staubwasser et al., 2003; Sarkar et al., 2000; Thamban et al., 2001). Such interesting results are collated in various reviews undertaken earlier (such as Staubwasser (2006), Prasad and Enzel (2006), Staubwasser and Weiss (2006), which provide useful information and recent advances).

The results of earlier studies, reveal substantial regional differences (Staubwasser, 2006). While comparing the palaeo monsoonal records from Southern Asia (Thamban et al., 2001; Burns et al., 2002; Staubwasser et al., 2002, 2003; Gupta et al., 2003), it has been pointed out by Staubwasser (2006) that monsoon histories derived from foraminiferal isotopic and bulk sediment proxy, records have provided strikingly different results. This significant observation necessitated to study palaeo monsoonal variations from different sectors along the Indian coast. Nevertheless, broad scale reconstruction of palaeo climatic conditions over different sectors of Indian sub continent during the late Holocene has been hindered by the paucity of sufficiently resolved records of climate changes.

It is therefore, important to develop other methods to establishing longer palaeo climatic records of the last few thousand years, with fine time resolution. Although, many earlier studies were based on the assessment of the strength of the summer monsoons over Western Arabian Sea, yet wind strength inferred from upwelling intensity in the Western Arabian Sea can not be used to reconstruct Holocene palaeo-monsoon rainfall, over South Asia in general (Staubwasser, 2006). Accordingly, continental

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shelves are being of more interest to the palaeo climatologists mainly because these regions are characterized by higher rate of sedimentation and hence are capable of developing records with decadal to century level time scales (Southward et al., 1975; Smith and Schafer, 1987; Nittrouer et al., 1994; Smith et al., 2005). These coastal regions are inherently sensitive towards climatic changes that takes place over land and therefore, allow to utilize various proxies in subsurface coastal marine sediments to understand the climatic changes in the past.

Various rivers on confluence to sea in the coastal regions, are known to affect the physical and chemical conditions and biological/geological processes of the continental shelf regions, adjacent to their distributaries mouths, thus giving rise to distinctive micro-environmental conditions in the river mouth area. The areal extent of these micro-environments depends upon the amount of fresh water discharge (linked with the intensity of the monsoonal precipitation over the catchment area) from the rivers, which in turn not only changes the salinity and water turbulence of the adjacent shelf water, but also changes the river borne terrigenous influx to the shelf regions. The detailed conceptual model to study palaeo monsoons through shallow coastal marine sediments has already been published (Nigam and Khare, 1995). Accordingly, the existence of palaeo monsoonal variations could be ascertained by examining the river borne terrigenous influx at the core site in the sub surface coastal marine sediments.

In view of the above, in the present study we have examined insoluble residue and $CaCO_3$ content in a shallow water sediment core, collected near the river mouth off central west coast of India with the sole aim of reconstructing palaeo monsoonal variations, that occurred during the last 4500 years.

2. Physiographic setting of the area

From the Western Ghats, the long chain of mountains rising steeply along the western coast of peninsular India, numerous short rivers flow into the Arabian sea, very often through a complex system of lagoons and backwaters spread over the coastal plains. An exception is the river Kali which, because of a hilly coastline, flows directly into the sea through a steep-sided low valley. This means that its sediments are supplied directly to the sea bed without any distortions resulting from the usual vagaries in estuarine plain formations (Caratini et al., 1994). The topography of the inner shelf is regular, forming a gentle slope covered by clayey silt (Hashimi and Nair, 1981). The catchment basin drained by the Kali river is large, the largest in the central part of the western Ghats.

The study area receives seasonal heavy rainfall, during the south-west monsoon (June to September) which is discharged through two main rivers, the Kali and the Gangavali. The approximate lengths of these rivers are 68 and 40 km respectively and the annual average discharges are 207 and 156 m^3/sec, respectively (Rao, 1979). The area of investigation is rather free from extensive storms which causes large scale erosions.

