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Reworked Permian and Jurassic-Cretaceous palynofossils from the Subathu Formation (late Ypresian-middle Lutetian) of the Lesser Himalayas, India and their palaeogeographic significance

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ABSTRACT

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The present paper documents the occurrences of reworked Permian and Jurassic-Cretaceous palynofossils from the Subathu Formation (late Ypresian to middle Lutetian) of the Lesser Himalayas, India. The reworked palynofloral assemblage consists of 23 genera and 27 species comprising pteridophytic spores, gymnospermous pollen and dinoflagellate cysts. Of these, 14 genera and 16 species belong to Permian whereas others are attributed to the Jurassic-Cretaceous. Permian palynotaxa, viz. *Densipollenites*, *Indotriradites*, *Scheuringipollenites*, *Virkkipollenites*, *Platysaccus* and *Caheniasaccites* show greater frequency in late Ypresian palynofloral assemblage in association with Eocene dinoflagellate cysts in Shimla Hills, Himachal Pradesh. On the contrary, Jurassic-Cretaceous palynofossils, viz. *Odontochitina*; *Leberidocysta*, *Pareodinia* and *Callialasporites* are found in association with land-derived elements in Lutetian palynofloral assemblage of the Morni Hills, Haryana. The distinction in the preservation of the Permian and Jurassic-Cretaceous palynofossils is well marked. The Permian palynotaxa are well preserved and possess distinct morphological features whereas the Jurassic-Cretaceous forms are commonly broken and show strong signatures of oxidization. The palaeogeographic significance of these reworked palynofossils in the Subathu Formation has been discussed to highlight their distribution patterns in the geological past.

Keywords: Reworked palynofossils, Permian, Jurassic-Cretaceous, Subathu Formation, Lesser Himalayas, Palaeoenvironment

INTRODUCTION

Occurrence of reworked palynofossils of older age in comparatively younger sediments is a common observation in the tectonically active regions of the Himalayas. Recognition of such palynofossils in an assemblage helps in proper evaluation of the indigenous palynofloral assemblage as well as in locating the source area of the concerned sediments. Reworked palynofossils from the Tertiary rocks of eastern Himalayas have been recorded by several workers (Banerjee et al. 1973, Salujha et al. 1973, Dutta 1978, 1979, Dutta & Singh 1980, Trivedi 1985, Singh et al. 1990). However, records of reworked palynofossils from the Tertiary rocks of the western Himalayas are scanty (Saxena & Sarkar 1983, Sarkar & Prasad 2000a, b) though such palynofossils are common in the lower Tertiary successions outcropping in the Lesser Himalayas. During the course of palynostratigraphical investigation of the Subathu Formation in the Lesser Himalayas, several reworked Permian and Cretaceous palynofossils have been recovered from the evaluated stratigraphic sections of Shimla Hills, Himachal Pradesh and Morni Hills, Haryana. The main objective of this paper is to record reworked Permian and Cretaceous palynofossils from some sections of the Subathu Formation (late Ypresian-middle Lutetian) of the Lesser Himalayas and to interpret their palaeogeographical significance in context of the palaeoenvironment.

GEOLOGICAL SETTING

The Palaeogene succession pertinent to the western Himalayas comprises four formations, viz. Kakara, Subathu, Dagshai and Kasauli in the ascending order of stratigraphy. These rocks are exposed as discontinuous strips right from the Jammu to the east of Nainital in Uttar Pradesh. These rocks occur either in a tectonic belt just north of the Siwalik, or in the form of isolated patches or as windows over pre-Tertiary rocks. In Himachal Pradesh and Haryana, it occurs in two distinct tectonic units, viz. the Bilaspur and the Surajpur units (Bhandari & Agarwal 1967, Raiverman & Raman 1971). Koshalia Nala section of Shimla Hills, Himachal Pradesh and Kharak River section of Morni Hills, Haryana fall under the Surajpur and Bilaspur tectonic units respectively. The Koshalia Nala section is situated near Koti in the Sirmur district of Himachal Pradesh. The Subathu Formation in this area is separated from the Kasauli Formation in the west by the Koti/Surajpur thrust. The Subathu Formation is about 110 m thick in this area. The lower part of the late Ypresian sequence comprises mostly grey splintery shales with few thin storm sand layers. The middle horizon contains mostly hard splintery shales intercalated with thin sandstone layers. The early Lutetian sequence is about 20 m thick. It is characterized by a thick limestone bed (1–2 m) at the base. It contains mostly green splintery shales. The overlying red bed sequence (~5.5 m) mostly comprises siltstones.

