

# POLLEN ANALYTICAL RECONNAISSANCE OF POST GLACIAL DEPOSITS FROM SUBTROPICAL ZONE IN NAINI TAL DISTRICT, KUMAON HIMALAYA

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## ABSTRACT

The paper embodies the results of pollen analytical investigations of modern as well as Post-glacial sediments from the Naini Tal District in subtropical zone of outer range of Kumaon Himalaya. The study of a series of moss cushions and surface samples from different altitudes in this region has demonstrated that approximately 50% of the total modern vegetation is represented in the pollen spectra. The peat profiles, one each from Naukuchiya Tal and Bhim Tal, have been studied. Based on the fluctuations in the forest plant communities it has been possible to recognize four vegetational stages during Holocene time and these are designated by the alphabetical letters as 'a', 'b', 'c' and 'd'.

The vegetational history begins with the dominant chir pine woods during Stage 'a', which was gradually succeeded by broad-leaved forest constituents during stages 'b' and 'c' and again into the pine-woods during Stage 'd'. The three-fold shift in the vegetation reflects on the three-fold climatic fluctuations, viz., cold-warm-cold. The hydrarch succession has also been studied.

The factors responsible for bringing out changes in the vegetational composition such as climatic, edaphic and biotic have been discussed. Efforts have been made to find out the influence of man and animal over the vegetation. The phytogeographical distribution of plant species has also been discussed in detail.

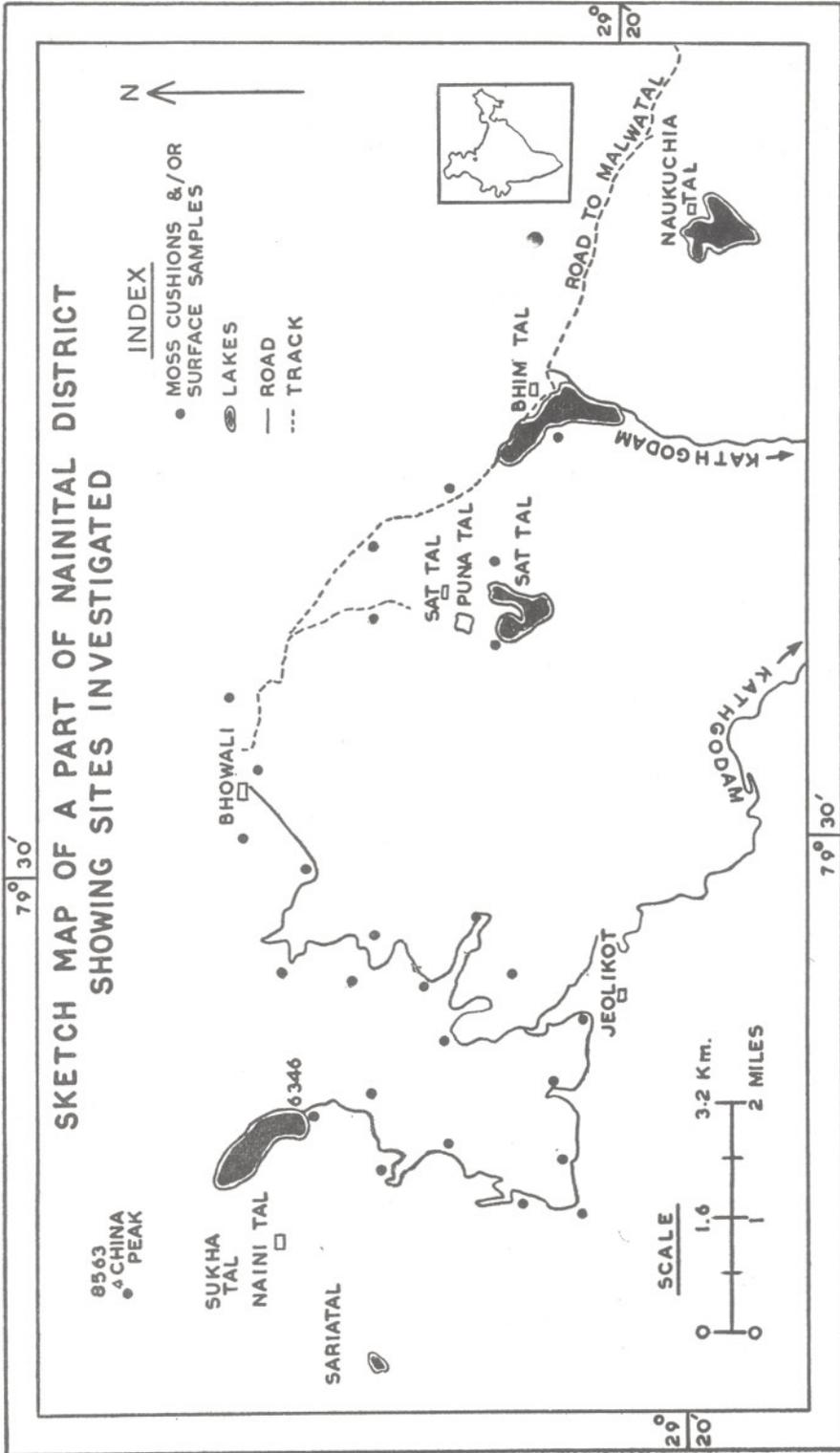
## INTRODUCTION

THE present studies are confined to the Naini Tal District in the outer Himalayan range (300-2000 m a.s.l.) of the Kumaon Himalaya which constitutes the eastern extension of the North-West Himalaya

The climate of Kumaon Himalaya varies greatly according to its elevation and exposure to the monsoons. Winters are severe at the higher elevations and snow falls down to 1666 m and occasionally lower, but melts rapidly below 2333 m and even above this. Sharp frosts are usually observed from December to February and occur even in the lower valleys which are frequently surrounded by mist in the moraines.

The Naini Tal District abounds in natural lakes, swamps and therefore, it is also famous by the name of "District of Lakes" or "Lakes Paradise". Bhim Tal, Malwa Tal, Naukuchiya Tal, Sat Tal, Khurpa Tal and Naini Tal are some of the important lakes (Map-1). Besides, there are many other smaller sheets of water such as Sukha Tal, Khuriya Tal and Sariya Tal etc. These groups of small lakes are closed basins without any outlet. The origin of these lakes has been much discussed from time to time and yet remains an open discussion. These might have been originated due to differential earth-movements (Mathur, 1955), landslips (Wadia, 1957) or glaciations (Raina, 1965).

*Vegetation*—The Bhim Tal and Naukuchiya Tal come under Himalayan subtropical chir pine forest (Champion, 1936; Champion & Seth, 1968). *Pinus roxburghii* constitutes the principal species in this forest type and no other species occur in the top canopy. Underwoods and shrubs are very rare and survive as seminatural. This shows a wide spread distribution of chir pine forest. Very little chir pine forest is seen until 1000 m is reached, although very few patches are seen at 700 m (Kenoyer, 1921). The upper limit for chir pine extends upto 2100 m or more. Generally the chir pine forests are very pure and open but there is an admixture of *Quercus incana* representing the second storey. *Pinus roxburghii* prefers the dry and exposed conditions whereas *Quercus incana* is adapted to humid situations within altitudes. On peaks between 1000 m to 2100 m it is usual to find pines occupying the ridges, and summits being occupied by the oaks. Chir pine and oaks are the constant competitors and in most places they are found striving for ascendance. It is common to find regeneration of chir pine under oaks and vice versa. On hot exposed slopes with shallow soil it is often replaced entirely by low level miscellaneous

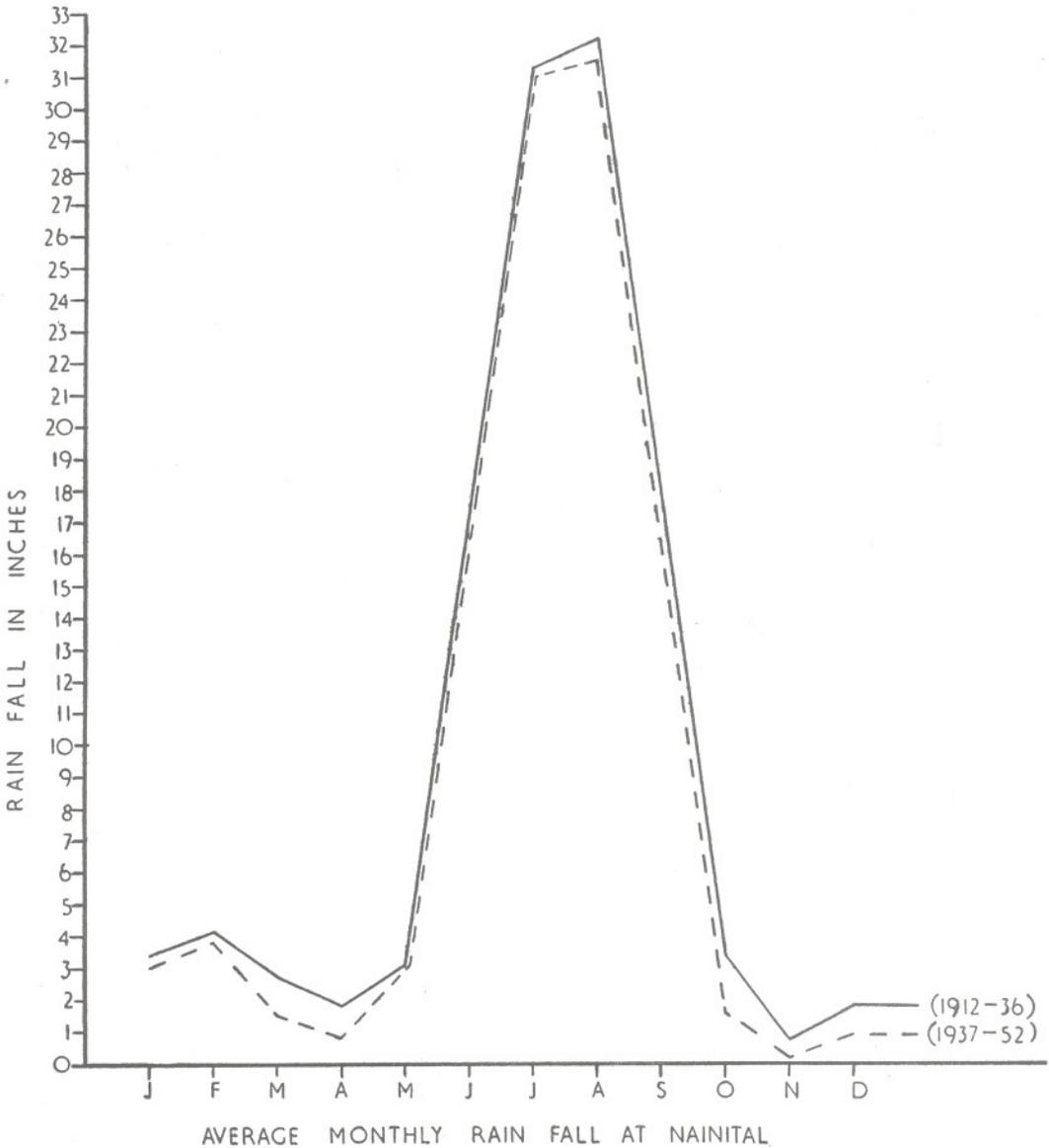


MAP 1

scrubs and broad-leaved species tend to take its place along water courses and in moist sheltered places. Towards the lower limit of its habitat it passes into the Sal forest and towards its upper limit it passes into oak woods (Working Plan U.P.). Fire encourages chir pine to spread upwards into the oak woods but appears to have the

opposite effect at its lower limit where Sal and other species gradually encroach into the pine forest (Champion, 1919). At higher levels the oak woods are, badly lopped and cut for fodder and firewood, being replaced by chir pine (Champion, 1923).

The predominant trees are *Pinus roxburghii* and *Quercus incana* with *Rhododendron*



TEXT-FIG. 1

*arboreum*, *Lyonia ovalifolia*, *Glochidion velutenum*, *Engelhardtia colebrookiana*, *Bauhinia variegata*, *Ficus roxburghii*, *Myrica sapida*, and *Pyrus pashia* as common associates. The understorey is chiefly composed of *Ougeinia dalbergioides*, *Syzygium cumini*, *Wendlandia exserta*, *Emblia officinales*, *Colebrookia oppositifolia* and *Indigofera pulchella*. *Woodfordia fruticosa* and *Rhus parviflora* form a dense undergrowth on hot and dry slopes at low elevations. *Alnus nepalensis*, *Salix* sp. and *Fraxinus excelsoir* are commonly found along the lake shores or moist shady ravines.

