

Indian fossil monocotyledons: Current Status, Recent Developments and Future Directions

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(Received 03 August, 2006; revised version accepted 17 April, 2008)

ABSTRACT

Bonde SD 2008. Indian fossil monocotyledons: Current Status, Recent Developments and Future Directions. *The Palaeobotanist* 57(1-2) : 141-164.

The megafossil records of monocotyledons assigned to Upper Cretaceous (Maastrichtian) onward from India have been reviewed along with their possible resemblances with the extant members to have a meaningful taxonomic and phylogenetic relationship. The early record of angiosperm megafossils assigned to the dicotyledons is from the Lower Cretaceous horizon of Rajmahal Hills, Bihar (now Jharkhand). A thorough search for the monocotyledons is yet to be made from these beds. The Deccan Intertrappean beds which belong to Maastrichtian (Upper Cretaceous) - Palaeocene age, are very rich in angiosperms comprising both dicotyledons and monocotyledons preserved especially in the form of permineralizations. The later epochs or series, however, are rich in compressions and impressions. The monocotyledonous flora is dominated mainly by palms (Family-Arecaceae) followed by the families of Scitamineae, Poaceae, Cyperaceae and Araceae.

In order to understand the early monocotyledonous diversification future work is to be concentrated in the Rajmahal Intertrappeans and contemporary horizons belonging to the Lower Cretaceous Period. Thorough search for entire herbaceous elements, woody juvenile and arborescent members (palms, pandans, aroids, liliales, grasses, Cyperaceae, etc.), reconstructions of entire plants based upon organic occurrences and associations in addition to the isolated reproductive and vegetative organs of taxonomic significance is to be given priority. In depth knowledge of morphology and anatomy of comparable extant flora is required for their phylogenetic assessments.

Key-words—Morpho-taxonomy, Monocotyledons, Megafossils, India.

भारतीय जीवाश्म एकबीज पत्री: वर्तमान दशा, अभिनव प्रगति एवं भावी दिशाएँ

एस.डी. बोडे

सारांश

भारत से प्राप्त एकबीज पत्री के स्थूल जीवाश्म अभिलेखों की ऊपरी क्रिटेशियस (मास्ट्रीशियन) से आगे निर्धारित विद्यमान सदस्यों से उनकी संभावित समरूपता सहित सार्थक वर्गीकरणत्मक एवं जातिवृत्तिय संबंधत्व की समीक्षा की गई है। द्विबीजी को निर्धारित आवृतबीजी स्थूल जीवाश्मों का पहले का अभिलेख राजमहल पहाड़ी, बिहार (अब झारखंड) के निम्न क्रिटेशियस क्षितिज से है। इन संस्तरों से एकबीज पत्री हेतु संपूर्ण खोज अभी होनी है। मास्ट्रीशियन (ऊपरी क्रिटेशियस)-पुरानूइन युग की दक्कन अंतःद्रानीन संस्तरों विशेषतः खनिक रूप में परिरक्षित द्विबीजी एवं एकबीजी पत्री दोनों सन्निहित आवृतबीजी प्रचुर हैं। फिर भी, बाद का युग या श्रेणी, संपीडाश्म एवं मुद्राश्म प्रचुर हैं। एकबीज पत्रीमय वनस्पतिजात मुख्यतः ताड़ (एरेकेसी-परिवार) के अनुवर्ती साइटामिरेसी, पोएसी, साइप्रेसी तथा एरेसी द्वारा नियंत्रित है।

प्रारंभिक एकबीज पत्रीमय विविधरूपण को समझने हेतु राजमहल अंतरद्रोपियन तथा निम्न क्रिटेशियस अवधि की समकालिक संस्तर-स्थितियों पर शोधकार्य पर ध्यान देने की जरूरत है। कार्बनिक प्राप्तियों एवं संगुणन विलग पुनर्उत्पादी के अलावा तथा वर्गीकरण सार्थकता के वनस्पति अंगों पर आधारित समूचे शाकीय तत्वों काष्ठीय बाल एवं वृक्षसम सदस्यों (ताड़, प्रैडन्स, घुईयाँ, लिलिएल्स, घास, साइप्रेसी इत्यादि), सूची वनस्पति की पुनर्संरचना हेतु बृहत खोज को प्राथमिकता देने की जरूरत है। तुलनीय विद्यमान पेड़-पौधे की आकृति विज्ञान एवं शरीर की संपूर्ण जानकारी उनके जातिवृत्तीय निर्धारण के लिए आवश्यक हैं।

संकेत-शब्द—आकृति-वार्गिकी, एकबीज पत्री, स्थूल जीवाश्म, भारत।

INTRODUCTION

A monograph on Revision of Fossil Monocotyledons from India was published posthumously in the name of Birbal Sahni in 1964. Although Daghlion (1981) reviewed the world record of fossil monocotyledons, it hardly represented the Indian material. The fossil record of monocotyledons has been reviewed here in view of the huge amount of published work and the recent morpho-anatomical investigations on extant plants.

Angiosperms comprise a dominant plant group throughout the world today having 2,58,650 species distributed in 490 families. Of these, the monocotyledons constitute 59,300 species assigned to 112 families comprising about 25% of the angiosperms (Thorne, 2002). Plants in the past, as today, lived in various habitats. However, those growing in or near the areas of sedimentary depositions had a chance of preservation. The megafossil record of monocotyledons is very meagre in comparison to the number of extant members. The fossil record may be scanty because majority of them are herbaceous in nature and do not get readily fossilized like those of the woody plants. They are described as permineralizations, impressions and compressions assigned to the families Agavaceae, Alismataceae, Amaryllidaceae, Aponogetonaceae, Araceae, Arecaceae (Palmae), Bromeliaceae, Butomaceae, Cannaceae, Centrolepidaceae, Ceratophyllaceae, Commelinaceae, Cyclanthaceae, Cymodoceaceae, Cyperaceae, Dioscoreaceae, Dracnaceae, Heliconiaceae, Hydrocharitaceae, Juncaceae, Juncaginaceae, Lemnaceae, Liliaceae, Marantaceae, Musaceae, Najadaceae, Orchidaceae, Pandanaceae, Poaceae (Gramineae), Pontederiaceae, Potamogetonaceae, Restionaceae, Smilacaceae, Sparganiaceae, Stemonaceae, Strelitziaceae, Taccaceae, Typhaceae, Xyridaceae, Zingiberaceae and Zosteriaceae (Collinson *et al.*, 1993).

Propalmophyllum liasinum Lignier (1895), *Alismaphyllum victor-masoni* (Ward) Berry (1911), *Sanmiguelia lewisii* Brown (1956), and *Acaciaephyllum spatulatum* Fontaine (Doyle, 1973; Hickey & Doyle, 1977) are the pre-Cretaceous records from the world. Angiospermous record prior to Maastrichtian from India is meagre and is known only from the Rajmahal Intertrappeans. However, many of them belong to the dicotyledons (Vishnu Mittre, 1956; Tripathi & Tiwari, 1991; Tiwari & Tripathi, 1995; Sharma, 1997; Banerji, 2000). The succeeding Deccan Intertrappean flora of the Maastrichtian (Upper Cretaceous) age, however, is very rich in monocotyledonous remains, along with the dicotyledons in comparison to the other Cretaceous or Early Tertiary floras. The monocotyledonous flora is dominated by palms (Family–Arecaceae) followed by Poaceae, Araceae, Musaceae, Liliaceae, Cyperaceae, Agavaceae, Pandanaceae and others. It also shows the sudden dominance of angiosperms.

Diversity of Monocotyledons

Following megafloral elements have been listed from different geological horizons in India. They have been arranged in alphabetical order of family, name of the genus, species, authority, year of publication, organ of the plant body, affinity or resemblance with the extant and / or extinct members wherever possible, locality, horizon and age. The question mark (?) indicates the need for reassessment for the affinity of the fossil.

Agavaceae

Dracaena- wood (Ambwani, 1982, 1999). Axis. Neyveli, District South Arcot, Tamil Nadu. Miocene.

Neyvelia awasthii Reddy (1995). Axis comparable to *Dracaena* Vand. ex L. Neyveli, District South Arcot, Tamil Nadu. Miocene.

Amaryllidaceae

Crinum eocenium Patil & Upadhye (1990). Pseudostem comparable to *Crinum asiaticum* L. (?). Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).

Araceae

Rhizocaulities palaeocenicus (= *Rhizocaulon palaeocenicum* Mehrotra, 2000) Mehrotra (2003). Rhizome comparable to *Aglaonema* Schott. (?). It appears to be a rhizome of Zingiberaceae. Buruai Colliery near Jowai, District Jaintia Hills, Meghalaya. Upper Palaeocene.

Rhodospathodendron tomlinsonii Bonde (2000). Aerial viny stem comparable to *Rhodospatha* Poepp. & Endl. Nawargaon, District Wardha, Maharashtra. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).

Viracarpon elongatum Sahni (1944) (= *Shuklanthus superbum* Verma, 1958; Chitaley & Patil, 1971); (= *V. chitaleyi* Patil, 1972; Bande & Awasthi, 1986). Inflorescence. Takli near Nagpur, Maharashtra; Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).

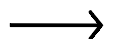
V. hexaspermum Sahni (1934) (= *V. sahnii* Chitaley *et al.*, 1969; Bande & Awasthi, 1986), Chitaley (1954, 1958), Nambudiri & Tidwell, 1978), Mahabale (1979). Inflorescence comparable to Mulberry like fruits of Moraceae, Araceae (*Monstera deliciosa* Liebm., *Amorphophyllum* Blume ex Decne. and related genera) (?). The affinities have also been suggested with families Cyclanthaceae and Pandanaceae. Takli near Nagpur, Maharashtra; Mahurzari, District Nagpur, Maharashtra; Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).

