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Age of the earliest transgressive event in the Krishna-Godavari Basin, India: evidence from dinoflagellate cysts and planktonic foraminifera biostratigraphy

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Abstract

A combined biostratigraphic study of dinoflagellate cysts and foraminifera was carried out on Early Cretaceous subsurface well cutting sediments from well A (DNG) (2800–2746 m depth) from the Krishna-Godavari Basin, India. The last appearance datum of marker species of dinoflagellate cysts and planktonic foraminifera was considered for the construction of the biostratigraphic framework. The study shows dominance of Early Cretaceous marker dinoflagellate cysts *Cassiculosphaeridia magna, Cribroperidinium perforans, Hystrichodinium voigtii, Kleithriasphaeridium eoinodes*, and planktonic foraminifera *Hedbergella aptiana, Hedbergella mitra, Hedbergella praelippa, Hedbergella tardita, Microhedbergella miniglobularis* and *Hedbergella mitra* species. In addition to this, the dinoflagellate cyst data were compared with the dinoflagellate biozones of Austral and Tethyan provinces. Based on earlier micropalaeontological records from the Krishna-Godavari Basin and the present study, a latest Barremian-early Aptian age has been determined for the earliest marine transgression in the Krishna-Godavari Basin. The early marine incursion during late Barremian-earliest Aptian in the Krishna-Godavari Basin compared to Albian age in Cauvery Basin suggests the opening of east coast from north to south.

Keywords: Biostratigraphy, Krishna-Godavari Basin, Palaeoenvironment

1 Introduction

The east coast of India was connected to Australia and Antarctica that separated from them during the Early Cretaceous which led to the opening of the eastern Indian Ocean (Fuloria et al. 1992; Fuloria 1993; Prabhakar 1993; Rangaraju et al. 1993; Kent et al. 2002; Lal et al. 2009; Gibbons et al. 2013). Despite the fact that a large number of studies on the tectonic evolution of the east coast of India have been carried out, no well-defined age for the opening of the Krishna-Godavari Basin has been proposed yet (Gibbons et al. 2013). The major constraint is the lack of well-preserved Early Cretaceous sediments and biostratigraphic framework from the eastern Indian margins (Prasad and Pundir 1999). The opening of the Krishna-Godavari Basin along the eastern part of India was a major event which contributed significantly in its development.

The Krishna-Godavari Basin is a typical rift passive margin basin that evolved during the Late Jurassic period (Rao 2001; McLaughlin 2001). Though the India-Australia rifting can be roughly estimated to have begun in Early Cretaceous, the exact timing of marine incursion and the early opening history of east coast is not substantive (Gibbons et al. 2013). The Early Cretaceous outcrops along the fringe of western margins of the Krishna-Godavari Basin exist as patches and lack well-preserved fossils (Prasad and Pundir 1999). On the other hand, more or less complete stratigraphic records with well-preserved fossils can be found in the subsurface of the Krishna-Godavari Basin (Prasad and Pundir 1999). The presence of huge oil reserves in the Krishna-Godavari Basin prompted Oil India Limited and Oil and Natural Gas Corporation Ltd. (ONGC) to drill several exploratory wells in the region during the last two decades (Rao 2001). The Early Cretaceous sediments in the Krishna-Godavari Basin are underlain by Precambrian basement and pre-Cretaceous

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Gondwana sediments, and overlain by Deccan Traps (Prasad and Pundir 1999; Rao 2001). As evidenced from the Krishna-Godavari Basin deposits, early syn-rift sediments were deposited during early extensional tectonic subsidence accentuated by the earlier rifted fault systems located at the basement (Gupta 2006). Differential basin subsidence continued from Late Jurassic to Early Cretaceous along the basement bound fault system accommodating syn-rift sediments (Gupta 2006). The basin witnessed its first marine transgression during the Early Cretaceous (Prasad and Pundir 1999; Gibbons et al. 2013). Based on gravity and magnetic anomaly data (Powell et al. 1988; Veevers et al. 1991; Frey et al. 1996; Bryan et al. 1997; Kent et al. 2002), the India, Australia and Antarctica assembly was considered to have been fragmented around 136–124 Ma by the volcanic activity. But the incomplete biostratigraphic records, disparity in gravity and magnetic anomaly data and lack of preserved fossils lead to the existence of various controversial issues regarding tectonic movement of greater India. In order to provide a precise stratigraphic age to the first marine transgression in the Krishna-Godavari Basin, a detailed dinocyst and foraminifera based biostratigraphic study on well cutting samples of DNG well (Oil India Limited), Kakinada, Krishna-Godavari Basin was carried out. An attempt has also been made to compare the dinocyst biostratigraphic zones of Tethyan and Austral provinces. Finally, the palaeoenvironmental inference regarding the early rifting history of India-Australia was determined.

2 Geology of study area

The half-crescent shape Krishna-Godavari Basin is a pericratonic basin of a passive margin, situated on the east coast of India. The Krishna-Godavari Basin extends from Kakinada in the north to Nellore in the south. It covers about 15,000 km^2 area onland and about 25,000 km^2 area of offshore region (Prasad and Pundir 1999; Gupta 2006). It consists of 6000–8000 m-thick sediments which correspond respectively from Early Permian to Recent in age. The Krishna-Godavari Basin sediments rest unconformably on highly metamorphosed Precambrian (Archean) basement (Fig. 1). The basin succession is divided into four groups viz. lower Gondwana Group (Chintalapudi Formation), Nizamapattanam Group, Gudivada Group and Vashishta Group (Table 1), each group being unconformably separated by the other. Gudivada Group of the basin is further subdivided into Raghavpuram Formation and Tirupati Formation. Raghavpuram shale which corresponded to Early Cretaceous (Barremian-Aptian to early Albian) in age, is well exposed at the western margin of the Dwarka-Tirumala town and unconformably overlies on Golapalli Sandstone. It has yielded mega fossils, plants, foraminifera and dinocysts (Prasad and Pundir 1999).

