Table 1. Average percentage nutrient contents (± SE) of various plant components of the grazing lands (July 1993–June 1994) expressed on oven dry weight basis. Values in parentheses are nutrient contents of the unburned grazing land

Plant component	N	P	K	Ca	Mg
Live shoot	1.05 ± 0.037 (1.41 ± 0.041)	0.07 ± 0.005 (0.10 ± 0.006)	0.54 ± 0.024 (0.45 ± 0.027)	0.45 ± 0.023 (0.48 ± 0.027)	0.10 ± 0.008 (0.14 ± 0.007)
Dead shoot	0.47 ± 0.010 (0.56 ± 0.034)	0.06 ± 0.005 (0.06 ± 0.007)	0.38 ± 0.016 (0.34 ± 0.017)	0.36 ± 0.010 (0.36 ± 0.010)	0.09 ± 0.005 (0.09 ± 0.003)
Litter	0.31 ± 0.048 (0.46 ± 0.017)	0.03 ± 0.005 (0.06 ± 0.004)	0.26 ± 0.039 (0.23 ± 0.015)	0.20 ± 0.030 (0.33 ± 0.008)	0.05 ± 0.005 (0.09 ± 0.005)
Below-ground	0.58 ± 0.052 (0.61 ± 0.047)	0.06 ± 0.004 (0.07 ± 0.004)	0.39 ± 0.021 (0.37 ± 0.016)	0.34 ± 0.019 (0.42 ± 0.020)	0.08 ± 0.010 (0.08 ± 0.005)

and arrow model. The uptake of nutrients (except K) was significantly higher ($P < 0.05$) in the unburned site than in the burned site. From the total uptake a larger amount of nutrients was transferred to above-ground parts than below-ground parts. Greater accumulation of nutrients in the live shoots is a characteristic feature of tropical grasslands[10,22]. The amount of nutrients absorbed from the soil and then released through litter and roots in these grazing lands was comparatively higher than in temperate grasslands[23]. In both the sites, the amount of nutrients returned to the soil through below-ground parts was more than through above-ground litter decomposition during the study period. Nutrient output to input ratios give an indication of nutrient use efficiency. In this study, burning stimulates nutrient use efficiency. It is concluded that burning of vegetation accelerates nutrient cycling through rapid release.

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ACKNOWLEDGEMENT. We thank the Ministry of Non-Conventional Energy Sources, Government of India for financial assistance.

Received 25 February 2002; revised accepted 9 May 2002

Late Quaternary peat deposits from Vembanad Lake (lagoon), Kerala, SW coast of India

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Vembanad lagoon is the largest backwater system on the Kerala coast and acts as a major depocentre for Quaternary deposits. Peat deposits have been identified at different depths in the boreholes between sandy clay and clayey sand sedimentary facies. These peat deposits gave a radiocarbon age of 40,000 yrs BP. Pollen analysis of peat revealed the existence of mangrove vegetation and evergreen forest, suggesting humid climate during that time. Presence of desiccated clays beneath the peat deposits suggests arid climate prior to the humid climate during 40,000 yrs BP.

THERE is an extensive estuarine system of backwaters on the southwest (Kerala) coast of India, of which the Vembanad lake/lagoon is the largest, extending 80 km in

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*For correspondence. (e-mail: acnarayana@cusat.ac.in) a NW–SE direction from Munambam in the north to Alleppey in the south. The width of the lagoon varies from 500 m to 4 km and the depth from < 1 m to 12 m. The Periyar river discharges into the lagoon in the north and the Muvattupuzha river in the central part. The rivers Meenachil, Manimala, Achanakovil and Pamba discharge into the southern part of the lagoon. The Vembanad lake/lagoon is characterized by its long axis running parallel to the coast and is separated from the sea by barrier spits interrupted by tidal passes. The coastal landforms of this region consist of Quaternary sediments, overlying a Precambrian terrain consisting of granulites, gneisses and greenstones (predominantly charnockites, gneisses, hornblende–biotite schists, khondalites and intrusive rocks). The surface sediments of the Vembanad lake are mostly a mixture of clay, silt and sand. The northern part of the lake is covered with clayey sand and silty sand, the central part with clayey sand and sandy silt, and the southern part is covered with silty sand and clayey silt[1,2].

