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Significant Dinoflagellate Cyst Biohorizons in the Upper Cretaceous–Palaeocene Succession of the Khasi Hills, Meghalaya

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Abstract: The Upper Cretaceous-Palaeocene rocks of the Khasi Hills, Meghalaya have yielded rich dinoflagellate cysts assemblages recovered from the Mahadeo Formation, the Langpar Formation, lower part of the Therria Formation and lower part of the Sylhet Limestone Formation. Occurrence of several globally recognized marker dinoflagellate cyst taxa, having well-established First Appearance Datum (FAD) and Last Appearance Datum (LAD), is noted in these assemblages. A succession of cosmopolitan dinoflagellate cyst biohorizons (based on comparisons with global records) are summarized, highlighting their potential in precise age determination and demarcation of time boundaries within Late Campanian–Late Thanetian interval. The dinoflagellate cyst evidence demonstrates that the succession is not older than Late Campanian in age.

Keywords: Dinoflagellate cysts, Biostratigraphy, Biohorizons, Upper Cretaceous–Palaeocene, Khasi Hills, Meghalaya.

INTRODUCTION

An almost continuous marine Upper Cretaceous–Palaeocene succession is exposed on the southern fringes of the Shillong Plateau (also known as the South Shillong Plateau) in Meghalaya (Fig. 1). The succession shows predominantly clastic sedimentation taking place during the Late Cretaceous–Early Palaeocene times, followed by the extensive development of carbonates (with minor clastic intervals) during the Late Palaeocene–Middle Eocene interval. The succession is well developed in the Khasi Hills, extending from Pynursla–Dawki area in the east to Gumaghat–Jadukata river in the west. Since the pioneering work of the Oldham (1858) and Medlicott (1869), several workers have contributed to the geology and lithostratigraphic framework of these sedimentaries in the Khasi Hills. Biostratigraphic control, however, is limited due to facies constraints as datable ammonites are poorly represented (Bhattacharya and Bhattacharya, 1981) and the occurrence of calcareous plankton (foraminifera, nannofossils) is restricted to select levels only (Nagappa, 1959; Pandey, 1981a; 1981b; Garg and Jain, 1995). Besides these, bivalves (Bhattacharya and Bhattacharya, 1981), larger benthic foraminifera (Nagappa, 1959; Pandey, 1973; Jauhri, 1994, 1996, 1998) and terrestrial palynomorphs (Biswas, 1962; Sah and Dutta, 1967; Dutta and Sah, 1970; Sah and Singh, 1977; Nandi, 1984, 1990; Kar and Kumar, 1986; Kar and Singh, 1986) have also been used for age interpretations in different parts of the succession. Studies on dinoflagellate cysts (Jain et al. 1975; Nandi, 1990; Garg and Jain, 1993; Garg and Khowaja-Ateequzzaman, 2000; Kumar et al. 2001; Garg et al. 2002) suggest that these organic-walled marine phytoplankton may prove to be extremely useful for dating and correlation of sedimentary intervals impoverished in calcareous microfossils as well as for integrated biostratigraphic studies.

Investigations of the South Shillong succession carried out by us in parts of the Khasi Hills show recovery of rich and datable dinoflagellate cyst assemblages from the Upper Cretaceous–Palaeocene interval. These assemblages include several globally recognized marker species capable of providing refined age control. The purpose of the present communication is to briefly report a succession of significant Dinoflagellate cyst Biohorizons (FADs and LADs) recognized in the Upper Cretaceous–Palaeocene succession of the Khasi Hills and to highlight their potential in precise age determination and demarcation of time boundaries during this interval.

GEOLOGICAL SETTING

The Shillong Plateau situated in Meghalaya, northeastern India forms a part of the Assam Shelf (Murty,

