of this layer. A similar process of cuticular development has been reported on the glandular trichomes of *Cannabis sativa*[8]. The probability of such a process taking place in a mature leaf, however, is extremely low. The presence of fungi on the leaf surface, on the other hand, indicates that the 'disturbed zone' could have been formed due to biochemical activity of the fungi.

In the leaf investigated, the surface of the leaf exposed to atmosphere shows fertile structures of Ascomycetes and hyphae of Deuteromycetes. Extant fungi are known to secrete cutin-hydrolysing enzyme(s). Cutinase – a serine hydrolase – has been purified from the extracellular fluid of fungi grown on cutin[9]. The process of fungal degradation of polyesters has been outlined in detail by Kolattukudy[2]. Though no direct evidence is available, it is assumed that one such cutin-hydrolysing enzyme released by the fungal hyphae inside the leaf tissue of *Thinnfeldia indica* leaf might have triggered the chemical degradation of the cuticular membrane. This could have changed the flat smooth topography of the inner surface of the amorphous layer to the one with indentations and formed cave-like cavities leading to the formation of the 'disturbed zone'. That no such degradation is seen on the outer surface of the amorphous layer shows that in the present case enzymatic penetration of the cuticle may not be involved. This is further confirmed by the fact that at places the fungal hyphae seem to enter the leaf through stomata[7].

1. Baker, E. A., in *The Plant Cuticle* (eds Cutler, D. F., Alvin, K. L. and Price, C. E.), Academic Press, London, 1982, pp. 139–166.
2. Kolattukudy, P. E., *Science*, 1980, **208**, 990–1000.
3. Holloway, P. J., in *The Plant Cuticle* (eds Cutler, D. F., Alvin, K. L. and Price, C. E.), Academic Press, London, 1982, pp. 1–32.
4. Archangelsky, S. and Taylor, T. N., *Am. J. Bot.*, 1986, **73**, 1577–1587.
5. Archangelsky, S., Taylor, T. N. and Kurmann, M. H., *Bot. J. Linn. Soc.*, 1986, **92**, 101–116.
6. Maheshwari, H. K. and Bajpai, U., *Palaeobotanist*, **45**, in press.
7. Bajpai, U. and Maheshwari, H. K., *Palaeobotanist*, 1988, **36**, 210–213.
8. Mahlberg, P. G. and Kim, E.-S., *Am. J. Bot.*, 1991, **78**, 1113–1122.
9. Lin, T. S. and Kolattukudy, P. E., *Biochem. Biophys. Res. Commun.*, 1976, **72**, 243.

Received 28 November 1995; accepted 9 April 1996

First report of fossil dinoflagellates from the west coast of India and some observations

Sri Ram*, T. R. Sreedhara Murthy†, Rajesh Reghunath and B. R. Raghavan

Department of Marine Geology, Mangalore University, Mangalagangothri 574 199, India

*Department of Civil Engineering, Government Engineering College, Srikaryam P.O., Trivandrum, India

Fossil dinoflagellates are reported for the first time from the west coast of India. These are recovered from two cores collected from the offshore of Mangalore. *Spiniferites pachydermus* is the dominant species in both the cores. *Spiniferites mirabilis* is abundant in the surface samples while *Operculodinium centrocarpum* is constrained to certain depths of the core only and *Lingulodinium machaerophorum* is restricted to the near shore core, *Spiniferites bentorii, S. ramosus* and *Tuberculodinium vancampoae* are restricted to offshore core.

DINOFLAGELLATES are mainly marine, unicellular biflagellate algae. They are characterized by a simple life cycle which involves a vegetative stage and an encysted stage. They are generally spherical to ellipsoidal or elongate, ranging in size from 25 to 250 μm. The variety of functions attributed to cysts include species dispersal, bloom initiation, bloom termination and survival through adverse conditions[1,2]. Fossilized dinoflagellates cysts have been used extensively in stratigraphic palynology[3] and its importance in palaeoceanography is briefed by Jain[4]. These fossils are abundant in marine clays, shales, siltstones, or mudstones. This paper forms the first published report of fossil dinoflagellates from the west coast of India.