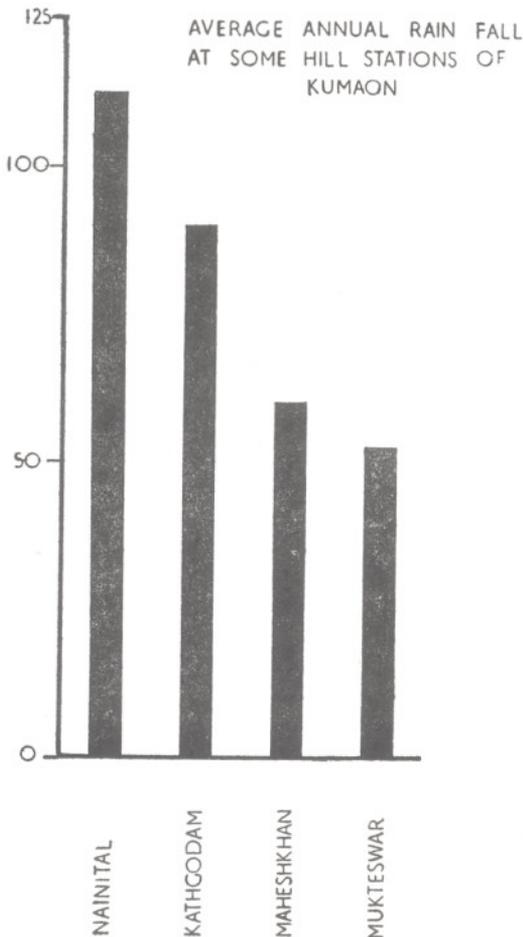
On higher elevations, oaks are the predominant species constituting western temperate broad-leaved forest. They extend

from the highest point 2866 m elevation to the chir pine zone, i.e. 2000 m. The transitional line between oak woods and chir pine is in vague but towards its lower limit oaks follow ravines down to about 1000 m and leaves the ridges and spurs to chir pine. In this type of forest three principal oak species, viz., *Quercus incana*, *Q. dilatata* and *Q. semecarpifolia* are recognized. The commonest oak is *Quercus incana* occupying a zone between 2000-2666 m. *Rhododendron arboreum*, *Lyonia ovalifolia*, *Carpinus viminea*, *C. pendulus* and *Ilex odorata* are the common associated trees below the oak canopy. *Acer oblongum*, *Alnus nepalensis*, *Myrica sapida* and *Pyrus pashia* form an evergreen second storey. There is a good deal of shrubby undergrowth of both deciduous and evergreen species and climbers are very rare. *Quercus dilatata* is comparatively more mesophytic type than *Quercus incana*. *Quercus semecarpifolia* is represented by the patchy occurrence at higher elevation.

The lower limit of chir pine is characterized by the occurrence of moist mixed deciduous forest which generally extends from 600 m to 1666 m along the exposed slopes with poor or no soil. The principal components of this forest are *Terminalia* spp., *Syzygium cumini*, *Ougeinia dalbergioides*, *Salmalia malabarica*, *Cordia dichotoma*, *Sterculia pallens* and *Euphorbia* spp. *Bauhinia vahlii* and *Pueraria tuberosa* are the commonest climbers attaining large size.

#### MATERIAL AND METHOD

*Field Work* — A series of moss cushions and surface samples were collected in order to study the vegetational composition of the forest. The material for pollen analysis was picked up by digging several bore-holes with the help of Hiller's peat-auger provided with 30 cm long chamber. After a detailed survey over the complete area, the samples were finally collected from the deepest bore-hole at an interval of 5 cm and 10 cm each from Naukuchiya Tal and Bhim Tal respectively. All possible precautions were observed to avoid contamination. The peat samples for pollen analysis were stored in the specimen tubes, corked and sealed with paraffin wax so to keep the samples moist and free of contamination till treatment



TEXT-FIG. 2

in the laboratory. Field notes pertaining to the nature of sediments and the vegetation around were recorded on the spot. Extra material for the study of seeds and fruits analysis and radio-carbon dating was also collected from different horizons in the profile.

*Laboratory Techniques* — The pollen slides from the herbarium material were prepared by Erdtman's method of acetolysis (Erdtman, 1952) and sealed with paraffin wax. To liberate the pollen grains/spores from moss cushions and sediments, the samples were first subjected to 10% KOH treatment and then the material was processed through the technique devised by Erdtman (1943).

As an ancillary to pollen-analytical investigations pollen morphology of five hundred plant species of the modern flora distributed in this region has been studied. The flora as a whole is akin to the flora in the N-W Himalayas of which the pollen-morphology has not been completely known. Hitherto, pollen-morphological studies of the N-W Himalayan flora have been made from the Kashmir Valley (Nair, 1966) which also includes quite a few species common to Punjab and Uttar Pradesh Himalayas and exclusive studies of local pollen flora was, therefore, considered all the more important for the identification of subfossil pollen recovered from the sediments.

Two hundred to five hundred arboreal pollen grains were counted in each sample and percentages for both arboreal and non-arboreal pollen grains were calculated in terms of arboreal pollen sum. Separate pollen diagrams for AP and NAP were constructed. Some subsidiary diagrams have also been constructed to illustrate some features of importance regarding hydrarch succession and climatic oscillations etc.

### MODERN POLLEN RAIN

Palynological investigations of a series of moss cushions and surface samples from subtropical zone in the Naini Tal District has been made in order to assess the present day vegetational composition in the pollen rain of the area around under investigation. While studying the moss cushions and surface samples the local representation of vegetation over the pollen contents, the differential pollen preservation, the long

transportation of the pollen through the winds and the effect of plant disease on pollen production have been well considered. The moss cushions were collected from the rocks, pine trees, oak trees and other places from the outskirts of the forest. Recently it has been realized that the composition of the forest is not adequately reflected by the study of moss cushions and surface samples in the Kashmir Valley and South Indian Mangroves owing to various limiting factors (Vishnu-Mittre & Robert, 1971; Singh *et al.*, 1973; Caratini *et al.*, 1973). Sharma (1973) while studying the moss cushions from Himachal Pradesh has pointed out that except for *Quercus*, *Picea*, *Abies* and *Cedrus*, the pollen spectra faithfully reflects the true picture of modern vegetation. However, the study of moss cushions has revealed the abundance of wind borne pollen grains whereas insect borne pollen grains are almost absent and hence this has been taken as the basic criterion for interpreting the vegetational developments reconstructed from the pollen analysis of the profiles from Kumaon Himalaya.

In order to collect the moss cushions from different altitudinal zones, a traverse was taken from Naini Tal (2117 m a.s.l.) to Bhowali (1700 m a.s.l.), a distance of 10 km. Another traverse was made from Bhim Tal (1500 m a.s.l.) to Sat Tal (1200 m a.s.l.), a distance of about 2.5 km.

Efforts have been made to minimize the local representation of the pollen coming from the plant itself. This is done by selecting either a rock in the open, dry and/or immature tree standing in the open.

The moss cushions analysed have been so arranged, as to give an idea of the important vegetational changes in accordance with the changing altitude. Two separate histograms have been constructed and all the moss cushions collected from higher elevation have been put at the top in the histograms and they are followed downwards by low elevation moss cushions and surface samples.

### NAINI TAL-BHOWALI BELT

Text-fig. 3

The general pattern of present day vegetation along this traverse is the subtropical chir pine-oak forest except for the starting point at Naini Tal which is perhaps the

transition of temperate broad-leaved forest and sub-tropical chir pine-oak forest. At the initial point the area is marked by high frequency of broad-leaved elements and considerably less subtropical elements. But as soon as one takes traverse down to Bhowali the proportion of subtropical elements increases gradually and the predominance of chir pine-oak woods is observed at the lower limits.

*Moss Cushion 1*—This was collected from the rock along the road side at Naini Tal (2117 m a.s.l.) at the transition of temperate broad-leaved forest and sub-tropical chir pine forest and reveals the low values of subtropical elements such as *Pinus roxburghii* (13%), *Quercus* (14%), *Ulmus* (12%), *Morus* (9%) and *Glochidion* (25%) are represented by high frequencies. *Celtis*, *Rhus* and *Fraxinus* are lowly present whereas *Bauhinia* is abundantly high. Amongst the shrubby vegetation Leguminosae dominates but *Jasminum* and *Strobilanthes* are rare. The herbaceous elements are comparatively very low. Compositae, Chenopodiaceae, Piperaceae, Polygonaceae, Gramineae, Cyperaceae and ferns are the only representatives of herbaceous vegetation.

The occurrence of temperate broad-leaved forest with a considerable admixture of subtropical elements is faithfully brought out through the study of moss cushion. The low values of *Pinus roxburghii* indicates relatively less occurrence of chir pine trees in the vicinity or their pollen grains may be interpreted as transported from the low elevation. The low values of non-arbores and high values of arboreals suggest the existence of thick forest.

*Moss Cushion 2*—This was collected at 2000 m a.s.l. and vegetation type is more or less same as in the moss cushion-1. The analysis of this moss cushion gives almost the same picture as in the preceding one except for *Quercus* which records higher values. *Pinus roxburghii* is further reduced. The frequencies for *Glochidion* also reduce considerably and *Bauhinia* is absent. *Betula* is recorded by the occurrence of a few pollen grains only. Amongst shrubby vegetation Leguminosae remains almost the same but *Jasminum* increases. The herbaceous elements such as Compositae, *Artemisia*, Urticaceae, Polygonaceae, Cyperaceae and ferns are present in reduced values. Piperaceae has comparatively increased values. This

further confirms the observations that the area was inhabited by temperate broad-leaved elements along with the subtropical chir pine forest constituents.

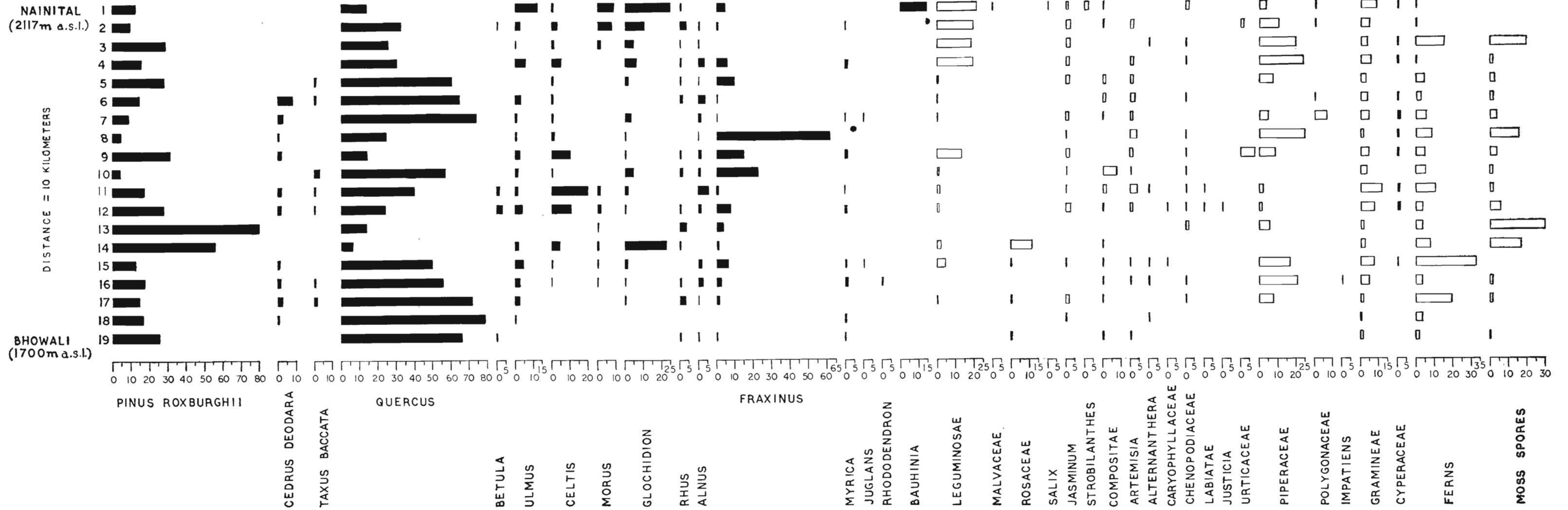
*Moss Cushion 3*—In this moss cushion the proportion of subtropical elements increases gradually and temperate elements are reduced considerably. *Pinus roxburghii* shows an increasing trend in the values followed by the relative decrease in *Quercus*. *Ulmus*, *Celtis* and *Morus* show considerable fall in their values. *Betula* is totally absent and *Glochidion* shows steep fall in the values. *Rhus* and *Alnus* are sporadically present. No fluctuation is noticed in the values of Leguminosae and *Jasminum*. Amongst the herbaceous elements Compositae, *Artemisia* and Urticaceae are not recorded but *Alternanthera*, Chenopodiaceae come up with very much reduced values. Piperaceae shows gradual rise. Gramineae and Cyperaceae remain  $\pm$  same except for minor fluctuations. Ferns are increased tremendously and moss spores are also encountered.

*Moss Cushion 4*—In this moss cushion the values for *Quercus* remain more or less the same but *Pinus roxburghii* shows considerable fall in its values. *Betula* is absent. *Ulmus* and *Celtis* are comparatively higher than the previous moss cushion. *Morus* is absent. *Glochidion* and *Rhus* remain almost same. *Alnus* and *Fraxinus* have comparatively high values. *Myrica*, *Jasminum* and Leguminosae do not show any fluctuation. Amongst herbaceous vegetation Chenopodiaceae, Gramineae, Cyperaceae and ferns are lowly present whereas Piperaceae show further increase in its values. Moss spores are very rare.

*Moss Cushions 5-7*—The analyses of these moss cushions have recorded tremendously high values of *Quercus* but *Pinus roxburghii* on the other hand shows decreasing trend in its values. *Taxus baccata* is represented by one or two pollen grains only. *Cedrus deodara* pollen grains have been recorded in 5th and 6th moss cushions. *Betula* is absent. *Ulmus*, *Celtis*, *Glochidion* and *Rhus* experience low values. *Alnus* and *Fraxinus* are fluctuatingly low. *Myrica*, *Juglans*, *Jasminum* and Leguminosae are sporadic. Amongst herbaceous vegetation Compositae, *Artemisia*, Chenopodiaceae, Gramineae, Cyperaceae, and ferns remain low. Piperaceae is much more reduced but Polygonaceae has increased values.

