Palyno-petrographical Study of the Siwalik Rocks of Some Areas of Arunachal Pradesh, North-Eastern India to Understand Palaeo-climatic Evolution of this Region

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Abstract

The palynological assemblages within the Siwalik shale rock samples from some areas of Arunachal Pradesh is studied to determine the palaeoclimatic condition. The petrographic study of the Shales also taken as the supportive to the determined palaeoclimate by the study of Palynological assemblages of 32 species and 30 genera taken separately from three distinct Siwalik strata, upper, middle and lower, collected from open exposures of Itanagar Banderdewa Roadside, Julu Village, and Pinjoli area of Arunachal Pradesh. The Palyno-petrographic study overall suggests that, during the lower siwalik, the region was highly coastal influenced with a dominating Tropical, humid climate. During the middle Siwalik, coastal influence was lowered, which shows coastline getting wiped out, and the temperature condition of Tropical-Sub-tropical climate. Upper Siwalik shows a further decreased coastal influence, with mainly a sub-tropical climate with an indication of temperate condition, which is indicative and supportive for the Pleistocene Glaciation in the global geological history.

Keywords: Arunachal; Palynology; Paleoclimatology; Siwalik

Introduction

The area of study includes some areas adjacent to Itanagar-Banderdewa Road and some areas of Julu village of Papumpare district where Upper and Middle Siwalik stratas are exposed respectively. The area of study also includes Pinjoli sector of West Kameng district where Lower Siwalik bedding have exposures. Both of these two districts are situated in the western part of Arunachal Pradesh, North-East India (Figure 1). The Siwalik rocks are underlain by Gondwana sequence which mainly comprises of carbonaceous shale, sandstone and coal with plant fossil. The Gondwana sequence is separated from the Lower Siwalik by Main Boundary Fault or MBF. Due to the MBF, Gondwana rocks are sometimes found overlying the Siwalik strata. The Siwalik strata are classified into three groups Lower, Middle, and Upper. The Lower Siwalik is essentially composed of well indurated sandstone, shale and siltstone, and abundant plant fossils. It is then further separated by a fault with the Middle Siwalik strata. The Middle siwalik is composed of weakly indurated sandstone with concretions, shale, siltstone and conglomerate, and abundant plant fossils. Middle and Lower Siwalik are separated by another fault. Lower Siwalik strata comprise mainly sandstone, claystone/shale and boulder beds/gravel beds, and abundant plant fossils especially petrified and carbonized wood. Assam alluvia or the quaternary deposits cover the whole Siwalik stratigraphy. Assam alluvia are separated from the Siwalik essentially by Main Frontal Thrust or MFT. Due to this MFT Siwalik strata in a number of exposures are found to overlie the quaternary deposits. The generalized stratigraphic sequence of the Kameng Dist., in which the major part of the studied area lies, is shown in Table 1.

Previous work

A Miocene palynoassemblage was recorded from the Siwalik rocks of lesser Himalayas of Kameng district by Dutta and Singh [1]. The assemblage also contains reworked palynomorphs of Palaeozoic and Eocene age. Dutta [2] also recovered palynomorphs from the Siwalik rocks of Kameng district. The palynoassemblage recorded from the Tertiary sediments in Arunachal Pradesh by Srivastava and Bhattacharya, largely shows the overwhelming presence of angiosperm pollen viz., Lakiapollis, Neocourperipollis, Arecipites, pteridophytic spores viz., Todisporites, Cyathidites, Striatriletes and Crassoretiltites. At some sections presence of dinoflagellate and acritarchs indicate marine intercalation in the area during early Tertiary. This palynoassemblage also contains reworked Permian palynomorphs. The palynological

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assemblages comprising angiosperm pollen, pteridophytic spores, fungal remains, gymnosperm pollen, dinoflagellate cysts, acritarchs and reworked Permian morphs have been reported from the Siwalik sediments ex-posed in Kameng, Subansiri and Siang districts by Singh and Saxena [3]. Khan, has recovered a palynoassemblage from the Upper Siwalik [4] sediments of Kimin Formation (Upper Pliocene-Lower Pleistocene), exposed at the road cutting section of Papumpare district, contain abundance of fungal remains followed by angiosperm pollen grains and pteridophytic spores and complete absence of gymnosperm pollen grains. This palynoassemblage indicates the prevalence of warm humid, tropical- sub tropical climate with occasional near shore condition during Upper Pliocene-Lower Pleistocene in the area [5].