Two cores were collected from the offshore off Mangalore, west coast of India (Figure 1). These cores were recovered in PVC pipes by gravity coring without disturbing the sequence of materials. The length of the nearshore core (CN) is 0.57 m, collected from a water depth of 11.4 m and at a distance of about 3.75 km from the coast. The length of the offshore core (CO) is 0.35 m, collected from a waterdepth of 50.9 m and at a distance of 35.50 km from the coast. Sample numbers CN1 to CN4 represent the nearshore core samples and CO1 to CO7 represent the offshore core samples.

Many methods of palynologic preparation have been published over the years[5,6]. The basic principle here is the removal of inorganics and unwanted organics from the original sample, thereby ensuring the concentration of palynomorphs. The different stages involved in the

†For correspondence

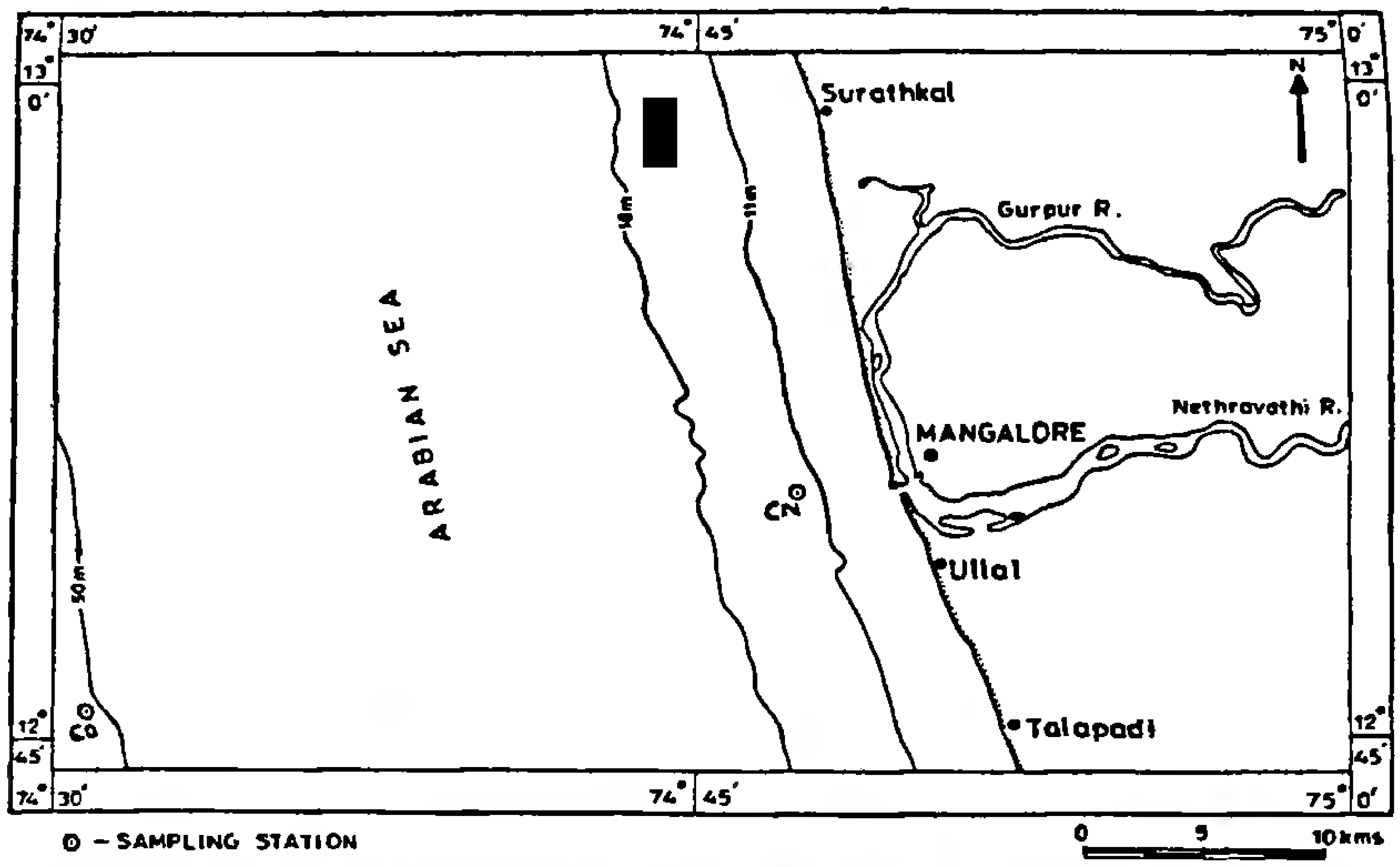

Figure 1. Study area with sample locations and bathymetry.

