

Fungal Remains from the Bhavnagar Lignite, Gujarat

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Ten genera and 16 species of fungal spores and three genera and four species of fruiting bodies have been recovered from the Bhavnagar lignite deposits of Gujarat. Out of these eight species are new. The fungal population suggests a humid, tropical climate and deltaic depositional environment.

Key-words—Fungi, Eocene, Bhavnagar.

INTRODUCTION

THE subsurface Bhavnagar lignite deposits are associated with Tertiary sediments of Gujarat. On the western fringe of the Cambay basin the Tertiary formations are exposed in Ghogha taluka of Bhavnagar district, southeast of Bhavnagar town and around villages Kuda, Kharsalia, Lakhanka, etc., The Bhavnagar deposits fall between Latitude 21° 26' and 21° 43' N and Longitude 72° 07' 30" and 72° 16' 30" E (Fig. 1) and covers an area of about 202 sq. km, with an extension of 60 to 70 km in length (North-South) and 2 to 3 km in width (East-West).

The geology of the area has been worked out by the Directorate of Geology and Mining (DGM), Gujarat. Deccan traps form basement for the overlying Tertiary sequence. The Deccan traps (Upper Cretaceous to Lower Eocene) are overlain by Supratrappean (Paleocene to Lower Eocene). These are in turn overlain by lignite bearing Kharsalia Clay Formation and is broadly considered to be of Eocene age (DGM). However, palynological study indicate Early Eocene age for the lignite deposits occurring in this formation (Samant 1994). The Kharsalia Clay Formation is unconformably overlain by the Guj Formation (Early Miocene). The sequence is capped by the Recent alluvium.

About 55 samples of lignite and clay/shale from the Kharsalia Clay Formation were provided by the Petrography and Mineral Chemistry Laboratory, Gandhinagar (Bore holes 569, 608, 617, 612, 703, 726, of villages Malekvadar, Surka, Thordi & Hoetad). The generalised lithological succession is given in Fig. 2.

SYSTEMATIC DESCRIPTION

Genus : *Brachysporisporites*
Lange & Smith 1971

***Brachysporisporites magnus* sp.nov.**

Plate 1, figs 1 & 2.

Holotype : Plate 1, fig.1 : Sl. No. C-113, 2.

Description : Fungal spores di- or multicellular; balloon shaped; about 59-80 x 43-48 µm in size; cells of unequal size, smaller cell at the apical end, apical cells hyaline and almost opaque, basal cell quite big and balloon shaped, opaque, about 40-48 µm in di-

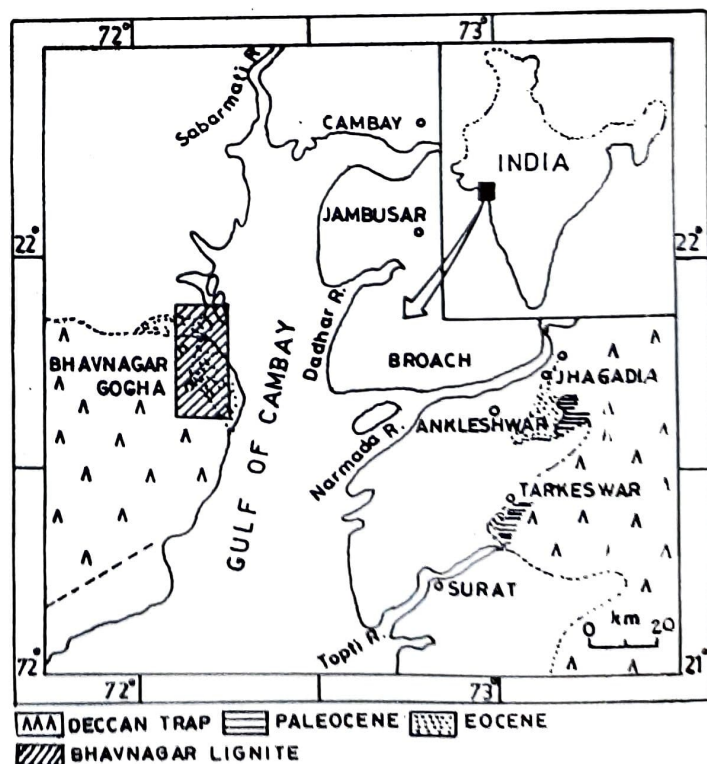


Fig. 1. Geological map of the Cambay basin (Modified after Mathur et al., 1968)

ameter; septate, septa 2-3 μm thick; spore wall about 1 μm thick, smooth.