3 Material and methods

A total of 18 well cutting sediment samples were collected from 2800 to 2746 m depth of 54 m thick sequence of DNG well (16°44′N, 82°04′E) drilled by Oil India Limited, near Kakinada, Andhra Pradesh, Krishna-Godavari Basin, east coast of India (Fig. 1). The samples are from Lower Cretaceous Raghavapuram Formation, and consisted of mostly shale with intermittent millimeter thin sandstone layers. The samples were analyzed for the study of foraminifera and dinoflagellate cysts.

For the study of organic-walled dinoflagellates, samples were processed according to the standard palynological methods (Tyson 1995). 10 g of sample were treated with 10% Hydrochloric acid (HCl) to remove the carbonate. They were washed thoroughly with distilled water afterwards to remove the acid traces. Samples were then treated with 40% Hydrofluoric acid (HF) for 48 h to remove the silicates. Samples were washed thrice with distilled water to remove the acid remains and later, were treated with 10% Nitric acid (HNO_3) to mildly oxidize the organic matter. The residues are sieved through 15 μm size. Permanent slides were prepared with polyvinyl alcohol and mounted with Canada balsam. Dinoflagellate cysts were scanned under 600 X, 1000 X magnification of Olympus Microscope BX53. Dinoflagellate cysts were scanned and identified based on published records (Cookson and Eisenack 1958; Davey 1966, 1974; Duxbury 1977; Backhouse 1988; Oosting et al. 2006; Brideaux, 1977; De Ren'eville & Raynaud, 1981; Drugg, 1978; Ioannides et al, 1976; Lucas-Clark, 1984;).

For the study of foraminifera, samples were processed following standard micropaleontological procedures (Krumbein and Pettijohn 1938). The samples were disaggregated for microfossil separation by soaking 10 g of sample in 5% Hydrogen peroxide (H_2O_2) for 24 h period. Soaked material was sieved with of 63 μm size and dried at room temperature (~ 25–35^0 C). The washed residue was examined under 160 X magnification of Leica M205C stereomicroscope. Microfossils were picked, identified based on morphology (Longoria 1974; Banner and Desai 1988; Banner et al. 1993) and mounted on faunal slides for a permanent record. Selected specimens were mounted on glass stub for Scanning electron microscope (SEM) and coated with platinum for microphotographing using an SEM (Jeol- JSM-7800F). All dinoflagellate cyst slides are stored in Birbal Sahni Institute of Palaeosciences (BSIP) museum (Locality no. 9622, Slide no. 16394–16406). The SEM images of foraminifera are illustrated in Fig. 2.

4 Results

The samples possessed well-preserved assemblages of dinocysts, pollen and spores. Amongst the palynomorphs, dinoflagellate cysts were dominant, whereas

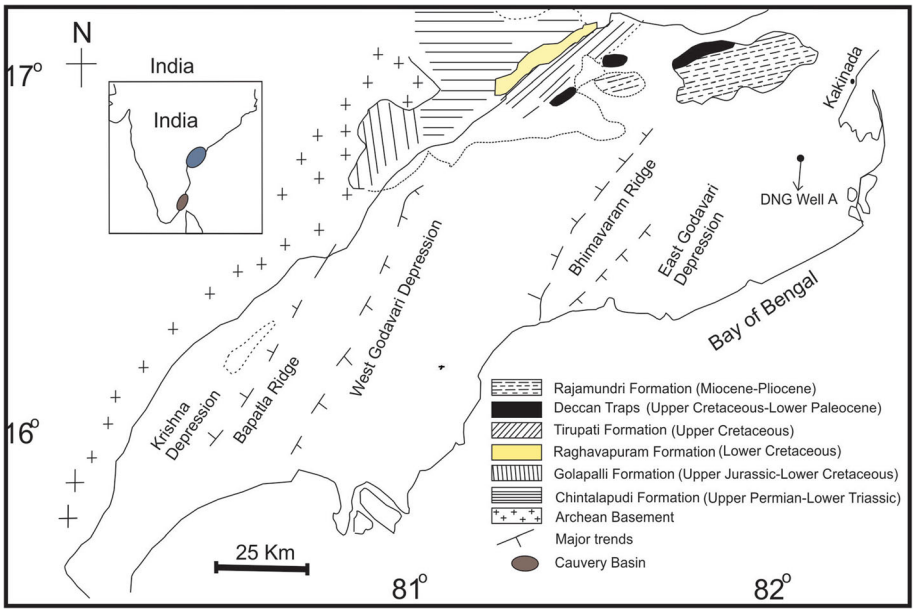

Fig. 1 Sketch showing location of the study area (modified from Chinnappa et al. 2014)

Table 1 Lithology, sedimentary environment and age of the Krishna-Godavari Basin, India (from Prasad and Pundir 1999)

GROUP	FORMATION	LITHOLOGY	AGE	SEDIMENTARY ENVIRONMENT
Vashishtha Group	Traps and Intertrappeans		Late Maastrichtian to Danian	
	……unconformity……			
	Dudukur	Limestone	Late Cretaceous (Maastrichtian)	Marine
	……unconformity……			
Gudivada Group	Tirupati	Sandstone	(Campanian to Early Maastrichtian)	Shallow marine
	……unconformity……			
	Raghavapuram	Shale	Early Cretaceous (Barremian – Aptian to Early Albian)	Shallow marine
	……unconformity……			
Nizama-pattanam	Gollapali	Sandstone	Early Cretaceous (Neocomian)	Shallow Marine
	……unconformity……			
Lower Gondwana	Chintalapudi	Sandstone	Late Permian	Non Marine (fluvial-to-lagoonal)
	……unconformity……			
Archean Basement		Khondalite	Precambrian	

