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A SEQUENCE OF DINOCYSTS FROM THE SUBSURFACE SEDIMENTS (VALANGINIAN-HAUTERIVIAN) OF THE KRISHNA-GODAVARI BASIN, INDIA

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ABSTRACT

The subsurface shales equivalent to the Raghavapuram Shale Formation of the Krishna-Godavari Basin yielded a sequence of dinocysts comprising seventy nine species belonging to forty one genera. A comparison with the Australian dinocyst sequence shows it to be of Valanginian-Hauterivian age. The overall palynomorph assemblage suggests that these shales were deposited in a very shallow marine nearshore, possibly brackish water environment with occasional influence of the open sea. Three new combinations are also proposed.

INTRODUCTION

The Krishna-Godavari Basin is situated at the eastern coast of the Indian Peninsula, approximately between latitude 12 and 18 degrees N and longitude 79 and 84 degrees E. It covers an area of approximately 29,650 square kilometers of which 9,580 square kilometers extend offshore down to the 200 M isobath. Thick sequences of sedimentary rocks crop out on the western margin of this basin, which is commonly referred to as "East Coast Gondwanas". Similar sequences of rocks are also found as isolated outliers along the eastern coast of peninsular India form Cuttack in the north to Tiruchirapalli (Trichinopoly) in the south, and most of these rocks are non-marine, and some asre shallow marine.

The stratigraphy, tectonics and evolution of the Krishna-Godavari Basin have been discussed by Sastri *et al.* (1973, 1974). Geophysical investigations indicate that, it is divided into three smaller sub-basins, namely the

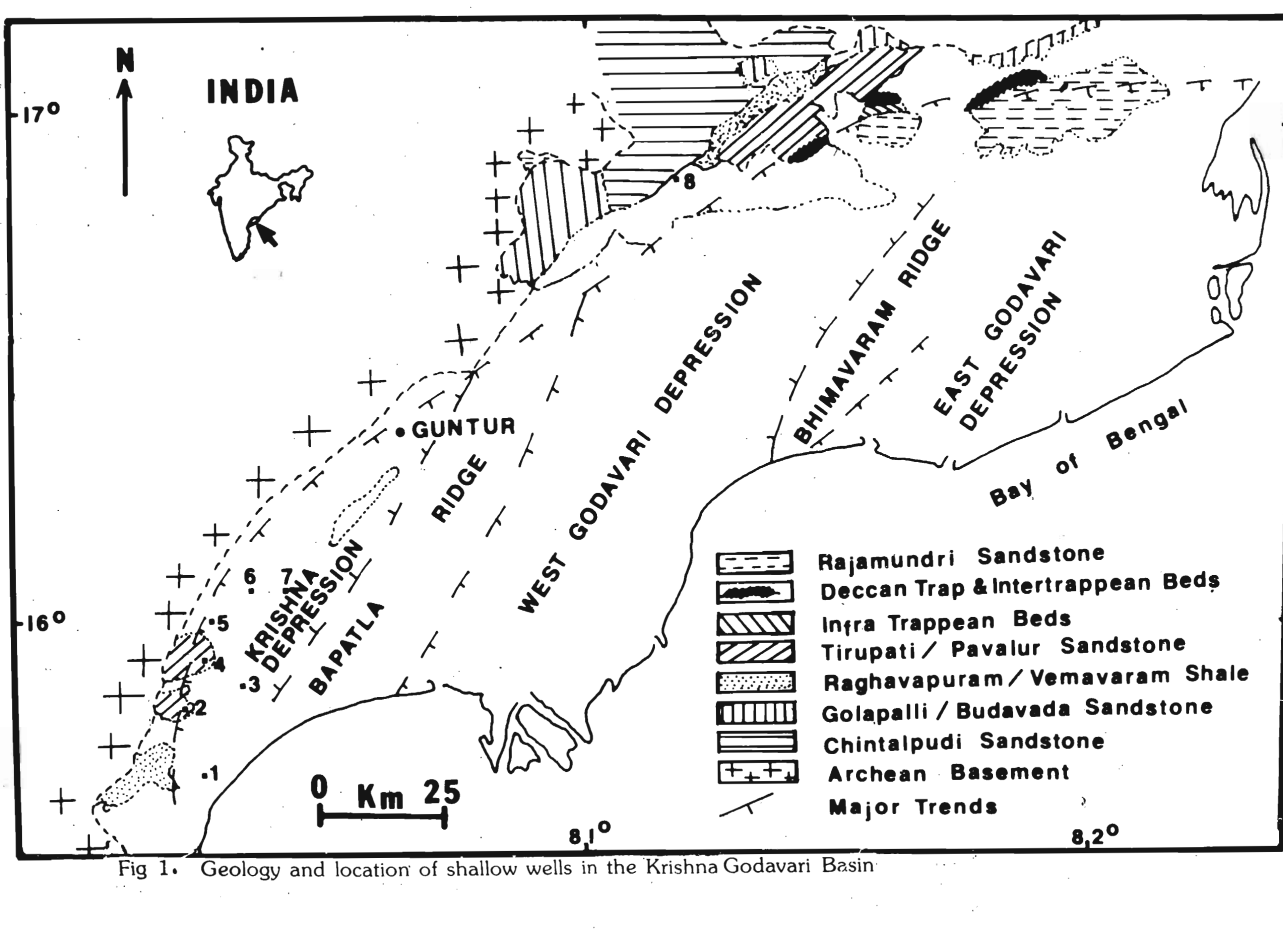

Fig 1. Geology and location of shallow wells in the Krishna Godavari Basin

Krishna Depression, West Godavari Depression, and East Godavari Depression, which are separated by the Bapatla-Vellupcharla Ridge and Bhimavarm —Tanaku Ridge respectively (Fig. 1).

This Basin contains an approximately 5,000 m thick column of sediments, ranging in age from Permian to Recent. Age, lithology and thicknesses of individual formations are given in tables 1 and 2. These rocks underlie Recent alluvium, except where they crop out at the western fringes of this basin (Fig. 1). The lithological sequence in the Kadavakoduru well (Fig. 2) indicates the typical nature of rocks in the suburface of this basin.

The position of the wells and the nineteen core samples from the eight shallow wells studied are shown in figure 1 and table 3. These shallow wells were drilled to a maximum depth of 200m, and cores were taken at various depths. The cores studied are all dark grey shales and represent rocks equivalent to Raghavapuram and Vemavarm Shale Formations (Sharma *et al.* 1977).