Comparison : The present species differs from *B. pyriformis* Lange & Smith (1971) in having balloon-like appearance. *B. tenuis* Kumar (1990, Pl. 1, fig. 11) in overall morphology resembles the described specimen but latter one is considerably smaller (23 - 40 x 14 - 32 μm).

Genus : *Callimothallus* Dilcher 1965

***Callimothallus* sp.**

Plate 1, fig. 5

Description : Ascumata semidiscoidal; about 70 μm in size along longest diameter; slightly eccentric; nonostiolate, radial and transverse hyphae form almost rectangular cells, individual cell porate, pores small, thick margined, cells towards center are slightly smaller than those towards periphery; distinctly marked constrictions along the peripheral margin.

Comparison : The recovered specimen resembles *Callimothallus dilcheri* Rao & Ramanujam (1976) reported from the Neogene beds of Kerala. However, the latter has bottle-shaped cells.

Genus : *Colligerites* Jain & Kar 1979

***Colligerites trochus* sp.nov.**

Plate 1, fig. 3

Holotype : Plate 1, fig. 3 : Sl. No. C-69, 4.

Description : Fungal spores multicellular; coiled; trochospiral coiling; 47-60 μm in diameter; nonaperturate; first cell smallest, dark in colour and almost indistinct, cells of inner circle dark and fused,

cell size gradually increases from center to outer region, individual cell rectangular in shape; spore wall smooth.

Comparison : *Colligerites chowdhryi* proposed by Jain & Kar 1979 possesses granulose spore wall. *C. kutchensis* (Kar & Saxena) Jain & Kar (1979, Pl.2, fig. 29) has rhomboidal to squarish cells and planispiral coiling pattern.

Genus : *Dicellaesporites* Elsik emend Sheffy & Dilcher 1971

***Dicellaesporites elsikii* sp.nov.**

Plate 1, fig.7

Holotype : Plate 1, fig. 7 : Sl. No. C-115, 6.

Description : Fungal spores bicellate; 40-45 x 20-26 μm in size; cells of unequal size; first cell almost circular, about 20 μm in diameter, second cell large and elongate, about 26 X 20 μm in size; septate, septa thin or 1 μm ; marked constriction between cells; spore wall thin (1 μm), smooth and hyaline.

Comparison : The described specimen resembles *D. disphaericus* Ambwani (1983) reported from the Neyveli lignite. However, the latter one is smaller in size, and have scabrate sculpture.

Genus : *Diporisporites* Van der Hammen emend. Elsik 1968

***Diporisporites granulatus* sp.nov.**

Plate 1, fig. 10

Holotype : Plate 1, fig. 10 : Sl. No. C-70, 3.

Description : Fungal spores diporate; dark brown; elliptical to elongate; 55-62 x 30-35 μm in size; pore

PLATE 1

(All figures x 1,000)

Figs.1 & 2. *Brachysporisporites magnus* sp.nov.

Fig.3. *Colligerites trochus* sp.nov.

Fig.4. *Callimothallus* sp.

Fig.6. *Dicellaesporites keralensis*

Fig.7. *D. elsikii* sp.nov.

Fig.8. *Diporisporites elongatus*

Fig.9. *D. piercei*

Fig.10. *D. granulatus* sp.nov.

Fig.11. *Fusiformisporites lineolatus*

Fig.12. *Multicellaesporites dilcheri* sp.nov.

