

# STUDIES IN THE LATE-QUATERNARY VEGETATIONAL HISTORY IN HIMACHAL PRADESH— 2. REWALSAR LAKE

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## ABSTRACT

The paper embodies the results of pollen analytical investigations carried out at Rewalsar lake in Himachal Pradesh. The whole pollen sequence has been divided into several stages (a-e) as to facilitate the description of the pollen diagram.

The Rewalsar lake is nearly 800 cm deep and is C-14 dated at two levels, i.e. 170 and 290 cm to  $520 \pm 55$  and  $1410 \pm 60$  years B.P. respectively. The date for bottom portion of the profile can be extrapolated to about 4000 years B.P. and thus whole sequence belongs to the "Post-glacial period".

The vegetational stages as marked in the pollen-diagrams do show the vegetational changes. The 'Stage a', the lowermost part of the lake basin is comprised of the forest in which oak appears to be the most dominant element followed by *Pinus* and *Corylus* with an undergrowth of grasses together with *Artemisia* and Cheno-Amarant. The succeeding 'Stage b' is almost in accordance with the preceding 'Stage a' except for a little rise in *Quercus*. 'Stage c' is differentiated from the preceding stages by the consistent rise in the values of *Corylus* and corresponding fall in the values of *Quercus*. The high altitude elements such as *Pinus wallichiana*, *Abies*, *Picea* and *Cedrus* have either gained or emerged during this stage. The ground flora except for minor fluctuations remain the same. 'Stage d' is marked by the tremendous decline in oaks and *Corylus* corresponding with a sudden rise in the values of *Pinus roxburghii* from the beginning of this stage. 'Stage e' is characterized by tremendous fall of *Quercus* giving place to the grasslands comprising Gramineae, Cyperaceae, Compositae, *Artemisia*, Cheno-Amarant type and Cerealia type.

## INTRODUCTION

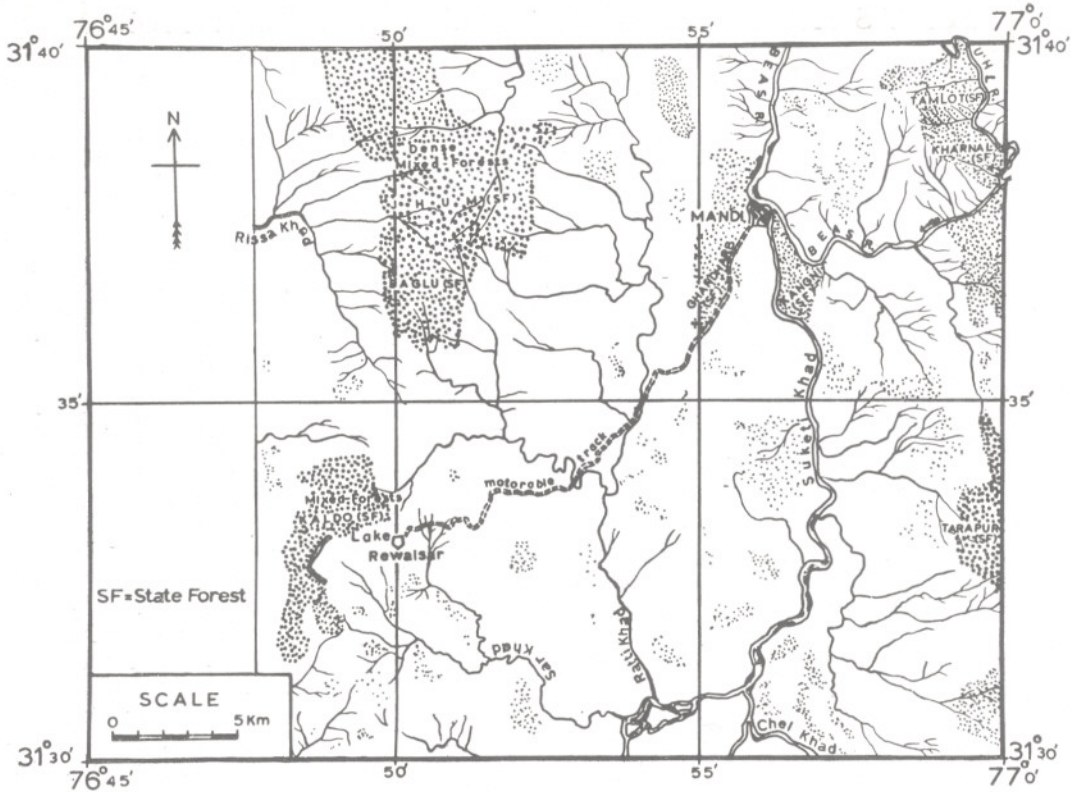
THE lake at Rewalsar ( $76^{\circ}50'E$ ,  $31^{\circ}33'N$ ) is situated on the eastern slopes of the outer Himalaya facing Suketi Khad, about 16 km south-west of Mandi, at an altitude of about 1,280 m. A.S.L. (Figs. 1, 2). The lake is more or less triangular in outline and its circumference exceeds one and a half kilometre. The open water is studded with, seven main 'floating islands' of different sizes

and shapes. The largest amongst these, called 'Parbati's island' (Kashyap, 1920) by the local people, measures about 18 and 3.6 m. in length and breadth respectively, whereas others are much smaller. A willow tree is also seen growing on one of the 'islands' known as 'Brahma's island'. The 'islands' are over grown with mainly *Phragmites communis* besides a few other grasses and herbs. The northern part of the lake-basin on the side of the main inlet, is filled with sediments consisting of organic detritus, clay, silt and gravel. The lake margins are grown with abundant *Phragmites communis*, and several other aquatics and amphibious plants.

It is mentioned that the lake was chosen as a place of retirement and devotion by the Rishi Lomas, whose name is mentioned in the 'Skandh Purana' of the Hindu mythology. It is said that the Rishi Lomas used to bathe in the waters of Ganga and Jamuna, and that, by the power of God, both the streams joined together to cast this lake for the Rishi (Punjab States Gazetteer, 1904). The lake is held sacred by the Hindus, the Budddists and the Sikhs. The presence of 'floating islands' (Sharma, 1971) is mainly attributed to its sanctity by the Buddhists. A number of places of worship have sprung up during the last century, though the religious sanctity of the lake may be of much greater antiquity. All around the lake, a narrow concrete road has been constructed for the pilgrims to circumambulate.

Rewalsar is one of the most important pilgrimage centres in Himachal Pradesh, and thousands of pilgrims flock to this place at the Baisakhi festival, held in the first half of April every year. Even though the local population of Rewalsar is rather small, the pressure of the pilgrims on the local vegetation at the time of festival is tremendous.

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TEXT-FIG. 1 — Detailed map showing the location of the lake site.

To the north and the west of the lake, lies the main catchment area, but the water entering the lake is small except during the rainy season. The lake has its permanent supply of water from subterranean springs (Kashyap, *loc. cit.*), and there is a narrow outlet situated in the south-west.

#### METHODS

Stratigraphy was built up with the help of Hiller peat-auger provided with 50 cm. long chamber and samples collected at an interval of 10 cm. each. These samples were prepared for pollen analysis following the technique of Erdtman (1943) with slight modification (Sharma and Singh, 1972).

