Neyveli lignites and associated sediments—their palynology, palaeoecology, correlation and age

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The Neyveli Formation is a subsurface stratigraphic unit, containing thick workable lignite deposits at its top, and is unconformably overlain by the Cuddalore Formation. The age of the lignite has remained a subject of controversy and therefore effort has been made here to date it by means of palynological evidence. Rich palynofloras have been recorded from the Neyveli Formation encountered in the Neyveli Mines-I and II in South Arcot District and Jayamkondacholapuram well-12 in Tiruchirapalli District, Tamil Nadu. These assemblages contain pteridophytic spores, angiospermous pollen and algal and fungal remains with angiospermous pollen being predominant. Based on the present day distribution and habitat of the families represented, a tropical climate with plenty of rainfall has been inferred during the sedimentation of the Neyveli Formation. The environment of deposition for these sediments has been deduced as coastal, ranging from back mangrove to mangrove, with a short transgressive phase before the deposition of lignite. The Neyveli Formation is divisible into three biozones, viz., *Neocouperipollis* spp. Cenozone, *Triangulorites bellus* Cenozone, and *Trilatiporites sellingii* Cenozone. These are identifiable by their characteristic significant and restricted palynotaxa and correlatable with the Late Palaeocene to Middle Eocene biozones of Kutch, Rajasthan, Bengal Basin, Garo, Khasi and Jaintia Hills of Meghalaya and Cauvery Basin. A Late Palaeocene to Middle Eocene age has therefore been assigned to the Neyveli Formation.

Key-words—Palynology, Palaeoecology, Correlation, Neyveli lignites, India.

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सारांश

निवेली लगुड़ांगार तथा सहयुक्त अवसादः परागाणविक अध्ययन, पुरापारिस्थितिकी, सहसम्बन्धन एवं आयु

रमेश कुमार सक्सेना

निवेली शैल-समूह एक उपसतही स्तरिक इकाई है जिसके ऊपर मोटे लगुड़ांगार निक्षेप विद्यमान हैं। ये शैल-समूह कुडलोर शैल-समूह के ऊपर असम्बद्ध रूप से विद्यमान हैं। इन लगुड़ांगारों की आयु विवादास्पद रही है अतःएव इस शोध-पत्र में परागाणविक प्रमाणों के आधार पर इन्हें कालनिर्धारित करने का प्रयास किया गया है। तमिलनाडु में तिरुचिरापल्ली जनपद में जयमकोंडाचोलापुरम कुआँ-12 तथा दक्षिण आरकोट जनपद में निवेली खान-प्रथम एवं द्वितीय में विद्यमान निवेली शैल-समूह से सघन परागाणुवनस्पतिजात उपलब्ध हुआ है। इन समुच्चयों में टेरीडोफाइटी बीजाणु, आवृतबीजी परागकण तथा शैवालीय एवं कवकीय अवशेष विद्यमान हैं। विभिन्न कुलों के वर्तमान वितरण के आधार पर अवसादन के समय अधिक वर्षा के साथ-साथ उष्णकटिबन्धीय जलवायु का होना सुनिश्चित किया गया है। ये अवसाद तटीय तथा मैंग्रोवी वातावरण में निक्षेपित हुए हैं तथा निक्षेपण से पहले कुछ धंसाव जैसी अवस्था विकसित हो गई थी। निवेली शैल-समूह तीन जैवमंडलों–(अ) निओकाउपरिपॉलिस जाति नवमंडल, (आ) ट्राइएंगुलोराइटिस बेल्लस नवमंडल, तथा (ई) ट्राइलेटिपोराइटिस सेलिंगाई नवमंडल में विभक्त किया गया है। ये सभी अपने लाक्षणिक वर्गकों के आधार पर पहचाने जा सकते हैं तथा कच्छ, राजस्थान, बंगाल द्रोणी एवं मेघालय की गारो, खासी और जयन्तिया पहाड़ियों तथा कावेरी द्रोणी के अर्नतिम पुरानूतन से मध्य आदिनूतन जैवमंडलों से तुलनीय हैं अतः निवेली शैल-समूह की अर्नतिम पुरानूतन से मध्य आदिनूतन आयु प्रस्तावित की गई है।

THE lignite deposits of Tamil Nadu, mined around Neyveli, are popularly known as Neyveli lignites. These deposits constitute the largest lignite reserve of India and have been able to attract attention of geologists, mining engineers, palaeobotanists and palynologists since last over fifty years. Till recently, the lignite was considered to be a part of the Cuddalore Formation. However, Siddhanta (1986) divided the Cuddalore Formation into two parts and named the lower part, which includes lignite, as the Neyveli Formation and retained the term Cuddalore

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Formation for the upper part.

