ON THE LATE QUATERNARY VEGETATIONAL HISTORY IN HIMACHAL PRADESH-3. PARASRAM TAL

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Abstract

The paper embodies the results of pollen analytical investigations of modern as well as Post-glacial sediments from Parasram Tal. Study of moss cushions from the lake site demonstrates partial representation of surrounding vegetation. The pollen diagram is divisible into four assemblage zones supported by seven radiocarbon dates.

The vegetational history begins with Chirpine-oak woods dated to 3140±100 b.p. Overall dominance of Chirpine-oaks together with other broad-leaved taxa is perhaps indicative of warm temperate and humid climatic conditions during this period. Second assemblage zone is more or less continuation of the previous one except for some decline in oaks and grasses and simultaneous increase in Caryophyllaceae, Cheno/Ams, *Peperomia*, etc. perhaps owing to anthropogenic activity. Third assemblage zone (upper part) dated to 960 ±110 bp., however, witnesses the increase in number of gymnosperm taxa like *Abies*, *Picea*, *Cedrus* and *Pinus walichiana*, probably due to cooler climatic conditions. The fourth or the last zone dated to 680±110 bp. begins with a significant fall in chirpine and other arboreal taxa with simultaneous increase in non-arboreal elements such as *Peperomia*, Poaceae, Cheno/Ams, Urticaceae, Ranunculaceae, etc. indicating large scale clearance for agriculture corresponding with the human activity in other parts of the western Himalaya.

Introduction

Parasram Tal (lat. 30° 30'30" N & long. 77°27'30" E), almost circular in outline and about 140 m in diameter (Map 1), is situated at an elevation of about 730 ma.s.l. in District Sirmur, Himachal Pradesh. It is surrounded by hills which rise up to 1000 meters or so. It is located south-west of Renuka Lake which is famous for bird sanctuary, and these two lakes are part of the same basin (Raina, 1967) connected with each other by a narrow ridge. Since the level of Renuka Lake is slightly higher, its water is drained in Parasram Tal by a narrow drain or nalla towards south-west. Similarly another nala drains out to Parasram Tal in the nearby Giri River from its southern margin which actually forms the main drainage of the area. Parasram Tal is approachable by all-weather road from Ambala cantonment to Dadahu via Naraingarh, Kala Amb and Nahan. From Dadahu the lake site is only about 1.5 km.

Geology

Geology of the basin area where Parasram Tal and Renuka Lake lie had been worked out by Auden (1935) and according to him the former is located on the infra Krols overlying which occur the Krols, the junction passing through the gap between Parasram Tal and Renuka Lake. However, Raina (1967) while dealing with the origin of some Himalayan lakes is of the opinion that these lakes are of glacial origin.

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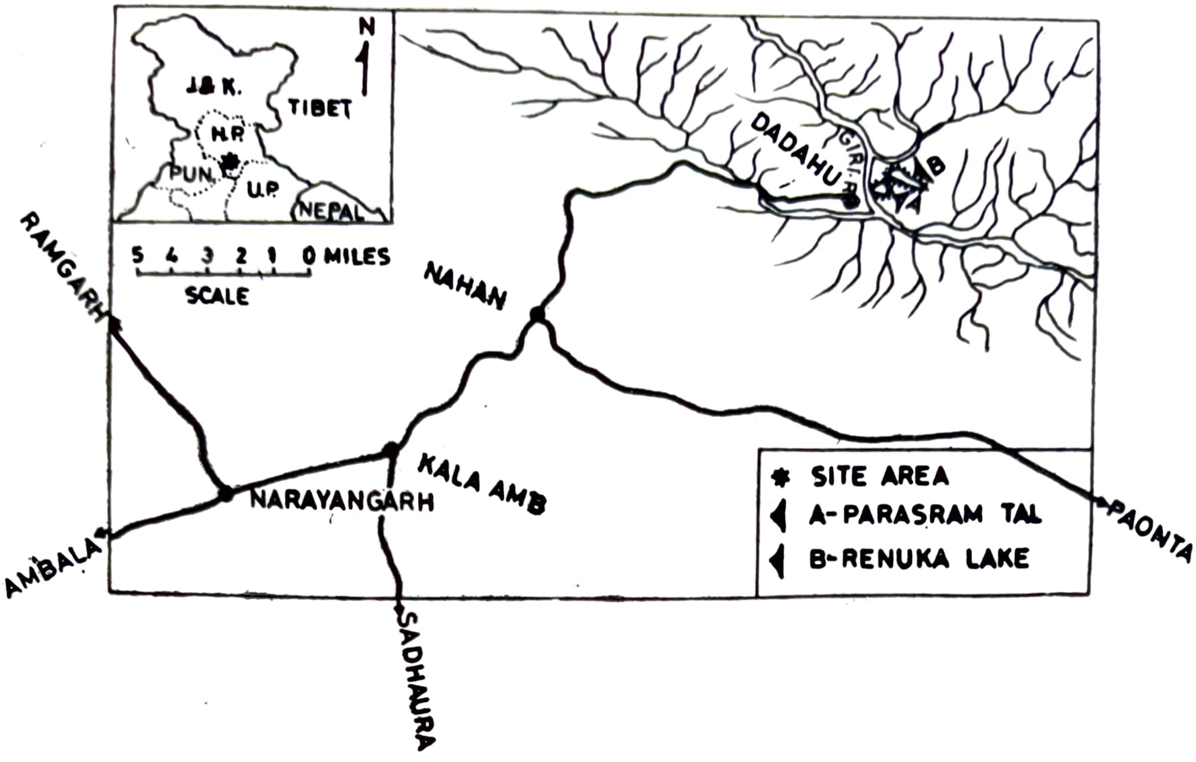


Map 1.