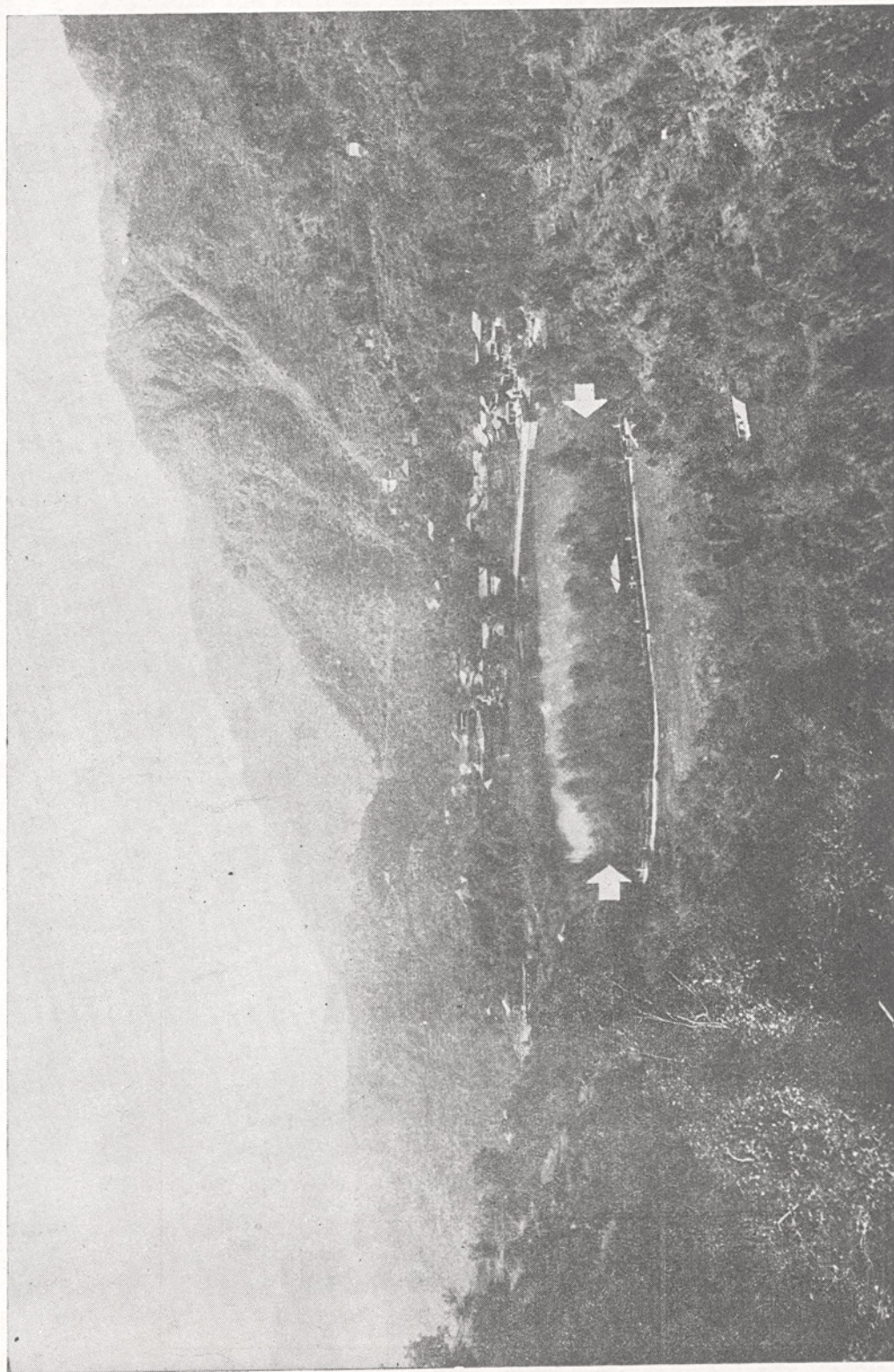
Pollen sum is based upon about 200 arboreal pollen grains except in some clay samples, in which the total sum was reduced to 150 arboreal pollen. All percentages were calculated in terms of this sum. Ar-

boreal and non-arboreal pollen diagrams have been constructed separately. In addition, a total pollen diagram showing both arboreal and non-arboreal elements has also been constructed, calculating percentage frequencies in terms of total land plants pollen, excluding Ferns and Bryophytes.

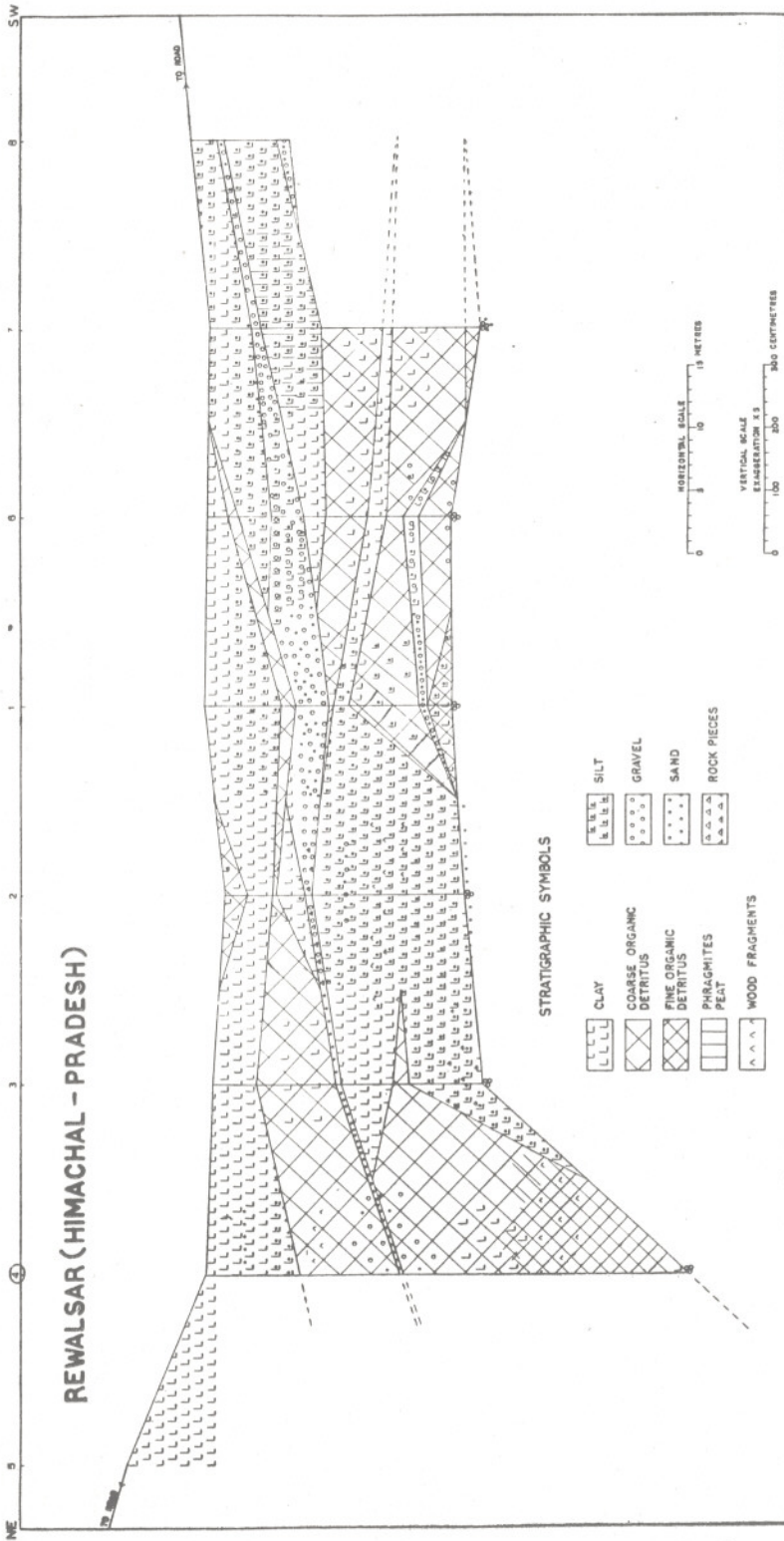
Percentages up to 0.5% are indicated by a plus (+) sign. The percentage frequencies of the elements met with extremely sporadically are given at right hand side of each AP and NAP diagram. In the case of the total AP/NAP diagram, the percentages are shown in the middle, as well as, to the right hand side of the diagram.

#### STRATIGRAPHY

The stratigraphy (Fig. 3) of the in-filled part of the lake-basin at Rewalsar, was studied by means of a series of eight boreholes made along a section running in the northeast-southwest direction. The lake deposit, which is underlain by gravel in the



TEXT-FIG. 2 — A panoramic view of the Rewalsar lake and its surroundings (The borings were made along the line between the two arrows shown in the picture).