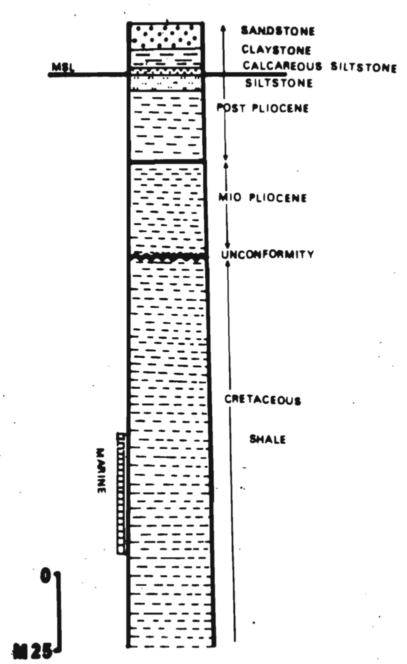

Fig. 2 Lithology of Dadavakoduru shallow well.

These shales were macerated by standard palynological techniques using HF and heavy liquid separation method for isolating the organic residue. The distribution of dinocysts in these nineteen samples is given in table 4.

This work was done during the author's employment with the Oil and Natural Gas Commission of India. The present paper is partly based on a report submitted by the author to the Institute of Petroleum Exploration, the Oil and Natural Gas Commission (Kumar, 1978), and a preliminary account of it was published later (Kumar, 1982). The present study, and the pollen and spores study of Sharma *et al.* (1977) was done on the same set of core samples and slides. The present paper re-evaluates the palaeoecological and age significance of the same dinocyst data (Kumar, 1978, 1982) in the light of recent morphologic and taxonomic advancements in dinoflagellate cyst studies.

Alphabetical list of dinocyst taxa

Genus *Achomosphaera* Evitt, 1963
? *A. neptunii* (Eisenack) Davey and Williams 1966a.
A ramulifera (Deflandre) Evitt, 1963

Genus *Apteodoinium* Eisenack, 1958
A. conjunctum Eisenack and Cookson, 1960
A. grande Cookson and Huges, 1964
A. granulatum Eisenack, 1958
A. maculatum Eisenack and Cookson, 1960
A. cf. spinosum (Alberti) Stover and Evitt, 1978 (Pl. 1, Fig. 1)

Genus *Ascodinium* Cookson and Eisenack, 1960a, emend. Helenes, 1983.
A. acrophorum Cookson and Eisenack, 1960a. (Pl. 1, Fig 10)

Genus *Bacchidinium* Davey, 1979b.
B. polypes (Cookson and Eisenack) Davey, 1979b.

Genus *Batiacasphaera* Drugg, 1970 emend. Dorhofer and Davies, 1980.
B. aptiense (Burger, 1980a) comb. nov.
B. crassiangulata (Burger, 1980b) comb. nov.
B. echinata (Gitmez and Sarjeant) Dorhofer and Davies, 1980
B. scrobiculata (Deflandre and Cookson) Burger, 1980b
B. spumosa (Brideaux, 1977) comb. nov.
Batiacasphaera sp. (Pl. 1, Fig. 4)

Genus *Batioladinium* Brideaux, 1975
B. micropodum (Eisenack and Cookson) Brideaux, 1975 (Pl. 1, Figs. 5-7).

Genus *Canningia* Cookson and Eisenack, 1960b emend Dorhofer and Davies, 1980 emend. Below, 1981.
C. colliveri Cookson and Eisenack, 1960b.
C. reticulata Cookson and Eisenack, 1960b emend. Below, 1981
Canningia sp. A. of Burger, 1980a

Genus *Cassiculosphaeridia* Davey, 1969a
C. magna Davey, 1974
C. reticulata, Davey 1969a

Genus *Chlamydophorella* Cookson and Eisenack, 1958
C. nyei Cookson and Eisenack, 1958

Genus *Cleistosphaeridium* Davey *et al.* 1966
C. aciculare Davey, 1969
C. granulatum Burger, 1980a
Cleistosphaeridium sp. of Brideaux 1977.

Genus *Coronifera* Cookson and Eisenack, 1958 emend. Davey, 1974.
C. oceanica Cookson and Eisenack, 1958 emend. May, 1980.

Genus *Cribroperidinium* Neale and Sarjeant, 1962 emend. Helenes, 1984
C. apione (Cookson and Eisenack) Helenes, 1984 (Pl. 2, Fig. 5)
C. muderongense (Cookson and Eisenack) Davey, 1969a.

Genus *Cyclonephelium* Deflandre and Cookson, 1955 emend.

Table 1. Outcrop sequence of Krishna-Godavari Basin. (Modified after Singh et.al., 1970)

AGE	FORMATION	THICKNESS IN METERS	LITHOLOGY
Recent to Subrecent		25	Alluvial sands. clays, marls and sandstones
Post Pleistocene		+200	Calcareous, Gypseous and Pyritous clays and silts
Mio-Pliocene	Rajamundry Sandstone	?720	Coarse grained, feruugenous Sandstone and Grits
Pre Miocene		+111	Clays and Sandstones
Eocene	Intertrappeans & Deccan Traps	133	Limestones, Clays and Marls interbedded with Basalts
Paleocene (unconfromity)	Infratrappeans	73	Grits, Calcareous sandstone and limestone
Barremian	Tirupati Sandstone	?830	Clayey and Lateritised Sandstone
Neocomian (unconformity)	Raghavapuram Shale	+167	Shale with lenses of Sandstones
Middle Jurassic (unconformity)	Golapalli Sandstone	200	Micaceous, Ferrugenous Sandstones with Clays
Upper Permian (unconformity)	Chintalpudi Sandstone	2000	Conglomerates, sandstones and shales
ARCHEAN BASEMENT			

Table 2. Correlation of various formations in Krishna-Godavari Basin. (Modified after Singh et.al. 1970)

AGE	WEST OF KRISHNA RIVER	BETWEEN KRISHNA AND GODAVARI RIVERS	EAST OF GODAVARI RIVER
		Post Pleistocene	
Mio-Pliocene	RAJAMUNDRI SANDSTONE		
	?	Pre Miocene Sediments	?
Eocene	?	Deccan Traps with Intertrappeans	
Paleocene (unconfromity)	?	Infra trappean Beds	?
Barremian (unconformity)	Pavalur Sandstone	Tirupati Sandstone	
Neocomian (unconformity)	Vemavaram Shale	Raghavapuram Shale	?
Middle Jurassic (unconformity)	Budavada Sandstone	Golapalli Sandstone	?
Upper Permian (unconformity)		Chintalpudi Sandstone	?
ARCHEAN BASEMENT			