Vegetation

Parasram Tal is a closed basin with hills all around supporting the moist subtropical forest type vegetation. It is a totally pine free zone. The lake margins are dominated by common sedges and several aquatic plants.

Material and method

A set of four moss-cushions was collected in order to study the modern pollen rain in the area. After a number of trial borings made with the Hiller's peat auger across Parasram Tal, the material for pollen analysis was finally collected from the deepest point at an interval of 5 cm each. These were stored in specimen-tubes and sealed with hot paraffin wax to avoid any contamination as well as to keep the material in moist condition. Simultaneously, seven samples for C^{14} dating were also collected from different depths of the sequence, and were packed in polythene bags with necessary precautions to avoid contamination.

The samples were processed for pollen counting by boiling 5 gms of material in 10% aqueous KOH solution to deflocculate the matrix, washing with water before treating with 40% HF to dissolve silica, and then the acetolysis by usual Erdtman's technique (1943). The samples were also treated with HNO_3 where deemed necessary to reduce extra organic debris. In case of moss-cushions, no HF treatment was given. Macerated material was then stored in 50% glycerine with a few drops of phenol to check any fungal attack. All the samples collected for C^{14} dating were passed on to the Radiocarbon Dating Laboratory at the Institute (BSIP) without any pretreatment.

The counting of pollen was done in Olympus microscope. The total number of pollen grains included in the pollen sum varies from 200 to 400 pollen, depending upon their frequencies recovered from the sediments. Percentages are calculated in terms of terrestrial pollen. Lithocolumn is drawn towards the left hand of the pollen diagram with C^{14} dates at the extreme left, scale in-between, and the AP/NAP plotted at the extreme right. The pollen diagram on its left represents the arboreals, followed by non-arboreals, and on the right aquatics are plotted, followed by Ferns and colonies of *Botryococcus* towards the end. Percentage up to 0.5% are indicated by a plus (+) sign. The four pollen assemblage zones, namely Parasram Tal or PT-1, PT-2, PT-3 and PT-4 are based on the recognised biostratigraphic units (pollen assemblage zones), and are derived from two or more prominent plant taxa of the pollen assemblage. These pollen zones are independent and are not comparable with the zones of the pollen diagrams published earlier from Himachal Pradesh (Sharma & Singh, 1964 a, b). The zone PT-1 is further divided into two subzones PT-1a and PT-1b to spell out the finer details of the pollen diagram.

Seven samples were dated at the Birbal Sahni Institute of Palaeobotany, Lucknow and the available C^{14} dates indicate that the vegetational history does not go beyond 3,000 b.p. or so.

Stratigraphy

The stratigraphy of the lake has been studied through different bore-holes, and the maximum depth reached is five metres. Further penetration was not possible due to limited capacity of the boring equipment. The basin is full of peat deposits, inter-beded with the thin bands of sandy clay at places, together with shells at the top as well as bottom of the sediment. The details of the bore-hole dug for collecting the samples are as under:

0-30 cm	Greyish brown peat, with shells and plant debris
30-50 cm	Blackish-brown peat, with shells and plant debris
50-100 cm	Black humified peat
100-150 cm	Clayey peat
150-200 cm	Greyish-brown peat
200-250 cm	Blackish peat
250-270 cm	Black clayey peat
270-300 cm	Black peat
300-400 cm	Black peat, *continuea*
400-450 cm	Blackish peat, with plenty of shells and plant debris
450-490 cm	Sandy grey clay, mixed with peaty material, shells and plant debris
490- ? cm	Hard substratum-probably rocky or gravel/boulder

Pollen Analysis

The pollen diagram (Text-fig. 2) has been divided into four local pollen assemblage zones. The zone PT-1 has been further divided into two sub-zones to express finer bio-stratigraphical details during the later part of Holocene epoch, as the base of the pollen diagram is radiologically dated to 3140±100 years b.p

Zone PT-1 (490-270 cm)

Pinus-Quercus-Larix-Poaceae assemblage zone—The lower limit of this zone can not be fixed as the stratigraphical sequence is incomplete. The Zone PT-1, is characterized by high values of *Pinus roxburghii* and *Quercus*. *Larix* though starts with low frequencies in the beginning but shows an increasing trend afterwards, maintains good values up to the middle of the sequence, and thereafter shows a declining trend. *Artemisia* is represented by a low continuous curve but for the increase in the middle of the zone.

Viburnum maintains low but almost a continuous curve throughout. Other arboreal taxa present in short continuous curves are *Alnus*, *Corylus*, Rosaceae, *Glochidion*, and Oleaceae whereas *Abies*, *Picea*, *Cedrus*, *Cupressus*, *Ephedra*, *Betula*, *Juglans*, *Mallotus*, *Rhus*, Myrtaceae Leguminosae, Tubiflorae and Liguliflorae are sporadic. Non-arboreal vegetation is dominated by high values of Poaceae. Cerealia pollen are recovered from the beginning of the profile, firstly sporadically and then forming a low discontinuous curve which is maintained till the end of the zone. Cheno/Ams curve shows a fluctuating trend throughout-up to 7%. Other non-arboreal constituents present in low but more or less continuous curves are Caryophyllaceae, Ranunculaceae (3-colpate), Urticaceae, *Polygonum*, Cyperaceae and Acanthaceae. *Polygonum plebejum* and *Peperomia* are recorded either sporadically or in short curves. Stray occurrence of *Justicia*, Ranunculaceae (porate), Lamiaceae, Apiaceae have also been recorded. Aquatic vegetation is represented by low values of *Potamogeton*, *Nymphaea*, *Typha* and Liliaceae. Fern spores, monolete as well as trilete, maintain fluctuatingly low values throughout the zone, the later type better represented. Colonies of *Botryococcus* are encountered throughout though in short curves. This zone is divisible into two sub-zones.