The Neyveli Formation (over 300 m thick) is a subsurface lithostratigraphic unit and consists of semiconsolidated sandstone and clay beds with occasional limestone intercalations followed by carbonaceous clay (about 1 m thick) and brownish black lignite (up to 23 m thick). It is overlain by the Cuddalore Formation (60 to 120 m thick) which is made up of ferruginous, arkosic, semiconsolidated sandstone exhibiting some herringbone type cross laminations. The contact between the two formations is marked by an erosional unconformity (Siddhanta, 1986, p. 63).

The geology and ground water aspects of the Neyveli Formation have been studied by Krishnan (1949), Balasunder (1968), Subramanyam (1969), Gowrisankaran *et al.* (1987), etc. The lignite and underlying clay bands are rich in palynofossils and a number of papers have been published on their study (Navale, 1962; Thiergart & Frantz, 1963; Ramanujam, 1963, 1966a, b, 1967, 1982; Ramanujam & Ramachar, 1963, 1980; Deb, 1972; Deb *et al.*, 1973; Venkatachala, 1973; Navale & Misra, 1979; Ambwani *et al.*, 1981; Bande & Ambwani, 1982; Reddy *et al.*, 1982, 1984; Ambwani, 1983; Ramanujam & Reddy, 1984; Sarma *et al.*, 1984; Saxena, 1984; Ramanujam *et al.*, 1984, 1985, 1988; Siddhanta, 1986; Sarma & Ramanujam, 1988; Sarma & Reddy, 1988; Singh & Misra, 1991a, b, c). However, most of the above studies are largely confined to the description of palynofloras and their interpretation for inferring palaeoclimate and environment of deposition with no or little stratigraphic consideration, particularly regarding age and correlation of the lignite deposits.

The age of the Neyveli lignites (belonging to the Neyveli Formation) has remained a subject of dispute. Till 1973, these deposits were believed to be of Miocene age. However, Venkatachala (1973), Deb *et al.* (1973) and Siddhanta (1986) on the basis of palynological and geological evidences inferred a Palaeocene-Eocene age. The possibility of these deposits being time-transgressive, ranging in age from Eocene to Miocene, has also been suggested. The controversy regarding the age of lignite appears mainly due to lack of studies from measured stratigraphic sections. Siddhanta (1986) recognized four palynoassemblages from: (i) carbonaceous clay (just underlying the lignite), (ii) basal lignite (0-1.5 m), (iii) middle lignite (1.5-15 m), and (iv) top lignite (15-23 m). The main objectives of the present paper are, therefore, to attempt dating of the lignite deposits on the basis of palynofossils and their correlation with the contemporary stratigraphic units and also to infer palaeoclimate and environment of deposition.

The palynological study on the Neyveli lignites has so far been done only on the material collected from the Neyveli Mines-I and II in South Arcot District, Tamil Nadu. This paper is based on the published palynological information from these mines as well as author's own palynological study on the Neyveli Formation of Neyveli Mines-I and II and also of Jayamkondacholapuram well-12 in Tiruchirapalli District, Tamil Nadu (Text-figure 1).

PALYNOLOGY

Rich palynofloral assemblages have been recovered from the Neyveli Formation of Néyveli Mines-I and II and Jayamkondacholapuram well-12. The assemblages consist of algal and fungal remains, pteridophytic spores and angiospermous pollen. Detailed description of these assemblages would be beyond the scope of the present paper. However, a list of palynotaxa recovered is given below.

Pteridophytic spores—Cyathidites australis Couper, *Garotriletes assamicus* Singh & Singh, *Gemmatriletes* sp., *Gleicheniidites* sp., *Intrapunctisporis gigantica* Kar & Kumar, *Intrapunctisporis* sp., *Laevigatosporites lakiensis* Sah & Kar, *L. tertiarus* (Dutta & Sah) Saxena & Khare, *L. variabilis* Saxena & Khare, *Lygodiumsporites eocenicus* Dutta & Sah, *L. lakiensis* Sah & Kar, *Neyvelisporites bolkhovitinae* (Ramanujam) Ramanujam, *N. cooksoniae* (Ramanujam) Ramanujam, *Osmundacidites* sp., *Polypodiisporonites mawkmaensis* (Dutta & Sah) Mathur & Chopra, *P. repandus* (Takahashi) Saxena & Khare, *Polypodiisporonites* sp., *Schizaeoisporites crassimurus* Dutta & Sah, *S. digitatoides* (Cookson) Potonié, *S. ghoshii* Ramanujam, *S. minimus* Ramanujam, *S. multistriatus* Rao & Ramanujam, *S. ramanujamii* Saxena & Khare, *S. sinuta* Ramanujam, *Seniasporites verrucosus* Sah & Kar, *Todisporites kutchensis* Sah & Kar and *T. major* Couper.

