A PRELIMINARY SURVEY OF THE POST-GLACIAL VEGETATIONAL HISTORY OF THE KASHMIR VALLEY

GURDIP SINGH

Birbal Sahni Institute of Palaeobotany, Lucknow

ABSTRACT

Pollen-analytical investigations of Post-glacial deposits from four sites (Toshmaidan, Braman, Walanwar and Damamsar) distributed over the Kashmir Valley slopes of the Pirpanjal Range constitute the subject matter of this paper. The study reveals for the first time the Post-glacial vegetational history of the Kashmir Valley especially with regard to Post-glacial climatic alterations, biotic influences on vegetational development and the phytogeography of the region.

The sequence is divisible into eight stages. The forest history began with an open vegetation with conifer woods consisting of blue pine (*Pinus wallichiana*) and cedar (*Cedrus deodara*). During the ensuing period a set of warmth and moisture demanding broad-leaved elements such as oaks, alder, birch (*Betula alnoides*), elm, walnut, maple and *Rhus* immigrated indicating a climatic trend towards increasing warmth. Later, forests comprised dominantly of broad-leaved elements established themselves marking thereby a phase of optimum warmth which in turn was followed by the re-establishment of conifers, a fact pointing towards the return of colder conditions. The conifer woods were mainly comprised of *Pinus wallichiana* and *Abies webbiana*.

Some of the changes in the vegetational sequence are also believed to have been induced by man's direct or indirect influence on vegetation. Evidence of maize cultivation in the past has also been brought out. The bearing of this work on the history of some of the mesophytic elements such as *Quercus* spp., *Alnus* and *Betula alnoides*, which are today absent from the Kashmir Valley, is also discussed.

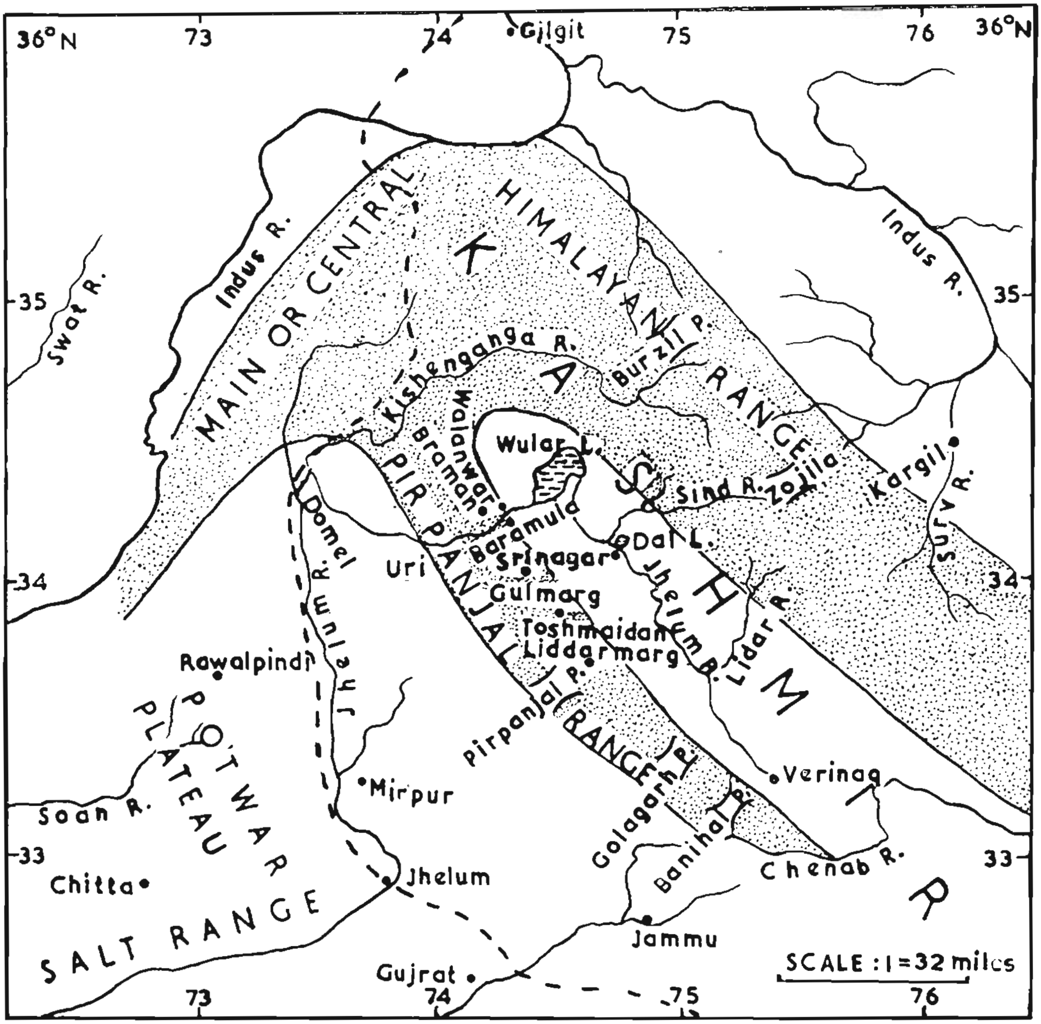
INTRODUCTION

GEOGRAPHY — The Kashmir valley (approximately 73° 55′ to 75° 35′ E and 33° 25′ to 34° 40′ N; TEXT-FIG. 1) lies towards the north-west of peninsular India. It is bounded on the north and east by the high mountains of the main Himalayan Range, whereas, towards the south and southwest, the Pir Panjal Range divides it from the plains of Jammu and Poonch. The valley is boat-shaped, with its floor lying at an altitude of about 1,560 m. and extends over an area of about 5,200 sq. km. Its deepest part lies along the foot of the Main Himalayas and is marked by the course of the main river Jhelum. The latter, along with its large number of tributaries, has shaped the present relief of this area, resulting in the extensive dissection of the Karewa beds and causing the formation of terraces and lowland swampy areas and lakes such as Wular, Manasbal, Anchar, Dal, etc.

The Pir Panjal Range — a sub-Himalayan mountain — rises abruptly from the plains and forms a major barrier between the Panjab and the Kashmir Valley proper. It rises to an average altitude of *ca.* 3,750 m. above sea level with peaks touching as high as *ca.* 4,660 m. The region above *ca.* 3,600 m. in particular has the characteristic appearance of a once glaciated area with a large number of high altitude lakes filling the old glacially scoured bowls and cirques.

Climate. — The present-day climate of the Kashmir Valley is considerably influenced by the position of the Pir Panjal Range. This is shown by the fact that although the region south of this range enjoys a subtropical climate, the corresponding area at similar altitude to the north (the Kashmir Valley) has a temperate climate. However, in the summit region of the Pir Panjal Range, the climate, leaving aside the rainfall, is more or less of the same 'cold arctic' type on either side, though the snow melts much earlier on the southern slopes than on the corresponding northern side during the summer months. The full impact of the monsoon in the entire Kashmir region occurs in July when stations such as Jammu, record rainfall as high as 305 mm. whereas Gulmarg on the lee side of the Pir Panjal Range, records barely 101 mm. and Srinagar even less (58 mm.) for the same period (TEXT-FIG. 2). These facts reflect markedly the effectiveness of the Pir Panjal Range as a barrier between the two sides of the range.

The humidity reaches its climax in the winter months in the Kashmir Valley, a fact which is caused by the fall of mild winter showers in the area. The temperature rises

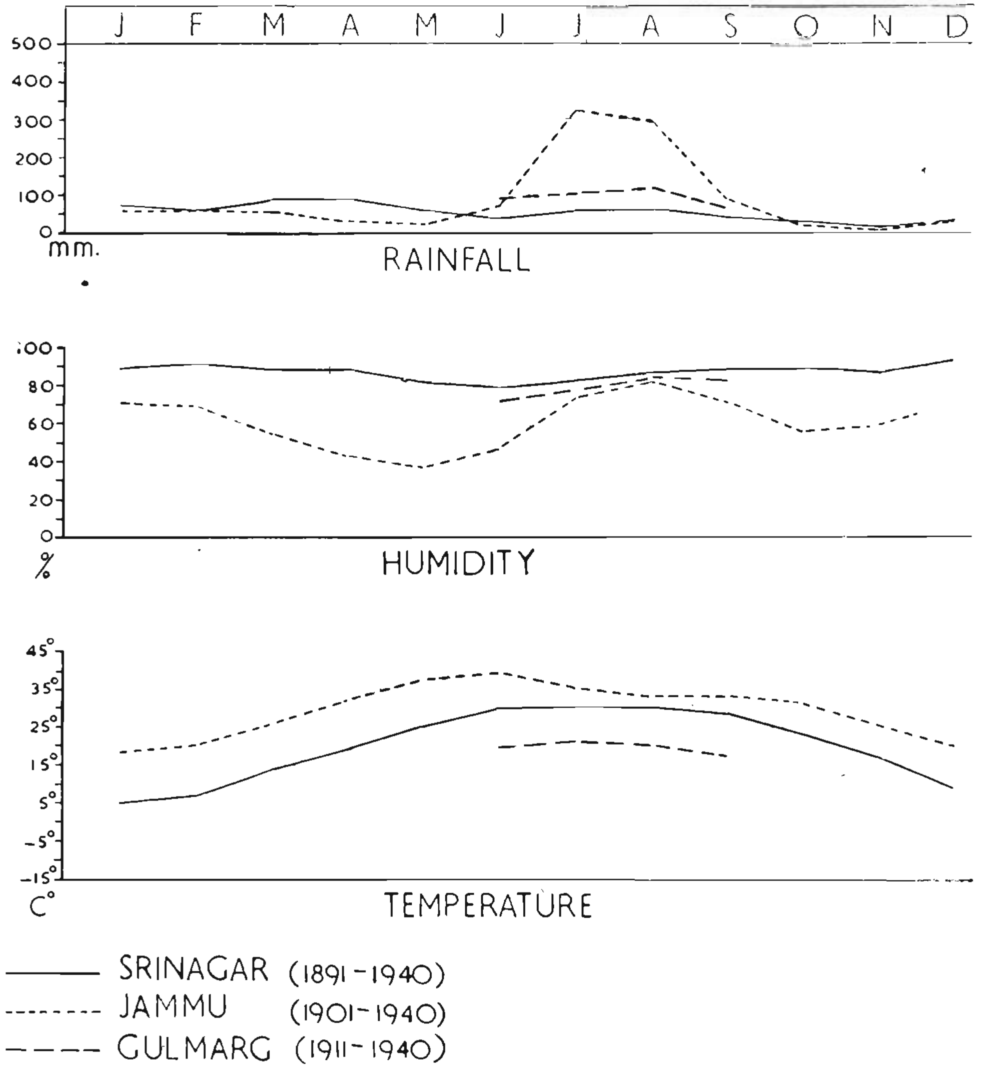


TEXT-FIG. 1 — Map showing Jammu & Kashmir (Based on Sahni, 1936, Fig. 1).

as high as 38°C during summer in the plains south of the Pir Panjal Range while it rarely exceeds 31° and 21° C at Srinagar and Gulmarg respectively. The winds in the Kashmir Valley blow from the northwest, west or southeast and storm or cyclonic conditions arise at the height of the monsoon in July.

Previous Work. — The Kashmir Valley is one of the few areas in the Indian subcontinent where unmistakable records of the Pleistocene 'Glacial Age' have been located and studied in detail. Four main oscillations of climate have been detected (DAINELLI, 1913; DE TERRA, 1938 and WADIA, 1938).

Palaeoecological studies in this region have so far been confined to early Quaternary deposits (GODWIN AUSTEN, 1864; MIDDLEMISS, 1911; WADIA, 1919; DE TERRA, 1932; WODEHOUSE, 1935; SAHNI, 1936; IYENGAR and SUBRAMANAYAN (1943); PURI, 1943-53; NAIR, 1960), while Post-glacial deposits have remained untouched. Nevertheless, from the geophysical and historical records in Northwest India, De Terra and Hutchinson (1936) inferred the first probable Post-glacial sequence of climate, in the alter-



TEXT-FIG. 2 — Normal monthly values of rainfall, rel. humidity and temperature in Kashmir (data by courtsey of India Meteorological Department).

nation of wet and dry periods and also recorded the existence of two Post-glacial 'Ice Advances', i.e., the Fifth and Sixth. The moraines of the latter have been shown to lie in an intermediate position between the terminal moraines of the Fourth Glaciation and the recent moraines of the existing glaciers.

De Terra and Hutchinson (1936) and De Terra and Paterson (1939) have mentioned the occurrence of Post-glacial deposits in the Kashmir Valley in the form of river terraces, yellow loess and morainic deposits but besides these, very little information is available on the large number of Post-glacial deposits in lakes, swamps and mires occuring in the Kashmir Valley. Detailed study of these sites comprising their ecology, floristics, nature of their sediments and other aspects in relation to pollen-analytical investigations have yet to be carried out.

Mukerji (1921, 1925), in a preliminary account has provided some information of the hydrarch succession at Dal lake (*ca.* 1,560 m.). He maintained that the plant communities of this lake culminate in different 'climax' of vegetation in different localities but that in general the plant succession is as follows: In the 'Aquatic Formation' plants such as species of *Potamogeton, Hydrilla, Myriophyllum* etc. dominate and constitute 'Deep water Association' with *Chara* forming a dense mat on the bed. The 'Floating-leaf' or 'Shallow water Association' is dominated by *Trapa, Nelumbium, Nymphaea, Eurale ferox* etc. Further the 'Reed-swamp Association' is dominated by *Typha, Sparganium, Carex* etc. and these plants along with 'Floating-leaf Association', form various Consocies. In the 'Marsh Formation', *Ranunculus aquatilis, Callitriche, Hippuris, Ceratophyllum, Juncus* etc. constitute the 'Herbaceous Marsh Association' and willows, sometimes poplars etc. along with an undergrowth of perennial herbs form 'Salicetum Association' and 'demp' land. The 'Meadow Formation' is dominated by grasses and perennial herbs. Both the 'demp land' and meadow stage' are converted into arable land by man. The meadow stage on the eastern and southern shores of the Dal Lake is succeeded by 'Gravel-slide' Formation or 'Xerophytic Bushland' Formation — constituted by *Rubus, Rosa, Crataegus, Astragalus* etc. This is succeeded by 'Mesophytic Bushland Stage' or Shrub Stage in the Arrah valley near Harwan, represented by *Viburnum, Prunus, Salix, Rosa, Ribes,* etc. The next stage is the 'Pioneer Conifer Forest' which develops higher up the Arrah Valley from Harwan upwards and consists of *Pinus excelsa* (Syn. *P. Wallichiana* — blue pine) as the pioneer element. Few plants of *Cedrus deodara* also occur mixed with many shrubs. The succession culminates into a 'Climatic climax Forest' at an elevation of 8,000 feet (*ca.* 2,400 m.) in the form of deodar forest.

Swamps and mires. — Swamps are distributed all over the Kashmir Valley floor, covering either the shallow margins of lakes such as those of Dal, Anchar, Wular, etc. or occupy the alluvial area of the Jhelum river and its tributaries. They generally occur between altitudes of *ca.* 1,500 m. and 1,650 m. and the bulk of their deposits is laid as a result of flooding and deposition by the incoming river currents. Organic deposits are infrequently formed at such sites. The swamps have developed a luxuriant growth of aquatic plants which are distributed ecologically much in the same manner as described by Mukerji (1921, 1925). The aquatic plants are regularly harvested by the inhabitants for the purpose of building floating arable plots within the lakes.

Post-glacial peat is formed in the Kashmir Valley in places which can best be termed mires[1]. They are formed on the valley slopes of the Pir Panjal Range and the Main Himalayas at heights between *ca.* 1,600 m. and 3,500 m. The mires, which are distributed within the forest belts, are generally small and usually measure between 10 and 30 m. in length and breadth. They are generally formed on gentle slopes, either singly or in successions of two or three situated one above the other on more or less flat terraces. On the valley slopes of the Pir Panjal Range which are covered over by a thick sequence of Pleistocene Karewa clay beds, the mires sometimes assume a quagmire type of development and peat is rarely developed.

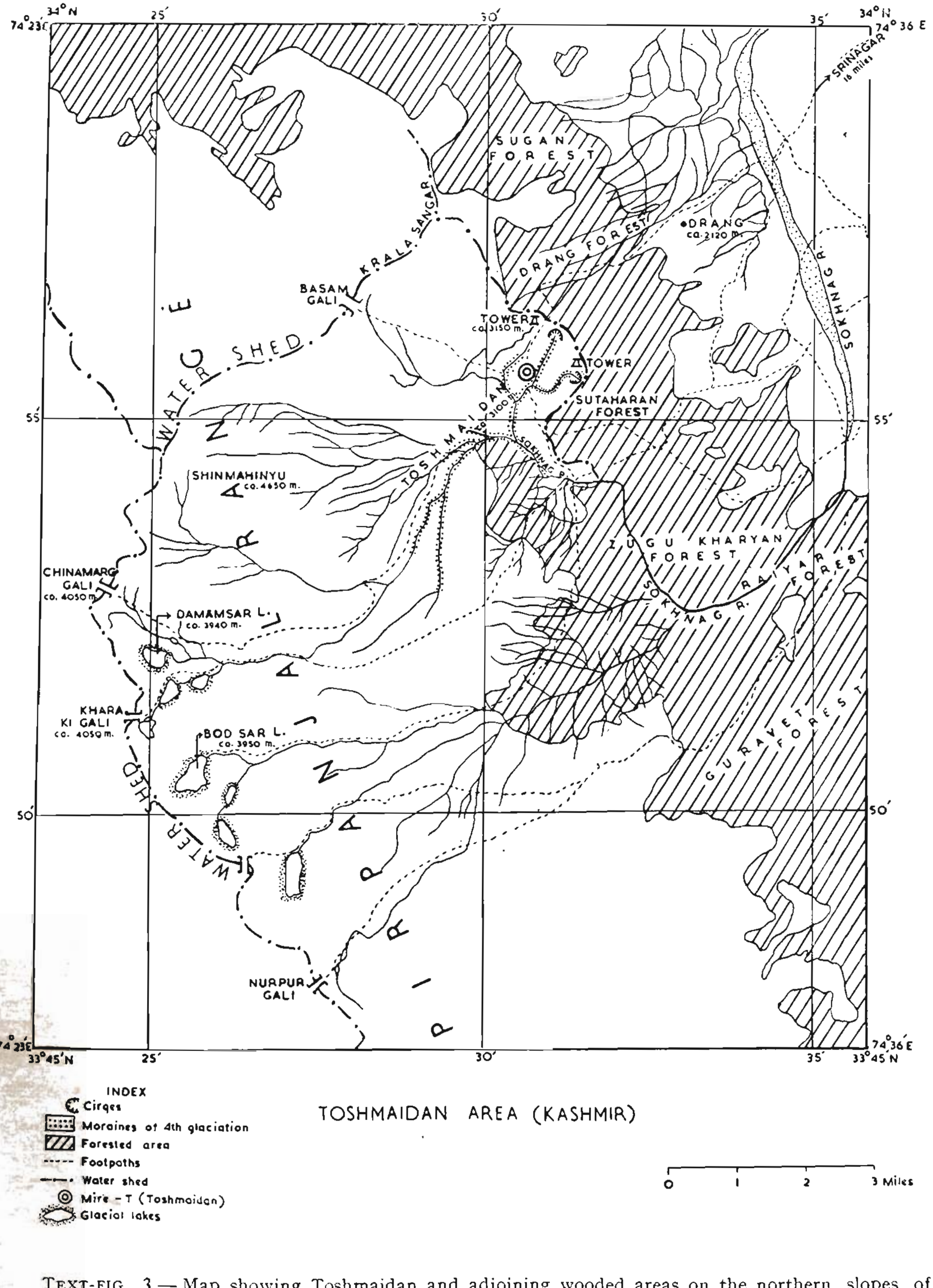
The mires occurring in the large number of glacially scoured basins occupying open patches within the forest or above the tree line have been occasionally found to accumulate fairly thick deposits of peat or organic mud. These basins commonly known as 'margs', 'pathris' and 'khals' are actually filled up glacial hollows or lakes generally situated on a mountain ledge or shelf enclosed by terminal moraines (Wadia, 1941). In that sense 'Gulmarg', 'Toshmaidan', 'Liddar marg', etc. form some of the best glacial basins or 'margs' on the northern slopes of the Pir Panjal Range, while 'Bod Bangas', 'Sonamarg', 'Minimarg' and 'Liddarwat' on the southern slopes of the Main Himalayas.