Sub-Zone PT-1a (490-370 cm)

In this sub-zone, *Pinus roxburghii* and *Quercus* maintain more or less uniform high frequencies with slight fluctuations. *Larix* and Poaceae show an increasing trend throughout this sub-zone. Acanthaceae and Cyperaceae are recorded sporadically. *Alnus* is represented in low values in the lower half only. Euphorbiaceae, *Glochidion* and *Ulmus* are recorded in low values in the sub-zone only.

The lower limit of this sub-zone is radiologically dated to 3140 $\pm$ 100 years b.p. Two more C^{14} dates are available from lower part (2835 $\pm$ 125 years b.p.) and upper part (2830 $\pm$ 125 years b.p.) of this sub-zone. Thus, the vegetational history about 3000 years ago begins with Chirpine-Oak forest. The lake vegetation is dominated by *Botryococcus*, *Potamogeton*, *Nymphaea*, *Typha*, Liliaceae, *Polygonum*, etc. The pollen of *Larix*, together with *Picea* and *Abies* seem to have come from comparatively higher altitudes.

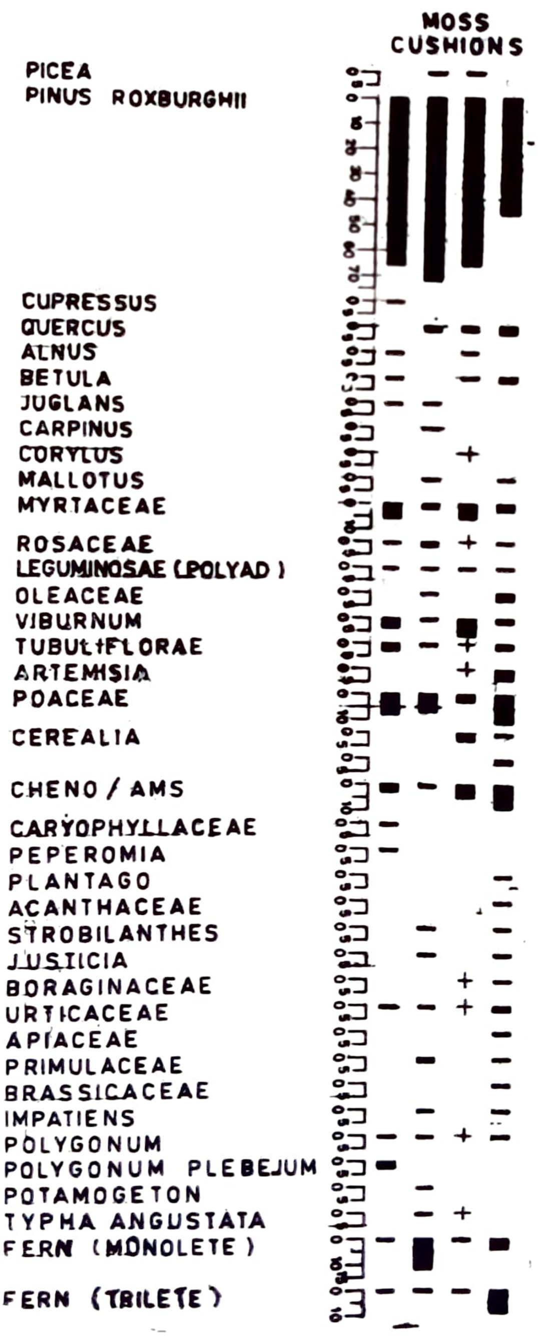
Sub-Zone PT-1b (370-270 cm)

The general pattern of the vegetation is evidently very much similar with that of the preceding sub-zone except that the values for *Pinus roxburghii* show an increasing trend and *Quercus* declining throughout the sub-zone. *Larix* maintains more or less the same values with slight fluctuations. *Alnus* becomes sporadic in the lower part, remains unrepresented in the middle, and reappears in low values in the upper part of the sub-zone. Leguminosae is recovered in low values in the lower part of the sub-zone only. Pollen of Apiaceae and Lamiaceae appear for the first time in sporadic values in the begining and disappears thereafter. Stray occurrence of *Typha angustata* pollen is noticed in this sub-zone only. Trilete fern spores are encountered in good numbers whereas monolete form a low discontinuous curve. Colonies of *Botryococcus* maintain more or less same values as in preceding sub-zone.