Angiospermous pollen—Acanthotricolpites brevispinosus Saxena & Khare, *A. microreticulatus* Saxena & Khare, *A. neyveliensis* Saxena & Khare, *A. robustus* Saxena & Khare, *A. tiruchirapalliensis* Saxena & Khare, cf. *Acanthotricolpites* sp., *Alangiopollis* sp., *Araliaceoipollenites matanomadhensis* Venkatachala & Kar, *Arecipites bellus* Sah & Kar, *A. punctatus* Wodehouse, *Arengapollenites achinatus* Kar, *Assamiapollenites* sp., *Bacutricolporites neyveliensis* Saxena & Khare, *B. triangulus* Saxena & Khare, *Clavaperiporites jacobii* Ramanujam, *Clavatricolporites leticiae* Leidelmeyer, *Cryptopolyporites* spp. 1 and 2, *Ctenolophonidites costatus* (von Hoeken Klinkenberg) von Hoeken Klinkenberg, *C. erdtmanii* Ramanujam & Rao, *C.*

ramanujamii Saxena & Khare, *C. saadii* Ramanujam & Rao, *C. stellatus* Navale & Misra, *Ctenolophonidites* sp., *Dracaenoipollis* sp., *Droseridites parvus* Dutta & Sah, *Echimonoporopollis grandiporus* Saxena *et al.*, *E. neyveliensis* Saxena *et al.*, *Echitricolporites* sp., *Ericipites sahnii* Ramanujam, *Foveotricolpites* sp., *Gemmamonocolpites* sp., *Gemmatriporopollis triangulus* Saxena & Khare, *Granustephanocolpites* sp., *Hippocrateaceaedites vancampoae* Ramanujam, *Incrotonipollis neyveliensis* (Baksi *et al.*) Jansonius & Hills, *Jacobipollenites magnificus* Ramanujam, *Lakiapollis ovatus* Venkatachala & Kar, *Longapertites cuddalorense* Ramanujam, *Margocolporites complexum* Ramanujam, *M. ghoshii* (Ramanujam) Saxena & Khare, *M. oligobrochatus* Ramanujam, *M. perforatus* Saxena & Khare, *M. siddhantae* Saxena & Khare, *M. sitholeyi* Ramanujam, *M. tsukadae* Ramanujam, *Margocolporites* spp. 1 and 2, cf. *Margocolporites* sp., *Matanomadhiasulcites kutchensis* (Saxena) Kar, *M. major* (Singh) Saxena & Khare, *M. ramanujamii* Saxena & Khare, *Meliapollis gratus* Saxena & Khare, *M. iratus* (Sah & Kar) Navale & Misra, *M. melioides* (Ramanujam) Sah & Kar, *M. navalei* Sah & Kar, *M. quadrangularis* (Ramanujam) Sah & Kar, *M. ramanujamii* Sah & Kar, *M. raoi* Sah & Kar, *M. venkatachalae* Saxena & Khare, *Meliapollis* sp., *Myricipites singhii* Saxena & Khare, *Myricipites* sp., *Neocouperipollis achinatus* (Sah & Kar) Kar & Kumar, *N. brevispinosus* (Biswas) Sarkar & Singh, *N. cymbatus* (Venkatachala & Rawat) Saxena & Khare, *N. donaensis* (Rao *et al.*) Saxena & Khare, *N. kutchensis* (Venkatachala & Kar) Kar & Kumar, *N. rarispinosus* (Sah & Dutta) Singh, *N. robustus* (Saxena) Saxena & Khare, *N. wodehousei* (Biswas) Saxena & Khare, *Neyveliapites indicus* Saxena & Khare, *Paleosantalaceaepites minutus* Sah & Kar, *Palmaepollenites plicatus* Sah & Kar, *Palmidites maximus* Couper, *P. naviculus* Kar & Saxena, *P. plicatus* Singh, *Pellicieroipollis langenheimii* Sah & Kar, *Periretitricolpites* sp., *Polybrevicolpites neyvelii* Saxena & Khare, *Polybrevicolporites punctatus* Saxena & Khare, *Polybrevicolporites* sp., *Proxapertites assamicus* (Sah & Dutta) Singh, *P. microreticulatus* Jain *et al.*, *Proxapertites* sp., *Pseudonothofagidites cerebrus* Venkatachala & Kar, *P. septaporatus* Saxena & Khare, *Psilastephanocolpites quadrangularis* Saxena & Khare, *Psilatricolporites* sp., *Retimonosulcites ovatus* (Sah & Kar) Kar, *Retipilonapites arcotense* Ramanujam, *R. delicatissimus* Ramanujam, *Retipollenites laevigatus* Saxena & Khare, *R. neyveliensis* Saxena & Khare, *Retistephanocolpites angeli* Leidelmeyer, *Retitrescolpites decipiens* Sah, *R. neyveliensis* Saxena & Khare, *R. oblongus* Sah, *Retitricolpites* spp. 1 and 2, *Retitricolporites minor* Saxena & Khare, *R. perforatus* Saxena & Khare, *Retitricolporites* spp. 1 and 2, *Spinainaperturites conatus* Venkatachala & Rawat, *S. densispinus* Venkatachala & Rawat, *Spinainaperturites* sp., *Spinizonocolpites echinatus* Muller, *S. neyveliensis* Saxena & Khare, *Stephanoporopollenites duttae* Saxena & Khare, *Tetrapollis* sp., *Thomsonipollis sahii* Saxena & Khare, *Thomsonipollis* sp., *Triangulorites bellus* Kar, *Triangulorites* sp., *Tricolpites crassireticulatus* Dutta & Sah, *T. matanomadhensis* Saxena, *T. minutus* Sah & Kar, *T. retibaculatus* Saxena, *T. reticulatus* Cookson, *Tricolpites* sp. cf. *T. crassireticulatus* Dutta & Sah, *Tricolpites* sp. cf. *T. margocolpites* Venkatachala & Rawat, *Tricolporopollis matanomadhensis* (Venkatachala & Kar) Tripathi & Singh, *T. rubra* Dutta & Sah, *Tricolporopollis* sp., *Trilatiporites erdtmanii* Ramanujam, *T. noremii* Ramanujam, *T. sellingii* Ramanujam, *Triporopollenites parvus* Sah, *T. tamilensis* Saxena & Khare, *Triporotetradites singhii* Saxena & Khare, cf. *Verrucolporites* sp., *Verrutricolpites* sp., and *Warkallipollenites reticulatus* Saxena & Khare.

