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Palynological studies in the Lower Siwalik sediments of Nahan, Himachal Pradesh, India

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ABSTRACT

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The present study highlights for the first time recovery of the Lower Siwalik palynoassemblage comprising algal, fungal, pteridophytic spores, gymnosperms and angiosperm pollen from an exposed section on Nahan-Ponta Saheb Road, Himachal Pradesh. The qualitative and quantitative analysis revealed that the algal and fungal spores are dominated by angiosperms, followed by pteridophytes and gymnosperms. The angiosperms show their maximum percentage in the total assemblage. Algal remains are feeble in number. The important taxa recovered are: *Psiloschizosporis microreticulatus* sp. nov., *Notothyrites* sp., *Lacrimasporonites barrelicus* sp. nov, *Lygodiumsporites lakiensis* Saxena, *Polypodiisporites perverrucatus* Nandi, *Crassoretitriletes vanraadshooveni* Germeraad *et al*., *Todisporites kutchensis* Sah & Kar, *Pinuspollenites crestus* Kar, *Araucariacites* sp., *Podocarpidites ruminatus* sp. nov., *Palmaepollenites kutchensis* Venkatachala & Kar, *Palmidites naviculus* Kar & Saxena, *Palaeomalvaceaepollis mammilatus* Kar, *Retimonosulcites circularis* sp. nov., *Retitribrevicolporites nahanensis* sp. nov., *Liguliforaedites pilatus* Kar, *Pseudonothofagidites kutchensis* Kar, *Meliapollis quadrangularis* (Ramanujam) Sah & Kar. On the basis of their affinities with modern equivalents, a humid tropical to sub-tropical climate has been indicated encompassing some fresh water bodies during the deposition of these sediments in this area. The gymnospermous taxa (cf. *Pinus*, *Podocarpus* and *Araucaria*) were possibly derived from uplands of nearby area.

Key-words—Palynology, Lower Siwalik, (Middle Miocene), Palaeoecology, Nahan, Himachal Pradesh, India.

भारत में हिमाचल प्रदेश के नाहन की निचली शिवालिक अवसादों का परागाणविक अध्ययन

महेश प्रसाद, एकनाथ जी. खरे, के. अंबवानी एवं संजय कुमार सिंह

सारांश

मौजूदा अध्ययन नाहन, हिमाचल प्रदेश नाहन-पोंटा साहिब मार्ग, हिमाचल प्रदेश खंड में अनावरित शैवालीय, कवकी टेरिडोफाइटी बीजाणुओं, अनावृतबीजी व आवृतबीजी पराग सन्निहित निचली शिवालिक परागाणु-समुच्चय की पहली बार प्राप्त मुख्य-मुख्य घटनाएं दर्शाता है। गुणात्मक एवं मात्रात्मक विश्लेषण से प्रकट हुआ कि शैवाल, कवकी बीजाणु टेरिडोफ़ाइटों व अनावृत बीजियों के अनुगामी आवृतबीजियों से प्रभावी हैं। समूचे समुच्चय में, आवृतबीजी अपने अधिकतम प्रतिशत दर्शाते हैं। शैवाल अवशेष की संख्या क्षीण है। प्राप्त महत्वपूर्ण टैक्सा *सिलोसायज़ीस्पोरिस माइक्रोरेटिकुलेटिस* जाति नवम, *नोटोथाइराइटिस* जाति, *लेक्रिमास्पोरिनाइटिस बैरलिकस* जाति नवम, *नायगोडियमस्पोराइटिस लेक्वीएन्सिस* सक्सेना, *पॉलीपॉडाइस्पोराइटिस पर्वेरूकेटस* नंदी, *क्रेसोरेटिट्रिलेटिस वनराड्शूवेनी* जमेंराड एवं अन्य, *टोडीस्पोराइटिस कुचेन्सिस* साह एवं कर, *पाइनसपोलेनाइटिस क्रेस्टस* कर, *एरूकेरिसाइटिस* जाति *पोडोकार्पीडाइटिस रूमिनेटस* जाति नवम, *पामेपॉलीनाइटिस कुचेन्सिस* वेंकटचला एवं कर, *पामीडाइटिस नवीकुलस* कर एवं सक्सेना, *पैलियोमाल्वेसीएपॉल्लिस मम्पिलेटस* कर, *रेटिमोनोसल्साइटिस सर्कुलेरिस* जाति नवम, *रेटिट्रिब्रेविकॉल्पोराइटिस नाहनेन्सिस* जाति नवम, *लिगुलिफ्लोरेडाइटिस पाइलेटस* कर, *स्युडोनोथोफेजीडाइटिस कुचेमिसस* कर, *मेलियापॉल्लिस क्वाड्रेंगुलेरिस* (रामानुजम) साह एवं कर हैं। आधुनिक तुल्यों से उनकी बंधुताओं के आधार पर, इस क्षेत्र में इन अवसादों के निक्षेपण के दौरान कुछ अलवण जल पिंडो को सम्मिलित करते हुए आर्द्र उष्णकटिबंधीय से उप-उष्णकटिबंधीय जलवायु इंगित की गई है। नजदीकी क्षेत्र की उपरिभूमि से अनावृतबीजी टैक्सा (के तुलनीय *पाइनस, पोडोकार्पस* एवं *एरोकेरिया*) संभवतः व्युत्पन्न हुए थे।

संकेत-शब्द—परागाणुविज्ञान, निचली शिवालिक, (मध्य मध्यनूतन), पुरापारिस्थितिविज्ञान, नाहन, हिमाचल प्रदेश, भारत।

