

STUDIES IN THE LATE-QUATERNARY VEGETATIONAL HISTORY IN HIMACHAL PRADESH—1. KHAJIAR LAKE

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ABSTRACT

The paper discusses the results of pollen analytical investigations of Late-Quaternary deposits from Khajiar Lake in Himachal Pradesh.

At about 2000 B.C. the vegetational history begins with the predominance of oak woods. The oak woods along with some associated elements remain dominant throughout the pollen sequence except for a temporary decline which corresponds to the rise in elm and walnut and dated to 150 A.D. This change is perhaps suggestive of deforestation. Oak woods again declined at about 700 A.D. and were replaced by deodar. This change in vegetation is attributed to the biotic factor.

INTRODUCTION

THE lake at Khajiar (76°4'E, 32°32'N) almost circular in outline and about 60 metres in diameter, is situated in the Ravi Basin of outer Himalayas, about 13 km north-east of Dalhousie on way to Chamba (Fig. 1). Lying at an altitude of about 1,950 metres A.S.L., it occurs in the centre of an open meadow, within the closed Deodar-mixed forest.

A small 'floating island' (Fig. 2) oval in outline, measuring about 15 and 10 metres in length and breadth with a thickness varying from 1.5 to c.2 metres and overgrown with *Phragmites communis*, occurs in the lake. The 'floating island' glides over the lake surface due to wind action, with *Phragmites* acting as sails, and is held sacred by the local inhabitants.

The lake has a surrounding wide marshy zone which is followed by a meadow, measuring about 2.5 km in its periphery, beyond which stands the surrounding mixed Deodar forest (Figs. 3 and 4). A short account of the ecology of the Khajiar Lake was first published by Sahni (1927). Our observations of modern vegetation are given below:

(i) *The submerged and floating vegetation* — Leafy aquatics, seen growing in the lake, are *Potamogeton natans*, *Callitriche*

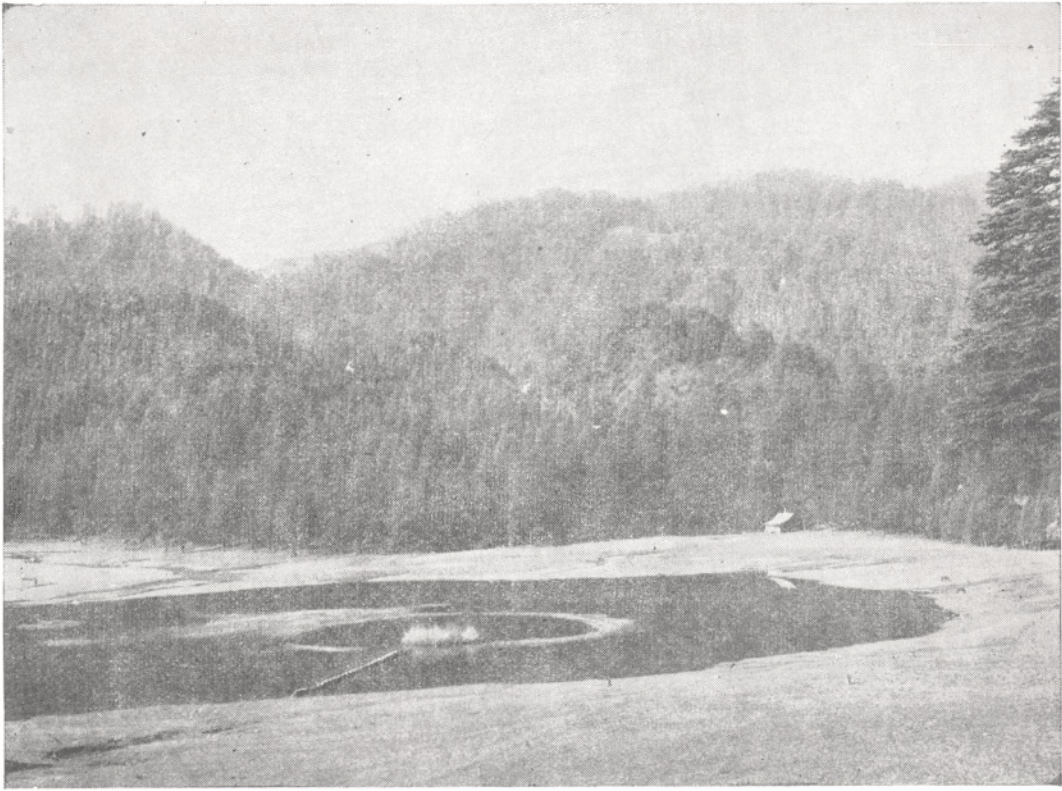
stagnalis, *Spirodela polyrhiza*, *Utricularia flexuosa*, *Myriophyllum spicatum* etc. The centre of the lake is apparently devoid of any vegetation.

(ii) *Phragmites communis Community* — A gregarious growth of *Phragmites communis*, which is constantly maintained by the active regeneration from old rootstocks is seen covering the whole of the 'floating island'. The reed is restricted to the 'island' only and is not seen elsewhere in the area within several miles. The other few plants seen growing on the 'island', are *Acorus calamus*, *Polygonum aviculare*, *Ranunculus diffusus*, *Rubus niveus*, *Ludwigia adscendens* and *Menyanthes trifoliata*.

(iii) *Vegetation of inner marshy zone* — In the marshy area surrounding the open water, *Acorus calamus* is the most dominant plant. Its other common associates are: *Scirpus mucronatus*, *Carex* spp., *Alisma plantago*, *Bidens cernua*, *B. tripartita* and some other aquatics, such as *Ludwigia adscendens*, *Potamogeton natans*, *Myriophyllum spicatum*, *Callitriche stagnalis*, *Spirodela polyrhiza*, *Utricularia flexuosa*, and *Marsilea* sp. In this zone are seen a few annuals, namely *Primula denticulata* (very common), *Lycopus europaeus*, *Prunella vulgaris*, *Verbena officinalis*, *Erigeron canadensis*, *Conyza aegyptiaca*, and *Arundo donax*.

(iv) *Vegetation of outer transitional zone* — In this region *Polygonum aviculare*, a small procumbent annual, is the most dominant species, and the other abundant annuals are *Limnophylla indica*, *Elatine triandra* and *Eleocharis chaetaria*. Besides these elements, other species frequently seen in this habitat are *Nasturtium palustre*, *Mazus laponicus*, *M. surculosus*, *Trifolium repens*, *Bidens tripartita*, *B. cernua*, *Anaphalis busua*, *A. adnata*, *Callitriche stagnalis*, *Ranunculus diffusus*, *Prunella vulgaris*, *Potentilla kleniana*, *Erigeron canadensis*, *Conyza aegyptiaca chinensis*, and a few sedges and grasses,

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TEXT-FIG. 1 — Close up of the Khajiar lake.

such as *Cyperus globosus*, *Polypogon fugax*, *Poa annua*, and *Echinocloa crusgalli*. Also sometimes small patches of *Riccia* sp. and mosses (*Potia* and *Webera*) are seen occupying this zone.

(v) **Meadow** — The chief meadow forming grass is *Bothrochloa pertusa*. Other plants met with are *Taraxacum officinalis*, *Plantago lanceolata*, *Potentilla kleniana*, *P. nepalensis*, *Cnicus argyranthus*, *Trifolium repens*, *Nasturtium palustre*, *Mazus japonicus*, *M. surculosus*, *Achillea millefolium*, *Veronica* sp., *Gentiana pedicellata*, *Prunella vulgaris*, etc.

