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High Resolution Biostratigraphy of Post-Gondwana Pre-Cretaceous and Cretaceous successions from Pennar Sub-basin, Krishna-Godavari Basin, India

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High resolution integrated palynostratigraphic and foraminiferal studies are undertaken on the Post- Gondwana Pre - Cretaceous and Cretaceous sediments encountered in the exploratory wells A and B drilled in the shallow offshore regions of Pennar Subbasin of Krishna-Godavari Basin. This study has been undertaken with an objective to determine precise age and depositional environment of various post-Gondwana Late Jurassic-Early Cretaceous synrift and Late Cretaceous passive-margin lithounits. The oldest Post-Gondwanic synrift sediments of Late Jurassic (Kimmeridgian - Tithonian) are recorded above the Precambrian basement in well A. The Kimmeridgian-Tithonian boundary is tentatively marked at 1650 m depth in well A and 3545 m in well B on the basis of record of LAD of age marker dinoflagellate cyst Senoniasphaera jurassica. The top of Tithonian is marked on the basis of recognition of LAD of dinoflagellate cyst *Pseudoceratium weymouthense* at 1420 m depth in well A and 2945 m in well B. The characteristic palynofossils of Permo - Triassic Gondwana and Lower to Middle Jurassic are not recorded, indicating the absence of complete Gondwana and major part of the Jurassic sediments from Hettangian to Oxfordian in the Pennar Subbasin. The post-Gondwana Late Jurassic-Early Cretaceous synrift sediments directly rest over the Precambrian Basement. Fifteen globally established Late Jurassic to Late Cretaceous dinoflagellate cyst bio-events, ranging from Kimmeridgian–Tithonian (155-145 Ma) to Turonian-Coniacian(89-85 Ma) are recognized in the studied sequences of above two wells that helped in precisely recognizing the stratigraphic boundaries of Kimmeridgian, Tithonian, Berriasian, Valanginian, Hauterivian, Barremian, Aptian, Albian, Cenomanian, Turonian and Coniacian in the Pennar Subbasin. Four important planktonic foraminiferal events are recorded in the Aptian-Albian-Cenomanian interval of the two wells. Aptian marker planktonic foraminifera *Hedbergella sigali* and *Globigerinelloides blowi* have been recorded. *Planomalina buxtorfi* and *Hedbergella gorbachikae* have been useful in demarcating Albian. Besides, *Favusella washitensis*, *Rotalipora gandolfi* and benthic aragonitic foraminifera *Epistomina* sp. are useful forms in the Albian-Cenomanian transition. The recorded palynofloral assemblages indicate the presence of oldest synrift sediments of Kimmeridgian-Tithonian age of Late Jurassic in the Pennar Sub-basin, deposited under the shallow marine conditions, whereas, middle to outer shelf conditions prevailed during Early Cretaceous. The Late Cretaceous sediments are deposited under inner shelf conditions. The present record of oldest synrift sediments of Late Kimmeridgian predates the break-up time of Indian Plate from East Gondwana land.

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INTRODUCTION

Krishna-Godavari (K-G) Basin is a pericratonic basin along the eastern continental margin of India, and has been recognized as an important basin for the hydrocarbon exploration and production. This basin is evolved as a result of fragmentation East Gondwanaland and consequent opening of the Indian Ocean during Late Jurassic (Tithonian) time (Powell *et al.,* 1988; Venkatarengan *et al.,* 1993; Prasad *et al.,* 1996). The above extensional regime of the break-up of east Gondwanaland gave rise to a series of NE-SW trending horsts and grabens structures in this basin and the Pennar Subbasin represents the southern most graben in the K-G Basin (Fig. 1). Thick piles of sedimentary successions of Gondwana, post-Gondwana Mesozoic and Cenozoic are spread over the K-G Basin in the subsurface that ranges from Permian to Recent. However, thick successions of post-Gondwana Mesozoic and Cenozoic sediments are developed over the Precambrian Basement and the Gondwanic sediments are not reported up to the drilled depth as Pennar Subbasin is located south of Ongole Cross Trend (Fig 1). However, precise dating of post-Gondwana Late Jurassic-Cretaceous sediments, that represent the synrift and passive-margin sequence, are lacking due to inadequate biostratigraphic data.

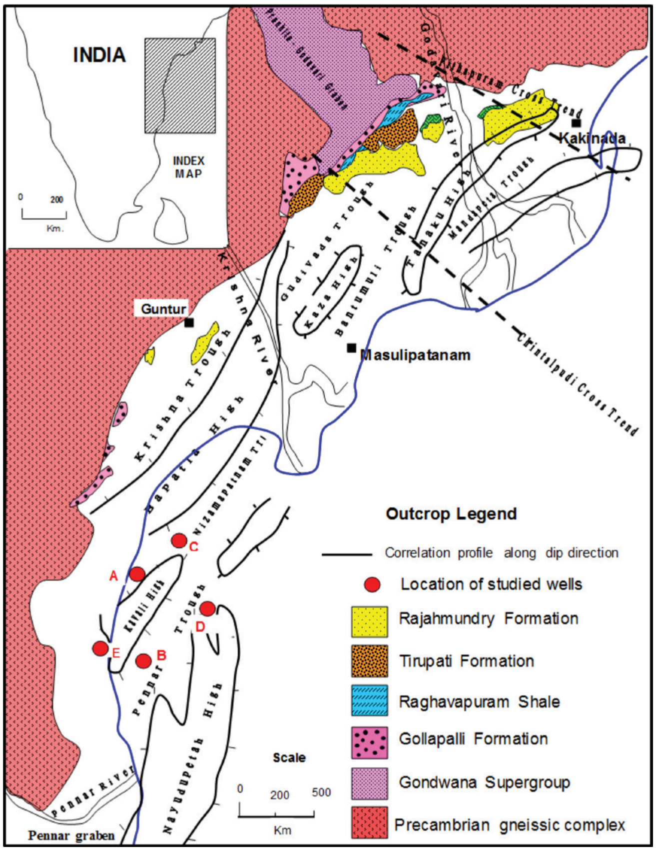


Fig. 1. Generalized tectonic map of Krishna-Godavari Basin (after Venkatarengan *et al*., 1993; Prasad 1999), showing the location of studied wells in Pennar Subbasin.

The present work covers the Pennar sub-basin and adjoining Nellore Ridge.

A detailed palynostratigraphic and foraminiferal study was undertaken on key wells from Pennar Subbasin and adjoining Nellore Ridge, *viz.*, well A and B, drilled in shallow waters offshore region of this Subbasin (Fig. 1). The main objective of present study is to identify and precisely date the oldest Post-Gondwana Mesozoic (Late Jurassic-Cretaceous) synrift and passive margin sediments and infer the depositional environment.

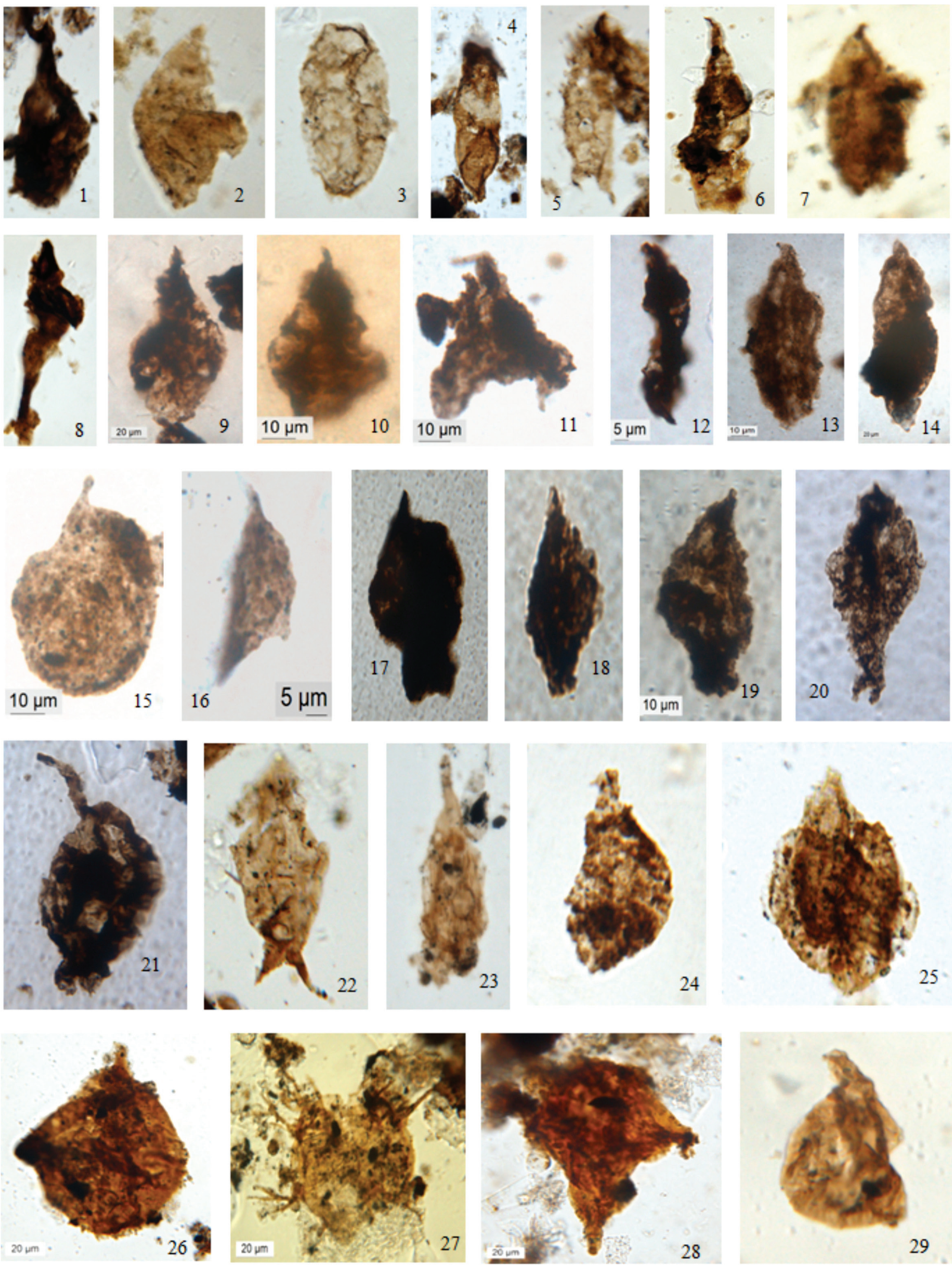
MATERIALS AND METHODS

Cutting samples of wells 'A' (interval 310-2150m) and 'B' (interval 510-5250 m) were examined for spore-pollen, dinoflagellate cysts and foraminifera for delineating the precise age boundaries and to decipher the depositional environments of various Late Jurassic-Cretaceous synrift and passive-margin lithounits. The samples were washed/ processed by using the standard processing techniques outlined by Pandey and Rao (1991). Important age marker spore – pollen, dinoflagellate cysts and foraminiferal bio-events are identified in the above two wells and presented through quantitative distribution and illustrated through frequency charts (Figs. 2-5). Photomicrographs of selected stratigraphic key species are given in Plates- I-V. Data interpretation on biostratigraphy, age and paleoenvironment is based on important age marker spore-pollen, dinoflagellate cyst and foraminiferal bio-events (LADs and FADs). Since different fossil groups and their species have differing mode of occurrence and preservation through the geological history, it is common to observe some amount of difference in the taxon ranges (LADs / FADs) of these fossil species especially in the well ditch cuttings where a lot of mixing and gravity cavings do take place. This problem of down-hole caving and rolling etc. sometimes results in disagreement in the faunal tops, so also on the stage top / bottom in the well. However, while integrating foraminiferal, nannofossil, dinoflagellates and spore-pollen data, care is taken to demarcate stage / age boundaries. Multi-microfossil analysis approach is being utilized to finalize the bio-chronostratigraphic divisions and ages. The planktic, intermittent benthic, arenaceous foraminifers, dinoflagellates cysts and spore pollens are studied with the help of standard references and their proposed respective zonations such as Bolli *et al*. (1985), Bolli *et al*. (1994) and several others. For precise dating and interpretation of Cretaceous and older sediments, publications referred include the work of Wilson and Clowes (1980); Bolli *et al.* (1985); Hart (1989); Williams and Bujak (1985); Haq *et al*. (1987); Helby *et al.* (1987); Williams *et al*. (1993); Prasad *et al.* (1995); Stover *et al*. (1996); Aswal *et al.* (2001); Prasad and Pundeer, (2002) and Prasad and Phor (2009). The absolute time, followed in the text, are taken from the GTS2004, outlined by Gradstein

