Occurrence of the marker dinoflagellate cyst *Apectodinium* in Narsapur Well-1, Krishna-Godavari Basin, India

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The morphology and taxonomy of the two dinoflagellate cyst taxa, viz., *Fibrocysta variabilis* and *Fibrocysta* sp., described by Mehrotra and Sarjeant (1987) from the subsurface conventional core samples collected at 2703-2706 m (cc 10) and 3621-3624 m (cc 13) depths of the Narsapur Well-1, Krishna-Godavari Basin, are discussed and reassessed. The two species are found to be the junior synonyms of *Apectodinium paniculatum* (Costa & Downie) Lentin & Williams 1977 and *Apectodinium quinquelatum* (Williams & Downie) Lentin & Williams 1981, respectively. A few other specimens comparable to *A. paniculatum* and *A. augustum* have also been described. The stratigraphic significance of the reported *Apectodinium* species is discussed. It is suggested that the dinoflagellate cyst assemblage at sample depth 2703-2706 m is latest Palaeocene-?earliest Eocene in age. The occurrence of *Apectodinium* species in infra-trappean sample at 3621-3624 m depth, dated as Maastrichtian by Mehrotra and Sarjeant (1987), indicates that this level is not older than the Late Palaeocene in age. This creates an anomalous situation because the youngest infra-trappean sediments at 3336-3339 m depth (cc 12), on planktonic foraminiferal data, are dated to be latest Maastrichtian. This discrepancy creates doubt over the slide/sample numbering which needs confirmation. Palaeoenvironmental significance of *Apectodinium* is discussed. A restudy of dinoflagellate cyst biostratigraphy of Narsapur Well-1 is recommended.

Key-words—Dinoflagellate cysts, Taxonomy, Biostratigraphy, Late Cretaceous, Maastrichtian, Late Palaeocene, Krishna-Godavari Basin, India.

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साराँश

कृष्णा-गोदावरी द्रोणी (भारत) में नरसापुर कुआँ-1 में सूचक घूर्णीकशाभपुटी ऍपेक्टोडीनियम् की उपस्थिति

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कृष्णा-गोदावरी द्रोणी में नरसापुर कुआँ-1 में 2703-2706 मीटर (सी-सी. 10) एवं 3621-3624 मीटर (सी-सी. 13) गहराई से एकत्रित उपसतही क्रोड़ नमूनों से प्राप्त एवं मेहरोत्रा व सर्जियेन्ट (1987) द्वारा वर्णित दो घूर्णीकशाभपुटीयों अर्थात् **फाइब्रोसिस्टा वेरियाबिलिस** एवं **फ़ाइब्रोसिस्टा** जाति की आकारिकी और वर्गिकी की विवेचना एवं पुनर्मूल्याँकन किया गया है। ये दोनों जातियाँ क्रमशः **एपेक्टोडीनियम पेनिकुलाटम** (कोस्टा व डाऊनी) लेन्टिन व विलियम्स 1977 तथा ए० **क्विनकुलाटम्** (विलियम्स व डाउनी) की कनिष्ठ पर्यायनामी पाई गई हैं। ए० **पेनिकुलाटम्** एवं ए० **ऑगस्टम्** से तुलनीय कुछ अन्य प्रादर्शों का भी वर्णन किया गया है। अभिलिखित **एपेक्टोडीनियम्** जातियों के स्तरिक महत्व की भी विवेचना की गई है। यह प्रस्तावित किया गया है कि 2703-2706 मीटर की गहराई से लिये गये नमूने से प्राप्त घूर्णीकशाभपुटी समुच्चय अनंतिमतम् पुरानूतन-प्रारम्भिकतम् आदिनूतन आयु की है। 3621-3624 मीटर की गहराई पर परा-ट्रेपीय नमूने में **एपेक्टोडीनियम्** जाति की उपस्थिति, जो मेहरोत्रा व सर्जियेन्ट (1987) द्वारा मॉस्ट्रिक्शियन आयु की कालनिर्धारित की गई थी, से प्रदर्शित होता है कि यह स्तर आयु की दृष्टि से अनंतिम पुरानूतन से पुराना नहीं है। इससे बड़ी असामान्य स्थिति उत्पन्न हो गई है क्योंकि प्लवकीय फ़ोरॅमिनीफ़री आँकड़ों के आधार पर 3336-3339 मीटर की गहराई पर अल्पतम् आयु के परा-ट्रेपीय अवसाद अनंतिमतम् मॉस्ट्रिक्शियन आयु के कालनिर्धारित किये गये है। इस विसंगति से स्लाइड़ों एवं नमूनों की क्रम संख्या के विषय में भ्रम उत्पन्न हो गया है जिसकी पुष्टी आवश्यक है। इस शोध-पत्र में **ऍपेक्टोडीनियम्** के पुरावातावरणीय महत्व की भी विवेचना की गई है। नरसापुर कुआँ-1 से प्राप्त घूर्णीकशाभ पुटी जैवस्तर-विन्यास के पुनर्अध्ययन हेतु भी अभिस्तावित किया गया है।

THE pericratonic Krishna-Godavari Basin is located on the eastern coast of the Indian peninsula. Sedimentary sequences ranging in age from Late Permian to Recent are exposed in the basin. The Narsapur Well-1 was drilled south-west of the Narsapur Village in the West Godavari District of Andhra Pradesh, 10 km inland from the coast.

