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PALYNOSTRATIGRAPHY AND DEPOSITIONAL ENVIRONMENT OF THE SUBATHU FORMATION(LATE YPRESIAN-MIDDLE LUTETIAN), MORNI HILLS, HARYANA, INDIA

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ABSTRACT

Palynostratigraphical investigations of the Subathu Formation (Late Ypresian - Middle Lutetian) in the Morni Hills of Haryana, India have been carried out. A total of 44 palynofossil genera and 64 species assignable to dinoflagellate cyst, acritarch, pteridophytic spore, gymnosperm and angiosperm pollen grains and fungal spores and ascostromata have been recorded. Out of these, one species of acritarch is new. Based on palynofossils distribution four distinct palynological assemblage zones have been recognised. Lateral extension of these palynofloral assemblage zones has been traced in the widely separated sediments of the Subathu Formation as exposed in Shimla Hills. Distributional patterns of palynological assemblage zones of the Subathu Formation have also been integrated and plotted against the global NP zones. The recorded palynoflora indicate a late Ypresian - middle Lutetian age of the Subathu succession in the present area of investigation.The overall palynofloral assemblage suggests that the rocks of older horizons were deposited in a very shallow marine (nearshore) environment with occasional influence of the open sea. However, the sediments of the younger horizons appear to have been deposited in an estuarine environment. Two transgressive and one regressive phases have been recognised during the early to middle Eocene transition in the present Subathu succession of Morni Hills.

Key words : Palynostratigraphy, Palaeoenvironment, Subathu Formation (late Ypresian-middle Lutetian), Morni Hills, India.

INTRODUCTION

The Subathu Formation represents the lowermost marine sequence of the Tertiary rocks in the Lesser Himalaya of Himachal Pradesh. It is overlain by Dagshai and Kasauli formations successively with gradationally conformable contacts. The rocks of Subathu Formation occur as a discontinuous outcrop 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, it occurs in two distinct tectonic units viz., the Bilaspur and the Surajpur units (Bhandari and Agarwal, 1967; Raiverman and Raman 1971). Palynological investigations on these sediments have been carried out extensively in the Shimla Hill which falls under the Surajpur tectonic unit. (Salujha, Srivastava and Rawat, 1969; Khanna, 1978; Singh, Khanna and Sah, 1978; Khanna and Singh, 1981; Singh and Sarkar,1987, 1992; Sarkar and Singh, 1988; Sarkar, 1991, 1997). However, very little is known about the palynological history of the Subathu succession developed in the Bilaspur tectonic unit of Morni Hills.

The present study has been carried out mainly with the objective to document the palynofloral assemblages within the Subathu Formation of Morni Hills. An attempt has also been made to find palynological basis for throwing light on age and depositional environment of this formation in the area of investigation.

GEOLOGICAL SETTING AND LOCAL STRATIGRAPHY

The Subathu Formation is well exposed in the Ghaggar river in Morni Hills, Haryana. The rocks of this formation rest unconformably on the pre-Tertiary Tundapathar limestones. The general geological succession of this area (Hore,1979) are as follows :

Subathu Group (Eocene)

----------? Unconformity----------

Tundapathar Group (pre -Tertiary)

----------Thrust Contact----------

Nahan Group (Lower Siwalik - Miocene)

The Tundapathar Group along with the overlying Subathu Group has been thrust over the younger Nahan Group as para-autochthonous unit along a major boundary fault (Bagi, 1992).

The present stratigraphic section is situated on the west bank of the river Ghaggar near the village

Kharak in Morni Hills of Haryana (fig.1). The exposed rock sequence at this locality is about 68m thick. The contact between the Subathu and Dagshai is overturned in this section and shows high dips varying from 75° to 80° in the SW direction with a NW-SE trending strike (Bagi, 1992). The lower part of the sequence mainly comprises black carbonaceous shales which is overlain by grey splintery shales in the middle. About 2m thick packstone band is present at 22m level. This packstone band is considered to be a marker horizon of the base of early Lutetian on the basis of Foraminifera (Bagi, 1992). Another very hard compact packstone is present at 37m level. The top 12m of the succession are mostly splintery shales followed by 1.5 m thick sandstone beds which represent a tempestite horizon. It is characterised by ripple lamination at the top as well as hummocky cross stratification. This is followed by about 4m thick horizon of soft shaly marl. the remaining ± 15m sequence comprises grey splintery shales. This sequence is overlain by a white quartzitic sandstone bed followed by the red nodular beds of the Dagshai Formation.

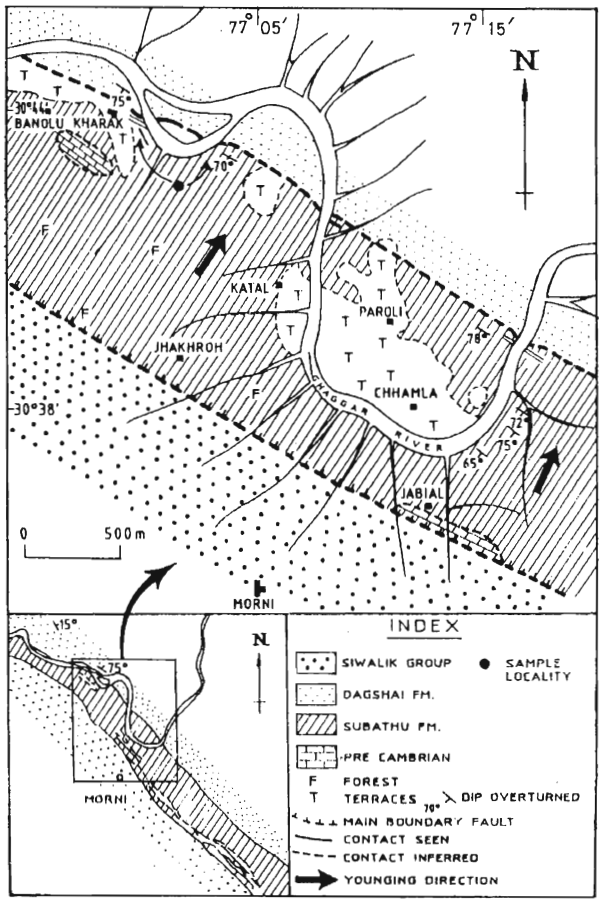

Fig. 1. Geological map of the Kharak area showing location of the stratigraphic section (after Bagi, 1992).

