

Palynostratigraphy of Subathu Formation (Eocene) in the Banethi-Bagthan area, Sirmaur District, Himachal Pradesh

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On the basis of the qualitative and quantitative distribution of the recovered palynoflora five distinct palynological assemblage zones have been recognised within the Subathu Formation in the Banethi-Bagthan area of Himachal Pradesh. In ascending order of stratigraphy the palynological assemblage zones are: *Todisporites* spp. Assemblage Zone, *Subathua sabnii* Assemblage Zone, *Cordosphaeridium inodes* Assemblage Zone, *Homotryblium* spp. Assemblage Zone, and *Cleistosphaeridium* spp. Assemblage Zone.

Key-words—Palynostratigraphy, Palynological zonation, Subathu Formation, Eocene (India).

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सारांश

हिमाचल प्रदेश में सिरमौर जनपद के बनेठी-बगथान क्षेत्र में सुबाथु शैल-समूह (आदिनूतन) का परागणुस्तरविन्यास

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हिमाचल प्रदेश के बनेठी-बगथान क्षेत्र में सुबाथु शैल-समूह से उपलब्ध परागणुवनस्पतिजात के गुणात्मक एवं परिमाणात्मक विश्लेषण के आधार पर पाँच विभिन्न समुच्चय मंडल बनाये गये हैं। स्तरविन्यास के आरोही क्रम ये टोडिस्पोराइटिस जाति समुच्चय मंडल, सुबाथुआ साहनाई समुच्चय मंडल, कोर्डोस्फेयरिडियम इनाइस समुच्चय मंडल, होमोट्राइब्लियम जाति समुच्चय मंडल, एवं क्लिस्टोस्फेयरीडियम जाति समुच्चय मंडल हैं।

MEDLICOTT (1864) for the first time used the term Subathu as "Subathu Series" for the Palaeogene sediments of Simla Hills. He named them after the town Subathu (30°59' : 77°1') where its type locality is situated.

Since then difference of opinion prevailed among the geologists regarding the exact stratigraphic status of this rock sequence. Different authors have treated the status of the Subathu sediments differently as Subathu Series (Pilgrim & West, 1928; Chaudhri, 1968), Subathu Group (Medlicott, 1864; Pascoe, 1964; Raiverman & Seshavaram, 1965; Karunakaran & Ranga Rao, 1979), Subathu Stage (Pascoe, 1964), Subathu beds (Krishnan, 1960; Mathur, 1968) and Subathu Formation (Pascoe, 1964). Considering the recommendations of the International Commission of Stratigraphic Terminology Khanna (1978) formally instituted the Subathu Formation on the evidences provided by the lithostratigraphy and biostratigraphy.

Subathu Formation represents the lowermost marine sequence of the Tertiary rocks in Himachal Pradesh. It is

conformably overlain by the Dagshai Formation. The status of the Subathu Formation in the present paper is followed after the concept of Khanna (1978). The Subathu Formation is exposed as a discontinuous outcrop along the narrow belt running right from Jammu in the west to the west of Dehradun in the east. The rocks of this formation are mainly characterised by the presence of calcareous, pale-olive, greenish-grey shales, limestone and siltstone bands. Palynological information from these rock sediments was scantily known until the last decade. Few noteworthy contributions during that period have been made by Mathur (1963, 1964, 1965) and Salujha *et al.* (1969). Only in the last decade a number of publications, viz., Mathur and Venkatachala (1979), Khanna (1978), Singh & Khanna (1978), Singh *et al.* (1978), Khanna *et al.* (1979) and Khanna and Singh (1979) have come out.

Singh *et al.* (1978) recognised seven distinct palynozones along with one barren zone within the Subathu Formation at its type locality (Subathu). Lateral extension of these palynozones has also been traced out

in 7 other localities of Kalka-Simla area. In ascending order of stratigraphy the palynozones are: (8) *Todisporites* spp. Cenozoone, (7) *Subathua sabnii* Cenozoone, (6) *Cordosphaeridium multispinosum* Cenozoone, (5) *Homotryblium* spp. Cenozoone, (4) *Hexagonifera* spp. Cenozoone, (3) *Cleistosphaeridium* spp. Cenozoone, (2) Barren Zone, and (1) *Cyclonephelium* spp. Cenozoone.