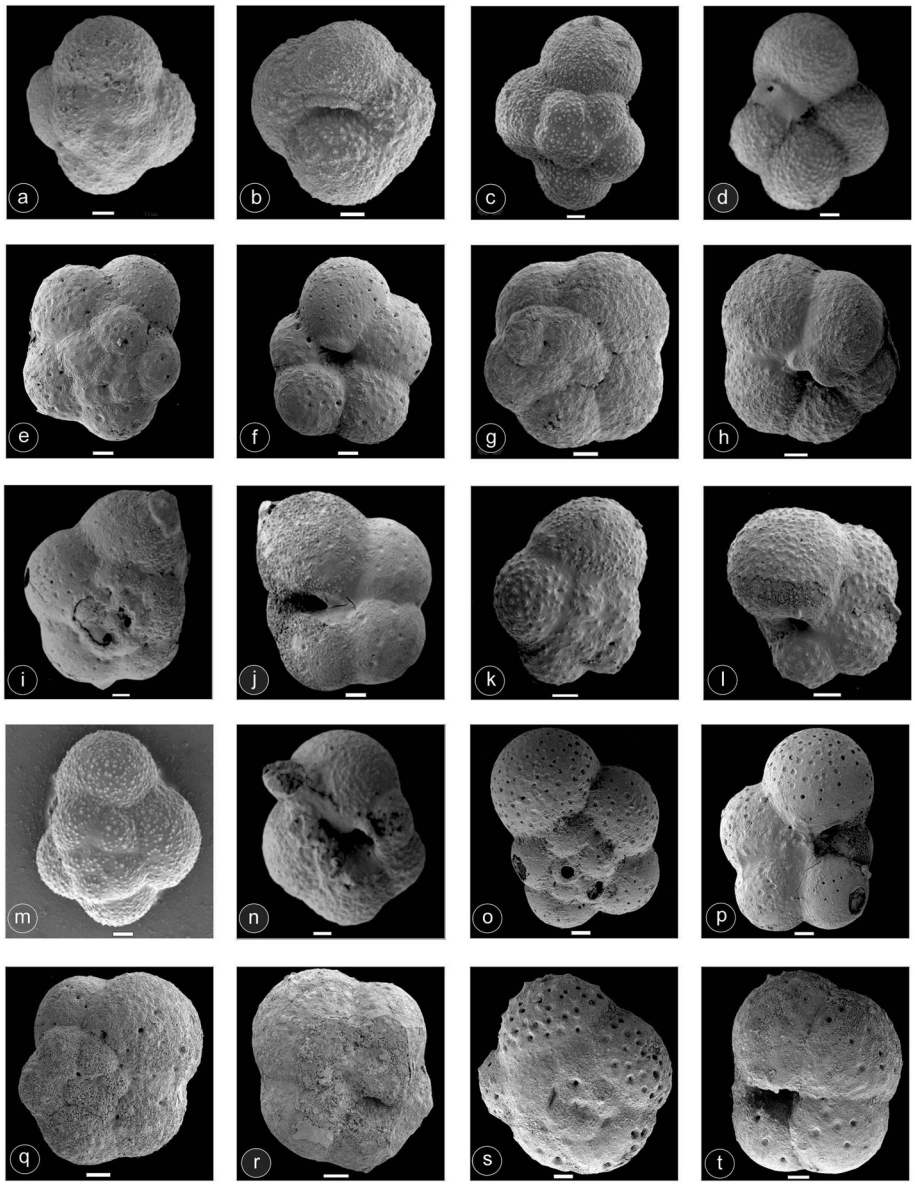

Fig. 2 SEM photograph of selected foraminiferal taxa from DNG well of the Krishna-Godavari Basin, India. **a**-**b** *Hedbergella tardita*. **c**-**d** *Hedbergella ruka*. **e**-**f** *Hedbergella excelsa*. **g**-**h, q**-**r** *Hedbergella gorbachikae*. **i**-**j** *Hedbergella praelippa*. **k**-**l** *Hedbergella infracretacea*. **m**-**n** *Microhedbergella miniglobularis*. **o**-**p** *Hedbergella aptiana. and* **s**-**t** *Hedbergella mitra,* Scale bars represent 10 μm

pollen and spores were moderate to rare in numbers. A total of 10 samples were analyzed for the study of dinocysts. The diversity of dinoflagellate cysts was low to moderate in all the samples (Fig. 3). However, foraminifera were found with high diversity only in sample no. 444 at a depth interval of 2782–2785 m thick (Fig. 3).

4.1 Dinoflagellate cyst biostratigraphy

The assemblage consisted of 14 dinocyst species belonging to 12 genera viz. *Cassiculosphaeridia magna, Cleistosphaeridium aciculare, Cribroperidinium edwardsii, Cribroperidinium perforans, Cyclonephelium distinctum, Dinopterygium dimorphum, Hystrichodinium voigtii, Hystrichosphaeridium tubiferum, Kleithriasphaeridium eoinodes, Litosphaeridium conispinum, Odontochitina operculata, Oligosphaeridium complex, Oligosphaeridium pulcherrimum* and *Polysphaeridium duma* (Fig. 4). Among these, the dominant species were *Cribroperidinium edwardsii, Polysphaeridium duma, Cassiculosphaeridia magna, Oligosphaeridium complex* and *Cribroperidinium perforans*. In the present study, first occurrence (FO) of *Hystrichosphaeridium tubiferum and Oligosphaeridium pulcherrimum* was recorded at depth of 2797 m while their last occurrence (LO) was found at depth of 2794 m (Fig. 3). FO of *Cassiculosphaeridia magna,*

