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PALAEOGENE PALYNOSTRATIGRAPHY OF SIMLA HILLS

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ABSTRACT

The Palaeogene succession of Simla Hills consists of Subathu, Dagshai and Kasauli formations in ascending order of stratigraphy. The palynostratigraphical information developed from the marine sequence of Subathu sediments throws light on the dating potential of the assemblages and also on the distributional pattern of various palynomorphs. Dependable palynological parameters in effecting correlation of various sections of the formation have been discussed. Reflections on the palynological spectra across the Subathu-Dagshai boundary and in the Kasauli Formation have been made.

Key-words — Palynology, Subathu Formation, Dagshai Formation, Kasauli Formation, Palaeogene (India).

सारांश

शिमला पहाड़ियों का पेलियोजीन कालीन परागाणुस्तरविन्यास – हरिपाल सिंह

शिमला पहाड़ियों के पेलियोजीन अनुक्रम में सुबाथु, दागशाई एवं कसौली शैल-समूह आरोही-क्रम में विद्यमान हैं। सुबाथु अवसादों के समुद्री अनुक्रम से प्राप्त परागाणुस्तरिकीय जानकारी समुच्चयों के सम्भावी काल-निर्धारण तथा विभिन्न परागाणविकरूपकों के वितरणात्मक ढंग पर भी प्रकाश डालती है। शैल-समूह के विभिन्न खंडों का सहसंबंध प्रमाणित करने के लिए निर्भर रहने योग्य परागाणविक परिसीमनों का विवेचन किया गया है। सुबाथु-दागशाई सीमा के पार तथा कसौली शैल-समूह में परागाणविक-स्पेक्ट्रमों पर भी प्रकाश डाला गया है।

INTRODUCTION

THE main object of the present paper is to review in detail the palynological information developed from the Palaeogene rocks of Himachal Pradesh, particularly from Simla Hills and also to discuss the further scope of work in this and adjoining areas. Systematic palynological investigations of the Palaeogene succession in Simla Hills were started by the author in 1971 in order to develop palynological information from these rocks with the following objectives:

1. To obtain palynofossils from various stratigraphical levels of the Palaeogene succession.
2. To resolve the age and stratigraphical position of the different formations based primarily on the evidence provided by palynological fossils.
3. To find out the possible affinity of the palynological fossils which might help in reconstruction of palaeoclimates and environment of deposition.
4. To explore the possibility of finding a palynological datum line which may help in the correlation of different stratigraphical horizons.
5. To establish reliable indices for the delimitation and recognition of fine stratigraphical horizons.
6. To select key/guide fossils with well established ranges, both in space and time.
7. Finally to establish the correlative value of the various biostratigraphical zones in the entire outcrop area.

The above objectives of study were selected as a sequel to the confused state of stratigraphy of the Palaeogene sediments in Simla Hills which consist of the (i) Subathu Formation, (ii) Dagshai Formation, and (iii) Kasauli Formation in ascending order of stratigraphy. The correlation of these sediments has been a difficult task because of the absence or impoverished

recovery of plant and animal fossils together with their unsatisfactory record of general distribution. The absence of dependable lithomarkers, because of enormous lateral variation of lithofacies on a regional scale, particularly in the Subathu Formation, has been another hurdle in effecting precise correlation of various stratigraphical horizons. Lastly the natural order of superposition has been disturbed by the tectonic activity during the great Himalayan uplift creating complexities to the understanding of this stratal sequence.

The selection of the Palaeogene succession, as the main target of geological and palynological study, has been guided by the occurrence of oiliferous horizon in the Subathu Formation. Rocks of similar age are producing oil in the Potwar region of Pakistan. The present study of the Subathu sediments has revealed beyond doubt that they represent marginal facies in the area of study and as such can be considered potentially important for the generation of hydrocarbons (Singh *et al.*, 1973).

The recovery of dinoflagellate-rich assemblages alongwith some other palynomorphs complexes from the Subathu Formation in the Kalka-Simla area paved a way for the establishment of palynological zonation of the Subathu Formation (Singh *et al.*, 1979) at its type area, the Subathu town, Simla Hills. On the basis of quantitative and qualitative analysis of the palynomorph assemblages, it has been possible to establish stratigraphical ranges of significant species which have wide geographical and restricted vertical distribution resulting in the establishment of 8 cenozones and 2 subzones. Now these zones can be reliably used as a stratigraphical tool for dating and correlation of the Subathu sedimentary succession. Singh and khanna (1980) have also worked out the distributional pattern of palynoflora within this formation and have also related some palynological dissimilarities in relation to the changing environment of deposition. Khanna *et al.* (in press) have established geological credibility of the various palynological zones when they correlated 8 stratigraphically measured and distantly located sections between Baroti and Barog along the Kalka-Simla Highway (Text-fig. 2). The most striking feature of the present study has been that the lithological boundaries, with a few exceptions, coincide with the palynological boundaries in addition to the fairly sharp and easily distinguishable change in the composition of palynoflora from one cenozone to another. The palynozones have been delimited on the basis of first appearance, acme and decline of the various taxonomic entities. Singh and Khanna (1978) and Khanna and Singh (1980) have worked out the palaeoecological significance of *Pediastrum* and *Subathua* in the Subathu Formation. Besides comparing the Subathu assemblage with the known Indian and extra-Indian comparable assemblages from the homotaxial rocks (Singh & Khanna, manuscript), environmental influence on the distribution of biofacies in the Subathu Formation based on the distribution of various species of microplanktons indicative of salinity, depth and distance from the shorelines has been worked out by Khanna and Singh (1981). Palynologically one major transgression of the sea in the lower part of the Subathu Formation followed by a westward regression in the upper part or during the close of Subathu sedimentation has been postulated.