Areaceae (Palmae)**Stems**

- Palmoxylon anjarii* Guleria (2005). Viri, South of Anjar, Kachchh. Anjar Formation. Upper Maastrichtian to Danian.
- P. arcotense* Ramanujam (1953). Comparable to *Livistona* R. Br. (?). Tiruchhitambalam, Pondicherry. Tertiary (?).
- P. arviensis* Ambwani (1981). Nawargaon, District Wardha, Maharashtra. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- P. barbatum* Sahni (1964). Locality & Age - Unknown.
- P. betulensis* Gayakwad & Patil (1989). Rambhakheri, District Betul, Madhya Pradesh. Upper Cretaceous.
- P. binoriensis* Guleria & Mehrotra (1999). Binori Reserve Forest, District Seoni, Madhya Pradesh. Upper Cretaceous.
- P. birbhumense* Bera & Banerjee (2001). Muhammaad Bazar, West Bengal, Late Pliocene - Early Pleistocene.
- P. blanfordi* Schenk (1882). Near Jhansi, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- P. canalosum* Guleria & Mehrotra (1999). Binori Reserve Forest, District Seoni, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- P. chhindwarens* Prakash (1958). Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- P. cordatum* Trivedi & Surange (1968). Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- P. coromandelensis* Mahabale & Rao (1973). Kateru, District East Godavari, Andhra Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- P. coronatum* Sahni (1964), Roy & Ghosh (1980). Comparable to *Borassus flabellifer* L. (?) (Kaul, 1967). Labpur, District Birbhum & Bishnupur, District Bankura, West Bengal. Tipam Series. Miocene.
- P. cribriforme* Sahni (1964). Locality & Age - Unknown.
- P. dakshinense* Prakash (1958). Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- P. deccanense* Sahni (1964). Maragour (? Maragsur), District Wardha, Maharashtra. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- P. dilacunosum* Ambwani (1984b). Silther, District Mandla, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- P. edwardsi* Sahni (1931, 1964). Near Jabalpur, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- P. eocenum* Prakash (1961). Mahurzari, District Nagpur, Maharashtra. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- P. feistmantelii* Rao & Achutan (1969). Comparable to *Mauritia*- like palms (?). Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- P. fibrosum* Menon (1965a). Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- P. ghoshii* Bera & Banerjee (1990, 2001). Comparable to *Borassus flabellifer* L. and *Raphia vinifera* Drude (?). Garbeta, District Midnapore, West Bengal. Lalgah Formation. Upper Pliocene- Lower Pleistocene.
- P. ghughuensis* Ambwani & Prakash (1983). Comparable to *Chrysalidocarpus*. Ghughua, District Mandla, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- P. hislopi* Rode (1933a). Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- P. hyphaeneoides* Rao & Shete (1989). Comparable to *Hyphaene* Gaertn. Nawargaon-Maragsur, District Wardha, Maharashtra. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- P. indicum* Sahni (1931, 1964). Locality & Age - Unknown.
- P. intertrappeum* Sahni (1964). Sindhivihira, District Wardha, Maharashtra. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- P. jammuense* Sahni (1931, 1964). Jammu & Kashmir. Upper Siwalik. Pliocene.
- P. kachchhensis* Guleria (1983). Mothala, District Kachchh, Gujarat. Kankawati Series. Pliocene.
- P. kamalam* Rode (1933a); Shukla (1939), Sahni (1964), Kulkarni & Mahabale (1973), Datar & Patil (2002). Comparable to *Roystonea regia* O.F.Cook. Mohgaonkalan, District Chhindwara, Madhya Pradesh; Pulpuldoh, District Chhindwara, Madhya Pradesh; Kondhali, District Nagpur; Maragsur, District Wardha, Maharashtra. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- P. kerianse* Trivedi & Verma (1971). Keria, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- P. khalsa* Sahni (1964). Locality & Age - Unknown.
- P. kondhaliensis* Mahabale & Kulkarni (1981). Kondhali, District Nagpur, Maharashtra. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- P. kraeuselii* Rao & Menon (1966). Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- P. krishna* Sahni (1931, 1964). Sitabaldi near Nagpur, Maharashtra. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- P. licualaense* Gayakwad & Patil (1989). Comparable to *Licuala* Wurm. Rambhakheri, District Betul, Madhya Pradesh. Upper Cretaceous.

- P. liebighianum* Schenk (1882). Sitabaldi, District Nagpur, Maharashtra. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- P. livistonoides* Prakash & Ambwani (1980). Comparable to *Livistona* R.Br. Nawargaon, District Wardha, Maharashtra. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- P. lunarianum* Guleria & Mehrotra (1999). Binori Reserve Forest, District Seoni, Madhya Pradesh. Upper Cretaceous (Maastrichtian).
- P. mahabalei* Rao & Menon (1967). Comparable to *Cocos* - like palms. Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- P. maheshwarii* Rao & Menon (1964a). Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- P. mandlaensis* Lakhanpal *et al.* (1979). Comparable to *Corypha* - like palms. Mohgaon - Palasundar, District Mandla, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- P. mathuri* Sahni (1931, 1964), Agarwal & Lalitha (1977), Agrawal (1995). Comparable to *Bactris pallidispina* Mart. (Kaul, 1938, 1967). Lacknipur, District Kachchh, Gujarat; Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian) - Tertiary.
- P. mohgaonensis* Trivedi & Surange (1970). (*Homonym* of *Palmoxydon mohgaonensis* Rode, 1934). Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- P. narayani* Rao & Menon (1962). Comparable to *Mauritia* - like palms (?). Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- P. nawargaoensis* Shukla (1941). Nawargaon, District Wardha, Maharashtra. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian). *Nomen nudum*.
- P. pantii* Trivedi & Surange (1971), Bonde & Biradar (1981). Bera & Banerjee (1997, 2001). Mohgaonkalan, District Chhindwara, Madhya Pradesh.; Dongargaon, District Chandrapur, Maharashtra. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian); Santiniketan, Garbeta, West Bengal. Late Pliocene- Early Pleistocene.
- P. parapaniensis* Lakhanpal *et al.* (1979). Comparable to *Cocos*-like palms. Parapani, District Mandla, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- P. parthasarathyi* Rao & Menon (1964b). Comparable to *Cocos*-like palms. Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- P. penchense* Trivedi & Verma (1972). Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- P. pondicherriense* Sahni (1931, 1964). Pondicherry. Cuddalore Series. Miocene.
- P. prismaticum* Sahni (1964). Affinity with *Corypha* - like palms. Locality & Age-Unknown.
- P. puratanam* Ramanujam (1958). Murattandichavadi, District South Arcot, Tamil Nadu. Cuddalore Series. Miocene-Pliocene.
- P. ramanujamii* Guleria (2005). Viri near Anjar, Kachchh, Anjar Formation. Upper Maastrichtian to Danian.
- P. raoi* Menon (1968). Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- P. rewahense* Sahni (1964). Hirwar near Tiki, South Rewa, Madhya Pradesh. Horizon & Age - Unknown.
- P. rodei* Varadpande & Sampath (1979). Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- P. sagari* Sahni (1964), Bonde & Biradar (1981). Sagar, Madhya Pradesh; Dongargaon, District Chandrapur, Maharashtra. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- P. sclerodermum* Sahni (1943), Shukla (1946); Shete & Kulkarni (1983). Comparable to *Astrocaryum vulgare* Mart.; Arecoid palms. Seoni, Madhya Pradesh; Nawargaon, District Wardha, Maharashtra. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- P. scottii* (= *P. sahnii* Menon, 1964a) Dayal & Menon (1965). Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- P. senii* Bera & Banerjee (2001). Garbeta, West Bengal. Late Pliocene- Early Pleistocene.
- P. seriatum* Sahni (1964). Kootkipara, District Kachchh, Gujarat. Cretaceous.