In the present paper an effort has been made to analyse the palynological data qualitatively and quantitatively from the Subathu sediments of Banethi-Bagthan area. On the basis of the available evidence, five palynological assemblage zones have been established.

AREA UNDER INVESTIGATION

The present palynological investigation was carried out near Nahan in the Sirmour District of Himachal Pradesh (Map 1). It covers an area measuring about 48 sq km between 30°38'25" and 30°43'20" north latitude and 70°17'45" east longitude. It falls in the Survey of India toposheet map no. 53/F/6. This area is covered by a dense forest with rugged topography. The average height of the area is around 1200 m from M.S.L. The main drainage is towards southeast. The Jalal River with a number of tributaries (the most important being Ghambar Ka Nala) follows the south-eastern direction.

Several traverses were undertaken at different localities to find out the well-developed suits of Subathu sediments in this area. Efforts were also made to understand the exact order of superposition of strata

including the thickness of various lithotypes with a view to observe the lower and upper contacts of the Subathu Formation. On the basis of these observations four geological sections were selected for measurement by using standard Brunton-tape method. Collection of rock samples for palynological studies was made from these sections. The lower contact of Subathu Formation has not been observed in any one of the sections whereas its upper contact is marked by the conformably overlying Dagshai Formation.

BIOSTRATIGRAPHIC ZONATION OF SUBATHU FORMATION

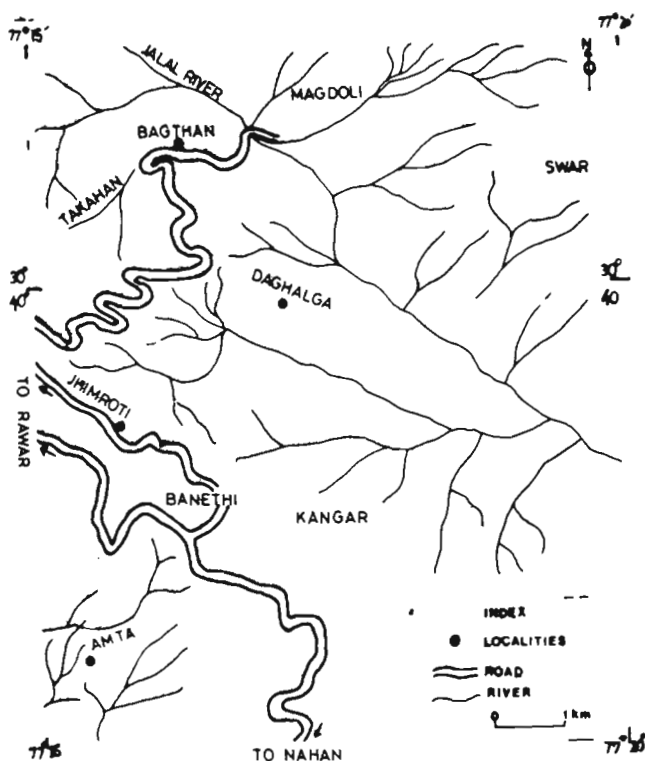
On the basis of qualitative and quantitative analyses of the recovered palynoassemblages, five distinct assemblage zones are proposed within the Subathu sediments of the present area of investigation. The upper and lower limits of the assemblage zones have been established considering the variation patterns observed within the spore-pollen and microplankton assemblages. In most of the cases the lithological boundaries coincide with the palynological boundaries and no major floral break seems to have occurred in any of the studied geological sections. From the distributional pattern of different palynofloral elements, it is apparent that the change in palynofloral composition from one assemblage zone to another is recognizable. Three most reliable parameters have been taken into consideration for the recognition of different assemblage zones, viz., the first appearance, the maximum development and lastly the decline of the various taxonomic entities. The concept of the assemblage zone strictly follows the Code of Stratigraphic Nomenclature proposed by the American Commission on Stratigraphic Nomenclature (1961).