The Dagshai Formation conformably overlies the Subathu Formation and has been investigated palynologically above the passage bed level at 3 different localities, viz., Dagshai, Dharmpur and Kumarhatti. The dinoflagellate rich assemblage of the shallow marine Subathu Formation vanishes completely in the lower part of the Dagshai Formation and is replaced by a distinct coastal type spore pollen assemblage (Singh & Khanna, 1980). This palynological evidence has been used in demarcating the boundary between the calcareous Subathu Formation and non-calcareous Dagshai Formation. The Dagshai assemblage, though impoverished qualitatively, is dominated by gymnospermous pollen grains along with pteridophytic and fungal spores. *Palmidites* and *Couperipollis* are also the striking constituents of the assemblage.

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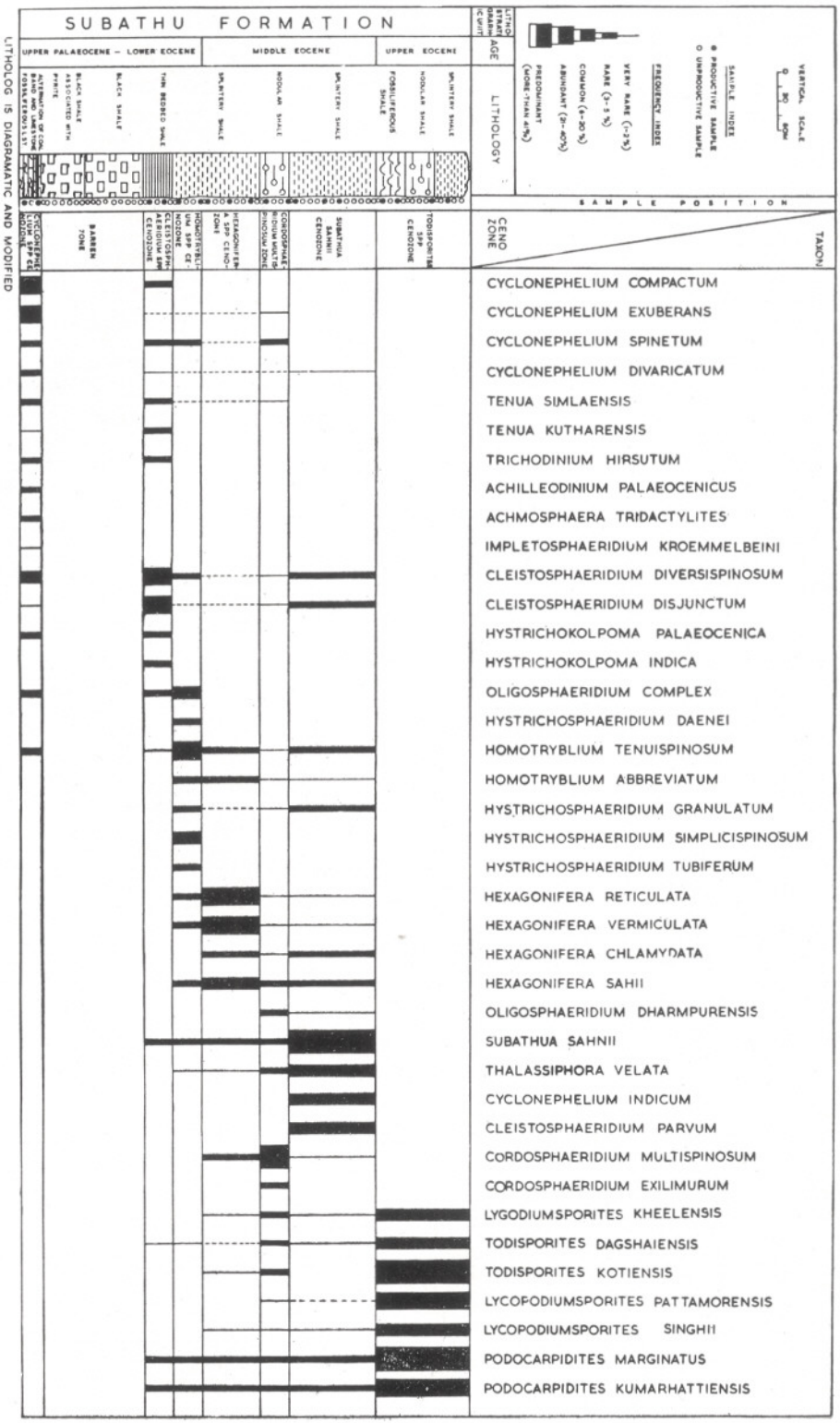
TEXT-FIG. 1 — Shows a scheme of palynological zonation of the Subathu Formation in Simla Hills. The distribution of different cenozones has been plotted against the litholog.


