

STRATIGRAPHY AND PALYNOLOGY OF THE TURA FORMATION IN THE TYPE AREA (PART III): DISCUSSION

RAM YASH SINGH

Birbal Sahni Institute of Palaeobotany, Lucknow-226007

ABSTRACT

Observations made on the geology and palynology of the Tura Formation have been interpreted in the present paper. Lithostratigraphically, Tura Formation has been considered in the formation rank and a 'biomere' on the basis of spores pollen studies. It has been demonstrated that the lower and the upper boundaries of this formation are diachronous and the entire lithofacies ranges from Palaeocene to Lower Eocene in age.

INTRODUCTION

THE stratigraphy of the Tura Formation based on field studies has been described in the first part of the paper. The second part deals with the description of spores and pollen. The present paper which is the third and the last part of these studies embodies the palynostratigraphic interpretations derived after long geological and palynologic studies carried out on this formation.

BOTANICAL CONSIDERATIONS

The palynological assemblages of the studied sections of the Tura Formation considered together consist of 110 species referable to 68 genera. Besides spores and pollen, the assemblages include algal and fungal remains, microforaminifera, and sponge spicules. The spores include three species referable to fungi and 29 species to Pteridophyta. The gymnospermous elements are rather meagre both in variety and quantity, being represented by two unspecified species. The angiospermous pollen of the assemblage appear to constitute a dominant element. They are represented by 60 species, of which 19 species are assignable to monocots and 41 species to dicots.

The pteridophytic group as a whole is rather well represented, constituting nearly 23 per cent of the total assemblage. Their variety and abundance indicate the prevalence of humid climatic condition.

The angiosperms constitute about 62 per cent of the assemblage. Of these, 38 per cent are assignable to families like Nymphaeaceae and Potamogetonaceae which indicate predominantly aquatic habitat. Pollen grains referable to the family Palmae constitute nearly 18 per cent of the assemblage, thus indicating close proximity to the shore line.

Representation of families like Palmae, Bombacaceae, Caesalpinaceae, Utricaceae, Rubiaceae, Malvaceae, Meliaceae, Nys-saceae and Onagraceae etc. indicate tropical to subtropical climate, which is evident from the table given below

FAMILIES

| TROPICAL TO SUBTROPICAL | COSMOPOLITAN |
|----------------------------|------------------|
| Palmae | Nyssaceae |
| Menispermaceae | Onagraceae |
| Malvaceae | Potamogetonaceae |
| Bombacaceae | Liliaceae |
| Meliaceae | Gramineae |
| Caesalpinaceae | Nymphaeaceae |
| Myrtaceae | Cruciferae |
| Polygonaceae | Droseraceae |
| Myrsinaceae | Labiatae |
| Utricaceae | Euphorbiaceae |
| Rubiaceae | |

PALAEOECOLOGICAL INTERPRETATION

The place of deposition of the Tura Formation was shallow and near-shore marine is indicated by the presence of hystricosphaerids, microforaminifera and sponge spicules. The various microplankton genera recorded during the present investigation are known only from the brackish water and near-shore marine environments.

Postulating the palaeoecological conditions during the deposition of the Tura Formation, it is reasonable to infer that the place of deposition was marginal with shallow' brackish water to marine environment. Probably the coastal conditions, e.g. lagoonal or deltaic seam to agree with the outcrop

pattern. This coastal strip might have followed an adjoining zone of swamp or inlet containing swamp vegetation, in which further accumulation of organic debris provided material for the formation of coal. Adjacent to the swamp zone there might have been a land strip, supporting a fairly luxuriant vegetation which was characterized by tropical to subtropical plants, ferns and epiphyllous fungi.

MIOFLORAL COMPARISON

Miofloral Comparison with known Eocene Assemblages of India—A comparison of the Tura palynological assemblage from the Indian Continent is greatly hampered by the scarcity of available information from this continent. The publications by Baksi (1962), Biswas (1962), Sah and Dutta (1966, 1968), Dutta and Sah (1970) and Sah *et al.* (1971) give all the available information on the Eocene palynological assemblages of Assam. Mathur (1963, 1966), Venkatachala and Kar (1969), Sah and Kar (1969, 1970) studied the palynology of the Lower Tertiary sediments in Kutch, Gujarat. Sah and Kar (1974) have described palynological fossils from the Lower Eocene lignites from Palana, Rajasthan. Mathur (1963, 1966), Salujha *et al.* (1969) have recorded palynological fossils from Subathu sediments (Lower Eocene), Himachal Pradesh, while Chitale (1951) has recorded a few spores and pollen grains from the Deccan Intertrappean (Lower Eocene) cherts of Madhya Pradesh.