MATERIALS AND METHODS

The present palynological investigation is based on 63 samples representing 68m of stratigraphic section of the Subathu Formation. Out of these, 30 samples yielded diagnostic dinoflagellate assemblages associated with angiosperm pollen grains, fungal spores and conidia, and pteridophytic spores. The location of productive samples is marked in fig.2. Samples were macerated using standard chemical processing techniques. The slides were prepared in polyvinyle alcohol and mounted in Canada Balsam. In general, the grey shales are very rich in palynofossils. All the figured slides are housed in the repository of the Birbal Sahni Institute of Palaeobotany, Lucknow. Dinoflagellate cyst nomenclature proposed by Lentin and Williams (1993) has been adopted in the present study. A checklist of the recorded palynofossils has been given as an appendix 1. Some stratigraphically significant palynofossils have also been illustrated (Plates I & II).

SYSTEMATIC PALYNOLOGY

Genus ***Veryhachium*** Deunf, 1954 emend. Sarjeant & Stancliffe, 1994

Veryhachium morniensis n. sp.

(Pl. I, figs.1, 4)

Derivation of name : with reference to the locality name Morni Hills, Haryana.

Holotype : Pl. I. Fig.1, Slide no. 12225, coordinates, 65x98.5, Birbal Sahni Institute of Palaeobotany.

Diagnosis : Test vesicular, triangular- tetragonal, kite shaped, body wall very finely granulose, each corner with taper to pointed ends, spines extremely short(0.5µm-1µm), no pylum observed, longitudinal thickening present on the ventral surface. Size range: Central body diameter varies from 16-20µm to 20-24µm.

Comparison : This species can be differentiated from any other known species by its tetragonal kite

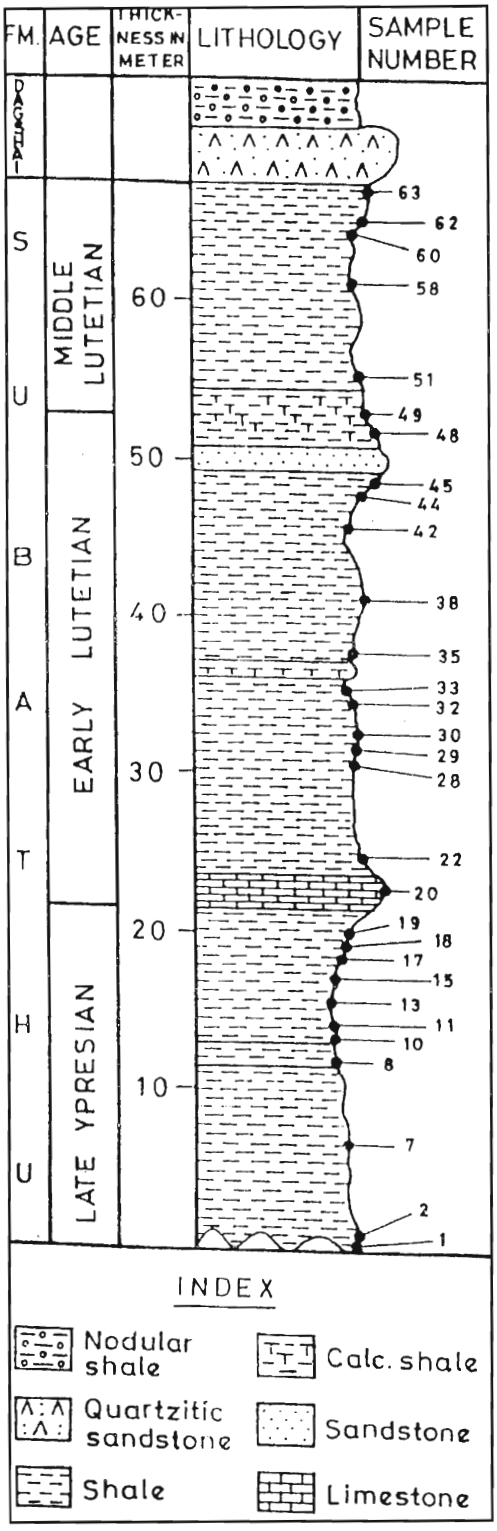

Fig. 2. Litholog of the Kharak section (after Bagi,1992) showing the position of productive samples in the sequence.

shaped body, granulose ornamentation and presence of extremely short spine arising out from the corners.

Remarks : In most of the cases, the specimens have been found to be tetragonal in shape, however, few triangular forms have also been recorded. Spines are mostly found in detached condition. Because of their abundance in samples, some body colour as the associated Eocene palynofossils and excellent state of preservation, these palynofossils have been considered as autochthonous . As the specimens of *Veryhachium morniensis* have been found only in association with fresh water alga *Pediastrum* spp., we have considered them as fresh water elements transported through river channels. This also supports the views of Benedek (1972) who suggested a fresh water habitat for *Veryhachium* spp.

Type locality, Horizon and Age : Kharak river section near Norni, Haryana; Subathu Formation (late Ypresian-early Lutetian).

DISCUSSION

The Kharak palynofloral assemblage consists mainly of dinoflagellate cysts along with pteridophytic spores, angiosperm and gymnospermous pollen and fungal spores and ascostromata. Additionally, acritarch and fresh water algae have also been recorded.A total of 44 genera and 64 species have been recorded,out of these one species of acritarch is new. Several species of fresh water alga *Pediastrum* of the family Hydrodictyaceae and acritarch *Veryhachium* have been recorded at several level of the stratigraphic succession. Among the pteridophytes, the family Osmundaceae is represented by three species viz, *Todisporites major*, *T. minor* and *Todisporites daghsaiensis*. *Cyathidites minor* and *Dictyophyllidites dulcis* have possible affinity with the family Cyatheaceae and Matoniaceae respectively. Both the genera are at present occuring in the tropical regions. Pteridophytic spores are present in high percentages only at certain levels of the succession. Angiosperms are represented by only two genera belonging to the family Palmae viz., *Neocouperipollis* and *Palmidites*. Fungal spores and Microthyraceous ascostromata are present in almost all the samples of the younger horizons in large quantities. Qualitative as well as quantitatively, the most dominant element of the Kharak assemblage