Quantitative analysis of each productive sample has been carried out after counting about 200 palynomorphs. The characteristic species of each assemblage zone have been plotted against the lithology of the standard section. The mean value of the spore, pollen and microplankton frequencies has been plotted under five different suites, viz., very rare, rare, common, abundant and predominant. The probable occurrence has been shown by the dotted line. The following five assemblage zones have been recognised in ascending order of stratigraphy, viz., (5) *Todisporites* spp. Assemblage Zone, (4) *Subathua sabnii* Assemblage Zone, (3) *Cordosphaeridium inodes* Assemblage Zone, (2) *Homotryblium* spp. Assemblage Zone, and (1) *Cleistosphaeridium* spp. Assemblage Zone.

As prescribed by the Code of Stratigraphic Nomenclature each assemblage zone together with necessary palynostratigraphic data is given below:

Cleistosphaeridium spp. Assemblage Zone

Localities—Bagthan-Savar Road Section; Dagalaghat Village—Banethi-Bagthan Road Section.



Map 1

Lithology—This assemblage zone is characterised by mostly laminated dark brown, calcareous shales and dark brown to greenish, ferruginous splintery shales. At Dagalaghat Section, some grey to blackish siltstone bands are present within the shales. The thickness of this assemblage zone varies from 34 to 50 m.

Lower contact—This assemblage zone forms the lowermost palynostratigraphical unit of the Subathu Formation exposed in the present area of investigation. The appearance of thinly laminated brown calcareous shales over light brown buff coloured clays mark the lower contact of this zone.

Upper contact—The upper part of the ferruginous green to purple shale, laminated with clays forms the upper contact of the *Cleistosphaeridium* spp. Assemblage Zone. It is overlain by hard, compact purple splintery shales intermixed with thin band of limestone at Bagthan which contains *Homotryblium* in abundance. At Dagalaghat Section the upper part is generally composed of pale olive shale over slightly ferruginous siltstone.

Significant species of this assemblage zone—*Cleistosphaeridium diversispinosum*, *C. flexuosum*, *Lingulodinium macherophorum*, *Operculodinium centrocarpum*, *Glaphyrocysta exuberans*,

Hystrichosphaeridium tubiferum, *Subathua sabnii*, *Graminidites media* and *Podocarpidites couperi* are the significant species of this assemblage zone. While *Adnatosphaeridium vittatum*, *A. multispinosum*, *Hystrichokolpoma salacium* and *H. cinctum* are the restricted species to this cenozoone.

Remarks—In this assemblage zone mostly marine forms have been recorded along with a few land derived elements. *Cleistosphaeridium diversispinosum* and *C. flexuosum* are the most dominant forms represented by about 25 per cent of the total assemblage. Many other dinoflagellate cyst species present here are below 2 per cent. These are *Homotryblium abbreviatum*, *H. tenuispinosum*, *H. latirictum*, *Glaphyrocysta divaricata*, *Subathua spinosa*, *Podocarpidites couperi* and *Todisporites rarus* which mark their first appearance in this assemblage zone. The presence of *Pediastrum* spp. is also noteworthy.

***Homotryblium* spp. Assemblage Zone**

Localities—Bagthan-Savar Road Section; Dagalaghat Village—Banethi-Bagthan Road Section.