Four significant research papers on the micropalaeontology of the Narsapur Well-1 have been published. These deal with planktonic foraminifera (Govindan, 1982), spore-pollen (Venkatachala & Sharma, 1982, 1984) and dinoflagellate cysts (Venkatachala & Sharma, 1982, 1984; Mehrotra & Sarjeant, 1987).

The stratigraphical details of the Narsapur Well-1 are best outlined in Govindan (1982; Text-figs 2, 3, 4). It provides a complete litholog of 4000 m subsurface sequence, indicating the positions of the fourteen conventional cores (cc), and of the three thin basaltic flows (approximately 14, 5 and 4 m in thicknesses) at a depth of 3300 m, thus clearly differentiating the infra-, inter- and supra-trappean sediments. For all practical purposes this bore-hole data is preferred for the present discussion.

Mehrotra and Sarjeant (1987, p. 15) analysed 20 samples within 1250 to 4016 m depth of the Narsapur Well-1; these included four core and sixteen cutting samples. Only three samples at the depths 2703-2706 m, 3621-3624 m and 3643-3649 m proved rich in dinoflagellate cysts. They mentioned their occurrence from cc 13, whereas only the latter two sample depths, 3621-3624 and 3643-3649 m, belong to cc 13 (Govindan, 1982; Text-fig. 4). The sample at a depth of 2703-2706 m should refer to cc 10 which has supra-trappean status. The conventional core 13 belongs to the infra-trappean sediments. Mehrotra and Sarjeant (1987) correlated these sets of samples with Palynozone-I (3621-3624 m & 3643-3649 m) and Palynozone-III (2703-2706 m) of Venkatachala and Sharma (1984). Infact, the latter sample depth correlates with the top of Palynozone IIIA of Venkatachala and Sharma (1984, pl. 2).

The present account mainly reviews and reassesses the morphological features of *Fibrocysta variabilis* and *Fibrocysta* sp. described by Mehrotra and Sarjeant (1987, p. 155-156). They have not indicated the exact location of the illustrated specimens on the slides, and hence all the available eighteen type and figured slides (listed below and housed at KDMIPE, ONGC, Dehradun), had to be thoroughly scanned. Only a few illustrated specimens could be located. Several similar other forms have also been observed in the slides.

LIST OF TYPE AND FIGURED SLIDES

IPEP/NSP-1/2703/3
IPEP/NSP-1/2703/5
IPEP/NSP-1/2703/6
IPEP/NSP-1/2703/13
— Sample depth at 2703-2706 m

IPEP/NSP-1/3621/1
IPEP/NSP-1/3621/2
IPEP/NSP-1/3621/3
IPEP/NSP-1/3621/4
IPEP/NSP-1/3621/5
IPEP/NSP-1/3621/7
IPEP/NSP-1/3621/8
IPEP/NSP-1/3621/9
— Sample depth at 3621-3624 m

IPEP/NSP-1/3643/1
IPEP/NSP-1/3643/2
IPEP/NSP-1/3643/3
IPEP/NSP-1/3643/4
IPEP/NSP-1/3643/5
IPEP/NSP-1/3643/7
— Sample depth at 3643-3649 m

TAXONOMIC COMMENTS

Genus—*Apectodinium* Costa & Downie *ex* Lentin & Williams 1977

Apectodinium paniculatum (Costa & Downie) Lentin & Williams 1977

1976 *Wetzeliella* (*Apectodinium*) *paniculatum* Costa & Downie, p. 608-609, pl. 92, fig. 1.

1977 *Apectodinium paniculatum* (Costa & Downie) Lentin & Williams, p. 9.

1987 *Fibrocysta variabilis* Mehrotra & Sarjeant, p. 155-156, pl 4, fig. 2 (Holotype), pl. 5, fig. 2; *non* pl. 5, figs 1, 5, 6).

Original diagnosis of Fibrocysta variabilis (after Mehrotra & Sarjeant, 1987, pp. 155-156)—"Cyst proximochorate, skolochorate, acavate and cingulotabulate. Ambitus pentagonal to rounded-pentagonal. Phragma thin, smooth, sometimes with finely punctate or finely granulate ornamentation. Processes numerous, apparently non-tabular, solid and generally fibrous, but varying markedly in character on each single specimen. The apical and antapical processes are usually most prominent. Each arises from a slight to prominent protuberance; one or both may be branched. Distinctive processes may be present along the line of the cingulum and may be especially prominent in lateral situation; these may be long and acuminate, particularly broad or branched distally. In specimens seen in dorso-ventral view, two lateral processes, each on the anterior side of the cingulum, may be particularly prominent. Elsewhere on the cyst, the processes are slender with expanded distal ends—bifid, trifid, cruciferate, cauliflorate, denticulate, serrate, recurved or secate. The nature of the distal terminations varies greatly, even on single specimens. In branched processes, each major branch has a bifid, trifid, cruciferate or cauliflorate distal extremity. Proximally, the processes are expanded and often exhibit basal connexions.

