

PALYNOLOGICAL INVESTIGATION OF THE SEDIMENT CORES FROM THE ARABIAN SEA. 2: DINOFLAGELLATE CYSTS AND ACRITARCHS

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ABSTRACT

The present paper incorporates the study of dinoflagellate cysts and acritarchs recovered from five sediment cores from the Arabian Sea. This assemblage is represented by 15 genera and 22 species. Of these, 14 species belonging to 11 genera are of dinoflagellate cysts and 8 species belonging to 4 genera are of acritarchs, besides two types which could not be referred to any taxa. One acritarch genus, viz., *Ornatasphaera* and 3 species are new. Among dinoflagellate cysts, *Hystriosphæridium* (3 spp.), *Surculosphaeridium* (2 spp.), *Tuberculodinium* (1 sp.) and *Lingulodinium* (1 sp.) and among acritarchs *Baltisphaeridium* and *Ornatasphaera* are the major elements. The distribution of the various species in different cores has been discussed. The assemblage has been compared with some other known Quaternary assemblages. A possible brackish water environment has been suggested.

INTRODUCTION

Recently, CHANDRA, SAXENA AND SETTY (in press) studied fungal spores from five sediment cores from the Arabian Sea. Besides fungal spores, the core samples also yielded dinoflagellate cysts, acritarchs and spores and pollen grains. The study pertaining to the dinoflagellate cysts and acritarchs is presented in this paper.

The material for the present study was collected by R/V *Oceanographer* during June 13 to June 23, 1967. One of us (SETTY) was a participant to this cruise and shared these samples with the U.S. Environmental Science Services Administration. The material belongs to five sediment cores from the Arabian Sea. Their location, water depth, core thickness, lithology, mineral contents and organic matter, etc. have been published by SETTY (1972 a, b). Core no. 1 at station 29 was collected from the slope region; core no. 2 at station 43 was collected from the basin; and core nos. 3, 4 and 5 at stations 66, 73 and 146, respectively were collected from the continental shelf. Core no. 5 has the maximum thickness of 2.35 m, while core no. 4 has minimum thickness of 0.50 m. Core no. 5 was nearest to the coast and core no. 2 was farthest from the coast. Nine samples were taken from three sections of core no. 1; 12 samples from four sections of core no. 2; 9 samples from three sections of core no. 3; 3 samples from one section of core no. 4 and 12 samples from four sections of core no. 5. Thus a total of 45 core samples were studied (Fig. 1, Table 1). RAJAGOPALAN, VISHNU-MITRE AND SEKAR (1978) determined the age of the top sample of core no. 4 and sample no. 7 of core no. 2 as 9830 ± 180 years and 20940 ± 450 years, respectively by radio-carbon dating method. Considering the rate of deposition as normal, the age of the oldest samples of these cores may be estimated in the range of 0.1 million years or even more. In general, a late Quaternary age may be safely assigned to these sediments.