The Subathu Formation rests unconformably on the pre-Tertiary Tundapathar limestones in the Morni Hills. The Tundapathar Group along with the overlying Subathu Group thrusts over the younger Nahan Group as parautochthonous unit along a major boundary fault (Bagi 1992). Kharak river section is situated on the west bank of the Ghaggar River near the village Kharak. The total thickness of the exposed section at Kharak is 68 m. The lower horizons comprise carbonaceous shales which are black to grey in colour and at places phyllitic; calcite veins as well as several shelly limestones/ oyster bands are present in this bed. The basal beds comprise mainly of black carbonaceous shales which are overlain by grey splintery shales in the middle. The younger horizons of the succession are mostly grey splintery shales. A white quartzitic sandstone bed followed by the red nodular beds of the Dagshai Formation overlies the sequence (Figure 1).

MATERIALS AND METHODS

The present palynological investigation is based on the study of samples which were collected from two measured stratigraphic sections of the Subathu Formation, viz. Koshalia Nala section of Shimla Hills, Himachal Pradesh and Kharak River section of Morni Hills, Haryana (Figure 2). The locations of the horizons yielding the reworked palynofossils are also marked in Figure 2. Investigated palynological samples from several measured stratigraphic sections of Jammu & Kashmir and Nilkanth area of Uttarakhand did not yield any reworked palynofossils (Khanna et al. 1985,

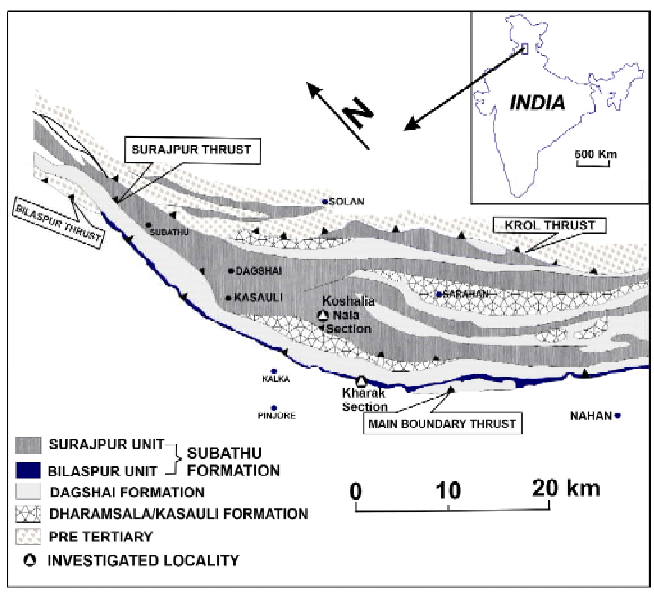

Figure 1. Geological map of Nahan area, Sirmaur district of Himachal Pradesh (After Kapoor et al. 1997).

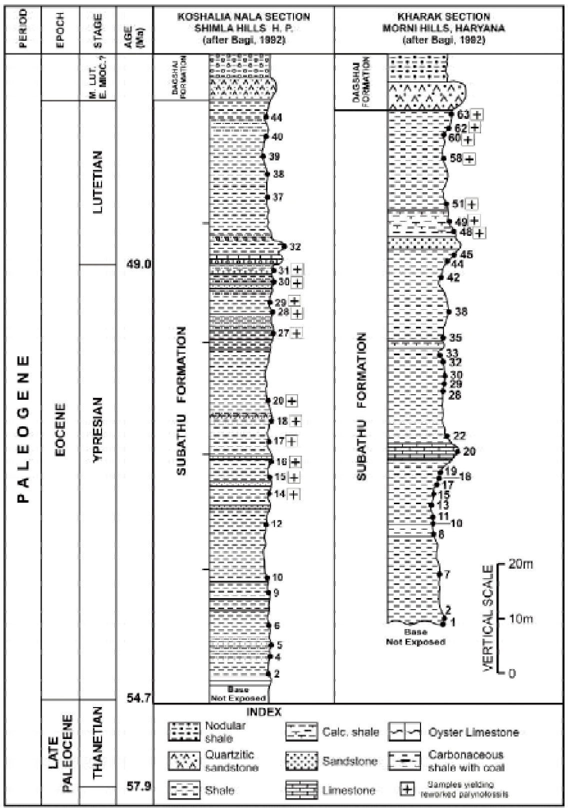

Figure 2. Lithocolumns of the studied sections showing location of productive samples yielding the reworked palynofossils in the Subathu Succession.

