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PALYNOLOGY OF THE EARLY EOCENE SURAT LIGNITE DEPOSITS OF GUJARAT, INDIA

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ABSTRACT

The paper records fossil pollen and spores representing 76 species, distributed in 57 genera, from the early Eocene Surat lignite deposits of Gujarat. Seven genera and eight species of these are derived from pteridophytes, the remainder are angiosperm taxa. One species of pteridophytic spores and five species of angiosperm pollen grains are described as new. Overall, the assemblage suggests the prevalence of deltaic to swampy vegetation and a humid tropical climate during the deposition of the Surat lignite.

Key words : Palynology, early Eocene, Surat Lignite, Gujarat, India.

INTRODUCTION

The subsurface Surat lignite deposits are located on the eastern margin of the Cambay Basin (fig.1). The lignite-bearing area extends from the Tarkeshwar village of Surat District in the south to the Valia village of Bharuch district in the north. The general direction of strike of the lignite seam is NNE-SSW and dip direction is WSW. The amount of dip is generally low, between 2° and 3°, but occasionally at trap contacts it increases to 5°- 8°. The depth of the lignite varies from 19.85 to 145.10 m and its thickness between 0.10 and 8.09 m.

The Directorate of Geology and Mining (DGM), Gujarat, is currently carrying out an exploratory survey of the lignite reserves in the area. According to DGM's unpublished report, the Surat lignite is a part of the early Eocene Cambay Shale. This Formation is underlain by the Vagadkhol Formation of lower Eocene to Palaeocene age. The middle Eocene Ankleshwar Formation is absent from the area. The Cambay Shale is unconformably overlain by the upper Eocene Amrawati Formation. All of these formations are covered by the Recent alluvium. A survey of the literature has shown that no palynological or palaeontological work has so far been carried out on these deposits. Detailed palynological investigations of this lignite sequence, therefore, was undertaken.

MATERIAL AND METHODS

Core samples of the subsurface lignite were collected from the Petrography and Mineral Chemistry Laboratory, Gandhinagar, with permission of the DGM, Ahemadabad, because the commercial mining of lignite has not yet begun. The samples provided by the laboratory are from the Tarkeshwar and the Valia areas of Gujarat. A generalized lithological column for the area is shown in fig.2.

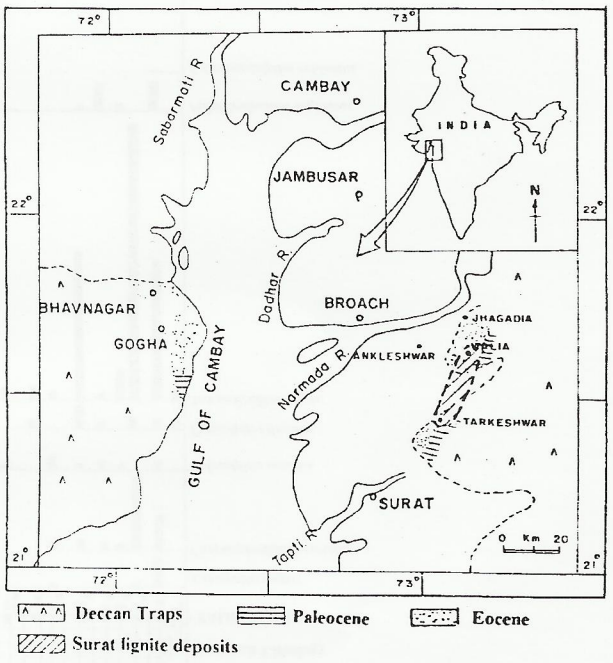


Fig. 1. Map showing the location of the Surat Lignite deposits.