The present Tura Assemblage of the Garo Hills corresponds closest to the Cherra palynological assemblage of South Shillong Plateau. This area had been investigated by Sah and Dutta from 1966 to 1970. The Cherra palynological assemblage consists of a total of 49 genera and 103 species. Out of these, 18 genera and 34 species belong to pteridophytes, one genus and one species to gymnosperms and remaining 27 genera and 68 species to angiosperms. The Tura palynological assemblage, on the other hand, comprises 53 spore pollen genera with 89 species. Of these, 19 genera and 29 species belong to pteridophytes and the remaining to angiosperms. Most of the spore pollen genera from Cherra Formation are common to Tura Formation. The following is the

list of species which are common to both the assemblages:

Cyathidites minor, *Stereisporites psilatus*, *Lygodiumsporites eocenicus*, *Foveotriletes pachyexinosis*, *Lycopodiumsporites palaeocenicus*, *Lycopodiumsporites speciosus*, *Dandotiaspora dilata* (*Biretisporites triglobosus*), *Sestrosporites dettmanni*, *Polypodiisporites tertiarus*, *Poligocenicus*, *Monolites discordatus*, *Monolites mawkmaensis*, *Schizaeisporites digitatoides*, *Retipilonapites cenozoicus*, *Assamiales emendatus*, *Couperipollis* (*Monosulcites*) *brevispinosus*, *C.* (*Monosulcites*) *rarispinosus*, *C.* (*Monosulcites*) *wodehousei*, *C. duttae* (*Monosulcites* sp. 1), *Liliacidites microreticulatus*, *Palmaepollenites eocenicus*, *P. communis*, *Proxapertites crassimurus*, *P. assamicus*, *Tricolpites levis*, *Polycolpites cooksonii*, *P. speciosus*, *Nyssapollenites barooahii*, *Tricolpites decoris* (*Lakiapollis matanamadhensis*), *Triporopollenites vimalii*, *Triorites communis*, *Meliapollis ovatus* and *Droseridites parvus*.

The following species are restricted to the Tura Formation:

Dandotiaspora plicata, *D. pseudoauriculata*, *D. telonata*, *D. densicarpa*, *Palmidites plicatus*, *P. maximus*, *P. eocenicus*, *Liliacidites giganticus*, *L. intermedius*, *Couperipollis ovatus*, *Leiotriletes punctatus*, *Todisporites* sp., *Lycospora* sp., *Osmundacidites* sp., *Symphlocospollenites granulatus*, *Triorites bellus*, *Compositoipollenites argulus*, *Pseudonothofagidites kutchensis*, *Verrucolporites* sp.

The following species are restricted to the Cherra Formation:

Stereisporites assamensis, *S. grandis*, *Dictyophyllidites* sp., *Corrugatisporites formosus*, *C. turpitus*, *Foveosporites triangulus*, *F. pseudoreticulatus*, *Microreticulatisporites densus*, *M. languidus*, *Lycopodiumsporites parvireticulatus*, *L. unsteuensis*, *Foraminisporis medius*, *Polypodiaceasporites haardtii*, *Polypodiisporites repandus*, *P. mawkmaensis*, *Schizaeisporites eocenicus*, *S. crassimurus*, *Sciadopityspollenites verrucatus*, *Monosulcites borassoides*, *M. magnus*, *M. planus*, *Liliacidites circularis*, *L. variegatus*.

A comparative analysis of the significant taxa reveals that the Tura Formation and Cherra Formation are homotaxial. The differences in composition is mainly related to local elements.

The Subathu palynological assemblage (Salujha *et al.*, 1969) comprises 28 genera and 45 species. Of these, 10 genera belong

to pteridophytes, 1 to gymnosperms, 12 to angiosperms and 5 to microplanktons. Palynological fossils described show extremely ill-preservation. Therefore, a more precise comparison could not be attempted. However, *Todisporites* (*Scabratriletes* sp., pl. 3, fig. 13), *Dandotiaspora* (*Psilatriletes lobatus*), *Osmundacidites* (*Scabratriletes* sp. A, pl. 3, figs. 10, 16), *Laricoidites* (*Psilanapecturites* sp., pl. 3, fig. 25), *Couperipollis* (*Echinomonoletes* sp., pl. 3, fig. 20), *Cicatricosisporites* (*Striatriletes* sp. C., pl. 3, fig. 15), *Palmaepollenites* (*Retimonocolpites* sp., pl. 3, fig. 38), *Tricolpites* (*Scabratricolpites* sp., pl. 3, fig. 43) and some microplankton species appear to be common to both the assemblages. A noteworthy feature observed in the Subathu palynological assemblage is the scanty representation of the angiosperms.

The Laki palynological assemblage, known so far, consists of 64 genera and 98 species. Out of these, 21 genera and 30 species belong to pteridophytes, 4 genera and 4 species to gymnosperms and 39 genera and 64 species to angiosperms. The following species are common to both the assemblages:

Laevigatosporites lakiensis, *Todisporites plicatus* (*Dandotiaspora plicata*), *Couperipollis rarispinosus*, *C. brevispinosus*, *C. wodehousei*, *C. perspinosus*, *Margocolporites tsukadae*, *M. sitholeyi*, *Lakiapollis ovatus*, *L. matanamadhensis*, *Stephanocolpites arcotense*, *Pseudonothofagidites kutchensis*, *Meliapollis ramanujami*, *Triorites bellus*.