EXPLANATION OF PLATE I →

Late Jurassic (Kimmeridgian-Tithonian) dinoflagellate cysts from the wells A and B of Pennar Sub-basin (address of each taxa is followed by well name, depth interval and microscope coord.; all magnification approx.750x). 1. *Pareodinia* sp., B, (2940-45m)/; coord. 95 x 63; 2. *Dingodinium* sp., B, (2940-45m)/; coord. 104x29; 3. *Fromea cylindrica,* B, (4025-30m)/; coord. 106x59; 4, *Omatia montgomeryi*, B, (3775-75m)/; coord.91.5x54.4; 5. *Broomea ramosa*, B, (2980-85m) /; coord.104x4; 6. *Batioladinium* sp., B,(2740-45m) /; coord. 97x53.3; 7. *Broomea* sp., B, (2940-45m) /; coord.109 x29; 8. *Kalyptea wisemaniae*, B, (2720-25m)/; coord.111x32.8; 9. *Pareodinia* sp., B, (3745-50m)/; coord.32x92.5; 10. *Tubotuberella* sp., B, (3745-50m)/; coord.107x28.5; 11. *Nannoceratopsis* sp., B, (4195-4200m)/; coord. 65x100; 12. *Kalyptea wisemaniae*, B, (3745-50m)/;coord. 93x31; 13. *Herendeenia* sp., B, (3745-50m)/; coord. 109x37.5; 14. *Herendeenia* sp., B, (4195-4200 m)/;coord. 37.5x106; 15. *Pareodinia* sp., B, (4195-4200 m)/; coord. 106x45.5. 16. *Kalyptea wisemaniae*, B (4195-4200m)/; coord. 108x 46.5; 17. *Tubotuberella apatela.* B, (3745x50m)/; coord. 107x28.5; 18. *Omatia montgomeryi*, B, (4195-4200)/; coord. 106x37.5; 19. *Tubotuberella apatela*, B, (3545-50m)/; coord. 36x111.8; 20. *Pseudoceratium* sp., B, (3545-50m)/; coord. 99.5x25.5; 21. *Pareodinia* sp., B, (3645-50m) /; coord. 100x57; 22. *Batioladinium longicornutum*, B, (1470-75m)/; coord. 61x102.7; 23. *Gardodinium attenuatum*, B, (1470-75m)/; coord. 33x108; 24. *Dingodinium jurassicum*, B, (4275-80m)/; coord. 100.5x62; 25. *Gardodinium trabeculosum*, B, (2820-25m)/; coord.102.5x31.5; 26. *Scriniodinium prolatum*, B, (2300-2305m)/; coord. 112x49; 27. *Systematophora aemula*, B, (2300-2305m)/; coord. 105x30.3; 28. *Pseudoceratium* sp., B,(1570-75m)/; coord. 41x101.5; 29. *Dingodinium* sp., B, (2300-2305m)/; coord. 113.5x40.

Plate I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Lithology	Depth (m)	Spore-pollen																																						Dinoflagellate cyst Events	Age	
		Asteropollis asteroides	*Triporoletes reticulatus*	*Phyllocladidites mawsonii*	*Murospora truncata*	*Microcachryidites antarcticus*	*Aequitriradites spinulosus*	*Coptospora cauveriana*	*Callialasporites segmentatus/*	*Polycingulatisporites reduncus*	*Contignisporites cooksoniae/*	*Camarozonosporites bullatus*	*Appendicisporites distocarinatus*	*Plicifera senonicus*	*Ornamentifera granulosa*	*Crybelosporites stylosus*	*Distaltriangulisporites mutabilis*	*Klukisporites scrarves*	*Foraminisporis wonthaggiensis*	*Cyclosporites hughesii*	*Trilobosporites* sp.	*Ceratosporites equalis*	*Murospora florida*	*Foraminisporis dailyi*	*Cooksonites variabilis*	*Concavissimisporites* sp.	*Impardecispora apiverrucata*	*Retitriletes watherooensis/*	*Aequitriradites hispidus*	*Staplinisporites caminus*	*Callialasporites dampieri*	*Matonisporites* sp.	*Gleicheniidites senonicus*	*Podosporites tripakshi*	*Retitriletes facetus*	*Contignisporites crenetus*	*Exesipollenites tumulus*	*Striatella jurassica*	*Calliasporites turbatus*		Stage	System
	305-310	2		2	1	1	1	1	1	1	1	1																													Turonian Coniacian	Late Creataceous
	330-335	4		2	1	1		1	1		1		1																											*C. ambigua*		
	355-360	3		1	2	1	2			2		2																												*C. edwardsii*	Cenomanian	
	380-385				1	1		1	2	4	3		2																													
	405-410	4		3	1	1	1			1	1	1			1																									*K. williamsii*		
	430-435	2		1	1		1	1	1	1	3					1	1																									
	455-460	2		1	1	2		1	2	1	2	2	1	2	2	1	2	1																								
	480-485				3	2	1		2	1	3		2	3		1																										
	500-505				2	3	1	2	2		2	2	2	2																										*L .arundum*		
	525-530					3	3	2										1																							Albian	Early Creataceous
	550-555	1			2	2	2				1	1	2	2		1																										
	575-580										1			2				1																								
	600-605	1			1	2		1	2			1	2	2	1																											
	650-655			2	2			1		2			1	1		2	1	1																								
	675-680	1			2		1			1			1																											*L .arundum*		
	700-705	1			1	2						1		1				1	1																							
	725-730							1			1				2		1																									
	750-755	1			1	1		1	1		1		2					1	1																							
	800-805	1		1	2		2			2		1		2			2		1	1	1																					
	800-805								2						1						1																					
	825-830			1				1														1																		*C. tabulata*	Aptian	
	850-855						1		2	2		1		1	1		1	1		1																						
	875-880	1																	1			1																		*A. neptunii*		
	900-905			1			1		2		2		2		2	2					2	1	1																			
	925-930	2			2	1				2		1			1				2					1																		
	950-955			2				1	1				1								1			1	1																	
	975-980				1		2		2			2		1				1	1			2		1																*K. scrutillum*		
	1000-1005			1		2	1				2		2									2			1	1															Barremian	
	1025-1030	1		1			1	2	2	1	1		2	1			2			1		2			1			1														
	1050-1055			1	2				1			2								2				1			1		1	1										*G. lowii*	Hauterivian	
	1075-1080					1	2	1	1	2	2					3						2							1									2		*M. simplex*		
	1100-1105			1				2			1		1		1			2			1		1	1		2	1	1	3												Valanginian	
	1125-1130	2					2		1			2				4		1	1					1			1		2		3	1								*F .cylindrica*		
	1155-1160						1	1		1				2				1												1		1										
	1175-1180			2		2			1							1			2		1		1			1			4				1									
	1195-1200	1						2	2		2		1		1	1				2		1				3		1				1										
	1220-1225					3					2					4			1			1			2				1		4											
	1245-1250			1				1		1				1				1				2					1			2	2			1						*K. wisemaniae*	Berriasian	
	1270-1275				1		1		1											1		1			1	2							2							*D. jurassicum*		
	1295-1300	2				1					2		1			4	3												1		2	1	2									
	1320-1325								2	5	2						2				1				1			1			2			1	1	1		1				
	1345-1350			1			2		1					2									2			1			1				1	1								
	1370-1375	1		1	1					1		1		1					1												1		1	1								
	1395-1400				1		1				4						4		4				2		1		1	1	2		2	2	1	3	1	2	1	4				
	1420-1425							1						1		2				3						1								2				3		*P .weymouthense*	? Kimmeridgian- Tithonian	Late Jurassic
	1430-1435	1				2	4	2	4	4	3		1		1	1		4		1	2		1		2	1			1	2	1	1				1	2	2		*D. swanense*		
	1445-1450	2												1						1					2	1		1			2			1				2				
	1470-1475					2		1	1			2		1		1				1			1			2			1			1										
	1480-1485	1							1				1												1							1		1		1						
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	1645-1650																						1																			
	1680-1685																																1							*O.patulum*		
	1695-1700	1		1			1		2					1	1	1		1		1			1																			
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Fig.2. Stratigraphic distribution of selected spore-pollen in the post-Gondwana Late Jurassic and Cretaceous sediments in well A of Pennar Subbasin (K-G Basin).

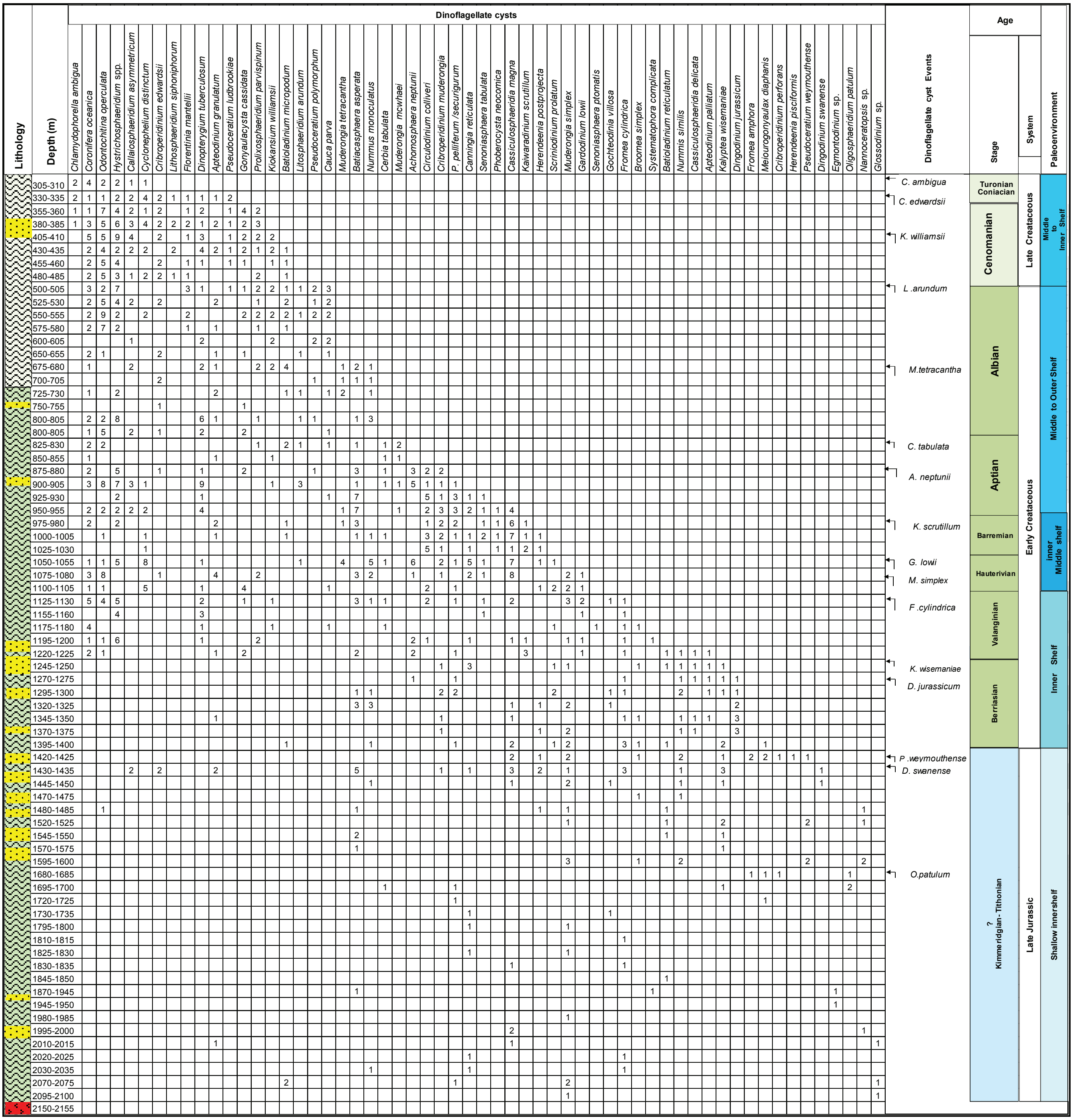

Fig.3 Stratigraphic distribution of selected dinoflagellate cyst taxa in the post-Gondwana Late Jurassic and Cretaceous sediments in well A of Pennar Subbasin (K-G Basin), with important age marker dinoflagellate cyst bioevents.

et al. (2004). Age marker and stratigraphically significant spore-pollen and dinoflagellate taxa are illustrated through photomicrographs (Pls. I-V).