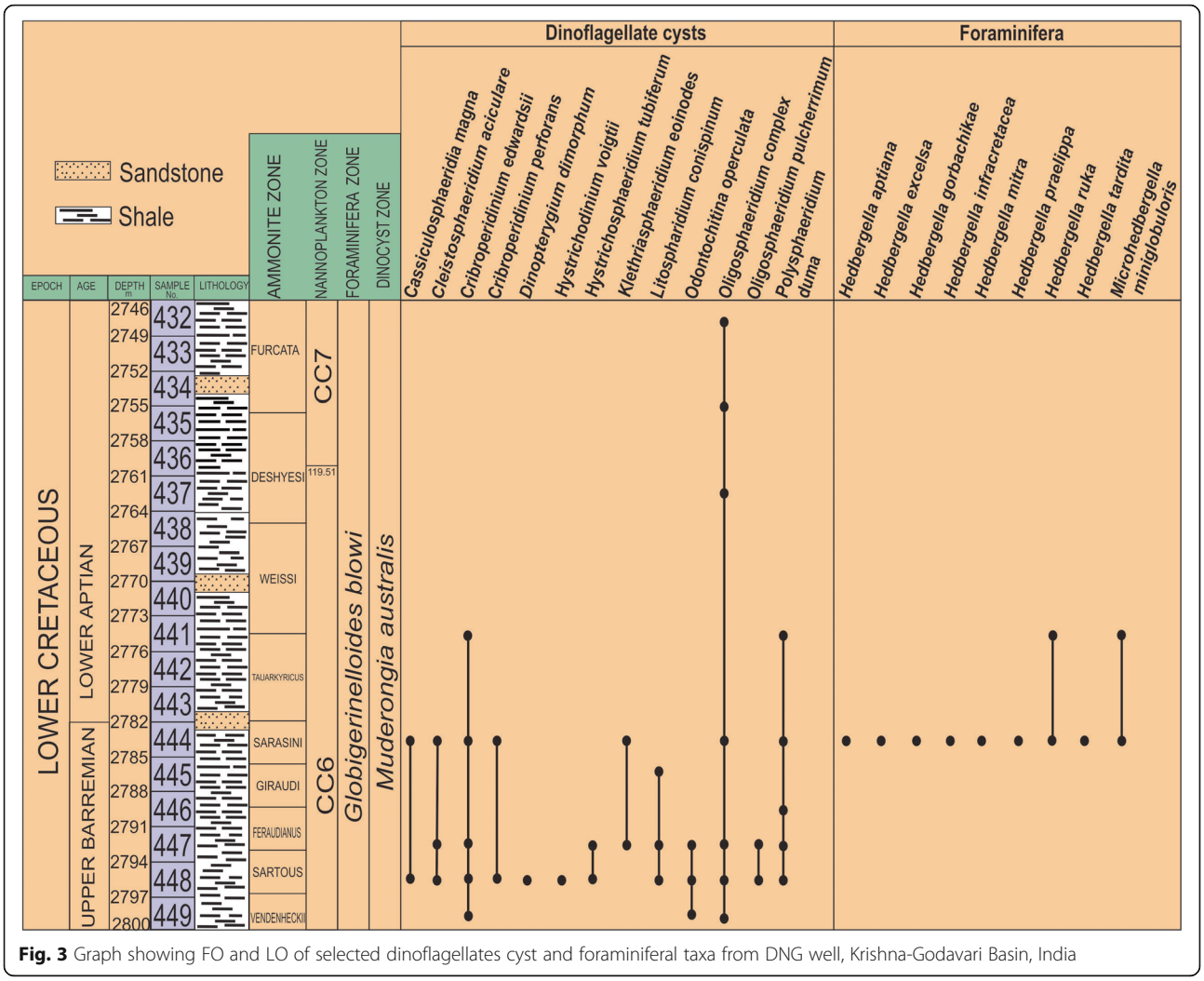

Fig. 3 Graph showing FO and LO of selected dinoflagellates cyst and foraminiferal taxa from DNG well, Krishna-Godavari Basin, India

Cribroperidinium perforans and *Cleistosphaeridium aciculare* was recorded at depth of 2797 m and their LO was found at depth of 2782 m. *Cribroperidinium edwardsii* which occurred abundantly in the succession was found to appear first at depth of 2800 m of the succession while its LO was recorded at depth of 2773 M. FO and LO of *Kleithriasphaeridium eoinodes* were found at depth of 2797 m and 2791 m, respectively. FO of *Litosphaeridium conispinum* was recorded at depth of 2794 m and its LO was found at depth of 2785 m. FO of *Odontochitina operculata* was recorded at the depth of 2800 m and its LO occurred at the depth of 2791 M. FO of *Polysphaeridium duma* was found at depth of 2797 m and its LO was recorded at 2773 m. *Oligosphaeridium complex* was found in large numbers at depth 2797 m and 2749 m.

4.2 Comparison of dinoflagellate cyst species

Cassiculosphaeridia magna, recorded in the sediments (Fig. 5a-c), differs from *Cassiculosphaeridia reticulata* in having a large sized cyst. *Cribroperidinium perforans* recorded at a depth of 2797 m (Fig. 5f), showed characteristic feature of thin perforated wall of theca and well developed bluntly pointed horn with distinct helicoid girdle. *Cribroperidinium* species (Fig. 5d-e) consisted of prominent long horn, precingular archeopyle, girdle helicoid, finely granular plates with pointed spines especially in apical and antapical region and hence was placed in *Cribroperidinium edwardsii*. *Hystrichosphaeridium* species having apical archeopyle with serrated processes tip (margin) was placed under *Hystrichosphaeridium tubiferum* (Fig. 5g-h). Dinoflagellate species placed under *Kleithriasphaeridium eoinodes* (Fig. 5i-j) bear strong ribbed tubular processes with denticulate margin and precingular archeopyle. Apical archeopyle, rounded antapex, non tabular, open processes of various length, width and shape are shown by *Cyclonephelium distinctum* (Fig. 6a-c).