INTRODUCTION

The Lower Siwalik fossil locality in Nahan area (30º36'30"N; 77º27'06" E) is situated about 3 km from Nahan Town on Nahan-Ponta Saheb Road, Sirmur District, Himachal Pradesh (Fig. 1). Lithologically, the Nahan Formation contains fine mudstone and variegated claystone alternating with fine to coarse sandstone beds with some pebbles (Fig. 2). The palynological studies of the Lower Siwalik (Middle Miocene) sediments of Himachal Pradesh have been carried out by Banerjee, 1968; Nandi, 1972, 1975; Singh & Sarkar, 1990; Singh & Saxena, 1981. The Siwalik microflora recovered by these workers predominantly represent pteridophytes, grasses and palms, whereas, the dicotyledonous angiosperms are very rare in the assemblage. The palynological samples for the present study were collected mainly from the thin clay-stone beds alternating with thick bands of sandstones (Fig. 3). Seven samples were processed and six were found productive containing a variety of palynofossils. It has been observed that the Siwalik sediments are well exposed around the Nahan area, but there is no previous record of palynological investigation from these sediments. The present study has been undertaken in view to build up the palynological data and to determine the past history and palaeoecology in this area. A lot of well preserved palynotaxa such as: *Psiloschizosporis, Notothyrites, Lacrimasporonites, Lygodiumsporites, Polypodiisporites, Crassoretitriletes, Pinuspollenites, Araucariacites, Podocarpidites, Palmaepollenites, Palmidites, Palaeomalvaceaepollis, Retimonosulcites, Retitribrevicolporites, Liguliforaedites, Pseudonothofagidites* and *Meliapollis* have been encountered and a detailed morphological observation of the recovered taxa has been worked out in this communication.

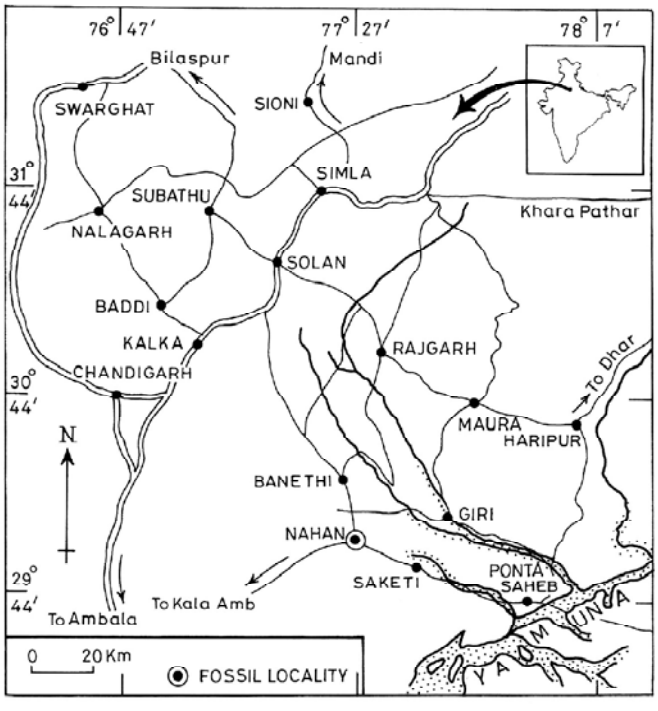

Fig. 1—Map showing the location of fossil locality from where samples were collected.

GEOLOGICAL SETTING

The world's most extensive clastic sequence referred to the Siwalik molasses occurs in a foreland basin along the southern front of the Himalaya. It exceeds more than 5 km in thickness and extends for about 2500 km along the tectonic strike from Brahmaputra River in the east to the Potwar Plateau and Bannu plains in the west. The Siwalik Group is characterized by alternation of sandstone-mudstone throughout the belt in the Lower, Middle and considerable part of the Upper Siwalik sub-groups. The terminal part of the Upper Siwalik sub-group is dominated by conglomerate, while the Lower Siwalik (Nahan Formation) is well exposed around Nahan area comprising brown, grey and purple grey claystones and fine to coarse grained sandstone. The sandstones are generally interbedded with thin brown and grey mudstone varying from 0.2-1.5 m in thickness (Figs 2, 3).

MATERIAL AND METHODS

The samples for palynological studies were collected from the claystone beds of Nahan Formation in the vicinity of Nahan Town, Sirmur District, Himachal Pradesh. For recovery of the palynomorphs, seven samples were macerated by standard chemical processing techniques using HCL, HF, HNO_3 and KOH reagents to complete the maceration process. Out of seven samples six samples were productive and contained a variety of palynofossils. The permanent slides were prepared in polyvinyl alcohol and mounted in canada balsam. Photomicrographs were prepared under Olympus (LM) microscope. All the negative and slides are deposited in the Museum of Birbal Sahni Institute of Palaeobotany, Lucknow.

SYSTEMATICS

Genus—PSILOSCHIZOSPORIS Jain, 1968

Type species—*Psiloschizosporis cacheutensis* Jain, 1968

Psiloschizosporis microreticulatus sp. nov.

(Pl. 1.22)

Diagnosis—Spores sub-circular to slightly triangular in shape; 80 x 90 µm in size; consist of two halves, furrow distinct; exine 1.6 µm thick, coarsely microreticulate, the meshwork towards inner side coarser, lumina darker, about 1 µm.