It is proposed by the Goshree Islands Development Authority (GIDA) to link the islands that exist across the backwater system with the mainland through flyover bridges. Boreholes were drilled across the backwater system to test the subsoil characteristics as a part of the construction work. The samples of a borehole located between Bolgatty island and the mainland were used in the present study (Figure 1). The sediments were sieved and pipetted to analyse their granulometry[3], and the lithofacies are shown in Figure 2. The radiocarbon dates for peat samples were determined at the Birbal Sahni Institute for Palaeobotany, Lucknow, following the procedure of Rajagopalan *et al.*[4]. The statistical error on the ages is one *s* value. Pollen analysis of peat was carried out at the French Institute, Pondicherry.

The borehole data reveal several sedimentary facies identified in the following sequence (Figure 2): silty clay with shells (0–18 m), a mixture of sand–silt–clay (18–20 m), lateritic clay (20–26 m), clayey sand (26–30 m), sandy clay (at 33–37 m and with peaty intercalations at 43–45 m and 54–56 m), sand (45–48 m), peat (30–33 m, 37.5–42.5 m and at 49–54 m), hard/desiccated clay (57–66 m) and clayey sand with carbonaceous matter (66–70 m). Peat occurs in three horizons at different depths, overlain by clayey sand, sandy clay and sand (Figure 2). The top bed of peat is overlain by clayey sand and underlain by sandy clay. The middle peat bed is overlain by sandy clay and also underlain by sandy clay but with peat intercalations, whereas the bottom peat bed is overlain by sand and underlain by sandy clay with peat intercalations. The peat samples of the middle and bottom horizons gave ^{14}C ages of 43650 ± 4150 and 44310 ± 5210 yrs BP respectively. The age of the peat deposits can be taken as minimum of 40,000 yrs BP (because of saturation). The peat of the top horizon could not be dated as the material available was limited. Pollen analysis of peat samples from the middle and bottom beds showed that it contains assemblages of around 40% pollen belonging to the family Rhizophoraceae in the middle bed and over 60% pollen corresponding to the forest trees such as *Mallotus* in the bottom bed. The pollen assemblages therefore, help to reconstruct in the past a mangrove corresponding to the middle peat bed and evergreen to semi-evergreen type of forest corresponding to the bottom peat bed.

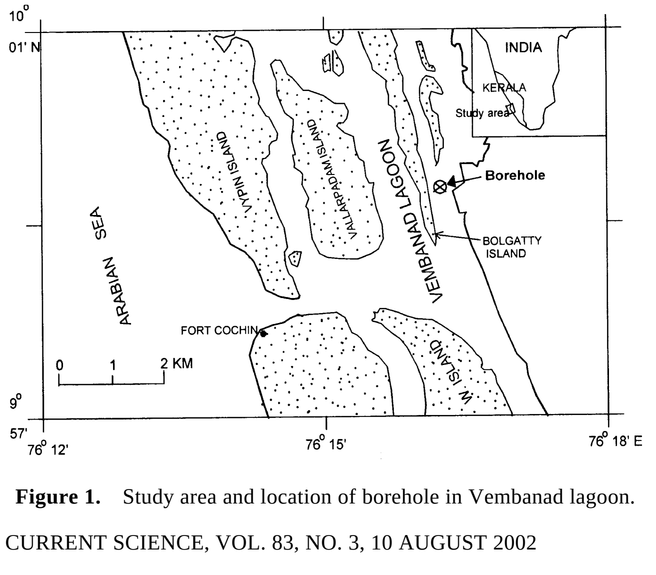

Figure 1. Study area and location of borehole in Vembanad lagoon.

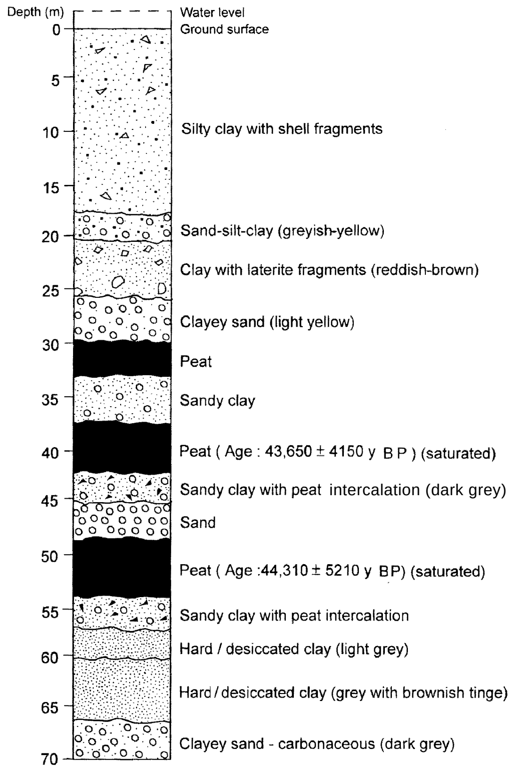

Figure 2. Lithofacies in vertical cross-section of a borehole and radiocarbon dates of peat samples.

