Pteridophytes during the Tertiary period of south India as revealed by their characteristic sporomorphs

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The Tertiary deposits (subsurface and/or surface) of south India show 31 genera and 66 species of pteridophytic spores referable to Lycopodiaceae, Gleicheniaceae, Osmundaceae, Ophioglossaceae, Hymenophyllaceae, Schizaeaceae, Parkeriaceae, Pteridaceae, Cyatheaceae/Dicksoniaceae and Polypodiaceae. Both in numbers and diversity the pteridophytes were much more abundant during Neogene (Miocene) than in Palaeogene. Schizaeaceae and Polypodiaceae constitute the predominant families. *Schizaeoisporites* and *Polypodiisporites* are the best represented genera. However, *Lygodiumsporites, Crassoretitriletes, Neyvelisporites, Schizaeoisporites, Pteridacidites* and *Polypodiisporites* taken together, may be considered as characteristic of the Miocene palynoassemblages.

Key-words— Palynology, Pteridophytes, Tertiary, South India.

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साराँश

दक्षिण भारत के तृतीयक कल्प से लाक्षणिक बीजाणविकरूपकों द्वारा निरूपित टेरीडोफाइट

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दक्षिण भारत के तृतीयक युगीन निक्षेपों (उपसतही/सतही) से लाइकोपोडिएसी, ग्लाइकीनिएसी, ओस्मुन्डेसी, ओफिओग्लोसेसी, हाइमेनोफिल्लेसी, शाइजिएसी, पार्केरिएसी, टेरीडेसी, सियथिएसी/डिक्सोनिएसी एवं पोलिपोडिएसी नामक टेरीडोफाइटी कुलों की 31 प्रजातियाँ एवं 66 जातियाँ प्राप्त हुई हैं। पुरानूतन की अपेक्षा पश्चनूतन काल में टेरीडोफाइटी पौधे संख्या में अधिक एवं विभिन्नता से युक्त थे, शाइजिएसी एवं पोलिपोडिएसी पूर्वबाहुल्यता वाले कुल हैं। *शाइजिओस्पोराइटिस* एवं *पोलिपोडाइस्पोराइटिस* नामक वर्गकों का सबसे उत्तम निरूपण है। तथापि, *लाइगोडियमस्पोराइटिस, क्रेसोरेटिट्राइलिटीस, निवेलिस्पोराइटिस, शाइजिओस्पोराइटिस, क्रेसोरेटिट्राइलिटीस, निवेलिस्पोराइटिस, शाइजिओस्पोराइटिस* मध्य नूतन कालीन परागाणु समुच्चयों की लाक्षणिक प्रजातियाँ हैं।

PALYNOLOGICAL studies of the Tertiary sediments (subsurface and/or surface) of the Krishna-Godavari, Cauvery and Kerala basins in south India, made during the last four decades have brought to light an impressive array of pteridophytic spore types. Many of these sporomorphs are characteristic in their overall morphography and hence could reliably be affiliated with and referred to the modern families, and in some instances even of extant genera. The aim and objective of this paper is to collate and analyse the total pteridophytic spore complement documented to date from the Tertiary strata of the various basins of south India and to highlight the floristic and stratigraphic relevance of the myriad spore taxa. Data available from various published works along with the author's unpublished records are considered in this overview (Thiergart & Frantz, 1962; Ramanujam, 1960, 1966, 1966-67, 1972, 1987; Rao & Ramanujam, 1978, 1982; Ramanujam & Reddy, 1984; Ramanujam, Srisailam & Reddy, 1981; Ramanujam, Sarma & Reddy, 1984; Ramanujam *et al.*, 1991; Ramanujam, Rao & Reddy, 1991; Rao, Reddy & Ramanujam, 1992-93; Ramanujam, Ramakrishna & Mallesham, 1985, 1986; Rao, 1990; Raha, Rajendran & Kar, 1987; Sarma & Ramanujam, 1988; Rajendran, Raha & Kar, 1989; Venkatachala & Rawat, 1972, 1973; Kar & Jain, 1981; Venkatachala & Sharma, 1984; Varma, Ramanujam & Patil, 1986; Singh *et al.*, 1992). Recently, Kar (1993) provided a brief conspectus of the geological history of some Tertiary pteridophytes with particular reference to North-East India and recognized two discrete associations, viz., *Lycopodiumsporites-Dandotiaspora* of the Palaeocene and Polypodiaceae-*Ceratopteris* of the Oligocene-Miocene.