# MOSS CUSHIONS FROM NAINITAL - BHOWALI

(PERCENTAGES CALCULATED IN TERMS OF AP)



TEXT-FIG. 3

The study of these moss cushions depicts that *Quercus incana* predominates over *Pinus roxburghii* in the subtropical forest.

*Moss Cushion 8* — It is represented by exceedingly high values of *Fraxinus*. *Pinus roxburghii* is represented by the sporadic values. *Quercus* has reduced values than before. *Cedrus deodara*, *Ulmus*, *Celtis*, *Glochidion* and *Alnus* are extremely low. The shrubs are almost absent. *Jasminum* is represented by only one or two pollen grains. Amongst herbaceous elements, *Piperaceae* and *Artemisia* record high values. *Chenopodiaceae*, *Gramineae* and *Cyperaceae* are sporadic. Fern and moss spores show increasing tendency.

*Moss Cushion 9* — In this moss cushion the values for *Pinus roxburghii* rose tremendously but *Quercus* shows further decrease in its values. *Celtis* and *Ulmus* show increasing trend whereas *Glochidion*, *Rhus* and *Alnus* remained almost the same as before. *Fraxinus* has extremely reduced values. Amongst shrubs, *Leguminosae* has increased but *Myrica* and *Jasminum* have reduced values. Amongst herbaceous elements *Artemisia*, *Chenopodiaceae*, *Urticaceae*, *Piperaceae*, *Gramineae* and *Cyperaceae* are recorded. Fern spores are present in reduced values.

*Moss Cushions 10-12* — In these moss cushions *Quercus* on the whole dominates over *Pinus roxburghii* but *Quercus* shows decreasing trend and *Pinus roxburghii* shows increasing trend in samples 11 and 12. *Cedrus deodara*, *Taxus baccata*, *Betula*, *Ulmus*, *Morus*, *Glochidion*, *Rhus* and *Alnus* have increased tendency. *Celtis* gained tremendously high values. *Fraxinus* has reduced considerably and its values in sample no. 11 are sporadic. *Myrica*, *Jasminum* and *Leguminosae* are represented by sporadic values. Herbaceous vegetation is represented by low values of *Chenopodiaceae*, *Labiatae*, *Justicia* and *Piperaceae*. *Artemisia*, *Compositae* and *Gramineae* show increasing tendency. *Cyperaceae* is lowly represented. Fern spores have slightly increased but moss spores are reduced considerably.

*Moss Cushions 13 & 14* — These two moss cushions have revealed exceedingly high values of *Pinus roxburghii* recording a maximum of 80% and corresponding decrease in the values of *Quercus*. The other components such as *Ulmus*, *Celtis* and *Morus* are represented by low values. *Glochidion*

is absent in sample no. 13 but appears with high values in sample no. 14. *Rhus* and *Fraxinus* maintain low values. Shrubby elements are absent in both the moss cushions. *Leguminosae* is lowly represented whereas *Rosaceae* has emerged with high values. Herbage is also poor and documented by very low values of *Compositae*, *Chenopodiaceae*, *Piperaceae* and *Gramineae*. Fern spores are present in low frequencies but moss spores record high values.

The analyses of these two moss cushions suggest the predominance of chir pine forest with a considerably low values of *Quercus* which is strictly in accordance with the present day floristic composition with comparatively drier conditions.

*Moss Cushions 15-19* — The investigation of the above moss cushions has revealed the dominance of *Quercus* over that of *Pinus roxburghii*. *Quercus* rose tremendously but *Pinus roxburghii* shows a steep fall. *Ulmus* maintains increased values. *Cedrus deodara*, *Taxus baccata*, *Betula*, *Celtis*, *Morus*, *Glochidion*, *Rhus*, *Alnus*, *Fraxinus* and *Myrica* are either sporadic or maintain very low frequencies. Shrubby vegetation is very sporadic. Amongst herbage *Piperaceae*, *Gramineae* and ferns dominate while other elements remain insignificant.

Pollen analyses of the moss cushions from Naini Tal-Bhowali belt suggest that palynodata are more or less in accordance with the broad vegetational pattern. The area is predominated by oak woods and chir pines are represented by a few patches on the exposed dry rocks. The frequency of chir pines increase considerably towards the lower limit. The high values of chir pine pollen in some of the samples could be assigned to the high pollen production and long transportation. However, in view of the above features the absolute pollen frequency of chir pine has not been considered for interpretation of vegetational composition rather they have been evaluated in the light of Iversen's (1947) numerical reduction.

#### BHIM TAL-SAT TAL BELT

Text-fig. 4

The general pattern of vegetation along Bhim Tal - Sat Tal Belt is marked by the subtropical chir pine-oak forest. The lower



limit below 1200 m a.s.l. is characterized by predominance of *Bauhinia* spp.

*Moss Cushions 1-3* — Pollen analyses of these three moss cushions have revealed a characteristic subtropical chir pine-oak forest in which the proportion of oaks is more than that of chir pine. This proportion of chir pine-oak trees in the sub-tropical region suggests the prevailing moist and humid conditions. The other associates recorded in good frequencies are *Ulmus*, *Celtis*, *Morus* and *Glochidion*. *Cedrus deodara* is also present in good frequencies. *Betula*, *Rhus* and *Myrica* are sporadic. The values for *Alnus* and *Fraxinus* are quite high in the first sample but they soon dwindle down in the subsequent samples. The shrubby vegetation, represented by Leguminosae, Rosaceae and *Jasminum* is recorded by low values. Amongst herbage, Compositae, *Artemisia*, *Alternanthera*, Caryophyllaceae, Chenopodiaceae, Polygonaceae and Cyperaceae are recorded by very low frequencies. Gramineae in sample no. 2 is very low but increases considerably in sample no. 3. Piperaceae experiences very high values in sample no. 2 but gradually reduces in sample no. 3. The ferns are recorded by very high values in sample no. 1 and reduces to very low values in sample no. 2 but regained high values in sample no. 3. Moss spores are sporadic. One pennate type of diatom has also been encountered in sample no. 1, which was collected from near the shore of Bhim Tal lake.

*Moss Cushions 4-6* — In these moss cushions *Pinus roxburghii* shows overall increase but *Quercus incana* decreases considerably. *Cedrus deodara*, *Taxus baccata* and *Betula* remain sporadic. *Ulmus* has quite high values except for sample no. 2. *Celtis* is present in good frequencies only in sample no. 6. *Morus* has high values in sample no. 4 but absent in sample no. 5 and reappears in sample no. 6. *Glochidion* is noticed in sample no. 6 only. *Alnus*, *Fraxinus* and *Myrica* are recorded in high frequencies in sample nos. 5 and 6. The shrubs such as Leguminosae and *Jasminum* show high values in sample no. 4 but reduced to very low values in subsequent samples. Rosaceae is sporadic. The herbage is represented by low values of Compositae, Chenopodiaceae, Piperaceae, Cyperaceae and *Alternanthera*. *Artemisia* has slightly higher values than before. Gramineae is recorded

by high values. Fern spores are represented by fairly high values. One pennate diatom (*Pinnularia*) has been encountered from sample no. 6 which was collected from near shore of Sat Tal lake.

The statistical analyses of a series of moss cushions and surface samples from Kumaon Himalaya have revealed that the relative percentages of the pollen grains and spores trapped in moss cushions do match to a great extent with the present day floristic composition of the area. However, some of the forest constituents and associates remain sometimes unrepresented or under represented. Recently, it has been worked out that the representativity of the individual taxon in the pollen spectra is governed by several vital factors rather than only two factors, viz., entomophily and differential pollen production (Caratini *et al.*, 1973). The major factors involved are as follows :

(a) *Differential production, dissemination and preservation of pollen and spores* — In this case species 'A' having good production of pollen grains and their long range of transportation and high resistance (i.e. more sporopollenin), stands better chance of representation rather than species 'B' which lacks the above characters. Thus the species 'A' will be over-represented and species 'B' will be under-represented in the pollen spectra.

(b) *Occurrence of entomophily in the plant species*. — The insect pollinated species are either totally absent or under-represented in the pollen spectra. In this case the best approach will be to multiply the insect borne pollen grains by ten and divide high producing wind-borne pollen grains by ten and then interpret the whole diagram.

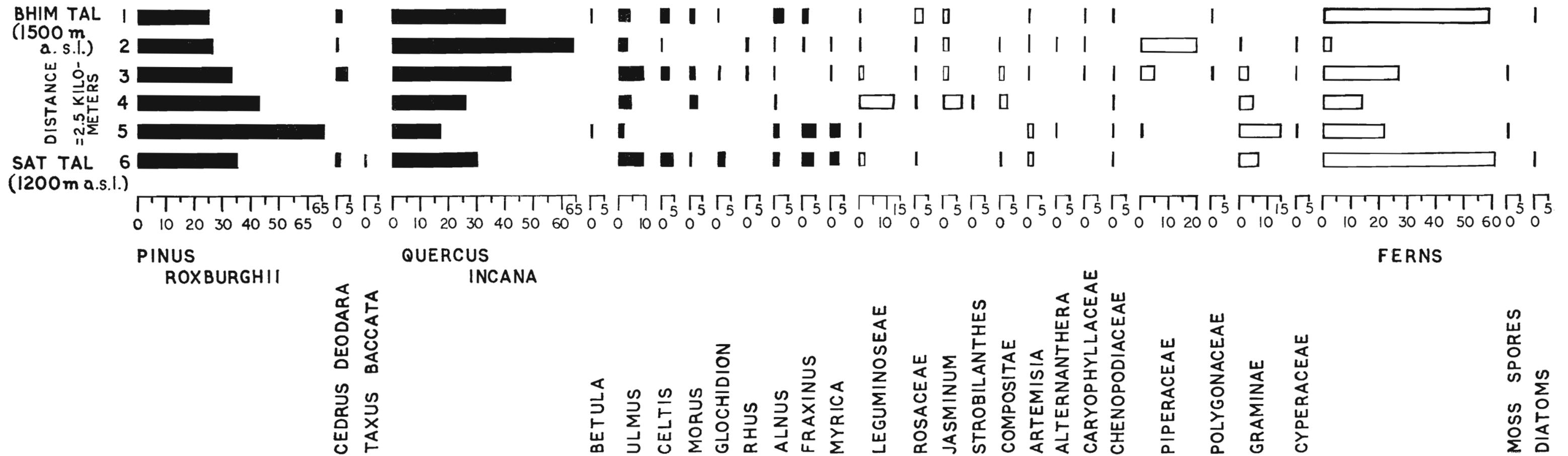
(c) *Biological and physico-chemical degradation of pollen and spores*. — Thus the feeble pollen and spores whether partially or totally decayed in the pollen assemblage can not be identified to their correct genera and species and therefore, it will not only give an incomplete but a very distorted and deceptive picture of the vegetation in the pollen diagram. To avoid such a complex identification and wrong interpretation the corroded pollen and spores have not been considered since their proper identification could not be made.

(d) *Existence of cleistogamy and autogamy*.

(e) *Stenopalyny* — In such cases it is necessary to study the size and shape statistics

# MOSS CUSHIONS FROM BHIMTAL-SAT TAL (NAINITAL)

(PERCENTAGES CALCULATED IN TERMS OF AP)



TEXT-FIG. 4

for identifying pollen, although it is not always a consistent character. Rosaceae, is represented by many genera in Naini Tal District, being stenopalynous, its genera could not be distinguished palynologically.

The representativity of pollen and spores also suffer from several sources of errors. Indeed, the composition of fossil pollen content vary according to the method of preparation of the samples for investigation. According to the difference of alkali treatment of the samples results are often variable. Furthermore, the peat is inadequately digested by alkali and some pollen will consequently be escaped from observations. Small sized pollen grains (*Quercus* etc.) escape attention more rapidly than the larger ones (*Pinus*) which in turn tend to be over-represented. This is a well known error and may, in certain cases, cause considerable difference in pollen percentage.

It is therefore, considered necessary for reconstruction of past vegetation and correct interpretation of pollen diagrams, that all the essential features related to a plant species be duly considered during the identification and interpretation of a plant species.

Approximately 50% of the total arboreal vegetation growing in the area is faithfully represented in the pollen spectra. The insect-pollinated species such as *Rhododendron arboreum*, *Engelhardtia colebrookiana*, *Myrica sapida*, *Pyrus pashia*, *Cotoneaster* spp. and *Rhus* spp. are abundantly growing in the area but they are under represented or absent from pollen spectra. There are some cleistogamous plant species, viz., *Impatiens* spp., *Viola* spp., *Oxalis* spp. and *Commelina bengalensis* whose pollen grains are not represented in the pollen spectra. In the pollen assemblage there is a possibility of 20-30% admixture of drifted pollen grains. *Ulmus*, *Betula*, *Cedrus deodara* etc. are some of the examples which have either drifted from the top or they have been recently planted in the near vicinity. *Pinus roxburghii* has largely come from the lower valley along with the upthermic winds, as a result of vertical transportation of pollen grains.