TEXT-FIG. 3 — Stratigraphical section of the lake deposit. The sampling was carried out from point 4, in the section.

section mainly comprises of fine and coarse organic detritus, intercalated with silt and clay. The lake basin is comparatively shallower in the southwest than in the northeast. Proceeding towards the southwest, the deposit is greatly influenced by the hill-wash, and several layers of silt, clay and gravel, are seen to form the basin deposit. The silt and gravel beds are intercalated with several layers of coarse organic detritus in the southwest. Fine organic detritus is mainly confined to the northeastern part of the section, where the lake depression appears to have been filled through a normal hydrosere succession followed by hill-wash, probably laid down as a result of deforestation in the area. The deposits in the southwestern part of the basin on the other hand, appear to have been laid down partly through the meandering action of the main inlet entering the lake basin. There is some evidence of *Phragmites*-peat, occurring together with silt, in the upper half of the deposit in the southwest of the section.

Bore-hole 4, made through the deepest part of the section, was selected for final sampling for pollen-analysis (Fig. 3). At this point, the lower-most sediment, after gravel, consists of fine organic detritus, a limnic deposit with abundant remains of *Botryococcus* colonies (Fig. 7), and some wood remains. The wood fragments appear to have been derived from some trees overhanging at the lake margins. This is succeeded by coarse organic detritus which is intercalated with a thin layer of sand. The organic detritus is overlaid by a thick sequence of silt and clay. The stratigraphical details of the bore-hole 4, as observed in the field and in the laboratory are as follows:

CM	
0-33	Grey clay, with seed of <i>Carex</i> and <i>Rubus</i> at 20 cm.
33-50	Grey clay, with one seed of <i>Chenopodium</i> .
50-70	Sand, wood fragments infrequent.
70-100	Dark grey clay, with a few wood fragments.
100-120	Silt, with a few wood fragments. <i>Carex</i> and <i>Chenopodium</i> seeds at 120 cm.
120-145	Silty clay, with some plant remains, and one seed of <i>Carex</i> .

145-150	Coarse organic detritus, with wood fragments.
150-155	Same as above.
155-200	Dark grey, coarse organic detritus. <i>Carex</i> seeds abundant; one seed of <i>Chenopodium</i> . Wood fragments frequent.
200-250	Coarse organic detritus with some sand and gravel. Wood fragments frequent.
250-300	Same as above, with a few seeds of <i>Carex</i> and <i>Scirpus</i> . Moss shoots also present.
300-305	Sandy.
305-350	Dark grey, coarse organic detritus with some gravel. Moss shoots rare. One seed of <i>Stellaria</i> at 310 cm. Wood fragments frequent.
350-400	Same as above, with one seed of <i>Rubus</i> .
400-450	Dark brown, coarse organic detritus with a little clay. <i>Carex</i> seeds, together with one seed of <i>Rubus</i> at 430 cm. Wood fragments frequent.
450-480	Same as above, but without seeds.
480-500	Dark brown, fine organic clay-mud. <i>Carex</i> seeds common. Wood fragments infrequent.
500-523	Same as above, but without seeds.
523-540	Same as above, but with one <i>Carex</i> seed.
540-550	Dark grey, fine organic detritus, with a few wood fragments.
550-600	Same as above, with one <i>Scirpus</i> seed at 580 cm.
600-650	Fine organic detritus. <i>Carex</i> and <i>Scirpus</i> seeds present. Moss shoots at 640 cm. Wood fragments very rare.
650-700	Fine organic detritus, with moss shoots. Some wood fragments present.
700-735	Same as above, but without moss shoots.
735-750	Fine organic detritus, with colour changing to light grey and becoming clayey.
750-770	Clay with gravel, with some wood fragments.
770-790	Gravel.

#### LOCAL VEGETATION

In view of its lower altitude, it enjoys a more or less subtropical type of vegetation and the hills around the Rewalsar



TEXT-FIG. 4 — A view of the plantation of *Pinus roxburghii* in the west of the Revalsar lake.



TEXT-FIG. 5 — A view of the deforested slopes, now under terrace cultivation in the vicinity of Rewalsar.

lake, but for a few young, isolated plantations of *Pinus roxburghii* (Fig. 4), and *Cedrus deodara*, are largely devoid of natural forests (Fig. 5). The presence of elements, such as *Quercus incana*, *Celtis australis*, *Toona ciliata*, *Litsea* etc., along with species like *Skimmia laureola* and *Sarcococca saligna* indicate that thick forests existed in the past. However, the local as well as the surrounding vegetation of Rewalsar may be summed up as follows:

Starting from the centre of the lake outwards, the chief floating or submerged plants growing in the open water are—*Spirodela polyrhiza*, *Azolla pinnata*, *Nymphaea* sp., *Trapa* sp., *Callitriche stagnalis* and *Utricularia* sp. The lake margins, but for a few gaps here and there, are lined with a gregarious growth of *Phragmites communis*. The infilled part of the lake, above the water, is grown with *Acorus calamus*, *Scirpus squarrosus*, *S. triangulatus*, *Alisma plantago*, *Marsilea* sp., *Ranunculus laetus*, *Origanum vulgare*, *Geranium nepalense*, *Oxalis corniculata*, *Epilobium royleanum*, *Aeschynomene indica*, *Plantago major*, *Nasturtium plaustre*, *Lepidium ruderales*, *Anotis calycina*, *Myriactis nepalensis*, *Swertia alata*, *Eschenbachia stricta*, *Erigeron canadensis*, *Potentilla kleiniana*, *Coix lachrym-jobi*, etc.

Apart from the above aquatic, semi-aquatic and terrestrial herbs, the marshy ground is also covered with some trees of *Salix tetrasperma* and *Alnus* sp. Trees, such as *Celtis australis*, *Toona ciliata*, *Machilus gamblei*, *Grewia optiva*, *Morus alba*, *Punica granatum*, *Murraya koenigii*, *Aegle marmelos*, *Prunus cornuta*, *Colebrookia oppositifolia*, *Clerodendrum fragrans*, *Rhamnus purpureus*, etc., grow a little away from the marshy areas.

But for the small gap in the southeast, the lake is completely surrounded by hills (Fig. 2), which, on the whole exhibit a rather bare and desolate landscape. The mountain slopes are almost completely devoid of woodlands (Fig. 5). Much of the area is under terrace cultivation, and the mountain slopes facing Rewalsar lake in the west and northwest, are covered with a young plantation of *Pinus roxburghii* (Fig. 4). The slopes on the opposite side of the ridge in the west, are covered by a mixed plantation of *Cedrus deodara* and *Pinus roxburghii*. The plantation occurs together with scattered trees of *Quercus*

*incana*. The oak trees are mostly found in a heavily lopped state, and appear to have been singled out for cutting purposes by the local inhabitants. The other most heavily lopped, of the timber trees, occurring in the area, is *Celtis australis*. Besides these, other trees and shrubs, commonly encountered on the slopes are *Euphorbia royleana*, *Berberis* sp., *Prinsepia utilis*, *Clerodendrum fragrans*, *Sarcococca saligna*, *Dodonaea viscosa*, *Woodfordia fruticosa*, *Viburnum* sp., *Rhododendron arboreum*, *Randia tetrasperma*, *Wendlandia heynei*, *Skimmia laureola*, *Mallotus philippinensis*, *Flacourtia indica*, *Litsea* sp., *Alnus* sp., *Ulmus wallichiana*, *Juglans regia*, *Betula alnoides*, *Ilex diphyrena*, *Acer* sp., *Cotoneaster* sp., *Colebrookia oppositifolia*, *Rosa brunonii*, *Rhamnus purpureus*, *R. virgatus*, *Myrica esculenta*, *Mahonia nepalensis*, *Zanthoxylum armatum*, *Adhatoda vasica* etc. The most abundant climbers of these forests are *Clematis grata*, *C. buchananiana*, *Rubia cordifolia*, *Tinospora cordifolia*, *Galium* spp., *Dioscoria glabra*, *Jasminum* spp., etc. The ground flora is also vast and varied, attaining maximum of luxuriance after the monsoon.