PREVIOUS WORK

Detailed biostratigraphic studies on the surface and subsurface sediments of Krishna-Godavari Basin have been carried out by earlier workers in the past decades. The important biostratigraphic contributions were made by Raju *et al*. (1991); Prasad *et al.* (1996), Prasad & Pundeer (1999, 2002) and Aswal *et.al*. (2001). Prasad *et al.* (1996) recorded Tithonian to Barremian sediments in the wells C and D and suggested the age of oldest synrift sediments in Pennar Subbasin as Tithonian. The available biostratigraphic data from well C, D and E are used for comparing and integration with the biostratigraphic data from wells A and B.

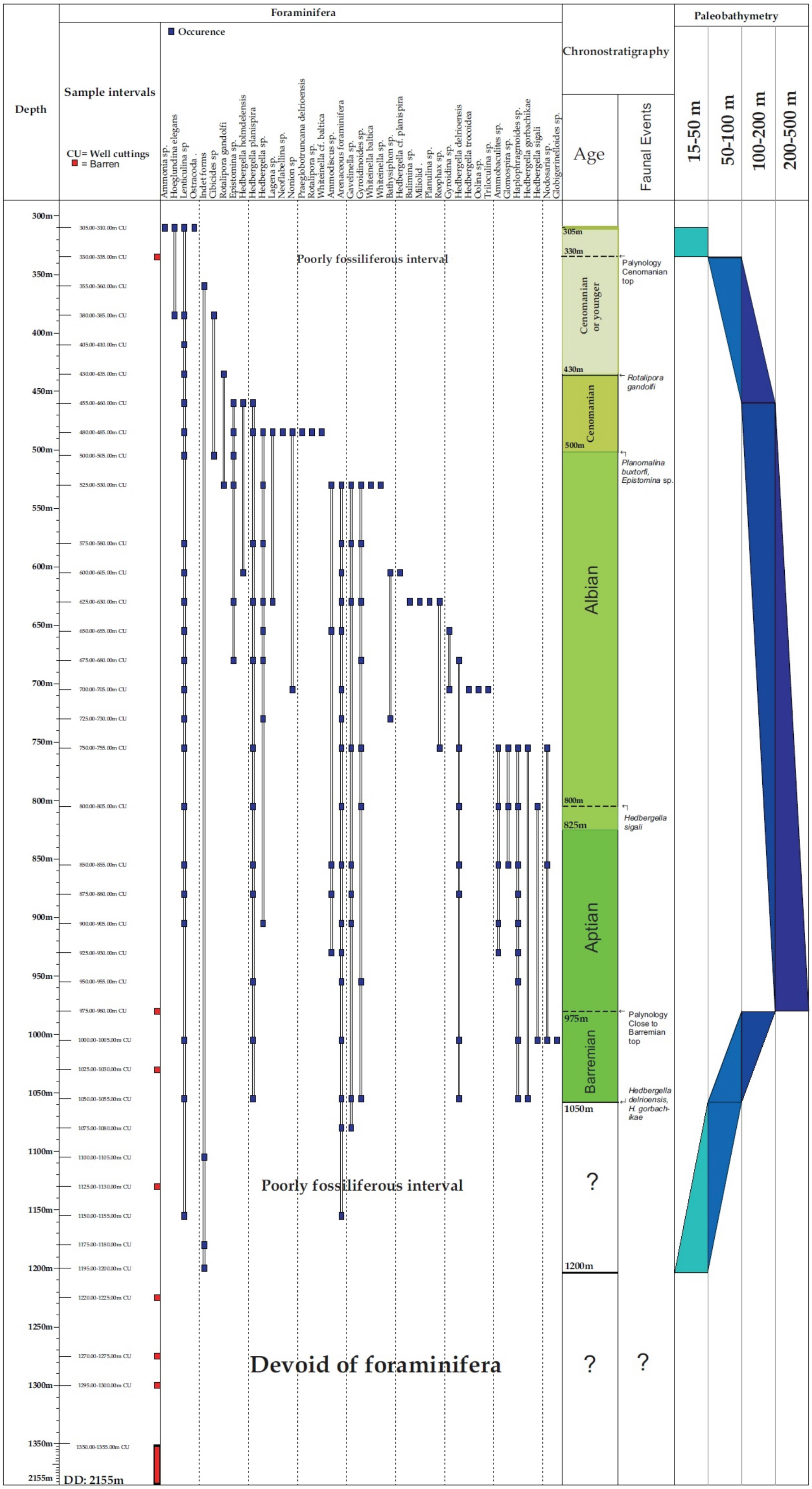

Fig.4 Distribution of foraminifera, age,bioevents and paleoenvironment in well A, KG Basin

EXPLANATION OF PLATE II

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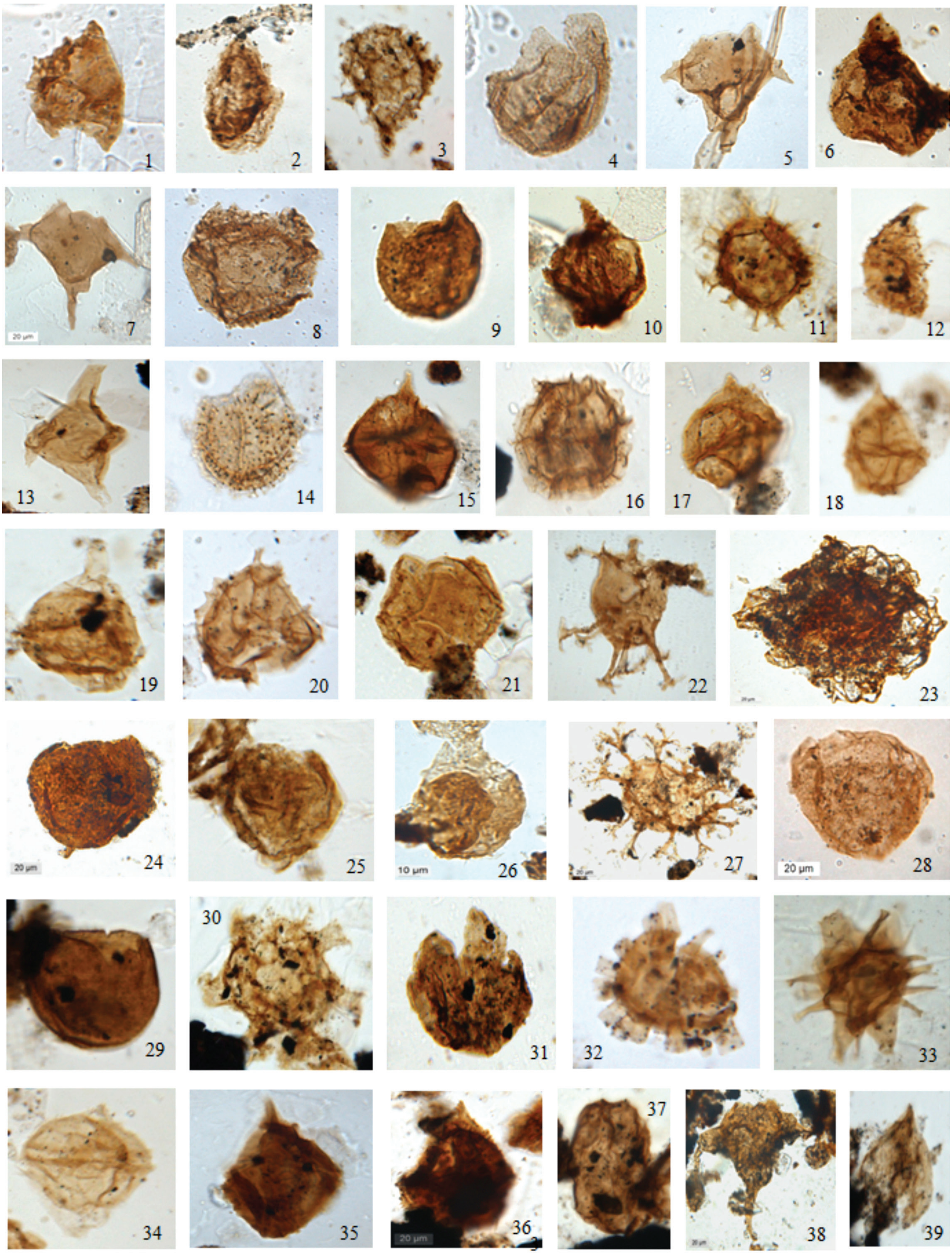
Early Cretaceous (Berriasian to Aptian) dinoflagellate cysts from the wells A and B as from Pennar Subbasin (address of each taxa is followed by well name, depth interval and microscope coord; all magnification approx.750x). 1. *Nannocerotopsis jurassica*, A, (1370-75m)/; coord. 94.8x101; 2. *Dingodinium swaense*, A, (1370-75m)/; coord. 98.5x27.5; 3. *Phoberocysta edgellii*, A, (1370-75m)/; coord. 106x29.5; 4. *Canningia* sp., A, (1395-1400m)/; coord. 98.5x27; 5. *Muderongia simplex*, A, (1420-25m)/; coord. 103.5x26.2; 6. *Apteodinium* sp., A, (1430-35m)/; coord. 108x22.5; 7. *Muderongia macwhaei*, A, (1430-35m)/; coord. 35x107.5; 8. *Canningia* sp., A, (1420-25)/; coord. 95x51; 9. *Batiacasphaera asperata*, A, (1420-25)/; coord. 101.5x50; 10. *Apteodinium granulatum*, A, (1430-35)/; coord. 95x58; 11. *Achomosphaera neptuni*, B, (1275-80)/; coord. 101x50; 12. *Gochteodinia villosa*, B, (955-60m)/; coord. 95x52; 13. *Muderongia mcwhaei*, B, (725-30m)/; coord. 98x45; 14. *Chlamydophorella ambigua*, B-1, (510-20m)/; coord. 101x50; 15. *Cribroperidium* sp., B, (540-50m)/; coord. 102x42; 16. *Dinopterigyum* sp., B, (570-80m)/; coord. 103x42; 17. *Apcteodinium granulatum*, B, (570-80m)/; coord. 102x32; 18. *Gonyaulasysta cassidata*, B, (595-600m)/; coord. 93x25; 19. *Dingodinium jurassicum*, B, (1275-80m)/; coord. 102x28; 20. *Gonyaulacysta serrata*, B, (695-700m)/; coord. 105x42; 21. *Batiacasphaera* sp., B, (695-700m)/; coord. 96x42; 22. *Kaiwaradinium scrutillium*, B, (2020-25m)/; coord. 102x 24; 23. *Rigaudella filamentosa*, B, (2120-25m)/; coord. 110x27; 24. *Cassiculosphaeridia magna*, B, (2120-25m)/; coord. 105 x 33; 25. *Senoniasphaera* sp., B, (2260-65m)/; coord. 93.5 x37.5; 26. *Dingodinium jurassicum*, B, (2260-65m)/; coord. 103.5 x51.5; 27. *Oligosphaeridium patulum*, B, (2180-85m)/; coord. 101x34; 28. *Scriniodinium attadalense*, B (2940-45m)/; coord. 111x 64; 29. *Batiacasphaera asperata*, B, (2515-20m)/; coor.d 100x43.5; 30. *Discorsia nanna*, B, (905-10m)/; coord. 99x25.5; 31. *Kellosphaeridium* sp., B, (2940-45m)/; coord. 98 x58; 32. *Litosphaeridium siphoniphorum*, B, (750-55m)/; coord. 97 x24; 33. *Florentinia mantellii*, B, (930-35m)/; coord. 96x42; 34. *Subtilisphaera* sp., B, (955-60m)/; coord. 43x 24; 35. *Cribroperidinium* sp., B, (930-35m)/; coord. 99x28; 36. *Gonyaulacysta* sp., B, (1250-55m)/; coord. 102.2 x52; 37. *Fromea cylindrica*, B, (1165-70m)/; coord. 108 x41; 38. *Muderongia mcwhaei*, B, (1300-05m)/; coord. 24.8x100.8; 39. *Nannocerotopsis* sp., B, (2680-85m)/; coord. 98x27.