POLLEN-ANALYTICAL INVESTIGATION

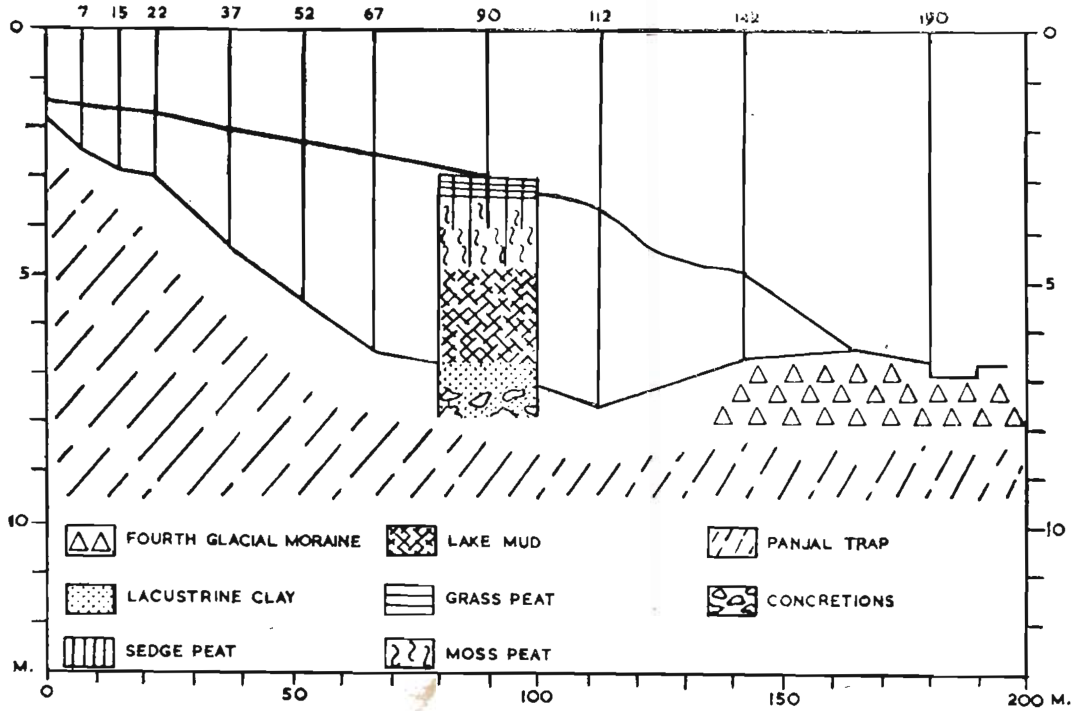
A. LOCATION, STRATIGRAPHY AND DEVELOPMENT OF THE MIRES

1. Toshmaidan; Mire-T: 74° 31′ E, 33° 56′ N (Text-figs. 1 & 3; Pl. 1, Figs. 1, 2): The locality Toshmaidan bearing Mire-T is an extensive meadow which covers an

1 According to Godwin and Conway (1939), "no word at present exists in English to convey the sense of the Swedish "myr", which is a term meaning both any kind of peat land, and at the same time the vegetation type characteristic of such land". They proposed the use of the English word "mire" in this general sense as a term embracing all kinds of peat lands and all kinds of peat-land vegetation.



TEXT-FIG. 3 — Map showing Toshmaidan and adjoining wooded areas on the northern slopes of the Pir Panjal Range.



TEXT-FIG. 4 — Semi-diagrammatic section of Mire-T at Toshmaidan.

area of about 10-15 sq. km. on the northern slopes of the Pir Panjal Range in the Kashmir Valley at an altitude of *ca.* 3,120 m. above sea level. It is situated under the shadow of huge massifs which form the watershed in the region and range between *ca.* 3,900 m. and *ca.* 4,500 m. in altitude.

Immediately after the 4th glaciation in Kashmir, the deposition of glacial moraines at various levels over Toshmaidan (DE TERRA AND PATERSON, 1939; TEXT-FIG. 3), blocked the free flow of water at several places; this resulted in the formation of a number of small lakes. In one of the many cirques scoured out by the fourth glaciation on the Toshmaidan side of the pass valleys, a series of moraines now occupies the banks of the present stream (TEXT-FIG. 3). The lakes impounded behind these moraines, now occur as extensive mires covering both flanks of the main stream.

Mire-T lies on the northwestern bank of the stream and measures about 180 metres from SE to NW and more than 200 metres from NE to SW (TEXT-FIG. 4). Towards the NE and SW, it almost merges with the other shallow mires covering the area, while it is bounded by a small hillock towards the NW and by a narrow channel on the SE. In between the channel and Mire-T, lie moraines of the 4th glaciation (TEXT-FIG. 4).

A level survey was undertaken along the SE-NW plane passing through the middle of the mire, with the bed of the channel as the base level. Along the same line a series of borings was made by means of a Hiller peat borer (TEXT-FIG. 4). After assessing the depth of the peat layers at various intervals, a point at 90 m. from the foot of the hillock, which was obviously the deepest and lay in the middle of the mire, was selected for final sampling. From a macroscopic analysis of the samples, the remains of several plants were recognized; for instance seeds of *Scirpus setaceus* and *Carex* sp., nucules of *Nitella* and *Chara*, moss shoots and algal colonies of *Botryococcus* and *Pediastrum*.

A record of the stratigraphy, built up from laboratory examination of macerated samples, is given below:

cm. 0-10 Brown fibrous peat with seeds of *Scirpus setaceus*, *Carex* sp., shoots of *Bryum alpinum*, *Aulacomnium palustre* and other unidentified leaf and root fragments.

10-125 Brown, humified, peat with the same plant remains as above. [2]*Pediastrum* 'very rare'; [2]*Botryococcus* 'very rare' to 'common'.

125-165 Light brown, humified peat with abundant shoots of *Webera* sp. and few fruits and seeds of *Carex* sp. *Pediastrum* 'very rare'; *Botryococcus* 'very rare' to 'common'.

165-196 Light brown, fine detritus organic mud with fruits and seeds of *Carex* sp.; moss shoots less common; *Pediastrum* 'less common' to 'very common'; *Botryococcus* 'very rare' to 'common'. *Nitella* nucules frequently present.

196-250 Grey, fine detritus organic mud with *Nitella* and *Chara* nucules. Detached moss leaves common, shoots rare; *Pediastrum* 'frequent' to 'abundant'; *Botryococcus* 'rare' to 'very common'.

250-280 Greyish brown fine detritus organic mud with exclusively *Chara* nucules and other unidentified leafy plant fragments. *Pediastrum* 'very rare' to 'rare'; *Botryococcus* 'frequent' to 'very common'.

280-324 Dark brown fine detritus organic mud with leaf fragments. *Botrycoccus* 'very rare' to 'common'.

324-368 Grey, clayey organic mud with rare occurrence of *Chara* and *Nitella* nucules, moss leaves and shoots. *Pediastrum* 'very rare' to 'very common'; *Botryococcus* 'very rare' to 'common'.

368-415 Bluish grey lacustrine clay with broken igneous trap-rock concretions frequently found towards the base. Both *Pediastrum* and *Botryococcus* absent except in the upper transitional layers; but even there, they are rare. The blue grey clays and the concretions as revealed by a preliminary petrological examination, owe their origin to the igneous basaltic trap which constitutes the rock matrix of the Pir Panjal Range. The chief mineral constituents in the clay are chlorite, epidote and small laths of augite and felspar. Although augite is mostly in an altered state, the felspars are mostly undecomposed, a fact which suggests that climatic conditions at the time of the sedimentation of the clays may have been essentially cold.

At present, the basalt at Toshmaidan is covered by a luxuriant meadow vegetation and in view of the relatively milder climate prevailing at the locality, the amount of weathering taking place is insignificant. Presumably in consequence of this, blue grey clays are not found in the surface layers of Mire-T; however, brownish clay with iron stains is found towards the hill side.

Development of Mire-T — The stratigraphy of the mire clearly shows that it started its development from a small glacial lake. This fact is substantiated by 1) the position of the 4th glacial moraine separating the mire basin from the channel, 2) by the deposition of unstratified bluish grey clays showing mostly undecomposed felspars and small concretions of broken traprock in the bottom layers and 3) the hydrosere succession from a limnic phase constituted by deep water plant associations to terrestrial peat formation. The second fact is significant since a similar deposition is seen today in the glacial lakes situated above 3,900 m. in the Kashmir Valley. The subsequent slow and uninterrupted deposition of organic mud and then of peat in Mire-T suggests that the basal clays may well date from the time of the recession of the last glaciers in the region. Thus the history of Mire-T in all probability goes back to the beginning of the Post-glacial period in the area. The Lake conditions seem to have continued until a level of 196 cm. had been reached after which the basin appears to have shallowed enough to allow a large scale invasion by mosses and afterwards by sedges. Since the upper limit of the lake deposits is at a higher level than the present morainic threshold, it seems clear that some erosion has taken place and that the original threshold was at a higher level. This seems to be substantiated by the sudden steepening of the gradient towards the channel between 112 m. and 180 m.

2. Explanation of the frequencies of algal colonies:

Below 5	colonies per unit area	—	'very rare'
from 6 to 10	,, ,,	—	'rare'
from 11 to 20	,, ,,	—	'frequent'
from 21 to 60	,, ,,	—	'common'
from 61 to 100	,, ,,	—	'very common'
above 100	,, ,,	—	'abundant'

The absence of any recognizable wood or fruit remains of tree elements in the mire sediments shows that perhaps the woods never encroached upon the site.

Vegetation— At present the mire is ecologically at the ' meadow stage ' of development. The ' Meadow Formation ' is dominated by ' grass sedge and annual-cum-perennial herb ' communities. Common elements among these are *Scirpus setaceous, Eleocharis palustris, Phleum alpinum, Potentilla sibbaldi, Ranunculus lobatus, R. rupestris, Trifolium repens, Primula rosea, Caltha palustris* and *Arenaria foliolosa*. The two most important species in the subdominant moss community are *Bryum alpinum* and *Aulacomnium palustre*. In relatively higher and drier situations away from the mire an additional assemblage of herbs dominate the ' Meadow Formation '. They are *Taraxacum officinalis, Euphorbia wallichii, Gentiana argyrophylla, G. tenella, Impatiens* sp., *Sambucus, ebulus Cnicus falconeri, Dipsacus inermis, Tanacetum longifolium, Inula royleana, Adonis chrysocyathus, Pleorogyne carinthiaca* etc. Still higher up these are succeeded by either ' bush land stage ' dominated by *Juniperus communis, J. squamata, J. recurva* and *Rhododendron anthopogon* communities or by ' white-birch woodland stage ' in which *Betula utilis* is dominant and its close associates are *Pyrus foliolosa, Salix elegans, Syringa emodii* and *Lonicera parviflora*. On the slopes below Toshmaidan lies the coniferous forest belt dominated by *Abies webbiana* for most of the middle zone and by *Pinus wallichiana* towards the upper and lower limits. Their common associates are *Picea smithiana* and *Taxus baccata* with occasional pockets of *Prunus cornuta, Acer caesium, Crataegus oxyacantha* and *Aesculus indica*. The undergrowth is mainly made up of shrubs such as *Viburnum nervosum, Skimmia laureola, Rosa macrophylla, Sambucus ebulus, Polemonium caeruleum* etc. Still lower down nearing the Kashmir Valley Basin, *Pinus wallichiana* occurs either in pure formations or in association with broad-leaved tree elements, such as *Juglans regia, Celtis alpina, Morus serrata, M. alba*, etc.

2. BRAMAN; Mire-B; 74° 16′ E, 34° 14·5′ N (TEXT-FIG. 1; PL. 2, FIG, 3): The name of the locality is taken from the village of Braman in the Baramula district of Kashmir. The village lies about 9 km. northwest of Baramula at an altitude of about 1,650 m. Mire-B, which lies within the cultivated fields NW of the village is a small swampy area measuring about 7 × 15 m. (N-S & E-W respectively). It is known to have been in existence beyond the memory of the villagers. The mire is fed by subsoil water seeping in from a nearby water course coming from the hill-side. The terrace supporting the mire has been reworked by the villagers for cultivation on either side but the mire site does not appear to have been disturbed. The samples did not yield many macroscopic plant remains and the sediments which are less than one metre deep consist of soft peaty clays with a few plant remains. They are underlain by Karewa silt which is hard to penetrate.

3. WALANWAR; Mire-W; 74° 19′ E, 34° 15′ N (TEXT-FIG. 1; PL. 2, FIG. 4): This locality is situated about 3 km. east of the village Braman and at about the same elevation. Mire-W is relatively larger and comparatively deeper than Mire-B. In fact there are two mires at this locality situated one above the other and fed by the same water channel but the lower one, the deeper of the two, was selected for study. Mire-W is about 1·20 m. at its deepest and is composed of soft peaty clays with few macroscopic plant remains. The bottom sediments merge with Karewa silt, which is hard to penetrate.

4. DAMAMSAR (lake); 74° 25′ E, 33° 52′ N (TEXT-FIG. 3): Damamsar is a glacial lake situated at *ca*. 3,940 m. above sea level near Toshmaidan. It remains bounded by snow almost all the year round and has been selected primarily for the study of bottom samples from the lake bed. The interest in this particular lake has been inspired by 1) the treeless nature of the area surrounding the lake, a fact that is likely to help in the study of the long distance transport of tree pollen in the region and 2) the close proximity of the lake to Toshmaidan mires. The lake lies nearly 9 km. from the tree line on the northern slopes of the Pir Panjal Range and about 4 km. from the tree line on the southern slopes from which it is separated by the range of hills almost 300 m. high which form the water shed.

The sediments accumulating at the lake bottom are fine bluish-grey clays with concretions of broken trap-rocks, a fact which reminds one of the occurrence of similar sediments in the deepest layers of Mire-T at Toshmaidan.

B. POLLEN ANALYSIS

Material and Methods

Field Work — The various samples were taken with the help of a Hiller peat borer equipped with a 30 cm. chamber. The samples were collected at 4-6 cm. intervals in the upper layers of the deposits but lower down the interval was reduced to 3-4 cm. For the levelling at Mire-T at Toshmaidan a ' dumpy level ' was used.

Laboratory Technique — Each sample was broken up in a little absolute alcohol and then treated with 5-10 cc. of 40% HF for a period of 24-72 hours. After decanting off the HF, the material was washed with a few c.c. of dil. HCL (2 parts acid, 1 part H_2O) followed by 3-4 washings with distilled water. The residue left after final centrifuging was shaken vigorously with 5 cc. of glacial acetic acid; the acid was then decanted off and the tube inverted on a filter paper. After this the usual acetolysis treatment was carried out as detailed by Erdtman (1952). The slides were prepared in glycerine jelly and ringed with molten paraffin wax.