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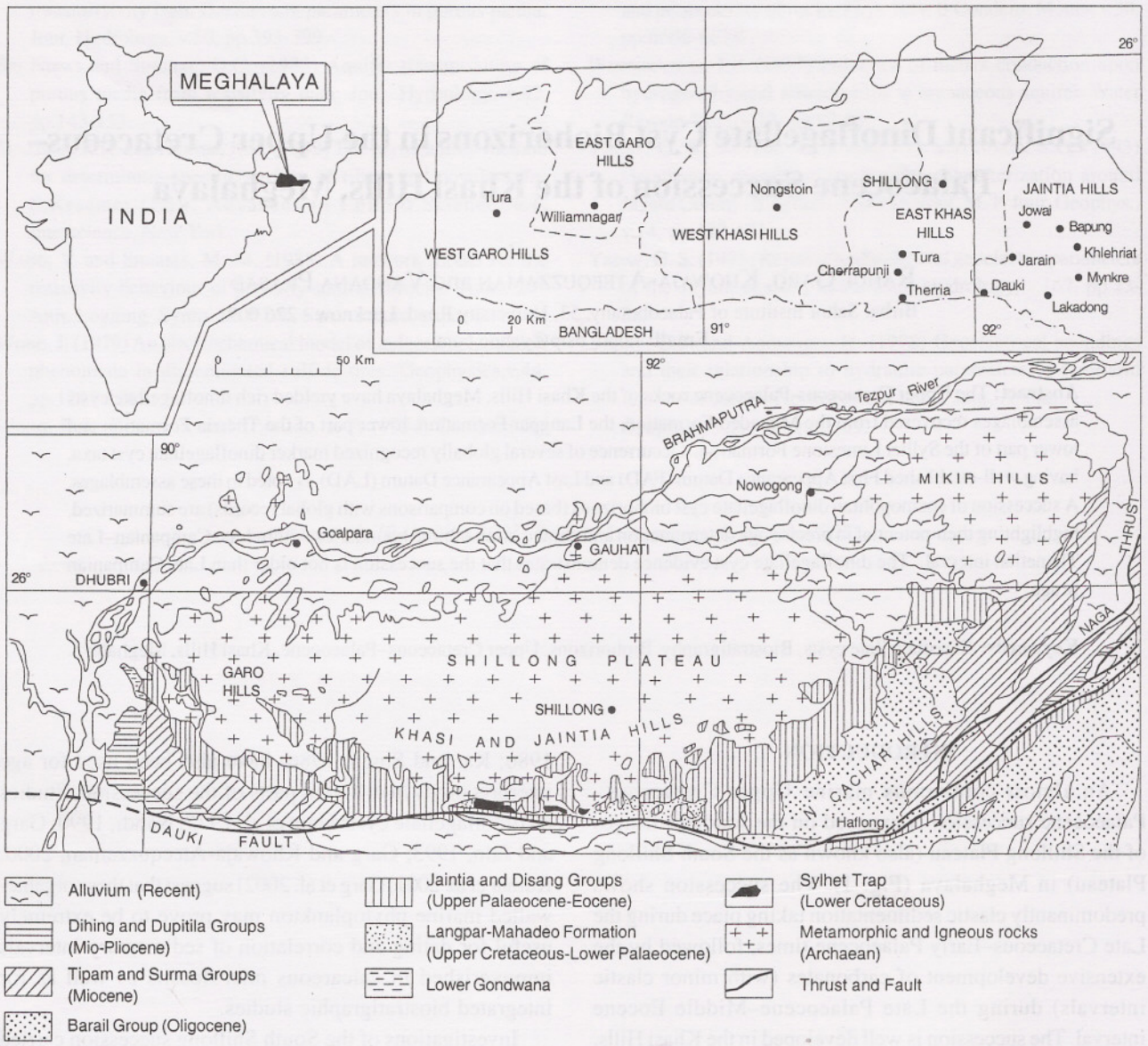

Fig.1. Location Map showing main geological features of the South Shillong Plateau (*after* Mathur and Evans, 1964).

1983). The Plateau area comprises the highlands of the Garo, the Khasi and the Jaintia Hills (Fig.1). The succession is well exposed on the plateau region as well as on its southern slopes bordering the plains of Bangladesh. The lithostratigraphic framework of the Upper Cretaceous–Lower Tertiary shelf sediments exposed in the Khasi Hills has been studied by several workers (Medlicott, 1869; Ghosh, 1940; Wilson and Metre, 1953; Biswas, 1962; Chakraborty and Baksi, 1972; Murthy et al. 1976; Pandey, 1981a, b; Bhattacharya and Bhattacharya, 1981; Raja Rao, 1981). The lithostratigraphic classification given by Raja Rao (1981) is followed here (Fig. 2). Some difference of opinion exists on the stratigraphic nomenclature of the lower part of the Cretaceous succession. The lowermost unit exposed on the plateau region is a thick conglomerate ("Bottom Conglomerate" of Medlicott, 1869), which has been named as Weilloi Conglomerate Bed (*see* Bhattacharya and Bhattacharya, 1981). On the southern fringes of the plateau, the basal most part of the succession consists of alternating conglomerate and coarse arkosic to pebbly sandstone. It has been assigned an individual status of a formation and has been variously named as the Jadukata Formation (Talukdar, 1966 in Bhattacharya and Bhattacharya, 1981; Balasundaram, 1972), the Gumaghat Formation (Chakraborty and Baksi, 1972) or the Um Sohryngkew Formation (Pandey, 1981b). However, Biswas (1962) and Raja

STAGE		AGE	FORMATION/ MEMBER		THICKNESS IN METRES	LITHOLOGY
EOCENE	UPPER	PRIABONIAN	KOPILI FORMATION		500	Alternations of fine to coarse sandstone, grey siltstone and shales with few limestone bands
EOCENE	MIDDLE	LUTETIAN-BARTONIAN	SYLHET LIMESTONE FORMATION	PRANG LIMESTONE	60-150	Bluish grey massive to thinly bedded foraminiferal limestones with marl and earthy limestone bands
EOCENE	MIDDLE	LUTETIAN-BARTONIAN	SYLHET LIMESTONE FORMATION	NARPUR SANDSTONE	15-26	Coarse to medium grained ferruginous sandstones with pyrite nodules and thin calcareous and shaly bands
EOCENE	LOWER	YPRESIAN	SYLHET LIMESTONE FORMATION	UMLATDOH LIMESTONE	70-110	Grey to pinkish grey foraminiferal limestones with calcareous sandstone partings
PALEOCENE	UPPER	THANETIAN	SYLHET LIMESTONE FORMATION	LAKADONG SANDSTONE	35-150	Predominantly buff to whitish, soft, friable, medium to coarse grained arkosic sandstone, often pyriteous with thin grey-black, frequently burrowed, carbonaceous shales and siltstones and thin coal seams
PALEOCENE	UPPER	THANETIAN	SYLHET LIMESTONE FORMATION	LAKADONG LIMESTONE	10-60	Grey to brownish grey foraminiferal-algal limestone, dolomitic at the base with thin grey shale, silty shale partings in the upper part
PALEOCENE	UPPER	SELANDIAN	THERRIA FORMATION		20-80	Hard, buff to brownish, medium to coarse, ferruginous sandstones with thin bands of pyriteous siltstone and carbonaceous shale; 'Thalassinoides Ichno horizon' near the top, thick limestone/calcareous sandstone at the base
PALEOCENE	LOWER	DANIAN	LANGPAR FORMATION		10-50	Grey to buff coloured earthy limestones and calcareous sandstones interbedded with calcareous silty shales and carbonaceous shale
UPPER CRETACEOUS		UP. CAMPANIAN - MAASTRICHTIAN	MAHADEO FORMATION		160-335	Massive, fine to coarse grained glauconitic sandstones containing grey shales, mudstones and calcareous sandstones in the upper part; conglomerates and pebbly sandstones at the base
LOWER CRETACEOUS			SYLHET TRAP		250-400	Aa and pahoehoe type basalts