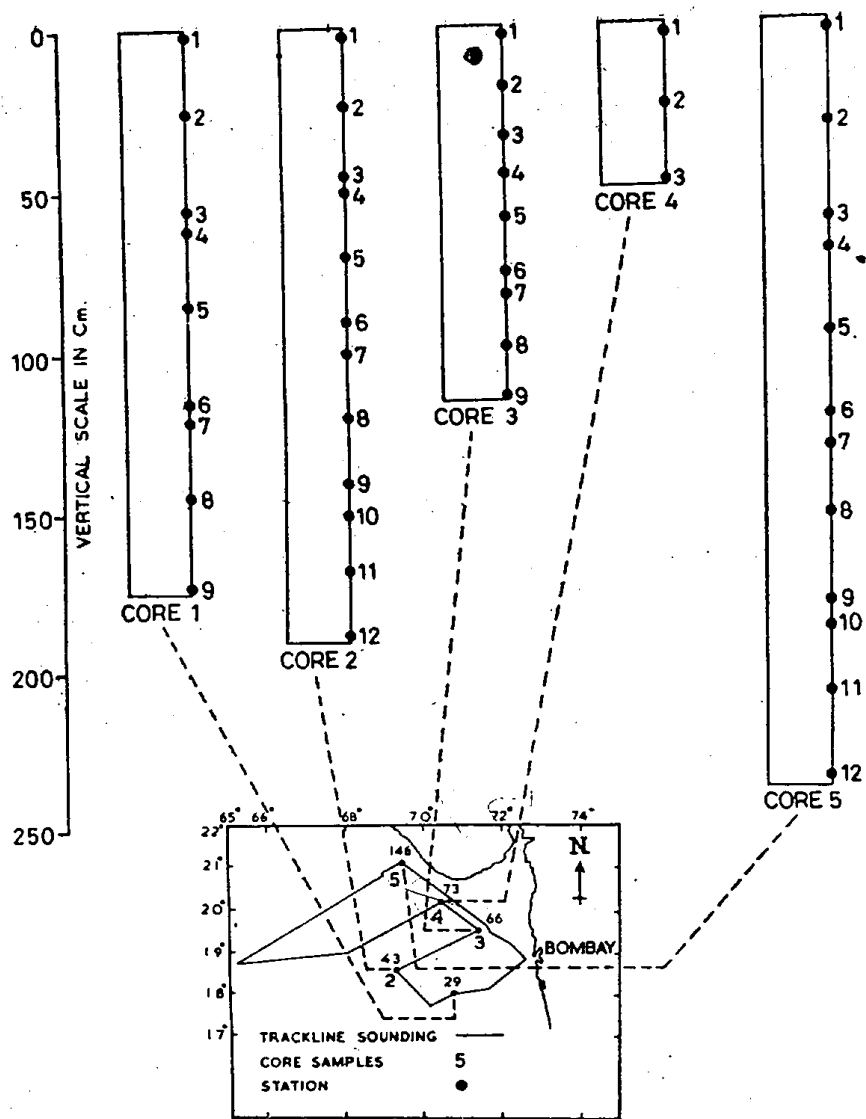


Fig. 1. Map showing the stations where the sediment cores were collected in the Arabian Sea (Setty, 1972a) including the length of the cores.

For palynological preparation, all the samples were gently warmed in 5-10 per cent KOH solution to remove the extraneous organic matter. These were then treated with hydrofluoric acid in the usual manner and after repeated washing were acetolysed. Permanent slides have been prepared in glycerine jelly and sealed with the gold seal. All the negatives, type and figured slides have been deposited in the repository of the Birbal Sahni Institute of Palaeobotany, Lucknow.

DINOFLAGELLATE CYSTS

Genus—**Adnatosphaeridium** Williams & Downie *in* Davey, Downie, Sarjeant & Williams, 1966

Adnatosphaeridium sp.

Pl. 1, Fig. 1

Table 1—Station location and other core data of the Scientific Cruise of U.S.C. and G.S.S. *Oceanographers*, Bombay—Bombay Leg (Setty, 1972a).

Core No.	Station		Location		Depth (Meters)	Core Length (Centimeters)
	Serial No. as per Oceanographer	Latitude North	Longitude East			
1	29	17°57.9'	70°46.0'		649	175
2	43	18°35.2'	69°17.2'		2960	190
3	66	19°32.8'	71°21.5'		64	145
4	73	20°10.0'	70°26.9'		73	50
5	146	20°04.5'	69°26.0'		63	235

Description—Chorate cyst, test spherical in shape. No parasutural features traceable, processes hollow and/or solid, connected distally by trabeculae, in some specimens trabeculae not well-developed. Test surface smooth. Archeopyle apical. Paratabulation not clearly indicated. Paracingulum visible but arrangement of paraplates not clear. Parasulcus not discernible.

Dimensions

Overall cyst size : 56-74 μm
 Size of body : 40-58 \times 35-50 μm
 Length of processes : 8-12 μm

Occurrence—Core no. 2

Genus—**Hemicystodinium** Wall, 1967

Hemicystodinium sp.

Pl. 1, Fig. 2

Description—Chorate cyst, test hemispherical. No parasutural features. Processes thin, hollow, numerous in number, bifurcated at distal ends. Test surface smooth or weakly structured. Archeopyle combination type, involving many apical and precingular plates, which are removed altogether, imparting hemispherical shape to the cyst. Paracingulum indicated by archeopyle margin while parasulcus is not discernible.