Bordering the above meadow occur thick *Cedrus deodara* forests (Fig. 5), mixed with some broad-leaved elements. The woodlands surrounding the meadow between 1,800 and 2,000 m A.S.L. elevation constitute the Khajiar Demarcated Protected Forest (D.P.F.C.I.) (Fig. 4). The net area of this forest is 190 acres. It comprises of thick and almost pure forests of *Cedrus deodara*, having a slight admixture of *Abies*

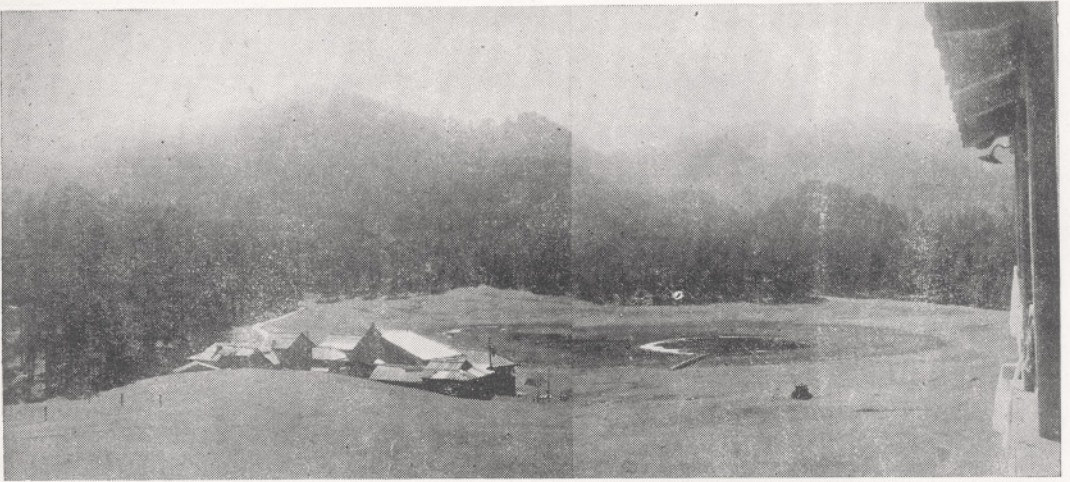
in depressions, and some oaks along the western boundary. Also a thirty years old *Cedrus* plantation, c. 35 acres is seen in the south-east of the Khajiar meadow.

To the north and west of the D.P.F.C.I. is the D.P.F.C. II with a net area of c. 107 acres situated at about 1,800 to 1,900 m elevation. It is mainly constituted of *Cedrus deodara* (80%), mixed with *Quercus incana* — the second dominant element, and scattered trees of *Abies* and *Picea*. Numerous small blanks indicating the sites of past fellings and now covered with shrubs (*Viburnum*, *Indigofera*, *Sarcococca*, *Spiraea*, *Rosa*, *Symplocos*, etc.) are found throughout the forest.

Towards the east-north-east of D.P.F.C. I. is the Kangar Rakh D.P.F., situated at about 1,300 to 1,800 m elevation. It is comprised of mainly oak and other broad-leaved elements, such as *Rhododendron arborescens*, *Celtis australis*, *Carpinus*, *Juglans regia*, *Ulmus wallichiana*, *Pyrus*, *Populus*



TEXT-FIG. 2 — The 'floating island' of *Phragmites communis* in the Khajiar lake.



TEXT-FIG. 3 — A panoramic view of the Khajiar lake and its surroundings.

ciliata, *Acer*, *Rhus*, *Rosa*, *Colebrookia*, *Ephedra*, *Berberis*, etc. *Pinus roxburghii* often growing in pure formation, occupies the lower elevations of this forest. Scattered trees of other conifers, such as *Cedrus*, *Picea* and *Abies* are met with in the upper elevations.

Towards the south-west of the Khajiar D.P.F. C. I. (Fig. 4) is situated the Khajrot D.P.F. at an elevation varying from 1,900 to 2,300 m with an area of c. 1,000 acres. This forest comprises of chiefly *Picea* and *Abies* (40% each), followed by *Cedrus* (10%) and scattered oak.



TEXT-FIG. 5 — A view of the *Cedrus* forest surrounding the Khajiar meadow.

chloric acid (1:2) after decanting off the hydrofluoric acid. Thereafter it was treated with 5 c.c. of glacial acetic acid in order to dehydrate the material. Acetolysis was then done by following the technique of Erdtman (1943), and the slides were prepared in 50% glycerine.

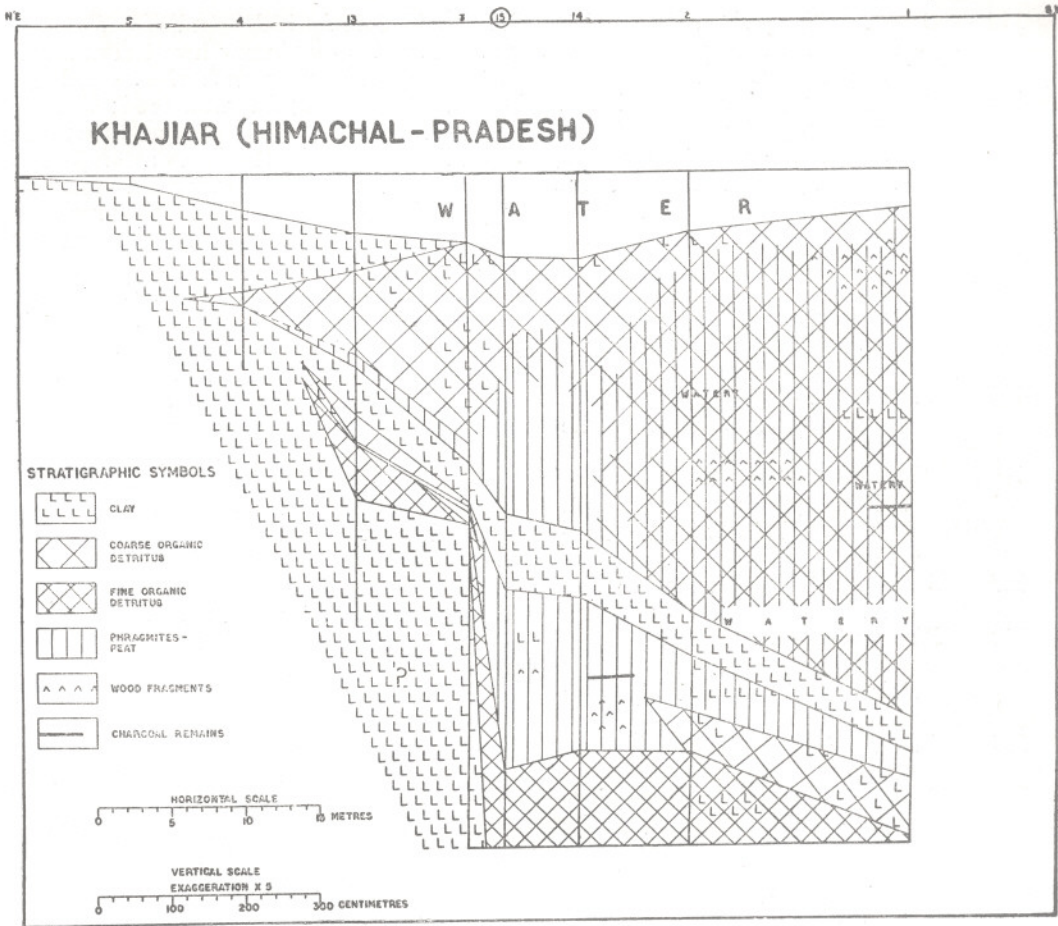
Pollen sum is based upon about 200 arboreal pollen grains. The percentages were calculated in terms of this sum. Arboreal and non-arboreal pollen diagrams have been constructed each of which is drawn separately. In addition, a total pollen diagram showing both arboreal and non-arboreal elements has also been constructed, calculating the percentage frequencies in terms of total land plant pollen excluding Ferns and Bryophytes. Percentages up to 0.5% are indicated by a plus(+) sign. The percentage frequencies of extremely sporadic elements met with are given at the right hand side of each AP and NAP diagram. In the case of the total AP/NAP diagram, the percentages are

shown in the middle, as well as, to the right-hand side of the diagram.