The cingulum is almost equatorial in situation. Not only is it marked by a marginal line of distinctly longer processes but also typically by low ridges and by lateral inflexures of the phragma. The sulcus is not clearly marked.

Archaeopyle precingular (type P), formed by loss of paraplate 3″. Though no parasutural features are developed, rarely an arrangement of a few processes

in groups may suggest an intratabular situation; however, no pattern of paratabulation is apparent."

Remarks—Mehrotra and Sarjeant (1987) attributed five specimens to *F. variabilis*. Out of these, only the holotype (pl. 4, fig. 2) and an additional specimen (pl. 5, fig. 2) could be located. The paratype A (pl. 5, fig. 5), paratype B (pl. 5, fig. 1) and another specimen (pl. 6, fig. 5) could not be traced.

Re-examination of the holotype of *F. variabilis* has revealed that the cyst was studied and illustrated in an incorrect orientation which is evident from the illustration and the description provided by Mehrotra and Sarjeant (1987, pp. 155-156; pl. 4, fig. 2). The remarkably clear pentagonal shape of the peridinioid cyst with distinctive horn/process development itself demands the cyst to be rotated 90° clockwise for correct apical-antapical orientation (Pl. 1, figs 1, 2 herein). The cyst wall is ruptured on one side (? dorsal) developing irregular folds along the margin; the ruptured portion of the wall on the lateral position has apparently been interpreted by Mehrotra and Sarjeant as an archaeopyle, the precingular type. The long apical and antapical processes mentioned by them are the two lateral horns, one appearing much longer due to outfolding of the torn cyst wall, while the other one is folded upon the cyst appearing much shorter. Likewise, the so-called prominent branched process on one lateral margin and two unequal processes on the other in the cingular region, represent an apical and two antapical horns, one of which is folded up, deceptively appearing to be shorter than the other. The wide range of variation in the nature of distal terminations, even in a single specimen, viz., bifid, trifid, cruciferate, cauliflorate, denticulate, serrate, recurved or secate, described by Mehrotra and Sarjeant, could not be observed in any of the specimens.

The other specimen (Mehrotra & Sarjeant, 1987; pl. 5, fig. 2) studied, is closely comparable with the holotype in overall morphological features. This specimen distinctly shows the presence of an intercalary (2a) quadra type archaeopyle (see pl. 1, fig. 7 herein).

In view of the above observations, the "*Fibrocysta variabilis*" cysts (Mehrotra & Sarjeant, 1987; pl. 4, fig. 2; pl. 5, fig. 2) are described as follows:

Cyst peridinioid, dorsoventrally compressed, pentagonal in shape with one apical, two lateral and two antapical horns; epicyst broadly subtriangular, hypocyst subtrapezoidal, cornucavate with pericoels developed below the horn bases; apical horn reduced with a tuft of processes, lateral horns moderately developed, longer than broad, may be distally bifid; antapical horns prominent, proximally broad, tapering with processes at distal ends, parasutural features absent; periphragm and endophragm closely appressed except at horn bases; periphragm giving rise to numerous non-tabular processes; processes long, slender, erect, hollow, simple, rarely bifurcate or branched, distally open with small, fine aculae or often closed with evexate or capitate tips; paratabulation indicated by archaeopyle alone; paracingulum not indicated; archaeopyle intercalary (2a) quadra type (Pl. 1, figs 1-2, 7 herein).

None of the specimens described under *F. variabilis* by Mehrotra and Sarjeant (1987) displays any of the characteristic features of the genus *Fibrocysta*, e.g., ellipsoidal-oval skolochorate cyst with a single wall layer (autophragm) bearing fibrous non-tabular processes, and a precingular archaeopyle. Instead, the observed morphological features demand their placement under *Apectodinium*. The two specimens described herein, including the holotype, appear closest to *Apectodinium paniculatum* in overall cyst shape and horn characteristics, except for their somewhat numerous and longer processes which are considered to be species level variations. *F. variabilis* Mehrotra & Sarjeant 1987 is therefore considered to be a junior synonym of *Apectodinium paniculatum* (Costa & Downie) Lentin & Williams 1977.

The two paratypes (A & B) designated by Mehrotra and Sarjeant (1987, p. 155, pl. 5, figs 5, 6 and fig. 1, respectively) differ markedly from each other as well as from the holotype, in cyst shape and the nature of processes and can not be included in the same species. A few better preserved specimens, observed in the type and figured slides, apparently similar to paratype B, possess cornucavate peridinioid cyst displaying processes arranged in groups (intratabular) with prominently secate or aculeate distal terminations and much longer and distinctive aculae. These specimens in all probability belong to a new species of the genus *Apectodinium*.