Dimensions

Overall cyst size : 77-82 \times 79-81 μm
 Size of body : 50-57 \times 48-57 μm
 Length of processes : 12-15 μm

Occurrence—Core nos. 1 and 2.

Genus—**Hystrichosphaeridium** Deflandre, 1937 emend. Davey & Williams in Davey, Downie, Sarjeant & Williams, 1966

Hystrichosphaeridium tubiferum (Ehrénberg, 1838) Deflandre, 1937 emend.

Davey & Williams in Davey, Downie, Sarjeant & Williams, 1966

Pl. 1, Fig. 3

Description—Chorate cyst, test spherical to subspherical in shape. No parasutural features. Intratabular processes tubular, hollow, smooth, open and sometimes bi-

furcated or very rarely trifurcated at distal ends. Test surface generally smooth. Paratabulation indicated by intratabular processes. Archeopyle apical. Paracingulum clearly seen in few specimens otherwise indicated by processes. Parasulcus not discernible.

Dimensions

Overall cyst size : 60-85 μm

Size of body : 45-64 μm

Length of processes : 9-15 μm

Occurrence—Core nos. 1 and 2.

Hystrichosphaeridium stellatum Maier, 1959

Pl. 1, Fig. 4

Description—Chorate cyst, test spherical in shape, processes hollow, distally open and are of two types, one process wider than the others. Archeopyle apical.

Dimensions

Overall cyst size : 56-66 μm

Size of body : 49-52 \times 45-47 μm

Length of processes : 10-17 μm

Occurrence—Core nos. 1 and 2

Hystrichosphaeridium sp.

Pl. 1, Fig. 5

Description—Test spherical. Intratabular processes hollow, tubular with calyxed distal ends. Archeopyle apical.

Dimensions

Overall cyst size : 57 \times 38 μm

Size of body : 38 \times 22 μm

Length of processes : 8-11 μm

Occurrence—Core no. 2

Remarks—The present species differs from *H. tubiferum* by its processes having calyxed distal ends.

Genus—**Lingulodinium** Wall, 1967 emend. Wall & Dale in Wall, Dale & Harada, 1973

Lingulodinium machaerophorum (Deflandre & Cookson, 1955) Wall, 1967

Pl. 1, Fig. 6

Description—Chorate cyst, test generally spherical, occasionally \pm ellipsoidal due to lateral compression. Archeopyle precingular, clearly seen only in few specimens, compound. Test surface weakly sculptured. Processes simple, broader at bases and tapering gradually towards the distal ends, hollow, tips closed. Paratabulation, parasulcus and paracingulum not indicated.

Dimensions

Overall cyst size : 65-80 \times 54-62 μm

Size of body : 48-62 \times 38-43 μm

Length of processes : 14-22 μm

Occurrence—Core nos. 1 and 5

Genus—**Membranilarnacia** Eisenack, 1963 emend. Williams & Downie *in* Davey, Downie, Sarjeant & Williams, 1966

cf. **Membranilarnacia** sp.

Pl. 1, Fig. 7

Description—Cavate cyst, endocyst and pericyst subspherical. No parasutural features. Endophragm thicker than periphragm, both closely placed and connected with each other by numerous slender, rod-like processes. Archeopyle presumably apical. Paratabulation, paracingulum and parasulcus not clearly indicated.

Dimensions

Endocyst size : $36 \times 34 \mu\text{m}$

Pericyst size : $48 \times 47 \mu\text{m}$

Length of processes : $7-8 \mu\text{m}$

Occurrence—Core no. 2

Remarks—Only one specimen was encountered. The position of archeopyle appears to be apical, but not certain. In all other characters, the specimen resembles *Membranilarnacia*, hence compared to it.

Genus—**Palaeohystrichophora** Deflandre, 1935 emend. Deflandre & Cookson, 1955

Palaeohystrichophora sp.

Pl. 1, Fig. 8

Description—Bicavate cyst, endocyst ellipsoidal enveloped by elongate-elliptical pericyst, forming cavity at apical and antapical ends, antapical cavity not well developed. Parasutural features not discernible. Processes flexible, hair-like, paratabulation indicated by paracingulum. Paracingulum clearly discernible. Archeopyle absent. Parasulcus indicated in some specimens as depressed area.

