μg/ml). The gels were run at 20 V for 18 h in TLE. The DNA fragment bands were photographed under a UV transillumination lamp (302 nm) through a yellow filter using polaroid film.

The *Bam*H1 and *Pst*1 fingerprints of the four EHV-1 isolates are shown in Figure 1. It can be seen from the restriction cleavage patterns that the 'UPPAL', 14208A, Sheva and 4056A isolates exhibited 13, 13, 13 and 15 cleavage sites, respectively with *Bam*H1. However, differences were noticed at three cleavage sites. While all cleavage sites were possessed by 4056A, the isolates 14208A and Sheva lacked bands 3 bis and 12 bis. The isolate 'UPPAL' lacked band 7 and 12 bis but possessed band 3 bis.

With *Pst*1, the only difference observed among the four viruses was for band 3 which is present in 'UPPAL' and 4056A and not in 14208A and Sheva.

The genome of isolate 'UPPAL' possesses about 121306 base pairs in the 14 different fragments of various sizes obtained with *Bam*H1. Amongst the fragments the largest and smallest have about 20893 and 2570 base pairs respectively.

A comparison of *Bam*H1 and *Pst*1 restriction endonuclease DNA fingerprints of the 'UPPAL' isolate of EHV-1 with two known abortigenic strains, i.e. 4056A and 14208A indicated that it has the same pattern as abortigenic strains. Among the four viruses studied, the two isolates 14208A and Sheva are comparable whereas 'UPPAL' and 4056A were close but not identical. It is interesting to note that the 'UPPAL' virus was isolated from respiratory tract of horses suffering with an acute respiratory disease at a race tract in concurrence with equine infectious anaemia (EIA). Since there were no breeding mares, behaviour of the virus in pregnant mares could not be known. The DNA fingerprints, however, establishes the virus to be abortigenic (EHV-1). EHV-1, though mainly responsible for abortion, has also been occasionally found to be involved in respiratory illness[1,2,7]. The *Bam*H1 fingerprints obtained in the present study for 'UPPAL' and other abortigenic viruses are in close agreement with those reported for foetal strains[5]. Minor differences observed in the *Bam*H1 and *Pst*1 fingerprints of the four viruses studied can be expected being of different epizootiological origin[9]. The Sheva and 4056A isolates appear to closely resemble with the IP prototype[7] of EHV-1 subtype-1 (now designated as EHV-1).

The EHV-1 viruses so far reported from India have been from abortion, still births, neonatal deaths and paralytic syndromes. Some of these have been identified serologically as subtype-1. The viruses isolate 'UPPAL' recovered from respiratory disease also fell in this category. The severe respiratory manifestation observed in the outbreak could be due to the concurrent EIA outbreak in these horses. Although in recent years some evidence has been gathered in serological studies for the possible presence of EHV-1 subtype-2 (EHV-4) in Indian horses (authors' unpublished data), this virus has not been isolated so far.

1. Studdert, M. J., *Arch. Virol.*, 1983, 77, 249–258.
2. Studdert, M. J., Simpson, J. and Roziman, B., *Science*, 1981, **214**, 562–566.
3. Bryans, J. T., *Proc. Ann. Meet. Am. Assoc. Equine Pract.*, 1968, **14**, 119–125.
4. Greenwood, R. E. S. and Simson, A. R. B., *Equine Vet. J.*, 1980, **12**, 113–117.
5. Sabine, M., Robertson, G. and Whalley, J., *Aust. Vet. J.*, 1981, **51**, 148–149.
6. Turtinen, L., Allen, G. and Darlington, R., *Am. J. Vet. Res.*, 1981, **42**, 2099–2104.
7. Allen, G. P., Yeargan, M. R., Turtinen, L. W., Bryans, J. T., and McCollum, W. H., *Am. J. Vet. Res.*, 1983, **44**, 263–271.
8. Uppal, P. K., Yadav, M. P. and Singh, B. K., *Virus Inf Exch. Newsl.*, 1990, 7, 16.
9. Chowdhury, S. I., Kubin, G. and Ludwig, H., *Arch. Virol.*, 1986, **90**, 273–288.

