

QUATERNARY VEGETATIONAL HISTORY OF OOTACAMUND, NILGIRIS, SOUTH INDIA 1. KAKATHOPE AND REES CORNER*

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ABSTRACT

The paper incorporates the results of pollen analytical investigations of profiles collected from Kakathope and Rees Corner, Ootacamund in the Nilgiris, South India. The study of these lake sediments has not only brought about the interesting features of the changes in the plant communities but has also reflected upon the climatic cycles during the past. The important aspect of this study concerns the formation and regeneration of shola forest.

The grasslands, as revealed by the pollen diagram from Kakathope, are the pioneer communities. The formation of shola forest commenced through gradual invasion of grasslands about 35-40,000 years B.P., and it gained optimum during 14,000 B.P. The sholas afterward declined giving pace to the grasslands.

The present day patchy distribution of sholas throughout the Nilgiris is due to the destruction of forests. The major and foremost reason affecting regeneration of sholas is climatic factor, although edaphic and biotic factors have also played a considerable role in not permitting the sholas to regenerate.

INTRODUCTION

TWO swamps, viz. Kakathope and Rees Corner were chosen for pollen analytical investigations at Ootacamund. The site Kakathope is situated about six kilometers north-west of Ootacamund city at an altitude of 7650' in Lat. 11°35' and Long. 76°52'. The Kakathope swamp comprises an area of about 25 acres on a flat undulating valley situated on the western slopes of Ootacamund. It is a part of large undulating swamp following the contours of the valley between round topped hills. A large part of it has been reclaimed by the District Agriculture Department and the parts of it are distributed amongst the private farmers for potato cultivation.

The area around Kakathope swamp is surrounded by the bara hill tops. The indigenous "shola forest" is extremely lacking and the area is extensively under cultivation. The plantations of *Acacias*, *Eucalyptus* and *Cinchona* are the only representatives of the arboreal vegetation.

The swamp Rees Corner lies in a depression near the Research Centre of the Soil Conservation Department, Government of India, about three miles south-west of Ootacamund. It is comparatively much smaller than Kakathope swamp, measuring 78×69 m north-south and east-west respectively. It is almost dry and inhabited by sedges, grasses, *Drosera*, *Equisetum*, etc. and along the margins by thick patch of shola forest. This swamp is fed by sub-soil water from a nearby water course flowing along its slope. This swamp is being regularly cleaned by the Soil Conservation Department and dykes have been constructed through the swamp for the purpose of drainage.

The destruction of vegetation, at Kakathope in particular and Nilgiris on the whole, is due to hill tribes such as the Badagas, Kotas, Kurambas, Irulas and Todas and the immigration of Britishers. Before 1812, the district was populated by hill tribes. Amongst them the Todas are the aboriginal settlers of this region and nomadic in nature while the rest of the tribes are cultivators and confined to selected places for cultivation. The crops grown by them before 1812, were mainly wheat, barley, peas, opium, garlic, mustard and millets. To provide land for cultivation these farming communities must have cleared the forests. Teak Sandal wood rattans canes and bamboos comprising the principal

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elements of the surrounding forests were largely fell in view of their economic usages (Grigg, 1880). Besides that plants growing on marshes such as *Andropogon schoenanthus* *A. citratum* etc. were also uprooted for their sweet scented roots.

Coffee is believed to be introduced by a Mohammedan pilgrim, Baba Buden. Since the British immigrants in the Nilgiris both tea and coffee plantations for which the forests were ruthlessly cut down, have been extensively carried out. Extensive grazing accompanied by lopping and cutting of trees for fuel, has considerably damaged the forests in this region.

MATERIAL AND METHOD

a. *Field work*—After the trial borings, the deepest bore hole was selected for final sampling. The samples were picked up with the help of Hiller's peat auger with 50 cm long chamber. 1

b. *Preparation of the samples*—Approximately ten grams of each sample were ground and boiled with 10 per cent KOH and sieved through a mesh to remove the coarser debris. The residue, after thorough washings was examined for seeds and fruits. The filtrate was centrifuged and the residue boiled with HF in a platinum crucible for half an hour. The material was centrifuged and washed repeatedly. To the residue was added glacial acetic acid and then treated with acetolysis mixture (acetic anhydride + conc. H_2SO_4 , 9:1) and heated in the water-bath till the water began to boil (Erdtman, 1943). After acetolysis the material was chlorinated with a mixture of $KClO_3$ +conc. HCl. The material after chlorination was washed several times and then kept in a few cc. of 50% glycerine for examination.

c. *Construction of pollen diagrams*—The percentages are expressed in terms of total counts, i.e. arboreal and non-arboreal pollen excluding aquatics. The individual taxon is represented by a vertical curve. The + sign denotes the values less than 1% percent. Besides resolved pollen diagrams a composite diagram is also constructed to elaborate several features of interest.

STRATIGRAPHY

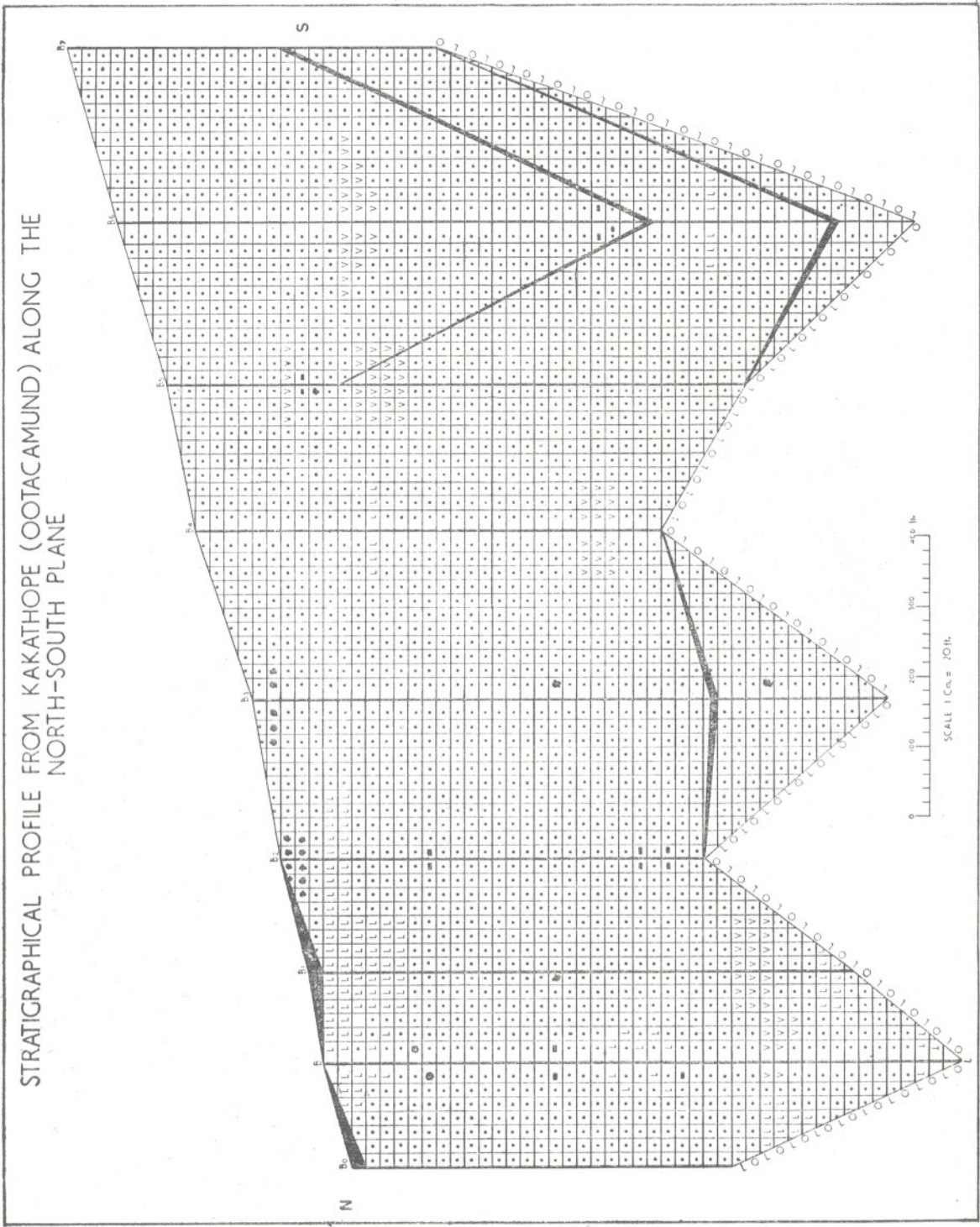
Attempts were made to find out the slope gradients of the entire swamp with respect

to the surrounding hills, with the help of borings all over the area. The boring and levelling survey was done along the north-south and east-west planes passing through the middle of the swamp. Several bore-holes were dug with the help of Hiller's peat-auger at close intervals illustrating the topography of the swamp.