PLATE 1



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| <p>a. Reconstruction of a plant of <i>Cyclanthodendron sahnii</i>.</p> <p>b. Cross section of apical region of <i>Cyclanthodendron</i> (<i>Musocaulon indicum</i>) showing convolutedly rolled young leaves in distichous phyllotaxy.</p> <p>c. Cross section of petiole (<i>Heliconiaites mohgaonensis</i>).</p> | <p>d. <i>Musa cardiospermum</i> - many seeded banana fruit.</p> <p>e. Inflorescence of <i>Tricoccytes trigonum</i> showing compactly arranged nine fruits in two alternate rows.</p> <p>f. <i>Musophyllum indicum</i> leaf with costa and secondary veins.</p> <p>g. Cross section of <i>Tricoccytes trigonum</i> showing three fertile seeds.</p> |
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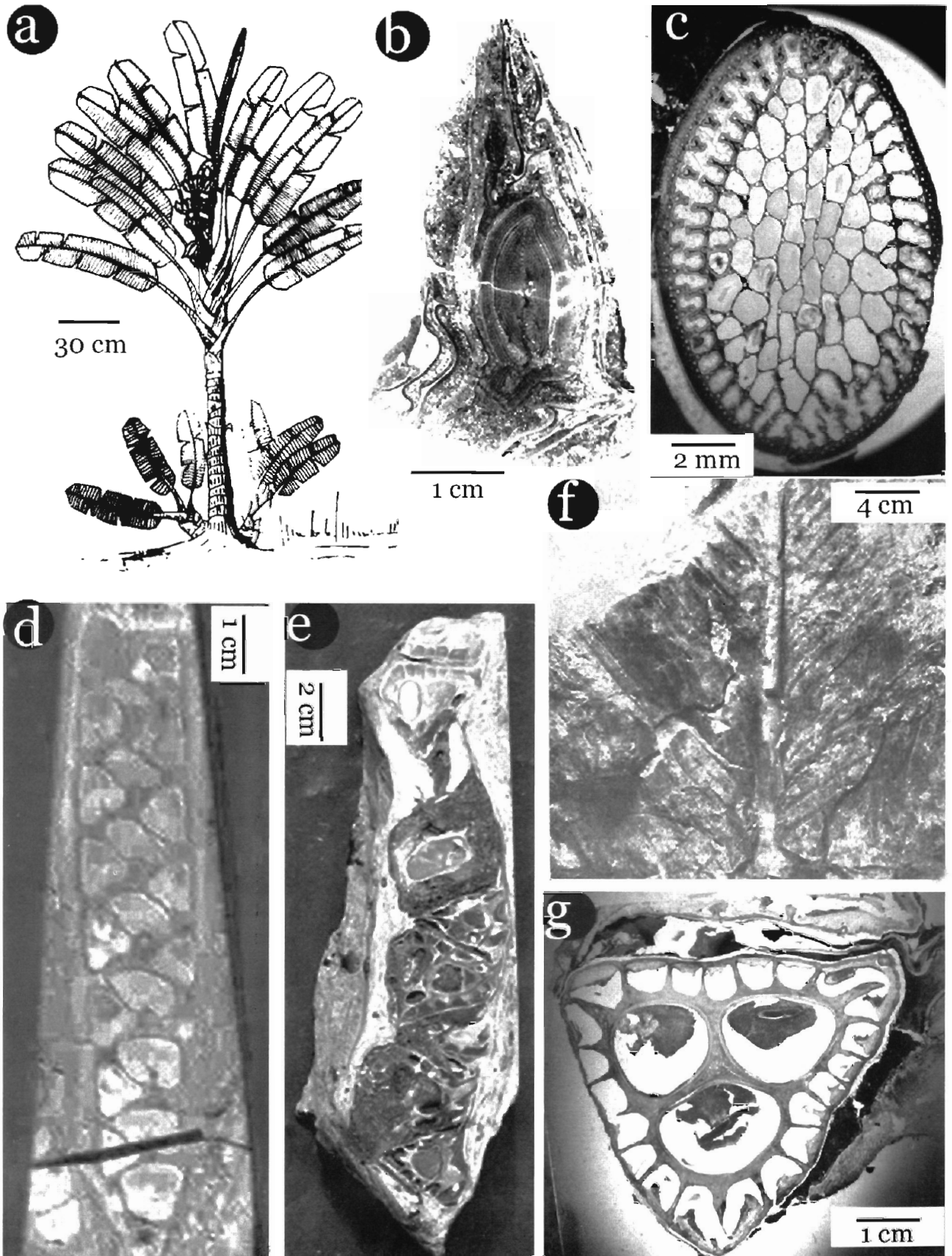


PLATE 1

- P. shahpuraensis* Ambwani (1983). Comparable to *Licuala* Wurmb. Ghughua, District Mandla, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- P. siltherensis* Ambwani (1984). Silther, District Mandla, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- P. splendidum* Trivedi & Chandra (1971). Keria, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- P. (Cocos) sundaram* Sahni (1946); Bonde *et al.* (2004). Sagar, Madhya Pradesh; Mahabale & Rao (1973), Kateru, District Rajahmundry, Andhra Pradesh.
- P. sundaram* var. *vidarbhai* Rao & Menon (1964). Comparable to *Cocos nucifera* L. Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- P. superbum* Trivedi & Verma (1971a). Keria, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- P. surangei* Laxanpal (1955). Keria, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- P. takliense* Kapgate (1995). Comparable to *Kentia* Blume (?). Takli near Nagpur, Maharashtra. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- P. taroides* Ambwani & Mehrotra (1989). Comparable to *Corypha* L. (?). Ghughua, District Mandla, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- P. trabeculosum* Sahni (1964). Saugor (?Sagar), Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- P. umariense* Rode (1935). Mohgaonkalan, District Chhindwara, Madhya Pradesh. *Nomen nudum*.
- P. vaginatum* Guleria & Mehrotra (1999). Binori Reserve Forest, District Seoni, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- P. wadii* Sahni (1931, 1964). Taranagri near Jammu, Upper Siwalik (Pliocene); Prasad (1987). Kalagarh, District Pauri Garhwal, Uttar Pradesh. Lower Siwalik (Miocene).
- Palmoxylon* sp. cf. *Phoenix* (Mahabale, 1959). Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous.
- Palmoxylon* sp. (Sahni, 1964). Locality - Unknown. Age - Miocene / Pliocene.
- Palmoxylon* sp. (Kar *et al.*, 1998). Locality - Amajiri, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- Dichotomously branched palm stem comparable to *Hyphaene* Gaertn. (Bonde *et al.*, 2008). Silther, District Dindori, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous.

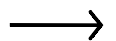
Roots

- Borassoid* root (Ambwani, 1981a). Nawargaon, District, Wardha, Maharashtra. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- Nypa* root (Verma, 1974). Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- Rhizopalmoxylon borassoides* Awasthi *et al.* (1996). Affinity with *Borassus* L. Nawargaon, District Wardha, Maharashtra. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- R. singulare* Bonde *et al.* (In press). Coralloid aerial roots comparable to *Phoenix sylvestris* (L.) Roxb. and *Hyphaene dichotoma* (White) Furtado. Nawargaon District Wardha, Maharashtra. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- R. sundaram* Mahabale (1966), Mahabale & Rao (1973). Kateru, District East Godavari, Andhra Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).

Petioles

- Parapalmocaulon costapalmatum* (= *Palmocaulon costapalmatum* Kulkarni & Patil, 1977) Bonde (1987). Comparable to costapalmate palms. Nawargaon, District Wardha, Maharashtra. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- P. hyphaeneoides* (= *Palmocaulon hyphaeneoides* Shete & Kulkarni, 1980) Bonde (1987). Comparable to *Hyphaene* Gaertn. Nawargaon-Maragsur, District Wardha, Maharashtra. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- P. surangei* Bonde (1987). Umariya, District Mandla, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian). [Trivedi & Verma (1981) considers *Palmocaulon raoi* Menon (1964) and *Palmocaulon*

PLATE 2



- | | |
|---|---|
| <p>a. Cross section of <i>Rhodopathodendron tomlinsonii</i>.</p> <p>b. Liliaceous corm—<i>Eriopermocormus indicus</i> showing nodes, internodes and root scars.</p> <p>c. Cross section of (2) showing cortical and vascular regions.</p> <p>d. Reconstruction of infructescence—<i>Viracarpon hexaspermum</i> showing crowded fruits on unbranched axis.</p> | <p>e. Cross section of the gramineous stem <i>Culmites eleusineoides</i> — through internode.</p> <p>f. Gramineous grains—<i>Graminiocarpon mohgaense</i>.</p> <p>g. <i>Pandanus eocenicus</i>—leaf showing spines on both margins.</p> <p>h. Reconstruction of inflorescence—<i>Monocotylostrobis bracteatus</i>.</p> <p>i. Vertical section of flower—<i>Deccananthus savitrii</i>.</p> |
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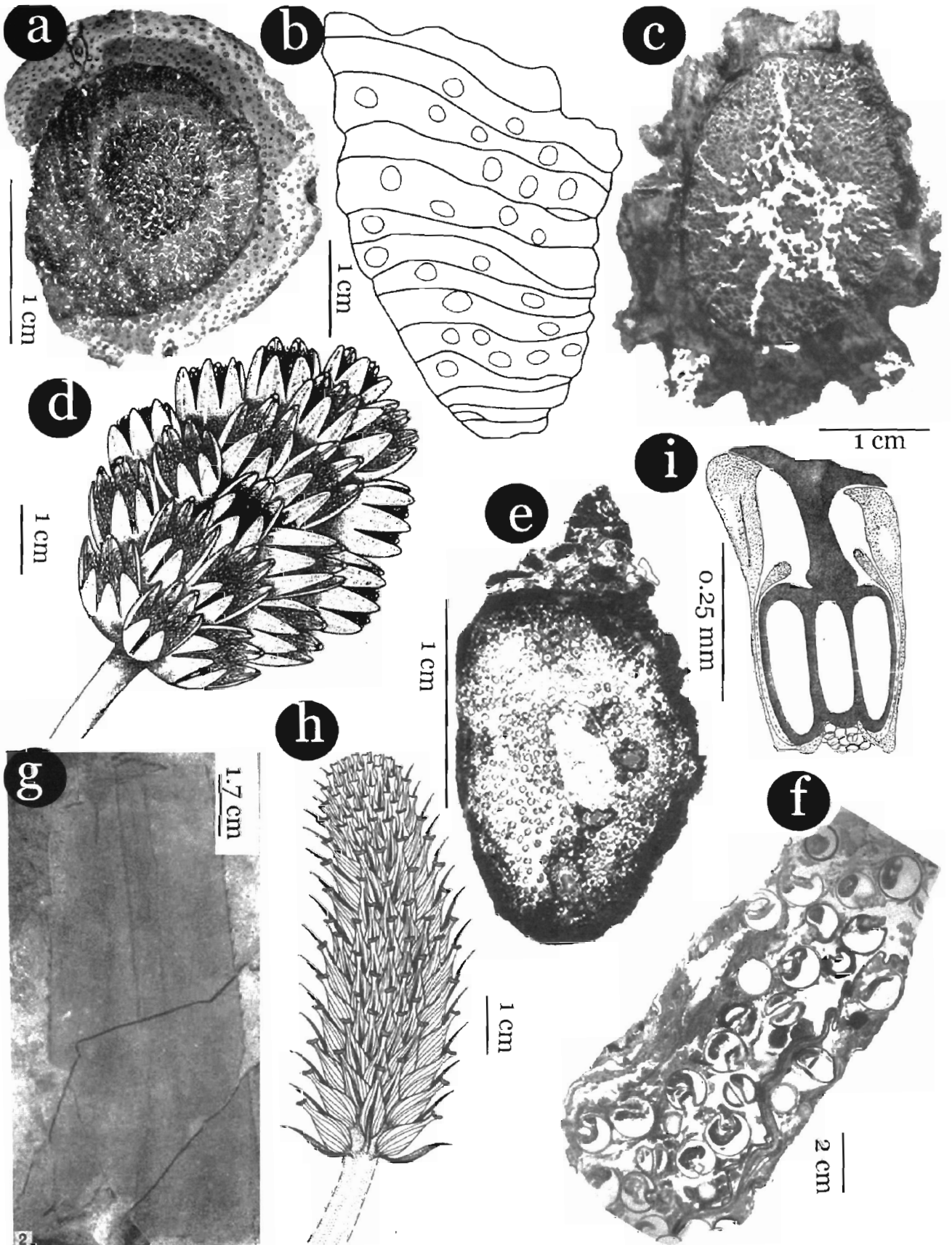