Received 22 August 1992; revised accepted 6 January 1993

On the possibility of allochtonous peat on the inner shelf off Karwar

A. Mascarenhas, A. L. Paropkari and C. Prakash Babu
National Institute of Oceanography, Dona Paula 403 004, India

Peat deposits occupying an area of more than 139 km^2, intercalated in sediments from the inner shelf of Karwar–Kumta, have been identified. Such organic-rich nearshore facies are rare and hence their presence is intriguing. Considering the fact that peat directly reflects massive plant production, and since it is well known that mangroves are prolific producers of peat, it would imply that vegetation once flourished as far as 11 to 18 km from the present shoreline. Since mangrove populations are capable of advancing seaward or retreating landward, they play a dual role in changing the tropical coastlines. But considering the geomorphic features of the coastal and offshore zones of Karwar–Kumta (open ocean, wave-dominated high energy environment, lack of favourable substrates for mangrove colonization), it is obvious that mangroves could not have prograded 18 km seaward as they essentially require a low energy and sheltered habitat. We therefore propose that these peat deposits were not laid down *in situ*, but judging from their physical, mineralogical and chemical characteristics, these intercalated peat layers on the inner shelf appear to have undergone transport and hence are of allochtonous origin.

THE accumulation and preservation of recent coastal deposits are governed by the rate of sea level rise, sediment influx, incident wave energy and antecedent topography[1]. Coastal Holocene sequences, from tropical regions in particular, are marked by the presence of organic-rich deposits normally termed as peat. At many low-lying onshore locations, adjacent to the present shorelines from Goa to Cape Comorin, peat deposits have been identified[2–4]. It would thus appear that such organic deposits which form prominent Holocene stratigraphic units are restricted to the present coastal regions alone.

Recently, a 6.7-m-long core was collected on board *ORV Sagar Kanya* of the NIO, on the inner continental shelf off Karwar at a water depth of 24 m. This core showed the presence of a well-preserved peat layer. An overlying 'mixed layer' with intervening normal marine sediments was also observed. This find, coupled with two other peat-containing cores collected in the vicinity[5], proves the fact that peat formation or deposition was an important phenomenon on the inner shelf during the Late Pleistocene/Holocene, at least in the region off Karwar–Kumta. Based on the location of these three cores, peat deposits occupy an area of over 139 km^2 off Karwar, and have been identified as far as 11 to 18 km from the nearest shore point (Figure 1).

Peat observed in our core is dark gray in colour and silty in texture. A conspicuous flaky component which resembles broken twigs is a remarkable feature of this intercalated layer. An appreciable mineral matter with occasional shell material was also observed. Chemical analyses showed that the whole sediment sample contains 3.85% organic carbon and 2.05% sulphur, whereas the twig-like constituents, black in colour, exhibit as high as 5.44% organic carbon. This organic layer contains 4.58% aluminium and 5.26% iron. Binocular microscopic observations (Gujar, pers. commun.) reveal an appreciable mineral matter which comprise pyrite grains, rounded pink garnet, sillimanite, andalusite, rounded rutile, hornblende, hypersthene, staurolite, quartz, microcline and mica. X-ray diffractometry also indicated the presence of quartz, potash feldspar (orthoclase), calcite and plagioclase as major minerals in decreasing order of abundance. The overlying 'mixed layer' shows 3.61% organic carbon, 2.35% sulphur and 5.30% aluminium.