**Objective of Present Work**

The objective of the present work is to study and understand the depositional environment and palaeogeography of the said area of Arunachal Pradesh during tertiary period by the palynological assemblage analysis and petrographical study as well of the collected rock samples of Siwalik shales.

**Petrography**

**Lower Siwalik:** It is a dark-colored, extremely fine grained rock composed of, in order of approximately decreasing abundance of sericite, clay, quartz, feldspar, iron oxide, biotite and chlorite. The most significant textural feature is the segregation of sericite-biotite-chlorite rich thin elongate patches (Figures 2-5). Sporadically through the rock; in such segregated patches there is distinct preferred orientation of micas along a particular direction, however, haphazard criss-cross pattern of orientation of sericite within the clay-rich part of the rock is also common. Both sericite and biotite (pleochroic from pale yellow to greenish brown) occur in the patchy segregations as thin elongate grains, occasionally forming bunches. Chlorite, apart from forming thin laths occurs also as medium sized subsequent flakes [6]. Iron oxides occur both as highly irregular brown limonitic grains as well as subhedral to anhedral equant to slightly elongate grains. Rarely thin rim of aggregates of biotite occur around black iron oxide grains. Iron ox-ide is more concentrated along the cracks. Sericite occurs within the clay commonly as sporadic needles [7].

**Middle Siwalik:** The mineralogical composition and order of abundance is same here as in the Lower Siwalik samples. It is also a fine-grained rock, but the grain size is coarser than the Lower Siwalik samples (Figure 6).

**Upper Siwalik:** The mineralogical composition is mainly like the previous samples sporadic and medium sized, angular hornblende
(strongly pleochroic from pale green to bluish green) thin lenticles of brown limonite occasionally show preferred orientation (Figure 7) through the fine-grained matrix [8]. The overall size of the matrix is similar to lower Siwalik. But the significant feature is the occurrence of coarser clasts of quartz throughout the slide within the extremely fine grained matrix. The bluish colour of amphibole grain is due to high concentration of Na in its crystal structure. This in turn indicates high pressure metamorphism of the source rock/ provenance from where it is derived (Figure 8).

**Palynology**

**Sample collection**

The samples were collected from the exposures of Siwalik Shales from Pinjoli area of West Kameng Dist. and Itanagar-Banderdewa Roadside and Julu Village of Papumpare Dist. of Arunachal Pradesh, N-E India. These are exposure samples, not the drilled one [9,10].

**Methodology**

For Palynological study usual maceration technique has been adopted for recovery of palynomorphs with particular caution to avoid contamination. Each sample weighing 10 gm. was treated with 10% aqueous solution of HCL to dissolve carbonates, if any, washed thoroughly with distilled water followed by 40% HF treatment for 24 hours to remove all the silica contents. The HF-free samples were then treated with concentrated HNO₃ for few hours to few days depending on the maturation status of the samples. After thorough washing the samples were treated with 5-10% KOH (to dissolve the humic matters), sieved, washed with distilled water and dried partially. The samples were then suspended in a heavy liquid of KI-CdI₂ mixture adjusted to a specific gravity of 2.3. To the supernatant liquid, five times distilled water was added and then few drops of 10% glacial acetic acid were added and kept for overnight, centrifuged, washed and finally preserved in distilled water or 50% glycerin. Fine slides (5.0 cm X 2.2 cm) were prepared and preserved by cover glass for study under biological microscope. The best-preserved forms were photo-graphed and studied through Image Analyzer for detailed morphologic character analysis including measurement. Each of the bioforms is stored in a hard disk of computer. The pre-pared slides are stored in the repository of palaeobotany- palynology laboratory section of the Department of Botany, University of Calcutta.

**Palynological characters**

The total number of Genus recovered is 30. And the total number of species recovered is 32, of which 15 are fungal spores, 8 are pteridophytes,
and 9 are angiosperms. The description of each individual Palynotaxa is given below.

The Description of the Microspores Present

**Fungi**

1. Genus- **Colligerites** Jain and Kar
   Species- **Colligerites kutchensis** (Kar and Saxena) Jain and Kar
   Description- spores multicellular, coiled, cells generally smaller, rounded in central region and bigger, Rectangular in outer region. Spore wall mostly levigate, some-times granulose. Pore may be present or absent in each cell.