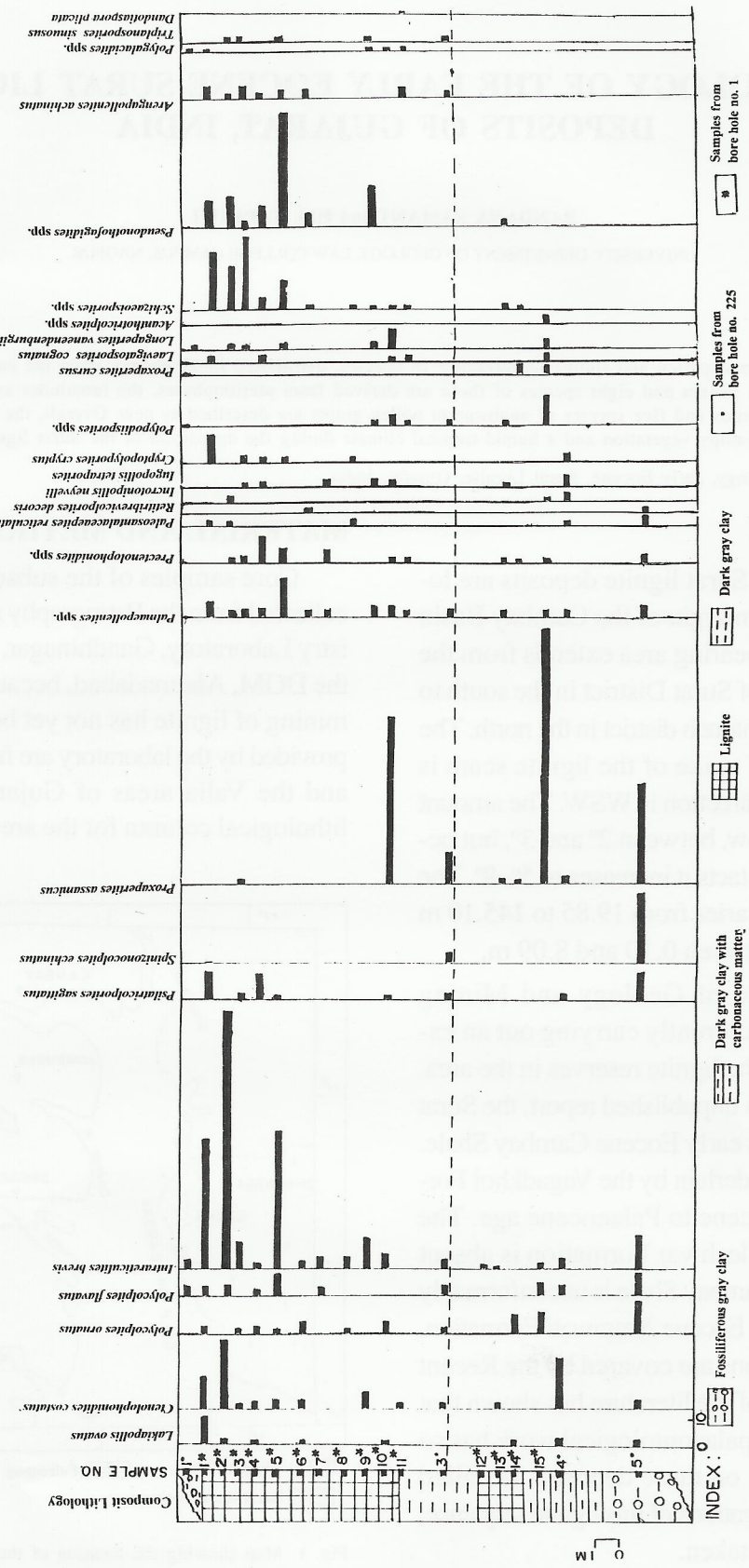


Fig. 2. Pollen diagram of the Surat lignite deposits.

The samples are of clay and lignite. In the laboratory all samples were given standard chemical (HCl, HF, HNO_3 and KOH) treatment. The organic residue recovered was mixed with polyvinyl alcohol and smeared on cover slips, which were then mounted on the glass slides using DPX. Usually 7-10 slides were found to be sufficient for the palynomorph study. All the holotypes are preserved in the Museum of the Department of Geology, Nagpur University, Nagpur.

PALYNOFLORAL ANALYSIS

Many pollen and spore taxa have been recovered from the Surat lignite deposits. Angiosperm pollen grains are the most common, followed by fungal remains (Samant and Tapaswi, ms) and pteridophytic spores. Frequency occurrence of pollen is good in lignite samples, whereas fungal spores and pteridophytic spores are dominant in the clay samples. Palynofloral analysis of the Surat lignite deposits shows that overall palynoflora of this lignite is less diverse in quantity as well as quality as compared to the nearby Rajpardi lignite deposits.

Overall palynofloral assemblage consists of 76 species referred to 57 genera; of these six species are new. Pteridophytes are represented both by monolete and trilete spores. These are placed in eight species belonging to seven genera. Amongst pteridophytes, the monolete genus *Schizaeoisporites* is the most common. Sixty eight species of angiosperms, referred to 50 genera, have been recovered, of which five species are described as new. The palynofloristic composition of the deposits is shown in Fig. 2.

SYSTEMATIC DESCRIPTION

Pteidophytic spores

Genus ***Schizaeoisporites*** (Pot.) Delcourt & Sprumont 1955

Type Species : *Schizaeoisporites eocaenicus* (Selling) Potonie, 1956

Schizaeoisporites suratensis n. sp.

(Pl. I, fig.3)

Slide no. : DGN/SM-1/3/10/44.

Holotype : Plate 1, fig. 3.

Description : Spores oval, measuring 40-53 x 27-31 μm in size; monolete; laesura extend the length of the long axis, slightly crassimarginate, ends of leasurae pointed to blunt; exospore 2 μm thick; striate, striations parallel to each other and bifurcating, grooves about 2 μm wide, grooves and ridges of approximately the same width.

Remarks : *Schizaeoisporites palanensis* Sah and Kar, 1974 (pl. 1, figs 4-5) is also oval in shape; however, it has broad ridges (3-7 μm). *S. ghoshii* Ramanujam, 1967 (pl. 1, fig. 28), has planoconvex shape, thick wall (2.5-4.5μm) and comparatively broad ridges and narrow grooves. The proposed species differs from all other species of this genus in being oval in shape and in having thick, parallel and bifurcating striations.

Lithology : Lignite.

Affinity : Schizaeaceae.

Angiosperm pollen

Genus ***Cupanieidites*** (Cookson & Pike) Chmura, 1973

Type Species : *Cupanieidites major* Cookson & Pike, 1954

Cupanieidites rugulatus n.sp.

(Pl. I, fig. 9)

Holotype : (Pl.-I, Fig. 9)

Slide no. : DGN/SM-1/13/2/49.

Description : Pollen grains rounded triangular in poler view; 22-26 x 23-24 μm in diameter; syncolporate; colpi long with thin smooth margins and form a distinct triangular polar island; ora small, tenuimarginate, smooth margined, slightly aspidate; exine 1.5 μm thick, sexine and nexine are almost equal in thickness; sculpture is rugulate in mesocolpial regions and almost psilate along the margin of colpi.