Two profiles, one each from marginal bore-hole and central bore-hole, have been collected from Kakathope. The part of the profile between 260 cm to 350 cm in the marginal profile overlaps with 260 cm to 250 cm of the central profile. This column of sediments of marginal profile consists of clay with kankar comprising washed-in material from the slopes. No doubt, this material has yielded pollen but they are not in continuity of vegetational sequence as seen in the underlying and overlying sediments. The pollen spectrum from this sediment does not, therefore, reflect a true picture of vegetation around and hence it is not considered for the recognition of stages and interpretation of pollen diagram. From Reas Corner only one profile at the centre is collected.

The field examination of the sediments has revealed that the degree of decomposition varies greatly in the different horizons but sharp demarcations are lacking. The swamp deposits comprise clay, black and brown silty organic mud which is largely mouldered but occasionally fibrous. The bottom clay is generally laminated but the lowest layer of clay is mixed with coarse sand and pebbles. The organic mud in both the cases (black or brown) is very soft, sticky and slippery when wet and dries to a hard brittle mass. The basin of the swamp is undulating and has a broad, soft shelf at the north-south plane (Text-fig. 1) which sinks abruptly to the deepest point at the centre lying in a trough like depression. East-westward (Text-fig. 2) the basin continues in more or less the same way as the previous one except it differs in not being very wide. The macroscopic examination has shown that the scattered woody fragments are present in the brown organic mud. Very few megafossils such as seeds of Cyperaceae, charcoal fragments, and one spikelet probably of paddy could be recognized in the field. The spikelet is recovered at 220 cm level. The details of bore-holes selected for pollen analysis are given below.

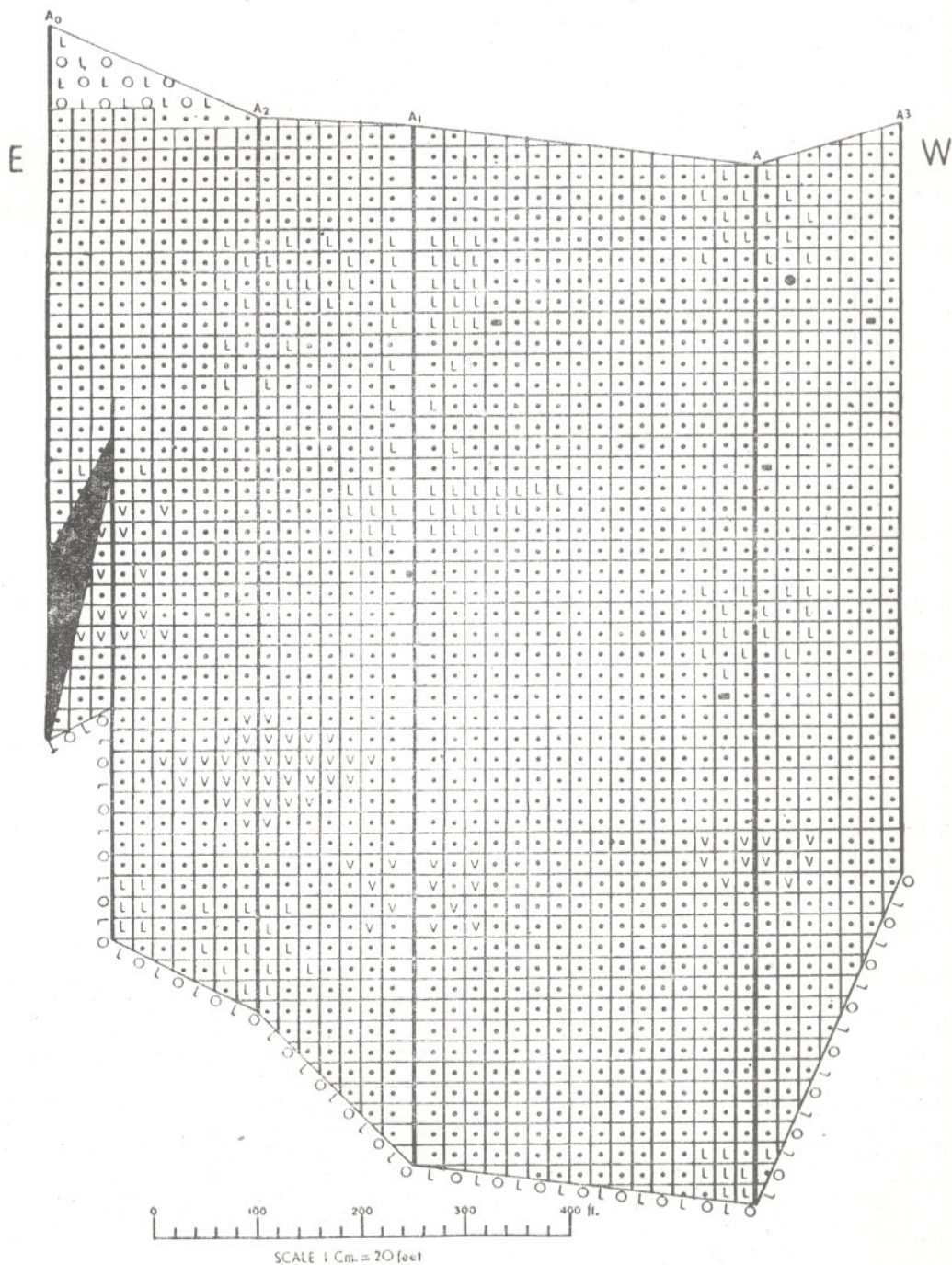
STRATIGRAPHICAL PROFILE FROM KAKATHOPE (OOTACAMUND) ALONG THE NORTH-SOUTH PLANE



0
100
200
300
400
450 ft
SCALE 1 cm. = 70 ft.

TEXT-FIG. 1

STRATIGRAPHICAL PROFILE FROM KAKATHOPE (OOTACAMUND) ALONG THE EAST-WEST PLANE



TEXT-FIG. 2

KAKATHOPE

Details of marginal bore-hole

- 0-35 cm — Clay with boulders. Plant debris absent.
- 35-260 cm — Black mouldered organic mud mixed with silt. Plant debris fairly frequent. Seeds and fruits almost absent.
- 260-350 cm — Clay with boulders. Plant debris absent.