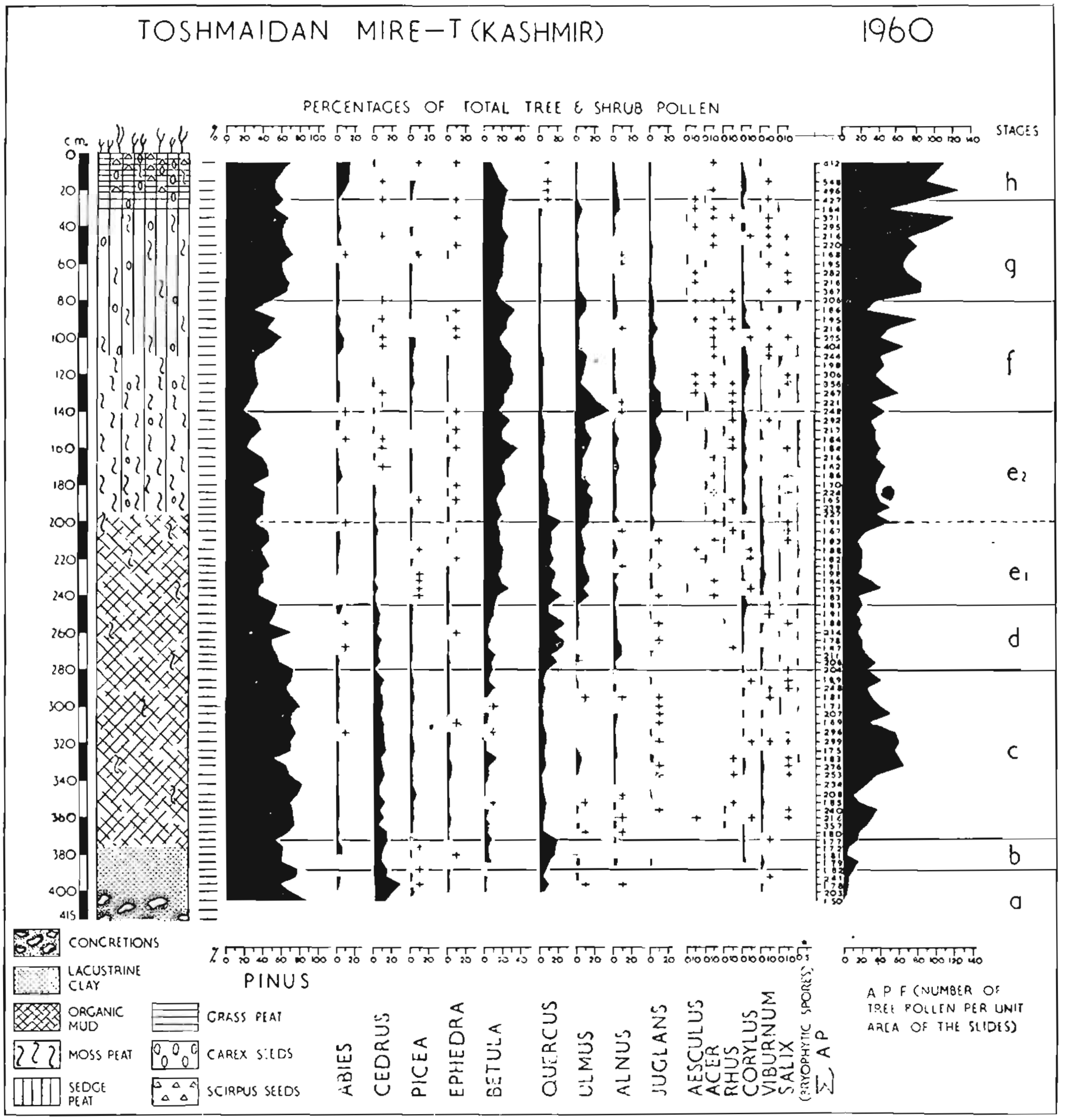
All the peat samples were taken in a more or less uniform quantity and were treated in accordance with the above standard technique with as little variation as possible. For clayey samples, however, the percentage of KOH was reduced from 10 per cent to 5 per cent or even 2 per cent.

The Construction of Pollen Diagrams — A standard sum of at least 150 arboreal pollen per spectrum was counted for each sample. Percentages were calculated on the basis of total AP count per spectrum and for one NAP diagram, on the basis of total NAP count. The former basis has been employed in the case of pollen diagrams from Braman and Walanwar mires, whereas the latter method has been utilized in preparing the NAP diagram for Mire-T. The pollen grains of the local aquatic elements have been excluded from the NAP sum. The bryophytic spores have been represented as percentage of the AP sum. The curves for algal colonies such as *Pediastrum* and *Botryococcus* are based on their number per unit area of the slides. Additional columns have been provided to illustrate the number of AP and NAP (NAP in case of Mire-T only) counted per spectrum and the relative representation of NAP versus AP has been indicated in each case. Besides this, the ' Absolute Pollen Frequency ' (number of tree pollen per unit area of the slides) is shown by a separate curve (APF) in the AP diagram from Mire-T. A separate diagram has also been prepared giving the distribution of the various species of *Quercus* and *Betula* separated statistically for each stage of the vegetational sequence.

Vegetational Developmental Stages — From the changes in the pollen curves of the ecological units of vegetation in the pollen diagrams eight vegetational stages (a-h *cf.* Mire-T pollen diagrams) have been recognized and broad conclusions regarding the climatic changes have been drawn. The above vegetational stages are still tentative and do not represent pollen zones, which can be considered only, when fuller data are available. In view of the more or less continuous stratigraphical development of Mire-T, the vegetational history revealed by this mire has been taken as standard for further correlation of pollen diagrams from relatively younger mires.

C. THE POST-GLACIAL, VEGETATIONAL SEQUENCE

Pollen Diagrams from Mire-T (TEXT-FIGS. 5-8) — In view of the peculiar physiographic situation of Toshmaidan, Mire-T is not only in a position to reflect the influence of the local vegetation but is also liable to record the wind blown pollen types from the relatively lower altitudes such as the floor of the Kashmir Valley and the southern slopes of the Pir Panjal Range. However, it is likely that the long distance transport of pollen would have affected the pollen diagrams from Mire-T more in the early Post-glacial phases, when the higher altitudes might not have been forested, than in the advanced stages, when the forests spread all over giving a more or less representative pollen rain for the whole region. Accordingly when dealing with the bottom sediments of Mire-T, more value has been placed on the nature of the sediment, Absolute Pollen Frequency (APF) and NAP/AP ratio whereas the tree pollen flora has been taken as a secondary evidence. Further in order to visualize the reality of the situation in this region, a blue grey clay sample was taken from the bottom of a glacial-lake namely Damamsar, which is situated near the summit of the range above Toshmaidan at *ca.* 3,940 m. and its pollen content was analysed (TABLE 1). It is seen that in the blue-grey



TEXT-FIG. 5 — Arboreal pollen (AP) diagram from Toshmaidan showing the percentages of total tree pollen, absolute pollen frequency (APF) and the Bryophytic spore curve from Mire-T.

clay, which is the only sediment deposited in this lake, the pine pollen amounted to almost 85 per cent of the total tree pollen, although the nearest pine tree grows at a distance of 9 km., and 600 m. lower on the northern slopes. On the southern slopes the nearest pine trees are 4 km. from the lake. The NAP accounts for 60 per cent of the total land plant pollen and the APF shows an extremely low value. This example makes it very clear that open alpine arctic vegetational conditions in this region can only be adjudged from the nature of the sediments deposited and from such factors as relative APF and NAP/AP ratios. Where pine pollen is preponderant, these considerations have to be borne in mind in attempting to draw conclusions as to the local conditions.

TABLE 1 — POLLEN-ANALYSIS OF A SURFACE SAMPLE FROM DAMAMSAR LAKE

Pollen grains	Number of pollen Grains counted	Percentage in terms of AP %
AP		
Pinus wallichiana	148	84·5
Abies	10	5·5
Juniperus	5	3·0
Betula	1	0·5
Ulmus	1	0·5
Alnus	7	4·0
Juglans	1	0·5
Corylus	1	0·5
Viburnum	1	0·5
Total AP	175	
NAP		
Cyperaceae	68	39·0
Centrospermae	11	6·0
Artemisia	1	0·5
Gramineae	18	10·0
Plantago	3	1·7
Ranunculaceae	37	21·0
Caryophyllaceae	1	0·5
Umbelliferae	1	0·5
?Rosaceae	100	57·0
Boraginaceae	12	7·0
Total NAP	264	
Total AP+NAP	439	
Ratio AP	40%	
NAP	60%	

Vegetational stages:

'Stage-a'; Blue pine — Cedar phase: (depth, 405-388 cm.)— This stage is characterized by the extremely high values for *Pinus wallichiana* pollen. Except for cedar and oak which compete to some extent with the blue pine, the pollen curves for the other trees remain quite insignificant. There are occasional pollen grains of *Abies, Picea, Alnus, Betula* (*utilis*), *Ulmus* and *Viburnum*. The oaks appear to be represented by predominantly *Quercus semecarpifolia* and *Q. dilatata* in this stage (TEXT-FIG. 6). *Ephedra* is represented to the extent of 2 per cent.

In view of the overwhelming presence of pine pollen in 'Stage-a' together with minimum APF and the highest NAP/AP ratio, it seems reasonable to infer that the blue pine and the other tree constituents did not occur locally at Toshmaidan during this stage but that they occurred some distance away on the relatively lower slopes. At Toshmaidan the conditions appear to have been quite cold (as also shown by the deposition of blue grey clays showing felspars in an undecomposed state and from the absence of the formation of organic lake mud and algal remains, both appearing only in subsequent stages). The meadow vegetation, however, had already taken its foothold and largely comprised of Compositae, Centrospermae, and Cyperaceae.

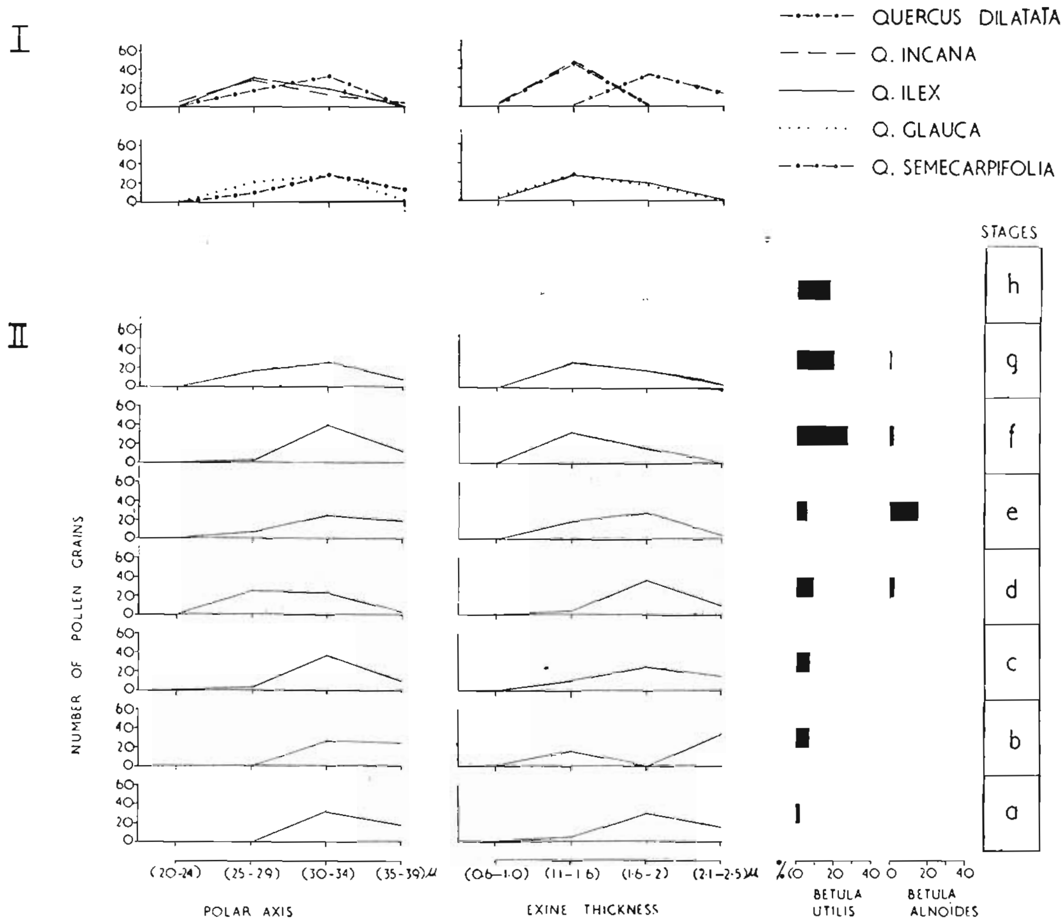
The miscellaneous Compositae pollen grains show a frequency as high as 48·5 per cent, Centrospermae 29 per cent, Cyperaceae 11 per cent, *Clematis ?buchnaniana* 8 per cent, Gramineae 2 per cent and *Artemisia* 1 per cent of the NAP sum at the beginning of 'Stage-a'. In the later samples the curves for Centrospermae, Compositae and *C.buchananiana* fall to low values, whereas the curves for Cyperaceae and *Artemisia* rise. The increase in the APF at the same time may well indicate the progressive encroachment of the region by woods. Other non-tree pollen types found in 'Stage-a' are *Typha, Tribulus* type, *Clematis grata, Utricularia* and *Plantago*.

The high values for the NAP curve in the beginning of 'Stage-a', provide further evidence for the earlier conclusion that open vegetational conditions seem to have prevailed in the area surrounding Toshmaidan. The subsequent decrease of the NAP curve can perhaps be attributed to the gradual increase in the tree vegetation as a whole.

'Stage-b': Blue pine — Oak phase: (Depth, 388-372 cm.)— This stage is characterized by the sudden fall of blue pine and cedar pollen frequencies accompanied by a gradual but steady rise of oaks predominantly *Q. dilatata* (TEXT-FIG. 6). The absolute pollen frequencies remain low.

In spite of the considerable decline suffered by blue pine (from 78 per cent to 52 per cent), it still continues to dominate. The case of *Quercus* is quite interesting since its pollen curve grows from relatively low values in 'Stage-a' to high values of 19 per cent. Simultaneously *Abies, Betula* (*utilis*) and *Corylus* also start their first continuous curves during this stage and show an increased representation over that in 'Stage-a'. Pollen of other tree constituents such as *Picea, Alnus, Ulmus, Juglans* and *Viburnum* continues to be present sporadically. *Ephedra* which was significantly represented in 'Stage-a', almost disappears in 'Stage-b'.

Of the NAP constituents the curve for Cyperaceae falls from 80 per cent to 60 per cent toward the top of this stage and the

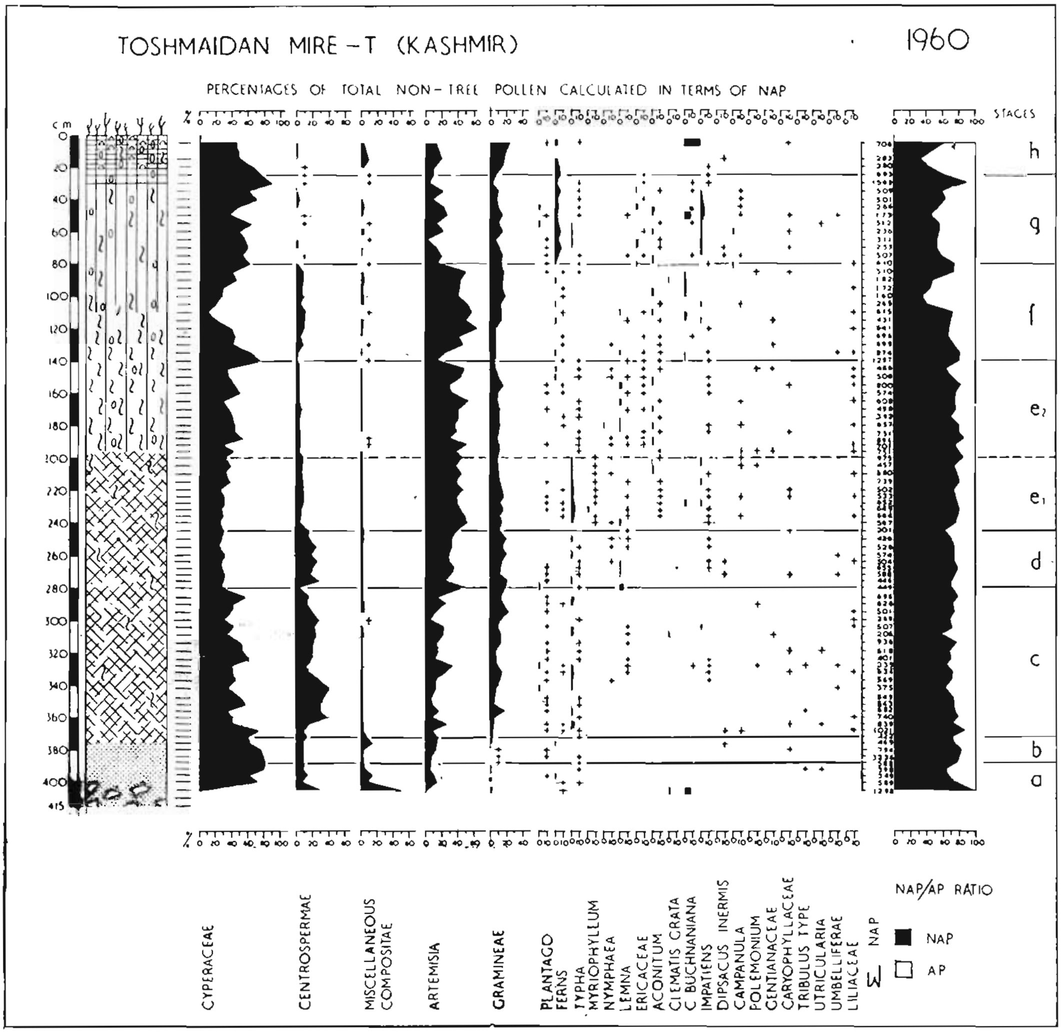


TEXT-FIG. 6 — I, size statistics of pollen grains of the five Western Himalayan species of *Quercus*; II, comparative size statistics of the sub-fossil pollen grains of *Quercus* and the relative frequencies of the sub-fossil pollen grains of the two Western Himalayan species of *Betula* in the sequence of Mire-T at Toshmaidan.

Artemisia curve along with Compositae increase slightly but the composites decline towards the close of the stage. Except for a small rise towards the top of the stage the curve for Centrospermae shows uniformly low values. The curve for Gramineae starts its first regular curve towards the close of this stage. Besides these, the other poorly represented non-tree pollen types are *Plantago*, ferns, *Typha*, *Dipsacus inermis* and Caryophyllaceae, the last two having only one grain of each while *Typha* values remain less than 0·5 per cent.

'Stage-c': Blue pine phase: (depth 372-280 cm.)— This stage is characterized by (1) the fall of *Quercus* and its continued uniformity of low values maintained throughout this stage, (2) the return of blue pine to high pollen frequencies once again, (3) the marked rise of the APF, (4) the appearance of algal colonies such as those of *Pediastrum* and *Botryococcus* which contribute, along with other plant constituents, towards the formation of organic lake mud from the beginning of 'Stage-c' and (5) the disappearance of blue grey clays.