Remarks : The diagnostic characters of this species are its distinctly rounded triangular shape, syncolporate aperture and rugulate sculpture pattern at the mesocolpial region. *Cupanieidites flaccidiformis* Venkatachala and Rawat, 1972 (pl. 2, figs 11-12) has ridge-like flanges in the mesocolpial region. *C. cauveriensis* Venkatachala and Rawat, 1972 (pl. 2, fig. 15) has a reticulate sculpture pattern in the mesocolpial region. *C. cooksonii* Ramanujam, 1987 (pl. 3, fig. 71-72) has a coarsely granulate to microreticulate sculpture.

Lithology : Lignite.

Affinity : Sapindaceae.

Genus ***Echimonoporopollis*** Saxena *et. al.*,1991

Type Species: *Echimonoporopollis grandiporus* Saxena *et. al.*, 1991

Echimonoporopollis circularis n. sp.

(Pl. II, fig. 1)

Holotype: Slide no. DGN/SA-279/3/5/45.

Description : Pollen grains spherical; 27-29 µm in diameter; monoporate, pore 10 µm in diameter, tenuimarginate with slightly irregular margins, spines extending up to spore margins; exine < 1 µm thick (excluding spines), sexine and nexine undifferentiable; sculpture spinose, spines about 1-1.5 µm long, with curved tips and bulbous base, scarcely placed and evenly distributed, interspinal area smooth.

Remarks : The above described morphotype differs from *Echimonoporopollis grandiporus* Saxena, *et. al.*, 1991 in having larger pore, thin exine and short spines. *E. neyveliensis* Saxena *et. al.*, 1991 has long spines and punctate to microreticulate interspinal area.

Lithology : Lignite.

Affinity : Unknown.

Genus ***Favitricolporites*** Sah, 1967.

Type species: *Favitricolporites eminens* Sah, 1967

Favitricolporites suratensis n. sp.

(Pl. I, fig. 13-14)

Holotype: Slide no. DGN/SP-225/4/2/46 (Pl. I, fig. 13).

Description : Pollen grain spheroidal in equatorial view, 36-42 µm in diameter; tricolporate, equatorialy placed aperture; colpi short, slit like and 12 µm in length, colpal ends pointed, sculpture extending upto colpal margins; ora lalongate, narrow and 8µm wide; exine 2 µm thick, sexine thicker than nexine, nexine uneven; sculpture reticulate, semitectate, columellate, homobrochate, simply to duply baculate.

Remarks: The genus *Favicolporites* Sah, 1967 includes tricolporate reticulate pollen grains. The proposed species differs from all the known species of the genus in having small size and slit like colpi and small ora.

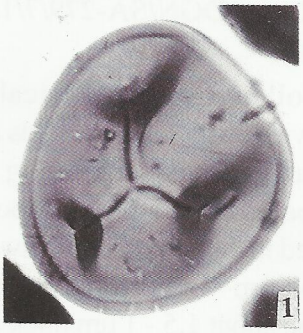
Lithology : Dark gray clay with carbonaceous matter.

EXPLANATION OF PLATE I ⟶

(All magnifications 1000X unless otherwise stated)

1. *Dandotiaspora plicata* (Sah & Kar) Sah *et.al.* DGN/SA-279/7/1/45 400X.
2. *Lygodiumsporites lakiensis* Sah & Kar DGN/ST-288/1/6/47 400X.
3. *Schizaeoisporites suratensis* n. sp. DGN/SM/1/3/10/44 400X
4. *Acanthotricolpites bulbospinosus* Kar DGN/ST-288/6/2/51 400X.
5. SEM photograph of the similer type.
6. *Acanthotricolpites kutchensis* (Venkatachala & Kar) Singh & Misra DGN/SP-225/2/3/52 400X.
7. SEM Photograph of the similer type.
8. *Cryptopolyporites cryptus* Venkatachala & Kar DGN/SM-1/3/10/44 400X.
9. *Cupanieidites rugulatus* n. sp. DGN/SM-1/13/2/49 .
10. *Ctenolophonidites costatus* Von Hoenken Klinkenberg DGN/SM-1/5/7/53.
11. *Anacolosidites trilobatus* Venkatachala & Rawat DGN/SA-279/1/6/54.
12. *Dermatobrevicolporites dermatus* (Sah & Kar) Kar DGN/SM-1/11/3/55.