Table 3. Sample Location

Shallow Well No.	Core Sample Number	Depth In Meter (C/T = centimeter from top)
1	1	168-170 (10-15 C/T)
2	2	44.30-46.30 (0-7 C/T)
2	3	108-110 (46-62 C/T)
2	4	132-134 (5-19 C/T0
2	5	153.50-155.50 (64-79 C/T0
3	6	168.20-170 (86-94 C/T)
4	7	138-140 (88-96 C/T)
4	8	198-200 (50-54 C/T)
5	9	198-200 (5-14 C/T)
6	10	150.5-152.5 (0-5 C/T)
7	11	108-110 (19-28 C/T)
7	12	108-110 (104-114 C/T)
7	13	108-110 (154-157 C/T)
7	14	135-137 (23-39 C/T)
7	15	135-137 (169-177 C/T)
7	16	155-157 (33-53 C/T)
7	17	198-200 (110-129 C/T)
8	18	38-40 (12-18 C/T)
8	19	92-95 (112-128 C/T)

Stover and Evitt, 1978.
C. areolatum Cookson and Eisenack, 1960b (Pl. 1, Fig. 9)
C. densebarbatum Cookson and Eisenack, 1960b (Pl. 1, Fig. 11)
C. distinctum Deflandre and Cookson, 1955
C. hystrix (Eisenack) Davey, 1978

Genus *Dapsilidinium* Bujak *et al.* 1980
D. multispinosum (Davey) Bujak *et al.* 1980 (Pl. 1, Fig. 12 and Pl. 2, Fig. 1)

Genus *Dingodinium* Cookson and Eisenack, 1958 emend. Mehrotra and Sarjeant, 1984
D. cerviculum Cookson and Eisenack, 1958 emend. Mehrotra and Sarjeant, 1984

Genus *Discorsia* Duxbury, 1977 emend. Ateequzzaman *et al.* 1985
D. nanna (Davey) Duxbury, 1977 emend. Ateequazzman *et al.* 1985.

Genus *Endoscrinium* (Klement) Vozzhennikova, 1967
E. luridum (Deflandre) Gocht, 1970b

Genus *Fromea* Cookson and Eisenack, 1958
F. amphora Cookson and Eisenack, 1958
F. fragilis (Cookson and Eisenack) Stover and Evitt, 1978
F. glabella (Singh) Lentin and Williams, 1981

Genus *Hystrichodinium* Deflandre, 1935 emend. Clarke and Verdier, 1967
H. oligacanthum Deflandre and Cookson 1955
H. pulchrum Deflandre, 1935

Genus *Hystrichogonyaulax* Sarjeant, 1969
H. serrata (Cookson and Eisenack) Stover and Evitt, 1978.

Genus *Hystrichosphaeridum* Deflandre, 1937b emend. Davey and Williams, 1966b.
H. arborispinum Davey and Williams, 1966b
H. tubiferum (Ehrenberg) Davey and Williams.

Genus *Kallosphaeridium* De Coninck 1969
K. granulatum (Norvick) Stover
K. norvickii (Burger) Lentin and Williams. 1981 (Pl.1, Figs.2-3)
K. romaense (Burger) Burger, 1980b.

Genus *Kleithriasphaeridium* Davey, 1974
K. eoindoes (Eisenack) Davey, 1974
K. simplicispinum (Davey and Williams) Davey, 1974 (Pl. 2, Fig. 2)

Genus *Leberidocysta* Stover and Evitt, 1978.
L. chlamydata (Cookson and Eisenack) Stover and Evitt, 1978.
L. defloccata (Davey and Verdier) Stover and Evitt, 1978.

Genus *Leptodinium* Klement, 1960 emend. Sarjeant, 1982.
L. simplex Burger, 1980a (Pl. 2, Fig. 3)

Genus *Lithodinia* Eisenack, 1935 emend. Gocth, 1975b.
L. cf. *jurassica* Eisenack, 1935 emend. Gocht, 1975b.

Genus *Mendicodinium* Morgenroth, 1970
Mendicodinium sp.

Genus *Muderongia* Cookson and Eisenack, 1958
M. mcwhaei Cookson and Eisenack, 1958 (Pl. 2, Fig. 4)
M. staurota Sarjeant, 1966c

Genus *Nummus* Morgan, 1975
N. monoculatus Morgan, 1975

Genus *Oligosphaeridium* Davey and Williams, 1966b
O. complex (White) Davey and Williams, 1966b.
O. dictyophorum (Cookson and Eisenack) Davey and Williams, 1969
O. pulcherrimum (Deflandre and Cookson) Davey and Williams, 1966b.

Genus *Pareodinia* Deflandre, 1947c emend. Stover and Evitt, 1978

Table 4 Distribution of dinocyst taxa in the core samples.

TAXA / SAMPLE No. →	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
ACHOMOSPHAERA ? NEPTUNII	X					X													
A. RAMULIFERA						X													
APTEODINIUM CONJUNCTUM	X																		
A. GRANDE									X										
A. GRANULATUM																		X	
A. MACULATUM	X																X		
A. SPINOSUM							X	X											
ASCODINIUM ACROPHORUM	X				X														X
BACCHIDINIUM POLYPES		X	X												X		X		X
BATIACASPHAERA APTIENSE									X										
B. CRASSIANGULATA							X		X							X	X		
B. ECHINATA															X	X			
B. MINOR								X	X		X		X		X	X	X	X	X
B. PILOSA	X							X			X								
B. SCROBICULATA									X	X									
B. SPUMOSA							X												
BATIACASPHAERA SP.										X									
BATIOLADINIUM MICROPODUM							X			X									
CANNINGIA COLLIVERI								X								X		X	X
C. RETICULATA															X				X
CANNINGIA SP. A OF BURGER, 1980								X		X									
CASSICULOSPHAERIDIA MAGNA																	X		
C. RETICULATA											X				X				
CHLAMYDOPHORELLA NYEI																	X	X	
CLEISTOSPHAERIDIUM ACICULARE	X									X	X	X	X		X	X			
C. GRANULATUM						X		X						X	X	X	X		
CLEISTOSPHAERIDIUM SP. OF BRIDEAUX, 1977		X																	
CORONIFERA OCEANICA						X													
CRIBROPERIDINIUM APIONE	X											X		X					
C. MUDERONGENSE	X		X										X		X		X		
CYCLONEPHELIUM AREOLATUM							X						X			X	X		
C. DENSEBARBATUM	X		X												X	X	X		
C. DISTINCTUM							X		X		X		X		X		X		
C. HYSTRIX	X																		
DAPSILIDINIUM MULTISPINOSUM							X				X								
DINGODINIUM CERVICULUM	X	X	X			X	X	X	X				X		X	X	X		
DISCORSIA NANNA								X											
ENDOSCRINIUM LURIDUM									X										
EXOCHOSPHAERIDIUM PHRAGMITES	X													X	X	X			
FROMEA AMPHORA									X										
F. FRAGILIS															X			X	X
F. GLABELLA	X																		
HYSTRICHODINIUM OLIGACANTHUM															X	X			
H. PULCHRUM																	X		
HYSTRICHOGONYAULAX SERRATA									X						X				
HYSTRICHOSPHAERIDIUM ARBORISPINUM				X	X		X						X						
H. TUBIFERUM									X										
KALLOSPHAERIDIUM GRANULATUM													X						
KALLOSPHAERIDIUM NORVICKII						X	X		X	X			X		X		X		X
K. ROMAENSE													X				X		
KLEITHRIASPHAERIDIUM EOINODES	X												X						
K. SIMPLICISPINUM		X			X			X											
LEBERIDOCYSTA CHLAMYDATA															X		X		X
L. DEFLOCCATA							X								X		X		X
LEPTODINIUM SIMPLEX	X	X		X			X						X		X				
LITHODINIA CF. JURASSICA									X										
CF. MENDICODINIUM SP.	X														X				X
MUDERONGIA MACWHAEI										X									
M. STAUROTA	X					X	X			X		X	X		X	X	X		
NUMMUS MONOCULATUS																		X	X
OLIGOSPHAERIDIUM COMPLEX											X	X	X		X			X	
O. DICTYOPHORUM				X	X	X													
O. PULCHERRIMUM								X		X							X		
PAREODINIA CF. CERATOPHORA							X	X		X							X	X	
PHOBEROCYSTA NEOCOMIA																			X
PROLIXOSPHAERIDIUM CAPITATUM							X										X		
P. CONULUM									X										
PROTOELLIPSOIDINIUM SP.							X												
RHYNCHODINIOPSIS APTIANA	X														X	X			
R. HYALODERMOPSIS	X																		
SCRINIODINIUM ATTADALENSE		X																	
SPINIFERITES ? PTEROSUS	X				X					X									
S. RAMOSUS GRANOMEMBRANACEOUS													X				X		
S. RAMOSUS RAMOSUS			X	X	X		X			X	X		X		X	X	X		
S. SCABROSUS						X							X						
TANYOSPHAERIDIUM CF. ISOCALAMUM							X	X	X										
WALLODINIUM GLAESSNERI								X											
FORMA – A							X	X											