2. Genus- **Inapertisporeta** Van der Hammen ex Rouse
   Species- **Inapertisporeta** sp.
   Description- Spores unicellular, sub-spherical to ellipsoidal, sizes between + 9-54 µm X 9-36 µm; light to dark brown in colour, in aperturate, without any folds, spore wall + 1-1.5 µm thick, psilate.

3. Genus- **Monoporisporites** Van der Hammen
   Species- **Monoporisporites** sp.
   Description- Spores unicellular, spherical to subspherical, ellipsoidal or obovate, sizes between + 6 X 4- 27 X 15 µm, dark brown in colour, monoporate, pore towards one side, simple, without folds. Spore wall + 1-1.5 µm thick, distinctly 2-layered, psilate.

4. Genus- **Quilonia** Jain and Gupta
   Species- **Quilonia** sp.
   Description- Body multicellular, filamentous, exine thick, margin undulated, Apical and Basal portions narrow, central [section] wide. Basal stalk prominent with one or two rectangular thick-walled cells; apical cell mostly in-complete, curved, central portion broad, elongate. With irregularly shaped furrow-like suture, inside the filament at different places occur one-four small, circular, ostiolate bodies.

5. Genus- **Dicellaesporites** Elsik
   Species- **Dicellaesporites** sp.
   Description- Spores two-celled, unisepate, uniseriate, inaperturate, 12 µm long, 4-5.5 µm broad, slightly constricted at joining of two cells, free ends rounded; cells apparently dissimilar, one clearly larger, longer than the broad, blackish brown; other cell small, broader than long, 3 µm elements, wall ca 0.5 m thick and relatively lighter in colour; septum transverse, prominent, 1 µm broad.

6. Genus- **Dyadosporites** Van der Hammen
   Species- **Dyadosporites** sp.
   Description- Fungal spores bilocular, elliptical, central septum simple, cell wall psilate to finely punctuate, pore at apex of each cell, sizes between 31-42 µm X 12-16 µm.

7. Genus- **Desmidiospora** Thaxter
   Species- **Desmidiospora** willoughbyi (Bradley) Ethridge, Brown and Elsik
   Description- Sporangia thick-walled and flattened in the plane of the substratum, circular, 8-22 µm diameter, to irregularly elliptical, up to as much as 22 µm long. Sporangia more or less deeply lobed, the lobes being separated by distinctive narrow invaginations, many of which have a characteristic circular enlargement at the proximal ends. In larger sporangia these invaginations commonly occur in radial sets of two or three length, each shorted invaginations being be-tween two next longer invaginations. Sporangia smooth or papillate, some having the persistent, thickened zoospore cyst, 2.5-3.5 µm diameter, ad germ tube. Many have clearly defined, circular exit pore.2-2.5 µm in diameter. Zoospores and rhizoidal axis unknown.

8. Genus- **Exesisporites** Elsik
   Species- **Exesisporites** sp.
   Description- Unicell difficulty, aseptate, psilate, monoporate fungal spores of circular outline with lenticular to spherical in shape. The centrally located pore in most specimens is surrounded by a dark circular patch which is interpreted as a thickened wall. This polar area is occasionally found free of the spore. Spores 17-30 µm in diameter in polar view.

9. Genus- **Fractisporonites** Clarke
   Species- **Fractisporonites** sp.
   Description- Fungal spores uniseriate, fragments consist of four to many rectangular to square cells, 16-28 µm high, 25-30 µm diameter. Overall dimensions 25-30 X 150-230 µm, sides generally parallel.

10. Genus- **Hypoxylonites** Elsik
    Species- **Hypoxylonites** sp.
    Description- Oval to elongate, aseptate, bilaterally, psilate fungal spores bearing an elongate scar, slit or furrow. At the level of transmitted light microscopy, at least one species is faintly sculptured. The elongate furrow is parallel to this axis and can be of various lengths. Apices rounded to pointed; usually of similar shape but some species have an attachment scar at one end; apices can also be thickened or otherwise modified. The spore wall in most specimens is generally rigid.

11. Genus- **Hypoxylonites** Elsik
    Species- **Hypoxylonites** gulfensis Elsik
    Description- Bilateral, reniform, aseptate, psilate fungal spores with a longitudinal furrow generally ½ or less of the length of the straight or concave side of the spore.
    Overall size 7-10 X 25-32 um. Spore wall 0.25-0.5 um or slightly thicker, thickening to a maximum of 1.5 um over the ends of the spore in a few specimens; not thickened in other specimen: Aperture a narrow furrow with rounded ends. Ends of spore sub-pointed or narrowly rounded.