are dinoflagellate cyst (above 80%). 42 species of dinoflagellates and acritarchs have been recognised in this assemblage and the vertical distribution of significant species are recorded in the range chart (fig.3). The most dominant dinocyst genera are *Kallosphaeridium*, *Homotryblium*, *Achomosphaera*, *Spiniferites, Cordosphaeridium,* and *Thalassiphora.* Forms like *Areoligera, Areosphaeridium, Glaphyrocysta* and *Adnatosphaeridium* are also very common in most of the samples. The dinocyst diversity is highly variable through out the section. Several dinoflagellate cyst taxa have been reported for the first time from the Subathu Formation viz., *Cordosphaeridium cantharellum*, *Areosphaeridium arcuatum*, *Kallosphaeridium brevibarbatum*, *Eatonicysta ursulae* and *Exochosphaeridium phragmoides*. Together with the Tertiary palynofossils some reworked Permian and Cretaceous palynofossils have also been recorded viz, *Callialasporites segmentatus, C. trilobatus*, *Cicatricosisporites* sp., *Araucariacites* sp., etc.The occurrence of these palynofossils in the Eocene rocks is very significant as it may throw some light on the source rock of Subathu Formation in the Morni Hills.The ranges and relative abundances of 56 species of palynofossils are used for biostratigraphic zonation. Four distinct palynoassemblages have been recognised on the basis of qualitative nature and proportional representation of the various palynofossils throughout the succession (fig. 3). The characteristics of the palynofloral assemblages are discussed below.

Palynological Assemblage Zone A

Samples covering about 16m of the succession from base have yielded diagnostic palynofossils of this assemblage. Most of the recovered palynofossils are however found in highly degraded conditions. The most dominant taxa in this assemblage are *Kallosphaeridium brevibarbatum* and *Cleistosphaeridium brevispinosum*. The other dinocyst taxa represented in this assemblage are *Cordosphaeridium fibrospinosum*, *Diphyes colligerum,Cleistosphaeridium diversispinosum, Glaphyrocysta divaricata Lanternosphaeridium lanosum, Operculodinium centrocarpum, Homotryblium abbreviatum* and *H. tenuispinosum.* Small spinose dinocyst taxa viz, *Kallosphaeridium brevibarbatum* and *Cleistosphaeridium brevispinosum* constitute more than 70% of the total assemblage, and this predominance can be taken as important character for distinguishing the overlying assemblage zone B dominated by *Homotryblium* spp. Very detailed comparison with other Subathu assemblages is not possible due to poor recovery of palynofossils in some of the samples excepts its strong resemblance with *Cleistosphaeridium* spp. Cenozone of Kalka - Shimla area (Singh *et al.*, 1978)

Palynological Assemblage Zone B

This palynofloral assemblage includes about 6 m stratigraphic succession in between 16-22m. There are 21 dinocyst species recognised in this assemblage *Homotryblium abbreviatum H . pallidum* and *H. tenuispinosum* are the most dominant taxa . *Achomosphaera multifurcata, A ramulifera, Adnatosphaeridium vittatum* and *Spiniferites membranaceous* are sub dominant. The other taxa recorded in this assemblage are *Operculodinium centrocarpum, Cordosphaeridium inodes, Hystrichokolpoma cinctum,* etc. This palynofloral assemblage alone includes more than 70% of *Homotryblium tenuispinosum and H . abbreviatum.* A large number of *Pediastrum* spp and *Veryhachium mornii* have been recorded in this zone .This assemblage zone can be demarcated from the overlying and underlying assemblage zone by overwhelming dominance of *Homotryblium* spp.

Palynological Assemblage Zone C

This palynofloral assemblage zone covers the 22m to 46m of the Subathu succession This assemblage is characterised by the presence of 32 species. Terrestrial Palynomorph taxa viz., *Neocouperipollis brevispinosum, N. pyrispinosus* and *Palmidites noviculatus* dominate the assemblage. Large number of pteridophytic spore genera and gymnosperm pollen viz., *Cyathidites minor, Todisporites major, T. minor, Dictyophyllidites dulcis, Podocarpidites couperi,* etc. have been recorded. Fungal conidia and microthyraceous ascostromata and *Pediastrum* spp. are also very common in most of the samples. Quantitatively dinocyst population drops substantially in this assemblage. *Cordosphaeridium inodes, Lingulodinium machaerophorum*