Fig.13. *M. elsikii*

Fig.14. *M. elongatus* sp.nov.

Fig.15. *Multicellaesporites* sp.

Fig.16. *Pluricellaesporites psilatus*

Fig.17. *Pluricellaesporites* sp. A

Fig.18. *Pluricellaesporites* sp. B

Fig.19. *Diporicellaesporites pluricellus*

Fig.20. *Phragmothyrites eocaenicus*

Fig.21. *Phragmothyrites ramanujamii* sp.nov.

Figs.22 & 23. *Pluricellaesporites globatus* sp.nov.

Fig.24. *Trichothyrites* sp.

Figs.25 & 26. *T. padappakkarensis*

Fig.27. *Palaeocirrenalia elegans*

Fig.28. Microthyriaceae germling



PLATE I

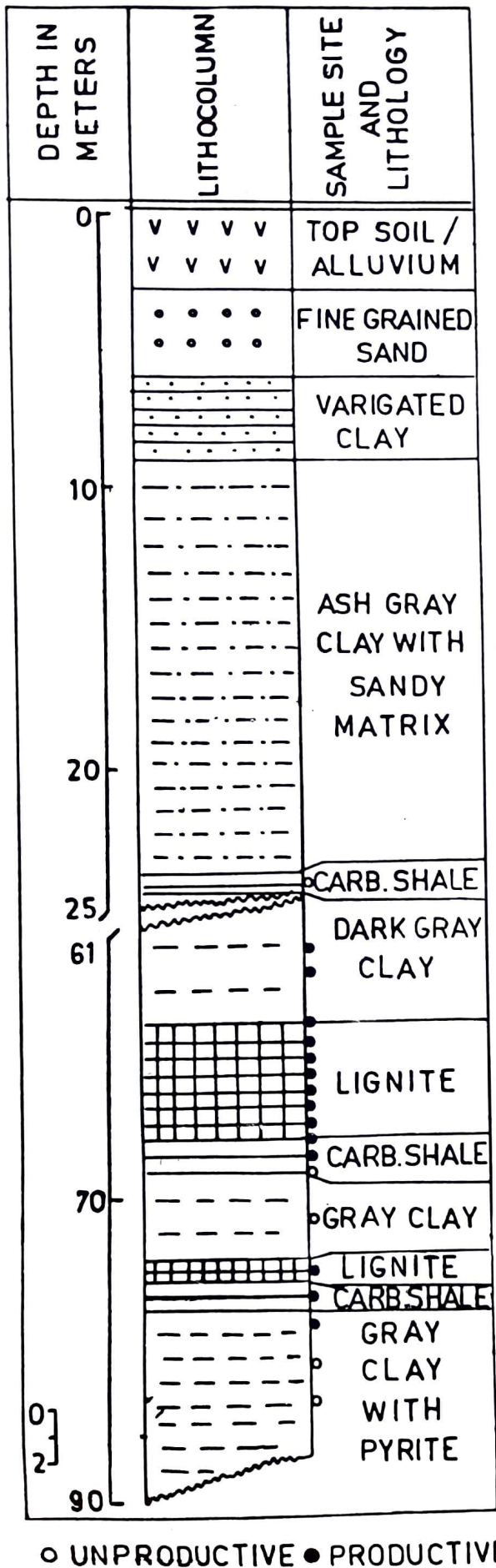


Fig. 1. Generalised Lithocolumn of the Bhavnagar Lignite.

3-4 μm in diameter, slightly protruding, slightly rimmed to thin margined; spore wall 0.5 to 1 μm thick, distinctly granulate.

Comparison : The above described spore differs from *D. piercei* (Varma & Rawat) Elsik 1968 in having larger size and distinctly granulate sculpture. *D. ankleshvarensis* Varma & Rawat (1963) is foveolate to pseudoreticulate.

Genus : *Multicellaesporites* Elsik emend. Sheffy & Dilcher 1971

***Multicellaesporites elongatus* sp.nov.**

Plate 1, fig. 14

Holotype : Plate 1, fig. 14 : Sl. No. C-111,6.