Sarkar, 1996, Panwar et al. 2021). For recovery of palynofossils, all the samples were processed by conventional palynological techniques of maceration with HCl, HF, HNO_3 and KOH. The slides were prepared in polyvinyl alcohol and mounted in Canada balsam. Two hundred palynofossils per sample were counted for quantitative analysis. All figured slides are housed in the repository of the Birbal Sahni Institute of Palaeosciences, Lucknow. A checklist of the recorded reworked palynofossils has been provided below and a chart illustrating the distribution and abundance of the major reworked palynofossils has been given in Figure 3. Some of the age diagnostic palynofossils have also been illustrated (Figure 4).

REWORKED PALYNOTAXA

Reworked Permian palynofossils

Caheniasaccites ovatus M.N. Bose & R.K. Kar 1966 (Figure 4.14)

Crescentipollenites brevis (M.N. Bose & R.K. Kar) Bharadwaj et al. 1974

Cuneatisporites densus Maithy 1969

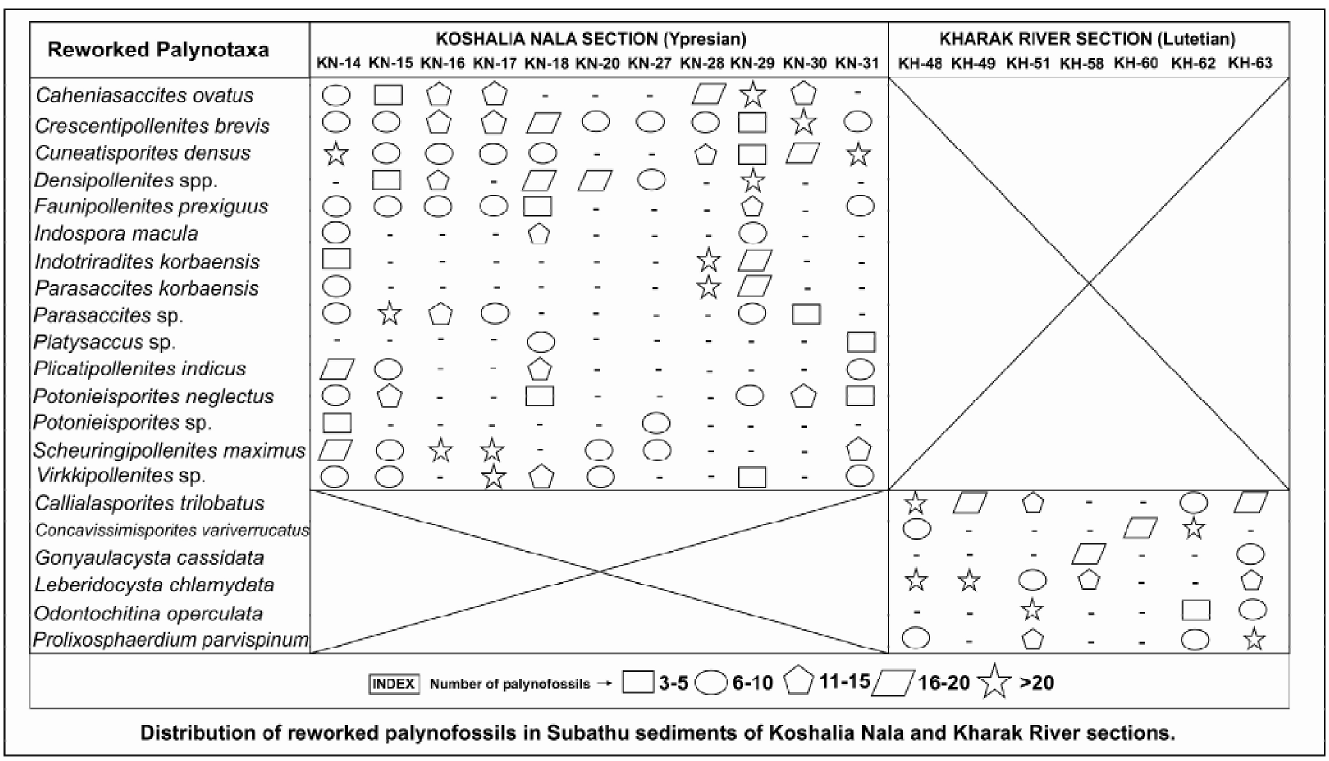

Figure 3. Distribution of reworked palynofossils in Subathu sediments of Koshalia Nala and Kharak River sections.