ANALYSIS OF PTERIDOPHYTIC SPORES

Thirty one genera of sporomorphs comprising 66 species (Table 1) have been recorded so far from the Tertiary sequence of the Krishna-Godavari, Cauvery and Kerala basins of south India (all such spore types either described or illustrated from the sub-surface and surface deposits are considered in this study).

Table 1—Distribution of pteridophytic spores in south Indian Tertiary deposits

Genera/Species	KG Basin	C Basin	K Basin
Lycopodiumsporites bellus	-	+	+
L. austroclavatidites	+	+	+
L. perplexus	-	-	+
L. speciosus	-	-	+
L. eocenicus	-	+	-
L. cuddalorensis	-	+	-
Verrucosisporites dakshinense	-	-	+
Camarozonosporites sp.	-	+	-
Gleicheniidites neyvelii	-	+	-
G. senonicus	+	+	+
Osmundacidites kutchensis	-	-	+
Osmundacidites sp.	-	+	-
Todisporites kutchensis	-	+	-
T. major	-	+	+
Foveosporites miocenicus	-	-	+
Foveosporites sp.	+	+	-
Lygodiumsporites padappakkarensis	+	+	+
L. lakiensis	-	-	+
Crassoretitriletes vanraadshooveni	+	+	+
C. ornatus	-	-	+
Intrabaculisporis quilonensis	-	-	+
Neyvelisporites bolkhovitinai	+	+	+
N. cooksonii	+	+	+
Schizaeoisporites digitatoides	+	+	+
S. goshi	-	+	-
S. minimus	-	+	+
S. sinuata	-	+	-
S. multistriatus	-	+	+
S. perforatus	-	+	-
S. phaseolus	+	+	+
S. grandistriatus	-	+	+
S. grandiformis	-	+	+
Hymenophyllumsporites raoi	-	+	-
Pteridacidites triangulatus	+	+	+
P. africanus	-	-	+
P. rotundus	+	-	+
P. sahii	+	+	+
P. congoensis	+	+	-
Striatriletes susannae	-	-	+
S. cauveriensis	+	+	-
S. howardii	+	+	-
Striatriletes sp.	-	+	+
Cyathidites australis	+	+	-
C. minor	-	-	+
Laevigatosporites ovatus	+	+	+
L. gracilis	-	+	-
L. arcotensis	+	+	+
Polypodiisporites ratnamii	+	+	+
P. magniverrucosus	-	+	-
P. delicatissimus	-	+	-
P. usmensis	-	+	+
P. multiverrucosus	-	+	+
P. ornatus	+	-	+
P. miocenicus	+	+	+
P. impariter	+	+	+
P. perverrucatus	+	+	+
P. repandus	-	-	+
P. turbinatus	-	-	+
Polypodiaceaesporites chatterjii	-	-	+
Verrucatosporites sparsus	-	+	-
V. bullatus	-	+	-
Seniasporites sp.	-	-	+
Microfoveolatosporis polyaperturata	-	+	+
Eximospora sparsus	-	-	+
Foveotriletes bifurcatus	-	-	+
Cingulatisporites sinuatus	+	-	+
Trilites scabratus	-	+	-
T. perverrucatus	-	+	-
Cyatheacidites pulcher	-	-	+
Biretisporites scabratus	+	+	+
Dictyophyllidites sp.	-	-	+
Cheilanthoidspora miocenica	-	-	+
Dandotiaspora sp.	-	-	+

contd.