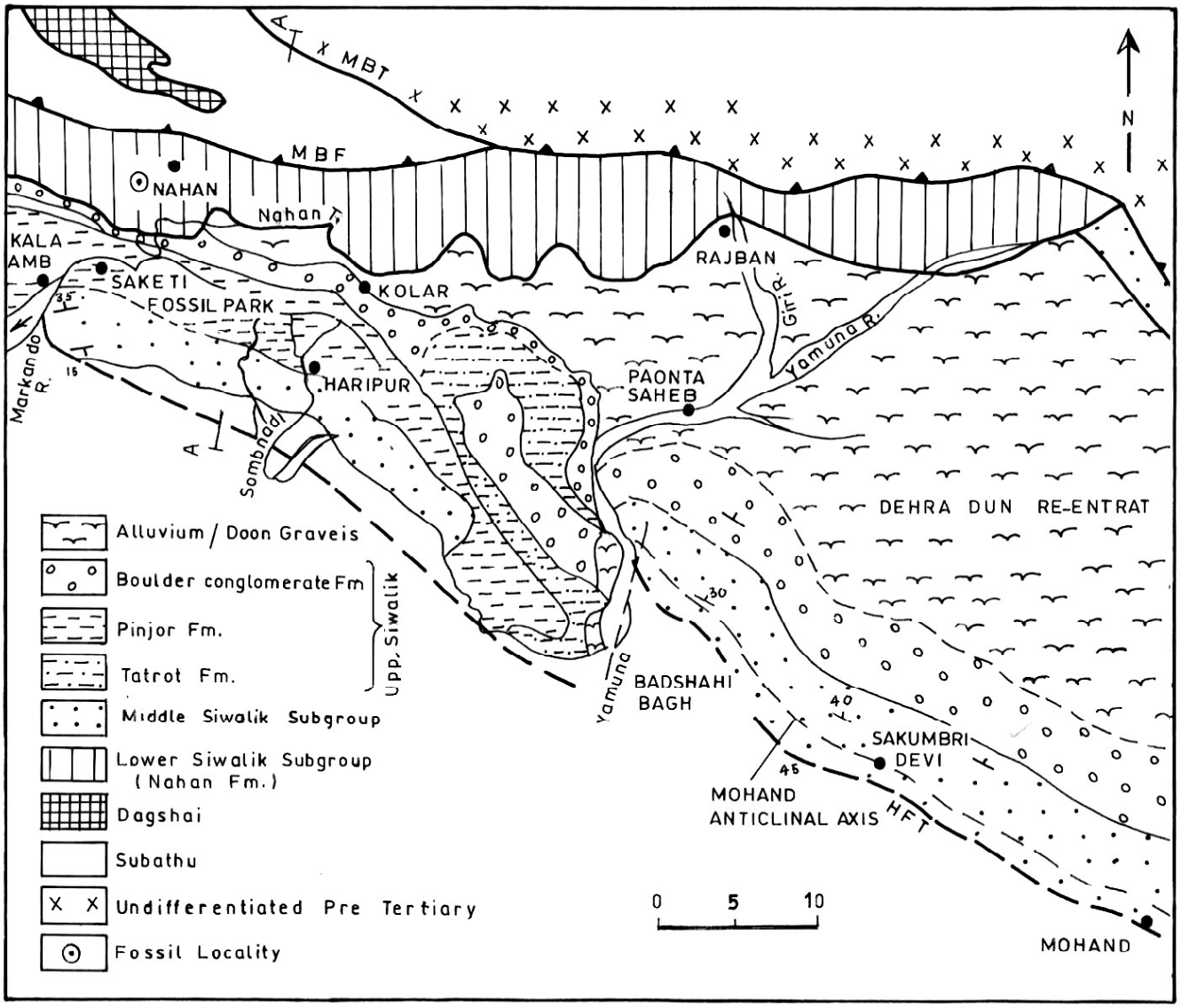

Fig. 2—Geological map showing Lower Siwalik outcrop around fossil locality (after Raiverman *et al.*, 1983).

Locality—Nahan-Ponta Saheb Road section, Himachal Pradesh, India.

Holotype—Museum No. BSIP 13775.

Horizon—Nahan Formation.

Age—Middle Miocene.

Remarks—The present specimen is comparable to *Psiloschizosporis psilata* Kar and Saxena, 1981 and *Psiloschizosporis* sp. Kar, 1985. However, it shows near similarity to *P. psilata* but has coarsely microreticulate exine with folded, uneven thickness while the meshwork towards the inner side gradually becomes coarser. Based on shape, size and exine characters the present specimen can be differentiated from the above species and hence assigned a new specific name *Psiloschizosporis microreticulatus* sp. nov.

Genus—NOTOTHYRITES Cookson, 1947

Type species—*Notothyrites setiferus* Cookson, 1947

Notothyrites sp.

(Pl. 1.1)

Description—Ascomata triangular to subcircular in shape, folded, 120 x 60 µm in size, four tentacles emerging from the outer layer of pseudoparenchymatus tissue, ostiolate, ostiole compact, protruding beak-like structure, tentacles 60-135 x 3-5 µm, straight, curved at the tip.

Remarks—The present specimen is comparable with *Notothyrites amorphous* Kar and Saxena, 1976; *Notothyrites*

sp. Kar, 1979 and *Notothyrites setiferus* Singh *et al*., 1986 in its general features but differs from above mentioned species in having long setae in the thallus with beak-like aperture.