STRATIGRAPHY

The stratigraphy of the lake has been studied by digging bore-holes along a line running NE-SW of the lake (Fig. 6). The maximum depth reached is nine metres, without touching the base. The basin is full of *Phragmites*-peat, intercalated with layers of coarse and fine organic detritus, a limnic deposit with abundant *Botryococcus* colonies. The *Phragmites*-peat is interrupted by a bed of clay, running \pm horizontally all through it.

A coarse organic detritus about one metre or so overlies the *Phragmites*-peat. The clay filling the meadow, along the shores of the lake appears to have been derived both from the hill wash, and from the boulder clay. Charcoal remains together with wood fragments, were encountered at various levels in the bore-holes. In view



TEXT-FIG. 6 — Stratigraphical section of the lake deposit at Khajiar. The sampling was carried out from point 15, in the section.

of the abundance of <i>Phragmites</i> -peat in the lake basin, it is certain that <i>Phragmites communis</i> , now confined solely to the 'floating island' once occupied the lake margins. The bore-core 15 (nos. 6-12 through the meadow not included in the stratigraphical section) was selected for final sampling. The stratigraphical details of which are as follows:	150-188	Brown coarse organic detritus, with <i>Carex</i> seeds. Moss shoots abundant.
	188-208	Brown coarse organic detritus with a few seeds of <i>Chenopodium</i> , <i>Scirpus</i> and <i>Carex</i> . Moss fragments abundant.
	208-220	Coarse organic detritus, with lesser proportion of moss shoots and <i>Carex</i> seeds.
cms	220-250	Brown coarse organic detritus, with <i>Phragmites</i> remains. Moss leaves abundant.
0-112		Open water.
112-135	250-260	<i>Phragmites</i> -peat. Moss leaves abundant, <i>Phragmites</i> leaf fragments present.
135-150	260-300	Brown <i>Phragmites</i> -peat. Moss leaves abundant.

- 300-350 Brown *Phragmites*-peat with moss leaves, *Phragmites* leaf fragments present.
- 350-400 Brown *Phragmites*-peat with a few *Phragmites* nodes, leaf fragments, and one *Carex* seed. Moss leaves abundant, with a few moss shoots and wood fragments.
- 400-452 Same as above but *Carex* seed absent.
- 452-535 Grey clay, with a few plant remains. Moss leaves rarely seen.
- 535-553 Same as above, but becoming slightly organic towards the bottom.
- 553-600 *Phragmites*-peat. Moss shoots and *Phragmites* nodes present. *Scirpus* and *Carex* seeds abundant.
- 600-627 Same as above, but with some clay.
- 627-650 *Phragmites*-peat. Moss shoots present along with a few *Scirpus*, *Carex* and *Lycopus* seeds.
- 650-675 Same, with some wood fragments at 652 cm.
- 675-700 Coarse, compact *Phragmites*-peat. Moss leaves and shoots present. *Scirpus* and *Carex* seeds also seen along with a few *Phragmites* nodes.
- 700-750 Same as above.
- 750-794 Coarse, compact *Phragmites*-peat. A few seeds of *Scirpus*, *Carex* and *Potamogeton*, together with a few *Phragmites* nodes. Moss leaves and shoots also present.
- 794-800 Dark-brown fine organic detritus. Moss leaves abundant.
- 800-850 Same as above, but becoming more humified towards the bottom.
- 850-900 Dark brownish-grey, fine organic detritus. Moss leaves present.
- 900-?

VEGETATIONAL DEVELOPMENT

ZONATION

At present, there is no common system of zonation for zoning the Late-Quaternary pollen diagrams in India. Despite the fact

that pollen-analytical studies of Late-Quaternary deposits in northwest Himalayas have been underway since the late fifties (Singh, 1960, 62, 63; Sharma, 1964; Vishnu-Mittre & Sharma, 1966; Gupta, 1966; and Vishnu-Mittre *et al.*, 1967), no attempt has so far been made to evolve a uniform system of zonation based on either regional parallelism, or absolute chronology by means of C-14 dating of successive levels in the pollen profiles. This has been due partly to the paucity of the pollen data available, and partly to the rather late introduction of technique of C-14 dating in the country.

In north western Himalayas the Pollen-analytical studies have so far been carried out in the temperate areas of the State of Jammu and Kashmir—centred on the Kashmir valley, and the subtropical areas in the district of Nainital.

In the present studies on Himachal Pradesh, the evidence of C-14 datings of the pollen profile has provided an absolute basis for the consideration of the pollen sequence in its proper chronological order. But, as there is only one more C-14 dated profile, so far, available from north-western Himalayas (Sharma & Singh, 1973) it is premature to evolve a common system of zonation for Himachal Pradesh, leave alone north-western Himalayas, as a whole. Hence, the vegetational sequence as deduced from the Khajiar pollen profile is independent of any other profile from western Himalayas and is divided into five stages, namely a, b, c, d, & e.

POLLEN DIAGRAMS (Figs. 7, 8 & 9)

'Stage a' (900-810 cm)—The lower limit of 'Stage a' cannot be fixed as the stratigraphical sequence is incomplete. The vegetation as judged from the combined 'tree and shrub' pollen ratios on the whole, presents the picture of a closed forest. The tree vegetation is dominated by high values of *Quercus* (80%). *Pinus roxburghii* pollen which occurs to the extent of 10-20%, appears to have come from comparatively lower slopes. The conifers, which form more or less continuous but short curves are *Pinus wallichiana*, *Cedrus deodara*, *Taxus baccata* and *Larix*. Broad leaved elements, such as *Alnus*, *Carpinus*, *Fraxinus*, *Ulmus* and *Viburnum* also form short but continuous curves. Other tree and shrub pollen grains

found in low frequencies are those of *Picea smithiana*, *Cupressus*, *Corylus colurna*, *Betula alnoides*, *Aesculus indica*, *Rhododendron*, *Betula utilis*, *Populus ciliata*(?) and *Celtis australis*. Single grains of *Skimmia laureola* and *Ilex dipyrena* are also met with in this stage.

Non-arboreal plants are comparatively poorly represented and chiefly consist of Gramineae, Cyperaceae, *Artemisia* and Chenopodiant type, whose values reach up to 20%, 15%, 7% and 3% respectively. Cerealia type pollen grains are seen almost from the beginning of the pollen sequence in low numbers and they even form a continuous curve in the lower half of 'Stage a'. Other non-arboreal elements represented sporadically, and rarely forming discontinuous curves, are Compositae (Tubuliflorae), *Cannabis sativa*, Caryophyllaceae, Umbelliferae and Primulaceae. The pollen of *Impatiens*, Boraginaceae, Labiatae, *Polygonum* type, *Ammannia* and Leguminosae occurs sporadically up to 0.5%.

The aquatic vegetation is largely represented by colonies of *Botryococcus* whose curve shows an ascending trend, attaining its maximum value of about 85% in the middle of the stage. It, however, shows a sudden decline immediately after reaching its maximum and is later met with in low frequencies. Amongst the other aquatics, *Potamogeton* forms a low, but an almost continuous curve. The pollen of *Typha angustata* occurs rather sporadically. *Nymphaea* occurs as a single grain and the colonies of *Pediastrum* are met with sporadically in the middle of the stage.