Fig.2. Lithostratigraphic classification of Upper Cretaceous-Eocene rocks of the Khasi Hills (modified after Raja Rao, 1981; Garg and Khowaja-Ateequzzaman, 2000).

Rao (1981) consider the "Bottom Conglomerate" and associated sandstone succession (*sensu* Medlicott, 1869) to be a part of the Mahadeo Formation, which has been followed here.

Sections Studied

The following sections (Figs. 3-5) have been investigated in the Cherrapunji - Mawsynram area for dinoflagellate cyst studies:

1. Um Sohryngkew river (Therriaghat) Section (for the upper part of the Mahadeo Formation, Langpar Formation and lower part of the Therria Formation).
2. Mawsmai-Shella Road Section (for the upper part of the Mahadeo Formation).
3. Shillong-Cherrapunji Road Section (for the upper part of the Therria Formation, Lakadong Limestone and the Lakadong Sandstone members of the Sylhet Limestone Formation).
4. Weilloi-Mawsynram Road Section (for the lower part of the Mahadeo Formation).
5. Jathang Hill section, Mawsynram (for the Lakadong Sandstone Member, Sylhet Limestone Formation).

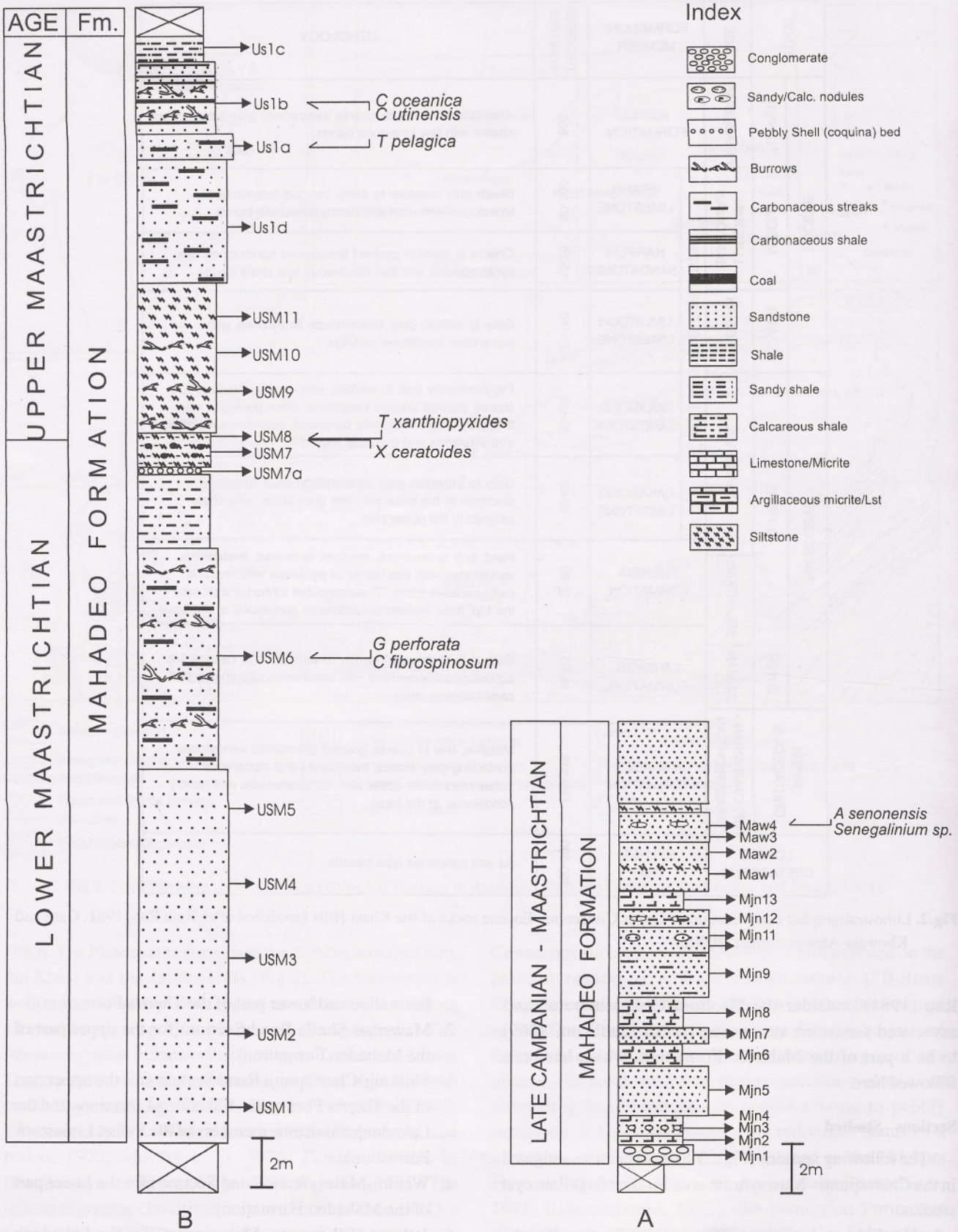

Fig.3. Lithological column of the sections exposed ca. 2 km north of Mawsynram along the Weilloi-Mawsynram road (A) and along an abondoned border road above the western bank of the Um Sohryngkew river, Therriaghat area (B).

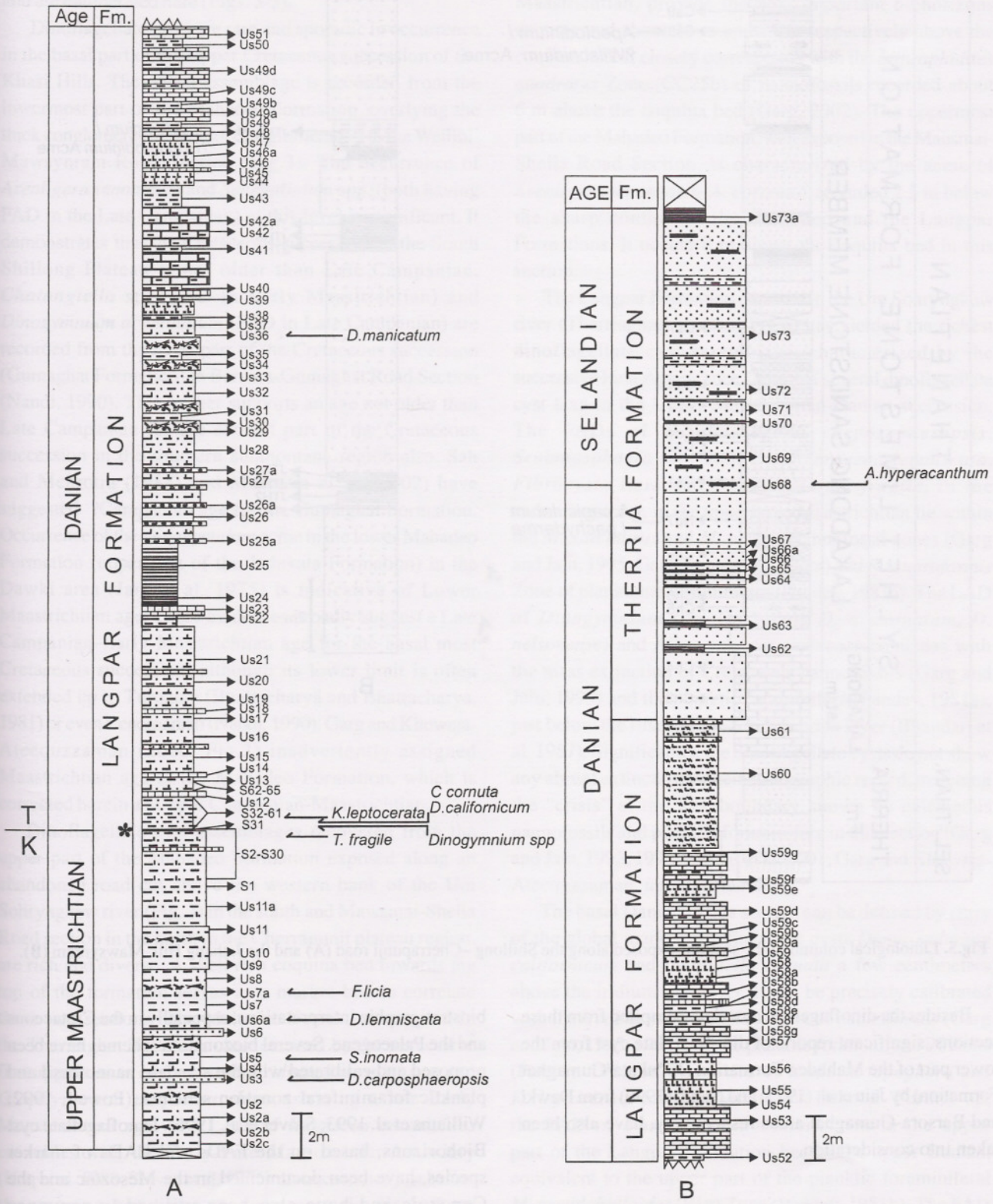

Fig.4. Lithological column of the section exposed along the western bank of the Um Sohryngkew river, Therriaghat. Star indicates Ir-rich K/T boundary layer.