Plate II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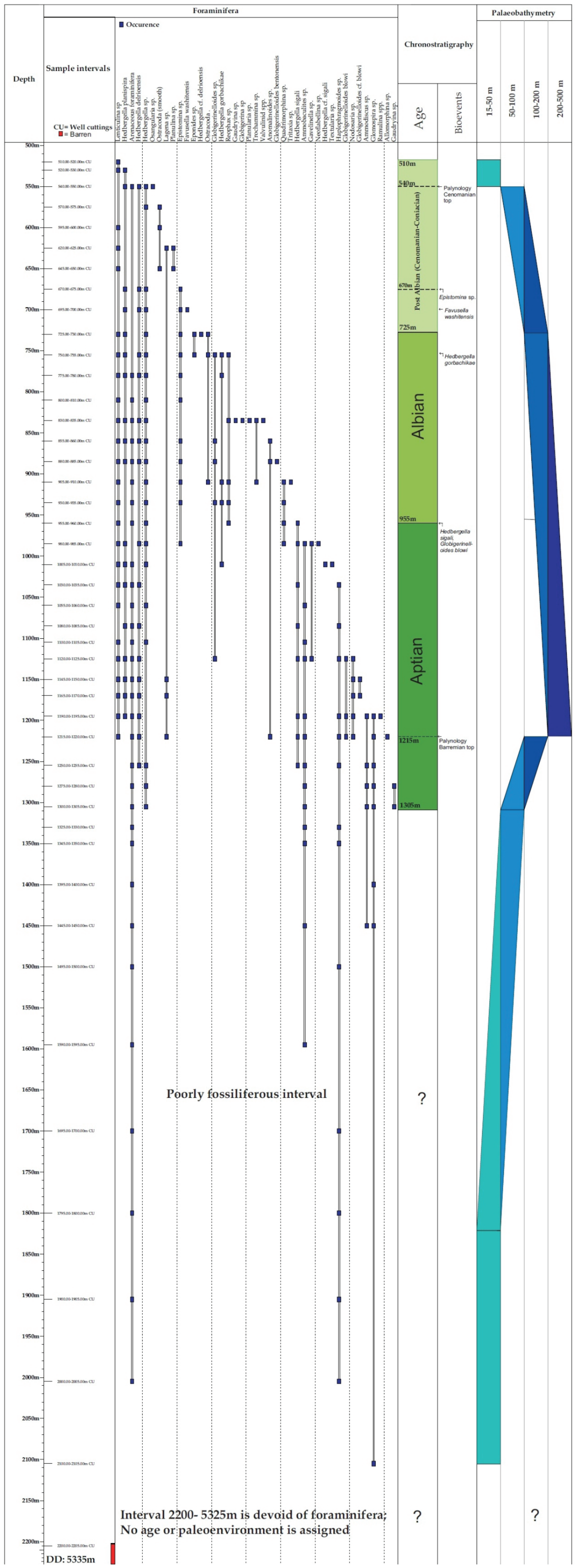


Fig.5. Distribution of foraminifera, age,bioevents and paleoenvironment in well B, KG Basin

BIOSTRATIGRAPHY

Integrated biostratigraphic data obtained through palynofossils (dinocysts and spore-pollen) on the Post-Gondwana, Pre-Cretaceous (Late Jurassic) and Cretaceous successions which cover the synrift and passive margin Mesozoic sequences in wells A and B are presented with inferring the precise age and depositional environments of various encountered lithounits. The recovered spore-pollen and dinoflagellate cysts assemblages are compared with the previously recorded assemblages from the East Coast basins, particularly other subbasins of K.G. Basin and adjoining Cauvery Basin for refining the age of these sediments.

The well A is situated on the Nellore- Kavali Ridge in the shallow waters in Pennar Subbasin of K-G Basin. The well is bounded by Nizampattanam Graben in the north and Pennar Graben in the south-east, having present-day bathymetry of 15 m. This well was drilled down upto 2174 m depth and the Precambrian Basement was encountered at 2153 m depth. The well B is located in the Pennar Subbasin and bounded by the Nellore- Kavali Horst in the north-west and Nayudupetta Ridge in the south-east. This well is drilled down to the depth of 5325 m and terminated in the Late Jurassic sedimentary succession of Post-Gondwana synrift sequence.

Details of the microfossils (dinoflagellate cysts, spore-pollen and foraminifera) recorded from different stratigraphic levels in wells A and B are briefly outlined below along with age marker taxa and their LADs, frequency and temporal distribution.

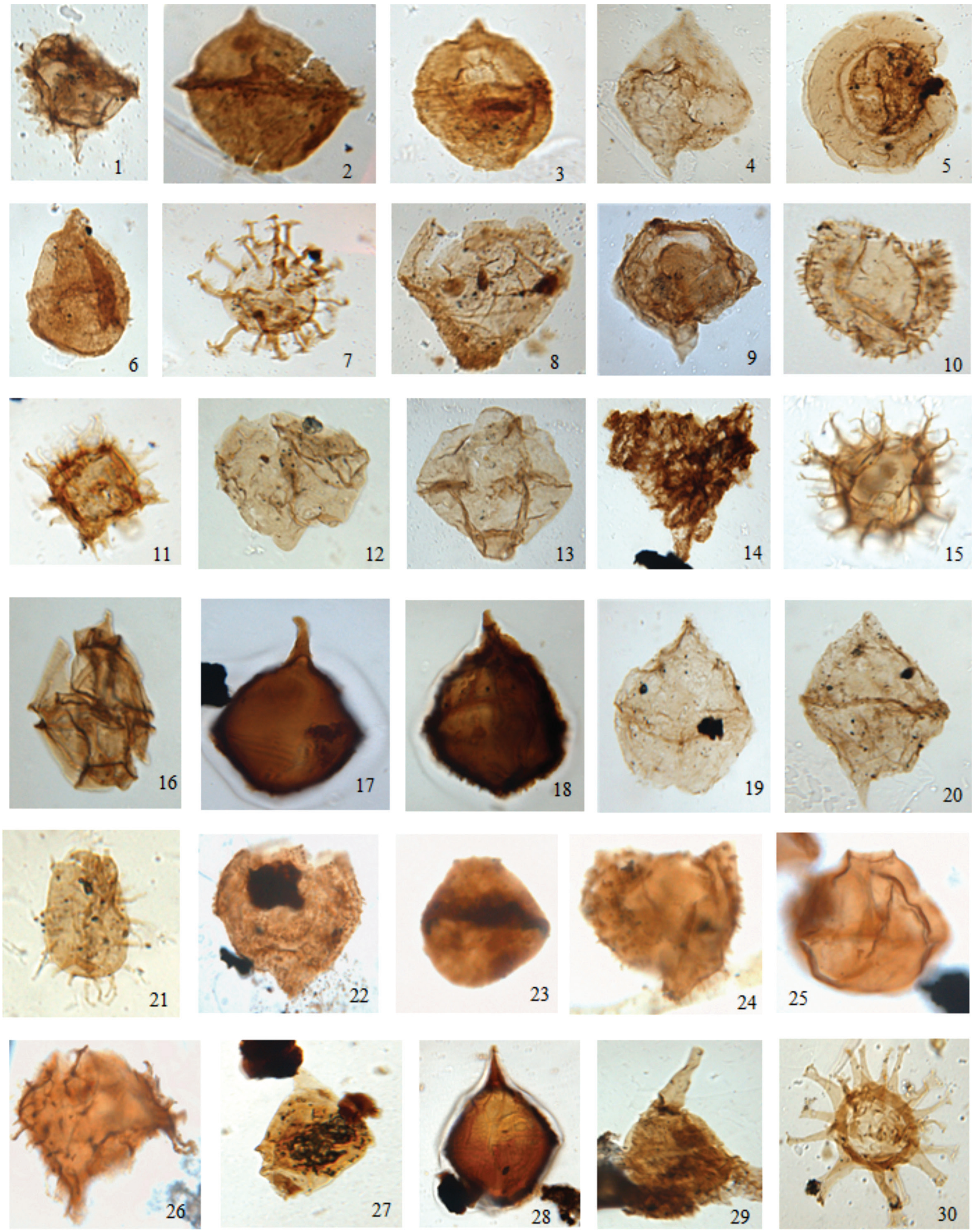
Post-Gondwana Synrift Mesozoic (late Jurassic to early Cretaceous) biostratigraphy

In different Subbasins of K-G Basin, Late Jurassic-Early

EXPLANATION OF PLATE III →

Early Cretacous (Aptian-Albian) dinoflagellate cysts from wells A and B of Pennar Subbasin (address of each taxa is followed by well name, depth interval and microscope coord.; all magnification approx.750x). 1. *Phoberocysta neocomica*, A, (700-05m)/; coord. 35x92; 2. *Cribroperidinium edwardsii*, A, (500-05m)/; coord. 31.4x99; 3. *Cribroperidinium aparsium*, A, (900-05m)/; coord. 98x46.5; 4. *Diconodinium pusilium*, A, (900-05m)/; coord. 99x66; 5. *Dinopterygium* sp., A, (900-05m)/; coord. 98x47.5; 6. *Apteodinium granulatum*, A, (1000-05m)/; coord. 103x67.5; 7. *Kiokansium williamsii*, A, (525-30m)/; coord.103x45; 8. *Senoniasphaera tabulata*, A, (975-80m)/; coord. 73x108; 9. *Phoberocysta edgellii*, A, (1025-30m)/; coord.104x42; 10. *Circulodinium deflandrei*, A, (1100-05m)/; coord.101x41; 11. *Phoberocysta* sp., A, (1075-80m)/; coord. 63.4x97; 12. *Circulodinium colleveri*, A, (1100-05m); 13. *Senoniasphaera tabulata*, A, (1175-80m)/; coord. 28x107.8; 14. *Phoberocysta edgellii*, A, (1125-30m)/; coord. 61.5x110; 15. *Achomosphaera neptuni*, A, (1175-80)/; coord.101x52; 16. *Gonyaulacysta cassidata*, A, (1100-05m)/; coord.99x42; 17. *Cribroperidinium muderongia*, A, (1100-05)/; coord.101x51; 18. *Cribroperidinium* sp., A, (1175-80)/; coord.110x42; 19. *Senoniasphaera* sp., A, (1195-1200)/; coord.104x35; 20. *Ascodinium* sp., A, (1195-1200m)/; coord.98x35; 21. *Prolixosphaeridium* sp.A, (1370-75m)/; coord.101x40; 22. *Pseudoceratum almondensis*, A, (1220-25m)/; coord. 111.5x48.5; 23. *Fromea* sp., A, (1270-75m)/; coord. 29x103; 24. *Pseudoceratium* sp., A, (1270-75m)/; coord. 102x40; 25. *Fromea* sp., A, (1295-1300m)/; coord. 37x 97.5; 26. *Pseudoceratium turneri*, A, (1220-25m) /; coord. 94x40; 27. *Dingodinium* sp., A, (1320-25m)/; coord.95x51; 28. *Apteodinium* sp., A, (1345-50m)/; coord.96x52; 29. *Dingodinium cerviculum*, A, (1320-25m)/; coord. 96x60.5; 30. *Florentinia cooksoniae*, A, (1370-75m)/; coord. 105x 64.

Plate III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Cretaceous synrift sequence is deposited directly above the Precambrian Basement or over the eroded surface of Gondwana after the major Jurassic unconformity.

Kimmeridgian-Tithonian: This succession is recorded just above the basement having characteristic dinoflagellates and spore-pollen of Kimmeridgian-Tithonian age in wells A (1420-2100 m), B (2945-4720 m).

Characteristic Palynoflora: The significant dinoflagellate cyst taxa recorded from these sediments include *Pseudoceratium weymouthense, Dingodinium swanense, Glossodinium dimorphum, Omatia montgomeryi, Meiourogonyaulax* sp., *Herendeenia postprojecta*, *Egmontodinium* sp., *Fromea cylindrica, Sirmiodinium prolatum, Tubotuberella* sp., *Sentusidinium* sp., *Pareodinia ceratophora, Senoniasphaera jurassica, Nannoceratopsis* sp., *Oligosphaeridium patulum, Batioladinium reticulatum, Kalyptea wisemaniae* and *Muderongia simplex.* The associated spore-pollen include *Retitriletes watherooensis*, *Cooksonites variabilis, Aequitriradites hispidus, Cicatricosisporites australiensis, Cancavissimisporites* sp., *Contignisporites cooksoniae, Staplinisporites* sp., *Striatella jurassica, Matonisporites* sp., *Callialasporites dampieri, Callialasporites turbatus* and *Exesipollenites tumulus.*

Suggested age and depositional environment: The above recorded palynoassemblages in this interval suggest Kimmeridgian-Tithonian age. The sediments were likely to be deposited in shallow marine conditions.