P. cf. *ceratophora* (Deflandre) Gocht, 1970b.
Genus *Phoberocysta* Millioud, 1969
P. neocomia (Gocht) Millioud, 1969
Genus *Prolixosphaeridium* Davey *et al.* 1966
P. capitatum (Cookson and Eisenack) Singh, 1971
P. conulum Davey, 1969a (Pl. 1. Fig. 8)
Genus *Protoellipsoidinium* Davey and Verdier, 1971
Protoellipsoidinium sp.
Genus *Rhynchodiniopsis* Deflandre, 1935 emend. Sarjeant, 1982
R. aptiana Deflandre, 1935 emend. Sarjeant, 1982
R. hyalodermopsis (Cookson and Eisenack) Sarjeant, 1982.
Genus *Scriniodinium* Klement, 1957
S. attadalense (Cookson and Eisenack) Eisenack, 1967
Genus *Spiniferites* Mantell, 1850 emend. Sarjeant, 1970
S. cf. pterotus (Cookson and Eisenack) Sarjeant, 1970 (Pl. 2, Fig. 6, 7)
S. ramosus granomembranaceous (Davey and Williams) Lentin and Williams, 1973
S. ramosus ramosus (Ehrenberg) Loeblich and Loeblich, 1966.
S. scabrosus (Clarke and Verdier) Lentin and Williams, 1975
Genus *Tanyosphaeridium* Davey and Williams, 1966b
T. cf. *isocalamum* (Deflandre and Cookson) Davey and Williams, 1969 (Pl. 2, Fig. 11)
Genus *Wallodinium* Loeblich and Loeblich, 1968
W. glaessneri (Cookson and Eisenack) Loeblich and Loeblich, 1968

MORPHOLOGIC AND TAXONOMIC COMMENTS:

Batiacasphaera DRUGG,1970 emend. DORHOFER DAVIES, 1980
Batiacasphaera aptiense (BURGER, 1980 a) Comb. nov.
Tenua apfiense BURGER 1980a, P. 26, Pl. 23. Figs. 1,5 and Pl. 24, Fig. 1
Batiacasphaera crassiangulata (BURGER 1980b) comb. nov.
Canningia crassinagulata (BURGER, 1980b P.268 Figs. 4c,d.
Batiacasphaera spumosa (BRIDEAUX, 1977) Comb. nov.
Canninga spumosa (BRIDEAUX, 1977, P.12 Pl.3, Figs 9-14.
Genus Leptodinium KLEMENT, 1960 emend. SARJEANT 1962.

Leptodinium simplex BURGER, 1980a.

(Pl, II—3)

Comments: *Leptodinium simplex* (Burger, 1980a) is only provisionally accepted by Sarjeant (1982) because of the uncertainty of the anterior ventral paratabulation. The present specimens are assigned to this species because they compare well with the description and illustration of Burger (1980a, Pl. 52, Figs. 1-5)

Genus Spiniferites MANTELL, 1850 emend, SARJEANT, 1970.

Spiniferites cf. *pterouts* (COOKSON and EISENACK SARJEANT, 1970

(Pl. III—6, 7)

Comments: Stover and Evitt (1978) have accepted this species only provisionally because ventral and apical paratabulation is unknown. Below (1981) considers it to be a junior synonym of *Pterodinium cingulatum* (O. Wetzel, 1933).

The present specimens show a gonyaulacacean paratabulation, whereas the paratabulation features of *Pterodinium* Eisenack, 1958 are unknown (Stover and Evitt, 1978), thus these specimens from India are assigned to the genus *Spiniferites* Mantell, 1850 emend. Sarjeant, 1970. The present specimens compare well with the description and illustration of *S. pterotus* in the literature, except that Indian specimens are subspherical and elongated along the apex-antapex axis rather than spherical.

This species has been recorded both from the Albian and Senonian of Australia (Cookson and Eisenack). Thus the presence of this species in the present sequence could be due to mixing with younger rocks as contaminents or possibly this species appeared earlier in India.

Genus Tanyosphaeridium DAVEY and WILLIAMS 1966b.

Tanyospheridium cf. *isocalamum* (DEFLANDRE & COOKSON) DAVEY & WILLIAMS, 1969

(Pl. II—11)

Comments: The processes in the present specimens are distally open with foliate, digitate or slightly bifurcate ends, whereas the processes in *T. isocalamum* ,have truncated ends. Secondly, the process length in the present specimens varies from 5- 8 m, which is smaller than the normal range of 10- 11 m in *T. isocalamum*.