A comparative analysis makes it clear that the Laki and Tura palynological assemblages are not closely related to one another. The dominant genera found in Tura Formation like *Assamialetes* and *Proxapertites* are either absent or present in insignificant numbers in the Laki assemblage. This difference in the assemblages can be attributed to the great distance separating the two miofloral provinces.

The Palana Lignite of Rajasthan consists of 32 genera and 47 species of pteridophytic spores and angiospermic pollen. The chief elements of the mioflora are — *Todisporites*, *Dictyophyllidites*, *Osmundacidites*, *Schizaeoisporites*, *Cheilanthoidspora*, *Retipilonapites*, *Palmaepollenites*, *Liliacidites*, *Couperipollis*, *Proxapertites*, *Tricolpites* sp., *Cupuliferoipollenites*, *Rhoipites*, *Caprifoliipites*, *Hippocrateaceadites*, *Margocolporites*, *Lakiapollis*, *Verrucolporites*, *Platoniapollenites*,

Calophyllumpollenites, *Kielmeyerapollenites*, *Meliapollis*, *Polybrevicolpites*, *Polycolpites*, *Pseudonothofagidites*, *Proteacidites* and *Triorites*.

Of these, *Osmundacidites*, *Schizaeoisporites*, *Retipilonapites*, *Palmaepollenites*, *Liliacidites*, *Couperipollis*, *Proxapertites*, *Tricolpites*, *Margocolporites*, *Lakiapollis*, *Meliapollis*, *Verrucolporites*, *Polycolpites*, *Pseudonothofagidites* and *Triorites* have also been recorded from the Tura assemblage. The Palana palynological assemblage is more closely related to the Laki assemblage than the Tura assemblage. This is natural as the two localities are in closer proximity to one another. The only feature common to the Assam assemblage and Western India assemblage is the presence of Onagraceae-type, Proteaceae-type, Monosulcate-spinose type, *Proxapertites* type and Polycolpate-types.

The Deccan Intertrappean palynological assemblage (Chitale, 1951) from Mohgaon Kalan, Madhya Pradesh comprises 8 types of spores-pollen genera, belonging to a number of species. A close comparison between the two assemblages is not possible, as the Intertrappean assemblage is partial and too badly preserved for specific identifications. However, the following spore elements seem to be common to both the assemblages:

Alete spm. = dispersed half part of *Proxapertites assamicus*

Monoletes spm. = *Laevigatosporites*

Trilete spm. 3 = *Deltoidospora*

Trilete spm. 4 = *Todisporites*

Pollen grains common to both are *Graminidites*, *Monosulcites*, *Monosulcites* (*Palmidites*), *Tricolpites* and *Tricolporites*. From the data it appears that the two palynological assemblages have some common elements. However, it will be rather too premature to draw any conclusion on the basis of such scanty data.

STRATIGRAPHICAL CONSIDERATIONS

The Pre-Cambrian granites and gneisses form the principal landmass of the Garo Hills. The western flank of this massif near the Halladayganj exposes an outcrop of Lower Gondwana Formation. The south-eastern extremity of the massif along the western bank of Jadukata River is fringed by a narrow strip of Sylhet trap. The Sylhet trap is overlain by Upper Cretaceous

sandstones which in turn are succeeded by the Lower Eocene sediments.

The Palaeozoic and in part Mesozoic sediments (Lower Gondwana and Upper Cretaceous sandstones) appear to have been deposited on the uneven and denuded surface of the Pre-Cambrian basement complex. Their arenaceous nature, characteristic bedding pattern, frequency of sand laminae and sedimentary structures like ripple marks, current bedding etc. indicate that they might have been deposited under shallow water environment. The southern slopes of the Garo Hills are uniformly covered by a thick succession of Lower Palaeogene sediments which are geologically known as the Tura Formation.

TURA FORMATION

The Tura Formation consists of alternations of coarse-grained sandstones, lithomargic clays and shales, generally interstratified with one or two and sometimes even three coal-seams. The basal member of the formation is a thick pebbly sandstone band, which rests unconformably over the metamorphics, except in the Jadukata River Section, where the pebble sandstone conformably overlies the Upper Cretaceous sandstones. Field studies have shown that of the three, only two seams, viz., the lower and the middle are workable. The middle seam ranges in thickness from 2 to 3 m and is seen to outcrop in almost all the sections studied so far. Another noteworthy feature observed was that the formation shows a comparatively much thinner development towards north and north-west. Such a development points towards the encroachment of the sea from the south and south-east. Of the large number of measured and traverse sections studied, not a single section was met with which exposes both the lower and upper contacts. This has put in limitation while ascertaining the maximum true thickness attained by the Tura Formation. The maximum thickness recorded is 240 m, while the average thickness seem to be 92 m.

Lower Contact—In most of the sections studied the Tura Formation unconformably rests over the denuded platform of the basement complex, except for the Jadukata River Section where the Tura

sediments conformably overlie the Upper Cretaceous sandstones.