Remarks: In well A the Late Jurassic (? Kimmeridgian -Tithonian) sediments 1420-2100 m are directly overlying the Achaean Basement, which shows a major unconformity, involving the absence of parts of Jurassic and Permo-Triassic sediments. Depth interval 2120-2150 m is unfossiliferous. While depth interval 4000-4720 m in well B, consists of dark hard fissile shale, highly compacted, ill-sorted and mixed with metaclast and micaceous sandstone. This section exhibits palynoassemblages which are deformed in shape, ill-preserved, very dark in colour and indicate Late Jurrassic age. The sediments in the depth-interval 4720-5245 m have not yielded any spore-pollen and dinoflagellate cysts. The interval is dominated by dark overcooked organic matter which turned black due to high temperature. The section is devoid of spore-pollen, dinoflagellate cysts, hence age and palaeoenvironment could not be assigned. The sections in both wells are devoid of foraminifera.

Berriasian: Berriasian sediments are recorded in well A-1 from 1245 to 1420 m depth and in B from 2120-2945 m depth.

Characteristic palynoflora: The significant dinoflagellate cysts assemblage in this interval are *Kalyptea wisemaniae, Pareodinia ceratophora, Batioladinium reticulatum, Pseudoceratium securigerum, Nannoceratopsis* sp., *Dingodinium jurassicum, Egmontodinium* sp., *Scriniodinium prolatum* and *Canningia reticulata.* The associated spores-pollen include *Klukisporites* sp., *Ceratosporites equalis, Contignisporites cooksoniae*, *Callialasporites trilobatus, Cicatricosisporites australiensis, Retitriletes watherooensis, Microcachryidites antarcticus, Cancavissimisporites* sp., *Matonisporites* sp., *Foveosporites* sp., *Trilobosporites* sp. and *Foraminisporis wonthaggiensis.*

Characteristic foraminifera: The sections in both wells are devoid of foraminifera.

Suggested age and depositional environment: The occurrence of *Kalyptea wisemaniae* and *Dingodinium jurassicum* along with the above recorded dinoflagellate cysts and spore-pollen suggests Berriasian age. The Berriasian top is marked at 1245 m in A and 2120 m in B based on the LAD of *Kalyptea wisemaniae.* The palynofossil contents suggest that the Berriasian sediments were deposited under the inner shelf conditions.

Valanginian: Valanginian sediments recorded in well A-1 (1125 -1245m) and B-1 (1820-2120m).

Characteristic palynoflora: The sediments of this depth interval yielded characteristic dinoflagellate cysts such as *Fromea cylindrica, Broomea* sp., *Gochteodinia villosa, Scriniodinium prolatum, Pareodinia robusta*, *Discorsia nanna* and *Pseudoceratium securigerum.* The associated spore-pollen include *Coptospora cauveriana, Clavifera triplex, Appendicisporites distocarinatus, Cyclosporites hughesii, Concavissimisporites* sp., *Crybelosporites striatus, Microcachryidites antarcticus* and *Callialasporites trilobatus.*

Characteristic foraminifera: The sections in both wells are devoid of foraminifera.

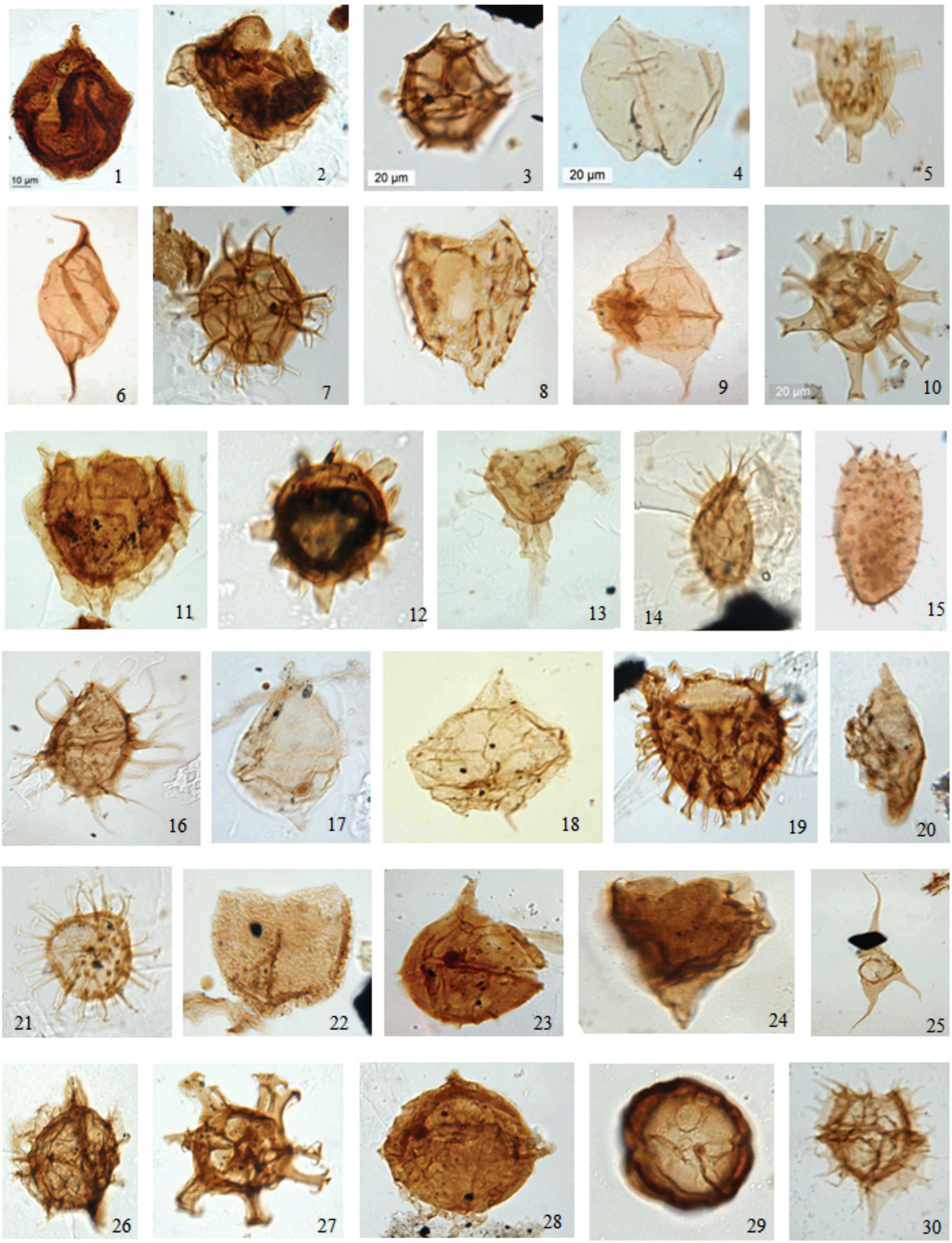
Suggested age and depositional environment: Based on the LAD of *Gochteodinia villosa* and *Fromea cylindrica* at 1125 m in A and at 1820 m in B, with associated spore-pollen suggests Valanginian age. The sediments of this interval were deposited under inner shelf conditions.

EXPLANATION OF PLATE IV

→

Early to Late Cretacous (Albian-Cenomanian to Turonian-Coniasian) dinoflagellate cysts from the wells of A and B of Pennar Subbasin (address of each taxa is followed by well name, depth interval and microscope coord; all magnification approx.750x). 1. *Cribroperidinium edwardsii*, A, (1050-55m)/; coord. 105x34; 2. *Pseudoceratium ludbrookiae*, A, (500-05m)/; coord. 29x102.5; 3. *Xiphophoridium alatum*, A, (400-05m)/; coord. 25x96.5; 4.*Circulodinium collieveri*, A, (405-10m)/; coord. 67x99; 5. *Litosphaeridium siphoniphorum*, A, (480-85m)/; coord. 29.2x93.4; 6. *Andaluciella polymorpha*, A, (330-35m)/; coord. 25x105; 7. *Achomosphaera neptuni*, A, (775-80m)/; coord.107x70; 8. *Pseudoceratium securigerum*, A, (525-30m)/; coord. 105x 67; 9. *Cerodinium diebelii*, A, (305-10m)/; coord. 53x97; 10. *Florentinia cooksoniae*, A, (480-85m)/; coord. 64x105; 11. *Pseudoceratium ludbrookiae*, A, (480-85m)/; coord. 61x108; 12. *Litosphaeridium arundum*, A, (750-55m)/; coord. 106x30.5; 13. *Muderongia mcwhaei*, A, (480-85m)/; coord. 43.7x111; 14. *Prolixosphaeridium parvispinum*, A, (480-85m)/; coord. 32x106; 15. *Prolixosphaeridium* sp., A, (1220-25m)/; coord. 42.5x108.5; 16. *Hystrichodinium pulchurum*, A, (480-85m)/; coord. 68x111.4; 17. *Subtilisphaera* sp., A, (500-05m)/; coord. 97x47.5; 18. *Paleoperidinium* cretaceum. A, (500-05m)/; coord. 112x47.5; 19. *Circulodinium deflandrei*, A, (500-05m)/; coord. 96x31; 20. *Dingodinium* sp. A, (1320-25m)/; coord. 103.5x32.5; 21. *Kiokansium williamsii*, A, (925-50m)/; coord. 101.5x26; 22. *Cerbia tabulata*, A, (480-85m)/; coord. 111x25; 23. *Cribroperidinium edwardsii*, A, (900-05m)/; coord. 95 x 25.5; 24. *Senoniasphaera tabulata*, A, (950-55m)/; coord. 103.5x 54; 25. *Odontochitina operculata*, A, (500-05m)/; coord. 46.5x109; 26. *Dinopterygium* sp. A, (800-05m)/; coord. 36.5x100; 27. *Callaiosphaeridium asymmetricum*, A, (800-05m); 28. *Cribrosphaeridium* acerus, A, (900-05m)/; coord. 98 x 46.5; 29. *Nummus monoculatus*, A, (950-55m)/; coord. 100.5x59; 30. *Phoberocysta neocomica*, A, (975-80m)/; coord. 51x101.

Plate IV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Hauterivian: Hauterivian sediments recorded in well A (1050 -1125 m) and B (1370-1820 m).

Characteristic palynoflora: This interval has yielded characteristic marker dinoflagellate cysts viz: *Pseudoceratium securigerum, Phoberocysta edgellii, Systematophora areolata, Gardodinium lowii, Muderongia simplex, Scriniodinium prolatum, Herendeenia postprojecta, Canningia reticulata, Batiacasphaera asperata, Canninginopsis intermedia, Nelchinopsis kostromiensis, Phoberocysta neocomica* and *Cassiculosphaeridia magna.* The associated spore-pollen include *Cicatricosisporites australiensis, Ornamentifera granulosa, Foraminisporis dailyi, Cooksonites variabilis, Contignisporites cooksoniae*, *Cyclosporites hughesii. Klukisporites variegatus, Appendicisporites distocarinatus, Callialasporites trilobatus,Contignisporites glebulentus* and *Polycingulatisporites reduncus.*

Characteristic foraminifera: This interval has yielded few calcareous benthic and arenaceous foraminifera in well A. These include *Gavelinella* sp., *Haplophragmoides* sp. and *Lenticulina* sp. In well B, *Ammodiscus* sp., *Ammobaculites* sp., *Gaudryina* sp., *Glomospira* sp. and *Haplophragmoides* sp. were recorded.

Suggested age and depositional environment: The occurrence of LAD of *Gardodinium lowii* and *Phoberocysta edgellii* that globally disappears close to Barremian-Hauterivian boundary, recorded at depth 1050m in A and 1370 m in B, suggests Hauterivian age for this depth interval. The sediments of this interval were observed to be deposited under inner to middle shelf conditions.

Barremian: Barremian sediments recorded in well A (975-1050 m) and B (1215-1370 m).

Characteristic palynoflora: The cutting samples of this depth interval have yielded significant dinoflagellate taxa like *Kaiwaradinium scrutillinum, Phoberocysta neocomica, Cassiculosphaeridia magna, Pseudoceratium securigerum, Aptea polymorpha, Cerbia tabulata, Achomosphaera neptunii* and *Hysrichosphaeridium pulcherum.* Associated spores-pollen taxa include *Appendicisporites distocarinatus, Polycingulatisporites reduncus, Microcachryidites antarcticus*, *Foraminisporis wonthaggiensis, Araucariacites australiensis, Cooksonites variabilis, Contignisporites glebulentus, Crybelosporites stylosus*, *Coptospora cauveriana, Polycingulatisporites reduncus* and *Cicatricosisporites australiensis.*

Characteristic foraminifera: In well B, few arenaceous foraminifera were recorded in this interval. These include *Ammodiscus* sp., *Ammobaculites* sp., *Gaudryina* sp., *Glomospira* sp. and *Haplophragmoides* sp. were recorded. This interval is devoid of foraminifera in well A.