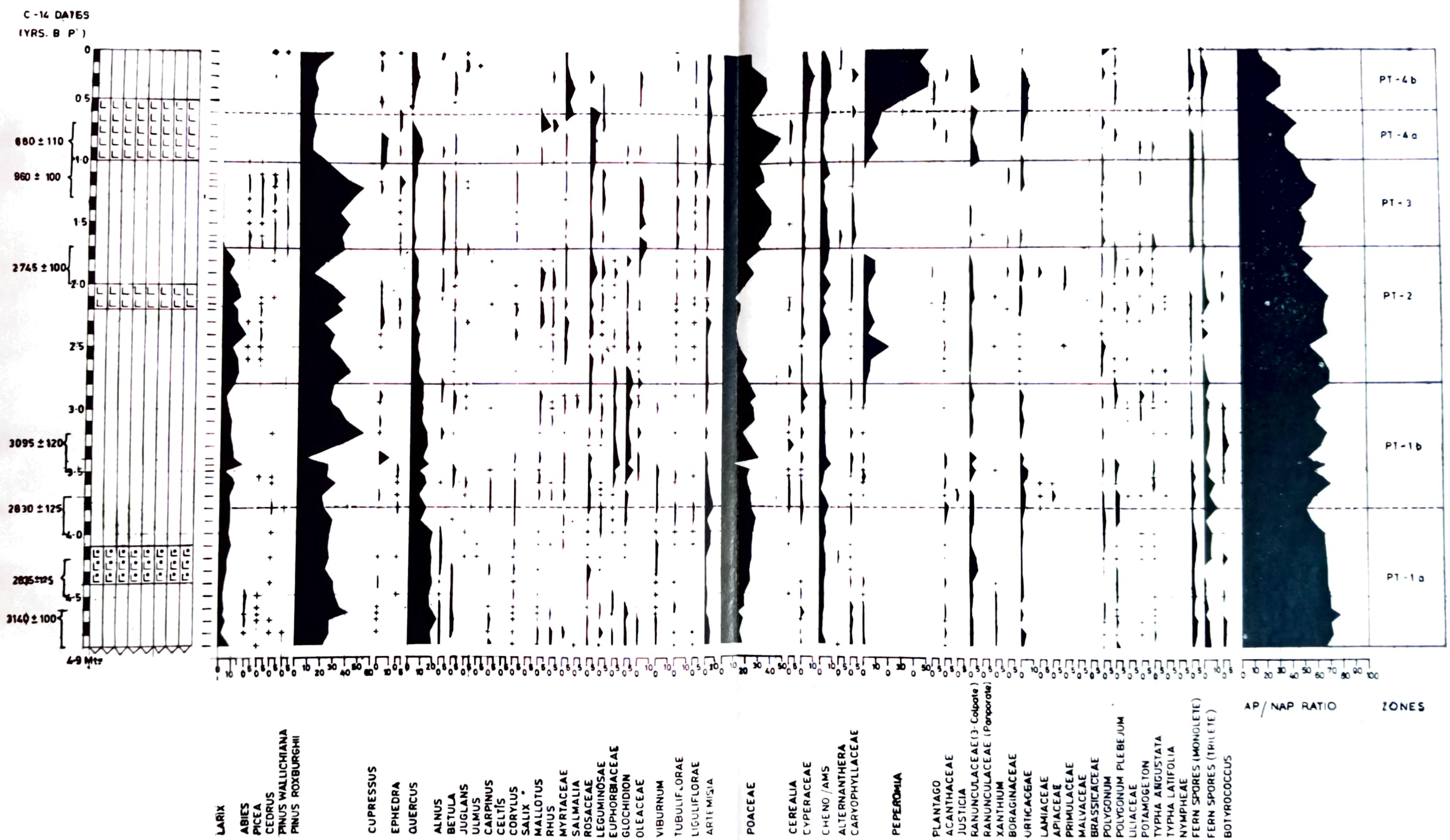
The C^{14} dates available from the middle of this sub-zone is dated to 3095$\pm$120 years b.p., which is older than the date from the deeper section of the profile, i.e. 2830$\pm$120 years b.p. In view of this anomaly in the dates, it is not feasible to extrapolate the rate of sedimentation except to infer that probably the rate of sedimentation was very quick throughout this zone. *Quercus* shows a definite declining trend towards the upper limit of this sub-zone. The lake vegetation remains more or less the same as in the preceding sub-zone. The AP/NAP ratio indicates the dominance of arboreals over non-arboreals throughout the zone with slight fluctuations.

ZONE PT-2 (270-160 cm)

Larix-Pinus-Quercus-Viburnum-Peperomia-Poaceae assemblage zone—This zone is marked by the increase in the values for *Larix*, *Viburnum*, *Peperomia* and decline in the frequencies of *Quercus*, Poaceae and *Pinus roxburghii*. *Larix* does maintain the increasing trend throughout the zone except for the upper part where it shows the declining trend. *Pinus roxburghii* shows a fluctuating trend and *Quercus* steadily a declining tendency. There is a noticeable increase in the values of *Viburnum*, *Peperomia*, *Betula*, *Rhus* and Myrtaceae. Tubuliflorae and Liguliflorae show a slight increase. Pollen of *Glochidion* and other Eu-



Text-Fig. 1. Recent pollen spectra from Parasram Tal, Himachal Pradesh (percentages calculated in terms of terrestrial pollen).



