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Late Pleistocene–Holocene monsoon variations on climate, landforms and vegetation cover in southwestern India: An overview

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ABSTRACT

Signatures of monsoon variability preserved in the Late Quaternary sediments of southwestern India have been decoded and addressed using biological proxies along with geochronological data. Barring sediments beyond the threshold for conventional ^{14}C dating, Late Pleistocene sequences have been recognized both in Konkan and Kerala basins. Konkan area has only subsurface continental/lacustrine Late Pleistocene, whereas Kerala coast has mixed facies. The landscape as well as the vegetation cover has been substantially modified and the fossil contents and related palaeoenvironment provided ample evidence to demonstrate the landscape and vegetation dynamics since Late Pleistocene. Evidence of *Myristica* swamps until Late Pleistocene and its subsequent replacement by riparian forest towards Late Holocene in Konkan has been a significant impact of monsoon variations on the tropical rain forests. The prevalence of such freshwater swamps and a sensitive habitat indicated that Konkan had enjoyed an extended period of rainfall due to the combined effects of both SW and NE monsoons until the Late Pleistocene. The tropical rainforest cover along Kerala coast has shrunken considerably and pieces of evidence suggest that the entire terrain west of Sahyadri (Western Ghats) was under dense forest cover during the Holocene Climatic Optimum (9.0–6.0 k yrs BP) when the region had witnessed heavy precipitation much higher than that of the present. The forest land has been converted into major wetlands and present ecology is unsuitable to support evergreen forests and it can be concluded that coastal plains and associated landforms were covered by thick tropical evergreen forests which got destroyed by flooding towards Middle Holocene. Development of a chain of wetland system all along Kerala coast, loss of sheltered habitat and mangrove cover, and loss of sensitive freshwater *Myristica* swamps are some of the significant aspects brought in while addressing the monsoon variability in southwestern India.

1. Introduction

The study of Quaternary geology has attained great significance in the recent years as the present day landscape and environment are the products of the geological processes caused by climatic variations, sea level changes and tectonics. The changes in sea level and climate have caused drastic alterations of the fluvial regime, landforms and ecology to a considerable extent and these changes are more pronounced in the coastal region than the interior parts of the India Peninsula. Superimposed on the natural changes on account of climatic and sea level changes are the drastic alterations to landscape caused by man to suit the requirements of agriculture and development. Inadequate sedimentary archives and also high resolution dating methods have been found to be major constraints while addressing aspects related to Quaternary study in India prior to the 1980s. Hardly there has been any data of Pleistocene environment and palaeoclimate signatures from the terrestrial archives of Peninsular India in general and south-western India in particular but for a few scattered reports available until 2000. Since then efforts have been made to address the Quaternary geology and the geological processes that have shaped the present day landscape and vegetation cover of the region and in this endeavor it has been possible to distinguish definite Pleistocene and Holocene sequences overlying the Tertiary (Neogene) laterites. The southwestern part of Peninsular India has a much better developed Quaternary sequence in the Kerala-Konkan Basin (KKB) than the rest of the west coast of India due to offshore link of the

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sedimentary province. In fact, the contributions of the groundwater exploration and exploitation by the Central Ground Water Board (CGWB) and the seismic surveys and drilling of deep wells in the offshore area by the ONGC have helped understanding the stratigraphy and facies of the coastal sedimentary basin of Kerala to some extent. Nair et al. (2006) have recognized a major sedimentary sequence, viz., South Kerala Sedimentary Basin (SKSB), which is the landward extension of the offshore KKB and it has a sediment fill of ~700 m of which 80–100 m constitute the Quaternary sediments.

The structural frame work and stratigraphic details of the SKSB (Nair et al., 2007) have laid foundation towards addressing the Quaternary geological processes and palaeoclimate study. Considering the conventional limit of radiocarbon date of 40,000 yrs BP most of the sediments have been dated >40,000 yrs and they were mainly assigned to Late Pleistocene and quite a few to Neogene. Accordingly, there used to be an overlap between the reworked Neogene and the Quaternary sediments of southwestern India while addressing the palaeoenvironment and palaeoclimate aspects of this part of Peninsular India. There are case studies of the so called Late Pleistocene deposits reported from Kerala Basin which are, probably the reworked Neogene sediments of Warkalli Formation (Narayana et al., 2002; Narayana, 2007; Farooqui et al., 2010) and contemporaneous of it reported from Ratnagiri in Konkan (Phadtare and Kulkarni, 1984). Despite the reworked sediments being the part of the Late Quaternary sedimentary archives, the taphonomical aspects have so far not been addressed and as such this issue is being dealt separately. However, the improved calibration methods available in recent years are found to be useful to go to the threshold level of the conventional ^{14}C dating and as such Late Pleistocene sequences can be easily distinguished in the Late Quaternary sedimentary archives. Further, retrieval of subsurface sediment archives with the help of mechanized drilling and better calibrated radio carbon dates obtained during the last one and a half decades have improved our understanding of Late Quaternary geological history of southwestern India to a reasonable extent.

