

caste groups where they vary between 32.13% (Yanadi¹⁵) and 65.09% (Konda Reddi¹⁷) in the male series and between 45.76% (Yanadi¹⁵) and 67.31% (Yerukala¹⁴) in the female series among tribal populations. Our study shows the highest proportion of fourth interdigital true patterns (M: 66.50% and F: 72.25%) than all the castes and tribal populations of Andhra Pradesh (Table 6) and is closer to only Konda Reddis¹⁷. Further, the incidence of true pattern on fourth interdigital area in general is relatively more in low caste populations like Madigas and tribal populations than the upper caste populations which is substantiated by our study.

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Can the possibility of some linkage of monsoonal precipitation with solar variability be ignored? Indications from foraminiferal proxy records

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Foraminiferal studies on a shallow water sediment core off Karwar, central west coast of India have revealed significant changes in the monsoonal precipitation during the last around 720 years. The results hint towards some possibility of linkage of monsoonal precipitation with solar variability during this period.

Keywords: Benthic and planktonic foraminifera, monsoonal variability, palaeoclimate, solar variability.

THE palaeoclimatic data play a key role in efforts to understand climate processes and potential for future climate changes by extending the long-term records with fine time resolution baseline of observations of past climatic changes. Such high resolution and long-term records of climatic variations from many different sections (marine mid-to-high latitudes) are required for climate models¹. Beyond the instrumentation era, proxy data complement and significantly extend such records in space and back in time^{2–7}. However, the extent and intensity of climate variability over the last 1000 years has received special attention^{8–10}. Such studies have suggested a number of climatic aberrations/boundaries throughout the world.

This communication intends to draw the attention of palaeoclimatologists to the need of looking at the monsoonal variability in view of the changes during the last millennium in the solar variability. The possibility of the modulation of monsoonal precipitation by the sunspot minima has been explored in the past through various studies across the world^{11–14}. Several important and interesting papers on the role of solar variability over climatic changes have prompted renewed interest in exploring the possibility to look for the causal link of monsoonal changes over the Indian subcontinent, with changes in solar activity. The detailed conceptual model to study palaeomonsoonal precipitation through foraminiferal variations (foraminifera are exclusive microscopic marine organisms extremely sensitive towards climatic/environmental changes) has already been published, in which we particularly considered freshwater run-off from rivers as indicative of monsoonal precipitation¹⁵.

The utility of morpho-groups of benthic foraminifera and planktonic foraminifera as a tracer of palaeomonsoonal

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precipitation in the coastal regions is well established^{16–22}. These studies showed that an abundance of angular-asymmetrical forms of benthic foraminifera along with increase in planktonic foraminiferal population are associated with decreasing intensity of the rainfall.

Therefore, in order to generate high resolution record of palaeomonsoons during the last millennium, we have examined variations in angular-asymmetrical forms of benthic foraminifera and planktonic foraminiferal population in a shallow water (at 22 m water depth) sediment core off Karwar (14°49'43"N; 73°59'37"E), near Kali river mouth, central west coast of India (Figure 1). This area receives seasonal heavy river discharge during southwest monsoon (June to September) through two major rivers, the Kali river whose approximate length and annual average discharge are 68 km and 207 m³ s⁻¹ respectively, and Gangavali river, having a length of about 40 km and annual average discharge of 156 m³ s⁻¹. The nature of sediments around the core location is generally clayey silt (Hashimi, unpublished data). The litholog of the core as prepared on the basis of visual observations at the time of sampling is provided in Figure 2. The time control in the top 80 cm of this core is provided by ¹⁴C date (2020 ± 40 yrs BP) at 140–145 cm down the core. This radiocarbon (¹⁴C) dating (No. Gif-8169) on organic matter in the sediment was obtained by *b*-counting at Centre des Faibles Radioactivites, CEA-CNRS, Gif-sur-Yvette (France)^{23,24}.

The top 80 cm has been considered for the present study as this portion covers the last about 720 years on which the present communication is based.

The uncalibrated ¹⁴C date (2020 ± 40 years BP) was calibrated for its conversion to calendar age using CALIB Rev 5.0.1 calibration software downloaded from the web site <http://radiocarbon.pa.qub.ac.uk/calib/download/>.

The uncalibrated age of the sample was based on the value of half-life (5730 ± 40 yrs), which was first corrected

for the more accepted half-life of ¹⁴C that is Libby half-life, by dividing the 5730 half-life radiocarbon age by 1.029, before the actual calibration²⁵. The calibration was done by using marine 04.14c dataset, laboratory error multiplier option and reservoir corrections with data from the web-site <http://radiocarbon.pa.qub.ac.uk/marine/>. After running the above CALIB Rev 5.0.1 program, the final calibrated age in calendar years at 140–145 cm down the core was computed as AD 687 (which is the median probability value). Based on this calendar age, the average rate of sedimentation in this part of the core appears to be of the order of 0.11 cm/yr. Assuming this rate of sedimentation as constant in the top portion of the core, the calendar ages at various levels down the core have been calculated.