Notothyrites sp. A

(Pl. 1.2)

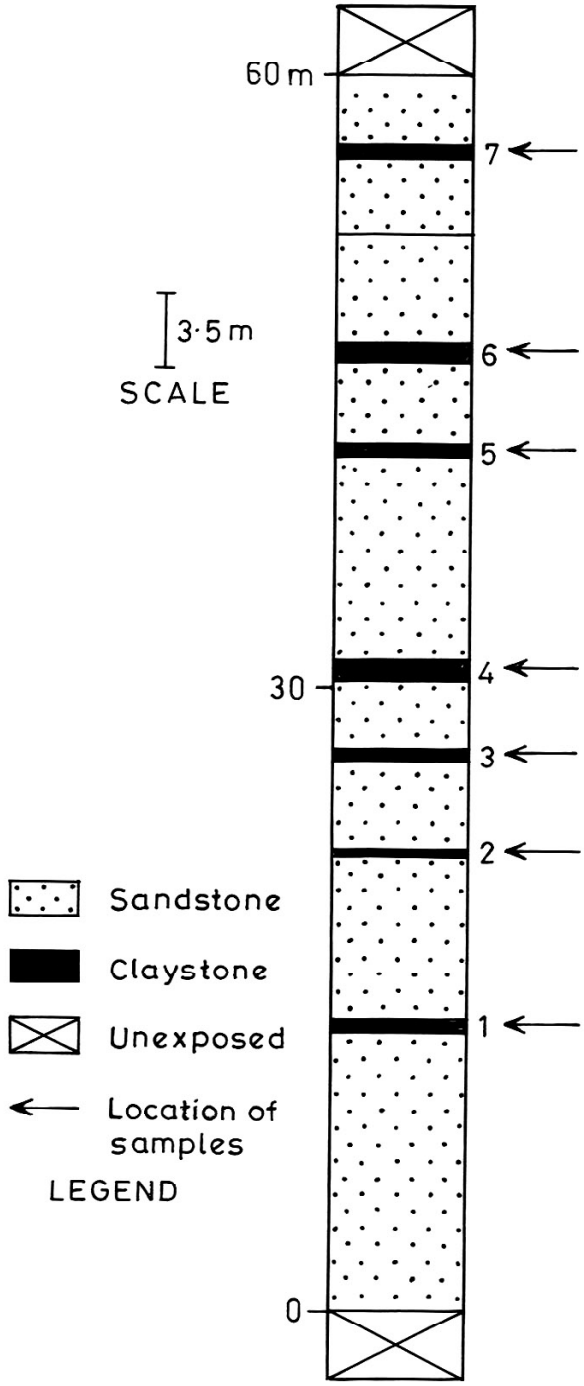

Fig. 3—Lithocolumn of a part of Siwalik section indicating the location of samples.

Remarks—The present specimen is comparable to *Notothyrites* sp. Kar, 1979 and *N. denticulatus* Ramanujam and Rao, 1973 in its general shape and the ring-like pore but it differs in having smaller size (55 μm in diameter); the central pore and pore membrane show fine papillae.

Genus—LACRIMASPORONITES Clarke (emend. Elsik, 1968)

Type species—*Lacrimasporonites levis* Clarke, 1965

Lacrimasporonites barrelicus sp. nov.

(Pl. 1.3)

Diagnosis—Spore 128 x 80 μm in size, aseptate, barrel shape, monoaperturate, smooth, with large flattened attachment scar at the proximal end, ostiolate, spore wall thin, wrinkled, a thick fold observed running from apex to base.

Locality—Nahan-Ponta Saheb Road section, Himachal Pradesh, India.

Holotype—Museum No. BSIP 13776.

Horizon—Nahan Formation.

Age—Middle Miocene.

Derivation of name—Based on the barrel shape body.

Remarks—The present species has been compared with *Lacrimasporonites longus* Kar, 1979 but it differs in having barrel shape body; spore wall with profuse wrinkles. A thickening can be seen from base to apex. It also differs from *L. westii* Elsik, 1968 in larger size. Based on the difference in size and nature of exine, the present species has been distinguished and named as *Lacrimasporonites barrelicus* sp. nov.

Genus—LYGODIUMSPORITES (Potonié, Thomson & Thiergart) emend. Potonié, 1956

Type species—*Lygodiumsporites adriensis* (Potonié & Gelletich) Potonié *et al*., 1950

Lygodiumsporites lakiensis Saxena, 1978

(Pl. 1.4)

Remarks—The present specimen is compared with *Lygodiumsporites lakiensis* Saxena (1978) and *Lygodiumsporites eocenicum* Sarkar *et al*. (1994). It closely resembles with *Lygodiumsporites lakiensis* Saxena, 1978 in almost all the characters except being smaller in size (55 x 50 μm).

Siwalik palynotaxa	Comparable modern families taxa/ Affinites	Climate
Psiloschizosporis microreticulatus sp. nov.	Algae	Tropical/ Fresh water
Lacrimasporonites barrelicus sp. nov.	Fungi	Tropical
Notothyrites setiferus	Fungi	Tropical
Polypodiisporites imparites	Polypodiaceae (*Polypodium*)	Tropical/Humid
Lygodiumsporites lakiensis	Schizaeaceae (*Lygodium*)	Tropical/Humid
Crassoretitriletes vanraadshooveni	Schizaeaceae (*Lygodium microphyllum*)	Tropical/Humid
Todisporites kutchensis	Pteridophyte (uncertain)	Tropical/Humid
Pinuspollenites crestus	Pinaceae (*Pinus wallichiana*)	Temperate/Upland
Podocarpidites ruminatus sp. nov.	Podocarpaceae (*Podocarpus*)	Temperate/Upland
Araucariacites sp.	Araucariaceae *(Araucaria*)	Temperate/Upland
Palmaedites naviculus	Arecaceae *Borassus / cocos*	Tropical
Palmaepollenites kutchensis	Arecaceae (not known)	Tropical/near shore
Palaeomalvaceaepollis mammilatus	Malvaceae (not known)	Tropical
Meliapollis quadrangularis	Meliaceae (*Melia*)	Tropical
Retitribrevicolporites nahanensis sp. nov.	Bombacaceae (*Bombax/Durio*)	Tropical
Pseudonothofagidites kutchensis	Fagaceae (*Nothofagus*)	Tropical
Liguliforaedites pilatus	Asteraceae (*Liguliflorae*)	Tropical
Retimonosulcites circularis sp. nov.	Arecaceae (not known)	Tropical

Fig. 4—Showing distribution of fossil taxa under different climatic conditions.