Attribution of the Late Cretaceous specimen of *Exochosphaeridium strialatum* (Deflandre) described by Corradini (1972, p. 147-148, pl. 21, fig. 9a, b) to *Fibrocysta variabilis* by Mehrotra and Sarjeant (1987, p. 156) is surprising as the two morphotypes are so markedly different from each other that they can not be included in the same species or even the same genus. Thus its transfer to *Fibrocysta* is not accepted and the original status is maintained.

Apectodinium sp. cf. *A. paniculatum* (Costa & Downie) Lentin & Williams 1977

Pl. 1, figs 5-6, 8, 11-12

Description—Cyst peridinioid, dorsoventrally compressed, cornucavate, rounded-pentagonal in shape, with one reduced apical and two prominent lateral and two antapical horns; epicyst short, broadly rounded,

arch-shaped, hypocyst elongate, subtrapezoidal; apical horn much reduced to only a short projection covered with processes (Pl. 1, fig. 6) or often absent (Pl. 1, fig. 11); lateral horns nearer to the apex than the antapex, usually broad and short to moderately long, often distally bifid; antapical horns long, distally tapering, covered with processes; wall layers thin, smooth, periphragm and endophragm closely appressed with prominent pericoels developed at horn bases; processes non-tabular, long, slender, erect or sometimes flexuous, hollow with distally aculeate tips; archaeopyle intercalary (2a) quadra type (Pl. 1, fig. 6).

Dimensions—Range (based on 5 specimens)

Length of cyst (excluding horns)	:	60-64 µm
Breadth of cyst (excluding horns)	:	60-70 µm
Length of antapical horns	:	10-20 µm
Length of lateral horns	:	12-26 µm

Remarks—The Narsapur specimens closely resemble *A. paniculatum* in their moderately developed two lateral and two antapical horns. However, they differ in having a short epicyst and an elongate hypocyst with lateral horns placed much nearer to the apex than the antapex, the characteristic features of *A. augustum*. The latter species further distinguishes itself in its extremely well developed and long lateral and antapical horns besides a somewhat more elongate cyst. The present forms thus appear to be transitional between the two species. Harland (1979) has also reported such transitional forms from the North Sea Basin. The Narsapur specimens are tentatively placed under *A. paniculatum* in view of their horn characteristics.

These forms are common to abundant at 2703-2706 m depth (cc 10). In all probability these forms must have also been counted by Mehrotra and Sarjeant (1987, table 1) as "*Fibrocysta variabilis*" for showing its abundance at this level.

Apectodinium quinquelatum (Williams & Downie) Lentin & Williams 1981

Pl. 1, figs 9, 10

1987 *Fibrocysta* sp., in Mehrotra & Sarjeant; p. 156, pl. 5, figs 3-4.

Original description of Fibrocysta sp. (after Mehrotra & Sarjeant, 1987, p. 156)—"Cyst proximochorate, skolochorate and cingulotabulate. Ambitus rounded-pentagonal. Autophragm thin (1 µm), exhibiting an overall reticulate ornamentation. The luminae are polygonal and quite broad (width 5-7 µm), the muri very thin and low (height 1 µm). Autoblast bearing numerous non-tabular, small, slender processes with open or closed distal ends; some of them are capitate. Apical process branched, arising from a small mamelon; antapical process also branched, a small but distinct protuberance being developed at its base. The cingulum occupies the region of maximum cyst width; its position is also suggested by two branched processes, one on each side of the cyst margin. In dorso-ventral orientation, a relatively long, branched process is seen to be present on the anterior lateral margin of the cingulum. Archaeopyle precingular (type P), formed by loss of paraplate 3". Sulcus not discernible."

Remarks—This cyst, too, has been described in its wrong orientation. The rounded-pentagonal shape of the peridinioid cyst with specific horn/process development clearly suggests that the lateral sides have been misinterpreted as apical and antapical sides. The figured specimen (Mehrotra & Sarjeant, 1987, pl. 5, fig. 3) should, therefore, be rotated 90° anticlockwise for correct orientation (see Pl. 1, figs 9, 10, herein). The branched apical process arising from a small "mamelon" described by Mehrotra and Sarjeant, is actually the group of processes at the lateral position. The small pericoels at the base of lateral horns have apparently been

PLATE 1 →

(All photomicrographs × 500; coordinates refer to Orthoplan microscope No. 042230 E4-7710-0012)

1-2, 7. *Apectodinium paniculatum* (Costa & Downie) Lentin & Williams 1977. 1-2. Same specimen in transmitted light and in phase contrast, respectively; Slide no. IPEP/NSP-1/3621/2, coordinates: 52.2 × 105.8 (Holotype of *Fibrocysta variabilis* Mehrotra & Sarjeant 1987). 7. Another specimen with archaeopyle; Slide no. IPEP/NSP-1/2703/13, coordinates: 44.9 × 105.3.