Suggested age and depositional environment: Occurrence of LAD of *Kaiwaradinium scrutillinum* at 975m in A and 1215m in Bwhich globally disappears close to Barremian-Aptian boundary, marks the Barremian top in both the wells in above depth. The above recorded significant dinoflagellate cysts and spores-pollen assemblage suggests Barremian age for the above depth interval. The sediments were inferred to be deposited under inner to middle shelf conditions.

Aptian: Aptian sediments recorded in well A (825-975 m) and B (955-1215 m).

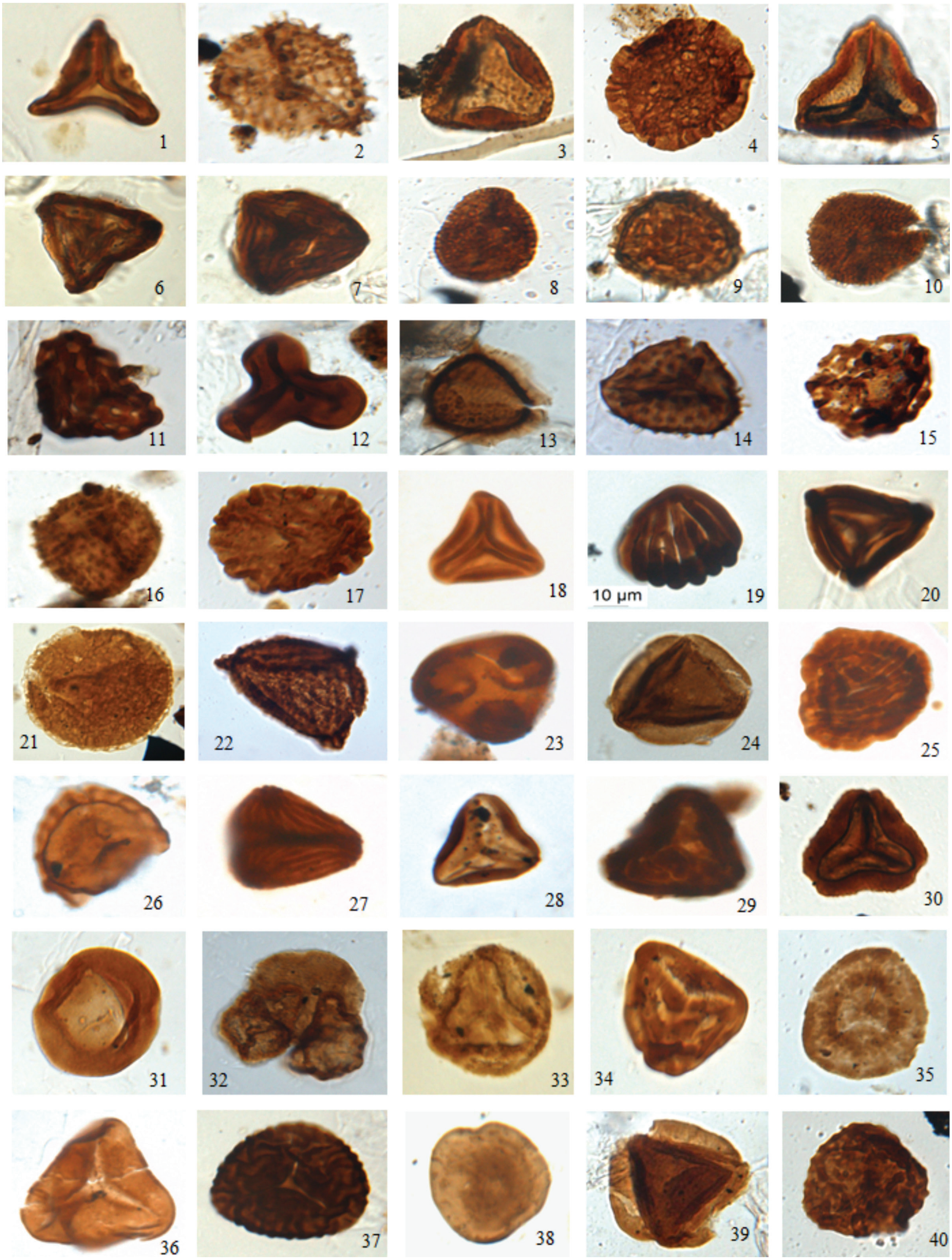
Characteristic palynoflora: A good and diversified number of palynofossil assemblage has been recorded in this interval. The diagnostic age marker dinoflagellate taxa include *Cerbia tabulata, Pseudoceratium pelliferum Tanyosphaeridium variecalamum, P. securigerum, Aptea* sp*., Paleoperidinium cretaceum, Cyclonephelium* sp*., Pareodinia ceratophora*, *Achomosphaera neptuni*, *Batiacasphaera asperata*, *Cerbia tabulata* and *Muderongia mcwhaei.* The other associated spores-pollen includes *Coptospora cauveriana, Callialasporites trilobatus, Polycingulatisporites reduncus*, *Contignisporites cooksoniae*, *Cyclosporites hughesii, Contignisporites crenulatus, Classopollis classoides* and *Foraminisporis wonthaggiensis.*

Characteristic foraminifera: This interval has yielded planktonic and benthic foraminifera including *Hedbergella planispira, H. delrioensis*, *H. sigali*, *H. gorbachikae*, *Globigerinelloides* sp., *Rotalipora* sp., *Ammodiscus* sp., *Ammobaculites* sp., *Gaudryina* sp., *Glomospira* sp., *Gavelinella* sp., *Gyroidinoides* sp., *Haplophragmoides* sp.,

EXPLANATION OF PLATE V →

Late Jurassic (Kimmeridgian-Tithonian) and Early to Late Cretaceous (Berriasian to Coniasian) spore-pollen from the wells of A and B of Pennar Sub-basin (address of each taxa is followed by well name, depth interval and microscope coord.; all magnification approx.750x). 1. *Gleichenidites circinidites,* A, (480-8m5)/; coord. 106x26; 2. *Ceratosporites equalis*, B, (2700-05m)/; coord. 94.3x33.2; 3. *Ornamentifera granulosa*, A, (1370-75m)/; coord. 104x29; 4. *Callialasporites segmentatus*, A, (1370-75m)/; coord. 103.5x55.5; 5. *Murospora truncata*, A, (1370-75m)/; coord. 104x55; 6. *Matoniesporites phlebepteroides*, A, (1395-1400m)/; coord. 115x36.2; 7.*Cicatricosisporites hughesii*, A, (1395-1400m)/; coord. 104x31.5; 8. *Retitriletes* sp., A, (1370-75m)/; coord.105x24.5; 9. *Retitriletes circoluminus*, A, (1395-1400m)/; coord. 105.5x24.5; 10. *Foraminisporis asymmetricus*, A, (1395-1400m)/; coord. 101.5x42.5; 11. *Klukisporites scrbatus*, A, (1430-35m)/; coord. 95.5x30.7; 12. *Trilobosporites* sp., A, (1430-35m)/; coord .106x68.5; 13. *Aequitriradites spinulosus*, A, (1430-35m)/; coord. 97x62; 14. *Ceratosporites equalis*, A, (1445-50m)/; coord. 109.5x61; 15. *Dictyosporites* sp., B (2720-25m)/; coord. 71x105; 16. *Retitriletes eminulus*, B, (2280-85m)/; coord. 93.4x39; 17. *Callialasporites segmentatus*, A, (1430-35m)/; coord. 105.5x28.2; 18. *Plicifera senonicus*, A, (355-60m)/; coord.108x67; 19. *Contigisporites cooksoniae*, A, (405-10m)/; coord. 96x31; 20. *Appendicispora distocarinatus*, A, (480-85m)/; coord. 96x33; 21. *Retitriletes australoclavatidites*, A, (480-85m)/; coord. 97.5X35; 22. *Appendicispora distotarinatus*, A, (900-0m5)/; coord. 96x51; 23. *Microcachryidites antarcticus*, A, (1510-15m) /; coord. 39x113.6; 24. *Callialasporite trilobatus*, A, (1100-05m)/; coord. 95x30; 25. *Contignisporites crenatus*, A, (1220-2m5)/; coord. 48x109.5; 26. *Staplinisporites caminus*, A, (1220-2m5)/; coord. 5.5x95; 27. *Cicatricosisporites australiensis*, A, (1245-50m)/; coord. 51x100; 28. *Ornamentifera granulosa*, B, (670-75m)/; coord. 97x45.5; 29. *Murospora* sp., A, (1295-1300m)/; coord. 54.5x94; 30. *Murospora truncata*, B, (725-30m)/; coord. 109x26; 31. *Coptospora cauveriana*, A (500-05m)/; coord. 47x106; 32. *Phyllocladidites mawsonii*, A, (1100-05m)/; coord. 96x35; 33. *Camarozonosporites bullatus*, B, (725-30m)/; coord. 105x43.5; 34. *Striatella jurassica*, A, (1395-1400m) /; coord. 07x31.5; 35. *Aequitriradites spinulosus*, A, (1320-25m)/; coord. 100x33.5; 36. *Concavissimisporites* sp. A, (1220-25m)/; coord. 62x97.5; 37. *Retitriletes eminulus*, A, (480-85m)/; coord. 99x32; 38. *Exesipollenites tumulus*, A, (1995-2000m)/; coord. 92x52; 39. *Callialasporites trilobatus* A, (1395-1400m)/; coord. 97x28.5; 40. *Retitriletes nodosus*, A, (1370-75m)/; coord. 96x30.5;

Plate V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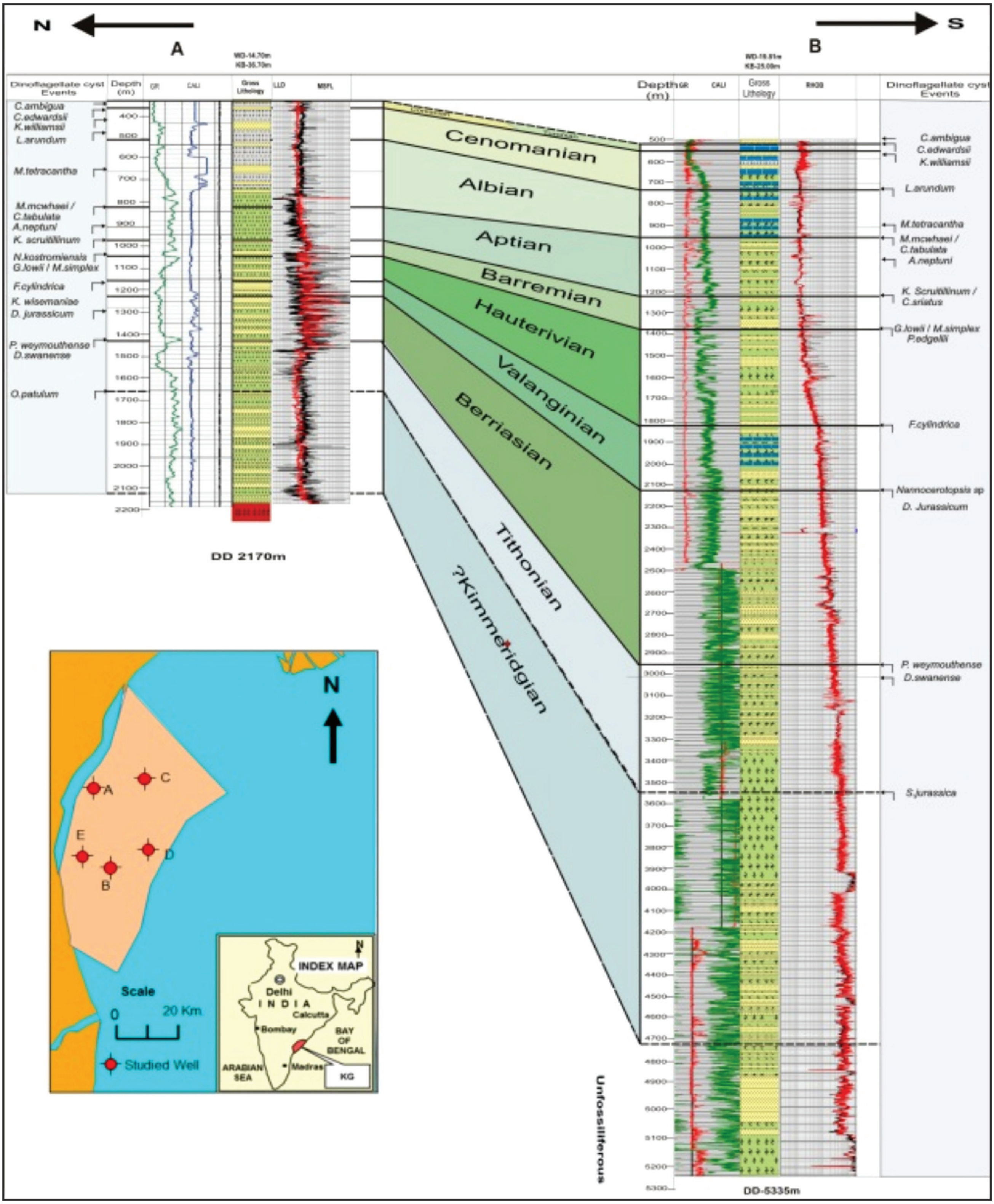

Fig. 6. Biostratigraphic correlation of post-Gondwana Late Jurassic and Cretaceous sediments in wells A and B of Pennar Subbasin (K-G Basin).