Text-Fig. 2—Pollen diagram from Parasram Tal, Himanchal Pradesh (percentage calculated in terms of total terrestrial pollen phorbiaceae reappear in sporadic values whereas *Pinus wallichiana* makes its appearance for the first time in the upper part of this zone. Other arboreal taxa, such as *Abies*, *Picea*, *Cedrus*, *Cupressus*, *Ephedra*, *Alnus*, *Juglans* and *Corylus* are recovered either sporadically or in short low curves. Among the non-arboreals, Poaceae, Urticaceae decline and *Peperomia* increases. The curve for Cheno/Ams shows a fluctuating trend throughout the zone. Cyperaceae and Ranunculaceae (3-colpate) are represented in low but continuous curves throughout the zone. Cerealia-type, *Alternanthera*, Caryophyllaceae, Acanthaceae and Lamiaceae are encountered in sporadic values. Ranunculaceae (porate), Primulaceae and Boraginaceae form short continuous curves. Aquatic vegetation is represented mostly by low and discontinuous curves of *Polygonum plebejum*, Liliaceae, *Nymphaea*, *Potamogeton*, *Typha angustata* and *T. latifolia*. Fern spores on the whole are poorly represented throughout than in the preceding zone. *Botryococcus* too, declines considerably and is represented only in the upper part of this zone.

The upper part of this zone is radiometrically dated to 2745±100 years b.p. There is a significant rise in the curves for *Larix*, *Viburnum* and *Peperomia* with simultaneous fall in *Quercus* and Poaceae. *Pinus roxburghii*, however, maintains fluctuating values. The AP/NAP ratio reflects the dominance of arboreals in the lower half whereas a declining trend in the upper half of this zone.

ZONE PT-3 (160-90 cm)

Pinus-Poaceae Cheno/Ams assemblage zone—This zone is delineated by fall in the values of *Quercus*, disappearance of *Larix*, *Viburnum*, *Peperomia* and considerable increase in *Pinus roxburghii* together with Poaceae and monolete ferns. There is over all increase in the values of most of the other gymnosperms, such as *Abies*, *Picea*, *Cedrus*, *Pinus wallichiana* and *Ephedra*. Other arboreal taxa recovered in low discontinuous curves are *Alnus*, *Betula*, *Corylus*, Myrtaceae, Rosaceae, Oleaceae, Tubuliflorae and *Artemisia*, together with stray occurrence of *Cupressus* and *Juglans*. Poaceae starts increasing from the beginning of the zone and maintains high frequencies throughout, whereas Cheno/Ams and Cyperaceae maintain more or less similar values throughout the zone. There is over all decline in the frequencies of non-arboreal taxa and many of them either become sporadic or remain unrepresented throughout the zone. Aquatic components were represented by transitory occurrence in the values of *Typha* and Liliaceae in the lower and upper part of the zone. *Polygonum plebejum* is represented throughout the zone though in low values. Monolete fern spores start increasing right at the beginning of the zone and maintain the same values throughout, whereas trilete fern spores are represented in low but continuous curves.

The upper part of this zone is dated to 960±100 years b.p. There is overall increase in gymnosperms and decrease in Oaks and non-arboreals except for Poaceae; thus indicating perhaps a trend towards a cool temperate climate. The AP/NAP ratio shows static values up to the middle of the zone with a declining trend in the upper part.

ZONE PT-4 (90-0 cm)

Peperomia-Poaceae-Cheno/Ams-Cyperaceae-Ranunculaceae-Viburnum-Pinus roxburghii assemblage zone—This zone is determined by steep decline in the values of *Pinus roxburghii* and gradual rise in *Peperomia* in the lower half but with a sudden rise in the upper half of the zone, attaining the maximum values of 80%. *Larix* remains unrepresented though Myrtaceae, Rosaceae, *Viburnum*, Cyperaceae, Cheno/Ams, Ranunculaceae, *Cupressus*, etc.

show increased values. This zone is further divided into two sub-zones, i.e. PT-4a and PT-4b.

Sub-Zone PT-4a (90-50 cm)

This sub-zone starts with significant fall in the curve of *Pinus roxburghii*. Most of the gymnospermous taxa, such as *Larix*, *Abies*, *Cedrus*, *Pinus wallichiana* disappear and remain unrepresented throughout the sub-zone *Cupressus* and *Ephedra* are, however, better represented in this sub-zone, whereas the values of *Quercus* show an increasing trend in the lower half and decline in the upper half of the sub-zone. Rosaceae shows an increasing trend throughout the sub-zone, and *Viburnum* a significant rise within the sub-zone. *Artemisia* is encountered in low but continuous curve, whereas *Alnus*, *Betula*, *Rhus*, Myrtaceae, *Glochidion*, Oleaceae, Tubuliflorae and Liguliflorae are recorded in low discontinuous curves. Amongst the non-arboreals, Poaceae and *Peperomia* show an increasing trend. Cyperaceae and Cheno/Ams maintain low but continuous curves. *Alternanthera* is encountered in low curve in the lower half of this sub-zone only. Ranunculaceae (colpate) shows sudden rise at the beginning and maintains more or less the same frequency thereafter. Monolete as well as trilete ferns are encountered in low continuous curves in the lower part and disappear in the upper part of this sub-zone. Other non-arboreal taxa, such as Cerealia-type, *Plantago*, Acanthaceae, Ranunculaceae (porate), Urticaceae are noticed sporadically.

Aquatic vegetation is represented by stray occurrence of *Potamogeton*, *Typha*, Liliaceae, and *Polygonum plebejum*. The lower border of this sub-zone is C^{14} dated to 680 ± 110 years b.p.