13,14. *Favitricolporites suratensis* n. sp. DGN/SP-225/4/2/46.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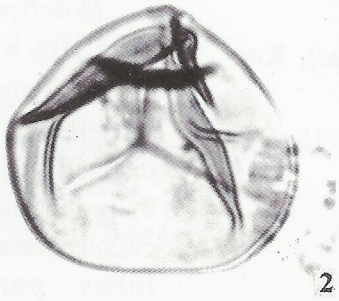
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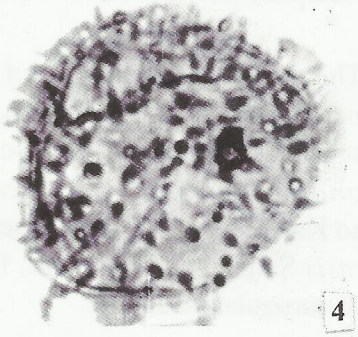
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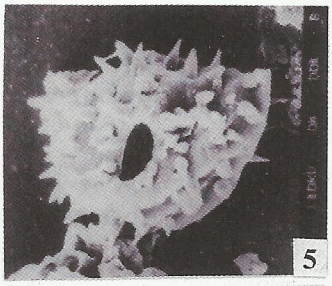
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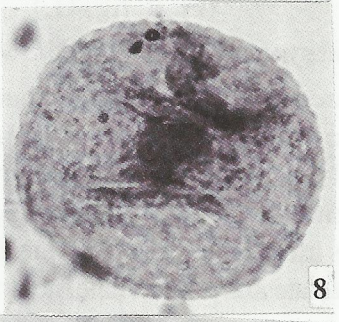
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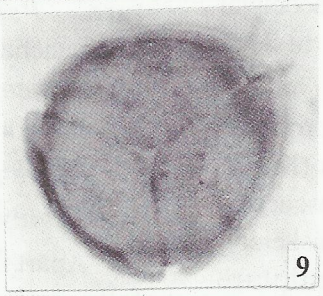
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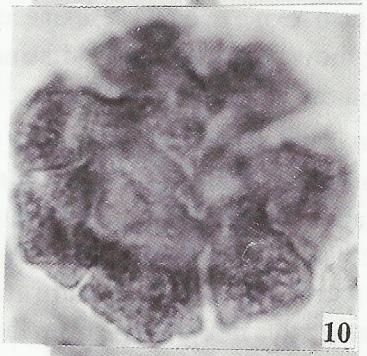
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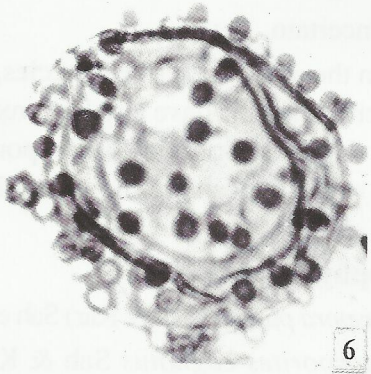
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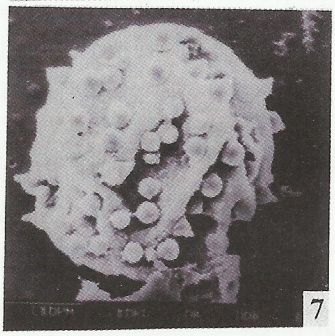
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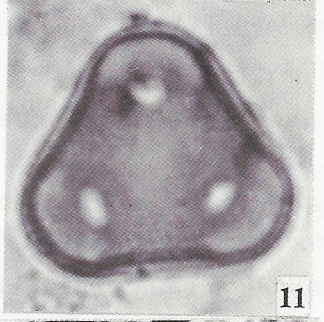
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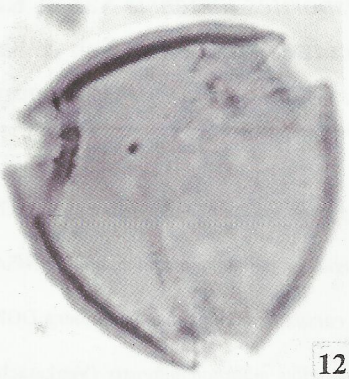
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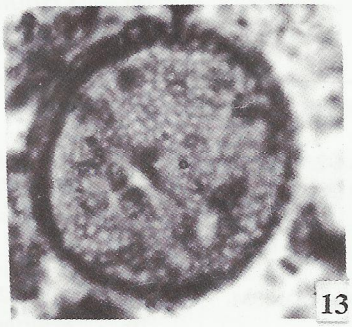
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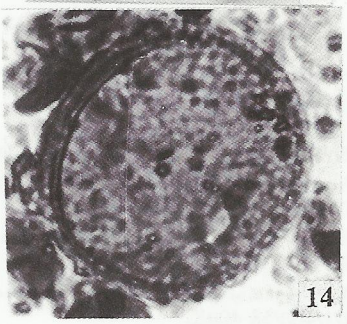
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Affinity : unknown.

Genus ***Intrareticulites*** (Sah & Kar), Kar, 1995.

Type Species: *Intrareticulites brevis* (Sah & Kar) Kar, 1985.

Intrareticulites scabratus n. sp.

(Pl. II, fig. 11.)

Holotype : Slide no. DGN/SM-1/2/9/50.

Description : Pollen grains rounded triangular in shape; 29-33 µm in size ; tricolpate; colpi about 10 µm long, narrow and slightly crassimarginate, colpal ends pointed with distinct thickening, colpal margins irregular to smooth; exine about 1 - 1.5 µm thick, tectate and columellate, nexine irreguler and thicker than sexine or equal to sexine at mesocolpial region; however, nexine is distincty thick at apertural region; sculpture scrabrate.

Remarks : In overall morphology the proposed morphotype appears similer to *I. brevis* (Sah & Kar) Kar 1985 (pl.2 fig.13); however, presence of distinct thickening at colpal end, nexinal thickening at apertural region and scabrate sculpture differentiate this morphotype from the latter.

Lithology : Lignite.

Affinity: Unknown.

Genus ***Pseudonothofagidites***, Venkatachala & Kar, 1969

Type Species: *Pseudonothofagidites kutchensis* Venkatachala & Kar, 1969

Pseudonothofagidites microreticulatus n. sp.

(Pl. II, fig. 8.)

Holotype : Slide no. DGN/SA-279/7/1/48 (Pl. II, fig. 8).

Description: Pollen grains spherical to subspherical in polar view, with lobed margins and distinctly raised apocolpial region; measuring 27-35 µm in diameter; polyporate, 5-7 pores; pores circuler and are situated in the depressions between lobes, pores 4-6 µm in diameter and crassimarginate; exine about 1.5 - 1 µm thick and slightly thicker around pores, sexine and nexine undifferentiable; sculpture microreticulate to almost psilate.