Description : Fungal spores rectangular in shape ; tri-cellate; all the cells of similar shape and size; about 100-109 μm long; individual cell rectangular in shape, about 23-25 x 14-16 μm in size, marked constriction between the cells; septate, septa about 1-1.5 μm thick; spore wall about 1 μm thick, psilate and hyaline.

Comparison : The proposed species differs from *M. prakashii* Ambwani (1982) in having smaller size and rectangular cells. *M. elsikii* Kar & Saxena (1976) is tetra- to pentacellate. *M. simplicissimus* Sheffy & Dilcher (1971, Pl.16, fig. 42) is very small in size with very thin septa, and cells without constrictions. Three cells, distinct rectangular shape and marked constrictions between cells are the diagnostic features of this species.

***Multicellaesporites dilcheri* sp.nov**

Plate 1, fig. 12

Holotype : Plate 1, fig. 12 : Sl. No. C-112,6.

Description : Fungal spores oval in shape; tetra-cellate, about 30-32 x 14-20 μm in size; terminal cell larger than the middle cells, about 10 x 12 μm , middle cells about 12 x 14 μm , ; longitudinal slit in the middle region; no constriction of cell wall between the cells; septate, septa about 2 μm thick, porate; cell wall about 1 μm thick, psilate and hyaline.

Comparison : Distinctly thick septa, longitudinal slit in the middle region and presence of bigger terminal cells are the diagnostic characters of this species. In *M. elsikii* Kar & Saxena (1976, Pl. 3, figs 29-30), all the cells are of equal size and septa is also consid-

erably thin. *M. ovatus* Sheffy & Dilcher (1971, Pl.16, fig. 44) is oval in shape and four celled, however it differs in having considerably smaller size and distinctly tapering one end. *M. ellipticus* Sheffy & Dilcher (1971, Pl. 16, fig. 49) is smaller in size with marked constrictions between the cells.

***Multicellaesporites* sp.**

Plate 1, fig. 15

Description : Spore cylindrical in shape; penta cellate; about 90 μm long; cells are almost of the same width; about 15 x 27 μm ; with constrictions between the cells; septate, septal wall about 1-1.5 μm thick; spore wall thin, less than 1 μm thick, with striations all over the surface.

Comparison : Distinct cylindrical shape and striations all over the surface are the diagnostic features of this sporomorph. Since only one specimen could be recovered from this assemblage, no specific epithet has been assigned.

Genus : *Phragmothyrites* Edwards 1922

***Phragmothyrites ramanujamii* sp.nov.**

Plate 1, fig. 21

Holotype : Plate 1, fig. 21 : Sl. No. C-112, 6.

Description : Ascomata discoidal; about 65-120 μm in diameter; nonostiolate; hyphal cells radiating; individual cell nonporate, rectangular to squarish, thick walled; marginal cells bigger, hyaline and smooth.

Comparison : The proposed species differs from *P. eocaenicus* Edwards (1922) in having distinctly thick walled, squarish to rectangular inner cells, and hyaline marginal cells. A good frequency of this species is present in this assemblage.

Genus : *Pluricellaesporites* Van der Hammen emend. Elsik 1968 *Pluricellaesporites globatus* sp. nov.

Plate 1, figs 22 & 23

Holotype : Plate 1, fig. 22 : Sl. No. C-116,8.

Description : Fungal spores globular in shape; tetra cellate; 46-49 x 28-33 μm in size; terminal cell with pore, pore thin margined, terminal cell smaller than rest of the cells; septate, septa about 2-4 μm thick, septal wall curved or straight, contact between septa

and spore wall smooth; spore wall about 1 μm thick, smooth.

Comparison : The presence of distinct globular shape, four cells, small terminal cell and thin margined pore are the diagnostic characters of this sporomorph. The described specimens differ from *P. psilatus* Clarke (1965) in having globular shape and 4 cells. *P. ellipticus* described by Kar (1985 Pl. 37, fig. 2) is also tetracellular, however it is elliptical in shape.