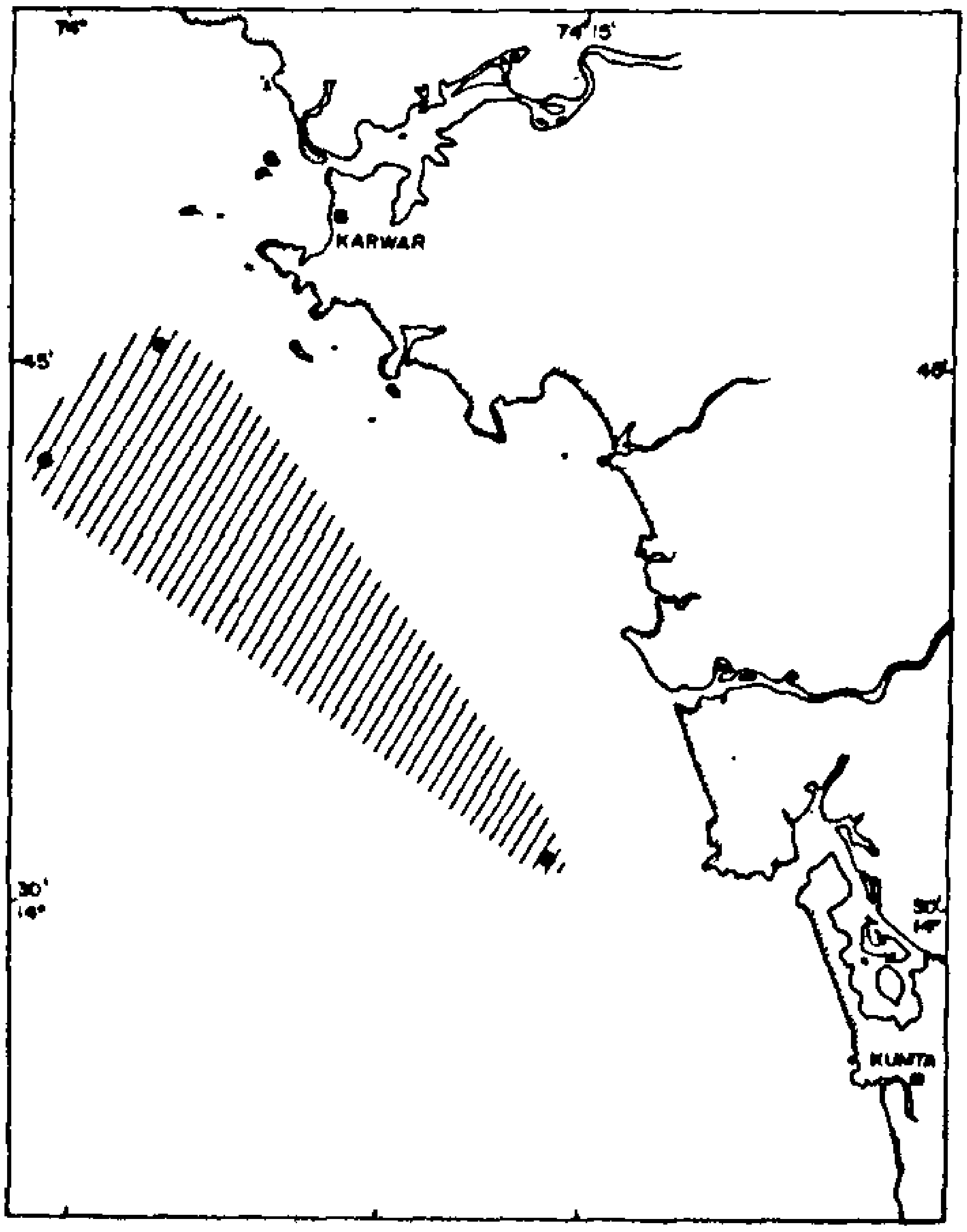

Figure 1. Inferred extension of peat deposits on the inner shelf off Karwar–Kumta. Closed circles represent location of cores.

Peats indicate a massive plant production where its preservation outpaced its destruction due to limited surface oxidation[6,7]. Since the environments of peat formation comprise enclosed basins, sheltered bays, lagoons or wet tropical plains, peats are essentially terrestrial or semi-terrestrial deposits. Therefore, the fact that intercalated peat is observed in cores up to 18 km offshore (Figure 1) and 31 m below the present sea level is somewhat intriguing and hence merits careful thought.