Besides the above spore/pollen taxa, the assemblage also contains algal spores (2 genera & 2 species) and fungal remains (13 genera & 26 species). Because of their limited stratigraphical and palaeoecological significance, they are not listed here.

PALAEOCLIMATE AND ENVIRONMENT OF DEPOSITION

Analysis of the Neyveli palynoflora provides some information regarding palaeoclimate and depositional environment which prevailed during the sedimentation of the Neyveli Formation. It is generally an accepted fact that the environmental requirements of the past plants had been the same as of their present day equivalents. The present day distribution of the extant plants therefore plays a key role in inferring palaeoclimate and depositional environment. A list of palynotaxa and their probable affinities and present day distribution is given in Table 1 which shows that majority of the families represented in the Neyveli palynoflora have their present day distribution in tropical (subtropical) regions. These families are: Schizaeaceae, Cyatheaceae, Gleicheniaceae, Arecaceae, Meliaceae, Rhizophoraceae, Bombacaceae, Araliaceae, Ctenolophonaceae, Alangiaceae, Rubiaceae, Caesalpiniaceae, Sapotaceae and Hippocrateaceae. Other families represented in the palynoflora are cosmopolitan in distribution and none of them is restricted to temperate (or even subtemperate) regions. Typical rain-forest elements, viz.,

Table 1—Botanical affinities of the palynofossils from the Neyveli Formation and present day distribution of their extant counterparts