4.3 Foraminifera biostratigraphy

The samples yielded nine species of well-preserved planktonic foraminifera viz., *Hedbergella aptiana,*

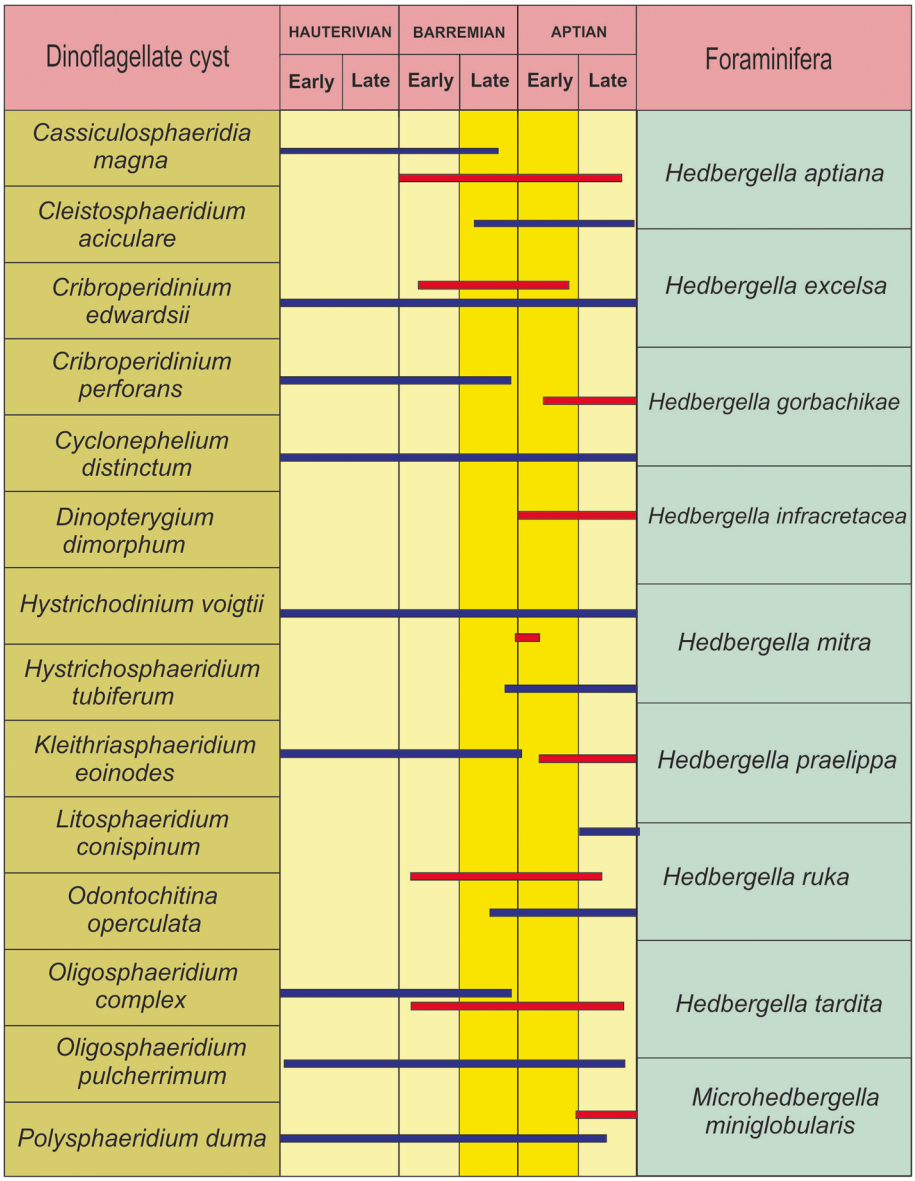

Fig. 4 Range chart of recorded dinoflagellate cysts and foraminifera of Early Cretaceous age

Hedbergella excelsa, Hedbergella gorbachikae, Hedbergella infracretacea, Hedbergella mitra, Hedbergella praelippa, Hedbergella ruka, Hedbergella tardita, and *Microhedbergella miniglobularis* (Fig. 4). The depth interval ranging from 2782 to 2785 m contains *Hedbergella ruka* and *Hedbergella excelsa* (the index taxa). The taxa range from Late Barremian to early Aptian age (Brovina, 2017). The species of *Hedbergella aptiana, Hedbergella tardita* and *Microhedbergella miniglobularis* were also recovered from the succession of the same interval indicating Early Cretaceous (late Barremian–early Aptian) age (Figs. 3, 4). Besides, this interval also yielded *Hedbergella praelippa* assigning an early Aptian age. *Hedbergella ruka* was also recognized in the *G. blowi* Zone (Brovina 2017). *Globigerinelloides blowi*, a marker species of *G. blowi* Zone was absent in the present study.

The ranges of planktonic species identified from the studied section are presented in Fig. 4. It is evident from the range chart that a large number of first and last occurrences of foraminifera are recorded in the succession. These species have been previously recognized on a global basis and thus form valuable stratigraphic markers. Index foraminifera which are necessary for precise age assignment were discovered from the succession, namely *Hedbergella excelsa* and *H. ruka*. Although the assemblage as a whole indicates late Barremian-early Aptian age, late Barremian to early Aptian part of succession is