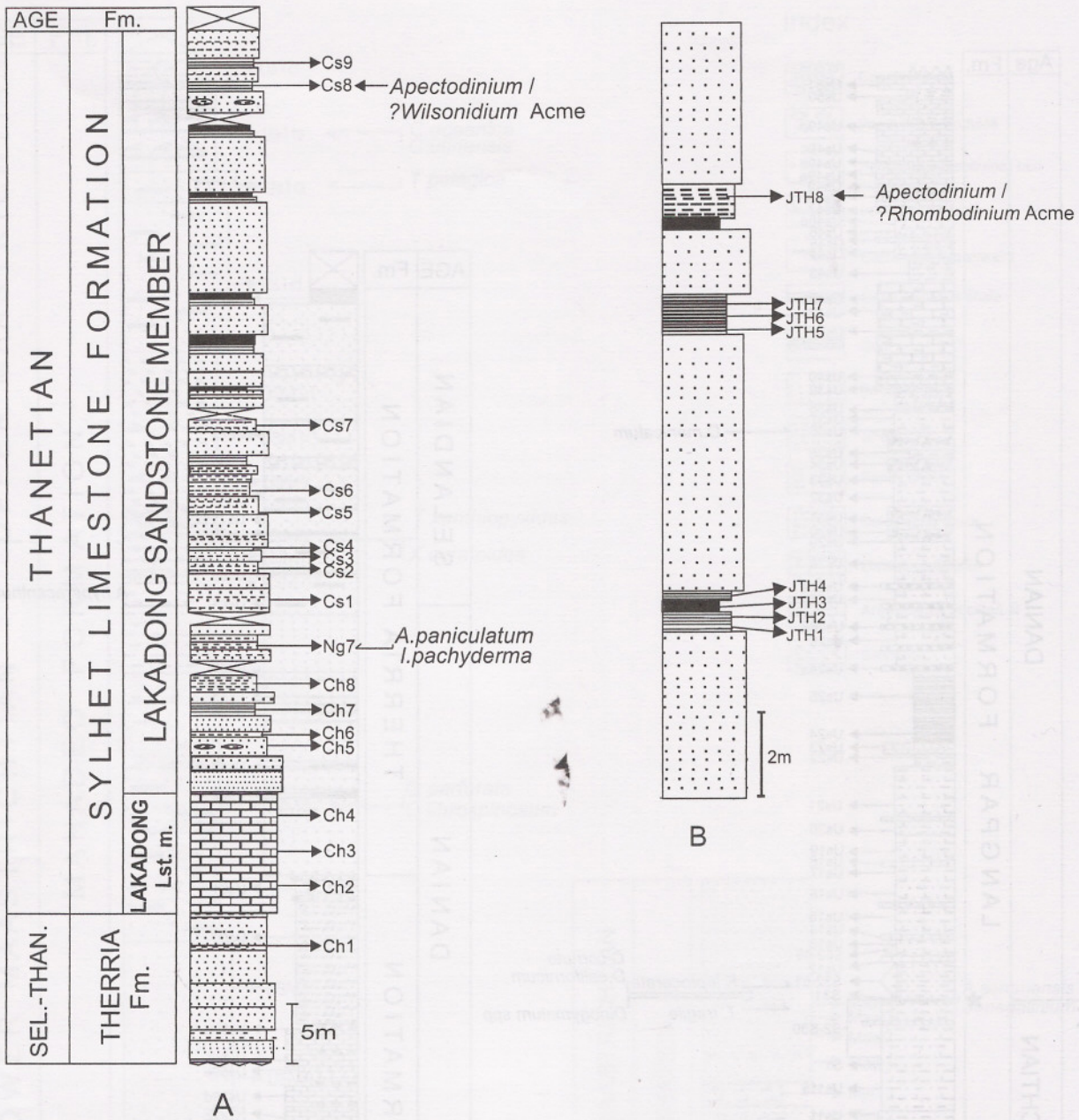

Fig.5. Lithological column of the sections exposed along the Shillong –Cherrapunji road (A) and the Jathang Hill, Mawsynram (B).

Besides the dinoflagellate cyst data compiled from these sections, significant reports of dinoflagellate cyst from the lower part of the Mahadeo Formation (Jadukata/Gumaghat Formation) by Jain et al. (1975) and Nandi (1990) from Dawki and Barsora-Gumaghat areas respectively, have also been taken into consideration.

DINOFLAGELLATE CYST BIOHORIZONS

During the past two decades, dinoflagellate cysts have been used globally for precise dating and integrated biostratigraphic interpretations, especially in the Cretaceous and the Palaeogene. Several biozonation schemes have been proposed and calibrated with the standard nannofossil and planktic foraminiferal zonation schemes (Powell, 1992; Williams et al. 1993; Stover et al. 1996). Dinoflagellate cyst Biohorizons, based on the FADs and LADs of marker species, have been documented in the Mesozoic and the Cenozoic and have also been utilized in sequence stratigraphic framework (Haq et al. 1988; Stover et al. 1996; Hardenbol et al. 1998). Several of these globally recognized Dinoflagellate cyst Biohorizons have been identified in the

Upper Cretaceous-Palaeocene succession of the Khasi Hills and are enumerated here (Figs. 3-5).