Dimensions

Endocyst size : $45-46 \times 35-38 \mu\text{m}$

Pericyst size : $50-54 \times 38-50 \mu\text{m}$

Length of processes : $5-9 \mu\text{m}$

Occurrence—Core nos. 2, 4 and 5

Genus—**Prolixosphaeridium** Davey, Downie, Sarjeant & Williams, 1966 emend. Davey, 1969

Prolixosphaeridium sp.

Pl. 1, Fig. 9

Description—Chorate cyst, test elongate-elliptical in shape. No parasutural features, autophragm contains numerous spinose, nontabular processes which are pointed at distal ends with closed tips. Archeopyle apical. Paratabulation indicated by archeopyle only. Paracingulum and parasulcus not indicated.

Dimensions

Overall cyst size : $120 \times 56 \mu\text{m}$

Size of body : $110 \times 42 \mu\text{m}$

Length of processes : $5-10 \mu\text{m}$

Occurrence—Core no. 2

Remarks—Specific assignment could not be made due to less number of available specimens.

Genus—**Spiniferites** Mantell, 1850 emend. Sarjeant, 1970

Spiniferites sp.

Pl. 1, Fig. 10

Description—Chorate cyst, test spherical to subspherical in shape. Endophragm and periphragm appressed between the processes. Parasutural features present in the form of ridges connecting process bases. Processes simple, hollow, broader at base and tapering towards distal ends, tips closed, bifurcated and/or trifurcated. Test surface smooth or granulose. Archeopyle distinct, precingular. Paratabulation indicated by archeopyle and parasutural ridges. Paracingulum and parasulcus not indicated.

Dimensions

Overall cyst size : 54-67 μm
Size of body : 42-52 \times 41-50 μm
Length of processes : 12-17 μm

Occurrence—Core no. 2.

Genus—**Subtilisphaera** Jain & Millepied, 1973

cf. **Subtilisphaera** sp.

Pl. 1, Fig. 11

Description—Bicavate cyst, test ellipsoidal in shape having no apical or antapical horns. Endocyst outline circular. No parasutural features. Endophragm and periphragm smooth having hollow processes which taper towards distal ends. Paratabulation, paracingulum, archeopyle and parasulcus not indicated. Apical end slightly protruded.

Dimensions

Endocyst size : 60 \times 33 μm
Pericyst size : 77 \times 33 μm
Length of processes : 9-16 μm

Occurrence—Core no. 5

Remarks—The present specimen resembles *Subtilisphaera* in being bicavate and having similar shape but differs in having processes.

Genus—**Surculosphaeridium** Davey, Downie, Sarjeant & Williams, 1966

Surculosphaeridium sp. 1

Pl. 1, Fig. 12

Description—Chorate cyst, test spherical to subspherical in shape. Autophragm only, smooth. Processes intratabular, slender, solid and branched at distal ends. Archeopyle apical. Paracingulum and parasulcus not clearly seen.

Dimensions

Overall cyst size : 58-72 \times 50-66 μm
Size of body : 40-52 \times 38-47 μm
Length of processes : 9-15 μm

Occurrence—Core nos. 1, 3 and 5

Surculosphaeridium sp. 2

Pl. 2, Fig. 13

Description—Chorate cyst, test oval. Autophragm only. Processes thin, solid and mostly bifurcated. Archeopyle apical. Paracingulum clearly seen and contains 5 or 6 intratabular processes. Parasulcus not indicated.

Dimensions

Overall cyst size : 70 × 62 μm

Size of body : 48 × 37 μm

Length of processes : 9-13 μm

Occurrence—Core no. 2.

Remarks—The present species differs from *Surculosphaeridium* sp. 1 in having more number of processes and well developed paracingulum.

Genus—**Tuberculodinium** Wall, 1967 emend. Wall & Dale, 1971

Tuberculodinium sp.

Pl. 2, Fig. 14

Description—Cyst subspherical in shape. No parasutural features. Autophragm and ectophragm form a cavity in between which is occupied by intratabular processes like tubercles. Archeopyle antapical, not clearly discernible in all the specimens. Test surface smooth to weakly sculptured. Paratabulation indicated by tuberculate processes and/or by archeopyle. Paracingulum and parasulcus not indicated.