Details of central bore-hole

- 0-90 cm — Greyish black organic mud mixed with clay and boulders. Plant debris scarce.
- 90-180 cm — Black mouldered organic mud. Plant debris frequent. A thin layer of woody fragments is recovered between 170-180 cm level.
- 180-210 cm — Black fibrous organic mud with abundant plant remains.
- 210-220 cm — Black mouldered organic mud with less plant debris.
- 220-250 cm — Black fibrous organic mud mixed with woody fragments.
- 250-350 cm — Black mouldered organic mud with less debris. One charcoal piece is recovered at 310 cm level.
- 350-385 cm — Black fibrous organic mud with abundant plant remains. Cyperaceous seeds also recovered.
- 385-390 cm — Clay mixed with sand and pebbles.
- 390-420 cm — Black fibrous organic mud with less debris.
- 420-505 cm — Black mouldered organic mud with less debris.
- 505-510 cm — Yellow clay with coarse sand.
- 510-570 cm — Black mouldered organic mud.
- 570 down-ward — Tough greyish yellow lacustrine clay with kankar and stones: frequently occur in the lower limits.

REES CORNER

- 0-30 cm — Laterite mixed with sand and kankar. Plant debris absent.
- 30-90 cm — Laminated gritty clay. No plant debris present.
- 90-190 cm — Black fibrous organic mud with less plant debris.
- 190-200 cm — Grey clayey organic mud mixed with silt.
- 200-235 cm — Black fibrous organic mud with abundant plant debris.
- 235-280 cm — Laminated clay mixed with sand and kankar. No plant debris present.
- 280-330 cm — Clay mixed with boulders.

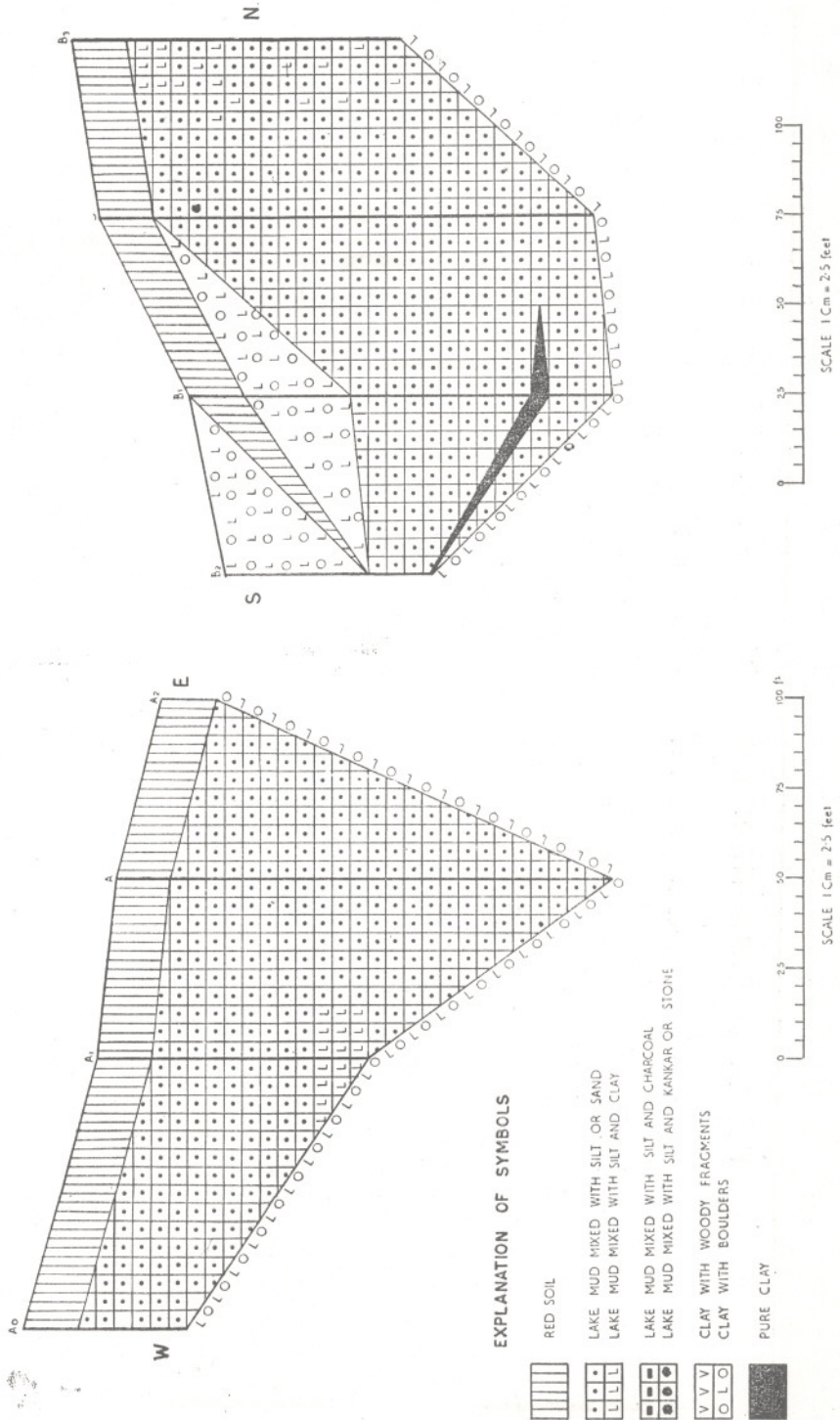
The sediments accumulated at the bottom of the lake are largely gritty clay overlain by mouldered sedge peat brown or black in colour and the basin of this swamp is more or less slanting (Text-fig. 3).