***Pluricellaesporites* sp. A**

Plate 1, fig. 17

Description : Fungal spore cylindrical in shape; 8 celled; about 60-66 x 20-21 μm in size; one opening present; all the cells of unequal size, basal cell almost elliptical, about 17 x 6 μm ; other cells rectangular; marked constriction between terminal and rest of the cells; septate, septa about 2-3 μm thick, distinct flap like tri-angular projection on the septa, septa thicker than spore wall; spore wall smooth, hyaline and about 1 μm thick.

Comparison : *P. alleppeyensis* Ramanujam & Rao (1978, Pl. 2, figs 29-30) is very big in size with narrow tail-like apical part and truncated basal part. Presence of 8 cells, distinctly elliptical terminal cell and rest rectangular cells are the diagnostic features of this species. Since only one specimen could be recovered from the assemblage, no specific name has been assigned.

***Pluricellaesporites* sp. B**

Plate 1, fig. 18.

Description : Fungal spore multicellular; 90 μm long; almost cylindrical; marked neck-like constriction after every four cells; individual cell rectangular, about 5-6 μm long; septate, septa about 2 μm thick, thicker than spore wall, in some septa distinctly triangular, flap-like structure is present, contact between septa and spore wall smooth; spore wall about 1 μm thick, psilate.

Comparison : Distinctly neck-like constriction after every four cells is the diagnostic feature of this type. Due to the recovery of a single specimen in the assemblage, no specific name has been assigned.

Genus: *Trichothyrites* Rosendahl 1943***Trichothyrites* sp.**

Plate 1, fig. 24

Description : Fruit body dark brown in colour; discoidal, about 71 μm in diameter; free mycellium absent; ostiolate, more or less rounded, concentric, without projections inside ostiole, encircled by 2-3 layered dark brown cells which are almost fused around ostiole, rest of the cells almost circular to rectangular, all the cells of almost same size, transverse and radiating hyphae considerably thick margined, margins of ascomata smooth to slightly undulating.

Comparison : The recovered specimens resemble *T. sastryi* Patil & Ramanujam (1988, Pl. 1, fig.2) in having smooth ostiole and presence of thick margined cells around ostiole. However, the former is considerably smaller in size with all the cells of equal size and almost circular to rectangular shape of cells. *T. padappakkarensis* (Jain & Gupta) Reddy *et al.* (1982, Pl.2, fig. 8) possess circular papillate cells inside the ostiole. Only one complete specimen could be recovered from the samples. However, numerous fragments of similar type were found in the dispersed condition.

Apart from the recovery of good frequency of fruiting bodies, variety of microthyriaceous germlings have also been recovered from this lignite (Pl. 1, fig 28).

List of known fungal remains recorded:

1. *Callimothallus pertusus* Dilcher 1965
2. *Dicellaesporites keralensis* Kumar 1990
3. *Diporicellaesporites pluricellus* Kar & Saxena 1976
4. *Diporisorites elongatus* Van der Hammen 1954
5. *D. pierceii* (Varma & Rawat) Elsik 1969
6. *Fusiforoesporites lineolatus* Sheffy & Dilcher 1977
7. *Monoporisorites keralensis* Ramanujam & Rao 1978
8. *Multicellaesporites elsikii* Kar & Saxena 1976
9. *Palaeocirrenalia eligans* Ramanujam & Srisailam 1980

10. *Phragmothyrites eocenicus* Edwards 192211. *Pluricellaesporites psilatus* Clark 196512. *Trichothyrites padappakkarensis* (Jain & Gupta) Reddy *et al.* 1982**PALAEOCLIMATE AND DEPOSITIONAL ENVIRONMENT**

For depicting climate and depositional environment fungal remains were compared with modern taxa (Table 1).

Table 1: Affinities of the fossil spores with extant taxa.