3,4. *Apectodinium* sp. cf. *A. augustum* (Harland) Lentin & Williams 1981. Same specimen in transmitted light and in phase contrast, respectively; Slide no. IPEP/NSP-1/3621/4, coordinates: 41.5 × 101.4.

5,6,8,11-12. *Apectodinium* sp. cf. *A. paniculatum* (Costa & Downie) Lentin & Williams 1977. 5-6. Slide no. IPEP/NSP-1/2703/2, coordinates: 48.0 × 92.8 and 34.4 × 92.7 respectively. 8. Slide no. IPEP/NSP-1/2703/2, coordinates: 32.1 × 91.9. 11-12. Same specimen in transmitted light and phase contrast, respectively; Slide no. IPEP/NSP-1/2703/13, coordinates: 47.0 × 104.3.

9-10. *Apectodinium quinquelatum* (Williams & Downie) Lentin & Williams 1981 (*Fibrocysta* sp. of Mehrotra & Sarjeant, 1987). Same specimen in phase contrast and in transmitted light, respectively; Slide no. IPEP/NSP-1/3621/4, coordinates: 41.6 × 111.0.

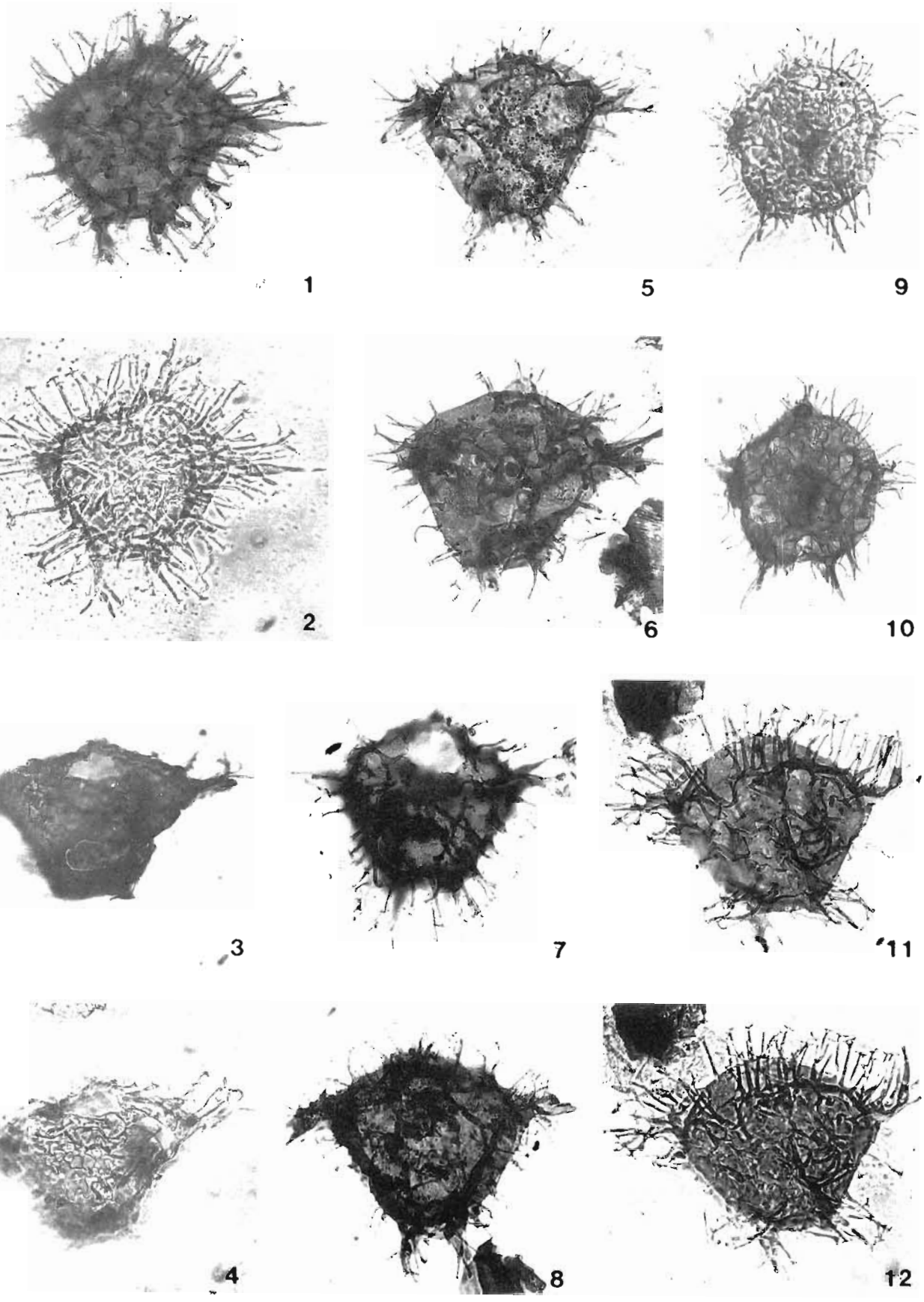

PLATE 1

mistaken as the "mamelon" and also as the "distinct protuberance" at the base of the so-called antapical process. Moreover, the two antapical horns have been misinterpreted as marking the position of an exceptionally broad cingulum "occupying the region of maximum cyst width". The reticulate ornamentation on the thin autophragm observed by Mehrotra and Sarjeant is, in fact, not indigenous but randomly distributed post-depositional mineral crystallite markings on the periphragm resembling pyrite relic structures (Neves & Sullivan, 1964, pp. 444-445).

In view of the above observations, "*Fibrocysta* sp." is redescribed as follows—Cyst peridinioid, dorsoventrally compressed, rounded-pentagonal in shape with one apical, two lateral and two antapical horns; cornucavate with small pericoels developed below horn bases; apical horn reduced with a few slender processes, lateral horns broad with tuft of processes, antapical horns prominent, long, slender, distally tapering, one slightly longer than the other; wall layers thin, both periphragm and endophragm closely appressed except at horn bases; periphragm giving rise to numerous non-tabular processes; processes variable in length but generally long, 1/4-1/8 cyst diameter, slender to distally tapering, hollow, erect or often sinuous with evexate, bulbous or rarely capitate distal tips; a few processes branched; parasutural features absent; paracingulum not indicated; archaeopyle indiscernible.

The figured specimen does not display any character of the genus *Fibrocysta*. The morphological features suggest its placement under *Apectodinium*, although the archaeopyle is not discernible. In cyst shape and horn characteristics, it comes closest to *Apectodinium quinquelatum*.

Apectodinium sp. cf. *A. augustum* (Harland) Lentin & Williams 1981

Pl. 1, figs 3, 4