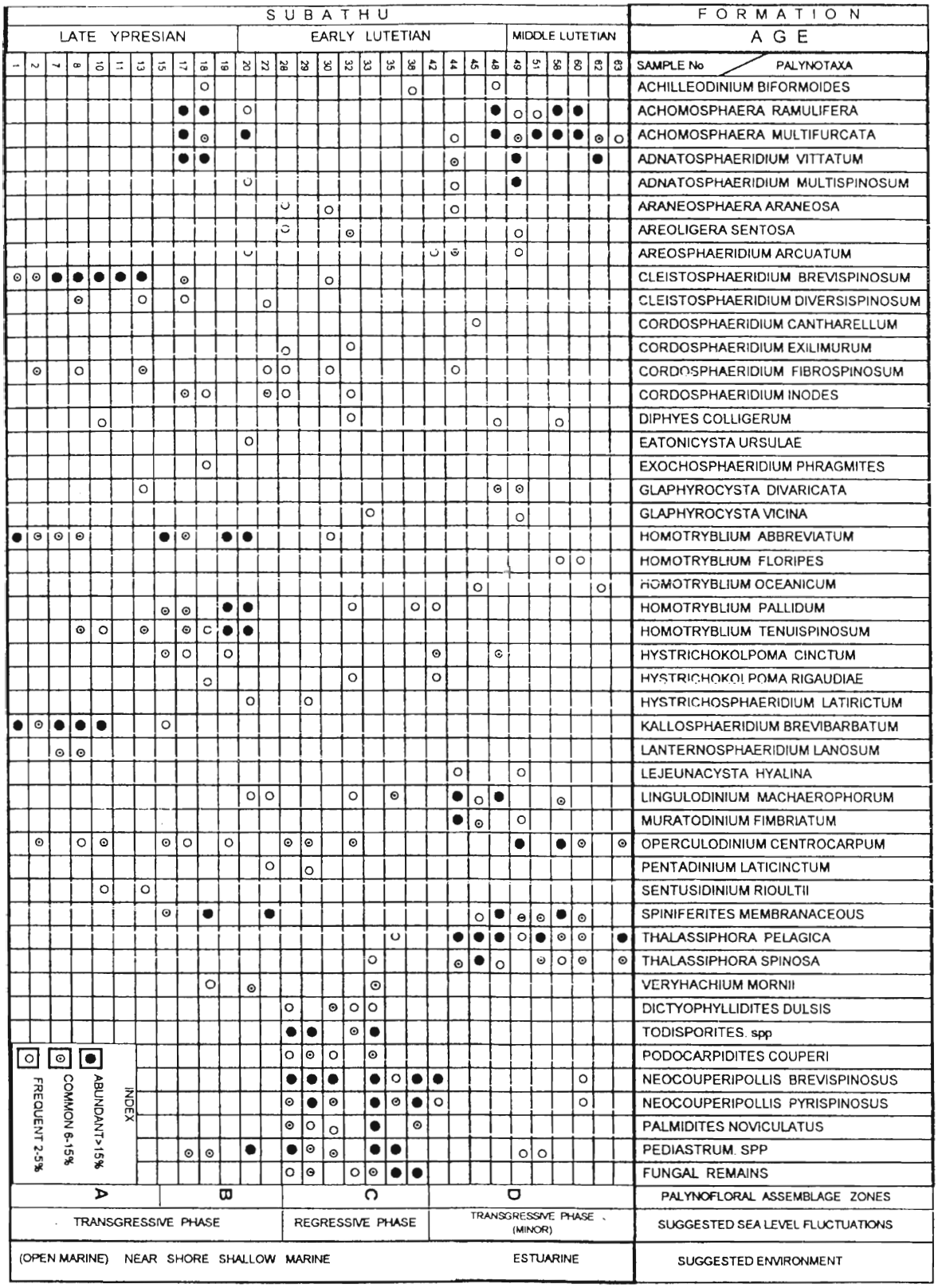

Fig. 3. Distribution of significant palynofossils in Kharak Subathu succession.

Operculodinium centrocarpum, Areoligera sentosa and *Homotryblium pallidum* in low percentages have been encountered in some of the samples. *Pediastrum* spp.are found in large numbers in some samples. This assemblage zone can be recognised by the dominance of pollen grains of *Neocouperipollis* spp. along with pteridophytic spores and fungal spores and ascostromata.

Palynological Assemblage Zone D

It covers the upper 22m of the Subathu succession. *Thalassiphora pelagica* and *Thalassiphora spinosa* dominate the assemblage with high percentage (>60%). *Spiniferites membranaceous, Achomosphaera multifurcata, A.ramulifera, Muratodinium fimbriatum, Lingulodinium machaerophorum and Operculodinium centrocarpum* are the subdominant taxa in the assemblage. Quantitatively, land derived elements decreased sharply in this zone. Several other dinocyst taxa present in this assemblage are *Glaphyrocysta divaricata, G.vicina, Areosphaeridium arcuatum, Adnatosphaeridium multispinosum, A.vittatum, Hystrichokolpoma cinctum* and *Lejeunecysta hyalina. Homotryblium floripes* and *H. oceanicum* are characteristic elements of the assemblage although their percentage is very low(<2%) .This assemblage zone can be demarcated from the underlying palynological assemblage zone by high frequencies of cavate dinoflagellate cyst viz., *Thalassiphora pelagica* as well as sudden decrease of land derived elements .

BIOSTRATIGRAPHIC CORRELATION

A comparative study of the present palynoflora with those recorded from equivalent horizons of Subathu Formation in other regions suggests correlation with the assemblages found by Singh *et al.*(1978) and Sarkar and Singh, (1988) from the Shimla Hills areas of Himachal Pradesh. A striking resemblance in the palynofloral development is apparent as palynofloral assemblage zones A,B,C and D closely correspond with *Cleistosphaeridium* spp. Cenozone, *Homotryblium* spp. (Cenozone, *Todisporites* spp. Cenozone and *Subathua sahni* (=*Thalassiphora* spp.)) Cenozone established in the type locality of the Subathu Formation (Singh *et al.*, 1978). The upper part of the Zone B seems to be equivalent to the *Cordosphaeridium inodes* Cenozone of Kalka Shimla area . However, this horizon is extremely thin in Kharak section. The occurrence of *Thalassiphora*-dominated horizons above the zone C is also noteworthy. The sharp contrast in these assemblages between the two areas in our opinion may probably be interpreted as facies controlled.The present palynofloral assemblage compares very well with the late Ypresian and early Lutetian palynofloral assemblages of the Koshalia Nala Section of Himachal Pradesh (Sarkar and Prasad, 2000). Several palynotaxa are common to both assemblages viz., *Adnatosphaeridium vittatum, A.multispinosum, Amphorosphaeridium multispinosum, Cordosphaeridium fibrospinosum, Cleistosphaeridium brevispinosum, Homotryblium abbreviatum, H. tenuispinosum, H. pallidum, Hystrichokolpoma cinctum, Operculodinium centrocarpum, Spiniferites membranaceous, Thalassiphora pelagica,* etc. Nannofossils of combined NP12 and NP13 zones of late Ypresian age were reported from the same horizons (Jafar and Singh, 1992). Larger foraminifera viz., *Assilina mamilata, A. spira abradi,, A. daviesi, A. granulosa, Nummulites atacicus, N. globulus,* etc. recorded from the same succession also support an early Eocene age (Bhatia and Singh,1991). The present Subathu succession has also been correlated with the faunal zones iv,v and vi of the Kalka-Shimla area, Himachal Pradesh on the basis of several marker larger foraminifera viz., *Assilina major, A. spira abradi,* etc. (Mathur,1978; Bagi,1992). The present assemblage compare best with the top of Pak D-VIII Zone of Patala Formation in Salt Range of Pakistan which is characterised by the presence of *Homotryblium tenuispinosum*. The interval from the FO of *H. tenuispinosum* to the FO of *H. oceanicum* has been correlated with NP11 / 12 zones (Kothe, Khan and Ashraf, 1988). Although a close comparison with none of the Eocene palynofloral zonations established in Europe is possible, several dinocyst taxa (viz., *Achilleodinium biformoides, Araneosphaera araneosa, Homotryblium abbreviatum, Areoligera sentosa, Glaphyrocysta divaricata* and *Thalassiphora pelagica)* are found to be common between the Kharak and microplankton assemblage zones of 3 and 4 of Bracklesham Beds