FAMILIES	PALYNOTAXA	PRESENT DAY DISTRIBUTION
Cyatheaceae	*Cyathidites australis*	Tropical-subtropical
Osmundaceae	*Osmundacidites* sp., *Todisporites kutchensis, T major, Intrapunctisporis gigantica, Intrapunctisporis* sp.	Cosmopolitan (shady places or swamps)
Polypodiaceae	*Polypodiisporonites repandus, P. mawkmaensis, Polypodiisporonites* sp., *Laevigatosporites lakiensis, L. tertiarus, L. variabilis, Seniasporites verrucosus*	Cosmopolitan
Gleicheniaceae	*Gleicheniidites* sp.	Tropical-subtropical
Schizaeaceae	*Schizaeoisporites digitatoides, S. ramanujamii, S. ghoshii, S. multistriatus, S. minimus, S. sinuta, Lygodiumsporites lakiensis, L. eocenicus, Neyvelisporites bolkhovitinae, N. cooksoniae*	Tropical-subtropical
Arecaceae	*Neocouperipollis wodehousei, N. brevispinosus, N. achinatus, N. cymbatus, N. rarispinosus, N. kutchensis, N. robustus, N. donaensis, Arecipites punctatus, A. bellus, Arengapollenites achinatus, Spinainaperturites conatus, S. densispinus, Spinainaperturites* sp., *Proxapertites assamicus, P. microreticulatus, Proxapertites* sp., *Trilatiporites sellingii, T erdtmanii, T noremii, Spinizonocolpites echinatus, S. neyveliensis, Echimonoporopollis grandiporus, E. neyveliensis, Acanthotricolpites brevispinosus, A. microreticulatus, A. neyveliensis, A. tiruchirapalliensis, A. robustus,* cf. *Acanthotricolpites* sp., *Palmidites maximus, P. naviculus, P. plicatus, Palmaepollenites plicatus*	Tropical-subtropical
Potamogetonaceae	*Retipilonapites arcotense, Assamiapollenites* sp.	Cosmopolitan (aquatic)
Liliaceae	*Matanomadhiasulcites kutchensis, M. major, Dracaenoipollis* sp.	Cosmopolitan
Meliaceae	*Meliapollis ramanujamii, M. navalei, M. iratus, M. raoi, M. quadrangularis, M. gratus, M. melioides, M. venkatachalae, Meliapollis* sp.	Tropical-subtropical
Brassicaceae	*Tricolpites minutus*	Cosmopolitan (grows in diverse situations)
Gunneraceae	*Tricolpites reticulatus*	Cosmopolitan
Araliaceae	*Araliaceoipollenites matanomadhensis*	Tropical-subtropical
Oleaceae	*Retitrescolpites decipiens, Tricolpites crassireticulatus, T. retibaculatus*	Cosmopolitan (chiefly tropical)
Rubiaceae	*Retitricolporites minor, Retitricolporites* sp.	Tropical-subtropical
Caesalpiniaceae	*Margocolporites tsukadae, M. sitholeyi, M. oligobrochatus, M. ghoshii, Margocolporites* sp.	Tropical-subtropical
Bombacaceae	*Lakiapollis ovatus, Tricolporopollis rubra, T. matanomadhensis*	Tropical-subtropical
Rhizophoraceae	*Paleosantalaceaepites minutus*	Tropical-subtropical
Sapotaceae	*Thomsonipollis* sp.	Tropical-subtropical
Myricaceae	*Myricipites* sp.	Cosmopolitan
Alangiaceae	*Pellicieroipollis langenheimii, Alangiopollis* sp.	Tropical-subtropical
Ericaceae	*Ericipites sahnii*	Cosmopolitan
Hippocrateaceae	*Hippocrateaceaedites vancampoae*	Tropical-subtropical
Betulaceae	*Triporopollenites parvus, T. tamilensis*	Cosmopolitan
Ctenolophonaceae	*Ctenolophonidites saadii, C. costatus, C. erdtmanii, C. ramanujamii, C. stellatus, Ctenolophonidites* sp.	Tropical-subtropical
Onagraceae	*Triangulorites bellus, Triangulorites* sp.	Cosmopolitan
Plumbaginaceae	*Warkallipollenites reticulatus*	Tropical-subtropical
Thymeliaceae	*Clavaperiporites jacobii*	Cosmopolitan (absent in extremely cold region)

Alangiaceae and Ctenolophonaceae and a good number of pteridophytic spores clearly point out towards a tropical climate with plenty of rainfall. This contention is further supported by profuse occurrence of a variety of epiphyllous microthyriaceous fungi and fungal spores.

The palynotaxa recorded from the Neyveli Formation are referable to the floral elements of diverse ecology, viz., (i) upland, (ii) fresh water swamps and water edge, (iii) back mangrove, (iv) mangrove, and (v) sand dune and beach (Table 2).

Table 2—Ecological expression of the palynofossils from the Neyveli Formation

ECOLOGICAL GROUPS	PALYNOTAXA
Upland elements	*Hippocrateaceaedites, Retitricolporites, Ericipites*
Fresh water swamps and water edge elements	*Schizaeoisporites, Polypodiisporonites, Laevigatosporites, Meliapollis, Ctenolophonidites, Margocolporites, Retipilonapites, Matanomadhiasulcites*
Back mangrove elements	*Meliapollis, Alangiopollis, Araliaceoipollenites*
Mangrove elements	*Paleosantalaceaepites, Warkallipollenites*
Sand dune and beach elements	*Palmaepollenites, Arecipites, Longapertites, Spinizonocolpites*

The lower part of the Neyveli Formation, represented by *Neocouperipollis* spp. Cenozone, is very rich in arecaceous pollen belonging to sand dune and beach floral elements which suggest a coastal environment slightly away from the storm-tide zone. The overlying part of the sequence, represented by *Triangulorites bellus* Cenozone, contains a mixture of upland, fresh water swamps and water edge, mangrove, back mangrove and only a few sand dune and beach elements. Such composition indicates deposition in mangrove swamps with local pockets of marine influence and sufficient fresh water supply. The overlying *Trilatiporites sellingii* Cenozone, comprising lignite part of the sequence, contains upland, fresh water swamps and water edge, back mangrove and sand dune and beach elements. This indicates deposition of lignite in back mangrove conditions. It may therefore be concluded that the Neyveli Formation was deposited in coastal environment, ranging from back mangrove to mangrove, with a short transgressive phase just before the deposition of lignite.

BIOSTRATIGRAPHIC ZONATION

Based on first and last appearance of palynotaxa and their maximum development, decline, restricted occurrence and absence, the Neyveli Formation has been divided into three biozones. In ascending order, these are: (i) *Neocouperipollis* spp. Cenozone, (ii) *Triangulorites bellus* Cenozone, and (iii) *Trilatiporites sellingii* Cenozone. A brief account of these biozones is given below.