DESCRIPTION OF POLLEN DIAGRAMS

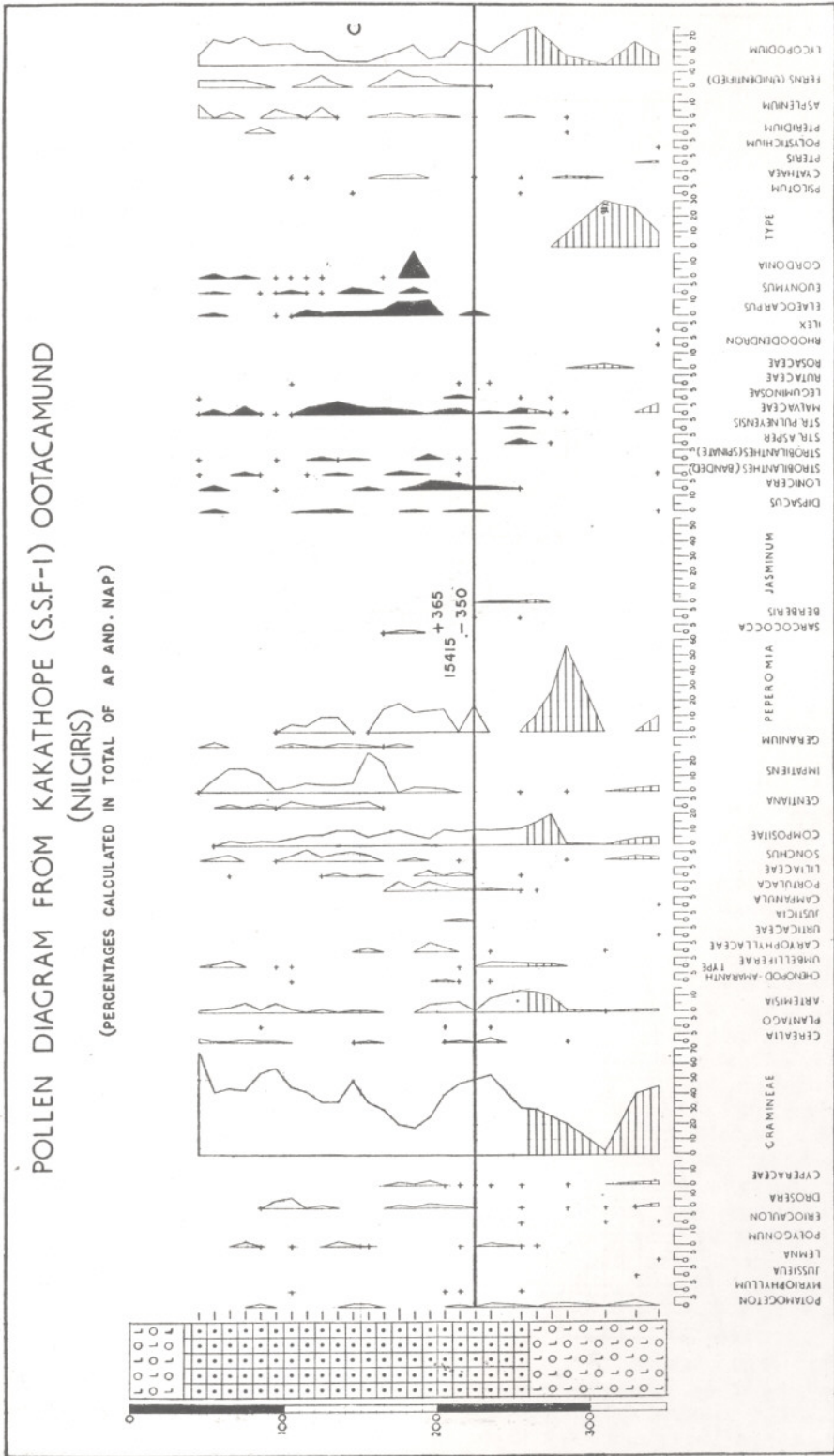
KAKATHOPE

Every possible attempt has been made to construct pollen diagrams from ecological view-point. Owing to the paucity of arboreal pollen in the sediments a single diagram, including aquatics, herbs, shrubs and trees, has been constructed (Text-figs. 4-5). In contrast to the arboreal vegetation, the shrubs on the whole are very well represented in the pollen contents of peat. The reason for scarce arboreal pollen may be assigned either to lack of arboreal vegetation in the forest, entomophily amongst arboreal vegetation, low pollen production of arboreal plants or to the stenopalynous pollen of the vegetation. To reconstruct the past vegetational history and climatic cycles from the pollen diagrams, I have depended more upon the shrubby vegetation as indicative of forest cover. The poor representation of arboreal vegetation in the pollen diagrams has made difficult the recognition of vegetational stages. However, the composite pollen diagram (Text-fig. 6), shows the relative changes in the herbs and shrubs along with the pollen curves of ferns, *Lycopodium*, *Impatiens* and *Peperomia*. At 440 cm level in the composite pollen diagram an important change in the vegetational

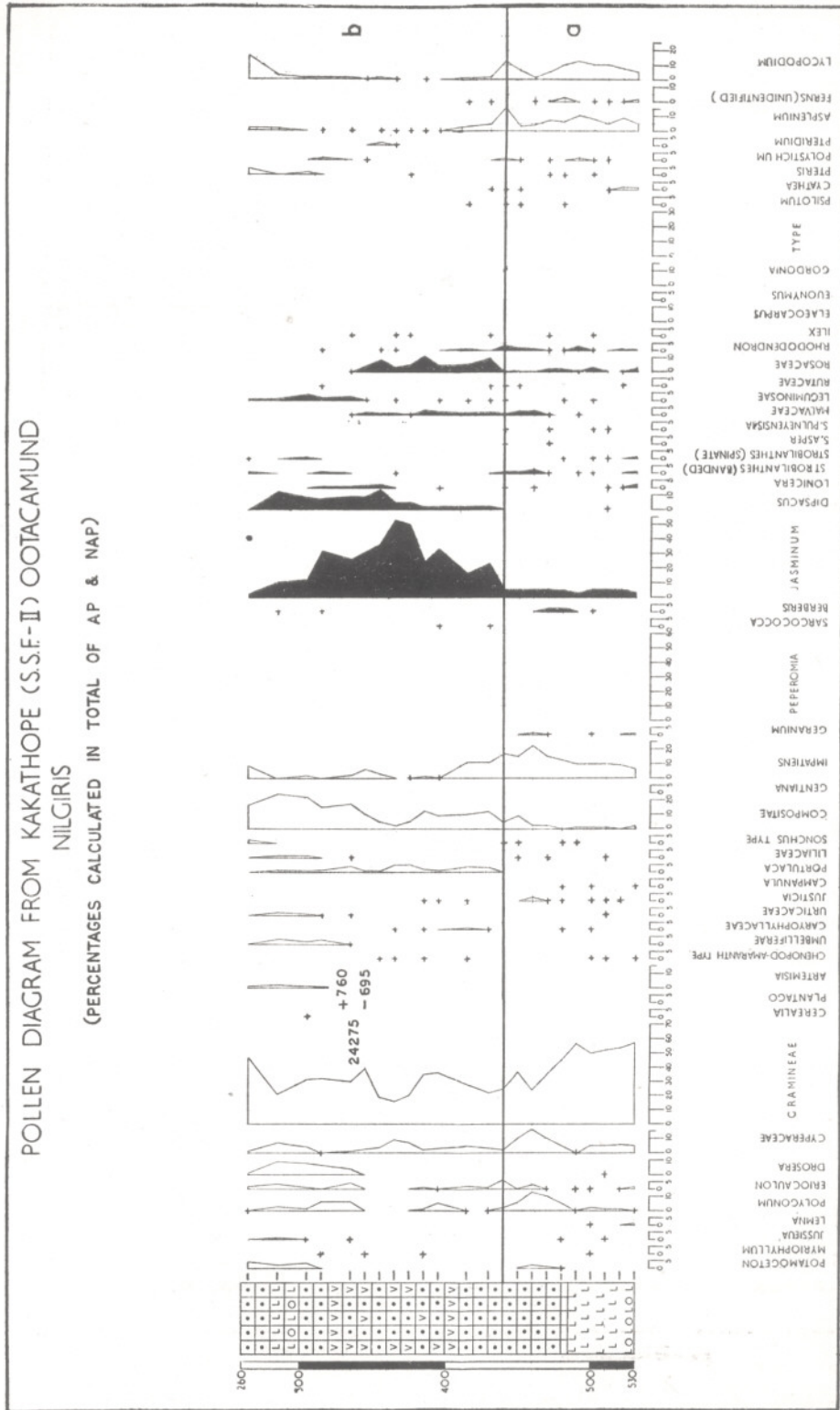
STRATIGRAPHICAL PROFILES FROM REES CORNER (OOTACAMUND) ALONG THE N-S AND E-W PLANES