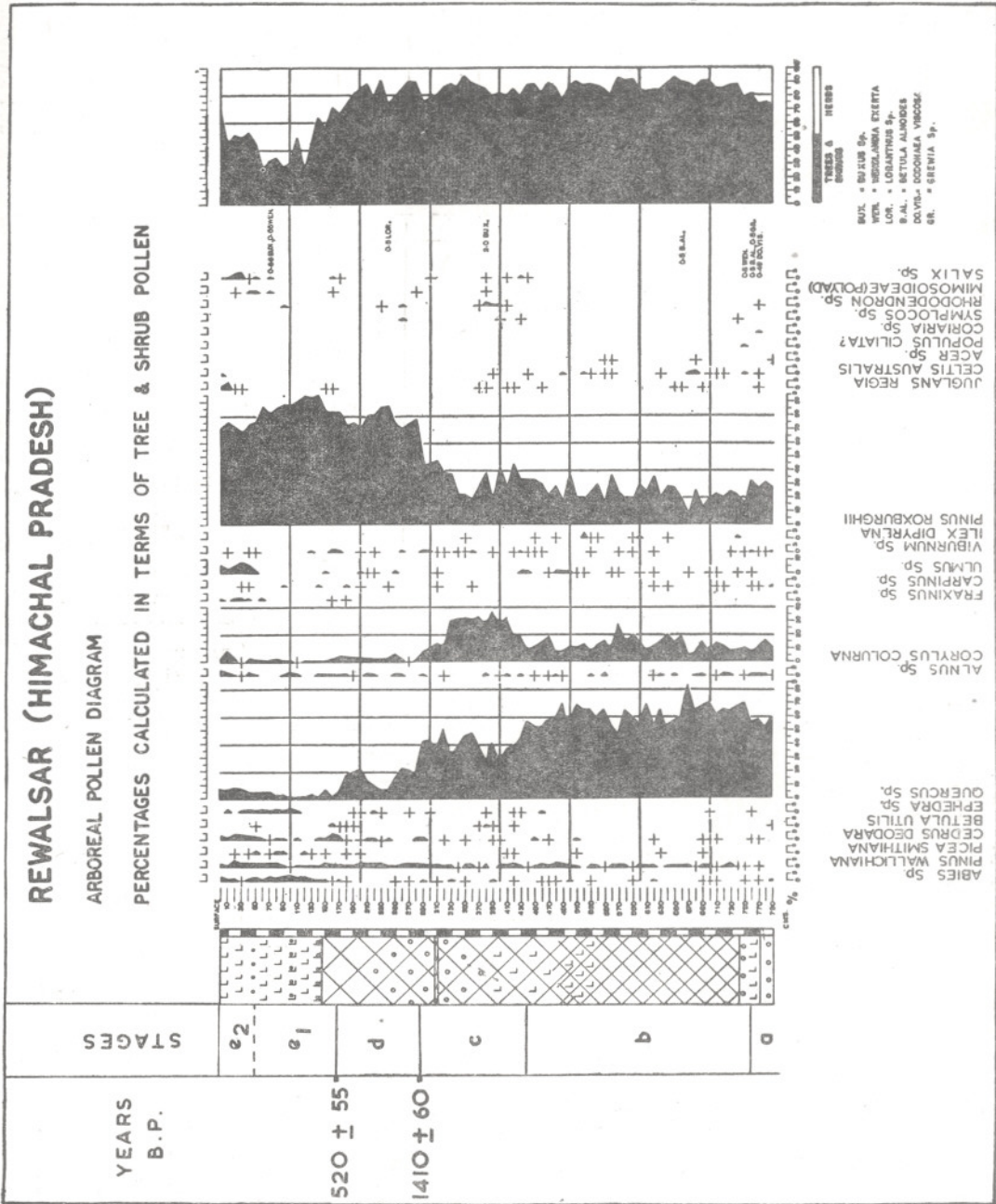
The main crops grown in the area are rice, maize, wheat, barley, gram, and millets, besides *Eleusine coracana*, *Panicum miliaceum*, *Fagopyrum emarginatum*, *F. esculantum*, *Setaria italica*, etc. (Punjab States Gazetteer, 1904).

#### POLLEN DIAGRAM

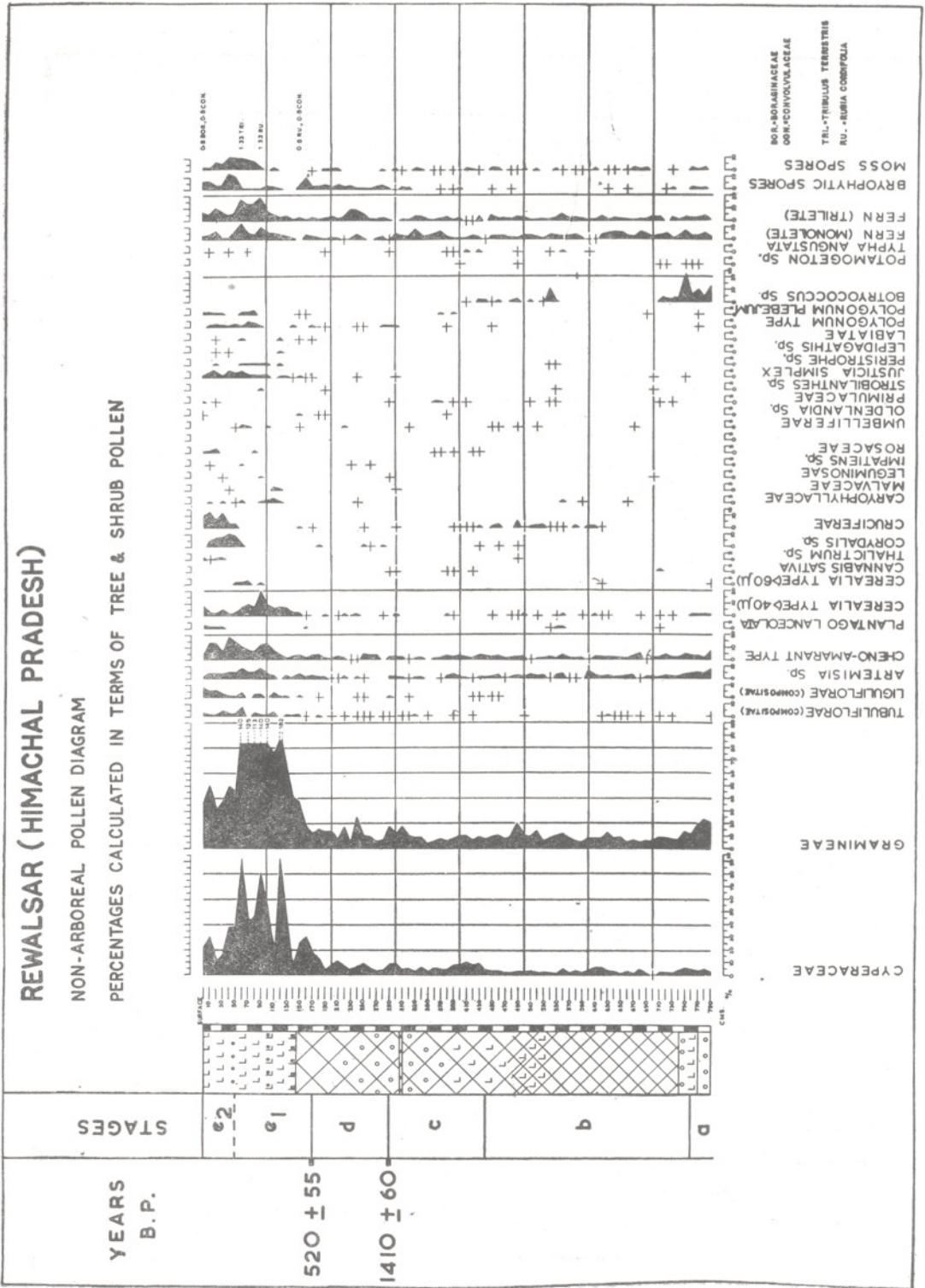
The vegetational sequence, as deduced from the pollen diagram from the Rewalsar lake, has been divided into five stages namely a, b, c, d and e (Figs. 6, 7, 8).

The lower border of 'Stage a' (790-760 cm.) is not certain. The vegetational sequence begins with a partly open forest, dominated by high frequencies of *Quercus*, followed by *Pinus roxburghii* and *Corylus*, whose values reach upto 60%, 30% and 15% respectively, in this stage. The non-arboreal pollen ratios remain around 25% but fall at the top of the stage. *Alnus* forms a short curve. The pollen of *Abies*, *Carpinus*, *Viburnum* and *Coriaria* is seen in low values. Stray pollen grains of *Pinus wallichiana*, *Cedrus deodara*, *Betula utilis*, *Ephedra*, *Ulmus*, *Juglans*, *Celtis*, *Betula alnoides*, *Acer*, *Rhododendron*, *Grewia* and *Dodonaea viscosa*, are met with occasionally in this stage.