Neocouperipollis spp. Cenozone

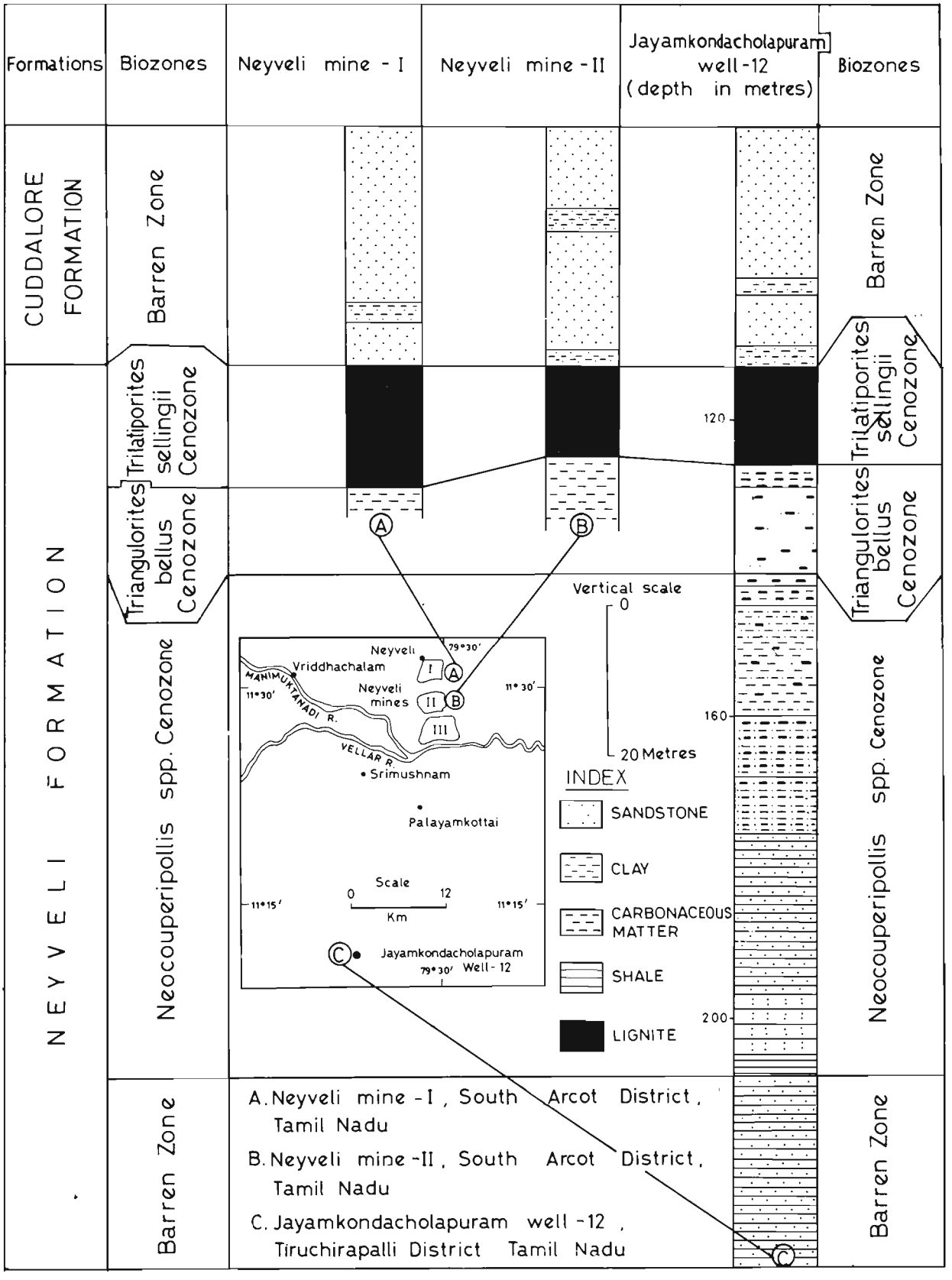
This biozone is designated in the Jayamkondacholapuram well-12 in Tiruchirapalli District, Tamil Nadu between 206 and 142 metres below ground level. The characteristic feature of this biozone is the overwhelming occurrence (85%) of a variety of spinose pollen grains, viz., *Spinainaperturites, Neocouperipollis, Arengapollenites, Spinizonocolpites, Echimonoporopollis* and *Acanthotricolpites*. Besides, other important palynotaxa of this biozone are *Lygodiumsporites eocenicus, Todisporites kutchensis, Meliapollis iratus* and *Triporopollenites parvus*.