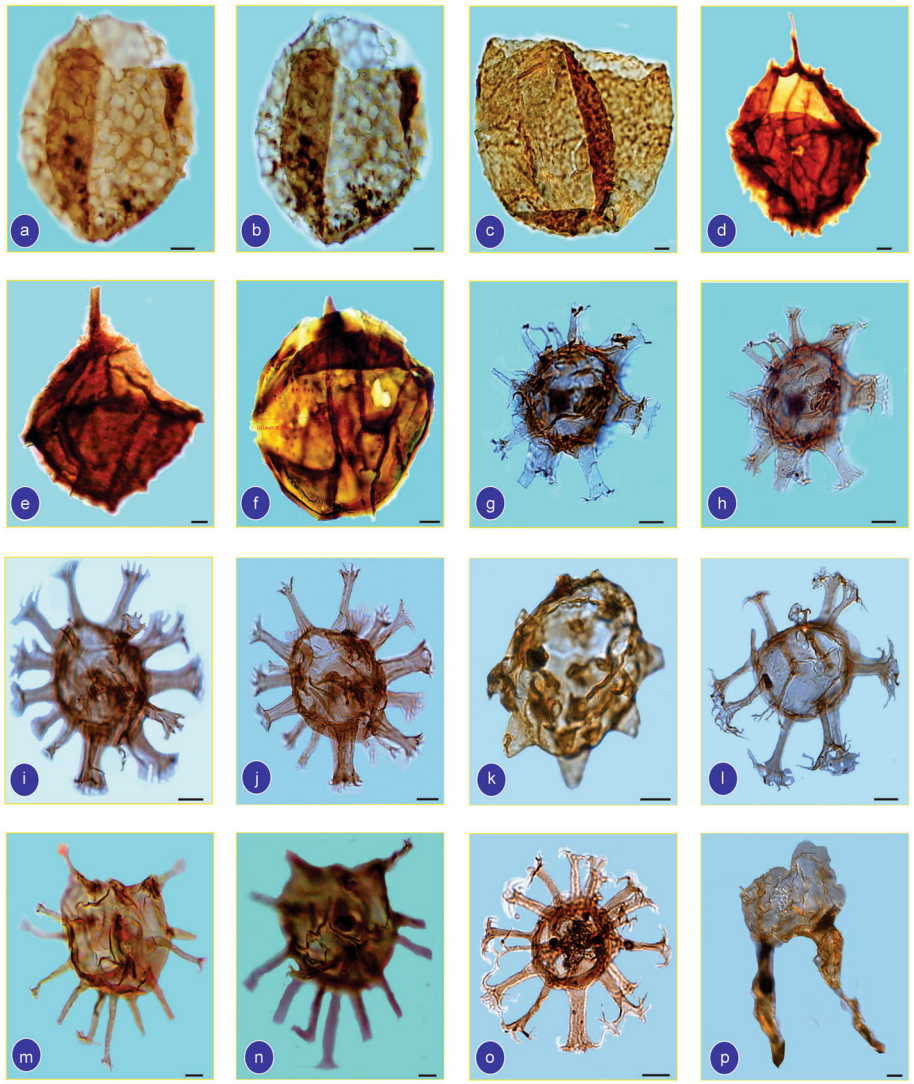

Fig. 5 Light microscopic photographs of selected taxa from DNG well of the Krishna-Godavari Basin, Kakinada, India. **a**-**c** *Cassiculosphaeridia magna,* BSIP-16395(A, B), 16394(C), EFC 21D/4 (A, B), 20 M/1(C). **d**-**e** *Cribroperidinium edwardsii,* Dorsal view BSIP-16395, EFC 20 L/1(D), 34 V/2 (E). **f** ventral view of *Cribroperidinium perforans,* BSIP-16397, EFC 21 W. **g**-**h** *Hystrichosphaeridium tubiferum,* BSIP-16398, EFC 13O/4; **i**-**j** *Kleithriasphaeridium eoinodes,* BSIP-16400, EFC 41 N. **k** *Litosphaeridium conispinum,* BSIP-16399, EFC 25E/1. **l** *Oligosphaeridium pulcherrimum,* BSIP-16401, EFC 17G. **m**-**o** *Oligosphaeridium complex,* BSIP-16400(M, N), 16402(O), EFC 39F (M, N), 25 M/3. **p** *Odontochithina operculata,* BSIP-16404, EFC 45P/2. Scale bars represent 10 μm and EFC Represents England Finder Coordinates

characterized by the presence of long-ranging planktonic species such as *Hedbergella aptiana, Hedbergella ruka, Hedbergella excelsa* and *Hedbergella mitra*. These species have been recorded in late Barremian to early Aptian sediments from different parts of the world as well (Banner et al. 1993; Banner and Desai 1988; Longoria 1974) (Fig. 4).

5 Palaeoenvironment

On the basis of published record, paleotectonic events and palaeoenvironment of the east coast of India (especially the Krishna-Godavari Basin and Cauvery Basin) remain open to discussion. The opening of the Krishna-Godavari Basin either from north to south (Powell et al. 1988; Frey et al. 1996; Gibbons et al. 2013; Chatterjee et al. 2017) or from south to north (Singh and Swamy 2006) still continues to be debatable. The sequence examined here corresponds to late Barremian-early Aptian age and supports the direction of opening of the basin from north to south because the Cauvery Basin opened in Albian time (Nagendra et al. 2011) which is situated towards the south of the Krishna-Godavari Basin. Sample no. 444 (depth ranging from 2782 to 2785 m) of DNG well yielded high diversity of dinoflagellate cysts and foraminifera, thus providing evidence for the first transgressive event and open marine conditions during