Since peats directly indicate intense plant productivity, it obviously means that forests grew in the immediate vicinity. It is well known that mangroves are the most remarkable trees that fringe tropical coasts. It has also been shown that tropical mangroves are the most prolific producers of peat[6–8]. The classical examples of mangrove peats are the Grand Cayman islands in the West Indies[6,7], the seaward mangrove islands in southwest Florida[8], and, to some extent, the Han river delta in southern China[9]. The occurrence of mangrove peat[4] and mangrove populations[10] in the hinterland along Karwar–Kumta is well documented; small mangrove islands are often encountered inside creeks and estuaries. It has also been concluded that along the west coast of India, mangroves reached an optimum growth around 11000 yrs BP which declined considerably by 6000 yrs BP (ref. 11). Judging from the presence of peats and the sizable area that they occupy off Karwar–Kumta, it has to be evaluated whether this region was an area once colonized by mangroves and related vegetation at a particular time during the Late Pleistocene/Early Holocene when the sea level was lower than at present.

Due to properties of adaptability, mangrove communities have shown the ability of promoting coastal progradation and have thus been viewed as 'makers of land' and also as 'trees that walk to the sea'[6]. Deltaic and estuarine areas are particularly susceptible to such rapid adjustments. Since topography controls their distribution, mangroves are opportunistic in colonizing the changing landform habitat. The geological role of mangroves from south west Florida had been recognized by Davis[12] who proposed that mangroves colonize marine shoals. The most recent examples of progradation are the Grand Cayman islands[7], and the landward islands in south-west Florida colonized by mangroves during the decelerating sea level since the last 3000 years[8].

However, simultaneous studies have also revealed that the role of mangroves as coastline progaders has been exaggerated. In tropical regions, stratigraphic observations have revealed that the development of mangrove swamps has been primarily controlled by the relationship between land and sea, the existing topography of the surface and also the prevailing wave and current energy conditions. The extension of mangroves has mostly been in a landward direction into the previously terrestrial environments[7]. For example, the Brazilian mangroves have never altered the offshore geomorphic setting[13]. Conclusive evidence has indicated that the extension of mangroves has occurred principally by incursion of brackish waters into previously terrestrial environments[7,13] and that the progradation of mangroves has been landward and not seaward.

The development and/or migration of coastal mangrove populations thus revolves around two schools of thought. The dual role of mangrove shorelines both as transgressive units during sea-level rise and as regressive overlaps wherein marine substrates are available for mangrove progradation has thus been recognized[6-8,13,14].

In view of these facts, if the area off Karwar–Kumta is considered, the following scenario emerges:

(1) The western continental shelf presently exhibits a smooth and featureless topography[15]; however, a series of coast parallel submerged (ancient) coral reefs and broad and linear ridge-like features have been identified[16]. Pinnacles once exposed but now buried under clay are also seen. These calcareous features, which indicate still stands of the sea, are noticed off Vengurla up to 20 m below the present sea-level, and hence may also be present off Karwar. Whether mangroves can or did colonize such calcareous substrates is not known as there is no evidence whatsoever.

(2) The west coast of India is a wave-dominated high energy environment as indicated by submerged terraces of the past[17,18] and the present configuration of sandy beaches and wave cut rocky cliffs. Such an energy dominated physical set-up is highly unfavourable and works against the ecological requirements of mangrove development.

(3) Several islands are located off the west coast of India, particularly off Karwar. Although mangroves prefer such habitats, they do not proliferate on these open ocean islands, some of which are almost barren. Vegetation on these islands is restricted to higher contour levels. These islands are under continuous wave onslaught as indicated by rocky shorelines and the absence of normal insular beaches.

(4) Shallow seismic north-south profiles off Karwar show buried channels beyond 30 m present water depth and are believed to represent a Pleistocene surface[19]; but the presence of a lagoon–barrier system can neither be visualized nor ascertained. No other such published literature for this area is available. To our knowledge, there are absolutely no indications which may suggest that the area off Karwar was once a protected bay or a sheltered lagoon which might have promoted the growth of mangroves and related vegetation. It has been conclusively proved that mangroves thrive above the mean sea level in sheltered areas and inside protected estuarine bays and along river banks and waterways far into the hinterland, irrespective of salinity conditions. A low energy environment (wave height < 10 cm)[8] and abundant precipitation[11] are the main prerequisites. The presence of mangrove islands inside the Kalinadi creek can be cited as modern examples. Mangroves therefore never face an open ocean, without an intervening barrier.