## POLLEN ANALYSES OF PEAT PROFILES

### NAUKUCHIYA TAL PROFILE

This, the lake of nine contours as the name implies, lies at a distance of 4 km

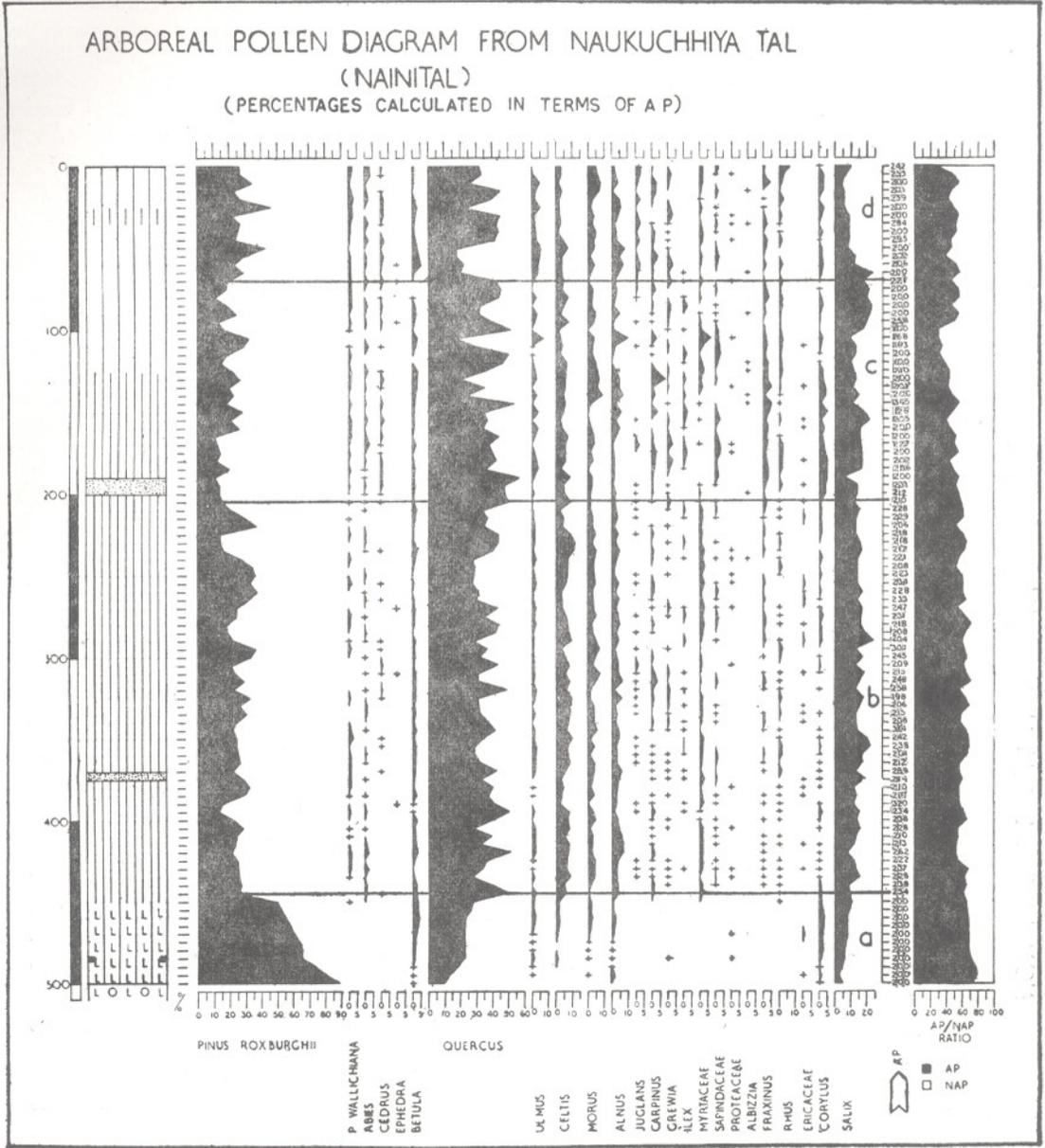
from Bhim Tal and 23 km from Naini Tal, in latitude 29°19'E and longitude 79°35'N at an elevation of about 1333 m. The lake is irregular in shape, being about 900 m long from north to south and 675 m broad at the widest part. The shore is indented with numerous bays which contribute a lot to the picture of the scenery. It is in fact the prettiest of all the Kumaon lakes, lying in basin with high mountains on three sides and with thick oak woods coming down to the water edge. The northern end is open, the water being held in by a low barrier, from the top of which a fine view is to be obtained of Bhim Tal and surrounding hills. In the north-west corner, there is a shallow bay covered with reeds and lotus which when in flower add much colour to the scene.

There is reason to believe that at a former period the lake covered a very much larger area as the surrounding country bears every appearance of having been subjected to the action of water. In this case water would have escaped through the lower strata of the hallow now occupied by the lakes of Naukuchiya Tal and Bhim Tal. Marginally, it is largely dominated by the aquatic and marshy vegetation such as *Nymphaea*, *Nelumbo*, *Phragmites* and sedges. *Limnanthemum* also occurs, though very rare.

The stratigraphy of the marginal area, owing to flooding by heavy rains, could not be carried out. The details of the bore-hole dug in the middle of swampy area are as follows :

- |           |  |
|-----------|--|
| 0-25 cm   | Pale yellow fibrous peat with abundant rootlets. Seeds of <i>Scirpus</i> and <i>Rubus</i> are very common. <i>Carex</i> , <i>Urtica</i> and <i>Cerastium</i> are less common.  |
| 25-35 cm  | Black decomposed peat with abundant plant remains such as cuticles, rhizomes, barks, rootlets etc. Seeds of <i>Scirpus</i> , <i>Carex</i> and <i>Rubus</i> are very common.  |
| 35-125 cm | Yellowish black fibrous peat with abundant rootlets and cuticles. Seeds of <i>Scirpus</i> are abundant but <i>Pseudocyperus</i> , <i>Rubus</i> , <i>Potamogeton</i> , Cyperaceae, Compositae, and <i>Chara</i> nucules are rare. |

125-150 cm	Greenish pale decomposed peat with less frequent plant remains. Seeds of <i>Scirpus</i> , <i>Pseudocyperus</i> , Cyperaceae, <i>Rubus</i> and <i>Chara</i> nucules are not very frequent.		cles abundant but seeds and fruits absent.
150-250 cm	Brownish grey organic mud with a thin layer of silt between 190-200 cm. Various types of seeds of <i>Potamogeton</i> are abundant and the seeds of <i>Scirpus</i> , <i>Pseudocyperus</i> , Cyperaceae, <i>Chenopodium</i> , <i>Ceratium</i> , <i>Urtica</i> , <i>Rubus</i> , <i>Linaria</i> and <i>Chara</i> nucules are less common.	465-475 cm	Black mouldered clayey peat. Plant debris abundant. Woody fragments present. A seed of <i>Rubus</i> at 475 cm depth is noticed.
250-300 cm	Black fibrous peat with abundant red coloured rootlets, cuticles and woody fragments. Seeds of <i>Scirpus</i> , Cyperaceae, <i>Chenopodium</i> , <i>Urtica</i> , <i>Linaria</i> and <i>Potamogeton</i> are rare.	475-485 cm	Black clayey peat mixed with silt and pebbles. Woody fragments abundant. A charcoal fragment and a seed of <i>Potamogeton</i> are encountered at 485 cm depth.
300-350 cm	Brownish grey mouldered peat. Rootlets, cuticles etc. less frequent. Seeds of <i>Scirpus</i> , <i>Carex</i> , Cyperaceae, Compositae, <i>Chenopodium</i> , <i>Potamogeton</i> , <i>Linaria</i> and <i>Chara</i> nucules are rare.	485-500 cm	Black clayey peat mixed with coarse sand and pebbles. Woody fragments abundant. Seeds and fruits absent.
350-400 cm	Black mouldered peat with some rootlets and cuticles. A thin layer of silt is present between 370-375 cm. Seeds of <i>Potamogeton</i> are abundant and of <i>Scirpus</i> , <i>Carex</i> , Cyperaceae and <i>Linaria</i> are very rare.	500-downwards	Sand and Kankar. Seeds, fruits and plant debris totally absent.
400-445 cm	Mouldered peat mixed with coarse silt. Plant fragments are intermittently found. Seeds of <i>Scirpus</i> , <i>Carex</i> , <i>Rubus</i> , <i>Potamogeton</i> and <i>Chara</i> nucules are very rare.		The arboreal pollen diagram (Text-fig. 5) constructed from Naukuchiya Tal reveals the occurrence of oak-chir pine forest comprising <i>Ulmus</i> , <i>Celtis</i> , <i>Morus</i> , <i>Alnus</i> and <i>Salix</i> in good frequencies and <i>Juglans</i> , <i>Carpinus</i> , <i>Grewia</i> , <i>Ilex</i> , <i>Corylus</i> , <i>Betula</i> etc. in very much reduced values. <i>Ephedra</i> , <i>Abies</i> and <i>Cedrus</i> are represented either sporadically or in very much reduced percentages. Myrtaceae, Sapindaceae, Proteaceae, Ericaceae <i>Albizia</i> , <i>Fraxinus</i> and <i>Rhus</i> are less frequently present during the lower half of the pollen diagram but tend to increase to about 5% in the upper half of the diagram.
445-455 cm	Black laminated mouldered peat. Cuticles and rootlets abundant. Seeds and fruits absent.		In the non-arboreal pollen diagram (Text-fig. 6) Gramineae, Cyperaceae, Urticaceae, Piperaceae, <i>Jasminum</i> and Rosaceae are represented by exceedingly high values, whereas the values for cerealia, <i>Plantago</i> , <i>Artemisia</i> , Chenopod-Amaranth type, Umbelliferae, Compositae, Caryophyllaceae, Boraginaceae, Ranunculaceae, <i>Spergula</i> , Labiatae, Scrophulariaceae, Primulaceae, Liliaceae, Rutaceae and <i>Myrica</i> , are not very high. <i>Alternanthera</i> , <i>Impatiens</i> , <i>Schizandra</i> , Papaveraceae etc. are present either sporadically or in very low frequencies. <i>Polypodium</i> , <i>Asplenium</i> and several other ferns are present in fair abundance.
455-465 cm	Black mouldered clayey peat. Rootlets, rhizomes and cuti-		



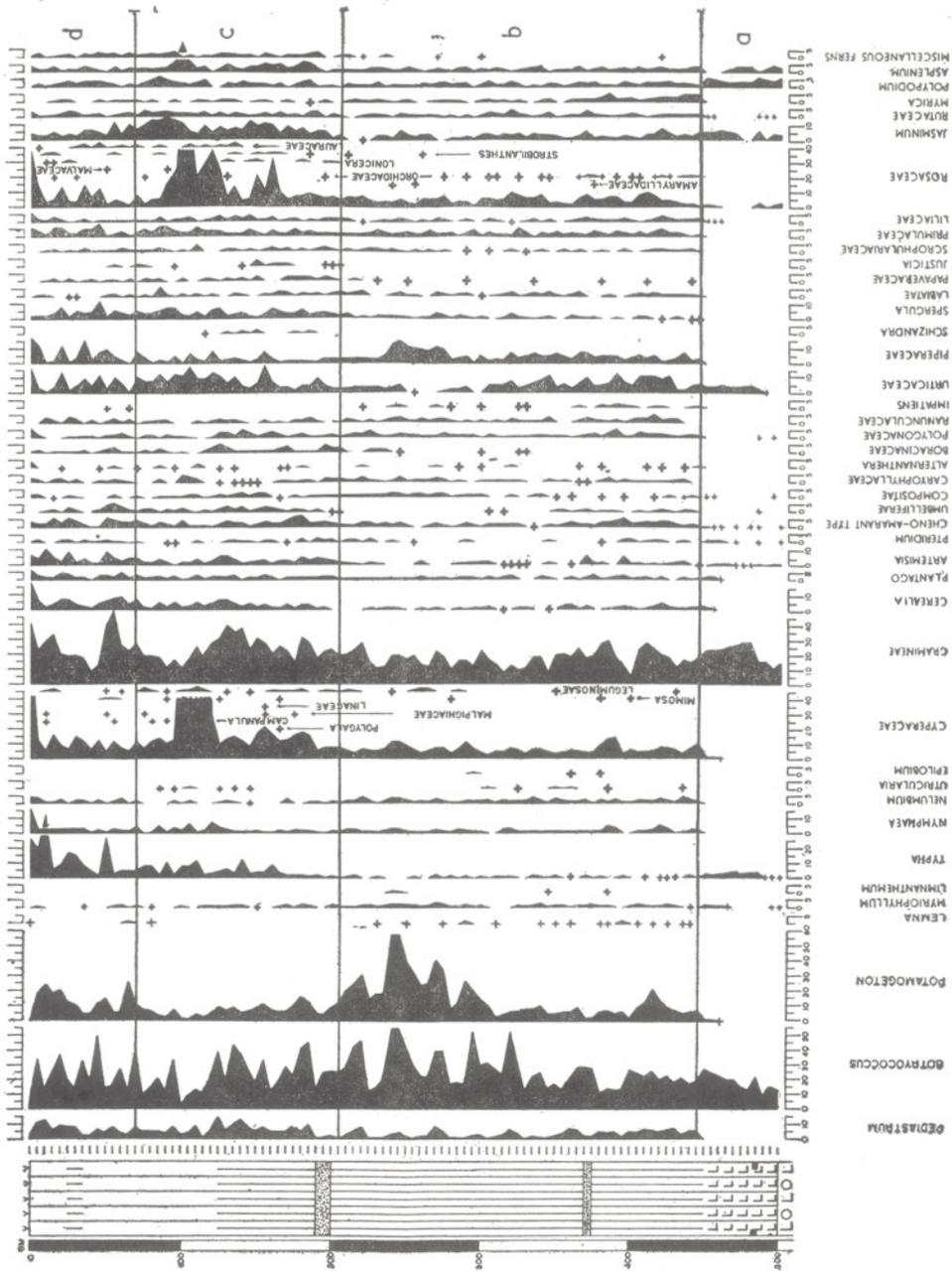
TEXT-FIG. 5

Amongst the aquatics, *Potamogeton* and *Typha* have high values whereas *Myriophyllum*, *Limnanthemum*, *Nymphaea*, *Nelumbo*, *Utricularia* and *Epilobium* are present either sporadically or in very low quantities. Three algae namely *Pediastrum*,

*Chara* and *Botryococcus* are also present. The latter alga is present in high frequencies whereas the former two are less frequent. The pollen curves for most of the above mentioned genera show fluctuations throughout the vegetational sequence. Based on

NON-ARBOREAL POLLEN DIAGRAM FROM NAUKUCHIYA TAI (NAINI TAL)

(PERCENTAGES CALCULATED IN TERMS OF AP)



TEXT-FIG. 6

the changes in some of the arboreal pollen constituents it could be possible to recognize as many as four major vegetational stages. All the stages do not always reflect climatic fluctuations since the oak-chir pine forest continues to remain dominant throughout the pollen diagram except at the base where the chir pine is dominant over that of oaks.

