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Early Cretaceous flora of India–A review

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ABSTRACT

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Earth's terrestrial ecosystem during the early Cretaceous was marked by the dominance of naked seeded plants and appearance of flowering plants. Tectonic changes and evolutionary processes affected southern floras of the globe during this time. Review of Indian early Cretaceous flora distributed in peri and intra–cratonic basins signify homogenity of composition with regional variations. The flora composed of pteridophytes, pteridospermaleans, pentoxylaleans, bennettitaleans, ginkgoaleans, coniferaleans, taxaleans and taxa of uncertain affinity along with sporadic occurrence of flowering plants represent a unique Indian early Cretaceous flora. Similitude of basinal floras with marginal differences can be attributed to taphonomic limitations and taxonomic angularity. A perusal of available data brings out an opportunity for novelty in floral composition and variable associations dictated by prevailed environmental conditions. The eastern, western and central regions of India hold distinct litho units encompassing plant mega fossils represented by leaf, wood / axis, seed, fructification and associated marker forms. Remarkable tenacity of certain plant groups, which even found in modern flora and vulnerability of many taxa constitute a blend of extinct and extant. The appearance and extinction of certain taxa can be explained as a cumulative affect of evolutionary and climatic factors. Perpetuation of gondwanic floral elements during the early Cretaceous along with newly evolved floral components testifies evolutionary innovations and changing ecological constraints.

Key–words—Early Cretaceous, Floristics, Peninsular India, Diversification, Gondwana, Evolution, Palaeogeography.

भारत की प्रारंभिक चाकमय वनस्पतिजात – पुनर्विलोकन

ए. रजनीकांत एवं चोप्पारप्पू चिन्नप्पा

सारांश

प्रारंभिक चाकमय के दरम्यान पृथ्वी का स्थलीय पारिस्थितिकतंत्र अनावृतबीज पादपों के प्राबल्य एवं पुष्पित पादपों के प्रकटन से प्रभावित था। इस काल में भू–मंडल की वनस्पतिजातें विवर्तनिक बदलावों एवं विकासीय प्रक्रमों से प्रभावित थीं। बाह्य और अंतः – क्रेटनी द्रोणियों में विभाजित भारतीय प्रांरभिक चाकमय वनस्पतिजात का पुनर्विलोकन आंचलिक परिवर्तनों के साथ संघटन की समांगता बताता है। पुष्पित पादप अभिलेखों की यदा–कदा प्राप्ति के साथ पर्णांगों, टेरिडोस्पर्मेल्स, पेंटॉक्ज़ाइलेल्स, बेनेटाइटेल्स, गिंकगोएल्स, कोनीफेरेलीज के संगुणन तथा अनिश्चित बंधुता की टैक्सा ने विशिष्ट भारतीय प्रारंभिक चाकमय वनस्पतिजात सृजित की। उपांतीय फर्कों सहित द्रोणिय कोणिकता को दिए जा सकते हैं। उपलब्ध आँकड़े का अवलोकन व्याप्त पर्यावरणीय स्थितियों से नियंत्रित पुष्पी संघटन एवं परिवर्तनीय संगुणनों में अनूठेपन हेतु अवसर प्रकट करता है। पत्ती, कष्ठ/अक्ष, बीज, फलन एवं संगुणित चिह्नकों से रूपायित पूर्वी, पश्चिमी और मध्य भारतीय अंचल पादप स्थूल जीवाश्मों को समाविष्ट करते हुए विशिष्ट अश्म इकाइयों को स्थान देते हैं। कुछ पादप समूहों की विलक्षण लगिष्णुता जो कि आधुनिक वनस्पतिजात और अनेक की दोषपूर्णता तक में मिलती है विलुप्त एवं वर्तमान के सम्मिश्रण गठित करते हैं। कुछ टैक्सा के आविर्भाव और विध्वंस विकासीय एवं जलवायवी कारकों के सुविवेचित (कारण) हो सकते हैं। प्रारंभिक चाकमय के समय नूतन विकसित होते पुष्पी अवयवों सहित गोंडवानी पुष्पी तत्वों का स्थायीकरण विकासीय नवीनताएँ तथा बदलते पारिस्थितिकीय व्यवरोध प्रमाणित करते हैं।

सूचक शब्द—प्रारंभिक चाकमय, पादपअध्ययन, प्रायद्वीपीय भारत, विविधरूपण, गोंडवाना, विकास, पुराभूगोल।

INTRODUCTION

THE Cretaceous period in the history of earth holds remarkable evidences of plant life. Collation of these data paint a new carpet of vegetation and some components even sustained through modern era with a new design and pattern. Life and climate coevolved during the early Cretaceous (Krassilov, 1973; Skelton *et al*., 2003; Föllmi, 2011). Global plant records indicate that the early Cretaceous represents culmination of floral innovations and the plant ecosystem included novel groups of plants with a foundation for modern vegetation. The period is aptly referred as 'Dawn of New Era' or the 'Era of Flowering Plants' (Seward, 1931).

The early Cretaceous witnessed major changes in the composition of floras and they continued with out getting extinct though minor extinctions reported in marine realm (Raup & Sepkoski, 1984; Sepkoski, 1996; Heimhofer *et al*., 2004). The pre–Cretaceous flora was mainly composed of non–flowering plants and gradually bennettitaleans as well as araucarians suddenly decreased in abundance and distribution (Graham, 2011). Subsequently this floral composition was replaced by flowering plants (i.e. the angiosperms), the dominant floral elements of the modern terrestrial plant ecosystems. Although, the group appeared as small initially, they later began to flourish and ultimately became dominant in most ecosystems on the earth, until the late Cretaceous (Vakhrameev, 1991; McLoughlin, 2001; McLoughlin & Kear, 2015). Climate played an important role in vegetation dynamics (Prentice, 1986) and floral evidences helped to deduce ancient climate (Krassilov, 1973; Vakhrameev, 1991).

The early Cretaceous ecosystem in India, known through plant macrofossils, exhibit floral variations and basinal floral differences. These evidences are documented from various sedimentary basins of India distributed in eastern (Cauvery, Palar, Krishna–Pranhita–Godavari and Mahanadi basins), western (Kutch, Rajashtan) and central (South Rewa, Satpura, and Rajmahal basins) regions (e.g. Feistmantel, 1876a; Sahni, 1928, 1931; Bose & Banerji, 1984; Sen Gupta, 1988; Sukh–Dev & Rajanikanth, 1989a, b; Bose *et al*., 1991; Sharma, 1997; Banerji, 2000; Rajanikanth *et al*., 2000; Prakash, 2008; Chinnappa *et al*., 2014a, b, c, 2015). It has been customary to group these litho units/formations of different sedimentary basins under 'Upper Gondwana' characterized by Ptilophyllum flora. Stratigraphic and lithologic criteria were the basis of this categorization based on evidences from plant records. Both the lithostratigraphic and biostratigraphic evidences were utilized to categorize Indian Gondwana into lower, middle and upper units/formations (Fox, 1931; Lele, 1964). Conventionally the tripartite division of Indian Gondwana was floristically demarcated by *Glossopteris*, *Dicroidium* and Ptilophyllum floras corresponding to Permian, Triassic and Jurassic–early Cretaceous (Feistmantel, 1877e; Bancroft, 1913; Lele, 1964; Bose, 1966b; Shah *et al*., 1971; Venkatachala, 1977).

The early Cretaceous plant macrofossils from India are preserved as impressions and compressions (see Rajanikanth & Prakash, 1994 and references therein). Besides these petrified fossil woods are also well known (see Rajanikanth & Tewari, 2004 and reference therein). Interestingly, some of the early Cretaceous sediments exposed at eastern margin of India also indicate marine influence (Spath, 1933; Rao & Venkatachala, 1972) and collectively called 'Coastal Gondwana'. The fluvio–lacustrine deposits along with occasional paralic intercalations in the peninsular India constitute a special group of litho units. The definition, geographic extent and age of these so called 'Upper Gondwana' have been the subject of contraversy and various views have been expressed to re–evaluate and reassess the concept (Oldham, 1893; Foote, 1873; Feistmantel, 1877e; Dutta *et al*., 1983; Venkatachala *et al*., 1993; Rajanikanth *et al*., 2000; Shah, 2004; Rajanikanth & Chinnappa, 2015b). Considering tectonic separation of India from southern Gondwana and existence of post Triassic lithologic hiatus suggest to separate early Cretaceous sequences from 'Upper Gondwana' perview (Garg *et al*., 1987; Venkatachala *et al*., 1993; Rajanikanth *et al*., 2000; Chatterji *et al*., 2013; Rajanikanth & Chinnappa, 2015b).

The early Cretaceous terrestrial vegetation was a major source of liquid and gaseous hydrocarbons in many parts of the world (Ramanathan, 1968; Thomas, 1982; Smith, 1988; Rao 1993, 2001; Swamy & Kapoor, 1999; Mehrotra *et al*., 2012). Recently some important contributions to the early Cretaceous flora of Krishna–Pranhita–Godavari basins indicating nature of past vegetation and the prevailed climate have also been made (Chinnappa *et al*., 2014a, b, c, 2015). In view of recent spurt in researches on the early Cretaceous, a comprehensive review of the Indian early Cretaceous flora has been attempted to understand the diversity of the flora. Evolutionary history of different plant groups, their differential distribution in peninsular India and comparative account of basinal flora constitutes the main framework of the present communication.

In the present paper 'Ptilophyllum flora' embodied sediments are treated under 'early Cretaceous realm'. Although leafy axes (leaves), woods and reproductive parts have been analysed, only diversity of leaves belonging to various plant groups have been taken into consideration to draw the floral diversity. The method is based on the assumption that the recovered woods or reproductive parts are related to any one of the leaf forms, which have already been described. The assignment of *Taeniopteris* leaves under pentoxylaleans followed in this paper is tentative. Some of these leaf types may belong to bennettitaleans. Similarly *Brachyphyllum* and *Pagiophyllum* may fall under two or more than two families such as Podocarpaceae, Araucariaceae and Cheirolepidiaceae. However, they are treated under a single family–Araucariaceae following Bose and Maheshwari (1974). Fossil petrified woods have been synthesized separately, which will be included in the next publication. Like wise plant fossils of Himalayan region are not considered in diversity studies, although they are listed in Table 11 and 12.

EASTERN INDIA

Cauvery Basin

The Cauvery Basin covers some 25,000 km^2 of the Tamil Nadu region, and extends into the Bay of Bengal and the Gulf of Mannar (Prabhakar & Zutshi, 1993). The basin constitutes the southernmost sedimentary basin along the east coast of India. Various litho units of this basin abundant fossils, lithologic variations and depositional patterns have attracted much attention from time to time. Recent researches have demarcated precise formational limitations and categorised fossil contents with their stratigraphic zonation (Sundaram *et al*., 2001; Nagendra *et al*., 2013). The Cretaceous rocks are generally grouped into three litho units namely Uttatur, Trichinopoly and Ariyalur in ascending order. The Uttatur Group has been sub–divided into Sivaganga ('Upper Gondwana'–paralic deposits), Dalmiapuram, Karai and Garudamangalam formations. Overlying the cratonic basement along the margin of the basin are exposures of sedimentary rocks of the early Cretaceous age identified as the Sivaganga Formation / Therani plant beds, which represent rift stage sediments (Sastri *et al*., 1973). Fine clay, coarse pebbly gritty sandstones are exposed in the outcrops and paralic shales and argillaceous sandstone represent subsurface sequence (Banerji, 1972). Mamgain *et al*. (1973) reported two Barremian ammonite species and one inoceramid species and assigned the early Cretaceous age (Ayyasami & Gururaja, 1977; Sastri *et al*., 1977; Ramasamy & Banerji, 1991,). These plant beds mark the first Cretaceous sedimentation in this basin (Ramkumar *et al*., 2011). The overlying Kallakudi Limestone /Dalmiapuram Formation, younger to the Sivaganga Formation, possibly represent episode of basinal deepening and paucity of clastic supply (Nagendra *et al*., 2013).

The early Cretaceous floristics of the Cauvery Basin is known through the studies of Feistmantel (1879), Gopal *et al*. (1957), Chowdhury (1958), Ayyasami and Gururaja (1977), Jeyasingh and Sudhersan (1985), Maheshwari (1986) and Suk–Dev and Rajanikanth (1989b). Feistmantel (1879) described number of plant fossils from this bed and assigned the Jurassic age. Later, Gopal *et al*. (1957) reported a small assemblage of gymnosperms and suggested middle–upper Jurassic age. Maheshwari (1986) reported plant fossils and

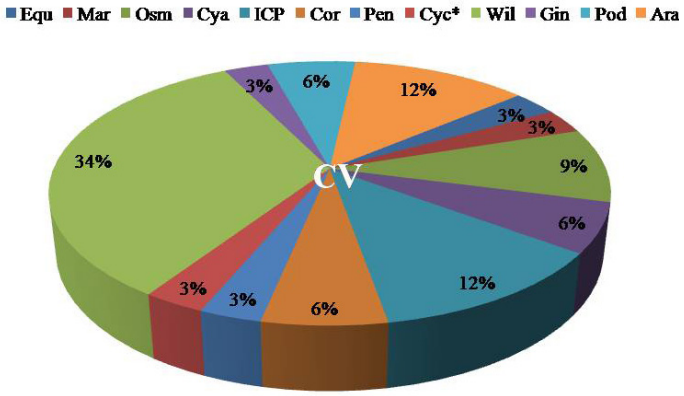

Fig. 1—Relative distribution of various plant groups in the early Cretaceous Sequence of Cauvery Basin.

discussed the taxonomic affinity of *Thinnfeldia indica* based on cuticle features and suggested a cycadophytic affinity. Jeyasingh and Sudhersan (1985) reported fertile pinnae of *Marattiopsis macrocarpa*, and this is the only fertile pinnae of fern known from the east coast sedimentary basins of India. Achyuthan *et al*. (1994) studied heteropigmentation of plant impressions and suggested prevalence of anaerobic reducing, and–oxidizing micro–environmental conditions, and shallow to deep, near shore lake deposition. Sukh–Dev and Rajanikanth (1989b) studied the fossil flora of Sivaganga Formation and identified the dominance of cycadophytes. They also suggested seaward margins of fluvio–deltaic environment for this formation.