Dimensions

Size of body : 40-55 × 33-50 μm

Length of tuberculate processes : 1.5-4 μm

Occurrence—Core nos. 2 and 5

ACRITARCHS

Genus—**Baltisphaeridium** Eisenack, 1958

Baltisphaeridium sp. 1

Pl. 2, Fig. 15

Description—Test spherical to subspherical in shape. Surface covered with numerous processes which are thin, solid, straight, needle-like with pointed tips. Test surface smooth to ±punctate. Aperture not discernible.

Dimensions

Size of body : 40-52 × 33-46 μm

Length of processes : 5-10 μm

Occurrence—Core nos. 1, 2 and 3

Baltisphaeridium sp. 2

Pl. 2, Fig. 16

Description—Test subspherical to oval in shape. Surface covered with small, spinose/conate processes, processes generally fewer in number. Aperture and paratabulation not indicated.

Dimensions

Size of body : 35-52 × 35-45 μm

Length of processes : Up to 5 μm

Occurrence—Core no. 3

Remarks—This species differs from *Baltisphaeridium* sp. 1 by having shorter, spinose/conate and fewer processes.

Genus—**Foveofusa** Lele & Chandra, 1972

Foveofusa sp.

Pl. 2, Fig. 17

Description—Palynomorphs elongated or quadrangular in shape, no suggestion of aperture. Wall psilate, thin, with some longitudinal folds and/or lineations.

Dimensions : 153-310 × 28-44 μm

Occurrence—Core nos. 1 and 2

Genus—**Aplanosporites** Kar, 1979

Aplanosporites robustus Kar, 1979

Pl. 2, Fig. 18

Description—Palynomorphs elliptical, circular or irregular in shape. Body with no aperture, occasionally small, longitudinally running folds or lineations present. A flagellum-like appendage is attached to one end of the body, wall psilate.

Dimensions

Size of body : 30-125 × 25-52 μm

Length of appendage : 30-75 μm

Occurrence—Core nos. 1, 2 and 3

Remarks—Some specimens in the present preparation are smaller in size than those described by KAR (1979).

Genus—**Ornatasphaera** gen. nov.

Type species—*Ornatasphaera globata* gen. et sp. nov.

Generic diagnosis—Cyst spherical, subspherical or elliptical. Very large in size. No indication of aperture. Wall 1.5-3.5 μm thick, either sculptured, viz. granulate, conate, corrugate, etc. or foveolate to finely reticulate, occasionally irregularly folded.

Comparison—The present genus is comparable with *Cephalia* Sah & Kar (1974) described from Palana Lignite, Rajasthan but can easily be distinguished by its larger size, ornamented wall and absence of plates and sutures. *Spinasphaera* Kar & Saxena (1976) differs in having very closely placed hair-like spines and smaller size.

Ornatasphaera globata sp. nov.

Pl. 2, Figs. 19, 20

Holotype—Pl. 2, Fig. 19, Size 115 × 105 μm; Slide no. 6350*/2-C5S12

Type locality—Arabian Sea, 20°04. 5' : 69°26.0', Core no. 5

Diagnosis—Cyst spherical to subspherical in shape. Aperture absent. Wall 2 to 3.5 μm thick, granulate, occasionally corrugate or ornamented by very small conic, folded.

Dimensions : 115-160 × 105-150 μm

Occurrence—Core nos. 1, 2 and 5

Ornatasphaera reticulata sp. nov.

Pl. 2, Fig. 21

Holotype—Pl. 2, Fig. 21, Size $110 \times 88 \mu\text{m}$; Slide no. 6295*/9-C1S1

Type locality—Arabian Sea, $17^{\circ}57.9' : 70^{\circ}46.0'$, Core no. 1

Diagnosis—Cyst subspherical or irregular in shape. Aperture absent. Wall $1.5\text{--}2.5 \mu\text{m}$ thick, foveolate or finely reticulate, meshes circular, polygonal or irregular. Irregularly folded.

Dimensions : $98\text{--}113 \times 95\text{--}109 \mu\text{m}$

Comparison—The present species resembles *O. globata* sp. nov. in shape, size range and inaperturate nature. However, it can easily be separated from latter by its foveolate-reticulate wall.

Occurrence—Core nos. 1, 2, 3 and 5

Ornatasphaera elliptica sp. nov.