*Stage 'a' — Chir-Pine-Oak Phase* — This stage is characterized by exceedingly high values of chir pine over all other arboreal constituents. *Quercus* also has high values, though comparatively much less than chir pine. *Salix* and *Alnus* form the other minor components of this vegetation. *Betula*, *Ulmus*, *Celtis*, *Morus* and *Corylus* have extremely sporadic values at the base of this stage. *Corylus* and *Betula* form continuous curves a little above the base but the continuous curves of *Celtis*, *Morus*, and *Ulmus* are found towards the top of this stage. Stray pollen grains of *Grewia*, Proteaceae and Ericaceae are also found. Some distance above the base of this stage, oak values increase with a corresponding decline in the values of chir pine.

The non-arboreal vegetation largely consists of Gramineae, Urticaceae, Rosaceae, *Artemisia*, *Jasminum* and ferns. The values of Gramineae increase towards the middle of this stage. *Pteridium*, Chenopod-Amaranth type, Umbelliferae, Compositae, Polygonaceae and Rutaceae are sporadically present. The curve for Urticaceae commences during the lower half of this stage.

The aquatic vegetation is largely represented by *Botryococcus* which shows an ascending trend throughout this stage. Both *Myriophyllum* and *Typha* are sporadic at the base of this stage. *Typha* attains higher values and forms a continuous curve right from middle of this stage whereas *Myriophyllum* forms a continuous curve towards the top of this stage.

During the Upper part of this stage chir pine shows a descending trend and its values are reduced from 90% to 50% and the curve for *Quercus* rose from 10% to 30% simultaneously.

*Stage 'b' — Oak-Celtis-Alder-Morus-Salix Phase* — This stage is marked by consistently high values of *Quercus* together with high values of *Celtis*, *Alnus*, *Morus*, *Salix* etc. and considerably reduced values of chir pine. The values of *Celtis* show a

rising trend, although fluctuating. *Morus* also has a rising trend with higher values in the middle than top and the base of this stage. *Alnus* has comparatively higher values at the base and shows a gradual decline upwards. Myrtaceae maintains a low continuous curve throughout. Sporadic values with occasional low curves are seen in *Juglans*, *Grewia*, *Ilex*, *Fraxinus*, *Rhus*, Sapindaceae, Proteaceae, Ericaceae etc. *Corylus*, which had a continuous curve in the preceding stage, is reduced to sporadic values towards the middle of this stage forming more or less continuous low curve towards the top of this stage. *Betula* maintains a continuous low curve. Pollen of *Ephedra* is extremely sporadic. *Pinus wallichiana*, *Abies* and *Cedrus* have either sporadic values or low discontinuous curves. The values of oaks rise towards the top of this stage.

The values of Gramineae on the whole are comparatively reduced than in Stage 'a'. Cyperaceae is comparatively higher during the upper half of this stage. Urticaceae has higher values except towards the top but Piperaceae attains higher values at the top. *Plantago*, *Artemisia*, *Pteridium*, Compositae, Chenopod-Amaranth type, Polygonaceae, Ranunculaceae etc. have low consistent curves with comparatively higher values towards the base of this stage. *Jasminum*, Rosaceae and Rutaceae maintain high values. *Strobilanthes* and *Lonicera* are of occasional occurrence. *Polypodium*, *Asplenium* and several other ferns form low curves.

*Botryococcus* is abundantly present especially towards the upper half of this stage and *Pediastrum* has a fluctuatingly low curve. The high values of *Potamogeton* are seen at the base which rise towards the top of this stage. *Myriophyllum*, *Typha*, *Nymphaea*, *Nelumbo*, *Utricularia*, *Epilobium*, *Limnanthemum* and *Lemna* are very sporadically present. Cerealia? pollen are first noticed at the extreme top of Stage 'a' and soon forms a continuous curve which is maintained throughout Stage 'b'.

*Stage 'c' — Oak-Elm-Carpinus-Fraxinus-Corylus-Salix Phase* — During this stage the oak values are much higher than in the preceding stages. *Ulmus* shows intermittently high values. The values for *Celtis* are comparatively reduced than in the previous stage. *Morus* attains higher values

and the values of *Alnus* are also higher. *Carpinus* forms a more or less continuous curve with higher values than before. Curve for Myrtaceae becomes sporadic, although with much higher values towards the upper part of this stage. Sapindaceae forms more or less a continuous curve. *Fraxinus* attains continuous curve with higher values and similar continuous curves are seen for *Rhus* and *Corylus*. The curve for *Salix* maintains higher values and increases towards the top of this stage.

The non-arboreal vegetation shows a considerable increase in Cyperaceae over that of Gramineae towards the top of this stage. Urticaceae, Piperaceae and Primulaceae also increase towards the top and there is an overall increase in the other constituents as well. A considerable increase is also noted among the shrubs of which Rosaceae attains very high values together with *Jasminum* and some ferns.

Aquatic vegetation continues to abound in *Botryococcus*. The values of *Pediastrum* also increase during this stage. *Potamogeton* is comparatively reduced and the ascending trend for *Typha* and *Nymphaea* curves is very much characteristic of this stage. *Myriophyllum* and *Nelumbo* show low discontinuous curves. *Utricularia* and *Lemna* have sporadic values towards the top of this stage.

The cerealia pollen curve becomes continuous and has high values towards the middle of this stage.

Stage 'd' — It is almost the continuation of the previous stage showing slight ascending trend in chir pine and slight decline in oaks value. Elm and *Morus* maintain comparatively higher values whereas *Celtis* is comparatively reduced. The decline of *Salix* sets in at the beginning of this stage. The arboreal constituents have comparatively reduced values except for *Juglans* which during this stage forms a continuous curve for the first time in the entire pollen diagram. *Ilex* is consistently reduced to sporadic values at the base of this stage and no pollen is seen during rest of the stage. *Betula* increases towards the base and the middle of the stage although showing declining trend. Low continuous curves but with comparatively higher values of blue pine (*Pinus wallichiana*), *Abies* and *Cedrus* are also seen during this stage.

The non-arboreal vegetation consists of high values of Gramineae with a declining trend of Cyperaceae which in turn shows a rise towards the extreme top of this stage. Urticaceae is more or less same as before. Increased values of Piperaceae alongwith several other herbaceous constituents are present. The shrubby vegetation is represented by Rosaceae which has reduced at the base but attains considerably high values towards the top.

*Botryococcus* and *Pediastrum* continue to maintain more or less the same position as in the preceding stage. Both *Potamogeton* and *Typha* maintain high values especially towards the top. *Nymphaea* and *Nelumbo* maintain more or less continuous curves showing increase towards the extreme top.

#### BHIM TAL PROFILE

Bhim Tal is one of the largest lakes in the district. The lake lies at an elevation of 1500 m a.s.l. in latitude 29°34' E and longitude 79°36' N. Its length including the swamp to the north-west is 1860 m, while its breadth is 497 m at the widest and 208 m at the narrowest point, occupies an area of about 155 acres. The details of the bore-hole selected for pollen analysis are as follows:

- |            |  |
|------------|--|
| 0-60 cm    | Brown fibrous peat with abundant plant fragments. Seeds of <i>Scirpus</i> , <i>Carex</i> , <i>Urtica</i> are abundant and <i>Cirsium</i> , <i>Sonchus</i> , <i>Rubus</i> , <i>Rumex</i> and <i>Cerastium</i> are very rare. Detached leaves of mosses (5-6 types) are in fair abundance. |
| 60-80 cm   | Brownish grey laminated peat alternating with fine silt. Plant fragments are very rare. Seeds of <i>Scirpus</i> , <i>Carex</i> , <i>Rubus</i> , <i>Urtica</i> and <i>Rumex</i> are very common.  |
| 80-100 cm  | Dark brown decomposed peat with abundant cuticles and rootlets. Seeds of <i>Scirpus</i> , <i>Carex</i> , <i>Nymphaea</i> , <i>Urtica</i> and <i>Rumex</i> are very rare but <i>Linaria</i> seeds are very common.  |
| 100-140 cm | Brown fibrous peat with abundant rootlets and cuticles. Seeds of <i>Scirpus</i> , <i>Carex</i> , <i>Rubus</i> , <i>Urtica</i> , <i>Rumex</i> , <i>Chenopodium</i> and <i>Linaria</i> are rare to common.   |



140-180 cm Grey clay with kankar. Plant debris rare. Seeds of *Scirpus*, *Carex*, *Rubus* and *Chenopodium* are very rare.

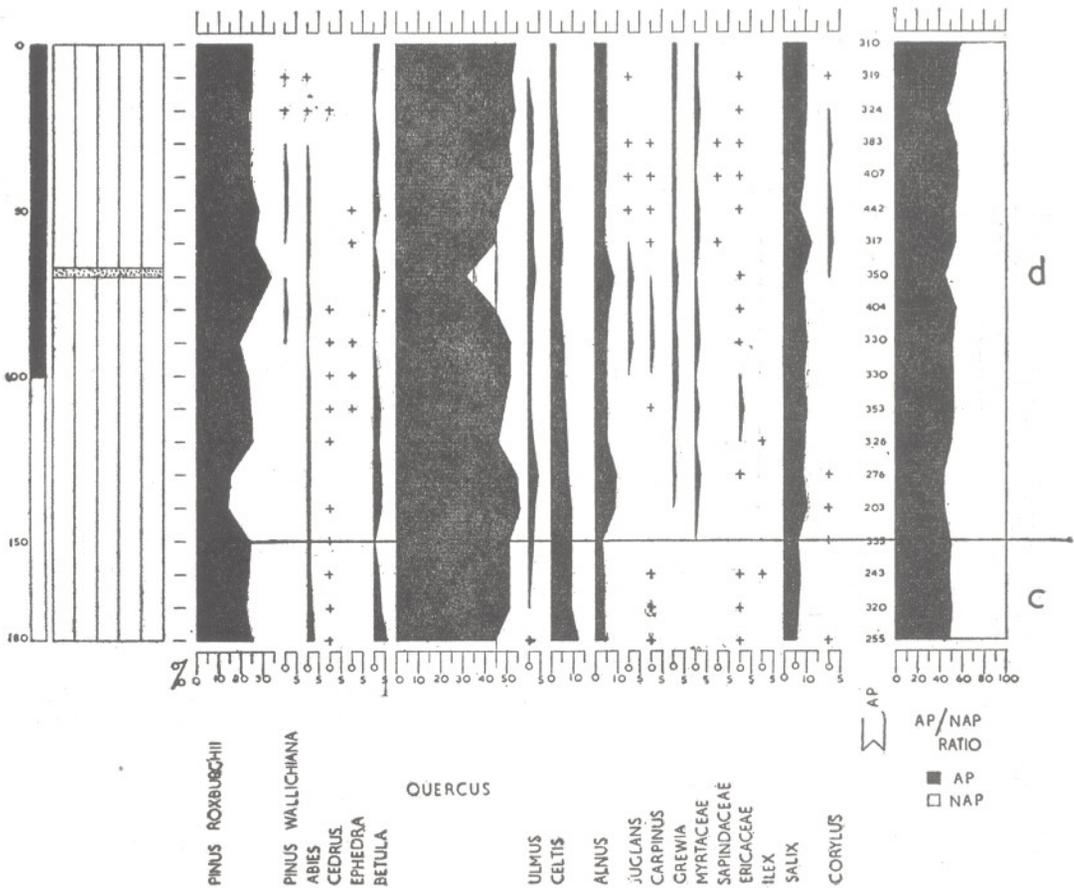
The arboreal pollen diagram from Bhim Tal (Text-fig. 7) shows a pattern of vegetation which is not very different from that of Naukuchiya Tal pollen diagram and more especially with the upper part of the pollen diagram. Based on the curves of *Ulmus*, *Celtis*, *Alnus*, *Grewia* and Myrtaceae it appears that only two vegetational stages

can be recognized in this diagram, viz., *Oak-Celtis-Alnus-Salix* phase between 180-150 cm and *Oak-Celtis-Alnus-Salix-Myrtaceae-Grewia* phase above 150 cm. Towards the top of the stage pollen grains of *Juglans*, *Corylus* and *Carpinus* appear.