12. Genus- **Multicellites** gen. nov.
    Species- **Multicellites** sp.
    Description- Multicellular, uniserial, inaperturate fungal spores; number of cells three to many; terminal cells usually smooth, of medium thickness, usually thinner than the septa (or septal base).

13. Genus- **Scolecosporites** Lange and Smith
    Species- **Scolecosporites** sp.
    Description- Scoleco- phragmospore of length 15-30 X the breadth, the outline of walls and septa ladder-like.

14. Genus- **Scleroderma** Persoon
    Species- **Scleroderma** echinosporites Rouse
Description- Spores small, circular in outline, with no obvious openings or pores in the wall. Ornamentation consists of fine spines radiating out from the wall. These cover the spore except at one place, which presumably was the place of attachment of the stergima. The wall also seems coarsely punctuate, with, thin areas more or less scattered onto the surface, size range 11-15um.

15. Genus- Phragmothyrites Edwards
Species- Phragmothyrites sp.

Description- Fossil forms belonging to the Microthyriaceae, the exact position of which is uncertain, but which appear to be most closely related to Phragmothyrium as defined by Von Hohnel. No free hyphae, ascostromata sub–circular- circular, dimidiate, non-ostiolate; hyphae radially arranged, interconnected to form pseudopar–enchamatomous cells; central cells + squarish sub circular, outer cells elongated, may be setose at margin and thickened. Cells with or without pore, generally cells in the middle region are more porate than outer ones.

Pteridophyta

1. Genus- Polypondiaecosporites Thiergart
Species- Polypondiaecosporites sp.

Description- Spore bean shaped, 54 um, monolete, exine 2um thick, exo–exinous layer very thin, exinelaevigate and weakly infrastructured.

2. Genus- Cyathidites Couper
Species- Cyathidites sp.

Description- Free anisopolar, trilete, laesuraeae distinct, long, spores triangular to sub-triangular, apices very broadly rounded and sides concave in polar view. Exine psi-late, 1.5 um thick, size ranges from 31-(35)-45 um.

3. Genus- Lygodiumsporites Potonie, Thomson and Thiergarte emend
Species- Lygodiumsporites sp.

Description- Spores sub-triangular size range 55-60 um, trilete distinct, extendint upo two-thirds the radius; exine laevigate.

4. Genus- Deltoidospora
Species- Deltoidospora sp.

Description- Trilete spore. Outline triangular with straight to convex sides in polar view. Laesuraeae distinct and long, exceeding 2/3 of the radius of the spore, Exine two-layered; surface of exine psilate and krytomes develop along the laesuraea. Size is 32.0 X 25.0um.

5. Genus- Polypondiosporites
Species- Polypondiosporites sp.

Description- Trilete, roundly triangular, cingulated spore with concave sides. Y mark distinct; laesuraea reaching the edge of the inner body; narrow and surrounded by exinal thickenings. Exine psilate; cingulum about 6.0 um side and psilate. Size is 35 um.

6. Genus- Pteridacidites
Species- Pteridacidites sp.

Description- Trilete cingulated spore. Contour triangular with rounded corners and slightly concave sides. Y mark dis-tinct; laesuraea thin and prominent, reaching upto the end of the spore body, but not entering the cingulum. Spore body covered, proximal and distal side with generally large polyanular, flat topped verrucae. Cingulum psilate and 4.0-6.0 um wide. Size is about 31.0-33.5uum.

7. Genus- Lycopodiumsporites Thiergart ex Doulcment and Spurmont
Species- Lycopodiumsporites sp.

Description- Spores triangular, 22-35uum, trilete distinct, rays extending upo three fourths of the radius; reticulate, proximal muri ill-developed, do not anastomose to form regular meshes, distal muri form a regular reticulum. Exine 2-3um thick.

8. Genus-Gleichenidites Ross
Species- Gleichenidites sp.

Description- Miospore triangular or sub-triangular, apices rounded, sides concave, size 27um-29.5um, trilete, Y-mark slender but distinct, rays extending more than 2/3rd of the spore radius, lip thin, ends pointed. Exine 1.5um-2um thick, surface laevigate. Distal face provided with three arcuate folds and proximal intertidal thickenings.