The relative species diversity of various plant groups in the Cauvery Basin (Fig. 1) shows predominance of bennettitaleans (34 %), followed by pteridophytes (33%), coniferaleans (18%), pteridospermaleans (6%) and pentoxylaleans, cycadaleans, and ginkgoaleans poorly represented (3% each). Interestingly, predominance of bennettitaleans over the coniferaleans has also been observed in other east coast basins like Krishna–Godavari, Palar and Mahanadi. The flora is categorized under *Weichselia–Onychiopsis–Gleichenia* assemblage zone (Sukh Dev, 1987).

Subsuface palynology of the basin is well documented (Venkatachala & Rajanikanth, 1987*)*.Characteristic palynomorphs include *Cooksonites, Neoraistrickia, Aequitriradites, Polycingulatisporites, Impardecispora, Staplinisporites, Crybelosporites, Klukisporites* and *Contignisporites* (Venkatachala & Sharma, 1974).

Lithounit	Lithology	Age
Dalmiapuram	Reefoidal limestone and black shale in subsurface consists of shale/ sandstone and minor limestone	Albian
Sivaganga	Coarse gritty and pebbly sandstone in outcrops /shale argillacepus sandstone and conglomeratic sandstone in subsurface ——————unconformity——————	Early Cretaceous (Neocomian–Aptian)
Archaean	Granite Gneiss and other metamorphic rocks	Archaean

Table 1—Generalised stratigraphy (Early Cretaceous) of Cauvery Basin (after Nagendra *et al*., 2013).

Palar Basin

The Palar Basin in Tamil Nadu covers an area of about 18,300 km^2 and it is extending up to Andhra Pradesh and Karnataka. The basement is composed of an Archaean metamorphic complex overlain by the fluvio–glacial deposits of early Permian (Lower Gondwana) that in turn overlain by the early Cretaceous Sriperumbudur Formation. The early Cretaceous sequences–Avadi and Satyavedu formations are deposited under littoral to near shore fluvial conditions of late Cretaceous age (Sastri *et al*., 1973; Rangaraju *et al*., 1993; Vairavan, 1993; Kumaraguru & Rao, 1994). Arenaceous and argillaceous rock units comprising splintery green shale, clays and sandstones with ironstone intercalations characterize the Sriperumbudur Formation. This formation is characterized by marine intercalations (Murthy & Sastri, 1961). The lithologic suites and fossil fauna indicate the deposition took place under shallow and brackish conditions, probably close to the shoreline (Sastri *et al*., 1973).

The early Cretaceous floristics of Sriperumbudur Formation known through plant macrofossils, mostly preserved in the form of leaves (Fiestmantel, 1879; Seward & Sahni, 1920; Sahni, 1928, 1931; Suryanarayana, 1954, 1956; Bose *et al*., 1991). These are represented by the species of *Cladophlebis*, *Taeniopteris*, *Dictyozamites* and *Pterophyllum*, *Ginkgoites*, *Araucarites* and *Conites*. Several species of pycynoxylic woods belonging to the conifers were also reported, which include *Cupressinoxylon coromandelinum*, *Mesembrioxylon* (*Podocarpoxylon*) sp. (Sahni, 1931), *M.* (*Podocarpoxylon*) *thirumangalense* (Suryanarayana, 1953), *Araucarioxylon giftii*, *Araucarioxylon rajivii* (Jeyasingh & Kumarasamy, 1994a), *Araucarioxylon mosurense* (Jeyasingh & Kumarasamy, 1995). Besides, *Pityospermum* Nathorst a winged seed has also been recorded by Jeyasingh and Kumarasamy (1994b). The diversity pattern of the early Cretaceous flora from the basin suggested the occurrence of pre–angiospermous flora dominated by bennettitaleans (Rajanikanth *et al*., 2010).

The flora is dominated by bennettitaleans, (42%), followed by coniferaleans (22%), ginkgoaleans and taxaleans (11% each), pteridospermaleans, pentoxylaleans, cycadaleans and some uncertain coniferaleans, each constitutes 5%

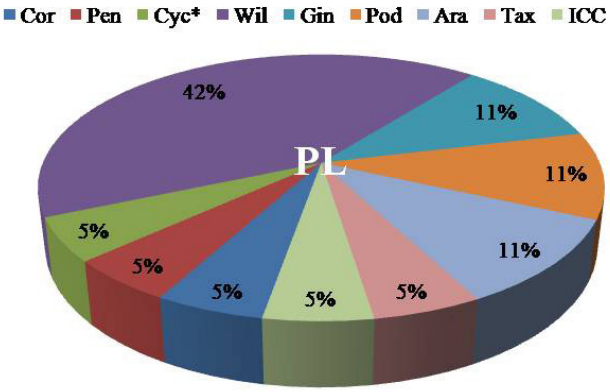

Fig. 2—Relative distribution of various plant groups in the early Cretaceous Sequence of Palar Basin.

(Fig. 2). Absence of ferns in the assemblage is notable, although fern spores are well represented in palynological assemblage. The Sriperumbudur flora was considered under *Allocladus–Brachyphyllum–Pagiophyllum* Assemblage zone and homotaxial to Gollapalli, Raghavapuram, Budavada, Vemavaram and Gangapur formations (Sukh Dev, 1987). The flora is Neocomian–Aptian of in age and is a gymnosperm dominant post–Gondwana flora (see Tables 11, 12).

Extensive palynological investigations on surface and subsurface sequences of this formation have yielded rich palynoassemblage of the early Cretaceous constituting of *Aequitriradites, Coptospora, Cooksonites, Foraminisporis, Staplinisporites, Sestrosporites, Ornamentifera, Klukisporites, Impardecispora, Cicatrisporites, Undulatisporites, Coronatisporites, Polycingulatisporites, Taurocusporites, Crybelosporites, Murospora* and *Microcachrydites* (Ramanujam & Srisailam, 1974; Ramanujam & Verma, 1977, 1981; Verma & Ramanujam, 1984). The Sriperumbudur palynoflora shows significant resemblance with the early Cretaceous palynoflora from Cauvery and Krishna Godavari basins. The early Cretaceous fauna in the form of ammonites *Pascoites crassus* and forams–*Pelosina complanata*, *Haplophragmoides concavus, H. footei, H. indicus, Bathysiphon* cf. *taurinensis, Ammodiscus cretaceous, Lituotuba* sp. and *Spiroplectammina indica* was also recorded (Murthy & Sastri, 1961).

Lithounit	Lithology	Age
Satyavedu	Coarse boulder beds, conglomerate, compact fine grain sandstone ————transgressive overlap————	Late Cretaceous
Sriperumbudur	Splintery grey and greenish shales, dark clays, partly gypseous interbedded with sandstones and thin bands of ironstones and limestones ————————unconformity————————	Early Cretaceous (Neocomian–Aptian)
?Talchir	Boulder beds and greenish shales	Permian

Table 2—Generalised stratigraphy (early Cretaceous) of Palar Basin (after Sastri *et al.*, 1973).

Krishna–Godavari Basin

The Krishna–Godavari Basin (KG) has received much attention in recent times due to its high petroliferous/ hydrocarbon source rock potential and associated plant fossil records (Kumar, 1983; Philip *et al*., 1991; Kapoor *et al*., 1995; Kapoor & Swamy, 1997; Swamy & Kapoor, 1999; Mehrotra *et al*., 2012, Chinnappa *et al*., 2014b, c, 2015; Chinnappa & Rajanikanth, 2015; Rajanikanth & Chinnappa, 2015a) and is one of the most important petroliferous basins of India occupying an area of 28,000 km^2 on shore and 24,000–49,000 km^2 off shore. The basin has been classified as a major intra–cratonic rift within the Gondwanaland until the early Jurassic period and it later transformed into peri–cratonic rift basin (Biswas *et al*., 1993).

Sediments correlatable to those of early Cretaceous are exposed near the western and northwestern fringe of the basin. The basin is divided into two depressions namely Krishna depression and Godavari depression. The Krishna depression includes the Budavada sandstone, Vemavaram shale and Pavalur sandstone. The west Godavari depression consists of three litho units, namely Golapalli sandstone, Raghavapuram shale and Tirupati sandstone. All these units are shown to be the facies variants. The sedimentation in these early Cretaceous litho–units is linked with the faulting of basement blocks as a result of reactivation of NE–SW trending Precambrian faults (Biswas, 1992).

Feistmantel (1877b, 1879) described a large number of fossil taxa, mostly of gymnospermous affinity. He compared the flora with that of Rajmahal flora and assigned Jurassic age for this. Later, Baksi (1967, 1968) described a small assemblage of fossil plants from Raghavapuram Formation and discussed the local and regional aspects of the flora, suggesting that local and regional variations in the flora are attributable to preservation limitations and limited palaeobotanical work. Bose and Jain (1967) identified a new taxon, namely *Otozamites vemavaramensis* from Vemavaram Formation, which they interpreted as a xeromorphic species, based on the prominent incurved margin and thick substance of lamina. Jain (1968) reported three taxa, namely *Pagiophyllum* sp., ?*Cladophlebis* sp. and ?*Dicroidium* sp. from Vemavaram Formation. Mahabale and Satyanarayana (1979) studied the fossil flora from Raghavapuram Formation and reported a large number of plants dominated by *Ptilophyllum*, which is represented by thirteen out of total nineteen taxa. However, it is highly dubious to consider too many species under a single genus, for a small local flora. The possibility to distinguish them precisely can also be attributed to lack of cuticle morphology. The variations observed among the specimens are possibly of intraspecific rather than interspecific. Vagyani (1984, 1985), Vagyani and Zutting (1986) and Vagyani and Jamane (1988) described fossil flora from the Vemavaram Formation and restricted their studies on the description of one or two plant taxa only. Pandya and Sukh–Dev (1990) recovered a large number of plant fossils composed of mainly gymnosperms from Golapalli Formation and suggested an early Cretaceous age. Pandya *et al*. (1990) added a new taxon–*Elatocladus vemavaramensis* to the existing list of flora from the Vemavaram Formation. More recently, Chinnappa *et al.* (2014b, c, 2015) discussed the taphonomy and palaeoecology of the flora. The study suggested marginal transportation for the flora before their burial, hence mostly includes local to regional elements, a shallow marine swampy settings and prevalence of warm and humid climate.

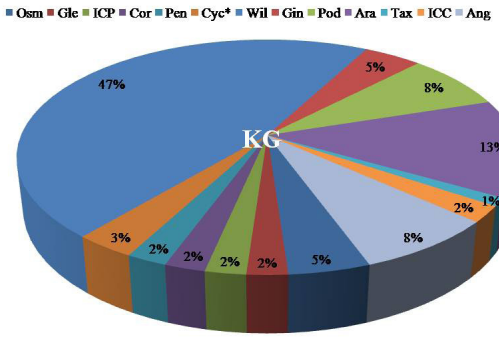

Fig. 3—Relative distribution of various plant groups in the early Cretaceous Sequence of Krishna–Godavari Basin.

Diverse flora is represented by bennettitaleans (47%), coniferaleans (24%), pteridophytes (9%), angiosperms (8%), ginkgoaleans (5%), cycadaleans (3%), pteridospermaleans (2%) and pentoxylaleans (2%) during the early Cretaceous (Fig. 3). The Golapalli, Raghavapuram and Vemavaram floras were categorised under *Allocladus–Brachyphyllum–Pagiophyllum* Assemblage Zone (Sukh–Dev, 1987).

Lithounit	Lithology	Age
Tirupati/Pavalur	Purple red–light brown sandstone/clay and caleritic sandstone	Late Cretaceous
Raghavapuram/ Golapalli/ Vemavaram/ Budavada	White pale–reddish earthy shale, red ferruginous claystone, light buff–greyish white glauconitic sandstone/shale containing carbonaceous matter	Early Cretaceous (Neocomian–Aptian)
	——————unconformity——————	
Chintalapudi/ Kamthi	Coarse grained feldspathic sandstone, alternating calcareous claystone	Permian

Table 3—Generalised stratigraphy (early Cretaceous) of Krishna–Godavari Basin (after Sastri *et al*., 1973).

Palynology of the basin is known through the work of Ramanujam (1957), Kar and Sah (1970), Venkatachala and Sinha (1986), Prasad *et al*. (1995), Prasad and Pundir (1999) and Mehrotra *et al.* (2010, 2012). Some of the important palynotaxa are *Staplinisporites, Contignisporites, Triletes, Impardecispora, Crybelosporites, Appendicisporites, Aequitriradites* and *Microcachrydites.*

The early Cretaceous sediments of the basin has also been well known for their marine fossils, which include ammonites–*Pascocites budavadensis*, *Gymnoplites simplex* and other associated arenaceous foraminifera dominated by *Ammobaculites*, bryozoans, lamellibranchs, gastropods and brachiopods support the early Cretaceous age (Spath, 1933; Bhalla, 1969; Sastri *et al*., 1977, Raju & Misra, 1996).

Pranhita–Godavari Basin

The Pranhita–Godavari Basin (PG) is one of the largest gondwanan basins in India and embodies almost complete succession of Gondwana rocks. The early Cretaceous sequences are exposed about 525 (including Gangapur/ Chikiala) meters in thickness. The sedimentation took place during the early Cretaceous after renewed rift activity (Biswas, 2003). These sediments are exposed in and around the village Gangapur (19°16' N; 79°26' E) in Adilabad District, Telangana, India. Historically these early Cretaceous outcrops were referred as "Gangapur beds" and placed under the Kota Group (King, 1881). However, based on the lithological distinction, Kutty (1969) separated these early Cretaceous sediments from the Kota Group and created a new lithounit and named as Gangapur Formation after the village Gangapur. The formation extends from north of Nowgaon (19°20' N, 79°24' E) to the west of village Gangapur (19°16' N; 79°26' E) and in the east up to Dharmaram and Paikasigudem (Kutty, 1969).