PLATE 2

mahabalei Menon (1965) as parts of *Cyclanthodendron sahnii* and not palm petioles].

Phoenicicaulon mahabalei Bonde *et al.* (2000). Leaf base comparable to *Phoenix* L. Umaria, District Mandla, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).

Sabalocaulon intertrappeum Trivedi & Verma (1981). Comparable to *Sabal* Adans.(?). Mohgaonkalan, District Chhindwara, (Maastrichtian). Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).

Leaf Impressions

Amesoneuron borassoides Bonde (1986b). Comparable to *Borassus* L. Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).

A. deccanensis Guleria & Mehrotra (1999). Fragmentary pinnate leaf.

(= *A. deccanensis* Mehrotra, 2000a).

(= *A. lakhanpalii* Mehrotra, 2000a).

Binori Reserve Forest, District Seoni; Ghughua, District Mandla, Madhya Pradesh. Upper Cretaceous (Maastrichtian); Tura Formation; Nangwalbibra near William Nagar, District East Garo Hills, Meghalaya. Palaeocene.

A. manipurensis Guleria *et al.* (2005). Upper Disang; Bijang, Imphal Valley, Manipur. Late Eocene.

A. sahnii Guleria *et al.* (2000). Kasauli Hills, District Solan, Himachal Pradesh. Kasauli Formation, Lower Miocene.

A. siwalica Prasad (2006) Fragmentary plicate leaf. Ranital near Jawalamukhi, Himachal Pradesh. Siwalik Formation. Middle Miocene.

Borassoid palm leaf (Trivedi & Chandra, 1971a). Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).

Cocos nucifera L. (Mahabale & Rao, 1968). Leaflets. Bommuru, Andhra Pradesh. Late Tertiary.

Livistona wadiai Lakhanpal *et al.* (1983). North East of Hemis Gumpa, Ladakh, Jammu & Kashmir. Hemis Conglomerate. Late Eocene-Oligocene.

Malpophyllum dakshinense (= *Palmophyllum dakshinense* Achuthan, 1968) Kumaran (1994). Mohgaonkalan,

District Chhindwara, Madhya Pradesh. Deccan Intertrappean beds. Upper Cretaceous (Maastrichtian).

M. mohgaonense (Mahabale, 1966) Kumaran (1994). Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappean beds. Upper Cretaceous (Maastrichtian).

Malpophyllum sp. (Chaudhari, 1969) comb. nov. Banog Grahath, Himachal Pradesh, Kasauli Series. Lower Miocene.

Nypa fruticans Wurb. (Kulkarni & Phadtare, 1980). Leaf epidermis. Dharmashala, District Ratnagiri, Maharashtra. Miocene.

Nypafruticans Wurb. (Mehrotra *et al.*, 2003). Leaf fragment. Makum Coalfield, Assam. Tikak Parbat Formation. Oligocene/ Lower Miocene.

Palmacites khariensis Lakhanpal & Guleria (1982). Palmate leaf fragment. Kharinadi bed, Goyela, District Kachchh, Gujarat. Khari Series. Lower Miocene.

Palmacites sp. (Mehrotra & Mandaokar, 2000). Leaf fragment. Manmow, Tirap District, Arunachal Pradesh. Oligocene.

Palmophyllum mohgaonense Mahabale (1966). Basal part of leaf with spines comparable to *Phoenix* L. Mohgaonkalan, District Chhindwara, Madhya Pradesh. Upper Cretaceous (Maastrichtian).

Phoenicites indica Guleria *et al.* (2005). Pinnate leaf fragment. Upper Disang, Bijang, Imphal Valley, Manipur. Late Eocene.

P. lakhanpalii Guleria & Mehrotra (1999). Pinnate leaf fragment. Binori Reserve Forest, District Seoni, Madhya Pradesh. Upper Cretaceous (Maastrichtian).

P. siwalikensis (= *Ramanujamipalmaephyllum siwalikensis* Banerjee *et al.*, 2005) comb. nov. Pinnate leaf. It could be a leaf of *Phoenicites* Brongniart (1828) as per the revision made by Read & Hickey (1972). Darjeeling Foothills, Geabdat Formation, Middle Siwalik, Miocene.

Sabalites sp. (Bose & Sah, 1964). Leaf fragment comparable to *Sabal* Adans. (?). Laitryngew, Jaintia Hills, Assam. Lower-Middle Eocene.

Sabalites sp. (Mathur *et al.*, 1996). Leaf fragment. Timber Trail Resort, Kalka-Shimla Highway, District Solan, Himachal Pradesh. Kasauli Formation. Lower Miocene.

Sabalophyllum livistonoides Bonde (1986a). Permineralized leaf segment (rib & lamina) comparable to *Livistona chinensis* R.Br. Nawargaon, District Wardha,

PLATE 3



- a. Reconstruction of vegetative axis of *Palmoxylon (Cocos) sundaram* with rooting base.
- b. *Mahabalea phytelephantoides* – a juvenile palm axis with rooting region, condensed stem and a crown.
- c. Cross section of (2) through crown region showing trimerous arrangement of young leaves.
- d. *Appamahabalea uhlii* – entire soboliferous matured acaulescent palm with rooting region- stem proper and apex.
- e. Cross section of (4) through crown region showing stem apex

- f. ensheathed with young leaves, leaf bases and a peduncle.
- f. Cross section of stem of (4) showing fibrovascular bundles.
- g. Cross section of a palm petiole - *Parapalmocaulon surangei*.
- h. Cross section of *Phoenicicaulon mahabalei* - sheathing leaf base.
- i. a palm rachilla - *Arecoideostrobis moorei* with flowers in the pits.
- j. Cross section of (9) showing vascular anatomy of rachilla and a floral pit.