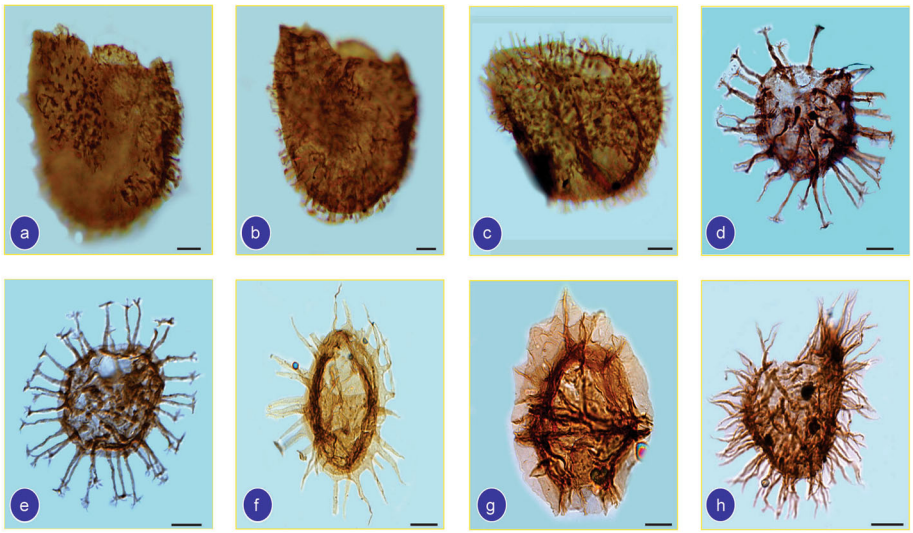

Fig. 6 Light microscopic photographs of selected taxa from DNG well of the Krishna-Godavari Basin. **a**-**c** *Cyclonephelium distinctum,* BSIP-16403, EFC 32O/2(A, B), 35 T/4(C). **d**-**e** *Polysphaeridium duma,* BSIP-16403(D), 16401(E), EFC 42E/3(D), 20F/2(E). **f** *Hystrichodinium voigtii,* BSIP-16399, EFC 16 L/4. **g** *Dinopterygium dimorphum,* BSIP-16397, EFC 29G/4. **h** *Cleistosphaeridium aciculare,* BSIP-16406, EFC 42S; Scale bars represent 10 μm and EFC Represents England Finder Coordinates

late Barremian-early Aptian in the Krishna-Godavari Basin.

6 Discussion and conclusions

The Krishna-Godavari Basin is a pericratonic basin which was formed during Hauterivian to Albian period following the fragmentation of Gondwanaland (Garg and Jain 1987; Prasad, and Pundir 1999). The lack of early records of marine transgression in the Krishna-Godavari Basin is attributed to the absence of Early Cretaceous outcrops from the region. Most of the Early Cretaceous sedimentary successions in the Krishna-Godavari Basin are under a thick pile of deltaic sediments and hence subsurface study remains the only alternative. A broad biostratigraphic framework based on foraminiferal biostratigraphy is available from the region (Bhalla 1965, 1969). While few dinoflagellate cysts based biostratigraphic studies provided broad Barremian-Albian age to the Krishna-Godavari Basin (Garg and Jain 1987; Prasad, and Pundir 1999). In the present study the dinocyst and planktonic foraminifera records from DNG well provide significant data for carrying out biostratigraphic study of the Krishna-Godavari Basin. Despite the problems of reworking and contamination in well cuttings, the age of the earliest marine transgression event of the Krishna-Godavari Basin can be determined with some confidence. Based on the FO and LO of some marker species of dinoflagellate cysts and planktonic foraminifera and their comparison with global marker species, Early Cretaceous biostratigraphic framework of the Krishna-Godavari Basin has been proposed. Dinoflagellate cysts have been prominently used in the correlation of marginal marine Early Cretaceous sequences of Austral region and based on that, a biostratigraphic framework has been given (Morgan 1979; Helby 1987; Backhouse 1988). However the dinoflagellate zonal schemes of the Austral and Tethys region are different, due to which some variations can be seen in the taxonomic identification of dinoflagellate cysts and their geological ranges (Oosting et al. 2006). The geological range of *Cassiculosphaeridia magna* is early Barriasian to late Barremian (Costa et al. 1992; Stover et al. 1996) while it is early Barremian in England, (Davey 1974) and early Aptian in western Australia (Fig. 7). *Hystrichodinium voigtii* was recorded in the late Valanginian to early Hauterivian in Poland (Alberti 1961) whereas the same species is defined and assigned different ages in different places: early to late Hauterivian in England (Costa et al. 1992), Barremian to Turonian in Germany, Barriasian to Barremian in England (Alberti 1961; Davey et al. 1969; Duxbury 1977; Sarjeant 1966) (Fig. 7). *Litosphaeridium conispinum* stratigraphically ranges from late Aptian to Cenomanian (Stover et al. 1996) while the same species is reported in England from late Albian to Cenomanian (Cookson and Hughes 1964) and from late Albian in France and England (Davey and Verdier 1973; Costa et al. 1992). Similarly, the geological range of *Cyclonephelium distinctum* is Kimmeridgian to Cenomanian in England (Stover et al. 1996) while the same species has been defined from Hauterivian to early Aptian in France (Millioud 1969), from late Barremian to Aptian in Canada (Jansonius 1986) and Senonian (upper Cretaceous) in western Australia (Deflandre and Cookson, 1955). *Polysphaeridium duma* is reported from