(5) Peat layers reported earlier[5] date back to 9000 yrs BP. In our case, based on the sedimentation rates of a nearby core[20], the inferred event of deposition of the organic-rich layer would correspond to around 8000 yrs BP. Along the west coast of India, transgression was not a significant factor in controlling the abundance of mangroves[11]. In comparison, since the sea level transgressed rapidly on the west coast of India during early Holocene[17,18,21,22], the possibility of a seaward advance of mangroves under these adverse conditions appears improbable.

From the preceding discussion it is obvious that the offshore area of Karwar was not at all favourable for the development of vegetation during Pleistocene/Holocene; there are no evidences which might indicate a seaward progradation of the present mangrove coast line. Peat observed off Karwar, which in fact appears to be a regional feature on the inner shelf, does not therefore owe its origin to the destruction of mangrove forests[5].

The problem whether peat deposits are indeed autochtonous or allochtonous has always been a subject of speculation. This is complicated by the fact that mangrove peat deposits from low-lying areas of the west coast of India show very wide geochronological variations, ranging in age from 4540–7230 yrs BP[2-4] to 125,000 yrs BP[23]. But a peculiar aspect of these deposits is that the ages appear erratic as younger dates have been recorded below older sediments. This anomaly is attributed to physical contamination by younger roots from above[23]. In peat areas, this is a common feature but very difficult to assess, particularly where peatification of post-depositional roots has occurred[7]. It is because of such interference that dates of peat sediments cannot be regarded as true ages[6,7,23].

Due to chronological anomalies and constraints, coastal peat deposits present a somewhat confusing picture. Since older peats are also reported in nearshore areas[23], they can be mistaken with recent organic formations of Holocene age found along the Goa–Kerala coastal belt[2–4]. Thus, there are at least two generations of organic deposits which are merged and hence not easily discernible[23]. For this reason, the amount and continuity of peat originally deposited is not exactly known, more so on the inner shelf where its lateral extent is inferred to be 139 km^2.

The following arguments can be put forward to trace the origin of peat on the western inner shelf of India:

A. If a matted nature of root fibres is observed in peats, then it generally implies that peats are 'autochtonous. On the contrary, the samples that we studied are conspicuously devoid of matted structures, roots and their fragments. Hence, a sedentary origin of this layer is doubtful.

B. The intercalated peat layer contains quartz, potash feldspar, plagioclase, rutile, hypersthene, and garnet, sillimanite, andalusite, a mineral suite which unquestionably points to an igneous/metamorphic rock provenance (Gujar, pers. commun.). Rock types such as granites and gneisses can only be found at higher altitudes in the Karwar hinterland. On the contrary, *in situ* mangrove peats are normally pure organic deposits[7] from coastal anaerobic environments of lower altitudes. Thus, peat on the inner shelf, 11 km from the nearest shore point, contains rounded igneous and metamorphic minerals from the hinterland which are mixed with organic material that is typical of coastal lowlands. This fact implies that transport of all these constituents is most likely.

C. The depositional environment can be deciphered from the carbon–sulphur relationship. If two values are plotted on a C–S diagram, both points clearly fall outside the field designated for normal oxygenated siliciclastic marine sediments[24]. Peat samples correspond to the field of anoxic sediments, conditions under which pyrite forms, and result in a surplus of sulphur in the C–S diagram. Pyrite grains have indeed been identified. If the same points are plotted on a comprehensive C–S plot for marine cores[25], they remarkably occupy the area designated for turbidites/mass sedimentation. This would lead us to argue that these sediments were formed in an anoxic coastal environment and were subsequently transported onto the inner shelf.

D. In our core, overlying the intercalated peat layer, a 'mixed layer' is present. This layer is also rich in organic carbon (3.61%), sulphur (2.35%), with 5.30% aluminium. This is in fact a mixed organic-clastic sediment. This seems to indicate that reworking and redeposition of older peat material can occur and has indeed taken place in this area.