Geology of the Gangapur Formation, along with other formations in the Pranhita–Godavari Graben, has been studied by Sen Gupta (1970, 2003), Rudra (1982), Bandyopadhyay and Rudra (1985), Raiverman (1986), Kutty *et al.(*1987), Lakshminarayana and Murti (1990), Lakshminarayana (1995, 1996, 2002) and Biswas (2003). The formation is characterized by coarse ferruginous sandstone with several pebble bands succeeded by an alternating sequence of sandstones and mudstones or silty mudstone. It unconformably overlies the Kota Formation. Although both the Gangapur and Chikiala formations are known to overlie the Kota Formation, the relationship between the Gangapur and Chikiala formations is not clear. There are neither floral nor faunal fossil evidences from the Chikiala Formation, while the Gangapur Formation yielded well preserved early Cretaceous flora (both macro–and micro–elements).

The plant fossil studies are well known for more than 100 years, and represented by rich and diverse assemblage of–cryptogams, pteridophytes, gymnosperms and angiosperms. Bose *et al*. (1982) reported plant taxa belonging to the pteridophytes and gymnosperms from a number of out crops of the Gangapur Formation. Their report includes a new coniferous taxon–*Elatocladus kingianus*. The authors considered late Jurassic age to these plant–yielding beds based on the floral assemblage. Rajeshwar Rao *et al*. (1983) mentioned a list of plant fossils belongs to pteridophytes and gymnosperms from the Gangapur Formation, but neither described nor figured them. Later on, Ramakrishna and Muralidhara Rao (1986) identified

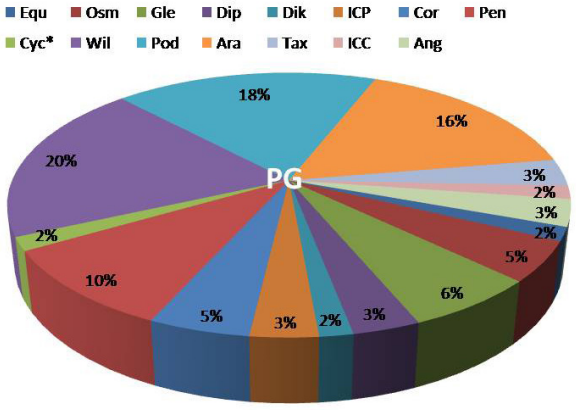

Fig. 4—Relative distribution of various plant groups in the early Cretaceous Sequence of Pranhita–Godavari Basin (after Kutty, 1969).

Lithounit	Lithology	Age
Deccan Traps	Infra/intertrappean beds: limestone, clay and sandstone	Late Cretaceous/ Palaeogene
Gangapur/ Chikiala	Coarse ferruginous sandstone, greywhite–pinkish mudstone and silty mudstone/shale ——————unconformity—————— Upper: Sandstone, siltstone and claystone Middle: Limestone Lower: Conglomeratic sandstone, siltstone trough cross stratified sandstone	Early Cretaceous (Neocomian–Aptian)
Kota		?Jurassic

Table 4—Generalised stratigraphy (early Cretaceous) of Pranhita–Godavari Basin (after Kutty *et al*., 1987).

Pterophyllum medlicottianum from this formation, the only report of the taxon from the Gangapur Formation. Muralidhara Rao and Ramakrishna (1988) described a taxacean plant taxa, *Torryetites sitholeyi* for the first time. Cone bearing shoots of *Elatocladus* and an isolated cone–*Conites sripermaturensis* are also reported later (Pal *et al*., 1988; Ramakrishna & Muralidhara Rao, 1991; Chinnappa *et al*., 2014a). Ramanujam *et al*. (1987) discussed the floristic and stratigraphic significance of the megafloral assemblage of Gangapur Formation. The age of the formation has considered as Aptian. Sukh–Dev and Rajanikath (1989a) described a number of plant fossils and they identified new forms like *Pachypteris gangapurensis*, *Dictyozamites gondwanensis* and *Pagiophyllum spinosum*. Rajanikanth (1996a, b, 2009) discussed the diversification pattern of the flora and their stratigraphic significance. Recently Chinnappa *et al.* (in press) identified the conifer dominance, specifically Podocarpaceae and Araucariaceae from this formation. The comparison with other early Cretaceous floras from India showed that the flora is close to the Satpura Basin.

Diverse plant groups of coniferaleans (36%), pteridophytes (21%), bennettitaleans (20%), pentoxylaleans (10%), pterodospermaleans (5%), angiosperms (3%), taxaleans (2%) and cycadaleans (2%) are variously represented (Fig. 4), however, the coniferaleans predominate. The overall composition of the flora indicates possible palaeovalley settings. Less abundance and diversity of bennettitaleans and cycadaleans, scarcity of broad leaved members (e.g. *Dictyozamites*) and presence of coniferaleans with narrow and scaly leaves indicate that the plants were under physiological stress conditions (Chinnappa *et al*., 2014a). This is substantiated by the presence of sunken stomata and presence of papillae (Bose *et al*., 1982; Sukh–Dev & Rajanikanth, 1989a). The Gangapur flora was considered under *Allocladus /Brachyphyllum /Pagiophyllum* Assemblage Zone (Suk–Dev, 1987).

Palynological studies from the Gangapur Formation have been carried out by Ramanujam and Rajeshwar Rao (1979, 1980), Bose *et al.* (1982), Rajeshwar Rao *et al*. (1983), Prabhakar (1987), Ramakrishna and Ramanujam (1987) and Ramakrishna *et al*. (1985, 1986). Significant palynotaxa are *Microcachryidites, Callialasporites, Araucariacites, Podocarpidites, Classopollis, Contignisporites* and *Cicatricosisporites*. Good preservation of spores and pollen indicates that the flora was growing around the depositional site (Rajeshwara Rao *et al*., 1983).

Mahanadi Basin

The Mahanadi Basin (Orissa) marked by the flow of Mahanadi River which divides the basin into two unequal parts. The Athgarh Sub Basin exposed to the north northwest and southeast of Cuttack and Bhubaneswar covers an area of about 800 km^2. The Athgarh Formation (Sandstone) constitute the northern most exposure of coastal gondwanas and first studied by Blandford *et al*. (1859) followed by Ball (1877a). This sandstone with an estimated thickness of 400 meters rests unconformably over Eastern Ghats granulites (Pre Cambrian) and at places on the Permian rocks (Kumar & Bhandari, 1973; Tiwari *et al*., 1987). The formation exposed near the western magin of the basin mainly consists of white to grey hard sandstones with intercalations of lenticular greyish white to pinkish clays and carbonaceous shales.

Fossil bearing horizons known from Naraj, Jagannath Prasad and Talbast (Cuttack District, Orissa) areas yielded plant fossils. Feistmantel (1877d) reported some plant fossils for the first time from Athgarh Formation, followed by Adyalkar and Rao (1963) and suggested the Jurassic age. Later studies by Jain (1968), Pandya and Patra (1968), Patra (1973 a, b, 1980, 1982, 1989, 1990), Patra and Patnaik (1974) and Pandya (1988) added many plant taxa to the then existing list.

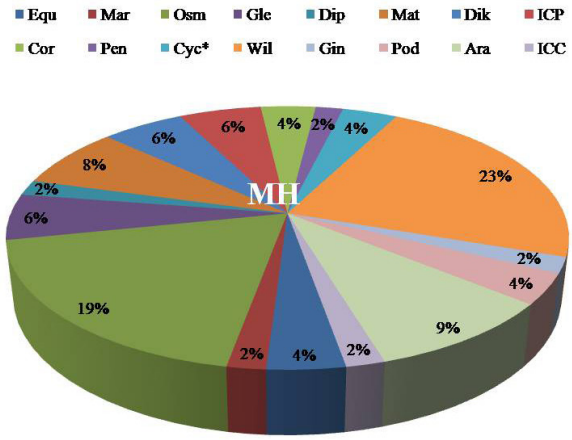

Fig. 5—Relative distribution of various plant groups in the early Cretaceous Sequence of Mahanadi Basin.

Lithounit	Lithology	Age
Recent	Alluvium, laterite	Holocene
Athgarh	Dolerite intrusive sandstone with intercalation of shale and clays ——————unconformity——————	Early Cretaceous (Neocomian–Aptian)
Talchir	Pale green splintery shale	Permian

Table 5—Generalised stratigraphy (early Cretaceous) of Mahanadi Basin (modified after Tiwari *et al*., 1987).

Patra and Sahoo (1992, 1995a, b, 1996) analyzed the fossil flora and suggested an early Cretaceous age (Neocomian–Aptian). Prakash and Sukh–Dev (1994) recorded a large number of plant fossils and considered the Athgarh fossil flora as extension of Bansa flora. Goswami *et al.* (2006) discussed the taxonomic diversity of Gondwana flora in Mahanadi Basin and listed 104 taxa from early Cretaceous Athgarh Formation, which shows equal dominance of pteridophytes and gymnosperms. The micro–and mega–floral evidences of the upper Mesozoic sediments of Mahanadi Basin (Athgarh Sandstone) are suggestive of the early Cretaceous age (Venkatachala & Rajanikanth, 1987). The flora is characterized by *Marattiopsis, Phlebopteris, Cladophlebis, Eboracia, Hausmannia, Cycadopteris, Onychiopsis, Anomozamites, Ptilophyllum, Araucarites* and *Brachyphyllum* (Tables 11, 12).

Overall pteridophytes (53%), bennettitaleans (23%), coniferaleans (15%), pterodospermaleans (4%), cycadaleans (4%), pentoxylaleans (2%) and ginkgoaleans (2%) represent the flora (Fig. 5). The Athgarh flora was categorized under *Weichselia–Onychiopsis–Gleichenia* Assemblage Zone (Sukh–Dev 1987).

Palynology of Athgarh Sandstone is known through the studies of Maheshwari (1975), Jana and Tiwari (1986), Jana (1990), Patra (1982, 1990), Sahoo (1993), and Goswami *et al*. (2006, 2008). Significant palynotaxa include *Impardecispora, Kluckisporites, Ischyosporites, Sestrosporites*, and *Contignisporites.* Typical early Cretaceous taxa recovered are *Coptospora cauveriana, C. kutchensis, C. microgranulosa, C. verrucosa* and *Podosporites tripakshi* (Goswami *et al*. 2008).

WESTERN INDIA

Kutch Basin

The Kutch Basin is a peri–cratonic rift basin situated at the west coast of India and formed in the western continental margin at the time of separation of India from Gondwana land (Biswas, 1999). The basin possibly opened up in response to the stress that ultimately led to the separation of Australia and Antarctica from India (Biswas, 1987, 1992, 1993). The early Cretaceous sediments were deposited in a transitional environment (deltaic) during regression. Lithologically, it is characterized by coarse clastics–conglomerates, sandstones, thin shale interbeds (Jai Krishna, 1987). The Jhuran Formation is overlain by Bhuj Formation with a gradational upper contact marked by first occurrence of ironstone band and last occurrence of calcareous sandstone. The Bhuj Formation consists of feldspathic, friable, brown ferruginous sandstone, kaolinitic shale, thin ironstone bands and occasional carbonaceous bands followed by olive green to dark green glauconitic sandstone, which is unconformably overlain by Deccan Trap. This formation is predominanted by sandstones constituted by diachronous deltaic wedge with marine intercalations and a fluviatile to deltaic environment. The shale interbeds contain early Cretaceous plant fossils. Plant beds exposed in Saurashtra–Dhrangadhra / Gardeshwar too are equivalent and later extension of (early Cretaceous) Bhuj Formation.

The Kutch Basin contains the plant–bearing, middle–late Jurassic, Jhuran Formation and early Cretaceous Bhuj Formation (Biswas & Deshpande, 1983). The plant fossils from these formations were studied by Bose and Banerji (1984). Of the two formations, i.e. Jhuran and Bhuj, plant fossils are mainly known from the latter and the former contains indeterminable plant debris. Morris (in Grant, 1840) first reported plant fossils from Mesozoic sediments of West Coast (Kutch Basin). Later, Feistmantel (1876b) has published a monograph on fossil flora of Kutch, which includes 29 species. Subsequently, Holden (1915), Seward and Sahni (1920), Sahni (1928), Jacob and Jacob (1954), Roy (1965, 1966, 1967, 1968), Sitholey and Bose (1971), Bose and Banerji (1980, 1981), Zeba–Bano and Bose (1981), Banerji (1982, 1987) and Mehra and Verma (1982) supplemented many taxa.

Bose and Banerji (1984) critically restudied the Mesozoic fossil flora from West Coast (Kutch Basin) along with new findings. They described more than 80 species belonging to 44 genera, out of which 3 genera, namely *Trambaua*, *Lorumformophyllum* and *Kachchhia* are new. Besides, many genera like *Thallites*, *Hepaticites*, *Hausmannia*, *Dictyophyllum*, *Coniopteris*, *Caytonia*,

Lithounit	Lithology	Age
Deccan Traps	Basaltic flows	Late Cretaceous/ Palaeogene
	——————unconformity——————	
Bhuj/ ?Dhrangadhra/ ?Gardeshwar	Mainly sandstone with shale inter beds	Early Cretaceous (Neocomian–Aptian)
	——————unconformity——————	
Jhuran	Sandstone, shale, calcareous sandstone alternation	?Late Jurassic–Early Cretaceous

Table 6—Generalised stratigraphy (early Cretaceous) of Kutch Basin (after Jai Krishna, 1987).