Upper Contact—The Tura Formation is disconformably overlain by the Siju Limestone Formation. A disconformable junction between the two is very clear in the western part of the Garo Hills where sideritic Siju Limestone is seen to be resting on the uneven surface of the Tura Formation. In the remaining part of the district, the break in sedimentation is represented by a pebble band either near the base or near the top of the uppermost horizon of the Tura Formation. At places, where both these characters are not distinguishable, the change in sedimentation is reflected by the abrupt change in sedimentary facies. The coarse-grained sandstone members are seen to be overlain by the deposition of the silicified Siju Limestone. Since silicification of marine limestone is a feature indicative of deep sea zone the latter, therefore, provides definite evidence favouring deep water deposition. Thus such marked change in sedimentation cycle should also be considered while delimiting formation boundaries. Similar changes in sedimentation cycle have already been used for determining the stratigraphic boundary between the Semri Series (Lower Vindhyan) and the Kaimur Series (Upper Vindhyan) of Vindhyan in Sone Valley (Auden, 1933, p. 217).

It has also been observed that both the Upper and Lower contacts of the Tura Formation show distinct evidence of disturbed conditions. Since a disturbed junction has been observed in majority of the sections, it seems reasonable to relate them to the earth movements to which the Garo massif has been subjected during post-Cretaceous times.

STRATIGRAPHIC STATUS OF TURA FORMATION

The stratigraphic status of Tura Formation has for long remained a subject of discussion. A review of the literature on the geology of Assam indicates that there is no unanimity in defining this sedimentary succession in the Garo Hills. Biswas (1962, p. 26) for the first time recognized that these sediments are distinctly a mappable unit and, therefore, raised it to the rank of a formation. For the present palynostratigraphical investigation this problem has

been studied in two ways —(1) in terms of rock unit, and (2) in terms of biostratigraphic unit.

ROCK UNIT ASPECT

Field studies reveal that the Tura sediments are extensively developed along the southern flanks of the Garo Hills. They stretch right from Damalgiri in the west up to the Jadukata River, which forms the south-eastern extremity of the Garo Hills. Towards north they have been observed as far as Rongrenggiri Coalfield and a few patches even beyond these occurrences. South of this range the outcrop area is fairly extensive and widespread. Further south they occur as subcrops under the Upper Tertiary sandstones. Thus, this unit appears to be lithologically homotaxial and extensively developed throughout the region occupying an area of nearly 1500 sq km.

The Lower Contact of these sediments is readily recognizable because of their generally unconformable nature with the Archaeans, except for a solitary occurrence at the Jadukata River. Although the contact is conformable here, the development of a distinct pebble band at the base helps in delineating it from the underlying Upper Cretaceous sediments. The Upper Contact is even more distinct because of the extensive development of a marine limestone facies of the overlying Siju Limestone Formation. A disconformable contact between the Siju Limestone and the underlying Tura sediments is apparent by an angular unconformity in the western part of the Garo Hills and in the remaining part of the district by a thick pebble band and a coarse-grained sandstone.

The extensive development of the Tura sediments, together with their distinct lithology, sharp contacts and mappability throughout the Garo Hills provides ample support to Biswas's suggestion that the sediments should be raised to the rank of a formation.

BIOSTRATIGRAPHIC ASPECT

The organic contents of the Tura Formation provide definite evidence in favour of raising the status of Tura sediments as a distinct, regional biostratigraphic unit.

The entire sequence comprising this formation is recognized by the following spore pollen species: *Assamiales emendatus*, *Dandotiaspora telonata*, *Palmidites plicatus* and *Proxapertites assamicus*.

The basal beds of the formation are characterized by a distinct palynological assemblage. The dominance of *Assamiales emendatus* together with the presence of restricted species like *Triorites communis*, *Proxapertites crassimurus*, *Droseridites parvus* and *Dandotiaspora dilata* demarcate the lower horizons. Similarly the upper beds are characterized by the dominance of *Proxapertites assamicus* and restricted species like *Margocolporites complexum*, *Cicatricosporites macrocostatus*, *Stephanocolpites tertiarus* and *Polypodiisporites speciosus*.

The gross microfossil features of the Tura Formation are characterized by the abundance of *Proxapertites assamicus*, *P. crassimurus*, *P. granulatus* and *Assamiales emendatus*. Of these, pollen grains referable to *Assamiales emendatus* constitute more than 50 per cent of the total assemblage. The three species referable to the genus *Proxapertites* seem to be related to the family Nymphaeaceae. The pollen referable to *Assamiales emendatus*, although of doubtful affinity, shows close morphological similarity with pollen grains referred to *Proxapertites* and in all likelihood they may be related to the family Nymphaeaceae. Thus, it becomes apparent that nymphaeaceous plants occupied a significant place in the regional vegetation when Tura sediments were being deposited. The family Nymphaeaceae is predominantly an aquatic family. A fresh-water to near-shore estuarine environment is also in favour of its dominant representation.

The above discussion makes it clear that the Tura Formation is characterized by (1) extensive development throughout the Garo Hills, (2) distinct lithology, (3) physically mappable rock unit, and (4) abundance of palynological fossils together with a number of marker species with short vertical range and wide geographical extent.