Fern spores (both monolet and trilete) are present in low frequencies.

A number of tree and shrub elements, such as *Abies*, *Pinus wallichiana*, *Cedrus*, *Larix*, *Taxus*, *Quercus*, *Carpinus*, *Ulmus*, *Aesculus* and *Viburnum* show sudden decline at varying intervals throughout. The inter-relationship between the fall in the curves of *Quercus*, *Taxus*, *Ulmus*, *Carpinus* and *Viburnum* on one hand, and the rise in the curves of Cyperaceae, Gramineae, Cerealia type and *Cannabis* in the lower half of the stage on the other, is particularly noteworthy, and may be well diagnostic of a small scale clearance in the otherwise closed forest. The curves for all the above non-arboreal elements fall together with the recovery of the oak curve in the second half of the stage, indicating a regeneration of the oak forest. The 'Stage a' ends at

810 cm, where the curve for *Abies* falls and that of *Cupressus* rises.

'Stage b' (810-560 cm)—It is divisible into two sub-stages 'b₁' and 'b₂'.

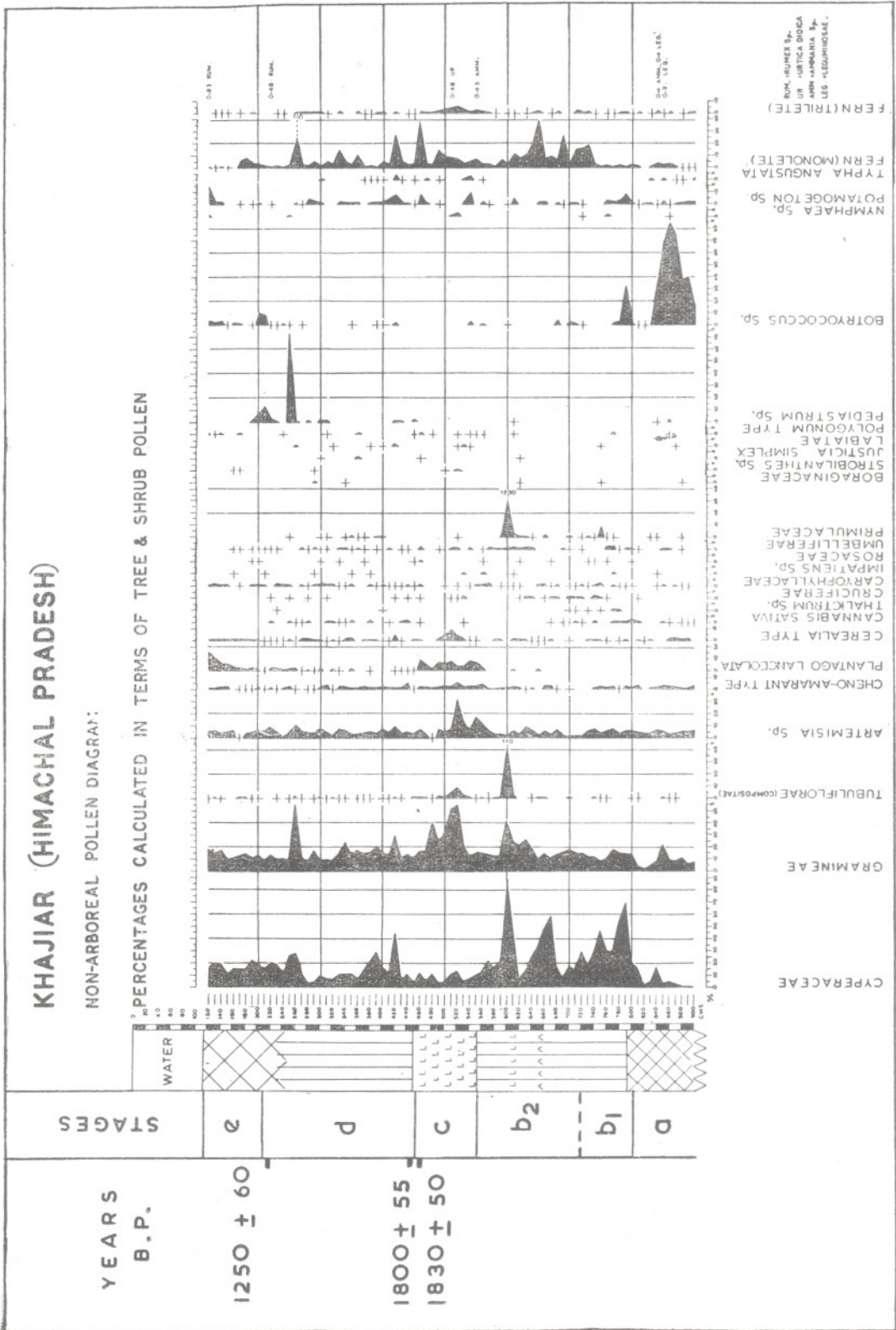
'Stage b₁' (810-560 cm)—It is divisible with the rise of the *Cupressus* curve, accompanied by a general fall in the 'tree and shrub' pollen ratios. The oak curve shows a sudden decline. Both *Carpinus* and *Fraxinus* mark a slight increase in their values. *Taxus* and *Corylus*, are not represented in this sub-stage. The curve for *Larix* becomes sporadic. Other tree and shrub elements present in low frequencies are *Abies*, *Pinus wallichiana*, *Picea smithiana*, *Cedrus deodara*, *Betula utilis*, *Alnus*, *Betula alnoides*, *Ulmus*, *Aesculus indica*, *Viburnum*, *Skimmia laureola* and *Celtis australis*. S ray pollen of *Juniperus*, *Juglans regia*, *Coriaria* and *Salix*, is also met with in this sub-stage. The curve for *Pinus roxburghii*, however, maintains more or less similar values as in the previous stage with slight fluctuations.

Non-arboreal elements show a considerable increase in this sub-stage. The curve for Cyperaceae reaches up to 70%, but soon declines afterwards. The values of Gramineae reach to about 20%. There is very slight increase in the values of *Artemisia* and the Chenopodiant type maintains an almost low continuous curve. *Cannabis sativa* begins a fresh curve and its values rise in the lower half of the sub-stage. Other non-arboreal elements represented either in short curves, or in a sporadic form, are Compositae (Tubuliflorae), Cerealia type, *Thalictrum*, Cruciferae, Caryophyllaceae, Rosaceae, Umbelliferae and Primulaceae. The pollen of Labiatae and *Polygonum* type, is also seen in this sub-stage.

Aquatic vegetation chiefly comprises of high values of *Botryococcus* colonies (33%), *Potamogeton* (8%) and of very low frequencies of *Nymphaea* pollen. The values of Cyperaceae, *Botryococcus* and *Potamogeton*, rise together at the beginning of the sub-stage, later on, they all decline.

Fern spores (both monolet and trilete) are represented in low values.

'Sub-stage b₂' (730-560 cm)—The 'sub-stage b' comes to an end at 730 cm and 'Sub-stage b₂' starts, where the *Cupressus* curve falls and those of *Abies* and *Cedrus deodara* rise. The curve for *Abies* declines in the later half of the stage. *Pinus wallichiana* forms a fresh, but discontinuous curve. The curves for *Carpinus* and *Fraxinus*



TEXT-FIG. 8 — Non-arboreal pollen (NAP) diagram from the Khajiar lake.

fall but the curve for *Carpinus* rise once again in the later half. The oak curve, but for the two isolated fluctuations, on the whole, tends to decline. Other tree and shrub pollen represented in low values are *Picea smithiana*, *Larix*, *Betula utilis*, *Cupressus*, *Alnus*, *Betula alnoides*, *Buxus*, *Ulmus*, *Aesculus indica*, *Viburnum*, *Celtis*, *australis*, *Populus ciliata*, *Coriaria* and *Salix*. The pollen of *Juniperus*, *Ephedra*, *Corylus colurna*, *Skimmia laureola*, *Juglans regia*, *Symplocos* and *Rhododendron* occurs sporadically. Single grain of *Acer* is also met with in this sub-stage. The curve for *Pinus roxburghii*, however, maintains almost similar frequencies as in the 'Sub-stage b_1 ' with some fluctuations.