Genus—POLYPODIISPORITES Potonié, 1934

Type species—*Polypodiisporites favus* (Potonié) Potonié, 1934

Polypodiisporites perverrucatus Nandi, 1972

(Pl. 1.5)

Remarks—The present specimen is comparable to *Polypodiisporites impariter* Potonié and Sah, 1960, *Polypodiidites ratnami* Ramanujam, 1966-67 and *Polypodiisporites perverrucatus* Nandi, 1972. It closely resembles *Polypodiisporites perverrucatus* except being bigger in size 41 x 25 μm and presence of verrucae interspersed with fine bacula.

Genus—CRASSORETITRILETES Germeraad *et al.*, 1968

Type species—*Crassoretitriletes vanraadshooveni* Germeraad *et al.*, 1968

Crassoretitriletes vanraadshooveni Germeraad *et al.*, 1968

(Pl. 1.6)

Remarks—The present specimen is similar to *Crassoretitriletes vanraadshooveni* Ramanujam *et al.* 1987. *Crassoretitriletes ornatus* Ramanujam, 1966 & 1967 shows similarity mostly in the characters such as ornamentation and size of the specimen. However, the spines in the present species are larger and sparsely arranged as in *Crassoretitriletes vanraadshooveni.*

Genus—TODISPORITES Couper, 1958

Type species—*Todisporites major* Couper, 1958

Todisporites kutchensis Sah & Kar, 1969

(Pl. 1.7)

Remarks—The present species is closely comparable with *Todisporites kutchensis* Sah & Kar, 1969 in almost all the characters except having larger size (100 x 80 µm) and presence of folds in the exine.

Genus—PINUSPOLLENITES Raatz, 1937

Lectotype—***Pinuspollenites labdacus*** (Potonié) Raatz, 1937

Pinuspollenites crestus Kar, 1985

(Pl. 1.8)

Remarks—The present specimen is similar with *Pinuspollenites crestus* Kar, 1985 reported from the Tertiary sediments of Kachchh but differs in size being comparatively smaller (60 x 45 µm) whereas central body is incipient and oblique in nature.

Genus—ARAUCARIACITES Cookson, 1947

Type species—*Araucariacites australis* Cookson, 1947

Araucariacites sp.

(Pl. 1.12)

Diagnosis—Pollen grains, circular 70 x 66 µm in size, non aperturate, folded, folds irregular, exine thin, fine microgranulate, sometimes puncta also present, grana about 1 µm high.

Remarks—The present specimen has been compared with *Araucariacites* sp. Cookson 1947; *Araucaria* sp. Rao, 2000 and *Araucaria* sp. Mandaokar, 1991 but it differs in being smaller size with number of folds and microgranulate exine.

Genus—PODOCARPIDITES (Cookson) Potonié, 1958

Type species—*Podocarpidites ellipticus* Cookson, 1947

Podocarpidites ruminatus sp. nov.

(Pl. 1.9)

Diagnosis—Pollen grains bisaccate, bilaterally symmetrical, 56 x 44 µm in size, central body dense, obovate, 32 x 44 µm in size, coarsely thick with ruminated ornamentation; sacci well developed, 44 x 28 µm in size, smaller than central body; sacci attachment more than half the diameter of central body.

Locality—Nahan-Ponta Saheb Road section, Himachal Pradesh, India.

Holotype—Museum No. BSIP 13774.

Horizon—Nahan Formation.

PLATE 1 →

1. *Notothyrites* sp., BSIP Slide No. 13773 (PNR4/4/8).
2. *Notothyrites* sp. A, BSIP Slide No. 13774 (PNR 4/1/18).
3. *Lacrimasporonites barrelicus* sp. nov., BSIP Slide No. 13776 (PNR 6/4/27).
4. *Lygodiumsporites lakiensis* Saxena, BSIP Slide No. 13777 (PNR 6/1/21).
5. *Polypodiisporites perverrucatus* Nandi, BSIP Slide No. 13775 (PNR 4/2/C)
6. *Crassoretitriletes vanraadshooveni* Germeraad *et al.*, BSIP Slide No. 13775 (PNR 4/2/a).
7. *Todisporites kutchensis* Sah & Kar, BSIP Slide No. 13777 (PNR 6/1/ 22).
8. *Pinuspollenites crestus* Kar, BSIP Slide No. 13780 (PNR 1/4/ 4).
9. *Podocarpidites ruminatus* sp. nov., BSIP Slide No. 13774 (PNR 4/1/20).
10, 11. *Podocarpidites* sp. Sah & Kar, BSIP Slide No. 13776 (PNR 6/ 4/31 & 13778 PNR 6/6/34).
12. *Araucariacites* sp., BSIP Slide No. 13778 (PNR 6/6/36).
13. *Palmaepollenites kutchensis* Venkatachala & Kar, BSIP Slide No. 13779 (PNR 6/5/32).
14. *Palmidites naviculus* Kar & Saxena, BSIP Slide No. 13776 (PNR 6/4/28).
15. *Palmidites kutchensis* Venkatachala & Kar, BSIP Slide No. 13781 (PNR 5/3/19a).
16. *Retimonosulcites circularis* sp. nov., BSIP Slide No. 13783 (PNR 4/5/12).
17. *Palaeomalvaceaepollis mammilatus* Kar, BSIP Slide No. 13774 ((PNR 4/1/B/180).
18. *Retitribrevicolporites nahanensis* sp. nov., BSIP Slide No. 13782 (PNR 5/5/1.
19. *Liguliforaedites pilatus* Kar, BSIP Slide No. 13773 (PNR 4/4/ 7).
20. *Pseudonothofagidites kutchensis* Kar, BSIP Slide No. 13775 (4/2/B).
21. *Meliapollis quadrangularis* Sah & Kar, BSIP Slide No. 13784 (PNR 2/1/7).
22. *Psiloschizosporis microreticulatus* sp. nov., BSIP Slide No. 13784 (PNR 4/2/26).