Forma—A

(Pl. II—8, 9, 10)

Description: These are proximate, oval-elongated cysts having two poorly developed antapical horns and one apical horn. Paracingulum and parasulcus are absent. Paratabulation is indistinct as neither the arrangement of paraplates nor the archaeopyle is discernible. Wall two-layered, the endophragm is thicker and reticulate, whereas periphragm is thin and psilate. Both the walls are in close contact except at the apical and antapical ends, and may also form other smaller lamellar extensions around the cyst. The development of irregular and interconnecting septa on the endophragm give a false appearance of paraplate boundaries. Since these septa are so irregular, no paratabulation pattern can be deduced.

Comments: Only three such specimens have been observed. They are quite unique in their morphology. Apparantly they appear to be similar to *Ellipsoidictyum* Klement (1960), but differ in not having an apical archaeopyle, and developing short apical and antapical horns.

DISCUSSION

(a) AGE OF THE ROCKS:

The systematic account of foraminifera of the Raghavapuram Shale Formation has been published by Sastri *et al.* (1961, 1963), Bhalla (1965, 1968, 1969a, b, 1972) and Baksi (1966). This foraminiferal assemblage is mainly arenaceous and the main genera recorded are *Haplophragmoides* and *Ammobaculites*. The age ot the Raghavapuram Shale Formation has been discussed by Bhalla (1969-a) as, "In the absence of marker species of foraminifera in the Raghavapuram Shales, it has not been possible to fix precisely the age of these beds, but the overall predominance of Lower Cretaceous forms indicates that Raghavapuram Shales were deposited during Lower Cretaceous (Neocomian) times".

Sharma *et al.* (1977) studied the same set of core samples and slides as I for the present study, and published the pollen and spores sequences. They concluded that the Raghavapuram Shale Formation and the Vemavaram Shale Formation contain the same flora and as such are homotaxial and they are taken to be of Lower Cretaceous age.

In the light of present uncertainties regarding the age of the Raghavapuram Shale Formation, the present sequence of dinocysts offers valuable information. Since there are no published accounts of Neocomian dinocyst sequences from the Indian subcontinent, the present sequence has been compared with other parts of the world, especially Australia. The comparison has been made with only recently published, well dated and comprehensive Neocomian dinocyst sequences. The comparison with the Australian region is based on data given by Burger (1980b, 1982a, b) Cookson and Eisenack (1958,1960b. 1974), Morgan (1975, 1980); with European by Bjaerke (1978), Davey (1979), Duxbury (1977, 1980), Piasecki (1979), Srivastava (1984); offshore Northwest Africa by Williams and Bujak (1980), and North America and North Atlantic by brideaux (1977), Habib (1975, 1978) and Habib and Drugg (1983). An analysis of these comparisons clearly reveals that the present sequence of dinocysts compares best with the Australian sequences of the same age. Although there are several common taxa present in the Indian and European sequences, such common taxa are many more in the Australian sequences. North American and North Atlantic sequences do not have many common taxa with present Indian assemblage at the species level.

Burger's (1982a) study of Neocomian dinocyst sequences from the Carpentaria Basin, Northern Queensland, Australia is both comprehensive and quite recent. He proposed three informal zones DK1, DK2 and DK3 for these sediments. The age assignment to these zones are based on the occurrence of diagnostic dinosyst taxa, whose ranges were well documented in various basins in Australia, Europe and North America. The present dinocyst sequence from India compares very well with the DK2 and DK3 zones of Burger (1982a), which has been dated as Valanginian and Hauterivian respectively. The common taxa are *Apteodinium granulatum, A. maculatum, Batiacasphaera aptiense, B. minor, B. pilosa, B. scrobiculata, B. crassiangulata, Batioladinium micropodum, Canningia reticulata, Cassiculosphaeridia magna, C. reticulata, Chlamydophorella nyei, Cleistosphaeridium granulatum, Coronifera oceanica, Cyclonephelium densebarbatum, C. distinctum, Dingodinium cerviculum, Exochosphaeridium phragmites, Formea amphora, F. fragilis, Hystrichodinium oligacanthum, H. pulchrum, Kallosphaeridium norvickii, K. romaense, Laberidocysta defloccata, Lepodinium simplex, Lithodininia* cf. *jurassica, Muderongia mcwhaei, M. staurota, Nummus monoculatus, Oligosphaeridium complex, O. dictyophorum, O. pulcherrium, paredoinia* cf. *ceratophora,* *phorum, O. pulcherrimum, pareodoinia* of. *ceratophora,* *tum, Spiniferites ramosus ramosus* and *Tanyosphaeridium* cf. *isocalamum*. Several taxa of the *Gonyaulacysta-Cribroperidinium* complex are also common to both sequence. The following six taxa from the above list also occur in the KD-1 zone. They are: *Apteodinium granulatum, Batiacasphaaera crassiangulata, Lithodinia* cf. *jurassica, Oligosphaeridium dictyophorum. Pareodinia* cf. *ceratophora* and *Prolixosphaeridium capitatum*. But these taxa could be reworked from older Jurassic rocks as they are reported in the Upper Jurassic assemblages from India (Jain *et al.* 1984) and (Kumar, in press).

Some of the taxa from the present sequence are long ranging and also occur in Barremian or younger sediments. But the absence of *Odontochitina operculata*, whose earliest occurrence in the Australian region is supposed to be Barremian (Burger, 1982a), suggests that the present dinocyst sequence could be older than Barremian.

Srivastava (1984) published an assemblage from the type Barremian from Southern France. Several of the French Barremian species are also found in the preent sequence from India. They are *Bacchidinium polyes, Batiacasphaera echinata, B. minor, B. norvickii, B. scrobiculata, B. spumosa, Batioladinium micropodum, Canningia colliveri, C. reticulata, Cassiculosphaeridia magna, C. reticulata, Chlamydophorella nyei, Cleistosphaeridia magna, C. reticulata, Chlamydophorella nyei, Cleistosphaeridium aciculare, Coronifera oceanica, Cyclonephelium distinctum, Dapsilidinium multi-*

spinosum, Dingodinium cerviculum, Exochosphaeridium phragmites, Hystrichodinium pulchrum, Hystrichospaeridium arborispinum, H. tubiferum, Muderongia mcwhaei, M. staurota, Nummus monoculatus, Oligosphaeridium complex, Phosberocysta neocomia and *Spiniferites ramosus ramosus*. This suggests the possibility of Barremian as the uppermost time limit for the Raghavapuram Shale Formation. This is also evidenced by the presence of *Ascodinium acrophorum*, which is a typically Aptian-Albian species, but also found in the Barremian (Helenes, 1983).

Thus it is concluded that the present dinocyst sequence is of Valanginian to Hauterivian age, but the upper age limit could possibly be Barremian also.