We sub-sampled this core at 2 cm intervals up to 80 cm (representing the last ~720 years). All samples were immediately transferred to polythene bags and sealed. A portion of these core samples from different levels was dried at 60°C and washed through a 230 mesh (63 µm). About 500 specimens of foraminifera from each sample were separated. A total of 93 species of benthic foraminifera were identified. For the study of morpho-groups, the whole benthic foraminiferal population was clubbed into two morpho-groups (i.e. angular-asymmetrical and rounded-symmetrical, which were complimentary to each other). These morpho-groups have been categorized on the basis of external test morphologies irrespective of taxonomic level. The dominating representative benthic species which constitute angular-asymmetrical morpho-group are *Dentalina communis* d'Orbigny, *Reussella simplex* (Cushman), *Siphogenerina virgula* (Brady), *Bulimina marginata* d'Orbigny, *Lagena laevis* (Montagu), *Siphovigerina porrecta* (Brady), *Virgulinitella pertusa* (Reuss) and *Bolivina durandii* Millett²². The respective percentages of only angular-asymmetrical forms were calculated.

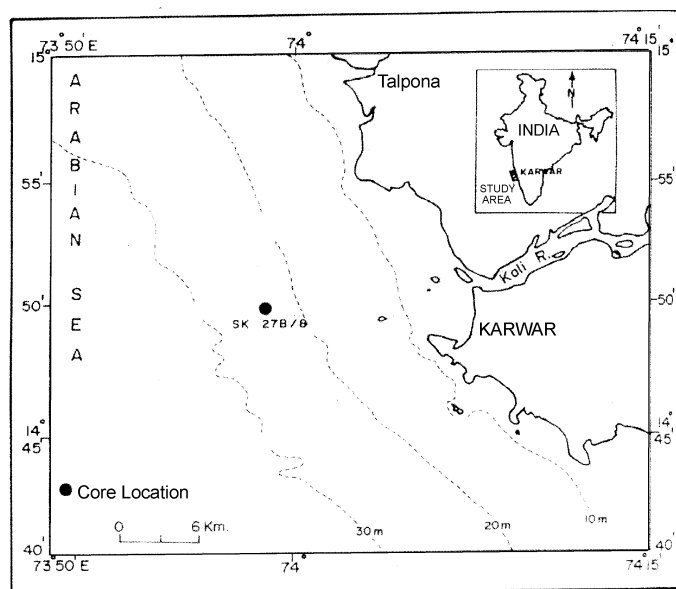


Figure 1. Location of the core (SK 27B/8).