Fossil Taxa	Affinities with extant taxa
<i>Brachysporisorites</i>	<i>Brachysporium</i> (Hyphomycetes)
<i>Colligerites</i>	<i>Habsonia</i> (Hyphomycetes)
<i>Fusiforoesporites</i>	<i>Cookeinia</i> (Ascomycetes)
<i>Multicellaesporites elsikii</i>	<i>Anellophorella</i> , <i>Stigira</i> , <i>Compacta</i> (Hyphomycetes)
<i>Palaeocirrenalia elegans</i>	<i>Cirrenalia</i> (Hyphomycetes)

Presence of foliaceous ascomata affiliated to the modern Microthyriaceae indicate moist climatic conditions at the time of deposition of this lignite. The recovery of spores and pollen of Cyatheaceae, Polypodiaceae, Schizaeaceae, Gleicheniaceae, Araceae, Araceae, Lecythidaceae, Draceneaceae, Araliaceae, Symplocaceae, Bombacaceae, Gunneraceae, Sapotaceae, Caesalpinaceae, Ctenolophonaceae, Proteaceae, Gonystylaceae, Ebenaceae, Alangiaceae, Pedaliaceae and Olacaceae also indicate moist tropical climate (Samant, MS).

The common occurrence of *Palaeocirrenalia*, throughout the lignite deposits is also significant as it is affiliated to modern *Cirrenalia* which is a characteristic fungus of brackish to marine waters (Ellis 1976). Therefore, it seems more probable that this lignite was deposited under the influence of brackish water in delatic to near deltaic environment.

The topmost layer of this lignite yielded thick hyphal mats and high frequency of fungal spores. In successively overlying clay/shale sequence, fossil pollen of *Spinizonocolpites* are abundantly present. The pollen of *Spinizonocolpites* is affiliated to the extant rhizomatic palm *Nypa fruticans*. The modern *Nypa*

is a typical member of true mangrove vegetation. Presence of thick hyphal mats, high frequency of fungal spores and *Spinizonocolpites* (*Nypa*) collectively indicate the near deltaic condition for the deposition of this lignite. Record of onset of Early Eocene transgression in the Cambay Basin (Bhandari & Raju 1991) further supports the deltaic depositional environment.

COMPARISON WITH OTHER CONTEMPORANEOUS DEPOSITS OF INDIA

Fungal remains of the Bhavnagar lignite are compared with its contemporaneous deposits i.e. Subathu Formation (Saxena & Sarkar 1986; Sarkar & Singh 1988), Mikir Formation (Mehrotra 1983), Cauvery Basin (Venkatachala & Rawat 1973), Rajpardi lignite (Bhattacharya 1987; Kar & Bhattacharya 1992; Samant & Phadtare 1997), Kadi Formation (Rawat *et al.* 1977), Cambay Basin (Koshal & Uniyal 1981), Kachchh (Kar 1978, 1985, Kar & Saxena 1981), and Palana lignite (Sah & Kar 1974). Overall comparison shows that *Lacrimasporonites*, *Monoporisporites*, *Circulisporites*, *Parmathyrites*, *Notothyrites*, *Kutchiathyrites*, *Inapertisporites*, *Sphaerialites*, *Frasnacritetrus* and *Dyadosporonites* which have been recovered from other paleogene localities, are absent in the assemblage of Bhavnagar lignite.

The comparative account further indicates that genera *Quilonia*, *Foveoletisporonites*, *Diploneurospora*, *Warkallisporonites*, *Spegazzinites*, *Exesisporites*, *Hypoxylonsporites* and *Retihelicosporonites* which are reported exclusively from Neogene sediments (Kumar, 1990), are absent from the present assemblage.

However, some of the Neogene forms such as *Diporisporites piercei*, *Dicellaesporites keralensis*, *Pluricellaesporites psilatus*, *Brachysporites* and *Colligerites* are present in the lignite deposits of Bhavnagar. The presence of these taxa in the Early Eocene lignite extends their lower age up to Eocene.

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