of Isle of Wight, Southern England (Eaton, 1976). We support the contention of Köthe *et al.* (1988) that the diferrence of dinocyst assemblages between European and Indian subcontinent may be due to palaeolatitude and /or palaeoecological factors. The present palynofloral assemblage zones have been integrated and plotted against the global NP zones (Martini,1971) and shallow-benthic foraminiferal zonation (Serra-Kiel, Hottinger, Caus, Drobne, Ferrandez, Jauhri, Less, Pavlovec, Pignatti, Samso, Schaub, Sirel, Strougo, Tambareau, Tosquella and Zakrevskaya, 1998) along with the established dinocyst biozonation of the Subathu Formation of India and Pakistan (fig.4) .

The Kharak palynofloral assemblage is dominated by dinoflagellate cyst taxa viz., *Kallosphaeridium*, *Homotryblium*, *Cordosphaeridium* and *Thalassiphora* which form over 80% of the total dinocyst population. Several species of *Glaphyrocysta*, *Adnatosphaeridium*, *Spiniferites* and *Achomosphaera* are also abundant in many samples. In addition to this, number of Eocene marker taxa viz. *Areosphaeridium arcuatum, Areoligera sentosa, Araneosphaera areneosa and Eatonicysta ursulae* have been recorded at several levels of this succession. Most of the dinocyst taxa recorded in this assemblage range within the late Ypresian and early-middle Lutetian. Among 64 species 46 species are known from the Kalka-Shimla, Banethi-Bagthan and Bilaspur Eocene assemblages of the Shimla Hills (Khanna, 1978; Sarkar and Singh, 1988; Sarkar, 1997). Singh *et al.* (1978) established seven palynological zones in the Subathu type locality encompassing late Palaeocene to late Eocene age. The present palynofloral assemblages have close similarities with several assemblage zones viz., *Cleistosphaeridium* spp Cenozone, *Homotryblium* spp. Cenozone and *Subathua sahnii* Cenozone of early Eocene age. Samples from the younger horizons were found to contain a dinocyst assemblage which included *Lejeunecysta hyalina, Areosphaeridium arcuatum, Cordosphaeridium cantharellum, and Homotryblium oceanicum*. All of these taxa have their first appearance in the middle Eocene (Powell,1992; Williams, Stover and Kidson, 1993). The boundary between the late Ypresian and Lutetian is well defined in this section on the basis of *Assilina spira abradi*, *N. obesus* and *N. lehneri* at 22m level (Bagi, 1992). Therefore, it is concluded that the present palynofloral assemblage is of late Ypresian to early-middle Lutetian in age.

ENVIRONMENT OF DEPOSITION

Two transgressive and one regresssive phases are identified in the Kharak Subathu succession (late Ypresian to early-middle Lutetian) on the basis proportional distribution of marine phytoplanktons and land derived palynofossils. Dinoflagellate cyst associations show a remarkable change in quality and quantity from older to younger horizons. Chorate cysts viz., *Homotryblium tenuispinosum, H. abbreviatum, H. pallidum, Cordosphaeridium fibrospinosum,* etc. decline sharply in the younger horizons. The abundance of dinocyst taxa viz., *Kallosphaeridium, Cleistosphaeridium Homotryblium* spp.; *Hystrichosphaeridium tubiferum* along with *Glaphyrocysta and Hystrichokolpoma* in older stratigraphic horizon indicates that sediments of this horizon were deposited in a very shallow, nearshore marine environment which was occassionaly influenced by open marine conditions. Presence of black carbonaceous shales in the lowermost part of the succession also supports this observation. This part of the succession represents a major transgressive phase of the epicontinental Subathu Sea in this area. The regressive phase of the Subathu sea is pronounced at 22m to 46m level of this section. Palynological samples from this horizon yielded high amount of land derived elements viz., pteridophytic spores,angiosperm pollen, fungal remains, trachieds and cuticles. Dinocyst percentage also drops abruptly to less than 20 % . The palynofloral assemblage is characterised by the abundance of palm pollen viz., *Neocouperipollis* spp. and *Palmidites noviculatus*. Faunal evidence also indicates a regression of sea in the early Ypresian times in this region (Mathur and Juyal,1998). Significant increase in dinocyst population and a decline in terrestrial elements in the interval from 46m to 68m are interpreted as an indication of reappearance of a minor transgression in the younger horizons. Dinoflagellate cyst taxa viz., *Thalassiphora pelagica*, *Achomosphaera multifurcata* and *Spiniferites membranaceous* provide cogent evidence for this inference. The