Lithology—This assemblage zone mostly consists of hard compact, dark purple splintery shales or grey

PLATE 1

(All photomicrographs are enlarged ca. $\times 500$ unless otherwise mentioned)

- Biretisporites crassus* Sarkar & Singh; B.S.I.P. Slide no. 6862, coordinates 14.9 \times 109.5.
- Spiniferites ramosus* (Ehrenberg) Loeblich & Loeblich; B.S.I.P. Slide no. 6896, coordinates 4.5 \times 94.5.
- Cleistosphaeridium flexuosum* Davey *et al.*; B.S.I.P. Slide no. 6922, coordinates 5.5 \times 85.5.
- Dapsilidinium pastelsii* (Davey & Williams) Bujak *et al.*; B.S.I.P. Slide no. 6917, coordinates 21 \times 113.5.
- Pediastrum angulatus* Singh & Khanna; B.S.I.P. Slide no. 8424, coordinates 6 \times 87.5.
- Graminidites media* Cookson; B.S.I.P. Slide no. 6860, coordinates 21.2 \times 118.
- Biretisporites* sp. B.S.I.P. Slide no. 6862, coordinates 15.5 \times 93.
- Amtaspora indica* Sarkar & Singh; B.S.I.P. Slide no. 6862, coordinates 15.5 \times 93.
- Amtaspora pseudostriata* Sarkar & Singh; B.S.I.P. Slide no. 6862, coordinates 15.5 \times 93.
- Monolites* sp.; B.S.I.P. Slide no. 6861, coordinates 8.2 \times 79.
- Dictyophyllidites* sp.; B.S.I.P. Slide no. 6860, coordinates 11 \times 110.5.
- Biretisporites potoniaei* Delcourt & Sprumont; B.S.I.P. Slide no. 6860, coordinates 1.5 \times 79.
- Hystrichokolpoma cinctum* (Klumpp) Damassa; B.S.I.P. Slide no. 6895, coordinates 14 \times 107.
- Polysphaeridium zobarei* (Wall) Bujak; B.S.I.P. Slide no. 6917, coordinates 20.2 \times 104.2.
- Podocarpidites decorus* Sarkar & Singh; B.S.I.P. Slide no. 6925, coordinates 14.5 \times 82.3.
- Todisporites rarus* Sarkar & Singh; B.S.I.P. Slide no. 6861, coordinates 21.8 \times 97.8.
- Operculodinium centrocarpum* (Deflandre & Cookson) Wall; B.S.I.P. Slide no. 6917, coordinates 19.5 \times 84.8.
- Operculodinium centrocarpum* (Deflandre & Cookson) Wall; B.S.I.P. Slide no. 6917, coordinates 19.5 \times 84.8.
- Striatriletes susannae* (Van der Hammen) Kar, B.S.I.P. Slide no. 6928, coordinates 7.4 \times 115.
- Palmidites noviculatus* Sarkar & Singh; B.S.I.P. Slide no. 6925, coordinates 14.5 \times 82.3.
- Couperipollis capitatus* Sarkar & Singh; B.S.I.P. Slide no. 6927, coordinates 13 \times 83.
- Todisporites major* Couper, B.S.I.P. Slide no. 6860, coordinates 20 \times 77.
- Sentusidinium rioultii* (Sarjeant) Sarjeant & Stover, B.S.I.P. Slide no. 6905, coordinates 8.2 \times 79.
- Adnatosphaeridium multispinosum* Williams & Downie, B.S.I.P. Slide no. 6923, coordinates 10 \times 86.5.
- Glaphyrocysta intricata* (Eaton) Stover & Evitt; B.S.I.P. Slide no. 6923, coordinates 14.5 \times 102.
- Thalassiphora velata* (Deflandre & Cookson) Eisenack & Gocht; B.S.I.P. Slide no. 6907, coordinates 19.5 \times 84.8.
- Homotryblium pallidum* Davey & Williams; B.S.I.P. Slide no. 6919, coordinates 19.5 \times 78.5.
- Subathua sabnii* Khanna & Singh; B.S.I.P. Slide no. 6908, coordinates 12.5 \times 92.
- Thalassiphora pelagica* (Eisenack) Eisenack & Gocht; B.S.I.P. Slide no. 6909, coordinates 14.5 \times 98.8.
- Cordosphaeridium inodes* (Klumpp) Morgenroth; B.S.I.P. Slide no. 6923, coordinates 13 \times 117.
- Multicellaesporites* sp.; B.S.I.P. Slide no. 6923, coordinates 13 \times 117.