Remarks : The diagnostic characters of this species are distinctly raised apocolpial region, 5-6 pores and almost psilate to microreticulate sculpture. *Pseudonothofagidites kutchensis* Venkatachala and Kar, 1969 has granulose sculpture. *S. bengalensis* Samant and Phadtare, 1997 is with rugulate to eurugulate sculpture.

Lithology: Lignite.

Affinity: Uncertain.

Apart from the above described species, the following pollen/spore taxa have also been recovered from the deposits. Some of the important palynomorphs of the deposit are shown in Plates I-II.

a) Pteridophytic spores

1) *Dandotiaspora plicata* (Sah & Kar) Sah et. al.
2) *Laevigatosporites cognatus* Sah & Kar
3) *Lygodiumsporites lakiensis* Sah & Kar
4) *Osmundacidites kutchensis* Sah & Kar
5) *Polypodiisporites ratnamii* (Ramanujam)

EXPLANATION OF PLATE II ⟶

1. *Echimonoporopollis circularis* n. sp. DGN/SA-279/3/5/45.
2. *Neotrichotomosulcites foveolatus* Samant & Phadtare DGN/SA-225/4/3(s)/56.
3. *Polybrevicolporites cephalus* Venkatachala & Kar DGN/SA-279/2/3/57.
4. *Matanomadhiasulcites kutchensis* (Saxena) Kar DGN/SM-1/1/4(s)/58 400X.
5. *Paleosantalaceaepites reticulatus* Samant & Phadtare DGN/ST-288/1/5/59.
6. *Polycolpites flavatus* Sah & Kar DGN/SP-225/4/2/68 400X.
7. *Retistephanocolpites williamsii* Germeraad *et al.* DGN/ST-288/11/3/61.
8. *Pseudonothofagidites microreticulatus* n. sp. DGN/SA-279/7/1/48.
9. *Proxapertites cursus* Von Hoeken Klinkenberg DGN/SM-1/9/3/62 400X.
10. *Retitribrevicolporites matanomadhensis* (Venkatachala & Kar) Kar DGN/SM-1/11/6/63 400X.
11. *Intrareticulites scabratus* n. sp. DGN/SM-1/2/9/50.
12. *Tripilaorites triangulatus* (Sah & Kar) Kar DGN/SM-1/3/2/64 252X.

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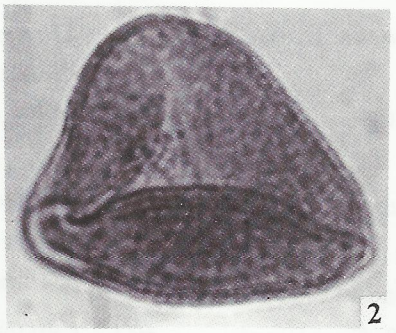

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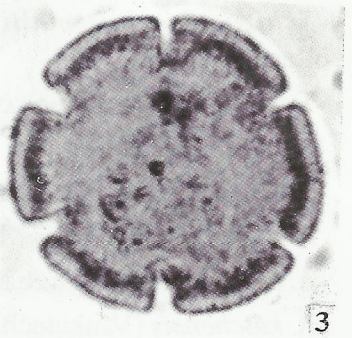

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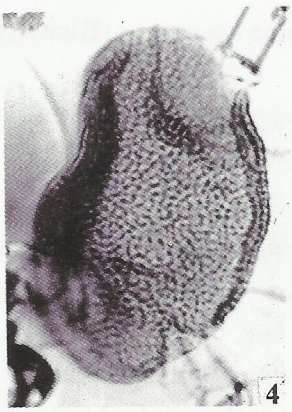

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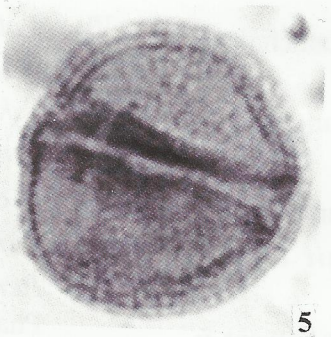

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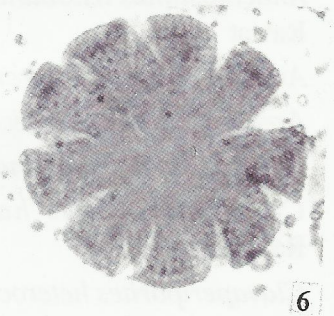

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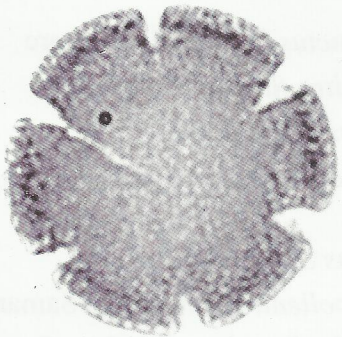

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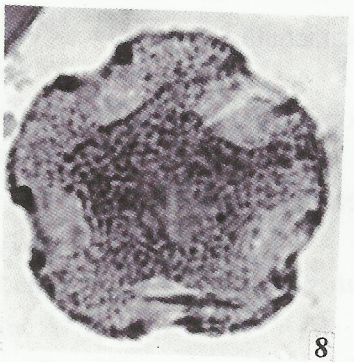