Dinoflagellate cysts are rare and sporadic in occurrence in the basal part of the Upper Cretaceous succession of the Khasi Hills. The oldest assemblage is recorded from the lowermost part of the Mahadeo Formation, overlying the thick conglomerate ("Weilloi Conglomerate") in the Weilloi-Mawsynram Road Section (Fig.3). The occurrence of *Areoligera senonensis* and *Senegalinium* spp. (both having FAD in the Late Campanian) at this level is significant. It demonstrates that the Cretaceous succession in the South Shillong Plateau is not older than Late Campanian. *Chatangiella* sp. (LAD in Early Maastrichtian) and *Dinogymnium acuminatum* (FAD in Late Campanian) are recorded from the basal part of the Cretaceous succession (Gumaghat Formation) in Barsora-Gumaghat Road Section (Nandi, 1990). This further supports an age not older than Late Campanian for the earliest part of the Cretaceous succession in the southern submontane region also. Sah and Mehrotra (1988) and Mehrotra et al. (2002) have suggested ?Campanian age for the Gumaghat Formation. Occurrence of the *Dinogymnium* acme in the lower Mahadeo Formation (upper part of the Jadukata Formation) in the Dawki area (Jain et al. 1975) is indicative of Lower Maastrichtian age. These evidences broadly suggest a Late Campanian–Early Maastrichtian age for the basal most Cretaceous succession; although its lower limit is often extended up to Turonian (Bhattacharya and Bhattacharya, 1981) or even Cenomanian (Nandi, 1990). Garg and Khowaja-Ateequzzaman (2000, Fig.2) inadvertently assigned Maastrichtian age to the Mahadeo Formation, which is corrected herein as Upper Campanian-Maastrichtian.

Dinoflagellate cyst assemblages recovered from the upper part of the Mahadeo Formation exposed along an abandoned road cut above the western bank of the Um Sohryngkew river (Fig. 3) in the south and Mawsmai-Shella Road section in the north in the Cherrapunji plateau region, are rich and diverse. A shell rich coquina bed towards the top of the formation serves as a marker bed to correlate these two sections. The Mahadeo Formation exposed in the Therriaghat Section is characterized by the successive first appearances of *Cordosphaeridium fibrospinosum* and *Glaphyrocysta perforata*, demonstrating a late Early Maastrichtian age. The LAD of *Xenascus ceratioides* coincides with the Early-Late Maastrichtian boundary (Haq et al. 1988; Stover et al. 1996). Its occurrence just below the coquina bed helps to demarcate the Early-Late Maastrichtian boundary in this section. *Tanyosphaeridium xanthiopyxides* also has its first appearance at this level. The FAD of *Thallasiphora pelagica* and the LAD of *Cannosphaeropsis utinensis*, which lie in the early Late Maastrichtian, provide the next important biohorizons documented about 14 m and 15 m respectively above the coquina bed. It closely corresponds with the *Lithraphidites quadratus* Zone (CC25b) of nannofossils recorded about 6 m above the coquina bed (Garg, 2002). The uppermost part of the Mahadeo Formation, well exposed in the Mausmai-Shella Road Section, is characterized by the acme of *Areoligera senonensis- A. coronata*, recorded 2.5 m below the sharp contact of the Mahadeo and the Langpar Formations. It occurs 8 m above the coquina bed in this section.

The Langpar Formation exposed in the Um Sohryngkew river (Therriaghat) section (Fig.4) has yielded the richest dinoflagellate cyst assemblage, characterized by the successive First Appearance Datum of several dinoflagellate cyst taxa in the Upper Maastrichtian-Danian succession. The FADs of *Disphaerogena carposphaeropsis*, *Senoniasphaera inornata, Disphaerogena lemniscata*, *Fibrocysta licia* and *Trithyrodinium fragile*, in the ascending order, in the uppermost Maastrichtian lie within the *Micula murus* and *M. prinsii* Nannofossil zones (Garg and Jain, 1995; Garg, *unpublished data*) and *R. stuartiformis* Zone of planktonic foraminifera (Pandey, 1981a). The LAD of *Dinogymnium* spp. (including *D. acuminatum*, *D. nelsonense*) and *Alisogymnium euclaense* coincides with the mass extinction of Cretaceous nannofossils (Garg and Jain, 1995) and the planktic foraminifera (Pandey, 1981a), just below the rust coloured iridium rich layer (Bhandari et al. 1987). Significantly, the dinoflagellate cysts do not show any abrupt extinction in their stratigraphic record, matching the "crisis" at the K/T boundary shown by calcareous nannofossils and planktic foraminifera in this section (Garg and Jain, 1993, 1996; Kumar et al. 2001; Garg and Khowaja-Ateequzzaman, *unpublished data*).

The basal Danian in this section can be defined by entry of the global marker dinoflagellate cysts *Damassadinium californicum* and *Carpatella cornuta* a few centimeters above the iridium rich layer. It can be precisely calibrated with the *Neobiscutum romeinii* Zone of nannofossils (Garg and Jain, 1995, 1996) and the planktic foraminiferal P0 Zone (Pandey, 1981 b). The FADs of *Kenleyia lopophora* and *K. leptocerata* also lie within this interval. Further up, the FAD of *Damassadinium manicatum* in the upper part of the Langpar Formation lies in the upper Danian, equivalent to the upper part of the planktic foraminiferal *M. pseudobulloides* (P1c) Zone (Pandey, 1981b). The FAD of *Apectodinium hyperacanthum* in the lowermost part of the Therria Formation matches closely with the P3 Zone and may help to demarcate Danian-Selandian boundary in

the Therriaghat Section. A comparison of the important early Palaeogene dinocyst events in the Um Sohryngkew section with those of the El Kef section, northwest Tunisia (Brinkhuis et al. 1994) is presented here to highlight their biostratigraphic potential, especially in the low latitudes (Fig. 6).

The upper part of the Therria Formation proved barren of dinoflagellate cysts while the overlying Lakadong Limestone Member of the Sylhet Limestone Formation yielded a poor assemblage containing only long ranging taxa.