TEXT-FIG. 6 — Arboreal pollen (AP) diagram from Rewalsar lake. Percentages calculated in terms of total tree and shrub pollen.



TEXT-FIG. 7 — Non-arboreal pollen (NAP) diagram from Rewalsar lake. Percentages calculated in terms of total tree and shrub pollen.

Non-arboreal vegetation mainly comprises of Gramineae, *Artemisia*, Cheno-Amarant type and Cyperaceae, whose values reach upto 23%, 7%, 7% and 5% respectively. Cerealia type of pollen is seen from the beginning of the pollen sequence in the form of a low continuous curve. Other non-arboreal elements, represented in very low values, are Compositae (Tubuliflorae) and *Polygonum* type.

The aquatic component is largely represented by high values of *Botryococcus* colonies, reaching upto 12%. Pollen of *Potamogeton* and *Polygonum plebejum* occurs sporadically. The curves for Fern spores (both monolete and trilete) attain frequencies upto 5% and 3% respectively. Bryophytic and Moss spores are seen in low but continuous curves.

The subdued nature of the *Quercus* curve at the beginning of 'Stage a' together with the well developed curves for Gramineae (23%), *Artemisia* (7%) Cheno-Amarant type (7%) and Cerealia type (1%), is perhaps indicative of a partly open forest.

'Stage a' is brought to an end at the 760 cm. level, and 'Stage b' (760-440 cm.) begins where the curve for *Pinus roxburghii* declines with a corresponding rise in the curves for *Quercus* and the 'tree and shrub' pollen ratios. *Pinus wallichiana* starts a more or less continuous curve for the first time in this stage. The curve for *Quercus* maintains high value upto 82%. The curve for *Corylus*, shows a fluctuating course with a small rise in the middle of the stage. The *Alnus* curve becomes sporadic. The pollen of *Ulmus* forms a short curve towards the top of the stage. Stray pollen of *Picea* is seen for the first time in this stage. The pollen of *Carpinus* occurs sporadically in the lower half of the stage. Other tree and shrub elements, represented either in short curves or in a sporadic form, are *Abies*, *Cedrus deodara*, *Ephedra*, *Viburnum*, *Ilex diphyrena*, *Juglans*, *Celtis* and *Acer*. Stray pollen of *Symplocos*, Mimosoideae (polyad) and *Betula alnoides* is also met with in this stage.

Non-arboreal elements are comparatively poorly represented, and are mainly comprised of Gramineae, Cyperaceae, *Artemisia* and Cheno-Amarant type, whose values reach upto 20%, 6%, 6% and 5% respectively. The curves for *Artemisia* and Cheno-Amarant type become discontinuous at some places. The curve for Cerealia type

becomes sporadic. A single grain of *Plantago lanceolata* is seen for the first time at 710 cm, and a short curve is also formed in the upper half of the stage. Stray pollen of *Corydalis* also occurs in the upper half. The pollen of Cruciferae is seen for the first time in the middle of the stage, and it continues thereafter, in the form of a discontinuous curve. The other non-arboreal constituents, present either in short curves or sporadically, are Compositae (both Tubuliflorae and Liguliflorae), Caryophyllaceae, Umbelliferae, Primulaceae, *Stribilanthes*, *Justicia simplex*, *Peristrophe*, and *Polygonum* type. A few pollen grains of *Cannabis*, *Thalictrum* and Leguminosae are also seen in this stage.

The aquatic vegetation is represented mostly by colonies of *Botryococcus*, which increase in their values, reaching upto 20% at the beginning of this stage, but soon decline afterwards and gradually disappear, reappearing once again in the upper half of the stage in low values. Other aquatics represented in low frequencies are *Typha angustata*, *Potamogeton* and *Polygonum plebejum*.

The curves for Fern spores (both monolete and trilete) maintain low values, as in the previous stage. The curve for Bryophytic spores becomes sporadic. Moss spores form a rather discontinuous low curve.

The fall in the ratios of the non-arboreal elements, coupled with the recovery of the *Quercus* curve at the beginning of this stage, is indicative of the regeneration and the closing-in of the oak forest. In the later part of the stage, there is little evidence of any large scale clearance, even though the fluctuating nature of the curve for the 'tree and shrub' pollen ratios, together with the occurrence of Cerealia type and *Plantago* pollen at the same levels, shows that occasional small-scale openings in the forest continued to be made throughout the stage.

'Stage b' comes to an end at 440 cm. and 'Stage c' (440-290 cm.) begins with a consistent rise in the values of *Corylus*, which reach upto about 35% at their maximum. Correspondingly, there is a fall in the curve for *Quercus*. The curve for *Pinus roxburghii* shows a slight increase at the lower end of the stage, accompanying the rise of the *Corylus* curve, but later on it falls, while the curve for *Corylus* reaches its maximum extent and importance. The

*Pinus roxburghii* curve, however, rises once again in the upper half of the stage, and the curve for *Corylus* falls to relatively lower values. The curve for *Pinus wallichiana* maintains low values, as in the earlier stage. The pollen of *Betula utilis*, which remain unrepresented in 'Stage b' is met with sporadically in the lower half of this stage. The pollen of *Salix* and Mimosoideae (polyad) is represented for the first time. The values of *Rhododendron* show a slight increase in the middle of the stage. The other tree and shrub elements, represented either in short curves or met with sporadically, are *Abies*, *Cedrus*, *Ephedra*, *Alnus*, *Ulmus*, *Viburnum*, *Juglans* and *Celtis*. Stray pollen of *Picea*, *Carpinus*, *Ilex*, *Symplocos* and *Buxus* is also seen in this stage.

The non-arboreal elements on the whole, are poorly represented. There is a slight increase in the curve for Cyperaceae at the beginning of the stage. Its values reach to about 10% and then decline, but rise once again at the top of the stage. The curves for Gramineae, *Artemisia* and Chenopod type remain low, but their frequencies rise towards the top of the stage. This rise is accompanied by the occurrence of the pollen of both Cerealia type and *Cannabis* in small numbers. Other non-arboreal elements represented in low frequencies in this stage, are Compositae (both Tubuliflorae and Liguliflorae), Cruciferae, Rosaceae, Primulaceae, *Polygonum* type and stray pollen of *Corydalis*, Malvaceae, Leguminosae, Umbelliferae, *Oldenlandia* and *Justicia simplex*.

The aquatic vegetation is represented only in the lower half of the stage, by low values of *Botryococcus* colonies, and the pollen of *Typha angustata*, *Polygonum plebejum* and *Potamogeton*.

There is a slight increase in the curves for Fern spores (both monoete and trilete). Bryophytic spores, in general, and Moss spores occur in low frequencies.

As the oak curve falls together with a small rise in the frequencies of plants of open habitat, such as Cyperaceae, *Cannabis*, Cruciferae, Rosaceae and Primulaceae at the beginning of the stage, it is suggested that the oaks perhaps fell as a result of some forest clearance. *Corylus* which, again is a tree of rather open forests, perhaps increased in response to this clearance. At first, the oaks fall and *Corylus* and *Pinus roxburghii* rise, but later on, oaks appear

to recover and *Pinus roxburghii* falls. Towards the top of the stage, *Corylus* declines and the frequencies of *Pinus roxburghii* rise once again.

'Stage c' is brought to an end at 290 cm. and 'Stage d' (290-170 cm.) begins with a sudden fall in the curve for *Quercus*, corresponding with a sudden rise in the curve for *Pinus roxburghii*. The *Corylus* curve declines still further, and becomes discontinuous. *Pinus roxburghii* attains its maximum values of about 87%, but declines in the upper half of the stage, corresponding with a recovery of the oak curve. The oak curve, however, falls again towards the top of the stage, and the *Pinus roxburghii* curve rises once again. *Pinus wallichiana* forms a low continuous curve for the first time in this stage. There is a slight increase in the values of *Cedrus* and *Alnus*. The pollen of *Betula utilis* and *Picea* is seen sporadically in the upper half of the stage only. Other tree and shrub species, represented either in the form of short curves or sporadically, are *Abies*, *Ephedra*, *Carpinus*, *Ulmus*, *Viburnum* and *Rhododendron*. They occur together with stray pollen of *Fraxinus*, *Symplocos*, Mimosoideae (polyad), *Salix* and *Loranthus*. The 'tree and shrub' pollen ratios show a fall with some fluctuations.