The above attributes conform to the circumscription of the term 'Biomere' (Palmer, 1965, p. 102) which is regarded as a basic member of the Biostratigraphic classification. A biomere occupies the same status in biostratigraphy as 'Formation' occupies in lithostratigraphic classification. It is therefore suggested that the Tura

sediments may be considered as a 'Nymphaeaceae Biomere' for biostratigraphic studies and the term "Tura Formation" should be retained for Lithostratigraphic studies.

PALYNOSTRATIGRAPHIC ZONATION OF THE TURA FORMATION

Palynostratigraphic zonation of the Tura Formation is mainly based on the variation pattern observable within the spore pollen assemblages recovered from different rock units in the sedimentary sequence exposed at Nongwal Bibra. Although no floral break of major significance is apparent anywhere along the stratigraphic section, the first appearance, maximum development and decline appear to serve as a fairly reliable basis for the recognition of palynological zones. Therefore, these features have been used in the delimitation of zonal boundaries. The concept of Cenozone (Assemblage zone) strictly follows the Code of Stratigraphic Nomenclature proposed by the Geological Survey of India (Balasundaram, 1971).

Four spore pollen Cenozones have been recognized within the composite section of the Tura Formation. The composite section and the selection of marker species have been derived by calculating the mean value of spore-pollen frequencies counted in the samples from 9 measured sections and several sections from different parts of the Garo Hills. Following are the four Cenozones recognized within the Tura Formation in order of ascending stratigraphy:

4. *Proxapertites assamicus* Cenozone Sah & Singh, 1974.
3. *Palmidites plicatus* Cenozone Sah & Singh, 1974.
2. *Dandotiaspora telonata* Cenozone Sah & Singh, 1974.
1. *Assamialetes emendatus* Cenozone Sah & Singh, 1974.

Each biostratigraphic zone is about 60 m in thickness and composed of sandstones, shales, mottled clays, coal and carbonaceous layers. They are characterized by the predominance of their respective palynotaxon after which they have been given the name. Detailed palynological biostratigraphy of this formation already has been discussed by Sah and Singh (1974).

PALYNOSTRATIGRAPHIC CORRELATION OF TURA FORMATION WITH PALAEOGENE SEDIMENTS OF ASSAM

Tura Formation exhibits a close resemblance with the Palaeogene strata of Khasi Hills comprising Cherra Formation and the lower members of the Sylhet Limestone Formation. This similarity is apparent under the following aspects:

The Cherra Formation is underlain by the Upper Cretaceous Formation around Cherrapunji and by granites, granite-gneisses or by Sylhet trap in other parts of the Shillong Plateau. Similarly, the Tura Formation is underlain by the Upper Cretaceous Sandstone in the Jadukata River and by the Pre-Cambrian granites and granite gneisses in other parts of the Garo Hills. Like the Cherra Formation, the Tura Formation also can be distinguished from the older sediments by the presence of a conglomeratic bed or a pebble zone at the base. The phenomenon of laterization generally observable at the base of the Cherra Formation can be equated to wide spread kaolinization present at the base of the Tura Formation.

The basal horizons of both the Tura and the Cherra formations are characterized by a thick suite of coarse-grained, gritty sandstones and lithomargic clay. Both the formations also correspond in having close lithological similarity consisting of sandstones, shales, carbonaceous shales, clays and coal. The sandstone members at both the places are generally coarse-grained and current bedded, indicating a shallow water deposition. Again both formations show similarity in the amount and direction of dip, ranging between 4-6°, towards south and south-east.

The Cherra and the Tura formations also show close identity in having three coal seams, separated from one another by an average thickness of nearly 80 m of sandstones and lithomargic clays. The coal at both the places is brownish to blackish in colour, fragile, and possesses sphaeroidal cleavage.

Palynological investigations show that the four biostratigraphic zones, recognized by Dutta and Sah (1970) within the Palaeogene succession (comprising the Cherra Formation, Lakadong Limestone and Lakadong Sandstone) of Shillong Plateau, closely correspond to the four palynostratigraphic

zones of the Tura Formation. The picture drawn from the palynological composition of each zone within the Cherra Formation is also reflected in the corresponding zones of the Tura Formation. This identity of palynological assemblage is readily apparent by the occurrence of high frequencies of *Assamiales emendatus*, *Dandotiaspora telonata* and *Proxapertites assamicus*.

The floral composition of the basal zone of the Tura Formation and the lower palynological zone (*Proxapertites crassimurus* Cenozoone Sah & Dutta, 1974) of the Cherra Formation are identical in having a high percentage of *Assamiales emendatus*, *Dandotiaspora dilata*, *Proxapertites crassimurus*, *Droseridites parvus* and *Triorites communis*. These species are closely followed by *Couperipollis rarispinosus*, *C. brevispinosus*, *Palmaepollenites communis* and *Triporopollenites vimalii*.

Similarly, the lower zone of the Tura and the middle zone (*Araliaceoipollenites reticulatus* Cenozoone Sah & Dutta, 1974) of Cherra formations are characterized by *Dandotiaspora telonata* and *Lycopodiumsporites palaeocenicus*. A fair representation of *Polycolpites speciosus*, *Assamiales emendatus*, *Polycolpites cooksonii* and *Laktiapollis matanamadhensis* has been observed in both the formations.