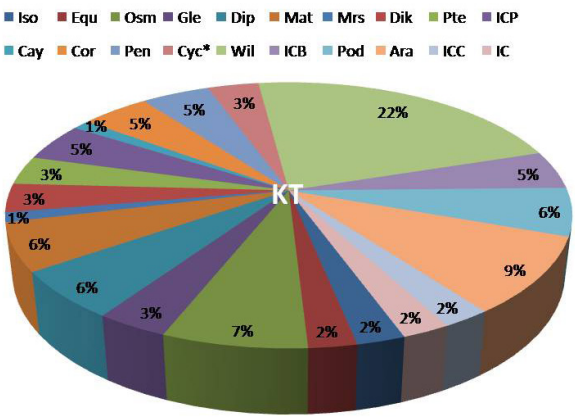

Fig. 6—Relative distribution of various plant groups in the early Cretaceous Sequence of Kutch Basin.

Linguifolium, *Ctenozamites*, *Pseudoctenis*, *Anomozamites*, *Nilssoniopteris*, *Dictyozamites*, *Bennettitocarpus* and *Allocladus* were also reported for the first time from the Kutch Basin. Based on megafossil assemblage they suggested Jhuran and Bhuj formations as facies variants from middle to late Jurassic. The authors also identified two distinct assemblages in the Bhuj flora. The first assemblage is dominated by pteridospermalean foliage (*Pachypteris* spp.). Other important plant remains in this assemblage are *Sagenopteris*, *Linguifolium* and *Nilssoniopteris*. *Elatocladus–Pagiophyllllm–*and *Araucarites–*like conifer leaves and cones, together with dipteridacean *(Hausmannia)* osmundacean (*Cladophlebis*) and matoniacean (*Matonidium*) ferns, bennettitaleans (*Pterophyllum*, *Ptilophyllum* and *Otozamites*) and pentoxylaleans (*Taeniopteris*). *Ptilophyllum–Brachyphyllum–*and *Allocladus* dominate the second assemblage. In addition, *Isoetites* and *Pagiophyllum* are also common (Bose & Banerji, 1984). Taxa like *Weltrichia*, *Kachchhia*, *Trambaua* and *Lorumformophyllum* are common in the Western Indian flora.

Banerji (2004) discussed the palaeo–ecological significance of the flora and identified four plant communities–swampy–marshy coastal heathland community, fresh water pond–brackish water lagoonal community, moist lush inland riparian community and upland forest community. The fluvio–deltaic depositional environment has inferred for Bhuj Formation based on the above plant communities.

Equivalent early Cretaceous sequence–Gardeshwar Formation in Saurashtra region, is known for plant fossils (Borkar & Phadke, 1974; Jana *et al*., 2013). The flora of this formation includes gleicheniacean (*Gleichenites*) and osmundacean (*Cladophlebis*) ferns together with pteridospermaleans (*Pachypteris)*, araucarian and podocarpacean conifers (*Brachyphyllum*, *Pagiophyllum* and *Elatocladus*). However, the flora has not been described thoroughly and most of the taxa are only known at generic level. Jana *et al*. (2013) investigated the fossil flora from early Cretaceous sediments of Gardeshwar Formation and identified 21 species belongs to 15 genera. The study showed that coniferaleans dominate the flora. The Dhrangadhra/ Himmatnagar/Gardeshwar flora (Borkar & Chiplonkar, 1973; Bose *et al*., 1983; Banerji *et al*., 1983; Kumaran *et al*., 1983) have been considered under *Weichselia–Onychiopsis–Gleichenia* Assemblage Zone, where as Kutch (Bhuj) flora was considered under *Dictyozamites–Pterophyllum–Anomozamites* Assemblage Zone (Sukh–Dev, 1987).

Overall, the early Cretaceous flora of Kutch Basin exhibit rich diversity (Fig. 6), and includes pteridophytes (38%), bennettitaleans (27%), coniferaleans (19%), pteridospermaleans (6%), pentoxylaleans (5%) and cycadaleans (3%). The flora also includes a few taxa of bryophytes (Bose & Banerji, 1984) also.

Palynology of Kutch Basin is known through a series of papers by Venkatachala and Kar (1970), Singh and Venkatachala (1987) and Maheshwari and Jana (1983, 2004). Significant palynotaxa recorded are *Concavissimisporites*, *Impardecispora, Bhujiasporites, Cingulatisporites, Coptospora, Aequitriradites* and *Cooksonites*.

Rajasthan Basin

The Rajasthan Basin has been divided into three Sub–Basins separated from each other by basement ridges/faults. These are Jaisalmer, Bikaner–Nagaur and Barmer–Sanchor Sub–Basins. The sediments are mainly represented by limestone, sandstone and shale (Jai Krishna 1987; Singh, 2006; Mude *et al*., 2012). The Mesozoic rocks are well exposed in the Jaisalmer Sub Basin and these sediments are classified into six formations: Lathi, Jaisalmer, Baisakhi, Badasar, Pariwar and Habur formations, out of these, the last two formations represent the early Cretaceous. The Pariwar Formation is represented by sandstone–shale intercalation with fossil woods representing an overall regressive phase with an intermittent marine incursion. Whereas the Habur Formation consists of limestone, sandy limestone and calcareous sandstone indicative of near shore environment with occasional effect of storm surges (Singh, 2006).

The flora from Rajasthan Basin is comparatively less known. Very little palaeobotanical work has been carried out on the early Cretaceous plant fossil–bearing beds of the Pariwar Formation and the Sarnu Hill (Bose *et al*., 1982; Banerji & Pal, 1986). Taxa common to both the formations include: *Pachypteris haburensis* and *Ptilophyllum acutifolium*. Maheshwari and Singh (1976), Bose *et al*. (1982) and Banerji and Pal (1986) reported a few plant taxa, viz. *Gleichenia*, *Pachypteris*, *Ginkgo*, *Pagiophyllum* and *Elatocladus*. This assemblage is compositionally more similar to the Bhuj. The Pariwar and the Sarnu Hill floras are categorized under *Dictyozamites–Pterophyllum–Anomozamites* Assemblage Zone (Sukh–Dev, 1987).

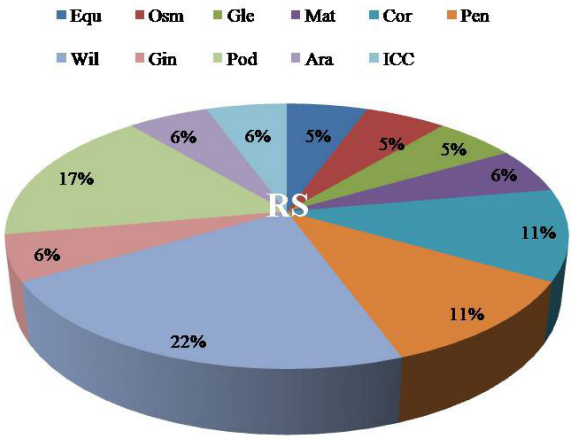

Fig. 7—Relative distribution of various plant groups in the early Cretaceous Sequence of Rajashtan Basin.

Overall, the flora consists of coniferaleans (29%), bennettitaleans (22%), pteridophytes (21%), pteridospermaleans (11%), pentoxylaleans (11%) and ginkgoaleans (6%) (see Fig. 7).

Palynogy of Rajashtan Basin is poorly known except record of palynoassemblage from Khara Tal Well No.1 by Banerji (1972), Lukose (1974) and Singh and Venkatachala (1987). Characteristic palynotaxa include *Apppendicisporites, Cicatricosisporites, Trilobosporites* and *Pilosisporites*.

CENTRAL INDIA

South Rewa Basin

The South Rewa Basin is represented by soft massive sandstones, white, yellow and pinkish shales with sporadic lignite and coal seams and limestone bands. The early Cretaceous Bansa beds (Jabalpur Formation) overlie the Vindhyans in the west and older gondwanan rocks of Parsora and Damuda units in the east (Dutta *et al*., 1983). These beds were first recognized by Krishnan and Jacob (1956) and were included under the Jabalpur Formation. Deposition of Bansa beds commenced in the northwestern extremity of the basin after a pronounced hiatus spread over entire Jurassic Period (Dutta *et al*., 1983). Lithologically Bansa beds are distinguished by sandstones, clay and carbonaceous clay and in turn overlien by the Lameta beds of Maastrichtian age (Mukherjee *et al*., 2012).

Feistmantel (1882) mentioned about some plant fossils previously reported from the early Cretaceous sediments of the basin by C.A. Hacket and Hughes. Later, Holden (1915) added some more plant fossils to the Feistmantel's list. Subsequently, the flora is studied by Sukh–Dev and Zeba–Bano (1977, 1980), Bose and Sukh–Dev (1958, 1959b, 1961, 1972) from the basin and supplemented many more taxa, which were not known previously. Sukh–Dev (1970, 1972) reported some ferns along with a newly described species *Hausmannia pachyderma*. Pant *et al*. (1983) instituted a new genus namely *Harrisiophyllum* for the leaves which are previously described under *Podozamites* Feistmantel known as impressions. They described five new species under this genus based on the external morphology and cuticular structure. Srivastava *et al.* (1984) described a few more coniferous shoots from Bansa beds. Prakash and Kumar (2004) discussed occurrence of *Ginkgo* from the early Cretaceous deposits of South Rewa Basin. The flora is mainly composed of araucarian and podocarpean elements. The bennettitaleans are rather rare and includes only two taxa, viz. *Yabiella hirsuta* and *Ptilophyllum gladiatum*. Pertified fossil woods are comparatively rare, only report of wood from the early Cretaceous sediments of the basin is *Podocarpoxylon bansaensis* Prakash and Rajanikanth (2004).

The fossil flora in general constitutes coniferaleans (49%), pteridophytes (25%), pteridospermaleans (17%), bennettitaleans (4%) and ginkgoaleans (5%) (Fig. 8). Pentoxylaleans are not recorded to date. The Bansa flora has been considered under *Weichselia–Onychiopsis–Gleichenia* Assemblage Zone (Sukh–Dev, 1987).

Palynological records are known by the contributions of Singh (1966a, b) and Maheshwari (1974). Important palynotaxa are–*Araucariacites, Callialasporites, Alisporites, Podocarpidites* and *Cycadopitys*.

Lithounit	Lithology	Age
Sanu	Unconsolidated, highly current bedded reddish, gluconitic sandstone and silty sandstone	Palaeogene
Pariwar / Habur	Limestone and feldspathic sandstone and grit	Early Cretaceous (Neocomian–Aptian)
Bhadasar	Black clays and shales, sand and sandstone, lignite, calcareous oolite sandstone	Late Jurassic

Table 7—Generalised stratigraphy (early Cretaceous) of Rajasthan Basin (after Singh, 2006).

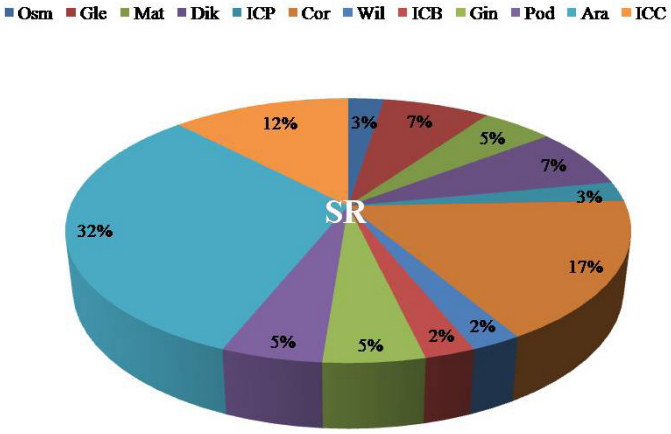

Fig. 8—Relative distribution of various plant groups in the early Cretaceous Sequence of South Rewa Basin.

Satpura Basin

The Satpura Basin of central India is the western most Indian Gondwana basin and is rhomb shaped. It is approximately 200 km long and 60 km wide. It has been designated as a pull–apart basin due to extension related to strike–slip movement along the Son–Narmada Lineament (Singh *et al*., 2015). The basin contains rocks of Permian to Cretaceous age unconformably overlying the Precambrian basement. The early Cretaceous Jabalpur Formation named after the Jabalpur City (23°10'30"N; 80°58'00"E), Madhya Pradesh forms the highest strata in Mahadeva hills. The early Cretaceous deposits occur at Sehora, Chaugan, Imjhiri, Hard and Sukkur rivers and in Achalpur area. The Sher River section near Sehora shows a maximum thickness of 30–35 m. These strata embody rich organic matter in fluvio–lacustrine sediments. This formation rests unconformably on the Precambrian rocks or at places by Bagra sediments (?Jurassic) and overlain by Lameta or Deccan traps (Infra–intertrappeans) (Crookshank, 1936; Khan & Shahnawaz, 2013; Singh *et al*., 2015). It consists of thick, soft, white to brown massive sandstone alternating with white clays, conglomerate, carbonaceous shale and beds of cherts (Singh *et al*., 2015).

Feistmantel (1877c) carried out the floristics of early Cretaceous Jabalpur Formation for the first time. Bose (1959b, c), described a new species of *Ptilophyllum institacallum* and a few pteridophytic remains namely *Cladophlebis*, *Onychiopsis*, *Coniopteris* and *Sphenopteris*. Bose and Roy (1968) reported two species of *Pachypteris* i.e., *P. indica* and *P. holdenii*, of these the former is a new combination and later is newly described one. Bose and Kasat (1969) described a new species of *Williamsonia*, i.e. *W. seniana*. Later on, Bose and Maheshwari (1973a, b) identified a new species of conifer namely *Brachyphyllum sehoraensis* and some detached cone scale of araucariaceae. Maheshwari and Kumaran (1976) described three new species of *Elatocladus,* viz. *E. pseudotenerrima*, *E. sehoraensis* and *E. bosei* and two new species of *Pagiophyllum*, viz. *P. sherensis* and *P. satpuraensis*. Additional floral components to the existing ones have been supplemented by Bose and Sukh–Dev (1959a), Shah and Singh (1964), Sukh–Dev and Zeba–Bano (1978, 1979, 1981a, b), Pant and Srivastava (1968, 1977), Zeba–Bano (1980), Singh *et al.* (1990), Srivastava *et al*. (1999) and Prakash (2003, 2008, 2013).