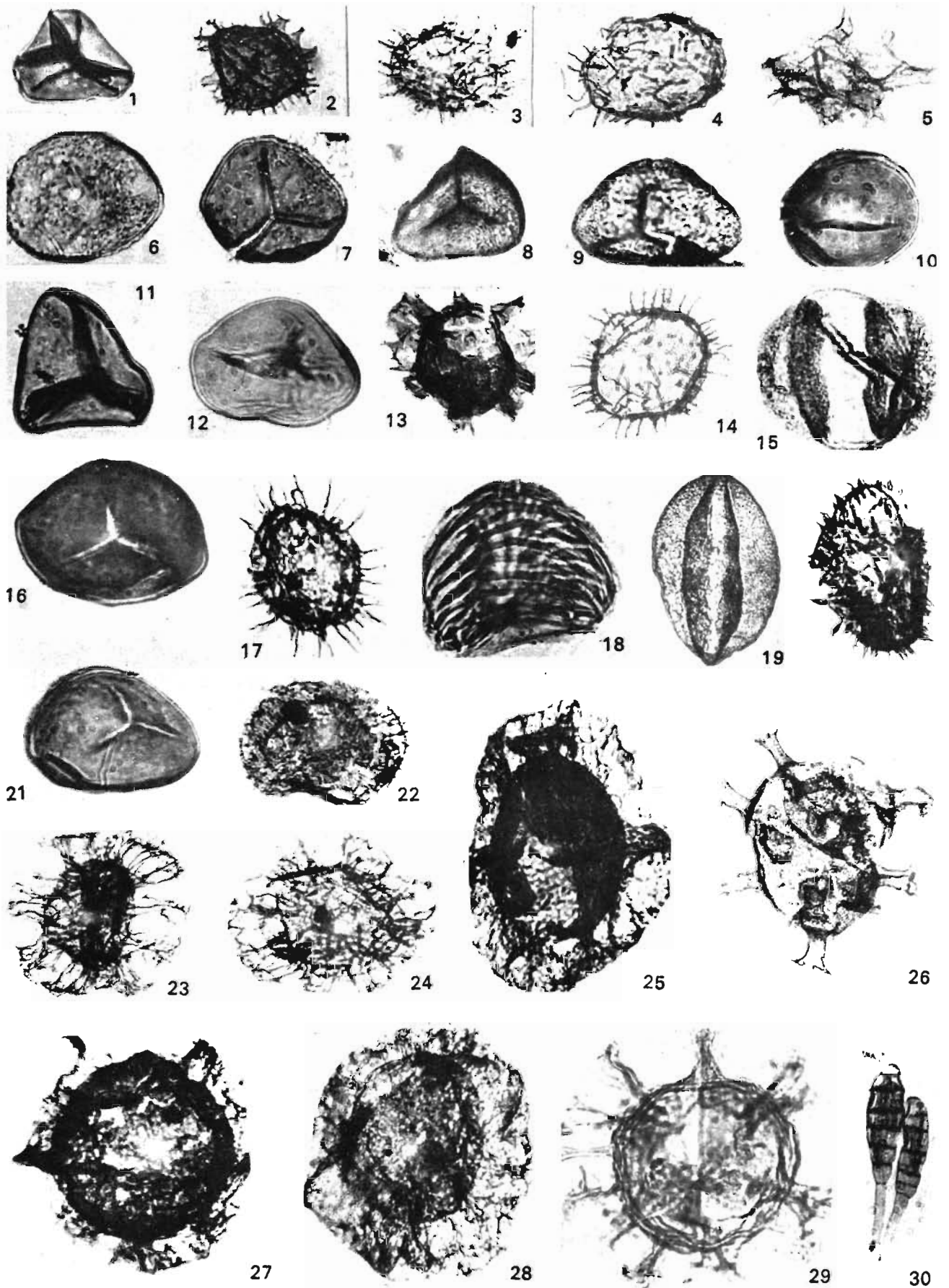