Age—Middle Miocene.

Derivation of name—Due to the ruminate nature of ornamentation.

Remarks—The present specimen shows near resemblance with *Podocarpidites khasiensis* Dutta and Sah, 1970; *P. cognatus* Kar, 1979, and *P. densicarpus* Kar, 1985 almost in all the general features, However, it differs from above species in having distinct obovate central body and thick exine (2 µm) having prominently ruminated ornamentation. Based on the above differences it has been assigned as *Podocarpidites ruminatus* sp. nov.

Genus—PODOCARPIDITES (Cookson) Potonié, 1958

Type species—*Podocarpidites ellipticus* Cookson, 1947

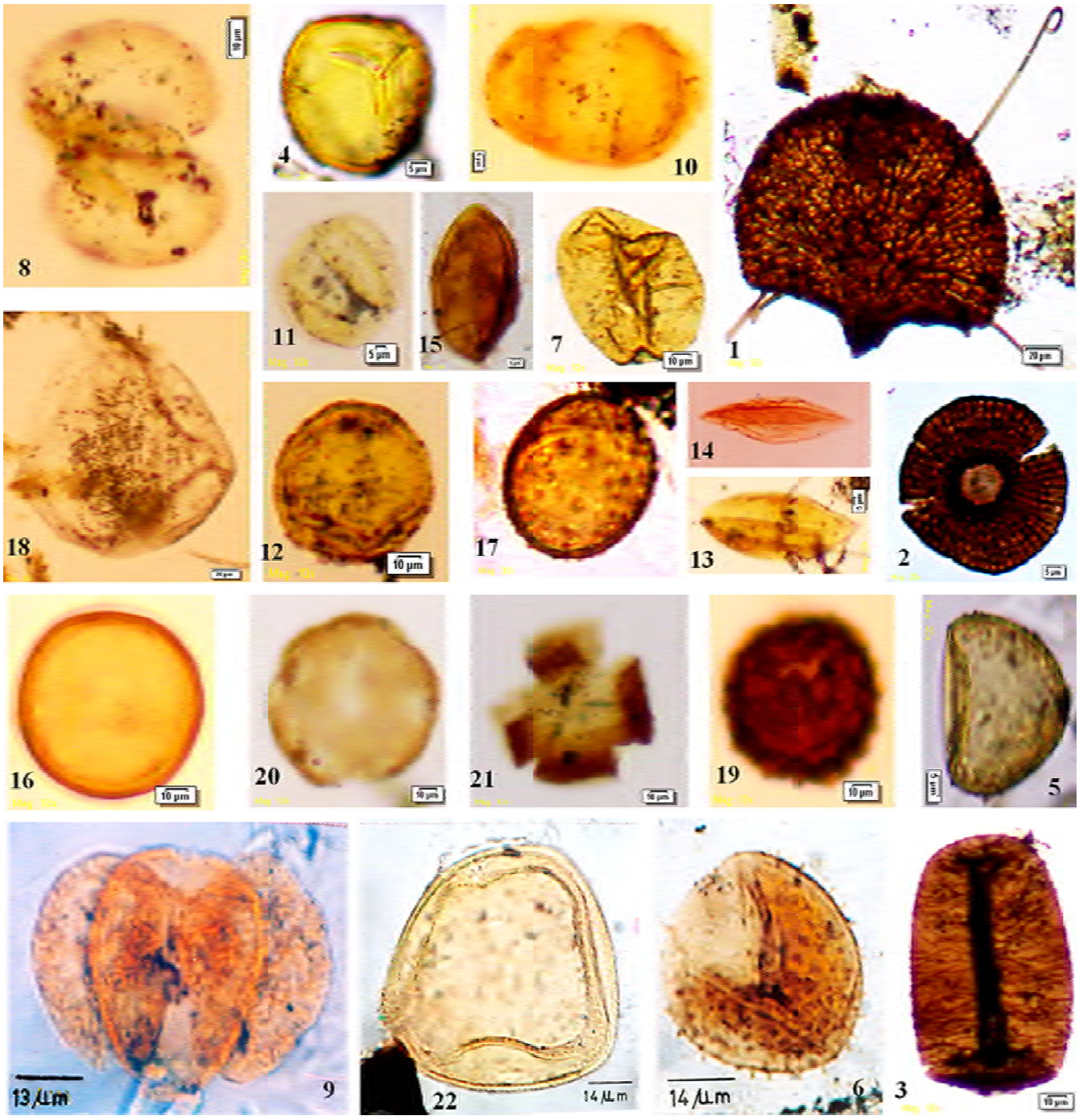

PLATE 1

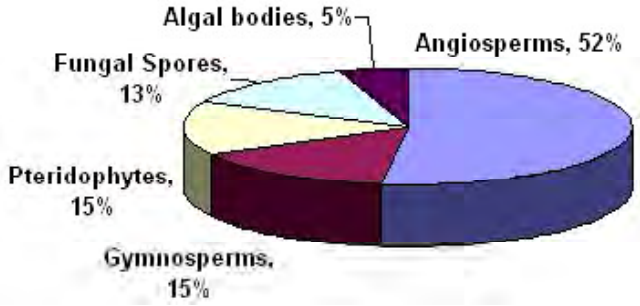

Fig. 5—Diagramatic representation of recovered palynoflora in different plant groups.