SUBATHU FORMATION
UPPER PALAEOCENE – LOWER EOCENE
MIDDLE EOCENE
UPPER EOCENE
AGE
LITHOLOGY
LITHOLOGY IS DIAGRAMATIC AND MODIFIED
SAMPLE POSITION
CENO ZONE
TAXON
BARREN ZONE
CYCLONEPHELIUM COMPACTUM
CYCLONEPHELIUM EXUBERANS
CYCLONEPHELIUM SPINETUM
CYCLONEPHELIUM DIVARICATUM
TENUA SIMLAENSIS
TENUA KUTHARENSIS
TRICHODINIUM HIRSUTUM
ACHILLEODINIUM PALAEOCENICUS
ACHMOSPHAERA TRIDACTYLITES
IMPLETOSPHAERIDIUM KROEMMELBEINI
CLEISTOSPHAERIDIUM DIVERSISPINOSUM
CLEISTOSPHAERIDIUM DISJUNCTUM
HYSTRICHOKOLPOMA PALAEOCENICA
HYSTRICHOKOLPOMA INDICA
OLIGOSPHAERIDIUM COMPLEX
HYSTRICHOSPHAERIDIUM DAENEI
HOMOTRYBLIUM TENUISPINOSUM
HOMOTRYBLIUM ABBREVIATUM
HYSTRICHOSPHAERIDIUM GRANULATUM
HYSTRICHOSPHAERIDIUM SIMPLICISPINOSUM
HYSTRICHOSPHAERIDIUM TUBIFERUM
HEXAGONIFERA RETICULATA
HEXAGONIFERA VERMICULATA
HEXAGONIFERA CHLAMYDATA
HEXAGONIFERA SAHII
OLIGOSPHAERIDIUM DHARMPURENSIS
SUBATHUA SAHNII
THALASSIPHORA VELATA
CYCLONEPHELIUM INDICUM
CLEISTOSPHAERIDIUM PARVUM
CORDOSPHAERIDIUM MULTISPINOSUM
CORDOSPHAERIDIUM EXILIMURUM
LYGODIUMSPORITES KHEELENSIS
TODISPORITES DAGSHAIENSIS
TODISPORITES KOTIENSIS
LYCOPODIUMSPORITES PATTAMORENSIS
LYCOPODIUMSPORITES SINGHII
PODOCARPIDITES MARGINATUS
PODOCARPIDITES KUMARHATTIENSIS

TEXT-FIG. 1

In spite of the fact that the rock samples have been collected extensively from the Dagshai Formation, recovery of palynomorphs has been discouraging because of the prevalence of largely oxidizing environment of deposition with high redexon potential. As such attempts to establish a palynological succession here have not been fruitful. However, rock samples from some stratigraphical levels of Dagshai Formation which are now being studied from the Surla-Jalal Section (Nahan area) have also confirmed the earlier observations that the assemblage is rich in bisaccate pollen grains together with the complete absence of microplanktons.

The Dagshai Formation conformably grades into the Kasauli Formation. Most of the Kasauli samples collected at the boundary level proved barren. A few samples collected from Koti and Barog yielded a poor and ill preserved assemblage being characterised by the virtual absence of *Inaperturopollenites* and by the presence of *Polypodiaceasporites*, colporate and monocolpate pollen grains alongwith spongy spicules. It is very likely that continued efforts to recover palynomorphs from ceratin favourable lithologies like shales and siltstones representing the Dagshai and Kasauli formations may provide an opportunity at a later date to establish palynological succession as has been done in the case of Subathu Formation.

LITHOSTRATIGRAPHICAL SUCCESSION

The term 'Subathu' was first used by Medlicott (1864) for a conformable sequence of Palaeogene sediments exposed in the Simla Hills, after the town Subathu, situated southwest of Simla. The original term included Subathu, Dagshai and Kasauli stages. Later in 1879, the term 'Sirmur Series' was given to the stratal sequence by Medlicott himself and the term 'Subathu' was restricted to its lowermost marine sequence.

The Subathu sediments occur along a narrow discontinuous belt in the extra-peninsular region of the Indian subcontinent from Jammu in the west to the west of Dehradun in the east. In Simla Hills, they are conformably overlain by the Dagshai sediments which, in turn, are overlain by the Kasauli succession. All the three formations constitute a thick sequence of Palaeogene sediments in Simla Hills. Chaudhri (1968) put forward a classification of the Palaeogene succession in the area proposing the following stratigraphic order (after making some modifications).

Age	Himalayan Foot-Hills
Lower Miocene to Upper Oligocene	Kasauli Formation (fluvio-deltaic)
Lower Oligocene to Upper Eocene	Dagshai Formation (coastal-transitional)
Upper Eocene to Upper Palaeocene	Subathu Formation (shallow marine)
..... Unconformity	
	Pre-Tertiary rocks

The Subathu Formation is mainly characterised by the predominance of calcareous olive green (oily looking), pale-olive grey, black and purple shales with subordinate lenticular bands of limestones, siltstones and occasional sandstones. The latter two are mostly restricted to the uppermost portion of the Subathu Formation. The siltstones are generally green in colour. A white quartzite zone generally marks the top of this formation.

The overlying Dagshai sediments are invariably non-calcareous and are characterised by having purple facies only. The purple facies have medium to fine grained sandstones, mottled shales/siltstones and claystones. The former two exhibit massive development and often contain haematitic nodules.

The Kasauli Formation overlies the Dagshai Formation conformably and is distinguished by having massive but micaceous sandstones mostly of arenaceous nature with minor intercalations of purple and olive green shales.

Area of Investigations

The present palynostratigraphical review of the Palaeogene sediments is confined to a part of Simla Hills covering approximately 288 sq km area between Lat. 30°50′ and Long. 76°55′ and 77°05′ E falling within the Survey of India Toposheet no. 53F/1 and 53B/13. All the geological sections examined, measured and described

are exposed along the Kalka-Simla Highway between Baroti and Barog, viz., Koti, Jabli, Dharmpur A, B, C, Dagshai and Kumarhatti excepting the type locality of Subathu. Exact locality, stratigraphic position and lithological details of the samples have been recorded and published by Khanna *et al.* (in press) and hence are not repeated here.

During the course of field study it was observed that the type locality, Subathu, exposes the best developed section of the formation right from its base to top in Kuthar Nala. In fact, this is the only section which exposes the base of the Subathu Formation and, therefore, has been regarded as the standard section. However, the contact of the Subathu Formation with the underlying Simla Slates is clearly unconformable. In an adjoining section of the same area faulted contact between the Subathus and Simla Slates has been observed. The Subathus unconformably overlie a variety of Pre-Tertiary rocks of different ages. Their upper contact with the overlying Dagshais has also been debatable. It is beyond the scope of this paper to discuss different views of the geologists. However, I concur with Chaudhri (1968) that no where the Subathus and the Dagshais show any discordance but the former conformably grades into the latter. Similarly the Dagshais grades into the Kasaulis and the discordance suggested by Krishnan (1956) has not been confirmed by Chaudhri (1968).