Triangulorites bellus Cenozone

This biozone is designated in the Jayamkondacholapuram well-12 in Tiruchirapalli District, Tamil Nadu between 142 and 127 metres below ground level. It can be differentiated from the underlying *Neocouperipollis* spp. Cenozone by the absence or rarity of spinose pollen and first appearance and dominant representation of *Tricolporopollis, Trilatiporites, Retipilonapites, Palmidites, Retipollenites, Cryptopolyporites, Tricolpites, Meliapollis, Lakiapollis, Ctenolophonidites, Psilastephanocolpites, Matanomadhiasulcites, Schizaeoisporites, Seniasporites, Gleicheniidites* and *Polypodiisporonites* and restricted occurrence of *Retipollenites laevigatus, R. neyveliensis, Margocolporites oligobrochatus, Triangulorites bellus, Tricolporopollis matanomadhensis, Tricolpites retibaculatus* and *Psilastephanocolpites quadrangularis*.

Trilatiporites sellingii Cenozone

This biozone is designated in the Jayamkondacholapuram well-12 of Tiruchirapalli District and Neyveli Mines-I and II in South Arcot District, Tamil Nadu. In Jayamkondacholapuram well-12, this biozone was marked between 127 and 114 metres below ground level whereas in Neyveli Mines-I and II, it includes lignite bed about 16 and 12 metres thick respectively. The characteristic feature of this biozone is the abundant occurrence of *Trilatiporites* and *Proxapertites* (in the upper part of the biozone) and absence of spinose pollen complex and *Triangulorites*. The significant genera



Text-figure 1—Palynostratigraphic correlation of the Neyveli Formation of Neyveli Mines-I and II (South Arcot District) and Jayamkondacholapuram Well-12, Tiruchirapalli District, Tamil Nadu.

of this biozone are *Trilatiporites, Proxapertites, Neyvelisporites, Meliapollis, Pseudonothofagidites, Schizaeoisporites, Tricolpites, Margocolporites, Cryptopolyporites, Palmidites, Retitrescolpites, Pellicieroipollis, Ctenolophonidites, Lygodiumsporites* and *Laevigatosporites*, whereas species restricted to this biozone are *Proxapertites assamicus, P. microreticulatus, Meliapollis raoi, Pseudonothofagidites cerebrus, P. septaporatus* and *Pellicieroipollis langenheimii* (Text-figure 1).

CORRELATION AND AGE

The palynofloral compositions of three biozones of the Neyveli Formation are distinctly different from each other. An attempt has been made here to correlate these biozones with the contemporary stratigraphic units and to deduce the age of the Neyveli Formation.

The bulk of the *Neocouperipollis* spp. Cenozone assemblage is constituted by spinose pollen grains, viz., *Neocouperipollis* (30 per cent), *Acanthotricolpites* (23 per cent), *Spinizonocolpites* (14 per cent), *Echimonoporopollis* (9 per cent) and *Spinainaperturites* (8 per cent) along with *Lygodiumsporites. Margocolporites, Meliapollis* and *Palmidites* also commonly occur in the upper part of this cenozone. It is a known fact that spinose pollen constitute a dominant and essential part of the well dated Late Palaeocene assemblages of India. Besides, other palynofossils of this biozone also commonly occur in them. The Late Palaeocene biozones, thus correlatable with the *Neocouperipollis* spp. Cenozone, are: (i) *Neocouperipollis brevispinosus* Cenozone (Saxena, 1981) of the Matanomadh Formation of Kutch, Gujarat; (ii) *Proxapertites cursus* Zone (Baksi & Deb, 1980, in part) and *Monocolpopollenites eocenicus* Zone (Baksi & Deb, 1980, in part) of Bengal Basin; (iii) *Palmidites plicatus* Cenozone (Sah & Singh, 1974) of the Tura Formation of Garo Hills, Meghalaya; (iv) *Lycopodiumsporites speciosus* Cenozone (Kar & Kumar, 1986) of the Lakadong Sandstone of Khasi Hills, Meghalaya; (v) *Palmidites ovatus* Cenozone (Tripathi & Singh, 1984) and *Apectodinium homomorphum* Cenozone (Tripathi & Singh, 1984, in part) of the Therria Formation of Jaintia Hills, Meghalaya; and (vi) *Proxapertites hammenii* Cenozone (Venkatachala & Rawat, 1972) of Cauvery Basin, Tamil Nadu. The *Neocouperipollis* spp. Cenozone is homotaxial to the SP. 4 Zone (Late Palaeocene) of Singh and Dogra (1988).