The middle palynological zone of Tura Formation and the upper palynological zone (*Tricolpites reticulatus* Cenozoone Sah & Dutta, 1974) of Cherra Formation are comparable in having a very poor representation of spores and pollen. The latter is characterized by *Monolites discordatus*, *Tricolpites reticulatus*, *Trifossapollenites constatus* and *Polycolpites speciosus*. In the Garo Hills, the middle palynological zone of Tura Formation is distinguished by the predominance of *Palmidites plicatus*, *P. maximus*, *Laricoidites maximus* and *Polycolpites cooksonii*. From the comparative study of both the places it is apparent that the environmental conditions were unfavourable for the growth of vegetation during the deposition of these beds. The Lakadong Limestone may have been deposited during this period in the Khasi and Jaintia Hills. Adverse conditions were also prevailing in the Garo Hills, are witnessed from the ferrugination of sandstones and an intense mottling of clays forming the middle palynological zone of Tura Formation. Therefore, these zones represent a definite decline of

miofloral elements throughout the Assam Plateau.

The *Proxapertites assamicus* Cenozoone of Tura Formation is again similar to the Lakadong palynological zone of the Shillong Plateau in having pollen grains of *Polycolpites cooksonii*, *Palmaepollenites communis*, *P. eocenicus*, *Triporopollenites vimalii*, *Couperipollis rarispinosus*, *C. brevispinosus* and spores of *Dandotiaspora plicata* and *Cyathidites minor* etc.

Thus, it is quite apparent from the above facts that the four biostratigraphic zones of the Palaeogene succession of Shillong Plateau (Sah & Dutta, 1958, 1974) have a close relationship with the four palynostratigraphic zones of the Tura Formation (Sah & Singh, 1974). It is quite likely that the latter may represent the lateral continuation of the former. Based on their close resemblance, these zones have been correlated as given below:

| | PALAEOGENE FORMATIONS | TURA FORMATION |
|------------------|--|--|
| | United Khasi and Jaintia Hills (Sah & Dutta, 1974) | Garo Hills (Sah & Singh, 1974) |
| | Lakadong sandstone palynological zone | <i>Proxapertites assamicus</i> Cenozoone |
| Cherra Formation | <i>Tricolpites reticulatus</i> Cenozoone | <i>Palmidites plicatus</i> Cenozoone |
| | <i>Araliaceoipollenites reticulatus</i> Cenozoone | <i>Dandotiaspora telonata</i> Cenozoone |
| | <i>Proxapertites crassimurus</i> Cenozoone | <i>Assamiales emendatus</i> Cenozoone |

The Tura Formation is unconformably overlain by the Siju Limestone Formation in the Garo Hills. This non-depositional phase (unconformity) between the Siju Limestone and the Tura Formation corresponds to the unconformity or palaeontological break between the Lakadong Sandstone and Nurpur sandstone in the Shillong Plateau (Wadia, 1957, p. 340).

Lithological, palynological and palaeontological evidences clearly show that of the known 240 m of Tura sediments, the lower 180 m, representing sediments from the base of the formation to the top of the third coal seam, correspond to the Cherra Formation of Shillong Plateau. The upper 60 m of Tura sediments correspond to the Lakadong Sandstone member of the Sylhet

Limestone Formation. The overlying Siju Limestone in turn corresponds to the Prang Limestone which is the uppermost member of the Sylhet Limestone Formation in Shillong Plateau. The Tura Formation thus appears to be dichronous in nature, and in Garo Hills represents the condensed thickness of Cherra Formation, Lakadong Limestone and Lakadong Sandstone of the Shillong Plateau.

AGE OF TURA FORMATION

The age and stratigraphical position of the Tura Formation has remained a controversial problem since 1842, when Bedford discovered coal in this formation. Divergent opinions concerning the geological age of this formation have been expressed from time to time. Scarcity of marker beds and more or less complete absence of invertebrate fossils within the formation seem to have been responsible for keeping the controversy alive.

The first reference to the age of the Tura Formation was by Oldham (1863) who ascribed it a Cretaceous age. This dating was subsequently supported by Medlicott (1874), Latouche (1882, 87), Medlicott and Blanford (1893), Pinfold (1919), Evans (1932) and Krishnan (1968).

Fox (1936-38), after surveying a large number of sections in Garo Hills, was the first to indicate that the Tura Formation might be of Tertiary age. This dating was also supported by Jacob (1949) and Pascoe (1963). These authors consider Tura Formation to be equivalent to the Cherra Formation of Shillong Plateau. Although they have not specified a precise age, it appears that they favour an early Tertiary dating for the Tura Formation. Sah and Dutta (1966, 68) and Dutta and Sah (1970) consider Cherra Formation to be Palaeocene and Lakadong Sandstone to be Lower Eocene in age.