The non-arboreal vegetation mainly comprises of Cyperaceae, Gramineae and *Artemisia*, whose values reach up to 60%, 26% and 6% respectively. Umbelliferae and Chen-Amaranth type form fresh curves in the second half of the sub-stage. Other non-arboreal elements, present either in short curves or sporadically, are Compositae (Tubuliflorae) Cerealia type, *Cannabis sativa*, Cruciferae, Rosaceae, Umbelliferae and Primulaceae. Stray pollen of *Thalictrum*, *Impatiens*, Boraginaceae, *Justicia simplex* and *Polygonum* type is also met with. A few pollen grains of *Plantago lanceolata* are seen for the first time in this sub-stage. At 600 cm, Primulaceae and Tubuliflorae attain exceptionally high frequencies reaching up to 1250 and 110% respectively, apparently as a result of the local occurrence.

Aquatic vegetation is represented by low frequencies of *Potamogeton*, and the sporadic occurrence of *Pediastrum* colonies.

The curve for Fern spores (monolete), shows a considerable increase with its values reaching up to 40%. It, however, declines in the second half of the sub-stage. Other type of Fern spores (trilete) continue to occur in low values.

The fall in the curves of *Abies* and *Quercus* at the beginning of 'Stage b', together with a general rise in the non-arboreal pollen ratios, especially in conjunction with the rise in the values of Cyperaceae, Gramineae, Chen-Amaranth type and *Cannabis*, and a little later of Cerealia type, is indicative of small scale clearance. In both the sub-stages the successive rise and fall in the oak curve corresponds respectively with the fall and rise in the Cyperaceae curve.

'Stage c' (560-460 cm)—The 'Sub-stage b_2 ' is brought to an end at 560 cm and 'Stage c' begins where the *Quercus* curve registers a sudden fall and *Ulmus*, *Juglans* and *Corylus* start fresh curves. The latter broad leaved three species reach their respective maximum at 38%, 8% and 6% in this stage. The *Cedrus deodara* curve abruptly ends. The curve for *Carpinus* becomes sporadic. The values for *Abies* show a rise from the middle of the stage and the curve for *Pinus wallichiana* tends to fluctuate throughout the stage. There is a slight increase in the curve for *Pinus roxburghii*. Other tree and shrub elements present in low frequencies are *Picea smithiana*, *Betula utilis*, *Alnus*, *Betula alnoides*, *Buxus*, *Aesculus indica* and *Viburnum*, together with very low frequencies of *Cupressus*, *Fraxinus*, *Skimmia laureola*, *Coriaria*, *Symplocos*, *Rhododendron* and Mimosoideae (polyad). The pollen of *Taxus baccata* and *Ilex diphyrena*, which remains unrepresented in 'Stage b' is met with sporadically in this stage.

There is a sudden rise in the frequencies of a number of non-arboreal elements, such as *Artemisia*, *Plantago lanceolata* and Chen-Amaranth type at the beginning of the stage, accompanying the fall in the *Quercus* and *Cedrus* curves. A little later Cerealia type, Compositae (Tubuliflorae), and Gramineae, also mark an increase in their values. Cruciferae, Caryophyllaceae, Umbelliferae and *Polygonum* type of pollen grains are either sporadic or are present in the form of discontinuous curves. Stray pollen of *Cannabis sativa*, *Urtica dioica*, *Ammannia*, *Impatiens*, Primulaceae, *Strobilanthes*, *Justicia simplex* and Labiatae, are also met with in this stage. While the curve for *Plantago* continues more or less uniformly throughout this stage, the curves for Gramineae, Compositae (Tubuliflorae), *Artemisia* and Cerealia type fall in the later half of 'Stage c' together with the recovery of the oak curve.

The aquatic vegetation is represented by low values of *Potamogeton* and *Typha*, together with stray occurrence of *Botryococcus* colonies and *Nymphaea* pollen.

The curve for Fern spores (both monolete and trilete) show an increasing trend in this stage.

The transitory increase in all the non-arboreal elements in conjunction with the fall in the values of oak and *Cedrus*,

KHAJIAR (HIMACHAL PRADESH)

ARBOREAL & NON-ARBOREAL POLLEN DIAGRAM

PERCENTAGES CALCULATED IN TERMS OF TOTAL LAND PLANT POLLEN

YEARS
B.P.