***Podocarpidites* sp.** Sah & Kar,1970

(Pl. 1.10, 1.11)

Remarks—The present specimen is comparable to *Podocarpidites* sp. Sah & Kar, 1970 in shape, size and exine characters. However, ornamentation of sacus partially developed and constriction between body and the sacci present.

Genus—PALMAEPOLLENITES Potonié, 1951

Type species—*Palmaepollenites transquillus* (Potonié) Potonié, 1951

Palmaepollenites kutchensis Venkatachala & Kar, 1969

(Pl. 1.13)

Remarks—The present specimen shows affinities with *Palmaepollenites neyvelii* and *Palmaepollenites indicus* Ramanujam, 1966 and *Palmaepollenites kutchensis* Venkatachala and Kar, 1969 but, it shows close similarity with *P. kutchensis,* though differs in the size (140 x 50 µm), its bigger size signifies ecological impact.

Genus—PALMIDITES (Chitaley) ex. Couper, 1953

Type species—*Palmidites maximus* Couper, 1953

Palmidites naviculus Kar & Saxena, 1981

(Pl. 1.14)

Remarks—The present specimen is similar with *Palmidites plicatus* Sah and Singh, 1974 and *Palmidites naviculus* Kar and Saxena, 1981 in its general characters. Its smaller size and lanceolate shape with much extended acute ends make the point of differences.

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Genus—PALMIDITES (Chitaley) ex. Couper, 1953

Type species—*Palmidites maximus* Couper, 1953

Palmidites kutchensis Venkatachala & Kar, 1969

(Pl. 1.15)

Remarks—The present specimen resembles with *Palmidites kutchensis* Venkatachala and Kar, 1969; *Palmidites plicatus* Sah and Kar, 1974 and *Palmidites naviculus* Kar and Saxena, 1981 in general characters. It has been found that except the size (64 x 35 µm) of pollen and laevigate nature of exine; most of the characters go in favour of *Palmidites kutchensis.*

Genus—PALAEOMALVACEAEPOLLIS Kar, 1985

Type species—*Palaeomalvaceaepollis rudis* (Kar) comb. nov., 1985

Palaeomalvaceaepollis mammilatus Kar, 1985

(Pl. 1.17)

Remarks—The present speciemen is comparable to *Palaeomalvaceaepollis rudis* Kar 1979 and *P. mammilatus* Kar 1985, though it has more number of pore, uniformly thick exine (2 µm) and evenly distributed spines with bulbous bases.

Genus—RETIMONOSULCITES Kar, 1985

Type species—*Retimonosulcites (Liliacidites) ellipticus* (Venkatachala & Kar) comb. nov.

Retimonosulcites circularis sp. nov.

(Pl. 1.16)

Diagnosis—Pollen grains anisopolar, circular in shape, monosulcate 80 µm in diameter, exine about 2 µm thick, intramicroreticulate, sulcus circular, bacula very fine, less than 1 µm in size.

Locality—Nahan-Ponta Saheb Road section, Himachal Pradesh, India.

Holotype—Museum No. BSIP 13783.

Horizon—Nahan Formation.

Age—Middle Miocene.

Remarks—*Retimonosulcites ellipticus* Venkatachala and Kar, 1969 is with elliptic shape and boat shape sulcus, while *Retimonosulcites ovatus* Sah and Kar, 1970 has funnel-shaped sulcus with microreticulate exine. In contrast, the present specimen is geometrically circular in shape with wide sulcus

and finely intramicroreticulate exine. In view of this the present specimen is assigned as new specific name *Retimonosulcites circularis* sp. nov.

Genus—RETITRIBREVICOLPORITES Kar, 1969

Type species—*Retitribrevicolporites (Lakiapollis) matanomadhensis* (Venkatachala & Kar) comb. nov.

Retitribrevicolporites nahanensis sp. nov.

(Pl. 1.18)

Diagnosis—Pollen grains some what triangular in shape, tribrevicolporate, 180 x 160 µm in size; apertures transluscent, distinct, colpi very shallow, 20 µm wide, pore thin, circular to slightly oval, 3 µm in diameter; exine 0.8-1.6 µm thick, microreticulate, muri and lumina less than 1 µm, sometimes thin folds present.

Locality—Nahan Ponta-Saheb Road section, Himachal Pradesh, India.

Holotype—Museum No. BSIP 13783.

Horizon—Nahan Formation.

Age—Middle Miocene.

Remarks—The present species is compared with *Retitribrevicolporites matanomadhensis* Kar, 1985; *R. granulatus* Venkatachala and Kar, 1969; *R. delicates, R. glabatus* and *Retitribrevicolporites* sp. Kar, 1985 and found that it differs from the above mentioned species in being smaller size and having microreticulate exine. Besides *Retitribrevicolporites granulatus, R. glabatus* and *Retitribrevicolporites* sp. have tetracolporate condition whereas the present specimen has only 3 apertures. In view of these differences mentioned above the present specimen has been assigned to a new species, *Retitribrevicolporites nahanensis* sp. nov. The specific name denotes the locality from where the material was collected.