Ghosh (1954) equated the Tura Formation of Siju Songmang River Section of Garo Hills with the lower to middle members of the Sylhet Limestone Formation of Therriaghat. Since the lower and the middle members of the Sylhet Limestone Formation are Lower to Middle Eocene in age, the age of Tura Formation should accordingly be Lower to Middle Eocene. Biswas (1962), Baksi (1962), Quddus (1963), Banerjee (1960),

Wadia (1966), Krishnan (1968) and Ghosh (1969) have also indicated a Lower to Middle Eocene age for the Tura Formation.

The present investigation shows that the Tura Formation contains a palynological assemblage which is more akin to the palynological assemblages of the Cherra Formation of Assam, Madh Formation of Gujarat, Palana Formation of Rajasthan and Subathu Formation of North-West Himalayas rather than any Upper Cretaceous assemblage of India or outside the country. Therefore, the age of Tura Formation is definitely Tertiary.

Since the Tura Formation has a discordant relationship with the Siju Limestone throughout the Garo Hills, Ghosh's opinion that the Tura Formation is conformably succeeded by the Siju Limestone and occupies a position of the lower-middle or only the middle members of the Sylhet Limestone Formation of Therriaghat with reference to the latter, can not be accepted.

The partial palynological assemblages described by Biswas (1962), Baksi (1962), Banerjee (1964) and Ghosh (1969) from this formation, seem to belong to the higher horizons of the Tura Formation. So their contention that this formation dates back to the Lower to Middle Eocene is admissible to a certain extent.

A close comparison of the mioflora has clearly demonstrated that out of the four palynological zones of Tura Formation, the lower three zones, viz., *Assamialetes emendatus* Cenozone, *Dandotiaspora telonata* Cenozone and *Palmidites plicatus* Cenozone are strictly similar to the three biostratigraphic zones of the Cherra Formation (Dutta & Sah, 1970). The Cherra Formation is disconformably underlain by the Langpar Formation which is believed to be Danian in age, because of the presence of some foraminifera like *Globigerina pseudobulloides* and *Globigerina triloculinoides* etc., while it has been conformably succeeded by the Lakadong Limestone which has yielded typical Ranikot fossils like *Nummulites thalicus*, *N. sindensis*, *Lockhartia hamei*, *Miscellania miscella*, *M. meandrina*, *Operculina* cf. *canalifera*, *Alveolina* sp., *Orbitosiphon tibetica* and *Discocyclina ranikotensis*, and is, therefore, Palaeocene in age. Thus the Cherra Formation may definitely be dated as Palaeocene in age.

The *Proxapertites assamicus* Cenozoone (the upper palynological zone) of Tura Formation on the other hand, shows a close floral similarity with the Lakadong Sandstone palynological zone of Cherrapunji Plateau. The Lakadong sandstones are underlain by the Lakadong limestones which are Ranikot (Palaeocene) in age and overlain by Umlatodoh Limestone which contains a typical Laki micro-fauna such as *Nummulites attaceous*, *Assilina granulosa*, *Orbitolites complanatus* and *Alveolina oblonga* etc. and is regarded as Lower Eocene in age. Therefore, the age of Lakadong Sandstone may also be considered as Lower Eocene.

Thus, from the foregoing discussion it has become clear that the three lower palynological zones of Tura Formation are equivalent to the Cherra Formation while the fourth one, i.e. the uppermost palynological zone of the former appears to be homotaxial with the Lakadong Sandstones. The Cherra Formation is Palaeocene in age whereas the Lakadong Sandstones are Lower Eocene. It is, therefore, apparent that the Palaeocene and Lower Eocene ages are both represented within the rocks of Tura Formation.

DEPOSITIONAL HISTORY

The geological history of the Garo Hills amply demonstrates that land conditions prevailed throughout the greater part of the Palaeozoic times. The occurrence of Lower Gondwana outcrops near the Halladayganj in the area and along the outer fringes of eastern Himalayas indicates the subsidence of land sometimes during the Permian Period. Fossil evidence reveals that the Garo Hill outcrops were deposited under the fresh-water conditions while the eastern Himalayas outcrop were accumulated under definitely marine environments. The Assam autochthon, comprising Garo, Khasi, Jaintia and Mikir Hills, was originally the north-eastern extension of Peninsular India. Geological evidences indicate that with the disfoundering of Gondwanaland, sometimes during the Cretaceous period, this eastern block got detached from the mainland. The disruption of Gondwanaland must have upset the isostatic balance of the region which in turn might have culminated into a variety of earth movements along the zones of weakness.

The major region coming under the tension zone appears to lie south of Garo, Khasi and Jaintia Hills along east-west direction. The unstable nature of the crust still seems to be in a more or less active phase. This is evidenced from the frequency in the occurrence of Sub-recent and Recent earthquakes. The Dawki Tear Fault is attributed to some early earth movements. Another important effect of this earth movement can be seen in the subsidence of the southern slopes of the Garo, Khasi and Jaintia Hills, leading to the encroachment of the sea from the south. That the southern fringes of the Assam Plateau continued to subside during the Eocene times is indicated by the widespread extension of the sea further north of the limits of the Cretaceous sea.