The *Neocouperipollis* spp. Cenozone is overlain by *Triangulorites bellus* Cenozone which is further

Table 3—Correlation of the Neyveli Formation with Palaeocene—Eocene biozones/palynofloras from various parts of India

					MEGHALAYA		
PRESENT STUDY	CAUVERY BASIN	KUTCH	RAJASTHAN	BENGAL	GARO HILLS	KHASI HILLS	JAINTIA HILLS
Trilatiporites sellingii Cenozone *Triangulorites bellus* Cenozone	—	*Triangulorites triangulus* Cenozone—Kar, 1978; *Tricolpites reticulatus* Subzone—Kar, 1985; *Meliapollis ramanujamii* Subzone—Kar, 1985	Palana lignite assemblage—Sah & Kar, 1974; SP. 5 Zone—Singh & Dogra, 1988	*Trilatiporites biswasii* Zone—Baksi & Deb, 1980 (in part); *Monocolpopollenites eocenicus* Zone—Baksi & Deb, 1980 (in part)	*Proxapertites assamicus* Cenozone—Sah & Singh, 1974; & Simsang Palynological Zone 1—Baksi, 1962		—
Neocouperipollis spp. Cenozone	*Proxapertites hammenii* Cenozone—Venkatachala & Rawat, 1972	*Neocouperipollis brevispinosus* Cenozone—Saxena, 1981	SP.-4 Zone—Singh & Dogra, 1988	*Monocolpopollenites eocenicus* Zone—Baksi & Deb, 1980 (in part) *Proxapertites cursus* Zone—Baksi and Deb, 1980 (in part)	*Palmidites plicatus* Cenozone—Sah & Singh, 1974	*Lygodiumsporites speciosus* Cenozone—Kar & Kumar, 1985	*Apectodinium homomorphum* Cenozone—Tripathi & Singh, 1984 (in part). *Palmidites obtusus* Cenozone—Tripathi & Singh, 1984

succeeded by *Trilatiporites sellingii* Cenozone. The latter one has been encountered in both the Neyveli mines and also in Jayamkondacholapuram. The collective palynofloral composition of the *Triangulorites bellus* and *Trilatiporites sellingii* Cenozones is very closely identical, and hence homotaxial, to those of the Early-Middle Eocene palynofloras of India known from: (i) *Triangulorites triangulus* Cenozone (Kar, 1978) of the Naredi Formation of Kutch, Gujarat; (ii) *Meliapollis ramanujamii* Subzone (Kar, 1985) and *Tricolpites reticulatus* Subzone (Kar, 1985) of the Naredi Formation of Panandhro area of Kutch, Gujarat; (iii) palynoflora from the Palana lignite of Rajasthan (Sah & Kar, 1974); (iv) *Monocolpopollenites eocenicus* Zone (Baksi & Deb, 1980, in part) and *Trilatiporites biswasii* Zone (Baksi & Deb, 1980) of Bengal Basin; (v) *Proxapertites assamicus* Cenozone (Sah & Singh, 1974) of the Tura Formation of Garo Hills, Meghalaya; and (vi) Simsang Palynological zone of the Sylhet Limestone Formation of Meghalaya (Baksi, 1962). SP.—5 Zone (Early Eocene) proposed by Singh and Dogra (1988) is synchronous to a part of the above sequence (Table 3).

The above account and the fact that the Neyveli palynoflora is not comparable to any post-Eocene palynoflora known till date, strongly suggest a Late Palaeocene to Middle Eocene age for the Neyveli Formation.

CONCLUSIONS

From the palynofloral study of the Neyveli Formation, following conclusions have been derived.

1. The palynoassemblage from the Neyveli Formation consists of algal and fungal remains, pteridophytic spores and angiospermous pollen. However, bryophytic and gymnospermous elements appear to be unrepresented.
2. The pteridophytic spores are represented by Cyatheaceae, Osmundaceae, Polypodiaceae, Gleicheniaceae and Schizaeaceae, whereas angiospermous pollen are referable to Arecaceae, Potamogetonaceae, Liliaceae, Meliaceae, Brassicaceae, Gunneraceae, Araliaceae, Oleaceae, Rubiaceae, Caesalpiniaceae, Bombacaceae, Rhizophoraceae, Sapotaceae, Myricaceae, Alangiaceae, Ericaceae, Hippocrateaceae, Betulaceae, Ctenolophonaceae and Onagraceae.
3. The palynoflora suggests a tropical (warm-humid) climate with plenty of rainfall during the sedimentation of the Neyveli Formation.
4. The environment of deposition has been deduced as coastal, ranging from back mangrove to mangrove, with short transgressive phase just before the deposition of lignite.
5. The Neyveli Formation is divisible into three biozones, viz. *Neocouperipollis* spp. Cenozone, *Triangulorites bellus* Cenozone, and *Trilatiporites sellingii* Cenozone. These biozones can be identified by their characteristic and restricted palynofossils. In Jayamkondacholapuram Well-12, all the above zones were encountered whereas in Neyveli Mines-I and II only upper zone could be located.
6. The Neyveli Formation is correlatable with Late Palaeocene-Middle Eocene biozones of Kutch, Rajasthan, Bengal Basin, Cauvery Basin and Garo, Khasi and Jaintia Hills of Meghalaya and hence has been considered synchronous to them.

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