KG basin : Krishna-Godavari Basin
C basin : Cauvery Basin
K basin : Kerala Basin
\+ : Present
\- : Absent

Table 2—Fossil pteridophytic spores referable to modern taxa

Fossil sporomorph	Affinities with modern taxa
Lycopodiumsporites	Lycopodiaceae (*Lycopodium*)
Verrucosisporites	Lycopodiaceae (*Lycopodium*)
Camarozonosporites	Lycopodiaceae (*Lycopodium*)
Gleicheniidites	Gleicheniaceae (*Gleichenia*)
Osmundacidites	Osmundaceae (*Osmunda*)
Todisporites	Osmundaceae
Foveosporites	Ophioglossaceae (*ophioglossum*)
Lygodiumsporites	Schizaeaceae (*Lygodium*)
Crassoretitriletes	Schizaeaceae (*Lygodium*)
Intrabaculisporis	Schizaeaceae
Neyvelisporites	Schizaeaceae (*Schizaea*)
Schizaeoisporites	Schizaeaceae (*Schizaea*)
Hymenophyllumsporites	Hymenophyllaceae
Pteridacidites	Pteridaceae (*Pteris*)
Striatriletes	Parkeriaceae (*Ceratopteris*)
Cyathidites	Cyatheaceae/Dicksoniaceae
Laevigatosporites	Polypodiaceae
Polypodiaceaesporites	Polypodiaceae
Polypodiisporites	Polypodiaceae (*Polypodium*)
Verrucatosporites	Polypodiaceae (*Polypodium*)
Seniasporites	Polypodiaceae

The Kerala Basin with 27 genera and 47 species has the maximum number of taxa followed by the Cauvery Basin with 20 genera and 45 species and Krishna-Godavari with 14 genera and 24 species. There is a greater degree of similarity between the Kerala and Cauvery basins with 17 genera (54.6%) and 24 species (36.9%) common to both. When all the three basins are considered together 13 genera (41.9%) and 16 species (24.2%) are common. Age-wise breakdown shows that, of the total complement of 31 spore types, only 10 have been recorded to-date from the Palaeocene-Eocene sediments. These are *Lycopodiumsporites, Gleicheniidites, Cingulatisporites, Cyathidites, Schizaeoisporites, Cheilanthoidspora, Laevigatosporites, Verrucatosporites, Seniasporites* and *Microfoveolatosporis.*

On the basis of the diagnostic features of morphography, 21 genera could be affiliated with the reliably referred to the modern taxa, viz., Lycopodiaceae (*Lycopodium*), Gleicheniaceae (*Gleichenia*), Osmundaceae (*Osmunda*), Ophioglossaceae (*Ophioglossum*), Hymenophyllaceae, Schizaeaceae (*Lygodium, Schizaea*), Parkeriaceae (*Ceratopteris*), Cyatheaceae/Dicksoniaceae, Pteridaceae (*Pteris*), and Polypodiaceae (*Polypodium*) — see (Table 2). Of these, Schizaeaceae and Polypodiaceae constitute the predominant families in all the three basins. Pteridaceae is fairly represented and may be considered as a characteristic marker of the Neogene deposits. Lycopodiaceae is poorly encountered in the Krishna-Godavari Basin but fairly recorded, particularly by species of *Lycopodiumsporites* in the Neogene of the Cauvery of Kerala basins. Gleicheniaceae, Osmundaceae, Ophioglossaceae, Hymenophyllaceae and Cyatheaceae/Dicksoniaceae have been meagrely reported in the Tertiary of south India. The characteristic spores of Parkeriaceae, viz., *Striatriletes* referable to *Ceratopteris* have been unearthed so far only from the Miocene sediments in south India, and that too in limited numbers, unlike the Northeastern and western parts of the country where they attained predominance during Oligocene-Miocene (Kar, 1984, 1985, 1993).

Dandotiaspora, a characteristic marker for the Palaeocene- Eocene in various parts of India (Sah, Kar & Singh, 1971) has been documented only from the subsurface Eocene of Kerala (Raha, Rajendran & Kar, 1986, 1987). It is relevant to mention that the *Dandotiaspora* recorded from the clay horizon underlying the lignite at Neyveli is quite different from the typical Palaeogene species of this spore type (Singh *et al.*, 1992) and *D. plicata* from the Miocene beds of Kerala Basin represents a reworked fossil (Rajendran, Raha & Kar, 1989).