Sub-Zone Pt-4b (50-0 cm)

This sub-zone records substantial increase in the values of *Peperomia* from the beginning and maintains its maximum values throughout this sub-zone. Cyperaceae and Cheno/Ams too, show an increasing trend. *Pinus roxburghii* maintains more or less the same values as in the preceding sub-zone. *Cupressus* dwindles down completely but reappears at the top spectrum Sporadic occurrence of pollen of *Picea*, *Cedrus* and *Pinus wallichiana* is noticed in the upper part, whereas *Quercus* starts with low curve, shows slight increase in the middle, and declines in the upper half of the sub-zone. The curve of Myrtaceae shows an increasing trend, reaches its maximum in the middle, and dwindles in the upper part. *Viburnum* remains unrepresented throughout the sub-zone, whereas the curve for Rosaceae reduces to sporadic values. *Betula*, Oleaceae and *Artemisia* are recovered in low curves in the lower half. Other arboreal taxa represented in sporadic values are: *Juglans*, *Rhus*, *Alnus*, etc. The ground flora is represented by very high values of *Peperomia* and Poaceae. Cyperaceae and Cheno/Ams are better represented than in the preceding sub-zone. The values of Ranunculaceae (colpate) show a declining trend in the upper part whereas *Polygonum plebejum* attains a low continuous curve. Other non-arboreal taxa recovered in low and discontinuous curves are *Alternanthera*, Caryophyllaceae *Plantago*, Acanthaceae, *Justicia*, Boraginaceae, Urticaceae, Malvaceae and *Polygonum*. Aquatic vegetation is represented by stray occurrence of *Potamogeton* and *Typha* only. Fern spores, both monolete as well as trilete, are better represented in this sub-zone than in the preceding one.

The lower border of this sub-zone is radiologically dated to the present time. There is an overall dominance of non-arboreals over the arboreals. This could perhaps be due to the forest clearance for agricultural purposes as has also been evidenced by the deposition of clay in the lithocolumn accompanied by the increase in the culture pollen. The AP/NAP ratio also portrays dominance of non-arboreals over the arboreal taxa.

Discussion and conclusions

Stratigraphy and the age of Lake deposits—The present studies have brought out the vegetational history of the later part of Post-glacial period only, as the lake sediments could not be penetrated beyond the depth of 5 m due to the limited capacity of hand-driven Hiller's peat borer.

The sediments at 5 m depth are composed of blackish peat, interbedded with sandy-clay and clay respectively. With the available C^{14} dates of the deepest sediment investigated, the profile does not extend beyond 3,000 years b.p., though it is quite obvious that the deposits of still older age lie further below the depth reached for the present investigations. The details of available C^{14} dates are as below.

Sl. no.	Depth	Date
1.	70-100 cm	680 ± 110 years b.p.
2.	100-130 cm	960 ± 100 years b.p.
3.	170-200 cm	2745 ± 100 years b.p.
4.	320-350 cm	3095 ± 120 years b.p.
5.	370-400 cm	2830 ± 125 years b.p.
6.	420-450 cm	2835 ± 125 years b.p.
7.	460-490 cm	3140 ± 100 years b.p.

Since there is no coherence in the above C^{14} dates at different levels, it could not be possible to determine the rate of sedimentation of the profile.

Pollen-vegetation relationship—Four moss-cushions were collected from different situations around Parasram Tal to study the pollen-vegetation relationship in the area. Parasram Tal is actually a closed basin surrounded by the moist sub-tropical forest, and its margins are dominated by numerous aquatic and marshy plants, such as *Nymphaea*, *Potamogeton*, *Phragmites*, *Polygonum*, sedges, Caryophyllaceae, etc.

The pollen spectra (Text-fig. 1) revealed the dominance of Chirpine attaining the values as much as 75%. Other arboreal taxa, namely *Picea*, *Cupressus*, *Quercus*, *Alnus*, *Betula*, *Juglans* and *Mallotus* exhibit low values. The shrubby vegetation is represented by low frequencies of *Viburnum*, Oleaceae, Asteraceae, Rosaceae and the majority of non-arboreal taxa by a poor percentage except for Poaceae and Cheno/Ams which do attain values up to 10% and 5% respectively. Similarly, *Plantago*, Cerealia-type, Caryophyllaceae, *Peperomia*, Acanthaceae, Boraginaceae, Apiaceae, Primulaceae, Brassicaceae, *Impatiens*, etc. are sporadic. Aquatic vegetation is represented by stray occurrence of *Potamogeton* and *Typha* and the fern spores, monolete and tirlete, are recovered in comparatively good number.

The pollen analysis of moss-cushions collected from Parasram Tal does not reflect a true picture of the surrounding vegetation which is amply demonstrated by the fact that the Chirpine is totally absent in the modern floristic composition of the area, whereas the recent spectra show that it is the most dominating taxon. Obviously, the Chirpine along with *Picea*, *Cupressus*, *Quercus*, *Betula*, *Alnus*, etc. have been transported from long distances.

Thus, the recent pollen spectra actually portray a highly distorted view of the arboreal vegetation. However, ground vegetation is represented more or less faithfully.

Comparison with other pollen diagrams from Himachal Pradesh—The palynological investigations of the lake sediments in Himachal Pradesh have so far been conducted only at two sites, namely Khajiar, District Chamba, and Rewalsar, District Mandi (Sharma, 1973; Sharma & Singh, 1974a, b). Few clay samples have also been investigated from Kalidhang, District Sirmur (Tewari *et al.*, 1979).

The comparative study of Parasram Tal pollen diagram with that of the two earlier investigated sites, Khajiar and Rewalsar, reveals that the vegetation pattern is not much different, rather it is in concordance with the previously worked out two pollen diagrams. Vegetational history in each case begins with Oak-mixed forests, and all the three pollen diagrams have been radiologically dated to 3,000 years b.p. or so. It is seen that the Cerealia-type pollen grains, together with culture pollen are noticed almost from the beginning of the pollen sequence in all the three sites, and also depict two-fold vegetational development reflecting the period of maximum warmth and the decreasing warmth.