TEXT-FIG. 3

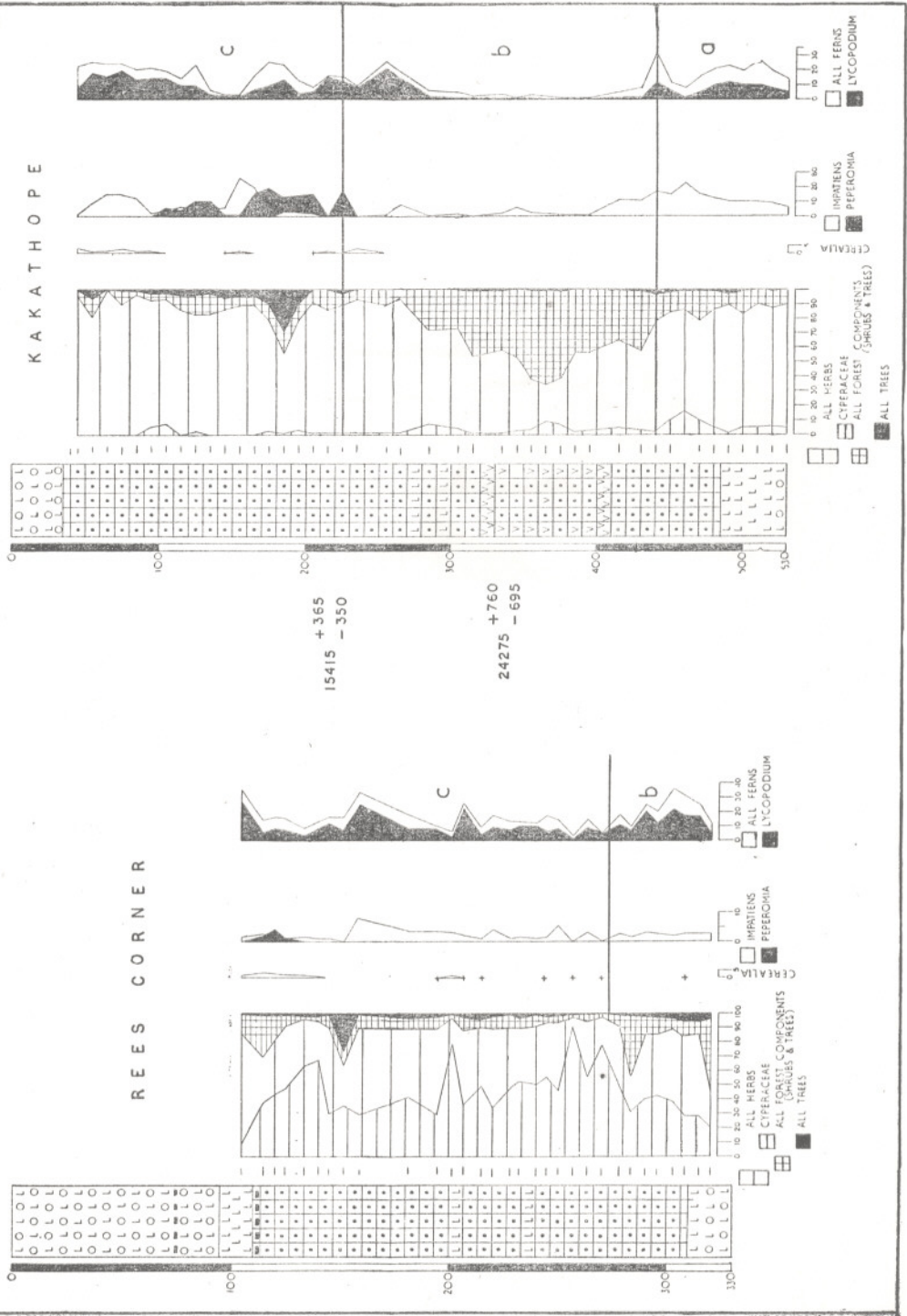


TEXT-FIG. 4



TEXT-FIG. 5

COMPOSITE POLLEN DIAGRAMS FROM REES CORNER & KAKATHOPE (OOTACAMUND)
 SHOWING COLLECTIVE SEQUENCE IN THE DEVELOPMENT OF HERBS, SHRUBS AND TREES ALONG
 WITH SEPARATE CURVES FOR CEREALS IMPATIENS PEPEROMIA LYCOPODIUM
 AND TOTAL FERNS



TEXT-FIG. 6

development is indicated. The herbs decline and shrubs gradually increase and attain a maximum over that of herbs between 300 and 400 cm. Several woody fragments at this level are also encountered in the peat. Another distinct change is noticed at 280 cm level where the shrubs decline and herbs regain their frequencies. It thus reveals that three distinct stages are easily recognizable, namely stage "a" between 530-440 cm, stage "b" between 440-225 cm and stage "c" between 225-0 cm.

Stage "a" — The stage "a" is characterized by open vegetation as the non-arboreals, especially Gramineae, dominate. Of the tree constituents *Rhododendron* is present in very low values whereas *Ilex* is sporadic. The undergrowth of the forest during this stage is marked by the low values of *Jasminum* and Malvaceae. The curve for Malvaceae tends to rise towards the close of this stage. Rutaceae, Leguminosae and *Strobilanthes* are sporadic throughout the stage. *Berberis* comes up only in the upper half of this stage.

Gramineae has very high values with a declining trend towards the top whereas Cyperaceae shows a rising trend towards the top of this stage. Chenopodiaceae, Caryophyllaceae, Urticaceae, *Liliaceae*, *Justicia*, *Campanula*, *Geranium* and *Sonchus* are present sporadically. The curve for Compositae is continuous but poor except it rises at the close of the stage. *Impatiens* has fairly high values with a rising trend towards the top. Ferns on the whole are abundant and out of these *Asplenium* and *Lycopodium* attain high values whereas *Psilotum*, *Cyathea*, *Pteris*, and *Polystichum* are sporadic.

Amongst aquatics *Eriocaulon* and *Potamogeton* are lowly present. *Polygonum* has a continuous curve with high values towards the top of the stage. *Myriophyllum*, *Jussiaea* and *Lemna* are either sporadic or in much reduced frequencies. Only one pollen of *Drosera* has been recovered from this stage.

Stage "b" — This stage is recognizable from the preceding stage in having abundance of *Jasminum* and *Dipsacus*. *Ilex* and *Rhododendron* are sporadic. Rutaceae, Leguminosae, *Lonicera* and *Strobilanthes* spp. are either sporadic or present in very low frequencies but *Leguminosae* maintains slightly high values towards the top of this stage. Rosaceae has consistently high values

but disappears from the top of this stage. Malvaceae attains a smooth curve though in very much reduced percentages. *Dipsacus* is represented by quite a low percentage in the lower half of the stage but soon it maintains high values and continues till the close of the stage. *Jasminum* is present in excessively high values and forms a maximum of 53% at 365 cm but soon after it declines towards the top of the stage. *Berberis* and *Sarcococca* are sporadic throughout.

The ground vegetation chiefly consists of Gramineae, though the values are slightly reduced than the preceding stage. *Artemisia* starts with low values in the upper half of the stage. Umbelliferae, Urticaceae and Liliaceae are present in a little above the middle of this stage but Chenopodiaceae, Caryophyllaceae and *Justicia* maintain very much reduced values. *Portulaca* attains comparatively high values than before and continues throughout the stage. Compositae has low values in the middle but rises considerably in the upper half of this stage. *Impatiens* maintains fluctuatingly low values.

Ferns such as *Psilotum*, *Cyathea*, *Pteris*, *Polystichum*, *Pteridium* and *Lycopodium* are either sporadic or have reduced values. *Pteris*, *Asplenium* and *Lycopodium* show increasing tendency towards the top of this stage.

Amongst the aquatics, *Potamogeton* is present in comparatively high values than before especially towards the top of this stage. *Myriophyllum* and *Jussiaea* are sporadic. *Polygonum* is comparatively low than before whereas *Eriocaulon* after low values in the lower part increases towards the top. *Drosera* maintains high values in the upper part of this stage.

Stage "c" — This stage is characterized by the tree constituents such as *Gordonia*, *Euonymus* and *Elaeocarpus* which are present in high values but all of them decline towards the top. *Ilex* and *Rhododendron* are extremely rare. Malvaceae is found in comparatively high values than before and maintains a continuous curve right from the beginning of this stage attaining higher frequencies towards the upper half of this stage. The values for Rosaceae, Rutaceae, Leguminosae and *Strobilanthes* spp. are either sporadic or very much reduced. *Lonicera* maintains good frequencies in the beginning but soon declines towards the top.

Dipsacus and *Sarcococca* are very much reduced but mainly concentrated in the lower half of this stage. *Berberis* is extremely sporadic.

Amongst herbaceous elements, *Peperomia* maintains exceedingly high values in the lower half but tends to decline upwards. Compositae is quite high but shows gradual decline upwards. *Gentiana* maintains low values in the upper part and *Sonchus* attains high values but in fluctuating manner. *Portulaca* and Liliaceae have low values in the beginning whereas the values for *Justicia*, *Campanula* and Urticaceae are extremely rare. Caryophyllaceae is found in good frequencies in the lower half of this stage whereas Umbelliferae is present in low values in the beginning. Chenopodiaceae and *Plantago* are sporadic while *Artemisia* attains high values towards the top of this stage. Gramineae is present in fairly high values throughout the stage except for its reduced values in the lower part of the stage.