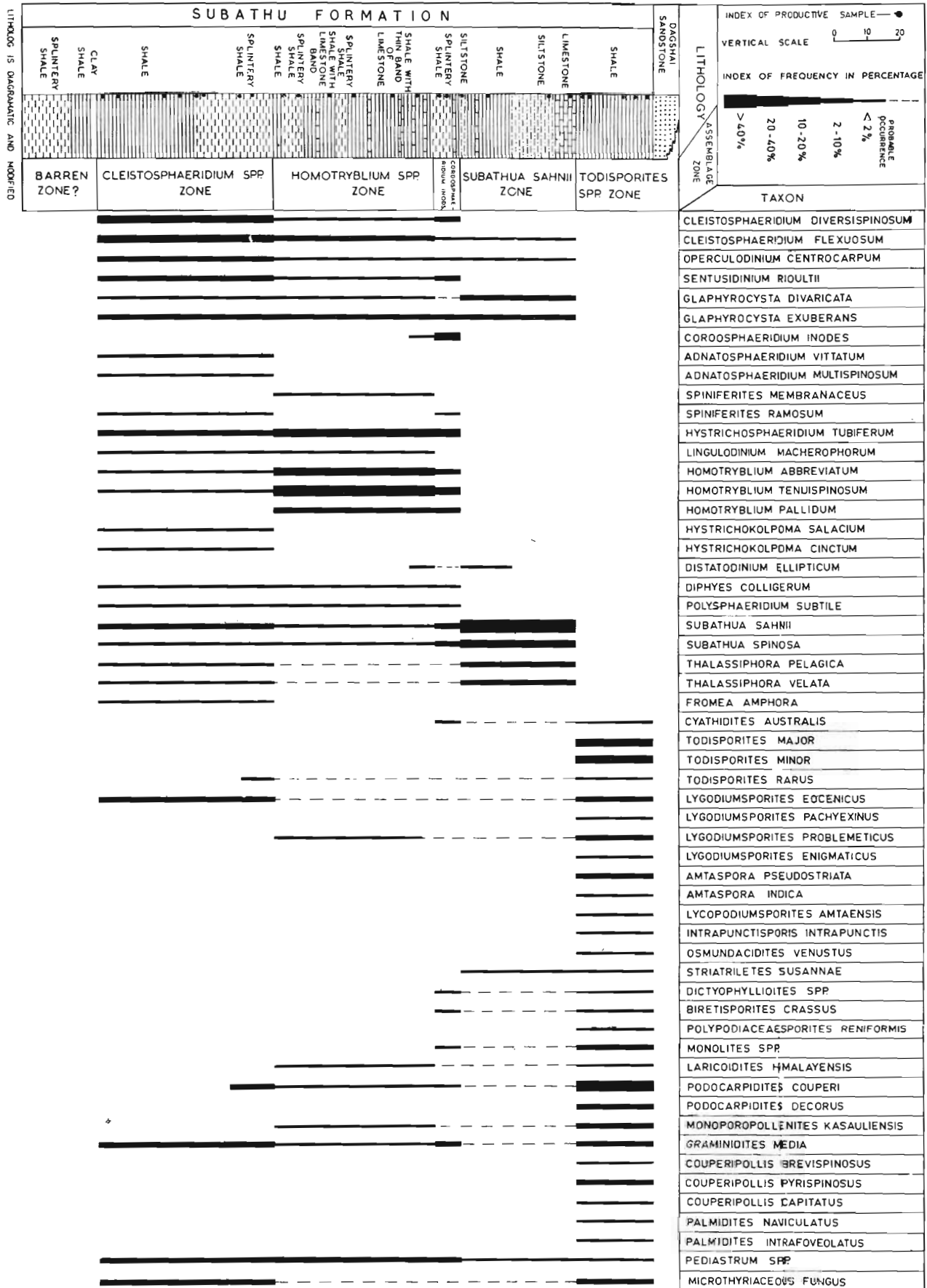