The blue pine pollen frequencies gradually rise and except for a short temporary decline in the middle of this stage they on the whole maintain high values. Cedar is fairly well represented throughout this stage. Both *Abies* and *Picea* show more or less continuous curves throughout 'Stage-c', though their frequencies never rise to more than 6 per



TEXT-FIG. 7 — Non-arboreal pollen (NAP) diagram from Toshmaidan Mire-T, showing the percentages of total non-arboreal pollen and the NAP/AP curve. A key to the stratigraphic symbols is given in Text-fig. 5.

cent. *Ephedra* is well represented throughout and attains values reaching as high as 6 per cent. Among the broad-leaved trees, the *Quercus* pollen curve, largely represented by *Q. semecarpifolia* and *Q. dilatata* (TEXT-FIGS. 5, 6) continues more or less uniformly throughout but, *Alnus*, *Betula* (*utilis*), *Corylus* and *Viburnum* have more or less intermittent curves. The rest of the tree curves remain more or less sporadic. However, almost all the broad-leaved tree elements such as *Betula* (*utilis*), *Ulmus*, *Juglans*, *Corylus*, *Viburnum*, *Salix* and *Quercus* appear to have received a short impetus at the cost of conifers during the middle of this stage and simultaneously the NAP elements such as *Artemisia*, and Gramineae, also seem to have had an added advantage to show increase in their relative frequencies. On the whole in 'Stage-c', Centrospermae increased to its maximum development whereas Cyperaceae and Compositae showed an overall decrease from the previous stages. *Lemna* made its first appearance in this stage and *Typha* is increasingly represented throughout. During 'Stage-c', as can well be seen from the gradual increase in the APF and from the gradual fall in the NAP/AP ratios, the tree vegetation seems to have increased and possibly many of the tree constituents had started encroaching upon the relatively higher slopes.

The introduction of free floating plants such as *Lemna*, *Nymphaea*, *Pediastrum*, *Botryococcus* and submerged plants such as *Chara* coupled with the formation of organic lake mud at the site of Mire-T shows that the environment at Toshmaidan had become fairly suitable for the growth of these elements and for the initiation of a hydrosere in the lake.

' Stage-d ': Blue pine — Oak phase (depth, 280-245 cm.)— This stage is primarily a transitional one and is characterized by the fall of the blue pine and cedar curve from relatively high levels to considerably lower values and by the emergence of *Quercus* which appears to be predominantly represented by *Q. semecarpifolia*.

' Stage-d ' is transitional in the sense that it represents a prelude to the next ' Stage-e ' during the course of which the climax development of the broad-leaved forest is reached resulting in their dominance over the conifers.

Besides *Quercus*, *Alnus* also increases towards the middle of ' Stage-d ' but later declines to relatively low values. The *Abies* curve breaks off quite frequently but that of *Picea* continues with low frequencies throughout the stage. The *Betula* curve remains at low values between 5 and 10 per cent while the curves for *Corylus* and *Ulmus* are rather more continuous than before. The *Betula* pollen grains are contributed by *B. utilis* and for the first time *B. alnoides*. *Ephedra* is represented to a fair degree in this stage.

The curve for Cyperaceae falls steeply from 56 per cent to 24 per cent and continues to show uniformly low frequencies in ' Stage-d '. The *Artemisia* curve rises steadily throughout the stage, but has a peak in one sample at the opening of the stage. Its fall as well as subsequent rise almost synchronize with the increase and decline of Centrospermae pollen curve in ' Stage-d '. The curve for Gramineae continues more or less uniformly throughout. *Lemna* pollen curve appears for the first time at the beginning of this stage. The rest of the NAP constituents occur more or less sporadically.

The moss spores are met with sporadically (TEXT-FIG. 5). *Pediastrum* remains poorly represented while *Botryococcus* curve is quite high though towards the end of the stage it declines to low values (TEXT-FIG. 8).

Of the Characeae *Chara* dominates until towards the close of this stage where *Nitella* appears.

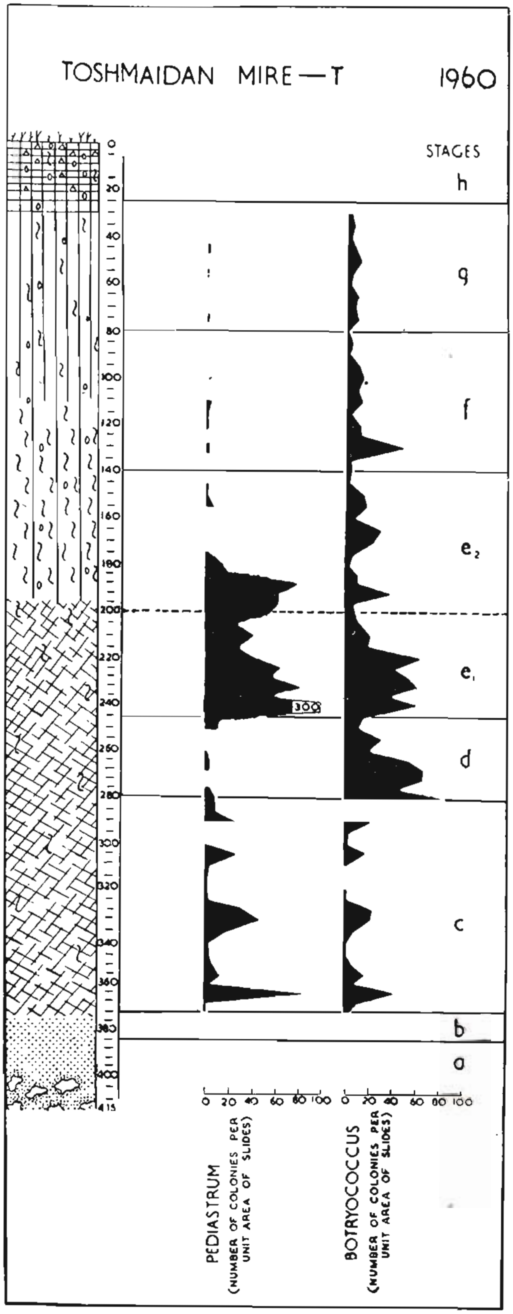
' Stage-e ': Broad-leaved tree phase (depth, 245-140 cm.)— This stage holds the most important place in the AP diagram from Mire-T since it represents the climax of the vegetational development which, having started from blue pine-cedar phase in ' Stage-a ', culminates in a mixed conifer broad-leaved forest in ' Stage-e '.

Primarily, ' Stage-e ' is marked by the sudden rise of *Ulmus* accompanied by the further decline of blue pine, as a result of which, the conifers as a whole become subordinate to broad-leaved elements in this stage. The cedar curve declines further and becomes more or less sporadic towards the end of this stage. *Quercus* which occurs in this stage is predominantly represented by *Q. dilatata* and *Q. semecarpifolia* (TEXT-FIG. 6).

Apart from this the local mire vegetation shows an increased growth and aquatic plants such as *Myriophyllum*, *Nymphaea*. *Lemna*, *Typha*, *Chara*, *Nitella*, *Pediastrum* and *Botryococcus* attain their highest frequency values in this stage.

' Stage-e ' is subdivided into ' substage-e_1' and e_2 ' in accordance with the pattern of the curves for the broad-leaved trees.

' Substage-e_1 ': Blue pine — Oak — Elm — Birch (*B. alnoides*) phase: (depth, 245-200 cm.) — At the beginning of this substage, the blue pine suffers a steep fall from 56 per cent to 35 per cent and for the most part of this substage, it has frequencies below 45 per cent. *Abies*, *Cedrus*, as well as *Picea*, maintain extremely low pollen frequencies. The *Alnus* curve continues to maintain low values as in ' Stage-d '. *Betula*, which is predominantly represented by *B. alnoides* (TEXT-FIG. 6) however, increases suddenly and for the first time attains high values. *Ulmus* holds an important position; its frequencies rise from 2 per cent to 14 per cent at the beginning of the stage and the relative high values are maintained throughout. A continuous curve for *Juglans* begins in this substage but its values do not increase beyond 5 per cent. *Corylus* declines whereas *Viburnum* attains its maximum development during this phase. *Ephedra* remains mort or less sporadic.



TEXT-FIG. 8 — Diagram from Toshmaidan, showing the distribution of *Pediastrum* and *Botryococcus* colonies in the sequence of Mire-T. A key to the stratigraphic symbols is given in Text-fig. 5.

The curve for Cyperaceae rises very slightly but the curve for Centrospermae suffers a sharp fall at the opening of the phase and thereafter does not rise above 10 per cent. The miscellaneous Compositae retains its continuous low curve, whereas *Artemisia* increases further and maintains frequencies above 40 per cent throughout this substage. The curve for Gramineae declines slightly but maintains frequencies between 10 per cent and 15 per cent through out. *Typha* pollen is more frequent, the values rising to 5 per cent, which is its maximum for the entire diagram; the curve gradually declines to low values towards the close of the substage. *Myriophyllum* pollen appears for the first time in this substage forming a short curve with values rising as high as 1 per cent of the NAP sum and dwindling away towards the close of the substage. *Lemna* remains sporadic for most of the part. Pollen of herbs, such as *Aconitum, Impatiens, Campanula, Polemonium* and ferns show increased frequencies. *Pediastrum* as well as *Botryococcus*, show their maximum frequency values in this substage and decline towards the close. The moss spores show a further rise in their values, though they still remain more or less rare. Apart from these the nucules of *Chara* and *Nitella* appear throughout the substage in large numbers.

'Substage-e_2': — Blue pine — Elm — Birch (*B. alnoides*)— Walnut phase: (depth, 200-140 cm.)— This substage is marked by a sharp decline of *Quercus* from 23 per cent to 10 per cent and its subsequent low level. On the other hand it is characterized by the highest development of broad-leaved trees in general and for *Ulmus, Betula* (*alnoides*) and *Juglans* in particular. Apart from this the substage is further marked by the rise of *Ulmus* and *Betula alnoides*. The blue pine curve continues to fall gradually but intermittently and finally towards the close of this stage reaches its lowest level of 19 per cent. *Abies* and *Picea* continue to maintain low frequencies. The *Cedrus* curve becomes sporadic towards the second half of this substage.

Quercus, after its fall, maintains frequencies between 3 per cent and 8 per cent. *Alnus* does not show any marked change but *Betula* (*alnoides*) develops vigorously along with *Ulmus*. They both attain high values in the beginning of the substage but whereas *Betula* continues to maintain them till the second half, thereafter attaining the highest values, *Ulmus* declines earlier. Towards the top of this stage the *Ulmus* values again increase and the curve reaches the maximum frequency of 36 per cent.

The *Juglans* curve shows gradually ascending values from a meagre representation at the beginning of the substage and attains the maximum frequency of 14 per cent towards its close. The *Corylus* curve does not increase beyond 6 per cent whereas *Viburnum* declines considerably and becomes more or less sporadic.

The occurrence of *Acer* as well as *Rhus* during this substage in their highest frequencies for the entire diagram is quite significant, though they are both found in rather low frequencies. *Aesculus* appears towards the close of the substage.

The curve for Cyperaceae gradually increases while *Artemisia* shows a corresponding decline, although on the whole the latter still continues to hold fairly high values. Centrospermae, miscellaneous Compositae and Gramineae continue more or less uniformly throughout the top of the substage. Fern spores, for the first time form a continuous curve towards the second half. *Lemna* increases to a considerable degree but dwindles away towards the top along with the rest of the aquatic elements. The *Aconitum* pollen frequencies increase but remain sporadic.

Pediastrum shows a marked increase in the beginning of the substage but soon dwindles away with the appearance of the moss phase of the mire. In the subsequent stages *Pediastrum* is met with sporadically in extremely low frequencies. *Botryococcus* continues to be well represented but shows sharp fluctuations throughout the substage. Moss spores attain their highest frequencies in this phase and form a more or less continuous curve. *Chara* is replaced by *Nitella* and hereafter the latter continues till the middle of the substage but later dwindles away.

' Stage-f ': Blue pine — Birch (*Betula utilis*)— Walnut-Hazel phase (depth, 140-80 cm.)— This stage is again a transitional one and is characterized by the reversal of the blue pine curve, which now rises rapidly at the cost of *Ulmus* which in turn suffers a steep fall from 36 per cent to 3 per cent in this stage. *Juglans* is the second major element which suffers a gradual fall in this period along with *Quercus* which further declines to frequencies ranging between 2 per cent and 5 per cent. *Quercus* here is apparently represented by *Q. dilatata* (TEXT-FIG. 6).

' Stage-f ' is transitional in the same sense as ' Stage-d ' but here it represents the phase of reversal from a broad-leaved physiognomy to one dominated once again by conifers. The basis for this change is evidently laid in 'Stage-f.'

In this stage the blue pine curve continues to rise along with *Abies* and *Picea* till the second half, after which, the conifer group as a whole suffers a temporary decline and *Ulmus* recovers to some extent but later it again falls to low frequencies.

The *Alnus* curve becomes more or less sporadic. *Betula* (*utilis*) continues to show high values throughout this stage. *Corylus* attains its highest frequencies for the whole vegetational sequence in this stage whereas *Viburnum* though represented in a continuous curve for the first half of this stage declines towards the close and becomes sporadic. *Aesculus* remains poorly represented.

The Cyperaceae curve declines for the first half but recovers in the second half of the stage. Conversely the curves for Centrospermae, *Artemisia*, miscellaneous Compositae and Gramineae show a constant rise in the beginning but later they all fall off. Ferns develop a continuous curve towards the close of the stage and the other NAP elements continue more or less sporadically.

The aquatics such as *Myriophyllum*, *Nymphaea*, *Chara* and *Nitella*, disappear. Moss spores, however, continue sporadically till the close of this stage. *Botryococcus*, though reduced comparatively, still maintains a continuous curve.

' Stage-g ': Blue pine — Birch (*Betula utilis*) phase (depth, 80-25 cm.)— This stage, is marked by complete revertance to a conifer phase. This is apparently seen in the re-establishment of blue pine forests together with *Betula* (*utilis*) as the next important constituent. The curves for all the other broad-leaved tree components except *Alnus* decline to extremely low frequencies. However, *Alnus* increases to a considerable extent towards the close of the stage.

Among the NAP, this stage is characterized by the increase in the Cyperaceae pollen frequencies which are accompanied by a corresponding fall in the *Artemisia* and Gramineae pollen values. Ferns and *Impatiens* increase a good deal and both of them reach their highest values. Centrospermae, however, declines to its minimum values and becomes more or less sporadic. *Typha* increases slightly and continues to be represented for most part of 'Stage-g' but declines towards the close of the phase. The Ericaceae pollen frequency increases and forms a regular curve for the first time in this stage and similarly *Aconitum* pollen curve is seen to increase a good deal. Both Ericaceae and *Aconitum* pollen curves attain their highest values in 'Stage-g'.

'Stage-h': Blue pine — Alpine fir (*Abies webbiana*) — Birch (*B. utilis*) phase (Depth, 25-5 cm.) — This stage is the last Post-glacial vegetational stage represented in Mire-T and is characterized by the sudden rise of *Abies webbiana* as an important unit of the pollen assemblage. The curve for blue pine still holds the dominant position. Alongside other conifers, *Picea* also shows an increased development at the cost of broad-leaved trees in general. The curve for *Alnus*, the last remnant of the broad-leaved tree associations, declines to insignificant values. *Betula* (*utilis*), though fairly well represented in the beginning declines towards the upper end. Forest constituents such as *Betula alnoides*, *Quercus*, *Viburnum*, *Juglans*, *Ulmus* and *Corylus*, either disappear or decline to extremely low values towards the close of this stage.

Whereas *Viburnum*, *Juglans*, *Ulmus* and *Corylus* are still found growing in the Kashmir Valley, the natural occurrence of *Quercus*, *Alnus* and *Betula alnoides* has not so far been reported.

The *Abies* pollen frequencies towards the close of 'Stage-h' though fairly high (14 per cent), actually do not correspond to the present day occurrence of the genus, which appears to form almost 30-40 per cent of the tree vegetation of the Kashmir Valley slopes of the Pir Panjal Range. Conversely blue pine is rather excessively represented in the pollen count. The reason for the discrepancy perhaps lies in the differential pollen productivity of the two constituents.

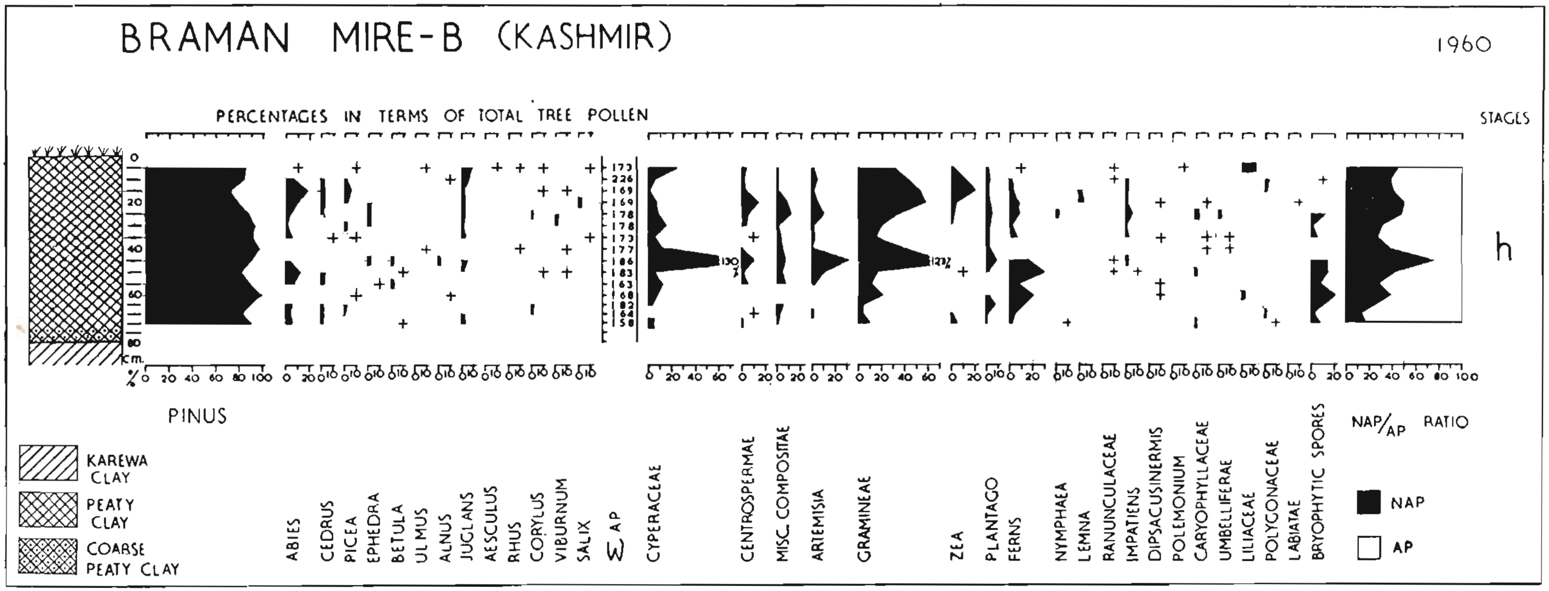
During this stage, the Cyperaceae curve declines to a considerable degree and Gramineae increases and attains its maximum value of 24 per cent. *Artemisia* also increases but falls off towards the close. Ferns which were fairly well represented in the previous stage decline considerably in this stage.