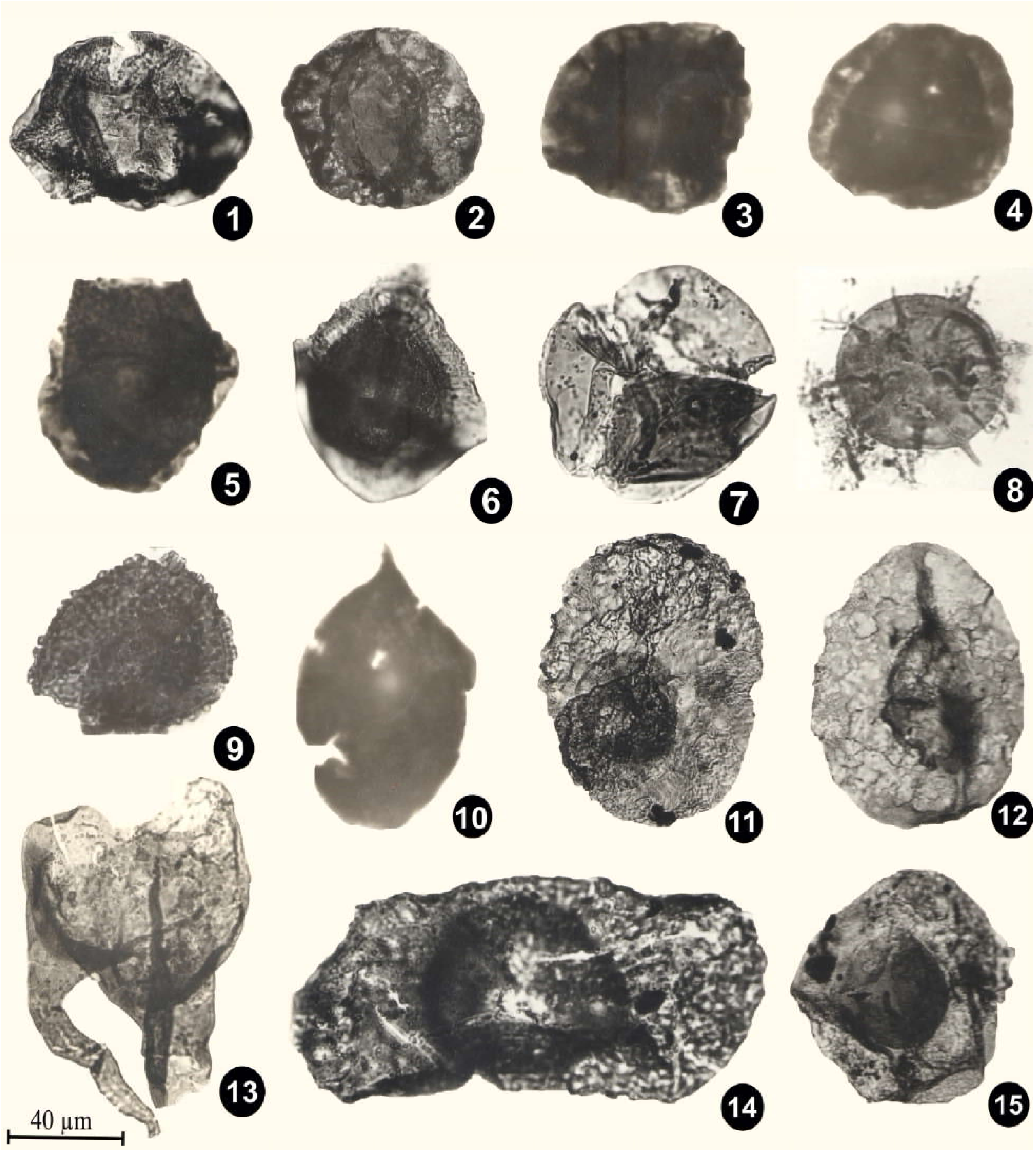

Figure 4 (All photographs are magnified ca ×500). **1.** *Faunipollenites prexiguus* Bharadwaj & Salujha 1965, BSIP Slide No. 6910, Coordinates 71 × 111. **2.** *Scheuringipollenites maximus* (Hart) Tiwari 1973, BSIP Slide No. 6910, Coordinates 65 × 109. **3–4.** *Callialasporites trilobatus* (Balme) Dev 1961, BSIP Slide No. 12731, Coordinates 41 × 102, 51 × 110. **5.** *Leberidocysta chlamydata* (Cookson & Eisenack) Stover & Evitt 1978*,* BSIP Slide No. 12732, Coordinates 65 × 108.5. **6.** *Indotriradites korbaensis* Bharadwaj & Tiwari, 1964, BSIP Slide No. 6910, Coordinates 47 × 109. **7.** *Microbaculispora indica* (Tiwari) Tiwari & V. Singh, 1981 (in tetrad condition), BSIP Slide No. 6910, Coordinates 44 × 105.5. **8.** Acritarch type–A, BSIP Slide No. 6910, Coordinates 65 × 101. **9.** *Indospora macula* Bharadwaj & Tiwari, 1964, BSIP Slide No. 6910, Coordinates 56 × 98. **10.** *Pareodinia* sp. BSIP Slide No. 12731, Coordinates 55 × 101. **11–12, 15.** *Densipollenites* sp., BSIP Slide No. 6910, Coordinates 69 × 100, 69 × 102 and 59 × 106.5. **13.** *Odontochitina operculata* (Wetzel) Deflandre & Cookson, 1955, BSIP Slide No. 12731, Coordinates 56 × 104. **14.** *Caheniasaccites ovatus* M.N. Bose & R.K. Kar, 1966, BSIP Slide No. 12733, Coordinates 43 × 100.