The Jabalpur flora is dominated by coniferaleans and *Elatocladus* is the dominant element. Bennettitaleans are taxonomically less dominant; they are represented by genera like *Dictyozamites*, *Otozamites*, *Anomozamites*, *Pterophyllum* and *Ptilophyllum*. The flora is more comparable to the early Cretaceous flora from the Gangapur Formation, Pranhita–Godavari Basin (Sukh–Dev & Rajanikanth,1989a; Chinnappa *et al*., 2014a).

The flora constitutes coniferaleans (39%), pteridophytes (29%), bennettitaleans (24%), ginkgoaleans (3%), pentoxylaleans (3%), cycadaleans (3%) and pteridospermaleans (1%) (Fig. 9). The Jabalpur flora has been categorized under *Allocladus–Brachyphyllum–Pagiophyllum* Assemblage Zone (Sukh–Dev, 1987).

The palynoflora of the Jabalpur Formation is dominated by *Araucariacites–Callialasporites* along with *Cooksonites, Cyathidites, Triporoletes, Coptospora, Aquitriletes, Crybelosporites* and *Podosporites* (Kumar, 1994).

Lithounit	Lithology	Age
Deccan Traps Lameta	Lava flows Coarse, calcareous, conglomerate, Limestone, purple grits / sills, Green sandstone	Late Cretaceous/ Palaeogene
	——————unconformity——————	
Bansa	Sandstone, alternating with clays, conglomerate, earthy haematite, coal carbonaceous shale, red clay and bed of chert	Early Cretaceous (Neocomian–Aptian)
	——————unconformity——————	
Parsora / Bandhavgarh/ Hartala	White coloured medium to coarse grained sandstone with clay clast having siliceous matrix; often with ferruginous cement with medium grained white coloured siliceous sandstone	?Jurassic

Table 8—Generalised stratigraphy (early Cretaceous) of South Rewa Basin (after Dutta et al., 1983).

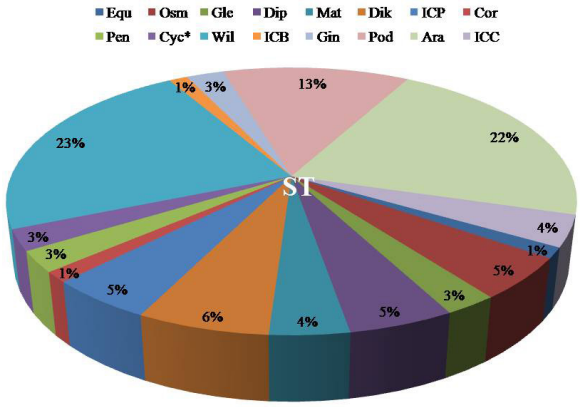

Fig. 9—Relative distribution of various plant groups in the early Cretaceous Sequence of Satpura Basin.

Rajmahal Hills/Formation

The Rajmahal Hills/Formation is known for a series of volcanic lava flows (Rajmahal Traps) and associated intertrappean sedimentary beds. The basin spread into eastern Jharkhand, dominantly composed of basalt. McClelland (1850) first studied the geology and plant fossils of Rajmahal Hills, followed by Oldham (1854, 1860, 1862). Ball (1877b) systematically mapped the Rajmahal and adjacent areas. The intertrappean sedimentary beds composed of sandstones, siltstones, arenaceous clays, white and grey coloured baked and carbonaceous shales, tuffites and cherts are characteristic of the Rajmahal Formation. The thickness of these beds vary according to individual lava flow and are well exposed in southern, central and northern regions of Rajmahal Hills. Sen Gupta (1988) did contribution on detailed stratigraphy of Rajmahal area. Pale green–grey Rajmahal flows are characterised by alkaline tholeiites to basaltic andesites (Sarbadhikari 1968). Radio metric dating of some of selected flows established the early Cretaceous age to Rajmahal intertrappeans–Rajmahal Formation (Agarwal & Rama, 1976; McDougall & McElhinny, 1970).

The Rajmahal Formation has long been considering as a paradise for Indian palaeobotanists. McClelland (1850) first described a few plant fossils from Rajmahal area. However, Oldham and Morris (1863) who described 46 plant macrofossil species belonging to different genera carried out the first systematic study of rich Ptilophyllum flora. Feistmantel (1877a) studied the Rajmahal flora in detail and correlated it with the other Gondwana basins of India, where similar Ptilophyllum flora occurs (Feistmantel 1877b, c, d, e, 1879, 1882). He described 50 plant macrofossil species from the early Cretaceous sediments of Rajmahal area, out of which sixteen species are new. He also suggested that the Ptilophyllum flora from Golapalli and Athgarh formations from the East Coast of India are analogous with the Rajmahal flora and assigned Liassic (Jurassic) age.

Seward and Sahni (1920) restudied many species of Rajmahal flora and made necessary taxonomic revisions on the basis of morphological, cuticular and anatomical characteristics. Some of the different species of *Ptilophyllum* were grouped together as *P. acutifolium* and many species of *Ptilophyllum* were transferred to *Nilssonia*. Sahni (1928, 1931, 1932, 1936, 1948) and Sahni and Rao (1933, 1934) continued further studies on the fossil flora of the Rajmahal Formation. Sahni (1932) reconstructed the tree *Williamsonia sewardiana* that bears *Ptilophyllum* leaf, *Williamsonia* flower and *Bucklandia indica* stem. He suggested Jurassic/middle Jurassic age for Rajmahal Formation. He also instituted a new 'synthetic group' namely Pentoxyleae in the year 1948. The group bears *Pentoxylon* stems, *Nipaniophyllum* leaves and *Carnoconites* a seed cone. Subsequently, Vishnu–Mittre (1953b, 1957) described pollen–bearing cones–*Sahnia* and published further observations on the *Pentoxylon*. Shukla (1957) reported a new species of *Pentoxylon*, i.e. *P. tetraxyloides*. A modification in Vishnu–Mittre's (1953b) restoration of male fructification was given by Bose *et al*. (1985) and Suthar and Sharma (1988). The enormous efforts of Sharma (1969a, b, 1972a, b, 1973a, b, 1974a, b, 1979, 1989), Bose and Harris (1984), Bose *et al*. (1985) and Suthar *et al*. (1988) helped to better understand many important

Lithounit	Lithology	Age
Deccan Traps Lameta	Lava flows Coarse, calcareous, conglomerate, Limestone, purple grits / sills, Green sandstone	Late Cretaceous/ Palaeogene
	——————unconformity——————	
Jabalpur	Sandstone, alternating with clays, conglomerate, earthy haematite, coal carbonaceous shale, red clay and bed of chert	Early Cretaceous (Neocomian–Aptian)
	——————unconformity——————	
Bagra	Conglomerates, limestone and variegated red clays	?Jurassic

Table 9—Generalised stratigraphy (early Cretaceous) of Satpura Basin (modified after Crookshank, 1936).

features of this interesting group. Recently, Sharma (1996) presented an overview on this interesting group.

Jacob (1937, 1943, 1950) described some new genera like *Tinpaharia* and a new species of cyatheaceous fern, viz. *Protocyathea rajmahalense*. An exhaustive study of Rajmahal flora was made by Rao (1943a, b, 1949, 1950, 1964) and he opined that the lower age limit of Rajmahal flora might extend below Rhaetic. Bose (1952, 1953a, b, 1959a, 1966a, 1967, 1968, 1974) critically studied the Triassic–Jurassic Gondwana flora of India and instituted the new genus *Morrisia* and many new species like *Ptilophyllum amarjolense*, *Brachyphyllum spiroxylum* and *Bucklandia sahnii* and suggested middle to upper Jurassic age to the Ptilophyllum flora of Rajmahal area. Investigation on some cycadophytes of Rajmahal Hills was done by Gupta (1954) and Gupta and Sharma (1968). Sah and Sukh–Dev (1958) contributed to pteridospermaleans of Rajmahal Formation. Bose and Sah (1968) studied the fossil pteridophytes of Rajmahal Hills and described some new species. Bose and Kasat (1972) studied about 3000 specimens of *Ptilophyllum* from different basins of India and came to conclusion that only 15 species of this genus in India are valid. Similarly, Bose and Zeba–Bano (1978) made a critical study of the genus *Dictyozamites*, while Bose and Banerji (1981) studied in detail the cycadophytic leaves from the Jurassic–early Cretaceous sediments of India. Sitholey and Bose (1971) described some bennettitalean fructification from Rajmahal area. The fossiliferous intertrappean bed of Nipania area of Rajmahal Hills was studied by Vishnu–Mittre (1956, 1957, 1958, 1959a, b) and noted a close resemblance of this flora to that of Jabalpur and Kota stage (now known as East Coast Flora). Sharma (1969c, 1971a, b, 1973c, d, 1975, 1980, 1997), Sharma *et al*. (1971) and Pal *et al*. (2009) studied the impressions and petrifications from Rajmahal Hills and supplemented many taxa to the existing list of flora

Sen Gupta (1988) carried out an extensive work on the stratigraphy and palaeobotany of Rajmahal Hills. He identified and systematically described 35 plant species belonging to Sphenophyta, Pteridophyta, Pteridosperamophyta, Cycadeodophyta and Coniferophyta. Among the 35 taxa, three species, namely *Thinnfeldia khatangiensis*, *Taeniopteris sarbadhikarii* and *Pterophyllum valentinei* were newly erected. Based on the distribution of the macrofossils he also established three biozones, namely *Ptilophyllum acutifolium–Gleichenites gleichenoides* assemblage zone (Zone 1; early Jurassic age), *Cladophlebis indica–Dictyozamites indica* assemblage zone (Zone 2; middle–late Jurassic age) and *Taeniopteris spatulata–Brachyphyllum rhombicum* assemblage zone (Zone 3; early Cretaceous age). According to him, Zone 1 includes the floral assemblage of Dubrajpur Formation, Zone 2 includes fossiliferous lower intertrappean beds of Rajmahal Formation and Zone 3 includes fossiliferous upper intertrappean beds of Rajmahal Formation. Later, Banerji (1990, 1992, 1993, 1995a, b, 1996), Prakash (2000), Banerji and Jana (1998, 2000) and Banerji and Ghosh (2006) recorded more plant macrofossils from the Rajmahal Formation.

Banerji (2000) discussed the megafloral diversity of Rajmahal Basin with comments on the age of floral assemblages. The flora includes 106 species belonging to 65 genera and four distinct megafloral assemblages are identifiable. The first assemblage is from the Dubrajpur

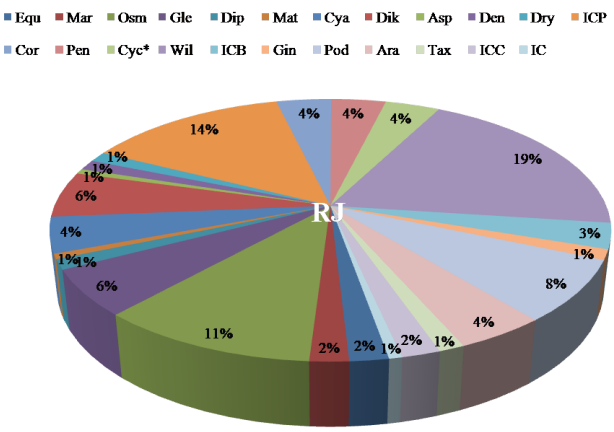

Fig. 10—Relative distribution of various plant groups in the early Cretaceous Sequence of Rajmahal Basin.

Lithounit	Lithology	Age
Undifferentiated deposits	Laterites, lateritic soil, lateritic grave ——————unconformity——————	Quaternary and Tertiary
Rajmahal	Volcanic traps with flows of basalt, pitchstone and intertrapean beds (sand, shale, ash)	Early Cretaceous (Neocomian–Aptian)
Dubrajpur	——————unconformity—————— Conglomerates, coarse to medium grained sandstone (occasionally mottled), grey siltstone, mottled shale	?Jurassic

Table 10—Generalised stratigraphy (early Cretaceous) of Rajmahal Basin (after Sen Gupta, 1988).

Formation and was assigned the late Jurassic age. The assemblage is dominated by cycadophytes–bennettitaleans and cycadaleans. The second assemblage belongs to the first to third intertrappean beds and is dominated by cycadophytes–bennettitaleans and cycadaleans and pteridophytes, followed by coniferaleans, pteridospermaleans, ginkgoaleans, and pentoxylaleans are relatively uncommon and this assemblage is considered as Neocomian in age. The third assemblage of late Neocomian age is found at Nipania, which is dominated by pentoxylaleans and coniferaleans, however, pteridophytes and cycadophytes are relatively rare. The youngest and the fourth assemblage is found at Sonajori locality, characterized by dominance of pentoxylaleans and coniferaleans as well as a few pteridophytes with some angiosperm remains. This youngest assemblage is considered as the late early Cretaceous (Aptian).

The major contribution to Rajmahal flora by above authors established unique early Cretaceous flora with ferns as major component. Many fern families such as Dennstaedtiaceae, Aspleniaceae and Dryopteridaceae are common in the Rajmahal flora, which are unknown from other early Cretaceous floras of India. Followed by bennettitaleans which constitute second major component of the flora. When compared to the other early Cretaceous floras of India, the foliar sizes of these bennettitaleans are comparatively larger. Coniferaleans are moderately represented. Pteridophytes (50%), bennettitaleans (22%), coniferaleans (15%), pentoxylaleans (4%), cycadaleans (4%), pteridospermaleans (4%) and ginkgoaleans (1%) represent the total flora (Fig. 10). The Rajmahal flora is categorized under *Allocladus–Brachyphyllum–Pagiophyllum* Assemblage Zone (Sukh Dev, 1987).