Correlating these two stages with the Naukuchiya Tal pollen diagram, the vegetational stage recognized between 150-180 cm corresponds with the top of Stage 'c' in Naukuchiya Tal pollen diagram and the rest of the Bhim Tal pollen diagram corres-

## ARBOREAL POLLEN DIAGRAM FROM BHIM TAL (NAINI TAL)

(PERCENTAGES CALCULATED IN TERMS OF AP)

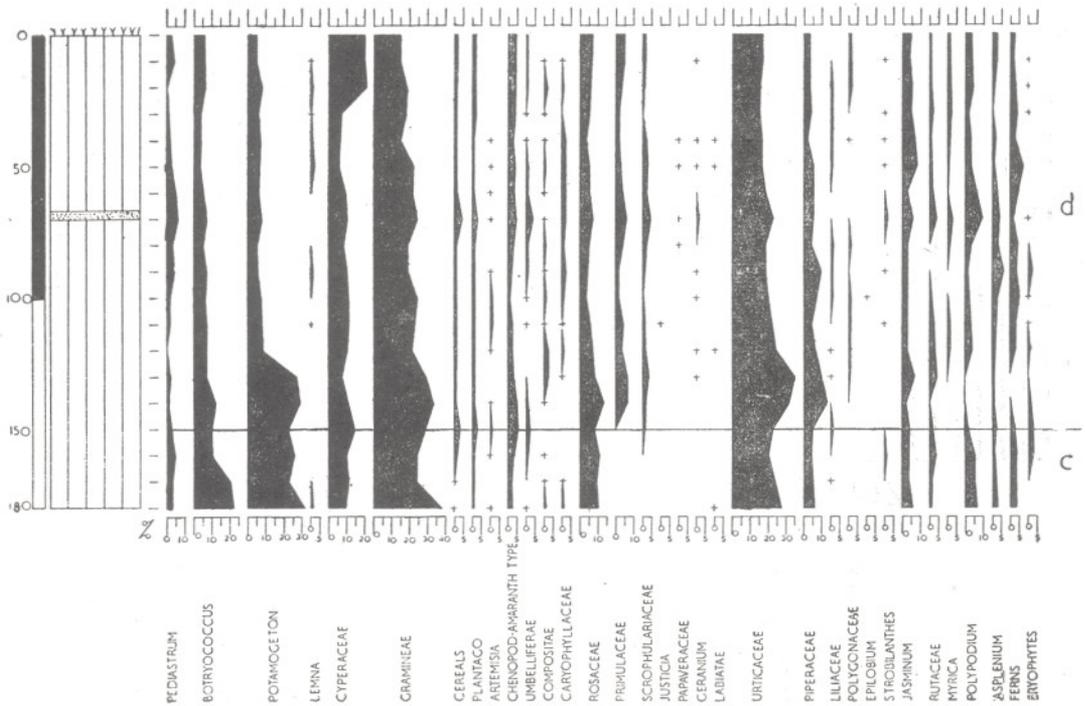


TEXT-FIG. 7

ponds with Stage 'd' of Naukuchiya Tal pollen diagram. Since these two sites are separated by a distance of about three miles from each other, minor vegetational differences noted may be attributed to the local factors. The general composition of the forest remains more or less the same, since the Bhim Tal-Naukuchiya Tal was one basin during the period of last glaciation and was occupied by two glaciers (Raina, 1965). Towards the extreme top of these two diagrams minor differences are noticeable in the fluctuations of oak and chir pine curves. For instance the oaks continue to show a rising trend in the Bhim Tal pollen diagram and the chir pine does not show any increase in contrast to a declining trend in the oak curve and rising values of chir pine in Naukuchiya Tal pollen diagram.

Stage 'c' — The non-arboreal (Text-fig. 8) vegetation during Stage 'c' chiefly consisted of Gramineae, Chenopod-Amaranth type, Rosaceae, Urticaceae, Piperaceae, *Jasminum*, *Polypodium* and other ferns which are present in fairly high values throughout this stage and almost all the curves after attaining maximum values show a declining trend towards the close of this stage except that of Piperaceae and Urticaceae which maintain their peaks slightly above the close of Stage 'c' but soon after they dwindle down. The values of cerealia pollen commence sporadically in the beginning of this stage but maintain a continuous curve showing an increasing trend towards the close of this stage. *Plantago* is present consistently throughout the stage and shows an increase in the values at the same horizon where the cerealia pollen attain maximum

NON-ARBOREAL POLLEN DIAGRAM FROM BHIM TAL (NAINI TAL)  
(PERCENTAGES CALCULATED IN TERMS OF AP)



TEXT-FIG. 8

values and so is the case with *Artemisia* which is not present in the lower half of the stage but maintains fairly high values towards the close of the stage. The curve for Umbelliferae behaves more or less in the same way as that of cerealia pollen. Compositae, Caryophyllaceae, Labiatae and Liliaceae are represented extremely sporadically whereas the values for *Justicia*, *Campanula*, Papaveraceae, Primulaceae, Scrophulariaceae, Polygonaceae etc. are absent from this stage. Amongst the shrubby vegetation *Strobilanthes* is very rarely met with and *Myrica* is altogether absent.

The aquatic vegetation during this stage is represented by exceedingly high values of *Potamogeton* and *Botryococcus*. *Pediastrum* attains a comparatively low curve and shows a declining trend towards the close of this stage. *Lemna* is present in very much reduced values. Cyperaceae is also present in comparatively reduced values throughout the stage.

Stage 'd' — In this stage all the curves for herbaceous and shrubby plants show a remarkable decline in their values and cerealia pollen curve shows increased values at the depth of 65 cm. Cyperaceae, on the other hand, continues in low frequencies throughout the stage except that it increases tremendously towards the top of this stage from 7% to 25% and continues in higher values till the end of the diagram.

*Potamogeton* and *Botryococcus* show steep decline in their values and maintain low values throughout the stage. *Pediastrum* after its decline in the beginning of this stage increases to a considerable extent and declines again but present in fair abundance towards the top. *Lemna* also attains higher values than before but does not form a continuous curve.

## VEGETATIONAL HISTORY

### FOREST HISTORY AND LAKE VEGETATION

Since Naukuchiya Tal is deeper and of greater antiquity than the Bhim Tal, its pollen diagrams have been taken as standard for describing the Post-glacial vegetational history of Kumaon Himalaya. The Naukuchiya Tal pollen diagrams bring out a succession between chir pine woods

and oak woods. It has been possible to recognize four distinct vegetational phases and these are designated by alphabetical letters 'a', 'b', 'c' and 'd' as four stages.

The vegetational history begins with dominant subtropical chir pine forest maintaining a value of about 88%. Oak woods were poorly represented, i.e. not exceeding more than 10%. The oaks during this phase probably occurred only in pockets and depressions where the conditions were moist and favourable for their growth. The other broad-leaved constituents such as birch, elm, *Celtis*, *Morus*, *Alnus*, *Corylus* and Ericaceae were of rare occurrence. *Salix* was present in very much reduced frequencies. The shrubby vegetation during this phase was poorly represented by Rosaceae and *Jasminum*. Rutaceae was extremely rare. *Polypodium* and *Asplenium* were fairly frequent.

Amongst the ground vegetation Gramineae had higher values and *Artemisia*, *Pteridium*, Chenopod-Amaranth type, Umbelliferae and Compositae were extremely rare.

The lake vegetation, along the shores *Salix* existed, was dominated by *Botryococcus*. *Myriophyllum* and *Typha*, though very rare were, also present.

The chir pine declined during the middle of Stage 'a' and there was a relative increase in oaks. The expansion of oaks was soon followed by the other broad-leaved constituents such as birch, elm, *Celtis*, *Alnus* and *Corylus*. This shift in the composition of forest was accompanied by rise in Gramineae and Urticaceae. *Botryococcus* and *Typha* also increased slightly.

During Stage 'b' oaks increased and chir pine reduced considerably from 88% to 50%. The establishment of the oak woods was also followed by an increase in birch, elm, alder, *Celtis*, *Morus* and *Corylus*.

The shrubby vegetation was largely made up of *Jasminum* and there were some Rosaceae too. *Polypodium* declined. The ground cover was much reduced as indicated by the decline in Gramineae. At this level large sized graminoid pollen (above 50  $\mu$ m) alongwith stray occurrence of *Plantago*, *Artemisia*, *Rumex*, Chenopod-Amaranth type, *Pteridium*, Umbelliferae and Compositae pollen have been encountered.

In the lake vegetation *Botryococcus* rose gradually and *Potamogeton* commenced at

this level. *Myriophyllum* and *Typha* were sporadic. Cyperaceae was present in low frequencies.

The vegetational pattern during Stage 'b' had considerably changed (Vishnu-Mittre *et al.*, 1967). In the broad-leaved forest which was now established, *Carpinus*, *Rhus* and Myrtaceae occurred sporadically.

In these predominated oak woods, *Celtis* was fairly abundant, probably inhabiting the swamps. *Morus* and *Alnus* were frequently present but declined afterwards. *Juglans*, *Carpinus*, *Grewia*, *Ilex*, *Corylus*, *Fraxinus*, Sapindaceae, Proteaceae, and Ericaceae were also present. *Salix* maintained high values.

The undergrowth now consisted of low values of Rosaceae and *Jasminum*. *Myrica* was present in fair abundance during the lower half of this stage but decreased later. *Strobilanthes* was rare as indicated by few isolated pollen grains.

In the succeeding Stage 'c' composition of the broad-leaved forest remained more or less the same as in Stage 'b' although chir pine was further reduced followed by a relative increase in oak woods, *Morus* and *Alnus*. Birch and elm also increased whereas *Celtis* gradually declined. Amongst the other arboreals, *Carpinus*, Myrtaceae, Sapindaceae, *Fraxinus*, *Rhus* and *Corylus* were present in fairly higher quantities than before. *Juglans*, *Grewia* and *Ilex* were sporadically present. Proteaceae, *Albizia* and Ericaceae were rare. *Salix* maintained high values throughout attaining to a maximum value towards the close of this stage. The values for *Pinus wallichiana*, *Abies* and *Cedrus* have slightly increased than in preceding stage.

The undergrowth is chiefly comprised of Rosaceae and *Jasminum*. *Strobilanthes*, Lauraceae and Rutaceae also attained higher values than before. *Myrica* was comparatively reduced than in the preceding stage.

The ground flora was largely made up of Gramineae which after attaining maximum values in the lower half of this stage declined towards the top. There was an overall increase in the values of *Plantago*, *Artemisia*, *Pteridium*, *Alternanthera*, Chenopod-Amaranth type, Polygonaceae and Ranunculaceae. Urticaceae increased considerably whereas Piperaceae decreased. *Schizandra*, *Justicia*, Labiatae, Papaveraceae, Scrophu-

lariaceae, Primulaceae and Liliaceae have also shown slight increase.

The lake vegetation was dominated by *Pediastrum* and *Botryococcus* except that they slightly declined towards the top of this stage. *Potamogeton* gradually declined to 1%. *Myriophyllum* was present in reduced values. *Nymphaea* increased gradually towards the upper half of this stage while *Nelumbo* and *Utricularia* were sporadically present. *Typha* also increased. The sedges rose tremendously showing more than 50% in the upper half of this stage.

Although it continued to be a dominant broad-leaved forest during Stage 'd', chir pine increased moderately till the top of the diagram and there was slight decline in the oak woods. Birch, elm, *Morus* and alder had comparatively higher values but *Celtis* had declined considerably. Walnut was consistently present. *Carpinus* had slightly reduced values than before but *Grewia* showed slight increase. There was a general decline in Myrtaceae, Sapindaceae, *Fraxinus*, *Rhus*, *Corylus* and *Salix* except that the latter three genera again increased towards the extreme top. Proteaceae and *Albizia* were extremely rare while Ericaceae became almost negligible. The values for *Pinus wallichiana*, *Abies* and *Cedrus* have also increased slightly.

Amongst the undergrowth, Rosaceae and *Jasminum* had a sharp decline but Rosaceae once again increased towards the extreme top of this stage. Rutaceae, *Myrica*, *Strobilanthes* and Lauraceae did not show much change over that in the preceding stage. Almost all the ferns gradually declined.

The ground flora largely consisted of high values of Gramineae. *Plantago*, *Artemisia*, Chenopod-Amaranth type and Umbelliferae were present in fairly good quantities while Compositae, Caryophyllaceae, *Alternanthera*, Boraginaceae and Polygonaceae have comparatively declined. Urticaceae decreased but there was increase in Piperaceae. *Spergula* after maintaining good frequencies in the middle showed a decline towards the top of this stage. Labiatae, Papaveraceae, Scrophulariaceae and *Justicia* maintained low frequencies whereas Primulaceae and Liliaceae slightly increased.

*Pediastrum*, *Botryococcus* and *Potamogeton* moderately increased and so did *Nymphaea*

and *Nelumbo* but *Lemna* and *Myriophyllum* were rare. *Typha* maintained exceedingly high values during this stage. Cyperaceae suffered a steep fall throughout this stage except towards the extreme top where it increased again.