E. The chemical analyses of peat layer indicate an appreciable aluminium content of 4.58%. This element is non-reactive and exclusively of lithogenous origin. Continental additions are thus indicated.

F. Compared to the present, the early Holocene period is marked by intense precipitation over southwest India[11]. Heavy rainfall must have led to higher continental drainage and increased runoff and could have been effective in eroding onshore peat formations.

In conclusion, these peat layers do not appear to be *in situ* deposits since oceanographic conditions on the shelf did not seem to promote vegetation. On the other hand, physical, chemical and mineralogical characteristics of this layer favour transport and deposition. Hence we are inclined to believe that these organic rich sediments are allochtonous.

1. Belknap, D. F. and Kraft, J. C., *Mar. Geol.*, 1985, **63**, 235–262.
2. Kale, V. S. and Rajguru, S. N., *Curr. Sci.*, 1983, **52**, 778–779.
3. Rajendran, C. P., Rajagopalan, G. and Narayanaswamy, *J. Geol. Soc. India*, 1989, **33**, 218–225.
4. Caratini, C. and Rajgopalan, G., *Indian J. Mar. Sci.*, 1992, **21**, 149–151.
5. Nambiar, A. R., Rajagopalan, G. and Rao, B. R. G., *Curr. Sci.*, 1991, **61**, 353–354.
6. Woodroffe, C. D., *Bull. Mar. Sci.*, 1982, **32**, 381–398.
7. Woodroffe, C. D., *Mar. Geol.*, 1981, **41**, 271–294.
8. Parkinson, R. W., *J. Sedimentol. Petrol.*, *1989*, **59**, *960–972.*
9. Zong, Y., *J. Coast. Res.*, 1992, **8**, 1–28.
10. Untawale, A. G., in *Mangroves of Asia and Pacific*, 1987, pp. 51–87.
11. Van Campo, E., *Quat. Res.*, 1986, **26**, 376–388.
12. Davis, J. H., *Papers Tortugas Lab.*, 1940, **32**, 303–412.
13. Schaeffer-Novelli, Y., Molero, G. C., Adaime, R. R. and De Camargo, T. M., *Estuaries*, 1990, **13**, 204–218.
14. Wanless, H. R., in *Environments of South Florida*, (ed. Gleason, P. J.) Miami Geol. Soc. Mem., 1974, vol. 2, pp. 190–200.
15. Nair, R. R. and Hashimi, N. H., *Proc. Indian Acad. Sci.*, 1980, **89**, 299–315.
16. Vora, K. H. and Almeida, F., *Mar. Geol.*, 1990, **91**, 255–262.
17. Nair, R. R., *Proc. Indian Acad. Sci.*, 1974, **79**, 197–203.
18. Nair, R. R., *Indian J. Mar. Sci.*, 1975, **4**, 25–29.
19. Karisiddaiah, S. M., Veerayya, M., Vora, K. H. and Wagle, B. G., *Mar. Geol.*, 1993, **110**, 143–152.
20. Caratini, C., Fontugne, M., Pascal, J. P., Tissot, C. and Bentaleb, I., *Curr. Sci.*, 1991, **61**, 669–672.
21. Kale, V. S. and Rajguru, S. N., *Bull. Deccan College*, 1985, **44**, 153–167.
22. Nair, R. R. and Qasim, S. Z., *Ind. J. Mar. Sci.*, 1978, **7**, 55–58.
23. Caratini, C., Delibrias, G. and Rajagopalan, G., *Palaeobotanist*, 1990, **38**, 370–378.
24. Stein, R., *Geo-Mar. Letts.*, 1990, **10**, 37–44.
25. Rao, P. S., Mascarenhas, A., Paropkari, A. L. and Rao, C. M., *Mar. Geol.*, 1993, (communicated).

ACKNOWLEDGEMENT. We thank Mr R. R. Nair for many stimulating discussions on this topic

Received 17 September 1992; revised accepted 8 February 1993