3. Materials and methods

A 4.80 m long shallow water (22 m water depth) sediment core SK 27 B/8 was collected from the inner shelf region off central west coast of India, near Karwar (at latitude 14° 49.43′N and longitude 73° 59.37′E), in the vicinity of the mouth of Kali river (Fig. 1). The core sample was sub-sampled at 5 cm intervals. In order to know the insoluble residue (in turn reflects river borne terrigenous influx) and calcium carbonate ($CaCO_3$) variations (in %) down the core (which is mainly biogenic from local production), the standard procedures were followed.

After coning and quartering of washed samples, a small quantity (roughly 40 gms) was dried at 60 °C. 100 ml of 0.1 N HCl was added to the sediment and stirred well to enhance the reaction. After initial reaction has ceased, we added additional 20 ml of 0.1 N-HCl and continued to add acid till no further reaction is observed and solution turned strongly acidic. The excess acid was decanted and sample was washed carefully in distilled water to remove $CaCl_2$. After this, the sample was evaporated to dryness and heated to 110 °C before weighing. The sediment sample was again weighed to find out the loss in weight (Carver, 1971). The total CO_3 content (in %) can be calculated using the following formula:

$$\%\ CO_3 = \frac{100 \times \text{weight loss}}{\text{Initial dry weight of sediment sample}}$$

The counter percentage incorporates insoluble residues.

The time control in this core is provided by ^{14}C date at three different levels 140–145 cm (corresponds to 2020 ± 40 years BP), 300–305 cm (corresponds to 3510 ± 60 years BP) and 445–450 cm (corresponds to 4325 ± 65 years BP). These radiocarbon (^{14}C) dating on organic matter in the sediment were obtained by β-counting at Centre des Faibles Radioactivities, CEA-CNRS, Gif-sur-Yvette (France). The conventional ^{14}C dates are given with $\delta^{13}C$ correction following Stuiver and Polach (1977). The sediments of this core have been deposited over the last five millennia, a period when the sea level was already stabilized at its present stand. This implies that the sedimentation processes have not been influenced by any significant change in sea level (Caratini et al., 1994).

The un-calibrated ^{14}C dates (2020 ± 40 years BP, 3510 ± 60 years BP and to 4325 ± 65 years BP) were calibrated by using CALIB Rev 5.0.1 calibration software which was downloaded from the web site (http://radiocarbon.pa.qub.ac.uk/calib/download/).

The un-calibrated Ages of the sample was based on the value of half-life (5730 + 40 years), which was first corrected for the more accepted half-life of ^{14}C that is Libby half-life by dividing the 5730 half-life radiocarbon age by 1.029, before the actual calibration (Stuiver and Polach, 1977). The Calibration was done by using marine 04.14c data set; lab error multiplier option; and reservoir corrections with the data from the web site (http://radiocarbon.pa.qub.ac.uk/marine/). After running the above CALIB Rev 5.0.1 programme, the final calibratedages have been obtained based on these calibrated ages the average rate of sedimentation in different portions of the core appears to be of the order of 0.18 cm/year between 450 and 305 cm, 0.11 cm/year between 305 and 145 cm and 0.07 cm/year between 145-top of the core.

4. Results and discussions

As shown in Fig. 2a, the average insoluble residue is marked by higher value (>72%) below ca. 3.00 m while, above 3.00 m it is low (>72%) and showing a general decreasing trend (Fig. 2a). On the contrary, the average carbonate content is generally less than 28% below ca. 3.00 m whereas, above 3.00 m it is generally more than 28% and showing a general increasing trend (Fig. 2b).

Knowing the fact, that an increase in the insoluble residue (an indicator of river borne terrigenous flux to core site) is accompanied by the increased intensity of rainfall over the catchment area, the distribution pattern of insoluble residue indicates that below ca. 3.00 m (corresponding to around 3500 years BP), the conditions of relatively increased river discharge and lower salinity existed at the core location whereas, above 3.00 m salinity content gradually increased due to reduction in the river discharge associated with the reduced rainfall. Such signature can also be seen in the sedimentation rates. If we notice the change in sedimentation rate at core site it is apparent that from the bottom of the core (4.80 m) to upto 3.00 m down the core the sedimentation rate has been around