AGE		NANNO-ZONE (Martini, 1971)	LARGER FORAMINI-FERAL ZONE (Serra-Kiel *et al*, .,1998)	FAUNAL ZONATION INDIA (Kalka-Shimla Area-Mathur. 1978)	PRESENT WORK PALYNOLOGICAL-ZONATION INDIA Kharak Section Morni Hills	PALYNOLOGICAL ZONATION INDIA (Kalka-Shimla Area-Singh *et al* ., 1978)	DINOCYST ZONATION PAKISTAN (The Surghar Range The Kohat Area, The Salt range, Kothe *et al* .,1988)
EOCENE	LATE	NP-21	SB-21				
		NP 19-20	SB-20				
		NP-18	SB-19			*Todisporites* spp. Cenozone	
	MIDDLE	NP-17	SB-18				PAK- DXI
			SB-17				
		NP-16	SB-16	ZONE-IX			
			SB-15	ZONE-VIII		*Subathua sahnii* Cenozone	PAK- DX
		NP-15	SB-14	ZONE-VII	ZONE-D	*Cordosphaeridium-multispinosum* Cenozone	
			SB-13	ZONE-VI			
		NP-14	SB-12		ZONE-C	*Hexagonifera* spp. Cenozone	
	EARLY	NP-13	SB-11	ZONE-V		*Homotryblium* spp. Cenozone	PAK- DIX
		NP-12	SB-10				
		NP-11			ZONE-B	*Cleistosphaeridium* spp. Cenozone	PAK- DVIII
			SB-8	ZONE-IV	ZONE-A		
		NP-10	SB-7	ZONE-III		Barren Zone	PAK- DVII
PALAEOCENE	LATE	NP-9	SB-6				PAK- DVI
			SB-5	ZONE-II		*Cyclonephelium* Cenozone	PAK- DV
		NP-8	SB-4				PAK- DIV
				ZONE-1			PAK- DIII
		NP-6	SB-3				PAK- DII
		NP-5	SB-2				PAK- DI
		NP-4					
	EARLY	NP-3	SB-1				
		NP-2					
		NP-1					

Fig. 4. Correlation of various biozones in Palaeocene-Eocene sediments of North-Western India and Pakistan.

abundance of fresh water alga *Pediastrum* in palynofloral assemblage zone C indicates that there was a fresh water influx in the basin through river channels during the deposition of these rocks.
The palynofloral assemblage of the younger horizons strongly suggests that deposition was in an estuarine environment at the top of a shallow basin.

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EXPLANATION OF PLATES

Plate I

(All photomicrographs are enlarged Ca x750, unless otherwise mentioned)

1, 4. *Veryachium morniensis, n. sp., B.S.I.P.* Slide no. 12225, Coordinates-65x98.5; Coordinates- 48x106.

2. *Pediastrum wilsonii* Singh & Khanna, 1978; B.S.I.P.Slide no. 12230, Coordinates- 48x104.

3. *Callimothallus assamicus* Dilcher, 1965; B.S.I.P. Slide no. 12233, Coordinates- 42x99.

5. *Lingulodinium machaerophorum* (Deflandre and Cookson, 1955) Wall, 1967; B.S.I.P.Slide no- 12236, Coordinates- 65x97.

6. *Achomosphaera multifurcata* Jain & Tandon 1981;B.S.I.P. Slide no. 12236, Coordinates- 38x104.5.

7. *Lejeunecysta hyalina* (Gerlach,1961) Kjellstrom,1972;B.S.I.P. Slide no. 12231, Coordinates- 53.5x95.

8. *Cleistosphaeridium brevispinosum* Jain & Millepied, 1975;B.S.I.P. Slide no. 12226, Coordinates- 62.5x104.5.

9. *Adnatosphaeridium vittatum* Williams & Downie, 1966;B.S.I.P. Slide no. 12237,Coordinates- 67.5x96.

10. *Kallosphaeridium brevibarbatum* (Decorinek, 1967) Jandu chene *et al.*, 1985; B.S.I.P.Slide no. 12235, Coordinates- 55x100.

11. *Araneosphaera araneosa* Eaton, 1976;B.S.I.P. Slide no. 12228, Coordinates- 61x108.

12. *Spiniferites membranaceous* (Rossignol, 1964) Sarjeant, 1970;B.S.I.P. Slide No. 12234, Coordinates- 59x111.

Plate II

(All photomicrographs are enlarged Ca x750, unless otherwise mentioned)

1. *Neocouperipollis pyrispinosus* Sarkar & Singh,1988.B.S.I.P. Slide no,12231 Coordinates- 34x89.

2. *Membralarnacia* sp. ;B.S.I.P. Slide no. 12229, Coordinates- 69x106.

3. *Homotryblium abbreviatum* Eaton, 1976; B.S.I.P.Slide no. 12237, Coordinates- 54x106

4. *Operculodinium centrocarpum* (Deflandre & Cookson, 1955) Wall, 1967;B.S.I.P. Slide no. 12237, Coordinates - 65x 97.

5. *Dictyophyllidites* dulcis Kar,1985;B.S.I.P. Slide no. 12231, Coordinates- 65x97.

6. *Areosphaeridium arcuatum* Eaton, 1971;B.S.I.P. Slide no. 12234, Coordinates- 57x 93.5.

7. *Adnatosphaeridium multispinosum* Williams & Downie, 1966;B.S.I.P. Slide no. 12240, Coordinates- 63x101 (X Ca 500).8. *Eatonicysta ursulae* (Morgenroth, 1966) Stover and Evitt, 1978;B.S.I.P. Slide no. 12232, Coordinates- 44x103.

9. *Cordosphaeridium cantharellum* (Brosius, 1963) Gocht, 1969;B.S.I.P. Slide no. 12224, Coordinates- 44x97.

10. *Glaphyrocysta vicina* (Eaton, 1976) Stover and Evitt, 1978;B.S.I.P. Slide no- 12230, Coordinates- 51x108.

11. *Hystrichokolpoma rigaudiae* Deflandre & Cookson,1955 ; B.S.I.P.Slide no. 12239, Coordinates- 68x104.

12. *Thalassiphora pelagica* (Eisenack) Eisennack & Gocht, 1960, B.S.I.P.Slide no. 12240, Coordinates- 47x103 (Ca x 500).