Similarly, the appearance of *Larix* pollen in Parasram Tal lithocolumn at 4.9 m depth, C^{14} dated to 3140 ± 100 years b.p., and later on its disappearance at about 2.0 m depth, of which the date is extrapolated to *ca* 1800 years b.p., is quite interesting in view of the fact that almost identical picture is drawn from the Khajiar Lake earlier reported, where *Larix* had its appearance right at the bottom of the profile at 8.8 m depth which is C^{14} dated to *ca* 4000 years b.p., and then disappears at the depth of 1.8 m, C^{14} dated to *ca* 1500 b.p. These observations have thrown much light on the past and present distribution of *Larix* when actually *L. griffithiana*, the only species in the Indian sub-continent, has a very patchy occurrence in central and eastern Himalayas, whereas it is totally absent throughout north-west Himalayas (Sharma & Gupta, 1984).

Vegetational history and climate—With the available C^{14} dates, and from the foregoing account of the investigated Parasram Tal sediments, the vegetational history seems to represent the later part of the Post-glacial period.

Zone PT-1—The picture of vegetation at the beginning of this zone is seen in a fully developed state with its earlier history remaining concealed in the lithocolumn further down which is not available for the present investigations. The stratigraphical continuity of a peat deposit without any apparent change in the nature of the sediment preclude the possibility of any climatic change at the beginning of the pollen sequence. The vegetational history begins with a forest in which Oak appears to be dominant. The Chirpine pollen represented by a prominent curve is either transported from the distant hills or the pine probably grew in the area in the recent past. Today, the forests around the lake or the area are devoid of Chirpine, though the study of recent pollen spectra from Parasram Tal depicts overall dominance of Chirpine pollen.

The occurrence of Cerealia-type pollen, together with culture pollen from the beginning of pollen sequence, firstly sporadically and later in low discontinuous curve is suggestive of agricultural practice in the region. *Botryococcus* colonies appear to have flourished well in the lake along with many aquatics, viz., *Potamogeton*, *Nymphaea*, *Typha*, and *Polygonum plebejum* along with some Liliaceae, etc. which also grew at the site.

The presence of *Larix* pollen right from the beginning of the investigated pollen sequence suggests that it probably existed in the vicinity of the site or atleast grew not very far from the area during the recent past, as opposed to its present day absence throughout the western Himalayas (Sharma & Gupta, 1984).

The overall dominance of Oak and Chirpine, together with other broad-leaved taxa, is indicative of relatively warm temperate and moist conditions at the beginning of the pollen sequence which is radiologically dated to 3140±100 years b.p. Thus it represents the later part of the Post-glacial climatic optimum which corroborates very well with the studies carried out on Khajiar and Rewalsar lakes.

The four C^{14} dates i.e. 3140±100, 2835±125, 2830±125, and 3095±120 years b.p., available for this zone from bottom upwards in sequence do not synchronise with respective depths of the lithocolumn. Hence, it is not feasible to determine the rate of sedimentation of the profile precisely, except to infer that the rate of sedimentation was quite fast as evidenced by the above four C^{14} dates.

Zone PT-2—This zone is marked by a significant fall in Oaks and Poaceae, but with a simultaneous increase in the values of *Peperomia*, Caryophyllaceae and Cheno/Ams. There is a slight increase in *Abies*, *Picea*, *Cedrus* as well as *Larix*. This change could be perhaps owing to anthropogenic activity coupled with a tendency towards decreasing warmth.

The lake vegetation witnessed a decline in *Botryococcus* colonies, whereas other aquatics, such as *Potamogeton*, *Nymphaea*, *Typha*. Liliaceae and *Polygonum plebejum*, however, maintain their existence as before. The upper part of this zone is radiologically dated to 2745±100 years b.p.

Zone PT-3—In this zone there is a sudden rise in *Pinus roxburghii*, *Abies*, *Picea*, *Cedrus*, *Pinus wallichiana*, *Ephedra* and Poaceae with a total disappearance of *Larix* and further reduction in Oaks. Also the lake vegetation shows a marked decline. All this can be attributed to perhaps cooler and drier conditions as a result of which there was an increase in the conifers and simultaneous decline in the taxa prefering wet conditions.

Zone PT-4—This zone, with its lower border radiologically dated to 680±110 years b. p., begins with a sudden and significant fall in the curves for Chirpine. Also there is a marked rise in the non-arboreal vegetation as evidenced by significant rise in *Peperomia* curve, as well as increase in the values for Poaceae, Cyperaceae, Cheno/Ams, Ranunculaceae and Urticaceae. The beginning of this zone is also characterized by the sudden fall in AP/NAP ratio. It appears that probably the arboreal elements were cleared on a massive scale for agricultural practices. It is supported by the marked change in the lithology also. Perhaps it was during this period that Chirpine started decreasing, and vanished completely from the area, perhaps as a result of human activity rather than due to some climatic change. In Khajiar lake pollen diagram too, this type of sudden decline in the arboreal vegetation is noticed at 520±55 years b.p., attributed to the human interference.

References

AUDEN, J. B. (1935). Traverses in the Himalayas. *Rec. geol. Surv. Indian*, **69**, pt. II

ERDTMAN, G. (1943). *An Introduction to Pollen Analysis*. Waltham, Mass. U. S. A.