PALYNOLOGICAL SUCCESSION

Subathu Formation

Among the palynological constituents of the Subathu assemblage (43 genera & 106 species), representatives of the Thallophytes predominate. The class Dinophyceae represented by a variety of dinoflagellates is predominantly distributed at various stratigraphical levels. Sporadic occurrences of *Pediastrum*, a member of Chlorophyceae has been noteworthy. The spores and pollen taxa representing pteridophytes, gymnosperms and angiosperms are rather poorly represented. The fungal spores and bodies are very rare in distribution. In short the plant microremains of continental origin constitute an average of 10 per cent (in term of population percentage) of the assemblage. Mathur (1963, 1964, 1965) and Salujha *et al.* (1969) reported the occurrence of palynomorphs in the Subathu sediments and carried out preliminary investigations.

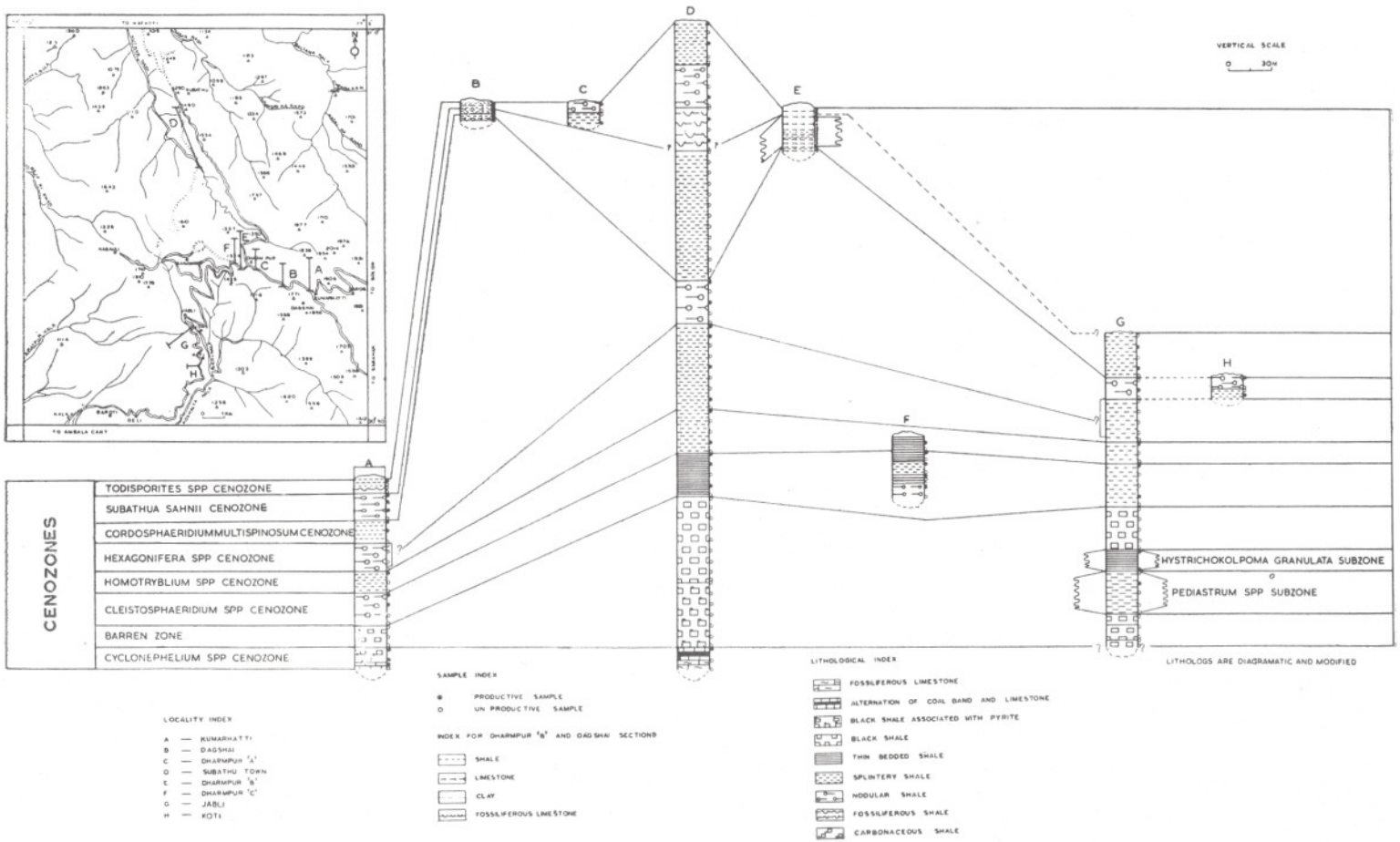
The gross palynofloral features of the Subathu Formation are characterised by the abundance of hystrichosphaerids together with other dinoflagellate cysts in the lower part of the formation, whereas the upper part of the formation is characterised by the trilete-rich spore assemblage or abundance of members of the family Thalassiphoraceae thriving in very shallow water and low saline conditions (Singh & Khanna, 1980). On the basis of further detailed analysis of palynodata by Singh *et al.* (1978) seven cenozones and one barren zone were established. Each cenozone, excepting the barren zone, is characterised by the abundance of a single genus with its one or more species together with the occurrence of a few restricted species which form distinct assemblage zones.

The salient features of the cenozones (Text-fig. 1) in ascending order of stratigraphy are enumerated below together with remarks on their relationship with different lithologies:

1. *Cyclonephelium* spp. Cenozone

This cenozone is about 15·75 m thick. The lithology consists of alternations of shaly limestone, limestone, carbonaceous shales or coal bands. The basal limestone member of the Subathu Section shows an unconformable tectonic contact with the Simla Slates. The black shale facies form the upper contact of this cenozone.