Palynology of the early Cretaceous Rajmahal Formation is known through the studies of Rao (1943c), Vishnu–Mittre (1953a, 1954), Sah and Jain (1965), Tiwari *et al.* (1984), Maheshwari and Jana (1983), Tripathi *et al*. (1990) and Tripathi and Tiwari (1991). Angiospermous pollen, such as *Sporojugiandoidites jurassicus, Retimonocolpites peroreticulatus* aff., *Clavatipollenites* sp. cf. *Stephanocolpites* sp.*, Retimonocolpites* sp.*, Liliacidites* sp. and cf. *Stellatopollis* sp. along with other pteridophytic and gymnospermous spore/pollen characterize Rajmahal palynotaxa.

DISCUSSION

In the peninsular India, the early Cretaceous successions are known from a number of discrete, intra–and peri–cratonic basins (Fig. 11). Ten basins have been recognized (Kutch/Saurashtra considered together in the present paper) and their macrofloral records (leaves only) were taken into consideration for the analysis of diversity trends. Although the flora are treated under 'Upper Gondwana' with different chronological connotations by earlier workers, their proximity to early Cretaceous floral components based on mega–and micro plant components made us to evaluate them under an early Cretaceous paradigm. A perusal of published literature hitherto demonstrates variable distribution of leaf fossils in different basins and their differential preservation. The taphocoenosis of various basins help to draw reasonable inferences based on variable distribution of various plant groups/taxa in geographically distant basins (Tables 11, 12, Figs 1–10). The early Cretaceous flora was enriched by gondwanan stock with intermingling of european representatives (Sukh–Dev, 1987; Bose *et al*., 1991; Rajanikanth *et al*., 2000). Climate homogeneity, non–selectivity probably resulted in diversity plateau. Numerical differences of leaf taxa were a result of taphonomic bias influenced by sedimentological processes dictated by tectonic forces. Regionalism in 'gondwanan' floras is well known in micro–and macro–floras (Dettmann & Thomson, 1987; Dettmann, 1992; Rajanikanth, 1996a, b; McLoughlin, 2001; Cantrill & Poole, 2002). An evaluation of early Cretaceous flora of India supports this view (Tables 11, 12).

The east coast early Cretaceous flora is treated under various floristic zones like *Dictyozamites–Pterophyllum–Anomozamites* (Athgarh/Pavalur/Satyavedu), *Allocladus–Brachyphyllum–Pagiophyllum* (Sriperumbudur, Gollapalli, Raghavapuram, Budavada, Vemavaram, Gangapur) and *Weichselia–Onychiopsis–Gleichenia* (Sivaganga) (Sukh–Dev, 1987). This flora is an essentially gymnosperm dominant post–Gondwana flora preserved in various environmental milieu (fresh water, lacustrine, fluvial, paralic, marginal marine). The floral elements which are common among all these east coast sedimentary basins are *Taeniopteris spatulata*, *Ptilophyllum acutifolium*, *Elatocladus plana* and *Araucarites cutchense*. The other taxa represented in various coastal basins constitute basinal flora with local variations. The evolution and diversification of east coast flora was concomitant with other equivalent homotaxial flora of central and western India. Some important selective distribution can be observed in all the east coast sedimentary basins, which share a common floristic bond, i.e. bennettito–coniferous dominance. Interestingly the number of taxa within the bennettitaleans and coniferaleans varies. The Cauvery and Palar basinal floras exhibit a difference in numerical distribution of pteridophytes, bennettittaleans and coniferaleans. Occasional angiosperm remains in Raghavapuram and Gangapur formations provide a clue to early angiosperm evolution on Indian craton. Sporadic reports of angiosperms from Krishna–Pranhita–Godavari basins opened avenues to search early angiosperms on Indian craton (Chinnappa & Rajanikanth, 2015). The Pranhita–Godavari basinal flora exhibits dominance of conifers and frequency of *Elatocladus.* Ginkgoaleans are totally absent from the Pranhita–Godavari floras. However, broad–leafed bennettiteleans and ginkgoaleans are common in Krishna–Godavari flora. The Mahanadi flora shows similar floristic pattern in diversity of ferns as seen in the Pranhita–Godavari. Dipteridaceae and Matoniaceae are well represented in the

Mahanadi basinal flora. Similarity of east coast flora and Australian/Antarctican floras is probably an outcome of geographical intimacy and prevalence of similar ecological (climate) conditions during the early Cretaceous. The Satpura basinal flora characterized by dominance of coniferaleans with *Elatocladus* as dominant element and resembles with Pranhita–Godavari flora. The Sourh Rewa basinal flora is mainly composed of araucarian and podocarpean elements. Rajasthan flora is comparatively less known. The Kutch basinal flora hold Caytoniaceae, a pteridospemous family well known in the form of leaves and reproductive parts, other taxa, viz. *Weichselia*, *Kachchhia*, *Trambaua* and *Lorumformophyllum* common in the flora. The Rajmahal basinal flora is well diversified and ferns are the major components. Fern families such as Dennstaedtiaceae, Aspleniaceae and Dryopteridaceae are unique to Rajmahal flora. Foliar size of bennettitaleans is comparatively larger in Rajmahal flora. Coniferaleans are relatively less represented in Rajmahal flora. Pentoxylaleans unique to Indian flora, now exend to other gondwanan continents (Drinnan & Chambers, 1985; Howe & Cantrill, 2001; Taylor *et al*., 2009) serves as a clue to plant evolution.

The early Cretaceous floras are widespread in other areas of Gondwana, being known from, South America (Archangelsky, 1963, 2001; Cúneo *et al*., 2010; Kunzmann *et al*., 2004), South Africa (Anderson & Anderson, 1985), Australia (Douglas, 1969; Drinnan & Chambers, 1986; Hills, 1994; McLoughlin, 1996; McLoughlin *et al*., 2000, 2002) and Antarctica (Gee, 1989; Bose *et al*., 1991; Césari, *et al*., 1998; Cantrill, 1995, 1996, 1997, 2000). The early Cretaceous flora from the Antarctica and Australia shows local variations depending on preservation potential. Combination of bennettitalean and coniferalean association is similar to Indian flora with a few records of angiosperms (taking into account taxonomic uncertainties) and constitute main feature of global early Cretaceous flora. Occurrence of *Ptilophyllum* (McLoughlin *et al*., 2011) from the Oligocene of Australia and wide distribution of this leaf genus and associated forms from non–gondwanan lands opened up new understanding of plant evolution. Distribution of ferns in other early Cretaceous gondwanan localities (Nagalingum *et al*., 2002; Nagalingum & Cantrill, 2006) to some extent can be compared with Rajmahal, Mahanadi and Kutch floras. Intensive efforts to create a global early Cretaceous plant data is required to

Fig. 11—Distribution of Mesozoic sedimentary basins of peninsular India.

delineate patterns of evolution. *Weichselia–Onychiopsis–Gleichenia* association found in South Rewa and Mahanadi basins needs special mention (Sukh–Dev, 1987) as these records can be utilised to reconstruct palaeoecology (Batten, 1974; Watson & Alvin, 1996; Pott *et al*., 2014). Taphonomic constraints always play a vital role in interpreting total floral distributed in various basins (Behrensmeyer *et al*., 1992, 2000; Burnham, 1993; Allison & Bottjer, 2011) and a multidisciplinary approach may provide a clue to prevailing limitations.

Status of Upper Gondwana

Evolution and diversification of early Cretaceous flora in different basins in peninsular India was concomitant with other equivalent gondwanan homotaxial flora (Tables 11, 12). However a 'mixed flora' existed during the early Cretaceous with an intermix of gondwanan and european forms. All these share a common floristic bond, i.e. bennettito–coniferous dominance. Recent spurt in angiosperm records world over including gondwana continents questioned validity of 'Upper Gondwana' concept on floristic basis. Contrary to the earlier studies based on plant macrofossil evidences, evidences from the faunal, floral (macro and micro) and tectonics suggest the early Cretaceous paradigm for these plant bearing 'Upper Gondwana' sediments (Rajanikanth *et al*., 2000). Moreover evolution of sedimentary basins in the east coast was attributed to continental rifting and seafloor spreading process that occurred during the early Cretaceous (Powel *et al*., 1988; Biswas *et al*., 1993; Lakshminarayana *et al*., 1992; Prabhakar & Zutchi, 1993; Lal *et al*., 2009). During this time India, Antarctica and Australia were closely associated and gradually got disjointed (Sastri *et al*., 1973, 1977, 1981; Veevers, 2004; Yoshida *et al*., 1993; Zeigler *et al*., 1996). Based on emerging evidences and representative fossils including flowering plants from 'Upper Gondwana' floral concept is debatable (Rajanikanth & Chinnappa, 2015b). Use of chronological terms like early Cretaceous is preferred. Such view gets support from associated evidences (Venkatachala & Rajanikanth, 1987; Prasad *et al*., 1995; Rajanikanth, 1996a, b, 2009; Mehrotra *et al*., 2010, Rajanikanth & Chinnappa 2015b, Chinnappa *et al*., 2014a, b, 2015) and fauna (Baksi, 1966; Bhalla, 1969; Sastri *et al*., 1963; Mamgain *et al*., 1973). Recovery of Ptilophyllum floral elements from Australian Oligocene sequence is a revelation to negate floristic basis for lithologic and chronologic inferences (McLoughlin *et al*., 2011).

Future scope

- Relative dominance of plant groups under different ecological niches provide a partial picture of total flora that lived. The incompleteness of evidences was a result of taphonomic attributes rather than their actual absence. Need concerted efforts to verify through plant records.
- The early Cretaceous sequences of India should be seriously explored for angiosperm remains and ecological categorization of flora.
- Most of the sequences are variously dated due to lack of definite markers and serious inputs are required to protect standard terrestrial / continental fossil locales/ sections.
- Mixed nature of early Cretaceous flora with cosmopolitan affinity as supported by palynological evidences needs more serious inputs.
- Role of climate and local habitat conditions in deriving taxonomic variability demand close scrutiny.
- Minor extinction event during early Cretaceous (Aptian) which mainly affected marine life should motivate an exercise on terrestrial floral records.
- Reports of existence of parallels between Aptian and present day merit serious attention. Episodes of environmental change during early Cretaceous should also be verified through terrestrial records. Global mega floral data may be handy to answer some puzzles.
- Taxonomic refinement and unanimity in combining various taxa named differently in different continents should also be attended.

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Name of the Basin	KG			PG	CV	PL	MH	KC			RS		ST	SR	RJ	HM
Name of the Formation	**Vm**	**Rg**	**Gl**	**Gn**	**Sv**	**Sp**	**At**	**Bj**	**Um**	**Gr**	**Pr**	**Sr**	**Jb**	**Bn**	**Rj**	**Fk**
List of the Taxa																
Equisetaceae																
Equisetum rajmahalensis Oldham & Morris	–	–	–	–	–	–	+	+	–	+	–	+	–	–	+	–
E. sehoraensis Singh *et al*.	–	–	–	–	–	–	–	–	–	–	–	–	+	–	+	–
Equisetum sp.	–	–	–	+	+	–	+	+	+	+	–	–	–	–	+	–
Marattiaceae																
Marattiopsis macrocarpa (O & M) Seward & Sahni	–	–	+	–	+	–	+	–	–	–	–	–	–	–	+	–
M. reversa Sharma	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
Rienitsia sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
Osmundaceae																
C. daradensis Bose & Banerji	–	–	–	–	+	–	–	+	+	–	–	–	–	–	–	–
C. denticulata (Brong.) Fontaine	–	–	–	+	–	–	+	–	+	–	–	–	–	–	+	–
C. indica (O & M) Sahni & Rao	–	–	–	+	+	–	+	–	+	–	–	–	+	–	+	–
C. kakadbhitensis Mehra & Verma	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–
C. kathiawarensis Roy	–	–	–	*	+	+	+	+	+	–	–	–	–	–	–	–
C. longipennis Seward	–	–	+	–	–	–	+	–	–	–	–	–	+	–	–	–
C. medlicottiana (Oldh.) Pascoe	–	+	–	–	–	–	+	–	–	–	–	–	+	–	–	–
C. sahnii Vishnu–Mittre	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
C. srivastavae Gupta	–	–	–	–	+	–	+	–	–	–	–	–	–	–	+	–
Cladophlebis sp. A & B	–	–	–	*	–	–	–	–	–	–	–	–	–	–	–	–
Cladophlebis sp.	+	+	+	+	+	–	+	+	+	+	–	+	–	–	+	–
Cacumen sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
Osmundopsis sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
Phyllopteroides laevis Cantrill & Webb	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
Raphaelia diamensis Seward	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+
Todites denticulatus (Brong.) Krasser	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
T. indicus (O & M) Bose & Sah	–	–	+	–	–	+	+	–	–	–	–	–	+	+	+	–
Gleicheniaceae																
Gleichenia bosahii (O & M) Pant & Srivastava	–	+	+	+	–	–	+	–	–	–	–	–	+	+	+	–
G. dhokutense Sharma	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
G. gleichenoides (O & M) Seward & Sahni	–	–	–	*	–	–	+	–	–	–	–	–	–	–	+	–