RAINA, B. N. (1967). A note on the origin of some Himalayan lakes. *Proc Seminar on Geomorphological studies in India*. Univ. Sagar (M. P.)

SHARMA, CHHAYA (1973). Recent pollen spectra from Himachal Pradesh. *Geophytology*, **3**(2) : 135-144.

Sharma, Chhaya & Gupta, H. P. (1984). Past and present distribution of *Larix griffithiana* Hort. ex Carr. in the Indian subcontinent as evidenced by palynology. *ZfA Z. Archaol.*, **18** : 239-246, Berlin.

Sharma, Chhaya & Singh, G. (1974a). Studies in the Late Quaternary vegetational history in Himachal Pradesh — 1. Khajiar Lake. *Palaeobotanist*, **21**(2) : 144-162.

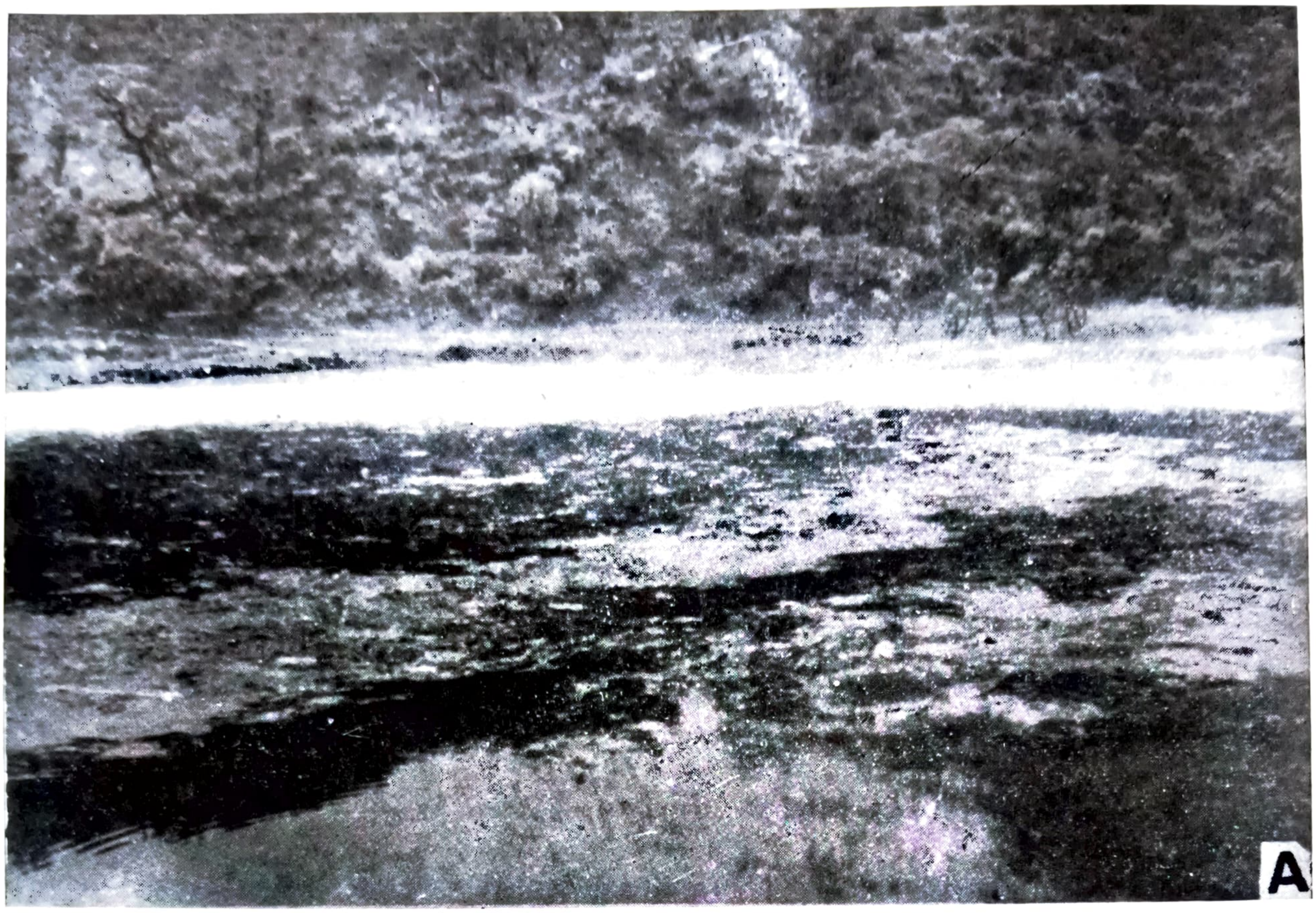
Sharma, Chhaya & Singh, G. (1974b). Studies in the Late Quaternary vegetational history in Himachal Pradesh — 2. Rewalsar Lake. *Palaeobotanist*, **21**(3) : 321-333.

Tewari, A. P., Swaine, P. K. & Sharma, Chhaya (1979). Pollen analysis of clay samples near Kalidhang, District Sirmur, Himachal Pradesh. *J. geol. Soc. India*, **20** : 132-134.

Explanation of Plate

A. Parasram Tal showing shallow waters with aquatic vegetation and scanty hilly forest in the background.

B. Renuka Lake showing clumps of *Phragmites communis* inhabiting the margins and nearby forests in the background.


A


B