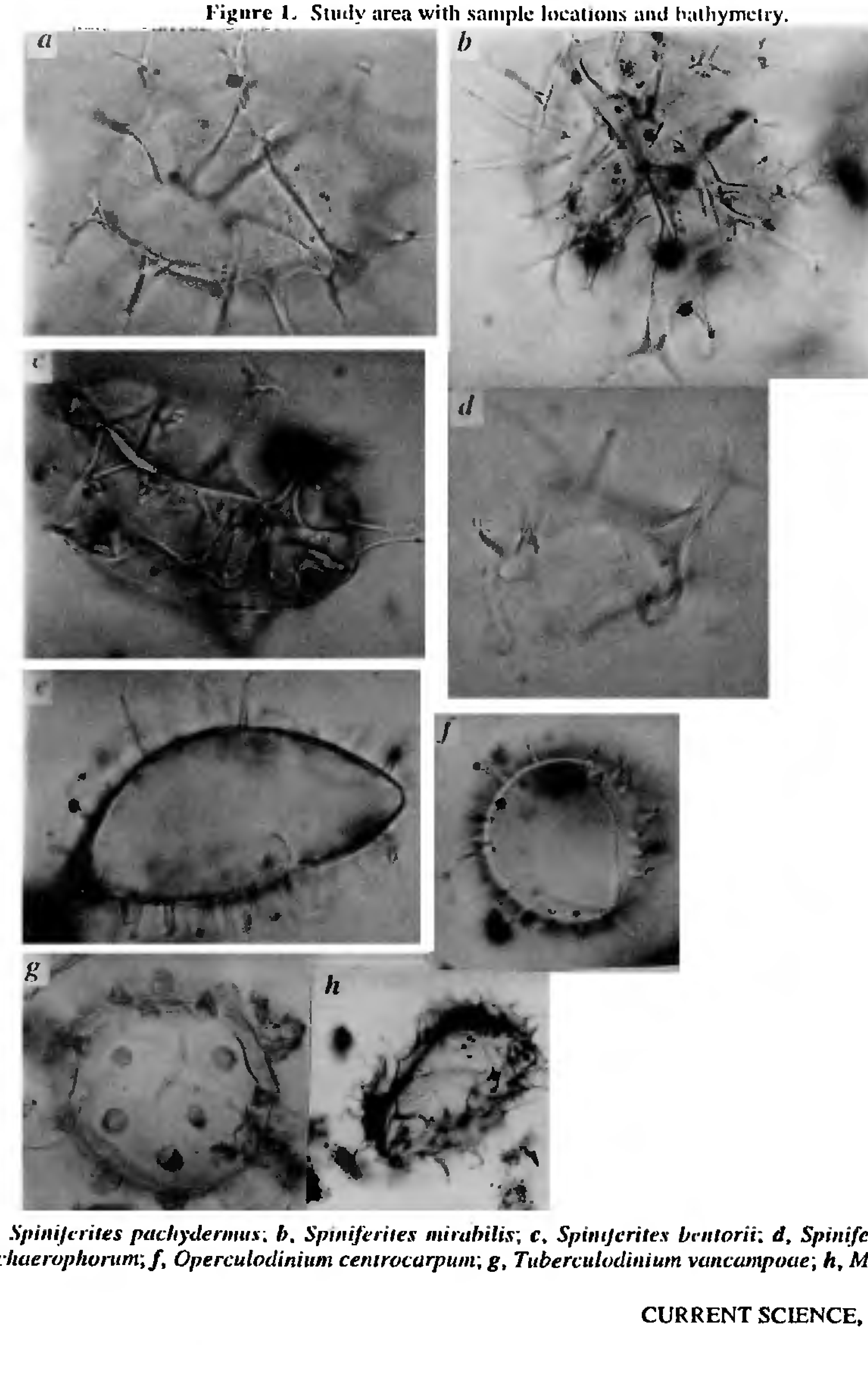

Figure 2. ***a***, *Spiniferites pachydermus*; ***b***, *Spiniferites mirabilis*; ***c***, *Spiniferites bentorii*; ***d***, *Spiniferites ramosus*; ***e***, *Lingulodinium machaerophorum*; ***f***, *Operculodinium centrocarpum*; ***g***, *Tuberculodinium vancampoae*; ***h***, *Multispinula* species.