The southernmost sedimentary basin, the Kerala-Konkan Basin (KKB) along the west coast of India, south of Saurashtra is the only basin that has any major representation on land and the rest of the west coast basins south of Mumbai, the post-Proterozoic sediments on land are insignificant. Only a small portion of the KKB, extending from Kollam to Kodungallur with a maximum width of 30.0 km provided a major depocenter of sediments comprising about 80.0 m thick Quaternaries and has been referred to SKSB. The SKSB extending along the Kerala coast between 8°45′ and 10°15′ N latitudes is the landward extension of the offshore KKB. Along with this and the data retrieved from over 120 bore holes drilled for ground water and geotechnical investigations, as well as stratigraphic studies (Najeeb, 1999) enable to understand the Quaternary geologic history. The northern extension of southwestern India has about 530 km long Konkan coast (15°45′–20°00′ N latitude) and the Quaternary sediments here are very much limited and are known to be developed in response to the transgression and regression of sea level during the Holocene (Sukhtankar, 1989; Deshpande, 1998). However, Kumaran et al. (2013) provided information on continental deposits of Late Pleistocene for the first time from the lacustrine archives of Kangvai in Konkan. Contributions to knowledge of Late Quaternary climate and vegetation dynamics have been steady ever since efforts were initiated from southwestern India and other parts of Peninsular India in the early 2000s (Nair et al., 2006; Kumaran et al., 2013, 2014). The accrued data so far retrieved from the Late Pleistocene and Holocene sequences in south-western India have been analysed while addressing the monsoon variability and its impact on landforms and vegetation.

The monsoon system of both Southwest (SW) and Northeast (NE) had a considerable impact on landforms and vegetation cover in southwestern India since Last Glacial Maximum (LGM). Further, sea level oscillations have brought in substantial modification of the landscape, ecology and forest cover since Late Pleistocene. The signatures of monsoon shift, landscape and vegetation dynamics have been decoded and the changing scenarios of the hydrodynamic regimes and their role in evolution and sustenance of wetlands have been well recorded in Kerala-Konkan Basin (Kumaran et al., 2005, 2013, 2014, 2016; Nair et al., 2006, 2010; Padmalal et al., 2014; Srivastava et al., 2016). A glimpse of these major observations and their appraisal has been highlighted in the present communication in a regional perspective. The present contribution is an overview and state of art of palaeoclimate study focusing monsoon shifts in the form of rainfall, landscape and vegetation dynamics in southwestern India. While dealing with the theme of monsoon variability on climate, landscape and vegetation dynamics in southwestern part of India the geological back ground of the two basins and basic stratigraphic aspects have been dealt. The study sites and case studies pertaining to palaeoclimate aspects dealt here are given in the figures at relevant places.

2. Geological setting and Quaternary sediments in SW India

The Quaternary sediments in southwestern India occur as isolated patches all along the coast and are hardly exposed in the inland and highland regions except in central part of Kerala where a sequence of ~80.0 m occurs in the form of landward extension of the offshore KKB (Nair et al., 2006). The data on Quaternary deposits are essentially based on subsurface sediment archives retrieved from boreholes as they remain submerged in the wetlands and coastal lowlands but within an elevation less than 10.0 m above the Mean Sea Level (MSL). The selected borehole locations in SKSB from where sediment cores obtained are shown in Fig. 1. The southwestern coast of India is endowed with about 700 m thick Cenozoic sediments preserved in SKSB located in between 8°45′ and 10°15′ N latitudes. SKSB is a landward extension of the southwest offshore sedimentary basins of India. This is the only area south of Narmada Rift along west coast of India, where the land area has subsided and the Neogene and Quaternary sediments have accumulated. The top ~80.0 m is made up of Quaternary sediments and the remaining constitutes the Neogene sediments of Lower Miocene age. Laterite deposits separate the Late Quaternary sediments from the rest of the sediments and hence forms a reliable datum to fix the lower boundary of the Late Quaternary sediments. More than half the thickness of Quaternary sediments at the deeper part of the basin is beyond the range of carbon datable limit and the sediments from this interval at a few locations have been dated >40,000 yrs BP based on conventional threshold limit of ^{14}C dates available prior to 2000. These sediments are found to be unconformably overlying the Neogene Laterites towards coastline, the Pre-Cambrian crystalline rocks towards inland region and/or both the lithologies at a few locations in the sub coastal lands. The datable sediments are represented essentially by Late Pleistocene and Holocene sediments (<40,000–2580 ± 100 k yrs BP) and have been assigned to “Vembanad Formation” by Raha et al. (1983).

The Deccan Traps constitute the most conspicuous geological formation and in fact, it covers the whole of Konkan with the exception of the southern part of Ratnagiri district. Barring a few reported occurrences of “Intertrappean beds” of varying thickness in and around Mumbai and the laterite associated carbonaceous deposits in the form of lignites in Ratnagiri district no other major sedimentary archives contributed significantly to the understanding of coastal and environmental dynamics of Konkan in the past until 1980 (Sharma, 1989). However, Guzder (1980) contributed