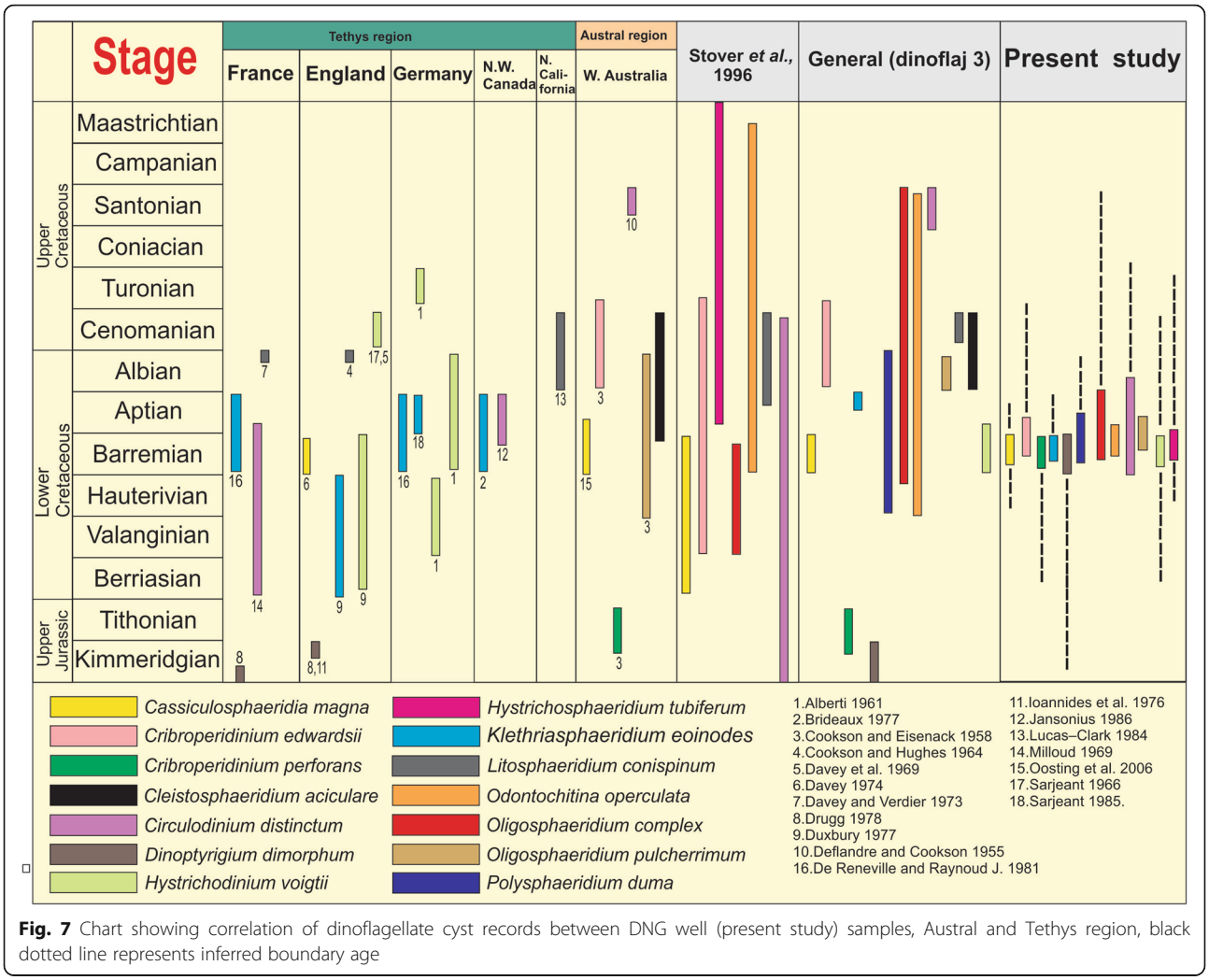

Fig. 7 Chart showing correlation of dinoflagellate cyst records between DNG well (present study) samples, Austral and Tethys region, black dotted line represents inferred boundary age

Hauterivian to Albian (Below 1982). *Cribroperidinium edwardsii* is reported from early Valanginian to early Turonian in France (Stover et al. 1996) (Fig. 7), early to late Cenomanian in England (Costa et al. 1992) and from Albian to early Turonian in England (Burger 1980). *Cribroperidinium perforans* is recorded from late Jurassic to Barremian in western Australia (Cookson and Eisenack 1958), in early Barremian from England (Davey 1974) and in early Aptian from western Australia (Oosting et al. 2006). As depicted in Fig. 2, *Odontochitina operculata* is described under *O. operculata* Zone (Oosting et al. 2006) and *O. operculata- Muderongia* australis Zone (Prasad and Pundir 1999). Some species like *Oligosphaeridium pulcherrimum* and those belonging to *Oligosphaeridium complex* are also placed under *Odontochitina operculata-Muderongia australis* zone (Prasad and Pundir 1999). The present dinocysts range from the DNG well, Krishna-Godavari Basin compares well with the Early Cretaceous ranges of Tethyan and Austral regions. The FO and LO of dinoflagellate cysts from the lower part of the succession (2797–2773 m of depth) of the DNG well compares well with the upper part of the *Muderongia australis* Zone (Stover and Helby 1987; Oosting et al. 2006) and lower part of the *Odontochitina operculata* Zone (Helby 1987) suggesting an age of late Barremian-early Aptian for the basal-most part of the succession (Fig. 7).

Foraminiferal data of the depth interval ranging from 2782 to 2785 m consists *Hedbergella aptiana, Hedbergella gorbachikae, Hedbergella infracretacea, Hedbergella praelippa, Hedbergella tardita,* and *Microhedbergella miniglobularis* suggesting an age of late Barremian-early Aptian. This interval also yielded *Hedbergella praelippa* and *Hedbergella mitra* foraminifera assigning an early Aptian age. Planktonic foraminifera species, namely *Hedbergella excelsa* and *Hedbergella ruka* (the index taxa) of late Barremian-early Aptian (Brovina 2017) is reported from 2782 to 2785 m in DNG well. The ranges of planktonic species identified from the section are

presented in Fig. 4. These species have been previously recognized on a global basis and thus form valuable stratigraphic markers. Based on the foraminifera and dinoflagellate biostratigraphy, the basal part of the DNG well corresponds to latest Barremian-early Aptian age.

Abbreviations

DNG: Well 'A' near Kakinada, Andhra Pradesh, Krishna-Godavari Basin, east coast of India; FO: First occurrence; LO: Last occurrence; O: *Odontochitina*; SEM: Scanning Electron Microscope

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Authors' contributions

AKM processed all the samples, analyzed and interpreted the present study data and prepared this manuscript. NM performed the foraminiferal morphology examination and helped to prepare their stratigraphic ranges. ADS reconstructed the palaeoenvironment of foraminifera in the present study and checked the manuscript thoroughly. DB has helped in the sample procurement and provided the lithological details and interpretations. VP designed the research problem and contributed major part in identification of dinoflagellate cyst and reconstruction of the paleoenvironment in the study. All authors read and approved the final manuscript.

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Availability of data and materials

The dinoflagellate cyst and foraminiferal slides have been deposited in the museum of Birbal Sahni Institute of Palaeosciences (Locality no. 9622, Slide no. 16394–16406). The data and other details of this study are available with the corresponding author Dr. Vandana Prasad and upon request all the data and slides can be made available.

Competing interests

The authors declare that they have no competing interests.

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