Although there is no denying the fact that the APF curve can be considerably influenced by factors such as the rate of sedimentation, nature of sediment etc., it is interesting to see that the APF curve from Mire-T still holds out a fair degree of promise. It continues to rise intermittently in the successive stages, declining temporarily with the decline of high pollen-producing blue pine in 'Stages-d and e_1' and reaches its maximum rise in 'Stage-h.' Similarly the NAP/AP ratios, after being strongly influenced by local *Artemisia* pollen in 'Stages-d, e and f,' decrease to their lowest values in 'Stage-h'. The evidence thus obtained from the curves of both APF and NAP/AP points out towards the same conclusion that perhaps not only did the vegetation cover extend itself progressively during the various successive stages of the Post-glacial period but probably there was also a gradual rise of the tree elements taking place over the non-tree vegetation since the earliest stages.

Pollen diagrams from Mires B & W (TEXT-FIGS. 9, 10). The pollen sequences from both Mire 'B' and 'W' must be considered 1) from the point of view of the altitude of their localities and 2) from the view point of the present day vegetational zone in which these localities are situated. Both the mires are situated at about 1650 m. above sea level and within the Kashmir Valley vegetational zone; the local vegetation is dominated by blue pine though the areas situated towards the centre of the Kashmir Valley have been largely brought under cultivation. (Note: the NAP pollen frequencies have been calculated in terms of the AP sum in the diagrams from Mires B & W).

Mire-B: (depth, 72-5 cm.) — In the pollen diagram from Mire-B (TEXT-FIG. 9), the blue pine pollen frequencies dominate the whole sequence reaching as high as 99 per cent but generally range between 80-95 per cent, declining to 72 per cent towards the top of the diagram. *Abies* which is represented by an interrupted pollen curve attains frequencies up to 18 per cent during the second half of the sequence but suddenly declines towards the extreme top. *Picea* and *Cedrus* pollen grains which are sparsely represented for most part of the sequence increase towards the top along with those of *Abies* but later they soon decline away. *Ephedra* pollen grains are met with sporadically.

Among the broad-leaved elements, *Alnus*, *Betula* (*utilis*), *Ulmus*, *Corylus*, *Salix*, *Rhus*, *Viburnum* and *Aesculus* are very insignificantly represented throughout the sequence. The only broad-leaved tree that is fairly common and which also increases towards the top is *Juglans*.



TEXT-FIG. 9 — Combined AP and NAP diagram from Braman Mire-B, showing the percentages of arboreal and non-arboreal pollen calculated in terms of total AP and the NAP/AP curve.

The AP curve shows a progressive decline towards the top of the sequence but on the whole continues to dominate. The progressive decline of AP curve is, however, suggestive of a successive clearing away of the woods.

Among the NAP constituents, the Cyperaceae curve generally has values below 24 per cent, but in the middle of the sequence, it mounts to 130 per cent. The curve for Gramineae after a low start gradually rises, but after shooting up to 124 per cent in the middle, declines, but on the whole maintains fairly high frequencies in the second half of the sequence. Although the Gramineae pollen curve has a fluctuating course, its general representation remains fairly high throughout. Except for a brief appearance at the base, maize pollen is not found until the second half of the sequence where the frequencies rise up to 19 per cent but they soon decline towards the top. The *Artemisia* pollen curve only appears towards the middle of the sequence and rises to 32 per cent synchronously with the maximum frequencies attained by Cyperaceae and Gramineae. Miscellaneous Compositae are fairly well represented along with *Plantago* and Centrospermae throughout the sequence. From low values at the base, the fern curve rises up to 25 per cent in the first half but declines gradually to low frequencies in the second half. *Nymphaea*, *Lemna*, Ranunculaceae, *Dipsacus*, *Polemonium*, Caryophyllaceae, Umbelliferae, Polygonaceae, and Labiatae grains occur only sporadically. *Impatiens* pollen grains, however, are fairly frequent during the upper half of the sequence and those of Liliaceae are fairly abundant towards the top. Bryophytic spores are commonly encountered during the lower half of the sequence.

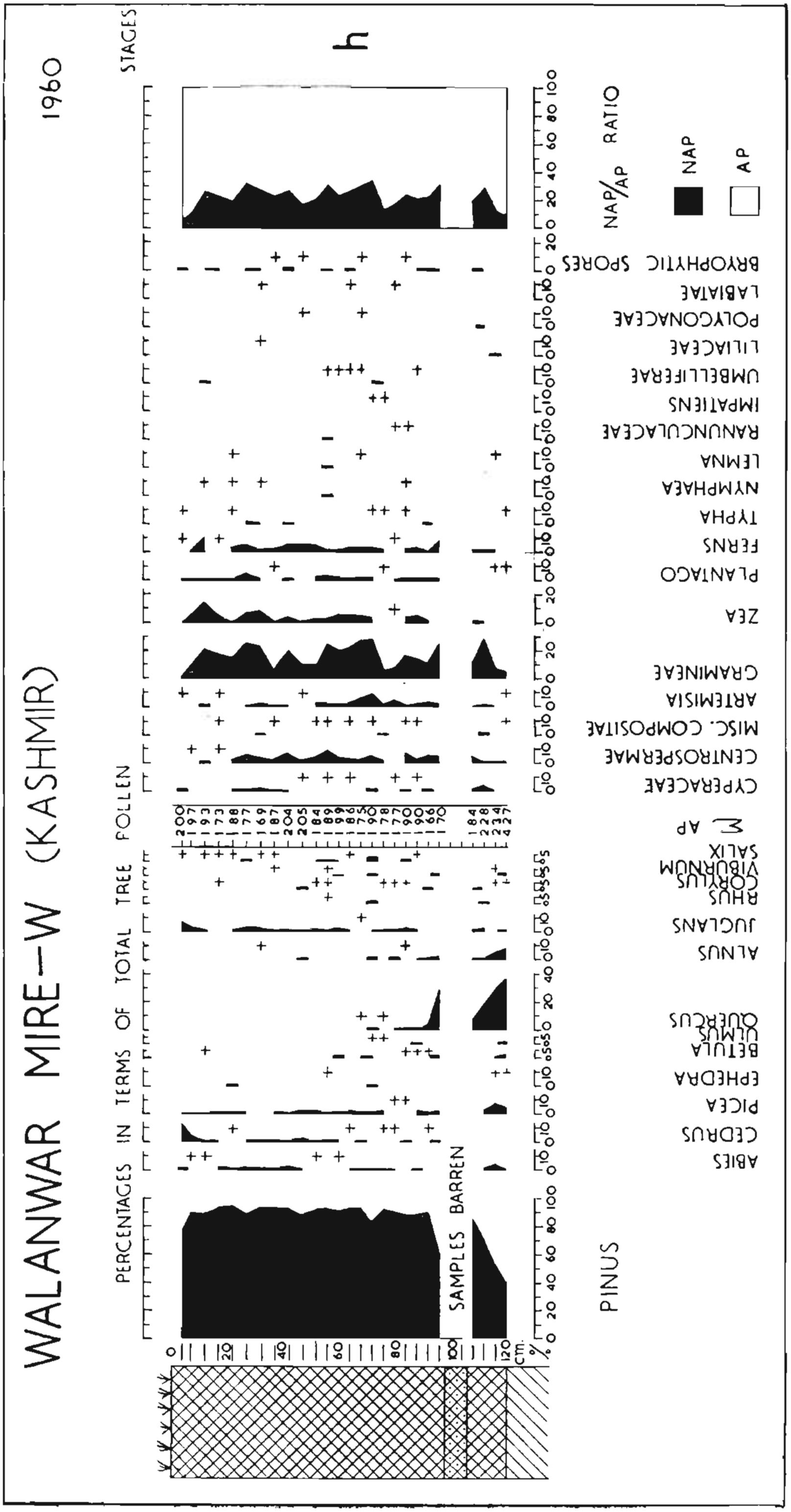
It is interesting to see that the first interruption suffered by the *Abies* curve is synchronized by the increase in Gramineae, Miscellaneous Compositae and ferns, and similarly the second fall is accompanied by a tremendous increase in Gramineae, Cyperaceae, *Artemisia*, *Plantago* and Centrospermae. Further up, the sudden decline in the blue pine is again synchronized with the increase first in Gramineae and later by maize. Collectively the NAP frequencies gradually mount up and reach as high as 77 per cent in the lower middle portion of the sequence. In spite of a sudden fall immediately afterwards, the frequencies in the upper half of the diagram, on the whole show a rising trend in relation to the lower part of the diagram.

Mire-W: (depth, 120-5 cm.)— The pollen diagram from Mire-W (TEXT-FIG. 10) shows a brief blue pine — oak phase at the bottom which abruptly gives place to a more or less pure blue pine phase. The latter continues to dominate throughout the rest of the vegetational sequence. Among the other tree elements *Abies* is represented to the extent of 4 per cent during the early phases but later has very low frequencies. *Cedrus* has low values before the middle of the profile, and does not rise to any significant degree till the top of the sequence where the curve rises abruptly. *Picea* is well represented at the base but later, it reduces to low frequencies. *Alnus* disappears altogether after a brief sporadic record. The *Juglans* pollen curve makes its regular appearance a little before the middle of the sequence and but for one interruption towards the top it continues in low values throughout, rising only towards the top to 6·5 per cent. *Quercus* (*dilatata*) is represented to the extent of 37 per cent in the beginning but it suddenly falls to 3·5 per cent and vanishes beyond the middle of the sequence. Other tree pollen is sporadic. *Salix*, however, though sparsely represented shows a continuous curve towards the top.

Gramineae, in spite of the fluctuating curve, is the most frequent pollen type. Though present from the base, maize does not have a continuous curve until the middle of the sequence, after which its frequencies rise as high as 15 per cent. *Artemisia* pollen frequencies mount up to some extent in the middle, but in the rest of the sequence they remain low. Centrospermae pollen on the whole, does not increase beyond 8 per cent and almost disappears towards the close. Fern spores, though sparsely represented in the beginning, later maintain fairly significant values. The rest of the NAP elements remain more or less sporadic throughout the diagram. The presence of the aquatics such as *Typha*, *Nymphaea* and *Lemna* is marked.

The high proportion of AP is suggestive of the continued dominance of the woods over the non-tree elements throughout the vegetational sequence.

Correlation of the Pollen Diagrams — The overall dominance of blue pine in the diagrams from Mires-B and W is in line with the features of 'Stage-h'. However, the



TEXT-FIG. 10 — Combined AP and NAP diagram from Walanwar Mire-W, showing the percentages of arboreal and non-arboreal elements calculated in terms of total AP, and the NAP/AP curve. A key to the stratigraphic symbols is given in Text-fig. 9.

excessive representation of *Quercus* in the earlier phase of Mire-W and the absence of *Abies* and *Betula utilis* phase at both sites appears incompatible with the characteristics of ' Stage-h ' at Toshmaidan. Considering the altitude of both the mires and their situation, far away from the high altitude vegetation, it seems reasonable to believe that blue pine was locally so abundant that *Abies* and *Betula utilis*, both of which grow in the higher regions, could not be represented to any significant degree. Nevertheless the case of *Quercus* (*dilatata*) is difficult to understand. Its presence in Mire-W to a high degree in the beginning and then its abrupt fall without any synchronous effect on the NAP goes to show that perhaps *Quercus* was not widespread but occurred locally in pockets which were eliminated in due course of time by the increasing encroachment of blue pine. *Alnus* also seems to have suffered the same fate and both these trees are no longer to be found in the valley. The presence of aquatic elements in Mires-B and W, which are absent in ' Stage-h ' of the Toshmaidan pollen sequence is again probably due to the low altitude of these mires in comparison to Mire-T. The aquatic elements represented in these mires normally grow at these elevations in the Kashmir Valley but at higher altitudes they do not exist today.

NOTES ON PLANT REMAINS

The plant remains recovered from the various Post-glacial deposits of the Kashmir Valley are described here with special reference to their individual distribution in the vertical sequence of the deposits, giving in important cases their present day ecological distribution in the Indian subcontinent.

The majority of the plant remains are pollen grains and spores. Others include moss shoots, nucules of *Chara* and *Nitella*, *Pediastrum* and *Botryococcus* colonies etc. Not many forms of seeds have been encountered except for those of *Scirpus setaceus* and *Carex* sp.

Every attempt has been made to identify each of the plant remains met with, by direct comparison with its closest living representatives in the herbarium or sporothek. Wherever there is uncertainty in the exact identification, an interrogation mark precedes the name ascribed.

PINACEAE

Pinus wallichiana ' Blue pine '— This subfossil pollen type is overwhelmingly represented in ' Stages-a, b, c and d ' and in the ultimate stages of the Post-glacial in the Kashmir Valley, when it reverts back from its lowest frequencies reached during ' Stage-e '.

P. wallichiana commonly known as ' blue pine ' is the only natural pine represented in the Kashmir Valley and grows abundantly all along the Northwestern temperate Himalayas from *ca.* 1,800 m. to 3,600 m. overlapping the whole coniferous belt except the lower *P. roxburghii* zone and extends well above the *Abies webbiana* zone. It is seen that blue pine is more frequent at the upper and lower limits of the range than in the central part where it occurs mixed with other conifers and broad leaved elements. In Kashmir it does not ascend beyond *ca.* 3,300 m. where it occupies the banks of ravines.

The sites occupied by blue pine tend to be those with conditions which are relatively xerophytic from various causes and moreover, it is a pioneer colonist on newly available sites such as gravel deposits along the streams, landslips, avalanche paths etc. (Champion 1936). In Kumaon dry situations along with winter snow fall favours its growth (Osmaston 1927).

Picea smithiana ' Spruce '— The subfossil grains of *P. smithiana* are common but their frequency curve at no stage becomes prominent. The pollen type is found almost throughout the Toshmaidan vegetational sequence. Except for a few short gaps, its curve continues to fluctuate within 6 per cent, rarely exceeding this value. In the Walanwar pollen sequence, it is significantly represented at the base of the profile, but later, it follows an intermittent course. In Mire-B it is sporadically met with.

P. smithiana is one of the two species represented in India and apart from its distribution in the Kashmir Valley between *ca.* 1,800 m. and 3,000 m., it occurs widely throughout the N.W. Himalayas up to *ca.* 3,300 m. In the Kashmir Valley it grows in association with *Pinus wallichiana* and *Abies webbiana* never exceeding 3·5 per cent; generally much less (Sher Singh, 1929). The other species *P. spinulosa* grows only in Eastern India.

Abies webbiana ' Alpine Fir '— Sub-fossil grains of *A. webbiana* are common but their frequency curve does not show any marked rise until 'Stage-h'. In this stage, *A. webbiana* becomes subdominant to *Pinus wallichiana*.

In the Kashmir Valley *Abies webbiana* grows in almost pure formations along with *Taxus baccata* and *Picea smithiana* in the middle ranges. Towards the upper and lower limits it grows with *Pinus wallichiana* and ranges between *ca.* 2,100 m. and 3,150 m. on the valley slopes of Pir Panjal Range. In the N.W. Himalayas it extends up to *ca.* 3,600 m. whereas in the E. Himalayas it ranges between *ca.* 2,550 m. and 3,900 m.

The growth of *Abies webbiana* is commonly associated with extremely cold temperate climate with sufficient winter snow fall. *Abies webbiana* apparently does not function as a pioneer species, but comes into the forest when it is approaching climatic stability (Dudgeon, 1925).

Cedrus deodara 'Deodar'— Subfossil grains of *Cedrus deodara* are met with in significant frequencies during 'Stages a, b and c' after which they decline but continue in relatively low values until 'Substage e_1'. Subsequently they become sporadic. In the vegetational sequence from Mire-T, its high values synchronize with the relatively dry and arid climatic phases. *Pinus wallichiana* and *Ephedra* happened to be its chief associates during these phases. In the Walanwar profile cedar increases towards the top of the sequence. In Mire-B, however, it remains sporadic.

Deodar which is a native of Himalayas is almost absent on the Kashmir Valley slopes of the Pir Panjal Range and grows only in a few isolated patches. Its absence from the valley slopes of the Pir Panjal Range is ascribed by Sher Singh (1929), to high humidity in the region in winter which is unfavourable to its normal growth.

Deodar commonly grows throughout the Western Himalayas between *ca.* 1,200 m. and 3,300 m. but most commonly from *ca.* 1,800 m. to 2,400 m. Brandis classifies deodar forests into three groups, the first in the dry arid zone of the inner Himalaya, the next covering the intermediate ranges and valleys and the last on the outer ranges, where the full strength of the monsoon is felt and where the rate of growth is faster than in forests nearer the main ramp of the Himalaya (Pearson and Brown, 1932). According to the above authors, excessive rainfall may be responsible in certain localities for the total absence of this species.

GNETACEAE

Ephedra spp.— Four different subfossil pollen types pertaining to *Ephedra* are met with in the Post-glacial sediments from the Kashmir Valley, but in view of the absence of proper pollen morphological records of the Indian species, specific identification was not possible.

Grains of *Ephedra* are frequently met with in the Toshmaidan pollen sequence in 'Stages a, c and d' up to 6 per cent. but later they become sporadic. They are found only rarely in the Braman and Walanwar profiles.

Ephedra usually occurs in inhospitable arid conditions and can withstand long periods of drought and extremes of temperature.

RANUNCULACEAE

Clematis ?grata — The frequency of this pollen type only becomes significant in 'Stage-f'; otherwise it remains extremely sporadic.

C. ?buchananiana — This pollen type is first seen in 'Stage-a' but is more regularly met with in 'Stages-f, g and h' of the Toshmaidan vegetational sequence.