Angiosperm

1. Genus- Palmaepollenites (Potonie) ex Potonie
Species- Palmaepollenites sp.

Description- Pollen grains bilateral, elliptical, 45uum in size, ends and bordered by thick exine, + 1.5 um thick, psilate.

2. Genus- Cupuliferoidaepollenites
Species- Cupuliferoidaepollenites sp.

Description- Tricolpate pollen grain, outline sub-circular in polar view; colpi narrow and long almost reach-ing the poles and are uniform width. Exine over 1.0 um thick, two layered; nexine is thicker than sexine; surface of exine psilate, size is about 15.0 um in diameter.

3. Genus- Betulaepollenites
Species- Betulaepollenites sp.

Description- Triporate pollen grain, outline small and triangular. Exine thin and psilate. It is characterized by the presence of arci connecting all the three pores and running nearer the equator and away from the poles. Size is 22.0 um.

4. Genus- Graminidites Cookson
Species- Graminidites media Cookson

Description- Pollen grains sub-spheroidal to sub-triangular, sides convex to slightly rounded, trilobite, poles somewhat flattened to rounded, 36-38um X 40um in size. Monoporate, pore rounded + 4 um in diameter, aspidate with thick annulus. Exine thin, surface granulate.

5. Genus- Dicolpolopollis
Species- Dicolpolopollis sp.

Description- Dicolpate pollen grains. Amb barrel shaped, biconvex in polar view. Colpi short, about 5.0 um deep and wide. Exine thin, about 1.0 um thick, atectate, psilate to chagrenate, size variable, small to medium. Size varies from 25.0-47.0um X 20.0-25.0um. verrucate with some scabrae.

6. Genus- Liliacidites Couper
Species- Liliacidites sp.
Description- Pollen grains elongate, ellipsoidal, monosulcate, 50 X 25um in size. Sulcus as the pollen length, open at both ends and of uniform width. Exine upto 1 um thick, tectate, surface reticulate.

7. Genus- Quercoidites
Species- Quercoidites sp.
Description- Pollen grains spheroidal in shape, 30 X 25.5um in size, tricolpate. Exine 1.5-2.0um thick, sculpture.

8. Genus- Araliaceopollenites Potonie ex Potonie
Species- Araliaceopollenites sp.

### Recovered Palynotaxa

| Recovered Palynotaxa | Nearest living Relative | Siwalik (Arunachal Pradesh) | Habit | Climate/Environment |
|----------------------|--------------------------|-----------------------------|-------|--------------------|
|                      |                          | Lower | Middle | Upper |                   |
| **Fungi**            |                          |       |        |       |                   |
| Inapertisporites sp  | Fungi imperfecti         |       | +      | +     | Thallophyta        |
| Monoporiisporites sp | Fungi imperfecti, amerosporae | +  |       | -     | Thallophyta        |
| Quillonia sp          | Fungi imperfecti, phragmosporae | - |       | +     | Thallophyta        |
| Dickiteasporites sp   | Fungi imperfecti, phragmosporae | - |       | +     | Thallophyta        |
| Dyadoporiisporites sp | Fungi imperfecti, amerosporae | - |       | +     | Thallophyta        |
| Desmidsospora willoughbyi | Fungi imperfecti, amerosporae |   |       | +     | Thallophyta        |
| Exelesporites sp      | Fungi imperfecti, phragmosporae | - |       | +     | Thallophyta        |
| Fraxitiforiniplorites sp | Fungi imperfecti, phragmosporae | - |       | +     | Thallophyta        |
| Hypoxylonitidae sp    | Fungi imperfecti, amerosporae | +   | +      | +     | Thallophyta        |
| Hypoxylonites guifensis | Fungi imperfecti, amerosporae | -  | +      | -     | Thallophyta        |
| Multites sp           | Fungi imperfecti, phragmosporae | - |       | +     | Thallophyta        |
| Scolcosporites sp     | Fungi imperfecti, phragmosporae | - |       | +     | Thallophyta        |
| Scleroderma echinosporites | Basidimycetes, sclerodermatales | - |       | +     | Thallophyta        |
| Phragmophyllites sp   | Ascomycetes, Microtyriace  | -   | +      | +     | Thallophyta        |
| Collertes kutchensi   | Fungi imperfecti, helicosporae | - |       | +     | Thallophyta        |
| **Pteridophytes**     |                          |       |        |       |                   |
| Poipodiumaenos-rites sp | Polipodiuma             | *    | +      | +     | Herb              |
| Cythidites sp         | Cythatheaeae             | _    | +      | +     | Herb              |
| Lygodiumsporites sp   | Lygodium of Schizaceae   | *    | +      | +     | Herb              |
| Deltiodiospora sp     | Lindseaaceae             | _    | +      | +     | Herb              |
| Polypodiisporites sp  | Denstaeiaeae             | *    | +      | +     | Herb              |
| Pteridicidites sp     | Pteridaceae              | *    | +      | +     | Herb              |
| Lycodiumsporites sp   | Lycodium                 | *    | +      | +     | Herb              |
| Gleichenidites sp     | Gleicheniaeae            | *    | +      | +     | Herb              |
| **Angiosperms**       |                          |       |        |       |                   |
| Palmacepollenites sp  | Areaceae                 | *    | +      | +     | Tree              |
| Cupuliferozoa-epollenites sp | Cupuliferae |   | *      | -     | Tree              |
| Betulacepollenites sp | Betulaeaeae              | *    | +      | +     | Tree              |
| Graminidites media    | Poaceae                  | *    | +      | +     | Grass             |
| Dicotopanis sp        | Calamus, palmae          | _    | +      | +     | Tree              |
| Liliacidites sp       | Liliaceae                | _    | -      | +     | Herb              |
| Quercoidites sp       | Fagaceae                 | _    | -      | +     | Herb              |
| Araliacepollenites sp | Areaceae                 | *    | -      | +     | Herb              |
| Rhoipites sp          | Anacardiaceae            | *    | +      | +     | Herb              |