The non-arboreal vegetation is poorly represented. It comprises of chiefly Cyperaceae and Gramineae, whose values in each case, increase in the upper half of the stage. *Artemisia* and Chenopod type form fresh curves in the upper half, and there is a slight increase in the pollen frequencies of Compositae (both Tubuliflorae and Liguliflorae) and Cerealia type. Other non-arboreal species represented in low values are *Corydalis*, Cruciferae, *Impatiens*, *Oldenlandia*, *Polygonum* type, Caryophyllaceae, Umbelliferae and *Strobilanthes*.

The aquatic vegetation is negligible and is represented by a single grain of *Typha angustata*. The curve for Fern spores (trilete), shows an increasing trend in the lower half of the stage. Bryophytic spores form a fairly continuous curve for the first time in this stage, and their values rise in the upper half. Moss spores form a short curve in the upper half of the stage.

The fall in the curves for *Quercus*, *Corylus* and *Pinus roxburghii*, at various intervals in this stage, invariably corresponds with a small rise in the values of Gramineae, Cyperaceae, *Artemisia*, Chenopod type

and Cerealia type, indicating small scale clearance of these tree elements at different intervals. The lower border of 'Stage d' is C-14 dated at  $1,410 \pm 60$  B.P. (WIS-417).

'Stage d' is brought to an end at 170 cm. and 'Stage e' (170-0 cm.) begins with the final decline in the curves for *Quercus* and *Corylus*. 'Stage e' is divisible into two sub-stages 'e<sub>1</sub>' and 'e<sub>2</sub>'. In 'Sub-stage e<sub>1</sub>' (170-50 cm.) the curve for *Pinus roxburghii* rises largely as a result of the fall in the broad-leaved species. This is quite apparent from the total diagram (Fig. 8), in which the absolute values of *Pinus roxburghii* actually fall together with other tree elements, indicating a general felling of the tree vegetation. This is further substantiated by the overall fall in the 'tree and shrub' pollen ratios in this sub-stage. *Abies* forms a fresh and an almost continuous curve in this sub-stage. The curve for *Pinus wallichiana* declines in the lower half but increases once again in the upper half. *Cedrus* forms a short curve in the lower half of the sub-stage, and *Ephedra* in the upper half. There is a slight increase in the pollen frequencies of *Picea*. The pollen of *Betula utilis* is seen only in the beginning of the sub-stages. *Alnus* forms a fresh, short curve, and there is a slight increase in the values of *Viburnum*. The pollen of *Juglans* which remains unrepresented in 'Stage d' is met with sporadically in the lower half of this sub-stage. Other tree and shrub elements represented in low values are *Carpinus*, *Ulmus*, *Rhododendron* and *Salix*; together with stray pollen of *Fraxinus*, Mimosoideae (polyad), *Buxus* and *Wendlandia*.

There is a sudden rise in the frequencies of most of the non-arboreal elements in this sub-stage. The curves for Gramineae and Cyperaceae increase from the beginning and their values reach upto 182% and 95% respectively, at their maximum. The curve for Cerealia type increases a little later, followed by Chenopodiate type, *Artemisia* and Compositae (both Tubuliflorae and Liguliflorae) Caryophyllaceae and Malvaceae form short curves for the first time in the middle of the sub-stage, and Umbelliferae, *Justicia* and *Peristrophe* in the upper half. The pollen of Labiatae and *Polygonum* type, also shows a slight increase. Other non-arboreal species represented in low frequencies are Leguminosae, *Impatiens*, Rosaceae, *Oldenlandia*, *Strobilanthes*, *Lepi-*

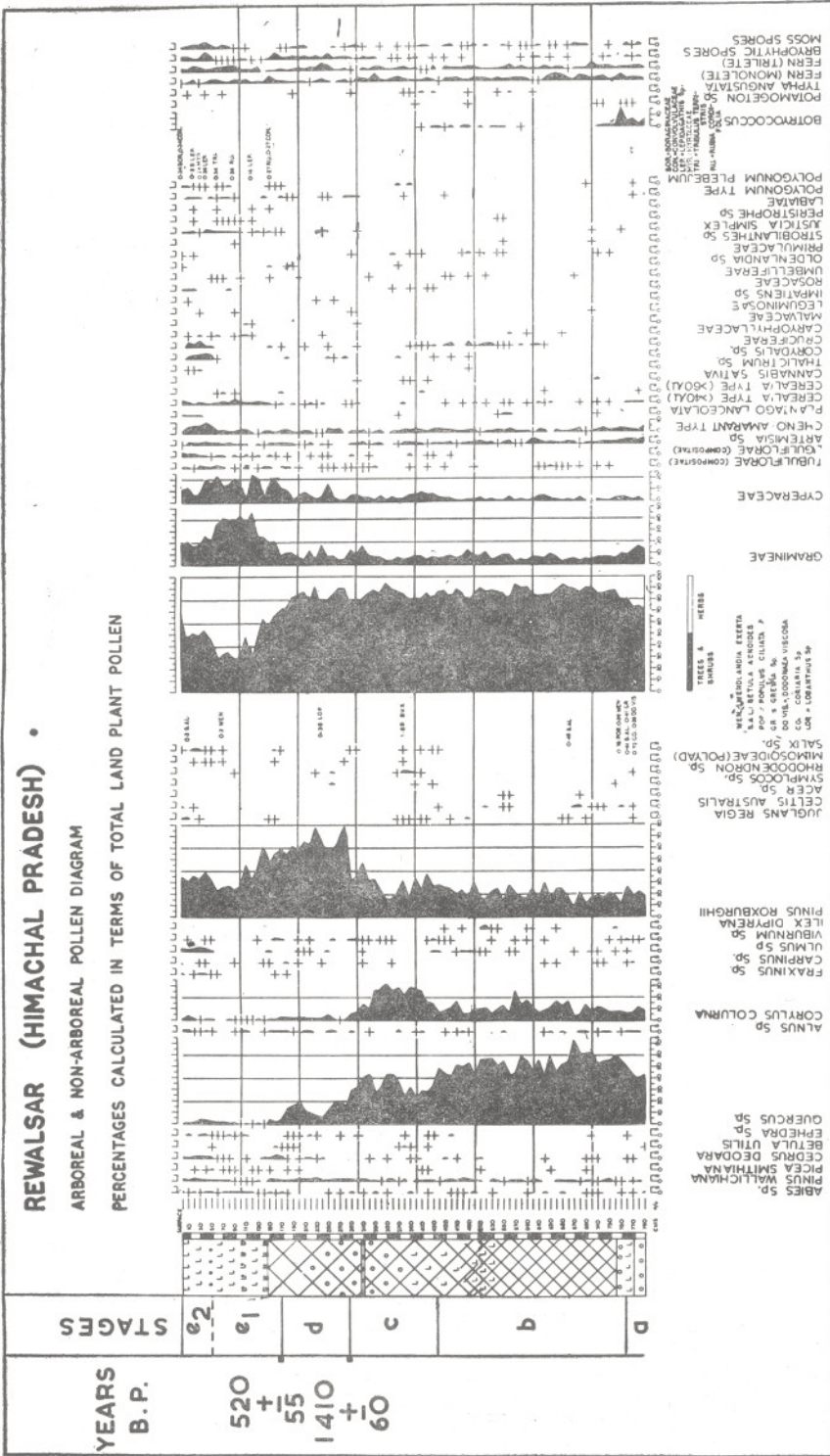
*dagathis*, *Rubia cordifolia*, Convolvulaceae and *Tribulus*.

The aquatic vegetation is represented by low values of *Polygonum plebejum* and *Typha angustata*. The curves for Fern spores (both monolete and trilete) increase in the upper half of the sub-stage. The Bryophytic spores show a slight increase in the beginning and then decline. The Moss spores occur in low values only.