Aconitum ?lycoctonum — This subfossil pollen type is not usually met with till the beginning of 'Stage-e' after which it is quite frequently seen but follows a discontinuous curve for a considerable period. In 'Stage-h' it is again rare.

The Ranunculaceae pollen grains in general occur only sporadically in the profiles from both Braman and Walanwar.

NYMPHAEACEAE

Nymphaea ?stellata — Subfossil grains of this species are mostly met with during 'Stages-d and e'. Subsequently they cease to be represented in the Toshmaidan profile but, continue to occur sporadically in 'Stage-h' of the Braman and Walanwar pollen sequences.

N. stellata grows at present in the Kashmir Valley in the Dal and other lower altitude lakes. Outside the Kashmir Valley, this species grows commonly throughout the warmer parts of India. In the present day climate, it is incapable of natural growth in the Kashmir Valley at elevations at which Mire-T is situated (3120 m.).

CARYOPHYLLACEAE

As many as five different subfossil pollen types referable to the family Caryophyllaceae are found in the Post-glacial sediments, but at no stage of the vegetational sequence, the curve for Caryophyllaceae appears to be of any significance. Caryophyllaceae pollen types appear first in 'Stage-b' and thereafter occur sporadically in all the subsequent stages of the Toshmaidan pollen sequence excepting 'Stages f and h'. In the Braman profile, however, they are sporadically met with throughout.

ZYGOPHYLLACEAE

Tribulus type — This pollen type is met with extremely rarely in 'Stages-a and c' and is not seen thereafter.

The different species of *Tribulus* are distributed in the arid regions of the Indian subcontinent.

GERANIACEAE

Impatiens spp.— Two different types of subfossil pollen grains pertaining to this genus are commonly seen, having either 3 or 4-colpate condition. In the Toshmaidan diagram they are first seen in 'Stage-c' after which they continue more or less sporadically throughout the vegetational sequence, attaining apparently significant frequencies in 'Stages-e, and g'. They decline in 'Stage-h' of the Toshmaidan pollen sequence but are well represented in the Braman profile and to a lesser extent in the Walanwar pollen sequence.

SAPINDACEAE

Aesculus indica — The subfossil grains of *A. indica*, rarely occur in significant proportion. In the Toshmaidan AP diagram, they are first seen in 'Stage-c', then in 'Stage-e' to some extent, but later in 'Stages-f and g' they are more common.

A. indica is widely distributed all over the W. Himalayas between *ca.* 1,200 m. and 3,000 m. In the Kashmir Valley proper it generally grows between *ca.* 1,500 m. and 2,250 m.

Acer ?caesium — This subfossil pollen type first appears in 'Stage-d' and gains its maximum frequencies in 'Substage-e_2', after which it declines.

Acer caesium still grows in the Kashmir Valley in small patches between *ca.* 2,100 m. and 2,700 m. and is widely distributed throughout the W. Himalayas.

ANACARDIACEAE

Rhus sp.— This subfossil pollen type first appears in 'Stage-c' and attains its maximum values in 'Stage-e', after which it declines.

Rhus is represented by several species in the W. Himalayas mostly distributed, in the subtropical to subtemperate regions.

ROSACEAE

The members of this family are very scantily represented in the subfossil pollen records, although their modern distribution in the valley of Kashmir is quite significant. So far, occasional pollen grains of *Potentilla ?argyrophilla*, *Pyrus ?pashia* and *P. ?foliolosa* have been encountered sporadically in the Kashmir Valley Post-glacial sediments.

HALORAGAE

Myriophyllum ?spicatum — This subfossil pollen type is first encountered in 'Substage-e_1' in which its curve reaches its highest values. Later it declines but continues sporadically until the beginning of 'Stage-f' after which it totally disappears.

M. spicatum commonly grows on the floor of the Kashmir Valley in Dal and other similar lakes at about 1,500 m. In the present day climate the species is incapable of existing in the Kashmir Valley at the altitudes as high as Mire-T (2,120 m.). Outside Kashmir the species descends to *ca.* 300 m. along the northern boundary of the Panjab (HOOKER, 1879, p. 433).

UMBELLIFERAE

The subfossil pollen types referred to this family occur in extremely low values throughout the vegetational sequence. They are first encountered in 'Stage-c' and occur sporadically in 'Stages-d and f' of the Toshmaidan pollen sequence. They occur sporadically in 'Stage-h' of the Braman and Walanwar profiles.

So far three different pollen types have been recognized, but in view of the stenopalynous character of the pollen grains in the family no attempt has been made yet to refer the fossil types to any definite genera or species.

CAPRIFOLIACEAE

Viburnum ?nervosum — This subfossil pollen type occurs quite frequently. It is first found in 'Stage-a' in low frequencies reaching up to 4 per cent in 'Stage-b' after which it declines but reappears in the next stage, where it forms a fairly continuous curve. Afterwards it occurs more or less sporadically up to the middle of 'Stage-d' but thereafter it rises rapidly and attains its maximum frequencies during 'Substage-e_1'. In the subsequent stages the subfossil pollen type declines and only occurs sporadically.

V. nervosum occurs with broad-leaved tree associations as well as with pure conifer formations such as is the case at present in the Kashmir Valley where it grows as a shrubby undergrowth of blue pine and *Abies webbiana* between *ca.* 2,100 m. and 3,150 m. Outside, it is distributed all over the temperate Himalayas up to Sikkim between *ca.* 3,000 m. and 3,900 m.

VALERIANACEAE

Valeriana sp.— This subfossil pollen type is extremely rare and so far only a single grain has been recovered, from 'Stage-c'.

DIPSACEAE

Dipsacus inermis — This subfossil pollen type occurs sporadically in 'Stages-b, c, d, g and h' of the Toshmaidan pollen sequence. It is also met with in low frequencies in the Braman profile.

D. inermis grows throughout the temperate Himalayas from Kashmir to Bhutan between *ca.* 1,800 m. and 3,600 m. and is widely distributed over the Pir Panjal Range.

COMPOSITAE

The subfossil pollen grains of the family Compositae have been recorded under two general headings. (1) *Artemisia*, of which four types were encountered and (2) miscellaneous Compositae.

Artemisia — The subfossil pollen grains of *Artemisia* play a significant role in the Post-glacial NAP diagram from Mire-T.

The *Artemisia* pollen curve rises to its maximum extent and importance between 'Stages-d and f' and is relatively sparsely represented in the early and later parts of the Post-glacial vegetational sequence. This seems to be explained by the fact that most of the 13 species of *Artemisia* represented in the Kashmir Valley are now confined to the drier alpine areas occupying high altitude forestless slopes. It is likely that *Artemisia* got an added impetus for luxuriant growth during the Post-glacial warmth period at higher altitudes. Moreover the low altitude species of *Artemisia*, now inhabiting the forestless floor of the Kashmir Valley also may have ascended the higher slopes during the warmth optimum and occupied high altitude meadows. These two factors may have resulted in the increased frequencies of *Artemisia* pollen in Mire-T during this period.

The decline of the *Artemisia* curve during 'Stages-g and h' is rather difficult to explain. It may possibly be that the pastoral activity of man caused the reverses in the *Artemisia* curve but since *Artemisia* is poisonous to grazing animals this seems unlikely. It seems possible, however, that since there is a simultaneous increase of fern spore frequencies, the conditions may have been wetter in Stages-g and h and that this may have retarded the growth of *Artemisia*.

In the pollen diagrams from Braman and Walanwar, *Artemisia* is not well represented. In the Braman profile, however, the *Artemisia* curve shows a significant rise along with Cyperaceae, Gramineae and Centrospermae in the middle of the sequence, at the same time as the sudden fall of *Abies*.

Miscellaneous Compositae — Among the subfossil pollen grains ascribed to this group are, one pollen type of Tribe Cichoreae, two of Anthimideae (apart from *Artemisia*) and three of Cynaroideae.

The pollen frequency curve representing miscellaneous Compositae begins in 'Stage-a' at the high level of 48·5 per cent of the NAP, but soon declines to 8 per cent, rising once again during the middle of 'Stage-b'. In the subsequent stages it remains extremely low but continues uninterrupted for most of the period. It rises slightly in 'Stages-c, d, f and g ', and reaches as much as 10 per cent during ' Stage-h ' of the Toshmaidan pollen sequence. It is equally well represented in the Braman profile. In the Walanwar sequence the miscellaneous Compositae grains are met with only sporadically.

CAMPANULACEAE

Codonopsis ?ovata — This subfossil pollen type is extremely rare and so far only two grains have been encountered, both from ' Substage-e_1 '.

Campanula sp.— Subfossil pollen grains of *Campanula* are quite frequently found after ' stage-d ' except for a single record from ' Stage-c, but their frequencies rarely exceed 0·5 per-cent. *Campanula* grains occur sporadically in ' Stages-c, e, f and g '.

ERICACEAE

Cassiope sp.— The subfossil tetrads, though slightly larger in size, resemble more or less those of *C. fastigiata*.

The tetrads are encountered first in ' Stage-e ' and thereafter continue sporadically till ' Stage-g '. The maximum frequencies occur during the latter stage.

Rhododendron anthopogon — This subfossil pollen type is found very rarely. The only two grains so far encountered are from ' Stage-h ' of Mire-T.

PRIMULACEAE

Primula ?rosea — This sub fossil pollen type is exceedingly rare although *P. rosea* forms a regular constituent of the alpine meadow-forming communities in the Kashmir Valley. The few grains met with are from ' Stage-h ' of the Toshmaidan pollen sequence.

GENTIANACEAE

Pleurogyne sp.— This subfossil pollen type is extremely rare and met with sporadically in ' Stages-c, e_2 and f '.

POLEMONIACEAE

Polemonium caeruleum — Subfossil grains of this species are found frequently in ' Substage-e_1 '. They are first encountered in ' Stage-c ' after which they occur sporadically until ' Stage-f ' of the Toshmaidan pollen sequence. In the Braman profile they continue to occur extremely sporadically.

LENTIBULARIACEAE

Utricularia ?minor — The subfossil grains of this species are extremely rare and so far only three grains have been encountered; they occur at widely spaced intervals in ' Stages-b and c '.

LABIATAE

Subfossil grains referable to this family are met with sporadically in the profiles of both Braman and Walanwar.

PLANTAGINACEAE

Plantago sp.— This subfossil pollen type is at first encountered in ' Stage-a ' after which it continues to occur sporadically in the subsequent stages. It is almost absent from ' Stages-f and h ' of the Toshmaidan pollen sequence. It is, however, well represented in the Braman and Walanwar profiles.

The subfossil grains are comparable to a great extent with those of *P. major*. The latter species grows in the Kashmir Valley between *ca.* 600 m. and 2400 m.

CENTROSPERMAE

Two different types of subfossil pollen grains have been ascribed to this group.

The pollen frequency curve for Centrospermae starts with ' Stage-a ' reaching its maximum development during ' Stages-c and d ' but thereafter declines to low values and almost disappears towards the close of ' Stage-h ' at Toshmaidan. It is well represented in the profiles of both Braman and Walanwar

POLYGONACEAE

The subfossil grains ascribed to this family are encountered sporadically in the profiles of both Braman and Walanwar.

THYMELAEACEAE

Daphne ?oleoides — This subfossil pollen type is extremely rare and so far only one grain has been encountered from ' Stage-c ',

URTICACEAE

Sub-family: ULMAE

Ulmus ?wallichiana, 'Elm'— The pollen frequency curve of *Ulmus*, after its sporadic representation in the first four stages, begins to rise at the beginning of 'Stage-e' in which it attains its maximum development; immediately afterwards it declines and remains low in the subsequent stages. During 'Substage-e_2', it appears that *Ulmus* gradually replaced *Quercus* and formed mixed conifer broad-leaved deciduous forest along with the diminishing *Quercus* and other constituents such as *Betula* (*alnoides*), *Alnus*, *Juglans*, *Viburnum*, *Corylus*, *Acer* and *Rhus*.

Ulmus wallichiana still grows in the Kashmir Valley on a small scale. Elsewhere, this species grows from Indus to Nepal between *ca.* 1,050 m. and 3,000 m. forming an important constituent of the Himalayan moist temperate deciduous forests. It flourishes either in association with Western mixed coniferous forests as in the Grahan Nal and the Parbatti Valley in Panjab or is found in the western oak-fir forests of the moist Garhwal Himalayas (Champion, 1936).

The other common elm of the Western Himalayas is *U. laevigata* which grows in the Panjab Himalayas and in the Kashmir Valley at relatively lower altitudes than the other species.

JUGLANDACEAE

Juglans regia, 'Walnut'— The pollen curve for *J. regia* holds quite an important place in the Post-glacial AP diagram from Toshmaidan. Pollen of *Juglans* is encountered sporadically in the first four stages, and starts occurring regularly almost simultaneously with the increase in *Ulmus* in the beginning of 'Substage-e_1'. Thereafter, its frequency curve increases gradually and rises to its maximum in 'Substage-e_2'. In the subsequent stages, it gradually declines to low values. In the profiles from Braman and Walanwar *Juglans* pollen though occurring sporadically tends to increase in frequency towards the top of the profiles.

J. regia still grows in the Kashmir Valley and is widely cultivated for its wood, bark and fruits which are all of great commercial value. The tree is distributed all along the Himalayas up to the Naga Hills in the Eastern Himalayas where it is found wild in evergreen climax forests (Bor, 1953). The moisture conditions best suited for its growth are more or less the same as for *Ulmus wallichiana* which generally grows in association with *Juglans* in the moist temperate deciduous forests.

CUPULIFERAE

Sub-family: BETULEAE

Betula, 'Birch'— The genus *Betula* is represented by two species, viz., *B. utilis* and *B. alnoides* in the W. Himalayas. The third Indian species, viz. *B. cylindrostachys* is confined to the Eastern Himalayas only. In general no attempt has been made to distinguish between pollen of these species. But in the case of Mire-T, every fifth sample has been re-examined with a view to making a specific identification of *Betula* pollen for each pollen stage. The criteria employed are (i) size; (ii) pore diameter; (iii) exine thickness; (iv) general shape of the grain and (v) position of the aspis, whether protruded or close to the surface of the grain. By close comparisons of the subfossil pollen with the pollen of the three living species, two species viz., *B. utilis* and *B. alnoides* have been recognized in the Post-glacial sediments of Mire-T. The dominance of one species over the other is depicted in Text-fig. 6, for each stage.

B. utilis is encountered for the first time in fair quantity in 'Stage-b', after which it continues to occur almost regularly in the subsequent stages. The pollen curve attains its maximum value in 'Stages f, g and h' and declines towards the top of the sequence. *B. utilis* is gradually replaced by *B. alnoides* after 'Stage-d', the stage in which the latter species makes its first appearance. *B. alnoides* attains its maximum development during 'Stage-e' along with the rest of the broad-leaved elements. *B. utilis* remains meagerly represented (TEXT-FIG. 6). *Betula* (*utilis*) grains are met with sporadically in low frequencies in the profiles of both Braman and Walanwar.

B. utilis is the high altitude birch which covers the whole Himalayan belt from Kashmir eastwards up to Bhutan. It commonly grows between *ca.* 3,000 m. and 4,200 m. altitude. *B. alnoides* is the low altitude birch of the Himalayas. It grows from Ravi eastwards, mainly in the moist subtropical and temperate parts at altitude between *ca.* 900 m. and 1,800 m. This species is absent in the Kashmir Valley, Hazara and the Murree Hills.

Alnus, 'Alder'— The subfossil grains, except for their slightly larger size, come closest to the grains of *A. nepalensis* but the possibility of the rare occurrence of a few grains of *A. nitida* cannot be ruled out.

The *Alnus* pollen curve, after its sporadic representation in the earlier stages, actually starts ascending in 'Stage-d'. It does not at any stage constitute a major element among the tree pollen. *Alnus* frequencies are fairly uniform throughout 'Stage-e' in the Toshmaidan pollen diagram but afterwards again become sporadic. However, towards the end of 'Stage-g' they rise once again to as much as 8 per cent but decline in 'Stage-h'. In the Walanwar profile *Alnus* pollen grains are represented to the extent of 8 per cent at the base but subsequently decline and after occurring sporadically until the middle of the sequence, finally disappear completely. In the Braman profile *Alnus* pollen occurs extremely sporadically.

Alnus represented by *A. nepalensis* and *A. nitida* in the Himalayas grows throughout W. Himalayas as a primary seral type occurring commonly along the banks of larger streams and is mostly limited to sites with permanent water supply. Generally it invades newly formed shingle beds on land slips and screes and in swampy ground. It has a wide altitudinal range extending from *ca.* 900 m. to 2,700 m. The genus *Alnus* is no longer represented in the modern flora of the Kashmir Valley.

Sub-family: CORYLEAE

Corylus colurna 'Hazel'— This subfossil pollen type is first encountered in 'Stage-b' but subsequently continues as a sporadic constituent until 'Stage-c'. After that the curve begins to ascend and it attains its maximum rise in 'Stage-f'. Thereafter, it declines but rises again in 'Stage-h', before its ultimate fall.

C. colurna grows throughout the Western Himalayas from Kashmir to Kumaon between 1,650 m. and 3,150 m. as a constituent of dry temperate dedicuous forests. Osmaston (1922) mentions pure woods of *C. colurna* on North aspects between *ca.* 2,500 m. and 2,800 m. in North Garhwal and according to him this is not paralleled in the moist forests where this species is only of sporadic occurrence.

QUERCINEAE

Quercus — Different types of *Quercus* (Oak) subfossil pollen grains are commonly encountered in the Post-glacial sediments, but while counting the pollen frequencies one is liable to confuse their identity. In view of this, all the types were counted under the generic name. But in order to get a broad picture of the interplay of different types during the Post-glacial, specific identification has been attempted in every fifth sample from Mire-T. Averages of the length of polar axis and exine thickness (*cf.* VISHNU-MITTRE & SINGH, 1962) were calculated for each of the pollen stages. The resultant curves have been interpreted in relation to the individual curves of the pollen grains of the five living species of *Quercus* in the W. Himalayas (TEXT-FIG. 6).

The occurrence of *Quercus* during the Post-glacial in the Kashmir Valley holds a lot of interest, since, none of the five species of *Quercus* existing in the W. Himalayas, is at present represented in the Kashmir Valley. Moreover, Puri (1945) has shown that all five species of *Quercus* were growing in the Kashmir Valley during the early Pleistocene, and he maintains that the present absence of *Quercus* from the area is due to altered climatic conditions consequent on the uplifting of the Pir Panjal Range.