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Genus—LIGULIFLORAEDITES Kar, 1985

Type species—*Liguliflorаedites pilatus* Kar, 1985

Liguliflorаedites pilatus Kar, 1985

(Pl. 1.19)

Remarks—The present species closely resembles with *Liguliflorаedites pilatus* Kar, 1985 almost in all the characters except having broader columella (about 3 µm) and have bigger size (about 80 µm).

Genus—PSEUDONOTHOFAGIDITES Venkatachala & Kar, 1969

Type species—*Pseudonothofagidites kutchensis* Venkatachala & Kar, 1969

Pseudonothofagidites kutchensis Kar, 1985

(Pl. 1.20)

Remarks—The present species is comparable to *Pseudonothofagidites kutchensis* Kar, 1985 and *Nothofagidites antiquum* Ramanujam (1966) but differs in having larger size and less number of pores with broadly punctuate exine.

Genus—MELIAPOLLIS QUADRANGULARIS (Ramanujam) Sah & Kar, 1970

Type species—*Meliapollis ramanujamii* Sah & Kar, 1970

Meliapollis quadrangularis Sah & Kar, 1970

(Pl. 1.21)

Remarks—The present pollen shows similarties with *Tetracolporites quadrangularis* and *T. melioides* Ramanujam, 1966. It differs only in having very thin exine and small colpi. However, in its general appearance and smaller size of colpi and exine pattern it is closer to *Meliapollis quadrangularis* (Ramanujam) Sah and Kar (1970).

DISCUSSION AND CONCLUSION

The palynoflora in the present investigation mainly comprise algal and fungal bodies, pteridophytes, gymnosperms and angiosperms. The assemblage consists of eighteen genera and nineteen species, viz. *Psiloschizosporis microreticulatus* sp. nov., *Notothyrites* sp., *Notothyrites* sp. *A, Lacrimasporonites barrelicus* sp. nov., *Lygodiumsporites lakiensis, Polypodiisporites perverrucatus, Crassoretitriletes vanraadshooveni, Todisporites kutchensis, Pinuspollenites crestus, Araucariacites* sp., *Podocarpidites ruminatus* sp. nov., *Palmaepollenites kutchensis, Palmidites naviculus, Palaeomalvaceaeopollis mammilatus, Retimonosulcites circularis* sp. nov., *Retitribrevicolporites nahanensis* sp. nov., *Liguliflorаedites pilatus, Pseudonothofagidites kutchensis* and *Meliapollis quadrangularis.* Out of the above, fungi is represented by *Notothyrites* sp. and *Notothyrites* sp. A (Notothyraceae) and *Lacrimasporonites barrelicus* sp. nov., while pteridophytes are represented by *Polypodiisporites imparites, Lygodiumsporites lakiensis, Crassoretitriletes vanraadshooveni* and *Todisporites kutchensis* belonging to the families Schizaeaceae, Polypodiaceae, Lygodiaceae respectively, whereas, the gymnosperms are restricted to only

three taxa, e.g. *Pinuspollenites crestus*, *Podocarpidites ruminatus* sp. nov. and *Araucariacites* sp. referable to Pinaceae, Podocarpaceae and Araucariaceae respectively. The angiosperm taxa dominate the assemblage by representing 8 species, e.g. *Palmidites naviculus*, *Palmaepollenites kutchensis*, *Palaeomalvaceaepollis mammilatus*, *Retitribrevicolporites nahanensis* sp. nov., *Pseudonothofagidites kutchensis*, *Meliapollis quadrangularis*, *Ligulifloraedites pilatus* and *Retimonosulcites circularis* belonging to families Arecaceae, Malvaceae, Meliaceae, Bombacaceae, Fagaceae and Asteraceae respectively.

The quantitative analysis of the palynotaxa revealed that the percentage of algal and fungal bodies, pteridophytic spores and gymnosperm pollen range 5%, 13%, 15% and 15% respectively, whereas, the angiosperm taxa show their maximum development in the total plant community and range upto 52% (Fig. 5). The presence of gymnospermous taxa (*Pinus*, *Podocarpus* and *Araucaria*) indicates an influence of upland flora possibly from the nearby high mountains. Occurrence of genus *Psiloschizosporites* of the family Zygnimataceae indicates the presence of fresh water environment, while the fungal and pteridophytic elements represent tropical and humid condition.

On the other hand, the presence of the genus *Retitribrevicolporites* belonging to the family Bombacaceae is very important from the view point of its dispersal as it indicates a shore as well as land habitat with enough humus (Croizat, 1952). Earliest records of Bombacaceae are known from Upper Cretaceous of U.S.A. (Wolfe, 1975) and from Palaeocene of Texas (Germeraad *et al.*, 1968); later on its occurrence has been noted till Oligocene-Miocene (Couper, 1953). Its occurrence in India is known only from Oligocene time onwards. The record of *Meliapollis* has been known in the sediments of Palaeocene-Eocene of Kutch, however its abundance has been observed in Miocene sediments (Ramanujam, 1966; Navale, 1961). Importantly, Fagaceae is widely distributed across the northern hemisphere and is concentrated in south east Asia where most of the extant genera are thought to have evolved before migrating to Europe and North America via land bridges. Members of the Fagaceae (such as *Fagus grandifolia, Castanea dentata, Quercus alba*) in the northeastern United States (or *Fagus sylvatica, Quercus robur* and *Q. petraea* in Europe) are often ecologically dominant in northern temperate forests (Croizat, 1952; Hutchinson, 1973).

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