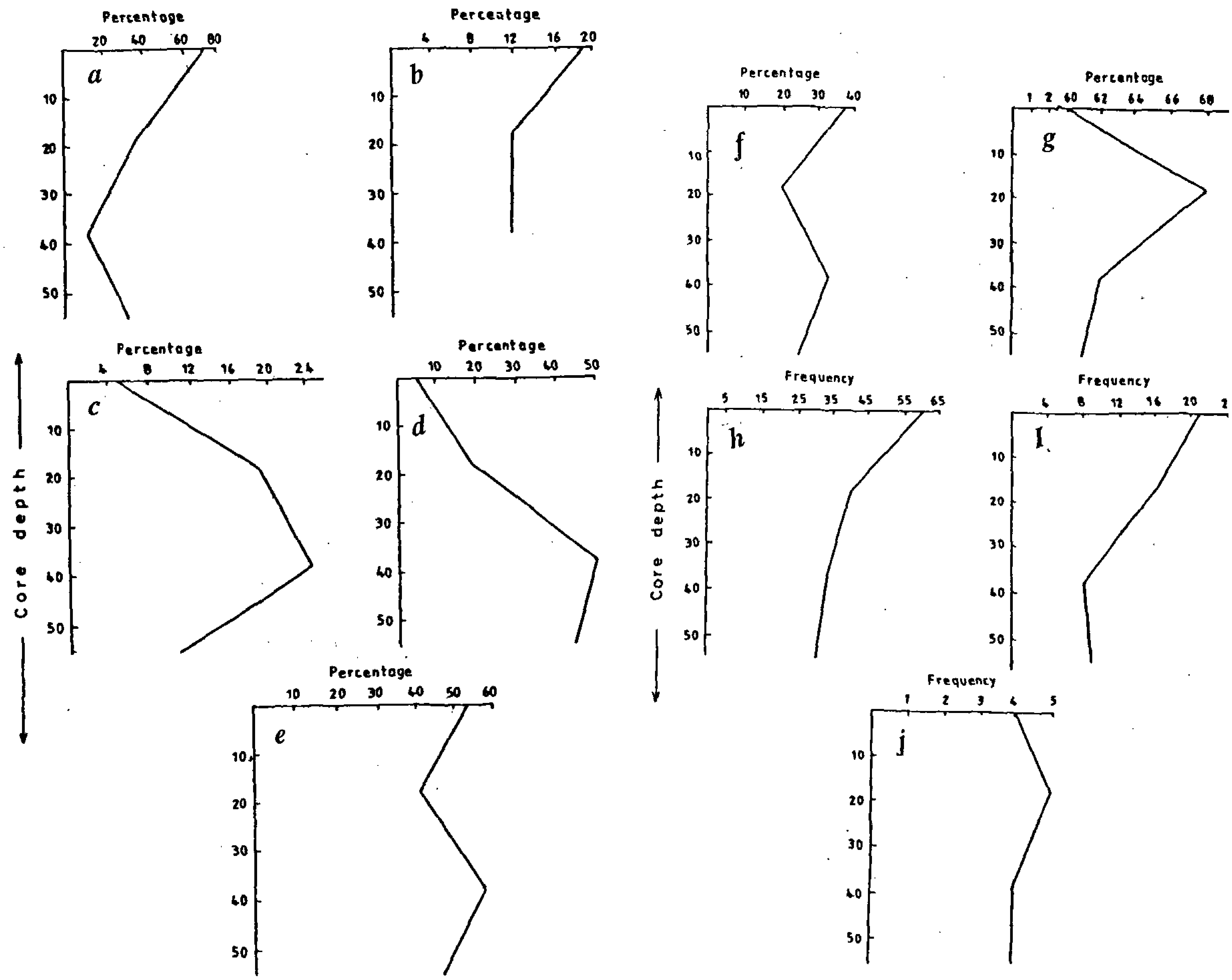

Figure 3 *a–j*. Down core variations in the near shore core. ***a***, *Spiniferites pachydermus*; ***b***, *Spiniferites mirabilis*; ***c***, *Lingulodinium machaerophorum*; ***d***, *Multispinula* species; ***e***, Copepodes/copepodes+dinoflagellate percentage; ***f***, Forminifera/foraminifera+dinoflagellate percentage; ***g***, Marine/marine+continental palynomorphs percentage; ***h***, Total number of palynomorphs per sample; ***i***, Total number of dinoflagellates per sample; ***j***, Total number of dinoflagellates species per sample.

Table 1. Relative abundance chart

	CN1	CN2	CN3	CN4	CO1	CO3	CO5	CO7
Spiniferites pachydermus	71	38	13	34	80	84	82	80
Spiniferites mirabilis	19	12	12	–	14	4	9	11
Spiniferites bentorii	–	–	–	–	–	4	3	2
Spiniferites ramosus	–	–	–	–	–	2	2	4
Lingulodinium machaeroporum	5	19	25	11	–	–	–	–
Operculodinium centrocarpum	–	12	–	11	–	1	–	–
Tuberculodinium vancampoae	–	–	–	–	1	–	–	–
Multispinula species	5	19	50	44	5	5	4	3