Psilotum, *Cyathaea*, *Pteris*, *Polystichum* and *Pteridium* are present either sporadically or in reduced values. *Asplenium* and other ferns are fairly frequent in the upper half of the stage whereas *Lycopodium* maintains high values throughout except for some fluctuations.

The values for *Myriophyllum*, *Jussiaea*, *Lemna* and *Eriocaulon* are extremely sporadic. *Potamogeton* is present in very low frequencies right from the beginning of this stage and continues till the top of the diagram. *Drosera* and *Polygonum* have high values in the upper half of the stage.

REES CORNER

The pollen diagram (Text-fig. 7) from Rees Corner differs from Kakathope pollen diagram in having high values of Cyperaceae which is of local origin. The recognition of vegetational stages in this diagram is based on comparison of special diagram from both the sites. High values of shrubs at the base of Rees Corner pollen diagram seem to find a parallel with a similar phase towards the top of stage 'b' in Kakathope pollen diagram. Therefore, the sequence between 275 cm—330 cm in Rees Corner pollen diagram is referred to the top of stage 'b' whereas the rest of the profile above 275 cm is referred to stage 'c' of Kakathope pollen diagram. The bottom of stage 'b' and

stage 'a' are absent in Rees Corner pollen diagram. This parallelism is further supported by the fluctuations in shrubs and trees within stage 'c' which occurs at 155 cm at Rees Corner and 180 cm at Kakathope.

Stage "b" — During stage 'b' *Rhododendron* and *Ilex* have continuous curves showing good frequencies. Myrtaceae is extremely sporadic. The undergrowth is represented by low but continuous curves for *Jasminum* and Rosaceae. *Lonicera*, Rutaceae and Leguminosae are sporadically present. *Strobilanthes* spp. are present either sporadically or in low frequencies except for *S. pulneyensis* and *asper* which enjoy fairly high values in the lowermost sample.

The forest cover is represented by low values of Gramineae, Compositae, Liliaceae, Caryophyllaceae, *Impatiens* and *Justicia* which eventually reduce to sporadic values towards the top of the stage. *Plantago* and *Artemisia* are sporadic. A single Cerealia type pollen is encountered at the middle. Chenopodiaceae, Umbelliferae, *Campanula*, Primulaceae, *Sonchus* and Malpighiaceae are extremely sporadic. The unidentified pollen type maintains high values towards the top.

The ferns and *Lycopodium* gradually decline towards the top. *Psilotum*, *Cyathaea*, *Botrychium*, *Onichum japonicum* and *Pteris* are sporadic.

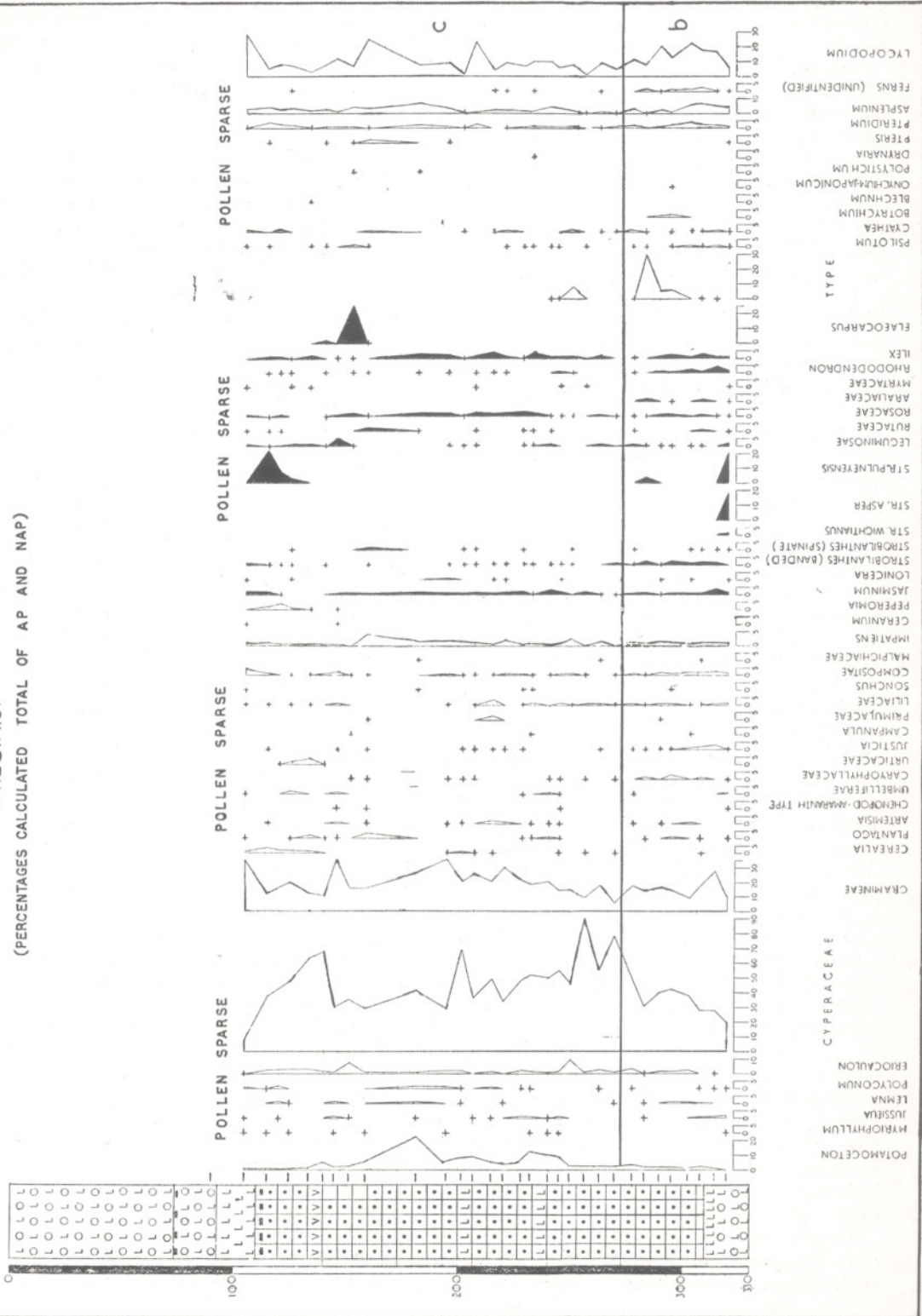
The aquatics are represented by low but continuous curve for *Potamogeton*, *Jussiaea* and *Lemna* while *Myriophyllum* is represented by single pollen. *Eriocaulon* has low and continuous curve showing high values in the upper half.

Stage "c" — *Elaeocarpus* maintains a value of 25% towards the top of the stage 'c' but before and after, the values are sporadic. *Ilex* maintains continuous curve showing high values in the middle. *Rhododendron* and Myrtaceae are sporadic. Rosaceae and *Jasminum* are lowly present and Rutaceae, *Lonicera* remain sporadic. *Strobilanthes pulneyensis* maintains a value of 25% at the extreme top while other species remain sporadic.

The ground flora is represented by exceedingly high values of Cyperaceae with a declining trend upwards. Gramineae has comparatively reduced values but increases towards the top. *Impatiens* has high values than before but decline upwards. *Peperomia* is seen only towards the top of this stage

POLLEN DIAGRAM FROM REES CORNER (OOTACAMUND)
(NILGIRIS)

(PERCENTAGES CALCULATED TOTAL OF AP AND NAP)



TEXT-FIG. 7

forming small and low curve. Cerealia type pollen maintain a continuous curve towards the top of this stage. *Plantago*, *Artemisia*, Chenopod-Amaranth type, Umbelliferae, Caryophyllaceae, Urticaceae, *Justicia*, Primulaceae, Liliaceae, *Sonchus*, *Campanula* and Compositae are present either in low values or sporadic.

Lycopodium has high and fluctuating curve. The curve for *Asplenium* and *Pteridium* are continuous. *Psilotum*, *Cyathaea* and *Pteris* are sporadic whereas *Blechnum* and *Polystichum* are extremely rare.