APPENDIX 1

Check list of palynotaxa

Dinoflagellate cysts

Achilleodinium biformoides (Eisenack) Eaton, 1976

Achomosphaera ramulifera (Deflandre) Evitt, 1963

A . multifurcata Jain&Tandon, 1981

Adnatosphaeridium vittatum Williams & Downie, 1966

A . multispinosum Williams & Downie, 1966

Amphorosphaeridium multispinosum (Davey & Williams 1966) Sarjeant,1981

Araneosphaera araneosa Eaton, 1976

Areoligera sentosa Eaton, 1976

Areosphaeridium arcuatum Eaton, 1971

Cleistosphaeridium brevispinosum Jain & Millepied, 1975

C. diversispinosum Davey et al, 1966

Cordosphaeridium cantharellum,(Brosius,1963) Gocht,1969

C. exilimurum Davey & Williams, 1966

C. fibrospinosum Davey & Williams, 1966

C. inodes (Klumpp) Eisenack, 1963

Diphyes colligerum (Deflandre & Cookson) Cookson, 1965

Eatonicysta ursulae (Morgenroth) Stover & Evitt, 1978

Exochosphaeridium phragmites Davey et al in Davey & Williams, 1966

Glaphyrocysta divaricata (Williams & Downie) Stover & Evitt,1978

G. vicina (Eaton) Stover & Evitt, 1978

Homotryblium abbreviatum Eaton, 1976

H. floripes (Deflandre & Cookson) Stover, 1975

H. oceanicum, Eaton,1976

H. pallidum Davey & Williams,1966

H. tenuispinosum Davey & Williams, 1966

Hystrichokolpoma cinctum Klumpp, 1953

H. rigaudiae Deflandre & Cookson, 1955

Hystrichosphaeridium latirictum Davey & Williams, 1966

Kallosphaeridium brevibarbatum (De Coninck) Jan du Chene et al, 1985

Lanternosphaeridium lanosum Morgenroth, 1966

Lejeunecysta hyalina (Gerlach) Kjellstrom,1972

Lingulodinium machaerophorum (Deflandre & Cookson) Wall, 1967

Membralarnacia sp.

Muratodinium fimbriatum, Drugg,1970

Operculodinium centrocarpum (Deflandre & Cookson) Wall, 1967

Pentadinium laticinctum (Gerlach) Benedek et al,1982

Polysphaeridium subtile Davey & Williams, 1966

Sentusidinium rioultii (Sarjeant) Sarjeant & Stover, 1978

Spiniferites membranaceous (Rossignol) Sarjeant, 1970

Thalassiphora pelagica (Eisenack) Eisenack & Gocht, 1967

Thalassiphora spinosa (Khanna & Singh) Stover & Williams, 1987

Acritarch

Veryhachium morniensis Sarkar & Prasad,sp.nov.

Fresh water algae

Pediastrun angulatus Singh & Khanna, 1978

P . diffusus Singh & Khanna, 1978

P . compactum Singh & Khanna, 1978

P . willsonii Singh & Khanna, 1978

Pteridophytic spores

Cyathidites minor Couper, 1953

Dictyophyllidites dulcis Kar, 1985

Todisporites dagshaiensis Khanna & Singh, 1981

T. major Couper, 1958

T. minor Couper, 1958

Lygodiumsporites lakiensis (Sah & Kar) Kar, 1978

Gymnospermous pollen

Podocarpidites couperi Sarkar & Singh, !988

Angiospermous Pollen

Neocouperipollis brevispinosum (Biswas) Sarkar & Singh, 1988

N . pyrispinosus Sarkar & Singh,1988

Palmidites noviculatus Sarkar & Singh, 1988

Fungal remains

Dicellaesporites levis Sheffy & Dilcher, 1968

Callimothalus pertusus Dilcher, 1965

Phragmothyrites eocenica (Edwards) Kar & Saxena, 1976

Multicellaesporites sp.

Reworked spore/pollen

Araucariacites sp.

Callialasporites segmentatus (Balmae) Dev,1961

C.trilobatus (Balmae) Dev,1961

Cicatricosisporites sp.