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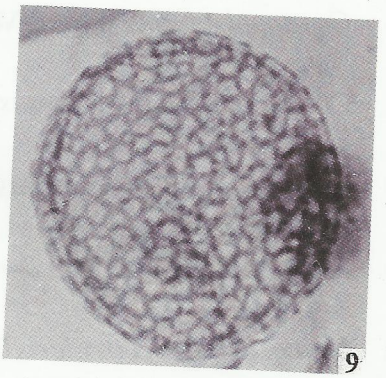

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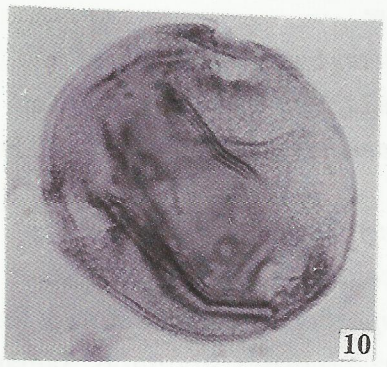

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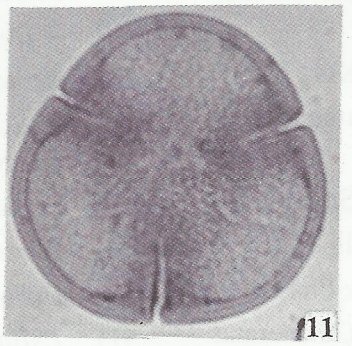

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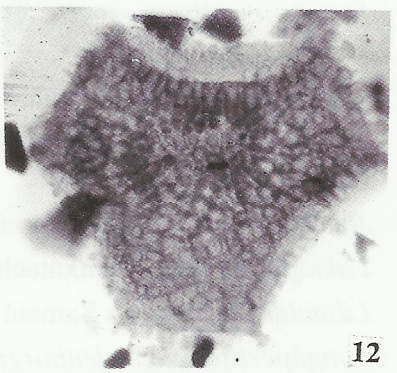

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SAMANT AND TAPASWI

Rao & Ramanujam

6) *Schizaeoisorites multistriatus* Rao & Ramanujam
7) *Triplanosporites sinuosus* Pflug

b) Angiosperm pollen

1) *Acanthotricolpites bulbospinosus* Kar
2) *A. complexus* Singh & Misra
3) *A. intermedius* Singh & Misra
4) *A. kutchensis* (Venkatachala & Kar) Singh & Misra
5) *Anacolosidites trilobatus* Venkatachala & Rawat
6) *Angulocolporites microreticulatus* Kar
7) *Arecipites bellus* Sah & Kar
8) *Arengapollenites achinatus* Kar
9) *Clavapalmaedites hammenii* Rao & Ramanujam
10) *Clavaperiporites heteroclavatus* Samant & Phadtare
11) *Cryptopolyporites cryptus* Venkatachala & Kar
12) *Ctenolophonidites costatus* Von Hoeken Klinkenberg
13) *Cupanieidites flaccidiformis* Venkatachala & Rawat
14) *Dermatobrevicolporites dermatus* (Sah & Kar) Kar
15) *Dracaenoipollis circularis* Sah & Kar
16) *Haloragacidites neyvelii* Ramanujam
17) *Incrotonipollis neyvelii* (Baksi *et. al.*) Jansonius & Hills
18) *Intrareticulites brevis* (Sah & Kar) Kar
19) *Iugopollis tetraporites* Venkatachala & Rawat
20) *Jacobipollenites ramanujamii* Samant
21) *Lakiapollis ovatus* Venkatachala & Kar
22) *Liliacidites clubensis* Samant & Phadtare
23) *Longapertites vaneedenburgii* Germeraad *et. al.*
24) *Margocolporites sitholeyi* Ramanujam
25) *Matanomadhiasulcites kutchensis* (Saxena) Kar
26) *Meliapollis ramanujamii* Sah & Kar
27) *Neocouperipollis ankleshwarensis* Kar & Bhattacharya
28) *Neotrichotomosulcites foveoloatus* Samant & Phadtare
29) *Paleosatalaceaepites reticulatus* Samant & Phadtare
30) *Palmaepollenites eocenicus* (Biswas) Sah & Dutta
31) *P. kutchensis* Venkatachala & Kar
32) *P. nadhamunii* Venkatachala & Kar
33) *P. ovatus* Sah & Kar
34) *Paravuripollis mulleri* Rao & Ramanujam
35) *Perfotricolpites rajpadiensis* Samant & Phadtare
36) *Plicatiaperturites retipilatus* Kar
37) *Polybrevicolporites cephalus* Venkatachala & Kar
38) *P. indistinctus* Samant & Phadtare
39) *Polycolpites flavatus* Sah & Kar
40) *P. ornatus* Dutta & Sah
41) *Polygalacidites magnus* Samant & Phadtare
42) *P. minutus* Samant & Phadtare
43) *Pometiapollenites reticulatus* Samant
44) *Prectenolophonidites primitiva* Samant & Phadtare
45) *P. distictus* Samant & Phadtare
46) *Proteacidites protrudus* Sah & Kar
47) *Proxapertites assamicus* (Sah & Dutta) Singh
48) *P. cursus* Von Hoeken Klinkenberg
49) *P. reticulatus* (Kar & Saxena) Kar
50) *Psilodiporites hammenii* Verma & Rawat
51) *Psilatricolporites sagittatus* Samant & Phadtare

Table 1 : List of palynomorphs with their possible botanical affinities and the present day distribution.