Description—Cyst peridinioid, dorsoventrally compressed, pentagonal in shape with a very much reduced apical, two long lateral and two long antapical horns; epicyst broadly rounded, arch- shaped; hypocyst much longer and elongate; cornucavate with pericoels developed below horn bases; wall layers thin, surface covered with post-depositional mineral crystallite markings (resembling pyrite relic structures); processes non-tabular, long, flexuous, simple, aculeate or evexate; paratabulation indicated by archaeopyle alone; archaeopyle intercalary (2a) quadra type.

Dimensions—

Breadth of cyst (excluding horns)	:	70 µm
Length of cyst (excluding horns)	:	60 µm

Remarks—The solitary specimen observed is badly preserved but closely corresponds to *Apectodinium augustum* in its characteristically elongate body and well developed lateral horns lying nearer to the apex and long, slender antapical horns. Due to oblique preservation, the antapical horns are not clearly seen in the illustrations except for being faintly visible in phase contrast (Pl. 1, fig. 4). In view of the above, no definite specific status is assigned.

DISCUSSION

The present find of *Apectodinium* in the Narsapur Well-1 has vital stratigraphic implications, especially on the age of traps in the Krishna-Godavari Basin. In our opinion, only the oldest core (cc 13) sample at 3643-3649 m depth is undoubtedly Maastrichtian in age. The absence of *Dinogymnium* and the occurrence of *Apectodinium paniculatum*, *Apectodinium* sp. cf *A. augustum* and *A. quinquelatum* in the slides of the overlying sample from the same core at 3621-3624 m depth clearly indicate an age not older than latest Palaeocene. The youngest sample from core cc 10 at 2703-2706 m contains *Apectodinium paniculatum* and *Apectodinium* sp. cf. *A. paniculatum* and is also latest Palaeocene-? earliest Eocene in age.

Previous studies (Sastri, 1961, 1963; Bhalla, 1966, 1967; Bhalla & Khan, 1969) on the outcrop samples from infra-trappean and inter-trappean sediments in the region have broadly suggested Palaeocene and Early Eocene ages, respectively, although the documented benthic foraminiferal and ostracod assemblages lack any age markers. Govindan (1982) documented precisely datable planktonic foraminiferal assemblages from infra-trappean, inter-trappean and supra-trappean sediments of Narsapur Well-1, and on that basis he dated the traps as Late Maastrichtian in age. The youngest infra-trappean sediments belonging to core cc12 at 3336-3339 m depth, immediately underlying the traps, have been assigned to the Late Maastrichtian, *Abathomphalus mayaroensis-Globotruncana stuarti* Assemblage Zone. The overlying inter-trappean sediments between 3310-3330 m interval also contain a characteristic Late Maastrichtian assemblage. The supra-trappean sediments immediately overlying the traps between 3100-3295 m, have been assigned an Early Palaeocene age equivalent to the P2 Zone. Due to the absence of P1 Zone assemblage, an unconformity has been postulated between 3296 and 3310 m depths.