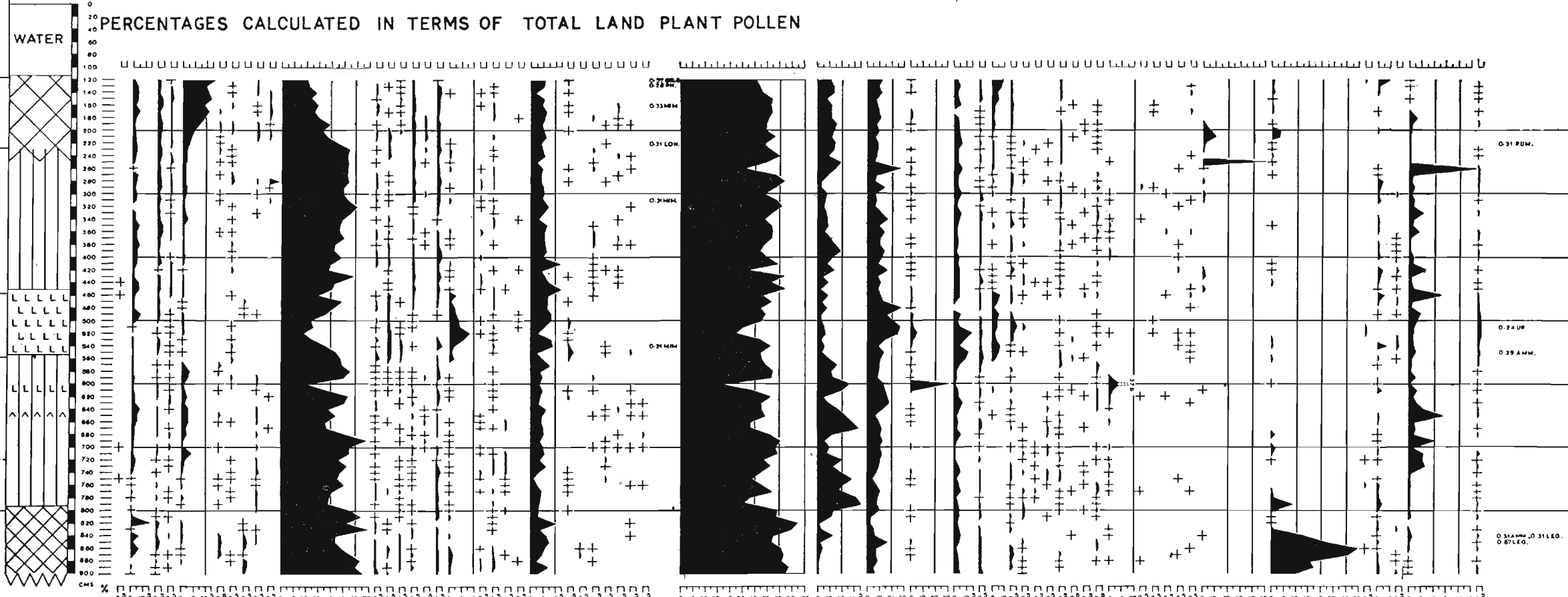
STAGES

WATER

1250 ± 60

1800 ± 55

1850 ± 50



- JUNIPERUS Sp.
- ABIES Sp.
- PINUS WALLICHIANA
- PICEA SMITHIANA
- CEDRUS DEODARA
- LARIX Sp.
- BETULA UTILIS
- TAXUS BACCATA
- CUPRESSUS Sp.
- EPHEDRA Sp.
- QUERCUS Sp.
- ALNUS Sp.
- CORYLUS COLORNA
- FRAXINUS Sp.
- BETULA ALNOIDES
- BUXUS Sp.
- CARPINUS Sp.
- ULMUS Sp.
- AESCULUS INDICA
- VIBURNUM Sp.
- SKIMMIA LAUREOLA
- ILEX DIPYRENA
- PINUS ROXBURGHII
- JUGLANS REGIA
- CELTIS AUSTRALIS
- POPULUS CILIATA?
- CORIARIA Sp.
- SYMPLOCOS Sp.
- RHOODENDRON Sp.
- SALIX Sp.
- TREES & SHRUBS
- HERBS
- GR. = GREWIA Sp.
- RH. = RHUS Sp.
- MIM. = MIMOSIDOEA (POLYAD)
- LON. = LONICERA QUINQUELO-CULARIS
- CYPERACEAE
- GRAMINEAE
- TUBULIFLORAE (COMPOSITE)
- ARTEMISIA Sp.
- CHENO-AMARANT TYPE
- PLANTAGO LANCEOLATA
- CEREALIA TYPE
- CANNABIS SATIVA
- THALICTRUM Sp.
- CRUCIFERAE
- CARYOPHYLLACEAE
- IMPATIENS Sp.
- ROSACEAE
- UMBELLIFERAE
- PRIMULACEAE
- BORAGINACEAE
- STROBILANTHES
- JUSTICIA SIMPLEX
- LABIATAE
- POLYGONUM TYPE
- PEDIASTRUM Sp.
- BOTRYOCOCCUS Sp.
- NYMPHAEA Sp.
- POTAMOGETON Sp.
- TYPHA ANGUSTATA
- FERN (MONILETE)
- FERN (TRILETE)
- RUM. = RUMEX Sp.
- UR. = URTICA DIOICA
- AMM. = AMMANIA Sp.
- LEG. = LEGUMINOSAE

TEXT-FIG. 9 — Total pollen diagram (AP/NAP) from the Khajiar lake.

accompanied by a stratigraphical change from *Phragmites*-peat to clay at the beginning of 'Stage c' is perhaps indicative of a large scale clearance of tree vegetation in this stage. The fall in the tree vegetation accompanied by an increase in the Cerealia type curve, shows that the clearance was perhaps carried out with the idea of short term agriculture. Further, in view of the fact that the oak values started rising once again in the second half of 'Stage c' accompanied by fall in the curves for Gramineae, Tubuliflorae, *Artemisia* and Cerealia type, it is evident that the forest closed once again. Thus, a 'landnam' type of agriculture (Iversen, 1949) appears to have been practised at Khajiar in 'Stage c' which entailed the cutting down of the forest as a first step. This was perhaps followed by a period of agriculture and later by the abandonment of the site, so that the forest started regenerating once again. The deposition of the clay during this stage perhaps resulted from the above clearance of forests in and around the Khajiar meadow, and the clay deposition ceased as soon as the oak forest was re-established in early 'Stage d'. The lower border of 'Stage c' is C-14 dated around the first century A.D. from the two C-14 dates 1800 ± 55 B.P. (WIS-416) and 1830 ± 50 B.P. (WIS-428) taken from the stages b/c boundary.

'Stage d' (460-220 cm)—The 'Stage c' comes to an end at 460 cm, with the fall in the curves for *Ulmus* and *Corylus*, and 'Stage d' begins with a consistent rise in the values of *Quercus*, which reach up to about 75% in this stage. *Abies* maintains more or less similar values as in earlier stage with slight fluctuations. There is slight increase in the values of *Pinus wallichiana* as compared to the earlier stages. The curve for *Pinus roxburghii* does not show any change, except that its values show a slight decline at the beginning of the stage. *Cedrus* and *Carpinus* start fresh curves. Their curves, together with that of *Betula alnoides* show a consistent rise, and while the curves for *Carpinus* and *Betula alnoides* show a temporary decline in middle of the stage, the curve for *Cedrus* continues unbroken. Both *Alnus* and *Corylus*, show a transitory rise in the lower half of this stage. Other tree and shrub elements present either in the form of low discontinuous curves, or met with rather

sporadically, are *Picea smithiana*, *Larix*, *Betula utilis*, *Cupressus*, *Ephedra*, *Buxus*, *Ulmus*, *Aesculus indica*, *Viburnum*, *Celtis australis*, *Populus ciliata* (?), *Symplocos* and *Rhododendron*. Of these, the values of *Picea* show a marked increase, as compared to the earlier stages. Stray pollen of *Juniperus*, *Ilex diphyrena*, *Juglans regia* and Mimosoideae (polyad) is also met with.

The non-arboreal pollen ratio fall in this stage. There is a sudden decline in the frequencies of *Plantago lanceolata* at the stages c/d boundary. As the fall in the curve for *P. lanceolata* is on the whole, accompanied by the rise in the values of tree vegetation, it is apparent that its decline resulted from the closing in the forest, following the 'landnam' phase of 'Stage c'. The curve for Chenopodiate type, is seen almost continuously up to the middle of the stage, after which it becomes discontinuous. The values of Cyperaceae and Gramineae tend to increase at the beginning of the stage, but later show a rather fluctuating trend. *Artemisia* maintains more or less similar values throughout the stage with slight fluctuations. Other non-arboreal elements present in low frequencies are Compositae (Tubuliflorae), Cerealia type, *Cannabis*, Cruciferae, Caryophyllaceae, Umbelliferae, Primulaceae and Boraginaceae. Stray pollen of *Thalictrum*, *Impatiens*, Rosaceae, *Strobilanthes*, *Justicia simplex*, Labiatae and *Polygonum* type, is also met with in this stage.

The aquatic vegetation is mainly represented by *Pediastrum* colonies, whose curve is seen in the upper half of the stage, with the values reaching up to 75%. *Potamogeton* forms a continuous curve in the beginning, becoming discontinuous later on. The pollen of *Typha angustata* and colonies of *Botryococcus*, are seen in low values. A few grains of *Nymphaea* are seen at the 250 cm level.

The curve of Fern spores (monolete) shows a fluctuating trend, with frequencies reaching up to 110%. The other type of Fern spores (trilete) decline in this stage.

'Stage e' (220-120 cm)—The 'Stage d' is brought to an end at 220 cm, where there is a consistent fall in the curve for *Quercus*, and 'Stage e' begins with the sudden rise in the frequencies of *Cedrus* whose values ascend gradually, and reach up to nearly 40% at the top end of the stage. There is a slight increase in the

curve for *Picea* and *Abies*. The former increases in the first half while the curve for *Abies* is seen to rise in the later half. *Cupressus* forms a short curve in the beginning, while *Ephedra* a little later. *Pinus wallichiana*, *Pinus roxburghii*, *Betula alnoides* and *Carpinus*, maintain pollen values more or less similar to 'Stage d'. The pollen of *Fraxinus*, which is not represented in 'Stage d' is seen in low values in this stage. Other tree and shrub elements present in low frequencies are *Larix*, *Betula utilis*, *Viburnum*, *Juglans*, *Celtis*, *Populus ciliata* (?), *Symplocos* and *Rhododendron*. Stray pollen grains of *Buxus*, *Aesculus indica*, *Ilex*, *Coriaria*, Mimosoideae (polyad), *Lonicera*, *Grewia* and *Rhus* are also seen in this stage.