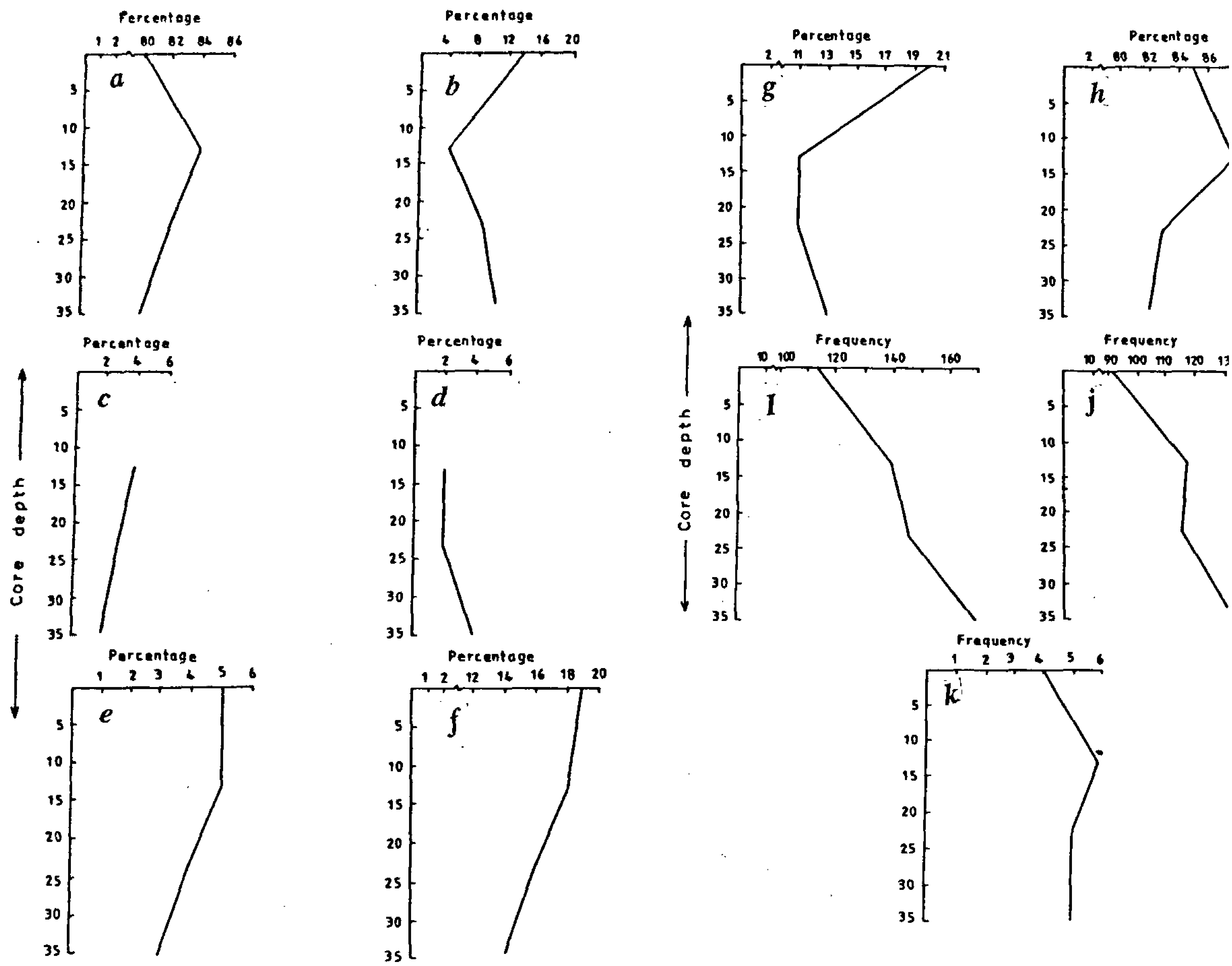

Figure 4 *a–k*. Down core variations in the off shore core. ***a***, *Spiniferites pachydermus*; ***b***, *Spiniferites mirabilis*; ***c***, *Spiniferites bentor* ***d***, *Spiniferites ramosus*; ***e***, *Multispinula* species; ***f***, Copepodes/copepodes+dinoflagellates percentage; ***g***, Foraminifera/foraminifer dinoflagellates percentage; ***h***, Marine/marine+continental palynomorphs percentage; ***i***, Total number of palynomorphs per sample; ***j***, Tot number of dinoflagellates per sample; ***k***, Total number of dinoflagellates species per sample.

Table 2. Distribution of other parameters

	CN1	CN2	CN3	CN4	CO1	CO3	CO5	CO7
Total number of dinoflagellates per sample	21	16	8	9	91	117	115	133
Total number of dinoflagellate species per sample	4	5	4	4	4	6	5	6
Copepodes/copepodes+dinoflagellate percentage	54	41	58	47	19	18	16	14
Foram/foram+dinoflagellates percentage	38	20	33	25	20	11	11	13
Marine/marine+continental palynomorphs percentage	60	68	62	61	85	88	83	82
Total number of palynomorphs per sample	61	40	33	30	114	139	145	169
Mean grain size in phi	7.20	8.09	6.91	6.57	3.13	3.41	9.24	8.82
Sand percentage	8.48	4.6	6.05	21	59.75	59.89	7.6	10.42
Silt percentage	56.04	50.26	63.91	51.35	19.17	20.49	28.63	31.83
Clay percentage	33.94	43.49	29.94	25.49	11.69	13.14	63.11	57.59

present work are demineralization (removal of carbonates and silicates), ultrasonic sieving[7] and preparation of slides.