Against this background information, the occurrence of *Apectodinium* spp. in infra-trappean sediments at 3621-3624 m depth in cc 13 is highly anomalous. If the sample depth 3621-3624 m marked on the type and figured slides is correct, the report of Late Maastrichtian planktonic foraminiferal marker *Abathomphalus*

mayaroensis and associated assemblage from core cc 12 (3336-3339), almost 290 m above, and also the entire P2 and P3 Zone assemblages of supra-trappean sediments (3100-3295 m and core cc 11 at 3064-3069 m) becomes dubious. There being no valid reason to doubt or discard planktonic foraminiferal data, we strongly suspect that in Mehrotra and Sarjeant's study either the slides/samples of a younger core have been wrongly labelled, or there was some contamination from younger levels. However, the dinoflagellate cyst assemblage found in slides of 3621-3624 m is quite similar to that of core cc 10 at 2703-2706 m depth but is entirely different from the typical Late Cretaceous dinoflagellate cyst assemblage encountered in core cc 13 at 3643-3649 m. This possibly rules out the contamination factor and calls for rechecking of slide/sample numbers. It is also significant to note that Venkatachala and Sharma (1984) have dated the interval between 3335-4032 m as Upper Senonian (Campanian-Maastrichtian) based on palynological data.

Occurrence of *Apectodinium paniculatum* and *Apectodinium* sp. cf. *A. paniculatum* in core cc 10 (2703-2706 m) is equally significant. The genus *Apectodinium* is an important stratigraphic datum marker as its FAD in northwest Europe lies in the uppermost Palaeocene (base of calcareous nannoplankton Zone NP9). Recently Powell (1992, pp. 176-178; figs 4.5, 4.6) instituted two Upper Palaeocene Interval Biozones, viz., *Apectodinium hyperacanthum* (Ahy Biozone) and *Apectodinium augustum*, (Aau Biozone). The older, Ahy Biozone is defined between the FAD of *Apectodinium homomorphum* and FAD of *Apectodinium augustum*, whereas the younger, Aau Biozone covers the body of strata between the first appearance of *A. augustum* and the first appearance of *Phelodinium magnificum*. Aau Biozone is characterised by the presence of *A. augustum*, *A. parvum*, *A. summissum*, *A. paniculatum* and *A. quinquelatum* which appear at the base of this zone. Aau Biozone has been caliberated with calcareous nannoplankton Zone NP9 (pars) of Martini (1971); planktonic foraminiferal Zone P5 (pars) plus P6a of Blow (1969) and Berggren (1972), and dinoflagellate cyst sub-biozone D5a of Costa and Manum (1988). The age of the Aau Biozone ranges from Thanetian (pars) to Ypresian (pars). Recently the LAD of *A. augustum* has been marked at the Palaeocene-Eocene boundary (Powell, 1988; Williams *et al.*, 1993, p. 119).

Lately, Brinkhuis *et al.* (1994) have recorded *Apectodinium hyperacanthum* from the early part of the Late Palaeocene near the Danian-Selandian boundary corresponding to the base of the planktonic foraminiferal zone P_3 in the low latitude El kef section. This implies that chronobiostratigraphic correlation using the "Base *Apectodinium* Datum" (BAD) in latest Palaeocene (Late Thanetian) may be problematic. However, a worldwide *Apectodinium* Acme occurs near the Palaeocene-Eocene boundary.

In the Indian subcontinent, the *Apectodinium homomorphum* plexus (*sensu* Harland, 1979) has been described from subsurface sequence of Vriddhachalam area, Cauvery Basin (Jain & Garg, 1986) and Lakadong Sandstone Member of Sylhet Formation, South-Shillong Plateau (Dutta & Jain, 1980). From these two dinoflagellate cyst assemblages, *A. augustum* has not been reported, but they show common presence of *A. parvum* and *A. hyperacanthum*. Besides, in the Vriddhachalam subsurface sequence, *Apectodinium paniculatum* and *A. quinquelatum* also occur along with the calcareous nannoplankton *Discoaster multiradiatus* (Jain *et al.*, 1983), which firmly assigns Late Palaeocene age, equivalent to the NP9 Zone.

We would also like to point out that the occurrence of *Apectodinium paniculatum* and *Apectodinium* sp. cf. *A. paniculatum*, the transitional forms between *A. augustum* and *A. paniculatum*, at sample depth 2703-2706 m suggests that cc10 is latest Palaeocene-earliest Eocene in age and may be confined to the dinocyst Biozone Aau that corresponds with the global acme of *Apectodinium*. Govindan (1982, text-fig. 3) has dated samples at 3015 m depth to be equivalent to P_3 zone and has tentatively inferred the core 2703-2706 m sample, lying in a poorly fossiliferous interval, to be equivalent to P_3-P_4 Zones.