Amongst the non-arboreal elements, *Plantago lanceolata* shows a progressive rise, and its values reach up to 15%. The curve for Cerealia type also becomes continuous. The pollen of Chen-Amaranth type and Caryophyllaceae forms a continuous curve in the upper half of the stage. The curves for Gramineae, Cyperaceae and *Artemisia* maintain more or less similar values as in 'Stage d' with slight fluctuations. Other non-arboreal elements present in low frequencies are Compositae (Tubuliflorae), Umbelliferae and *Polygonum* type, together with stray pollen of *Impatiens*, *Rosaceae*, *Strobilanthes* and *Rumex*.

The aquatic component is represented by the transitory occurrence of colonies of *Pediastrum* and *Botryococcus* in the lower half of the stage. *Botryococcus*, however, forms a curve once again in the upper half, together with *Potamogeton*. Its values reach up to 15%. *Nymphaea* pollen is seen at low value at the top end of the stage.

Fern spores (both monolete and trilete) are poorly represented.

The rise in the curve for *Plantago lanceolata*, Cerealia type, Umbelliferae, Chen-Amaranth type, accompanying the fall of the *Quercus* curve, is indicative of clearance, for perhaps agriculture in the vicinity of Khajiar. The spectacular increase in the *Cedrus* curve in 'Stage e' may be mainly due to the large scale replacement of *Quercus* by *Cedrus* around Khajiar as a result of selective felling of oak and the artificial plantations of *Cedrus* carried out during the last several decades. A level just below the lower border of 'Stage e' has been C-14 dated at 1250 ± 60 B.C. (WIS-418).

DISCUSSION AND CONCLUSIONS

STRATIGRAPHY AND THE AGE OF THE LAKE DEPOSIT

The present studies have brought out the vegetational history of the later part of the Post-glacial period only, for the lake sediment at Khajiar could not be investigated beyond the depth of nine metres which though is the maximum depth hitherto penetrated for the Late-Quaternary sediments in India by means of a Hiller peat borer. Further penetration was not possible due to the limited capacity of the boring equipment available. But it is envisaged that in future it will be possible to penetrate the sediment to a deeper extent and thus, bring to light the remaining part of the Post-glacial history of vegetation and climate.

The deepest sediment reached at nine metres is comprised of fine organic detritus (Fig. 6). The lake basin deepens abruptly in the north-eastern part of the section. The lake deposits are largely organic in nature derived through a normal hydrosere succession. The lake bottom was not reached except at the lake margins where the organic sediments lie directly over a derived clayey material. The profile obtained from point 15 in the section is incomplete as a part of the organic deposit at the base remains inaccessible. The three C-14 dates — 1800 ± 55 B.C. (WIS-416), 1830 ± 50 B.P. (WIS-428) and 1250 ± 60 B.P. (WIS-418), first two from about the middle and third from the upper part of the profile investigated, may not extend 4000 years B.P. It is quite obvious that deposits of still older age lie at the depths below the levels reached under the present investigations.

VEGETATIONAL HISTORY

With the available C-14 datings, and from the foregoing account of lake deposit investigated at Khajiar, the vegetational history seems to represent the later part of the Post-glacial period.

'Stage a'—The picture of vegetation at the beginning of 'Stage a' is seen in a fully developed state rather than as one emerging as a result of some climatic change. The stratigraphical continuity of fine organic detritus below 'Stage a' deposit, without any apparent change in the nature of

sediments, preclude the possibility of any climatic change at the beginning of the pollen sequence. The vegetational history begins with a closed forest, in which *Quercus* appears to have been preponderant. The pollen of *Pinus roxburghii*, which is represented by a prominent curve, appears to have come from comparatively lower slopes as it is seen in the present-day surface samples from this site (Sharma, 1973). Other trees and shrubs are lowly represented. The overall dominance of *Quercus* is in great contrast to the present-day conditions at Khajiar, in which *Cedrus* dominates the landscape, together with other conifers, such as *Abies* and *Picea*. Almost pure *Quercus* forests are now, seen occupying the lower slopes below Khajiar. *Quercus* occurs regularly at higher elevations, together with *Abies* and *Picea* forests but mostly in small numbers. The overall preponderance of *Quercus* may, thus, be indicative of relatively warmer conditions than that of the present-day, in this stage. To this extent the purely broad-leaved character of the forests compares closely with mid-post-glacial part of the Toshmaidan pollen sequence from Kashmir, which is taken to represent the Post-glacial 'Climatic optimum' in the area (Singh, 1963). The C-14 datings from Khajiar, in fact, do suggest that the history of 'Stage a' may extend only up to about 4000 B.P. and may, therefore, represent the later part of the 'Post-glacial Climatic Optimum'.

The presence of *Larix* pollen up to 5%, in this stage, suggests that *Larix* was perhaps present, in Himachal Pradesh, in the past, as opposed to its present-day absence in the western Himalayas. Sub-fossil pollen grains, tentatively identified as those of *Larix*, are also recorded from Post-glacial vegetational sequence from Toshmaidan, indicating the extension of this species westwards up to Kashmir, during the later half of the Post-glacial period (Singh, 1960).

The occurrence of Cerealia type of pollen together with that of *Cannabis*, from the beginning of the pollen sequence, in low frequencies, suggests that cereal cultivation was perhaps prevalent in the area. The history of cereal agriculture in Himachal Pradesh, is almost unknown. In the plains of N.W. India, however, cereal cultivation is definitely known to have been practised since the Harappan times (2,500 B.C.).

That the practice of cereal cultivation at Khajiar is accompanied by small scale clearance is shown by the small decline in the curves for *Quercus*, *Taxus*, *Ulmus*, *Carpinus* and *Viburnum* together with a corresponding rise in the curves for Cyperaceae, Gramineae, Cerealia type and *Cannabis*, in the lower half of the stage. The curves for all the above non-tree elements, however, fall with the recovery of the oak curve in the second half of the stage, indicating that the forest closed once again.

Locally, *Botryococcus* colonies appear to have been preponderant in the lake waters, and aquatics, such as *Potamogeton*, *Nymphaea* and *Typha angustata* perhaps grew at the site. *Pediastrum* colonies are represented only in the middle of the stage.

'Stage b'— This stage is marked by the establishment of a mixed oak-conifer forest. *Quercus* occurs together with *Cupressus* to start with, and is later joined by *Cedrus* and *Abies*. In 'Sub-stage b₁', there is a progressive rise in the *Cupressus* curve, together with a slight increase in the curves for *Fraxinus* and *Carpinus*. Later, in 'Sub-stage b' *Cupressus* declines, accompanied by a general rise in the curves for *Cedrus* and *Abies*. The oak curve tends to decline as a whole in this stage. The tendency towards the establishment of a mixed oak-conifer forest in 'Stage b', may be indicative of perhaps a slight change in the environment towards colder conditions favouring the growth of conifers. All the above coniferous elements, i.e. *Cupressus*, *Cedrus* and *Abies* grow in association with each other at altitude above 1800-2100 m (6,000'-7,000') with *Abies* occupying highest position.

There is no evidence of any large scale cutting of forests but there is clear possibility that small scale cutting of trees continued throughout this stage.