(b) PALAEOGEOGRAPHY AND PALAEOECOLOGY: More than fifty percent of the dinocyst species from the present sequence are common to the age-equivalent assemblages described from Australia. Such a close comparison becomes quite obvious, if we look at the Cretaceous (100 ± 10 m.y.b.p.) map of Smith *et al.* (1973). Although the Neocomian would cover the time period between 120 to 140 m.y.b.p. (Palmer, 1983), this map gives us a good approximation of the proximity of India and Australia during Neocomian times. The Krishna-Godavari Basin in India and most of the sedimentary basins of Australia consulted in this study are quite close to each other and fall between 45° to 55° south latitude. It could be argued that both regions had similar climatic conditions and also had possible sea connections.

A Barremian paleogeographic map of Srivastava (1984) erroneously shows the east coast of the Indian peninsula as a land area. The Barremian time in the Krishna-Godavari Basin is represented by the Tirupati Sandstone Formation, which contains some ammonites and belemnites along with bivalves like *Trigonia, Inoceramus, Pseudomonotis, Lima* and *Pecten* (Krishnan, 1960). This definitely indicates the presence of a marine environment in the region during the Barremian and Early Neocomian as also indicated by the presence of dynocysts in the Raghavapuram Shale Formation. This sea was most probably connected with the Neocomian seas of the Australian region.

Both the age and depositional environment of the Raghavapuram Shale Formation are problematic. Bhalla (1965) concluded that these shales were deposited in a shallow, brackish, rather marshy environment. According to Baksi (1966) the lower and middle part of these shales were deposited in a nearshore, brackish water lagoonal evironment, and the upper part of this sequence was deposited in open marine conditions. Bhalla (1968) refuted Baski (1966), and after an extensive discusstion, he concluded that, "deposition of the Raghavapuram Shale Formation commenced in a nearshore, shallow water environment which had open sea connections, thus allowing the free but sporadic movement of a few ammonite and other megafossils to the site of deposition. Thereafter sea regressed and the basin gradually became land locked. The salinity of the water body also decreased appreciably due to intake of fresh water from the adjacent land area, resulting in the development of marshy conditions. This is evident from the exclusive occurrence of arenaceous foraminifera in the upper beds of the Raghavapuram Shales". Sastri *et al.* (1973) studied the subsurface core samples from the shallow wells, and further commented, "in the beginning of the Early Cretaceous (Neocomian) a marine transgression initiated paralic sedimentation, which resulted in the formation of the Raghavapuram Shale Formation and its equivalents found in the shallow wells".

The subsurface equivalents of the Raghavapuram and Vemavaram Shales also have arenaceous foraminifera indicating that they are equivalent to the upper part of the Raghvapuram Shale outcrops studied by Bhalla (1968). The palynomorph assemblage of these subsurface sediments is dominated by land derived spores and pollen along with abundant cuticular and woody tissues in most of the core samples. Generally dinocysts are under represented in the assemblage of palynomorphs. Few core samples are rich in dinocyst assemblages, but numerically they are either equal to or less than pollen and spores. This would indicate that these subsurface shales were deposited in very shallow, nearshore marine possibly in a brackish water environment, which was occasionally influenced by open marine conditions.

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The views expressed in this paper are of the author only, not necessarily of ONGC.