Nodosaria sp., *Nonion* sp. and *Lenticulina* sp. In well B-1, *Hedbergella planispira, H. delrioensis*, *H. sigali*, *Hedbergella* sp., *Globigerinelloides blowi*, *Globigerinelloides* sp., *Allomorphina* sp., *Anomalinoides* sp., *Ammodiscus* sp., *Ammobaculites* sp., *Epistomia* sp., *Eponoides* sp., *Gaudryina* sp., *Glomospira* sp., *Gavelinella* sp., *Gyroidinoides* sp., *Haplophragmoides* sp., *Lagena* sp., *Neoflabelina* sp., *Nodosaria* sp., *Nonion* sp. and *Lenticulina* sp. and *Planularia* sp. were recorded.

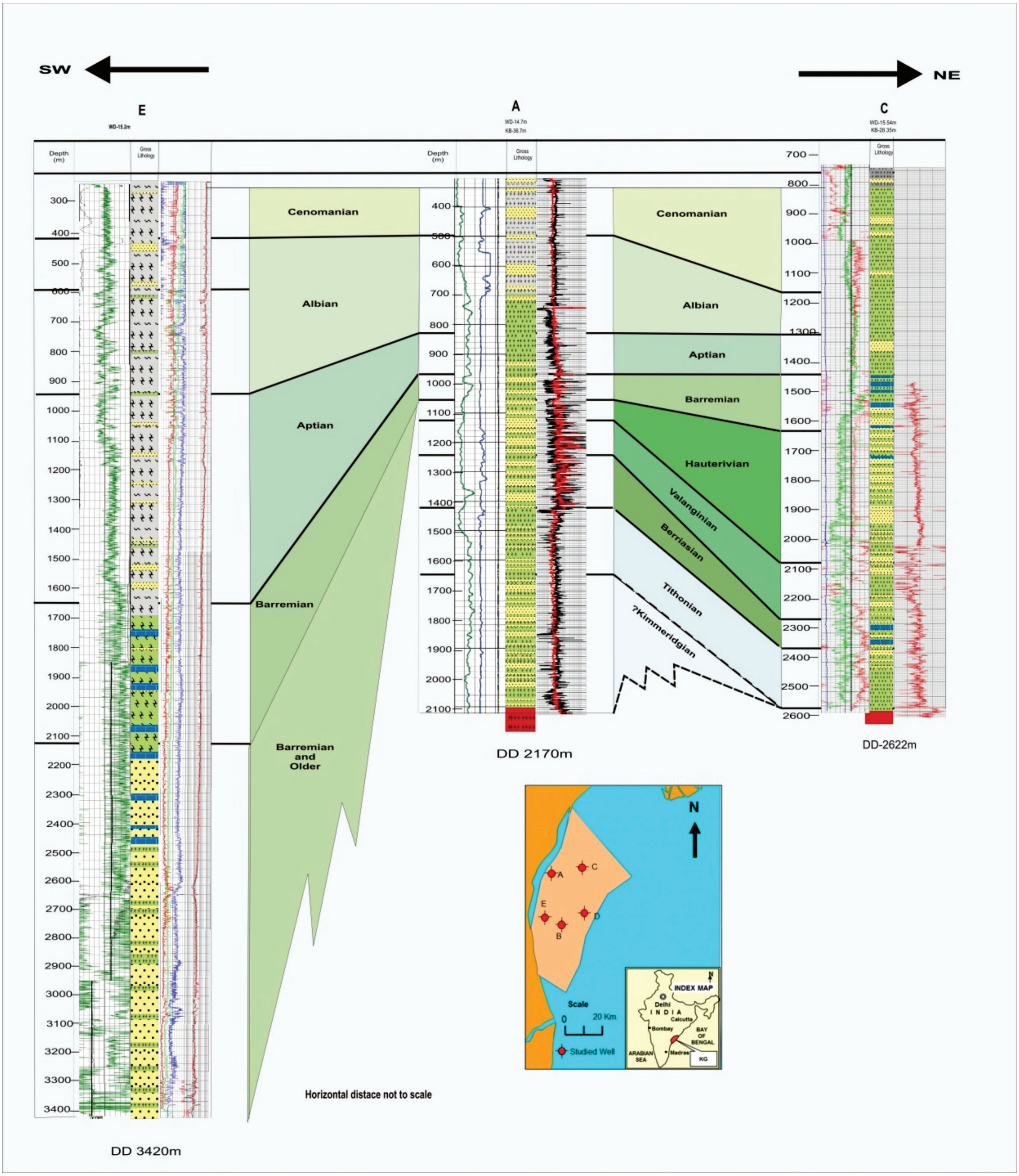

Fig. 7. Biostratigraphic correlation of post-Gondwana Late Jurassic and Cretaceous sediments of well A with wells of E and C of Pennar Subbasin (K-G Basin).

Suggested age and depositional environment: Occurrence of LAD of *Cerbia tabulate, H. sigali* and *Achomosphaera neptunii,* at 825m in A and at 955m in B, suggests Aptian age for the above depth interval. These sediments were deposited under outer shelf- upper bathyal conditions.

Albian: Albian sediments recorded in well A (500-825 m) and in B (725-955 m).

Characteristic palynoflora: The section is characterized by the presence of age marker dinoflagellate cysts which include *Batioladinium micropodum*, *Cauca parva,*

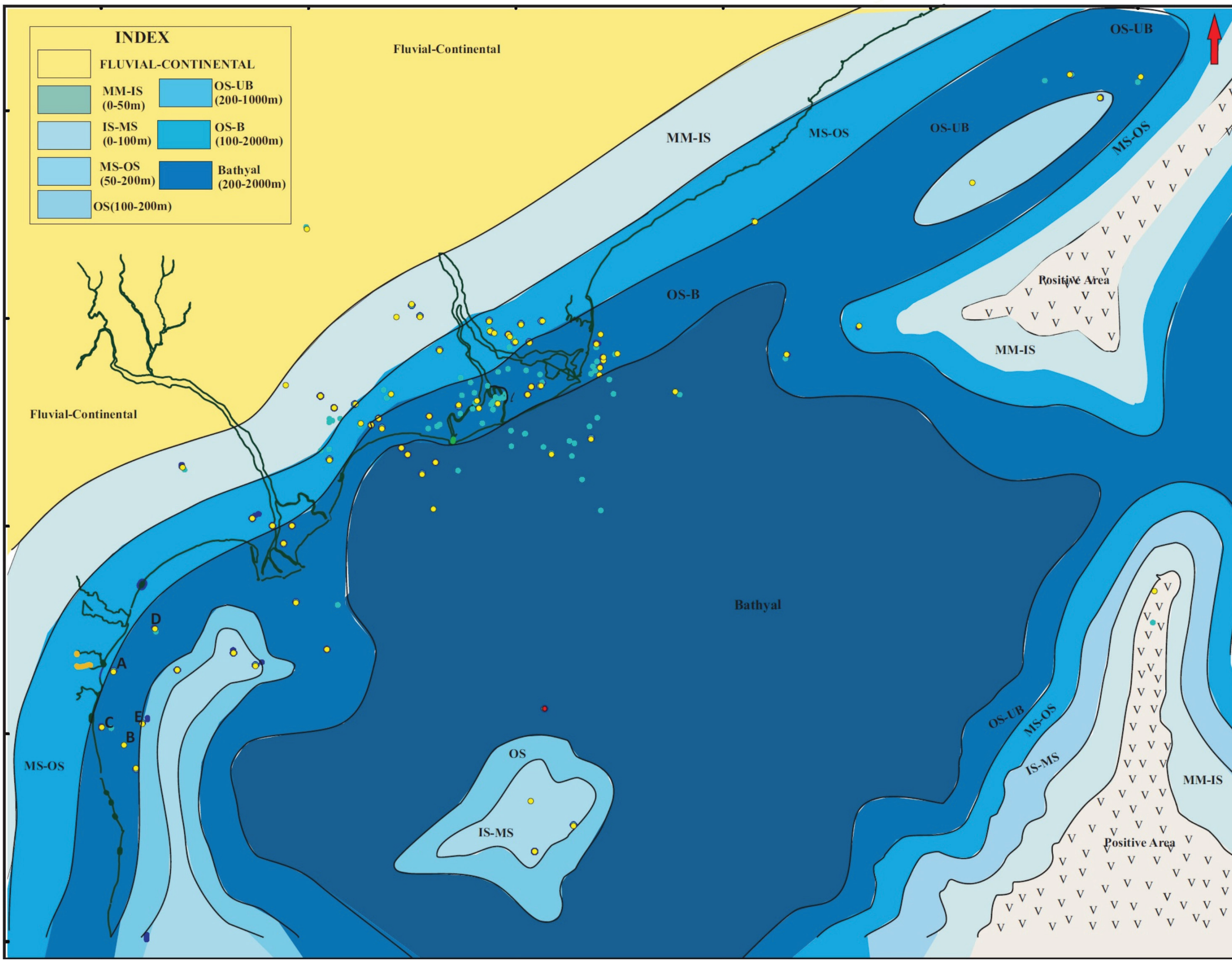

Fig. 8. Paleogeographic map of Krishna Godavari Basin at Albian top.

Litosphaeridium arundum, Pseudoceratium polymorphum, Pareodinia ceratophora, Aptea almohadensis, Nummus monoculatus and *Muderongia tetracantha*. The associated spore - pollen assemblage is represented by *Triporoletes reticulatus, Ornamentifera senonicus, Classopollis classoides, Cicatricosisporites hughesii*, *Aequitriradites spinulosus, Contignisporites cooksoniae* and *Appendicisporites distocarinatus*.

Characteristic foraminifera: This interval has yielded planktonic and benthic foraminifera in well A, including *Hedbergella planispira, H. delrioensis*, *H. trocoidea*, *Hedbergella* sp., *Rotalipora gandolfi*, *Rotalipora* sp., *Planomalina buxtorfi*, *Praeglobotruncana delrioensis*, *Whiteinella balthica*, *Whiteinella* sp., *Ammodiscus* sp., *Ammobaculites* sp., *Bathysiphon* sp., *Cibicides* sp., *Epistomia* sp., *Eponoides* sp., *Lagena* sp., *Nonion* sp. and *Lenticulina.* Well B-1 has yielded *Hedbergella planispira, H. delrioensis*, *Hedbergella* sp., *Favusella washitensis*, *Epistomina spinulifera*, *Epistomina* sp., *Ammobaculites* sp., *Eponoides* sp., *Lenticulina* sp. and *Lagena* sp.

Suggested age and depositional environment: Occurrence of above recorded assemblages of palynomorphs and foraminifera *viz. H. trocoidea, Planomalina buxtorfi* and *Epistomina* sp. suggests Albian age. Top of Albian is marked at 500 m in A and 725 m in B based on LAD of *Litosphaeridium arundum* and LAD of *Planomalina buxtorfi* in A-1. The sediments were deposited under outer shelf to deeper conditions.

Passive Margin Mesozoic (Cenomanian to Maastrichtian) biostratigraphy

In all the sub-basins of K-G Basin, major unconformity varying ca. 3 Ma to 10 Ma have been recognized at top of Early Cretaceous (Prasad *et al,* 1995; Prasad and Phor, 2009). This unconformity corresponds to change of basin set-up from synrift to passive-margin phase that lead to complete isolation of Indian plate from Antarctica and Australia. The complete isolation of Indian plate and subsequent easterly tilting of Indian Craton led to major marine transgression during Cenomanian and deposition of thick marine sediments of inner to middle shelf from Cenomanian to Maastrichtian. Thus, Cenomanian to Maastrichtian sediments in K-G Basin are placed into the passive-margin Cretaceous sediments (Prasad and Phor, 2009).