Pl. 2, Fig. 22

Holotype—Pl. 2, Fig. 22, Size $119 \times 57 \mu\text{m}$; Slide no. 6308*/1-C1S8

Type locality—Arabian Sea, $17^{\circ}57.9' : 70^{\circ}46.0'$, Core no. 1

Diagnosis—Cyst elliptical-spindle shaped. Inaperturate. Wall up to $2 \mu\text{m}$ thick, corrugate, granulate or conate, grana/coni small in size.

Dimensions : $118\text{--}142 \times 58\text{--}82 \mu\text{m}$

Comparison—The present species resembles *O. globata* in having similar wall ornamentation but can be differentiated by its elliptical-spindle shaped structure. *O. reticulata* differs in having subspherical shape and foveolate-finely reticulate wall ornamentation.

Occurrence—Core no. 1

Ornatasphaera sp.

Pl. 2, Fig. 23

Description—Palynomorphs elliptical in shape. No aperture visible. Wall ornamented with few, robustly built and sparsely placed coni/tubercles.

Dimensions : $107 \times 49 \mu\text{m}$

Occurrence—Core nos. 1 and 4

Remarks—The present specimen is comparable with *Ornatasphaera elliptica* in shape and size but can be distinguished by its robustly built and sparsely placed coni/tubercles.

Phytoplankton type A

Pl. 2, Fig. 24

Description—Chorate cyst, test elliptical in shape. Autophragm only, no parasutural features, processes hollow, dissected, denticulated or spinose laterally as well as at distal ends. Test surface finely granulose. Archeopyle, paratabulation, paracingulum and parasulcus not clearly indicated.

Dimensions

Overall cyst size : $92 \times 52 \mu\text{m}$

Size of body : $60 \times 40 \mu\text{m}$

Length of processes : $26\text{--}42 \mu\text{m}$

Comparison—Only one specimen of this type was encountered. It resembles *Arco-sphaeridium* Eaton (1971) in having denticulated processes. However, no indication of archeopyle, paratabulation paracingulum and parasulcus precludes precise allocation.

Occurrence—Core no. 1

Phytoplankton type B

Pl. 2, Fig. 25

Description—Chorate cyst, test subspherical. No parasutural features, processes simple, conical or small spine-like, broader at base but pointed distally, tips closed. Test surface smooth or weakly intrastriated, irregularly folded. Archcopyle not discernible, paratabulation paracingulum and parasulcus not clearly indicated.

Dimensions

Overall cyst size : 196-210 × 159-166 μm

Size of body : 192-204 × 154-160 μm

Length of processes : 4-9 μm

Comparison—Only 4 specimens of this type could be studied. This type resembles *Conosphaeridium* Cookson & Eisenack (1969) in having conical or spine-like processes. However, in the present specimens the processes are not striated and archcopyle paratabulation, paracingulum and parasulcus are not clearly indicated.

Occurrence—Core no. 1.

DISCUSSION

The dinoflagellate cysts and acritarchs from five sediment cores from the Arabian Sea consist of 15 genera and 22 species in addition to 2 forms which could not be assigned to any taxa. Of these, 11 genera and 14 species are of dinoflagellate cysts and the rest belong to acritarchs. One acritarch genus, namely *Ornatasphaera*, and its three species are newly proposed.

Analysis of this assemblage (Table 2) reveals that the distribution of the dinocysts and acritarchs is not uniform in all the cores. Core no. 2 (1.90 m thick, basin, water depth 2960 m) yielded maximum dinoflagellate cysts, both qualitatively and quantitatively. Similarly core no. 1 (1.75 m thick, slope, water depth 649 m) yielded maximum acritarch species and is second to core no. 2 in having dinoflagellate cysts. Core no. 4 (0.50 m thick, shelf, water depth 73 m) showed poorest yield of both dinoflagellate cysts and acritarchs. Core no. 3 (1.15 m thick, shelf, water depth 64 m) and core no. 5 (2.35 m thick, shelf, water depth 63 m) also have poor representation of dinoflagellate cysts and acritarchs in number and variety. Such inconsistent representation of these microfossils in various cores appears to have a direct relationship with the location of core, water depth and distance from the coast. The frequency of these cysts increases with the increase in water depth of cores and their distance from coast. In general, the present assemblage is not very rich as only a few species show some appreciable frequency while the others are sporadically represented. This precludes their sample-wise counting and a detailed quantitative analysis. Among dinoflagellate cysts the main genera in order of their relative abundance are : *Hystichosphaeridium* (3 spp.), *Surculosphaeridium* (2 spp.), *Tuberculodinium* (1 sp.) and *Lingulodinium* (1 sp.) while amongst acritarchs, *Baltisphaeridium* and *Ornatasphaera* are the major elements. Other dinoflagellate and acritarch genera are represented by a few (less than 8) specimens. The occurrence of various species in each sediment core is shown in Table 2.