PLATE 1



laminated shales (calcareous in nature) intermixed with purplish grey shaly limestone. Minor partings of white limestones have also been observed in Bagthan Section. In Dagalaghat Section this zone is mainly characterised by pale olive to purplish shales together with greyish brown siltstone bands. The thickness of this assemblage zone varies from 27 to 38 m.

Lower contact—In Dagalaghat Section, pale olive and slightly ferruginous siltstone grades into the purplish shales forming the lower contact of this assemblage zone, whereas in Bagthan Section the purple splintery shales overlie the greenish splintery shales marking its lower contact.

Upper contact—The top layers of the shale which are purplish to pale olive in colour form the upper contact of this assemblage zone. Minor partings of white limestone have been found in the Bagthan Section.

Significant species of this assemblage zone—*Homotryblium tenuispinosum*, *H. abbreviatum*, *H. pallidum*, *Hystrichosphaeridium tubiferum*, *Cleistosphaeridium flexuosum*, *C. diversispinosum*, *Glaphyrocysta exuberans* and *Graminidites media* are significant species of this assemblage zone. *Spiniferites membranous* is the only restricted species to this assemblage zone.

Remarks—This assemblage zone is overwhelmingly dominated by various species of the genus *Homotryblium* (47%) whereas the abundance of *Cleistosphaeridium* sharply declines from 25 per cent to 7 per cent. The distribution of many forms is less than 2 per cent. These forms are *Sentusidinium rioultii*, *Operculodinium centrocarpum*, *Glaphyrocysta divaricata*, *Polysphaeridium subtile*, *Subathua sabnii*, *S. spinosa*, *Lygodiumsporites problematicus*, *Laricoidites himalayensis*, *Monoporopollenites kasauliensis* and *Pediastrum* spp. Forms like *Cordosphaeridium inodes*, *Distatodinium ellipticum*, *Lygodiumsporites problematicus*, *Laricoidites himalayensis*, *Monoporopollenites kasauliensis* show their first appearance in this assemblage zone. Another interesting feature of this assemblage zone is the presence of relatively high percentage of different species of *Pediastrum* (16%).

***Cordosphaeridium inodes* Assemblage Zone**

Localities—Bagthan-Savar Road Section, Dagalaghat Village—Banethi-Bagthan Road Section.

Lithology—This assemblage zone mainly consists of splintery purplish shales intercalated with shaly siltstone and its thickness varies from 4 to 15 m.

Lower contact—The appearance of splintery shales over the purplish shales with limestone partings marks the lower contact of this assemblage zone.

Upper contact—The upper part of the purplish shale

with siltstone bands form its upper contact. It is overlain by a limestone band which contains *Subathua* in abundance.

Significant species of this assemblage zone—*Cordosphaeridium inodes*, *Homotryblium tenuispinosum*, *H. abbreviatum*, *H. pallidum*, *Sentusidinium rioultii*, *Hystrichosphaeridium tubiferum*, *Subathua sabnii*, *S. spinosa* and *Graminidites media* are the significant species to this assemblage zone.

Remarks—In this assemblage zone *Cordosphaeridium inodes* is the most dominant element which appears for the first time in the upper part of the *Homotryblium* spp. Assemblage Zone and sharply rises from 2 to 17 per cent. The distributional frequency of some dinoflagellates forms, viz., *Spiniferites ramosus*, *Glaphyrocysta exuberans*, *Cleistosphaeridium diversispinosum*, *C. flexuosum* and *Polysphaeridium subtile* is less than 2 per cent. Forms like *Biretisporites crassus* and *Monolites* sp. make their first appearance in this assemblage zone.

***Subathua sabnii* Assemblage Zone**

Localities—Bagthan-Savar Road Section; Dagalaghat Village—Banethi-Bagthan Road Section, Jhimroti-Banethi Road Section.

Lithology—This assemblage zone is mainly composed of argillaceous limestone with massive development of grey shales with intercalation of thin bands of purple shales and grey siltstone. The thickness of this assemblage zone varies from 5 to 26 m.