In Naukuchiya Tal a well defined hydroserie succession is noticed. Separate frequencies for plant communities such as submerged, floating, marshy, Cyperaceae, Gramineae and lake shore plants have been put together so as to find out the plant succession, if any, in lake vegetation (Tex-tfig. 9). *Botryococcus* and *Pediastrum* are the predominant taxa of submerged plant community during Stage 'a'. The other submerged and floating plants are almost absent or sporadic in this stage and their commencement is seen only towards the close of the Stage 'a'. The marshy plants are present in the upper half of this stage. During Stage 'b' the submerged as well as floating plants show increasing tendency whereas marshy plants after showing increased frequencies in the lower half of Stage 'b' decreased considerably. The values for Cyperaceae and Gramineae remain low. During Stage 'c' there is an overall increase in the values of floating and marshy plants but submerged plants show abrupt decline. Cyperaceae maintains tremendously high values in the upper half of Stage 'c'. During Stage 'd' the vegetational pattern remains almost the same except for minor fluctuations in most of the plant communities. Cyperaceae experiences a tremendous fall in its values.

#### CLIMATIC OSCILLATIONS

For interpreting the climatic oscillations during Post-glacial time in Kumaon Himalaya, the author has much depended upon the trees as macro-climatic and aquatics as micro-climatic indicators. The modern distribution of plant species alone is not always a safe basis for the establishment of climatic indicators (Iversen, 1961). However, the best indicators of the regional temperature may be found amongst trees and water plants. The trees, being high up in the air are less dependent on micro-climate than other plants. The trees have very slow immigration speed whereas aquatics migrate very quickly. The aquatics

behave more like pioneers in the climatic changeover, nevertheless, they should not be ignored as thermic indicators (Gupta, 1973). The shifts in the floristics from chir pine forest to oak woods are some of the important indications of broad climatic changes whereas the changes in the aquatic vegetation are considered as due to the microclimatic changes.

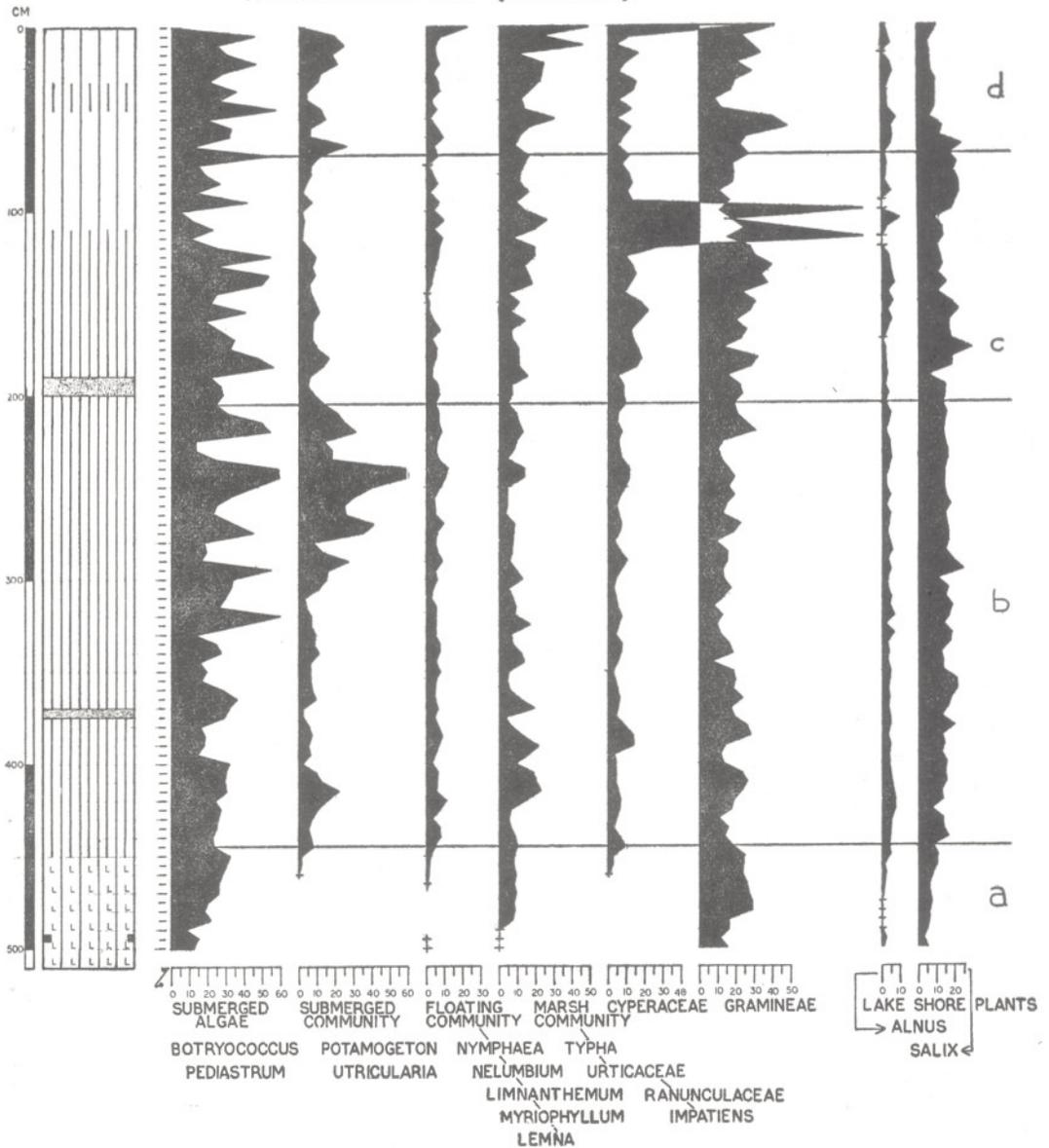
Four stages have been recognized in the vegetational development interpreted from the pollen diagrams of Kumaon Himalaya. During Stage 'a' the vegetation comprising predominant chir pine woods, is very much different from that of dominant broad-leaved forest during the successive stages. The change-over from the chir pine woods to broad-leaved woods is obviously suggestive of change in climate. Pure chir pine woods today occur in the Himalayas where warm and dry climate prevails and they constitute subtropical zone of the outer Himalayas. Within the chir pine forest, oaks, if associated, are present in moist depressions, otherwise they are chiefly confined to the higher hills. Usually the change-over of the chir pine into the broad-leaved forest takes place where mixed chir pine-oak woods have been subjected to fire. The evidence of charcoal fragment in the middle of Stage 'a' is indicative of either natural fire or early mans' attempts towards clearances by fire.

The establishment of broad-leaved forest, the rising values of *Salix*, *Alnus*, *Impatiens*, *Piperaceae*, and the presence of *Myrtaceae* and *Grewia* are strongly suggestive of a much warmer and moister climate during Stage 'b'. A striking change-over in vegetational pattern seen towards the close of Stage 'a' and the beginning of Stage 'b' may be attributed to a change in climate which becomes moist and warm.

Judging from the face value of broad vegetational pattern attained during stages 'b', 'c' and 'd' hardly any distinct evidence of a change in climate can be inferred. Oaks remain dominant throughout. The fluctuations in other broad-leaved components are not so significant as to indicate the climatic phases such as the period of climatic optimum and period of onset of cooler climate.

Some interesting indications of change-over are, however, noticeable in the arboreal pollen diagram towards the close of

SUCCESSION OF AQUATIC PLANT VEGETATION  
NAUKUCHIYA TAL (NAINITAL)



TEXT-FIG. 9

Stage 'b' and beginning of Stage 'c' when elm shows consistent rise but *Alnus* and *Morus* decline. The last two and several other constituents regain high values during the succeeding stage. The decline

of *Salix* during Stage 'd' may indicate somewhat comparatively drier climate.

The non-arboreal pollen diagram especially the succession of aquatics and sedges does, however, provide some useful informa-

tion regarding the changes in lake vegetation. During Stage 'b' the submerged vegetation like *Potamogeton* increases considerably indicating maximum wet conditions and this is corroborated by the high values of Piperaceae. In Stage 'c' *Potamogeton* declines. *Typha* and sedges show considerable increase in the free-floating aquatics too. *Impatiens* is absent. Piperaceae declines to lower values. This probably suggests comparatively drier climate. During Stage 'd' sedges are comparatively reduced except at the extreme top. *Typha* continues to show high values and there is also slight increase in *Potamogeton* except for a sharp decline at the top. Slight increase in Piperaceae and stray pollen of *Impatiens* suggest the onset of slightly moister conditions again.

A glance at the pollen curves for blue pine, *Abies*, *Cedrus* and *Ulmus* seems to provide some indications of the climate becoming comparatively cooler. The pollen curves for the above mentioned genera show a comparatively slight rise during Stage 'd' as compared to Stage 'c'.

From the distribution of these genera in the Himalayas it is found that these genera are mostly restricted to the upper limit of the subtropical zone. The association of blue pine and deodar is only seen towards the upper most limit of the chir pine forest from above 1666 m a.s.l. Here chir pine is associated with *Quercus incana* and the other broad-leaved constituents. In the pure *Q. incana* forest, *Ulmus wallichiana* is found as a common constituent and deodar and blue pine may be found associated with *Q. incana* forest at the higher elevation. In the pure *Q. dilatata* forest, *Pinus wallichiana*, *Cedrus deodara*, *Abies pindrow* and *Ulmus wallichiana* are also associated.

At the bottom of Naukuchiya Tal pollen diagram, chir pine is dominant. Upon the chir pine zone follows a zone with mixed forest trees, then peak development of the mixed-oak forest and thereafter blue pines, alder, birch, deodar and silver fir are established. Thus the Naukuchiya Tal pollen diagram, reveals a succession of climate from Stage 'a' to Stage 'd'. During Stage 'a' the climate was warm and dry, during Stage 'b' it became moist and warm and perhaps attained the optimal conditions. The climate became moist and less warm

during Stage 'c' and perhaps cooler during Stage 'd'.

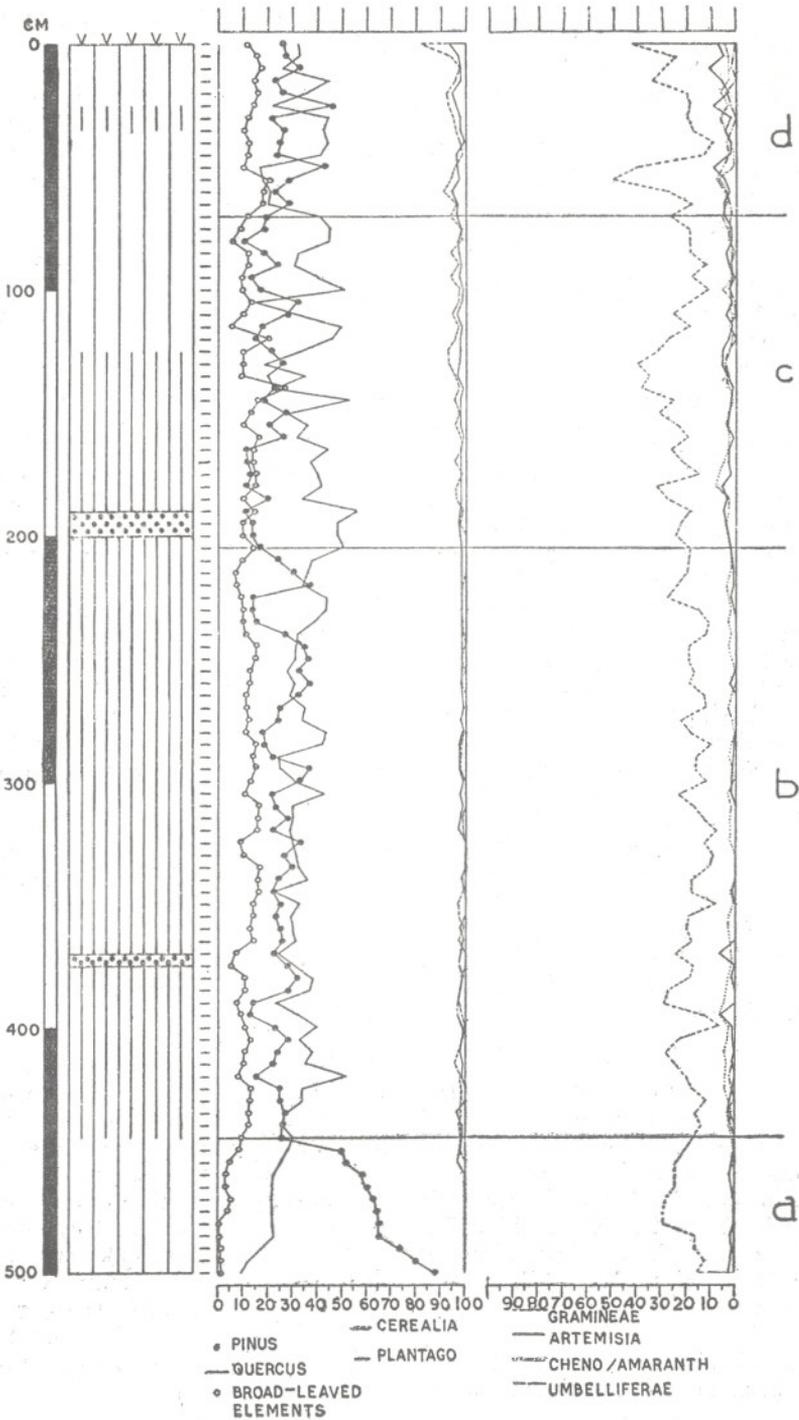
#### INFERENCE OF PAST PASTORAL AND ARABLE ECONOMY

The inference of past agriculture is rather a difficult task to be based on pollen evidence alone owing to homogeneous nature of grass pollen. Recently, it has been observed that besides size, cerealia pollen possess smooth exine and broadened annular area in contrast to wild graminoid pollen. Vishnu-Mittre (1973) is of the opinion that amongst two thousand members of Gramineae existing in India, it is not possible to draw demarcation line between the cultivated and wild grass pollen because of the overlap of pollen characters. He (*op.cit.*) further suggests that in addition to cerealia pollen evidence, decline in forest vegetation and recovery of the forest are some of the features to be considered for the inference of past agriculture.