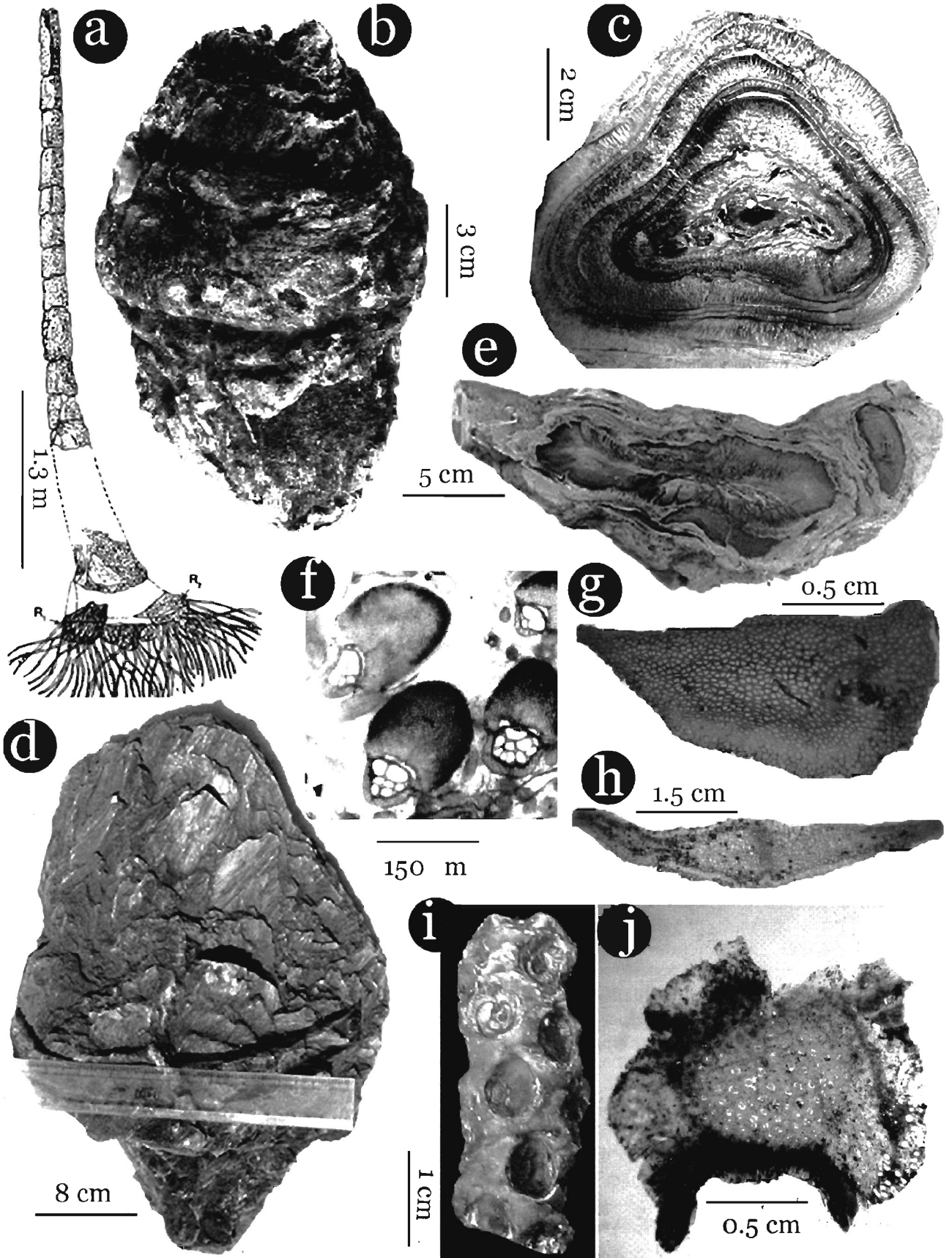


PLATE 3

- Maharashtra. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- Trachycarpus ladakhensis* Lakhanpal *et al.* (1984). Comparable to *Trachycarpus* H. Wendl. Puga, Ladakh, Jammu & Kashmir. Liyan Formation. Miocene.
- Zalaccites jaintiensis* Barman & Daura (1970). Unsegmented pinnate leaf comparable to *Salacca* (= *Zalacca* Rumph. ex Blume) Reinw. (?). Cherra Sandstone at Tkhiah, District United Khasi and Jaintia Hills, Assam. Palaeocene.
- Compressed bark / Leaf sheath / Shoot with crown of leaves – Fragmentary remains (Chatterjee & Bhattacharya, 1965). Neyveli, District South Arcot, Tamil Nadu. Miocene
- Inflorescence axis & flowers**
- Arecoideostrobus moorei* Bonde (1996). Rachilla with flowers comparable to Arecoid palms. Nawargaon, District Wardha, Maharashtra. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- Deccananthus savitrii* Chitale & Kate (1974). Flower. Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- Palmostroboxylon arengoidum* Ambwani (1984a). Inflorescence axis resembling *Arenga* Labill. ex DC. Ghughua, District Mandla, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- Palmostroboxylon indicum* Biradar & Bonde (1979). Inflorescence axis comparable to *Phoenix* L. Dongargaon, District Chandrapur, Maharashtra. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- P. sahnii* Bonde (1995). Inflorescence axis. Mohgaon-Palasundar, District Mandla, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- P. umariense* Bonde (1990). Inflorescence axis. Umaria, District Mandla, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- Fruits**
- Areca intertrappea* Senad & Paradkar (1989). Affinity with *Areca* L. (?). Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- Arecoideocarpon kulkarnii* Bonde (1990a). Affinity with Arecoid palms. Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- A. palasundarensis* Bonde (1995). Mohgaon-Palasundar, District Mandla, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- A. prismaticum* Agarwal *et al.* (2007). Arecoid palms. Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- Carpolithus striatus* Jain & Dayal (1966). Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- Cocos intertrappeansis* Patil & Upadhye (1984). Comparable to *Cocos* L. (?). Its resemblance with *Cocos* L. is doubtful as the characteristic ‘three pores’ have not been observed. Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- C. pantii* Mishra (Mishra, 2003; Tripathi *et al.*, 1999). Its resemblance with *Cocos nucifera* L. is doubtful as the characteristic ‘three pores’ have not been observed (?). Amarkantak, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- C. plumosa*, *C. coronata* (Mahabale & Rao, 1968). Fruit impression. Bommuru near Rajahmundry, Andhra Pradesh. Oligocene-Miocene.
- C. sahnii* Kaul (1951). Comparable to *Cocos* L. Kapurdi, Jodhpur, Rajasthan. Early Tertiary - Eocene.
- Eugeissonocarpon indicum* Shinde & Kulkarni (1989). Resemblance with *Eugeissona* Griff. Pawas, District Ratnagiri, Maharashtra. Ratnagiri Lignite. Miocene.
- Hyphaenocarpon indicum* Bande *et al.* (1982). Resemblance with *Hyphaene* Gaertn. Ghughua near Shahpura, District Mandla, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- Nypa* aff. *fruticans* Wurbm (*Nypa burtini* [Brongniart] Ettingshausen) (Emended – Tralau, 1964; Chitale & Nambudiri, 1995). (= *Nipadites compressus* Rode, 1933; Sahni, 1937). Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian). (= *Nipadites hindi* Rode, 1933; Sahni, 1937). Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian). (= *Nypa sahnii* Lakhanpal, 1952). Kalaichar, Garo Hills, Assam. Miocene.

PLATE 4



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|--|--|
| <p>a. <i>Trachycarpus ladakhensis</i> – lamina of a palmate palm leaf.</p> <p>b. <i>Amesoneuron borassoides</i> – a borassoid palm leaf with parallel veins and rectangular areoles.</p> <p>c. Endocarp impression of a fruit – <i>Cocos sahnii</i>.</p> <p>d. Cast of the fruit <i>Nypa</i> aff. <i>fruticans</i> (<i>N. sahnii</i>).</p> | <p>e. <i>Hyphaenocarpon indicum</i> cross section showing fruit wall and single seed.</p> <p>f. Longitudinal section of fruit <i>Arecoideocarpon palasundarensis</i> showing fruit and seed with incipient rumination.</p> <p>g. Longitudinal section of flower <i>Deccananthus savitrii</i> showing perianth, anthers and carpel.</p> |
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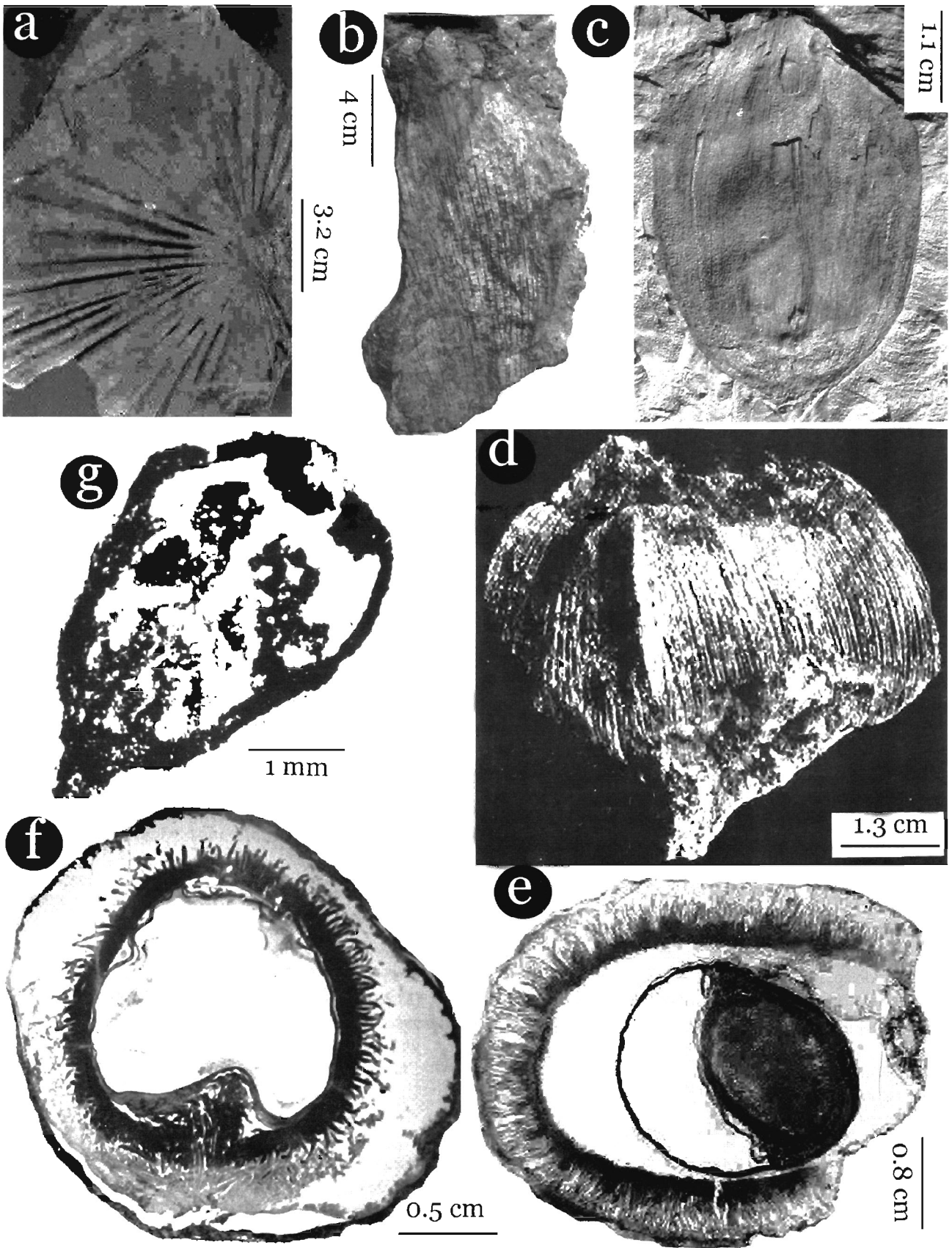


PLATE 4

(=*Nipadites* sp. Bhattacharya, 1967). Cherrapunji and Laitryngew in Khasi and Jaintia Hills, Assam. Lower-Middle Eocene.