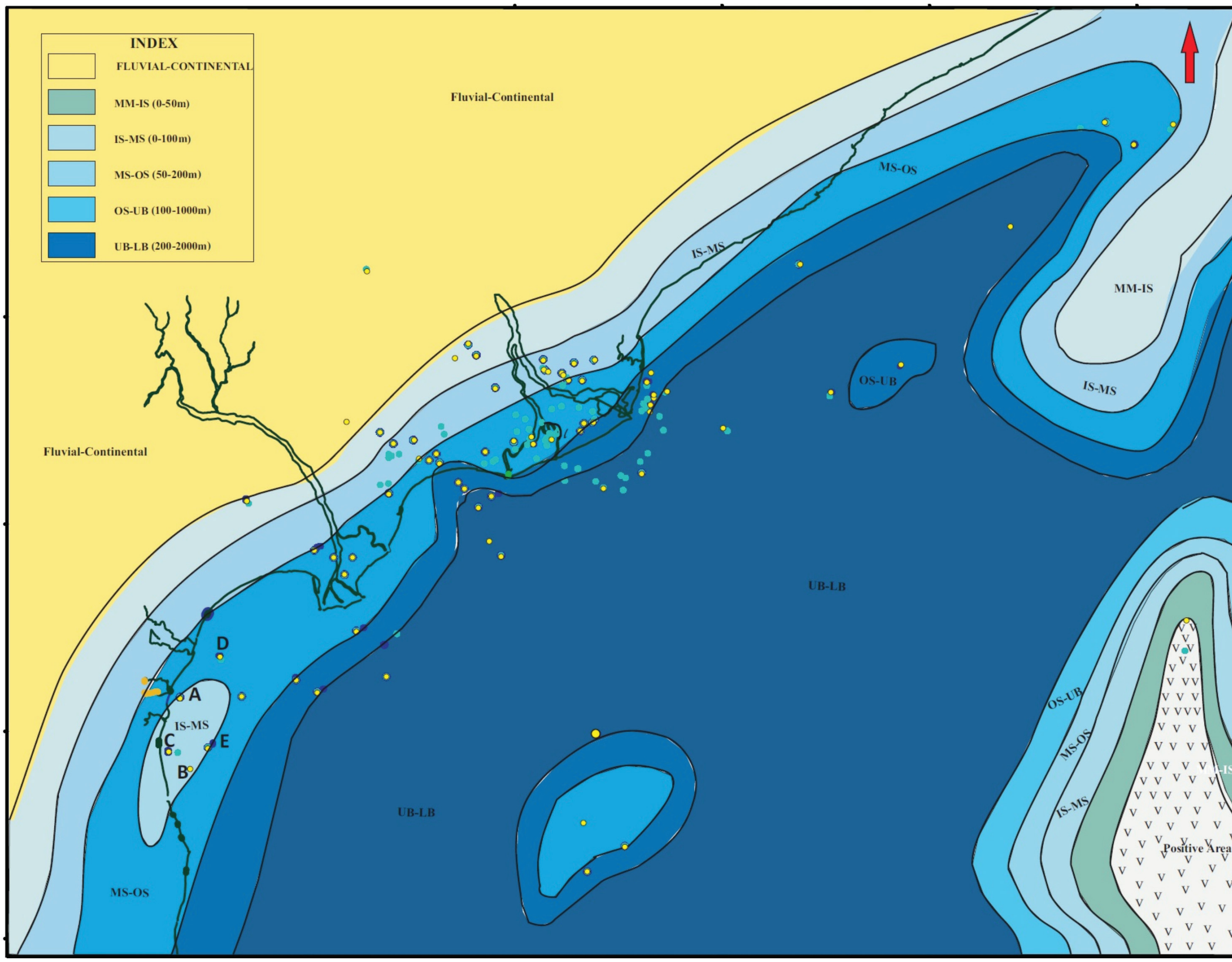

Fig. 9. Paleogeographic map of Krishna Godavari Basin at Cretaceous top.

Cenomanian: Cenomanian sediments recorded in well A (330-500 m) and B (540- 725 m).

Characteristic palynoflora: The cutting samples have yielded rich and diversified dinocyst assemblage viz. *Apteodinium granulatum, Pseudoceratium ludbrookie, Florentinia cooksoniae, Kiokansium williamsii, Prolixosphaeridium parvispinum, Cribroperidinium edwardsii, Cyclonephelium distinctum, Odontochitina costata, Hysrichosphaeridium* sp., *Gonyaulacysta cassidata* and *Diconodinium pusillum.* Associated spores-pollen include *Appendicisporites distocarinatus, Triporoletes reticulatus, Microcachryidites antarcticus, Murospora truncata*, *Contignisporites glebulentus, Plicifera senonicus, Crybelosporites stylosus* and *Foraminisporis wonthaggiensis.*

Characteristic foraminifera: In A-1, the interval has yielded few lenticulinids, while in well B, the interval recorded *Hedbergella planispira*, *H. delrioensis*, *Hedbergella* sp., *Lagena* sp., *Lenticulina* sp., *Osangularia* sp., *Planulina* sp., arenaceous foraminifera and few ostracodes.

Suggested age and depositional environment: Occurrence of LAD of dinoflagellate cysts *Cribroperidinium edwardsii* and *Litosphaeridium siphoniphorum* at 330 m depth in A and at depth 540m in B along with the above recorded dinoflagellate cysts, spores-pollen assemblage suggests Cenomanian age. The presence of planktonic foraminifera and rich occurrence of dinocysts suggest that the Cenomanian sediments were deposited under middle to outer shelf conditions.

Turonian-Coniacian: Turonian-Coniacian sediments recorded in well A (305-330 m) and B (510-540 m).

Characteristic palynoflora: The sediments have yielded characteristic dinoflagellates viz. *Chlamydophorella ambigua, Dinogymnium* spp., *Coronifera oceanica, Florentinia mantellii, Hystrichodinium* spp.*, Oligosphaeridium complex, Litosphaeridium siphoniphorum* and *Cribroperidinium edwardsii.* Associated spore-pollen includes *Appendicisporites distocarinatus, Phyllocladidites mawsonii, Murospora truncata, Triporoletes reticulatus, Cicatricosisporites australiensis, Plicifera senonicus, Asteropollis asteroides* and *Distaltriangulisporites mutabilis*.

Characteristic foraminifera: In well B, the interval recorded rare *Lenticulina* sp. and few indeterminate smaller benthic foraminifera. The interval is devoid of foraminifera in well A

Suggested age and depositional environment: The occurrence of *Chlamydophorella ambigua Stiphrosphaeridium anthophorum* at the top most sample in A-1 at 305 m and B at 510m alongwith record of LADs of *Cribroperidinium edwardsii* and *Litosphaeridium siphoniphorum* marks the Turonian-Cenomanian boundary at 330 m and 540 m in A and B and indicates Turonian-Coniacian and younger age for this interval. The sediments of this interval were deposited under inner shelf conditions.

DISCUSSION

Integrated multimicrofossil biostratigraphic studies comprising dinoflagellate cysts, spores-pollen and foraminifera helped in demarcating the precise age and biostratigraphic boundaries along with depositional environment from ?Kimmeridgian-Tithonian to Turonian-Coniancian. The recorded bioevents facilitated in dividing the sediments into ?Kimmeridgian-Tithonian (Late Jurassic), Berriasian, Valanginian, Hauterivian, Barremian, Aptian and Albian (Early Cretaceous), Cenomanian and Turonian-Coniancian (Late Cretaceous). Quantitative distribution of selected dinocysts in these wells and identification of appearance and disappearance (FADs & LADs) events of age marker taxa at different stratigraphic levels enabled recognition of fifteen distinct biohorizons in well A and B which range from Late Jurassic to Late Cretaceous. ?Kimmeridgian palynomorphs recorded are *Glossodinium dimorphum, Sentusidinium* sp., *Pareodinia ceratophora* and *Senoniasphaera jurassica* at 1650 m in well A and 3545 m in well B. This characteristic assemblage of Kimmeridgian occurs sporadically, hence definite boundary could not be marked between the Kimmeridgian and Tithonian. However, Tithonian-Berriasian (Jurassic-Cretaceous) boundary is marked based on the LAD of dinoflagellate cyst *Pseudoceratium weymouthense* which is recorded at 1420 m in well A and 2945 m in well B, with associated occurrence of spore-pollen taxa, such as *Striatella jurassica, Callialasporites dampieri, Callialasporites turbatus* and *Matonisporites* sp. The recognition of Tithonian- Berriasian boundary is supported by *Kalyptea wisemaniae* and *Dingodinium jurassicum*. Valanginian and Hauterivian and Barremian top are also precisely marked based on the recognition of important age marker dinocysts bioevents (LADs) at depth 2120 m, 1820 m, 1370 m, 1215 m in B and at 1245 m, 1125 m, 1050 m and 975 m in A respectively. Aptian top is recognized at 955 m in B and at 825 m in A, respectively. Albian top is recognized at 725 m in B and at 500 m in A. Aptian marker planktonic foraminifera *Hedbergella sigali* and *Globigerinelloides blowi* have been recorded. *Planomalina buxtorfi* and *Hedbergella gorbachikae* have been useful in demarcating Albian. Besides, *Favusella washitensis, Rotalipora gandolfi* and benthic aragonitic foraminifera *Epistomina* sp. are useful forms in demarcating the Albian-Cenomanian transition.

The sediments were deposited under the inner to middle shelf conditions. The biostratigraphic studies based on different parameters revealed the presence of Late Jurassic (?Kimmeridgian-Tithonian) sediments in the studied area, which represent the oldest synrift sediments deposited over the Precambrian Basement and indicates the absence of major part of Jurassic and older Permo-Triassic Gondwanic sediments. Biostratigraphic correlation with nearby drilled wells C, D and E indicates that Late Jurassic (?Kimmeridgian -Tithonian) thickness increases in basinal direction in southern side while in north and north eastern side the Late Jurassic sediments are relatively thin (Figs. 6 & 7).

The recorded biohorizons of dinoflagellate cysts and spore-pollen suggest the occurrence of Late Jurassic (Kimmeridgian) to Early Cretaceous (Albian) synrift sediments in the wells A and B. However, the study revealed that the sedimentation in the area commenced during Late Jurassic (?Kimmeridgian) in basinal direction in southern side, where Late Jurassic sediments thickness increases while in north and north eastern side the Late Jurassic sediments are relatively thinner. The Late Jurassic sediments are recorded up to the drilled depth in well B and directly overlie the Precambrian basement in well A. The palynoassemblages of Permo-Triassic Gondwanic sediments and Middle to Lower Jurassic sediments are not recorded, indicating the absence of major part of Jurassic and Gondwanic sediments in the studied area, and it is represented by a major hiatus.

This record predates the breakup of East Gondwana land from Tithonian (Prasad *et al.,* 1996; Prasad and Phor, 2009) to Kimmeridgian time. However, additional work on the early synrift sediments in the other Subbasin of K-G Basin is required to corroborate the latest finding of the older synrift sediments of Kimmeridgian age.

Depositional environments

The biostratigraphic data obtained from the studied wells have yielded characteristic palynoflora that helped in understanding the depositional set-up of different units. The palynofossil associations from ?Kimmeridgian–Tithonian sediments of the studied wells suggest a shallow inner shelf depositional environment. During Berriasian to Barremian, inner to middle shelf conditions prevailed. The deposition of Aptian-Albian exhibited by prolific amount of dinoflagellate cysts and abundance of fauna indicate outer shelf to deeper conditions. The overlying Cenomanian to Turonian-Coniacian sediments were deposited under middle to inner shelf conditions, respectively.

CONCLUSIONS

1. The oldest synrift sediments of Kimmeridgian (Late Jurassic) are recognized in the Pennar Subbasin of (K-G Basin) on the basis of age marker dinoflagellate cysts and spore-pollen that predates the earlier opinion of oldest synrift sediments of Tithonian age in the K-G Basin.

2. Biostratigraphic boundaries of Tithonian, Berriasian, Valanginian, Hauterivian, Barremian, Aptian and Albian are precisely established in the synrift sequence of Pennar Subbasin on the basis of record of global age marker dinoflagellate cysts and foraminifera.
3. Biostratigraphic boundary of Cenomanian, Turonian and Coniacian are also precisely established in the passive-margin sequence of Pennar Subbasin on the basis of record of global age marker dinoflagellate cysts.

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