Table 2: The chart for palynotaxa recovered from various Strata and the palaeo-environmental analysis with reference to their nearest living relatives and habit.
Environmental Analysis

The Palaeo-environment can be concluded from the systematic analysis of the percentile distribution of the palynomorphs in the Upper, Middle and Lower Siwalik strata.

Conclusion

Although the systematic and quantitative analysis of the palynotaxa recovered (Table 2) shows that the predominance of fungal spores over angiosperms and pteridophytes all over the Lower and Middle Siwalik (Figures 9 and 10). However, a slight decrease in frequency of fungal elements has been observed in Middle Siwalik than that of Lower Siwalik sediments. In contrast to Lower and Middle Siwalik sediments, the sediments of Upper Siwalik age show the dominance of angiosperms over fungal spores and pteridophytes (Figure 11) [11-15]. The palynoassemblages of Lower Siwalik sediments suggest that the overall climatic conditions during the Lower Siwalik was mostly Tropical and humid. However, presence (~18% total) of Cupuliferidaepollenites sp. and Polypodiisporites sp. indicates towards a slight influence of temperate climate (Figure 12). Cosmopolitan Graminidites sp. was present as usual. A major percentage of Palmae indicates that the region was mainly coastal. The thallophytes dominated all over. In Middle Siwalik, frequency of recovery of palm pollen grains of Dicolpopolis sp. and Palmaepollenites sp. Decreased (Figure 12) than that of Lower Siwalik sediments. This indicates that the coastal influence is lowered during the Middle Siwalik times. The pteridophytes, which grow in the tropical to sub-tropical condition, dominate the pteridophytic assemblage. So the overall climatic condition during Middle Siwalik was mostly tropical to Subtropical with a lowered coastal influence. Frequency of Palmae has been reduced in The Upper Siwalik sediments than Lower and Middle Siwalik sediments indicating a lesser influence of coastal environment in the Upper Siwalik. A reduced recovery of thallophytes indicates a less humid condition (Figure 11).

That means the coastline moved further away during Upper Siwalik and as effect humidity decreased [16]. And the presences of mainly Tropical to Sub-tropical taxas are dominating. But there is a
major percentage (~20% total) of Sub-tropical to Temperate condition favouring Queroidites sp. and Betulaepollenites sp. (Figure 12) Angiosperms indicates that the climatic condition was mainly Sub-tropical to temperate during Upper Siwalik. The large percentage of fungal spores during all over the Siwalik, however, does indicate the high rate of deposition. Petrographic study also indicates to a coastal vicinity influence (Figures 13 and 14).

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