Pollen/spore taxa	Modern affinity	Geographical distribution Trop.	sub-trop.	Tem.
Ptridophytic spores				
Dandotiaspora plicata	?Matoniaceae	———		
Osmundacidites kutchensis	Osmundaceae	———		
Lygodiumsporites lakiensis	Schizeaceae	———		
Schizaeoisporites spp.	Schizeaceae	———		
Triplanosporites sinuosus	?Gleicheniaceae	———		
Angiosperms				
Clavaperiporites heteroclavatus	Linaceae	———		
Haloragacidites neyvelii	Haloragidaceae	———		
Polygalacidites spp.	Polygalaceae	———		
Arengapollenites achinatus	Arecaceae	———		
Clavapalmidites hemmenii	-do-	———		
Longapertites spp.	-do-	———		
Neotrichotomosulcites spp.	-do-	———		
Palmaepollenites spp.	-do-	———		
Paravuripollis mullerii	-do-	———		
Incrotonipollis neyvelii	Euphorbiaceae	———		
Margocolporites sitholeyi	Caesalpiniaceae	———		
Meliapollis ramanujamii	Meliaceae	———		
Polycolpites ornatus	Lentibulariaceae	———		
P. flavatus	Pedaliaceae	———		
Spinizonocolpitea echinatus	Arecaceae (*Nypa*)	———		
Anacolosidites trilobatus	Olacaceae (*Anacolosa*)	———		
Cryptopolyriporites cryptus	Gonystylaceae	———		
Ctenolophonidites costatus	Ctenolophonaceae	———		
Prectenolophonidites spp.	-do-	———		
Cupanidites spp.	Sapindaceae (*Cupaniopsis type*)	———		
Pometiapollenites reticulatus	-do- (*Pometia*)	———		
Dracenoipollis circularis	Dracaenaceae (*Dracaena*)	———		
Florschetzia rajpadiensis	Sonneratiaceae	———		
Intrareticulites brevis	Gunneraceae (*Gunnera*)	———		
Iugopollis tetraporites	Sapotaceae	———		
Tetracolporopollenites brevis	-do-	———		
Lakiapollis ovatus	Bombacaceae (*Durio*)	———		
Paleosantalaceaepites reticulatus	Rhizophoraceae	———		
Perfotricolpites rajpadiensis	Covolvulaceae (*Merremia*)	———		
Proteacidites protudus	Proteaceae	———		
Psiltricolporites sagittatus	Ebenceae	———		

Trop. = Tropical, Subtrop.= Subtropical, Temp.= Temperate.

52) *Pseudonothofagidites bengalensis* (Mathur & Chopra) Samant & Phadtare

53) *Retimonocolpites thanikaimonii* Samant & Phadtare

54) *Retistephanocolpits brevicolpatus* (Mathur) Saxena

55) *R. kutchensis* Saxena

56) *R. williamsii* Germeraad et. al.

57) *Retitetracolpites medicolpus* Mathur & Jain

58) *Retitricolpites crassireticulatus* (Dutta & Sah) Samant & Phadtare

59) *Retitribrevicolporites decoris* (Dutta & Sah) Kar & Kumar

60) *R. matanomadhensis* (Venkatachala & Kar) Kar

61) *Spinizonocolpites echinatus* (McIntyre) Stover & Evans

62) *Tripilaorites triangulatus* (Sah & Kar) Kar

63) *Tetracolporopollenites brevis* Frederiksen

PALAEOCLIMATE

The palynotaxa recovered from the Surat lignite deposits have been affiliated to thirteen plant families which thrive exclusively in tropical part of the world (Table 1). The presence of representatives of Bombacaceae, Convolvulaceae Ctenolophonaceae, Dracenaceae, Ebenaceae, Gonystylaceae, Gunneraceae, Olacaceae, Proteaceae, Rhizophoraceae, Sapindaceae, Sapotaceae and Sonneratiaceae in the assemblage suggests the prevalence of tropical climate during the deposition of the Surat lignite.

In addition to the pollen and spore indicators, fungal remains, especially the representative of the epiphyllous microthyriaceae, are also good indicators of palaeoclimate. For the growth of epiphyllous fungi, heavy rainfall is essential (Cookson, 1947; Selkirk, 1975; Reddy *et. al.*, 1982). The presence of many epiphyllous fungi in the assemblage (Samant and Tapaswi, ms) suggests heavy rainfall at the time of deposition of the lignite. Hence, there is a good evidence to suggest that

the area in which lignite is preserved, must have experienced humid tropical climatic conditions with plenty of rainfall.

PALAEOECOLOGY AND DEPOSITIONAL ENVIRONMENT

The palynoassemblage of the Surat Lignite can be grouped into the following ecological niches.

A) Fresh water aquatic members

Haloragacidites	Haloradidaceae
Polycolpites ornatus	Lentibulariaceae

B) Swamp and Water edge members

Laevigatosporites	Polypodiaceae
Polypodiisporites	-do-
Lygodiumsporites	Schizaeaceae
Schizaeoisporites	-do-
Triplanosporites	?Gleicheniaceae
Cryptopolyporites	Gonystylaceae
Intrareticulites	Gunneraceae
Ctenolophonidites	Ctenolophonaceae
Prectenolophonidites	-do-
Lakiapollis	Bombacaceae
Polycolpites	Pedaliaceae
Clavaperiporites	Linaceae
Perfotricolpites	Convolvulaceae
Meliapollis	Meliaceae