The presence of *Apectodinium augustum* world over, has been recognised to be equivalent to the *M. velascoensis* Zone which has not been identified in the Narsapur Well-1 (Govindan, 1982, text-fig. 3). The occurrence of *Apectodinium* sp. cf. *A. augustum*, *A. quinquelatum* and *A. paniculatum* at "3621-3624 m" (probably representing younger level) is, therefore, complimentary and would prove very significant in defining and identifying the latest Palaeocene sediments in the subsurface of Krishna-Godavari Basin. Further, there is every possibility to precisely demarcate the Palaeocene/Eocene boundary in the Narsapur Well-1, if the restudy of dinoflagellate cysts through the bore-hole is carefully worked out.

Predominance of *Apectodinium* is considered to be indicative of low salinity, estuarine or near shore environment (Downie *et al.*, 1971; Costa & Downie, 1976). According to Hielmann-Clausen (1985) its acme represents reduced salinity in a depositional setting below wave base with anoxic bottom conditions (see Powell, 1988). In India, its association with nannofossil assemblage containing tiny braarudosphaerids in Gopurapuram subsurface sequence, Cauvery Basin has been attributed to low salinity, near shore, restricted marine conditions (Jain & Garg, 1986). The predominance of *Apectodinium* at 2703-2706 m depth (cc 10) in Narsapur Well-1, Krishna-Godavari Basin, is considered

to indicate the similar palaeoenvironmental conditions. The occurrence of mineral crystallite structures (pyrite relic structures), suggesting biodegradation of cyst walls, may indicate reducing depositional environment.

SOME OTHER OBSERVATIONS

(i) In the text (Mehrotra & Sarjeant, 1987, p. 169), a solitary record of *Dinogymnium acuminatum* is mentioned from Slide no. IPEP/NSP-1/3643/5 at the sample depth 3643-3649 m, whereas in the explanation of plate (pl. 4, figs 3-4), the depth is shown as 3621-3624 m. We could locate the specimen in the former slide (Coordinates: 45.3 × 103.1; Leitz Orthoplan Microscope).

(ii) The re-examination of the figured specimen (Slide no. IPEP/NSP-1/3643/2, cc 13, 3643-3649 m) described and illustrated as *Dinogymnium* sp. by Mehrotra and Sarjeant (1987, p. 170; pl. 3, fig. 4), revealed that it is an elongate cyst having broken apical region without any indication of archaeopyle and with a part of antapical horn preserved showing acrocavate nature, characteristic of the genus *Andalusiella*. The reported longitudinal ribs are infact the periphragmal folds. The deformity of lateral margins of the cyst due to bad preservation has been misinterpreted as "well developed cingulum". This specimen does not display any character of the dinoflagellate cyst genus *Dinogymnium*.

(iii) The distribution of *Tityrosphaeridium gracilis* (Eisenack) Sarjeant 1981 is reported to be infrequent at 2703-2706 m depth and absent in the underlying samples at depths 3621-3624 m and 3643-3649 m (Mehrotra & Sarjeant, 1987, p. 158, table 1). They reported the figured specimen from Slide no. IPEP/NSP-1/2703/5 at 2703-2706 m depth (p. 158), but in its explanation of plate (pl. 7, fig. 4), the depth is referred to be 3643-3649 m (cc 13). This prompted us to re-check the slides of both the samples. The figured specimen could be located in Slide no. IPEP/NSP-1/3643/5 (Coordinates: 53.4 × 102.5, Leitz Orthoplan Microscope), representing the same depth 3643-3649 m. The distribution of *Tityrosphaeridium gracilis* documented in these samples thus becomes unreliable and needs careful reassessment.

CONCLUSIONS

1. *Fibrocysta variabilis* Mehrotra & Sarjeant 1987 is a junior synonym of *Apectodinium paniculatum* (Costa & Downie) Lentin & Williams 1977.
2. *Fibrocysta* sp. in Mehrotra and Sarjeant (1987) belongs to *Apectodinium quinquelatum* (Williams & Downie) Lentin & Williams 1977.
3. Observations revealed that the dinoflagellate cyst assemblage at 2703-2706 m (cc 10) depth is strikingly dominated by *Apectodinium* spp. Its dominance is attributed to low salinity, shallow inner neritic, probably restricted marine environment with low oxygen bottom conditions.
4. Occurrence of *Apectodinium* spp. in type and figured slides of "3621-3624 m" depth (cc 13) is anomalous due to infra-trappean status and definite Late Maastrichtian age of these sediments. Re-checking of the slide/sample number is necessary.
5. Occurrence of *Apectodinium* sp. cf. *A. paniculatum* along with *A. paniculatum* at 2703-2706 m depth sample indicates the presence of latest Palaeocene-?earliest Eocene sediments equivalent to the planktonic foraminifer zones P5 (pars) + P6 (pars).
6. The dinoflagellate cyst data from Narsapur Well-1 is incomplete and needs thorough revision before being used for biostratigraphic analysis. A restudy of dinoflagellate cyst biostratigraphy of Narsapur Well-1 is recommended.

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