Nypa fruticans Wurm. (Mehrotra *et al.*, 2003). Tikak Parbat and Upper Bhuban formations; Makum and Dilli-Jeypore coalfields, Assam and Stone Quarry near Kolasib, Mizoram. Oligocene,-Lower Miocene.

Palmocarpon arecoides Mehrotra (1987). Comparable to *Areca* L. Its affinities with *Areca* L. or even with arecoid palms is doubtful (Bonde *et al.*, 1990a). Samnapur near Nainpur, District Mandla, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).

P. cocoides Mehrotra (1987). Comparable to *Cocos* L. (?). Its resemblance with *Cocos* or even with Cocosoid palms is doubtful as the characteristic 'three pores' have not been observed (Bonde, 1990a). Ghughua near Shahpura, District Mandla, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).

P. compressum (Rode, 1933) Sahni (1937). Mohgaonkalan, District Chhindwara. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).

P. coryphoidium Shete & Kulkarni (1985). Comparable to Coryphoid palms. Nawargaon, District Wardha, Maharashtra. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).

P. indicum Prakash (1960). Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).

P. insigne Mahabale (1950). Comparable to *Cocos* - like palms. Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).

P. mohgaense Prakash (1955). Mohgaonkalan, District Chhindwara. Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).

P. splendidum Trivedi & Chandra (1973). Mohgaonkalan, District Chhindwara. Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).

P. sulcatum Prakash (1960). Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).

Palmocarpon sp. Mehrotra (1987). Ghughua near Shahpura, District Mandla, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).

Entire palm plant axis

Appamahabalea uhlii Bonde (In press). Soboliferous acaulescent palm axis with roots, stem, petioles, leaves and inflorescence axes. Affinity with *Phonex* L. Umaria, District Mandla, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).

Mahabalea phytelephantoides Bonde (In press). Juvenile baby palm axis with roots, condensed stem, apex, petioles and leaves. Affinity with Phytelephantoid palms. Umaria, District Mandla, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).

Cannaceae

Cannaites intertrappea Trivedi & Verma (1971b). Pseudostem comparable to *Canna* L. Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).

Cyclanthaceae (?)

Cyclanthodendron sahnii Sahni & Surange (Rode, 1933, 1933a; Sahni, 1937; Shukla, 1950; Sahni & Surange, 1953; Chitaley, 1956; Ramanujam, 1959; Rao & Menon, 1963; Jain, 1964a; Trivedi & Verma, 1972a, b, 1978; Paradkar & Chitaley, 1978; Bonde, 1985; Verma & Upadhyay, 1989). Trivedi & Verma (1981) considers *Palmocaulon raoi* Menon (1964) & *Palmocaulon mahabalei* Menon (1965) as parts of *Cyclanthodendron* stem. Biradar & Bonde (1990) revised the taxon based upon the organic occurrences of stem (*Cyclanthodendron sahnii* Sahni & Surange) with pseudostem (*Musocaulon indicum* Jain, 1964a) and petiole (*Heliconiaites mohgaensis* Trivedi & Verma, 1972a, b) and inflorescence axis with fruits (*Tricoccites trigonum* Rode, 1933). They had suggested, *Cyclanthodendron sahnii* as a woody plant having underground soboliferous rhizomatous stem with aerial continuation having pseudostem *Musocaulon indicum*, petiole *Heliconiaites mohgaensis* and inflorescence axis bearing *Tricoccites trigonum* fruits showing its *Protoscitaminean* affinity (combination of characters of Strelitziaceae, Heliconiaceae & Musaceae). Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).

Cyperaceae

Cyperaceocarpon sahnii Dutta & Ambwani (2005a). Fruit - Achene. Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).

Cyperaceoxylon intertrappeum Chitaley & Patel (1970). Stem with leafsheaths and roots. Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).

Scirpus lacustris L. (Carter, 1852). Impressions. Worli & Malabar Hills, Bombay, Maharashtra. Upper Cretaceous.

Scirpusoxylon indicum Shete (1989). Rhizome comparable to *Scirpus* L. Nawargaon, District Wardha, Maharashtra. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).

Heliconiaceae

Heliconiaites mohgaoensis Trivedi & Verma (1972a, b). Petiole comparable to *Heliconia* L. Biradar & Bonde (1990) transferred to *Cyclanthodendron sahnii* Sahnii & Surange. Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).

Liliaceae

Eriospermocormus indicus Bonde (2005). Corm comparable to *Eriospermum abyssinicum* Beker. Nawargaon, District Wardha, Maharashtra. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).

Liliaceopushpam deccanii Narkhede & Patil (2006). Flower not assigned to any extant taxon. Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).

Liliaceous inflorescence Bonde & Kumaran (1993). Inflorescence, Flowers with *Matanomadhiasulcites* pollen grains. Bonde & Kumaran (1994) rejected the objection taken by Awasthi & Mehrotra (1994) for its affinity with Liliaceae. Umaria, District Mandla, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).

Marantaceae

Donax kasauliensis Srivastava & Guleria (2004). Leaf impression. Near MES water works, Kasauli, District Solan, Himachal Pradesh. Kasauli Formation. Lower Miocene.

D. lishensis (= *Clinogyne lishensis* Antal & Prasad, 1995) Srivastava & Guleria (2004). Leaf comparable to *Donax dichotoma* (= *Clinogyne dichotoma* Salisb). Lish river near Bagrakot, District Darjeeling, West Bengal. Middle Siwalik. Middle Pliocene.

D. ovatus (= *Clinogyne ovatus* Awasthi & Prasad, 1990). Srivastava & Guleria (2004). Leaf impression. Near MES water works, Kasauli, District Solan, Himachal Pradesh. Kasauli Formation. Lower Miocene.

D. ovatus (Awasthi & Prasad, 1990; Arya & Awasthi, 1995) Srivastava & Guleria (2004). Shiv Shakti Temple, Kasauli, District Solan, Himachal Pradesh. Kasauli Formation. Lower Miocene.

Musaceae

Musa cardiospermum (= *M. cardiosperma*) Jain (1964). (= *Callistemonites indicus* Bande *et al.*, 1986); Bande *et al.* (1993). Fruit comparable to *Musa* L. (?). Manchester & Kress (1993) excluded from Musaceae but retained in Zingiberales (Scitamineae). Mohgaonkalan, District Chhindwara, Madhya Pradesh; Ghughua, District Mandla, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).

Musocaulon indicum Jain (1964a). Pseudostem comparable to *Musa* L. Biradar & Bonde (1990) transferred to *Cyclanthodendron sahnii* Sahnii & Surange. Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).

Musophyllum indicum Prakash *et al.* (1979). Leaf impression comparable to *Musa* L. Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).

Musostrobocaulon skutchii Bonde (In press). Inflorescence axis comparable to *Musa* L. Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).

Pandanaceae

Pandanaceoxylon kulkarnii Patil & Datar (2002). Rhizome with roots comparable to *Pandanus* L. Nawargaon, District Wardha, Maharashtra. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).

Pandanus eocenicus Guleria & Lakhanpal (1984). Leaf impression. Panandhro, District Kutch, Gujarat. Lower Eocene.

Pandanusocarpon umariense Bonde (1990). Fruit comparable to *Pandanus* L. Umaria, District Mandla, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).

Poaceae (Gramineae)

Bamboo sp. (Lakhanpal *et al.*, 1986). Leaf & culm impressions. Ranital, District Kangra, Himachal Pradesh. Lower Siwalik. Miocene.

Bambusa siwalika Awasthi & Prasad (Prasad, 1994). Leaf impression comparable to *Bambusa tulda* Roxb. Kathgodam, Himalayan foot hills, Uttar Pradesh. Siwalik Formation. Middle Miocene.

Bambusa sp. (Antal & Awasthi, 1993). Leaf & culm impressions. Ghish & Ramthi rivers near Oodlabari, District Darjeeling, West Bengal. Lower/Middle Siwalik. Miocene-Pliocene.

Bambusa sp. (Guleria *et al.*, 2005). Bark. Upper Disang, Keirambi, Imphal Valley, District Imphal, Manipur. Late Eocene.

Culmites cutchensis Sahnii (1964). Locality & Age -Unknown (may be from North of Kaira Fort, Kutch, Gujarat).

C. deccanensis Paradkar (1975). Stem axis with leafsheaths infected with fungus - *Chlamydosporites gramineum* Paradkar. Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).