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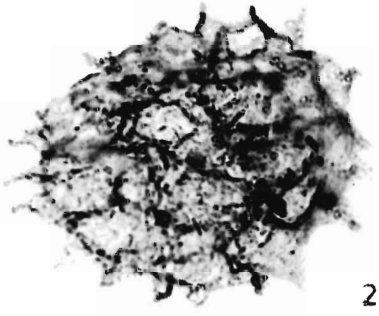
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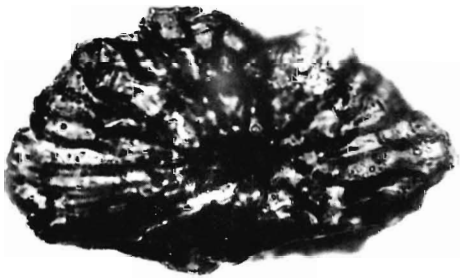
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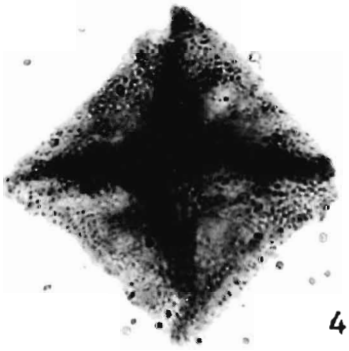
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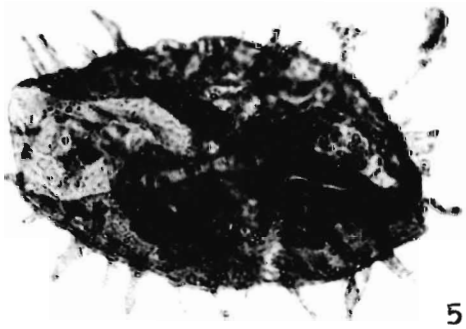
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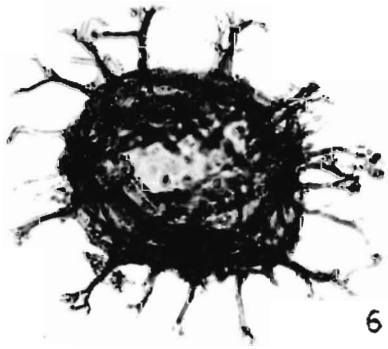
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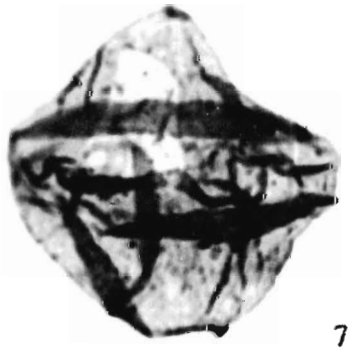
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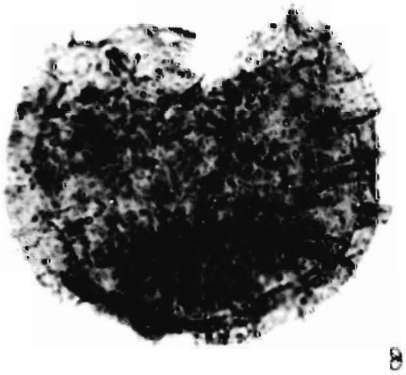
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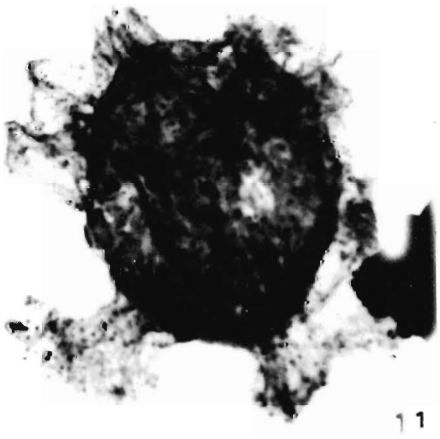
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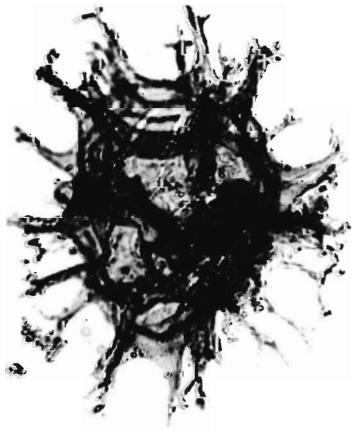
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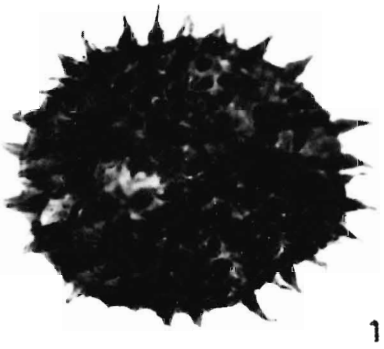
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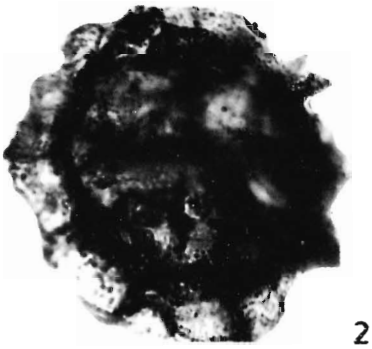
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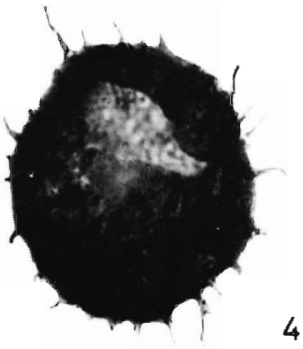
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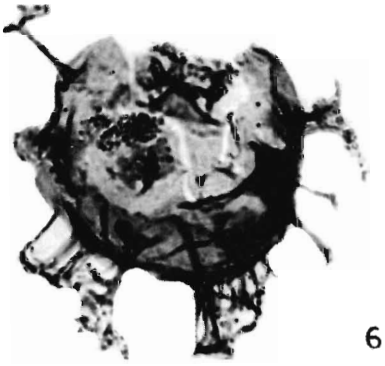
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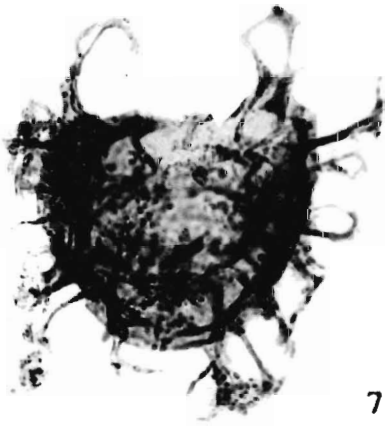
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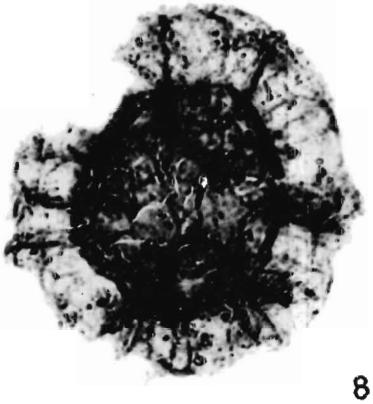
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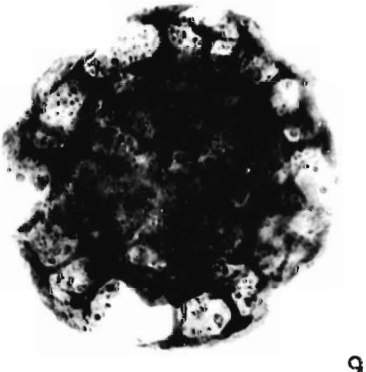
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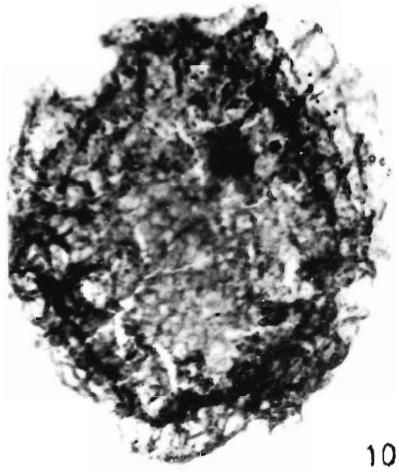
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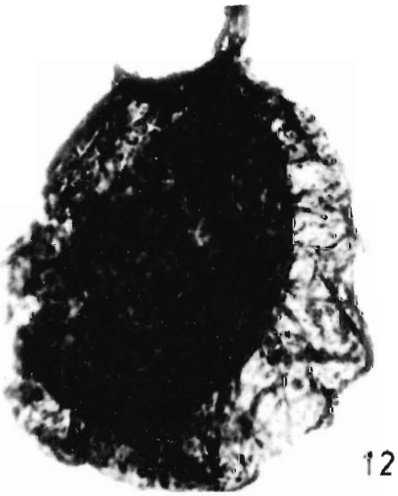
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