In the AP diagram from Mire-T, *Quercus* grains are seen in minor quantities almost from the beginning of the sequence. They seem to be mainly represented by *Q. semecarpifolia* in 'Stage-a' and *Q. dilatata* in 'Stage-b' in which the *Quercus* pollen curve rises to 19 per cent declining immediately afterwards in 'Stage-c'; in the latter stage the oak pollen was comprised of perhaps both the above mentioned species. In 'Stage-d' *Q. semecarpifolia* predominates and the *Quercus* pollen curve rises to its maximum value. In 'Stage-e' *Quercus* declines and keeps on declining in the subsequent stages till it almost disappears in 'Stage-h'. In 'Stages e, f and g', it appears to be represented by *Q. dilatata*, though *Q. semecarpifolia* also seems to have been represented in 'Stages e and g'. During the last phase *Q. incana* and *Q. ilex* also seem to have accompanied to some extent the other two dominant forms.

In the Walanwar profile the genus *Quercus* is represented by predominantly *Q. dilatata*. This pollen type appears in extremely high frequencies at the base of the Walanwar profile but progressively declines to low frequencies and totally disappears towards the middle of the sequence.

Of the two species of *Quercus* found most commonly during the Post-glacial period in the Kashmir Valley, *Q. semecarpifolia* grows in exposed moderately moist situations at high elevations from Afganistan to Bhutan between *ca.* 2,400 m. and 3,600 m. It occurs in association with scattered *Abies pindrow* or *A. webbiana*, sometimes blue pine and *Picea smithiana*. In sheltered sites it is replaced by *Abies pindrow* forest. At the top of the altitudinal range it merges into the alpine forests of *Abies webbiana, Rhododendron* and birch (*B. utilis*) but it often abuts on the alpine pastures (Champion, 1936).

Q. dilatata is the most common W. Himalayan Oak and occurs from Afganistan to Nepal, between altitudes of *ca.* 1,500 m.-2,700 m. It grows gregariously in all situations but seems to prefer cool and moist localities. At its uppermost limit it merges with the *Q. semecarpifolia* forests whereas towards its lower limit it occurs in association with *Q. incana*.

SALICACEAE

Salix — The occurrence of *Salix* pollen is more or less sporadic throughout the pollen sequence.

Two species of *Salix* namely *S. wallichiana* and *S. elegans* are quite commonly met with in Kashmir. Whereas the former species grows in the Kashmir Valley zone between *ca.* 1,500 m. and 2,250 m.; the latter covers the alpine regions between 3,150 m. and 3,600 m.

LILIACEAE

As many as 6 subfossil pollen types are referable to the family Liliaceae but in no case it has been possible to reach the species or even the genus, and as such, the subfossil grains have been recorded under the family name. The liliaceous grains are first encountered in 'Stage-c' but thereafter they continue to be seen sporadically up to 'Stage-f', after which they are not met with in the pollen sequence from Toshmaidan. They are, however, sporadically met with in the profiles of both Braman and Walanwar and reach as high as 12 per cent of the AP sum towards the top of the Braman sequence.

TYPHACEAE

Typha ?angustata — Subfossil grains of this species occur irregularly in extremely small quantities in 'Stages-a and b', but become fairly regular in 'Stage-c' in which they attain a relatively higher degree of prominence but again decline in 'Stage-d'. In 'Substage-e_1' their frequency curve develops to its maximum extent of 5 per cent but dwindles away in 'Substage-e_2' and almost disappears during 'Stage-f'. In the subsequent stage (Stage-g) *Typha* grains continue to occur in low frequencies but in the last stage (*Stage*-h) they almost disappear from the Toshmaidan pollen sequence. However, they continue to occur sporadically throughout the Walanwar profile.

T. angustata grows throughout Northern India from Kashmir to Manipur and Southwards to Sindh and Coromandel (Hooker, 1894, p. 489). At present *T. angustata* does not grow in the Kashmir Valley at elevations as high as that of Mire-T (3,120 m.).

T. ?latifolia — So far only a single subfossil tetrad has been recovered from 'Stagec'.

T. latifolia grows in marshes all over N.W. India.

LEMNACEAE

Lemna ?minor — Subfossil grains referable to *Lemna* are first met with in 'Stage-c' but the highest percentages are found in 'Stage-e', after which they again dwindle away. They occur sporadically in 'Stage-h', in the profiles of both Braman and Walanwar.

L. minor grows "throughout India" and Western Tibet up to 2,850 m. (HOOKER, 1894, p. 556). In the present climate, this species does not appear to grow in the Kashmir Valley at elevations as high as that of Mire-T.

CYPERACEAE

A variety of pollen types, which cannot be identified at the specific or even to the generic level, can be ascribed to the family Cyperaceae. They apparently belong to a number of species of *Carex, Scirpus, Eleocharis* and other peat-forming sedge ocmmunities.

At Toshmaidan, Cyperaceae pollen frequencies ascend to 81 per cent of the NAP in 'Stage-a' but start declining gradually in 'Stages-b, c and d' but in 'Substage-e_2' they again rise gradually to 75 per cent, declining immediately afterwards in 'Stage-f'. In the subsequent stage, Cyperaceae pollen again soars to high frequencies but shows a relative decline in 'Stage-h'.

Seeds of *Carex* first occur in the profile of Mire-T in the beginning of 'Substage-e_2' and are present in all the subsequent stages. Seeds of *Scirpus setaceus* are also found towards the end of 'Stage-g' and thereafter both types are present up to the top of the profile.

Cyperaceae pollen grains are found regularly in the Braman profile but occur only sporadically in the Walanwar sequence.

GRAMINEAE

Subfossil grains referable to the family Gramineae have all been counted under the family name except *Zea mays* (maize). Maize pollen grains were only detected in the relatively low altitude and younger mires of Braman and Walanwar. Apart from these, three other distinct pollen types of Gramineae have been isolated but it has not been possible at this stage to refer them to any definite genera.

The value of the Gramineae pollen curve differs with the diagrams from different areas. In the NAP diagram from Toshmaidan, the Gramineae pollen curve becomes apparent only towards the end of 'Stage-b' but thereafter it develops gradually and is almost uniformly represented throughout the vegetational sequence. The Gramineae curves in the Braman and Walanwar pollen diagrams have been amply discussed in dealing with the pollen sequence.

FILICES

Twelve different subfossil types of pteriodophytic spores have been recorded but in view of their uncertain generic identification, they have all been counted under the title 'ferns'.

Although the fern spores are encountered sporadically throughout the Post-glacial sequence, their frequencies rise to significant levels only in 'Stages-g and h'. This rise was perhaps induced by the presumed increase in the atmospheric humidity coupled with change over to more temperate climate, the factors which are most favourable to the growth of these plants.

BRYOPHYTA

This is another group of dispersed plant remains which are not yet fully identified but which are met with quite frequently in Post-glacial sediments. They are represented either as sterile moss shoots or as spores. So far, mosses such as *Bryum alpinum*, *Aulacomnium palustre* and *Webera* sp. have been indentified from among the many peat forming mosses in the Kashmir Valley.

The relative frequency of the moss shoots has been illustrated in the stratigraphical column provided with the pollen diagrams and bryophytic spores have been counted; their frequencies are calculated on the basis of AP sum.

Seven different spore types probably of bryophytic origin have so far been recovered. In Mire-T their first record is seen in 'Stage-c', but their greatest prominence is in 'Stages-d, e and f' after which they almost disappear. They occur quite frequently, however, in the early phase of the Braman sequence but become sporadic after the middle phase. In the Walanwar profile they are met with sporadically throughout the sequence.

ALGAE

Family: HYDRODICTYACEAE

Pediastrum sp.

Pediastrum colonies occur abundantly in 'Stages-c and e_1', while in the rest of the stages they are rare; *Pediastrum* is totally absent from 'Stages-a, b and h'.

Family: CHARACEAE

The distribution of *Chara* and *Nitella* in the vertical sequence of Mire-T is detailed along with the record of the stratigraphy.

Family: HETEROCAPSINEAE

Botrycoccus sp.

Botrycoccus colonies are absent in 'Stages-a and b', but are met with frequently from 'Stage-c to g'; subsequently, in 'Stage-h', they gradually disappear. The maximum frequency is attained in 'Stages-d and e'.

DISCUSSION AND CONCLUSIONS

The present investigation in the Kashmir Valley constitutes the first attempt towards the study of the Post-glacial vegetational history in India (SINGH, 1961, 1962). Keeping in view the montane physiography of the Kashmir Valley, the insufficient data available regarding the ecology of the forests in the region and the limited number of the sites investigated, the conclusions arrived at are still tentative.

The interpretation of the Post-glacial diagrams is beset with a number of difficulties. Firstly the montane physiography of the Kashmir Valley has led to the disposition of vegetation in altitudinal zones which might have shifted (upwards or downwards) with the past changes in the climate. Secondly in view of the fact that the Kashmir Valley borders the tropics, tree vegetation must have existed not far removed from the Kashmir Valley during the early Post-glacial. Consequently long distance transport of tree pollen from the wooded lower altitudes to the forestless higher altitudes (such as at Toshmaidan) must have influenced the pollen rain considerably. However, by keeping in view the factors governing the vegetational distribution in the valley and considering the stratigraphy of the mires, NAP/AP ratios, APF etc. the effect of long distance transport of pollen can be minimized to a great extent and from the collective data the events of Post-glacial vegetational history and climatic changes may be brought out.

Post-glacial Vegetational History and Climatic Alterations— From an overall review of the factual data available so far, an attempt can now be made towards the elucidation of the Post-glacial vegetational history; and from this there can also be deduced a broad picture of the major climatic alterations that may have taken place during this period. Of the four sites investigated the longest profile comes from Mire-T and it seems likely from the local topography and the stratigraphy of the mire that the whole of the Post-glacial period is represented. As pointed out earlier, the pollen spectrum exhibited by the earliest part of 'Stage-a' in this mire appears to represent an open type of vegetation. Since blue pine pollen preponderates and there is a low APF together with an overwhelming majority of NAP, it is possible that no trees existed at or near the site. It seems likely that the tree pollen in the earliest samples was wind transported over a long distance and that the forests from which it was derived occupied either the lower slopes or areas far removed from the Kashmir Valley. The local vegetation appears to have comprised Compositae, Centrospermae, *Artemisia* and *Clematis buchananiana*.

Later, since an increase in APF and in AP/NAP ratios is found in the subsequent samples of this stage, it appears that blue pine and cedar became more common in the area; thus presumably indicating an amelioration of the climate in the region.

In 'Stage-b' the increased pollen frequencies of *Quercus*, *Ulmus*, *Juglans*, *Alnus*, etc. and the appearance of Caryophyllaceae and *Dipsacus inermis* in the pollen flora probably indicates that these elements began to grow closer to the mire than before and that there was a definite improvement in the climate towards conditions favouring relatively more mesophytic elements.

Subsequently, however, the rise in the blue pine curve accompanying a corresponding decline in the oak pollen curve (Stage-c) shows that the tree vegetation probably changed in character resulting in the return of blue pine. Oak-woods appear to have temporarily declined and pure pine-woods together with diminishing cedar, constituted the major part of the tree vegetation; this perhaps indicates a phase of brief revertence to colder conditions. Nevertheless, the climate in 'Stage-c' seems to have markedly improved in comparison to 'Stage-a', as is evidenced by the increase in APF and the change of sediment from clay to organic detritus mud. Besides, from the gradual rise in the APF values coupled with the more regular occurrence of the pollen of such elements as *Betula utilis*, *Alnus*, *Viburnum*, *Abies*, *Picea* and *Juglans*; and with the entry of *Aesculus*, *Salix* and *Rhus* pollen, it appears that the tree vegetation could not have been far removed from the site at this stage. Locally, the meadow vegetation also appears to have had fresh additions to its flora as indicated by the first occurrence of *Impatiens*, *Campanula*, *Polemonium caeruleum*, Gentianaceae, Umbelliferae and Liliaceae pollen in the sequence. On the whole, the herbaceous vegetation appears to have been dominated by Centrospermae. Among the aquatics, floating elements *Lemna*, *Nymphaea*, and the algae (*Pediastrum*, *Botryococcus*, *Chara*) also made their first appearance in the sequence in this stage.

The rise of the *Quercus* curve ' in Stage-d ', which may well indicate the development of pine-oak woods, together with the increased amounts of *Alnus* and *Ulmus* and the first occurrence of the pollen of *Betula alnoides*, presumably indicates a change to much warmer conditions. The fall in APF in this stage is probably exaggerated by the decline of pine which produces much greater quantities of pollen than the oaks, which now became preponderant.

The relatively high pollen frequencies of *Ephedra* and Centrospermae in ' Stages a and c ' accompanied by the high values of pine and cedar in ' Stage-a ' and of pine in ' Stage-c ' show that the climate governing these woods may have remained largely dry and cold. The development of oak woods in ' Stages-b and d ', however, shows that the conditions were perhaps warmer and moderately moist. On the whole the sequence of vegetation from ' Stage a to d ' shows that despite a temporary set back in ' Stage-c ', the amelioration of the climate was progressive and this phase can justifiably be regarded as a period of increasing warmth.

Later, in ' Stage-e ', the fact that blue pine pollen frequencies fell to their minimum, and that high frequencies of oak were accompanied by relatively higher values of *Ulmus, Juglans, Betula alnoides, Alnus, Corylus, Viburnum, Rhus, Acer* and *Aesculus* pollen, it seems that apparently moist, warmth-loving broad-leaved forests had established themselves in the region. With the fall of the oak pollen curve in ' Substage-e_2 ', elements such as *Ulmus, Juglans*, and *Betula alnoides* increased to their highest values and appear to have constituted the bulk of the forests. Further addition to the local flora is apparent from the first occurrence of *Myriophyllum* pollen amongst aquatics and Ericaceae and *Aconitum* amongst the herbs. From the high pollen curve shown by *Artemisia* it appears that the meadow vegetation may have been largely constituted by *Artemisia* during ' Stage-e '. The aquatic vegetation seems to have shown its maximum development at Toshmaidan during this phase as evidenced by the highest pollen frequency values attained by *Typha, Myriophyllum, Nymphaea* and *Lemna*. Similarly, *Pediastrum, Botryococcus, Chara, Nitella* and mosses reached their highest extent and importance. Since the assemblage of forest elements in ' Stage-e ' was the most mesophytic in comparison to the rest of the vegetational sequence, and since all the warmth-loving elements rose to their greatest prominence, it seems highly probable that during this stage the climatic conditions were at their warmest. Thus ' Stage-e ' may perhaps be regarded as a period of maximum warmth.

After ' Stage-e ', almost all the above thermophilous elements declined (Stages f, g and h) and the fact that the conifers returned to their original dominance suggests that the climate reverted to colder conditions in this phase and a period of decreasing warmth had evidently set in. In the early part of this phase (Stage-f), *Ulmus* had a sudden fall and the pollen spectra suggest that pine-birch (*B. utilis*)— hazel woods had an enhanced development. *Juglans* started declining gradually and *Artemisia* increased to its maximum extent with a corresponding decrease in Cyperaceae.

Later, in ' Stage-g ' *Corylus* declined and pine-birch (*B. utilis*) woods seem to have established. Cyperaceae increased while *Artemisia* declined and the frequency of fern spores rose to a significant extent for the first time. Similarly the pollen percentages of *Impatiens, Ericaceae, Aconitum* and *Campanula* rose to their maximum.

During the last phase (Stage-h) blue pine alpine fir (*Abies webbiana*)-birch (*B. utilis*) woods appear to have established themselves. Amongst the herbs, Compositae and Gramineae increased while the rest declined.

Some thermophilous elements such as *Ulmus, Juglans, Rhus* and *Acer* apparently persisted into ' Stage-f '. However, the fact that all the moisture-loving elements including aquatics declined at the beginning of this stage; and that elements such as *Corylus, Artemisia* and Centrospermae had a significant rise suggests that ' Stage-f ' may have been characterized by a more or less dry climate in relation to the immediately preceding and subsequent stages. In ' Stages g and h ' the rise of *Abies webbiana*, Cyperaceae and ferns, accompanied by the decline of *Artemisia* and Centrospermae and broad-leaved trees in general, may well signify the setting in of a relatively much cooler and moister phase.

In the sequences from Mires-B and W occupying the relatively lower elevations the abundance of blue pine together with *Abies* and *Juglans* and ferns is also suggestive of the cold and moist conditions as characteristic of 'Stage-h'. The presence of thermophilous aquatic elements such as *Typha, Nymphaea* and *Lemna* in 'Stage-h' in the profiles of Mires-B and W is due to the low altitude of the mires; these plants normally grow at these elevations in the Kashmir Valley today.

Thus on the whole, the sequence of vegetational history deduced from the pollen-analytical evidence suggests that there was a period of increasing warmth followed by a period of maximum warmth and this was in turn followed by a period of decreasing warmth. This finding lends additional support to the similar worldwide scheme of Post-glacial climatic change put forward by von Post (1946).

The only other sequence of Post-glacial climatic change from N.W. India, with which comparisons might be made, is that compiled by De Terra and Hutchinson (1936) from geophysical evidence. But since the above authors refer only to successive dry and wet periods, their data have only a partial comparative value. Moreover, in the absence of exact age determinations of the various Post-glacial events studied by De Terra and Hutchinson and of the phases described in this paper no correlation between the two series of climatic sequences can yet be made.

Anthropogenous influence on Post-glacial vegetation — Disforestation and the introduction of agriculture by man is closely bound with the history of the people of a region, which according to the historical records of the Kashmir Valley, is traceable to about 2000 B.C. when the Aryan invaders entered the Indian subcontinent and spread out in successive waves. An advanced pre-Aryan civilization existed to the south-west of the Kashmir Valley at Mohenjo Daro and Harapa situated in Sindh and Punjab respectively as far back as 3000 B.C. Besides this, palaeolithic artifacts comprising the flakes of Levallois type and the flaking tradition of Neolithic age has been described from the Kashmir Valley by Hawkes (1934, p. 7) and De Terra & Paterson (1939).