The occurrence of peat deposits from various onshore locations along the Kerala coast has been reported earlier[5–7]. The ^{14}C ages of peat deposits recovered at Tellicherry (north Kerala) and Tannisseri (central Kerala) were reported as 7230 ± 120 and 6420 ± 120 yrs BP respectively[7]. The peat beds which form Quaternary units in Kerala indicate their formation from submerged coastal forests, i.e. initial subsidence of the coast and consequent transgression of the sea[6,7]. It is suggested that flooding related to transgression occurred during 8000–6000 yrs BP and destroyed the mangrove vegetation giving rise to peaty soil. Most of these peat deposits were of 1 m thickness and occurred at a depth of 2 m from the surface, except a tree root that was recovered at 16.75 m depth in Wellingdon island, which gave an age of 8080 yrs BP, as reported by Agrawal *et al.*[5]. However, as the Wellingdon island is an artificially developed landform consequent to the construction of the Cochin harbour, the source and depth of occurrence of root material and its age data have constraints for the interpretation of either sea-level changes or palaeoenvironmental aspects. A coral recovered at a depth of 8 m from an onshore site near Vazhakala, 6 km east of Ernakulam, gave a ^{14}C age of ~ 40,000 yrs BP[8]. Radiocarbon ages of onshore deposits of earlier studies indicate that the sea-level was higher than the present level and during the period of higher sea-level, the coastal mangrove vegetation was inundated to give rise to onshore peat deposits.

A question to be addressed is whether the present deposition of the earlier shallow peat beds at a maximum depth of 54 m is due to the sea-level changes or tectonic faulting. On the basis of the ^{14}C age of onshore shell deposits occurring in the coastal plain of Baindur, Karnataka, Caratini and Rajagopalan[9] suggested that the sea-level was about 3 ± 1 m below the present level at 6400 yrs BP. The occurrence of peat deposits along the Goa coast has led Mascarenhas and Chauhan[10] to conclude that the sea-level was 1 to 3 m lower during the mid-Holocene and the climatic conditions were wet and humid. The sea-level changes along the west coast of India may be compared with the sea-level curve described by Fairbanks[11]. According to this sea-level curve, exceedingly rapid sea-level rise of 24 m was observed during 12,000 yrs BP. The rate of sea-level rise was at a minimum at 11,000 yrs BP and again at 9500 yrs BP it was marked by increasing rates of sea-level change. Hashimi *et al.*[12] suggested that the sea-level rose along the west coast at a rate of ~ 10 m/1000 yrs around 12,500 yrs followed by a standstill for about 2500 yrs. From 10,000 to 7000 yrs, the sea-level rose at a very high rate (~ 20 m/1000 yrs) along the west coast. Further, the sea-level was slightly higher at 3000 yrs than at present.

The occurrence of peat at different depths in the present study area and its radiocarbon age indicate that the central Kerala coast was covered with intensive mangrove and other forest vegetation even at 40,000 yrs BP, and it was inundated during higher sea-level stands. The climate factor accounts for the development of mangrove vegetation, as the abundant rainfall increases the continental drainage. The mangrove extension expresses an increase of monsoonal rainfall, as early as ~ 16,500 yrs BP[13]. The southwest flux was first reinforced on the SE Arabian Sea, where the southern tip of India remained more humid at 10° N (ref. 13). Mangrove vegetation can only grow on banks and islands[14] and along waterways parallel to the coast which are in constant contact with the sea by small gaps in the sandy bars[15]. Hence, it can be suggested that coastal geomorphic features that supported mangrove vegetation might have existed along central Kerala coast at 40,000 yrs BP. But the subsequent tectonic subsidence, or alternately, rise in sea-level or both, might have resulted in the occurrence of peat deposits at such depths. The studies of Kumar[16] and Kailasam[17] suggest the formation of trenches, grabens and normal faults, and the continuation of vertical epeirogenic movements on the western continental margin of India through the Quarternary to the Present time. Their observations strongly support the tectonic activity and possible submergence of peat deposits in this region.