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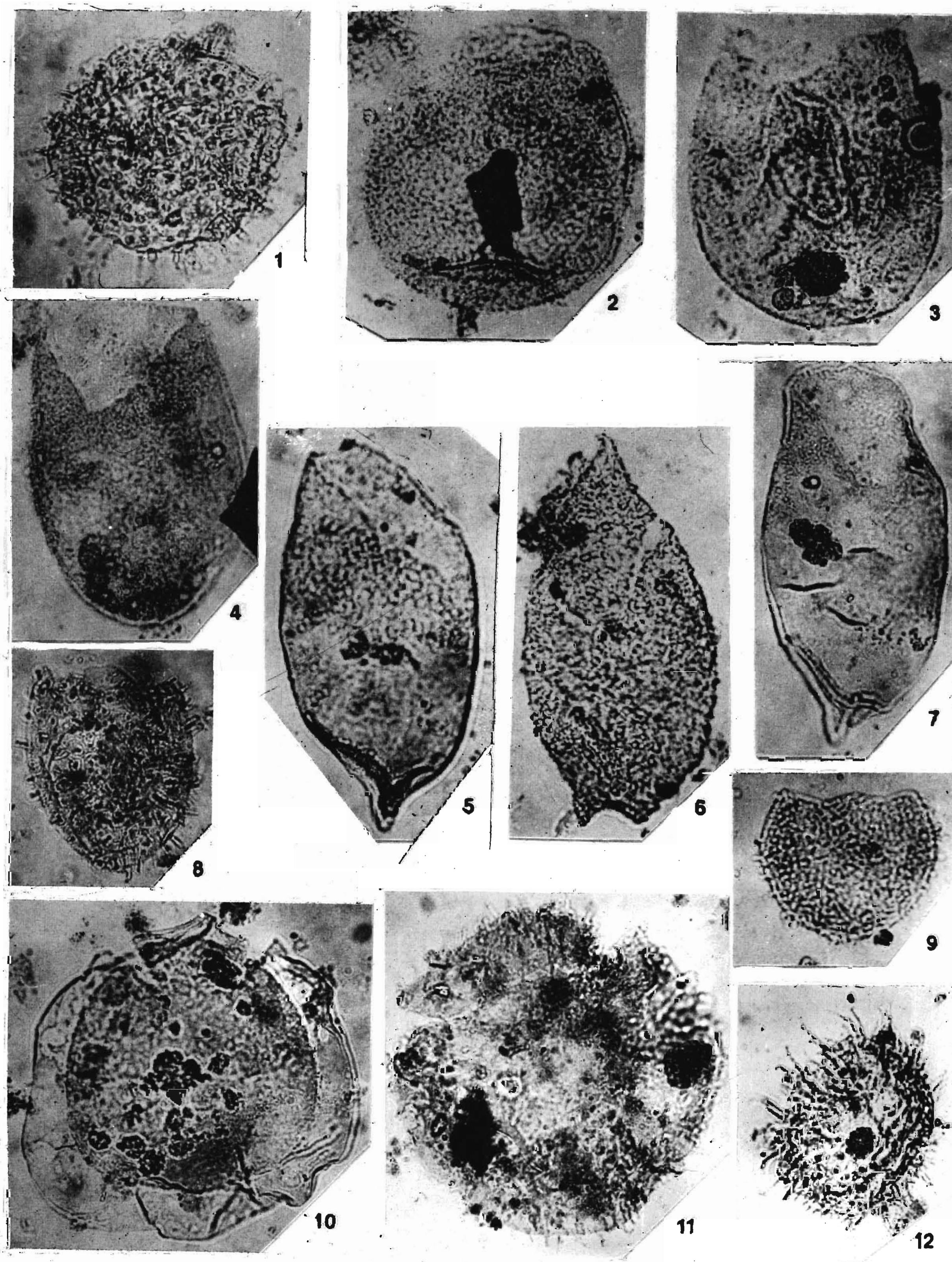
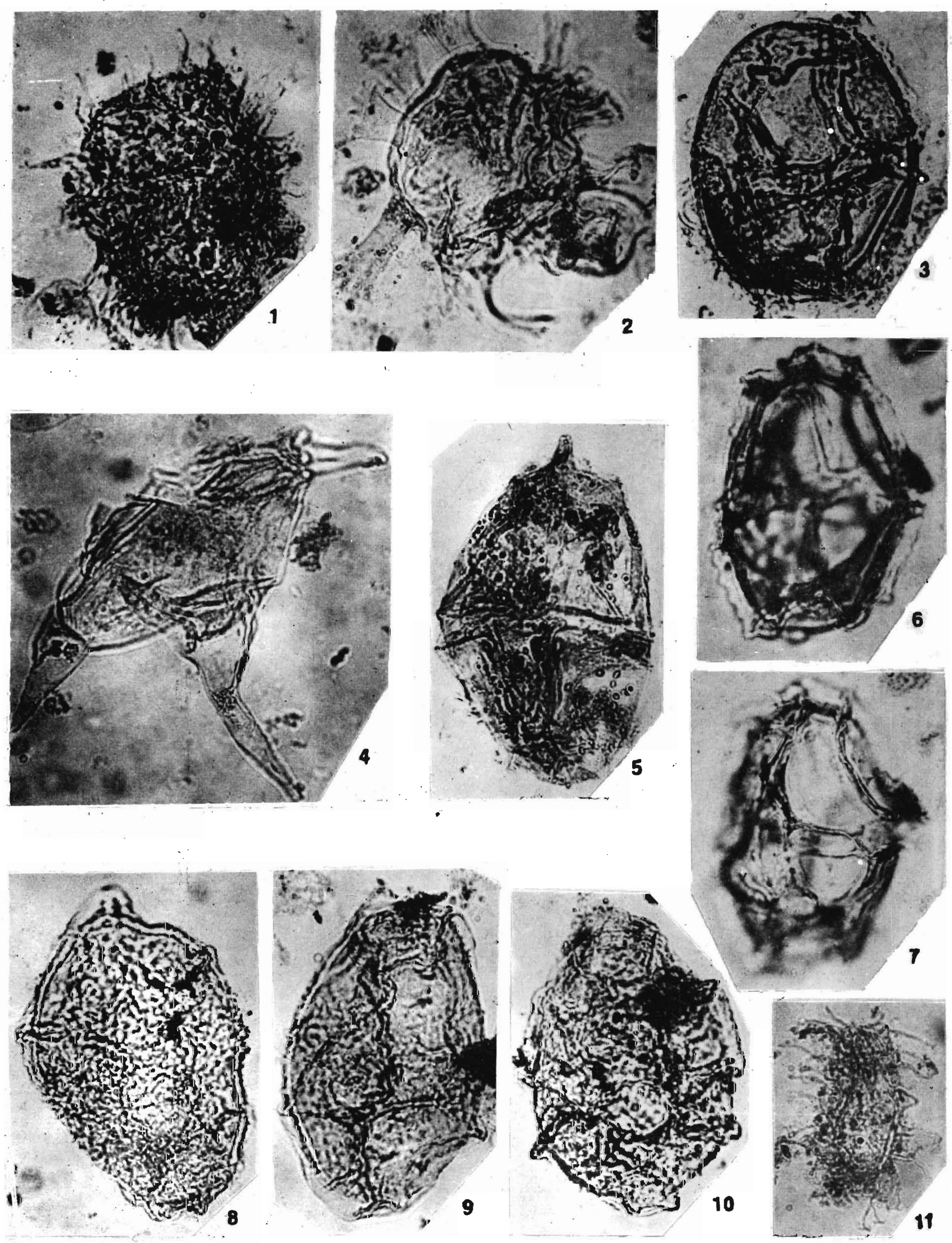
PLATE I



KUMAR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EXPLANATION OF PLATES

(Approximate Magnification X 650)

PLATE I

1. *Apteodinium cf. spinosum*
2–3 *Kallosphaeridium norvickii.*
4 *Batiacasphaera sp.*
5–7 *Batioladinium micropodum*
8 *Prolixosphaeridium capitatum*
9 *Cyclonephelium areolatum*
10 *Ascodinium acrophorum*
11 *Cyclonephelium densebarbatum*
12 *Dapsilidinium multispinosum*

PLATE II

1 *Dapsilidinium multispinosum*
2 *Kleithriasphaeridium simplicispinum*
3 *Leptodinium simplex*
4 *Muderongia mcwhaei*
5 *Cribroperidinium apione*
6–7 *Spiniferities cf. pterosus*
8-10 *Forma A*
11 *Tanyosphaeridium cf. isocalamum*