Biostratigraphic studies suggest that while the pre-Tertiary sea invaded a considerable part of the Shillong Plateau, it never exceeded beyond a small area along the south-eastern corner of the Garo Hills. This means that most of the Garo Hill area remained high ground throughout the Cretaceous times. There is, so far, no evidence which might suggest that this sea extended beyond the eastern limits of the Shillong Plateau. From the present day distribution of the Cretaceous formations, however, it appears that the Cretaceous sea was confined between longitudes 92°08' E-90°11' E and latitudes 25°11' N-25°21' N. This sea partly spread over the Sylhet trap and partly over the older crystallines, over which the conglomerates were deposited first, followed by an alternating succession of sandstones, shales, limestones and other clastic sediments.

During the close of the Cretaceous Period the Garo Hills appear to have witnessed severe earth movements which resulted in the change of planation of the Tura Range from east-west to west-north-west and east-south-east. These movements might also have been instrumental in lowering the southern slopes of the Garo Hills, in which Lower Eocene sediments were deposited. It appears that when the southern flank of the Garo massif was gradually sinking, the Shillong Plateau was rising perhaps because of the disturbance in the isostatic balance of the region. This caused widespread transgression of the sea towards the Garo Hills and a corresponding withdrawal of

the same sea from the Shillong Plateau. These transgressive and regressive phenomena of the sea are evidenced from the extensive development of Tura Formation in the Garo Hills and a corresponding decrease in the area of development of Cherra Formation, in the Shillong Plateau. These eustatic changes of sea level are further supported by the occurrence of marine limestone bands overlying and underlying the fresh-water, near-shore sediments of the Cherra Formation. The Tura Formation, on the other hand was deposited under definite brackishwater estuarine condition. The transgressive phase of the sea in Garo Hills is proved by the occurrence of rich fossil microplankton (both hystrichosphaerids and microforaminifera) in almost all the levels of this formation, together with the instances of regional overlapping of the Cretaceous rocks by the Tura Formation in greater parts of the Garo Hills.

From the detailed field observations and identical subsurface palynological data from different depths it appears that in both the places in Lower Eocene times, a huge deposition of the sedimentary cover comprising the Cherra and Tura formations, extended enormous hydrostatic pressure on the unstable foreland spur of Assam Autochthon. This resulted in the gradual sinking of the whole continental shelf and its replacement by oceanic depths. This concurrent sinking of the sea floor along with deposition can be seen in the sagging nature of the coal seams belonging to Lakadong Sandstone, Cherra and Tura formations. Thus, during a long span of time covering Palaeocene to Lower Eocene, a large thickness of sediments ranging from 180 to 240 m were deposited on the southern flanks of the Assam Plateau. These comprise the Cherra Formation, Lakadong Limestone, Lakadong Sandstones and the Tura Formation.

CONCLUSION

From the field as well as the laboratory investigations carried out on the Tura Formation, it is obvious that Tura Formation consists of several hundred metres alternating bands of the arenaceous and argillaceous facies. These rest unconformably over the archaeans in greater part of

the area excepting in Jadukata River Section where Upper Cretaceous sediments are seen conformably underlying the formation.

This formation is further divisible into four palynological zones in ascending order:

4. *Proxapertites assamicus* Cenozoone Sah & Singh, 1974
3. *Palmidites plicatus* Cenozoone Sah & Singh, 1974
2. *Dandotiaspora telonata* Cenozoone Sah & Singh, 1974
1. *Assamialetes emendatus* Cenozoone Sah & Singh, 1974

Biostratigraphic evidences indicate a Palaeocene age for the *Assamialetes emendatus*, *Dandotiaspora telonata* and *Palmidites plicatus* Cenozoones and a Lower Eocene age for the *Proxapertites assamicus* Cenozoone. These biozones are identical in composition with the *Proxapertites crassimurus*, *Araliaceipollenites reticulatus*, *Tricolpites reticulatus* Cenozoones and Lakadong Sandstone Palynological Zone of the Palaeogene sediments of the Khasi Hills respectively established by Sah and Dutta (1974).

A rather rich palynological assemblage has been obtained from almost all the levels of Tura Formation. The described microflore includes 110 species referable to 68 genera of spores, pollen, microplanktons and epiphyllous fungi. There is no evidence to show any major floral break within the formation. This is apparent from the gradational evolution of the microfloral succession from the base up to the top.

The microflora of the Tura Formation contains high frequencies of microplankton species and pollen grains referable to the families Palmae, Nymphaeaceae and Potamogetonaceae. The assemblage, thus favours a near-shore brackishwater environment of deposition. That the place of deposition might be deltaic or lagoonal is also evidenced by the occurrence of frequent alternation of fine-grained and coarse-grained sediments. The fine-grained sediments are represented by clays, shales and coal, while the coarse-grained sediments are represented by medium- to coarse-grained sandstone.

The palynological assemblage includes the continental elements referable to Rubiaceae, Urticaceae, Caesalpinaceae etc. Their presence suggests that a warm temperate to subtropical climate prevailed towards

the southern part of the Garo Hills during the early Tertiary times.

Finally, the present study clearly demonstrates that there is no disagreement between palynological, palaeontological and lithological evidences for a Palaeocene-Lower Eocene dating of the Tura Formation.

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