C. eleusineoides Bonde (1986). Culm with a swollen node & bud comparable to *Eleusine* Gaertn. Nawargaon, District

- Wardha, Maharashtra. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- C. mohgaense* Sheikh & Kolhe (1998). Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- Elymus deccanensis* Patil & Singh (1984). Pseudostem comparable to *Elymus interruptus* Buckl. Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- Festucophyllites intertrappeaense* Patil & Singh (1984). Pseudostem comparable to *Festuca* L. Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- Glycerioxylon mohgaonense* Trivedi & Bajpai (1982). Stem comparable to *Glyceria* R.Br. Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- Graminocarpon mohgaense* Chitaley & Sheikh (1971). Fruit-caryopsis comparable to *Triticum vulgare* Vill., infected with fungus *Helminthosporites mohgaense* Chitaley & Sheikh. Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- G. stellatus* Dutta & Ambwani (2005). Fruit - caryopsis. Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- Gramineous leaf (Navale, 1973, 1974). Neyveli, District South Arcot, Tamil Nadu, Cauvery Basin. Miocene.
- Hygrorhizos deccanii* Trivedi *et al.* (1985). Root comparable to *Hygroryza* Nees. Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- Poacites kasauliensis* Srivastava & Guleria (2004). Kasauli, District Solan, Himachal Pradesh. Lower Miocene.
- P. rajaoriensis* Sahni (1964); Mathur (1978). Rajaori, Poonch, Jammu & Kashmir, Murree Series. Miocene.
- P. sivalicus* Sahni (1964). Garala-Gorah road, Sudnatti, Poonch, Jammu & Kashmir. Lower Siwalik. Miocene.
- Poacites* sp. A, sp. B, sp. C. (Mathur *et al.*, 1996). Leaf impressions. Near Kumarhatti, Kalka-Shimla Highway, District Solan, Himachal Pradesh. Dagshai Formation. Oligocene.
- Phytolith morphotypes (*Matleyites indicum*, *Vonhueneites papillosum*, *Pipernoia pearsalla*, *Chitaleya deccana*, *Thomassonites sinuatum*, *Eliasundo lameti*, *Jainium pisdurensis*, *Stebbinsana intertrappea*) Prasad *et al.* (2005) - recovered from Dinosaur coprolites. Pisdura, District Chandrapur, Maharashtra. Late Cretaceous.

Smilacaceae

- Smilacites mohgaensis* Nambudiri (1966a). Leaf impression comparable to *Smilax* L. (?). Mohgaonkalan, District

- Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- Smilax* sp. (Lakhanpal & Dayal, 1966). Leaf. Jawalamukhi, Punjab. Lower Siwalik. Miocene.

Sparganiaceae

- Sparganium* Mahabale (1953). Leaf, stem, roots, inflorescence & fruits comparable to *Sparganium* L.(?). *Sparganium* L. is a temperate taxon. Its occurrence in the Deccan Intertrappeans is doubtful. Mohgaonkalan, District Chhindwara & Rama Kona, District Sausar, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).

Typhaceae

- Aerophyllites intertrappea* Chitaley & Patil (1970). Leaf comparable to *Typha angustata* Bory & Chaub. (?). Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).

Xyridaceae

- Axis of Xyridaceae (Patil, 1979). Comparable to *Achlyphila* Maguire & Wurdack (?). Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).

Zingiberaceae

- Amomocarpum affine* Sahni (1964). Fruit comparable with *Amomum* L. Locality and Horizon unknown. Probably Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).

Fossils with uncertain affinities

- Monocotylostrobos bracteatus* Lakhanpal *et al.* (1975, 1982); Bande (1993). Inflorescence comparable to Palmae and Liliaceae. Bonde (1996) suggested its affinity with Arecaceae than Liliaceae. Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- Sahnipushpam shuklae* (= *Sahnipushpam glandulosum* Prakash, 1956) Verma (1956); Prakash & Jain (1963); Chitaley (1964). Flower comparable with Araceae, Arecaceae, Cyclanthaceae, Myrtaceae, Sonneratiaceae. Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).
- Triloculocarpon mahabalei* Kapgate (1990). Triangular, trilocular capsule. Affinity with Amaryllidaceae, Liliaceae & Commelinaceae (?). Mohgaonkalan, District Chhindwara, Madhya Pradesh. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).

Velamenorhizos intertrappeanum Barlinge & Paradkar (1978). Monocotyledonous roots with velamen tissue. It could be a root of Orchidaceae, Araceae, Arecaceae. Mohgaonkalan, District Chhindwara, M.P. Deccan Intertrappeans. Upper Cretaceous (Maastrichtian).

DISCUSSION

Fossil monocotyledons have been recorded as impressions, compressions and permineralizations of different plant parts. Resolution of these elements to their extant counterparts requires well acquaintance with the morpho-anatomical variations in the extant flora. Fortunately, quite a substantial amount of data is now available. Information on Red Data plants is of great help in this connection (Nayar & Sastry, 1987, 1988, 1990). Anatomical analysis of monocotyledons by Cheadle (1942), Cheadle & Uhl (1948, 1948a), French & Tomlinson (1984), Metcalfe (1963), Tomlinson (1970, 1973, 1984), Tomlinson & Zimmermann (1967, 1969), Zimmermann & Tomlinson (1972) is of primary help in the resolution of the permineralized material to a particular order or family. Moreover, some of the major families / orders like Agavaceae (Tomlinson & Zimmermann, 1969a; Zimmermann & Tomlinson, 1970), Araceae (Nicolson, 1960; French & Tomlinson, 1980, 1981, 1981a, b, c, 1983, 1984; Keating, 2003); Arecaceae / Palmae (Cormack, 1896; Drabble, 1904; Schute, 1912; Mahabale & Udawadia, 1960; Tomlinson, 1961, 1990; Corner, 1966; Seubert, 1996, 1996a, 1997, 1998, 1998a; Tomlinson & Zimmermann, 1966); Commelinales – Zingiberales (Tomlinson, 1969); Cyclanthaceae (Surange, 1950; French *et al.*, 1983; Tomlinson & Wilder, 1984); Cyperaceae (D' Almeida & Ramaswamy, 1948; Metcalfe, 1971); Dioscoreales (Ayensu, 1972); Helobiales (Tomlinson, 1982), Hydrocharitaceae (Ancibor, 1979); Juncales (Cutler, 1969); Pandanaceae (Zimmermann *et al.*, 1974); Poaceae/Gramineae (Metcalfe, 1960); Velloziaceae (Ayensu, 1973, 1974); Xanthorrhoeaceae (Fahn, 1954) have been thoroughly investigated. Morpho-anatomical resolution of the fossils will remain incomplete without taking into account of the above work.

Archaeofructus liaoningensis Sun *et al.* (1998) and *A. sinensis* Sun *et al.* (2002) are the earliest record of herbaceous aquatic basal angiosperms (Family – Archaeofructaceae) belonging to lower part of the Upper Jurassic/ Lower Cretaceous Yixian Formation of China, about 124.6 million years old. The other well known plants are *Prisca reynoldsii* Retallack & Dilcher (1981), *Lesqueria elocata* Crane & Dilcher (1984), *Archaeanthus linnenbergeri* Dilcher & Crane (1984), *Joffrea speirsii* Crane & Stocky (1985), *Caloda delevoryana* Dilcher & Kovach (1986) and others. All these reconstructions belong to the dicotyledons. However, monocotyledonous reconstructions are very few. *Sanmiguelia lewisii* Brown (1956) is a well known pre-Cretaceous record of a monocotyledon established for a simple large pleated leaf resembling with that

of a palm. However, it lacks a definite midrib and cross veins (Read & Hickey, 1972; Doyle, 1973). Read & Hickey (1972) considers it to be a Cycadophyte. Tidwell *et al.* (1977) reconstructed a 60 cm tall plant of *Sanmiguelia lewisii* having helically arranged broad elliptical leaves with acute apex, clasping base and plicate lamina with four orders of parallel veins, on a conical woody stem, *Synangispadixis* a staminate organ, *Axelrodia* a pistillate organ and suggested its affinity with *Veratrum* of Liliaceae. Cornet (1986, 1989) referred it as a primitive angiosperm that shares features of monocotyledons and dicotyledons. Martin *et al.* (1993), however, think *Sanmiguelia* as an angiosperm ancestor.

Palmoxylon (Cocos) sundaram (Sahni, 1946; Bonde *et al.*, 2004) is a reconstructed 4.5 meter tall palm stem axis with rooting base comparable to *Cocos nucifera* L. Biradar & Bonde (1990) reconstructed the plant of *Cyclanthodendron sahnii* Sahni & Surange and suggested its affinity with Scitamineae (Zingiberales) combining the characters of Musaceae, Heliconiaceae and Strelitziaceae instead of Cyclanthaceae or Palmae. *Mahabalea phytelephantoides* Bonde (In press) is a 15 cm tall permineralized juvenile palm axis with adventitious roots, short obconical stem crowned with a rosette of leaves in trimerous phyllotaxy suggesting its affinity with *Phytelephas* restricted now to Northern South America and *Appamahabalea uhli* Bonde (In press) is a 46 cm tall matured soboliferous acaulescent palm comparable to *Phoenix* L.

Palms which dominate the woody monocotyledonous flora in fossils are represented by number of organ genera for stem, root, leaf, inflorescence axis, rachilla, flower, fruit, seed and pollen grains. Permineralized woody monocotyledonous stems are generally assigned to the organ genus *Palmoxylon* Schenk (1882) established for woods presumably belonging to the palms. There are about 200 species throughout the world including 74 species from India. Large number of species of *Palmoxylon* may be parts belonging to outer or inner, basal or apical region of the stem or some times parts of leaf or inflorescence axis established on the basis of anatomical characters such as form and distribution of fibrovascular bundles, type of sclerenchyma, number of metaxylem vessels, size and shape of phloem, presence of fibre bundles, nature of ground tissue, structure of vessel endplate, etc. (Stenzel, 1904; Sahni, 1943, 1964; Mahabale, 1958). These characters are highly variable even within the genus and species of Arecaceae. Until one is familiar with and takes into account the variability of these characters in different parts of the same species and in different species in the genus and tests it statistically, the applicability of these characters in the resolution of *Palmoxylon* to natural genera has a limited scope.