G. nordenskioldii Heer	–	–	–	+	–	–	+	–	+	–	–	–	–	+	–	–
G. rewahensis (Feist.) Pant & Srivastava	–	–	–	*	–	–	–	–	–	+	–	–	+	+	+	–
G. sonajoriense Bohra & Sharma	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
Gleichenia sp.	–	–	–	*	–	–	–	–	–	–	–	–	–	–	–	–
Gleichenia sp. A	–	–	–	+	–	–	+	+	+	–	+	–	–	–	+	–
Dipteridaceae																
Dictyophyllum indicum Bose & Jana	–	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–
Dictyophyllum sp.	–	–	–	–	–	–	–	+	+	+	–	–	–	–	–	–
Hausmannia buchii Andreae	–	–	–	+	–	–	–	–	–	–	–	–	+	–	–	–
H. cookshankii Shah & Singh	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–
H. crenata (Nath.) Moller	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
H. dichotoma Dunker	–	–	–	–	–	–	–	+	+	–	–	–	+	–	–	–
H. pachyderma Sukh–Dev	–	–	–	–	–	–	–	–	+	–	–	–	+	–	–	–
Hausmannia sp.	–	–	–	+	–	–	+	+	–	–	–	–	–	–	+	–
Mattoniaceae																
Matonidium indicum Sahni	–	–	–	–	–	–	–	–	+	–	–	–	+	–	–	–
Matonidium sp.	–	–	–	–	–	–	+	+	+	–	–	–	–	–	–	–
Phlebopteris arcuta Sukh–Dev	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–
P. athgarhensis Jain	–	–	–	–	–	–	+	–	–	–	–	+	–	–	–	–
P. indicus Prakash	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–
P. minutifolius Banerji	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–
P. polypodiodes Sukh–Dev	–	–	–	–	–	–	+	–	–	–	–	–	+	–	–	–
Phlebopteris sp.	–	–	–	–	–	–	+	–	+	+	+	–	–	–	+	–
Piazopteris branneri (White) Lorch	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+
Weichselia reticulata (Stokes & Webb) Ward	–	–	–	–	–	–	–	–	+	–	–	–	–	+	–	–
Schizaeceae																
Klukia rajmahalensis Sharma	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
Klukia sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
Mohriopsis sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
Schizaeangium jurassica Bohra & Sharma	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
Marsileaceae																
Marsilea sp.	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–
Cyatheaceae																

Haydenia thyrsopteroides Seward	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
Protocyathea cyatheoides (Unger) Feist.	–	–	–	–	+	–	–	–	–	–	–	–	–	–	+	–
P. cretacea (Stenzel) Ogura	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
P. rajmahalense Jacob	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
P. tokunagae (Ogura) Jacob	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
P. trichinopoliensis Feist.	–	–	–	–	+	–	–	–	–	–	–	–	–	–	+	–
Dicksoniaceae																
Coniopteris hymenophylloides (Brong) Seward	–	–	–	–	–	–	–	+	+	–	–	–	–	+	+	–
C. minturensis Brick	–	–	–	–	–	–	–	+	+	–	–	–	–	–	–	–
C. quinqueloba Phill.	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–
C. tatungensis (Sze). Shuying	–	–	–	–	–	–	–	–	–	–	–	–	+	–	+	–
Coniopteris sp.	–	–	–	*	–	–	+	–	–	–	–	–	+	–	+	–
Culcitites madagascariensis Appert	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
Dicksonia rajmahalensis Sharma	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
D. speciosa Sharma	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
Dicksonia sp.	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–
Eboracia lobifolia (Phill.) Thomas	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
Onychiopsis psilotoides (Stocks & Webb) Ward	–	–	+	–	–	–	+	–	+	–	–	–	+	–	–	–
O. paradoxus Bose & Sukh–Dev	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–
Onychiopsis sp.	–	–	–	–	–	–	+	–	–	–	–	–	–	+	+	–
#*Tinpaharia sinuosa* Jacob	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
Pteridaceae																
Actinopteris peitata Schenk	–	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–
Actinopteris sp.	–	–	–	+	+	–	–	–	+	–	+	–	–	–	–	–
Acrostichopteris sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+
Adiantopteris sp.	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–
Aspleniaceae																
Murlipaharopteris indica Banerji	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
Dennstaedtiaceae																
Asplenites sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
Dennstaedia rajmahalensis Sharma	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
Dryopteridaceae																
Dryopteris cladophleboides Sharma	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–

D. indicus Sharma	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
Miscellaneous Ferns																
Rhizomopteris chukschu Ganju	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
R. rajmahalense Gupta	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
R. sahnii Gupta	–	–	–	–	–	–	–	+	–	–	–	–	–	–	+	–
Rhizomopteris sp.	–	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–
Sphenopteris anderssonii Halle	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–
S. arguta Lindley & Hutton	–	–	–	–	–	–	–	–	+	–	–	–	+	–	+	–
S. bindrabunensis Feist.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
S. elaminata Sharma	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
S. hislopii Feist.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
S. imbricata Sharma	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
S. khairbaniensis Ganju	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
S. membranosa Feist.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
S. metzgerioides Harris	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–
S. naukhoffiana (Heer) Halle	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
S. otagoensis Arber	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–
S. patagonica Halle	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
S. rajmahalensis Sahni & Rao	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
S. sakrigaliensis Sah	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
S. tiruchirapalliense Sukh–Dev & Rajanikanth	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–
Sphenopteris sp.	+	+	–	+	+	–	+	–	+	+	–	+	+	+	+	–
Eboracia lobifolia (Phillip) Thomas	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–

Table 11—Distribution pattern of fern taxa in various early Cretaceous litho–units of India.

Name of the Basin	**KG**			**PG**	**CV**	**PL**	**MH**	**KC**			**RS**		**ST**	**SR**	**RJ**	**HM**
Name of the Formation	**Vm**	**Gl**	**Rg**	**Gn**	**Sv**	**Sp**	**At**	**Bj**	**Um**	**Gr**	**Pr**	**Sr**	**Jb**	**Bn**	**Rj**	**Fk**
List of taxa																
Caytoniaceae																
Sagenopteris sp. cf. *colpodes* Harris	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–
Corystospermaceae																
Cycadopteris auriculata Bose & Sukh–Dev	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–

C. brauniana Zigno	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–
C. indica Bose & Sukh–Dev	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–
C. majus Bose & Sukh–Dev	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–
C. pulcherrima Bose & Sukh–Dev	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–
Cycadopteris sp.	–	–	–	–	–	–	+	–	–	–	–	–	–	+	–	–
Pachypteris gangapurensis Sukh–Dev & Rajanikanth	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–
P. haburensis Bose *et al*.	–	–	–	–	–	–	–	–	–	–	+	+	–	–	–	–
P. indica (Oldh. & Morr.) Bose & Roy	+	+	+	–	–	–	+	+	+	–	–	–	+	+	+	–
P. specifica (Feist.) Bose & Banerji	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–
P. cf. *elegans* Archangelsky	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–
P. cf. *specifica* (Feist.) Bose & Banerji	–	–	–	*	–	–	–	–	–	–	–	–	–	–	–	–
Pachypteris sp.	–	–	–	–	–	–	–	–	+	+	+	–	–	–	–	–
Thinnfeldia amarjolensis Sharma *et al*.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
T. indica Feist.	–	–	–	–	+	–	–	–	–	–	–	–	–	–	+	–
T. khatangiensis Sen Gupta	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
T. nirmali Roy	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
T. vemavaramensis n. sp.	+	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–
T. cf. *lancifolea* (Morr.) Walkom	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
Thinnfeldia sp.	–	–	–	–	+	+	–	–	–	–	–	–	–	–	–	–
Pteridosperms																
Trambaua apiculata Bose & Banerji	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–
Pentoxylaceae																
Nipaniophyllum raoi Sahni	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
Taeniopteris crassinervis (Fesit.) Walkom	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
T. haburensis Bose & Banerji	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–
T. kutchensis Bose & Banerji	–	–	–	*	–	–	–	+	–	–	–	–	–	–	–	–
T. longifolium Sukh–Dev & Rajanikanth	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–
T. oldhamii Bose & Banerji	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
T. sarbadhikarii Sen Gupta	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
T. spatulata McClelland	+	+	+	+	+	+	+	+	–	–	+	–	+	–	+	–
T. vittatum Brong.	–	–	–	–	–	–	–	–	+	–	–	–	+	–	–	–
T. cf. *uwatokoi* Oshi	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+
T. cf. *daintreei* McCoy	–	–	–	*	–	–	–	–	–	–	–	–	–	–	–	–

Taenopteris sp.	–	–	*	–	–	–	–	+	–	–	–	–	–	–	+	+
Taeniopteris sp. A	–	–	–	*	–	–	–	–	–	–	–	–	–	–	–	–
Cycadaceae																
Ctenis imjhiriensis Bose & Zeba–Bano	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–
C. rajmahalensis Banerji	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
Ctenozamites kachchhensis Bose & Banerji	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–
C. surangei Sukh–Dev & Bano	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–
Cycadites rajmahalensis (Oldh.) Bose & Banerji	–	–	–	–	–	–	+	–	–	–	–	–	–	–	+	–
C. wadianus Bose *et al*.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+
Cycadospadix sp.	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–
Macrozamiphyllum mucilagica Sharma *et al*.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
Morrisia dentata (Rao & Jacob) Bose & Banerji	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
M. mcclellandii Bose & Banerji	+	+	+	–	+	+	–	–	–	–	–	–	–	–	+	–
M. rajmahalensis (Feist.) Bose & Banerji	–	+	–	–	–	–	–	–	–	–	–	–	–	–	+	–
Pseudoctenis fragalis Bose & Banerji	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–
Pseudoctenis sp.	+	–	–	–	–	–	+	–	–	–	–	–	–	–	–	+
Williamsoniaceae																
Anomozamites amarjolense (Sharma *et al*.) Bose & Banerji	+	–	–	–	–	+	–	–	–	–	–	–	–	–	+	–
A. crenata (McClelland) Bose & Banerji	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
A. fissus (Feist) Bose & Banerji	+	–	–	–	+	–	+	+	–	–	–	–	–	–	+	–
A. haburensis Bose & Banerji	+	–	–	–	+	–	–	–	–	–	+	–	–	–	–	–
A. hasnapurensis Bose & Banerji	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–
A. jungens Feist.	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
A. cf. *minor* (Brong.) Nath.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+
Anomozamites sp.	–	–	*	?	+	–	–	–	–	–	–	–	+	–	+	+
Dictyozamites falcatus (Morr.) Medli. & Blan. Bose & Bano	+	–	+	–	+	+	–	–	–	–	–	–	–	–	+	–
D. feistmantelii Bose & Zeba–Bano	+	+	+	–	+	+	–	–	–	–	–	–	+	–	–	–
D. gondwanensis Sukh–Dev & Rajanikanth	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–
D. hallei (Sahni & Rao) Bose & Zeba–Bano	*	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
D. indicus (Feist.) Bose & Zeba–Bano	+	+	+	–	+	+	–	–	–	–	–	–	+	–	+	–
D. sahnii (Gupta & Sharma) Bose & Zeba–Bano	–	–	+	–	–	–	–	–	–	–	–	–	–	–	+	–
D. ommevaramensis n. sp.	*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Dictyozamites sp.	–	–	–	+	–	–	–	–	–	–	–	–	–	–	+	–

Otozamites angustatus Feist	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–
O. bengalensis (Oldh.) Shimp.	+	–	+	–	–	+	+	+	–	–	–	–	–	–	–	–
O. exhislopi Bose	+	–	–	–	–	–	+	–	–	–	–	–	+	–	–	–
O. goldiaei Brong.	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–
O. gondwanensis Bose	+	–	–	–	–	–	+	–	–	–	–	–	–	–	+	–
O. imbricatus Feist.	+	–	–	–	–	–	+	+	+	–	+	+	–	–	+	–
O. kachchhensis Bose & Banerji	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–
O. vemavaramensis (Bose & Jain) Bose	+	–	+	–	–	+	+	–	–	–	–	–	–	–	–	–
O. walkamotaensis Bose & Bano	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–
O. cf. *goldlaei* Brong.	–	–	–	–	+	–	–	+	–	–	–	–	–	–	–	–
Otozamites sp.	+	–	+	+	–	–	+	+	–	–	–	+	–	–	–	–
Pterophyllum braunianum Göpp.	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–
P. distans (Morr.) Bose & Banerji	+	–	–	–	–	–	–	+	–	–	–	–	+	–	+	–
P. footeanum (Feist.) Bose & Banerji	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
P. guptai Bose & Banerji	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
P. incisum (Sahni & Rao) Bose & Banerji	+	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
P. kingianum (Feist.) Bose & Banerji	–	–	+	–	–	–	–	–	–	–	–	–	–	–	+	–
P. medlicottianum (Oldh. & Morr.) Bose & Banerji	–	–	–	+	–	–	–	–	–	–	–	–	+	–	+	–
P. morrisianum (Oldh.) Bose & Banerji	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
P. princeps (Oldh. & Morr.) Bose & Banerji	–	–	–	–	–	–	–	–	+	–	–	–	+	–	+	–
P. valentinei Sen Gupta	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
P. cf. *footeanum* (Feist.) Bose & Banerji	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
Pterophyllum sp.	+	–	–	–	+	–	+	–	–	–	+	–	–	–	+	+
Ptilophyllum acutifolium (Morr.) Bose & Kasat	+	+	+	+	+	+	+	+	–	–	+	+	+	–	+	–
P. amarjolense (Bose) Bose & Kasat	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
P. cutchense (Morr.) Bose & Kasat	+	+	+	+	+	–	+	+	–	–	–	–	+	–	+	–
P. deodikarii Mahabale & Satyanarayana	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–
P. distans (Feist.) Bose & Kasat	–	–	–	+	–	–	–	+	–	–	–	–	+	–	–	–
P. gladiatum Bose & Sukh–Dev	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–
P. heterophylla n. sp.	*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
P. horridum (Roy) Bose & Kasat	–	–	–	+	–	–	–	+	+	–	–	–	+	–	–	–
P. indicum (Jacob & Jacob) Bose & Kasat	–	–	–	–	–	+	–	+	+	–	–	–	–	–	–	–
P. institacallum (Bose) Bose & Kasat	–	–	–	–	–	–	–	+	–	–	–	–	+	–	–	–