The aquatic vegetation is characterized by high values of *Potamogeton* in the middle but declines at the top. *Myriophyllum*, *Jussiaea*, *Lemna* and *Polygonum* are sporadic. *Eriocaulon* is lowly represented.

VEGETATIONAL HISTORY

i. History of the Forest and Lake Vegetation

The pollen diagrams constructed from Kakathope depicts succession from grassland to forest and again to grassland. At present the site Kakathope is devoid of indigenous forest but during Late Quaternary time the forest did exist in the near vicinity of the site.

During stage "a" the vegetation chiefly consisted of herbaceous elements with a few scattered shrubs indicating an open grassland. The herbaceous vegetation was dominated by Gramineae. *Impatiens* was present in good frequencies. *Jasminum*, a shrub of forest and open downs was lowly present.

The trees during stage "a" were very scarce. Amongst them *Rhododendron* maintained discontinuously good percentages whereas *Ilex* was extremely sporadic. *Lycopodium* and *Asplenium* were fairly high while rest of the ferns were rare.

The sheets of water in the lake were poorly populated by the submerged and free-floating plant communities represented by *Potamogeton*, *Myriophyllum*, *Jussiaea* and *Lemna*. The lake shores were populated by abundant *Polygonum* and sedges. *Eriocaulon* is found in low frequencies and *Drosera* was extremely sporadic.

During stage "b" a change-over from the open grasslands to the initiation of the forest took place. *Jasminum*, a shrub was the

first to invade the grasslands and soon attained dominance in the middle of the stage. *Dipsacus* an inhabitant of open land also invaded and gradually it increased. *Rhododendron* and *Ilex* remained rare. The Gramineae decreased considerably. Compositae had a gradual rise perhaps indicating the shrubby constituents in the forest. *Artemisia*, Umbelliferae, Caryophyllaceae, Urticaceae and *Sonchus* had a general rising trend towards the top of the stage. There was an overall decline in ferns.

The aquatics such as *Potamogeton*, *Myriophyllum*, *Jussiaea*, etc. occurred scarcely but the shores of the lake were thickly populated by *Polygonum*, *Eriocaulon*, *Drosera* and sedges.

During stage "c" arboreal vegetation comprising *Gordonia*, *Euonymus* and *Elaeocarpus* was established which declined towards the top of the pollen diagram. *Ilex* and *Rhododendron* became extremely rare. Malvaceae had fairly high values. *Lonicera* had high values in the lower part of the stage but declined towards the top. *Strobilanthes* spp. had fairly high values throughout the stage. *Dipsacus* had declined and *Berberis* and *Sarcococca* were rare.

The non-arboreal vegetation was characterized by the abundance of *Peperomia*. Gramineae increased considerably at the upper part of the stage. *Impatiens* maintained high values and continued till the top of this stage. Compositae had high values showing a declining trend upwards. *Sonchus* attained quite high values in the upper half of the stage. *Artemisia* commenced in high frequencies in the beginning but declined upwards showing its association with forest constituents. *Lycopodium* and *Asplenium* were quite frequent throughout the stage.

Potamogeton almost disappeared from the upper part of the stage. *Drosera* gained comparatively high values. *Myriophyllum*, *Jussiaea*, *Lemna*, *Polygonum* and *Eriocaulon* became poor.

ii. Climatic Oscillations

The vegetational stages not only reflect upon the vegetational development but also on the climatic changes of the past. The succession of open vegetation consisting of grasslands with occasional shrubs and *Rhododendron* into a dense shrubby vegetation and its replacement by trees and the

eventual decline of the shola forest might have been due to differential climatic changes. A three-fold succession of vegetation, i.e. grassland-forest-grassland seems to reflect three-fold climatic sequence. In this temperate oasis of the tropics of South India, an open vegetation suggests cold and dry climate and shrubby and arboreal vegetation, a warm and humid climate. Thus the whole vegetational pattern indicates that the Late Quaternary climate in Ootacamund followed a three-fold succession, viz.

1. Decreasing cold and less humid climate in stage "a".

2. Warmth optimum and much humid climate in stage "b".

3. Decreasing warmth and less humid climate in stage "c".

The general nature of vegetation reconstructed from pollen analysis reveals a temperate climate. Indications for the precise nature of climate can be had from genera like *Impatiens*, *Peperomia* and *Potamogeton*. *Impatiens* is very much susceptible to frost and can not thrive well under heavy frost. It is, therefore, indicative of warm and humid climate and its pollen curve can be used with some reliability towards the inference of past climate. *Impatiens* was present during stage "a" when open conditions prevailed, it gradually increased towards the close of stage "a" and gained maximum towards the beginning of stage "b" indicating progressively warm and humid climate which in stage "a" must have deteriorated more. During stage "b" the establishment of shrubs characteristic of shola forest corresponds to the decline of *Impatiens*. This decline, as interpreted from its curve might have been due to deterioration of climate but at the same time dense shrubby cover is indicative of an increase in the warm and humid climate. Thus, the decline of *Impatiens* is perhaps due to its being entomophilous in nature and that its pollen was not contributed to the pollen rain because of the dense cover of shrubby vegetation. The decline of shrubs and establishment of arboreals has almost the same effect on *Impatiens*, although its values are comparatively higher than the preceding stage. The overall trees and shrubs in stage "c" do not indicate a dense forest cover as corroborated by high values of Gramineae and accompanying herbs. However, its

lower values perhaps suggest the prevalence of less warm and humid climate.

Peperomia, a dominant herb of shola forest, occurs in very high frequencies in the sediments between 216-250 cm which is obviously a washed-in material. On account of this much importance can not be attached to the pollen of *Peperomia* which otherwise indicates much humid climate.

Potamogeton, a submerged plant, is poorly developed throughout the pollen diagram. Its poor values are perhaps suggestive of less humid conditions.

iii. Prehistoric Plant Husbandry

The inference of plant husbandry is largely determined from Cerealia pollen, culture pollen curves and Radiocarbon datings. The first Cerealia type pollen in Kakathope pollen diagram is seen in the upper half of stage 'b' and afterwards it disappeared. The occurrence of Cerealia pollen does follow a slight depression in the values of Gramineae and other shrubby vegetation. The date for this level can be extrapolated to 20,000 years B.P. This change obviously indicates the destruction of the forest either due to climatic or edaphic changes but not due to biotic factors as the occurrence of single Cerealia type pollen at this level can be easily overlooked owing to the size overlap between cultivated and wild grasses. So far no indication about the destruction of forest by man in order to clear the land for cultivation, is obtained. The region is inhabited by Todas, the earliest tribe, who are the graziers. The farming tribes such as Kotas, Kurambas, Badagas and Irulas are known to have invaded the region later than Todas (Grigg, 1880).

The appearance of Cerealia type pollen along with other culture pollen such as *Artemisia* and Caryophyllaceae and its correspondence with the sharp decline of Gramineae and other forest constituents is decidedly suggestive of forest clearance by Man.

The Cerealia pollen grain almost disappears till the middle of stage "c". *Artemisia* continues in very much reduced values in the lower part of stage "c" but increases considerably upwards maintaining a value of about 15%. Chenopod-Amaranth type is sporadic in the middle whereas Umbelliferae forms a small curve a little below the middle of stage "c". Com-

positae attains fairly good values at the same horizon where *Artemisia* increases. The sporadic occurrence of Cerealia type pollen is related with the increase in submerged vegetation of *Potamogeton* and a tremendous increase in *Peperomia*, perhaps suggestive of heavy rains adversely affecting farming.