The catastrophic decline in the 'tree and shrub' pollen ratios, corresponding with the tremendous rise in the frequencies of almost all the non-arboreal elements, is indicative of large scale decimation of the tree vegetation. The rise in the Cerealia type curve, together with a similar rise in the values of other culture pollen, indicates that the clearance was followed by intensive agriculture in the area. The lower border of 'sub-stage e<sub>1</sub>' is C-14 dated at  $520 \pm 55$  B.P. (WIS-419).

'Sub-stage e<sub>1</sub>' ends at 50 cm. and 'Sub-stage e<sub>2</sub>' (50-0 cm.) begins with a small increase in the curves for *Quercus*, *Cedrus* and *Ulmus*. *Pinus roxburghii* also appears to mark a real increase, as seen in the total diagram (Fig. 8). The values of *Alnus*, *Corylus*, *Juglans* and *Salix*, also show a slight increase in the upper half of this sub-stage. *Fraxinus*, forms a short curve for the first time, and *Abies*, *Pinus wallichiana* and *Ephedra*, maintain low values. Other tree and shrub elements, represented either in short curves or sporadically, are *Picea*, *Carpinus*, *Viburnum*, *Celtis*, Mimosoideae (polyad) and *Betula utilis*.

Amongst the non-arboreal species represented, the curves for Gramineae, Cyperaceae and Cerealia type fall considerably, followed by Compositae (Tubuliflorae) and *Artemisia*. There is a sudden rise in the frequencies of *Corydalis* and Cruciferae. Both the elements form continuous curves for the first time in this sub-stage. The curve for Compositae (Liguliflorae) shows a slight increase and *Plantago lanceolata* forms a fresh low curve in this sub-stage. The pollen of Rosaceae and *Thalictrum*, also forms short curves. The curves for Chenopodiate type, *Justicia* and *Polygonum* type follow a fluctuating course throughout the sub-stage. Other non-arboreal elements represented in low values, are Caryophyllaceae, Malvaceae, Leguminosae, *Impatiens*, Primulaceae, *Oldenlandia*, Boraginaceae Con-



TEXT-FIG. 8 — Total pollen (AP/NAP) diagram from the Rewalsar lake. Percentages calculated in terms of total land plant pollen excluding Ferns and Bryophytes.

volvulaceae, *Peristrophe*, *Lepidagathis* and Labiatae.

Aquatic vegetation is represented by a low curve of *Polygonum plebejum*, and the sporadic occurrence of *Typha angustata* pollen.

The curves for Fern spores (both monolet and trilete), together with those of Bryophytic spores, follow a fluctuating course in this sub-stage. The values of Moss spores tend to decline.

The rise in the curves for most of the arboreal elements, together with a corresponding fall in the frequencies of non-arboreal plants, is indicative of a phase of regeneration of the forests. This phase may have started with the demarcation of reserved forests and with the recent forest plantations carried out by the State Forest Department.

## DISCUSSION AND CONCLUSIONS

### Stratigraphy and the Age of Lake deposit

The lake sediment at Rewalsar, remain to be investigated at a greater length than what, has, now been possible with the limited capacity of the boring equipment available. The lake sediments, so far, investigated, appear to constitute only a fraction of the Late-Quaternary deposit.

The gravel pan at the base (Fig. 3), gives the impression of a glacially scoured surface, but the outward impression seems to be incorrect as the gravel may have been deposited through the meandering action of flood stream entering the lake in the north of the lake basin. This view is substantiated by the two C-14 dates,  $1410 \pm 60$  B.P. (WIS-417) and  $520 \pm 55$  B.P. (WIS-419), from the upper half of the pollen profile (Fig. 3 point 4; Figs. 6, 7, 8) showing that the history of entire deposit studied may not extend beyond the last 4000 years, if due allowance is given for the differential rates of deposition at various intervals of the profile. It follows that either the deposits of the earlier period lie below the gravel pan or they were eroded before the deposition of the sediments overlying the gravel pan. But for the extreme north-eastern part of the section, the Rewalsar lake basin appears to have been under the influence of secondary deposition which may have been derived from the hill-wash. This is clear from the repeated interruptions

seen in the organic deposit, which is intercalated with inorganic material at close intervals (Fig. 3). The north-eastern part of the section, except in the upper levels, is almost free of the effect of hill wash; here one witnesses the deposition of organic matters through a normal hydrosere succession. The absence of relatively older deposits in this part of the section may be due to the marginal position of the profile at point 4 (Fig. 3) with respect to the basin proper, as the section passes at a tangent to the deeper parts of the lake-basin. It is most likely that deposits of relatively older age lie below the open water in the deeper part of the lake basin.

### Vegetational History

It is already established from the foregoing account that lake deposits investigated at Rewalsar is representative of the later part of the Post-glacial period, and reflect the history of vegetation of its area, through the pollen sequence worked out. The vegetational history uncovered, is however, limited to the present day sub-tropical belt, as the lake site is situated within this belt. The vegetational sequence is overwhelmingly dominated by *Quercus*, during early stages. The lower altitude of the site and its location in the outer Himalaya, has, however, resulted in the greater representation of the sub-tropical pine (*Pinus roxburghii*), in the pollen profile and other conifers are extremely lowly represented. The curve for *Corylus* is well developed which may partly be due to the comparatively drier conditions found in the Rewalsar area. *Corylus colurna*, the only species of *Corylus* represented in the western Himalayas, grows at 1524-3048 m., in dry temperate deciduous forests (Bor, 1953).

*Stage a* — The forest history, which starts with 'Stage a' at the bottom of the stratigraphical column (Figs. 6, 7, 8), is representative of a partly open forest, in which, *Quercus* appears to have been by far, the most dominant element. *Pinus roxburghii* and *Corylus*, come next in order of importance, but as *Pinus roxburghii* pollen, is carried to long distances it is not certain whether the pine forest existed any where near the lake site. Considering the overall dominance of oak pollen in the pollen spectra in 'Stage a', which in terms of modern

pollen rain can only come from a fairly closed oak forest, it is likely that *Pinus roxburghii* grew at a relatively lower altitude, or at a considerable distance from the lake site.

*Corylus*, whose European relative *C. avellana* is known for its large pollen production, is much less known, as far as the Indian species *C. colurna* is concerned. The surface samples from Himachal Pradesh studied so far (Sharma, 1973), have failed to show up this element in any significant quantity, but this may be due to the present-day scanty distribution of this species in the areas visited. Thus, while no firm conclusion can be drawn regarding the actual relative abundance of *Corylus* at Rewalsar, from its pollen curve, it may well be that the species was more widely distributed in the outer Himalaya than the present-day, and that it was perhaps present in the vicinity of the Rewalsar area in 'Stage a'.

The partly open character of the forest, is testified by the AP/NAP curve, and also by the well developed nature of the curves for Gramineae, *Artemisia* and Cheno-Amarant type, all of which are well known light demanders. The presence of Cerealia type of pollen, from the very beginning of the sequence, together with the partially open character of the forest, is perhaps indicative of a phase of forest clearance, for agriculture.

The broad-leaved character of the forest vegetation in 'Stage a' at Rewalsar, is reminiscent of the mid-Post-glacial forest development in the Kashmir valley during the Climatic Optimum (Singh, 1963).

*Stage b* — In this stage, *Quercus* frequencies rise and attain their maximum values, and the non-arboreal elements decline, indicating the closing of the oak forest. *Pinus wallichiana* forms short curves for the first time in this stage, and it may have been represented in small number in the area. The introduction of the curve for *Pinus wallichiana*, a temperate element in the sequence, can be regarded as indicative of cooler climate, and this development may be compared with the onset of the period of decreasing warmth in Kashmir (Singh, 1963). *P. wallichiana* at present, grows at 1,829-3,048 m. (6,000'-10,000') in the temperate Himalaya.