The Lakadong Sandstone Member (Sylhet Limestone Formation) exposed in the Cherrapunji plateau region is considered to be largely the lateral facies equivalent of the upper part of the underlying Lakadong Limestone Member in the southern basinal areas in Therriaghat (Garg and Khowaja-Ateequzzaman, 2000). The first appearance of *Apectodinium homomorphum, A. paniculatum* and *Ifecysta pachyderma* in the dinoflagellate cyst assemblages recovered from the coal bearing Lakadong Sandstone (Shillong- Cherrapunji road section; Fig.5) indicate a Late Thanetian age, close to the Palaeocene-Eocene Boundary (Garg and Khowaja-Ateequzzaman, 2000). The close stratigraphic correspondence of *Apectodinium* Acme (Aau Biozone of Powell, 1992) with *Ranikothalia nuttalli-Miscellanea miscella* Assemblage Zone of larger foraminifera (SBZ5-SBZ6, Jauhri, 1996, 1998; Sierra-Kiel et al. 1998) in the Late Thanetian in the Khasi Hills has been suggested (Garg and Khowaja-Ateequzzaman, 2000). Similar assemblages are also known from the Jowai-Badarpur Road Section, Jaintia Hills (Dutta and Jain, 1980; Tripathi and Singh, 1984; Tripathi, 1989; Garg and Khowaja-

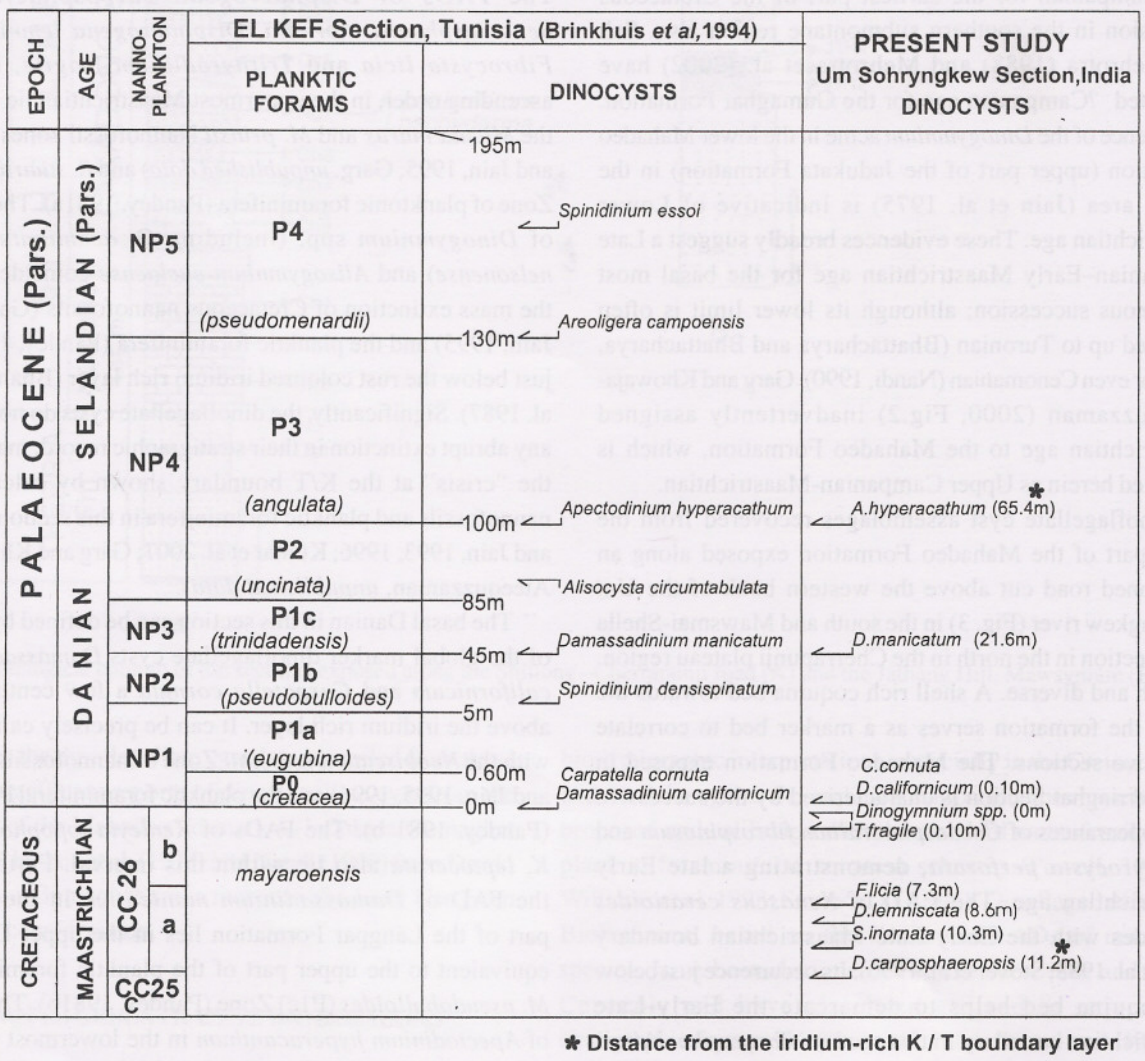

Fig.6. Comparative summary of important Early Palaeocene Dinocyst events in the El Kef section, Tunisia (Brinkhuis et al. 1994) and the Um Sohryngkew section, India.