Eight species of dinoflagellates which fall in 5 genera are recorded from the sediments of these two cores. All the species belong to Pyrrhophyta division, Donophyceae class and Peridiniales order. Table 1 provides the relative abundance chart.

Among the dinoflagellates, *Spiniferites pachydermus* (Figure 2 *a*) is the dominant species in both the cores. In the nearshore core it varies from 13 to 71% (Figure 3 *a*) and in the offshore core it varies from 80 to 84% (Figure 4 *a*). Single species dominance in a fossil dinoflagellate assemblage indicates low salinity[4] and the dominance of *Spiniferites pachydermus* is very clear in the offshore core. *Spiniferites mirabilis* (Figure 2 *b*) is present almost equally in both the cores and it is abundant in the surface samples (Figures 3 *b* and 4 *b*). *Operculodinium centrocarpum* (Figure 2 *f*) is present only at two depths (15–20 cm and 50–55 cm) in the nearshore core, whereas in the offshore core it is present only at 10–15 cm depth. *Lingulodinium machaerophorum* (Figure 2 *e*) is present only in the nearshore core (Figure 3 *c*), whereas *Spiniferites bentorii* (Figures 2 *c*, 4 *c*), *Spiniferites ramosus* (Figures 2 *d*, 4 *d*) and *Tuberculodinium vancampoae* (Figure 2 *g*) are found only in the offshore core. *Multispinula* species (Figure 2 *h*) is present in both cores, its percentage is higher in the nearshore core (5–50%, Figure 3 *d*) than in the offshore core (3–5%, Figure 4*e*), *Spiniferites mirabilis*, *S. ramosus* and *Operculodinium centrocarpum* are suggested to be temperate species[8].