Densipollenites sp. (Figure 4.11–12, 15)

Faunipollenites prexiguus Bharadwaj & Salujha 1965 (Figure 4.1)

Indospora macula Bharadwaj & Tiwari 1964 (Figure 4.9)

Indotriradites korbaensis Bharadwaj & Tiwari 1964 (Figure 4.6)

Microbaculispora indica (Tiwari) Tiwari & V. Singh 1981 (Figure 4.7)

Parasaccites korbaensis Bharadwaj & Tiwari 1964

Parasaccites sp.

Platysaccus sp.

Plicatipollenites indicus Lele 1964

Potonieisporites neglectus R. Potonié & Lele 1961

Potonieisporites sp.

Scheuringipollenites maximus (Hart) Tiwari 1973 (Figure 4.2)

Virkkipollenites sp.

Reworked Jurassic–Cretaceous palynofossils

Callialasporites trilobatus (Balme) Dev 1961 (Figure 4.3–4)

Callialasporites sp.

Concavissimisporites variverrucatus Couper 1958

Concavissimisporites sp.

Cicatricosisporites sp.

Mulleripollis bolpurensis Baksi & U. Deb 1981

Gonyaulacysta cassidata (Eisenack & Cookson) Sarjeant 1966

Leberidocysta chlamydata (Cookson & Eisenack) Stover & Evitt 1978 (Figure 4.5)

Odontochitina operculata (Wetzel) Deflandre & Cookson 1955 (Figure 4.13).

Pareodinia sp. (Figure 4.10)

Prolixosphaeridium parvispinum (Deflandre) Davey et al. 1969

Acritarch type–A (Figure 4.8).