P. jabalpurense (Jacob & Jacob) Bose & Kasat	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–
P. nipanica (Vishnu–Mittre) Bose & Kasat	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
P. oldhamii (Jacob & Jacob) Bose & Kasat	–	–	–	–	–	–	+	+	–	–	–	–	–	–	–	–
P. raghudevapurense Mahabale & Satyanarayana	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–
P. rarinervis (Feist.) Bose & Kasat	+	–	+	*	–	–	–	–	–	–	–	–	–	–	+	–
P. rewaensis Sukh–Dev & Bano	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–
P. sahnii (Gupta & Sharma) Bose & Kasat	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
P. sakrigaliensis (Sah) Bose & Kasat	–	–	–	–	–	–	–	+	–	–	–	–	–	–	+	–
P. tenerrimum (Feist.) Bose & Kasat	–	–	+	–	–	–	–	–	–	–	–	–	–	–	+	–
P. cf. *acutifolium* Bose & Kasat	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–
P. cf. *amarjolense* Bose & Kasat	–	–	+	–	–	–	–	+	–	–	–	–	–	–	–	–
P. cf. *distans* Bose & Kasat	*	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–
P. cf. *gladiatum* Bose & Sukh–Dev	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–
P. cf. *horridum* (Roy) Bose & Kasat	–	–	+	–	–	–	–	–	–	–	–	–	+	–	–	–
P. cf. *institacallum* (Bose) Bose & Kasat	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–
P. cf. *jabalpurense* Bose & Kasat	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–
P. cf. *sahnii* Bose & Kasat	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–
Ptilophyllum sp.	–	–	–	+	–	–	–	+	–	–	–	–	+	–	+	+
Zamites chunakhalensis Banerji	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
Bennettitaleans																
Nilssoniopteris variabilis Bose & Banerji	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–
Rajmahalia paradoxa Sahni & Rao	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
Rajmahalia sp.	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–
Yebiella hirsuta (Bose & Sukh–Dev) Sukh–Dev	–	–	–	–	–	–	–	–	–	–	–	–	+	+	–	–
Scale leaves																
Cycadolepis indica Gupta	–	–	+	–	–	–	–	–	–	–	–	–	–	–	+	–
C. oldhamii Bose & Jain	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
C. pilosa Feist.	–	–	–	–	–	–	–	+	+	–	–	–	–	–	+	–
Cycadolepis sp.	+	–	–	–	–	–	–	+	–	–	–	–	+	–	+	–
Ginkgoaceae																
Baiera sp.	–	–	–	–	–	–	+	–	–	–	–	–	?	–	–	–
Ginkgo biloba L.	–	–	*	–	–	–	–	–	–	–	–	–	–	+	–	–
G. crassipes Feist.	+	–	+	–	–	+	–	–	–	–	–	–	–	–	–	–

G. feistmantelii Bose & Sukh–Dev	–	–	+	–	–	–	–	–	–	–	–	–	+	+	–	–
G. lobata Feist.	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–
G. rajmahalensis (Sah & Jain) Zeba–Bano *et al.*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
G. cf. *rajmahalensis* (Sah & Jain) Zeba–Bano *et al.*	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–
*Ginkg*o sp.	–	–	+	–	–	+	–	–	–	–	+	–	–	–	+	–
Araucariaceae																
Allocladus bansaensis Sukh–Dev & Zeba Bano	–	–	–	+	–	+	–	–	+	–	–	–	+	+	+	–
A. biswasianus Bose & Banerji	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–
A. patensis Banerji	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–
Brachyphyllum bansaensis Sukh–Dev & Bose	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–
B. brevifolia Srivastava *et al.*	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–
B. eikaiostomum Sukh–Dev & Bose	–	–	–	–	–	–	–	–	–	–	–	–	+	+	–	–
B. expansum (Sternburg) Seward	+	+	+	–	+	–	+	+	+	–	–	–	+	+	+	–
B. feistmantelii (Halle) Sahni	+	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–
B. florinii Vishnu–Mittre	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
B. jabalpurensis Prakash	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–
B. pantii Srivastava & Nautiyal	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–
B. regularis Borkar & Chiplonkar	–	+	–	–	+	–	–	–	+	–	–	–	–	–	–	–
B. rhombicum (Feist.) Sahni	*	–	+	+	–	+	+	–	–	+	–	–	+	+	–	–
B. rhomboidalis Srivastava *et al.*	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–
B. royii Bose & Banerji	–	–	–	–	–	–	–	+	+	–	–	–	–	–	–	–
B. sehoraensis Bose & Maheshwari	–	+	–	+	–	–	–	–	–	–	–	–	+	–	–	–
B. spiroxylum Bose	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
B. suryanarayanaii Sukh–Dev & Bose	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–
B. theraniense Sukh–Dev & Rajanikanth	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–
Brachyphyllum sp.	*	+	–	+	+	–	–	–	–	–	–	+	+	–	+	+
Pagiophyllum amlexicaulis Srivastava *et al.*	–	–	–	–	–	–	–	–	–	–	–	–	+	+	–	–
P. bansaensis Bose & Sukh–Dev	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–
P. chawadensis Bose & Banerji	–	–	–	–	–	–	–	+	–	–	–	–	+	–	–	–
P. feistmantelii Halle	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
P. gollapallensis Pandya & Sukh–Dev	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–
P. grantii Bose & Banerji	–	–	–	–	–	–	–	+	+	–	–	–	–	–	–	–
P. indicum Srivastava *et al.*	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–

P. magnipapillare Wesley	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–
P. marwarensis Bose & Sukh–Dev	–	–	+	+	–	–	–	–	–	–	–	–	+	+	+	–
P. morrisii Bose & Banerji	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–
P. ommevaramensis n.sp.	*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
P. peregrinum (Lindley & Hutton) Schimper	–	–	–	+	–	–	–	–	–	+	–	+	–	–	+	–
P. rewaensis Bose & Sukh–Dev	–	–	–	*	–	–	–	–	–	–	–	–	–	+	–	–
P. satpuraensis Maheshwari & Kumaran	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–
P. sherensis Maheshwari & Kumaran	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–
P. spinosum Sukh–Dev & Rajanikanth	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–
P. cf. *grantii* Bose & Banerji	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–
P. cf. *marwarensis* Bose & Sukh–Dev	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–
P. cf. *peregrinum* (Lindley & Hutton) Shimper	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–
Pagiophyllum sp.	+	–	–	+	–	–	+	–	–	+	+	+	–	–	–	–
Marwaria latifolia (Feist.) Sukh–Dev & Bose	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–
Satpuria sehoraensis Sukh–Dev & Zeba–Bano	–	–	–	+	–	–	–	–	–	–	–	–	+	–	–	–
Satpuria sp.	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–
Cone scales																
Araucarites cutchensis Feist.	+	+	+	+	+	+	+	+	+	+	+	–	+	–	+	–
A. fibrosa Sukh–Dev & Bose	–	+	–	–	–	–	–	–	–	–	–	–	–	+	–	–
A. janaianus Bose & Banerji	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–
A. macropterus Feist.	–	+	–	–	–	+	–	–	+	–	–	–	+	–	–	–
A. minutus Bose & Maheshwari	+	–	–	+	+	+	+	+	–	+	–	–	+	+	+	–
A. mittrii Bohra & Sharma	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
A. nipaniensis Singh	–	–	–	–	–	–	+	–	–	–	–	–	–	–	+	–
A. pantiana Bose & Maheshwari	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–
A. raghavapurensis n. sp.	–	–	*	–	–	–	–	–	–	–	–	–	–	–	–	–
A. sehoraensis Bose & Maheshwari	–	–	–	–	–	–	+	–	–	–	–	–	+	–	–	–
A. cf. *nipaniensis* Singh	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–
A. cf. *macropterus* Feist.	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–
Araucarites sp.	–	–	*	+	–	–	–	–	–	–	–	–	+	–	+	–
Podocarpaceae																
Elatocladus bosei Maheshwari & Kumaran	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–
E. chawadensis Bose & Banerji	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–

E. conferta (Oldh. & Morr.) Halle	–	+	+	+	–	–	–	+	+	–	+	–	+	+	+	–
E. heterophylla Halle	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–
E. jabalpurensis (Feist.) Sahni	+	–	–	+	–	–	–	+	–	–	–	–	+	–	+	–
E. kasatii Prakash	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–
E. sherensis Prakash	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–
E. kingianus Bose *et al*.	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–
E. loyolii n. sp.	*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
E. andhrensis n.sp.	–	–	–	*	–	–	–	–	–	–	–	–	–	–	–	–
E. plana (Feist.) Seward	+	–	+	+	+	+	–	–	–	+	–	–	+	+	+	–
E. pseudotenerrima Maheshwari & Kumaran	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–
E. sahnii Vishnu–Mittre	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
E. sehoraensis Maheshwari & Kumaran	–	–	–	*	–	–	–	–	–	–	–	–	+	–	–	–
E. tenerrimus (Feist.) Sahni	*	–	–	+	+	+	+	+	–	+	+	–	+	–	+	–
E. vemavaramensis Pandya *et al*.	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Elatocladus cf. *plana* (Feist.) Seward	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+
Elatocladus cf. *bosei* Maheshwari & Kumaran	–	–	–	*	–	–	–	–	–	–	–	–	–	–	–	–
Elatocladus sp.	–	–	+	+	–	–	+	–	+	–	+	–	+	–	+	–
Nipanioruha curvifolia Vishnu–Mittre	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
N. lanceolata Vishnu–Mittre	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
Stachyotaxus sp.	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–
Indophyllum nipanica Vishnu–Mittre	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
I. raoi Vishnu–Mittre	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
I. sahnii Vishnu–Mittre	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
Sitholeya rajmahalensis Vishnu–Mittre	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
Taxaceae																
Elatides sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+
Taxites lanceolata Ganju	–	–	–	*	–	–	–	–	–	–	–	–	–	–	+	–
Torreyites constricta (Feist.) Seward & Sahni	+	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–
T. sitholeyi Ganju	–	–	–	+	–	–	–	–	–	–	–	–	–	–	+	–
Conifers																
Harrisiophyllum hacketioides Pant *et al*.	+	–	+	–	–	–	+	–	–	–	–	–	+	+	–	–
H. indicum Pant *et al*.	–	–	–	–	–	+	–	–	–	–	–	–	+	+	–	–
H. lanceolatus n.sp.	–	–	–	*	–	–	–	–	–	–	–	–	–	–	–	–

H. linearis Pant *et al.*	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–
H. oblanceolatus Pant *et al.*	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–
H. spatulatus Pant *et al.*	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–
Harrisiophyllum (*Desmiophyllum*) sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	+
Strobili/Cones																
Conites sessilis Sahni	+	–	–	–	–	+	–	–	–	–	–	–	–	–	+	–
C. sripermaturensis Sahni	–	–	–	+	–	+	–	–	–	–	–	–	–	–	–	–
Conites sp.	+	–	+	–	–	–	–	+	–	+	–	–	–	+	–	–
Winged seeds																
Pityospermum godavarianum n.sp.	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–
P. krassilovii n.sp.	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–
Pityospermum sp.	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–
Incertae Sedis																
Lorumformophyllum dentatum Bose & Banerji	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–
Muralipaharopteris indica Banerji	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
Carpolithes sp.	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–
Angiosperms																
cf. *Trapa* sp.	–	–	*	–	–	–	–	–	–	–	–	–	–	–	–	–
Palmacites sp. A	–	–	*	–	–	–	–	–	–	–	–	–	–	–	–	–
Palmacites sp. B	–	–	*	–	–	–	–	–	–	–	–	–	–	–	–	–
Angiosperm floral Spike	–	–	*	–	–	–	–	–	–	–	–	–	–	–	–	–
Montsechites sp. cf. *ferreri* Teixeira	–	–	–	*	–	–	–	–	–	–	–	–	–	–	–	–
Sahniophylllum indica gen. *et* sp. nov.	–	–	–	*	–	–	–	–	–	–	–	–	–	–	–	–
Petals of flower	–	–	*	–	–	–	–	–	–	–	–	–	–	–	–	–
?Angiosperm sp.	–	–	*	–	–	–	–	–	–	–	–	–	–	–	–	–
Monocotyledon sp. A	–	–	*	–	–	–	–	–	–	–	–	–	–	–	–	–

Table 12—Distribution pattern of gymnosperms and angiosperms in various early Cretaceous litho–units of India.

LEGEND:

"#": Fossil with organic connection; "–": absent: "+"; present; "*": reported in the present study

Ang: Angiosperms	**KG/KGB**: Krishna–Godavari Basin
Ara: Araucariaceae	**Mar**: Marattiaceae
At: Athgarh	**Mat**: Matoniaceae
Bj: Bhuj	**MH**: Mahanadi Basin
Bn: Bansa	**Osm**: Osmundaceae
Cor: Corystospermaceae	**Pen**: Pentoxylaceae
CV: Cauvery Basin	**PG/PGB**: Pranhita–Godavari Basin
Cya: Cyatheaceae	**PL**: Palar Basin
Cyc: Cycadaceae	**Pod**: Podocarpaceae
Dik: Dicksoniaceae	**Pr**: Pariwar
Dip: Dipteridaceae	**Rg**: Raghavapuram
Equ: Equisetaceae	**RJ**: Rajmahal Basin
Fk: Fukche	**RS**: Rajasthan Basin
Gin: Ginkgoaceae	**Sp**: Sriperumbudur
Gl: Golapalli	**Sr**: Sarnu Hill
Gle: Gleicheniaceae	**SR**: South Rewa Basin
Gn: Gangapur	**ST**: Satpura Basin
Gr: Gardeshwar	**Sv**: Sivaganga
ICC: *Incertae Sedis* (conifers)	**Tax**: Taxaceae
ICP: *Incertae Sedis* (pteridophytes)	**Um**: Umia
Jb: Jabalpur	**Vm**: Vemavaram
KC: Kutch Basin	**Wil**: Williamsoniaceae

Table 13—Legend for figures and tables.

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