'Stage c'— This stage is characterized by the rise in the frequencies of *Ulmus*, *Corylus* and *Juglans*, accompanied by a sudden fall in the curves for *Quercus* and *Cedrus*. The curve for *Carpinus* becomes discontinuous. The sudden fall in the frequencies of *Cedrus*, *Quercus* and *Carpinus*, appears to be associated with the felling of these elements as their decline is accompanied by a corresponding rise in the frequencies of *Artemisia*, *Plantago*, Chenopodium type and Ferns, followed by those

of Gramineae, Compositae and Cerealia type, indicating the opening of the forest, for perhaps short-term agriculture. The clearing of the forest, also appears to have resulted in bringing about soil instability over mountain slopes, leading to the deposition of clay in this stage. The clearing was in all probability, affected in the present-day meadow surrounding the Khajiar lake. From the two C-14 dates — 1800 ± 55 B.P. (WIS-416) and 1830 ± 50 (WIS-428) available from the stages b/c boundary, the date of this clearance can be placed around the first century A.D. This period was marked by the expansion of Buddhism in India, and Buddhist places of worship were founded in many parts of the country. But, whether the clearance of the forest at Khajiar in 'Stage c' was in any way associated with this phenomenon cannot be ascertained. Elsewhere, in the Himalayas, Buddhist have established several centres, mostly around natural lakes, which are invariably held in high esteem.

The rise in *Ulmus* and *Juglans* frequencies, is of a temporary nature, and it may have been induced as a result of some local plantations at the site. The increase in the relative frequencies of *Corylus*, an element of open, dry, sunny habitats, on the other hand, appears to be natural, and may have resulted from the opening of the forest in this stage. Oak values start rising once again in the second half of the 'Stage c' accompanied by a fall in the frequencies of non-arboreal elements, indicating that the forest closed afterwards.

'Stage d'—This stage is characterized by the re-establishment of the mixed oak-conifer forest which is marked by the consistent increase in the values of *Quercus* and the slight rise in the values of *Abies*, *Pinus wallichiana*, *Cedrus*, *Carpinus* and *Betula alnoides*. The deposition of clay ceases with the regeneration of the forests, and it appears that the soil is stabilized once again in early 'Stage d'. *Alnus* and *Corylus* show a transitory rise in the lower half of the stage, but decline afterwards. All the non-arboreal elements, whose frequencies rise as a result of forest clearance in 'Stage c' decline in 'Stage d'. The curve for Cyperaceae, which shows a transitory rise at the beginning of the stage, falls afterwards. However, it rises once again, towards the top end of the stage.

'Stage e'—This stage is characterized by a sudden rise in the frequencies of *Cedrus*, accompanied by an equally significant fall in the *Quercus* pollen curve. There is little evidence of the destruction of the oak forest through felling, as there is little change in the curve for AP/NAP ratios, prior to the establishment of the *Cedrus* forest. Thus, the possibility of large scale clearance followed by *Cedrus* plantation, as being the primary cause can be eliminated. In the absence of any large scale forest clearance, however, the question is raised as to how the *Cedrus* forest had come to replace the ancient *Quercus* forest which is seen to have been so well established in the area, since the mid-post-glacial times. That the change had come as a result of some alteration in the climate is ruled out, as other coniferous elements, fail to respond in the same manner as *Cedrus*. The answer in all probability lies in the selective felling of oak over a long period (a practice still prevalent in the area) which appears to have given an edge to the growth of *Cedrus* in the area. It would be interesting to note that in the otherwise demarcated forest, oak trees are still allowed to be felled for firewood by the forest department, as a result of which, stumps of oak trees can be seen scattered in the almost pure *Cedrus* forest. From the single C-14 date 1250 ± 60 B.P. (WIS-418), available from a level slightly below the stages d/e boundary, the beginning of the *Cedrus* rise can be dated around 1200 B.P. (700 A.D.).

Apart from the *Cedrus* curve, there is slight increase in the values of *Picea*, *Abies*, *Cupressus* and *Ephedra* but the extent to which their rise is influenced through the felling of the oak forest cannot be ascertained.

In the later half of 'Stage e' the rise in the curves for *Plantago lanceolata*, Cerealia type, Umbelliferae and Chen-Amaranth type, together with further fall in the oak curve, is indicative of a marked clearance in the area for perhaps agriculture.

Phragmites ceases to exist in the organic sediment in this stage. This is particularly interesting as *Phragmites* is totally absent at and around Khajiar except for a small patch constituting the 'floating island'. The disappearance of *Phragmites* from the edges of the Khajiar lake, appears to have been affected at about the beginning of

'Stage e', together with the fall in the oak curve. It is likely that both the felling of the oak forest, started with the establishment of permanent settlement in the Khajiar area dating back to about 1200 B.P. (700 A.D.).

ORIGIN OF 'FLOATING ISLAND'

Sahni (1927) was the first to report the occurrence of a 'floating island' in the Khajiar lake. He was greatly impressed by the abundant *Phragmites communis* growing on the 'floating island' at this site, for the plant is completely absent on the fringes of the lake as well as elsewhere in the area within several miles. Sahni (*loc. cit.*), further stressed upon the need for successional studies to unravel the mystery of the 'floating island'.

It has been already established from the stratigraphy of the deposits at Khajiar (Fig. 6) that but for the upper half to one metre of the lake deposit, the peat comprised of mainly *Phragmites* remains, and forms the bulk of the organic deposit filling the lake basin. It is also clear from the section that prior to the deposition of *Phragmites*-peat, fine organic detritus, a limnic sediment with abundant remains of *Botryococcus* colonies, was being laid down under deep water conditions. The sequence of *Phragmites*-peat, is interrupted by a bed of clay running laterally all through the deposit. Immediately following the deposition of the clay bed, *Phragmites* appears to have become preponderant once again in the upper levels. The otherwise, continuous sequence of *Phragmites*-peat is interrupted by watery gaps, from which it seemed reasonable to believe that thick mats of *Phragmites*-peat floated unanchored over the open waters of the lake in the past. It is clear that *Phragmites* continued to grow at Khajiar-lake-site throughout the sub-recent history of the lake, except for the time span of the upper half to one metre of the lake deposit. The extermination of *Phragmites communis* from the lake margin would, therefore, seem to be a recent phenomenon. It is needless to say that the *Phragmites* growing on the 'floating island' is a remnant of the once flourishing *Phragmites communis* stand in the lake at Khajiar.

It is also clear that the 'floating island' which may have been a part of the *Phragmites* stand in the long past, perhaps started its independent life after getting separated from the mother stand. Whether the phenomenon was purely a chance occurrence or it was initially induced through the agency of man is difficult to answer.

The reason for the extermination of *Phragmites communis* from the lake margin is not clear. It is possible that either the *Phragmites* stand was cut down by man for thatching purposes at the time of the establishment of the Khajiar Village, or it was eaten away by domestic animals.

The 'floating island', however, does not appear to have been separated prior to the deposition of the clay bed, as the stratigraphy of the 'floating island' does not show any band of clay intercalated in the peat profile, as it is seen in the stratigraphy of Khajiar lake deposit. On the other hand vegetational history built from the 'floating island' (Sharma, 1972) compares closely with the main characteristics of 'Stage e' of the Khajiar pollen diagram. The lower part of 'Stage e' in the main profile is C-14 dated at 1250 ± 60 B.P. (700 A.D.) (WIS-418), but the pollen diagram from the 'floating island' may not represent the whole time period of 'Stage e'. In any case, the history of the 'floating island' at Khajiar, cannot be pushed back any further than 'Stage e' that is 700 A.D. Actually, it may be much younger unless it is assumed that the bottom of the 'floating island' has continued to be eroded from time to time through its contact with the shallower parts of the lake basin.

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