This cenozone is characterized by the presence and abundance of *Cyclonephelium compactum*, *C. exuberans*, *C. divaricatum* and *C. spinetum*. The other important constituents of this cenozone belong to the following genera: *Tenua*, *Trichodinium*, *Oligosphaeridium*, *Cleistosphaeridium*, *Hystrichokolpoma* and *Homotryblium*. The distribution of 3 species, viz., *Achmosphaera tridactylites*, *Impectosphaeridium rugosum* and *T. koemmelbeini* is restricted to this cenozone together with the virtual absence of land derived elements.



TEXT-FIG. 2 — Shows a scheme of palynostratigraphical correlation of the different sections of the Subathu Formation in Simla Hills. The distribution of different sections has been shown in the area map.

2. Barren Zone

The Barren Zone consists of 105 m thick black shale facies (Subathu Section) and is totally devoid of palynological fossils. This facies was deposited under foul environment which is not conducive for the preservation of organisms. The black shale facies grades into the greenish grey shales marking the upper contact of this zone.

3. *Cleistosphaeridium* spp. Cenozone

This cenozone is about 30 m thick (Subathu Section) and consists of greenish grey, calcareous splintery shales which may change to pale olive green shale facies in other sections. It is overlain by grey splintery shales which register the abundance of *Homotryblium*.

The abundant occurrence of *Cleistosphaeridium diversispinosum*, *C. disjunctum*, *Tenua kutharensis* and *T. simlaensis*, the first appearance of *Hystrichokolpoma indica*, *H. palaeocenica* and *Todisporites dagshaiensis* alongwith the restricted distribution of *H. indica* and *H. palaeocenica* are some of the salient features of this cenozone.

4. *Homotryblium* Cenozone

This cenozone is also approximately 30 m thick having grey shales and is identified by the dominance of *Homotryblium tenuispinosum* and *H. abbreviatum*. Besides the occurrence of some other significant dinoflagellate species, *Hystrichosphaeridium tubiferum*, *H. daenei*, *H. simplicispinosum* and *H. asterium* are restricted to this zone while *H. aesterium*, *H. granulatum*, *Hexagonifera reticulata*, *H. vermiculata*, *H. sahii* and *Thalassiphora velata* make their first appearance.

5. *Hexagonifera* spp. Cenozone

The lithounits of this cenozone consist of olive green, calcareous splintery shales with alternations of limestone sands. The salient features of this cenozone are the dominant occurrence of *Hexagonifera reticulata*, *H. vermiculata*, *H. chlamydata* and *H. sahii*. Two species, viz., *Oligosphaeridium dharmpurensis* and *Lycopodiumsporites singhii* have been observed for the first time in this zone. This cenozone lacks the presence of any restricted species.

6. *Cordosphaeridium multispinosum* Cenozone

A 30 m thick sequence of monotonous shales varying from grey to olive green in colour (Subathu Section) is identified by the acme period of *Cordosphaeridium multispinosum*. The needle shales lying over the splintery shales of *Hexagonifera* spp. Cenozone denote the lower limit of this cenozone. Though it is difficult to recognize the upper contact because of the absence of a lithomarker unit, the appreciable fall in the percentage of *Cordosphaeridium multispinosum* from 42 per cent to 2 per cent together with the marked increase in the percentage of *Subathua sahnii* demarcates palynological distinction between the two. The other striking constituents of the assemblage are *Cordosphaeridium fibrospinosum*, *C. exilimurum*, *Subathua sahnii*, *Todisporites* spp. *Lygodiumsporites barogensis* and *Thalassiphora velata* along with some other forms. Species of restricted distribution have not been observed in this cenozone.

7. *Subathua sahnii* Cenozone

The principle lithounit of this cenozone consists of arenaceous, pale olive green shales with siltstone bands. The upper limit of this cenozone is marked by a purple shale facies. The characteristic species of this cenozone are *Subathua sahnii*, *Cyclonephelium indicum* and *Cleistosphaeridium parvum*. The latter mentioned species along with *Heteraulacacysta ?leptalea* and *Thalassiphora pelagica* are restricted to this cenozone. Additionally the presence of *Oligosphaeridium complex*, *Cleistosphaeridium diversispinosum*, *C. disjunctum*, *Homotryblium tenuispinosum*, *Hystrichosphaeridium granulatum*, *Hexagonifera chlamydata* along with some other species, which show a declining trend in percentage, seems to be a characteristic feature of this cenozone. This cenozone has been considered to be one of the most important zones in this study as its upper limit denotes a sharp change in the environment of deposition. The dinoflagellate rich assemblage registers a crash fall and is replaced by a trilete-rich

spore assemblage. The total absence of dinoflagellates has been used as a reliable parameter in demarcating the top of Subathu Formation.

8. *Todisporites* spp. Cenozone

The arenaceous pale olive green shales with siltstone bands are intercalated with purple shales. Lenses of sandstone are quite common. The upper limit of the Subathu Formation is marked by the development of quartzose sandstone.

This cenozone exhibits a mixed type of assemblage. The samples collected from the basal part of this cenozone contain a few specimens of dinoflagellate cysts belonging to the following forms: *Homotryblium tenuispinosum*, *Hexagonifera reticulata*, *Hystrichosphaeridium granulatum*, *Cordosphaeridum multispinosum*, *Subathua sahnii* and *Thalassiphora velata* whereas its upper part is rich in trilete spores (at some places in gymnospermic pollen grains) along with the complete absence of dinoflagellates — so very characteristic of the brackish water environment of deposition. Significant species of this cenozone are: *Todisporites dagshaiensis*, *Lycopodiumsporites pattmorensis*, *L. crossii*, *L. singhii*, *Interapunctisporites intrapunctus*, *Lygodiumsporites bargoensis*, *Podocarpidites marginatus*, *P. kumarhattiensis*, *Cyathidites cooksonii*, etc. The mixed type assemblage of this cenozone indicates the onset of coastal transitional environment.