The non-arboreal vegetation, mainly comprises of Gramineae, Cyperaceae, *Artemisia* and Cheno-Amarant type. A single grain of *Plantago lanceolata*, is seen for the first

time in the lower half of the stage, and later, a short curve is seen to develop in the upper half. There is little evidence of any large scale forest clearance in this stage, even though, the occasional occurrence of the pollen of *Plantago lanceolata* and Cerealia type, together with the fluctuations seen in the curve for the 'tree and shrub' pollen ratios, shows that perhaps small scale felling of trees continued in the otherwise closed forest. As the rise in the curve for *Corylus* in each case, corresponds with the fall in the *Quercus* curve, it is likely that *Corylus* benefitted from such small scale clearance. The curve for *Pinus roxburghii*, also appears to play a more or less identical role, together with *Corylus*, in this stage. This is understandable because both *Pinus roxburghii* and *Corylus* prefer dry sunny slopes, and are able to encroach upon newly vacated areas with ease.

*Stage c* — This stage is marked by a consistent rise in the values of *Corylus*, corresponding with a fall in the *Quercus* curve. The curve for *Pinus roxburghii*, also shows a relative increase at the beginning of the stage, but later on, declines; it, however, rises once again, towards the top of the stage. *Pinus wallichiana* continues to occur in the form of short curves, as before, and the pollen of other temperate species, such as *Abies*, *Picea* and *Cedrus* also begin to occur more frequently. *Betula utilis*, the high altitude birch in the Himalaya, which remains unrepresented in 'Stages a and b', is represented by its pollen in 'Stage c'. All this can be taken to indicate the continuation of the trend towards decreasing warmth in the area, as suggested earlier, in 'Stage b'. Isolated grains of *Salix*, Mimosoideae (polyad) and *Buxus*, occur for the first time in this stage.

The fall in the oak curve is accompanied by the rise in the values of Cyperaceae, and a general fall in the 'tree and shrub' pollen ratios. The pollen of Cerealia type and *Cannabis*, also occurs frequently in small numbers in this stage, from which it is suggested that the oak forest fell as a result of forest clearance by man, for agriculture. *Corylus* and *Pinus roxburghii*, which are both light demanders, perhaps increase as a result of the above clearance. As the curve for *Quercus* falls in the beginning of the stage, the frequencies of both *Corylus* and *P. roxburghii* rise, but later on, oaks appear to recover and the *P.*



*roxburghii* values fall. *Corylus* declines towards the top of the stage and the curve for *P. roxburghii* rises, once again. As there is a small rise in the curve for Gramineae towards the top of the stage, it is likely that *Corylus* also fell as a result of forest clearance. The newly vacated areas appear to have been occupied by *Pinus roxburghii*, whose values continue to rise, hereafter. It has been argued earlier, that *Pinus roxburghii* was probably, not represented locally in the almost pure oak forest of 'Stages a and b'. In 'Stage c', on the other hand, it appears that the opening of the forest provided the opportunity for the expansion of *Pinus roxburghii*, into areas hitherto occupied by oak and hazel.

*Stage d* — The lower border of 'Stage d' is C-14 dated at  $1,410 \pm 60$  B.P. (540 A.D.) (WIS-417) and starts with the fall of the oak forest. The oak pollen curve, shows a consistent decline at the beginning of this stage, but recovers to some extent in the second half, falling, once again, towards the top end of the stage. Correspondingly, the *Pinus roxburghii* curve rises to high values. As there is no pronounced increase in the ratios of non-arboreal elements to match the catastrophic fall in the oak curve, it appears that *Pinus roxburghii*, actually replaces the oak forest, and that there is little change in the absolute forest cover over the area. It may well be that the elimination of the broad-leaved species, that is oak and hazel, in 'Stage c', disturbs the natural equilibrium of the forest, and it becomes relatively easy for *Pinus roxburghii* to make inroads into the oak-hazel forest, in 'Stage d'.

*Corylus* falls to insignificant values in this stage. It seems like that it is kept in check by *Pinus roxburghii*, which normally does not allow any undergrowth.

*Pinus wallichiana* forms a continuous curve, for the first time in this stage, and there is a slight increase in the values of *Cedrus* and *Alnus*. The pollen of *Betula utilis* and *Picea*, is seen sporadically in the upper half of the stage.

The non-arboreal vegetation is poorly represented. It comprises of mainly Cyperaceae and Gramineae. *Artemisia* and Chenopodiant type pollen forms fresh curves in the upper half of the stage, and there is also a slight increase in the pollen of Compositae and Cerealia type, at more or less the same level.

*Stage e* — This stage, whose lower border is C-14 dated at  $520 \pm 55$  B.P. (1430 A.D.) (WIS-419), begins with the final decline in the curve for *Quercus* which, hereafter, becomes an almost insignificant element. There is a marked rise in the non-arboreal vegetation, as evidenced by the general rise in the curve for Gramineae, Cyperaceae, Compositae, *Artemisia*, Chenopodiant type, and Cerealia type. The beginning of this stage is also marked by the sudden fall in the 'tree and shrub' pollen ratios, from which, it seems almost certain that the tree vegetation, in general, is cleared on a massive scale. Besides *Quercus*, which is suggested to have been completely decimated, *Pinus roxburghii* also appears to have been felled on a large scale, as it is clearly brought out in the total diagram (Fig. 8). This episode apparently took place in the early 15th century A.D., and was perhaps responsible for the clearance of forests in the Rewalsar area. There is at present, no historical record to connect this episode with any large-scale human migration into the area, but at the same time, it is difficult to visualize such massive clearance without some compelling reason, connected with the human history of this region. It may, however, be that the religious importance of the Rewalsar lake, which is now thronged with thousands of pilgrims every year, at the time of numerous religious festivals connected with Hindus, Buddhists and Sikhs, first rose to its present eminence during this period.

'Stage e' is divisible into 'Sub-stages  $e_1$  and  $e_2$ '. In 'Sub-stage  $e_1$ ' besides the aforementioned characteristics of the beginning of 'Stage e', there is general increase in the values of *Abies*, *Pinus wallichiana* (upper half) *Cedrus* (lower half), *Ephedra* (upper half), *Picea Alnus* and *Viburnum*. There is a sudden rise in the frequencies of most of the non-arboreal elements in this sub-stage. The curves for Gramineae and Cyperaceae increase considerably from the beginning of the sub-stage and reach their maximum values in each case. The curve for Cerealia type, increases a little later, followed by Chenopodiant type, *Artemisia* and Compositae. Caryophyllaceae and Malvaceae form short curves, for the first time in the middle of the sub-stage, and Umbelliferae, *Justicia* and *Peristrophe*, in the upper half of the sub-stage. The pollen of *Polygonum* type and Labiatae also show a slight increase.

The rise in the curve for Cerealia type, together with other culture pollen, suggests that the clearance is followed by intensive agriculture in the area, in this sub-stage.

'Sub-stage e<sub>2</sub>' shows a small increase in the curves for *Quercus*, *Cedrus* and *Ulmus*. *Pinus roxburghii*, also appears to have marked a real increase, as shown by the total diagram (Fig. 8). The values of *Alnus*, *Corylus*, *Juglans* and *Salix*, also show a slight increase in the upper half of this sub-stage, and *Fraxinus* forms a short curve for the first time.

The non-arboreal vegetation on the whole declines, but there is a sudden rise in the frequencies of *Corydalis* and Cruciferae. The pollen of Compositae (Liguliflorae), *Plantago lanceolata*, Rosaceae and *Thalictrum*, also increases slightly.

The rise in the curves for arboreal elements, and the corresponding fall in the frequencies of non-arboreal plants, is perhaps indicative of some regeneration of the forest, which may have resulted from the Govern-

mental protection given to the forest areas, in recent years, and also the forest plantations carried out by the State Forest Department. At present, the area surrounding the Rewalsar lake is devoid of natural thick forests; only young plantations chiefly of *Pinus roxburghii*, *Cedrus deodara* etc., occur in small patches, here and there.

The tentative sub-divisions of the present pollen sequence into five 'Stages a, b, c, d, and e' is independent of the one at Khajiar (Sharma and Singh, 1972), which is also situated in Himachal Pradesh. Although there is a strong similarity between the quality of pollen assemblages in the two pollen sequences, nevertheless, it is premature to suggest a common system of zonation from the two sites worked out, though both the pollen profiles are C-14 dated. It is envisaged that it will be possible to suggest a uniform system of zonation for the western Himalayas, in due course, as soon as sufficient number of C-14 dated Post-glacial pollen sequences are available from this region.

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