The middle of Stage 'a' is marked by the decline of the chir pine forest and the occurrence of a charcoal fragment at the depth of 485 cm. The evidence of charcoal fragment may be a result of fire by prehistoric folk in view to clear off the area but at the same time natural forest conflagration can also not be ruled out. The frequency of non-arboreal pollen rises immediately after the fire. It is succeeded by Chenopod-Amaranth type, Gramineae, Umbelliferae, *Artemisia*, *Pteridium* etc. and then *Plantago* appears for the first time towards the close of Stage 'a' — (Text-fig. 10). *Artemisia*, a field weed and an associate of *Plantago* continues to be present right from the beginning of Stage 'a'. The values of Gramineae at this level may be attributed to wild grasses of the ground vegetation in chir pine-oak woods.

With the absence of cerealia pollen in Stage 'a', the earliest clearance phase seems to be due to the natural fire. After this clearance, oaks begin to increase and invade the chir pine woods. Towards the middle of this stage where oaks rise and chir pine declines, Gramineae attains very high values (upto 30%), thereafter the curve for Gramineae declines. In the forest succession, the open conditions favour the expansion of grasses.

COMPOSITE POLLEN DIAGRAM FROM NAUKUCHIYA TAL (NAINI TAL) SHOWING RELATIVE CHANGES IN ARBOREAL VEGETATION, CEREALIA, CULTURE POLLEN AND TOTAL GRAMINEAE



TEXT-FIG. 10



The cerealia pollen curve is represented by very meagre frequencies throughout the Stage 'b' and ultimately disappears from the extreme top of this stage. The curve for *Plantago* shows a considerable decrease and maintains low frequencies towards the top of this stage. *Artemisia*, Chenopod-Amaranth type and Umbelliferae are sporadically present. Compositae on the other hand shows a slight rise in its values.

The low value for cerealia pollen is associated with an increase in submerged plant community such as *Pediastrum*, *Botryococcus* and *Potamogeton*. *Nymphaea* and *Nelumbo* have comparatively higher values. The tremendous increase in the values of submerged plant community is perhaps suggestive of either flooding episode (cf. stratigraphy) or torrential rains.

During this period oak woods show a slight declining trend and the chir pine shows a slight rising trend followed by an increase in the shrubs. The curve for Gramineae also shows declining trend. These events suggest regeneration of the forest encroaching upon the grass lands and because of the above reasons the grasses declined considerably.

The cerealia pollen frequency increases gradually a little above Stage 'c' where it maintains continuous but low curve and gradually shows an increasing trend upwards maintaining high frequencies throughout Stage 'd' where it has higher values than before attaining three summits of 9%, 7.5% and 18% respectively. It obviously reflects that there was a progressive increase in agricultural activity over that of Stage 'c'.

An increase in the cerealia pollen curve in the middle of Stage 'c', corresponds with an increase in the values of *Plantago*, *Artemisia*, *Pteridium*, Chenopod-Amaranth type, Umbelliferae, Compositae, Caryophyllaceae, reveals the progressive development in the arable economy.

After a sharp decline towards the end of Stage 'c', the cerealia pollen curve again rises in the beginning of Stage 'd' where it is accompanied by further rise in *Plantago*, *Artemisia*, Chenopod-Amaranth type and Umbelliferae. Gramineae also increased simultaneously. *Pteridium* shows a comparative decline. Urticaceae and Piperaceae rose soon after the decline of cerealia pollen curve.

Towards the extreme top of Stage 'd' cerealia pollen curve once again experienced an increase maintaining a maximum value of 18%. This rise is accompanied by the rise in *Plantago* and Gramineae but decline in *Artemisia*, *Pteridium*, Chenopod-Amaranth type and Umbelliferae is noticed.

In the upper half of the Stage 'c' the cerealia pollen curve together with other culture pollen after attaining a peak declines and maintains low consistent curve. Gramineae is reduced considerably and there is a comparative rise in the shrubs such as Rosaceae, Rutaceae and *Jasminum*. Ferns and Chenopod-Amaranth type pollen also increase. In the corresponding arboreal diagram at this level oaks are reduced showing fluctuating values but chir pine shows a rise. This is another interesting instance of regeneration of forest adversely affecting the farming. This change in the forest composition and the one witnessed during the earlier phase may perhaps suggest selective felling of the oaks either during management of the forests or for other uses or being at favourable altitude for cultivation and inhabitation. The oak forest (*Q. incana*) is very much exposed to damage and destruction through human agencies.

Seedlings of oaks suffer much from goat browsing and cattle also eat the young shoots. The extensive lopping for fodder, felling of poles and cutting of trees for firewood is the worst form of injury to which the trees are subjected. Because of the extensive lopping by native villagers, the crowns gradually thin out, and in time the trees die.

The oak trees are also affected to some extent by the heavy frost. But it suffers severely from fire particularly on steep slopes where there is heavy inflammable undergrowth. The ban oak (*Quercus incana*) is also subjected to the attacks of certain loranthaceous parasites (Troup, 1921).

#### PHYTOGEOGRAPHICAL COMMENTS

A striking contrast, however, is noted in the present and past vegetation in the vicinity of these lakes. The chir pine forests occur on the warmer localities while the oak woods on the higher hills. The impor-

tant constituents of chir pine forest are *Crataegus crenulata*, *Bauhinia variegata*, *Woodfordia fruticosa* and *Rhus* spp.

The lower canopy in the oak woods is formed by *Pyrus pashia*, *Berberis* spp., *Myrica nagi* etc. *Juglans regia* and *Morus serrata* occur in patches only and they are perhaps planted. The recent plantations carried out by the Panchayat and not by Forest Department include those of *Juglans regia* and *Cupressus torulosa*. The biotic influences affecting these forests include lopping and grazing which largely damage the oak woods.

The pollen analysis reveals a succession of forest community in the vicinity of these lakes. During Stage 'a' chir pine forest dominated the region with patches of oak woods. Perhaps the effects of climate and fire brought about catastrophic change as a result of which the broad-leaved forest comprising oaks, *Celtis*, *Alnus* and other constituents was established. Patches of chir pine continued to exist here and there. Further climatic change during Stage 'b' increased oak woods over that of chir pine and with these oak woods, *Pinus wallichiana*, *Cedrus deodara* and *Abies* were also associated in some proportion. Since these conifers are largely associated with *Quercus semecarpifolia* and occasionally with *Q. incana*, it indeed becomes difficult to interpret the increased values of these in the pollen diagram during stages 'c' and 'd'. The possibilities seem to suggest (i) the pollen of these conifers might have been transported from higher altitude and deposited in the sediments. This contention seems to receive support from the occurrence of pollen of these taxa in the topmost samples whereas these genera are today absent from the vicinity, (ii) the occurrence of *Alnus* as an associate of oak woods together with blue pine, deodar, *Abies*, etc. probably suggests the shift of the *Q. semecarpifolia* forest down to the vicinity at a lower altitude as a result of the onset of cooler conditions during stages 'c' and 'd' as interpreted above.

The second possibility seems to suggest that the *Q. incana* probably existed in threshold of *Q. semecarpifolia* belt which not only explains the downward transport of pollen of the temperate conifers but also their stray occurrence in this region. Judging from the present day distribution of

the forest types in the vicinity, the increased values of these high altitude conifers towards the top of the diagram enables to conclude that their pollen grains are due to downward shift or downward transport of the upper vegetational belt in response to deterioration of climate.

The curve for *Celtis australis* is fairly interesting, since it shows a gradual and progressive decrease towards the top of the diagram. *Celtis australis* is a deciduous tree usually found in forests associated with deodar, blue pine, oaks and other broad-leaved species. It also grows on dry rocky places and gregariously on low level swamps. It is also frost hardy. Its wood is tough and elastic and used for oars, tool handles and ploughs. It is also much lopped for cattle fodder and is, therefore, frequently cultivated around the villages. Its decline, as observed from its ecology, does not seem to have been due to change in climate. Biotic factor especially man has largely been responsible for its decline. The early folks might have used its wood for oars, tool-handles and ploughs making and its shoots for cattle fodder. The reclamation of the swamp in this region might have resulted in its further decline.

*Salix* too, seems to have been affected by recent reclamation of lakes and swamps as it is quite apparent by its sudden decline towards the top of the diagram.

A rise in *Juglans* curve towards the extreme top of the pollen diagram reflects the recent plantation in the region.

#### DISCUSSION AND CONCLUSION

The pollen analytical investigations of modern and Post-glacial sediments of a subtropical zone in the outer range of Kumaon Himalaya, have revealed very interesting features as regards to the vegetational developments, climatic changes, origin and progressive development of farming and phytogeographical distribution of plant species. The pollen analyses of moss cushions and surface samples from this region do not present a correct picture of the total modern floristic composition. Approximately 50% of the total vegetation is represented in the pollen spectra.

The vegetational history begins with dominant sub-tropical chir pine forest during Stage 'a'. The oaks were poorly present and probably confined in the pockets and depressions where the moist conditions prevailed. The other forest constituents were very scanty. The shrubby vegetation too was poor. Gramineae, *Polypodium* and *Asplenium* represented the ground vegetation. The lake vegetation was dominated by abundance of *Botryococcus* — a submerged alga. The middle of Stage 'a' is marked by decline of chir pine and relative increase in oak woods. Stage 'b' is characterized by the establishment of oak woods along with the patchy distribution of other associates such as *Betula*, *Ulmus*, *Alnus*, *Celtis*, *Morus* and *Corylus*. During this phase shrubs were represented by *Jasminum* spp. and members of Rosaceae. Amongst herbage, Gramineae had tremendous fall which is characterized by the onset of cerealia type pollen accompanied by *Plantago*, *Artemisia*, *Rumex*, Chenopod-Amaranth type, Umbelliferae and Compositae. The lake vegetation is characterized by further increase in *Botryococcus* and commencement of *Potamogeton*, *Typha* and *Myriophyllum*. In the succeeding stages 'c' and 'd', the composition of the oak wood forest remained more or less same as in Stage 'b' except for the minor fluctuations. The status of Gramineae remained very uncertain. It increased to the high values in the lower half of this phase but soon after it declined. This decline corresponds with the overall increase in the values of culture pollen.

While defining the Late Quaternary climate von Post (1946) recognized three climatic phases, viz., the period of increasing warmth, the warmth maximum, and the period of decreasing warmth. The Kumaon pollen diagrams, however, seem to indicate more or less a similar three-fold pattern of climate during the Post-glacial time. Stage 'a' represents the period of warm and dry, stages 'b' and 'c' correspond with the period of climatic optimum, i.e. warm and wet and Stage 'd' corresponds with the period of decreasing warmth or the beginning of climatic deterioration, i.e. cold and dry.

The changeover of the pine woods into the mixed-oak woods during the close of Stage 'a' in Naukuchiya Tal pollen diagram has been marked by the occurrence of

charcoal piece indicating the forest fire. In Stage 'b' the establishment of oak woods and decline of chir pine forest seems to be induced chiefly by the climate. But during stages 'c' and 'd' the fluctuations in the forest community are due to both climatic and biotic factors.

The three-fold vegetational sequence of Naukuchiya Tal pollen diagram shows much similarities with the pollen diagram from Toshmaidan Mire, Kashmir (Singh, 1963). On comparison, both the diagrams from Naukuchiya Tal in Kumaon Himalaya and Toshmaidan Mire in Kashmir show a succession from pine forest to broad-leaved forest and again to pine forest reflecting upon a three-fold climatic oscillation, viz., cold-warm-cold. Recently, Toshmaidan pollen diagram has been radiometrically dated to  $15,250 \pm 4\%$  b.p. (Singh & Agrawal, 1976) at the base of the organic mud at 280-295 cm depth. If the above comparison is taken into consideration then the base of Naukuchiya Tal pollen diagram will be at par with the Toshmaidan pollen diagram. However, its authenticity can be relied only when the radiometric dating of Naukuchiya Tal pollen diagram is done.

#### ACKNOWLEDGEMENTS

I record my sincere thanks to Dr Vishnu-Mittre, Head of the Department of Holocene Palynology and Archaeobotany at Birbal Sahni Institute of Palaeobotany, Lucknow for keen interest and supervision throughout the completion of this project. My thanks are also due to Shri R. S. Soni, the then Chief Conservator of Forests, U.P. for extending all facilities to work in the Naini Tal forest division; to Mr D.C. Pande, the Silviculturist, Hill Division, U.P. for discussing the problems concerning the present status of arboreals in Naini Tal forest division, Naini Tal.

It is with pleasure to acknowledge my sincere thanks to Dr S. Sinha, and late. Dr H. Santapau, then Professors of Botany, Botany Department, Agra College, Agra and St. Xavier's College, Bombay respectively for according permission to procure needful polliniferous material from their respective Herbaria.

I also extend my thanks to U.P.C.S.I.R. for financing this project at Birbal Sahni Institute of Palaeobotany, Lucknow.

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