In addition to the institution of above cenozones, two Subzones represented by *Pediastrum* spp. Subzone and *Hystrichokolpoma* Subzone have been formally designated. Though their occurrence is purely local in the Jabli section, each one of them separately identifies a stratum of 30 m thick.

AGE

The age of the Subathu Formation has been discussed in detail by Khanna and Singh (in Press). Palynological basis have been the main theme of the work though data from other disciplines, viz., the order of superposition and palaeontology have been taken into consideration. Pilgrim and West (1928), Cox (1931), Vokes (1937), Singh (1952), Mandwal (1959) and Pascoe (1964) expressed diverse opinions in regard to the age of the Subathus. However, the gap of divergence was appreciably narrowed down by the works of Datta *et al.* (1955), Bhandari and Aggarwal (1966) and Chaudhri (1968) who believe that the Subathus range from Upper Palaeocene to Upper Eocene in age. The Kakara Series, which is exposed near the Kakara-Chapla villages, has been shown to be Palaeocene in age on the basis of stratigraphical as well as palaeontological basis (Srikantia & Bhargava, 1967). Palynological studies of these sediments have not been done as yet which, of course, are likely to ascertain the proposed age. In short, the palynological evidence supported by other related studies confirm that the Subathus range from Upper Palaeocene to Upper Eocene in age. On the basis of a detailed palynological zonation scheme prepared by Singh *et al.* (1979), it has been possible to date the different cenozones of the Subathu Formation as follows:

1. Upper Palaeocene-Lower Eocene (represented by the base of *Cyclonephelium* spp. Cenozone to the top of *Homotryblium* spp. Cenozone).
2. Middle Eocene (between the base of *Hexagonifera* spp. Cenozone to the base of *Todisporites* spp. Cenozone.
3. Upper Eocene (the remaining *Todisporites* spp. Cenozone).

ENVIRONMENT OF DEPOSITION

It is a well documented fact that the Subathu sediments were deposited in a shallow linear epicontinental sea opening north-westwards. Bhandari and Agarwal (1966) postulated the presence of parallel to subparallel ridges on the floor of the basin because of which isolated basinal condition developed leading to different environment of depositions in different parts of the basin. On the basis of fluctuating sea-land level changes, Chaudhri (1976) suggested two regressive and transgressive phases of the sea during the Subathu sedimentation cycle. Raiverman (1964) opined that the environment of deposition of Subathu Formation varied from marine to brackish water. Palynological studies carried out by Singh and Khanna (1980) have demonstrated that the Subathu sediments were deposited under the trans-

gressive phase of the sea followed by regression towards the close of Subathu sedimentation, contrary to the opinion held by Chaudhri (1976). Palynologically, observations of Raiverman (1964) have been confirmed as the rock sequence, encompassed between the *Cyclonephelium* spp. Cenozone and *Cordosphaeridium multispinosum* spp. Cenozone, represents true shallow marine environment whereas the stratigraphical interval between the *Subathua sahnii* Cenozone till to the base of *Todisporites* spp. Cenozone conforms to brackish water environment. The upper horizon of *Todisporites* spp. Cenozone is supposed to have been deposited under fresh water environment. These distinction have been made on the basis of field studies and wide occurrence of such forms which inhabit marine and brackish water environment (Khanna & Singh, 1981). The absence of microplankton cysts and the presence of land derived elements in the upper horizons of Subathu sediments has been attributed to the establishment of fresh water environment.