Sahni (1943) in an attempt to resolve the organ genus *Palmoxylon* to natural genera formulated a combined system of classification for palms by Mohl (1845) and Stenzel (1904) based upon external morphology and shape of sclerenchyma as seen in cross section. Knowledge of morpho-taxonomy

and anatomy of these members is required for the resolution of the organ genera erected for different plant organs. Moreover, *Palmoxylon* might comprise many natural genera of Palmae as it is a very large family of woody plants comprising 212 genera and 2779 species distributed in 5 subfamilies (Uhl & Dransfield, 1987). Some of the species of *Palmoxylon* as well could be other monocotyledons belonging to the families Agavaceae, Araceae, Boryaceae, Cannaceae, Cyperaceae, Heliconiaceae, Musaceae, Pandanaceae, Poaceae, Velloziaceae, Zingiberaceae and others. A combined system suggested by Bonde *et al.* (In press) based upon terminologies used by Mahabale & Udawadia (1960) and Seubert (1997) will be feasible to resolve the artificial genus *Rhizopalmoxylon* Gothan. *R. borassoides* Awasthi *et al.* (1996) is a palm root comparable to extant palm genus *Borassus*. *R. singulare* Bonde *et al.* (In press) is a aerial mantle of coralloid roots comparable to *Hyphaene dichotoma* Furtado and *Phoenix sylvestris* L. *Sabalocaulon* Trivedi & Verma, *Parapalmocaulon* Bonde, *Phoenicicaulon* Bonde *et al.* are the petioles; *Palmostroboxylon* Biradar & Bonde is a inflorescence axis; *Arecoideostrobilus* Bonde is a rachilla; *Cocos sahnii* Kaul (1951) and *C. pantii* Mishra (2003); *Hyphaenocarpon* Bande *et al.* (1982) and *Nypa* aff. *fruticans* Wurm (=*Nypa burtini* [Brongniart] Ettingshausen; Emended by Tralau, 1964). (= *Nipadites compressus* Rode, 1933; Sahni, 1937; = *Nipadites hindi* Rode, 1933; Sahni, 1937; = *Nypa sahnii* Lakhanpal, 1952; = *Nipadites* sp. Bhattacharya, 1967) are the fruits comparable with those of *Cocos*, *Hyphaene* and *Nypa* respectively. *Eugeissonocarpon* Shinde & Kulkarni (1986), *Arecoideocarpon* Bonde (1990) are the fruits comparable to *Eugeissona* and *Areca* respectively. *Deccananthus savitrii* Chitaley & Kate (1974) is a flower showing its affinity with Palmae. Mahabale (1978) considers Indo-African region as one of the centre of the origin of *Cocos*. Occurrence of *Cocos*, *Hyphaene*, *Nypa* and other coastal/marine elements in the Deccan Intertrappean sediments suggest the transgression of sea arm in Central India (Sahni, 1946; Kaul, 1951, Bande *et al.*, 1981, 1982; Bande, 1992; Bonde & Kumaran, 2002; Bonde *et al.*, 2004, 2008; Chitaley & Nambudiri, 1995).

Cyclanthodendron sahnii (Sahni & Surange, 1953; Biradar & Bonde, 1990) is a rhizomatous soboliferous Scitamineous plant of medium height (2-3 m) having woody aerial continuation covered with overlapping leaves in two ranks with petiole *Heliconiaites intertrappea*, pseudostem *Musocaulon indicum* and fruits *Tricoccites trigonum*. *Musostrobocaulon skutchii* Bonde (In press) is a musaceous inflorescence axis with a sheath. *Musophyllum indicum* Prakash *et al.* (1979) is a Musaceous leaf whereas *Cannaites intertrappea* Trivedi & Verma (1971) is a pseudostem of *Canna*. *Musa cardiospermum* Jain (1963) is a triangular multiseeded syncarpous berry comparable to the seeded banana fruit. However, the fruit exhibits several differences from extant *Musa* such as lack of laticifers in the pericarp,

absence of perianth remnants at the fruit apex and a single row of seeds in each locule of the fruit. It requires further work for its affinities with *Musa* or other members of Scitamineae (Manchester & Kress, 1993).

Pandanus eocenicus (Guleria & Lakhanpal, 1984) a leaf, *Pandanocarpon umariense* (Bonde, 1990) a fruit and *Pandanaceoxylon kulkarnii* (Patil & Datar, 2002) is a rhizome of Pandanaceae. However, the rhizome, *Pandanaceoxylon kulkarnii* appears to be a rhizome of Scitamineae or Araceae. It needs reinvestigation in the light of the work done by Cheadle & Uhl (1948) and French & Tomlinson (1980, 1981, 1981a, b, c, 1983, 1984; Tomlinson, 1969).

Viracarpon Sahni is a pedunculate, spiny, aggregate fructification consisting a unbranched central axis bearing densely arranged, sessile, ebracteate, hexangular fruits with single seed in each locule, arranged in longitudinal rows; ovary inferior, outer wall of ovary extends upwards in six perianth lobes, forming a cup like structure, free apically and conate basally with a vertical ridge running the entire length of the middle of the inner surface of each lobe, margin of lobes thickened, inside of the lobes densely covered with long hairs. These combined characters are not known in any of the extant family. *Viracarpon* may represent an extinct family. Further work on vegetative parts associated with *Viracarpon* would help to come nearer to its relationship with the extant members.

Rhodospathodendron tomlinsonii Bonde (2000) is a viny aerial axis resembling *Rhodospatha* of Araceae. *Rhizocaulities palaeocenicus* Mehrotra (2003) is a rhizome comparable to *Aglaonema* Schott. However, it looks like a rhizome of Zingiberaceae.

Glycerioxylon mohgaoensis Trivedi & Bajpai (1982) is a gramineous culm comparable to *Glyceria*. *Festucophyllites intertrappeense* Patil & Singh (1984) and *Elymus deccanensis* Patil & Singh (1984) are the pseudostems comparable to hydrophytic member *Festuca ovina* L. and *Elymus* L. respectively. *Culmites eleusineoides* Bonde (1986) is a stem with thin culm, swollen node and dormant bud comparable to *Eleusine* Gaertn. *Graminocarpon mohgaoense* Chitaley & Sheikh (1971) and *G. stellatus* Dutta & Ambwani (2005) are the caryopsis type of grains. Poaceae is considered to be originated in the Upper Cretaceous Period based upon the occurrences of generalized modern appearing grasses (Wolfe, 1978), fossil pollen record (Linder, 1986) and phytoliths extracted from the coprolites of Titanosaur sauropods (Prasad *et al.*, 2005).

Cyperaceoxylon intertrappeum Chitaley & Patel (1970) is a Cyperaceous axis with stem, roots and leafsheaths. Whereas *Scirpusoxylon indicum* Shete (1989) is a rhizome comparable to *Scirpus* L. *Cyperaceocarpon sahnii* Dutta & Ambwani (2005a) is a achene type of fruit.

Eriospermocormus indicus Bonde (2005) is a liliaceous corm comparable to *Eriospermum* Jacq. The family Liliaceae is also represented by the inflorescence with inaperturate, monosulcate to trichotomosulcate pollen grains resembling

Matanomadhiasulcites (Bonde & Kumaran, 1993). *Monocotylostrobos bracteatus* (Lakhanpal et al., 1982; Bande, 1993) is a inflorescence showing its resemblance with Liliaceae and Palmae.

Neyvelia awasthii Reddy (1995) is a axis comparable to *Dracaena* Vand.ex L. of Agavaceae. A wood comparable to *Dracaena* has also been reported earlier from the same horizon (Ambwani, 1982, 1999).

Future directions

The earliest record of flowering plants from India, though meagre, has been made from the Rajmahal Intertrappean beds dated to belong to the Lower Cretaceous Period (Vishnu Mittre, 1956; Tripathi & Tiwari, 1991; Tiwari & Tripathi, 1995; Sharma, 1997; Banerji, 2000). These beds are very rich in Bennettitales and Pentoxylales. Angiosperms are considered as monophyletic along with the Bennettitales, Pentoxylales and Gnetales (Doyle & Donghue, 1987a, b, 1993). If we accept the view that primitive angiosperms were monocotyledons in their vascular organization then one can look for the monocotyledonous taxa in the Rajmahal intertrappeans and contemporary horizons belonging to the Lower Cretaceous periods. A thorough scanning of these beds may lead towards the discovery of early record of monocotyledons.

In order to understand the diversification of fossil monocotyledonous flora, utmost care is required to be taken at the initial stage during the field work to look for entire plants especially the herbaceous elements as majority of the extant monocotyledons are herbaceous in nature; woody juvenile or stemless plants having roots, stem, leaves, inflorescence, flowers, infructescence, fruits and seeds in organic connections. A special attention is required to be given towards the analysis of flowering, fruiting organs and their affinities with the extant flora as they exhibit more or less unchanged characters employed for phylogenetic and environmental interpretations.

In the field generally we get association of roots with stem, leaves, inflorescences, rachillae, fruits, seeds, shaded flowers and pollen grains. A thorough scanning in the field supplemented with the morpho-anatomical characteristics may lead towards the reconstructions of tall arborescent plants like *Ravenala madagascarensis*, *Borassus flabellifer*, *Hyphaene dichotoma*, *Corypha umbraculifera*, *Livistona jenkinsiana*, *Trachycarpus martiana*, *Phoenix sylvestris*, *Nypa fruticans*, *Cocos nucifera*, *Syagrus schizophylla*, *Areca catechu*, *Roystonea regia*, *Phytelephas macrocarpa*, etc.

Acknowledgements—The author is thankful to Dr J.S. Guleria, Birbal Sahni Institute of Palaeobotany, Lucknow, and anonymous referee for critical review and suggestions for the improvement of the text; to Dr V.S. Rao, Director, Agharkar Research Institute, Pune for the facilities; and to

Shri P.G. Gamre and Shri S.V. Chate for their help in compiling the data and scanning of the photographs.

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