The Schizaeaceae is represented by five genera, viz., *Lygodiumsporites, Crassoretitriletes, Intrabaculisporis, Neyvelisporites* and *Schizaeoisporites.* The last two are monoletes and the rest are triletes. The exact relationships of *Intrabaculisporis* are not yet deciphered. It resembles, however, the spores of some species of *Lygodium.* The other four fossil spore taxa show remarkable resemblance with the spore types of the extant *Lygodium* (*Lygodiumsporites* and *Schizaeoisporites*). *Crassoretitriletes* is a consistant marker for the South Indian Neogene deposits. A recent analysis brought to light that Schizaeaceae enjoyed better representation during the Jurassic- Early Cretaceous than in the Tertiary (Ramanujam, Varma & Reddy, 1993). A comparison

with the Tertiary palynoassemblages of North-eastern and western parts of India highlights that Schizaeaceae is best represented both qualitatively and quantitatively in the Tertiary (Neogene especially) sediments of south India than elsewhere.

Both *Lygodium* and *Schizaea* show restricted distribution in south India. The former is seen in parts of Tamil Nadu, Kerala and Andhra Pradesh, while the latter is confined to the Palghat area in Kerala. However, both *Lygodium* and *Schizaea* were the components of the Neogene pteridophytes of all the three southern states. *Lygodium* is a tropical creeping shade-loving fern preferring thickets and forest edges, whereas *Schizaea* is cosmopolitan and inhabits mineral-poor and more or less swampy open areas (Kubitzki, 1990).

The Polypodiaceae also shows both monolete and trilete spores. The South Indian Tertiary deposits yielded more or less exclusively the monolete spore types which are bean-shaped, concavo-convex and either psilate (*Laevigatosporites, Polypodiaceaesporites*) or variously and often differentially sculptured with verrucae, tubericles, coni, etc. (*Polypodiisporites, Verrucatosporites, Seniasporites*). Though encountered in the Paleogene, *Polypodiisporites* attained predominance numerically and distributionally during the Miocene. The best representation of this taxon is in the Miocene deposits of the Kerala Basin. *Seniasporites,* a Palaeocene spore-type from the Laki Series of Kutch in Gujarat (Sah & Kar, 1969), has been recorded in south India only from the sub-surface Palaeocene-Eocene of Kerala (Raha, Rajendran and Kar, 1987). The verrucate sporomorphs of *Polypodiisporites* show similarities with the spore of some species of *Polypodium* (Santha Devi, 1977).

The exact affinities of the following sporomorphs, viz., *Microfoveolatosporis, Eximospora, Foveotriletes, Cingulatisporites, Trilites, Cyatheacidites, Biretisporites, Dictyophyllidites, Cheilanthoidspora* and *Dandotiaspora* are not yet known. The possibility that many of these may have been derived from some Fern families, however, cannot be ruled out.

GENERAL REMARKS

The pteridophytic sporomorphs are generally poorly represented in the Tertiary sediments of south India. When the total complement of the Tertiary palynofloras is considered, the pteridophytes constitute only 15-20 per cent. Numerically as well as diversity-wise the pteridophytes were much more abundant in Neogene than in Paleogene. The families encountered consistently in reasonably frequency in the Krishna-Godavari, Cauvery and Kerala basins are Schizaeaceae, Pteridaceae and Polypodiaceae. Of these, Schizaeaceae and Polypodiaceae, however, are best represented. All these three families enjoy extensive distribution predominantly in the tropics and contribute to the undergrowth of the dense moist forests (Kubitzki, 1990).

Lygodiumsporites, Crassoretitriletes, Neyvelisporites, Schizaeoisporites, Pteridacidites and *Polypodiisporites* taken together may be considered as characteristic of the Miocene palynoassemblages. *Schizaeoisporites* and *Polypodiisporites* show the maximum number of species and high degree of morphographic diversity.

Of the two dominant Indian Palaeocene taxa, *Lycopodiumsporites* and *Dandotiaspora* (Kar, 1993), the former is poorly recorded and the latter is altogether lacking in the south Indian Palaeocene strata. Similarly, Parkeriaceae as represented by *Striatriletes,* an abundant taxon of the Oligocene-Miocene of the western and North-eastern India, is only occasionally encountered in the south Indian Miocene. Schizaeaceae is a predominant taxon of the Miocene palynofloras of south India in contradiction to its poor status in other regions of India. Polypodiaceae, however, maintained its prominent position uniformly in all the Oligocene-Miocene palynofloras of India.

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