RELATIONSHIP OF BIOFACIES WITH LITHOFACIES

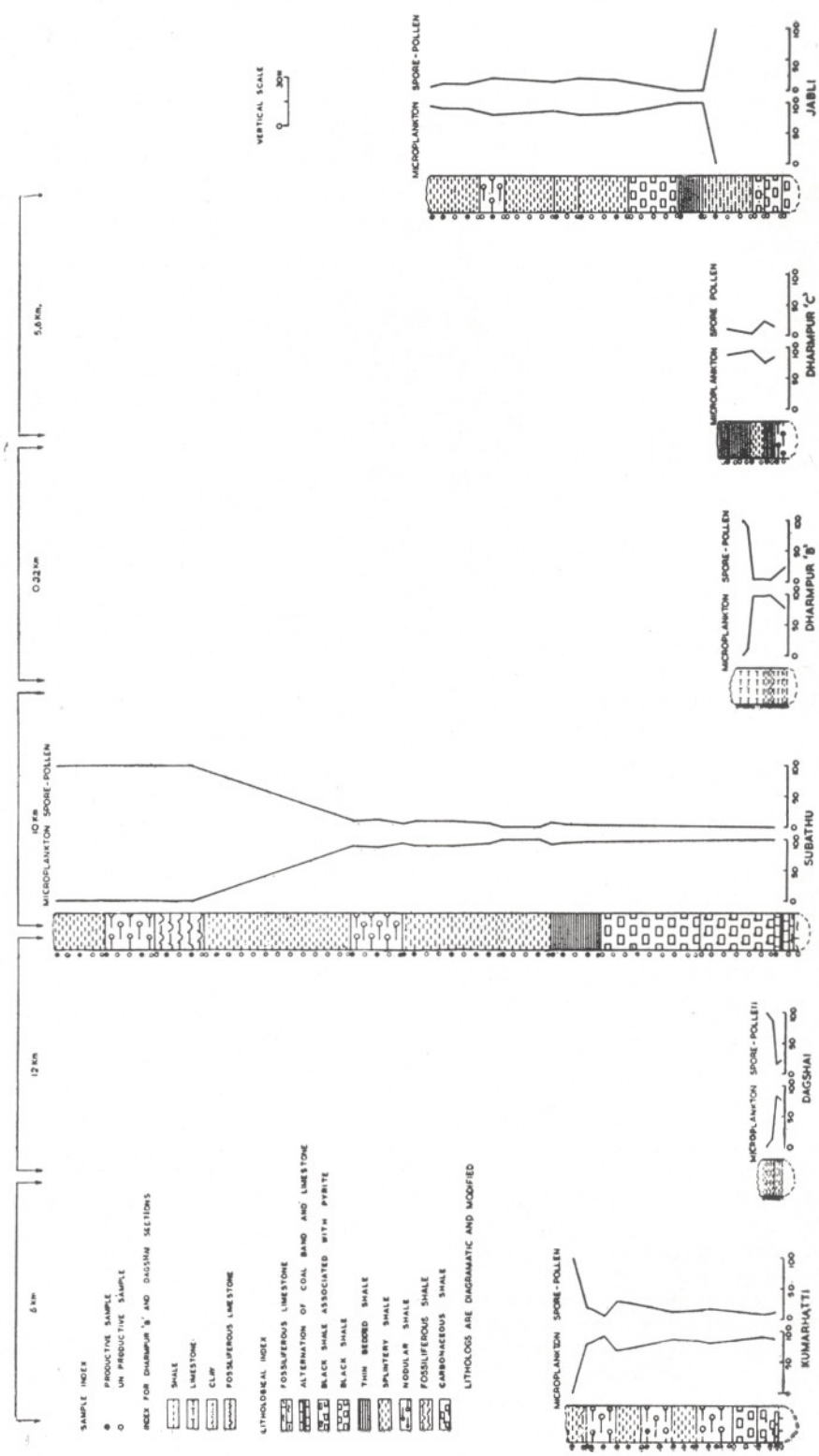
Evolution, undoubtedly, has been one of the major factors controlling the qualitative spectrum of the past palynofloras. Of late, it has been observed that, besides palaeolatitudes, the influence of environment has been appreciable in modifying composition of the assemblages both in terms of quantity and quality. Critical observations of Staplin (1961), Wall (1965), Scull *et al.* (1966), Williams (1970) and Sarjeant (1974) paved a way towards the recognition and application of this dimension in interpretation of dissimilar biofacies as related to the changing pattern of environment.

Singh and Khanna (1980) observed the selective distribution of various palynomorph complexes in the sediments of Subathu Formation and later on selected 6 measured sections to confirm the observations and interpretations. The results of the study have been embodied in a paper (Khanna & Singh, 1981) which deals with the environmental influence on the distribution of biofacies in the Subathu Formation. The details of this interesting study are difficult to record here yet an attempt is made to discuss its salient features.

Of the six sections studied, viz., Koti, Jabli, Dharmpur 'B', Dagshai, Kumarhatti and Subathu, the first five fall on the Kalka-Simla Highway and the last one lies at a distance in the northwest direction. As per location of these sections, Koti and Jabli represent the south-western margin, Dagshai and Kumarhatti represent the north-eastern margin whereas Subathu and Dharmpur 'B' represent deeper and perhaps the central part of the basin. Palynological composition of the marginal sections though closely comparable exhibits variation mainly on 3 counts: (i) minor variations reflected by the abundance of some common long ranging species, (ii) local development of a particular morphotype, and (iii) occurrence of stratigraphically insignificant morphotypes. Also the marginal assemblages contain such forms which prefer to inhabit mesohaline and relatively shallow water environment, viz., *Cleistosphaeridium diversispinosum*, *Cyclonephelium exuberans* and members of the family Thalassiphoraceae. It has been observed that *Cleistosphaeridium disjunctum* and *Cyclonephelium compactum* flourish in normal saline and deeper condition of deposition. The *Hexagonifera* spp. Cenozone occurs in highly calcareous facies showing thereby its association with the hypersaline environment. *Cordosphaeridium multispinosum* is euryhaline and thus it is uniformly distributed in all the sections studied so far. It has been observed that the total microplankton ratio is 97 : 3 in the lower part of the Subathu Formation which runs in an inverse proportion towards its top where the assemblage consists of spore-pollen and land derived elements (Text-fig. 3). Palynological analysis of the Subathu Formation at its north-eastern and central parts of the basin throws light on the bathymetric and variable conditions of environment of deposition. Modification in composition of the assemblages has been minor to pronounced depending upon the interaction of the variable environment controlling the development of biofacies.

DAGSHAI FORMATION

In some localities like Kumarhatti and Dharmpur the top of the Subathu and the base of the Dagshai formations are intercalated by a 10 m thick passage bed.

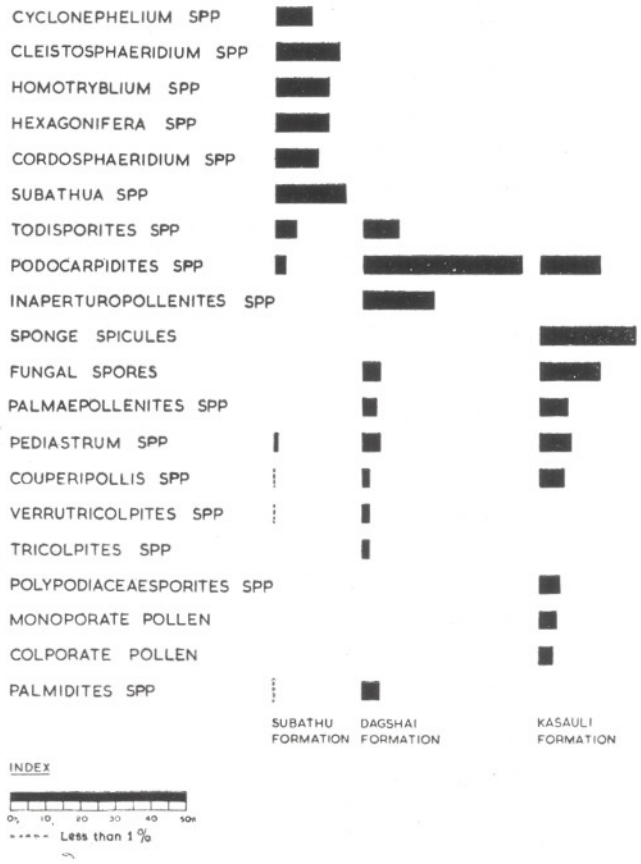


TEXT-FIG. 3 — Shows the microplankton/spore-pollen ratio occurring in the different sections of Subathu Formation, Simla Hills.