DISCUSSION

The reworked palynofloral assemblage of the Subathu Formation consists of 23 genera and 27 species of pteridophytic spores, gymnospermous pollen and dinoflagellate cysts. Of these, 14 genera and 16 species belong to Permian whereas others belong to Jurassic-Cretaceous. The indigenous palynoflora of both the sections were described and illustrated in detail earlier (Sarkar & Prasad 2000a, b). On the basis of the distribution of age diagnostic dinoflagellate cysts, the present succession has been dated as early Ypresian to middle Lutetian. An early Eocene age of Koshalia Nala stratigraphic succession was also supported by the presence of nannofossils pertinent to the combined NP12 and NP13 zones of the late Ypresian age (Jafar & Singh 1992) as well as by the presence of the characteristic larger benthic foraminifera, viz. *Orbitolina mamillata* (described as *Assilina mamillata*), *Assilina spira abrardi*, *A. daviesi, A. granulosa*, *Nummulites atacicus* and *N. globulus* (Bhatia & Singh 1991). The Kharak palynofloral assemblage consists mainly of dinoflagellate cysts along with pteridophytic spores, angiosperm and gymnosperm pollen, and fungal spores and ascostromata. Dinoflagellate cyst is the most dominant element of the assemblage. Pteridophytic spores are present in high percentages only at certain levels of the succession. Fungal spores and microthyriaceous ascostromata are present in almost all the samples of the younger horizons in large numbers. The palynofloral assemblage zone D which covers the middle Lutetian part of the Subathu succession has yielded most of the reworked palynofossils (Figure 2) in the Kharak River Section (Sarkar & Prasad 2000b). Terrestrial palynomorph taxa, viz. *Neocouperipollis brevispinosum*, *Cyathidites minor*, *Todisporites major*, *Podocarpidites couperi*, etc. have been recorded in large quantity. Dinocysts are poorly represented in this horizon. The entire late Ypresian-early Lutetian succession of the Subathu Formation of the Koshalia Nala section (Assemblage Zones 1–3) has yielded rich and diversified dinocyst assemblage consisting mainly of representatives from genera *Homotryblium*, *Cordosphaeridium* and

Hystrichokolpoma. The associated dinocyst taxa in this assemblage are *Cyclonephelium* sp., *Glaphyrocysta divaricata*, *Adnatosphaeridium vittatum* and *A. multispinosum* (Sarkar & Prasad 2000a). Reworked palynofossils have been recorded in the dinocyst assemblage zone 2. The identification of reworked palynofossils in any indigenous palynological assemblage is a very difficult task. In the present investigation, the reworked palynofloral assemblage is determined on the basis of mainly three criteria which were earlier proposed by Wilson (1964), viz. (i) palynofossils of more than one geological age in the assemblage; (ii) palynofossils with different biological stain reactions in the assemblage; and (iii) palynofossils showing differential levels of preservation. It has been observed that in most of the cases reworked palynofossils are poorly preserved than those of the indigenous assemblage as well as the display of significant color differentiation of palynofossils in the same sample. In the present palynological investigation, reworked elements mainly consist of miospores, acritarchs, as well as dinoflagellate cysts which originate from Permian, Late Jurassic to Early Cretaceous and Late Cretaceous sediments. It has been observed that the distribution pattern of the reworked palynofossils is quite different in the Subathu succession of both the Shimla Hills and the Morni Hills. Reworked Jurassic-Cretaceous palynofossils are found mainly in the early Lutetian palynoflora of Morni Hills which is dominated by high amount of land derived elements, whereas, Permian palynotaxa are more frequent in late Ypresian palynoflora in association with dinoflagellate cysts in the Shimla Hills. The lower Permian palynofossils, viz. *Caheniasaccites, Parasaccites, Densipollenites*, *Indotriradites*, *Scheuringipollenites, Virkkipollenites* and *Platysaccus* are found mainly in the Shimla Hills. On the contrary, the Late Jurassic-Early Cretaceous palynofossils, viz. *Odontochitina*, *Leberidocysta*, *Pareodinia* and *Callialasporites* are restricted to the Morni Hills. Permian palynotaxa show distinct morphological features owing to excellent preservation while the Jurassic-Cretaceous forms are generally broken and highly oxidized. The present palynological investigation proves that the occurrence of reworked palynofossils in the Subathu Formation is restricted to a particular horizon in both areas during different time periods. Generally, the reworked palynofossils are poorly preserved, however in the present investigation Permian palynotaxa recorded from the Shimla Hills show excellent morphological features which indicates that they were transported from a short distance. Quantitative analysis of the palynoflora shows that the number of reworked palynofossils is also very poor as none of the taxa could figure in percentage count of an individual sample. However, few taxa, viz. *Plicatipollenites*, *Indospora* and *Parasaccites* are present in large number in some of the samples. It has also been noticed that the reworked palynofossils are very common in the horizons of late Ypresian/early Lutetian transitional period of the stratigraphic succession. A comparison of the present reworked palynofloral assemblage with the known records of Permian, Late Jurassic and Early Cretaceous palynofloral assemblages (Srivastava 1991) make it clear that the palynofossils recorded here have a close affinity with the Barakar palynofloral assemblage whereas Cretaceous palynofossils have affinity with the Cenomanian and Early Maastrichtian palynofloral assemblages.