C) Thick Forest Members

Anacolosidites	Olacaceae
Psilatricolporites	Ebenaceae
Margocolporites	Caesalpinaceae
Iugopollis	Sapotaceae
Tetracolporopollenites	-do-
Cupanieidites	Sapindaceae
Pometiapollenites	-do-
Lanagiopollis	Alangiaceae
Incrotonipollis	Euphorbiaceae
Longapertites	Arecaceae
Arecipites	-do-
Clavapalmidites	-do-
Palmaepollenites	-do-

D) Montane Members

Dandotiaspora	?Matoniaceae
Proteacidites	Proteaceae

E) Mangrove and Back mangrove Members

Spinizonocolpites	Arecaceae (*Nypa*)
Paleosantalaceaepites	Rhizophoraceae

The palynotaxa of the Surat lignite deposits indicate that swamp and water edge elements viz. *Schizaesporites*, *Triplanosporites*, *Cryptopolyporites*, *Intrareticulites*, *Ctenolophonidites*, *Prectenolophonidites*, *Lakiapollis*, *Polycolpites*, and dense forest elements such as *Tetracolporopollenites*, *Palmaepollenites*, *Longapertites*, and *Arengapollenites* are the dominating members of the assemblage and the frequency of montane members is very low. The presence of mangrove members, e.g. *Spinizonocolpites* (*Nypa*) and *Paleosantalaceaepites* (Rhizophoraceae) in the assemblage is significant as they suggest marine influx in the basin. The occurrence of few grains of *Haloragacidites* and *Polycolpites ornatus* in the assemblage indicate fresh water influence at the time of deposition.

The palynotaxa recovered from these deposits have helped in assessing the depositional environment. The lowermost bed, i.e. fossiliferous grey clay (fig. 2) contains megafossils of fish otoliths and teeth (Samant and Bajpai, Ms) shells of bivalves (*Macoma safaedensis* and *Discors soriensis)* and gastropods *(Euspira soriensis)*. These megafossils collectively suggest the shallow marine environment. Among the palynotaxa, most significant is the presence of the mangrove pollen *Spinizonocolpites echinatus*, which is related to modern *Nypa*, is a typical palm of mangrove habitat. The presence of *Spinizonocolpites*, and *Paleosantalaceaepites* (yet another member of a mangrove family Rhizophoraceae), together with the megafossils,

Table 2: Stratigraphic range of some of the important pollen/spore taxa of the Surat lignite deposits.

Taxa	Paleocene	Eocene			Oligocene	Miocene
		L	M	U		
Ctenolophonidites costatus	———	———	———	———	———	———
Meliapollis ramanujamii	———	———	———	———	———	———
Lakiapollis ovatus	———	———	———	———		
Retitribrevicolporites matanomadhensis	———	———	———	———		
Polycolpites flavatus	———	———	———	———		
Proxapertites cursus	———	———	———	———		
Arecipites bellus	———	———	———	———		
Longapertites vaneedenburgii	———	———	———	———		
Proxapertites assamicus	———	———	———	———		
Retistephanocolpites williamsii	———	———	———	———		
Iugopollis tetraporites		———				
Anacolosidites trilobatus		———				
Cryptopolyporites cryptus		—				
Tripilaorites triangulatus		—				
Arengapollenites achinatus		—				
Angulocolporites microreticulatus		—				
Dermatobrevicolporites dermatus		—				

collectively indicate deltaic to shallow marine depositional environment.

The overlying gray clay with carbonaceous matter and lignite (fig. 2) contains typical swamp members such as *Durio (Lakiapollis), Ctenolophon (Ctenolophonidites)*, and *Gunnera (Intrareticulites)*. These palynomorphs suggest a change in depositional environment from deltaic to swampy. However, the overlying dark gray clay bed shows marked decrease in pollen and spore assemblage. This change could be attributed to the overflooding of the basin probably due to transgression of the sea. The overlying lignite bed is marked by sharp increase in population of pteridopytes and palms. Distinctly swamp dwellers such as *Durio (Lakiapollis)*, members of *Ctenolophon, Gunnera (Intrareticulites)* and *Gonystylus (Cryptopolyporites)* were also fairly well established especially in the upper part of the lignite The topmost lignite bed has also yielded the mangrove pollen *Palaeosantalaceaepites*. The basin experienced further change in the depositional environment from deltaic to shallow marine during the deposition of the uppermost fossiliferous gray clay sequence, as this bed contains shells of bivalves, gastropods (*Venericardia soriensis, Tetrastomella? pseudohumulis* and *Pyrenomitra anachis*), fish otoliths, teeth and depletion of pollen spore taxa. Overall microfloristic composition suggest shallow marine environment of deposition.

AGE OF THE SURAT LIGNITE

Palynological study indicates that the Surat lignite deposits contain palynomorphs which can be used in age determination. Some of the important palynotaxa recovered from these deposits with

known stratigraphic distribution in other Tertiary deposits of India, are shown in Table 2. The pollen grain species, *Anacolosidites trilobatus, Tripilorites triangulatus, Arengapollenites achinatus, Cryptopolyporites cryptus, Angulocolporites microreticulatus* and *Dermatobrevicolporites dermatus* collectively suggest the early Eocene age for the deposits.

Apart from the above described palynomorphs, gastropods such as *Euspira soriensis* and *Tetrastomella pseudohumulis* and bivalves species such as *Macoma safaedensis* and *Venericardia soriensis* suggest an age range of Ypresian to early Lutetian. (Eames, 1951, 1952). Overall pollen/spore assemblage as well as megafossils collectively suggest early Eocene age for the Surat lignite deposits.

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