The Cerealia type pollen maintains the continuity of curve towards extreme top. The increase in the Cerealia type pollen curve reveals that the establishment of farming was about 3500 years B.P. The pollen of *Plantago* are seen only at this stage.

iv. Phytogeographical Comments

The present day open conditions of vegetation and plantations around Kakathope are largely held due to human factor. But during stage "b" the region around Kakathope bore forest vegetation. Further change in climate together with introduction of agriculture resulted in the decline of shrubs and establishment of forest constituents such as *Elaeocarpus*, *Gordonia* and *Euonymus* which declined later obviously at the hands of man.

There is a certain proportion of Himalayan elements in the Nilgiris flora. Of these *Berberis*, Caryophyllaceae, *Geranium*, Umbelliferae, Rosaceae and *Rhododendron* are largely found during stages "a" and "b" and very scarce in the succeeding stage "c". These are perhaps the survivals of the Himalayan elements which reached here during early Quaternary period. Some of the genera like *Elaeocarpus*, *Gordonia*, *Euonymus*, *Rosa*, *Viburnum*, *Lonicera* and *Sarcococca* are of east Himalayan origin and largely present during stage "c".

Phytogeographically, aquatics are quite interesting. *Jussiaea* is today absent in the Nilgiris but its pollen has been encountered in the top of stage "b". *Jussiaea* is pollinated by insects and birds and that perhaps explains the source of its pollen. *Potamogeton* and *Lemna* have been important constituents of aquatic vegetation during Late Quaternary, but these are absent today from Ootacamund. *Potamogeton*, in the Nilgiris, has been introduced recently.

DISCUSSION AND CONCLUSION

The pollen-analytical investigations from Kakathope, the temperate region of South

Indian tropics, in the Nilgiris, has brought out very interesting features of the vegetational development, the climatic changes and the origin and progressive development of farming. The vegetational history in the Nilgiris reveals the successional development of the shola forest from the grasslands.

In Ootacamund during stage "a" the vegetation was open and largely comprised of grasslands with a few scattered shrubs and trees. During this phase the herbaceous vegetation was dominated by Gramineae and *Impatiens* was also quite frequent. The shores of the lake were inhabited by *Polygonum* and sedges. *Myriophyllum*, *Jussiaea*, *Lemna* and *Potamogeton* existed in the water sheet. During stage "b" the grassland was first invaded by *Jasminum* which was later followed by other shrubs. There was an overall decline in the values of *Lycopodium* and ferns. The decline of shrubs was followed by an increase of herbaceous elements. *Potamogeton*, *Myriophyllum* and *Jussiaea* were very rare but the shores were thickly populated by *Eriocaulon*, *Drosera* and *Polygonum*. The arboreal vegetation consisting of *Gordonia*, *Euonymus* and *Elaeocarpus* was established during stage "c" which soon declined. The non-arboreal vegetation comprised of *Peperomia*, *Lycopodium* and Gramineae.

The determination of these vegetational stages is not only based on the pattern of vegetation but also on indications of changes in climate. While defining the Quaternary climatic cycles Von Post (1929) was of the opinion that cyclic changes in the forest history were essentially due to climatic causes. Von Post (1946) further suggested the existence of reversion in Interglacial and Postglacial pollen diagrams. He divided the vegetational succession into three stages as terminocratic elements dominating the early and late stages whereas mediocratic element were confined to their middle part. He was of the opinion that the vegetational changes are chiefly due to the climatic fluctuations and hence three major climatic phases were recognized as the period of increasing warmth, warmth maximum and the period of decreasing warmth. The Kakathope pollen diagram seems to indicate much less humid climate but these observations will remain tentative until some more pollen diagrams are constructed from this region. Menon (1968) has investigated Post-glacial deposits from Pykara, Ootacamund

and could not encounter any pollen belonging to the arboreal vegetation. Palynologically South Indian flora is so alike that it is difficult to discriminate from one another unless statistical evaluation of pollen is made. Based on non-arboreal vegetation Menon (*l.c.*) thinks that dry climate prevailed during early stages which was succeeded by humid climate as indicated by the dominance in Gramineae and ferns respectively.

The interpretation of factors governing the development of vegetation is indeed, a difficult task in view of the combined effect of climate, soil and man during Late Quaternary period. This difficulty has led to divergent views advocating the exclusive influence of climate, or man or soil (Von Post, 1946; Iversen, 1960; Anderson, 1966), although the consensus of opinion is in favour of dual effect of climate and man (Troels-Smith, 1960).

The Kakathope pollen diagram in Nilgiris, however, does not provide any concrete evidence as regards the anthropogenous influence at the change-over in the vegetational development. The farming in Ootacamund seems to have commenced a little lower than middle of stage "c" which soon after declined in the middle of stage "c". The values for Cerealias type pollen again started towards the top of stage "c" and continued in comparatively good frequencies till the end of the diagram showing the period of increased prosperity. The present investigations tend to show that both climate and man are responsible for the changes of vegetation in Ootacamund.

The stratigraphical studies in Kakathope swamp provide information of the origin of swamps in Ootacamund. As revealed by stratigraphy the swamps in Ootacamund were formed in depressions between the hills which became round-topped after weathering perhaps due to torrential rains. Clay is chiefly formed by degeneration of gneissose rocks. The disintegrated rocks were first laid down in the basin which was later colonized by aquatics, sedges, etc. giving rise to an uniform deposit of organic mud. The silt and sand deposited in the swamp is largely washed-in sediments from slopes during annual rainfall.

For the history of vegetation and climatic oscillations, the results of these investigations are quite fascinating and hence it was thought desirable to have results checked radiologically. The samples for C14 dating

were collected with the help of Hiller's peat-auger at three horizons, viz. 530-500 cm, 350-320 cm and 230-200 cm from Kakathope swamp essentially marking the vegetational zonations. Out of three samples only two upper ones yielded enough radioactive isotope of carbon to date them. The radio-carbon measurements were carried out at Tata Institute of Fundamental Research, Bombay, to which I am very grateful. The results stated are in years B.P. and 1950 has been used as the base year.

TF-695, organic mud (2.0-2.3 m)
15415+365
-350

TF-696, organic mud (3.2-3.5 m)
24275+760
-690

The most important aspect, which pollen analytical investigation at Kakathope swamps in Ootacamund has revealed, concerns the regeneration and formation of shola forest and also the status of shola forest versus grasslands in the Nilgiris. The present day occurrence of shola forest in pockets between the hills or along the slopes of hills and the wide spread occurrence of grassland is indeed, a current problem to the ecologists. The grasslands are the pioneer communities but at the same time it is believed that the grasslands in the Nilgiris are derived from the destruction of shola forest (Champion, 1936). Recent clearances of the indigenous forest by men tend to support the later view. The regeneration of shola forest from the grassland is not seen anywhere. The shola forest in the Nilgiris is gradually dying and hence it has been described as a living fossil plant community (Vishnu-Mittre & Gupta, 1968). The degenerating of shola forest can be attributed either due to climate or weathering of thick humus on which it grows.

The entire sequence of vegetation reconstructed from Kakathope suggests the manner in which the shola forest had originated. The initiation of shola forest took place under the regime of warm and humid climate which was free of frost as indicated by high values of *Impatiens* during stage "a". Thus, the shola forest in Ootacamund had originated through gradual invasion of the grasslands about 35,000 years ago, corresponding in time to last Glaciation

in North India (Vishnu-Mittre & Gupta, 1971). The advancement of shrubs characteristic of shola forest seen in stage "b" is radiologically dated to $24,275 \pm 700$ B.P.)-690

TF-696. The shola forest comprising *Euonymus*, *Gordonia*, *Elaeocarpus* along with a few shrubs such as *Dipsacus*, *Lonicera*, *Strobilanthes*, Malvaceae and Leguminosae was established at the beginning of stage "c" about 15415 ± 365 B.P.-TF-695.
350

The prevalence of open vegetation during stage "a" decidedly indicates the pioneer status of grasslands. The formation of shola forest commenced in seral stages from few shrubs and *Rhododendron* in grasslands to a dense vegetation characteristic of shola forest.

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