The presence of Permian and Jurassic-Cretaceous palynofossils in the late Ypresian and early Lutetian sediments of Himachal Pradesh and Haryana is rather diffficult to explain as in these regions there are no known exposures of Permian and Mesozoic rocks. In Shimla Hills and Morni Hills, the pre-Tertiary rocks are mainly represented by Precambrian as well as Cambrian rocks. In Morni Hills, the pre-Tertiary rocks are mainly represented by Tundapathar limestone which is Precambrian in age. The possibilities of these palynofossils being transported from the Tethyan Himalayan region cannot be ruled out as there is an extensive development of Permian, Late Jurassic and Early Cretaceous rocks in the Spiti areas of Himachal Pradesh. In due course, these sediments had been eroded and redeposited in the Eocene sediments of Shimla Hills and Morni Hills. Therefore, in our opinion the Permian, Late Jurassic and Early Cretaceous sediments containing reworked palynofossils possibly acted as a source for the Subathu sedimentation in Shimla Hills. The land derived sediments in the Subathu Formation were derived from a mixed source terrane in the proto-Himalayan suture belt, which included all sedimentary rocks of the Indus suture zone. The Permian and Jurassic-Cretaceous rocks are well developed in the Salt Range of Pakistan which is far away from the present area of investigation. Although, there is every possibility of reworking of palynofossils from that area, due to excellent preservation and fine sculpture of the palynofossils it is very clear that these palynofossils came from nearby localities and got redeposited during the sedimentation of the Subathu Formation in the Shimla Hills. Recent discovery of Cretaceous palynofossils from the Kakara Formation near Nahan area of Himachal Pradesh also points toward the probable occurrence of Late Cretaceous rocks in nearby areas (Thakur et al. 2013). The occurrences of Permian and Late Jurassic – Early Cretaceous palynofossils in the Eocene palynofloral assemblage of the Subathu Formation is definitely due to the reworking phenomenon. Jafar and Kapoor (1989) reported reworked Late Maastrichtian-Danian nannofossils species from basal beds of the Subathu Formation suggesting possible presence of Cretaceous outcrops sandwiched between Precambrian rocks in the Lesser Himalayan terrain. K/T boundary species with Early Eocene nannofossils were also discovered from the Subathu Formation, Shimla Hills in Himalayas, India (Jafar & Singh 1992). Reworked Jurassic-Cretaceous palynofossils might have come from this exposure of the Kakara Formation of the Nahan area and redeposited in the Morni Hills during Eocene times. The occurrence of reworked palynofossils in these sediments indicates that considerable amount of material for the sedimentation of the Subathu Formation was supplied by the Kakara Formation which is exposed in the Nahan Area of Himachal Pradesh that is very close to the investigated areas of the Shimla Hills as well as of the Morni Hills.

CONCLUSIONS

1. The present study demonstrates that reworking of palynofossils occurred on a much larger scale in the Shimla Hills and its adjoining areas during late Ypresian-middle Lutetian period than in the other areas of Lesser Himalayas.
2. Reworking of palynofossils also points towards an increased tectonic regime towards and beyond late Ypresian/early Lutetian transitional period during the deposition of Subathu rocks.
3. The studied reworked palynofloral assemblage consists of 23 genera and 27 species. Of these, 14 genera and 16 species belong to Permian whereas others belong to Jurassic-Cretaceous.
4. The frequent co-occurrence of reworked time separated species in the Subathu succession points towards a much more complicated palaeogeography of the hinterland during the Ypresian stage.
5. The occurrence of reworked palynofossils indicates that bulk of the material for the Subathu Formation sedimentation of Shimla Hills was derived from the pre-existing Permian and Late Jurassic-Early Cretaceous sediments from the Spiti areas of Himachal Pradesh whereas reworked palynofossils of Morni Hills may come from some isolated outcrops exposed near the Nahan area of Himachal Pradesh.

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