Dinoflagellate count is related with the count of copepodes, foraminifers (organic walled) and spores and pollen (continental palynomorphs). The main results are enumerated below.

The percentage of copepodes/dinoflagellates+copepodes is higher in the nearshore core, 41–58% (Table 2 and Figure 3 *e*) as compared with that of offshore core (14–19%, Table 2 and Figure 4 *f*). The low values of this ratio in the offshore core may be due to the relative abundance of dinoflagellates.

The percentage of foraminifera/dinoflagellates+foraminifera is higher in the nearshore core, 20–38% (Table 2 and Figure 3 *f*) than the offshore core, 11–20% (Table 2 and Figure 4 *g*). The low values of this ratio in the offshorecore may be also due to the relative abundance of dinoflagellates.

The percentage of marine/continental+marine palynomorphs is higher in the offshore core 82–88% (Table 2 and Figure 4 *h*) than in the nearshore core, 60–68% (Table 2 and Figure 3 *g*). The high values of this ratio in the offshore core may be due to the relative scarcity of spores and pollen.

The total number of palynomorphs per sample is high in the offshore core, 114–169 (Table 2 and Figure 4 *i*) than the nearshore core, 30–61 (Table 2 and Figure 3 *h*). This may be due to the abundance of dinoflagellates in the offshore core than the nearshore core. The higher percentage of dinoflagellate cysts in an assemblage indicates an environment away from the shore line[4]. The total number of dinoflagellates per sample is high in the offshore core, 91–133 (Table 2 and Figure 4 *j*) than the nearshore core, 8–21 (Table 2 and Figure 3 *i*). The total number of dinoflagellates species per sample is almost equal in both the cores (Table 2 and Figures 3 *j* and 4 *k*).

In the case of nearshore core, *Multispinula* species percentage increases down core, whereas *Spiniferites pachydermus* percentage, *S. mirabilis* percentage, total number of dinoflagellates per sample and total number of palynomorphs per sample decrease down core. Mean grain size in phi also moderately decreases down core in this core (Table 2). In the case of offshore core, the total number of dinoflagellates per sample, total number of palynomorphs per sample, mean grain size in phi, silt percentage and clay percentage increase down core, whereas *Multispinula species* percentage, copepodes/copepodes+dinoflagellate percentage and sand percentage decrease down core (Table 2). It is evident from this study that the occurrence of dinoflagellates in the shelf-sediments off the west coast of India could be useful in future palaeoclimatic reconstructions.

1. Wall, D., *Geosci. Man.*, 1971, **3**, 1–15.
2. Anderson, D. M., *Am. Chem. Soc. Symp. Ser.*, 1984, **262**, 125–138.
3. Evitt, W. R., *Geosci. Man.*, 1970, **1**, 29–45.
4. Jain, K. P., *Curr. Sci.*, 1991, **61**, 697–700.
5. Gray, J., in *Techniques in Palynology* (eds Kummel, B. and Raup, D. M.), Freeman, 1965, part III, pp. 469–706.
6. Sereant, W. A. S., in *Fossil and Living Dinoflagellates*, Academic Press, London, 1974, p. 182.
7. Caratini, C., *Int. Comm. Palynol. Newslett.*, 1980, **3**, 4.
8. Long, D., Bent, A., Harland, R., Gregory, D. M., Graham, D. K. and Morton, A. C., *Mar. Geol.*, 1986, **73**, 109–123.

ACKNOWLEDGEMENTS. We thank Dr C. Caratini, Head, Department of Palynology, French Institute of Pondichery, for providing laboratory facilities and for constructive criticism. We also thank Dr B. R. J. Rao, Deputy Director General, Marine wing, G.S.I. for providing the necessary samples for this study. Facilities at the Department of Marine Geology, Mangalore University are acknowledged.

Received 29 December 1995; revised accepted 27 March 1996