SETTY (1972a) pointed out that core nos. 3 and 5 (shallowest and closest inshore) have some common features like sapropelic sediment, colour, texture and organic matter contents. He, thus, concluded that the entire core no. 3 is similar and equivalent in all respects to a portion of core no. 5 (0-0.65 m). Similarly, he correlated part of core no. 5 (1.47-2.35 m) with the entire core no. 4 because both have oolites and oolitic lenses;

Table 2—Distribution of the dinoflagellate cysts and acritarchs in each core.

Species	Cores	1	2	3	4	5
<i>Ornatasphaera elliptica</i>	—————			
Phytoplankton type-A	—————			
Phytoplankton type-B	—————			
<i>Hemicystodinium</i> sp.	—————			
<i>Hystrichosphaeridium stellatum</i>	—————			
<i>Hystrichosphaeridium tubiferum</i>	—————			
<i>Foveofusa</i> sp.	—————			
<i>Aplanosporites robustus</i>	—————			
<i>Baltisphaeridium</i> sp. 1	—————			
<i>Ornatasphaera</i> sp.	—————		—————	
<i>Ornatasphaera reticulata</i>	—————		—————	—————
<i>Ornatasphaera globata</i>	—————			—————
<i>Surculosphaeridium</i> sp. 1	—————	—————		—————
<i>Lingulodinium machaerophorum</i>	—————			—————
<i>Adnatosphaeridium</i> sp.		—————		
<i>Hystrichosphaeridium</i> sp.		—————		
cf. <i>Membranilarnacia</i> sp.		—————		
<i>Prolixosphaeridium</i> sp.		—————		
<i>Spiniferites</i> sp.		—————		
<i>Surculosphaeridium</i> sp. 2		—————		
<i>Palaeohystrichophora</i> sp.		—————	—————	
<i>Tuberculodinium</i> sp.		—————		—————
<i>Baltisphaeridium</i> sp. 2		—————		
cf. <i>Subtilisphaera</i> sp.				—————

oolitic layers alternating with marl; detrital grains; and a similar number and variety of foraminifers and other kind of fossils. CHANDRA, SAXENA AND SETTY (in press) observed no such similarity in the fungal spore assemblages from these cores. A comparison of the various species described here from these cores reveals that only one, of the two types recovered from core no. 4, is found in the basal part of core no. 5. On the other hand, *Surculosphaeridium* sp. 1 and *Ornatasphaera reticulata* are common to the middle (0.70-0.90 m) and basal (1.80-2.35 m) parts of core no. 5. It is, however, not possible to draw any conclusion on the basis of the present data.

Comparison—Studies on the Quaternary dinoflagellate cysts have remained neglected for long time. It is only in the last two decades that literature on these microfossils has started coming and research on this group has taken pace. Excellent con-

tributions by ROSSIGNOL (1961, 1962, 1963, 1964), WALL (1965, 1967), WALL AND DALE (1967, 1968a, b, c, 1969, 1970, 1974), HARLAND (1968), EVITT AND WALL (1968), WILSON (1968), DOWNIE AND SINGH (1969), WALL AND WARREN (1969) and others have enriched our knowledge on the Quaternary dinoflagellate cysts.