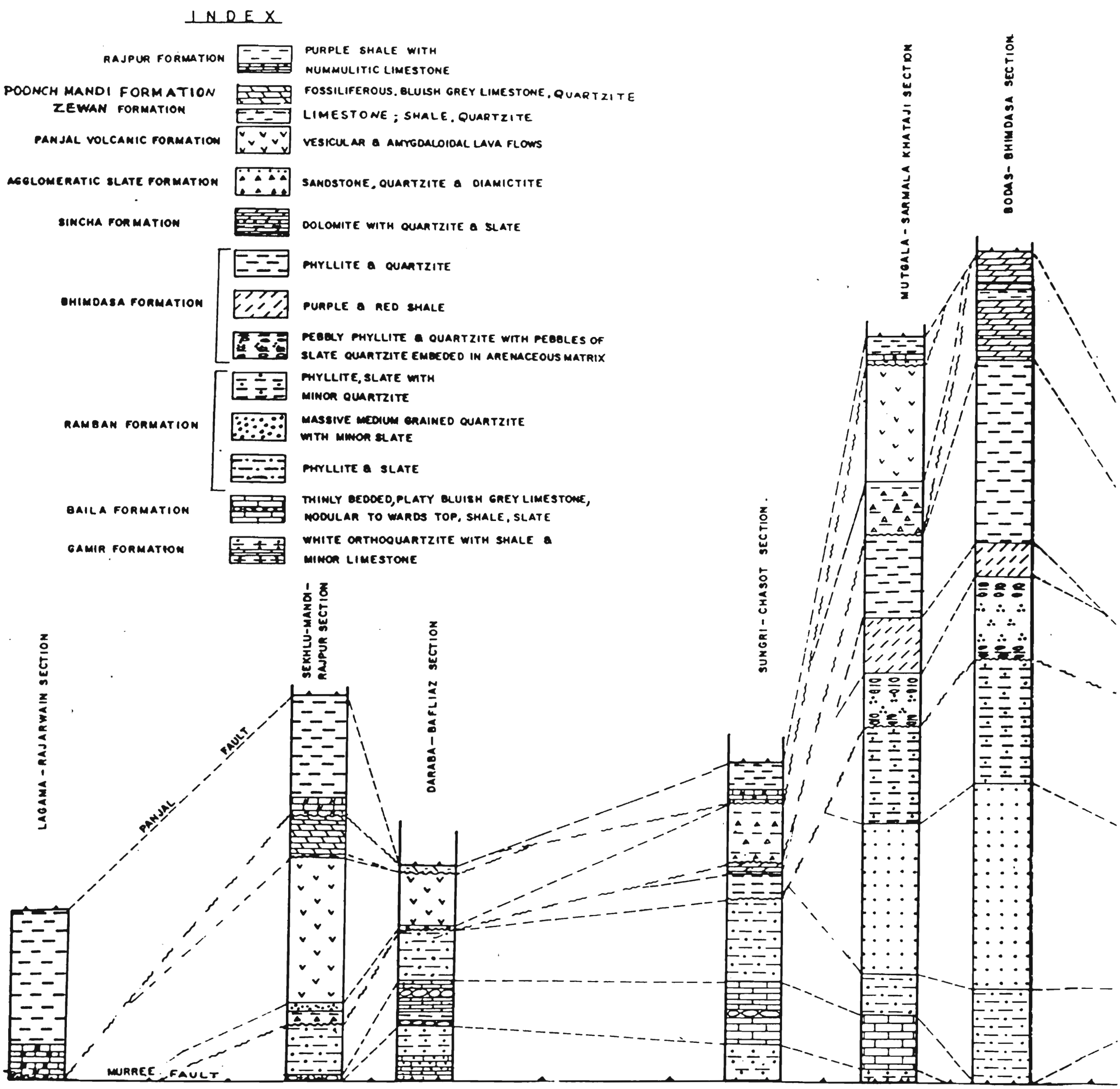
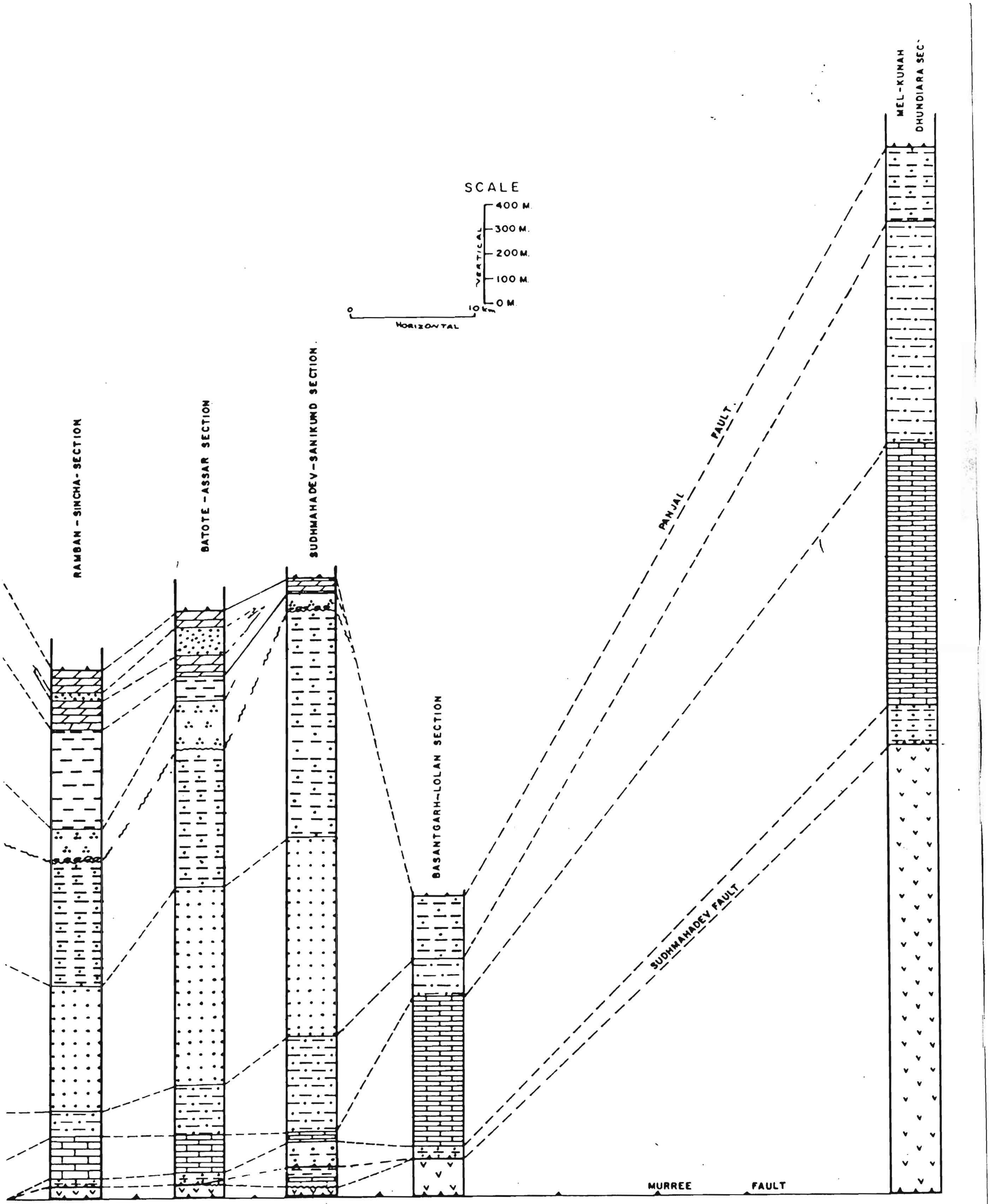


Fig. 2

B.S. JANGPANGI[1], G. KUMAR, DES RAJ PATHORE[2] AND SABIR DUTTA[3]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BATOTE - ASSAR SECTION
SUDHMAHADEV - SANIKUND SECTION
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DHUNDIARA SEC
SCALE
400 M.
300 M.
200 M.
100 M.
0 M.
VERTICAL
0
10
HORIZONTAL
PANJAL FAULT
SUDHMAHADEV FAULT
MURREE FAULT