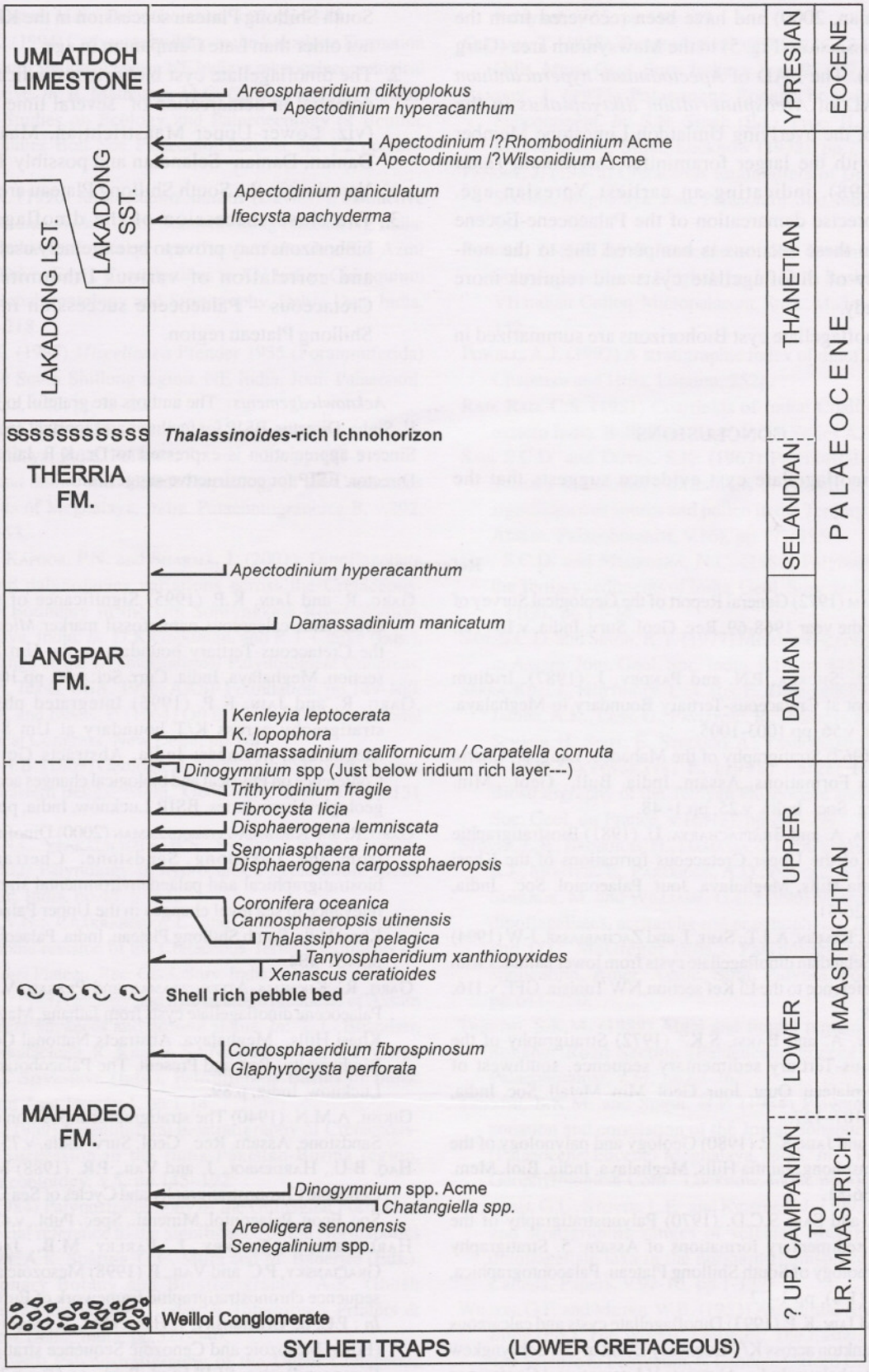

Fig.7. Schematic representation of the significant Late Cretaceous-Palaeocene Dinoflagellate cyst Biohorizons in the South Shillong Plateau succession of the Khasi Hills.

Ateequzzaman, 2000) and have been recovered from the Jathang Hill Section (Fig. 5) in the Mawsynram area (Garg et al. 2003)). The LAD of *Apectodinium hyperacanthum* and the FAD of *Areosphaeridium diktyoplokus* in the basal part of the overlying Umlatdoh Limestone Member coincides with the larger foraminifer *Daviesiana ruida* (Jauhri, 1998), indicating an earliest Ypresian age. However, precise demarcation of the Palaeocene-Eocene boundary in these sections is hampered due to the non-productivity of dinoflagellate cysts and requires more detailed study.

The Dinoflagellate cyst Biohorizons are summarized in Fig. 7.

CONCLUSIONS

1. The dinoflagellate cyst evidence suggests that the South Shillong Plateau succession in the Khasi Hills is not older than Late Campanian in age.
2. The dinoflagellate cyst biohorizons indicate a strong potential in demarcation of several time boundaries (viz. Lower-Upper Maastrichtian, Maastrichtian-Danian, Danian- Selandian and possibly Thanetian – Ypresian) in the South Shillong Plateau area.
3. The close succession of the dinoflagellate cyst biohorizons may prove to be extremely useful in dating and correlation of various lithounits in Upper Cretaceous – Palaeocene succession in the South Shillong Plateau region.

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