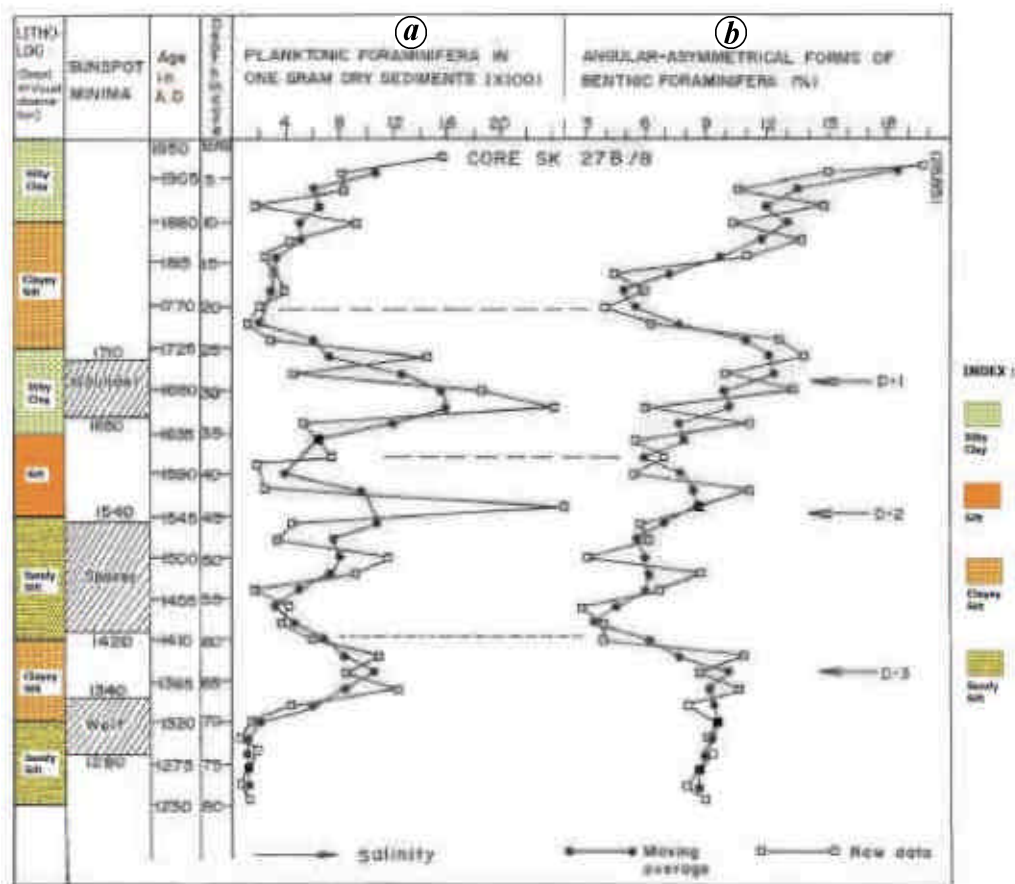


Figure 2. Down core (SK 27B/8) variations in (a) planktonic foraminiferal population in 1 g dry sediment (in numbers), and angular-asymmetrical forms of benthic foraminifera (in %) D-1, D-2 and D-3 denote dry periods. Dotted lines join the periods of increased monsoonal precipitation.

Similarly, total planktonic foraminiferal population (represented by the species like *Globigerina bulloides* d'Orbigny, *Globigerinoides ruber* (d'Orbigny), *Globigerinoides sacculifer* (Brady), *Globigerinoides conglobatus* (Brady), *Neogloboquadrina pachyderma* (Ehrenberg), *Neogloboquadrina dutertrei* (d'Orbigny), *Globoquadrina conglomerata* (Schwager), *Globorotalia menardii* (d'Orbigny) in 1 g dry sediment was also calculated. The three-point moving average is considered to highlight the significant climatic changes (Figure 2).

The down core profiles of these parameters (Figure 2 a, b) show considerable fluctuations with three major troughs, intermittent with peaks. Since angular-asymmetrical forms and planktonic foraminiferal population are directly proportional to salinity fluctuations, the troughs occurring at around 60, 40 and 22 cm down the core suggest low salinity (increased river discharge and thus more rainfall) conditions at the core site. These wet phases are alternated by dry conditions approximately from 70–66, 56–46 and 36–32 cm in the core.

For the purpose of comparing the events inferred from these two different parameters, we have joined the wet phases by dotted lines (Figure 2). On the basis of the rate of sedimentation (approximately 0.11 cm/yr), episodes of

higher salinity conditions appear to correspond approximately around AD 1320–1355, AD 1445–1535 and AD 1625–1660, whereas wet phases are noticed at around AD 1410, AD 1590 and AD 1750.

The time slots under discussion are interesting in the light of signals of sunspot activity. Eddy²⁶ extended sunspot records back to about AD 1100. Based on direct reports of solar observations, old auroral records and notably ¹⁴C analysis of tree rings, low sunspot activity events known as the Wolf Minima (AD 1280–1340); Spörer Minima (AD 1420–1540) and the Maunder Minima (AD 1650–1710) have been inferred²⁷, as shown in Figure 2. These periods coincide with the reduced sunspot activities and total solar irradiance. Any change in solar forcing causes distinct regional effects on climate¹⁰.

Therefore, the initial results of the present study apparently pick up the signatures of relatively better monsoonal precipitation at around AD 1410, AD 1590 and AD 1750, close to the ending of sunspot minima. Our inferences are in agreement with the findings of earlier workers, who reported high lake levels from Mono Lake¹¹ and Chad Lake¹² in the vicinity of solar minima. Similarly, the Nile river in Africa²⁸ too witnessed high level at around AD 1750 and AD 1575²⁸.

Although providing a causal mechanism is beyond the scope of the present study, the occurrence of periods of enhanced monsoonal precipitation slightly after the termination of the Wolf, Sporer and Maunder minima periods (less sun activity) and concomitant temperature changes could be a matter of further intense research. A number of similar studies need to be carried out at geographically distinct localities supported by many ^{14}C dates to arrive at comprehensive conclusions and better understanding of the causal linkages between solar activities and climatic changes. Such relationship, if confirmed by further measurements, may also assist in modelling studies of the Little Ice Age climate changes.

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Crustal deformation in the Indo-Burmese arc region: implications from the Myanmar and Southeast Asia GPS measurements

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Several models of plate boundary and convergence between the Indian and South China plate across the Indo-Burmese arc (IBA) region have been proposed, which include active subduction, transform, oblique and no plate boundary. We theoretically compute the dis-

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