A perusal of the published literature reveals some very interesting distributional pattern of dinocysts in the Quaternary sediments of the Black Sea, Mediterranean Sea, Red Sea and Caribbean Sea reflecting salinity and temperature tolerance range of some genera (WALL & DALE, 1974). Comparing these assemblages with the present one, we find that *Spiniferites* and *Lingulodinium* are common to all the assemblages. However, *Tectatodinium* and *Operculodinium* which are abundant in Black Sea, Red Sea and Mediterranean Sea assemblages are completely absent from the present assemblage. Similarly, *Nematosphaeropsis* and *Leptodinium* of Red and Mediterranean Sea assemblages are absent from the present assemblage while *Hemicystodinium* is common in all the three assemblages. The present assemblage is also comparable with Caribbean Sea assemblage in common occurrence of *Lingulodinium*, *Hemicystodinium* and *Tuberculodinium*. However, absence of *Hystrichosphaera*, *Nematosphaeropsis*, *Leptodinium*, *Operculodinium* and *Tectatodinium* in the former and *Hystrichosphaeridium*, *Surculosphaeridium*, *Adnatosphaeridium* and *Spiniferites* in the latter indicate their dissimilarities. Absence of *Nematosphaeropsis* and *Leptodinium*, which are abundant in highly saline or hypersaline Red and Mediterranean Sea (WALL & DALE, 1974) indicates possibly a brackish water environment. However, it is difficult to draw any conclusion on this evidence alone as other factors, e.g. temperature, pH, etc. also play an important role in the distribution of dinoflagellates.

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EXPLANATION OF PLATES

(Slides marked with asterisk (*) belong to statement no. 455 of a paper by Chandra, Saxena and Setty (in Press). 'C' is for Core Number and 'S' is for Sample Number).

PLATE-1

1. *Adnatosphaeridium* sp. $\times 500$, slide no. 6319*/2, C2—S7.
2. *Hemicystodinium* sp. $\times 500$, slide no. 6722/1, C1—S7.
3. *Hystrichosphaeridium tubiferum* (Ehrenberg) Deflandre emend. Davey & Williams in Davey, Downie, Sarjeant & Williams, $\times 500$, slide no. 6312*/3, C2—S2.
4. *Hystrichosphaeridium stellatum* Maier. $\times 500$, slide no. 6721/1, C1—S6.
5. *Hystrichosphaeridium* sp. $\times 750$, slide no. 6729/4, C2—S12.
6. *Lingulodinium machaerophorum* (Deflandre & Cookson) Wall $\times 750$, slide no. 6721/5, C1—S6.
7. cf. *Membranilarnacia* sp. $\times 750$, slide no. 6726/5, C2—S5.
8. *Palaeohystrichophora* sp. $\times 750$, slide no. 6732/5, C5—S12.
9. *Prolixosphaeridium* sp. $\times 500$, slide no. 6313*/10, C2—S2.
10. *Spiniferites* sp. $\times 500$, slide no. 6314*/6, C2—S2.
- 11: cf. *Subtilisphaera* sp. $\times 500$, slide no. 6346*/3, C5—S10.
12. *Surculosphaeridium* sp. 1 $\times 500$, slide no. 6345*/3, C5—S10.

PLATE-2

13. *Surculosphaeridium* sp. 2 $\times 500$, slide no. 6727/5, C2—S9.
14. *Tuberculodinium* sp. $\times 750$, slide no. 6314*/19, C2—S2.
15. *Baltisphaeridium* sp. 1 $\times 500$, slide no. 6324*/19, C2—S12.
16. *Baltisphaeridium* sp. 2 $\times 750$, slide no. 6730/5, C3—S1.
17. *Foveofusa* sp. $\times 200$, slide no. 6302*/5, C1—S3.
18. *Aplanosporites robustus* Kar, $\times 500$, slide no. 6308*/4, C1—S2.
- 19, 20. *Ornatasphaera globata* sp. nov., slide nos. 6350*/2 $\times 500$ (Holotype), C5—S12, 6725/6 $\times 500$, C2—S5.
21. *Ornatasphaera reticulata* sp. nov., $\times 500$, slide no. 6295*/9 (Holotype), C1—S1.
22. *Ornatasphaera elliptica* sp. nov., $\times 500$, slide no. 6308*/1 (Holotype), C1—S8.
23. *Ornatasphaera* sp. $\times 500$, slide no. 6731/1, C4—S1.
24. Phytoplankton type A $\times 500$, slide no. 6719/6, C1—S4.
25. Phytoplankton type B $\times 200$, slide no. 6297*/2, C1—S1.