Palynological composition of this bed reveals that the genus *Pediastrum* constitutes about 90 per cent of the assemblage, spores and pollen grains being relegated to a meagre of 10 per cent or sometimes even less. Bhatia and Mathur (1965) reported the occurrence of *Bulinus?* and *Planorbis*, the two fresh water gastropods, in the same beds indicating the appearance of fresh water conditions during the close of Subathu sediments.

The Dagshai assemblage is identified chiefly by the absence of microplanktons (marine biota) and by the presence of pteridophytic, gymnospermic and angiospermic spores and pollen grains. The significant constituents of the assemblage are: *Lygodiumsporites*, *Lycopodiumsporites*, *Todisporites*, *Intrapunctisporis*, *Cyathidites*, *Podocarpidites*, *Inaperturopollenites*, *Laricoidites*, *Couperipollis*, *Palmidites*, *Palmaepollenites*, *Tricolpites* and *Verrutricolpites*. Specimens of *Pediastrum* and fungal spores have also been identified. The qualitative and quantitative changes in the distributional pattern of the palynoflora in the Dagshai Formation seem to be in response to the change in the environment of deposition from brackish to fresh water (Text-fig. 4). Additionally, palynological data in hand do not support the earlier views that the Dagshai sediments were deposited in brackish water environment. On the contrary, the presence of *Palmidites*, *Palmaepollenites* together with trilete spores tend to indicate coastal transitional environment for the Dagshai Formation.

It has not been possible to attempt a detailed palynological scheme of zonation as it has been done in the case of Subathu



TEXT-FIG. 4 — Shows the distribution of stratigraphically significant palynomorphs in the Subathu, Dagshai and Kasauli formations of Simla Hills.

Formation, obviously for lack of sufficient palynological data from the largely unfossiliferous rock samples collected from the Dagshai Formation. Recently the author has succeeded in locating some more productive horizons in the Dagshai sediments of Surla-Jalal Section near Banethi in Nahan region. A diversified assemblage of well-preserved bisaccate pollen grains of gymnospermic origin occurring in good numbers has been recovered and is being studied morphotaxonomically. Further location of productive horizons from the stratigraphically located samples is necessary before any significance can be attached to the present data in hand.

KASAULI FORMATION

The overlying Kasauli sediments are largely unfossiliferous. Attempts for the recovery of palynomorphs have mostly proved abortive. The samples collected from Koti yielded meagre palynological information which has been considered and discussed here for the worth it deserves. The Kasauli assemblage consists of the following constituents: spongy spicules (27%), angiospermic pollen grain represented by *Palmaepollenites* spp., *Couperipollis* spp., some monoporate and colporate pollen grains (24%). *Podocarpidites* spp. (17%), fungal spores (17%) and *Pediastrum* (9%) constitute the remaining components of the assemblage.

CONCLUSIONS

The lithostratigraphical and palynostratigraphical investigations of the Subathu, Dagshai and Kasauli formations have resulted in the following conclusions:

1. The Subathu Formation unconformably overlies the pre-Tertiary sediments exhibiting variable lower contact due to tectonic disturbances and, in turn, is conformably overlain by the Dagshai Formation which grades into the Kasauli Formation.
2. The Subathu Formation represents one major transgression followed by regression of the sea. This conclusion has been substantiated by the spore-pollen/microplankton ratio which runs in an inverse proportion from the base upwards thereby indicating one major transgression of the Palaeocene-Eocene sea in the lower part of the formation followed by a northwestward regression towards the close of Subathu sedimentation.
3. The Subathu assemblage is mostly identified by the dominance of dinoflagellate cysts excepting in the case of some top horizons thereby confirming the earlier view that the Subathu sediments were deposited under shallow marine condition.

On the basis of restricted distribution and variable abundance of various palynomorphs in different stratigraphical horizons seven cenozones alongwith one barren zone have been recognized. The selective association and distribution of the palynomorphs have been ascribed to the changing environment of deposition.

Biostratigraphical evidences and the evidences from other complimentary disciplines indicate an Upper Palaeocene to Lower Eocene age to the stratigraphical column ranging in between *Cyclonephelium* spp. Cenozone and *Homotryblium* spp. Cenozone. The stratigraphical interval from *Hexagonifera* spp. Cenozone to *Subathua sahnii* Cenozone represents Middle Eocene age whereas the *Todisporites* spp. Cenozone corresponds to Upper Eocene age.

A close similarity in palynological succession between Jabli and Kumarhatti sections indicates marginal environment of the basin whereas dissimilarities of local importance are apparent in the assemblages of Subathu and Dharmpur 'B' sections which are located away from the margin. Qualitative and quantitative analysis of palynomorphs allow distinction of marine, near-shore and coastal transitional zones. Spores and pollen grains, though scantily represented, indicate the prevalence of subtropical to tropical climate during the Subathu sedimentation. A major palynological change occurs across the Subathu-Dagshai boundary. This sharp change is related to changes in the depositional conditions from shallow marine to coastal-transitiona. Finally, palynological information from the Kasauli Formation, though meagre, is important in the sense that the degraded nature of the organic matter reflect fluvial environment of deposition in a fast sinking basin.

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