The occurrence of hard/desiccated clay below peat deposits at 57–67 m depth with a thickness of about 10 m, underlain by clayey sand, is an interesting phenomenon. The top 3 m of desiccated clay is light grey in colour and the bottom 7 m is grey with a brownish tinge. Notably, the bedrock is not encountered even at 70 m depth, but only compact clayey sand is recorded. Hard/stiff mud deposits in similar Late Pleistocene environments have also been reported from elsewhere[18,19]. In marked contrast to the Pleistocene, the Holocene mud is very soft to moderately compact, grey to dark olive grey and black, and has high organic matter content. Yim and Tovey[19] state that these desiccated clays were formed by the sub-aerial exposure of marine deposits during oxygen-isotope stages 7 (M3), 9 (M4) and 11 (M5). The existence of desiccated clays can be directly linked to acid-sulphate soil development caused by the sub-aerial exposure of marine deposits, and they are valuable markers for environmental changes and stratigraphic correlation. These clays provide information about land surfaces during low sea-level stands prior to burial by a younger marine transgression. Terrestrial oxidizing conditions are responsible for the formation of the desiccated crusts[20].

An arid climate existed during 22,000–18,000 yrs BP in the Kerala region due to a weak southwest airflow, a great reduction of summer monsoonal rainfall, and reduced run-off of the Western Ghats rivers[13]. Such arid conditions may have existed prior to the formation of peat deposits, i.e. prior to 40,000 yrs BP, which led to the deposition of desiccated clays now seen at 57–67 m depth.

The present study reveals the existence of mangrove vegetation at 40,000 yrs BP that led to the formation of peat deposits in the central Kerala coastal region. Whether the subsidence of these beds to depths of 50 m was due to progressive transgression of the sea and sea-level changes, and how far such subsidence is aided by tectonics need focused attention. Further work is in progress in this direction.

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ACKNOWLEDGEMENTS. We thank Dr G. Chandramohan (GIDA) and J. Chakravarti of G.S. Jain & Associates, for their kind permission and help to collect the samples. We also thank Prof. B. L. K. Somayajulu for his help and valuable suggestions. Prof. S. K. Tandon and the anonymous referee are sincerely thanked for critically reviewing the manuscript. Prof. K. S. Valdiya, Dr D. R. Bridgland and Sri T. M. Mahadevan are thanked for going through the manuscript and for their suggestions.

Received 5 January 2002; revised accepted 14 May 2002

Superoxide dismutase activity in haemocytes and haemolymph of *Bombyx mori* following bacterial infection

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The haemocytes and haemolymph of the silkworm *Bombyx mori* L. were analysed for their superoxide dismutase (SOD) activity following *Bacillus subtilis* inoculation using a photochemical assay system consisting of methionine, riboflavin, and p-nitro blue tetrazolium. The SOD assay had a maximum activity at pH 7.8 with light exposure optima of 15 min. The optimum concentration of the crude enzyme source for the assay was 80–90 μg equivalent protein of haemocytes and 248–284 μg protein of plasma. The enzyme activity was ca. 5-fold higher in the haemocytes than the plasma, and it maintained a plateau throughout the test period (10 min to 9 h) in both fractions in healthy condition. However, upon infection after an initial burst (10 min), the SOD activity sharply declined at 30 min and then significantly enhanced in larval haemolymph from 1 h post-inoculation. In haemocytes, on the other hand, infection caused a depression in SOD activity except during 1–3 h, when a transient enhancement was noticed. This implies that modulation of superoxide anion generation is an early response as part of the defensive process against pathogen invasion. Also, the haemolymph and haemocytes trigger such response differentially by which this deleterious flux of superoxide is scavenged in its turn by the SOD enzyme.

MOLECULAR oxygen is an essential element of life, yet as a result of incomplete reduction of oxygen to water, reactive oxygen species (ROS) are generated in all aerobes. Most ROS are generated as superoxide anions (O_2^-), and are rapidly dismutated either non-enzymatically or enzymatically by the action of superoxide dismutase (SOD) to hydrogen peroxide and oxygen[1]. Pathogen-derived generation of O_2^- by NADPH oxidase in mammalian neutrophils is a common feature[2]. In fact, the bactericidal effect of polymorphonuclear leucocytes depends on their superoxide generative capacity[3,4], and biosynthesis of SOD is mainly controlled by increased intracellular

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