Lower contact—The appearance of argillaceous limestone band over the siltstone of *Cordosphaeridium inodes* Assemblage Zone forms the lower contact of this assemblage zone.

Upper contact—The uppermost part of the argillaceous limestone band where the limestone is mostly compact and yellowish green in colour form the upper contact of this assemblage zone.

Significant species of this assemblage zone—*Subathua sabnii*, *S. spinosa*, *Thalassiphora pelagica*, *T. velata*, *Glaphyrocysta divaricata* and *G. exuberans* are significant species of this assemblage zone.

Remarks—Not a single species has been found to be restricted in this assemblage zone. It is mostly dominated by various members of the family *Thalassiphoraceae*, viz., *Thalassiphora pelagica*, *T. velata*, etc. The other species present in this zone are: *Cleistosphaeridium flexuosum*, *Operculodinium centrocarpum*, *Distatodinium ellipticum* and *Striatriletes susannae*. Each of these species are present in very small quantity and their percentage in terms of frequency is never more than 2.5 per cent each. The spores of *Striatriletes susannae* show their first appearance in this assemblage zone.

Todisporites spp. Assemblage Zone

Localities—Bagthan-Savar Road Section; Dagalaghat Village—Banethi-Bagthan Road Section; Jhimroti-Banethi Road Section; Amta-Surla Briddle Path Section.

Lithology—This assemblage zone mainly consists of alternation of calcareous grey and purple shales. Limestone is completely lacking in this assemblage zone. The thickness of this assemblage zone varies from 6 to 59 meters.

Lower contact—The appearance of purple shales over the limestone band marks the lower contact of this assemblage zone.

Upper contact—The base of the overlying Dagshai sandstone forms the upper contact of this assemblage zone and in most of the cases the shales are highly purplish in nature.

Significant species of this assemblage zone—*Todisporites major*, *T. minor*, *Lygodiumsporites pachyexinus*, *L. enigmaticus*, *Amtaspora pseudostrata*, *A. indica*, *Lycopodiumsporites amtaensis*, *Intrapunctisporis intrapunctis*, *Osmundacidites venustus*, *Polypodiaceae-sporites reniformis*, *Podocarpidites decorus*, *Couperipollis brevispinosus*, *C. pyrispinosus*, *C. capitatus*, *Palmidites noviculatus* and *P. intrafoveolatus* are the significant species of this assemblage zone.

Remarks—At the base of this assemblage zone a few microplanktons, viz., *Homotryblium tenuispinosum*, *H. pallidum*, *H. abbreviatum*, *Hystrichosphaeridium tubiferum*, *Glaphyrocysta divaricata*, *Polysphaeridium subtile*, *Operculodinium centrocarpum*, *Cleistosphaeridium flexuosum*, *Subathua sabnii* and *S. spinosa* have been recorded. Each of these species is present in very meagre quantity and their percentage in terms of frequency is never more than one per cent. Most probably they denote a coastal transitional environment in between the *Subathua sabnii* and *Todisporites* spp. assemblage zones. At the top of this assemblage zone the dinoflagellate cysts completely disappear and the palynofloral assemblage is totally replaced by a trilete rich spore assemblage. A noteworthy feature of this assemblage zone is the sharp fall in the percentage of *Pediastrum* (less than 2% of the total assemblage). Some of the samples belonging to this assemblage zone have yielded bisaccate gymnospermous pollen.

CONCLUSIONS

On the basis of the frequency of various palynofossils in different stratigraphical horizons the Subathu Formation is divided into five distinct assemblage zones which in the ascending order of stratigraphy are: (5) *Todisporites* spp. Assemblage Zone,

(4) *Subathua sabnii* Assemblage Zone, (3) *Cordosphaeridium inodes* Assemblage Zone, (2) *Homotryblium* spp. Assemblage Zone, and (1) *Cleistosphaeridium* spp. Assemblage Zone.

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