From the meagre records of the pre-Aryan settlements in the Kashmir Valley it may be that human influence on vegetation previous to the immigration of the Aryans was negligible. The Aryans were, however, an agricultural and pastoral people and according to the historical records (*cf.* The Mahabharata) they burnt away huge stretches of dense woods for cultivation and pastures (STEBBING, 1921-26). Despite the large scale disforestation by the early Aryans the forests in the north of the Panjab were still dense at the time of Alexander the Great (326 B.C.). According to Stebbing (*loc. cit.*) the intensive destruction of the forests in the country was slowly brought about by the constant invasions of the Central Asian peoples who brought their flocks with them. This period culminated with the Mohammadan conquest of a large portion of N.W. India and the Mughals may have been responsible for further clearing of the forests and also introducing some of the exotic elements in our flora.

Instances of the supply of timber from the Kashmir Valley are known as far back as the times of Alexander the Great who got the supply of wood from Kashmir via the R. Jhelum (the Hydaspes of the old Greek writers) for construction of boats (STEBBING, *loc. cit.*). Later, after the annexation of the Panjab by the British in 1849, regular steps were taken to exploit the forest wealth of the area; and the Kashmir state (then under Maharaja Gulab Singh) also commenced cutting and exporting timber to the Panjab markets. In the year 1866, the British Government planned systematic conservancy of the forests of the Panjab and Kashmir.

At present an overwhelming majority of the human population is settled on the alluvial floor of the Kashmir Valley between *ca.* 1500 m. and 2100 m. where most of their cultivation is carried out. At higher altitudes, neither the physiography of the mountain slopes nor the prevailing climate allows any cultivation. Nevertheless, the thickly forested slopes above 2100 m. have been and are frequented for timber supply. The summit region of the Pir Panjal Range and the Main Himalayas, are frequented by 'Gujars' (herdsmen) every year during the summer months. They take their flocks and herds high up on the mountains from various directions, so that there is but a small area of the loftiest perpetually-snow-covered mountains that is left unfrequented (DREW, 1875). These areas never constitute their permanent abodes.

The Toshmaidan pollen diagrams which represent a complete Post-glacial vegetational sequence surprisingly yield little, if any, information of human interference with natural vegetation. This is due to its being situated at high altitude and also since the cultivation in this region has been confined to the valley floor. This is evidenced by the absence of maize pollen grains which are very conspicuous in the mires at lower altitudes (Mires B and W).

The elements such as Gramineae, *Plantago*, *Artemisia* etc. which have been noted to be the immediate successors after forest cuttings, fires and catastrophic destructions of forests by other means in the European diagrams and have won the title of culture pollen (IVERSEN, 1949) behave differently in the NAP diagram from Toshmaidan. Whereas *Plantago* is insignificantly represented throughout the sequence, grass pollen plays a uniformly steady role after ' stage-b '. *Artemisia*, however, after having been sparsely represented in ' stages a, b and c ' rises immensely in ' Stages d, e and f '. Its rise in ' Stage-d ' and ' Sub-stage-e ' does synchronize with the sudden fall of blue pine but in the absence of any accompanying increase of Gramineae or *Plantago* and moreover without any recognizable rise in the NAP curve in general, it appears that the fall of blue pine in the region was mainly due to an amelioration of climate which showed itself in the corresponding rise of broad-leaved elements. The increase of *Artemisia* appears to have been local at Toshmaidan for it alternates with Cyperaceae in ' stages d, e and f '. It declines towards the close of ' Sub-stage-e_2 ' presumably due to the increasing moisture and increases during ' Stage-f ' suggesting a relatively 'drier phase'. In the latter stage its rise is again accompanied by the sudden fall of *Ulmus* — an instance which in the absence of other accompanying indicators of forest clearance can be interpreted either in terms of climatic reversion from warm to cold or a widespread disease or in terms of a decline caused through lopping of elm for fodder (HEYBROCK, 1963). Heybrock, who made an intensive study of the practice of lopping of elm for fodder in Kashmir and other adjoining areas gives great credence to this practice as a possible cause of prehistoric elm decline. *Plantago* is almost absent in ' Stage-f ' and Gramineae remained much the same as before.

Furthermore, the commencement of grazing is also not clear from the Toshmaidan NAP diagram. The sudden fall of the NAP curve in 'stages-f, g and h' is perhaps suggestive of this activity which might have existed since the earlier periods. One remote indication favouring this possibility is the overwhelming representation of *Artemisia* at Toshmaidan since ' Stage-d '. In view of the poisonous and consequently unpalatable nature of *Artemisia*, any increase in the grazing activity in the meadows or pastures where *Artemisia* forms a member of the vegetation is likely to result in its proportionate increase in the pollen rain.

In the pollen diagram from Mire-B of which the vegetational sequence is correlated with ' Stage-h ', the sudden decline in forest tree elements corresponds with the sudden rise of the NAP frequencies in general and of Gramineae in particular. Here it is the *Abies* which suffers most. Its sudden decline from 12 per cent to 2 per cent is synchronous with the sudden rise in Cyperaceae from 6 per cent to 130 per cent, *Gramineae* from 18 per cent to 123 per cent, *Artemisia* from 10 per cent to 32 per cent and *Plantago* from 2 per cent to 8 per cent of the AP sum. Similarly, the decline in the blue pine towards the top of the profile is accompanied by an increase in Gramineae and maize. Both the above vegetational shifts appear to reflect the activity of man in the area in the recent past. The increasing values of *Juglans* towards the top of the profile are suggestive of plantations of walnut by man.

The pollen sequence from Mire-W, presents evidence of a more or less continuous agricultural activity in the region as is clear from the regular curve of maize but the NAP/AP curves hardly present any evidence of clearance. The rise in the frequencies of both *Juglans* and *Cedrus* towards the top of the profile is suggestive of plantations of walnut and cedar by man.

The discovery of maize pollen in the mires at Braman and Walanwar is rather interesting. For a long time maize (*Zea mays*) has been considered to have had a Mexican origin (DARLINGTON and JANAKI AMMAL, 1945) and this has been supported by playnological evidence recently (BARGHOORN, et. al. 1954). But according to Anderson and Stonor (1949) maize reached the Americas from the old World. Earlier in 1945 Anderson suggested Upper Burma as a possible centre of origin from where maize had spread to the west coast of the New World via Java, Timor etc.

At present it is not possible to say anything about the antiquity of maize in the Kashmir Valley and its bearing on its origin, largely because of the shallow depth of the Mires B and W. However, it is hoped that pollen-analytical investigations of deeper mires from the valley might enable us to determine the antiquity of maize in Kashmir and to solve the controversial problem of its origin.

Phytogeographical Considerations — From the account of the Post-glacial vegetational history of the Kashmir Valley, it becomes apparent that the modern distribution of the natural flora of this region has been largely influenced by the changes in the Postglacial climate leaving aside the artifically forested or the forestless regions created by man for which very little and insufficient information has been obtained from the present investigation. The sites examined come only from the northern slopes of the Pir Panjal Range and obviously they reflect largely the vegetational changes along the Kashmir Valley slopes of this range in particular and of the Kashmir Valley in general. However, since the evidence of the vegetational history is based upon pollen grains, an allowance has to be made for the wind blown pollen coming either from the southern slopes of the Pir Panjal or from other places far removed from the Kashmir Valley.

While the majority of the plant species represented in the profiles find their living representatives in the modern flora of the Kashmir Valley, there are certain elements such as *Quercus*, *Alnus* and *Betula alnoides* which though represented by pollen in the profiles to the extent of 37 per cent, 8 per cent and 15 per cent of the total tree pollen respectively at their maximum do not grow in the Kashmir Valley today. Out of these, however, the first two do grow on the Southern slopes of the Pir Panjal Range but not in Poonch region adjoining Toshmaidan. Five species of *Quercus* occur on the southern slopes of the Pir Panjal Range in Udhampore, Rampur, Mirpur, Muzaffarabad and Jhelum Valley and one species of *Alnus* in Muzaffarabad, Ramban and Udhampore (LAMBERT, 1933). *Betula alnoides*, however, grows from Ravi eastwards in the Panjab Himalayas.

The chief interest in the above three constituents centres round their occurrence in the Kashmir Valley during the early Pleistocene and the belief that they were exterminated from this region due to the uplift of the Pir Panjal Range towards the end of First Interglacial (SAHNI, 1936; DE TERRA & PETERSON, 1939; PURI, 1945, 1947). The Pir Panjal Range is believed to have acted as an effective barrier against the advancing monsoon winds into the Kashmir Valley, resulting in a change of climate unfavourable to Oak, *Alder* and *Betula alnoides* eventually bringing about their extinction from the valley. In the light of their high representation in the pollen profiles, the problem that confronts us is whether these elements really immigrated into the valley or not during the Postglacial climatic optimum.

It need not be pointed out that the vegetation on the southern slopes of the Pir Panjal Range (of which *Quercus* and *Alnus* form a part), must have reacted to the Postglacial climatic alternations in much the same way as the vegetation on the corresponding northern slopes. It is likely that there was an upward shifting of the broadleaves forest belt during the ' Post-glacial optimum '; it is also possible that a fraction of the subfossil pollen preserved in the Kashmir Valley mires might have come from the southern slopes of the Pir Panjal Range. The pollen spectrum from one of the surface samples from Toshmaidan showed the presence of both *Quercus* and *Alnus* pollen grains to the extent of 0·5 per cent and 2 per cent respectively. A more or less similar situation with 4 per cent *Alnus* and no *Quercus* was seen in the Damamsar sample from the summit of the range. No subfossil pollen of either of the above two genera was recovered from the surface samples of Mires-B. and W. This evidently shows that a certain amount of wind transported pollen crosses over the range from the southern flank towards the Kashmir Valley.

However, there is no denying the fact that during the early stages of the Post-glacial period when an open vegetation existed on the Kashmir Valley slopes of the Pir Panjal Range, wind transported pollen would have influenced the pollen spectra considerably (*cf.* ' Stage-a ', Mire-T). But in the later phases, considering the relatively high values of these elements, it seems doubtful whether the presence of this pollen can be ascribed to long distance transport. The Pir Panjal Range is crossed, however, by a number of Passes among which the lowest is the Baramula Pass (*ca.* 1560 m.) through which flows the main R. Jhelum. The other Passes are situated at *ca.* 2,800 m. (Banihal), *ca.* 3,420 m. (Pir Panjal) and above. How far these passes acted as routes for the immigration into the valley during the climatic optimum for *Quercus*, *Betula alnoides* and *Alnus* is yet to be ascertained. But that their role must have been considerable cannot be denied.

It is hoped that the future work in this region will be able to solve this vexing problem.

ACKNOWLEDGEMENTS

The author wishes to express his deepest gratitude to Dr. R. N. Lakhanpal for his keen interest and guidance throughout the progress of this work. The author is especially indebted to Professor G. Erdtman, Director of the Palynological Laboratory, Stockholm-Solna, Sweden, for kindly imparting the necessary practical training in the field-and laboratory techniques during his stay at the Birbal Sahni Institute of Palaeobotany, Lucknow, as a Visiting Scientist. The author is also deeply obliged to Dr. Alan G. Smith of the Botany Department, Queen's, University, Belfast and to Dr. Vishnu-Mittre for their constructive criticism and valuable suggestions so kindly given during the preparation of this paper.

To Professor R. N. Chopra of the Botany Department, Punjab University, Chandigarh, the author is sincerely thankful for rendering help in the identification of sub-fossil mosses. To Dr. A. D. Kharkwal of the Geology Department, Lucknow University, the author is thankful for his kind help in the petrological examination of the rock and clay samples from Toshmaidan and Damamsar (Kashmir).

The author is also thankful to the authorities of the Birbal Sahni Institute of Palaeobotany, Lucknow, for the award of an Assistantship at the Institute and to the Council of Scientific and Industrial Research, New Delhi, for the award of Senior Research Fellowship during the combined tenure of which the present work has been carried out.

The author also wishes to express his sincerest thanks to the authorities of the Forest Department of Jammu and Kashmir State for their kind co-operation during the field work in the Kashmir Valley and to the India Meteorological Department for kindly supplying the meteorological data.

REFERENCES

ANDERSON, E. & STONOR, C. R. (1949). Maiez among the Hill People of Assam. *Ann. Mo bot. Gdn.* **36**: 355.

BARGHOORN, S. E., CLISBY, K. H. & WOLFE, M K. (1954). Fossil Maize from the valley of Mexico *Bot. Mus. Leafl. Harv.* **16**(9): 229-39.

BLATTER, E. (1927-28). Beautiful flowers of Kashmir. I & II. *London.*

BOR, N. L. (1953). Manual of Indian forest botany. *London.*

CHAMPION, H. C. (1936). A preliminary survey of the forest types of India and Burma. *Indian For. Rec.* **1**: 1-236.

DAINELLI, G. (1923-35). De Filippi Expedition to the Himalaya (1913-14), Memoirs and other publications, Vol. I-XXX. *Bologna.*

DARLINGTON, C. D. & AMMAL, E. K. J. (1945). Chromosome Atlas of cultivated Plants. *London.*

DE TERRA, H. & HUTCHINSON, G. E. (1936). Data on Post-glacial climatic changes in Northwest India. *Curr. Sci.* **5**: 5-10.

DE TERRA, H. & PATERSON, T. T. (1939). Studies on the Ice Age in India and Associated human cultures. *Washington.*

DREW, F. (1875). The Jummoo and Kashmir territories. *London.*

DUDGEON, W. (1925). The ecology of Tehri Grahwal: A contribution to the ecology of the Western Himalaya. *J. Indian bot. Soc.* **4**(7 & 8): 233-285.

ERDTMAN, G. (1952). Pollen morphology and Plant taxonomy. Angiosperms. *Waltham. Mass.*

GODWIN, H. & CONWAY, V. M. (1939). The Ecology of a raised bog near Tregaron, Cardiganshire. *J. Ecol.* **27**(2): 313-363.

GODWIN-AUSTEN, H. H. (1864). Geological notes on part of the north-western Himalayas. *J. geol. Soc. London.* **20**: 383-88.

HAWKES, CHR., J & DE TERRA, H. (1934). Palaeolithic human industries in the north-west Punjab and Kashmir and their geological significance. *Mem. Conn. Acad. Arts Sci.* **8**: 1-14.

HEYBROCK, H. M. (1963). Diseases and Lopping for Fodder as Possible Causes for a Prehistoric Decline of Ulmus. *Acta. Bot. Nearlandica* **12**: 1-11.

HOOKER, J. D. (1872-1897). Flora of British India. I-VII. *London.*

IVERSEN, J. (1949). The influence of prehistoric man on vegetation. *Danmarks geol. Unders. Ser.* 4. **3**(6): 1-25.

IYENGAR, M. O. P. & SUBRAHMANAYAN, R. (1943). Fossil diatoms from the Karewa beds of Kashmir. *Proc. nat. Acad. Sci. India.* **13**(4).

LAMBERT, W. J. (1933). List of trees and shrubs for the Kashmir and Jammu circle, Jammu and Kashmir State. *For. Bull. Dehradun.* **80:** 1-40.

MIDDLEMISS, C. S. (1911). Sections in the Pir Panjal Range and Sind Valley, Kashmir. *Rec. geol. Surv. India.* **41:** 115-144.

MUKERJI, S. K. (1921). The Dal Lake (Kashmir): a study in biotic succession. *Proc. Eighth Indian Sci. Cong.; Proc. Asiat. Soc. Bengal.* (N.S.) **17:** 185-187.

Idem (1925). The ecology of the Dal Lake Region, Kashmir. *Proc. Twelfth Indian Sci. Congr.*: 188-189.

NAIR, P. K. K. (1960). Palynological investigation of the Quaternary (Karewa) of Kashmir. *J. sci. industr. Res.* **19B**(6): 145-54.

OSMASTON, A. E. (1922). Notes on the forest communites of the Garhwal Himalaya. *J. Ecol.* **10:** 129-67.

Idem (1927). A Forest Flora for Kumaon. *Allahabad.*

PEARSON, R. S. & BROWN, H. P. (1932). Commercial timbers of India. **1.** *Calcutta.*

PURI, G. S. (1945). The genus *Quercus* in the Karewa deposits of Kashmir with remarks on the oak forests of the Kashmir Valley during the Pleistocene. *Proc. Indian Acad. Sci.* **22:** 232-56.

Idem (1945). Some macroscopic plant remains referred to the Betulaceae from the Karewa Deposits of Kashmir. *Ibid.* **22:** 257-73.

Idem (1947). Fossil plants and the Himalayan uplift. *J. Ind. bot. Soc. Iyengar Commemoration Vol.*: 167-84. 1946.

Idem (1948). The flora of the Karewa series of Kashmir and its phytogeographical affinities with chapters on the methods used in identification. *Indian For.* **74:** 105-22.

SAHNI, B. (1936). The Karewas of Kashmir. *Curr. Sci.* **5:** 10-16.

SHER SINGH (1929). The effect of climate on the conifers of Kashmir. *Indian For.* **55:** 189-203.

SINGH, G. (1961). Further Studies in the Plynology of Kashmir. *Ph. D. Thesis, University of Lucknow, Lucknow.*

Idem (1962). Post-glacial Vegetational History of the Kashmir Valley. *Internat. Conference on Palynology, Tucson (Ariz.), Abstr. Pollen et Spores* **4**(2): 376-377.

STEBBING, E. P. (1921-26). The Forests of India. Vol. I-III *London.*

VISHNU-MITTRE & SINGH, G. (1963). On the Pollen of the Western Himalayan Oaks. *J. Indian bot. Soc.* **42** (1): 130-134.

VON POST, L. (1946). The prospect of pollen analysis in the study of earth's climatic history. *New Phytol.* **43:** 193-217.

WADIA, D. N. 1938. Deposits of the Ice Age in Kashmir. *Quart. J. geol. min. & met. Soc. India* **10**(4). 191-99.

Idem (1941). Pleistocene Ice Age deposits of Kashmir. *Proc. nat. Inst. Sci. India* **7:** 49-59.

Idem (1953). Geology of India. *London.*

WODEHOUSE, R. P. 1935. The Pleistocene pollen of Kashmir with an introductory note by H. De Terra. *Mem. Conn. Acad. Arts Sci.* **9:** 1-18.

EXPLANATION OF PLATES

PLATE 1

1. Toshmaidan Panorama.
2. Site of Mire-T at Toshmaidan.

PLATE 2

3. Site of Mire-B at Braman with cultivated fields and blue pine-alpine fir mixed woods in the background.

4. Site of Mire-B at Walanwar with blue pine-alpine-fir — broad-leaved mixed woods in the background.

1

2

3

4